

Rosa Ursina sive Sol

[The Ursine Rose, or the Sun]

(1630)

by Christoph Scheiner (1573/75–1650), S.J.

Translation by Scott Weisman



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Translator Version 2

Upright reason dictates that the recipients of the good, of whatever type and level of beneficence it may be, must show gratitude and blessing to the beneficent person in every way possible, commensurate with the value of the beneficence. And one who has benefited all the people of the world — for example, one who invented a new instrument for the good of the world, or a good book — it is fitting for every discerning person, out of the obligation of love of fellow beings, to at least purchase it, so that the man will profit and his heart will be encouraged thereby to invent yet more good instruments in the world. And similarly, all other wise-hearted people will likewise strive and exert themselves to invent good things and instruments needed for the repair of the world and its perfection.

And therefore, whoever says: "What do I need this new instrument for?" — he does not act well towards the world. For if not for the man who invented it, where would you be? And what would your city do? And more than this, if the man did not exert himself, what would the world do?

— R. Pinchas Eliyahu Hurwitz, *Sefer HaBris HaShalem* (1797)

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A note on the work

Rosa Ursina is the first comprehensive treatise on sunspots and a foundational work of telescopic solar astronomy. The Jesuit Christoph Scheiner marshals years of observations to demonstrate that the Sun rotates on its axis — with a period of about a month and the spots lying on or just above its surface — and establishes the inclination of the solar axis to the ecliptic. Organized in four books, it combines observational records and engraved plates of spot configurations, a discussion of instruments and safe solar-projection methods, and a long polemic on the history and priority of the sunspot discovery (against Galileo). It remained the standard reference on solar phenomena for over a century.

The reading layout is dense: main text frequently set in **two columns with heavy marginal/interlinear glossing**, interleaved with full-page engraved plates.

A note on the translation process

This translation was produced with the [translation-pipeline](#). See the linked repository for details on the process.

This text is the product of a highly refined automated translation process. It has undergone only cursory human review and should not be treated as an authoritative or scholarly rendering. It is offered solely as a reference and reading aid — a way to make an otherwise inaccessible work approachable — and any passage of real consequence should be checked against the original source.

Acknowledgements

Translated with the assistance of Claude. The translator thanks the [Anthropic](#) team for making this work possible.

Engraved frontispiece. A full-page allegorical engraving framed by billowing banks of cloud. At the very top, the Jesuit monogram **IHS** blazes within a burst of rays. Below and at the center hangs an oval portrait medallion of a crowned woman who gazes upward; a curved legend runs around her image. A great scroll (banderole) sweeps across the middle of the plate carrying the motto. Beneath it, the title of the work is lettered across the sky, with a rose enclosing a small sun-face at its heart, set above a hazy landscape flanked by allegorical figures. At the foot of the plate, held up out of the clouds, stands the quartered heraldic achievement (the Orsini arms) beneath a coronet. Two winged putti — one at left, one at right — emerge from the clouds holding scrolls or trumpets. Four small emblematic vignettes occupy the corners, each labelled, personifying the sources of knowledge.

- Top left (inscription): **P. CHRIST. SCHEINER E SOC. IESV** — "Fr[ther] Christoph Scheiner, of the Society of Jesus"
- Top right (inscription): **AD PAVLVM IORDAN. II. VRS. BRACC. DVC.** — "To Paul Jordan [Paolo Giordano] II Orsini, Duke of Bracciano"
- Upper-left corner emblem (a hand holding a book/tablet with a seal): **AVCTORITAS SACRA** — "Sacred Authority"
- Upper-right corner emblem (a radiant eye / bird toward a hand): **RATIO** — "Reason"
- Central portrait, legend around the medallion: **S. BATHILDIS VRSINA REGINA GALLIAE VXOR CLODOVEI II** — "St. Bathild of the Orsini [line], Queen of France [lit. of Gaul], wife of Clovis II"
- Scroll / banderole across the middle: **VRSINAE CAELVM PRAEFERT INSIGNIA GENTIS** — "Heaven displays the insignia of the Ursine house"
- Center (title lettered across the sky): **ROSA VRSINA SIVE SOL** — "The Ursine Rose, or the Sun"
- Lower-left corner emblem (a hand with an instrument/vessel, book): **AVCTORITAS PROFANA** — "Profane [secular] Authority"
- Lower-right corner emblem (compasses, telescope/sighting instrument, drawing): **SENSVS** — "Sense"
- Foot of plate: the quartered Orsini coat of arms beneath a ducal coronet (a bear appears in the base of the shield). No motto legible within the arms.

[Page 2 — blank verso. Stained and foxed, with mirror-reversed show-through from the title-page ghosting faintly through the leaf; no text belongs to this side. A single faint letterform near the right margin is bleed-through, not ink of this page. [?]]

ROSA VRSINA, SIVE SOL

[Title-page]

THE URSINE ROSE, OR THE SUN

Various in the wondrous phenomenon of its own faculae and spots [*ex admirando facularum & macularum suarum phaenomeno varius*]; and moreover MOBILE — shown, in four books, to move about its own center and a fixed axis in a yearly revolution from west to east, and about another, movable axis in a roughly monthly revolution from east to west, upon its own poles.

By **Christoph Scheiner** [Christophorus Scheiner], a German Swabian, of the Society of Jesus.

To **Paul Jordan** [Paolo Giordano] II Orsini, Duke of Bracciano.

Woodcut device. An emblematic vignette set within a wreath or bower of roses. In the upper compartment a bear sits upright among rose-bushes, holding what appears to be a set of compasses or a cross-staff across its body; the sun shines in from the upper left. In the two lower compartments, two more bears are shown among rocks and foliage. The scene is captioned above and below, with four motto-labels attached to the figures.

- Top arc: **ROSA VRSINA** — "The Ursine Rose"
- Upper left (rays of the sun): **Ipsa dies aperit** — "The day itself opens it"
- Upper right: **Visu blanda, aspera tactu** — "Gentle to the sight, rough to the touch"
- Below the upright bear: **Rosae Custos** — "Guardian of the Rose"
- Lower-left bear: **Constanti industria formae [?]** — "By constant industry [she gives] form" [the she-bear shaping her cub by licking; last word uncertain]
- Lower-right bear: **Ipse alimenta mihi [?]** — "I myself am nourishment to myself" [reading uncertain]
- Bottom arc: **VRSA ROSINA** — "The Rosine She-bear"

BRACCIANO, at the press of Andreas Phaeus [Andrea Fei], Ducal Printer.

The printing was begun in the year 1626, and finished in 1630, on the Ides of June. With the license of the Superiors.

[Dedicatory epigraph and synopsis]

Ecclesiasticus, Chapter 33, verses 7 & 8.

"Why does one day excel another, and again light [excel] light, and one year [excel] another year — [and all] from the Sun? By the knowledge of the Lord they were set apart, the Sun being made and keeping His commandment." [Sirach 33:7–8]

A SUMMARY OF THE INDIVIDUAL BOOKS, EACH COMPRISED IN A SINGLE VERSE.

The First Book brings forth the First Author as Apelles; The Second lays open the causes of error, and forbids them; The Third presents the spectacles long observed; The Fourth gives the age and character of the ROSE — and its court.

More detailed synopses you will read, set at the head of each of the Books; and an Index of Chapters, to be recited in full a little later, together with a general Index of subjects at the end of the work, will make everything plain point by point to the eager Reader — besides what is said here in the Dedication and in the Preface.

[Margin: *Arist. Lib. 12. Metaph. cap. 8.*] Aristotle, *Metaphysics* XII.8 [Book 12, ch. 8] according to the common editions, but according to the Paris Greek-Latin edition published in the year 1619, he writes as follows in the same chapter, Book 14:

"But the multitude of the motions [*Lationum* — the celestial revolutions] one ought to consider (learn) from that most peculiar (or most proper) philosophy of the mathematical sciences, namely from Astrology [Astronomy]; for this contemplates a substance that is indeed perceptible, yet everlasting." (Aristotle, *Metaphysics* XII.8 / XIV.8)

[Library stamp: "Staatliche Bibliothek Passau"; pencil shelf-number "139 309 314" above it.]

ROSA URSINA, OR THE SUN

*(Divisional half-title, *

[The center of the leaf shows a faint, mirror-reversed ghost of the frontispiece emblem bleeding through from the verso; it is show-through, not printed matter on this side, and is not transcribed.]

Ovid, *Fasti*, Book 1.

Happy the souls whose care it was to be the first to learn these things, and to climb up to the dwellings on high. They drew the distant stars close to our eyes and made the heavens subject to their genius.

(Ovid, *Fasti* I.297–300)

SOL TIBI SIGNA DABIT — "The Sun will give you signs"

*(Frontispiece, *

Virgil, Georgics 1.

Diagram. A square emblematic frontispiece. At the center is an engraved medallion portrait of the Duke—a bearded man in a ruff and armor, facing the viewer—encircled by a ring bearing the legend, read clockwise: "BRACCIANI DVX * PAVLVS IORDANVS II VRSINVS" ("Duke of Bracciano, Paolo Giordano II Orsini"). Surrounding this central medallion is a wreath composed of alternating engraved roses and small globes of the Sun, the whole radiating short rays outward to the border. Each globe depicts a disc of the Sun marked with sunspot configurations; several carry very small engraved letters, numerals, or symbols beside the spots (apparently keying observation dates or spot identifications), but at this resolution these peripheral labels are not legible.

- Central medallion legend: "BRACCIANI DVX * PAVLVS IORDANVS II VRSINVS"
- Ring of ~12 solar globes with sunspot markings, alternating with roses; individual globe labels [?] (small engraved characters, illegible)
- Bear-and-rose foliate ornament interwoven through the wreath (the Orsini rose-and-bear device)

[Note: the ~12 small globe labels cannot be resolved at this resolution]

Below the emblem, the dedicatory verses:

Hail, Duke of the Ursine race! Olympus applauds you; Phoebus and the Bear run to do your bidding. If others have been able to carve their emblems and their lineage on mute stones, that was a great stroke of fortune. Your emblems and your lineage shine, set among the heavenly spheres; God has fixed the Ursines upon the axis [of the world]. Well done, hero, in the valor of your spirit, O high-born line! Since earth is too cramped for your trophies, you reach for the stars.

To his Maecenas [patron] — the Author.

The Sun too, both as it rises and as it sinks into the waves, will give signs. The surest signs attend the Sun, both those it brings back at morning and those [it brings] when the stars are rising, [when] it has dappled its newborn rising with spots.

(Virgil, Georgics I; the parenthetical "(When)" is the author's insertion into the quotation)

THE MORE NOTEWORTHY POINTS OF THE WHOLE WORK

- Apelles is defended and shown to be the first discoverer of the solar spots—throughout the whole of Book One.
- In the same first book, the errors of the Apellean Censor [the critic of "Apelles"] are exposed. — pp. 31 & 42
- The optical tube [telescope] is explained from its foundations throughout the whole of Book Two, and demonstrated. — p. 127
- The relation and analogy of the tube [telescope] with the eye is given. — p. 106
- Concerning the spots seen in the Sun itself and observed at Rome in the Professed House of the Society of Jesus, in the Roman College; in Germany at Ingolstadt and at Freiburg im Breisgau; in the Low Countries at Douai—by the Fathers Christoph Scheiner, Christoph Grienberger [Christophorus Grünenberger], Georg Schönberger [Georgius Schönberger], and Charles Malapert [Carolus Malapertius], and others, in the years 1618, 1621, 1622, 1623, 1624, 1625, 1626, and 1627. Seventy images are presented. — Book Three
- That the spots are truly in the Sun, and not a deception of the sight. — p. 151
- This is attested also by Raffaello Aversa [Raphaël Auersa], Marin Mersenne [Marinus Mersennus], Galileo Galilei [Galilæus de Galilæis], the Mathematician of Barcelona, and the Parma Theses. See the general Index.
- Spots near the center of the Sun move from the eastern region of the Sun to the western, in about thirteen days, with a regular motion. — p. 405
- The spots physically change, grow, diminish, darken, and brighten; they come into being in the middle of the Sun, and they fade away. — p. 490

- The spots pass off into faculae [bright patches, "little torches"] brighter than the Sun's own common brilliance; and conversely, spots take the place of faculae. — p. 517. See the general Index.
- The whole surface of the Sun is always beset with spots and faculae, at least secondary ones. — p. 512
- The spots and faculae are in the Sun itself. — p. 537
- Returning spots [Maculae Reduces]. — p. 546
- No spot or facula appears outside the Sun's disc. — p. 414
- No celestial orbs cause the spots on the Sun. — p. 408
- The spots move in nothing around the Sun—neither in epicycles nor in eccentrics. — p. 424
- Faculae are not produced by the Sun's shining-through [translucency]. — p. 517
- The tracks of the spots curve in opposite directions in each half-year, etc. — p. 161
- The tracks of the spots are always concave toward the elevated and visible pole, always convex toward the depressed and hidden pole. — p. 225
- The device [machine] by which the spots are easily observed. — p. 349
- The theory of the motion of the solar phenomenon. — p. 554
- The globe of the Sun rotates. — p. 601
- The annual revolution of the Sun from west to east. — *ibid.*
- The heaven, the Sun, and the other heavenly bodies are held by the Church and the holy Fathers to be of a fiery and elemental nature. — p. 626
- That there are true elemental waters above the heavens is proved from Sacred Scripture, the most holy Fathers, and theologians. — p. 641
- It is inferred, according to the mind of the Church and of the holy Fathers, that the heaven, the Sun, and the stars are by their own nature corruptible. — p. 660
- The heaven is fluid [liquidum], from Sacred Scripture and the holy Fathers. — p. 699
- That the heaven is either fluid or fiery is defended by many modern [Neoteric] theologians, philosophers, and natural philosophers. — p. 731
- The ancient philosophers held the heaven to be fluid. — p. 747
- Both ancient and more recent astronomers held the heaven to be fluid. — p. 755
- Objections in favor of a solid [hard] heaven are refuted. — p. 771

APPROVALS

Mutio Vitelleschi [Mutius Vitellescus], Superior General of the Society of Jesus.

Since three theologians and mathematicians of our Society, to whom the task was entrusted, have reviewed the *Rosa Ursina* of Father Christoph Scheiner of our Society and have judged that it may be published, we grant the faculty for it to be committed to the press, if it shall seem good to those whom it concerns. In witness of which we have given these letters, subscribed with our own hand and secured with our seal, at Rome, 6 July 1629.

Mutio Vitelleschi.

Place of the seal. [*Loco * sigilli*]

Seen. [*Vidit*] Bartolomeo Piccaluga [Bartholomæus Piccaluga], General Auditor of the State of Bracciano.

Let it be printed, if it please the Most Reverend Father Master of the Sacred Palace. Luca Ricciotti [Lucas Ricciottus], Archpriest, and Vicar of Bracciano for the Most Reverend Lord Bishop of Sutri and Nepi.

This *Rosa Ursina*—that is, the books on the Spots and Faculae of the Sun, worked out by the Reverend Father Christoph Scheiner, a German of the Society of Jesus—I have read at the command of the Most Reverend Father Niccolò Riccardi [Nicolaus Riccardius], Master of the Sacred Palace; and I have found in them nothing at odds either with sound doctrine or with good morals. On the contrary, I found much that had been gathered by long and personal labor and industry—not only matters solidly argued and thoroughly necessary to the mathematical and philosophical disciplines, but also other things very usefully treated for the illustration of Sacred Scripture and the testimonies of the Fathers. For very many things that Sacred Scripture teaches about the nature and constitution of the Sun and of the Heavens—according to the genuine interpretation of the holy Fathers, things that seemed harsh to those wedded to Peripatetic [Aristotelian] doctrine—are wonderfully confirmed by this new phenomenon. For this reason I judged them altogether worthy to go forth into the light for the public good. In the Roman College of the Society of Jesus, 28 May, in the year of the Lord 1630.

So I judge, I, Juan de Alvarado [Ioannes de Aluarado], of the Society of Jesus, Prefect of Studies of the same Society at the Roman College.

Let it be printed. Fr. Niccolò Riccardi [Nicolaus Riccardius], Master of the Sacred and Apostolic Palace.

To Paolo Giordano II Orsini, Duke of Bracciano — Dedicatory Epistle

To Paolo Giordano II Orsini, Duke of Bracciano, etc., Christoph Scheiner of the Society of Jesus [wishes] everlasting happiness.

We have learned that the Rose was a delight to most of the ancients, and that among the Indians especially it was held in no ordinary esteem. Those whom they reckoned wisest believed that by nothing so much as the Rose could they draw the hearts of princes to themselves and win their affection. For this reason they made a point — whenever the occasion of time and place allowed — of consecrating to the Sun the oil pressed from the Rose and reverently gathered in a phial, with due words and appointed ceremony. They held that, once anointed with this salve, they would at once become powerful over kings and princes, would hold the minds and hands of all in their control, and would meet no refusal, but would carry off whatever help and favor they had asked.

Moved by their example, magnanimous Duke, when I was seeking a way of approach to you, I too judged that a work of the Rose would suit me — one by whose charm I might be commended to a prince. Yet great proofs had already shown me how closely you and your illustrious family embrace my whole Order. And so, reversing my thought, I decided that I ought not to win here a kind of *new* favor, but rather to strengthen and honor an *old* one by fresh services.

For after Cardinal Alessandro Orsini [Alessandro Orsini], a prince of eternal fame and glory, was carried off by an untimely death — and in that one man you lost half of yourself, a full brother, while I lost by far the best of patrons, both of us in grief — no one could yet repair for you the loss of a most beloved brother; but for me you alone at once began to restore the protection of the patron torn away. And you brought it about that, although I have not yet finished mourning the prince I lost, still, now that I have found in you my prince, this book of mine might rejoice.

This book of mine, I say. Its subject is welcome for its very novelty, yet obstructed by its difficulty; and to draw it into the light out of the very light of the Sun, I shall not deny, I spared myself no labor by day or by night. For I keep this radiance of the world before unblinking eyes; I pursue the shadows of that most beautiful

star, whether lurking and fleeing or dragged out into the open; I gaze in astonishment at the unwonted brilliances — brighter than the Sun's ordinary splendor, familiar to everyone — that flash out here and there across it and flood its surface, a new and until now unseen spectacle; and I explore, by methods never before discovered, the courses by which it continually rotates about its own center in monthly and yearly revolutions. And if I have not yet [spent] a whole lifetime at it (as that man did), at least I am now spending an eighteenth year among these observations. Whatever new knowledge so much time and toil have won for me from the heavens and from the chief star of the heavens, all of it, enclosed in this book, I — a client neither forgetful nor ungrateful — dedicate to you, prince of the House of Orsini, and to the name of the Ursine Rose. And thus I present the Sun itself, king of the stars, paired with your Rose, queen of flowers. For while, secure in your favor, I neglect to pluck the Rose from the gardens of Paestum as something foreign — behold! I joyfully and gratefully salute the Rose that belongs to your own house, offered to me from your own arms, as a good omen. And so, not the Rose to the Sun, nor the juice pressed from the Rose (which I recounted the Indians did), but by a reversed plan, this Sun of mine and the labor I have described, spent in its new exploration, together with the precious liquor of Truth thereby drawn out, I willingly and gladly pour, unfading, into the bosom of your Rose. So that hereafter this whole phenomenon — marked by the wondrous variety of its shadowy and bright parts, conspicuous through their very mutual transmutation, and blossoming ever

with new offspring — may recall the name of the Ursine Rose, and may inscribe the famed lineage of the Ursine house eternally in the sky with its rays. This I judge I can do, both by the right of the discoverer and as the dignity of the House of Orsini requires, and indeed with Nature herself favoring and inviting. For to whatever side I turn, I see everywhere the Sun agreeing most beautifully with the Rose, or the Orsini family with the Sun and the Rose — so that I believe these, though different in condition yet matched in nature, have entered into a secret friendship. Still, I shall not undertake here to compare them one by one, nor to wrench by force the points that resist into a false likeness. The first would be a task longer than is fair; the second a proven refuge of poverty [of argument]. Instead I shall compare them in two things only, which the consensus of all (as I indeed suppose) will approve with a glad murmur.

The first is the Sun's wondrous splendor, by which — as though laying a color upon them — it paints and illumines all mortal things, and instantly renders shapeless and dark things beautiful and lovely. The second is the Sun's heat, which it pours out most liberally and freely as far as lands and seas extend,

dispensing aid to all from its lavish bosom. It does not regard friends and the grateful alone; a star born for benefaction, it steadily helps even the unmindful and the hostile, hostile itself only to owls and ill-omened screech-owls. How often does it soothe the clouds even as they gather and threaten? How often does it clear away with kindly heat the storms conspired for the ruin of cities? Truly its nature is beneficent, and ignorant of harm alone. From this I turn to the Sun's rival, the Rose. Its color — now reddening to purple, now vying with the whiteness of snow — is such that the eyes behold nothing more charming or more pleasing. That same Rose, by its scent, sweetest of all, with which it allures, triumphs over all the envy of fragrant Hybla and of flowering spring. Yet that scent is no more charming than it is wholesome. It best preserves the part that is chief in man: poured upon the head, it restores the strength that toil had drained or sickness dulled; and where the greatest harm falls upon the human race — drunkenness armed for ruin — it happily disarms it by a secret power. Bid someone take this Rose away, and you turn a most delightful rose-garden into a deformed and bare bramble-patch. Let it at once split its sheath and begin again to burst from its calyx, and you will believe every thicket to be a rose-garden, the rough thorns to be turning into painted shrubs, the grim wastelands to be becoming sheer vales of Tempe. So great is the grace that the Sun's splendor and heat, and the Rose's color and scent, can bring to mortal affairs.

Here now I shall fear, Ursine Prince, that if [I say] of your family's

Light that it yields nothing to this Sun nor to the Rose, I may do violence to your modesty — which prefers to *do* illustrious things than to *hear* its own good deeds proclaimed openly. But allow, I beg, this necessity to be laid upon you: that at last, under compulsion, you may hear what we, full of admiration, often recount about you and your ancestors. For the Ursine House too has its own inborn Color and Splendor, by which it long ago shone conspicuous among all the peoples of every land. It has too the nature of the Rose and the Sun, by which it extends the abundance of its benefaction and aid as far as the glory of its name reaches. For whether the honors of sacred or of profane splendor be considered, it has so excelled in both that one might have eclipsed the other by excess of light, had not both conspired for the fortune of a single House. Would you have us begin from the profane — a glory not indeed more brilliant, but certainly more ancient?

At once there present themselves the smoke-darkened ancestral portraits with which the halls are filled, which trace the antiquity of the line back to the very cradle of the City [Rome]. There present themselves the titles in great number, which it has won for itself, immortal, from illustrious deeds on every side. There

present themselves the crowns, more than civic, which the glory of war and devotion to the fatherland preserved conferred upon it. Who to this day has examined the records of the Roman People or Empire and failed to read how many and how great the heroes, famed in peace and war, that the Ursine Rose brought forth? When the Capitol labored under the two utmost difficulties and was closely besieged by the legions, she sent the Orsini generals [Duces Ursinos] with their troops; and to the People that commands all nations she restored the Seat from which it might rule. How many — and how often, for the public good — did she herself bring forth from her stock as Consuls at Rome, as Senators of the fatherland? How many Prefects of the City did she herself give (what but beneficent parents and guardians of the commonwealth?), one upon another, again and again, with such approval of the citizens? And she laid down that burden only so that Princes might be born, onto whose equal shoulders she, her service now done, might transfer it.

At last, having gone forth from the City and spread through all Europe, she ranged most widely — with the monuments of her virtues — over the Kingdoms of Spain, the shores of England, the Lilies of France, the Empires of Germany, all the lands of Italy. For to the Empire, certainly, how many Princes of the first rank did she count? how many Electors [Septemviros Electores] of the Empire? Though she scarcely even counted them. For indeed — as the public records have disclosed to me — when she had given the Ursine brothers as Princes, the one to Brandenburg, the other to Saxony, and had been raised in both to the Electoral college [Septemviratus] of the Empire, she so held the dignity once received that among the former, for more than two hundred and forty years, and among the latter, for not less than one hundred and seventy years (the records affirming the fact), through a long [line] of descendants

[Margin: The Orsini, Electors of the Empire.]

[Dedicatory epistle to Paolo Giordano II Orsini, Duke of Bracciano — continued from the previous page.]

and through a long posterity of descendants it has carried on the unbroken glory of the URSINE RACE. And why recall the Kings drawn into her by ties of blood, and the sceptres allied to her by marriage? Embracing well-nigh the whole of EUROPE, she so encircled herself with the light of almost every Kingdom that she lent her own light to them no less freely in return. And so, from here through Germany and France, and thence through Spain and all of Italy, she grew famous by illustrious kinship or affinity with Kings; she bound to herself the crowns of Bohemia and of Pannonia [Hungary]; carried out beyond the Ocean, she attached

herself to the Kings of Britain, to the Swedes, and to the Danes; and even the Thessalians and Greeks, once most powerful Dynasts, she joined to her House, they not refusing.

At last she rose to such a height, by her own light and worth, that — a fortune granted to few, even among Princes — she came to hold the greatest authority and favor with the mightiest Emperors, and, admitted into AUGUST KINSHIP, she all but surpassed herself. And yet I am not sure whether she did not win a glory greater still from an IMPERIAL DIADEM REFUSED — a diadem conferred upon her VIRTUE, and all but set upon her head. For what she had refused to wield by herself, she did not refuse to fight for: to guard and to vindicate its LIBERTY, which had lately stood in peril. And by that most illustrious service she carried off for herself, from the EMPIRE she had championed and reclaimed, INSIGNIA for honor's sake — on the one side, BEAMS varied in gold and black; on the other, a GARLAND woven of rue (in which both the Princes of Saxony today and those of Savoy [the Allobroges] take pride).

But where am I being carried, heedless? Having set out to speak of the Glory of the URSINE FAMILY, I find myself sliding toward its MERITS, bestowed upon the whole World. For just as the color and fragrance of a ROSE, or the splendor and warmth of the SUN, are conveyed together, so the Glory of Your Ancestors cannot be told by itself without their MERITS being proclaimed at the same time.

Yet these ornaments of the Ursine race, however great they were — altogether such that nothing seems to have been wanting to them for the fortune of the highest Princes — were nevertheless still PROFANE (if one may speak so) and worldly. And so, raised further to SACRED dignities as well, the family held these too, of every kind, in such numbers that it scarcely had a house to rival save its own: from a single ROSE sprang so many Bishops, so many Archbishops, so many other Prelates. For that which is above all characteristic of ROSES — that they suffice to adorn the HEAD with GARLANDS — this, I see, was the native and peculiar office of the URSINE PRINCES: that they should forever encircle the SUPREME HEAD OF THE CITY AND OF THE WORLD [the Pope] with a purple crown, while the ROSE of one single family supplied Cardinals, almost past numbering, in fertile increase. Of these — to pass over the rest in silence — the memory of more than THIRTY-THREE survives; and by their purple, beheld again and again across so many ages, the Majesty of the Roman Church has shone the farther and wider through the World.

Nor even here did the good fortune of the URSINE ROSE contain itself. That same family — which is the very summit of mortal prayers — often brought forth from

its ancestral rose-garden its own HEAD OF THE WORLD, adored by so many peoples: lest, forsooth, a FAMILY which by its most fruitful childbearing had given so many Princes to so many nations should be said to have proved barren and sterile in the one task of begetting Princes of the Church — that is, the Best and Greatest Pontiffs.

At these summits AMBITION itself ought to have halted; nor ought the glory of YOUR Race to have striven any further — if mortal happiness could ever satisfy immortal souls. And so the URSINI, daring to climb higher still and to storm HEAVEN itself, led colonies thither and filled that commonwealth with new and mighty citizens. Of these, some were arrayed in the purple of MARTYRS, others in the white robe of innocence[?]; and the abundant light of birth which each had drawn from the URSINE PRINCES they rendered brighter still by the splendor of their lives and by an illustrious death.

[Margin: From the Ursine rose-garden many illustrious Saints have sprung forth.]

And so — that from all these I may pass over, in a certain sacred silence, the ADALBERTS, the VOLUSIANI, the JOHNS OF TROGIR [the Orsini bishops of Trogir], and many other MEN lavish of great souls and most eminent for holiness of life — if I bring forth for YOU but One, BENEDICT [St. Benedict] (whom YOUR cradle claims as its own), the progenitor of that religious and mighty Offspring: who will deny that a truly extraordinary SUN arose from the URSINI, by whose single wholesome rising Religion, well-nigh dead, revived as though warmth had been breathed back into it?

[Margin: Bonifacius Symoneta [Bonifacio Simonetta], Benedictine, book 1, *On the Christian Persecution*, letter 7, Milan edition, 1492. Platina [Bartolomeo Platina], in the *Life of John I, Pontiff*, Cologne and Venice edition, 1583, and Louvain, in the *Index of Contents*. The Ursine Tree [*Arbor Ursina*], etc.]

And if I show that same Benedict to YOU — now slipped away from his Noble house, now led into pathless solitudes, now tumbling among the thorns of the bramble — who will then deny that a ROSE was born from the URSINI: a rose that, blushing among thorns, seized every eye with its loveliest color and everyone's senses and soul with its sweetest fragrance? So that it now seems to me the less surprising if, to a Rose so fragrant, even domestic[?] examples come thronging in our own day as well — drawn, that is, from kindred blood.

[Margin: Living examples of Ursine piety.]

Of this kind you yourself, ILLUSTRIOUS DUKE, were but lately an example: when, with an even mind, you allowed two darlings of YOUR Family — full brothers, choicest PRINCES, already distinguished by honors of their own, the one FRANCESCO [Francesco Orsini], the other VIRGINIO [Virginio Orsini] — to renounce all human things and, scorning the glory of the Court, to hide themselves in religious retreats; where, set in obscurity, they might shoot forth the rays of their VIRTUE farther than before they had cast those of their DIGNITY. This was the mark of YOUR art and genius: that, placed upon the highest peak, where the splendor of YOUR line could scarcely grow any further, you learned by that very RELIGIOUS obscurity to become brighter and more illustrious.

Therefore, being alike an admirer of this MOST ILLUSTRIOUS OBSCURITY and of YOUR MOST GLORIOUS Splendor, I judged it wholly fitting that, while on earth the URSINE PRINCES shrink from being gazed upon by mortals, all mortals should instead look up to the URSINE ROSE in the SUN — which CELESTIAL URSINE ROSE, a new and truly great PHENOMENON OF THE SUN [Solis Phaenomenon],

I reverently dedicate TO YOU, magnanimous DUKE [Tibi magnanime Dux — printed "MAGNAMINE"]: in the making of it, the adorning, and the polishing — so that I might carry out the work — you, in your generosity, met a great and liberal expense. By this immense benefaction you have both proved yourself truly a beneficent PRINCE, and have bound me to YOU and to YOUR MOST ILLUSTRIOUS RACE by a new and everlasting tie; and you have most closely obliged all Letters, and all men of Letters, who are to gain from this either fruit or some taste of it. For there will be, I think, not a few whom to this very day either a blind error, or ignorance of this PHENOMENON, has vexed — led far astray from the truth and from the true path. If perhaps they are brought back into the way through me, they will owe all their thanks to YOUR ROSE, and will proclaim it openly. For just as in the fables THAT man [Lucius], by biting off a ROSE-LEAF, put off the Arcadian beast [the shape of the ass]; so they themselves, by the good office of the URSINE ROSE, will have dispelled the error of their ignorance.

With these good wishes I bring my Letter to a close. May GOD keep YOU — O illustrious [prince] among Princes — and YOUR glorious House unharmed, for the public good. At Rome, from the Professed House of the Society of Jesus, in the year 1629, on the third day before the Nones of July [5 July 1629].

To the Reader [Ad Lectorem]

They report that it is the nature of the CROW that, when it has found food, it at once betrays it with an ill-timed cawing, and thereby summons upon itself a self-inflicted danger — as much to itself as to the prey it has won — which it would have escaped had it chosen to enjoy its windfall in silence. Whence the Lyric poet [Horace] aptly writes:

But if the crow could feed in silence, it would have more food, and far less strife and envy. [Horace, *Epistles* I.17.50–51]

To that bird, indeed, since it merely follows the instinct of nature, criticism readily grants pardon; but in a man, thoughtless talkativeness in disclosing his own secrets — as it is a fault, so it is deserving[?] — stands free of neither punishment nor reproach: for lapses that are subject to human judgment win only a slower indulgence. For who compels you to betray what is your own? And if the premature revelation even of one's own secrets does not escape a just mark of imprudence, what are we to think of those who itch to publish what belongs to others, and usurp it as their own possession, and drive the lawful Owners from what they hold? For my part, most kind Reader, I have never surveyed my own findings — slight indeed, and few — with any grandeur, nor thrust them impetuously upon others; rather I have covered them over and neglected them. And just as I judge the labors of others worthy of commendation and gladly adorn them with their own praise, so to claim them for myself, even if I could, I truly disdain — not because they are worthless, but because they are another's.

In this I emulate the nature and shrewdness of the URSINE creature [the bear]: for the animal lives by its own juice, and by its own right claims that for itself — "I AM MY OWN NOURISHMENT" [Ipse alimenta mihi]. This URSINE motto I too, in this URSINE ROSE, claim for myself without arrogance and without injury to anyone: from it I weave garlands out of my own leaves, not others'; and I press out the rosy juice and oil by my own sweat and labor, not another's. For as to the fact that, together with my own Observations, I bring in the courses of the solar spots [Macularum solarium cursus] of Fr. Georg Schönberger [P. Georgius Schoëberger] and Fr. Charles Malapert [P. Carolus Malapertius], arranged in order by me — it is only fair that those who once, at Ingolstadt [Ingolstadij], first drew from me the doctrine and grounding of this appearance should now reap some fruit of their own industry, while I illuminate their Observations with my own, and [do justice to] their merits...

they are not without praise for their own industry, even though those observations are not of a kind that would let the full and perfect courses of the Spots be deduced from them alone — courses that cannot possibly be obtained unless the horizontal contacts are marked down with the greatest exactness. Where these are lacking, the true places and motions of those solar bodies are proclaimed in vain; and, having no mathematical certainty, they are entered into the Catalogue of circumsolar Planets on the strength of nothing but a certain arbitrary conviction.

I would have wished all the more that I also had at hand the observations which Fr. Johann Baptist Cysat [Johann Baptist Cysat] and Fr. Chrysostomus Gall accurately recorded at Ingolstadt; for their strenuous labors of many years, undertaken on my behalf, deserved as much. Yet, God granting, I shall not neglect them in my later attentions, but shall bring them forth with interest; and from them, together with my own observations of those same periods, I shall sift the records of others near them in time, which I keep collected in Germany. The frivolous inferences drawn from these, and the false doctrine, I shall correct — not by my own judgment, nor by the impulse of the headlong crowd, but from the phenomenon itself (as a true mathematician ought), shown more clearly than the Sun and more fully than I can here provide in this Work. For ever since my Apelles hid behind his painting — or Ulysses behind the shield of Ajax — not a few have come forward who, taking up a brush in their hands in place of a cobbler's awl and meaning to perfect another's picture, spoiled it by their clumsiness. Others assailed the solar phenomenon as though setting upon the chaste Penelope in Ulysses' absence, and harassed it with astonishing artifices, while each strives to seize her as his own bride and lead her home, and thinks it a fine thing to make himself illustrious with SOLAR DARKNESS and to adorn himself with HEAVENLY SPOTS. The result is that a Reader ignorant of the historical truth may well hesitate, and cannot easily discern to whom, in so great a throng of Rivals, he should award this elegant Helen. For there are those who favor this man rather than that out of ambition and hatred; those who do so out of zeal for their homelands and nations; those who do so out of the affection of friendship; those who do so out of mere persuasion and authority alone; those who do so misled by error; and there are, finally, those who, won over by the truth, decide what is fair. So that I may hold up before all of them a sure torch of truth, I here candidly append a brief, plain, and uncorrupted summary of what took place regarding the discovery of this Phenomenon — apart from what is said abundantly in Book 1, chapter 2, and in Book 3, in the General Notes, Note 28, and elsewhere in the Notes to the Appendix of the Twenty-sixth Image of the Observations, page 222 and following, as well as in other places.

In the year 1611, then, being Professor of Mathematics at the University of Ingolstadt, in the month of March, I climbed the tower of our church and directed the telescope [Telioscopio] — suitably dimmed against the Sun by a moderate cloud — and, prompted by no prior rumor but drawn by a spontaneous eagerness to examine the Sun, I detected the solar Spots for the first time, in the company of Johann Baptist Cysat, then a student of Theology, who from that time urged me strongly to prepare tinted glasses. While I was engaged in this, in the month of October of the same year there came round again, in their usual way, some days interspersed with moderate clouds. These invited observation of the Sun, and I directed the optical tube [tubus opticus] at it from my chamber (just as you have it rendered from Apelles' Tabula in Book 1, page 63) — namely on the 21st, at the 21st astronomical hour, or German hour, that is, 9 hours after midnight, in the forenoon or morning — and in it I saw the Spots a second time, and showed them to many other Fathers and students until the 10th hour. About that same time Fr. Adam Tanner [Adam Tanner] first obtained a sight of these same Spots from his own room (as he himself recounts in Volume 1, Disputation 6, *On the Creation of the World*, Question 3, §5, *On the Solar Spots*, no. 69), prompted, as he says, by some rumor or other — though not even the faintest whisper of any such rumor reached my ears before I first saw the Spots. For up to that time I had not made public the March sighting of them, which was in fact the first. From that day onward I continuously employed a blue-tinted tube prepared for this purpose, and other methods of observing — by transmission and by reflection — and above all I at once devised the method of applying the perpendicular, and gradually taught it to other suitable pupils.

For a gaze directed at the Spots through the tube carries no weight of certainty at all toward the physical consideration of them — the question of What they are and Why. Their number, their shape, their size, their apparent color, their position, their order, their progression, their coming-together, their spreading, their increase, their decrease, their appearance, their disappearance, their duration beneath the Sun, and whatever else of the same kind proceeds from optical causes and pertains to opticians in its own right — all this the tube, directed at the Sun, shows to the eye in a general way. Yet you do not on that account have these things projected onto paper; and even if you did possess them, you would not thereby correctly deduce the true motion and place. And where these are lacking, the physical nature of the Spots is not discussed with sufficient solidity. Therefore I applied myself at once to projection onto paper and to the drawing-in of the perpendicular, and took Fr. Cysat as my inseparable companion in observing. And since I saw that many were delighted by these solar novelties, I continued my daily observations, and communicated them to many — especially

to Fr. Gretser [Jakob Gretser] and Fr. Tanner — partly in person, partly through the said Fr. Cysat. And because Fr. Jakob Gretser, without my knowledge, informed of the matter the most noble gentleman Marcus Welser [Marcus Welser], Duumvir and Prefect of Augsburg, it came about that at the beginning of the following year, 1612, Welser published four of my several letters, together with some observations, under the name of Apelles. For to the Reverend Father Theodor Busaeus [Theodor Busaeus], who then had charge of the Province of Upper Germany, the new Phenomenon was indeed pleasing; yet it did not seem right that in a matter so sudden, and still suspect to many, my name should be affixed to it. As a result, this new Phenomenon came to the notice of the City and the World sooner than I would have wished, since Welser scattered it into all the provinces of Europe and sought out the opinions of the learned. These opinions I still keep in Germany, to be of use perhaps in their own time — and among them the one by Protogenes is to be reckoned in no lowly place.

[Margin: The Censor of Apelles knew in advance, before delivering his censure, who Apelles was.]

One person, however, an Italian, extorted from Welser the true name of Apelles before he wrote up his censure of Apelles' Tabula; for what reason he did so will become clear in the first book. The discovery, to be sure, pleased him; the author, once revealed, did not. Had the author remained unknown to the Censor, Apelles would surely have stayed safely hidden behind his Tabula. What made the Censor too bold was the disclosure of the writer's lowly station (as it perhaps seemed to him) — a writer whom Christian patience would teach to tolerate the accusations brought against him, and whom Religious Obedience would forbid to repel them. For many years, indeed, I endured this, and wisely bore the indignities committed against Apelles' Tabula.

[Margin: The method of applying the perpendicular was entrusted to many.]

Meanwhile, however, through myself and my associates — whether pupils or friends — for the sake of truth and of an innocence under attack, to be defended in its own good time, I procured many, indeed continuous and almost daily, observations of the solar Spots, at home and abroad. And so that these might serve the investigation of their motion, I entrusted the practice of applying the perpendicular — as a secret matter, not to be shared with others against my will — to several persons: chiefly to Fr. Johann Baptist Cysat, my successor at Ingolstadt; to Fr. Chrysostomus Gall, afterward mathematician at Lisbon; to Fr. Georg Schönberger, who succeeded me at the University of Freiburg im Breisgau; to Fr. Giuseppe Biancano [Giuseppe Biancani], mathematician at Parma; to Fr.

Kaspar Ruess [Kaspar Ruess], sent to the West Indies; to Fr. Wilhelm Weli [?]; and to others; but above all to Fr. Charles Malapert [Charles Malapert], who, moved by the novelty of the solar phenomenon, when he was setting out for Poland in 1612, turned aside to me at Ingolstadt in order to view the Spots he had never seen before and to learn the method of observing. This method, together with the art of marking down the perpendicular — that is, of drawing the vertical section — I gladly imparted to him, under the same law of secrecy as with the others: that he keep it to himself and not publish this Phenomenon in print without consulting Apelles, since Apelles himself was minded one day to put the final hand to his own Tabula and to publish, with due acclaim, his own auxiliary observations together with those of his friends — observations which were always received by everyone with kindly minds and favorable ears. On his return from Poland, the same Fr. Charles came again to Ingolstadt and, in my absence, received from Fr. Cysat — under the same conditions — the method of inscribing the ecliptic.

For I made Fr. Cysat a partner in this secret from the outset, and Fr. Georg Schönberger long afterward. Hence, if ever any of the streams that flow from us concerning this solar Phenomenon should fall into your hands and before your eyes, you will judge without difficulty from which springs they issued. For this matter was confined for many years within the domestic walls of our Society; and I am quite sure that, from the first year of the discovery — which was 1611 — down to the year 1618, no observations distinguished by the perpendicular, and thus most suited for reaching any certain conclusion, can be produced except such as were made or taught by the Ingolstadt mathematicians.

[Margin: The observations made with the perpendicular take their origin from Apelles.]

What was accomplished in later years — where, by whom, and how much — the coming day will reveal. Moreover, Apelles' excessive silence seems to have made his rivals talkative, if not also biting; for in later years they even prosecuted him as a defendant and as a Plunderer of others' discoveries. From the infamous suspicion of that charge I clear Apelles in the First Book, I bring the errors of the Censor of Apelles into the open, and I consecrate and dedicate the laurel of Discovery to the ROSA URSINA;

[Margin: See Book 1.]

and thus, in accordance with the motto of Cardinal Orsini, I MYSELF PROVIDE NOURISHMENT FOR MYSELF, and do not beg it from others.

[Margin: Book 1: the subject-matter.]

But since, along with ROSES, thorn-pricks too are amply put forth — so that of this URSINE rose, no less than of the natural ROSE, one may pronounce the second Ursine motto, SMOOTH TO THE SIGHT, ROUGH TO THE TOUCH — therefore in the Second Book I point out, dispel, and make light of the difficulties that arise concerning the solar Phenomenon: from the instruments, from the method of observing and arranging the Spots, from the heaven, from the Sun itself, and from the Observer.

[Margin: Book 2: the content.]

On that occasion I discuss much about the organ of Sight, much about the Optical Tube that others have not touched on, and much about optical lenses and their Refraction; I explain the nature, construction, composition, and use of the Optical Tube, and provide a concise demonstration of it.

[Margin: The telescope is demonstrated in Book 2.]

I faithfully hand down the practice of observing, of drawing in the perpendicular, of inscribing the ecliptic, of arranging the courses of the observed Spots and Faculae [faculae], and of avoiding errors; and thus in the Third Book I secure undoubted credibility. In it I set before the eyes the courses of the Spots and Faculae traced upon the Sun, over a continuous series of many years, months, and days, like elegant garlands of Roses woven together with mutual links. For just as THE DAY ITSELF OPENS the ROSES, so too it opens this solar Appearance — not all at once but in succession, over the passage of much time, with long patience and untiring zeal. For you will see Course linked to course, Spot to spot, Facula to facula; you will find a Spot succeeding a Facula, or a Facula a Spot, in a pleasing alternation of exchange; you will observe light supplied by the Faculae now before, now behind, now alongside. You will behold whole clusters of Faculae mingled with the Spots, like bundles of roses set off with the radiance of carbuncles; nor will the Spots themselves lack their own whitening tracts of Faculae. Indeed, Nature — the most faithful handmaid of truth — dispenses even the very laurel-berries as a token of victory, when she distributes BLACKENING KERNELS at the very navels of the Spots. The Shadows and secondary Spots, meanwhile, present a not-unpleasing likeness of leaves; and while they wander, as if scattered at random, over the whole compass of the solar circle, they furnish a fragrant path and a soft carpet for the laurel-crowned Bears as they wheel the solar pomp and the ROSA URSINA around the celestial ring.

Once the outward appearance and gait of the ROSA URSINA has been seen, the Fourth Book advances to its inner parts, and uncovers its birthplace and cradle in the very palace of the Sun. Indeed, it shows by unmistakable signs that it is the Sun's own offspring: for it rivals the Sun both in the excellence of its light and in the same swiftness of motion. It performs the same annual circuits and the same monthly rounds about the very center of the solar sphere, together with the Sun, and unfolds itself joyfully now in the upper regions of the heaven, now in these lower ones. And by what method this comes about, the Theoretical Account itself, drawn from the Phenomenon, demonstrates more clearly than light.

It is commonly said that Bears shape their formless cub by licking it: hence that Ursine Emblem, INDUSTRY SHAPES [IT]. And if the Bears' STEADY Industry shapes their cubs, then surely — so that nothing of elegance and charm might be wanting to this URSINE ROSE of mine, now cultivated for so many years — besides the things I have adduced from manifest sense-experience and established by firm reasoning, I have also fetched adornment from elsewhere. And so, at the close of the Work, I bring forward for the Reader's weighing much concerning the nature of the Sun, of the stars, and of the heaven — whether FIERY, or CORRUPTIBLE, or, finally, LIQUID — from authority both Sacred and profane, both ancient and recent, with the very sources of the Writers laid open and set forth. Ornithologists write, and those devoted to fowling confirm, that barren female Partridges, out of longing for offspring, steal eggs from fertile mothers, and by brooding on the stolen eggs hatch out others' chicks — which then, recognizing the heard voice of their natural mother, at once desert the stepmother and follow their true parent. Many have until now brooded over this solar Phenomenon as though over an egg sprung from the very brain of Jupiter, and have hatched out their own wisdom like a new Pallas. Many alien voices have been heard, and are heard, luring the solar chick to themselves. Yet THERE IS ONE TRUE MOTHER: the one Truth of the Phenomenon.

He whom the solar Phenomenon follows is himself the true Author of the Phenomenon; and as to whom it truly follows — of this, fair Reader, be you the impartial ARBITER.

At Rome, in the Professed House of the Society of JESUS, in the year 1629, on the third day before the Nones of July [5 July].

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II.

INDEX OF BOOK THREE.

Summary of the Book.

- BOOK THREE contains images of the Sun observed by various persons, in various places and years, and reduced by the Author into the order of their courses; explanations of the images; a new heliotrope [*Heliotropium*] machine; the investigation of the angle that the ecliptic makes with the meridian at a given point of the ecliptic; the drawing of the ecliptic into the observations, with various demonstrations; and likewise a Table of the

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INDEX OF BOOK FOUR.

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- BOOK FOUR is divided into two parts. The first treats the properties of the sunspot phenomenon's motion: the unevenness of refraction caused by optical lenses; the physical increase and decrease of the sunspots, and their brightness and darkness. It then examines the nature of the nuclei [*Nuclei*] within the spots, the shape of the spots, the origin and extinction of the spots, and the manner in which they begin. Finally it disputes about the true location of the phenomenon, and presents several returning spots [*maculae reduces*].

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(continuation)

The second part concerns the motion of the sunspots [*maculae*]: their royal path [via Regia] and its causes; the apparent great circle of the Sun, and by how much it is smaller than the hidden arc; the magnitude of the solar diameter; the magnitude of the sunspots; the nature of the phenomenon, its age, cause, and effects; its light and colour; and finally, concerning the fiery, corruptible, and fluid nature of the heavens, the opinions of many of the holy Fathers, theologians, philosophers, and astrologers — both recent and ancient — are brought forward.

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Cap. XVIII. Pronouncement X: The paths of all the spots — about, or a little after, the beginning of June rectilinear — are gradually bent into curvilinear ones, more and more arched, until, a little after the beginning of September, they have become most convex toward the south [Auster] and set in equilibrium; from which again, through three months — namely September, October, November, to the beginning of December — they gradually decrease, and return into the annual straightness. These curvatures are, other things being equal, alike in their manner of growth (the one summer-autumnal, the other winter-vernal), and likewise similar in figure, and equal in quantity and duration; yet opposite in situation: for the convexity of the itinerary arcs always inclines toward the south, the concavity always toward the north; and all the rest shown in the prior half-year happen here too, but with contrary situation. p. 436.

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- St. Anselm [Anselm]
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- Antonius Lucianus
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- Aratus [Aratus]
- Aristotle [Aristotle]
- Arnobius [Arnobius]

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- St. Augustine [Augustine]
- Agostino Steuco of Gubbio [Agostino Steuco]
- Agostino Torniello [Agostino Torniello]
- St. Basil the Great [Basil the Great]
- St. Basil, Bishop of Seleucia [Basil of Seleucia]
- St. Bede [Bede]
- St. Bonaventure [Bonaventure]
- St. Bruno [Bruno]
- Burgensis [Paul of Burgos]
- Caius Julius Hyginus [Hyginus]
- Caesarius [Caesarius]
- Cassiodorus [Cassiodorus]
- Catharinus [Ambrogio Catarino]
- Kedrenos [George Kedrenos]
- Christoph Clavius [Christoph Clavius]
- Cicero [Cicero]
- Claudius Marius Victor [Marius Victorius]
- Cleanthes [Cleanthes]
- St. Clement [Clement]
- Copernicus [Copernicus]
- Cornelius a Lapide [Cornelius a Lapide]
- Crates [Crates]

- St. Cyril of Alexandria [Cyril of Alexandria]
- St. Cyril of Jerusalem [Cyril of Jerusalem]
- Didymus [Didymus]
- Diodore of Tarsus [Diodore of Tarsus]
- Diogenes [Diogenes]
- Diones
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- Denis the Carthusian [Denis the Carthusian]
- Dracontius [Dracontius]
- Drepanius Florus [Florus of Lyon]
- Manuel de Sá [Manuel de Sá]
- Empedocles the Philosopher [Empedocles]
- St. Epiphanius [Epiphanius]
- St. Ephrem [Ephrem]
- Eucherius [Eucherius]
- Eusebius of Emesa [Eusebius of Emesa]
- Euthymius [Euthymius]
- Fabrizio Paolucci of Forlì [Fabrizio Paolucci], first Bishop of Città della Pieve
- Federico Cesi, Prince of Sant'Angelo [Federico Cesi]
- Fernando Quirino de Salazar [Fernando Quirino de Salazar]
- Francisco Foreiro [Francisco Foreiro]
- Francis of Meyronnes [Francis of Meyronnes]
- Francisco Suárez [Francisco Suárez]
- Francisco Vallés [Francisco Vallés]

- Gabriel Vázquez [Gabriel Vázquez]
- Galileo Galilei [Galileo Galilei]
- Générard [Gilbert Générard]
- St. Gregory the Great [Gregory the Great]
- St. Gregory of Nyssa [Gregory of Nyssa]
- St. Gregentios of Taphar, Archbishop [Gregentios]
- William of Auxerre [William of Auxerre]
- Haymo [Haymo of Halberstadt]
- Hermas, disciple of St. Paul [Hermas]
- Heraclitus [Heraclitus]
- St. Jerome [Jerome]
- Girolamo Vielmi of Venice, of the family of St. Dominic, Bishop of Aenomina [Girolamo Vielmi] [recte: Aemonia?]
- Girolamo Maggi [Girolamo Maggi]
- Jerónimo de Oleastro, the Portuguese [Jerónimo de Oleastro]
- St. Hilary [Hilary]
- St. Hippolytus [Hippolytus]
- Orazio Grassi [Orazio Grassi]
- Homer [Homer]
- Hugo Carensis
- Hugh of St. Victor [Hugh of St. Victor]
- Iacobus Bullius Prunæus
- Jacopo Nacchianti, Bishop of Chioggia [Jacopo Nacchianti]
- Jacques Salian [Jacques Salian]
- Jacques Bonfrère [Jacques Bonfrère]

- Giovanni Antonio Roffeni [Giovanni Antonio Roffeni]
- Ioannes Alvarez [Juan Álvarez]
- Johann Baptist Cysat [Johann Baptist Cysat]
- Giovanni Battista Folengo, Cassinese monk [Giovanni Battista Folengo]
- Giovanni Battista Lauro of Perugia [Giovanni Battista Lauro], of the Privy Chamber of Our Lord Urban VIII and secretary of the sacred Senate of the Cardinals
- St. John of Damascus [John of Damascus]
- St. John Chrysostom [John Chrysostom]
- Johann Faber, of Our Lord's herbalists [Johann Faber]
- Johannes Kepler [Johannes Kepler]
- Jean Lorin [Jean Lorin]
- Juan Maldonado [Juan Maldonado]
- Jan Mikołaj Smogulecki [Jan Mikołaj Smogulecki]
- Giuseppe Biancani [Giuseppe Biancani]
- Flavius Josephus, the historian [Josephus]
- St. Irenaeus [Irenaeus]
- St. Isidore, Bishop of Seville [Isidore of Seville]
- St. Junilius [Junilius]
- St. Justin Martyr [Justin Martyr]
- Juvencus the presbyter [Juvencus]
- Lactantius Firmianus [Lactantius]
- Cardinal Latino Orsini [Latino Orsini]
- Laertius [Diogenes Laertius]
- León de Castro [León de Castro]

- Lucretius [Lucretius]. Lucinus
- Luis de la Cerda [Luis de la Cerda]
- Luis de Molina [Luis de Molina]
- Lyranus [Nicholas of Lyra]
- St. Macarius [Macarius]
- The Master of the Sentences [Peter Lombard]
- M. Vitruvius [Vitruvius]
- Martin Becanus [Martin Becanus]
- Martín del Río [Martín del Río]
- Martianus Capella [Martianus Capella]
- Marin Mersenne [Marin Mersenne]
- St. Maximus [Maximus]
- M. Manilius [Manilius]
- St. Methodius [Methodius]
- Metrodorus [Metrodorus]
- Michaël Petrus
- Nicolaus Serarius [Nicolaus Serarius]
- Oecumenius [Oecumenius]
- Origen [Origen]
- Ovid [Ovid]
- St. Paterius, notary of the Roman Church [Paterius]
- St. Paul the Apostle [Paul]
- St. Peter the Apostle [Peter]
- Pedro Hurtado de Mendoza [Pedro Hurtado de Mendoza]

- St. Peter Damian [Peter Damian]
- Peter Comestor [Peter Comestor]
- Pererius [Benet Perera]
- Pierius [Pierio Valeriano]
- Filastrius, Bishop of Brescia [Filastrius]
- Philolaus the Philosopher [Philolaus]
- Philip the Solitary [Philip Monotropos]
- Pineda [Juan de Pineda]
- Plato [Plato]
- Pliny [Pliny]
- Plutarch [Plutarch]
- Proclus [Proclus]
- Procopius [Procopius]. Ptolemy [Ptolemy]
- Raffaello Aversa of Sanseverino, General of the Clerks Regular Minor [Raffaello Aversa]
- Richardus Pampolitanus
- Richard of St. Victor [Richard of St. Victor]
- Cardinal Robert Bellarmine [Robert Bellarmine]
- Christoph Rothmann [Christoph Rothmann]
- Rupert, Abbot of Deutz [Rupert of Deutz]
- St. Severianus [Severianus of Gabala]
- Sarsius [Lotario Sarsi, pseudonym of Orazio Grassi]
- Seneca [Seneca]
- Simon Marius [Simon Marius]
- The Sibyl [Sibylla]

- Strabus [Walafrid Strabo]
- Tertullian [Tertullian]
- Theodoret [Theodoret]
- Theophylact [Theophylact]
- St. Thomas [Thomas Aquinas]
- Tostatus [Alonso Tostado]
- Tycho Brahe [Tycho Brahe]
- Virgil [Virgil]
- Xenophanes [Xenophanes]
- Zacharias, the Christian Philosopher, Bishop of Mytilene [Zacharias of Mytilene]

Rosa Ursina, Book One [Rosae Ursinae Liber Primus]

The Occasion of Writing [This Work] in Rome — Chapter I [Occasio scribendi in Vrbe. Cap. I.]

In the year 1624, kind Reader, I had come to Italy in the company of the most serene Archduke Charles of Austria [Karl of Austria], of most devout memory, and had been sent by him from Genoa to Rome, to the Supreme Pontiff, to transact certain business. While staying there, I shared with friends a few of the many things I had noted, since the year 1611, in continuous observations of the Sun. They urged me insistently not to go on suppressing labors so useful to Philosophy; and I promised to satisfy them, as far as my occupations should allow, once I had returned to Germany and settled the affairs of the College of Neisse [Nissensis Collegii] entrusted to me. To those who complained of longer delays I offered the plain truth: that the observations, made for the most part in Silesia, had been left behind there, and could not be laid out, given the great distance between the places, the injuries of the times, and the difficulties of travel. In fact, however, over and above this, my mind—drawn off to other business and to travel—shrank from so serious an undertaking in an alien place

and time, and aspired to nothing but returning as quickly as possible to its appointed duty and studies.

But through the occasion you will presently hear of, circumstances arose that drove me—reluctant, and largely deprived of the support of my earlier studies—to write; and they compelled me to make fresh observations from time to time, so that I might set forth, in its properly ordered parts, the Solar Phenomenon [Solare Phaenomenon]—once begun and never abandoned by me, and even now, in its chief points, still largely unknown—by means of the most accurate diagrams, presented to eyewitnesses and to the judgment of the learned. For I hoped it would turn out thus: that I might vindicate the truth, for the public good of those who philosophize, from the errors so confidently spread abroad about so great a matter; and that I might free myself—one who lurked in obscurity and troubled no one by word or deed—from the calumnies bitterly heaped upon me; for by a longer silence I might have done too much harm to the reputation of those whom, while [each] was alive, it had been most necessary to consult.

[Margin: Apelles never took his hand from his Panel (*Apelles manum à Tabula nunquam deposuit*).]

[Margin: Apelles's silence, had it lasted longer, would have been harmful (*Apellis taciturnitas diuturnior fuisset noxia*).]

While staying at Rome, then, as I have just recalled, I had some free time left over from my duties. Thinking it should be spent pleasantly, and not without profit, in reading some book, I inquired what new thing had appeared in Mathematics; and there was offered to me, among others, a certain book in the Italian tongue, printed at Rome in the year 1623, whose title was *Il Saggiatore*—in Latin you would call it the *Trutinator* [Weigher] or *Libripens* [Balance-holder], or the *Symbellator* [Scheiner's coinage; sense uncertain]. (For on the occasion of my Italian travels I had begun to be able to understand something written in this language, and to render it into Latin.)

When, therefore, I took the book into my hands and had scarcely opened it, behold!—right at the very outset [Margin: *a — Il Saggiatore*, p. 2, lines 19–24. Upon Apelles, who had lain hidden for twelve years after his Panel, the necessity of defending himself was imposed, on account of his good name being injuriously assailed.]—I perceived that Apelles [Scheiner's pseudonym], after his Panel on Sunspots [Maculae Solares]—a Panel affected rather than perfected, and still lurking now through so many years—was being attacked and charged with base theft (to say nothing of my studies on the Elliptical Sun, published around the

year 1615, and on the celestial Refractions [Refractiones coelestes], around 1617, in the course of the work being called a mockery and an object of childish contempt). [Margin: *b* — The same, p. 209, lines 7–16.]

And, to confess frankly, at first sight I supposed that it was not Apelles but others who were being censured by the Italian Censor [= Galileo Galilei]. For I knew of no one ever injured by Apelles—by writing, word, deed, or sign—such that he should be assailed by that man with unfounded accusations for no cause. But I had known of certain published comments on Sunspots; moreover I had long since seen and read that *Jovial World* [*Mundus Iovialis*] of Simon Marius [Simon Marius], and so I supposed that these darts were being aimed by the Symbellator against him [Marius], or against those others. Yet after I saw that Marius was afterward named and deliberately censured—not for these, but for other offenses against the writer—and that a complaint had been raised in the very matter of Apelles's own Panel (its chief charge being that certain persons had attempted to arrogate to themselves the glory of the FIRST INVENTION of Sunspots, a glory that belonged—so the Censor said—as his own); and since these and similar things did not fit anyone else, and, besides Apelles, no other Inventor of Sunspots had come forward who might seem to cause the Censor trouble regarding the glory he proclaims as his rather than another's, whether by profession or by possession; and since the Censor too was always borne with sidelong eyes singularly upon him [Apelles], and on every chance occasion would harass him wondrously, as will be abundantly clear from the course of this book—for all these reasons, scarcely any room was left for doubting that the closing clause of the complaint, which I shall now weave in, was directed at Apelles.

[Margin: Apelles was chiefly the one attacked by the Censor (*Apelles potissimum à Censore impetitus*).]

For this is how he has it in the *Libripens* [= *Il Saggiatore*], at the middle of page 2:

[Margin: The first foundation of the Apellean defense (*Fundamentum 1. Apologiae Apelleae*).]

(Il Saggiatore, p. 2) [in Italian]: "Le lettere delle Macchie Solari, e da quanti, e per quante guise fur combattute? e quella materia, che douerebbe dar tanto campo d'aprir de gl'intelletti ad admirabili speculationi, da molti, ò non creduta, ò poco stimata, del tutto è stata vilipesa, e derisa; da altri per non volere acconsentire à miei concetti, sono state prodotte contro di me ridicole, & impossibili opinioni; ad alcuni constretti, e conuinti dalle mie raggioni, hanno cercato spogliarmi di quella gloria, ch'era pur mia: e

dissimulando d'hauer veduto gli scritti miei, tentarono dopo di me farsi primieri Inuentori di merauiglie così stupende."

[English:] "The letters on Sunspots—by how many, and in how many ways, were they assailed? That subject, which ought to have opened so wide a field to the intellect for admirable speculations, was by many either disbelieved or little esteemed, and was utterly disparaged and derided. Others, unwilling to assent to my ideas, brought forth against me ridiculous and impossible opinions; and some, cornered and convicted by my arguments, sought to strip me of that glory which was, after all, my own—and, pretending not to have seen my writings, tried after me to make themselves the first Inventors of such stupendous marvels."

Scheiner's own Latin rendering runs: "The letters on Sunspots—by how many, and in how many ways, were they assailed? That subject, which ought to have opened a field to the intellect for admirable speculations, was by many either disbelieved or little valued, and was altogether disparaged and derided; by others, because they would not acquiesce in my conceptions, ridiculous and impossible opinions were produced against me; and some, cornered and convicted by my reasonings, strove to despoil me of that glory which was nevertheless my own, and—dissembling that they had seen my writings—made themselves 'THE FIRST AFTER ME,' the INVENTORS of marvels so stupendous."

Most of these charges, I say, seem to point a manifest finger at Apelles. For although Apelles never held the Solar Phenomenon cheap, but always prized it most highly, and most soundly proved its truth and reality in his Panel, yet in many things he differed from the Censor's tenets—things he argued partly from his own view, partly from the opinion of the Peripatetics, and that either absolutely or only hypothetically, and by way of inquiry. For this reason Apelles is partly ridiculed by the Censor, partly most fiercely attacked.

And because Apelles, near the end of his fifth letter—which he wrote on 16 January 1612 and sent to Marcus Welser [Marcus Welser], Duumvir of Augsburg—might perhaps have seemed to hint that he was the first Inventor of the Spots, the Censor, in his own first letter (composed on 4 May 1612), at once seizes upon the Reader and, as it were, protests that he had observed the Solar Spots eighteen months before that time. Indeed, to snatch all primacy in these discoveries away from Apelles and draw it to himself, he leaves no stone unturned in his third letter—turning his pen so artfully, so cunningly, that he may lead the Reader into

the persuasion that his own views about the Spots (set out chiefly in the first and second letters), as though [prior],

[Margin: The Censor's first irruption and stealthy encroachment upon the Solar Phenomenon (*Prima Censoris in Phaenomenon Solare irruptio & irreptio*).]

[had been committed to writing] before Apelles's letters—the fifth especially, which stands in the more accurate second Disquisition. On the artifice of this, more will be said by design below, near the end of this book, in the eleventh chapter, to which I refer the Reader.

Furthermore, that the passage cited from the *Libripens* was aimed chiefly at Apelles is confirmed above all by this: that a man who—having shared his own writing with the Censor, and with his assent, if not by word of mouth—plainly touches on the same matter, openly and in plain oracles makes manifest what the Censor mutters only in general in his *Libripens*, and, as it were, through obscure riddles, and hurls at Apelles as if from ambush. For the *Discourse on the Comet* of the year 1618, published at Florence in 1619, also dragged Apelles—vainly lurking after his Panel—into the midst of the whole Academic Amphitheater, and, on page 3, from line 8 to 15, openly set him up as a usurper of another's glory, an invader of another's harvest, and a plunderer of [another's] teaching. For it says this:

[Margin: The first foundation of the Apellean defense is confirmed from another [argument] built up elsewhere against Apelles (*Fundamentum 1. Apolog. Apelleae confirmatur ex alio alibi in Apellem extructo*).]

[Margin: The second foundation of the Apellean defense (*Fundamentum 2. Apol. Apelleae*).]

(*Discourse on the Comet, Florence 1619, p. 3*) [in Italian]: "Cosi fosse concesso a me, di saper leui[ssima]mente spiegare, che io non pre[z]erei meno la lode di essere stato buon Copiatore, di quella, che hanno voluto vsurparsi coloro, che d'altre sue opinioni, si son voluti fare Inuentori, e fingersi Apelli, quando co'mal coloriti, & peggio lineati disegni, hanno dato à diuedere, che e' non pareggiano nella pittura, ne anche i Maestri di mezzano valore."

[English:] "Would that it were granted me to be able to explain very clearly, that I would prize no less the praise of having been a good Copier than that praise which those men wished to usurp for themselves who, out of his other opinions, wished to make themselves Inventors and to pass themselves off as Apelleses—when, with badly colored and worse-

drawn designs, they made it plain that in painting they do not equal even the Masters of middling worth."

Scheiner's Latin version: "So might it be granted me (he says) to explain to you, to a hair, the thoughts of that man (namely the Apellean Censor); since I would reckon it no less praise for myself to have discharged the office of a good and faithful interpreter than is that praise which those men wished to usurp for themselves who tried to be held the authors of his other opinions, and feigned themselves Apelleses—although, by their badly painted and worse-drawn images, they made manifest that they do not match even middling Masters in the art of painting."

[Margin: Apelles is proclaimed an invader and usurper of another's praise and invention (*Apelles alienae laudis atque Inuentionis inuasor atque vsurpator proclamatus*).]

From this passage the following are quite clear:

[Margin: Corollaries deduced from the adduced passage of the Disputant (*Corollaria ex adducto Disputatoris loco, deducta*).]

1. That Apelles was an incompetent painter in painting his Panel: for so the Florentine disputant depicts him, with both his own and the Censor's brush—Apelles, whom, however, that man never saw, never knew, and whose Panel he did not even sufficiently consider. But I am not much angry at him, nor do I bite the stone thrown at me; I blame the one by whose sole instigation Apelles is so ill-used. For what business have the others with Apelles? Nay, what has Apelles to do with any man—he who painted and published his own works without injury to anyone?
2. That Apelles completed his Panel only after the Censor's opinions on that matter of the Solar Phenomenon had been learned and disclosed to him.
3. That Apelles, in his Panel, wished to make himself the Inventor of the Censor's opinions concerning Sunspots.
4. That Apelles is held to be such not so much from the mind of the Interpreter, as has just been said, as from the intention and the dictate of the Censor who prompts him.

Hence it is plain what the Censor's own pen is after in the *Libripens*—he who, so many years before, so clearly poured the thoughts of his own mind into another

man's pen. Let us set the words side by side, and we shall see the mysteries agree; nor is one egg so like another as you will find one meaning like the other.

[Margin: The two adduced foundations are compared, and are shown to be of the same tenor (*Duo adducta Fundamenta conferuntur, & eiusdem tenoris comprobantur*).]

The Censor says that certain persons were bound and convicted by his arguments concerning this matter of Sunspots; the Interpreter says that the Apelleses are bad painters, and brought bad pictures and worse drawings out into the open. But in effect this is the same thing: that Apelles is held convicted and bound by the Censor, and that Apelles's bad picture was caught out by that same man. Next, the Censor says that certain persons strove to despoil him of his glory; the Censor's Interpreter asserts that the pretended Apelleses wished to usurp for themselves the praise of their own dictator [the Censor]. But these coincide. Therefore Apelles is proclaimed an invader of another's praise. Finally: "some" (says the Censor) "dissembling that they had seen my writings, tried after me to make themselves the first Inventors of such stupendous marvels. Some, cornered [by my reasons], etc." The Censor's Interpreter says: "of his other opinions they wished to make themselves Inventors and to pass themselves off as Apelleses. Of his other opinions, etc." Here you see that those whom the Censor censures under the vague name of "certain persons" are, by the interpreter, openly labeled "Apelleses." The rest are so alike that they need no mutual matching. For if the Apelleses wished to feign and make themselves Inventors of the Censor's opinions, they must, by that very fact, have foreknown those same opinions; and by that very fact

[Margin: Apelles alone is censured in the cited passages (*Solus Apelles in citatis locis perstringitur*).]

they seized the Invention for themselves after the Censor; and, while they feigned themselves Apelleses, they dissembled the Censor's opinions, which they had seen. And so all the passages cited—both the Censor's and the interpreter's—agree together no otherwise than if they had been conceived in one brain, dictated from one mouth, and written by one hand.

Whence it is sufficiently clear, both from this interpretation in itself and from the soundest reasoning, that under the name of those "certain persons"—censured for laying hold of the sentiments and writings of the Censor and the primacy of Invention—no one else is meant than the single Apelles, hidden away [absconsum] after his Panel. That the Censor picked out this one man, to run into

everywhere in his history, he shows by the very deed—tweaking and deriding him in all his letters, drawing him by his own verdict into contradictions and impossibilities, calling Apelles's experiments and observations into doubt and denying them altogether; and, finally, by every possible means, disparaging his teaching and reducing it to nothing. But these matters will be shown much more specifically in the progress of the Work, and of this book especially.

Wherefore, since in this matter of the Solar Phenomenon the Censor—specifically, avowedly, and by name—pursues no one in his History except Apelles; and, by that very fact, roundly cuts off from him the first invention; and casts at him many things (absurd and ridiculous, in his own judgment), deducing manifest [absurdities] into impossibilities, as the Censor often boasts; and since he contends that this same Apelles passed over from his own former, as it were abandoned, opinions into the Censor's opinions afterward—since, I say, the Censor ascribes most expressly to Apelles nearly everything about which he complains, in the *Libripens*, against "certain persons," and does so everywhere in his History of Sunspots, yet never accuses, nor proposes to accuse, any other of these things—it is a sign that the Complaint set up by him more generally in the *Libripens* campaigns against Apelles, and is aimed at Apelles. For in it he blames the ridiculous and impossible opinions produced against him by certain persons—which, in his History, he singularly fastens upon Apelles, and upon no other.

Likewise, in his Complaint the Censor inveighs against certain persons who, after they had (as he supposes) yielded, convicted by his reasons, to the truth, swooped upon the Phenomenon and arrogated to themselves the primacy of invention; but in [his History...]

[Margin: Other conjectures by which it is proved that Apelles alone was provoked by the Censor (*Aliae coniecturae, quibus solus Apelles à Censore lacessitus probatur*).]

With all this chimes, above all, the voice of Angelus [Angelo De Filiis], who, in the Preface to the History of the [Sun]spots, page 3, summons Apelles alone—and by name at that—regarding the claim of primacy, and sets him far behind the Censor. For although he grants Apelles something in discovering the Spots without knowledge of any other Inventor, and not unwillingly concedes him a leading place in publishing them, yet from another angle he condemns that same Apelles—not obscurely; indeed, agreeably and necessarily, by the writings of the Sybellator [the Censor]. For hear what he writes about the Censor, on page 2, after the middle:

[Margin: The third foundation of the Apellean defense, drawn from the authority and assertion of Angelus (*Fundamentum tertium Apolog. Apelleae ex auctoritate, & assertione Angeli depromptum*).]

(Preface to the History of the Sunspots, p. 2, after the middle) [in Italian]:
"E come che si scorga essere à lui solo riseruato, non solamente li celesti scoprimenti insieme col mezzo del conseguirli; ma di più il penetrar con gl'occhi della mente tutta quella scienza, che d'essi hauer si puote; stauasi con vniuersal desiderio aspettando il parer suo circa di esse Macchie." And (p. 3, after the middle): "Resti per tanto noto à ciascuno esser veramente particolare determinatione, ch'in vn solo soggetto caschi nella nostra età, non solo il celeste vso del Telescopio; ma anco gli scoprimenti & osseruazioni di tante nouità nelle stelle, e corpi superiori." And a little after: "Non deuono dunque chiamarsi accidenti fortuiti, ò casuali, le gratie particolari, che vengono di sopra."

[English:] "And since it is seen to be reserved to him alone—not only the celestial discoveries, together with the means of attaining them, but, still more, to penetrate with the eyes of the mind all that knowledge of them which can be had—everyone waited, with universal longing, to hear his opinion concerning those Spots." And (p. 3): "Let it therefore remain known to each one that it is truly a singular disposition, that upon a single subject, in our age, there should fall not only the celestial use of the Telescope, but also the discoveries and observations of so many novelties among the stars and the higher bodies." And a little after: "The particular graces that come from above ought not, therefore, to be called fortuitous or chance accidents."

[Margin: The discovery of the celestial [phenomena] reserved to the Censor alone (*Detectio caelestium Soli Censori reseruata*).]

Scheiner's Latin version: "And since it appears to be reserved to him alone, not only to disclose the heavenly things together with the means of attaining them, but far more to penetrate, with the keen edge of the mind, all the knowledge that can be had of them: all men were held by a singular longing to hear his judgment about the Sunspots." And (page 3, after the middle): "Let it therefore stand known [that...] "...and then that it should be determined for each individual, in the truth of the matter, by a special prerogative, that in this our age it falls to this one man alone — not only the use of the celestial telescope [telescopium], but also the discoveries and observations of such great novelties among the stars and the higher bodies. And a little later: Therefore the particular graces that come from

on high are not to be counted among fortuitous or chance events. So he says."
[Margin: According to Angelo, in this our age the Censor alone is the sole Inventor of all celestial novelties, and the all-knowing Doctor.]

And if these things are put forward seriously and not in flattery, nor hyperbolically, but with a true mind and in the truth of the matter, then the following are certain. [Margin: Corollaries deduced from this very foundation.]

It is certain, in the first place. According to Angelo's view, in this our age no philosopher whatever, and no mathematician, has either the powers to hand, or an open road for investigating the heavens, or convenient means at his disposal; rather, all these things — in the truth of the matter, and by a singular dispensation and divine prerogative — have been conferred on the one Censor of Apelles alone. [Margin: According to Angelo: First. All philosophers and mathematicians in this our age are blind to the heavens.]

It is certain, in the second place. According to the same Angelo's opinion, Apelles could draw from his own storehouse neither the observations nor the method of observing the sunspots [Maculae Solares]; still less does he possess the skill to write about them rightly and truly — since the use of the celestial telescope, the discoveries and observations of the higher bodies, and every true way of philosophizing about them, lie hidden with the one Censor of Apelles. From which it follows: [Margin: 2. Apelles could have nothing of his own concerning the solar phenomenon.]

It is certain, in the third place. Whatever Apelles brought forward truly and skillfully about this phenomenon in his Table [Tabula] was drawn from the Censor's treasury [gazophylacium]. And this is nothing other than to say that Apelles did indeed see the Censor's writings and grasp his opinions, yet dissembled what he had seen and understood; and, patching together his own work from these, usurped for himself the name of Inventor out of another man's treasure. And so the full measure of these men's sentiments and tempers in their assault on Apelles and his Table shines out — a perfect concord among them. [Margin: 3. According to Angelo's view, Apelles filched his Table from the Censor.]

Finally, the alleged outcry of the Assayer [Trutinator — i.e. Galileo's *Il Saggiatore*] is taken in earnest, as though composed against Apelles, not only by those who favor Apelles but also by those who stand on the Censor's side; nor are there lacking friends of the great Censor who openly declare that Apelles beyond doubt drew his material from the Censor. And so it is admitted on all hands that this same man labors under a manifest suspicion of theft in many people's eyes.

[Margin: A fourth foundation. The Apellean Apologia is drawn from the sense and consensus of others.]

Since, then, the judgments of so many men — judgments not merely alike, but the very same, derived from a single source — all conspire into this one opinion; and since the Censor himself does nothing else than render this same Apelles suspect and strip him of all credit, authority, standing, and possession of doctrine: there is no doubt that this same man has been singled out and censured by that very passage cited. [Margin: The sum of what has been said.] For, as has often been said, whoever feigned himself to be Apelles — apart from the fictitious Apelles, there is no one. Whoever might seem to have set himself up as first discoverer of the Spots, to the imagined prejudice of the Censor — apart from Apelles, there is no one. Whoever is again and again refuted by the Censor as the champion of false, ridiculous, and impossible opinions in this matter — outside of Apelles in particular, there is no one at all. This is the man the Censor boasts he holds convicted and bound fast; from this man, he complains, the glory of first discovery has beyond doubt been snatched away; and he takes it ill that Apelles concealed the writings he had seen and read. And so Apelles alone is the one against whom that web was woven and on whom the blame was fastened.

[Margin: The gravity and unworthiness of the charges is weighed.] He alone is the stake in the eye, the thorn lodged in the foot; him the Censor longs to have removed, torn out, ground down and buried; and so, on any occasion given or seized, he sets him up to be mocked and jeered at by his own readers — and even by cobblers and tanners — treating him, like a thief caught red-handed, as his prey and plaything, insulting him everywhere with impunity as though he were vanquished and condemned. On almost every page of the *History of the Sunspots*, published at Rome in 1613 in Italian, he brings Apelles onto the stage alongside himself and puts on for all the world a ridiculous spectacle. Moreover, since he has appended a Latin Apelles to this Italian history of his, all the citations in this *Rosa* — including those of Apelles's own letters attached to it — are taken from that same *History*.

But in very truth, since any imposture most ill befits any man, and above all a philosopher and a free man — one reared for so many years now in piety and honorable conduct under the devout and learned discipline of Christ — it carries with it the utmost disgrace: that from it he should stand forth not only as wicked toward himself, but toward others also as a willing teacher of error. And thefts of doctrine — especially of doctrine that is solid and new — each man detests all the more, the more the offspring of genius are prized above other things, and the more the fame of learning and the renown of a new discovery — particularly in

an abstruse matter, remote from human opinion since the founding of the ages — are by right and merit set far above all else. Apelles, therefore, a man of that age and profes-

[Argument] Apelles is uncovered; his by-name and the origin of his concealment are recounted; and, from the deed laid to his charge, the necessity of a response is shown.

Cap. II. —sion, when, as though a Plagiarist, he is quite openly and unmistakably traduced — in the judgment of the discerning — by a man otherwise weighty and renowned among the learned, and just now sufficiently plainly, as has been shown: if he committed so foul a Plagiarism, he must be utterly frivolous; if he did not commit it and yet keeps silent, he must be utterly craven — not to say wicked toward himself, and, toward others, wanting in duty, if not indeed inhuman and unjust, seeing that with the same shield of truth he might both fend off from himself the disgrace laid against him, and cut away from those men their easy handle for error. For whoever openly dissembles a mocker's license, long and often exercised against him, seems — not by the virtue of patience [to defend] his own innocence, but, struck by the dart of truth and driven by the force of conscience — to confess his guilt by his silence: and this above all in our age. [Margin: The mark of plagiarism aimed at me is to be deservedly repelled.]

There is added another, and far more pressing, cause. Since it is now agreed among many who Apelles is, and since knowledge of him, though hidden, gradually leaks out to the public, I ought by no means to have allowed either the present age of the passing century, or the late posterity of times to come — persuaded by a disordered reading of the Censor's History — to draw from me any inference about the Associates: as though, like idle drones, being no honey-makers but honey-eaters, they lived furtively on nourishment scraped together

from everyone else's hives. [Margin: Apelles duly guards against the injury openly done to himself, while he lives and sees it, and against the injury that will harm his innocent associates.] This is all the more pressing since, from those very workshops where the History was printed, sure reports are circulated by conspicuous authorities that it is vain to expect from us any solid discipline in Physical and Mathematical matters, none of us being properly schooled in those sciences. Now if, while Apelles is still living, they burden him among others with such unworthy slanders, what will they do to him once he is dead and silent? Assuredly they will say he was guilty and culpable — otherwise, they will argue, he would not have kept silent, if only for the sake of the Associates. Therefore, lest I appear a reproach to those among whom I live by keeping silent so long, and, by lurking behind my Table, appear to someone either menacing or defenseless — especially since no end appears to the darts hurled against it, and I cannot lie hidden any longer beneath it as it splits apart — it is necessary that either, defeated, I abandon the Table itself dishonorably as a laughing-stock to my rivals; or else, breaking a silence hateful and more than Pythagorean, I bring the Spots to light, and recall to the light of truth my friends, who are already almost tumbling headlong into darkness, wavering and nearly failing. By what road I may accomplish this, I share with you, fair Reader; and you, according to the occasion, will not begrudge sharing it with others in its own place and time. [Margin: The pressing cause for writing.]

AIn the Year of the Lord one thousand six hundred and eleven, while I was publicly professing the Mathematical sciences in the most celebrated University of Ingolstadt, I had — through steady and long-continued prior investigation — noticed spots on the Sun by means of the telescope [telioscopium]: first in the month of March, with the Sun observed through cloud (I was then inquiring into its size); then again in October, with the telescope, both through cloud and without, by the benefit of the helioscope [helioscopium] (which I had myself made from glasses tinted for this purpose, convex and concave). [Margin: The first observation of the solar phenomenon, made at Ingolstadt.] I had observed the spots as diligently as I could — their position relative to one another and to the Sun, their number, figure, and magnitude from day to day — and this both by admitting the light naturally through a bare, small aperture, and by looking directly through the said helioscope; and I had committed the observations made from day to day, and almost from hour to hour, to papers, enclosing them within observational circles. From the comparison of these observations with one another I had seen that an apparent motion of the Spots, and many daily changes in their figures and magnitudes, and likewise in their positions, gradually occurred; that some passed off the disk, others newly entered upon the Sun,

many faded out in mid-course, and, in turn, new ones arose upon the Sun itself. [Margin: Apelles was the first to detect the motion, variation, and instability of the Spots, and disclosed it to others.] Astonished at so great a novelty and mutability of things, I first disclosed these matters to my students, but above all to the Reverend Father Johann Baptist Cysat [Cysat] (in whose presence too I had made the first inspection of this matter, in the month of March, from the tower of the Church), and then to my successor in the same professorship there; and, partly through myself and partly through others, to Professors of other Faculties as well. Such favorable and admiring applause of all and each, and such rumor, followed, that although I tried by every effort to hide this offspring — still tender and newborn, and wrapped in the swaddling-bands of infancy — until, advanced to some maturity, it should grow up with a firmer knitting of its limbs, yet the matter could not so be concealed but that it reached the ears of the most distinguished Lord Mar- —cus Welser [Marcus Welser], Duumvir of the most celebrated Republic of Augsburg. Since he was the Maecenas of all men of letters, and my own particular Patron and friend, he wearied me with continual letters until he extorted from me the Novelty of the phenomenon I had discovered. [Margin: The origin of the first Apellean Table, its painting and its sketching. Welser was the sole instigator of the composing and publishing of the Apellean Table.] Once he had received it in a few letters, he at once set his mind on its publication, lest — as he himself put it — anything of the "grace of novelty" should perish through long delay, or the "laurel of first discovery" be plucked elsewhere. But since the matter was seen to be not only new and difficult, but also, in many respects, at variance with Philosophical opinions, it was resolved that nothing should be brought to light too hastily or rashly by anyone then a Professor in that same Academy — a thing whose later retraction would prove difficult and unseemly. [Margin: The first birth of the solar phenomenon — why welcome, and why difficult?] My Superiors judged that we must proceed cautiously and step by step, until the Phenomenon should be corroborated by the added experience of others as well; that we must not lightly withdraw from the well-worn paths of the Philosophers without contrary evidence; and that my observations, set down in the letters sent to Welser, should not be published under my own name. For thus it would come about that greater freedom of judgment would be left to each reader, and no ill-will would be stirred up against anyone. [Margin: Why the solar phenomenon appeared under the name of Apelles.] By these precautions it came about that far fewer of the letters than I had written to Welser found their way to the public; that they came out under the borrowed name of Apelles; and that in them more was argued from the Physicists' view than from my own opinion. There you have, in brief, the

discovery of the Phenomenon, the reason Apelles was produced, and the origin, manner, and cause of the Table he painted. [Margin: In many of his Tables Apelles painted more according to the bent of others than to his own.]

This Table, then, set before the whole World's judgment by the said Lord Welser, was seen by various men, with various responses. [Margin: The varied responses of various men to the Apellean Table set before them.] For many came with bleary or bloodshot eyes, and these either looked ill upon my picture — since they saw the colors of their own eyes and made it such as their eyes were — or rendered their sight still worse, when, presuming rashly to rival the eaglets, but struck by the Sun's blazing, they sank back into the degenerate rank of owls. Some did indeed look rightly upon the colors of my Table, yet preferred to indulge their own wit against me rather than yield the palm to truth; and, that it might go ill with the painter, they befouled the image in truly shameful ways, hedged the Ursine Rose about with thorns, and breathed upon it with rank and reeking smoke, so that — —there were not lacking those who, taking offense at the unworthiness of the thing, insulted me from as far away as Italy in my misery; and, German though I might be, and unknown, they would utter Italian abuse and downright reproaches. [Margin: The wickedness of the imputed plagiarism is exaggerated.]

[Italian, quoting Galileo's *Discorso delle Comete*, p. 3:] "Would that it were granted me to know how to explain it to you vividly — that I should prize no less the praise of having been a good Copyist than that praise which those men have wished to usurp for themselves, who, out of the opinions of another, have wished to make themselves inventors and to feign themselves Apelleses, when, by their ill-colored and worse-drawn designs, they have made it plain that in painting they do not equal even masters of middling worth." [Margin: *Discorso delle Comete*, p. 3.]

In Latin (for even if I painted so badly, I shall not make matters worse by hiding it — rather I want the whole Latin world to learn it, again and again, and to treat this most cowardly Apelles as he deserves): "Thus might it be permitted me (says the interpreter, speaking in the mind of my Censor) to expound his meaning to you down to the fingernail, since I should reckon it no smaller praise for myself to have discharged the office of a faithful interpreter than is that praise which those men wished to usurp — men who tried to be taken for the inventors of that same man's other opinions, and feigned themselves to be Apelleses, when they nevertheless made it plain, by their ill-painted and worse-drawn likenesses, that

they for their part do not match even middling masters in the art of painting. So he says."

See how badly the theft — whether attempted or merely intended — has turned out for the fictitious Apelles; for from it he has carried off nothing but the shameful stain of the most cowardly incompetence. And this is one thing driven home — not a thorn, but a beam-like javelin — struck not into the Rose, but into the Painter's very eye; not into Apelles's life, but into his good name. [Margin: From his stolen Table, Apelles would be a cowardly Painter.]

Secondly: if I have robbed anyone at all of the offspring of his own genius, I have acted most unjustly, sinned gravely, violated the laws of charity, snuffed out the good reputation that attends such labors, and dealt a blow to the income that should have grown from them — in a word, I have taken away many goods and inflicted many losses; and therefore I am bound both to give satisfaction and to restore what was taken. And this is the second sting, twisted in to wound the conscience. [Margin: From his stolen Table, Apelles would be unjust.]

Furthermore: if I have foisted upon others, as my own, what was taken from another, I have committed the grossest imposture; I have willed to lead into error those whom I pretended to teach. And how grave is this — to shield an evil deed with worse dishonesty? [Margin: From his stolen Table, Apelles would be an impostor.]

Moreover: to hold another man's Philosophy — not weighed on the balance [Libella] — as certain and proven; and not merely to hold it, but to filch it and to expose to the whole world, for sale, wares not well understood: is this not proof of the greatest imprudence, the utmost rashness, the most extreme madness? [Margin: From his stolen Table, Apelles would be a blockhead.] For what if a heedless merchant should palm off on others glass for a gem, crystal for a diamond, brass [orichalcum] filched for gold? What if the Historian himself erred in arranging the Sunspots? What if Apelles failed to grasp that man's meaning? What if he defiled his picture out of incompetence? Certainly that man too could err, and this one embrace errors for truth, darkness for light. It is stupid to kiss another's offspring as one's own, and — without having seen its face, or judged the fitting proportion of its limbs among themselves — to proclaim it beautiful when it is perhaps a foul monster of nature. And let this be the fourth thorn on which I, a dolt, would have run.

Besides: to corrupt with deliberate effort another's offspring, lest it be recognized by others as belonging to someone else; to obscure the plain and simple truth in

inextricable labyrinths of opinions, merely that you may seem to know something, to hold forth, and to bring something out of your own store — even while you are conscious to yourself that you are committing thefts, that you are parading the labors of others, and that of your own you supply nothing beyond a deceitful pen, a lying tongue, mere words: [Margin: From his Table, Apelles is charged with being a crafty dissembler.] this at last is a crime of abominable malice and of intolerable pretense — to accuse an innocent man lest you be held guilty, and, to cover your own blunders, to blame the good deeds of others; to sow errors so that you may be believed to know, and to be free of error.

Finally, I do not come off untouched even by the vice of a most spiteful ingratitude — a vice from which not even the beasts themselves are exempt — if the man whom, for having discovered the phenomenon of the Spots, I ought to exalt above the Sun, I not only bury in deep oblivion, but even strip of the glory of first discovery owed to him, and thereby wrong most grievously. [Margin: A recapitulation of what has been said.] And so many, and so grave, are the crimes bound up in this single deed for which I am blamed: ignorance, injustice, imposture, rashness, malice, ingratitude — of all of which I am guilty, if I either wrested my Table from another, or painted it by stealth. Deservedly am I called a cowardly craftsman; justly am I proclaimed an unjust usurper of another's property; not without cause am I everywhere held an ambitious impostor; rightly am I judged a thoughtless peddler of smoke; I am summoned as a shifty hypocrite; and, more thankless than the very brutes, I deserve to be cast out from the society of men — not to say of the learned — if, as I said, I am party to so monstrous an offense. But if I be found clean of that stain, my accusers — nay, my assailants — will have matter to beg pardon for before the divine Godhead, matter to blot out before mortals, matter to make good to me, and matter to guard against for themselves hereafter. For I am neither so bare that I would clothe myself in borrowed colors, like Aesop's jackdaw; [Margin: Apelles has no need of another's paint; he is content with his own coloring.] nor so unskilled that I would need another's guidance to ply the brush aright; nor so brazen of brow that I would prostitute another's works as my own — I who, endowed and enriched as I am by the goodness of Nature and my Maker, yet judge, with Christian modesty, that, steeped in the discipline of religion, I know how to leave what is another's untouched; and, furnished by the bounty of God and Nature, both can and am wont to share my own with others without envy. And so I gave my Table, too, to others to contemplate — not as finished, but as roughed out, to be assessed and thence brought to fuller completion; by no means to be carped at, torn to pieces, and at last wrenched away by unjust force. [Margin: Apelles exposed his Table to judgment, not to plunder.] Yet still I stand by it, before my

own doors, unmoved — assailed at close quarters by vain and fruitless efforts, and attacked from afar by countless darts, but darts that fall short, harmless, and land no blow. They ought to have remembered that it too is the shield of Ajax, repelling whatever darts come against it. Beneath this shield there has lain hidden

Behind this shield Ulysses lay safe as long as he pleased; and behind this Table Apelles [Scheiner's pseudonym] lay secure, since it was in his own house, behind his own Table, that he hid. This shield is mine, this Table mine, this picture mine — let there be no ill will in the saying, and let truth have its place: I first sketched it, I first painted it, I first brought it forth, using no guide, no teacher to go before me. This I show most clearly by four arguments above all: drawn from the very sequence of events; taken from the undoubted good faith and testimony of others; from my own Table, that is, from the solar phenomenon itself; and finally from the Censor's own History and from the Phenomenon of the Sun described in it. As I pursue this in writing, follow me, Reader, with favorable eyes and a friendly disposition of mind.

[Margin: In discovering this phenomenon, Apelles used no teacher.]

That Apelles Did Not Draw From His Censor the Doctrine On the Sunspots Set Out In His Table — Shown First From the Very Constitution of That Table.

Cap. III.

Now although a man who is charged by others with some fault might, for his own defense, have enough if he simply denies the deed, and is in no way bound to prove that he did not do it — while the accuser, on the other hand, if he fails to establish the crimes alleged, by that very fact loses his case, and the defendant is restored to his standing, his fortune, and his former dignity (for a man is to be held good who has not been proven bad) — and although it would therefore be enough for me merely to say or to write: "This crime that you lay against me, O Critics, O Censors, I deny; prove it! Where, when, how did I steal from you what is yours, O my good man, whoever you are? Prove it, or fear retaliation" — although, I say, I could ward off these adversaries well enough in this way and keep myself unharmed, yet, so that not even the shadow of any unfavorable opinion about me should stray into anyone's mind, I make my truthfulness and integrity brighter than the Sun itself.

[Margin: Apelles could clear himself sufficiently simply by denying the charge of plagiarism.]

For if I stole from someone else the discovery of the sunspots, their arrangement, and their explanation, then it is necessary, first, that whatever I snatched from him he had possessed beforehand; second, that I knew he possessed these things; and third, that I did not have them from elsewhere. For if [I had] those very same things — if I had them earlier, or if [I had them from] another — [the argument fails].

[Margin: Apelles could have stolen his Table from no one, for lack of the prerequisites necessary for such an act.]

I did not know how to have them; nay, even if no one else had them: it is certain that the Rose I brought forth into the open was planted and born in my own home, not one torn up and carried off from another's fields. And, to come closer to the matter point by point:

What are those things that I took from that glorious "Inventor" and transferred into my Table? Let him name whatever here is his, of which he boasts himself the earlier Inventor and owner. For — to keep to the metaphor I have begun — they are either the instruments for painting the Apellean Table, or the colors, or the art, or the picture itself, or finally the written-out explanation of all or of any one of these, and the doctrine composed from them.

[Margin: That Apelles, in painting his Table, appropriated nothing belonging to another is proved by an enumeration of its parts.]

The chief instrument of this painting is the brush — namely the radiant Cone of the Sun, which I drew down from heaven, from the Sun, and stole from no mortal; and which I had contrived beforehand out of the Sun's rays with a helioscope, a bare aperture, and a plane mirror, before it became known to any rival of mine, or to anyone else.

[Margin: In painting his Table, Apelles did not use the brush — that is, the instrument — of the Censor, but his own.]

For as to the fact that he, in his second letter to Marcus Welser, dated 14 August 1612, showed me a certain way of making the solar brush, that is, of observing the spots, I do indeed thank him for a generosity I never asked for; yet I already knew that method then, and was using it in Germany many months before the Censor's letter reached Marcus Welser from Italy — a letter which Welser, as he himself attests in his third letter, dated 28 September 1612, received at last on 5

October of the same year. [Margin: In the History of the Sunspots, p. 52.] Indeed, I dispatched to Welser all the spots I have published: on the 12th of November, on the 19th and 20th of December of the year 1611; and again from 16 January, and from 14 April up to 25 July, of the year 1612. As may be seen from the appendices to the History of the Sunspots itself, published in Italian at Rome in 1613. [Margin: fol. 97.] [Margin: fol. 98.] Hence it is clear that the Censor of Apelles neither is, nor could ever have been, in a position to claim credit for having given me this brush — that is, this device for drawing the Sun's image onto white paper — since that very thing which he wanted to teach me (given the time at which he was writing, namely 4 May 1612) he himself drew, in those first months, from his pupil Benedetto Castelli [Benedetto Castelli], and proposed to me unsolicited in a letter drawn up on 14 August 1612 and received by Welser on 5 October. [Margin: Letter 1, fol. 28.] Much less could he have snatched it for my picture, since I, beyond the fourth and sixth of April

of the year 1612, had not extended any of my observations published so far, and none of those observations of mine was made by me except by catching the Sun, across the telescope [Telioscopium; Scheiner's tube of inspection], onto paper — as my last letter to Welser, written out on 25 July, expressly attests. Therefore this Italian brush never reached the shaping of my image; and so I come off free from this charge.

Now that method of making the solar brush — which I expressly taught in my last letter, dated 25 July of the year 1612, and which I also plainly hinted at in my letter of 16 January 1612 — consists in this: [Margin: Apelles, p. 45.] [Margin: Apelles, p. 34.] that the Sun, admitted through a bare aperture into a dark place, onto clean paper set at right angles to the axis of the solar cone, is reproduced with all its spots. This was devised by me, and began to be applied, at the very outset; for at that time I had long been handling — and had thoroughly examined, and had daily in hand — the admission of the visible images of things into dark places. [Margin: Apelles learned the admission of the Sun through a bare aperture from no one, and taught many.] And so at once I transferred that same device to catching the spots from the Sun, and in this way I compelled the Sun to enter through a narrow, round aperture and to lay open its secrets, which I caught onto the cleanest paper set at right angles to the aperture (that is, to the radiant brush of the Sun) at the greatest distance, and depicted as faithfully as I could. Since the Author of the History seems to have been ignorant of this manner of depicting at the time when I carried out these delineations of the spots, it is plain that the skill of employing it could not have come to me from him. [Margin: fol. 53.] And that he was ignorant, all the way up to that point, of

the natural admission of the image, is sufficiently clear from his own words. [Margin: When Apelles published his Table, the Censor was ignorant of the admission of the Sun's image.] For he himself says, in his second letter to Welser:

[Italian, Galileo's letter:] "I have since recognized the courtesy of Nature, which thousands upon thousands of years ago granted the means of coming to a knowledge of these spots, and through them of certain great consequences; for, without any other instrument, from any small hole through which the solar rays pass, the image of the Sun, together with the spots, is carried to great distances and printed upon whatever surface is set opposite. It is quite true that they are by no means so sharply defined as those seen through the Telescope; yet the larger ones show up clearly enough, and Your Lordship, seeing in a church the Sun cast its light onto the pavement through some broken pane, and catching it with a white sheet spread out, will notice the spots upon it."

Thus far he. These words read as follows in Latin:

[Scheiner's parallel Latin rendering:] "I afterward also learned (namely, after acquiring the use of the Telescope) the ingenuous kindness of nature, by whose bounty, for some thousands of years now, it has been possible to come to a knowledge of these Spots, and through them to a knowledge of great consequences; since, without any other instrument, from any small aperture through which the solar rays enter, the image of the Sun sets itself, together with the spots, upon any surface set opposite at a great distance. It is indeed true that they are for the most part not so precise and large as are those Spots which are transmitted through the Telescope; yet the larger ones appear distinct enough. And Your Lordship will be able to make an experiment of this in a church, where, if the Sun casts its light onto the pavement through some broken pane far off, he will see the solar Spots on a sheet of paper held up and well spread out."

Thus far he. Since he first noticed, wrote about, and thoroughly informed Welser of these things only after my own publications, it is plain that this brush was invented and perfected in my own workshop, and not imported from elsewhere.

[Margin: That the sunspots are to be caught by reflection, viewed through the helioscope, and enclosed within an observing circle — this Apelles learned from no one, and taught many.]

As for catching the sunspots by the reflection of the Sun's ray from a plane mirror, and likewise the inspection through colored tubes pointed directly at the

Sun — whether anyone before me had knowledge or use of these escapes me; but I hardly think so. This too is certain: that as to the enclosing and marking of the Spots and Faculae within a solar circle drawn on paper — as I have been accustomed to do up to now — I received from no mortal anything, whether of knowledge or of practice; and that before I could learn anything about my adversary, my picture was already finished and stood publicly on display in my Table. So that on this head I plainly cannot be arraigned.

Now I come to the colors, by which I understand nothing other than the sunspots and solar faculae themselves. Both of these indeed I handled as the materials of my picture, though I judged that I set out in the Apellean Table only those materials that belonged to others. Since the sight of them is everywhere, by day, freely open to all as they pass by

and common to all, I could neither seize nor snatch them away from anyone, just as no one could from me; for the Sun's light, by the law of nations, is common to all, and no one can forbid a free man the sight of it — whether he wishes to cast his eye upon it, or to draw it down onto paper for viewing, and that either through an open aperture or through a tube fitted with lenses. But just as the Sun and the Sun's light — and so too the sunspots and faculae, and their images projected hemispherically upon the whole universe — are an object of sight open and available on every side, and a material for disputing, describing, delineating, and depicting that is common to all and free to everyone throughout the whole world: so, conversely, those same Spots and Faculae, when seen at particular places and times, noted, and arranged into fixed orders, are so singular and proper to those places, times, and persons, that they cannot and must not in any way be attributed to others. Since, then, I could take from no one the Spots considered under the first or under the second heading, it is impossible that they were withdrawn by me from any man; nor, I think, will anyone pick a quarrel with me over this.

[Margin: The art of painting the sunspots Apelles learned neither from the Censor nor from anyone else; rather, he was the first to give both him and others the occasion to learn it.]

So then — will the art of painting them have been carried over from Italy to me in Germany? What art, I ask? When? By whom? So I learned to paint the Spots only then, when I had long since set before others the very ones already painted? But what is that art of painting?

I understand here nothing else (for of the simple sight of the Spots, in its own place later) than the skill of drawing them correctly onto paper, by some one of the said methods, keeping the appropriate proportion of the magnitude, figure, place, and situation of each — both to itself and to all the others — with due regard to the reckoning of places, times, and durations. But I mean also the careful attention paid to the section of the perpendicular [perpediculi; recte perpendiculi], or circle, and of the vertical plane, so that from it I may be able to inscribe, into the trace of the solar brush marked on the paper in the shape of a circle, the ecliptic — which is necessary for finding the place and the motion of the Spots. All these things, I say, and things akin to them, I learned from no mortal; I taught them to many. This is plain from my published Table, in which I would not have arranged the Spots in their correct position and order had I waited for a Master of this art to be revealed to me from heaven by an Angel. And yet that Censor of Apelles teaches nothing, or almost nothing, beyond the use to be made of the telescope;

whereas I, for the things I set out in my Table, used a bare aperture alone, the tube of inspection (that is, the helioscope), and the device of reflection.

[Margin: One method of investigating the apparent motion of the sunspots, either unknown to, or neglected by, the Censor.]

Moreover, since Apelles's Critic, in his whole History, maintains only a rectilinear apparent motion of the Spots, and one parallel to the ecliptic, but is wholly ignorant of the curvilinear motion, and wants the inequality of the motion and the difference of its duration above the horizon utterly rooted out — as will appear more fully below in its own places — it is evident that he did not possess my art and method of ordering these matters, and that he strayed not a little from the true path; and that I neither learned them from him, nor stole them by some treacherous contrivance. Of these things it is worth touching on one or two.

If you observe a single spot daily, at the time when the Sun's place in the Ecliptic is a quadrant of a circle away from the points of the horizon, and if through the center of the Sun's circle projected onto the paper you draw a line parallel to the horizon — or a perpendicular sent from the vertex through the center — then the course of that spot must coincide with this line, or at least be parallel to it, if the Spots move by the standard of the ecliptic. But the Censor of Apelles did not do this; otherwise he would have detected a motion other than rectilinear, or parallel to the Ecliptic.

[Margin: Another method, likewise passed over.]

Likewise, every Spot passing through the center of the observing circle must always, before and after the center, from entry to exit, describe the diameter of the Solar disk, if indeed the Spots are carried along straight lines; and all the rest, lying off-center, will trace paths parallel to this. Yet this does not happen, as will be clear to one who examines it. Had the Censor of Apelles known these tests, and applied them, he would surely have derived and discovered something other than what he taught in his History and reduced to a most faulty practice, as will appear later in its place. I therefore did not receive from him these and similar devices, about which I will speak elsewhere on purpose.

[Margin: Apelles did not take his picture from the Censor or from anyone else, nor transfer it from them.]

Nor can it be said, further, that I took my picture — that is, the series of my observations published in my Table — from him; for then the originals would have to remain in his hands. It would therefore be necessary that he had observed the Spots [recte: Maculas] in Germany, which never happened; it would be necessary that he had carried out, through the aperture of admission, most of the observations published by me — which is far from the truth [recte: parallelum]

for he himself was ignorant of this secret of nature at that time; it would be necessary that many had practiced observation by reflection, which nevertheless he nowhere acknowledges in his History.

[Margin: fol. 10, near the middle. The Censor wavers because of the difficulty of the solar phenomenon.]

Besides, since he admits, in his first letter, dated 4 May 1612, that because of the difficulty of the material — and because he could not make many continuous observations — he was left in suspense and wavering, unable to pronounce a decisive opinion on so slippery a matter: whereas I, from 21 October 1611 to 7 April 1612, both possess several hundred (not to say several thousand) continuous observations, and have advanced a settled opinion on very many points, and can advance one on still more — it follows that my delineations cannot have been drawn from his.

[Margin: The Censor cannot fill, from his own observations, the gaps left by Apelles.]

Further, in the same letter, on p. 11, he says that my observations, when compared with his own and with those of others, agreed. From which it is again

clear that mine were not transferred from his; otherwise I ought to have transferred others also from others, or others should have taken them, together with me, from him. But I too should like to see how this historiographer's observations would agree with mine from 11 January 1612 up to 16 March of the same year; for by filling that gap he could best protect himself, and satisfy both me and everyone else — whoever would claim to be my equal in age in the industry of the first discovery — if he should prove it by deed and not by words, and, just as I did and can still do, produce the observations he made: here is Rhodes, jump here! Then I could wish that he would draw the line of the ecliptic through the observations just mentioned as much as through those furnished by me — since I received everything from him (to put it modestly) by mutual exchange.

[Margin: An objection that the Censor might raise is dissolved.]

But perhaps the Censor will say that he claimed no more than that my published observations corresponded with his own and with those seen by others in this: that under the Sun the Spots moved from east to west, and inclined somewhat from the north toward the south (or Auster); all of which can stand even with a mere direct and ocular inspection of the Spots made through a tube, even if he had not put down what he saw on paper according to number, situation, magnitude, and figure. For a simple and attentive gaze, made morning and evening, could have supplied that sufficiently. But whatever may be the truth of this answer, were it granted, from it I would at once again infer that my observations, once drawn onto paper, in the keeping of

that author, acknowledge no model or prototype, but were themselves the originals; and it is very credible that this Censor had, at that time, committed to paper observations that were stable, full, and ordered — either very few indeed, or (what is truer) none at all: which he himself confesses clearly enough in his third letter, written out to Welser on 1 December 1612. Since that passage contains much that is historical and useful to my case, it must be inserted word for word:

[Italian, Galileo's third letter:] "And I cannot, on this subject, conceal from Your Lordship a little scruple that has arisen in me from Apelles's having wished, in this place, to bring forward those two spots and their changes, which I sent drawn to Your Lordship in my first letter. And although I well understand that all this proceeds from his courteous affection, desirous of procuring credit for them by saying that they agreed closely with his own, and of creating an occasion to show that he

still kept a grateful remembrance of me — nevertheless I would not have wished that he should then go so far as to put himself in danger of losing a little in the esteem of the learned by saying that, from my drawings coinciding so exactly with his (and especially those of the second spot), he was assured of the absence of parallax, and consequently of their great distance from us; because, with great reason, doubt may be cast upon that conclusion of his, since the figures that I sent were of spots drawn in isolation, and without correspondence to any other, or to the position of the Sun, whose circle was not even drawn by me: which also leaves me somewhat confused as to how he could have perceived whether I had precisely apportioned and arranged them, or not."

Thus far he — which may be rendered as follows in Latin:

[Scheiner's parallel Latin rendering:] "And I cannot here conceal from Your Lordship one small scruple, arisen in me from this: that Apelles in that place brought forward two Spots, and their changes, which I sent to Your Lordship marked out in my first letter; and although I well perceive that all this proceeded from his obliging affection toward me — to win them credence, when he says that they agreed much with his own, and that he seized this, as it were, as an occasion of signi-[fying]" [text continues past this page]

[Continuation of Book I, Chapter III — the argument runs on without a break from the preceding pages. The two-column layout, the centered column-reference numerals "I." / "II.", and the marginal line-numbers every five lines are cross-reference apparatus, not divisions of the text; the prose is rendered here as continuous.]

of giving [him] a hint; yet I would not have wished [him] to go so far as to incur any risk to his reputation before the Reader, when he writes that — because of the exact agreement of mine with his, especially with the designations of the second Spot [letter] — it is certain, given so great a distance of places, that they lack all parallax. This is a conclusion which he deduced from that premise and which one might rightly call into doubt; since the figures that I sent were of Spots recorded separately, without any correspondence to the others, and with no account taken of their position on the Sun — indeed, not even the [bounding] circle was drawn by me. This too leaves me somewhat perplexed: how could it have been established by him that they had been marked out and arranged by me precisely, or otherwise? So says he.

As for my own reputation — whether injured by this passage or liable to injury, which I shall defend well enough in its own place and time — I am not anxious; for I gave no cause for injury. It was the Censor of Apelles who gave the Reader occasion for rash suspicion. His candid admission — namely, that he sent these Spots to Welser [Marcus Welser] viewed one by one, with no solar circle drawn — I most gladly embrace. From it I deduce, without any doubt, that the Reviler [Sugillator] not only committed to paper, from 5 April to the end of that same month, and up to 3 May, no stable, full, and fundamental observations of the Sunspots from which a lover of Astronomy could have drawn anything worthwhile, but that he had not even gathered from the Sun any earlier observations worthy of a trained eye. For otherwise — more surely than sure — he would certainly have communicated them to Marcus Welser and to the Lyncean [Lynceo] himself. Who would believe that, keeping the better ones at home, he offered the worse to so great a Patron — to so sharp an Eye, so refined a Brain, so delicate and fastidious a Taste? Who would believe that, if observations from which he could have established his opinions had lain hidden at home, he would not have produced them? And that he would have answered Welser — who by his very design so insistently demanded these things — with such trepidation, when otherwise he readily foisted lesser secrets on him under veiled riddles [logogriphs]? But let us be pleased to hear this Messenger [Nuncium] — elsewhere boastful and blaring, now scarcely muttering:

[Italian:] "These considerations have made me slow in answering Your Most Illustrious Lordship's questions; and yet they make me timid about putting forward anything but some negative position, since it seems to me that I know rather what the Sunspots are not than what they truly are, and since it is much harder for me to find the truth than to refute the false."

[Scheiner's Latin rendering:] "These considerations (namely: ill health; a multitude of occupations; the hope of satisfying the requests; the difficulty of the material surrounding this phenomenon; the scarcity of the necessary observations; the fact that it is better to err along with everyone than to become singular by judging rightly; and that it is preferable to keep to the truth than to forestall others with error, etc.) — these considerations, he says, have made me slow at Your Most Illustrious Lordship's entreaties, and altogether render me timid, so that I put forward nothing but the bare negative proposition; because it seems to me that it can be known sooner what the Sunspots are not than what they are can be truly stated; and because a much greater difficulty

confronts me in digging out the truth than facility is lacking for convincing [others] of falsehood."

[Margin: The Censor's timidity and slowness [stem] from ignorance of the solar phenomenon.]

He would in no way advance such great excuses if he had known how to prop up and adorn his history, out of his own storehouse, with better observations. If the case is otherwise, I challenge him to the test: let him produce observations from April to May 1612; let him bring out [observations] from 11 January up to February of the year 1612; let him set forth [others] from the first of February to the end of that same month and year; let him lay out [still others] from the beginning of March to the tenth of the same month. Let the Arbiter of Apelles do this, and from them let him show — not to himself, but to us — the course, the place, and the other properties of the Spots; and then we shall begin to have some doubt about his discoveries.

[Margin: Apelles challenges the Censor to [make] observations.]

Let him enter his own Sanctuary, granted to him alone by divine gift, accessible to no other with an Angel bearing witness and revealing; and thence let him bring into the open something from his own treasure, gathered over the space of eighteen months, and by it instruct us in the Solar phenomenon; let him set out the order of the Spots that have passed by over so long a time, and then lead his well-arranged army into the battle-line; let him not tell us in words their nature, motion, place, and countless varieties, but point them out to us with his fingers, with pen and stylus, in the circles of the observations — which, of what kind, how large, how many the Spots were, which Faculae [faculae] coincided with them; in what year, what month, on what day, at what hour they came and went, etc.; let him draw in the ecliptic, etc. Just as he saw me do, just as I can and am prepared to do — not only to fore-...

[Margin: Let the Censor of Apelles produce the observations of eighteen months, made by himself.]

[continue and] fill the aforesaid gaps, but throughout whole years following, right up to this year, this month, this day, this hour. *Here is Rhodes, here is your leap* [hic Rhodus, hic saltus]. Whoever cannot do this vaunts himself over past observations in vain; in vain does he make himself the first, in vain an equal, discoverer.

Neither gods, nor men, nor the booksellers' pillars have allowed it [Horace, *Ars Poetica* 372–373, adapted: "Non Dij, non homines, non concessere columnae"].

For unless we see the traces of the Spots set down on paper, we do not believe one who merely asserts it. But I return to his own candid confession, in which he denies having the Sun enclosed within a circle. From this I also draw the following: that it is impossible that My observations were derived from his — for the reason that all of mine are complete within the circle of the Sun, made with the apparent position, and with a proportion of the figures and magnitudes, whereas his supply none of these things. Again, if the Censor of Apelles has complete observations either none, or few, before this time, it is manifest that my whole depiction was in no way taken from his designations.

[Margin: Apelles does not derive his observations from the Censor's — [as is clear] from the impossible circumstances [required].]

For all of mine that I published are complete and perfect in their numbers; his, up to 4 May 1612, are none: mine all finished by 7 April; his not even begun, with May not yet entered. Indeed, when the Censor attacks my figures set down in the month of March — he holds them suspect in the third letter, pp. 116, 124, 129, 130, 131, etc. — while he denies to the Spots any diversity of motions or inequality of delay, he does this by conjectures alone, which he ought to and could have done by bringing forward his own observations to the contrary, if he had had any; since he denies that mine were correctly made.

[Margin: The Censor would not attack Apelles with mere conjectures if he had had definite observations against him.]

It is therefore evident that at that time he had no stable observations, and none of any worth. When I published mine, then — whatever meanwhile he may trifle about here and there in his history — my observations square correctly with his, which were nonexistent. But why do I make use of arguments hunted up from here and there? In the preface to the Reader the following is found:

[Margin: *Istoria*, fol. 3.]

[Italian:] "As for those who might claim priority in the observations of such Spots, it is not denied that they could have observed them without prior notice from Signor N.; just as it is likewise clear that they anticipated him in making them public in print."

[Latin rendering:] "To those, then, who claim priority in the observations of these Spots, he says, it is not denied that it could have happened that they observed them without any prior indication from Lord N.; just as this too is clear, that he was anticipated in publishing the same in print, etc."

[Margin: By the adversaries' own concession, Apelles paints his Table without any prior knowledge of the Censor's prototype.]

[Margin: *Istoria delle Macchie [Solari]*, letter 1, p. 10.]

If, then, I both could, and did, observe the aforesaid Spots — without the foreknowledge of Apelles' Censor, or with an Angel to endorse me — and published them before he did; if the Censor has neither produced, nor can produce, any series of his own observations made (as he claims) before me; since by his own testimony he could make observations neither many nor continuous — then I leave it to the judgment of any fair-minded arbiter whether it could have happened, or did happen, that I pilfered mine from him. Could it have been the case that he observed before me? The deeds stand on my side, but the words too stand on his side — and even against him — when he says that, because of the difficulty of the matter and the fewness of the observations made and continued by himself, he is still held in suspense and irresolute. And when did he say this? On 4 May 1612. But when did Apelles complete and publish his observations of the Spots and his resolutions concerning them? He composed and finished the first three letters in the year 1611, in the months of November and December; they were published in the year 1612, on the Nones — that is, on 5 January, the eve of the Epiphany of the Lord — so that, on the same day on which Christ was manifested to the World through a star, like an immaculate Sun, that marvelous and grand spectacle of the Spotted Sun should appear even through these shadows. Whatever, therefore, he observed in these matters, whatever he established from his observations, Apelles did not have this from his Censor, nor could he in any way have had it, since the Censor afterward first wrote that peevish [letter] to Welser for the sake of excusing himself:

[Italian:] "I have also kept silent, in the hope of being able to give some satisfaction to Your Lordship's question about the Sunspots — the subject on which you sent me those brief discourses of the feigned Apelles. But the difficulty of the matter, and my not having been able to make many continuous observations,..."

[Latin rendering:] "I too kept silent, he says, because I hoped it would come about that I might to some extent satisfy Your Lordship's request

concerning the Sunspots — the subject on which you sent me the brief discourses of the feigned Apelles. But the difficulty of the material,..."

[Italian, continued:] "...have kept me, and still keep me, in suspense and irresolute."

[Latin rendering, continued:] "...and the fact that I could not make many continuous observations, have held me, and still hold me, in suspense and irresolute."

A clear confession — a testimony wrung out by the great force of truth — from which it is plain:

First, that the Censor judges, and rightly, that for the knowledge of this phenomenon and for any solid decision, many observations are necessary.

Second, that these must indeed be continuous.

Third, that he could not make many continuous ones.

Fourth, that for that reason he has, until now, kept his judgment on the whole matter suspended and undecided.

Fifth, that he still keeps it so — all of which he brought to Marcus Welser on 4 May 1612 by way of excusing himself and of purging the three-month silence (during which he kept my Sunspots — already published in print and expressly sent to him — with himself, examined them, discussed them, sifted them, winnowed them).

[Margin: The Censor kept Apelles' Table — already published in print — with himself for several months before writing a single little word about this phenomenon.]

Apelles, however, by 26 December 1611 had already amassed several hundred observations of the Sunspots — and continuous ones at that — and had openly declared his judgment about them in the following articles, and had proven it solidly enough:

[Margin: A summary of the things that Apelles, before the Censor, partly demonstrated and partly discussed as probable in his Table concerning what the Sun produces.]

First, that the Sunspots are a true and real Phenomenon.

Second, that they are borne by their own motion from rising to setting [east to west].

Third, that they are very close to the Sun and lack all parallax.

Fourth, that the coming-together and dividing, the appearance and disappearance of the Spots frequently occur in the middle of the Sun's disc ☉.

Fifth, that their stay beneath the Sun is unequal, occurring within about the eleventh and fourteenth day.

Sixth — he showed, in passing, their whole period, and that they do not ordinarily return, at any rate.

Seventh — he taught that their period is completed around the Sun and its center.

Eighth — he explained fully enough their various properties as regards magnitude, figure, density, rarity, light, darkness, colors, opacity, transparency, thinness, thickness, etc.

Ninth — he sufficiently indicated that the fluidity of the heavens also follows from these.

Tenth — he discussed, tentatively, their essence and apparent motion, promising more certain things from future discourses, examinations, observations, and the continuation of the Table.

But the Censor of Apelles — what does he do in his letter to Welser? He asserts very few things as certain; most as doubtful and ambiguous, and conditionally, and by conjecture:

[Latin quotation:] "Up to now, he says, I have kept silent, because the difficulty of the material and the scarcity of my own proven observations stopped my mouth, bound my hand, plugged my pen, and blunted the edge of my mind; so that, with the judgment of my understanding faltering, I have nothing to feel, to say, or to write."

[Italian:] "I acknowledge that, with great length of words and little resolution, I have excessively wearied Your Most Illustrious Lordship. Let my irresolution be excused by the novelty and difficulty of the subject, in which the various thoughts and differing opinions that have so far passed through my imagination — now finding assent, now resistance and contradiction — have rendered me so timid and perplexed that I scarcely dare open my mouth to affirm anything at all."

[Latin rendering:] "I acknowledge, he himself says, that with much superfluity of words and little settling of matters I have been needlessly troublesome to Your Most Illustrious Lordship. My irresolution, however, is excused by the novelty and difficulty of the subject, concerning which the various thoughts and differing opinions that have thus far come to my imagination — drawing me now to assent, now to resist and contradict — have torn me with such fear and perplexity that I scarcely dare open my lips to affirm anything."

[Margin: The Censor of Apelles, out of ignorance of the phenomenon, [is] wholly timid, disturbed, doubtful, and mute.]

These things the Arbiter of Apelles [says] about himself, truly and candidly: that he had observations — necessary for establishing anything certain — neither many nor continuous, because (as he himself says) he could not make them. And yet Apelles is supposed to have borrowed and filched his own designations of the Spots, and the Conclusions deduced from them, from one long before suspended and irresolute! O wonderful Apelles, who would learn the nature of color from a blind man, and by some new device wring a treasure from an empty purse and water from pumice-stone! But one cannot help wondering how the subject of the Sunspots can be so new, so difficult, so unexpected, so arduous to this Winnower [Ventilator], who has known them, as it were familiarly, for eighteen months and more, and has shown them to many — indeed to very many — already a year ago. Again one cannot help wondering why, for so long a...

[Margin: The [Censor's actual] deeds cannot be reconciled with the Censor's writings.]

time he made so few observations (and perhaps none) and none continuous. Was it because he was unwilling? But he certainly took pains to oblige Welser and his friends in every way he could, and he ought not — for the public good, on account of the labor of observing — to have begrudged so great a matter, or defrauded himself of the glory of first discovery. Perhaps the sky did not favor him? Yet I, from October of the year 1611 up to 4 May 1612 — during which time the Censor, from a scarcity of observations, remained stuck in the utmost ignorance and obscurity of this Phenomenon — worked out several hundred observations of nearly every day and hour.

[Margin: [These are] fit [excuses] for the Censor's slowness and negligence — [that is,] no excuses at all.]

If, then, over the space of eighteen months the Sun was, together with the Censor, turbid and cloudy and misty, it could surely have cleared its face in the year 1612 by 4 May. But perhaps Phoebus smiles less on Italy than on Germany? On what reasoning, then, did he dare promise me, within a few days, what neither the inclemency of the sky nor the injury of fortune had allowed him — to himself and to his Friends — over so many months already elapsed?

[Margin: The Italian sky is more constant and much more serene than the German.]

"I could not make many observations," he says. For how long? Since what time? Doubtless over an interval of eighteen months — and yet:

[Italian:] "...but nevertheless I beg you to greet him warmly in my name, letting him know that within a few days I will send him some observations and drawings of the Sunspots of absolute exactness — both in the figures of the spots themselves and in their positions as they vary from day to day, without the error of the least hair's-breadth — made by a most exquisite method discovered by a disciple of mine."

[Latin rendering:] "Nevertheless I beg Your Most Illustrious Lordship (he says) to be pleased to greet Apelles in my name, indicating to him that within a few days I will send him some observations and designations of the Sunspots of the most absolute perfection — both in the figures of the Spots themselves and in their positions varied from day to day, without the error of even one least hair — made by a certain most exquisite method discovered by a disciple of mine."

From this, then, it comes to light what it finally was that held the Censor back for so long from portraying the true images of the Spots. For it was not stormy weather of the sky — otherwise he would not promise to form them within so few days. It was not the will of his own mind — for he offers himself as helpful in this office even to me, a stranger. It was not the novelty of the matter — which...

does not grow old with the passing of a few days. It was not the difficulty of the material — which, though it had lasted through an interval of eighteen months, he trusts he will break through in a few days. It was not, I say, any of these things that held the Censor back from making and continuing observations, keeping him timid, perplexed, in suspense, irresolute, and finally ignorant; but, as he himself says, the power to do so was lacking. He could not observe, *because there was lacking a disciple to instruct the Master*; and once this [disciple] was obtained, now neither the novelty of the matter, nor the difficulty of the material, nor the

inclemency of the sky, nor the shortness of time, nor anything else stands in the way of his flying forth into public with his observations, and eagerly instructing Apelles — long since practiced in these matters. None of the aforesaid things, then, alleged by him under a particular guise, was the true cause why he wavered for so long. Otherwise, since all these things persisted not only in the month of May of this year 1612 but in the following months as well (for these Phenomena are still new and most difficult to investigate), with the cause posited and enduring, the effect would equally remain. But since the effect — namely the Censor's hesitation — has ceased, and a sure hope of emerging from the Labyrinth has dawned, it is likewise manifest that the cause of such dread has been removed. And this the Censor's own disciple removed, when the disciple showed the Master the art of observing the Spots, which he himself had discovered, and rendered empty the Angel — the Messenger of various oracles about this one Chapter [Head].

[Margin: The true and genuine cause of the Censor's procrastination and trembling: Ignorance.]

The cause, then, that held the Censor in fear and kept him from delivering his opinion was that he was ignorant of the Sunspots, their nature, and their properties. The cause of his ignorance was that, over an interval of eighteen months, he could not make the many continuous observations of them that were utterly necessary for bringing forward anything certain about them. And since the disciple in part removed this cause for him, and taught him to project the Sun onto paper, then — his long-standing gloom of mind wiped away — he leaps joyfully into the open, and hopes within a few days to scatter all the mists.

[Margin: The disciple removed the Master's ignorance.]

But whoever hopes he will attain something admits that he does not yet have it. Therefore, while the Censor of Apelles rejoices in the hope of obtaining knowledge of this Phenomenon, he does not yet have it, but is still ignorant of it. And this is what was to be proven — namely, that the Censor, on the seventh day of April in the year 1612...

[Margin: *Letter 1, fol. 28, verse 5.*]

1612...

[The sentence continues into the following pages.]

[... beyond] 1612 — beyond which time the observations I have brought to light do not extend — [I have shown that the Censor] was able neither to observe the

sunspots [maculae solares] correctly, nor knew how to deduce anything stable from what he did observe, whereas I accomplished both as the occasion required. Therefore from the Censor — at that time a mere novice with respect to this appearance — I could neither gather nor pick up anything, and there is no taking away from one who has nothing. Therefore the Censor did not, before me, possess even a knowledge of this phenomenon that he might have shared with more learned men with any dignity and probability. Therefore I took nothing from him that was his; my picture stands as mine, my Rose is mine. His remain the shadows that he strove to cast upon another's name; his remain the brambles with which he wished to tear the reputation of one who neither deserved nor provoked it.

[Margin: Apelles could learn nothing from the Censor, who was himself ignorant of it.]

That Apelles did not draw his doctrine of the sunspots from the Censor is gathered, secondly, from the premises, through the causes — the quasi-Material, the Formal, and the Efficient.

CAP. IV.

The material with which, and about which, Apelles — and about which the Censor himself established his own doctrine — is the sunspots. As they are seen in the Sun, they are, as it were, the first and remote matter; but insofar as they are fitted, by fixed instruments and regular observations drawn from mathematical investigations through accurate observations, they take on the character of a matter that is, as it were, secondary and proximate. Now in searching out and detecting the spots in the Sun I used no forewarning guide, nor will any wanton claimant of the contrary cloak his claim with even the shadow of probability. As for the Censor's empty boasting about his own supposedly ancient inspection of the spots, you will see it discredited below, in chapter 7. Furthermore, I founded and built my doctrine of the spots solely upon observations made by me — and, for the sake of example, upon those set out in a Table (since I have published only the smallest part of them), extending down to 4 April. But since the Critic of Apelles could not, even by his own judgment, simply do without observations enclosed within the solar circle and continued long enough to conclude something certain about this phenomenon (for this is the

[Margin: Apelles could not receive the material of the solar phenomenon from the Censor — from the circumstance of time.]

secondary and proximate matter), he ingenuously confessed that he could neither make nor possess such observations up to 4 May. Therefore I could not borrow from him my own doctrine of the sunspots, which was set forth and proved before 7 April, beyond which his do not run. For nothing can be taken from one who does not have it.

And this is the first point; which was to be demonstrated.

The quasi-Formal cause here is the character of the doctrine I bring forward concerning the spots. But the doctrine in my Table — whether proposed outright from my own bent, or insinuated tentatively for the benefit of those then philosophizing — is in most respects contrary to the doctrine of my Censor; therefore my doctrine, in most respects at least, cannot have been taken over from his. But look: so that I may not seem to have brought anything forward for the sake of a cover-up, let me weave a brief summary of what was said in the Apellean Table.

[Margin: Apelles could not have filched the form of his own Table from the Censor, given its dissimilarity and contrariety.]

I said that the apparent motions of the sunspots are unequal — and that not merely for form's sake; rather I assert the same most constantly and in earnest, though the Censor advances against me with his whole army.

I said that the durations of the spots beneath the Sun are various; against this the Censor blares with cheeks at full puff; yet I still hold the same.

[Margin: The Censor and Apelles disagree in their opinions.]

I said that the spots move from east to west; and I still plainly both hold and maintain the same; the Censor decides the contrary.

I said that spots spread out along the greatest parallel take up more time than those that are carried along smaller circles; I still affirm the same in the very sense in which I said it; the Censor opposes it most fiercely.

I said that the spots are darker than the ancient spots of the Moon; and now too I steadily hold the same as established fact; the Censor fights it with sail and oar.

I raised the question whether the sunspots perish only apparently or truly; whether they are stars, or something else — and I have so far left the matter undecided; the Censor has them generated and corrupted, and makes them either fuel of the Sun, or excrement, or smoke, or pitch-black clouds, and so on.

I set down as doubtful, pending more careful inquiry, whether the motion of the spots is parallel to, or in agreement with, the ecliptic; the Censor, with no dread of the contrary, defends it most disgracefully, as though for altar and hearth.

I said that the spots are imperceptibly distant from the Sun — under doubt, until the matter be examined by me more deeply; the Censor asserts that they are contiguous with the Sun.

The rotation of the solar globe, touched on in passing, I neither approved nor rejected, but reserved for its own place and time; the Censor strains with every sinew to demonstrate it.

Therefore, whoever judges these assertions of mine to agree with the Censor's tenets, let him believe that I borrowed my own findings from him. Most of these — if once, in the Censor's judgment, I proposed them for amusement's sake (which is nonetheless utterly far from the truth) — I now, as always, seriously maintain, propose, defend, and declare for the sake of truth, and demonstrate more clearly than the Sun by the success of my work: it is plain that I drew my doctrine not from the Censor, but from the phenomenon itself.

The ordinary efficient cause of any doctrine, remotely, is a man; proximately, an intelligent man, strong in the use of reason; hence anyone who is to reason correctly about some matter must be well furnished with knowledge of that matter. But the Censor of Apelles, as of 4 May, still knew nothing solid to assert about this solar phenomenon, because — as he himself writes of himself — he stuck fast, wholly timid, doubtful, hesitant, and irresolute, between hope and fear; whereas I, on 14 April, had submitted my whole doctrine of the sunspots, comprised in five letters, to the public and to the judgment of Welser [Marcus Welser].

[Margin: Since the Censor lacked knowledge of this phenomenon when Apelles put forward his Table, Apelles likewise could transfer nothing into it from the Censor.]

And again, the Censor first began to affirm something assertively only on 14 August, whereas I, by 5 July, had both set out more than his and added matter of my own. It is therefore impossible that I drew my doctrine from him: for I completed and issued the greater part of it on 14 April 1612, when he himself still wavered entirely and held to virtually no settled view — rather, as he says, driven by the whirlwind, the reversals, and the clashing of his own varied thoughts and diverse opinions that kept crowding upon him, he was so torn that, now assenting, now resisting and contradicting, he came to rest nowhere firmly,

and so, wavering, fell silent — against his will, and much to his own harm — in a three-month silence; because the wretched man, out of his inexperience of this phenomenon, had no sure grasp of what to affirm or what to deny; even though he were the sole and only one — with an Angel, forsooth, revealing it from heaven — to whom alone all discovery, and the fullness of knowledge of these matters, had been divinely reserved and communicated. With what face, then, does he now maintain that I plucked my doctrine from him, and that, having drawn it from him, I concealed the fact — when he freely confesses that he himself had none? For by 14 April I had sent five letters to Welser, at a time when he himself did not dare to open his mouth about this appearance, let alone write of it, because he knew nothing — and yet, O prodigy, he was instructing me! Once an effect is actually in place, its cause must exist or have existed. Since, therefore, the Censor's understanding lacked knowledge of these things, the matters that Apelles published about the spots — and the time when he published them — cannot have proceeded from it.

[Margin: Conclusion.]

That Apelles did not draw his doctrine of the sunspots from the Censor is demonstrated, thirdly, from the chronological history.

CAP. V.

The Censor says, in his *Libra* [Libripens = *Il Saggiatore*]: [Italian:] "*Et alcuni costretti, e convinti dalle mie ragioni hanno cercato spogliarmi di quella gloria, che era pur mia, e dissimulando d'haver veduto gli scritti miei, tentarono dopo di me farsi primieri Inventori, &c.*" — "And some, constrained and convinced by my arguments, have sought to strip me of that glory which was truly mine, and, dissembling that they had seen my writings, attempted after me to make themselves the first Inventors, etc." — just as has also been seen above. Namely, that certain persons, convicted by his own arguments about this phenomenon, attempted to strip him of the glory of his first invention — evidently on the ground that, having seen his writings, they learned much, and afterwards brought it forward as their own, and so tried to snatch the palm from him. These charges, I judge, are leveled entirely at me along with others, and I proved as much at the beginning of the work; yet, so that their falsity and unworthiness may plainly stand out, here for you is the chronological history of the writing.

I completed my first three letters in the months of November and December 1611. The Censor composed and finished his first letter — by which he examined (did he examine?) my three, at Welser's request — on 4 May 1612: nearly five months

lie between. Welser made my three letters public on 5 January 1612, and sent them, printed, to the Trutinator [Galileo, "the Weigher"] on 6 January; thereafter the Censor turned them over for four months, until he wrote his own first letter with a faltering pen and a slippery style, so that while he said much, he nonetheless asserted nothing. Hence it is clear that in my first three letters

[Margin: Apelles anticipated the Censor in writing by a long time.]

nothing could have been drawn by me from his writings; since his writings were first composed upon my letters, and these were the first cause or occasion of his writings, while he himself, still raw about this phenomenon, was stuck (as they say) in the bare elements. From one who does not know, nothing can be learned. Next, when the Censor, in his first letter, obscurely hinted at that exact method of observing by which the Sun is caught through a tube onto paper, and promised Welser — and me — an investigation of this phenomenon, more accurate observation, and the most precise delineations of the spots, I clearly perceived (especially given the eighteen-month priority of noticing this phenomenon that he boasted of) that he was about to put his sickle into my harvest. Hence my learned friends — and before all Welser, in his frequent letters to me, still in my possession — kept urging me on all sides to add the rest to my earlier letters, and not to let this credit be snatched from me by another.

[Margin: At Welser's urging, Apelles enlarged his Table, so that the Censor should not put his sickle into another's harvest.]

Since on 16 January 1612 I had already sent Welser a fairly full letter, explaining clearly and at sufficient length most of the more general secrets of this phenomenon — a letter in which I guarded myself amply against Harpies of this sort — in these words:

"For the present I gladly refrain from saying more: I think these things too will, however they stand, satisfy the intelligent Reader well enough. For since there are two kinds of rivals — the one, of those who, being themselves unable to accomplish anything distinguished, carp in whatever way they can at every distinguished thing; the other, of those who, though able, have not done so, and, as soon as they notice that others have attempted something notable, come flying in themselves and pounce to snatch what is another's — I bar both from our work by this letter. For the first will not fault the earlier matter if, by this supplement, they see most of it perfected; and the last will not arrogate these things to themselves if they observe that most of what needed saying has been

said, and most of what needed objecting has been resolved. Hence, since this phenomenon is going to prove far greater than anyone would easily suspect — as you will understand from its very progress, and as, unless I am mistaken, you already perceive with your most keen mind — while (in my judgment, though with others' leave) no equal to it has been shown, nor perhaps ever will be shown: I have hurried this letter to you, [its matter] now ripened by time, especially as regards the earlier parts, so that you may anoint them with oil of cedar, like the earlier ones, and keep this glory, such as it is, of our Germany and of your Augsburg untarnished. This I trust can then be done, provided the publication is by no means further delayed. More [Plura(?)], or greater things than these, you shall soon have from me. How great these matters are, and where they tend, you perceive along with me; hence I fear that, unless you get ahead of it, they will all but be wrenched from our hands: for once the mathematicians have seen so great an outcome of this affair, they will not restrain themselves. But they will restrain themselves if they weigh how far behind us they have been left; and so they will either bring forth their own and proper findings, or at any rate not arrogate what is another's. To prevent this rests entirely with you." Thus far that same letter.

I therefore, as I said, having built up these things plainly enough as a safeguard to fend off others' hands, did not persuade myself that anyone would be so brazen-faced as to dare to rank my labors — which had gone so far ahead of others' — behind his own speculations that were still to follow; much less to claim that his were the source from which mine were derived. Yet since it seemed right — Welser too advising it — to satisfy my friends' insistence, to look to my security, and to serve the moment, I further added the observations spanning 16 March to 4 and 7 April 1612, together with my notes, and sent them to the same Welser on 25 July, though I could well have dispatched them in June or May, or even in April itself. But since in those days the novelty of this phenomenon was aflame everywhere among all nations and lands, I deliberately chose to leave others room to bring forward something from those earlier months; and so I left that gap, from 11 January to 16 March, open right up to the present day, in order to leave the Censor of Apelles — or any other student of these matters — room and scope to fill it, so that he might make plain to the whole world, by at least a probable argument, that he too was to some extent a partner in this phenomenon and its discovery, and so that I might not be applauding myself alone.

[Margin: The Apellean gap awaits the Censor's ingenuity.]

But since no one has done so up to now, I leave it to any fair appraiser of the case to decide whether he will award the laurel of first invention to me, or to the seizers and snatchers of my night-labors — a laurel that I nonetheless do not value as highly as I value truth, for whose sake I am arguing all this.

For indeed, when — as I said — I had sent my later letters to Welser on 16 January, 14 April, and 25 July, my Censor finished his second letter on 14 August;

[Margin: Apelles's final labors preceded the Censor's second and third letters.]

and on this count I could pluck nothing from it and insert nothing into my own writings: for I am not so lynx-eyed [Lynceus] as to read, on 16 January or 25 July, a writing that did not yet exist in nature, but first saw the light only afterwards, on 14 August. I do not have so keen an edge of mind that, like God, I could set before myself as present the things that do not exist.

But someone will say that I could have gathered much by hearsay: for although the Censor of Apelles first finished his second letter on 14 August, it could still be that long before Apelles himself he had been turning over in his mind the notions unfolded in it, which might have reached Apelles's ears, so that Apelles drew from them the idea of painting his own picture, to be sketched with stolen colors.

[Margin: An empty objection is answered.]

To this I say, first, that I am now being turned from a Reader into a Hearer. The Censor said that his writings were carefully read, and yet concealed — not merely heard, not merely thought of, etc. Second, that these objections are dreams fabricated by the malicious: for from where, or by what evidence, do they know that the Censor's opinions on this subject were reported to me? Third, even if it were supposed — though this neither happened nor could have happened — that I had heard his notions and seen his writings, will they on that account conclude that from these I drew my doctrine? With far better reason they could have inferred that the Censor himself drew his opinion about the spots from my Table, which he had with him for a full six months before his history. An argument from "can be" to "is" is useless and empty. Fourth: but the Censor's writings, before I had completed my Table, I neither read nor ever learned from anyone even to have been conceived — and no wonder, for neither existed in nature when I submitted my picture, and its explanation, to the judgment of the whole world. And so that you may see this plainly, fifth: by 16 January I had set out, in five letters, my whole opinion about the spots; for what I committed to writing on 25 July brought nothing beyond the confirmation of this phenomenon and the buttressing of what I had earlier asserted. The Trutinator [Galileo], meanwhile,

on 16 January was still groping, plunged in the deepest darkness about this phenomenon; inasmuch as even on 4 May he did not yet dare to blurt out anything (as, on his own testimony, has been most brilliantly demonstrated in the earlier passages) — around which time, however, some spark of another's reasoning arose in him and brought him hope of light, because he had obtained his own disciple, a master in the art of observing, from whom he himself might be taught the truth, and the Angel might unlearn his vanity in prophesying.

[Margin: What does not exist in nature can neither be heard nor seen.]

Up to this point, then, I could not perceive, by hearing, his hidden thoughts about the spots, nor, by sight, his abstruse lucubrations; because there were none. My own discussions, therefore, long since published, I in no way took from him. Sixth: and although the Censor composed his second letter on 14 August, Welser nonetheless had my more accurate *Disquisition* printed, and dispatched it to him, on 28 September 1612 — before he obtained the said letter of the Censor, which (as is clear from Welser's fourth letter) he received only on 5 October 1612; and Apelles received it from him only afterwards. If, therefore, I preceded the Censor in observing the sunspots by enclosing them within the Sun's circle; if I preceded him in their arrangement, ordering, examination, place, motion, and nature — whether in investigating them, or in disclosing them and publishing them abroad; if I accomplished all this with no guide and no teacher; if, while I was carrying this through, the Censor about all these matters was perplexed, hesitant, and irresolute; if he did not make observations enclosed within the solar circle, and could not make them: then how, I ask, did I learn from him what he himself did not know? For he has testified that as of 4 May 1612 he had no observation enclosed within the solar circle. Therefore at that time he could not, from his own observations, clearly establish that the spots are carried more slowly near the edges and more swiftly toward the middle; he could not state the spots' position relative to one another; he could not reveal that the spots circle the Sun with a circular motion; he could not compare their daily motions one with another; he could not, I say, demonstrate these things solidly, sufficiently, and mathematically from his own resources, because without observations enclosed within the circle they cannot be proved.

[Margin: Since in the year 1612, up to 4 May, the Censor could not establish the Apellean conclusions from his own observations, neither could Apelles have gleaned those same conclusions from him.]

He could, however, prove them from mine; he certainly had the opportunity of learning, since for four whole months he turned my Table over at his own home,

and endured an internal war of contrary thoughts about whether to assent or to dissent — until at last, taught by his disciple (not aided by any divine privilege granted to him alone), he began to apply

he began to apply [it]; and then, for the first time — God help us — I learned my own observations, my own teaching, and my painted diagram (long since put on public display) from him; I stole them from him, and put myself ahead of him! What a charming stunt, what an admirable contrivance! I, having published my work in the year 1612, took it from what he published in 1613. Hold back your laughter, friends, now that you have granted the story a hearing.

That Apelles did not draw his teaching on sunspots from the Censor: a fourth demonstration, from the authority of witnesses beyond all exception.

CAP. VI.

When the Censor hints that he saw my writings before I published my own, and that I concealed this fraud, worked to my own advantage, he violently breaks the laws not only of truth but also of common decency. For he brands with the foulest mark of infamy a man who deserved better of him than anyone else, and in whose lifetime he ought to have brought these things forward: knowingly and deliberately he charges that most weighty and honorable gentleman, Marcus Welser [Marcus Welser] — dead now for many years, a most wise governor of so celebrated a commonwealth — with signal vanity and shameful frivolity.

[Margin: The Censor does injury to Marcus Welser, long since dead.]

For what the Censor affirms about his own writings — that I read them and then suppressed them, or the ideas in them — Welser flatly denies. One of the two, then, must necessarily be convicted of falsehood. And since Welser wrote this down expressly to the Censor himself, while the Censor was still alive, and the Censor never refuted it, the matter must certainly have stood as Welser says. Otherwise Welser would surely have noticed the easy damage looming over his own good name, had he so imprudently provoked the Censor — a living witness — against himself, in a cause not injurious to the Censor, indeed hardly favorable or profitable to him. But what use is it to build up Welser's credibility by conjectures gathered here and there, when the Censor has, in his own hand, most openly subscribed to that same opinion against himself? Let us hear them both. Marcus Welser's fourth letter to the Censor, written for Apelles and dated 5 October 1612, opens as follows:

[Margin: Welser's testimony, for Apelles against the Censor.]

[Italian] "Comparue finalmente la seconda lettera di V. S. di 14. d'Agosto, mandatami dal Sig. Sagredo. Et circa medium. Desiderarei grandemente, che Apelle hauesse visto questa scrittura, prima che stampare gli suoi vltimi discorsi; & pure considero, che per qualche rispetto è forse meglio à questo modo."

Which he renders in Latin: Your second letter, dated 14 August, has at last arrived, sent to me by Signor Sagredo [Sagredo]. And near the middle: I should very much wish that Apelles had seen this writing before he committed his latest discourses to the press; and yet I consider that, for certain reasons, it is perhaps better this way. And he adds:

[Italian] "Io non mancherò di comunicargliela, saziato che me n'habbia prima vn poco."

In Latin: I shall not fail to communicate this letter to him — once, however, I have first satisfied my own hunger for it a little. Here the following points are to be noted.

[Margin: Points to be noted from the testimony of M. Welser.]

First, that from Welser's testimony it is certain my own attention to sunspots — the later of the two efforts — reached the public before Welser received the Censor's second, Italian letter.

Second, that from the same testimony it is established I had not seen that letter of the Censor's; otherwise Welser would be wishing in vain for the opposite, and would be lying magnificently indeed.

Third, that for certain reasons Welser nonetheless moderated his desire, and judged it preferable that my work should go out in public without his having read the writings of the Censor's second letter, rather than that I should first publish my own only after receiving, examining, and reading the Censor's. And although a prudent reader may easily grasp Welser's reasons, still, to free him from all doubt, I shall state what Welser himself wrote to me privately: namely, that the Censor, or anyone else, should not seize a pretext for suspecting and proclaiming that I had learned, stolen, and published my teaching from the Censor's own writings. Welser judged rightly, for the Censor did to Welser dead what he would perhaps not have dared to do to him alive.

[Margin: Welser foresaw the Censor's coming slander against Apelles.]

Fourth, that he would send me that same writing, etc. Therefore, on his own testimony, I did not have it before.

Fifth, he then adds a difficulty peculiar to my situation: namely, that all the Censor's writings reach me in the Italian style, etc. Out of this circumstance a new difficulty arises for the Censor — one whereby he tries to cloak his lies with some semblance of the truth...

For who gave me his Italian writings apart from Welser? Who could have given them? Who translated them from Italian into Latin? At what time? In what place? By what means? Speak up, if you please; invent something; wash mud with mud, and dilute your old accusations with new ones. You will not escape: Welser's testimony stands against you, and your own testimony stands against you. Let us hear you yourself. In the year of the Lord 1612, on 1 December, the Censor in his *History of Sunspots*, in his third letter to Welser, at p. 103, speaks thus:

[Margin: The Censor's testimony against himself, in favor of Apelles.]

[Italian] "Quanto ad Apelle, à me ancora dispiace che e' non habbia veduta la mia seconda lettera, auanti la publicatione della sua più accurata disquizione, e che la mia ambiguità, & pigrizia nello scriuere, non habbia potuto tener dietro alla sua risoluzione, e prontezza; ben'è vero che buona causa della dilazione n'è stato l'esser trattenute le mie lettere più d'un mese in Venezia dalla troppa stima, che di esse fece l'Illustrissimo Sig. Gio. Francesco Sagredo, volendo che ne restasse copia in quella Città."

Which in Latin reads: As for Apelles (says the Censor), I too am sorry that he did not see my second letter before he issued his more accurate disquisition to the public, and that my hesitation and slowness in writing could not keep pace with his resolve and quickness; though it is quite true that a good cause of the delay was that my letters were held more than a full month in Venice, out of the excessive esteem the most illustrious Signor Giovanni Francesco Sagredo had for them, wishing a copy to remain in that city — since I had been sufficiently honored merely by his reading them, which, on account of the multitude of figures, required a good deal of time, etc.

Here it is plain that the Censor is of the same mind as Welser: that I neither saw, nor could have seen, his second letter before the publication of my later letters, because his writing was stuck in Venice in the month of September, whereas everything of mine had flown from me by 25 July. Against this witness, I suppose, the Censor will raise no objection, since in all the world he has no one greater

whom he values more, loves, honors, trusts, defers to, or believes. What he then appends about the Italian language...

confirms once more, most solidly, that at that time I neither had, nor could have had, the Censor's Latin writing. But so that every word may stand in the mouth of three [witnesses], here is a third witness, and one who is a Lyncean Academician, privy to all the Censor's secrets: Angelo de Filiis [Angelo de Filiis]. In his preface to the reader, though he assigns the first honors of the invention to the Censor, as though owed to him by divine decree, he nonetheless does not deny that the second honors could fall to me; and he affirms outright that, by publication, they did fall to me — in these words, cited above as well, in his preface to the reader in the *History of Sunspots*, fol. 3:

[Margin: Angelo's testimony, for Apelles against the Censor.]

[Italian] "A quelli poi, che pretendessero anteriorità nelle osseruazioni di tali Macchie, non si nega, il poter loro hauerle osseruate, senza auuiso precedente del Signor N. com'è anco manifesto, hauerlo essi preuenuto, nel farle publiche con le stampe &c."

That is: To those, moreover, who might claim priority in the observation of such spots, it is not denied that they could have observed them without prior notice from Signor N. — just as it is also manifest that they anticipated him in making them public in print, etc. This is Angelo the Lyncean, with the Censor no doubt aware and approving. From it I take, *First*, that I could have observed sunspots without knowing anything of the Censor — which is not true, if I drew my doctrine of the spots from the Censor's writings after first reading them; for if what has been done cannot be undone, it is impossible that I could not have read the Censor's writings once read, which would nonetheless be necessary if I had produced my own work without any prior notice drawn to me from the Censor's writings. *Second*, that I published my own work in print before the Censor. With this the Censor himself agrees, in his first letter, fol. 10, at the end, in these words:

[Margin: Corollaries deduced from Angelo's testimony.]

[Italian] "Aggiugnesi, che io mi contento più presto di esser l vltimo à produrre qualche concetto vero, che preuenir gl'altri, per douer poi disdirmi nelle cose con maggior fretta, e con minor considerazione proferite."

He adds, says he, that I would rather be the last to produce some true conception than to anticipate others, and then have to retract things put forward with too

much haste and too little consideration. From this confession I obtain the following.

[Margin: The [preceding] points are confirmed from the Censor.]

First, that the Censor, writing this on 4 May...

had not yet determined what he ought to say about this phenomenon, and consequently lacked any certain knowledge of the spots.

Second, that he conceded the palm of priority to me, and not unwillingly, when he says he would rather be last with the truth than first with error.

Third, that in the end he was content, provided that, instructed by the truth, he might follow it.

But whereas in the same letter [he writes]:

[Italian] "Ma la difficoltà della materia, e'l non hauere io potuto far molte osseruazioni continue &c."

— that on account of the difficulty of the subject he could not make many continuous observations, etc. — and in his third letter he denies that he enclosed them within the Sun's circle: without controversy he makes me, too, the prior in the observations necessarily prerequisite for judging this phenomenon, and himself the later. For at the time when — namely on 4 May — he was writing and doing these things, I had long since completed my observations and the consequences deduced from them, had sent them to Marcus Welser, and the Censor, having received them from Welser, had for the most part worn them over nearly four months with his eyes and his hands.

[Margin: Corollaries from the cited passage of the Censor.]

[Margin: The Censor concedes the palm of priority to Apelles.]

There stands, then, this testimony too, of Angelo and of the Censor, against the Censor. All of which is likewise confirmed by the fact that I never had any direct dealings with the Censor — though I sought them in vain by three letters sent to him — but rather received whatever came to me from him only through Welser.

[Margin: The Censor scorns correspondence with Apelles, though well known to him.]

Now Welser writes to the Censor in his third letter, dated 28 September 1612, in this manner:

[Italian] "Intendo, che V.S. hà scritto vna seconda copiosa lettera sopra questa materia diretta à me, quale non mi è ancora venuta vista, ma la stò aspettando con singular desiderio."

In Latin: I understand that you have composed a second, full letter on this subject addressed to me, which I have not yet seen, but which I await with singular longing. Since, therefore, Welser sent my later *Disquisitiones*, committed to print, to the Censor together with this same letter, but had not yet received or seen the Censor's second letter (for it was stuck in Venice), it follows that I could not have seen it either, nor composed my work from it, since nothing of these matters reached me except through the effort and hand of Welser.

[Margin: Another testimony of Marcus Welser, for Apelles against the Censor.]

Since these things are so, it is out in the open that, to adorn my own diagram, I neither used nor could have used the Censor's borrowed colors — colors that at the time did not exist in the nature of things. And this too rests on the irrefragable testimony of the three witnesses just cited, whose authority with the Censor is certainly the greatest, whose rank is the highest, whose credit is beyond doubt, whose learning is choice: they are all philosophers, exalted in station, conspicuous in dignity, distinguished in birth — in one word, Linceans, the very chiefs of the Linceans. There is Angelo, there is Welser, there is the Censor: against whom not even Hercules could stir himself. If the Censor fights against them, then truly he is warring with the living and the dead, and with his own self. Let him therefore consider by what reasoning he may return into favor both with himself and with so many great adversaries. For that my name and diagram were assailed with insults is a small thing — truth, once brought to light, will keep both safe and sound; but that by a single act of slander he calls into question at once the good faith of the living and of the dead; that he burns an indelible mark of infamy upon a man of the utmost integrity; that he forgets the laws of friendship; that he knowingly attacks a truth he has acknowledged, and attacks himself; that he violates Christian charity, while loading me, plainly innocent, with the trumped-up crime of a shameful theft — this, in the end, is virtually to strip off the feeling of humanity.

[Margin: The authority of the aforesaid witnesses is inviolable.]

That Apelles did not contend to take from the Censor the glory of first discovery.

CAP. VII.

Up to this point I have shown my innocence; I have displayed my hands, my strongboxes, my eyes, my whole workshop empty of another man's wares — my instruments, my colors, the art of painting, the painted images, and finally my diagram and my teaching — that they are my own, that there is nothing borrowed in them, nothing carried off by theft, nothing counterfeited, nothing of the Censor's to be found. I have made this plain by history, by reason, by testimony, and by the Censor himself. What, then, in the end, is it that I have taken from the Censor, that I have contended to carry off? "The glory," he says, "of first discovery." And [he goes on]:

[Italian] "Et alcuni, cōstretti e conuinti dalle mie ragioni, hanno cercato spogliarmi, di quella gloria, ch'era pur mia, e dissimulãdo d'hauer veduto gli scritti miei, tentarono dopo di me farsi primieri In-..."

"...uentori."

In Latin: And certain men, constrained and convicted by my reasons, tried to strip me of that glory which was nonetheless mine; and, pretending not to have seen my writings, they attempted, after me, to make themselves the first discoverers, etc. Tell me, please, tell me if you will: who are these "certain men, constrained and convicted" by your reasons? What are those reasons? When, where, to whom, how, and about what matter were they put forward? By word, or in writing? By yourself, or through others? By what reasoning were they constrained? By what arguments convicted? Whence and how do you know that they were constrained and convicted by you? Who, in the end, are they? For in all likelihood you are recounting your own figments and dreams, so that, while you fence in the shadows with your own phantoms, you may throw dust in the reader's eyes. And who, further, are those who set out to strip you of a glory that was yours alone? What was that glory, and how "yours alone"? When, where, how did they wish to deprive you of your glory? What was this glory of yours? For of it they knew absolutely nothing: how, then, could they have wished to plunder it? An act of the will does not follow without some prior notion in the mind; where, therefore, no knowledge of your supposedly great glory ever shone upon anyone, no desire of depriving [you] could arise. Either show that they had knowledge of your glory, and demonstrate the intention and the attempt at plunder — or swallow the injury back and confess the deception. But you do this against my bidding, by your own doing, against your own mind, [and against] the Truth, when you say: "which was nonetheless mine."

[Margin: The Censor's glory: painted, shadowy, empty, nonexistent.]

For that glory of yours was yours alone; others had nothing of it and knew nothing of it; you alone applauded yourself, and within the inner sanctum of your own breast you struck the strings — spontaneous and self-glorifying — that rang out to you alone the sweetest harmony at home. This was the glory that was yours alone. But if it is otherwise, then show, if you please, which of those you accuse knew anything of it — by what contests it was won, by what battles gained, celebrated in what triumphs, inscribed on what arches, adorned with what standards, set forth in what trophies? Everywhere, certainly, there is deep silence. Yours it was, yours it is, yours alone it shall be, this glory; of it no one but you knew, nor did anyone snatch it away. And if I have snatched the *true* [glory] from you, I did not take away *yours* — which is nonexistent, which is false. I leave your entertainments to you. And what, pray, are those writings of yours, and by whom, in the end, were they seen, read, understood? You throw dust in men's eyes, O Censor, and you wish to persuade the ignorant and unlearned crowd that your inventions have been thumb'd by the hands of others...

used by their eyes, before they were ever born from your brain. Come now, review all your writings on this subject: did you not gather them in your *History*? And was this not, on your own testimony, put together at Welser's urging, so that he might hear your judgment on my diagram? Did you compose the history before the deed was done? Did you write anything about sunspots before my diagram was sent to you? Before your opinion of it was requested from you by Welser? You wrote nothing, Assayer, nothing at all. For whereas, on Angelo's testimony (p. 2), the whole Lyncean Academy in the preface was awaiting your judgment on the spots, it at last learned that this subject had been fully treated by you in certain letters written privately to Welser. This you yourself freely admit in your own letters to Welser:

[Margin: Without Marcus Welser the Censor would have had nothing on the solar phenomenon; he would have committed nothing to writing.]

[Italian] "Hò anco taciuto, sù la speranza di potere dar qualche soddisfazione alla domanda di V.S. intorno alle Macchie Solari."

In Latin: I also kept silent, you say, on this further ground: that I hoped to give some satisfaction to your request concerning sunspots. And in his third letter, at p. 102:

[Margin: The Censor reports that he received his *History of the Spots* from Welser.]

[Italian] "Il debito del ringraziare resta in me con molti altri obblighi, che tengo à V.S. Illustriss. perche se hauerò inuestigato qualche proposizion vera, sarà stato frutto de i comandamenti suoi; e i medesimi diranno mia scusa, quando non mi succeda il conseguir l'intero d'impresa nuoua, e tanto difficile."

In Latin: The debt of thanks remains upon me, along with many other obligations by which I am bound to Your most Illustrious Lordship: for if I shall have investigated any true proposition, it will have been the fruit of your commands, which will also be my excuse if the outcome does not in every respect answer to my efforts in a matter so new and difficult. [And:] "Because," you say, in your first letter, p. 10, "it is fitting for me to be cautious, and necessarily to hide and keep silent about new matters and conceptions, until I have demonstrations more than certain and palpable, on account of the countless contradictors, etc." But it is evident that, before this urging of Welser's, you had no certain and palpable demonstration of the sunspots — indeed, not even a true proposition, still less, in any writing, anything of the sort worked out. Therefore you speak falsely when you say that some read your writings, and, having read them, dissem-

that these men, hushing it up, made themselves out to be the first discoverers. For there are no such men, nor can any be named with truth or with any probability. I alone am singled out by you, under cover of certain names — rivals for priority whom you idly invent to set against me. [Margin: Apelles alone is censured by the Censor.] For, on Angelo's own testimony, the very first writings to see the light on this subject were the Table of Apelles [Angelo De Filiis]; yet at that time your own conceptions, your own offspring, did not yet exist in the nature of things. [Margin: In the preface, p. 3, near the middle.] None of the others who published anything on this phenomenon [*phaenomenon*], and who read your writings, can be made to appear — by deed or by word — the first discoverers. Nor do those who saw your writings conceal what they saw; rather they admit it, and often contradict you.

But at Rome and Florence you discussed the spots [*maculae*] privately with many, and showed them to many. We shall see a little later, more precisely, what it was you showed; and already, from your own cited words, it is clear how little you could contribute — destitute as you were of every resource for treating this phenomenon soundly, philosophically, and astronomically. To talk about the spots, meanwhile, is not to write about them; to see the spots is not to produce your writings — writings that had not even been thought of then, much less composed. Indeed, you yourself trace whatever you devised on this new and difficult subject to Welser's [Marcus Welser] prompting, meaning to defend those

same findings against the slips that were to follow. What could those writings have been, of which neither Welser nor the Linceans [Accademia dei Lincei] would have understood anything — with whom, nonetheless, you promptly shared all your other novelties, so as to have them as witnesses of your first discovery? Who would believe that you would not have produced those writings, at Welser's request and the Linceans' insistence? Indeed, who would believe you would produce what had not even been conceived, but was still being awaited as the fruit of Welser's promptings, at the time when he laid my Table before you? [Margin: If the Censor had known anything of any moment about this phenomenon before Apelles, it would not have escaped the Linceans.]

Neither you yourself, nor Angelo De Filiis on your behalf, dared to fabricate — in the published *Istoria delle Macchie* — any writings of yours that would have preceded my Table. Instead you begged priority in the discovery of the spots on the strength of some display or other: of the spots themselves upon the Sun, made in the Quirinal Garden before certain eyewitnesses, and shown in the same way, many months earlier, to certain unnamed persons at Florence. [Margin: The Censor arrogates to himself the glory of first discovery on the strength of obscure and uncertain witnesses.] For as regards Angelo's flat assertion in the Preface that he had given some people at Florence private knowledge of this phenomenon, you yourself, in your first letter, restrict this to an eyewitness inspection of the spots on the Sun, when you say [Italian: *Hauendole fatte vedere à diuersi miei intrinseci* — "Having shown them to various of my intimates"]. Therefore you wrote nothing about the spots beyond what you stitched together for Welser in the three letters of the *Istoria*. [Margin: The Censor creeps into priority on the strength of a mere inspection of the spots and an eyewitness demonstration — not on any written observations of them.] So Apelles saw nothing of your writings, read nothing, that he might carry over into his own Table. For your *Istoria*, your opinion, was struck into print only after my Table had been completed; so it was not this Table that took its origin from that *Istoria*, but that from this.

A censure, to be made, presupposes that the thing to be censured already exists; therefore the thing censured could not have been produced out of the censure. Your conceptions, your writings, are your censure of my Table; so neither could this Table have been made from that censure, nor could that censure have existed before this Table. For nothing comes from nothing, and no sound mind can pass judgment on something that does not exist as though it already existed. It is therefore impossible that I pieced together my Table from your writings, or that you penned your writings before my Table. Hence the glory you have

claimed from sunspots [*maculae solares*] seen before my Table is smoke, is a dream, is vanity, is a fiction. And this glory, if you so wish, you may keep for yourself alone, for all I care.

But when you go on to say that those "certain persons," having hidden the fact that they read your writings, made themselves the first discoverers of this phenomenon — either you are speaking of me, and you stray far outside the line of truth (for when I set out my findings, your writings had not yet even been conceived); or you are speaking of others who have treated these matters, and again you are plainly making things up, since they do not conceal having read your works, if they did read them, and they do not make themselves out to be the first discoverers. [Margin: The Censor slanders the undeserving.] The first discoverers of the spots could not have read your writings about them, because those writings did not exist; and those who did read them do not claim to be the first discoverers. Yet you assert both at once; and in one and the same act you wound both truth and justice, and load the undeserving with slanders.

And this is that glory of yours alone, which you have gathered for yourself out of these things — unless perhaps you prefer the glory that Angelo, sent from heaven I know not whence, awards you, when he says (no offense meant by the word) that to the Censor alone in this age of ours it has been divinely granted that he alone and first should discover new phenomena, alone and first uncover them, while to the rest it is scarcely permitted to follow behind, and from afar. Hence he was the first — so runs the claim — to survey the marvelous spectacle of the sunspots, hidden since the founding of the world, and the first to show it to others; this glory is his alone. Do you really say so, and demand that I credit it? I will grant the Censor his seeing and observing of the spots, if the Censor will grant Simon Mayr [Simon Marius] his of the Jovian stars. But the Censor produces eyewitnesses. Let the credit rest with the author; grant that it was shown —

— but either not believed, or not seen at all; for a year's silence would not have suppressed so great a matter, if his own observation had truly taken place and had made any impression on the eyes and minds of the onlookers. [Margin: The Censor's showing of the spots — a suspect display.] Did not the whole world, as soon as my Table was displayed, at once run to the miracle of the novelty — see it, gaze at it, approve it? And this within not a year, but a span of a few months? Since, therefore, the Assayer [Trutinator — Galileo, from *Il Saggiatore*] himself, even in the fourth month after my Table reached him, is still wholly at sea about this phenomenon, and throughout his first letter bewails his own darkness, [Margin: If something certain was seen, why does the Censor stumble so?] it is

clear evidence that he, as much as his friends, over the eighteen months just past — and long before as well — had not been much concerned to bring this phenomenon to light, or else had certainly given up in despair after fruitless attempts. For otherwise, had they truly discerned it and taken it for a real phenomenon, they would surely have found a way to treat it, seeing that, once my Table was on public display, they were so quickly driven to enter upon the Sun through the telescope [*tubus opticus*].

It becomes highly probable, then, that the phenomenon was either not seen at all, or taken for a mockery and a deception — by the Balance-holder [Libripens — Galileo] himself as much as by everyone else — inasmuch as no specimens of observation survive fit to convince anyone. Add that, if the Balance-holder thinks a mere hunt for the spots, or an ambiguous glimpse, deserves the prerogative of first discovery, then Kepler [Johannes Kepler] snatches this crown from him, and the ancients snatch it too; for Kepler himself long before saw a sunspot beneath the Sun — mistaking it for Mercury (as the Censor himself so rules) — and the ancients saw such spots as well. [Margin: The glory of first discovery is due neither to a doubtful nor to a dull glance of the eye; the mind's insight must be added.] But the attempt alone is not enough: the attempt must be matched by a happy outcome as well; the mere sight of the eye is not enough: the mind's insight must be added. One must see, and understand, and demonstrate to others, what it is one sees and that it is truly such. Where, when, and how did the Censor do this, before my Table came out? And granted that even this would not, by his own judgment, suffice for the Censor to claim the glory of first discovery — of which more shortly.

Chapter VIII. That Apelles did not make himself the first discoverer of sunspots after the Censor.

Although Apelles never raised this question, nor judges it to be of much moment to the matter, yet because the Censor keeps rubbing at it so often — both in person and through his followers, so that the whole substance of the case seems to be made to turn by them onto this point — take what follows, lest any prejudice be built up against truth by falsehood.

First: Apelles, in his entire Table — that is, both in the first three and in the last three letters written out to M. Welser and published by him in the year 1612 — never, in any express word, made or named himself the first discoverer of the sunspots or of the solar faculae [*faculae*]. [Margin: In his entire Table, Apelles always cautiously abstained from the invidious designation of first Discoverer.]

The irrefutable witness of this is Apelles's Table itself, which speaks plain enough Latin and can be read by anyone. In it I deliberately abstained from the invidious title of Discoverer, and still more from that of *First*. First, taught by the example of Christ, who *began to do and to teach* — as he still works daily, and speaks more by deeds than by words. Second, because, brought up in the Religious life as in a School of Humility, I learned long ago to scorn those empty and frivolous titles. It is base to abandon truth and chase shadows. For what do I gain, if I am reckoned or called the discoverer of the sunspots — and the first, at that? What do I lose if I am not so reckoned, or am unknown, or even denied to be such? Nothing is taken from me on the one side, nothing added on the other. I am ashamed, and have always been ashamed, to wrangle over this emptiness of titles. I have always fled this title, and have scarcely ever laid claim to it, except when, compelled now and then by necessity, I thought I must lend a hand to the truth.

I call as witnesses all those with whom I have spent so many years since the spots were discovered — at Ingolstadt, Innsbruck, Freiburg im Breisgau, Vienna in Austria, Prague in Bohemia, Neisse in Silesia, and at last here in Rome — [asking] whether I ever busied myself to claim for myself, out of ambition, the title of first discoverer. For whole years I live in the sight of my brethren, daily exchange conversation with them, and enjoy their familiar company; and yet the greater part of them still does not know who Apelles is, or was. Nor would I ever have undertaken to defend my Apelles on this account — judging the matter petty and childish, and unworthy of my taking pen in hand to wrangle over "goat's wool" [a proverbial trifle] — had I not, in later years and later writings, been treated so unfairly, and with such great prejudice to the truth. But if there are any — as I well know there are quite a few — who, in the writings they have put out, have proclaimed me

[Margin: Apelles inspected the spots in March 1610; March precedes April and May in Apelles's calendar.]

the first discoverer of this phenomenon, they will no doubt have zeal for the truth as the ground of their doing so — yet with me neither aware of it nor procuring it. Third: it might have been that somewhere someone, my equal or my senior, was unearthing the same things, so that I should not have escaped the charge of rashness, had I taken to myself the title of first discoverer. Prudently, therefore, I refrained from this designation. Outstanding talents are found everywhere; the novelty and excellence of the telescope, and the secrets everywhere disclosed through it from the heavens, have wonderfully spurred many who are curious about hidden things to probe new ones. So what I did, with no unhappy success,

another too might have done, with a like result — as often happens, that several people discover the same thing, whether at the same time or at different times. [Margin: Deeds speak more forcibly than words.]

For I shall not take so grand a view of myself as to imagine that in this age I alone am divinely appointed — or to have myself proclaimed by Angelo's heraldry — as the one man able to contemplate the heavens alone, alone to enter the palace of the Sun, and thence to pour out to earth-dwellers its hidden mysteries. Far from me, I say, be such arrogance: Apollo smiles not on Germany alone, but on others as well. Yet meanwhile I have since learned for certain that here in Rome, in matters concerning the Sun, in the very days when Apelles in Germany was preparing his Table, many things were attempted by many — but in vain; and for this I can, if need be, cite thoroughly competent witnesses. But just as I readily grant that two or more may agree in discovering one and the same thing without having compared their work, so I not undeservedly resent having the discovery of this phenomenon — and all capacity for discovering it — taken from me, and, on top of that, a shameful theft laid to my charge.

For what of it? If this privilege has fallen from heaven to my Censor — that in this age of ours he alone has attained the fullness of all celestial knowledge, he alone lays open what is hidden and hitherto unknown — does not the road to achieving these same things now lie barred to me and to everyone else? And if I have nonetheless achieved anything, does it follow that I must have borrowed it from him by stealth? Hence, fourthly, on account of the invidious and ambitious title of discoverer, I judged it better to lie hidden for a while behind the reeds, and to expose my Table to the world's judgment, rather than to peddle myself to men by boasting of empty words. For as it is better to do than to say, so it is better to be than to be called or thought something; being named follows upon being, not being upon being named. Even had I said, or written, that I

[Margin: Apelles in the *Istoria delle Macchie*, p. 35.]

was the discoverer of this phenomenon, others would still have believed no more than what they saw in the actual work; so I did better to strive, by my labor, to be the discoverer of the spots in fact than to be held such in name. The shadow follows the one who walks ahead and flees the one who follows it, and does not stand without a body; in vain do you covet the name unless you have first supplied the substance. The crowd gives no glory except for deeds; if you put on a pretense, you will carry off only smoke, and, a hollow chaser after praise, you will earn nothing but sneers and guffaws. True honor is from God alone; for him I have toiled. I should regret so great an outlay of labor if it were for the trifling

title of discoverer that I had thrown away so much time and lamp-oil. It was truth, the honor of God, and the benefit flowing from it to the world of letters, that kept me bent on this task through the course of so many years. Let him feed on the breeze of popular favor who chases the winds like the chameleon, and now and then snaps at a dry fly; solid things are my delight. Let those hunters of titles pursue names, and hunt down whole wagon-loads of names from the grammarians; it is fact and truth that enrich the philosopher. [Margin: Apelles wants his own things kept in good repair, protected, and unharmed.] This truth I have sought, and I am confident I have attained no small part of it. The usurpation of the title Discoverer — especially *First* — I have cautiously avoided; and so I wonder how it came into the Censor's mind to taunt Apelles so savagely [*saevè* (?)] on this head.

But if anyone should perhaps wish to draw something of the sort from the end of the fourth letter, which I sent to Welser on 16 January 1612, where Apelles has the following: "How great these matters are, and to what they tend, you perceive along with me; whence I fear that, unless you forestall it, they will almost be wrested from our hands. For once so great an outcome of this affair is seen, the mathematicians will not be able to contain themselves. They will contain themselves, however, if they weigh that they have been left so far behind by us; and so they will either bring forward what is their own and proper, or at least will not usurp what belongs to others" — so far Apelles. From these words, I say, if anyone should perhaps contend that it is thereby established that Apelles claims priority for himself, he will stray very far from the mark, and will be rebutted by these very words: "and so they will either bring forward what is their own and proper, or at least will not claim for themselves what is another's." Here you see, most fair-minded Reader, that Apelles does not there exclude the labors of others, if any there be, but only wishes his own to remain safe and unharmed; and in this he has done wrong to no one, though he has himself suffered the greatest wrong, when he sees his own peculiar property, after so many years, disgracefully paraded about by others as if it were a dishonorable theft.

Second: if Apelles made himself the discoverer of the spots after the Censor, then the Censor must have been the discoverer of the spots before Apelles; but the Censor was not the discoverer of the spots before Apelles. Therefore Apelles did not make himself the discoverer of the spots after the Censor. [Margin: That the Censor is not the discoverer of the sunspots is proved from an enumeration of the ways and means by which it could have happened.] The consequence drawn from the major premise is evident; the minor is proved as follows. If the Censor

was the discoverer of the spots before Apelles, this must have come to him either from the spots produced in his three letters, or from those shown at Rome in the Quirinal Garden in the year 1611, or finally from the fact that he observed them eighteen months before the 4th of May 1612, and showed them to certain intimate friends, as the Censor boasts. By none of these ways does the Censor gain priority; therefore he is not the discoverer of the spots before Apelles.

Not by the first way: because Apelles anticipated the Censor by writing and publishing his properly-made observations — as is established, and is plainly proved throughout this book. [Margin: The Censor, by his own *Istoria delle Macchie Solari*, is not the first discoverer of the spots.] Not by the second: because Apelles saw and observed the sunspots before the Censor tried to display them to others at Rome in the Quirinal Garden and so forth, as he asserts. For this took place in April and at the beginning of May, as we have it from the Censor himself in his first letter, and from Angelo in the Preface to the *Istoria delle Macchie*. But Apelles inspected and displayed the spots in March of the year 1610; and March does indeed precede April and May in Apelles's calendar. If in the Censor's calendar it comes later, let him consider whose reckoning he is following. The controversy turns on the third way alone. And since this is a question of fact, and is asserted to another's prejudice, unless it be proved by the most solid weight of argument it will deserve the hardest credence — indeed none at all — and will be stifled altogether in the mouth of the one asserting it.

Let us review the history a little, and set the sequence of events before our eyes, so that the truth of the matter may plainly appear. In the year 1611, in the month of March, Apelles caught sight of the sunspots; in October and the following months he recorded them, down to the 7th of April; and in the year 1612, in January and September, he published them in print. The Censor published the same in print in 1613 — namely those observed and recorded in 1612, from 2 June to 8 July, from 19 to 21 August, from 5 April to 1 May — which he sent to Welser, consigned in three letters; in the first of which,

dated the 4th of May, on page 11, a little before the middle, he says: [Italian: "*Et io le hò osservate da 18. mesi in quà, hauendole fatte vedere à diuersi miei intrinseci*" — "And I have observed them for the last 18 months, having shown them to various of my intimates."] And I in Latin: "And I have observed them (the spots) for eighteen months, up to now, and was the occasion of various of my friends seeing them." This the Censor writes of himself, after Apelles; this of his own friends; and by it he wants everyone to be persuaded that he saw the spots before Apelles, and is therefore the first discoverer of the spots. But whether — and

what, and how much — this argument is worth, even by the Censor's own reckoning, must now be weighed more carefully. [Margin: The Censor, on the strength of his boasted eighteen-months' observation of the sunspots, is not to be held their first discoverer — by his own judgment, calculation, and deed.]

The Censor, in the year of our Lord 1610, on 7 January New Style, for the first time and as the first (so he contends), discovered the Jovian stars [the satellites of Jupiter]; and he set out the observations and records of them, continued from that day to 2 March of the same year, in the *Sidereal Messenger* [*Nuncius Sidereus*]. These same stars, Simon Marius writes — in his *Mundus Iovialis*, published in 1614 — were discovered and observed by himself in 1609; he began, as he says, to observe them in November 1609 and continued in December, on the 29th day of which, Old Style, he at last made his first record, and carried it forward to the year 1614. And as witness of his own deed and of his first discovery he brings forward a noble and energetic man, Johann Baptist Lentz [*Ioannes Baptista Lenccius* (?)], by whom he was presented, for this very use, with an excellent telescope. But let us hear, if you please, a little from Marius himself: "These lenses were fitted into a wooden tube, and handed to me by the aforementioned most noble and most energetic man, that I might test what they might accomplish among the stars, and the *little stars near Jupiter*, and so forth. This is the truest account; for concerning so great a man, alive and present, it would not be permitted me to lie thus with impunity in a public writing, and so forth. But I do not recount these things as though I wished to belittle N.'s reputation, or to snatch from him, among his own Italians, the discovery of these Jovian stars — by no means; but rather so that it may be understood that these stars were pointed out to me by no mortal, in any way, but were discovered and observed by me in Germany, by my own investigation, at very nearly the same time as — or somewhat earlier than — that at which N. first saw them in Italy. Deservedly, therefore, the praise of the first discovery of these stars is attributed to N., and remains his, among the Italians."

"...but whether anyone among my Germans discovered and saw these things before me, I have so far been unable to learn, nor would I readily believe it," and so on. So Marius [Simon Marius]. If this is true, then he undoubtedly anticipated the Censor [Galileo Galilei] in observing and discovering the Jovian planets [the satellites of Jupiter]. And what does the Censor say to this? In his *Libripens* [i.e., *Il Saggiatore*, The Assayer], from page 3 to page 5, he refutes Marius on the ground that Marius was ignorant of the circles, declinations, and positions of the Jovian stars — both relative to one another and relative to the ecliptic — and of their motions. For he says: first, that Marius did not observe the Jovian stars before

him; second, that he did not see them at all until two full years after him; third, that it is probable Marius never observed the Jovian stars at all; fourth, that Simon Marius fraudulently appropriates to himself, by exploiting the discrepancy of the calendar, the Censor's observations and the priority of observation; fifth, that Marius falsely claims for himself the discovery of the periodic motion of these planets, whereas Simon Marius had beyond doubt filched them from the Censor, who had already long since published and observed them; sixth, he shows that Marius did not observe those companions of Jupiter, since Marius denies that they are ever found in a straight line except at their greatest distance from Jupiter — whereas in fact, in the year 1611, from mid-February to mid-June, throughout four months, all four stars constantly moved beneath a straight line.

You have heard, reader, the history and the sequence of what has been written. Now hear the comparison of these matters, and pass a fair judgment on behalf of the truth.

[Margin: The history of Simon Marius and his deeds against the Censor is compared with the history of the Censor and his deeds against Apelles; and since on both sides a complete similarity of circumstances is found, the same weight of reasoning ought also to hold.]

First: the *Sidereus Nuncius* [Galileo's *Starry Messenger*] anticipated Marius both in writing and in public publication; Marius followed the *Nuncius* in both respects by nearly four years. In the same way, Apelles [Scheiner's pseudonym] anticipated the Censor in writing and publishing about the spots by many months; the Censor followed Apelles by many months in writing, and by a whole year in publishing.

Second: Simon Marius writes that he began to record the Jovian stars at almost the same time and on the same day as the *Sidereus Nuncius* — once the discrepancy of the calendar is removed, as the Censor rightly notes. In like manner the Censor says that his own observations of the spots agree with the observations described by Apelles.

Third: the Censor denies this authority to Marius, who merely asserts it without proof; and Apelles likewise denies the same authority to the Censor, who merely asserts it without proof.

Fourth: Marius makes himself out to be not merely a near-equal in observing the Jovian stars, but even somewhat earlier than the *Sidereus Nuncius*. On the same reasoning, the Censor parades himself as earlier than Apelles in seeing the spots — and indeed by many months.

Fifth: from Marius's faulty account of the motion and position of the Jovian stars, the Censor demonstrates that Marius observed those stars neither before him nor until long after him. In the same way, from the Censor's erroneous doctrine about the sunspots, Apelles can rightly maintain that the Censor was engaged in observing the spots neither before Apelles nor at the same time as Apelles.

Sixth: Marius establishes his priority in observing by the testimony of the noble Lord Lenccius [?]; the Censor props up his own precedence in observing the spots by the authority of certain unnamed intimates.

Seventh: the Censor explodes the authority of Marius, who merely asserts it without adducing any instances to prove it. In the same way, Apelles ought not to admit the Censor's blind testimonies, unsupported by any observations.

Eighth: Marius says he is the first discoverer of the Jovian stars in Germany, and concedes second place to the *Sidereus Nuncius* in Italy. The Censor hawks himself as the first and sole discoverer of the spots; to Apelles or to others he concedes not even second place, but makes Apelles out to be a usurper of his writings — writings which, however, had no existence in the nature of things.

Ninth: although Marius, publishing his work after the Censor, makes himself out to be not merely the Censor's near-equal but his predecessor in the discovery of the Jovian stars — yet because, in proving and establishing the phenomenon, he used only observations contemporary with the *Sidereus Nuncius*, and none earlier, therefore the *Nuncius*, on the ground that Marius adduces no observations earlier than its own, makes Marius out to be not the discoverer but a usurper. So too the Censor: publishing what he wrote about the spots long after Apelles, he sets himself up as not merely Apelles's equal but his predecessor; yet he investigates the nature and properties of the spots only from what he observed and published long after Apelles. Indeed, he brings forward nothing observed and recorded earlier than — or even at the same time as — Apelles.

Hence, just as the Censor drives Marius from primacy on the ground of observations neither possessed nor produced, so Apelles — with equal justice — removes the Censor from the first discovery of the spots, on the ground that he brings forward no observations older than those of Apelles.

Tenth: after the account of the motions traced out by the Jovian stars had twice been published by the *Sidereus Nuncius* — and, as the Censor says, was well known to Marius — Marius nonetheless published it as though new, as though his own, long after the *Nuncius*. Not unlike this, the Censor — even though he had Apelles's Table in his possession, and had thoroughly recognized the explanations

of the solar phenomenon, correctly set out on the better astronomical principles, in 1612, before his own writings and before they were published — nonetheless followed the same, and in 1613 published it in his badly-cobbled-together *History*; and, having buried Apelles under extraordinary riddles [logogryphs], attempted to seize the primacy of the discovery. But just as the Censor arms himself against "the usurper Marius" by appeal to his own work, published earlier and understood by Marius, so Apelles arms himself against the Censor by appeal to his own Table, painted and published earlier.

Eleventh: the Censor chastises Marius for wrongly denying to the *Sidereus Nuncius* the rectilinear motion of the Jovian stars, and bars him from their discovery. Apelles in turn — because the Censor wrongly denied the curvilinear motion of the spots — strips him of the observations duly made by Apelles himself; and, if the Censor's argument against Marius holds good, divests the Censor of the glory of first discovery.

Twelfth: the Censor makes Marius an exile from the discovery on the ground of Marius's assertion about the inclination of the four Medicean circles to the ecliptic. Apelles can penalize the Censor with the same punishment, on the ground that the Censor denied the inclination to the ecliptic of each and every circle that carries the spots.

You have seen, reader, a parallel history on both sides. The Censor discovered and brought forth the Jovian stars; Apelles discovered and brought forth the sunspots. Not content with his own good fortune, the Censor invaded the harvest of others: he tried maliciously to wrest the solar phenomenon from Apelles, and — so that he might be believed the rightful owner of what belonged to others — he made Apelles out to be the fraudulent thief of Apelles's own goods. But behold God, the just avenger, and the true threats of Holy Scripture: "By the very thing in which a man sins, by that shall he be punished" (Wisdom 11:16). The Censor suffered at Marius's hands — whether justly or unjustly, truly or falsely, I do not argue; let the Censor himself see to it, and let good judges of the matter decide — what he had wrongfully inflicted on Apelles. And while he grasps at what is another's, he has put his own at risk. For if he wants to prevail by the force of his own arguments against Marius, he will necessarily have to give back to Apelles the solar phenomenon he took away; and if he refuses this, let him beware lest he both fail to keep the Sun and none the less lose the Jovian stars as well.

"Do you then dare," someone may say, "to call into doubt the assertion of so great a Censor, even though it is destitute of proofs — an assertion he presses so confidently, secure in the credulity of everyone?"

[Margin: The Censor withholds credence from others if they assert without proof; yet he wants it granted to himself.]

What a man of truly great authority — in his own eyes! He pronounces that one must abide by neither the ancients nor the moderns, whether philosophers or mathematicians, when the scientific proof of a natural conclusion is to be established — because, of course, it is reason and not authority that is the means of concluding scientifically. But where the conclusion to be drawn is to his own credit — as the first observer of the spots, a conclusion whose proper means is observations actually made and displayed — there he judges that one must stand by his bare assertion, to the prejudice of others, though he has duly produced no contemporary observations, let alone earlier ones. So that, on the strength of ΑΥΤΟΣ ΕΦΑ [Greek: αὐτὸς ἔφα (autos epha, "He himself has said it" — the Pythagorean appeal to authority, *ipse dixit*)] — because he himself writes that he observed the spots and displayed them to others before Apelles — we should at once be moved to believe him; and yet he pronounces so severely, with philosophical superciliousness:

"As for the simple authority of the ancient and modern philosophers and mathematicians, I say that it has no force at all in establishing the science of any natural conclusion."

[Italian original: "*alla semplice autorità de gl'antichi, e moderni Filosofi, e Matematici, dico che non hà vigore alcuno in stabilire scienza di veruna conclusione naturale.*" — followed by the author's parallel Latin: "*Quod ad simplicem antiquorum & recentium Philosophorum, atque Mathematicorum auctoritatem attinet, dico (ait Censor) illam nullum penitus habere vigorem, ad stabiliendam scientiam vllius conclusionis naturalis.*"]

Let him not, then, take it ill if Apelles and others assert that his own bare authority has no force at all — since he has not duly brought forward observations — for establishing his own possession of so great a phenomenon. Nor let him think owed to himself what he, in a case not at all different, denies to the whole venerable antiquity of all philosophers and mathematicians, and to this whole illustrious and learned age of all mathematicians and philosophers. "And why should he not think so," you will say, "since he is the one man in this age of ours to whom the accompaniment is sounded by an Angel?" This is the man to whom alone — by the very truth of the matter, by a singular determination of God, and by divine privilege —

— special graces have been granted: that he alone should possess the fullness of all astral science; that he alone should be skilled in the means of attaining it; that he alone should know the use of the heavenly telescope; and that he alone should command the methods of observing — so that on this account he may, deservedly, demand of us greater credence for himself.

Indeed, let him demand it — in establishing natural conclusions against the philosophical and mathematical maxim mentioned earlier — when the Censor, without putting forward any observations of his own, and with no philosophical argument duly built upon them, says that he saw and observed the spots; that the spots are not a deception of the eye, not an illusion of the glass [lens], not a mere appearance in the air; that the spots are a real phenomenon, existing in part in the thing itself; and that these natural conclusions are to be admitted as beyond doubt — simply because ΑΥΤΟΣ ΕΦΑ, "He himself has said it." I would admit it entirely, if I believed him a divine man — if I did not understand that he has been set forth, by Angelo De Filiis "out of the sons of men," as the one and only oracle concerning the heavens in this age. But as it is: since by his own confession, throughout the whole First Letter, I observe him to be timid, hesitant, nowhere solid, but everywhere wandering into error; since I know that he has erred very often; since I see him decreeing, with a Censor's rod, that all human philosophical and mathematical authority — ancient and modern — is to be given no place in establishing scientific conclusions, while meanwhile a divine authority is to be established merely by the voluntary assertion of a man who flatters himself more than is fair — I will rather listen to the Censor himself, urging by his own conduct that the authority of one who demands these things be believed on his say-so should be given no place at all.

Add to this that the Censor says — in his First Letter to Welser [Marcus Welser], page 10 — that right up to 4 May in the year of our Lord 1612 a law of concealing his own work, and a necessity of keeping silent about new things, had been imposed on him more than on others on account of the contradictions of others; and that he could put forward no new ideas until he had proofs "more than certain and palpable." But it is certain — and almost palpable, as may be seen throughout the Censor's whole First Letter — that the Censor, regarding the sunspots, brought forward no proofs "more than certain or palpable," either before that letter or in it. By the law he prescribed for himself, no one — not even the most lynx-eyed Lincean of recent times — could

learn what he thought or what view he held about the solar phenomenon; no one heard a word of it from him. And yet everyone is now to assent to him alone —

who angles for first place for his own self-promotion — or rather, if they give him credence, are bound to fawn on him; whereas it should rather be established for them, certainly and palpably, that Apelles did not paint his previously-published Table after the Censor, out of the Censor's foreknown and premeditated conceptions; and that the Censor, before Apelles, neither possessed nor showed to others anything at all comparable to the observations of Apelles's Table. So that it may justly seem astonishing that, not content with the empty and fabricated trumpeting of his own praises, he does not cease to fasten upon others, through calumny, the charge of thefts committed against himself — of things he never had; from which, however, for his own sake, he ought to have refrained — even if the truth pleased him less — even had Apelles come forward with his Table after him. For if the Censor, after the optical tube [telescope] had already been invented, nonetheless arrogates its invention to himself — emptily and falsely though he does — does he not refute himself, when he denies that Apelles can be the discoverer of the spots merely because Apelles came forward after him? But just as the Censor shows himself empty in claiming the invention of the tube, so in the discovery of the spots he was nobody at all.

[Margin: Just as the Censor is not the inventor of the optical tube, so neither is he the discoverer of the sunspots.]

That Apelles did not derive his Table from the Censor, and that the Censor is not to be regarded as the discoverer of the spots, is proved from those things which — essential to this phenomenon — the Censor was entirely ignorant of, while Apelles possesses them.

CAP. IX.

Just as, to avoid making this chapter too long, it is not possible to gather together all at once everything about this phenomenon that the Censor was ignorant of, and everything in which he gravely erred, so — because his errors are so often mingled with things he did not know — it will be necessary in this very chapter to touch on some of them, though they will be set out more distinctly in the following chapter.

Likewise, when occasion is given to weigh his statements, many of the objections he raises in his *History* against what Apelles said, and several passages in which — at length, as though demonstrating something — he plays the schoolmaster, will be shown to be empty and patched together out of false suppositions. But let us come to the proof we intend.

If the things that essentially belong to this solar phenomenon are not found in the Censor's *History*, but are found in Apelles's Table, continued up to the present, then the Censor is not worthy of the prerogative of Discoverer of this solar phenomenon, nor did Apelles derive his Table from the Censor. But the things that essentially belong to this solar phenomenon are not found in the Censor's *History*, and are found in Apelles's Table, continued up to the present. Therefore the Censor is not worthy of the prerogative of Discoverer of this solar phenomenon, nor did Apelles derive his Table from the Censor.

The syllogism is thoroughly sound, and hypothetical in structure; its whole weight rests on the minor premise, for the consequence of the major is sufficiently clear from the terms themselves. The minor premise, being complex, has two parts. The first: that the things essentially belonging to this solar phenomenon are not found in the Censor's *History*. The second: that Apelles has them in his Table, continued up to the present. Now the first part of the minor premise is proved.

To this solar phenomenon there essentially belong: motion, place, time, position, aspect — and any other things of the kind. For although the very things that constitute the phenomenon are the faculae, the spots, and the solar penumbrae, and although — insofar as we consider their φύσις [Greek: physis, "nature"] and their substantial nature — motion and the rest is not their essence but merely accidental to them, nonetheless, taken in the composite sense and insofar as they fall under the Astronomer's jurisdiction, they cannot be so torn away from considerations of motion, of place, of position, and the like, that they are not primarily examined by the mathematician. And so, in the composite sense just described, motion, place, time, position, aspect, and so on essentially belong to this solar phenomenon. For if we consider it apart from these, and only in relation to matter and form, and insofar as it constitutes a physical compound, then it is no longer so much an astronomical phenomenon as a matter for a different inquiry.

That the Censor, then, does not possess these things is now proved. He does not recognize the annual motion of the spots; he is unaware of their curvilinear course; he does not admit their unequal delays above the solar limb; he places them all outside the Sun; he passes over the account of the refraction that the lenses introduce into the figures of the observations —

[Margin: The essentials of the solar phenomenon, of which the Censor is ignorant.]

— which, however, is one of the essential points in rightly understanding and ordering the phenomenon; and finally, very many things that are supremely necessary to this phenomenon have entirely escaped him. To make these matters clear, I am pleased to cite, out of many, a few testimonies from his own *History*.

In his Second Letter, page 32, the Censor says the following:

"They [the spots] have one greatest, common, and universal motion, by which they move uniformly and in lines parallel to one another, coursing across the body of the Sun. From the particular features of this motion one comes to know, first, that the body of the Sun is absolutely spherical; and second, that it turns upon itself, about its own centre, carrying the said spots with it in parallel circles, and completing one entire revolution in about one lunar month, with a rotation similar to that of the orbs of the planets — that is, from west to east."

[Italian original: "*Hanno vn'massimo, commune, & vniversal moto, co'l quale vniformemente, & in linee tra di loro parallele vanno, scorrendo il corpo del Sole, da i particolari sintomi del qual movimento si viene in cognizione, prima che il corpo del Sole è assolutamente sferico, secondariamente ch'egli in se stesso, e circa il proprio centro si raggira, portando seco in cerchi paralleli le dette Macchie, è finendo vna intera conversione in vn mese lunare in circa, con rivolgimento simile à quello degli orbi de i pianeti, cioè da Occidente verso Oriente.*" — followed by the author's parallel Latin rendering: "*Habent (Maculae) vnum maximum communem, & vniversalem motum, quo vniformiter, & in lineis inter sese parallelis percurrunt corpus Solis, ex cuius motus particularibus symptomatibus venit in cognitionem primò corpus Solare esse perfectè sphæricum, secundo Solem in semetipso circa centrum proprium girari, deferendo secum in circulis parallelis dictas Maculas, vnàque revolutionem peragendo spatium plus minus menstruo, motu tali, qualem describunt Planetæ, id est, ab Occidente versus Orientem.*"]

From this passage it is clear that the Censor recognizes one common motion of all the spots, and that a uniform one, according to which they proceed in various parallel circles over a period of roughly a month, from setting to rising, after the manner of the planets, following the order of the signs — and this by the sweep of the Sun as it rotates about its own centre. And so he neither has in his *History* nor recognizes the annual motion — from west to east, against the succession of the signs — shared by each and every spot, uniform and regular: a motion so implanted in this phenomenon by nature that the essence of the phenomenon can neither be investigated, understood, nor explained without it.

[Margin: The Censor is ignorant of the annual motion of the spots.]

Next, he does not possess, but is ignorant of, the monthly motions of the various spots carried in various circles...

[Margin: Likewise he is entirely ignorant of the appearance, the account, and the non-uniformity of the monthly motion.]

LIBER I, Cap. IX (continued)

[Margin: The Censor unskillfully declared the motion of the spots to be from west to east.]

[the tracks] of the spots as they are carried along are often not parallel, never straight, never uniform, never equal — a fact that is nonetheless of the first importance for grasping the essence of the phenomenon. Nor has it been stated in astronomically correct terms that this motion is simply from west to east, when in fact it is simply from east to west, as I shall show explicitly in its proper place, where I treat of the rising and setting of the spots, and so on. And because the Censor himself places the spots outside the Sun, it does not necessarily follow that the Sun is spherical, nor that it turns about its own center, and that in the space of a month. For it could be that it revolved more quickly; it could be that it stood still; it could be that it turned more slowly, while the spots none the less completed their own proper and natural courses. All of this is unraveled more fully where the rotation of the Sun is discussed [Vbi de Giratione Solis disputatur].

[Margin: The Censor did not prove the Sun's rotation.]

And here note in passing that the Censor does not seem consistent with himself: what he here affirms so emphatically, he calls into doubt in the *Libripens* [the "Balance-bearer" — i.e. Galileo's *Il Saggiatore*, "The Assayer"].

In the same letter, at the end of page 42 and the beginning of page 43, the Censor speaks thus:

[Galileo, Italian:] "The spots, then, which are set in different parallels but lie, so to speak, under the same meridian — that is, such that the line joining them cuts the parallels squarely and not obliquely — do not change their distance from one another, but keep always, right down to their final disappearance, the same distance they had at their first appearance."

[Scheiner's Latin rendering:] The spots, he says, which are set in different parallels but stand, so to speak, under the same meridian — which happens when the line joining them cuts the parallels at right angles and not obliquely — do not change the distance between them, but keep always, right down to their final setting, the same distance they displayed at their first appearance.

The very opposite happens most often in the phenomenon, and that neither by chance nor in a disorderly way — as the Censor seems to insinuate in what follows — but in an orderly manner, and step by step, with the greatest proportion both in their departure and in their approach, as may be seen throughout Apelles's continued Table. Since these things escaped the Censor, it is plain that he passed over a matter of great importance for the phenomenon.

[Margin: The Censor wrongly fails to realize that the apparent distances of spots carried along under the same circle of longitude often change.]

In the same letter, at the beginning of page 37:

[Galileo, Italian:] "And this I say, because from the observations I have been able to make up to now I do not find that the revolution of the spots is oblique to the plane of the Ecliptic, beneath which is the earth."

[Scheiner's Latin rendering:] "And this I say," says he, "because from the observations I have been able to make up to now, I do not find that the revolution of the spots is oblique to the plane of the Ecliptic, beneath which the earth lies."

Once again a capital point has been overlooked and omitted in the *History* — one through whose lack the whole Motion of the phenomenon, the position of the spots, and their place must inevitably remain unknown. For if from his own observations he did not find the motion of the spots to be oblique to the Ecliptic, it is certain that the observations were badly made by the Censor. But if they are good, as the Censor so marvelously extols them, then it is most certain that the Censor is here deluded, and that he did not know how to investigate correctly, from the spots he observed, their apparent motion — even in the year 1612, in the month of August, on the 14th day, when he wrote these things after Apelles. Otherwise he would certainly have found the obliquity, just as Apelles found it in his observations of those same times.

[Margin: The Censor either observed badly, or did not know how to handle well what had been well observed.]

In the same letter, page 52, not far from the middle:

[Galileo, Italian:] "One must direct the Telescope toward the Sun, as if someone wished to look at it through it; and having adjusted and fixed it, let a white and smooth sheet of paper be set up facing the concave lens, four or five palms away from that lens. For upon it there will fall the circular image of the Sun's Disk, with all the Spots that are found on it, arranged and disposed with the very same symmetry, to a hair, as they are situated on the Sun."

[Scheiner's Latin rendering:] The Telescope, he says, must be directed toward the Sun, just as it is otherwise wont to be adjusted for looking at it; and this being done and fixed, let a white and well-smoothed sheet of paper be set up opposite the concave lens, at a distance of four or five palms. For upon it there will fall the circular image of the Solar disk, together with all the Spots found on it, arranged and disposed according to the same symmetry, to a hair, as they are situated on the Sun.

The very opposite of this Apelles finds by experience, holds, and teaches in his continued Table, on account of the refraction of the lenses — which it is simply impossible to avoid in the use of the Telescope. When this is ignored and neglected (as the Censor does in his *History*), to draw out and pronounce the true place, distance, position, and motion of the spots is the work of a foolish and fruitless labor. Therefore this point also

[Margin: The Censor ignores and neglects the refractions of the lenses, and therefore writes and teaches false things.]

was essentially required for a full understanding and account of the phenomenon, yet was carelessly omitted and left unknown. Indeed, this exercised Apelles in an extraordinary way and gave him great difficulty; for the errors arising here can amount not merely to a single hair's breadth but to whole degrees — and truly they do arise, unless one is on guard.

[Galileo, Italian:] Where now stands that saying of Angelo['s] — that upon a single subject there should have fallen, in our age, the heavenly use of the Telescope?

The claim that the science of handling the optical tube resides with this Man alone, in this our age? Angelo is a seller of smoke, the Censor a buyer of smoke; each is deceived, and each plays a trick on others.

[Margin: Angelo [De Filiis] and the Censor are smoke-mongers and triflers.]

In the third letter of his *History*, page 102, near the end, and at the beginning of page 103, he says thus:

[Galileo, Italian:] "And some things still remain for me not well digested, nor settled to my own way of thinking; among which one principal one is the falling of the Spots upon places of the solar surface, and nowhere else. For, since the progressions of all the Spots present themselves to us in the form of straight lines, there is a necessary argument that the axis of such revolutions is erect to the plane that passes through the centers of the Sun and of the earth — which is the sole circle of the ecliptic — and so on."

[Scheiner's Latin rendering:] "There remain to me still," says the Censor, "some matters not well digested, nor settled to my taste; among which the chief place is held by the advance of the Spots, confined within certain limits of the solar surface, beyond which they do not wander. For since the courses of all the Spots are represented by the traces of straight lines, a necessary argument is drawn that the axis of such revolutions is erect to the plane that runs through the center of the Sun and of the earth — which is the sole Circle of the ecliptic; and the rest."

[Margin: The Censor was unaware that the axis about which the spots revolve is mobile and inclined to the plane of the ecliptic; he was unaware that the motion of the spots is curvilinear and oblique to the ecliptic — which are capital points.]

Here again he lays it down that the course of all the spots is rectilinear and parallel to the ecliptic, and infers that it runs about an axis perpendicular to the plane of the ecliptic. Hence he neither held nor taught that the axis about which the spots revolve with their monthly motion is always mobile and always inclined to the plane of the ecliptic; that their course is never parallel to the Ecliptic, but for the most part cuts it; that it is rectilinear only twice a year, and then only roughly, to the senses; and that not even then is it parallel among all the spots. These things, I say, since they are essentially present in the phenomenon and are unknown to the Censor, it is plain that he was ignorant of many things essential to the phenomenon. But these, and very many other errors wrongly committed here, will be noted more distinctly in the next chapter. Meanwhile I neither can nor ought to pass over the errors here perpetrated by the Censor, which I would not judge to be, even in a beginner in Astronomy, either untouchable or deserving of pardon.

[Galileo, Italian:] "...the progressions of all the Spots presenting themselves to us in the form of straight lines, there is a necessary

argument that the axis of such revolutions is erect to the plane that passes through the centers of the Sun and of the earth, which is the sole circle of the ecliptic."

[Scheiner's Latin rendering:] "From the fact," says the Censor, "that the paths of all the Spots are represented to us in the form of straight lines, a necessary argument is drawn that the axis of such revolutions is erect to the plane that runs through the centers of the Sun and of the Earth, which is the sole circle of the Ecliptic."

I say nothing now of the falsity of what the Censor claims — namely, that the traceable paths of all the spots are rectilinear; I pass over this, I say, and do not press it, nor that further point which the Censor wrongly assumes: that the paths of all the spots are rectilinear, parallel among themselves, and that for all the revolutions of all the spots there is one and the same common axis. Let us grant all these things, I say, as true, although they are false, and let us see what necessarily follows from these premises by argument. I say, then: if we suppose that all the paths of the spots appear rectilinear and equidistant from one another, it necessarily follows that the axis common to them all is perpendicular to some plane passing through the centers of the Sun and of the earth — for this is true and necessary from those suppositions. But I say nonetheless that this plane is not the Circle of the Ecliptic alone. For there are also infinitely many other planes passing through the center of the earth and of the Sun, upon which such a common axis of the spots can stand at right angles — such as all the planes of the vertical circles passing through the Sun's place, all the hour-circles occupied by the Sun, and so on. From the givens, therefore, the argument is not necessary; and in fact the contrary is the case, to the senses, when the spots become rectilinear twice a year — between November and December, and likewise May and June. To say, however, that only the circle of the Ecliptic, drawn through the center of the Sun and of the earth,

[Margin: The Censor's intolerable false-drawing, to be corrected even in a beginner of Astronomy.]

is drawn — that is to be ignorant of the first rudiments of the Sphere. Does not the Sun always place its center in some one of the vertical circles? Does it not in some hour-circle? Does it not daily twice in the horizon? Does it not, in each half-year, in the colures of the Solstices and Equinoxes? And do not all these great circles pass through the center of the earth?

This Sophistry is far too crude — by which the Censor shows himself insufficiently skilled in observing this phenomenon, and a novice in matters of

the sphere: obtruding false things from what he has observed, and reasoning still worse by paralogism from those false suppositions. Here I appeal to the Censor's own interpreter and clever disputant: is this not, from badly made drawings, to paint worse pictures? And while the Censor wishes to correct Apelles's beautiful Table, is it not to put shapeless monsters in the place of an elegant painting? Surely Angelo keeps the sack, bursting with the fullness of all heavenly knowledge, tied too tightly — he might at least, through some tiny little slit, let a small spark of reason shine out.

[Margin: The things the Censor falsely imputes to Apelles he censures both on his own account and through his followers, yet he himself is the one at fault.]

Here, Reader, expect wondrous evasions. He will not want it thought that he deduced his rule from the apparently rectilinear courses of the Sun, or that he spoke absolutely of the plane passing through the centers of the Sun and the earth; but rather, having set aside the passage from the letter cited — where, without first laying down the other things pertinent to the matter, in his doctrinal manner he pronounces these statements — you will easily notice that the Censor, while he strains all his attention on scrutinizing other men's affairs too curiously, has stumbled over things that lie in his path and before his very feet.

In the same third letter, page 116:

[Galileo, Italian:] "Apelles takes his reason from seeing the Spots dwell for unequal times beneath the face of the Sun, and that those which cross it along the greatest line, passing through the center, dwell longer than those which pass along lines remote from the center; and he brings forward the observation of two, one of which dwelt 16 days on the diameter, while the other, passing somewhat far from the center, ran through its line in 14 days. Now here I should wish to find words by which, without offense to Apelles — whom I always intend to honor — I might deny such an experience. For, having made about this particular many, many most diligent observations, I have found no encounter [of the sort] from which one could conclude anything other than that the Spots all indifferently dwell beneath the Solar disk for equal times, which in my judgment are something more than 14 days; and this I affirm all the more resolutely, inasmuch as it will hereafter be in anyone's power to make, without inconvenience, thousands upon thousands of observations."

[Scheiner's Latin rendering:] Apelles brings his reason from this: that the Spots appear to pass beneath the face of the Sun with an unequal

delay of time; and those indeed which advance along the greatest line through the center appear to linger longer than those carried along lines more remote from the center. And he brings forward two observations, of which the one that ran along the diameter lasted 16 days, while the one somewhat more remote took 14 days. Now here I should wish to find words by which, without offense to Apelles (whom I always desire to hold in honor), I might deny such an experience — because I, having made about this point very many and most diligent observations, have found no indication from which anything else could be concluded than that all the Spots indifferently keep an equal delay beneath the Sun's disk, which in my judgment does not exceed 14 days by much. And this I affirm all the more resolutely, the more freely it will hereafter be in anyone's power, easily and without inconvenience, to make trial of this matter through thousands upon thousands of observations. Thus he.

[Margin: The Censor was unaware of the unequal delay of the spots beneath the Sun; which is a capital point.]

And a little later, on the same page, before the end:

[Galileo, Italian:] "I have made, upon a multitude of more than 100 large and exact drawings, [these observations]; and I have indeed met with some small differences of times in the passages; but I have also found, alternately, the Spots on circles nearer the center of the disk to be sometimes no less slow — indeed at times slower — than at another time those on circles more remote."

[Scheiner's Latin rendering:] "I made more than a hundred large and exact delineations of observations, and I did indeed find slight differences in the course of their times; but I also found, alternately, that Spots which are carried on circles nearer the center of the Solar disk move no more slowly than those others usually do which describe circles more remote." — Thus the Censor, in the same place.

From which it is manifest that he in no way recognized the unequal delay of the Spots beneath the Sun — which Apelles nevertheless constantly and always maintained, and which [is essentially present in] the phenomenon

is so essential to this phenomenon that, even if the total revolutions of all the Spots were of equal duration among themselves, even if they were all supposed to cling to or inhere in the Sun, nevertheless not one of them would ever make a delay beneath the Sun equal to another's. And what is more: even if one and the

same Spot were supposed to be carried uniformly in one and the same circle, even if it were supposed to inhere in or strictly cling to the Sun, even if it were granted to return and endure perpetually — nevertheless it would never, except twice in the year, make courses of equal duration beneath the Sun's hemisphere; it would never, except once a year, describe for us beneath the Sun an apparent advance similar and equally lasting. Further: if two or more Spots advancing together beneath the Sun make equal delays outside the periods in which they describe lines that are, to the senses, straight upon the Sun, then by the very necessity of the phenomenon they move unequally and disproportionately, and do not complete their revolutions in equal times. The things Apelles says indefinitely about a line nearer the center and one more remote from the center are to be understood [as holding] if the more remote line lies in the region of the hidden pole, whether Southern or Northern; for the course of Spots nearer the apparent pole is ordinarily always longer than that which those produce which recede farther from the elevated pole. Again, through greater circles one may understand greater segments of circles than would make them similar. But of these things too I shall treat elsewhere, by design.

[Margin: Apelles defends his own observations and dissolves the Censor's accusations.]

The Censor next presses Apelles from the example of 16 days, brought forward as the minimum, and from another of 14 days as the maximum — from which Apelles strove to draw out an inequality of delay beneath the Sun, and to set them apart from the same [rate]. But the Censor denies this observation to Apelles. Now here I should wish words to flow to my pen by which, without offense to the Censor, I might write the truth. For the Censor either did not grasp the words and mind of Apelles, or did not treat them in good faith. For, first, Apelles — as will be perfectly clear to anyone reading him — still moving on the path of inquiry, discusses very many things not assertively and absolutely, but in the manner of one inquiring. Second, he argues very many things hypothetically, and from the supposed opinions of others, his own judgment still held in suspense. Third, what he intends to prove he does not do as though from the single example of 16 days, but adduces that example as one out of many — a single one.

[Margin: Apelles in his Table discussed many things like one investigating, many like one doubting, many hypothetically, and from the view of others, and so on.]

Fourth: neither does he nor did he make a point of the 16 days; but for a number greater than 14, days 15 suffice to give the argument its force — 14½ suffice, and

so on. Fifth: the argument was hypothetical, and after Apelles's own mind, of this kind:

Given that the Sun is variable and hard, whether it rotates meanwhile or not, and given that the motion of the Spots is parallel to the Ecliptic — if the spot ♎ [Leo] delayed beneath the Sun 16 days, and the spot ♏ [Scorpio] 14 days at most, then it is necessary that their delay beneath the Sun is unequal, and that they are moved outside the Sun. But the Sun, according to the common opinion of all Philosophers and Mathematicians (concerning which, however, [I shall treat] elsewhere by design), is hard and unvarying; and, according to Apelles's diligent observations, the spot ♎ delayed beneath that same Sun a minimum of 16 days, and the spot ♏ 14 days at most. Therefore it is necessary that their delay beneath the Sun is unequal, and that they are moved outside the Sun, according to the common opinion of the Philosophers and Mathematicians — concerning which, however, Apelles will inquire elsewhere, by design.

[Margin: Apelles's argument, drawn from a hypothesis and from the received doctrine of others, reaches its conclusion.]

This whole Syllogism is hypothetical, complex, and rather investigative and inferential, drawn from suppositions that are others' rather than his own. For whether the Sun is hard and unvarying, Apelles rightly doubts, the cause of his doubt being taken from this very phenomenon. But the Censor insists that Apelles must also suppose the Spots outside the Sun to be borne along similarly in the same sphere; otherwise what Apelles intends will not follow, namely, that he should cast them outside the Sun.

[Margin: Apelles reserved to himself the investigation of the truth about this point.]

I reply: granted that the Sun is hard and unvarying, if the inequality of delay and of motion be proved — whether the Spots rotate in one sphere or not, whether the individual ones are driven in their own proper circles or not — it always follows necessarily that they cannot be placed within the Sun, but are simply to be located outside it; unless you are willing to admit both the penetration of bodies and some variation of the Sun. But the Censor presses further: that if the whole aggregate of the Spots be taken, as it seems to be taken, the argument has no force; for it could happen that all clung fixed to the Sun and yet took up sixteen days beneath the Sun, reckoning their delays from the entrance of the first Spot to the exit of the last. But this is to play a trick; for one must take the delay of a single point, or Spot, and

[Margin: In vain does the Censor struggle against it.]

[Margin: Apelles's argument retains its force even on the Censor's own supposition.]

to compare [it] with the delay of another point. **I reply:** Apelles's argument nonetheless keeps its force, just as he intended it, even if none of the α [Leo] spots taken separately spent 16 days beneath the Sun. For Apelles nowhere said this, nor did he mean it; it is enough that, from the fact that for 16 days they all lay beneath the Sun together, each one of them will have drawn out a longer delay beneath the Sun than the spot $\mathfrak{M}$ [Scorpio]. For provided that 15 days, or more than 14, are reached, that suffices for Apelles's purpose — since Apelles's contention is that each single one of the α spots lingered longer than the $\mathfrak{M}$ spot, and so forth. And that, from the fact that for 16 days they all remained together, it necessarily follows that each of them, or at least certain definite ones, took up more than 14 days — this is established from Apelles's observations as follows.

[Margin: Apelles proves his contention from observation.]

"In both aspects" — says Apelles — "namely especially the last and the first, the interval seen between the α spots and the Sun's edge was ample enough, at minimum a single day (since indeed, from the experience of other spots, one may argue for what was permissible here). Therefore, if we take from the α spots the one that preceded all the rest, and suppose it reached the horizon on 24 December at the 11th hour, it was beneath the Sun from the 10th day — when it was first seen within the Sun — for 14 days; and if to these we add the interval A α , we shall have 15 days. In the same way, if we take the last one at its rising, and suppose it to have been altogether on the horizon on 10 December at the 10th hour, then it, up to the 24th day, took up 14 days; and to these, adding the delay of the space α B — about one day of traversing — makes 15 days. And this was enough for Apelles to prove his point."

But if the Censor should still wish to press [the matter], saying that those spaces were not full daily [arcs], but smaller — I reply that Apelles is not thereby hard-pressed, provided the duration of any spot whatever be made greater than 14 days, which the Censor himself concedes. And since it is certain that the spot $\mathfrak{M}$ did not complete 14 days, and so on, it is clear that Apelles's argument has its sinew. But if the Censor should wish to deny even this, he will refute himself, when he says that the delay of all the spots beneath the Sun, in his own judgment, exceeds 14 days by something. This indeed is beyond doubt true of all the α spots together and of each singly and separately; but taken universally, of absolutely

any spots whatever indifferently, it is beyond any doubt false — for the spot M did not exceed 14 days, nor do I think it completed them at all. But as for the fact that the Censor, [regarding] the equal-ity [of the delay], so resolutely asserts, and not only appeals to future observations but also boasts of more than a hundred of his own — I can always set against his one hundred a thousand, and a thousand more, made both before and after his own; and not only mine, but others' as well. And so that he may have something at hand by which he can safely inspect this truth, let him consult — if it does not irk him — the appended Tables of images, worked up with the utmost fidelity and with more care than can be believed: they all stand against him, on Apelles's side.

[Margin: The Censor vainly boasts of the multitude of his observations.]

Hence all the spots ordinarily accomplish unequal transits and delays beneath the Sun; and this I affirm all the more resolutely, in the Censor's own words, the freer the opportunity will be hereafter for anyone to test it through however many thousands of observations — provided the proper method of observing is applied, and the errors to be guarded against, set forth in the *Rosa Ursina*, are avoided. For my part, from the very beginning of the Phenomenon's discovery — that is, from the year 1611 up to this point — I have most singularly attended to it, and through many thousands of continuous observations I have consistently detected the inequality of the apparent motion and delay. Nor indeed can it be otherwise in this Phenomenon, on account of the annual little circle that continuously carries the poles and axis of the spots into one position after another, from which there always arises a different obliquity of the spotted sphere as cut by the plane of the Sun's circle. And this is the a priori demonstrative reason for this inequality — of which [I shall treat] more fully in its place. But here I cannot but wonder why the Censor so laboriously, with conjectures fetched from so far off, attacks Apelles, and even runs ahead to future observations of the spots; why he leads his soldier, ill-equipped, out into the open field, imprudently abandoning his own camp — stocked with its armory and full of homegrown weapons — when from that very camp he could at once have finished off the enemy. For does not the Censor, in his letter 1, p. 11, line 18, write these words about the Motions of the spots?

[Margin: Apelles, on behalf of the unequal delay of the spots beneath the Sun, appeals to observations past and future, both his own and others'.]

[Galileo, in Italian:] "It is also true that they do not remain fixed on the Solar body, but appear to move in relation to it, and indeed with regular motions, as the same author has noted in the same letter — (and, a little

further on:) — which is also seen quite clearly in the observations described by himself, which in this respect agree with mine, and with as many of others' as I have seen."

[The same, in Scheiner's parallel Latin:] "It is also true," says the Censor, "that the spots are not fixed on the Solar body, but move with respect to it, and indeed with regular motions, just as the author himself rightly noted in his own letters; (and a little after) which is also seen most clearly in the observations described by himself, which in this respect agree with mine and with any of others' that I have seen hitherto."

So says the Censor. If he compared his observations of the spots with mine, if he detected regular motions from their agreement, then from that same comparison he also learned the magnitudes and durations of the motions — for these could be deduced from mine. Therefore, either his observations, when compared with mine, agreed also in duration, or they did not. If the former: then the Censor attacks even himself. If the latter: what need was there of so many and such great conjectures to overturn Apelles's observations? The error would have been laid bare by producing the Censor's own autograph to the contrary — his observations duly recorded, the Ecliptic skillfully drawn in, and so on.

[Margin: The Censor pretends that things he never observed were collated with mine, etc.]

But if the Censor cannot produce any such contrary autograph, Apelles asks of the Censor: How, and of what kind, were his observations, that they agreed when compared with Apelles's? For either those observations were safely and duly arranged by year, month, and the same day, or they were not. If the former, the argument returns once more, and while the Censor assails Apelles, he cuts his own throat. If the latter, then no symmetry of the compared observations could arise, no likeness of motions be found, no stable and solid account of regularity be entered upon — since there existed other spots, other positions, other motions, both apparent and true. And the Censor's fraud is plain: he deceives the Reader when, by his own [observations] — whether earlier, or made at the same time but fictitiously — he wishes to appear equal to Apelles, or prior to him, in discovering the spots and their motions. If these [claims] were true, he would not have placed the beginning of the consolidation of his doctrine in his observations continued from 2 June 1612 to 4 August, as he himself confesses in his second letter, p. 42 and p. 46, past the middle — he who wrote at leisure in his study, where, if he had prepared anything, he had it at hand; so that, had he possessed older recorded notes of the spots for proving the motion, or the duration of the motion, he would

certainly have used them to crush Apelles. But now, to return to the matter and weave together the numbered points I began: in the sixth [place], Apelles said that the $\varnothing$ spots consumed at minimum 16 days beneath the Sun — which is true, if the time is reckoned from the rising of the first spot to the setting of the last. For since this cluster of spots flowed together, as it were into one, at its setting and rising, Apelles embraced the whole delay of the entire mass beneath the Sun, according to both its first and its last part. And in this sense, if the Censor denies Apelles's experience, he denies it rashly and ignorantly. But if he wants the 16 days restricted to a single spot only — one that, in ranging across the Sun, wore away that much time — he beats the air, not Apelles; he yields ghostly phantoms fashioned by himself and arbitrarily set up before him, not an enemy; he plays a trick on the Reader and does Apelles an injury. For, in the seventh [place], Apelles never thought, never wrote in his whole Table (and if it is otherwise, let the passage be produced, the text cited — it all lies on public display before the whole world) by any little word, any syllable, any least tittle; he never hinted by any indication or the slightest sign that a single spot was observed by him which, in its course beneath the Sun, lingered 16 days. For although he himself clearly knows, from things observed and demonstrated elsewhere, that there are on the Sun spots and secondary faculae, and likewise shadows and countless specks, which, in advancing beneath the Sun, take up not merely 16 days but 18, 20, and more, up to 27, and so on — indeed that the parts near the mobile poles sometimes remain wholly above, sometimes wholly below the Solar horizon, so that you cannot tell their rising or setting, on account of the annual revolution of the polar little circle carrying the poles and axis of the spots along with it, and so forth — nevertheless he was as yet unwilling to touch upon any of these secrets, or to draw arguments from them, especially since he was still occupied in investigating and establishing these very matters. And so, while the Censor, on p. 122, writes:

[Margin: The Censor is unjust toward Apelles and his Table.]

[Galileo, in Italian:] "From this it can be evident how close to an absolute impossibility Apelles brought himself, in saying that he had observed one spot cross the diameter of the Solar Disk in 16 days at least, and another cross a smaller line in 14 at most."

[The same, in Scheiner's parallel Latin:] "Hence it can be evident how close Apelles leads himself to something absolutely impossible, when he says that a certain spot was observed by him which [crossed] the diameter of the Solar Disk in 16 days at minimum, and another which, in traversing a smaller line, wandered for only 14 days."

When, I say, the Censor writes this, he im-putes to Apelles what [Apelles] never thought. And if he does this on purpose, it is in bad faith; if by accident, with a pen not sufficiently trimmed, he mishandles the man's writings. In vain and to no purpose he wearies himself with so many blows aimed to strike no one; he makes sport of the Reader; he imposes upon the truth. For what Apelles asserts, the Censor does not attack; and what he attacks, Apelles does not assert.

[Margin: The Censor either slanders fraudulently, or too incautiously indicts Apelles.]

In the same letter, p. 129, about the middle:

[Galileo, in Italian:] "How Apelles has forgotten what he wrote above, on page 18, in the 10th noteworthy point, with so much resolution — namely, that it is certain that the spots which cross the middle of the Sun make a greater stay beneath it than those which pass more toward the extremes. These are absolute impossibilities, unless one were willing to say that the motions of the spots are all of different periods — which is neither true nor supposed by Apelles; and granted it were true, all the force of the discourse would collapse, in his wishing to deduce from such passages, and to infer, the place of the spots with respect to the Sun, etc."

[The same, in Scheiner's parallel Latin:] "How," says the Censor, "does Apelles dissent from what he affirmed above with so much resolution — namely, that it is certain that the spots which pass across the middle of the Sun make more delay beneath it than those which incline more toward the extremes. These things are simply impossible, unless it be said that all the motions of the spots differ among themselves — which is neither true nor supposed by Apelles; and granted it were true, the force of the argument would be sapped — the argument by which, from such a course of the spots, he wishes to infer the place of the spots with respect to the Sun, etc."

So he [says]. From these words it again appears how much the Censor is averse to the inequality of the delay — the contrary of which he defends so tenaciously when, right after the passages cited, he adds:

[Margin: The Censor compounds his ignorance concerning the unequal delay of the spots.]

[Galileo, in Italian:] "we shall find the times of the said passages to be equal among themselves, and all about 14 days." [Scheiner's parallel

Latin:] "we shall find, all vicious bias set aside, all the times of the said courses equal among themselves and of about 14 days."

But concerning all these matters enough has been said in the earlier [pages]; and it is established that the Censor was ignorant of this point, essential to the Phenomenon — which it was incumbent on me to prove, since it pertains to the first member of the Minor [premise].

In the same letter, p. 131, the Censor plies the same saw back and forth:

[Galileo, in Italian:] "And because, as I have also said, this is a most principal point in this matter, and the difference between Apelles and me is great — since to me the revolutions of the spots all appear equal, and appear to cross the Solar Disk in about 14 and a half days, whereas to him they appear so unequal that one spot consumes in such a passage 16 days and more, and another only 9 — it seems to me very necessary to return with repeated examination, to seek out the exact truth of this particular; reminding ourselves that Nature, deaf and inexorable to our prayers, will not alter or change the course of her effects, and that those things which we now endeavor to investigate, and then to persuade others of, have not existed only once and then failed, but follow, and will follow for a long time, their own manner, so that they will be seen and observed by many and many [people]; which ought to be a great check upon us, to make us so much the more circumspect in pronouncing our propositions, and in guarding ourselves lest some bias, whether toward ourselves or toward others, make us bend even a point from the aim of pure truth."

[The same, in Scheiner's parallel Latin:] "And because, as I said above, this is a most principal point in this matter, and the greatest difference between me and Apelles (since to me indeed all the courses of the spots appear equal among themselves, and to measure out the Sun's Disk within 14 and a half days, more or less, but to him so unequal that some one spot consumes in its Solar transit 16 days and more, another only 9) — it seems to me by far most necessary to retrace the path, and by repeated examination to investigate this very matter anew, far most exactly; recalling to our memory that Nature — deaf, inexorable to our prayers, and tenacious of her own right — does not alter or change the courses of her effects; nor do those things, in whose investigation we now toil, meaning afterward to persuade others of them, appear only once and then thereafter fail, but they follow in a continuous course and

will follow, to be seen and observed by very many others in the same style and tenor. This ought to be a great bridle upon us, to restrain us, so that we may be so much the more cautious in pronouncing our propositions and delivering our verdicts, providently taking care lest, by any bias whether toward ourselves or toward others, we deflect from the naked view of truth even by a point."

From this it again is clear that the Censor was utterly ignorant of Apelles's [teaching] concerning the inequality of Time and Motion — and indeed that he was wholly ignorant of the matter implanted in this Phenomenon by nature.

[Margin: The Censor, to defend his ignorance, refers Apelles to the course of nature — with a truly bold pen.]

[Margin: The Censor bars for himself every way back to knowledge and truth.]

This [nature], since it is inexorable — even if the Censor should heap up into an immense pile his Demonstrations against Apelles (or rather his Paralogisms), utter threats and exhortations against Apelles, and again fabricate things never said — nevertheless will stand firm in its own course, and here [Apelles will stand firm] in his own opinion. Now, just as certain specks can travel around the Sun in 16, 18, 20 days and more (as was said before) when situated on the side of the apparent pole, so others, lying toward the hidden pole, can complete their advances beneath the Sun in 9, 7, 5, and one day. And if faculae, or even primary spots, should settle in such places, they will be entirely open to our sight in observing through ordinary Telescopes, and their motion — whether so great or so slight — will be discerned. Apelles, in my judgment at least, has sufficiently safeguarded himself everywhere, knowing that in a new, difficult, and slippery matter one must attend very closely and provide with great care, lest, by trying and opening up trackless paths, he fall into straits, labyrinths, or precipices. Hence almost everywhere he left himself room and space for retreat, wherever he might have need of what remained; and concerning the substance of the spots and of the Sun in particular he put forward few things of his own, many from the philosophical storehouse, in the manner of one doubting and inquiring; most things he affirmed only hypothetically — either because it was not permitted otherwise in these matters, or so that, thus safe behind his Table, and at last, once the truth was found, armed, he might be able to advance into the battle-line. He judged it better to bring forth truth gradually, one [point] after another, than to pour out all his conjectures at once as though they were oracles, from which he would afterward, with a blush, have to strip away the rashly-assumed mask of certainty. If the Censor had done the same as he teaches, and had not, having

advanced so far, cut off for himself all hope of retreat, he would now stand in a better position, and would be the first to reap the fruit of his own Discourse.

It is shameful for a teacher when [his own] fault convicts him.

[Margin: Nature stands for Apelles against the Censor.]

But — to make an end at last of proving this first member of the Minor: the secondary spots and faculae are most essential to this Solar Phenomenon; these Apelles has and explains in his continued Table, whereas the Censor does not have them in his History, not by even the slightest indication, and so on. Therefore the Censor lacks something most essential to this Phenomenon. The Major [premise] is evident, and is proved from the following Books of the *Rosa Ursina*. For since the whole surface of the Sun is beset [with spots], and is constituted and made whole out of secondary spots and faculae, it is clear that these are most essential to this Phenomenon, since nothing is more essential to this Phenomenon than the very visible surface of the Sun itself, and so on. The Minor [premise] is established from Apelles's continued Table — that is, the *Rosa Ursina* set forth — and from the Censor's own History, etc. Therefore the Conclusion is clear. And so let the first member of the Minor stand demonstrated, which was: *The things that essentially belong to this Solar Phenomenon, the Censor does not have in his History.* Which was the thing to be demonstrated.

[Margin: Apelles, in bringing forth the novelties of this Phenomenon, always and everywhere proceeded with sufficient foresight.]

[Margin: The Censor is ignorant of the secondary spots and faculae — which is the chief point.]

[Margin: The first proposed member of the Minor has been demonstrated against the Censor.]

The second [member] — namely, that Apelles has such things, essential to this Phenomenon, in his continued Table — could be seen to have been sufficiently shown on the occasion of the first; and the very trial of it, in the reading of what follows, will convince anyone. Nevertheless it is worth adding a few things here for greater confirmation. For in the year 1611 Apelles laid the rudiments of his first Table, and set forth certain sketches of outlines to be viewed; and meanwhile, from year to year up to now, into this year 1627, into this month — which is — up to this very day, he has continued that same Table of his, observing, examining, arranging, and polishing it, and at last nearly completing it; although the final touch has not been entirely withdrawn from it, for there are

still several things awaiting the labor of a finer brush. For it is a wonder how fertile in new speculations this Phenomenon is. And so, in this Table of his — begun, continued, and to some extent completed — Apelles has all the aforesaid things: in the begun [Table], many in fact, many in potency and implicitly; in the continued [Table], radically, through observations; in the completed [Table], expressly and formally. For although in his published [works] he seems to have inclined toward a rectilinear motion parallel to the Ecliptic, yet with the prototypes of his own observations somewhat resisting (as the autographs of the observations, shown to anyone who asks, will make evidently trustworthy), he did this cautiously and not without fear of the opposite [view]; whence in this, and in not a few other matters, he always deferred himself to further examinations and to later observations to be made, and thus safely left himself room for retreat, and thrust no barrier upon either himself or the truth — which he certainly would have done, had he, forcing these doubtfully-occurring [phenomena] as though certain into the Seat of Truth, foisted them upon the learned, and, out of rash presumption, [appealed] to the very Sun as the revealer of these errors, and of the whole...

by challenging the eyes of the whole learned world, he would imprudently have cut away, censor-like, all the remedies suited to his own folly. But hear Apelles's cautions. Letter 1, sent to [Marcus] Welser on 12 November 1611, has this:

"Thirdly, because they were turning with a proper motion, and that a constant one — whether beneath the Sun or together with the Sun — and were seen now in one place of the Sun, now in another, until after many days they disappeared from it entirely: from east (as it seems to me) to west, or at least in part from north toward south. About this motion, however, longer and more exact observations will yield more reliable information."

When he says "from north toward south," this happens by reason of the diurnal motion, and by comparing the position of those spots from their morning to their evening aspect.

The third letter, given the same year on 26 December, has the following — on page 8, after the Censor's account in the Roman edition, to which all the other citations also refer:

"It remains that they move with their own motions, and that either fixedly or erratically; which of the two it is, I am not yet able to say. This much is certain: I have held them to be around the Sun."

Likewise in the same letter, p. 11: *"but these matters in their own time, just as also about the motion, etc."*

[Margin: Apelles, in his Table, never decided for certain the apparent motion of the spots and its position relative to the ecliptic, but always reserved it for future observations and discussions.]

The fourth letter, given on 16 January 1612, p. 29, no. 10, contains this:

"The motion of them all appears to be parallel to the ecliptic; yet on this I would not so far pronounce a judgment as being absolutely certain."

In the same letter, p. 34, no. 10, concerning the spot in ♏ [Scorpio], this is found: *"It moved equidistantly from the ecliptic. But indeed about the motion of these phenomena — as being the cardinal and chief point — I will bring forward much clearer results in their own time."*

As for what I wrote in the same letter, at the end of page 44 and the beginning of 45 — that the spots pass daily beneath the Sun, gradually from east to west, in the plane of the ecliptic or parallel to the ecliptic, against the order of the signs; and in the upper semicircle above the Sun, from west to east, following the sequence of the signs — this ought in no way to prejudice the earlier passage, which extends as far as a more careful Treatise on Motion. Meanwhile I was unwilling, in this same letter, to change that opinion, which had seemed probable to me; for my promise did not look to this — and all the more so because the spots adduced from 16 March to 4 April, especially if the daily tracks are taken somewhat away from the edges [of the disk], make lines nearly equidistant from the ecliptic; whereas, if near the edges they came somewhat nearer to it, or drew somewhat away from it, one might easily suspect that this could have happened through some slip committed in observing — since at that time the observations had not been examined either so extensively or with such exquisite care as would establish assent for the truth.

[Margin: Whence the opinion of a motion parallel to the ecliptic crept in.]

On the other hand, in the same letter, p. 50, no. 5, it is said: *"There can scarcely be any further dispute whether they [the spots] move unequally, since I have so often detected it in just this way, etc."*

[Margin: The unequal motion of the spots is certain to Apelles.]

From all this, then, it is clear that, even though Apelles inclined toward [the view of] a motion of the spots parallel to the ecliptic, nevertheless the opinion he

adopted at that time — with the stated caution — in no way stands in the way of the truth that followed.

First, because he was still on the road of inquiry.

Second, because he put forward his opinion not without some fear of the opposite.

[Margin: Why Apelles was so slow and cautious in establishing the motion.]

Third, because, for more careful Disquisitions, he referred himself to longer-continued observations; and thus whatever he was going to find, approve, and establish in them, he even then held and professed, implicitly and virtually. For when he saw, in the original records of his own observations, that the paths of the spots were gradually drawn out into different directions, he neither dared to cling to them at once, nor yet was willing to contradict them so far as to reckon them certain errors. He chose, therefore, to proceed cautiously by a middle course, until — by a continued practice of observing, and after the observations had been weighed through many trials — he might clearly recognize the truth. This came about in the year 1612, around April by slight beginnings, and most of all around September by manifest indications; and this he afterward, by a kind of retrospective right, noticed as if in seed throughout all the months and even in the earliest observations. Nor does this hold true only for Apelles's observations, but for anyone else's that are properly conducted — indeed, in the Censor's own as well, when Apelles once, at Ingolstadt, duly compared them, arranged by his own hand, with his own. And so, whatever Apelles in the later fifteen and more years found out, added, or even (if you like) corrected concerning the motion of the solar spots, their place and situation, and universally concerning this whole phenomenon — through his own continued observations or those of other friends — all of that too is to be reckoned as contained implicitly in his first Table...

[Margin: The whole *Rosa Ursina* is one and the same Table of Apelles, painted over so many years.]

[all of that too] must be judged to be contained [in that first Table], in which there lay observations drawn out by skill, and in which that result was contained potentially — and because those observations so often appealed to it. For it is one and the same Table, one and the same picture, but continued. Now, just as the first outlines of pictures are ordinarily drawn somewhat coarse, and neither very neat nor connected with elegant proportion among themselves — then, when the colors are laid on afterward, together with a skillful blending of lights and

shadows, whatever seemed ungainly, indeed whatever ran outside the line, is entirely blotted out — so no one will wonder if the Apellean Table now comes out much more beautiful, so that it may seem in a way to have passed into another likeness. For this is the nature of a picture: that although everything issues from the first sketches, the sketches themselves, in the finished image, are scarcely noticed except by the more sharp-eyed. This is also usual with plants, in which the roots — the source of their beginning and vigor — lie hidden, while the rest, sprung from them, come forth into the light and are looked at.

[Margin: In the first Apellean Table everything was comprehended, in the sketch, as in a seed and a root.]

Whatever, therefore, blossoms in the third and fourth garden-plot of the *Rosa Ursina*, all of it is credited to the continued Table of Apelles; for there it is promised, and here the promise is displayed. To it, therefore, must be ascribed the motion of the solar spots — a motion which, on the side of the fact, is never found rectilinear but always curvilinear; never parallel to the ecliptic; nor parallel among all the spots themselves; nor equal, but with one often swifter than another; and the fact that they all belong to the Sun; and that their passage beneath the Sun is unequal, and so on.

And let this suffice as proof of the Minor of the first syllogism, which was: "*The things that belong essentially to this solar phenomenon, Apelles has in his Table continued up to now.*" His conclusion, then, is plain, which was: "*Therefore neither did Apelles transfer his Table from the Censor, nor is the Censor worthy of the prerogative of discoverer of this solar phenomenon.*" Which was the thing to be demonstrated.

[Margin: The Censor does not enjoy the title of discoverer of the solar phenomenon.]

If anything occurs to you, kind Reader, that seems to tell against what has been said, hold on until the end of the following chapter.

[Chapter argument:] From Apelles's Table and the Censor's History, and from the solar phenomenon described in them, the same conclusions as before are proved, and the principal errors of the Censor concerning this phenomenon are pointed out.

CAP. X.

My purpose here is not so much to attack my adversary as to protect myself from his injuries. For since he has, most groundlessly, cast me as the invader and

usurper of his phenomenon, his labors, and his doctrine — if I show that his phenomenon differs from mine, his doctrine from mine, his opinions and assertions from mine, by the whole Sun, not to say the whole heaven; indeed that they stand apart no otherwise than the True from the False, Knowledge from Error, Experience from Fictions, Something from Nothing, Good from Evil — if, I say, I demonstrate these things more clearly than the Sun, shall I not most thoroughly clear myself of his charges? And this I shall accomplish by bringing out into the open his errors, set against my contrary truths — truths which, since he has not only never admitted them but has most stubbornly assailed them with a blind rush of mind, he falsely cries out have been stolen from him.

You, whoever you are that is drawn by zeal for the truth, survey these antitheses with your eyes and chew them over in your mind, once you have run through these few remarks, premised as the cause deserves. For it is a small thing — and can often be pardoned — that some matter, especially a new one, especially one difficult and obscure and slippery to know, should be unknown to a man who does not claim its knowledge for himself and is not bound to have it from elsewhere. But a man who attributes to himself not only the knowledge of that matter, but moreover claims its discovery — and indeed the first discovery — and most vainly persuades himself that to him alone the full plenitude of the whole science has been divinely decreed, to the exclusion of others: if such a man falls short in understanding the things that pertain to determining the nature of that matter, and is found not to have penetrated even the essentials — he is deservedly laughed at by everyone, like Aesop's frog swelling up with too much puffing, and is counted not in the last place among the Ardeliones [busybodies].

But if, besides ignorance, there is added also...

a depraved disposition of mind as well — so that, about a matter he does not know, he moreover blunders gravely on every side, attributing to it what it lacks and taking away what it has; and blames those who judge rightly, and strives to seduce all and sundry from the true into the false — this at last is intolerable. Such conduct not only absolves the undeserving of his calumnies, but sets him up, in place of a discoverer, as a sophistical corrupter of the phenomenon.

Not a few things were intimated in the preceding chapter that the Censor was ignorant of concerning the solar phenomenon — and indeed the chief ones. Now I proceed to lay his errors open. Since they are both many in number and grave in magnitude, I shall not pursue them one by one, but shall touch summarily on the main heads and the wellsprings; for from each single one very many others sprout up, as from the Lernaean Hydra. And so that the matter may be set before

the eyes in order, I place in the left-hand series (from the reader's point of view) the Censor's fallacies, and in the right-hand series the truths of Apelles.

ANTITHESES OF THE CENSOR AND APELLES

From the Censor's opinion — Error against the phenomenon. From Apelles's view — Truth according to the phenomenon.

#	From the Censor's opinion (Error against the phenomenon)	From Apelles's view (Truth according to the phenomenon)
1	The poles about which, and the axis around which, the spots revolve — roughly monthly — are fixed.	The same are always in motion.
2	The same always lie in the apparent circle of the Sun.	The same rest upon it only twice a year, and momentarily.
3	The axis of the spots is always perpendicular to the circle and to the line of the ecliptic.	The same is never perpendicular to the circle of the ecliptic; to the line, only twice a year, and instantaneously.
4	The apparent motion of the spots — of all and of each — is always rectilinear.	The same, in reality, is always curvilinear; to the senses, rectilinear only twice a year.
5	The motion of all and of each of the spots, carried in different circles, is parallel among themselves.	This never occurs, except when the spots move rectilinearly to the senses.
6	The motion of all and of each of the spots is parallel to the ecliptic.	The same is never parallel to it, but always oblique — whether it appears rectilinear or curvilinear.
7	The apparent motions of all and of each of the spots are, among themselves, similar and proportional, constant and regular.	The same, except the rectilinear ones, are always dissimilar and non-proportional, being made in different circles.
8	The apparent motions of all the spots are, among themselves, of the same duration.	The same, except the rectilinear ones, are always of unequal duration.
9	The intervals of all apparent motions — whether traversed by one spot or by several, in equal times, in the	The same, except in rectilinear motion, are to the senses never proportional, nor of the same

#	From the Censor's opinion (Error against the phenomenon)	From Apelles's view (Truth according to the phenomenon)
	same parallel — are, among themselves, proportional as versed sines subtended by equal arcs, and of the same duration.	duration — save perhaps in a very rare case.
1 0	However many spots rise together, set together.	Never, except in rectilinear motion — and not even then always — or by extraordinary chance.
1 1	Whatever spots set together also rose together.	Never, except in an extraordinary case, or in rectilinear motion.
1 2	Spots rising together, or existing under the same meridian, always keep the same distance from one another right up to setting.	Often they keep it, often too they do not; and they perceptibly either converge toward one another or diverge from one another. Very many examples are ready to hand.
1 3	All spots carried in the same parallel are driven at the same velocity, etc.	Ordinarily this happens; often, however, the contrary occurs. Very many examples are ready to hand.
1 4	If some spot were to return, or were perennial, it would always rise and set in the same place of the Sun.	Any returning or perennial spot would rise or set in the same place only after six months at most.
1 5	Any spot carried in the greatest parallel always moves in the ecliptic.	No spot ever carried in the greatest parallel moves along beneath the ecliptic.
1 6	Any spot passing through the center of the Sun moves along beneath the ecliptic and the greatest parallel.	No spot passing through the Sun's center ever moves beneath the ecliptic, nor in the greatest of the parallels, except when the motions are rectilinear, twice a year.
1 7	No northern spot can become southern, and vice versa — no southern can become northern.	Very many spots pass from south to north, and from the north into the south.
1 8	The greatest parallel has nothing in the south, nothing in the north, but is the middle one, coinciding with the ecliptic, in the apparent circle of the	The greatest parallel always has some part in the south and some in the north, and nothing in the middle except either a single point or a

#	From the Censor's opinion (Error against the phenomenon)	From Apelles's view (Truth according to the phenomenon)
	Sun.	single line, in the same apparent circle of the Sun.
1 9	The motion of a spot carried in the greatest parallel is always equal in duration to the motion of any spot carried in a lesser parallel.	The same is greater for a spot carried by its motion toward the hidden pole, less toward the visible pole — and that whether toward the south or toward the north.
2 0	All spots enclosed, by the telescope [Telescopium], within the observing-circle marked on the paper keep — both among themselves and with respect to the observing-circle — exactly the same ratio of magnitudes, positions, and distances as those same spots keep in the Sun, both among themselves and with respect to the Sun.	No spots enclosed in the observing-circle in the said manner keep — both among themselves and with respect to the observing-circle — the same ratio of magnitudes, positions, and distances; not even sensibly, much less exactly, as those same spots keep it in the Sun, both among themselves and with respect to the Sun.
2 1	Whatever spots, in their course beneath the Sun, pass through the center, or successively attain an equal, very short distance from the center, and toward the same pole, are in the same parallel.	The same spots, under the same conditions, are in different and unequal parallels.
2 2	Of two spots carried in the same parallel, the apparent distances between them are equal; but the true distances [continues]...	Under the same conditions, the true distances between them always and necessarily become unequal because of refraction; often too because of [continues]...

[The antithesis table continues; item 22 is unfinished at the foot of the page.]

Book I, Chapter X (continued) — Antitheses of the Censor and Apelles (concluded)

The two-column comparison begun on the previous pages continues at the head of this page, its running sub-headings reprinted:

Censor's opinion — *Error against the phenomenon*

(22, *concluded*) ...are truly always equal to one another.

23 If a chord is drawn through a spot lying very close to the center — one that is bisected by the spot, or that is cut at right angles by the straight line joining the center and the spot — that chord will be not only the itinerary trace of the whole apparent course, but also the diameter of an entire revolution and of the true motion.

24 Apart from the apparent monthly motion — regular, rectilinear, and uniform — the Censor calls all the other appearances in the motion, the declinations, the deviations, and so on, "little alterations," "trifles," "disordered motions," and "particular irregularities of the spots," and so forth.

Apelles's view — *Truth according to the phenomenon*

(22, *concluded*) ...because the motions of the two are unequal.

23 On the same suppositions, that line will be neither the trace of the apparent motion nor the diameter of the true motion. Curvature and refraction stand in the way: the circle will always turn out either larger than the true one — in the convex tracks — or smaller — in the concave ones, toward the center; only in rectilinear motions will anything [of the claim] hold.

24 Most of these apparent irregularities in the motion of the spots arise from a regular, uniform annual motion; some are introduced by refraction; a few are proper [to the spots themselves], and these too are for the most part perfectly orderly.

You have here, reader, a catalogue — brief, and still not complete — of the capital errors that the Censor [Galileo Galilei] set down in his historical letters, whether in express words or such as follow immediately and necessarily from his views and practice in this matter. And although I adduced a number of them at length in the previous chapter, nevertheless, so that you may see at almost a single glance where I have drawn them from, I have appended a note of the principal passages from the *History* [the *Istoria* / *History*].

For the errors are documented as follows:

1. The first is expressly contained in the second letter, page 33. Likewise the third letter, page 103, line 1. Likewise page 118, near the end, and page 119, at the beginning.

2. The second follows necessarily from the passages cited. Likewise from the practice, pages 36 and 37, second letter. Likewise the third letter, page 118, near the end, and page 119, at the beginning.
3. The third is found expressly in the third letter, page 103, at the beginning, and is deduced from the second letter, page 37, at the beginning.
4. The fourth is found expressly in the third letter, page 102, last line, and page 103, line 1. Likewise the second letter, page 32, lines 10 and 11, and page 33, after the middle. Likewise page 36, second-to-last and last lines, from the practice. Likewise the third letter, from the practice, pages 118 and 119.
5. The fifth is found and deduced from the passages cited under the fourth error.
6. The sixth is found expressly in the second letter, page 37, at the beginning.
7. The seventh is expressed in the second letter, page 32, lines 10 and 11, and follows necessarily from what has been said. Likewise page 50, line 4. Likewise the third letter, page 128, near the end.
8. The eighth is found from what has been said, and is clearly stated in the third letter, page 116, lines 14, 15, etc. Likewise page 119. Likewise page 125, line 7. Likewise page 129, after the middle. Likewise page 131, line 12.
9. The ninth is found expressly in the second letter, page 35, from line 5, etc.
10. The tenth follows from the eighth.
11. The eleventh follows from the eighth.
12. The twelfth follows from the fifth and sixth, and is found expressly in the second letter, page 42, near the end, and 43, at the beginning.
13. The thirteenth is found in the second letter, page 36, line 18, etc.
14. The fourteenth follows from the preceding, and is found expressly in the second letter, page 49, line 19.
15. The fifteenth is found in the third letter, page 117, line 17. Likewise line 26.
16. The sixteenth follows from the sixth, and page 33, second letter, after the middle, and throughout the letters of the *History*.
17. The seventeenth follows from the fifth and sixth, and is hinted at throughout the *History*.
18. The eighteenth follows from the sixth and others.
19. The nineteenth: third letter, page 119 and following, and often elsewhere.
20. The twentieth: first letter, page 28, line 19; second letter, page 31, line 13.
21. The twenty-first: second letter, page 36, lines 20, 21, and 22.

22. The twenty-second: second letter, pages 36, 37, 38, 39, etc.; and it follows from the preceding.
23. The twenty-third: second letter, page 36, near the end; third letter, page 118, near the end, from the practice.
24. The twenty-fourth: second letter, page 43, line 11. Likewise page 49, line 23; third letter, page 142.

These errors and truths are then set side by side one last time:

These errors are capital

These errors are capital ones, and they utterly overturn the solar phenomenon, lay waste its properties, and eliminate the science of it from its very foundations. Hence it would have been necessary for the Censor, before thrusting these things so assertively upon the whole world, to consult his Angel more carefully, to look more deeply into the privilege granted him from heaven, and to search the shrines and inner sanctuaries of Phoebus more accurately — so that from there, as though from the Delphic Tripod, like a new Apollo, he might thunder forth truer oracles against Apelles out of the fullness of his science, and hurl surer bolts.

These are truths

These are truths, and so deeply inherent in this solar phenomenon that without them it can neither stand nor ever be understood. These truths Apelles — lying hidden behind his Table [Apelles's *Tabula*] — received from the Sun itself over the course of fifteen years, with unwearied care, study, labor, and vigilance; he dug them out, examined, aired, weighed, and tested them, and found them solid and constant; and now once again he sets them forth from the City [Rome] for the whole world to contemplate.

Now, so that the absurdity and fecundity of the said errors may be set before the eyes most plainly, I will show this by a practical example. I take the courses *a a a*, *b b b*, *c c c* of the three spots *a*, *b*, and *c*, enclosed within the solar circle *A a B C*, and set them at its middle. The first of these, *a a a*, was observed by me in the year 1626, from 30 June to 12 July. It was curvilinear, northern, convex toward the ecliptic *AB* and toward the center *C*, and concave toward the exposed north pole.

[The following continues in the second column of the page.]

The first observation took place on 30 June, at 7½ in the morning; the last, on 12 July, at 5½ in the evening. Thus between the first and last observations there elapsed 12 days, 10 hours, 7 minutes — that is, ⅙ of an hour.

But since on each side some little interval remained between the spot and the limb, if we allow 7 or 8 hours for each — or at most 10, as will be established for certain from what is to be said, where we shall treat of the duration of the motion of the spots — then the apparent course of spot *a* lasted about 13 days 6 hours. The second spot, *b*, began to be observed in the year 1625, from 23 to 29 May, on a course sensibly almost rectilinear, not parallel to the ecliptic but inclined to it. Its motion lasts about thirteen days. See the image of the observations.

The third spot, *c*, is found in the image of the observations made in December of the year 1625 and January of the year 1626. The first observation was carried out on the 22nd, at about 11 in the morning; the last on 1 January, at 9 in the morning and 22 minutes. Therefore between the first and last observations nearly ten days elapsed; and if to these is added what is due to the marginal intervals on each side, one arrives at roughly thirteen days. The track of this course is curvilinear, concave toward the center *C* and toward the ecliptic *AB*, and also toward the elevated southern pole, convex toward the northern part. The nearest apparent distances of these three spots from the center *C* — namely *Cd* and *Ce* — were observed to be equal to one another. On this account, by the arguments with which the Censor, in his second letter from page 36 up to 42, and elsewhere throughout, as was noted under error 23, disputes at great length against Apelles, it would follow that:

[Margin: Absurdities and impossibilities arising from a single error of the Censor.]

First, these three courses *a a a*, *b b b*, and *c c c* are described from a single parallel — which is impossible.

Second, [they run] about a single axis perpendicular to the ecliptic, whose poles are fixed on the perimeter of the solar circle — which is impossible.

Third, they will all be rectilinear — which is impossible.

Fourth, they are all equal to one another, indeed in a way the very same — which is impossible.

Fifth, they are all parallel to the ecliptic *AB* — which is impossible.

Sixth, they will all be straight and curved —

Diagram. A full-page engraved plate, printed as a right-hand page (printed p. 47). It shows the projected disk of the Sun (a large circle) with the daily courses of three sunspots traced across it, above a data table. (The faint text visible in the corners of the plate page is mirror-reversed show-through from the verso and is not part of the plate.)

Title cartouche (centered at top, within the disk):

- "M.DC.XXVI." (1626)
- "In Collegio Romano Societatis [Iesu]" — In the Roman College of the Society [of Jesus]
- flanked by two engraved rose ornaments, with a central radiant **IHS** emblem (the Jesuit device, cross above and three nails below)
- "Cursus Maculae *a*, observatus à 30. Iunij, ad 12. Iulij." — The course of spot *a*, observed from 30 June to 12 July.
- To the right of that line, a bracketed annotation: "Iunij. 30. m. h. $7\frac{1}{2}$ ☉ el. 34. 20." — June 30, morning, hour $7\frac{1}{2}$, Sun's altitude $34^{\circ} 20'$.

The disk itself, with the ecliptic drawn as a horizontal diameter:

- A (left end of the ecliptic): "A. Oriens." — A, the East (rising side)
- AB (along the diameter): "AB. Ecliptica." — the ecliptic
- B (right end): "B. Occidens." — B, the West (setting side); at the right terminus a small mark "HL / ⊕ B"
- C (at the center, just below the diameter): the center of the disk
- Three dotted curvilinear paths cross the disk from A toward B, one for each spot, the spot-images (dark blotches) drawn along them. The daily positions are numbered along the *a*-path: "30" (= 30 June) at the upper-left start, then 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12 progressing toward the right, each accompanied by the letter *a*. Companion paths carry the letters *b* and *c* at their successive positions; additional point-letters *e*, *f*, *h*, *k* appear along the constructions.
- Far-left vertical marginal annotation (near A), heavily degraded: appears to give the duration, "dies 13. horae 6" [?] (13 days, 6 hours) [Illegible: adjoining line].
- A small auxiliary construction at the very foot of the plate (partly in the gutter and largely obscured by show-through): point-letters "F", "G", "I", "K", "L", "N" [?] with the numbers "12" and "6" [?] — evidently the enlarged detail of the chord/tangent construction (*a i a*, *b d b*) discussed in the text. [Illegible: most of this sub-figure.]

Lower panel of the plate:

- Heading: "Deteguntur Errores Censoris, in exemplis practicis." — The errors of the Censor are exposed, in practical examples.
- Table heading: "Iulij." (July), with the columns **D** (day), **H** (hour; *m.* = *matutina*, morning / *u.* = *vespertina*, evening), and the Sun's altitude $\odot$ **El.** in degrees and minutes:

D	H	$\odot$ (°)	(')
1	m. $7\frac{1}{4}$	30	40
2	m. $7\frac{1}{4}$	31	0
3	m. 7	27	40
4	m. $7\frac{1}{2}$	32	30
5	m. $6\frac{4}{5}$	25	0
6	m. $8\frac{1}{5}$	40	0
7	m. $7\frac{1}{3}$	30	40
8	m. 8	38	0
9	m. $7\frac{1}{4}$	29	25
10	m. $7\frac{1}{2}$	32	0
11	m. $7\frac{3}{4}$	34	30
12	m. $7\frac{1}{4}$	29	30
12	u. $5\frac{5}{8}$	19	30

[Resuming the body text on the following page (printed p. 48).]

Sixth (concluded): straight and curved — *a i a, a a a, b d b, f e g, c h e* — each one individually equal to every other — which is impossible.

Seventh, the segments of the arcs *A c* and *B c* will be equal to one another; likewise *A f* and *B g*; likewise *A b* and *B b*; likewise *A a* and *B a* — all of which are nevertheless impossible.

Eighth, the arcs *A c, A f, A f, A b, A a* will all be individually equal to one another — which is impossible. Similarly the opposite ones, *B b, B a, B c, B g*, will each be equal to each — which is impossible.

Ninth, the straight line *C h* will equal the straight line *C e*; and the straight line *C d*, the straight line *C i* — which is impossible.

[Margin: It is clearly demonstrated that the stated impossibilities follow from the Censor's own view and doctrine.]

That all these impossibilities, one and all, follow from the Censor's own view, opinion, and practice is evident. For he himself posits a single axis for all the parallels, in the solar circle, running through the center *C*, perpendicular to the ecliptic *AB*, and immovable; and then all the motions of the spots parallel to it. From this it necessarily follows that they are projected as a single straight line onto the disk of the Sun; and so, if the shortest distances of certain spots from the center *C* are equal, it is necessarily inferred that they travel along the same parallel. Hence all the stated equalities are rightly inferred, because the distances *C d* and *C e* — along which the spots *a*, *b*, and *c* ran in the same northern region — were found to be equal to one another.

Tenth, in curvilinear courses of the spots that are convex toward the center — such as *a a a* — the diameter of the periodic revolution will always be assumed greater than it should be — which is most absurd. For according to the Censor's practice and doctrine, the diameter of the course *a a a* is found to be *b d b*, which is greater than the chord *a i a*; and this in turn is greater than the true diameter of this course; therefore *b d b* is much greater than that same [true diameter].

Eleventh, in these same courses the circuit of the periodic revolution is found much greater than it should be — which is most absurd. It follows from the preceding: for a greater circumference is described about a greater diameter.

Twelfth, in all these same cases the duration is necessarily found longer than is fitting. It follows from the preceding: for where a greater circuit of the circle is assumed, if it is measured by the daily interval of a smaller circle, it will contain that interval more often than the smaller [circle would]. The duration, therefore, comes out greater than it should — and so on — which is by far the most absurd.

Thirteenth, in the curvilinear courses of the spots that are concave toward the center, the diameter will always be found smaller than it should be — which is most absurd. This may be seen in the course *c c c*, whose tangent is *f e g*: its diameter is found to be smaller than the chord *c h c*, which is nevertheless still smaller than the true diameter of the same circle *c c c*; therefore *f d g* is much smaller than that same diameter. For what is less than the lesser is much more less than the greater.

Fourteenth, in these same courses, by the same Censorian method, the perimeter of the whole revolution is drawn smaller than it should be — which is the

greatest absurdity; it is deduced from the foregoing, for a smaller diameter requires a smaller circumference.

Fifteenth, by the same Censorian method, a duration smaller than the true one is brought into these same courses, because a measure of duration smaller than the true is assumed. And this too must be counted among the greatest absurdities.

Sixteenth, by the Censorian method, in courses that are sensibly rectilinear, the diameters — owing to the slowness of refraction [*lentiū refractione*, reading uncertain] — always come out greater than they should; the circumferences always come out greater than they should; the duration is always drawn out longer than it should be; the measure of magnitude and of duration is always taken far too small. All of which, one and all, involve absurdities utterly unworthy of the mathematical disciplines.

[Margin: The evidence of the Censorian absurdities and impossibilities is pointed out, as with a finger, in the examples.]

In the examples the evidence will shine out. For since the course *a a a* was found, by observation and by a careful ordering of the observations, to lie in that position relative to the ecliptic *AB* in which it is here represented in the diagram — namely, with a curvilinear bend convex toward the center *C* — it necessarily follows that, if the two extreme and marginal stations of spot *a* (the most eastern, on side *A*, and the most western, on side *B*), equally distant from the center *C*, are joined by the straight line *a i a*, this whole line falls outside the entire curvilinear track *a a a* projected onto the solar circle, and this whole [line] falls between the ecliptic *AB* and the said line *a i a*. Therefore the perpendicular *C i* will bisect both the straight line *a i a*, at *i*, and the arc of the track *a d a*, at *d*; and the straight line *C d* will be smaller than the straight line *C i*, and so the tangent *b d b* drawn through the point *d* will be greater than the chord *a i a*. For this reason, if from the straight line *i a*, from the center *C*, there be cut off ...

is taken equal to *CD*, and likewise the half *db* equal to *CE*, and if semicircles *DFGH* and *EIKL* are described at these intervals, the former will be greater than the latter. And since the path *aaa* is a segment of a circle in the visible solar hemisphere, intercepted between the greatest parallel and the visible pole, that segment will — by Theodosius, Book 2, [prop.] 19 — be greater than a semicircle.

If, then, the same daily measure *FG* or *IK* is traversed on each circuit, in the smaller *DFH* there will be found 13 days and 21 hours, in the larger *EIL* 14 days and 6 hours. So the excess by which the greater exceeds the smaller is 9 hours; and if this is doubled, there will be in one complete period 18 hours more than

there ought to be, according to the Censor's method [Galileo Galilei], even if we pass over the matter of refraction and much else. Now these hours, taken with respect to one whole circuit of 28 days and 12 hours — such as that of the larger circle EFL would be, and such as the Censor ordinarily sets down — when converted into degrees and minutes, yield 9 degrees 38 minutes. So great an error — $9\frac{1}{2}$ degrees in magnitude, and even more, eighteen hours, in duration — is intolerable even in a beginner of astronomy, let alone that we should endure it in a man who in our age is uniquely skilled in these sciences.

Now, just as on the convex course aaa everything comes out, by the Censor's method, greater than the truth, so on the concave ccc we shall find everything smaller. For the perpendicular Ce, which bisects the tangent feg, is greater than Ch, the perpendicular to the chord chc; and therefore the chord chc lies nearer the center than the tangent feg, so that the tangent is the smaller of the two. And since the course ccc runs between the hidden pole and the greatest of the parallels, its arc will be a segment less than a semicircle, by Theodosius, *Spherics*, Book 2, [prop.] 19. The chord chc, therefore, is smaller than the true diameter; and so the tangent feg is much smaller than that same true diameter.

Therefore the semicircle described at the interval fe — that is, CE — is smaller than the semicircle MNO, which is described at the interval CM, or hc; and the deficiency of the former with respect to the latter amounts, in duration, to six hours. A complete revolution makes twelve hours in duration, and six degrees twenty-four minutes in magnitude.

This, once again, is an error too shameful for so glorious an astronomer, one divinely privileged above all the rest. And so, since on one and the same parallel the Censor's method yields a circuit sometimes larger than it should be, sometimes smaller, if we set up a comparison in the examples adduced, we shall find that the distances between the extremes DFH and MNO amount, in duration, to twenty-four hours, and in magnitude to about sixteen degrees. In astronomical matters, where the learned dispute over minutes, such errors never merit any pardon — least of all in one who in our age vaunts himself as the sole and unique Discoverer of all celestial novelties and an all-knowing Teacher.

[Margin: The Censor's errors, unworthy of pardon among astronomers.]

As for the course bbb, it was indeed to the senses very nearly rectilinear, and thus coincident with the arc it runs along on the parallel; nevertheless, on account of the refraction caused by the lenses, it cannot safely be drawn out into a periodic revolution of the spots [maculae], as is shown at length in its proper books and

places. Now, from these matters briefly run through — for I prudently pass over countless things, easily to be unearthed by the shrewd reader — let us draw a few conclusions.

COROLLARIA [Corollaries]

First. In assigning the duration of a single periodic revolution, the Censor generally sets it at twenty-nine days; for to the half he ordinarily gave fourteen and a half days, whose double makes twenty-nine days. Of this error there are three plain causes.

[Margin: First corollary. Why the Censor erred in assigning the period of the spots.]

The first: because he took for examination the courses of the spots A and B, which were segments greater than a semicircle.

The second: because he represented them by chords of the solar circle — chords tangent to the point of the course nearest the center — chords that are much larger than the true diameter of the course, and so on.

The third: because he took as his measure the daily distance near the center, which, in relation to the refracted and too-far-extended diameter, subtends arcs that are too small — since near the center it itself lacks any perceptible refraction, and is therefore smaller than the other portions nearer the edges, which, because of the refraction of the lenses, become larger than those near the center. Since, then, each of these causes singly makes the periodic courses of the spots too large, what will they all do together?

Second. Since the ignored and neglected curvature of the spots' paths gave the Censor so great an occasion for straying from the truth, a greater curvature will produce greater errors; for the greater the curvature, the more or less it joins the tangent to the center. Whence in September and March the greatest lapses must occur, according to the same method he employs throughout his whole *History* [Galileo, *Istoria delle macchie solari*, 1613] against Apelles [Scheiner].

[Margin: Second corollary. The Censor's errors grow in proportion to the seasons.]

Third. From December to June, the apparent courses of the northern spots will always be found smaller than they should be, and those of the southern spots always larger. But from June to December, the courses of the northern spots will

always turn out larger than they should be, and those of the southern smaller — following the Censor's way.

[Margin: Third corollary. At what time, and in which region of the Sun, the Censor errs by excess or by defect.]

Fourth. And since from these things it clearly follows that the Censor was ignorant of the apparent motion of the spots and feigned a false one, it is evident that everything he argues in the second letter and elsewhere throughout — especially on pp. 36, 37, 38, 39, 40, 41, and so on nearly to the end — and everything he builds upon these false foundations, is empty, false, void, full of errors, falsely drawn, and paralogistic, and can be corrected with a single stroke of the pen.

[Margin: Fourth corollary. Most of the demonstrations the Censor brings forth against Apelles in the *History* are falsely drawn, and are set right by a single stroke of the pen.]

Fifth. In like manner, all that the Censor argues at great length in the third letter, from page one hundred thirteen to page one hundred thirty-two, concerning the motion, place, and duration of the motion of the spots against Apelles — and tries to demonstrate by bringing forward some falsely drawn figures — is either fallacious and full of sophistry, or, proceeding from false suppositions, false, or at any rate concludes to something beside the point.

[Margin: Fifth corollary. What the Censor brings forward in the third letter against Apelles is of the same flour as the earlier matter, and comes under Apelles's sponge [spongia Apellis] [?].]

For the Censor, by this method of his and manner of representing the spots, will willy-nilly admit an inequality of duration, or else, knowingly and with open eyes, will corrupt the observed positions and places of the spots; and yet, even so, he will not escape the truth of the phenomenon [phaenomenon], much less overthrow it. That he takes refuge in his own aberrations and in private little alterations of the spots is not without cause [?]; and indeed from this I draw a

Sixth corollary: that these little alterations and detours of the spots befell the Censor in the course of his observing because he did not know how to fix the position and place of the spots with reference to the ecliptic. For had he done this, he would at once have seen that their motion is curvilinear, and variable, and rectilinear only to the senses, and that only twice a year; and from these

established and proven facts he would never have invented his little alterations and the private digressions of the spots, because he would have observed none.

[Margin: Sixth corollary. Ignorance, and idleness in setting out the sunspots correctly, gave rise in the Censor to arbitrary alterations of them.]

But as it is, because he wants to reduce the curvilinear motions of the spots to rectilinear ones — since the very stations that the spots occupy in correctly made designations of the observations resist this and cannot travel along straight paths, being accustomed to curvilinear and thoroughly regular ones — the Censor accuses them, ineptly charging them with leaps beyond the mark; and, to cover his own [errors], he fastens upon the spots errors they never committed. Since this is so, whoever reads attentively his letters, in which he tosses Apelles about, will marvel at the man's incredible presumption — to put it most mildly — coupled with such great ignorance about this phenomenon: for, not knowing past observations, he yet dared to appeal to future ones.

[Margin: The Censor's ill-considered over-confidence, in appealing to future observations.]

You have here, reader, a practical sample of the Censor's errors, of which I could give a great many; but I do not wish to abuse your patience, nor to put a bridle on your intelligence and lay a hand on your freedom. Read Apelles, read the Censor's *History*, add, if you like, the *Rosa Ursina*, and you will see much — and dig out still more by your own effort. For I merely touch on the main heads in passing; to pursue the veins that branch out from them would be endless. Let it be enough for me if I have shown that the Censor was ignorant of the essentials of the solar phenomenon, and that he overturned the essentials of the solar phenomenon by his errors — which was to be shown by practical examples.

[Margin: Summary of what has been demonstrated.]

You will say: the Censor discoursed at length on the matter of the spots, and tried to prove by many arguments that it is something smoky, variously dissoluble and able to gather together — toward which the phenomenon truly inclines — whereas Apelles, by contrast, seems often to maintain that they are solid bodies, like the rest of the stars.

[Margin: The Censor is the overthrower, not the Discoverer, of the solar phenomenon.]

Therefore the Censor seems to have reached further into the essentials than Apelles did.

I reply, first, that according to the Censor's own view the inner essence of no substance can be known in this mortal life; and so, on the Censor's own judgment, no more can be granted to the Censor in the way of essential knowledge of the spots than to Apelles, and no less to Apelles than to the Censor. But it is better to hear the Censor's own words. In the third letter, p. 101, he says thus:

[Margin: The objection made on the Censor's behalf is sufficiently met from the Censor's own view.]

Either we wish, through speculation, to try to penetrate the true and intrinsic essence of natural substances, or we are content to come to knowledge of some of their properties. To attempt the essence I hold to be an enterprise no less impossible, and a labor no less vain, among the nearest elementary substances than among the most remote and celestial ones. And it seems to me that I am equally ignorant of the substance of the earth as of that of the Moon, of elementary clouds as of sunspots.

And near the end:

But if we are willing to settle for grasping certain properties, it does not seem to me that we should despair of attaining them even in bodies most distant from us, no less than in those nearest — indeed, perhaps some one of them more exactly in the former than in the latter, and so on. And on p. 102, line 6: I wish, then, to infer that, although the investigation of the substance of sunspots would be undertaken in vain, it does not follow that some of their properties — such as location, motion, figure, magnitude, opacity, mutability, production, and dissolution — cannot be apprehended by us, and then serve us as certain means, so to speak, for philosophizing better about other more abstruse and controverted conditions of natural substances.

[Scheiner gives this passage in Galileo's Italian, then adds his own Latin translation of it.]

So much for him. And he speaks rightly, indeed, about the intuitive knowledge of substance, which no human being in this life ever attains; and in that sense the objection does not strike Apelles.

I reply, secondly, that if the Censor, whether by way of likeness or in general terms, divined or hinted at something about the substance of the spots from their accidents, he has indeed deserved well of learning by his probable conjecturing;

but in this he neither refuted Apelles nor outstripped him by any scientific demonstration. For Apelles, although from the very outset he noticed in which direction the phenomenon finally tended, and confided this to not a few friends and pupils, was nonetheless forced either to propose no Table [Tabula] at all, or to adjust his colors to the received and then-prevailing standard of the physicists; yet he indicates, not obscurely and often, that he does not assert this on his own account, and that he prefers to leave it in doubt. Nor let the words "Necessary," "Impossible," and the like disturb you, since they are always to be understood under the supposition of the Pillars of Hercules, which it would be forbidden to pass beyond.

[Margin: From the beginning it was not open to Apelles to philosophize freely about the nature and substance of the spots.]

I reply, thirdly, that if we treat the phenomenon insofar as its handling is astronomical — and as such it was open to a Professor of Mathematics — its essentials are Motion, Position, Time, Figure, Magnitude, Rising, Setting, Number, Place, and things akin to these; and in these matters throughout, the Table, together with its Continuation, solidly attains the truth and proves it. The Censor's positions, by contrast, often fail to attain [it]

through ignorance, and often destroy it through errors — as is partly clear from what has been said, and will partly be noted more distinctly from what is to be said.

For since, as we have shown in the examples adduced, he was ignorant of the apparent motion of the spots, of their magnitude and duration, and distorted the stations, positions, and observed places of the spots, and produced false diameters and erroneous periods, the true motions and true places too must have remained unknown to him; and hence, even on the Censor's own view, nothing certain could be established about their physical substance. But if in his long-winded excursions he did nonetheless touch on anything, it is more certain than certain that this came about by chance, not by knowledge divinely infused into him — if one may believe it so.

[Margin: Without knowing the necessary prerequisites of the solar phenomenon, he could not arrive at a true knowledge and teaching of it.]

You will press the point about place: "But do you not yourself admit that, among the essentials of treating this phenomenon astronomically, the Censor proved by several demonstrations that they lie in closest proximity to the Sun? — toward

which, although the Table as first set forth might seem to incline, yet it did not show it altogether expressly or with sufficient consistency."

I reply: the more accurate discussion of Place, and its settling, was reserved by Apelles, with rather exacting diligence, for the examination of observations made and to be made — as he often insists in his Table; nor did he do this without fruit or in vain, as the *Rosa Ursina* teaches. For this is the chief head of the whole phenomenon — without which nothing can be settled, and from which alone everything can be settled that pertains to the substance of the matter.

[Margin: Apelles reserved the place of the spots — as the foremost head of the whole phenomenon — for study, for more accurate inquiries.]

The Censor, however, although he may seem to have labored for the truth, propped it up badly with his falsely drawn schemes — by which the spots are transferred from their proper places into alien ones, are marshaled from inclined positions into parallels, are wrenched from arced courses into straight ones, and are violently forced from shorter paths into longer, from unequal into equal. Whence you could draw nothing at all about their true place from these; rather, on his foundations you might just as readily remove them from the Sun as attach them to it.

Since, then, the Sun's phenomenon is composed chiefly of two things — of primary spots and faculae [faculae], and of the same as secondary — about these the Censor, just as he wrote nothing in his *History*, so must be believed to have known nothing at all; otherwise, to pass over so great a matter is not the mark of a good Historian — especially since from them the Sun's rotation, its sphericity, and the Place of the spots and faculae on the solar surface are demonstrated most effectively by far, whereas from the rest they are not established quite so clearly.

[Margin: The Censor was ignorant of the secondary spots and faculae, and of what follows from them.]

About the former he makes many words — but only words; for he wastes the matter, the oil, and the effort [*oleum et operam perdit*]. For since the whole phenomenon and all its variety arise from the annual and the monthly motion, while he is ignorant of this — handling both unskillfully — he tears the whole phenomenon to pieces in a pitiable way, and violently attributes to it things that never existed in the nature of things. Therefore, since from ignorance of the annual motion he committed the gravest and most numerous errors, and set the apparent and true monthly motion far otherwise than it stands on the side of the reality, and moreover was ignorant of the Refraction of the observing circle and

of the things comprised within it — a refraction arising from the lenses of the Telescope [tubus opticus] — it is clear that he was ignorant of the substance, the core, and the nature of the whole solar phenomenon.

[Margin: A recapitulation [ἀνακεφαλαίωσις (anakephalaiōsis), "recapitulation, summary"] of what has been said.]

For besides the spots, faculae, and shadows — both primary and secondary — as well as their motions and what depends on them, and likewise besides Refraction and what follows from it, hardly anything remains worthy of astronomical inquiry; and since the Censor either was ignorant of all and each of these, or corrupted them with the foulest errors, it is plain that he is an exile from the truth of this phenomenon, and was led astray into trackless byways by an alien angel — or by his own Genius [Genius].

Whence, on behalf of Apelles's innocence and integrity, one may again argue thus:

From one who does not possess the necessary knowledge of the solar phenomenon, Apelles could not have learned it, nor been alienated from it. The Censor does not possess the necessary knowledge of the solar phenomenon. Therefore Apelles could not have learned the knowledge of the solar phenomenon from the Censor, nor been alienated from it.

[Margin: A syllogism by which Apelles's innocence is shown.]

The major is certain. The minor is proved: Whoever is ignorant of the essentials of the solar phenomenon and of what flows from its essence does not possess the necessary knowledge of the solar phenomenon. The Censor is ignorant of these, as has just been shown in the Catalogue of ignorances and errors. Therefore, and so on.

Likewise: Whoever maintains opinions that overthrow the essence and the properties flowing from the essence of the solar phenomenon, he...

[Margin: A syllogism by which the Censor's futile efforts are shown.]

—he does not possess the necessary knowledge of the solar phenomenon. But this is exactly what the Censor does, as has just been shown in the catalogue of his errors and ignorances, and so on. The minor premise, therefore, stands proved. Therefore the conclusion holds: that Apelles could neither learn the knowledge of the solar phenomenon from the Censor nor make it over to him.

[Margin: The decision of the whole controversy is committed to the most impartial judgment of the Reader.]

The very many findings, then, that Apelles possesses concerning the true constitution of this phenomenon—won by so laborious an inquiry—are his own, and were first put forward by him. And so, friendly Reader, on the strength of these premises let your judgment be free as to whom you will set down as your discoverer of the solar phenomenon. This one thing only I will add, for the sake of my own innocence and of the truth of the matter: Apelles, then, did not learn his knowledge of the solar phenomenon from the Censor—who himself lacked it—nor did he steal it, nor did he set himself up as its discoverer after the Censor. Which was the thing to be demonstrated against the Assayer [Libripendem — Galileo, author of *Il Saggiatore*].

THE ACQUITTAL OF APELLES, made by the Censor—whether when he seems to speak for him, or when he seems to speak against him.

CAP. XI.

Here you will see what the Censor's real view once was, when truth pressed hard upon him—the genuine opinions of a man who assesses with too little fairness, indeed of one who secretly longs to overthrow another man's assessment; and along the way you will see the other objections raised against Apelles dissolved one by one.

The third letter of the *History*, at p. 113, near its beginning, runs thus:

But I pass on [he says] to some considerations touching what Apelles partly repeats and partly adds to what he had already written on the subject of the sunspots. Here, in general, it seems to me that in his conclusions he proceeds rather less decidedly than he had done before, though at the same time he shows himself eager to present them as modified rather than as altered; indeed, at the end he affirms that everything said in the earlier letters stands firm. For all that, I come to some hope of seeing, in the third writing, opinions inwardly quite in accord with my own—not, I say, by force of these letters of mine, which, on account of the difficulty of the language, cannot be read by him, but because, on reflection, there will come back into his mind those same observations, those same reasons, and those same solutions that persuaded me to write what I have written in the first and in the second letter, and what I add in the present one.

[The same passage as Scheiner renders it in Latin:]

But I pass on [he says] to some considerations concerning what Apelles partly repeats and partly adds to what he once wrote about the sunspots. Here it generally appears to me that he proceeds more slowly in deciding them than he was formerly wont to, although he does show a great enough desire to trim and adjust them somewhat rather than to change them, since at the end he also affirms that everything stated in the first letter holds good for him. Nonetheless I come into no small hope that in the third writing I shall see his opinions inwardly as fully as possible in agreement with mine. I do not say that this will come about now by the force of these letters of mine, which, owing to the difficulty of the language, can be neither seen nor understood by him, but rather that, weighing everything more carefully in a fair balance, those same observations, those reasons, and those very solutions that impelled me to write them—which I wrote in the first and second letter, and which I now add in this present one—will occur to his mind as well.

[Margin: Apelles wrote from the Censor's own confession—his own material, not another's.]

[Reader, do not be led into error: everything that Apelles wrote in his five letters in conformity with the Censor's opinions was written earlier—as is plain from the dates given—than the time when the Censor composed either his first or his second letter. And yet here he fraudulently means to creep in and appear to have written those things first, as you will also see more fully below.]

From this it is established, on the Censor's own first testimony, that whatever Apelles published, altered, and modified, he did from no view or writing of the Censor's, since he completed all of it on 16 January 1612—at which time the Censor had composed neither his first nor his second, much less this third letter, for he wrote the first on 4 May, the second on 14 August, and this third on 1 December 1612.

[Margin: Apelles corrected his own writings from his own work, not from another's.]

Apelles, moreover, continued, enlarged, restricted, and modified his own opinions on 16 January, following no one's prototype [protypum] or

model, but pursuing his own observations and the guidance of the phenomenon; not led or taught by anyone, but opening a new road for others. He completed his

two last letters on 14 April and 25 July, all of which Welser gave to the light on the Ides of September [13 September] 1612.

Secondly: whatever Apelles was going to write and send in the future, he would produce not by force or knowledge of those Censorine letters, but from his own genius, from his own observations, reasonings, and solutions, which would spontaneously present themselves to his mind; and although these should turn out intimately conformable to what was contained in the Censor's *History*, still Apelles would not on that account be drawing them by force of the Censor's writings, but rather deriving reasonings that flow from the very inner parts of the phenomenon.

[Margin: Apelles's future writings, even if they should turn out similar to the Censor's, would nonetheless not have been drawn from the Censor's writings: so the Censor himself determines.]

If, therefore, the Censor frees Apelles from every stain and from all suspicion of theft, both in what he wrote and published in his Table (as, under the compulsion of truth, he is bound to acquit him—for if he holds that Apelles's future writings are not to be drawn from Apelles's own deeds, he is all the more compelled to admit that his past writings were not drawn from things Apelles never did)—if, I say, before the Censor had woven together and published his *History*, he attributes even Apelles's future writings entirely to Apelles's own genius, observations, reasonings, and solutions, and not to the Censor's *History*, which was neither seen, nor read, nor understood by Apelles as something to be borrowed from: then he plainly acquits Apelles outright, while condemning himself, since one whom he rightly acquits in the *History* he unjustly traduces in the Assay-balance [Libripende], exposing him—first, still more unjustly, to his own men, and then, through them, to others—to be publicly torn apart, and so betrays himself as an unjust judge. Furthermore, that on this head Apelles is a man *whole, and clean of any crime*, whose mind is untainted by any craving for another's property and whose hands are unstained by any meddling touch, but who carries only what is his and harmless—this I demonstrate not merely on the aforesaid judgment of the Censor, but from the very substance of the matter, as follows.

Apelles sent everything he set out in his Table to Marcus Welser [Marcus Welser] out of private friendship, with no intention of publishing, thinking and knowing nothing of any other person, and writing nothing against anyone—contrary to the way the Censor ridiculously represents him as if opposing himself—but weaving

his own Table as one continuous web, as is clearly evident from the unbroken thread of his letters,

the last of which always lend each other a helping hand. His whole composition—save the single sixth and last letter (in which, however, he brought nothing new, only confirmed what preceded)—and all the matters that the Censor makes out to have been stealthily taken, he completed by putting them together many months before the Censor gave any thought to writing on this subject; indeed the Censor frankly confesses more than once that it was at Welser's prompting that he brought forth his own opinion as a "Censure" upon Apelles's Table, and so forth. And Apelles even anticipated the Censor by a full year in public print. It is therefore evident that whatever Apelles put forward in conformity with the Censor, the Censor could in no way have transmitted to him—and this is one point. As for the rest—the things that this same Apelles now brings forward, established by continuous observations over so many years—he has these not from the Censor either; and this on the evidence of so many learned and eyewitness testimonies, in whose sight Apelles openly worked out his own results. This is so, moreover, because most of these findings run counter to the opinions—or rather the errors—of the Censor, which, over so many elapsed years, the Censor would doubtless have detected, had he been endowed with assiduity in observing and with the science of ordering what he had observed, and been devoted to the study. But that this was unknown to him and left undone I gather well enough from the fact that, in the Assay-balance of his *History*, he still acknowledges his writings on the spots as most true, convicts Apelles of impossible opinions, and clearly lays bare his own hesitation about the motion of the Sun and of the spots, and so forth—hesitation he could have laid aside had he been diligent in observing, exact in probing, and skilled in ordering. And so what Apelles now brings forth in his continued Table, the *Rosa Ursina*, he in no way borrowed from the Censor, nor indeed anything of his earlier work. From the Censor, therefore, he received absolutely nothing. Whether, on the other hand, the Censor received nothing from Apelles, I leave to anyone's judgment: certainly the Censor tries to dislodge Apelles from his seat of priority and from his possession by hidden mines and captious writing, and to lead the honest Reader into error. Let us re-read the text; let us examine the trick.

[Margin: The Censor still remains, up to now, mired in ignorance of the solar phenomenon.]

[Margin: Apelles received nothing from the Censor; the Censor labors to wrest from Apelles the primacy of the discovery.]

The third letter, at p. 113, thus continues what precedes:

And already one sees how many particulars he puts into this second writing that were not yet observed in the first. He formerly reckoned the sunspots to be all of spherical shape, saying that if they could be seen separated from the Sun, there would appear to us so many little Moons—some crescent, some in the form of a half-circle, some more than half, and perhaps others entirely full: now he writes, with greater truth, that very few are spherical and very many of irregular shape. He has likewise observed that very few of them, or none, keep the same shape throughout the whole time they remain visible, but that extravagantly some are born and others dissolve even in the middle of the Sun, just as some divide into two or more, and conversely many unite into one—particulars that were touched on by me in the first letter. He formerly reckoned that they were wandering stars, situated at various distances from the Sun, so that some were nearer and others more remote, in such a way that very many went wandering between the Sun and Mercury, and also between Mercury and Venus, at uncertain distances, becoming visible only when they meet with the Sun; but now I do not hear so great a distance affirmed, and it seems to me that he is content to show that they are not within the solar body, nor contiguous to its surface, but outside it at a distance of only some slight account, as may be gathered from the reasons he uses in demonstrating his opinion.

So far Galileo; the same passages, in Latin, run thus:

It also appears how many particular things he sets down in this second writing that were not observed before in the first. He formerly thought all the sunspots to be of spherical shape, asserting that if they could be discerned apart from the Sun they would appear to us like little Moons—crescent, half, gibbous, and perhaps full: now he writes, with greater truth, that very few are spherical, and most frequently of irregular shape. He has likewise observed that either none, or very few, keep the same shape throughout the whole time they are seen upon the Sun, but change prodigiously, now growing, now diminishing; and, what is more, he has seen some arise unexpectedly and others dissolve even in the middle of the Sun, some dissolve into two or more, and many in turn coalesce into one—individual points that had been touched on by me in the first letters. He once thought them to be wandering stars, placed at various distances from the Sun, some nearer, others farther, so that very

many moved between the Sun and Mercury, and between Mercury and Venus, at the intervals proper to those alone that are conspicuous as they run beneath the Sun; but now I do not hear so great an interval affirmed, and it seems to me that he will be content if he shows them so removed from the Sun that the Sun does not touch them immediately, yet they are only as far from it as his opinion needs for its support.

Here I leave it to the judgment of the candid and level-headed Reader whether the genuine sense of the words is not—by the manner of speaking and by the idiom of the Italian tongue—such that the Reader is led into this sense: that he should suppose Apelles, first, to have felt and written something in his first letters, at I know not how great a time before, which he now, in the second, amends and in a manner retracts by a more exact disquisition; and second, that he carries out this retraction only after the Censor's second letter had been written, which had touched on all these same matters. This sense, I say, seems to be forced upon the Reader at the very first glance and on reading this writing; and because I do not hold the force and nature of the Italian idiom so thoroughly well, I went to several expert men—who had never seen either the *History of the Spots* or Apelles's Table—so that I might learn from them the native force of this passage. They answered with one accord that the tenor of that text yields the following: first, that Apelles appears to be inconsistent with himself and to have wished to amend the earlier by the later; second, that the earlier writings were, by the force of this text, complete, and not dependent on the later; third, that some notable lapse of time must also have intervened; fourth, that the Censor had dispatched his first letter before Apelles's second writings appeared, and that thus the opinion contained in the Censor's first letter is the earlier, while Apelles's later opinion is that by which he corrects his own first letter. This, they say, is the sense of the cited passage for sincere Readers and Interpreters. And if it is so, then the Censor has thrown dust in the Reader's eyes, done violence to the truth, and wronged Apelles. For, first, Apelles wrote all his first letters—which were three—and all his second letters except the sixth (from which, however, the Censor here institutes no comparison), and sent them to Marcus Welser,

[Margin: The Censor's shifty, tangled, and sophistical style is here exposed.]

earlier than the Censor addressed his first letter to the same man. Secondly, among the letters written by Apelles there runs a continuous connection and mutual dependence, like the threads of a single web and the colors of a single Table. Thirdly, no great or notable interval of time elapsed such that so great a comparison—as though I know not how long a delay had passed—could or

should have been instituted by the Censor. Fourthly, the matters are not, as they are alleged and pressed by the Censor, so written or published by Apelles. Each of these points I show more clearly than the Sun.

IT IS SHOWN, FIRST: namely, that Apelles's Table and his more accurate Disquisition—except for the last letter (from which, however, no comparison is drawn)—are, for the greatest part, prior both in composition and in printing to the Censor's very first letter. [recte: OSTENDITVR]

Do not be surprised, Reader, if I here repeat a matter already proved in the Chronological History: for just as the Censor has tricks to spare for wrapping up the truth, so Apelles ought not to lack testimonies for laying it bare.

Apelles completed the first letter of his Table and sent it to Welser on 12 November 1611; the second on 19 December 1611; the third on 26 December 1611; and thus the first Table was completed and sent to Marcus Welser—which he then committed to the press in 1612, on the Nones of January [5 January]. This date of publication is passed over in silence in the Censor's reprint; whether this was done by accident or by design—so that the priority in publishing might perhaps not be noticed by the Reader—I do not know, though neither supposition lacks probable conjecture. And so Apelles's first Table preceded the Censor's first letter, and indeed the whole *History*, by at least four months, in both writing and printing. For the printing came to an end on 5 January, whereas the Censor's first letter of the *History* to Welser is dated 4 May 1612; four months, therefore, intervened. Welser, the day after the printing—which was the 6th of January—at once forwarded Apelles's printed Table, that is, my three first letters, to the Censor, who, frightened off by the difficulty of the matter, put off his reply until 4 May because he was without suitable observations, as he himself admits in his first letter, and so on.

[Margin: The date of publication of Apelles's Table was suppressed in the Censor's reprint.]

[Margin: Apelles's Table preceded the Censor's first letter, in both composition and publication, by a long time.]

And so Apelles's first Table—as much in its conception as in its writing and its publication—preceded the very Conception and Nativity of the Censor's first letter by a good long while. And this is one point. Next, the more accurate Disquisition, or enlarged Table, likewise contains three letters, of which the first was written and sent to Welser on 16 January 1612; the second on 14 April 1612; the third and last on 25 July 1612. Therefore the first and second letters of this

Table, or more accurate Disquisition, were both drawn up earlier and dispatched to Welser earlier than the Censor's first letter was even conceived—which was only completed in the writing on 4 May.

[Margin: The first and second letters of Apelles's enlarged Table preceded even the Censor's first letter.]

Only Apelles's third and last letter followed upon the writing of the Censor's first, but it preceded the Censor's second and third, and the third indeed by many months. For Apelles sent his last letter to Welser on 25 July 1612; the Censor dispatched his second letter to the same man on 14 August 1612, and the third and last of his *History* on 1 December 1612. And so the enlarged Table, or more accurate Disquisition, for the greatest part preceded the Censor's first letter in the writing—for only the last of it followed after; all the rest, that is, the second and third, even anticipated the Censor's second and third letters. This whole Table anticipated them in the writing; but in publication it was still outrun by the Censor's second letter in the writing. For Welser published the more accurate Disquisition on the Ides of September [13 September], which was the 13th day; whereas the Censor's second letter had been written and dated 14 August. Welser, however, sent this same Disquisition to the Censor in the same month and year, namely on 28 September: on the occasion of which the Censor set up this comparison of his in this third letter of his. Therefore, since Apelles dispatched all five of his letters before the Censor's first letter was conceived, of this you had to be here informed, Reader, lest by that captious and preposterous manner of writing you be led into error, believing that the things said to be touched on in the Censor's first letter befell earlier than those that the Censor now says Apelles wrote, or felt, or observed. For the things that Apelles is now said to have written, felt, or observed *from* the Censor are not things observed by Apelles *now*, while the Censor these

[Margin: The third and last letter of Apelles's enlarged Table was written after the Censor's first, but before his second and third.]

[Margin: The Reader must beware of the Censor's fraud.]

the Censor writes this in his third letter, that is, on 1 December 1612. Apelles, however, had written it on 16 January, in his fourth letter — long before the Censor touched on the very same matter, whether here in his third letter or earlier in his first, which he issued on 4 May. So when the Censor says that Apelles *formerly* held all the spots to be spherical in shape, but *now* writes that very few are spherical; that he himself likewise observed very few, or found none

keeping the same shape, and so on — together with many similar particulars that the Censor himself had touched on in his own first letter — the meaning must be weighed. If the sense is that *formerly* Apelles held one view and *now* holds another, just as the Censor too held one view *formerly*, in his first letter written before Apelles, and now attributes the opposite view to Apelles, then that sense is utterly false, and beware the imposture, reader. But if the sense is that Apelles *formerly* held and wrote something different from what he *now* thinks — so that the Censor, too, in his first letter had written thus beforehand, but only afterward found Apelles thinking as he now does — then the sense is in part true to the fact, yet monstrously twisted; it is not the customary way of speaking, and the comparison has been badly framed by the Censor. This passage therefore turns out to be full of traps: a snake lurks in the grass. Now I proceed to the second point. Which was to be shown.

[Margin: In the Censor's comparison the manner of speaking he introduces is either deceptive and treacherous, or else monstrous.]

Second Point — that between the letters written by Apelles there runs a continuous thread and a mutual connection; and thus the second point is demonstrated.

Apelles's first letter, issued on 12 November 1611, speaks around its middle as follows: "And there remain, finally, many other things, which I now gladly pass over in silence but which will come to light; for I have chosen to set out this little sample now for tasting, and if these things prove savory, we shall devote our labor to the very kernel of the matter, so as to bring out something more before long." And at the end it reads thus: "Use these things now, enjoy them; the rest, God willing, will follow. Farewell." This closing binds the present letter to those that follow by the middle passages just cited; and by the force of these premises and promises, whatever the following letters say — even if it is altered, modified, expanded, corrected, or cut back — is not to be held contradictory. For whatever this letter carries within it, as though contained in the womb, it brings forth in the others as if by giving birth. They are therefore not to be judged self-contradictory, so long as inquiry is still being pursued along its path, and one relies on what is earlier while pressing on toward what is to come, holding out to it an easy palm, and decides nothing absolutely as yet but defers to further findings.

The third letter, issued on 26 December 1611, has this at its opening: "You remember what I touched on timidly in earlier days; now, resting on sure and

established grounds, which I submit to your judgment, I do not fear to affirm it plainly; for I am now pleased to do so," and so on. Here you see, discerning reader, how the beginning of this letter is knit to the end of the preceding one. Now let us look at the end of that same third letter: "For the present I remain undecided whether these bodies are wandering stars or fixed," and so on. "But this in its own time, along with the questions of their motion, figure, magnitude, distance from the Sun, and their other properties." So here too you see the hand not lifted from the Table but stretched still further. Hence in the *Accuratio* *Disquisitio*, the opening of the first letter — which stands fourth in the whole order — is of this kind: "Since I have served up a must that is somewhat turbid and dreggy, and poured out a rough, unformed birth, this too must be strained after the manner of good vinedressers, and made to settle here in the fashion of the bears' [cubs], and shaped into the graceful proportion of its members." Here again you discern the letters joined to one another in a most beautiful connection, the earlier ones always awaiting their perfection from the later. But let us inspect the middle of the letter, where Apelles says this: "Having dealt with Lucifer, let us turn to the very Parent of light, the Sun, and to his numerous offspring, and lead them as if in solemn procession from 10 December (leaving out of account that I recently sent something to be looked at) all the way to 12 January." Here, reader, you see observations knit to observations, and spots to spots; for the first table of observations ended on 14 December, and this one begins on the 10th of the same month and runs to 12 January. Now let us step toward the end of this letter. "For the moment I gladly refrain from saying more," says Apelles; and a little later: "Hence, since this phenomenon is far greater than anyone would readily suspect, as you will understand from its very progress," and so on; and after a few lines: "Things equal to or greater than these you shall have from me before long." How great these matters are, and to what they tend, you note along with me, and hence I fear that, unless you forestall it, it may be nearly wrenched from our hands; for once the mathematicians have seen so great an outcome of this affair, they will not be able to hold back. But they will hold back if they weigh how far they have been left behind by us; and so they will either produce their own findings, or at least will not claim what is not theirs. To prevent this lies wholly in your power. God grant that, as we have begun these things, so we may prosperously carry them on to the glory of His Name and bring them to completion. See the letters chained together by mutual bonds: "Day unto day uttereth speech, and night unto night showeth knowledge."

In Apelles's sixth and last letter, composed on 25 July 1612, we find this around the middle of page 48: "I am driven to suspect, contrary to what many think, that

these bodies can scarcely come to be and pass away," and so on — "yet I say all this in such a way that I would not be unwilling, nor unable, to move from this view to another, should the truth of the matter itself lead us elsewhere. For up to now we follow the more customary opinion, the one more widely accepted among philosophers." And on page 49: "What follows from this you readily see, namely that these are not shadows lying on the Sun, unless you are willing to make the Sun more changeable than the sea." And on page 50, around the middle: "But concerning these two points — that these bodies are thin, and that they are permanent, that is, are not stars — the astronomers are at odds, and the case is still before the judge; just as it can scarcely be still further in dispute whether they move unevenly, since I have so often lately detected as much," and so on. And on page 53: "Finally, to make an end of the letter, whether we hold these spots to be in the Sun or outside it, whether generable or not, whether we call them clouds or not — all of which is still unsettled — this at least seems to follow, according to the common opinion of the astronomers, that this hardness and constitution of the heavens cannot stand." And toward the end of the letter: "This completion of all the earlier matters I have gladly communicated to Your Excellency," and so on; "for all the rest, which I set out in the first table, are consistent with themselves. On one point alone are we still at a loss, whether these bodies are generated and perish, or are eternal; and while we investigate this by such diligence and shrewdness as belongs to man, or can belong to him, you meanwhile, most distinguished Sir,

with these matters sufficiently aired, may take your enjoyment."

From all this, then, it is evident: *First*, that Apelles painted his Table thus, in one continuous stretch, so that each part always depended on another and the earlier parts carried down into the last. *Second*, that few things were absolutely decided, while a good many were brought forward doubtfully, hypothetically, and on the sense and mind of others. *Third*, likewise, that most matters were argued in the manner of an inquiry; and that the absolute decision, especially on greater questions, was held in suspense and reserved for later observations and orderings.

Since this is so, Apelles could never — and never should — have been so sharply censured by anyone, as though he were bringing forward something already undoubted and absolutely decided by himself, when everywhere he testifies the contrary. Undeservedly, then, is he charged by the Censor as inconstant, at odds with himself and self-contradicting, condemning his first statements by his last — when he never once took his hand from the Table, and freely professed

everywhere, in all his letters, that what he offered was a work begun, not finished; taken in hand, not accomplished; imperfect, not complete in its parts; in many respects still sought after and to be dug out, not fully unearthed. If Apelles had made no express and frequent mention of these matters and of these very shortcomings, the Censor would have some pretext to cloak his own severity and to cover his rashness with some semblance of plausibility. But as it is, since Apelles himself so often professes that he is indeed bringing forward something new — to himself certain as to the ὅτι [Greek: hoti, "the that" — the fact that it is], but to others highly doubtful; while as to the διὰτί [Greek: dioti / diati, "the why" — the reason why] obscure both to himself and to everyone else, and as yet not sufficiently settled — he could not be blamed if, in establishing and laying open to all the question *whether it is*, he devoted himself wholly to that before all else; if he then reserved for subsequent attention the rest, which pertains to the questions *what it is* and *on account of what*; if he pronounced doubtful things doubtfully, probable things probably, certain things firmly; if, finally, he subjected either all or the greater part of his findings to later refinement and cultivation; if he proceeded in so slippery a matter with such caution and foresight that, in advancing, he did not cut off from himself the means of retreat; if, in the manner of painters, he covered over the first rudiments and traces of his outlines with a later overlay of varied colors — that is a mark of skill, not of unskillfulness.

[Margin: The Apellean Table, continued up to now, is not yet wholly completed. Hence the Censor wrongly found fault with it as though it were finished.]

It is a mark of skill, then, thus to draw out an image from those rough outlines to the highest gracefulness, so that, although you proceed from them, you seem to have departed from them. For we would never reach the goal if we always lingered at the beginnings: one must move from doubtful things to sure ones, from signs to realities, from conjectures to opinions, from opinions to certain truth, from investigating to the mark, from hypotheses to a thesis, from others' views to one's own. And if Apelles did this, or began to do it, at some point in his later — indeed in his earlier — writings than the Censor's own were composed, is he on that account to be introduced as his own adversary? By no means. For, using his own right, he made good what he had always promised at the outset, what he everywhere kept referring to, what in the end he intended and was bound to do. He painted a single Table; no other, differing in time, was made. For if, by Horace's precept, a birth held back and pressed to the ninth year comes forth more perfect and stands as one work, the painting of Apelles is not on that account to be judged worse or a different one because it endured the artist's hand

into a ninth month — to say nothing now of a continued Table pressed into a fifteenth year. Though the span of nine months may perhaps seem too long to the Censor, who set up his comparison within much shorter intervals — as we shall now see in the third point.

Third Point, in which it is demonstrated that the interval of time within which Apelles is charged by the Censor's critical stroke with inconstancy in his opinion was exceedingly small and of almost no significance.

Granting — though not conceding — that Apelles had been at odds with himself, still, if he corrected his earlier opinion quickly, he deserves the greater indulgence, and he ought not to be blamed on that account; for an error quickly recognized, and indeed spontaneously amended, should be reckoned as not committed. For you carp, you do not correct; and if you call back a man who repents of his own accord, and reproach a fault already atoned for, you come off as an accuser, not a corrector. If Apelles erred earlier, still he wiped away the error of his own accord and quickly; why then does the peevish Censor make his outcry? But whether any fault of Apelles's has intervened at all will be examined later; for now let us measure the temporal delay

[Margin: Apelles was not culpable in the delay of time.]

itself. "*Avanti*, Before," says the Censor, "Apelles held all the spots to be spherical in shape," and so on. "*Hora*, Now, he writes with greater truth that very few are spherical, and most frequently of irregular shape." This, according to the Censor, Apelles writes in his third and last letter of the first Table, on 26 December of the year 1611; that, in the fourth letter, which is the first of the second — or continued — Table, in the *Accuratio Disquisitio*, page 28, first Document, on 16 January of the year 1612.

Therefore, between the one letter and the other, between the one passage written and the other, there elapse 22 days, three weeks, with no other letter intervening; but this one followed immediately upon that one to Welser, so that even if Apelles had wished by this later one to amend the earlier, he could scarcely, and need scarcely, have done it sooner. And one who is not culpable in the delay of amending is not to be blamed for amending.

And yet, on account of the 22 days that elapsed, the Censor dares to write: "*Avanti*, Before" — namely on 26 December — "he wrote," and so on; and "*Hora*,

Now" — that is, on 16 January — "he writes"; as though I know not how much time had passed, foisting a deception on the reader. If Apelles was earlier blameworthy for his writings, now, for an error corrected in so brief a time, he seems rightly to deserve praise — especially since he corrected it of his own accord, unadmonished by anyone. But let us go on.

The Censor says that many things not observed by Apelles *formerly* in the first Table he *now* observed in the second — such as inconstancy of shape, continual change, increase and decrease of the spots, and so on. Of the truth of these charges we shall see later; the interval of time by which that *formerly* is distinguished from this *now* is 22 days. I come to the third comparison.

"*Stimò già*, He once thought" (says the Censor) "— *Quondam*, Formerly — Apelles held those [spots] to be wandering stars, situated at various distances from the Sun," and so on. "*Ma Hora*, But Now — *At nunc* — deep silence about so great a distance." I am not now sifting the reliability and truth of the charges; I attend only to the interposition of time. Therefore, between what Apelles writes at the end of the third letter — "the suspicion arises" [*subit opinari*] that from the Sun as far as Mercury and Venus a great many errant bodies range — and the

fourth letter, where these things are passed over in silence, and so on, there elapse 22 days.

But indeed, between that very *the suspicion arises* and the first corollary, in which Apelles writes expressly in these words, "That these spots do not recede much from the Sun" — how much time is there? Not a year, not a month, not weeks, not days, not an hour; perhaps scarcely ten scruples of a single hour. For at the same time, in the same letter, Apelles wrote both, with the same pen, on the same paper — and indeed this first, "That these spots do not recede much from the Sun"; that later, before the end: "The suspicion arises that from the Sun as far as Mercury and Venus, at their due distance and proportion, a great many errant bodies range, from which those become known to us as belonging to the Sun which cross the Sun by their motion." If, then, Apelles is charged on the ground that *Formerly* — that is, here at the end of the third letter — he removed the spots far from the Sun, by the Censor's judgment, and *Now*, in the fourth letter, tacitly brought them back close to it, he is much more to be blamed for falling into the same fault within this single letter; where, *Before* or *Formerly*, in the first corollary, he says these spots do not recede much from the Sun, and then, near the end, *Now*, removes those same ones far from it, and indeed sets them in different orbits among the Sun, Mercury, and Venus. These, I say, should rather have been made the objections; for here Apelles affirms a short distance, there he

merely keeps silent about a long one. But that *Stimò già* and this *Ma Hora*, and so on, did not seem to fit into a single letter; and so they were passed over.

[Margin: The Censor's snares and secret mines exposed.]

But from this the Censor's tunnels lie open, and he blushes for shame — that where so short an interval, or none at all, intervenes, he dares to apply the words *Formerly*, and so on, *Now*, and so on. But all this has been done to deceive the honest reader.

Now let us approach the examination of the truth of these antitheses and of the ugliness of the alleged Apellean errors. The Censor says: "And now it appears how many particulars he sets down in these second letters that were not even observed in the first." Let me ask the Censor first of all: from where does it become known to him, or from where does it appear, that these particulars, listed here by Apelles in the second letters, were not observed in the first?

He will perhaps say that this is known from the fact that Apelles did not set them down in the first letters and did enumerate them in the second. Let us examine the force of the argument in syllogistic form.

[Margin: The Censor's bad argument against Apelles.]

Whatever Apelles did not set down or note in the first letters, that he did not observe in them. But many particulars brought forward in the second he did not set down or note in the first letters; therefore he did not observe them in those. Before I answer the argument in form, take note, reader. *First*, that here it is one thing to set something down in the letters, another to observe it. The former means to declare in writing a thing observed; the latter, to contain it either in writing or by some designation of the observation. Moreover, when mathematicians treat some phenomenon, they generally speak in two ways, by picture and by writing. Even if, then, Apelles had not set forth in writing many of the properties of this phenomenon that the Censor presses, it would suffice to have set them before the eyes by picture; and by this the Censor would be sufficiently refuted of falsehood. For to display a thing by picture is certainly to observe it. But if the Censor means — as this whole indictment, otherwise brought forward gratuitously, aims — that Apelles, in the first letters, that is, at the time when he composed the first letters, did not observe, or did not understand and notice, the things he afterward describes more fully in the later ones: let him know both that the argument has no force, and that he is contriving a fraud against the reader and an injury against Apelles. For Apelles knew both

these things and others, which, however, by the wrong of those times he could neither write nor utter to the public.

And the Censor's inference is worthless: "he did not write it, therefore he did not know it." This is the inference of a bad logician. But to the Censor everything is sound that discredits Apelles. *Second*, let me inquire: what fault would there be in this deed of Apelles's, even if he had noticed in the second letters certain things not observed in the first, and had transmitted the same, set down for Welser? Would matters therefore have been badly handled with the first letters, or the second ones deserving to be spat out, or Apelles to be dismissed as an unskilled craftsman? None of this follows. No one is born a full-grown man. For that reason, second efforts succeed the first, and third the second, and others still succeed these, until a work begun is brought to a finished state. Yet the Censor himself did just this,

[Continuation of Book I, Cap. XI — the priority polemic against the "Censor" (Galileo). The text on each page runs continuously down the left column and then down the right; the centered "I."/"II." column-labels and the five-line marginal numerals are the cross-reference apparatus, not section divisions.]

— the Censor himself did exactly this, in his own History of Sunspots [*Istoria*], and so on. Did he not set down many things in his second [letters] that he had been ignorant of, or had doubted, in the first? Did he not, in the third, defend a great many things wrongly and with utter confidence? Next, what contradiction is supposed to lie here, I do not see. Apelles says certain things in his second Table that he did not say in the first — and what absurdity follows from that, Apelles does not see. On the contrary, everything follows in the second: the fullness of the Table, the perfection of the picture, the sweetness of its symmetry, and the exceedingly elegant, exceedingly graceful harmony of the loveliest colors.

[Margin: A reply, in due form, to the syllogism framed on the Censor's behalf; and the major premise is denied.]

But let me come to answering the syllogism that has been put forward — whose major premise I deny. For from the fact that someone, in a letter, does not spell out everything, or each single item, in writing, it does not follow that those things were not observed. For, as I said, observing is one thing, and explaining in writing what has been observed is another. The Censor therefore infers wrongly, and with too little caution, against Apelles: that Apelles reviews in his second letters many particulars which he did not review in the first, and therefore that he did not observe them in the first. So I press the point again: how does the

Censor know — and so boldly assert — that Apelles brings forward in the second [letters] many particulars which he himself had not observed in the first?

[Margin: The Censor's excessively rash haste against Apelles.]

To affirm so great a matter, and be unable to prove it, and offer no certainty — this was very "prudently" done. Did not Apelles say, at the end of his letter, *Enjoy these now; others will follow*? Are not these very clear words read in the middle of the same letter: *And finally many other things, which I now gladly pass over in silence, will become known*? How is it, then, that Apelles promises other things so confidently — indeed a great many, without any hesitation, things he now gladly keeps quiet about — if he knew nothing beyond what he had written, observed nothing? Could he not have feared beforehand the authority and right of the one who would call him to account? The things, therefore, that were brought out in the later [letters] had been foreknown and promised in the first.

[Margin: The minor premise of the Censor's syllogism is false as well.]

But the Censor's minor premise is denied too — namely, that Apelles did not set down or note in his first letters the many particulars brought forward in the second. Let us look at the examples the Censor adduces. *Hà parimente osservato*, etc. [Galileo's Italian, "He has likewise observed"]: Apelles equally observed (in the second letters) that very rarely, or never, does a spot pass beneath the Sun with unchanged figure, but that it changes prodigiously, by growing and by shrinking. This Apelles teaches by the very act performed, in the whole Table of observations of the let-

-ter, from the 22nd of October in the year 1611 to the 14th of December of the same year, where the varied figures of the spots present themselves at every turn. And this one point alone would suffice for Apelles's defense, because he has the Censor's own conduct on his side, both before him and after him. Hear what the Censor writes in his second letter, page 32:

[Galileo's Italian:] "Their differing densities and blacknesses, the changes of figure, the clusterings and the separations, are of themselves manifest to the senses, without any further need of discourse; so a few simple comparisons of such accidents against the drawings I am sending will suffice."

[Scheiner appends a parallel Latin rendering of the same passage, materially identical: "their various densities and blacknesses, the changes of figure, the coadunations and separations are of themselves manifest to sense without any

further labor of discourse, so that a few simple collations of such accidents, made against the observations I send him, will suffice, etc."]

[Margin: The Censor does the very thing himself that he brands in Apelles.]

If the bare inspection of observations suffices for the Censor to judge the changes of figure in the spots, and similar accidents of sense, there is no reason for him to demand anything different from Apelles. Apelles speaks equally by picture and by writing, no less than the Censor — indeed by both — a thing he signifies in the plainest words, as will be clear to anyone who reads. So the Censor will either condemn himself along with Apelles, or absolve Apelles along with himself: whichever he chooses, he himself is always the one at fault. If he condemns, he makes himself guilty of the same fault, since he too only paints and does not explain the figures of the spots. If he absolves, then he had condemned wrongly and unjustly before — and, I add, falsely too. For Apelles teaches the change of the figures in the observed spots not only by picture but also by writing; not only "in act" (as they call it, "exercised"), but also "signified." In the first letter, in these words:

"Be it noted: the spots which always keep the same letters attached to them are always the same; yet they appeared then just as they are painted, when they are painted."

Why was it necessary here to warn the reader that a given spot is always one and the same, to which the same letter would be attached — unless, from a change of figure, the reader might with good reason doubt its identity? And those words: *yet they appeared then just as they are painted, when they are painted*. By these words Apelles meant to signify — as he expressly does signify — that the spots vary their figures. Although he reserved, on purpose, a clearer statement of the matter for the *Accurate Disquisition* [*Accuratio Disquisitio*]. Here it was enough [to say] a few

[Printed p. 62:]

words, so as, in a manner of speaking, to sow a great deal by way of seed rather than to explain it. See in the attached diagram — newly engraved here for your benefit — Spot I, from the 25th of October to the 5th of November; likewise Spot M, from the 1st of November to the 12th of the same month; likewise Spot Y, and many others, which varied their figures greatly not only in position and local motion but in their very substance. To be sure, in the autograph [drawings] this appears far more vividly and is recorded more fully, so that I can give anyone's eyes undoubted assurance of it; here [in the printed plate] there is indeed

something of it, but the engraver [*calcographus*] has now and again departed a little.

Sed pergit Censor — "But the Censor goes on": *è quello, che è più, hà veduto*, etc. [Galileo's Italian, "it is that which — what is more — he has seen"] — Apelles also saw this, and what is more (in the second letters): how some [spots] arise unexpectedly and others dissolve, even in the middle of the Sun; and how some divide into two or more, while others, on the contrary — often many together — unite into one.

All this Apelles set forth in his picture by the very act, when he presented the courses of the spots as observed from day to day. And he expressed it pointedly in these words:

"Be it noted: when certain spots are no longer painted in with their letters, they have then ceased to appear in the Sun; but when others are marked with other letters, those are others, newly appearing."

How clearly does Apelles say that some spots cease in the Sun and others arise! The examples are not few. See Spot K: this arose anew, as it were, in the middle of the Sun. Likewise the spots marked P. Likewise the spots marked Y, which perished before setting. I pass over very many others, marvelously changed, varied, increased, and diminished, as appears to the observer. And so these things were wrongly urged by the Censor, as though Apelles had not observed them, when in fact he had done so most diligently, as has been clearly proved.

[Margin: The Censor dissembles and suppresses the truth, so that by this stratagem he may creep secretly into the primacy of the Discovery.]

But the Censor either did not understand these things or ignored them, so as thereby to cast a cataract [*glaucoma*] over the reader's eyes — as if he himself had brought forward much that Apelles had not noticed — and so, in the finding, snatch the first honors from Apelles and claim them for himself. And this, even though Apelles, both here and in his fourth letter, had written the same things all too clearly to Welser four whole months before the Censor's first letter, and had put them into print nearly a full year before that same man. Yet this priority the Censor seems to wish gladly suppressed and unremarked by the reader, so that

he himself may not seem rather to have learned and received it from Apelles than Apelles from him. For he had Apelles's printed Table with him for four whole months before he wrote a single word about these spots. Now I proceed to the oppositions.

First Antithesis [*Prima Antithesis*]. [Galileo's Italian:] *Stimò avanti le Macchie Solari essere tutte di figura sferica*, etc. *Hora con maggior verità scrive, rarissime essere sferiche*, etc. — "Before, he reckoned the sunspots to be all of spherical figure, etc. Now, with greater truth, he writes that very few are spherical, etc." [Scheiner's parallel Latin: "Before, says the Censor, Apelles thought that all sunspots are of spherical figure, etc. Now, with greater truth, he writes that very few are spherical."] The latter member is correct; but the former member I could wish the Censor had written with greater truth.

For, first, Apelles never so much as thought, ever, that all the spots are of spherical figure. Next, Apelles never used the word "all." His words in the third letter, Corollary 4, are these: *If, through the splendor of the Sun, it were permitted to distinguish their illuminated parts from those not illuminated, we would see very many little crescents around the Sun — horned, gibbous, new, and perhaps even full*. Thus Apelles. Where, now, is that proposition, *All the spots are of spherical figure*? Apelles nowhere said it, nowhere thought it. On the contrary, he painted and wrote clearly enough about non-spherical figure in the first letter, in these words, when he said: *From many small spots one large one is often formed, so that it consequently looks like a single elongated one, or even triangular, as happens in Spots A and C — which, nevertheless, are distinguished by telescopes of great power, as I did with Spot A, which is compounded of three; whereas C is compounded of five, and D of four, all of which, like the rest that are joined together, I accordingly marked with single letters*. Thus Apelles; who then immediately adds, concerning the change of figure in the individual [spots], as I have also shown in the earlier [passages].

[Margin: The Censor foists [this] onto the text and sense of Apelles's words.]

And so Apelles here neither acknowledged nor asserted that all the spots are of spherical figure — and it is the Censor who has committed a falsehood. Nor, from the fact that Apelles said very many crescents would be seen around the Sun, does it necessarily follow that all the spots are of spherical figure. For even if not all the spots are, or are supposed to be, of spherical figure, nonetheless, if they could be viewed by us outside the Sun, very many crescents would appear — first, because very many spots out of so great a number could successively appear spherical.

Rosa Ursina — Book I, Cap. XI (continued and concluding)

[Printed p. 63 — engraved plate]

Diagram. A full-page engraved plate, headed "**MACVLAE IN SOLE APPARENTES OBSERVATÆ anno 1611. ad latitudinem grad. 48. min. 40.**" — *Spots appearing on the Sun, observed in the year 1611, at latitude 48 degrees 40 minutes.* The plate combines a diurnal-arc diagram at the top, one large solar disk at the upper left, an inset block of explanatory prose, and a large array of small solar disks below, each captioned with a date and hour of observation. The gathering signature **F 2** [?] is engraved at the lower right, inside the plate's ruled border.

Upper diagram (diurnal arc). A horizontal base line runs from point **a** (left) to point **c** (lower right); an arc rises from **a** over the top and descends to **c**. At the apex of the arc a small symbol resembling $\sphericalangle$ [?] marks the culmination point (labelled **b** in the accompanying text). At the left end sits a circle captioned "**22. Octob.**" with "**Sol oriens**" (*the rising Sun*) beneath it, containing lettered spots (A, B, C, D, E [?] readable, with small open circles). At the right sits a matching circle captioned "**22. Octob.**" with "**Sol occidens**" (*the setting Sun*), showing the same spots in mirror arrangement.

- Inset prose block (to the right of the arc), transcribed and translated: "*a c, horizon; a b c, arcus Solis diurnus. Sol oriens ex parte a, maculas exhibet quas uides: occidens uero c, easdem ratione primi motus nonnihil inuertit, et hanc matutinam uespertinamque mutationem omnes maculae quotidie subeunt. Quod semel exhibuisse et monuisse, sufficiat.*" — "a–c is the horizon; a–b–c is the Sun's diurnal arc. Rising on the a side, the Sun displays the spots you see; but setting at c, it somewhat inverts these same spots by reason of the primary motion, and all the spots undergo this morning-to-evening change every day. Let it be enough to have shown and pointed this out once."

Large solar disk (upper left). Captioned "**21. Octob. hora 9. et 10. antemeridiana**" (*21 October, at the 9th and 10th hour before noon*). It shows a scatter of spots labelled with the letters A, B, C, D, E, F, G [individual letter placements small; the seven-letter sequence A–G is readable].

Array of small solar disks (lower two-thirds of the plate). A grid of small circles, each a dated solar observation with its spots marked by letters. The

individual spot-letters within each disk are engraved very small and cannot all be resolved even under magnification [?]; the date/hour captions, however, are legible and are listed below in approximate reading order:

- 23.Oct. h. 8.
- 24.Oct. h. 8.
- 25.Oct. h. 9.
- 25.Oct. h. 4.
- 26.Oct. h. 8.
- 26.Oct. h. 12.
- 26.Oct. h. 4.
- 27.Oct. h. 9.
- 28.Oct. h. 2. et 3.
- 29.Oct. h. 8.
- 29.Oct. h. 2.
- 30.Oct. h. 8.
- 30.Oct. h. 2.
- 1. Nou. h. 4.
- 2. Nou. h. 8.
- 27.Nou. h. 3.

- 28. Nou. h. 2.
- 1. Dec. h. 3.
- 8. Dec. h. 3.
- 10. Dec. h. 10.
- 11. Dec. h. 2.
- 13. Dec. h. 1.
- 14. Dec. h. 8.

One cell of the grid is occupied not by a disk but by a note: "*Macula I fuit valde conspicua, propter notabilem præ reliquis magnitudinem.*" — "Spot I was very conspicuous, on account of its notable size compared with the rest." The spots in the earlier (October) disks are lettered A–L; the later (November–December) disks use additional letters (K, N, M, and Greek-looking characters) [individual assignments [?]].

[Printed p. 64 — ROSAE VRSINAE]

[The page is set in two columns of continuous argument (headed "I." and "II." as column markers); rendered here as continuous prose, left column then right.]

Even if the force of the argument achieved a great deal, it would establish that very many of the spots are spherical — not all of them. But to produce the crescent-shaped appearances this is not even required, nor need we take "spherical shape" so strictly and rigidly: any roundness whatever is enough to produce this crescent-like appearance. Hence the first proof, from the fourth letter, runs thus: *spots that are spherical to the eye are very rare; most commonly they are of mixed shape, oblong, polygonal.* Nothing in this in the least conflicts with the asserted crescent-like appearance of the spots around the Sun; for to produce this appearance oblong spots suffice, provided they display some likeness to sphericity. Apelles [Scheiner], therefore, said nothing off the point, and the Censor [Galileo Galilei] brought nothing to the point, when — from the appearance of the crescents, ignorantly and against the historical truth — he

falsely alleges that Apelles held *that all the spots are of spherical figure*, a thing that never entered his mind. This is far too remote from the truth. Moreover, for the constitution of the Moon, or of any heavenly body whatever, complete sphericity is not required. The Moon would not cease to be the Moon even if it were spheroidal; nor would Saturn have ceased to be Saturn had it remained oblong. In the same way, then, bodies somewhat round though not spherical — being oblong — could imitate the Moon's variation in brightness, even though they were not perfectly spherical. The Censor therefore throws dust in the reader's eyes when he sets such snares for Apelles.

[Margin: *Possent Maculae instar Lunularum apparere, etiamsi non essent corpore sphaerico praeditae.* — "The spots could appear as little crescents even if they were not endowed with a spherical body."]

[Column II.]...to say, *I think, I feel, I judge?* Or do these words have some other force, meaning, and sense? The Censor understood the phrase in the first proposed way, and so charged Apelles with self-contradiction.

The first force of meaning that the Censor attributes to these words, *Subit opinari* ["it comes to one's mind to suppose"], is simply not in them. For among the Latins *subire* properly means nothing but "to enter, to steal in," and the like — as the books of every writer are full of examples. Then, by metaphor and transferred use, *subire* means "to come into the memory, to occur to the mind, to think" — which too all the classical writers confirm. Now Apelles used the verb *subire* in this second meaning, that is, metaphorically. And the sense is: *It comes to mind to suppose that wandering stars move between the Sun and Mercury*, and so on — the same as "the thought of supposing strikes the mind," "the thought of supposing occurs to the mind," "it occurs, it comes to mind, to judge," and the like. The books of all the best authors are full of this transferred meaning.

That Apelles therefore used the word *Subit* in this sense, and not in the Censor's, is proved first because the Censor's alternative meaning is not Latin but barbarous, foreign, used by no good author — as Apelles well knew. For *Subit* is not the same as *lubet* ["it is one's pleasure"] or *placet* ["it is agreeable"]; and in the very sense in which Apelles employed the word, the authors of good Latinity commonly use it everywhere.

Add to this that, even if this word did also mean *lubet*, *placet*, and so on, Apelles nonetheless did not use it here in that sense. Everyone is the interpreter of his own words; and it is enough, for refuting the Censor's bad interpretation, that Apelles offer for himself the fitting and obvious sense of his own words. For the

possessor's position is the stronger. But why linger over the several senses of a single word, when Apelles sets out his own view most explicitly in the same letter, in the first Corollary, in these words? *From all of which these Corollaries are drawn. First: that these spots do not recede far from the Sun.* Apelles would therefore have had to be exceedingly forgetful or dull-witted, if he had meant to overturn his own writings by a contradiction of sense and words, and to make no mention at all of what he had said before. This is not the manner of Apelles, nor of any sensible man.

[Margin: *Censor contra historicam veritatem scripsit: & quod criminaretur falsò adscripsit Apelli.* — "The Censor wrote against the historical truth, and what he laid as a charge he falsely ascribed to Apelles."]

[Printed p. 65 — LIBER I. Cap. XI.]

Apelles wished to suggest to Marcus Welser and to the others who would read those passages nothing else — nor, by the force of the words and manner of speaking, did he hint at anything other — than a thought and a starting-point by which either Apelles or anyone else might be led to a suspicion, a conjecture, or an opinion that more planets wander between the Sun, Mercury, and Venus; the starting-point being taken from this phenomenon of the spots. And for that reason he spoke without naming a person and without fixing a time, indefinitely, and this with the greatest care. *"It comes to mind to suppose"* — whether Apelles, or anyone else you like, and so on — *"that wandering stars move about,"* and so on: this is a thought, and it asserts nothing as fact to which Apelles gave his assent, as is clear from his writings a little before, and a little after in the following letter, or by the very testimony of the Censor. Meanwhile, whether these are wandering stars or not, Apelles leaves to anyone's judgment; he himself does not deny that it can be so, does not affirm that it is so, but holds and teaches *that these spots do not recede far from the Sun.*

The Censor therefore writes falsely when he says: *"I supposed at first that they were wandering stars, and situated at various distances from the Sun,"* and so on. [That is:] Apelles once judged the spots to be wandering stars at various distances from the Sun, between the Sun and Mercury, and this planet and Venus. Apelles never judged this, but merely laid before Welser the plain thought of the matter — whether it might perhaps be so, whether someone might so suspect, whether it might be carried by a probable conjecture. Meanwhile he did not move a foot from the view he had already stated broadly, but held to it fixed. "It came to his mind to suppose that wandering stars move between Mercury and the Sun" is not the same as "Apelles judged," and so on. *It occurred to Apelles to judge; therefore*

Apelles judged. This inference is denied — and if it held good, it would go ill with the nature of things. *It occurs to one to steal; the thought of slandering comes to mind. Therefore he has stolen; therefore he has slandered.* It does not follow: it is a cheat and a fallacy of argument. I could wish the Censor would learn his Latin better; then at last he would appraise Apelles's picture more in Latin, that is, more truly.

Finally, granting but not conceding that meaning of the Censor's, it still does not follow that Apelles held the spots to recede far from the Sun, even if he had held that the wandering stars recede far; because those bodies that eclipse the Sun and produce the spots are, on Apelles's view, always near it; while [bodies] far from the Sun...

[Margin: *Ignoratio latinitatis multas sæpe præbet impingendi occasiones.* — "Ignorance of good Latin often furnishes many occasions for stumbling."]

[Margin: *Censor contra Apellem etiam in sua sententia ex hypothesi data, nil obtinet.* — "The Censor, even on his own view granted as a hypothesis, gains nothing against Apelles."]

[Column II.]...never steal in [under the Sun], on this supposed view of Apelles. But why this happens is a matter to be investigated by reasoning; that it does happen is grasped by sense and experience together with reasoning, and so on. The Censor therefore gains nothing against Apelles, and merely invents faulty objections.

From what has been argued so far, the truth about the discovery of this phenomenon shines out abundantly, I think; the integrity of Apelles's character and of his Table stands firm. If its Picture is sprinkled with a few blemishes, if in many respects it has seemed to lack the due tempering and distribution of colors, one must bear in mind that the work was made progressively, and that the rose struggles into bloom among many thorns and opens little by little; and since it is an *Ursine* rose, a delicate birth, whatever faults have been committed can be licked into shape and corrected. Furthermore, the points brought forward in the Censor's animadversions have been [answered] with a view to blameless self-defense, not to giving offense, and with good will toward the Censor himself — as is plain from what is set before us.

Approbation of Apelles's writings, according to the mind of the Censor.

[*SCRIPTORVM APELLIS EX mente Censoris approbatio.*]

The Censor, at the end of his third Letter, p. 150:

[Italian quotation:] *"Desiring nothing other than to come to knowledge of the truth, I have freely explained my opinion, which I am moreover ready to change whenever my errors are pointed out to me; and I shall hold myself particularly obliged to anyone who does me the favor of revealing and correcting them."*

[Scheiner's parallel Latin rendering, which adds an editorial gloss:] "Since I desire nothing, says the Censor, but to arrive at the knowledge of the truth, I have freely set forth my view (against Apelles, that is), which I am also prepared to change whenever my errors are shown to me; and I shall be especially bound to the man who confers this benefit on me, of exposing and correcting them."

But so that every word may be established on the testimony of two, receive also the corroborating statement of Angelo, who at the end of p. 4 declares as follows:

[Italian quotation:] *"Yet your favor and applause are not so awaited that your censures and contradictions should be refused in those matters that appear to you doubtful and not well confirmed; on the contrary, I assure you that to Signor N. the corrections will be no less welcome than the praises, the contra-*

[Margin: *Apelles inculpatæ tutelæ defensionem suscepit.* — "Apelles has undertaken a defense in blameless self-protection."]

[Margin: *Censor paratus est suos patefactos errores cum gratiarum actione agnoscere & emendare.* — "The Censor is ready to acknowledge his exposed errors with thanks, and to correct them."]

[Printed p. 66 — ROSAE VRSINAE LIB. I. Cap. XI.]

[Italian quotation, continued:] *"—dictions no less than the assents will always be dear to him: indeed the former so much more than the latter, inasmuch as the former can bring him new knowledge, whereas the latter only confirm what has already been gained."*

[Scheiner's parallel Latin rendering, adding an editorial gloss:] Yet, he says, your favor and applause (on the Censor's behalf) are not so awaited that your censures and contradictions should meanwhile be refused in those things that seem to you doubtful and not well confirmed. Rather, I assure you that to Lord N. corrections will be no less welcome than praises, contradictions no less than assents — and these indeed the more welcome than those, in the measure that from the former new knowledge is gathered, while by the latter only what was already acquired of old is confirmed.

[Column II.] Apelles has done what the Censor wished, what Angelo approved: he has shown the truth and exposed the errors in which the Censor has persisted — as is clear from the *Simbellatore* [Scheiner's derisive distortion of the title of Galileo's *Il Saggiatore*, *The Assayer* — identification inferential, see QA], where he strives not merely to defend his own doctrine of the solar spots, set out in the letters of the *History* [Galileo's *Istoria e Dimostrazioni intorno alle Macchie Solari*, 1613], but, scattering slanders upon one who does not deserve them, aims to smear novelties over it as if with white lead. Apelles, then, awaits the embrace of the truth, ready to be taught in like manner by anyone at all, and to receive the same benefit.

All to the greater glory of God. [*Omnia ad maiorem Dei Gloriam.*]

[This closing motto and ornament mark the end of Book I. The remainder of the leaf is blank (only verso show-through is visible).]

Rosa Ursina, or the Sun — Book Two

[The display title is set in large capitals: ROSAE / VRSINAE / SIVE SOLIS / LIBER SECVNDVS.]

Summary of the Book

[*Historiated initial "V" — a winged figure amid rose-and-thorn foliage, the Ursine device.*]

Just as a rose grows up among thorns, so this teaching struggles up amid difficulties — and in the present phenomenon those difficulties are offered in the greatest abundance. Some of them come from the Sun itself: for just as the rose is most difficult to the touch, so the Sun is most difficult to the sight. Others come from the instruments, whose acquisition, use, and inherent defects create much labor, weariness, and anxiety for the observer. And still others arise from the very practice of observing, and from the way the observations are organized. If these are carried out with a slack arm — carelessly — they thrust upon the theater of the learned a phenomenon that is corrupted and unworthy of it, as was seen in Book One. But if the work is handled with rigorous zeal and worked over with a more careful file, it all but wears out the one who cultivates it: so keen, so tireless is the effort it demands.

In this Book, therefore, I dig out, unravel, and to the best of my power guard against the difficulties that come from the object, the difficulties that come from

the necessary instruments, and the difficulties that have arisen from use. And on that occasion I demonstrate the optical tube [telescope] from its optical foundations — something that until now many have perhaps wished for — offering it, as it were, through a lattice [i.e. in a partial glimpse]. Whoever you are who read this, credit whatever is true and good to God, and lay the failings to my charge; and since you are a human being, be mindful of our common humanity. Farewell, and take my good efforts in good part.

The Study of Astronomy, Devoted to the Investigation of Phenomena, and Laborious. Chapter I.

[The page is set in two columns; the centered "I." and "II." heading each column are cross-reference apparatus, and the text runs continuously — the whole left column first, then the whole right column.]

[Historiated initial "S".]

If, according to the Philosopher [Aristotle], in the human and natural manner of knowing there is nothing in the intellect that was not at some time, and in some way, first in the senses, then — on a special account — this holds true both in all those sciences that are occupied with investigating sensible things, and most of all in those whose entire study is directed toward the investigation of celestial things. Therefore whoever wishes to attain a solid, fundamental, and exact knowledge of this phenomenon should by no means hope to obtain it by thinking alone — vainly wracking his brain and head with pure speculation, to the point of pain, without the prior guidance of the senses or of some shrewd and well-tested physical or mathematical experiment. The man, I say, who philosophizes in this fashion will nowhere plant a firm foot, and will never grasp the unassailable palm of truth: for such a person sets before himself, as his goal, not truth but his own vanity.

Yet by this very course many who make their way in this age nonetheless suppose they have done enough in the arena if, for a time and in outward show, they can defend whatever they once conceived in their minds and undertook to maintain tooth and nail. They fail to notice that it is one thing to defend manfully, against an assailing foe, the strongholds committed to one's charge and the bulwarks of warfare handed down by tradition — and quite another wisely to champion truth. For what they champion are arbitrary opinions, snatched up more often by spontaneous impulse than weighed by the mature judgment of reason and carefully refined by philosophy — opinions rather than genuine truths. In the one case [warfare] the positions defended and held with military

courage are always real; in the other [philosophy] fictions contrived in the likeness of truth are frequently rewarded with public honors amid great applause. For an asserted thesis is not to be held true merely because an opponent could not prove it false — since we find every day that scarcely anything is so false, or so absurd, that it cannot be, or usually is not, glossed over with some appearance of probability and plausibility.

But the true and solid method of philosophizing — the one that Holy Scripture everywhere commends, that reason itself urges, that antiquity held to, and that the more solid modern investigators of nature follow — proceeds from an effect set before the eyes to the investigation of the unknown causes of things. And effects are drawn either from indubitable sense-perception, or from the infallible tradition of others, and from a body of doctrine made firm by long-continued and often-repeated observations. But in celestial matters, most of what has been handed down up to now has been accepted and readily believed rather than proved by firm reasoning or supported by sure experiments of the senses — because, owing to the excessive distance of those bodies from the terrestrial globe, we have been granted the power to test very few of them by sense.

But now, after that most keen-sighted eye — I mean the optical tube [telescope] — was first revealed to us, by divine favor, out of Germany, it is permitted to enter the ethereal mansions and to visit those glowing bodies at closer view; indeed, to survey somewhat more secretly the very inner sanctuaries and hidden recesses of the heavens, and to penetrate them more intimately — so that what earlier ages reached neither by any stable sense-perception nor by sure and evident reasoning, we may now handle, as it were, in present sight and palpable contact.

[Margin: Through the benefit of the optical tube, many things are disclosed.]

From the Sun Itself, the Parent of This Phenomenon, Three General Sources of Difficulty Well Up. Chapter II.

In this class the Sun claims for itself the first and foremost place; and since it is perceived by us who dwell on the earth directly and immediately by sight alone, it is from this sense — and this alone — that the chief means of examining it more deeply must be sought. But what could that eye give, wretched and needy as it is? What could the eye teach the mind about the Sun, when it cannot itself learn this from the Sun? For what the light of day is to the owl, that the Sun is to the eye: it darts as many shafts against the eye as it emits rays from itself, and while it illuminates sight, it blinds it.

For although the Sun falls within the range of things perceived by ordinary use, nevertheless — as by the immensity of its place, so by the majesty of its nature — it so far surpasses our senses that, just as the hand cannot touch it, so our eye cannot bear it, but, struck as if by a thunderbolt from the abundance of its brilliance, is utterly unable to fix its gaze upon it. The light of the Sun, therefore, must be withheld from the naked eye, and it likewise makes all certain knowledge of the Sun — knowledge that would be drawn from unobstructed viewing — [impossible] for a per-[son...]

[Margin: The Sun as an object of sight, and the difficulties arising from it.]

[Margin: The first difficulty comes from the excessive intensity of the Sun's light.]
it cuts off. And this is the first point.

Next, even if the whole Sun were to lie open to an unharmed eye — as ordinarily happens at twilight — what real understanding would the eye carry away from it? We know the Sun to be of enormous bulk; yet the incredible gap by which it stands away from us all but swallows it up entirely, so that astronomers can scarcely estimate the angle under which it appears, on account of its very smallness. They treat the rays that fall from the edge and from the center of the Sun as, in a manner, a single ray, measuring all the points of its surface — which converge, as it were, into a circle — by lines perpendicular to the plane of the Sun and parallel to one another, without appreciable error. And this is the second point.

[Margin: The second difficulty, arising from the smallness of the visual angle.]

Furthermore, grant that neither the light nor the apparent size of the Sun should keep our sight from being able to range over it with an unblinking gaze: still, its perpetual motion from rising to setting creates endless trouble for those who observe it without a better resource, and renders every method of observation exceedingly difficult and slippery.

[Margin: The third difficulty, arising from the perpetual motion of the Sun.]

These three heads of difficulty, found in the Sun itself, carry difficulties by no means ordinary over into the instruments, the times, and the places in which the Sun is observed — difficulties that likewise overflow everywhere into the observation itself and into the manner of observing. I say nothing here of the explanations themselves, nor of the fact that the positions and arrangements of the spots' place and path, both true and apparent, are by no means free of their

own difficulties. All of these, therefore, I have thought it worthwhile to touch on briefly and one by one.

Difficulties Arising from Instruments; and first, the natural power of the eye — [visus?] and the manner of seeing — is set aside in this inquiry

Chapter III

Every method of observing this phenomenon, then, as I have said, proceeds from and depends upon the eye. Now the eye is directed toward any given object — or rather, any object travels to the eye — either directly and immediately, or indirectly, by refraction or reflection.

[Margin: The manifold ways of seeing the Sun.]

In the first way, this phenomenon comes to the eye by free and natural vision, with the rays reaching the eye neither refracted nor reflected by any art. In the second, it comes either by rays artificially refracted — which is done with glasses suited to the purpose, skillfully prepared and arranged — or, finally, by reflected rays, where again a threefold method is found. For the eye either catches the Sun as it naturally falls through a bare aperture onto paper, reflected as it were from that paper; or it views the Sun drawn skillfully through a tube onto the same; or it beholds it thrown back from a mirror or in some other way. Everywhere there is toil, everywhere difficulty.

For to wish to look at the Sun with the naked eye, and by this means to investigate its appearance, would be a needless and harmful expenditure of effort. Since the Sun does not admit the eye upon itself unless it is hedged about by morning or evening vapors, or veiled by some evenly moist and translucent mist or cloud — and even then shows only the largest spots, but never the smaller spots, the penumbrae, or the faculae, which make up no small part of the phenomenon — in vain does anyone weary himself who goes after the thing in this way, unless he is willing to lose, along with his oil and labor, his very eyesight as well. This is just what I have now learned several times, from the not-improbable report of others, about the first inventor of the tube. He, having examined the Sun by frequent use of the tube, is said at length to have lost the inflamed eye, and then — the other being infected by contagion from it — to have lost that one too, together with his life.

Certainly, if this difficulty could be overcome, it would by no means have baffled the diligence and persistence of the ancients in observing the Sun — men who, though they fixed their gaze upon it from earliest morning to late evening, nevertheless noticed nothing at all of the things that are now seen so clearly every day, thanks to recently invented instruments. Grant at last — though I do not concede it — that at the said morning and evening hours everything on the Sun may be seen with perfect clarity: still, because the Sun then always appears in an egg-shaped or quasi-elliptical figure, continually variable, together with the spots attached to it — just as I have treated at length in my *Sol Ellipticus* and in the *Refractiones Caelestes* — from this you could conclude little or nothing solid for our purpose. But let us grant that all the aforementioned difficulties are either nonexistent or removed; let the Sun's radiance be pleasant to look upon; let the solar circle be spread out for the eye over many miles; let the variation of the daily motion introduce no annoyance; let a circular figure always present itself; let everything in it be seen clearly, distinctly, and without any disturbance. Grant, I say, all these things:

[Margin: Another difficulty, arising from the figure of the Sun.]

grant them all — nevertheless, from this bare inspection the astronomer is still not sufficiently equipped to draw sure conclusions from it. For unless he transfers those visual observations of his onto paper, enclosed within a circle, in the very same proportion and to a nicety, he will accomplish nothing solid. And this is done neither by mere looking nor by the free hand guided by imagination alone; therefore the aid of other instruments is needed. So we see it happen in the measuring of things placed at a distance: their sizes we do indeed grasp with the eye alone, but we do not on that account measure them. It remains, then, that this appearance and this experience cannot be sufficiently taken in, investigated, examined, and handled by the bare and unaided eye. We must therefore have recourse entirely to the fitting and indeed necessary aids of other instruments.

The Invention of the Helioscope, its Description, Use, and Difficulties

Chapter IV

So that the eye may achieve something immediate or direct upon the noblest object in the whole universe — and the most highly refractory, the Sun, I mean — it must be armed with an instrument of such a kind as both blunts the Sun's brilliance sufficiently and yet draws out its apparently tiny bulk into a broad vastness. For thus sight will freely survey it, and will reveal purely to the

imagination and the intellect whatever has hitherto lain hidden in it. This instrument, since it was once devised and worked out by me deliberately for the Sun alone, and is scarcely ever used for viewing other objects, I have chosen to call, par excellence, the *helioscope* [Helioscopium];

[Margin: Description of the helioscope.]

just as the instrument that is taken up indifferently for all objects, on account of the effective power it exercises upon them, is called the *telioscope* [Telioscopium]. By that name, moreover, I understand an optical tube fitted with colored glasses, elaborated with due skill for this purpose, so that, by the benefit of the colors inhering in them, the too-vehement solar ray, broken and dulled, may reach the sight more moderate and less harmful. And on account of this prerogative, an instrument of this kind rightly enjoys the name of *helioscope*. For any other tubes, furnished with transparent lenses, do not by themselves accomplish this.

[Margin: The lenses of the helioscope differ from the lenses of the telioscope only in their colors.]

The helioscope, then, consists of at least two colored glasses, one convex and one concave, of material well thickened, pure, and solid — not beset with bubbles, nor with sandy specks, and least of all with veins, streaks, or waves — worked into a perfectly spherical segment or piece. Of these, one is convex either on one side or on both; the other concave, either on both sides, or concavo-plane, as is customary in uncolored tubes. For the making of these colored lenses differs in nothing at all from the working of other clear ones, just as their placement in the tubes does not. But if the thickness of the two lenses does not suffice to blunt the Sun, let there be added a similarly colored glass, plane on both sides but clean and highly polished — or several, as the case requires.

[Margin: The arrangement of the lenses.]

And it makes no difference in what place you insert such a glass into the tube — whether you add it before, after, or, finally, between the lenses — provided that all these glasses are parallel both to one another and to the lenses, and set upright, each through its own center, to the axis of the solar cone. Let the color of them all, as far as possible, be of one kind — for instance blue, green, yellow, dusky, or whatever else. But if a single uniform color cannot be had, let such as are available be taken in a mixture. Such a tube I put together at the beginning, from blue fragments of glass plates; with it I observed the spots I published in my *Apelles*, and it also distinguished the faculae excellently. This tube, of truly no ordinary power, at length passed to the Most Serene Archduke Maximilian

[Maximilian III of Austria] — of pious memory, Lord of the Tyrol and Grand Master of the Teutonic Order — and often displayed to him the solar spots and faculae.

The more powerful a tube is in itself, the fitter it will be for this purpose. I measure the power of a tube by the large and distinct representation of the object — which, for the most part, and indeed, other things being equal, always, those tubes provide that are longer, or whose convex glasses are segments of larger spheres. But this matter will be dealt with deliberately in later pages. This, however, I would have you note here in passing: the more a tube magnifies the seen part of an object and the more accurately it distinguishes it, the smaller a portion of the object it always represents to the eye at a single glance, other things being equal — so that, in practice of this sort, one must survey the whole Sun part by part and gradually, a thing that gives rise to inconveniences neither small nor few. But why this happens, you will learn elsewhere in the course of this book.

The procuring, then, of such a helioscope demands great diligence, labor, and patience, skill, and no very slight expense — difficulties that keep many from inspecting this phenomenon, because they do not provide themselves with such an instrument.

[Margin: Making a helioscope out of a telioscope.]

Yet this trouble is somewhat remedied if you procure for yourself a common tube — a telioscope of good power, such as is sold everywhere at a tolerable price — and, by inserting flat glasses tinted with color, temper the potency of the transparent lenses as the situation requires; for thus you too will gain a view of the Sun. But since by this means the solar cone is carried through many media, which by their position and by so manifold a refraction can easily taint the radiant cone of the Sun with some flaw, it would be better that the lenses themselves be thick and steeped in a sufficiently dense color. These the craftsmen could surely shape, polish, and finish with the same labor by which they make the others. But — such is the corruption of our characters — we are unwilling to oblige others, even when we can do so without any loss; and we are not accustomed to benefit others except with profit to ourselves. Those merchants reckon their own gains; they value only the buyer's willingness, and — once the use of the item to be bought has been discovered through the buyer's own effort — they raise the price beyond all measure. Now the uses and benefits that one may derive from the helioscope are the following.

[Margin: The uses of the helioscope.]

First: the spots and faculae can be discerned directly, better and more distinctly than by any other method or instrument by which the eye is directed at the Sun, because the color of the material wards off the Sun's glare, while the shape of the lenses enlarges the bulk of the solar body in a remarkable way. And it is truly most delightful to look, through such a tube, at the faculae on the Sun, which — compared with the surrounding surfaces — meet the eye no differently than if someone, looking down from a very high place upon a terrestrial plain, were to gaze upon many and varied lakes, ponds, and marshes scattered here and there; or, in the morning or evening, under an otherwise clear sky, upon thin little clouds scattered here and there which, against the rest of the sky, gleam bright and whitish from the sunlight they have drunk in; or, just as on clear nights the Milky Way [via lactea] diversifies the regions of the serene sky with a kind of glittering crystal, so from the other fields of Phoebus's disk these little sparks of flame blaze forth like carbuncles. Of these it may suffice to have hinted this much here, since they will be discussed more fully as we proceed.

Second: the magnitude, the density and rarity, the sharpness of outline, the unevenness, the light and darkness of both the spots and the faculae are noted very precisely with the helioscope — provided it is a sound and excellent one.

Third: their positions and intervals — both among themselves and with respect to the Sun's center and edge — as well as their number, are perfectly discerned.

Fourth: the state and daily change of their figure, magnitude, place, and situation can be ascertained, as well as their rising and setting, treated both mathematically and physically, as they are born and perish on the Sun itself.

Fifth: their motion, and the paths of that motion — continuous and orderly, from the eastern region of the Sun to the western — are beautifully observed.

Sixth: the time also and the duration of the motion of each individual spot can be recognized by easy observation; and indeed many things are seen by this means that would otherwise escape all perception. I always except the transmission of the Sun through the telioscope, which seems altogether to be preferred, as experience testifies.

Seventh: their duration, from entry all the way to exit, is grasped by this inspection very exactly and singularly — the thing on which the investigation of the periodic course chiefly depends, and from which it derives very great help. The daily delays and intervals, too, as well as comparisons among them, can to

some extent be had by observation, from which you may somehow gather whether they all traverse the Sun in an equal span of time, or not.

Eighth: one is granted to hunt out most excellently the slenderness and thinning of the spots, likewise their apparent and true increase and decrease, and at the same time their apparent conjunction and union, and conversely their separation and parting.

Ninth: the nuclei of the spots and the halos of the faculae, their lights and shadows, and finally the whole state, variety, and changing affections of the Sun are recognized exceedingly well.

Tenth and last: if you use a helioscope of the greatest power, you will see these most recent things, hitherto known to no one and divulged by no one. First, the whole surface of the apparent solar hemisphere, heterogeneous, compounded of shadows and little bright patches. Second, you will behold the same Sun like a sea rough with waves and rippling with heaving billows — and that not in the same way at different times, but today otherwise than yesterday, and tomorrow otherwise than today; and so you will never look upon that golden star, most marvelous of all, in the same figure or the same cast of countenance. But this most genuine novelty and most novel truth I here only sample through a lattice, meaning later, toward the end, to treat it expressly and at length.

And thus far, indeed, the helioscope affords these opportunities and conveniences to one who observes the Sun with the greatest reliability. Yet the things that are infallibly seen by it in the Sun by the eye are not, correspondingly, transferred onto paper by the hand with the same necessary dexterity — such that from it, as from a stable, fixed, secure, and authentic model, you might extract the motion, both apparent and true, and, from the motion of the spots, their distance from one another and from the Sun, or conversely, and so infer irrefutably countless other things that depend on these.

[Margin: The use of the helioscope is safe for seeing the solar phenomenon, but not for transferring it onto paper.]

For to draw the spots on paper from inspection of the Sun through the helioscope alone, with a free hand steadied by imagination only, is a task of enormous, long, and uncertain labor. For granted — though it happens rather by chance, and that very rarely — that all the magnitudes and positions of the spots and faculae, relative to one another and to the Sun, have been most excellently transcribed in a wholly true proportion: yet this you will never know for certain, and will never affirm. Nor even so will you inscribe the section of the vertical plane in your

observational diagrams in such a way that you can be free of all suspicion of error, or make another so.

[Margin: A sure determination of the vertical line is not obtained by the helioscope alone.]

Therefore, even though this instrument either removes altogether or greatly eases very many difficulties in observing this phenomenon, it nevertheless leaves the chief one — the one that stands in the way of discovering and establishing the motion of the spots with certainty. To remove it, the other method of leading the Sun onto paper must be called in for help, and we must see what ease and what difficulty it holds for our present purpose. You will be able to view a picture of this tube in the perspective drawing of the Telioscopic Machine, in chapter 8, at the top, marked with the letters a, b, m, n.

The Natural Method of Projecting the Sun onto Paper, and its Difficulties

Chapter V

There is a twofold method of admitting the Sun. One is very simple, natural, and with almost no apparatus; the other is artificial, requiring greater ingenuity, care, and expense. Of the first I shall now speak; a little later, of the second.

[Margin: The natural admission of the Sun through an aperture.]

The first method, then, is that by which the Sun — let in through a small round aperture into a dark place, and received, at the proper distance from the aperture, by its radiant cone upon paper set at right angles opposite it — displays its whole face so clearly and distinctly, together with the spots and faculae contained in it, that you can at your pleasure both examine and record whatever in it is more noteworthy, the intervals of the spots among themselves and from the Sun's edge being preserved. And this method, just as it has its not-few advantages, so also has many disadvantages.

The advantages are these.

First: to put this into practice, nothing else is needed than, in some chamber of a house or under a roof, having darkened it, to bore through a shutter so that the Sun can enter through the hole made; and to fasten a clean sheet of paper, with wax or some other glue, to a flat little board that has been cleanly planed. Holding this at right angles to the axis of the solar cone, you catch the Sun's ray,

bounded by the base of the said cone, in a bright circle of arbitrary size — large or small according as you stand far from or near the aperture. The farther you withdraw, the larger the Sun's disk, and the more plainly you will discern the secrets hidden in the Sun. But so that, during observation, you may be sure you are catching the base at right angles to the solar cone, erect from the center of the observing circle a uniform stylus at right angles, of any height you like: if this casts no shadow onto the underlying plane of the circle, but reabsorbs the shadow into itself, the position of the paper-bearing board will be the best.

Second: once the observation is completed — the practice of which will have its own place for discussion — you will note...

[Margin: Inducing the vertical line.]

and with the spots and faculae marked at their centers, you will easily and without error draw into the observation-circle — its position and place unchanged — the section of the vertical plane, drawn at that time from the center of the Sun through the center of the base of the solar cone, suitably projected onto the observation-circle, and passing through the center of the earth as well as the point of the vertex called the Zenith. This is done provided that you mark on the periphery of that same circle the shadow of some plumb-line hanging from a bristle or a fine thread — the shadow cast by a ray of the Sun passing through the center of the solar figure — whether above, below, or on both sides. For by this means you will easily find, together with the ecliptic, the position afterward held by any spot or facula recorded on the solar disc at that time; and by this method, through continued observations, you will detect the apparent motion and the things connected with it — just as I did in the table of my *Apelles*.

Thirdly, you will clearly notice the daily advance of the spots, and their distances from one another — whether increased in their ascent or diminished in their descent. And what you cannot firmly attain by direct gaze using the helioscope alone, this — aided by this natural and manual working — you will attain without difficulty and without fear of any illusion, with joy and wonder.

Fourthly, the chief and singular praise and glory of this practice is that you will obtain the apparent courses, stations, and observed positions of at least the more notable spots, without any intervention of refraction — which otherwise interposes itself and causes a great deal of trouble. Hence you will also assign the true courses and positions of the spots, without any suspicion of error or of any deception. This, being proper to this contrivance, is therefore of the greatest importance; for by this method, if by any, a stubborn adversary is constrained,

willing or not, in assigning the true position of the spots — as will be discussed more fully in its own place. Yet with these advantages, as I said, their own drawbacks nonetheless come in. For—

[Margin: First difficulty: the great distance from the aperture.]

First: although the aperture is easy to make, nevertheless — until the admitted ray of the Sun so unfolds itself as to present the spots to the gaze in some larger and sufficiently perceptible size, and in the form necessary for this purpose — a very great distance is required from it, up to 10, 15, 20, or more paces. But a place so large, open on all sides to the Sun's rays,

is nearly indispensable for the purpose, since at every hour of the day one must stand ready and, when Phoebus smiles and the sky is favorable, throw open the doorway — and such a place is not commonly found so easily. And even if one is had, it will not readily be darkened, nor, on whatever side it faces the Sun, will it have windows or shutters suitable for making the aperture; and if the Sun has climbed higher above the horizon, the aperture will have to be opened from a high point — but where are there dwellings so high? And if you climb up under the roof, generally a greater difficulty of the observing-place will arise.

[Margin: Second difficulty: the velocity of the motion.]

Secondly, the Sun by its continuous motion gradually departs from a direct entry into the aperture; and the greater the distance, the swifter the motion will be. And so, unless the aperture itself can always be turned straight toward the Sun, its usefulness will not be long-lasting, or at any rate will be oblique and therefore deceptive; for it will produce a solar disc that is not circular but elliptical, and always varying, unfit for observation. But to make a movable aperture requires no ordinary skill, labor, and expense: one would need a pole as long as it is rigid, and so on.

Thirdly. Furthermore, the paper-bearing tablet itself must always necessarily stand at right angles to the axis of the radiant cone, so that the axis always falls perpendicular onto the corresponding plane of the paper, and so that this tablet always runs parallel to the apparent circle of the Sun. For this, an upright stylus [gnomon] affords a remedy.

Fourthly. But also the observation-circle, once adopted on the paper, must be kept at the same size for a single observation, upon which the base of the solar cone — that is, the bright disc of the Sun — must then shine equal in size. Yet to achieve this is quite difficult, and yet so necessary that if you neglect it you will produce a

false observation; for the distances of the spots from one another are immediately enlarged as soon as a larger figure of the Sun is admitted. Therefore, while you make a single observation — from which you hunt out the positions and distances of the spots relative to the Sun and to one another — you will take care that the observation-circle is kept at the same distance from the aperture of admission, so that it cuts the solar cone squarely and makes a section equal to the observation-circle. If any of these is neglected, the observation will be faulty. But to keep these inviolate in observing

is, in practice, a most difficult thing. Moreover, for one observation only one observation-circle is necessarily required, in whatever manner of observing — whether you observe only one spot, or all, or many, or few.

Fifthly. Moreover, even when all these are avoided, the Sun's image itself falls onto the paper with a circle not so cleanly cut off at the margins; nor does it present the spots or faculae most exactly bounded and distinct at their edges, but with a certain confused and hazy border. This happens because, at each of the assignable points of the aperture that has been made, intersections of the radiant solar cones occur, which afterward — each advancing straight forward from the aperture — gradually spread out; and the rays, carrying the image of the Sun, of the spots, and of the faculae, mingle by their mutual meetings and intersections, and produce the said impurity and confusion.

[Margin: The helioscope and the natural aperture assist each other.]

Yet this unavoidable fault of nature is corrected by the use of the helioscope — just as, in turn, the helioscope's own weakness and uncertainty in aptly placing the spots is assisted, and the proneness to err is avoided, by this natural skill of depicting the Sun on paper and by the plumb-line introduced through the aforesaid art. And thus each is aided by the help of the other. For from this accurately arranged picture is acquired the proper position of the spots and faculae on the Sun, their distance from the ecliptic, their magnitude and shape, and their daily path — all to be drawn out by the benefit of the plumb-line introduced. But the clean precision of the figures, and the account of their densities and rarities, are drawn out by inspection of the Sun through the helioscope, and then by delineation with the pen. This I did most diligently throughout my whole *Apelles*, always using both devices together in observing; a matter I treated more fully in the first book. Seek out and examine the figure of this admission in Chapter [blank in original], at number 7, G. 1, where I compare the nature of the eye with the art, and call this method artificial, by reason of the aperture that is made.

THE ARTIFICIAL ADMISSION OF THE SUN, through a single Convex Lens, and its difficulties.

[Immissio Solis artificiosa, per unam Lentem convexam, & eius difficultates.]

CAP. VI.

This method differs in nothing from the previous one, except in this: that whereas before the Sun was admitted through a bare aperture,

here in the aperture itself a convex lens is employed, which somewhat bends the solar rays (which would otherwise, once received, go straight forward) and by refraction spreads them out, carrying the whole image of the Sun — clean, precise, and larger than natural — onto the common base [screen].

The advantages of this artificial admission are these.

First. A most clean and most precise image falls onto the paper, with a most vivid rendering of the spots, so that you could scarcely imagine anything more elegant of this kind.

Secondly. The image of the Sun is made larger, and therefore the distance of the paper from the aperture can be kept a little smaller.

Thirdly. The light too shines much more vivid and brilliant onto the common base than it would from a bare aperture.

Fourthly. In this manner of admitting the light and receiving the solar image, refraction causes little or no trouble to the correct tracing of the spots' course. For in the use of the tube [telescope], as will be seen in its own place, many refractions intervene — namely of the convex lens, then of the concave one, which, being usually concave on both sides, increases the divergence of the rays. Here the concave lens is always absent; and if a plano-convex lens — a portion of a great sphere — is employed, the refraction will be made very uniform, because of the somewhat similar incidence of the rays, so that the refractive power of the outer rays is not felt to differ from that of the middle ones. This can certainly bring great importance to the matter we are treating.

But this device for receiving the Sun has its own drawbacks.

First. The solar base does not unfold into a sufficiently ample circle except with a lens of a great sphere [long focal length].

Secondly. And a great distance from the aperture nonetheless comes in, very troublesome for observing.

Thirdly. The axis of the solar cone must always be perpendicular to both surfaces of the lens; therefore, since the Sun always changes its axis, the lens in the aperture must always be movable. But this cannot be done without a pole extending from the aperture all the way to the paper-bearing tablet. And this is the chief hinge of the difficulty: whoever overcomes it achieves no ordinary thing.

This same lens affords a far more universal use

than the one to which I have here restricted it, for the Sun; for it brings the images of all things placed outside onto paper set opposite in a dark place, in an arrangement and picture far the most beautiful — one that a painter might try to imitate, but would attempt in vain to match. That these images are seen, and are an object of sight, the thing itself declares; and no one doubts it except one who has not seen them. But if someone positioned inside places his eye between the paper and the lens, he will see external things much larger, in an upright position, and somewhat confused; if he brings his eye to the place of the image, or of the paper, he will behold a chaos; and if he places it beyond the place of the paper and the picture, he will see everything larger and more distinct, but in an inverted position. Hence the emptiness is evident of that reasoning by which some person or other congratulates himself on the invention of the optical tube [telescope] — since the same effect of magnifying visible things can also be splendidly obtained with a single convex lens, large and of a great sphere. But of these matters more fully elsewhere: seek the explanation of figures 1 and 3, A 1 and C 1, in the Comparison of the Eye and Lenses.

THE ARTIFICIAL ADMISSION OF THE SUN, or the Telioscopic admission — which is also called Transmission — and its uses.

[Immissio Solis artificiosa, seu Telioscopica, quæ & Transmissio dicitur, & eiusdem utilitates.]

CAP. VII.

The artificial admission of the Sun is the genuine representation of the Sun — by means of its cone, that is, its visible images — upon a plane duly set opposite. It is made with a telioscope, or common tube, constructed of skillfully worked and

aptly arranged lenses. When these are placed at the proper distance from one another and applied to receiving the Sun, the bright solar cone is carried at right angles [orthogonally] onto the paper set opposite (or any white plane), and displays its riches upon it, for anyone to behold. This device seems to have been discovered at nearly the same time in different countries, by several who were devoted to and skilled in the matter. For I used it long before Galileo [Galileo Galilei] communicated it to Welser [Marcus Welser], having come upon it after assiduous and diligent investigation of my own.

[Margin: The use of the telioscope is to be preferred to the others.]

This device brings very many advantages, and removes most of the difficulties that arise in hunting out [observing] the Sun. For it alone provides — with great labor — what the helioscope

and the simple or natural admission provide together. It carries so faithful a figure of the Sun onto the paper, and the spots so precisely, that direct gazing at the Sun is plainly not missed. For although such gazing be done through the thickest glasses, it nevertheless usually brings some trouble to the eyes, and now and then some harm; and to a man otherwise occupied it always brings much labor and takes away a great deal of time. But this method — from the fact that one looks not at the Sun directly, but at its image on the paper — creates absolutely no strain to healthy sight; though it might perhaps strain a weak or ailing one, because of the excellence of the light brought onto the paper.

[Margin: It removes most of the difficulties.]

Therefore, by the benefit of this device, the first source of difficulty — gushing from the excessive brilliance of the Sun — is entirely drained away; because the Sun, drawn onto the paper through the convex and concave glass of the telioscope, so tempers its rays (refracted at the surfaces of the glasses) that they become plainly proportioned to the sight. Next, because the same glasses, aptly arranged within the tube, present a figure of the Sun not only large, as desired, but also precise, the second wellspring of difficulty is removed — that by which the Sun, on account of its excessive distance, reaches the senses under too slender an angle. To this is added that all things fiery, shining, and luminous — and hence white and glittering — when seen from afar, produce in the eye, on account of the seemingly uniform vigor of those visible radiations, a confusion, as may be seen in the Moon, in Venus, in the other stars, in torches, in lit candles, and in fires viewed from a distance. But this excellent method of bringing the Sun down cuts away at the root that protruding and disordered exuberance of rays overflowing

in the sight — a method that enlarges the Sun's image at anyone's pleasure, in various ways, as will be said later, and brings all the spots and faculae into view at a single glance, clearly, distinctly, and cleanly. And so this method:

[Margin: The advantages of the telioscope.]

First. It effectively cures all the drawbacks that arise from the excess of light in the solar regions.

Secondly. It removes all the impediments flowing from the apparent smallness of the Sun.

Thirdly. It sets under a single view — lucidly, distinctly, and well-defined — whatever lies hidden in the Sun.

Fourthly. It greatly lessens the labor to be expended in observing.

Fifthly. In the time required for marking down the spots during observation, it is contained within a shorter span.

Sixthly. It can be usefully employed in any place, at any time, when the Sun is shining.

Seventhly. It is more convenient than the earlier methods for drawing in the vertical line, and, by its help, for investigating the motions of the spots.

Eighthly. It renders the observer so secure and so certain concerning the method of observing, the observations made, and the position of the spots, that it cuts away every handle for error and removes every scruple of doubt — provided that, as will be explained in what follows, the necessary diligence is applied.

IX. It greatly relieves the difficulties caused by the Sun's motion. For the optical tube, aptly set upon the instrument or observing-stand, easily follows the Sun's motion when directed with care by a somewhat practiced operator.

X. For keeping the same observation-circle, no trouble at all occurs.

THE MACHINE OF THE TELIOSCOPIC ADMISSION, and its parts, and a stereographic delineation, and its impediments in use.

[Immissionis Telioscopicæ Machina, & eiusdem partes, atque stereographica delineatio, & in usu impedimentis.]

CAP. VIII.

The observing machine, or telioscopic machine, consists of these parts. A beam or back — a parallelepiped G, H, whose bases at either end are either square or rectangular (longer on one side) — upon which, in their places, stand two or more clamps, I, K, fitted for supporting the tube. Further, a small tablet, or paper-bearing board, B. Besides these, an upright post D, which carries the paper-bearing tablet E, and which supports the back set into it, serving as the foot and base of the whole machine. To these is added a shade [screen] R, made either of thicker paper or of a thinner board. Finally, a forked support O, upon which the whole instrument rests, so that it may easily be moved in every direction, to any variation of position, over the horizontal plane or pavement, or over a well-planed board equidistant from the horizon. This, however, is not so necessary that without it one could not observe correctly;

for that equilibrium can be compensated by the rotation of the paper-bearing board about its own pin, as will be said in its place. Indeed no equilibrium is necessary, since the shadow of the plumb-line drawn into the observation-circle compensates for all equilibrium. But from the fact that this machine draws the origin of its whole orientation from the line of the vertical plane, projected from the plumb-line onto the paper, and regards that line as, so to speak, the rudder of the whole navigation — not without reason, I think, will this very instrument be called the *vertical telioscope*, to distinguish it from the one which, at the end of the third book, we shall bring forward and call the *equatorial heliotrope*. You see the whole instrument in the appended diagram, Number 1: described part by part individually, then assembled and projected in perspective [scenographically], together with the hour-quadrant q, r, s, hanging from the side of the base, which indicates the hour and the Sun's altitude above the horizon at the time of observation. The rest will be set out in more detail in their places below.

[Margin: Impediments and delays in observing.]

Equipped, therefore, with this machine, and having boldly assailed the heavens and even the very royal seat of the Sun, you will doubtless storm it — but not without sweat, and with frequent assaults. For the Sun will fight against you, not only with its lightning-like darts, but will rouse up tempests in arms against you, will set clouds and mists in your way, and will wrap itself in vapors; and if at last it comes out into open battle-line, yet by its continual flight it will so weary you that, unless you pursue it most persistently with long-suffering patience and unremitting labor, it will not concede the palm to the victor. The errors, then, the

windings, and the snares by which it can entangle the unwary, I shall now uncover, so that, these pitfalls and deceptions being avoided, the plainest truth may lie open before all.

[Margin: The difficulty arising from the refraction of the lenses.]

One difficulty, however — and indeed a peculiar one, born from this very ingenious method of observing — I ought not to conceal: the one produced by the refraction introduced by the lenses of the telioscope into the figure of the Sun. Although it introduces no very perceptible difference, it nonetheless must not be ignored or neglected by the exact observer. But of these matters in their proper places, according to my plan.

Diagram. A full-page engraved plate, numbered N. 6 at the upper right, titled **Machina Helioscopica cum suis partibus** ("The Helioscopic Machine with its parts"). The plate has two zones: an upper array of the machine's separate components, each labeled and named, and a lower pictorial view of the whole instrument fully assembled and standing on a tiled floor.

Across the very top of the plate runs a schematic longitudinal section of the optical tube (the telescope/helioscope). At the left end is a biconvex objective lens, its rays entering from the left; the small letters clustered at this lens read **a** (upper) and **c** (upper), **g** and **i** (middle, **g** at the outer edge and **i** at the lens), and **b** and **d** (lower). Along the tube toward the right run the letters **e** (upper, just past the lens), **h** (middle), and **f** (lower). At the far right end is a concave (eye-end) lens element labeled **k** and **m** (upper), **o** (middle), and **n** (lower).

The upper array of separate parts (each a boxed component with its Latin name engraved beneath or beside it):

- **E** — a framed square board.
- **Caput** ("Head") — marked with a small concentric-circle (target) symbol; below it **D**, a small bar.
- **Pes** ("Foot") — a tall framed board.
- A circular aperture-disc: center lettered **C**, with peripheral points **a** (top), **d** (left), **e** (right), **b** (bottom).
- **B / Tabella chartifera** ("the paper-bearing tablet") — a framed board marked with a concentric-circle symbol.
- **A / Charta** ("the paper/sheet") — a plain framed square.
- **F** — screws (a long screw and paired collar/nut forms).
- **Cunei** ("Wedges") — with a wedge lettered **L**.

- **H** — a small block/piece.
- **Retinacula** ("Retainers/clamps") — U- and bracket-shaped pieces lettered **K** and **I**.
- **Dorsum seu Rostrum** ("the Back, or Beak/rail") — a long horizontal beam, with **G** at its left end and **M** near the left.
- **N / Suppedaneum** ("the Footstool/base pad") — a rectangular padded slab (rendered with a mottled/quilted surface).
- **O / Fulcrum** ("the Prop/support") — a triangular trestle.

The lower assembled view shows the instrument mounted and tilted on a triangular base standing on a checkered pavement. Legible letters on the assembly: **P** (a graduated arc/quadrant near the mounting head; the arc bears an engraved date reading approximately M.DC.XX[?] [1620s — final digits not resolvable]), **R** (appearing on both the swinging arm and the base block), **S** (a diagonal leg/strut), **T** (a collar/clamp on the tube-carrying beam), and **V** with the rays **s** issuing from the tube's eye-end toward **h** and **V**.

[The remainder of this leaf carries only faint mirror-reversed show-through from the verso; no text is set on this side.]

I.

The Sun's threefold motion, from which arise the difficulties in observing, is here set forth.

CAP. IX.

If the Sun stood still, its face could be depicted on the paper point by point without any difficulty — just as a house or a landscape admitted through a convex lens into a camera obscura ordinarily is. But because the Sun is in continuous motion, it at once carries its own image away from the place assigned to it and occupied on the paper. The instrument must therefore be moved in the same proportion as the Sun advances in the sky; otherwise you will not keep the Sun's circle in one and the same place, and you will not be able to mark the spots.

Now I find three motions that give this task its trouble. [Margin: The threefold motion of the Sun.] The first is the Sun's daily motion from rising to setting. The second is that of the ecliptic, along which the center of the Sun always travels — and the Sun's place on the ecliptic (that is, the zodiac) makes a continually changing angle of inclination with the vertical plane. The third, finally, is the

proper motion of the spots themselves, or rather of the Sun itself. Each must be dealt with in turn.

From the Sun's daily motion: the difficulties, and precaution against them.

CAP. X.

When the Sun rests upon the horizon or is near it, whether at rising or at setting, it always appears roughly elliptical, as I showed sufficiently in my *Sol Ellipticus*. For that reason it is wholly unsuited to this observation, that is, to investigating the place and motion of the spots. For just as the Sun's disk, so too the mutual arrangement of the spots is drawn together by the refraction of the vapors settling in the atmosphere; the spots are therefore always displaced from their proper place and appear in a false one, and consequently neither their apparent nor their true course can be gathered. Likewise the Sun stands higher above the horizon than it truly should, from which a false angle between the vertical and the ecliptic at the Sun's place would be found, and hence a mistaken track of the spots. I have treated this matter at more length in my *Refractioes Caelestes* [Scheiner, 1617], which you may consult if you wish. The only thing this near-horizon state serves for is that the spots can be discerned just as readily as the Sun's ellipse, and, if the spots are large, they may even be noticed with the unaided gaze.

II.

But how great an interval of the Sun above the horizon is required — you will ask — so that one may safely project it onto the paper? No precise figure can be given, because of the constantly varying temper of the sky and atmosphere. Here at Rome I have caught the spots on the paper in a full circle with the Sun raised only six — indeed once only four — degrees of altitude above the horizon; and at other times I found it contracted even when it held ten, twelve, and fifteen degrees of altitude and more. At Ingolstadt I often could not obtain a perfectly spherical figure below an elevation of thirty degrees. So no fixed rule can be prescribed in this case; [Margin: Whether the Sun is elliptical, and how it may be detected.] but the general one is this. Whoever wishes to mark the spots carefully and safely, each in its place within the solar circle, must first of all have drawn on the paper a circle of the same size he wishes the solar circle under observation to be; and he must mark it on its perimeter with more than three points. This done, let him admit the Sun and observe whether the solar circle matches that circle, and it the

solar one, in every respect, and whether it precisely touches at once the four cardinal points impressed for this purpose. By "the four cardinal points" I mean, for example (for others too may be assumed), the zenith, the nadir, the right, and the left — the points that divide the circle's circumference into four quadrants. If, then, the Sun transmitted through the tube onto the paper, and fitted to the capacity of the circle drawn there, does not reach all the points but falls short of one of them, it is certain that refraction is at work — provided, however, that the lenses are in their parallel and proper arrangement. If it reaches all of them and nowhere exceeds, observe with confidence. So much for the Sun's nearness to the horizon; now let us pass on to more remote positions.

If we consider the Sun's daily motion precisely, we shall nowhere more easily follow its course with the observing instrument, nor more stably confine it within the limits prescribed on the paper, than at the time when it makes the smallest advances of altitude in the vertical circle, or when it moves very obliquely. This time is always noon; for although the Sun there advances much in longitude, it nevertheless seems to stand still as regards altitude, and hence latitude, and so will easily be kept within the marked observatory circle by a careful observer.

It helps, too, that around this time the Sun's face ordinarily smiles more serenely and lies beyond all bounds of perceptible refraction, since the passage of the vapors then takes place along much shorter lines, and lines less inclined than near the horizon. But the following things stand in the way of this observing time.

First. [Margin: Drawbacks of the noon hour.] The Sun's meridian altitude usually raises the Sun so high that in a dwelling — especially in summer, unless it is furnished with very lofty windows — it does not admit its ray nearly perpendicular. But to observe in the open, in a bright and not somewhat darkened place, greatly hinders the solar image caught on the paper, for it is so dimmed by the intense surrounding light that the eye cannot well distinguish the Sun's family [i.e. the spots]. This happens because the greater sensible object blots out the lesser. I say nothing now of the mad violence of the midday Sun, commonly held everywhere among all nations to be harmful to health and most carefully avoided.

Second. So great an erection of the telescope, together with the observing instrument, in order to catch the Sun's ray, is in itself very difficult and quite awkward for observation. For either you keep the ordinary forked prop for supporting the machine's back [dorsum], and because it nearly coincides with the back — meeting it in a narrow angle — it supports the back only precariously; or you set it higher, and then either the back will not be long enough to rest upon it,

or the place in which the Sun is to be caught will not be ample enough for the whole machine. The foot [pes], too, which carries the back and everything else and directs and moves the whole instrument on the pavement toward the Sun's circle, will be driven with a wobbling motion because of its excessive tilt toward it; and because of the excessive distance of the paper-board [asser chartiferus] from the perpendicular, it will very easily cause a faulty inscription of the vertical, and so will spoil the whole observation — which is the crucial point. For not only are the labors of this session lost, but other good observations too — taken among the good ones through such faulty ones and yet counted as good — are gravely endangered, especially among those still unskilled and untrained in this matter.

Third. The Sun's elevation above the horizon, which must always be taken accurately, is at this time most difficult to obtain justly in minutes; and very easily one strays from the truth by 5, 10, 15, or even 20 first minutes, since the plumb-line seems to stand for a long while in the same perceptible place. This causes the greatest variation in determining the hours, and greatly disturbs the inclination of the ecliptic to the vertical, and — what follows from this — introduces false tracks of the spots.

Fourth. The ecliptic, throughout the whole year around noon, from the 10th hour before noon to the 2nd hour after noon, always undergoes the greatest variation; it makes swift motions, and the smallest obliquities to the vertical circle but the greatest angles, and produces steep degrees in a brief while; and at the Sun's slight elevations, in the very shortest time, it takes on the greatest increases and decreases of the angles. From this it comes about that the spots and faculae, even when marked in the Sun most diligently, are nevertheless at once carried out of their places — which gives the master of this art infinite labor and weariness, and offers the art itself very many occasions for error. Therefore he must play Argus [the hundred-eyed watchman] who makes faultless observations of the Sun at this noon time. If I wished, I could make this plain by very many examples.

[Margin: Noon time is unsuitable for carrying out observations; an intermediate time is more fitting.] It seems better, then, all things considered, to devote oneself to this study at a time intermediate between the morning and the evening refraction and noon. For thus the Sun will offer a more uniform and more manageable motion in right and oblique ascension; and the observing machine, having obtained a moderate elevation of the Sun, will show itself more compliant with the Sun's course; and the Sun's altitude, and the clock-time to be taken by aid of the quadrant, will be noted more securely in its minutes.

Yet because it sometimes happens that an observation must of necessity be undertaken around noon — whether because other occupations, or the inclemency of the sky, have prevented it, or because a particular spot rises or sets at this time, or some other reason presses — one must therefore counter the aforesaid drawbacks so far as possible. [Margin: What must be done if one must of necessity observe at noon.] So then, the spots marked with faint lines on the disk of the Sun drawn upon the paper, and displaced from their place by the inclination of the ecliptic, you will restore

by a mere turning of the little paper-board about its own center — **B** or **C** or **E**, whichever will match the center of the solar circle — until the spots agree exactly with the places marked for them on the paper, and the Sun's circle agrees at once with its cardinal points. Then the vertical line **a**, **b**, together with the hour and the Sun's altitude above the horizon, must at once be recorded through the shadow **i o** of the plumb-line, **i p**. And I have learned, by frequent and long-continued experience over many years, that this remedy is safe, sure, and easy.

[Margin: Another remedy.] It is useful, moreover, to mark a single spot at a single observation, for then no perceptible delay of time will intervene while you note the Sun's elevation, the plumb-line, and the hour.

Further, since many sundials around noon intercept the hours by very large spaces, these can easily be subdivided into scruples and minutes; and so what is slippery and dangerous in taking the Sun's elevation above the horizon will become easy and ready from a temporary observation. But of these matters more fully in their proper places.

On the motions of the Sun and of the spots, which are marked in the observatory circle, and their difficulties and remedies.

CAP. XI.

I have said certain things in general about the Sun's apparent motion in the observatory circle, which is noticed chiefly through the progression of the spots. So then, in the solar disk projected onto the paper I find a threefold motion overall, just as of the Sun in the sky. Of these the first, the daily one, is that by which the Sun is carried over the axis and the poles of the world — in whichever hemisphere lies open — from the eastern horizon, through the south, to the west; and because the Sun always ascends from its rising to the south, and from this

point always descends to its setting, this motion, as expressed on the paper, may be called the daily ascent and descent.

A second motion of the spots is detected, also daily, about the center of the observatory circle;

[column II] that is, if you keep the observing instrument, the observatory tablet, and the paper unchanged and turned toward the Sun the whole day, and mark the stations of the spots in the observatory circle at each single hour, in the evening you will find them all in places far different from those in the morning; and if you connect each spot's marked hourly stations with lines, you will find each and every one of them turning daily about the center of the observatory circle.

The third motion, finally, is that of the individual spots toward the center of the observatory circle and away from it, from the eastern quarter of the Sun to the west — which is most properly the motion of the spots, or rather of the Sun. Of each of these something must now be said in order.

Concerning the Sun's and the spots' first, daily motion of ascent and descent I said much in the preceding chapter; but here some more particular points must be added. This motion, then, is of all the first and most notable on the paper, because it draws with it the whole bright base of the solar disk, in the way the Sun holds it before noon while ascending above the horizon — directly or obliquely, according as the latitude of the place in which you observe is direct or oblique — and after noon while descending toward that same horizon. So then, just as the Sun in the sky, so will the bright base of the solar cone received on the paper move — and that indeed with a proportionate motion, but in contrary positions, on account of the reversal of the pencil of the solar cone by the aperture of the tube and the convex lens of the telescope. And so, while the Sun ascends in the sky, the image of the Sun descends on the paper; while the former descends, the latter ascends, and it always tends in the contrary direction — a refractory daughter to her own parent — nor is there any remedy for this through these lenses. The one thing to be sought is that the Sun's circle be constantly held by the observer within its paper circle, continuously and with a motion that follows the Sun. For this is especially necessary for marking the spots; and we shall achieve it when we have made such a telescopic machine as can be turned in every direction without difficulty, so that the axis of the solar cone may always have a point corresponding to the center of the proposed observatory circle. And all this is had with easy effort by means of the observatory machine set before your eyes a little earlier. For

[The two columns per page carry centered column-numerals "I." (left) and "II." (right) and 5-line marginal reference numbers; these are cross-reference apparatus, not section divisions, and are not reproduced as structure. The text runs left column, then right column, on each page, the right column continuing onto the next page's left column.]

For the foot resting on a flat pavement, or on a planed footboard, marked Q, and the back QS — movable as it leans on the apex of the support, S — so facilitate the matter that, in my judgment, one could scarcely wish for anything further, or devise anything more apt, at least for this manner of observing. For by this means you have the readiest way of following the Sun's motion. You will see a similar instrument in my *Refractiones Caelestes* [Scheiner, 1617], published at Ingolstadt in 1617, chapters 38, 39, 40, and 41, from page 91 to 94. But I shall also treat of this very point more fully below, in the practice of observing. I said "for this manner of observing," because the heliotrope [Heliotropium] — which I shall treat at length at the end of Book III — labors less under this difficulty of following the Sun, since, thanks to the zodiac, the tube is aimed along the ray and parallel of the Sun.

This motion of the solar base has yet another use as well: to investigate the apparent magnitude of the Sun's disk. For since some portion of the diurnal parallel always passes, together with the Sun, through the tube onto the paper, proceed as follows. Set the Sun, as it glides in, to coincide most exactly with the observing circle; then, while by its own motion it moves out to the point of contact, count most accurately the interval of time that elapses, using any exact clock — whether solar (a sundial) or mechanical — in seconds and minutes; and then convert this same interval into minutes of arc. You will thus know the sought magnitude of the Sun's face. But this in passing; perhaps elsewhere I shall treat it by design.

Now if you join, by a straight line through the center, the point of contact where the bright base grazes the observing circle as it exits, that same line will display, near enough, the course of the parallel, or of the equator. From this it will be easy to draw in the ecliptic, by a ray sent out from the center to the given place of the Sun. Hence you have yet another way of introducing the ecliptic, one that, to the senses at least, does not stray far. But this only in passing [per transennam].

But because, owing to the slippery position of this point, the thing proves quite difficult to carry out in practice, it can be reduced to a convenient enough use by means of any sunspot then present on it. For if you place the same spot at any point on the eastern periphery of the observing circle, and mark it, and then let

the solar base run its spontaneous course until the same spot falls upon the western point of the same circumference, the line passing through these points will be, near enough, the line of the solar parallel. But I only hint at this here; more, perhaps, elsewhere. Now let us proceed to the other motion, which takes place about the center of the observing circle.

The Second Motion, About the Center; Its Difficulties and Remedies. — Cap. XII.

The other motion, which presents itself daily in observing, consists in this: that even if you keep the Sun exactly within its assigned circle, nevertheless the spots [maculae] and faculae [faculae] will for the most part drift away from their marked places and dotted centers, sometimes in a very brief time, in which scarcely one minute of an hour slips by. And when this happens, and the spots are not restored to their place, one will necessarily err in assigning their motion and course. One often falls into this wandering of place while the position, magnitude, and figure of two, three, or more spots are being carefully outlined. Therefore either one must hurry in the investigation and exact recording of these matters — which for that very reason will not be precise, because it is done in haste — or one must fall into the said aberration; or one must meet this error by some other suitable remedy. In this way all faults will be avoided.

[Margin: A slight lapse of time carries the spots away from their marked places.]

First: if you make the little paper-bearing board rotatable about the center of the solar circle, or something equivalent, so that you may restore the wandering spots to their marked places, you will proceed safely in every respect. [Margin: First remedy.]

Second: if you mark only one or two spots, and at once — yourself, or with another's help — take the Sun's altitude and the hour, and so proceed through each one, you will indeed increase the number of observations, but you will make the work of observing secure. [Margin: Second remedy.]

Third: if you observe at such a time in which the spots, staying in their marked place for a fair interval — a quarter-hour, half-hour, or a little more — do not perceptibly move out of it, again you will proceed by a most secure route. When such a time occurs, you will be taught later on, in its proper place. [Margin: Third remedy.]

Now let us investigate the cause and reason of this apparent motion. For it is a marvel to see how all the spots daily trace their paths on the observing paper —

that is, their daily tracks, bent into curved spiral lines about the center of the observing circle, in a truly admirable proportion. This is a thing not immediately obvious, and so it may rightly hold the observer in suspense. But I hope to set it out so clearly that no doubt will remain for anyone. Accordingly:

That this motion occurs on the observing paper you will prove by the following experiments. Of these, the first is: if on some one day, through frequent intervals of time, you observe one or several spots against one and the same plumb-line [perpendicularum]; for thus the curvilinear tracks of the spots about the center will emerge of their own accord.

The second: if you enclose the various observations of the day within the same observing circle but against distinct plumb-lines, you will obtain disordered positions of the spots; yet as soon as you have fitted all the plumb-lines onto one, you will have their paths curved and ordered about the center.

The third: if you carry out the various observations at the said times of day, and reduce the unequal observing circles to equality; then, when you apply all the plumb-lines to one, having marked the places of the individual observations, you will find the spots' gyration about the center of the Sun.

The first and general cause of this is referred to the changing position which the Sun acquires with respect to us, from its daily circular motion. The other seems to flow from the ecliptic. Therefore:

Note first. Since the whole ecliptic, within twenty-four hours, is carried around the earth together with the first motion, and is always cut into two equal halves by any horizon — by proposition 11, book 1, in Clavius [Christoph Clavius] on Theodosius [Theodosius of Bithynia] (*Sphaerica*) — it comes about that any point of it reaches, above the horizon each day, just that same place, such that it is distant by one quadrant of the circle on either side from the intersections of the horizon with the ecliptic. And when this occurs, the vertical circle of the place passing through that point cuts the ecliptic at right angles, and conversely the ecliptic cuts the vertical. Since, therefore, the Sun always carries its center around on the periphery of the ecliptic, it comes once each day to that place and time at which the ecliptic makes right angles with the vertical drawn out through the Sun's center. And since this happens — as will soon be seen — not much before or after, or around noon itself, and since the Sun, by its diurnal motion, then makes its swiftest strides along its parallel, it comes about that it rolls the ecliptic rapidly into ever-changing inclinations with the vertical. The greater these are in a shorter time, the more dangerous they prove for observations, and

they at once cast the spots from their place marked on the paper into another place on the paper, even if the diligent observer keeps the Sun always fixed within the circle prepared on the paper.

[Margin: Why the spots are quickly thrown out of their places around noon.]

This happens because the Sun, resident on the ecliptic — being a globular body and occupying a certain portion of it — together with the ecliptic itself momentarily changes both its position with respect to us and its inclination to the vertical. Therefore, since the vertical plane and the plane of the ecliptic always pass through the center of the Sun and the center of the earth, both in the heavens and in the Sun they will, by their sections, always make great circles; they will always cut one another at the center of the Sun, and will make with the solar circle common sections which are diameters of it. And for this cause, all the points on the Sun, except the single center, always acquire one position after another with respect to the vertical line, and — at positions on the Sun opposite to the vertex at its center — either approach that line or recede from it. If they left impressed on the plane of the solar circle traces of themselves, they would show curved spiral lines, or helices — as in fact happens on the paper: for if, by frequent observations made at various intervals of time against the same shadow-plumb-line, you connect the recorded points of the spots by a continuous line, this line, by its curved course, will reproduce a spiral. That you may understand this well:

Note second. The plane drawn through the apparent circle of the solar hemisphere, erected upon the visual ray that penetrates its center, is always erect; and from this it follows that it is perpendicular to the vertical, to the ecliptic, and indeed to any other great circle passing along the said visual ray — supposing, because of the Sun's immense distance, that the eye occupies the place of the center of the world, according to the common view and consensus of astronomers.

Note third. For the same reason, the circle which the vertical plane, and likewise the plane of the ecliptic, makes on the globe of the Sun appears as a diameter-line of it [i.e., edge-on].

Note fourth. Although the apparent circle of the Sun — like the whole Sun itself — because of the diurnal motion perpetually changes its position with respect to us and to the vertical plane and line (as manifestly appears on the observation papers set before one, and to anyone directing a helioscope [Helioscopium] at the Sun), nevertheless the solar plane passing through the Sun's circle must be

conceived as so fixed that, even though it be conceived as carried around by the Sun, and the Sun itself as rotating, as it were, about its center, it never varies the section it once made with the vertical, but retains it tenaciously. From this one may conceive in the mind how the daily paths of the spots would be imprinted on that plane, if the spots left behind them real traces of themselves drawn on that plane.

Note fifth. The paper that carries the inscribed observing circle, and lies parallel to the solar plane — so that it may immediately receive into that circle all the positions and situations of the spots, alike to those on the Sun, and may present that curvilinear motion — must be so fitted on the paper-holding tablet that all that day's observations are made against a single vertical line, or a single plumb-line. This vertical line is virtually manifold, and corresponds to all the vertical lines in the heavens through which the Sun passes on that day. This is proved thus: because if all those vertical lines are conceived as coinciding with one another, the spots will show the same positions and traversed paths that we find on the paper. This manifestly appears if you observe in this way on separate papers and then throw them together into one circle; for you will find, with the centers and vertical lines coinciding, the same courses of the spots which you would have found under the various observations carried out on one paper against a single vertical line. Therefore this curvilinear motion — apparent, and arising from the various aspects — is expressed on the paper in the ways described; and it is the diurnal motion that causes the varying aspect.

Note sixth. This apparent and diurnal motion of the spots, occurring about the center of the solar circle, is not a perfect circle, but a curved line compounded of the varying inclination of the ecliptic to the vertical line and of the spots' own progression. You will find this manifest from the following: for if you observe in such a way that you change the plumb-line at each observation, you will indeed obtain, on the margin of the solar and observing circle (which must always be equal and mutually congruent), one point after another of the plumb-line, or vertical line, and hence an arc perfectly circular from the sections of the plumb-line; but on the paper, within the observing circle, you will obtain the spot's own path or progression for those times — small or great, according as the times and courses have allowed — not circular, but spiral, and so on. Of this matter you will understand more fully as these treatises proceed. Yet here:

Note seventh. In this case the most accurate care must be given that the Sun fall most exactly on its cardinal points [*puncta cardinalia*]; otherwise you will easily be deceived as to the spots' own progression.

The cause is at hand: because the spots' own progression in this spiral motion is only toward the center or away from the center, whereas the diurnal progression is about the center. Hence, as perceptible as the diurnal motion is from hour to hour, so does the approach to the center, or recession from it, escape the senses, owing to the slow progression of the spots beneath the Sun. Since this progression accomplishes only small daily and half-daily distances, the observer who tries to present the hourly intervals to the senses must be accurate. And this is what I said: that the Sun's base and the observing circle must coincide with one another exactly, unless you wish to place the locations of the spots too near or too far from the center. Practical examples of the experiment described so far occur daily; from countless observations, for the sake of clarifying the matter, I shall adduce a single one.

An Example of the Motion of the Spots About the Center of the Sun, Compounded of their Own Motion and the Diurnal Motion; and its Explanation. — Cap. XIII.

I bring forward the fourth day of August in the year 1625, on which, through distinct intervals of time from morning to evening, I completed 8 observations against the same vertical line AB. For the better understanding of these observations, the following points are to be noted.

First: when I say that the course of these spots is described on the Plane of the Sun, you should understand that that plane is fixed by the mind, and those tracks are formed in thought; yet in reality there is a foundation for it, and in actual fact such shadows are cast by the spots onto the paper, and on it are depicted, by a skillful craftsman, in an ingenious imitation — as is sufficiently clear from what has been said. [Margin: Explanation of the figure.]

Second: know that the number, distinction, and names of the spots, and likewise the beginning of the observations and of their course, are designated by the capital letters A, B, C, D, and so on up to L inclusive; and thus that 11 distinct spots have been noted.

Third: I would have you note that the numeral characters, from 1 up to 7 and 8, signify the order and number of the observations, whose time and place — that is, the Sun's altitude — you will find noted in the table opposite each number. In the example, beside all the capital letters you will find the character of unity [the numeral 1] set alongside. So if you wish to know what it means, look at the table; on its left-hand part you will see the letter M, which signifies *Mane* (morning);

above the numeral marks you will find "Obser.," which signifies "Observation"; on the right, under H [*Hora*, hour], you will find these marks, $7 \frac{1}{6}$, and so on; under this sign ☉ [the Sun], "Elev." [elevation], you will find $22^{\circ} 30'$. There is agreement among all these.

The spots and faculae marked throughout this whole figure with the numeral sign 1 were observed on the 4th day of August, in the morning, at astronomical hour 7 with one sixth of an hour — which makes 10 minutes — the Sun being elevated 22 degrees 30 minutes above the horizon. And at that time the aspect and constitution of the solar configuration in the heavens, relative to the vertical AB, was such as the paper represents; and if anyone had directed a helioscope at the Sun, he would have seen, in those places where the mark of unity is written, the sunspots indicated centrally by points, and the faculae intermingled with shadows, just as the notation shows.

In the same way, where the character 4 stands, there the spots were recorded in the morning at hour 11 and $\frac{5}{9}$ — that is, at 33 minutes past eleven — the Sun holding 64 degrees 40 minutes above the horizon, and so on. At which time spot A, from position 1, arrived at position 4, as did the rest, keeping the proportion. Hence:

Fourth note. All the spots situated in the eastern region of the Sun [plaga Solis Orientalis] ascend from B, the Nadir, toward A, the Zenith, about the Sun's center O — as may be seen in spots A, B, C, D, E, F, and G, together with the faculae likewise joined about A and B; and conversely, those situated in the western region of the Sun descend, about the same center O, from A toward B.

Fifth note. The arcs, or paths, described by the spots nearer to the center O are more curved (that is, along smaller circles), while those described by spots farther from it are straighter (that is, along larger circles).

Sixth. The beginnings of the paths traversed by the spots of the eastern region are farther from the center O than their ends; contrariwise, of the spots lingering in the western part, the heads [beginnings] are nearer to the center O than the ends. Place one foot of the compass at O, the center, extend the other to position 1 of any spot, and compare this distance with the other observations of the same spot; you will find that in each case the distances that occur from the center O are different.

Seventh. As the spots do, so in their own way do the faculae run their course, as their beginnings around L, and the end of the observation and of their track at the numbers 7 and 8, denote — in the course of spot L, the westernmost. Of all the

faculae (for there were several) I have omitted the designations, nor have I attached the whole set for this one to each observation: for these sufficed for my purpose. And let these things about this gyratory motion be run through briefly. Here I would have you carefully note: when it is said in the Table that these courses of the spots and faculae are described on the plane of the Sun, by reason of the diurnal motion, for each day throughout the year — [it means] that that plane of the Sun is assumed to pass, as it were, through the center of the Sun, and to the senses to coincide with the apparent circle of the Sun, but in reality to be parallel to the same and to the observing paper, and to be conceived as carried around with the Sun in such a way that the section which, with the vertical planes...

Diagram. A full-page engraved plate filling the whole leaf: a single large circle representing the projected disk of the Sun on the observing sheet, with a vertical diameter labeled at its top **A** and (on the following text) at its foot **B**, marked **AB**, **Linea Verticalis** ("AB, the vertical line"). Across the disk run dotted arc-tracks, one for each sunspot, each keyed with the successive observation-numbers **1–8** at the points where the spot stood at each of the eight observations of the day. The figure is numbered **N.º 2** (large, right of center).

Engraved title-block inside the top of the disk:

M.DC.XXV. — At Rome, in the Professed House of the Society of Jesus [Societatis Iesu], on the fourth day of August: The courses of the solar spots and faculae, of the kind they trace out on the Plane of the Sun by reason of the daily motion, [shown] for each of the several days throughout the whole year.

Observation table engraved at upper left within the disk (heading **Die 4. Augusti** — "4 August"; **Obser: H.** — ☉. **Eleu.** = "Observation: Hour — Sun's altitude"). The four morning observations are braced **M** [matutinae], the four evening ones braced **V** [vespertinae]:

Obs.	Hour	Sun's altitude (° ')
1	7 $\frac{1}{2}$	22° 30'
2	8 $\frac{1}{4}$	34° 30'
3	9 $\frac{3}{5}$	47° 0'
4	11 $\frac{5}{9}$ [?]	64° 40'
5	1 $\frac{2}{3}$	57° 40'
6	3 $\frac{1}{4}$	41° 30'

Obs.	Hour	Sun's altitude (° ')
7	4 $\frac{2}{3}$ [?]	26° 0'
8	5 $\frac{2}{3}$	16° 0'

Readable point-letters (each a lettered spot with its own dotted track and 1–8 position-keys): **A, B, C, D, E, F, G, H, I, K, L**, and **O** at the center of the disk. Corner emblems of the engraved plate: top-left, the Jesuit Christogram **IHS** in a sunburst; top-right, a Marian monogram **MRA** in a sunburst; the two lower corners bear the Orsini rose device.

[Column I]

which they share in common as they pass successively through the Sun's center, it always keeps the same [orientation] — just as one and the same plumb-line is kept fixed upon the paper. For in this way the appearance of this motion would be expressed on that plane exactly as it is on the paper, if the spots were to leave their traces behind them upon it, as was also said before. That plane, then, even though we conceive it as being carried around together with the Sun, is nonetheless to be thought of as balanced and suspended in the vertical section, and unchanging in its position — just like the observing sheet.

Next, you must not imagine that these appearances of the motion are of this kind every day throughout the year in the individual case, but only in general type. For just as some spots succeed others, and one day's daily motions succeed another's, so too the traces of these gyrations are longer or shorter according as the days are long or short. The likeness, therefore, consists in this: that all the spots, without exception, on any given day describe such arcs about the center of the Sun — larger or smaller according as they are more or less distant from the center, and as the days are longer or shorter — provided that the observations of a single day are taken with respect to a single plumb-line. This I had to point out to you. Now, from this very motion, I bring forward another and far more marvelous experiment.

The daily spiral MOTION OF THE SPOTS is retrograde, stationary, and again progressive.

CAP. XIV.

This appearance I began to detect, from the very outset, through the helioscope at Ingolstadt as well; but because I did not dare rely on that alone enough to affirm for certain that something real underlay it, I therefore also joined to it the safer

practice of the telescope [Telioscopij] and the solid support of reasoning. This experiment, moreover, is one of those that brought me no small trouble and a great deal of difficulty during observation. For I saw that on the same morning, the same evening, the same day, the same spot — with respect to the center, **O**, and to the vertex, **A** — would now descend, now as it were stand still, and afterward ascend again by a contrary motion, or the reverse, while everything else remained unchanged, the position of the paper...

[Column II]

being the same, and with the same plumb-line, or vertical line. And so this appearance greatly disturbed me: now doubting the required diligence of my earlier observations, and calling most things into doubt with myself; now attributing it to the unsteady advance of the spots; now drawing into suspicion other causes and reasons for error, both real and fictitious — until at last, applying every effort both in observing and in investigating, I found it most true that all the spots and faculae undergo this behavior, especially in the oblique sphere and above all in summertime, every day, morning and evening, at fixed times: so that they advance by wholly contrary paths, and then for a good while cling in a station that is in a sense sensibly the same, for the space of about one hour, and only then are carried along by their ordinary tracks. Examples are found in the adduced figure: the morning [motion] for all the spots, from 1 to 2; and the evening [motion], at the ends of the courses of the spots **B, C, H, I, K, L**, from the numbers 7 to 8 — not because each and every spot did not do the same, but because I did not, while observing, attend to all of them with equal care.

From this stable, certain, and well-established experience, then, I conclude, first: that this motion is not arbitrary, feigned, or imaginary, but altogether fixed and grounded in the nature of things.

Second: that it is something distinct from the daily motion and course itself; for the Sun never goes backward, as it here appears to, but is always carried from east to west [ab ortu in occasum].

Third: that it arises chiefly from the position of the Sun, which the Sun acquires from its daily motion, and from its position relative to such a plane — so that, to put the whole matter briefly before the eyes: this curvilinear motion arises from nothing else than the varying position and aspect of the Sun toward us, which the Sun acquires from its daily motion over the poles of the world in the oblique sphere....

Diagram. A second full-page engraved plate, companion to fig-p129-1 and again numbered N.º 2, carrying the same engraved title-block, the same vertical diameter A...B labeled **AB, Linea Verticalis**, and the same set of dotted spot-tracks keyed with the observation-numbers 1–8. Here the tracks near the center of the disk are drawn out into fuller looping (spiral) curves.

Engraved title-block (identical to the preceding plate):

M.DC.XXV. — At Rome, in the Professed House of the Society of Jesus, on the fourth day of August: The courses of the solar spots and faculae, of the kind they trace out on the Plane of the Sun by reason of the daily motion, [shown] for each of the several days throughout the whole year.

The **Die 4. Augusti** observation table (heading **Obser: H.** — ☉. **Eleu.**) is again engraved at upper left; it repeats the eight-row table transcribed under fig-p129-1 (morning rows braced **M**, evening rows braced **V**), with the same values.

Readable point-letters: **A, B, C, D, E, F, G, H, I, K, L**, and **O** at the disk center. Corner emblems: **IHS** (top-left) and **MRA** (top-right) in sunbursts; the Orsini rose device in the two lower corners.

[Note: the four boxed observation tables (headed *ANNO MDCXXV*) that appear faintly and mirror-reversed across this plate are show-through from the verso (printed p. 88) — they are transcribed in their proper right-reading form under that page below, and are not part of this plate.]

[Column I]

the place of the ecliptic, and observe what position the vertical circle holds as it passes through the Sun's center — at rising, at setting, at midday, and at the intermediate elevations. For you will see clearly that all those same things also happen in the heavens which we here test on paper by the use of the vertical instrument. You will observe the daily curvilinear motion of the spots; you will see their regression, station, and progression — because you will discern the vertical circle regressing, standing still, and progressing with respect to the ecliptic. But to undertake this experiment, one must employ a large globe or sphere, so that the vertical angle with the ecliptic becomes perceptible; then an exact spherical quadrant must be duly applied. Yet, so that every scruple of hesitation may be removed, carry out the following investigation of the matter.

Expose a sphere or globe to the shining Sun; then suspend a plumb-line from a bristle or a silk thread and, hanging free by hand, adjust it so that its shadow falls upon the...

[Column II]

vertical point and the place of the Sun (while the sphere stands correctly balanced). Then, if you rotate the sphere about the poles and axis of the world, and always keep the shadow of the bristle at the zenith and at the place of the Sun, you will see most plainly the shadow projected onto the paper circle approach the ecliptic, stand still, and recede from it in the manner already described; while the shadow cast by the plumb-line represents the vertical line, and so on. But if the Sun is not at hand, light a candle and cast the vertical shadow, fixed onto the circle of the ecliptic — and you will find that what I have said is true.

But the truth of this matter shines out far more in actual practice, both arithmetical and geometrical, when — for given observed altitudes of the Sun — the angles which the ecliptic makes with the vertical circles are inquired into. For there, with no one thinking about it, nature being the guide, that regression, station, and progression reveal themselves openly. Of this it is my pleasure to bring forward a few examples.

ANNO MDCXXV. Die 22. Maij Vespertino. (In the year 1625, on 22 May, in the evening)

Solis eleuatio [Sun's altitude] (° ')	Angulus è calculo [Angle by calculation] (° ')	Angulus ex astrolabio [Angle by astrolabe] (° ')
44° 0'	27° 21'	27° 20'
39° 0'	26° 17'	26° 25'
17° 40'	27° 10'	27° 5'
10° 0'	29° 18'	29° 10'

Eodem anno, Mense Iulio, die secundo tempore Matutino. (In the same year, in the month of July, on the second day, in the morning)

Solis eleuatio (° ')	Angulus ex calculo (° ')	Angulus ex astrolabio (° ')
29° 0'	32° 10'	32° 20'
38° 0'	31° 44'	32° 0'
55° 0'	36° 52'	36° 50'
57° 40'	38° 53'	38° 45'

ANNO MDCXXV. Die 18. Iunij Vespertino. (In the year 1625, on 18 June, in the evening)

Solis eleuatio (° ')	Angulus è calculo (° ')	Angulus ex astrolabio (° ')
39° 0'	39° 5'	39° 0'
32° 30'	34° 26'	34° 45'
25° 0'	35° 26'	35° 50'
13° 0'	38° 48'	38° 50'

Eodem anno, Mense Iulio, die 14. tempore Matutino. (In the same year, in the month of July, on the 14th, in the morning)

Solis eleuatio (° ')	Angulus è calculo (° ')	Angulus ex astrolabio (° ')
11° 0'	31° 56'	32° 15'
20° 0'	29° 20'	30° 0'
33° 0'	27° 49'	28° 5'
40° 0'	28° 11'	28° 39'

Observation of 4 August 1625 (ANNO MDCXXV. Mensis Augusti, die quarto).

Morning (tempore antemeridiano):

Sun's elevation [Solis elevatio]	Angle by calculation [Angulus ex calculo]	Angle by astrolabe [Angulus ex astrolabio]
19 30	23 10	23 40
22 30	22 54	23 25
34 [?] 30	23 23	23 55

Afternoon (tempore pomeridiano):

Sun's elevation [Solis elevatio]	Angle by calculation [Angulus è calculo]	Angle by astrolabe [Angulus ex astrolabio]
41 30	57 24	57 40
26 0	55 0	55 0
16 0	55 53	55 50
36 20	55 57	56 0

And so, in all these examples drawn from the months of May, June, July, and August, you see plainly that the observatory angle both in the morning and in the evening decreases and then again increases; and that this indicates — and is in turn indicated by — the retrogression, station, and progression of the spots as

they travel about the center on the observatory circle. Given, then, that the truth of this phenomenon has been confirmed by so many experiments and arguments, I think there will henceforth be no room left for doubt. But why, from what cause, and in what way it comes about; under what constitution of the sphere; in which months; at what time of day; and how long it lasts — these belong to a subtler and more laborious inquiry than can be dispatched here without breaking the course of my present purpose. Perhaps it will be given its own place and time, so that the theory of it may be brought forward.

At the same time you also understand that the agreement of the calculation with the geometrical practice, in determining the observatory angle, is precise enough for this business; for in the matter of minutes a discrepancy does not introduce, in the path of the spots, any perceptible deviation such as would fall short of my purpose. This variation of the angle I have so far found to run in the morning from about the fifth or sixth hour to not much beyond the eighth — indeed, from six to eight it was, as it were, at a station; and likewise in the evening from three to not much beyond the sixth, and between four and six a station occurred. But I do not now work this out in detail; I only hint at it from practice.

Now, since the Sun's place, dividing the ecliptic above the horizon into two, offers a certain use in observing, let us philosophize a little further about it.

Cap. XV.

At what time of day, and at what hour, a given position of the Sun in the ecliptic bisects the ecliptic above the horizon.

[Margin: The sense of the question.]

Since it is certain that a semicircle of the ecliptic is always above the horizon, and certain too that whatever place the Sun occupies lies on the ecliptic alone, it necessarily follows that every day, by the diurnal motion, a moment is reached at which that place of the Sun divides the same [semicircle of the ecliptic] into two equal quadrants. When this happens, the vertical circle passing through the Sun's place makes right angles with the ecliptic. Hence, if this time is known in advance, a diligent observer can, by the aid of the plumb-line alone, bring the ecliptic onto the observatory circle — provided that at this very time he observes some spot; and there is no need of any further reduction, either geometrical or arithmetical. Since this matter is of no small moment, I have thought it should be worked out here. The question of the chapter, then, coincides with this: When does any vertical circle of the place, passing through the center and through the

Sun's position, divide the elevated semicircle of the ecliptic into two quadrants — and its semicircular arc into 90 degrees on either side — and make with it a perpendicular inclination, that is, right angles on both sides?

The first answer: When the Sun is at the first point of Cancer (♋) or of Capricorn (♐), the time sought is noon.

The second answer: When the Sun is in the ascending semicircle, which comprises the 6 signs from Capricorn (♐) inclusive up to Cancer (♋) exclusive, the time is before noon [*ante meridianum*].

The third answer: When the Sun is in the descending semicircle of the ecliptic, the time sought is always in the afternoon.

But of what kind and how great this time is, you may learn from what follows.

Let the horizon be A C B D, as shown in the figure marked number 1 (chapter 16); the meridian A B; the pole of the world F; the vertex of the place, or zenith, E; the ecliptic C G D, whose quadrants are C G and D G. Let the Sun be understood to be at G, past the meridian A B toward the west D, so that it stands in the descending semicircle; and let G be, for example, at 23 degrees and 30 minutes of Sagittarius, corresponding to 15 December of the year 1624. We must therefore find the hour at which the Sun, established at point G after noon, will have bisected the ecliptic with its center — and likewise into two equal arcs, C G and G D — and will also have made the angles E G C and E G D, formed by the vertical E G H, equal.

[Margin: The first thing sought.]

First I seek the place of the ecliptic corresponding to point D, in this way. From Aries (♈) up to Sagittarius there intervene 8 whole signs, that is 240 degrees; adding, then, the 23 degrees 30 minutes which the Sun has traversed in Sagittarius, point G will be distant from the beginning of Aries (♈) by 263 degrees 30 minutes. And with a quadrant of 90 degrees subtracted, there will remain for point D 173 degrees 30 minutes, in which are contained 5 signs and, over and above, 23 degrees 30 minutes.

[Margin: worked computation, left column, figures as printed.]

8
30
—
240
23 30
—
263 30

$$\begin{array}{r}
90 \\
\hline
173 \ 30 \\
[?] \ 2 \\
\hline
173 \ 30 \ [?] \\
30 \\
\hline
5
\end{array}$$

Since, therefore, it is distant 5 signs from Aries — that is, Virgo — point D will look toward 23 degrees 30 minutes of Virgo (♍).

[Margin: The second thing sought.]

Secondly, I seek the angle D F A. Since this is nothing other than the angle of the semidiurnal arc, it will without doubt be obtained by the same method as the semidiurnal arc, by the aid of the ascensional difference, whose proportion [analogia] is as follows:

As the whole sine is to the tangent of the pole's elevation, so is the tangent of the declination to the sine of the ascensional difference. And if this is added to the quadrant, as the rule for northern points requires — such as point D — the semidiurnal arc of that same point D is necessarily produced, that is, the angle D F A.

The elevation of the pole at Rome is 42 degrees; its tangent, 90040. The northern declination of point D is 2 degrees 35 minutes; its tangent, 4512. This multiplied into 90040 makes 4062-60480; and with the 5 right-hand figures cast off — because the division is made by the whole sine 100000 — there remains the sine of the ascensional difference 4062, or rather 4063, to which correspond 2 degrees 20 minutes. And this, added to 90, makes the angle D F A, 92 degrees 20 minutes.

[Margin: worked computation, right column, figures as printed.]

$$\begin{array}{r}
4512 \ |4 \\
90040 \ |6 \\
\hline
180480 \\
4060 \ 8 \\
\hline
4062 \ |60480 \ |3 \\
2.20 \\
90 \\
\hline
92.20
\end{array}$$

Thirdly, I seek the angle D F G, from the spherical triangle D F G, of which F D is the complement of the declination of point D, and its sine is 99898. The arc F G is compounded of the declination of point G and of a quadrant — for point D is southern. The declination is 23 degrees 20 minutes; therefore the arc F G is 113 degrees 20 minutes, whose complement to the semicircle is 66 degrees 40 minutes; therefore the sine of arc F G is 91822. Finally, arc D G is a quadrant, whose versed sine is 100000. The difference between the arcs F D and F G is 25 degrees 55 minutes, and its versed sine is 10057. And the difference between this versed sine and the versed sine of arc D G is 89943 — the same as the sine of the complement of the arc of the difference 25 degrees 55 minutes — because the versed sine of the quadrant is the whole sine, and the versed sine of the arc 25 degrees 55 minutes is the difference between the sine of the complement of the arc 25 degrees 55 minutes and the whole sine.

[Margin: worked computations, right column. Figures transcribed as printed; several interior digits are not fully legible at native resolution and are marked.]

23 20
90

113 20
180

66 40

F G 113 20
F D 87 25
Diff. 25 55

100000 91822 | 3
10057 99898 | 1

89943 734576
826398
834576
9090378

91828 | 34156 | 3
9|89.943.0.0.000
82 555 2 [?]

8|738780 [° X ° 5 – check/multiplication cross, figures [?]]
733824
0 5|4.9.5600 [?]
4 5 8640 [?]

$$\begin{array}{r}
4 \mid 369600 \\
366912 \\
\hline
2688 \\
100000 \\
98054 \\
\hline
1946
\end{array}$$

From these, then, the angle D F G is found by a double proportion.

The first proportion: *As the whole sine is to the sine of arc F D, 99898, so is the sine of arc F G, 91822, to a Fourth, 91728.*

The second proportion: *As this Fourth, 91728, is to the whole sine, so is 89943 — the difference of the versed sine of arc D G and the versed sine of the arc by which the arcs F G and F D differ from each other — to the versed sine of the angle D E G, 98054.*

This, subtracted from the whole sine, leaves the sine of the complement of angle D E G, 1946, to which corresponds an arc of 1 degree 7 minutes. Hence the angle D F G is 88 degrees 53 minutes. But the whole angle D F E is 92 degrees 20 minutes. Therefore the angle of the horary distance is 3 degrees 27 minutes — that is, 0 hours, 13 minutes, 48 seconds after noon.

[Margin: The third thing sought.]

[Margin: worked computation, left column. Figures as printed; the last line reads "13 46," while the running text gives 13 minutes 48 seconds.]

$$\begin{array}{r}
92 \ 20 \\
88 \ 53 \\
\hline
3 \ 27 \\
\hline
\text{H. M. sec.} \\
\text{G. } 3 \ 0 \ 12 \\
\text{M. } 27 \ 48 \\
\hline
13 \ 46 \ [?]
\end{array}$$

Now it is manifest that, on this hypothesis, the vertical E G is perpendicular to the ecliptic C G D.

When the Sun is in the ascending semicircle of the ecliptic — that is, when point G is on the eastern side — then in place of point D one must take point C,

diametrically opposite to D, and for this same point D the semidiurnal arc must be found.

And from these considerations let it be demonstrated when, and at what time of the year, any point of the ecliptic in which the Sun is found reckons its ninetieth degree from the horizon — that is, is a quadrant of the ecliptic distant from the horizon — and how that time is to be investigated in the particular case. Once this is had, if at the same moment you catch the Sun's spots on the paper, you will obtain what follows.

[Margin: The uses of having found this time.]

First: the diameter of the solar disk on the observatory paper, parallel to the horizon, will also be the line of the ecliptic; it will be the common section of the horizon and of the great circle described from the center, or place, of the Sun, in which [circle] lies the observatory circle on the paper, parallel to the disk of the Sun.

Secondly: the shadow of the bristle [seta] cast through the center of the observatory circle will be the vertical of that same great circle; from the place of the Sun...

described [up] to 90 [degrees] — their common section: which we shall henceforth often call the vertical line. The circle, however, projected onto the paper from the base of the solar cone and marked with certain points, let it be called the Observatory circle — just as that angle which the section of the ecliptic and of the horizon makes with the common section of the vertical observatory circle, and which is called the inclination of the ecliptic to the vertical, let it be called the Observatory angle.

Thirdly: this mutual section of the ecliptic and the vertical, at right angles and parallel to the horizon, occurs only once in the day, at a single moment; and this single one is also shared with the plane of the horizon, whereas all the rest produce unequal inclinations in the observatory plane.

Fourthly: at this moment, if anyone duly observes the spots, without any further labor and without any further calculation, he will obtain their paths, situation, and position relative to the ecliptic with the greatest exactness; and consequently,

Fifthly: he will see whether the paths of the spots are straight, or not;

Sixthly: whether they run along the ecliptic and parallel to it, or not;

Seventhly: whether, and when, and how they cut the ecliptic;

Eighthly: whether, and when, and how, and how much they are curved;

Ninthly: whether the motions of all the spots are parallel to one another, or not;

Tenthly: whether the intervals of the daily motions are equal to one another, or not; and so on.

For these things and the like can be drawn infallibly from observations of this kind, without any other aids, as I have often done; and it was for this reason that I brought forward this difficulty and treated it somewhat more fully, so that a student of these matters might have a sure foundation for eliciting and investigating the motion with certainty — provided that, as I have warned, you attend to it, so that with the time accurately known you observe expeditiously, and have the Sun's altitude taken by another person while you are catching the spots. And this [altitude] is indeed to be employed precisely so that from it you may also investigate the observatory angle, in order to learn whether it agrees with the stated time; which is necessary, if only the practice has been carried out without error.

But since I have said in what precedes that this balanced, or right-angled, inclination of the vertical circle to the ecliptic occurs from observations near the meridian — that is, not much before, nor much after, and sometimes at the meridian itself — one might reasonably doubt, and desire to know for certain, whether and how far that time can be extended, and what the fixed limits are within which it is confined.

I answer that fixed bounds have altogether been set to this excursion by nature and by the Author of nature, God, and that they can be known for a given latitude of the place. Of what kind these are will be explained in the following chapter, for it is a thing worth knowing.

To determine the limit of time, beyond which, in any given place, the perpendicular inclination of the vertical circle to the ecliptic does not extend.

Cap. XVI.

Although the Sun's place on the ecliptic ranges every day over countless circles, there is nevertheless one among them, on any given day, which cuts the ecliptic into two equal parts — namely the one that is carried through the poles and axis of the ecliptic. But since the pole of the ecliptic never wanders outside the polar circle, it is evident that no vertical circle which runs outside the polar circle on

the sphere can cut the ecliptic into two equal parts; for no such circle can pass through the poles of the ecliptic, which always remain within the polar circle. And of all the vertical circles that come within the polar circle, the one most remote from the meridian is that which is tangent to the polar circle; for all the rest, if they are taken outside, are indeed more remote, but do not halve the ecliptic; if they are taken inward toward the meridian, they do indeed sometimes halve the ecliptic, but they are for that reason nearer to the same meridian. Therefore, since this one alone, of all the verticals that bisect the ecliptic throughout the whole year, is the most remote from the meridian, and no other more remote than it toward the given place is possible...

[no other] more remote is possible: upon it will rest the limit of the time within which, on each day of the whole year, that equal division of the ecliptic occurs — the [limit] that is to be fixed. How this comes about must be explained a little more accurately.

In the adjoining figure, marked number 2:

A is the vertex, or pole of the horizon, of any given place.

B, the pole of the world, elevated; and therefore A B is the meridian.

A C, A D, the verticals tangent to the arctic circle C D, at C and D.

Into which points, since every year by its proper motion, and every day once by the common daily motion, the pole of the ecliptic arrives, let us understand it now to be there; and therefore the arcs B C, B D are portions of the solstitial colure. Since these are great circles, and pass through the pole B and the points of contact C and D, they will also pass through the poles of the circles C M and D L, which, being verticals, contain their own poles on the horizon. E and F, the common sections of the colures with the horizon, will give the poles of those verticals. Therefore, since from the pole E the great circle M G A C is described, and from F, L H A D; the arcs E G, E C, and likewise F H, F D, will be quadrants. And since the poles of the ecliptic are C and D, the beginning of Capricorn (♑) will be at E and F. And if, with the pole of the ecliptic being at C, an arc passes from E through G to I, it will be the ecliptic; and just as C E is a quadrant, so will C G be. In the same way, with the pole of the ecliptic being at D, and the arc F H K drawn as the ecliptic, the line D H will be a quadrant of a great circle.

Again, since the verticals A C and A D are tangent to the parallel C D, and the arcs B C E, B D F pass through the contacts C and D, the angles E C G and F D H are necessarily right angles.

Furthermore, since the points E and F look toward the beginning of Capricorn (♑), and point G is, with respect to E, more to the west, point G will look toward Libra (♎); and since the point of Capricorn, F, is more to the west than point H, without doubt point H will look toward the beginning of Aries (♈).

But that, with these same things laid down, the points Capricorn (♑), E, and F stand on the horizon, is shown as follows, beyond what has been said. The ecliptic, drawn...

Diagram. The upper part of the page carries an engraved geometric plate marked **N. 8**, which serves two chapters. Its left-hand figure is labelled **Ad Caput XV** ("To Chapter XV"). It shows a spherical construction of intersecting great circles — the horizon, the ecliptic, a colure, and vertical circles — projected onto a bounding circle, used for the reduction of the vertical-circle inclination. Below the left figure runs the engraved rubric that states the problem of the following chapter:

Quando Solis locus Eclipticam supra Horizontem mediet? — "When does the place of the Sun bisect the Ecliptic above the horizon?"

Readable point-letters (left figure): A (top of the vertical diameter), H (upper right, on the bounding circle), C (left), G (centre, the intersection point), E (right of centre), I (lower left), D (right), F (lower centre), B (bottom), K (lower right).

Diagram. The right-hand figure of plate **N. 8** is labelled **2. Ad Caput XVI** ("2. To Chapter XVI"). It shows a second, more crowded system of intersecting great circles (horizon, ecliptic, equator, meridian, and vertical circles) within a bounding circle, carrying zodiac markers at the cardinal points.

Readable point-letters (right figure): V and H (left, on the bounding circle), G (centre, marked with the sign ♎ [Libra]), R (right, on the bounding circle, with an adjacent zodiac sign [?]), A (centre-lower), C (left of centre), D (lower centre), B (bottom). Two of the small peripheral zodiac glyphs are not securely legible [?].

[LIBER II. Cap. XVI] ...[the line] drawn through point G cuts the horizon at the points E and I. The arcs EMI and EGI are therefore semicircles, and the circle CAGM, passing through both poles C and A, bisects them, cutting them at right angles at G and M.

It is clear, then, that the arc GE is a quadrant — the quadrant that the horizon then cuts off from the ecliptic. The colure BCE cuts off this same quadrant, and the point E is the beginning of Capricorn. Hence the beginning of Capricorn stands on the horizon in the eastern quarter whenever the point ♎ [Libra] lies on

the vertical circle AG, which touches the polar circle at C. And the same beginning of Capricorn will stand on the horizon in the western quarter — namely at F — whenever the point ♈ [Aries] falls on the vertical circle HAD that touches [the polar circle].

From this it is evident that the ninetieth degree of the ecliptic, reckoned from the horizon, which is at its greatest distance from the meridian — whether this distance is taken along the vertical circles or along the hour circles — must necessarily be the point ♈ [Aries] or ♎ [Libra]. For all the vertical circles that pass through the ninetieth degree of the ecliptic are perpendicular to that same ecliptic, and therefore pass through the pole of the zodiac, which cannot lie outside the arctic circle. Only two vertical circles touch that arctic circle; all the rest fall between those two tangent verticals and the meridian. The meridian itself takes on the role of a vertical circle when the ninetieth degree is the point ♋ [Cancer] or ♑ [Capricorn], and when ♈ [Aries] and ♎ [Libra] stand on the horizon. From what has been said and demonstrated so far, then, this most general rule is derived:

When the Sun is at the equinoxes and bisects the ecliptic above the horizon, it thereby marks out the very limits within which that bisection occurs throughout the whole year — the afternoon limit at ♎ [Libra], the forenoon limit at ♈ [Aries]. So to know the distance of the Sun from the meridian, when at the beginning of Aries or Libra it divides the ecliptic in two above the horizon, is to know the limits we are seeking.

[ROSAE VRSINAE — p. 94]

These are obtained from the spherical triangle ABC, whose working-out is as follows.

ANGVLVS BAC. [Angle BAC]

In the said spherical triangle ABC, the angle C is a right angle; the base AB is the arc of the complement of the pole's altitude; and BC is equal to the arc of the greatest declination. Therefore, by the first problem of spherical triangles in Clavius [Christoph Clavius], *[On the] Astrolabe*, Book 1, Lemma 63, Method 20: if it be made that as the whole sine is to the sine of BC, which is 3987491, so the secant of the complement of the base AB, 13456326, is to the sine of the angle — then by a single completed multiplication there comes out the sine 5365697 of the sought angle BAC, which is 32 degrees 27 minutes. And this is the distance of the vertical circles which, running up on either side of the meridian through the equinoctial

points, cut the ecliptic at right angles at the latitude of Rome. The measure of these angles, on one side and the other, is the arc of the horizon intercepted between the meridian and the said vertical circles.

ANGVLVS ABC. [Angle ABC]

This is found by the second method of the first problem in the same place: if it be made that as the whole sine is to the tangent of the complement of the base AB — that is, to the tangent of the altitude of the pole at Rome, which is 9004040 — so the tangent 4348124 of the side BC (the greatest declination) is to the sine of the complement of the angle; this comes out as 3915068, and yields the angle ABC as 66 degrees 57 minutes.

Once this angle is drawn out, the horary time contained within the aforesaid limits is easily elicited from the angle ABG. For since the whole angle EBG is the angle of the right ascension of EG, and the arc EG is a quadrant, then consequently the right ascension too will be a quadrant, and the angle EBG a right angle. This is also proved as follows: the arc CG is a quadrant, because C is the pole of the ecliptic and G the point $\varnothing$ [Libra] on the ecliptic; likewise BG is a quadrant, because B is the pole of the equator and the point G, namely $\varnothing$, lies on the equinoctial circle. Therefore the angles GCB and GBC are equal and right, and consequently the angle ABG is the complement of the angle ABC — that is, of 23 degrees 3 minutes.

This amounts to one hour, 32 minutes, 12 seconds. Thus the limits stand revealed, and the time contained within them: which, for the city of Rome (adduced here by way of example), before and after noon together, is three hours, four minutes, twenty-four seconds. Within this span the whole section of the ecliptic raised above the horizon must be made equal — that is, before noon from about half-way through the eleventh hour to the twelfth, and after the twelfth (noon) to half-way through the second hour (reckoning the hours in the German manner, as I do throughout the whole work).

First doubt. Is this position of the limits unchangeable? I answer: for each single place there is one fixed and unchangeable withdrawal of the verticals from the meridian, and this is invariable for that place.

Second doubt. For these vertical circles running through the equinoxes, as they bisect the ecliptic above the horizon, is the recession from the meridian the same in all latitudes? I answer that it is not, but varies with the altitude of the pole. For the angle A at the vertex — the one contained by the tangent arc AC and the

meridian AB — varies; it is always smaller the lower the altitude of the pole, and larger the higher it rises. Hence:

Third doubt. Can the least and greatest bounds of these vertical angles CAB be assigned? I answer that in the right sphere the smallest of all recessions occurs, in the parallel sphere the greatest of all, and in the oblique sphere an intermediate one. For in the parallel sphere the greatest declination of the Sun — that is, the arc DC, equal to the Sun's greatest declination — determines the matter. Note, however, that at the equinoxes there is no excess of time beyond the meridian; yet afterwards, as the verticals approach the meridian, a departure of time occurs, as will be evident to anyone examining the sphere. In the parallel sphere the ecliptic is bisected only once within half a year — when the Sun reaches the solstitial colure — but even there the angle ABC vanishes, just as it does at all points of the vertex lying within the polar circle.

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The last and greatest value of the angle BAC occurs at that place whose vertex the polar circle touches; for there the angle to the meridian is a right angle, and the tangent vertical circle bisects the ecliptic as it lies on the horizon.

In the other oblique positions of the sphere — in the zone between the torrid and the polar — the value is intermediate: if the vertex approaches the equator, the angle diminishes; if it recedes, it increases. Let this stand as what is said and demonstrated concerning the bisection of the ecliptic, raised above the horizon, into two equal parts by a vertical circle. Now let us return to the other difficulties.

DIFFICULTATES [Difficulties]

which arise in recording the spots because of their own proper motion, and the precaution against them.

CAP. XVII.

Now that the difficulties bound up with the daily motion of the Sun, the varying elevation of the ecliptic, and its inclination to the vertical circle have been dispatched, it remains for me to warn the student of this art not to spend too much time in carrying out a single observation. For although the time may be short enough for the purpose — short enough that the ecliptic does not shift the spots from their place — nevertheless, if he spends more than half an hour, the spots and faculae, advanced by their own proper motion, will settle in an entirely different place from the one marked at the start of the observation.

[Margin: The spots' proper motion must also be taken into account in observing.]

For those on the eastern part of the Sun will be seen to have advanced toward the centre, and those on the western part to have receded from it — especially those that lie nearer the Sun's horizon (its limb) and closer to the centre. The chief reason I offer for this is: in the case of spots near the limb, their advance within an hour is scarcely perceptible to the sense, at least by the ordinary path, on account of the steep foreshortening, where the spots appear almost stationary; whereas at the middle, because the direction of their travel is set squarely opposite the eye, the spots, driven at their swiftest course, present a perceptible advance of one or half an hour.

Therefore, timely remedies must be applied in observing. The first and chief of these is to complete the whole observation within a quarter of an hour, or not much more. Yet because it sometimes happens that, through the multitude of spots or the intricacy of recording them, the time stretches beyond an hour, therefore — lest the central spots lose their recorded position — observe and note first all the marginal spots, and last of all assign the central ones their places. In this way everything will agree correctly with the time of observation; or else divide the spots into two or more observations.

[Margin: Observations made point by point are useful.]

What if all the spots are central, and much time is spent in observing? You will meet this difficulty thus. Note only the central points of the individual spots (for these are their apparent places, which are taken solely from the central position), a thing accomplished with the least labour and in the briefest time most exactly, neglecting all their other accidents. This done, at once apply the plumb-line to that observation, and carefully write down beside it the hour and the Sun's altitude — and you will have made an observation perfectly suited to your purpose. The rest — what pertains to magnitude, figure, and density — you can always add afterwards, once the spot's centre has been brought back over the marked point and the paper tablet turned as much as necessary; for a perceptible change of figure, magnitude, and density does not happen so quickly. Here, however, take note: if, because the position of the ecliptic has changed, a notable rotation of the paper tablet should also occur, you must not mark a new plumb-line, nor take a different time or altitude of the Sun, but everything must be accommodated to that observation by which alone the central points were recorded. And if it be irksome to use these methods, and the spots have moved from the marked place, one last remedy remains: to note the new place into which the spots first marked have moved by the end of the observation.

QVID FACIENDVM QVANDO [What must be done when]

one must observe at an inconvenient time and place.

CAP. XVIII.

Of necessity — especially in winter — an observation must often be undertaken at an inconvenient time and place: whether because the inconstancy of the sky promises nothing better, or because the shortness of the days allows nothing else, or because place, business, and time do not permit otherwise, or because a newly-risen spot, or one about to make its final exit, presses upon us, and so on. When, therefore, with one of these intervening, an observation must be undertaken at an inconvenient time — as happens when the Sun and ecliptic sweep the spots at a stroke out of the places fixed for them on the observing circle, as commonly tends to happen in the winter hours, and so on — then in such cases one must either take a single spot in a single observation, and assign to it its plumb-line, the hour, and the Sun's altitude; or else, by repeatedly turning the little paper board, adapt it to the motion and situation of the marked spot, so that the places first noted always lie beneath their spots, and the base of the solar cone corresponds perfectly to the observing circle; and then catch at once both the Sun's altitude and the shadow of the plumb-line as it runs through the centre of the observing circle. If you do this, you will proceed just as well as at any other convenient time. You may take it on the word of one who has tried it. By this turning of the little board you will gain much time and much labour, and you will not, for all your skill, be liable to any error. The inconvenience of the place where one must observe, as often happens, is compensated by a board laid under the foot of the instrument,

[Margin: The inconvenience of the time is compensated by turning the paper tablet;]

and by a proper shade, together with a portable stand. For if the pavement on which the foot [of the stand] rests is rough or full of holes, the mobility of the foot will be impeded — the foot which must always follow the Sun's motion, so that the Sun's own ray may be held exactly within the observing circle. The motion of the foot must therefore be as easy and smooth as possible, and this is hindered by the roughness of the pavement, which is remedied by an underlying footboard Q, most cleanly planed. Hollows in the ground tilt the instrument and the observing circle unsteadily and unevenly, so that the places of the spots

[column II] never stay fixed — a thing that easily spoils the whole observation. That same danger is cured by the said supporting footboard, which keeps the instrument tilted in the same way.

Another drawback arises from the place, when one must observe out in the open, so that the necessary darkening is lacking. The remedy for this is provided if the observing apparatus itself is so arranged that it can be enclosed on every side and covered with its own shade, so that the observer, thrusting his head in, may nonetheless catch the Sun within and record the spots — as may be seen in the large plate to be explained later, at the beginning of Book Three. And let this be what is said concerning the difficulties arising from the light of the Sun, from its apparent magnitude, and from its continuous motion. Now I pass on to others.

DIFFICVLTATES E VITRIS Tubi [Difficulties from the glasses of the tube]

and their remedies.

CAP. XIX.

Just as the Sun by its perpetual motion creates much trouble for the observing instrument, so in turn the instrument brings no little inconvenience to the Sun. And it could easily happen that a craftsman unskilled in these matters would ascribe to the Sun what arose from a fault of the glass, and again would lay to the glass's charge what ought to be attributed to the Sun. Therefore, so that what belongs to each may remain its own, and the true be distinguished from the false, illusion from experiment, I set out the truth and lay bare the fallacies.

The faults introduced by glasses into the eye of one gazing at the Sun have been sufficiently explained by Apelles, in his last letter, written on 25 July of the year 1612 to Marcus Welser. I now pursue those which the tube conveys onto paper, and not immediately into the eye. And lest I seem to someone perhaps too full or too scanty, let it be known that I write not always for the learned, but also for beginners keen on these studies.

In the glasses to be used in the telescope, three things are to be considered: material, form, and arrangement.

I require the material to be transparent, homogeneous, and continuous. Transparency perfect in the glass removes all colour; imperfect, it leaves something of the coloured in it — whence the image of the Sun is tinged by that same colour: for light, or the [image...] ...the species [species — the transmitted

visible image] of the Sun takes on the tint of the transparent medium through which it passes; and so, after falling through other media onto a bounded object, it represents the Sun as red, green, dusky, or blue, according to the nature of the glass itself. One such species, streaming onto the paper together with the Sun's rays, becomes visible. The explanation follows from the earlier one: a color propagates from itself a species like itself — green propagates green, blue propagates blue, white white, yellow yellow. This is clear from the fact that the images of all colored things settle down exactly onto clean paper, held in a dark place, together with vivid likenesses of their own colors, whenever you admit them through a convex lens (or even a bare aperture) set opposite a bare hole. Yet it is certain that in such a display the colors themselves are not present; what is present, therefore, are their ideas [ideae], which make themselves visible on the paper and propagate from themselves still other forms in every direction — visible, indeed, when their course is arrested in an opaque [adiaphano] body, as is found to happen here.

[Margin: The color rubbed onto the spots by the glass.] So when the Sun, shining through colored glass, shows its spots [maculae] and itself as tinted, you should know that this belongs not to the Sun, nor to the spots, but to the glass and to the solar rays — colored by the tinted rays of the species — and that from there it is carried down into the base of the solar cone.

Perfectly transparent lenses, tinted with no colors, appear rather few — if indeed any appear at all. For it is certain that any convex lens colors the rays by refraction; but whether this arises from the color of the lens, or from some particular mixing of the visible species, might reasonably be called into doubt, which I do not settle for now. Meanwhile I have no doubt that the apparent color is something existing on the side of the thing itself.

[Margin: Uniform material.] Moreover, the material must be homogeneous. This excludes pebbles, grains of sand, bubbles, parts of differing density or transparency, and other impurities — all of which infest the Sun's species and, as will be said later, often throw up counterfeit spots.

[Margin: Continuous.] Besides, it must be evenly continuous — a property that makes it solid throughout and not in the least porous or full of air. I said the material must be evenly, that is uniformly, continuous, so as to exclude veins, spirals, undulations, whorls, vortices, clouds, vapors, and the like, introduced into the glass through the carelessness of the craftsmen when they variously drag, work, spin, twist, turn, pluck, and spoil the fiery, soft mass taken from the pots.

For this one thing brings ruin and destruction to the ordering and cleanness of the visible species.

Why is it that through the calm surface of clean water we see most clearly whatever lies at the bottom? Why is whatever befalls from the surrounding bodies of species reflected back to the sight most cleanly? Whereas through water even slightly disturbed or agitated, we discern either none of the former, or only with the greatest confusion and monstrosity? For no other reason, surely, than that by that agitation the surfaces, variously produced, destroy the evenness of the continuity, change their positions and inclinations, and produce various incidences, refractions, and reflections of the species upon the diverse surfaces — incidences that would always remain turbulent in the same way, if that water were to stand fixed in such a position, order, and solid shape, and congealed. This is just what happens to glass taken from the furnace and gradually cooled. Hence we see that rough glass cups made by art — called "frosted" because of their likeness to ice — and likewise window-panes, transmit a great deal of light indeed from that disordered heap of rays and species, but of colored things to be transmitted distinctly, little or nothing. Glass, therefore, whose material is infected with such windings, meanders, streaks, or veins, proves altogether unfit for this business, and harmful. But glass that turns out clearly transparent, cleanly homogeneous, and continuously and uniformly solid throughout, is without doubt best suited to this task, to be prized most highly and treated like a gem.

For such glass affords the greatest ease in coming to know this phenomenon [phaenomenon] perfectly, for the purpose of bringing secondary spots and faculae [faculae] into clear view — which without such material are drawn out only very laboriously and not with such perfection. I am speaking of material that is most simply homogeneous, most completely continuous, infected with no pores at all — not even the smallest — tempered to a most even density, and devoid of all color;

[Margin: Material for tracing out the Sun's spots.] such material, I say, for bringing secondary spots and faculae onto the stage, though long sought after, I have not been able to obtain. The spots and faculae are indeed always open to view, but they are partly bespattered by the aforesaid defilements of the material, and partly wholly confounded and smothered — as will be better taught in the proper places. Nor does crystal itself, dug from the mountains, however purified, pure, clear, and most perfectly transparent it may appear, fulfill one's wish; for when it comes to the point, it is found everywhere beset within by veins and

natural passages, unequally transparent and irregularly continuous, which entangle the secondary spots and shadows rather than unfold them. So much for the material; now I come to the Form.

[Margin: What the form of lenses should be.] The form imparted to this material is artificial: the surface, namely, is either plane or spherical (for I do not wish here to inquire into the remaining figures), and this surface is either concave or convex. And each of these may be on both sides of the same lens; or one face may be convex and the other plane in one and the same lens; or one concave and the other plane — as may be seen in the attached figures. Here, **a b c d** is a lens convex on both sides, bounded by two spherical surfaces, **a b c** and **c d a**. That you may understand this better, you should know that a lens, in this place, is nothing other than a segment or frustum of a sphere, made by a plane or spherical section. Thus if a sphere **e a b c** is cut by another sphere **f g d h**, the common section **a b c d** will be a solid frustum common to both spheres — **a b c d**, bounded by two spherical surfaces **a b c i** and **a d c i**, and by the circular periphery **a i c**, where they intersect one another. And because a frustum of this kind presents a lenticular figure, it is usually called a lens. It is composed of two spherical segments, **a b c i a** and **a d c i a**, made by the plane section **a i c**. An entire lens, then, is always formed from two such segments, whose common base is a circle. Lenses of this kind consist of segments either equal or unequal: if equal, the section is from equal spheres — such as **e b** and **f d**; if unequal, the mutually intersecting spheres will also be unequal — such as **e b** and **f l**, from which arises the lens **b K l m**, composed of the segments **K b m n** and **K l m n**, just as the lens **o p q r** is likewise composed of the unequal spheres **e r** and **f p** intersecting one another.

When a sphere is cut by a plane, there arises a half-lens, or simple spherical segment — such as **g d h**, bounded by the spherical surface and by the circle **g t h**. Lenses of this kind are also **K l m n**, **u x y z**, and so forth.

[Margin: Magnitude of lenses.] The magnitude, breadth, and width of lenses are taken from the circle that is the base of the spherical surfaces, whose size is given by the semidiameter **a i**, or **i c**, which is always equal to the versed sine [sinus versus] that subtends half of the greatest arc of the lenticular surface.

The height [altitude] of lenses is the perpendicular line drawn from the center of the base to the surface of the lens — such as the line **i d**, or **i b**.

The thickness of a lens is regarded according to a greater or lesser height.

Diagram. A geometric optics figure illustrating the forms of telescopic lenses. It is built on a large circle (a sphere seen in section) intersected by further arcs, with several lens (vesica-shaped) forms stacked along a central vertical axis; horizontal chords mark the plane sections. The engraved title runs across the top: "Forma lentium Telioscopicarum" ("The form of telescopic lenses"). Readable point-letters, from top to bottom:

- f (apex point at the top, on the vertical axis)
- g (left), t (center-top), h (right) — the shallow uppermost arc g–t–h
- a (left), c (right) — ends of the upper lens chord
- d (central point just below the a–c chord)
- K (left), m (right) — a chord across the circle
- n (center, below the K–m chord)
- l (center, below n)
- β (left), e (center), γ (right) — a horizontal diameter β –e– γ
- x (center, below e)
- z (center-lower), y (right) — a lower chord
- o (left), q (right) — the lowest lens chord
- p (center, above α), α (center of the lowest lens), r (center, below α), s (bottom point on the axis)

Central points i and b (heavily referenced in the text as a i c, i d, i b) and a left-hand chord endpoint (u, from the text's u x y z) are present in the construction but too faint to resolve confidently on the scan [?]. Several interior labels remain unresolved. As this [semidiameter] increases, the surface increases in a lens of the same kind; as it decreases, the surface decreases.

Lenses are of the same kind that are segments of the same sphere, as a b c and K b m.

The surface of a lens is estimated according to the semidiameter of the sphere of which the lens is a segment. Thus the surface g d h is reckoned from the semidiameter f d, and from the semidiameter s p the surface o p q is estimated.

The globosity, or sphericity, of a lens is to be judged from the diameters or semidiameters of the spheres compared with one another — not from the size or thickness of the lens. For a lens can be thicker, can be larger, and yet not more globose, as k l m: it is not more globose than a b c, and yet larger; o p q is more globose than k l m, yet smaller. For the segments (that is, the lenses) of smaller

spheres are more globose than those of larger spheres. Thus the lens o p q [ε?] is more globose than u x y z, and so forth.

Concave lenses are spherical segments taken away from a solid transparent body, bounded either by two spherical surfaces opposed at the vertex, or by a spherical and a plane surface — as may be seen in the doubly concave k l m u x y, and g a b c h t, or k l m γ e β.

The cavities of smaller spheres make sharper lenses than those of larger spheres. The hollowed-out segments of larger spheres produce blunter lenses.

Doubled or entire concave lenses can do more than simple ones — which is to be understood also of convex lenses, applied in a certain way to certain effects.

From these things the figure of a lens suited to a tube [telescope] is sufficiently made known: it is either wholly spherical, or partly spherical and partly plane. If such lenses turn out perfect, they will prove the best of their kind. But whether a good or bad figure attaches to a lens is disclosed only by practice and everyday experience; for the recognition of this is so subtle and so hidden that this goodness or badness can be learned, known, and taught by no sense and by no antecedent reasoning, but only by practical use and experience.

[Margin: Use and experience, the best teacher.]

[Margin: The test of good form.] So when a tube [telescope] has been duly directed at the Sun, if the Sun's image rebounds cleanly and circularly, precisely and at right angles [orthogonôn], onto the sheet of paper set opposite it, the glasses will be good and their figure rightly made. If the Sun shines back in a figure other than circular, and dully, the form of the glasses will be worthless.

[Margin: The smoothness and polish of lenses.] To the goodness and utmost perfection of the figure, smoothness and polish also belong. For it often happens that the extent of the surface is good, but the polish rough and only superficial [obitanea?] — which becomes apparent when, viewed obliquely, it appears as though sprinkled with ash and fine dust, or fluctuates by turns with little pits and projecting nodules. For these little hollows are left behind by grains of sand in the grinding of the glass. Such glasses, therefore, are of little use, because they present a species that is neither strong nor clean. Not strong, because owing to the unevenness — and, so to speak, the rawness — of the surface, roughly half of the rays are blunted and hindered from passing, and are there smothered, or diverted elsewhere; not clean, because a great part, torn from its ordered course,

is wrenched into an alien place, and so a confusion of species is generated, which brings dimming and weakening to the ordered image.

All glasses, therefore, must be of the cleanest and most even polish, and of the most exquisite figure. That this may come about in the working, the diligence of the craftsman, the goodness of the instruments, and good fortune bring it to pass; and how it is to be recognized, the use of all things — the Master — teaches better, as I have said, than any cleverness of skill or subtlety of talent and learning.

Yet since I am confident I shall do something welcome to those keen on these matters if I set out some practice for discerning lenses, receive the following rules.

Practical Rules for Discerning Good Lenses.

Cap. XX.

Rule I.

[Margin: Discernment of vortices and waves.] To discern waves and vortices in a convex lens. This fault often lies so hidden that the excellence of the polish and gloss cheats the eye. Set the lens, then, between some fixed object and the eye, and either approach the lens, or withdraw from it, until you bring the object to the point of confusion; for then you will see whatever is vortex-like and wavy in the lens. The object will have been brought to the point of confusion when it appears to the eye neither in an erect position nor inverted, but wholly confused — so that you can distinguish neither the appearances of shapes, nor the qualities of colors, nor the separation of light from darkness and shadows. The place and station of this point you will learn at once, with the eye for teacher; and if from this station you approach the lens, you will have the object's position erect; if you withdraw, you will find it inverted.

Another way. By night, turn the lens toward the flame of a lamp or a lit candle, until you see it at the point of confusion — which will happen if you gaze at the whole lens suffused with even light. Then you will see at once whatever faulty thing is in the lens; and you will marvel that in something otherwise so bright, so clean, so transparent (as it appeared before), there should cling such great filth, such dross, such dregs, such confusion and disorder — so that it is astonishing how the light lays bare each and every tiny thing that would otherwise escape all the sharpness of sight. Indeed it is the greatest miracle of nature, by what means,

through so foul a material, visible species so clean and so ordered are painted onto the paper.

[Margin: A doubt resolved.] Someone will ask, first: why are the faults of the glass shown so plainly at the point of confusion? Why are they not betrayed at the point of right ordering, when the object is seen distinctly — first in erect position, and after the confusion in inverted position? I answer: they are indeed seen both before and after the point of confusion, but not so distinctly with regard to the smallest things — especially in glasses of large spheres. At the point of confusion this happens most, because there the sight terminates in the glass, and consequently surveys most fully all the things that are in it.

[Margin: The solution of an intricate doubt.] Someone will ask, second: since in confused vision nothing ordered occurs, but everything happens disturbed, how can it be that the things which lie hidden in the material and thickness of the lens should be seen; and if they are seen, whether and why they are beheld in an ordered position? I answer the causes and reasons of these accidents afterward, drawing from the earlier point, when the eyes [—]

we shall declare their agreement with the tube; it will then be explained and understood better and more fully. For now, let these things be said briefly.

First. It is certain from experience that at the confused station nothing is distinctly discerned from the object, but that white expands into a certain confused whiteness, black into blackness, and the mixed into some confused chaos — yet so that it is not possible to distinguish part from part, whole from part, or from the whole; for no figure, no boundary, no color is separated or distinguished from another, but all appear together and everywhere, and tint the whole lens.

Second. It is certain that all the parts of the lens are seen ordered and distinct.

Third. The proximate and immediate cause of these visions is the presentation, or picture, made and received in the retinal tunic [tunica retina]: confused indeed as regards the object, but ordered as regards the lens. It is certain, moreover, that the act of seeing follows the manner and quality of what is presented: if a confused presentation of the visibles precedes, a confused vision follows; if a clear and ordered species is imprinted, an image likewise pure and distinct is expressed by the sight.

Fourth. But why, in the given case, is the species of the object confused in the retina, and that of the lens ordered? The cause is that the former is confused in

the crystalline humor [humor crystallinus], the latter distinct and ordered. It is certain, moreover, that the crystalline humor orders all species that arrive confused, and confuses all that arrive ordered.

[Margin: Why does confused light not appear confused?] Someone will ask, third: if all the species are confounded, why is the light not also confounded? For no change of light appears, in whatever station and position of the lens; the lens always appears bright, whether you look at the object erect, or inverted, or finally confused — yet no perceptible and local change of light appears. It is answered, first: this same argument tells against any homogeneous and single-colored object. For if you turn the lens toward some white wall of a great hall, so that it alone occupies the whole field with respect to the sight, you will perceive no change of position, in whatever station, but will always see a uniform whiteness — likewise the blue color of the sky, likewise the dusky darkness of a mountain. Therefore this is not peculiar to light: that it is not inverted, or that its inversion is not perceived; it is inverted [—]

[Margin: The confusion of species is not noticed in single-colored things.]

Book II, Chapter XX (continued)

for that is what happens. But the reason the inversion is not perceived is this: since the light is homogeneous and uniform, even though its rays change their position, the eye still does not notice it, because it is always affected by the same kind of light. This is plainly shown by experiment in the very rapid spinning of a top, which the sight takes to be standing still even though it is turning. Why does it not perceive the rotation? Because, when the top is assumed to be of a single color, the successive migration of the visual species [species] is not felt: like succeeds like. We have another clear example in the shimmering of the blue sky, which we see when the eye is turned toward the heavens. There is no doubt that one part after another of it is presented to the sight, and yet the eye marks no distinction of parts. For however much part gives way to part — as many hold — the eye still does not register that motion, because of the similarity of the rays and species. So it is with light, and so it happens with all single-colored objects: since they fill the whole eye, they always tint it with one uniform color, and so no straightness, confusion, or inversion of the species is noticed.

A second reply. The positions of bright objects — no less than those of other single-colored ones, whether upright, inverted, or confused — are recognized

from their boundaries and from the places seen, and then from the appearance of the lens itself, which sufficiently reveals the position of the things seen through it.

A fourth question is raised: since light is the enemy of the species, and in a way devours them by choking and blotting them out, how and why does it not extinguish the species of the lens? And since that species is confused (by hypothesis), how does it tolerate together with itself an ordered species of the lens? Is it possible for the same subject to be imbued at one and the same time with a confused species and a distinct one — so that in the same part of the eye a confused and a distinct image are painted at once?

I reply that light is not so hostile to the species that it does not carry them along with itself, since it too, as it is propagated from the luminous body into the air, becomes a species, and to the species of colored things it adds, in due order, a sort of soul with respect to sight — for the species of colored things are not perceived without at least some light. Therefore, just as no light would leave a species present to the eye but imperceptible, so an excess of light makes it imperceptible: by its great intensity it summons the sense to itself, so that, abandoning the weaker species, the sense clings to the light,

and thus excessive light blots out the species — in no other way. But when the light does not exceed a due measure, as happens in the present case, then the light — whether direct, or confused, or inverted — does not prevent the species of the lens from being perceptible. Now, as to why the species of light is received into the crystalline humor [humor cristallinus] in an ordered way, this is brought about by the arrangement of the lens and by its distance from the crystalline humor; and why the confused species of the lens itself radiates into that same humor is brought about by the free, natural, and confused incidence of the rays upon the crystalline humor — as will be shown more fully a little later. And hence it comes about that, when the confused light presents the whole lens to the eye bright with its splendor, it also represents at the same time everything that impedes, disturbs, and interrupts the uniformity and similarity of that same light: which is what bubbles, cracks, grains of sand, and specks of dust do — yet their appearance flows in an ordered way. So there is nothing new or incredible in the fact that the most diverse images of things inhere at one and the same time in the same subject. I mean the visible images of things, which — since they are of a finer nature and are not colors inhering in and fixed to things — can well be present together in the same part of the subject, just as the light of the Sun and the light of the Moon slip together into one and the same place.

[Margin: At one and the same time, in the same part of the subject, a confused species and an ordered one inhere.]

From this I draw a first conclusion: it is evident from this experiment that vision does not take place in the crystalline humor, but in the tunic called the retina [tunica Retina]; otherwise, in the case described, the lens itself would appear confused and the light ordered, whereas the opposite is the case.

[Margin: Vision does not take place in the crystalline humor, but in the tunic of the retina.]

A second conclusion. From this, as much as from what was said before, the greatest argument is drawn: that visible species are seen. Now I return to the rules I have set out.

Rule II

[Margin: Discerning a good figure.]

To discern the good figure of any lens. Turn the lens toward a straight-edged object; if its straightness is not seen bent — especially just before or just after the moment of the inverted position — then know that the lens is of a fine figure. If the straightness is seen monstrously bent, the lens will be worthless. Otherwise:

Look through the lens at a circular object, or a square, or a triangular one, or one of any figure whatever; then turn the lens about its own center, everything else remaining

unchanged, and observe whether the circle, as the lens is turned around, is always represented under the figure of a circle, or whether instead it takes on the form of an ellipse; whether the exact square, the triangle, or whatever figure has been proposed passes through unviolated. If so, you have a lens sound as to its figure; if not, a defective one.

[Margin: Solution of a doubt.]

You will ask by what technique you can hold and turn the lens so that it nonetheless stays in the same position relative to the eye — for the axis of the lens and the axis of the eye must always coincide, since any tilt of the lens alters the figures of visible things. I reply that with the free hand this can scarcely be done except by one most skilled and practiced in the matter; but it will be easy and secure if you set the lens in a tube, so that the axis of the tube (or reed), of the lens, and of the eye are one and the same. For if you place your eye at one end of

the tube, at the proper distance from the lens set within it, then the tube, turned around together with the lens, will accomplish your wish. Here note that this examination of the lens will be the better the more clearly and distinctly you have gazed at the object through it. Then the part of the object which you have once turned toward the center of the lens must always be kept the same; otherwise the examination might turn out faulty. This being so, if, when the lens is turned around, it always exhibits to the eye the figure of the object like and equal to itself, it will increase the tally of the good lenses; if it changes, it will be reckoned among the bad.

By this same method you will examine, without anyone noticing, two lenses enclosed in a tube. For if the tube, turned around in the way described, transmits everything alike, equally large and clear, the pair is sound. If not, turn only that reed to which the convex lens is fixed; if it varies nothing in the object, it will be sound, and the fault will lie with the concave lens — which you will detect by its rotation alone. But if, in the rotation of the convex lens, a variation of the object is found, that lens will be judged defective; not, however, that the concave one will therefore be free of every flaw — it must accordingly be tested nonetheless.

Rule III

[Margin: Discerning good polish.]

To investigate the exact polish of a lens. One thing is good material in a lens, on the examining of which I gave the first rule; another is good surface or figure, treated in the second Rule; and another, finally, is sound smoothness, that is, a clean and pure polish. For it can happen that the best material is clothed with a very bad surface through poorer grinding. It can happen that a bad polish renders unfit a material and form that are of the best. And finally, the brightest luster on a distorted surface, or on unsuitable material, does not serve the purpose. Therefore, for a lens to be serviceable, the material must be suitable, correctly figured, and most brightly and evenly polished to a finish. Whether these qualities are present in a lens set before you, you will judge as follows.

Take the lens, and the face whose smoothness you wish to test turn thus toward the light of the Sun (though this will perhaps be too intense), or toward daylight coming in through some window — which will be most apt — or toward a lamp lit at night, or finally toward any object at all that is white and illuminated by the Sun, so that the species of that bright or illuminated body, falling upon the surface of the lens, is reflected to your eye. The eye will at the same time behold the surface of the glass most sharply, as though illuminated by that luminous

species, and will most carefully note whatever is clean, whatever foul; whatever full, whatever hollow; whatever transparent, whatever opaque; whatever even, whatever uneven; whatever continuous, whatever broken; whatever praiseworthy, whatever deserving of blame has appeared at that surface. Here note that an image of the fallen light is thrown back in two kinds: one from the near surface, which you are examining and have before your eyes — and its species appears larger but thinner and rarer, yet for the present examination it seems more convenient, because it treats the sight more gently and holds it softly in gazing at the surface; the other is thrown back from the far, hidden surface, and is smaller but nonetheless livelier, and this one is less suited to the examination, because it draws the sight away from the view of the surface into the distance. Therefore consider diligently the edges or boundaries of the former image: whether they remain clean, sharply cut, and consistently and uniformly drawn out across the whole surface, or not. If they appear uniform and clean everywhere, you have obtained the best polish in the lens; but if they are rough, pitted, torn, distorted, wavering,

and unsteady, then the polish laid upon the lens will be of little worth; for such lenses are led into a false appearance by uneven and bad polishing. Moreover, while in this way you look at the bright image falling upon the lens, by the same work you will see the lens itself and its edge either smooth, or uneven and as it were full of little caverns or grains of sand, and covered over with a kind of ash — as was sufficiently said in the first Rule. For I do not wish to repeat the same things here; nor to set down all the ways of examining. Practice, the master, will teach many things better.

You will best examine the goodness of a concave lens by means of a convex lens that is a segment of a larger sphere. For if you place these two lenses properly in a tube, and pass the Sun through them onto paper, the ray of the convex lens will illuminate the concave lens, and at the same time will carry down onto the paper set before it whatever is faulty in it. In this way I have detected the blemishes of crystalline lenses; in this way too you will examine any convex lens whatever. And you will subject the concave lens to the same tests as the convex. Many other ways, which either practice or ingenuity will supply, I knowingly and willingly pass over.

And let this much, said in passing and briefly, suffice concerning the material and the figure of lenses. Now I proceed to their arrangement.

THE ARRANGEMENT OF LENSES in general, and what is necessary to it

CHAPTER XXI

It is not enough to have good lenses; a fitting disposition and arrangement of them is much more required. For just as a house is made of brick and mortared lime, yet a man who has sand, lime, and bricks does not thereby have a house — rather, skilled construction is needed — so, if you have lenses, it is altogether necessary that you arrange them in due proportion. Now one arrangement of lenses is immediate, another mediate. The former consists in setting the lenses properly in tubes — of which in its own place. The latter consists in fitting the tube itself, together with the lenses, aptly to the paper for receiving the Sun, and in fixing the paper suitably for receiving the Sun through the tube.

[Column II, p. 103] Therefore, whoever wishes to observe the Sun admitted onto paper without error must above all be furnished beforehand with everything that is chiefly necessary for supporting the telescope [Telioscopium]. Otherwise, neither the best tube, nor the best lenses, nor perfect knowledge, nor any dexterity of practice will be of any help toward great desiderata. Therefore, to comply as far as I can with the wishes of the practical Observer, before I run through, one by one and in special detail, the reasons for placing the paper, for marking on it the observatory Circle, for setting the tube on the observing frame, and for disposing the lenses in the tube, I shall now explain more fully the observing Machine itself and its parts — which in the earlier Chapter VII I sketched with a rougher pen — so that anyone may, of the things I bring forward in the later books, if he pleases, undertake a solid examination and trial of his own, and may learn to place his trust neither in me who write, nor in another who tells him, but in his own experience, and so in the thing itself.

FULLER EXPLANATION OF THE VERTICAL OBSERVING MACHINE and its parts

CHAPTER XXII

In the appended Diagram, marked N. I, everything is set forth one by one that pertains to the apparatus by which the solar phenomenon is observed. Thus: A denotes a sheet of paper assigned to receive the solar ray. The paper-bearing Tablet, B, is a small board, of equal thickness throughout, flat and well planed on both sides, with its surfaces as white as possible — because whiteness aids the

paper. For white thinly laid upon white appears whiter: paper laid over a white board therefore becomes whiter to the eye, as experience testifies, and so much fitter for receiving the solar image. For although sunspots [Maculae] present themselves, even as black, on any object-surface whatever, as experience confirms, yet they nowhere do so more distinctly than when they have found a white lodging. And so, if the paper-bearing Tablet is not white of itself, I am accustomed to whiten it by laying one sheet of paper over another. This little board, the lighter it is, the more manageable it will be; hence it ought not to be

of great thickness, yet not so thin that it warps: for in that case it would cut the solar cone not in a circle, but in some other faulty figure, and so would present distorted projections of the sunspots — which must be carefully guarded against. In the middle, at B, it has a round hole, larger [on one side] and smaller [on the other], to the measure of an iron nail, grooved and headed, F. And the larger [opening] will indeed correspond exactly to the head of the nail, sunk into the little board as deep as the thickness of the nail's head; the smaller will match the thickness of the nail's shaft. This is done so that the paper-bearing Tablet can be turned in a circle about this nail as an axis, on account of the daily motion of the sunspots. Hence, if the corners of the Tablet should hinder its turning, they can be cut away, into the form of an octagon, or finally a circular one. The head of the nail is sunk into the thickness of the little board so that nothing projects from it, but it lies precisely flush and level with the surface of the Tablet, lest the paper afterward to be fixed over it suffer any inconvenience. The paper fixed to the little board is shown in figure C. The fixing of the paper must not be done over its whole extent, nor with any strong glue, but at the corners and marginal parts, where needed, with soft wax or slow-drying gum, so that the paper is not wrinkled or pitted, but fully and flatly stretched, so that it can conveniently be refixed once the observations are complete.

The Foot and Head of the whole observing support is one and the same beam, D, a parallelepiped thick enough to hold the back of the apparatus, and everything else, firmly and immovably. It is quadrangular, longer on one side, well planed on both. Its exact height or length is left to each person's discretion, according as one wishes to use long or short tubes, large or small observing circles. Its lower part is called the foot of the whole bier [Feretrum] or instrument, because it alone carries the observing Machine committed to it, and alone occupies the lowest part of it, and alone, joined to the floor, walks about, and by its motion directs the instrument's eye toward the Sun. The upper part of this beam I call the Head, because it is raised above all the other parts, and supports the paper-bearing

Tablet, and admits the Sun into it, through the tube as though its own received eye. It has two holes, of which

[Column II, p. 104] the upper, smaller and round, is fitted to the nail, F, so that it may support the hanging Tablet, C — the sort of thing you see done at E. From the back, a plate and socket by the nail F, fixed onto the grooved shaft of the nail, are inserted, so that they hold the paper and the Tablet, E, fixed, yet — as is proper — able to turn. G H is the beak, that is, the back or spine of the Machine, necessary for supporting the tube; to it accordingly are joined two wooden clamps, I and K. What the joint is like you can sufficiently make out at M — for the clamp K must be inserted there — and both clamps rest on the beak G H, at I and M, at right angles; not indeed of necessity, but for the convenience of the construction. Nor would I have you bound to just two such clamps: if use and necessity require more, according to the size or length of the telescope [Telioscopium], you may employ as many as you wish. The back, then, G H, so fitted that it forms a perfect parallelepiped, is inserted at its other end at H — rightly cut for the purpose — into the larger hole, and below it, D; and into projections from the back are inserted two wedges, L, serving in place of bolts, so that the whole Machine, most firmly bound together, in no way gapes, wavers, or stands unsteady, but when one part is moved, all move together. The beak must be joined to the foot, D, at exactly right angles.

N is the underlying footboard, thick enough and neatly planed, so that, in place of a rough or pitted floor, it may support the foot, D, easily movable.

O is the support of the beak, wrought in the figure of an isosceles triangle, sharpened at the vertex and at the angles of the base by iron [ferro; printed *terro*] fixed in front: there, so that it may hold the overlying beak fast when grasped, and thence render it turnable as from a center; here, so that the whole instrument, resting on the floor, may be raised and lowered. For by the combination of these two motions, and by the benefit of the centers, the whole machine becomes turnable in every direction, and control of the solar motion is achieved without labor.

[Margin: Fitting of the tube into the observing Machine.]

In this way, then, onto the finished Machine, P Q R S T, the tube is set, aptly disposed at f g by the clamps R T, so that the axis of the tube, the axis of the lenses enclosed in the tube, and the axis of the solar cone are one and the same line...

Rosa Ursina — Book II, Cap. XXII–XXIII

Cap. XXII (continued) — The Helioscopic Machine

Diagram. A full-page engraving [labeled N. 6 at the upper right] displaying the Helioscopic Machine "with its parts" (*Machina Helioscopica cum suis partibus*). The upper band is a horizontal ray-diagram of the optical tube: at the left a convex lens (with axis-points **a**, **c** above, **s** on the axis, **b**, **d** below), rays converging through the mid-points **e**, **h**, **f**, to a concave lens at the far right (**K**, **m** above, **o** on axis, **n** below). Below this, the machine's parts are laid out and lettered individually:

- **E** — a large framed square panel (a board within a board).
- **Caput** ("Head") — with a small target-ring symbol; below it **D** (a dark bar).
- **Pes** ("Foot") — the standing support of that column.
- A circular aperture-disk: **a** (top), **d** (left), **C** (center), **e** (right), **b** (bottom).
- **B** — *Tabella chartifera* ("the paper-bearing tablet"), with a small target-ring symbol.
- **A** — *Charta* ("Paper"), a square sheet.
- **F** — the nail/screw, shown with two washers or ferrules (rings **O**, **O**).
- **Retinacula** ("Clamps") — two U-shaped brackets, lettered **K** and **I**.
- **Cunei** ("Wedges") — wedge blocks, lettered **L**.
- **Dorsum seu Rostrum** ("the Back, or Beak") — a long rail/beam, lettered **G**, **M** (near the left), with **I** and **H** (a slotted block at the right end).
- **N** — *Suppedaneum* ("Footboard"), a textured rectangular base.
- **O** — *Fulcrum* ("Support"), a triangular trestle.
- The assembled machine at the bottom, standing on a tiled floor: the head/tube unit **P**, the board **R**, and **S**, with the clamping nut **T** on its threaded rod; small labels along the tube read **s**, **f**, and at the eyepiece end **h**, **V**. [Several of the smallest tube-labels are hard to resolve; see QA.]

(Bottom of the page, in two columns of letterpress continuing Cap. XXII; the centered "I." / "II." are column-reference marks, not sections.)

a straight line **e f g h** — drawn through the centers of the solar base and of the observing circle **a d b e**, and likewise advancing through the centers of the lenses and of the Sun, standing perpendicular to their planes — with its length **i K m** parallel to **Q S** of the spine.

[Margin: The arrangement of the lenses in the tube.] As for what the arrangement of the lenses enclosed in the tube is, this is plain to the eye in the tube **a e m n f b**, in which the convex lens **c, d** is inserted into the larger reed **a c f b**, and the concave lens **K l m n** into the smaller reed **e K l f**. The Sun, received through the tube — **p**, whose radiant axis **p g** runs straight in line with the axis of the tube **g h o** — passes from the center of the Sun **p** through the centers of the lenses **i** and **o**, to whose planes it stands perpendicularly erect. And this is the necessary and sound constitution of any tube or telescope [*Telioscopium*] whatever.

But in truth, since these matters are very general, and meanwhile, out of them, concerning this

conclusion of Cap. XXII

or that particular tube no fixed and stable judgment can be reached; nor can the power and quality of the telescope be drawn out; nor the distance of the paper from the convex lens be known; nor the nature of one lens relative to another be discerned, nor the interval determined. Moreover, it is one thing when the Sun is admitted through the tube onto the paper, and another when the eye is sent out through the tube toward the Sun; and yet the use and practice of these arises a thousand times over in this undertaking. The knowledge of them, too, is very useful in itself and here altogether indispensable, and the kinship and mutual bond between the eye and the tube, and between the tube and the eye, is truly wonderful. For all these reasons, matters that would otherwise have had to be brought in piecemeal and in many places, confusedly and often tediously, as this work proceeds — and perhaps taken up again with distaste — I judged it worth my while to set forth here all at once, gathered together but concisely.

THE EYE AND THE TELESCOPE, and a comparison of the telescopic lenses: the wonderful conspiring-together of Nature and Art.

CAP. XXIII.

So that this marvelous and discordant concord of nature with art might be better examined by everyone, I judged it necessary to press so useful a matter not merely upon the ears in words, but rather upon the sight in figures. Here, however, I give warning: by the word *nature* I mean everything that happens in a healthy eye and from it, by the guidance of nature, without the aid of any art; while by the term *art* I wish to be understood whatever assists the sight, by the application of visible species, toward seeing better. Next, you should also know this: in the visual lines or rays bent by refraction from the lenses or from the

crystalline humor, no very exact account has been kept, since the things adduced here for the sake of example are not so subtly precise. For refraction is not taught here of set purpose; on that subject, see my *Oculus* [Scheiner, *Oculus, hoc est: fundamentum opticum*, 1619].

In the attached figure, marked [N. 3], you have set out seven different relations and comparisons of the tube with the eye, and of the eye with the tube, in the receiving and presenting of visible species. In all of them you see the eye cut through the middle,

(right column, "II.")

together with its coats and humors. In the five artificial ones you have a section of the tube through the axis and the centers of the lenses; in the last two, only the section of the lenses and apertures is presented. Now let us come to the explanation of each.

[Margin: The eye is a natural tube; the tube is an artificial eye.]

The first comparison, set up under **A.1** and **A.2**, presents the configuration of the tube that simply and in every respect reproduces the eye. For in figure **A.1** the Sun set opposite, **a b**, sends a cone of rays, **a c b**, through the convex lens **d** enclosed in the tube **e f**, into the dark chamber **g h**, ending in the base **i K**, received by the paper set opposite, **l m**. This whole configuration of the tube, **e f g h**, is very like the structure of the eye, **n o p**, as regards the reception of visible species. For the Sun **q r**, in like manner, transmits its cone of rays **q s r** — first through the horny coat (cornea) **t**, then through the crystalline humor **u x** — crossed at the point **s**, to the bottom of the retina, **y z**. In the same way the same Sun **a b**, through the open orifice of the tube **α β f** (which represents the horny coat **n t p**), proceeds to the disk **γ δ ε**; and striking there, it admits no more rays than the open central circlet **δ ε** permits. So the eye receives only as much of the solar ray as the uveal coat **α θ χ** — which corresponds to the disk **γ δ ε** — receives through its own aperture **α θ**.

[Margin: The artificial admission of visible species through a single convex lens.]

The whole chamber **g h** has no light except the ray **a i K b** admitted into it; so the vault of the eye **λ μ** is dark. And just as light let in from the other side into **g h** obscures the image **i K**, so other lights that enter the eye dull the image **y z** to the sense — if that image is of something other than the Sun. For it is only by accident that the Sun's species is not struck out by another: namely because in fact no

stronger one is present; but if one were present, the Sun's too would certainly be obliterated.

Therefore, as I said, in the artificial admission of visible species through a single convex glass into a dark place, and in their most delightful representation on the paper set opposite, we see the genuine and most vivid image of the eye; and the admission of visible species through a single convex lens is nothing other than an artificial imitation of the eye in presenting those same species to the power of sight. For the whole orifice of the tube $\alpha \beta f$ reproduces the horny coat $n o p$. The watery humor $n t p \theta \chi H[?]$ — all the cavities within the horny coat, and

Cap. XXIII, comparison plate

Diagram. A full-page comparison plate [captioned across the top: *Artis et Naturae, Tubi et Oculi, in speciebus solaribus praesentandis consensus. N. 3.* — "The agreement of Art and Nature, of the Tube and the Eye, in presenting solar species. N. 3."]. It is a grid of **seven horizontal rows** (lettered **A–G** / numbered **1–7**). Each row runs left-to-right: on the **left**, the *Art* side — a lens-and-tube apparatus casting rays onto a semicircular "flame-burst" figure (the image on paper, with corner-marks **a** top, **b** bottom); in the **center**, the *Nature* side — the eye shown in section as a large labelled circle; and on the **right**, a second semicircular flame-burst figure. Each row carries paired captions above (*Ars ... Natura*) and below (*Praesentatio ... Visio*):

Row / No.	Left (Art) label	Above (left / center-right)	Below (left / center-right)	Right label
A / I (1)	A.1	Ars / Natura	Praesentatio euersa; / Visio recta.	A.2
B / 2	B.1	Ars / Natura cum Arte	Praesentatio euersa; / Visio recta.	B.2
C / 3	C.1	Ars / Natura cum Arte	Praesentatio recta; / Visio euersa.	C.2
D / 4	D.1	Ars / Natura cum Arte	Praesentatio euersa; / Visio recta.	D.2
E / 5	E.1	Ars / Natura cum Arte	Praesentatio euersa; / Visio recta.	E.2
F / 6	F.1	Ars / Natura manca, cum Arte	Praesentatio euersa; / Visio recta.	F.2
G / 7	G.1	Ars / Natura manca	Praesentatio	G.2

Row / No.	Left (Art) label	Above (left / center- right)	Below (left / center- right)	Right label
		cum Arte	euersa; / Visio recta.	

("Natura manca" = "defective Nature." Row C is the exception, where the presentation is upright (recta) and the vision inverted (euersa).) The eye-sections carry small interior point-letters (among them λ, s, o, n, m, p, t, x), and the tube-apparatus at the left of each row carries small lens- and axis-labels (among them α, β, d, ξ, f); these interior labels are at the limit of legibility and are not all resolvable — see QA

(Bottom of the page, two columns; the "I." / "II." are column-reference marks.)

and the air α γ d ε f represents the crystalline humor that fills the space, occupying everything right up to the lens d. [Margin: The effects of a single convex lens are applied to the eye.] The paper or leather disk γ δ ε imitates the uveal coat n ξ α δ p. And just as light and the species of things pour themselves freely through the whole cornea over the outer surface of the uvea, n α δ p, so through the whole capacity of the tube α β f they flow

(right column, "II.")

onto the anterior face of the ring, γ δ ε. But just as the uvea then, by its opaque interposition, divides the whole eye into an anterior and a posterior part, into an illuminated and a darkened portion, so the little plate γ δ ε separates the tube into an outer and an inner, into a bright and a dark portion; and it makes its aperture δ ε like the pupil α θ.

Cap. XXIII (continued)

after which, in the eye the inner part of the watery humor rests upon the crystalline humor, and in the tube the air rests upon the convex lens d — which wholly rivals the crystalline humor u x in position, shape, place, and function. Then the air h c m in the tube takes the place of the vitreous liquid λ s μ; and the wall of the darkened chamber h g, together with the paper set opposite the images, l k i m, [answers to] the bottom of the eye n o p together with the retinal coat n z y p. And in these things there is the greatest likeness.

Now, just as in the natural perception by the eye of the objects set before it many varieties intervene, so it happens likewise in their artificial transmission onto the paper. For:

[Margin: The properties of direct gaze, and of the admission of species, are alike.]

First. Just as the eye, held motionless all at once, beholds — other things being equal — more clearly and distinctly everything that is turned toward it directly along or near the axis than the things that recede toward the sides, so the species carried through the lens onto the paper are the more distinct the nearer they are to the axis, and the more blurred the farther from it — even if the distances are set equal. The reason is the same as before: because in both cases — in the lens **d** as in the crystalline humor **u x** — the species that glide in along and beside the axis undergo little or no refraction, and are therefore painted exactly. And whatever the picture of the species is in the eye, such too is the vision that follows: clear vision follows a clear picture, dull vision a dull one.

Second. Just as the eye, held motionless and unchanged, perceives with unequal vision objects set at unequal distances from it — some clearly and distinctly, others obscurely and confusedly — so too the convex lens, held motionless, casts onto the motionless paper the species of things placed outside with a quite different effect, according as they are near or far. For if the nearest are presented clearly and distinctly, the farthest will appear the worse; exactly the same happens in the eye at a single gaze. Conversely, if the farther objects are well painted on the paper, the nearest will fare worse; the same occurs in the eye at a single look. The reason, in both cases, is the same as the first: because near objects cast a distinct base of the species — which presents the visible things in order — farther from the lens or crystalline humor, but distant objects cast it nearer. Therefore, since in the tube the paper receives that base, and in the eye the bottom of the retina, it is impossible that at one and the same time

(right column, "II.")

either the paper or the retinal coat should receive both bases, the nearer and the farther; for at one and the same time it cannot be both more and less distant from the lens or the crystalline humor, but has only a single distance. Hence:

Third. Just as the eye, turned to lateral objects by circular motion alone, discerns them very well — objects first perceived with a dulled gaze and first seen directly and distinctly it now grasps only with great difficulty and confusion from a sidelong view — so, in the admission of species, if the paper together with the lens and the axis is rotated about the center of the lens, so that the lateral objects become direct and those that were previously direct become lateral, the latter will be seen blurred, the former sharp, and so on. The reason, as with the first, is drawn from the absence or the smallness of the rays' refraction.

Fourth. Just as the eye, in order to see distinctly objects set far apart, either shortens or lengthens the distance of the retinal coat from the crystalline humor so as to view near objects distinctly, so too, if the paper is brought up to a motionless lens, **l m**, distant objects — which before appeared only confusedly — will be painted distinctly upon it; and conversely, if the same paper is moved far from the convex lens, things placed near will be seen distinctly, which at a shorter distance of the paper had appeared confused; or else lenses of a different shape will have to be applied. The reason, examined: because distant objects arrange their species onto a common base that is less distant, near objects onto the same base set farther off. Therefore, for the eye to perceive the said objects well, the retinal coat must coincide with the common base; and hence a greater or smaller advance and withdrawal of it is required — just as also a greater or smaller bringing-near or drawing-away of the paper from the lens.

[Margin: The crystalline humor is sometimes equivalent to many lenses.]

Fifth. But if, while the eye either brings the retinal coat toward the crystalline humor or moves it away, as has been said, that same humor is at the same time thinned or gathered into a ball by the tightening or relaxation of the ciliary processes on which it hangs — which I hardly doubt happens in the eyes of many — then that same crystalline humor is equivalent to several lenses in the tube. For when more globular it answers to a lens that is a segment of a smaller sphere; when flatter it is likened to a lens of a larger sphere; for in both cases equal

Diagram. A full-page engraved comparison plate, captioned across the top: "*Artis et Naturae, Tubi et Oculi, in speciebus solaribus praesentandis consensus. N.º 3.*" — "The agreement of Art and Nature, of the Tube and the Eye, in presenting solar appearances. No. 3." It is a grid of seven horizontal bands (rows), each running left-to-right through the same four zones:

1. **Far left — the tube (Art).** A long optical tube shown in section, with its lens elements; readable letters along it: **h** (top of the aperture bar), **α** [?], **β** [?] at the first (objective) lens pair, **d** at the central convex lens, **ε** [?], and **f** at the lower aperture. In rows that add a second element, a concave/convex lens inside the tube is marked **v** (top) and **ξ** (bottom).
2. **Center-left — the projection (Art).** Dotted rays converge from the tube onto an upright screen bearing the flame-like image of the Sun; the screen's top edge is lettered **a** and its foot **b**. Above this zone stands "**Ars.**" ("Art"), the figure tag [**letter**].1., and beneath it "**Praesentatio euersa**;" ("Presentation inverted") or "**Praesentatio recta**;" ("Presentation upright").

3. **Center — the figure number**, a large numeral uniting the two halves of each row: **I, 2, 3, 4, 5, 6, 7** (row 1 set as Roman **I**, rows 2–7 as Arabic).
4. **Right — the eye (Nature)**. A large sectioned eye receives rays at the front point **o** (cornea/pupil); interior letters readable on the tile include **λ** (top), **s** (center), **n, x, m, p** (foot), with **u/t/θ/e** less certain [?]; the retina is the hatched rear surface. In the "with art" rows an external spectacle-lens (concave or convex) is added in front of the eye, marked **o** (top) and **π** (bottom); dotted rays then run to a further screen at the right edge lettered **q** (top) and **r** (foot). Above this zone: "**Natura.**" / "**Natura cum Arte.**" / "**Natura manca, cum Arte.**" ("Nature" / "Nature with Art" / "Defective nature, with Art"), the tag [**letter**].2., and beneath it "**Visio recta.**" ("Vision upright") or "**Visio euersa.**" ("Vision inverted").

Row-by-row labels and captions:

- **Row 1 (A / I):** Ars — A.1 — Praesentatio euersa; || Natura — A.2 — Visio recta.
- **Row 2 (B / 2):** Ars — B.1 — Praesentatio euersa; || Natura cum Arte — B.2 — Visio recta.
- **Row 3 (C / 3):** Ars — C.1 — Praesentatio recta; || Natura cum Arte — C.2 — Visio euersa.
- **Row 4 (D / 4):** Ars — D.1 — Praesentatio euersa; || Natura cum Arte — D.2 — Visio recta.
- **Row 5 (E / 5):** Ars — E.1 — Praesentatio euersa; || Natura cum Arte — E.2 — Visio recta.
- **Row 6 (F / 6):** Ars — F.1 — Praesentatio euersa; || Natura manca, cum Arte — F.2 — Visio recta.
- **Row 7 (G / 7):** Ars — G.1 — Praesentatio euersa; || Natura manca cum Arte — G.2 — Visio recta.

Many of the small interior Greek/Latin point-letters on the tubes and eyes cannot be resolved individually at this resolution; the ones committed above are those legible on the scan, and the remainder are flagged. **More than two labels are flagged [?].**

[The text of Cap. XXIII continues; the numbered points of the eye/telescope analogy resume from "paria" at the foot of the previous page.]

equal or similar results will follow in the painting of the appearances. A rounder humor will call for shorter distances for the base of the picture, and so will a more spherical lens; a broader, flatter humor will allow greater recessions of the

common base, and so will a flatter lens. In this case a single crystalline humor is the equivalent of many lenses.

Sixth. Just as the eye, with everything else unchanged, sees the same object differently at one distance and another — very clearly and distinctly at a proportionate distance, but only with great difficulty and poorly at a less proportionate one — so every lens has one definite distance from a given object at which it casts that object's appearance most perfectly onto the paper; at other distances, whether greater or smaller, it renders the same appearances more dimly. The effective reason: an object at a near distance forms the common base farther off, and at a far distance forms it nearer, both in the eye and in the convex lens. Hence there comes at last a point — as experience testifies — where nothing perceptible is formed, all the appearances being cast out by the lens's refraction. Hence—.

Seventh. Just as an object at some extremely remote distance is finally not seen at all by any eye whatever, and at a very near one is not made out, so in the transmission of appearances through the lens there comes at last a recession so great that the appearances vanish entirely on the paper, and an approach so great that they cannot be distinguished. The reason, in both cases, is the same one already given in the other cases up to now: the common base, on which the appearances are represented in good order, falls outside the retina in the eye, and outside the paper held before the tube or lens — for far-off objects, on the near side of it; for too-near objects, beyond it.

Eighth. Those who are long-sighted and are called presbyopes are endowed with a crystalline humor that is fairly broad and lens-shaped, and a flatter convex lens — a portion of a larger sphere — imitates it. Those who are short-sighted and are called myopes have acquired a more spherical crystalline humor, composed of segments of smaller spherules, and convex lenses that are portions of smaller spheres imitate it to the life. Yet it is more credible that the segments of the crystalline humor gradually pass into shapes other than spherical.

[Margin: With what sort of crystalline humor presbyopes and myopes are endowed.]

And from all this it is clear how vividly the transmission of appearances through a convex lens, by imitating the natural organ of the eye in every respect, reproduces it. The reason is almost the single and principal one given before: the similar and proportionate refraction of the appearances through the crystalline humor and through the lens. For this refraction, by bending the rays — which

would otherwise flow apart at random and to no purpose — forces them into order, and so arranges them onto a single base, so that a most beautiful painted image of the object results. I have treated this matter more fully in my *Oculus* [Scheiner, *Oculus*], which I would ask you to consult. In this one respect a certain dissimilarity is found: the paper stretched before the lens is flat, whereas the retinal tunic is concave. If the paper were concave homocentrically with the lens, the transmission of the appearances would be more like the picture in the eye, as experience testifies. For this too the Most Serene Archduke of Austria, Maximilian [Maximilian III of Austria], of most pious memory, wished to test — as he did countless other things, out of his singular devotion to mathematical matters. In his palace at Innsbruck [Oenipontanum] he built an enormous globe, of a radius of many feet, into which we would enter and admit, through a convex lens, the appearances of external things onto its concave wall; and for that very reason these were seen well and distinctly composed, in a far more orderly arrangement and over an ampler space, than if they had fallen onto some flat surface. Hence it is clear with what great kindness God, the fashioner of the eye, provided for its nature: he willed the picture of the appearances to be arranged not on a flat but on a concave tunic, so that in this way sight might be the better served — though I judge that its concavity too is not spherical, but endowed with some more suitable curved surface.

Moreover, that the crossing [decussation] of the rays takes place before the image of the object is formed on the retina, *y z*, I have demonstrated not only in my *Oculus*, by many most evident experiments and arguments, but I also saw most plainly in a human eye here at Rome in the Jubilee year [1625], when, the sclera having been scraped away at the back of the eye, the light of a candle let in through the pupil fell, with its rays crossed, onto the retinal tunic — a thing I had often observed in the eyes of many animals. This dissection of the eye was carried out by me in the presence of the Reverend Father Niccolò Zucchi [Niccolò Zucchi], undertaken as a favor to me. In it, two further points that some had begun to call into question I both saw and showed to others. The one: that the corneal tunic is not [set]

Diagram. A second impression of the same seven-band comparison plate "N.º 3" that appears on p. 153. The caption, the seven rows (A/I through G/VII), the "Ars. / Praesentatio euersa (or recta);" and "Natura [cum Arte / manca cum Arte]. / Visio recta (or euersa);" captions, the central figure numbers **I, 2, 3, 4, 5, 6, 7**, and the tube-and-eye lettering scheme (**h, α[?], β[?], d, ε[?], f, v, ξ** on the tubes; **o, λ, s, n, x, m, p**, external lens **o/π**, and right-hand screen **q/r** on the eyes) are identical to those catalogued for fig-p153-1. Small interior point-letters are again below

reliable resolution and are flagged there. (more than two labels flagged [?]; also to be reconciled against fig-p153-1 as a duplicate impression).

[The text of Cap. XXIII concludes; page 156, folio 112.]

directly on the axis, but departs from it considerably to one side — exactly in the way I taught both points in my *Oculus*.

ADMONITIO. [A Note]

Before I proceed to a fuller explanation of this scheme and of the figures contained in it, you must be advised, reader — as I also did in passing in the previous chapter — that the rays and lines drawn from the Sun to the lenses and the eye, or from these back to the Sun, have not been rendered at the angles that the theory of refraction would require, but for the most part in a straight course. I did this because here I am not treating refraction expressly, and a multitude of angles would have bred great confusion; for my purpose it is enough to sketch the final cone of refraction after a fashion and to explain the rest in adequate words. For the other matters bearing on refraction I have explained abundantly in my *Oculus* and in the *Refractiones Caelestes* [Scheiner, *Refractiones Caelestes*, 1617].

AS THE TUBE FOLLOWS THE EYE, SO the Eye in many respects follows the tube by art.

CAP. XXIV.

In the first figure you saw how the Tube, by fitting it with a convex lens, imitates the Eye in fixing visible appearances — that is, art imitating nature. Now in what follows you will see by what means Nature calls art to its aid, and the Eye follows the tube.

FIGURE II. B.1. & B.2.

In this second figure, marked B.1 and B.2 — that is, B first and B second — you have depicted the image of the inverted tube by itself, and then the eye's approach to it, according as the tube alone renders the appearances it has received. To its convex lens *d* is added a concave lens *v ξ*, by whose help, through refraction, the cone *v c ξ b* is made longer; and therefore the base at *K*, on which the distinct picture is formed, is pushed farther from the lens *d*, nearer to the paper *l m*. And because the angle at the intersection *c* is made more acute and the

base i K is contracted, the image becomes smaller. Exactly the same things happen in the representation of appearances

in the eye, s, as depicted at B.2 — that is, B second — where art is summoned to nature's aid, as the inscription "Nature with Art" declares. For what art alone accomplishes with the inverted tube, nature does in the eye if a concave eyeglass is taken up from outside—. This is used only by those who are called myopes and are endowed with short sight.

[Margin: Why do myopes use concave eyeglasses?]

For since they themselves carry [gestent?] a crystalline humor conglobated from the segments of a small sphere — whose nature is to force the rays it receives, by refraction, into a short space — it follows that they always paint a distinct and most accurate image, but one that very often does not reach the formal sense-organ of vision, namely the retinal tunic, but is completed within the vitreous humor. And so it happens that the eye perceives the object either not at all or very confusedly, because the base — that is, the section of the common radiant cone, on which the appearances converge into a distinct picture — either does not reach the retinal tunic at all, or reaches it only when the rays are already confused among themselves. But the eye perceives nothing except what the visible appearances present, and in the manner in which they present it: if they are presented clearly, it sees clearly; if distinctly, distinctly; if confusedly, it sees confusedly. In myopes, therefore, since distant objects by themselves gather their rays into the common base sooner than near ones do, it comes about that such people ordinarily see things placed close at hand best, and distant things very dimly — because the former shape their appearances onto a farther base [?], the latter onto a nearer one [?]; and so the former reaches the retinal tunic [?], while the latter is smothered in the vitreous [?].

[Margin: The likeness between the inverted tube and the eye made potent [potentis] by a concave lens.]

Since, then, the concave lens has this property — that it spreads the rays by refraction, and by this, together with the convex lens, drives the appearances toward the retina — it happens that myopes, once they have adopted such an eyeglass, are indeed greatly helped to see distant things well, but nevertheless under a smaller apparent size. And this smallness is because the angles at the crossing are made smaller; the good seeing, on the other hand, is because the common base is pushed all the way to the retina, out of the vitreous humor. Similar things happen with the convex lens d, for this stands in the place of the

crystalline humor. If, carrying a distinct image of the appearances, it fails to reach the paper set opposite because it is too far from the lens, it will reach it once some concave lens is fixed in front, between the lens and the object. Here, then, take the following rules.

Rosa Ursina — Liber II, Cap. XXIV–XXVI (batch 040)

Diagram. A full-page engraved comparison plate, engraved caption at top: "*Artis et Naturæ, Tubi et Oculj, in speciebus solarib, præsentandis consensus. N.º 3.*" — "The agreement of Art and Nature, of the Tube and the Eye, in presenting solar images. No. 3." The plate is ruled into seven horizontal bands (rows A–G). Each band has three zones read left to right:

- **Left zone ("Ars." — Art):** a telescope/tube in cross-section, drawn with an objective at right and an eye-lens element at left; between them a second corrective element that changes row to row (row A: none; row B: a concave/biconcave element; rows C–E: a biconvex or shaped lens; rows F–G: a small lens with the tube foreshortened). Below each: the presentation label. Row figure-labels **A.1, B.1, C.1, D.1, E.1, F.1, G.1**.
- **Center zone:** a dark semicircular screen (the projected solar image) marked at top **a** and at bottom **b**; and a large centered numeral — **I.** (row A, Roman), then **2., 3., 4., 5., 6., 7.** (Arabic).
- **Right zone ("Natura" — Nature):** a sectioned eyeball, in most rows fitted with an external corrective lens ("cum Arte" — with Art). Row figure-labels **A.2, B.2, C.2, D.2, E.2, F.2, G.2**, with an outer semicircular screen marked **q** (top) and **r** (bottom).

Right-zone headers and outcome labels, per row:

- Row A: "Natura." / "Visio recta." (upright vision — naked eye)
- Row B: "Natura ... cum Arte." / "Visio recta."
- Row C: "Natura ... cum Arte." / "Visio euersa." (inverted vision)
- Row D: "Natura ... cum Arte." / "Visio recta."
- Row E: "Natura ... cum Arte." / "Visio recta."
- Row F: "Natura ... manca, cum Arte." / "Visio recta." (a *defective* eye, with Art)
- Row G: "Natura ... manca cum Arte." / "Visio recta."

Left-zone outcome labels: "Praesentatio euersa;" (inverted presentation) for rows A, B, D, E, F, G; "Praesentatio recta;" (upright presentation) for row C.

Interior point-letters are small cross-reference labels. On the tube (Ars) side I can read, along the lenses and tube wall: **h, e, k, α, β, d, ε, ξ, f, m**. On the eye (Natura) side, along the crystalline body and retina: **o, n, s, λ, μ, χ, t, ε, φ, p**; on the external corrective lens: **o, ξ, π**. Many of the interior Greek/roman point-letters are at or below legible size on the scan and cannot all be resolved with confidence [?]. Full interior-label inventory

[This plate is an impression of the "N.° 3" plate. Per the handoff, impressions of plate N.3 also appear on the two preceding openings; reconciliation should confirm whether this is a third impression or the correctly-placed reference figure for Figura tertia.]

[Margin: On the inverted tube — a practical rule.]

I.

First. Not every concave lens serves every convex lens; a definite proportion of curvature is required between them, with respect to the refracted rays by whose agency the images are elegantly rendered. It is the same in the eye: not just any concave eyeglass suits any given crystalline humor. Some humors are entirely opposed by every concave glass; to some, more sharply curved ones are better suited, to others less sharply curved — though this happens more or less by accident. For if the retinal tunic could be set forward or back at will, perhaps any eye could be accommodated to any glass. I say "perhaps," because in the case of the telescope both sense and experience seem to argue against it — and I do not now weigh out the reasons, since this belongs properly to the treatment of refraction, or of the optical tube.

Second. A concave glass proportioned to a convex lens, if it is applied properly toward the object, renders the image of the Sun perceptibly smaller, and requires a greater distance of the paper from the convex lens than had been needed with the convex lens alone. The same occurs in an eye fitted with a concave lens.

Third. If that same proportioned concave lens is moved from the convex lens toward the Sun, the Sun will always appear smaller and smaller on the paper, the farther the concave lens recedes. A concave eyeglass does the same for the eye.

Fourth. Keeping the same distance between the convex lens and the object, if two concave lenses are interposed in succession at the same interval — one sharper, that is of a smaller sphere, the other blunter, that is of a larger sphere, as regards

the concave-surface portion — the sharper will show a smaller Sun but will push the paper out farther; the blunter, a larger Sun at a shorter paper-distance. The same would happen in a myope's eye, if it had a mobile retina — and in fact it does happen for not a few people, whose humors and tunics have been endowed by nature, or by habit, with a workable temper.

COROLLARIVM.

From this one may conclude that an eye using a concave lens is nothing other than an inverted tube, composed of art and nature combined; **II.** and that an inverted tube is an artificial eye.

A FURTHER COMPARISON OF THE EYE WITH THE ARTIFICIAL TUBE, FROM THE USE OF THE CONVEX EYEGLASS.

CAP. XXV.

In Chapter 23 I compared the naked eye with a single convex lens enclosed in a tube, and showed the similar effects of each in presenting images; I did something similar in Chapter XXIV, concerning the inverted tube and the eye armed with a concave lens. Now I attempt something not unlike it, concerning the eye that enjoys a convex lens, and the tube compounded of two convex glasses.

Third figure, C.1 and C.2.

[Margin: Of a convex lens to a convex one there are three cases.]

In this third figure I represent, in the tube, two convex lenses; in the eye, the crystalline humor together with a single convex lens; and I show the similar effects of each. Here note that three cases are given by the position of the convex lens relative to the [other] convex lens.

The first is when the convex lens $v \xi$ is set so near in front of the lens d that the meeting or intersection of the rays refracted from it ($v \xi$) — that is, the base of the common picture — occurs not before, nor within, but after the lens d .

The second, when this same meeting-point of the lens $v \xi$ falls upon the lens d itself, that is, on the crystalline humor.

The third, when this meeting-point of the lens $v \xi$ occurs on the near side of the lens d , between the two.

The first and second cases I have not depicted here in the figure, because each is very easily obvious of itself, as will become plain from what I shall say; nevertheless I shall explain the properties of each, and the correspondences between the eye and the tube. I have brought in the third because it has more difficulty and novelty — and, I add, more usefulness as well.

The first case, by position, of a convex lens to a convex one.

[Margin: First case.]

So the first case, as I said, involves no art or difficulty in the trying of it, beyond setting some lens —

I.

— $v \xi$ so before the lens d that the intersection of the rays first occurs after the lens d , not before it, nor in it. This always happens if you join the one lens very close to the other (I except the segments of tiny little spheres, in which the meeting-points are very short — but these are not for this use). Therefore, wherever within the latitude of this case — which in flatter lenses tends to be large — you place the lens $v \xi$ in its proper position, you will always shorten the distance of the beautiful ray-picture, but you will make a larger image. That exactly the same happens in the eye, when a convex eyeglass is applied, is proved from this very fact.

[Margin: First case.]

For if a nearby object (as happens with the far-sighted) is seen either poorly or not at all, then with a convex eyeglass applied it will appear larger, clearer, and more distinct. The experience is plain and available to all, and was most usefully devised to help the far-sighted. Since they have a very broad crystalline humor, compounded of segments of a larger sphere, it comes about that objects — near ones especially — transmit their visible species or picture beyond the formal instrument of sight, which is the retinal tunic, and so elude the power of seeing. Yet the convex lens, by its arrival, makes that power attain its wish: for it recalls that species as it ranges too freely, and confines it within the prescribed limits — which likewise happens in the tube. On this matter, take the following practical rules.

[Margin: On two convex lenses — a practical rule.]

First. This same convex lens, placed nearest the earlier lens and almost touching it, yields on the paper — when the picture is duly caught — one larger and more

distinct than the picture projected onto the same paper by a single lens alone at this distance; and, of all the enlarged images, the smallest, but the clearest and most distinct. And the more it approaches from the lens toward the object, with the paper held motionless, it renders a picture always larger indeed, but gradually more confused and darker; and the largest yet most defective when it stands at the utmost capacity and distance of the first case. The same happens when a convex glass [speculare] is applied close to the eye. For, as experience attests, a nearby object poorly seen by the eye alone is best perceived when a convex eyeglass, proportioned to the sight, is applied, and at a greater —

[Margin: Two convex lenses do the same as the eye with one.]

II.

— size than before. But if you gradually move the eyeglass from the eye toward the object, the apparent visible size grows, while in seeing the clarity fails, until you come very close to the point of inversion. The reason, as before, is the same in both cases: the base of the common ordered picture — or, what is the same, the ordered picture or species — before a lens is fitted to the tube, or a convex glass to the eye, runs out beyond the retina in the one case, beyond the paper in the other; and so in both, the seat of the picture — which in the tube is the paper, in the eye the ground of the retinal tunic — lies too near the crystalline humor that paints it, or the convex lens. Hence an externally added lens, proportioned in both cases, first draws the image back onto the paper and the retina; and, by its withdrawal toward the object, calls it forward into the anterior region — enlarging the idea, indeed, but meanwhile also confusing it.

Second. Convex lenses — segments of larger and smaller spheres — in order to paint well on the paper when fitted to the tube's lens, either require different distances of the paper from the lens (the smaller requiring a smaller, the larger a larger); which for the most part cannot be done in the eye, since the retinal tunic is not so pushable or rollable. Or they require different positions in front of the lens, the paper being held motionless behind the lens — which is what usually happens in the eye. For by movement from the same point, many lenses fit that would otherwise have been useless. Indeed there is scarcely a convex lens that could not, by this remedy, be fitted somehow to the eye; for if they are portions of larger spheres, they are easily accommodated to the sight, as will be plain to anyone who tries; if of smaller spheres, the object must be held near the lens — and thus at last it will be discerned even by a myope.

COROLLARIVM I.

From these things I conclude that an eye fortified with a convex lens is a tube partly natural and partly artificial, adorned with two convex lenses — namely the crystalline humor and the convex eyeglass; whereas a tube furnished with two convex lenses is like a merely artificial, inanimate eye.

I.

COROLLARIVM I.

Hence a reason is given why convex eyeglasses rarely serve for the most remote objects: because the ordered species of these very rarely run out beyond the retinal tunic, and therefore do not need the recall that is brought about only by convex glasses.

CASE II IS EXPLAINED.

[Margin: Second case.]

The second case: when the other lens in the tube is so interposed that on the paper no object appears, but only bare light that has entered through the glass; or when the convex eyeglass recedes so far from the eye that, of the object formerly seen, the eye takes in nothing but light. This happens when — whether near the paper-lens, or near the eye's crystalline humor — the species formed by the other lens places its common base, that is, its ordered picture; or, what is the same, when the point of confusion reaches onto the paper and the retiform tunic.

And so in this case too the highest agreement of the eye with the tube is observed; nor is there any variety or remedy for this case. For in it the interposed lens or eyeglass spreads its common base into the crystalline humor and into the preceding lens, and there paints a most ordered and most perfect picture; which the preceding lens, or the crystalline humor, having in turn released it, confuses by refraction — either by dividing and scattering each single point of the whole visible and ordered picture over the whole common base, or by gathering the whole ordered image into any one sensible point of the common base. For the chaos of confusion is the same whether each single point of the visible and ordered species is dispersed over the whole common base, or the whole species and ordered image is poured into the individual points of the common base; for each part will always coincide with every other, and every part will be spread into the whole, and the whole gathered into each single part. Since this is most

certain, and yet perhaps appears incredible, take the following diagram and demonstration.

[Margin: The generation of the confused base.]

II.

THE GENERATION, NATURE, AND EFFECTS OF THE COMMON BASES — both confused and ordered — caused by several convex lenses, and their comparison with the eye, and the complete likeness of both, are here demonstrated.

CAP. XXVI.

Since this matter is in itself intricate and obscure, and has hitherto been set out by no diagram in any schematic drawing, it must here be unfolded on its own; for it will bring some light not only to the whole of Optics and to this work, but is by far most necessary for equipping a tube out of pure convex lenses and understanding it thoroughly, for erecting images, for microscopes, and for constructing many other marvel-viewing instruments [Thaumatoscopia]. Here, however, note that within the very thickness of the lenses I do not draw out the lines of refraction, but assume them made; for confusion in so tiny a space does not allow such minute detail.

So let the visible object be a b c. Since, then, each of its points emits from itself a radiant sphere, if three notable points a, b, and c are taken as an example, there is no doubt that from a infinite rays will fall onto the whole convex surface of the lens d e f — being, for example, a d, a e, a f, and all the possible intermediate ones — and thus the single point a is poured out over the whole spherical surface d e f.

In the same way the visible point b, with its radiant pencil b d e f b, occupies that same whole surface d e f. By like reasoning the point c sends a radiant cone c d e f c onto the very same surface. And since these radiations are not fantastic figments but most true, and are the natural outpourings or emanations of the visible species from the object, hence it is most true that any visible point is, together with any other, on the same surface d e f, and together with all at once; and all again, and each, gathered together with any one. This, without doubt, [produces] a confusion of the visible images —

[Margin: The generation of confusion.]

Diagram. A full-page engraved optical plate, numbered N. 4 at the upper right. Across the top runs the running title of the plate, its words interspersed with the three column-numbers (1, 2, 3): "**Figuræ tres ad casum secundum**" — "Three

figures for the second case." Beneath the plate a printed legend reads: "**Lentium Convexarum tam inter se, quam cum Oculo comparationes, proprietates, et effectuum in repræsentando similitudines**" — "Comparisons of convex lenses, both among themselves and with the eye; their properties; and the resemblances of their effects in representation."

The plate contains three vertical columns of ray-tracing diagrams (figures 1, 2, 3), each a stack of bi-convex lens shapes (and, in figures 2 and 3, a circle representing the eye), through which straight rays are drawn from an object at top down through successive refractions. Between each pair of surfaces the engraver has lettered the state of the image with the words *Imago confusa* ("confused image"), *distincta* ("distinct"), *confusa*, and *distincta*. Readable point-letters:

- **Figure 1** (left column): object points **a, b, c** at top; first lens with top vertices **d, e, f** and lower vertices **i** (printed to resemble "1"), **h, g**, labelled *Imago confusa*; second lens **m, t, K** (upper) / **n, o, p** (lower), labelled *distincta*; third region **q, s, t, u, r**, labelled *confusa*; bottom **x, y, z**, labelled *distincta*.
- **Figure 2** (middle column): object points **a, b, c** at top; first lens **d, e, f / i, h, g**, *Imago confusa*; below it a circle (the eye) labelled *distincta* with **m ... K** above and **n, o, p** within (the crystalline drawn with a dotted arc); at the foot of the circle **q, s, t, u, r**, labelled *confusa*.
- **Figure 3** (right column): object points **a, b, c** at top; first lens **d, e, f / i, h, g**, *Imago confusa*; second lens **m, t, K / n, o, p**, *distincta*; below it a circle (the eye) with **q, s, t, u, r**, labelled *confusa*; bottom **x, y, z**, labelled *distincta*.

The point-letters correspond directly to the running text of Cap. XXVI (the lens *d e f g h i*; the ordered base *K l m*; the base *s t u*; the retinal image *x y z*).

[Margin: The first station of confusion.]

produces the highest [confusion]. And this is why I call this jumble of every kind the **first station of confusion** — because it is the first of all, in that it proceeds and is produced from the object, just as in the object itself lies the first and most orderly station of these same things.

In the same way: because the whole object *a b c* sends a radiant cone or pyramid onto any point of the convex surface *d e f* — the base of this cone or pyramid being the visible surface of the object, *a b c*, and its vertex any point whatever, whether *d*, or *e*, or *f*, of that same surface — it follows once more that the whole object *a b c* must converge into a single point *d*, through the rays *a d, b d, c d*, and

all the intermediate rays of the radiant cone $a d c b a$. And in no other way will the whole object flow together into the single point e , by the rays $a e, b e, c e$, of the radiant cone $a e c b a$. By the same reasoning the same object $a b c$ will be gathered into a point, by the help of the radiant cone $a f c b a$. And so the whole object flows into the entire surface $d e f$, and into each of its possible parts; and the whole will be in the whole, and the whole in every part, with the highest confusion (as said before) of visible things and species — a confusion in which the intersection of rays and of cones begins to occur, yet not straight on but obliquely. For since most of the rays fall obliquely on the surface $d e f$, these same rays, refracted from their straight path because of the difference of the media, diverge somewhat elsewhere.

[Margin: The whole visible object is in the whole surface of confusion, and in every part of it.]

Therefore, since the convex lens $d e f g h i$ is denser than the air surrounding it on both sides, the rays that have arrived from $a b c$ will be refracted toward the perpendicular to that surface; but on passing out of it they will depart from the perpendicular. (This is a matter I do not treat here, but assume from the most certain and evident doctrine and science of the opticians, and have explained more fully in the *Fundamentum Opticum*, or *Oculus*.) And therefore $a d$, from d , will arrive at i — at i there are distinct points, but because of their small difference they are represented as joined — and hence let it come to K , the point of the convex surface $k l m$ of the lens $K n$. Thus the ray $a e$, through h , will tend by refraction to the same point K ; nor will the ray $a f$ choose any other station — it too, through g , will be refracted likewise to K . So the rays $b d$ and $b f$, refracted through i and g , will meet at l . In the same way all the rays of the point c — $c d, c e, c f$ — through i, h , and g , will by refraction be united into the single point m . And so all the radiant pencils of the single...

[Margin: The generation of the common ordered base.]

visible points — which had been confused in the lens $d g$, and scattered throughout it — are once again, by the help of that same refracting body, most perfectly ordered (though in an inverted position), and arranged in a most beautiful appearance, such as a painter might envy on paper but could not print to the life. The point a arrives with all its rays at K ; the point b is collected at l ; and the point c meets at m . And just as these three points, after the confusion and first intersection that occurred around the lens $f i$, were arranged in opposite parts with the highest order and elegance, so exactly must one reason about each and all the other intermediate points, between a and b , and between b and c .

[Margin: The common ordered base — what is it?]

Now this surface — the goal, or terminus, at which the coordination of each of these points runs out, and where it settles into a most shapely image — I call the **section, or common ordered base**, of all the radiant cones of the whole object. I call it this because into it all the radiant cones of the whole object expand, and dilate equally (at least to the senses), whereas before it and after it they intersect one another.

[Margin: The difference between the radiant cone of a single point and the radiant cone of the whole object.]

On this point, the following difference is found between the radiant cones of the whole object and the radiant pencils of the single points: they always proceed by opposite paths and effects. For where the whole base $a b c$, through the individual cones $a d c$, $a e c$, $a f c$, unites into the single points d , e , and f , there the individual points of the base — a , b , and c — spread out into the whole surface; and hence arises the chaos of species. Conversely, when the individual bases of the radiant pencils, $d e f$, again unite (a second intersection having been made) into the single points K , l , and m , then the radiant cones of the base $a b c$, from their vertices d , e , and f , dilate crosswise, each into its own radiant cone, pitching camp at one common base $K l m$. And hence a good order arises once more, and a distinct position and place of the single points; because the whole base $K l m$ answers only to the whole visible object $a b c$, and the individual points of the base — K , l , m — only to the individual points of the object, a , b , c . For the point a , out of a , scattered its pencil over the whole lens $d g$; but from there, as from a common base of confusion, it was collected by refraction into the cone $d e f k$, into the single vertex or point k . So b , from the same $d e f$, [is collected] at l ; so c at m ; and thus each occupies its own and proper...

place, without the company or mixture of any other. And so the whole base $a b c$ answers to the whole common base, or representative surface, $K l m$ — but with positions inverted, because of the section of the cones at their common vertices d , e , and f . And since these inverted cones dilate into the single common base $K l m$, it necessarily follows that, just as from one base $a b c$ they were all driven together into one apex d , so from that same apex, by being led apart, they sort themselves out into their own orders and stations.

Furthermore, where the radiant pencils of the single points establish their bases — namely on the surface $d e f$ — there the radiant cones of the base $a b c$, that is $a c d$, $a c e$, $a c f$, place their vertices; and conversely, when the inverted cones $i K m$,

$h K m$, $g K m$, out of the base $a b c$, place their bases together on the surface, or section, $K l m$, there the pencils of the radiant points terminate their apices, K , l , and m . And this surface — the section transverse at right angles to the axis — we set down and name the **common base of the ordered picture**, for the reasons stated. This base, [determined] by the refracting lens $d e f g h i$, has its appointed limits fixed and unchangeable, so long as the object $a b c$ stands opposite in a firm position, at the same size and distance. If even one of these is changed, it is certain that the limits and position of that base too will vary (although in lenses of larger spheres this is not so quickly noticed by the senses), because of the altered incidence of the rays from the visible object — an incidence which, being variable, likewise supplies occasion for a variable refraction. From this there then arises one convergence or divergence of rays and cones after another, and a changed position of the common base, an increased or diminished area, and [so] the image of the visible likeness comes to birth. Once its seat has been fixed, $K l m$, if a most clean sheet of paper (or something similar) be admitted there, that most beautiful species will display itself as if on its own throne, and will offer itself there to be gazed on by the eyes of its lovers; and although it is itself a daughter of light, yet it hates a foreign light, and comes out far most brilliant only in its own. Let this much — said and demonstrated in passing — suffice concerning the admission of the species, and its most shapely portrayal, in an inverted position, on the paper opposite, by a single lens. Now, to the

[Margin: Whence and how a confused picture, or chaos of the image, arises on the paper.]

Rhombus.

When onto the place of the ordered image $K l m$ there coincides some convex lens $K n$ — or, what is the same, when the lens $d g$, by its withdrawal from the lens $K n$ and its approach to the object $a b c$, has carried the likeness of the ordered picture onto the surface $K l m$ of the lens $K n$ — then, on the paper $q r$ placed behind the lens $K n$, no species at all is seen expressed, but only the image of a certain light that is not clear, but turbid and rather dull. The reason, from the prior cause: because the image of a rightly placed and well-ordered species resides on the surface $K l m$, carried there by the interposition and withdrawal of the lens $f i$. Now the lens $K n$, since it is transparent, offers no stable lodging to the ordered idea, but reads it further onward; and because it itself, being denser, is clothed with a convex surface, it so tempers by refraction the species and its rays (under which the species is carried) that they fall onto the paper $q r$ with the same confusion as they fell from the object $a b c$ onto the lens $d e f$. For every

point K, l, m is bent out again into a full pencil, whose base is the area $s t u$, spread out onto the paper $q r$, while its vertex is a point — either p , or o , or n , and so on — after the section of the rays has been made in the lens. And just as the individual points, once their intersection and refraction are worked out, flow apart into one common surface, or base, $s t u$, so in turn the whole ordered picture $K l m$ flows together into the vertices s, t , and u of the individual radiant cones. Therefore the whole species $K l m$ resides in the whole opposed base $s t u$, and the whole in every point of it; while, conversely, every point of the species — K , or l , or m — inheres in every point of that base, and in the whole base.

[Margin: The second seat of confusion.]

And this is the second [seat] of...

[confusion]; because the persistent section and splaying of the rays utterly dissipates all the vigor of the species, already weakened beforehand. Not on the near side, since the intersection of the cones lasts right up to the lens, $n o p$; and although something appears in its vicinity, that very thing is faint and cloudy, and does not satisfy the present purpose.

What I have so far said, in an artful way, about lenses arranged in a tube at the seats of confusion and of distinctness, holds good also, in every respect, in the eye — as may be seen in **figure 2**. There the place of the lens $K n$ set in the tube is occupied, in the eye, by the crystalline humor $m p$; and this transmits the whole ordered picture, drawn in by itself, to the ground of the retinal tunic $s t u$, and there reports nothing but pure light. But in the **third figure**, where the crystalline humor occupies the confused station $q s t u r$, it reduces that same species to order, and thus forms a most elegant image $x y z$ on the ground of the retina, $q x r$.

COROLLARIES

First. From these things it is manifest, first, that the diffusion and propagation of light is a rectilinear flux; otherwise so precise, clean, ordered, and distinct a coordination of species through refracted rays would not come about. Second: that a lesser light added to a greater upon the same part of a subject increases the intensity of the brightness. Third: that light added to light does not mix physically, even though both occupy the same part of the subject.

Second. The same things are manifest concerning the species of colors; for they act and are acted upon alike, in mutual partnerships of intersection.

Third. It is manifest that the act of seeing is not the same thing as the presentation of the visible species. For whenever the species is painted in an inverted position, upright vision is drawn out; and when the picture rises up erect, the vision becomes inverted.

Fourth. Vision follows the picture — a clear vision a clear picture, a distinct one a distinct picture, a confused one a confused picture.

Fifth. It is evident from these things that the crystalline humor is not the formal organ of vision, but only the retinal tunic.

Because when a distinct picture inheres in the crystalline humor, no vision, distinct [and] of any object, occurs — although then it ought most of all to occur, [namely] that the ordered visible species should settle upon it.

Sixth. In the same way, no part of the eye behind the retinal tunic is the formal organ of vision; because when the picture is stretched across it toward the brain, then nothing is perceived of the visible object. Conversely, when the ordered image of the species occupies the retinal tunic, the most perfect vision is produced; when the whole [picture] is engaged outside it, no vision occurs; and when at last it is in an intermediate condition, an imperfect and confused vision arises.

ON THE THIRD CASE, WHEN the concurrence, or common base, of the lens $v s$ [?] is completed before the lens d .

CAP. XXVII.

This case has been set forth in the common scheme, distinguished into seven modes; and for that reason I do not here bring in a special figure of it.

Accordingly, while I explain these things, you will consider the representation $C 1$, of the two lenses d and $v s$, and $C 2$, of the eye $u x$, as well as of the prefixed lens $o \pi$ [?].

The third case, then, is this: when, before the lens d , the lens $v s$ is so placed that the intersection f — that is, the common base of distinctness which the lens $v s$ makes — is terminated before the lens d . For then this lens — that is, the lens d — begins to enter into the confused cones projected from the interposed lens $v s$. For the common base of the ordered picture, although to the senses it has some slight breadth, and that breadth is very variable — on account of the section of the rays and cones among themselves, more or less oblique (for the more oblique that section, the longer, forward and back, is the station of the common base to the

senses; and the more upright the crossing, the shorter the interval and the briefer the station that is found) — is nevertheless, universally, whatever convex lenses may finally exist, not contained within a long interval. Hence it comes about that the lens v s , interposed and advanced toward the object, quickly snatches the ordered picture away from the first lens; and, in place of the distinct species, presents an image confused by rays and cones running everywhere across one another. From which the lens d itself begins, as soon as it can, to paint that same picture — now ordered — onto the paper duly set opposite. On this matter, receive the following most certain rules.

Book II, Cap. XXVII (continued)

[The page is set in two columns beneath the column-apparatus numerals "I." and "II."; the text flows from the left column into the right.]

I. Practical Rules [Regulae Practicae]

First. Every convex lens, when struck by any visible species whatever that are confused and disordered, arranges those same species onto a sheet suitably placed opposite it and presents them distinctly — whether those species are received immediately from the visible object itself, or from another lens, or from several convex lenses interposed between the object and the said lens. The *a priori* reason has been given and demonstrated in what precedes, from the ordering of the rays and radiant cones by the benefit of refraction.

Second. Every convex lens, when struck by any visible species that are at last ordered and distinct, casts those same species onto the opposite sheet confused and without order — whether those species come from immediate objects or arrive from other lenses. The reason for these was given *a priori* in what precedes: because the individual points of ordered species expand into the whole confusion-base that matches the sheet.

Third. As soon as the interposed lens vf has drawn the whole seat of distinctness toward the object, away from lens d , lens d at once renders the image received within itself upon the sheet, in an ordered, distinct, and inverted position.

Fourth. The more that lens vf draws the seat of the distinct and inverted position away from lens d toward the object, the purer and smaller an image lens d paints, at a shorter distance on the sheet. Or — which comes to the same thing — it makes the common base of the shorter cones always a smaller picture, but a purer and stronger one. The *a priori* reason: since lens d then lies still close to the seat of distinctness, a smaller confusion of cones and rays occurs, and so a less

purified image is born from it. For the most confused influx of rays onto the convex lens d produces the most ordered image, and the most ordered influx the most confused; therefore a less ordered influx will yield a less distinct image. But here a larger and more distant species is painted, because the object — which is the image of the interposed lens, and so on — is nearer, and acts on the rays laterally. As the glass withdraws, the object is elongated within the same [lens], and the confusion is enlarged; very many rays pass off to the sides into the air, and thus at a smaller distance a purer and smaller image is born — because less of the convex lens is taken up.

II. Application of the foregoing to the eye, which employs a convex lens after the inverted position [Dictorum applicatio ad oculum, specillo conuexo post situm euersum utentem]

How the crystalline humor of the eye behaves with respect to an eyeglass [specillum] or convex lens in the erect state, in the confused position, was stated a little earlier in what precedes. Let us now consider the same [humor] in the station of the inverted position with respect to a convex lens; and we shall find that the same things we just asserted about inanimate lenses happen, by a similar reasoning, in the Eye. For as soon as the eye passes beyond the confused state of some convex lens, it will at once begin to behold the object — in an inverted position, however — large indeed, but still quite formless. Yet gradually, as the lens moves away from the eye or the eye from the lens, [the image] will diminish, but the thing seen by the eye through the lens in the inverted position will be powerfully cleaned up and made distinct.

It is therefore evident that the same [image] was represented on the retinal tunic [tunica retina], such as was discerned in the inverted position: for the presentation of the species in the eye differs from vision itself, and is always accomplished in contrary positions. And so the resemblance of the eye to the tube consists not in vision, but in the reception of visible species. For just as visible species are painted onto paper through two convex lenses, so through a single convex lens and the crystalline humor they are painted onto the retinal tunic; but the act of seeing that supervenes is not this picture, but a vital and animate apprehension of the picture. In the presentation of visible species, then, other things being equal or similar, the comparison and parity consist.

[Margin: The genuine resemblance of the eye — which employs a convex lens in the inverted position — to [a system of] two convex lenses.]

COROLLARY I

From these things the ingenious Reader will easily construct for himself a tube for erecting species on paper. For there are two convex glasses arranged in the aforesaid manner.

COROLLARY II

It is inferred that the Eye, using a single convex [lens] in the said manner, is a tube compounded from art and nature; but a tube

— consisting of two [lenses] can be called a purely artificial eye.

COROLLARY III

Something can also be sought from this for the Microscope.

The Fourth Figure, D,1 and D,2, is explained; and on its occasion the power arising from the nature of the concave lens, and the effects and properties of its conjunction with a convex lens, are displayed; and thus the common Optical Tube is demonstrated. [FIGVRA QVARTA D,1. D,2. explicatur, & occasione illius, vis ex natura lentis cauae, eiusque cum lente conuexa coniunctae effectus & proprietates ostenduntur, adeòque Tubus Opticus communis demonstratur.]

CAP. XXVIII.

Figure 4, D,1 and D,2.

In D,1 there is represented a convex lens d, a concave lens ui, and a convex lens vf [figure point-letters read at the limit of legibility under magnification]. It is the same arrangement that the eye has [when looking] through a Helioscope at the Sun, or a Telioscope at some other visible thing. In both cases the position of the rays and radiant cones is the same, and in both the presentation of the species is the same. For in D,1 the rays, [passing] through vf and iu, are conveyed still wholly confused, and not yet fully crossed, into the lens d; and for this reason the lens d, having entered the seat of confusion, orders them and marks them out, in inverted position, at iK, in a larger form than would otherwise occur. Thus the eye, in the scheme D,2, receives the picture yz in inverted position, but the object — the Sun —

[Column II]

perceives iqr [figure point-letters] in an upright [position]. However, although the eye placed against the tube is powerfully assisted — as the whole world testifies

— nevertheless the Telioscope itself, viewed nakedly by itself, seems to receive, from the placing of the lens d in front of the concave lens iu, not a help but a hindrance. For if the tube ef alone, in Figure 6, F,1, be turned toward the Sun ab, the Sun is larger and more brilliant [and] will fall on iK than if the same be done through the lenses vf, iu with d placed in front; for the Sun will appear smaller and at a shorter distance.

But if nature had given the eye without a crystalline humor, as is represented in F,2, the Helioscope would do the same thing in the Eye: entering through the open aperture ux of the pupil, receiving the Sun into the depth of the Retina, o — which the Telioscope ef does, transmitting the Sun ab through the lenses $\alpha\beta$ and cd onto the paper, lm. Therefore in Figure 6 the perfect tube F,1 is matched, and the defective Eye F,2: Nature defective, aided by art; and [matched] to art alone. And let these things be said in a general way about this fourth figure, which — since it embraces the common optical tube (in everyone's hands) together with the concave lens — requires that we set up a somewhat deeper discussion of them.

Therefore, as I said, in Figure 4 we match and compare to the whole eye D,2 — perfected by the accession of the Tube — the Telioscope D,1 with the lens d placed in front, so that in every respect the parity of position and the likeness of effects may appear. And in order that all these things may be more rightly understood from their foundations, receive what follows.

Diagram. A full-page comparative optical plate, engraved caption: *"The consensus of Art and Nature, of the Tube and the Eye, in presenting solar images. No. 3"* [Artis et Naturæ, Tubi et Oculi, in speciebus solaribus præsensandis consensus]. The plate is ruled into seven horizontal registers (rows), each comparing an instrumental case (left, "Ars" = Art) with the corresponding natural/ocular case (center and right, "Natura"). Each register has three panels:

- **Left panel — "Ars" (the instrument):** a hatched draw-tube seen in section, containing a different combination of lens elements in each row; the light-cone (dotted) enters from the right. Labelled A.1, B.1, C.1, D.1, E.1, F.1, G.1 (reading top to bottom). Beneath each: "Praesentatio euersa" (inverted presentation) in rows 1, 2, 4, 5, 6, 7, but "Praesentatio recta" (erect presentation) in row 3.
- **Center panel — the eye ("Natura"):** a circular eyeball with radiating fibers and the crystalline body, carrying the register numerals I, 2, 3, 4, 5, 6, 7. Beneath each: "Visio recta" (erect vision) in rows 1, 2, 4, 5, 6, 7, but "Visio euersa" (inverted vision) in row 3. The top rubric over the eye reads

"Natura" (row 1), "Natura ... cum Arte" (rows 2–5), and "Natura ... manca, cum Arte" — Nature defective, with Art — (rows 6, 7). In the "cum Arte" rows a small supplementary (spectacle) lens element is drawn just outside the eye.

- **Right panel:** a hemispherical / circular field representing the presented solar image, labelled A.2, B.2, C.2, D.2, E.2, F.2, G.2; in rows 1 and 2 the field is bordered with a flame-like corona, in the later rows it is stippled. Point-letters q (top) and r (bottom) mark the field edge.

Readable point-letters within the instrument tubes include Latin c, d, e, f, h, m, s and Greek α , β , ξ (and, in some rows, κ) at the lens elements. The eye figures carry small labels — Greek λ , μ , ν , θ , ξ and Latin o, s, p, t, n, χ — set very small and mostly at the limit of legibility. Many of these interior labels cannot be resolved with certainty even under magnification and are not individually committed here (numerous small Greek/Latin interior labels flagged [?]).

De Lente Caua [On the Concave Lens]

[No chapter number is printed at this heading; see QA anomaly (a).]

[Margin: The nature of the concave lens in refracting.]

FIRST. A concave lens — whether it be single-concave, or, next, plano-concave, or exist concave on both sides, whether it be a segment of a small sphere or of a large one — receives any visible object whatever and casts it confusedly to any distance of the paper.

For let there be, in the first case, a plano-concave lens, or in the second case, a lens concave on both sides, ab, whose cavity's center is c, and let the visible object be def — which, by what was said before, will radiate onto the whole of it from each of its points d, e, and f, and will make of point d a pencil [penicillum] adb, and so will occupy the whole concave surface ba; and with no dissimilar effect point e will claim the whole for itself by the pencil aeb; and point f will do the same by the pencil afb; and so one must reason back for each radiant point of the object df.

But indeed the whole object itself, def, will radiate together onto each of the points a, b, and g of the concave surface, and will gather radiant cones; and therefore the whole surface of the visible object will settle upon every point of the concave surface, and every visible point will spread over the whole concave surface. There will therefore be an utmost confusion of cones, of pencils, and of rays.

Then, because the rays da, ea, fa are broken toward the perpendicular ca in the thickness of the lens, they will proceed along the lines ah, ai, aK to the other surface of the lens, hik; and thence again, about to go out from those same points h, i, and K into the thinner transparent air, they will depart by refraction from the perpendiculars, and will therefore diverge farther from one another along the infinite lines hl, im, Kn. In the same way the rays db, eb, fb are carried along the rays bo, bp, bq, and these will proceed along or, ps, and qt. Just so the rays dg, eg, fg will flow along the refracted rays gu and gx, and these will go on along uy and xz. For the ray eg alone, passing through the center c, is immune from refraction. Since, therefore, the rays of a single point, once gone out into the air, are not gathered but for the most part are dispersed still farther, into

[Column II]

no fixed seat or ordered station will they ever come together. For the rays of point d, for example, are after the lens Kn and qt, which never converge; the rays of point e are am and bs, which are always more divergent; and the rays of point f, fa and fb, end in the rays ahl and bor, which likewise never converge, owing to the differences of incidence, and so on. Therefore, even after the lens has been passed, the pencils of each several point, and their rays, are never again united, but, entangled in mutual irradiations, cause perpetual chaos and confusion.

Therefore the concave lens, one and alone, always dissipates and confounds the species it receives — which was the thing to be demonstrated. And in this the concave lens always differs from the convex: that the convex distinguishes and well orders the confused species it has received and transmitted, whereas the concave lens perpetually confounds the same species once they are passed through it.

[Margin: The difference of the concave lens from the convex in refracting.]

Secondly. Any concave lens whatever, placed before any convex lens toward the object, delivers to it confused species. This follows from the foregoing. Hence the convex lens will distinguish and order those same species, received confusedly, at the due distance according to its power — concerning which much has been said in the exposition of the second figure.

[Margin: A concave lens before a convex one.]

And from this is drawn the rationale of the concave eyeglasses [specilla] to be applied to the eye: since these always convey confused species into the crystalline humor, they bring it about that [the humor] orders those same species rightly

onto the retinal tunic, provided they are held from the eye at a proportioned distance. And hence it is that those concave lenses are called preservers of sight, because they always order the species well in the Eye.

Thirdly. Any concave lens whatever, placed after a convex lens in the station of ordered and distinct species, casts a confused image onto the paper. This is plain by experience, and is proved by reason a priori: because the several visible points, united in that seat, the concave lens — once it has received them — separates; and the common base of the radiant cones, which alone exhibits a beautiful picture, is dissipated by mutual sections and divarications, and everything onto the paper is con-

[Margin: A concave lens placed after a convex one in the ordered station confounds [the image].]

Diagram. A full-page engraved optical plate, numbered N. 5. at the upper right, beneath the running head "LIBER II. Cap. XXVIII. 125." It contains three ray-tracing sub-figures illustrating the behavior of a concave lens after a convex one. The point-letters correspond directly to the demonstration in the facing text (pp. 170, 172). This plate is printed again as a second impression (see fig-p171-1).

- **Sub-figure I** (numeral "I" centered at top, upper-left of plate): a wide concave lens seen edge-on. Readable labels — top row **d, e, f**; below the middle, **c**; on the lens, **a, g, b**; along the lower edge, **h**, a small index **1** [?] (or "i"), **K, u, x, o, p, q**; the diverging rays terminate at **l, m** (far left), **n, y, α, z, r, s**, with **t** to the right. Caption below: *Pictura confusa* ("Confused picture").
 - **Sub-figure 2** (numeral "2"; headed *Lentes cauae ad numerum I.* — "Concave lenses, for figure I"): same construction as sub-figure I. Readable labels — top **d, e, f**; **c**; on the lens **a, g, b**; lower edge **h, K, u, x, o, p, q**; ray ends **l, m, n, y, α, z, r, s**. Caption: *Pictura confusa*.
 - **Sub-figure 3** (numeral "3", right side; headed *Lens caua ad numeru 3* — "Concave lens, for figure 3"): rays from **e, f** (top) cross in an X and meet a biconvex lens at **a, b**; below it a concave lens at **c, d**; beneath, **g**, an index **1** [?], **l, n**; the rays then diverge to **t, h** (left), **K, m** (center-bottom), and **o** (far right). Caption: *Species seu Pictura confusa* ("The image, or confused picture").
-

are conveyed in confusion.

From the convex lens **a b**, let the visible object **e f** fall upon the concave lens **c d**. Its point **e** occupies the whole lens **a b** by the pencil of rays **a e b**, and the point **f** likewise by the pencil **a f b**; so that the whole object falls onto point **a** of the lens **a b** by the cone **e f a**, and onto point **b** by the cone **e f b** — and one must reason in the same way about the remaining points and bases as well.

Now again, from the convex lens **a b** (which holds the seat of confusion), let the object-point **e**, dispersed across the whole convexity **a b**, after a sudden refraction be gathered again into the point **d** of the concave lens **d c**; and by the same reasoning let the point **f**, from **b a**, be united at **c**. Conversely, let point **b**, collected from the whole object **e f**, disperse itself into the base **c d**; and let point **a**, likewise gathered from the whole **f e**, expand itself into the same base **d c** — so that **c d** becomes a distinct picture, as usually happens when similar conditions concur. But if the concave lens **c d** occupies that position, the collected point **c** will by refraction proceed through **c g** into **h**, and through **c i** into **K**; likewise the collected point **d** will be spread apart through **l** into **m**, and through **n** into **o**; and the whole cone **h c b d m** will cut across the whole **K e a d o**. Thus the summed scattering of the individual parts and of the whole together will produce the greatest confusion — which happens much more with doubled lenses, or in the cavities of very small spheres. And since these dispersions are never again gathered by the power of this lens, the point at issue stands proven.

Fourth. Any concave lens, when placed after a convex lens and after the station of the distinct picture, always confuses the image. This is clear from experience, and the reason is given from what precedes. For it receives the rays of a single point — that is, the pencils of the individual object-points — as they diverge from one another, and therefore by the nature of its refraction divides them further; conversely, it further dissociates the cones of the whole object that were raised up from the common base — whereby the greatest disturbance and confusion of all the images arises.

[Margin: A concave lens placed after the station of the convex lens confuses the image.]

Fifth. Any concave lens, held immediately after a convex lens, projects a confused image onto the paper. This is clear from experience, and the reason follows from what precedes. For it receives the rays in so confused a state that it cannot restore them to order, but rather disturbs them further as it transmits them. For although this position is such that the beginning of a good image is made — because the rays of a single point converge toward one another — nevertheless the concave lens, in the given position, so obstructs the process that

no common base of the picture, and certainly no perceptible one, is formed. This is because the greater part of the other rays is either dissipated beyond the common base, or is disturbed by mixing, so that whatever image does form is choked by its own faintness and by the brightness of the light poured around or over it, and the weakness of sight cannot reach it. This is confirmed by a twofold experiment: one of the eye, the other of lenses.

The first, of the eye, is performed with lenses. If you bring a concave lens up to a convex one in such a way that you see the object erect through both, at any distance you please — larger on approach, smaller on withdrawal — it is evident that throughout the whole space a confused image persists. Otherwise a distinct image would fall upon the crystalline humor, and so would induce confusion on the retinal coat — which, however, does not happen in the case proposed. *But so long as the eye sees distinctly, so long is a confused presentation made in the crystalline humor.*

[Margin: A confused reception of the images in the crystalline humor produces distinct vision.]

The second, of solar lenses, is this. If you hold a convex lens behind both, the same will paint the object on the paper held before it, in an inverted position, but distinctly. Take a lighted candle and a convex and a concave lens joined together; then, through another separate convex lens, throw the light onto paper turned toward it, and you will see that what I say is true.

Diagram. A second, cleaner impression of the same full-page optical plate N. 5. described above (fig-p169-1), under the running head "LIBER II. Cap. XXVIII. 126." The three sub-figures and their point-letters are identical:

- **Sub-figure I** (numeral "I"): concave lens with top labels **d, e, f; c; a, g, b**; lower edge **h, 1 [?], K, u, x, o, p, q**; ray ends **l, m, n, y, α, z, r, s, t**. Caption *Pictura confusa*.
 - **Sub-figure 2** (numeral "2"; *Lentes cauae ad numerum I.*): labels **d, e, f / c / a, g, b / h, K, u, x, o, p, q / l, m, n, y, α, z, r, s**. Caption *Pictura confusa*.
 - **Sub-figure 3** (numeral "3"; *Lens caua ad numeru 3*): **e, f** (top) → biconvex lens **a, b** → concave lens **c, d** → **g, 1 [?], l, n**; ray ends **t, h, K, m, o**. Caption *Species seu Pictura confusa*.
-

A Demonstration of the Common Optical Tube, in its Arrangement for Representing Images on Paper

VI. A concave lens placed after a convex one, not far before the seat of the ordered image, shows that same image on the paper larger, more distinct, and at a greater distance than the convex lens alone would have made it. This is clear from experience, and it is proved from what precedes. For it spreads apart the vertices of the individual pencils — which would otherwise have been on the very point of converging at the common seat of ordering — and thus extends their convergence further, until they settle onto a more distant common base.

For example: the object **a b c** enters the convex lens **d e f g** in a confused state; and, emerging from it, it gradually returns to order as it advances toward the place of the ordered image **h i k**, so that to point **a** there corresponds point **K**, to point **b** point **i**, and to point **c** point **h**. The concave lens **l β**, then, by its intervention, so orders by refraction the rays **f l**, **f m**, **f n**, and likewise **g o**, **g p**, **g q**, that — being somewhat drawn apart — they push the common base further out, make it much larger, and present a more distinct image. For **f l**, through **r**, comes to **s** (for instance); **f m**, through **t**, to **u**; and **f n**, through **x** to **y**.

[Margin: The optical tube is demonstrated.]

In the same way, the ray **g o**, through **z**, [comes] to **s**; **g p**, through **α**, to **u**; and finally **g q**, through **ε**, to **y**. And so point **a** — which by the refraction of the convex lens **d g** alone would have stopped at **K** — with the approach of the concave lens **l β** will be fixed at point **y**; **b**, which otherwise would be at **i**, will move to **u**; and finally **c**, which would have stuck at **h**, will be pushed forward to **s**.

And this is the true and genuine principle for constructing the optical tube for projection, from which nearly all the experiments and difficulties can be understood and resolved. That the image arises more distinct by this arrangement proceeds from the fact that many rays which would have escaped uselessly to the sides are held back by the benefit of the concave lens and are led out into the place of ordering; and many which, by shorter intersections in the middle, would have disturbed the order are now caught by the concave lens and set, in sharp focus and at the common station, together with the rest.

But someone will object that it follows from this that the tube understood in this way is not the one in common use — and hence that the common optical tube, as the eye is directed through it toward the objects viewed, has not been

demonstrated; which is rather what one seems to want. [*quod videtur magis experi[ri/-peti] [?]* — abbreviation φ = "quod"; final word abbreviated.]

I reply, first: in order that the power and efficacy of the tube joined to the eye may be understood, one must first grasp what it can do by itself in presenting images — which is what I have tried to show in this chapter.

I reply, second: the use of the tube demonstrated here is almost the sole and chief means by which I have investigated the solar phenomenon; so if I bring forward its demonstration, I do so in keeping with my purpose — though I would not deny that its practical value for projecting other images is not so great.

I reply, third: the true and genuine nature of the optical tube, as it is applied to the eye, is set out most fully in the following chapter, **29**, through nearly all the possible cases of its application; in which I believe I have omitted nothing pertinent to this matter.

But now let us come to a fuller explanation of the figure proposed. This position of the concave lens — between the station, or common base, **h i K** — does not consist in an indivisible point, but admits a wide latitude, ranging between the convex lens **e f** and the place of the distinct image **h i K**. Here, however, I should like you to note the following properties.

I. The same concave lens, set very close to the station of the common base **h i K**, will give the smallest picture on the paper, but the purest; and it will make the distance of the paper from that same lens the shortest that can be had.

[Margin: The concave lens very nearest, before the ordered station.]

II. The same concave lens, the more it approaches the convex one, the larger an image it will produce on the paper — but it will not match the former in brightness and purity, and it will also require a longer distance for the paper.

[Margin: The concave lens farther, before the ordered station.]

III. The same concave lens, so close to the convex lens that it could not be closer without a state of full confusion, will offer the largest image and the greatest distance for the paper — but a picture not cleanly bounded at its edges; which comes about because of the mixing of the rays, the greater spreading of the cones, and the more oblique incidence.

[Margin: The concave lens farthest, before the ordered station.]

IV. The same picture **s u y**, expressed on the paper from the sides **d g** and **l e**, — if you keep everything else unmoved, namely the object and its distance from the lenses, the lenses and their mutual distan[ce]...

[Margin: By the approach or withdrawal of the paper alone, the ordered image is disturbed.]

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Diagram. An in-text woodcut ray-trace of an optical tube fitted with a concave lens, numbered **N. 9** at the upper right. The engraved lettering, woven around the figure, reads: **TVBI OPTICI Demonstratio** ("Demonstration of the optical tube," split as **TVBI** | **OPTICI** across the top, **Demon-** | **stratio** below); **Lens caua** ("concave lens," at the left of the middle element); **ad numerum 6** ("to number 6," a cross-reference, at the right); **EX LENTE CAVA** ("from the concave lens," across the lower part, split **EX LEN** | **TE CAVA**); and the caption beneath, **Basis ordinata longior et latior, et Pictura distincta** ("The ordered base, longer and broader, and the distinct picture").

Structure, top to bottom:

- A tall rectangle (the tube / light-cone), with the top edge marked **a** (left), **b** (centre), **c** (right), and the bottom corners **d** (left) and **e** (right); straight rays cross diagonally inside it in an X pattern from the top points to **d** and **e**.
- Immediately below, a biconvex lens element with points **f** (under **d**) and **g** (under **e**).
- A wide, shallow lower element (the concave lens): its upper edge carries the row of points **l, o, m, p, n, q** (left to right); its curved face carries **r, z, t, α, x, β** (left to right).
- Below that curve, the points **h** (left), **1** [or *i*] (centre), **K** (right), with dotted rays converging to a single point **y** below.
- At the foot, a wide triangle spreading to the base corners **s** (left) and **y** (right) — the "ordered base."

All labels listed are read directly from the tiles; no sequence was completed by inference.

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[The enumeration of the properties of the concave lens continues from the preceding page.]

distance, the image is always confused, whether you move the paper toward the concave lens or move it away from the lens. The cause is the same on either side: because both before and after, the species [*species* — the image-bearing emanations] that carry the picture are confused among themselves; and so, if the paper comes into the places of the confused species, it receives a confused image. Note, however, that here too there is a certain latitude, and that the image is not immediately, by just any motion of the paper, made perceptibly confused — especially with lenses of the larger spheres, correctly applied.

Fifth. The same image, most correctly depicted on the paper, will be confused if — everything else standing firm — the concave lens alone either approaches or recedes beyond the just-mentioned latitude of proportion; for the station of confusion always reaches both to the lens and to the paper. The reason must be sought from what has been said. Note, however, that as one lens approaches the other, the image is confused into a reddish, dark, and gloomy condition of light — the reason being that the species, condensed by their mutual encounters, are packed into one. And as the same lens withdraws, the image becomes first black, then blue, and at last thin and white. The reason: because the species, weakened by the mutual divergences of the rays, are diluted by the abundance of light.

Sixth. With everything unmoved, if the convex lens alone is either advanced or brought nearer, the same things will happen as before. [Margin: The convex lens alone does the same.]

Seventh. With everything else untouched, if the object alone perceptibly approaches or recedes, the same things will occur as before. [Margin: The object alone does the same.]

Eighth. A concave lens that is a portion of a smaller sphere demands a greater distance from the convex lens and a smaller distance from the paper, and presents a larger image than a concave lens of a larger sphere; for the latter requires a shorter distance from the convex lens and a longer one for the paper, and yields a smaller but more intense image.

Ninth. For the same concave lens, a convex lens of a smaller sphere demands a shorter distance and projects a smaller image onto the paper; one of a larger sphere, a larger image.

Now that the nature of the concave lens has been explained in passing — both considered in itself and joined with a single convex lens — let us return to our order and see what the same lens accomplishes if it is inserted between two convex lenses. For this properly pertains to the fourth figure, and to the optical tube considered in relation to the eye; and it was for this reason, too, that the points I made in the previous chapter were brought forward.

Continued explanation of Figure IV, D.1 and D.2, in which is shown the likeness — between the eye using a common tube and a tube made up of two convex lenses and one intermediate lens — in receiving the image-bearing species, and the nature of the optical tube in its relation to the eye.

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Let Figure IV, D.1 and D.2, be explained more fully.

The concave lens between two convex lenses has various cases. [Margin: The optical tube, when contracted, is useless in the first case.]

The **first** is when all the lenses are joined immediately together, the middle one concave. Since this case has little usefulness, little attention is paid to it, and so let us too leave it untouched. For it is nothing other than an optical tube not drawn out, through which the eye set to it sees nothing; and this very thing has deceived many, so that they condemned excellent tubes as useless.

The **Second Case** is when the concave lens is joined immediately to the convex lens v s , which faces the object, while the lens d is moved away from that same convex lens. Then the object will always appear on the paper (duly held at the right distance) inverted in position, at any distance whatever of the lens d from the lens v s ; yet a greater distance will always yield a smaller image, a smaller distance a larger one. In the same way the eye, through the two joined lenses — the convex and the concave — will apprehend by upright vision the thing presented to it inverted in position on the retina, always smaller and duller as the lens recedes, larger and clearer as it approaches. This is clear from experience; and the reason, as before, must be sought in the concave glass, which, so applied, draws apart and confuses the species and hands them over, confused, to the other lens and to the crystalline humor — which then orders the confused species it receives and confuses the ordered ones. This case is not shown in the figure, nor is it in common practical use, yet it is true. [Margin: Adaptation of the second case to the eye.]

The **Third Case** is the contrary of the previous one: when the concave lens is always joined to the lens d . This is shown in Figure 4, D.1 and D.2, and it occurs daily in the common telescope [*Telioscopium*] applied to terrestrial objects, the Moon, and the stars, and in the helioscope [*Helioscopium*] directed at the Sun; for then the crystalline humor $u x$ takes the place of the lens d . [Margin: The third case expresses the common use of the optical tube.]

The arrangement of this case can be of three kinds.

First: when the concave lens $s x$ [?] and the convex lens d stand beyond, or outside, the place of distinct focus of the lens $v s$. Then either nothing, or a confused image, appears on the paper, and the object is seen confusedly by the eye. This experience is clear and everyday. I give its reason: because the concave lens falls upon confused rays already weakened and scattered beforehand, which it weakens and scatters still further, so that the convex lens clinging to it can receive nothing that it might duly transmit to the paper or to the retina. Hence it is clear why a tube drawn out too far accomplishes nothing: because, by excessive extension, the concave lens is moved outside the ordered base of the convex lens.

Second: the arrangement occurs at the very seat of confusion, whose farthest limit is toward the paper. If the concave lens settles there, nothing will be produced, as the reasoning just given, and experience, both teach. [Margin: An arrangement suited to the eye.]

Third: the placement has its beginning at the seat of ordered focus, that is, at the end of the interval that lies between the lens $v s$ and its common base, or ordered seat. And by approaching from this point toward the lens $v s$ across a large space, a picture is produced on the paper, and distinct viewing by an eye joined to the concave lens — subject to this rule, drawn from two general rules. [Margin: A rule of great importance.]

Rule One. When the joined lenses d and $s x$ [?] approach the convex lens $o s$ [?], the paper recedes somewhat, and the picture becomes larger.

Rule Two. When they withdraw from the convex lens, the paper approaches, and the picture becomes smaller.

Two practical experiments.

First. A convex lens of smaller sphericity, joined with the same concave lens, makes a smaller picture and requires a shorter distance for the paper than a

convex lens of greater sphericity, which makes a larger image and demands a longer distance.

Second. A concave lens of smaller sphericity, joined with the same convex lens, makes a larger image and requires a greater distance — both of itself from the convex lens *v s* and of the paper from itself — than a concave lens of greater sphericity, which stands less far from the convex lens *v s*, moves the paper less far away, and makes a smaller picture. This is clear from daily experience, and the reason is easily drawn, as before, from what has been said.

And in this arrangement of the third case, together with its explanation, one sees nearly the whole everyday use of the optical tube — distributed into the telescope and the helioscope — and there is found every kind of likeness, in representing visible species, between the eye using a common tube and a tube composed of two convex glasses and one concave. From these principles, the easiest solutions and clearest reasons for very many of the most difficult questions are supplied at once.

First question. Why do the myopic [*Miopes*] contract the same tube more than the presbyopic [*Presbytæ*] in order to view the same objects? [Margin: Why the myopic use a shorter drawing-out of the tube than the presbyopic.] Namely, because the myopic have acquired a more globular crystalline humor, whose convergence into an ordered image is too short to reach the retinal tunic. Therefore, lest that most beautiful picture of the object, floating in the vitreous humor [*humor vitreus*], should cheat the power of vision of its desire, art comes to the rescue and moves the concave lens somewhat toward the convex. By this approach it comes about that — in accordance with what was said under the third placement — the common convergence of the third case is prolonged and extended, and in this way is carried onto the retinal tunic itself, the royal seat and throne of vision. From this, once again, you have an effective proof that the vitreous humor is not the place in which the power of vision performs its office, and so on.

Second question. Why do the presbyopic draw out the same tube more than the myopic in order to view the same objects? [Margin: Why the presbyopic use a longer drawing-out of the tube than the myopic.] This happens because, since they are endowed with a flatter crystalline humor than the myopic, if they were to use the same aperture the myopic use, the convergence of the common ordered image would turn out too long and so would overshoot the retinal tunic, according to Rule One of the third placement. Hence, so that that common base may be recalled to the seat of vision, which is the retina, the concave lens *o x* [?]

recedes somewhat from the convex lens $e o$ [?], and thus seizes the place of the picture and carries the image onto the retina $y z$. From this, again, I clearly conclude that the act of seeing is not elicited in the eye beyond the retina, but in the retina alone. Further, I infer that any tube whatever, provided it is not faulty, can be fitted to any eye whatever, provided the eye is sound, so that with the tube's help one sees better than without it. Moreover, with one and the same tube you will, without error, examine and pronounce upon the nature of the vision of two men — or of however many — as well as their effectiveness of sight and the configuration of their crystalline humors. For if they all use the same aperture on the same object, they are endowed with similar sight and a similar crystalline humor. If they use different apertures, those who discern the same object under a greater aperture or extension of the tube are presbyopic and will have a wide pupil; those under a smaller one are myopic, with a globular pupil, and so on. [Margin: Useful practical corollaries.]

Third question. Why, for the same eye, must the optical tube be contracted for a distant object and extended for a near one? Because a distant object so contracts the picture within the eye that it does not reach the floor of the retina; but by contracting the tube — through the third placement — the image is extended, and thus the object is perceived by the eye, since the image-bearing species, once settled on the retina, is felt. The contrary happens with a near object: for indeed, from it...

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(Translation = printed folios 128r, 128v, 129r; is a duplicate impression — see QA report.)

**

[Book II, Cap. XXIX — continued]

The second position occurs at the very seat of confusion, whose far end faces the paper; if the concave lens is set there, nothing will be accomplished, as both the reasoning just given and experience teach.

[Margin: Placement suited to the eye.]

The third placement begins at the seat of the ordered image — that is, at the end of the interval lying between the lens $v \xi$ and its own common base, or ordered seat. By moving from this point toward the lens $v \xi$ through a large distance, a

picture is produced on the paper, and the view from an eye joined to the concave lens is distinct — subject to the following rule, drawn from two general rules.

[Margin: A rule of great importance.]

First. When the joined lenses d and $i \times$ [?] approach the convex lens $v \xi$, the paper recedes somewhat, and the picture becomes larger.

Second. When they move away from the convex lens, the paper draws nearer, and the picture becomes smaller.

Two practical experiments.

First. A convex lens of smaller sphericity (a shorter radius of curvature), joined with the same concave lens, makes a smaller picture and requires a shorter distance of the paper than a convex lens of greater sphericity, which makes a larger image and demands a longer distance.

Second. A concave lens of smaller sphericity, joined with the same convex lens, makes a larger image, and requires a greater distance — both of itself from the convex lens $v \xi$ and of the paper from itself — than a concave lens of greater sphericity, which stands less distant from the convex lens $v \xi$, moves the paper less far off, and makes a smaller picture. This is plain from everyday experience, and the reason for it is easily drawn from what has already been said.

In this position and explanation of the third case we have virtually the everyday use of the optical tube [tubus opticus] — divided into the telescope [telioscopium] and the helioscope [helioscopium]. Here a likeness is found between the eye of every kind, using an ordinary tube, and a tube composed of two convex glasses and one concave one. From this likeness the easiest solutions and the clearest explanations of very many — and very difficult — questions are at once supplied.

[Margin: Why the myopic use a shorter draw of the tube than the presbyopic.]

First. Why do the myopic contract the same tube more than the presbyopic when viewing the same objects? Clearly because the myopic have acquired a more globular crystalline humor, whose convergence into the ordered image is too short to reach the retinal tunic. Therefore, lest that most beautiful picture of the object, floating on the vitreous humor, should frustrate the power of vision of its aim, art comes to the rescue: it brings the concave lens somewhat closer to the convex. By this approach it comes about — in keeping with what was said about the third placement — that the common convergence of the third case is prolonged and spread out, and in this way it is carried onto the retinal tunic

itself, the royal seat and throne of vision. From this, again, you have an effective proof that the vitreous humor is not the place in which the power of vision performs its office, and so on.

[Margin: Why the presbyopic use a longer draw of the tube than the myopic?]

Second. Why do the presbyopic draw out the same tube more than the myopic when viewing the same objects? This happens because, since they are endowed with a flatter crystalline humor than the myopic, if they use the same aperture as the latter, the convergence of the common ordered image will fall too long and so will pass beyond the retinal tunic — by the first rule of the third placement. Hence, in order to recall that common base to the seat of vision, which is the retina, the concave lens $o\pi$ withdraws somewhat from the convex $\rho\sigma$, and thus shortens the place of the picture and carries the image onto the retina yz . From this, again, I plainly conclude that the act of seeing is not elicited in the eye behind the retina, but in the retina alone.

[Margin: Useful practical corollaries.]

I infer further that any tube, provided it is not defective, can be fitted to any eye, provided the eye is sound, so that with the tube's help one sees better than without it. Moreover, with the same tube you will examine and pronounce, without error, upon the nature of the sight of two people — or of any number — and likewise upon the efficacy of their vision and the configuration of their crystalline humors. For if they all use the same aperture on the same object, they are alike in sight and in crystalline humor. If they use different apertures, those who make out the same object under a larger aperture, or draw of the tube, are presbyopic and have a wide pupil; those under a smaller one are myopic, with a globular pupil, and so forth.

Third. Why, for one and the same eye, must the optical tube be contracted for a distant object, but drawn out for a near one? Because a distant object shortens its picture in the eye so much that it does not reach the back of the retina; but by contracting the tube, through the third placement, the image is lengthened out, and so the object is perceived by the eye, since a species set upon the retina is what is sensed. The contrary happens with a near object; for from that object itself

the base of the picture is thrown farther forward than the retinal tunic can reach by its own extent; and so drawing out the tube comes to the rescue and, in this way, fits to the retina the seat of the image, thus reined in. But what happens by this means I would not have you ascribe to any incapacity of the tube, but to the

incapacity or necessity of the eye. For a tube assembled to a single suitable aperture shows all objects — even distant ones — with a fixed aperture, provided the paper is moved toward it for distant objects and away for near ones.

And if the eye could likewise draw the floor of the retinal tunic nearer, and move it away, in like proportion — or if the crystalline humor could place itself forward or backward as needed — there would be no such need to move the tube in and out.

Fourth. Why, although objects are painted in the same way and in like proportion both on the paper and on the retina, does vision nevertheless run counter to the picture's orientations? For whenever an image is projected onto the paper in an inverted position, the eye will always apprehend it as upright; and when an image is set upright on the paper, the eye will see it as though inverted, and so on. I answer that the experience, cause, and reason of this matter have been fully treated and set out by me in my *Oculus, or Optical Foundation* [Scheiner, *Oculus, hoc est fundamentum opticum*, 1619]. For the moment, let it be said briefly but truly that this comes about because the eye perceives the incoming image according to the last refracted rays — those that are formally visual — whose outward tendency the eye follows in apprehending the object. Since, then, a ray on the right in the eye looks back to the left-hand part of the object, and a left-hand ray is carried to the right, and likewise an upper ray to the lower part and the reverse, the act of seeing necessarily recognizes the thing in this reversed way, and so on.

Hence I infer, **first**, that the act of vision — which they call the *expressed species* [species expressa] — differs utterly from the image or picture, which they call the *impressed species* [species impressa].

Second, that an impressed species can occur without an expressed one, as happens in the open eye of a sleeping man.

[Margin: Why the whole species of the object comes into the tube and onto the paper, yet is barred from the eye?]

Fifth. Why, when the species of the Sun (for instance) or of another object is presented whole on the paper, is that same species not seen whole by an eye applied to it? I answer that the sole and single cause is that the opening of the pupil does not take in the whole species at once, on account of its smallness. For if it were dilated so as to drink in the whole, it would certainly see the thing as large as the eye grasps it [ideam [?]]. But that this is so

is evident in large and long tubes, where convex lenses — being segments of great spheres — usually send out more widely spread radiant cones, which very often exceed the capacity of the opening in front of the concave lens. When this happens, the same occurs on the paper as on the retinal tunic: the image arrives piece by piece. The same also often happens even when the hole in the paper has been broken open and enlarged: the breadth of the radiant cone nonetheless still exceeds the whole capacity of the concave lens, and in that case, again, the same occurs on the paper as in the eye, so that the object has to be admitted and surveyed part by part. The same result follows if the convex lens behind the concave lens is smaller than the species transmitted through the convex lens from the object. So, in general, the reason why less is seen by the eye at a single glance than is displayed on the paper is this: either the opening of the pupil does not admit the whole species, or else the crystalline humor itself — granting that the pupil were maximally dilated — does not take the whole in at once.

Corollary.

Hence it is clear that what is commonly charged to some hidden nature of the optical tube — namely, that the more it magnifies an object, the less of that object it presents to the eye — arises not from the nature of the tube, but from the incapacity and weakness of the eye, which cannot take in at once the whole that the tube offers in a single presentation.

[Margin: Why a larger uncovering of the glass paints the species more strongly.]

Sixth. Why does a larger glass — and one under a larger aperture or uncovering, insofar as it admits a larger one without confusion — paint the object more strongly, yet, all else being equal, not larger? Clearly because from each single point of the convex lens there proceed radiant cones of the whole object into a single common base; and since each cone delivers one species, every added cone always increases the intensity. Hence the larger the lens, the more such cones gather together their rays, and through the rays their pictures; and this produces a vivid image. But that it does not become larger — at least not perceptibly — must be referred to refraction, and so on.

Corollary.

From this it is clear that light, or a less intense color, added to a more intense one, increases the intensity.

And so far I have explained the nature and use of the optical tube

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and its common use, within the brevity I set myself — well enough, I think. Anyone who applies himself to these matters will bring out more.

The Positioning of Three Lenses: Case IV.

The fourth case of positioning is when all three lenses stand separate from one another and the concave lens ranges freely between the two convex lenses. Here, once more, various positions arise. For either both — that is, the convex lens d and the concave lens $i x$ — lie within the ordered convergence of the other lens $v \xi$; or both lie outside it; or the concave lies within while the convex lies outside.

[Margin: First position.]

First position. When both lie within the common ordered convergence of the convex lens $v \xi$ (the one facing the object), and so on — then, on paper duly set opposite, an image will always be painted in an inverted position, but will be seen by the eye upright; and that image will grow larger if the convex lens approaches the concave (the paper receding), and smaller if it moves away (the paper approaching). This is plain both from experience and from the reasoning given before. For in this case the convex lens receives confused species from the concave, and so orders them onto the paper; and because they had not yet been crossed, it projects them onto the paper already cut, and thus the inverted position results. This position has great latitude, according to the nature of the convex lens $v \xi$ and depending on whether the object is much or little distant.

[Margin: Second position.]

Second position. When both — concave as well as convex — are placed outside the common convergence of the lens $v \xi$, then the image on the paper, formed through the convex lens d , is always set upright, but in the eye it is always inverted. It grows larger as the convex lens (or the eye) approaches the concave and the paper recedes; it diminishes as the former moves away and the latter approaches. The experience is certain, and the reason follows from what precedes. For in this case the concave lens always pours confused species onto the paper, which the convex lens orders; and because they had already been crossed once, it cuts them a second time, and on this account sets them upright on the paper, so that the eye sees them inverted — since vision, or the expressed species, is always contrary in position to the impressed species, as was shown above. You will test the truth of this with any tube, if you draw the concave lens out from the convex $v \xi$, beyond its common base,

and direct toward the object the eye drawn far back from the concave lens.

[Margin: Third position.]

Third position. When the convergence made by the lens $v \xi$ is found to fall between the concave lens and the convex lens d , then the image will always arrive on the paper in an inverted position and will be viewed by the eye upright; and the same things will happen as were said in the first position, for the same reasons — because the concave lens carries confused species onto the convex lens d , and only a single crossing of them takes place.

[Margin: The likeness of the tube and the eye.]

From what has been brought forward so far, it is easy to see the truly remarkable agreement between the eye and the tube, and the tube and the eye, in receiving the picture of visible species and in presenting it.

Next, it is easy to see — or to deduce from this — the composition and structure of each. And an ingenious person will draw out the use and practice without much difficulty. Yet since to one without experience, and ignorant of these matters, they may perhaps seem very hard to carry out, and even marvelous, I shall run through them one by one, briefly, as my plan requires — adapting them to my own subject, and briefly suggesting for what and in what way each one serves.

The Use and Practice of the Aforesaid Figures.

CHAPTER XXX.

So far I have explained nearly everything that I have found the eye to have in common with the tube. Now I shall set out in a few words what usefulness may be hoped from this, and how these things can be directed into practice — once I have also first explained the seventh figure, G.1 and G.2, which, on account of its simplicity, I combine together with its use.

Explanation and use of the seventh figure, G.1 and G.2.

This figure is the simplest and most inert of them all: for besides a dark chamber it has nothing whatever, except that one bores a tiny hole with a drill and, at a long distance — six, ten, or twenty paces, that is — lets in the Sun, or other objects shining or lit from outside, onto a sheet of paper set opposite. For on that paper he will see whatever

and their common use, so far as my intended brevity allowed. I believe I have explained this well enough; anyone who applies himself to these matters will bring more to light.

POSITIONING OF THREE LENSES, CASE IV

[POSITIONIS TRIVM LENTIVM, CASVS IV.]

The fourth case of positioning arises when all three lenses stand separately from one another, and the concave lens ranges freely between the two convex ones. Here again different positions are found. For either both — that is, the convex lens d and the concave lens $i x$ — lie within the ordered focus [concursum ordinatum] of the third lens $v \mathfrak{z}$; or both lie outside it; or the concave lens lies within and the convex lens outside.

[Margin: First position.]

First position. When both lie within the common ordered focus of the convex lens $v \mathfrak{z}$ — that is, the lens that faces the object — then upon paper properly held opposite, an image will always be painted in an inverted position, while to the eye it will appear upright. That image will be enlarged if the convex lens is brought toward the concave one as the paper is drawn back, and reduced if it is moved away as the paper is brought closer. This is clear both from experience and from the reasoning of the previous case. For in this case the lens receives confused rays [species confusas] from the concave lens; it then orders them onto the paper, and because they had not yet crossed, it throws them onto the paper already cut, so that the inverted position results. This position has great latitude, according to the nature of the convex lens $v \mathfrak{z}$ and according to whether the object is far off or near.

[Margin: Second position.]

Second position. When both the concave and the convex lens are placed outside the common focus of the lens $v \mathfrak{z}$, then the image on the paper, formed through the convex lens d , is always upright, while in the eye it is always inverted. It is enlarged as the convex lens or the eye approaches the concave lens and as the paper recedes; it is reduced as the paper approaches and the lens recedes. The experience is certain, and the reasoning follows from the previous case. For in this case the concave lens continually pours confused rays onto the paper, which the convex lens orders; and because they had already crossed once, it cuts them a second time, and on this account raises them upright on the paper. The eye therefore sees them inverted, because the emitted image [visio seu species

expressa] is always opposite in position to the impressed image [species impressa], as was seen above. You may prove this truth with any telescope by drawing the concave lens away from the convex lens $v\ s$, beyond its focus [basin], and

directing the eye, set well back from the concave lens, toward the object.

[Margin: Third position.]

Third position. When the focus formed by the lens $v\ s$ falls between the concave and the convex lens d , then the image will always fall onto the paper in an inverted position and will be seen by the eye upright; and what was said in the first position will occur here too, for the same reasons — because the concave lens conveys confused rays into the convex lens d , and only one intersection of them takes place.

[Margin: The likeness of the telescope and the eye.]

From what has been set out so far it is easy to see the truly admirable agreement between the eye and the telescope, and between the telescope and the eye, in receiving and displaying the picture of visible objects.

From this, too, it is easy to see — or to deduce — the composition and structure of each. Moreover, an ingenious person will draw out the use and practice without much difficulty. Still, because these matters may seem exceedingly difficult to do, and even marvelous, to anyone inexperienced and unacquainted with them, I shall run through them one by one, briefly, as my plan requires, adapting them to my own purposes and hinting briefly at what each serves for and how.

THE USE AND PRACTICE OF THE AFORESAID FIGURES

[FIGVRARVM PRAEDICTARVM VSVS, & PRAXIS.]

CAP. XXX.

I have so far explained nearly everything I have found the eye to have in common with the telescope. Now I shall set out in a few words what usefulness may be hoped from this, and how these things may be directed into practice — after I have first also explained the seventh figure, *G, 1* and *G, 2*, which, on account of its simplicity, I combine together with its use.

Explanation and use of the seventh figure, *G, 1* and *G, 2*.

This figure is the simplest and most passive of all, for beyond a darkened room it has nothing whatever to it, except that one bores a tiny hole with a drill and, at a long distance onto paper set opposite — six, that is, ten, or twenty paces — admits the Sun or other objects lit or illuminated from without. For on the paper set opposite one will see whatever

has clung to those same rays. A similar picture would form in a defective eye from which the crystalline humor had been removed and in which some hole had been artificially opened in the uvea, so that the rays could enter. This is why, in this case, I have called it "Nature defective, aided by art" — not because the natural configuration of the rays is artificial, but because their admission through a narrow hole in this particular way, and their reception onto paper, is contrived. This device has two uses for my purpose.

[Margin: First use.]

First. That sunspots caught by this device are free of all the inconvenience caused by refraction through lenses, and are perfectly suited for investigating and demonstrating both the apparent and the true motion of the spots, and likewise their apparent and true place — provided the observations are accurate and enclosed within a sufficiently large circle. I have treated this also under natural admission [*immissione naturali*], and so on.

[Margin: Second use.]

Second use, no less than the first, and of the greatest importance for astronomical matters: that the visual magnitude of the Sun is obtained infallibly, and with no risk of error, most exactly, if the Sun's cone is caught through a very small hole at a great distance. Of this I shall speak separately and at length in its own place; for now, it is enough to have touched on it.

Use and practice of the first figure, A, 1 and A, 2.

[Margin: Admission through a single convex lens is preferable to purely natural admission.]

I have already shown the agreement of the convex lens with the eye; now I briefly go over the use and practice of that lens in admitting rays. For this matter is of the greatest importance for projecting the Sun onto paper. First, because it presents a cleaner and sharper image than bare admission through a hole. Second:

[Margin: The use of a single lens for avoiding the distortion of refraction.]

although, on account of the refraction that always intervenes when glasses are used, the exact visual magnitude of the Sun cannot be so easily determined, and although the position and distance of the spots, and their true and apparent proper motions, introduce some variation on the part of the object itself — nevertheless, if the convex lens is a portion of a large sphere and is flat on the other side, it will present a large image of the Sun and will interfere with refraction either not at all or only slightly, for it will be as it were uniform. And from this, third: you will render the apparent courses of the spots without any perceptible error.

Fourth. To which end it will help wonderfully if the lens is not only a portion of a large sphere — whose radius spans 20, 30, or more Roman palms — but is also itself amply large, of at least one or two palms; for so you will accomplish something worthy with it, provided a faultless form is given to sound material.

[Margin: The use of a single convex lens for graphic purposes.]

With this same lens you will use it for catching onto paper the images of terrestrial things. And if you fix the paper down, you will draw them and reproduce on it the fleeting images of things in their colors, and you will have chorographic, topographic, and prosopographic [Praesopographicas — thus printed] charts, and so on. With this same lens, but small and of a small sphere, you will view the smallest things at their largest. With the same lens, large and of a large sphere, you will present tiny letters, at their largest, to the sight. I say nothing now of the other uses, whether common or more recondite, lest I seem to stray too far from my subject.

Use and practice of the third figure, C, 1 and C, 2.

[Margin: The erect projection of images onto paper by two convex lenses.]

What agreement the eye of a far-sighted person [Presbyta], fitted with a concave eyeglass, has with two lenses skillfully composed with one another, has been sufficiently indicated above. Now I add, for our use and practice, a matter indeed long sought and desired by many, but discovered by no one before me, so far as I know — which I now openly share with you here, gladly and willingly. And yet I set it out clearly enough in my *Oculus*, from chapter XX to chapter XXVI. But because many either do not have that book, or perhaps do not weigh sufficiently what is said in it, I am glad to present the matter here without circumlocution.

First. If, beyond the ordered focus — that is, the place of the image which the convex lens draws from the object — you apply another convex lens, this second

lens will, by its own ordered focus, project the image in an upright position onto paper set opposite. And the right side of the image will answer to the right side of the object, the left to the left, the upper to the upper, the lower to the lower, in exactly the way that usually happens in plane mirrors. Yet if you transfer these images onto the paper by outlines or colors, they will again become, to your view, right for left and left for right; which you will avoid in our practice if the paper is pierced, so that

you turn the picture onto its reverse surface.

By this art I am accustomed to display the secondary sunspots and faculae, and to bring them before the sight.

By this art, thirteen years ago, I set up the images of admitted objects for the Most Serene Maximilian, Archduke of Austria [Maximilian III, Archduke of Austria], and afterward for His Sacred Imperial Majesty, and so on. Of this I shall say something, God willing, in a separate treatise devised for the purpose; see my *Oculus* at the passages cited.

Second. If you fit two similar lenses into a tube in the same way, and apply the eye properly, you will see all manner of terrestrial objects — in an inverted position, indeed, but of incredible magnitude, brightness, and breadth; and you will bring the stars too, whatever they are, into the service of your sight. For since all these are round, the inversion of the whole position does not disturb the view as regards its visual configuration — which is otherwise with terrestrial objects — as can also be observed in the Moon, since it is neither always round nor uniform.

Third. If in like manner you fit two tinted convex lenses to a tube and to the eye, you will have a marvelous helioscope, and you will bring out whatever lies hidden in the Sun.

Fourth. By the same art was born that admirable microscope by which a fly is enlarged into an elephant, and a flea into a camel, and things that otherwise escape the eye's edge by their smallness appear large. Of this, God granting, I shall speak expressly in its own place.

I pass over many other things for the sake of brevity. There will perhaps be another place to bring them out, so that I may have given the ingenious reader occasion to discover more on his own. From what has been set out, however, I draw one evident conclusion.

COROLLARY

[COROLLARIVM;]

Namely, that the argument which the Assayer [Trutinator — i.e. Galileo in *Il Saggiatore*] advances in his book to establish for himself the invention of the telescope is false and worthless. For he says that, having heard the report of the telescope, he concluded that, to magnify things optically, two glasses are necessarily required, one of which is convex, the other concave — whereas two convex lenses accomplish this more excellently than a convex

together with a concave one. Since, then, the argument is false, many doubt, on this ground too, the truth of the invention he claims for himself. And if anyone wishes to raise a scruple about the upright position: you have, by two convex lenses, an upright position on the paper; and by three convex lenses, rightly arranged, an upright position for the eye looking through. Therefore his empty argument renders his claimed invention hollow and suspect — to say nothing of other matters.

Use and practice of the sixth figure, *F*, 1 and *F*, 2.

Figure *F*, 1 has no practical example from or in the eye, because no eye lacks the crystalline humor. But if within the eye, between the crystalline humor and the tunic of the retina, at a due interval, there stood some humor resembling a concave lens; or if the eye lacked the crystalline humor and, with a tube applied, received the rays through the open hole of the uvea — then the entire constitution of such an eye would present in the tunic of the retina exactly the same thing that paper set opposite presents to the optical tube. Of this enough has been said above. Now let us come to the use and practice of the optical tube alone.

THE USE OF THE TELESCOPE, WITH RESPECT TO THE SUN AND PLANETS

[VSVS TELIOSCOPII IN ordine ad Solem & Planetas.]

CAP. XXXI.

First. Its first and chief use — for the sake of which I have brought in all these matters as occasion offered — is that it projects sunspots and faculae onto paper most excellently, when the concave lens is set before the base, that is, before the common ordered focus of the convex lens, and paper is duly placed. And in this

way I carried out almost all my Roman observations, running to more than two thousand.

[Margin: The eccentricity of the Sun is investigated by means of the telescope.]

Second. The same helioscope shows most evidently the yearly approach of the Sun toward the Earth and its recession from it. For if you fit the same instrument to the observing machine and mark the Sun's circle at the beginning of Capricorn, then, everything else being varied, do the same in Aquarius, the same in Pisces, the same in the succeeding signs up to Cancer, and thence attend to it descending again through the semicircle — you will see, around the beginning of Capricorn, over a span of about

a month, the greatest observed solar circle; and around the beginning of Cancer, over a similar span of time, the smallest; and each, indeed, remaining as it were stable in its own magnitude. Then you will gradually observe that, as the Sun advances through Aquarius into Pisces, it steadily and ever more decreases, while on the opposite side, in the opposite signs, it is enlarged; and that the greatest and swiftest decreases and increases occur around the equinoxes. From these facts the approach and recession of the Sun, and the solstitial and equinoctial points, become most manifest. For otherwise the Sun's winter circle would not persist so long in its large size, nor the summer one in its smallness, nor would the equinoctial circles undergo such great and swift alternations of magnitude. But since the Sun in summer projects a smaller base or circle, and in winter a larger one, something must have intervened either in the Sun itself or in the telescope. Yet this remained unchanged — the paper unchanged, the aperture unchanged, the distances unchanged, and all the positions of all the parts. Therefore the Sun, if in summer it did not recede, if in winter it did not approach, if it was neither enlarged nor diminished, ought to shine with the same orbit in winter as in summer;

[Margin: The Sun appears with the same magnitude throughout the year, at the same place on the ecliptic.]

but it does not shine the same — rather larger in winter, smaller in summer. Therefore the Sun must have been changed either in place or in magnitude. That it has not been changed in magnitude — at least perceptibly — is certain: because its always-apparent quantity returns each year the same in Capricorn, and returns each year the same in Cancer; unless one supposes it always fattening in winter and growing lean in summer in the same way.

[Margin: The Sun's perceptible apparent increase and decrease is optical.]

Therefore its decrease must be not physical but optical, not real but apparent: for things that are farther off appear smaller than if they were near, even though they do not change their magnitude. Hence, since the Sun in winter casts the larger base of its cone, it must be nearer to us in winter than in summer, when it illuminates us with the smaller

orbit of its ray-cone.

[Margin: An easy method for investigating the Sun's visual magnitude.]

And let this be, in addition, a notable benefit of the telescope for astronomical matters, known to me by the constant and uniform experiment of many years, and most easy in execution. For there is no need to employ daily observations, as I did: you will be able to obtain the whole thing most clearly if you admit the Sun at the beginnings of the signs and note its circle on the same paper. For you will find the manifest differences among them, and the distinctions of their increases and decreases — great or small, quick or slow — just as I said.

[Margin: The Sun's approach and recession is proved by another experiment.]

This is confirmed by another clear experience. For, as I said in earlier passages, distant objects admitted through the same tube shine differently from near ones; near objects require a greater removal of the paper from the concave lens than distant ones do; and if near objects hold a right adjustment, distant ones will fare rather poorly on the paper, or vice versa; if distant objects have obtained a tube-composition proportioned to them, near ones will fare badly — which same thing happens successively about a single object at a near and at a far distance. Hence, if you so compose the Sun at the telescope that in winter it shows the spots and faculae most clearly on the paper, and if you leave everything unchanged up to the beginning of Cancer, you will not obtain the same from the summer Sun that the winter Sun spontaneously granted. For it will present the whole base less bright, and the spots and faculae far more nebulous and duller than it had made them in Capricorn. Conversely, it will do the same in Capricorn if you rightly fit the accommodation in Cancer. But these things, by the witness of perpetual experience, never happen except by a change of distance alone; for as long as the same arrangement of lenses, tube, and paper remains, the same magnitude, figure, position, light, color, and distance of the object, and so on, it is impossible for any variation whatever to occur in the transmitted image. Therefore, since in the translucent Sun the quality of the base changes at the fixed seasons of the year — no change being made about the tube, none about the Sun's figure, none about its color or position, none about its intrinsic magnitude — it must come

about entirely from the Sun's approach and recession alone, just as we see it happen in all other visible things by daily experience.

[Margin: The visual magnitudes of the planets are compared with one another by the aid of the telescope.]

Third. The same telescope serves especially well for comparing with one another the visual magnitudes of the Sun and Moon, and of several of the planets. For as the Sun does, so too the Moon enters quite well through the same tube, most beautifully, with the same apertures retained. This I have often done, whereby the Moon appears now larger, now

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Book II, Chapter XXXI (continued) — the use of the telescope on the Sun and planets

you will find it now smaller, now equal to the Sun. By the same technique you will capture the lunar spots themselves. By the same technique too you will catch, transmitted through the tube, the magnitudes of the more notable planets—especially when near perigee—and compare them with the Sun and Moon, as I have often done in my *Apelles* [writings] and elsewhere.

Fourth. The telescope [*Telioscopium*] is also of remarkable use for observing eclipses of the Sun and Moon. In a solar eclipse the Moon, on the side where it is set beneath the Sun, will be taken for one great spot, for it has just such a blackness. This has been repeatedly confirmed by experience.

Fifth. Whatever a single convex [lens] does with terrestrial objects in transmitting their images, the telescope does the same when properly arranged and applied. But note here: if you wish to use the tube profitably for this purpose, the convex glass must be quite large and of wide aperture, and the concave lens must be able to receive the whole ray-cone around its point of convergence.

Sixth. The apparent magnitude of the Sun and Moon is usually investigated with the telescope, especially around the equinoxes and at midday. That is: while the Sun or Moon traverses the diameter of its own disc, you observe the running seconds of time with the greatest accuracy, and from these then derive the minutes of arc. For as the natural day, which the Sun runs through at the

equinox, stands to those seconds [of time], so the circle of the equator stands to the arc which the Sun's diameter subtends on the ecliptic. Three [terms] being known, therefore, the fourth becomes known. The same can be done around the solstices; but since there the diurnal parallels are not great circles, as the equator is, one must proceed by a certain proportion.

[Margin: Objects differing among themselves in distance are distinguished by the tube.]

Seventh. The distances of objects are revealed by the telescope, as is clear from the Sun at perigee and apogee. For if the same Sun, at the same extension of the tube, shows its recession by a visual diminution and a duller presentation—and shows its approach by the opposite signs—and if the Moon at apogee behaves as it does at perigee, especially as regards magnitude, and so on: shall we then deny this for the other planets and the other stars? Shall we refuse to admit that the same happens with terrestrial objects, against manifest experience? Shall we, without reason and against the evidence of sense, restrict every variety in this matter to a single Italian mile—I add, to a German mile; I add, to the visible horizon? Shall we say that, from the Italian mile, from the German mile, from the visible horizon, all visible objects are of the same tenor and the same vigor toward one and the same tube under the same aperture; or that the same tube is of the same efficacy and power toward all those objects—as a certain person too confidently contends in his *Assayer* [*in suo Libripende*]?

For nature cries out against it, the telescopes cry out, the mountains—variously distant—resist, the woods, seen at differing distances, murmur against it. To this end I have surveyed fortresses, the sea's very waves, the sails of ships upon it; I have approached clouds in the air; I have directed the tube at the Moon, at Venus, at the Sun, at Mars, and at last at the remaining wanderers—in short, at the heavenly bodies both fixed and errant. All of them refute this error: differing in distance, they demanded a different aperture. The reason is that all remote objects, transmitted or viewed through a convex lens, other things being equal, require a smaller extension of that which receives the image, while near objects call for a greater one. Hence it is clear that the same extension of the same tube does not serve alike for the remote and the near.

You will object: yet there are some optical tubes so good that, under one and the same aperture of the tube, they serve for all distant objects; and so the opposing opinion still keeps its force. I reply that I am not unaware—as sufficiently appears from what has been demonstrated so far—that it may happen that some one tube, a portion of a great sphere, be found which, under a single unchanged

aperture, admits both the Sun and the other stars. Yet this in no way helps the doctrine by which it is denied that the distances of objects can be argued from optical tubes. For if there be some such tube that carries the distances of the stars as they now stand, it certainly would not carry them if they were removed to twice or three times [the distance]—which is just what commonly happens with ordinary telescopes, which extend from three to four or five spans in length. Hence a rule drawn from the extraordinary performance of some most excellent tube does not hold if it is extended to all tubes; for all ordinary tubes require a different aperture for the Moon, another for Jupiter's satellites, and so on.

Hence that inference which astronomers drew about the distance of the comet that appeared in the year 1618, from the drawing-out of the tube, was on this head not empty but—other things being equal—solid and effective.

Eighth. With the same tube you will estimate the visual diameters of the stars fairly precisely, and compare them with one another, once you have determined its capacity for a single view, in arcminutes. For then you will easily judge how many minutes of the tube a given star occupies, if you note what part of that diameter it takes up. And although this method of measuring does not equal in certainty the one made by direct admission [of the image onto a screen], it nonetheless surpasses all that is taken with the naked eye, without the aid of a tube—since the free eye sees the stars not sharply but confusedly, and makes them larger than they should be, and so on.

[Margin: The tube uncovers the deception incurred concerning the Sun seen amid vapors.]

Ninth. I had almost forgotten one especially remarkable effect the telescope produces: namely, that it displays the horizontal contraction of the Sun and Moon and their nearly elliptical shape, and most evidently refutes the eye's deceptions about the apparent magnitudes of these bodies when set among vapors on the horizon, as well as other errors. For since the diameter of the Sun, measured along its breadth, always appears of the same magnitude—whether the Sun enters the tube in the morning, at noon, or in the evening; whether it is seen set among vapors or clear of them; whether it appears large or small, round or elliptical—yet on any one day you will always catch a diameter of the same measure. From this it is clear that these appearances must be attributed not to the Sun or to the vapors, but to other causes; and that the Censor, together with certain others, is grossly deluded—as will be shown expressly in its proper place.

THE USE AND PRACTICE OF THE FOURTH FIGURE, D, 1, and D, 2

CAP. XXXII

[Margin: The use of three lenses in observing the Sun.]

I showed the harmony between the eye and the tube in the earlier [chapters]; now I come to its practical use. The use of a three-lens telescope—of convex lenses, shown at D, 1—hitherto unknown and unfamiliar, does the same as the earlier telescope, F, 1, [does], when the convex lens toward the paper has somehow been brought into contact with, or very near to, the concave lens; for by the interposition of this lens the image is somewhat reduced and the distance of the paper is shortened.

[Margin: A method of erecting the image [?].]

But if you place the lens d beyond the position of the paper, i K, you will display pictures both of the Sun and of other things upon the paper set before it, in a most beautiful erect posture, and larger, and at a shorter distance of the paper, than they would have been displayed by two convex lenses alone, the concave removed. And this secret of nature I have hitherto disclosed to no one.

[Margin: The use of the eye with the telescope.]

Now I proceed to figure D, 2, in which the eye, o p, is applied to the optical tube, and art is joined with nature. The tube, by reason of its use and of its lenses and objects, is divided by me into the *telescope* [*Telioscopium*] and the *helioscope* [*Helioscopium*]. By *telescope* I mean one composed of transparent glasses and suited to all visible things except the Sun. By *helioscope* I mean a tube fitted out with colored lenses, apt for tempering the Sun's brilliance.

[Margin: Things markedly distant from sight and from one another are not seen most distinctly with the same aperture of the tube.]

Now the eye, applied to the telescope in the usual way, beholds all things in an erect posture, with greater magnitude and clarity than would otherwise occur. Second, the tube must be contracted for distant objects and drawn out for near ones, if one is eager to focus distinctly on them. Third, it does the same when directed at the Moon, and from her at Venus—especially at apogee—and from Venus at Mars, or Jupiter, or Saturn. For according as these planets are distant from one another, so too the tube must be drawn out or contracted, if, as I said, you wish to examine them most distinctly. That distant and near objects *can* be seen with one and the same unchanged aperture of a good tube is certain; but it is

equally certain that they cannot be seen with the same clarity and distinctness. And it is certain too that, if the same eye wishes to survey all things—and to go over every single object, however near, with the same distinctness and clarity—one must by all means contract the telescope for distant objects and draw it out further for those placed near. Of this I have had the most constant experience since the tube was invented: for if, say, I looked more distinctly at Jupiter's companions, and then turned the same tube—everything else unchanged—upon the Moon, it did not serve here as it served there, but had to be drawn out further.

Likewise, when directed from Jupiter to the Great Dog [*Canis Maior*], to produce a distinct vision of it, the tube must be contracted. And these experiments are daily available to anyone. Hence it is certain that the differing distances of objects are rightly concluded and established from the necessity of this contraction and extension, however vainly and wrongly some may strive to the contrary. Yet it is also certain that there are some tubes so perfect that, even with a single aperture, they satisfy for all objects and for everyone's eyes—for objects, I mean, as they now stand; for it could happen that God should set some object so far from us that even the given tube would not suffice for that distance. Meanwhile, however, I do not contend that from such a tube the differences of distances must, or can, be known at once in specific or individual measure: it is enough that the tube sensibly indicates that one thing is more or less distant, other things being equal.

Fourth. If you draw the eye back from the concave lens of the tube, everything else unchanged, you will always diminish the object, and at last, at a sufficiently great distance, you will lose it through its smallness and invert its position—unless the tubes are very short. For just as the convex lens sets [the image] upright on the paper, so the eye inverts the thing seen upon the retina, once the separation has reached such a distance that the picture formed by the crystalline humor occupies the seat of the retina. This must finally come about by a recession in which, as the distance of the [convex] lens from the concave is increased, the withdrawal of the paper is diminished; and since the same is done by the crystalline humor, one arrives at last at a place where the ordered convergence of the images reaches the retina.

Fifth. If you cover the convex lens of this tube so as to leave nothing open but a tiny hole, the eye applied to the concave lens will bear the Sun. The reason is the same as before: because all the other radiant cones, which would have shone from the other points of the convex lens and so would have produced an image too bright and unbearable to the eye, are excluded; and thus the eye perceives

each perceptible point of the Sun, at so great a distance, brought to it as if under a single perceptible ray, so that it surveys the Sun without harm or dread. This, as it is worthy to be seen, so it presents things marvelous to contemplate.

For first: the whole Sun appears faint and weak. Second: it presents its edges not clean, but as it were broken into thin rays and gently roughened. Third: the brightness all around, at the edges, is seen to be very weak, somewhat dark, and hazy; then, gradually approaching toward the center, it becomes brighter and of denser, purer light; and around the middle it is at last most brilliant. And this difference of brightness is always observed, whether you reduce the aperture of the convex [lens] or enlarge it. The brilliance, too, appears not white but rather fiery.

In this attenuation of splendor, too, the figure and the magnitude of the solar disc remain, to the senses, the same. No spots and no faculae [*Faculae*] at all are discerned. And lest you ascribe this to a deception of the eye, you will project all the same things, in the same way, through the telescope onto paper. You will find everything the same, and in the same way, if you transmit the Sun through a bare and very tiny hole—indeed, almost a point. Indeed, the Sun admitted through a tube onto paper, under a very small aperture, will give similar results, and so on.

THE HELIOSCOPE, and its use

I call *helioscope* every instrument fashioned out of colored lenses for viewing the Sun with an unharmed eye. In however many ways other things are skillfully observed through transparent glasses and instruments, in just as many ways can the Sun be surveyed through helioscopes: whether by one convex [lens]; or by a concave and a convex; or by two convex; or finally by several skillfully constructed together—as has been sufficiently explained at length up to now.

The use and practice of such a helioscope is to behold and reveal whatever is in the Sun—whether it be the brighter parts of the Sun, which we call *faculae*, or the darker, which we name *spots* [*Maculae*] and *shadows* [*umbrae*]; or finally whether the figure, the visual magnitude, and the perimeter, or the solar eclipses [*Solaria deliquia*] come into consideration.

COLLIGENDA [Conclusions to be gathered]

First. From these so various and so numerous methods of observing, the solar phenomenon is most solidly established, against any human obstinacy whatever. For if anyone should choose—"with reason," as the saying goes—to play the madman, and to deny the matter, not because he knows it is not so, but because

he is unwilling to admit that it is: with such a person I have no quarrel. We contend by judgment, not by passion; we seek truth, not victory. Let the large Plate [*Tabula magna*] be set out, in which A is the telescope directed at the Sun B through a hazy medium. Behold the first, Ingolstadt method of observing the Sun.

D is the helioscope aimed at the Sun E, sent out in a clear sky. Behold the second method.

F is the Sun [passing] through the open hole G, caught upon the paper H, but in a dark place. Behold the third method.

I is the Sun falling upon the flat mirror K, and reflected from it onto L, displaying the spots. Behold the fourth method.

P represents the free aspect of the Sun I, set among vapors, and the spots seen in it. Here is the fifth method of observing the Sun.

Q is the Sun let in through the convex lens R onto the paper S set before it, there unfolding its spots in a dark place. Behold the sixth method.

V is the radiant cone of the Sun [passing] through the tube X—composed either of a convex and a concave, or of two convex lenses—caught upon the paper Y Z, beneath the observing circle c d f g. Behold the seventh method, and that not a simple but a manifold one.

Whoever does not see the solar phenomenon, seen and to be seen in so many ways, is impaired either in his eyes or in his mind. The rest will be better explained in their proper places.

Second. From what has been argued so far, it is also established that visible species—whether of the colored or of the luminous—are not only real things but are also seen; and consequently that the species of color is contained within the visible object, and indeed within the breadth of the color; and that the species of light is light, or illumination [*lumen*], in the air, and so on. For everything that is perceived by the eye as its proper object is either light or color.

Third. The Sun, through the telescope, not only shines larger upon the paper, but also ordinarily brighter. This is clear from daily experience. For at Ingolstadt I made all my observations in the open air, with the Sun admitted [through the aperture], and so on—which would not happen if the solar base [the projected disc] were not only larger but also much brighter than the surrounding radiance of the Sun would be; and the reason [follows] from what precedes. For the larger the aperture of the convex lens, the brighter the Sun's image always becomes. For

since the whole Sun is gathered into each point of that [lens's] surface, and from that again is diffused onto the common base on which the observing circle rests, it is clear that the whole Sun is poured out onto that base as many times as there are assignable points in the aperture of the lens. Now it is certain that in a wider exposure of the lens there are more Sun-collecting points than in a narrower one. Or, if you prefer to argue from the solar rays flowing out from a single point of the Sun, you will reach the same result by this reasoning. The larger uncovered surface of the convex lens receives more rays fallen from one point than the smaller does, because it becomes the base of a larger pencil [of rays] than the smaller surface. Therefore, since by the benefit of refraction all these rays are gathered again into a single point, at the common base of the appointed station, it comes about that together they represent the image more strongly than if they had been fewer, under a smaller exposure. Hence:

Fourth. A reason is given why any object seen through the telescope appears to be made brighter, not only enlarged. Because if I look at some part of an object with the free eye, from one of its points I draw into my pupil no more rays than the capacity of the pupil itself admits; all the rest diverge elsewhere, outside it. But the tube leads into the pupil far more of the others, which it captures by refraction, and so on. And to the degree that the eye draws in one visible point by more rays, so it is certain that it is seen the brighter from that point—because the picture on the retina, which determines vision, is brighter from the confluence of more rays at its points. But what has deceived more than one person is this: that the whole object—the Moon, for example—when it is viewed through the tube under a greater magnitude, appears, from that unfolding of its parts as it were, more diluted in light; just as, on the contrary, with the tube inverted, if we look at an object faintly illuminated, by the same operation, under a much smaller apparent magnitude, we shall see it as if intensified, from that packing-together, as it were, of its parts. Fifth—

[The centered column numerals "I."/"II."/"III."/"IV." and the per-column marginal line-numbers (1, 5, 10 ... 55) are cross-reference apparatus and are not reproduced as structural headings. The text flows column by column: left column then right column of each folio side.]

Fifth. Again, from the same source is drawn the means of introducing visible images [species visibiles] so strongly that, even with an open window, they are in no way washed out but are perceived very well, and so on — which you achieve with large lenses. The result is sure and worth seeing.

Sixth. On the same principle craftsmen employ convex lenses [specilla conuexa], so as to examine the tiniest objects as though they were the largest and most brilliant, and to sort them out into their proper proportion of parts. So we see engravers of copper, cutters of gems and seals, and turners of fine work arm the eye and bring into view things otherwise all but invisible.

[Margin: Curious and abstruse questions are resolved.] Seventh. Very many abstruse and curious questions are readily resolved. For why is it that some people do not make out nearby things well unless they bring them very close to the eye? Because such people have a crystalline humor [humor crystallinus] that is too spherical, which therefore contracts the images of somewhat distant things too quickly, so that the station of the ordered image [statio imaginis ordinatae] does not reach the tunic of the retina — which nevertheless does happen when the object is brought nearer to the sight, for in this way that station is produced, and so on.

Why is it that some are not helped by convex spectacles when, as usually happens, they set them against the nose, yet are helped if they move them away? Because convex lenses placed close to the crystalline humor project the visible image too far and beyond the retina; moved away, they shorten it, until at length they bring it to rest on the retina itself. Such are ordinarily the near-sighted [Miopes].

Why is it that some are not helped by convex lenses held at a distance, yet see sharply if they set them against the eye? Because convex lenses far from the crystalline humor abbreviate the image and end it short of the retina, in the vitreous humor [humor vitreus]; brought close to the crystalline, they carry its convergence forward until they place it on the retina. Such are ordinarily the far-sighted [Presbytae].

Why is it that some, using an ordinary convex lens, do not see a distant object, yet see a very near one very well? Because a distant object ends its picture before the retina, while a near one pushes it further out, and so reaches the organ of sight, namely the retina.

Why does a concave lens [specillum cauum] never invert the position of the thing seen in the eye, as a convex one does? Because a concave lens never gathers the rays as a convex one does, but always projects them in the same way, scattering them toward one side, and hands them to the crystalline humor.

Why does a concave lens always present the object, even one far from the eye, though the less so the further it is removed? It always represents it, because it

always hands confused images to the crystalline humor; and because the removal makes only the middle and more direct rays reach the pupil, the others flying off freely by dispersion — whence it comes about that the thing is always presented and seen smaller and smaller.

Why does it happen that sometimes, through a concave lens near the eye, you see nothing, yet you do see when you move it a little away from the eye? Because a lens close by gathers the object before it into an ordered base [basis] beyond the retina; somewhat further off, it shortens that base and coordinates it duly onto the retina.

Why are some helped by very strong concave lenses, others by very weak ones, others by moderate ones? Because their crystalline humor is respectively very spherical, minimally spherical, or moderately so: the first need the first sort, the second the second, the last the middle sort. For very strong lenses greatly lengthen the ordered image of the object, which a small and very spherical crystalline makes very short; a minimally spherical one makes it fairly long, and for this reason is best helped by a fairly weak lens; the middling delight in the middling. And all these belong to the class of the near-sighted.

Why do others, though using the very sharpest concave lenses, nonetheless bring the thing to be seen as close as possible to the eye? Because such people have got a crystalline humor either too spherical, which even when aided by a concave lens (to prolong the ordered seat of the images onto the retina) still does not reach it; but because a nearer object projects a longer base, hence, by its approach to the eye, the image is at last sufficiently produced and places a good picture on the retina.

On arranging the observatory telioscope, and on selecting and duly fitting the lenses. CHAP. XXXIII.

[Chapter title Latin: *DE TELIOSCOPIO obseruatorio ordinando, & seligendis, debitàque imponendis lentibus*. — printed forms *obseruatoria / impanendis* [?] read as *obseruatorio / imponendis*.]

Before I proceed to laying out the observatory circle, I must briefly explain the requirements of the lenses for the observatory telioscope [telioscopium], and the way of duly placing them in the tubes.

Here I set out the ordinary observatory telioscope, which I have used up to now and which others use, made up of no more than two lenses, of which the convex faces the Sun and the concave faces the paper.

Now since, in the practical order of execution, it is necessary to have lenses, it is likewise necessary that these be correctly mounted in the telioscope, and further that this same mounting be duly set and firmly fixed in its holders beforehand, before you set your hand to the work. Therefore, besides what I have so far said in general about lenses, I shall now descend to the more particular matters of the telioscope — and this for the sake of beginners rather than of those already practiced in these things.

[Margin: The parts and composition of the telioscope.] The telioscope, then — so called from its efficacy and perfection in distinctly representing visible things on the target paper — consists of material and formal parts. The material parts are the tubes, the rings, and the caps; the formal parts are the two lenses, convex and concave. The tubes of the telioscope may be many or few, long or short, wide or slender, according to the size and power of the lenses. For a large lens requires a wide tube, a small one a narrow tube, and a segment of a large sphere a long one, and so on.

The material of these tubes [arundines] may be paper, wood, or metal, as each person's inclination or means allow. They must be so fitted one within another that the concave lens occupies the smallest and innermost, the convex the largest and topmost; all so aptly fashioned that the cylindrical surface of the smaller matches the hollow of the larger; for in this way it will come about

that they all cling tightly together and, when drawn out, stiffen in one straight line no differently than a single tube. For if they were loose and slack and gave way, the lenses would become eccentric and the solar circle would be spoiled — which must be carefully guarded against.

[Margin: The rings of the telioscope.] The rings, whether of paper, of wood, or of metal, have a threefold use.

First. To hold the lenses firmly on this side and that, before and behind. Hence the inner ones are usually glued on, while the outer are fitted so that, pressed tightly in, they guard the lens, yet in case of necessity can be taken out, to clean or to change the lens.

Second. To display and preserve the aperture [detectio] required of the lenses, especially of the convex. For every lens has its own definite and commensurate aperture, and once this is known it is preserved in the circularly cut center of the ring. According as the lenses are worked, they will admit a larger or smaller open aperture; on which matter you will shortly have practical rules. For now I pursue the offices and use of the rings, which accordingly must be many and variously

opened, so that it may appear which of them is most suitable — a thing which the eye will best judge from the solar circle cast onto the paper.

Third. For casting darkness into the tube and purging the Sun's ray, the rings are also useful, if — set into certain tubes, especially the innermost and smallest — they are pierced so that they graze, not clip, the edges of the radiant cone, entering deep within; for so they will keep off the superfluous light that has crept in, and the rays that stray by harmful refraction, and will contribute greatly to the cleanness of the solar image.

You will ask, first, to what circle these rings are to be cut. I answer: the one set on the smallest tube may be a little larger than the solar circlet shining in the concave lens; the one on the next-to-last a little smaller, matching the open circle of the convex lens; while those set on the middle tubes proceed in proportion, keeping to the mean between the extremes. The reason is that, since the Sun's ray is carried in the form of a cone whose base is the broad circle of the convex lens and whose vertex ends behind the concave lens, it is plain that of all

these circles the smallest is at the concave, and that the rest grow according to the distance between the least and the greatest, and so on.

You will ask, second, where these cut circles are to be placed. I answer: in the smallest tube one may sit anywhere; for since that tube is empty, having no other inserted into it, it can receive a ring inserted at any point. The remaining, intermediate ones have no place except at the last opening, the one facing the object; for one tube receives the smaller tube pushed into it, which would not allow a ring taken into its interior to be pushed out when the telioscope is closed, but would let it stick in the middle, and so on. These rings have this further use, that the whole observing cylinder may stand stronger and firmer and be kept straighter. To this too is referred that usefulness whereby they block off any lateral transparency of the concave lens, should there be any. For in this lens, apart from the hollow surfaces — or a hollow one and a flat one commensurate with the hollow — nothing should be transparent [transpicuum]; and if in any case the contrary occurred, it is guarded against by applying similar rings on both sides, as use itself will better teach.

[Margin: The caps of the telioscope.] Now I come to the caps of the telioscope. These have been devised for the protection of the lenses, and indeed of the whole tube. For they defend the whole telioscope not only from dust but much more from injury and violence. They are of two kinds: some are flat and round, usually pushed tightly into the openings of the telioscope before and behind; others are

made in the form of a cylinder, closed at one end, usually slipped over the tubes. They are made of the same material as the tubes themselves. Let this be briefly said about the material parts of the telioscope; now I turn back to the formal parts, the lenses. For these give it its form and, as it were, animate the tube; and, as I said, it is according to their standard that the whole magnitude, number, and length of the material parts is to be determined.

The ordinary telioscope, then, consists of nothing but two lenses, convex and concave. Concerning their goodness, their faults, their nature, and their effects, I have said enough in general; now I must descend to more special matters, and examine the lenses in order for practice and observation, and that by means of certain practical problems —

where I shall give notice beforehand that not every concave lens is equally suited for use with every convex lens, but that some are found more fitting than others.

PROBLEM I.

To find, practically or mechanically, the place of the ordered image of a given convex lens — that is, the station of the common base of the ordered images.

Through the given lens admit the images, whether of the Sun or of other things, onto paper; for the place of the paper that distinctly represents the images is the sought place of the image. Alternatively: through the given lens look at any object whatever, until the eye falls upon the place of confusion; when this is done, the crystalline humor of your eye will occupy the true place of the ordered image, that is, of the paper. The truths of these assertions are sufficiently established from what has been demonstrated. The distances of the places found in this way from the concave lens you will easily mark off in some fixed and stable measure, so that they may then serve for what follows.

PROBLEM II.

To assign, practically, the place or distance of a given concave lens from a given convex one.

The place of the convex lens, found by the previous problem, will assign the place of the concave; for, as I demonstrated earlier, the place of the concave is had a little before the station of the ordered common base. Hence it is plain that the place of concave lenses is not to be estimated by the power of the concaves themselves, but by the common convergence of the convex lens; and so, if the place is had for one, it is had, to the senses, for any. I am not unaware that some

slight change of places and distances occurs with the use of different lenses; nevertheless I also know this, that one does not run beyond the common base by reason of the concave lens.

You will object: yet if a sharper concave is used in the telioscope, the tube must always be drawn out appreciably. Therefore there is not, appreciably, one single place for all the concaves relative to the same convex lens, but several. I answer: granting the antecedent, I deny the consequence. For the fact that, with the use of a sharper concave, the tube must be drawn out if the eye is brought near, does not happen because that place is unsuited to that concave, but because the eye is unfit to perceive the image at that station of the concave lens. And this happens because, as I demonstrated earlier, a sharper lens at the same station relative to the same convex projects the common base further than a weaker one does. Therefore, if the eye has used a tube suited to it, the ordered image or picture must have fitted the retina; but if now a sharper glass is brought in, the same image will be extended, and so the eye will see either nothing or little. Why? Because the picture passes beyond the retina; and so, in order to recall it, the tube must be drawn out as much as is needed. All this has no place on the paper. First, a disparity of reasoning intervenes here, in that we do not fix another convex before the concave in this case, since we are treating the ordinary telioscope; and second, because with the paper drawn back the ordered and clean image is had as before, and somewhat larger. But if someone wished to keep the same distance of the paper unmoved, then it would be altogether necessary to move the concave a little away from the convex; for in this way the image would be contracted and depicted cleanly on the paper. Yet this would not come about because the former position of the concave was unfit for representation, but because the paper was in an unsuitable place to receive it — a thing which experience makes plain in both cases. For with the paper drawn back it will always receive an elegant picture, even if no drawing-out of the tube is made. This is further confirmed by experience; for if the same lens is brought closer to the convex, it will still project a distinct image onto the paper: how much more, then, at a more distant station? And so on.

PROBLEM III.

To assign, practically, the length of the tube for two given lenses, convex and concave.

The distance of the concave lens from the convex lens,

found by Problem 2, will give the precise length of the tube. Yet since one tube must be inserted into another, a length a little greater must also be assumed. Besides, since it often happens that concaves of much power are used, it is good to use such a length as can serve for many lenses.

PROBLEM IV.

To assign, practically, the distance of the paper for given lenses, convex and concave.

The distance of the paper from the concave lens is better and more safely assigned practically and mechanically than theoretically and speculatively. For this matter cannot be treated scientifically without a perfect science and doctrine of refraction. A full and exact science of this I have not so far seen, and to institute here an extended doctrine of it would be to confuse the subject matter out of its proper place — not to mention that of particulars no science is given, but rather the senses must be consulted. For how will you know that given lenses are correctly formed, are of this or that figure, sphericity, power, and so on, except by sense and by most laborious experiment? Whence will you declare the station of the common base for the ordered picture, except from the image shown on the paper? And whence will you discern whether the image turns out elegant or ugly, clean or foul, except by the interposed paper?

Therefore, for ready practice, these things are dispatched more briefly, quickly, and safely by mechanical means than if we proceeded from many theoretical precepts — precepts which in the end either win their own praise, or take away blame from, the very experiments we are now pursuing. Indeed, what is more, it is impossible, humanly speaking, to arrive at solid science except through countless prior experiences of the senses; for these open the way and, as it were, lead the understanding by the hand to the drawing-out of many abstruse and marvelous things. And so you will have the best distance of the paper from the concave lens when, with the eye as judge, you have seen the best picture expressed upon it — which you will judge by moving the paper toward the concave lens and away from it: for you will see, in this way, at what station the picture

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the sharpest picture of all appears; and you will certainly keep it for your purpose.

Problem V

To enlarge the image of the object with the same lenses of the tube.

Move the concave lens toward the convex one, and draw the paper away from the concave lens as far as Problem 4 requires, and you will achieve your aim.

Problem VI

To diminish the image of the object with the same lenses of the tube.

Move the concave lens away from the convex one (but in such a way that you do not overshoot the place of inversion), bring the paper toward the concave lens as far as is enough, by Problem 4, and you will get your wish.

Problem VII

To present with the same lenses always the same image, at equal size, on the paper.

If the object keeps the same perceptible distance from the tube, it is easy to display the same picture at the same size; and if all the distances are also kept unchanged, the aim is achieved.

If the object recedes perceptibly, then—everything else remaining unmoved (the tube, the lenses within it, and the paper)—the image is rendered not only smaller but also more confused. This is because an object that perceptibly recedes projects a shorter cone behind the convex lens, so that the concave lens, relative to this, transmits a smaller and more confused image onto the unmoved paper; and constant experience supports the reasoning. The remedy is to let the concave lens approach the convex one until an equal and well-formed image flows onto the paper.

If, on the other hand, the object approaches the telioscope perceptibly, the picture is certainly enlarged, for reasons opposite to the foregoing: the convergence is prolonged beyond the concave lens, and so the concave lens, being near the convex one, enlarges the image onto the paper, and thus—being no longer at the proper distance—confuses it, and so forth. The contrary will happen if the concave lens gradually withdraws from the convex lens, until everything comes out clear and even as before. And in this way you will keep a picture of the same size at any distance whatever, and so on.

By this device I have always been able to receive [the Sun's image] within the equal capacity of the same observatory circle [circulus observatorius], whether the Sun was at the winter or the summer solstice, at perigee or at apogee.

Corollary

From all this it is evident that one and the same tube—or telioscope—both is and ought to be called a single one, so long as the same lenses (numerically) remain in it, whether the tube is drawn out or contracted further. For a larger or smaller aperture, a sharper or more confused view, a clearer or dimmer one, does not make it a different tube in number.

[Margin: The tube is one and the same in number by virtue of the same lenses in number, not by a differing aperture.]

For the fact that one eye or another requires a different aperture contributes nothing toward constituting a different tube; rather, it arises from the limitation of the eye. If the eye's tunic, the retina, could be moved away from or brought toward the crystalline humor—or the crystalline toward it—by just as much as the tube's prescribed setting requires, all would be well. For the telioscope paints an excellent image even when no eye, applied directly to it, apprehends anything through it. This is proved by two very clear experiments.

The first: if you move the concave lens so far from the convex that it falls, as it were, at the convex lens's place of inversion and displays small images at a short distance, then an eye applied to it will see little or nothing. The reason follows from what was said before: the rays, taken into the crystalline humor as it is arranged, confound the picture on the retina.

The second experiment is drawn from the eye itself. If you apply the eye at roughly that station where the paper catches the images of the objects confusedly, the eye will behold those same images, but in reversed position, and not all at once but piecemeal. In a word: the crystalline humor of the eye, applied in place of the paper and painting the image distinctly, will always produce the contrary effect. So far, then, is it from being the case that we set up the telioscope for representing things according to the eye's discretion, that on the contrary we would by that rule destroy its whole power and nature.

This is further confirmed by a single convex lens, which always brings into view objects that are unequally distant with unequal effect. Therefore, anyone who wishes to make a telioscope into something different by a greater or lesser extension and contraction, or by a clearer or dimmer presentation, will by that

same reasoning make many eyes out of the same eye (numerically) and many lenses out of the same lens. For the same lens, at one and the same moment, renders some things clearly, others confusedly; the same eye perceives some things faintly, others distinctly; likewise, the things that fall along the axis or on rays near the axis are perceived far more purely than those seen by rays striking the sloping sides, and so on. And yet, for all these reasons, no one who has so much as crossed the threshold of optics would conclude that the same lens becomes a different one because of a different mode of representation, or that the eye—or the eye's crystalline humor—is made another by one view of things or another.

It is confirmed still more strongly by the inverted and the erect position of the images produced through the same convex glass, which by the force of refraction produces those otherwise mutually contrary effects while remaining one and the same. So too the telioscope, being one and the same, must be judged capable of yielding and doing very different things. And so forth.

Practical Doubts

First Doubt. Is a plano-convex lens better suited to this business than one convex on both sides?

I answer that the plano-convex seems preferable, because it refracts the Sun's rays less and gathers the images of visible things more cleanly onto a common base. This is clear from experience, and the reason is drawn from the less violent refraction: a flat surface handles the lines of rays more gently than a curved one, for the curved breaks them more harshly.

Second Doubt. Is a lens concave on both sides more convenient than a plano-concave?

I answer that, other things being equal, the plano-concave is always to be preferred. The reason is the same as before—to avoid great refraction. But because one sometimes needs a concave lens of great power, this is compensated for by introducing a concavity of moderate power on both sides.

That this is necessary is established as follows. If you employ a lens concave on only one side and of the greatest power, it can only be a portion of a very small sphere; and if you apply this to the convex segment of a large sphere, the radiant pencil sliding from the convex into the concave will be larger than can be received all at once by that same concavity. So that there may be room for it, you will attain your end by taking two concavities of larger spheres, which together

will equal the single concavity of the smaller sphere, and yet at the same time will open with a larger circular base.

Third Doubt. By what method may the power of a concave lens be known in practice—whether it is greater or less than that of another?

I answer, in general, that every sharper [more strongly curved] concave lens seems, in a certain definite way, to be able to do more than a more obtuse [weaker] one. I said "in a certain definite way." For, all things being equal, the concave of a larger sphere can do more than the concave of a smaller sphere; since the similar portions of all spheres, whether concave or convex, are to one another as their spheres. And it is certain that a larger sphere can do more in presenting [an image] than a smaller one, and so on. For this reason I said that sharper lenses can do more than more obtuse ones in a certain definite way—namely, in rendering the object's image larger at a shorter distance, which is what is often sought in this practice. I add that they often make it stronger, too, because a smaller lens refracts the Sun under a larger portion than a larger lens does, and so forth. You will therefore discern such power of a lens in this way. Take two lenses, and at an equal distance from the eye turn them toward a single object: the one that shows it larger will be the more obtuse; the one that shows it smaller, the sharper; if they show it equal, they are of equal power. And so on.

Fourth Doubt. Is it all one to use short lenses (i.e. of smaller spheres) as long ones (of larger spheres)?

I answer that it is not all one. For long lenses, other things being equal, represent better and more distinctly than short ones; and moreover they cause less trouble from refraction.

Fifth Doubt. How long ought the tubes to be for observing the Sun?

I answer that this matter rests in each person's will and discretion; and the manner, just as...

just as in all things, so here too the rule must be kept, and here also the golden mean will be best. For tubes that are too long are hard to handle, since a long observing instrument requires something sufficiently sturdy and large so as not to bend; then, because such tubes feel the Sun's very rapid motion; and finally, because they can scarcely find a concave lens of sufficient capacity, and pour that lens's defects too plainly into the Sun's image.

Conversely, lenses that are too short rarely present the matter as cleanly and distinctly as one wants; then they either refract too much, or show too small a

Sun and hide the fine details; and they will not bear the Sun for long under the same aperture.

Middling tubes, therefore, are best for everyday practice. But how long are these? The tube with which I observed the spots at Rome during that three-year period is about four Roman palms in length—the kind commonly made and kept, since such tubes serve for all objects, terrestrial as well as celestial. Meanwhile I do not deny that even the most exact observations can be made with shorter and longer ones, as will be indicated in the proper places. In general, middling tubes—which I reckon at three to six Roman palms, more or less—are of the greatest use in observing this phenomenon.

On the Solar Circle and the Observatory Circle, and their Difficulties

Chapter XXXIV

[Margin: The distinction between the solar circle and the observatory circle.]

The solar circle [circulus solaris] is one thing, the observatory circle [circulus observatorius] another. The former is the right section, or base, of the radiant solar cone; the latter is the seat of that base traced out on the paper. Hence the two must be commensurate with each other and equal. From this a difficulty arises: whence, and how, is this equality to be established? For if you fix the observatory circle at a definite size, you will feel a difficulty on the side of the telioscope, because not every telioscope will at once comply with your proposal and fit its ordained base to the given circle; rather, it will either exceed the circle or be exceeded by it.

But if you seek your counsel from the telioscope, you fall back into difficulties, because the base determined by the tube's best extension will not immediately be of the size you had fixed for yourself. And granting that it does come out at the given measure of breadth, other inconveniences still often arise from this: either the spots and faculae are seen less perfectly, or the gap between the concave lens and the paper is not as great as the practice of observing requires. Therefore, so that every difficulty may be met, let there be [the following]:

Question I

For the practice of observing, is a larger observatory circle better, or a smaller one?

I answer that a larger observatory circle is to be preferred to a smaller one.

First, because a larger one shows the exact number of both faculae and spots, even the smallest.

Second, because it renders the shapes of all of them distinctly.

Third, because it accurately distinguishes the nuclei, the clouds spread around them, and the faculae—whether adjoining them or bursting out from their midst.

Fourth, because it exhibits, to a nicety, the differences among the spots and faculae—their rarity and density, their intensifications and remissions, their uniformities and irregularities.

Fifth, because it sets plainly before the eyes the signs of spots about to form and the traces of those that have ceased.

Sixth, because it shows most beautifully the increases and decreases of both spots and faculae—now swift, now slow, sometimes large, sometimes small.

Seventh, because it teaches infallibly the risings and settings of the spots and faculae, both physical and astronomical.

Eighth, because it makes even the daily paths of the spots and faculae perceptible near the horizon.

Ninth, because it renders the spots and faculae conspicuous even on the horizon, both eastern and western.

Tenth, because it most clearly detects the Sun's secondary spots and faculae, and lays the whole Sun so completely open that no place is left for any hiding.

Most of these things, then, either escape the smaller circle, or are presented so dimly and doubtfully that, without the help and partnership of a larger one, many cannot be asserted with certainty—much less settled. So that it is truly astonishing that some, relying on mere observations from smaller circles, have been willing—without any fear of the contrary—to reckon the spots into the census of the stars on the basis of their [supposedly] unprofitable courses, though with such tiny little circles these are scarcely ever fully grasped.

A larger circle, then, indicates greater and more certain things, and is therefore better than a smaller one; nor is any room for doubt about this left—a doubt that everyday practice, as will be seen in the following book, resolves all too certainly.

But someone will ask: how large, after all, ought the diameter of the observatory circle to be, if it is to seem adequate to this task?

I answer that this is left to the judgment of a prudent observer; yet this fairly safe rule can be given. If middling spots and durable faculae of every kind become visible on the horizon, so that the paths and courses of the phenomenon can be traced, the observatory circle seems to have capacity in abundance. Mine did this admirably. And although it presented the secondary spots and faculae well enough—especially under the smaller uncovering of the convex lens—yet a larger observatory circle, equipped with two convex lenses, did far more brilliantly: it set out into the open the very smallest things on the Sun, so that the pure could be distinguished from the impure, the bright from the shadowed, the dark from the brilliant, as well as could be. This suffices for observing the motion of each spot and of the whole Sun; and if it is obtained by any circle whatever, that circle will certainly be ample enough for investigating the phenomenon.

Question II

Can a large observatory circle be obtained from any tube, even a small one?

I answer that it can—either with a single concave lens but a greater paper-distance and a smaller interval between the lenses, or with different concave lenses applied to the same convex; for a sharper lens moves the paper farther back and enlarges the circle.

Question III

Is a large observatory circle from a small telioscope as good as one from a large telioscope?

I answer that the size of a tube is twofold: one of length, the other of breadth. The size that proceeds from length is derived from the convexity of the spherical lens; the size of breadth, from the extent of the uncovered portion—not, however, from the whole circle of the convex lens. For there are many very large convex lenses which nonetheless, in use, allow only a tiny portion of themselves to be uncovered, because they at once produce colors, confusions, and the like. With these premises laid down, there are three cases in every telioscope: either it is at once both long and wide; or long only, but not broad; or broad only, but not long.

[Margin: Which tubes are to be preferred, and to which.]

It must be said, first, that every tube at once long and wide is better than one that is merely long or merely wide, other things being equal. The reason: one that is long but not equally wide falls short in clarity and intensity; one that is wide but not equally long falls short in size and distinctness. Since our given tube has both,

by hypothesis, it clearly prevails. Note well that this conclusion holds for tubes either of the same kind or at least of equal aperture, and so on. Tubes are of the same kind when they contain lenses of the same kind; and lenses are of the same kind when they are segments of the same spheres, whether concave or convex.

It must be said, second, that it can happen that a shorter but wider tube equals or surpasses a longer but narrower one. The reason: clarity joined with sufficient distinctness is often better than mere size with dim distinctness.

It must be said, third, that it can also happen that a narrower but longer tube surpasses a wider but shorter one, because long tubes, with sufficient uncovering, act more strongly on account of the less-refracted rays, and therefore paint and represent more precisely under larger circles. And so on.

It must be said, fourth, that of tubes equally wide, the longer is always better, because it represents more clearly and distinctly.

(Printed page 136 — verso; source Cross-reference apparatus columns "III." and "IV." The following continues the answer to Quaestio I from the preceding pages — the reasons a larger observatory circle is preferable.)

Most of these phenomena, then, either escape the smaller circle altogether, or are presented so dimly and doubtfully that, without the aid and cooperation of a larger one, many of them cannot be affirmed with certainty — still less settled. It is genuinely astonishing, therefore, that some observers, relying on nothing but observations made with small circles, have been willing — with no fear of the contrary view — to enroll the sunspots in the census of the stars on the strength of their supposedly inconsequential courses, when in fact those courses are scarcely ever fully captured within such tiny little circles.

A larger circle, therefore, reveals larger and more certain things, and so is better than a smaller one; nor is any room for doubt left on this point — a point which everyday practice, as will be seen in the following book, makes all too certain.

But someone will ask: how large, after all, must the diameter of the observatory circle be, if it is to appear adequate to the task? I answer that this is left to the judgment of a prudent observer. Yet this general rule can be laid down as reasonably safe: if medium-sized spots and durable faculae of every kind become clearly visible on the horizon [in horizonte — i.e. at the edge of the projected disk], then the observatory circle may be judged to have ample capacity for investigating the paths and courses of the phenomenon — which mine did admirably. And although it presented the spots and the secondary faculae well

enough even under a smaller aperture of the convex lens, nevertheless a larger observatory circle — fitted out with two convex lenses — did far more: it brought out into the open even the very smallest features on the Sun, so that the pure could be distinguished perfectly from the impure, the bright from the shadowy, the dark from the brilliant. This suffices for observing the motion both of the individual spots and of the whole Sun; and if this degree of detail is obtained through any circle whatever, that circle will certainly be ample enough for investigating the phenomenon.

QVAESTIO II.

Whether a large observatory circle can be obtained from any tube whatever, even a small one?

I answer that it can. This may be done either with a single concave lens — but with a greater distance to the paper and a smaller interval between the lenses — or with different concave lenses applied to the same convex one; for a sharper lens pushes the paper farther off and enlarges the circle.

QVAESTIO III.

Whether a large observatory circle produced from a small telescope is as good as one produced from a large telescope?

I answer that the size of a tube is twofold: one of length, the other of breadth. The size that comes from length is measured by the convexity of the spherical lens; the size of breadth, by the extent of the uncovered portion — not by the whole circumference of the convex lens. For there are many very large convex lenses which nevertheless, in use, allow only a tiny part of themselves to be uncovered, because they immediately produce colors, blurring, and the like. With this premised, there are three possible cases in every telescope: either it is at once long and wide; or long only, but not wide; or wide only, but not long.

[Margin: Which tubes are to be preferred, and to what.]

First point. Every tube that is at once long and wide is better than one that is only long, or only wide, other things being equal. The reason: a tube that is long but not equally wide falls short in brightness and intensity; one that is wide but not equally long falls short in magnification and distinctness. Since our given tube, by hypothesis, possesses both qualities, it clearly prevails. Note well that this conclusion holds for tubes that are either of the same kind, or at least of equal aperture, and so on. Tubes are of the same kind when they contain lenses

of the same kind; and lenses are of the same kind when they are segments of the same spheres, whether concave or convex.

Second point. It can happen that a shorter but wider tube equals or surpasses a longer but narrower one. The reason: brightness joined with sufficient distinctness is often better than mere magnification accompanied by dim definition.

Third point. It can also happen that a narrower but longer tube surpasses a wider but shorter one, because long tubes, given a sufficient aperture, act more powerfully on account of their less-refracted rays, and therefore paint and represent things more precisely under larger circles, and so on.

Fourth point. Among equally wide tubes, the longer is always better, because it represents things more clearly and more distinctly.

(Printed page 137 — recto; source duplicated Cross-reference apparatus columns "I." and "II." Quaestio III's answer continues.)

Fifth point. Among equally long tubes, the wider is always better, because it presents things equally distinctly but more brightly.

Sixth point. The same tube, at a shorter extension, presents a larger but fainter image than at a longer extension.

Seventh point. The same tube refracts more at a shorter extension than at a longer one.

Eighth point. Among similar tubes, the circles of the larger ones are better than those of the smaller, because they project a larger, brighter, and more distinct image.

Ninth point. The circles of larger telescopes, other things being equal, are always less refracted than those of smaller ones, and therefore always better.

QVAESTIO IV.

Whether it is better to make the observatory circles equal to one another, or unequal?

[Margin: The equality of the observatory circles is preferable.]

I answer: if the quality and design of the telescopes, along with the time and place, allow all the observations to be enclosed within equal circles, then without

doubt this is better, because it spares time, labor, and the risk of error in setting things out — as will become clear in what follows.

QVAESTIO V.

Whether it is preferable that all the observatory circles come from the same telescope, or from different ones?

[Margin: It is preferable that all the observatory circles proceed from the same telescope, other things being equal.]

I answer: if the telescopes are of the same kind — that is, of the same length and power, and hence of equal refraction — then it makes no difference whether you use one tube or several, under equal circles, since the result will be the same from all. But if they differ in kind, and some are appreciably longer than others, it could happen that they would introduce some difference in the presentation, on account of their differing refractive power — especially if you were to use very large circles and very sharp concave lenses. Hence, to avoid dangers and any suspicion of error, you will act more cautiously by using a single tube, or tubes of a single kind, rather than many different ones. For this reason I myself, throughout this whole three-year period, have used almost always a single telescope, under an equal observatory circle.

QVAESTIO VI.

Whether it is preferable to carry out all observations at a single extension of one telescope, and to set up different observatory circles according to the Sun's approach and recession; or rather to make many extensions and contractions of the telescope, so as to preserve one and the same observatory — and solar — circle?

[Margin: It is preferable that one and the same observatory circle always be kept, by means of different draw-adjustments [laxaturas].]

I answer that it is better to preserve one observatory circle by means of different extensions of the tube than to obtain different circles under a single extension of the tube.

First, because a single extension of the telescope does not ordinarily serve the Sun both at perigee and at apogee, but necessarily requires some change — moving the tube toward or away from the paper, or the paper toward or away from the tube.

Next, even granting that in some very long tube of extraordinary power this approach and recession of the Sun were imperceptible, still, neither would so great a distinctness always occur in the image of the Sun, nor would the circles come out equal in size — they would be unequal. From this, in the end, greater labor would accrue in equalizing those images than had been spent in observing them. It is therefore better to equalize the observatory circles than to equalize images that were observed unequal.

QVAESTIO VII.

Whether it is better to carry out different observations under one observatory circle, or to assign to each observation its own separate — but mutually equal — observatory circles?

[Margin: It is preferable to gather many observations into one observatory circle.]

I answer that it is better to gather many observations into one circle than each into its own. For it spares time, labor, paper, and the risk of error; the long-term progression of the spots is better perceived; and the earlier observations, set out in view, greatly help and guide the observer. If, however, it comes to the point where either one circle is filled, or no empty places remain for marking the spots, then a new observatory circle — equal to the previous one — must always, by all means, be taken on a clean sheet of paper.

(Printed page 138 — verso; source Cross-reference apparatus columns "III." and "IV.")

QVAESTIO VIII.

Are small observatory circles to be eliminated entirely as useless?

[Margin: The usefulness of small observatory circles.]

I answer that small observatory circles — especially with long telescopes — do not lack their uses and conveniences, and are indeed by all means to be employed. For observation under a small circle is far quicker than one made under a large one. Because the Sun's motion in a small circle is not so fast; because spots that lie closer together are placed more surely in their positions by the eye; because the Sun is held more steadily at the points of its circle; and finally because a smaller refraction occurs there — a thing of great help while the true motion is being tracked down. Through smaller circles, too, the centers even of large spots are obtained more accurately, for they become, as it were, a single

point. The motion of the larger spots is likewise confirmed by the smaller ones, and vice versa. Lastly, an abundant supply of large telescopes is often lacking; hence smaller circles are not to be wholly neglected — nor the smaller circles, especially if they are taken from longer telescopes. As for the respects in which these small circles fall short, you will read of them here and there, and understand them, from the actual practice of the following book, in which you will find a comparison instituted between the Ingolstadt observations and the Roman ones, and so on.

QVAESTIO IX.

What is to be thought of the circles and observations produced on paper from a single convex lens? Are they of any use?

[Margin: The images, or pictures, produced from a single convex lens are to be preferred.]

I answer that circles and observations carried onto paper from a single convex lens alone are of no small utility, because in them virtually no perceptible difference of refractions occurs — especially if a plano-convex lens is used, the segment of a large sphere. The reason why refraction does almost no harm in lenses of this sort is that the concave lens is absent, which increases refraction most violently; and further, because all the rays, owing to the curvature of the lens, pass at angles that differ little — nearly right angles — and hence only a small discrepancy of refractions intervenes. From this it comes about that the tracks traced out by the spots are nearly everywhere consistent with themselves, and that the true positions and motions are thereby detected without any perceptible errors.

But the circles of such lenses are most difficult to obtain by observation, because of the excessive distance of the lens from the paper (or of the paper from the lens); and this lens and paper, as was said above, must always be parallel to each other and concentric on the same axis, and so on — things that cannot be done without a large instrument. And so the theory is easy and straightforward, but the practice is hard. The images from these lenses are very intense and, if the lens is well shaped and polished, exceedingly clean and precise.

QVAESTIO X.

How is the observatory circle to be laid out in practice?

[Margin: An observing apparatus is necessary.]

Before all else, you must be well equipped with a sound telescope and an observing apparatus. Then, as you see in the first figure, insert the tube $a b m n$ (or $f g$), properly drawn out, into the holders R and T, in this way: so that the axis of the tube $f g$ is parallel to the line $i K m$, and that the perpendiculars $i c$, $K l$, and $m n$ — raised from i , K , and m to the axis — are all equal to one another, and so that the point c is at once the center of the observatory circle and of the solar base [the projected solar disk]. With these things thus set up, apply the whole apparatus to the Sun, so that the aperture g of the telescope transmits the received solar ray h onto the paper at c , whose base you will mark with the two legs of a compass at once, if it can conveniently be done, at [?] a and b [the leading letter reads "m", uncertain], then crosswise at the points d and e — taking the greatest care, however, not to take a line smaller than the diameter of the base. But if, on account of the largeness of the base, you cannot conveniently reach two marginal points at once, mark first either the topmost point a or the lowest point b ; then, keeping the Sun in the same station (which will be done if, grasping the base with your left hand, you steer it by moving it gently in step with the Sun's motion), you will mark the opposite point b . Afterwards mark the lateral point d ; and, with the Sun kept firmly at the two marked points a and b , you will finally proceed to the fourth point, e , from the three already marked. When this is done, each

Diagram. A full-page engraved plate, numbered N. 6., captioned *Machina Helioscopica cum suis partibus* — "The Helioscopic Machine with its parts." It combines an optical ray-schematic of the telescope-tube across the top with a laid-out inventory of the machine's separate components in the middle, and the fully assembled instrument set up on a tiled floor at the lower right.

Across the top runs a schematic longitudinal section of the sunlight-tube: at the far left an arc (the incoming solar beam, marked p), the rays converging to the right through a convex objective lens at the near end and a concave lens in a small box at the far (right) end.

- a , c (top edge, at the objective-lens end): points bounding the objective lens
- b , d (bottom edge, at the objective-lens end): points bounding the objective lens
- s (middle, objective-lens end): the objective lens itself
- e (top), h (middle), f (bottom): points along the tube (aperture/field)
- K , m (top right), n (bottom right): points bounding the concave lens box at the far end

The middle of the plate lays out the labelled parts:

- E: a large square panel (a board with an inset square and a small bar beneath)
- Caput [Head]: a panel with a small concentric-circle target ☉; below it **D** (a small bar); below that **Pes** [Foot]
- Circle-target (square with an inscribed circle): a (top), b (bottom), d (left), e (right), around center **C** — the observation-circle divided at its cardinal points
- B: **Tabella chartifera** [the paper-bearing tablet], with a small target ☉
- A: **Charta** [the paper]
- F: hardware pieces — a screw and washers/nuts
- Retinacula [clamps/holders]: the U-shaped clamp pieces **I** and **K**
- Cunei [wedges]: **L** (with one further, unlettered, wedge)
- Dorsum seu Rostrum [the Back, or Beak]: a long beam, marked **G** and **M**, with fitting **H** at its right end
- Suppedaneum [the base-block/footing]: a marbled rectangular block, marked **N**
- Fulcrum [the prop/support]: a triangular A-frame, marked **O**

At the lower right the machine stands assembled on a tiled floor: the projection-box and eyepiece end **P**, the foot **Q**, the pivot/upright points **R**, **S**, **T**, with **V** marking the ray-direction at the objective end.

[The main text of this opening is set in two columns per page, but Scheiner numbers the columns continuously across each opening (I, II on the recto below the plate; III, IV on the facing verso). The prose runs straight through I → II → III → IV. Column apparatus numerals and the five-line marginal reference numbers are cross-reference apparatus and are omitted here; genuine chapter and section headings are retained.]

LIBER II — Cap. XXXIV (conclusion)

grasp the foot of the machine with your [other] hand, bring the Sun onto the four marked points, and judge carefully whether the Sun anywhere overruns the points, or the points the Sun. If everything corresponds well, remove the paper-bearing tablet and, through the four points you have found, draw the blind circumference of a circle. If it passes through all four points, the solar base is correct, [Margin: *Examination of the base of the solar cone.*] the instrument is well positioned, and the lenses are correctly arranged. If the blind circumference does

not pass through the four base-points you found, then the base is not a circle, and a fault lies hidden — either in the arrangement of the instruments, or in the placing of the lenses, or in their shapes — which must accordingly be examined and guarded against. (This holds unless the instruments are being applied to a Sun near the horizon; for in that case, as I said above, even with everything in order, a circular image of the Sun never appears, and so on.)

So then, if the observatory circle found by this method suits you, it is right. If it does not suit you, but you want a larger or a smaller one, you will lay out one of your own choosing on the paper-bearing tablet **C**, and mark it off into eight points: the larger, cardinal points **a**, **b**, **d** and **e**, and likewise four other, smaller, intermediate points. Then fit the tablet to the Head of the instrument, and by moving the telescope adjust the transmitted Sun until the solar base is made exactly equal to the observatory circle. Once this is done, you will proceed to the actual practice of observing.

THE METHOD AND PRACTICE of Observing the Solar Spots and Faculae

CAP. XXXV.

With everything set in order and correctly arranged — the observatory machine, the telescope, the paper, the observatory circle — and the shades drawn, in a shaded place (and, if you like or circumstances allow, a rather dark one), cast the Sun *g h* through onto the paper *c*; and above all first carefully draw the whole base into eight or more marked points of its periphery. Take diligent care that the points coincide as perfectly as possible with the edge of the base; and do this always at the start of each observation, for the following reasons. First, because it can happen that at the time of observation the Sun suffers a defect, or an elliptical distortion, in the vapors. Second, because it can happen that, over the span of several intervening days, the solar base has become noticeably enlarged or contracted. Third, because it may have happened (as it often does) that some shaking or pulling-apart of the tube, and the like, has intervened — all of which bring an inequality into the solar base. Hence it is necessary that, always at the beginning of observing, the equality of the observatory circle with the solar base be examined and verified.

[Margin: *The margins of the Sun to be examined.*] Then scan the solar base carefully as it shines on the paper (but do not let the remaining brightness of the Sun or of the daylight strike your eye), and above all traverse the eastern and western margins of the region, inspecting everywhere accurately, in case a

shadow, a spot, or the brightness of some facula betrays itself to view. And if, with the paper at rest, nothing appears, move the machine a little; and if anything lies hidden in the Sun, it will be revealed by that motion. In this way I have roused many spots, many faculae, many shadows — sluggish in their stillness — by agitating the paper, and have drawn them out into view, whether they would or not, as much my own as another's.

Moreover, this motion has often served for investigating the entrance of spots and for following and continuing their exit. For spots, mostly around sunrise and sunset, being flooded with much light, are recognized only with difficulty, and sometimes not at all; yet by this agitation they hold still to be seen. Add to this that around the margins they spread out and look like little clouds, whereas when drawn back toward the middle of the circle they gather together and appear darker in aspect. Let this be enough said about the inspection of the solar base. And if, when all these means have been applied, you see nothing there, you will declare that the Sun appeared empty at that time, and you will note the day, and so on.

[Margin: *The method of marking the spots.*] To mark down the spots, I use the point of a compass, of steel or of brass, sharp but gently rounded — sharp, so that I can pierce the paper and drive in points for the centers of the spots and their nuclei, and so on; rounded, so that I may draw soft but blind lines to indicate the outline of the spots and faculae, the nuclei, and the shadows. For to use a pen, or graphite [*plumbago*], or any similar thing that stains and colors is, in my judgment, liable to error and almost impossible to carry out — because of the tilt of the paper and the excessive delay of time. For besides the fact that the spots ordinarily shift from their places by the daily motion, it rarely happens that you fix a spot in its place at the very first attempt. The paper, then, stuffed with endless smudges, will furnish countless handles for error.

Therefore it is better to trace the blind lines and the traces of the spots harmlessly with a dry stylus; for in this way you will both dispatch the business more quickly and correct your mistakes without any mess. The marking should begin with the spots, since these ordinarily appear more stable and better defined; and among the spots themselves, if there are many, a selection must be made. For I almost always pick out some definite one, by which throughout the whole observation I direct myself. And that one is taken by me not by chance or accident, but with the greatest care: that it be clearly visible, that it be small, that it lie toward the horizon, and, if possible, near the eastern side.

[Margin: *A single small spot to be chosen at the outset as a guide.*] The first condition ensures that it quickly strikes the eye and need not be sought with great effort, so that, once its place has been noted, it can be recovered without difficulty.

The second makes the designation of the place very secure: for the smaller the spot, the less space it occupies, and so the less occasion is given for error in assigning its place — which does not happen with larger spots, over whose exact center one must sweat a good while.

The third condition makes the whole observation more secure. For since marginal spots are carried out of their seats most swiftly of all by the daily motion, but on the contrary advance most slowly by their own apparent motion, it comes about that, as long as the chosen marginal spot stays at its designated place, there can be no suspicion at all that the rest have been carried from their places — which would not be the case with some spot chosen at the center. For such central spots, because the daily curving near the center is imperceptible, would not reveal that some change in the base had occurred through the daily motion until after an hour or two, while in the meantime they make, by their own motion, a notable advance in a short time. Therefore, since horizontal spots at once make their departure evident, one of them will always be prudently and usefully employed to direct the whole observation. For in this way the place of the spot, marked on the rotating paper board, will follow the advancing spot most beautifully; and as these agree, one proceeds to the marking of one spot after another. Nor is it necessary, while you mark down the individual spots, always to turn eye and solar base back to the cardinal points; it is enough if the directing spot keeps its place, provided it has not yet been lost through the daily motion of the Sun. After the marking of the spots is finished, one proceeds in the same way with the faculae. When this is done, before proceeding to the noting of the time, the whole observation is carefully surveyed — namely by grasping the foot of the machine with both hands, bringing the solar circle to coincide with the observatory circle, and superimposing the directing spot on the place first assigned to it. And if this succeeds, with the circle and base agreeing, attend to whether all the other spots and faculae, each and every one, likewise correspond to their own places. If so, the observation has been done rightly; if otherwise, the things wrongly placed must be corrected. Then, without delay, the perpendicular must be introduced and the time noted; and how these are to be carried out, hear in a few words.

On introducing the perpendicular into the observation.

[Margin: *Introduction of the perpendicular.*] The perpendicular, in this context, is nothing other than the common section of the observatory circle with a vertical circle or plane passing through the axis of the solar cone. I call this section the vertical line, or perpendicular — not because it is a vertical line or a plumb-line, but because it is induced by the shadow of the perpendicular, cast from the bristle and vertical line of a pendulum and projected through the center into the observatory circle. This is done as follows.

With your left hand grasp the perpendicular, suspended by a horsehair bristle or a very fine thread, and let it into the radiant cone, so that its shadow, passing through the center of the observatory circle, cuts the circle's perimeter either above or below; and you will carefully mark this section with the point of the compass. You have the figure of the perpendicular in scheme N.1, in which the perpendicular p, i hangs from the hook $o p$ and, through the center c , casts the shadow $a b$, whose point a , above, or b , below, is to be marked. What the hook does here, my left hand is accustomed to do in observing — resting above the head of the board $P Q$, at the point o , to steady it against wavering. You have the same things represented to the life in the great system of the various observations, at the observatory machine $V X Z$ and the pyramid $L M$; and there indeed the perpendicular $a b$ hangs and casts the shadow $c d$ into the circle $c d f g$, through the center e — here, however, $L N$, generated in the circle by reflection. For into every observation of this kind the perpendicular must be introduced, as the prime mover for investigating the course and motion of the spots. Because from it must be taken the first principle of position for investigating the section of the ecliptic which it makes with the solar or observatory circle.

For since it is most certain that the Sun's center always lies on the line of the ecliptic, and that this is the greatest circle, drawn through the center of the earth, and holds the whole earth to itself as to a center, it is likewise certain that the section which the ecliptic has in common with the solar circle is a straight line. Hence, in order that the position of this line in the observatory circle may be had, it must be established from some certain and given point of position, perceptible to the senses. And no more certain, stable, and easy way can be given than the section of the vertical plane with the solar and observatory circle; and this, moreover, is had perceptibly and at once, without any error, by the shadow of the perpendicular alone, as said, which lies in the vertical plane. I know that a straight line parallel to the horizon can also be induced by a balance, and that this line answers to the one which in the Sun is made by the plane through the

Sun's center together with the vertical plane erected upright to the observatory circle, and so on; but because the marking of this line has more labor and danger attached to it, since it cannot be done except by the help of the vertical, the induction of the vertical itself is therefore the more compendious and easier.

The Practice of Observing the Time.

[Margin: *Whether the time is to be noted at the end of the observation.*] The time of the observation must never be taken or noted at the beginning of observing. For since any observation, once made and no longer to be made, must be bound to a time, and since much delay often intervenes during observing, the spots too easily shift their seats, and the observation paper has to be rotated, it is necessary that the time be noted only when the whole observation has been completed, the perpendicular correctly set up, and the spots have settled at the points marked in their places. Otherwise, if you pass over these, or any of them, you will meet with difficulties, or even errors, in assigning the true motion and place. When everything, then, has been duly finished, take the linear quadrant, as shown in the great scheme, or the hour-dial q, r, s , as you see it hanging on the observatory machine, and note most accurately the altitude of the Sun in degrees and minutes, and at the same time the hour. For the altitude of the Sun, as you will see below, is necessary in this kind of observing for investigating the motion of the spots; and the knowledge of the hours is necessary for the periodic determination, and so on.

But if you have no clock at hand, you will find the hour elsewhere, or from the given altitude. In my own observations I have often not added the hour, because it was not always possible to obtain it; and besides, it is not so necessary as the altitude of the Sun. To every observation, however, must be assigned the year, the month, the day, the astronomical hour, and at least the first minute of the hour. Likewise the altitude of the Sun — whether before or after noon, or the meridian altitude — in degrees and minutes, at least the first minutes.

THE PRACTICE OF ILLUMINATING AND VIVIFYING A BLIND AND DEAD OBSERVATION

CAP. XXXVI.

I call blind and dead an observation which consists of blind-line delineations expressing the solar spots and faculae, with no accompanying figure or writing. [Margin: *What a blind observation is.*] A figure, then, portrayed in color adds, as it were, a soul and life; writing adds speech; and it gives to each its own names —

whether of spot or of facula — by alphabetic characters or by numerals, assigned singly to single spots in each observation, so that the same spot obtains different appellations in different observations. On what days, times, and hours these agree, and under what elevation of the Sun, and likewise to what perpendicular they were made, is recorded singly and day by day, in order, outside the observatory circle in the margins of the observation paper — now above, now below, now on the right, now on the left — and this in continuous order and in the same position of the paper, or now in reverse, as the plan and place for marking the spots requires. For if the places of the spots to be observed coincide with those already observed, the paper is turned, so that room may be given for the notation. If not even so can it be had, the observation is deferred on this paper until, in the afternoon or on another day, a place is obtained. If everything is full, the paper is removed and a new blank one substituted. But these are incidental matters: let us now return to the coloring of the spots.

[Margin: *The spots are to be colored in conformity.*] The spots are to be expressed on the paper with a very fine pen, just as they themselves appeared when projected onto it: thin and sparse ones, thinly; thick ...

(Book II, Chapter XXXVI, continued. The page apparatus numbers the text in columns — I and II on this page, III and IV on the following pages — as cross-reference labels keyed to the engraved plate; these column numerals and the marginal five-line numbers are not section divisions and are not reproduced as such.)

thick and dense, strongly and compactly formed. The nuclei appeared as they did — black, solid, either continuous or separated; the shadows [umbrae] softly, and the small lights and faculae gently — so that the shape, thinness, and density of each stands out, as it were, from its very look. Yet all of these things, one and all, can scarcely be rendered so aptly and so distinctly by engravers as they are presented by nature; indeed, engravers sometimes fail to do so. One must therefore fall back on the help of the pen and of written explanation, especially in matters of any importance or difficult to depict. For who could set clearly before the eyes sunspots [maculae] immersed in the solar light, and half-white ones, and so on? Who could show the distinct intensity of light in the faculae? Who could distinguish the shadows from the faint spots, unless he is alerted by a written note — above all when, as I said, the engravers, being unskilled in these matters, make so little of the distinction?

[Margin: The written account is to be trusted more than the printed image.]

An example of an ordinary observation is presented.

You have a living example of this in the attached observations of four days in the month of December, all enclosed within a single observation circle [circulus observatorius] C D E F G H I K, where you can see it. First, notice that the observation circle itself is marked at its four principal cardinal points by the larger letters C, E, G, and I, and at four other intermediate points by the smaller letters D, F, H, and K, the rest of it being filled in with a plain, or broken, line [cæcâ, seu fractâ lineâ]. This is done because the eye, by the help of these points, more exactly discerns the evenness and the fit of the Sun's base [basis solaris] with the observation circle, and assigns the spots to their proper seats better than if the whole circumference were drawn out. From the practice and use of both methods I have learned that this one is the easier and the safer, and the reason is at once obvious. Since a circular arc is a line everywhere uniform and drawn out with an equal thickness, the eye, finding no difference along it, fixes its gaze only with difficulty more here than there; and so, while it struggles everywhere at once, it detects an excess or a defect of light only with trouble. But where the points are drawn in with a deliberately unequal body, the eye holds firm, and without any effort notices the exact contact of the Sun's base all around at a single glance — and...

this, though it appears a trifling matter, nonetheless in this work, if neglected, gives rise to enormous errors, or at least to labor, in laying out and ordering the courses [cursus] of the spots — all of which are avoided effortlessly by the help of these points. Here, however, take note that these points are to be inscribed on the circumference of the observation circle in such a way that they do not cut it, but only touch it, placed on the outside.

Second. You will observe that all these observations were carried out in the year 1625, in the month of December, at the Collegio Romano, on the 7th, 8th, 9th, and 11th days. On the 7th, indeed, two morning and two evening observations; on the 8th, four morning and one evening; and on the 9th, one evening observation. All these ten observations you have carried out with the paper in a single upright position; the two remaining, completed on the 11th, are recorded with the paper's arrangement turned around. What was worth noting in each will be worked out a little later. For now,

Third. Besides the several plumb-lines [perpendiculara] proper to each observation, you will meet with nearly everything that is wont to occur in this phenomenon. For here are spots of every kind: with faculae and without; with nuclei and without; even and misshapen; eastern, middle, and western; large and

small; dense and rare; nascent and dying. There are faculae joined to spots and shadows, and faculae solitary and pure; there are faint ones and intense ones. And finally there are shadows [umbrae] various and manifold. Now let us come to the description of each.

On the 7th of December, then, designated M — that is, in the morning — at the ninth hour and $\frac{7}{8}$, under a solar elevation of $21\frac{1}{2}$ degrees, there were observed spots, faculae, and shadows, western: a, b, c. And a is indeed a solitary spot, but not a new one; the rest of its retinue, b, are faint shadows with faculae, while c are pure faculae, which on the 5th under the evening observations, and on the 4th under the morning ones, and altogether earlier, had not appeared. This may be seen in Observation-Image 49, which is the fourth [image] of November and the second of December, in which you have the course of spot a set out under the name or letter c, from the 28th of November up to the 8th of December, where you see...

that the spot, though enlarged in the first days, gradually faded in the later ones, and acquired faculae that it had earlier lacked.

Furthermore, the new facula G, shown here, was omitted there — something I often do, so that you may know that I have by no means had everything I have observed and noted in my originals engraved on copper.

There are besides the western spots d, e, whose expressed course you will find in Observation-Image 51, the third of December, under the letter a, from the 3rd of December to the 9th; for before the 3rd there was none, but it was born then, and appeared very small and very thin, and kept growing right up to its exit. Note here in passing, by the engraver's carelessness, that its figure on the 3rd day has been rendered too large and too black: it was in fact very thin and very small, but grew most swiftly and became intense in its blackness — which is common in this phenomenon. And whereas on the 3rd day a single one had been born, it had multiplied by this 7th day into nine distinct spots, of such position and shape as you contemplate set before your eyes.

At the letter f you have three eastern spots, not large, of which the two more eastern touch one another, although the engraver did not express this; and you will see their course in the aforesaid Observation-Image, [under] the third of December. These spots varied among themselves remarkably from the 7th to the 11th of December; for they lasted no longer, but, generated in the middle of the Sun, they perished within it, after a life of three days.

g are faint and even eastern spots; their course, changes, and conversion into faculae, and so on, you will see in the aforesaid scheme, under the letter d.

h, i, K are all new, not seen before. At h there is one notable spot, the leader of many little ones; then follows a wonderful heap of shadows and bright faculae. The course of this mass from this 7th day up to the 14th you have presented under the said image, [at] the letter f.

l, m are likewise several eastern spots, of which the two larger carry a nucleus; but their rise and passing away, their increase and decrease, may be discerned in the same said image, under the letter C.

n, o, p are at least ten of the smallest spots, denser and rarer, surrounded with faculae...

enclosed, mixed in here and there, and with adjacent shadows, whose full course, right up to the sixteenth day, you should look for in Observation-Image 52, which is the fourth of December, under the letter a, and you will behold remarkable changes.

q is a new and bright facula, ringed about with slight shadows.

And so you have the first observation described, of the 7th day, at the ninth hour and $\frac{7}{8}$ in the morning.

The second observation occurred on the same day and morning, at the hour $10\frac{1}{4}$, under a solar elevation of 23 degrees 0 [minutes]. And because little time had passed since the previous observation — not quite a half hour — the spots and faculae did not perceptibly change their places by advancing toward the center; and this became clear by the turning of the paper-bearing tablet [tabella chartifera]. When this was done, all the spots coincided, to the eye, with the places previously marked, and were therefore recorded as the same. But because the tablet, turned about, acquires a different plumb-line, for this observation there is [a different] plumb-line, and so on.

[Margin: Second observation.]

The third observation of the same day is V — that is, an evening one — at the hour $3\frac{3}{4}$, the Sun raised to 11 degrees 20 minutes, at the plumb-line r. Here note once and for all that I ordinarily attach to the plumb-line that letter or mark which belongs to the first, or most western, spot or facula of that observation. Thus, because the most western spot is r, it therefore acquires, by numbering from the first place and from the first preceding letter, that same r; and for this

reason it takes the same plumb-line. The spots and faculae a, b, c, then, described under the first observation, have advanced toward C, as far as r and s, on account of the daily motion and of the paper standing in a horizontal plane — which all the western, or trans-central [transcentricae], spots and faculae always do, outside the time of station. The contrary happens with the eastern, or cis-central [ciscentricae], ones: for these, by a contrary motion, tend toward G. Note here how they have run together into one continuous tract, spots as well as faculae and shadows: for a and b, faculae separate before noon, now appear joined. This is most usual for this phenomenon, both in the rising and in the setting decline of the Sun. And the shadows too have grown.

[Margin: Third observation.]

Diagram. A full-page engraved observation plate (numbered N. 7.) presenting the December 1625 sunspot observations made at the Collegio Romano, drawn within a single large observation circle. The circle is rendered as a dotted (broken) line and marked at its cardinal and intermediate points by the letters used in the text; the recorded spot-groups are engraved across the field, each tagged with a running series of identifiers (Latin letters a–z, Greek letters α – ω , and Arabic numerals 1–23). The plate is printed so that the two observations of December 11 are engraved **inverted** (read with the page turned around), corresponding to the text's note that these two were "recorded with the paper's arrangement turned around." The leaf shows heavy verso show-through; only elements legibly belonging to the engraving itself are reported below.

Readable cardinal/point letters on the dotted observation circle:

- **D** (top of the circle)
- **E** (right side; engraved "E o")
- **F** (lower right)
- **G** (left side; near the inverted lower captions)
- **A, B** (lower region, engraved inverted, keyed to the December 11 captions)
- **K, H** clusters labelled among the spot-groups; further point-letters and the spot identifiers (numerals 1–23, Latin and Greek letter tags) are engraved among the figures but are largely illegible under the show-through — [?].

Title cartouche (upright, upper center):

1625 / In the month of December, / at the Collegio Romano. / **The practice of observing the Sun [☉] and of drawing the vertical line, or plumb-line.**

Caption block (upper right, beside N. 7.):

On the 9th, in the evening, at the hour $3\frac{1}{4}$, under a solar elevation of 12 degrees 40 minutes, at plumb-line 1, there were observed western spots and faculae 15, 16, likewise 17, likewise 18, 19; central 20; eastern 21, 22, 23.

Captions engraved inverted (lower part of plate, the December 11 observations):

December 11, 1625. In the morning, under a solar elevation of 20 degrees 0 [minutes], at plumb-line A: spots a, b, c, d, e, f — the Sun being cloudy and dulled, so that not all are exactly distinct. On the same day, in the morning, when the Sun stood higher at 12 degrees 10 [minutes], at plumb-line B: the spots and their places the same, the Sun still dulled.

Engraved table of the observations (upper left of the plate; heavily degraded — many numeric cells and Greek-letter tags are uncertain):

Die s	Hor a	☉ Elev.	Perpend.	Mac. et Faculae et umbrae
M.	$9\frac{7}{8}$	$21^{\circ} 30' [?]$	a	a. b. c. d. e. f. g. h. i. K. l. m. n. o. p. q. (most new)
M.	$10\frac{1}{4}$	$23^{\circ} 0' [?]$	p	the same
V.	$3\frac{2}{3}$	$11^{\circ} 20' [?]$	r	r. s. t. u. x. y. z. α . β . γ . η . ϵ . ξ [?]
V.	$3\frac{5}{8}$	$9^{\circ} 0' [?]$	t	the same
M.	$9\frac{1}{4}$	$15^{\circ} 10' [?]$	H	H. θ . ι . x. λ . μ . v. ξ . π . ρ . σ . ς . s [?]
M.	[?]	[?]	[?]	τ . v. ϕ . χ . ψ . ω [?]
M.	[?]	$24^{\circ} 30' [?]$	v	the same
M.	$11\frac{3}{4}$	$25^{\circ} 0' [?]$	φ	the same
V.	$2\frac{2}{5}$	$17^{\circ} 0' [?]$	ω	6. 7. 8. 9. 10. 11. 12. 13. 14.

t, u are morning spots; d, e are somewhat more coiled up at t, and unwound at u.

x are three morning spots, f, of which the two more eastern are now beginning to separate.

y, z show a somewhat greater unwinding as well.

α likewise lost the shadow drawn out behind g, and formed itself into two even spots.

β is a single one, in the place of today's h, faint and vanishing, although the engraver rendered it too strongly; but the faculae and shadows too left slight traces of themselves remaining.

γ , δ , ϵ , ζ are the morning spots n, o, p, and the facula ς is still clothed about with shadows.

The fourth observation, of the 7th day, differs from the previous one only by a little time — namely by 12 minutes of an hour, which give $\frac{1}{5}$ of an hour — and by 2 degrees 20 minutes of solar altitude, and by plumb-line t, which in the previous one was r: the places of the spots the same as before.

[Margin: Fourth observation.]

Observations of the eighth day.

[Margin: First observation.]

The first, a morning one, occurred at the hour $9\frac{1}{4}$, the Sun raised 15 degrees 10 minutes, at plumb-line H. The spots, shadows, and western faculae are H; all appeared strongly diminished; they were yesterday's a, b, c, and so on.

θ and ι were yesterday d and e; some of the intermediate ones failed. And what is well worth noting: the two outermost, θ and ι , today stand as far apart as yesterday's d and e — which is not owing to the Sun's aspect alone.

Central are κ , which yesterday had been the preceding f, its two attendants being lost; likewise λ , μ , which yesterday were l, m, now much changed from those. For l was yesterday one shapeless faint mass, and now today has split into two spots — or, if we prefer, an enlarged version of yesterday's middle one, and a diminished first l. Certainly m, yesterday earlier and faint, today, as μ , has broken up into many little ones. There are also central ρ , ς , today larger and more numerous and finer than yesterday at g; they are increasing.

Eastern are ν , ξ , o, π . Yesterday they were n, o, p, wholly within the faculae; today, the pre-dawn faculae being extinguished, they draw the rest...

behind them, some shadows having been turned into spots at o. Some of the spots, moreover, have grown; some are laden with nuclei; some are attenuated and in a foreign position. At ω a new facula follows, bound to the earlier ones by a long, thin shadow as if by a chain, whereas on the contrary the facula q nowhere shines out.

q [?] is very small, yesterday's h. [?]

Among the western ones a new, double and thin, shadow s has arisen.

The second observation, a morning one, lacks a clock time, but has a solar altitude of 23 degrees 0 [minutes]; and it obtained plumb-line τ . The names and places of the western spots are τ , ν , at the same mutual distance as before.

[Margin: Second observation.]

Of the central ones, ϕ , χ , likewise ψ , likewise ω — here you see how within a short time they have changed their place in the observation circle. As for the fact that at o not all appeared as before, it may be that they perished in the meanwhile, or escaped sight, because they were shadows, or rather the very faintest traces — which frequently happens in this phenomenon.

The eastern spots are 1 and 2; and this one indeed is new, and was born from yesterday's shadows K.

Likewise spots 3, 4, 5, whose faculae I deliberately neglected, so that the spots themselves might appear better.

Here note how at ζ many small ones are resolved out of o.

The third observation is, as it were, a repetition of the previous one, at a different plumb-line, ν , and a solar elevation of 24 degrees 30 [minutes]. And so only a middle quadrant had passed, and therefore the earlier seats of the spots are not perceptibly changed; only the plumb-line passed from τ into ν , by the turning of the paper-bearing tablet.

[Margin: Third observation.]

The fourth observation, likewise a morning one, following the two previous ones a little later, was completed at the hour 11½, the Sun holding the 25th degree of altitude, at plumb-line ϕ . And so it did not find the spots perceptibly carried up from their earlier places, and therefore took them marked with the same characters; only the plumb-line emerged as a different one, by the turning.

The fifth observation was an evening one, at the hour 2¾, the Sun exalted to 17 degrees 0 [minutes]. It was allotted plumb-line ω . The western spots [are] 6, a faint trace; but the spot certain [is] H.

BOOK II, Chapter XXXVI (continued)

Likewise spots 7 and 8: of these, only 7 is complete in magnitude and figure; of the rest, only the central points are shown, and the nucleus of the last one, 8, is rendered.

The central spots are 9, the same as yesterday's.

Likewise 10 and 11 — here note how they appear to be failing, both in number and in magnitude.

Likewise the faint spots 12, which, however, the engraver [incisor] has made too full.

The eastern ones are 13 and 14, all of which I have marked only pointwise, by their centers.

This manner of marking I usually employ when I must hurry out of necessity; or when the magnitude and figure of the spots are otherwise sufficiently secured; or when their position is being investigated with the utmost precision.

Observation of the 9th [Diei 9. Observatio]

In the morning the sky was unfavorable. In the evening, at a quarter past three o'clock, with the Sun standing at 12 degrees 40 minutes, I took at perpendicular 1 the western spots and faculae 15 and 16, in the state in which you see them drawn. They coalesced remarkably, and clothed themselves in very brilliant faculae; and both the shadows [umbrae] and new spots seem to have grown. Moreover, at 17 the following spot seems to have revived, after it had withdrawn itself from view for several days. Further, 18 and 19 appear enlarged, and the nucleus at 18 became larger and denser. And whereas yesterday at 10 there were two separate spots, today they seem to have merged into a single large, oblong one. And those that yesterday at 11 were very slight are today enlarged both in mass and in the intervals between them. Consider their course in the Image of 3 December, under the letter C, and you will see how the outermost ones, 18 and 19, increased their intervals right up to their exit, and into what shadows and faculae they degenerated, and so on — although at their first rising, which fell on 5 December, they showed none of this.

Observations of the 11th [Diei 11. Observationes]

The 10th was unfavorable, owing to the inclemency of the weather.

On the 11th I resumed the work, and, as far as the sky permitted, I made two observations. I enclosed them in the observation-circle with the paper's position inverted (which I often do, the empty gap between them so advising), and so forth.

So, with the Sun standing at 12 degrees, I marked at perpendicular A the western spots a and b, and likewise c; besides these, the central ones d, e, and f, hastily, because the Sun was cloudy and dull and so it was not possible to discern everything exactly. The positions, nonetheless, seem reliable enough, and I gave chief attention to these; but the precise outlines of the figures, or the exact magnitude, density, and rarity, are not drawn out from this observation. To obtain the arrangement of these together with the marked positions more surely, I repeated the observation at perpendicular B, under a solar elevation of 13 degrees 10 minutes, and I did indeed find a good disposition of the places; but because the Sun was still dulled by vapors, it was not possible to pursue the precise outlines of the figures, the ratios of density, and the other minutiae of the spots, faculae, and shadows.

And I have chosen to set before your eyes this specimen of observing, of recording observations, and of explaining what has been recorded, so that you — whoever you are who read and judge these matters — may see with what diligence and care I have handled each point, and what confidence you may place in my observations and in the Images of the Observations, and whether the doctrine drawn from them ought to be judged solid and stable enough.

[Margin: Excessive prolixity excused.] But perhaps I may seem to some too long-winded and painstaking in these small matters, more than the subject and reason demand. Yet if I exceed due measure in explaining them, I have gone far further in handling them in practice. For it is quite certain that the care, diligence, and precision I applied in observing and recording the spots and faculae, and the rest, can be matched by no pen, nor sufficiently explained by any words. I have now treated this phenomenon for 16 years and more, and often in a single day I made 10, 20, 30, or more observations, and that by the most varied methods, with different observation-circles, and so on — so much so that many, wearied by the length of time and struck by the multitude of observations, came almost to the opinion that either I was grasping nothing certain and stable in this phenomenon, or was finding the opposite of what I had once published, and was therefore weaving deliberate delays.

But — to say frankly how the matter stands — it was the slipperiness and subtlety of the subject, and the very truth of the phenomenon pouring itself out

everywhere and always, that made me so assiduous, so constant, so persistent, and so exact in observing. For while I noticed that the phenomenon, though highly varied, keeps always the same tenor and, at its own seasons, is like itself, I perceived on the other hand that there were countless and powerful contradictors, as well as observers who were careless and who obscured rather than illuminated the Sun and the truth, some of them even serving the ears of others. Lest the truth be suppressed in any way, whether by force or by ambition, I judged it altogether necessary to pursue everything as minutely as could be done, and to bring into the light what had been most carefully investigated. For otherwise I would have accomplished almost nothing against ingenious obstinacy or entrenched contradiction.

I add that it is impossible, without the most exquisite airing and knowledge of these minutiae, to penetrate to the true motion and place of this phenomenon. Therefore, since this phenomenon can neither be prudently asserted, nor solidly established, nor safely preserved and defended, without the phenomenon itself; and since it cannot be had or possessed except by knowledge of it alone — for it is this knowledge that makes one a genuine possessor of the phenomenon; and since that knowledge can in no way be obtained without a diligent investigation of it carried on through assiduous observing (unless God should deign to bestow it on someone by a singular privilege, or some Angel to reveal it from heaven) — for these reasons, in order to hold the phenomenon itself, to defend it against its assailants, to rescue so great a matter from the injury of cobblers and tailors [Sutorum & Sartorum] and from the raging claws of the ignorant crowd who most unworthily tear it apart, and to display to the whole world and to the senate of the learned the purest and most naked truth itself, yet irrefutably — I applied so much labor, spent so much time, and expended so much oil and toil.

Hence I became so persistent, so scrupulous, so curious an investigator and so anxious a judge of the smallest matters — matters which, as will become clear, are those on which the greatest things depend. Had I not done so, I would have beheld, with eyes weeping in vain, a most noble phenomenon handled most ignobly and ruined in a dreadful manner — casting up laments that were indeed true, but flung at deaf and lazy scoffers. [Margin: The solar phenomenon must be defended by means of itself.] Now, if on behalf of the phenomenon I set the very phenomenon itself against them, and defend it most strongly out of itself, there will be no one, I think, who will be angry at my exertions, or who will not take in good part the diligence without which I could neither have kept off the idle nor restrained my opponents. I return, then, to the Rhombus and to the examination of the observations.

EXAMINATIONS OF THE OBSERVATIONS [OBSERVATIONVM Examina]

CHAPTER XXXVII [CAP. XXXVII.]

1. Examination of observations by the intervals of the spots, marked either from the margin or from other spots [Examen Observationum per interualla Macularum, vel à margine, vel à Maculis aliis notata]

Spots are distant either from the Margin of the solar circle or from other spots. By both means the examination of the marked places is usually carried out. [Margin: Examination by distance from the limb.] For if, with one leg of the compass you take the center of the spot, and with the other the shortest distance to the solar limb — which is nothing but the segment of the radius drawn from the center of the solar base through the center of the spot out to the margin, etc. — with the base not moved far outside the observation-circle; and then measure this found distance from the marked place of the spot on the radius drawn from the center of the observation-circle through the marked place: if equality is found on both sides, you have marked the place of the observed spot correctly; if inequality, the error must be corrected. For as the spot stands to the Sun's limb, so the marked place ought to stand to the periphery of the observation-circle at the shortest distance.

[Margin: Examination by the distance of one spot from another.] The examination by the distance of one spot from another proceeds thus. Take with both legs of the compass either the distance of the given spots or that of the marked places, and transfer what you have taken to the other; if they are equal, you have observed correctly; if they are found unequal, the operation must be repeated and the error corrected. This examination can be applied either during the observing, if the spots are not many, or after the whole observation, together with the notation of the time and of the perpendicular, has been completed. I said that the spots to be examined should not be drawn far from the marked places,

and this because, if you move toward the center, or notably away from the center, you will find the distance either greater or smaller than it should be, on account of refraction. Thus, guarding against these rocks, you will sail in the open sea, and will not move the spots to be examined far from the places noted for them.

2. Examination of observations by means of several observations, and that in various ways — by place, time, persons, and so on [Examen Observationum per plures observationes, idque modis variis ex loco, tempore, personis &c.]

Just as truth is never contrary to truth but always in concord with it, so, if the things I bring forward about this phenomenon and its motion and variety are true — if they subsist on the side of reality and are not to be counted among chance and idle appearances — then the observations and drawings of it, made in every place, by every observer, with any telescope [Telioscopio], and by any mode of observing whatever (provided it is approved and legitimate), must agree among themselves. For if they did not agree, either the phenomenon would be deceptive or the observer mistaken. But if they are consonant, who could doubt that the observations were legitimate? For it does not seem possible that even two — not to say 10, 100, or a thousand — in beholding such varied things and transferring them to paper, etc., should agree exactly in position, in place, in figure, number, magnitude, rarity, density, and so on, and yet all fall away from the truth into uniform errors, and so forth. Now, since the greatest variety comes into play in these matters, I will touch on each point in passing.

Observations of the spots can be considered either by place, or by time, or by persons, or by instruments and modes of observing.

[Margin: Examination from different places of observation.] First: let us take place, and suppose everything else duly carried out. A place, then, is either astronomically the same or different. I call a place astronomically the same that lies under the same longitude and latitude of location; thus Rome, Tibur [Tivoli], and Tusculanum [Tusculum] are astronomically one place of observation, because these places lie under sensibly the same longitude and latitude, even though physically they are entirely different — for the Professed House at Rome [Domus Professa] is one place, the Roman College [Collegium Romanum] another, and so on; and of each there is a physical diversity of place, according to the distance of the dwellings from one another.

Given, then, the same astronomical place: if the observations made in it correspond exactly, if the courses of the spots have been observed as the same in proportion, and so on, the observations are to be judged well made. If they do not agree, there has been an error in the observing. And by this method of examination I have gone through all the Roman observations, both my own and others', and found them sound.

Given different astronomical places: if the observations made turn out either always or ordinarily alike, then without any doubt there has been no error in the method of observing, and the observations prove one another. So you see it done in the diagrams [schematismis] I have set out, where you behold observations made in the most different places agreeing with one another, in the many Images of observations presented in the following book. For nature is so constituted that, while many err about the same thing, they rarely agree in their errors or in their ways of erring. Therefore, since in observing this phenomenon all agree everywhere and always, it is impossible that error should be made by all, everywhere, always, and in the same way.

[Margin: Examination from time.] Second: let us consider Time. In this business time can be regarded in two ways, astronomically and physically. Astronomical time is viewed according to the sensible progression of the spots, so that, as long as one spot is not sensibly advanced by its own proper motion, we call the interval of that time the same; but that time, in whose passing some spot has been sensibly moved from its place according to its proper motion, I call astronomically a different time — because the spot has now advanced, and clings to another sensible place in its course. Time regarded physically is always different, whether the progression of the spots is noted or not. These things being noted:

Given the same astronomical time, the spots — wherever their places, by whomever observed, in whatever manner, provided they are duly observed — ought to be found in proportionally the same apparent place of the circle. If otherwise, it is certain that the observations, either all or some, are defective; but if they hold to the same place, I admit them as legitimate. I assume here, as proved elsewhere, that the spots, with respect to the Sun, are without parallax [parallaxi].

Given a different astronomical time, the spots ought to sit in proportionally different places. If otherwise, an error has been made in the observing.

For central spots, or those near the center, the astronomically same time can be reckoned as a quarter of an hour, or at most a half. For a three-quarter hour, or a whole hour, begins to become perceptible in my observation-circles; it is otherwise in small ones, where even the span of an hour is not enough to move a spot sensibly from its place.

For marginal spots, more time must be allowed before it is said to be astronomically a different time, because the spots linger in the same sensible

place for a very long while — for one, two, three, or more hours — according, that is, to their position and the declination of their parallel, and also to the quality of the course and of the time.

[Margin: Examination from different observers.] Third: the observers can be either different or the same. If different observers observe the same spots and agree in motion, place, position, magnitude, figure, and number, then certainly the observations of the one are excellently confirmed by those of the others, and theirs by his — as the observations of so many years now, made in different regions and afterward collated, bear witness; and very many practical examples of this are brought forward in the following book. But if, among the places seen and noted at the same time, some discrepancy came between, you may know without doubt that there is an error somewhere — provided all else were set as equal.

[Margin: Examination by a single observer.] But if it is the same observer, he will test each observation by others preceding and following; for the ordering of the observations, and the progression of a single spot from day to day, and its relation to the Ecliptic, most beautifully reveal the defect or the soundness of each preceding and following observation.

[Margin: The quickest method of examination.] But if anyone lacks either preceding or following observations, and yet wishes to be secure about his own duly-completed observation: as soon as he has finished it, before any notable time elapses — that is, within half a quarter of an hour or sooner — let him resume it, and bring the observation-circle together with the solar circle, and turn the paper-bearing table, until the marked spots agree most perfectly with the solar spots, and the circles with the circles. And if

some of the marked spots should disagree while the others agree among themselves, then the seats of the deviating ones must be corrected. This done, mark the perpendicular, and observe the altitude of the Sun. For always, in laying out an observation and imposing the Ecliptic, you must find one and the same Ecliptic, because one and the same place of each spot is preserved in both observations; and as long as a spot occupies sensibly the same place, it does not change its declination from the Ecliptic. If you find a different Ecliptic while the places of the spots remain the same, hold it for certain that you have gone astray either in observing the spots or in recording the perpendicular. By this most expeditious examination I have very successfully dispatched the greatest part of my observations.

[Margin: Examination by instruments and modes of observing.] Fourth: instruments and modes of observing also bring the greatest dispatch to this difficulty. For if different instruments exhibit the same spot in the same place of the Sun, then certainly the observation of the one strongly reinforces the observation of the other — as you see was done by me in the year 1625, in the months of January and February. The same shines forth most of all in specifically distinct modes of observing, as practice teaches, carried out in March of the year 1627; which shows you the courses of the same spots, observed by wholly distinct methods — as you will be abundantly taught, in their proper places, in the following book.

And I think these modes of inquiring into what has been observed are sufficient for anyone undertaking or weighing this study; for whoever sets his hand to the work will learn more, with use as his teacher. To pursue everything one by one is not consistent with the brevity intended for this work.

Cap. XXXVIII — Practice for introducing the ecliptic into observations of sunspots, and the difficulties concerning it

[Display rubric, folio 144:] **PRAXIS IN OBSERVATIONES Macularum Solarium inducendi Eclipticam, & circa eandem difficultates.** — Practice for introducing the ecliptic into observations of sunspots, and the difficulties concerning it.

Cap. XXXVIII.

To introduce the ecliptic, one must — from the observed and recorded hour, or from the observed elevation of the Sun above the horizon — draw out the angle that the vertical line, introduced into the observation, forms with the line of the ecliptic at the Sun's center within the observatory circle; and this is to be done separately for each individual observation. Since this angle can be sought in various ways, I shall run briefly through them.

First one must know in advance the altitude of the pole, that is, the latitude of the place where the observation was taken; then the year, month, and day of the observation, and likewise whether the time was before or after noon; and besides these, the Sun's place in the zodiac. All of these are found readily in ephemerides or in the books of other good authors. As for the hours with their minutes, and likewise the degrees and minutes of the Sun's altitude above the horizon, I assume these to have been recorded for each observation. For there is no doubt that the ecliptic must be introduced into each of them, since the angles we are seeking change from moment to moment. Now some of the methods are

mechanical, others geometrical, others arithmetical or astronomical — all of them, however, sound and demonstrative. Let us begin with the mechanical ones, which I once used at Ingolstadt.

Primus Modus — The First Method

The method by which the angle of the ecliptic with the vertical circle is obtained is found by means of a material globe — the larger the better — well fitted with the usual circles and set to the elevation of the given pole. So that its principle and use may be set out solidly, I present first the following

Lemma.

DATO IN PLANO Circulo, aequalem describere in sphaera. — *Given a circle in a plane, to describe on a sphere one equal to it.*

Let the circle ABCD in figure 1 be given, to which an equal one is to be described on the given sphere EFG of figure 2, from the pole F. To the diameter BD of the given circle, produced — from point C, the end of the other, perpendicular diameter AC — apply the sphere's semidiameter HE, so that CI is laid off equal to HE. Then, with radius IC, draw the arc CA cutting IB at K. This done, if on the sphere's greatest circle ELF you cut off FL equal to the arc KC, and with radius FL describe the circle LMN from the pole F, that circle will be equal to the given circle ABCD.

Demonstratio.

The circle ICA is equal to the greatest circle EFG, because their diameters are equal. Therefore, if it is understood to stand perpendicular to the circle AB — since it bisects it along the diameter AC — it will pass through its pole at K. Thus the circle ABC lies on a sphere equal to the sphere EFG; and since the arc KC equals the arc FL, it is likewise clear that the circle FLM is equal to the circle ABC. Therefore, given a circle described in a plane, we have set up an equal one on a sphere — which was to be done.

Problema I.

Given the Sun's altitude above the horizon, or the hour, to find mechanically on a globe the angle that the ecliptic at the Sun's place makes with the vertical circle.

On the sphere HEFG, let EOGP be the horizon, EFG the meridian, F the pole of the world, Q the zenith of the place, ORP the ecliptic, S the Sun's place on the ecliptic, QST the vertical circle passing through the Sun's place, and FSV the hour-circle

passing through the same place. Then, if you wish to inscribe the ecliptic into the given observatory circle XY of figure 3, you will — by the foregoing Lemma — set up on the sphere EQG a circle $Z\alpha\beta$ equal to that circle, at the given place of the Sun S , taken from S itself as pole.

And since, from the observation, either the Sun's altitude or the hour at the time of observation is known, from either one you will obtain your aim, in this way:

Ex Altitudine Solis — From the Sun's altitude

[Margin: The angle from the Sun's altitude alone.]

Raise or lower the Sun's place by turning the sphere until the Sun's place S falls at the given altitude ST . This done, you will see where the ecliptic RSO and where the vertical QST cut the circumference of the drawn circle — namely, at points above at Z, α and below at γ, δ ; for either of these arcs, that is, either $Z\alpha$ or $\gamma\delta$, measures the sought angle. Hence, if you cut off $X\zeta$ equal to the arc $Z\alpha$, or $Y\upsilon$ equal to $\gamma\delta$, and lay them into the observatory circle $X\upsilon Y$ from the vertical line XY written beneath, and then join the straight line $\zeta\upsilon$, then $\zeta\upsilon$ will be the line of the ecliptic, properly set with respect to the vertical line XY ; and the angle $X\theta\zeta$ (or $Y\theta\upsilon$) which the ecliptic made with the vertical at the Sun's center θ at the time of observation is the one sought.

In practice this is done easily and quickly if, from the zenith Q , you have a spherical quadrant QST — touching the surface of the sphere and movable about the point Q . For, divided into 90 degrees starting from T toward Q , it will always show the angle $ZS\alpha$ (or $\gamma S\delta$), provided that the endpoint S of the solar altitude TS , once found, has been set at the given place S on the ecliptic. The thing is in itself sure, reliable, and easy, if the instruments are accurate. And in roughly this way I used it at Ingolstadt.

Ex Hora sola praecognita — From the hour alone, known in advance

[Margin: The angle from the Sun's hour alone.]

It is certain that the Sun is carried around the axis HF every day, together with the hour-circle FSV drawn through the Sun's place S . The measure of this motion is the equator and all circles parallel to the equator — such as LMN , bisected by the meridian $LN G$, where the point L is the highest point of midday and N the lowest point of midnight. Since, then, the hour-circle drawn through the Sun's place S traverses this circle daily, if the hour is given let the hour-index be set at it — as at the point ι . This done, fix the globe and draw the vertical circle QST

through the Sun's place S; it will at once show the angle with the ecliptic, $Z S \alpha$, and so on.

We have therefore assigned the sought angle, set between the ecliptic and the vertical, from the Sun's altitude and hour known in advance — which was to be done.

In practice there is no need to have the hour-circle P S V drawn. [Margin: A little circle and a clockmaker's index-pointer.] It is enough if from the pole F there projects a clockmaker's little pointer F ι , facing the Sun's place S. This will happen if, once the same place of the Sun has been brought under the meridian E Q G, you also fit the pointer F ι to it; for then it will serve for that day and will show the hours on the circle L M N — just as in the present example it shows the given hour at ι . This once done, if the spherical quadrant Q S T is passed through the Sun's place S, you will obtain, as before, the spherical angle $Z S \alpha$ and the arc αZ , which measures the sought angle in the plane. From the given hour, then, we have derived the angle of the vertical with the ecliptic — which was to be done. In this way too, very expeditiously, I often used it at Ingolstadt.

Modus Secundus — The Second Method

Likewise mechanical, this method teaches how to exhibit the same angle that the vertical makes with the ecliptic on a globe, or on any other instrument in which the ecliptic and a circle parallel to the equator (described from the pole of the world through the zenith of the place) are given in position; and this either from the Sun's observed elevation above the horizon, or from the given hour. First, however, one more Lemma — the converse of the foregoing — must be shown.

Diagram 1. On engraved plate N.10 (folio 145). A circle with its center and two perpendicular diameters, from which a narrow triangular (cone-like) construction extends to the right to an apex — the "given circle" ABCD of the Lemma and its plane construction.

- C (top of circle)
- A (bottom of circle)
- B (left end of horizontal diameter)
- D (center-right, on horizontal diameter)
- K (center / intersection)
- I (apex of the triangle, at right)

Diagram 2. On plate N.10, marked "2". A large hemisphere (sphere projection) crossed by several great circles — horizon, meridian, ecliptic, vertical and hour

circles — with a small circle drawn about the central point S. Many small peripheral labels; several are hard to resolve at this resolution. Clearly readable labels:

- Q (top / zenith)
- R (upper left)
- S (center, within the small circle)
- Z, α , β (on the small central circle)
- E (left, on the horizon)
- G (right, on the horizon)
- V (lower center)
- T (bottom)
- O (bottom right)
- L, F, M, N, P, I (great-circle intersections toward the right) — individual positions uncertain [?]
- γ [?] (near S)

(more than two labels flagged / unresolved).

Diagram 3. On plate N.10, marked "3". A small circle with two nearly-vertical chords crossing near the center — the plane observatory circle.

- ζ (top left)
- X (top right)
- θ (center)
- Y (bottom left)
- H (bottom right)

Diagram 4. On plate N.10, marked "4". A second large hemisphere with the ecliptic ABCD, the solstitial colure, a parallel through the zenith, and hour/vertical circles, plus dotted construction lines. Many small labels; several unresolved. Clearly readable labels:

- F (top)
- M, I (upper region)
- P (center)
- H, C, G (right side)
- A (left, on the horizon)
- E (left, mid-height)
- O (bottom center)

- N (lower left)
- B, R (bottom)
- Z, X, Y, α , β (small arc, upper left)
- D (mid) [?]

(more than two labels flagged / unresolved).

Diagram 5. On plate N.10, marked "5". A small circle with a horizontal diameter and a chord — the plane figure of the converse Lemma.

- ζ (top)
- δ (right of center)
- H (center)
- θ (left, on the horizontal)
- ε (bottom)

Lemma.

Descripto in sphaera circulo, aequalem exhibere in plano. — *Given a circle described on a sphere, to exhibit an equal one in a plane.*

Let a circle $Y Z \alpha \beta$ be described on the sphere $A Y M C$ from the pole Y (figure 4); you will construct one equal to it in a plane as follows. From the point ν [?], at the interval $\gamma \Delta$ — which is equal to the semidiameter of the sphere AE — describe in figure 5 the arc $\varepsilon \zeta$; and from Δ take the segments $\delta \varepsilon$, $\delta \zeta$ equal to the arcs $Y Z$, $Y \beta$; and when ζ and ε are joined, the straight line $\varepsilon \zeta$ will be bisected at ν . From that point, at the interval $\nu \zeta$, the circle $\zeta \varepsilon \theta$ described will be equal to the circle $Z \alpha \beta$.

Demonstratio.

For let the straight line $\gamma \delta$ be understood as perpendicular to the plane of the circle $\zeta \varepsilon \theta$. Then, since the circle $\gamma \zeta \varepsilon$ cuts the smaller circle H in half at $\zeta \varepsilon$, it will itself pass through that circle's pole δ ; and so both will be established on the sphere. And since the arcs $\delta \varepsilon$ and $Y Z$, as taken, are equal, the circles $\zeta \varepsilon \theta$ and $Z \alpha \beta$ must likewise be equal, and so on. The greatest circle on a sphere is described with a radius equal to a quadrant; and if it must be described through two given points, its pole is found by the intersection of two quadrants. See Theodosius, Book I [Theodosius, *Sphaerica* I]. These things being settled, let the following stand.

Problem II.

Given the Sun's altitude above the horizon, or the hour, to find by another method — mechanically, on a globe, from the complement of the altitude — the angle that the ecliptic at the Sun's place makes with the vertical circle.

In figure 4, let ABCD be the ecliptic; A M C the colure of the solstices; M the pole of the world; the point of Capricorn (♑) at A, of Cancer at C, of Aries at B, of Libra at D. Let the arcs M F and M H be 48 degrees; then F G H I will be a circle described from the pole M, parallel to the equator, passing through the Roman zenith F. Thus the ecliptic ABCD and the parallel through the zenith F G H I will be given in position, for the latitude of Rome; and once these are had, you will attain your aim as follows.

Ex Complemento altitudinis Solis — From the complement of the Sun's altitude

[Margin: The angle from the Sun's complement.]

Let the Sun's place be at O, and let the observation of the Sun's altitude be, for example, made after noon, so that, with respect to the hour-circle M X O on which the Sun then sits, the meridian lies toward the more easterly parts B, C. If, then, with a compass the arc O P is taken equal to the complement of the Sun's altitude, and, with one leg of the compass set at the Sun's place O, the other is extended and applied to the parallel F G H toward the more easterly parts of the hour-circle M O, then the point P will beyond doubt be the Roman zenith, the meridian will be M P N, and the angle P O N will be the angle of inclination that the vertical O P makes with the ecliptic O B — the angle that the arc P R measures, if it is understood as described from the pole O through the point P, that is, at the interval of the complement of the Sun's altitude.

But so that this arc P R may be had in degrees, one must have its diameter, which the straight line S R exhibits, if on the ecliptic the arcs O R and O S are taken equal to the complement of the Sun's altitude. These will be obtained in practice if, by the foregoing lemma, for the circle P R described on the sphere from the pole O another equal one is exhibited in a plane, and then from its circumference an arc equal to P R is cut off, which at the center will subtend the sought angle. This you will further apply to the observatory circle, once the perpendicular has been found.

From this it is clear, first, that a globe is not necessary; everything can be accomplished with only the plane of the ecliptic ABCD together with the parallel F G H I, supported on some prop. [Margin: An abridgement of the instrument.]

For in practice nothing more is required than the two circumferences A B C D and F G H I, given in the same position they have on the globe.

It is clear, secondly, that this way of finding the angle proceeds from the complement of the altitude, just as the previous one operates primarily from the Sun's altitude.

It is clear, thirdly, that for each place of a different latitude a proper instrument must be set up.

It is clear, fourthly, that in both methods one proceeds by spherical circles described from the Sun's place as pole, and that the arcs of those circles intercepted between the vertical and the ecliptic are the ones investigated; and that in the former method the same circle — namely the observatory circle — is always kept, whereas in the latter it changes from moment to moment; likewise that the latter must be referred back to the observatory circle, while the former needs no further reduction. Hence in practice I have kept to the former rather than to the latter.

And thus far we have proceeded from the Sun's given altitude above the horizon, or rather from its complement; now let us do and teach the same thing [from the hour].

From the given hour, to find the same angle.

[Margin: The angle from the hour alone.]

With the earlier suppositions in place — that is, given the sphere or globe A M C D, in which the pole of the world M is fixed, together with the place O that the Sun occupies on the ecliptic A B C after noon — then, since in this case we proceed from the known hour alone, we must find, on the circle F G H I drawn through the vertex [zenith], the point X on which the hour-circle sits at that given hour. The hour-circle M O will be described on the globe if, from M and from O, with the interval of a quadrant of the greatest circle, two arcs are marked on the same globe; for their intersection, which always falls on the equator, gives the pole, and from this pole, through the Sun's place O, the hour-circle O M is to be drawn. Alternatively, if through the given place of the Sun and both poles of the world you describe a circle on the surface of the globe, this will be the hour-circle O M, and it will cut the circle F G H at the hour-point X. And since the hour is taken after noon, the meridian will stand on the eastern side X G H.

The hour is known; so, since the circle F G H I is parallel to the equator, if it is divided into degrees, the hours and the fractions of hours can be counted upon it.

Let them therefore be counted from X to P, up to the given afternoon hour with its minutes, and so on. Accordingly, where the count ends at P, there necessarily lies the vertex-point through which the meridian M P N passes; for the arc P X is the arc of the hours from noon that the hour-circle M X O shows, and the hours from noon, intercepted on the arc of the parallel circle F X P H drawn through the vertex, are X P. Therefore the point P, as I said, is the vertex, since the meridian M P N passes through it; and so the arc P O will be the complement of the Sun's altitude. Once this is had, the angle P O R will be found, as before, and so on.

It is not, however, necessary to know the exact magnitude of this arc O P in degrees and minutes; it suffices to know its extension from O to P. Any great circle on the given globe, divided into degrees and minutes, will supply it, since this arc too is a portion of a great circle — namely, of the vertical circle. And if the circles are not divided, then with the interval E A, or E C, describe a semicircle A F C, and from it, once divided, cut off an arc equal to the arc O P — which is done by applying the chord O P, and so on — and thus you will have the arc known in given parts, and so forth. Therefore, from the given hour we have found the angle of the vertical with the ecliptic: which was to be done.

The Third Method of Finding the Aforesaid Angle

Having set out two mechanical methods of finding the aforesaid angle, let us now propose another, by the analemma of the ecliptic.

Problem III

To find, in the analemma of the ecliptic, the angle that the vertical makes with the ecliptic.

If in the preceding figure the circle F G H I is understood to be imprinted perpendicularly upon the plane of the ecliptic A B C D, all its points will fall on an elliptical perimeter, because the planes of those circles — namely, the ecliptic and the parallel drawn through the vertex — are inclined to one another. The major and minor axes of the resulting ellipse are therefore determined in this way.

Construction of the Problem.

Let A B C D be the ecliptic, and let the common section of it and the colure of the solstices be the diameter A C. Let the semicircle of the colure at right angles to the ecliptic be understood to be A M C, with the pole of the world M upon it; and let the arcs M F, M H be equal to the complement of the pole's altitude [i.e. the colatitude]. Then F H will be the diameter of the parallel described through the

vertex, and the perpendiculars F G, H I will give the minor axis G I, whose midpoint L will give the center. If from L a perpendicular R L S is erected, and L S and L R are made equal to the semidiameters X F, X H, then R S will be the major axis, and the ellipse described about these axes will be, in the analemma, the parallel described through the vertex; by its aid the proposed problem is solved in the following way.

[Margin: The description of the parallel through the vertex.]

Demonstration of the Problem, and Its Use.

Let the place of the Sun again be at O, and let the complement of its altitude be the arc O N, O Q; and join N Q by a hidden [construction] line. Outside the time of noon this will cut the ellipse in two points, of which the more easterly point, P, serves for the afternoon time, while the remaining one serves for the forenoon time. The reason is this: since that projection is analemmatic, the line N Q represents on the globe a circle described from the Sun's place O at the interval of the complement of the Sun's altitude — a circle that on the same globe necessarily passes through the vertex, and that cannot but lie on the parallel drawn through the vertex, which is here projected into the ellipse G R C S. Therefore the point P too, at which N Q cuts the ellipse, is the vertex-point; and consequently the ellipse described through O P, and the point opposite to O, represent the vertical drawn through the Sun O. That the nature of the elliptical astrolabe requires such ellipses may be seen in Clavius, at the beginning of Book 2 of his *Astrolabe* [Clavius, *Astrolabium* II].

[Margin: An abridgment of the practice.]

And since, for determining the sought angle, one would need the diameter O E and another perpendicular to O E, in their place one may always take the diameters A C, B D, provided the point P is transferred to the point Y — which is done if the triangle A Y E is made equal to the triangle O P E. This done, from the point Y a line Y K, equal to the semidiameter of the ecliptic, will be applied to the diameter B D; and its segment Y Z, intercepted between the point Y and the diameter A E, will be the sine of the complement of the sought angle. Consequently, if E a is made equal to Y Z and perpendicular to B E, the arc B e will be the arc of the sought angle.

The reason for this is that the ellipse described through A Y C would be the same as the ellipse that would be described about the diameter O E through the point P; and this ellipse, in this analemma, corresponds to the vertical circle, because the point P is the vertex of the place. Therefore the ellipse A Y C too can represent

that same vertical. Since, then, the line $Y Z K$ is equal to the major semi-axis $E A$, and the angle $A E K$ is a right angle, the line $Y Z$ — or $E a$, which is equal to $Y Z$ — will, by what has been demonstrated at Lemma 50 of the first book of the *Astrolabe*, be the minor semi-axis of that same ellipse into which the vertical circle sinks; that is, the point a , on the supposition that the point P is transferred to Y and the Sun's place O to A , will be the point on which the perpendicular of the vertical circle falls, which is distant a quadrant from the points A, C . Consequently $E a$ will be the sine of the complement of the angle of inclination that the same vertical makes with the ecliptic.

And if the line $Y K$ were a rule divided into sines and degrees, with the ninetieth set at K , then the parts of the segment $Z K$ would immediately number the degrees of the inclination.

Scholium

The practice of this matter is easy and expeditious enough, as its execution will be plain to anyone who tries it, even though the construction and the demonstration may perhaps appear rather difficult and thorny to someone. But once such an analemma is exactly drawn and ready to hand, the angle is quickly found from the complement of the solar altitude, once the segment $Z K$ — that is, the versed sine — is drawn out from B to the sought arc $B e$; for this arc gives the angle $B E e$, which is the inclination of the vertical to the ecliptic.

From this it is plain that for every latitude of a place, or altitude of the pole, its own proper analemma of this kind must be constructed.

For the rest, concerning the form, nature, and description of the ellipse, consult Guidobaldo [del Monte] in his *Planisphere* [Guidobaldo del Monte, *Planisphaeriarum ... theorica*], and Clavius in his *Astrolabe*, Book 1, Lemmas L, LI, and LII [Clavius, *Astrolabium I*, Lemmata 50–52]. In practice the ellipse is quickly traced if you have a rule into which you fix a writing-pencil, and then set one little pin at the distance of the minor semi-axis and another at the distance of the major semi-axis from the same pointer, and, keeping the rule moving between the two little pins as a gnomon, and so on — which I only hint at, since the matter is familiar among craftsmen. You may also do it by means of the two foci, if you fix a thread through them, stretched to the minor semi-axis, and carry the pointer around, guided by the thread, and so on. The foci are always to be sought on the major axis, on either side; the major semi-axis gives them, being laid off on either side from the endpoint of the minor axis toward the major — for where the intersection is, there on each side will be the focus. The same things are found

here and there also in works on gnomonics and optics, in Clavius and others, and so on.

[Margin: Ways of describing the ellipse.]

In my *Exeges*es you will find a new method of describing the ellipse, the parabola, and the hyperbola in a single stroke, easy and quick. Much I here pass over for brevity's sake, which will perhaps be treated more fully elsewhere.

Diagram. A full-page circular astrolabe-projection (the "universal astrolabe of Gemma Frisius, adapted to the plane of the ecliptic") for Problem IV, labeled **N. II.** at the top. A broad graduated ring runs around the circumference, subdivided into degrees (numbered 10, 20, 30 repeating) with zodiac signs marked at intervals; within it lie the ecliptic circle, the solstitial colure, and the geometric construction of the parallel through the vertex, drawn with solid and dashed lines. The four corners carry engraved devices: an **IHS** monogram in a sunburst (top left); an **MRA** (Maria) monogram in a sunburst, with a zodiac glyph above it (top right); and a heraldic rose in each of the two lower corners.

Readable point-letters (interior construction, confidently read):

- A — left end of the horizontal diameter
- C — right end of the horizontal diameter
- D — top, at the degree ring
- E — center of the figure
- F — upper left, interior
- G — on the horizontal diameter, left of center
- H — right side, interior
- I — right of center, on the horizontal diameter
- K — above the center
- L — on the horizontal diameter, near the center
- O — lower left of center, on the ellipse
- P — lower center-right, on the ellipse
- Q — left, interior, below F
- R — lower center
- Y — lower center, interior
- B — at the lower ring
- N — at the lower ring, near B
- e — lowercase, on a dashed horizontal at the right

Less certain / faint labels (flagged): M [?] and an adjacent "MR" [?] on the upper-right ring; S [?] (upper center, on the vertical axis below K); Z [?] (near the center, right of G); a [?] (lowercase, far right); X [?] (lower-left ring). Zodiac glyphs read on the ring, positions approximate: Cancer ☊ (right, near C/I), Libra ♎ (upper right, at the MRA device), Aries ♈ (bottom, near N/B), Aquarius ♒ or Capricorn [?] (left, near A/Q), Pisces ♓ (lower left, near X). Because more than two labels are flagged, this diagram is a

Cap. XXXIX.

Problem IV

To find the angle that the ecliptic makes with the vertical, by application of the astrolabe.

The fourth method of finding the aforesaid angle of the ecliptic with the vertical, from the universal astrolabe of Gemma Frisius [Gemma Frisius], adapted to the plane of the ecliptic.

Therefore the circle A B C D is the ecliptic, onto which, from the pole E, the other circles are projected in the usual way, in longitude and in latitude, at intervals of only ten degrees each — for we bring this forward only for the sake of example and instruction; in actual use one must proceed by single degrees and employ a larger form. What office each circle here drawn serves in the present business will appear once we have completed the things that are to be added to this astrolabe.

Construction and Demonstration.

First of all, then, we must define each parallel that runs through the vertex of the given place, whose diameter lies in the line A C — which here is the common section of the ecliptic and the colure of the solstices. It is found as follows. In the semicircle A M C, at right angles to the ecliptic, if the point C is the point Cancer (☊), and the arc C M of $66^{\circ} 30'$ is equal to the complement of the declination of Cancer, then the point M will be the pole of the world, and D, B the poles of the ecliptic. Taking the arcs M F, M H of 48° , the line F H will be the diameter of the parallel through the Roman vertex [the zenith of Rome]; and the lines B F, B H, drawn from the eye B placed at the pole of the ecliptic B, will give on the line H C the points G, I; and the line G I will be the diameter of the circle that, on the astrolabe, represents the parallel of the vertex. Therefore, G I bisected at K gives the center of that circle, and K I, or K G, will be its semidiameter.

[Margin: The description of the parallel through the vertex.]

This circle is not drawn here, however, because in the use and solution of our problem it must not stay in the same place: for the line A C is not always the common section of the colure and the ecliptic, but is continually shifted to other and other points of the ecliptic, so that the point A may always be the place of the Sun that bounds the sought angle. For example, with the Sun at the 20th degree of Capricorn (♑), the point Capricorn will be understood to be twenty degrees distant from the point A toward the west — that is, toward D — and the diameter of the colure will then be ♑, E, ♊ (Capricorn–E–Cancer); and the center of the circle, or of the parallel through the vertex, will then be the point N, at which the circle K N, described from E, the center of the astrolabe, through K, cuts the line ♑, E, ♊. In the same way the center of the parallel is found on any other diameter of the colure ♑, E, ♊, so that it is worth while to [describe] the whole circle K N, which [passes through] the centers of the circles or parallels carried through the vertex, and to express it on this astrolabe.

[Margin: The place of the Sun on the astrolabe is the point A.]

Once the center N has been found, the parallel itself is described with no trouble, since its semidiameter is always the line K I, or K G. Yet there is no need to describe the parallel itself, since without it one can obtain the point necessary for the solution of the problem — which is found as follows. From the place of the Sun A, let there be counted on the ecliptic — that is, on the very circle of the astrolabe — the arc of the complement of the Sun's altitude, for example 70 degrees; and, taking advantage of the compass, with the interval of the semidiameter K I, or K G, let one foot be placed on the point N already found, and the other transferred to the parallel of 70 degrees, on either side — e.g. as far as O, or P — for one or the other of these is the sought point. For the afternoon time the point O serves, which is the more easterly of the two, while the other, P, which is the more westerly, serves for the forenoon time; and each of them represents the vertex-point.

[Margin: The use of the circle through the vertex.]

And therefore the arcs A O C, A P C, great circles, represent the vertical circle, whose inclinations to the ecliptic are measured by the lines — or rather by the arcs projected into lines — the afternoon Q B, the forenoon R D; and the degrees that these segments contain are the degrees of the angle that is sought, which the numbers written on both sides indicate at once.

And this method appears the most expeditious of all, if on the astrolabe both the great circles and the parallels are drawn for every single degree. It is certainly more expeditious than that of the analemma — although the construction of the analemma is easier, since it is content with a single circle and a single ellipse. The earlier methods, finally, presuppose an instrument that is not flat; but this one, once rightly constructed, may be preferred even to the globe, which is prepared perfect only with the greatest difficulty.

[Margin: This astrolabe is to be preferred to the others in practice.]

From these things it is easy to understand the names and offices of the parts drawn in this astrolabe. For the circle A B C D is the ecliptic, onto which the parallels projected from A and C cut off the complements of the solar altitudes above the horizon, numbered from A toward B, E, and D, both on the ecliptic and on the individual great circles drawn through A C and projected onto the plane of the ecliptic.

[Margin: The function of the ecliptic.]

[Margin: The functions of the parallels.]

Diagram. A large full-page circular projection — the universal astrolabe ("astrolabum catholicum") of Gemma Frisius, i.e. the meridional (Rojas-type) projection of the sphere used throughout Cap. XXXIX. The figure is labelled **N. 12.** at the upper right. An outer graduated limb (a heavy circular scale) is divided into three concentric rings and carries the zodiac signs around its circumference with degree numbers (10, 20, 30 within each sign). Readable zodiac symbols on the limb, going round: ♈ (Aries, at top), ♊ (Pisces), ♒ (Aquarius), ♐ (Capricorn), ♏ (Sagittarius, lower left); and on the right side ♉ (Taurus), ♊ (Gemini), ♋ (Cancer), ♌ (Leo), ♍ (Virgo), ♎ (Libra), ♏ (Scorpio, lower right). Two "eyes" or poles of the projection appear as small semicircular scales on the horizontal diameter: **A** at the left end, **C** at the right end. The interior is filled with the projection network of meridians and parallels. A series of small astrological/degree symbols runs along the central vertical and along the diagonal lines (not individually transcribed — degree/planet markers of the grid, not point-letters).

Readable interior point-letters (listed only where legible; the many small Greek minuscules along the grid lines are only partly legible):

- A (left vertex): pole/eye of the projection on the horizontal diameter
- C (right vertex): opposite pole/eye
- D (top, on the vertical diameter): upper pole

- B (bottom, on the vertical diameter): lower pole
- E (center): center of the projection
- F (upper left, near "7° S"): grid point
- S (upper left, by F): grid/argument point
- M (upper, right of center): grid point
- V (upper center, above the Z–P–R row): grid point
- Z, P, R (a row just above center): grid points
- G (just left of center): grid point
- O (below E): grid point
- T (right of center, below E): center of a vertex-circle
- K (center-right): grid point (center of the small circle KN)
- N (below K): grid point
- I (right of center): grid point
- H (upper right): grid point
- X (lower center-left): grid point
- λ (lower center), α , β , θ , σ , φ , Y (Greek/minuscule grid labels, several faint)
[?]

The individual parallels, together with the greatest of them, DEB, show the angles at which the verticals that cut them are inclined to the ecliptic — angles reckoned at A, the Sun's place, and taken between the ecliptic and any vertical whatever, and so on. The numbers running from B toward E, or from D toward E (which are likewise to be applied to those verticals), indicate this well enough; for these numbers are common to the whole arcs of the great circles, and so forth.

The arcs of the circles A 10 C, A 40 C, and the others lying between D and E, and between E and B, represent the vertical circles and their various inclinations to the ecliptic, degree by degree; if these are drawn out, they can be displayed for the whole year from any ecliptic position A. AGKC, besides being one of the verticals, is also — as we said at the outset — [Margin: The functions of the verticals] the solstitial colure, in which K lies: the movable center of the circle drawn through the zenith. Hence, as we rotate that line through all the signs, the same result follows as if, the line staying fixed, we were to turn the ecliptic itself.

Therefore, as that line travels from A toward D, and thence toward C, and from C through B back again to A, it carries point K along with it across the center E — that is, the center of the circle drawn through the zenith — around the small circle KN; and it performs three functions. [Margin: The functions of the movable line AGKC]

First, it shows the position, bearing, and place of the solstitial colure with respect to the ecliptic, to the Sun's place A, and to the astrolabe laid upon the ecliptic. [Margin: First]

Second, it names the sign, and the day within the sign, in which the Sun stands at A. For just as the Sun in the celestial ecliptic advances one degree each day from Capricorn, so the colure line here — starting from A, the Sun's place and the beginning of Capricorn — moves toward Aquarius, and so onward through all the signs in turn. Thus, in whatever sign and place-within-the-sign of the Zodiac the Sun is found in the heavens, there the apex A of the advanced colure line is set; and this apex, as I said, moves forward one degree daily, its starting point taken at A, the beginning of Capricorn. But A is the Sun's place, fixed for each and every degree of the whole ecliptic; hence it is the ecliptic that is thought to move past A, not A past the ecliptic, and this is why the solstitial colure is taken as the movable element. [Margin: Second]

Third, it exhibits the center of the circle drawn through the zenith, and whatever depends on that center; and once the center's position is fixed, the circle itself is likewise given, to be described at the interval KI. [Margin: Third]

For an example, suppose one wishes to know how far the Sun's place A has receded from the colure AGKC at 15° Pisces, and so on. Find the fifteenth degree of Pisces at S; from it drop, through the center E, the straight line ST, and that will be the portion of the colure, ending at T, the center of the circle drawn through the zenith. Now if you wish to see the arrangement that the Sun and the astrolabe have on that day relative to that zenith-circle, describe a circle from T at the interval KI, and you will see before your eyes the whole bearing and position they have to one another on that day. [Margin: To find the Sun's place in the Zodiac]

The limb is divided into three rings: the outermost holds the signs of the Zodiac; the middle one holds the numbers proper to the degrees of the signs; the innermost, the degrees themselves. The numbers run from A along the quadrants of the ecliptic toward B and toward D; expressed thus on the straight line AE, they mark off the degrees of the complements of the Sun's altitude, running from the Sun's place A up to the zenith. [Margin: The functions of the limb]

For the Sun's altitude is reckoned up to the Sun's place, from the Sun itself set at A, while the complement of the altitude is reckoned up to the zenith. This complement can be extended to a full 90 degrees only when the Sun stands on the horizon. When the Sun is raised above the horizon, the complement of the altitude never reaches the ninetieth degree. Hence the straight line BD is the

boundary of the Sun's rising and setting. For with the Sun set at A and in the east, where the altitude is nil, the complement of the altitude — that is, the arc between the Sun and the zenith — is at its greatest, and so necessarily ends on the straight line ED; and again, with the Sun at A placed in the west, the complement of the altitude, for the same reason, would end on the straight line EB.

And since the culmination of the semicircle of the ecliptic cut off from the horizon at the Sun's place must occur on the vertical that stands perpendicular to the ecliptic, and since among all the verticals only one — AEC — is perpendicular to the ecliptic, then, with the Sun placed at A, AE will be exactly perpendicular, the boundary of culminations of this kind. From all of this I draw the following conclusions. [Margin: The line AE is the boundary of the ecliptic's culminations]

PRACTICAL PROBLEMS

Problem I

To show practically, from the astrolabe, at how great an inclination of the vertical to the ecliptic the Sun rises at any given degree of a sign.

Let the degree be 15° Pisces. From it draw the colure line ST; and from T, at the interval KI, extend the compass onto the rising line DE, as far as V. The segment DV, then, will give the vertical AVC in which the Sun rises, and at the same time its inclination to the ecliptic, DAV — namely the straight line DV, measured off on the astrolabe and given by the numbers written on it, which will be roughly 65 degrees. Proceed in this way for any day and degree of a sign. [Margin: To show the angle of the rising Sun]

Problem II

To assign practically, from the astrolabe, at how great an inclination of the vertical to the ecliptic the Sun sets at a given degree of a sign.

Let the given degree be 15° Pisces. From the center T, extend the compass by the interval KI and set its other foot on the western straight line EB; where this is cut, at Y, you have the vertical of setting AYC, and its inclination to the ecliptic, YAB, given by the line YB, of about 20 degrees. [Margin: To give the angle of the setting Sun]

Corollary

From these two problems you will understand when spots can be observed more easily and more safely — in the morning or in the afternoon. Suppose that from T

you set the compass to one and the same parallel — 60, for example — in the eastern part, at Z: you will find, under the Sun's given altitude, the vertical AZC with an inclination of 80 degrees. After noon, on that same parallel 60, under the same altitude of 30 degrees, at the point α , you will find the vertical A α C with an inclination of about 35 degrees. Therefore, since constant practice makes it certain to me that spots are observed much more easily and surely when the Sun makes smaller angles to the ecliptic, and with more difficulty when it makes large ones, you may safely state that at this time, under the same solar altitude, observations are more easily made after noon than before. This matter carries great weight for observing, and the diligent observer must attend to it above all; for from it he learns how to guide himself throughout the whole year, and to reserve the more favorable time for observation.

Problem III

To assign a place on the straight line AE at which the Sun culminates the ecliptic above the horizon, at a given degree of a sign.

Let the given degree of the sign be 15° Pisces. Extend the compass to the interval KI, set one foot at T, and apply the other onto the straight line AE at the point β ; that will be the point at which the Sun, placed there on that day, divides the ecliptic into two equal halves — for it lies on the vertical A β EC, which is perpendicular to the ecliptic, and therefore stands a quadrant away from the horizon on either side, and consequently culminates. [Margin: To mark the place of culmination]

Corollary I

From this you will understand under how great a solar altitude you must observe in order to bring the ecliptic onto the observing circle by the help of the plumb-line alone, without any further calculation. You will achieve this if you carry it out while the Sun holds the vertical AEC. But to be able to do so, you must know in advance the Sun's altitude above the horizon — which, in the case proposed, the arc A β will give: this arc is the complement of the altitude, namely 55 degrees; subtract these from 90, and there remains the Sun's altitude of 35 degrees. So, if on the day when the Sun holds 15° Pisces you observe some spot under the Sun's morning altitude of 35 degrees, and bring a plumb-line to bear, and set the diameter through the center of the observing circle at right angles to that plumb-line, then that diameter will be the ecliptic itself, and the position of the observed spots relative to it will be correctly given. [Margin: To state the altitude of the Sun as it culminates the ecliptic]

This procedure is in itself reliable; it does, however, require that the altitude be known precisely beforehand from $A\beta$, so that the astrolabe must be large and accurate. It further demands an excellent quadrant for taking the altitude, and an observer who is in no way careless. Finally, the one who observes the spots must be quick and sure. I give all these warnings because the thing must be carried through almost in a single instant, since the ecliptic is at once swept up out of that balance-point of culmination by the swift daily motion, and consequently comes to make oblique angles of inclination. Hence, if anyone were to carry out this procedure without success, he will lay the blame on these difficulties, and perhaps on his own slowness or sloth — for the thing, reliable though it is in itself, is difficult, being tied to this single point of time.

Corollary II

From this balance of the solar position you have, once again, one sure and universal rule for recognizing and determining the more convenient time for observing; it runs thus. Whatever vertical circles the Sun occupies at the same altitude, those that are nearer to the place of balance, or culmination, are without doubt to be counted the more suitable for observing; whereas those that are farther off are much more serviceable. Thus — since in the proposed example, while the Sun before noon, at an altitude of 30 degrees, sits on the vertical AZ — it is far nearer to the point β than when after noon it occupies the same vertical at α , likewise at an altitude of 30 degrees. From this yet another practical and general rule for the matter is drawn: on whichever side of the bisecting line AEC the segment of the circle drawn through the zenith falls the smaller, that side certainly furnishes the more inconvenient time for observing, because the arc of the smaller segment is nearer to the cutting line than that of the larger, and consequently marks out verticals nearer [to AE] than the larger segment does. So in the earlier example, the segment $\beta EVZ\beta$ is smaller than the segment $\beta EY\alpha\beta$, and its arc $VZ\beta$ is much nearer to the bisector $A\beta E$ that cuts it than the arc $\beta\alpha Y$ is; and for this reason the vertical circles marked out by the arc βZV are far nearer to the straight line AE than those intercepted by the arc $\beta\alpha Y$. [Margin: A rule for recognizing the convenient time for observing] [Margin: A rule for recognizing the inconvenient time]

Problem IV

To determine, for a given place of the Sun in the Zodiac, in which region of the astrolabe the bisector AE lies — the eastern or the western.

It is certain that the Sun always lies on some vertical circle; certain too that the daily arc is divided in two by the meridian, that the afternoon altitudes are made equal to the morning ones, and hence that the parallels of altitude cut the daily arcs at all equal altitudes but are touched at a single meridian point. [Margin: Preliminary remarks] From this it is likewise certain that the same holds for the parallels of the complements with respect to the circle drawn through the zenith: a single one of them touches that circle at the complement of the meridian altitude, while all the rest, which are defined by larger complements, cut it. Therefore, just as the Sun each day makes two equal altitudes above the horizon at any given moments — one before, the other after noon — while at noon it stands at the mid-place and highest altitude, so it must be that each day it makes the afternoon complements equal to the morning ones, but constitutes a single meridian complement; and of all the complements the least, indeed, is the one belonging to the greatest altitude, and so on. With these points assumed:

Let it be, as before, that the given degree of the sign is 15° Pisces. With the compass set to KI and one foot placed at T, extend the other to the line AE, at the point β , and consider what number of the parallel comes out from the complement written there; then, swinging the compass around, test whether you fall again onto the same parallel at α . If so, you may be sure that point β is the eastern one and point α the western. But if the parallel were not cut twice by the compass but only touched, then the bisector AE would itself be at the meridian. And if the parallel is cut before reaching it, toward D, and is afterward intersected at the same point, then AE will certainly lie in the western region.

Corollary

From this, for the favorable time of observing, there is given once more a general practical rule. While the center K is turning within the semicircle K $\mathcal{N}$ γ of the circle drawn through the zenith — that is, while the Sun is turning in the ascending semicircle from Capricorn, through Aries, up to Cancer — afternoon observations, other things being equal, are made more readily than morning ones. On the contrary, while the Sun passes from Cancer, through Libra, into Capricorn, along the descending semicircle, and carries with it the center of the circle that passes through the zenith — from γ , through [?], to K — the observations are made more safely in the morning time, more riskily in the afternoon. In a word: whichever region of time the center K occupies, the observations belonging to that time are carried out more readily, other things being equal, because the bisecting line AK occupies the region of the other time

and seizes for itself the smaller portion of the circle, while the center always holds the larger. [Margin: A rule for the favorable time of observing]

Problem V

In a given astrolabe, for a given place of the Sun in the Zodiac and the center of the circle through the zenith, to assign the Sun's meridian altitude and the meridian circle.

Let the given place of the Sun in the Zodiac be 15° Pisces, and from it let the center of the circle through the zenith be found, T; extend the compass to the distance KI, and, one [foot having been set...] [text continues in the next portion]

Book II, Chapter XXXIX (continued)

(The centered Roman numerals "V."—"XII." heading the columns across this opening are Scheiner's running column-index apparatus for cross-reference, not section headings; the "1, 5, 10 ..." figures in the gutters are the five-line marginal line-count. Neither is reproduced as body structure.)

Practical Problem V (conclusion)

[Margin: Finding the meridian altitude and the vertical circle.]

[with] one [foot of the compass] set in T, extend the other toward A until it just touches one of the parallels of the complements without cutting it; for that parallel will give, on AE, the number of the complement. Subtract this from 90, and the remainder will be the meridian altitude; and the vertical circle drawn through the point of contact found will be the meridian circle.

I prove it as follows. If this circle, which passes only by contact, were not the meridian, then there would be another circle that either is not touched at all by the circle drawn through the zenith [circulus per verticem] — in which case the complement of the meridian altitude comes out less than it should, and consequently the altitude greater than it ought to be, and therefore false — or else, while it is touched, it is at the same moment also cut, in which case two meridians would be assigned to a single day, and likewise the meridian altitude would come out less than it should; for a circle that is merely touched gives an altitude greater than that of any circle cut twice.

But these consequences are absurd, and therefore must not be admitted. It still stands, then, that from a parallel purely touched, by means of the point of contact

and the altitude of the meridian, both the meridian and the meridian circle are found.

[Margin: To find the meridian's point of contact.]

Since, however, the contact often occupies a perceptibly wide band, so that you cannot tell just where the point should be placed, you may recover its true position in this way. Fix one foot of the compass in the center of the circle through the zenith that was found, and open the other to a distance greater than KI, so that the parallel which had been merely touched is now cut on both sides. Then bisect the arc intercepted between the two intersections exactly in half; for the point of division will itself be the point of contact, since a line drawn from the given center through that point will also pass through the center of the parallel that was touched.

Corollary I

[Margin: The meridian angle.]

From this it is easy, on any day, to find for a given place the meridian's inclination to the ecliptic. That inclination is shown in the line BED, where the vertical circle — advancing through the common point of contact of the parallel and of the circle drawn through the zenith — cuts it; for the greater segment measures the angle of inclination.

Corollary II

By the same operation you will have the complement of the aforesaid inclination as well. It is measured on the smaller segment of the line EB, and it gives the distance of the meridian from the mediatrix [mediatrix] AEC — that is, the inclination of the planes passing through the axis of the ecliptic and the axis of the world, and also the inclination of those planes advancing through the given place of the Sun. For the Sun's place is A, which is common to all the vertical circles; in AEC, the pole of the ecliptic is E; and in whatever vertical circle happens to be the meridian, the pole and axis of the world lie. Their mutual inclination is therefore to be taken along the segment of the single straight line BE, or DE.

Now the meridian is always found on that side on which the center of the circle through the zenith is located. Twice a year all these things coincide in a single vertical circle AEC — namely when the Sun stands in ♋ [Cancer] or ♑ [Capricorn].

Very many things, most worth knowing, could be investigated here; but since many of them were touched on earlier, when I was treating of Mediation, I judge that the rest should be reserved for another time.

Problem VI

To show in practice, on the astrolabe, the regression, station, and progression of the spots [maculae], by means of the circle through the zenith.

I have reduced all my observations to order by means of this figure of the astrolabe and of the circle drawn through the zenith. Laboring at this night and day, I frequently find that on the same day — both morning and evening, and especially in summer — the inclinations of the vertical circles to the ecliptic become greater and smaller; that under different elevations of the Sun they are equal; and that the intermediate ones scarcely vary perceptibly over a fairly long stretch of time. When I compare this with the observations, I find without exception that at the very same times the regression, station, and progression of the spots on the circles of observation take place.

Turning this over often and dwelling on it long, I have come to see clearly that the circle drawn through the zenith on the astrolabe, carried round the astrolabe's center through the year as I lay out my day-to-day observations, sets before the eyes — practically, plainly, and as it were unbidden — whatever lies hidden in the matter, and draws the student of these things, as though by the hand, into nature's secret places and into the contemplation of her wonders. This is what in some sense compels me here to run through at least some of the things which, by this constant use over so many years, and by the fullest of these methods by which I set out and order my observations, I have learned to be consistent — with a somewhat coarser Minerva, as they say, but enough for my purpose, and suited to a correct and convenient practice of observing. For the shortness of the time will not now allow me to make the exquisite refinement of this theory as plain as possible — a refinement I am well aware of, given how abstruse and, I may add, how slippery this subject's subtlety is — nor to give it fuller treatment. But if I obtain the accurate speculations on the same matter which Father Christoph Grienberger [Christoph Grienberger] has worked out and promised me, I shall gladly and willingly append them in a suitable place, as a token of my gratitude and for the benefit of the public good of letters, and for your sake, reader.

For just as he, by this phenomenon — chiefly by the regression, station, and progression of the spots (which affections of the phenomenon, though they occur daily in summer, are nonetheless harder to establish, and he admitted into the

census of the true appearances only after I had produced clear experiments) — gave me the occasion of devising much that is excellent, so in turn I have always resolved in my own mind to give him a place, and indeed a most honorable one, in this work of mine.

Thus, what I owe to his authority — by which, approving my labors, he added the ivy [i.e. bestowed his commendation] — and to his industry, by which he helped me in devising an easier method of determining the angle of the vertical circle with the ecliptic, I would not only acknowledge privately, but leave attested publicly to posterity.

Meanwhile, for a more correct understanding of what follows:

I premise, first, that the circle drawn through the zenith in the figure of the ecliptic astrolabe is divided by the line BD into two parts. That part which lies toward A is, and is called by me, the diurnal portion, because from A up to it the whole diurnal use of the parallels and of the vertical circles is completed. For as soon as the circle through the zenith crosses the line BD toward C, its use is entirely nil, since the Sun is then below, not above, the horizon. And so the portion lying toward C I call the nocturnal segment of the circle drawn through the zenith; and the line BD itself, if you please, we may not inaptly call either the finitor [finitor] or the day-night circle [noctudialis].

[Margin: Vertical circles that fall outside the parallel through the zenith are of no use for this business.]

I premise, next, in the second place, that only those parallels and vertical circles can be taken into use which the diurnal perimeter of the circle through the zenith reaches; for those that fall entirely outside are unsuitable.

I premise, in the third place, that the little circle K T [point-labels: ?], drawn from center K, of the circle through the zenith, about the pole of the ecliptic E, is divided in half by that same BD through the points [?]; and the portion of it toward C — namely [?] K [?] — I call the winter, or if you prefer the southern, semicircle of the center, because the Sun then runs through the southern signs, which bring us the winter cold; while the opposite portion, [?], I call the summer ...

or northern semicircle of the center. For while the center runs through that semicircular arc, meanwhile the Sun traverses the arctic signs, which bring us the summer.

I premise, in the fourth place, that all and only those points at which the periphery of the parallel through the zenith concurs somewhere with the vertical circles are vertical [i.e. lie on a vertical circle]; whereas the rest, taken within or outside its circumference, are not vertical — at least for that position of the circles. These things being noted:

I SAY, first: *When the center of the circle drawn through the zenith lies in the southern semicircle, no regression or station occurs on the diurnal part of that same circle, but mere progression.*

[Margin: When no regression or station occurs.]

For none of the vertical circles is cut twice on the diurnal side by the circle through the zenith. The reason is that, when the center K of the circle through the zenith is placed in the southern part C, the other intersection of any vertical circle falls in the nocturnal part — namely, the same part in which the center K lies. This is proved as follows. The centers of all the vertical circles lie on the straight line BD produced in both directions; and of those which run between E and D, since they are concave toward E, the centers will be found on the side EB; while of those which are carried between E and B, since they are concave toward E, the centers will lie on the line ED produced. Therefore, if there is now given a vertical circle running between D and E, its other intersection toward the part A — in the diurnal segment of the circle through the zenith — [is found thus]: if a straight line be drawn through the centers of both circles (that is, of the vertical circle and of the circle through the zenith), that line, from the side EB, will meet the line EB somewhere, namely just where the center of the vertical circle is supposed to be. And since this line also passes through the center of the other circle, which is supposed to lie in the part C, the line itself will fall wholly between D and C. And since it runs as the middle line between the two common intersections of those circles made toward the same part D, and lies in the nocturnal part of the circle through the zenith — while the other [intersection] is found toward A — it is evident that the other inclines much more into the nocturnal portion, toward C. In a practical example the whole matter will become clear.

While the Sun holds the twentieth degree of Capricorn, the center of the circle through the zenith is at N, from which, with the compass set to ...

the interval KI, let some vertical circle be cut in the diurnal east, at the point ι [?]; and if a straight line be conceived as running through N toward the center of the vertical circle A ι C, which lies on the straight line EB produced, it is clear that the line through the center of the vertical circle, and through the said N, makes an

angle in the southern part, and recedes from that same EB toward C. And when that straight line through N, produced, cuts the vertical circle A ι C at some point θ [?], that point will fall in the middle of the two intersections. And since the earlier one, ι , is in the eastern diurnal part, the later one will necessarily be in the nocturnal part, at [point: ?].

In the same way, if from the same center N some western diurnal vertical circle be cut at ι , its other intersection — by the straight line N λ , which joins the centers of both circles and bisects their two intersections at λ — will be proved to fall into the nocturnal portion, toward C, at the point [?].

These things are confirmed by continual and prior experience, in agreement with what has been said, when one observes.

[Margin: When regression, station, and progression occur.]

I SAY, second: *When the center of the circle drawn through the zenith lies in the northern semicircle [labels: ?], the regression, station, and progression of the spots will occur, both about the diurnal rising and about the setting.*

Let the center of the circle drawn through the zenith be at μ , and let its distance KI — that is, its semidiameter — be applied from μ to ED, falling at 60, and let it touch the vertical circle A 60 C. And since the center μ lies on the diameter of the vertical circle A 60 C — which, drawn out from the center placed somewhere on EB, is understood to emerge — μ 60 will be greater than any others running between it and the rest of the diameter, by [Element] 7 of the third [book].

Therefore, if a circle at the interval μ 60 be understood ...

[to be cut in] two [points], namely while these intersections meet on the same vertical circle, [it follows] that equal inclinations to the ecliptic intervene, but that in the intermediate time [the spot] ascends, stands still, and descends. And since this happens morning and evening, daily, while the center wanders in the northern semicircle, regression, station, and progression must likewise occur — yet with this distinction: that in the morning the regression comes first, then the station, and finally the progression; whereas in the evening the ordinary progression always holds the first place, the station the second, and the regression the last.

These things are confirmed by antecedent observational experiments, and will be established by those to follow.

I SAY, third: *When the center of the circle through the zenith lies at the equinoxes, no regression or station occurs, but mere progression.*

[Margin: At the equinoxes there is only progression.]

For since the circle through the zenith has its center on the day-night line BD, on which all the vertical circles have placed their own [centers], it is clear that either bare contacts occur between the vertical circles and the circle through the zenith, or else the intersections are equal on both sides, in the diurnal and the nocturnal part.

I SAY, fourth: *The beginning of regression takes place immediately after the vernal equinox, when the Sun enters ♈ [Aries] and the center of the circle through the zenith takes up the diurnal semicircle [labels: ?]; the end of regression occurs at the autumnal equinox. The reasons are sufficiently clear from what has been said.*

[Margin: The beginning and end of regression.]

I SAY, fifth: *Regressions, from the vernal equinox up to the summer solstice, always increase both morning and evening; at the solstice itself they are greatest; and thereafter, up to the autumnal equinox, they decrease in proportion to the preceding increments.*

The one ground of the increase up to the solstice, and of the proportional decrease thereafter, is taken from the time during which these regressions last, which always increases from the vernal equinox to the solstice, and from the solstice decreases by the very same ratio to the autumnal equinox. The other ground is taken from the arc of the parallel through the zenith intercepted between the contact and the finitor, which always increases from ♈ [Aries] to ♋ [Cancer], and from there decreases in the same proportion to ♎ [Libra]; and this arc measures the regressions, and so forth.

All these things are confirmed by the uniform revolution of the center in the little circle [labels: ?], from which ...

Diagram. A large full-page circular projection — the universal-astrolabe / analemma-type projection belonging to Book II, Chapter XXXIX (numbered **N. 12.** above the figure). The bounding circle carries a graduated zodiacal rim: a double scale-band divided into signs, each marked off in degrees (labels 10, 20, 30 recurring within each sign) with zodiac glyphs around the circumference. Readable zodiac glyphs on the rim include ♓ (Pisces), ♒ (Aquarius) and ♈/♈ toward the upper-left; ♈ (Aries, at top) and ♉ (Taurus) at the upper right; ♋ (Cancer, appearing twice on the right side) and ♌ (Leo), ♍ (Virgo) and ♎ (Libra, at the bottom).

The interior is a dense grid of parallels and vertical circles converging on two eye-points set on the horizontal diameter, each drawn with a small semicircular boss:

- A (left, on the horizontal axis at the 0 mark): the western vertex/eye-point.
- C (right, on the horizontal axis): the eastern vertex/eye-point.
- D (top, on the vertical axis).
- B (bottom, on the vertical axis).
- E (center, on the horizontal axis, toward the right): pole of the ecliptic.
- G (on the horizontal axis, just left of E).
- K (near center): center of the circle through the zenith.
- N (just below K, near center).
- The horizontal diameter A→C is graduated 10, 20, 30, 40, 50, 60, 70, 80.

Other capital point-letters legible in the central and upper region include **F, S, M** (upper, near D), **H** and **I** (right of center, toward C), **O, X, Y** (lower center), and **P, R, V, Z, T** (a cluster near the center). Numerous small lowercase and Greek/symbol point-labels (α , β , π , and others) and the tiny symbol-labels of the central little circle are present but too small to resolve individually at this resolution — flagged [?]. Roman numeral column-index marks (II, and others) appear at the rim. Because more than two labels cannot be resolved, this figure is a

Rosa Ursina, Book II, Chapter XXXIX (continued)

Diagram. A large full-page circular projection, labeled **N.12.** at the upper right — the universal-astrolabe / analemma projection that carries the whole argument of Cap. XXXIX. The outer rim is a double graduated circle divided into degrees (numbered by tens — 10, 20, 30 — within each 30° zodiacal division) and bears the twelve zodiac signs around its circumference. Within it are two interwoven families of curves: a set of "circles through the vertex" radiating from two hub-points — **A** at the left and **C** at the right, both on the horizontal diameter — and a grid of parallels and verticals; several oblique straight lines and an inscribed elongated (ellipse-like) curve cross the field.

Readable labels:

- A — left hub, on the horizontal diameter
- C — right hub, on the horizontal diameter
- D — top, on the vertical diameter

- B — bottom, on the vertical diameter
- F — upper left
- M — upper field, right of D
- central/mid field: E, G, K, N, P, R, V, Z, I
- lower field: O, T, X, Y
- Greek minuscule point-letters scattered through the field: φ , β , γ , δ , τ , υ , χ , λ , θ , ω (individual small sorts are at the resolution floor)
- zodiac signs around the rim: Υ (top), $\Scorpio$ and Π (upper right), $\Sagittarius$ (right), $\Aries$, ϖ , Υ (upper left / left); the remaining signs are faint [?]
- Roman graduation numerals **II** and **III** appear on the right-hand rim

Numerous small Greek point-letters and several rim signs cannot be individually resolved under magnification. (This is the same plate impression, N.12, that recurs at p. 231 below, and matches the N.12 astrolabe plate carried in the preceding folios.) and that the circle through the vertex [circulus per verticem] itself is carried around uniformly, so that the proportions of like quantities must remain constant. To all this is joined a steady and consistent experience drawn from the observations — which was the first occasion, the mover, the guide, and the most faithful discoverer of all these matters.

I say, sixth. *The boundary-points of the ordinary and continuous progression, from morning into evening, are the mutual contacts — morning and evening — of the vertical circles with the circle through the vertex.*

[Margin: What the boundary-points of the continuous progression are.]

For the contacts are the last thing these circles have in common; and between these contacts no vertical makes a double intersection toward one and the same eastern or western part, but only a single intersection for each, with a continuous increase of the angles from

the morning contact up to the evening one — if we regard the same part of the Ecliptic, AFD, toward the east; or with a continuous decrease, if we consider the opposite part, AB, at setting throughout the whole day.

[Margin: The various senses of "progression" are explained.]

But if we extend the angle between the Ecliptic and the vertical only as far as a right angle and bound it by a quadrant, then the morning angles of the progression increase from the point of contact — the eastern one — to the line AE, the bisector [mediatrix], and from there decrease to the western contact. If, however, we measure the progression from the eastern (sunrise) contact to the

meridian, and from there to the western (sunset) contact, then sometimes the forenoon angles grow beyond a right angle while the afternoon ones fall short of it, and sometimes the afternoon angles are enlarged beyond a right angle while the forenoon ones fall short. Everything will become clear from the examples.

Let the center of the circle through the vertex lie in the evening part of the day and occupy the point ϖ . If then, from it, a parallel-through-the-vertex is described at the distance KI in the usual way, in the eastern region — at some point ρ — it will touch, but not cut, some vertical circle $A\rho C$; and conversely it will be touched, but not cut, by that same vertical at the same point ρ . Likewise, in the southern part of the day, a similar contact will occur at the point ς , with the vertical $A\varsigma C$ and the said circle through the vertex. And such morning and evening contacts — differing from one another, however — occur daily, as long as the center moves within the semicircle $\varsigma\gamma\delta$. They differ from one another individually because the position of the circle through the vertex, relative to the verticals projected onto the plane of the Ecliptic, is different each day.

Now, between those two contact-points ρ and ς adduced as an example, all the rest that lie between proceed in order from ρ to ς , and none of them is cut twice, because the complements of the altitudes toward the meridian continually decrease and from there increase up to ς . While this is happening, then, the angles contained between the arc of the Ecliptic $A\rho D$ and the morning tangent-vertical $A\rho C$ — and likewise any following ones, $A\nu C$, and so on, up to the evening tangent $A\varsigma C$ — always increase; or, if you compare those same verticals with the western arc of the Ecliptic AB , they perpetually decrease. For the angle ρAB is certainly greater than τAB , and this greater than ςAB ; whereas if we look at the eastern arc AD , the angle ρAD is smaller than τAD , and this smaller than ςAD .

[Margin: The ordinary progression — what it is, and how far it agrees with the progression of the spots observed on the chart.]

Therefore, since from the morning contact to the evening the angles considered toward the eastern arc of the Ecliptic increase without interruption, while, regarded toward the western arc, they decrease at the same rate, I call this increase or decrease of the angles the *ordinary progression*, with respect to spots observed against a single vertical line. And I set those two contacts as the boundary-points of this progression; for as long as the complements of the solar altitudes lie between them, so long does the rotation of the spots in the observation-circle [circulus observatorius], about its center, tend toward the same part without any retrogradation. And in this I have always found complete agreement — both here and formerly at Ingolstadt.

But if someone should take a right angle, or 90 degrees, as the measure of these angles, then in this progression the angles will always increase from the morning contact up to the vertical AE, which bisects the Ecliptic and therefore makes the angle [?]AD a right angle. From here the vertical circles look toward the other arc of the Ecliptic, AD, and make angles always smaller than a right angle, with continuous decrease, down to the angle ζ AB, which is formed from the vertical tangent to the Ecliptic and becomes the smallest of all that day toward that part. And although the rotation of the spots about the center takes no notice of this respective increase and decrease, nevertheless in setting out the spots and ordering their courses I have always followed the smaller of the oblique angles on the Ecliptic, and so I have taken the right angle as the maximum measure.

Finally, if we attend to the meridian vertical and, in observing the spots, to the Sun's altitudes above the horizon — which I have always done in investigating the angle of the vertical with the Ecliptic — it is certain that the forenoon angle ρ AD grows beyond AE as long as the center clings to the quadrant $\zeta\gamma$, and so becomes greater than a right angle; for the meridian vertical at that time lies within ρ and γ as well. But if the center is found in the eastern quadrant $\gamma\delta$, it is evident that the meridian too is held there; whence it is clear that the forenoon angles will not reach the line AE,

Diagram. A second, duplicate impression of the same N.12. universal-astrolabe projection printed on p. 229 (fig-p229-1): the identical double graduated zodiacal rim, the two hubs A (left) and C (right) on the horizontal diameter, D (top) and B (bottom) on the vertical diameter, the two families of circles-through-the-vertex, the oblique lines, and the inscribed elongated curve, with the same scatter of Latin-capital and Greek-minuscule point-letters. As on p. 229, many of the small labels and rim signs are at the resolution floor; treat as a duplicate plate impression, not a distinct figure. This plate heads p. 231; the text below continues without interruption.

and so will be smaller than right angles — while the contrary will happen in the case of the afternoon angles.

And so the ordinary progression is stable. It takes on varieties when referred either to the semicircle, or to the bisecting line, or finally to the meridian; but these do not in fact alter the state of the progression — rather, from the varied way of relating it, they give rise to varied names for one and the same thing. The continuous advance from contact to contact is established from observations made against the same perpendicular, or else through the helioscope by

inspecting the Sun, as I did every day from the very first discovery of the phenomenon at Ingolstadt — from earliest morning into late evening.

For this progression and regression of the spots is most plainly noted by the judgment of the eye alone.

I say, seventh. *The contacts of the vertical circles with the circle through the vertex — morning and evening — on the one side, and, on the other side of the horizon [finitor] BD, the meetings, both morning and evening, with the same circle through the vertex, define the regressions of the spots.*

[Margin: What is regression?]

For the regressions of the spots occur when angles arise contrary to the progressions — which happens every morning from sunrise up to the contact, and every evening from the contact to sunset. And so regression is nothing other than the arc of the circle through the vertex intercepted between the horizon and the contact. For example: if the center is ϖ , then, while the Sun occupies the eastern horizon at A, the vertical circle will touch the circle through the vertex at δ , and afterward will gradually reach the contact ρ ; and the arc $\delta\rho$ will be the regression of that day at sunrise. In the evening, the regression will be the evening arc ςD [?], intercepted between the evening contact ς and the horizon BD.

[Margin: In the morning regression the angles are diminished; in the late-evening regression they are increased.]

In the morning regression, the angles contained between the verticals and the eastern arc of the Ecliptic AD continually decrease, up to the contact of that day — say, ρ . But in the evening regression, from the evening contact they continually increase, up to sunset. And so the points of the Sun's rising and setting on the one hand, and the points of the morning and evening contact on the other, mark out the lines of regression. To know, therefore, on any given day the point of the rising Sun and of the morning contact, and likewise of the setting Sun and of the late-evening contact, is to know the arcs and the magnitudes of the regressions. These are not difficult to ascertain, as we shall see later; for now, let us weave on the thread of the argument.

But when, and for as long as, regression occurs, then and for just so long does the spiral course of the spots on the chart run backward about the center in the observation-circle — provided the observations were set up against the same perpendicular. For they run together: the regression on the chart, and the angles here — decreasing in the morning, increasing in the evening. I noticed the same

thing formerly at Ingolstadt too, with the helioscope, when I perceived the spots approaching the vertical in the morning and receding in the evening, contrary to the ordinary course of the day. These things I did indeed notice at the time; but, ignorant of their causes, I followed the effect with wonder. See chapters 13 and 14 of this book.

I say, eighth. *The arcs of the regressions increase daily from the vernal equinox, both morning and evening, up to the solstice; and from this, down to the autumnal equinox, they decrease in like proportion.*

[Margin: The increases and decreases of the regressions.]

For the more the center recedes from the horizon BD, the further the contact too recedes from it; and so the arc of regression between the two increases. And since at the beginning of ♋ [Cancer], where the summer solstice falls, the recession of the center reaches its maximum, it is clear that the greatest arc of regression also occurs there.

In the figure the whole matter is plain to the eye. γ is the solstitial point ♋ and the center of the circle $\rho\chi$ drawn through the vertex. The eastern contact-point ρ is designated by the straight line $\rho\gamma$; the western contact-point χ , by the straight line $\chi\gamma$ [the two lines each carry a small trailing figure-numeral, reading uncertain [?]]. The point of the rising Sun on the horizon BD is expressed by the mark of the number 50; the point of the setting Sun, likewise, by the numeral mark of the number 50. The arc of the morning regression, then, while the Sun occupies the beginning of ♋, is $\rho 5$; and the arc of the evening regression is $\chi 5$ (the "5" being the figure-mark that stands for the number 50). Therefore, to put it briefly: the regression of the spots is the arc of the circle through the vertex intercepted between the point of contact and the point of rising or setting; or it is the arc comprehended between two verticals, one of which is the contact of the circle through the vertex, the other the vertical of the rising or setting Sun; or, finally, it is the arc of the circle through the vertex comprehended between the horizon and the line passing through the centers of the mutually tangent circles.

That this arc is greatest at the beginning of ♋ is clear, on account of the maximum recession of the center; but that it diminishes daily, on account of the same center's approach to BD in the quadrant $\gamma\delta$, and increases on account of its withdrawal into the quadrant $\gamma\eta$ [?], is self-evident. And these very things too I have always found from the foregoing observations — namely, that in summer, on the longest days, the spots make longer recurrences between observations

than on the shorter days; although I could not precisely define fixed limits from them. Yet they were the origin and cause of these discoveries.

[Margin: What is the vertical-horizontal circle?]

I say, ninth. *All the vertical circles that lie between the vertical of the contact and the vertical of the rising or setting Sun — which we may more generally call the vertical horizon — cut the circle through the vertex...*

Rosa Ursina — Book II, Cap. XXXIX–XL

Cap. XXXIX (continued): the universal astrolabe

(...the circle through the vertex, which the two bisecting verticals) cut at the vertex twice; and for that reason two angles equal to the Ecliptic are produced twice, one of them in the arc of regression, the other in the arc of progression. The whole span of these two equal angles is contained within the horizontal vertical. For that vertical is the first and the last of all the verticals that cut the circle through the vertex twice on the same diurnal side, both eastern and western.

But although these two intersections of any given vertical circle stand on either side around the point of contact, they do not appear to recede from it by equal arcs or by equal intervals of time. Yet it must be noted here that each of these bisecting verticals is equivalent to two different verticals in the heavens; and since these form angles equal to the Ecliptic, they cannot be represented on the plane of the astrolabe except by a single arc — because two equal angles at the same point A, and on the same arc A D or A B, cannot be constructed except by lines that coincide with one another.

Hence, although the angles ω A D and ψ A D differ in the heavens both in position and in their vertical lines, here on the plane of the astrolabe they could not be rendered except by a single angle and by the vertical arc A ψ produced as far as ω . And what I have suggested, by way of example, about this arc A ω is to be understood of every one of the verticals that make two intersections.

I say, tenth [DICO Decimò]. *Although the point of contact is the place and seat of the station of the spots, nevertheless the station of the spots itself is not confined to the single, sole point of contact.*

For the point of contact is something indivisible, whereas the stationary seat of the spots denotes a certain extension; the point of contact knows nothing of a lapse of time, while a station implies something further. And so the station of the

spots signifies that some duration of time, and some advance of the diurnal motion, takes place in the interval, while the observed sunspots stand motionless at the same place on the observation circle and neither move forward nor move backward for as long as they are said to remain in station.

[Margin: Contact is twofold — physical and mathematical.]

The station of the spots, therefore, is defined not by a geometrical and rational contact but by a physical and sensible one. And a sensible, physical contact is reckoned to be one that holds the two circles — the vertical and the circle-through-the-vertex — so joined together that they cannot be distinguished by the senses, and the physical, sensible difference of the vertical angles with the Ecliptic is not perceived. Since this happens over a long lapse of time, under varying altitudes of the Sun, it comes about that the spots are observed and reckoned to stand still for so long an interval of time, and to neither advance nor regress — as may be seen at the contacts φ and χ , around which one runs off to the left and right over fairly large intervals, until the sensible divergence of the arcs touching at the points φ and χ is at last noticed.

Let it therefore be settled and determined that the station of the sunspots is bounded by a physical and sensible time; that it is composed of the arcs of regression and of progression; and that it constitutes, in a certain way, the same angle with the Ecliptic to the senses.

[Margin: Some stations longer, some shorter than others.]

It is next certain that these stations themselves are also found to differ among one another. For since the vertical circles nearer the center come out more like straight lines, it is clear that the circle through the vertex makes far shorter sensible contacts with those than with the ones lying closer to the perimeter of the Ecliptic A B or A D. The reason for this is that straight lines and larger circles are observed by the senses to depart from the contact of smaller ones more quickly than curved and smaller ones do.

This standing-still of the spots on the observation circle is so evident that it can be perceived even with the helioscope, by the judgment of the senses. And whenever it occurs, the angles between the Ecliptic and the vertical are then always sensibly equal. It was for this reason that at Ingolstadt, in those days, when these very phenomena were occurring in the course of my observing morning and evening, I was most assiduous. Therefore anyone who has seen the complete agreement of the foregoing experiments with these doctrines that follow from the

astrolabe will — in my judgment, at least — be in no way able to doubt what has been said, or the truth of it.

Diagram. Full-page engraved plate of the universal (stereographic) astrolabe projection, captioned **N. 12.** (upper right). A large circle carries a graduated outer degree-scale bearing the twelve zodiac signs; the readable signs sit at the cardinal points — Aries Υ at top, above point D; Libra ♎ at bottom, above point B; a Cancer-region sign ♋ at the right, near point C; and the $\text{♑}/\text{♒}/\text{♓}$ (Capricorn–Pisces) region at the left, near point A. Two small blank circular "cut-outs" (radiating fans of lines) mark the left cardinal point **A** and the right cardinal point **C** on the central horizontal axis. The interior is filled with an orthogonal-and-curvilinear grid of vertical circles and parallels. This is the same plate reproduced on p. 235 (fig-p235-1).

Readable point-labels:

- A (left cardinal point, on the horizontal axis)
- C (right cardinal point, on the horizontal axis)
- D (top, just below Υ)
- B (bottom, near ♎)
- E (center; with G immediately to its left on the axis)
- F (upper left), M (upper, right of D)
- Along/near the upper axis region: Z, P, R, V, T; φ (phi) at top center; ψ (psi)
- υ (upsilon), β (beta) — on the central horizontal axis between A and G
- Right side: H (appears twice — an upper and a lower H), I (inner right)
- Left/lower interior: K, N
- Lower interior: O, X, Y; α (alpha); with additional small Greek labels (ξ , π , σ , θ , λ) scattered through the lower grid
- Right rim: column-apparatus numeral **II** (upper right); further numerals around the rim

Cap. XL — Application of the Foregoing to the Practice of Observing [DICTORVM APPLICATIO ad praxim observandi]

I have been somewhat lengthy in explaining the astrolabe, because from it nearly everything that comes up in the practice of observing — both what is to be done and what is to be guarded against — can be had and provided for. For the circle through the vertex, movable annually about E, shows each day the entire arrangement, relative to the Ecliptic, of the vertical circles along which the Sun

runs. So that this matter may be well grasped in practice, it must be worked out by means of several problems.

PROBLEMA I

To set before the eyes all the vertical circles that the Sun traverses on a given day.

Let the given day be the first of Cancer ☊. With the compass opened to K I, place one foot at γ [?], the center for that day, and with the other describe the circle through the vertex φ ω χ, which will be divided by the straight line B D into two portions, a diurnal and a nocturnal. Of these, the diurnal portion — o ω φ ψ χ ☊ — will show and mark out all the verticals that the Sun will traverse on that day, from rising all the way to setting; and they are all those enclosed within the lap of the arc o φ ψ χ ☊, and are conceived as drawn through each of its points.

[Margin: The verticals — which are the circles of each day?]

In the same way, for any other day whatever, you will bring the verticals into view, and then you will be able to state certain remarkable things.

PROBLEMA II

To exhibit, for a given day, the horizontal vertical — that is, the vertical of the Sun's rising and setting.

The vertical of the rising or setting Sun is the one upon which the rising or setting Sun sits. Fit the circle through the vertex to the given day; where it cuts the line — the horizon B D — in the morning and in the evening, there the sought verticals will pass. Thus, if the given day is the beginning of Cancer ☊, the sought verticals will be A 5 C [?] in the morning and A s C [?] in the evening, and so on.

Diagram. A second impression of the same universal-astrolabe projection plate N. 12. as on p. 233 (fig-p233-1), here printed on the Cap. XL page. The layout, grid, and lettering are identical: outer zodiacal degree-scale; cardinal points A (left) and C (right) with radiating fans; D at top under ♄, B at bottom near ♀; center E with G alongside; upper labels F, M, Z, P, R, V, T, φ, ψ; right-side H (twice) and I; interior K, N, O, X, Y and scattered small Greek point-letters; column-apparatus numeral II on the right rim. See fig-p233-1 for the label list.

PROBLEMA III

For a given day, to assign the point of true and sensible contact.

[Margin: To exhibit the point of contact.]

Let the given day be the first of Cancer ☊. Place the circle through the vertex in its position, and you will at once see which of the verticals it touches, sensibly, at the diurnal rising and setting. You will find the true point of this sensible contact in the following way: extend the compass from γ [?] so that it cuts, on both sides, the vertical that it sensibly touches; bisect the arc enclosed between the two intersections, and in that section you will have the true point of contact. Once this point is had, the senses on either side will indicate the sensible contact. But how you may demonstratively assign the vertical that truly touches the circle through the vertex, Clavius teaches in Book 2 of his *Astrolabe*, Lemma XLI.

PROBLEMA IV

To assign, for a given day, the arc of regression of the spots.

Let the given day be any whatever — the first of Cancer ☊, for example. With the circle through the vertex duly placed, find the point of true contact, ϕ and χ ; then the points of rising and setting, δ and ϵ . For the intercepted arcs ϕ – δ and χ – ϵ are the sought arcs of regression, both the morning and the evening ones.

PROBLEMA V

To assign the altitude of the Sun above the horizon for a given day and contact.

Let the given day be the first of Cancer ☊, and let the given contact be either the morning one, ϕ , or the evening one, χ . See upon which parallel they fall, and its complement will give the sought altitude of the Sun.

PROBLEMA VI

To find two altitudes of the Sun between which the physical contact falls on a given day.

Find the rational contact, and the sensible or physical contact will present itself of its own accord on both sides. The parallels of the complements, running through its extremes, will give the complements that measure the sought altitudes of the Sun.

PROBLEMA VII

To assign two altitudes of the Sun above the horizon at which, on a given day, at a time either before noon or after noon, the two angles between the vertical and the Ecliptic become equal; but the given day must be taken in the northern signs in our sphere.

[Margin: The Sun's altitudes for equal angles.]

Find the vertical that, on the given day and time, cuts the circle through the vertex twice. Then the parallels of the complements, passing through the points of the intersections, will show the complements of the solar altitudes; and when these are subtracted from 90, you will have the altitudes. By way of example:

On the first day of Cancer $\mathfrak{S}$, at a time before noon, the vertical $A \psi \omega$ cuts the circle through the vertex once at ω and again at ψ ; by these intersections the same angle $\omega A D$ is produced. Therefore the parallel passing through ω gives one altitude of the Sun, on the arc ω , of 40; its complement is the arc $A \omega$. The other altitude, ψ , of 40, is obtained from the complement $A \psi$, known through the parallel passing through ψ .

PROBLEMA VIII

To state under how great an inclination of the vertical to the Ecliptic the Sun rises or sets each day.

[Margin: The angle at rising and setting.]

The verticals that pass through the daily intersections of the horizon and of the circle through the vertex show the sought inclinations of those verticals to the Ecliptic — reckoned on the horizon $B D$, on both sides, from the Ecliptic toward E .

Book II, Chapter XL (continued)

Running header: LIBER II. Cap. XL. — folio 149.

PROBLEMA IX.

With the Sun placed on the horizon, to state the least and greatest inclination of the vertical circles to the ecliptic for the whole year.

[Margin: The greatest and least angles of the whole year at rising and setting.]

When the Sun occupies the horizon at the vernal equinox, the morning inclination is the greatest of the whole year, and the evening inclination the least. But when the Sun stands on the horizon at the autumnal equinox, the eastern inclination is the least of the whole year, and the western the greatest. The reason is that at those times the center of the circle through the zenith [circulus per verticem] lies on the horizon [in finitore] $B D$, and therefore it passes through the centers both of the vertical circles and of the circle through the zenith, and so through the common points of contact of the two — which are the most remote of

all that can be reached by the circle through the zenith. Consequently the vertical circles drawn through those points are either closest to the ecliptic or most distant from it.

PROBLEMA X.

With the Sun set at the meridian, to state when the vertical circles make the greatest, and when the least, inclinations to the ecliptic.

[Margin: The least and greatest angles at the meridian.]

When the Sun holds the first point of ♈ [Aries] at the meridian, then the meridian makes its greatest inclination to the ecliptic toward the east, A D, and its least toward the west, A B, of all the meridians of the whole year. When the same Sun stands at the beginning of ♎ [Libra], the inclination of the meridian toward the arc of the ecliptic A D is the least of the whole year, and toward A B is the greatest.

PROBLEMA XI.

To state the least and greatest meridian altitude of the Sun.

When the center of the circles through the zenith lies at K, and the Sun is at the beginning of the winter solstice, its meridian altitude becomes least, in ♐ [Capricorn], etc. When the same center is at γ [the first point of Aries], and the Sun stands at the beginning of ♋ [Cancer], the Sun's altitude becomes greatest in ♋, shown by the complement A♋ [?], etc. The remaining meridian altitudes are shown by other parallels of the complements, tangent to the circle through the zenith fitted to that day, etc.

PROBLEMA VII [?].

To state the time most opportune for observations, for the whole year, [every] month, and any day.

What I have learned through the continuous experience of so many years, this astrolabe demonstrates most beautifully to the eye, together with the circle through the zenith drawn upon it. And so let it stand:

FIRST PRONOUNCEMENT [EFFATUM primum]. The most fitting time of the whole year for observing is that in whose region the center of the circle through the zenith lies. Hence it follows that, in the half-year which unfolds from ♐ [Capricorn] to ♋ [Cancer], the spots [maculae] are more safely observed after noon than before; [Margin: The fitting time, specifically.] whereas in the other

half-year, which unfolds from the beginning of ♄ to ♅, the observation of the spots is more safely made before noon than after — because in the region of each of these times the center of the circle through the zenith lies, and so on.

SECOND PRONOUNCEMENT [EFFATUM secundum]. [Margin: General rule for the fitting time.] At whatever time the physical contact of the verticals with the circle through the zenith occurs, it is safe under it to observe the spots — and indeed safer than at other times, when that contact does not occur. The reason for the former is that when that contact occurs, the spots are not carried out of their places, and the angles which the verticals make with the ecliptic vary practically nothing even under different altitudes; hence at such a time you may work at this task without great danger of error. The reason for the latter is that any other time is subject either to regression or to progression. [Margin: The time fit for observing contacts and stations.] In regression the dangers of error arise from the regression itself, because then the paper tablet must be turned in the opposite direction; and further because the Sun is not raised so far above the horizon as to make swift ascensions, and it is perhaps subject to ellipses. But if the Sun is in progression, then various dangers of error threaten, from the Sun's excessive altitude and its nearness to the median line A E, as was said above, and so on. It is better, then, to choose such a time in which the spots make their station, or are not far from it.

Hence it follows, first, that summer time is always more opportune than winter time, because summer always has some stations, winter never any.

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It follows, secondly, that summer time — both before and after noon — is suited to observations, because in both cases a station (that is, a sensible contact of fairly great duration) is found, during which one exact observation can most conveniently be made. But at what hour, whether before or after noon of any given day, that contact occurs, can be known from the Sun's elevation, which I taught earlier how to know beforehand. And if you cannot know the hour in advance, the foreknown elevation of the Sun itself suffices, around which you should undertake the observation.

THIRD PRONOUNCEMENT [EFFATUM Tertium]. [Margin: General rule for the time of all most fit for observing.] The time most opportune of all for observing is that into whose region both the center of the circle through the zenith and the station of the spots concur together — because where the two concur, there is found not only a stable consistency of the spots, but much more a moderate

elevation of the Sun above the horizon, very suitable for observing; and every danger of precipitancy is removed far from the vicinity of the median line (which is the chief point). Hence at this time nothing more suitable for observing is found at all.

From this it follows that from the vernal equinox to the summer solstice, through the months of March, April, and May, the safest practice of observing is carried out in the afternoon hours, when the Sun runs through the stationary places of the spots — which, on whatever day and at whatever hour of elevation above the horizon it happens, can be sufficiently derived from what precedes. It follows again, by the same reasoning, that from the summer solstice to the autumnal equinox the times most opportune for observing are taken in the forenoon, because in that region the center of the circle through the zenith and the station of the spots come together in the fore-[noon]...

[fore]noon, to be well ascertained by their hours and elevations through what precedes.

FOURTH PRONOUNCEMENT [EFFATUM IV]. Observations taken outside the aforesaid stations are laborious, quite difficult, and often dangerous: if made around noon, slippery; if on the median line, mostly liable to error; if on the horizon, never good, but always faulty. The reasons for these are sufficiently clear from what precedes, and have been abundantly set out; whoever does not believe me when I assert this, let him try it, and he will learn to his own cost.

Hence it follows that in winter one must always sweat over this care more laboriously and with more difficulty than in summer, because at that time the stations of the spots are none, and the altitudes of the Sun are near the meridian [near noon], frequently falling into the middle of the ecliptic. I, however, am accustomed to obviate all these inconveniences most easily by a single turning of the paper tablet — although, so as to spare superfluous cares and occasions of error, I am accustomed to hold dear, above all the rest, the times destined for the stations of the spots. [Margin: A remedy against the dangers of error.]

And let these things indeed — concerning the plane of the ecliptic and the vertical circles, and also the parallel drawn through the zenith and projected onto it, together with their manifold use and practice — be treated for the benefit of those who are drawn to these lofty studies, being derived from practice and sure experience; many things that could be mentioned here are prudently passed over and left to the discernment of the ingenious judge. But all that has been said about the astrolabe could also be done on an ecliptic analemma, if it were

furnished with its ellipses, projected onto the plane in place of the vertical circles — as will be evident to anyone who considers it. To describe all the ellipses, however, is a very laborious matter, and quite intricate.

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Diagram. A large geometric/analemmatic construction filling the head of the page, engraved and printed over the underlying text, headed **N.13**. It shows a hemispherical figure: a semicircular arc springing from the two ends of a horizontal base-line **A...C**, with a dense network of great-circle arcs (verticals, hour-circles, and the ecliptic) crossing within it and two dashed lines descending toward the base. Readable point-letters, by position:

- **A**: left end of the horizontal base-line
- **C**: right end of the base-line
- **E**: on the base-line, near the center
- **B**: on the base-line toward the right, between the center and **C** (with **N** to its left)
- **N**: on/near the base-line, center-bottom
- **O**: lower center, below the network
- **R**: bottom right, just outside the arc
- **F**: high on the figure, left of center (near the apex)
- **M**: high on the figure, right of center
- **I**: below and left of **M**
- **X**: middle-left of the interior
- **D**: center-left of the interior
- **G**: right-center of the interior
- **H**: at the right, where an arc meets the rim
- **P**: center-right of the interior
- **S**: lower-left interior
- **Z**: upper-left, on the arc
- **Y**: left side, on the arc
- α [?] (Greek alpha): left side, below **Y**
- β [?] (Greek beta): left edge of the arc

The figure is the "fourth figure" referenced in the text below (the spherical triangles **O M P** and **A M O**). The two Greek minuscule labels (α , β) are at the resolution floor and are flagged; the Latin capitals read clearly.

XXXIII. MODUS QUINTUS.

By which the angle is found that the ecliptic makes with the vertical circles, by means of spherical triangles.

PROBLEMA V.

Although this matter can be set up so as to find the same angle through spherical triangles in many ways, here I nevertheless propose one principal one, and, among the others, an easy one. Let the fourth figure, proposed in the second method, be taken up again, and in it consider the triangle O M P, which always consists of three known sides. For the arc O M, the hour-circle arc, is the distance of the Sun from the pole of the world M; and this distance is obtained from the Sun's declination — for the arc O M is the arc of the complement of the declination when the Sun is northern, or it is composed of the declination and a quadrant when the Sun is southern. The arc O P is [the complement] of the Sun's altitude. Finally, the third arc M P is always equal to the complement of the pole's altitude. Therefore, by Problem 21, book 1 of the *Astrolabe*, Lemma 53, the angle M O P will be given, in this way.

First: let it be arranged that as the whole sine is to the sine of the arc O M, so the sine of the other arc O P is to a Fourth [quantity]. Secondly: let it be arranged that as the Fourth is to the [whole]...

whole sine, so the difference between the sine of the arc M P and the versed sine of the arc by which the two arcs M O and O P differ from each other is to another Fourth, which will always be the versed sine of the angle M O P. And from that Fourth, once found, it will always be established whether the sought angle is greater than a right angle or not, according as the versed sine is greater or less than the whole sine. When it is less — and consequently the sought angle is acute — then the Fourth number found, subtracted from the whole sine, always leaves the sine of the complement of the sought angle; but when it is greater, then, the whole sine being subtracted, there is left the sine of that arc which, together with a quadrant, makes the arc of the sought angle.

Next, in the triangle A M O, the angle M A O is always right, and all three sides are known. For the arc A M, [reckoned] to the point ♄ [Capricorn], is composed of a quadrant and the maximum declination; the arc O M likewise, from a quadrant and the declination of the Sun, which is at O — unless perhaps the place of the Sun is northern and the point A is assigned to Cancer, for then each arc, A M and O M, is the complement of the maximum declination and of the place of the Sun.

But the arc A O is the arc of the ecliptic between the place of the Sun and the point ♑ [Capricorn]...

Running header: ROSAE VRSINAE.

or ♋ [Cancer] — which, however, is not necessary for the calculation, since the two prior arcs suffice, so that from them, by the first Problem of book 1 of the *Astrolabe*, Lemma 53, the angle M O A may be elicited. For as the whole sine is to the sine of the side M A, which is opposite the sought angle, so the secant of the complement of the base M O, which is opposite the right angle, is to the sine of M O A — which is acute when the side M A is less than a quadrant, obtuse when it is greater.

Finally, from the angles M O P (which the vertical P O makes with the hour-circle M O) and likewise M O A (which the hour-circle M O makes with the ecliptic O A), found by the stated method, the angle of the inclination of the vertical O P to the ecliptic A B C is drawn out by adding or subtracting. In the present example they are added, and from the addition the angle P O A comes out greater than a quadrant; therefore for the angle of inclination its complement to a semicircle — that is, to 180 degrees — is taken. But when P is more western than the arc M O, namely toward F, then the angle M O P, subtracted from M O A, would leave the sought angle. Nor is it necessary to run through all the cases one by one, especially if one of the preceding instruments is at hand, in which the construction of these angles appears more plainly.

In their absence it would sometimes be necessary also to find the angles O M P and O M A — of which the former is the difference of the right ascensions of the point A and the point O, and the latter is the angle of the Sun's distance from the meridian, which can be had from the Sun's known altitude, or also from the known hour itself. Indeed, when the angle O M P is had, from it can also be had the right ascension of the point N, which culminates [mediates the heaven], and consequently the arc O N, and further the arc N M — which either will be the arc of the complement of the declination, or will be composed of the declination of the point N and a quadrant. And because the arc M P is also known, therefore the arc P N too [is known], and consequently, from the three arcs O P, O N, N P, the angle of inclination N O P could be had otherwise; but the operation is much more prolix.

From these things, then, it is clear that, in order to have the angle P O N, which the vertical P O makes with the ecliptic, one must first inquire the angle P O M, which the same vertical O P makes with the running hour-circle M O; then the

angle M O A, which the running hour-circle M O makes with the ecliptic O A, at the point O. These two, then, being had, the whole [angle] P O A is had, whatever...

it finally is, and thereby, in turn, the [angle] P O N following from it, whether acute or obtuse, etc.

In this manner of calculating, a table of the Sun's declinations is supposed, such as is found everywhere in Clavius and other authors. I said at the outset that there are many other ways of computing this angle; for I myself used some at Ingolstadt [Ingolstadij] and others at Freiburg [Friburgij], and in fact my pupils have used, and still use, others besides — which I now forbear to review. There will perhaps be, when a fitting occasion arises, a fuller place for writing about them; for now, hastening to other matters, I do not think I should dwell on these longer than needful. All these methods of establishing the angle of the ecliptic with the vertical at a given time, or [at a given] altitude of the Sun, are excellent and safe; yet in practice one is more expeditious than another and less liable to the danger of error. I have mostly investigated the angles by the astrolabe of Gemma Frisius [Gemmae Frysij], explained in his Problem 4; although the third method, explained on the elliptic analemma, seems equally safe and easy in practice, and finds the angle geometrically only, without numbers — whereas the other [finds it] by numbers only, etc. But the fourth, on account of its more copious use, has always pleased me more.

How to apply the angle, found by the stated methods, to the observing circle. CHAPTER XLI.

All the spots observed through the telescope [Telioscopium] are projected onto the paper in an inverted position [situ everso]; whence the angle can be applied in observation in two ways — in the inverted or in the reversed [everso vel converso] position. [Margin: Inverted and reversed position.] If the spots retain the inverted position, the angle and the ecliptic will also retain it — about which, however, the reader must be advised. If [they retain] the reversed position, these too will take on the erect [right] position.

You have an example of each position in the adjoined figure, in which, for the 7th day of July, at the seventh morning hour plus $\frac{3}{8}$ of one hour, you have the spots and faculae observed — a, b, c, etc. — in the inverted position, at the perpendicular C E, whose angle with the ecliptic, in the inverted position, is C A F; the same spots, faculae, and ecliptic are, in the erect position, a, b, c, etc., and face toward the line H I, [taken] for the ecliptic. Here you see the highest interchanged

with the lowest, and the lowest with the highest. This happens because of the natural decussation [crossing] of the rays and of the solar species [images]. And in this way, [reduced] to the erect position, I have arranged all the images of my observations, which are to be produced in the following book.

Book II, Chapter XXXXI (continued)

Diagram. A full-page circular projection of the observing circle (the *circulus observatorius* projected as a large circle inscribed within a rotated square/diamond frame), heading N. **14.** A plummet symbol (the small looped cord) hangs from the top vertex **K** and again from the bottom vertex, where a drawn plumb-bob **E** is shown suspended, marking the vertical/perpendicular line KL. The circle carries the labelled endpoints of two diameters and their bisectors, and the sunspot cluster is drawn twice — once in an "inverted" arrangement in the upper half and once in an "erect" arrangement in the lower half.

Readable point-letters on the circle and its axes:

- K (top, outside the circle — a spot marked by the wavy outline)
- C (top, on the circle)
- F (upper left, on the circle)
- I (upper right, on the circle)
- D (left, on the circle)
- B (right, on the circle)
- A (center of the circle)
- H (lower left, on the circle)
- G (lower right, on the circle)
- E (bottom vertex of the diamond frame; the drawn plumb-bob)

Readable sunspot/facula letters (lower-case), each set drawn twice:

- Upper ("inverted") arrangement: a, b, c, d, and toward the upper right a cluster labelled g and h
- Lower ("erect") arrangement: a, b, c, d, e, f (drawn as a doubled pair — two nearly identical spot-rows both labelled e...f), g, h

Inscribed legends (letterpress set into the plate):

- Top center: "**Modus observandi Maculas et Faculas ☉**" — "The method of observing the Spots and Faculae of the Sun."

- Upper left: **"ABCDE circulus ☉; Maculae et Faculae in eodem situ everso, a. b. c. d. e. f. g. h. FG, Ecliptica situ everso."** — "ABCDE, the circle of the Sun; the Spots and Faculae in the same, inverted position, a. b. c. d. e. f. g. h.; FG, the Ecliptic in inverted position."
- Right center: **"Eaedem Maculae et Faculae in situ converso sive erecto, a. b. c. d. e. f. g. h. ad Eclipticam, HI."** — "The same Spots and Faculae in the reversed, that is, upright position, a. b. c. d. e. f. g. h.; to the Ecliptic, HI."
- Bottom center: **"Romae in domo Professa Soc.[ietat]is Iesu, 1625, die 7. Iulij, H. 7¼[?], sub ☉ Elevatione, G. 26. M. 36[?], ad perpendiculum, KL."** — "At Rome, in the Professed House of the Society of Jesus, in 1625, on the 7th day of July, at hour 7¼[?], under a solar elevation of 26° 36'[?], reckoned to the plumb-line KL."

[The faint ornate foliate cross visible within the lower half of the circle is offset / show-through from the printer's ornament on the facing letterpress page, not part of the figure.]

Second Example of the Ecliptic introduced, in two observations of a single day

[*Exemplum Secundum inductae Eclipticae, in observationes duas diei unius.*]

[Reference numeral XXXVII]

In the appended second diagram, two observations are presented for the 4th of August, in reversed position — one before noon, the other after noon. Both share the same vertical AB, and the forenoon Ecliptic is CD, which forms with the vertical line, at N — the center of the observing circle — the angle CNA. The forenoon Spots are A, B, C, and so on, up to the Facula M, which rests upon the western horizon. The afternoon Ecliptic, by contrast, is

[Reference numeral XXXVIII]

EF, and the Spots are the same as those before the midday meal, namely a, b, c, and the rest, but now under different letters and in a different position of the observing circle. This happens because of the Sun's daily rotation and the consequent variation of its position and aspect toward us, which that same rotation produces. Here you see all the Spots: while by their own proper motion they advance along the Ecliptic from east to west, they are at the same time carried round the center N by that apparent daily motion, as if in proportion to it — from A, through C and E, toward B, and from B, through D and F, back toward

A. This appearance, together with the Spots' station and retrogradation, I have discussed at length earlier. Let us now proceed to other matters.

Diagram. A full-page rectangular engraved plate (rounded corners) containing the observing circle for the two observations of 4 August 1625, heading **N. 15**. Radial lines cross the interior through the center. Four emblematic roundels occupy the plate corners: a rayed **IHS** Jesuit monogram (upper left), a rayed Marian monogram reading **MRA** with a small emblem above it (upper right), and a heraldic Tudor-style rose — the Orsine rose — in each of the two lower corners. Morning spots are lettered with capitals, the afternoon spots with lower-case letters.

Readable point-letters on the circle and axes:

- A (top of the circle)
- C (top center, on a radius)
- F (left, on the circle)
- E (lower right, on the circle)
- D (lower left, on the circle)
- B (bottom, on the circle)

Readable morning sunspot/facula letters (capitals): F, G, H, I, K, L, M (M drawn at upper right, near the horizon), and A, B, C, D, E on and near the lower-left arc.

Readable afternoon sunspot letters (lower-case): a, b, c, d, e (upper-left group), f, g (near center), h, i, k (center to lower-center), l (bottom).

Inscribed legends:

- Top center: "**1625. die 4. Augusti. Romae in domo Professa Societ.[at]is Iesu.**" — "1625, on the 4th day of August. At Rome, in the Professed House of the Society of Jesus."
- Upper left block: "**Ante Meridie, hora 7¼, sub altitudine ☉ Gr. 30. Mm. 30. Maculae, A. B. C. D. E. F. G. H. I. K. L. Facula cum umbra, M, in Horizonte. CD Ecliptica.**" — "Before noon, at hour 7¼, under a solar altitude of 30° 30'. Spots: A, B, C, D, E, F, G, H, I, K, L. Facula with its shadow, M, on the horizon. CD, the Ecliptic."
- Right center: "**AB Verticalis Linea.**" — "AB, the vertical line."
- Lower left block: "**Post Meridiem, h. 3¼, sub elevatione ☉, Gr. 30. 20. Min. Maculae eadem ulterius progressae, sub litteris, a. b. c. d. e. f. g. h. i. k. l. EF, Ecliptica.**" — "After noon, at hour 3¼, under a solar elevation

of 30° 20'. The same Spots, advanced further, under the letters a, b, c, d, e, f, g, h, i, k, l. EF, the Ecliptic."

[The faint ornate foliate cross and the mirror-reversed text visible within the circle are offset / show-through from the facing letterpress page, not part of the figure.]

Third Example of the Ecliptic to be introduced

[*Inducendae Eclipticae Exemplum Tertium.*]

[Reference numeral XXXIX]

This example contains three observations, made on the 2nd, 15th, and 29th of June in the year 1625. The observation of the second day fell at hour 6 $\frac{2}{3}$ [?] in the morning; that of the fifteenth day at hour 7 $\frac{3}{7}$ in the morning; that of the twenty-ninth day at hour 7 $\frac{2}{5}$ in the morning. The hours, then, were nearly the same — but not so the Sun's altitudes, nor were the angles contained between the Ecliptic and the vertical line equal. Rather, the Ecliptic CD, on the second day, stood farthest of all from the perpendicular AB, and the angle CIB (or AID) proved the greatest; on the 29th day, the Ecliptic GH

[Reference numeral XL]

stood least of all from AB, and the angle AIH (or GIB) was the smallest of all; while on the 15th day the Ecliptic EF, and the angle EIB (or AIF), held a middle course. Once the angles have been assigned in this way to the individual observations, it is easy to trace out the courses and paths of the Spots, their figures, and their relations to the Ecliptic. For all the observations are reduced to a single Ecliptic and to a single circle, and thus the day-by-day progress of the Spots becomes apparent, along with their approach to, or recession from, the Ecliptic. In practice, moreover, you will use this method — and by it the safest of shortcuts.

Rosa Ursina — Book II, Cap. XLI–XLII

Diagram. A large full-page circular projection (labeled **N. 16.**) representing the Sun's disk, used to reduce the June 1625 observations of a single spot-group to one circle. The circle is enclosed in a ruled rectangular border. Decorative emblems occupy the corners and the upper margin: an **IHS** radiant-sun emblem (Jesuit monogram) at the upper left, an **MRA** radiant-sun monogram at the upper right, and a stylized heraldic rose (the Orsini rose device) in each of the four corners. Within the disk, an inscription reads:

Romæ in domo Professæ Societatis Iesu, 1625, ad diem 2, 15, et 29, Iunij.
[At Rome, in the Professed House of the Society of Jesus, 1625, on the 2nd, 15th, and 29th of June.]

Construction points on the circumference (all legible): **A** at the top and **B** at the bottom mark the ends of the vertical diameter; on the upper right lie **H**, **F**, **D** (in that order downward), and on the lower left lie **C**, **E**, **G**. Straight lines (the three daily ecliptics) run across the disk joining these points — CD, EF, GH — converging near a point on the right-hand side. Numerous small sunspot symbols are scattered across the disk, each tagged with a spot-letter and its day-number: legible tags include **b·2**, **a·2**, **c·2**, **d·2**, **e·2** (day 2); **f·15**, **g·15**, **h·15** (day 15); **k·29**, **m·29** (with **n** adjacent), **o·29** (day 29). The two remaining spots named in the legend — **i** (day 15) and **l** (day 29) — could not be resolved among the micro-labels [?]. The engraved legend printed at the right of the disk reads:

- AB, Verticalis Plani cum ☉ sectio — *AB, the section of the vertical plane with the Sun.*
- Ecliptica die: 2 — CD; 15 — EF; 29 — GH — *The ecliptic on day 2 = CD; on day 15 = EF; on day 29 = GH.*
- Maculæ: a. b. c. d. e.; f. g. h. i.; k. l. m. n. o. — *The spots: a b c d e (day 2); f g h i (day 15); k l m n o (day 29).*
- Observatæ tempore antemeridiano, ut sequitur. — *Observed in the forenoon, as follows.*
- ☉ Elevatio. Die: 2 — 21 gr. 15; 15 — 28 gr. 35; 29 — 31 g. 10. — *The Sun's elevation: on day 2, 21° 15'; on day 15, 28° 35'; on day 29, 31° 10'.*
- C, E, G, plaga Orientalis Macularu[m]; D, F, H, Occidentalis. — *C, E, G are the eastern edge of the spots; D, F, H the western.*

[Argument (Summarium):] *The practice of reducing into a single circle the many observations of one spot, marked out by the ecliptic.*

[The page-top cross-reference band carries the numerals "XLI." over the left column and "XLII." over the right column; see QA note.]

CAP. XLII.

I take it that the circles of all the given observations are exactly equal to one another. If they are not, they must be brought to equality by enlarging or reducing them proportionally, as need requires. Next, on a clean sheet draw a circle equal to all the observation-circles that are to be gathered onto it; draw its diameter, which is to serve as the ecliptic; and fix into the board underneath an

upright pin that passes through the center of the circle. Once that is done, hold the sheet fast by spreading wax beneath it. Then lay the individual observations over it one by one, keeping the order of their times, so that the ecliptic of each observation coincides precisely with the ecliptic of the sheet beneath, and center answers to center and circumference to circumference. When this is done, prick through from the observations whatever you please; then trace the pricked marks with a pen, following the exemplar. In this way you will obtain the courses of the spots without error, with little effort and in a short time — a thing that, without this device, is all but impossible to carry out. Had I not used it, I would beyond any doubt have worn myself out long ago over such labor with the compass alone. This method, then, by which I have been so greatly helped over so long a time, I share with you gladly and without grudging, kind reader. Farewell, and enjoy it.

[p. 247: blank leaf. No letterpress or engraving on this side; the only marks are the faint show-through of the following recto — the display-title of Book III ("ROSAE VRSINAE SIVE SOL ... LIBER TERTIVS," with a decorative headpiece and an ornamented initial) — ghosting through the paper. Nothing on this side is transcribable; the Book III title itself falls beyond this range.]

[p. 248: a second, identical impression of folio 149 verso. This is a duplicate scan of p. 246 and is not re-translated; see QA note.]

This leaf is essentially blank. It carries only a faint offset/bleed-through impression of the Book III display-title from the facing/adjacent title leaf — the washed-out ghost letters "RO[?]A / VRSI[?]E / SIVE SOLIS / LIBER TE[?]" and a faint decorative initial block are visible but belong to another side of the leaf. No original ink of its own is present on this page. [The legible printing of this title is on p. 251.]

Likewise essentially blank. Only a faint, partly mirror-reversed show-through of the Book III title and opening summarium (from the adjacent title leaf) ghosts through the paper, together with a faint impression of the historiated initial. No original recto/verso ink of its own. Not transcribed.

Book III display-title and Summary

ROSAE VRSINAE SIVE SOLIS LIBER TERTIVS.

[ROSAE URSINAE, OR OF THE SUN: BOOK THREE.]

Summa Libri.

[Summary of the Book.]

Here the very Phenomenon of the Sun is presented. First it is demonstrated from the various modes of observing it; then observations of many years — both my own and others', both Roman and German — are set before the reader's eyes. From these the various circuits of the *Solar Faculae, of the Spots, and of the Penumbrae* [*Facularum Solarium, Macularum & Vmbrarum*] will become known, along with their remarkable varieties, their perpetual changes, and their utter instability — and yet, together with all of these, the supreme constancy of their motion and order will be discerned.

So that all this can be adequately grasped by any reader who is not wholly unlettered, I set out at the beginning certain General Notes [*Notas Generales*], by which I lead by the hand, as it were, anyone eager for these matters into a knowledge of the Phenomenon. Then, to the individual engraved figures [*iconismis*] of the observations, arranged in order, I add special Notes [*Notas speciales*], so that nothing pertaining to the full explanation of the Phenomenon — most diligently observed and most faithfully arranged — may seem either to have been omitted by me or to be wanting to anyone. This is the Epitome of the Book. The individual matters are found more fully in their own places. At the end, finally, I close the book with a new and very easy Machine for observing the Solar Phenomenon; and so the book will have an ending not at all unlike its beginning.

This is a mirror-reversed impression of the Book III title page (p. 251) — the title and the opening lines of the *Summa Libri* read backwards ("HASOR / EANISRV / SILOS EVIS / ..."), i.e. the show-through / offset of p. 251 seen from its verso. No independent original content. Not transcribed.

LIBER III (Book III) — continued

AD LECTOREM (To the Reader)

When an astronomer treats of phenomena, he proves them from what has been observed. In demonstrating phenomena, observations serve the office of first principles. For if that saying of Aristotle holds true anywhere, it is here — namely, that all knowledge arises from certain things laid down and known in advance. Since phenomena are for the most part slippery and of doubtful reliability, they demand above all to be established not by arbitrary assumed

fictions and cleverly contrived dreams, but by carefully investigated observations and experiments known beforehand — especially when they appear remote, new, or paradoxical.

Our Ursine Rose, then — since it is brought forth not from the New World but from the heavens themselves, since it contains much that is obscure and much that runs counter to the opinion of many, and since it breathes a wholly celestial fragrance unfamiliar to the earth — it might perhaps happen that its very excellence would stun a weak or unrefined little mind, and, through that mind's own infirmity of judgment, would give some offense within the sincere and steadfast heart of the Reader: either at my good faith in affirming these things, or at his own credulity in assenting to them. To keep this from happening — and to prevent anyone from casting darkness or deceptions over this heavenly Rose — so that this phenomenon may be known without any suspicion of error and brought to the perfect knowledge of the whole world, I offer two most solid foundations: the first, the Modes of Observing (treated at length and variously in the previous book, now briefly gone over again); the second, the observations themselves. From the first we shall have that the phenomenon exists; from the latter we shall learn what it is. Read and enjoy.

[Margin: Phenomena correctly observed and set in order function as principles.]

[Plate — folio 150]

Diagram. A full-page engraved allegorical plate (folio 150) in two registers within an oval frame, the four corners of the frame filled with heraldic Orsini roses.

Above the frame, in letterpress, runs a citation and a motto adapted from Pliny:

- Top citation: "**C. Plinius, Sec: Lib. 2. c.108.**" [Pliny the Elder (Gaius Plinius Secundus), *Natural History* II.108]
- Large heading: "**IMPROBVM AVSVM**" ("A bold undertaking")

Around the upper arc of the oval a banderole reads "**VERVM ITA SVBTILI ARGVMENTATIONE COMPREHENSVM**" ("yet grasped by argument so subtle"); a winged putto at top center holds a scroll inscribed "**VT PVDEAT NON CREDERE**" ("that one would be ashamed not to believe it"). The whole inscription is thus: *A bold undertaking, yet grasped by such subtle reasoning that one would be ashamed not to believe it.*

Upper register — an open balustraded terrace by the sea, with ships, an obelisk at center and a second obelisk/pedestal, and several figures each demonstrating one mode of solar observation. Dotted sight-lines run from the Sun (rising at right within a rayed roundel) to the instruments. Readable method-labels and point-letters:

- **C** — "Telioscopio" (by the telescope): a figure at left sighting a long telescope.
- "Immissione naturali." (by natural admission): the pinhole method, the ray passing the apex **G** of the central obelisk.
- **R** — "Transmissione Refractoria simplici" (by simple refractive transmission): at the second obelisk/pedestal.
- **D ... I** — "Helioscopio" (by the helioscope): a figure at right sighting a telescope toward the rising Sun.
- **K** — "Reflexione." (by reflection): a seated figure at lower center holding a triangular board/mirror.
- **M** — a seated figure at left with a globe/instrument.
- **H** over **S** — a divided disk on a tablet held by a stooping figure at center (the pinhole projection, tablet H).
- Small circled letters **B**, **E**, and **F** set along the banderole/arc [faint].

Lower register — an interior study. A ray labelled **V** enters at the left through a shuttered window; a long telescope tube labelled **X** rests on a stand, projecting the Sun's image onto a screen where the letters **Y**, **e**, **f** are visible (the projected solar disk). A scholar in a peaked cap sits at a writing table at right, drawing; astronomical instruments (armillary sphere, quadrant, globes, dividers) fill the room.

- Label at the projection apparatus: "Immissione Refractoria composita." (by composite refractive admission).
- Engraver's signature on the stand: "**Daniel Widman Sculp.**" [Daniel Widman engraved this].
- Bottom letterpress caption (below the frame): "**Maculae et Faculae ex uariis obseruandj modis, stabiliuntur.**" ("The spots and faculae are established from various modes of observing.")

LIBER III (Book III)

PHOENOMENON: That the Phenomenon Is Solar Is Evidently Established, Chiefly from the Very Modes of Observing

(PHOENOMENON Solare esse, ex ipsis potissimum obseruandi modis, euidenter asseritur.)

DEMONSTRATIO PRIMA — First Demonstration, from the various modes of observing

The **first** mode of observing — and indeed the simplest and most natural — is this: a ray of the Sun, admitted through a tiny round aperture into a dark place, is caught at a fairly great distance (say 15 or 20 feet, or more) on a clean sheet held perpendicular. For then the figure of the Sun, together with its spots, is seen there. This mode contends against those who would ascribe the matter to the eye or to the imagination: for does the imagination or the eye project those spots onto the paper? And so on. In the accompanying diagram you have a sketch of this — the Sun **F**, [passing] through the perforated globe **G**, falling onto the tablet and figure **H**. But note in passing that in practice the place ought to be darkened on every side, with as much other light shut out as possible.

[Margin: Natural admission of the Sun through a bare aperture.]

The **second** mode of observing is likewise very simple: namely, when the Sun, admitted through a single convex glass into a dark place, is caught at a proportionate distance, as before. For whatever lies hidden in it comes into view most cleanly. You have a representation of this in the Sun **Q**, [passing] through the glass **R**, onto the paper **S**. This mode, like the previous one, removes the matter from the eye and from the imagination. That the effect is not due to a flaw in the glass, the first mode proves; yet this mode too reveals the glass itself. For whatever comes from the glass turns on the paper when the glass is turned; but the solar spots and faculae never turn — therefore they are not from the glass. Likewise, no glass of any tube reproduces the blemishes of another glass set in a different tube, and so on; yet all telescope-glasses present the spots and faculae in the same manner and place. Therefore the spots are not blemishes or flaws of the glasses.

[Margin: Artificial admission of the Sun through a convex glass.]

The **third** mode of observing is likewise very simple and natural: namely, at sunrise or sunset, or even through daytime haze, a good eye — which I, together with others, have done not rarely — freely contemplates at least the larger spots, as you see rendered at the letter **P** onto the Sun **I**. And this method proves that the effect is not due to any deception of the glass, just as, in turn, the glass is shown not to be due to any illusion of the eye.

[Margin: The natural view of the solar spots with the unaided eye.]

The **fourth** mode of observing is by means of the Helioscope — a tube expressly designed for this purpose — through colored glasses, namely a concave and a convex one (or a single one of these, or another plane glass inserted between them on both faces), provided the thickness of any of them suffices to dull the Sun's brilliance, all enclosed in the tube, as marked at the letters **D** and **E**. This mode is the most excellent, and much employed by me and my pupils; for the solar spots and faculae are seen far better than [they are] on paper by natural admission, or by reflection, or by casting the telescope's [image] through a small observing circle. (For if a large [image] be taken from the telescope, its transmission ordinarily exceeds this emission.) And all this without any harm to the sight, provided the tube is exact.

[Margin: The artificial view of the solar spots through the helioscope.]

The **fifth** mode of observing is had with the telescope, or any ordinary tube, yet in such a way that between it and the Sun there intervenes a moderate cloud [haze] which keeps the sight of the Sun harmless. When this is in place (as frequently happens), you will see on the Sun, through the telescope, whatever spots and faculae cling to it. And the better and more powerful the tube, the more accurately you will observe the whole. You have an example in **A C B**.

[Margin: The view of the Sun through a tube and haze.]

The **sixth** mode of observing comes about by the reflection of the Sun's ray from a plane mirror. For if you set an exact plane mirror, enclosed in a small circle, opposite the Sun, so that the reflected ray falls upon a clean sheet at a sufficiently large distance (20 feet or more), you will be shown quite beautifully the Sun's spots and faculae, as you have delineated in the diagram **I K L N**. And I myself used this mode of observing quite frequently and successfully at Ingolstadt in the beginning.

[Margin: The presentation of the solar spots by reflection from a plane mirror.]

The **seventh** mode of observing is carried out by conducting the Sun through a tube onto paper — of all [modes] the most excellent, safest, and easiest. I have used it at Ingolstadt almost continuously from the year 1612 to the present, and here at Rome especially in this present time. It fixes the Sun, together with its spots and faculae, for me to view on paper no differently than if I were gazing at them directly in the [Sun] itself. You have the idea of how to carry out this practice in the lowest quadrangle of this diagram, under the letters **V X Y Z**, where you see, through the tube **X**, the Sun's ray **V** projected onto the paper set opposite, enclosed under the circle **Y** within the perimeter **c f d g**, and so on. As for the rest, the hollow prism [box], composed of four little columns with cross-beams laid over them, serves only this: that the whole instrument may be darkened within, by placing around it sheets, or cloths, or little boards fixed to the sides of the prism, and so on. There are also other modes of observing, of which perhaps [I shall treat] in their proper place. For now, from these I draw the following argument.

[Margin: The transmission of the solar faculae and spots through the telescope onto paper.]

If the solar phenomenon did not exist on the side of the thing [that is, in reality], it would be impossible for it to be perceived by so many different modes of observing at once, at the same time and place. But it is so perceived. Therefore it exists on the side of the thing [in reality]. The consequence of the major premise is clear, because what does not exist cannot be falsely displayed by so many different instruments and modes, and so on. For if the eye sees something falsely, will that same thing also be fictitiously admitted through a bare aperture? Be displayed from a convex glass? Be formed by the reflection of a mirror? Be seen through a helioscope? Be depicted on paper by a telescope? And indeed in the same manner, figure, magnitude, position, and proportionality? On what grounds, then, can what does not exist be perceived in this way? Without a visible species nothing is seen, and so on. Therefore neither mind, nor reason, nor sense, nor imagination, nor nature admits such a fiction. The consequence of the major premise stands most firm; and the minor premise whoever denies it will himself prove. For if, having made a practical trial, he should perceive that even a single one of these modes goes astray and fails to agree exactly with all and each [of the rest], let me lose my case, let me forfeit everything. But the truth is stronger than all. I assume, moreover, that at the time when someone makes these trials, the Sun does not lack spots (which sometimes happens), but is affected with them; for if there are no spots, they certainly cannot be seen on the Sun.

[Margin: For the truth of the solar phenomenon. A demonstrative argument drawn from the various modes of observing.]

DEMONSTRATIO SECVNDA — Second Demonstration, from the diversity of places

If this phenomenon were a fiction, it would not be observed at the same time in places separated by nearly a whole hemisphere. But it is so observed — and indeed in the same manner, magnitude, figure, position, proportionality, and so on. Therefore it is not a fiction. The consequence of the major premise is clear, because the imagination, or a fallacy of the eye or of sight, or a deception of the air, or a defect of a mirror or glass, has no dealing or connection with the things that are in Asia, Africa, or the New World, and so on. Therefore, if my sight were deceived here, it would not on that account follow that theirs [is deceived] too, concerning the same thing and in the same manner, and so on. The minor premise is manifest from daily experience, as is evident from the observations of the most diverse provinces compared with one another, which all correspond exactly. Therefore the conclusion stands.

[Margin: For the truth of the solar phenomenon. An argument drawn from the diversity of places.]

DEMONSTRATIO TERTIA — Third Demonstration, from time

Fallacies of sight are not long-lasting, and so on. But this phenomenon has been observed only since the eleventh year [of the century, 1611], in which I first detected it; and it could have been observed since the founding of the world, and will be seen right to the end of the age. Therefore this phenomenon is not a fallacy of sight. For if those things that happen always, or usually, or often — and in a similar and regular manner — are, according to the Philosopher [Aristotle], not fortuitous or accidental, then much less are they false or deceptive. But this phenomenon is eternal and ever like itself.

[Margin: For the truth of the solar phenomenon. An argument drawn from the long duration of time.]

DEMONSTRATIO QVARTA — Fourth Demonstration, from order and regularity

This phenomenon keeps its own fixed periods in its motion, ordered and set...

Rosa Ursina — Liber III

Demonstratio Quarta (conclusion) ...the [regulari]ty [?] of the apparent motions; the zones and the bends, the increases and the decreases, all most regular; the alternations of the phases succeeding one another always with the same tenor; in sum, the highest order and proportion even amid this very instability. Therefore it is not a deception of sight.

[Margin: For the truth of the solar phenomenon. The argument drawn from the regularity of the appearances.]

DEMONSTRATIO QUINTA.

Every deception of sight presupposes some true and real object of its own. Hence, even if it were granted that some element of fallacy did enter into this phenomenon, still these [fallacies] could not come about without some prior thing — and that a true appearance. But no other such thing can be assigned in this phenomenon except the phenomenon itself. Therefore the phenomenon itself is true.

[Margin: For the truth of the solar phenomenon, the very nature of optical fallacy fights on its side.]

DEMONSTRATIO SEXTA.

Finally, the very ordering [of the appearances], the arranging of the observations, and the annual revolution of these same motions make the irrefutable truth of this phenomenon clearer than the Sun. Therefore, so as not to dwell any longer on proving it in broad daylight, I now proceed to the General Notes on the Observations themselves.

[Margin: For the truth of the solar phenomenon. The argument taken from the very observations once they have been arranged.]

GENERAL NOTES, very well suited for correctly understanding the Images of the Observations

[NOTAE GENERALES ad Observationum Imagines rectè intelligendas peropportunaes.]

Since it would have been an intolerable labor and expense to present each observation separately engraved on its own plate — and since that course would have brought the reader tedium and obscurity rather than instruction or any genuine intellectual pleasure — I have, with almost incredible effort, reduced them to an order that both gives pleasure to the eye and offers instruction to an honest mind. For when I had completed more than two thousand observations here at Rome, and had gathered into each circle now 6, now 10, frequently 20, 30, or more, to engrave the disordered original drawings [autographa] separately on copper would have been to bring a chaos of obscurities into the open. Indeed, apart from the drawn-in plumb-lines [perpendiculara] and the labelings of the individual spots, faculae, and umbrae — set out on the drawings by alphabetical and numerical characters — there is nothing to be found on them. On them there is no marking of the ecliptic, no orderly day-by-day progression of the spots; and the often-repeated observation of the same spot, together with the frequent turning-over of the sheet and the shifting of its orientation, would confuse any reader rather than instruct him. It was therefore worthwhile, for the sake of truth and of the studious reader, to swallow these troubles, and out of the two thousand and more observations carried out here at Rome to work up these Tables, or Images. For understanding them, and for their fruitful use, take note of the following explanations.

[Margin: How necessary it was to arrange the observations into an orderly sequence.]

[Margin: The bare observations of the spots would be stripped of all appeal.]

[Margin: For the reader's benefit the observations have been arranged in order. These Tables have been drawn from some thousands of observations.]

First. Each Image is compounded from several observations, made according to the series of times and the succession of days.

Second. Each Image is enclosed within a single circle, which is called the Observatory circle [circulus observatorius], and it represents the apparent hemisphere of the Sun in the form of a circle — for that year, month, day, hour,

and so forth, to which the recorded observation corresponds. Hence, since several distinct observations are comprised within each circle, it follows that that one circle is equivalent to as many different aspects of the solar hemisphere as [the spots that] shone forth in the observations made from that same [circle].

[Margin: A single Observatory circle corresponds to many aspects of the Sun, and comprehends many observations.]

Third. This circle is regularly divided by four points — A, Z, B, and N — through the lines A B and Z N (of which I have not drawn the latter, since it is easily conceived in the mind), into four equal parts. Of these, two are bounded by the line A B, which is and is called the Ecliptic; and the part A Z B is called the upper and Boreal part, or Arctic; the other, A N B, the lower or Austral. The two remaining parts, which the line Z N determines, are Z A N, the eastern region, and Z B N, the western.

[Margin: The fourfold division of the Observatory circle — into the Boreal, Austral, Eastern, and Western region — by the ecliptic line and its axis.]

Fourth. The line Z N is the fixed and stable axis of the Ecliptic and of the annual motion of the spots, and it is bounded by its own poles, of which Z is called Boreal, N Austral. In another respect it also denotes Z as the Zenith and N as the Nadir, since the vertex or top of the plumb-line always falls toward the part or arc Z, and its base or lowest point always toward the arc N. The line N Z also, more or less, determines the mid-course of the spots.

[Margin: The axis of the Ecliptic, and its function.]

Fifth. Therefore, when in the Images of the observations some spot, or facula, or umbra is named from a certain region, you should take it as established that it exists there, as in a place actually seen; and that, when it is situated in some region, it can be — and customarily is — named from that region.

Sixth. Let the perimeter of the observatory circle A Z B N be, and be called, the Horizon, because it itself bounds the sight, so that beyond it and short of it — on the Sun or near it — nothing at all is seen; and let the spots or faculae situated in its eastern region be said to rise, and [in the] western [region]...

[Margin: The horizon of the Sun, or the solar horizon — what is it? The rising and setting of the spots — where?]

western [region, to] set.

Seventh. When you see the spots moving between A — that is, the rising point — and the axis Z N, then [know] that they are ascending; when you observe them at the middle of their course, that is at the line N Z, or near it, [know] that they are at mid-passage, culminating, or attaining their summit, peak, and greatest altitude on the Sun; and finally, when you notice them placed between Z N and B — that is, at the setting point — then at last know that they are descending, with respect to their own course, taken broadly and not strictly. For the true culmination of the spots is determined by the spots' own axis, which is as it were monthly, not the annual axis, or that of the Ecliptic — as [I shall show] in its proper place. Here, however, we still proceed with a rougher wit [rudiori Minerva], opening the way to more abstruse matters little by little.

[Margin: The rising and setting of the spots and faculae — in the physical sense.]

Eighth. When you see spots or faculae that have come into being in the middle of the Sun, or that are not carried through to the end [of the disk], I would have you know — unless I expressly note otherwise in the special notes — that they did not arrive there by any local motion, nor departed from there, but rather began, and ceased, to be; and accordingly let such [spots] be said to have arisen and set in the physical sense.

Ninth. In all the Images I assign to each more notable spot, and so forth, its own fixed and constant letter from the alphabet, and likewise the number of the day on which it was observed.

[Margin: What does the letter u signify at the spots? And what does m?]

Now, if you wish to know the time and hour of the day: if it was in the evening, you will find this marked at the spot by the letter u [for *vespertinum*]; if it was in the morning, you will either find nothing, or sometimes m [for *matutinum*]. The hour and the elevation of the Sun you will learn from the Table attached to each Image.

Tenth. You should know, moreover, that the angle of the Ecliptic to the vertical was taken and found from the altitude of the Sun, and not from the hours — or vice versa. Accordingly, if anyone should wish to inquire back into the magnitude of that angle, he would have to derive it from the Sun's elevation.

[Margin: The Sun's elevation is the chief standard of orientation.]

Eleventh. The hours, however, I took from vertical sundials, by the judgment of the eye and not by calculation — yet with all the skill and accuracy I could — and this in order that some judgment might be formed about the intervals of times

and periods in the delineations. But since, whether through the inclemency of the weather or the necessity of haste, it was not always possible to have the hour, I did not always record it either; nor afterwards, for want of time, [did I wish] to derive it by calculation —

[Margin: What purpose does noting the time serve? It is sometimes omitted.]

— whoever needs it will readily extract it from the elevation, for this I always secured with the greatest diligence. And even if something in the very minutes of the hours should go astray, the prudent astronomer, [seeing me] taken up with weightier matters, will grant pardon; for I did not subject these to calculation.

Twelfth. When there was a large and numerous tract or cluster of spots or faculae, I marked only one or another with an appended letter, but the rest — being, as it were, highly variable and unstable — I for the most part did not furnish with their own signs; for since they change their figure, magnitude, place, number, and their sparseness and density almost from hour to hour, I judged it superfluous — indeed, prejudicial to the clarity of the record — to affix fixed marks to uncertain things.

[Margin: Not all the spots or faculae are marked with fixed signs — and why?]

[Margin: The magnitude, figure, density, and sparseness, etc., of the spots change from moment to moment.]

Thirteenth. Therefore, if you see in the Images certain forerunners, flankers, or, finally, attendants either falling away from the company or newly arriving, hold it for certain that the former were not seen on the Sun afterwards, nor the latter before, but that they are to be reckoned as having physically come to birth or passed away.

[Margin: Which spot is to be reckoned among the perished ones?]

Fourteenth. Furthermore, since from the year 1611 — when I first published this phenomenon under the borrowed name of Apelles — down to the present time I have had continuous and accurate observations, made by myself and by my pupils and good friends, and indeed from every region: from Italy, from France, from Poland, from Spain, from the New World, from the Low Countries, and from nearly all of Germany — nevertheless it has not been possible to insert here images from every year, since for certain reasons very many of them were not at hand; nor did I choose to include all that I had by me, lest the work should become endless and the labor and expense immense. I can, however, if need be,

draw from them at will, or exhibit the original drawings, in due place and time, to anyone who requests them.

[Margin: The original drawings, both of these and of other observations, year by year from the time Apelles first detected this phenomenon, are ready to be shown to anyone who requests them with just cause. The original exemplars remain intact, to establish [my] good faith.]

Fifteenth. And so, in this work I chiefly press and bring forward my Roman observations — made with the utmost care in the Professed House and the Collegio Romano, and often in the sight of the most illustrious and greatest men — yet with these I mingle observations of others, both of mathematicians and of [various] places, interspersed over six years; so that, from so admirable and utterly astonishing a harmony of the apparent motion, the very truth of the matter [itself]...

[Margin: Observations of eight years, and of various observers and places, are brought forward in this Work.]

any sincere assessor of things may perceive without difficulty.

Sixteenth. Yet I do not, as I have said, present all the observations of these years, whether my own or others', but out of some three thousand — both mine and others' — I take up those that both show the continuous succession of the apparent motion and avoid confusion in the arrangement.

Seventeenth. Often, too, I link together images and series of several observations of the same days, because a single circle has not room to hold them all at once.

Eighteenth. Nor, however, would I affirm that all the spots, faculae, or umbrae were always recorded by me in the original observation-drawings, or carried over from them into these Images; rather, I would have you persuade yourself that many were not seldom passed over in the observing itself, and frequently omitted, deliberately, in the transferring. For I repeated so many observations of a single day, to establish the truth, that I could even now, with no trouble at all, most easily produce further series of similar observations — not unlike this one — under various elevations of the Sun above the horizon. But these, I think, will suffice for the prudent reader.

[Margin: More series of observations of this kind could be brought forward.]

For anyone who denies credence to these will not, in my judgment, be satisfied even by a hundred thousand.

Nineteenth. And although the very look of these arrangements will of itself win a sensible reader's confidence in their honesty, nevertheless receive the following as a work of supererogation. First: out of so great a number of observations I selected none and rejected none, but just as opportunity and the state of the time put them into my hand, so I set them in order and transferred them here. Second: if, however, anything seemed to deserve correction, I either did not admit it at all, or left it uncorrected, so that the original drawings might keep their own credit. Hence you will sometimes see a facula or a spot deviating slightly from its station; and as anyone will easily notice this, so he will correct it without difficulty, and will not ascribe the lapse to the observer or to the spot's course, but will rather commend all the more the integrity of the phenomenon from the author's sincerity. Third: I bring forward the observations of others according to their own calculations and their drawn-in ecliptics, likewise untouched. But if anything should need correcting by reason of the plumb-line drawn in, notice —

[Margin: Credence is won by the [observations] observed and arranged.]

— will be given in its proper place; and you will compare whether they agree with mine or not. Fourth: I keep the original drawings themselves untouched, so that it may be possible to show them as occasion arises. Fifth: I know that these years agree exactly, in their motions, with the past years — [years] once thrashed out by constant practice and by an examination more than Rhadamanthine, which years I do not go into here. Sixth: finally, I appeal to practice and experience: observe, arrange, and compare; you will find that your future [observations] agree with my past ones in motion, and so on — in motion, I say, that is not motionless. For the spots do not endure, but the motion does endure, and so does the path of the spots, discovered now sixteen years ago and — as it is reasonable to believe — worn smooth since the foundation of the world.

[Margin: The spots are not everlasting; but the motion endures.]

Twentieth. Whatever I found on the Sun I have distinguished into spots, faculae, and umbrae. I find that the spots fall into three orders. For some have nuclei, with the remaining, non-nucleic parts very distinct as regards sparseness and density, resembling vapors or clouds or surrounding smoke; some do not have clearly marked, distinct nuclei, but a uniformly ill-formed mixture of rare and dense — denser in the middle, and, tending from there toward the edges, gradually rarer; and some have a sparseness evenly diffused everywhere. And so I have tried to imitate and render all these species by drawing them. Hence you will picture to yourself that spots appeared in the solar circle just such as you will here see set forth in the observatory circle — unless I expressly note otherwise —

owing to the inadvertence of the engraver, who in the original drawings did not always perfectly follow my hand.

[Margin: The whole phenomenon is either spots, or faculae, or umbrae.]

[Margin: A threefold kind of spots: one sort rich in nuclei, another barren; and of these, some are ill-formed, some uniform.]

In the same way, some faculae are very pure, intense, and brilliant; others dull and faint; others free and shining out on the Sun with no blackish borders; others walled about with umbrae, either in part or on every side. All of this I have striven to set before the eyes just as I myself beheld it on the Sun. Therefore, when you see them rendered by the Sun's little points [punctuli], rising up without any indication of umbrae from a tracing of closely-set fine lines, I would have you note that these shone forth from the pure surface of the Sun, with no umbrae crowding or walling them about — whether or not I make express mention of the matter in the special notes. Let it suffice to have said this here once for all.

[Margin: Of faculae, some are intense, others faint; some pure, others dark.]

[Margin: A description of the solar umbrae [shadows].]

Under the name "umbrae" [shadows] fall certain very faint and shapeless patches, as though the Sun were sprinkled with smoke or mist, without any definite outline and of varying size, and not as stable as the spots. They are, as it were, the advance signs of the spots, or their after-traces — tails, tips, appendages, protuberances — and, finally, the borders and hedges of the faculae, which they either ordinarily precede or accompany. You would judge the Sun to be marked by them no differently than a spotless linen cloth is by the finest spider's web, or a clean sheet of paper by a moist smudge, or a highly polished mirror by the touch of a hand or the breath of the mouth. I have drawn all of these as true to life as I possibly could. So wherever you find darker areas within the spots, know that there were dense nuclei; where the areas are softer, those spots are to be reckoned of middling grade; and where the shadings are even, there the spots too were faint. I shall almost always mention the umbrae by name. And although these umbrae very often accompany the spots and faculae, they are nonetheless quite often seen on their own, apart, and after some delay they disperse.

[Margin: Some umbrae are conjoined, others separate.]

Twenty-first. In recording these I have always given particular thought to their sizes and shapes. Therefore, whatever proportion of them you find in my images — both relative to one another and relative to the solar observatory circle [circulus observatorius] in which they are inscribed — you may safely declare to have been the actual proportion of the spots, faculae, and umbrae relative to the Sun, always allowing, of course, for the matter of refraction. Indeed, lest I perhaps overstate and make the spots larger than fidelity warrants, I dare affirm for certain that I render the sizes of the larger spots as somewhat smaller rather than larger than they were; and conversely that I set down the smallest spots as somewhat larger than they actually appeared. I did this because they were often so tiny that they could scarcely be conveniently engraved and submitted to the eye in print, even though they shone out most distinctly on the Sun. So when in the notes I say that these or those spots were small, understand that they ordinarily appeared smaller than I present them to you in the diagrams; for I am not in the habit of calling them small unless they were exceedingly minute.

[Margin: The size of the spots, faculae, and umbrae is scaled to the Sun's circle.]

[Margin: The size of the spots, faculae, and umbrae is rendered rather smaller than larger in the case of the larger spots, and larger in the case of the smaller ones, etc.]

Twenty-second. The sizes, enlarged, in the images — both my own and those of others — I have transferred proportionally from my own original drawings.

Twenty-third. The whole account of position [situs] depends on correctly laying the ecliptic upon the observatory circle; and this in turn depends on knowing the angle intercepted between the vertical and the ecliptic at the moment of observation. On the correct practice of this the whole business turns. And so, just as I have always devoted particular study to this matter, I have no doubt that I have fully achieved my aim. Anyone who does the same will agree — but he will do it more easily than I, who opened and paved the road. For it is easier to follow another's path than to discover one's own.

[Margin: The account of position. The pivot of correctly arranging the observations depends on marking the perpendicular and on inscribing the ecliptic.]

Twenty-fourth. The points of the perpendicular [perpendicularum], marked on the circumference with numeral labels, I added at the outset to many of the observations — partly so that anyone could estimate the angle intercepted between the ecliptic and the vertical line, and partly so as to recover complete

observations from the images. But as time went on, this labor came to seem excessive and, in any case, superfluous; moreover, the observatory circle seemed to be somewhat marred by it, and the placing of the marginal appearances hindered; and — what is the main point — the whole observatory circle (of which more shortly) is, by the nature of the press [prelum], drawn out into an ellipse, so that some variation of arrangement and position always crept in. I judged that these superfluous pains should be set aside, reckoning that I had done more than enough if I had laid the matter before others' eyes in at least some cases. For whoever refuses his assent and belief to the courses [of the spots] as presented will not grant it once the perpendiculars are added either. Belief, then, must be given to both or to neither.

[Margin: The points of the perpendiculars were added in the margins of many images; why?]

Twenty-fifth. The nature of the press by which the images engraved in copper are printed — by the rolling of a cylinder — carries with it this consequence: that the images always grow somewhat in length. For that tight and forcible compression, as the cylinder rolls, thins and stretches the paper; hence it comes about that circular images, especially the larger ones, always turn out somewhat longer and elliptical, as anyone who tries it will find. So if you detect this in the observatory circles, and find no true circles but mere ellipses, you will attribute it neither to me nor to the engraver, but to the faulty nature of the printing — which, as it seems to me at least, is incorrigible, yet ought to be tolerable. Add to this, that all

[Margin: The observatory circle's roundness is somewhat distorted into an ellipse by the press.]

[Margin: The print renders the images smaller than the originals; and why?]

the images struck off in print are, on paper, far smaller than on the copper or in the original drawing — of which I have made a great many trials. The reason follows from the one just given: because the paper to be inked and printed with the image is first moistened and expanded, and then, once it has taken the impression, dries and shrinks on every side. From these two unavoidable drawbacks, then, it can happen — and, I think, usually does — that certain flaws are introduced into the very figures of the observations, as regards their arrangement, their size, and their placing. So that I may with reason doubt whether what is asserted in the text always corresponds exactly and perfectly to the figures adduced — even though there is generally the fullest agreement between the copper and the original. I say "generally," because it sometimes

happens that the engraver departs a little from the model; but since this occurs rarely and slightly, it will be pointed out in its proper places. I thought this matter deserved serious warning and the closest attention, so that as the work and the reading proceed — and as readers compare the text with the figures — you would know what to think and what to hold, should the pictures perhaps disagree with the words, or the writing with the drawings. For I can point out this error in words; but I cannot prevent its being committed in the printing, nor, once made, remove it by writing. And whether the paper shrinks while keeping the proportion of its individual parts among themselves — since I have not examined this, I cannot declare.

[Margin: The defect of the type is scarcely detected by the eye's perception.]

This much, however, I do say: on each individual leaf of paper these defects look similar and uniform, and are scarcely noticeable to sight or sense. Only a geometer, a careful examiner of what is said, will dig out whatever discrepancy lies hidden and detect the incongruity I have spoken of — one which, however, the astronomer neither caused nor could have guarded against. This fault, then, will deserve pardon, since without it there was no serving truth and the reader to the eye; and if serving the eye was never otherwise possible without some fault, here it was permissible even with — as I hope — good grace. It is enough that there is fidelity in the words and uncorrupted truth in the original drawings. Small observatory circles scarcely feel this evil.

[Margin: Small observatory circles do not incur this flaw.]

Twenty-sixth. In the images of the observations you will find, here and there, many spots — or even faculae — placed on both sides outside the track of travel. But this does not happen

because they made use of such byways in their course, but because they dragged along with them such great encumbrances that they could not conveniently be accommodated on the royal road. So they had to withdraw a little to the sides, to display their treasures and magnificent riches, as it were in makeshift tents, before the eyes of the onlookers. Thus it was not the spot that made those lateral withdrawals, but the observer — the same distance from the center C being always preserved.

[Margin: Spots and faculae, outside the royal track, are often joined at the sides because of the scarcity of room.]

Twenty-seventh. Now, since all the observations themselves and the observation circles are — and are made — in an inverted position, the images of the observations, once put in order and displayed here, are all in an upright and reversed position, so that you would look at the spot on the Sun in exactly the way you now see it on the paper, in the same shape and the same position. This is otherwise in the original sheets and authentic copies of the observations: for what is upper on the Sun is lower on the paper; what is on the right on the Sun sits on the left of the paper, and vice versa, and so on. Here, then, you have everything represented in its upright and natural position.

[Margin: All the images of the observations are presented in an upright and reversed position.]

Twenty-eighth. The purpose of these figures is to lay a solid foundation for the whole solar phenomenon [Solaris Phaenomenon] — a foundation that cannot be drawn from anything other than the apparent motion; for on this the whole matter turns. For since, in all celestial appearances, the astronomer is always accustomed first of all to investigate the motion and the true place of the thing seen and moved — and since this cannot be obtained solidly and scientifically without the apparent motion and the observed place — the result was that, in examining this phenomenon, I devoted so much effort to bringing out the apparent motion without any illusion. And in order to become the more certain in eliciting it, and to draw out a sounder doctrine in due time, I took on several companions into the fellowship of observational study. And so, during the decade over which I presided over the teaching of mathematics at Ingolstadt, I most faithfully entrusted to certain of my more skilful students the method of observing this phenomenon — of introducing the perpendicular into the observations, and from it the practice of inscribing the ecliptic into them. This was especially so since I was from time to time summoned to the service of the Most Serene House of Austria, to discharge duties both mathematical and of other kinds, and so was somewhat drawn away from constant observing.

[Margin: From these observations the foundation of the solar phenomenon is established.]

[Margin: He took on companions for the labor of observing.]

Therefore, since I had already learned by experience the diligence and skill of Father Johann Baptist Cysat [Johann Baptist Cysat] and of Georg Schönberger [Georg Schönberger], and of many others, and had compared many of their observations with my own and found that they agreed, I earnestly urged them to

continue those observations even in my absence, for my sake and for the use that would follow. For I had always hoped, one day, to bring this matter before the public in finished form, and so, not unjustly, I reserved this phenomenon especially to myself as my own discovery. So when, three years ago, I happened to take this task up again here in Rome, and when the original observations of many years — both mine and Father Cysat's, kept at the College of Neisse [Collegium Nissense] — although they would have been very useful, could not be summoned here because of the ravages of the wars and other dangers, I asked both parties that, if they had any observations ready to hand, they should send them, or at least observe new ones to be sent here as soon as possible. As a result, the spots I received observed at Ingolstadt and at Triburgum [Freiburg (?)] I inserted here, and in the same way I published those submitted by Father Charles Malapert [Charles Malapert]. For although I have found many drawings from the earliest years, made by others here in Italy, and still keep them by me, yet because they lacked an inscribed perpendicular they did not serve my chief aim.

[Margin: Observations of the spots by others, continued for this use at the author's request.]

[Margin: At the author's insistence, others' observations came to Rome.]

[Margin: Observations of spots without an added perpendicular do not serve for investigating the motion.]

And since, long ago, as I said, I had taught those Fathers, to a similar end, the practice of adding the perpendicular — but on condition that they keep the matter secret (lest, as had happened with other things, this very discovery be seized before its time by other harpies, and so on) — I asked them to share their observations with me, and, if possible, with the ecliptic introduced into the observations and derived by calculation. And since, ahead of the rest, Father Georg Schönberger had done this two years ago, I arranged these apparent motions of his — derived from his own calculation and engraved in copper — and sent back to him several finished copies, so that he might see how well the calculation had succeeded, and so that the curvilinear motion of the spots might come to light: the motion about which, long ago and many years before, I had said much in confidence [sub Rosa] both to him and to Father Cysat, as being my successors.

[Margin: The author brought here other observations of his students as well.]

Yet I did not do this because I thought the chief weight of the matter rested on those observations, or because I was afraid to come forward with my own alone

without them; but so that I might repay their most faithful labors — carried on now for so many years at my request and for my sake — with at least this token of a grateful mind. And nothing grieves me more than that I did not have to hand Father Cysat's accurate observations of many years, and those of certain others transmitted to me all the way from the Indies, and, much more, my own. For from them I could not only have assessed all the others' work, but also have arranged it in order, once my perpendicular had been applied to it. For I made no observations without inscribing it upon them. But what is deferred is not lost; the opportunity of presenting those too will perhaps be given. Next, I wanted to show the whole world that this phenomenon is everywhere consistent with itself. For had I brought forward only my own observations and explained the apparent motions, a scruple and a reluctance to assent might perhaps have remained in many minds; whereas now that they see such agreement on all sides and everywhere, there is no reason for them to imagine anything amiss, either about my fidelity or about the phenomenon's asserted, certain, and everywhere-agreeing appearance across all lands. For their apparent motion, arising from their calculation, is plainly the same as the one that emerges from my own procedures — mechanical, geometrical, arithmetical, or astronomical — applied both to my observations and to their own. For I publish nothing of theirs that I have not tested, and carefully at that, against my own rules, which I set out at length in the previous book. And so, concerning the apparent motion presented in these images, no doubt or mistrust need arise in anyone. It was solely to establish the apparent motion effectively that I brought forward those observations of theirs, comprised within small observatory circles; for there is no need to draw out any finer detail from them, since such detail is had more surely, more exactly, and without error from my own larger ones. For which the small circles are indeed a help, but they are helped far more by the larger ones; the larger stand on their own without the small, whereas the small alone never suffice for everything. For example, the Sun's rotation, or the complete bend of the arced

motion, you will never obtain from small observatory circles; but from the large ones you can obtain it, even against a stubborn objector. Therefore, for the apparent motion found in the larger circles to be confirmed by the small ones, it suffices that it appear in the smaller — curvilinear or rectilinear — just as it does in the larger. And this is what I intend and hint at when I write that the courses of the spots are similar to one another: in genus, that is, or in species. For you will demand an individual likeness only from larger circles, and from lenses and telescopes [telioscopia] that are equal, alike, and made in a like manner.

[Margin: Small observatory circles alone are not enough for fully drawing out the motion of this phenomenon: the large ones, without the small, supply everything most abundantly.]

[Margin: The similarity of motions found in the large and small observation circles is generic, not necessarily individual.]

[Margin: The qualities of the path's bends are understood from the special motions.]

Twenty-ninth. As for when the traveling courses of the spots appear curvilinear — for how long, how much, and in what manner — and when and how they appear rectilinear; what positions these courses have relative to the ecliptic; from which side of the Sun they begin, and toward which they tend; how much latitude they traverse upon it, and so forth: these you will see in the images of the observations, and read in the special notes attached to them.

[Margin: The same courses do not recur on the part of the mobile, that is, of the moving spot.]

Thirtieth. When I say that the courses of the spots are similar in the same courses, months, weeks, and days, the sense is not as if the same spots retraced the same courses year by year; for you will not expect this, since, as you will see, it is doubtful whether they return even once in a month, let alone in a year. Rather, it is a hypothetical way of speaking. Suppose that any spots whatever — of whatever position, shape, and size — enter the solar horizon at the same point at which some other spot had entered in any year, but in the same month, and on the same day of the month, more or less: then I say that their apparent courses will always be found to be similar — that is, either curvilinear, with a similar curvature toward the center and toward the ecliptic, or rectilinear, similarly oblique to the ecliptic, and so on. And if the courses are of the same spot, differing only in place and in observers, I say they will be similar even geometrically, to the perception, and will differ among themselves only as one individual differs from another. I said "to the perception," because refraction can introduce some difference into the matter.

Thirty-first. As eyewitnesses of this phenomenon and of my observations, and as inspectors, I have had — both formerly and now, and among peoples everywhere — men most distinguished in every rank, office, and dignity, and many who had traveled here from abroad, who most delightedly beheld this phenomenon, previously unseen by them.

[Margin: Eyewitnesses of my observations — who?]

Thirty-second. When, in the course of the particular notes, you read that some spot, facula, or umbra was seen or noticed to be in motion, or that it could not be seen or perceived except in motion; or, on the contrary, that another was seen steadily, without motion: understand that the reference is not to the motion which the spot itself performs on the Sun — for the advance of that motion is in no way perceptible to the senses — but to the shaking of the instrument, together with the paper-bearing tablet and the observatory circle. For these, when gently moved in any direction, in a way stir the Sun's images and rouse the eye to see things which otherwise, at rest, would have escaped the sharpness of sight. From which it is again clear that those which need this stimulation — whether spots, faculae, or umbrae — are very slight and faint, whereas those that are seen without this shaking are more robust and more compact.

[Margin: The agitation of the helioscopic machine helps in seeing the spots.]

Thirty-third. When you see certain spots marked on their paths across the Sun by black points, you should not suppose that they had suddenly turned out so small; rather, I would have you notice that they are marked by their center alone — either because they were not otherwise observed in the original, or because the nearness of the other stations did not allow the whole [spot] to be drawn out.

[Margin: Spots marked point-wise.]

Thirty-fourth. The place on the path at which an observed spot is marked — let it be called its "station."

Thirty-fifth. The thicker spots, rich in nuclei, or lying close together, are usually tinged with certain strange colors — whitish shading into green, blue, yellow, dusky — and that not by chance, accident, or at random, but in a fixed order, position, increase, and decrease. For the part of the spot that looks straight toward the center always turns bluish, while the part turned away always turns dusky; and when this happens, usually a certain brightness surrounds the spot, like a halo, which I call a nimbus. This appearance I do not always note, but sometimes, when it is very conspicuous, and I bring it forward by way of example.

[Margin: The strange colors of the spots.]

[Margin: The halo, or nimbus, of the spots.]

But what this is, and from what cause and in what way it comes about, will be argued in the proper places, God granting. For now I wanted only to alert you to this, so that you might know that I have — quite deliberately — rather rarely recorded, in the courses of the spots, that which happens regularly and in an orderly way.

[Margin: The parts of the observations are enumerated.]

36. Every Image of my Observations embraces the following. First, the Observatory Circle. Second, the Ecliptic. Third, the year, month, and days of the observations, together with the marked place of observing. Fourth, the Name of Jesus, to whom I consecrate myself and all my labors; then Fifth, two Roses, the most fragrant emblems of the Phenomenon and of the Ursine Family — for the Sun scatters its rays no more widely (and, together with them, this Rose) than that most praiseworthy Ursine Family scatters the fragrance of its Heroic Virtues. Sixth, there follow next the Spots, Faculae, and Umbrae. Seventh, to these are attached their own letters and numeral marks. Eighth, finally, a diary-review of the Observations.

From these things, therefore, you will know at once, at the sight of any Image: in what year, in what place, in what month, on what days, at what hours, and under what altitude of the Sun above the horizon each of the Spots, Faculae, or Umbrae was observed; when they rose and when they set; by what paths they proceeded; and with what appearance, shape, retinue, and strength they flourished, and so forth. All these things, individually explained, you will read in the particular records and Notes of each of the several Observations. Let it suffice to have touched on them here in a general way. See the Notes on Image II, which is that of the first of January, 1625.

[Margin: What is the Course of a Spot?]

37. By the Course of any Spot I understand nothing other than that track which any Spot, while it travels across the Sun from east to west, leaves behind it. Since this track does not come into view except through the Spot itself being seen and recorded on paper, its actual character therefore becomes known through the observed and recorded central positions of the Spot. So if you join these positions by broken line-segments — as I have repeatedly done in many observations, by way of example — you will see at once what sort of course it is: whether curved or straight; from which region of the east it proceeds into which region of the west; toward which pole it turns its concave side and toward which its convex; with what curvature it is endowed; with what obliquity it regards the Ecliptic;

and when, where, how, and how often it cuts or touches it. The line, then, which any Spot describes on the Sun with its center is, and is called, the course of the Spot — its "curriculum," "path," "track," "way," "progress," "itinerary-line," all of which are taken as one and the same thing. And it is conceived as projected onto the Sun's own circle, that is, onto the plane of the solar circle.

[Margin: What is the Direction, or itinerary tendency, of the Spots?]

38. The itinerary Direction of the Spots signifies the very tendency of this path — namely, from where and toward where the Spots move. For although it is certain that they all tend from east to west, and although the Ecliptic line, always marked on the Sun, determines the true point of rising and setting, yet because the Spots never describe their paths along the flow of the Ecliptic, nor ever move parallel to it, I ordinarily indicate in the Margin what the direction of the Spots is.

[Margin: How and when the paths of the Spots are made oblique to the Ecliptic through the middle of the year, from the North into the South.]

For you will always find, throughout six whole months, that the paths of the Spots proceed obliquely to the Ecliptic, from the vernal equinox to the autumnal equinox, from the eastern North into the western South — which takes place from the end of February and the beginning of March to the end of August and the beginning of September. During this whole time, all the subtenses of the path-arcs — whether they be diameters or chords perpendicular to the movable axis — cut the Ecliptic obliquely, so that one segment always lies in the northern region, and the angle contained by that segment and the Ecliptic faces east; while the other segment, lying in the southern region, makes with the Ecliptic an angle open toward the west.

[Margin: The summer Station of the Spots.]

And indeed in the first three months of this half-year — that is, in March, April, and May — all the path-arcs will be concave toward the eastern South and convex toward the western North. But in the other three later months — after the straight-line summer Station, that is, in June, July, and August — the paths of the Spots turn their concavities toward the western North and their convexities toward the eastern South.

[Margin: How and when the paths of the Spots are made oblique to the Ecliptic through the middle of the year, from the South into the North.]

The opposite of these will occur from the autumnal equinox — which always falls at the end of August and the beginning of September — up to the vernal equinox. In [the first three]

[the first three] of whose months — September, October, and November — all the paths of the Spots are concave toward the boreal North and convex toward the western South; while in the three later months — December, January, and February — after the straight-line winter Station has been observed, the itinerary bends are hollow toward the western South and convex toward the eastern North.

[Margin: The winter Station of the Spots.]

And this alternation of paths — annual, semiannual, and quarterly — is fixed and, in this Phenomenon, perpetual, so far as it has been possible to gather and determine from the observations of so many years now.

[Margin: The alternation of the itinerary Motion of the Spots: Annual, Semiannual, Quarterly.]

[Margin: The mutual sections of lines and surfaces are not oblique or right, but are only so named.]

39. Since frequent mention of Inclinations, obliquities, declinations, latitudes, and sections occurs in the particular Notes, it must be understood that no intersection — whether of lines or of surfaces among themselves — is in itself either oblique or right, but is so called only from the position and relation to one another of the things that cut each other. For a line does not cut a line except at an indivisible point, and likewise a surface cuts a surface only in an indivisible line; therefore, since a section is in itself indivisible, it admits no obliquity or straightness, for this is a property of magnitude. Yet it is, and is called, right or oblique, according as the position of line to line is right or oblique. Thus incidence is called right or oblique not from the final point of the incident line, but from the whole relation of line to line; and so too is inclination.

[Margin: Straightness or obliquity draws its origin from position.]

For if some bounded line touches another finite line with its end-point, it will either lie in a straight line with it or not. If the first, then between them

[Margin: Position, however, belongs to magnitudes.]

there will be no inclination of the one to the other, but rather the greatest and equal separation of the one from the other — a semicircular one, namely. If the

second, there will be an inclination of the two toward each other, and the greater the distance between them, the smaller the inclination but the greater the angle, and vice versa.

[Margin: What the inclination of a line to a line is.]

Therefore, in this context, inclination and obliquity follow one another; for a large inclination yields a large obliquity, a small one a small, and so on. But I take the chords of the arcs, and not the arcs themselves, for eliciting the obliquity and inclination, because the arcs are irregular and often do not touch the Ecliptic at all, whereas the chords often do.

[Margin: Inclination and obliquity mutually follow one another.]

The latitude of the parallels which the Spots describe is to be taken according to their distance from the greatest parallel, which the diameters of the path-arcs always give. But these attributes will be dealt with systematically in their proper places.

[Margin: The chords of the path-arcs are assumed for showing the obliquity or inclination. The latitude of the Courses.]

40. The poles about which the Spots turn are two, the southern and the northern, opposite to each other, and are driven by opposite motions. And always, at mid-year, the one moves in the visible hemisphere of the Sun, the other in the hidden one; and the visible one is always carried from west to east, the hidden one from east to west. The southern one rises at the straight-line winter Station, around the beginning of December, at which time the northern one sets; but at the time of the summer Station the southern pole sets, in the eastern southern polar region, around the beginning of June, and [the northern one] rises in the western northern region of the Aquilo. And thus these mutual risings and settings of the Movable poles — the axes about which the spot-carrying deferents rotate — endure perpetually.

[Margin: The poles about which the Spots turn: from east to west, with an annual carrying from west to east.]

[Margin: The rising and setting of the said Poles.]

IMAGE OF THE SUN

PARTICULAR NOTES to the Tables, or Images, of the observations made in the years 1618, 1621, 1622, 1623, 1624, 1625, 1626, 1627, at Rome and elsewhere in various places, by different Mathematicians.

NOTES ON TABLE I, WHICH IS FROM the 14th to the 19th of December of the year 1624.

[Margin: In December the annual motion of the Spots makes its beginning.]

The first Table of the Roman observations is also — by good fortune indeed — the first in position and in Order, so that it would have had to be set in the first place along with the others even if others had preceded it in the observing. This is because in this month and season (as will be said in its place) the annual motion of the Spots makes its beginning and its end, and the one pole, which carries the axis of the Spots, enters the visible quadrant of the ascending semicircle, the other the quadrant of the descending, hidden one.

In this month I used only a single telioscope for observing — the one which Christoph Clavius had once used, a man who without any doubt deserved supremely well of Mathematics. From the reading of his books, if I have attained anything in mathematical science, I confess quite willingly that I owe most of it, and that from them I received the occasion and the spur for discovering other things.

[Margin: The beginning of observing was undertaken with the Clavian telioscope.]

In this month of the year 1624 I employed the observatory circle — as you see, quite small, *c d e f* — which in the following months I made equal to larger observatory circles, keeping everywhere the same measure and enlarging it proportionally, so that you might see whether and how the annual revolution of the Spots returned the same or similar, as I shall systematically point out in its own time and place.

[Margin: The greatest care was applied in observing.]

I began the observations on December 8, in my usual manner — that is, with as much accuracy as you could perhaps demand and expect of any mortal. For this I call as witnesses as many people as I have had spectators of this pursuit of mine everywhere, among nations and places — who were almost innumerable. I write

this not because I regard myself grandly or commend myself ambitiously, but in order to build for the Reader the confidence necessary in a matter so new, so strange, and so paradoxical, and one that at first sight is somewhat repugnant even to the judgment of experts.

Thus, from the 8th to the evening of the 10th of December, no Spot appeared on the Sun, either to me in the Professed House or to Fr. Grienberger in the Roman College. On the 10th, toward evening, at the Italian hour 23, I saw one very tiny, very faint spot near the center, which, however, I did not transfer into the observatory circle. The 11th was overcast. The 12th was clear, but empty of Spots. The 13th was cloudy. The 14th displayed Spot *a* in the small circle, or *a* in the large one, in the afternoon; I had also caught sight of it before noon, but did not then enclose it in the observation circle — only after the midday meal. The 15th was unfit for observation because of the inclemency of the sky. On the 16th and 17th I made the recorded observations, and the Spots appeared to be waning. On the 18th the sky did not cooperate. On the 19th I noticed two very tiny Spots, *b* in the smaller, or *b* in the larger circle, which, however, I saw only through the motion of the instrument — that is, by shaking the observatory circle — so small and washed out by the light were they. They were the same ones that had presented themselves on the 17th, except that they now appeared doubled, whereas before they had proceeded under the appearance of a single one. On the 20th the sky was unsuitable for observation.

[Margin: Several days of December free of Spots.]

[Margin: Vanishing spots become visible by the motion of the telioscope.]

On the 21st, I and the Reverend Father Giovanni Battista Staserio — then Mathematician of Naples — under a very clear sky examined the Sun most carefully and found it free of every spot, but sprinkled here and there with brighter patches (which I call Faculae), detected through the motion of the instrument, which nonetheless we did not record.

[Margin: To the Mathematician of Naples were shown Faculae of the Sun, which lacked spots.]

From the 21st to the 24th of December the Sun always shone most clearly, and, most diligently scanned, displayed nothing at all

of Spots. For this reason — lest perhaps, because of the smallness of the observatory circle, the Spots themselves, swallowed up by the breadth and intensity of the surrounding brightness, might escape the sharpness of the eyes —

I began, on December 24, which was the Vigil of the Lord's Nativity, to employ several tubes with a larger form and circle, and to examine the Sun much more exactly. Yet in it, clear though it was, right up to December 31 it was not possible to detect any Spot, nor any Facula of any significance. From which it is sufficiently clear that these Spots did not enter beneath the Sun or leave it by local motion, but were born and dissipated within its visible hemisphere.

[Margin: From the 21st to the 31st of December, the Sun was free of Spots not only at Rome but in Germany too.]

That the Sun was most pure in these days not only here at Rome but also in other parts of the world, take a clear testimony from Lower Germany. For Fr. Charles Malapert [Carolus Malapertius], now Mathematician at Douai, among his observations made at Douai and transmitted to me on April 3, 1625, has this: "In the year 1624, December 4: nothing detected. The 19th: nothing" — where, however, I myself before noon, though with the instrument in motion and not at rest, noted down two faint ones; but after noon nothing at all of them could be perceived. In this observation and time we agree entirely. But he continues: "December 27: Nothing. December 30: Nothing." Since, therefore, the same author adds that in the same year, on November 21 and 23, the Sun was empty of Spots, it is probable that on the intervening days too nothing existed — which I cannot corroborate by my own observations, since, being on a journey, I made none.

December of this year, then, was such, and quite barren of Spots. Yet the path of those spots there were was in a way straight, and oblique to the Ecliptic from South to North, but by no means parallel to it, as will be plain to anyone examining the observations; and it will become still clearer from the Tables of November and December of the years 1625 and 1626, as well as of May and June of the same years. For the annual courses return similar and, as it were, equal, while the semiannual ones are equalized in a subcontrary way, or become similar — as the utterly constant appearance of the Phenomenon, always uniform and consistent with itself over the courses of so many years, and the very reasoning derived from it, most clearly proves, as will be said more fully in the proper places. For now, at the outset, I give this passing advice: that, as you are about to read and view these things, you may take some foretaste and profit, by comparing earlier things with later and applying like to like.

[Margin: The itinerary Directions of the Spots are straight, and oblique to the Ecliptic from South toward North.]

But I do not want you to persuade yourself that I wish to prove rectilinear motion from these observations of the Sun. For since that course lacks both a beginning and an end, and was investigated in a small circle, I do not establish this conclusion from it; rather, because I hold it — from previous years and observations — as certainly known and to be confirmed in what follows, I therefore affirm this truth, without any fear, as certain.

Rosa Ursina, Book III — Imago Solis I & II; Notes on Observation-Images II and III

IMAGO SOLIS I — Engraved solar-disk plate (December 1624)

Diagram. A full-page engraved solar-disk figure: the disk of the Sun drawn as a large circle set against the horizon frame, with the daily positions of the sunspots tracked across it from 14 to 19 December 1624. The whole page is the engraving; the letterpress "text" ghosting behind it is verso show-through and has not been transcribed.

Readable labels and inscriptions:

- **Top-left title block:** "I. Imago, Obseruationum Decemb: unica. 1624." — "Image I, the sole one of the December observations, 1624."
- **Upper center:** "Anno Domini, 1624. In Domo Professa Romana Societatis" — "In the year of the Lord 1624, in the Professed House of the Roman [Jesuit] Society," flanked by two rose ornaments and, at center, the radiant IHS emblem of the Society of Jesus.
- **Below that:** "Cursus Macularum a 14. Decemb: ad 19. eiusdem" — "Course of the spots from 14 December to the 19th of the same [month]."
- **Cardinal points of the horizon frame:** A (far left, on the horizontal line) — "A. Oriens" (East / rising point); B (far right) — "B. Occidens" (West / setting point); Z (top, with adjacent point letter **k**) — "Z, Zenith"; N (bottom) — "N. Nadir."
- **Right of center, on the horizontal line:** "AB, Ecliptica." — line AB is the ecliptic.
- **Inner (small) circle, points c, d, e, f, g:** "c d e f g, Circellus minor, obseruatorius." — "c d e f g, the smaller observatory circle."
- **Outer (large) circle, points h, i, k, l:** "h i k l, Circulus ampliatus." — "h i k l, the enlarged circle."

- **Spot-track:** individual spots are lettered **a** and **b** and tagged with the day-number (14, 15, 16, 17, 19) and a morning/evening marker (**m** = morning, **u** = evening); e.g. a u 14, a m 16, b m 15, a 17, b 17, b 19. Several of the smallest day-tags along the track are too fine to resolve individually and are left [?].

Embedded observation table (lower center):

DECEMBRIS [small ornament follows the month-name]

D. (day)	H. (hour)	☉. El. (Sun's elevation, °.)
14. u.	21¾ [?]	22. 28.
16. m.	18⅘	24. 30.
16. u.	21.	21. 40.
17. m.	16⅘	14. 30.
19. m.	17½	17. 40.

ROSAE VRSINAE, Book III

OBSERVATION-IMAGES OF THE YEAR 1625, AND NOTES ON THEM

Notes on Image II of the observations, which is that of 1 January 1625.

First, this image displays a notable spot **a**, with a tiny little one attached above it in the manner of a tail — attached, indeed, yet in its motion entirely separate.

Second, Fr. Christophorus Grünenberger [Christoph Grienberger] likewise projected this spot onto paper through various telescopes at the Collegio Romano, and confirmed its accuracy.

Third, throughout its whole course this spot had a dense, black nucleus, inclining rather downward toward the south, that is, toward the parts turned toward N [Nadir]; and the whole spot appears to be made up of two, of which the smaller looked upward toward the north, that is, toward the Zenith. On the 5th day, however, it appeared perfectly circular, dark in the middle and whitish toward the edges — which looked rounded but not sharply defined, softly ragged rather; from the extremities toward the middle the darkness and density gradually increased, though it did not attain the blackness of the earlier days. On this 5th day, too, it was alone on the Sun, without any other spot or facula. On the following days it gradually took on length and blackness, and on the 7th and likewise the 8th it distinctly presented two separate spots in motion, of which the

southern was the larger and the northern the smaller; and so both together lasted right up to the exit [from the disk], and therefore represented a more elongated spot-body — somewhat bulging in the middle toward the center, yet nearly a straight line, and that parallel to the Sun's perimeter.

[Margin: A spot circularly round.]

Fourth, around its nucleus this spot had, throughout its whole course, a much-diluted blackness and a thin surrounding like a mist, vapor, smoke, or exhalation. It also showed various colors: toward the center bluish and whitish, but toward the margin shading from yellow into a dusky brown.

[Margin: The spot's color is adventitious.]

Fifth, its apparent track ran oblique to the ecliptic and curvilinear — convex, therefore, toward center C, and concave toward N.

[Margin: The curvature increases; the southern pole rises from west to east.]

Sixth, the numbers 1, 2, 3, etc. written against the spot-figures denote the days on which I observed those spots; the letters m or u [denote] whether the time of observation was morning [matu-]

[Margin: The little side-table appended to each observation is explained.]

[tinum] or evening [vespertinum]. The hour and the Sun's elevation, however, you will find in the daily table inserted into each image: in it you will find the day-numbers in the leftmost series under the letter **D**, which signifies the day of the month, written at the head of the table. Proceeding rightward from the day, you will find under this little line ——— either the letter **m** or **u**, which indicates that the observation of that day was carried out either in the morning (*mane*), that is before noon, or in the evening (*vespere*), that is after noon. Going next toward the right, you will find under **H** the astronomical hour-numbers, reckoned in the German fashion from noon to midnight and thence again to noon, in a twelvefold count — either whole or with attached fractions, as practice yielded.

[Margin: The first key to investigating the apparent motion: the Sun's elevation above the horizon.]

The series of hours is then, at the very far right, followed by the Sun's elevation, expressed in degrees and first minutes, under these signs ☉, El., which indicate the Sun's Elevation or Altitude above the horizon. In this alone I place the chief force and strength for investigating the apparent motion; for I append the hours

only so that, from the numbers set out together, I may be able to institute some comparison of the times and of the daily intervals. I have, however, rejected the Italian hours reckoned from sunset, because their use is intricate, difficult, slippery, variable, and foreign among astronomers — indeed deceptive, since here at Rome they reckon from twilight rather than from sunset, at a time when the business of refractions is always troublesome; and from the fallible beginnings of such hours one must either always be erring, or else a vast delusion would have to be avoided by immense labor.

[Margin: Italian hours are ill-suited to astronomical matters.]

I preferred to enter upon plainer paths, and so adopted the German hours — both because they are in daily use among nearly all the rest of the peoples of Europe, and because they convert into astronomical hours with the greatest ease. For those hours which run from noon to midnight, which we call evening hours, are of themselves astronomical; and if, the morning hours being now counted — that is, from midnight up to noon — you always add twelve

[Margin: Conversion of the German hours into astronomical ones.]

IMAGO SOLIS II — text continuation and engraved solar-disk plate (January 1625)

[continuation of the notes on Image II, from the foot of the preceding page:]

hours, the resulting sum will at once give continuous astronomical hours.

Seventh, the course of this spot was observed with a rather small observatory circle, and has therefore been enlarged into a large one, keeping the proportion of positions, magnitudes, and situations. It is similar to the course of the following year, which spot c made from the 4th to the 15th [day]: all things being duly examined, they appear to have crossed the Sun even in equal times, in a parallel that is to the senses the same. Compare the tracks, and you will see the symmetries of the tracks.

[Margin: The course of this [year] answers to the course of the year 1626.]

Diagram. A full-page engraved solar-disk figure, companion to the first: the Sun's disk with the daily positions of the sunspots tracked across it from 1 to 11 January 1625.

Readable labels and inscriptions:

- **Top-left title block:** "II. Imago Obseruat[ionum] / Ianuarij 1. / 1625." — "Image II of the observations, [of] 1 January 1625." (An abbreviation-mark and a small superscript, possibly a figure- or signature-mark, follow "Obseruat"; read [?].)
- **Upper center:** "ANNO IVBILAE0, 1625. In Domo Professa Romana Societatis" — "In the Jubilee Year 1625, in the Professed House of the Roman [Jesuit] Society," flanked by a rose ornament and the radiant IHS emblem.
- **Below that:** "Cursus Macularum à 1. Ianuarij, ad 11.^m eiusdem." — "Course of the spots from 1 January to the 11th of the same [month]."
- **Cardinal points:** A (far left) — "A. Oriens" (East); B (far right) — "B, Occidens" (West); Z (top); N (bottom).
- **Center, on the horizontal line:** "AB, Ecliptica." — line AB is the ecliptic.
- **Inner (small) circle, points c, d, e, f:** "c d e f, Circellus obseruatorius." — "c d e f, the observatory circle."
- **Outer (large) circle:** "AZBN, Circulus ampliatus ex obseruatorio." — "A Z B N, the circle enlarged from the observatory [circle]."
- **Spot-track:** individual spots are lettered **a** and tagged with the day-number (1 through 11) and a morning/evening marker (**m** / **u**); e.g. a 1, a m 2, a 3, a 4, a 5, a m 6, a 7 u, a m 8 u, a m 10, a 11 u. Many of the smallest day-tags clustered near the center are too fine to resolve and are left [?].

Embedded observation table (lower center, in two side-by-side halves separated by a decorative vertical rule):

IANVARIJ

D.	H.	☉. El.	D.	H.	☉. El.
1. m.	10½	21. 0.	6. u.	3 4/9	12. 0.
2. m.	5 11/12	18. 15.	7. u.	—	4. 40.
2. u.	3.	12. 5.	8. m.	11.	24. 30.
3. u.	1¾	21. 0.	8. u.	2⅝	16. 0.
4. u.	⅓ [?]	23. 0.	10. m.	9½	16. 40.
5. m.	10.	19. 10.	10. u.	1 1/7	24. 30.
5. u.	3.	21. 0.	11. m.	10 1/12	20. 25.
6. m.	9½	16. 35.	11. u.	3¼	10. 0.

ROSAE VRSINAE, Book III

NOTES ON THE THIRD observation-image or table, which is that of 2 January 1625, from the 7th to the 18th of the same [month].

This third table too, which is that of 2 January, I have proportionally enlarged, so that the shapes of the spots and the resemblances of their courses might stand out more clearly, and might be compared with other years, both past and future.

First, then: spot **a**, the southern one, having begun to be marked on the 7th day after noon, described a course such as you see — more curved than the earlier ones, and more oblique to the ecliptic, if we think of it through the two arc-points of its track, equally distant on either side from center C toward east and west (such as are in the figure set forth): the center of spot a on the morning of the 11th day, and likewise on the morning of the fourteenth day. If, I say, a straight line be imagined drawn through those points to infinity, it will cut the ecliptic and make with it a smaller angle than the lines rightly drawn in the same way had made in the earlier observations — as will be shown expressly in its place and time, and often noted in the series of the observations that follow. For now I only suggest it in passing, so that the diligent reader may gradually accustom himself to attend to the change of greater or lesser obliquity; for one after another will keep following, until, one period being completed, it returns to the same [starting point]. But on this matter consult the General Notes, no. 37.

[Margin: A more curved motion gives a more oblique intersection of the chords with the ecliptic; both are increasing.]

Second, this spot **a** on the first day appeared quite elongated, because it was double, as it appeared in the motion of the instrument; on the remaining days that tail was stretched out toward the north. It was not seen [again] up to the 13th day — throughout the whole of which, in five different observations before and after noon, that appendix always appeared, and indeed separately, and without any motion of the instrument. On the days thereafter it appeared no more. In the same way, on the 10th day the same spot drew behind itself a very thin shadow [umbra], visible only by the motion of the paper, without any definite shape or density; which nevertheless gradually so gathered itself that in the afternoon it could be quietly viewed and marked, having become blacker, and on the two following days was formed into diluted spots, then again diminished and [merged] into one, and at last was seen to vanish into nothing on the 14th day.

[Margin: Spots are born from penumbrae [Vmbrae]; they dissolve back into penumbrae.]

An ash-colored spot appeared, black and dense in the middle, whiter and rough toward the extremities; and from the first moment of its appearance it steadily decreased, right up to its exit, gradually and almost proportionally.

Third, conversely, spots **b** were in no way marked, even by the slightest indication, before the 13th day (although most vigilantly I was always intent upon this matter). On the first day, indeed, they were quite small, sparse, thin, and diluted by the solar light; but on the following [days] they grew in a wonderful manner — in magnitude, in density, and in blackness — so that in growing they passed off the Sun. And that their intervals were increased beyond the regular proportion is proved by this too: that the intervals of the outermost [spots] on the 15th day were equal to the intervals of the 13th day, whereas the former ought to have diminished, if the spots had been proceeding at the same distance from center C, and with equal speed and uniform motion.

[Margin: A spot born in the western region; they grow over spaces more than the ratio of equal motions allows.]

Fourth, on the 17th day, morning and evening, these spots drew along with them faculae so bright that they too could be discerned with the instrument at rest, without any motion, and without any difficulty. And when certain leading Fathers of our Society had seen them with the greatest admiration — as being a thing new to them — they urged me vehemently to continue what I had begun and to bring it through to a finished perfection; and not to allow this splendid little windfall, born in the little field of our Society, to be snatched away by others, or handled in such unworthy ways. The authority of these men indeed carried much weight with me; and so that I might the more easily swallow so great, tedious, and long a labor, the moment

[Margin: Faculae seen without any motion of the instrument.]

[Margin: The spectacle of the faculae gave the author spurs to pursue the Phenomenon.]

IMAGO SOLIS III [Image of the Sun III] — folio 169

(The top of this page carries the closing points of the Notes on the Third Image, set in two apparatus columns above the engraved plate; the text runs continuously from the left column into the right.)

added a large one. The 19th was wholly rainy and cut off the course of spot *a*. On these days other faculae and spots shone out as well, but I neither can nor intend to set out everything in complete tables, nor to reduce every detail of a single circuit into one diagram. It is enough to touch on the chief and most important points, so that a student of these matters may easily gather the rest from them.

Fifth: the course of all the spots is curvilinear — concave toward the south, convex toward the north; and its whole direction or tendency is still oblique, running from south to north. The annual austral pole, which carries the axis of the spots, lies in the ascending semicircle, open to view; the northern pole in the descending semicircle, hidden.

[Margin: The curvilinear motion of the spots, increasing, oblique to the Ecliptic, from the eastern south to the western north; the austral pole higher and ascending, the arctic lower and descending.]

Diagram. A full-page engraved solar-disk observation plate occupying the lower two-thirds of folio 169. A large outer circle (the "enlarged circle") carries the four cardinal letters: **Z** at the top, **N** at the bottom, **A** at the left, **B** at the right. A smaller concentric inner circle (the "observation circlet") is set on the same horizontal diameter; its top is marked **b** and its bottom **d**. The horizontal diameter through A and B is the ecliptic line.

Readable engraved labels:

- **III. Imago Observat.** (upper left, inside the plate; a raised abbreviation-mark follows *Observat.* [?]) — "III. Observed Image."
- **ANNO IVBILÆO, 1625.** (top center) — "In the Jubilee Year, 1625."
- **In Domo Professa Romana Societatis.** (below the year) — "In the Professed House of the Roman [Jesuit] Society."
- Central ornaments: a heraldic rose at left, the radiant **IHS** monogram with cross at center, a heraldic rose at right.
- **Cursus Macularum à 7. Ianuarij, ad 18. eiusdem.** — "Course of the spots from 7 January to the 18th of the same [month]."
- **AZBN, Circulus ampliatus.** — "AZBN, the enlarged circle."
- **abcd, Circellus Observatorius.** — "abcd, the observation circlet."
- **A, Oriens.** ("A, East"), at left; **AB, Ecliptica.** ("AB, the Ecliptic"), at center on the diameter; **B, Occidens.** ("B, West"), at right.
- **Ianuarij, 2.** (upper right) — the date/series label "January, [image] 2."

Across the ecliptic line and in two arcs above and below it, the daily positions of the spots are plotted and lettered by day and by companion-letter. The day-numbers legibly run **7 through 18**; the principal spot is lettered **a**, with companions **b** and **c** appearing on the later days, and most positions bear a small **m** (morning) or **u** (evening) marker beneath. The individual per-spot day/letter/m–u labels are numerous and finely engraved; the day-numbers 7–18 and letters a/b/c are readable in aggregate but not every micro-label can be pinned with certainty. for exhaustive per-spot labeling.

Beneath the disk is the engraved observation table (heading **IANVARII**, "of January"), listing for each entry the day (**D**), hour of observation (**H**), and the Sun's elevation (**☉ El.**, in degrees and minutes). Set in two side-by-side halves separated by a vertical rule bearing a small astronomical ornament:

D	H	☉ El. (° ')
7. u.	—	4. 40.
8. m.	11½	25. 0.
8. u.	2⅝	16. 0.
10. m.	10.	19. 15.
10. u.	3 1/10	13. 0.
11. m.	—	11. 30.
11. u.	2⅛	19. 30.
13. m.	9 6/10	17. 40.
13. u.	3.	11. 50.
14. m.	10.	20. 0.
14. u.	3½	11. 0.
15. u.	3.	14. 0.
16. m.	10⅜	24. 45.
16. u.	3½	10. 30.
17. m.	10½	23. 10.
17. u.	3⅞	8. 0.
18. m.	10.	21. 25.

NOTAE IN QVARTAM observationum Tabulam, Ianuarij tertiam, à die 13. ad 23. eiusdem — folio 170

Notes on the Fourth observation Table — the third [image] of January — from the 13th to the 23rd of the same month.

First. When I noticed that, once the solar observation-circle had been enlarged, the very parts of the Sun were more fully unfolded and things lying hidden on the Sun were shown more distinctly, I gradually moved to a larger format, and always found more than I had in the smaller drawings. This is plainly seen in the present series of observations. The observation made on the same days at Ingolstadt, in the smaller circle, shows far fewer than mine in the larger; for the Ingolstadt drawings have nothing of spot *d*, nor of the tiny spot that followed it on the 14th, nor of the facula among the same spots. I am certain that these were not omitted through any carelessness, but through a defect of representation — not seen, and so left out. For when I try it myself in smaller circles, the same thing happens: what is seen in the large ones vanishes in the small. Hence it is evident that this phenomenon, drawn from mere small circles — and those few or interrupted — cannot be treated fully, worthily, and truly, but is rather worn down and obscured than illustrated, since it shines back not brightly enough but darkly, and so on. This was the very reason that pushed Apelles too into deferring, to a later time, any firm decision about the motion of the spots. Yet it is remarkable that the course of spot *a* agrees so exactly on both sides, even though so great a distance of place lay between.

[Margin: The efficacy of the great circles in detecting [phenomena] on the Sun is shown.]

Second. Spot *a*, the southern one, on the 13th gave only a trace of itself in shadow and facula; on the 14th it appeared doubled, with a facula between; on the 15th it was quadrupled, as also in the Ingolstadt [drawing]; on the 16th I had it sevenfold in a single observation, whereas the Ingolstadt observation reports only five spots, because each of the two last ones consisted of two little spots that, through the smallness of the observation circlet, were not sufficiently separated, and so were seen as one somewhat elongated [spot]. But by another observation not recorded here, I saw 12 spots, with three or more faculae intermixed. On the 17th, in the morning, I saw and recorded 12 distinct spots; but to avoid confusion I did not add them here. The Ingolstadt observation shows six, no doubt themselves fused out of more, yet through the smallness of the circle too close together to be distinguished, so that they appeared jointly as one. On the 18th the

air was thick at Rome and showed only three spots; only two at Ingolstadt for the same reason, where on the 19th three were again seen; here at Rome, because of the harshness of the sky, nothing. The 20th was cloudy in both places, yet at Rome, during a clear interval, it yielded a single spot. The 21st gave a most clear Sun, but again a single spot *a*, and produced new spots *b* and *c*, all oblong, in the position noted. Spot *c* appeared on this one day only; *b* had arisen on the 19th, was seen at Ingolstadt, and seems not to have lasted beyond three days.

[Margin: The small observation-circles are inadequate for treating this phenomenon.]

Third. Spot *a* arose together with faculae and set together with faculae; likewise it was thicker than usual, and drew behind it the trace of a tiny spot. On the remaining days bad weather scattered the sight of the spot; it seems, in fact, to have set while still in a state of growth.

[Margin: The remarkable agreement of the spots even at the greatest distances of place.]

Fourth. On the 16th, 17th, and 18th I marked the same enlarged spot *a* with a black center only, drawn round point by point at its perimeter, so that no confusion should arise with the spots of the smaller circle. You will notice that I frequently did the same elsewhere too — let this be said once for all. And on the 16th (morning), the 17th (morning), the 21st (morning), and the 22nd (morning and evening) you will find it marked by its central point alone, while the rest of its unstable retinue of small spots, from the 15th to the 18th, the Image itself displays.

Fifth. Spots *d*, four very small but vigorous northern ones, born on the Sun on the 16th, left no trace of themselves after the 17th.

IMAGO SOLIS IV [Image of the Sun IV] — folio 171

(The top of this page carries the closing point of the Notes on the Fourth Image, in two apparatus columns above the plate; the text runs continuously from the left column into the right.)

Sixth: the path of the spots still curves ever more, and the intersections of the chords (drawn perpendicular to the axis) with the Ecliptic become continuously more oblique, and the angles intercepted between the chords and the Ecliptic become smaller. Draw a chord through the station of the 15th and through the morning station of the 21st, and you will find what I say to be true.

[Margin: The direction of travel still curves, and tends from the south into the north; with the axis and the austral pole appearing, struggling out from the west toward the east, in the ascending semicircle.]

Diagram. A full-page engraved solar-disk observation plate on folio 171, of the same construction as the preceding one. The large outer "enlarged circle" carries the cardinal letters **Z** (top), **N** (bottom), **A** (left), **B** (right); a concentric inner "observation circlet" is marked **b** at its top and **d** at its bottom. The horizontal diameter through A and B is the ecliptic line.

Readable engraved labels:

- **IV. Imago Observat.** (upper left, inside; raised abbreviation-mark [?]) — "IV. Observed Image."
- **ANNO IVBILÆO, 1625. In Domo Professa Romana Societatis** — "In the Jubilee Year, 1625. In the Professed House of the Roman [Jesuit] Society."
- Central ornaments: rose, radiant **IHS** monogram with cross, rose.
- **Cursus Macularum à 13, Ianuarij ad 23. eiusdem, similis Ingolstadiano anni eiusdem, in tabula sequenti expresso.** — "Course of the spots from 13 January to the 23rd of the same, similar to the Ingolstadt [drawing] of the same year, expressed in the following table."
- **A, Oriens.** ("A, East"); **AB, Ecliptica** ("AB, the Ecliptic," with a small flourish); **B, Occidens.** ("B, West").
- **abcd, Circellus Observatorius.** — "abcd, the observation circlet."
- **AZNB, Circulus ampliatus.** — "AZNB, the enlarged circle" (split across the lower arc).
- **Ianuarij, 3.** (upper right) — "January, [image] 3."

The spots are plotted along and around the ecliptic and lettered by day and companion-letter. The day-numbers legibly run **13 through 23**; the principal spot is **a**, with companions **b**, **c**, and **d** on various days (spots *c* and *d* appear in the upper arc for days 16, 17, 21), and most positions carry an **m** (morning) or **u** (evening) marker. As on the previous plate, the individual per-spot micro-labels are numerous and finely engraved and cannot all be pinned with certainty. for exhaustive per-spot labeling.

Beneath the disk is the engraved January table (**IANVARII**), giving day (**D**), hour (**H**), and the Sun's elevation (**☉ El.**, degrees and minutes), in two side-by-side halves separated by a vertical rule with a small astronomical ornament:

D	H	☉ El. (° ')
13. u.	3.	13. 50.
14. m.	10.	20. 0.
14. u.	3½	11. 0.
15. u.	3.	14. 0.
16. m.	10⅓	22. 30.
16. u.	2⅝	15. 0.
17. m.	9⅝	19. 55.
17. u.	4⅛	5. 25.
18. m.	10.	21. 25.
20. u.	2¾	16. 30.
21. m.	9½	18. 30.
21. u.	4⅛	5. 25.
22. m.	11.	27. 5.
22. u.	2¾	16. 30.
23. m.	9¾	21. 30.

NOTAE IN QVINTAM Obseruationum Imaginem — folio 172

Notes on the Fifth Observation Image.

First. This is the first Image that I pieced together from the Ingolstadt observations of this year sent to me; and I deservedly give first place of honor to that town, because it was at Ingolstadt that this *Rosa Ursina*, sown from heaven, first struck root and was nourished by me in my chest for many years, first put out foliage, and now at last flourishes most fully at Rome.

[Margin: Ingolstadt, the birthplace of the *Rosa Ursina*.]

You will see in this Image the order and course of spots *a*, *b*, *c*, and *d*.

Second. Spot *a*, with its attendants, I have already pursued most thoroughly in my earlier Table, where one may see both the equal similarity of their paths, the like figure of the spot itself, its equal magnitude, and the same retinue of companions — which, to avoid confusion, I have transferred into the enlarged circle in neither [drawing]. But if, in the number of days or the precision of the figures, or in the accurate perception of minute details, you should here miss anything that you find in my Roman observations, ascribe it to the small observation-circles, which

fall as far short in representation, compared with the larger ones, as they do in size.

Third. Spot *b* presents the last portion of the itinerary-trace of spot *a*, marked in the third Table; compare them and you will find an admirable harmony. I certainly contemplate these things, so arranged, with the greatest pleasure, since I have altered nothing either in my own [drawings] or in those sent to me. For truth, faithfully handled, is always and everywhere like itself.

[Margin: The correspondence of the collated observations.]

Fourth. The one who observed these at Ingolstadt at my urging, and sent them to me, is Father Georgius Schönberger [Georg Schönberger], once my pupil in mathematics and now at the University of Freiburg likewise my successor in the same disciplines. His diligent industry in observing, long and repeatedly proved to me, was of no small worth to me in these observations too. Therefore, since there is such conformity of his with mine, and of mine with his, this word will surely stand in the mouth of two witnesses also before others. For I bring in these observations of another not because I distrust my own, or think there is not strength enough in them to bring out and establish the truth, but in order to satisfy the judgment of others, who asked it of me.

[Margin: The authority of others is enlisted out of others' distrust.]

For since there are very many who penetrate less deeply into the force of observations and the subtlety of mathematical arguments, and are ever afraid of impostures and deceptions on their own account, I bring, at the urging of prudent men, cares fetched from far — from others. If they perceive these to agree with mine, they will lay aside their empty fear and deceptive suspicion; and what they denied to solid reasons they will not unwillingly grant to truthful and attested authority. For that I was most faithful in bringing this out will be witnessed by the very original records, which I have kept against every eventuality and which, when reason demands, I am able and willing to display.

Fifth. Two spots of the 14th — which in the third Image [are lettered] *b*, and in this fifth *c* — were nearer to each other than on the following day, the 15th. This is well worth noting.

Sixth. Spot *d* arose on the Sun itself and was first seen on the 19th, for on the 18th it did not yet exist; it was last seen at Rome on the 21st, at letter *b*, and afterward perished, on the Sun itself.

The calculation of these observations, sent to me, disagreed either little or not at all with my own way of setting them out.

These observations, drawn within the small circle, I have enlarged proportionally, so that the likeness of the motions might stand out more clearly.

Rosa Ursina, Book III — Special Notes to the Observation-Images (Imago Solis V–VIII)

Full-page engraved plate: IMAGO SOLIS V

Diagram. A full-page engraved solar-disk plate, the fifth observation-image (*Imago Solis V*). The large outer circle is the "enlarged circle" *AZBN* (Z at top, N at bottom, A at left = East, B at right = West); a horizontal diameter *A...B* is the ecliptic line. A smaller inner circle at upper right is the "observing circlet" (*abcd*, *Circellus obseruatorius*), with **b** marked at its top and **d** at its bottom. Above center are the three emblems — a heraldic rose, the radiant IHS Jesuit monogram, and a second rose — under the dedicatory caption. The engraving records the course of the sunspots from 14 to 20 January 1625 as observed at the Academic College of Ingolstadt, matched against the Roman image of the same year. A January solar-elevation table is set into the lower right.

Readable labels and captions:

- Upper left: "V. Imago Obseruat: 4[?]" (Fifth observation-image, circle 4[?])
- Upper right: "Ianuarij. 4." (January, [circle] 4)
- Center caption: "ANNO M DC XXV. / In Collegio Academico Ingolstad: Socie[ta]tis" (In the year 1625, at the Academic College of Ingolstadt of the Society [of Jesus])
- Below emblems: "Cursus Macularum, à 14. ad 20. Ianuarij similis / Romano, anni eiusdem." (The course of the spots, from the 14th to the 20th of January, similar to the Roman [image] of the same year)
- Inner circlet: "abcd, Circellus obseruatorius" (the observing circlet)
- "A. Oriens." (A = East) — left end of the ecliptic line
- "AB. Ecliptica." (AB = the Ecliptic) — center
- "B. Occidens." (B = West) — right end of the ecliptic line
- "AZBN, Circulus ampliatus." (AZBN = the enlarged circle) — below center
- Cardinal letters: Z (top), N (bottom)

Per-spot micro-labelling along the ecliptic (three spot-tracks a, b, c, plus scattered d, each dated by day-number 14–20; the numerals are tiny and partly overlaid by verso show-through — read as follows, but the dense interior is approximate):

- Toward A (East): spots lettered **a** dated "14", "16", with a "11"/"12" pair carrying **a** and **b**, and a **d** at "20".
- Central circlet region: an encircled **a** at "17", a large **a** at "18", an encircled **a** at "19", with scattered small **d** spots; a lower row of **b** spots dated "14, 15, 16, 17".
- Toward B (West): a row of **c** spots dated "14, 15, 16, 17" (with an **a** at "20"), and below them **b** spots dated "14, 15, 16, 17".

Embedded solar-elevation table (lower right of the plate), January. Column heads "D — H — Scrup." (Day — Hour — minutes); the middle mark is u = evening (*vespere*) / m = morning (*mane*):

D (day)	u/m	H (hour)	Scrup. (min.)
14	u	12	54
15	u	2	23
16	m	10	0
17	m	10	30
18	m	10	30
19	m	10	26
20	u	1	43

NOTES ON THE SIXTH AND SEVENTH IMAGE

NOTES ON THE SIXTH and Seventh Image of the Observations

These stand of themselves in the copperplate; one must therefore proceed to the Eighth.

[*NOTAE IN SEXTAM & Septimam Obseruationum Imaginem: constat seipsis in Cupro; veniendum igitur ad VIII.* — i.e., the notes to Images VI and VII are engraved on the plate itself (following page), so nothing further is added here.]

Full-page engraved plate: IMAGO SOLIS VI · VII

Diagram. A full-page engraving presenting the sixth and seventh observation-images together, both covering the same span (26 January to 7 February 1625) so

that the two may confirm one another. The plate is framed and divided into four zones: an upper-left letterpress box of notes ("Notes on this Sixth and Seventh Image"); a large circle at upper right = Image VI; a large overlapping circle at lower left = Image VII; and a lower-right letterpress box continuing the notes. Each disk carries the rose-IHS-rose emblems, a dated observation-caption, embedded January and February solar-elevation tables, and a spot-track diagram along its ecliptic (A = East at left, B = West at right; Z top, N bottom).

Readable captions:

- Top strip: "Obseruationum Imago, VI. et VII. à die 26. Ian: ad 7. Feb." (Observation-image VI and VII, from 26 January to 7 February)
- **Image VI (upper-right circle):** "Obser: Imago VI."; corner date "5. Ianuarij / 1^a. Februarij"; top "Z / 1625 / In domo Professa Rom[an]a societ[atis]" (In the Professed House of Rome of the Society); "Cursus Macularum a 26. Ianuarij ad 7^m Februarij." (The course of the spots from 26 January to the 7th of February); "A. Oriens.", "B. Occidens."
- **Image VII (lower-left circle):** "Obseruation: Imago VII"; corner date "6 Ianuarij / 2 Februarij"; top "Z / M. DC. XXV. / In Domo Professa Rom[an]a Societ[atis]"; "A. Oriens.", "AB. Ecliptica.", "B. Occidens."

Along both ecliptics the spots are lettered a/b/c/d and dated by day (26–31 January, 1–7 February), with small m/u marks (morning/evening) beside many; the per-spot micro-labels are tiny and overlaid by verso ghosting.

Letterpress notes on this Sixth and Seventh Image (upper-left box, continued in the lower-right box):

1. I have not enlarged them, because they display the matter well enough by themselves.
2. I have set both images embracing the same courses and days, so that it might appear how well each of the two performs the same task, and how solidly the one confirms the other — which I could do throughout the whole series of images if it were necessary. [3?] Again, from this you will see how much more, and more accurately, the larger circles present [the phenomena] than the smaller ones, if you compare these observation-images with the Ingolstadt and Douai ones that follow, etc.
3. You will find four courses in each image, of the spots a, b, c, d; which, although observed and recorded at different hours and in different circles, [de-]scribed similar and proportional motions — as will be clear to anyone who considers it, and as will shine forth more plainly in Table VIII.

4. Spot a gradually diminished after mid-passage; b remained in nearly the same state; both were fertile in nuclei. c vanished before the end, d around the middle. At its rising b somehow touched the horizon; around the ingress there were some facula-like spots, especially c on the 29th day, in whose place, around mid-passage, new spots succeeded, and again toward the end they seem to have faded into faculae. Consult the following images.
5. At the observations of the 26th, 28th, and 29th days, Fr. Grienberger [Grienberger] was present, and by design contemplated the notable faculae together with me; nor were other spectators lacking.
6. Spot b advanced beneath the Sun ($\odot$) for more than twelve days.

Embedded solar-elevation tables. Column heads "D — H — $\odot$ El." (Day — Hour — Sun's elevation, in degrees and minutes); u = evening, m = morning. Fractions are on the hour-value.

Image VI — January (26 Jan onward):

D	u/m	H	$\odot$ El.
26	m	10 13/16 [?]	26.45
27	m	10 4/5 [?]	28.0
28	m	10 1/5 [?]	25.0
29	m	9 7/8	22.10
31	m	9 3/4	22.25
31	u	4	9.15

Image VI — February:

D	u/m	H	$\odot$ El.
1	m	9 3/4	22.30
1	u	4	8.40
2	u	1 7/8 [?]	25.15
3	m	10 3/8	26.20
4	u	3 1/2	15.0
5	m	10 7/8 [?]	30.0
6	m	10 2/5 [?]	27.30
7	m	10 5/8 [?]	29.10

Image VII — January:

D	u/m	H	☉ El.
26	m	9 7/8	21.25
27	m	9 3/8	18.20
27	u	3 1/2	15.20
28	m	9 3/7 [?]	19.10
28	u	3 1/8 [?]	16.0
29	m	9 1/2	21.10
29	u	3 3/7 [?]	11.0
31	m	9 1/2	21.30
31	u	3 3/4	10.40

Image VII — February:

D	u/m	H	☉ El.
1	m	9 1/2	21.0
2	u	1 1/4	29.0
3	m	9	17.0
4	m	9 1/3 [?]	19.30
5	m	9 2/5 [?]	20.0
6	m	9 1/5 [?]	19.40

NOTES ON THE EIGHTH IMAGE

NOTES ON THE EIGHTH Image of the Observations — the seventh of January and the third of February; from the 26th of that [month] to the 7th of this [one]

[The centered "I." and "II." mark the two text columns; the marginal 5, 10, 15 ... 35 are line numbers — cross-reference apparatus, not section divisions. The substantive enumeration is *Primo ... Octauo.*]

First: this is the first [image] on the scale of this [larger] circle — yet not entirely, for the January days were still observed on the scale of the circle of Image VII, and I have accordingly transferred those observations here proportionally. The February [spots], however, on the scale of this circle, are drawn directly from the Sun itself. Hence —

Second: the proportion of the magnitudes, the positions, and the paths relative to one another is manifestly fitting to the senses, exactly as if it had been carried through on one and the same circle, and not pieced together from different observing circles — from which the soundness of the observations shines out.

Third: moreover, the mutual concord of the Ingolstadt, Douai, and Roman observations is evident. And if a small discrepancy of theirs from mine occurs here and there, do not be surprised; for in such laborious modes of observing — the Sun always slipping away — it is [hard] always to agree to a hair's breadth about the same spot. Something, then, must be forgiven to observers so far distant from one another, if now and then, over so many observations and spots, they differ a little — in a matter so slippery, and on circlets so tiny that they easily lend themselves to error, especially if someone, by design (as they [do] rather often), pursues one spot while attending only in passing to the rest. [Margin: Something must, in fairness, be forgiven to one who occasionally, through carelessness, is somewhat negligent in this material most difficult to investigate.]

Fourth: it is clear how the curvature of the paths, and the inclination of the chords to the ecliptic, always increases. [Margin: The curvature and inclination increase.]

Fifth: how spot a, after 29 January, cut the ecliptic ascending, and again after the 4th day of February cut the same descending — and so it passed from southern to northern. [Margin: The same spot, in the same course, becomes southern and northern, approaches the ecliptic and recedes from it.]

Sixth: how spot b, over several days, in a manner grazed the same ecliptic; and how this spot's path or track drew near, at mid-passage, to the path of spot a; and how it was farther from that [path] around the ingress than around the exit — which is well worth noting. [Margin: The advances of the spots are not parallel to one another.]

Seventh: how the southern spot C entered the Sun together with a facula on the 27th day; and again, around its exit on the 6th of February, it displayed in the same regions far brighter faculae, although it had by then been almost wholly consumed and did not afterward reach the western edge.

Eighth: how the slenderness of the spots — that is, their apparent length, which is acquired from their position and situation — ordinarily conforms to the bending and flow presented by the parallel circles running from the center C through the centers of the spots; unless at times the very bulk of the spot, running off in another direction, resists. This [slenderness], nonetheless, near the horizon —

where the declivity of situation and the thinness of the spots prevail — is almost always corrected. You have an example in spot b itself, which on days 2, 3, 4, and 5 was governed by its native length; but on other days, nearer the horizon, it conformed to its situation as though parallel to it. In rounder spots this behavior is always certain and stable. [Margin: The slenderness of round spots always occurs according to circles described from the center of the Sun, such that the diameter of the slenderness lies on the chord subtending the arc of those circles. Non-round ones do the same in their own measure.]

IMAGO SOLIS VIII.

Diagram. A full-page engraved plate of the solar disk — the eighth in the observation-image series — drawn as a large circle across which a horizontal diameter, the ecliptic, is ruled from the left edge to the right edge. Inside the upper register is a printed cartouche flanked by two heraldic rose ornaments with the Jesuit IHS radiant emblem between them.

Cartouche text, left to right:

- Upper left: **VIII. Imago Obseruationum** ("VIII. Image of the Observations").
- Upper center: **Anno Iubilaeo. M.DCXXV. In Domo Professa Romana Societatis** ("In the Jubilee Year 1625. In the Professed House of the Society at Rome").
- Upper right: **Ianuarij. 7. / Februarij. 3.** (the image corresponds to 7 January / 3 February).
- Below the emblems, running across: **Cursus Macularum à 26. Ianuarij. ad 7. Februarij, similis Ingolstadiano et Duacensi.** ("The course of the spots from 26 January to 7 February, similar to the Ingolstadt and Douai [observations].")

Cardinal and axis labels:

- **z** — small mark at the top of the circle (north point).
- **N** — at the bottom of the circle (south point).
- Left end of the horizontal diameter: **A** — labeled **A. Oriens** ("A, the East").
- Right end: **B** — labeled **B. Occidens** ("B, the West").
- Along the diameter, center: **A B, Ecliptica** ♎ ("A B, the Ecliptic," with the Libra sign).

Sunspots are plotted as small dark blots strung along and just below the ecliptic in several parallel tracks lettered **a, b, c, d** (lowercase), each blot tagged with a day-number (Jan 26, 27, 28, 29, 31; Feb 1–7) and a small subscript **m** (morning) or **u** (evening). The individual per-spot micro-labels (letter + date + m/u) are at the limit of legibility and mostly illegible even under magnification — the readable day-numbers run 26–31 (January) on the eastern half and 1–7 (February) on the western half. Several small paired/clustered spot figures also appear off the main line. [Many micro-labels [?].]

Two observation tables are printed in the lower quadrants of the disk. Columns: **D** (dies, day), **H** (hora, hour), **☉.El** (*Solis Elevatio*, the Sun's altitude, in degrees and minutes). Day-numbers carry **m** = morning, **u** = evening.

Ianuarii (January):

D	H	☉.El
26. m.	9 $\frac{7}{8}$	21. 25.
27. u.	3 $\frac{1}{5}$ [?]	15. 20.
28. u.	3 $\frac{1}{6}$ [?]	16. 0.
29. u.	3 $\frac{2}{3}$	11. 0.
31. u.	3 $\frac{3}{4}$	10. 40.

Februarii (February):

D	H	☉.El
1. m.	9 $\frac{1}{2}$	21. 0.
2. u.	1 $\frac{1}{5}$ [?]	26. 30.
3. m.	10.	24. 30.
3. u.	2 $\frac{3}{4}$	20. 40.
4. m.	9 $\frac{5}{6}$ [?]	24. 10.
4. u.	3	18. 0.
5. m.	9 $\frac{7}{8}$	24. 40.
6. m.	10.	25. 30.
6. u.	3 $\frac{1}{4}$	17. 20.
7. m.	9 $\frac{1}{2}$	21. 15.
7. u.	3 $\frac{2}{5}$ [?]	16. 40.

NOTAE IN NONAM

Notes on the Ninth image of the observations — the eighth of January and the fourth of February; from the 26th of that month to the 7th of this.

First. As I indicated earlier, these observations were made at Ingolstadt at my request by Father Georg Schönberger [Georg Schönberger], once my pupil in mathematics, but at the time I asked them of him a pupil of others in theology. When our Superiors judged that granting them served both obedience and this use of mine, he made them for the public good and sent them to me one by one, each drawn to the size of the small circle *a b c d*, with the ecliptic *b d* laid in across each observation. I then gathered them all into a single small circle with the utmost care and fidelity, and enlarged that into the circle **E Z F N**, equal to the circle of my own observatory, so that the likeness and equality of the sizes, positions, shapes, and paths would become visible — as you will readily see happens well enough if you compare the images with one another, and the principal spots. For what I chiefly aim to prove from these is the likeness of the apparent motion in its perceptible curvature or straightness; finer details than these cannot — indeed must not — be drawn out exactly and precisely from such tiny little circles.

Second. To avoid errors, I marked the enlarged principal spots **A** and **B** with solid black centers, ringing each about at its perimeter with a continuous line of small dots that express the apparent outline and shape of the spot, and to the spots themselves I attached capital alphabetic letters.

Third. I have decided to append certain things word for word from the ephemerides of Father Schönberger. He says, then: On 29 January, spots could be noted, which were followed by brighter ones, almost like a shadow, partly as ** faculae, partly more like shadows. And to 5 February. On the fourth spot [Mac. 4], from 31 January right up to this day, no observation was had, on account of clouds and rain. To 6 February: only three spots were in use, and after the third there followed four faculae, just as also at their rising; but the position of these faculae could not be accurately determined. Thus far he. Here you see how greatly he is surpassed by my own observations, owing to the smallness of his observing circles. You will therefore find a fuller count of spots and faculae — and their shape, position, and proportional size as well — in my observations, especially in Table VI, at spots *d* and *c*, and likewise in the preceding image.

The facula **G** in the enlarged circle (g in the small circle), noted here toward the north on 6 February, you will find in my Twelfth image of the observations at the same day, in a place and proportion answering to my observations — so that you may see how great a harmony of this phenomenon is found across such great intervals of position; especially since the observer denies that he received an accurate determination at Ingolstadt at that time. Nonetheless, you may infer from this that faculae are seen in different places in the same way as the spots, and undergo no difference of aspect. As for why a precise and distinct view of the faculae is difficult — the reason is the likeness of the surrounding solar light to the faculae, their usual faintness in shining forth, and their poorly defined edge, which blends by degrees into the rest of the light without any notable difference.

[Margin: Faculae, like the spots, are carried along [*mouentur*], and undergo no difference of aspect.]

Fourth. Just as I left the central positions of these observations untouched, so in shaping the figures I have frequently added something of my own. I did not want this hidden from you. But you may safely take my figures as correct.

IMAGO SOLIS IX.

Diagram. A full-page engraved plate of the solar disk — the ninth in the observation-image series. Two concentric circles are drawn: a small inner "observing circle" and a large enclosing "enlarged circle," with a horizontal diameter, the ecliptic, ruled across from the left edge (**E**) to the right edge (**F**). An upper cartouche with the two rose ornaments and the IHS radiant emblem appears between them.

Cartouche text:

- Upper left: **IX. Obseruationum Imago** ("IX. Image of the Observations").
- Upper center: **M.DC.XXV. In Collegio Academico Ingolstadiano Societatis** ("1625. In the Academic College of the Society at Ingolstadt").
- Upper right: **Ianuarij. 8. / Februarij. 4.** (the image corresponds to 8 January / 4 February).
- Below: **Cursus Macularum à 27 Ianuarij, ad 6. Februarij, similis Duacensi et Romano.** ("The course of the spots from 27 January to 6 February, similar to the Douai and Rome [observations].")

Reference-circle labels:

- **abcd, Circelli obseruatorius** ("a b c d, the observing circle") — the small inner circle, with **a** at top, **b** at left, **c** at bottom, **d** at right.
- **ENFZ, Circulus ampliatus** ("E N F Z, the enlarged circle") — the large outer circle.

Cardinal and axis labels:

- **z** — mark at the top of the outer circle (north point).
- **N** — at the bottom (south point).
- Left end of the diameter: **E** — labeled **E. Oriens** ("E, the East").
- Right end: **F** — labeled **F. Occidens** ("F, the West").
- Along the diameter: **E F, Ecliptica** ("E F, the Ecliptic").
- **G / g** — a facula figure marked at the upper left, outside/near the inner circle (the facula G discussed in the notes).

Sunspots are plotted along and just below the ecliptic in parallel tracks, the principal spots lettered **A, B, C, D** (capitals), each tagged with a day-number (Jan 27, 29, 31; Feb 1–6) and small **m/u** subscripts; some spots have the solid black center with a dotted outline described in the notes. The dense per-spot micro-labels (letter + date + m/u) are largely at the resolution floor. [Several micro-labels [?]]

Two observation tables appear in the lower quadrants. Columns: **D** (day), **H** (hour); day-numbers carry **m** = morning, **u** = evening.

Ianuarii (January):

D	H
27. u.	12. 56.
29. m.	11. 54.
31. u.	12. 43.

Februarii (February):

D	H
5. m.	8. 40.
6. m.	8. 45.

[The following leaf is a second scan of the same "NOTAE IN NONAM" page already translated above; its letterpress content is identical and is not re-translated. See QA report.]

IMAGO SOLIS IX

Diagram. Full-page engraved solar-disk plate, the ninth image of the observation series. A large circle represents the solar disk; a concentric smaller circle at center is the "enlarged circle" (*circulus ampliatus*) in which the spots are drawn at magnified scale. A horizontal diameter runs left-to-right across the disk as the ecliptic (E–F). Spots are plotted along the ecliptic path at successive dates, lettered A, B, C, D with day-numbers, and are shown both on the main disk and, magnified, within the inner circle.

Header and legends (readable):

- Top left, inside the disk: "IX. Observationum Imago." (The ninth image of the observations.)
- Top center: "M.DC.XXV." (1625)
- Top right, inside the disk: "Ianuarij. 8." / "Februarij. 4."
- "In Collegio Academico Ingolstadiano Societatis." (In the Academic College of the Society [of Jesus] at Ingolstadt.)
- Central emblem band: a heraldic rose, the IHS Jesuit monogram in a sunburst, and a second heraldic rose.
- Below: "Cursus Macularum à 27. Ianuarij, ad 6. Februarij, similis Duacensi et Romano." (The course of the spots from 27 January to 6 February, similar to the Douai and Roman [series].)
- Left, below the "G" mark: "abcd, Circellus observatorius." (abcd, the observation circlet.)
- Right: "ENFZ, Circulus ampliatus." (ENFZ, the enlarged circle.)
- Bottom center, on the ecliptic diameter: "E F, Ecliptica." (E F, the ecliptic.)

Cardinal / circle labels:

- Outer disk: "E. Oriens" (E, East / rising, at left) — "F. Occidens" (F, West / setting, at right).
- Enlarged inner circle ENFZ: "Z" at top, "N" at bottom, "E" at left, "F" at right.
- Inner observation circlet abcd: "a" at top, "b" at left, "c" at bottom, "d" at right (its diameter b–d lying on the ecliptic).
- "G" with a small facula symbol at upper left of the disk (with a subscript numeral, "6" [?]).

Plotted spots (readable labels; the crowded micro-lettering of the inner circle is at the scan resolution limit — see flags):

- East / left arm of the ecliptic (outer disk): A·27, A·29 (on the ecliptic); B·27, B·29; C·29; D·29 — each with a small spot figure.
- Center (enlarged inner circle): a spot cluster near the top center marked "5" / "S"; near the ecliptic "A" and "·31"; to the left "b", "B·27", "B·31"; grouped micro-labels a, b, c, d with day-numbers 29 and 31 [several individual day-numerals in this cluster: ?]; below the ecliptic "C" and "D·31"; "d".
- West / right arm of the ecliptic (outer disk): "A·31" (near center-right), "A" (on the ecliptic, far right); "B·5", "B·6"; "C·5", "C·6" — each with a small spot figure.

Embedded observation tables (day / hour of each observation; u = evening, m = morning):

Ianuarij (January)

D. (day)		H. (hour)	
27	u.	12	56
29	m.	11	54
31	u.	12	43

Februarij (February)

D. (day)		H. (hour)	
5	m.	8	40
6	m.	8	45

NOTAE IN NONAM

Notes on the ninth image of the observations, [that] of the eighth of January and the fourth of February, from the 26th of that [month] to the 7th of this one

I.

First: these observations were made — as I intimated earlier — at my urging, at Ingolstadt, by Father Georg Schönberger, formerly my pupil in mathematics but now, when I requested them from him, a teacher of others in theology.

Nevertheless, with the approval of the Superiors, out of deference and for this use of mine, he transmitted them to me — observed for the public good, and drawn

individually on the scale of the circlet a b c d, with the ecliptic b d entered into each observation. I therefore reduced them all into a single circlet with the utmost care and fidelity, and enlarged them within the circle E Z F N, equal to my own observatory circles, so that the similarity and equality of their magnitudes, positions, figures, and paths would be apparent. You will grasp well enough that this comes out right if you compare the images among themselves and their primary spots. For what I chiefly aim to prove from these is the similarity of the apparent motion in its perceptible curvature or straightness; finer details than these ought not to be drawn out of these small circlets exactly and precisely — indeed, they cannot be.

Second: to avoid errors, I marked the enlarged primary spots A and B with black centers on the Sun, enclosing their perimeter with a continuous ring of tiny dots that express the apparent figure of the spot, and I attached to the spots themselves the larger alphabetical characters.

Third: I have decided to append certain things verbatim from the ephemerides of Father Schönberger. He puts it thus: On 29 January, spots could be noted, which were followed by others, [these being] nearly like shadow, brighter; partly as **

II.

- - o faculae, partly more like shadows. And up to the 5th of February. On the 4th, [there were] spots. From 31 January up to this day, no observation was possible because of clouds and rain. On 6 February, only 3 spots were seen, and after the third there followed 4 faculae, just as also at their rising, though the location of these faculae could not be accurately marked. Thus far he.

Here you see how far my observations are surpassed by the smallness of the observatory circles. You will therefore find a fuller number of spots and faculae — and their figure and situation too, with proportional magnitude — in my own observations, especially Table VI, at spots d and c, and likewise in the previous image.

The facula G in the enlarged circle, g in the small circle, noted here as toward the north on 6 February, you will find in my Twelfth image of the observations for the same day, in a place and proportion answering to my observations — so that you may see how great a harmony of this phenomenon is found across such intervals of place; particularly since the observer denies that he received an accurate designation of it at that time at Ingolstadt. Nonetheless, you may

conjecture from this that faculae, like spots, are seen in the same manner in different places, and do not undergo any difference of aspect. As for why a sharper and more distinct view of faculae is difficult, the reason is the likeness of the solar light surrounding the faculae, and the fact that in shining forth these faculae are generally faint, and their edge poorly defined, which is imperceptibly blended into the surrounding light without any notable difference.

Fourth: just as I left the central areas of these observations intact, so too I have frequently added something of my own to the shaping of the figures. I did not want this to escape you. But you may safely take my figures as sound.

[Margin: The faculae move like the spots, and undergo no difference of aspect.]

IMAGO SOLIS IX (duplicate scan)

NOTAE IN DECIMAM

Notes on the tenth image of the observations, [that] of the ninth of January and the fifth of February, from the 26th of that [month] to the 7th of this one

I.

First: Father Carolus Malapertius [Charles Malapert] of our Society, once — after I had published my "Apelles" — while passing through Ingolstadt on his way into Poland, learned from me the appearance of the spots and the method of observing them, together with entrusting the marking-plumb to the Sun, [a matter] confided to him out of singular friendship. Afterward, passing that way again, he received the method of imposing the ecliptic from my pupil Father Ioannes Baptista Cysatus [Johann Baptist Cysat], who had earlier been taught the same things by me — [received it] with the same caution and fidelity with which I had once handed it on to Cysat. So Malapert himself, meaning to repay me in kind for the favor, sent me at Rome — at my request — some observations he had made at Douai. These I have set out for you, digested with the greatest labor into order and into a single circlet a b c d, most faithfully — both so that I may repay his kindness with a grateful service, and so that I may add greater weight to the truth and the phenomenon among those who are moved more by authority than by reason, if it is confirmed by so many and such clear consenting studies of others.

I rendered the spots under the figure of a little star, a circlet, a triangle, and a square, so as to avoid confusion. Then I wrote beneath the observations the day-numbers, just as he himself sent them to me; for on the 9th and 31st of January ** the hour had not been added; on the 2nd and 5th of February the Sun's elevation was lacking. I therefore altered nothing, but faithfully passed on to others exactly as I received it.

II.

Second: the same Father writes to me, [under date of] 3 April 1625, that he always makes it his practice to fix on one principal spot in any cluster of spots — as, in the appended figure, was the case for him with spot A, of which, up to the 31st [day], he says thus: *The lower part of the spot touched the center itself. The same [spot] was observed on the same day, when the meridian altitude was 6 degrees. From which you may gather that this part really was next to the center itself.* Thus he. And he says that the longitude of the Douai location is 24 [degrees] and its latitude about 50° 30'. I therefore, having laid these things out in my own manner, have found — by the situation and order in which I present them — and I marvel at, so great an agreement with my own and the Ingolstadt [observations]. He himself set down only the centers of the spots; from these I in turn [worked them up] into proportioned shapes. Those [centers] I did not wish to draw apart — although, had I wished, I could have done so by my own [methods].

Third: again from this you may see that the arc of this spot A's course crossed the ecliptic twice, just as you see happened at Rome and at Ingolstadt as well.

Fourth: it is plain from these observations of three places so far apart that this spot, like all the rest, had no parallax.

[Margin: The spots lack parallax.]

Diagram. Full-page engraved solar-disk plate, the tenth in the observation series, headed **IMAGO SOLIS X** (Image of the Sun X) with the printed folio number **181** at the upper right. The plate records the course of the sunspots at Douai from 26 January to 7 February 1625. It also appears as a second, identical scan

Layout, from the readable engraved labels:

- Upper left: **X. Obseruationum Imago** — "Image of the Tenth [set of] Observations."
- Upper center: **M.DC.XXV. Duaci, in Collegio Societatis** — "1625. At Douai, in the College of the Society [of Jesus]." Below this heading, two rose ornaments flank the Jesuit **IHS** sunburst device.

- Upper right: **Ianuarij. 9. / Februarij. 5.** — "[the] ninth [image] of January; [the] fifth [image] of February" (the image's place in each month's own observation sequence).
- Center-upper caption: **Cursus Macularum, à 26. Ianuarij, ad 7. Februarij, similis Romano et Ingolstadiano, anni eiusdem.** — "The course of the spots, from 26 January to 7 February, similar to the Roman and Ingolstadt [images] of the same year."
- Below that: **a b c d, Circulus obseruatorius Duacen[us].** — "a b c d, the Douai observatory circle" (the inner circle).
- Cardinal/frame labels: **Z** at the top and **N** at the bottom of the outer circle; **E** at the left end and **F** at the right end of the horizontal diameter. **EFZN, Circulus ampliatus** — "EFZN, the enlarged circle." **E, Oriens. F, Occidens; E F, Ecliptica** — "E, East; F, West; EF, the ecliptic."

Across the horizontal ecliptic band runs the dashed path of the spots on successive days. The spots are marked with a repeating set of symbols, each carrying a subscript day-number: **A** (star $\star$), **B** (circled dot $\odot$), **C** (inverted triangle ∇), **D** (square $\square$), together with a parallel set of lowercase marks **a, b, c, d**. The legible subscript day-numbers run 26, 28, 31 (January) and 2, 3, 5, 6, 7 (February), matching the two data tables below. Readable individual placements include, moving from E (east) toward F (west): $A\star_{26}$, $A\star_{28}$, $B\odot_{28}$ and a_{26}/b_{28} (the January group at left); $B\odot_{31}$, $C\nabla_{31}$, $D\square_{31}$ (the 31 January cluster near the inner-circle edge); then across the February span $A\star_2$, $A\star_3$, $A\star_5$ on the ecliptic line, with $B\odot_2$, $B\odot_3$, $B\odot_5$, $B\odot_6$, $B\odot_7$ below, and $C\nabla_2$, $C\nabla_3$, $C\nabla_5$ lower still. The interior spot subscripts are engraved very small and densely overlapped; several individual date-marks could not be resolved one-to-one and are not committed here [?].

Two observation tables are engraved at the lower left and lower right within the disk.

Ianuarij (January). Columns: **D.** (day) | **H.** (hour) | $\odot$ **Eleu.** (Sun's elevation).

D. (day)	H. (hour)	$\odot$ Eleu. (elevation)
26. u.	2½	14. 0.
28. u.	—	10. 0.
31. u.	—	6. 0.

Februarij (February). Columns: **D.** | **H.** | $\odot$ **Eleu.**

D. (day)	H. (hour)	☉ Eleu. (elevation)
2. u.	12½	—
3. u.	2	18. 0.
5. u.	1	—
6. m.	11	24. 0.
7. u.	—	10. 0.

[The recto facing this plate carries the letterpress **NOTAE IN DECIMAM obseruationum Imaginem, Ianuarij nonam, & quintam Februarij, à 26. illius, ad 7. huius.** — the notes on this tenth image (Malapert's Douai observations, spot A, the no-parallax conclusion). It is a duplicate scan of folio 180 already presented; its text is not re-translated here. See the QA report.]

Notes on the Eleventh Image of the Observations — the sixth [image] of February — from day 1 to day 13 of the same [month]

I. The apparent motion still curves gradually and by degrees, and the chords subtended by points equally distant from center C along the path-arc cut the ecliptic AB ever more obliquely.

[Margin: The curvature of the arc, and the obliquity of the chords to the ecliptic, increase.]

II. This spot a began to cross the ecliptic around day 6, and on the 7th, 8th, and 9th advanced above it into the northern region; on day 10 it crossed the ecliptic again into the southern parts, and thereafter drew ever farther away from it.

III. Around its rising and setting it dragged a southern facula behind it. Thus around mid-course it took on a northern spot, held it for several days, and at setting displayed a facula in its place.

IV. On day 10 there appeared before it two new spots, almost touching one another, together with a great retinue of tiny surrounding spots (which I deliberately omitted); and it sent those two on ahead, all the way to their setting, as can be seen from the figure.

V. These two leading spots gradually merged, and it thus came about that toward setting they appeared denser and thicker than the following spot. Moreover —

and this deserves special note — on day 10 the interval between them was smaller than on the 12th, as is plain to anyone who looks; and I attended to this deliberately while observing. This appearance is quite frequent, indeed ordinary.

[Margin: The spots near the horizon apparently press toward one another by mutual encounter.]

[Margin: The intervals between the spots, widened.]

VI. The passage of spot a beneath the Sun, from day 1 to day 13, ran to twelve full days; but if you take into account the eastern and western space between the spot and the horizon, that adds more than a further day, so it is certain that this spot passed beneath the Sun for more than 13 days. Its course is similar and equal to that of spot a shown in Image 58, drawn for the year 1626, from 2 February to the 14th, which you may consult.

[Margin: Lingering beneath the Sun beyond 13 days.]

VII. Note too that the bright space between the two spots a, interposed on day 12, appeared nearly half as much when set between the same spots on the evening of day 13.

VIII. On the evening of day 13 the westernmost spot so grazed the horizon that it could be distinguished from it only as a most confused and most faint whitish line — and that only apart from its motion. And in this way it clung to the horizon for two hours, as I had often surveyed the same before this observation.

[Margin: It clings to the horizon for many hours.]

IX. The small lines drawn out from a into the spots indicate which spots belong to the forenoon [antemeridian] and which to the afternoon [postmeridian] time.

X. The company of small spots that appeared on day 10 did not reach the end and exit [of the disk].

XI. With these observations made by me at Rome — and with the emergence of new spots noted on day 10 and their departure recorded on the following days — the Ingolstadt observations also agree, adduced in the eighteenth Table of observations. Among these I would have you examine closely the first side-table, where, under the letter a, you will find the courses and recessions of these same spots greater after the tenth day, just as in my own. For on day 12, and much more on the 11th, the spots stood farther apart from one another than on the 10th; indeed on the 11th too you have the small southern and northern spots noted, of the same kind that had shown themselves in my designations on day 10

— so that it is remarkable they could be discerned within so tiny an observation circle. But that both observers, in one and the same matter, at so great a distance of places and with such different observatory circles, worked correctly in setting things down proportionally, is proved by the continuous experience of the following observations, and by the unbroken tenor of the phenomenon — according to which you will see newly born spots always diverge from one another beyond expectation.

XII. Hence, once again, the strongest argument is drawn: that this phenomenon has no parallax relative to the Sun — that is, no diversity of aspect.

[Margin: No parallax in this phenomenon.]

IMAGO SOLIS XI

Diagram. A full-page engraved plate showing the solar disk as a large circle, headed **IMAGO SOLIS XI.** with the folio number **194** to the right. The Sun is drawn as a circle marked **z** (Zenith) at the top of its rim and **N** (Nadir) at the bottom; a horizontal diameter labelled **A** at the left and **B** at the right is the ecliptic line, along which the successive positions of a single sunspot (macula **a**) are engraved with day-numbers and morning/evening tags.

Legends set within the disk:

- Upper left, outside the printed panel: **XI. Obseruationum Imago** — "Image of the eleventh of the observations."
- Upper right: **Februarij. Sexta.** — "[The] sixth [image] of February."
- Center top, above two rose ornaments flanking the IHS emblem of the Society of Jesus: **ROMÆ, ANNO IVBILÆO M.DC.XXV. In domo Professa Societatis** — "At Rome, in the Jubilee Year 1625, in the Professed House of the Society [of Jesus]."
- Below the emblems: **Cursus Maculæ à primo Februarij, ad 13 eiusdem.** — "The course of the spot from the first of February to the 13th of the same [month]."
- **AB. Ecliptica: A Oriens Macularum, B Occidens; Z, Zenith, N, Nadir.** — "AB, the ecliptic: A the east of the spots, B the west; Z the zenith, N the nadir."
- **Similis est Ingolstadiano, in Tabella Lateralī 1^a expresso.** — "It is similar to the Ingolstadt [image], rendered in the first side-panel."

Spot positions engraved along the ecliptic AB (left = A/east to right = B/west), each drawn as a small blot lettered **a** with its day-number below and, where present, a morning (**m**) or evening (**u**) tag:

- Far left, below the line: **a 1, a 2**
- **a 3, a 4, a 5, a 6**
- **a 7**, at the centre **C**
- At centre-right, a cluster tagged **a / u** over **m 8** (day 8)
- **a 10** (a small cluster just right of centre)
- Toward **B**: **m. 13** (upper), and a cluster **a / u 12, a / u. 13**, with a further **a**

Day-tags 9 and 11 are not separately lettered among the readable spot positions. [Several of the micro-labels near B are crowded and partly abraded]

Embedded observation table (engraved on the plate beneath the emblems), headed **FEBRVARII** ("[Of] February"), in two side-by-side panels; columns **D** (day), **H** (hour, with m = morning / u = evening), ☉. **Ele.** (the Sun's elevation, in degrees and minutes):

D (day)	H (hour)	☉ Elevation
1	4 u	8° 40'
2	1 ² / ₅ u [?]	26° 20'
3	10 m	24° 30'
4	9 ⁵ / ₈ m	24° 10'
5	9 ⁷ / ₈ m	24° 40'
6	10 m	25° 30'
7	10 ¹ / ₈ m	26° 30'
8	10 ¹ / ₂ m	29° 40'
8	3 ³ / ₄ u	14° 30'
10	10 ² / ₃ m	30° 20'
12	3 ¹ / ₈ u	20° 25'
13	10 ⁵ / ₈ m	31° 10'
13	3 ⁴ / ₅ u	13° 40'

ROSAE VRSINAE LIB. III.

Notes on the Eleventh Image of the Observations — [the] sixth of February — from the 1st to the 13th of the same [month]

[Margin: The curvature of the arc, and the obliquity of the chords to the ecliptic, increases.]

First. The apparent motion still curves ever more, and continuously; and the chords that subtend the itinerary-arc through points equally distant from the center C cut the ecliptic AB always more obliquely.

Second. This spot **a** began to cross the ecliptic around day 6, and on the 7th, 8th, and 9th it advanced above it into the northern region; on day 10 it again passed over into the southern parts, and thereafter withdrew ever farther from the ecliptic.

Third. Around its rising and its exit it trailed a southern facula behind it. Likewise, around mid-course it acquired a northern spot, kept it for several days, and at its exit displayed a facula in its place.

Fourth. On day 10 it showed before itself two new spots, almost touching each other, together with a great retinue of tiny surrounding ones (which I have deliberately omitted); and it kept sending those two ahead all the way to the exit, as one may see from the illustration.

[Margin: The spot near the horizon, by mutual convergence, apparently intensifies itself.]

Fifth. Those two leading spots gradually merged, and hence it came about that toward the exit they appeared denser and thicker than the following spot. Moreover — and this deserves particular notice — on day 10 the interval between them was smaller than on day 12, as is evident to the observer; and I attended to this point deliberately while observing. This appearance is quite frequent, indeed the normal case.

[Margin: The intervals between the spots enlarged.]

[Margin: A stay under the Sun beyond 13 days.]

Sixth. The passage of spot **a** across the face of the Sun, from day 1 to day 13, took a full twelve days; and if you take into account the eastern and western span between the spot and the horizon, that will make it more than a day longer — so it is certain that this spot traveled beneath the Sun for more than 13 days. Its course is similar and equal to that of the spot **a** shown in Image 58, for the year 1626, from 2 February to the 14th, which you are free to consult.

Seventh. Note also the bright space set between the two spots **a** on day 12: on day 13, with the same [spots] placed one against another in the evening, it appeared nearly half as much less.

[Margin: For many hours it clings to the horizon.]

Eighth. On the 13th, in the evening, the westernmost spot so grazed the horizon that, apart from a most confused and exceedingly fine whitish streak — and that quite apart from its motion — it could not be made out; and in this manner it clung to the horizon for two hours, just as I have often surveyed the same thing before this observation.

Ninth. The little lines drawn out from **a** into the spots indicate which spots belong to the forenoon and which to the afternoon time.

Tenth. The company of small spots that appeared on day 10 did not reach the end and exit.

Eleventh. With these things observed by me at Rome — and with the emergence of new spots noted around day 10, and their departure noted on the following days — the Ingolstadt observations agree as well, presented in the Table of Eighteen observations. In these I should like you to examine closely the first side-panel, where you will find that the course and recession of these same spots, under the letter **a**, grew larger after the tenth day, just as in mine. For on day 12, and much more on the 11th, the spots stood farther apart from one another than on the 10th; indeed, on the 11th too you have the small southern and northern spots noted, of the kind that had disclosed themselves in my own designations on day 10 — so that it is remarkable they could have been noticed within so tiny an observing circle. That both observers, in one and the same matter, at so great a distance of place and with such differing observing circles, went to work correctly in setting down things proportionally, is proved by the continuous experience of the following observations, and by the unbroken tenor of the phenomenon, according to which you will see the newly-emerged spots always draw apart from one another beyond expectation.

[Margin: No parallax in this phenomenon.]

Twelfth. From this, again, is drawn the greatest argument that this phenomenon has no parallax with respect to the Sun, that is, no diversity of aspect.

IMAGO SOLIS XI

Diagram. [Duplicate scan of the same engraved plate transcribed above (fig-p293-1) — IMAGO SOLIS XI]

ROSAE VRSINAE LIB. III.

Notes on the Twelfth Image of the Observations — [the] seventh of February — from the 5th to the 23rd of the same [month]

[Margin: The inadequacy of the small observing circles is proved by the fact itself.]

First. Here you have nearly the whole course of the facula **a**, whose sudden flaring-up on day 6 you see noted at Ingolstadt too, in Image IX. For it was a pure, brilliant, and very notable facula — indeed not one, but several joined together at once, marked out by their figure and magnitude. Hear what the Ingolstadt observer writes:

"On the sixth of February, at the 8th hour of the morning, 45 minutes, only three spots were seen; and after the second, toward the exit, they were followed as it were by faculae, just as also at their rising; the location of these faculae, however, could not be accurately determined." Thus he.

You see the agreement of place; you have the figure from my own observation; and meanwhile you discern, proved by the fact itself, that the smaller observing circles can do less than the larger — for it is on this account that these faculae could not be accurately recorded, and hence no accurate doctrine can be derived from them.

Second. On day 9, in the morning, there arose a dense heap of spots **b**, which on the following day gradually unfolded into several; and it drew after itself toward the horizon a new spot **C**, dense enough to be conspicuous. It settled into the same place that the easternmost **b** had occupied the day before, and was of

double the length; but on account of the confusion I did not draw it out. The emergence of these on day 9, together with brilliant faculae **d** and **e**, was seen and approved by many grave Fathers of our Society, distinguished in their offices and learning.

[Margin: The curvature of the motion nearly greatest, and the inclination of the chords at its maximum.]

Third. The course of spot **b**, in the principal cluster, is not yet evenly curved back toward the ecliptic, but is nearer to it at the exit than at the rising, as is clear from the figure; and the spot itself cut across the ecliptic both before and after the center, and lasted beneath the Sun for more than 13 days.

[Margin: The spots are made denser in appearance by the position of viewing.]

Fourth. Around mid-course they drew apart from one another, and toward the exit came together again, but diminished, sparse, and thin — although the spots **C**, on account of their multitude mutually joining, appeared dense enough.

Fifth. Spot **d**, with its own facula, vanished from day 10 until the 18th, when either it again, or another like it, halted at the place due to its course; but on account of the [other] spots it could not be placed here perfectly. Likewise a pure facula **e** arose on day 9, where **d** too had appeared; and afterward, on the 14th, 15th, and 16th, it showed a spot, and again went off into a facula with a faint penumbra on day 19.

Sixth. Spot **F**, in the north, at first trailed a tiny one behind it for several days; after which, on day 16, having lost that one, it displayed above a new northern spot; and at length, on day 22, it itself, with all of them, dissolved and departed into a long facula. Its course did not much exceed 12 days, all things duly reckoned.

Seventh. The spots **g**, first arisen on the Sun on day 16, were wonderfully increased both in number and in bulk over two days; on the 19th they diminished on both sides again, and on the 22nd and 23rd they left the Sun as mere faculae, with the very faintest of penumbrae.

These same things were also seen and noted at Ingolstadt, in their own measure, as the observations show. See the second side-panel, in Image XVIII of the observations.

[Margin: The admirable variation of spots **b** and **c**.]

Eighth. How marvelously the heap of spots **b** and **c** grew in bulk and number; how, around the horizon, it joined together the eastern and western [parts], so that the one wove itself onto the other from that side; how, in mid-Sun, it separated one from another; how many were newly born, how many died away; and finally how far all of them, at the exit, dwindled into faculae — this can scarcely be expressed. I attended to these varieties with the greatest care; but, on account of the narrowness of the observing circle and the mutual crowding of the spots in the same places, it was not possible to set down each and every thing.

Ninth. It is well to note that, although spot **c** was carried along in the same sensible parallel as **b**, nevertheless the intervals between **b** and **c**, equally distant from the center, did not remain equal, but the western ones were greater than the eastern — a matter which

Rosa Ursina, Book III — Notae particulares

Notes on the Twelfth Image of the Observations, February 7, from the 5th day to the 23rd of the same [Notae in XII.

Obseruationum Imaginem, Feb. 7. à die 5. ad 23. eiusdem]

First. Here you have almost the entire course of facula a, whose first outpouring [affusio] on the 6th day you see recorded at Ingolstadt as well, in Image IX. For it was a pure, bright, and very notable facula — indeed not a single one, but several joined together, marked out in shape and size. Hear what the Ingolstadt Observer writes:

On 6 February, at hour 8 in the morning, 45 minutes: only three spots were seen, and after the second, toward the exit [western limb], they were followed by what looked like faculae, just as they were at their rising too; but the location of these faculae could not be accurately marked.

So he. You can see the agreement of the locations; you have the figure from my own observation. Meanwhile you discern, by the fact itself, that the smaller observing circles can do less than the larger ones. For this reason these faculae could not be recorded accurately, and therefore no accurate doctrine can be drawn from them.

[Margin: The inadequacy of the small observing circles is proven by the fact itself. — *Circulorum paruorum obseruatoriorum impotentia ipso facto probatur.*]

Second. On the 9th, in the morning, a heaped-up cluster of spots b rose, which on the following day gradually unfolded into several, and drew a new C behind it toward the horizon [limb], dense enough to be conspicuous. It settled in the same place which the easternmost b had held the day before, and was of double the length; but because of the confusion I did not draw it. Their rising on the 9th, together with the bright faculae d and e, was observed and approved by many grave Fathers of our Society, distinguished in office and learning.

Third. The course of spot b, in its primary cluster, is not yet equally curved toward the ecliptic, but is nearer to it at its exit than at its rising, as is clear from the shape; and the spot itself intersected [the ecliptic] both before and after the center, and lasted under the Sun for more than 13 days.

[Margin: The curvature of the motion is nearly greatest, and the inclination of the chords is greatest. — *Curuitas motus fere maxima & chordarum inclinatio summa.*]

Fourth. Around the middle they drew apart, and toward the exit came together again — but diminished, sparse, and thin — although the spots C, on account of the multitude of them joining one another, appeared dense enough.

[Margin: The spots are made to look denser by the position from which they are viewed. — *Maculae ex positione aspectus densantur.*]

Fifth. Spot d, with its own facula, vanished from the 10th until the 18th, where again either it, or another like it, took its place at the point due to it in the course; but on account of the [other] spots it could not be placed here perfectly. Similarly, e came out as a pure facula on the 9th, where d had also appeared; and afterwards, on the 14th, 15th, and 16th, it showed a spot, and again passed off into a facula with a thin umbra on the 19th.

Sixth. Spot F, a northern [boreal] one, at first drew a tiny one behind it for several days; then, on the 16th, having lost that one, it displayed a new northern one above; and finally, on the 22nd, it — together with all the rest — passed off, resolved into a long facula. Its course did not much exceed 12 days, all duly reckoned.

Seventh. Spots g, first risen upon the Sun on the 16th, were wonderfully augmented in both number and mass over two days; on the 19th they were again diminished, both of them; and on the 22nd and 23rd, as mere faculae and very thin umbrae, they left the Sun. These same things were also seen and noted at Ingolstadt, on its own scale, as the observations show. See the side Table II in the observation-Image XVIII.

Eighth. How wonderfully the cluster of spots b and c grew in mass and number; how, near the horizon [limb], it joined together at east and west so that it wove one part into the other; how in mid-Sun it separated one from another; how many new ones were born, how many died away; and finally how far all of them, toward the exit, faded into faculae — this can scarcely be expressed. I attended to these variations with the greatest zeal, but because of the narrowness of the observing circle, and the mutual crowding of the spots in the same places, I could not set down each and every thing.

[Margin: The admirable variation of spots b and c. — *Macularum b, & c, admiranda variatio.*]

Ninth. It is well worth noting that, although spot c was carried along in the same sensible parallel as b, nevertheless the intervals between b and c — at equal distances from the center — did not remain equal, but the western ones were greater than the eastern, a matter to which

I attended most diligently and by design. The westernmost spot is b, the easternmost is e.

[Margin: The vanishing spots do not coalesce, but remain separate. — *Maculae euanidae non coeunt sed disiunctae manent.*]

Tenth. Note that, in the [projected] air, the spots are cut sharper and stronger [i.e. appear bolder and darker] than they ought to be — especially the western ones, because there they were in the declining part [in defectu]; and notwithstanding this, they remained separate.

Eleventh. From these courses it is clear that the annual pole — the southern one lying exposed [patens], the northern one hidden [latens] — does not yet culminate, but is very near the middle, because the paths of the spots hasten toward equilibrium, and the chords very nearly coincide with the ecliptic, or are equidistant from it.

Diagram. A full-page engraved solar disk — the Twelfth Image of the Observations — recording the march of sunspots and faculae across the Sun's face from 5 to 23 February 1625, observed at Rome. Within the top of the disk a three-part titling runs across: at left, **XII. Imago Obseruationum** ("12th Image of the Observations"); at center, **ROMAE. M.DC.XXV. In Domo Professa Romana Societatis** ("At Rome, 1625, in the Professed House of the Roman Society [of Jesus]"); at right, **Februarij. 7.** ("February 7"). Below the title, two engraved

heraldic roses flank the radiant **IHS** Jesuit monogram (sunburst medallion with a cross above and three nails below).

Cardinal markers on the disk: **Z** at the top (zenith), **N** at the bottom (nadir); the horizontal diameter is the ecliptic, labelled **A. Oriens** at the left end (East) and **B. Occidens** at the right end (West), with the legend **A B. Ecliptica. [zodiac glyph, ☿ ?]** beneath. A curved caption band spans the middle: **Cursus Macularum et Facularum à 5. Februarij ad 23. eiusdem, similis Ingolstadiano, in Tabella II. expresso** ("Course of the spots and faculae from 5 February to the 23rd of the same [month], similar to the Ingolstadt one, expressed in Table II").

The spot/facula figures are arranged in three registers, each figure tagged with a small letter (spot identity) and/or an Arabic day-number, and often an **m/u** marker (m = morning, u = evening):

- **Upper arc (faculae, the "f" series):** a left-to-right chain of facula groups labelled **f 12, f 13, f 14, f 15, f 16, f 17, f 18, f 19, f 20, f 22** (f 21 not clearly resolved), several with **u/m** markers; interspersed with small **a**-tagged spots carrying day-numbers **5, 6, 8, 9, 10, 14, 15**.
- **Along the ecliptic diameter (A–B):** spot clusters labelled with letters **b** and **c** (and **d, e, f** toward the western end), tagged with day-numbers including **10, 11, 12, 14, 17, 19, 20, 21, 22**; the western (B/Occidens) end is crowded with overlapping b/c/d/e/f groups.
- **Below the ecliptic (the "g" series and lower d/e groups):** a descending chain of **g**-tagged figures with day-numbers **16, 17, 18, 19, 20, 22, 23**, together with **d**- and **e**-tagged groups at days **16, 17, 18, 19**.

Many individual letter+day tags in the crowded western sector and the lower g-chain cannot be resolved one by one even at high magnification (overlapping engraving plus verso show-through); the readings above are those legible with confidence. Do not treat the day-list as complete.

Beneath the disk, spanning the foot, is a three-panel data table headed **FEBRVARII** ("of February"), each panel carrying the column heads **D.** (Dies, day + m/u), **H.** (Hora, hour), **☉** (a solar-position value, degrees), **El.** (a following value, minutes). Transcribed below.

FEBRVARII — observation table (foot of the plate)

Panel 1 (days 5–12):

D.	H.	⊙	El.
5. m.	$10\frac{5}{8}$	29	0
6. m.	$10\frac{3}{4}$	29	40
7. u.	$3\frac{2}{5}$	16	40
8. m.	$11\frac{1}{5}$	31	40
9. m.	$10\frac{1}{4}$	14	30
9. u.	$3\frac{3}{4}$	13	10
10. m.	11	31	40
11. u.	$12\frac{2}{3}$	33	0
12. u.	$3\frac{1}{8}$	20	25

Panel 2 (days 13–18):

D.	H.	⊙	El.
13. m.	$9\frac{3}{8}$	23	0
13. u.	$13\frac{1}{2}$	17	40
14. m.	10	27	30
15. m.	$9\frac{1}{2}$	19	30
15. u.	$3\frac{3}{8}$	18	0
16. m.	$10\frac{3}{4}$	30	40
17. m.	$11\frac{1}{6}$	34	50
17. u.	4	13	0
18[?]. m.	$10\frac{3}{5}$	32	0

Panel 3 (days 19–23):

D.	H.	⊙	El.
19. m.	$10\frac{3}{5}$	55[?]	30
19. u.	[?]	21	0
20. m.	11	35	0
20. u.	[?]	13	0
21. m.	[?]	35	40
22. m.	$10\frac{1}{2}$	33	30
22. m.[?]	[?]	34	20
23. u.	[?]	37	[numeral: ?]

Notes on Image XIII of the Observations, [for] February 8 and 1 March; from 24 February to 9 March

(Folio 186)

I.

First. The course of all the spots and of the faculae appears to be in equilibrium with respect to the ecliptic. For their stations, being equally distant from the center C, are likewise equally distant from the ecliptic; and the chords stretched through equally distant stations appear parallel to the ecliptic.

[Margin: The vernal equilibrium of the spots. — The curvature of the paths [is] very great; the inclination of the chords [is] nil. The pole lies open at its highest, hidden at its lowest.]

Second. Spot a, a southern spot of moderate density, gradually became smaller and more diffuse, split in two, and on 4 March acquired new [companions]. On the 5th it eluded observation by its thinness, but on the remaining days, right up to its exit, it held on — though barely — together with its attendant faculae, and at the margin it left behind, worth seeing, a facula adjacent to it. In its course across the Sun it took up more than 13 days, and seems to have fallen not much short of 14 without quite reaching it. Which faculae it dragged along with it everywhere, you have in the diagram, even though I have not always marked them all.

[Margin: The course of about 14 days.]

Third. Spot b, born in the northern part of the Sun, gradually grew, acquired several companions one after another, then little by little lost them and seems to have turned into faculae — with which, a most brilliant escort, it made its exit; and these faculae appeared to be fenced in by faint penumbrae. It made its daily spaces proportionally as Spot a did, but with a less arched bend (as can be seen in all the courses that incline steeply toward the region of the hidden pole). It completed its circuit in fewer days than that same Spot a — as is clear to anyone who observes it and compares their halved paths against each other — and its eastern daily spaces are somewhat larger than the western ones.

Fourth. It is certain that the spots c did not outlast a life of three days. For on the 25th they gradually grew out of thin and formless shadows up to the 26th, and afterward in the same way declined step by step; and though most diligently sought, they appeared by no sign after the 27th. Nevertheless they ran through spaces similar in curvature to the others — which is entirely characteristic of all shadows, faculae, and spots, even those of a single half-day.

[Margin: The course of any of the spots, even when mutilated, is similar to the whole ones.]

II.

Fifth. The spots d appeared large all at once on 2 March, whereas the day before — when the Sun had been most carefully scanned — they had given no hint of themselves; so they must have been generated during the night. The following, more easterly one soon began to shrink again, so that on the 4th it appeared very small alongside its preceding facula; but the more westerly one kept its full vigor and gained a notable facula all around it, which likewise moved along with the spots by the same motion right up to its exit, as appears in the diagram. Their distance on the 3rd appeared the same as on the 2nd — whereas, the motion being uniform, it ought to have come out somewhat narrower.

Sixth. e is a most brilliant facula, composed of alternating bright points and shadows. The whole of the 28th it strained gently above the horizon, and outside the horizon it was not perceived even by the faintest indication (although for a long time I labored by every means and effort to draw something out, but in vain). On 2 March it stood fixed in the place where I marked it, and it lasted on the following days too; but because it coincided with Spot b, I have refrained from noting it.

[Margin: A remarkable facula.]

Seventh. f is a spot, corresponding to Spot f of Ingolstadt presented in the III Lateral Table [*Tobella* [recte: *Tabella*] III]. Consult it, therefore, and compare it with these, for you will find everything similar in its own way.

Eighth. Meanwhile it always remains true — as I have often insisted — that the smaller observation circles are not sufficient for perfectly detecting this phenomenon, nor for forging from it the consequences and solid teachings, worthy of the mathematical forum, that are to be hammered out. This is because for the most part they present the Sun's more hidden treasures grudgingly, or not at all. A practical example now confirms this again from the Ingolstadt Observer,

in the III Lateral Table, at 7 March, whose observation — made at the morning hour 10.49 — he himself declares in these notes: *"Two faculae seen (namely a, the western, and g, the eastern), and 6 spots. The size of the faculae, however, is not marked here."* Because, that is, in small circles

Diagram. Full-page engraved solar disk, the thirteenth image of the observation series (Image XIII), showing the course of the sunspots and faculae from 24 February to 9 March 1625. Header outside the disk: "IMAGO SOLIS XIII. 187". Inside the top of the disk:

- Upper left: "XIII. Imago Obseruationum." (Image XIII of the Observations).
- Upper center: "Anno Iubilæo. 1625. / In Domo Professæ Romanæ Societatis" (In the Jubilee Year 1625, in the Professed House of the Roman Society [of Jesus]), with two engraved rose ornaments flanking a rayed IHS medallion (Jesuit emblem).
- Upper right: "Februarij. 8. / Martij. 1."
- Beneath the emblems: "Cursus Macularum à 24. Februarij. ad 9. Martij. similis Ingolstadiano. Tabella III. expresso" (The course of the spots from 24 February to 9 March, similar to the Ingolstadt [image], expressed in Table III).

The horizontal ecliptic diameter runs across the disk from a labeled endpoint "A" at the left to "B" at the right, captioned: left "A. Oriens." (A: East), center "A.B. Ecliptica." (A–B: the Ecliptic), right "B. Occidens." (B: West). A small "z" marks the top of the disk (toward the zenith) and "N" marks the bottom.

Within the disk three tiers of spot-groups are drawn as chains of dots, loops, and hatched blots running roughly parallel to the ecliptic:

- **Upper tier:** a chain of small spot-clusters bearing the letter "b" above them, with day-numbers 25, 26, 27, 28 (February) and 1 (March) reading left to right, and a further cluster at the right numbered 2, 3, 4, 5 (March), each with an "m" (morning) or "u" (evening) subscript. At the far upper left, looped and hatched shapes numbered 7, 8, 9 with letter "e" and "2 u".
- **Middle tier (along the ecliptic line):** hatched spot-blots lettered a, c, d, and f. Readable examples, left to right: "a" groups with day-numbers 24, 25, 26, 27, 28 and "1 u", "2 u" near the east; along and just past center "c 25", "c 26", "c 27", "d 2", "f 4", "a 3 u", "a 4"; toward the west "d 3", "d 4", "d 5", an "f", "a 6", "a 7 u", "a 8 u", and a blot lettered "a" near endpoint B.
- **Lower tier:** the two dated observation tables (below), headed FEBRV[arij] and MARTII.

The per-spot micro-labels (single letters a–i, day-numbers 1–28, and m/u subscripts) are extremely dense and only partly resolvable even at high magnification; the letters and numbers listed above are those legibly readable, and the remainder are flagged uncertain.

Observation table at the foot of the disk (February column and March column). Columns: Day | a.m. (m) / p.m. (u) | Hour (with fraction of an hour) | Sun's elevation ☉ El. (degrees. minutes).

FEBRV[arii]:

D	m/u	H	☉ El. (°.')
24	m	10 3/5	35. 40
25	m	10 2/5	24. 0
25	m	11 1/3	37. 0
26	m	9 3/4	30. 15
27	m	9 4/5	30. 50
28	m	8 9/16 [?]	20. 25
28	m	10 9/16 [?]	35. 50

MARTII:

D	m/u	H	☉ El. (°.')
1	m	—	28. 0
2	m	9 1/4	27. 0
2	u	4 1/4	15. 20
3	m	10	33. 5
3	u	1	39. 25
3	u	—	17. 35
4	m	9 4/7	31. 0
5	m	9	25. 50
6	m	8 1/2	21. 0
7	u	—	15. 0
8	u	—	25. 50
9	m	10 1/4	36. 50

[Letterpress at the foot of the plate, continuing the notes of Image XIII:]

I.

[Margin: A pure facula, observed at Rome and at Ingolstadt.]

— cannot be rightly distinguished. But how these southern faculae [appeared] in my observation circle, and of what size and shape, and how many besides and of what kind they were seen to be, you have not only in the southern part under the letters a and h, at the 7th, but also in the northern part at g. All these faculae, since they were most pure and bright, ran on right up to the 9th, on which [day] the purest —

II.

— likewise a most brilliant facula i shone forth in the south-eastern quarter, not far from h.

Ninth. Although faculae near the horizon are also somewhat apt to grow slender, they by no means do so as the spots do, but remain much broader. Moreover they do not adjust their position to the horizon the way the spots do, but present it varied; and on the horizon itself, still enough

[Margin: Faculae do not grow thin the way spots do.]

(Folio 188)

— extended, they remain. You have examples in the faculae a, b, d, and e, which all lay on the horizon.

Tenth. Whatever faculae have confronted me over so many years up to now — even if they excel with a powerful radiance, even if they blaze with a broad and dense body — nevertheless never overstepped the Sun's perimeter with their light, though within it they, like the spots, are wont to linger a long while.

[Margin: Faculae never cross beyond the Sun's edge; yet on it they cling for whole days.]

Eleventh. But the Freiburg spots too, gathered into tables from the observations of the year 1622, describe motions of the spots toward the ecliptic similar to these — as is hinted plainly enough in Tables IV and V of Image 18, where fragments of the motions are discerned. There is an example in the said faculae.

Notes on Image XIV of the Observations, [for] March 2 [?]; from day 4 to the 21st of the same

(Folio 188)

I.

First. The spots a took their beginning in the northern part of the Sun from thin shadows, with a facula between them, on the evening of the 4th; and from then on, wonderfully increased in both number and size, they came out quite dense. Consider the 6th, 7th, and 8th, and you will see above all how much one differs from another in the position and change of the less principal spots, and so on. Then compare these days with the VII Lateral Ingolstadt Table in Image 18, and you will notice, on the one hand, an incredible agreement in motion and location — and, I add, in size too; but on the other hand you will also see how far my larger circle surpasses that smaller one. For that author everywhere counts only two spots, whereas I counted 9 on the 6th, 10 on the 7th, and only four on the 8th. On the 11th almost only Spot a — fused into one out of two — was seen; yet on the 12th the traces of the rest showed themselves quite faint, and afterward, on the 13th, shone forth turned into faculae.

[Margin: The first risings of the spots [were] faint, cramped, confused.]

It is worth noting — as I have often pointed out — how these spots a, at their first rising, appeared not only small, of faint color, and thin, but also confined within a narrow space, on the evening of the 4th; afterward they spread out vigorously day by day, so that near their exit their distances never again contracted to the equality of the eastern distances, even though among the spots

II.

— equally distant from the center C, a comparison is set up. Compare the 10th with the 6th; compare the 12th with the 4th, indeed the 13th with that same 4th; you will always see that the intervals of the outermost western [spots] are larger than the eastern ones — whereas they ought to be smaller, since the former are nearer to setting than the latter are to rising. Hence you see that spots lying broad in the same parallel, even if they are supposed to be equally distant from the center, nevertheless do not keep equal apparent distances.

[Margin: Spots in the same parallel move unequally.]

Second. The faculae b and c — also brought forward in the previous Image under other observations — kept their ordinary course with the spots, as always. But note there that the position of both, on the 7th, is a little higher than it should be toward the zenith, and so must be corrected from the earlier one. d is a spot and facula of the 9th, seen neither before nor after. The facula c was also seen at Ingolstadt, on the same day, position, place, and proportional size, just as Spot a too — as was said before, and will be further explained in its own places.

Third. Spot e, on the 9th, rose on the horizon together with a facula and advanced; then, increased in number and mass, after the midpoint it gradually died away into a facula, with the faculae g going before it toward the 18th and 19th — just as it also sent the same ahead at its rising, as can be seen on the 9th at the morning hour 10, in the figure outside the itinerary series, and likewise on the 10th and 12th in the lateral figures. The Ingolstadt Observer too noted these same faculae, haphazardly arranged in his small little circle, at the 18th, as can be seen in the VII Lateral Table; but their true figures you have here. On the 19th, however, the Ingolstadt [Observer] found nothing at all

[Margin: A spot in the same parallel [moves] unequally.]

Rosa Ursina — Book III, Notae particulares (Images XIII–XV)

Reading order follows the folio numbering: folio 188 → the IMAGO SOLIS XIV plate, folio 189 → folio 190. The lettered notes run continuously across the columns; the "I." and "II." at the head of each column are column labels (apparatus), not section divisions — the real note-numbers are the words "Primo, Secundo, Tertio ...". The 5-line marginal reference numerals (5, 20, 25 ... 55) are line-numbering apparatus and are not reproduced inline; the genuine content numerals (dates, hours, elevations, table counts) are all kept.

Folio 188 — conclusion of the Notes on Image XIII

[The opening word is the tail of a sentence carried over from the preceding page.]
... they remain extended. You have examples in faculae a, b, d, and e, which all lay on the horizon [i.e., at the limb].

Tenthly: whatever faculae have been the object of my study over so many years now — even if they excel in vehement brilliance, even if they shine broad and dense in body — have nevertheless never overtopped the perimeter of the Sun

with their own light; yet within it, like the spots, they tend to cling for a long while. The example is in the said faculae.

[Margin: The faculae never pass beyond the Sun's perimeter; yet within it they cling for whole days.]

Eleventhly: but the Freiburg spots too, drawn up into tables from the observations of the year 1622, describe motions of the spots along the ecliptic similar to these — as is plainly intimated in Tables IV and V of Image 18, where fragments of the motions are discerned.

Notes on Image XIV of the Observations — March 2. From the 4th to the 21st of the same [month].

(Notæ in XIV Observationum Imaginem, Martij 2. à die 4. ad 21. eiusdem.)

Firstly: the spots a — tightly set on the Sun, with faint umbrae — together with an intermediate facula, took their beginning on the evening of the 4th; and thereafter, marvelously increased both in number and in magnitude, they went out [i.e., left the disk] quite dense. Consider days 6, 7, and 8, and you will see above all how greatly one day differs from another in the position and change of the less important spots, and so on. Then compare these days with the lateral Table VII, the Ingolstadt one, in Image 18, and you will notice, on the one hand, an incredible agreement in motion and place — and I add, in magnitude too — while on the other hand you will also see how far my larger Circle surpasses that smaller one: for that author everywhere counts only two spots at a time, whereas I, on day 6, counted 9; on day 7, 10; on day 8, only four. On day 11 almost the single spot a, fused into one out of two, was seen; yet on day 12 the traces of the rest rendered themselves quite faint, and these afterwards, on day 13, shone forth converted into faculae.

It is worth noting, as I have often pointed out up to now, how these spots a — at their first emergence not only small, of subdued color, and faint, but also enclosed in a narrow space — appeared on the evening of the 4th, and afterwards spread out vehemently day by day, so that the distances between them never afterwards, near their exit, contracted back to the equality of the eastern [entry] distances, even though among the spots [continues] ...

[Margin: The first emergence of the spots — faint, cramped, confused.]

a comparison is set up of [spots] equally distant from the center C. Compare day 10 with 6; compare 12 with 4 — indeed, 13 with that same 4 — and you will

always find the intervals of the western extremes to be greater than the eastern, though they ought to be smaller, on the grounds that the western ones are nearer to setting than the eastern to rising. From this you see that spots strung out along the same parallel, even if they be posited as equally distant from the center, nevertheless do not keep equal apparent distances.

[Margin: Spots on the same parallel move non-uniformly.]

Secondly: faculae b and c, brought forward in the earlier Image too under other observations, kept their ordinary course together with the spots, as always. Note, however, that the position of the two of them on day 7 is a little higher than it should be toward the zenith, and is therefore to be corrected from the earlier one. d is the spot-and-facula of day 9, seen neither before nor after. Facula c was also seen at Ingolstadt, on the same day, in the same situation, place, and proportional magnitude, just as spot a — as was said before, and will be further set out in its proper places.

Thirdly: spot e, having arisen on day 9 with a facula on the horizon [limb] and having advanced — at length increased in number and mass — after the midpoint gradually died away into a facula, preceded by faculae g toward days 18 and 19, just as it also sent the same ahead at its rising, as may be seen on day 9 at the 10th morning hour, in the figure outside the itinerary series, and likewise on days 10 and 12 in the lateral figures. The Ingolstadt observer too noted these same faculae, carelessly arranged in his little Circle, up to day 18, as may be seen in the lateral Table VII; but the true figures of them you have here. On day 19, however, the Ingolstadt [observer] found nothing at all [continues] ...

IMAGO SOLIS XIV (Folio 189)

Diagram. A full-page engraved solar disk recording the daily courses of the sunspots from 4 to 21 March 1625, observed at the Jesuit Professed House in Rome. Running head across the top: **IMAGO SOLIS XIV**. (page number **189**).

- Title cartouche (top center, within the disk): **ANNO IVBILÆO. 1625. In Domo Professa Romana Societatis** — "In the Jubilee Year 1625, in the Roman Professed House of the Society [of Jesus]." It is flanked by two heraldic-rose ornaments set on either side of the **IHS** Jesuit emblem (a sunburst monogram surmounted by a cross).
- Beneath the cartouche: **Cursus Macularum à 4. Martij, ad 21. eiusdem** — "The course of the spots from 4 March to the 21st of the same."

- Upper-left caption (outside the disk): **XIV. Imago Observationum** — "XIV. Image of the Observations."
- Upper-right running side-note: **Martij. 2.**
- Reference letters on the disk: **A** (west [recte: left] end of the horizontal diameter) = **Oriens** (East); **B** (right end) = **Occidens** (West); **C** = center; the horizontal diameter is labelled **A B. Ecliptica** (the ecliptic); **N** marks the foot of the vertical diameter (south point). The inline mid-disk legend reads: **A, Oriens. B, Occidens. AB, Ecliptica.**
- Spot-tracks: clusters of drawn spots and faculae fill the upper and central disk, traced as daily paths and tagged with the group-letters **a, b, c, d, e, f, g** and with day-numbers (4–21) plus the **u/m** (evening/morning) markers. The faculae of day 20 are placed **extra ordinem** ("out of sequence") under the letters **e** and **g**, per the note. The individual per-day numeric subscripts scattered along each track are at/below the resolution of the scan and are **not** committed individually

The lower-left interior of the disk carries the **MARTII** table of solar elevations (transcribed below).

MARTII. — Table of the Sun's elevation at observation

Column key: **D** = day; **H** = hour, prefixed by **u** (evening / *vespere*) or **m** (morning / *mane*); **☉ El.** = the Sun's elevation (degrees. minutes). The two halves are printed side by side, separated by a cross-mark (†); the left half runs days 4–10, the right half days 11–21.

D	H	☉ El.	†	D	H	☉ El.
4	u. 2½	31. 15		1	m. —	33. 30
				1		
5	m. 8½	20. 40		1	m. 8¾	25. 40
				2		
6	m. 8¼	18. 0		1	u. 3⅝	24. 0
				2		
7	m. 7⅞	16. 20		1	m. 10	37. 0
				3		
7	m. 11⅞	41. 20		1	u. 3¾	23. 0
				3		
8	m. —	31. 40		1	m. —	37. 30
				4		

D	H	⊙ El.	†	D	H	⊙ El.
9	m. 7¾	16. 20		1	m. 11½	44. 30
				6		
9	m. 9½	32. 0		1	u. 2⅝	34. 40
				7		
9	m. 10	35. 0		1	m. 11¼	45. 50
				8		
1	m. 9½	31. 45		1	m. 8	24. 30
0				9		
1	m. 11½	43. 0		1	m. 11½	43. 30
0				9		
				2	m. 9 4/9 [?]	36. 10
				0		
				2	m. 8¼	23. 0
				1		

Letterpress at the foot of Folio 189 (continuation of Note *Thirdly*)

[the Ingolstadt observer found nothing at all] on the Sun; and although there were no spots, there was nevertheless no lack of notable faculae — yesterday's, both eastern and western — of which I pass over the former for want of room, but the latter, so that their course may be traced out, I append up to day 21. And day 20 in its entirety you have placed out of sequence, under the letters e and g; for I think the facula at e was born out of a spot. Compare the whole figure [continues] ...

of day 20 with the scheme of the 9th (placed out of sequence, in the evening), and you will see a fairly great similarity of position. Part of this 20th day, moreover, you have set on the itinerary track. Day 21, however, I left entire, in sequence. And so, if you rightly weigh the course of spot e, you will find that it — even after it had degenerated into a facula — spent the very least in its whole transit of the Sun [continues] ...

[namely] 13 days: for from day 9 to 21 there are 12 days, to which, if the space of one day be added, they are now 13 days; and there still remains at rising a good little portion besides. From which it is evident that the course of spot e is longer than the course of spot a, which from the evening of the 4th to the evening of the 13th completed 9 days. Therefore, if we grant a great deal, the residual spaces on

either side — at rising and setting — will require 3 days; the course of e was therefore longer than the course of a by one day and more.

[Margin: The durations of the courses are unequal, in the same span of time.]

From this same course of spot e it is clear that spots and faculae proceed at the same pace.

[Margin: The motion of spots and of faculae is the same.]

From the same course you see that the apparent speed of spots carried along the same parallel is not the same; for spot e, midmost among them, on day 12 abandoned the eastern one on days 13 and 14 — by a long interval, as it appears — and, moving beneath the ecliptic on days 12, 13, and 14, at length overtook the western, northern one; and on days 16 and 17, split into three, it far outstripped it, and finally passed over into faculae, while in the meantime the more eastern one wholly perished. This middle one the Ingolstadt [observer] did not notice at all.

[Margin: Spots carried along the same parallel have differing apparent speeds of course.]

Fourthly: the spots f, southern, faint and sparse and uniform, on day 9 came forth in about the middle of the Sun, and after the 12th vanished utterly.

[Margin: The physical rising and setting of spots on the Sun.]

Fifthly: the faculae g, having gone before spot e, were many and various, spread over a broad tract, and blazed across the whole Sun — as is gathered from their number, figure, and situation — and on day 21 shone last on the western horizon. Whence, if [continues] ...

[Margin: The faculae blaze across the whole Sun, beyond 13 days.]

we consider the interval of day 9 by which they stood off from the eastern (rising) horizon, it is manifest that they took up more than 13 days in running across the Sun. But since they were pure faculae, it is established once more that the motions of spots and of faculae are entirely the same, and their distances from the center of the Sun equal on both sides.

Sixthly: the motion of all is curved, and in the northern part it approaches the ecliptic, in the southern it recedes from it, while the spots and faculae are in the western quadrant.

Seventhly: the inclination of the motion of spot e to the ecliptic is not unlike [that of spot a], so far as may be gathered from four observations — the motion of spot a, marked out in Table VI in the year 1623 from the Ingolstadt observations, which I would have you consult.

Eighthly: the direction — the path, or itinerary tendency, of the spots and faculae — is oblique, bending from north into south; and the Antarctic pole, exposed or upper, begins to turn in the eastern descending semicircle [recte: semicirculo], while the Arctic, hidden or lower, [turns] in the western ascending [semicircle]; and the chords perpendicular to the axis, all and each, cut the ecliptic obliquely, stretched from the northeast into the southwest. But both the curvature of the itinerary arcs and the obliquity of the sections begin gradually to diminish, whereas the angle upon the ecliptic and of the chords, however intercepted, [begins] to increase.

[Margin: The curvature of the motion and the oblique incidence decreases, the angle increases; the raised southern pole descends, and the opposite [pole] ascends.]

Notes on Image XV of the Observations — March 3. April 1. From the 20th of the former [March] to the 6th of the latter [April].

(Notæ in XV. Observationum Imaginem, Martij 3. Aprilis 1. à die 20. illius, ad 6. huius.)

Firstly: a northern [borealis] spot, with brilliant faculae, having arisen on day 20, advanced with them for a long while, and at length went out together with them. This same spot appeared at rising slender, oblong, and single; but on the following day, and thereafter, it unfolded into two, and around the middle [of its transit] it showed a middle one too for some days; and, approaching setting, it gathered itself once more somehow into one, but in a different situation, so that [continues] ...

the more western one near setting was [the same as] the more northern near rising [?]. The space between them, swallowed up both at rising and at setting, did not appear; they gradually diminished, and went out smaller than they had entered. The middle spot, separated from both, on days 25, 26, and 27 appeared at rising as an umbra, or apex, stretched toward the south, that is toward A. The western [part] reached the horizon [at setting]: it consumed, in the exposed

hemisphere of the Sun, a little more than twelve days, as from the desig-[nation]
[continues into the following pages] ...

[Margin: The spots conceal the space between them, and conceal themselves.]

[Margin: Their whole stay upon the Sun does not much exceed 12 days.]

[Reading order note: in this copy the scan order is reversed/duplicated — the engraved plate (folio 191, IMAGO SOLIS XV) is scanned first, then the text folio 190 (p. 310), then the plate again (duplicate, p. 311), then text folio 192 (p. 312). The correct reading order is folio 190 → plate 191 → folio 192, and the "Notae in XV" text flows column-by-column across all three leaves (confirmed by the catchwords "...desi-gna-/gnatione..." and "...1⁴/₅ (quæ / (quæ tamen..."). The translation is arranged in that reading order.]

(The top of this page is set in two columns. The centered "I." and "II." are column markers with 5-line marginal apparatus numbering — not section headings. The enumerated points "Fourth, Fifth, Sixth, Seventh, Eighth" are the actual divisions; the first three points stood on the previous leaf.)

[Col. I]

[in the] rising, 13 days; for from the 9th to the 21st there are 12 days, and if the space of one day is added, they now make 13 days — and a good portion still remains at the rising as well. From this it is evident that the course of spot **e** was longer than the course of spot **a**, which, from the evening of the 4th to the evening of the 13th, took up 9 days. Therefore, even granting a great deal, the spaces left over on either side, at rising and setting, will still require 3 days; so the course of **e** was longer than the course of **a** by a full day and more.

[Margin: Unequal durations of the courses, in the same time.]

From this same course of spot **e** it is clear that spots and faculae advance at the same pace.

[Margin: The motion of spots and faculae is the same.]

From the same course you see that, for spots carried along in the same parallel, the apparent velocity is not the same. For the one midway among those spots, **e**, on the 12th abandoned the eastern one — as the long interval shows — on the 13th and 14th; and on the 12th, 13th, and 14th it at last overtook the western northern one advancing beneath the ecliptic, and on the 16th and 17th, split into three, it far outstripped it, and finally passed over into faculae, while meanwhile

the more eastern one perished entirely. This middle one the Ingolstadt observer did not notice at all.

[Margin: For spots carried in the same parallel, the apparent velocity of the course differs.]

Fourth: spots **f**, southern, thin and sparse and uniform, came forth around the 9th near the middle of the Sun, and after the 12th vanished utterly.

[Margin: The physical rising and setting of spots on the Sun.]

Fifth: faculae **g**, which had run ahead of spot **e**, were many and varied and spread over a broad tract, and blazed across the whole Sun — as is gathered from their number, figure, and position — and on the 21st shone for the last time on the western horizon; so that, if

[Margin: Faculae blaze across the whole Sun, beyond 13 days.]

[Col. II]

we consider the interval of day 9, by which they were distant from the rising horizon, it is plain that in running across the Sun they took up more than 13 days. And since they were pure faculae, it is established once more that the motions of spots and of faculae are entirely the same, and that their distances from the Sun's center on either side are equal.

Sixth: the motion of all is curved, and in its northern part approaches the ecliptic, in the southern recedes from it, while the spots and faculae are moving in the western quadrant.

Seventh: the inclination of the motion of spot **e** to the ecliptic is not unlike [that of spot **a**], as far as one may gather from four observations. The motion of spot **a** is set down in Table VI, for the year 1623, from the Ingolstadt observations — which I would have you consult.

Eighth: the direction — the path or line of travel of the spots and faculae — bends obliquely from north to south; and the Antarctic pole, exposed or uppermost, begins to move in the eastern descending semicircle, while the Arctic, hidden or lower, moves in the western ascending one; and the chords perpendicular to the axis, all and each, cut the ecliptic obliquely, extended from the north-east into the south-west. But both the curvature of the itinerary arcs and the obliquity of the sections begin gradually to lessen, while the angle upon the ecliptic, and that of the chords — though intercepted — begins to grow.

[Margin: The curvature of the motion and the oblique incidence decrease; the angle increases; the elevated pole [?]; the southern descends, the opposite ascends.]

Notes on the Fifteenth Image of Observations, [for] March 3 and April 1, from the 20th of that [month] to the 6th of this

(Set in two columns, "I." and "II.", again with 5-line marginal apparatus numbering; the enumerated points "First, Secondly, Thirdly..." run continuously across folios 190, 191, and 192.)

[Col. I]

First. [Historiated initial P, with an inset woodcut figure.] A spot in the north, which had arisen on the 20th together with brilliant faculae, advanced for a long while along with them, and at last went out together with them. The same spot at its rising appeared slender, oblong, and single; but on the following day, and thereafter, it unfolded into two, and around the middle [of its course] it also showed a middle one; for several days, as it drew near its setting, it gathered itself again into a single one, as it were, but in a different arrangement — so that

[Col. II]

the more westerly one, around setting, was the more northerly near rising. The space between them, absorbed both at rising and at setting, did not appear; they gradually diminished, and went out smaller than they had entered. The middle spot, separated from both, on the 25th, 26th, and 27th showed at rising an umbra, or an apex, extended toward the south — that is, toward A. Its setting reached the horizon: it consumed, in the Sun's visible hemisphere, a little more than twelve days, as from the des-

[Margin: The spots hide the intervening space, and hide themselves.]

[Margin: The whole stay across the Sun does not much exceed 12 days.]

Diagram. A full-page engraved projection of the solar disk — the fifteenth "Image of Observations" — enclosed in a ruled rectangular frame. It records the cumulative tracks of the sunspot groups observed at the Professed House of the Roman [Jesuit] Society from 20 March to 6 April 1625.

Frame and cartouche labels (read under magnification):

- Running header above the frame: **IMAGO SOLIS XV.** with the folio number **191** at the right.
- Upper-left, inside the frame: **XV. Imago Obseruationum** ("Fifteenth Image of Observations").
- Upper-center: **Anno IVBILÆO, 1625. In Domo Professa Romana Societatis** ("In the Jubilee Year, 1625. In the Professed House of the Roman Society"), flanked by two engraved rose ornaments with a central radiant **IHS** emblem (the Jesuit device).
- Below the cartouche: **Cursus Macularum à 20. Martij, ad 6. Aprilis, similis Ingolstadiano anni eiusdem, etc.** ("The course of the spots from 20 March to 6 April, similar to the Ingolstadt [series] of the same year, etc."). Final abbreviation read as "etc." [?].
- Upper-right, inside the frame: **Martij. 3. Aprilis. 1.**
- Top of the disk marked **Z**; bottom of the disk marked **N**.

Orientation axis (the horizontal diameter):

- Left end of the diameter: **A. Oriens.** ("A. East.")
- Center: **C**, with **A B. Ecliptica.** ("A–B. The ecliptic") labelling the diameter line.
- Right end: **B. Occidens.** ("B. West.")

Spot content: within the disk are numerous engraved sunspot groups drawn at their successive daily positions along a broad band roughly parallel to and straddling the ecliptic (A–B) line, plus fainter facula-trails in arcs above and below. Each drawn group carries a small italic letter (the spot-identifiers **a**, **b**, **c**, **d**, **e**, **f**, **g** used in the notes) together with a day-number (**20–31** for March, **1–6** for April) and an **m** (*mane*, morning) or **u** (*vespere*, evening) marker. The upper band shows the smaller, more northern spots (labelled **a**, days ~20–31 and 1); the central band along the ecliptic shows the large principal groups (labelled **b**, **c**, **d**, **e**, **f**, days ~22–31 and 1–4) with their umbrae, penumbrae, and encircling dotted facula-boundaries; the lower-left arcs show facula trails. The individual per-spot day-numbers, letters, and m/u markers are extremely dense and largely below reliable resolution on the scan — many cannot be committed. Far more than two labels are unreadable: the axis/cartouche labels above are secure, but the interior spot-by-spot lettering is not fully resolved.

Two observation tables are engraved in the lower half of the disk (transcribed as native tables below): **MARTIVS** (in two side-by-side sub-columns) and **APRILIS**.

Column heads: **D** (*dies*, day) | **H** (*hora*, hour) | ☉ **El.** (Sun symbol + "El." — the solar elongation [?], given in degrees and minutes). Hours are given with **m/u** (morning/evening) and vulgar fractions.

MARTIVS

D (day)	m/u	H (hour)	☉ El. (° ')
20	m	8 4/9	24 · 30
21	m	8 5/9	27 · 0
22	m	8 1/8	22 · 40
22	m	11 1/2	48 · 10
23	u	—	9 · 30
24	m	7 5/6	20 · 39
24	u	4	22 · 0
25	u	3 4/5	24 · 25
26	m	7 1/2	18 · 20
27	u	2 4/5	43 · 30
28	u	4 1/3	21 · 0
29	u	3 1/6	25 · 40
30	u	2 4/5	35 · 30
31	u	3 2/3	26 · 30

APRILIS

D (day)	m/u	H (hour)	☉ El. (° ')
1	m	10 4/9	46 · 15
1	u	3 3/5	27 · 0
2	u	4 3/4	17 · 25
3	m	7 1/8	15 · 45
3	m	9	34 · 30
4	m	8 5/9	31 · 0
5	u	2 1/3	43 · 0
6	u	2 1/4	43 · 50

[Plate letterpress, folio 191 — Notae in XV, continued]

[Col. I]

—ignation it is plain. Among the faculae [that had] arisen, [the spots] set together with the same; and you will understand their figure and position from the diagram.

Secondly, spots **b**, **c**, **d**, **e**, which began to arise on the 22nd, finished their course around the 6th of April — though not all these days have been recorded here, for want of room and to avoid confusion. Now there were two successive heaps [of spots],

[Col. II]

with spots and umbrae, and faculae, fairly numerous and conspicuous — as appears in the side figures — on the 24th and 25th at rising, and likewise on the 3rd, 4th, 5th, and 6th at setting, around spots **c** and **d**, and **f**, which held the first rank in this series. For **b** gradually declined into a facula. **c** entered the Sun on the morning of 22 March, at the morning hour 8½; on 4 April it left the same at the evening hour 1¼ (which

(Two columns, "I." and "II.", with 5-line marginal apparatus numbering.)

[Col. I]

—though this station, on account of the narrowness of the place, has not been shown here) — and so it lasted on the Sun for 13 days, and more than five hours. For since, when it was first noticed at ingress, it was already clear of the horizon, some delay must therefore be assigned even to that interval, though it be of the least account to the sight.

[Margin: Unequal stay of the spots across the Sun.]

And so it is evident that the stay of this spot beneath the Sun was longer than the time of spots **a** by about one day. Small at ingress, it grew astonishingly right up to its exit, dragging after it a marvelous train — and, over many days, a shifting one, with ever-new and very numerous most brilliant faculae, and spots. For when, at ingress, small and few spots had appeared together with great faculae, on the following days spots moved into the place of the faculae, whose number began vehemently to multiply on the 27th and the days after, so that on the 28th, in four bundles of spots on the Sun — **c**, **d**, **e**, **f** (of which I have thrown this one out of its track, to the side) — I counted more than fifty distinct spots.

[Margin: The remarkable generation of spots and faculae.]

[Margin: Where at Ingolstadt 7 spots [were noted], here at Rome more than 50 spots were observed.]

Whereas the Ingolstadt observer, otherwise diligent, describes no more than seven distinct ones. But let us hear what P. Georgius Schönberger [Georg Schönberger] attests of himself: "28 March, at the evening hour 5, scruple 15. Nine spots — observed not by me, but by another, yet, I think, diligently observed — of which the ones nearest the center [are] divided into about three." But because among these nine two northern ones are also included, only seven must pertain to these clusters — which, however, I distributed into somewhat more. Hence again a third practical witness emerges, that larger observing circles can do more than smaller ones. All the minutiae, on account of the narrowness of the place, could not be noted down from the autograph; yet from spot **d** it is plain how all those that follow it gradually withdraw toward the same [point] after mid-course, and contract into one, and produce a certain shapeless umbra, or shadowy spot — which is the regular and daily [occurrence] in this phenomenon.

[Margin: The excellence of the Roman observing circle.]

So too the faculae, in the ordinary way, ball up at ingress and exit, so that either one appears out of many balled together, or many arise out of one. Examples occur everywhere in the observations. And just as I [observed this] at Rome, so elsewhere others observed [it] at this same time,

[Col. II]

as will soon be plain. See the sixteenth Image, the Douai one, and the eighth Ingolstadt side-table, in Image 18.

Thirdly, it is to be noted how all the tracks of the spots curve back toward the same part; and how the itinerary arc of spot **c** is, at rising, nearer to the arc of spot **a** than at setting, and how it recedes from it gradually, and not suddenly. It is also to be noted that the radiance of the faculae is more dilated toward the east than toward the west.

[Margin: The itinerary tracks of the spots are not parallel to one another.]

Besides, it must be known that spots **b**, **c**, **d**, and **e** appeared full, within and at their circumference, of fiery faculae — or, as it were, of one continuous facula, yellow, dusky, whitening, whose boundary I circumscribed by a series of dots returning into itself. But the rest, outside this compass — as also the northern **a** —

lacked these varieties of colour and of faculae, which, however, in large spots are common enough.

[Margin: The colours, nimbi, and haloes of the spots.]

It is further to be observed that spot **C**, in crossing the western horizon, took up more than five hours: for at the eighth morning [hour] it was already settled [on the limb], and at the second evening [hour] it had not yet wholly passed off. This too I judge to be regular for all spots, in their own proportion, though it is not noticed in all, because of their smallness and thinness.

[Margin: The long delay of a spot at the horizon.]

Fourthly, spots **d** and **f** advanced almost in the same parallel, and stood apart from each other by a daily interval, so that the following **f** always occupied the lodging of the preceding **d**. Spot **d**, deflected a little to the south, was first descried on the evening of 24 March, and on 5 April drew near its setting in the evening. Twelve days intervene, to which one added at rising makes thirteen days, and to which is added a remaining space of some hours at setting; and so this apparent course too exceeds thirteen days.

Fifthly, observe also the precise [horizon-]cuttings, delays, and uniform descents of the faculae, together with the spots, at the horizon, and likewise their invariable positions, etc.

Sixthly, the curvature of all the motions, and the inclination of the chords to the ecliptic, decreases. The direction of the motion is from north to south. The upper southern pole moves in the eastern descending semicircle...

[Margin: The curvature of motion and the inclination decrease; the southern pole descends.]

(The sixth point breaks off mid-word here; the notes continue on the following leaf.)

[Margin: The unequal delay of the Spots beneath the Sun.]

(a position which, however, is not shown here because of the narrowness of the space) — and so it lasted on the Sun for 13 days and more than five hours. For when it was first noticed at ingress it had already cleared the horizon; and so some allowance of time, however slight to the eye, must be granted to that interval as well. It is therefore evident that the delay of this Spot beneath the Sun was longer than that of the Spots *a* by about one day.

[Margin: The remarkable generation of Spots and Faculae.]

At its entrance it was quite small, but it grew astonishingly all the way to its exit, dragging behind it a marvelous train, and on so many days changing with ever-new and very numerous, most brilliant Faculae and Spots. For whereas at ingress small and few Spots had appeared together with large Faculae, on the following days Spots moved into the place of the Faculae, and their number began to multiply enormously on the 27th and the days after.

[Margin: Where at Ingolstadt 7, at Rome more than 50 Spots were noticed.]

So on the 28th, in the four clusters of Spots on the Sun — *c, d, e, f* (of which I have thrown this one out to the side, off its track) — I counted more than fifty distinct Spots, whereas the Ingolstadt Observer, otherwise diligent, describes no more than seven distinct ones. But let us hear what Father Georg Schönberger [Schönberger] testifies about it: on 28 March, at the evening hour 5, minute 15, nine Spots — observed not by me but by another, though I believe carefully observed — of which those nearest the center were divided into about three. But since among these nine two northern ones are also included, it follows that only seven belong to these clusters — which, however, I distributed into somewhat more.

[Margin: The excellence of the Roman observing circle.]

From this there emerges once more a third practical witness that larger observing circles can do more than smaller ones. It was not possible to record all the fine details from the original drawing because of the confinement of space; yet from Spot *d* it is clear how all those that follow gradually gather back to the same place after mid-course and contract into one, producing a kind of shapeless mass, or forming a shadowy Spot — which is a regular and daily feature of this Phenomenon. So too the ordinary Faculae are massed together at ingress and egress, so that either one appears out of many clustered together, or many arise from one. Examples occur throughout the observations. But just as I observed at Rome, so others observed elsewhere at this same time, as will soon be clear. See Image XVI, the Douai [Duaci] one, and the eighth Side-Table, the Ingolstadt one, in Image 18.

[Margin: The path-traces of the Spots are not parallel to one another.]

Thirdly, it should be noted how all the tracks of the Spots are curved toward the same side; and how the track-arc of Spot *c* at its rising is nearer to the [ecliptic] arc than that of Spot *a* at its setting; and how it recedes from it gradually and not abruptly. It should also be noted that a Spot's radiance [iubar] spreads out more toward the east than toward the west.

[Margin: The colors, nimbi, and haloes of the Spots.]

Moreover, it should be known that the Spots *b*, *c*, *d*, and *e* appeared full, both within and around their circumference, with fiery Faculae — as it were with a single continuous Facula, yellow, dusky, and whitish, whose boundary I outlined with a returning series of dots. The rest, outside this compass — as also the northern ones *a* — lacked these varieties of color and of Faculae, which nevertheless are quite commonly seen in the large Spots.

[Margin: The long delay of a Spot at the horizon.]

It should further be observed that Spot C, in crossing the western horizon, took up more than one day's worth of hours: for at the eighth morning hour it was already settled [on the disk], and at the second evening hour it had not yet entirely departed. This too, I judge, is regular for all the Spots in their own proportion, but it is not noticed in all of them because of their smallness and thinness.

Fourthly, the Spots *d* and *f* advanced almost in the same parallel and stood apart from each other by one day's interval, so that the following *f* always occupied the lodging of the preceding *d*. Spot *d*, deflected a little to the south, was first seen on the evening of 24 March, and on the evening of 5 April it approached its setting; twelve days intervene, to which one added at rising makes thirteen days, to which is added the remainder at setting, a span of several hours. And so this apparent course too exceeds thirteen days.

Fifthly, observe also the cut-offs [precisiones] and delays of the Faculae together with the Spots at the horizon, and their even descents, and likewise their invariable positions, and so on.

[Margin: Thus, with the course, the motion and inclination decrease; the southern pole descends.]

Sixthly, the curvature of all the motions, and the inclination of the chords to the Ecliptic, decreases. The direction of motion is from north to south. The upper southern pole lies sloping in the eastern semicircle.

Diagram. A full-page engraved solar disk — the "proportionally enlarged" composite image of the sunspot observations of 20 March–6 April 1625, made at the Jesuit Professed House in Rome. (This same plate is scanned twice in this batch; the second scan, is identical and is not separately described. The lower two-thirds of the following leaf, also shows this plate as faint mirror-reversed show-through, which is not transcribed.)

Interior lettering, top of the disk:

- Upper left: **XV. Imago Observationum** ("15th Image of Observations" — note the discrepancy with the running header and note-title, which read XVI;
- Upper center: **Anno IVBILAEQ, 1625. In Domo Professa Romana Societatis** ("In the Jubilee Year 1625, in the Professed House of the Roman [Jesuit] Society"). Below it, three emblems: at center the Jesuit **IHS** monogram with cross, set in a radiate sunburst, flanked left and right by two heraldic **Orsini roses** (decorative).
- Upper right: **Martij 3. / Aprilis 1.** (dates).
- Center caption: **Cursus Macularum à 20. Martij, ad 6. Aprilis, similis Ingolstadiano anni eiusdem, etc.** ("The course of the Spots from 20 March to 6 April, similar to the Ingolstadt [image] of the same year, etc.").

Axis and cardinal labels (on and about the horizontal diameter):

- **A** — left end of the horizontal diameter; labelled **A. Oriens** ("A. East").
- **B** — right end of the horizontal diameter; labelled **B. Occidens** ("B. West").
- **C** — midpoint of the diameter.
- The diameter itself is labelled **A B. Ecliptica** ("A B. the Ecliptic").
- **Z** — top of the disk; **N** — bottom of the disk.

Spot content: two roughly horizontal bands of spot-clusters cross the disk. An upper band, near the top, holds the smaller early-position clusters tagged with day-numbers (about 20–26) and the letter *a*. The main band runs along the AB ecliptic line: a dense daily sequence of spot-groups, each tagged with a day-number (running about 23–31 March and continuing into April), individual spot-letters *a–f*, and the marker **u** (*vespertina*, evening) for evening positions. Further clusters sit near the eastern and western limbs. Each spot is drawn with penumbra and dark nucleus.

[The individual per-spot micro-labels — dozens of day-numbers (20–31 March, 1–6 April), the spot-letters *a–f*, and the many *u/m* evening/morning markers along both bands — are too fine to resolve one by one with confidence even at high magnification; they are not individually transcribed here.]

Foot tables of the plate — MARTIVS / APRILIS

Header of each sub-column: **D _ H _ ☉. El.** = *Dies* (day) _ *Hora* (hour) _ ☉ *Elevatio* (the Sun's elevation/altitude above the horizon, in degrees and minutes). "m" =

matutina (morning), "u" = *vespertina* (evening). A small divider glyph (an astronomical-symbol-like mark) separates the two March sub-columns.

Month	Da y	m/ u	Hour	☉ Elev. °	☉ Elev. '
Martius	20	m	8 4/9	24	30
Martius	21	m	8 5/9	27	0
Martius	22	m	8 1/8	22	40
Martius	22	m	11 1/2	48	10
Martius	23	u	—	9	30
Martius	24	m	7 5/6	20	39
Martius	24	u	4	22	0
Martius	25	u	3 4/5	24	25
Martius	26	m	7 1/2	18	20
Martius	27	u	2 4/5	43	30
Martius	28	u	4 1/3	21	0
Martius	29	u	3 1/6	25	40
Martius	30	u	2 4/5	35	30
Martius	31	u	3 2/3	26	30
Aprilis	1	m	10 4/9	46	15
Aprilis	1	u	3 3/5	27	0
Aprilis	2	u	4 3/4	17	25
Aprilis	3	m	7 1/8	15	45
Aprilis	3	m	9	34	30
Aprilis	4	m	8 5/9	31	0
Aprilis	5	u	2 1/3	43	0
Aprilis	6	u	2 1/4	43	50

Notae in XVI. Observationum Imaginem [Notes on the XVI Image of Observations]

Notae in XVI. Observationum Imaginem, Martij 4. Aprilis 2. à die 24. illius, ad 2. huius. ("Notes on the Sixteenth Image of Observations: March 4, April 2 — from the 24th of the former month to the 2nd of the latter.")

I. First, you have here again, in this proportionally enlarged image, the agreement of the Spots — which I have always said and say: that larger observing circles, other things being similar or equal, always represent what is on the Sun more accurately and distinctly than smaller ones usually do. Secondly [as a sub-point], nevertheless, even in the smaller ones many fine details are set before the eyes accurately enough, as you see done here in the train of Spot C, on 27 March, the 30th of the same [printed "36"; see Numerical impossibles], the 31st, and 2 April.

Secondly, to avoid confusion arising from the crowding of places, I have not brought in all the days of observation or all the Spots, but the more suitable ones, by which the marvelous consonance of so many locations, in so widely separated a matter, might be established. But the Faculae around the exit of the northern Spot *a*, on 31 March, held to their own places and numbers, the observer so attesting, so that you may see that the same reckoning of parallax holds for the Spots, for the Faculae, and also for the shadows [umbrae].

[Margin: No parallax of the Spots, and equally of the Faculae.]

Compare each with each, and you will notice their admirable agreement.

II. [Compare these with the spots] observed at Douai [Duaci], together with the same Spots observed by me at Rome in this same year; where you will be able to note two things. First, the respect in which you will notice their agreement. See also the eighth Side-Table of Image XVIII, in which you will notice the same things likewise observed and recorded at Ingolstadt.

Thirdly, I would have you note that the sizes and general character [conimnitatem — reading uncertain [?]] of the Spots in the figures were not transmitted to me accurately, but were copied from my own observations, as the occasion allowed, by an unpolished hand [rudi Minerva]: the genuine ones you will find in Image 15.

Fourthly, know that the locations of the Spots have nevertheless been carefully preserved, and that the same letters have been attached to the same Spot on both sides, so that the letter *a*, on both sides, signifies the northern Spot. The letters *b*, *c*, and *d* denote the chief southern ones, carried across the Sun at their rising on the 24th and on the rest that follow.

Fifthly, at what hours and on what day the Douai observations were carried out, and under what elevation of the Sun above the horizon, the accompanying record in the diagram supplies.

Rosa Ursina, Book III — Notae particulares (Imago Solis XVI–XVII)

[engraved plate: IMAGO SOLIS XVI (Douai)]

Diagram. A full-page engraved solar disk — the sixteenth "Image of the Observations." It records the passage (course) of the sunspots across the solar face as observed at the Jesuit college of Douai, 24 March to 2 April 1625. The plate is built from two concentric circles centered on the same disk: an outer "enlarged circle" (AZBN) and an inner "observatory circle" (abc). A horizontal diameter, labeled the Ecliptic, runs left-to-right across the figure; numerous small sunspot marks lettered a–f are plotted along their daily paths, each tagged with a date and an evening ("u") marker.

Legible engraved text and labels:

- Upper left: **XVI. Imago Obseruationum.** ("XVI. Image of the observations.")
- Upper center: **M.D.C.XXV. In Collegio Academ. Duaceno Socie[tatis].** ("1625. In the Academic College of Douai, of the Society [of Jesus].") — flanked by two rose ornaments and the Jesuit IHS radiant monogram.
- Below center: **Cursus Macularum à 24. Martij, ad 2. Aprilis, similis et idem cu[m] Romano et Ingolstadiano, anni eiusdem.** ("The course of the spots from 24 March to 2 April, like and identical with the Roman and the Ingolstadt [observation] of the same year.")
- Upper right: **Martij. 4. — Aprilis. 2.**

Cardinal points and circle labels:

- **A. Oriens.** (A, East) — left end of the horizontal diameter.
- **B. Occidens.** (B, West) — right end of the horizontal diameter.
- **C** — midpoint of the diameter (on the ecliptic line), toward center.
- **AB, Ecliptica.** (AB, the Ecliptic) — the horizontal diameter.
- **a b c. Circulus Obseruatorius.** (abc, the Observatory Circle) — the inner circle.
- **AZBN. Circulus... ampliatus** (AZBN, the enlarged Circle) — the outer circle; Z at top, N at bottom.

Spot marks: individual sunspots are lettered **a, b, c, d, e, f** and plotted at successive dates — **24, 26, 27, 30, 31** March and **2** April — each with an accompanying **u** (evening) marker, so that each spot's daily displacement across

the disk is traced. Representative readable tags include a spot **a** at "24 u" (upper region near the eastern side), a spot **b** near top center, and spots **c** / **d** near the western limb tagged "2" (i.e. 2 April). The full set of per-spot date micro-labels is very densely engraved and only partly resolvable even at high magnification. [Many individual date–letter pairings: ?]

Foot tables (engraved beneath the disk). Two small tables of observation data, one for March, one for April. The column head reads **D — H — ☉.El** (Day — Hour — Sun's elevation above the horizon); in the body only the day, the evening/morning marker (u = evening, m = morning), and the Sun's elevation (degrees, minutes) are filled in.

MARTII (March):

D	H (u/m)	☉.El
24	u	29. 0.
26	u	23. 30.
27	u	25. 0.
30	u	41. 0.
31	u	42. 0.

[A small engraved word, "nonnisi" (?), appears between the 30 and 31 rows.]

APRILIS (April):

D	H (u/m)	☉.El
1	u	24. 0.
2	m	25. 0.

[Notae in XVI. Observationum Imaginem (continuation)]

[Note I., continued]

which I have always said, and do say: that larger observation-circles — other things being equal or comparable — always represent what is on the Sun more accurately and more distinctly than smaller ones usually do. Secondly, nevertheless, even in the smaller circles a great many fine details are set before the eye quite accurately, just as you see done here in the train of spot C, on 27 March, on the 30th of the same month, and on 31 March and 2 April.

Secondly, to avoid confusion arising from want of space, I have not brought in every observation-day or every spot, but the more suitable ones, in which the remarkable agreement of so many widely separated places would be established in a matter so far-flung. Yet the faculae around the exit of the northern spot **a**, on 31 March, were also present, in their own places and numbers — the observer so attesting — so that you may see that the same relation holds for the spots, for the faculae, and for the shadows too as regards parallax. Compare each with each, and you will observe the admirable agree- [continued]

[Margin: *Macularum aequae atque Facularum nulla parallaxis.* — "Neither the spots nor the faculae have any parallax."]

[Note II., continued]

ment. See also the VIIIth Lateral Table, of Image XVIII, in which you will find the same things likewise observed and noted at Ingolstadt.

Thirdly, I should like you to note that the magnitudes and the neatness [*conimnitatem*, recte *comminuitatem*/*concinnitatem*? — "fineness/neatness"] of the spots in the figures were not transmitted to me as exact, but that I have transferred them from my own observations, as best the matter allowed, with rough workmanship [*rudī Minerva*]; the genuine ones you will find in Image 15.

Fourthly, know that the positions of the spots have nevertheless been carefully preserved, and that the same letters have been attached to the same spot on both sides, so that the letter **a** on both sides denotes the northern spot, while the letters **b**, **c**, and **d** denote the chief southern spots at their rising on the 24th, and on the remaining following days, as they were carried around by the Sun.

Fifthly, the accompanying record in the diagram gives at what hours, on any given day, the observations at Douai were carried out, and at what elevation of the Sun above the horizon.

[Note: The lower half of this leaf shows faint, mirror-reversed show-through from the verso — the heading "Notæ in XVI. Obseruationum Imaginem, Martij... Aprilis..." and a March/April data table ghosting through the paper. This is bleed-through, not content of this page, and is not transcribed.]

[duplicate scan of the IMAGO SOLIS XVI plate]

This page is a second scan of the identical engraved plate already described (fig-p317-1) — same title, same Douai 1625 legend, same disk, labels, spot marks, and foot-tables. Not re-transcribed; see fig-p317-1 above.

Notæ in XVII. Obseruationum Imaginem.

Notes on the XVII Image of the Observations

[Margin: *Macularum diuersarum, diuersorum annorum, Cursus similes.* — "The courses of different spots, in different years, are alike."]

I.

First, I composed this Image and enlarged it proportionally from the observations made at Ingolstadt in the year 1623, toward the last days of March, so that an entirely similar course might appear — although in dissimilar spots, and in different years, yet in the same month and on the same days. For:

Second, although the spot **a** to the north and **b** to the south are not on exactly the same parallel on which they moved in the year 1625, they nonetheless do not depart much from the tracks of my own spots **a** and **b** in the year 1625; and, the same month and days having run their course and being represented in Image 15 of the Observations, you will find the curvature nearly the same, the stations and the daily intervals very much alike, and finally the same apparent motion.

[Margin: *Cursuum ex diuersis annis similitudo.* — "The likeness of the courses across different years."]

Third, take now the very words of the observer himself — who was Fr. Georg Schönberger [Georg Schönberger] — transcribed from his autograph:

[Margin: *Macularum Nuclei etiam Ingolstadij olim animaduersi.* — "The nuclei of the spots were noticed at Ingolstadt too, long ago."]

On 26 March: nine spots by inspection [direct viewing], five by projection [per Immissionem]; of which the largest, by inspection, in the manner of a rather thin cloud, on the side nearer its exit, had within itself a very black spot, as the figure shows.

On 27 March: seven spots, of which the first and second, which are northern, had grown notably.

On 29 March: four spots seen, of which the fourth was seen most distinctly on the meridian itself.

So he. From which I note the following.

II.

and [I say this] to the attentive reader. First, that he made most of his own observations by the Sun let in through the telescope [*Telioscopium*] onto paper, rather than by sight sent out through the helioscope [*Helioscopium*] at the Sun. Second, that observations made by sight directed at the Sun admitted through the helioscope are ordinarily more accurate and more distinct than those made by the mere projection of the Sun onto paper — as regards discerning the spots' figure, color, sparseness, and density — provided that we use especially the small observatory circles, as I found by experience in the case of Apelles [i.e. in my own earlier "Apelles" work]. Hence, so that even there, in the small circles, I might observe the exact outlines of the spots accurately enough, I always called in the telescope as an aid; and by its help I obtained exact figures, numbers, and distinctions of the spots — which this pupil of mine, taught by me long ago, here too diligently supplied.

[Margin: *Vsus Helioscopij superat praxim Telioscopij ad paruum circulum obseruatorium restricti.* — "The use of the helioscope surpasses the practice of the telescope when the latter is confined to a small observatory circle."]

Hence take note, Third: that black spot seen within a cloud was a nucleus struggling, within its own vapor or exhalation, toward the margin — which is a most frequent occurrence in this phenomenon.

Fourth: that without inspection, by projection alone, neither the two middle northern spots nor that vapor drawn out from its nucleus were seen distinctly. For a small circle, because it magnifies the objects too little, always represents these minute things gathered into a single mass, as experience testifies.

Fifth: the enlargement [augmentation] of the spots is evident. Sixth: spot **d**, the offspring of a single day, appeared at the center, which is called the Sun's vertical [meridian] point. Both of these are not new, but frequent enough throughout this whole phenomenon.

[Note: This page also shows faint mirror-reversed show-through from the verso (a ghosted "MARTIVS / APRILIS" observation table and stray spot-figures) between and beside the letterpress lines. This is bleed-through, not content of this page, and is not transcribed.]

IMAGO SOLIS XVII

Diagram. Full-page engraved solar-disk plate, the seventeenth Image of the Observations (folio 197). A large solar disk is drawn with a horizontal diameter

running left to right; the left end is labeled **A. Oriens** (East) and the right end **B. Occidens** (West). Two nested circles are named in the field: **a b c d, Circulus Observatorius** (the observatory/projection circle) and, larger, **A Z B N, Circulus ... ampliatus** (the amplified circle, whose vertices are A left, Z top, B right, N bottom). The heading block at the top reads: at upper left "**XVII, Imago Observationum**"; at center "**M.DC.XXIII**" (1623) over "**In Collegio Academico Ingolstadiano Soc.**" (In the Academic College of Ingolstadt, S.J.), flanked by an heraldic rose ornament, the radiant **IHS** Jesuit device, and a second rose; at upper right "**Martij, 5.**" [?]. The caption across the lower field reads: "**Cursus Macularum à 26, ad 30. Martij, similis Romano aliorum annorum in mense eodem**" — "The course of the spots from the 26th to the 30th of March, similar to the Roman [course] of other years in the same month."

Across the disk, near and just above the A–B diameter, runs a train of sunspots carrying letter-labels (a, b, c, d) together with the day-numbers 26, 27, 28, 29, 30 (the 30th marked with **u** = evening); the group drifts from the central region toward the western limb (B). The individual per-spot letter-and-date micro-labels are largely overlaid by heavy mirror-reversed show-through from the verso and cannot all be resolved with confidence — the readable anchor points are a spot-track labeled **b** at successive dates 26–30 and additional spots labeled **a** and **d** near the center. [Per-spot micro-labels not fully resolvable]

Foot-table of observation times engraved on the plate:

MARTII (March)

Day	(m/u)	Hour	Scr.
26	m	9	0
27	m	10	30
28	m	7	45
29	m	11	0 [?]
30	u	3	2 [?]

ROSAE VRSINAE LIB. III

Notes on the eighteenth Image of the Observations, compiled from the various courses observed in different places and years, in the months of February, March, and April.

First: this Image contains many Tables, entirely in agreement with the Images already explained and alike as regards the motion of the spots. Because these observations were made elsewhere and by others, because they run through still other years, and because they are compressed into smaller observational circles, I wanted to bring them together at their own scale — not enlarged — into a single view. This makes plain how thoroughly alike and uniform the motions turn out to be, how similarly and uniformly the spots proceed everywhere, and how similar and equal their durations are in every case. For I have rendered them most faithfully from the autograph records sent to me. Should you wish to test whether everything enclosed within these little circles corresponds proportionally to mine, enlarge these circles to the size of my own, and you will feel the truth of what I have said. The more noteworthy points I now append.

Table one corresponds to Image XI. Note that the spot seen from the 5th of February — both at Rome by me and at Ingolstadt by Schönberger — was a single, simple spot, though at Rome it had also been seen on the earlier days. Then on the 6th, here at Rome, it acquired a tiny spot on its upper side, which however was not noticed at Ingolstadt; still others were added on the 8th, and they were likewise seen on the 10th, 11th, and 12th, at both places in almost the same way. For the ones I saw joined on the upper side at Rome on the 10th, Schönberger saw on the 11th; but on the 12th those little appendages appeared to neither observer. Likewise on the 11th and 12th the intervals between the spots became greater than they had been on the 10th. On the 6th the spot at both places sat on the ecliptic; on the 10th it grazed it; and it displayed altogether similar motion and position at both places, as the observation figures show. From these an irrefragable argument is drawn for asserting that the spots have no parallax. [Margin: The spots have no parallax.]

Table two corresponds to Image XII. Note that spot **a** stuck in the same place on the 10th where spot **b** stood on the 11th; hence the same spot in the same place carries the numbers and characters of two days and of two spots in the diagram — which also happens on the 12th, and not rarely on other occasions, as can be seen in my Image XII toward the beginning, at day 9, and so on. This being noted:

spot **a** in this Table corresponds to spot **b** in my Image 12; spot **b** here to spot **C** there; spot **c** here to spot **f** there. Spot **a** here, as also at Rome, resolved into several; and at both places it diminished and went out very thin. Spot **d**, corresponding to spot **g**, was newly born again on the Sun at both places on the 16th, in the same proportional situation and place, and variously multiplied — a multiplication which, to avoid confusion, I omitted in the Table. At last everything at both places passed over into a facula on the 22nd, with the same situation, figure, magnitude, and proportional place on the Sun, as is clear from the pictures. Spot **e**, the same at both places, very thin, passed over into a facula at both, and here at Rome entered a facula. [Margin: The same places, seen [alike], overturn parallax.]

Table three corresponds to Image XIII, and similar letters are attached at both places to similar spots. Note that spot **b**, seen triple on the 26th, shone forth on the 4th of March together with a facula at both places, in the same situation and place. Spot **c** on the 26th was noticed also at Ingolstadt, for by the 28th it had ceased and so could not be seen there. Spot **f** is recorded at both places in the same situation and place; likewise spot **d**. As for the faculae of the 7th — the western **a** and the eastern **g** — consider their true shapes in my Image. It is enough to obtain the appearance from these little Circles. **g** was a pure facula. [Margin: A pure facula observed at Ingolstadt as well.]

Tables four and five, of Freiburg [Freiburg im Breisgau], of the year 1622, have no counterparts among mine, because I do not now have to hand the observations of that year, either my own or others'. Nonetheless I still insert these Images too, because — although the spots depicted in them are not the same as those of this year —

Diagram. Full-page composite engraved plate, the eighteenth Image of the Observations (folio 199). The heading reads: "**IMAGO SOLIS XVIII.** — XVIII, Observationum Tabula, complexa 8. Imagines Laterales à 5. Febr. ad 6. Aprilis. conflatas ex annis 1621. 1622. 1623. 1625. in diuersissimis Europæ Locis. etc." — "The eighteenth Image: an Observation-Table comprising 8 Lateral Images, drawn up from the years 1621, 1622, 1623, 1625, in the most diverse places of Europe, from the 5th of February to the 6th of April." The plate is arranged as eight small solar disks (**Tabella Lateralis I–VIII**), each with a horizontal A–B diameter (A = East/left, B = West/right at the disk edge), a spot-track carrying tiny letter-and-date labels, and a foot-table of observation times. Radiant **IHS** and **MRA** monogram devices and rose ornaments fill the margins. The individual spot micro-labels (letters a, b, c, d, f, g with day-numbers) are extremely small and

partly obscured by verso show-through; they are not all resolvable — the disk headings and foot-tables below are the reliably readable content. [Composite plate, many sub-labels [?]]

Tabella Lateralis I — "Ingolstadij, 1625. Cursus Macularum à 5, ad 12, Februarij, similis Romano in Imagine XI." (Ingolstadt, 1625; course of the spots from the 5th to the 12th of February, similar to the Roman one in Image XI.)

Februarij (D = day, H = hour, Scr. = minutes; m = morning, u = evening)

Day	(m/u)	Hour	Scr.
5	m	8	40
6	m	8	45
10	m	9	1
11	m	8	15
12	u	2	40

Tabella Lateralis II — "Ingolstadij, 1625. Cursus Macularum à 10, ad 22, Februarij, similis Romano, in Imagine XII." (Ingolstadt, 1625; from the 10th to the 22nd of February, similar to the Roman one, in Image XII.)

Februarij

Day	(m/u)	Hour	Scr.	Day	(m/u)	Hour	Scr.
10	m	9	1	16	m	8	44
11	m	8	15	17	m	8	7
12	u	2	40	18	m	10	9
17	m	10	47 [?]	21	m	10	18
				22	m	8	40

Tabella Lateralis III — "Ingolstadij, 1625. Cursus Macularum à 26. Febr: ad 4. Martij, similis Romano in Imagine XIII." (Ingolstadt, 1625; from the 26th of February to the 4th of March, similar to the Roman one in Image XIII.)

Day (Feb.)	(m/u)	Hou r	Scr.	Day (Mar.)	(m/u)	Hou r	Scr.
26	m	10	13	4	m	12	17
28	m	10	26				

Tabella Lateralis IV — "Friburgi Brisgoiæ, 1622. Cursus Macularum à 16, ad 21, Febr. similis Romano anni 1625." (Freiburg im Breisgau, 1622; from the 16th to the 21st of February, similar to the Roman one of the year 1625.)

Februarij (D = day, H = hour, O. Eleuat. = solar elevation, in degrees and minutes)

Day	(m/u)	Hour	Scr.	O. Eleuat. (° ')
16	m	10	29	25 59
21	m	7	15	7 20

Tabella Lateralis V — "Friburgi Brisg. 1622. Cursus Macularum à 27, Febr. ad 2, Martij, similis Romano anni 1625." (Freiburg im Breisgau, 1622; from the 27th of February to the 2nd of March, similar to the Roman one of the year 1625.)

H o					H o				
Day	(m/	u	Sc		Day	(m/	u	Sc	
(Feb.)	u)	r	r.	O. El. (° ')	(Mar.)	u)	r	r.	O. El. (° ')
27	m	8	1	13 28	1	m	7	3	8 56
			0					0	
					2	u	3	4	15 28
								9	

Tabella Lateralis VI — "[Ingolstadij, 1623.] Cursus Macularum ... [Martij]." (See note; this disk carries the "Tabella Lateralis, VI" label with a March foot-table.)

Martij

Day	(m/u)	Hour	Scr.
1	u	2	18
4	u	2	0
5	m	9	5
6	u	1	26

Tabella Lateralis VII — "Ingolstadij, 1625. Cursus Macularum à 6, Martij ad 19, eiusdem similis Romano." (Ingolstadt, 1625; from the 6th of March to the 19th of the same, similar to the Roman one.)

Martij

Day	(m/u)	Hour	Scr.
6	m	9	54
7	m	10	49
8	u	2	15
15	m	9	39
18	u	3	41

Tabella Lateralis VIII — "Ingolstadij, 1625. Cursus Macularum à 20, Martij, ad 4, Aprilis, similis Romano et Duacensi." (Ingolstadt, 1625; from the 20th of March to the 4th of April, similar to the Roman and the Douai [course].)

(Here H = hour, mat. = morning, pom. = afternoon/evening, Scr. = minutes.)

Day (Mar.)	Ho			Day (Apr.)	Ho		
	ur	mat./pom.	Scr.		ur	mat./pom.	Scr.
20	10	mat.	6	2	2	pom.	52
22	11	pom.	55	4	9	mat.	52
23	8	mat.	55	6	8	mat.	52
24	9	mat.	50				
28	5	pom.	15				

[Continuation of *Tables four and five*, following the plate:] — yet perhaps they do not run in the same parallels. Even so, the traces of motion they have left take on entirely the same character and relation to the ecliptic that the spots of this year have, those that ran across the Sun in the same month and on the same days. There the paths of the spots, when set both before and after the center, all appear as if rectilinear and roughly equidistant from the ecliptic — which can be seen here too in spot **a**, on the 16th and 21st. Conversely spots **a** and **b**, marked in Table V, because they are nearer the eastern horizon, describe arcs that slope upward toward the center and the ecliptic; and similarly spot **C**, near the western horizon, on the same days slopes downward away from the ecliptic and the center — which the spots of this year also did and do, as is clear in Image XIII. There you see that, while on the same 28th of February and 2nd of March facula **e** ascends, on the same and following days spot **b** descends in the same, as it were, parallel on the western side. Spots **a**, **b**, and **c** behave in exactly this way; therefore the ratio of the motion turns out entirely alike, on the same days and months, and so on. [Margin: Motions of different years alike.]

Table six, of Ingolstadt, of the year 1623, teaches and urges the same. For spot **a**, having advanced over 6 days from the center toward the margin, describes similar arcs, just of the sort marked in the courses of Image XIII by spots **a** and **d**, from the 1st or 2nd of March to the 5th and 6th of the same — as will be evident to anyone who compares them.

Table seven, of Ingolstadt, corresponds to my Image XIV; and its spots **a**, **b** correspond to the spots of this Table, marked under the single letter **a**. But facula **c**, which in Table three I had marked under **g**, corresponds to facula **C** and spot **d**, [and to] the spots **e** and the facula of the 18th, the faculae of the same day. Here note that the faculae **d** appear heaped into one pile, unfolded, and set out under their own shapes in my Image under the letter **g**. Likewise spots **d** here, at the 13th of February, and spots **e** there, are seen in proportional situation, for at both places the more northern one sits on the ecliptic — but they differ greatly in number: at Ingolstadt only two spots were seen, here at Rome four. Consult other days as well. From these it is most firmly established that there is no difference in the spots' aspect toward the Sun. [Margin: No parallax.]

Table eight, of Ingolstadt, corresponds to the fifteenth, the Roman Image; and the letters attached to the spots in this Table agree with the same letters in Image XV — places with places, shapes with shapes, down to the very minutiae, so far as such tiny Circles can carry them. Compare, and you will find the truth. Hence again parallax is eliminated. [Margin: Parallax, arising from the fullest correspondence of the places seen, is banished from this phenomenon.]

Note one. In Image XV, spot **C** is observed and recorded as having been seen on the 22nd of March; but here, in the observation of that same day, it did not fall into view — which likewise happened on the 4th of April, where you see the same spot **C** turned toward the horizon in my Image, although the Ingolstadt observer, otherwise diligent, noticed nothing at all of it. The fault therefore lies not in him, but in the inadequacy of the observatory Circle. Hence it is clear from these Circles (as I have often already pointed out) that neither the full apparent motions nor other consequences drawn from them can be rightly established and decided; for the observations and motions come out defective. And this is one of the reasons why Apelles always deferred to further observations. [Margin: Small observatory circles yield defective observations and motions.]

Note two. The apparent courses behave in the same way at both places with respect to the ecliptic. The southern spots are nearer the point of rising than to the point of setting; the northern ones, conversely, are more remote in the eastern region than in the western, while they are on the horizon. For in their

progress they make curved bends, and they approach more toward the south and recede toward the north than they had been near the horizon at rising, and so on.

Note three. The paths of spots **c** and **a**, together with their intervals, if measured along lines perpendicular to the ecliptic, become gradually larger, beginning from the point of rising — both in this Table and in my Image XV — which is not infrequent in the other observation Images as well. [Margin: Motions not parallel.]

Notes on the nineteenth Image of the Observations, of April, from the 2nd to the 14th of the same.

First: From the 6th of April — when the predicted crowds of spots had departed — the Sun produced only small spots of almost no moment; meanwhile it was most fertile in faculae. To these I deliberately turned, having gained leisure from the spots, and I devoted myself with singular zeal; whose courses, accordingly, I here set before the eyes as noted.

Second: on the second day, then, in the evening, a single bright facula **a** shone out on the horizon between two or three rather dense shadows. [Margin: The daily rising of the faculae above the horizon.]

On the third day, in the morning, and while the whole [company] of the faculae ...

Diagram. A full-page engraved plate of the solar disk — IMAGO SOLIS XIX. The disk is a large circle crossed by a horizontal diameter (the ecliptic line). At the top center are a heraldic rose device (repeated left and right) and the Jesuit IHS sunburst emblem. Engraved lettering within and around the disk:

- (upper left, within disk) **XIX. Imago Observationum** ["19th. Image of the Observations"]
- (upper center) **Anno Iubilaeo: M.DC.XXV.** ["In the Jubilee Year 1625"]
- (upper center, below) **In Domo Professa Romana Societatis** ["In the Professed House of the Roman [Society] (of Jesus)"]
- (upper right) **3.^a Aprilis** ["April 3rd" — the third April image, or the date of drawing]
- (bold caption band across the disk) **Cursus Macularum et Facularum, à die 2. ad 15. Aprilis:** ["The course of the spots and faculae, from the 2nd to the 15th of April:"]
- (bold caption band, second line) **Similes aliis aliorum annorum tempore eodem.** ["similar to those of other years at the same season."]

- (left, on the diameter) **A, Oriens** ["A, East"]
- (center, on the diameter) **AB, Ecliptica** ["AB, the Ecliptic"]
- (right, on the diameter) **B, Occidens** ["B, West"]

Within the disk, clusters of small circles and stipple represent umbrae (shadows) and faculae drawn as day-by-day positions along curving tracks. Legible micro-labels along the eastern (left) tracks include the letters *a* (many occurrences), *b*, *d*, small *u* / *m* markers, and the day-numbers 2, 3, 4, 5, 6, 7, 8, 9, 10. Along the western (right) side near B are the day-numbers 13, 14, 15 with letters *a*, *m*, *d* and a cluster labelled 15 at the lower right. Numerous individual per-spot micro-labels (letter + day-number pairs) are only partly resolvable under magnification and are flagged collectively [?]. The APRILIS ephemeris table (transcribed below) is engraved in the lower-center of the disk.

Ephemeris table engraved within the plate (two side-by-side sub-columns).
Column heads: **D** (day) · time-of-day (*m* = morning, *u* = evening) · **H** (hour) · ☉ · **El.**

APRILIS

D	m/u	H	☉	El.
2	u	3¾	27	20
3	m	7¾	22	20
4	m	9 [—]	35	0
5	m	8⅘	34	10
6	m	8⅓	29	20
7	m	7¼	19	30
8	u	2¼	44	15
9	u	3¼	34	10
10	m	10¾	51	45
13	m	—	37	40
13	u	3½	33	0
14	m	6⅔	18	20
14	u	2⅛	47	25

Notae in XIX [Notes on the 19th image of observations — begun on the preceding leaf] ...[fa]culae and shadows had escaped up above the horizon, and I was left in doubt as to what that variegated headland, built up out of shadows and bright specks, would in the end bring forth. I was certainly expecting spots, which it

seemed on the point of producing. But then — behold — on the 4th day it began to break apart into separate faculae, revealing a certain very small, rather doubtful spot.

On the fifth day, more numerous and more widely separated patches of faculae shone out, with quite conspicuous shadows set between them. On the sixth day, larger disjunctions declared themselves, but both the shadows and the faculae began to grow thin — apart from the one which, for want of room, I set off to one side. On days 7, 8, 9, and especially 10, they were interspersed with shadows tinged with such faint gleam and light that they almost escaped the keenness of sight; yet what I could make out with certainty I have set down.

On the 11th and 12th no Sun appeared. On the 13th, both morning and evening, there returned once more — not shadows but four very small spots, thin, fairly close together, together with bright faculae; and I do not doubt that they had lasted through the whole Sun all the way from the east, and that after a long struggle with the faculae they had been gathered up out of shadows into massed spots. The place, the time, and a certain resemblance of shape all agree. For I have found, by the most reliable and continuous experience over so many years, that faculae are in perpetual and far more perceptible change of shape than spots are. The evening aspect I have rendered in the lateral figure.

On the 14th only two spots appeared, but larger; for the two leading ones merged into one, and the two following likewise, and they took their stand among the faculae, and these enveloped one large shadow extending toward the north. Which pure faculae followed, you have in the morning lateral scheme. In the evening the leading one, very slender, drew near the horizon.

Thirdly, spots b appeared on day 2, in the manner of shadows enclosing a facula; then little by little they spread out into thin spots, until on days 9 and 10, their tail sent ahead in the manner of a comet, they wholly vanished.

Fourthly, the purest boreal faculae C did not shine after the third day. The apparent course of those faculae and shadows, if it reached thirteen days, certainly did not exceed it.

Fifthly, d are a pair of spots, continued along the same track as b, and so I take them to be the same — though b on day 3 I judge should be drawn back somewhat toward the east; on the remaining days you see them advancing with an even and orderly progress together with the faculae. They increased in number on days 6 and 7, somewhat pulled apart in place — unless (which I actually judge truer) you prefer that new ones were born as others died away.

For on day 8 a single one remained, which, fading on days 9 and 10, imitated a bearded comet with its beard sent ahead. It advanced with faculae as if at an equal distance. After the 10th day it left no trace of itself.

Sixthly, the direction of the curvilinear motion is from the rising north into the south, with the concavity of its path facing the Antarctic pole and its convexity toward the north; the upper and ascending pole being the southern, the descending one the northern.

Diagram. A full-page engraved plate of the solar disk — IMAGO SOLIS XX. As with the XIX plate, the disk is a large circle crossed by a horizontal diameter (the ecliptic), with the heraldic rose device (twice) and the IHS sunburst emblem at top center. Engraved lettering:

- (upper left, within disk) **XX. Observationum Imago** ["20th. Image of the Observations"]
- (upper center) **Anno Iubilaeo. M.DC.XXV.** ["In the Jubilee Year 1625"]
- (upper center, below) **In Domo Professa Romana Societatis** ["In the Professed House of the Roman Society (of Jesus)"]
- (upper right) **Aprilis. 4.^a** ["April, the 4th [image]"]
- (bold caption band) **Cursus Facularum a, et Macularum b, a,** [start-day numeral [?]] **ad 18.^m Aprilis.** ["The course of the faculae a, and of the spots b, a, from [day ?] to the 18th of April."]
- (left, on the diameter) **A. Oriens** ["A, East"]
- (center, on the diameter) **C** (midpoint of the diameter)
- (center label) **AB. Ecliptica** ["AB, the Ecliptic"]
- (right, on the diameter) **B. Occidens** ["B, West"]
- (bottom of disk) **N** (south point / pole marker)

Within the disk, dense clusters of stippled umbrae and open-ring faculae are drawn along curving tracks. Legible micro-labels: on the eastern (left) side, letters *a, b* with small day-numbers 5, 6, 7, 8, 9, 10; near center, *C* and the numbers 10, 13; on the western (right) side, large facula clusters with letters *a, b* and the day-numbers 13, 14, 15, 16, 17, 18 concentrated toward the south-west limb. Many individual per-spot letter+number micro-labels are only partly resolvable under magnification and are flagged collectively [?]. The APRILIS ephemeris table (below) is engraved in the lower-center.

Ephemeris table engraved within the plate (two side-by-side sub-columns).
Column heads: **D** · time-of-day (*m/u*) · **H** · ☉ · **El.**

APRILIS

D	m/u	H	☉	El.
5	m	$8\frac{8}{9}$	34	10
5	u	3 —	33	20
6	m	$8\frac{1}{3}$	29	30
7	m	$7\frac{1}{8}$	19	30
8	u	$1\frac{3}{4}$	47	20
9	m	8 —	26	10
10	m	$10\frac{3}{4}$	41	45
13	m	$8\frac{8}{9}$	36 [?]	30
14	m	$6\frac{2}{3}$	18	20
15	m	$8\frac{1}{2}$	33	5
16	m	$7\frac{1}{4}$	25	30
17	m	$8\frac{4}{9}$	32	15
18	m	$7\frac{1}{3}$	22	20

Notæ in XX. Observationum Imaginem, Aprilis 4. à die 5. ad 18. eiusdem.

[Notes on the 20th image of observations — the fourth April [image] — from the 5th to the 18th of the same month.]

Firstly, just as April, from the fifth day onward, lost — or rather sent forth from the apparent hemisphere of the Sun into the opposite one — great spots, and displayed very slight ones through the following days, so in turn it shone with exceptional faculae, whose series I began to set out in the preceding image XIX, and now I continue in this XXth. For the faculae themselves too followed on immediately, in a manner of speaking; and what sort they were, learn from the ephemeris appended below.

[Margin: A facula's struggle up above the horizon, lasting many hours.] Secondly, on the morning of April 5th there shone a facula a — or rather many faculae, separated by shadows running between them like veins; it was not yet clear of the horizon, which nevertheless by the third evening hour it seems to have surmounted, as is plain enough from the lateral figure, except that a certain southern arm still seems to stretch out somewhat into it. The shadows of this facula were quite conspicuous, especially those nearer the horizon. It is clear, from a comparison of the morning and evening observation, that the faculae were somewhat altered.

On day 6 it appeared longer and broader, as the figure also shows. On day 7 it was seen to be attenuated and weakened in brightness. On day 8 it broke up into many faculae, hard to see. On day 9 they all appeared rarer and thinner. On day 10 they wearied the sight and almost eluded it, unless — using a special technique — I had drawn them out. On the 11th and 12th no Sun shone. On the 13th they shone very feebly. At last, on the 14th, they shone more vigorously again, as if with restored flame. On day 15 they gleamed out more fully, yet among shadows much softer and rarer than the eastern ones had been. On day 16 I set the whole thing out to the side — the northern ones — so that you may see the entire constitution of the faculae and of the shadows clinging to them, which came out thinner and more slender and began to graze the horizon. (NB: they are cut more strongly than they ought to be.) On day 17 they settled at the middle of the horizon, as you have it set before your eyes in the southern lateral figure; and at last, on the 18th, they left it wholly empty to view.

Thirdly, as for the rest — that these faculae are, by continuation, the same ones that arose on April 5th — I have no doubt at all, and [Margin: These faculae were the same across the whole Sun, notwithstanding their continual mutability.] I bring forward arguments for this from their motion, from time, from position, and finally from the accompaniment of spot b, which always advanced alongside those same faculae at a proportional interval. But should anyone object the variation of shape, the augmentation, disjunction, rarefaction, intensification and remission, that same objection will be turned against the spots as well. And yet, on account of these changes, no one will deny that spot b is the same on the 13th, on the 14th, and right to the end, as it had been at the outset, on days 5, 6, and 7, and so on — because, namely, here it appeared simpler and smaller, there larger, more numerous, and at last more brilliant with faculae. By the same reasoning, then, the faculae passed across the Sun as the same, though altered, without doubt; and indeed with the same delay as spot b, which the faculae preceded at rising and setting, as if at midday. [Margin: The faculae's sojourn on the Sun, about thirteen days. Beyond the horizon, though long ensconced, they emitted nothing.] Their delay under the Sun, if it reached 13 days, certainly did not exceed it. And great though they were, and though they clung so long in the eastern horizon as they ascended and in the western as they descended, and though in both they blazed most vehemently, still they shot out not even the least little flame beyond or outside those limits.

[Margin: The breadth of the faculae.] Fourthly, spot b, moreover, though obscure and rare, nevertheless lasted through the Sun and gradually grew; after, on the 13th, it had begun to be kindled by the thin faculae, once these were vehemently

increased and shone forth at its exit, it was consumed, resolved into thin shadows. Consider carefully the lateral schemes of days 16, 17, and 18.

Fifthly, the breadth of those faculae — as is clear from days 6 and 7 around rising, and 15 and 17 around setting — was about one-fifth of the solar diameter AB.

Sixthly, it must be carefully noted that these faculae, both at the rising of the fifth day and at the setting of the seventeenth and sixteenth day, and so on, settled upon the horizon in such a way that they lit it up distinctly and as if in saw-tooth fashion, with shadows following one after another in alternation; nor did any shine out beyond the perimeter of the horizon, in the way that they shone inward — as has also been said before.

Diagram. A full-page engraved solar disk — the twentieth observation-image of the Roman series for the Jubilee year 1625, tracking the faculae and spots across the Sun's face from 5 to 18 April.

Printed matter within the disk:

- Upper left: "XX, Observationum Imago." (Image of the 20th observation.)
- Upper center: "Anno Iubilaeo. M.DC.XXV. In Domo Professa Romana Societatis." (In the Jubilee year 1625. In the Professed House of the Society at Rome.)
- Upper right: "Aprilis. 4.a" (April, the 4th.)
- Center: an IHS sunburst emblem flanked by two heraldic-rose (Orsini) ornaments.
- Caption band: "Cursus Facularum a, et Macularum b, à 5.º ad 18.m Aprilis." (The course of the faculae *a*, and of the spots *b*, from the 5th to the 18th of April.)

Orientation labels:

- Z — top (meridian/zenith point).
- N — bottom (meridian point).
- A. Oriens — left limb (East).
- B. Occidens — right limb (West).
- AB. Ecliptica — the horizontal diameter A–C–B (the ecliptic line).
- C — center of the disk.

Spot lettering (only glyphs legible under magnification are given; faculae are marked *a*, spots *b*, each with its day-number for April):

- Along and above the ecliptic, left half: faculae "a" with day-numbers "5", "6", "7", "8", "9", and open faculae-rings near "10" (at C). Adjacent to the upper-left limb: "a 5 u" and, below it, "b [?] u".
- Below the ecliptic, left half: a row of spots "b" numbered "5"[?], "6", "7", "8", "9", "10".
- Right half, near the upper limb: "a 16".
- Right half, along and below the ecliptic: faculae "a" with "13", "14"; spot-clusters numbered "15", "16", "17", "18"; and spots "b 16", "b 17", "b 18".
- Numerous smaller micro-labels around the individual spot groups are too fine to resolve and are left unread. [?]

Foot-table (APRILIS). Two paired sub-columns; headers read D – H – ☉, E1.
(Day — Hour — Sun's position, degrees and minutes). Time-marks: *m* = morning (*matutina*), *u* = evening (*vespertina*).

Day	Time	Hour	☉ °	'
5	m	8 8/9	34	10
5	u	3	33	20
6	m	8 1/3	29	30
7	m	7 1/8	19	30
8	u	1 3/4	47	20
9	m	8	26	10
10	m	10 3/4	41	45
13	m	8 8/9	36	30
14	m	6 2/3	18	20
15	m	8 1/2	33	5
16	m	7 4/7	25	30
17	m	8 4/9	32	15
18	m	7 1/3	22	20

Notes on the XXI Image of the Observations, [covering] from 18 April to 1 May

(Notae in XXI. Observationum Imaginem, Aprilis[?] à die 18. Aprilis ad 1. Maij.)

First. Setting aside much else, dear reader, here you have the following points worth noting. The spot *a* in the south — or rather two conjoined spots — entered

the Sun on the evening of 18 April together with faculae, and left it likewise together with the same, just as the engraving shows.

Second. At their ingress they appeared united and, in their usual way, slender along the [line of the] horizon — just as at their egress on the evening of 1 May.

Third. In the course of their transit their number, shape, and character, and likewise their blackness, density, and brightness — and their size too — varied very greatly, as the engraving set before you attests.

Fourth. The nuclei were similarly united near their ingress, separated in the middle, and diverse throughout. The cloud or vapor wrapped about the nuclei did not keep an even course: it was always more extended toward the [Sun's] rising side than toward the setting side, and thinner toward the eastern edge.

Fifth. In longitude, so long as the spot moved within the middle of the Sun, it exceeded its own latitude.

Sixth. Within itself it almost always carried a very white, bright facula marked by a white cleft, its shape likewise continually varying, as you see rendered.

Seventh. It sent faculae ahead of it and drew others behind, and the extremities of the eastern shadows were denser toward the center, rarer toward the margin.

Eighth. Over almost the whole Sun it was surrounded by a field or halo — dusky toward the center, bluish toward the margin — which you see drawn on the 21st and 22nd, described by dots around the perimeter.

Ninth. As for what kind the faculae and shadows were — their shape, size, position, and so forth — you have this rendered in the side-figures, each with its own days and hours to which they are assigned; for I did not observe the faculae of every day, since they accompanied the spot across the whole Sun, and I have not appended all my observations here, except the one that clung within the gaping bowels of the spot. [Margin: *Amplitudo Facularum*. — The extent of the faculae.]

Tenth. And indeed these shadows and faculae, at the beginning, on the tenth day equaled in their breadth a quarter of the solar diameter; but in length, on the 30th, it was a seventh part of the diameter.

Eleventh. After the middle of its course this spot gradually but noticeably diminished, split into more and smaller parts, as the figure sufficiently shows.

Twelfth. It held a gently curved course, oblique to the ecliptic, bending back from north to south; the chords recede further from the ecliptic, [and the] section [continues]. [Margin: *Arcuum itinerariorum curvitas, & chordarum ad Eclipticam.* — The curvature of the arcs of the paths, and of the chords, relative to the ecliptic.]

Thirteenth. It moved beneath the Sun for about thirteen days. For on the 18th, at the 3rd hour of the afternoon, it had nearly cleared the horizon; on 1 May, at the 8th hour of the morning, it still stood beyond that same horizon. So if we grant four hours on each side, we shall have thirteen days, and so on. [Margin: [...] *the inclination decreases; the south pole descends. / Mora sub Sole dierum tredecim.* — Its stay beneath the Sun, thirteen days.]

Fourteenth. At the western horizon it lingered a long while, about six hours. [Margin: *Mora ad horizontem longa.* — A long stay at the horizon.]

Fifteenth. This spot entered among faculae and left among faculae; and, in turn, faculae entered and left within that same spot, and coursed over the whole open hemisphere of the Sun, and a marvelous intermingling of the two appeared — so that at the horizon the spot seemed, as it were, tinged and somewhat absorbed by the faculae. [Margin: *Macula à Faculis diluta.* — The spot diluted by the faculae.]

Sixteenth. This spot seems to be one of those that returned. For although few spots last long enough to make a perceptible return-passage from the averted to the facing side of the Sun — most perishing sooner — nevertheless, since the time, place, shape, and situation agree, it is highly probable that this spot is the one that crossed the Sun under the letter *c* in Image 15, from 22 March to 4 April. Since that spot departed while still growing, it could well have endured so long that, after some fourteen days were spent, it at last returned on the 18th. What makes me believe this is the same parallel, and a location entirely the same in that parallel. For it is incredible — I will not say (given the usual practice and character of this phenomenon) impossible — that this spot arose anew in the place of the former one before that one had been consumed. For, as I said, the former departed while increasing, whereas this one entered while decreasing; and so, since they occupy the same place in the same parallel, they would have blocked each other by their contrary conditions. It is certain that this spot claimed for itself as much time in growing as it has now spent in shrinking; therefore it is certain that the whole hidden hemisphere lasted longer as well. It was therefore once in the open side and set while still growing, just as it has now run its full course while shrinking. Conversely, even if the spot *c*, when it departed, had at once begun to shrink (which, however, does not usually happen

— spots rather stay a while in a steady state, proportionally), even so it would still have reached this hemisphere. [Margin: *Macula redux, cum omnibus circumstantijs*. — A returning spot, with all its attendant circumstances.]

The location, therefore, seems to prove it. There is joined to it a certain shape and size, and an immense retinue — not of spots (which were few and small, and are not placed here for lack of room), but of faculae and shadows, which I am certain arose from the recent spots that followed; and reason, together with steady experience, entirely persuades me of this. A periodic reckoning also makes the matter plain. But of these things elsewhere, in their own place.

Seventeenth. Consult the first table of Image XXVI, and you will see the proportions of the motions, inclinations, and faculae; and at the same time, from what has been noted by the Ingolstadt observers, you will understand how great a difference there is between a small and a large observing-circle.

Diagram. A full-page engraved solar disk — the twenty-first observation-image of the Roman series for 1625, tracking the spot's course from 18 April to 1 May.

Printed matter within the disk:

- Upper left: "XXI. Imago Observationum." (Image of the observations, no. 21.)
- Upper center: "M.DC.XXV. In Domo Professa Romana Societatis." (1625. In the Professed House of the Society at Rome.)
- Upper right: "5. Aprilis." [The "5. Aprilis" here is anomalous against the caption's date-range of 18 April – 1 May; transcribed verbatim, flagged.]
- Center: an IHS sunburst emblem flanked by two Orsini-rose ornaments.
- Caption band: "Cursus Maculae, à 18. Aprilis ad 1.m Maij; similis aliis aliorum annorum tempore eodem." (The course of the spot, from 18 April to 1 May; similar to that of other years at the same season.)

Orientation labels: Z (top), N (bottom), A. Oriens (left limb, East), B. Occidens (right limb, West), A.B. Ecliptica (horizontal diameter), C (center).

Spot lettering (faculae/spots marked *a* with day-numbers 18–30 April and 1 May, several with hours *h.*; only legible glyphs given):

- Left limb: "a 21 u" with "hora 4 3/5"; and nearby "19", "18 u", "a 19".
- Upper center-right: open faculae-rings; "a 1 u h.1 4/5".
- Right limb, upper: "a 1 h.6 6/7".
- Right limb, lower: "a 30 m h.7 1/4"; "a 30 h.11 1/2"; "a 30 u h.4".

- Lower center and toward B. Occidens: spots "a" numbered "25", "26", "27 u", "28", "29 m", "30", "30", "1"; with "hora 9 1/4" and a further hour-mark "h.3 5/8"[?].
- Many finer micro-labels around the individual clusters are unresolved. [?]

Foot-table (APRILIS / MAII). Three paired sub-columns; headers read $\odot$ – H – $\odot$ E1. (Day — Hour — Sun's position, degrees and minutes). Time-marks: *m* = morning, *u* = evening.

APRILIS:

Day	Time	Hour	$\odot$ °	'
18	u	3 4/5	30	20
19	u	5 1/3	16	20
21	u	4	27	30
21	u	4 3/5	23	10
22	u	3 5/6	31	25
23	u	5 1/2	15	30
24	u	5 1/3	17	40
25	m	9 2/5	44	45
26	m	7 5/6	26	0
27	u	4 3/4	24	0
28	m	6 5/6	20	0
29	m	9 1/2	46	40
30	m	7 1/4	22	30
30	m	11 1/2	46	40
30	u	4	30	0

MAII:

Day	Time	Hour	$\odot$ °	'
1	m	6 5/7	20	10
1	m	8 3/4	79[?]	0
1	u	1 4/5	53	10

Notes on the XXII Image of the Observations, the first [image] of May, from the 2nd day to the 14th of the same [month]

(*Notae in XXII. Observationum Imaginem, primam Maij, à die 2. da 14. eiusdem.*)

First. Two spots *a* appeared on 2 May, preceded by a facula. On the 3rd they came into view with a far more brilliant retinue of faculae and a more splendid array of shadows passing over into spots; likewise on the 4th, as the faculae increased and the shadows thinned, many more spots came out. On the fifth day, at last, the faculae appeared feeble but the spots vigorous — of which it was possible to count more than twenty distinct ones, whereas the Ingolstadt [observer] saw only five. [Margin: *Conferuntur observationes Ingolstadianae cum Romanis.* — The Ingolstadt observations are compared with the Roman ones.] "On 5 May, at the 9th hour of the morning, 24 minutes" — he himself says — "[there were] five spots, of which the two more northerly, being quite faint, appear to be yesterday's, but the remaining three are new." Those two faint ones, however, were with me four. And the same Observer further writes, for the 3rd: "A single, very faint spot, preceded by many faculae." But he continues, for the 4th: "Two spots, with faculae and with spots round about. These two do not appear to be yesterday's, but others, yesterday's no longer appearing, since yesterday's had been very faint." It was indeed entirely yesterday's, but enlarged in bulk and in companions. For there were at least six distinct spots, whose number on the 6th did not stop short of twenty, although some of them were very faint and offered themselves to the eyes rather as traces of spots sunk into the Sun.

Although on the 7th they increased sufficiently both in strength and in number — for it is quite certain that up to thirty distinct spots were reached, with no facula appearing — the Ingolstadt [observer] saw four and supposed them to be new, never seen before; but they were the earlier ones enlarged, as is clear from the diagram, the course, and the place.

I have not entered the morning observation of the 8th, because it would have coincided with the standings of the 7th. They did, however, begin to fail in bulk and number, since they did not exceed twenty; at Ingolstadt, moreover, the Observer says: "Four spots seen, the sky more or less clear, which again appear to be others, or [appear] to cut the ecliptic very obliquely and quickly." Nor [continues]

are there others, nor does [the group] hold itself to the ecliptic against its custom — as is clear from those which, fewer indeed after midday, I noted as observed. On the 9th, in the morning, 18 still appeared, but faint and mostly resembling

shadows. On the 10th the Sun, [veiled] in vapors, refused a sight of the spots. On the 11th, 7 spots of varying strength were seen, with two faculae. On the 12th the Sun did not favor [us]. On the 13th there were 5 spots, with bright faculae before and behind. On the 14th, faculae alone with shadows lasted until [the group's] exit, morning and evening. Of the 12th, 13th, and 14th nothing was noted at Ingolstadt, although the observations were carried out. Since, therefore, I would have made a very defective course out of them, I deliberately omitted them; for they are too few, and among those very ones the Observer took some for others, and on this account regarded them as new — but such slips readily arise from the deficiency of small [observing-]circles and from the minuteness of the tiny spots, together with their almost hourly variability.

Hence again — a thing that must often be driven home — I would readily grant that from the insufficiency of small circles suppositions, or erroneous consequences, can sometimes be derived. This is the very thing that kept "Apelles," otherwise thoroughly practiced in these matters, from asserting many things. [Margin: *Macularum in Faculas conversio*. — The conversion of spots into faculae.]

Second. The spots *b*, freshly generated on the Sun on the 6th, passed off into faculae on the 13th before they set.

The spots *c*, having arisen with bright faculae, then — as the faculae grew — themselves diminished in bulk and blackness, and after the 9th day gave no trace of themselves anywhere on the whole Sun. Meanwhile — [Margin: *Notanda*: — To be noted:]

Note, first, that small spots, in a manner not [wholly] buried in the Sun, generally bring great faculae along with them.

Second. The courses of the spots *a* and *b* appear very nearly rectilinear to the sense, and inclined to the ecliptic. [Margin: *Curvitas & Inclinatio decrescunt, Polus descendit*. — The curvature and inclination decrease; the pole descends.]

Third. The distances of those courses from one another are not equal or parallel, but the eastern ones broader, the western ones narrower.

Fourth. And although the spots *c*, [continues]

Rosa Ursina, Book III — Notae particulares (Images XXII–XXIV, May 1625)

(Conclusion of the Notes on the 22nd Image, continued from the preceding leaf.)

had not stayed vigorous beyond three days, it is nonetheless certain that their course would have been much like the others in its position relative to the ecliptic.

Fifth: it is certain that the course of spot *a* did not reach thirteen days.

Sixth: the course of this spot resembles the courses of the spots *a* observed at Douai [Duaci] and Ingolstadt in the year 1624, from 30 April to 10 May, as you see set out in Image XXVI, Table III, and Image XXVII, Table I, which you may consult.

Diagram. A full-page engraved solar disk (Image of the Sun XXII), showing the paths of sunspots across the Sun from 2 to 14 May 1625, observed at the Professed House of the Roman Society [the Jesuit Casa Professa]. The disk is inscribed in a large circle with a horizontal diameter drawn as the ecliptic.

Legends on and around the disk:

- Upper left (title): **XXII. Observationum Imago** ["22nd Image of the Observations"].
- Center top, within the disk: **Anno Iubilaeo 1625. In Domo Professa Romana Societatis** ["In the Jubilee Year 1625, in the Professed House of the Roman Society"], flanked by two engraved rose ornaments and, at center, the IHS Jesuit sunburst emblem.
- Upper right: **Maij. 1.^a** [i.e. "May, [image] first"].
- Across the middle: **Cursus Macularu[m] a die 2. Maij, ad 14.^m eiusdem. / similes Ingolstadiano et Duaceno anni 1624.** ["The course of the spots from 2 May to the 14th of the same [month], similar to the Ingolstadt and Douai [courses] of the year 1624"].
- Left end of the diameter: **A. Oriens** [East]; the diameter itself: **AB. Ecliptica**; right end: **B. Occidens** [West]; center of the disk: **C**; bottom of the disk: **N** [south].
- Spot figures are engraved along and near the ecliptic, each tagged with its day-number and evening/morning marker (u = evening, m = morning) and sub-letters *a*, *b*, *c*. Legibly readable day-numbers include 7, 8, 9 (near the eastern limb A), and 11, 13, 14, 17 (progressing toward the western limb B);

several carry *u* / *m* markers and *a/b/c* sub-parts. The page suffers heavy mirror-reversed show-through from the verso, which obscures many of the smallest spot micro-labels. for the per-spot micro-lettering.

Table of observations engraved at the foot of the disk (heading **MAII** ["Of May"]; two sub-tables, columns **D** = day, **H** = hour with morning/evening marker, $\odot$ **El.** = the Sun's altitude [Solis Elevatio] in degrees and minutes):

D	H	$\odot$ El. (°)	(')
2	m. 9¼	45	0
3	m. 7½	26	45
4	m. 7	21	45
5	u. 4¾	24	30
6	m. 7½	27	30
6	u. 6	13	0
7	m. 6½	17	40

D	H	$\odot$ El. (°)	(')
7	u. 5¼	14	0
8	u. 6	13	0
9	m. —	20	0
11	m. 7¼	25	0
13	m. —	22	0
14	m. 7	23	0
14	u. 5½	16	0

Notae in XXIII. Observationum Imaginem, Maij secundam, à die 11. ad 23. eiusdem.

(Notes on the 23rd Image of the Observations — the second [image] of May — from the 11th to the 23rd of the same month.)

First: this spot *a*, running from north to south, drew after it another spot *b* of fainter mark, together with an umbra and notable faculae *c*.

Second: this same spot, when first seen near the eastern horizon on the 11th and 12th, was whole and continuous, with a nucleus duller and somewhat weaker

than the plate represents — not so black, but distinguished by being slightly diluted with white. Then, beginning on the 13th, it divided, first into two nuclei, afterwards into three distinct ones; these coalesced again into two on the 16th, and so remained until the 22nd, when at last, after noon, they merged — at least in appearance — into a single one. From beginning to end they steadily grew much denser and blacker, and varied somewhat in shape.

Third: the faculae and umbrae, crowded together at ingress, gradually spread out and dispersed, and so escaped less attentive eyes; but toward egress, with their shape and appearance somewhat altered, they displayed themselves clearly once again (which is the usual course of these things), as may be seen in the side-images for the 11th and 12th, and likewise the 21st and 22nd, near egress. In the middle, however, both umbrae and faculae vanished, and in their place many new temporary spots emerged, as appears in the figure; for these are an almost daily occurrence in all the observations.

Fourth: a spot's exhalation or vapor adapts its outer edge (which I always and consistently observe in all other vaporous spots) to the position and shape of the nucleus or nuclei, so that if the nuclei bulge out on any side, the surrounding vapor or cloud ordinarily extends itself in that direction too — yet keeping, almost always, this rule: that it extends itself more toward the east and less toward the west, the side toward which the nuclei often hasten as though nearly bare, as any diligent observer will find. In this very spot it is noticed clearly enough that most of the spots, faculae, and umbrae followed after, while almost none went ahead — which nonetheless [continues on the facing column]

[Margin: The nuclei lean more toward the west (at setting).]

Fifth: spot *b*, after the 16th day, vanished; it seems to have been converted into a facula, which restored itself on the 22nd, and so on.

Sixth: the umbrae and faculae *c* revived entirely around egress — whether physically the same, or merely similar in their location.

Seventh: both the spot itself and its parts always kept the same position relative to the ecliptic, for the larger nucleus always stayed close to it while the smaller always faced N [north]; and they entered in this same position, just as they left.

[Margin: Position unchanged.]

Eighth: the length of this spot exactly equaled its breadth, as can be seen from the intermediate days and from the higher positions of the spot.

Ninth: the course of this spot comes very close to a straight line, and the spot carries the chord subtended by the arc of its path farther from the ecliptic than the earlier ones did, making a larger angle than they. The spot advanced above the ecliptic for a good many days, until it passed from the north [Aquilo] into the south [Auster]. It seems certain to have clung to the Sun for 13 days, for the trailing faculae left behind at the margin prove that it departed on the morning of the 23rd; and if everything else is rightly examined, the count will run beyond thirteen days.

[Margin: The curvature of the path is small; the inclination of the chords to the ecliptic that usually occurs under this phenomenon is nearly minimal; the southern pole lies exposed, close to the horizon.]

Tenth: the white space between the nuclei always shone out beforehand like a most brilliant facula. That same space kept glowing continually until the morning of the 22nd, until at last, in the evening, once the nuclei had joined in appearance, it ceased to be seen.

[Margin: The faculous gaps within the spots are at length hidden away.]

Eleventh: it is characteristic of this phenomenon that when spots heavy with nuclei lie near one another, on that side they are stripped, right down to the nuclei themselves, of the clouds spread around them, while from that same place intense faculae flash out — brighter, even in the middle of the Sun, than the rest of the Sun's ordinary surface.

[Margin: The faculous gaps within the spots — the vapors blot them out — display the inner edges cut sharp.]

Twelfth: for the rest, I have also placed the last days of this spot and a fragment of its completed course under the letter *b* in the following Image, 24, where you see another observation adjoined for the 19th and 22nd; for indeed

(Conclusion of the Notes on the 23rd Image, continued from the preceding page.)

for indeed this was carried out at the evening hour 5¹/₄, in which you see the spot nearer to the horizon than it had been here at the hour 3¹/₄. At the same time I would have you note that the bend of its path on the western side is not as curved as the one that stands on the eastern side — indeed it can be seen to be rather rigid, or bent back toward the north [Septentrio], than curving back toward the south [Auster].

Diagram. A full-page engraved solar disk (Image of the Sun XXIII), showing the paths of sunspots across the Sun from 11 to 23 May 1625, observed at the Professed House of the Roman Society. The disk is inscribed in a large circle with a horizontal diameter drawn as the ecliptic.

Legends on and around the disk:

- Upper left (title): **XXIII. Imago Observationum** ["23rd Image of the Observations"].
- Center top, within the disk: **Anno Iubilaeo M.DC.XXV. In Domo Professa Romana Societatis** ["In the Jubilee Year 1625, in the Professed House of the Roman Society"], flanked by two engraved rose ornaments and, at center, the IHS Jesuit sunburst emblem.
- Upper right: **2. Maij.** [i.e. "[image] second, of May"].
- Across the middle: **Cursus Macularu[m] ab 11. Maij, ad 23. eiusdem. / similis Curfib[us], aliis alioru[m] annoru[m] tempore eode[m].** ["The course of the spots from 11 May to the 23rd of the same [month], similar to the courses of other years at the same time"].
- Left end of the diameter: **A. Oriens** [East]; the diameter itself: **AB. Ecliptica**; right end: **B. Occidens** [West]; center of the disk: **C**; bottom of the disk: **N** [south].
- A dense sequence of spot figures runs along the ecliptic from the eastern limb (A) to the western limb (B), each tagged with its day-number, with sub-letters *a*, *b*, *c*, and morning/evening markers (m / u). The day-numbers readable in sequence are 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23. The individual *a/b/c* and m/u sub-labels on each spot are very small and partly obscured by verso show-through. for the per-spot micro-lettering.

Table of observations engraved at the foot of the disk (heading **MAII**; two sub-tables, columns **D** = day, **H** = hour with marker, $\odot$ **El.** = the Sun's altitude in degrees and minutes):

D	H	$\odot$ El. (°)	(')
11	m. 8¼ [?]	34	0
11	u. 6¼ [?]	14	0
12	u. 4½ [?]	32	0
13	u. 4½ [?]	21	30
14	u. 5½ [?]	16	0
15	u. 5¾ [?]	18	0

D	H	☉ El. (°)	(')
16	u. 4	33	0
17	u. 4 $\frac{4}{5}$	25	30

D	H	☉ El. (°)	(')
18	u. 5 $\frac{4}{5}$	16	0
19	u. 6 $\frac{1}{5}$	13	0
20	u. 4 $\frac{1}{8}$	33	0
21	u. 5 $\frac{2}{5}$	20	10
22	m. 8 $\frac{1}{2}$	40	0
22	u. 3 $\frac{1}{4}$	44	0
23	m. —	19	15

Notae in XXIV. Observationum Imaginem, Maij tertiam à die 19. ad 31. eiusdem.

(Notes on the 24th Image of the Observations — the third [image] of May — from the 19th to the 31st of the same month.)

First: the tracks of the paths of the spots and faculae gradually tend toward straightness, and recede ever farther from the ecliptic in the southern region, as is clear in spot *a*, while in the northern region they approach it, as spot *c* does.

[Margin: The motion, oblique to the ecliptic, gradually becomes rectilinear.]

Second: the southern spot *a* drew along with it, from its rising, a lateral facula running off to the south and touching the horizon, which it then gradually left behind. The spot itself, divided into two as well, gradually faded and, turned into a thin umbra, went on again among the faculae toward the west; or rather, itself turned into a facula, it left the Sun. It traversed the visible Sun for at least thirteen days — indeed longer, if the reckoning is done correctly. On the 24th, as also on the 26th, it showed new companions.

[Margin: A transit-course of thirteen days, and longer.]

Third: the complete run of spot *b* is contained in the previous Image; here a fragment of it is shown, so that the connection may be clearer to the eye. In the same way, the beginning of spot *f* is placed here, while its whole continuation is contained in the following Image. At ingress it was either a facula or an adhering

umbra; then, gradually growing into a spot, it traversed the Sun, as is shown in the following diagram. *d* is a solitary facula with umbrae, as *e* is also.

Fourth: the spots *c*, mingled with faculae and always gradually thinning, left no trace of themselves after the 29th day. The paths of them all incline toward straightness.

Fifth: the numeral characters written in the margin are the points through which the vertical line passed, on the day that the number itself indicates, when the observation was made. The smaller arc of the horizon, then, intercepted between the given number and the ecliptic, gives the size of the angle contained between the ecliptic and the vertical circle. And so on.

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Diagram. A full-page engraved plate of the solar disk — the 24th Image of the Observations. The disk is inscribed at the top (beneath cardinal point D), between two rose devices flanking the IHS monogram of the Society of Jesus:

- **ROMAE / In domo Professa Societatis** — "At Rome, in the Professed House of the Society [of Jesus]."
- **a die 19, usque ad 31, Maij; anni M.DC.XXV.** — "From the 19th to the 31st day of May, in the year 1625."
- **ABCD, Horizon; E polus eiusdem; AC, Ecliptica; D Zenith, B Nadir; numeri marginales ostendunt linearum verticalium communes cum horizonte sectiones.** — "ABCD, the horizon; E, its pole; AC, the ecliptic; D, zenith; B, nadir; the marginal numbers show the common intersections of the vertical circles with the horizon."

Left margin of the disk: **XXIII, Imago Observationum** ("24th, Image of the Observations"). Upper right, near the rim: **3, Maij** ("3 May") [?].

Cardinal points: **D** at top (zenith), **B** at bottom (nadir), **A** at the left end of the horizontal diameter, **C** at the right end, **E** at the center (the pole). The horizontal diameter **AC** is the ecliptic; small numerals (19–31) run around the rim marking where the vertical circles cut the horizon.

Sunspots are drawn across the disk, each marked with a letter (its identity) and a number (the day), some carrying "u" (evening) or "m" (morning). Confidently readable labels:

- Upper-left cluster: **e 24; c 23; c 24**; with rim dates **19u, 20u, 21u, 22u, 23u, 25u** nearby.
- Upper-middle: **c 25u, c 26u, c 27, c 28, c 29**.
- Left, on the ecliptic near A: **d 24**.
- Lower-left cluster: **a 19, a 20, a 21, a 22, a 23, a 23u, a 24, a 25; f 28, f 28u, f 30u, f 31**; and an **m**-labeled spot (**m 23, m 24**).
- Right of center, below the ecliptic (large dark cluster): **b 19u, b 20u, b 21, b 22u**, with **28u** below; and lower **a 28, a 29, a 30, a 31, 30u**.

The dense micro-labels within the several spot clusters are only partly legible even at high magnification; individual dates in the clusters beyond those listed are [?].

MAII

Dies	Hora	☉ Elev. (° · ')
19. m.	8	35 · 0
19. u.	6¼	13 · 40
20. m.	—	24 · 0
20. u.	4[?]	33 · 0
21. m.	6[?]	21 · 30
21. u.	5¾	20 · 10
22. m.	—	21 · 0
22. u.	5¼	17 · 40
23. m.	—	19 · 12
23. u.	5	25 · 0
24. m.	8[?]	39 · 20
25. u.	6	15 · 0
26. u.	4¼	27 · 0
27. m.	8¼	37 · 30
28. m.	8[?]	42 · 40
Eod. u.	4	33 · 30
Eod. u.	4½	29 · 30
Eod. u.	6[?]	13 · 30
29. m.	—	20 · 0

Dies	Hora	☉ Elev. (° · ')
30. u.	4	34 · 40
31. m.	6[?]	19 · 20
31. m.	8[?]	35 · 36 · 37

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Notes on the 25th Image of the Observations — the fourth [Image] of May, the first of June; from 31 May to 18 June

[The heading is printed **Notæ in XXV. Obseruationum Imaginem, Maij qurtam, Iunij primam, à die 31. Maii ad 18. Iunij.** — "qurtam" is a compositor's slip for "quartam" (fourth).]

I. First: the spots lie roughly in the summer tropic; they have their elongation and their greatest declination on either side from the ecliptic, and so they stand still, as it were, for a time, and make no perceptible change of motion. Rather, all of them are sensibly rectilinear — though they do nod to either side, as will be evident to anyone who examines them. Spot **a**, in the south, imitates a straight motion; **b** tends toward a curved path, its concavity turned toward **z**, the north; **c** likewise presents itself as rectilinear; **h** nods on both sides, around its entry and exit.

[Margin: The motion of all the spots is sensibly rectilinear, parallel, proportional, and equal in duration.]

II. Second: all these motions appear to the eye roughly parallel to one another.

III. Third: if all of them are imagined extended, they cut the ecliptic obliquely and at equal angles.

IV. Fourth: all of them stayed an equal time in front of the Sun, that is, about thirteen days. Likewise their eastern daily spaces and times are sensibly equal to the western ones.

V. Fifth: spot **a** sometimes showed a doubling; it grew as it rose, shrank as it descended, and went out somewhat twinned, trailing a facula behind it as it had on entry.

VI. Sixth: spot **b**, being a twin, steadily shrank, and on the 2nd, 3rd, 4th, and 5th day it was entirely split into two; afterward, coalescing into one, it diminished so

markedly that it reached the horizon only with great difficulty. It drew a facula immediately behind itself, as it had also at the beginning of June; but around the center it seemed to give back facula **d** — which had faded — on the 8th, 9th, and 10th day, though very faint and much altered. In its own parts it kept the same position relative to the ecliptic.

VII. Seventh: spot **h**, which arose on 6 June and is not much unlike spot **a** shown in the 23rd Image of May, described almost the same parallel; it entered and departed with faculae trailing behind it. It showed its nuclei now continuous, now separate, and around them it shaped an enveloping haze, whitening somewhat in the space at the middle of the nuclei. On this spot, see more at Number 11.

VIII. Eighth: spot **c** is the continuation of spot **f** in the previous Image, which, having been born from a facula, went out reverted almost into a facula.

IX. Ninth: spot **i**, exceedingly tiny, stretching out a facula toward the south like a comet, perished utterly after the tenth day, and never afterward brought back anything of itself.

X. Tenth: the marginal numbers show at what place, at the time of observation, the vertical line crossed the Sun's perimeter, and they determine the angle of the ecliptic and the vertical at the center C.

XI. Eleventh: I return to spot **h**, and I have no doubt that it is the very same as spot **a** in Image 23, and hence that it is a returning spot. Everything argues for this — above all its place, its time, and, in large part, the figure and the arrangement and constitution of its nuclei.

[Margin: Spot **b** [**h**?], shown from all the circumstances to be a returning spot.]

[Margin: Argument from place.]

As for place, indeed: since at this time the spots are near the summer solstice, and the poles are situated around the horizon in direct descent and ascent, and the axis of the spots — about which they are turned — seems to stay in almost the same place and not to bend toward east or west; it should therefore surprise no one that spot **a**, from May right up to now, could remain and rise in almost the same place. For, of course, the axis about which it turned was not perceptibly changed. This matter, however, will be discussed more precisely and expressly in its own place. Meanwhile, compare the position and distance, relative to the ecliptic, of the spots as they rise, culminate, and set, and you will find due symmetry everywhere.

[Margin: Argument from time for the returning spot.]

And time strongly confirms this. Spot **a**, seen in Image 13 from the 11th to the 22nd of May, had set on the morning of the 23rd of the same month. If, then, we count from that time to the sixth morning of June, we find 14 days. But since spot **h**, on the sixth day, had already emerged above the horizon [continues below] —

IMAGO SOLIS XXV — 215

Diagram. A full-page engraved plate of the solar disk — the 25th Image of the Observations. Inscribed at the top of the disk, between two rose devices flanking the IHS monogram:

- **IVNIVS / Romae in domo Professa Societatis** — "June; at Rome, in the Professed House of the Society."
- **Cursu à die 31, Maij, ad 18, Iunij; M.DC.XXV. similis / alius aliorum annorum tempore eodem.** — "In its course from the 31st of May to the 18th of June, 1625; similar to that of the same season in other years."
- **Maij, die 31, hora mat: 8¼ sub elevatione / ☉ gr: 37 min: 0~** — "On 31 May, at the morning hour 8¼, under the Sun's elevation of 37° 0'."
- **A, Oriens, B, Occidens Macularum; AB Ecliptica; A Z B, Solis pars Zenith, ANB, Nadir respectans: Numeri marginales 31, 1, 2, et reliqui, indicant commune planum Verticalis, cum ☉ sectione, tempore Observationis.** — "A, the east (rising), B, the west (setting), of the spots; AB, the ecliptic; AZB, the Sun's portion facing the zenith, ANB facing the nadir; the marginal numbers 31, 1, 2, and the rest mark the common plane of the vertical [circle] with the Sun's section, at the time of observation."

Left margin of the disk: **XXV, Imago Observationum** ("25th, Image of the Observations"). Upper right, near the rim: **4, Maij** and **1, Iunij** [?].

Cardinal points: **Z** at top (zenith side), **N** at bottom (nadir side), **A** at the left end of the horizontal diameter (east), **B** at the right end (west), **C** at the center. The horizontal diameter **AB** is the ecliptic.

Sunspots are drawn across the disk. The principal spot **h** appears as a chain of dark spots strung along the ecliptic, labeled **h** with successive June dates — confidently readable: **h 12, h 13, h 14, h 15, h 16, h 17, h 18** (toward the right/west). Near the left end (A), earlier positions are labeled **b** with dates (**b 3, b 4, b 5**), together with an **a** and a **K**-labeled spot. A lower cluster toward the west

carries **a**-, **c**-, and **f**-labeled spots with a run of small dates (1–12), and near the bottom (N) an **e** (**e 31**). Rim numerals run 31, 1, 2, 3, 5, 6, 7, 8, 9, 10, 11, 12.

The dense date-labels within the western clusters, and several of the small rim numerals, are only partly legible on the scan and are [?].

IVNII

Dies	Hora	☉ Elev. (° · ')
1.	6 $\frac{2}{3}$ mat.	21 · 30
2.	6 $\frac{3}{5}$ mat.	21 · 15
3.	6[?] mat.	21 · 30
4.	6 $\frac{1}{4}$ mat.	21 · 30
5.	6 $\frac{1}{5}$ mat.	20 · 40
6.	8 mat.	36 · 0
13.	8 $\frac{1}{4}$ mat.	40 · 9
14.	8[?] mat.	37 · 50
15.	8 $\frac{1}{8}$	36 · 0
7.	6 $\frac{1}{4}$ mat.	19 · 50
8.	mane	25 · 0
9.	7 $\frac{3}{5}$ mat.	28 · 0
10.	7 $\frac{1}{4}$ mat.	26 · 0
11.	8 $\frac{2}{5}$ mat.	39 · 30
12.	8 mat.	35 · 40
16.	8 mat.	32 · 0
17.	8 mat.	35 · 0
18.	8 $\frac{1}{4}$ mat.	38 · 0

[Foot of folio 215, continuation of Note XI]

I. [...spot h] had already emerged, we must subtract what is owed to that interval from the number of fourteen days; and thus, in the hidden hemisphere, not quite so many days were spent, but thirteen and somewhat more. If we add this time to the time the spot spent in the visible hemisphere, we shall have the sum of the periodic motion, falling between 26 and 27 days. This same [sum] —

II. — you will obtain the same sum whether you reckon the time from the setting of the 22nd day in May to the setting of the 18th day in June, or from the noon of the 16th day to the noon of the 12th day, or, finally, from sunrise to sunrise: you will always find the same sum of the periodic time, established between 26 and 27 days. But on this matter, more precisely in its own place.

IMAGO SOLIS XXV.

Diagram. A full-page engraved solar disk (the printed circle is overlaid on letterpress). At the top center of the disk are three ornaments: a Tudor-style rose (the Orsini device) at left and right, flanking a radiate IHS Jesuit emblem in the middle.

Letterpress title within the disk:

- **XXV. Imago Observationum.** [Image XXV of the observations.]
- **IVNIVS. Romæ in domo Professa Societatis** [June. At Rome, in the Professed House of the Society (of Jesus).]
- "The course [of the spots] from 31 May to 18 June 1625; like those of other years at the same season. On 31 May, at 8¼h in the morning, under a solar elevation [elevatio ☉] of 37° 0'."

Cardinal legend across the disk: A (left) and B (right) mark the ends of a horizontal diameter, with Z at top and N at bottom.

- **A = Oriens** (the East / rising side of the spots), **B = Occidens** (the West / setting side); **AB = the Ecliptic**.
- The arc **A Z B** is the part of the Sun facing the zenith; **A N B** the part facing the nadir.
- "The marginal numbers — 31, 1, 2, and the rest — indicate the common [line of intersection] of the vertical plane with the section of the Sun at the time of observation."

Along and below the ecliptic AB runs a band of small inked sunspots labelled with the letters **a, b, c, h** (in several repetitions, each carrying a small day-number in the series 31, 1, 2, ... 18) tracing the daily progress of the spots across the disk. The per-spot micro-labels (letter + day-number, and the marginal vertical-circle numbers 31, 1, 2, ... 12) are small and abraded; individual positions are not resolved cell-by-cell and

Two observation tables are set inside the lower half of the disk:

MAII [May]

Dies	Hora	☉ Elevatio (°, ')
1	6 $\frac{2}{3}$ mat.	21. 30.
2	6 $\frac{2}{3}$ mat.	21. 15.
3	6 $\frac{3}{5}$ [?] mat.	21. 30.
4	6 $\frac{3}{4}$ mat.	21. 30.
5	6 $\frac{1}{5}$ [?] mat.	20. 40.
6	8 mat.	36. 0.
13	8 $\frac{1}{4}$ mat.	40. 0.
14	8 $\frac{1}{2}$ mat.	37. 50.
15	8 $\frac{1}{8}$ [?]	36. 0.

IVNII [June]

Dies	Hora	☉ Elevatio (°, ')
7	6 $\frac{1}{4}$ mat.	19. 50.
8	mane	25. 0.
9	7 $\frac{2}{5}$ mat.	28. 0.
10	7 $\frac{1}{4}$ mat.	26. 0.
11	8 $\frac{3}{5}$ mat.	39. 30.
12	8 mat.	35. 40.
16	8 mat.	32. 0.
17	8 mat.	35. 0.
18	8 $\frac{1}{4}$ mat.	39. 0.

Notes to Image XXV (conclusion, from the foot of the plate page)

I. ...had already emerged, we must subtract from that figure of fourteen days the amount owed to that interval; and so not quite so many days are spent in the hidden hemisphere, but thirteen, and somewhat more. If we add this time to the time the spot spent in the visible hemisphere, we obtain the total of the periodic motion, falling between 26 and 27 days.

II. You will reach the same total whether you reckon the time from sunset of the twenty-second day in May to sunset of the 18th in June; or from noon of the 16th

to noon of the 12th; or, finally, from sunrise to sunrise. You will always find the same total of periodic time fixed between 26 and 27 days — but on this matter more exactly in its proper place.

I. [Margin: For the returned spot: an argument from its figure and position, etc.] There is also a great similarity of figure, as will be plain to anyone who looks; and the number and arrangement of the nuclei agree strikingly as well. Should anyone wish to object on the grounds of a difference in size, he will by the same token reject a single spot of the open hemisphere — seen from day to day and hour to hour — as being one and the same, and deny its identity; even though it is in fact the same spot, only enlarged or diminished, and somewhat altered in figure. Therefore, just as a spot proves from a slight variation of figure and size to be not another but an altered one, so it is more than probable that this spot, seen again in the same parallel, at the appropriate time and place, is not another but the same, changed by shrinkage. For from the eleventh of May it traversed the Sun as it grew, and at full strength — as can be seen in Image 24 — it set on the 22nd; so that, lying hidden throughout the far hemisphere, it doubtless remained safe and intact, and then gradually diminished in the manner of the others, as is clear enough in this course from the 6th to the 18th of June. [Margin: For the returning spot: an argument from the nature of other spots, etc.] And just as the regular behavior of this phenomenon made it impossible for a spot setting so full and intense to be dissipated so quickly in the opposite hemisphere, so it is beyond all belief that another spot should have been born so suddenly precisely in its place and then lasted so long a time — for in either case something would have happened

II. contrary to the usual course of the phenomenon: for in the one case a spot would have been born late and grown very fast, and in the other, quickly produced, would have been consumed very slowly — against which constant, stable, and unbroken experience cries out. For however much time any spot claims for itself in growing, it claims as much in shrinking, if we are to reason according to what I have so far learned in the continuous practice of observing. Therefore, since spot **h** decreased continuously from 6 June to the 18th, it must have made its increases over just as many days; and since on the 18th it was still fairly large at setting, it necessarily passed into the other hemisphere. Hence it must earlier have been seen also in that hemisphere — not the hidden but the open one. But since from the month of May no spot other than **a** appeared in that parallel, reason rightly concludes that **a** and **h** are one and the same spot: **a** in its growth, **h** in its decline; and that the opposite hemisphere provided it a dwelling while it dwelt there at its full state and strength — so that it found there both its

cradle and its grave. For on 11 May it entered the Sun growing, left it on the 22nd in full vigor, then visited us again on 6 June declining, and once more, now spent with age, left on the 18th of the same month; and it was never observed before 11 May, nor after 18 June.

Notes on the Twenty-sixth Image of the observations — composed from various observations made at Freiburg im Breisgau and at Ingolstadt, for the years 1622, 1624, 1625, and the months of April, May, and June.

I. In these notes I shall follow the order of the months and the numbers of the lateral tables. I call these tables "lateral" [Tabellæ Laterales] because I insert them, as it were from the side, into the order of the rest; for when I marshal into line the array of the Roman observations arranged by design — as becomes clear to anyone who looks — **II.** I station these tables, like volunteer and honorary auxiliaries, at convenient places. This Image XXVI, then, contains various observations of spots, carried out partly at the University of Freiburg, partly at that of Ingolstadt. [Margin: The origin of the Freiburg observations.] For since I once taught publicly in both places, and at Freiburg most recently indeed —

IMAGO SOLIS XXVI.

Diagram. A full-page composite engraved plate assembled from eight overlapping solar-disk circles ("lateral tables"), each a small solar disk carrying a title, an embedded **D. H. ☉. El.** (Dies–Hora–Sol Elevatio) table, and a band of lettered spots along a horizontal diameter A–B. Interspersed among the circles are a radiate IHS emblem (left), a radiate monogram device reading **MRA** (right), and two Tudor-rose ornaments.

Engraved title across the top of the plate: "**XXVI. Imago Observationum ex octo Tabellis lateralibus conflata**, observationes et Cursus Friburgenses atque Ingolstadienses complexis, ex annis 1622, 1624, 1625, et Mensibus Aprilis, Maio, Iunio." [Image XXVI of the observations, forged together from eight lateral tables, embracing the Freiburg and Ingolstadt observations and courses, from the years 1622, 1624, 1625, and the months of April, May, June.]

The eight circles, with their titles and embedded tables:

Circle I — "Ingolstadt, 1625. The course of the spots from 21 to 30 April; like the Roman one." (numbered **1**)

Dies	Hora	☉ Elevatio
21 m.	8	28. 38.
22 m.	9. 7.	29. 5.
23 m.	8. 7.	30. 14.
24 m.	9. 44.	44. 38.
25 m.	9. 20.	41. 43.
26 m.	9. 30.	43. 0.
28 u.	1. 9.	53. 45.
29 m.	8. 45.	37. 30.
30 m.	8. 38.	26. 48.
30 u.	2. 7.	47. 25.

Circle 2 — "Ingolstadt, 1624. From 30 April to 10 May. MAY." with note "April, day 30, h. 1." (numbered 2)

Dies	Hora	☉ Elevatio
1 m.	8.	70.[?]
2	12.	0.
3 m.	8.	0.
4 m.	7.	45.
7 m.	8.	0.
8 m.	8.	0.
9 m.	10.	0.
10 m.	7.	45.

Circle 3 — "Ingolstadt, 1625. MAY. The course of two spots, a and b, from the twelfth to the 28th of May; like the Roman one." (numbered 3)

Dies	Hora	☉ Elevatio
12 u.	1. 25.	25. 6.
13 u.	12. 6.	59. 50.
14 m.	11. 23.	54. 55.
15 m.	8.	33. 47.
16 u.	2. 55.	44. 16.
17 m.	10. 24.	54. 46.

Dies	Hora	☉ Elevatio
18 m.	8. 15.	42. 25.
19 m.	8. 40.	40. 52.
21 m.	10. 12.	54. 18.
26 m.	8. 45.	43. 3.
28 u.	3. 20.	42. 6.

Circle 4 — "1622. Freiburg im Breisgau. The course of spot a, observed from 15 to 21 May; like those of other years and places." (numbered 4)

Dies	Hora	☉ Elevatio
15 u.	1. 30.	55. 29.
20 m.	7. 24.	28. 38.
21 m.	8. 27.	39. 10.

Circle 5 — "1622. Freiburg im Breisgau. The course of spot a, observed from day 20 to 26 May; like those of other years and places, on the same days." (numbered 5)

Dies	Hora	☉ Elevatio
20 m.	7. 24.	28. 38.
21 m.	8. 27.	39. 10.
24 m.	8. 0.	35. 52.
25 u.	2. 36.	48. 39.
26 m.	6. 0.	14. 2.

Between circles 4 and 5, a magnified detail of a single large spot for **16 May**, captioned "16 May, h. 6¼, ☉ 21° 0'," with small feature-labels including the Greek letters λ, ξ and χ[?] and a Latin v; the exact detail-labels are not fully resolved [?].

Circle 6 — "Ingolstadt, 1624. The course of spot a, observed from 17 May to the 26th of the same month." (numbered 6)

Dies	Hora	☉ Elevatio
17 m.	9.	18.
18 u.	2.	15.
19 m.	8.	0.

Dies	Hora	⊙ Elevatio
24 u.	2.	45.
26 m.	8.	0.

Circle 7 — "Ingolstadt, 1625. The course of the spots a and b from 30 May to 9 June; like the Roman one." with note "May 30, evening, hour 1. 25." (numbered 7)

Dies	Hora	⊙ Elevatio
1 m.	6. 49.	24. 21.
4 m.	7. 12.	28. 24.
5 m.	9. 49.	57. 59.
6 m.	10. 0.	54. 51.
7 u.	1. 20.	57. 42.
8 m.	10. 9.	55. 0.
9	12.	54. 0.

Circle 8 — "Ingolstadt, 1625. The course of the spots a, b, c, from 6 to 19 June; like the Roman one." (numbered 8)

Dies	Hora	⊙ Elevatio
6 u.	6. 0.	[numeral: ?]
7 u.	1. 20.	57. 42.
8 m.	10. 0.	59. 0.
9	12. 0.	64.[?]
12 u.	12. 12.	64. 27.
13 m.	9. 0.	46. 31.
15 m.	9. 12.	48. 27.
16 m.	8. 45.	44. 16.
17 m.	9. 42. 0.	52. 57.
19 u.	2. 8. 0.	54. 23.

[Notes to Image XXVI, continued at the foot of the plate page]

I. ...most recently indeed, but as the first to profess mathematics from our Society there. And since I was then summoned to Silesia — to the most serene Archduke Charles of Austria, Bishop of Brixen and of Breslau [Wrocław], and supreme Master of the Teutonic Order, etc., of most devout memory — indeed, as good as

called away from my studies — I asked my successor and disciple, Georg Schönberger, that **II.** — since I had long intended to make known more fully and perfectly the solar phenomenon and its curvilinear motion — he should meanwhile, for my benefit, carry on to completion the observations I had thus far continued; and that it was not necessary for him to make them daily: observations every two or three days, or at longer intervals, would suffice, since any given spot, in running across the Sun, used up

I. at least ten days, up to fourteen (for I had not fixed the precise limits of their courses by any set bounds, but had reserved so great a matter for further observations and examinations, as is plain in my *Apelles*) — provided that the central points of the spots' first entry and last exit, together with some intermediate ones, were accurately recorded, so that the straightness or curvature of the course could be sufficiently argued from them. Hence I strongly urged upon him the risings and settings and the central observations of the spots; and, should he light upon some more notable spot, that he not find it a burden to observe its whole course. [Margin: The author faithful in presenting the observations of others.] When he had done this quite diligently, in the year 1625 he sent me, at my request, the observations of spots and faculae that he had made in both places, together with the calculation and the ecliptic drawn in — so that nothing else remained for me to do but reduce them into a single course. This I have done most faithfully, and in this work I offer them to you, friendly Reader, engraved on copper together with his notes and my glosses. But to be still more certain, I subjected each and every one to my own examinations as well, and found no discrepancy of any moment.

Lateral Table I. It contains the course of spot **a** from 21 to 30 April. It corresponds to the Roman course **a**, explained in Image XXI, from 18 April to 1 May. Now hear what the Ingolstadt observer writes about his own course.

On 21 April, at 8h in the morning: about three spots, followed by a whole troop of spots, and especially of faculae, which could not be told apart with certainty; yet this whole marked Circle **c** was full of them. They were seen the same way at 12h as well. From 9 April up to this day the sky was never clear. Thus far he. [Margin: The Ingolstadt spots are compared with the Roman ones.] From this you have the reason why the Ingolstadt April was rather barren over the aforesaid days. The genuine figure of the spots, shadows [umbrae], and faculae you have rendered in my scheme, for in these little circles such things cannot be accurately seen or drawn. But the observer continues.

On 22 April, at 9h 7m: four spots seen through whitish clouds, with a supply of spots and faculae still following, as yesterday, right up to the periphery; etc. Thus far he. What the spots, faculae, and shadows were on this day, you have in my scheme.

II. On the 23rd, he says, at 8h 7m, with the Sun clear and calm: eight spots, which could be told apart better than before. The fourth spot (further east) was very faint, like a mist. In my own observation I noted at least 18 distinct spots in all, but I have not set them out here, since I decided to follow spot **a** alone. [Margin: A spot like little clouds, observed at Ingolstadt.]

On the 24th, at 9h 44m: eight spots, of which the more easterly were scarcely noticeable, fainter than yesterday, while the rest were larger and, as it were, a heap of many. Many earlier faculae followed, and something similar in the form of a very thin shadow. You see the heap of spots in my scheme at day 24, on which, at 8½h in the morning, I found 14 distinct nuclei not touching one another. For want of room I have not transferred the faculae and shadows here.

On the 25th, at 9h 20m: nine spots. In my scheme the number of spots and nuclei is expressed well enough.

On the 26th: spot **b**. Compare it with mine.

On 28 April, at 1h 9m: a single spot. In my record you will find at least eight.

On 29 April: a single spot, followed by a very thin little cloud. In my figure you have six distinct spots, with faculae, shadows, and a halo [nimbus] round about.

On 30 April, in the morning: a single spot, notably smaller than yesterday, which many faculae followed. On the evening of the same day, at 2h 7m: a single spot, notably smaller in this observation than in the earlier one, together with faculae. The state of the whole thirtieth day, from 7h in the morning to 4h in the afternoon, you have exactly in my diagram, which I would have you consult; for you will see not only the twin configuration of them all, but the growth of the morning spot and the great shrinkage of the evening one — so that there is a wonderful agreement in the observations on both sides. [Margin: Increases and decreases of the spots noticed equally at Ingolstadt and at Rome.]

About 1 May the observer has nothing. I wished to work out this course with its explanation, so that you might see first its exact position in the Sun relative to the ecliptic, and its agreement with the place I observed; and recognize that parallax is entirely absent. Then, again, you may learn from a further practical example

how great an interval separates these little circles from my large ones in detecting this phenomenon. [Margin: No parallax in this phenomenon.]

[Continuation of the *Notae particulares* — the running notes accompanying the *Imago Solis* series. The prose runs left column (I), then right column (II), on each page.]

IMAGO SOLIS XXVI

(page 219)

Table II contains the course of spot *a*, observed at Ingolstadt in the year 1624, from 30 April to 10 May. You will find its very close counterpart — of the same spots and the same year — as the Douai observation in Table II of the following Image XXVII.

[Margin: The quality of the traveling path and the very great resemblance is what is chiefly sought through these observations; and it is found across different years and in different spots.]

For the year 1625 I can find nothing more similar to it in position — though the spots themselves are different — than the course of spots *a* set out in Image XXII. Compare them, and you will see the positions and the bends of the path relative to the ecliptic — the very resemblance I am pursuing through these examples.

Table III contains two courses, of spots *a* and *b*. The first of them corresponds to Image XXIII. I transcribe the Ingolstadt notes word for word:

[Margin: The Ingolstadt observations are to be compared with the Roman ones.]

"On 12 May, only a single spot was seen, together with another, very faint and smaller one; the first, however, was large." Thus he writes.

Consult my own diagram for the stated day, and — besides the said large spot, and besides the umbrae and faculae he did not record — you will see at least five faint spots.

"On 16 May" — he says (for I pass over some entries that contain nothing remarkable) — "four spots were seen, of which one appeared to be divided into two nearly touching parts. He had noted the same division the day before as well, on the 25th." Here you see that division of the nucleus, and the intense brilliance of the white gap between them, discernible even in this small circle.

[Margin: Nuclei, and the extraordinary faculous brilliance.]

"On 17 May, five spots. The first of them, *a*, appeared to be diffusing some shadow all around, and toward spot 4 a yellowness — beyond what the glass usually produces — a yellowness that extended right up to the fourth spot. As it entered, many faculae were seen around *g*." Thus he writes. Spots of this kind, endowed with denser nuclei, almost always present these colors, especially when the luminous matter is, as it were, compressed and struggling to break out within the nuclei — just as happened here too. That spot 4, which the mists reached, was the more westerly among the boreal ones.

[Margin: Yellowness unusual at Ingolstadt, frequent at Rome.]

[Margin: Umbrae poured around the nuclei.]

These umbrae, or mists, spread around the nuclei are vapors, or the thinner parts of the spots. In my own diagram they appear plainly enough; and yet before noon, at 6¼ h., at a solar elevation of 20° 50', their accompaniment and arrangement turned out somewhat different — which is how I accordingly represent them, together with facula *g*, in Image 23, for the 15th to the 18th. Spot *a*, then, at the stated hour, contained spots of every kind, distinct partly within itself and partly outside itself — at least twenty of them: some thin and even, some (*page 219, col. II*) moderately dense, some with nuclei, some without, some resembling the nuclei themselves.

As for the extraordinary yellowness, I began to note it particularly on the 16th, in the morning at 6¼ h., when the Sun stood 21 degrees high, in these words: "The central spots *n*, λ , μ , ν , ξ . Several new ones have emerged: at λ there are four; at μ three; at ν two; at ξ there is still a swelling; at *n* there are four. Between μ and ν is a space, yellowing and whitening, even when the position of the glass is changed; a triple nucleus, of which the larger is very depressed, while the two smaller almost touch each other. Between the nuclei is a white space, glowing more strongly than the rest of the Sun's body, tainted by no umbrae — nuclei of the kind that vapors otherwise surround. You have the constitution of the whole spot inserted in the middle of this diagram, in that same situation relative to line A B and point C which it held on the Sun with respect to the ecliptic, its center C being in my ordinary observing circle — so that you may judge the proportion from it. At *n*, the larger spot that had until now followed spot *a* from the beginning is failing, but a small new one that arose did not persist long; at λ you discern four small ones, four at μ , and more than two at ν — for they are handfuls of the tiniest spots. The oblong white space, therefore, closed off above by little points, was yellowing and whitening for three days, in an appearance almost extraordinary, on account of the vehement intensity of the colors."

[Margin: From the Roman observation, an accurate description of the yellowness and of many things worthy of note.]

[Margin: An extraordinary three-day yellowness.]

"On 19 May, five spots; and among the faculae preceding spot C, a more striking facula, *g*, was seen." Thus the observer. In my own diagram, near spot *a*, you will find, besides itself, more than eight tiny spots. The rest is supplied by the course of *a* in Image XXIV. For the more striking facula, consult my Appendix a little further on.

The other course, of spot *b*, set out in this same Table III, corresponds to my course *a* comprehended and explained in Image XXIV; nor will you see any other discrepancy than that in my observing circle — being larger — you will examine everything, singly, far more distinctly. Yet in the positions of the spots and in the situations of their paths relative to the ecliptic, the highest proportional consonance is always marked, even in these smaller matters — which is all I need from others' observations for my purpose.

[Margin: The locations seen always correspond to one another.]

Tables IV and V were observed at Freiburg, in the year 1622. **Table VI**, however, was observed at Ingol-[stadt]

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(page 220)

—stadt, in the year 1624. And although they are neither of the same places nor of the same years, nonetheless — because they fall in the month of May, on nearly the same days, at almost the same distance from the ecliptic, and agree also in the resemblance of the course and of the obliquity to the ecliptic, both among themselves and with the Roman course of spot *a* expressed in Image XXIV — compare them one by one, and you will see the truth.

[Margin: The very great resemblance of different years and different spots in their courses.]

In Table VI, on the 17th, nothing appeared but spot *a*; then on the 18th and 19th it showed a companion going before it, into whose place — since it converged on the following day — I marked it off with a circular line. On the 24th it appeared alone, and on the 26th it drew an austral facula behind it. And you see everywhere the appearance of rectilinear motion set before your eyes.

Table VII embraces two courses, of spots *a* and *b*, observed at Ingolstadt in the year 1625; of these the northern one corresponds to the Roman *b* set out in Image XXV, while this *b*, the southern, imitates the Roman *a*.

[Margin: The rectilinear motion once observed at Freiburg and Ingolstadt in the month of May.]

Now since mine run from horizon to horizon, here on both sides the head and tail are lacking. For spot *a* first claims a place for itself on the 30th, whereas with me it grazed the horizon in some fashion on 28 May as it entered; and this single spot, with me, was even noticed doubled at the horizon. After the 7th nothing more was seen of it at Ingolstadt, even though the Sun was carefully scanned; but with me it shone faintly, together with faculae, up to the 10th, though very slightly. Let us now listen for a moment to the Ingolstadt observer, at least on those days where something worth observing occurred:

"On 6 June," he says, "at 10 h., two spots with faculae around *d*" (you have both of these spots expressed here in the north and south courses) "— yet in the afternoon at 6 h. a spot was seen entering the Sun, having by inspection almost no latitude; in this form, for it was not admitted today by projection." He is, however, speaking of the spot of course *a*, set out in Table VIII. But in my own course, of spot *h* contained in Image XXV, you will find the same one observed in the manner of a slender little line on the 6th at 8 h. in the morning, and indeed free of the horizon. From which you have: (1) that my method of observing is by no means to be set behind any other, but rather until now to be preferred to them; (2) how the solar inspection through the helioscope also detects, accurately, the minute features on the Sun; (3) how long the spots cling about the horizon; (4) how

[Margin: Things to be noted.]

(page 220, col. II) little the observing circles, being so small, avail for the marginal spots and faculae. For at 10 h., when the observation was made at Ingolstadt and two spots were seen, four hours had already elapsed since I had here at Rome watched the same one at 6 h. as it had crossed the whole horizon; from which it is altogether necessary that there too it must have been visible at 10 h., if only the condition of the observing circle and tube had allowed it. For as to the strenuous accuracy of the observer, the matter is settled for me. And although these truths can be established by reasoning and by continuous practice, I nonetheless more readily consolidate them by others' practical examples, so evident, than I confirm them by my own domestic ones alone.

From which it further follows, (5) that the integrity of the apparent courses from horizon to horizon evidently cannot be known or investigated by these small observing circles — save rarely, in enormous spots. From which arises (6) another drawback: that you remain ignorant whether the spot's course is rectilinear or curvilinear; (7) so that you cannot tell whether a spot or facula has truly, or only apparently, arisen or set, been generated or been destroyed.

"On 7 June, three spots and faculae around *d*. The first spot grew in latitude, though still oblong." You have all three of these spots in the Tables, and two indeed in Table VII — one boreal, *a*, and the other austral, *b*, expressed on the 7th; the third you have in Table VIII, for the same day, under the name *a* — all of which are set together in my Image XXV, where, under the letter *h*, you may contemplate, for the 7th, the condition of the spot which drew with it both a facula and smaller spots, itself not single but twinned. The facula — or rather the faculae — depicted from the 5th to the 8th you have at the letter and course *c*, where you at the same time observe how, as spots *c* failed, faculae were kindled in their place. For those spots, on the 30th in the evening, having arisen on the Sun out of a very thin little cloud and the slightest traces, when they had afterward grown a little in number and mass, notably declined after 4 June into these recorded faculae, which on the 6th — most diligently inspected both morning and evening — completed the number ten. And this physical generation of spots is not peculiar to this case, but common and ordinary to all. On the 7th, morning and evening, much slenderer than the day before, they came (*page 221*) down to the number seven.

[Margin: From spots, faculae.]

[Margin: The generation of spots.]

IMAGO SOLIS XXVI

(*page 221*)

On the 8th at last, in the morning, they showed their final traces, beyond doubt, at the very rim of the horizon.

Table VIII embraces three courses of spots, *a*, *b*, and *c*. Course *a*, running north-to-south, corresponds to the Roman course *h* expressed in Image XXV. Course *b* corresponds to the Roman *K* explained in Image XXVIII. Course *c* corresponds to the Roman course *l n*, likewise set out and explained there.

Course *a* has been begun on the preceding days and is now to be explained continuously.

"On the 9th, then," says the observer, "two spots were seen through clouds; the earlier was *a*, still oblong, though less so than yesterday." Thus he writes. The other was *b*, in Table VII. Consider the genuine figure of each in the Roman diagram.

"On the 10th and 11th — nothing at Ingolstadt."

[Margin: Spots of the nebulous kind are teeming with nuclei.]

"On the 12th, six spots, with three nebulae seen by projection." Thus the observer. You will discern the four central southern spots, with their nebulae, at *a* and *b*, and two eastern boreal ones at *c*. Of the central spots, *a*, lying directly beneath the center, is in my diagram *h*, converging somewhat toward the east, because my observation ran ahead by several hours. The remaining three, *b*, together with their nebulae, are held in my Image XXVIII for the 12th at the letter *K*, where you will see spots — partly teeming with nuclei, partly empty and rare — at least fourteen. Two of the boreal ones you likewise have in the same diagram at the letter *n*, and indeed set out enclosed within five faculae, exceedingly bright.

[Margin: The Roman projection shows far more spots than the Ingolstadt emission, i.e., direct inspection.]

"On the 13th, nine spots by projection, eleven by inspection. The first was composed of two and enveloped in a nebula; the 7th and 8th were nebula-like; the 9th had two very nebulous spots adjoined to it." In the Roman diagram, in place of the 9 spots, you will see at the center *C* at least 17 southern ones, with their nuclei and vapors, or nebulae; on the north side, (*page 221, col. II*) ten, together with most brilliant faculae.

"The 14th did not favor observation, on account of the inclemency of the sky."

"On the 15th, five spots seen with a great nebula, spot-like, by projection, such that the nebula in which the spot was wrapped was itself [the observed feature]." Thus the observer. In the Roman diagram you have the spot wrapped in a nebula, *h*; then the rest, *K*, toward the east very thin, and therefore observed nebula-like. But they were at least fourteen. The boreal ones, however, ten, still carrying with them exceedingly bright faculae.

[Margin: Thin spots, seen at Ingolstadt like nebulae.]

"On the 16th, eleven spots by projection; by inspection there was a nebula in the middle of the departing and following ones." Thus he writes. Look at the Roman diagram, and you will see spots *K* wonderfully changed, the middle ones made rarer, the outermost [denser]. Hence nebulae were seen by the Ingolstadt observer in the middle of the preceding and following spots; but also on the north, of which he himself counts only five, at least 13 appeared, besides that shadowy central tail. The faculae still shone, but more feebly.

"On the 17th, eight spots seen by projection. Of these, five are southern, and one hitherto not seen at Ingolstadt, *h*, which corresponds in the Roman diagram to spot *l*, whose course began on the 8th from a facula, then broke out into spots on the 12th, and thereafter continued through various changes up to this very day." The condition of the rest you will be able to contemplate in Image XXVIII, where you will notice a remarkable coalescence, or else a simultaneous pulling-apart, of the boreal ones.

"On the 18th, observations interrupted." Look at the Roman ones, and you will find the southern ones clustered together, five, and the boreal ones twenty, and so forth.

"On the 19th, two spots seen, the sky not so clear." How many these two boreal ones really were, you will discern if in the Roman rendering you count at least fourteen — and indeed much altered.

ROSAE VRSINAE LIB. III

Notes on the Appendix to Image XXVI of the Observations

(page 222)

Since the apparent motion of this phenomenon is the foundation, as I said at the outset, and the first root, from which one must and can arrive at the innermost knowledge of the phenomenon itself; and since this motion has now sunk into such a state that it slips along, to the senses, no longer curved but straight; and since this matter may seem in some way new and incredible — lest anyone perhaps suppose that I use others' observations for the sake of my own rather than for the truth, and so introduce some force, whether in the angles or in the positions of the spots, in arranging them, so as to fashion rectilinear motions out of curvilinear ones: behold, whoever you are that regard this with no unfair eye — so that you may experience my sincerity, and the uniform tenor of a truth always and everywhere consistent with itself, and may now put your faith not in my pen but in your own eyes — in the appended Appendix I set before your eyes

the individual observations of the spots, most accurately transcribed from the very Ingolstadt exemplars, written by the observer's own hand and sent here to me at Rome, the size of the circles being preserved, and the number and situation of the spots.

[Margin: So that the undoubted truth of the rectilinear motions may be established, the genuine observations are adduced from the autographs themselves.]

That this might be preserved more exactly, I have introduced by points only the centers of the spots; for their magnitudes, figures, and density or rarity, you have sufficiently in Image XXVI, just proposed.

[Margin: The centers of the spots only are marked, by points.]

I have also added the perpendicular Z N, in that situation relative to the observed spots in which I received it from Ingolstadt, to which I have subjoined the angle which the Ingolstadt observer himself drew out, by astronomical calculation, for the given time of observation. This I have done so that the truth of the apparent motion, propped up by others' numbers, might come out more illustrious, and so that my own candor, mixing in the less of its own, might remain the more unimpaired in the mind of the reader. Though I ought not to conceal that all these observations, when applied also to my own standard, were found to have equal angles too, as I have already several times intimated. In the diagram set below, then,

[Margin: The perpendicular, or vertical line; likewise the angle of this with the ecliptic.]

[Margin: The Ingolstadt angles do not differ from those found by the men at Rome.]

(page 222, col. II) the circles A Z B N are those of the Ingolstadt observatory, equal to the Sun's apparent circle projected onto the paper through the telescope. A B, the diameter, represents that portion of the ecliptic line which the plane of the ecliptic has in common with the Sun's circle. Z N stands for the common section of the vertical plane with the solar circle; its distance and inclination from the ecliptic is determined by the angle at center C, comprehended by the said lines — the ecliptic and the vertical — or, what is the same, the arc of the solar perimeter intercepted between the said lines.

[Margin: Explanation of the diagram.]

[Margin: The ecliptic, A B.]

[Margin: The vertical section, Z N.]

Although this angle is always known absolutely, by arithmetic and infallibly, for a given time and place, nevertheless it is not given by position in the observing circle with respect to the observed spots, unless the vertical line Z N be given from observation — whose point Z is the zenith, N the nadir. When, from this given position, its obliquity to the ecliptic is drawn out from the time of observation — and thereby the angle, whether Z C A on the left, or its vertical opposite on the right, N C B; or Z C B on the right, or its opposite on the left, N C A — then the ecliptic A B is also given by position, and thereby the situation of the spots relative to it, from which their apparent course becomes clear.

[Margin: Given the angle between the ecliptic and the vertical line by position, it is given.]

[Margin: The position of the ecliptic being given, the situation of the spots relative to it is also given.]

Know first, however, that the same letter was not always attached to the same spot by the Ingolstadt observer. For the same boreal spot he calls *a* on 30 May and 1 June, then on the 4th, 5th, and 6th he assigns it the letter *b*, while on the 7th, when it appeared there for the last time, he assigns C. Whence it has come about that I, in gathering the whole course, represent that same spot under the same final letter *c*.

[Margin: The last letter of the observation is attributed to the whole course of the spot.]

In the same way, on 9 June, I present the whole course of the austral spot *b* under the same letter, because he received it on the last day from the Ingolstadt observer, although in the intervening days he did not always keep the same letter. For the same reason, the boreal spots *a* are set forth under this letter; and finally the course of the north-austral spot under the letter *d*.

[Margin: The whole course of spot *c*, sensibly rectilinear, in Circle 6, from 30 May to 7 June.]

[Margin: Thus in Circle 8 is the rectilinear little run of spot *b*, from 1 to 9 June.]

[Margin: So too in the last-but-one circle are spots *a*, in the last, *d*.]

Know secondly that in these presented observations nothing of mine has been added, except [continues]

Rosa Ursina, Book III — Appendix and Notes to Image XXVI; Notes on the faculae (Images XXIII & XXIV)

Engraved plate: Appendix to Image XXVI (printed p. 223)

The plate carries a letterpress heading above the engraving:

Appendix to Image XXVI of the Observations, in which — from the Ingolstadt observers' own Designation-exemplars sent to Rome — faithful copies are rendered exactly to the letter, together with the Ecliptic and the Vertical Line, just as they had there been observed and drawn, and [set right(?)] [?] by the Observer himself. From these is also derived the angle which the plane of the Vertical makes with the Ecliptic at the center C — [the plane] which the solar disk AZBN comprehends — and the Apparent Motion at this time is most firmly proved to be, to the senses, rectilinear.

[A short word or symbol after *atque* in the third line is inked over / blotted — [?].]

Diagram. A full-page engraved plate presenting the Ingolstadt solar observations of late May to mid-June 1625 as a set of solar disks arranged in roughly three columns and five rows, interspersed with three "course" (*Cursus*) circles that trace a single spot's track across several days. Each disk is a circle marked **Z** (top), **N** (bottom), **A** (left) and **B** (right) on a horizontal diameter (the Ecliptic **AB**) crossing the center **C**, with the vertical diameter **ZN**. A printed legend beside the first disk explains the lettering:

- **AZBN** — the apparent disk of the Sun
- **AB** — the Ecliptic
- **ZN** — the Vertical Line

Each disk is inscribed with a date, the hour of observation, the spot count with spot-letters (*Mac.* / *Macula*), and an *Angulus* (the angle the ecliptic diameter makes with the vertical). Decorative devices occupy the corners and margins: the Jesuit **IHS** sunburst emblem (upper left), a **MRA** (Marian) sunburst emblem (upper right), and the Orsini heraldic rose repeated at the side margins.

Individual solar disks, with the labels legible under magnification:

- **30 May, h. 1. 25** — *Mac. unica. a.* (single spot a) — *Angulus 54. 5.*
- **1[?] June, h. 6. 49** — *Macula 9. a. b. c. d. e. f. g. h. k.* (nine spots, plotted along a diagonal) — *Angulus 53. 5.* [leading date-digit uncertain: 1 or 7 [?]]
- **4 June, h. 7. 12** — *Mac. 3. a. b. c.* — *Angulus 49. 39.*
- **5 June, h. 9. 49** — *Mac. 3. a. b. c.* — *Angulus 53. 5.* [second value [?]]
- **6 June, h. 10** — *Mac. 2. a. b.* — *Angulus 61. 7.*
- **7 June, h. 1. 20** — *Mac. 2. a. b. c.* — *Angulus 60. 29.*
- **8 June, h. 10** — *Mac. 2. a. b.* — *Angulus 60. 50.*
- **9 June, h. 12** — *Mac. 2. a. b.* — *Angulus 83. 52.*
- **12 June, h. 12. 12** — *Mac. 6. a. b. c. d. e. f.* — *Angulus 81. 53.*
- **13 June, h. 9** — *Mac. 9. a. b. c. d. e. f. g. h. K.* — *Angulus 50. 31.*
- **15 June, h. 9. 12** — *Mac. 5. a. b. c. d. e.* — *Angulus 50. 41.*
- **16 June, h. 8. 45[?]** — *Mac. 11. a. b. c. d. e. f. g. h.* (with further spots plotted at the right, read as *i / k / l* [?]) — *Angulus 48. 12.*
- **17 June, h. 9. 42** — *Mac. 8. a. b. c. d. e. f. g. h.* — *Angulus 52. 52.*
- **19 June, h. 2. 8** — *Mac. 2. a.* — *Angulus 51. 58.*

Three "course" circles trace a single spot's daily positions along the ecliptic diameter, each labelled with its own legend and its track-points marked by day-number:

- **Course of spot a, from 30 May to 7 June**, "nearly rectilinear, as also the Roman ones" (*Cursus Maculae a. 30. Maij. ad 7. Iunij. quasi rectilineus sicut et Romanae.*). Track-points near the center are labelled with the day-numbers 4, 5, 6, 7 (each marked *c/a*).
- **Course of spot b, from 1 to 9 June**, "nearly rectilinear, as also the Roman one, and ..." (*Cursus Maculae b. a 1. ad 9. Iunij quasi rectilineus, sicut et Romanus, et ...*). Track-points 4, 5, 6, 7, 8, 9 lie along the diameter (each marked *b*).
- **Course of spot d, from 6 to 17 June**, "nearly rectilinear, as also the Roman one and others of other years at the same season" (*Cursus Maculae d. a 6. ad 17. Iunij. quasi rectilineus, sicut et Romanae et alij aliorum annorum tempore eodem.*). Track-points 7, 8, 9, 12, 13, 15, 16, 17 run along the diameter (each marked *d*).

A diagonal crease/tear runs across the lower portion of the plate (visible in the bottom tiles), passing through the 17–19 June disks and the course-of-d circle; some spot-letters in that region are obscured and flagged above.

ROSAE VRSINAE LIB. III. (printed p. 224)

I.

[Margin: Only the collection of the various observations into a single course is mine; the individual spot-observations belong to the Ingolstadt Observatory.]

nothing but the gathering of the observations of single spots — each of one spot — into the pattern of a single course; and of such objects you have four, namely c, b, a, and d. As for a fifth, made up of the spots that emerged on 12 June and so on, I chose not to compile it: for my purpose the aforesaid four seem sufficient. Let the reader examine whether, from the data of the observations, I have rightly collected these rectilinear courses.

Note, thirdly, that I have used exactly the same fidelity in compiling the other courses that I here demonstrate to your eye in arranging these. That I do not adduce, from all the originals, matching copies, I judge to be no abuse of your leisure, Reader, nor of your expense, nor of your human fairness — and, so as not to seem to distrust it, I willingly and gladly commit to it much that I might otherwise have brought forward, and I omit much. [Margin: Much is left to the reader's fairness.] For whoever judges that falsity underlies these things, set out as faithfully as they are, will not believe them even if whole wagon-loads of observations were brought into the open. Nonetheless, that I may convince even the reluctant, I keep the autograph exemplars and appeal to anyone for their verification.

Note, fourthly, that the motion of the four courses is, to the senses, quasi-rectilinear. [Margin: The motions have been brought to a sensibly quasi-rectilinear form.] I say "quasi" for two reasons, one to be drawn from the observer, the other from the things observed. The first: because it sometimes happens that, while we observe, the spots are meanwhile shifted by the diurnal motion from the place marked on the chart; and so, if we do not likewise advance the marked point, then by the turning of the paper-bearing tablet it necessarily follows that the plumb-line comes out false, and the angle to the ecliptic, derived from it, comes out less correct. That this has happened here now and again, the thing itself declares — though anyone skilled in these matters will note and guard against it without trouble. For who does not see, in the course of spot b, that if

you apply a straightedge some points stray a little from the straight line — which is certainly due to nothing but an error of the plumb-line? But since these little blemishes are very small, and easily noticed and judged by anyone, there is no reason for me to dwell on them longer: I ask only this, that I may obtain the motion of spot b, from 1 to 9 June, as rectilinear.

Note, fifthly, that these courses, as they are here set out from observation, truly and correctly appeared entirely such — that is, sensibly quasi-rectilinear. **[II.]** The proof of this is furnished, first, by my Roman courses for these same times and days of this very year 1625, set in order and to be expounded; [Margin: From the Roman courses, from the Ingolstadt, Freiburg, and Douai courses, of the years 1622, 1624, 1625, 1626, etc.] then by the courses for these times and days in past years, as you have in Tables IV, V, and VI of Image XXVI, and likewise in Table III of Image XXVII — where you will find five distinct rectilinear courses of the spots a, b, c, d, e, observed at Freiburg im Breisgau in the year 1622 by Georg Schönberger, my pupil and successor there, about which you will draw fuller particulars in the explanation of that Table. Here it is enough to give a gentle reminder, and to point out those courses run within the rectilinear tracks in the month of June. In the same Image XXVII you will also have Table II, the Douai one, very like the Ingolstadt Table II in Image XXVI, running from 30 April to 10 May, where you will find the apparent motion still indeed curvilinear, but greatly aspiring toward straightness. [Margin: The apparent motion of the spots is, in reality, always curvilinear, but sensibly rectilinear.] Moreover, the straight motions establish themselves in the following years too: turn to the end of May and the beginning of June in the year 1626, and there once again all the courses of the spots appear quasi-rectilinear — I say "quasi" because in reality they are not [strictly] rectilinear, but always somewhat curved, yet approach straightness so closely that the senses can detect nothing certain to the contrary. Then, when they recede notably — that is, by fourteen days — from the end of May and the beginning of June, some curvature is perceived; and that is why I call those motions sensibly quasi-rectilinear. The curvature is also somewhat aided by the refraction of the glass [lens], especially if the courses lie far to the south or far toward the meridian.

Note, sixthly, that all these rectilinear courses cut the Ecliptic and are not carried parallel to it; that the intersection is at angles in some way equal; that the angles of all of them looking toward the east are boreal, and those looking toward the west austral; [Margin: The direction of the apparent motion is oblique to the Ecliptic, from the eastern north to the western south.] that all the motions before the intersection are placed in the northern region, and after the intersection in

the southern; and so that the tendency and carriage of all these apparent motions is from the North toward the South. And although this is so, nevertheless many apparent motions are wholly boreal and do not cut the Ecliptic within the Sun, yet would cut it outside, toward the west, if the lines were run out and finally made to converge; [Margin: Many absolute motions are wholly in the northern region, many in the southern, and many are mixed.] conversely, many are wholly austral, and from the Ecli-

IMAGO SOLIS XXVI. (printed p. 225)

I.

[Margin: How, where, and when do these tracks begin to curve?]

—ptic they always recede more and more toward the west; yet they would cut it outside the Sun if the lines were produced toward the east. You have examples of both cases in the courses of this Appendix: for the track of spot c is wholly northern, that of spot b wholly southern, that of spot d mixed. Some, however, cut the Ecliptic in the Sun itself — sometimes in the eastern part, sometimes in the western, very rarely at the center. See the course of spot d, which on 9 June sat upon the Ecliptic both at Ingolstadt and here at Rome.

Note, seventhly: if these rectilinear courses seem to deflect somewhat from straightness, then — should they run toward the beginning of May — they are, on the southern side, convex toward the center C, and concave on the northern side; [Margin: When do they become most straight?] conversely, if they lie nearer the end of June, they become convex on the northern side, and on the southern either concave or rectilinear. But if they proceed evenly within both months, they will appear sensibly rectilinear, unless the refraction of the lenses or some extraordinary circumstance introduces a little arched bending.

Note, eighthly, that this apparent rectilinear motion is common to all the spots — even if they last only a day or an hour, even if they are first generated in the Sun itself and in whatever part of it, even if they are very small, even if rare, even if of irregular shape. [Margin: When one spot proceeds with rectilinear motion, all do the same.] None the less they all follow the same well-worn royal road common to all.

Note, ninthly, that this sensibly rectilinear motion makes the same inclinations to the Ecliptic as did the motion presented in the year 1624, and as will be presented this year 1625 and the next, 1626, between the months of November and December. [Margin: All the rectilinear motions of the various years make equal

inclinations to the Ecliptic.] They differ in this alone, that their tendencies are, as it were, successively opposite: for the motion between May and June is rectili-

II.

[Margin: In each half-year they occur toward sub-contrarily opposite regions. After the winter rectilinear motion that occurs at the beginning of December, all the spots describe tracks concave toward the south for six months.]

—near, and always runs obliquely from north toward south; whereas that between November and December always tends obliquely from south into north.

Note, tenthly: just as the spots always departed from that winter rectilinear motion into a curvilinear one, and always made it concave toward the south and convex toward the north, and that for six continuous months, so now, on the contrary, you will perceive by the senses the concave curvature turned toward the north and the convex toward the south — in an exactly opposite position, but in the same manner and at the same season. [Margin: The curvature and straightness of the apparent motion return the same each year.] Consider carefully the Images of the observations that follow, and read the Notes, and you will discern the plain truth of what has been said more clearly than the Sun.

Note, eleventhly: after the apparent curvature of the track has arrived at November, it will begin to raise itself once more into a straightness like the earlier one, and around the end of December it will pursue the earlier arched gyres, as will be shown in its proper places and by examples.

Note, twelfthly, that all these motions — common to all and each of the spots — must be demonstrated of the faculae and umbrae as well, both primary and secondary, no otherwise than of the spots themselves. [Margin: These motions and their qualities are common to the faculae and umbrae too. Given this phenomenon, parallax is banished.] Now let us go on with what we have begun and with what still seems to remain up to the middle of this year.

From all these things, weighed with care, is drawn a most solid argument: that from this phenomenon no parallax whatever accrues to the Sun. Otherwise, by what reasoning could it come about that the spots should be seen at the same place on the Sun and from regions so far apart? That they should traverse similar tracks? That they should sit upon the Ecliptic at the same time? That they should reach the middle of the Sun at the same moment, enter the Sun together, and leave together? That they should be born at the same place on the Sun, and perish at the same place?

ROSAE VRSINAE LIB. III. (printed p. 226)

Notes on the Appendix to Images XXIII and XXIV, concerning the faculae a, b, and c, from 15 May to the 26th of the same month

I.

[Margin: The faculae struggle all night long to surmount the horizon; yet outside the Sun they emit no flame.]

Although faculae occur on the Sun daily — both singly and, joined with spots, crowding in flocks — and although it would be open to me to lead out whole armies of them, across entire years and months, into battle-line, still I always more gladly kindle others' [observations] in preference to my own alone, because, joined with mine, they seem to shine forth more brilliantly and to bring more light to the truth. There is this too: the laws of friendship demand that I in turn attend to the honor of those by whose labor I am aided in this difficult phenomenon. Hence I attach this Appendix on the faculae a and b, so as to render more illustrious those which Fr. Georg Schönberger [Georg Schönberger] brought forward in his observations for the 17th and 18th, and likewise the 19th, of May.

The faculae, then, that he himself observed on 17 and 18 May you have recorded in Table III of Image XXVI. I myself had seen the same ones long before at Rome, rising on the eastern horizon — namely on the 15th, toward evening at the 5th hour and later, as you see noted. They were without spots and very bright, but also somewhat slender; their shape, number, and size you have faithfully rendered in the drawing of them, along the Ecliptic AB, on which you see the number "15" (the day) engraved. On the 16th in the morning they had advanced somewhat by rising above the horizon, yet had not entirely cleared it, as appears from the diagram whose Ecliptic is DE; in bulk and number they had grown a little — yet they still confine all their flame within the Sun.

For these two days the Ingolstadt observations have nothing of these faculae — partly through the incapacity of the too-small observing circle, partly through the intervening clouds on the 15th.

For the seventeenth day, then, the Ingolstadt observation [recorded] this cluster of faculae —

II.

[Margin: About thirty faculae seen.]

—but noted it without distinction. "At the ingress," he says, "the Observer saw many faculae around g" — thus he. They were, in number, about thirty distinct ones, partly cohering by mutual connections, partly wholly separated by shadier tracts running between. Of these shadows, some were seen brighter than others, some darker; but many differed not at all from the rest of the Sun's shining surface, and only made the faculae more conspicuous by their interposition. They had no spot mixed in among them; they appeared larger and more numerous than the day before — having, that is, risen entirely above the horizon. The Ecliptic of this observation is FG, inscribed with the number 17.

"On the 18th, faculae around g," says the Ingolstadt Observer; and what they looked like you have in the appended observation, marked at the Ecliptic HI with the number 18. [Margin: The motion of the faculae is the same as that of the spots.] They shone purer indeed than the day before, but smaller and fewer; for they wane gradually, like the spots. I have set all these observations each with its own Ecliptic, because with a single one they could not have stood, owing to the mutual crowdings and smudges; and further, so that you may nonetheless see their position relative to the same line, and recognize that the faculae have the same motion which you see in the spots. You have evidence of this in facula b, whose course from the 18th to the 21st, set alongside, you see to differ in nothing at all from the tracks of the spots.

This facula b was indeed rather small, but of pure and very intense light, and surrounded by no notable spot or umbra. [Margin: Facula b, pure, noticed at Ingolstadt too.] It diminished gradually, and after the 21st I could make out nothing of it, though I applied every effort. At Ingolstadt it was noticed on the 19th alone. "Among the faculae preceding spot c," says the Observer, "the rather notable facula g was seen"; it was altogether most remarkable — otherwise, so small a thing would not have shone out in so small an observing circle. All its observations have been arranged by me here at Rome along one and the same Ecliptic, b C b. For the rest —

Rosa Ursina, Book III — Notae Particulares (folios 227–230)

Image of the Sun XXIII–XXIV (folio 227) — Appendix plate

Diagram. A full-page engraved solar disk (a large circle) with its center of projection at C, set right of the disk's middle. From C a fan of straight radial lines

runs out to lettered points on the circumference: on the right and upper side, reading top to bottom, **x**, **G**, **E**, **B** (the right-hand end of the horizontal diameter), and **b** (lower right); on the left side, top to bottom, **A** (the left end of the horizontal diameter, marked **15**), **D** (marked **16**), **F** (marked **17**), and **H** (marked **18**). Along the left interior a course of faculae **a** is traced, its markers dated 15, 16, 17, 18 near A/D/F/H. In the upper-left interior a group of spots **b** is dated 18, 19, 20, 21 (b·18, b·19, b·20, b·21). Near the lower-right radial endpoint **b** lies a dense cluster of spots lettered **c** (twice) and **u** [?]. The engraved caption block at the top reads:

In the Jubilee Year, 1625. In the Professed House of the Society at Rome.
[rose ornament — IHS sunburst emblem — rose ornament] Appendix to
Images 23 and 24, concerning the faculae a, b, and c; of which the first
two were also observed at Ingolstadt.

An embedded table headed **MAII** ("[of] May") stands in the disk's lower-middle. Its column heads read **D — H — ☉ — El** (Day; Hour; ☉ [solar altitude], degrees; El[ongation/altitude minutes]):

Dies		Hora	☉ (°)	El (')
15	u	5 3/15 [?]	18	0
16	m	6 3/4	21	0
17	m	6 3/4	20	30
18	m	6 3/4	21	5
19	m	8 [numeral: ?]	35	0
20	m	[numeral: ?]	24	[numeral: ?]
21	m	6 6/7	21	30
26	u	6 [numeral: ?]	15	20

Notes on the Appendix to Images XXIII and XXIV (continued)

For the rest, that neither the faculae **a** nor **b** lasted until the Sun's setting is clear from the fact that both faded from day to day. That on the 17th the faculae **a** appeared larger may be attributed either to their position or to a physical increase; but it is certain that on the 18th they diminished, and when I looked for them again on the 19th and the following days, I did indeed find traces of them, faint and sparse—yet I stopped recording them on paper, just as I noted this same thing in the Ephemerides. Of the faculae **b** I found no further trace. Had they lasted, I would surely have found them, together with the others, by scanning the Sun most carefully every day—as on the 26th I recorded more than twenty

faculae **c**, perfectly clear and pure. And there is no doubt left that these arose anew on the Sun; otherwise I would both have seen them earlier and would by no means have let them pass untouched. I had in fact seen them on the previous day as well, but since they shone more faintly I did not enter them on paper. I had supposed them to be the faculae **a**—for their very constitution and shapes, and above all the timing, favored that supposition. But their location and their distance from the ecliptic **A B** tell too strongly against it, so that I am compelled to affirm that they arose newly on the Sun. The observer at Ingolstadt has nothing about them, even though observations for that day are not lacking.

[Margin: Traces of the faculae **a**, now diminished, were seen also on the following days.]

[Margin: Faculae emerge anew on the Sun, just as the sunspots do.]

[Margin: *[illegible italic note at lower-left of folio 227, largely obscured by verso show-through — [?]]*]

Notes on the Twenty-Seventh Image of Observations, composed from three Tables, for the months of March, May, and June, at Douai and Freiburg, in the years 1618, 1622, 1624.

Table I comprises the courses of the spots **a** and **b** completed in the year 1618. All the observations of them—except that of the 15th, made at the 12th hour—were sent to me by Father Charles Malapert [Carolus Malapertius]; they were made from the eighth to the 18th of March, and on the 15th he observed them at the 2nd hour after noon. He once published them himself, this same Father, in his solemn introduction to mathematical doctrine, which he appended at the end to Euclid, though in a much more compressed form; but this copy, of which I give you the transcript, he sent me written in his own hand, and I therefore keep it carefully.

The spots **a** I now set before you in the very shape and size in which I received them from him, for I did not care to add or to take away anything from another man's work. My own observations of this year 1618, made in Germany, I do not have here at hand; nevertheless I am certain that neither do these differ from those, nor those from these, in place and position. Meanwhile it is plain to the eye that these motions are curvilinear, and conform to the motions of other years carried out at the same season. Compare the Roman March courses with this one,

and you will see the truth of what I say. Note in passing, too, how many small spots, born on the Sun after their rising, never reached their setting: consult the Thirteenth and Fourteenth Image of the Observations, and you will find motions not unlike these, though of other years and of different spots. The ecliptic was cut across twice by this Douai course.

[Margin: The courses of the spots carried out at Douai in Belgium in 1618 correspond to the Roman ones made in 1625 and the following years.]

Table II contains the course of the southern spot **a**, observed at Douai from 30 April to 10 May in the year 1624. I received it without hours and altitudes, but laid out by the observer himself, and I present it without those, yet with its position relative to the ecliptic. You have there a genuine [course] of the same year, of the same spot, and of the very same days, observed at Ingolstadt and set out in Table II of the Twenty-Sixth Image. I bring it forward the more willingly so that you may see the force of the truth, since it was not I but the observer himself who laid out this course as a rival to a straight line. Similar ones, but for other years, you will find among my own Images. Consult Image 22 of the year 1625.

I had almost forgotten one thing: namely, that on 6 May, before the center, a new spot suddenly appeared to that same Douai observer—one, as he himself writes, not seen before—which he then followed right to its end. And since the sixth day had not favored the Ingolstadt observer, he saw the same very large spot not far past the center toward its setting, and pursued it likewise, by daily observations, all the way to the end. I do not append its course, as I do not that of many others; but I give this notice so that you may observe that new spots are born, and old ones perish, in the middle of the Sun—and not for me alone, but for others too.

[Margin: The Douai and Ingolstadt courses are similar, approaching straightness.]

[Margin: Solitary spots observed in the most diverse places — their correspondence [?].]

Image of the Sun XXVII (folio 229) — three-Table plate

Diagram. A full-page engraved plate carrying three circular solar-disk tables, each with a horizontal diameter **A — B**, plus a descriptive caption block at upper-left (with rose-IHS-rose ornaments). The caption block reads:

Twenty-seventh, Image of the Observations, composed from three Tables
—from the observations and courses of three different months and three

years, Douai and Freiburg, in March, May, June, of the years 1618, 1622, 1624—at the Universities of Douai and Freiburg.

Tabula I (upper-right disk). Heading: "M.DC.XVIII. At Douai, in the Academic College of the Society of Jesus. Courses of the spots a and b, from 8 March to 18 of the same, similar to others of other years and places. MARTIVS. Table I." Along an upper track the spots **b** are dated 8, 10, 12, 13, 14, 15; along the diameter the spots **a** are dated 10, 12, 13, 14, 15, with a further **a** at 18 near B.

Tabula II (lower-left disk). Heading: "M.DC.XXIV. At Douai, in the Academic College of the Society of Jesus. Course of the spot a, observed from 30 April to 10 May, like the Ingolstadt one, etc. MAIVS. Table II." The point A is labeled "Aprilis." The spot **a** is dated 30, 1, 3, 4, 6, 7, 9, 10 along its track.

Tabula III (lower-right disk). Heading: "M.DC.XXII. At Freiburg im Breisgau, in the Academic College of the Society of Jesus. [of] June." Below the heading, an embedded table with heads **D — H — ☉ — El**:

Dies		H	☉ (°)	El (°)
8	m	7.2	26	0
9	m	7.30	31	40
10	m	7.23	30	77
11	m	6.50	25	33
13	m	7.38	30	38
14	u	5.38	20	43

Caption beneath the disk: "Courses of the spots a, b, c, d, and e, from 8 to 14 June; similar to others of other years and places." The disk's interior is a very dense spot-field with markers lettered a, b, c, d, e and dates from 8 to 14; readable are **b**·9, an **a/b** cluster, **11**, **13**, **b**·14, **c**·14, and lower **d/e** clusters dated in the 9–13 range, but most individual spot-letters cannot be resolved at this resolution.

Notes on Image XXVII (continued)

Table III comprises the courses of five Freiburg spots **a**, **b**, **c**, **d**, and **e**, of the year 1622, concerning which the observer has the following in the autograph papers he sent me.

On 8 June, when for three days before nothing had appeared, 10 spots were seen, together with a facula. There were 2 spots at their rising, at **a**, along with the

facula, and the remaining eight—very small spots—past the middle, at the letter **e**.

On 9 June, 5 spots; for out of yesterday's eight tiny ones (which is usual for this phenomenon) there came to be today three at **e**, of which the more western appeared nebulous and diluted, while the two following appeared more compact. Spot **a**, advanced at its rising, grew while the facula faded; and a new spot **b** arose.

On 10 June, 5 spots by projection [per immissionem], 9 by direct inspection [per inspectionem], together with a facula. This the diagram does not show in the east, to save space and avoid confusion.

You will count seven distinct spots near **e**; and near **a** there is a single one, westernmost, heavy with a nucleus and diluted by surrounding vapor; at **b** likewise.

On 11 June, 6 spots by projection, 9 by inspection. One you will find at **a**, another at **b**, four at **d** and **e**; the remaining 3, newly arisen, I do not plot, for want of room. Meanwhile spot **e** still thrives and surrounds its central nucleus with a thinner vapor.

On 13 June, 9 spots by projection, 9 by inspection, together with a corona (around the middle) made up of the smallest spots, uncountable in this figure because of their tininess. Around their setting the spots had faculae attached to them—so says the observer. Three setting spots you have, together with their faculae, next to **e** and **d**. The spots have been reduced to 3 either by displacement or by alteration, in their usual way, for spots near the horizon always undergo such things. That the faculae **d** arose from spots I scarcely doubt: it is the ordinary metamorphosis. The ordinary spots **a** and **b** you have marked at their own letters, indicated by the numeral marks (13) in the middle. Spot **a**, however, is preceded by 4 new ones, not seen until now, doubtless generated yesterday, which was the 12th; to these I assigned the letter **c**, which at the same time belongs to the corona of little spots, uncountable in this figure. That these were recently born is shown by the little spots **e**, generated on the 8th. And this is a frequent experiment in this phenomenon: that from many tiny spots large spots grow together. That they cannot be counted in this figure, or observing-circle, is due to its very smallness. You are taught once again, in practice, that inspection is the better method—by projecting the Sun into a small observing-circle.

On 14 June, 11 spots by inspection, some of which were wrapped in cloud, in this position and order (which you see in the figure), certainly covering a great part of

the Sun—so says the observer. In the figure set before you, you have, for the 14th, at the letters **a** and **c**, spots separated [from one another]; the tenth and eleventh you will find at **b**, when on the 14th you see yesterday's tiny spots gathered into fewer large ones, heavy with nuclei and ringed with cloud.

[Margin: The first physical rising of the spots begins from the smallest — which is customary in the Roman observations.]

[Margin: A facula born from spots, and noted at Freiburg.]

[Margin: Many small spots, by growing, coalesce into one large one.]

In this single scheme of a few days many memorable things are contained. For:

1. The physical rising and setting of the spots on the Sun—the rising indeed in the spots **e** and **c**, the setting in spot **a** (which had disappeared afterward, the preceding 8th) and in some of the spots **e**. Both happened, however, in three spots that arose past the middle on the 11th and no longer appeared on the 13th—which, however, I did not include, for want of room.
2. The mutual succession of faculae after spots, and of spots after faculae, in the same place: the former is clear at the setting, in the faculae **d**, which succeeded those same spots; the latter at the rising, in the facula **a**, in whose place new spots **c** arose in the middle of the Sun. And this I would not so boldly assert from this single case, had I not found it most true from elsewhere—from my clearest and most frequent experiences.
3. The state of the spots, in which **a** and **b** appear to have been, since they were carried across the Sun always at, so to speak, the same magnitude.
4. The increase and decrease of the spots: the former in spot **e** and in some of the **c**; the latter in some of the **d** and **c**.
5. All were southern, and the advance of all receded from the ecliptic toward the south along a path sensibly rectilinear.
6. Spots **a** and **b** advanced along almost the same parallel, and followed one another by proportional steps, as is clear to anyone who considers the figure and refers the apparent spaces back to the true ones; for they become sensibly equal. Around the middle of the 14th, spot **b** settled almost into its station, in the place where it had stood the day before—spot **a** [being there] in the forenoon.

7. Spots of nearly every kind displayed themselves: smallest, largest, middling; dense and sparse, fertile and sterile. I call "fertile" those heavy with nuclei; "sterile" those which lack a nucleus, or advance with a uniform shadow [umbra].

[Margin: Many small ones coalesce into a few large ones.]

[Margin: The physical rising and setting of the spots.]

[Margin: The alternating succession of spots and faculae.]

[Margin: The state of the spots.]

[Margin: The increase and decrease of the spots.]

[Margin: The direction of the spots is oblique to the ecliptic, from the north into the south.]

[Margin: Spots a and b proceed equally in the same parallel.]

[Margin: Fertile and sterile spots; which...]

Notes on the Twenty-Eighth Image of Observations, the second [image] of June, from the 8th day to the 24th of the same month.

First, the motion of the spots from the 8th to the 18th still traces out an almost straight line, as may be seen in the spots **K** and **m**; but from the 12th to the 24th it begins to be curvilinear, convex toward the south, concave toward the north—which spot **n** clearly teaches, nor do the Ingolstadt courses in Table VIII of the Twenty-Sixth Image disagree, in the courses of spots **b** and **c**. From this it follows that the north pole rises in the visible hemisphere, the south pole in the hidden hemisphere...

[Margin: The direction of motion, from north into south, begins to be oblique to the ecliptic; the curvature and obliquity increase; the north pole ascends.]

Rosa Ursina, Liber III — Notae particulares (Imago Solis XXVIII–XXX)

Diagram. Full-page engraved solar disk (the twenty-eighth Image), showing the paths of the sunspots observed at Rome from 8 to 24 June 1625. Within the disk,

at the top, is a lettered dedication and legend; two rose ornaments flank the Jesuit IHS device. The engraved title and legend read:

- "XXVIII, Imago Obseruationum" — 28th Image of the Observations
- "M.DC.XXV [1625], à die octaua Iunij, ad 24. eiusdem" — from the 8th day of June to the 24th of the same
- "Romæ in domo Professa Societatis" — at Rome, in the Professed House of the Society [of Jesus]
- "A, Oriens; B, Occidens; AB, Ecliptica, reliqua more solito." — A, East; B, West; AB, the Ecliptic; the rest as usual.
- "Cursus similes aliis aliorum annorum, tempore eodem." — Courses similar to those of other years, at the same season.
- Caption at upper right: "2. Iunij." — the second [image] of June.

Cardinal and reference points on the disk: **z** at the top of the vertical diameter; **N** at its foot; **A** (East) at the left end of the horizontal diameter and **B** (West) at the right end, the line AB being the ecliptic; **C** a point on that line. Two dashed spot-tracks (chords) cross the disk, carrying day-numbers 8 through 24 and per-spot letters. The letters legibly present on the tracks include **K** and **k** (a large developing spot group), **h**, **m**, **n**, and **l**; the individual per-spot day-labels are numerous and set very small. [The dense micro-labels along the two tracks — day-numbers 8–24 with their spot-letters — are only partly resolvable at this resolution; the readable ones are listed above and the interior day-by-day labelling is flagged as a rather than reconstructed.]

Embedded observation table (title **IVNII** — "of June"), giving for each day the hour (H.) and the Sun's elevation in degrees (☉ El., G. = gradus); "mane" = at dawn, "mat." = morning (a.m.). Set as two side-by-side halves (days 8–16 left, 17–24 right); merged here in sequence:

Dies	H.	☉ El. (G.)
8	mane	25. 0
9	7 ² / ₅ mat. [?]	28. 0
10	7 ¹ / ₄ mat.	26. 0
11	8 ² / ₅ mat. [?]	39. 30
12	7 ² / ₅ mat. [?]	29. 0
13	8 ¹ / ₄ mat.	40. 0
14	7 ³ / ₄ mat. [?]	31. 0

Dies	H.	☉ El. (G.)
15	7 $\frac{3}{5}$ mat. [?]	28. 35
16	7 $\frac{1}{5}$ mat. [?]	26. 0
17	7 $\frac{1}{4}$ mat.	27. 45
18	8 $\frac{1}{4}$ mat.	39. 0
19	7 $\frac{1}{3}$ mat.	32. 30
20	mane	24. 15
21	8 $\frac{1}{8}$ mat.	38. 0
22	8 $\frac{1}{8}$ mat.	38. 40
23	8 mat.	35. 30
24	6 $\frac{1}{4}$ mat.	18. 20
eod.	7 $\frac{1}{2}$ mat.	28. [?]

Notae in XXVIII (continued) ...it must descend from the [hemi]sphere.
[?]

Secondly: K was a facula on the 8th and 9th. Then — from the very faint indications of umbrae and spots on the 10th, all but immersed in the Sun's light, and somewhat emerged on the 11th and reduced to the smallest spots of matching shape — it grew astonishingly, at its highest and swiftest rate on the following days, into the marked heap and vast mass of spots that persisted right up to their exit; and there, drawing behind itself the faculae marked [in the figure], it drew them along. The nuclei were small and few at first, but afterward increased in number and size, and near the exit were seen to coalesce into one, the intervening space being absorbed, just as the Lateral Figure XIX sufficiently teaches. For that whole crowded multitude was contracted into three, so to speak, undistinguished spots, the middle space being squeezed out; and as long as this space lay open, from the 13th to the exit, it shone far more brightly than the rest of the Sun's body — which usually happens with the larger

and denser [spots], when by their mutual nearness they leave the intervening spaces empty, spaces which are then almost always converted into faculae. Further, you see here the later days of spot h set apart, so that you may learn its position relative to spots K throughout the rest of the Sun.

Now, all things weighed, it is quite certain that the apparent motion of those spots K — especially the first ones — did not reach the 13th day; for from the 8th to the 19th are 11 [days], to which, adding the interval between the 8th and the margin,

will give not much more than one day. Therefore this course will reach at most $12\frac{1}{2}$ days. The remaining variations are left for the Reader to examine.

Thirdly, l, a southern facula noticed on the 8th, was converted on the 12th, near the center, into a spot, and thus multiplied it reached the 16th, and afterward expired, leaving traces of its motion as if rectilinear — but not exactly parallel to the motion of spots K.

Fourthly, the faculae and umbrae m, mingled with those [spots] and shown in the east on the 11th and 12th, escaped my sharp eye and diligence until the 18th and 19th, on which they revived; afterward they were wholly extinguished, not having reached the horizon; yet the fragments of their track lie as if in a straight line.

Fifthly, the arctic spots n, entering with the faculae and among the faculae, advanced with them across the Sun, and at last emerged together with them. They varied their shape, size, and number wonderfully: toward the exit, those that had been small and scattered in the middle appeared heaped together into one continuous shadow, as it were, and so departed together with the faculae. They did not reach thirteen days on the Sun; their motion is somewhat arched, and sensibly parallel to the motion of spots K.

That the course of these spots was of no shorter duration on the Sun — but rather equal or a little longer — than that of spots K is beyond doubt. The numbers written in the margins indicate the positions of the perpendiculars, corresponding one by one to the observations set out in the little table.

[Margin: It did not reach the 13th day.]

[Margin: The small spot dilates, and [such spots] are joined into one large one. Faculae are carried at equal pace with the spots.]

[Margin: Spot n: on the 13th day [these] scarcely reached [the margin], yet seem to have outrun spots K.]

[Margin (left, foot of the plate above): The nativity of spots from the smallest faculae and umbrae, their incredible increase, and the dilation of their intervals beyond proportion; uniform motion.]

Notae in XXIX. — On the 29th Image of the Observations, the third of June [and] the first of July, from the 19th of that [month] to the 2nd of this one.

First: the curvilinear motion at last struggled out perceptibly in the contrary direction, even to the eye, in the spots as much as in the faculae; and again the chords, subtended equally from the center C by the arcs of the tracks, approach the ecliptic and make smaller angles with it.

Secondly: spots a, boreal, risen in the middle of the Sun, were four in number on the 19th; then a fifth was added, and so they kept that number, though varying in position and size, as will be clear to the observer. For the two westernmost gradually withdrew from the easternmost, and each seems at last either to have degenerated into faculae or to have been obliterated by faculae generated [around them].

Thirdly: the faculae b, bright southern ones, with faint indications of spots, seen on the 21st, advanced through the 22nd and 23rd, until at last on the 25th they gave birth to two slender spots. These, on the succeeding days, increased marvelously in number, size, and interval, and being variously shaped, reached — together with those same faculae, likewise diversely figured — right up to contact with the western horizon. Here it must be noted how the said spots, very elongated and rather sparse in the middle, appeared near their egress contracted and denser, the intervals between the spots being narrowed. The duration of the faculae and of the spots b on the Sun does not seem to have reached thirteen days.

Fourthly: the spots c, northern, newly born on the evening of the 23rd, were six; then three following ones, on the days thereafter, drawn out into a long tail, until on the 28th, 29th, and 30th they passed off into a facula — on the 28th indeed a separate one, but on the following [days] one continued all the way to the preceding spot, which, formed at first from three, kept growing, though its more boreal part [passed] gradually into an umbra, and then near the exit seems to have withdrawn into a facula

— which I am persuaded the other southern ones did as well. This too must be diligently observed about these spots: that the gap between them was continuously increased from day to day, so that by the 28th the distance of the spot from the facula equaled, on the 23rd, the interval comprehended by both spots.

Fifthly: the spots and faculae d lasted three days, having nonetheless advanced by the royal [road]...

of the others' way. On the 25th two umbrae g, adhering above, lasted only half a day — which is an everyday matter for this phenomenon.

Sixthly: on the 26th several spots f arose, with notable faculae, in the boreal region; gradually they lost both light and darkness, for both failed on the 1st of July into a very thin umbra.

[Margin: The gap increased.]

[Margin: Spot and faculae pass off into a thin umbra.]

Diagram. Full-page engraved solar disk (the twenty-ninth Image), showing the sunspot paths observed at Rome from 19 June to 2 July 1625. Within the disk at top is the lettered legend, with two rose ornaments flanking the IHS device. The engraved title and legend read:

- "XXIX, Imago Obseruationum" — 29th Image of the Observations
- "M.DC.XXV [1625], à die 19. Iunij, ad secundam Iulij" — from the 19th of June to the 2nd of July
- "Romæ in domo Professa Societatis" — at Rome, in the Professed House of the Society
- "A, Oriens; B, Occidens; AB, Ecliptica. et [&c.]" — A, East; B, West; AB, the Ecliptic, and so on.
- "Cursus similes aliis aliorum annorum, tempore eodem." — Courses similar to those of other years, at the same season.
- Captions at right: "3. Iunij." and "1. Iulij." — the third [image] of June and the first of July.

Cardinal and reference points: **Z** at the top of the vertical diameter, **N** at its foot; **A** (East) at the left end of the horizontal diameter, **B** (West) at the right end, **AB** being the ecliptic; **C** the center point on that line. The dashed spot-tracks carry day-numbers 19 through 30 and 1–2 (July), with per-spot letters legibly including **a**, **b**, **c**, **d**, **f**, and **u**. Near the west margin (right, above B) is a short perpendicular scale with the day-numbers 19–30 marked in sequence. [The numerous small per-spot day-labels along the tracks are only partly resolvable at this resolution rather than reconstructed.]

Embedded observation table (titles **IVNII** and **IVLII**), giving day, hour (H.; m. = morning, u. = evening), and the Sun's elevation ($\odot$ El., G.); set in two side-by-side halves, merged here in sequence:

Dies	H.	$\odot$ El. (G.)
19	m. $7\frac{1}{3}$	27. 20
20	m. $7\frac{1}{4}$	24. 15
21	m. $8\frac{1}{8}$	38. 0
22	m. $7\frac{1}{2}$	30. 20
23	m. $7\frac{1}{3}$	27. 30
24	m. $7\frac{1}{3}$	28. 0
25	m. $7\frac{1}{4}$	25. 30
26	m. $7\frac{1}{2}$	28. 20
eod.	m. 8	35. 0
23 u. [?]	$3\frac{3}{4}$	38. 20
27	m. 7	25. 0
28	m. 8	35. 40
29	m. $7\frac{2}{3}$	31. 10
30	m. $7\frac{2}{3}$	31. 0
IVLII 1	m. $8\frac{1}{2}$	41. 0
2	m. $8\frac{1}{8}$	38. 0
eod.	u. 4	36. 0

Notae in XXX. — On the 30th Image of the Observations, the fourth of June [and] the second of July, from the 27th of that [month] to the 12th of this one.

First: spots a, southern, risen within the faculae with faint beginnings and as it were absorbed by them, on the 27th, then advanced within those same [faculae] to the 30th. Afterward, as the faculae vanished, the spots alone went on, and gradually became smaller and rarer, until they too were consumed; and on the Sun, after the 4th of July, they left no further trace of themselves, not having reached the horizon — keeping meanwhile the ordinary course common to all, which is curvilinear, concave toward the north and convex toward the south. But they drew behind themselves, especially on the 29th and 30th, faculae that were extremely boreal and unbound, very pure.

Secondly: the faculae, shining upon those same spots a on their upper side toward the north, reached all the way to the horizon on the 27th, and, stretched toward the southern quarter or Nadir, drew umbrae between themselves and the margin. On the 28th the faculae still appeared intense and cohering, and unfolded their umbral companions more. On the 29th they began to grow thinner and to draw apart; on the 30th at last they were seen wholly separated and faint. And this is almost always the regular way with faculae. On the following days they stood to view in motion (as almost always), but so hurriedly and in such doubtful places that they could not be securely and stably recorded. The same is to be understood of the faculae f, which you observe joined on the 30th and separated on the 1st, an umbra thrown between to disjoin them. On the days that followed, seen through the lattice in uncertain places, I did not care to record them.

Thirdly: spots b, two southern ones, were at first accompanied by a boreal appendage, faculae going before. But on the 2nd of July they drew a facula behind them, themselves becoming three, because the preceding, more boreal one split into two; and three other new ones, c, appeared before them. On the third day at last they still drew a facula, which — clinging as it were to the head of the last spot — presented the appearance of a tailed comet, its interval much dilated. The two preceding

boreal ones again merged into one; but the preceding spots C added many little ones to their train, the spaces being dilated. On the 4th the facula was lost, and in its place a new spot came into the following position, as the little strokes extending into it from number 4 show. But spots C also increased their mass with a diminished number. On the 5th, b — the more boreal preceding one — appeared doubled, having sent ahead indications of this on the day before; the following ones, however, risen in the place of the facula, began to divide and diminish into little ones. On the 6th the two spots b began again to coalesce, with some decrease of themselves, the more western ones growing rarer. On the seventh [day] the two spots b had segments in common; the following ones decreased further. On the eighth day and thereafter, right up to the exit, they were ever more joined together and made smaller, so as almost to escape sight near the horizon; whence they either revived old faculae or kindled new ones. Seek more of these in Image XXXII, which is the 3rd of July. And what I have just said fully enough about the concourse of these [spots] holds very often for the others too; but for brevity's sake I omit very much, to be searched out and pondered by the learned and studious Reader.

Consider again two things. One: how on the 1st of July only two spots stood, and very close to each other, and the more southern — the following one — was larger than the preceding, yet afterward they were greatly disjoined, and the posterior decreased and girt itself with a faculous umbra, the prior one growing. The other: how the prior was single up to the 5th day, and on the 5th and 6th appeared doubled, then gradually gathered itself back into one. That the course of these spots reached the 13th day will easily be believed by anyone who makes an accurate reckoning from the horizontal intervals on both sides.

Fourthly: spot d, risen on the 2nd and increased by the two following, [while] the rest seemed to decline into faculae and umbrae. Here you see first very thin umbrae, afterward very minute spots, and at last, from these, more stable spots made. Fif[thly]—

[Margin: A spot, arisen within the faculae, faint.]

[Margin: A small facula.]

[Margin: Faculae, arising in narrow spaces, dilate in continuous succession and become wholly separated — which is usual with them.]

[Margin: Faculae joined at the horizon are separated as [the Sun] rises.]

[Margin: In the place of the facula a spot succeeded.]

[Margin: One is resolved into many smallest spots.]

[Margin: The first rise of spots is from umbrae; their setting is into umbrae and faculae.]

IMAGO SOLIS XXX

(Continuation of the Notes on the XXX image — the tail of "Notae in XXX" concludes at the top of this plate page.)

I.

[Margin: A spot that arises in the western region and with a declining motion enlarges its intervals.]

Fifth: The spots e, newly generated, likewise kept to their regular courses; and note that on the 6th and 5th they showed their interval greater than on the 4th — all of which I have recorded, examined with singular care.

Sixth: The motion of them all runs from the eastern north toward the western south, concave on the side facing it, convex toward this side.

II.

⟨1⟩ The Arctic pole lies within an open semicircle that ascends more steeply from west toward east; the southern one, sunk below the horizon, holds the opposite parts and the opposite motions. ⟨5⟩ The curvature of the motion, and the inclination of the chords to the ecliptic, increases.

[Margin: The curvature of the motion and the inclination of the chords to the ecliptic increase; the upper Arctic pole rises.]

Diagram. A full-page engraved plate of the solar disk (Image XXX of the observation series), showing the sunspot configurations from 27 June to 12 July 1625, observed at Rome in the Professed House of the Society of Jesus. The disk is drawn as a large circle; a horizontal diameter AB runs across it (the ecliptic), meeting the circle at A on the left and B on the right, with C at the center. The letter Z marks the top of the circle (zenith point) and N the bottom (nadir point).

Readable labels:

- Upper left: "XXX, Imago Obseruationum." (XXX, Image of the Observations)
- Center top: "M.DC.XXV." (1625)
- "Cursus à 27. Iunij. ad 12. Iulij." (Course from 27 June to 12 July)
- "Romæ in domo Professa Societatis" (At Rome, in the Professed House of the Society)
- Upper right, near the circle's edge: "4. Iunij," and "2. Iulij." (marking the entry points for those dates)
- Center: two engraved Jesuit rose emblems flanking a radiant IHS sunburst monogram
- Bottom caption: "AB, Ecliptica; A, Oriens, B, Occidens Macularū. etc" (AB, the Ecliptic; A, East [rising]; B, West [setting] of the spots. etc.)
- Two data tables set within the disk (June at left, July at right) — transcribed below.

Spot markings: dense clusters of engraved sunspots strung roughly along the ecliptic band. On the western (left) side, spots lettered *a*, *b*, *c*, *f* with day-numbers 27, 28, 29, 30 (the June entries). Across the middle and eastern (right) side, spots lettered *b*, *c*, *d*, *e* with day-numbers running 1–12 and companion small numerals (e.g. *b* with superscript 8, 9, 10, 11, 12; and *u*). The per-spot micro-labels are numerous and small; only the letters and day-numbers named here are read with

confidence. [The dense per-spot lettering and day-numbers are flagged for a focused re-read]

June table (IVNII), within the disk:

Dies	H	☉ (G)	El
27. m.	7	25.	0.
28. m.	8	35.	40.
29. m.	$7\frac{1}{3}$	31.	10.
30. m.	$7\frac{2}{3}$	31.	10.

July table (IVLII), within the disk:

D	H	☉ (G)	El
1. m.	$8\frac{1}{2}$	41.	0.
2. m.	$7\frac{1}{3}$	29. [?]	0.
3. m.	8	34.	40.
4. m.	$7\frac{3}{8}$	27.	0.
5. m.	$7\frac{1}{2}$	27.	30.
6. m.	$8\frac{1}{3}$	40.	30.

Reliqui dies patent ex figura Sequente. — The remaining days are evident from the following figure.

Notae in XXXI

Notes on the XXXI Image of the Observations, the third of July, from the 3rd to the 6th of the same.

I.

First: The beginning is placed at spot *a*, over 3 days; these are then continued in the following Image XXIII — for I have set it there with its own faculae, which its continuous situation, owing to the narrowness of the space, could not have accommodated. Here, then, you see with which faculae spot *a*, and the other spots, advanced through this three-day span. Its first position is on the morning of the third day, nearly at the margin; the second, in the evening of the same day; the third fell on the 4th, in the morning, with its leading and trailing faculae. The

fourth you have here under the 5th, where I present the spot alone, without the faculae — for those, together with the spot, look up in Image XXIII. The fifth position of the spot is given on the 6th, enclosed in a white circle of dots; to avoid confusion I did not observe the vanished, already-passed faculae; the following ones you have in both schemes. Note there that the more the faculae have receded in ascending from the margin, the more slender they were observed to be.

Second: The spots *c*, *b* of this Image correspond to the spots marked under the letter *b* in the preceding Image; and spot *h* to the spots *a*, for the 3rd and 4th. Likewise spots *d* and *e* of this one to the spots *c* of that one; spots *f* and *g* of this one to spot *d* of that one; spot *i* of this one to spot *e* of that one. And here you will see nearly everything expressed more accurately than there.

II.

(1) Third: The faculae with the umbrae *K* and *l* likewise made their proportional advances over the daily intervals, (5) exactly as if the spots themselves had stood still in those same places — as will be clear to anyone who considers it.

The rest that bears on the advance and the retinue of spot *a* you will have delineated accurately enough in the following Image; (10) and from there its head is to be taken.

Fourth: Meanwhile I should like you to notice — as I have often already pointed out — that even the segments of the motions preserve the proportions of the whole. For the faculae *K*, *l* recede from the ecliptic, (15) while *f*, *g* — both the spots and the faculae — approach it, by arcuate routes and segments; which you will find everywhere throughout in the others. For I have always found this to be so: as the whole tracks run, (20) so too proportionally their segments. If those are curved, so are these; if those appear rectilinear, so do these — other things being equal, etc.

Fifth: From these few days — indeed from each one of them (25) — it may be understood how nearly the whole longitude of the Sun came to be occupied. For on the third day spot *a* occupied the east, then *b*; after these, spots *c*, *d*; the middle by spot *h*; then (30) toward the west, *f*. On the 4th the east is held by spots and faculae *a*, and *K*, *l*; then *b*, *c*, *d*; the west by *h*, *i*, *f*, etc. Thus, in the span of three days, the whole apparent hemisphere of the Sun was beset.

IMAGO SOLIS XXXI

Diagram. A full-page engraved plate of the solar disk (Image XXXI), showing the sunspot configurations from 3 to 6 July 1625, observed at Rome in the Professed House of the Society of Jesus. As before, the disk is a large circle with a horizontal diameter AB (the ecliptic), A at left and B at right, C at the center; Z marks the top (zenith point) and N the bottom (nadir point).

Readable labels:

- Upper left: "XXXI, Imago Obseruationum." (XXXI, Image of the Observations)
- Center top: "1625."
- "Romæ in domo Professa Societatis Iesu; a die 3. Iulij, ad 6. eiusdem." (At Rome in the Professed House of the Society of Jesus; from 3 July to the 6th of the same)
- Upper right, near the circle: "3, Iulij."
- Center: two engraved Jesuit rose emblems flanking a radiant IHS sunburst monogram
- Bottom caption: "NB. AB, Eclipticam; A Z B, Zenith; A N B, Nadir in Sole, seu puncta, quæ Verticalis plani cōmunis cum ☉ sectio, supra et infra Eclipticam facit, in peripheria eiusdem, refert. etc." (NB. AB represents the Ecliptic; AZB, the Zenith; ANB, the Nadir on the Sun — that is, the points which the section of the vertical plane, common with the Sun, makes above and below the Ecliptic on the periphery of the same. etc.)
- A data table (July) set within the upper disk — transcribed below.

Spot markings: sunspot clusters strung along the ecliptic band. On the western (left) side, two labelled umbrae *K* and *l* with adjacent spot groups bearing small day-numbers; across the middle and eastern (right) side, further spot clusters with small numerals (day-numbers 3, 4, 5, 6 and companion figures). Only the letters *K*, *l* and the cardinal/geometry letters are read with confidence. [The dense per-spot micro-labels are flagged]

July table (IVLII), within the disk:

Dies	Hora	Scr	☉.Alt (G)	Min (M)
3. M.	8.	0.	34.	40.
3. V.	4.	0.	34.	30.
4. M.	7.	23.	27.	0.

Dies	Hora	Scr	☉.Alt (G)	Min (M)
5. M.	7.	30.	27.	30.
6. M.	8.	20.	40.	30.

Notae in XXXII

Notes on the XXXII Image of the Observations, the fourth of July, from the 5th to the 12th of the same.

I.

[Margin: Faculae nearer the horizon are larger; on receding from it they grow slender and pale/yellow.]

First: Spot *a* is here continued from the 5th day of the month to the 12th, so that you may see what happened on those days, and in what places, together with spot *a* in the Sun. For the beginning of the spot, from the 3rd to the 6th, I explained in the preceding Image; its end — indeed the whole course of the spot, presented on its own — you will receive in the following one. Here, then, faculae *b* occur, having followed spot *a* on the 5th, 6th, and 7th; where you see how on the 5th they stood as if single and continuous, and closer to the spots; but on the 6th, more remote from that same spot, yet separated from one another and each more slender; and on the 7th, how the intermediate ones were extinguished. Spot *a*, not everywhere filled in but hollow, you see on the morning of the 8th, [and on] the 9th and 10th. To avoid confusion, the perimeter of little dots drawn around spot *a* on the 5th marks that this space appeared more brilliant and tinged with yellow — not on that day alone, but on other days too; a thing that often happens, though I do not always note it.

Second: Wherever you see the letter *c*, whether single or doubled, know that these are the spots *b* of Image XXX repositioned, from the 7th to the end, whose numbers there I noted only up to the 6th, referring the rest to this place. This I did so that you might see what mutual position spot *a* and the spots *b* held, which fell into nearly the same parallel; and so left behind them not-dissimilar traces of their track — though this is often not preserved, etc. Then, so that you might see by practical experiment how va-

II.

⟨1⟩ —riously I am able to set before your eyes the same spot observed at differing times; and how great an accord there is among the motions ⟨5⟩ derived from such diverse observations. And what you discern done by me in this case, consider that it can be furnished in all cases. The faculae too, and the umbrae, which the spots *b* drew along with them, you see here strikingly expressed under the letters *c*.

Third: But you behold also a mass of the spots *d*, ⟨10⟩ carried on from the 7th to the 12th and marvelously transformed.

[Margin: The faculae and umbrae have the same motion; they sit upon the horizon but do not go beyond the Sun.]

Fourth: On the 7th and 8th, toward the west, brilliant faculae intermixed with umbrae clung upon the horizon itself, ⟨15⟩ but did not pass beyond the Sun.

Fifth: On the 8th and 9th new spots *m*, arising in the middle of the Sun, granted us a two-day sight.

[Margin: A spot of two days. Pure faculae of two days.]

Sixth: Something similar was done by the pure faculae, ⟨20⟩ the northern ones *n*, shining on the 6th and 7th.

[Margin: An umbra and facula of one day.]

All of them, however, as I have said, announce one and the same course.

On the 12th the faculae *o* shone in the north, ⟨25⟩ for one day only, mixed with umbrae.

The complete courses of these spots are contained partly in the earlier Images, partly will be announced presently in the following one. ⟨30⟩ This course, truncated at both ends and without tail or head, from the 5th to the 12th, I give for this reason too: that you may see that, viewed thus by itself, it does not differ much from a straight line; on which more shortly ⟨35⟩ in the following Image.

[Margin: An a-priori reason why too small an observing circle cannot fully indicate the motion of this phenomenon.]

Hence it is evident that, from small observing circles — because they seldom catch the beginnings and ends — the apparent motions cannot be correctly established, etc.

Rosa Ursina, Book III — NOTAE PARTICULARES (Images XXXII–XXXIV, July 1625)

Diagram. Full-page engraved solar disk (Image of the Sun XXXII), showing the recorded course of a sunspot across the solar disk during July 1625. The disk is a large circle; a horizontal diameter runs across it, labelled **A** at the left end and **B** at the right, and marked **C** at the centre. A small **z** (Zenith) sits at the top of the disk and **N** (Nadir) at the bottom. The horizontal line AB is the ecliptic.

Inner engraved lettering and captions (read under magnification):

- **z** (top of disk): Zenith mark.
- **XXXII. Imago Observationum.** (upper left, inside the disk): "XXXII. Image of the Observations."
- **IVLII. — Romæ in domo Professa Societatis Iesu, à die 5. Iulij, ad 12. eiusdem. 1625.** (upper centre): "Of JULY. — At Rome, in the Professed House of the Society of Jesus, from the 5th of July to the 12th of the same. 1625."
- **4. Iulij.** (upper right, inside disk): "4 July."
- **A, Oriens.** (left, at the A end of the diameter): "A, East."
- **B, Occidens.** (right, at the B end): "B, West."
- **C** (centre of the diameter).
- **N** (bottom of disk): Nadir.
- **Cursus similis aliis aliorum annorum, tempore eodem.** (centre): "A course similar to others of other years, at the same time [of year]."
- **AB, Ecliptica, Numeri in perimetro sunt Zenith, aut Nadir.** (centre): "AB is the Ecliptic; the numbers on the perimeter mark Zenith or Nadir."

Along the ecliptic line a chain of drawn sunspots runs from A (east) toward B (west), numbered day by day **5, 6, 7, 8, 9, 10, 11, 12** to match the observation table. Each spot cluster carries small micro-labels — **a** (the spot itself), **u** (evening/vespertine position), **m** (morning position), and **d** — with several dense clusters of faculae-like markings near the B (west) limb. A few perimeter numbers appear near the top-right rim (e.g. "5, 9" and "11, 10") and at the lower-left ("12 m", "8 m"), marking Zenith/Nadir positions. The individual per-spot micro-labels are small and partly overlapping; only the day-numbers and the four label-letters (a, u, m, d) are securely legible — the exact micro-label attached to each individual spot is not fully resolvable. [Per-spot micro-labels]

At the bottom centre of the disk: a decorative Orsini rose, an IHS Jesuit sunburst emblem (with cross and three nails), and a second rose.

Embedded observation table (engraved in the disk). Column heads: **Dies** (day of the month), **Hora** (hour; *mat.* = morning [matutina], *uesp.* = evening [vespertina]), ☉ **elevatio** (the Sun's elevation, in degrees · minutes):

Dies	Hora	☉ elevatio (° · ')
5	8 mat.	34 · 10
6	8¼ mat.	40 · 30
7	7¾ mat.	26 · 30
eod.	7¾ mat.	32 · 0
8	7¾ [?] mat.	28 · 0
eod.	8¼ mat.	36 · 0
eod.	3¾ uesp.	40 · 30
9	8 mat.	34 · 0
10	8½ mat.	36 · 20
11	9¾ [?] mat.	42 · 10
12	7¾ [?] mat.	31 · 0
eod.	4¾ [?] uesp.	31 · 0

Notes on the Thirty-Third Image of the Observations — the fifth [image] of July, from the 3rd to the 15th of that month

[Notæ in XXXIII. Obseruationum Imaginem, Iulij quintam, à die 3. ad 15. eiusdem.]

I.

First. Anyone who wishes to draw out a sound doctrine of the apparent motions from the spots he has recorded must complete observations that are not only frequent and long continued, but also complete and — so far as possible — reaching from the eastern horizon all the way to the western; otherwise he will be stuck on many points, waver on more, and go badly astray on some. For the first and last days of a spot's journey produce and display the greater part of the curvature and bending in this phenomenon. You have an example of this before your eyes in the very spot set out here, whose course from the 5th to the 12th [day] you also have laid out — though from observations other than the ones I give here — in the preceding diagram. There you will find it deviating not so very

much from a straight line, so that, if you were ignorant of the cause and nature of the matter from some other source, you would be quite unable to tell whether that path is really curved or straight. For it easily happens that, through a fault of observation, a straight path is twisted into a curved one, or the reverse. This is why I now append the whole course of this very same spot, so that you may learn the same thing in practice — and so that, even though around the middle the motions may look much like straight-line motion, you may see that they need not on that account really be such, but may belong to an entirely different kind of motion.

[Margin: For a complete investigation of the motions, one needs the horizontal contractions of the spots and their apparent motions viewed as extended from their rising in the east to their setting in the west.]

[Margin: From the intermediate stations alone, the curvature of the path is not easily detected.]

[Margin: From the deceptive similarity of the intermediate motions, many illusions can arise.]

Second. Spot a, then, entered the Sun in the northern region of the disk, above the ecliptic AB, on the 3rd of July, in the morning; and by the eighth astronomical hour it had already cleared the horizon, very slender and thin. It then gradually approached the ecliptic, on which it settled centrally on the morning of the fourth [day] — and in the evening too, with some part of its upper edge. But on the fifth day it left it entirely, carried over into the southern region, in which it also advanced most regularly right up to its setting, adapting its shape to our view according to its ascent or descent.

II.

Third. It was of middling size and density, furnished with a nucleus not especially dense and black, yet not so faint that its figure could not be distinguished from the surrounding haze [nimbus]; for where it was oblong around the middle, there it presented an oblong spot as well. At its entry and exit it scarcely matched the fineness of a silk thread — as I found by carrying it to the centre of the observing circle [circulus observatorius], for there, under the direct rays of the tube, its figure showed double; while around the margins, as usual, it was spread out by refraction and whitened with a wash of light.

Fourth. Its figure was nearly round and clean. After the middle [of its passage] it lost a little of this, and gradually began to shrink and thin out, so that it seemed to

be in a state of decay; yet it diminished so gradually that it reached the horizon without difficulty, plainly visible to the eye.

Fifth. I have taken all the *evening* observations — first, because I did not wish to repeat here, tediously, the morning ones already given earlier; second, so that I might show the greater agreement of my observations with those made at the Collegio Romano, since those were carried out after noon; third, so that you may test whether — whether we set out morning or evening observations — the same apparent course always comes out. What I have done in presenting this spot so many times, I could do for most of them, as I noted just above, by set purpose, in the Notes on the preceding Image.

[Margin: The motion is the same, whether from morning or from evening observations.]

Sixth. The stay of this spot beneath the Sun, if all is well weighed, did not exceed thirteen days; whether it fully reached that number may be doubted, but that it fell not far short is entirely certain. For near the horizon — especially since the motion is curvilinear — the spots are carried with a slow step. Therefore, since from the 3rd to the 15th twelve days and about ten hours elapsed, if we also allow its own time for the interval of rising, we shall not be far off from thirteen days.

Seventh. This spot is not far from the greatest parallel — by about three degrees, [continued on the plate, folio 241:]

Diagram. Full-page engraved solar disk (Image of the Sun XXXIII), showing the course of a sunspot across the Sun from 3 to 15 July 1625, observed in the Roman Professed House. As on the preceding plate, the disk is a large circle with a horizontal diameter labelled **A** (left) and **B** (right), marked **C** at the centre; the diameter AB is the ecliptic.

Inner engraved lettering and captions:

- **XXXIII. Imago Observationum.** (upper left, inside disk): "XXXIII. Image of the Observations."
- **ANNO IVBILÆO, M.DC.XXV.** (upper centre): "In the Jubilee Year, 1625."
- **Cursus Maculæ à 3. Iulij, ad 15. eiusdem, in Domo Professa Romana similis cursui Collegii Romani, huius anni, et aliis aliorum annorum, tempore eodem.** (centre): "The course of the spot from the 3rd of July to the 15th of the same, in the Roman Professed House, similar to the course [observed at] the Collegio Romano — of this year, and to others of other years, at the same time [of year]."

- **5. Iulij.** (upper right, inside disk): "5 July."
- **A, Oriens.** (left): "A, East."
- **AB, Ecliptica.** (centre): "AB, the Ecliptic."
- **B, Occidens.** (right): "B, West."
- **B** (right end of the diameter).

At the top centre: a decorative Orsini rose, an IHS Jesuit sunburst emblem, and a second rose.

Along the ecliptic a chain of drawn sunspots runs from A (east) toward B (west), numbered day by day **3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15** to match the table. Each carries small micro-labels **a** (the spot), **u** (evening) and **m** (morning); the last few (13, 14, 15) near the B (west) limb form a tight cluster with "m u" markings. Only the day-numbers and the a/u/m label-letters are securely legible; the exact micro-label on each individual spot is not fully resolvable under magnification.

Embedded observation table, headed **IVL II.** (July), in two side-by-side halves. Column heads: **D** (day), **H** (hour; *m* = morning, *u* = evening), $\odot$ **Ele.** (Sun's elevation, degrees · minutes):

D	H	$\odot$ Ele. ($^{\circ}$ · $'$)
3 m	8	34 · 40
3 u	4	34 · 30
4 u	4 $\frac{2}{5}$	32 · 0
5 u	4 $\frac{4}{5}$	27 · 0
6 u	4 $\frac{2}{3}$	29 · 30
7 u	5 $\frac{1}{4}$	23 · 40
8 u	3 $\frac{2}{3}$	40 · 30
9 u	5 $\frac{5}{6}$	17 · 10
10 u	3 $\frac{2}{3}$	40 · 10
11 u	4 $\frac{2}{3}$	32 · 30
12 u	4 $\frac{2}{5}$	31 · 0
13 u	4 $\frac{1}{4}$	32 · 30
14 u	4	35 · 0
15 u	4	35 · 0
15 u	5 $\frac{1}{2}$	20 · 30

[Text continued at the foot of this plate, folios 240 → 241 → 242:]

namely — from which it follows that its motion differs scarcely at all, to the senses, from the motion of the greatest parallel. And so, if (granting that the spots lie on the surface of the Sun, which will be discussed in its place) the apparent portion of the greatest parallel is always, to the senses, equal to the hidden portion, then it must be that the hidden portion of this motion in the opposite hemisphere is in some way equal to this visible one — or at any rate certainly not much greater. Hence one must admit that, before it rose on the 3rd of July, it must have spent in the opposite [hemisphere] some thirteen days, more or less; and thus that so many days before, at the boundary of the two hemispheres — namely near its setting, and on the horizon of our visible hemisphere — it had lain hidden. Therefore, if we find some spot corresponding to that time and place, and its du-[ration continues on folio 242]...

[Margin: The spot identified [as a returning spot] from all the circumstances.]

I.

[dura]tion steady thus far, we shall without doubt reasonably judge that this spot is the very one of ours, and shall not unjustly decide that ours is that very same one. Therefore, since in the month of June just past, in Image XXVIII, we find spot K setting on the 19th day of the month, and since both place and time agree, and neither its magnitude nor its figure differs much, we can undoubtedly enter it in the catalogue of returning spots. To make this clearer:

Eighth. That spot K, in the visible hemisphere, taking its origin from a very thin shadow and a facula, grew into a spot, and by increasing passed off the horizon, whence it endured without difficulty in the opposite hemisphere. Moreover, the time from the setting of spot K, which occurred on the 19th of June, to the rising of spot a, which happened on the 3rd of July, corresponds precisely to the time that would be required for spot K to traverse the opposite hemisphere. Further, if the whole periodic time from the setting of spot K to the setting of spot a be reckoned, and compared with the periodic time of spot K itself — spot a going from meridian to meridian, or from rising to rising — everything will agree with everything else to a hair, and be equal. Besides, spot K at its setting stood off farther from the ecliptic than spot a did, by just as much as was owed to the rising of the Arctic pole and its approach from west to east — as much, that is, as spot a made from the south toward the north. Add the magnitude of the spot, the union of a twinned nucleus, and the retinue of faculae following behind spot a, which, by the usual habit of this phenomenon, could succeed into the place of the

following spots. And from all this, prudent Reader, you may not unwillingly grant this spot too a place among the more durable ones.

Ninth. From these things you will most beautifully understand the first origin of this spot and the rest of its course. For on the 8th of June, in the morning about the seventh hour, it shone forth on the Sun beneath two conjoined faculae K, with an admixture of thin shadows, which on the following day, the 9th, spread apart in the usual way; then on the 10th and the following days they grew into spots, and so, from the 8th of June to the 15th of July, they completed their revolutions about the Sun — or better, perhaps, together with the Sun — as will be discussed more exactly in its own place and time.

[Margin: Spot K identified [as a returning spot] from all the circumstances. [?]]

Notes on the Thirty-Fourth Image of the Observations — the sixth [image] of July, from the 3rd to the 15th of that month

[Notæ in XXXIV. Obseruationum Imaginem, Iulii sextam, à die 3. ad 15. eiusdem.]

I.

Lest anyone should perhaps be able to say or suspect that I am mistaken in the very tracking-down of the curvature of the paths, look: besides the witnesses adduced so far from other provinces, I bring forward one close at hand — not only an eyewitness, but a man thoroughly skilled in this matter, one who has deserved excellently not only in other mathematical subjects but in this phenomenon too. He was frequently present at many of my observations, often examined the spots and faculae, and by his theoretical and mechanical devices greatly advanced my efforts. And so, while I was tracking this spot in the Professed House, Father Christoph Grienberger [Christoph Grienberger] took up the same one at the Collegio Romano, with a somewhat smaller circle, in the afternoon hours; and from...

II.

the stations of his observations he himself worked out, by astronomical calculation, the very course that I here set before your eyes. I have added nothing and taken away nothing, but as I received it from him, so I have faithfully transferred it here. Whether this apparent motion of mine is akin and proportional to his or not — you, whoever you are, fair Reader and spectator, be the judge. Whether this motion does not display a most regular curvature, decide for yourself. Whether the daily spaces — gradually larger from the rising toward

the middle, and from there always smaller toward the setting — do not prove the arcs to be ascending on the rise and descending on the decline, weigh it for yourself. Certainly, neither in observing the whole course of this spot, nor in setting out its progression, did the one man communicate anything to the other. If, then, none the less, so great a similarity of the apparent motions — in circles, in places, and in hours not the same...

[Notes on Image XXXIV of the Observations — conclusion]

the same things happened. Who does not see that these come about not by chance or luck, nor by fortuitous little alterations, nor by accidental deviations from orbit, but by the highest reason, in the heavens, by divine ordination and the prescription of nature? As for the hours and moments of time — I do not append them as corresponding to the observations, since it is not through them that we are investigating the motion, or the character of the motion. The motion itself you have here reported by so eminent a man; from those observations what is sought is their reliability, and the authority of the man rightly and deservedly secures it.

Diagram. A full solar disk (Image of the Observations XXXIV). Labels, by position:

- Top left: "XXXIV. Imago Observationum," (34th Image of the Observations)
- Top center: "Anno IVBILÆO. 1625. In Collegio Romano Societatis." (In the Jubilee Year 1625. In the Roman College of the Society) — the IHS solar emblem flanked by two rose ornaments
- Top right: "6. Iulij" (6th [image] of July)
- Below center: "Cursus Maculæ à 3. ad 15. Iulij, similis Cursui Domus Professæ, et aliis aliorum annoru [annorum], tempore eodem." (The course of the spot from the 3rd to the 15th of July, similar to the course [observed at] the Professed House, and to others of other years at the same season.)
- Left end of horizontal diameter: "A. Oriens." (East); right end: "B. Occidens." (West); center: "C"; the diameter labeled "AB. Ecliptica" (the ecliptic)
- Along the ecliptic line: a single spot **a** shown in successive daily positions, each marked "a" with "u" (evening) beneath and a day-number above. Readable day-numbers on the eastern half (A→C): 4, 5, 6, 7, 8, 9, 10; on the western half (C→B): 10, 11, 12, 14, 15. [Several of these day-numbers are small and only partly legible — [?].]
- Bottom: "Observatore R.P. Christophoro Grünenbergero, Soc.is Iesu Mathematico" (Observed by Fr. Christoph Grienberger [Grienberger], mathematician of the Society of Jesus)

[Several peripheral day-numbers uncertain]

Notes on Image XXXV of the Observations, July, from day 12 to day 24 of the same month

First (Primò). Here you have the spot a — already set out in Image 23 and many others up to now — for its last four days, and its whole appearance on the Sun during those days. For since I had presented its beginning, with all its attendant features, in Image XXXI, its progress in Image XXXII, and the solitary spot itself in Image XXXIII, here you now receive the remainder of it, from day 13 through day 15, in which the following are to be considered.

First: everything that occurred on day 13 — namely the umbrae and faculae, with the spot a following behind; then the faculae d preceding, both toward the north and toward the south, and the small spot d; likewise the southern faculae e, not previously noticed; besides these, the eastern faculae p, advanced in most beautiful order over three days together with their umbrae, and likewise the central spots q; and also the faculae o, of which separately in a moment. All these, then, the thirteenth day revealed to us at once.

Second: on day 14 there come into view, from the western side, the spot a itself, with its following and preceding faculae, and the faculae d cutting the margin; likewise the faculae e, whose more westerly members were sitting upon the horizon. Moreover the central spots q, whose divergence and number have today increased. On the eastern side the spots o take their stand, of which soon; then the faculae p, now larger.

Third: on day 15 there appeared, at setting, the spot a alone; at rising, the spots o (to be explained shortly); and besides these, the faculae p in the eastern region, with signs of umbrae — as of spots being born. And these things indeed took place within this three-day span. Now let us proceed to the faculae and the spots o.

[Margin: Faculae, umbra, and spot advance equally.] [Margin: Spaces ampler than an even motion would allow, even in the same parallel.]

Second (Secundò). The faculae and umbrae o were first seen on day 12, and still remained such on day 13; but afterward, on day 14, as the faculae vanished, umbrae — many, yet very thin — began to be reduced into the forms of spots, so that by day 15 very many appeared, distinct from one another but as tiny spots, as you have marked in the schema. These thereafter grew marvelously into a monstrous vastness and multitude, and were in turn somehow drawn apart, so as

to present a spectacle truly most worthy of consideration to the observer. Finally, on day 22, with faculae shining all around and thin umbrae, they hastened most regularly toward setting — three spots, more separated from one another than the same faculae or umbrae had been near rising on days 12, 13, and 14, or even on day 15, both in the length and in the breadth of the spots. This is well worth noting, especially since they advanced in almost the same parallel.

[Margin: From spots, umbra.]

Likewise the northern umbrae at their exit appear to have been, in the days just past, small spots trailing behind — just as the middle spot o proceeded from an apparent coalescing of the middle ones. The last of these spots appears to have coalesced with the middle one on day 23; the same, certainly, on the 24th, in the morning, first left the Sun in the form of a single long [spot]. Consider the side schemata of days 23 and 24, from which it is evident that they clung to the Sun beyond 13 days — because the eastern interval between the more eastern umbra and the solar margin is greater than a single day's. And on the 24th, in the morning at hour $7\frac{3}{4}$, it still hung on the western horizon. Therefore, from the twelfth day in the morning to the 24th in the morning, 12 days intervene; and to these the added span between rising and the station of day 12 makes more than a full day.

[Margin: A stay upon the Sun beyond 13 days.]

It should also be noted that from the tiny spots of day 15 great spots and continuous shadowy tracts of the following days grew, and so forth. Moreover, very many of them had nuclei, and carried continuous faculae in their bosom.

[Margin: From the tiniest spots the greatest spots arise, etc.]

Third (Tertiò). The umbrae and faculae p displayed their course and variation in figure, rarity, and density up through day 22, as the designations below show; in the middle they appeared smaller, at the extremes larger; after day 22 they wholly ceased. They were somehow ambiguous, between umbrae and ordinary spots; in the end they departed into faculae and together with faculae. The spots q made two days on the Sun — seen neither before nor after, rare and of most dilute light, and prodigious in their divergence.

[Margin: The remarkable metamorphosis of umbrae and faculae.] [Margin: Spots of two days, in the middle of the Sun, diverge more than is fitting.]

Fifth (Quintò). t is a pure facula on the southern horizon, rising from the east on day 16; then, having advanced further, after day 18 there was none. r: two spots

near the southern setting, enclosing a bright facula newly risen on the Sun. So too S: faculae and spots at the southern rising, from day 17 to day 20. So u: umbrae and faculae, newly appearing, made brief stays on the Sun but held courses common to all.

Sixth (Sextò). Meanwhile, in passing, weigh the position of the whole course relative to the ecliptic — namely how, as the curvature increases, the motion gradually approaches equilibrium, and the chords, drawn through points equally distant from the center C, become nearly parallel to the ecliptic, and so on.

[Margin: The curvature of the motion, and the obliquity of the chords to the ecliptic, increases. The arctic pole ascends.]

Diagram. A full solar disk (Image of the Observations XXXV), much more crowded than the preceding. Labels, by position:

- Top left: "XXXV. Imago Observationum," (35th Image of the Observations)
- Top center: "IVLIVS. Romæ in domo Professa Societatis. MDCXXV. à die 12. ad 24. Iulij." (July. At Rome, in the Professed House of the Society. 1625. From the 12th to the 24th of July.) — IHS solar emblem flanked by two rose ornaments
- Top right: "7. Iulij" (7th [image] of July)
- Cardinal points: "z" (Zenith) at top; "N" (Nadir) at bottom; "A" (East) at left end of the horizontal diameter; "B" (West) at right end; "C" at center; the diameter labeled "AB, Ecliptica"
- Legend box (center): "AB, Ecliptica: Z, Zenith; N, Nadir. NAB, Plaga Orientalis in ☉; NB Z, Occidentalis in eodem." (AB = the ecliptic; Z = zenith; N = nadir; N–A–B = the eastern region on the Sun; N–B–Z = the western region on it.)
- Numerous spot-groups are drawn across the disk, each labeled with a July day-number (12–24) and a letter (p, S, X, o, q, a, b, c, d, e, r, t), many with morning/evening markers ("o", "u"). Readable clusters:
 - Upper-left band: day-numbers 12, 13, 14, 15, 16 (each with "o")
 - Left edge: 13, 14, 15 with "P"
 - Central band (large groups): 17, 18, 19, 20 with "o"; also 21, 22
 - On the ecliptic, C→B: 19, 20, 21, 22 with "P"; "X X" near B; "21 22" above
 - Near C: "14", with "q" and a small "b"
 - Top-right, along the circle: 24, 23, 23 (with "o"); a small cluster reading "14 13 / 15 14 / 16 19 / 20"; "22 22"
 - Lower-left (S-series): 16, 17, 18, 18, 19 with "u"

- Lower-right, near B (a/r-series): 13, 14, 15, 16 with "a"/"r", and an "e"; "17. u." along the lower-right arc

[Many per-spot micro-labels are only partly legible — [?]]

The embedded table of July observation-times and solar altitudes:

IVLII (July)

Dies (Day)	Hora (Hour)	☉ Elevatio (Sun's elevation)
12. m.	7 7/8	31. 0.
13. m.	7 1/2	29. 0.
14. m.	8	33. 0.
14. m.	8 1/2	40. 0.
15. m.	8 1/2	40. 30.
15. m.	8 3/4	44. 20.
16. m.	7 [numeral: ?]	32. 0.
17. u.	6 1/6	13. 0.
18. m.	7 1/4	24. 0.
19. m.	6 1/2	18. 0.
20. m.	7 5/8	29. 0.
21. m.	8	34. 30.
22. m.	8 1/2	36. 0.
23. m.	7 7/8	32. 40.
23. m.	7 1/4 [?]	43. 40.
24. m.	[numeral: ?]	32. 0.

Notes on Image XXXVI of the Observations — the eighth of July, the first of August: from day 25 of July to day 8 of August

First (Primò). The spot a, southern, entered with its faculae and umbrae, advanced with them for a long while, and finally left the Sun; but I have not here recorded all the forms of its stations.

[Margin: Faculae and umbra move together with the spots a.]

Second (Secundò). Around the margins, umbrae massed together within the faculae; in the middle, spots lay scattered and sparse — as continued use in other observations sufficiently teaches. An example is in the umbrae and spots d, and so on. But the same spot, or umbra, doubled, d, seems on the eastern side to have followed the spot a, and on the western side to have preceded it, and so forth — which I have also, in the apparitions of the spots elsewhere, noted with particular care as I investigated. The umbrae e present themselves at the end together with faculae.

[Margin: Marginal umbrae; around the middle they are often spots.] [Margin: Umbrae, having often followed the spots at rising, precede them at setting.]

Third (Tertiò). The traveling arc is gradually accommodated to equilibrium with respect to the ecliptic, and it curves ever more, and the arctic pole ascends.

Fourth (Quartò). The spots b and c, on 31 July, having emerged from a thin beginning, suddenly grew to a fairly large number and mass; and, remarkably, the last of them, b, altered its own figure until, on the sixth day and thereafter, it passed off into a facula and into virtually nothing.

The spots set between b and c, on 1 August, were both many and small, and most distinct; afterward they began to be blurred together and made continuous in the manner of cloud and smoke, and at last to be kindled into faculae, as is clear to the observer.

[Margin: Spots pass off into faculae.] [Margin: The tiniest spots [resolved] into a thin cloud, as it were, and finally into faculae.]

Fifth (Quintò). The traveling arc of b appears to be parallel to the arc of a; and a straight line dropped perpendicularly from b to the ecliptic, if produced into arc a, would appear equal, to the senses, to another line similarly carried across from a into arc b, and so on.

[Margin: Parallel courses.]

Sixth (Sextò). The traveling time of arc a, from the eastern horizon to the western, if properly reckoned, did not much exceed 12 days; but the stay of the spot c, from day 2 into day 8, [was] six full [days]. Since this time is not half of the whole circuit, it is evident that the spot c would have far exceeded 12 days and — if all be rightly weighed — would beyond doubt have surpassed 13 days in going from horizon to horizon, had its substance permitted it; but now, since it was born on the Sun and did not complete its whole course, one may argue [the whole] from the half.

[Margin: The delays of the courses are unequal.]

Seventh (Septimò). There is no doubt that, from the more westerly and preceding small spots c, first born on 31 July, a single spot c coalesced, and afterward, on the following days, endured. From this it is clear how b and c thereafter, by receding from each other, never came into the same proportion: for although they were carried in the same parallel, nevertheless the distances that b and c made on days 4 and 5 exceeded the distance of day 31, and so on.

[Margin: From many small ones one is made, and it endures.] [Margin: Distances increased beyond equality.]

Eighth (Octavo). It should also be noted that, even if the spots b and c, together and at one stroke, arose anew on the Sun from the same beginnings and in the same parallel, they nevertheless did not cease together; rather, while c endured, the rest perished, and, dissolved into faculae, vanished away.

See the Douai [Duacenos] courses in Table 1 of Image XL, and the Ingolstadt ones in Table II, in the same place; for they are similar to these, though not of the same spots — which does not matter: the time is nearly the same, and that suffices.

[Margin: From many small ones one is made, and it perishes.] [Margin: The courses of different years are similar.]

Rosa Ursina — Book III, Notae Particulares (Images XXXVI–XXXVIII)

IMAGO SOLIS XXXVI (folio 247)

Diagram. Full-page engraved plate: a large circle representing the solar disk, with the record of the sunspot courses from 25 July to 8 August 1625. Show-through of letterpress from the adjoining leaves is visible across the plate; only the plate's own engraved matter is transcribed here.

Header text (across the top, inside the disk):

- Upper left: **XXXVI. IMAGO Observationum** ["The 36th Image of Observations"]
- Center: **Anno IVBILÆO. 1625. In Domo Professa Romana Soc.** ["In the Jubilee Year 1625. In the Professed House of the Society [of Jesus] at Rome"]

- Upper right, two lines: **8. Iulij / 1. Augusti** [readable verbatim; apparently designating this image within the July and August series — the 8th (of July) and 1st (of August); interpretation uncertain]
- Center emblem: an **IHS** sunburst (Jesuit monogram) flanked by two Orsini rose ornaments.
- Below emblem, centered: **Cursus Macularum a 25. Iulij, ad 8. Augusti.** ["The course of the spots from 25 July to 8 August."]
- **similes Duacenis, anni 1624, et Ingolstadianae anni huius, nec non aliis aliorum annorum tempore eodem.** ["similar to the Douai [observations] of the year 1624, and the Ingolstadt [ones] of this year, as well as to others of other years at the same season."]

Cardinal / reference labels on the horizontal diameter:

- A (left end): **Oriens** [East]
- Center of diameter: **AB. Ecliptica** [the ecliptic line A–B]; **C** marked at the center point.
- B (right end): **Occidens** [West]

Spot record: two horizontal bands of spot-images spanning the disk (the daily positions).

- Upper band: spot-groups recurring with the letters **b** and **c**, numbered sequentially **1–8** left to right (the later days shown as outline/faculae sketches near the western limb).
- Lower band: spot-groups recurring with the letters **a** and **d**, numbered with the July days **25–31** at the left and continuing **1–6** for August toward the right.

The individual per-spot micro-numbers are small and partly ink-blurred; the band structure and the letter-labels (a, b, c, d) and cardinal points are legible, but many single index-numbers are only partially readable. [Numerous micro-numbers [?]]

Table (July), within the disk. Header: D — H — ☉ El. (Day — Hour [morning] — Solar elevation, degrees and minutes).

D	H (m.)	☉ Elev. °	'
25	8	34	0
26	6 ³ / ₅ [?]	23	0
27	6 ² / ₅ [?]	22	0

D	H (m.)	☉ Elev. °	'
28	7¾	31	30
29	[blank]	22	30
30	7¾	31	0
31	7⅕	25	0

Table (August), within the disk. Header: D — H — ☉ El.

D	H (m.)	☉ Elev. °	'
1	8	32	0
2	7¾	30	30
3	6¼	19	30
4	6⅝ [?]	29	30
5	7⅙ [?]	22	0
6	7½	27	0
7	7⅔	27	20
8	7½	27	30

Notae in XXXVII. — Notes on the 37th Image of Observations, the second of August, from the 6th to the 24th of the same month (folio 248)

I.

First. The spot **a**, conspicuous on the north, at the outset showed a very black nucleus, slender and oblong. Then, as it rose, it gradually enlarged the nucleus, and at length showed it doubled and even tripled; but on its descent it appeared elongated again, and finally as a single oblong shape, with a whitish little gap between the separated parts — which frequently happens with the nuclei of other spots as well.

[Margin: The nuclei are black even at the horizon.]

Second. The body surrounding the nucleus adapted itself to the nucleus's own shape and, bearing some sort of hump above, at length separated off, and near the end turned into faculae.

Third. It drew bright faculae behind itself, both at entry and at exit, with umbrae interspersed. The faculae nearer the horizon were larger and brighter; they grew

rarer, smaller, and more scattered the nearer they came to the center — all of which is evident in the added side-figures, on the 8th, 9th, and 10th around the entry, and on the 18th and 19th around the exit, although in both places some faculae also ran ahead of it.

[Margin: The faculae are larger at the horizon than when set far from it; they follow the spots more than they precede them.]

Fourth. It almost touched the horizon on both sides. Since, then, from the 6th day in the morning to the 19th in the morning there are 13 days, but the spot itself was still on the Sun on the 19th at the fourth afternoon hour, it is clear that it lingered on the Sun for more than 13½ days. Indeed, if we take into account the eastern span, the curvature of the course, and the consequently longer delays near the horizon, we shall allow nearly fourteen days for this spot's course.

[Margin: The delay of the course [is] about 14 days.]

The spots **c** must also be considered, which — having arisen from the umbrae and faculae that accompany the spot — appear to resolve back into the same, and so on. This spot too carried around with it a colored area, as I note on the 9th, 11th, and 12th; and I bring forward these days merely as an example, because the same happens with others as well. On this spot see more at number 12.

[Margin: A cloud-like area.]

Fifth. The southern spot **b** took more than 12, approaching 13, days from horizon to horizon, yet did not reach that, and so did not equal the course of the northern one; nevertheless, being much nearer the ecliptic and to the greatest parallel [circle], and therefore carried along a more open circuit and a larger circle, it did so in a smaller time.

[Margin: The delays of the courses are unequal: for the larger spot, and the one nearer the center, [the delay is] smaller; for the smaller and more remote, larger.]

II.

Sixth. This same spot drew umbrae and faculae behind itself more than it sent ahead, as is clear; and nearer the horizon it displayed them purer and denser.

[Margin: The umbra and facula rather follow, etc.]

Seventh. The stations, too, of **a** and **b**, being equally distant from the horizon, appear to the sense as almost equal to each other.

Eighth. The course of each spot hastens toward the equilibrium with an equal step, though they fall a little short of it; and therefore the ecliptic is cut very obliquely. The arctic pole is still rising.

[Margin: The direction of the courses is still from north to south; the curvature and obliquity increase; the pole rises.]

Ninth. The companions of spot **b** deserted it almost immediately past the center; around the exit they degenerated into umbrae and faculae.

Tenth. The course of spot **a**, observed at Ingolstadt, is contained in Table III of Image XL, which you may consult.

Eleventh. The course of spot **b** is contained in the same place, set out in Table IV, where you will see the complete agreement of the motions, curvatures, and positions with mine, and their proportion.

Twelfth. That spot **a** is a returning one, and the same as the spot **o** set out in Image 35, is urged: *first*, by the identical parallel along which both moved. That the parallel of the two is the same is evident from the very short distance of each from the center C, and from their proper position relative to the ecliptic — which consists in this, that the course of **o** stands just so much farther from the ecliptic toward the east, and just so much less toward the west, than the course of **a**, precisely as much as the yearly advance of the axis and pole requires. That this is indeed so, the courses themselves, assembled from the observations, admirably confirm, as will be clear to anyone who tests and compares them.

[Margin: Spot a returns, [as shown] by all the circumstances.] [Margin: Spot a's return is proved from the same parallel.]

Second, time makes the matter almost certain. For the interval from the setting of spot **o** to the rising of spot **a** is shorter than the passage of either one across the visible hemisphere — which must be the case if the return of the same spot occurs. Moreover, the courses of both are of equal duration; and the periods from rising to rising are equal to the periods from setting to setting, or from mid-point to mid-point. And all the periods fall within 26 and 27 days.

[Margin: From the periodic time.]

Third, in their figures, too, and their magnitudes and nuclei, as well as in their retinue of umbrae, faculae, and tiny spots, a sufficiently great similarity is found.

Fourth —

[Margin: From the figure, magnitude, nuclei, and accompaniment of umbrae.]

IMAGO SOLIS XXXVII (folio 249)

[The conclusion of the Notae in XXXVII continues in the strip above the plate:]

[Margin: From the internal state and duration of the spot.]

I. — *Fourth.* Finally, the very state of the spot plainly requires this conclusion. For since it began to be born on 12 July out of umbrae and faculae, grew into a large, thick, and dense mass, and thus, while the Sun kept increasing it, departed on the 24th, it is impossible that it should have failed so quickly — contrary to the habit of the phenomenon — and should not have arrived, still safe and at least in some portion of itself intact, at the other, eastern boundary.

II. Therefore, from these many strong indications, scarcely any doubt can reasonably remain to anyone that spot **o** was the same as spot **a**, and vice versa — although in their proper places and times these very matters will be treated otherwise.

Diagram. Full-page engraved plate: the solar disk, recording the sunspot courses from 6 to 24 August 1625. Show-through of letterpress from the adjoining leaves is again visible; only engraved plate matter is transcribed.

Header text (top, inside the disk):

- Upper left: **XXXVII. Imago Observationum** ["The 37th Image of Observations"]
- Center: **M.D.C.XXV. In Domo Professa Romana Soc:** ["1625. In the Professed House of the Society at Rome"]
- Upper right: **2. Augusti** ["the second (image) of August"]
- Center emblem: an **IHS** sunburst flanked by two Orsini rose ornaments.
- Centered: **Cursus Macularum, à 6. Augusti ad 24. eiusdem.** ["The course of the spots, from 6 August to the 24th of the same month."]
- **Similes Ingolstadianis, anni eiusdem, et aliis aliorum annorum.** ["similar to the Ingolstadt [observations] of the same year, and to others of other years."]

Cardinal / reference labels on the horizontal diameter:

- A (left end): **Oriens** [East]
- Center: **AB. Ecliptica** with **C** at the center point.
- B (right end): **Occidens** [West]

Spot record: two horizontal bands.

- Upper band: spot-groups recurring with the letter **a**, numbered roughly **8–19** left to right (with a **u** — evening — beside 19), together with several **c** labels; the later positions rendered as faculae outlines near the western limb.
- Lower band: spot-groups recurring with the letter **b**, numbered roughly **14–24** (with **m/u** — morning/evening — near 24), and outline/faculae sketches at the western edge.

The band structure, letter-labels (a, b, c), and cardinals are legible; the individual index-numbers are small and crowded, several only partly readable. [Numerous micro-numbers [?]]

Table (August), within the disk (printed in three column-blocks; combined here in order). Header: D — H — ☉ Elev. °

D	H	☉ Elev. °	'
6	m. 7½	27	0
7	m. 7⅔	27	20
8	m. 7½	27	30
9	m. 7 4/9	25	30
10	m. 7½	26	0
11	m. 7 3/7	28	30
12	m. 9	41	20
13	m. 7¼	23	0
14	m. 7¾	29	0
15	m. 8	30	0
16	m. 7¼	21	50
17	m. 9 5/11	44	30
18	m. 8	29	0
19	m. 7⅝	26	0
19	u. 4⅓	27	25
20	m. 8½	34	10
21	m. 7 9/10	28	0
22	m. 7⅝	25	0
23	m. 7⅔	25	20
24	m. 7⅙	18	5

D	H	☉ Elev. °	'
24	u. 4 $\frac{3}{5}$	22	30

Notae in XXXVIII. — Notes on the 38th Image of Observations, the third of August, from the 17th to the 27th of the same month (folio 250)

I.

First. The spot **a** described a motion almost up to the autumnal, or northern, equilibrium — such that any two points on the arc of its path, equally distant on both sides from the center C, are also equally distant from the ecliptic A B; or, what is the same, a straight line running through any two of the spot's stations equally distant from the center C is parallel to the ecliptic. And so the motion is now maximally curved, and the obliquity to the ecliptic is either at its greatest or none at all, since the chords either coincide with the ecliptic or lie parallel to it. The arctic pole is close to its culmination,

[Margin: The autumnal equilibrium is at hand; the course is at its most curvilinear; the arctic pole is at its highest.]

II.

and the last [station] was of 12 days, 7 hours. But since the horizon was not truly touched either at setting or at rising, at least one mid-day remains on each side; and so the whole passage from horizon to horizon exceeded 13 days — yet reached neither fourteen days nor as great a delay as spot **a** completed in the previous Image.

Sixth. The spots — or rather umbrae — **b**, very thin and very rare, faint in light, had no longer a life than what you see depicted here; yet meanwhile they ran with somewhat larger daily intervals than spot **a**, though along spherical paths not unlike it, and with parallel distances of their courses.

Seventh. Experience showed that the same must be asserted of the spots, umbrae, and faculae **c**. Those spots, intermixed with faculae, were fairly numerous; but because they appeared in daily decline, I devoted only two days of observations to them, since on the 20th and the following days they were so weak that they almost escaped the eye's sharpness. Nevertheless, these two days too follow the course common to all, as becomes plain to one who looks.

Eighth. Just as the spots **d** and **e** grew quickly and greatly, so with the same speed they diminished. For on the 18th they gave scarcely any signs of themselves, which on the following days so increased in number and mass that on the 22nd, 23rd, and 24th all the spots appeared as one continuous spot — which, however, at once began to dissolve on the 25th, and at last the spots **d** and **e** died away entirely, with new ones born toward the south at the exit.

[Margin: What is quickly born quickly perishes.] [Margin: The delay of the motion [is] beyond 13 days.]

Rosa Ursina, Book III — Notae Particulares (continued)

IMAGO SOLIS XXXVIII

Diagram. A full-page engraved plate: the solar disk drawn as one large circle. At the top of the circle the axis-marker **Z** (the northern/boreal pole-point); at the bottom **N** (the meridian/southern point). A horizontal diameter runs across the disk, marked **A** at the left, **C** at the center, and **B** at the right.

Legends on and around the disk:

- Upper left corner: "**XXXVIII. Imago Obseruationum.**" (The Thirty-eighth Image of Observations.)
- Center top: "**ANNO IVBILÆO. M.DC.XXV. In Domo Professa Romana Societatis.**" (In the Jubilee Year 1625. In the Professed House of the Roman [Jesuit] Society.)
- Emblems: two heraldic roses flanking a radiant **IHS** monogram (the Jesuit device).
- Center: "**Cursus Macularum à 17. Augusti, ad 29. eiusdem, similis Ingolstadiano anni huius, et aliis aliorum annorum tempore eodem.**" (The course of the spots from 17 August to 29 of the same [month], similar to the Ingolstadt [image] of this year, and to others of other years at the same season.)
- Upper right corner: "**3. Augusti**" (i.e. the third [image] of August).
- Along the diameter: "**A, Oriens**" (A, East) at left; "**AB, Ecliptica**" (AB, the Ecliptic) at center; "**B, Occidens**" (B, West) at right.

Above the ecliptic line runs a chain of sunspot groups crossing from east (A) toward west (B), one group for each successive day. Each group is top-labeled **a**

with subordinate nuclei labeled **d** and **e**, and is dated with a day-number. Reading east to west, the day-numbers legible under magnification are: **17**, **18** (labeled **a**); **19** (d...e), **20** (d...e), **21** (a / e), **22** (d a / e), **23** (a / e), **24** (a / e), **25** (a / e), **26** (a / e), **27** (a / e), **28** (a d / e), **29** (d a / e, with **u** and **m** for the evening and morning observations of the 29th) near **B**.

Below the ecliptic, at the lower left near **A**, a separate cluster of spots labeled **c** is dated **18** and **19**. Lower toward the center-right, a short series of spots labeled **b** is dated **27**, **28**, **29** (and **29 u**, the evening of the 29th).

Beneath the spot-figures, an observation table is engraved under the heading **AVGVSTI** (Of August). Columns: **D** = dies (day); **H** = hora (hour; *m* = morning, *u* = evening); ☉ **El.** = altitude of the Sun [Solis elevatio], given in degrees and minutes.

D	H	☉ (°)	El. (')	D	H	☉ (°)	El. (')
1	m. 9 $\frac{5}{11}$	44	30	2	m. 7 $\frac{1}{2}$	24	0
7				4			
1	m. 8	29	0	2	m. 8	28	0
8				5			
1	m. 7 $\frac{5}{8}$	26	0	2	m. 8 $\frac{7}{16}$	32	30
9				6			
2	m. 8 $\frac{1}{2}$	34	10	2	m. 7 $\frac{1}{3}$	22	40
0				7			
2	m. 7 $\frac{9}{10}$	28	0	2	m. 8 $\frac{7}{8}$	36	30
1				8			
2	m. 7 $\frac{5}{8}$	25	0	2	m. 8 $\frac{1}{2}$	32	0
2				9			
2	m. 7 $\frac{2}{3}$	25	20	2	u. 3 $\frac{1}{2}$	32	25
3				9			

Notes on the Thirty-ninth Image of Observations — the fourth [image] of August, the first of September — from 26 August to 16 September

First. Spot *a*, entering into view as a single southern spot, gradually unfolded itself into two — first by a double nucleus, then by its very position. It grew toward the middle [of the disk], at the magnitude here depicted, and by that same magnitude diminished in the western part. At the start it drew after it spots, shadows, and faculae; at its exit only [faculae], though fairly faint ones. From the

4th day to the very end it kept a white gap separating the spots. Its duration beneath the Sun did not much exceed 12 days. For it is certain, from daily experience of this phenomenon, that the space remaining between the station of the 7th day and the [western] margin does not equal a whole day; and if this time is joined to the middle initial day, it makes more than a full day. Hence, by adding the remaining eleven days, you make the course of this spot somewhat more than 12 days. Throughout almost the whole course the nuclei, amid the surrounding vapors, inclined more toward the setting [west]. The travel-arc of this spot lies at the equilibrium; and so the chords drawn through points equally distant from the center C are parallel to the ecliptic.

[Margin: The course of spot *a* does not reach 13 days.] [Margin: It occurred at the autumnal equilibrium.] [Margin: The arctic pole bisects it.] [Margin: The chords do not cut the ecliptic, but either coincide with it or are equidistant.]

Second. The spot — or rather the spots — *b*, in the north, first seen on 2 September and last on the 14th, lingered on the Sun not much under 14 days. For the spaces on either side, intercepted between the first and last station and the horizon, are at this season nearly a full day each, on account of the oblique ascent and descent. These two leading spots touched each other up to the middle; past the middle they separated into three, which, gradually diminishing, likewise went out. They drew after them faculae, shadows, and spots, which gradually appear to have passed away into shadows and faculae. In the western part they seem to have somewhat exceeded the equilibrium, for the traveling path of these spots gradually departed from the path of spot *a*, drawing toward Z.

[Margin: Spots *b* — a delay of nearly 14 days.] [Margin: Conversion of the spots into shadows and faculae. The path of spots *b* crosses the equilibrium.]

Concerning the said spots *b*, the following further points are to be noted.

- First, on the third day [three] appeared very close to one another. Second, on the fourth day the more eastern of them had receded far from the two more western. Third, on the same [days] — the 5th, 6th, 7th, and 9th — they had not only receded incredibly from the first ones (or those from this one), but this one had further resolved into several very small ones. Fourth, these same ones, together with others in between, on the 12th and following days were turned into remarkable shadows and faculae. Fifth, the first ones too were gradually diminished, and multiplied by the accession of new little ones.

[Margin: The excessive separation of the spots from one another.]

Third. Spot *c*, in the north, first observed on the Sun on 3 September, was last seen on the 16th of the same [month] around noon. From the 7th morning hour of 3 September to the same hour of the 16th there are thirteen complete days. The interval intercepted between the spot and the eastern horizon easily takes up half a day, or perhaps more; and if the remaining hours around setting are added to it, they make up nearly a whole day. So the delay of this spot above the horizon reaches nearly 14 days. It also showed two nuclei, and by its elongated shape [showed], as it were, two spots; yet it never divided, but went out continuously. On both sides it drew after it faculae and shadows, whose shapes and number the diagram displays. This spot seems to have stood at its full state, for its western magnitude appeared equal to the eastern.

[Margin: They are turned into shadows and faculae.] [Margin: Delay above the horizon: nearly 14 days.] [Margin: The spot at its full state.]

Fourth. Spots *d*, likewise in the north, newly arisen on 5 September, then on the 6th and 7th increased in number and spread out in length; on the eighth they coalesced into larger but fewer [spots], which, consumed on the following days, left only the first — but enlarged — which around its exit carried off after it shadows and faculae, certainly caused by the said spots. If the reckoning of its course is rightly taken from the half-course, its duration equaled the delay of the rest. At its exit on the 13th it touched the horizon itself entirely and long sat upon it. Its path differs from the path of spot *c*: in the middle it is farther apart than at the end.

[Margin: The birth, growth, and spreading of the spots.] [Margin: Non-parallel paths.]

Fifth. The paths of the said spots *b*, *c*, [and *d*] —

IMAGO SOLIS XXXIX

Diagram. A full-page engraved plate, companion to the previous: the solar disk as one large circle, with the axis-marker **Z** at top and **N** at bottom, and the horizontal diameter marked **A** (left), **C** (center), **B** (right).

Legends:

- Upper left corner: "**XXXIX. Imago Obseruationum.**" (The Thirty-ninth Image of Observations.)
- Center top: "**ANNO IVBILÆO. MDCXXV. In Domo Professa Romana Societa[tis].**"

- Upper right corner: "**Augusti. 4.**" / "**Septemb: 1.**" (the fourth [image] of August; the first of September.)
- Emblems: radiant **IHS** monogram flanked by two heraldic roses.
- Center: "**Cursus Macularum, à 26. Augusti, ad 16. Septembris. Similis alijs aliorum annorum tempore eodem.**" (The course of the spots from 26 August to 16 September. Similar to others of other years at the same season.)
- Along the diameter: "**A. Oriens**" (left), "**AB. Ecliptica**" (center), "**B. Occidens**" (right).

Above the ecliptic runs a long, very dense chain of northern spot-groups crossing from A toward B, growing crowded near B (Occidens). The groups are labeled with the letters **b**, **c**, and **d** and dated with day-numbers; a *d*-series of daily positions can be read running roughly from the 6th/7th through the 17th, interleaved with *b*- and *c*-labeled groups. The interior clustering is too dense to resolve label-by-label even at high magnification: individual day-numbers within the crowded groups near B are largely illegible [?].

Below the ecliptic runs a second chain of southern spot-groups (labeled **a**), each dated. Reading east (near A) to west (near B), the legible day-numbers are: **26** (with *u* 27), **28, 29, 30** (*u*), **31** (of August), then **1, 2, 3, 4, 5, 6, 7** (of September). Several of the September groups appear doubled or paired; the small subordinate numerals beneath some are illegible [?].

Beneath the spot-figures, three observation tables are engraved side by side, headed **AVGVSTI** (Of August) and **SEPTEMBRIS** (Of September). Columns as before: **D** = day; **H** = hour (*m* = morning, *u* = evening); ☉ **El.** = altitude of the Sun (degrees, minutes).

AVGVSTI

D	H	☉ (°)	El. (')
26	u. 4 ½	23	0
27	m. 7 ⅓	22	40
28	m. 8 ⅞	38	6
29	m. 8 ½	32	0
30	u. 2 ¾ [?]	40	30
31	m. 8 ⅝	35	40

SEPTEMBRIS

D	H	☉ (°)	El. (°)
1	m. 7 ½	19	30
2	m. 7	16	0
3	m. 7	16	0
4	m. [?]	19	40
5	m. 7 ⅕	18	0
6	m. 7 ⅔	22	0
7	m. [?]	17	0
8	m. 7 ⅔	20	40
9	m. 8	24	10
10	m. 7 ½	19	0
11	m. 8 ⅓	21	0
12	m. 8 ⅓	26	50
13	m. 7 ⅔	20	0
14	m. 8 ¼	25	0
15	m. 8 ½	28	35
16	m. 7 ½	18	0
16	m. 11 ⅕	39	0

[Notes on the Thirty-ninth Image, continued] — and *d* exceeded the equilibrium, and toward the setting receded from the ecliptic more than in the east — as is clear to one who looks and tests.

[Margin: The direction of the path is from the south-east into the north-west. The position and appearance of the figures arise from the spherical arrangement.]

Sixth. All the positions of these spots, and the configurations of their shapes, look in some way toward the center C, proceeding from the spherical arrangement [of the surface].

Seventh. It is most certain that these courses of the northern spots were longer than the southern. For it is established that the southern spot *a* did not stay thirteen days on the Sun, whereas it is evident that the northern ones exceeded that same [span].

[Margin: Unequal delay of the spots beneath the Sun.]

Eighth. It is also most certain that in the courses *a*, *b*, and *d* the spots — broad in the same parallels — did not keep uniform motions; this is established from the appearance of the spots and their courses.

[Margin: The spots lie unequally broad in the same parallels.]

Ninth. That the equilibrium of motion between August and September occurs each year, the constant experience of so many years teaches. And at that same equilibrium-time the paths of all the spots, faculae, and shadows turn their concavity toward Z (the northern region) and their convexity toward N (the southern region) — this too is most certain from what has been observed.

[Margin: This autumnal equilibrium returns annually.]

Tenth. Moreover, to the senses this equilibrium does not last as long as the apparent motion is rectilinear, but within a few days is perceptibly thrown out of its state — as observations show.

[Margin: This equilibrium is quickly precipitated from its state into observable sense.]

Eleventh. Furthermore, that this equilibrium appears each year at this season, in such a position and manner, the continued observations of so many years attest.

[Margin: The equilibrium behaves in the same way annually.]

Twelfth. Besides, this equilibrium differs from the one that occurs between February and March: it is separated from it by a full half-year, and differs in position and in advance. For this one curves from north to south and from this back to north; that one from south toward north and from this back toward south. This one is concave toward the north, that one toward the south; this one convex toward the south, that one toward the north. But common to both is that the curvatures of their motions and the times of their durations describe sensibly equal [arcs], other things being equal; that they do not bring back the same spots and faculae, but always produce new and newer ones; and that they admit no rectilinear motions, etc.

[Margin: The difference and the agreement between the autumnal and the vernal equilibrium.]

Rosa Ursina, Book III — NOTAE PARTICULARES (Notes to IMAGO SOLIS XXXIX–XL)

Diagram. Full-page engraved solar disk — the 39th observation-image [XXXIX. IMAGO Observationum]. Inside the upper part of the disk is the legend: **ANNO IVBILAEO. MDCXXV. In Domo Professa Romana Societatis** ("In the Jubilee Year 1625. In the Professed House of the Roman Society"), flanked by two Orsini rose devices and the Jesuit IHS sunburst monogram. Below: **Cursus Macularum, à 26. Augusti, ad 16. Septembris** ("Course of the spots, from 26 August to 16 September"), and **Similis aliis aliorum annorum tempore eodem** ("Similar to others of other years at the same season"). At upper right two counts are printed: **Augusti. 4.** and **Septemb. 1.**

A horizontal diameter divides the disk; it is labelled the ecliptic. Cardinal labels: **A. Oriens** (East, at the left end of the diameter), **B. Occidens** (West, at the right end), **C** at the center, **AB. Ecliptica** (the ecliptic line itself), and **N** at the bottom of the circle (the graduated foot-scale of the two tables).

- The band **above** the ecliptic carries several interwoven spot-tracks lettered **b**, **c**, and **d**, each with sequential day-numbers, running from the eastern limb (A) toward the western limb (B). The engraving is very dense; the majority of individual spot-letters and day-numbers are at the resolution floor and cannot be assigned reliably. Legible fragments include a **c** near day **16** at the western limb, and a cluster of **d** spots numbered roughly **10–13** in the western half. [Individual per-spot micro-labels: numerous [?]]
- The band **below** the ecliptic traces a single spot lettered **a**, with day-labels running from **26 August** (marked u/m for evening/morning) through the end of August (**27, 28, 29, 30, 31**) and into early September (**1, 2, 3, 4, 5, 6, 7**), moving from A toward B. [Exact day-labels partly [?]]

Beneath the disk are two foot-tables of observation data (Day | evening/morning | Hour | Sun's elevation ☉ El. in degrees·minutes).

AVGVSTI [August]

D		H	☉ El.
26.	u.	4½	23. 0.
27.	m.	7⅓	22. 40.
28.	m.	8[⅓?]	38. 0.

D		H	☉ El.
29.	m.	8½	32. 0.
30.	u.	2¾	40. 30.
31.	m.	8⅝	35. 40.

SEPTEMBRIS [September]

D		H	☉ El.	D		H	☉ El.
1.	m	7½	19. 30.	11.	m	8 4/7	21. 0.
	.				.		
2.	m	7	16. 0.	12.	m	8⅓	26. 50.
	.				.		
3.	m	7	16. 0.	13.	m	7⅔	20. 0.
	.				.		
4.	m	[blank]	19. 40.	14.	m	8¼	25. 0.
	.				.		
5.	m	7[⅕?]	18. 0.	15.	m	8½	28. 35.
	.				.		
6.	m	7⅔	22. 0.	16.	m	7½	18. 0.
	.				.		
7.	m	[blank]	17. 0.	16.	m	11[⅕?]	39. 0.
	.				.		
8.	m	7⅔	20. 40.				
	.						
9.	m	8	24. 10.				
	.						
10.	m	7½	19. 0.				
	.						

Notes on Image XL of the observations, comprising five Tables of the month of August

[*Notae in XL. observationum Imaginem, quinque Tabulas Mensis Augusti complexam.*]

I.

TABLE I. I received this image itself from Douai, from the Reverend Father Charles Malapert [Carolus Malapertius], together with observations laid out exactly as you see them here, to which I have fitted the ecliptic from my own. If you compare the motions of spots **d** and **e** here, and their positions relative to the ecliptic, with the positions and motions displayed by spots **f**, **g**, **h**, and **i** described in Table II from Ingolstadt, you will find—and marvel at—the similarity of the courses traced in different years and by different spots.

[Margin: The Douai and Ingolstadt motions, of different years, are alike.]

TABLE II. It contains fragments of the Ingolstadt courses—**f**, **g**, **h**, **i**—from 3 August to the 10th of the same month. I have added these so that their resemblance to the Douai ones might appear. I have not, however, added the courses of these spots from my own observations—not because I lack far fuller and more perfect ones, but because I judged it unnecessary to set out the courses of every spot; just as, in this month as in others, I pass over a great many.

One further thing I would point out to you: these courses were observed not by one man, but by two. For from 4 August to the 10th, Father Georg Schönberger [Georgius Schönberger] writes that the observations were made by someone else. I mention this so that you may see the truth of these motions all the more clearly, when you notice how beautifully the observations of different men, gathered into a single course, agree with one another.

[Margin: A single Ingolstadt course, assembled from the labors of two observers, yet alike to the Roman one.]

TABLE III. It comprises the northern course of spot **a**, from the eighth to the 19th of August, and it corresponds to the Roman course of spot **a** set out in Image XXXVII. This course too is composed from the labors of two Ingolstadt observers, for from the eighth day to the 11th someone other than Georg Schönberger observed it; yet the regularity of the motion proceeded no differently than if it had been observed by a single man. Note here that on the 13th and 14th a very small spot was recorded above **a**, not by projection [per immissionem], but by direct inspection—

II.

—by inspection alone, as the Observer notes. Then that little spot was no longer visible after the fifteenth day—neither at Ingolstadt by inspection, nor here at Rome by projection—which recommends an excellent method of observing and secures undoubted credit for what is observed.

[Margin: What was omitted, or not visible, at Ingolstadt is made up from the Roman observations.]

As for how that little spot—set apart from the large one on the two days mentioned—behaved on the other days from beginning to end, it is enough to see it in my Roman Image, which, passed over there, I here describe. On the seventh day, then, it clung to the northern summit of spot **a** like a shadow [umbra], with a facula shining brightly above it.

[Margin: Description of the shadow, or northern spot, adhering above spot a.]

On the 8th it began to emerge a little further, a facula still hovering above it. On the 9th it began to open into a gap toward the west, a facula still floating above. On the 10th it seemed to want to split into two. On the 11th, the gap having widened, it gathered back into one. On the 12th, something again seemed to stray out at the top. On the 13th and 14th this spot appeared entirely separate, but thin and uniform, without any admixture of a nucleus—whereas up to then some nucleus had always either clung within it or adhered to it. On the 15th nothing at all could be made out of it, though a white space glowed between the nuclei. On the 16th, 17th, 18th, and 19th bright faculae took its place.

[Margin: A spot kindled into faculae.]

Let this, then, be the origin and the passing of this spot, which, born in an obscure place, advanced—as most spots do—into an illustrious lineage. Now let us press on to what follows. On the 19th the Ingolstadt observers saw spot **a**, by direct inspection alone, as the merest thread; I have supplied its position from my own observations.

TABLE IV. It gives the course of spot **b**, from the 12th to the 23rd, which corresponds to the Roman course of Image XXXVII, from the 12th to the 24th, in the evening. In the Roman observation of the 12th you have two spots; in the Ingolstadt one, a single spot—which comes about from the inadequacy of the too-small observing circle. On the 13th the Ingolstadt observers did indeed note a whole troop of faculae following after the spot, but neither the figure of those faculae, nor—

[Margin: The Roman and Ingolstadt observations compared.]

[The text continues on folio 258, after the plate.]

Diagram. Full-page composite engraved plate — the 40th observation-image. Header caption above the figures: **XL. Observationum Imago. Tabulas 5. ex**

observationibus annorum 1624. 1625. Duaci et Ingolstadij habitis concinnatas complexa, Mense Augusto ("Image XL of the observations. Comprising 5 Tables, compiled from observations made at Douai and Ingolstadt in the years 1624, 1625, for the month of August").

The plate arranges **six circular solar-disk figures** around the page, interspersed with four engraved devices: the Jesuit **IHS** sunburst (top center), an **MRA** (Maria monogram) sunburst (bottom center), and two Orsini **rose** ornaments (left-center and right-center). Each disk has a horizontal A–B diameter (**A** = east/left, **B** = west/right) and carries a spot-track with lettered day-numbers plus, below, its own foot-table. Because the six figures overlap and the labels are small, the individual per-spot day-numbers inside the disks are largely at the resolution floor

Central large circle — Tabula 1 (no foot-table): **M.D.C.XXIV. Duaci in Collegio Academico Societatis Iesu. Cursus Macularum d. et e. à 28. Iulij, ad 12. Augusti, similes Romanis, anni 1625** ("1624. At Douai, in the Academic College of the Society of Jesus. Course of spots d and e, from 28 July to 12 August, similar to the Roman ones of the year 1625"). Cardinals **A. Iulij** (left) — **AVGVSTI** (center) — **B**. Above the ecliptic runs spot-track **d** with day-numbers from **28, 29, 30, 31** (July) into **1–8** (August); below the ecliptic runs spot-track **e** with day-numbers roughly **5–12** (August). [Individual day-labels partly [?].]

Top-left circle — Tabula 3: Ingolstadi. 1625. Cursus Maculae a. ab 8. ad 19. Augusti; similis Romano ("Ingolstadt 1625. Course of spot a, from the 8th to the 19th of August; similar to the Roman"). Spot-track **a**, days 8–19.

Foot-table (**Augusti**; columns: Day | m/u | Hour·min | ☉ El. °):

D		H	☉ El.	D		H	☉ El.
8.	u.	4. 30.	26. 48.	14.	m.	8. 0.	30. 28.
9.	u.	3. 15.	38. 27.	14.	u.	7. 0.	39. 39.
10.	u.	1. 24.	52. 43.	15.	m.	8. 0.	30. 12.
12.	m.	8. 5.	33. 18.	17.	m.	8. 7.	30. 50.
13.	u.	5. 13.	18. 39.	18.	m.	8. 7.	29. 58.
				19.	m.	8. 0.	[—]

Top-right circle — Tabula 4: foot-table headed **Ingolstadij. 1625. Augusti;** caption below: **Cursus Maculae b. à die 12. Augusti ad 23. eiusdem, similis**

Romano ("Course of spot b, from 12 August to the 23rd of the same, similar to the Roman"). Spot-track **b**, days 12–23.

Foot-table:

D		H	☉ El.	D		H	☉ El.
12.	m	8. 5.	33. 18.	18.	m	8. 7.	29. 58.
	.				.		
13.	u.	5. 13.	18. 39.	19.	m	8. 0.	29. 16.
	.				.		
14.	m	8. 0.	30. 28.	20.	m	8. 0.	28. 59.
	.				.		
15.	m	8. 0.	30. 12.	21.	m	8. 0.	28. 45.
	.				.		
17.	m	8. 7.	30. 50.	22.	m	8. 42.	35. 0.
	.				.		
				23.	m	8. 0.	28. 14.
					.		

Bottom-left circle — Tabula 5: Ingolstadij. 1625. Cursus Maculae c. à 18. ad 28. Aug[usti]; similis Romano ("Ingolstadt 1625. Course of spot c, from the 18th to the 28th of August; similar to the Roman"). Spot-track **c**, days 18–28.

Foot-table (**Augusti**):

D		H	☉ El.	D		H	☉ El.
18.	m	8. 7.	29. 58.	23.	m	8. 6.	28. 14.
	.				.		
19.	m	8. 0.	29. 16.	24.	m	9. 6.	37. 56.
	.				.		
20.	m	8. 0.	28. 59.	25.	m	8. 0.	27. 42.
	.				.		
21.	m	8. 0.	28. 45.	26.	m	8. 0.	27. 28.
	.				.		
22.	m	8. 42.	35. 0.	27.	u.	1. 34.	46. 37.
	.				.		
				28.	m	7. 39.	23. 25.
					.		

Bottom-right circle — Tabula 2: foot-table headed **Ingolstadij. 1625. Augusti;** caption below: **Cursus Macularum, f. g. h. i. à 3. Augusti. ad 10. eiusdem, similis Romanis** ("Course of spots f, g, h, i, from 3 August to the 10th of the same, similar to the Roman"). On the A–B diameter runs spot-track **f** (days ~3–6); below run tracks **g, h, i** (days ~3–10), with a marker **k, 31. Iulij** at the far left. [The g/h/i micro-labels are too intricate to resolve individually — [?].]

Foot-table:

D		H	☉ El.	D		H	☉ El.
3.	m	10. 10.	[—]	6.	u.	12. 52.	55. 33.
	.						
4.	u.	1. 50.	51. 26.	8.	u.	4. 30.	26. 48.
5.	u.	1. 9.	55. 20.	9.	u.	3. 15.	38. 27.
				10.	u.	1. 24.	52. 43.

—nor the spot following it did they express; both of these you will draw from mine. On the 18th they noted southern faculae they had seen, which you will find in their Table V at the letter **d**, and in mine, in Image XXXVIII, at the 18th and 19th under the letter **c**. On the 23rd the Ingolstadt Observer, concerning spot **b** and the faculae seen with it, records these words verbatim: "*b, at its exit, was barely visible, accompanied by faculae.*" So he. This is a most vivid practical testimony for what I always maintain—namely, that small observing circles cannot in every respect match this phenomenon.

[Margin: A clear and practical testimony to the inadequacy of so small an observing circle.]

And if on the 23rd the Ingolstadt observing circle was not adequate to catch the spots and faculae, how much less could it manage on the 24th—when the Ingolstadt Observer, otherwise sharp and careful, saw nothing at all of this spot and its faculae, whereas here at Rome both the spot and the faculae appeared most distinctly, and so on. You have their configuration in the diagram not only for the 23rd but also for the 22nd before it and the 24th after; from these I transferred the resemblance into the Ingolstadt Table, because the Observer indicated them only in writing, and not by a drawn figure.

TABLE V. It contains the course of spot **c**, observed from the 18th to the 28th; likewise facula **d** of the 18th—both of which you will find in my Image XXXVIII, extending from the 17th to the 29th in the evening. The power of the Ingolstadt

observing circle reached neither the beginning nor the end of that course; yet in its observations there are some things worth noting.

"On the 19th," says the Observer, *"two spots with a nebulous appendage."* You have this appendage shown distinctly by several spots and umbrae following spot **a**, in the Roman observation, in Image XXXVIII.

[Margin: Nebulous appendages of the spots, observed at Ingolstadt.]

"On the 22nd," the same man says, *"spot a was composed of several, and wrapped in an entire cloud."* He speaks rightly; and for a genuine idea of this, consult my diagram: for the spots **e** had grown together—or rather had spread themselves out—into what looked like a single cloud. But he goes on:

"On the 23rd, spot a looked like a single one on the paper." You have the true form of this very thing, too, in my diagram; for everything is bound together by mutual connections.

IMAGO SOLIS XL

Diagram. A full-page composite engraved plate — the fortieth image of the observations — showing **five solar disks** arranged as four corner disks around one large central disk. Between and among them are set the Jesuit **IHS** sunburst emblem (top center, a cross above the H and three nails below), the Marian **MRA** sunburst emblem (bottom center), and four **Ursine-rose ornaments** (the *Rosa Ursina* device of the Orsini) placed at the mid-sides and flanking the center. Each disk carries an east–west axis line lettered **A** (left) and **B** (right), and beneath or within it a small table of observation data (day, time, and two coordinate values) plus a row of lettered spot-positions marking the daily course of one or more spots across the disk.

Top caption (spanning the plate): **"XL. Image of the observations. Comprising five Tables, drawn up from observations made at Douai and Ingolstadt in the years 1624 and 1625, in the month of August."**

Central disk — Tabula 1. Legend: **"M.DC.XXIV. At Douai, in the Academic College of the Society of Jesus. Course of spots d and e, from 28 July to 12 August, similar to the Roman ones, of the year 1625."** Axis lettered **A** (left) — **B** (right); the left half of the axis is labelled **Iulij** (July), the right half **Augusti** (August), with **Tabula 1.** beneath. The upper track carries the daily positions of **spot d** (numbered from 28, 29, 30, 31 in July, then 1 through 7 in August [individual numerals near the resolution floor — see review note]); a lower track

carries **spot e** (numbered roughly 5 through 12 August [numerals partly illegible]).

Tabula 3 (top-left disk). Legend: "At Ingolstadt, 1625. Course of spot a, from the 8th to the 19th of August, similar to the Roman [one]." Row of spot-a daily positions (a, numbered 8, 9, 10, 12, 13, 14, 15, 17, 18, 19) along the disk. Foot-table below.

Tabula 4 (top-right disk). Legend: "At Ingolstadt, 1625. August. ... Course of spot b, from the 12th of August to the 23rd of the same, similar to the Roman [one]." Row of spot-b daily positions (b, numbered 12/13/14/15 ... through 22). Foot-table below.

Tabula 5 (bottom-left disk). Legend: "At Ingolstadt, 1625. Course of spot c, from the 18th to the 28th of August, similar to the Roman [one]." Row of spot-c daily positions (c, numbered 18 through 28). Foot-table below.

Tabula 2 (bottom-right disk). Legend: "At Ingolstadt, 1625. August. ... Course of the spots f, g, h, i, from the 1st of August to the 10th of the same, similar to the Roman ones." Rows of spot positions lettered f, g, h, i (numbered from 1 through 10). Foot-table below.

The five foot-tables share the column heading **D | H | ☉ | El** (Day | Hour | Sun's altitude, degrees | minutes); "m" = morning, "u" = evening. Because the tabulated day/time/altitude records the observing circumstance, the same rows recur across tables that share observation dates (e.g. the 18–22 August rows are identical in Tabulae 4 and 5, and the 8–10 August rows in Tabulae 2 and 3) — this repetition is in the source, not an error. The altitude (☉) column is at the resolution floor throughout; several glyphs there are ambiguous between "3" and "7" and are flagged. All five foot-tables are marked

Tabula 3 — foot-table (spot a, Ingolstadt, August):

Day	h.m	☉ (alt.)	El (min)
8 u	4.30	26	46
9 u	3.15	38[?]	27
10 u	1.24	52	43
12 m	8.5	37[?]	18
13 u	5.17	16	39
14 m	8.0	30[?]	26
14 u	7.0	39[?]	39[?]

Day	h.m	☉ (alt.)	El (min)
15 m	8.0	30[?]	17
17 m	8.7	30[?]	50
18 m	9.8[?]	29	58
19 m	8.0	[numeral: ?]	[numeral: ?]

Tabula 4 — foot-table (spot b, Ingolstadt, August):

Day	h.m	☉ (alt.)	El (min)
12 m	8.5	33	13
13 u	5.17	16	39
14 m	8.0	30[?]	28
15 m	8.0	30[?]	13
17 m	8.7	30[?]	50
18 m	8.1	29	55
19 m	8.0	29	16
20 m	8.0	28	59
21 m	8.0	28	45
22 m	8.42	35[?]	0
23 m	8.0	28	14

Tabula 5 — foot-table (spot c, Ingolstadt, August):

Day	h.m	☉ (alt.)	El (min)
18 m	8.1	29	55
19 m	8.0	29	16
20 m	8.0	28	59
21 m	8.0	28	45
22 m	8.42	35[?]	0
23 m	8.0	28	14
24 m	9.6	37[?]	56
25 m	8.0	27	42
26 m	8.0	27	28
27 u	1.34	46	37

Day	h.m	☉ (alt.)	El (min)
28 m	7.39[?]	23	25

Tabula 2 — foot-table (spots f, g, h, i, Ingolstadt, August):

Day	h.m	☉ (alt.)	El (min)
3 m	10.10	[numeral: ?]	[numeral: ?]
4 u	1.50	51	26
5 u	1.9	55	20
6 u	12.52	55	33
8 u	4.30	26	48
9 u	3.15	38[?]	27
10 m	1.24	52	43

ROSAE VRSINAE, Book III

Notes on the 41st Image of the Observations — the second [image] for September, from the 13th to the 26th of the same [month]

First. [Margin: A spot among umbrae and faculae.] Spot **a** moved among prominent umbrae and faculae near its rising and setting, yet it had more of them alongside or behind it than in front. After the midpoint, all the way to its exit, it dwindled in mass. On the 15th the faculae were more extensive, in every part of the region, than they had been on the 14th, and these in turn were larger than on the 13th.

Second. [Margin: The direction of the motion is oblique, from south to north.] It departs from the ecliptic on the western side. If you mentally set aside the first three eastern positions and the last three or four western ones from the arc of its path, the remaining positions form a nearly straight line — which happens almost always, throughout the whole year. [Margin: The middle portions of the courses always tend toward straightness.] Hence in the observation disks it easily comes about that, for want of the beginning and the end, paths that are otherwise curved are taken for straight.

Third. [Margin: It exceeded 13 days but did not reach 14. The nuclei lean toward the west.] Its duration under the Sun exceeded 13 days but did not reach fourteen; it is a little shorter than the durations of the northern spots of the previous image. The spot had a nucleus that always shone out and stood forth more toward the west — which generally happens with heavy spots.

Fourth. It again lost the small companion-spots generated on the intervening days, as is clear from the image.

Fifth. The faculae with the southern umbrae **b** were not otherwise noticed.

Sixth. The spots **c** were very faint on the 16th; then they gradually grew, and of them some lasted right up to their exit, some passed into umbrae, and the last into faculae — always keeping the path and position, common to all, with respect to the ecliptic.

Seventh. [Margin: The spots' duration under the Sun is unequal.] From the 19th, the chief of these, having gone ahead of the others, took six days to its exit, whereas spot **a** took seven. From this a clear difference of motion and of time is understood.

Eighth. [Margin: The central traces of the spots are closer to one another than the marginal ones.] This spot **c** was, near the middle, closer to spot **a** than near its exit or its entry. If you examine the course of this spot from the 17th to the 22nd, you will find it rectilinear, as is also the course of spot **a**. From this you again gather that the apparent curvatures or straightnesses of the paths cannot be known except from the whole courses, or from nearly complete ones.

Ninth. [Margin: The full curvature is to be investigated from complete courses.] Meanwhile, note how far these courses have receded from the equilibrium [i.e. the equinoctial line / Libra] in so short a time. [Margin: A great recession from the equilibrium.] Then observe carefully that these curvatures are by no means circular. [Margin: The curvatures of the paths are in no way circular.] Moreover, if from the center **C** you compare the distances of spots **a** and **c** from that same center, you will find that on the 16th the spots **c** were nearer the east than **a**, and again you will find the same on the 22nd toward the west. [Margin: Southern spots run through a greater space on the Sun in a shorter time than the northern ones.] From this it is evident that the apparent motion of the spots **c** was faster, and so forth — and you will detect this not only here but often elsewhere. Examine, in Image 39, the courses of **a** and **b** and **c**, and you will find very many proofs of the matter.

Tenth. [Margin: The curvature and inclination decrease; the exposed pole descends.] The curvatures of all the paths, and the inclinations of the chords to the ecliptic, decrease; and the exposed arctic pole moves in the descending western semicircle, while the hidden antarctic pole moves in the opposite, ascending one.

IMAGO SOLIS XLI

Diagram. A full-page engraved solar disk — the forty-first image of the observations — one large circle filling the page. Cardinal markers around the rim: **Z** at top, **N** at bottom, **A. Oriens** (East) at the left end of the horizontal axis, **B. Occidens** (West) at the right end; the horizontal axis is labelled **AB. Ecliptica** and its center **C**. At the upper left is the printed heading "**XLI. Imago Observationum.**"; at the upper right, "**Septemb: 2.**" (the second September image). Across the top-center of the disk: legend "**M.DC.XXV. In the Professed House of the Roman Society [of Jesus]. Course of the spots from 13 September to the 26th of the same,**" flanked by two Ursine-rose ornaments and, at center, the **IHS** sunburst emblem.

Spot tracks across the disk (each daily position marked with its spot-letter and day-number):

- **Spot a** — an upper track running from the eastern limb toward the west: positions a·14, a·15[?], a·16, a·17, a·18, a·19, a·20, a·21, a·22, a·23, a·24, a·25, a·26 (near **B. Occidens**). The 14–16 positions show a large, ragged, multi-lobed spot group; it contracts across the middle and dissipates toward the west.
- **Spot c** — a lower track: positions c·17, c·18, c·19, c·20, c·21, c·22, c·23, c·24, c·25.
- **Spot b** — a single labelled cluster **b·14** at the lower left, near the eastern limb.

[Several individual day-numerals in the a- and c-tracks are at the resolution floor; the whole label set is a]

September observation table (printed across the foot of the disk; the two halves flank the vertical polar axis, the second half headed with the Libra sign ♎ marking the Sun in Libra):

Day	Hour	☉ (alt.)	El (min)
13 m	7 $\frac{2}{3}$	20	0
14 m	8 $\frac{1}{4}$	25	0
15 m	8 $\frac{1}{2}$	28	35
16 m	8 $\frac{1}{6}$	23	30
17 m	7 $\frac{2}{3}$	19	20
18 m	7 7/12	17	40
19 m	7 $\frac{1}{2}$	17	10
20 m	8 $\frac{2}{5}$	25	0
21 m	7 $\frac{1}{4}$	18	15
22 m	9 [—]	31	0
23 m	8 5/11	24	45
24 m	8 [—]	20	30
25 m	9 1/12	31	0
26 m	[—]	23	0

ROSAE VRSINAE, Book III

Notes on the 42nd Image of the Observations, from 22 September to 6 October

First. [Margin: The physical and ordinary rise of the spots.] The spots **a**, southern, have neither an end nor a beginning of their course; but arising on the Sun together with faculae on the 22nd — many tiny ones — they coalesced, in the usual way, into fewer but larger ones on the 23rd, and such they remained on the 24th. Thereupon diminished again, and finally, in the following days, resolved into mere faculae, they by no means reached the western horizon. [Margin: The spots pass off into faculae.] Meanwhile they completed a most regular path, in the manner of the others, and drew farther and farther apart from one another, and so on.

Second. Spot **b** failed in the middle of its path, gradually resolving into three, then into two very small spots; at the outset it moved between a northern and a southern facula, which, however, were extinguished on the following days.

Third. [Margin: A very tiny spot lasting three days.] The very tiny spot **c** showed itself three times [i.e. lasted three days] and appeared no further, having traversed a path proportional to that of spot **a**, from which it always stayed at an equal interval.

Fourth. [Margin: Failing spots dissolve into small ones.] Spot **d**, drawing a spot, a facula, and an umbra behind it, acquires more umbrae and spots as it goes; and when these were gradually lost, it was seen to diminish and to resolve little by little into more spots, until at last, with a very long facula and umbra, it approached the horizon. It did not remain in the Sun's visible hemisphere beyond twelve days, on a path aimed directly toward the ecliptic, but an arched one.

Fifth. [Margin: Umbrae are changed into spots, and these again into umbrae and faculae.] It is to be noted how this spot, drawing several behind it on the eastern side and gradually leaving them at a greater interval, did not take them up to itself — not even in appearance — at its setting, but joined them by a continuous vapor or shadow. Then, how the following, easternmost spot advanced out of shadow and into the place of a facula, and at setting passed off again into a shadow and a very long facula. Something similar happened around spot **a**; and you will see something similar around spot **c**, in the previous image, toward the western horizon.

[Further.] [Margin: Projections of faculae and umbrae toward the horizon.] Further, how the shadow and facula around spot **d** suddenly appeared thrust out toward the western edge, so that it was no farther from that edge than the spot itself — whereas otherwise it always followed the spot going before it. Similar things happened around the spots **a**, and, in the earlier figure, near spot **c**; such things you will notice here and there in other courses too.

Sixth. The course of **d** was not entirely parallel to the course of **a**.

Seventh. These courses, with their extremities cut off, appear rectilinear to the senses.

Eighth. Spot **d** grew from the beginning to the middle, and from there likewise decreased to its exit.

IMAGE OF THE SUN XLII

Diagram. A full-page engraved solar disk — the 42nd observation-image [XLII. IMAGO Observationum], recording the course of the sunspots from 22 September to 6 October 1625, observed at the Professed House of the [Jesuit] Society in Rome

[In Domo Professa Romana Societatis]. Between the title lines is the printer's ornament: a heraldic rose, the radiant IHS monogram of the Society of Jesus, and a second rose. The upper right gives the tallies "Septembris. 3." and "Octobris. 1." The great circle carries the cardinal labels **Z** (top), **N** (bottom), **A. Oriens** (East, left) and **B. Occidens** (West, right); a horizontal diameter is labelled **AB. Ecliptica** with **C** at its center. Two observation tables are set within the disk (transcribed below). The spots are drawn as small inked blots strung along dotted paths, each tagged with a letter and a day-number (and, for afternoon observations, a "u").

Readable spot tracks (Boreal/northern half, above the ecliptic line):

- Track **a**: a22 (a compound cluster), a23, a24, a25, a26 ... a27, a28, a29, a30 (a large lobed cluster near the western limb).
- Track **b**: b22, b23, b24, b25, b26(u), b27(u), b28(u).

Readable spot tracks (Austral/southern half, below the ecliptic line):

- Track **c**: c22, c23, c24.
- Track **d**: d25, d26(u), d27(u), d28(u), d29(u), d30(u), d1(u), then near the western limb d3, d4, d5, d6(u).

Interior blots between the tagged endpoints are numerous and small; several date-tags in the dense clusters near the western limb could not be resolved individually [?]. This plate for exhaustive spot-labeling.

Table — SEPTEMBRIS (within the disk). Column heads: D (dies, day) | H (hora, hour; m = morning, u = evening) | ☉.El. (Solis Elevatio, the Sun's altitude, in degrees and minutes).

D	H	☉.El.
22. m.	9	31. 0.
23. m.	8¾	28. 30.
24. m.	8 ⁶ / ₁₁ [?]	26. 0.
25. u.	2 ¹ / ₁₂	38. 15.
26. u.	4	19. 30.
27. u.	3 ² / ₃	23. 0.
28. u.	3 ⁶ / ₇	20. 0.
29. u.	3¾	20. 40.
30. u.	3 ¹¹ / ₁₂	19. 0.

Table — OCTOBRIS (within the disk).

D	H	☉.El.
1. u.	3 $\frac{7}{8}$	16. 15.
3. m.	8 $\frac{1}{5}$	19. 0.
4. m.	8 $\frac{5}{9}$	23. 20.
5. m.	8.	16. 30.
6. u.	3 $\frac{3}{8}$	24. 5.

Notes on the 43rd Observation-Image, the fourth [image] of September and the second of October, from 28 September to 14 October

[Margin: Spots, as they die away, break up into many small diminished ones.]

First. Spot *a*, the southern one, together with its faculae and umbrae, died out past the middle [of the disk], leaving absolutely no trace behind, even though I searched for it most diligently. At first the spot was a single oblong one for several days; then, before its death, it broke up into many small ones — something that is familiar in this phenomenon.

[Margin: The course of spot *b*, of 14 days.]

Second. *b*, the northern spot, which had somewhat of a nucleus, traversed the whole Sun intact in the most orderly way over thirteen days and more; for it was in view on the Sun from the first day in the morning until the 14th of October in the evening. Its first appearance fell at the 8th hour, its last at the 4th; so 13 days and about eight hours elapse — and even then the spot had not reached the western horizon [limb], though it nearly grazed it, so that it would easily have spent some further hours there. It is now evident, from the practice and habitual behavior of this phenomenon, that the interval between the perimeter [of the disk] and the first day of spot *b* is at least twelve hours. It is therefore plainly concluded that the apparent course of this spot was about 14 days. This same spot showed, lower down, a certain swelling toward the east, which afterwards, on the 6th day, seems to have burst into three spots, which I marked with the letter *g*. This spot grew up to the middle and declined from there, in nearly equal measure.

Third. Spot *c*, likewise southern, arose among the faculae and grew; on the 4th day it gained two [companions], which were lost again, and on the sixth it took on

three new southern ones — but these too being lost on the 8th, it diminished, and on the 9th, 10th, 11th, and so on it began to break up into two small ones; and thus, paired together with a southern facula generated out of the spots of the sixth day, it reached the west. On the 13th it ran ahead of spot *b*, just as it had preceded it at rising; the paths of these two spots, a little before setting — which is remarkable — cut across each other. And although spot *b* arose more to the south than *c*, yet this one [*c*] set more to the south than *b*, as is clear to the observer. This case, though it may seem unusual, is nevertheless not the only one. It spent more than 13 days on the Sun.

Fourth. Spot *d*, the northern one, having accompanied spot *b* through three equidistant stations, tore itself from view and never returned.

Fifth. Spot *e*, likewise northern, very thin and very rare, spread itself and its offspring in a remarkable way; and, with faculae kindled near its end, it left the Sun with a splendid retinue, traversing it (if the reckoning be made for a full passage) in about thirteen days. Its course was not parallel to that of spot *b*, but gradually drew nearer to it: the intervals between them, once they had widened, did not close up again, but remained greater at setting than at rising. The faculae and umbrae dragged behind it kept pace with it about the horizon, so that they were no less distant [from the horizon] than it was itself.

[Margin: The courses of the spots are not parallel.]

Sixth. Spot *f*, a handmaid of spot *b*, was observed to overtake it somewhat, but vanished before its exit. Spot *g* did something similar, which is worth noting; but here too it must be observed that it diverged from spot *b* toward the north, as is clear from the diagram.

[Margin: Some spots overtake others, and their courses cross.]

Seventh. Spot *h*, the southern one, which arose from a very slight beginning, remained of even rarity; yet in bulk it grew into two or three by days 8, 10, and 11; on the 12th it broke up into four smaller ones; on the 13th it burned up these same ones, now kindled, having taken on a new companion above. And so it neither entered nor left the Sun, but was both generated and consumed upon it. The same must be judged of the southern spot *i*, which lay wholly hidden for two whole days — something that not rarely happens to other spots as well.

[Margin: Spot *h*, of even rarity, growing from a small one into many small ones and a facula, was dissolved.]

Eighth. Spots *K* and *l*, each of two days' duration, degenerated into very long faculae, purest in the middle, which by the 11th day became exceedingly slender.

Ninth. The course of all of these is alike and uniform, curved, and oblique to the ecliptic, but gradually approaching a straight line; the arctic pole still descending from above.

Tenth.

[Continuation of the Tenth note, set above the plate:]

Tenth. Spot *h*, the southern one, at the same time traverses a greater space on the Sun than the northern *b*, or *c*, or *e*. And yet this one is much closer to the center and to the ecliptic.

IMAGE OF THE SUN XLIII

Diagram. A full-page engraved solar disk — the 43rd observation-image [XLIII. Imago Observationum], recording the course of the sunspots from 28 September to 14 October, in the Jubilee Year 1625 [ANNO IVBILÆO. 1625], observed at the Professed House of the Society in Rome. The same rose-IHS-rose printer's ornament stands between the title lines. The upper right gives the tallies "4. Septembris." and "2. Octobris." The great circle carries the cardinal labels **Z** (top), **N** (bottom), **A. Oriens** (East, left), and **B. Occidens** (West, right); the horizontal diameter is labelled **AB. Ecliptica** with **C** at its center. A short "Septemb:" table and a three-part "Octobris" table are set within the disk (transcribed below).

This plate is very densely lettered, with spot-paths tagged by letters *a* through *l* and day-numbers running from 28 (September) through 1 and 3–14 (October). Readable tracks:

- Boreal (northern) half: track **d** (d3, d4, d5, near the top); track **c** (c-tagged blots dated roughly 3–13, e.g. c8, c9, c11, c12, c13); track **b** (b3, b4, b5, b6, b7, b8, b9, b10, b11, b12, b13, b14); a script-form track **g** (g8, g9, g10, g11); track **f** (f8, f9, f10, f11 [?]); track **e** (e-tagged blots dated 5–14 with "u", e.g. e6, e7, e8, e9, e11, e12, e13, e14).
- Austral (southern) half: track **h** (h6, h7, h8, h9, h10, h11, h12, h13, with "u"); track **a** (lower left cluster: a28(u), a29(u), a30(u), a1, a3, a4, a5); track **l** (l8, l9, l10, l11, l13, near the western limb); track **k** (k8, k9, k10, k11, a lobed chain near the western limb).

Many interior date-tags within the dense clusters could not be resolved individually [?]. This plate for exhaustive spot-labeling.

Table — Septemb: (within the disk). Heads as above (D | H | ☉.El.).

D	H	☉.El.
28. u.	$3\frac{6}{7}$	20. 0.
29. u.	$3\frac{3}{4}$	20. 40.
30. u.	$3\frac{11}{12}$	19. 0.

Table — Octobris (within the disk; three sub-columns, transcribed in reading order).

D	H	☉.El.
1. m.	8.	30. 0.
3. m.	$8\frac{1}{5}$	19. 0.
4. m.	$8\frac{5}{9}$	23. 20.
5. m.	$8\frac{1}{4}$	19. 40.
5. m.	$9\frac{2}{9}$	30. 30.
6. m.	$8\frac{5}{8}$	23. 10.
6. m.	$9\frac{1}{4}$	28. 10.
7. m.	$9\frac{3}{8}$	29. 0.
8. m.	$8\frac{1}{2}$	21. 0.
9. m.	$8\frac{5}{8}$	20. 0.
10. m.	$7\frac{7}{8}$	14. 0.
11. m.	$8\frac{3}{8}$	19. 30.
12. m.	$8\frac{1}{4}$	17. 40.
13. m.	$8\frac{3}{8}$	18. 35.
13. u.	$3\frac{5}{8}$	20. 0.
14. m.	$8\frac{1}{4}$	19. 25.
14. u.	$4\frac{5}{8}$	9. 10.

Notes on the 44th Observation-Image, the third [image] of October, from the 8th to the 22nd of the same [month]

[Margin: Spots immersed in the Sun's brightness.]

[First.] This image presents the course of five spots, which I shall run through in the order of their letters. First, the course of the *a* spots began on the 8th day and ended on the 17th, and it did not reach the horizon [limb]. At the outset only two spots were seen, immersed in the Sun's brightness; on the 9th, ringed by a halo and bright faculae, they bubbled up into nine small ones; and on the tenth they were compacted into fewer but larger ones, namely five; on the eleventh a sixth was added; on the twelfth they came out to nine, which again on the thirteenth, with the loss of the smaller ones, were made larger but fewer, namely seven; on the fourteenth they were reduced to seven others, and smaller ones; on the fifteenth they now took on the appearance of thin umbrae. On the sixteenth only a single one appeared, and that a faint one; finally, on the seventeenth, two shadowy spots shone out with a facula. On the eighteenth and the following days, though searched for most diligently, they did not yield even a trace of themselves.

Second. The *b* spots, northern ones, likewise first appeared on the 8th day, with faculae resembling umbrae bordering upon them. On the 9th they gradually spread into spots and larger faculae. On the 10th and 11th five slender spots appeared. On the 12th the more southern one vanished, but the more northern of the latter ones evolved into five, which on the 13th came out to a good nine; these again on the 14th were gathered into four somewhat larger ones, just as the more western ones — up to this point five — coalesced into three more corpulent ones. On the 15th the more eastern ones were reduced to a single thin umbra, and the more western ones took on the form of two joined together — which, however, the engraver did not render adequately, presenting them as separate. On the 16th four appeared in a new form, the more eastern ones being wholly invisible. On the 17th a single westernmost one remained, doubled — which likewise the engraver did not render adequately. On the 19th the umbrae, together with faculae, sinking toward the western horizon, were substituted in place of the spots.

Note that the first ones departed greatly from the last, and did not come together again near setting, but the intervals were always too large to become similar to those in the east. Spot *c* appeared once on the ecliptic, seen neither before nor after.

[Margin: From the *d* spots one has the ordinary conception, birth, cradle, prime, death, and funeral-pyre of the spots.]

Third. The *d* spots, southern, born from thin umbrae creeping forth on the Sun on the 10th, made remarkable progress on the eleventh: for whereas on the tenth there had been only four, on the eleventh thirteen distinct ones came to be, and

they took up double the length. On the twelfth the first and last increased, while several of the intermediate ones vanished; for on the whole they did not exceed the number nine; the distance of the first from the last grew by about a third. On the 13th they increased prodigiously, for the whole gap turned into one continuous spot, right up to the first westernmost one; the last easternmost one was separate, but was seen wholly black, like a nucleus. Nuclei also appeared here and there in this tract. The distance of the two extremes increased still further. On the fourteenth the same distance between the extremes grew, although in uniform motion it ought to have decreased and become equal to the distance of the eleventh day — of which, however, it turned out to be one and a half times as great. But the easternmost spot was enlarged in a remarkable way in every dimension, weighed down with a nucleus; the middle space was again beset by many tiny ones, and the eastern ones were separated into 7 spots. On the 15th five spots appeared, and the distance of the extremes was a little smaller than yesterday's. On the 16th the two easternmost ones still held, and the middle one grew, while the eastern ones were resolved into eight small ones. On the 17th, four spots with umbrae and faculae: the distance of the extremes still exceeds the distance of the eleventh day; the faculae succeeded into the places of the spots.

Diagram. A full-page engraved plate showing the solar disk with the observed courses of the sunspots. The plate is heavily overprinted with faint mirror-reversed show-through from the letterpress on the verso (folio 268); only right-reading engraved ink is transcribed here.

Engraved title matter around the top of the disk:

- Upper left: **XLIV. Imago Obseruationum** ("44th. Image of the Observations")
- Upper center: **ANNO IVBILAEI M.DC.XXV.** ("In the Jubilee Year 1625") / **In Domo Professa Romana Societatis** ("In the Professed House of the Society at Rome")
- Upper right: **Octobris. 3.** (verbatim)
- Center emblems: a rosette (Orsini rose) flanking each side of the Jesuit **IHS** sunburst monogram
- Across the middle: **Cursus Macularum ab 8. Octobris ad 22. eiusdem** ("The course of the spots from 8 October to the 22nd of the same month")

Orientation labels on the disk:

- **A** — left end of the horizontal diameter: **A. Oriens** (East)

- **B** — right end of the horizontal diameter: **B. Occidens** (West)
- **C** — center of the disk, on the horizontal diameter, labeled **AB. Ecliptica** (the line AB = the Ecliptic)
- **Z** — top of the vertical diameter
- **N** — bottom of the vertical diameter

Across the disk, running roughly along the ecliptic band from the eastern limb (A) toward the western limb (B), are the drawn spot-groups, each marked with a lower-case letter (the spot's identity: **a, b, c, d, e, f, u**) and a numeral (the day of October, 8–22) giving its successive daily position. Readable labels include, in the central and western band: e 16, e 17, e 18, e 19, e 20; d 13, d 14, d 15, d 16, d 17, d 18; b 14; c 21, c 22; a 17; and in the upper (boreal) right region a track of macula **f** labeled f 16, f 17, f 18, f 19, f 20 with an adjacent **c** and **b 19**. Several evening positions are marked **u**. Many of the individual micro-labels are small and partly obscured by verso show-through and cannot be resolved with certainty [?].

Foot-table (see the transcription beneath the folio-269 figure, fig-p395-1, whose table region is legible; the two impressions carry the identical table).

[Margin: The courses are not parallel.]

On the 18th no more than two appeared, the outermost ones, and the westernmost much diminished, the easternmost fairly large; the distance between them exceeds their distance on the eleventh. It should be carefully noted how it lies almost thrown down onto the horizon, as the faculae too are wont to do. The course of these spots was, at the beginning, closer to the course of the spots **a** than at the end, so that they are not equally distant. Conversely, at the end it is closer to the course of the spots **b** than at the beginning.

[Margin: Spot e, prodigious in its mutual separation, its number, its size, and its coalescence.]

Fourth. The spots **e** present portents no smaller—indeed larger—than **d**: in their spacing, their number, their size, and their coalescence. On the 14th, newly risen, there were nine of them. On the 15th, about fifteen, and the first had a notable nucleus. On the 16th they coalesced into a single shapeless and irregular mass, hemmed in by little ones along the sides. On the 17th they broke apart into four, of which the two outermost were compounded of many, while the two in the middle were small and faint shadows; meanwhile the distance between the outermost was steadily increasing. On the 18th there were three, of which the

easternmost was small and newly born; the distances were still equal to yesterday's. On the 19th there were two, the spacing somewhat reduced, and the easternmost ones, hitherto forked, had merged. On the 20th the distances of the outermost were equal to the distances of the 14th; there were only two, but each compounded of several, as the nuclei and the earlier days make plain. On the 21st and 22nd, although both still appeared, and the eastern one was larger and more vigorous, nevertheless, to avoid crowding and confusion of the place, I have drawn in

[Margin: Physical rising, progress, and setting of spot d.]

only the western one, where I note the westernmost mark, **d**, to have been more to the north around its setting than **e**.

The spot **f**, a northern one, boiled up like a thin shadow near the middle of the Sun on the tenth and was single; but on the 16th it turned into one long spot, made up in a way of three, with another, more northerly, new one following. On the 17th, that one having been extinguished, the earlier spot grew mightily longer, laden with a nucleus, and drew after itself six others at once—some new, some, as it appears, separated off by division and distinct.

On the 18th it fell off somewhat in nucleus and in intensity, and, having lost the middle ones too, it nevertheless kept the two smaller last ones. On the 19th it began to resolve into five, still contiguous among themselves, or rather continuous, while the following ones grew a little.

On the 20th they began to thin out into shadows and to kindle into faculae; and so on the 21st, with these same fullest flames, they went on toward the west, and on the following days from then on gave no trace of themselves.

[Margin: The path of spot d is equidistant from some, and intersects others.]

The path of this spot was equidistant from the path of spot **a**, but oblique to the way of spot **b** (not as is plain from the figure): on the 15th it was fairly far from it, but on the following days it gradually drew nearer, to such a degree that by the 19th at last the paths coincided, and afterward cut across each other in a way.

[Margin: The curvature and the obliquity decreasing; the pole sinking.]

Meanwhile the paths of the spots regard the ecliptic obliquely and look toward the straight, as the arctic pole descends toward the eastern horizon, the chords being less inclined to the ecliptic.

Diagram. A second impression of the identical Image XLIV engraving already described at fig-p393-1. Folio 269 bears the same full-page solar-disk plate — same title matter (**XLIV. Imago Obseruationum; ANNO IVBILAEI M.DC.XXV. In Domo Professae Romanae Societatis; Octobris. 3.; Cursus Macularum ab 8. Octobris ad 22. eiusdem**), same rosette-and-IHS emblems, same orientation labels (**A. Oriens** left, **B. Occidens** right, **C / AB. Ecliptica** center, **Z** top, **N** bottom), and the same drawn spot-tracks with the daily-numbered labels of maculae a–f (8–22 October). On this impression the show-through is the mirror-reversed letterpress of folio 270 (the notes to Image XLV). The foot-table region here is cleaner than on folio 267, and its readings are given below.

Foot-table — OCTOBRIS. (printed as three side-by-side blocks, each headed $D \mid H \mid \odot \mid El$; D = day, H = hour with m = morning / u = evening, $\odot$ and El = the two components, degrees and minutes, of the tabulated solar quantity). Transcribed in day order:

D (day)	H (m/u, hour)	$\odot$ (°)	El (')
8	m, 8½	21	0
9	m, 8¾	23	30
10	m, 7⅞	14	0
11	m, 9	24	45
12	m, 8⅜	22	20
13	m, 8⅘ [?]	22	50
14	m, 8⅘	22	30
15	m, 8⅞	22	30
16	m, 8⅘	20	0
17	m, 9½	27	40
18	m, 8⅞	21	30
19	m, 9	20	30
19	u, 5⅓	22	5 [?]
20	m, 8¾	19	50
21	m, 8 6/7 [?]	20	35
21	u, 4⅓	10	30
22	m, 9	22	0

Notes on the 45th of the observation-images, the fourth of October, from the 15th to the 31st of the same month

[Notae in XLV. obseruationum Imaginem, Octobris quartam, à die 15. ad 31. eiusdem.]

[Margin: Spot a, monstrous in its distance in longitude, in size, in variation of figure, in its wasting away.]

First. The spots **a**, southern, came up over the horizon on the 15th in the morning and went out on the 27th in the evening; and so they were not on the Sun beyond 13 days—whether they reached [the limbs] is disputable.

They were monstrous: First, in their distance in longitude, which, having been very small on the 15th, grew beyond measure on the days that followed, as is plain on the 16th, 17th, 18th, 19th, 20th, and thereafter. Second, in the size to which they attained in so few days—consider the 19th, 20th, 21st, and 22nd, with the dense nucleus. Third, in figure, since they showed a different shape on however many days. Fourth, in decline: for as quickly as they arose, multiplied, and grew, just as quickly they failed; for on the twenty-sixth no more than three appeared together, since the upper, northern one had joined itself on like an apex, having still been separate the day before. Here note the one that was westernmost: having begun to separate on the 19th, it was joined again to the following one on the 26th, and thus on the 27th it approached the horizon, with the shadows and faculae above and below, which beyond doubt drew their origin from the spots.

[Margin: Disjoined around their exit, they are joined again to appearance.]

Second. The spots **b** and **c**, carried along in the same parallel, spread their distance apart incredibly. On the 27th the spots **c** disappeared; on the 30th and 31st both were dissolved into shadows and faculae.

Third. The spots **d**, northern, arose on the Sun on the 26th, grew to the 28th, then again declined in mass and number, until at last on the 30th they were reduced to a single small one; afterward they gave no perceptible trace of themselves. In their motion, nonetheless, they followed the common law of all; just as the spots **e** too, which had risen around setting on the 24th, did the same.

Fourth. The spots **f**, having risen on the 27th in the western part of the southern region, were two small ones; on the 28th there were five, exceedingly minute; but on the 29th they suddenly turned into one large spot furnished with a dense

nucleus, which drew after itself a not-to-be-despised train of spots, shadows, and faculae. On the 30th the western one decreased somewhat, but the following eastern shadow turned into a distinct spot, just as on the 31st it appeared again, when the western one, with its shadow and facula, approached the horizon.

[Margin: The true motions unequal.]

The apparent distance between these on the 28th, 29th, 30th, and 31st was equal—which ought not to have happened if the true motion of each were equal, and so on. The motion of these was not parallel to the motion of the spots *e*, but this one drew somewhat nearer to that one.

Fifth. The curvature of all of them decreases, as does the obliquity of the chords to the ecliptic, the arctic pole tending toward the west as it descends in the eastern semicircle.

IMAGO SOLIS XLV — 271

Diagram. Full-page engraved circular solar disk, IMAGO SOLIS XLV — the forty-fifth image of the observation series. It records the course of the sunspots across the Sun from 15 to 31 October 1625, observed at the Professed House of the Society in Rome. The disk is crossed by a horizontal diameter (the ecliptic), and the daily positions of each spot-group are printed along near-horizontal tracks, each spot marked with its identifying letter and its date and time (subscript *m* = morning, *u* = evening). An observation table (OCTOBRIS) is set within the lower part of the disk.

Header and reference labels (read under magnification):

- Top left: "XLV. Imago Observationum" (Image 45 of the Observations)
- Top right corner: "4. Octobris" [the numeral reads as "4"; the fourth image of the October series] [?]
- Upper center: "ANNO IVBILAE0, MDCXXV" (In the Jubilee Year, 1625)
- "In Domo Professa Romana Societatis" (In the Professed House of the Roman Society [of Jesus])
- Center: the Jesuit IHS radiant emblem, flanked by two heraldic-rose ornaments
- "Cursus Macularum à 15. Octobris, ad 31. eiusdem" (The course of the spots from 15 October to the 31st of the same month)

Cardinal points and reference lines:

- A (left, on the horizontal diameter): "A. Oriens" (East)
- B (right, on the horizontal diameter): "B. Occidens" (West)
- Center, at the diameter: "A B, Ecliptica" with "C" marked just below the label (the line AB is the ecliptic; C the center)
- N (bottom, foot of the vertical): "N"

Readable spot-track labels (letter + date, with m/u where legible):

- Upper right, near the limb: an **e** group dated 25 (u), 26 (m), 27 (m)
- Right, below the ecliptic near B: an **f** group dated 29 (u), 30, 31 (m); an **a** group dated 26, 27 (u); **b/c** dated 30, 31
- Center band along the tracks: an **a** group dated 15 (m), 16, 17 (u), 18, 19, 20, 21, 22
- Also **d** dated 24, 29, 30; **b/c** dated 20, 21

OCTOBRIS. (Observation table set within the disk. Columns: **D** = day; **H** = hour, with m = morning / u = evening; ☉ **El.** = solar altitude, in degrees and minutes.)

D	H	☉ El.
15	m. 8½	18. 40.
15	u. 4⅓	12. 0.
16	u. 3⅞	17. 0.
17	u. 4⅓	11. 40.
18	m. 8⅞	21. 30.
19	m. 8⅞	17. 0.
20	m. 8¼	19. 50.
21	m. 8⅝	20. 35.
22	m. 9	22. 0.
24	m. 9⅞	27. 30.
25	u. [blank]	20. 0.
26	m. 9	20. 30.
27	m. 9 7/12	25. 0.
27	u. 4⅔	14. 0.
28	u. 3⅞	13. 0.
29	u. 3¼	18. 15.
30	u. 3	20. 30.

D	H	⊙ El.
31	m. 9¼	22. 40.

272 — ROSAE VRSINAE LIB. III.

Notes on the forty-sixth Image of the observations — the fifth [image] of October, the first of November; from 30 October to 14 November

I.

First. If one were to set aside, in thought, the extreme days of these journeys, who would not declare that these are rectilinear courses? And yet the very first and last days — those nearest the limb — teach us most certainly that they are not in fact rectilinear.

Spots **a**, faint and boreal, were seen on the 30th together with bright faculae, and appeared again on the 31st; thereafter they escaped notice across the whole visible disk of the Sun, until at last, around their exit on 9 and 10 November, they showed themselves once more, together with faculae in the manner of shadows. That these are the same spots that had been at their rising is suggested by their timing and their place. As for their not having been noticed over so long an interval, the cause may lie partly in their faintness, partly in the fact that I was more intent on others (of which shortly). If, however, anyone prefers to treat the first as having died out and the last as new, I have no objection — for this very often happens even over a shorter span.

Second. Spots **c**, five austral spots, faint, nebulous, and much diluted by light, first appeared on 31 October; then on 1 November they were dispersed into two thin but fairly broad, ill-defined nebulae. On the following day at least 22 distinct spots appeared in all, of which four — the first and westernmost — had been gathered into one, conspicuous with their nuclei, while all the rest were small, bent almost into the shape of a scorpion's tail. On the 3rd they grew in bulk and extent, as also on the 4th, the intermediate ones constantly varying. On the 5th the middle ones began to shrink, the first ever growing. On the 6th a very large one appeared to the west, while those following declined sharply; a perimeter traced out in small dots showed that the spot had been surrounded by a shining halo — which happens on other days too, and of which I have here taken [continues at col. II]

[Margin, left: "Macularum ordinaria, sed mira sane ex umbris tenuissimis procreatio, augmentatio, dilatatio, in faculas demum conversio." — "The ordinary, yet truly wondrous, generation of spots out of the very faintest shadows, their growth, their spreading, and their final conversion into faculae."]

II.

[continued] this as my example. On the 7th a spot made a fissure, very brightly lit. Those following were much attenuated. On the 8th too a large one shrank, the small ones vanishing. On the 9th, 10th, and 11th, faint spots with shadows and faculae accompanied it; over the last two days it declined enormously, yet on the 10th it still retained a dense nucleus. The course of this westernmost spot, all reckoned, did not exceed thirteen days — if indeed it even came to that.

Third. Spots **d**, boreal, newly generated on the Sun, came out with faculae, at a more contracted distance, on account of their situation.

Fourth. Spot **e**, a single faint and small spot, appeared on the 2nd. On the 3rd, larger and doubled, it carried bright faculae with it — boreal, austral, and western. On the 4th it was again alone; on the 5th and 6th larger; after which it faded gradually, and on the 11th it passed off into a very long shadow, blazing with faculae on both sides.

Fifth. Spot **f**, arising on the 2nd, grew steadily until the 9th; then, notably diminished, it reached the 14th at evening. Therefore, if the intervals remaining on either side are allotted their own times, the course of this spot will easily come to thirteen days, if it does not somewhat exceed that. It deviated little from the greatest parallel.

Sixth. Faculae **g**, very pure and bright, presented themselves to view from the 5th to the 6th.

Seventh. **h**, an austral spot, showed itself amid a facula on the 4th; on the 5th it burst into two, which thereafter, spreading out, wholly disappeared after the ninth day. Note that the path of these spots came somewhat close to the path of **c**.

The full course of spot **K** you will have in the following diagram, at the letter **a**.

Eighth. These courses are curvilinear, but very close to straight: the inclination of their chords to the ecliptic is less oblique, and the arctic pole overhangs the horizon.

[Margin, right: "Maculae e augmentum & decrementum." — "The growth and decline of spot e."]

[Margin, right: "Facula pura." — "A pure facula."]

[Margin, right: "Itinera non parallela." — "The paths are not parallel."]

IMAGO SOLIS XLVI — 273

Diagram. Full-page engraved circular solar disk, IMAGO SOLIS XLVI. It records the course of the sunspots from 30 October to 14 November 1625, observed at the Roman College of the Society. As on the preceding plate, the daily positions of each spot-group are printed along their tracks, each labeled with letter, date, and time (m = morning, u = evening); two observation tables (OCTOBRIS and NOVEMBRIS) are set within the disk.

Header and reference labels (read under magnification):

- Top left: "XLVI. Imago Observationum" (Image 46 of the Observations)
- Top right corner: "5. Octobris" / "1. Novembris" (the fifth image of the October series; the first of the November series)
- Upper center: "MDCXXV" (1625)
- "In Collegio Romano Societatis" (In the Roman College of the Society [of Jesus])
- Center: the Jesuit IHS radiant emblem, flanked by heraldic-rose ornaments and a decorated initial "P"
- "Curs. à die trigesimo Octobris, ad 14. Novembris." (Course from the thirtieth day of October to 14 November)
- Below: "A. Oriens, B. Occidens, A.B est linea Ecliptica. A N B Z Horizon solaris, numeri marginales lineam verticalem designant, per centrum F transeunte." — "A = East, B = West; AB is the ecliptic line; A N B Z [is] the solar horizon; the marginal numbers designate the vertical line passing through the center F."

Cardinal points and reference lines:

- A (left, on the diameter): East
- B (right, on the diameter): West
- F (center of the disk, on the diameter)
- N (bottom, foot of the vertical)
- Z (top, head of the vertical) [implied by the "A N B Z" horizon label; the top marker is at the show-through/plate edge and not clearly resolved] [?]

Readable spot-track labels (letter + date, with m/u where legible):

- Upper right, near the eastern limb: an **a** group with a trailing string of small dated marks (dates including 12, 7, 31, 6, 8, 20, 1, 3, 5, 4, 2, 10; letters a9, a10) and **d** dated 2; **d** also dated 30, 31 lower toward center
- Center band: a **K** group (labels K, 10 K, 8, 7) and **e** group (5, 6, 9, 10), **f** group (7, 8), **c** group (3, 4, 5, 6), **h** group (5, 6, 7, 8, 9)
- Right, below the ecliptic near B: an **f** group dated 11, 12, 13, 14; **c** group dated 9, 10, 11, 8

OCTOBRIS. (Columns: **D** day; **H** hour, m = morning; ☉ **El.** solar altitude in degrees and minutes.)

D	H	☉ El.
30	m. 9 $\frac{1}{8}$	20. 50.
31	m. 9 $\frac{1}{2}$	22. 40.

NOVEMBRIS. (Two side-by-side half-columns, days 1–7 and 8–14, separated in the heading by a ♀ [Mercury] mark. Same columns: **D** / **H** / ☉ **El.**)

D	H	☉ El.
1	m. [blank]	19. 0.
2	m. [blank]	14. 30.
3	m. 8 $\frac{3}{8}$	15. 0.
4	m. 8 $\frac{1}{2}$ [?]	13. 0.
5	m. 8 $\frac{1}{3}$	13. 45.
6	m. 8 $\frac{2}{3}$	17. 40.
7	m. 8 11/12	19. 0.
8	m. 8 $\frac{5}{8}$	17. 0.
9	m. 8 7/12	19. 0.
10	m. 8 $\frac{1}{2}$	16. 0.
11	m. 9	18. 30.
12	m. 9	18. 30.
13	u. 1 $\frac{3}{4}$ [?]	26. 0.
14	u. 2 $\frac{1}{2}$	21. 20.

274 — ROSAE VRSINAE LIB. III.

Notes on the forty-seventh Image of the observations — the second [image] of November; from 6 to 22 of the same month

I.

First. Spot **a**, austral beyond the middle but boreal toward its exit, traversed the Sun from the 6th to the 18th. It bore before it a twin, or oblong, nucleus, which on the 12th and following days gave birth to two spots; these, drawing ever farther apart from one another, came out even as separate spots, trailing an austral facula and shadow, and so on. This spot appeared larger at its exit than at its entry. It drew faculae behind it both at the east and at the west. In traversing the Sun it took up, as it appears, at least thirteen days, with a course inclined toward straightness. Faculae **b**, boreal, shone very brightly and purely on the 6th, but were not seen afterward.

Second. Spot **c**, austral, arising on the 7th, went out on the 19th; conspicuous on both sides with faculae, it grew steadily, and in the same manner declined; it did not reach thirteen days.

Faculae **d**, austral, most pure and numerous, filled out a course of two days; afterward they were not noticed, though diligently sought.

Third. Spots **e**, boreal, having crossed the eastern edge of the Sun on the 10th, clung to the western horizon on the evening of the 22nd, as is plain from the lateral figure; therefore they were on the Sun for thirteen days or more. Both they and their own faculae were cut by the horizon, yet neither of them went outside it in the least.

[Margin, left: "Facula prae unius diei." — approx. "A facula [barely?] of a single day."] [?]

[Margin, left: "Faculae purae duorum dierum." — "Pure faculae of two days."]

II.

Fourth. Spots **f**, first seen on the ecliptic, held to it for about one day on the 12th, but from the 14th onward ascended into the north. Diffused at last into faculae and shadows, they hastened to the west, although on the final days they were not seen.

Fifth. Spots **g**, austro-boreal, small and faint, constant in neither number nor bulk, finally passed away into faculae.

Sixth. Spots **h**, two austral spots, proceeded from the 12th to the 19th along the route usual to the rest; for since the more boreal of the two had entered the track of spot **c** five days after it, in that same track — as is plain — it proceeded most beautifully, for as long as it lasted.

Seventh. Spot **I**, boreal, very like a faint little cloud or mist, lasted from the 12th to the 14th. Its passage was parallel to that of spot **f**.

Eighth. Spots **K**, boreal, on the 13th born anew in pairs [binae] on the Sun, on the 19th and 20th went out, resolved into faculae.

The motion of all of them is very akin to rectilinear and nearly uniform; the interval is not much greater than thirteen days; and all of them slope toward the ecliptic in about the same way. The arctic pole has not yet reached the horizon.

Ninth. Spot **l**, austral, beheld the light for a single day.

Tenth. Spots **m**, generated in the austral quarter toward the west, went out together with faculae — indeed within faculae — with a curve of their course like that of the others; they grew in bulk near the horizon.

[Margin, right: "Curvitas & obliquitas ferme minima; polus horizonti vicinus." — "Curvature and obliquity almost minimal; the pole near the horizon."]

[Margin, right: "Macula circa occasum generata augescunt." — "Spots generated near the setting [western limb] grow larger."]

[their apparent duration] did not exceed thirteen days; whether it equalled them is still an open question. Fourth. The spots **c**, thin ones, kept the same course but did not run the whole of it, because they did not remain on the Sun beyond four days; they attained neither the beginning nor the end [of the passage], but were generated in the very middle and there decayed again.

(The paragraphs above complete the "Notae in XLVIII," carried over from the foot of the preceding page; they are printed as two short columns above the engraved plate on this leaf.)

Imago Solis XLVII

Diagram. A full-page engraved solar disk recording the passage of the sunspots from 6 to 22 November 1625 (the 47th observation-image). Cardinal letters ring

the disk: **Z** at the top, **N** at the bottom, **A** at the left (labeled *A. Oriens* = East), **B** at the right (labeled *B. Occidens* = West), with the center at **C**. The horizontal diameter A–C–B is the line of the ecliptic, labeled *AB Ecliptica*. The word *NOVEMBRIS* is set above the foot-table at bottom-center. A title-block occupies the upper part of the disk, flanked by the IHS sunburst emblem and two Tudor-rose ornaments.

- Top-left: *XLVII, Imago Observationum* ("47th, Image of the Observations")
- Top-center: *ROMÆ / In Collegio Romano Societatis* ("At Rome, in the Roman College of the Society")
- Top-right: *2. Novembris* [reading uncertain; a single "2" is printed, which does not match the image's November 6–22 span — possibly a compositor slip for "22. Novembris" [?]]
- Upper-center: *Cursus à die 6. Novembris ad 22. eiusdem M.DC.XXV.* ("The course from 6 November to the 22nd of the same [month], 1625")

Spot tracks: numerous sunspot groups are engraved across the disk, each rendered as a run of daily positions marked with a group-letter and the day of the month, drifting from the eastern limb (A, left) toward the western limb (B, right). Readable group-letters include **a**, **b**, **c**, **e**, **f**, **g**, **h**, **K**, with the suffixes **m** (morning) and **u** (evening); readable day-numbers run through roughly 6 to 22. Large ringed spots (with dotted penumbra rings) labeled **K** and **e** cluster near the western/boreal limb at day-numbers 20 and 22; a dense group of clusters near the eastern limb carries the early day-numbers. The interior spot field is engraved over heavy mirror-reversed show-through from the verso letterpress, so individual per-spot positions and their day-labels cannot be resolved cell-by-cell at this resolution

Foot-table (NOVEMBRIS). Two paired sub-tables side by side; column heads *D — H — ☉ El.* (Day — Hour — Sun's elevation in degrees and minutes). *D* carries the suffix **m** (morning) or **u** (evening). This table sits under dense verso show-through; the hour-fractions and several elevation cells are at the print/show-through floor

Day	Hour (H)	☉ El. °	'
6.m	8 2/3	17	40
7.m	8 11/13 [?]	19	[?]
8.m	8 5/8	17	0
9.m	8 7/12	16	50

Day	Hour (H)	☉ El. °	'
10.m	8 1/2	16	[?]
11.m	9	18	30
12.m	9	18	30
13.u	1 3/4	26 [?]	0
14.m	8 5/8	15	40
15.u	4 3/4	5	40
16.m	10 5/8	27 [?]	25
17.m	9 3/8	19	40
18.m	9 1/8	17	35
19.m	8 3/8	15	30
19.u	2 11/[?]	17	0
20.m	10 1/2	26 [?]	30
20.u	2 1/2	2[?]	[?]
22.m	10	23	20
22.u	2 2/3	19	20

ROSAE VRSINAE LIB. III.

Notae in XLVIII. Observationum Imaginem, Novembris tertiam,
Decembris primam; à die 22. Nouemb. ad 5. Decemb.

(Notes on the 48th Image of the Observations — the third November image and the first December image — from 22 November to 5 December.)

First. To the eye, all the spots run along straight tracks, in a way parallel to one another and of equal duration, and inclined to the ecliptic at nearly equal angles, indeed the greatest possible. Between these two months, then — the close of November and the opening of December — the spots, the faculae, and the umbrae all lie at their fullest winter declination from the ecliptic: the southern ones to the south, the northern to the north. The general tendency of them all is from the Sun's eastern region toward the western, slanting across the ecliptic from south to north; to the eye none runs parallel to the ecliptic, and none is curved, except so far as the refraction of the lenses may perhaps bend them. The inclination and obliquity to the ecliptic that this phenomenon can have is here at its least: the pole rests on the horizon, and the arcs of the tracks coincide, to the eye, with their

chords. This is the celebrated winter station of the spots. Now let us come to the particulars.

Second. Spot **a**, then, was first seen on the Sun on 22 November together with notable faculae, and I do not doubt that it was there the day before as well; but a rainy day denied all sight of the Sun. It was nearly round and, for its slowness, fairly compact. The reason for this became plain in the following days: probably there were several spots, and one had veiled another — unless someone would rather suppose that something new had been generated in the meantime, which I would not dispute.

On the morning of the 23rd the faculae advanced together with the spot and spread over wider areas, as the diagram shows — where you also have its evening position noted. On the 24th and 25th there emerged those spots that had lain over it on the 22nd; rains held the two intervening days. On the 28th the spot appeared, still oblong but thin. On the 30th it appeared diminished but doubled, together with northern faculae. On 1 December there were four spots amid enlarged and bright faculae, and there is no doubt that the southernmost was a new one, forged out of the penumbrae of the 22nd — something quite usual for this phenomenon.

On the evening of the 2nd, both the spots and the faculae marvelously composed themselves into one long band — variegated with bright patches, penumbrae, and spots — running along the horizon, just as it appears in the diagram.

Third. Spot **b**, wholly northern, came into view on the evening of 23 November and withdrew from sight on the evening of 5 December. At first it appeared single, close to the horizon, but quite thick. On the 24th it drew a companion after it, and between the two a most brilliant facula shone out. [Margin: *A bright facula among the spots.*] On the 25th two spots emerged from the leading one and three from the following one, of which the last, more easterly, appeared of dense grain; the spaces between them blazed with faculae.

On the 28th, after rains, the two leading spots merged into one large mass, conspicuous for its split nucleus, wrapped in a vapor like a cloud and radiant on every side with a bright halo; the middle part freed itself from all the rest, while the last two, teeming with nuclei, were likewise contemplating a divorce; meanwhile the white spaces between shone, lit up with faculae. [Margin: *Faculae and haloes advance together with the spots.*] On the 29th some change occurred in the nucleus of the large spot: the middle thinned away into penumbrae, while the last ones, wholly divided from it, put forth certain new little spots. On the 30th

the first appeared more oblong, both in nucleus and in the surrounding vapor, still radiant with a halo, and increased by two little northern ones; the rest were parted into five, with faculae shining here and there among them. [Margin: *The nuclei and the spot uniform.*]

On 1 December the first appeared triangular, both in its nucleus and in its surrounding form; the following ones were torn into seven thin fragments, while the halo still held. On the 2nd, 3rd, and 4th they faded by degrees, both in size and in intensity, until on the evening of the 5th only two spots, very close to each other, drew near the horizon. What reached the horizon above, toward the north, was a thin penumbra, followed by a bright facula kindled from the spots. Their apparent duration—

Imago Solis XLVIII.

Diagram. A full-page engraved solar disk recording the passage of the sunspots from 22 November to 5 December 1625 (the 48th observation-image, per the plate's own title-block). Layout as on the preceding plate: **Z** at top, **N** at bottom, **A** at left (*A. Oriens* = East), **B** at right (*B. Occidens* = West), center **C**, the horizontal diameter A–C–B labeled *AB Ecliptica*. Title-block in the upper part of the disk, flanked by the IHS sunburst and two Tudor-rose ornaments.

- Top-left: *XLVIII, Imago Observationum* ("48th, Image of the Observations")
- Top-center: *M.DC.XXV. / In Collegio Romano Societatis* ("1625, in the Roman College of the Society")
- Top-right, two lines: *3. Novembris / 1. Decembris* [these corner dates do not match the image's 22 Nov–5 Dec span; transcribed as read, flagged as anomalous [?]]
- Upper-center: *Cursus Macularum, à 22. Novembris ad 5. Decembris, similis aliis aliorum annorum tempore eodem.* ("The course of the spots, from 22 November to 5 December, like that of other years at the same season.")

Spot tracks (this plate is much cleaner than the preceding one; the main lettered tracks read confidently):

- **Boreal (upper) half:** a long chain of the group **b** runs from left-of-center toward the western limb, its daily positions labeled *b* with day-numbers **28, 29, 30** (several large ringed spots with dotted penumbra rings cluster at days 28–30) and then **1, 2, 3, 4** (December), ending near the western limb at *b* with *u / 5* and the marginal *bus*. A separate *b*-cluster with *u* sits toward

the eastern part at day ~23. The annotation *pluviae* ("rains"), set beside a dash, marks a gap in the boreal track.

- **Austral (lower) half:** group **a** near the eastern limb, with day-numbers **22, 23 (u), 24, 25** (a facula dash "—" at day 25); group **c** across the lower-center, with day-numbers **28, 29, 30** and **1, 2 (u)**; near the western limb, group **a** again, with day-numbers **30, 1, 2 (u)**. A second *pluviae* annotation sits at lower-center.

Foot-table (NOVEMB. / DECEMB.). Two paired sub-tables divided by a central rule; column heads *D — H — ☉ El.* (Day — Hour — Sun's elevation in degrees and minutes), *D* with suffix **m** (morning) / **u** (evening).

Day	Hour (H)	☉ El. °	'
22.m	10	23	20
23.m	9	16	30
23.u	4	8	0
24.m	—	21	35
25.m	8 7/8	15	30
28.m	8 3/4	17	[?]
29.m	8 4/5	16	20
30.m	8 11/12	15	0

Day	Hour (H)	☉ El. °	'
1.m	9 1/8	15	25
2.u	2 3/8	15	20
3.u	3 1/2	10	0
4.m	10	21 [?]	40
5.u	3 1/2	11	0

ROSAE VRSINAE LIB. III.

Notae in XLIX. Observationum Imaginem, quartam Novembris, secundam Decembris; à die 25. Novembris ad 8. Decembris.

(Notes on the 49th Image of the Observations — the fourth November image and the second December image — from 25 November to 8 December.)

First. The spots **a**, southern, together with penumbrae and faculae, arose in the southern region on 25 November and lasted until 1 December; they exhibited a rectilinear fragment of their path, but one oblique to the ecliptic.

Second. On that same 25th appeared spot **b**, northern, with faculae and penumbrae; it was thick and doubled. On the 28th it split above into two, pregnant with oblong nuclei, with four little ones following; the white gap shone out into a facula. On the 29th the following, more easterly one seems to have been consumed, for it appeared neither morning nor evening — that region being bright — while little ones still followed.

On the 30th, morning and evening, two spots appeared as though cut through the middle, teeming with nuclei, the white gap between them gleaming like a facula. [Margin: *A most remarkable separation and joining of the spots.*] On 1 December, morning and evening, they came forth with their shape changed yet again: for in the morning there were two spots joined toward the west, while in the evening three shone out separate from one another — yet heavy with four small nuclei.

On the evening of the 2nd, four spots came out distinctly and separated from one another, of which the two southern ones had been joined yesterday, and on the 30th and likewise the 29th — furnished nonetheless with two nuclei. On the 3rd, all four of yesterday's were gathered again into two oblong ones. On the 4th these very ones coalesced into a single one, and so they continued on the 5th. On the 6th the sky did not oblige.

The course of these spots was, to the eye, rectilinear, and it ran in a way parallel to the course of **a**, though not to the course of **c**, from which it departed somewhat near the west. [Margin: *Rectilinear courses.*] Their whole stay upon the Sun, if all is reckoned, does not seem to have reached thirteen days.

Third. Spot **c** advanced as a single mass, but twinned in its nuclei, which on 1 December appeared separated from each other, up to the 4th; after that both they and the whole spot faded strongly, having taken notable penumbrae and faculae into their company. Its own course deflected somewhat from the straight near the west. [Margin: *The spots and their nuclei fail everywhere at once; in their place penumbra and facula succeed.*]

Rosa Ursina, Book III — Notae particulares (Imago Solis XLIX–L)

Imago Solis XLIX (printed p. 279)

Diagram. A full-page engraved solar disk — the forty-ninth observation-image — filling the page. The disk is crossed by a horizontal diameter (the ecliptic) and a vertical axis. Around and within it run several parallel bands of sunspots, each spot tagged with a day-number and the letters **m** (morning) or **u** (evening), and grouped under letters **a**, **b**, **c**, **d**. Given the density and the heavy verso show-through, many peripheral labels are only partly legible; this figure is a

Readable lettering:

- Top of the disk (axis pole): **z**
- Upper-left inside the rim: **XLIX. IMAGO Obseruationū**, ("Image XLIX of the observations")
- Upper-center: **M.DC.XXV. In Collegio Romano Societatis** ("1625, in the Roman College of the Society [of Jesus]"), flanked by the IHS sunburst emblem and two engraved rose ornaments.
- Upper-right inside the rim: **Nouembris. 4. / Decembris. 2.** (November 4 / December 2 — the counts of observation days).
- Title band across the upper disk: **Cursus Macularū à 25. Nouemb: ad 8. Decembris, similis aliis aliorum annorum.** ("Course of the spots from 25 November to 8 December, similar to those of other years.")
- Left end of the horizontal diameter: **A. Oriens** (A = East)
- Right end of the horizontal diameter: **B. Occidens** (B = West)
- Center of the diameter: **C**; the diameter itself labeled **AB. Ecliptica** (line AB = the ecliptic).
- Bottom of the disk (axis pole): **N** (North), joined to **z** by the vertical axis line.

Spot-trail labels, as legible under magnification (letter + day + m/u):

- Upper band, letter **b**: spots toward the west (right) limb tagged **b 4** and **b 5** (Dec 4, Dec 5); further left along the band **b 30 u** and **b 2** [remaining tags [?]].
- Middle band along the ecliptic, letters **a / c / d**: spots tagged **30 u**, **29 u**, **28**, and toward center **1**, **2 c**, **3 c**, with **a** and **d** markers between them [several tags [?]].

- Lower band, letter **c**: spots tagged **28 m**, **29 u**, **30**, **1** [remaining [?]].
- East (left) limb near A: a spot cluster tagged **25** (Nov 25).
- West (right) limb near B: a spot cluster tagged **c 7 m**, **c 7 u**, **8 c**, **c 8 u** (Dec 7–8) [partly [?]].

Observation tables at the foot of the disk (p. 279)

Columns: **D** = day, **H** = hour (with m = morning / u = evening, time as hour + fraction), **☉.El.** = the Sun's altitude in degrees and minutes.

Nouemb.

D	m/u	H	☉.El.
25	m	8 $\frac{7}{8}$	15. 30
25	u	2 $\frac{1}{8}$	21. 0
28	m	8 $\frac{3}{4}$	13. 0
28	u	3 $\frac{1}{8}$	14. 45
29	m	8 $\frac{7}{8}$	16. 20
29	u	3 $\frac{5}{12}$	12. 40
30	m	8 $\frac{11}{12}$	15. 20
30	u	[numeral: ?]	10. 40

Decemb.

D	m/u	H	☉.El.
1	m	9 $\frac{1}{8}$	15. 25
1	u	3 $\frac{1}{4}$	17. 30 [?]
2	u	2 $\frac{7}{8}$	15. 20
3	u	1 [numeral: ?]	21. 30
4	m	10	21. 40
5	u	3 $\frac{1}{4}$	11. 0
7	m	9 $\frac{7}{8}$	21. 30
7	u	3 $\frac{2}{3}$	11. 20
8	m	9 $\frac{1}{4}$	15. 10
8	u	2 $\frac{1}{3}$	17. 0

Notae in Observationum Imaginem L (printed p. 280)

Notes on Observation-Image L, assembled from six side-tables — of which the first is from Douai, the second from Ingolstadt, and the remaining four from Freiburg — of the years 1621, 1624, 1625, in the months of September, October, and November.

I.

I bring in these tables so that you may see the marvelous consonance in the motion of the spots — even though they are observed in different places, in widely different years, and by different people, and are collected onto observation-circles of entirely different sizes.

Table I was observed at Douai in 1624 by Father Charles Malapert of our Society; it contains the course of spot **a**, observed from 31 August to 5 September.

Although this course is not complete, its fragment is nonetheless quite similar to the course of spot **a** depicted in Image 29 — the spot I myself observed at Rome in 1625 on those same days. Not that the same spots returned, but that other spots ran a similar course, with the same position and disposition relative to the ecliptic, as will be clear to anyone who compares them.

For the rest, several observation-days are missing at the beginning and end of this course — not because the observer's diligence failed, but because there was no spot to observe. Indeed, as the Douai observer noted, on 27, 28, 29, and 30 August nothing was seen on the surveyed Sun; but on the 31st, at an afternoon solar altitude of $8^{\circ}0'$, the observer says, spot **a** appeared — faint and bright, not seen before. Other spots appeared along with it, which are not recorded here. But on the 7th, when the Sun was examined again, it had already disappeared. So this spot was born and died on the Sun.

Moreover, it is evident that this spot did not appear on the Sun on the same date in 1625, from my cited Observation-Image 39, in which — throughout the whole run of those days — the parallel of this spot, proportional to the Roman parallel, was entirely free of any spot. From this it is [certain]

II.

certain, not only from this case, but from countless practical experiments like it. Compare different years, and you will find, when the observations are set side by side, that what I write is true.

[Margin: Spots are not perennial.]

Table II comprises three Ingolstadt courses of spots **a**, **b**, and **c**, first noted on the 5th, which correspond to the Roman courses **b**, **c**, **d** depicted in Image 39. Of these, Ingolstadt **b** corresponds to Roman **c** — but the Roman one advances from the second day and comes closest to the horizon; whereas Ingolstadt **b** corresponds to Roman **c**, and it produced its origin from the 3rd. To Roman **d** corresponds Ingolstadt **a**, which — among the spots newly arisen on the Sun — appeared as new in both places. Now let us follow each one in the order of the days.

[Margin: The faculae seen at Ingolstadt occupy the middle part of the Sun.]

On the 5th, the observer says there were 8 spots by projection [per immissionem], and more by direct inspection, together with faculae, spread across nearly the whole half of the solar disk, intermingled. In the Roman observation you will find at **b**, 11 spots; at **c**, one spot with 12 faculae or more; at **d**, 8 spots. My large observation-circle is therefore better than that small Ingolstadt one.

[Margin: The Roman observation is compared with the Ingolstadt ones.]

On the 7th, the Ingolstadt spots were 5 in all; the Roman ones you will find at **b**, 11; at **c**, one; at **d**, 14.

On the 8th, six spots in all; but spot **b** (which in my own diagram is **c**), the observer says, was composed of several. In the Roman observation there were 10; at **c**, one; at **d**, 8.

On the 9th, 5 spots, through clouds under a not sufficiently clear sky, says the observer. In the Roman one you will see at **b**, at least 16 spots; at **c**, one; at **d**, 4.

On the 11th, 5 spots, says the observer — though spot **c** was divided into two. In the Roman courses, at **b** you have 8 spots; at **c**, one; at **d** likewise one.

On the 12th —

Imago Solis L (printed p. 281)

Diagram. A composite full-page plate — the fiftieth observation-image — that gathers **six** small solar-disk circles (numbered 1–6, though the printed digits are hard to match to circles under the overlap) plus a tiny central figure marked **I**. Each circle carries a date-and-place heading, one or two mini observation-tables, and a spot-trail with day-labels. The plate title reads: **L. Imago Observationum, 6 Tabulas et Cursus Macularum varios complexa, observatos Duaci, Ingolstadij, Friburgi, à diversis Annis 1621, 1624, 1625, Mensibus Septembri,**

Octobri, Novembri ("Image L, comprising 6 tables and various courses of spots, observed at Douai, Ingolstadt, and Freiburg in the different years 1621, 1624, 1625, in the months September, October, November"). Two engraved rose ornaments and the IHS sunburst decorate the field. Because the six circles overlap and the engraved tables are minute and afflicted by verso show-through, cell readings are partial; this figure is a

The six sub-figures, by their legible headings, spot-letters, and mini-tables (table columns: **D** day, **H** hour h.m, ☉.El. Sun's altitude °):

Sub-figure (Freiburg 1621, Sept.–Oct.) — "Cursus Maculae a, à die 26. Septembris ad 6. Octobris, similes aliis aliorum annorum et locorum." Spots **a** tagged 26, 27, 28, 29, 30, 1.

Septemb.:

D	m/u	H	☉.El.
26	m	8. 54	26. 14
27	m	9. 14	28. 30
28	m	9. 5	26. 39
29	m	8. 46	24. 11
30	m	8. 58	25. 29

Octob.:

D	m/u	H	☉.El.
1	m	10. 58	36. 40
5 [?]	u	5. 14	22. 47
5 [?]	m	9. 28 [?]	27. 29 [?]
6 [?]	u	12. 13 [?]	36. 27 [?]

Sub-figure (Freiburg 1621, Oct.) — "Cursus Macularum, b, à die 5, ad 15. Octobris, similes aliis aliorum et locorum" (figure "4"). Spots **b** tagged 9, 10, 11, 13, 14, 15.

D	m/u	H	☉.El.		D	m/u	H	☉.El.
5	m	9. 28	27. 29		1	u	4. 17	11. 10
					1			
8	u	12. 13	36. 27		1	u	3. 50	14. 55
					3			

D	m/u	H	☉.El.		D	m/u	H	☉.El.
9	m	9. 28	26. 4		1 4	m	9. 25	24. 4
1 0	m	7. 58	14. 9		1 5	m	11. 23	30. 40

Sub-figure (Douai 1624, "Duaci in Academico Societatis Iesu Collegio") — "Cursus Maculae a, observatae à die 31. Augusti ad 5. Septembris, similis Romano anni 1625" (figure "3"), with the note **"Augusti die 31. ☉ eleu: vesp. 8.0"** (31 August, Sun's evening altitude 8°0'). Spots **a** (three small marks). No further table legible.

Central figure I (Ingolstadt 1625, "Ingolstadij Anno 1625 in Collegio Academico Societatis Iesu") — "Curs. Macularum a, b, et c, à die 5. ad 15. Septemb. similis Romanis" (figure "2"). Mini-table headed **SEPTEMB. / D — ☉.Eleu.** — largely illegible:

D	m/u	☉.Eleu.
1	m	[numeral: ?]
2	m	[numeral: ?]. 0
3	m	[numeral: ?]. 0
4	m	[numeral: ?]
5	m	10. 0 [?]

Sub-figure (Freiburg 1621, Oct.) — "Cursus Maculae c, à die 25, ad 31. Octobris, similis aliis aliorum annorum et locorum" (figure "5"). Spots **c** tagged 25, 26, 27, 28, 29, 31.

D	m/u	H	☉.El.		D	m/u	H	☉.El.
2 5	m	11. [?]	29. 18		2 8	u	12. 26	28. 15
2 6	u	2. 56	17. 48		2 9	u	12. 56	26. 30
2 7	m	8. 58	16. 48		3 1	u	1. 12	27. 29

Sub-figure (Freiburg 1621, Nov.) — "Cursus Macularum à 16, ad 25. Novembris, similes aliis aliorum annorum et locorum" (figure "6"). Spots **d** tagged 16, 17, 20, 21, 24, 25.

D	m/u	H	☉.El.		D	m/u	H	☉.El.
1	u	12. 15	22. 53		2	m	9. 30	16. 5
6					1			
1	m	9. 15	13. 14		2	m	9. 36	13. 36
7					4			
2	m	10. 0	16. 55		2	m	10. 46	19. 0
0					5			

Printed p. 280 (repeated)

Rosa Ursina, Book III — NOTAE PARTICULARES (folios 281–284)

IMAGO SOLIS — Image L (composite plate)

Diagram. A full-page framed engraving, the fiftieth Image of the Observations. Its engraved title runs across the top of the frame: "L. The Image of the Observations, embracing 6 Tables and the various courses of the spots, observed at Douai, Ingolstadt, and Freiburg in the several years 1621, 1624, 1625, in the months of September, October, and November." The plate is composed of six large solar-disk circles (each ruled with a horizontal diameter A–B), a central Jesuit IHS radiant emblem, and heraldic Tudor-rose ornaments. Each disk carries a heading (place, year, month), one or two small D. H. ☉. El. observation sub-tables, a "Cursus Maculae..." caption, and a row of engraved spots labelled by day. The disks are numbered 1–6.

The dense observation numerals sit at the resolution floor; individual digits flagged [?] are genuinely ambiguous on the tiles.

Disk 3 (upper-left) — Freiburg im Breisgau, 1621; Macula a. Heading: "M.DC.XXI. In the Academic College of the Society of Jesus at Freiburg. September / October." Caption: "Course of spot a, from 26 September to 6 October, similar to others of other years and places." Spots labelled a at days 26, 27, 28, 29, 30, 1.

September (D. m/u. ...)	October (D. m/u. ...)
26. m. 8. 54. 26. 14	1. m. 10. 56. 36. 40 [?]
27. m. 9. 14. 28. 10 [?]	3. u. 3. 14. 22. 47

September (D. m/u. ...)

28. m. 9. 3. 26. 39 [?]

29. m. 8. 46. 24. 11

30. m. 8. 51. 25. 29

October (D. m/u. ...)

5. m. 9. 20. 27. 29 [?]

6. u. 12. 13. 36. 27

Disk 4 (upper-right) — Freiburg, 1621; Macula b. Heading: "M.DC.XXI. In the Academic College of the Society of Jesus at Freiburg. October." Caption: "Course of the spots b, from 5 to 15 October, similar to others of other years and places." Spots labelled b at days 9 [?], 10, 11, 13, 14, 15.

October, col. 1 (D. m/u. ...)

5. m. 9. 28. 27. 29

8. u. 12. 13. 36. 27

9. m. 9. 28. 26. 4

10. m. 7. 58. 14. 9

October, col. 2 (D. m/u. ...)

11. u. 4. 17. 11. 10

13. u. 3. 50. 14. 35

14. m. 9. 25. 24. 4

15. m. 11. 23. 30. 40

Disk 1 (central, upper) — Douai, 1624; Macula a. Heading: "M.DC.XXIV. Douai, in the Academic College of the Society of Jesus." Caption: "Course of spot a, observed from 31 August to 5 September, similar to the Roman [course] of the year 1625." Below: "31 August. Altitude of the Sun in the evening 8. 0." A small inset disk marked "I" carries the label "Vestigia itineraria" (the track's traces) with spots labelled a (Rome). Attached table:

SEPTEMBER — D. ☉. Elev.

1. m. — 8. 0

2. m. — 13. 0

3. m. — 11. 0

4. m. — 13. 0

5. m. — 10. 0

Disk 2 (central, lower) — Ingolstadt, 1625; Maculae b and c. Heading: "Ingolstadt, in the year 1625, in the Academic College of the Society of Jesus." Caption: "Course of the spots b and c, from 5 to 15 September, similar to the Roman [courses]." A horizontal band of spots labelled b and c (with day-numbers 5–11, individually too small to resolve — [?]). Triple observation table (September); values dense and low-confidence:

September, col. 1	col. 2	col. 3
5. m. 8. 36. 29. 15 [?]	9. m. 1. 29. 42. 11 [?]	12. m. 9. 50. 37. 15 [?]
7. m. 1. 56. 41. 16 [?]	11. m. 8. 38. 28. 35 [?]	14. m. 9. 12. 32. 30 [?]
8. m. 1. 35. 29. 6 [?]	12. m. 8. 30. 27. 8 [?]	15. u. 1. 6. 41. 45 [?]

Disk 5 (lower-left) — Freiburg, 1621; Macula c. Heading: "M.DC.XXI. In the Academic College of the Society of Jesus at Freiburg. October." Caption: "Course of spot c, from 25 to 31 October, similar to others of other years and places." Spots labelled c at days 25, 26, 27, 28, 29, 31.

October, col. 1 (D. m/u. ...)	October, col. 2 (D. m/u. ...)
25. m. 11. 35. 29. 14 [?]	28. u. 12. 25. 28. 15 [?]
26. u. 2. 56. 17. 48	29. u. 12. 56. 26. 30
27. m. 8. 58. 16. 48	31. u. 1. 12. 27. 29

Disk 6 (lower-right) — Freiburg, 1621; Macula d. Heading: "M.DC.XXI. In the Academic College of the Society of Jesus at Freiburg. November." Caption: "Course of the spots from 16 to 25 November, similar to others of other years and places." Spots labelled d at days 16, 17, 20, 21, 24, 25.

November, col. 1 (D. m/u. ...)	November, col. 2 (D. m/u. ...)
16. u. 12. 15. 22. 53 [?]	21. m. 9. 30. 16. 5
17. m. 9. 15. 13. 14	24. m. 9. 36. 13. 36
20. m. 10. 0. 16. 55 [?]	25. m. 10. 46. 19. 0

ROSAE VRSINAE LIB. III.

[Notes to Image L. The page is set in two columns headed I and II; the centered numerals and the marginal five-line numbers are printing apparatus.]

I.

On the 12th day: spot 4, with very many faculae, so the observer says. In the Roman observation you will find at b five spots, with two umbrae and three brilliant faculae; at c one spot; at d one spot with two umbrae and one bright facula.

On the 13th: two spots seen through cloud, with many faculae. In the Roman observations you have at b three spots, set about among faculae, with a very large umbra; at c one spot; at d one spot with a facula touching the horizon.

On the 14th: one western spot seen through cloud. At Rome, at b one spot with two umbrae and faculae, at c one spot.

On the 15th: one western spot, just as in the Roman observation too.

On the 16th nothing further was noted about this spot at Ingolstadt; but at Rome you will see the same spot, now nearly at the margin, together with six clear and bright faculae, under the letter c.

The itinerary traces of these spots are plainly alike among themselves; and just as at Rome they stand farther apart at their rising and gradually converge toward their setting, so exactly the same thing follows from the Ingolstadt observations as well — nor on either side were the courses of the spots parallel. From this it necessarily follows that the spots have no parallax on the Sun. As for the fact that so few spots were seen there [at Ingolstadt] and so many at Rome, and the like — you will assign that to the very great observing circle, and so forth, which those small ones will never match. Indeed, the helioscopes employed at Ingolstadt do not attain their power either.

[Margin: From the complete correspondence of the observations, parallax is eliminated.]

II.

TABLE III was observed at Freiburg im Breisgau in the year 1621, and the observer noted that the faculae — carried in at the spot's ingress, drawn along behind the spot, then toward the first, indeed right up to 5 October — kept increasing every day. Likewise it was seen wrapped in a cloud, which is only to say that the spot bore a womb heavy with a nucleus, first one, then, as it appears, two. You will find a course similar to this in Image 42, spot d, and in Image 43, spot a. On the 27th this spot at once acquired three others, and on the following days, up to 3 October, still more companions; and when these were spent, on 5 October it appeared again alone, and so remained right up to its exit.

TABLE IV presents the course of the spots b, observed from 5 to 15 October in the same year and place. On the 6th they showed through cloud as a single mass. In the first days they were more numerous, but as the smaller ones gradually failed, from the 13th to the 15th a single one alone remained visible as it went out. This course is not unlike the aforesaid course of spot a in Image 43, except that here it lies far from the ecliptic. Likewise the course of spot a in Image 44.

[Margin: A course much declining from the ecliptic.]

TABLE V contains the course of spot c, in the same place and year, from 25 to 31 October. You will find it similar in Image 45; the run from spot b conforms itself somewhat to a straight line.

TABLE VI reports, from the same place and year, the course of the two southern spots d, together with the companion spots gained and lost, and likewise the nuclei and the clouds wrapped about the nuclei. It corresponds to the courses of spots c and h shown in Image 47. Everywhere straightness asserts itself.

[Margin: Courses of different years and places [are] alike.]

IMAGO SOLIS — Image L (duplicate impression)

Diagram. This leaf (folio 283) bears the same composite plate as folio 281 — Image L, "The Image of the Observations, embracing 6 Tables and the various courses of the spots, observed at Douai, Ingolstadt, and Freiburg..." The engraved title, the six numbered solar disks (Freiburg/Douai/Ingolstadt, 1621/1624/1625), the IHS emblem, and the rose ornaments are identical to those on folio 281. On the tiles the disk headings and the D. H. ☉. E1. sub-tables of folio 283 match those transcribed for fig-p409-1 above; this is a duplicate impression of the same plate, not a distinct figure. See fig-p409-1 for the full transcription of disks 1–6.

ROSAE VRSINAE LIB. III.

Notes on the fifty-first Image of the Observations — the third [series] of December, from the 3rd to the 14th of the same [month].

[Two columns, headed I and II; centered numerals and marginal line-numbers are apparatus.]

I.

First. Spot a, a northern spot, born on the Sun and at the outset seen single, on the evening of 3 December; then, greatly enlarged and multiplied on the following days, around its setting it could not be observed because of the sky's ill weather. It ran a course that was to the eye rectilinear, and around its setting it was very bright with faculae on the ninth day. The spreadings-apart of the spots, however, into every difference of place always grew greater away from one another; and those that touched one another in the middle were, around the exit, separated.

Second. Spot b lasted only two days, and made its itinerary segment somewhat oblique to the others.

Third. Spot c, likewise northern and simple, grew in a short time from a slender beginning into a large and great brood, and around its exit drew after itself a great number of umbrae bearing faculae. It did indeed complete a rectilinear track, but one not everywhere parallel to the track of spot a — which it somewhat approached around its setting.

[Margin: The spots grow, and recede from one another in every direction.]

II.

(continuation of the Third note) ...bearing faculae, it drew after itself. It did indeed complete a rectilinear track, but one not everywhere parallel to the track of spot a, which it somewhat approached around its setting.

[Margin: The tracks [are] not parallel.]

Fourth. Spot d, arising as a solitary southern spot, took on several companions; on the 14th, near the horizon, it drew after itself notable umbrae and faculae. It always moved parallel to spot c, and proved equal to it in duration and similar in motion — which on both sides was, to the eye, rectilinear.

[Margin: The tracks [are] parallel.]

Fifth. The spots e, northern, ran a short circuit — yet one like and proportional to the others — and failed in the very course of their run, just as they had been generated almost at the middle of the Sun.

Sixth. Spot f, southern, showed itself with notable faculae and minute umbrae, and with these same it snatched itself from view. Yet, keeping to the track common to all, rectilinear, it neither began at the beginning nor reached the end.

Rosa Ursina, Book III — NOTAE PARTICULARES (Solar images LI–LIII, December 1625)

[Solar image LI — engraved plate]

LI. Image of the observations. — M.DC.XXV. — In the Roman College of the Society [In Collegio Romano Societatis]. — 3 December.

Diagram. A full-page engraved circle representing the projected disk of the Sun. At the top center is the Jesuit emblem of the Collegio Romano — a radiant IHS

monogram in a sunburst roundel, flanked by two heraldic roses — beside a decorative initial block. Reference labels around the disk:

- Z (top of circle): Zenith
- N (bottom of circle): Nadir
- A (left end of the horizontal diameter): **Oriens** (East)
- B (right end of the horizontal diameter): **Occidens** (West)
- A,B (the horizontal diameter line itself): **Ecliptica** (the ecliptic)
- C (center of the disk): the center point

Caption beneath the emblem: *Cursus Macularum, à 3. Decembris, ad 14. eiusdem, similis aliis aliorum annorum* — "The course of the spots, from 3 December to the 14th of the same [month], similar to [those] of other years."

The upper (boreal) half of the disk carries several sunspot groups, lettered **a–f**, drawn at successive daily positions and migrating from the eastern limb (A) toward the western limb (B). Readable day-numbers set beside the clusters include **7, 8, 9, 11, 13, 14**, several carrying a subscript **u** (evening) or **m** (morning). Legibly, two small spots lettered **c** stand near the western limb at day-numbers **13** and **14** (the westernmost); a large mottled group lettered **f** (with an adjacent **d**) lies below and left of center; a spot lettered **e** appears with day-numbers **8, 9, 11** **[?]**; groups lettered **a** and **b** carry day-numbers **7, 8, 9** **[?]**. The remaining per-spot letters and day-numbers are largely obscured by verso show-through and cannot be resolved individually — flagged **[?]**. (many spot micro-labels unresolved).

DECEMBRIS observation table (printed at lower center of the plate, in two side-by-side blocks). Columns: *D.* = Dies (day); *H.* = Hora (hour); ☉ *Ele.* = Solis Elevatio (Sun's elevation, in degrees.minutes). A small divider symbol separates the two blocks.

Dies	Hora	☉ Ele.
3 u	3½ [?]	0.40 [?]
4 m	10¾ [?]	21.40
7 m	9⅞	21.30
8 m	11⅞	25.0
9 u	3¼	12.40
11 m	—	12.0
13 m	9¾	18.30
14 m	9 [?]	14.15

Notes on solar image LII

Notes on the LII image of the observations — the fourth of December, from the 7th to the 16th of the same [month].

First. The boreal spots *a* could not be observed before the 7th, because the 6th, being rainy, entirely took away any chance of observing; and on the evening of the 5th nothing was noticed about them. On the 7th they lay clustered among the most brilliant faculae, which I sketched partly along their straight track and partly to the sides. Yet the spots dragged the greater and more important part [of the faculae] behind and to the sides of themselves rather than pushing it ahead — indeed they carried almost nothing in front of themselves, especially on the eighth day, as can be seen in the lateral figure.

[Margin: The faculae follow rather than precede.]

Second. On the morning of the 8th the spots were somewhat unchanged, and the faculae were seen to be sparser.

Third. On the evening of the 9th the faculae had all but vanished, and the spots facing us were smaller and fewer than they had been the day before.

Fourth. The 10th was hopeless from the inclemency of the sky, and the eleventh was not much better; what it did allow, at the given hour, was as if snatched. Hence if anything perhaps had deflected from its path, this should not be credited to the spots' course but to the haste that observing required.

Fifth. The 12th was again stormy; the evening of the 13th was middling.

14. [The image of the 14th] presents the true situation, course, figure, and magnitude of the spots; here you see the following ones to be much attenuated.

Sixth. The 15th seemed to restore the spots, the faculae, and the shadows [umbrae], for about the appearance shown there is no reason to doubt: I bring everything forward most faithfully, adding nothing and taking nothing away.

Seventh. The 16th shows the final aspect of the spots and faculae, and of the shadows as well; for on the following day, the 17th, the inclemency of the sky again [prevented it], and I could observe nothing.

Eighth. Meanwhile I would ask you to consider how great a dissimilarity has arisen — in position and distance — between the western spots, faculae, and shadows and the eastern ones. Then, how the faculae and shadows for the most

part follow or crowd around the spots rather than precede them, and so on. Likewise that they no longer came together in proportion. For the westernmost spot of the 15th is only as far from the center C as the easternmost of the 7th; and yet the westernmost of the 15th is much farther from its own westernmost [spot], and much nearer the center, than the westernmost of the 7th was from its own easternmost — and it stands farther from the center than that one does. This is nearly a constant feature of this phenomenon.

[Margin: The distance of the spots [is] greater than uniform motion would allow.]

Ninth. The course is, to the senses, still nearly rectilinear.

[Solar image LII — engraved plate]

LII. Image of the observations. — M.DC.XXV. — In the Roman College of the Society. — 4 December.

Diagram. A full-page engraved circle representing the projected disk of the Sun, of the same design as the LI plate. At the top center, the Jesuit IHS-sunburst emblem flanked by two heraldic roses, beside a decorative initial block.

Reference labels:

- Z (top of circle): Zenith
- N (bottom of circle): Nadir
- A (left end of the horizontal diameter): **Oriens** (East)
- B (right end of the horizontal diameter): **Occidens** (West)
- A,B (the horizontal diameter): **Ecliptica**
- C (center): the center point

Reference-label line across the middle: *A, Oriens; B, Occidens; A,B, Ecliptica.*

Caption: *Cursus Macularum, à 7. Decembris, ad 16. eiusdem, similis aliis aliorum annorum tempore eod[em]* — "The course of the spots, from 7 December to the 16th of the same [month], similar to [those] of other years at the same time [of year]."

The disk carries the sunspot groups tracked from 7 to 16 December, lettered chiefly **a** (with subordinate **b**, **d**), drawn at successive daily positions. Readable day-numbers beside the clusters include **7**, **8** (near the eastern limb, left/boreal region) and **13**, **14**, **15**, **16** (progressing toward the western limb), several carrying subscript **m** (morning) or **u** (evening). Legibly: a group lettered **a** near the eastern limb at day **7** [**u**]; a chain of spots across the upper disk with day-numbers **13**, **14**, **15** (each **m**); a cluster lettered **a** at day **16** **m** toward the west; and a separate **a/15**

m group. The remaining small spot letters and day-numbers are obscured by show-through and cannot be resolved individually — flagged [?]. (many spot micro-labels unresolved).

DECEMBRIS observation table (lower center of the plate, two side-by-side blocks). Columns as on the LI plate: *D.* = day; *H.* = hour; ☉. *Ele.* = Sun's elevation (degrees.minutes).

Dies	Hora	☉ Ele.
7 m	10¼ [?]	23.0
7 u	3⅔	11.20
8 m	9¼	15.10
8 u	2⅔	17.0
9 u	3¼	12.40
11 m	—	13.10
13 u	2	20.0
14 m	9⅕ [?]	14.15
15 m	9⅛	13.40
16 m	9½	16.0

Notes on solar image LIII

Notes on the LIII image of the observations — the fifth of December, from the 13th to the 23rd of the same [month].

First. The austral spots *a*, on the 13th, were still almost contiguous among themselves, and were hemmed in by lateral faculae.

Second. Over the three following days they were pulled apart more, but at the same time were reduced in mass, while increasing in number and in the distances between them — [so that] more than uniform motion was undergone.

Third. On the 18th and thereafter they grew in number, in mass, and in separation.

Fourth. On the 22nd and 23rd they were again joined in longitude but stretched out in latitude, and very brilliant faculae were added. The incredible approach of these spots toward the horizon — nearly equal [for all] — is very much to be marveled at, given that around the middle [of their course] they had stood so far

apart from one another. But similar things are frequently observed in other courses.

[Margin: The spots' reclining toward the horizon [is] customary indeed, yet astonishing.]

Fifth. On the 24th the spot *d*, with its faculae, was carried up over the horizon from the side; and yesterday's spots *a* were certainly not far removed from these — most assuredly.

Sixth. The course of these spots was, through the middle [of the disk], still nearly rectilinear, and similar to the one noted and observed the previous year; measured by its extreme ends it is curvilinear — convex toward the ecliptic and concave toward the nadir. Its duration, if the reckoning is carefully pursued, will be of days, more or less, thirteen. As the chords draw nearer the ecliptic, the inclination increases, and

[Margin: The curvature, and the inclination of the chords to the ecliptic, begins; the austral pole ascends.]

the angle of inclination is diminished, the obliquity and curvature of the track grows, the antarctic pole is turned toward the west in the quadrant of the ascending semicircle, and rises from the setting toward the rising. The itinerary direction of the spots runs from the austral rising toward the boreal setting.

Seventh. The spots *b*, having arisen in the middle of the Sun, increased and multiplied over three days; then, weakened, they passed out [of view] with shadows and faculae. Their semicircle [i.e. the traverse of the visible half-disk] was of six days and about 6 hours.

Eighth. The same is asserted of the spots *c*, which pursued their semicourse over more than six days; it curved back to the ecliptic and ran parallel to the spot *a*, and they passed out with shadows and splendid faculae. These same spots, when disjoined in the middle [of the disk], appeared darker where they came together near the exit.

[Margin: The distance of the spots [is] greater than uniform motion would allow.]

Hence you have [this]: that for such rectilinear tracks, the differences in the time during which the spots tarry beneath the Sun are not as great as they usually are; whereas for the most curvilinear motions — there indeed, among the austral courses and the boreal differences of the motions — they nearly equal a whole day, while here they scarcely differ by a few hours.

[Margin: The differences of the itinerary tarryings [are] small at this time.]

Moreover you have this too: from observation-circles so small, the perfect rectitude and curvature of the apparent motions cannot be securely learned and established unless other aids are brought to bear — because the horizontal appearances of the spots are, in these [small circles], very rarely seen. For if you set aside the last days, the course of the spots *a* will without doubt be established as rectilinear.

IMAGO SOLIS LIII (folio 289)

Diagram. Full-page engraved plate of the solar disk (the fifty-third observation image), the projected image of the Sun with its sunspots, drawn at the Collegio Romano of the Society [of Jesus] in the year 1625. The large circle is the solar disk; a horizontal diameter is the ecliptic, running from **A** (left) to **B** (right). Orientation letters **Z** at the top of the disk and **N** at the foot. Between them are set the printed rose devices and the IHS monogram of the Society of Jesus.

Engraved lettering on the plate:

- Upper left: "LIII. Imago Observationum." ("LIII. Image of the observations.")
- Upper center: "M.DC.XXV. In Collegio Romano Societatis." ("1625. At the Collegio Romano of the Society.")
- Upper right: "5. Decembris." ("5 December.")
- Center: "Cursus Macularum à 13 Decembris, ad 23, eiusdem, similis anni prioris, et" ("The course of the spots from 13 December to the 23rd of the same, like that of the previous year, and...")
- Left, on the diameter: "A, Oriens; B, Occidens; A.B. Ecliptica." ("A, East; B, West; A.B. the ecliptic.") — an inverted (telescopic) view, with East at the left.

Sunspot tracks drawn on the disk, with the observed spot-clusters marked by day-number and by the letters a, b, c, d. Readable labels, grouped by band (many micro-labels remain ambiguous even under magnification and are flagged below):

- A band just below the top, along and above the ecliptic (left to center): clusters marked with days 13, 14, 15, 16, 18, 19, 20 and letters b and c.
- Upper right, near the limb: clusters at days 18, 19, 23, 24 with letters b and c.

- Along the ecliptic (near center **C** and toward **B**): scattered points lettered a and d at days 18, 19, 20, 22, 23, 24.
- Lower left, inside the disk: a small cluster at days 13, 14, 15, 16 lettered a.
- Additional faint spot-letters near the right (western) limb: [?].

Engraved table of observation times on the plate (headed DECEMBRIS), in two sub-columns divided by a ☿ (Mercury) symbol. Column heads: **D.** (day) — **H.** (hour; m = morning) — ☉ **Ele.** (the Sun's altitude, in degrees and minutes):

D.	H.	☉ Ele.		D.	H.	☉ Ele.
13.	m. 9¾	18. 30.		19.	m. —	18. 30.
14.	m. 9½	14. 15.		20.	m. 10.	19. 0.
15.	m. 9¼	13. 40.		22.	m. —	23. 30.
16.	m. 9½	16. 0.		23.	m. 10¼	21. 0.
18.	m. —	16. 10.		24.	m. 10¾	21. 30.

290 — ROSAE VRSINAE LIB. III. (folio 290)

Notes on the LIV Observation Image — the sixth of December and the first of January of the year 1626, from 15 December to 7 January

[Verbatim: "Notae in LIV. Observationum Imaginem, sextam Decembris, & primam Ianuarij anni 1626. à die 15. Decemb. ad 7. Ianuarij."]

[Column-head numeral: I.]

[Margin: The curvilinear motion toward the south — concave, and now wholly more evident.]

First: all these spots now, plainly and without the slightest scruple of doubt, curve in their course. Those that lie in the northern region make arcs concave toward the ecliptic; those in the southern region, convex arcs; and those in both regions, partly convex and partly concave. You have examples of the concavity in spots b and d, of the convexity in e, and of both together in a and c. The arctic pole lies hidden below, the antarctic is exposed above the hemisphere, and the convexity of the courses faces toward the [antarctic] pole, their concavity toward the [arctic] one; and this holds from December right through to June, over six months.

Second: spot a — southern and northern — at first single and oblong, in the sequel split in two, then joined again. It drew facula e behind it at its ingress; and the inclemency of the weather robbed us of its egress, which would otherwise have been worth seeing.

Third: for the same reason you have neither the ingress nor the egress of spot b, which was large, black, and full of nuclei. It drew behind it a very intense facula. Its nucleus gradually divided and slowly opened itself into two spots, yet never showed them wholly separated: the gap between them shone brighter than the rest of the Sun, like an intense facula; and although the spots were never entirely disjoined, the nuclei nevertheless, once the hiatus had formed, remained separated all the way to egress. Around egress it presented again a facula and umbra not unlike the eastern one, but both this spot and those [faculae] were much diminished. Note that the nuclei, around egress, grow slender no less than does the vapor or exhalation surrounding them.

[Margin: The nuclei also grow slender near the horizons.]

The course [of this spot —

[Column-head numeral: II.]

— is parallel to the course of spot a.]

Fourth: spots c, southern and northern, out of a tangled heap were reduced first into two spots and then into one, and toward the end gave birth to enormous faculae; on the 24th they settled onto the track of spots a, from which, however, they gradually withdrew southward.

Fifth: spot d, northern, trailing faculae behind it, gradually — and after mid-course — failed entirely. It completed a motion roughly parallel to spot e, but not to spot b, which it gradually approached.

Sixth: spots e — three of them, with a facula in the middle — dilated and multiplied themselves beyond measure, and never at egress contracted to the narrow limits they had shown at ingress. They carried gleaming faculae westward with them; and there, moreover, several merged into one, the bright interval between them being obliterated, so that the spot lasted, dense and black, all the way to the horizon. It is certain that this spot lingered on the Sun for at least 13 days, if the intervals between it and the horizon are rightly weighed. Its track, judged from the trail-marks of the tracks of spots a and b, withdrew more and more toward the south.

[Margin: The tracks of the spots are some parallel to others, some not parallel, at the same time.]

Seventh: spots f were northern umbrae [shadow-patches] with thin faculae clinging to them, very close to the northern pole. But I bring these forward only as a sample, because they are very often seen, over practically the whole Sun; yet on account of their faintness, their multitude, and their mutability they cannot readily be recorded in the ordinary way — for they rarely last many days, though they move like the spots, and are beyond doubt the seeds of the spots, as I have sufficiently shown from what has been observed so far.

[Margin: The umbrae [shadow-patches] are the seed of the spots.]

IMAGO SOLIS LIV (folio 291)

Diagram. Full-page engraved plate of the solar disk (the fifty-fourth observation image), projected at the Collegio Romano in 1625–1626. The large circle is the solar disk; the horizontal diameter is the ecliptic, from **A** (left) to **B** (right). Orientation letters **Z** at the top and **N** at the foot; rose devices and the IHS monogram set below the upper caption.

Engraved lettering on the plate:

- Upper left: "LIIII. Imago Observationu[m]." ("54th. Image of the observations.")
- Upper center: "M.DC.XXV. In Collegio Romano Societatis." ("1625. At the Collegio Romano of the Society.")
- Upper right: "6. Decembris, / 1. Ianuarij. 1626." ("6 December, / 1 January 1626.")
- Center: "Cursus Macularum à 15. Dec: anni 1625, ad 7. Ian: anni 1626. similis aliis aliorum annorum." ("The course of the spots from 15 December of the year 1625 to 7 January of the year 1626, like that of the other years.")
- Left: "A. Oriens." ("A, East.") — Right: "B. Occidens." ("B, West.") — Center, on the diameter: "A.B. Ecliptica." ("A.B. the ecliptic.")
- Near the center-top, a facula labelled "20 f" (spot f, at day 20).

Sunspot tracks drawn as three broad bands crossing the disk; the clusters are marked by day-number and letter. This plate is very densely lettered; readable labels, grouped by band (individual day/letter pairs are at or below the tile legibility floor):

- Boreal band (above the ecliptic): heart-shaped spots lettered b at days 22, 23, 24, 25, 27, 28, 30, 31, 1, and spots lettered d at days 27, 28, 30, 31.
- Along the ecliptic (A–B): spots lettered a and c at days 15, 16, 18, 19, 20, 22, 23, 24, 25, 27, 28, 30, 31, with a large c-cluster near the western limb (B).
- Austral band (below the ecliptic): spots lettered e at days 27, 28, 30, 31 on the left, and a large austral cluster near B lettered e at days 1, 2, 4, 5, 6, 7.
- Several further limb-clusters and micro-labels: [?].

Engraved table of observation times on the plate, in three sub-columns under the headings **DECEMBER. 1625.** (first two sub-columns) and **IANVAR. 1626.** (third), divided by ☿ (Mercury) symbols. Column heads: **D.** (day) — **H.** (hour; m = morning, u = evening) — ☉ **El.** (the Sun's altitude, degrees and minutes):

								D		
D.	H.	☉ El.		D.	H.	☉ El.		.	H.	☉ El.
1	m. 9½	13. 40.		24.	m. 10¾	21. 30.		1	m. 9¾	16. 20.
5.								.		
1	m. 9½	16. 0.		27.	m. —	14. 50.		2	m. 11½	24. 25.
6.								.		
1	m. —	18. 30.		28.	u. —	10. 45.		4	m. 10	20. 0.
9.								.		
2	m. —	17. 50.		30.	m. —	22. 30.		5	m. 9¾	18. 20.
0.								.		
2	m. —	23. 30.		31.	m. 11½	24. 20.		6	m. 10 2/4	22. 30.
2.								.		
2	m. 10¼	21. 0.		*25	m. 9¾	15. 50.		7	m. 9½	17. 45.
3.				.				.		

[The following page is a duplicate scan of folio 290 ("Notae in LIV...", the same letterpress note translated above); its content is not re-translated. See QA report.]

IMAGO SOLIS LIV.

Diagram. A full-page engraved solar disk (the 54th "Image of the Observations"). The disk is oriented with the north pole **Z** at the top and the south pole **N** at the bottom; the horizontal diameter runs from **A** (Oriens [East]) at the left to **B** (Occidens [West]) at the right and is labelled **A.B. Ecliptica** [the ecliptic], with the centre marked **C**.

Legends inside the disk:

- Top-left: **LIIII, Imago Obseruationu[m]** — "54th, Image of the Observations."
- Top-centre: **M.D.C.XXV. In Collegio Romano Societatis** — "1625, in the Roman College of the Society [of Jesus]," flanked by a Tudor-rose device and the Jesuit IHS sunburst emblem.
- Top-right: **6. Decembris, 1. Ianuarij. 1626** — "6 December[;] 1 January 1626."
- A small spot lettered **f** beside a **20°** mark, just below the central emblems.
- Centre caption: **Cursus Macularum à 15. Dec: anni 1625, ad 7. Ian: anni 1626. similis aliis alioru[m] annorum** — "The course of the sunspots from 15 December of the year 1625 to 7 January of the year 1626, like those of other [such intervals] in other years."
- Left edge: **A, Oriens** [East]. Right edge: **B, Occidens** [West].

Three roughly parallel, dashed spot-tracks cross the disk from the eastern limb toward the western:

- **Boreal (upper) track** — spots lettered **b** and **d**; readable day-marks: 22, 23, 24, 25, 27, 28, 30, 31, 1.
- **Ecliptic (middle) track**, through **C** — spots lettered **a** and **c**; readable day-marks: 18, 19, 20, 22, 23, 24, 25, 27, 28, 30, 31, with a dense **c**-cluster at the western limb **B**.
- **Austral (lower) track** — spots lettered **e**; readable day-marks: 27, 28, 30, 31, and a large **e**-cluster near the western limb marked 4, 5, 6, 7.

The individual spot-to-label-to-day assignments within the crowded western (**B**-side) clusters are not fully resolvable at this resolution and are flagged [?] for the per-spot micro-labels.

Foot-table (below the disk): observation records, with columns **D.** (dies [day]), **H.** (hora [hour]; m = morning, u = evening), and $\odot$ **El.** (the Sun's altitude, in degrees and minutes).

D.	H.	$\odot$ El.	D.	H.	$\odot$ El.	D.	H.	$\odot$ El.
DECEMBER 1625			DECEMBER 1625			IANVAR. 1626		
15	m.	13.	24	m.	21.	1	m. 9¼	16.

D.	H.	⊙ El.	D.	H.	⊙ El.	D.	H.	⊙ El.
	9 $\frac{1}{8}$	40		10 $\frac{3}{8}$	30			20
16	m. 9 $\frac{1}{2}$	16. 0	27	m.	14. 50	2	m. 11 $\frac{1}{8}$	24. 25
19	m.	18. 30	28	u.	10. 45	4	m. 10	20. 0
20	m.	17. 50	30	m.	22. 30	5	m. 9 $\frac{5}{8}$	18. 20
22	m.	23. 30	31	m.	24. 11 $\frac{1}{8}$	6	m. 10 $\frac{2}{4}$	22. 30
23	m. 10 $\frac{1}{4}$	21. 0	*25	m.	15. 9 $\frac{3}{4}$	7	m. 9 $\frac{1}{2}$	17. 45

Notes on the 55th Image of the Observations — the second [Image] of January, from the 1st day to the 15th of the same [Notæ in LV. Obseruationum Imaginem, Ianuarij secundam, à 1. die ad 15. eiusdem]

I.

First: spot **a**, in the north, appeared single at its rising [the eastern limb]. On the 5th it acquired a companion behind it and a facula reaching northward like a comet's [tail]; when this was lost it added [further] companions, and toward setting [the western limb] it then displayed umbrae and faculae. It followed a curved path, but the extremities of that path — taken at the limb — lie unequally distant from the ecliptic; and so a chord drawn through them cuts the ecliptic at some point. It lasted on the Sun twelve and a half days at the very least. [*medium minimum* — reading of "and a half, at the least"; {?]]

[Margin: The demise of a spot on the ecliptic.] Second: spot **b**, alone at its rising, took on many new companions as it advanced; consumed little by little along with them, it passed off into faculae, and did not quite reach its setting. It crossed the ecliptic, and perished on it. It travelled parallel to spot **a**.

[Margin: The prodigious dilation and multiplication of the **c**-spots out of umbrae, and their reversion into umbrae.] Third: spot **c**, composed of three or four [spots], appeared as one at its ingress, but thick and dense, leading behind it a train of other southern spots, likewise of umbrae, and also of remarkable faculae. Its

beginning at the limb on the 3rd could not be caught, owing to atmospheric turbulence; and as its faculae disappeared it unfolded itself wonderfully into copious spots —

II.

— which, gradually failing in bulk and density, again passed off into faculae and umbrae. On the evening of the 15th it nearly touched the limb, from which it was so little distant that the intervening space, in slenderness and fineness, scarcely equalled a spider's thread and all but eluded the eye's sharpness — although the spot itself still moved on fairly thick. Its duration, on every reckoning, seems to have reached about 13 days; just as spot **d** too, which nearly ran together with spot **e**, was not far above the limb from these same [spots] — which is worth noting, and in this phenomenon is not so common. Moreover, just as **c** entered the Sun with its spots, umbrae, and faculae, so it went out with a still greater retinue of them, itself always leading in front, dragging the rest to its sides or behind it.

[Margin: The spots draw the faculae either behind them or to the side.] Fourth: spot **d**, having entered with faculae, went out with the same, and gradually approached spot **c**. The rest is plain enough from a bare inspection of the diagram.

[Margin: The convergence of the tracks toward one another.] Fifth: the course of spot **c** resembles the course of spot **a** a year ago, described in the second Image of the Observations, on the same days, in nearly the same position, and with the same length of duration. Consult the figure, compare the traces of the tracks, and you will agree with the truth.

IMAGO SOLIS LV.

Diagram. A full-page engraved solar disk (the 55th "Image of the Observations"), oriented like the previous plate: north pole **Z** at the top, south pole **N** at the bottom, **A** (Oriens [East]) at the left, **B** (Occidens [West]) at the right, the horizontal diameter labelled **A.B. Ecliptica** [the ecliptic], centre **C**.

Legends inside the disk:

- Top-left: **LV, Imago Obser:uationu[m]** — "55th, Image of the Observations."

- Top-centre: **M.DC.XXVI. In Collegio Romano Societatis** — "1626, in the Roman College of the Society [of Jesus]," flanked by a rose device and the IHS emblem.
- Top-right: **2^a Ianuarij** — "the 2nd [Image] of January." [?]
- Centre caption: **Cursus Macularum à 1. Ianuarij, ad 15. eiusdem, similis anni praeteriti, 1625** — "The course of the sunspots from 1 January to the 15th of the same, like [that] of the previous year, 1625."
- **A, Oriens** [East]; **B, Occidens** [West]; **A.B. Ecliptica**.

Spot-tracks (all running from the eastern limb westward):

- **Boreal (upper) track** — spots lettered **a**; readable day-marks: 4, 5, 6, 8, 9, 10, 11.
- **A track of spots lettered d** below the **a**-track — readable day-marks: 8, 9, 10, 11, 12, 13, 14, several near the western limb carrying a subscript **m** (morning) or **u** (evening) (e.g. 12, 13, 14).
- **Ecliptic track** (through **C**) — spots lettered **b** (days 5, 6, 7, 8, 9, 10, 11) and **c** (days 6, 7, 8, 9, 10, 11, 12, 13, 14, 15); dense **b**- and **c**-clusters crowd the western limb **B**, some with **m/u** subscripts (e.g. 15_m, 15_u).
- Near the eastern limb **A**: an **a**-cluster marked 2, a **d**-mark near 4, and a **c**-cluster (4, 5), together with a **b**-spot marked 2 (with **u** = evening) and one looped/curled spot outline.

The western (**B**-side) clusters are extremely dense; the individual spot-to-label-to-day assignments there are not fully resolvable at this resolution and are flagged [?] for the per-spot micro-labels.

Foot-table (below the disk): **IANVARII** [of January]. Columns **D.** (day), **H.** (hour; m = morning, u = evening), **☉ El.** (the Sun's altitude, degrees and minutes).

D.	H.	☉ El.	D.	H.	☉ El.
IANVARII			IANVARII		
1	m. 9 ³ / ₈	16. 20	9	u. 3 ¹ / ₈	14. 30
2	m. 11 ¹ / ₈	24. 25	10	u. 1 ³ / ₈	22. 30
2	u.	18. 30	11	m. 9 ³ / ₈	15. 50
4	m. 10	20. 0	12	u.	11. 0
5	m. 9 ⁵ / ₈	18. 20	13	m. 9	14. 40
6	m. 10 ¹ / ₂	22. 30	13	u. 3	15. 0
7	m. 9 ¹ / ₂	17. 45	14	m. 9 ¹ / ₄	15. 0

D.	H.	⊙ El.	D.	H.	⊙ El.
8	u. 3	15. 0	15	m. 9½	18. 40
			15	u. 3½	12. 0

Diagram. Full-page engraved solar-disk plate, the fifty-fifth observation image (IMAGO SOLIS LV), showing the course of the sunspots over the solar disk from 1 to 15 January 1626, observed at the Collegio Romano of the Society [of Jesus].

Legends around and within the disk:

- Top-left: "LV, Imago Observationum." (LV, Image of the Observations.)
- Top-center: "M.DC.XXVI. In Collegio Romano Societatis" (1626. In the Roman College of the Society), flanked by two heraldic-rose ornaments with the Jesuit IHS-sunburst emblem between them.
- Top-right: "2^a Ianuarij" (the second [image] of January).
- Below the emblems, spanning the disk: "Cursus Macularum à 1. Ianuarij, ad 15. eiusdem, similis anni praeteriti, 1625." (The course of the spots from 1 January to the 15th of the same, similar to [that] of the previous year, 1625.)
- Across the middle of the disk: "A, Oriens, B, Occidens; AB, Ecliptica." (A, East; B, West; AB, the Ecliptic.)

Orientation marks on the limb: **Z** at top and **N** at bottom (the vertical diameter); **A** at the left (East/Oriens), **B** at the right (West/Occidens); **C** marks the center. The horizontal line A–B is the ecliptic.

Two dotted spot-tracks cross the disk:

- **Boreal track** (above the A–B line): a group of round spots labelled **a** on the upper dotted line and a parallel group labelled **d** below it. Legibly numbered day-marks run across from the eastern limb toward the western: a-spots at roughly 2 through 13 and d-spots at roughly 5 through 14; near the eastern limb (A) is a cluster of small spots and faculae (swirled outlines); near the western limb (B) a dense cluster with **m** (morning) and **u** (evening) sub-marks and d-spots numbered 12, 13, 14.
- **Austral track** (below the A–B line): a group labelled **b** (with **u** and **c** sub-marks near the eastern limb) and a group labelled **c**. Legibly numbered marks: b-spots about 4–8, c-spots about 6–11; near the western limb (B) a dense elongated cluster with c-spots numbered 12, 13, 14, 15 and m/u sub-marks.

Many of the small per-spot letter-and-number micro-labels cannot be resolved individually at this resolution; individual pairings beyond those listed are flagged [?].

At the foot of the disk, the observation table:

IANVARII. [January] — Day (with m = morning / u = evening) · Hour [Hora] · the Sun's altitude [☉ Elevatio, in degrees.minutes]. Printed in the source as two side-by-side sub-columns (days 1–8 | days 9–15).

Day	Hour	☉ altitude
1.m	9 3/8	16.20
2.m	11 1/8	24.25
2.u	—	18.30
4.m	10	20.0
5.m	9 5/8	18.20
6.m	10 1/2	22.30
7.m	9 1/2	17.45
8.u	3	15.0
9.u	3 1/8	14.30
10.u	1 3/5	22.30
11.m	9 3/8	15.50
12.u	—	11.0
13.m	9	14.40
13.u	3 [?]	15.0
14.m	9 1/4	15.0
15.m	9 1/2	18.40
15.u	3 1/2	12.0

Notes on the LVI Image of Observations, the third [image] of January, from day 17 to 29 of the same.

(Notae in LVI. Observationum Imaginem, tertiam Ianuarij à die 17. ad 29. eiusdem.)

I.

First. The faculae **a**, northern ones from the lower hemisphere, shining out on the 17th ahead of the spots that followed, on the 18th displayed themselves entire;

and because after the 20th rains blocked the ways of observing, once these [faculae] had been used up, on the following days nothing at all of what remained was noticed — yet the segment of the course thus begun corresponds to the rest. Note that although these faculae were cut off by the horizon, they were nonetheless very bright.

[Margin: A facula cut off by the horizon shows nothing at all outside the Sun. (*Facula ab horizonte secta, extra Solem nil penitus ostendunt.*)]

Second. The spots **b**, southern, arising together with faculae and umbrae, on the 18th spread out into twins in the ones that followed, and toward setting contracted somewhat, the faculae behind being taken up again in sequence.

Third. In the same way the spots **c**, northern, lacking an [observed] entry because of the weather, changed themselves variously in the middle [of the disk], and at the end went down together with their umbrae and faculae, taking up scarcely half the journey over more than 6 days. But from the fact that after the 25th they were so notably diminished, and around [their exit turned into thin spots and bright faculae]—

II.

—around their exit turned into thin spots and bright faculae, I conclude that they too were born on the Sun during that turbulent three-day span, for it is certain that from the 18th to the 20th they had not existed. Those that perish quickly are also quickly born, and vice versa, as experience so far established in this phenomenon teaches. One should also note the great recession of the spots from one another: for since on the 24th they stood at the middle of their course, the outermost ones there ought to have been more distant from each other on both sides than on the 25th and 26th, when, moving away from the center C, they were carried down the decline — yet the contrary happened. And from this very fact a clear argument is drawn for their birth on the Sun; for they are always neighbors at their physical origin, and only afterward do they first divide from one another.

[Margin: The mutual recession of the spots from one another, produced disproportionately by a uniform motion. (*Macularum à se mutuus recessus, motu uniformi improporcionatè natus.*)]

Fourth. You will find courses not unlike these in Images III and IV of the previous year.

All of these you see bent toward the same southern part of the Sun, even if they are not complete — the southern pole being on the rise, of course, and so the curvature of the paths and the inclination of the chords to the ecliptic increasing.

Diagram. Full-page engraved solar-disk plate, the fifty-sixth observation image (IMAGO SOLIS LVI), showing the course of the sunspots from 17 to 29 January 1626, observed at the Collegio Romano.

Legends around and within the disk:

- Top-left: "LVI, Imago Observationum." (LVI, Image of the Observations.)
- Top-center: "M.DC.XXVI. In Collegio Romano Societatis" (1626. In the Roman College of the Society), flanked by two heraldic-rose ornaments with the Jesuit IHS-sunburst emblem between them.
- Top-right: "3^a Ianuarij" (the third [image] of January).
- Below the emblems: "Cursus Macularum, à 17. Ianuarij, ad 29. eiusdem, similis aliis aliorum annorum." (The course of the spots, from 17 January to the 29th of the same, similar to others of other years.)

Orientation marks: **Z** at top and **N** at bottom (vertical diameter); **A** at the left (East), **B** at the right (West); **C** at the center. The horizontal line A–B is the ecliptic.

Two dotted spot-tracks:

- **Boreal track** (above A–B): near the eastern limb (A), a group labelled **a** with day-marks 17, 18, 19, 20 (with **u** = evening sub-marks) and faculae (swirled outlines) at 17–18. Toward the western limb (B), a group labelled **c**: legible marks at 24, at 25 (**m**) and 26 (**u**) in a central cluster, and **c** at 29 near the limb.
- **Austral track** (below A–B): near the eastern limb, a group labelled **b** with marks 18, 19, 20 (with **u**) and faculae. Along the middle of this track is written "**intemperies coeli**:" ("the inclemency of the sky" — i.e. an observation gap, days ~21–23), with the mark 24. Toward the western limb, b-spots at 24, 25 (**m**), 26 (**u**), and 29 near the limb, in dense clusters.

Individual per-spot micro-labels beyond those listed are not fully resolvable at this resolution and are flagged [?].

At the foot of the disk, the observation table:

IANVARII. [January] — Day (m = morning / u = evening) · Hour [Hora] · the Sun's altitude [☉ Elevatio, in degrees.minutes].

Day	Hour	☉ altitude
17.m	11	25.30
18.m	10 1/5	22.30
19.u	2 1/4	21.30
20.u	2 4/5	17.15
24.m	9	16.0
25.m	9 1/8	16.20
25.u	2	24.20
26.m	—	17.40
29.m	8 3/4	15.15

Notes on the LVII Image of Observations, the fourth [image] of January [and] the first of February, from day 20 January to 2 February.

(Notae in LVII. Observationum Imaginem, Ianuarij quartam, Februarij primam, à die 20. Ianuarii ad 2. Februarij.)

I.

First. The spot **a**, a single continuous one at entry, afterward — on the 24th and thereafter — appeared divided into several; and once the northern ones of these had been lost and more or less consumed, the southern one still went out holding on, and at its exit drew off notable faculae, especially in the place of the northern spots.

Second. The course of this spot fills at least thirteen days; it is like and equal to the one that occurred in the previous year, in the same month, marked out in Image VIII, with spot and course C — which, although it happened some days later, is nonetheless very like this one, nor is its stay below the Sun [subsolar delay] unequal.

The spot at its exit grazed the horizon, and outside the Sun nothing of it at all appeared.

Third. The spot **b**, deprived by the turbulent sky of the head of its course, gradually bent away southward from the path of spot **a**, as is plain. Its horizontal exit could not be observed, through the sky's ill-treatment. Meanwhile in its progress it grew, and varied its nucleus, and in keeping with the variety of the

nucleus it likewise shaped the surrounding vapor — or whatever it is — as can be seen on the 24th, 29th, and [30th, like]—

II.

—all the rest: for a round nucleus produced a round mass of the spot, an oblong one an oblong mass, an angular one an angular mass; which also happens almost always and everywhere in the others. Nor should it go unremarked that on the 29th and 30th it acquired a new spot, turned into a facula around the exit.

[Margin: According to the shape of the nucleus, the spot is ordinarily formed. (*Secundum figuram nuclei, conformatur ordinariè Macula.*)]

Fourth. The spots **c**, southern, arose around the exit; they had not been there before, yet they proceeded along the common path.

Fifth. In the same way the spot **d**, northern, carried out from its entry a journey like the others, together with pure faculae following.

Sixth. If you compare the paths of this Image with those which are half a year distant from it, they will be proportional and similar to one another; and if they have run over the same parallels, they will be, for the most part, equal in their arcs and times. See July of the previous year, from the 12th up to the 8th of August, in two Images; for I have none exactly corresponding to these days.

Seventh. Recall also to memory that the more the course is arched toward the ecliptic and made convex toward the center C, the greater the delay of the spots that is always spent above the horizon, other things being equal. Consider the observations, examine the delays and compare them with others, and you will always find this truth, other things being equal.

[Margin: A greater curvature of the travel-arcs argues a greater delay, other things being equal. (*Maior arcuum itinerariorum curuatura maiorem arguit caeteris paribus moram.*)]

Diagram. Full-page engraved solar-disk plate, titled **IMAGO SOLIS LVII** ("Image of the Sun, 57") above the frame. The disk is a large circle with a horizontal diameter A–C–B representing the ecliptic; the Sun's spots are drawn as a nearly straight, dashed track running just below and along this line, west-to-east across the face. Legend and orientation labels:

- Frame title (above disk): **IMAGO SOLIS LVII** — Image of the Sun, 57
- Top-left (inside): **LVII, Imago Observationum** — 57th, Image of the Observations

- Top-center: **M.DC.XXVI. In Collegio Romano Societatis** — 1626, in the Roman College of the Society [of Jesus]
- Top-right: **4. Ianuarij, 1. Febr.** [?] — apparent date note; this conflicts with the caption's range (20 Jan – 2 Feb) and is transcribed as read (see anomaly a)
- Central emblems: two heraldic roses flanking the **IHS** sunburst (Jesuit device) — decorative
- **z** (top of disk): Zenith; **N** (bottom): Nadir
- **A** (left end of diameter): **Oriens** — East
- **B** (right end): **Occidens** — West
- **AB** (the horizontal line): **Ecliptica** — the ecliptic; **C** its midpoint (disk center)
- Engraved caption below the emblems: **Cursus Macularum, à 20. Ianuarij, ad 2. Febr. similis illi, qui fuit ante annum** — "The course of the Spots, from 20 January to 2 February, similar to that which occurred a year before."

Spot lettering (only labels legible under magnification are committed; the crowded 29 Jan – 2 Feb cluster near B is only partly resolvable):

- **Upper track** (above the ecliptic line), marked **d**: dated **24, 25** (an irregular large blob), **26**.
- **Main track** (along the ecliptic), two parallel sub-rows marked **a** (upper) and **b** (lower), with evening marks **u** and third-class marks **c**:
- **a**: 20, 24, 25, 26, 29, 30, 31, and (February) 1, 2
- **b**: 24, 25, 26, 29, 30, 31, and (February) 1, 2
- **u** (evening observations): beneath a-20; at 30; at 31
- **c**: near 30 (30 Jan) and near 1 February ("c 1")
- The 29 Jan – 2 Feb cluster near B is densely overlapping; several of its a/b/c date-labels are uncertain [?].

Foot-table engraved on the plate (m = mane/morning, u = vesperi/evening; ☉. El. = the Sun's altitude [Solis Elevatio], in degrees and minutes):

D	H	☉. El.
IANVARII		
20	u. 2¾	18. 10.
24	m. 9	16. 0.

D	H	☉. El.
25	m. $9\frac{1}{8}$	16. 20.
26	m. $9\frac{1}{2}$	18. 50.
29	m. $8\frac{3}{8}$	15. 15.
30	u. $2\frac{1}{2}$	21. 5.
31	u. $3\frac{1}{4}$	16. 40.
FEBRVARII		
1	m. $8\frac{1}{4}$	12. 0.
2	m. 9	20. 20.

Notes on the fifty-eighth Image of the Observations — the second for February, from the 2nd to the 14th of the same month

First. Three southern Spots, a, having crossed the horizon on the 2nd, held between them — at differing positions — a very bright facula in the middle; the last of the Spots all but grazed the horizon. On the evening of the 3rd these same Spots, now advanced onto the Sun, appeared greater in number, in mass, and in their intervals: for seven Spots were seen, most of them rich in nuclei, while the distance between the outermost had grown more than threefold in longitude and by half in latitude. On the 5th there were ten Spots. The westernmost of these had coalesced from two into one, its nucleus and the surrounding vapor enlarged in every dimension; the easternmost, though still spread over some space, was very thin, as were the intermediate ones. The distance between the outermost, measured along longitude, is about six times the distance on the 2nd; the latitude did not change at all. On the 6th the easternmost vanished, the middle ones merged into fewer, the westernmost altered its shape somewhat, and the separation between them in longitude grew still greater. On the 7th the westernmost held its course while the one immediately following it shrank; the two remaining that followed were attenuated in body and pushed farther back from the first. From the 7th to the 10th, turbulent skies took away the chance to observe. On the 10th the two westernmost stood apart in their nuclei but joined in their bodies; four followed, thin, the remnants of the recent ones, whose distance from the first equals the distance of the 6th — that is, the distance between the first and the two next-to-last eastern ones. On the 11th and 12th only the two westernmost appeared, now more closely united and already growing slender. On the 13th and 14th Spot a appeared, with faculae and shadows behind it. The shadow of the 13th, denser in the middle, is probably the remnant of the Spots of the 10th — [together with] the westernmost of those following.

[Margin: The Spots dilated in length and breadth.] [Margin: Spots previously disjoined become joined.] [Margin: Spots turned into faculae and shadows.]

But the shadow and the last, sparser faculae are the traces of the eastern Spots that had not appeared since the 6th and 7th. From this it is quite certain that the apparent distance of the last ones at setting, on the 14th, was never as narrow as it had been at their rising on the 2nd — even though Spot a ran into the horizon itself on the fourteenth day. This course of the first Spot lasted about thirteen days, just like the course of Spot a of the previous year set out in Image XI, from the 1st to the 13th of February — from which it was not very different, although this one deviated more from the ecliptic. The course of the last Spot, had it lasted, seemed likely to be longer, as will be clear to anyone who reasons it out, since it lagged somewhat behind in the separation.

Second. Spot b, which arose on the 2nd, set on the 14th. On the 5th and 6th it gained a tiny spot above; it moved as if in a settled state, pregnant with a not very dense nucleus, and at its exit it shone hemmed in by faculae — just as on the 5th it moved parallel to the westernmost of the a Spots, whose time under the Sun it also seems very nearly to have matched (which is unusual). In the twelfth Image of the Observations you will find for this Spot b a course like that of Facula a; compare the diagrams and you will see the agreement.

[Margin: Course of thirteen days.]

Third. The c Spots, very rare and thin, born on the Sun on the 6th, were reduced to two by the 7th, then somehow revived on the 10th, seven in number, likewise on the 11th, but appeared very small, with greater distances in longitude than they would have shown midway, at the point of their physical origin. They presented a fragment of their course, similar and proportional to the others. They carried along with them the northernmost Spot of all — the smallest, no bigger than a point, yet extremely black and conspicuous — as may be seen after the numeral marking the day.

[Margin: The separation of the Spots is greater than a uniform rate of motion would allow.]

Fourth. The direction of the tracks from south to north, the curvature of the arcs, and the inclination of the chords to the ecliptic all increase; the southern pole rises from west toward east.

Diagram. Full-page engraved solar-disk plate, titled **IMAGO SOLIS LVIII** ("Image of the Sun, 58") above the frame. As in the preceding plate, a large circle with

horizontal diameter A–C–B (the ecliptic) carries a dashed spot-track across the face. Legend and orientation:

- Frame title (above disk): **IMAGO SOLIS LVIII** — Image of the Sun, 58
- Top-left (inside): **LVIII, Imago Observationum** — 58th, Image of the Observations
- Top-center: **M.DC.XXVI. In Collegio Romano Societatis** — 1626, in the Roman College of the Society [of Jesus]
- Top-right: **2^a Februarij** — 2 February
- Central emblems: two heraldic roses flanking the **IHS** sunburst — decorative
- Legend line: **AB, Ecliptica: A Oriens Macularum, B Occidens, Z, Zenith, N, Nadir** — "AB, the ecliptic; A, East of the Spots; B, West; Z, Zenith; N, Nadir."
- Engraved caption: **Cursus Macularum, à secundo Februarij, ad 14. eiusdem, Cursui prioris anni similis, et duratione æqualis** — "The course of the Spots, from 2 February to the 14th of the same, similar to the course of the previous year, and equal in duration."

Spot lettering (only labels legible under magnification are committed; the day 12–14 cluster near B is a large overlapping blob):

- **Upper track** (above the ecliptic line), marked **b**, with third-class marks **c**: **b** dated 2, 3, 5, 6, 7, 10, 12, 13, 14; **c** marks at 6, 10, 11 (a possible fourth **c** near 7 is uncertain [?]).
- **Lower track** (along/below the ecliptic), marked **a**: **a** dated 2, 3, 5, 6, 7, 10, 11, 12, 13, 14.
- The days 12–14 near B (bottom-right of the track) form a heavy overlapping blob; individual a/b date-labels there are only partly resolvable [?].

Foot-table engraved on the plate, in two side-by-side day-columns (m = morning; ☉. Ele. = the Sun's altitude, degrees and minutes; days 4, 8, 9 are not tabulated):

D	H	☉. Ele.
Februarij		
2	9. m.	20. 20.
3	. u.	21. 10.
5	8 ³ / ₈ m.	13. 35.
6	9 ¹ / ₈ m.	19. 50.

D	H	☉. Ele.
7	8½ m.	15. 0.
10	8⅞ m.	18. 30.
11	. m.	24. 30.
12	. m.	31. 5.
13	10⅝ m.	31. 0.
14	. m.	13. 15.

Notes on the fifty-ninth [Image] of the Observations — the third for February, from the 12th to the 27th of the same month

First. This Image, rich in many courses, presents first of all two courses of a single group, a and b, whose beginning was noticed on the evening of the 12th, in mere faculae and shadows. On the 13th Spot a came forth, with attendant shadows and faculae, which however have been omitted here for lack of room. On the 14th several Spots b came forth, and the faculae following Spot a were also marked — which you see done likewise on the 15th, when it shows Spots b more numerous and larger toward the west. For on the 14th they appeared as a small, thin group that spread out into four Spots covering the whole range of the region. On the 16th the a Spots greatly failed, their faculae disappearing; but b, on the contrary, gathered into one nearly continuous mass, growing. On the 17th Spot a was seen as a single one; b, however, between two rather broad but thin ones, showed the seed of new ones. On the 18th, a was still single, and b increased in number and mass. On the 19th a fades by thinning; b, the westernmost, begin to gather together, while the easternmost spread into one even mass. On the 20th there was no trace of Spot a; b, on the other hand, do thin out, yet still approach one another. On the 21st the earlier b grow very slender, the later ones vanish through thinness. On the 22nd, in the morning, only the westernmost of the b Spots, with a thin facula, appeared in place of the rest; and in the evening not even these, but only a single thin Spot was seen. The courses of these Spots a and b are very similar to the group of Spots b and c set down in Image XII a year before; for the Spots b here answer to the Spots b there, and the Spots a here to the Spots c there; and there is the greatest resemblance of place, time, curvature, and dilation. Consult and compare the figures on both sides.

[Margin: The faculae are extinguished before they reach setting.]

Second. Spot c, northern, arisen with pure northern faculae d, appeared simple on the 15th but distinct in three nuclei, and afterward passed into that many,

then more, spots; on the 16th it was gradually spread into several, accompanied behind and at the sides by the shining faculae d, northern, and by others no less bright. On the 17th, the faculae being extinguished, the Spots bore two black, sharply defined nuclei, and elsewhere gave signs of them here and there. On the 18th the upper northern Spot did not appear, and the southern ones too failed in density. On the 19th a trace of the northern one appeared; the southern ones were further attenuated, and the nucleated Spots themselves also begin to diminish. On the 20th none of the northern Companions was present; two southern ones remained, the rest seem to be decreasing. On the 21st new southern ones were born toward the west, and the Spots themselves were marvelously twisted and evolved into three or more nuclei, with a white space flickering between. On the 22nd, morning and evening, the southern Spots grew in mass and number, while the principal ones themselves gradually fail in mass and density. On the 24th (the 23rd was rainy) Spot c was again gathered into one, into a single nucleus, its southern companions somewhat attenuated and contracted. On the 25th and 26th, a single Spot drew behind it and at its sides, toward north and south, marvelous shadows and most brilliant faculae. That the course of this Spot reached 13 days is not credible. It has much affinity with the course of Spot f set out in Image XII.

[Margin: Notable variations of Spot c.] [Margin: A facula in the middle of the spot's body.] [Margin: The shadow and faculae mostly incline to the sides, or follow after the Spots. Course of about 13 days.]

Third. Spot e, southern, with facula and shadow, settled on the horizon on the evening of the 17th and reached the middle of the disk on the 24th; on the 25th, attenuated into shadows and faculae, it did not appear thereafter. Its half-course was not far short of seven days, and so the whole would have reached about 14 days.

Fourth. Spot f, southern, appeared on the 18th and grew somewhat toward the center, but soon, made smaller on the 24th, it took on the form of three Spots — a form it kept, though smaller, on the 25th as well; on the 26th it was single but smaller, and on the 27th appeared as the smallest; after this it was left without any trace of itself.

The curvature of these tracks increases and gradually approaches the spring equilibrium; the inclination of the chords grows; the southern pole rises.

[Margin: The course would be about 14 days.]

Rosa Ursina, Book III — Notae Particulares (Images of the Sun LIX–LX)

Image of the Sun LIX (engraved plate)

Diagram. A full-page engraved plate showing the solar disk (a large circle = the solar limb) plotted with the tracks of the sunspots.

- Title cartouche, upper part of the disk:
- Left: "LIX, Imago Observationu[m]." — "LIX, Image of the observations."
- Center: "M.DC.XXVI. In Collegio Romano Societatis [Iesu]" — "1626. In the Roman College of the Society [of Jesus]."
- Right: "3.^a Februarij." — "The third [image] of February."
- Emblems below the title: a central IHS sunburst (the Jesuit monogram) flanked by two Orsini rose devices.
- Central caption (below the emblems): "Cursus Macularum à 12. Februarij, ad 27. eiusdem, similis anni praecedentis et aliorum." — "The course of the spots from 12 February to the 27th of the same [month], similar to that of the preceding year and of others."
- Cardinal / reference labels:
- "A. Oriens." at the left of the disk — the East (A).
- "B. Occidens." at the right of the disk — the West (B).
- "AB. Ecliptica" — the horizontal diameter, running from endpoint A (left) to endpoint B (right), is the ecliptic.
- The disk carries numerous sunspot groups drawn as day-by-day tracks. Each plotted position is tagged with a letter (a, b, c, d, e, f), a day-number (running roughly 15 through 27), and an "m" (morning) or "u" (evening) marker. Readable groupings include: an upper-left (northern, near-eastern) cluster tagged c/d with days 15–18; a lower-left cluster tagged a, b with days 12–13 and e with days 17–18; a series tagged a, f, e running along the ecliptic through days 19–25; a right-hand (western) sequence tagged b (days 20–22, with m/u) and f (days 26–27); and an upper-right cluster tagged c with days 24–26. The individual micro-labels are too small and are overlaid by verso show-through; they are not transcribed one by one here. [The per-position spot lettering]

Observation table on the plate: FEBRVARII (February)

Columns: **D** = day; **H** = hour (with m = morning, u = evening); ☉ **El.** = the Sun's elevation, given in degrees and minutes.

The table is set in two side-by-side sub-columns. The left-hand sub-column (earlier February days) is largely obscured on this scan by verso show-through and gutter shadow and could not be read reliably; its cells are flagged. The right-hand sub-column (later February days) reads as follows.

D (day)	H (hour)	☉ El. (deg.)	(min.)
20.	u. 3 $\frac{2}{3}$	20	30
21.	m. 9 $\frac{1}{2}$	26 [?]	30
22.	m. 9 $\frac{1}{2}$	27 [?]	0
22.	u. 4 $\frac{1}{2}$	10	40
24.	m.	38	30
24.	u. 3 $\frac{4}{5}$	18	0
25.	u. 3 [numeral: ?]	18 [?]	0
26.	m. 8 [numeral: ?]	19 [?]	30 [?]
27.	m.	36	30

Left-hand sub-column (days ~12–19): [numeral: ?] throughout — illegible on this scan (show-through / gutter).

Notes on Image LX

Notes on Image LX of the observations — the fourth [image] of February, the first of March — from 24 February to 15 March.

I.

First. The spots a, in the north, were first seen on the evening of the 24th, then on the morning of the 25th with an enclosed facula; on the 26th following, only the earlier spot appeared, and it then withdrew over the next seven continuous days. Finally, on the evening of 5 March, three umbrae with faculae presented themselves to view once more; and on the evening of the 7th, at hour 3 $\frac{1}{4}$, under a solar elevation of 27 degrees 30 minutes (which was omitted from the time-table through carelessness), broken up into scattered spots and with faculae going before them, they approached the horizon. Whether these were the same spots that had appeared near sunrise on the 24th, I do not affirm as certain: in terms of

time, place, and situation they may be the same; but given the inconstancy of the phenomenon, they may be new ones, the earlier having been utterly extinguished. I leave this to the observer's judgment, for there is no lack of examples on either side.

Second. The spot b, in the north, settled on the horizon on the evening of the 25th, with a shadowy facula; then on the 27th it still appeared, single and thin. Over the two intervening days — 28 February and 1 March, both rainy — nothing was observed. Finally, on 2 March there were four; on the third, three; on the fourth, two; and on the fifth day one was seen again — a fading spot, which on the 7th passed off into shadows between two very bright faculae. Its passage seems to have been very close to equilibrium. It corresponds to the course of spot b recorded in Image XIII. All things reckoned, it is certain that this spot did not exceed 12 days; whether it reached that number is doubtful.

[Margin: The course of spot b did not exceed 12 days.]

Third. The spots c, likewise northern, on the 26th were in the morning close to the horizon; on 27 February and 2 March they showed only a single one; but on the 3rd they grew to three, and on the 4th to four; then again on the 5th they were reduced to three thin ones, and on the 6th to two thin and small ones; finally on the 7th they turned into broad shadows and bright fac-

[Margin: Conversion of the spots c into shadows and faculae.]

II.

—ulae. Their course seems to have fallen somewhat short of equilibrium, and not to have much exceeded the 12th day; for, given the scarcity of physical duration, it was not possible to state the whole course from the observed data.

Fourth. The spots d, southern, first seen on the 2nd, drew after them immediately bright faculae, which shadows crowded, and these in turn gleaming faculae, with shadows stretched almost to the horizon. To these there clung, toward the south, the spot h, still thin, and more like a shadow than a spot. On the 3rd the spots d unfolded into four, while the faculae and shadows were very greatly dilated in every direction of place — just as newly-arisen spots almost always are. I say "almost," because I doubt whether it has ever happened otherwise; certainly no example comes to mind. On the 4th the spots d were five. On the 5th a shadow was added, with a southern facula. On the 6th the spots were still five, but drawn out lengthwise. On the 7th only two were seen, the sky being murky. On the 8th five again — indeed nearly six — presented themselves, the northern ones

coalescing into one. On the 9th only three; on the 10th again five were seen, and spot h returned with interest, for together with its companions it made six, and a remarkable facula appeared. On the 11th the spots d partly came together into dilated shadows and partly went off into white faculae, six spots h following meanwhile. On the 12th the spots d proceeded in the same way with faculae, but in a more slender figure, four spots h following and enclosing conspicuous faculae. On the evening of the 13th the spots d stood at the horizon with faculae, with shadows, faculae, and spots h following. Observe carefully how the spots h spread out into broad shadows — which rarefying spots frequently do, or undergo, as they tend toward faculae or toward extinction. The course of spot d, if a correct reckoning is made, lasted from horizon to horizon nearly fourteen days; for by the eastern interval between the spot and the limb, at least [continued on folio 304]

[Margin: Spots tending to extinction ordinarily rarefy into broad shadows.]

[Margin: A course of nearly fourteen days.]

Image of the Sun LX (engraved plate)

Diagram. A full-page engraved plate showing the solar disk with the tracks of the sunspots for the interval 24 February – 15 March 1626.

- Title cartouche, upper part of the disk:
- Left: "LX, IMAGO Observationu[m]." — "LX, Image of the observations."
- Center: "M.DC.XXVI. In Collegio Romano Societatis" — "1626. In the Roman College of the Society [of Jesus]."
- Right: "4.^a Februarij. / 1.^a Martij." — "The fourth [image] of February; the first of March."
- Emblems: a central IHS sunburst flanked by two Orsini rose devices.
- Central caption: "Cursus Macularum à 24. Febr: ad 15. Martij, similis cursui anni praeteriti et aliorum." — "The course of the spots from 24 February to 15 March, similar to the course of the past year and of others."
- The horizontal diameter (the ecliptic) is marked with the letter "C" near its center and again toward its right end [the full endpoint labels — an "Oriens/Occidens" pair as on plate LIX — are faint/illegible here; flagged [?]].
- The disk is densely plotted with sunspot tracks running from the eastern limb (left) to the western limb (right). Individual positions are tagged with a letter (a, b, c, d, e, f, g, h), a day-number (running from about 3 through

15), and an "m"/"u" (morning/evening) marker. A prominent, heavily-hatched dark spot-group sits at the lower-left (eastern) limb (tagged d, h with day-numbers 2–3); the ecliptic line carries a chain of small spots tagged f, e, g; and a dense western cluster (right limb) carries tags e, f, g, h, u with day-numbers 11–15. The individual micro-labels are extremely small and partly overlaid by show-through and are not transcribed one by one. [The per-position spot lettering]

Observation tables on the plate: FEBRVARII and MARTII

Columns in each sub-table: **D** = day; **H** = hour (m = morning, u = evening); ☉ **El.** = the Sun's elevation, in degrees and minutes.

Februarii (February)

D	H	☉ El. (deg.)	(min.)
24.	u.	18	0
25.	m. 8½	20	25
25.	u. 3½	18	0
26.	m. 8⅞	19	10
27.	m.	36	30

Martii (March)

D	H	☉ El. (deg.)	(min.)
2.	m. 9	26	5
3.	m. 10 1/12	35	0
4.	u. 3¼	25	30
5.	m. 8⅛	19	10
5.	u. 3⅜	25	0
6.	m.	21	45
7.	m. 8¼	21	0
8.	m. 8⅞	27	5
9.	m.	28	30

Martii (March), continued

D	H	☉ El. (deg.)	(min.)
10.	m. 7⅞	18	30

D	H	☉ El. (deg.)	(min.)
11.	m. 8 $\frac{1}{8}$	21	20
12.	u. 5	9	50
13.	u. 3 $\frac{1}{2}$	28	40
15.	u. 3 $\frac{7}{8}$	22	50

Notes on Image LX (continued)

I. (continuation of the Fourth note)

at least two and a half days are owed, as is evident from the distance of spot g to the 5th day, which is equal to the distance of spot d. Therefore, if we add two and a half days to the 11 days and 6 hours, we shall not be far from the 14 days which I have no doubt spot h completed. The course of this spot d — in its position, its duration, and its equilibrium — is very similar to the course of spot a in the year 1625, set out in Image XIII, and to the itinerary-track of spot a, likewise, of the year 1627, to be explained below in its proper place. Hence the apparent course of this spot d exceeded the courses of spots b and c by more than a whole day.

[Margin: The course of spot d is engaged around the vernal equilibrium; it exceeds the northern courses by more than a day.]

Fifth. The spots e, f, g, belonging to a single group, having arisen on the third day, dilated in a remarkable way, and on the 5th advanced among bright faculae; after mid-course they decreased both in number and in mass, and finally degenerated for the most part into faculae and shadows, with which they reached the west. For the rest, note: (1) that spot f appeared closer to spot g at rising (which the engraver did not sufficiently express) than to spot e — the contrary being

[Margin: The group of spots e, f, g was engaged in the vernal equilibrium.]

[Margin: Spots are converted into faculae and shadows.]

II.

—the case at setting. (2) that the distance of the spots e, g is greater at setting than at rising. (3) that the course of spot g was nearly 14 days. (4) that the itineraries of this group are somehow in equilibrium. (5) that in Image XIV something similar is to be found, with respect to the course, e.

Sixth. You have, noted in this diagram, also the shadows and faculae — on the 3rd the southern ones a, but the northern b and c; likewise on the eighth day, d and e — which I adduce by way of example and as the more notable, because phases of this kind over the whole Sun are daily and in the greatest abundance.

Seventh. The sum of it: in equilibrium there is curvature of the arcs, and no inclination of the chords to the ecliptic, but all of them either coincide with it or are equidistant from it; the southern pole culminates, the northern is most deeply depressed; and the latter begins to ascend in the hidden hemisphere, the former to descend in the visible one; and the latter crosses over into the eastern region, the former into the western; and the direction of the spots, and the cutting of the ecliptic by the chords, proceeds from north to south.

[Margin: The character of the vernal equilibrium.]

Rosa Ursina, Book III — Notae Particulares (Images of the Sun LX–LXI, Feb–Mar 1626)

Image of the Sun LX

Diagram. A full-page engraved solar disk (the whole page is the plate). The Sun is drawn as a large circle with the ecliptic marked as a horizontal diameter. At the top center is the Jesuit IHS sunburst emblem, flanked left and right by two heraldic rose ornaments (the Orsini device). Titles printed within the disk:

- Top left: "**LX. Imago Observationum.**" — "LX. Image of the Observations."
- Top center: "**M.DC.XXVI. In Collegio Romano Societatis**" — "1626. In the Roman College of the Society [of Jesus]."
- Top right: "**4ta Februarij. / 1a Martij.**" — "The fourth [image] of February; the first [image] of March" [?] (this composite plate joins the February and March series).
- Below the emblem: "**Cursus Macularum à 24. Febr. ad 15. Martij, similis cursui anni praeteriti et aliorum.**" — "The course of the spots from 24 February to 15 March, similar to the course of the past year and of others."

The disk is filled with many sunspot figures set along and near the ecliptic diameter, each labelled with a day-number (24–27 for February, 2–15 for March) and small letters (a–h) with subscript **m** (morning) / **u** (evening) marking the successive observations of each spot group. The individual per-spot micro-labels are numerous, tiny, and partly overrun by verso show-through; the readable day-

numbers include 24, 25, 26, 27 (upper-left, February) and 2–15 (March), with letter clusters (e, f, g near the ecliptic; d, g, h below it). Individual spot lettering is not reliably resolvable at this resolution. [Many per-spot labels [?]]

Foot-tables printed beneath the disk (columns as engraved: **D** = day, **H** = hour with **m**=morning/**u**=evening, $\odot$ and **El.** = the two-part measure, most likely the Sun's altitude in degrees and minutes; see Parsing notes):

Februarii (February):

D	H	$\odot$	El
24	u. —	18	0
25	m. $8\frac{1}{2}$	20	25
25	u. $3\frac{5}{6}$	18	0
26	m. $8\frac{3}{7}$ [?]	19	10
27	m. —	36	30

Martii (March):

D	H	$\odot$	El
2	m. 9	26	5
3	m. $10\frac{1}{12}$	35	0
4	u. $3\frac{1}{4}$	25	30
5	m. $8\frac{1}{8}$	19	10
5	u. $3\frac{3}{8}$	25	0
6	m. —	21	45
7	m. $8\frac{1}{4}$	21	0
8	m. $8\frac{7}{8}$	27	5
9	m. —	28	30
10	m. $7\frac{7}{8}$	18	30
11	m. $8\frac{1}{8}$	21	20
12	u. 5	9	50
13	u. $3\frac{1}{3}$	28	40
15	u. $3\frac{7}{8}$	22	50

Rosae Ursinae Book III

Notes on the LXI Image of the Observations, the second of March, from day 10 to day 22 of the same [month].

This spot, a, was not very far from the Ecliptic and from the greatest parallel [parallelo Maximo], and therefore much can be gathered from its course, which deserves particular note.

First. It arose bellied — or rather headed — in its upper part toward the north, and tailed in its lower part toward the south. The cause of the "belly" it disclosed even then: a nucleus, indicated none too obscurely, which on the 11th plainly revealed itself as five distinct nuclei, though small and separate. On the 12th these appeared gathered into four; on the following day, the 13th, the more easterly one had grown, while the western ones, small but more numerous, appeared. Again, on the 15th, they seem to have coalesced and been reduced to three — the southern and northern larger and longer, the middle one very small — which nonetheless on the same day at evening were four, as you have it marked in the diagram at **a**, **a**, and **u** for the 15th, that is, at the evening observation of the fifteenth. On the 16th, both morning and evening, you see the same nuclei increased by coalescence but reduced in number: there were three, a number they never afterward exceeded. For on the 17th three very black nuclei appeared, but joined together, and thereafter they were never again separated across the whole Sun, but always more united, as the diagram makes clear day by day up to the 22nd. And from this progress of the nuclei, and their evident growth — which I have often observed on other occasions too, and presented in these figures — it is plain that in the generation and increase of the nuclei nature keeps, for this phenomenon, the same principle it keeps in the production of the spots themselves: which always coalesce from thin, minute, and mostly scattered umbrae into one, and then grow to every difference of place. Anyone not blind has noticed how these nuclei grew. For if all these nuclei, on each of the days from the 10th to the 15th, be in-

[Margin: The generation and growth of the nuclei, as observed, is described.]

[Margin: The nuclei and the spots follow exactly the same principle in being born and growing; they wax and wane through every difference of place, like a spot.]

-spected, then, although they were more numerous than on the 16th and the following days, they do not equal them in mass. For the 15th at evening, the 16th, 17th, and 18th in the morning, and likewise the 21st at evening, I have presented

only the genuine figures and magnitudes of the nuclei; for the 19th evening gives only a point, which is the center or place of the nucleus.

But wherever, among these nuclei, you find a white space, know that it was left there not by the engraver's chance but by the observer's deliberate care, and that a most brilliant facula is thereby indicated. So much for the nuclei of this spot.

[Margin: A facula among the nuclei.]

Second. Let us now come to the cloud thrown around the nucleus, that is, to the figure of the spot itself. We shall see it conform to the position and figure of the nuclei; for from the 10th to the 15th it was the more elongated from south to north, as were the nuclei. And as soon as the nuclei, from the 16th to the 19th, were formed into a triangle, the whole spot took on the same pattern. On the 21st and 22nd it turned oblong again, as at its rising, because the nuclei had likewise thinned to the view in the same way. And this mutual resemblance of figures — of the nuclei with the vapor, and of this with the nucleus — usually occurs not only in this spot but with all other fertile spots.

[Margin: The body of the spot imitates the figure of the nucleus.]

Third. About the retinue of this spot, take the following. It consisted of umbrae, faculae, and spots. Umbrae walled it in at its rising, as did most brilliant faculae, as you perceive from the 10th and 11th. That shadowy tail, tapering to the south, was on the 10th a true spot, but thin; on the 11th it appeared enlarged, and at length, by its progress, seems to have passed off into several thin spots — just as from the northern umbrae, and others too, several spots undoubtedly erupted, which you may study at will on the 13th, 15th, 16th, 17th, 18th, and 19th. For on the 21st and 22nd they were again, beyond dispute, transmuted into many umbrae and faculae, because the spot approached and left the western horizon between umbrae and faculae. But the nimbus girdling the spot — such as on the 12th and 15th was marked around its circuit with conspicuous points — [was noted] not only on those days, but from the 12th

[Margin: The retinue of this spot — in umbrae, faculae, and nuclei — is described.]

[Margin: Umbrae change into spots, and these again into umbrae.]

[Margin: A nimbus, or halo, or area, surrounding the spot.]

Image of the Sun LXI

Diagram. A full-page engraved solar disk (the whole page is the plate), showing the passage of a single spot **a** across the Sun. The ecliptic is drawn as a horizontal diameter running from the eastern limb (left) to the western limb (right); at the top center is the IHS sunburst emblem flanked by two rose ornaments. Titles and cardinal labels printed within the disk:

- Top left: "**LXI. Imago Observationum.**" — "LXI. Image of the Observations."
- Top center: "**M.DC.XXVI. In Collegio Romano Societatis**" — "1626. In the Roman College of the Society."
- Top right: "**2a Martij.**" — "The second [image] of March."
- Below the emblem: "**Cursus Maculae a, à die 10. ad 22. Martij, similis aliis annorum praeteritorum et sequentium, tempore eodem.**" — "The course of spot a, from day 10 to 22 March, similar to [that of] other years, past and following, at the same season."
- Left endpoint of the diameter: "**A, Oriens**" — "A, East [rising]."
- Center of the diameter: "**AB, Ecliptica**" — "AB, the Ecliptic."
- Right endpoint: "**B, Occidens**" — "B, West [setting]."

Along the ecliptic the spot **a** is drawn at successive positions labelled by day-number 10, 11, 12, 13, 15, 16, 17, 18, 19, 21, 22, most with a morning (**m**) and/or evening (**u**) mark. Near the western limb are further letters **b** and **c**, and two engraved hour-annotations: "**22. u. h. 2½**" and "**22. u. h. 4⅝**" (observations of the 22nd, evening, at hours 2½ and 4⅝). The finer per-spot lettering (the individual m/u marks and the umbra/facula stippling around each position) is dense and partly overrun by verso show-through — not fully resolvable at this resolution. [Some per-spot labels [?]]

Foot-table printed beneath the disk (columns **D** = day, **H** = hour with **m/u**, $\odot$ / **El.** = two-part measure, see Parsing notes):

Martii (March):

D	H	$\odot$	El
10	m. 7⅞	18	30
11	m. 8⅞	21	20
12	u. 2 5/7 [?]	31	45
13	u. 3⅓	28	40

D	H	☉	El
15	m. $8\frac{1}{8}$	21	20
15	u. $3\frac{7}{8}$	22	50
16	m. $8\frac{3}{8}$	25	50
16	u. —	11	10
17	m. $7\frac{2}{3}$	18	30
17	u. $4\frac{1}{4}$	21	0
18	m. $8\frac{1}{8}$	24	0
18	u. $4\frac{7}{12}$	16	0
19	m. —	29	30
19	u. —	9	5
21	m. —	30	0
21	u. $4\frac{3}{8}$	19	10
22	m. $9\frac{1}{12}$	34	0
22	u. $2\frac{1}{2}$	37	0
22	u. $4\frac{5}{8}$	17	0

(Notes continued, foot of folio 307.)

[from the 12th] to the 19th it was noticeable; for example's sake I marked it on those days, by which I mean nothing other than a certain extraordinary, shifting brilliance poured around the spot — something that almost always happens with large or dense spots.

Fourth. We must consider the path of this spot and the disposition of its path relative to the Ecliptic — namely, how the curving of its advance is no longer in balance, but the western part preponderates, and the spot's course recedes farther from the Ecliptic at setting than at rising, as can be seen in the diagram. Next, how this same spot settled on the Ecliptic at its rising on the 12th, and entirely crossed it on the 13th, 15th, and 16th, and again-

[Margin: The curvature of the path, and its position relative to the Ecliptic, is described.]

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-fell back onto it on the 17th, but on the 18th and thereafter left it entirely. And so it came about that this spot changed from southern to northern, and from

northern back again to southern; and that some segments of its course were convex toward the Ecliptic — such as the eastern one on the 10th–12th and the western on the 18th–22nd — while the remainder lying between these, from the 12th to the 18th, stood concave toward that same Ecliptic. Note, however, that the [two] stations of the 15th are a little out of their proper places: for the morning one is somewhat nearer the Ecliptic, and the evening one farther from it than it should be, as anyone can at once notice.

[Margin: The spot's long lingering at the horizon. The spots [keep] within the same [region], but not outside the field of view.]

Fifth. Note too this spot's long lingering at the western horizon, and its passage amid bright faculae and widely spreading umbrae, as the side-figure drawn out toward the north presents it. There you see how the faculae, girdling the whole spot and leading it off into the opposite part of the hemisphere, do not permit even a spark of their flame to flash out beyond the Sun's orb; and then how, at the 2nd evening hour, when the spot reached the horizon, they too advanced with it at a proportionate pace, right up to about the 5th hour, as you see expressed in the diagram. From all this, weighed together, there is no doubt that this spot took up, in touching the horizon, at least 6 hours. Here note (of which I had a most singular reckoning) that when the spot was near the horizon before midday, its recession from the Ecliptic, B–m, was smaller than b–a, which it had at half past the 2nd evening hour; and that this in turn was smaller than the distance c–a, which occurred at the evening hour 4½. Although on other occasions I had often noticed this and been perplexed — whether it should be ascribed to a real motion of the spots or perhaps to an error in observing — I established at length, by sure and consistent observations, that it is no delusion of the observer, but the truth of the apparent motion. Moreover, the spot appeared far more vigorous around half past the 2nd hour than around the 4½ hour; for here it showed itself flocculent, weak, scattered, and diluted like a thin cloud, whereas there it was still black and vigorous — no wonder, since it was still directing its greater part toward us, while by the 4th hour it had passed the larger part over to the opposite side. But notice the distances

[Margin: A spot lingering at the horizon shows a greater departure from the Ecliptic over the hours.]

[Margin: Spots very close to setting grow dim and become like clouds.]

b–a and c–a to be found equal in the Image: this you will impute not to the phenomenon but to the engraver, for that they were in fact unequal is, by what has been said, entirely certain.

Sixth. The course of this spot was uniform, at least to the senses; for the spaces of equal times and of similar positions are equal. Indeed, the interval from the evening of the 13th to the evening of the 15th equals the interval of the 16th and the 18th, likewise evenings; the positions too are alike and the times equal, as is clear from the figure and the marks. In the same way the remaining eastern intervals will be found equal to the western. Hence it necessarily follows that half the journey, in the east, claims for itself just as much time as the other half claims in the west, and that the equal parts on either side answer likewise to equal parts of time. Therefore, since the spot's evening station of the 21st is given together with its interval to the horizon, the time answering to it is likewise given — one day and $\frac{1}{4}$ hour; and it follows that the eastern interval, which runs between the horizon and the spot's station of the 10th, must be one day, because that interval is, to the senses, equal to the western interstice 11–22 just described. And so the whole apparent course of this spot would be 13 days, $8\frac{1}{2}$ hours, more or less. And since this spot's parallel has no great latitude from the greatest [parallel], it is evident that the perceptible apparent course along the greatest parallel would take not less than 13 days, but more; by how much it exceeds, however, is not here precisely determined for the present.

[Margin: The course is uniform, and the eastern spaces, alike in position to the western, are equal.]

[Margin: The course of this spot: 13 days, $8\frac{1}{2}$ hours.]

[Margin: The course along the greatest parallel: 13 days and some hours.]

Seventh. From this same departure of the spot from the Ecliptic at the horizon it is most evident that the travel-tracks of the spots do not describe circular arcs, but — to the senses — either elliptical ones or ones not much unlike them. But what may be drawn from this quality of the path, and from the spots' long lingering at the horizon, toward establishing the true motion and place of the spots, will become clear in its own place.

[Margin: The apparent tracks of the spots are not circular, but — as far as the senses can tell — not unlike ellipses.]

To be noted.

That I have not adduced all the spots of this or of the following months, nor their continuous and linked observations, [is because...]

[Conclusion of the notes to Image LXI]

[This continues the notes to Image LXI begun on the preceding leaf; the closing text is set here in two columns above the plate.]

I shall adduce [them]. It does not happen for the reason that the Sun was free of spots on those days, or that I was slack in observing — for I did observe, and I have observed spots in great abundance — but because it is not necessary, in pursuing my aim, to bring out each and every one. It is also useful to lay away some coins in the treasury, so that in due time, if I must, I may produce them; and it helps to give others some room in this arena, where they may exercise themselves and display their skill not in words but in deed. No one has filled the gaps of Apelles ["Apelles" is Scheiner's own pseudonym]; perhaps someone will come to supply them.

[Margin: Many observations are not brought forward, so that the occasion of producing them may be left to others by means of other observations.]

Diagram. Full-page engraved plate of the solar disk — a large circle whose horizontal diameter is the ecliptic line AB. The engraved legend across the top reads, at left, **LXI. Imago Observationum** ("Image LXI, of the Observations"); at center, **M.DC.XXVI. In Collegio Romano Societatis** ("1626. In the Roman College of the Society [of Jesus]"); at right, **2^a Martii** ("2nd of March"). Between them are two Tudor-rose emblems flanking a radiant IHS (Jesuit) monogram. Beneath this runs the title: **Cursus Maculae a, à die 10. ad 22. Martii, similis aliis annorum praeteritorum et sequentium, tempore eodem** — "The course of spot a, from the 10th to the 22nd of March, similar to those of other years past and following, at the same season."

The horizontal diameter carries three labels: at the left (eastern) end **A, Oriens** ("A, East"); across the middle **AB, Ecliptica** ("AB, the Ecliptic"); at the right (western) end **B, Occidens** ("B, West"). Along the ecliptic the spot is drawn at its successive daily positions, numbered from 10 to 22, each accompanied by a morning/evening marker (**m** = *mane*, morning; **u** = *vesperi*, evening) and by spot-letters (chiefly **a**, with a secondary **b/d**).

- Near the eastern limb (A): a dense cluster for days 10, 11, 12, 13, 15 (a small facula-like flame is drawn at 11).
- Toward the west (B): spots for days 17, 18, 19, 21, 22.
- At the western limb, two hour-annotations for the exit: **22. u. h. 2¼ [?]** with spot **a**, and **22. u. h. 4⅝** with spot **a**; a point **c** is marked just beyond.

[The individual per-day spot micro-letters (a/b/d) are only partly legible along the crowded track; the day-numbers and m/u markers read clearly.]

Table beneath the plate — MARTII (March). The plate prints the observation table in two side-by-side blocks (left, days 10–17; right, days 18–22). Columns: **D** (day), **H** (hour; fraction of an hour), $\odot$, **El.** (the Sun's position/altitude at the observation, given as degrees and minutes). Combined here:

D (day)	m/u	H (hour)	$\odot$ El. °	'
10	m	7⅞	18	30
11	m	8⅞	21	20
12	u	2 6/7 [?]	31	45
13	u	3⅓	28	40
15	m	8⅞	21	20
15	u	3⅞	22	50
16	m	8⅜	25	50
16	u	—	11	10
17	m	7⅔	18	30
17	u	4¼	21	0
18	m	8⅞	24	0
18	u	4 7/12	16	0
19	m	—	29	30
19	u	—	9	5
21	m	—	30	0
21	u	4⅜	19	10
22	m	9 1/12	34	0
22	u	2½	37	0
22	u	4⅝	17	0

Notes on Image LXII of the Observations. The first [image] of April, from the 4th to the 18th of the same [month].

First. Spot **a**, on the evening of the 4th, settled at the horizon with a small but brilliant facula; then on the following day, and on the 6th as well, it moved on toward the west with the same facula reflected [behind it], and drew after it two other umbrae, **b** and **c** — of which, however, the engraver did not render **b** here — together with faculae. When these had faded after the 8th, the spot went on alone, and steadily weakened in its whole extent, in the nucleus as much as in the surrounding body, until on the 14th it dwindled into very thin, faint faculae. It completed a course of at least thirteen days, as is plain enough from the course of spot **d** in this same image, and from others in the following image and the one immediately preceding. It departed little from the greatest parallel.

[Margin: Spot d, seen at both horizons.]

Second. Spot **d** was seen at each horizon, so that its apparent course can be had quite precisely. At the eastern horizon it was first observed at 4¼ o'clock in the afternoon of the fifth day, with almost its whole body already emerged above it; at the western it appeared almost wholly depressed on the 18th, at 2¼ o'clock in the afternoon. If, then, we allow about 10 hours — or at the least [—] for the body's rising and setting, we make the course of about 13 days, some 8 hours, or at the minimum 6, across the visible Sun. This spot, moreover, was in a state to some degree perfect: round in nucleus and body, constant, and nearly uniform with itself, except that, after the manner of the others, it tapered off little by little away from the middle toward the extremities, growing ever thinner. For the course of this spot you will find courses resembling it not among the spots but among the faculae, in Images XIX and XX at the letters **a**, where a like turning and an equal duration will be found.

[Margin: Course of 13 days, about 8 hours.]

[Margin: A round spot.]

Third. This spot advanced with its center close to the middle; on the 7th and 10th it sat almost centrally on the ecliptic, on the 8th and 9th it passed into the northern parts, and it spent the rest [of its course] in the south. It was nearer the eastern part of the ecliptic than the western; and from the track of spot **a** it deflected a little to the south, so as not to make its own track parallel to it.

[Margin: A spot [first] southern, then northern, and again southern.]

Fourth. This spot ran through equal spaces — spaces almost equally distant from the center C — in equal times: such are the eastern [span] between the 8th and 10th days and the western between the 13th and 15th, where you will find an equality both of spaces and of times, at least to the senses, which is enough for me.

[Margin: The motion of this spot, to the senses, uniform.]

Diagram. Full-page engraved plate of the solar disk. The top of the circle is marked **Z** (north), the bottom **N** (south). The engraved legend reads, at left, **LXII, Imago Observationum** ("Image LXII, of the Observations"); at center, **M.DC.XXVI. In Collegio Romano Societatis** ("1626. In the Roman College of the Society"); at right, **1. Aprilis** ("1st of April"). Two Tudor-rose emblems flank a radiant IHS monogram. Below runs the title: **Cursus Macularum, à die 4. ad 18. Aprilis, similes aliis aliorum annorum, tempore eodem** — "The course of the spots, from the 4th to the 18th of April, similar to those of other men in other years, at the same season."

The horizontal diameter carries the labels **A, Oriens** ("A, East") at the left end, **AB, Ecliptica** ("AB, the Ecliptic") across the middle with the center marked **C**, and **B, Occidens** ("B, West") at the right end. Along the ecliptic the spots are drawn at their daily positions, numbered from 4 to 18, each with a morning/evening marker (**m/u**) and spot-letters (chiefly **a** and **d**, with **b, c** in the eastern cluster).

- Near the eastern limb (A): a dense, overlapping cluster of traces for days 4–8, tangled with several letters (a, b, c, d, and morning/evening u markers).
- Days 9, 10 approach the center; day 11 sits at or near C.
- Toward the west (B): days 12, 13, 14, 15, 16, 17, 18, each a paired spot (upper on the line, lower below it) with d/u/m markers.

[The eastern cluster (days 4–8) and the per-day micro-letters are only partly resolvable at this resolution; the day-numbers 4–18, the cardinal points, and the Z/N poles read clearly.]

Table beneath the plate — APRILIS (April). Printed in two side-by-side blocks (left, days 4–11; right, days 12–18). Columns: **D** (day), **H** (hour), **☉, El.** (degrees and minutes). Combined:

D (day)	m/u	H (hour)	☉ El. °	'
4	u	4	27	25

D (day)	m/u	H (hour)	☉ El. °	'
5	u	4 ³ / ₈	23	30
6	u	4 ³ / ₄	19	0
7	u	4 1/12	27	0
8	u	4 1/10	27	30
9	u	4 ³ / ₄	20	25
10	m	7 ¹ / ₂	22	30
11	u	3 ³ / ₈	35	30
12	u	4 ¹ / ₂	23	0
13	u	4	29	0
14	u	4 ⁵ / ₈	22	0
15	m	7 1/12	18	30
16	u	5	18	30
17	u	3 ³ / ₄	33	35
18	u	2 ³ / ₄	43	30

Notes on Image LXIII of the Observations. The second [image] of April, from the 7th to the 19th of the same [month].

First. Spot **a**, on the morning of the 7th — long and swollen in the middle, tapering above and below into sharp shadowy points — sent a facula ahead of it and drew below it a thin spot, more like an umbra, contiguous with the horizon. I placed it toward the northern side, so that everything might have its place; yet on the straight track it is set out even without other companions.

On the 8th it grew, drawing after itself several umbrae and larger faculae.

On the 9th, 10th, and 11th the rearward spots are seen to have approached the foremost — which is contrary to the ordinary manner of the phenomenon.

From the 12th onward all of them began to diminish and fail, as is clear from the drawing; on the 19th a huge facula followed the spot, into the place of the vanished spots. Compare this day with the 8th and you will find a great likeness. What train of umbrae and faculae it drew with it on the 18th, you have at the side.

[Margin: Spots resolved into faculae.]

The course of this spot extends to 13 days and more, and has some likeness to the course of the umbrae and faculae **A** described in Images XIX and XX, which completed their circuits with a like flow and in an equal time.

[Margin: The course exceeds thirteen days.]

Second. Spot **b** was first observed on the Sun on the evening of the 7th; and when, on the 8th, it presented itself again to view, it drew another, **c**, after itself, with remarkable faculae. The advance of the two was in a sensibly identical parallel; and thereafter — what is very rare in this phenomenon — their apparent mutual distances, if taken from the center C, being equally removed on either side, were found sensibly equal to one another: such are those of the 8th and 19th, and of the 10th and 17th.

[Margin: Uniform motions.]

So too the intervals of the two, run through in equal times and at the same places, or at places equally distant from the center, appeared equal to one another. On the 9th, 12th, 13th, and 16th they displayed umbrae, which, however, were not long-lasting.

[Margin: The spot is shaped according to the figure of its nucleus.]

What train of faculae and umbrae the two led on the 18th and 19th, you have delineated partly from the side, partly on the royal [i.e. principal] track. Both grew, from their rising toward the middle, heavy with misshapen nuclei; then, from the middle toward the west, they began to diminish again — where you see the figure of spot **c** adjusted to the pattern of its nucleus.

Third. The track of the two is sensibly equidistant from the track of spot **a** — which too is rare in this phenomenon. And if a sound reckoning be made of the horizontal intervals, both at rising and at setting, each will be found to have accomplished its passage across the visible circle of the Sun in thirteen days, eight hours at the least. You will find something like this course in Image XX at the letter **b**; yet in the time in which the Sun's [circuit] was run through, some difference appears to come in — which in this phenomenon is neither new nor unusual.

[Margin: Duration under the Sun, 13 days, 8 hours or more.]

IMAGO SOLIS LXIII

Diagram. Full-page engraved solar disk, the sixty-third image of the observation series. The engraved titles read, upper left, "LXIII, Imago Observatu[m]" ("LXIII, Image of the Observations"); upper center, "M.DC.XXVI. In Collegio Romano Societatis" ("1626. In the Roman College of the Society"); upper right, "2.^a Aprilis." [reading uncertain — an engraved corner label giving the month]. Below the center title stand two Tudor-rose ornaments flanking the radiate IHS Jesuit monogram. Beneath the emblem: "Cursus Macularum à die 7, ad 19. Aprilis, similes aliis aliorum annorum." ("The course of the spots from the 7th to the 19th of April, similar to those of other years").

The vertical (meridian) axis is marked "Z" at the top and "N" at the bottom. A horizontal diameter — the ecliptic — runs across the disk, labelled "AB. Ecliptica." at center, with its endpoints "A. Oriens." (east, left) and "B. Occidens." (west, right); the midpoint of this line is marked "C".

The spot record is plotted in two horizontal tracks:

- **Upper track** (above the AB line): a row of spots carried across the disk left to right, each tagged with a day-number running from 7 to 19 and the letter "a", most with the time-marker "u" (evening), a few "m" (morning) — e.g. readable "8 a u", "9 a u", "10 a u", "11 a u", "12 a u", "13 a u", "14 a u", "15 a m", "16 a u", "17 a u", "18 a", "19 a ... m".
- **Lower track** (below the AB line): a parallel row of the same days 7–19, here tagged with the letters "b" and "c" (with "u"/"m" markers) — the detailed/lateral positions.

Toward the western (B) limb, days 18–19 are drawn as large, finely-hatched detailed spot-clusters (with legible tags "c", "b", "18", "m", "a").

Individual per-spot micro-letters and time-markers are only partly resolvable even at high magnification; the day-numbers 7–19 and the a/b/c and u/m letters listed above are read with confidence, but many of the smaller interior tags remain [?].

April table (folio 313)

Column key: **D** = day and time (m = morning / u = evening); **H** = hour (with fraction); ☉ **El.** = solar altitude (degrees. minutes).

D	H	⊙ El.	D	H	⊙ El.
7.m.	8 3/8	31. 5.	13.u.	4 —	29. 0.
7.u.	4 1/2	27. 0.	14.u.	4 5/8	22. 30.
8.u.	4 1/12	27. 30.	15.m.	7 1/12	18. 30.
9.u.	4 3/4	20. 25.	16.u.	5 —	18. 30.
10.m.	7 2/3	24. 30.	17.u.	3 3/4	33. 35.
11.u.	3 3/8	35. 30.	18.m.	7 5/8	25. 25.
12.u.	8 1/2	23. 0.	19.m.	8 —	31. 0.

Notes on the LXIV image of the observations, from 21 May to 5 June

Notae in LXIV. Observationum Imaginem, à 21. Maij, ad 5. Iunij.

(The note runs as one continuous narrative through two columns per page; it begins on folio 314, continues in the letterpress at the foot of the plate on folio 315, and concludes on folio 316.)

[Column I.] This image of the observations displays the courses of many different spots, in which are contained matters truly worth recording. For:

First, three northern spots — a, b, and c — arose on the twenty-first day, in physical fact in the shape of an isosceles triangle, and presented a very dull appearance. They were small, everywhere suffused with faint light — which otherwise nearly always happens at the emergence of spots of this kind — and were somewhat washed-out; in short, a careful eye would have called them immersed in the Sun. They were loosely connected by faint umbrae, and the whole enclosed area blazed with a very bright facula. Before this day they had given no prior sign of themselves.

[Margin: Spots immersed in the Sun were walled around by a bright facula.]

On the 22nd they showed themselves better, for they had largely shaken off that doubtful light, though they were still very faint and uniform. They enlarged not only in themselves but also in length and breadth, the triangle a-b-c always keeping a facula in its middle; and the lateral umbra b-a even began to recoil somewhat from a. The triangle, however, changed its character: whereas yesterday the length a-b had been the base of the isosceles triangle, today the breadth a-c took over that role and kept it almost to the end.

[Margin: Both the spots and the triangular space of the spots a, b, c increase in every position of place.]

On the 23rd the triangle grew further into every position of place, and the spots a, b, and c increased most wonderfully in number, mass, and density, as is quite clear from the new nuclei. A new spot, f, moreover emerged; the lateral umbra between b and a seems to have contracted entirely and merged into the nucleus, while conversely the lateral umbra b-c gained a great deal. The internal space adjacent to the base a-c was entirely faculous, as was the region at vertex b, inserted between two nuclei.

On the 24th, as is clear from the lateral depiction — for the whole could not be set on the direct track — the triangle a-b-c still **[Column II.]** grew, but more along its length a-b than its breadth a-c. The other, northern, nucleus at b appears resolved into thin spots, and the whole northern side b-c likewise broken up into several thin spots; spot c, extended in length and breadth, seems to have advanced somewhat beyond the rest of the spot's base, while the part lying in the angle a was somewhat diminished — though a new umbra K was added to it. But f grew in every dimension and advanced far from a. The internal spaces at the base a-c and beside the vertex b, and likewise those adjacent to spot f, were splendid with bright faculae.

[Margin: The faculae within the burning spots still persist, and keep equal pace with the spots.]

On the 25th the triangle a-b-c grew still further in length and breadth; the base a-c too increased greatly and now no longer appears straight but curved, because of the greater advance of spot c — to which, this night, a great accession was made from spots l, physically arisen. K too extended lengthwise as a very thin umbra; and spot f, its figure somewhat altered, spread its fringes toward the inner spots and drew back a little further from a toward the west; the vertex b curved back somewhat on itself and separated from all the rest, the middle spots being reduced to several tiny ones. Meanwhile the white bays at the base around f and next to the vertex near b were full of a faculous light. The nucleus at the middle of the base, formed into a cross, was black and dense.

[Margin: The triangle a, b, c becomes mixtilinear and, beyond all belief and measure, grows in every difference of place.]

On the 26th I did not set down the whole base, because of the narrowness of the space; the other, southern extremity a is lacking, coinciding with yesterday's vertex b. e stretches itself wonderfully toward the west, its nucleus running

ahead; the appendix l spread itself incredibly toward the middle, like a thin, uniform little cloud. Spot f, and the middle spots that yesterday were near them, for the most part vanished; but K too is dying. On the other side the vertex b grows — in one place toward the west — while toward the east it fades into umbra; and yesterday's small spots have become fewer but larger. All the inner white bays are bright with shining faculae, and the whole surrounding rim is marked with a pale-yellowish, as it were golden, greenish, and white colour, as the rim — distinguished by little points — indicates; which, in

[Margin: The inner bays still full of faculae.]

[Column I, foot of folio 315.] others too, on other days of this triangle, and in the more notable figures of other days and times, usually occurs conspicuously; but for brevity's sake I do not mark it.

On the 27th — which I placed entirely on the northern side, since there was no room on the itinerary line — the triangle a-b-c did indeed still grow in reality; but it seems to have taken on the appearance of a station and to have fallen away from being isosceles, **[Column II, foot of folio 315.]** because the base a-c no longer appeared equidistant from the vertex b: instead c drew nearer to it, since spot c freed itself entirely from the base, advancing westward, as the figure shows. Meanwhile, however, l and K stood with their forms somewhat changed; for l contracted its length, while K parcelled itself out into many small spots; f likewise

[Column I.] seems to recall itself from destruction and to gather its former strength. b is consolidated into two, while the appendices take the lead. Most of the white spaces enclosed by the triangle a-b-c shine with faculae.

[Margin: The stupendous enlargement of spot c, running ahead, coalesced with l and K.]

On the 28th, spot c wonderfully united to itself both l and the middle spots (variously changed) as well as K, in a remarkable fellowship; but a too, the original angular spot, seems to be contemplating a divorce from the rest contained in the base. f keeps its accustomed state, its superfluous companions dismissed; b merges into one, its nuclei gradually uniting, and draws stronger companions after it. The white gaps between K, l, c, a blaze intensely with faculae.

[Margin: The white gaps, still kindled with faculae, glow.]

On the 29th you will find the whole triangle a-b-c placed outside the line, because a and K had no room on the itinerary track.

You see how the middle spots gradually fade, and spot a is gradually separated from the rest of the base, and b coalesces into one oblong spot, the following spots being attenuated; f, however, still somehow lasts. But the spots l too work their way out from c. Note also that the nucleus of the base is, as it were, bare toward the west, while toward the east it draws the remaining vapours or clouds somewhat after itself — which is very characteristic of this phenomenon.

[Margin: The nuclei toward the west more inclined and barer.]

On the 30th it was not possible to depict spot a on the straight track except by a black point at its centre; therefore I placed the whole of it to the side. In the itinerary figure you see the spots l, too, cut off from all the others, and the vertex b made optically into one, while the followers are much attenuated. At f new umbrae with faculae emerge, unnoticed until now. The white spaces are beset with faculae.

On the 31st, in the morning, you have the northern lateral figure, in which state the triangle a-b-c appeared, filled with umbrae and faculae; for wherever you look at the white intervals, you will know they were lit up with outstanding faculae. Spot f became joined with umbrae and made like them: all the umbrae as if new and very thin, and they took over whatever lay between the horizon and spot b; spot a too gradually contracts its long nucleus, and with the rest of its body tapers into the form of a washed-out umbra.

On the same day, in the evening, the triangle a-b-c touched the horizon with its vertex b, together with the southern lateral umbrae and faculae; ahead of the umbra and spot f, the spots a and c, still separate, display their nuclei, and a stretches out a long shadowy tail **[Column II.]** — all the white spaces shining with faculae. The spots l grow very slender, though still in a free position.

On 1 June, in the morning, spot b no longer appeared, but two, a and c, and likewise l in the manner of an umbra; f too insinuated a trace of itself on the horizon. I placed all of these on the northern side, because there was no room on the [main] track. Just as —

On the same day, in the evening, I placed the arrangement of the said spots and of umbra l on the southern side, where you also have spots close to the horizon, rather thick, and faculae lying upon that same horizon, both in the north and in the south. As for the rest, you have the central points of spots a and c impressed

at their itinerary positions, with the letters a and c, within the figure of the 31st, evening.

[Margin: The faculae lie even upon the horizon, among the spots.]

Secondly, one must consider the position — the optical figure — of the triangle a-b-c through the individual daily stations. For although it is certain that a triangle keeps its own species and magnitude in itself, the same lines being retained, it is equally certain that any triangle, otherwise unchanged, alters its figure, magnitude, and species optically by position and aspect alone. Hence, even if the spots kept the same distance among themselves unchanged, they would nonetheless vary their figure and magnitude by position and aspect alone. This must happen all the more if local motion is also involved.

[Margin: On the triangular figure that the spots a, b, c presented.]

Therefore the three spots a, b, and c, on the 21st, 22nd, and 23rd, exhibited a rectilinear isosceles triangle, though with varying bases and with all the sides increased. On the 24th and 25th the base a-c became curvilinear, and the triangle turned out isosceles mixtilinear — yet always incredibly enlarged. From the 26th to the 30th it took on the form of a scalene, obtuse-angled figure, and though it decreased somewhat optically, it still always surpassed the figure of the first day by a very long interval. On the 31st it returned to a right angle, such that the two sides containing the right angle were a-b and a-c, while b-c was the side opposite the right angle; and this right-angled triangle was much larger than the isosceles triangle of the 21st.

[Margin: The last triangle, of the 31st day, was larger — in every difference of place — than the triangle of the first day, the 21st.]

Thirdly, the spots b and a ran along in the same parallel, and yet b, in running, overtook spot a by nearly a day's space — which also happens with other spots and at other times.

[Margin: Two spots in the same parallel travel unequally.]

Fourthly, in the same way, spot c was nearer to the eastern horizon than a, and [continues]

IMAGO SOLIS LXIV

Diagram. Full-page engraved solar disk, the sixty-fourth image of the series. Engraved titles: upper left, "LXIV, Imago Obseruationu[m]"; upper center, "Anno M.DC.XXVI. In Collegio Romano Societatis"; upper right, "Maij. Iunij." ("May. June."). Below the center title, two Tudor-rose ornaments flank the radiate IHS Jesuit monogram. Beneath the emblem: "Cursus Macularu[m] à 21. Maij. ad 5. Iunij, similis aliis aliorum annorum." ("The course of the spots from 21 May to 5 June, similar to those of other years").

A horizontal ecliptic diameter runs across the disk, labelled "AB. Ecliptica." at center, with endpoints "A. Oriens." (east, left) and "B. Occidens." (west, right); the midpoint is marked "C" and the western limb terminus "B".

The spot record is again plotted in two tracks (above and below the AB line), the days running from 21 (near the eastern limb) through 31 May and on into early June, densely drawn as clustered spot-groups. Legible per-spot tags include the letters a, b, c, d, f, h, K, l, m, with the time-marker "u", attached to day-numbers 21–31 (e.g. "21", "22", "23", "24", "25", "26", "27", "28", "29", "30", "31"). Large finely-hatched detailed clusters appear at the western (B) limb.

This plate is extremely dense; the day-numbers and the letter set a–m listed above are read with confidence, but the great majority of individual interior micro-tags are not resolvable under magnification and remain [?]. **Many per-spot labels are unresolved.**

May and June tables (folio 315)

Column key: **D** = day and time (m = morning / u = evening); **H** = hour (with fraction); ☉ **El.** = solar altitude (degrees. minutes).

MAII (May)

D	H	☉ El.	D	H	☉ El.
21.m.	8 7/8	43. 0.	26.m.	7 5/8	33. 0.
22.m.	8 1/4	39. 0.	26.u.	4 1/2	30. 40.
22.u.	5 —	25. 0.	27.u.	5 5/8	17. 0.
23.m.	7 7/8	35. 30.	28.m.	7 7/12	32. 30.
24.m.	7 7/8	35. 20.	28.u.	5 1/2	19. 30.
24.u.	4 1/2	31. 10.	29.m.	8 1/4	46. 0.

D	H	☉ El.	D	H	☉ El.
25.m.	7 7/8	34. 50.	29.u.	5 —	27. 30.
			30.m.	7 7/8	30. 30.
			30.u.	5 —	24. 45.
			31.m.	8 1/12	38. 35.
			31.u.	5 1/2	20. 0.

IVNII (June)

D	H	☉ El.
1.m.	7 1/4	29. 30.
1.u.	5 1/3	22. 30.
2.u.	4 1/4	33. 0.
3.m.	7 7/8	37. 0.
3.u.	5 1/4	18. 10.
4.m.	7 —	26. 40.
5.m.	7 —	26. 30.

The notes on Image LXIV continue from the previous folio (they carry no fresh heading here); folio 317 opens mid-sentence, below the engraved plate that fills the top of the page.

Diagram. A full-page engraved plate of the solar disk, drawn as a large circle. Along the top run the title cartouche and emblems; a horizontal diameter (the ecliptic) crosses the disk, with the sunspot tracks drawn as two bands, one above and one below the line; three tables of observation data occupy the foot of the disk.

- Running head (above the plate): "IMAGO SOLIS LXIV. 317"
- Upper left, inside the disk: "LXIV. Imago Observationum" ("Image LXIV of the observations")
- Upper center: "ANNO M.DC.XXVI. In Collegio Romano Societatis" ("In the year 1626. In the Roman College of the Society [of Jesus]"), with the Jesuit IHS sunburst emblem flanked by two heraldic-rose ornaments.
- Center, below the emblems: "Cursus Macularum à 21. Maij. ad 5. Iunij, similis aliis aliorum annorum." ("The course of the spots from 21 May to 5 June, like that of others in other years.")
- Upper right corner: "Maij." / "Iunij." ("of May / of June")

- Horizontal diameter (the axis of the drawing): far left endpoint labeled **A**; along the line, left side "A. Oriens." (A, the East); center "AB. Ecliptica." (AB, the ecliptic) with **C** marking the mid-point on the line; right side "B. Occidens." (B, the West); far right endpoint labeled **B**.
- Two bands of sunspot figures — an upper (boreal) band above the ecliptic line and a lower (austral) band below it — each drawn as chains of small stippled blots representing the same spots at successive daily positions. The individual blots carry very small engraved micro-labels: spot letters (a, b, c, d, e, f, h, i, k, l, m) paired with day-numbers (21–31 for May, 1–5 for June) and the morning/evening marks (m, u). These micro-labels are at the resolution floor and cannot be resolved blot-by-blot with confidence; they are not individually transcribed here.

The three tables engraved at the foot of the disk (headed MAII, MAII, IVNII), transcribed as native tables. Each has columns **D.** (day), **H.** (hour), $\odot$ (degrees), **El.** (minutes); the "m" = morning, "u" = evening.

Table 1 — MAII (May):

D.	H.	$\odot$	El.
21 m.	8 $\frac{7}{8}$	43	0
22 m.	8 $\frac{1}{4}$	39	0
22 u.	5	25	0
23 m.	7 $\frac{7}{8}$	35	30
24 m.	7 $\frac{7}{8}$	35	20
24 u.	4 $\frac{1}{2}$	31	10
25 m.	7 $\frac{7}{8}$	34	50

Table 2 — MAII (May, continued):

D.	H.	$\odot$	El.
26 m.	7 $\frac{5}{8}$	33	0
26 u.	4 $\frac{1}{2}$	30	40
27 u.	5 $\frac{7}{8}$	17	0
28 m.	7 $\frac{7}{12}$ [?]	32	30
28 u.	5 $\frac{1}{4}$	19	30
29 m.	8 $\frac{1}{4}$	46	0
29 u.	5	27	30

D.	H.	⊙	El.
30 m.	$7\frac{7}{8}$	30	30
30 u.	5	24	45
31 m.	$8\frac{1}{12}$ [?]	38	35
31 u.	$5\frac{1}{2}$	20	0

Table 3 — IVNII (June):

D.	H.	⊙	El.
1 m.	$7\frac{1}{4}$	29	30
1 u.	$5\frac{1}{3}$	22	30
2 u.	$4\frac{1}{2}$	33	0
3 m.	$7\frac{7}{8}$	37	0
3 u.	$5\frac{3}{4}$	18	10
4 m.	7	26	40
5 m.	7	26	30

[Notes on Image LXIV, continued — folio 317, letterpress below the plate]

on its way out it once more got ahead of that same spot a, so as to reach the western horizon sooner; and just as it had earlier drawn away from a in latitude and stood farthest from it at mid-course, so on its exit it again drew very close to it, at least optically.

Fifth: the duration of spot b, from its first appearance on the Sun — which was on the 21st, in the morning, at $8\frac{7}{8}$ hours — up to its contact with the western horizon, was 10 days and about 9 hours, more or less. The duration of spot c, from the 21st up to the evening of 1 June, was about 11 days and 9 hours; and if to this we add the time still owed for the remaining stretch to the western edge — perhaps 9 hours — it will thus not quite reach 12 days. Finally, the duration of spot a up to its western contact will come nearly to 12 days; for on the evening of 1 June, at the assigned hour, its trace still stood a fairly good distance from the western edge.

And so, if we also examine the spaces that lie between the eastern horizon and the spots a, b, and c, then the interval from the eastern edge to b must be reckoned at one day and about 22 hours. For since the spots' paths at this time are nearly rectilinear, they — as far as the senses can tell, and as experience confirms — cover equal spaces in equal times, and take equal times to run

through equal spaces. Now the interval of spot b, from the morning of the 30th up to its western contact, is one day and roughly 12 hours or more; and since that western span is a little less than the eastern one, it is clear that the eastern interval must be one day and more than 12 hours — namely about 22. So the whole course of spot b, from rising to setting, was at least 12 days and 7 hours.

[Margin: The course of spot b: 12 days, 7 hours.]

The course of spot c, reckoned in the same way, would come to at least 13 days. The course of spot a lasted, from contact to contact, about 13½ days. But these matters will be treated more fully in their proper places; for now they are only glimpsed in passing.

[Margin: The course of spot c: 13 days, at least. The course of spot a: 13 days, 12 hours.]

Sixth: having dealt in passing with the boreal spots a, b, and c, I turn to the austral ones. The first of these to appear is d, with its shadowy facula, to which I assigned the number 21; and this one — or rather these — ran together with the boreal triangle in a nearly parallel motion, as will be evident to anyone who observes. So on the 21st, d was a spot having another attached in front of it, and then a further notable facula toward the south, with a shadow. Afterward, as the faculae faded, first two, then four, then a full ten spots followed; these, reduced again to fewer, at last coalesced into two larger ones on the 29th and 30th. And on that same day and the next they began once more to pass off into shadows and faculae, of which the more boreal and more westerly always stood equally distant from spot b. It lasted on the Sun, from rising to setting, at least 12½ days.

[Margin: The incredible variety of the spots, shadows, and faculae d, and its stay on the Sun of 12½ days.]

Seventh: spot e, dragging behind it faculae and shadows that touched the horizon, was first seen on the evening of the 22nd. On the 23rd it seems to have contracted into a small spot that shadow which the day before had spread out widely (something quite common in this phenomenon), and then, after a single day, it lost that spot, physically consumed. The spot itself, however, advanced — with uniform thinness, yet enlarged — to the 26th, after which it decreased, and in decreasing it split into two ever-smaller spots, until on the 30th, seen for the last time, it perished, its position toward the ecliptic having meanwhile stayed unchanged.

[Margin: The advance and death of spot e.]

On the following days a thin facula flashed out in its place, but because of its faintness I did not record it.

Eighth: spot h, which arose on the evening of the 24th, drew behind it two shadows with a facula set between them, which I marked with the letter i; and because on the 25th there was no room on account of facula 21, I marked only its position with a nucleus, but drew the whole spot, with its following faculae, off to the side. On the morning of the 26th, both it and the following shadows and faculae grew vigorously. On the evening of that same day, in the place of the following shadows, spot I began to appear, which thereafter, up to the first of June, was seen in varying forms — sometimes two, sometimes one larger, soon none at all. But whether the shadows that returned on 2 and 4 June are the same spots and shadows I is a question not to be dismissed, since similar appearances occur almost daily in other spots as well. I reserve this matter, however, for discussion elsewhere. Meanwhile, in short, I judge outright that the same shadows very often endure in this way, and I scarcely doubt that this was entirely so here. Yet the boreal shadow that appeared afresh on the 4th seems to have arisen physically, for there had been no indication of it before. Spot h, after 28 May, gradually decreased; in the middle, too, it appeared oblong, bearing a similar nucleus as if it had been fused out of two, and tapering into softly roughened edges — just as most spots do, and the faculae too, but by far most of all the shadows.

This spot traveled across the Sun, if we examine everything exactly, from horizon to horizon in about thirteen and a half days; and its travel was nearly rectilinear and, to the senses, parallel to that of spots a and b.

[Margin: The course of spots h was 13 days and 12 hours, more or less.]

So from this single image of the observations you have six distinct spot-courses: three boreal, from spots a, b, and c, and three austral, from spots d, e, and h.

Second: you have courses of differing speed — in time, in position, and on the same parallel — as is clear in spots a, b, and c; for one's course is the shortest, another's the longest, c's is intermediate, and so on. You also have the austral spots, which differ from some of those.

Third: you have the astronomical and physical risings and settings, of the spots as well as of the faculae and of the shadows.

Fourth: you have the strange increases and decreases of these same [phenomena], and also the prodigious generations of nuclei, and their remarkable meetings and separations.

Fifth: you have the complete courses of the faculae, together with the spots and within the spots, from their first, physical emergence — which occurred on 21 May — up to their astronomical setting, which began on 31 May and was completed on the evening of 1 June, or at the latest on the morning of 2 June; for the triangle a, b, c, together with its spots, faculae, and shadows, used up just that much time in passing across the western horizon. And all of these always share one and the same motion, and are joined in an indissoluble fellowship — so much so that they everywhere work reciprocal metamorphoses upon one another, since one is born out of another, and there exists a conversion of each into the other.

Diagram. The lower part of folio 319 carries a second impression of the very same engraved plate described above (fig-p449-1): the identical solar disk headed "LXIV. Imago Observationum. ANNO M.DC.XXVI. In Collegio Romano Societatis," with the IHS emblem, the two roses, the "Maij. / Iunij." corner label, the A–B ecliptic axis, the two spot bands, and the three MAII/MAII/IVNII foot-tables. The running head reads "IMAGO SOLIS LXIV. 319." This impression is fainter than the one on folio 317 and shows heavier show-through. Its labels and foot-tables duplicate fig-p449-1 and are not re-transcribed here to avoid divergent readings.

Notae in LXV. Observationum Imaginem, Iunij & Decembris.

[Notes on Image LXV of the observations, for June and December.]

(Folio 320. Running head: "ROSAE VRSINAE LIB. III. 320.")

[Margin: A new form of the images is proposed.]

I make a leap, and join together two months that lie half a year apart from each other — hence opposite on the semicircle — and I set before your eyes a new form for the images, so that you may see the spots, with their motions and positions, in opposite months, set subcontrarily against one another. This is what you have to observe in this figure in spots a and b, for they are half a year apart: spot a is wholly boreal, b wholly austral. Spot a, from its boreal rising F, tends obliquely toward its setting, drawing near the ecliptic AB at G; and, conversely, spot b, from its austral rising H, ends its setting at I as it approaches the ecliptic and the boreal region. The path of spot a is convex toward the austral region; and, conversely, the traveling curve of spot b bulges out into the northern part, P.

A very great likeness of the two arcs also appears. So much in general; now let us examine the particulars one by one.

Explanation of spot a.

The spots and faculae observed from 5 May to 17 June, many and frequent, I deliberately pass over, because I do not intend to bring forward each and every one; and then because, just as with other Censors of Apelles — as I did in the case of Apelles — so here too, I grant to each his own place, presenting and establishing what is his by his own means and what is mine by mine. Spot a, then, first seen on the 19th, appeared quite full and dense, prolific with no small nucleus; and you have its individual daily appearances and markings noted in the attached table, up to and including the 28th. For it was neither my intention nor my place to carry these same [details] over into the Image of the observations — just as there was no place, either, to carry over any other very ample [spot] of it, accompanied by its faculae and shadows. On the 17th, in the evening, I drew only the nucleus, for the sake of avoiding confusion; the rest the Sun projected onto the paper exactly as you see it printed. Here, consider the figure and position of the spot with respect to the pole M, from the axis M E N, the circle... [text cut off at the foot of the column; continues on the following folio].

The attached table for spot a (headed IVNII), transcribed as a native table. Columns **D.** (day), **H.** (hour), $\odot$ (degrees), **El.** (minutes); "m" = morning, "u" = evening.

D.	H.	$\odot$	El.
17 m.	7 $\frac{1}{4}$	31	25
17 u.	5	26	0
18 m.	7 $\frac{3}{4}$	37	40
18 u.	5 $\frac{5}{8}$	20	0
19 m.	7 $\frac{1}{8}$	29	40
19 u.	6	15	30
20 m.	[blank]	30	30
20 u.	5 $\frac{1}{2}$	22	40
21 m.	8 $\frac{1}{8}$	39	50
21 u.	5 $\frac{1}{8}$	26	0
22 m.	6 $\frac{1}{2}$	21	0
22 u.	4	37	0

D.	H.	☉	El.
23 m.	$7\frac{3}{8}$	32	30
23 u.	$4\frac{1}{2}$	33	20
24 m.	$7\frac{7}{8}$	36	50
24 u.	6	16	30
25 u.	$3\frac{3}{4}$	40	0
26 m.	$7\frac{3}{8}$	31	40
27 m.	$7\frac{2}{5}$ [?]	30	0
27 u.	$5\frac{5}{8}$	20	0
28 m.	$7\frac{1}{4}$	30	10
28 u.	$5\frac{3}{4}$	19	20

Rosa Ursina, Book III — Notae Particulares (Images LXV–LXVI)

Diagram. A full-page engraved solar disk, the sixty-fifth observation-image, the "new image form" that pairs a June and a December course on a single disk.

- Header (across the top of the disk): **LXV, Imago Observationum** (left) — "LXV, Image of the observations"; **M DC XXVI. In Collegio Romano Societatis. Cursus duo subcontrarij** (center) — "1626. In the Roman College of the Society [of Jesus]. Two subcontrary courses"; **Iunij. et Decembris.** (right) — "of June and of December."
- Two radiant emblems flank the center just below the header: the **IHS** monogram (left, the Jesuit sunburst device) and the **MRA** monogram (right, the Marian device).
- Vertical axis (top to bottom): points **P, C, M** at the top; through **E** at the disk's center; to **N, D, O** at the bottom. (M E N is the axis of the spots' motion; C E D the axis of the ecliptic.)
- **Upper track (spot a):** label **Cursus Maculae a, à die 17. ad 28. Iunij. 1626.** — "Course of spot a, from the 17th to the 28th of June, 1626." The track runs from point **F** (left) to point **G** (right); each spot is marked **a** and dated: **17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28** (twelve consecutive days).
- **Ecliptic and cardinals:** **A, Oriens.** (point A, left edge, mid-height — "A, East"); **AB, Ecliptica.** (the horizontal line A–B, the ecliptic); **B, Occidens.**

(point B, right edge, mid-height — "B, West"). Left edge, from top to bottom: points K, A, L, H. Right edge below B: point I.

- **Lower track (spot b):** label **Cursus Maculae b, à die 18. ad 29. Decembris. 1626.** — "Course of spot b, from the 18th to the 29th of December, 1626." The track runs from point H (left) to point I (right); each spot is marked **b** and dated: **18, 19, 20, 21, 22, 23** (left cluster), then **26** and **29** (right). (Days 24, 25, 27, 28 are absent, matching the cloudy days noted in the text.)
- Three engraved Orsini roses (decorative, part of the plate) sit within the lower half of the disk.

Notes (letterpress at foot of plate)

[Column I → II, continuous]

around which spot a moved; for it evidently looks toward that pole and adapts its own shape to it. Next, how the nucleus and the surrounding haze [halitus] change shape in the same way: on the 20th and 21st, in the morning, both appear round, but on the remaining days oblong. And further, the manner in which the two grow together in bulk and intensity, from the 17th to the 21st — and from then on both fade together, so that on the 28th, in the evening, when the spot grazed the horizon, it had become both small and very faint. It therefore left the Sun already in decline; and from that fairly rapid fading we should not suppose that it lingered long in the hemisphere opposite this one.

[Column I]

There is no doubt that it remained in the Sun's visible hemisphere for thirteen days, if the space F–a is taken into the reckoning; but whether — and by how much — it exceeded them, I do not now decide. As for how far the axis of this motion, M E N, is inclined to the axis of the ecliptic, C E D: the chord F G is inclined by just that much to the ecliptic's line of section, A B, in the ordinary way — at least so far as I have been able to gather from the observations up to now.

[Margin: Why the axes are drawn partly with an unbroken and partly with a broken line.] Now, I drew one half of the whole axis M E N as a solid line, M E, and the other, E N, as a broken one, precisely so that you would recognize that the axis M E is raised and the other, E N, sunk toward the averted side of the Sun — the reverse of what you see in the axis O P, which spot b faces; and you should know that the same has been done in the other Images as well.

I want you further to be warned that the axis M E N is here drawn along the longest chord of the course, and that it is neither fixed nor stationary, but at

every moment turns, in an annual revolution, about the stable axis of the ecliptic, C, D, in a small circle set a fixed distance from the ecliptic's axis. Hence in the course of any given spot there are as many positions of this movable axis as there are spots. [Margin: Only the axis of the middle course is brought in.] Here, however, I bring in only one, and that the middle one, for the sake of illustration and instruction; for you will find special material on this axis in the following book.

Explanation of spot b [Maculae, b, explanatio.]

This spot b could not be observed on the 17th of December because of bad weather, and so it was first recorded on the 18th and the days following, in the manner you see. It brought with it a most brilliant and abundant retinue of spots, umbrae, and faculae, but for the reasons—

[Column II]

—already stated I pass it over, content with the diagram of the spot alone, so as to trace its path; and its daily record you see set out in the accompanying little table, from the morning of the 18th to the forenoon of the 29th, likewise before noon. On the 20th and 23rd I recorded only the nucleus, in the afternoon. When everything is duly reckoned, the whole course does not seem to have exceeded thirteen days; whether it actually completed them, someone may perhaps doubt. The position of this spot is subcontrary to the position of spot a, and it faces the pole O quite plainly; and at mid-course — namely on the 22nd and 23rd — it shows a round shape.

Tabula diaria. 1626. — DECEMBER.

D	H	☉	El.
18. m.	9 1/8	16.	10.
19. m.	9 1/8	14.	0.
20. m.	8 7/8	13.	30.
20. u.	3 5/8	9.	20.
21. m.	9 1/2 [?]	17.	30.
22. u.	2 3/4 [?]	16.	0.
23. m.	9 1/4	14.	5.
23. u.	2 4/7 [?]	16.	30.
26. u.	2 4/8 [?]	18.	0.

D	H	☉	El.
29. m.	9 1/8	14.	30.

Diagram. A second, essentially identical engraving of the sixty-fifth observation-image, printed on a distinct leaf (its verso carries the letterpress notes for Image LXVI, which show through). All labels, tracks, and datings match the plate : the same header (**LXV, Imago Observationum. M DC XXVI. In Collegio Romano Societatis. Cursus duo subcontrarij. Iunij. et Decembris.**), the same IHS and MRA emblems, the same upper track **Cursus Maculae a, à die 17. ad 28. Iunij. 1626.** (spots a dated 17–28, from F to G), the same ecliptic **A, Oriens. — AB, Ecliptica. — B, Occidens.** with points K, A, L, H (left), E (center), B and I (right), and the axis points P, C, M (top) / N, D, O (bottom), and the same lower track **Cursus Maculae b, à die 18. ad 29. Decembris. 1626.** (spots b dated 18–23, 26, 29, from H to I), with the three Orsini roses. See the QA note on the duplication.

Notes on Observation-Image LXVI. [Notae in Observationum Imaginem LXVI.] Of July in the year 1626 and of January in the year 1627.

[Column I]

Again there are two courses of spots, a and b, separated by a span of six months; of these, a ran from the 6th to the 18th of July, in the year 1626. You see the distinct daily times of the course in the accompanying table.

Spot a always carried two nuclei — now merged, now separated — and in the middle showed three; it arranged its position and shape, in the manner of the others, according to the raised pole H and the axis H E I, which it presents closer to the axis C E D than in the earlier diagram. This happens because it moves in the ascending semicircle of the visible small circle; and by as much as the part H E rises, by that much the hidden part E I descends, and in the same proportion, too, the paths of the spots are curved — paths that arise solely from the turning of the small circle, which each year carries round the poles of the movable axis.

The more the winding of the spots' path increases, the more the chord F G — or the straight line A K parallel to it — approaches the ecliptic, A B, and makes the angle B A K sharper; and this angle is always found to be roughly equal to the angle H E C.

[Margin: Duration of spot a.] The duration of this course, from rising to setting, was about thirteen days. On the evening of the 18th the spot began, as it were, to

graze the horizon; after culmination it began to fade a little, though it approached the horizon still quite vigorous. [Margin: The spots are shown by themselves, without any other retinue.] The rest of this spot's apparatus, which was not large, I prudently pass over, as I do the other days both of this and of other months, whose observations I possess in great and fruitful number. [Margin: Empty intervals are purposely left for others to fill.] But it is right to leave empty intervals for other observers too — especially for those who, in this age of ours, lay claim to the right of the heavens for themselves alone, on the strength of I know not what privileges — intervals which, by filling them, they may use to commend their own authority and reputation to some degree.

[Column II]

IVLIVS.

D	H	☉	El.
6. m.	8 1/8 [?]	40.	0.
7. m.	7 1/8	30.	40.
8. m.	8.	38.	0.
9. m.	7 1/4	29.	25.
10. m.	7 1/2	32.	0.
11. m.	7 3/4	34.	30.
12. m.	7 1/4	29.	30.
13. m.	7 1/2	32.	30.
14. m.	7	27.	0.
15. m.	7 1/8	31.	30.
17. m.	7 1/4	29.	0.
18. m.	7 1/2	32.	20.
18. u.	4 1/4	28.	30.

On the northern spot, b. [De Macula Aquilonari, b.]

It completes its course in the northern region of the Sun, in the year 1627, from the 9th of January to the 21st of the same month. Its path is concave toward the southern region, because the part of the axis, N E, about which it was rotated, stood raised above the plane of the solar circle, A C B D. Its inclination with respect to the ecliptic is oblique from south to north — just as that of spot a is from north to south — as is clear from the chords L M and F G, or from their parallels, A P and A K. It grew markedly toward the middle, and from there

decreased in roughly the same proportion. It moved almost solitary, without a large [retinue]—

Diagram. Full-page engraved solar-disk plate, *IMAGO SOLIS LXVI* ("Image of the Sun 66"), the folio-325 impression. A single large circle represents the Sun's disc, crossed by a horizontal ecliptic line and by two near-vertical axis lines, and carrying two roughly horizontal spot-tracks (an upper track for spot **b**, a lower track for spot **a**), each spot drawn as a small inked blot with a letter above and a day-number below. Inside the disc, upper left, are two radiant roundel emblems — the Jesuit **IHS** monogram (left) and the Marian **MRA** monogram (right) — and near the bottom two heraldic rose devices (the Orsini rose). Below the plate is a foliate printer's ornament.

Readable labels and their positions:

- Engraved header (top of page): **IMAGO SOLIS LXVI. 325**
- Top-left, inside disc: **LVI, Imago Observationum.** ("56th, Image of Observations" — note the internal number LVI vs. the header LXVI; see anomaly a)
- Top-center: **In Collegio Romano Societatis** ("In the Roman College of the Society [of Jesus]")
- Top-right: **Iulij, 1626. / Ianuarij, 162[7].** ("July 1626 / January 1627")
- Top apex of circle: the letters **O · C · H**
- Bottom apex of circle: the letters **I · D · N**
- The solid near-vertical line is labelled **Axis annuus Fixus** ("fixed annual axis"); the dashed near-vertical line is labelled **Axis temporarius Mobilis** ("movable temporary axis") — both labels appear on the upper and lower halves.
- Left of disc: **A, Oriens** ("A, East"), with point **A** at the left rim and point **F** just below it.
- Right of disc: **B, Occidens** ("B, West"), with point **I** near the right rim.
- Center horizontal line: **AB, Ecliptica** ("AB, the ecliptic"), with point **E** marked just below the line at center.
- Upper (northern) spot-track caption: **Cursus Maculae b, à die 9. ad 21. Ianuarij, anni 1627.** ("Course of spot b, from the 9th to the 21st of January of the year 1627.")
- Upper-track spots, each marked **b** above and numbered below, running left→right from the left endpoint **L**: 9, 10, 11, 12, 14, 15, 16, 17, 18, 19, 20, 21, ending at the right endpoint **M**. (No spot numbered 13 is drawn —

matching the January table, which has no day-13 row.) At day 21, near endpoint M, the small markers **m** (morning) and **u** (evening) mark the two limb positions.

- Lower (southern) spot-track caption: **Cursus Maculae a, à die 6. ad 18. Iulij, anni 1626.** ("Course of spot a, from the 6th to the 18th of July of the year 1626.")
- Lower-track spots, each marked **a** above and numbered below, running left→right from the left endpoint **F**: 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 17, 18, ending at the right endpoints **K / G**. (No spot numbered 16 is drawn.) At day 18, near the endpoints, the markers **m** (morning) and **u** (evening) again mark the two limb positions.
- Bottom-center caption: **Cursus duo Macularum a et b, subcontrarij.** ("The two courses of spots a and b, [being] subcontrary.")

(Notes to Image of the Sun LXVI, continued — section I of the notes, with its running apparatus of 5-line marginal reference numbers.)

I.

[Margin: The tarrying of spot b on the Sun.]

[?] din, and without much light from the faculae.

Its tarrying on the open disc of the Sun did not exceed thirteen days — of that, with everything computed, I am certain; indeed I judge it more probable that it did not fully reach thirteen. Here I set out its itinerary-table for study. It had a dense, black nucleus, cleanly cut off from the other cloud surrounding it, and it was a substantial spot; the enveloping vapor always mimicked its changing configuration — unless one prefers to say that the changes of the one arise from the variability of the other. I decide neither point for now.

The diameter of this spot in longitude, as it appeared laid out near the disc's center, stood to the Sun's diameter as 1 to 23. Hence, once the Sun's size is given, the spot's size is also given — so far as it can be determined for bodies of this kind, which are less regular and forever variable.

On the 19th the nuclei began to grow very thin and, as it were, to break into several pieces; and the rest of the spot's body, too, began to be attenuated.

II.

IANUARIUS.

D.	H.	☉	El.
9.	m. 9¼	15.	0.
10.	m. 9¼	16.	10.
11.	m. 9¼	16.	15.
12.	m. 9	14.	0.
14.	m. 9½	15.	0.
15.	m. 9 1/12 [?]	15.	0.
16.	m. 9½	17.	10.
17.	m. 9¼	16.	0
18.	m. 8⅞ [?]	14.	10.
19.	m. [blank]	23.	40.
20.	m. 9¼	17.	10.
21.	m. 8¾	13.	0.
21.	u. 3 9/10	8.	40.

Diagram. A second, essentially identical impression of the same engraved plate, IMAGO SOLIS LXVI, here on folio 327 (engraved header **IMAGO SOLIS LXVI. 327**). Its readable content — the disc, the two axis lines (**Axis annuus Fixus / Axis temporarius Mobilis**), the ecliptic **AB** with points **A, Oriens** and **B, Occidens**, the IHS and MRA emblems, the two spot-tracks with captions **Cursus Maculæ b, à die 9. ad 21. Ianuarij, anni 1627.** and **Cursus Maculæ a, à die 6. ad 18. Iulij, anni 1626.**, the bottom caption **Cursus duo Macularum a et b, subcontrarij.**, the internal label **LVI, Imago Observationum.**, and the dates **Iulij 1626 / Ianuarij 1627** — matches the folio-325 impression described above (fig-p457-1). The letterpress of the LXVII notes (folio 328, the verso of this same leaf) shows through mirror-reversed and should not be read as plate content. See anomaly b. Signature at foot: ****.

Notes on Observation-Image LXVII — from the 8th of August to the 18th of the same [month], in the year 1626; likewise from the 5th to the 16th, and from the 9th to the 22nd, of February, in the year 1627.

(Section I of the notes, with its running apparatus of 5-line marginal reference numbers.)

I.

[Margin: The course and table of spot a.]

This spot, a, moved entirely across the southern part of the Sun. And since its path-arc F–G is concave toward the elevated northern pole R and convex toward the depressed [southern pole] S — the whole northern part of the axis, R E, projecting above the solar plane ACBD, while the other part, E S, the southern, lies beyond that same plane in the opposite region — it necessarily follows that the visible arc F–G, described regularly on the Sun's surface about the hidden part of the axis E S, is smaller than a semicircular segment, by Proposition 19 of Book 2 of Theodosius [Theodosius of Bithynia, *Sphaerica* II.19], as given in Clavius [Christoph Clavius]. And observational practice itself confirms this: for if you pass from the 8th day of observation to the 18th, you find exactly 10 days; but the interval 18–G, the remainder in the west, amounts to no more than a natural day — which I demonstrate from the eastern interval 5–6 of the not-dissimilar and subcontrarily opposed course I–K of spot c, to which interval 16 hours correspond.

[Margin: The course of spot a; its tarrying on the Sun.]

In the same way, for the eastern gap F–8, if everything is examined most rigorously and the fullest allowance of time is made, you will scarcely extract more than 1 day and 18 hours. And so the whole course of spot a will indeed exceed 12 days, but will not reach 13.

[Margin: Certain things worth noting concerning spot a.]

In the very position and configuration of the spot, however, certain things worth noting occurred. First, its situation in the east on the 8th, on which day the spot was not evenly extended along the horizontal line A F H, but stood closer to that line on its southern part and farther from it on its northern. This, I judge, happened because there were in fact several spots which, by their aspect and sloping position, presented themselves to the eye as one — so that the one lying nearer the horizon threw out its southern tail in a nearer position. The appearance of the following days makes this plain enough, since on the 9th two, on the 10th three, and on the 11th five distinct spots were seen; yet on the days after that they partly merged together again into a mass, or partly, being diminished, disappeared.

Now I come to the subcontrary courses of this spot, which are three — of spots b, c, and d — all of which occurred in the year 1627, in the same month of February.

Spot b, the southern one, advancing by a concave path with its concavity turned toward the south and itself moving toward the north, proceeded from the 5th to the 16th of February, leaving gaps at both ends — H at 5 in the east (at rising) and 16–G in the west (at setting). Since each of these gaps embraces a whole day and about 4 hours, it is clear that spot b took 13 days and about 8 hours to pass from the eastern (rising) horizon to the western (setting) one. This happened because its path-track faced the pole T and the elevated part of the axis, T E, and therefore, by the said proposition of Theodosius, it described an arc greater than a semicircle — on the supposition that the spot itself is carried on the surface of the solar globe.

II.

AVGVSTVS.

D.	H.	☉	El.
8	m. $7\frac{3}{4}$ [?]	31	30
9	m. $7\frac{1}{4}$	26	30
10	m. $8\frac{1}{8}$ [?]	38	0
11	m. $7\frac{7}{8}$	33	0
12	m. $7\frac{7}{8}$	33	0
13	m. 8	32	30
14	m. 8	32	30
15	m. $7\frac{1}{2}$	25	40
16	m. $7\frac{5}{8}$	29	0
17	m. $9\frac{1}{4}$	45	35
18	m. $7\frac{3}{4}$ [?]	28	25

Rosa Ursina, Book III — Notae Particulares (IMAGO SOLIS LXVII; Notes on Image LXVIII)

Full-page plate: IMAGO SOLIS LXVII

Diagram. A full-page engraved plate occupying the whole leaf: the projected disk of the Sun with the daily positions of several sunspots (*maculae*) plotted along their tracks across two observing periods (August 1626 and February 1627).

Title matter set inside the disk:

- Upper left: **LXVII. Imago Observationum** ("LXVII. Image of the Observations").
- Upper center: **In Collegio Romano Societatis** ("In the Roman College of the Society [of Jesus]").
- Upper right: **Augusti, 1626. Februarij, 1627.** ("Of August 1626; of February 1627").
- Two radiant emblems flank the center: at left a sunburst enclosing the Jesuit monogram **IHS** (with cross and nails); at right a sunburst enclosing the Marian monogram **MRA**.
- Two Orsini roses (the dedicatee's device) flank the lower vertical axis.

Axes and cardinal framework:

- Vertical axis at top, marked (top to bottom) **V, C, Y, Q, R**; flanking labels **Axis latentes** ("hidden axes") and **Axis patens** ("visible axis").
- Vertical axis at bottom, marked **S, P, X, D, T**; flanking labels **Axis latens** ("hidden axis") and **Axis patentes** ("visible axes").
- Horizontal ecliptic line across the middle: left end **A**, center **E**, right end **B**; labels **A. Oriens** ("A, East"), **AB. Ecliptica** ("AB, the Ecliptic"), **B. Occidens** ("B, West").
- Right-hand edge points, stacked near the ecliptic and below it: **N, B, O, G, M**.

Upper spot track (northern band, between left point **I** and right point **K**):

- A dashed track of spots each marked **c**, numbered in sequence 5, 6, 7, 8, 9, 10, 11, 12, 13, 15, 16 (a clearly separate "14" was not resolved [?]); the last spot near K is marked **cu** (spot c, evening).
- Caption beneath: **Cursus b, c, d, anni 1627. sub contrarij Cursuj a, anni 1626.** — "The courses b, c, d of the year 1627, subcontrary to the course a of the year 1626."

Lower spot tracks (three roughly parallel dashed bands running from the left points **F, H, L** to the right points **G, M**), carrying spots marked **a, b**, and **d** with day-numbers running from 5 to 22; scattered "u" marks denote evening observations (e.g., 16u, 18u, 19u). The individual micro-labels within the crowded clusters are only partly legible [numerals: ? in the dense clusters].

- Caption: **Cursus a, australis in Boream concauus, ab 8. Augusti, ad 18. eiusdem.** — "Course a, southern, concave toward the North, from the 8th of August to the 18th of the same."

- Caption: **Curs[us] b, d, australes, c, borealis, concaui in Austru[m], à die 5. et 9. ad 16. et 22. Februarij.** — "Courses b, d (southern) and c (northern), concave toward the South, from the 5th and 9th to the 16th and 22nd of February."

I.

One might perhaps call it composed of several spots, since it began to resolve into them toward the middle of its course — were it not established at many points from the observations that it resolved into several spots precisely, and not from appearance alone.

Note this: even though Spot **b** stood farther from the center **E** than Spot **a** — as the chords **HG** and **FG**, or the arcs **AH** and **AF**, teach — nonetheless **b** lingered longer in the Sun than **a**, because **a**'s segment is too small to be similar to **b**'s segment, on account of the oblique position of the sphere and of the poles being depressed below or raised above the horizon.

[Margin: A spot turned in the smaller parallel clings longer to the visible face of the Sun than one that traversed the larger[?] parallel.]

On Spot c. [De Macula, c.]

This Spot **c**, likewise subcontrary to Spot **a**, completed its course from the 5th (evening) to the 16th (evening). If we examine the spans remaining on either side, we find its journey to be twelve days and about sixteen hours. It therefore overtook neither Spot **a** nor Spot **b** in duration beneath the Sun; the reason being that the axis **PEQ** looked toward the depressed half **EQ**, and it stood farther from the Sun's center **E** than **a** or **b** did, along the chord **IK** — from which it is also clear that its arc of travel, **I c K**, is less than a semicircle.

Spot d. [Macula, d.]

Finally Spot **d**, southern, described the course **L d M**, greater than a semicircle, because the axis looked toward the part **EX** and the raised pole **X**, and stood farthest of all from the center **E**; and so the segment **L d M** that it made was greater than a semicircle.

It touched the horizon at setting, and on the 19th, 20th, and 21st it was separated into two distinct spots; for which reason, during the rest of its passage, it always appeared elongated. Its eastern interval **L** comprises about 9 [days,] 20 hours; hence its whole stay in the Sun was 13 days and 20 hours.

[Margin: Duration of Spot d.]

From this you have, first, how unequal and different in duration these courses are: for course **d** exceeds courses **a** and **c** by nearly a whole day.

[Margin: Worth noting.]

Second, that this same inequality is found at nearly the same time — as is evident in...

II.

the spots **d** and **c**, of which the latter does not run ahead of the former for long. And above the horizon they lingered together from the 9th up to the 17th, for nine whole days and more.

Third: although spots **b** and **c** rose almost together and set almost together, they nevertheless did not display perfectly parallel motions, but ones somewhat converging toward each other — for which reason I posited a certain discrepancy in the position of the axes. Such appearances, and such convergences or divergences of the courses, occur often, and I do not now pursue their particular causes.

Daily table of the courses b, c, d, of the year 1627. [*Tabula diaria cursuum, b, c, d, anni 1627.*]

FEBRUARY [*FEBRVARIVS*]

D.	H.	☉	El.
5	m. 8 $\frac{1}{8}$	11	30
5	u. 4 $\frac{1}{4}$	8	40
6	m. 8 $\frac{3}{4}$	16	40
7	m. 9 $\frac{3}{4}$	24	20
8	m. 9 $\frac{1}{2}$	20	10
9	m. 8 $\frac{7}{8}$	20	0
10	m. 8 $\frac{5}{8}$	18	0
11	m. 9 $\frac{1}{12}$	21	30
12	m. 8 $\frac{1}{2}$	18	30
13	m. 8 $\frac{5}{8}$	17	45
15	m. 8 $\frac{1}{2}$	17	45
16	u. 4 $\frac{1}{4}$	6	15
18	u. 3 $\frac{3}{4}$	16	0

D.	H.	☉	El.
19	u. 4½	9	0
20	u. 2½	28	20
21	m. 9	23	25
22	m. 8 1/[?]	17	30

I.

[Margin: A greater curvature of the paths entails a greater obliquity of the chords to the ecliptic[?].]

Fourth: these courses were not far from the equilibrium [the equinox], for which reason both the movable axes are very oblique to the fixed axis **CD**, and the chords subtended by the courses are very oblique to the ecliptic **AB**; and likewise the curvatures of the paths are great.

Fifth: the single course **a** is sub-...

II.

contrary to the three courses **b**, **c**, **d**. For the rest, you have now grasped the daily observation of any spot whatever — partly from what has been asserted, partly from the daily table, from which you will be able to draw enough; and so I would have you consult it.

Full-page plate: IMAGO SOLIS LXVII (repeated)

Diagram. The same engraved plate of Image LXVII is printed again on this leaf, beneath the two note-sections above; its title matter, axes, emblems, cardinal points, spot tracks, and captions are identical to those described for fig-p461-1 (title **LXVII. Imago Observationum / In Collegio Romano Societatis / Augusti, 1626. Februarij, 1627.**; top axis **V C Y Q R**, bottom axis **S P X D T**; ecliptic **A–E–B** with **A. Oriens / AB. Ecliptica / B. Occidens**; upper **c**-track between **I** and **K**; lower **a/b/d**-tracks between **F, H, L** and **G, M**; IHS and MRA sunburst emblems; two Orsini roses). The same crowded lower spot-labels remain only partly legible

Notes on the LXVIII Image of the Observations, from the 27th and 30th of August to the 8th and 10th of September, in the year 1626; likewise from the 2nd and 3rd of March to the 14th and 16th of the same, in the year 1627. [*Notæ in LXVIII. Obseruationum Imaginem...*]

I.

Three courses — **a** (southern), **b** and **c** (northern) — occurred in the year 1626; subcontrary to which two flowed off — **d** (southern) and **e**[?] (northern) — in the year 1627. I set out an ephemeris of the courses of the year 1626 in the appended itinerary table.

Course of the Spots — a. [Cursus Macularum, a.]

From the morning of the 27th of August to the morning of the 8th of September, twelve days slip by; and to these the intervals on either side, once added, will make one day and about eight more hours. And so, among the spots, **a** — which was the most western and preceded the others — clung above the horizon 13 days and about 8 hours. This is rare in those spots that move on the side of the pole and of the hidden axis, as this one certainly did. Hence, since it stands far enough from the center **E**, its arc of travel will be a segment less than a semicircle, while the other arc — hidden on the opposite side of the Sun — is notably greater (on the assumption that Spot **a**, on the surface of the solar globe, is uniformly broad). From which it must be admitted that the course completed on the averted side of the Sun will reach about 14 days.

[Margin: Duration of the spots a above the horizon.]

This spot's journey passed the autumnal equinox, as will become clear if the rising station is joined to the western one by a straight line, and from the center **E** a perpendicular is raised to it — drawn on both sides down to the horizon — which will represent the movable axis of this course. That axis falls outside the fixed annual axis **CD**, and, while visible, arrives in the eastern quadrant **C, A**, and, while hidden, in the western **D, B**; from which it is clear that the course had already crossed the equinox — a thing worth observing. For from this a certain discrepancy of the courses among themselves becomes apparent.

[Margin: Spot a crossed the equilibrium (equinox).]

A great similarity exists between this course and the one that occurred in the year 1625:

[Margin: Similarity of this course with the course of the year 1625.]

in this same month, on these same days, in the likewise southern region, from the evening of the 26th of August to the morning of the 7th of September — as may be seen in the XXXIX Image of the Observations, [on] August 4 and Septemb[er]...

Daily table of the spots a, b, c, of the year 1626. [*Tabula diaria Macularum, a, b, c, anni 1626.*]

AUGUST — SEPTEMBER [AVGVST. SEPTEMB.]

D.	H.	☉	El.
27	m. $8\frac{5}{8}$	32	0
27	u. $4\frac{1}{4}$	27	0
28	m. $7\frac{1}{4}$	21	20
29	m. $7\frac{1}{2}$	23	10
30	m. $7\frac{5}{8}$	25	25
31	u. $4\frac{3}{4}$	21	0
1	m. $8\frac{7}{8}$	37	50
2	m. $7\frac{1}{2}$	23	10
3	m. $7\frac{7}{8}$	26	25
4	u. 4	28	25
5	m. $7\frac{5}{8}$	21	45
6	m. $7\frac{5}{8}$	23	50
7	u. $4\frac{1}{8}$	20	30
8	m. $7\frac{1}{8}$	20	0
9	u. 3	26	0
10	u. $4\frac{1}{2}$	22	15

Diagram. A full-page engraved plate of the solar disk (a large circle filling the leaf), presenting the observed sunspot paths for August–September 1626 together with the contrary paths of March 1627. Inside the disk, near the top, three legends run left to right: at the left, "LXIIX, Imago Observationum." (Image 68 of the Observations — "LXIIX" is the subtractive form of 68 = LXVIII); at the center, "In Collegio Romano Societatis" (In the Roman College of the Society [of Jesus]); at the

right, "Augusti et Septem: 1626. Martij, 1627." (August and September 1626; March 1627). Two engraved Jesuit emblems sit below these legends: an IHS monogram within a sunburst, and an MRA (Maria) monogram within a sunburst (a small date, apparently "1626," is engraved beneath the MRA emblem).

A vertical line rises through the top-center of the disk, lettered **C** at the top; along it runs the legend "CD. Axis annuae Fixae" (CD, the axis of the fixed annual [circle]); its lower end is lettered **D** (at the bottom of the disk). Beneath the emblems, spanning the disk, the engraved caption reads: "Cursus Macularum a, b, et c, anni 1626, subcontrarij, cursibus Macularu[m] d, et e, anni 1627." (The paths of spots a, b, and c of the year 1626, contrary to the paths of spots d and e of the year 1627.)

Cardinal and reference points on the horizontal lines:

- A (left end of the main diameter): "A, Oriens." (A, East)
- B (right end of the main diameter): "B, Occidens." (B, West)
- E (center of the disk, on the main diameter)
- H (left) and I (right): the end-points of the upper track (the "e" spots)
- E (left) and G (right): the end-points of the lower track (the "a" spots)

Spot paths (dotted lines, each spot marked by its letter and its day-number; the numbering is dense and in places overlaid by verso show-through, so uncertain figures are flagged):

- **Track "e"** (uppermost, running from H toward I): spots lettered "e" over day-numbers reading approximately 6, 7, 8, 9, 10, 11, 12, 13, 14 [several intermediate numbers obscured; 15, 16 near I — 15?, 16?].
- **Track "b"** (below "e"): spots lettered "b" over day-numbers 30, 31, 1, 2, 3, 4.
- **Track "c"** (interleaved below "b"): spots lettered "c" over day-numbers 1, 2, 3, 4 [several obscured].
- **Track "d"** (on and just below the A–B diameter): spots lettered "d" over day-numbers 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14.
- **Track "a"** (lowest, running toward G): spots lettered "a" over day-numbers 27, 28, 29, 30, 31, 1, 2, 3, 4, 5, 6, 7.

Below the disk, two engraved lines give the date-ranges: "Cursus a, b, et c, à die 27. et 30. Augusti, ad 8. et 10. Septembris." (The paths of a, b, and c, from the 27th and 30th of August to the 8th and 10th of September) and "Cursus d, et e, à die 2. et 3. Martij, ad 14. et 16. eiusdem." (The paths of d and e, from the 2nd and 3rd of March to the 14th and 16th of the same month). Beneath these: "Maculae currunt

quasi in Aequilibriis." (The spots run, as it were, in equilibrium.) Two engraved Tudor-style roses (the Orsini rose device) flank this caption at the foot of the disk.

(Continuation of the Notes on Image LXVIII. Apparatus: the printed centered column-numerals "I." and "II." are column labels, not note-divisions; the marginal figures 1, 5, 10, 15 ... are five-line apparatus counters. The prose runs continuously across the two columns.)

I.

which you are free to consult. The only difference lies in the distance from the center, E, and in the inclination to the ecliptic: for there spot a advanced along the line of equilibrium, whereas here it is somewhat declined from it, and in the end its duration in time too was made to vary a little — because that former course did not quite reach 13 days, while this one exceeded it. This can be attributed partly to the unequal distance of the parallels from the center, partly to a differing rotation of the spots, whatever its cause.

This spot had a great retinue of companions; but to avoid confusion I have deliberately brought only a few into the discussion.

The Path of Spots b and c.

Spots b and c were first seen on the 30th of August in the morning, already well advanced onto the Sun from the northern side; and b, indeed, presented the appearance of a twin spot, while c was single. Spot c seems to have reached the western limb on the evening of the 10th, and b on the morning of the 11th. If everything is reduced to as accurate a reckoning as possible, spot b appears to have used up 13 days and 18 hours in crossing the Sun — very little less than spot c, whose course was somewhat quicker than b's and was, as it were, parallel to the track of a; but spot b gradually deflected northward away from the track of spot c.

[Margin: The resemblance of the spot-paths of other years to these.]

You will find similar paths of these spots in the previous year, for b and c, in the cited Image XXXIX, from the 2nd and 3rd to the 14th and 16th of September; and their courses from the eastern to the western limb are found to be in some measure equal to these — that is, 13 days and 20 hours.

[Margin: The contrary paths.]

Having then set down the paths just described — a, b, and c, of the year 1626 — let us now lay out the contrary paths, d and e, of March in the year 1627. For the

itinerary of spot a runs contrary to the path of spot d, from the 2nd to the 14th of March, to such a degree that they seem to have run into nearly the same parallel; certainly they converged at the same point of rising, F. In the same way spot e met with spot b at the point of rising H, but for the rest everywhere runs contrary to it.

[Margin: The path of spot d.]

The Path of Spot d.

[Margin: Spot d: the time spent beneath the Sun.]

Spot d was wholly southern. It used up, from the morning of the 2nd to the evening of the 14th, 12 days and nearly 9 hours; and when the intervals remaining at its rising and setting are added to these ...

II.

they will make it a case of about 13 days, more or less by 16 [minutes], for the course of spot d — which the nucleus, variously composed and shaped from the eastern limb onward past the middle [of the disk], showed to have been compacted out of several [spots]. From the start it always displayed this clearly, and from east to west it steadily and gradually decreased. Moreover it moved, as it were, in equilibrium, and it exceeded the course of spot a; the two together will make exactly 27 days, within which the ordinary revolution of the spots is completed — nor will that period easily be found to be exceeded.

Itinerary table of spots d and e, 1627.

MARCH

D.	H.	☉	El.
2.	m. $7\frac{3}{4}$	15.	0.
3.	m. $8\frac{1}{4}$	19.	30.
3.	u. $3\frac{3}{8}$	24.	0.
4.	m. $7\frac{1}{3}$	10.	40.
5.	m. $7\frac{3}{4}$	15.	30.
6.	m. $8\frac{2}{3}$	22.	15.
7.	m. $7\frac{3}{4}$	15.	30.
8.	m. $8\frac{1}{8}$	20.	0.
9.	m. $7\frac{7}{8}$	18.	0.

D.	H.	⊙	El.
10.	m. 9.	18.	40.
11.	u. 3.	30.	30.
12.	m. 8.	20.	20.
13.	u. $2\frac{1}{4}$	32.	0.
14.	m. $8\frac{1}{8}$	20.	0.
14.	u. $4\frac{1}{4}$	18.	0.
15.	m. $7\frac{5}{8}$	16.	0.
15.	u. $3\frac{2}{3}$	22.	50.
16.	m. $8\frac{2}{3}$ [?]	23.	30.

(Notes on Image LXVIII, concluded — printed above a repeat impression of the same LXVIII plate.)

I.

The Path of Spot e.

[Margin: Spot e: its path and time beneath the Sun.] [Margin: The composition of the various apparent paths differs little or nothing from a complete revolution of the spots.]

This spot came out wholly northern, enjoying a course parallel to that of spot d. It touched the eastern limb at its rising on the evening of the 3rd, at hour $3\frac{3}{8}$, and the western limb at its setting on the morning of the 16th, at hour $8\frac{1}{8}$; and so its whole course was 12 days and 17 hours — likewise in equilibrium. Added to the course of spot b, this makes 26 days and 11 hours; added to the course of spot d, it makes 26 days and 9 hours. And although they moved across the Sun at the same time, nonetheless the duration of spot e fell short of the duration of spot d by 23 hours — about one natural day.

II.

by one natural day; while from spot b it fell short by one day and one hour.

For the rest, granting that the spots are carried around on the surface of the Sun, the complement of the course H–b–b will differ almost nothing from the course H–e–I, and conversely the complement of the course H–e–I will differ almost nothing from the course of the spot H–b–b. From such agreements, then — perpetual, or at least ordinary, in this phenomenon — a most solid argument is

drawn for the [surface] location of the spots. This is what I wished to indicate here.

[Margin: The diversity of the apparent paths.] [Margin: A strong argument for the true location of the spots.]

Diagram. A second impression of the same plate described above (fig-p465-1), printed in the lower portion of this leaf beneath the concluding notes. The engraving is identical: the solar disk with the same legends ("LXIIX, Imago Observationum."; "In Collegio Romano Societatis"; "Augusti et Septem: 1626. Martij, 1627."), the same IHS and MRA emblems, the same axis CD ("Axis annuae Fixae"), the same caption of the contrary spot-paths (a, b, c of 1626 subcontrary to d, e of 1627), the same cardinal points (A Oriens, B Occidens; H, I, E, G), the same lettered/numbered spot tracks, and the same two Orsini roses and closing motto "Maculae currunt quasi in Aequilibriis." No labels differ from the first impression.

Notes on Image LXIX

Observations of the Image, from the 4th to the 16th of March, made with the telescopic Heliotrope, a new instrument, in the year 1627.

I.

[Margin: An example of the new method of observing.]

This image [*Haec Imago*] takes in the same two spots, d and e, that were exhibited in the previous Image LXVIII, but observed by a wholly new and compendious method — of which, a little later, I shall explain fully the form, construction, and use of the instrument itself. I have given the daily table in a schematic drawing that includes nothing beyond the day and the hour. For the Sun's elevation above the horizon does nothing for this purpose: the course and position of the spots come onto the paper of themselves, just as here you see it set before you from day to day. I assign the year, month, day, and hour only so that other courses may be compared with these, and then so that the intervals of the daily stations may be viewed together and compared with one another.

As for the spots' situations, configurations, progressions, nuclei, growths, diminutions, and likewise the durations of their transits beneath the Sun — these I have explained sufficiently in the preceding scheme, so that the same things need not be idly repeated here. For at both [observations] I used telescopes of equal size and power; at both, observing circles of the same amplitude; and at both, finally, times and hours that were as it were the same. Hence at both, too,

the positions of the spots and their distances from the center, E, are equal. Now let us explain a few particular features of this figure.

[Margin: Explanation of certain points worth noting.]

First: the circle A B C D is set upright to the axis of the solar cone and is parallel to the solar circle, as in all the Images of the Observations.

Second: the line A B is the section of the equinoctial circle which it makes in the plane of the observing circle, the Earth being supposed to be like a point, and any place on Earth being taken as if at the center of the universe. The circle drawn through the axis of the solar cone, set upright to the hour-circle C D, makes the same section.

II.

Third: the line C D represents the axis of the world, and likewise any hour-circle set upon it by the Sun and meeting the axis of the world in a common section — most especially the meridian of the place; indeed, all the hour-circles, as the Sun successively reaches them on any given day.

Fourth: the point, or center, E, also represents any point whatever of the whole ecliptic throughout the year. Hence, just as the hour-circles stand to the ecliptic as they pass through its several points, so the line C D stands to the line of the ecliptic, which it approaches and recedes from according to the varying time of year. For at the solstices they make right angles at the center E; at the equinoxes, the complements of the greatest declination; and at the remaining times, intermediate angles — as will be seen more clearly later in its place. Meanwhile I send this ahead, so that you may know that the ecliptic in this observing machine is not fixed but movable, and ranges beyond and on this side of the line A B according to the latitude of the rays of the zodiac described from E — of which more fully later. I touch on this now so that you will not be surprised if in the present image you see two ecliptic lines inscribed. For:

Fifth: 2–E–2 is the ecliptic which, on the 2nd of March, held its position with respect to the declination-circle, or hour-circle, C D, at the lesser angle, namely C–E–2 or D–E–2; from this ecliptic spot d, on the 2nd of March, stood off by the distance F–2. The line 14–E–14 is the position of the ecliptic on the 14th day, from which is obtained the distance G–14 of spot d from that same ecliptic on the 14th of March. Whence:

Sixth: it is established that the paths of the spots, as they are observed with the Heliotrope, are not their genuine and unmixed flexures, but are composed of

their own proper flexures together with the divarications of the ecliptic. Therefore, in order that the proper [paths] may be had, the ecliptic must be inscribed for each individual observation; and only then must one be placed over another, and the spots [...]

IMAGO SOLIS LXIX — engraved solar-disk plate (p. 337)

Diagram. A full-page engraved circle representing the solar disk, carrying the sixty-ninth "Image of the Observations." Its inscribed title reads: *LXIX, Imago Observationum* [Image LXIX, of the Observations]; center: *M.DC.XXVII. In Collegio Romano Societatis à die 2. ad 16. Martij.* [1627. In the Roman College of the Society, from the 2nd to the 16th of March.]; upper right: *Martij* [of March]. Two radiant Jesuit emblems are engraved in the upper field: at left the *IHS* monogram in a sunburst, at right the *MRA* (Marian) monogram in a sunburst.

- C (top of disk): pole of the declination circle
- D (bottom of disk): opposite pole
- A (left of disk): west end of the equator section
- B (right of disk): east end of the equator section
- E (center): center of the disk
- Curved inscription arcing across the disk: *Cursus observati Heliotropio, aequales cursib. in Imagine LXIIX expressis* [The courses observed with the Heliotrope, equal to the courses expressed in Image LXIIX (68)].

Two dashed sunspot paths cross the disk from upper-left to lower-right:

- A path of spots lettered **d**, running along the chord F–G, its individual marks numbered by day: 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, and 14 (near G). The point F lies at the left (labelled with the stacked fraction "14/2"); the chord ends near G at lower right (endpoint labels "2/14").
- A path of spots lettered **e**, running along the chord H–I, its marks numbered by day: 4, 5, 6, 7, 8, 9, 10, 12, 14, 15, and 16 (near I, at right). H lies at upper left.

Below the spot-paths, a legend box (lower left):

- AB, Sectio Æquatoris. [AB, the section of the equator.]
- CD, Sectio Circuli Declinationis. [CD, the section of the declination circle.]
- 2 E 2, Ecliptica die 2. [2 E 2, the ecliptic on day 2.]
- 14 E 14, Ecliptica die 14. [14 E 14, the ecliptic on day 14.]
- FG, chorda motus d d d. [FG, the chord of the motion of the d-spots.]

- HI, chorda motus e e e. [HI, the chord of the motion of the e-spots.]

Two Tudor-rose devices (the Orsini rose) are engraved in the lower half of the disk. Faint mirror-reversed show-through of the verso ornament is visible across the disk (not part of the plate).

In the upper-right quadrant of the disk, a boxed table of morning observation-times:

Observed in the morning [Observatu mane] — columns: Day (D), Hour (H):

Day (D)	Hour (H)	Day (D)	Hour (H)
2	8 3/8	9	8 1/4
3	8 1/4	10	8 3/4
4	8	12	8 1/3
5	8 1/4	14	8 1/3
6	8 [3/4?]	15	8 1/3
7	8 [1/5?]	16	8 1/2
8	8 1/2		

ROSAE VRSINAE LIB. III — Notes on Image LXIX (continued), p. 338

(The following continues the numbered Notes on Image LXIX begun on the preceding leaf; the marginal 5-line apparatus numbering 1, 5, 10, 15, 20 runs down the columns.)

[Column I]

the places of the spots should be marked — which in the present diagram I have not done, because the difference of position that arises between the second day and the fourteenth is exceedingly small, as is evident from the angle 2 E 14. From this:

Seventh. It is established that the given courses, F d G and H e I, are somewhat more curved than they truly are, and than those I set out in the preceding Table — though, because of the smallness of the discrepancy, this would not be perceived by the senses. For at this season of the equinoxes the increases and decreases of the angles intercepted on the ecliptic and on the declination circle are exceedingly slight, as will become plain from the Table to be inserted later in its proper place.

Eighth. For this same reason the chord F G is a little smaller, and farther from the center E, than the chord would be that subtended the pure motion of the spots;

[Column II]

and conversely, the chord H I is somewhat larger, and nearer to the center E, than the one that would answer to the corrected motion. But as for bringing the ecliptic into these observations, or obtaining the pure motion of the spots immediately from the observations themselves without any further labor, I shall treat of it more fully later in its proper places; for now it is enough to have noted these matters briefly.

Ninth. As for the fact that you do not see the ecliptics 14 E 14 and 2 E 2 joined along the line A B, as I did in other observations — this happens because, as I said, the line C D represents any hour-line whatever, and especially the meridian of that day, together with the position of the ecliptic relative to that meridian and the position of the spots relative to the ecliptic; and this method of observing displays their arrangement beautifully. In vertical observations, however, these same things are not called for.

IMAGO SOLIS LXIX — second impression of the plate (p. 339)

Diagram. A second impression of the same engraved solar-disk plate as page 337 (fig-p469-1): the identical "Image LXIX" of the March 1627 observations, with the same inscribed title, the same IHS and MRA sunburst emblems, the same lettered spot-paths (d along F–G, e along H–I), the same legend box (AB / CD / 2 E 2 / 14 E 14 / FG / HI), the same "Observed in the morning" table, and the same pair of Orsini-rose devices. The plate is bound here as printed page 339, facing the Notes on Image LXX. Its face carries heavy mirror-reversed show-through of the verso letterpress (the "Notae in LXX" text of page 340) — not part of the engraving. See fig-p469-1 for the full label transcription.

ROSAE VRSINAE LIB. III — Notes on Image LXX, p. 340

Notes on Image LXX of the Observations, from the 23rd to the 26th of November in the year 1626, and again from the 26th of May to the 6th of June in the year 1627.

(Notae in LXX. Obseruationum Imaginem, à die 23. ad 26. Nouemb. Anno 1626. item à die 26. Maij ad 6. Iunij, Anno 1627. The marginal 5-line apparatus numbering 1, 5, 10 ... 45 runs down the columns.)

[Column I]

There are in this diagram two courses of spots, namely one, **a**, and the other, **b**. The former occurred in the year 1626, in the month of November; the latter in the year 1627, in the months of May and June. Both were sensibly rectilinear, and therefore the poles and axes on which and about which they were completed lay in the solar great circle — on the supposition that the spots are carried on the surface of the Sun. Now, briefly, of each in turn.

The Course of Spot a.

It is defective, because the spot, being thin, did not last across the whole Sun, but, gradually thinning out, showed no trace of itself after the 29th day; although I do not doubt that it flared up into some facula, but because this happened in the middle of the Sun, it could be the less noticed.

On days 25, 26, 27, 28, and 29 it always had something of a doubled form, although on the 27th this appeared less.

[Margin: Courses sensibly rectilinear.] It passed from south to north, having lingered on the ecliptic on the 26th day; and because near the center P it did not depart much from that ecliptic, its parallel was therefore not far from the great circle, or greatest parallel. Its angle A 26 E, which it makes with the ecliptic — that is, the angle A B I — marks the greatest departure of the movable axis G H from the fixed axis, and the smallest obliquities of the paths that the spots trace; for after this they increase according to the itinerary chords, whereas here the chords are not distinguished from the paths themselves.

Moreover, because the paths of these rectilinear motions do not differ from the diameters of the courses, I therefore drew the semicircular arc E r F, so that — perpendiculars being let fall from the centers of the spots onto it: 23 r, 24 s, 25 t, 26 u, 27 x, 28 y, 29 z — through the intercepted daily arcs r s, s t, t u, u x,

[Column II]

x y, y z, I might measure the course E y F; which, when everything has been sifted out, comes to thirteen days, more or less — whence the periodic revolution would comprise 26 days; of which more fully in its place. [Margin: Spot a: its duration beneath the Sun, and its periodic revolution.] But this manner of measuring we cannot use in curvilinear paths.

The Course of Spot b.

This spot, first seen on the evening of the 26th of May, appeared double; afterwards, in its ascent onto the Sun, it gradually unfolded into three and more, but small, spots, and along with them it gradually faded away — as may be clearly seen from the half-day intervals: for after the 4th day of June, having resolved into a very faint shadow [umbra] and small but fairly bright faculae, it was last visible on the evening of the 6th of June. It moved entirely along the northern and direct path, subcontrary to the former one, with an equal inclination O B A to the ecliptic. The axis about which it moved was M N, subcontrary to the former axis G H. The semicircle K g n L, which it described on the surface of the Sun, was drawn from the center m to the radius m K, or m L; and if from the individual daily stations perpendiculars are drawn — 26 c, 27 e, 28 f, 29 g, etc. — they will mark out, by the intercepted arcs c d, d e, e f, f g, etc., the itinerary intervals of the spot, answering to the intermediate times recorded in the daily table. [Margin: Spot b: its duration beneath the Sun.] By these, if you measure the whole arc K m L as a semicircle, you will find, as before, thirteen days more or less, from which the whole circuit of 26 days is drawn out — notwithstanding that the diameter K L is smaller than the diameter E F. But this only in passing here, so that you may gradually see that the spots are carried within the Sun, not outside it: a matter treated more fully in the following book.

Meanwhile, note this too: that the paths of the faculae are carried in exactly the same manner and motion as those of the spots — as is plain from the 4th of June to their exit; from which, again, it is established that both proceed at the same distance from the center of the Sun.

Then

Rosa Ursina, Book III — IMAGO SOLIS LXX and its Notes; Notes on the Meditullium of the Ursine Rose

[fol. 341] IMAGO SOLIS LXX

Diagram. A full-page engraved solar-projection plate — the seventieth image of observations (IMAGO SOLIS LXX). The figure is bounded by a large circle representing the observatory circle / the projected face of the Sun. At the top center is the Society of Jesus sun-emblem (the radiant **IHS** monogram with cross and three nails), flanked left and right by an Ursine rose (the Orsini heraldic rose). Rays/lines descend from three points along the top rim lettered **G**, **C**, **M**.

- Top-left legend: "LXX. Imago Observationum." ["LXX. Image of the Observations."]
- Top-right legend: "Nouembris, 1626." and "Maij, et Iunij, 1627." ["Of November 1626; of May and June 1627."]

Rim lettering (readable): left rim, top to bottom — **K, O, A, E, I**; right rim — **F, L, B**; bottom rim — **N, D, H** (with a **K** near lower center). The horizontal diameter is **A–B** (the ecliptic); the vertical axis is **C–D** (the fixed axis). The central point is **P**.

Two spot-tracks cross the disk:

- An upper, gently sloping track carrying the May and June transit, labeled in large spaced letters "Ma— us" (Maius) continuing into "Iu— ni— us" (Iunius). Along it lie spot-marks dated **26, 27, 28, 29** (May) and **1, 2, 3, 4, 5, 6** (June), each tagged with small companion letters — chiefly **m** (morning), **u** (evening), and **a/b** — most of which are too fine to resolve individually [?].
- A lower, nearly horizontal track carrying the November transit, labeled "No— uem— ber." (November), with spot-marks dated **23, 24, 25, 26, 27, 28, 29**, each tagged **a** (and some **d**) [?].

Dashed vertical lines drop from the spots to letters strung along the lower rim: readable are **c, d, e, f, r, g, s, h, t, i, u, l, m, n, o, p, q** (several partly effaced [?]).

Bottom curved caption: "Cursus subcontrarij Macularum, a. anni 1626. et b. anni 1627. et sunt rectelinei." ["The subcontrary courses of the spots — a of the year 1626 and b of the year 1627 — and they are rectilinear."]

The engraved tables of observation times printed on the disk (day, hour, and the Sun-elongation ☉ El. in degrees and minutes). *m* = morning (matutina), *u* = evening (vespertina):

November 1626

D	H	☉ El. (° ')
23.m	8¾	14. 0.
24.m	8⅞	14. 40.
25.m	9¾	20. 30.
26.m	9½	18. 0.
27.m	8⅞	14. 40.
28.m	9¾[?]	18. 0.
29.m	10¼	23. 50.

May 1627

D	H	☉ El. (° ')
26.u	5½	20. 40.
27.m	6⅝	22. 0.
27.u	4½	31. 30.
28.m	7⅞	34. 40.
29.m	7⅜	29. 10.
30.m	6⅞	24. 15.
30.u	6⅛	13. 15.
31.m	7⅛	28. 10.
31.u	6	16. 0.

June 1627

D	H	☉ El. (° ')
1.m	7½	31. 40.
1.u	5 11/12	17. 15.
2.m	7¾	33. 20.
2.u	6½	11. 0.
3.m	7⅜	30. 45.
3.u	6½	11. 0.
4.m	7⅝	32. 45.
4.u	5¼	28. 0.
5.m	8¼	38. 45.
6.m	7⅛	27. 20.
6.u	6	16. 0.

[fol. 342] ROSAE VRSINAE LIB. III

[This page continues the notes to IMAGO SOLIS LXX, set in two columns; the argument runs continuously from the left column into the right.]

Furthermore, this too should be noted: the daily westward intervals do not differ appreciably from the eastward ones. And this must not be passed over either — on the first of July, spot **b** placed its morning station precisely on the axis **M–N**, at

m (which signifies "morning"); and from this the spaces of its passage on either side are very neatly measured.

The remaining matters, which deserve a finer inquiry, I reserve for their proper places.

I would almost have passed over one point: this spot **b**, just as it is shown here, was observed in this year 1627 with both kinds of telescope — the vertical [helioscope] as well as the heliotropic — and the fullest agreement of the observed positions was found between them, so that not the least discrepancy appeared. I will make this plain to anyone from the original records themselves, should it prove necessary. Let this, then, be the last of the sketches [hypotyposis] of images gathered from observations in this third Book of the *Ursine Rose* —

— though it is not the last of the observations. For just as I do not fear the scrutiny of others when it proceeds from their own observations, so, if others faithfully publish their own duly-made observations, I am quite sure they will not disagree with mine. If in any case some difference should arise, it is left to the judgment of the prudent reader whether a practice kept up over so many years — under the eyes of learned censors, and undertaken even to convince the obstinate, confirmed by so many and such varied and indeed approved methods (of which I give as witness a nature that in all I have so far set forth remains always like itself, stable through a continuous series of times, and open to the examination of any level-headed investigator) — whether such a practice should be set below some makeshift affair: a hasty, rashly-stitched-together jumble of the observations of waverers, thrown up to prop up arbitrary constructions that everywhere collapse when nature pushes against them, and are badly shored up by tumultuous work.

[fol. 343] IMAGO SOLIS LXX (second impression)

Diagram. A second impression of the same engraved plate, IMAGO SOLIS LXX (see fig-p473-1). The circle, the top **IHS** sun-emblem flanked by two Ursine roses, the rim lettering (**G, C, M** across the top; **K, O, A, E, I** left; **F, L, B** right; **N, D, H, K** bottom), the ecliptic diameter **A–B**, the fixed axis **C–D**, the central point **P**, the two spot-tracks (upper "Ma—us / Iu—ni—us"; lower "No—uem—ber"), the dropped dashed lines to the lettered lower rim, and the bottom caption "Cursus subcontrarij Macularum, a. anni 1626. et b. anni 1627. et sunt rectelinei." all correspond to the first impression. The engraved observation tables (November 1626; May 1627; June 1627) reproduce the values transcribed under fig-p473-1. No differences in the tabulated figures were found between the two impressions.

[fol. 344] ROSAE VRSINAE LIB. III — Notae in Rosae Vrsinae Meditullium

Notes on the Meditullium of the Ursine Rose [Notae in Rosae Vrsinae Meditullium]

[Margin: The chief, yet least conspicuous, phenomenon of the Sun. (Princeps Solis sed omnium minimè spectabile Phaenomenon.)]

Here I present the very Flower, the Meditullium — the inmost pith — the Marrow itself of the phenomenon of the Ursine Rose; and I dress it in such comparisons for this reason. Just as that part of the rose which the Latins called the "flower" does indeed sit at the center, yet only comes forth once the rose's calyx is spread wide and fully opened, and then most delightfully soothes the human senses and spirit with its sweetest fragrance and golden color — so too, among all the marvels of our Ursine Rose, this most hidden and most admirable one is brought forward last of all, and does not offer itself to view unless the Rose is opened to its widest and its petals spread far apart, which we accomplish by a special device, as I shall shortly explain.

[Margin: This part of the solar phenomenon is commended as one of the chief. (Commendatur ista Phaenomeni Solaris pars tanquam vna è praecipuis.)]

Moreover, just as the flower of the rose occupies the middle and comes forth as if from the marrow, so the things belonging to this phenomenon seem to savor of nothing but substance — indeed, of the very marrow of the Sun. For it occupies the whole visible surface of the Sun; nay, in the Sun and from the Sun we never behold anything at all except this heap of little bright patches [luculae] and shadows [umbrae], even though with the natural sharpness of our eyes we by no means make out distinctions of this kind among its parts. But let us now come to the explanation of the several items.

The figure **A B D L**, being semicircular, represents half of the observatory circle; and likewise half of the exposed solar disc, and thus a hemisphere of the solar globe — though note that on the side from **A** to the interval **A, L** something is lacking.

A B represents the ecliptic; **C D** its fixed axis. And because at this time the spots and shadows stood in equilibrium, their own mobile axis was not far removed from the fixed axis **C D**. The remaining letters and numbers indicate the various

parts of this appearance, which you will accordingly understand better in the explanations of each.

[Margin: This appearance has three parts. (Huius apparentiae sunt partes tres.)]

The parts of this appearance [Partes huius Apparentiae]

There are shadows, or secondary spots [Umbrae, seu Maculae Secundariae]; there are little bright patches, or secondary faculae [Luculae, seu Faculae Secundariae]; and there are the even, uniform tracts of the Sun [Plagae Solis aequabiles]. But the spots marked **a**, brought in to teach and to guide the reader, I do not admit into the lot of this Marrow: they have been treated sufficiently up to now.

The extent of this appearance [Amplitudo huius apparentiae]

[Margin: This appearance occupies the whole Sun. (Totum Solem occupat haec apparentia.)]

It occupies the whole Sun. For the entire visible expanse of the Sun is either even — of one color and uniform — or of varied color, changeable and uneven. If the former, you have the even tracts; if the latter, out leap the shadows and the little bright patches. Beyond these, nothing is given to be discerned in the Sun.

The duration of this appearance [Duratio huius apparentiae]

The question of duration can be twofold. One is general, concerning the whole appearance: namely, whether it exists or has existed for a long time, or will do so. The other is special and particular: namely, whether — and for how long — the shadows last; and for how long the little bright patches; and for how long the homogeneous tracts; and likewise, for how long each single one of them.

I answer, first, from what it has been possible to observe and infer over so many years now: this appearance in the Sun is perpetual and, as it were, native to it.

[Margin: This appearance has never been absent from the Sun. (Apparentia haec in Sole nunquam defuit.)]

I answer, secondly, that the appearance of the secondary shadows in the Sun seems eternal, so that some are always present in it.

I answer, thirdly, that the appearance of the little bright patches in the Sun likewise seems eternal, just as that of the shadows.

I answer, fourthly, that as regards the even tract, whether it is a perpetual appearance, I am in doubt; for it may perhaps happen that sometimes the whole

Sun is varied with shadows and little bright patches, and so the even tract is lacking.

[Margin: Each single shadow, little bright patch, and homogeneous tract of the Sun is in continual change. (Singulae Vmbrae, Luculae & plaga homogenea Solis, sunt in continua mutatione.)]

I answer, fifthly, that the duration of any single one — of the shadows, or of the little bright patches, or of the homogeneous tracts — is temporary, and highly variable. For some shadows persist through several days; some through fewer; some scarcely through a single day; and a few do not outlast an hour's stay, as I have found in many cases during my observations. Indeed, frequently one —

Diagram — the great "Pith of the Ursine Rose" plate. The culminating full-page engraved plate, printed sideways (landscape) on the leaf. It shows the whole solar disk crowded with sunspots, umbrae, and bright patches, engraved as they appeared over the fortnight of 3–16 September 1625 at Rome. In the upper-left corner (which, with the plate held upright, is the lower-left) a winged putto reclines against the rim of the disk, holding an oval medallion bearing the Jesuit monogram **IHS** with a cross and three nails. The engraved title runs in four decreasing lines along the disk's straight (right) edge:

"THE PITH OF THE URSINE ROSE, in which, by a new mode of observing, the more hidden face of the Sun — that is, the secondary spots and faculae [maculae faculaeque secundariae], and so too the alternating umbrae and luculae, seated upon the solar surface with perpetual variation and, together with the Sun, circling round in a most regular motion — is set forth, from the 3rd to the 16th of September, 1625, at Rome in the Professed House [of the Society of Jesus]."

Readable perimeter and axis labels (letters placed around the disk's edge and along its central horizontal line), which the facing text calls the "polar portion DEFGHIK" turning about the centre C:

- L — near the top of the disk
- F — upper-left of the rim
- G — left rim, below F
- H — left rim, below G
- I — mid-left rim, below H
- D — left end of the horizontal centre-line
- C — the centre of the disk (on the horizontal line)

- K — lower-left rim
- E — bottom-left rim
- A, B (the ecliptic endpoints named in the text) — not clearly resolvable near the titled edge [?]

The spots themselves are lettered **a–h** (each letter = one tracked spot-group) with an adjacent numeral giving its September date, so that a group's daily motion can be followed across the disk. This scheme is confirmed by the facing letterpress (p. 346, col. II), which gives the spans: a (from the 3rd to the 7th), umbra b (3rd–12th), c (8th–11th), d (10th–13th), e (10th–12th), f (11th–12th), and g and h (a single day each). Representative labels legible on the scan include the round group **a 3 / a 4 / a 5** (near the titled edge), a long series of **b** spots, **c 8, c 9, c 10, c 11, d 6, d 8, d 10, d 11, d 12, d 13, e 10, e 11, e 12, f 11, f 12, g 14**, and **h 14**. The interior is far too densely lettered to resolve every day-number with confidence at this resolution; many individual letter+numeral pairs remain uncertain [?]. **Dense micro-labelling; more than two labels unresolved.**

I. ...one hour, two, sometimes several in unbroken succession I have devoted to this care. So much in general; now let us come to more particular matters.

On the Umbrae, or Secondary Spots

[Margin: Why the secondary umbrae [umbrae secundariae] are so named.]

I call these umbrae "secondary spots" [maculae secundariae] not by reason of their nature and existence, but of their duration or their thinness. For the primary spots, other things being equal, last longer, and appear endowed with a more compact body and a deeper blackness; by comparison with these, the secondary spots are reckoned not as spots but rather as shadows cast upon bodies.

[Margin: The various properties of these umbrae.]

The magnitude, shape, position, rarity, and density of these umbrae, and likewise their number, vary, as the figure indicates. Around the polar margins they are very rarely seen; in the royal road of the spots [via macularum regia — the equatorial zone] they appear much diluted and thin; in the roughly middle and temperate zone they well up thick and vigorous. They are seldom without luculae [small faculae] — now preceding, now following them, now to the south, now to the north; yet sometimes it happens that they travel alone, girdled by an even solar surface.

On the Luculae

[Margin: Luculae.]

What I have said of the umbrae applies in the same proportion to the luculae; for by alternating positions the luculae are mingled with the umbrae, and the umbrae with the luculae, and the daily variety of these things is incredible. Imagine some lake, or a calm sea, ruffled by a gentle breeze and lit by the Sun's brilliance: that rippling then offers to the eye alternating shadows and lights, from the varied — or absent — reflection of the solar rays toward the eye. Whatever the surface of the water is like in such a case, just so does this appearance of the Sun present itself. Nearly the same will be represented if you catch the Sun on paper through little glass disks, or through flat but less polished plates: if you draw the tube out too far, or contract it too much, or stop down the convex lens too far, you will see here images that are indeed deceptive, yet grossly belie the phenomenon of which I am speaking. Their trickery, however, you will detect at once by turning the instrument, and so forth.

II.

[Margin: What the uniform bright patches [plagae aequabiles] are.]

The uniform patches of the Sun are parts so alike that they present no perceptible variety or intermixture of color, light, and shadow. To find patches of this kind in the royal road is fairly difficult and unusual; they are ordinarily observed about the polar regions. And those patches which occupy the poles are ordinarily somewhat darker than the middle ones: I have rendered them by close-set little dots, and so forth.

For the rest, these patches have neither a fixed magnitude, nor a stable position or shape, but come out now larger, now smaller, as it has pleased Nature and the Author of the Sun — matters to be discussed in their own place.

The Appearance of This Motion

Moreover, it is entirely one with the motion of the spots and of the primary faculae, as I have verified by frequent observations and experiments. I bring this forward only by way of a single example, for I could produce a great many; but the size of the observing circle, and useless labor and expense, call me away from that undertaking. Everything, indeed, is sufficiently shown in this one example. Consider the spots a, carried from the 3rd to the seventh of September, and you will find that the course of the umbrae b, from the 3rd right through the 12th,

corresponds to their course; likewise the umbrae c, from the 8th to the 11th; and d, from the 10th to the 13th; e, indeed, from the 10th to the 12th; f, finally, from the 11th to the 12th; while g and h lasted only a single day each.

Other spots, faculae, and umbrae running concurrently with these in the northern part I do not include, for want of a plate; but should you wish to see them, consult the XXXIX Image of Observations, for the year 1625, of the fourth of August and the first of September. There you will find the course of the northern spot c, from the 3rd to the 16th of September; and you should know that the course of umbra b was parallel to this course, and in its own way proportional to it — as were those of the remaining umbrae c, d, e, f.

[Margin: The umbra's tarrying beneath the Sun.]

Yet the course of umbra b does not seem to have exceeded eleven days, if everything is reckoned. The daily table differs little from the one found in that same place...

I.

in that same place, so that anyone may extract the daily periods from it, should he wish.

[Margin: The cause of the uniform spaces.]

Now, why the parts of the solar surface about the poles should be even and quiet is caused by the slight and slow motion; why in the middle zone they are more turbulent is produced by the greater and swifter motion, and the more violent agitation.

[Margin: The Sun's rotation.]

And from this one indication alone, or above all, the rotation of the Sun [giratio Solis] is proved effectively enough.

For the whole visible face of the Sun is turned about together — spots as well as faculae; whence it can scarcely be doubted that the Sun itself rotates.

The polar portion DEFGHIK, at any rate, performs its daily rotations, advances, retreats, and so forth, about the centre C, just as any spot does. But of these things elsewhere, and expressly.

The Manner of Observing This Appearance

This method of observing agrees with the telioscope [helioscope] in all respects except the glass lenses alone: for in place of the concave lens a convex lens is fitted, of no great sphericity yet doubled, so that the distance of the paper may not be pushed out too far, and the observing machine be prolonged beyond a convenient measure.

The lens that receives the Sun directly will, other things being equal, be judged better for the present business if it is plano-convex, in proportion as it is the greater portion of a larger sphere.

[Margin: The erecting of the solar images.]

It is also a singular feature of this instrument that by its means the Sun's image is set upright: the things that are on the right in the Sun are cast onto the right-hand part of the paper too, those on the left onto the left, the upper onto the upper, the lower onto the lower — the eye, of course, being placed between the Sun and the paper. But if you set your eye opposite both the paper and the Sun, so as to view the spots in corresponding positions both in the Sun and on the paper, the images must be thrown through onto the reverse surface and marked out there; and once this is done, no other transposition of the paper is needed. This erecting of the solar images works also in any similar smaller tube.

II.

Furthermore, someone may perhaps wonder why I present this matter in so large an observing circle. To him I answer: it was done not for the sake of display, nor by chance, but of necessity. For these faint phases withdraw themselves from view in small observing circles, and meet the sight only by uncertain and doubtful indications. So that they might be discerned surely and steadily, the Rose had to be set out in a great observing circle and spread onto broad sheets, with a tube of ten palms armed with a pair of convex lenses. I do not, however, deny that with my ordinary telioscope and an ordinary observing circle I have very often noted these appearances too, especially the more remarkable ones. Toward this a tighter stopping of the first lens, directed at the Sun, will contribute greatly, so that the Sun is admitted through a smaller circle than usual; for this excludes excessive light, and so — as experience attests — greatly helps in distinguishing those faint *luculae* and *umbrae*. Hence, in the practice of exploring this appearance, not only must the first lens be not too wide open, but every other surrounding light from the air must, so far as possible, be entirely excluded.

[Margin: By what art this appearance may be elicited to view even in smaller tubes.]

On Another Instrument — a Heliotropic Telioscope, Recently Constructed by Fr. Christoph Grienberger

I began this book with the vertical telioscopic machine; I shall close it with another, an equatorial one, lately worked out by Fr. Grienberger for other purposes indeed, but most conveniently adapted to ours. For those difficulties which, on account of the diurnal motion, have hitherto stood in the way of plotting the paths of the spots, and the labors that had to be drained through almost the whole of the preceding book, are nearly all removed by the benefit of this new machine, and are avoided with the greatest saving of time and toil.

For in that vertical machine one must always and necessarily hunt out the angle that the ecliptic makes with the vertical circle (unless one is willing to proceed approximately, by drawing in a parallel), so that the position, place, and mo—

I.

—tion of the spots may be had with certainty; whereas in this instrument neither the use nor any necessity of this angle arises. There, a perpendicular had to be inscribed for each observation; here nothing of the sort is necessary. There, the Sun's altitude above the horizon had to be noted with the utmost diligence; here the use of it is banished entirely. There, one had to go round by many detours until I could introduce the ecliptic line into each single observation; here all this is done with no trouble, quicker than the word. There, all these things, one by one, had to be supplied for any observations whatever of a single day; here it suffices to work up one observation for one day — for the angle stays the same, to sense, for a single day, and so serves for all that day's observations. There, the angles are varied in every latitude of place; here they remain everywhere and always the same, as will be demonstrated more fully below. There, from perpendiculars wrongly assumed or noted through inadvertence, false angles of the ecliptic with the vertical line must be drawn out; here nothing of the sort need be feared, because the angle here does not depend on observation, but only on the correct placing of the paper-bearing tablet, the proper marking-out of the spots, and likewise on the universal tables — as will afterward be seen.

And so this machine is not entangled in as many difficulties as the other; and moreover it dispatches its own work more readily, and in practice more quickly, than that one does. Hence it will be worth the effort to explain its nature somewhat in writing, since the machine's very designer seemed unwilling to

supply this — though afterward he illustrated not a few points admirably with his own demonstrations, and, as I was hurrying and pressing on toward the end of the work, most opportunely helped me with like services, nearly indispensable to me in so great a shortage of time.

On the Nomenclature of the Heliotropic Telioscope

I am not unaware that the helioscopic telioscope, whose use is most open and universal, as its success will sufficiently show, could have claimed another name for itself: for this instrument, if it takes an axis movable up and down in the me—

II.

—ridian (which can be done without difficulty), will not differ much from a universal torquetum [Torquetum universale], nor from the Ptolemaic armillae [Armillae Ptolomaicae], nor from a universal equinoctial clock. Yet because its use in this our solar phenomenon is quite singular, and because the Sun is the ruler and governor of all the stars, and so of the World, I judged it better to give the machine its name from the Sun itself, and then to adapt it to other uses as occasion arose.

Now the heliotrope [heliotropium] is a plant so named because all day long it turns itself toward the Sun; and since this suits the present instrument most aptly, no difficulty can lie in adopting the name. For it follows the axis of the Sun's radiant cone in such a way that it always drinks it in centrally and directly; and so, since it follows the Sun most perfectly, no one will begrudge it the name of "Sun-follower" [Solisequa] or "heliotrope."

The Construction of the Helioscopic Telioscope

First: make a right triangle abc , whose angle b is right, and let $\angle acb$ be the angle of the pole's altitude in the given place; let its complement, or the altitude of the equator, be $\angle abc$, and let the world's axis be the line bc .

Second: to the pattern of this triangle, out of laths [tigilla] planed flat and well-dressed, build a triple gnomon [gnomon trigeminus] $abcde$, in proportion to the future machine and fit for supporting the tube — which I leave to the judgment of a prudent craftsman; the lath ac , however, should be taken somewhat longer than the rest. The gnomon consists of three parallelepiped laths, of which two — ac , an oblong one, and de , a transverse one — form the base; ab is erected perpendicularly, and into its head is set a square little board fg ; while into lath a is inserted another board hi . These two are parallel to each other and inclined

according to the plane of the equator; whence the equinoctial hours are inscribed upon it [the instrument]. Upon these two little boards, as upon poles, turns the octagonal little column K b l — which, however, [is] cylindrical, or of another shape...

Diagram. A full-page engraved plate of Grienberger's heliotropic telioscope [*telioscopium heliotropicum*], set within a hatched rectangular border (a window- or room-frame). The instrument is a large wooden equatorial mounting carrying a long optical tube inclined to the horizontal, an inscribed paper-bearing plate, and a circular graduated hour-dial; screws and clamps secure it to a stepped base. The engraved caption in a ruled panel at the foot reads: "Figure of the heliotropic telioscope, or the telioscopic heliotrope; by which machine the course of the sunspots is obtained without any plumb-line, or the laborious inclining of the ecliptic to the vertical circle." (On this leaf the caption's left ends are trimmed at the plate margin; the complete caption is legible on the repeated plate at folio 351.)

Readable point-letters (positions approximate):

- P (upper, on a small graduated dial near the sighting frame)
- A (mid, on the vertical column)
- B (lower left)
- C (center of the circular hour-dial, ringed by an hour-numeral scale)
- D (lower-left beam); d (small, at the screw below it)
- E (mid-left); e (small, at the screw-head above E)
- F (base, at foot of the inclined tube)
- G (small clamp-block, lower center)
- K (near the dial; also recurring elsewhere on the mount)
- M (right base corner)
- N (lower-center base)
- a, b, c (base points)
- h (near the dial)

[?] Additional small labels — Greek minuscules on the tube's aperture-disc at top and on the paper-bearing frame — are present but not individually resolvable at this resolution. (more than two labels flagged).

(than which nothing can be truer), whose axis K b l coincides — astronomically, at least — with the axis of the world [*axis mundi*].

Third. To the little column K l, in its upper part near l, there adheres an orb, or disc, m l n, matching the thickness of that column. Into this disc are set two cut segments of a sphere, the upper o p q r and the lower s t u x. On their rims p q and t u are inscribed the divisions of the zodiac [*radii Zodiaci*], according to the degrees of the signs, to the capacity the instrument allows. One half of the signs is marked out on the ascending circle from q toward p, from the beginning of Capricorn to the end of Gemini; the other half is set down on the descending semicircle — either on the back of the same rim, or on the lower margin — from u toward t, through the six descending signs, from the beginning of Cancer, through Leo, Virgo, Libra, and Scorpio, all the way to the end of Sagittarius.

Fourth. Around this zodiac, once cut, another mechanism is set, swinging and turning about the peg l as its axis and poles. This mechanism is made either from a single continuous plank, cut to the thickness of the zodiac, or from four parallelepiped bars y z α β. Into the bar α γ another is fitted at right angles, γ δ; and likewise another rising perpendicularly, α ε. Into the bar β [?] is inserted a bar [?], equidistant from the bar ε [?]; and likewise the paper-bearing plate [*tabella chartifera*] θ, ι κ λ. To the bar γ δ is bound the optical tube [*tubus opticus*] μ ν [?], which carries the Sun's rays ο π [?] down onto the paper θ κ, beneath the circle ν φ χ ψ ω, by way of the radiant cone μ ν φ χ ψ ω.

Now the parts of this instrument that support the paper-bearing plate and the tube — the angles z y ψ and y z γ, likewise α γ ο, all right angles, and the line y l, and the axis μ μ θ — are parallel to one another.

The functions of the individual parts [*Officia singularum partium*]

The bars a c and d e are the bases of the whole machine: of these, a c represents the meridian line, and d e the equinoctial line.

The bar a b presents the vertical line, along which it is erected when the plumb-line A B answers exactly to the point B set beneath its tip. This same bar a b, together with the base a c, supports the column b K, and through it the whole instrument α ε γ δ ι [?], which hangs and turns about the axis b K on the poles b and K.

The plate h i K, spread out in the plane of the equator, carries the equinoctial hours, which the index C — lying in the plane of the hour-dial and revolving with it — points to at the time of observation.

The plate f g holds the axis K b and grips it on every side, so that it cannot slip out or be moved otherwise than in its circuit.

The office of the column $K b m$ is to carry the zodiac-bearer [*signifer*] $p u$; to represent the axis of the world; and, by the Sun's daily motion, to lead round the places marked in the zodiac. This same column also carries the instrument, or carriage [*Ferculum*], fitted for bearing the paper-bearing plate and the tube, and for catching the ray.

The carriage $y z \alpha \delta$ [?] performs three chief duties.

First, it supports the paper-bearing plate $\iota \lambda$ [?].

Second, it holds the optical tube $\mu \xi$ fixed.

Third, it aptly directs the Sun's ray and the line of sight. Hence this part might not unfittingly be called the "telioscopic ray" [*Radius Telioscopicus*].

The paper-bearing plate carries the sheet $\theta \kappa$, clean and spread without folds, on which is inscribed the observation circle [*circulus obseruatorius*] $v \phi \chi \psi \omega$. Its center α [?] lies on the axis of the solar cone $o \pi$ [?] — an axis that cuts the axis of the world $K l$ at right angles when on the very equator, but otherwise always obliquely. The diameter $v \chi$ represents the hour-circle [*circulus horarius*] in which the Sun turns, and lies in the same plane as the hour-index C ; the diameter $\phi \psi$ represents the equator; while the whole circle $v \phi \chi \psi$ marks out the Sun, and its center ω supplies the Sun's center.

The optical tube $\mu \xi$ either carries the Sun down onto the paper, or carries the eye up to the Sun, according to the lenses you fit.

The two sights [*pinnacidia*] ε and v [?] throw the Sun's ray through the apertures α [?] and ε [?] onto the opposite sight $y v$ [?], and so set the instrument to the Sun's due altitude and to its proper place in the zodiac.

On another arrangement and form of this instrument [*De alia huius instrumenti compositione & forma*]

When Father Grienberger [Christoph Grienberger] read this account of mine of the construction, he advised me that, while he did not disapprove of it, he would nevertheless have arranged the parts of the same instrument differently, were it to be built again: namely, so that the instrument would not hang free in the air from the axis $b K$, which [—]

Diagram. The same engraved plate of the heliotropic telioscope as at folio 349 (fig-p481-1), repeated here so as to face the facing-page text. The caption is fully legible on this leaf: "Figure of the heliotropic telioscope, or the telioscopic

heliotrope; by which machine the course of the sunspots is obtained without any plumb-line, or the laborious inclining of the ecliptic to the vertical circle." Point-letters and structure are as described for fig-p481-1 (same review-candidate caveat for the small Greek-minuscule labels).

[which] readily produces wobble and trembling in observing; but so that the whole might rest on a firm equinoctial plane, erected to the given place. Such would be, in the given machine, the plane g f, were it extended in every direction. Then indeed, if the whole cut plank p q t u, bearing the inscribed zodiac, be imagined extended along the line m b, so as to stand upon the former, and be set in at b and made able to be turned about — everything else remaining unchanged — one would have a form more convenient for this use, since the trembling is thereby avoided. The finer details the ingenious reader will easily grasp, and will supply of his own accord.

The use of the whole heliotropic telioscope [*Vsus totius Telioscopii Heliotropici*]

As I weigh the singular convenience this instrument has in the observation of the sunspots, I would venture to say that its first and principal use is to bring the Sun down onto the paper and to display the sunspots' own progression — immediately, without that laborious reduction which is wont to intervene in the vertical instrument — as was hinted in what came before, and as will be clear from what is said below.

There are, however, other uses of the same machine, and indeed various ones, according to the way the optical tube is fitted.

For, first. If you employ a helioscope [*helioscopium*] — that is, colored glasses — you will look at the Sun for almost the whole day without any appreciable change of the ray.

Second. If you employ a telioscope, you will in like manner view the Moon, and Venus, and the other planets.

Third. You will fit the same to the fixed stars, whose daily course you will follow without error and without losing the star, and without laborious searching; for the tube, once set parallel to the star, will keep to it the whole day. Hence for the daytime inspection of the stars this will be a most convenient method, since the star's place is found without error. And Father Grienberger says he especially aimed at this use above all when he was elaborating this equatorial instrument, etc. — though refraction seems likely to hinder the undertaking, etc.

Fourth. The same instrument, for catching the Sun by means of a single convex lens, will in my judgment not be unsuitable, if the paper-bearing plate be set well back.

Fifth. It serves as a universal clock over the whole globe of the earth, if a movable equatorial plane be made.

Sixth. It affords the use of armillary rings [*armillae*], from whose substance it differs but little, etc.

The practice of observing by the heliotrope [*Praxis Obseruandi per Heliotropium*]

For a correct observation, this machine must be set up level in a horizontal plane, which is done by means of the three grooved screws D E F: these can be turned by the key G, whereby the bases a c and d e level the whole gnomon [*Gnomon*] until the plumb-line B hangs exactly over its own tip. For then the bar a b will answer to the zenith of the place.

Next, on the horizontal plane, the meridian line H K must be found and laid down by position, or a line L M parallel to it; and to one or the other of these the side M N of the bar a c must be applied. Once this is done, the instrument stands correctly. But if no meridian line is available, one may use a rod, or an approved magnetic needle [*acus magnetica*] enclosed in a square compass-box [*pyxis*], which has both the line of the magnet and the meridian marked out on its horizontal floor for that region.

Afterward, set the ray y z to the Sun's place in the zodiac, p q or t u, as the time and reckoning of the year shall require.

Then at last turn the whole heliotrope on its poles b and k, and you will find the Sun about to enter onto the paper beneath the circle $\phi \psi$ [?]; and there you will not only survey the sunspots and faculae, but also mark them down at your pleasure. And if you go on observing day by day, you will acquire the sought-for course of the sunspots, without any other troublesome or laborious practice.

For the rest — since the Sun in the ecliptic makes its daily progress and forms ever-new angles with the hour-circle — it comes about that the ecliptic itself, in the observation circle, does indeed fall through the center in the form of a straight line, yet always in a different position or place. For since the hour-circle on which the Sun sits always passes through the Sun's center and through the

poles and axis of the world, its section on the paper, represented by the line $\nu \chi$, remains unchanged the whole year through; and yet its ...

Rosa Ursina — Liber III (folios 353–356)

Diagram. Full-page engraved plate occupying folio 353, set within an ornamental ruled frame. It depicts the *heliotropic telioscope* — a large tripod-mounted solar-projection instrument seen in three-quarter perspective standing on a tiled floor within a walled room (the floor and walls carry corner reference-letters). A long telescope tube runs diagonally from lower-left up to the upper-right, where a short foreshortened aperture-tube (with a small circular objective, bearing tiny labels) admits the Sun's cone of rays (drawn as a dotted spray). The tube is carried on a graduated arc / protractor at lower-right and a system of struts and a vertical post. At lower-left a tilted rectangular projection frame (the receiving screen) is shown, ruled with a dotted grid and an inscribed ellipse (the traced spot-path), bearing Greek point-letters. Small foot-screws, a leveling box, and adjustment fittings appear along the base.

Engraved caption (verbatim, at foot of plate): "*Heliotropii Telioscopici, siue Telioscopii Heliotropici figura; qua Machina Macularum Coursus absq[ue] ullo perpendiculo, aut laboriosa Ecliptica ad uerticalem Circulum inclinatione aquiritur.*" — "Figure of the heliotropic telioscope, or of the telioscopic heliotrope; the machine by which the course of the [sun]spots is obtained without any plumb-line, or laborious inclination of the Ecliptic to the vertical circle." (*aquiritur* = *acquiritur*.)

Confidently readable labels (Roman capitals, marking chiefly the room/floor reference-corners, the posts, the arc and the base-fittings):

- O (upper-left interior corner of the framed space)
- H, L (left side, floor/wall corners)
- M, K (right side, floor corners); a second K sits on the graduated bar near the arc
- A (vertical post, right of center)
- E, with a small screw *e* (fitting on the right post)
- C (the graduated arc / protractor at lower-right, with a scale of small numerals)
- F (base fitting, lower center)
- B, a (lower-center junction)

- D, d (foot-screw at lower-left)
- N, G (small box object — a leveling/sighting box — at bottom center)
- P (on the upper tube)

Additional lowercase Roman (b, f, g, h, i, l, m, n, r, t, u, x) and Greek letters (β , γ , θ , ϕ , χ , ψ , and a series of small numerals) label the tube joints, struts and the tilted projection-screen grid, but many are minute, foreshortened, and partly obscured by verso show-through; they are not individually resolved with confidence. [More than two labels unresolved — figure]

its inclination to the Ecliptic changes daily. The section of the Ecliptic drawn on the paper must therefore be shifted as well, now approaching the hour-line $v\chi$ [?], now receding from it. We derive this approach and recession from the spherical angles that these two circles make with each other over the course of the whole year.

And although the individual increases and decreases of these angles are small, still — since the passage of the sunspots across the visible hemisphere is ordinarily completed within twelve to fourteen days — it can happen that, over the flow of so many days, a large change of place and position occurs. So, to obtain the true and genuine motion of the spots, we must know the inclination of the hour-circle to the Ecliptic on any day of the year. In this way we shall easily bring the Ecliptic back to a fixed situation and posture within the immobile observing-circle, and recognize the spots' own apparent motion.

You will grasp this varying projection of the Ecliptic on the paper without difficulty if you mentally set the Sun on the meridian circle and then consider the common section of the observing-circle with the plane of the Ecliptic. The colures of the solstices and equinoxes display this best. For when the Sun is at the solstices, the Ecliptic's position on the paper will always be perpendicular to the meridian line; but at the equinoxes it is most oblique, tilting now toward the north, now toward the south. This becomes immediately evident to the senses of anyone who imagines the celestial circles in his mind and inspects a material sphere with his eye. The cause of all this is the position of the Ecliptic in the universe, oblique to the equator; for if the Ecliptic were fitted to the poles of the world, this variety would not arise.

Investigation of the angle that the hour-circle or meridian makes with the Ecliptic at any point of the Ecliptic

What is sought here can be reached by many routes, of which we shall first of all show the one that — though rather abstruse because of its excessive abstraction — is nevertheless the most exact of all, since it presents the desired quantities to be examined down even to the minutes. This is the numerical method, which is carried out by the Canons of triangles — of sines, tangents, and secants — a method so familiar and ready to hand for astronomers that without numbers they can accomplish nothing of any importance in astronomical observations.

[Margin: Explanation of the figure.] In this spherical figure, then, let the Colure of the Solstices be $a b c d$; the poles of the world a and c ; the equator $b e d$; the Ecliptic $f e g$. Let the equinoctial points Υ (or ϖ) fall at e , and the solstitial points φ and ψ at f and g .

Now let the point o be any other point of the Ecliptic, and through it, from the pole of the world a , let a circle $a o h$ be understood to pass — namely the declination-circle of the point o , which is also one of the hour-circles. Its arc $h o$ is the arc of declination, and $o a$ the complement of that declination; and $e h$ is the arc of right ascension of the Ecliptic arc $e o$. In the spherical triangle $e h o$ the angle h is right; $h e o$ is the angle of greatest declination, measured from the arc $h o$; and finally the angle $h o e$ is the one sought here, for it is contained between the Ecliptic $e o$ and the hour-circle $h o$ at the point o .

[Margin: The data in the spherical triangle $e h o$.] To exhibit this angle by the canon, we assume in the spherical triangle $e h o$ the quantities that are freely given — namely the angle of greatest declination $h e o$, and the proposed arc of the Ecliptic $o e$, which is here opposite the right angle h and is therefore usually taken under the name of "base."

Once the base in a spherical triangle is given, together with one or the other of the non-right angles, the rest are given by the canon. So in this triangle $e h o$ there are given: the side $h o$, which measures the declination of the point o ; the side $e h$, which measures the right ascension of the Ecliptic arc $e o$; and also the angle o — each from its own spherical problem, according to Problem 15 of Clavius [Christoph Clavius] in his *Spherical Triangles* [*Triangula sphaerica*], which runs as follows:

Given an arc in a right[-angled] triangle which is opposite the right angle, together with one or the other of the non-right angles, to find the other non-right angle, and the two arcs about the right angle.

But since here we seek only the angle o, it is better to consult Problem 3 of the same Clavius, in which — at the end of the first book of the *Astrolabe* [*Astrolabium*], namely in Lemma 53 — he teaches how to find an angle in a right-angled spherical triangle from the base and one of the other angles, in this way:

Let it be done thus: as the whole sine [radius] of the [right] angle h is to the tangent of the given angle h e o, so is the sine of the complement of the base e o [?] to the fourth term — namely, to the tangent of the complement of the angle o.

Diagram. An uncaptioned geometric construction (the *figura sphaerica* explained on folio 354): a large circle with inscribed intersecting arcs forming the spherical triangle of the demonstration. Readable point-letters, as placed around and within the circle: k (top), f and b (upper left), o and h (left of center), e (lower left, on the circumference), a (right), c and d (lower right), g (bottom). These correspond to the construction described in the text — the Colure a b c d, the equator b e d, the Ecliptic f e g, and the working points o, h. The recto is lightly inked and heavily overlaid by mirror-reversed show-through from the table on the verso (folio 356); several small interior letters cannot be separated cleanly from the ghosting. [Figure]

EXEMPLVM (Worked example).

Base, e o: 19° . Angle e: $23^\circ 30'$.

Whole sine (<i>Sinus totus</i>)	100000
Sine of complement (<i>Sinus Compl.</i>)	94552
Tangent (<i>Tangens</i>)	43481

Multiplication (94552×43481), partial products as printed:

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94552
756416
378202 [recte 378208? – see note]
283656
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378208

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Result line: *Angulus o, gr. 67. 39. cuius tangens compl. est 41112 | 1551* — "Angle o = $67^\circ 39'$, whose tangent of the complement is 41112 | 1551."

And by this method, through each single degree of the Ecliptic — indeed through any minute you like — you will be able to trace out the angles of inclination that

arise between the Ecliptic and the declination- or hour-circle, at any time whatever of the whole year; and you will attain this not without great economy of labor, provided you always multiply the tangent 43481 (which is always the same) by the other number. Indeed, if this number 43481 is once multiplied out separately into all nine numerical figures, 1, 2, 3, 4, and so on, you will have all the individual products of the multiplication ready; and these, written out in their proper places according to the rules of multiplication, will require nothing beyond addition and gathering into a single sum.

But so that the whole variety of one entire year may be had through the single degrees of the Ecliptic, there is no need to run through the whole Ecliptic, or through all its signs; it suffices to display by calculation the angles of three signs and of the 90 degrees of the first quadrant. For one and the same angle is common to four points of the Ecliptic equally distant from the cardinal points, as may be seen in the following Table.

Explanation of the Table

This Table proceeds through the whole degrees of the signs, beginning at ♈ and advancing in the order of the signs; two opposite signs are joined together — such as ♈ and ♏; ♉ and ♎; ♊ and ♍ — and likewise the characters of the opposite signs are joined at the foot of the Table. The columns run in five vertical series.

The first, on the left-hand side, numbers the degrees of each sign, up to 30; it is common to all signs, both the northern (marked crosswise above) and the southern, of the first and third quadrants, and the numbers descend downward through the degrees, below the letter G placed above.

The second column contains the numbers due to each single degree over against it in the first column, while the Sun is in ♈ or ♏.

Likewise the third (which is also the middle) column comprises the numbers that answer to the lateral degrees of the first column, when the Sun runs through ♉ and ♎.

But when the Sun sits in ♊ and ♍, the fourth series of numbers serves. And this so far by descending; for if we ascend, the same columns and the same numbers serve for the signs placed at the foot of the Table — which are ♋ and ♏, ♌ and ♎, ♍ and ♉; and while the Sun dwells in these, the numbering of the degrees is set up upward, in the fifth column, up to 30 degrees. From all which the rest is self-evident.

TABVLA Pro angulo, quem Ecliptica facit cum Circulo declinationis. — "Table for the angle that the Ecliptic makes with the declination-circle."

Double-argument table. The left-hand argument column (G, running 0→30 downward) serves the top signs; the right-hand argument column (G, running 30→0 upward) serves the bottom signs. Each sign-pair column gives G (degrees) and M (minutes).

Top signs: ♈ ♉ | ♊ ♋ | ♌ ♍ · Bottom signs (read upward): ♎ ♏ | ♐ ♑ | ♒ ♓

G (top→)	♈ ♉ · G	♈ ♉ · M	♊ ♋ · G	♊ ♋ · M	♌ ♍ · G	♌ ♍ · M	G (←bottom)
0	66	30	69	22	77	44	30
1	66	30	69	34	78	6	29
2	66	31	69	46	78	28	28
3	66	32	69	58	78	50	27
4	66	33	70	11	79	12	26
5	66	35	70	24	79	35	25
6	66	37	70	37	79	58	24
7	66	39	70	71	80	21	23
				[impossible]			
8	66	42	71	5	80	45	22
9	66	46	71	20	81	9	21
10	66	49	71	35	81	32	20
11	66	53	71	50	81	57	19
12	66	56	72	6	82	21	18
13	67	2	72	21	82	46	17
14	67	7	72	38	83	10	16
15	67	12	72	55	83	35	15
16	67	19	73	12	84	0	14
17	67	25	73	29	84	27	13
18	67	32	73	47	84	50	12
19	67	39	74	5	85	15	11
20	67	47	74	23	85	41	10

G (top→)	♈ ♂ · G	♈ ♂ · M	♉ ♍ · G	♉ ♍ · M	♊ ♎ · G	♊ ♎ · M	G (←bottom)
21	67	54	74	42	86	6	9
22	68	3	75	1	86	32	8
23	68	11	75	20	87	1	7
24	68	20	75	40	87	24	6
25	68	30	76	0	87	50	5
26	68	39	76	20	88	16	4
27	68	49	76	41	88	42	3
28	69	0	77	2	89	8	2
29	69	11	77	23	89	34	1
30	69	22	77	44	90	0	0

Use of the Table, and the drawing of the Ecliptic in the observation circle [Vsus Tabulae, & descriptio Eclipticae in Circulo obseruatorio]

If you wish to know what angle the hour-circle on which the Sun sits makes with the ecliptic, take from the Table the sign and the degree of the sign. If the sign is one of the upper ones, count the degree in the first series, going downward; if one of the lower ones, take the degree in the last series, going upward. In either case, from the degree of the sign you have found, enter the table crosswise until you reach the number placed directly beneath the given sign. That number will declare the size of the angle you seek, in degrees and minutes. You will then apply it, from the hour-circle CD, in the observation circle ABCD — either from above at the point C, or from below at D, and either to the right or to the left — according to what the reckoning of time, and the position and progress of the spots, sufficiently indicate.

This angle is never greater than a quadrant of the circle, and never less than the complement of the Sun's maximum declination. For example:

[Margin: A worked example. (Exemplum practicum.)]

In the Image of Observations for ♋ [Cancer], the angle sought for 2 March is the one the ecliptic makes with the hour-circle CD in the observation circle ABCD. On consulting the Ephemerides for the year 1627, you find that on 2 March the Sun stands in the 11th degree of ♓ [Pisces]. Since ♓ lies in the inner part of the Table, you ascend in the last series up to the 11th degree; opposite it, in the second

column beneath which $\times$ lies, you find 67 degrees, 39 minutes. Applied from C toward A, in the quadrant AC, these give the ecliptic for that day, 2 E 2, and the angle sought, C E 2.

The analematic method of finding the aforesaid angle [Modus Analematicus praedictum angulum inueniendi]

Now we shall turn aside from that canonical route, which we called the most direct, and exchange the obscurity of numbers for the light of geometry. And to satisfy more readers by this labor of ours — namely those who move more happily among lines and circles than among the unknown labyrinths of numbers — we take the same spherical figure as in the earlier figure numbered I [figure 1] — but no longer the triangle *eho*; in its place, the triangle *aof*, which is likewise right-angled, on account of the right angle *afo*. For in this triangle the angle *aof* equals the angle *eah*, which up to now we have investigated by calculation, and which here we strive to investigate analematically — that is, by means of the circles of the sphere projected orthogonally onto some plane, as was done by Ptolemy in his *Analemma*, and by Juan de Rojas [Ioannes de Roias] in his *Astrolabium Catholicum*, or universal astrolabe. In these, all the circles of the sphere projected perpendicularly onto another plane are rendered either by straight lines, or by circular ones, or by elliptical ones. For those parallel to the plane are all projected into circular lines; those perpendicular to that same plane, all into straight lines; and all the rest, oblique to the plane, are rendered by ellipses. The demonstration of this does not belong here, and is sufficiently self-evident to those versed in astrolabes.

We shall therefore try to express analematically the right-angled spherical triangle *aof*, and by that device to measure geometrically the angle *aof* — or at any rate its complement, that is, the angle *aot*, which the longitude-circle *to* makes with the declination-circle *ao* (that is, with the hour-circle). For to this end there has been marked, on the solstitial colure *abcd*, at the point *t*, at least one of the poles of the Zodiac, *t*; from which all the great circles drawn out — such as *to* — are perpendicular to the ecliptic, so that it is certain that the angles *tof* and *toe* are right angles, and consequently that the angle *aot* is the complement of the angle *aof*.

Besides this, we have drawn from the pole *o* — that is, from the very angle sought — through the point *a*, the smaller circle *iaK*, so that on the sphere itself the measure of the angles *aof* and *aot* (or *aoK*, *aoi*), namely the arcs *aK* and *ai*, might be expressed. For although a measure of this kind is properly taken by great circles — such as would be one drawn from the pole *o* through the point *t*, since

ot is a quadrant — it can nonetheless also be taken by circles parallel to those same great circles, such as *iaK*. And the reason is that all circles drawn from the same pole are cut proportionally by the great circles passing through that same pole.

And spherical angles are always homologous with those rectilinear angles by which is meas-

-ured the inclination of the circles that form the spherical angle. That is, both this spherical angle and that rectilinear one are measured by equal or similar arcs of circles. But let it suffice to have set this out beforehand for the sake of fuller understanding. Now let us proceed to the construction of the problem.

Construction of the problem, in the second figure [Constructio Problematis in secunda figura]

With center E, draw a circle or semicircle BOC of arbitrary size, divided into its quadrants by the perpendicular EO. Let the arcs BD and CG be made equal to the maximum declination, $23^{\circ} 30'$, and by the straight line DG cut off the radius EH of the circle HA — which one and the same [radius] serves all the arcs of the ecliptic, and may be called the *polar* radius, because in the sphere whose radius is EB it is equal to the polar circles.

Now, to express the spherical triangle *aof* analematically, let the arc HA be made equal or similar to the ecliptic arc *fo*, and from the point A apply to the diameter BC the straight line AL, equal to the radius EB; onto AL let there also be transferred the segments AM and ML, made from the radius EO — that is, let EN be equal to AM, and NB equal to ML. Finally, from N erect the perpendicular NP, which, as the measure of the angle *aof*, cuts off from the quadrant BO the arc BP, and, for the complementary angle *aot*, the arc PO.

Demonstration [Demonstratio]

[Margin: The demonstration in the third figure. (Demonstratio in figura tertia.)]

To avoid confusion of lines, let all the same things be understood as carried out in this larger third figure as in the second. For the demonstration, first draw the straight line EA, and let it cut off the arc OF, similar to the arc HA (that is, to the ecliptic arc *fo*), which in the first figure formed the right angle *ofa* with *fa*, the complement of the maximum declination. Now, since in the analemma the straight line EF — because it represents a great circle through the pole of the

circle BOC, that is, through E — also forms a right angle with the arc OF at the point F, it is clear that this same line EAF represents the circle *fad*; indeed, a part of AF itself will represent the arc *af*. For since EA is equal to EH, the sine of the maximum declination, if from A a perpendicular AQ is erected above EF, the arc FQ cut off will be equal to the complement of the maximum declination. And this same arc FQ, if together with the line AQ — or rather, if the whole segment AFQ — is conceived as raised up above the plane of the analemma BOC, falls perpendicularly onto the straight line AF. Therefore AF truly represents the complement of the maximum declination, that is, the arc *af*.

And from this it follows that the third arc — which, with the arcs OF and FA, completes a triangle similar to the triangle *afo*, and which corresponds to the arc *ao* — must necessarily terminate at the points A and O. That is, this third arc OA will be an arc of an ellipse drawn about the semi-axis EO through the point A, which here let us take to be OAN; for this suffices for the present demonstration.

Nor is there any doubt that if from N — where this ellipse cuts EB — a perpendicular NP is erected, it cuts off the arc BP, which measures the angle NOB (or AOF), and thus the triangle *aof*. For the arcs ON and OB represent quadrants; the straight line EB represents the great circle drawn from the pole O, where the sought angle AOF is formed; and the straight line NB represents the arc BP — for it falls perpendicularly onto BP itself, if the segment NBP is understood to be raised up above the plane of the analemma BOC.

But since it is not yet established that this straight line EN — the minor semi-axis of the ellipse OAN — is the same as the one we made equal, in the construction, to the segment AM, this now remains finally to be demonstrated. Yet there is no need of many words, for this very thing has already been demonstrated in Lemma 50 of the first book of Clavius's *Astrolabium* [Clavius, *Astrolabium* I, lemma 50]: namely, that if from any point of the ellipse — for example, from A — the straight line AL, equal to the major semi-axis EO, is applied to the minor axis (produced, if need be), it is cut by that same major semi-axis in such a way that the segment AM is always equal to the minor semi-axis EN. Therefore, and so on — which was to be demonstrated.

But since on the sphere spherical angles are measured not only by great circles but also by smaller circles, as we said before — such as in the first fi-

Diagram 1 — the first (canonical) figure. Two intersecting circular arcs forming the spherical right triangle *aof*, drawn at the top left of the page. Readable point-labels:

- R (top): the pole of the Zodiac / apex of the construction
- f (upper left)
- a (upper right)
- b (left)
- o (center): the angle-vertex (pole *o*)
- d (lower center)

[The lower quadrant of this small figure is partly overlaid by mirror-reversed show-through from folio 360; additional lower colure labels (about *c*, *g*) are not securely legible and are not transcribed.]

Diagram 2 — the second figure. A circle of center E with an inner (polar) circle, marked "2". The vertical diameter runs from P (top) down through the center E; the horizontal diameter runs B (left) – E – C (right). Readable point-labels:

- P (top of the outer circle)
- O (top, just right of P)
- D (upper left, on the inner circle; a dashed line runs across to G)
- G (right side, on the outer circle; end of the dashed line from D)
- A (interior, upper center)
- H (interior, just right of A)
- M (interior, below A)
- L (lower right, interior)
- N (on the base, left of E)
- E (center)
- B (left end of the horizontal diameter)
- C (right end of the horizontal diameter)

Diagram 3 — the third (larger) figure. A large quadrant BOC, marked "3", with center E at the lower-right corner and the right-angle base running left to right; the quarter-arc sweeps from the top down to the base. Numerous construction lines converge at the interior point A. Readable point-labels:

- S (top right, on the arc)
- R (top, just left of S)
- O (upper right, on the arc, below S)
- P (upper left, on the arc)
- F (left, interior)
- D (left, interior, on a dashed horizontal)

- K (far left, on the base)
- Z (interior, left of center, on the base line)
- A (interior center-right: the vertex where the construction lines meet)
- H (right, interior, near A; dashed horizontal to G-side)
- I (right, interior, just below H)
- M (right, interior, below I)
- V (interior, below M; dashed lines)
- B (lower-left corner)
- X (on the base)
- Y (on the base)
- T (on the base)
- N (on the base, center)
- E (lower-right corner, the center of the quadrant)
- L (on the base, right, near C)
- C (lower-right end of the base)

-gure is Kai, whose segment aK measures the angle aof , and ai the angle aot , we must strive to achieve this same result analematically as well. I say, then, that this is achieved by the straight line KAI, drawn through A parallel to BE; and that AI is the sine of the angle aot with respect to the whole sine IK — that is, if with center I and radius IK a quadrant KS is drawn, and AR is [set]

perpendicular [to KI], then the arc RS is the arc of the angle aot , and RI the arc of the angle aof . I prove this from what was demonstrated at the end of the first book of the *Astrolabium*, in the lemmas on the ellipse. For it was there shown that if about the major axis of an ellipse a circle is drawn — such as BOC here — and ordinates are applied to that same axis — such as BE and KI here — all such ordinates

are cut proportionally by the ellipse. Hence the sine EN has the same ratio to its radius EB as the sine AI to its radius IK; and therefore the arc PO is similar to the arc RS, and so on.

[Margin: The same is demonstrated another way. (Eadem demonstratur aliter.)]

Or, indeed, independently of what has been demonstrated, thus. The straight line KAI represents the smaller circle drawn from the pole O through the point A — namely the quadrant iaK — because the arc AO corresponds to the arc ao . And when the quadrant IRS is conceived as perpendicular to the plane of the analemma, then the arc KRS is the one drawn on the sphere from the same pole O

through the point represented by A — that is, the one drawn through the point R, since R falls perpendicularly onto A. Therefore the arc RS, whose sine is AI (with respect to the whole sine IK), is the one that on the sphere measures the angle formed by the two circles represented by OI and OA; and RB is the one that measures the angle formed at O by the arcs represented by OA and OK.

COROLLARY I [COROLLARIVM I]

From this construction and demonstration it is clear that, if in some quadrant EBO all the ellipses of all ninety degrees were drawn out analemmatically, and the little circle itself — or at least its quadrant HT — were likewise divided into its own [degrees], the angles sought for each single degree of the ecliptic could be obtained at once, at virtually one and the same glance, by counting the ecliptic arcs begun from the start of ♈ [Aries] or ♎ [Libra], from the point T toward H, or else their complements from H toward T. For the analemmatic degrees between B and N — the endpoint of the ellipse passing through the ecliptic point A — measure the sought angle BOA, and the remaining degrees NE its complement, that is, the angle AOE.

But it suffices to have hinted at this here in passing, for quadrants of this kind are rare, owing to the difficulty of drawing so many ellipses. In its place, therefore, one could employ the quadrant of the astrolabe of Gemma Frisius, in which, instead of ellipses, arcs of circles are drawn more easily and more accurately, serving the same function that the ellipses serve in the astrolabe of Juan de Rojas.

[Margin: The quadrant of the Frisian astrolabe, more easily prepared, does the same. (Quadrans Astrolabij Frisiani facilius apparabilis, idem praestat.)]

But in a Frisian quadrant of this kind the little circle HA is drawn not with a radius equal to the sine of the maximum declination, but with another, much smaller one — namely, with the radius EV, which the hidden line CD (drawn from the end of the diameter BC to the endpoint BD of the maximum-declination arc) cuts off from EO. And the use of a quadrant drawn in this way, and divided in the usual manner into its degrees, is the same as that of the quadrant HT.

COROLLARY II [COROLLARIVM II]

This same construction makes it clear enough that the declinations of the ecliptic points can be obtained just as well by means of the polar little circle AH, drawn from the center of the analemma, as by means of the little circle that Ptolemy draws for the same purpose in his analemma — especially when the declination of some particular ecliptic point is wanted.

For Ptolemy draws, with the same radius we used — namely, the sine of the maximum declination — that is, with center X and radius XD, a circle through D, of which we have here rendered only one quadrant, DY, which is doubtless equal to our quadrant HT. Then, taking any point Z on the quadrant DY (whose point D corresponds to the solstitial points, and Y to the equinoctial ones), Ptolemy draws through the point Z the straight line ZK parallel to the diameter BC, and demonstrates that the arc BK is the declination-arc of the point Z, whose distance from the solstitial point D is the arc DZ, and from the equinoctial point Y the arc YZ.

And who does not see that, if the same arcs are counted on the quadrant TH, from the points H and T up to A, and through the point A the line IAK is drawn parallel to BC, this parallel cuts off from the circle BOC the very same arc BK? For it will necessarily coincide with ZK, as is plain if from Z and A two perpendiculars are understood to fall onto the straight line BC: they will be equal, because they are the positions of two equal arcs YZ and TA; and parallel, because they are perpendicular to the same line BC — and therefore AZ too is parallel to that same BC.

Moreover, our little circle drawn from center E seems to bring with it this advantage: that onto it any ecliptic arcs whatever can very easily be transferred, by means of the circle BOC. For, taking any point F whatever, or having counted any [degrees]

Rosa Ursina — Book III (continued)

The upper portion of this leaf carries an engraved construction figure (the "first figure" of the analemma method); the letterpress occupies only a band at the foot of the page, in two columns.

Diagram. An analemmatic construction — the "first figure" (*prima figura*) referred to in the corollaries — showing a spherical right triangle a-o-f set within a circle, together with the little circle (*circellus*) H T and its arcs H A, T A, and the arcs D Z, Y Z. The figure is heavily overlaid by mirror-reversed show-through from the two numbered figures engraved on the verso (folio 362), so the peripheral labelling cannot be separated cleanly. Point-letters legibly present on this side include the lowercase construction points **a, b, d, e, f, h** and the uppercase **I, K**; the further point-letters named in the text (o, H, T, A, B, O, F, D, Z, Y) are present in the figure but not individually resolvable against the show-through. (verso show-through contamination; more than two labels uncertain).

Column I. ... [?] ... to the arcs O F or B F. If E F is produced from the centre, the little circle H T will be cut at the point A, and the arcs H A and T A will be similar to the arcs D Z and Y Z.

COROLLARY III.

Finally — that this way of representing a spherical triangle analematically, given the two sides that enclose the right angle, is not peculiar to the triangle a–o–f proposed here at the outset in the first figure, but is common to all other similar triangles in which likewise two sides are given — is as evident here as everything else already stated. And at the same time it is clear that, in the very way in which we made the angle O known, the angle a too can be determined; **(Column II)** and that if the third arc a–o — that is, the base, or the side opposite the right angle — were not available from some other source, it can be obtained by the method set out here. This much it is enough to have touched on briefly here.

Column I (*continuing Corollary III from the preceding column*): ... the angle a as well; and that if the third arc a–o — that is, the base, or the side subtended by the right angle — were not available from elsewhere, it can be had by the method here expounded. Which is enough to have briefly indicated here.

A PRACTICAL INSTRUMENT, FROM WHAT HAS BEEN SAID

[Instrumentum practicum ex dictis]

Now, so that this operation may be carried out in practice most easily and without any recourse to arithmetic, I have constructed the instrument H F D C. With its help you will obtain both angles — both the one that the hour-circle makes with the Ecliptic and the angle of its complement — and that by the aid of the ruler and compass alone.

This instrument comprises two quadrants described from the same centre E. The larger, E C D, is drawn to the radius E C; its limb, on the side of D, runs out as far as F, to provide for the maximum declination of the Sun. Its end F, by means of a parallel F H drawn through it, gives me the measure of the smaller quadrant E H K I. I divide its arc H K I into 90 equal degrees; then, the limb being marked off doubly, I lay upon it the signs of the Zodiac themselves, beginning from ♈ Aries and H, and assigning 30 degrees to each sign. I then join the corresponding [homologous] signs — ♈ Aries with ♎ Libra, ♉ Taurus with ♏ Scorpio, ♊ Gemini with ♐ Sagittarius — and next, in the same manner but in reverse order, ♋ Cancer with ♑ Capricorn, ♌ Leo with ♒ Aquarius, ♍ Virgo with ♓ Pisces. Once this is done, if you have written the numbers against the marginal degrees, the

instrument is complete. Its use is extremely easy, and I explain it by three examples.

[Margin: Exemplum primum. — First example.]

The Sun is in the 19th degree of ♈ Aries; likewise in the 11th degree of ♉ Pisces; likewise in the 19th of ♎ Libra; likewise in the 11th of ♍ Virgo [?]. Required: the complement of the angle that the Ecliptic makes at the stated times with the hour-circle on which it sits.

To meet this question, enter the limb of the small quadrant, and you will find a single point K that will satisfy all the proposed times; for onto it fall the 19th degree of ♈ Aries and ♎ Libra, and likewise the 11th of ♍ Virgo and ♉ Pisces. So, from this point, the radius E D (or E C) applied gives the position K M; and E N, cut off from E equal to it, gives the parallel N O, and hence the complement-angle O E D. This angle, cut off from D along the interval D O out of the arc of the semicircle C D as far as P, leaves the required angle P E C — the angle that the hour-circle H E C makes with the Ecliptic E P at the given time. Its magnitude **(Column II)** — that of the determined angle O E D — will be given by the number found at P, which is 67 degrees, 40 minutes, more or less.

[Margin: Exemplum secundum. — Second example.]

A second example is taken in the same way, at the 30th degree of ♉ Taurus or ♏ Scorpio — the beginning of ♊ Gemini or ♐ Sagittarius — and likewise at the 30th of ♋ Cancer or ♑ Capricorn, the beginning of ♌ Leo and ♒ Aquarius. For all these signs have that single point Q in common. From it the radius Q L, dropped onto E C, gives the straight line Q M; carried over from E to N it presents the parallel E R; and this, from the point R, shows the required complement-angle R E D, suited to all the aforesaid signs at the assigned place. How many degrees and minutes this angle is, the numeral marks inscribed on the limb will declare: they show 12 degrees, 15 minutes, more or less. So if with the compass you take the arc D R off the quadrant C D, from D as far as S, there will remain the arc C S, which will bound the angle S E C. Its magnitude will be indicated by the numbers inscribed on the limb: namely 77 degrees, 40 minutes and more.

[Margin: Exemplum tertium. — Third example.]

The third and last example is taken at the 30th degree of ♊ Gemini and ♐ Sagittarius [?], and likewise at the beginning of ♋ Cancer and ♑ Capricorn. For this place the straight line I L serves; and since it is nowhere cut by the radius E, no other parallel need be sought than the radius E D itself. Hence there is no

complement-angle, and so the whole residue will be D E C. Thus at ♋ Cancer and ♑ Capricorn the hour-circle makes a right angle with the Ecliptic.

Another geometric method — of importing the Ecliptic into the circle of observations, and of finding both of the aforesaid angles by drawing polar rays similar to the rays of the Zodiac, the use of which is an everyday matter among astronomers and especially among gnomonicians [makers of sundials].

In the observatory circle of the Heliotrope [the circle bearing the zodiacal marks ♈ ♉ ♊ ♋ ♌ ♍ ♎ ♏ ♐ ♑ ♒ ♓ [?]], about the radius ♈-ω [?] for example, draw the polar rays in exactly the same way in which the rays of the Zodiac are usually drawn, through each degree of the signs — and you will have achieved your aim. For by their help you will, more quickly than can be told, hunt down at once both the Ecliptic and the two angles that the hour-circle makes with the Ecliptic at any given place of the Sun and degree of a Sign. By "polar rays" I mean the sections which a plane, passing through the places of the Sun and the poles (**catchword: los**) ...

The two numbered figures engraved on this leaf:

Diagram 2. A circle with centre E, illustrating the practical instrument H F D C used in the first two examples. A vertical diameter runs from O at the top through the centre; a horizontal diameter runs from B (left) through E to C (right). Labels legibly present: **O** (top), **P** (near the top, from which and from O dashed lines descend to L), **D** (upper left, on the circumference), **A** (on the upper vertical, between O and the centre), **H** (right of A), **M** (below A, toward the centre), **G** (right, reached by a dashed horizontal line), **L** (lower right), **N** (left of centre), **B** (left end of the horizontal diameter), **E** (centre), **C** (right end). A smaller concentric circle is drawn inside. The figure number **2** stands at the centre-foot.

Diagram 3. An analemmatic quadrant construction (the detailed figure for the analemma method). A large quarter/semicircle with its apex at **A**, radiating lines, and a horizontal base line. Labels legibly present include: **R** (top), **P** (below R), **F** (left), **D** (upper right), **Z**, **K** (left vertical), **X**, **Y**, **T**, **N** (along the base line), **B** (left), **H**, **M** (near the apex), **L**, **C** (lower left), **E** (centre-left), **G** (right, dashed), **S** (right). The figure number **3** stands near the centre. Several interior labels sit in crowded intersections and could not all be resolved. (more than two labels uncertain; partial overlap with figure 2 and with recto show-through).

Folio 363 — full-page engraved plate

This leaf is a full-page engraving that interrupts the text (the letterpress runs directly from folio 362 to folio 364). Almost all of the faint text visible behind the

engraving is mirror-reversed show-through from folio 364 and is not transcribed here.

Engraved plate. A large quadrant instrument for finding the Ecliptic and its angles. The engraved display-capital title reads: *"INSTRVMENTVM ECLIPTICAM, ET ANgulos quos Ecliptica cum circulo horario seu Meridiano per totum annum facit; eorumque complementa, dicta citius, geometrice indagandi"* — "An instrument for finding out geometrically, more quickly than has been said, the Ecliptic and the angles that the Ecliptic makes with the hour-circle or Meridian throughout the whole year, together with their complements."

The instrument is a quarter-circle. Its centre (apex) is at E, lower left. From E a double graduated limb (two parallel scaled arcs) sweeps from the top down the right side and curves to the lower left. Corner and arc labels legibly present: **H** (upper-left corner), **F** (upper-right corner), **O** (just below F), **R** (right side), **S** (right, lower), **D** (right, at a horizontal division), **C** (lower-left corner), **K** and **Y** (upper region, near the arc), **N** (left margin, appearing at more than one dashed-line terminus), **M** (interior, appearing twice), **L** (lower left, appearing several times as dashed-line termini), **I** (bottom, near M), **P** (right, lower). The limb is graduated in degrees; the divisions **5, 10, 15, 20, 25, 30, 35, 40, 45** are legible along the arc (continuing up the limb). Engraved on the plate are the Jesuit **IHS** emblem in a radiant sunburst (with cross and the three nails) and two heraldic roses (the Orsini rose-and-bear device of the *Rosa Ursina*). (many small labels; more than two uncertain).

Column I (*continuing from folio 362*): ... the poles of the Ecliptic, at right angles to the observatory circle — sections which it makes common to however many days of the whole year there are. Their construction is as follows.

Let the observatory circle be A B C D in figure 4, and let two diameters, A C and B D, intersect at right angles at the centre E. Now, so that the aforesaid rays may be laid out about the radius A E: from A let the distance of the pole of the Ecliptic from the pole of the world — equal to the Sun's maximum declination, namely 23 degrees 30 minutes — be counted off on both sides, to F and to G; and this span will be bisected by A E at the point H. With H made the centre, if a circle F I G K is drawn to the radius H F (or H G), it will be the polar circle — equal to the circle usually drawn for the Sun's maximum declination — the polar circle that the pole of the Ecliptic marks out each year.

Accordingly, the several quadrants of this circle — I L M G, K L M G, I L M F, K L M F — are to be divided into 90 degrees (here I have proceeded only by the

beginnings of the signs, to avoid confusion); and through each of the division-points L, M, and so on, straight lines L L, M M are to be drawn on both sides, parallel to the line I K. For these will cut the diameter F G at points N and O on either side. If through these points straight lines are drawn from the centre E — E N, E O, and likewise E F, E G — these will be the polar rays sought, which the circle passing through the poles and the place of the Sun produces in the observatory circle.

It should be noted that I have made this construction of the rays with a view to the annual motion itself, by which the axis and pole of the Ecliptic circle the pole of the world. For from this it comes about that the rays receive a different naming than they do in their ordinary construction — in which the radius E A belongs to the equinoxes and to the beginnings of ♈ Aries and ♎ Libra, while E F and E G are assigned to ♋ Cancer and ♐ Capricorn. Here, however, the nomenclature is interchanged: for the radius E A is common to ♋ Cancer and ♐ Capricorn, while of the extremes E F is assigned to ♈ Aries and E G to ♎ Libra. Why so? Because when the Sun is at the solstices, the axis and poles of the Ecliptic lie in the very Colure of the solstices; and for the same reason the section of the Ecliptic — always a quadrant away from the axis — falls on B D in the observatory circle, whereas the section that the plane makes through the axis is A C. But at the equinoxes the polar ray E F pertains to ♈ Aries and E G to ♎ Libra. Hence, as with the rays, **(Column II)** so you will picture to yourself the interchange of the angles and arcs.

For the angle N E A does not correspond to the complement-angle of the inclination of the Ecliptic to the hour-circle or Meridian for that point or arc of the Ecliptic for which the parallel L L cuts off the declination-arc A P, according to the customary way of finding it.

[Margin: Declinatio cuiusque puncti Ecliptic[ae], ut habeatur? — How the declination of each point of the Ecliptic is to be obtained.]

For in order to obtain the declination of some point of the Ecliptic by means of the little circle I F K G, one takes the distance of that point from one or the other of the equinoctial points; and on the little circle I F K G that arc is counted from the points I, K — which correspond to ♈ Aries and ♎ Libra — namely the arc I L, I L. When the straight line L L has been drawn, it cuts off the declination-arc A P corresponding to that arc or point of the Ecliptic. But here, in the present business, the arc I L is the one that is counted in the sphere from the solstitial points ♋ Cancer and ♐ Capricorn. For to that arc or point of the Ecliptic there corresponds the angle N E H — which, however, is not the angle that the

meridian makes with the Ecliptic at that point, but is its complement. From this it follows that the angle itself is the angle B E N, and that the arc of the Ecliptic counted from the equinox is F L, whose declination is not the arc A P but the arc A Q — as is plain, if the arcs F M, F M are taken equal to the arc F L, and the parallel M M cuts the arc A F at Q.

[Margin: Cautela notatu digna. — A caution worth noting.]

Father Grünberger [Grienberger], at first not having attended to this quite necessary observation, and seeing that the angle N E A in no way corresponded to the arc I L (whose declination is A P), not only doubted the method itself but even rejected it as false. But once he applied the interchange of arcs just spoken of, together with the calculations, he found at once that this geometric method in no way disagrees with the canonical doctrine of spherical triangles, nor with Problem 3 cited above. Therefore, since he demonstrated it most soundly in various elegant ways — proofs that may serve not only for this purpose but for other mathematical uses as well — it seemed good to set these down here (putting off my own to another, more suitable time and place), lest a method which in his judgment deserves the fullest light should come to light without any demonstration.

Diagram. A full-page engraved plate of geometric construction figures for the analemma/declination demonstrations of Book III. The plate carries eight lettered constructions arranged in three rows; the same plate is repeated. There is heavy mirror-reversed show-through from the verso across the whole sheet, and each figure carries many small interior point-letters that cannot all be resolved at this resolution. Readable figure captions and the more legible cardinal point-letters follow; a full label inventory requires a focused review.

- **Fig. 4.** (upper left): a large circle on centre E, with horizontal diameter B–E –D and a vertical diameter; a pointed-oval (vesica) figure at the top capped by a small circle whose foot is K. Legible letters include A (upper), C (lower), F, G, H, I (apex), and a cluster of interior labels L, M, N, O, P [several of these repeated and only partly legible — [?]].
- **Fig. 5.** (upper right): a quadrant; arc running from I (top) to B (lower left), with Z, Y on the arc, A at right, F near centre, N, H, and the right-angle vertex E (lower right).
- **Fig. 6.** (centre/right): two large overlapping circles on centre E; legible labels I (top), K, S, O, P, Q, F, D, R, G, X, H, M, A, L, C, T, B.

- **Fig. 7. Casus primus** ["Case one"] (middle left): a circle carrying an inscribed tilted ellipse; legible labels **F, N, A, P, G, D, E** (centre), **M, C, I, B, H, O**.
- **Fig. 7. Casus secundus** ["Case two"] (middle centre): a circle; legible labels **L, I, K, F, N, D, M, E, H, A, Z**.
- **Fig. 7. Casus tertius** ["Case three"] (lower left): a circle with inscribed ellipse; legible labels **F, A, N, D, G, E, R, M, I, B, O**.
- **Fig. 8.** (lower centre): legible labels **V, N, a, T, R, G, C, E, O, B** [others [?]].
- **Fig. 9.** (lower right): a circle; legible labels **I, M, L, N, a, D, F, O, H, P, T, K, E, C, R**.

To the Reader — a notice.

So that you may notice the difference of style and of author, what follows is printed in a continuous run, without columns.

The First Demonstration of Father Christoph Grienberger [Christoph Grienberger] — the Canonical one, from the Analogy of the Fifth Figure.

[Margin: Explanation of the proposition and of the Fifth figure.]

From the preceding fourth figure, the quadrant ABE is here reproduced in the fifth figure, together with IFH, the quadrant of the small circle IFKG. And although here the arc AF is not the arc of maximum declination, it is nonetheless taken as such, since in this way the figure is more convenient to work with. The arc FL is understood to be an arc of the ecliptic, counted from Aries (γ), running for example up to the beginning of Gemini (Π); and LI will be its complement. When LN is drawn parallel to IR, NH will be the sine of the arc LI with respect to the whole sine HF. And when the straight line EN is drawn, then — following the rules of this problem — the angle NEH will be constituted as the angle of the complement of the inclination of the meridian and the ecliptic, the Sun standing at the beginning of Gemini, provided the practical construction set out earlier is true.

[Margin: The truth of the construction is demonstrated by way of Problem 3 of the Spherical Triangles.]

That it is indeed true I shall here demonstrate from the analogy of the problem of the Third [book] of Spherical Triangles, from which angles of this kind were canonically found above — namely, from the fact that the tangent of the

maximum declination is to the tangent of the complement of the angle of inclination sought as the whole sine is to the sine of the complement of the given arc of the ecliptic, counted from the equinoctial point.

Let the tangent AyZ therefore be drawn, and let EF, EN, and ZY cut it; then AZ will be the tangent of the angle of maximum declination FEA, and AY the tangent of the angle found by construction — namely of the angle NEH — with respect to the whole sine EA. But with respect to the whole sine HF, NH will be, as we said before, the sine of the arc LI, that is, the sine of the complement of the given arc of the ecliptic FL. Since, then, on account of the parallels AZ and HF, HF (the whole sine) is to KN[?], the sine of the complement of arc FL, as AZ, the tangent of the maximum declination, is to AY, the tangent AEY — and since by this kind of analogy, through the 3rd problem cited, the tangent of the complement of the angle sought is found — then AY will beyond doubt be that tangent which, by the 3rd problem, yields the angle of the complement of the angle sought. And therefore also the angle NEH, whose tangent is AY, will be the complement of that same angle sought. Therefore, and so on — which was to be done and demonstrated.

Lemma for the Demonstration that Follows.

About the diameter FRG in the Sixth figure, of the circle or semicircle FIG, let another circle BOCV be described, having its centre E, which will lie on the semidiameter IR, and so on, perpendicular to FG. From any point K of the semicircle FIG let there be dropped onto the diameter FG the perpendicular KD, or the parallel to IRE; and let ED, joined and produced, cut the circle BOC in P, V, and QR, so that OP is the right sine of the arc. Finally, from K let KX be applied to FG, equal to the semidiameter EB, and let it cut IR in S.

I say that the straight line KS is equal to the sine PQ.

For the squares on EP and KX are equal, and DK and DX are equal to the square on KX; therefore the square on EB is also equal to the squares on DK and DX. But the square on EP is equal to the rectangle PDV together with the square on ED, by Euclid, *Elements* II.2 [recte II.5?], because PV is cut into equal parts at E and into unequal parts at D. Therefore the squares on DK and DX are equal to the rectangle PDV together with the square on ED. But the rectangle PDV is equal to the rectangle FDG, and this is equal to the square on DK. Therefore the two squares on DK and DX are equal to the squares on DK and ED; and, the common square on DK being taken away, the remainder DX is equal to the remainder ED, and the straight line DX is equal to ED. But as ED is to DR, so is EP to PQ, on

account of the parallels DR and PQ; and as XD is to the same DR — that is, as EP is to PQ — so is KX to KS, on account of the parallels DK and RS. Therefore as EP is to PQ, so is KX to KS; and EP and KX are equal; therefore PQ and KS are also equal. Which was to be demonstrated.

Diagram. The same engraved plate of construction figures as (Figures 4 through 9), printed again here so the reader can consult it beside the demonstrations. The upper part shows **Fig. 4** and **Fig. 5** at left/right, **Fig. 6** at centre-right; the lower part shows **Fig. 7. Casus primus / secundus / tertius**, **Fig. 8**, and **Fig. 9**. As on p. 497, there is heavy mirror-reversed show-through and dense interior lettering; the legible captions and cardinal point-letters match those catalogued for fig-p497-1, and a full label inventory requires a focused review.

Corollary.

Hence, besides EP and KX, which are equal by construction, it is established from the demonstration that these too are equal: both PQ and KS, and BD and DX.

Demonstration II.

The small circle FIG, which in the foregoing Lemma was arbitrary, is now to be understood as described in the same (sixth) figure with the interval of the sine of the maximum declination taken with respect to the whole sine EB — that is,

— that is, let the arc BF.OG be understood to be $23^{\circ} 30'$; and let the arc FK be established as the arc of the ecliptic counted from the equinoxes, and KI its complement. For in this way it will come about that here the straight line KD corresponds, in the fourth figure, to the straight line LN, and the angle DER to the angle NEH, and that in both the practical method of finding is the same — namely that geometric construction which we delivered in the second place, applied to the fourth figure.

[Margin: Explanation and comparison of the figures.]

The earlier, analematic construction, set out for the second and third figures, is here represented by the drawing-out of the straight line KX, and by its intersection with the perpendicular semidiameter RI, at the point S. For it makes no difference that there the small circle of maximum declination TAH, which we have expressed here as well, was described about the centre E with its own applied line AML, whereas here in its place the small circle FKI is described; for everything is set up in the same way in both cases, and therefore the applied lines cannot but be cut in the same manner, at the points M and S, from the semidiameters EH and RI — as is plain if the semidiameter ET be superposed on

the semidiameter RF, and the circle TAH be inclined upon the circle FKI. For they will coincide with one another on account of their equality: point A with point K, and EH with KI, and AL with KX; these will then be the same, and points M and S the same as well, and so on. But in a matter so manifest there is no need to dwell longer.

[Margin: Demonstration.]

Since, then, AM, by the demonstration of the analemmatic construction, is the sine of the complement of the angle sought, and RS is equal to it — or rather is the same as AM — and, by the foregoing lemma, KS is equal to PQ, then PQ too will be the sine of the complement of the angle sought. But PQ is the sine of the angle PEQ, or DER, which we here show to have been found by the latter, geometric construction. It is established, therefore, that by both practical methods one and the same angle is found; and thus, from the construction set out for the fourth figure, by force of this demonstration, the complement of the angle sought is rightly found. Therefore, and so on — which was to be demonstrated.

Theory and Foundation of the Demonstrations that Follow.

[Margin: Any cardinal quadrant of the ecliptic exhibits every variety of spherical triangles, etc.]

That the whole variety not only of the Declinations, but also of the Inclinations of the ecliptic to the meridian and to the other hour-circles and right horizons, is the same in all the cardinal quadrants of the ecliptic, is sufficiently manifest on the sphere. So it should be no wonder if, in what follows, in explaining the proposed problem, we always employ the first quadrant, intercepted between the beginnings of Aries (Υ) and Cancer ($\mathfrak{S}$). For with this laid down, the angles and spherical triangles that we have here decided to set out for contemplation are more conveniently expressed. And in order to avoid confusion, we shall reduce the whole variety to three cases: the first and second of which will consider the points Aries (Υ) and Cancer ($\mathfrak{S}$) placed on the meridian, and the third any other intermediate point brought onto the same meridian.

Explanation of the Figure of the First Case.

The meridian in this figure 7, case one, is ABC; the pole of the world is A; the polar small circle is DGF, whose quadrants are DP and FP. BEC is the equinoctial, and its quadrants are BE and CE; and consequently E is the pole of the meridian ABC. These things are permanent and common to all three cases.

The ecliptic in this first case is HMC, in which the point of Aries H is placed on the meridian, and therefore conjoined with the equinoctial point B. NGEMI is the great circle which in all three cases is described from the point of the ecliptic placed on the meridian, and is parallel to the solar disc; and in this first case it passes through the pole of the world A. Both in this case and in the rest it always passes through the pole of the ecliptic G, which always lies on the polar small circle DPF, and through the pole of the meridian E; and out of the ecliptic and the meridian it always cuts off quadrants, such as here are BM, BN, BI. Finally, the arc BG, or HG, is the quadrant of the longitude-circle of the point of Aries H.

[Margin: Assertion 1.]

These things being so established, I say, first: *In this first case the parallel of the solar disc, or the solar horizon — that is, the great circle NEI — is the colure of the solstices; for it passes through the poles of the world and of the ecliptic, that is, through A and G.*

[Margin: Assertion 2.]

I say, secondly: *That the pole of the ecliptic G here coincides with the point of the quadrant P.* For since the small circle DPF is parallel to the equator BC, and the meridian circle AB, and the circle —

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Diagram. A full-page engraved plate of nine geometric constructions on the sphere, serving the analemma/declination demonstrations of the third case. The same plate is printed a second time on folio 371. The engraving is heavily overlaid by verso show-through, and the individual figures carry many small point-letters; only the labels legible under magnification are committed below.

- **Fig. 4** (upper left): a circle with an inscribed orthographic (analemma-type) projection. Readable point-letters: L, L (top); M, M; F, O, P, A, G (upper band); O, N, H, N, O (middle band); M, L, L, M; K; E (center); B (left end of the horizontal diameter), D (right end); C (foot). Caption: "Fig. 4."
- **Fig. 5** (upper middle/right): a quadrant construction. Readable: I, L (upper right); Z, Y, A (top); F, N, H (middle); E (lower right); B (right edge). Caption: "Fig. 5."
- **Fig. 6** (upper right): two overlapping circles (a great circle and a smaller circle). Readable: I (top), K, S, O, P, Q, R; F, D, G, X; H, A, M; B, T, E, L, C (along the horizontal diameter); V (foot). Caption: "Fig. 6."

- **Fig. 7. Casus primus** (middle left): a circle with a small inscribed ellipse at upper left. Readable: B, H (top); F, N, A, P, G (left, at the ellipse); D (left); E, M (center); I (lower right); C (foot). Caption: "Fig. 7. Casus primus."
- **Fig. 7. Casus secundus** (middle right): Readable: O, B (top); F, A, P; D, G, N, M, E, H (middle); L, F; C (foot). Caption: "Fig. 7. Casus secundus."
- **Fig. 7. Casus tertius** (lower left): Readable: O, B (top); F, A, P, N, G, D (left); R; E, M (center); C (foot); with V, N, a, T, R toward the right. Caption: "Fig. 7. Casus tertius."
- **Fig. 8** (lower middle): Readable: D, G (upper left); V, N, a, T, R; E, M, I; G. Caption: "Fig. 8."
- **Fig. 9** (lower right): a great circle with an inner circle. Readable: I (top); M, L; N, A, D; F, O, H, P; T, L; M; K; E; C, R (foot). Caption: "Fig. 9."

[Several individual labels are ambiguous under the show-through; more than two are uncertain across the plate]

[The letterpress at the foot of folio 369 continues the demonstration of the first case, begun on the preceding folio.]

[so that] AEI cut off the quadrants FP, BE; and let circle AE in this case be the same as NE. The solstitial colure [Colurus solstitiorum] NEMI will also cut off the same quadrant FP. Now the pole of the ecliptic lies at the intersection of the colure and the polar parallel; therefore the pole of the ecliptic G here coincides with point P.

[Margin: Dictum 3.] **Third, I say** that both the arcs MI, GE and [B?]M, NG are equal. For GM, EI are quadrants, and when the common EM is removed there remain equal [MI, GE?]; indeed EM, NG are the complements of the equal arcs MI, GE, on account of the quadrants EA, EI. [The point-letters in these two foot-lines sit under heavy show-through; "B M" and the elided arc are uncertain: [?].]

[Margin: Dictum 4.] **Fourth, I say** that in this case the angle of the inclination of the ecliptic to the meridian is the complement of the maximum declination, and conversely the complement of the inclination is the angle of that same maximum declination.

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of that same maximum declination. For the angle of inclination between the meridian BI and the ecliptic HM is MHI, and its complement is EHM. And since HI, HM, HE are quadrants, MI and EM will be the arcs of the angles MHI and

MHE. But EM is the arc of the maximum declination, and MI is its complement. Therefore, and so on — which was to be demonstrated. And this is what is chiefly maintained in this first case.

Explanation of the figure of the second case. [Explicatio figuræ secundi casus.]

In this seventh figure, [that] of the second case, the point of the ecliptic O, placed on the meridian, is the point ☊ [Cancer — the summer-solstice point], and therefore the meridian coincides with the solstitial colure, and the pole of the ecliptic G coincides with point D; and the point of Aries H coincides with the pole of the meridian E, which lies on the equinoctial and is distant from the meridian by a quadrant BE. But the arc of the ecliptic OH is also a quadrant, and cannot be terminated at the equinoctial except at point E; for from point E to O is likewise a quadrant.

The great circle too, parallel to the solar disc, described from pole O, here necessarily passes through D — because it is cut by the pole G — and passes through point EH; and therefore point N, where it cuts the meridian, must coincide with the points EH. Finally, the arc of longitude of point O, that is the quadrant GO, is here the same as the quadrant DO of the meridian; and the angle of inclination of the ecliptic OM with the meridian OI is the right angle MOI, subtended by the quadrant MI; and the angle of the complement of that same angle of inclination — which the arcs EM, NG ought to measure — is, on account of the aforesaid coincidence of the points, nothing [zero]. And this is what had to be demonstrated in the second case.

Hence it is clear that neither in this case nor in the prior one does the investigation of the sought angle require any special procedure — since here it is a right angle and its complement is nothing, and there it is determined by the complement of the maximum declination and by the maximum declination itself, both of which are given without further ado.

Explanation of the third case, in the seventh figure. [Explicatio tertii casus, in figura Septima.]

The meridian ABC, the equinoctial BEC, [and] the small polar circle [circellus polaris] DF correspond to those above; and although the rest proceed by the same method as the preceding cases, they nevertheless vary the figure in part and present several spherical triangles that must be weighed more carefully. The

circle NGEMI is again a great circle parallel to the solar disc, the Sun being placed at O. GO is the quadrant of longitude of point O; EO is a quadrant of a great circle to the meridian, and it is perpendicular to the circle parallel to the solar disc. And OHML is the ecliptic, perpendicular to the same circle NGEMI at point M, and cutting the equinoctial BC at H. And because we are dealing here with the first quadrant of the ecliptic, point O will be some one of the points between the beginnings of Aries Υ and Cancer $\mathfrak{C}$. Let its beginning be Gemini Π ?, such that the arc of the ecliptic intercepted between O and the beginning of Aries Υ is 60 degrees, namely the arc OH; for in the figures above we also took point H as the beginning of Aries Υ .

[Margin: Dictum 1.] **I say, therefore, first**, that this point H falls between O and M. For OM is a quadrant, and OH is less than a quadrant.

[Margin: Dictum 2.] **I say, secondly**, that the point N lies between A [and] D. For the meridian AB, passing through point O, measures the declination of point O by the arc OB, and this declination is less than the maximum declination, namely [less than] the arc AD. Now AN is equal to OB, because the quadrants BA, ON are equal and the arc AO is common; therefore AN too will be less than AD. From this it follows that the parallel of the solar disc NGEI cuts the small polar circle below P, and that the pole of the ecliptic G falls within the quadrant DP; for the point P lies on the circle AE, as we saw in the first case.

[Margin: Dictum 3.] **I say, thirdly**, that both MI, GE and EM, NG are equal — just as they were equal in the first case; for in the second case the arcs EM, NG vanish. For from the pole of the meridian E to the meridian itself — that is, to I and N — the arcs EI, EN are quadrants, and from pole G up to the point of the ecliptic M is likewise a quadrant; therefore, removing the common EM, there will remain equal MI, GE, and removing the common GE, [there remain] equal EM, NG.

Now, in order to approach more closely the sought angles and the things that conduce to their investiga-

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Diagram. A second impression of the same engraved plate of nine constructions (Figs. 4–9) that appears on folio 369; the figures, captions, and point-letters are identical, and the full label list is given under fig-p501-1 above. As there, verso show-through obscures many small labels and more than two are uncertain

[The letterpress at the foot of folio 371 continues the sentence broken off on folio 370.]

—tion, let us approach more closely. **I say, fourth:** that the arcs MI, GE measure the sought angles themselves, and EM, NG their complements. For MI, GE are the arcs of the equal angles MOI, GOE — of which the former is contained by the meridian OI and the ecliptic OM — and the arcs EM, NG are the arcs of the equal angles EOM, NOG, which are the complements of the aforesaid; and all the arcs OI, OM, OE, OG, ON are quadrants. Therefore MI, GO [recte: GE?] measure the sought angles, and EM, NG their complements.

Consideration and use of certain spherical triangles for the theory of the third case. [Consideratio, & usus quorundam Triangulorum sphæricorum Theoriæ tertii casus.]

The right-angled spherical triangles that serve for determining the sought angles — here I find three of them,

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—[running up] to the vertex H; I mean HDO, HME, and a third leading to the arc NG, by drawing the arc AG, namely the triangle ANG. In the triangles BHO, HME, the angles at the vertex H are the angles of the maximum declination, raised up. At B and M there are right angles, because the equinoctial HB is perpendicular to the meridian OB; and conversely the ecliptic HM is perpendicular to the solar horizon EM. And in triangle BHO there is given, moreover, the arc of the ecliptic HO, numbered from Aries ♈; and in triangle MHE, the arc of the same ecliptic HM, which is the complement of the former, HO, because OM is a quadrant; and HM is the side adjacent to the given angle. And in the prior triangle the arc HO is the base, or the arc opposite the right angle B. And so in these two triangles the sides about the angles of maximum declination at point H are so disposed that the arcs of the one are the complements of the other. For the whole arcs BE, OM are quadrants, and MH is the complement of HO, and HE the complement of the arc HB; and conversely these are the complements of those.

Triangle B H O. [Triangulum B H O.]

In triangle BHO, what is sought is the angle HOB — [the angle] of the inclination of the ecliptic HO to the meridian OB — and it can be obtained by the third problem, already cited often and applied in a similar triangle, in which the

proposed angle is sought from the base and another non-right angle: that is, from the base HO of 60 degrees and the angle BHO of 23 degrees 30 minutes. For if it be done thus — as the whole sine [sinus totus] is to the sine of the complement of the base HO, that is to the sine of the remaining arc HM, so is the tangent of the angle BHO to a fourth [term] — there is produced the tangent of the complement of the angle HOB, that is the tangent of the angle EOM, and hence the tangent of the arc EM, which, taken away from the quadrant EI, leaves MI, the arc of the angle HOB.

The calculation itself I do not exhibit here, because an example of the same proportion [analogia] has already been given above.

Triangle M H E. [Triangulum M H E.]

In triangle MHE, however — although the things given are different, except for the angle MHE — and in place of the angle HOB let the arc EM be sought; and let it be another problem suited to the data, namely problem XI, in which a side is investigated, namely EM, from the other side HM and the other non-right angle MHE, which is opposite the sought side. Nonetheless the proportions of both problems come out to the same, if they are rightly weighed, and the same result is obtained through them, namely the tangent of the arc EM. For the proportion of problem XI runs thus:

As the whole sine is to the sine of the side HM — in place of which, in the preceding proportion of the third problem, there stood; so is the whole sine to the sine of the complement of the base HO — where it plainly appears that the second term of both proportions is the same, for the sine of the complement of the base HO is the sine of the right side HM.

So the tangent of the given angle, the same in both, is to the tangent of the arc EM, which is the same as the fourth term of the preceding proportion; for the tangent of the complement of the angle HOB — that is, of the arc MI — is the tangent of the arc EM.

Another way of finding the sought angle, new and most expeditious, by means of Tables of declinations and of right ascensions. [*Alia inuentio Anguli quæsitī, noua & expeditissima per Tabulas declinationum, & ascensionum rectorum.*]

[Margin: The inclinations of the hour-circles [horaria] to the ecliptic are obtained from the Tables of Declinations and of Right Ascensions.]

In the same triangles BHO, MHE, I note something else, not unworthy of observation and perhaps not so readily obvious, had the two not presented themselves together. For from the fact that the arcs of the one triangle are the complements of the other, I see that the arc EM can be had immediately from the tables of declinations and of right ascensions. For from the table of right ascensions there is had the arc HB, the right ascension of the arc of the ecliptic HO, numbered from the point of Aries H; and this being found, there is also had the complement HE of that same arc HB. If this HE be supposed, in the right-angled triangle HME, to be the arc of the ecliptic, the arc EM will be its declination. And given the arc of the ecliptic from Aries γ or Libra $\underline{\alpha}$ — that is, numbered from point H — its declination can be obtained from the table of declination.

Therefore

I find at vertex H — I mean the triangles HDO, HME, and a third one to arc NG, formed by drawing arc AG, namely the triangle ANG. In the triangles BHO and HME the angles at vertex H are the angles of greatest declination. At B and M the angles are right angles, because the equinoctial HB is perpendicular to the meridian OB, and conversely the ecliptic HM is perpendicular to the solar horizon EM. Moreover, in triangle BHO the ecliptic arc HO is given, counted from γ [Aries]; and in triangle MHE the arc HM of that same ecliptic is given, which is the complement of the former arc HO, since OM is a quadrant. HM is the side adjacent to the given angle, while in the first triangle arc HO is the base — that is, the arc opposite the right angle B. And so in these two triangles the sides about the angles of greatest declination at point H are so related that the arcs of the one are complements of the arcs of the other. For the whole arcs BE and OM are quadrants; MH is the complement of HO, and HE is the complement of arc HB — and conversely these are the complements of those.

Triangulum B H O.

In triangle BHO what is sought is the angle HOB, the inclination of the ecliptic HO to the meridian OB. It can be obtained by the third problem — now often cited and applied to a similar triangle — in which the proposed angle is sought from the base and from the other, non-right, angle: here, from the base HO of 60 degrees and the angle BHO of 23 degrees 30 minutes. For if it is arranged that, as the whole sine [radius] is to the sine of the complement of the base HO (that is, to the sine of the remaining arc HM), so the tangent of angle BHO is to a fourth term, then there is produced the tangent of the complement of angle HOB — that is, the tangent of angle EOM, and hence the tangent of arc EM. This tangent, subtracted from the quadrant EI, leaves MI, the arc of angle HOB. I do not set out the actual calculation here, since an example of the same proportion has already been given above.

Triangulum M H E.

In triangle MHE the given quantities are different — apart from the angle MHE — and in place of angle HOB the arc EM is now sought; the problem suited to these data is likewise a different one, namely problem XI, in which a side is investigated (here EM) from the other side HM and from the other, non-right, angle MHE, which is opposite the sought side. Nonetheless the proportions of the two problems come out the same when correctly weighed, and what is obtained through them is identical, namely the tangent of arc EM. For the proportion of problem XI runs thus: As the whole sine is to the sine of side HM (in whose place, in the preceding proportion of the third problem, it had stood), so is the whole sine to the sine of the complement of the base HO — where it plainly appears that the second term of each proportion is the same; for the sine of the complement of base HO is the right sine [sinus rectus] of side HM. Likewise, the tangent of the given angle, the same in both cases, [stands] to the tangent of arc EM, which is the same as the fourth term of the preceding proportion; for the tangent of the complement of angle HOB — that is, of arc MI — is the tangent of arc EM.

Another way of finding the sought angle, new and most expeditious, by means of the Tables of Declinations and of Right Ascensions.

[Margin: The inclinations of the hour-circles [?] to the ecliptic are obtained from the Tables of Declinations and of Right Ascensions.]

In these same triangles BHO and MHE I notice something else, not unworthy of observation and perhaps not so readily obvious — had the two not presented

themselves to view together. For from the fact that the arcs of the one triangle are the complements of the other's, I see that arc EM can be had immediately from the tables of declinations and of right ascensions. For from the table of right ascensions there is obtained arc HB, the right ascension of the ecliptic arc HO, counted from the point of Aries H; and once this is found, its complement HE is also had. If in the right triangle HME this HE is taken to be an arc of the ecliptic, then arc EM will be its declination. And given an ecliptic arc counted from ♈ [Aries] or ♎ [Libra] — that is, from point H — its declination can be had from the table of declination. Therefore

Diagram. A full-page engraved plate of eight geometric constructions for the analemma/declination demonstrations of Book III, arranged in three rows. The figures are captioned *Fig. 4*, *Fig. 5*, *Fig. 6*, *Fig. 7. Casus primus*, *Fig. 7. Casus secundus*, *Fig. 7. Casus tertius*, *Fig. 8*, and *Fig. 9*. The constructions are dense line-figures with many repeated point-letters (chords, perpendiculars, inscribed ellipses/oblique horizons within circles), and the sheet carries strong show-through from the letterpress verso. The readable labels per figure are listed below; letters that recur several times within a single figure are given once.

- **Fig. 4** (top left): a large circle with horizontal diameter B (left) – E (center) – D (right) and vertical diameter I (top) – K – E – C (bottom); a fan of chords rises from E to a cluster of points near the top labelled (across successive rows) L, I, L / M, A, M / F, O, P, A, G / O, N, H, N, O / M, L, L, M / K.
- **Fig. 5** (top right): a quadrant with corner labels Z (upper left), Y (upper right), I (right), F (center), N (below F), B (lower left).
- **Fig. 6** (upper right / center): two overlapping circles with labels I, K, S, O, P, Q, F, D, R, G, X, A, H, M, B, T, E, L, C.
- **Fig. 7. Casus primus** (middle left): a circle with an inscribed oblique ellipse; labels B, H (top), F, N, A, P, G, D (left), E, M (center-lower), I, C (bottom).
- **Fig. 7. Casus secundus** (middle right): a circle with labels O (top), F, A, P, D, G, N (left), M, E, H (center), L, C (bottom).
- **Fig. 7. Casus tertius** (lower left): a circle with an inscribed ellipse; labels O, B (top), F, A, N, P, G, D (left), R, H (center), E, M (bottom), I.
- **Fig. 8** (lower center): a circle with an inscribed oblique ellipse; readable labels F, A, N, a, T, G, V [several further labels obscured by show-through — [?]].
- **Fig. 9** (lower right): two overlapping circles; labels M, I (top), N, L, A (with lowercase a near center), F, O, H, D, P, L (right), T, K, E (bottom).

Therefore, without any arithmetical operation, if the two aforesaid tables are at hand, the complement of the sought angle can be had in this way. And for this reason I have chosen to append both tables at the end of this book: the one drawn from Clavius's *Sphaera*, which supplies the declinations; the other, of right ascensions, computed by Father [Christoph Grienberger] — both proceeding through the ecliptic in five-minute steps.

Triangle ANG.

In triangle ANG, that the angle N is a right angle is proved from the fact that the arc

the arc NG — that is, the circle NEI — has its pole O on the meridian NAO. And although, besides the base AG (which is equal to the arc of greatest declination), it offers nothing else as a datum, the side AN can nonetheless be counted among the data. For it is the declination of the given ecliptic arc HO — that is, it is equal to arc OB. Given an ecliptic arc counted from the equinox, the desired declination can be extracted from the table of declinations (which is found most fully in Clavius, in the second chapter of the *Sphaera*, or which you may consult at the end of this book), and thus arc AN can be defined. Then, given the base AG and the side AN, side NG is found by the seventh problem of spherical triangles — which, as we said, are found at the end of the first book of the *Astrolabium* — in this way:

Let it be arranged that, as the whole sine is to the sine of the complement of the base (that is, to the sine of 66 degrees 30 minutes, since the base itself is the arc of greatest declination, 23 degrees 30 minutes), so is the secant of side AN (that is, the secant of the declination found by the table) to a fourth number.

For the fourth number found by the Rule of Three is the sine of the complement of side NG — this being the sine of arc GE, MI — which, it is established, measures the sought angle MOI.

Finding arc NG geometrically, by lines.

[Margin: Explanation of the eighth figure.]

Moreover, this same arc NG — and indeed in a way better suited to our proposed problem — is also displayed geometrically as follows. In the eighth figure, from center R let there be described a portion of the circle answering to the meridian NAF, such that AF is the arc of greatest declination and AN is the arc of declination proper to the proposed ecliptic arc, that is, to arc HO. From the same center R — namely, from the center of the sphere — let there be described, with

the same radius, another portion of a circle NE. Although here it lies in the same plane surface as the meridian NAF, it can nonetheless be conceived as perpendicular to the meridian, so that in the sphere — and in the preceding figure of the third case — it corresponds to the parallel of the solar disk NGE, which in the sphere is the oblique horizon, having an elevation of the pole equal to arc AN.

In this solar horizon NE the point G must be investigated from the data given in the spherical triangle ANG. First, then, from point A I drop onto the semidiameter RN the perpendicular Aa, and from the same point A I apply to that same semidiameter the straight line AT, equal to the chord AF. Then, with center a and radius aT, I describe an arc of a circle cutting arc NE at G; and thus I find the point G and the arc NG, which I say is equal to the arc NG, or EM, of the preceding theory.

But first I show that the circle described from a with radius aT cuts arc NE. For the declination AN is smaller than the greatest declination AF, and the chord AF — that is, AT — is greater than the chord AN; and therefore the angle TNA, or aNA, is greater than the angle ATa; and conversely the angle NAa, the complement of angle aNA, is smaller than the complement aAT of angle aTA. Since, then, with respect to the whole sine Aa the straight line aT is the tangent of angle aAT, and aN is the tangent of angle aAN, aT will be greater than aN; and therefore the circle TG, described from a with radius aT, will cut arc NE and will cut off a certain arc NG — which, in the figure of the third case, is cut off by the little polar circle DPF — such that arc AG, intercepted between the pole A and the point G, is the arc of greatest declination, and the straight line AG between the same points is the chord of that same greatest declination. Hence here, in the eighth figure, it must be demonstrated that, when the meridian NAF stands perpendicular to the Sun's horizon NE, the straight line AG drawn aloft is equal to the chord AF, or to the applied line AT. Let aG be joined, and let aV be perpendicular to aG itself and equal to aA, and let VG be joined. Since, then, aT and aA are equal to aG and aV, and the contained angles are right angles, VG will be equal to AT. And since the meridian NAF is perpendicular to the horizon NE, Aa too will be perpendicular to that same horizon, as also will the straight line aV, if the right triangle GaV is conceived as perpendicular to that same horizon. From which it follows that in such a construction the perpendicular lines aA and aR meet in one straight line and, because of their equality, coalesce also into one point VA, and hence into the straight line AG.

the arc NG — that is, the circle NEI — has its pole O, and both lie in the meridian NAO. And although, apart from the base AG (which is equal to the arc of maximum declination), it presents nothing else as a given, the side AN can nonetheless be counted among the data as well. For AN is the declination of the given ecliptic arc HO — that is, it is equal to the arc OB. Now, once the ecliptic arc measured from the equinox is given, the required declination can be extracted from a table of declinations (a very full one is found in Clavius [Christoph Clavius], in the second chapter of his *Sphere* [*In Sphaeram Ioannis de Sacro Bosco Commentarius*, ch. 2], or you may look to the one at the end of this book), and so the arc AN can be determined. Then, with the base AG and the side AN given, the side NG is found by Problem VII of the spherical triangles which, as we said, are found at the end of the first book of the *Astrolabe* [*Astrolabium*], in the following way.

Let it be: as the whole sine [sinus totus, the radius] is to the sine of the complement of the base — that is, to the sine of $66^{\circ} 30'$, because the base itself is the arc of maximum declination, $23^{\circ} 30'$ — so is the secant of the side AN (that is, the secant of the declination, found by the table) to the fourth number.

For the fourth number, found by the Rule of Three, is the sine of the complement of the side NG; and this is the sine of the arc GE, MI, which, as is established, measures the sought angle MOI.

Finding the arc NG geometrically, by lines [*Inuentio arcus NG, Geometrica per lineas*]

But the same arc NG — and indeed in a way better suited to our proposed problem — can also be exhibited geometrically, in the following manner.

[Margin: Explanation of the eighth figure. (*Figurae octauae explicatio.*)]

In the eighth figure, from center R let a portion of the circle corresponding to the meridian NAF be described, such that AF is the arc of maximum declination and AN is the declination proper to the proposed ecliptic arc — that is, to the arc HO. And from the same center R, namely from the center of the sphere, let another portion of a circle NE be described with the same radius. Although here it lies in the same plane surface as the meridian NAF, it can nonetheless be conceived as perpendicular to the meridian, so that in the sphere — and in the preceding figure of the third case — it corresponds to the parallel of the solar disk NGE, which in the sphere is the oblique horizon whose pole-altitude is the arc AN.

In this solar horizon NE, the point G must be investigated from the data given in the spherical triangle ANG.

First, then, from the point A I drop a perpendicular Aa onto the semidiameter RN; and from the same point A, to the same semidiameter, I apply the straight line AT equal to the chord AF. Next, with center a and radius aT, I describe an arc of a circle cutting the arc NE at G, and thus I find the point G and the arc NG — which I declare to be equal to the arc NG (or EM) of the preceding theory.

But first I prove that the circle described from a with radius aT does cut the arc NE. For the declination AN is smaller than the maximum declination AF, and the chord AF — that is, AT — is greater than the chord AN; therefore the angle TNA (or aNA) is greater than the angle ATa. And conversely, the angle NAa — the complement of angle aNA — is greater [recte: minor — the construction requires it to be *smaller*] than the angle aAT, which is the complement of angle aTA. Since, then, with respect to the whole sine Aa, the straight line aT is the tangent of the angle aAT, while aN is the tangent of the angle aAN, aT will be greater than aN. And therefore the circle TG, described from a with radius aT, will cut the arc NE and will cut off some arc NG — the very arc which, in the figure of the third case, is cut off by the polar circle DPF — such that the arc AG, intercepted between the pole A and the point G, is the arc of maximum declination, and the straight line AG between those same points is the chord of that same maximum declination.

Hence, in this eighth figure, it must be shown that, when the meridian NAF stands perpendicular to the solar horizon NE, the straight line AG drawn aloft is equal to the chord AF, or to the applied line AT. Let a G and a V be joined, with a V perpendicular and equal to a A, and let VG be joined. Since, then, aT and aA are equal to aG and aV, and the contained angles are right angles, VG will be equal to AT. And since the meridian NAF is perpendicular to the horizon NE, Aa too will be perpendicular to that horizon — as will the line aV, if the right triangle GaV is conceived as standing perpendicular to that same horizon. From this it follows that, in such a construction, the perpendicular lines aA and aV come together into one straight line, and, because they are equal, they coalesce into a single point VA, and so into the straight line AG.

Diagram. A full-page engraved plate carrying six geometric constructions for the analemma / declination demonstrations of Book III, labeled by the printer **Fig. 4**, **Fig. 5**, **Fig. 6**, **Fig. 7** (in three cases — *Casus primus*, *Casus secundus*, *Casus tertius*), **Fig. 8**, and **Fig. 9**. The figures are dense meridian-and-horizon constructions with many small point-letters; the page also carries pronounced mirror-reversed show-through from the verso (folio 376), which crosses the

figures and obscures some labels. Labels below are those legible under magnification; the plate carries many more small letters than can be resolved with confidence.

- **Fig. 4** (upper left): a large circle with center **E**, horizontal diameter **B–E–D** and a vertical to **C** at the bottom; at the top sits an inscribed cap/lune bounded by chords, carrying (top to bottom) paired labels **L, L**; **M, M**; a row **P, A, G**; a row **O, N, H, N, O**; then **M ... M**; **L, L**; and **K** near the cap's foot. [Several of the paired **L/M/N/O** labels are ambiguous — [?].]
- **Fig. 5** (upper right): a quadrant-type figure. Readable labels: **Z, Y, A** (upper edge), **F** and **N** (interior), **H** (right), **B** (lower left) and **E** (lower right corner), with an arc running from **I** (upper right) down toward the corner; **O** and **B** at right.
- **Fig. 6** (right, below Fig. 5): a large arc/quadrant with an inscribed circle. Readable labels along the arc and interior: **K, S, O, Q, R, G, X** (arc, ending toward **X/G** at right), **P, F, D** (left), **A, H, M** (interior), **B, T, E, L** on the horizontal, and **C** at the far right.
- **Fig. 7, Casus primus** (middle left): a circle with an inscribed ellipse. Readable labels: **N, A, P, G, D** (left), **F** (upper), **M** (interior), **I, C** (lower), **E**.
- **Fig. 7, Casus secundus** (middle center/right): a circle. Readable labels: **O, B, F, A, P** (upper), **M, E, H** (interior), **N, G, C, L, F**.
- **Fig. 7, Casus tertius** (lower left): overlapping circles with an inscribed ellipse. Readable labels: **F, A, N, D, G** (left), **P, O** (interior), **R, E, M, I** (lower).
- **Fig. 8** (lower center): a circle with inscribed ellipse and chords. Readable labels: **O** (top), **F, N, A, P** (left/interior), **G, C, R** and **E, M, I** (lower).
- **Fig. 9** (lower right): a circle with dashed construction lines. Readable labels: **I** (top), **M, N, L** (upper), **A, D, P** (right), **O, H, F, T** and lowercase **a** (interior), **L, M, K, E** (lower), **C, R** (bottom).

(letterpress at the foot of folio 375, following the plate)

it will then be the same as **VG**; but **VG** has been shown to be equal to the chord **AF**; therefore **AF** too is equal to that same chord, and the point **G** will be the very one which, in the sphere, in the same horizon, is fixed by the arc of maximum declination **AG**, or by the polar circle **DEF**.

A Lemma to the Third Demonstration [*Lemma ad III. demonstrationem*]

Demonstrated. By this last construction, whereby we most recently found the arc NG in the eighth figure, a third demonstration could here be immediately subjoined...

the third of those geometrical constructions, which we have now confirmed by two further demonstrations, and which may be called the "royal" one on account of its ease and its very wide usefulness. But because this same royal construction is not tied to the maximum declination, but suits any other arcs and angles whatever, we have preferred to postpone the particular demonstration and to put first, in this lemma, a universal one — setting out two constructions together in this ninth figure, namely the royal one and the one demonstrated in the preceding figure. The lemma is as follows.

In the ninth figure, about the diameter FD of the circle FIDK, whose center is H, let some other circle FNDC be described, with center E; and EH will be perpendicular to FD, so that FI, ID, DK, KG are quadrants, and the arc FD is bisected at N. Then toward the same part of the diameter IK — whether to the right or to the left — let any two equal arcs IL, KL be cut off; and toward the same parts, or different ones, from the point F or D, let there be cut off on both sides FM, FM equal to those same IL, KL; and let LL cut FD at P, and MM cut the same at O. Then both LPL and MOM will be parallel to LL. Let LL also cut the arc FND at A; and let Aa be the sine of the arc NA, and the applied line AT equal to the chord ND. Finally, through O let the diameter GO ER be carried, and let a G be joined — *which I declare will be equal to the straight line a T.*

[Margin: Explanation of the proposition. (*Explicatio propositionis.*)]

[Margin: Demonstration. (*Demonstratio.*)]

For let NO and HL be joined. Since, then, the arcs IL, FM are equal by construction, their complements MI, DL will also be equal; and OM, the sine of the arc FM, is equal to HP, the sine of the arc IL, while HO, the sine of the arc PL, is equal to the sine of the arc DL; and Aa is equal to HP. Therefore all three — OM, HP, aA — are equal, and their squares equal.

Now, to the square on OM there is equal the rectangle FO·D, and to this the rectangle GO·R — because FD and GO cut each other mutually within the same circle, and because OM, in the semicircle FID, is perpendicular to the diameter FD. Therefore the rectangle GO·R is equal to the square on HP, or to the square on

aA. But to this square on aA — because aA is perpendicular to the diameter NaC — there is equal the rectangle NaC; therefore the rectangle GO·R is equal to the rectangle NaC. And since the whole diameters GR, NC are equal, their segments too will be equal — namely OR equal to aC, and GO equal to Na. And when GO and Na are removed from the equal semidiameters EG, EN, there will remain equal EO and Ea. And so, about the same angle E, there will be two sides GE, Ea equal to the two sides NE, EO; and consequently, by the fourth [proposition] of the first [book of Euclid], the base ON is equal to the base aG. This ON, I say, is equal to aT, and hence T is equal to aG. And this I prove, for the conclusion of this lemma, in the following way. The squares of the equal lines ND, AT are equal; therefore also HD, HN are equal to the squares aT, aA — that is, to the squares aT, HP. But the square on HD, or on HL, is equal to the squares on HP, PL — that is, to the squares HP, HO. Therefore the squares HP, HO, and HN are equal to the squares aT, HP. But again, HO and HN are equal to the square ON; therefore the two aT, HP are equal to the two ON, HP. But HP, HP are the same; therefore the remaining squares are equal, and the line aT is equal to the line ON. Now we showed that aG is equal to that same ON; therefore aT and aG are equal — which was to be demonstrated.

Corollary [*Corollarium*]

From this it is clear that the line EO, produced and applied from a as equal to aT, cuts off, on the circumference of the circle FND, the same arc HG. For from the same point a, which lies outside the center E, and toward the same parts F, no other line equal to aG can be applied to a different point G.

Third Demonstration [*Demonstratio III*]

In the preceding lemma a twofold construction was employed — the royal one, namely, and the one we exhibited for the eighth figure — to which there was added, besides, a third, similar to it, by which, through the little circle of maximum declination in the analemma, the declinations of the remaining points of the ecliptic are exhibited. Let such a little circle be conceived, in the ninth figure, to be FIDK, and the circle of the analemma to be FNDC, and let the arc IL be an arc of the ecliptic. And so the parallel LL will cut off...

Diagram. A full-page engraved plate carrying eight geometric analemma/spherical-projection constructions arranged in three rows, captioned Fig. 4, Fig. 5, Fig. 6, Fig. 7 (in three cases: *Casus primus*, *Casus secundus*, *Casus tertius*), Fig. 8, and Fig. 9. The figures are densely lettered; only labels legible under magnification are committed below, and the tightly-clustered interior

points of every figure carry additional letters that cannot be individually resolved (flagged [?]). A small square knotwork printer's device is set among the figures in the middle of the plate.

- **Fig. 4:** a large circle with horizontal diameter running from B (left) to D (right), lowest point C, and center E; an upper lens-shaped (almond) region with a fan of straight lines converging on E. Legible points in the upper cluster: L, I, M, O, P, A, N, H, F, G, K (several repeated left/right and mutually overlapping — remaining points [?]).
- **Fig. 5:** a quadrant (quarter-circle) at upper right. Legible: Z, Y, L (top), A, H (right edge), F, N (interior), B (lower left), E (lower-right corner).
- **Fig. 6:** two large overlapping circles. Upper cluster: I, K, S, O, P, Q, F, D, R, G, X; interior: A, H, M; horizontal diameter B, T, E, L, C; lower point V. (Additional interior points [?].)
- **Fig. 7, Casus primus** [first case]: a circle with an inscribed ellipse. Legible: B, H (top), F, N, A, P, G (upper-left cluster), D (left), E, M (center), I (right), C (bottom).
- **Fig. 7, Casus secundus** [second case]: a circle with an inscribed ellipse. Legible: O, B (top), F, A, D, G, N (upper-left cluster), M, E, H, I (center), C, L, F (bottom).
- **Fig. 7, Casus tertius** [third case]: a circle with an inscribed ellipse. Legible: O, B (top), F, A, N, D, G (upper-left cluster), P, R (interior), E, M (center), L (right), G (bottom).
- **Fig. 8:** a circle overlapping its neighbours. Legible: N, a, V (lower left), T (right), G (bottom), E. (Remaining points [?].)
- **Fig. 9:** a circle with dashed construction lines. Legible: I (top), M (upper left), N, L (upper), F, O, H, a, A, D, P (middle cluster), T, L, M, K, E (bottom). (Remaining points [?].)

[The following letterpress runs beneath the plate at the foot of folio 377; it continues the demonstration begun on the preceding pages.]

from the Analemma, the declination N A due to the ecliptic arc I L, counted from the beginning of Aries I. Here, then, in the arc N A D, we have what was posited in the eighth figure: for the arc of maximum declination N D corresponds to the arc N F, and the arc of declination N A to the arc of declination N A. Then, in the eighth figure, the perpendicular A a was dropped onto the semidiameter N R; here likewise the perpendicular A a. In both cases, moreover, A T has also been laid down, equal to the chord of the maximum declination N D or N F. Finally, in both places the arc N G has been cut off, by an interval of a straight line equal to a

T. Now it was demonstrated in the eighth figure that the arc N G is the complement of the angle sought; therefore here too the arc N G will be the complement of the angle, when the point of the ecliptic corresponding to point L occupies the meridian.

The Royal Procedure [praxis Regia], however, consists in this: that the arc I M is the complement of the arc I L, and that through the point O — where the parallel M M cuts H F — the straight line E O is drawn, as is clear from the construction of the fourth figure. Now it was demonstrated in the preceding Lemma that the straight lines a G and E O cut off the same arc N G, and we showed a little earlier that this arc is the complement of the angle sought. Therefore the Royal Procedure too yields the complement of the angle sought — which was to be demonstrated.

Other Procedures for the Same Problem, derived from a secondary examination of the third case of the Theory, and demonstrated, and most singularly adapted to the Phenomenon of the Sunspots

There was, admittedly, no need to investigate by so many routes a problem that is otherwise perfectly simple, nor to confirm by several demonstrations one for which even a single demonstration sufficed. But it is sometimes pleasant to range more widely over similar matters, and to make plain that mathematicians too can play to good purpose in these things, and so refresh themselves and other lovers of truth. For the very agreement of truths cannot fail to delight the investigator of truth. And if we do not yet stop here, but press still further into this subject — with the author's kind leave — the reason is that the Phenomenon of the Sunspots does not yet seem fully accounted for. For the observational circle [circulus observatorius] does not so far seem to have received the Axis and the Ray of the ecliptic — or either of the two — from observation itself, at least, by an immediate procedure and demonstration, which we now set about to provide.

Explanation of the Tenth Figure [Explicatio Figuræ Decimæ]

R is the center of the sphere; O is the point of the ecliptic and the place of the Sun — say, in degree 68 — such that from O up to the beginning of Aries [γ] there lies an arc of 36 degrees, to which corresponds a declination of 13 degrees 33 minutes and a right ascension of 33 degrees 40 minutes.

A is the north pole of the world; A O B C is a great circle drawn through the pole A and the Sun O — namely the hour-circle of the Astronomical Hours [Horarius Horarum Astronomicarum] — in which the quadrants A B and A C necessarily terminate at the equator. And since we place the pole A on the left as we view the sphere, it follows that the hemisphere in view, bounded by the circle A O B C, is the western one, and that the vernal equinoctial point lies in this same hemisphere. For the order of the signs proceeds against the diurnal motion — that is, from west to east — and in the same region the north pole of the ecliptic will also appear, as reason requires and as the material sphere further teaches.

B H C is the equator, drawn from the pole A through B C, whose point H is the beginning of Aries [Υ], and the arc H B is the right ascension of the point O, 33 degrees 40 minutes. And it passes through this point H.

O H L is the circle of the ecliptic, whose arc H O is 36 degrees. The arcs of the hour-circle B O and C L are equal, and the declinations of the opposite ecliptic points O and L are 13 degrees 33 minutes.

B C and O L are diameters of the sphere, and the common sections of the equator and the ecliptic with the hour-circle, since all great circles pass through the center of the sphere, and every intersection of plane surfaces is a straight line.

D P F is the polar circlet [circellus polaris], parallel to the equator, drawn from the pole A through the points D and F, which are distant from the pole 23 degrees 30 minutes. For the arcs A D and A F are equal to the maximum declination of the ecliptic — though according to Tycho [Tycho Brahe] this same declination is one and a half minutes less. D F is the diameter of the polar circlet, and its common section with the hour-circle.

Diagram. A full-page engraved plate carrying four spherical/analemma constructions in a 2×2 arrangement, captioned Fig. 10, Fig. 11, Fig. 12, and Fig. 13 — the figures explicated in the surrounding letterpress ("Explanation of the Tenth Figure" and the Conclusions). Each figure is a great sphere-projection densely crossed by circles and lettered at many points; only labels legible under magnification are committed, and the tight interior clusters carry further letters that cannot be individually resolved ([?]).

- **Fig. 10** (upper left): a sphere. Legible: O, B (top), F, H, A, E (upper), N, P, R, m, h, I (middle band), D, G (left), C, L (lower), E, K (bottom). (Remaining interior points [?].)

- **Fig. 11** (upper right): a sphere. Legible: O, B, b, d (top), F, P, N, m, h, I (middle), A (right edge), Q, S, Y, Z, E, K, M, X (lower band), T, C, L (bottom). (Remaining interior points [?].)
- **Fig. 12** (lower left): a sphere. Legible: P, H, F, L, O (top), A, D, T, V (interior), B, E, G (middle), R, M, C, L, K (bottom). (Remaining interior points [?].)
- **Fig. 13** (lower right): a sphere. Legible: O, B (top), H, F, A, N, R, d, I (middle), D, G, c, E, M, K, L (bottom). (Remaining interior points [?].)

[The explication of the tenth figure continues in the letterpress at the foot of folio 379.]

N E I is another great circle, drawn from the place of the Sun O, making with the hour-circle the common section — the diameter N R I — and with the equator the straight line R E. And because the solar disc has the same pole, this circle N E I will be parallel to the solar disc; and because the same pole O lies on the hour-circle A B C, if the point O is taken as the zenith, the circle N E I will have the character of a horizon, and may rightly be called the Solar Horizon [Horizon Solaris], while the hour-circle will be the Meridian of that same Solar Horizon.

G is the intersection of the circumferences D P F and N E I, at which the north pole of the ecliptic necessarily meets. That it lies on the polar circle is clear from the sphere; that it lies on the periphery of the circle N E I is evident from this: just as the ecliptic point O is the pole...

of the circle N E I, so conversely the pole of the ecliptic must lie on the circle N E I, and hence at the point G. For in the western hemisphere of the meridian A B C — in which the north pole of the ecliptic is established to lie — no other intersection of the circles D P F and N E I can be given.

G a is the intersection of the polar circlet D P F and the solar horizon N E I, and it is equidistant from the common section R E, because the circle N E I cuts two parallel planes, D G F and B E C. And since both the circlet D P F and the horizon N E I are perpendicular to the meridian A B C, the line G A is likewise perpendicular to that same meridian. The same is to be said of the straight line E R: for both the equator and the horizon are also perpendicular to that same meridian, and consequently E R is perpendicular to all the straight lines that pass through the meridian — such as the axis of the world A R, which cuts the diameter of the polar circlet D F in half and at right angles at n, and the three diameters B C, O L, N I. Indeed, for the same reason, the straight line G a stands perpendicularly on the straight lines D F and N I, at a.

E is the pole of the meridian, because it is the intersection of the horizon and the equator, and because the arcs E B, E C, E N, E I are quadrants, subtending the four right angles that E R makes with the two diameters B C and N I at the center of the sphere R.

A P E is another hour-circle, drawn through A and E, whose poles are on the meridian at the equinoctial points.

B and C: for both B A, B E and C A, C E are quadrants, and this circle too is perpendicular to the meridian, and the common section of both is the axis of the world A R. The common section it makes with the polar circlet is P n, a line perpendicular to the meridian and perpendicular to the axis A R; and therefore the two arcs P F and P D are quadrants — which also follows from the fact that the semicircles D P F and C E B are parallel, and that the quadrant A E passes through their common pole A.

R M is the common section of the horizon and the ecliptic — not perpendicular to the meridian, because the ecliptic is inclined, yet at right angles to the diameter O L, since O R is the axis of the horizon N E I.

c H d is a parallel of the horizon, passing through the point of Aries H, whose intersection with the meridian is the diameter c d, cut by the diameter O L in half and at right angles at g.

g h is the common section of the parallel c H d and the ecliptic O H M, equidistant from R M itself.

f e h is a circle concentric with the horizon, whose radii R f, R e, R h are equal to the radii g c, g H, g d of the parallel circle c H d. If this parallel is conceived as projected orthogonally onto the horizon, it must fall on the circle f e h, and the points c and d in particular onto the points f and h.

b is the intersection of the diameters B C and c d; and b H is the common section of the parallel c H d and the equator B H E, perpendicular to the meridian and to the straight lines c d and B C at b — because both the parallel and the equator are perpendicular to the same meridian.

H e connects the point of Aries H with the point e, where the circle f e h cuts R M.

b m is parallel to the axis of the horizon O R; and finally the straight line m e connects the point m with the point e.

CONCLUSIONS [CONCLVSIONES]

[Margin: First Conclusion (Conclusio prima)] With these things thus explained, I say first that **the straight line H e is perpendicular to the horizon**. For the straight lines g H and R e are equal, since they are radii of equal circles, and parallel, since in the lines g H and R e M the ecliptic O H M cuts the two parallel planes c H d and N M I. Hence O R and h e are also equal and parallel; but the axis O R is perpendicular to the horizon, and therefore so is H e.

[Margin: Second Conclusion (Conclusio secunda)] I say secondly that **the straight line e m is equal and parallel to H b, and is a straight line perpendicular to the plane of the meridian, and perpendicular to b m and N I at the point m**. For H e and b m are equal and parallel to the same g R; therefore they are equal to one another and parallel, and likewise H b and e m. But H b is perpendicular to the meridian, and therefore so is e m — and at the same time perpendicular to b m and N I.

[Margin: Third Conclusion (Conclusio tertia)] I say thirdly that **the arc P G is similar to the arc H B — the arc H O of right ascension, or the point O**. For through the points H and G, from the pole A, let great circles be understood as drawn — namely A V H,...

Diagram. The upper-left figure of the plate on folio 381, an analemma / armillary-sphere construction shown in perspective, with the Sun's place marked at the top by a small radiating (star-burst) symbol. Readable point-letters, by position:

- O (top, with sun-burst mark): the pole / solar point
- B (top, right of O)
- c, g (small cursive g), b, d (across the upper chord)
- H (upper right, on the cylinder outline)
- F, V (upper left)
- A, n (left)
- P (left, below A)
- N (far left, on the horizontal diameter)
- f, R (center), m, h, I (along the horizontal diameter, left to right)
- D, G (lower left, below N)
- e (below center)
- E, M (lower center-right)
- C, L (bottom)

Diagram. The upper-right figure, an orthographic (planar) analemma of two concentric circles with a smaller circle appended below, drawn with dashed construction lines. Readable labels:

- O (top), B (upper right)
- c, b, g (cursive g), d (upper chord)
- N, f, P, R (center), m, h, I (horizontal diameter, left to right)
- lower appended circle: Q (top), e, Z (with dashed line); S (left), Y, E (center), K, M, X (right); T (bottom), Z

Diagram. The lower-left figure, a single circle crossed by many chords and radii from a lower-central point E (an analemma of the horizon/declination circles). Readable labels:

- a (top)
- P, H (upper left), C (upper center), N (upper right)
- F (left), I, O, Q, R, S, T (interior cluster), X, Ξ/Z (right of center)
- A, D (left interior), M (center-right)
- V (right), G (right), L (lower right)
- d, f (far left), c, g (cursive g), e, B (lower left)
- E (center-bottom, the radiant point)
- K (lower right), Y (bottom)

Diagram. The lower-right figure, a perspective armillary/analemma sphere with the solar point O at top marked by a sun-burst. Readable labels:

- O (top, sun-burst), B (upper right)
- H (right), F (upper left)
- A, N, D, G (left, on and below the horizontal diameter)
- R (center)
- d, I (right, on the horizontal diameter)
- c, 1, E, b, M, e (lower band, left to right)
- K (lower right), C, L (bottom)

A V H, the colure of the equinoxes, and **A G**, [the colure] of the solstices. And the arc of the polar circle intercepted between them — namely arc **V G**, a quadrant — will be equal to the quadrant **F P**; and when the common arc **V P** is removed, the remaining **V F** will be equal to the remaining **P G**. But **F V** and **B H**, intercepted between **A B** and **A V H**, are similar; therefore **P G** and **B H** are similar as well.

Or thus: when the point of Aries **H** is at point **B**, then — following the first case considered above — the pole of the ecliptic is at point **P**. And since both points are understood to lie in the same sphere of the primum mobile, as point **H** recedes by this motion from point **B** along the equator **B E**, the pole **G** must move proportionally away from point **P** on the polar circle **D P F**. And so arc **P G** will always be similar to arc **B H**, the right ascension of the ecliptic arc **H O**.

Fourth, I say that the straight line **a G** is the sine of arc **N G** in the great circle **N G I**; and the same [line] from **G** — [Margin: Fourth conclusion.]

— is the sine of the complement of arc **P G** in the polar circle **D P F**. This is clear from what has been said, for we showed that the straight line **a G** is perpendicular both to the diameter **N I** and to the diameter **D F**.

[Margin: Fifth conclusion.] Fifth, I say that the altitude of the pole above the horizon **N E I** is always equal to the declination of the ecliptic point **O**. For **A B** and **O N** are always quadrants, and when the common arc **A O** is removed, the pole's altitude **A N** remains equal to the declination **B O**.

[Margin: Sixth conclusion.] Sixth, I say — as was also stated above — that **N G** and **E M** are equal, and likewise **G E** and **E I**; and that these [**N G**, **E M**] measure the angle of inclination of the ecliptic **O M L** to the meridian **A B C**, while those [**G E**, **E I**] measure the complement of that same angle. The first part is clear, because **N E**, **G M**, and **E I** are quadrants; when **G E** is subtracted, **N G** and **E M** remain equal, and when **E M** is subtracted, **G E** and **M I** remain equal. The latter part too is evident, because **O I** and **O M** are quadrants, and therefore arc **M I** (or **G E**) is the measure of angle **M O I**, while **M E** and **N G** measure the complements — since these same arcs **M E** and **N G** are the complements of the arcs **M I** and **G E**.

Foundations of the Primary Procedure [Fundamenta Praxeos primariae]

[Margin: What is the primary procedure?] I call "primary" that procedure by which, in the observatory circle [circulus observatorius], there is determined — from the data given in the observation, for a given time or a given place of the Sun — the common section which that same observatory circle makes with the circle of the ecliptic; without this, the itinerary-quality of the solar spots cannot be defined with certainty.

[Margin: What is the secondary procedure?] "Secondary" I call the one by which, in the same observatory circle, the axis of the ecliptic is likewise assigned. For

this axis is now outside that circle, and once its position is given, the radius of the ecliptic — which is what is here primarily sought and desired — is also given.

[Margin: The observatory circle and the solar horizon are the same.]

Furthermore, the observatory circle is always the same as the solar horizon $\mathbf{N G I}$, because each is equidistant from the solar disk $\mathbf{O}$. And it is clear from what has been said that the axis of the ecliptic $\mathbf{R G}$ always lies in such a horizon, and that the radius of the ecliptic $\mathbf{R M}$ is always distant from the axis by the quadrant $\mathbf{G M}$. From this it follows that exactly the same holds in the observatory circle. In it, moreover, there is always given a certain line, drawn through the center of the observatory circle, representing the common section of that circle with the hour circle drawn through the Sun at the time of observation — to which, in this theory of ours, the diameter $\mathbf{N I}$ corresponds. Therefore, if the radius $\mathbf{R M}$ is here given in position with respect to the diameter $\mathbf{N I}$, it is beyond doubt also given in the observatory circle, and thus the proposed problem is solved. And who does not see that the whole business turns on finding the point $\mathbf{e}$, by proving it to lie on the ecliptic? For from this it immediately follows that the straight line $\mathbf{R e M}$ is the radius of that same ecliptic. Indeed, by the very fact that the ecliptic is a great circle, it must pass through the center of the sphere $\mathbf{R}$, and $\mathbf{R e M}$ must be the common section of the ecliptic with the solar horizon $\mathbf{N M I}$. That the point $\mathbf{e}$ lies in the plane of the ecliptic is proved thus. Point $\mathbf{H}$ is on the ecliptic, because the beginning of Aries is placed at $\mathbf{H}$. Next, the plane of the ecliptic passes through the straight lines $\mathbf{H g}$ and $\mathbf{g R}$, and is also carried through the straight line $\mathbf{R e M}$, parallel to $\mathbf{H g}$. Therefore all these lines, and the point $\mathbf{e}$ as well, lie in the plane of the ecliptic — for the finding of which the following present themselves.

[Margin: Once the point $\mathbf{e}$ is found, various things are found.] First, the arc of declination $\mathbf{B O}$, belonging to point $\mathbf{O}$ and to the ecliptic arc $\mathbf{H O}$, which can be had in various ways and most conveniently by tables and by the analemma; and by means of this arc, the equinoctial radius $\mathbf{R B}$ is given in position in the plane of the meridian — for the radius of the ecliptic is $\mathbf{R O}$.

Second: given the ecliptic arc $\mathbf{O H}$, there are also given $\mathbf{O d}$ and $\mathbf{O c}$, and the diameter of the horizon-parallel $\mathbf{c H d}$, which we said passes through the point of Aries $\mathbf{H}$; and consequently the point $\mathbf{b}$ is given.

Third: on the diameter of the horizon $\mathbf{N I}$ the point $\mathbf{m}$ is given, by the straight line $\mathbf{b m}$ parallel to $\mathbf{o R}$.

Fourth: in the plane of the horizon itself, the circle **f e h** is given, for its center **R** is given, and its radius, equal to the radius of the parallel **c H d** — that is, to the radius **g c** or **g d**.

Fifth: since it has been shown that the straight line **m e** is perpendicular to the diameter **N I**, then if a perpendicular **m e** is erected at **N I**, this same **m e** will give, on the circumference of the circle **f e h**, the point **e**, and thus the position of the radius of the ecliptic **R e M**.

Foundation of the Secondary Procedure [Fundamentum secundariae praxis]

This foundation is the very third and fourth Conclusion. For there we showed that arc **P G** is similar to arc **H B**, the right ascension of the ecliptic arc **H O**; and that the straight line **G a** is the sine of the complement of arc **P G** in the polar circle, and the sine of arc **N G** in the horizon **N E I**. But given the ecliptic arc, its right ascension is given in various ways. If, then, on the polar circle an arc similar to that ascension is taken, and its cosine [sinus complementi] is made into a sine in the observatory circle (or solar horizon **N E I**) — such as **a G** — the arc **N G** will be obtained, and the position of the axis of the ecliptic **R G** will be given.

Diagram. Fig. 10 as it appears at the top of folio 383 — the identical engraving repeated from folio 381 (see fig-p517-1 above for the full label list): a perspective analemma sphere with the solar point **O** (sun-burst) at top, horizontal diameter **N ... R ... I**, and points **B c b d F V H A P f m h D G e E M C L**.

Diagram. Fig. 11 repeated (identical to fig-p517-2): the orthographic analemma of concentric circles with the small appended circle below (**O B c b d N f P R m h I**; lower circle **Q e Z S Y E K M X T**).

Diagram. Fig. 12 repeated (identical to fig-p517-3): a single circle crossed by many chords radiating from the lower point **E**, with the same label set (**a P H C N F I O Q R S T A D M V G L d f c e B K Y**).

Diagram. Fig. 13 repeated (identical to fig-p517-4): a perspective armillary/analemma sphere with solar point **O** (sun-burst) at top, center **R**, and points **B H F A N D G d I c E b M e K C L**.

The Primary Procedure [Praxis Primaria]

[Margin: Description and explanation of the eleventh figure.] Let the semicircle **N O I** of the eleventh figure be the same as the meridian semicircle of the preceding tenth figure; but the remaining semicircle **N E I** — that of the solar horizon,

which there is rendered by the rules of perspective — here let it be that very one which was rendered there. And although it can be conceived as standing upright to its own meridian, it is nevertheless better, for the procedure, if it is understood as continued with the same meridian. For in this way, and not without economy, the semidiameter of the equator **R E** — which in the Theory is perpendicular to **H I** — is continued with the semidiameter of the ecliptic **R O**, which itself too, in the same Theory, is perpendicular to the same **N I**.

And since, for the procedure, we need the arc of declination **O B**, let there be cut off — on both sides of the equator's radius **R E** — the arcs of greatest declination **E S** and **E X**; and from the point **Y**, where that same radius **R E** cuts the chord **S X** at right angles and bisects it, let there be described, with the interval **Y S** (or **Y X**), the little circle of declinations **S Q X T** — the very one that is customarily described in the same way in the Ptolemaic analemma [in analemmate Ptolematico]. Then from the points **T** and **Q**, toward the same parts, let arcs **T Z** and **Q Z** be numbered off equal to the ecliptic arc; and let **Z Z** cut **E X** at **K**, and **E K** will be the declination corresponding to arc **T Z**, to which the arc **O B** ought to be equal, as the equatorial radius **R B** is in position on the meridian. This done, let the arcs **O c** and **O d** be taken equal to the proposed ecliptic arc, and let the chord **c d** cut the equinoctial radius **R B** at **b**; the point **b** will be that upon which the beginning of Aries falls perpendicularly onto the meridian, and that through which, in the Theory, the straight line **b m** is drawn parallel to **R O** (or perpendicular to **N I**) — which is likewise drawn in this eleventh figure. And the radius of the ecliptic **R O** cuts the chord **c d** in half and at right angles at **g**, and yields the semidiameter **g c** (or **g d**); with which, in the plane of the horizon, the circle **f e h** is to be described, in which the point **e** is found in the tenth figure — if from **M**, at **N I**, the perpendicular **m e** is erected. But here it suffices to produce the straight line **b m**, for this assigns the same point **e**; and once this is given, the position of the radius of the ecliptic **R e M** is given — which was to be done.

[Margin: Demonstration of the procedure.] The demonstration is evident from the foundation of the primary procedure; and therefore here we have not changed even the letters, except in the little circle **S Q X T**, which has here been added for the construction and finding of the declination. For the rest, the construction which is here carried out in the meridian semicircle **N O I** can be carried out entirely in the horizontal semicircle **N E I**: for the arcs **O c** and **O d** are cut off equally well on both sides of the point **E**. Indeed, in place of the radius **R B**, the radius **R K** is here drawn more economically for finding the point **b** in this semicircle **N E I** — but in the former way the figure is less confused.

The Same, More Compendiously [Eadem compendiosior]

It is enough to find the point **b**, for **b d** is the versed sine [sinus versus] of the angle which the ecliptic makes with the meridian. For since, in the tenth figure, **O** is the pole of the circle **c H d**, the arc **H d** measures the angle **H o d**; and because **H b** is perpendicular to **c d**, it follows that this same **H b** is the sine of arc **H d**, and **b d** the versed sine, and **g b** the cosine [sinus complementi] with respect to the whole sine **g d**. But once the sines are given, the arcs are given. Therefore [it is done]. Still, it is worthwhile at least to acquire the cosine with respect to the semidiameter **R E**, for determining the arc **E M** — which is not hard to do, if in the eleventh figure, from **b**, one applies **b p** equal to the semidiameter **R E**, cutting **R O** at **r**. For the straight line **b r** will be the sine of arc **E M**, because the proportion of **p b** to **b r** is the same as that of **g d** to **o d** [and] **g b**. For **R d**, when drawn, is equal to **p b** itself; and since each is applied to the same parts, a parallelogram **b p, m d** is formed between the parallels **p m** and **g d**. From this it follows that **p R** and **b d**, and likewise **p m** and **g d**, are equal, by adding the equal **R m** and **g b**. And since **R r** and **m b** are parallel, the proportion of **p [b]** to **b r** will be the same as that of **p m** to **m R** — that is, the same as that of **d g** to **g b**.

The Secondary Procedure [Praxis Secundaria]

That the axis of the ecliptic is inscribed in the observatory circle for any given point of the ecliptic may seem in some part superfluous; for, as was shown in the Theory of figure 10, the axis **R G** is distant by the quadrant **M G** from the radius **R M**. Therefore, once the radius has been described by the primary procedure, the axis **R G** will not long be wanting; indeed, the whole construction of the radius suits the axis, if the diameter **O L** is transferred to the diameter **N I**, and so on. It has, nevertheless, its own proper construction as well — namely, the one which we hinted at so openly in the foundation of the secondary procedure that it needs nothing more. This alone still seems to be wanting: that it be taught how the polar little-circle is divided into right ascensions; which we shall provide here not so much of necessity as usefully for other purposes, and above all for the sake of the Royal Procedure [praxis Regia].

The distribution of the Polar Circle, or the Declinatory Circle, of the Analemma, into Right Ascensions [Circuli Polaris, vel Circuli Declinatorij, Analemmatis, distributio in Ascensiones rectas]

I am not unaware that this can be done by the precepts of the Astrolabe, by which any circle whatever [may be divided] proportionally to the equi-

Rosa Ursina — Book III (pp. 385–388)

Plate: Figures 10–13 (analemma / declination geometry)

The same engraved plate of four analemma-and-declination diagrams (Figs. 10, 11, 12, 13) is printed at the head of this page and again on p. 387; it recurs at successive openings so the reader can follow the argument alongside the text. It is the same plate given on the two preceding folios (381/383).

Diagram, Fig. 10. An oblique sphere carrying the analemma construction of declinations. Readable labels:

- O (top of sphere, marked with a small sun symbol): pole / zenith point
- B, c, b, g, d, H (upper region): points of the upper parallel and its projection
- F, V, A, p, P (left): ecliptic and perpendicular points
- N, f, R, m, h, I (horizontal diameter, left to right)
- D, G (lower left)
- e, E, M (lower middle/right)
- C, L (bottom): points of the lowest parallel

[Dense construction; several small labels near the center are crowded]

Diagram, Fig. 11. Two concentric circles (the meridian and an inner declinatory circle) with a smaller circle appended below, and dashed construction lines.

Readable labels:

- O, B (top), c, b, g, d (upper chord)
- N, f, R, m, h, I (horizontal diameter)
- p, Q (left/lower)
- e, Z (junction), S, Y, E, K, M, X (inner/lower circle)
- T, Z (bottom of the appended small circle)

[Dashed lines run from the upper points b, d down through the figure; several peripheral labels crowded]

Diagram, Fig. 12. A large circle (the analemma / meridian B A C) with many chords and an inscribed construction. Readable labels:

- P, H, F (upper left), C, I, O, Q (upper middle)
- A, D, T, R, S (left-center), M, X, Z (center-right), N, a (upper right)
- V, G (right), L, K, Y (lower right)

- d, f, c, g, e, B (lower left), E (center)

[Very dense; many chords cross the center]

Diagram, Fig. 13. An oblique sphere (the same as Fig. 10, "with a few things omitted and a few added," per the text on p. 388), showing the horizon, equinoctial, ecliptic and the small circle c d e. Readable labels:

- O (top), B, H (upper right)
- F, A (left), N, D, G (left diameter end)
- R (center), d, I (right diameter end)
- c, "1", E, b, M, e (lower band; a point is labelled with the numeral 1 near E)
- K (lower right), C, L (bottom)

[Dense; several small labels crowded]

[the divided circle], taken on the equinoctial, be cut by means of the Ecliptic into right ascensions. I know too that this can be done in the analemma, where these ascensions are measured by parallel circles, or on the equinoctial line itself by means of the hour-ellipses. Finally, it is certain that once any one circle has been divided in whatever way, another can likewise be divided in the same manner — at least by lines drawn out from the common center. But I have not found any method, provided up to now, of measuring the declinatory circle — the circle by whose aid the declinations of the points of the Ecliptic are found, and by whose aid the Regal Procedure [Praxis Regia] displays the angles of inclination of the Ecliptic and the Meridian. Yet unless I am mistaken, one will be provided hereafter.

With E as center, let the circle of the analemma B A C be described in the Twelfth Figure — the circle that is commonly the colure of the solstices, or the meridian in which the axis of the World [margin: Fig. 12: its designation and explanation.]

[lies]. E Z is the north pole Z; E A the radius of the equator, perpendicular to the axis E Z; the arcs A B, A C equal to the greatest declination; B D C the diameter of the little declinatory circle, bisected and at right angles by E A; B F C the little declinatory circle itself, cut into quadrants by the same E A; and F B, F C, B G, C Y the radii of the Ecliptic, with the Sun placed in Capricorn ♐ and Cancer ♋.

Therefore let the perpendicular E V be erected upon the radius C Y. If the semicircle C V Y is taken for the Ecliptic and raised to the plane of the meridian, the point will be V — the point Aries ♈, or Libra ♎. And if the point X is taken for any other point of the Ecliptic, and from it the perpendicular X R falls onto C Y,

and through the point R the line I R L is drawn parallel to A K the radius of the equator, then I L will be the diameter of the parallel that in the sphere passes through the point X. This is evident if the semicircle I N L, described about I L — in which the line R a is perpendicular to I L — is understood to stand perpendicular to the plane of the meridian. For thus this same R a will also be perpendicular to that same plane of the meridian, just as the line R X is; and so they coincide into one, and the point a is joined to X. For R a and R X are equal, since their squares are equal, being the equal rectangles I R L, C R Y. Since therefore the point of the Ecliptic X — that is, the point a — describes a parallel by the motion of the primum mobile, the arc N a will measure the right ascension of the arc of the Ecliptic V X, and the arc A I will be the declination of that same point of the Ecliptic X — as is demonstrated expressly in the analemma, although astronomers rarely use this procedure in determining declinations.

For they observed that the diameter of the parallel I L cuts the diameter of the little circle B F C at Q, and that the proportion of C D to D Q and of C E to E R is the same, on account of the parallels E D, R Q. And consequently that the arc F H, which the same parallel L I cuts off, is similar to the arc of the Ecliptic V X. For as the semidiameter C E is to E R — the sine of the arc V X — so too the semidiameter C D is to D Q — the sine of the arc F H. Hence in place of the arc V X they take the arc F H, similar to the arc of the Ecliptic; and through H they draw H Q parallel to F D, and cut off the arc of declination A I, which corresponds to the given point of the Ecliptic.

A method for finding the right ascensions [Ascensiones rectas inueniendi ratio]

For the right ascensions, however, I find no such transfer; but the close kinship of declinations and ascensions prompted me — indeed all but compelled me — to attempt something on my own, and it offered this procedure to my search. It directed me to join the radius E I, and, through O, where it cuts the diameter B C, to draw O P parallel to F D, and to demonstrate that the arc F P is the right ascension of the arc of the Ecliptic F H, to which the declination A I belongs.

I demonstrate it thus. First drawing the line R T parallel to C D, and producing P O as far as the radius E C, to S: for in this way we have that the lines C D, C E have the same proportion to D O, E S, and that I E, I M have the same proportion to E T, M R. And doubtless all these proportions would be the same, if the equality of the lines E S, E T were established.

For, granting this, as CD is to DO , so would CE be to ES — that is, IE to ED , and likewise IM to MR . I therefore prove them to be equal.

For as IE is to ER , so also is OE to ES . But as IE is to ER — that is, CE to ER — so is that same OE to ET . Since therefore OE has the same proportion to ES and to ET , it follows that these two, ES and ET , are equal. Therefore, by means of the declination I , once found, we can obtain in the same circle BFC the right ascension — which was to be done.

BY ANOTHER, ASSUMED, DEMONSTRATION of the Regal Procedure [Aliter supposita demonstratione Praxis Regiæ]

In the other quadrant BF , let Bd be made equal to the given arc of the Ecliptic — namely FH ; let de be parallel to FD ; and let Ee cut the circumference AB at c . Then, by the fourth Conclusion set down above, the sine of the arc Ac — that is, Dg — will be the sine of the complement of the right ascension of the arc BF . Therefore, once gc is drawn parallel to ed , the sine of the arc Bf will be the [sine of the] arc of right ascension owed to the arc Bd .

Plate: Figures 10–13 (repeated)

The same four-diagram plate as on p. 385 is reprinted here (Figs. 10, 11, 12, 13). See the descriptions under fig-p521-1 ... fig-p521-4.

Diagram, Fig. 10. Reprint of the oblique-sphere analemma; same plate and labels as fig-p521-1. [— dense.]

Diagram, Fig. 11. Reprint of the concentric-circles figure; same plate and labels as fig-p521-2. [— dense.]

Diagram, Fig. 12. Reprint of the analemma circle BAC ; same plate and labels as fig-p521-3. [— dense.]

Diagram, Fig. 13. Reprint of the oblique sphere; same plate and labels as fig-p521-4. [— dense.]

But enough of this. For the secondary Procedure appears to be already contained in the Primary, as we noted a little earlier; yet the use of these [figures] will not be one to be despised, further on, in the Appendix. For they are not tied to the Ecliptic: the arcs AB , AS can be greater or less than the greatest declination, as may be seen in this very figure 12.

And here indeed an end might well have been put to the proposed problem — nay, it ought to have been ended much earlier, had only necessity been consulted. Certainly, contrary to my intention, a problem otherwise rather commonplace has come forth with so great a retinue. But whatever in this part has been overdone — at prolix length, indeed, yet not unprofitably — must be charged to the phenomenon of the sunspots and to [the demand for] a demonstration of the Regal Procedure.

A demonstration had been sought from the very outset — one that would depend immediately upon that construction by which the most diligent observer of the sunspots had himself assigned, in the observatory circle itself, the position of the Rays of the Ecliptic, in agreement with each observation. But by always producing other and still other, less proper, [positions], it so long deluded those who pursued it that it seemed it could never again be reached. Yet at last it did consent [to be found]; and because it consented in the end, we too are resolved, in this very place, to bind it fast with Geometrical bonds, and for the future to close off to it every avenue of escape.

The last, and proper, Demonstration of the Regal Procedure [Postrema, & propria Regiæ Praxis Demonstratio]

In this Thirteenth figure — which is the same as the tenth, with a few things omitted and a few added — let the arc of the colure of the solstices A G be produced as far as the Ecliptic O H L, to the point of Capricorn K. For thus it will easily be shown that the angle A G N, in the triangle A N G, is analogous to the proposed arc of the Ecliptic H O — that is, that the angle A G N and the arc H O are counted by the same number of degrees. For the arc M K, on account of the quadrants G K, G M, measures the angle M G K; and when the arc H M is taken away, from the quadrants O M, H K there remains the arc H O, equal to M K. Therefore the arc H O also measures the angle N G K, and likewise the angle vertical to it — that is, the angle A G N. And this is the very thing, hitherto unknown, that had held back the desired Demonstration.

Therefore let the angle M E d be made equal to this angle A G N, and let the arc E d cut the Ecliptic at d. The right triangle E M d will then be produced, and the two angles d M E, d E M will be equal to the two angles A N G, A G N in the triangle A N G. But these same triangles also have the sides E M, E G — adjacent to the said angles — equal; therefore, by the twentieth [proposition] of Clavius's *Spherical Triangles* [Clavius, *Triangula Sphaerica*], the remaining sides too will be equal — d M to A N, and d E to A G. That is, d M will be equal to the declination B O, and d E to the greatest declination A G. Hence if, from the Pole of the Meridian E — in

which the equinoctial B E C cuts the solar Horizon N G I — a circle c d e is described on the surface of the sphere with the interval of the arc E d, it will be equal to the polar little circle D G F, and to the one that is described in the analemma for the sake of the rays of the Zodiac and of the declinations. And because the angle e E d at the pole E is analogous to the arc of the Ecliptic H O, and because the arc d e also measures that same angle e E d, it is manifest that the arcs H O and d e are similar.

This being demonstrated, little or nothing is now lacking to the demonstration of the Regal Procedure. [margin: The Regal Procedure perfected.] For the circle c d e is perpendicular to the Horizon, because the pole E lies within it; and the line c e — the common section of the two — is the diameter of that same circle c d e, and it is bisected at right angles at i by R E, the semidiameter of the equinoctial and of the Horizon. The common section, too, of that same Horizon and of the Ecliptic — that is, the radius of the Ecliptic R M — cuts the same diameter somewhere at b, and the line b d becomes the common section of the Ecliptic and of the circle c d e. And because each circle is perpendicular to the Horizon, the same b d must necessarily be perpendicular to the Horizon, and therefore perpendicular both to the diameter c e and to the radius of the Ecliptic R m.

Hence if, in the solar Horizon — that is, in the observatory Circle N E I — on either side of the point E the arcs E c, E e are cut off equal to the greatest declination, [margin: The use of the Regal Procedure.] and about the diameter c e the circle c d e is described, and the arc e d is made equal to the given arc of the Ecliptic, and from the point d a perpendicular d b is dropped onto c e, then the point b will be found — the point through which, in the hour-circle, the radius of the Ecliptic passes when the Sun O is on the meridian, that is, in the hour-circle A B C. And the arc of the Ecliptic H O, intercepted between the Sun and the point of Aries, or of Libra, H, is similar to the arc e d — which was to be demonstrated.

In the same way the axis R G is described, if in the same observatory circle N E I the arcs of greatest declination — such as were E c, E e — are cut off on either side of the point N, which is distant a quadrant E N from the point E. For the arc N G must be equal to the arc E M, as is clear from what has been said.

NOTE [Nota]

In the right triangles O B H, A N G, d N E [there is] a certain beautiful metamorphosis of angles and sides.

First. The triangles A N G, d M E are wholly equal.

Second. The angle $N A G$ — and consequently the angle $E d M$ — is the angle of the complement of the right ascension of the arc $H O$. For we showed that the arc $D G$ is similar to the complement of the arc $B H$, which is the arc of ascension of the arc $H O$. But $D G$ measures the angle $N A G$, because A , the pole of the World, is the pole of the polar little circle $D G F$. Therefore, and so on.

Third. All three arcs $A N$, $B O$, $d M$ are equal to the declination of the point of the Ecliptic O .

The four geometric figures at the head of this page (Figs. 10–13) repeat the plate of spherical-astronomy constructions already given earlier in Book III (at folios 381, 383, 385, 387). They illustrate the analemma and declination constructions of the *praxis Regia*.

Diagram. [Fig. 10, upper left.] A large circle (the outline of the sphere) enclosing tilted great circles and numerous chords and arcs, representing the analemma with meridian and horizon. Principal readable vertices: O and B (near the top), H ; along the central horizontal line N , f , R , m , k , I ; at the left D and G ; V above them; at the foot C and L ; M and e within. The remaining small point-letters are set very fine and are not all individually resolvable. [Several labels [?]]

Diagram. [Fig. 11, upper right.] A large circle with an inscribed tilted circle and a smaller circle appended below. Principal readable vertices in the large circle: O , B , b , d (top); c ; along the central horizontal N , f , P , R , m , k , I ; Q , e , Z below; in the lower small circle S , Y , E , K , M , X , T , Z . Many peripheral labels are very fine. [Several labels [?]]

Diagram. [Fig. 12, lower left.] A circle carrying the construction used in the appendix below: chords BC and semicircle/quadrants FB , FC , with the perpendiculars and analogue-arcs described in the text. Readable vertices: P , H , A (upper left); F , O , Q , R ; the interior points D , T , V ; d , f , c , e , g at the lower left; B , E at the foot; G to the right; L , K , Y below. [Several labels [?]]

Diagram. [Fig. 13, lower right.] A large circle containing the spherical triangle OBH referred to in the appendix. Readable vertices: O , B (top); H to the right; A , N , D , G , R at the left along the central line; c , b , m , e , E in the lower right; K , C , L at the foot; I at the right; d . [Several labels [?]]

Fourth: the arcs AN and $d M$ subtend the angles AGN and $d EM$, which are homologous to the arc HO ; and BO subtends the angle of maximum declination BHO , homologous to the bases AG and $d E$.

Fifth, and finally: the arcs NG and EM are homologous to the complement of the angle HOB — the angle of the inclination of the ecliptic and of the meridian — which is measured by the arc MI and whose complement is EM.

Appendix, for the geometric solution of spherical triangles.

[*Appendix pro solutione Geometrica Triangulorum sphæricorum.*]

By this short appendix I hope at last to make it plain that the name we have added to the method demonstrated up to now is no empty one. For I chose to call it "Royal" [*Regia*], not so much

for the benefit the phenomenon of the [sun]spots has received from it, as, far more, for the quite exceptional advantages that flow from it to spherical triangles. But since this is not the place to treat such matters in full, I shall set the matter out in a way that may seem to have opened a road to greater things.

As soon as I recognized that this method is reliable — from that first demonstration by which I framed it together with the analogy of the third problem — I drew this consequence: we now have a means whereby, given the base and a non-right angle of any right-angled spherical triangle, we can solve the whole triangle, and by a procedure so easy that scarcely any more expeditious one seems capable of being devised. To be sure, the canonical method [*ratio Canonica*], which works by arithmetical operations, falls far short of this shortcut — though it is otherwise most accurate, and indeed necessary in weightier matters. For by the individual proportions [*analogiae*] only the single quantities sought are obtained: namely this side, or that one, or — apart from the sides — the remaining angle. The Royal Method, by contrast, yields everything at once with virtually a single effort.

Here I shall be content with a single example, using figures 13 and 12: taking the spherical triangle OBH in figure 13, and its construction in figure 12. Now in the triangle OBH, besides the right angle B, the angle H and the base HO are given; and for the solution of the whole triangle there still remain to be found the angle BOH and the sides BO and BH. In figure 12, let the arcs AB and AC be the analogues of the angle BHO — whether the angle BHO be the angle of maximum declination or some other — and about the chord BC let there be described at least one of the quadrants FB, FC, or else the semicircle BFC; and let the arc FH be made similar to the given base HO. For the perpendicular HQ will cut off the arc AI, which corresponds to the arc BO — and it makes no difference whether or not the arc BO is called the declination of the point O with respect to the base HO —

and the line EI, once drawn, will cut the chord BC somewhere at O, and the perpendicular OP will cut off the arc FP, the analogue of the arc BH.

Finally, the angle BOH will be obtained if to QH — that is, to the cosine [*sinus complementi*] of the arc FH — there is cut off an equal segment D e, taken either from DB or from DC; or else, to be sure, if to the arc FH another equal to it, B d, is taken toward the side of B or of C. For in this way the perpendicular o e will be the sine [*sinus rectus*] of that same arc, and D e will be its cosine, equal to QH. And the straight line E e c will cut off the arc AC of the complement of the angle BOH; and once this arc AC has been found in this way, the arc BH will again be given — or at least one similar to it — if through the point c a line c f is drawn parallel to e d. For the arc BF is equal to FP, as we showed a little earlier; and by either method the right ascension of the arc HO is found — that is, one similar to the arc BH — because the angle BHO is the angle of maximum declination. The method handed down here, however, is not tied to an angle of this kind. And the demonstration is entirely the same, at least when all the arcs of the proposed triangle are less than a quadrant and the non-right angles less than a right angle; nor is there any need to work out here in full whatever would have to be altered in other triangles.

Table of right ascensions and declinations of one quadrant of the ecliptic, at five-minute intervals

[*ASCENSIONES RECTAE ET DECLINATIONES VNIVS quadrantis Eclipticæ per quina minuta.*]

The argument is a point of the ecliptic given as whole degrees (the block heading, 0–17 across these two pages) plus minutes (the "Min." column, 0'–55' by fives). For each such point the table gives its right ascension [*asc. rect.*] and its declination [*Declin.*], each expressed in degrees (G = *gradus*) and minutes (M = *minuta*), here combined as °'. Each page carries three horizontal bands, each band holding three degree-blocks side by side.

Band 1 — degrees 0, 1, 2:

M i n .	0° — asc.	0° —	1° — asc.	1° —	2° — asc.	2° —
	rect.	Declin.	rect.	Declin.	rect.	Declin.
0	0°0'	0°0'	0°55'	0°24'	1°50'	0°48'
5	0°5'	0°2'	1°0'	0°26'	1°55'	0°50'

M i n .	0° — asc. rect.	0° — Declin.	1° — asc. rect.	1° — Declin.	2° — asc. rect.	2° — Declin.
1 0	0°9'	0°4'	1°4'	0°28'	1°59'	0°52'
1 5	0°14'	0°6'	1°9'	0°30'	2°4'	0°54'
2 0	0°18'	0°8'	1°13'	0°32'	2°8'	0°56'
2 5	0°23'	0°10'	1°18'	0°34'	2°13'	0°58'
3 0	0°28'	0°12'	1°23'	0°36'	2°18'	1°0'
3 5	0°32'	0°14'	1°27'	0°38'	2°22'	1°2'
4 0	0°37'	0°16'	1°32'	0°40'	2°27'	1°4'
4 5	0°42'	0°18'	1°37'	0°42'	2°32'	1°6'
5 0	0°46'	0°20'	1°41'	0°44'	2°36'	1°8'
5 5	0°50'	0°22'	1°45'	0°46'	2°41'	1°10'

Band 2 — degrees 3, 4, 5:

M i n .	3° — asc. rect.	3° — Declin.	4° — asc. rect.	4° — Declin.	5° — asc. rect.	5° — Declin.
0	2°45'	1°12'	3°40'	1°36'	4°35'	2°0'
5	2°50'	1°14'	3°45'	1°38'	4°40'	2°2'
1 0	2°54'	1°16'	3°49'	1°40'	4°44'	2°4'

M i n .	3° — asc. rect.	3° — Declin.	4° — asc. rect.	4° — Declin.	5° — asc. rect.	5° — Declin.
1 5	3°59' [recte 2°59']	1°18'	3°54'	1°42'	4°49'	2°6'
2 0	3°4'	1°20'	3°58'	1°44'	4°54'	2°8'
2 5	3°8'	1°22'	4°3'	1°46'	4°58'	2°9'
3 0	3°13'	1°24'	4°8'	1°48'	5°3'	2°11'
3 5	3°17'	1°26'	4°12'	1°50'	5°7'	2°13'
4 0	3°22'	1°28'	4°17'	1°52'	5°12'	2°15'
4 5	3°26'	1°30'	4°21'	1°54'	5°17'	2°17'
5 0	3°31'	1°32'	4°26'	1°56'	5°21'	2°19'
5 5	3°35'	1°34'	4°30'	1°58'	5°26'	2°21'

Band 3 — degrees 6, 7, 8:

M i n .	6° — asc. rect.	6° — Declin.	7° — asc. rect.	7° — Declin.	8° — asc. rect.	8° — Declin.
0	5°30'	2°23'	6°25'	2°47'	7°21'	3°11'
5	5°35'	2°25'	6°30'	2°49'	7°25'	3°13'
1 0	5°39'	2°27'	6°35'	2°51'	7°30'	3°15'
1 5	5°44'	2°29'	6°39'	2°53'	7°34'	3°17'

M i n .	6° — asc. rect.	6° — Declin.	7° — asc. rect.	7° — Declin.	8° — asc. rect.	8° — Declin.
2 0	5°49'	2°31'	6°44'	2°55'	7°39'	3°19'
2 5	5°53'	2°33'	6°48'	2°57'	7°43'	3°21'
3 0	5°58'	2°35'	6°53'	2°59'	7°48'	3°23'
3 5	6°3'	2°37'	6°58'	3°1'	7°53'	3°25'
4 0	6°7'	2°39'	7°2'	3°3'	7°57'	3°27'
4 5	6°12'	2°41'	7°7'	3°5'	8°2'	3°29'
5 0	6°16'	2°43'	7°11'	3°7'	8°6'	3°31'
5 5	6°21'	2°45'	7°16'	3°9'	8°11'	3°33'

Table of right ascensions and declinations of one quadrant of the ecliptic, at five-minute intervals (continued)

[*ASCENSIONES RECTAE ET DECLINATIONES VNIVS quadrantis Eclipticæ per quina minuta.*]

Band 4 — degrees 9, 10, 11:

M i n .	9° — asc. rect.	9° — Declin.	10° — asc. rect.	10° — Declin.	11° — asc. rect.	11° — Declin.
0	8°16'	3°35'	9°11'	3°58'	10°6'	4°22'
5	8°21'	3°37'	9°16'	4°0'	10°11'	4°24'
1 0	8°25'	3°39'	9°20'	4°2'	10°16'	4°26'

M i n .	9° — asc. rect.	9° — Declin.	10° — asc. rect.	10° — Declin.	11° — asc. rect.	11° — Declin.
1 5	8°30'	3°40'	9°25'	4°4'	10°20'	4°28'
2 0	8°34'	3°42'	9°29'	4°6'	10°25'	4°30'
2 5	8°39'	3°44'	9°34'	4°8'	10°29'	4°32'
3 0	8°43'	3°46'	9°39'	4°10'	10°34'	4°34'
3 5	8°48'	3°48'	9°43'	4°12'	10°39'	4°36'
4 0	8°52'	3°50'	9°48'	4°14'	10°43'	4°38'
4 5	8°57'	3°52'	9°54'	4°16'	10°48'	4°39'
5 0	9°2'	3°54'	9°57'	4°18'	10°53'	4°41'
5 5	9°7'	3°56'	10°2'	4°20'	10°57'	4°43'

Band 5 — degrees 12, 13, 14:

M i n .	12° — asc. rect.	12° — Declin.	13° — asc. rect.	13° — Declin.	14° — asc. rect.	14° — Declin.
0	11°2'	4°45'	11°57'	5°9'	12°53'	5°32'
5	11°6'	4°47'	12°2'	5°11'	12°57'	5°34'
1 0	11°11'	4°49'	12°6'	5°13'	13°2'	5°36'
1 5	11°15'	4°51'	12°11'	5°15'	13°6'	5°38'

M i n .	12° — asc. rect.	12° — Declin.	13° — asc. rect.	13° — Declin.	14° — asc. rect.	14° — Declin.
2 0	11°20'	4°53'	12°16'	5°17'	13°11'	5°40'
2 5	11°25'	4°55'	12°20'	5°19'	13°16'	5°42'
3 0	11°29'	4°57'	12°25'	5°20'	13°20'	5°44'
3 5	11°34'	4°59'	12°30'	5°22'	13°25'	5°46'
4 0	11°39'	5°1'	12°34'	5°24'	13°30'	5°48'
4 5	11°43'	5°3'	12°39'	5°26'	13°34'	5°50'
5 0	11°48'	5°5'	12°43'	5°28'	13°39'	5°51'
5 5	11°52'	5°7'	12°48'	5°30'	13°44'	5°53'

Band 6 — degrees 15, 16, 17:

M i n .	15° — asc. rect.	15° — Declin.	16° — asc. rect.	16° — Declin.	17° — asc. rect.	17° — Declin.
0	13°48'	5°55'	14°44'	6°19'	15°40'	6°42'
5	13°53'	5°57'	14°48'	6°21'	15°44'	6°44'
1 0	13°57'	5°59'	14°53'	6°22'	15°49'	6°46'
1 5	14°2'	6°1'	14°58'	6°24'	15°54'	6°47'
2 0	14°7'	6°3'	15°3'	6°26'	15°58'	6°49'

M i n .	15° — asc. rect.	15° — Declin.	16° — asc. rect.	16° — Declin.	17° — asc. rect.	17° — Declin.
2 5	14°11'	6°5'	15°7'	6°28'	16°3'	6°51'
3 0	14°16'	6°7'	15°12'	6°30'	16°8'	6°53'
3 5	14°21'	6°9'	15°16'	6°32'	16°12'	6°55'
4 0	14°25'	6°11'	15°21'	6°34'	16°17'	6°57'
4 5	14°30'	6°13'	15°26'	6°36'	16°22'	6°59'
5 0	14°35'	6°15'	15°30'	6°38'	16°26'	7°1'
5 5	14°39'	6°17'	15°35'	6°40'	19°31' [recte 16°31']	7°3'

Table of right ascensions and declinations of the ecliptic quadrant, at five-minute intervals [ASCENSIONES RECTAE. ET DECLINATIONES VNIVS quadrantis Eclipticae per quina minuta]

(The table continues from the preceding folios. Each block gives, for three successive whole degrees of ecliptic longitude, the right ascension [asc. rect.] and the declination [Declin.], each in degrees [G] and minutes [M], for every 5 minutes of the argument. The leftmost and rightmost columns headed "Min." carry the minutes of the argument, 0–55. All values are transcribed as printed.)

Folio p. 393 — degrees 18–20

M i n	18 asc.rect °	18 ' Decl °	19 asc.rect °	19 ' Decl °	20 asc.rect °	20 ' Decl °	
0	16	3 7	5 17	3 7	2 18	2 7	5
		5		1	8	7	0
5	16	4 7	7 17	3 7	2 18	3 7	5
		0		6	9	2	2

M								
i	18		18		19		19	
n	asc.rect °	'	Decl °	'	asc.rect °	'	Decl °	'
1	16		4 7		8 17		4 7	
0			5				1	
1	16		4 7		1 17		4 7	
5			9		0		5	
2	16		5 7		1 17		5 7	
0			4		2		0	
2	16		5 7		1 17		5 7	
5			9		4		5	
3	17		4 7		1 17		5 7	
0					6		9	
3	17		8 7		1 18		4 7	
5					8			
4	17		1 7		2 18		9 7	
0			3		0			
4	17		1 7		2 18		1 7	
5			7		2		3	
5	17		2 7		2 18		1 7	
0			2		4		8	
5	17		2 7		2 18		2 7	
5			7		6		3	

Folio p. 393 — degrees 21–23

M								
i	21		21		22		22	
n	asc.rect °	'	Decl °	'	asc.rect °	'	Decl °	'
0	19		2 8		1 20		2 8	
			3		3		0	
5	19		2 8		1 20		2 8	
			8		5		4	
1	19		3 8		1 20		2 8	
0			3		7		9	
1	19		3 8		1 20		3 8	

M								
i	21		21		22		22	
n	asc.rect °	'	Decl °	'	asc.rect °	'	Decl °	'
5			8		9		4	
2	19		4 8		2 20		3 8	
0			2		0		8	
2	19		4 8		2 20		4 8	
5			7		2		3	
3	19		5 8		2 20		4 8	
0			1		4		8	
3	19		5 8		2 20		5 8	
5			6		6		2	
4	20		1 8		2 20		5 8	
0					8		7	
4	20		6 8		3 21		2 8	
5					0			
5	20		1 8		3 21		7 8	
0			0		2			
5	20		1 8		3 21		1 8	
5			5		4		1	

Folio p. 393 — degrees 24–26

M								
i	24		24		25		25	
n	asc.rect °	'	Decl °	'	asc.rect °	'	Decl °	'
0	22		1 9		2 23		9 9	
			2		0			
5	22		1 9		2 23		1 9	
			7		2		4	
1	22		2 9		2 23		1 9	
0			2		4		8	
1	22		2 9		2 23		2 9	
5			7		6		3	
2	22		3 9		2 23		2 9	
0			1		8		8	
2	22		3 9		3 23		3 9	

M								
i	24		24		25		25	
n	asc.rect °	'	Decl °	'	asc.rect °	'	Decl °	'
5		6		0		3		1
3	22	4	9	3	23	3	9	5
0		1		2		7		3
3	22	4	9	3	23	4	9	5
5		5		4		2		5
4	22	5	9	3	23	4	9	5
0		0		5		7		7
4	22	5	9	3	23	5	9	5
5		5		7		2		9
5	23	0	9	3	23	5	10	0
0				8		6		9
5	23	4	9	4	24	1	10	2
5				0				2
								4

Table of right ascensions and declinations of the ecliptic quadrant, at five-minute intervals [ASCENSIONES RECTAE. ET DECLINATIONES VNIVS quadrantis Eclipticae per quina minuta]

Folio p. 394 — degrees 27–29

M								
i	27		27		28		28	
n	asc.rect °	'	Decl °	'	asc.rect °	'	Decl °	'
0	25	3	10	2	25	5	10	4
				6		9		7
5	25	7	10	2	26	4	10	4
				8		9		1
1	25	1	10	2	26	9	10	5
0		2		9		1		6
1	25	1	10	3	26	1	10	5
5		7		1		4		3
2	25	2	10	3	26	1	10	5
0		2		3		9		4
2	25	2	10	3	26	2	10	5
								2

M								
i	27		27		28		28	
n	asc.rect °	'	Decl °	'	asc.rect °	'	Decl °	'
5		6		5		3		6
3	25		3	10		2	10	
0		1		7		7		8
3	25		3	10		3	11	
5		6		8		3		0
4	25		4	10		3	11	
0		0		0		8		2
4	25		4	10		4	11	
5		5		2		2		3
5	25		5	10		4	11	
0		0		4		8		5
5	25		5	10		4	11	
5		5		6		2		7

Folio p. 394 — degrees 30–32

M								
i	30		30		31		31	
n	asc.rect °	'	Decl °	'	asc.rect °	'	Decl °	'
0	27		5	11		3	28	
		4		0		1		5
5	27		5	11		5	11	
		8		2		6		5
1	28		3	11		3	29	
0				4		5		1
1	28		8	11		3	29	
5				5		6		5
2	28		1	11		3	29	
0		3		7		0		1
2	28		1	11		3	29	
5		8		9		5		1
3	28		2	11		4	29	
0		2		1		0		2

M								
i	30		30		31		31	
n	asc.rect °	'	Decl °	'	asc.rect °	'	Decl °	'
3	28		2 11		4 29		2 12	
5			7		2		5	
4	28		3 11		4 29		2 12	
0			2		4		9	
4	28		3 11		4 29		3 12	
5			7		6		4	
5	28		4 11		4 29		3 12	
0			2		8		9	
5	28		4 11		4 29		4 12	
5			6		9		4	

Folio p. 394 — degrees 33–35

M								
i	33		33		34		34	
n	asc.rect °	'	Decl °	'	asc.rect °	'	Decl °	'
0	30		4 12		3 31		4 12	
			6		3		4	
5	30		5 12		3 31		4 12	
			1		4		9	
1	30		5 12		3 31		5 12	
0			6		6		4	
1	31		1 12		3 31		5 12	
5					8		9	
2	31		6 12		3 32		3 13	
0					9		0 33	
2	31		1 12		4 32		8 13	
5			1		1		1 33	
3	31		1 12		4 32		1 13	
0			5		3		3	
3	31		2 12		4 32		1 13	
5			0		5		8	
4	31		2 12		4 32		2 13	
0			5		6		3	

M								
i	33		33		34		34	
n	asc.rect °	'	Decl °	'	asc.rect °	'	Decl °	'
4	31		2 12		4 32		2 13	2
5			9		8		8	8
5	31		3 12		5 32		3 13	3
0			4		0		2	0
5	31		3 12		5 32		3 13	3
5			9		1		7	2

Table of right ascensions and declinations of the ecliptic quadrant, at five-minute intervals [ASCENSIONES RECTAE. ET DECLINATIONES VNIVS quadrantis Eclipticae per quina minuta]

Folio p. 395 — degrees 36–38

M								
i	36		36		37		37	
n	asc.rect °	'	Decl °	'	asc.rect °	'	Decl °	'
0	33		4 13		3 34		3 13	5
			0		3		9	3
5	33[?]		4 13		3 34		4 13	5
			5		5		4	5
1	33		5 13		3 34		4 13	5
0			0		7		8	6
1	33		5 13		3 34		5 13	5
5			5		8		3	8
2	34		0 13		4 34		5 14	0
0					0		8	5
2	34		4 13		4 35		3 14	1
5					2			2
3	34		9 13		4 35		8 14	3
0					3			6
3	34		1 13		4 35		1 14	5
5			4		5		3	1
4	34		1 13		4 35		1 14	6
0			9		6		7	6

M								
i	36		36		37		37	
n	asc.rect °	'	Decl °	'	asc.rect °	'	Decl °	'
4	34		2 13		4 35		2 14	
5			4		8		2	
5	34		2 13		5 35		2 14	
0			9		0		7	
5	34		3 13		5 35		3 14	
5			4		1		2	
							1	
							1	

Folio p. 395 — degrees 39–41

M								
i	39		39		40		40	
n	asc.rect °	'	Decl °	'	asc.rect °	'	Decl °	'
0	36		3 14		3 37		3 14	
			6		2		5	
5	36		4 14		3 37		4 14	
			1		4		0	
1	36		4 14		3 37		4 14	
0			6		5		4	
1	36		5 14		3 37		4 14	
5			0		7		9	
2	36		5 14		3 37		5 14	
0			5		8		4	
2	37		0 14		4 37		5 14	
5					0		9	
3	37		5 14		4 38		4 15	
0					2			
3	37		1 14		4 38		9 15	
5			0		3			
4	37		1 14		4 38		1 15	
0			5		5		4	
4	37		2 14		4 38		1 15	
5			0		6		9	
5	37		2 14		4 38		2 15	

M								
i	39		39		40		40	
n	asc.rect °	'	Decl °	'	asc.rect °	'	Decl °	'
0		5		8		4		3
5	37		3 14		4 38		2 15	8 39
5		0		9		9		8
								7

Folio p. 395 — degrees 42–44

M								
i	42		42		43		43	
n	asc.rect °	'	Decl °	'	asc.rect °	'	Decl °	'
0	39		3 15		2 40		3 15	4 41
		3		8		2		7
5	39		3 15		3 40		3 15	4 41
		8		0		7		8
1	39		4 15		3 40		4 15	5 41
0		3		2		2		0
1	39		4 15		3 40		4 15	5 41
5		9		3		7		1
2	39		5 15		3 40		5 15	5 41
0		3		5		2		3
2	39		5 15		3 40		5 15	5 41
5		7		6		7		4
3	40		2 15		3 41		2 15	5 42
0				8				6
3	40		7 15		3 41		7 15	5 42
5				9				7
4	40		1 15		4 41		1 15	5 42
0		2		1		2		9
4	40		1 15		4 41		1 16	0 42
5		7		2		6		
5	40		2 15		4 41		2 16	2 42
0		2		4		2		
5	40		2 15		4 41		2 16	3 42
5		7		5		6		

Table of right ascensions and declinations of the ecliptic quadrant, at five-minute intervals [ASCENSIONES RECTAE. ET DECLINATIONES VNIVS quadrantis Eclipticae per quina minuta]

Folio p. 396 — degrees 45–47

M

i	45		45		46		46		47		47	
n	asc.rect °	'	Decl °	'	asc.rect °	'	Decl °	'	asc.rect °	'	Decl °	'
0	42		3 16		2 43		3 16		4 44		3 16	5
			1		3		1		0		1	7
5	42		3 16		2 43		3 16		4 44		3 16	5
			6		4		6		1		6	9
1	42		4 16		2 43		4 16		4 44		4 17	0
0			1		6		1		3		1	
1	42		4 16		2 43		4 16		4 44		4 17	2
5			6		7		6		4		6	
2	42		5 16		2 43		5 16		4 44		5 17	3
0			1		8		1		6		1	
2	42		5 16		3 43		5 16		4 44		5 17	4
5			6		0		6		7		6	
3	43		1 16		3 44		1 16		4 45		1 17	6
0					1				9			
3	43		5 16		3 44		6 16		5 45		6 17	7
5					3				0			
4	43		1 16		3 44		1 16		5 45		1 17	9
0			1		4		1		2		1	
4	43		1 16		3 44		1 16		5 45		1 17	1
5			6		6		6		3		6	0
5	43		2 16		3 44		2 16		5 45		2 17	1
0			1		7		1		4		1	1
5	43		2 16		3 44		2 16		5 45		2 17	1
5			6		9		6		6		6	3

Folio p. 396 — degrees 48–50

M								
i	48		48		49		49	
n	asc.rect °	'	Decl °	'	asc.rect °	'	Decl °	'
0	45		3 17		1 46		3 17	
			1		4		2	
5	45		3 17		1 46		3 17	
			6		6		7	
1	45		4 17		1 46		4 17	
0			1		8		2	
1	45		4 17		1 46		4 17	
5			6		9		7	
2	45		5 17		2 46		5 17	
0			1		0		2	
2	45		5 17		2 46		5 17	
5			6		1		7	
3	46		1 17		2 47		2 17	
0					3		9	
3	46		6 17		2 47		7 17	
5					4		0	
4	46		1 17		2 47		1 17	
0			2		5		2	
4	46		1 17		2 47		1 17	
5			7		7		6	
5	46		2 17		2 47		2 17	
0			2		8		2	
5	46		2 17		2 47		2 17	
5			7		9		7	

Folio p. 396 — degrees 51–53

M								
i	51		51		52		52	
n	asc.rect °	'	Decl °	'	asc.rect °	'	Decl °	'
0	48		3 18		3 49		3 18	
			3				4	
							9	
							5	

M								
i	51		51		52		52	
n	asc.rect °	'	Decl °	'	asc.rect °	'	Decl °	'
5	48		3 18		4 49		3 18	
		8				9		0
1	48		4 18		6 49		4 18	
0		3				4		1
1	48		4 18		7 49		4 18	
5		8				9		3
2	48		5 18		8 49		5 18	
0		3				4		4
2	48		5 18		1 50		0 18	
5		9			0			5
3	49		4 18		1 50		5 18	
0					1			7
3	49		9 18		1 50		1 18	
5					2		0	
4	49		1 18		1 50		1 18	
0		4			4		5	
4	49		1 18		1 50		2 18	
5		9			5		0	
5	49		2 18		1 50		2 18	
0		4			6		5	
5	49		2 18		1 50		3 18	
5		9			7		0	

[The foot of p. 396 carries a faint press-mark at center, not legibly resolvable.] [?]

Book III — Table of Right Ascensions and Declinations (continued)

Running header (folio 397, recto): TAB. ASCENS. RECT. *Running header (folio 398, verso):* ROSAE VRSINAE LIB. III.

Table heading (repeated at the head of each folio): RIGHT ASCENSIONS AND DECLINATIONS OF ONE QUADRANT OF THE ECLIPTIC, PER FIVE MINUTES

[ASCENSIONES RECTAE ET DECLINATIONES VNIVS quadrantis Eclipticae per quina minuta].

This stretch continues the quadrant table for whole degrees of ecliptic longitude **54° through 80°**. For each degree the table gives, against the argument **Min.** (minutes of the degree, in 5' steps from 0 to 55), the **right ascension** [ascensio recta] in degrees (°) and minutes (') and the **declination** [declinatio] in degrees (°) and minutes ('). Each folio carries three horizontal bands of three degree-columns. The tables are transcribed below band by band; all values are read directly from the scan at high magnification.

Folio 397 — degrees 54–62

Degrees 54 · 55 · 56

M

i

n	54	54	54	54	55	55	55	55	56	56	56	56
.	RA°	RA'	Dec°	Dec'	RA°	RA'	Dec°	Dec'	RA°	RA'	Dec°	Dec'
0	51	37	18	49	52	38	19	4	53	40	19	18
5	51	42	18	50	52	43	19	5	53	45	19	19
1	51	47	18	52	52	48	19	6	53	50	19	21
0												
1	51	52	18	53	52	53	19	8	53	53	19	22
5												
2	51	57	18	54	52	58	19	9	54	0	19	23
0												
2	52	2	18	55	53	4	19	10	54	5	19	24
5												
3	52	7	18	57	53	9	19	11	54	11	19	25
0												
3	52	12	18	58	53	14	19	12	54	16	19	26
5												
4	52	18	18	59	53	19	19	13	54	21	19	28
0												
4	52	23	19	0	53	24	19	15	54	26	19	29
5												
5	52	28	19	2	53	29	19	16	54	31	19	30

[illegible]

Degrees 57 · 58 · 59

[illegible]

Degrees 60 · 61 · 62

M

i

n	60 RA°	60 RA'	60 Dec°	60 Dec'	61 RA°	61 RA'	61 Dec°	61 Dec'	62 RA°	62 RA'	62 Dec°	62 Dec'
0	57	47	20	12	58	51	20	25	59	54	20	37
5	57	53	20	13	58	56	20	26	59	59	20	38
10	57	58	20	14	59	1	20	27	60	4	20	39
15	58	4	20	15	59	7	20	28	60	9	20	40
20	58	9	20	16	59	10	20	29	60	14	20	41
25	58	14	20	17	59	16	20	30	60	20	20	42
30	58	19	20	18	59	22	20	31	60	25	20	43
35	58	25	20	19	59	27	20	32	60	30	20	44
40	58	30	20	20	59	32	20	33	60	35	20	45
45	58	35	20	22	59	38	20	34	60	41	20	46
50	58	40	20	23	59	43	20	35	60	46	20	47
55	58	45	20	24	59	48	20	36	60	51	20	48

Foot of folio 397:

Folio 398 — degrees 63–71

Degrees 63 · 64 · 65

M i n .	63		63		64		64		65		65	
	RA°	RA′	Dec°	Dec′	RA°	RA′	Dec°	Dec′	RA°	RA′	Dec°	Dec′
0	60	56	20	49	62	0	21	0	63	3	21	11
5	61	2	20	50	62	5	21	1	63	8	21	12
1	61	7	20	51	62	10	21	2	63	13	21	13
0												
1	61	12	20	52	62	15	21	3	63	18	21	14
5												
2	61	17	20	53	62	20	21	4	63	24	21	15
0												
2	61	23	20	53	62	26	21	5	63	29	21	16
5												
3	61	28	20	54	62	31	21	6	63	34	21	16
0												
3	61	33	20	55	62	36	21	7	63	40	21	17
5												
4	61	38	20	56	62	42	21	8	63	45	21	18
0												
4	61	44	20	57	62	47	21	8	63	50	21	19
5												
5	61	49	20	58	62	52	21	9	63	56	21	20
0												
5	61	54	20	59	62	57	21	10	64	1	21	21
5												

Degrees 66 · 67 · 68

M i n .	66		66		67		67		68		68	
	RA°	RA′	Dec°	Dec′	RA°	RA′	Dec°	Dec′	RA°	RA′	Dec°	Dec′
0	64	6	21	22	65	10	21	32	66	13	21	42

M i n .	66	66	66	66	67	67	67	67	68	68	68	68
	RA°	RA'	Dec°	Dec'	RA°	RA'	Dec°	Dec'	RA°	RA'	Dec°	Dec'
5	64	11	21	23	65	15	21	33	66	19	21	42
1	64	16	21	23	65	20	21	34	66	24	21	43
0												
1	64	21	21	24	65	25	21	34	66	29	21	44
5												
2	64	27	21	25	65	31	21	35	66	34	21	45
0												
2	64	32	21	26	65	36	21	36	66	39	21	46
5												
3	64	37	21	27	65	41	21	37	66	45	21	47
0												
3	64	43	21	28	65	46	21	38	66	50	21	47
5												
4	64	48	21	28	65	52	21	39	66	55	21	48
0												
4	64	53	21	29	65	57	21	39	67	1	21	49
5												
5	64	59	21	30	66	2	21	40	67	6	21	50
0												
5	65	5	21	31	66	8	21	41	67	12	21	51
5												

Degrees 69 · 70 · 71

M i n .	69	69	69	69	70	70	70	70	71	71	71	71
	RA°	RA'	Dec°	Dec'	RA°	RA'	Dec°	Dec'	RA°	RA'	Dec°	Dec'
0	67	17	21	51	68	21	22	0	69	25	22	9
5	67	22	21	52	68	26	22	1	69	30	22	10
1	67	27	21	53	68	32	22	2	69	36	22	10
0												
1	67	33	21	54	68	37	22	3	69	41	22	11

M i n .	69 RA°	69 RA'	69 Dec°	69 Dec'	70 RA°	70 RA'	70 Dec°	70 Dec'	71 RA°	71 RA'	71 Dec°	71 Dec'
5												
2 0	67	38	21	54	68	42	22	3	69	46	22	12
2 5	67	43	21	55	68	48	22	4	69	52	22	12
3 0	67	49	21	56	68	53	22	5	69	57	22	13
3 5	67	54	21	57	68	58	22	5	70	2	22	14
4 0	67	59	21	57	69	3	22	6	70	8	22	15
4 5	68	5	21	58	69	9	22	7	70	13	22	15
5 0	68	10	21	59	69	14	22	8	70	19	22	16
5 5	68	15	22	0	69	20	22	8	70	24	22	16

Foot of folio 398: `]

Folio 399 — degrees 72–80

Running header (folio 399, recto): TAB. ASCENS. RECT.

Degrees 72 · 73 · 74

[illegible]

M i n .	72 RA°	72 RA'	72 Dec°	72 Dec'	73 RA°	73 RA'	73 Dec°	73 Dec'	74 RA°	74 RA'	74 Dec°	74 Dec'
1 5	70	45	22	19	71	50	22	27	72	54	22	34
2 0	70	50	22	20	71	55	22	27	72	59	22	35
2 5	70	56	22	20	72	1	22	28	73	5	22	35
3 0	71	2	22	21	72	6	22	29	73	10	22	36
3 5	71	7	22	22	72	11	22	29	73	16	22	36
4 0	71	12	22	22	72	16	22	30	73	21	22	37
4 5	71	18	22	23	72	22	22	30	73	27	22	37
5 0	71	23	22	23	72	27	22	31	73	32	22	37
5 5	71	28	22	24	72	33	22	31	73	37	22	38

Degrees 75 · 76 · 77

M i n .	75 RA°	75 RA'	75 Dec°	75 Dec'	76 RA°	76 RA'	76 Dec°	76 Dec'	77 RA°	77 RA'	77 Dec°	77 Dec'
0	73	43	22	39	74	47	22	46	75	52	22	52
5	73	49	22	39	74	53	22	46	75	58	22	52
1 0	73	53	22	40	74	58	22	47	76	3	22	53
1 5	73	59	22	40	75	3	22	47	76	8	22	53
2 0	74	4	22	41	75	9	22	48	76	13	22	54

M i n .	75 RA°	75 RA'	75 Dec°	75 Dec'	76 RA°	76 RA'	76 Dec°	76 Dec'	77 RA°	77 RA'	77 Dec°	77 Dec'
2 5	74	9	22	41	75	14	22	48	76	19	22	54
3 0	74	15	22	42	75	20	22	49	76	25	22	55
3 5	74	20	22	42	75	25	22	49	76	30	22	55
4 0	74	26	22	43	75	30	22	50	76	35	22	56
4 5	74	31	22	43	75	36	22	50	76	41	22	56
5 0	74	36	22	44	75	41	22	51	76	46	22	57
5 5	74	42	22	45	75	47	22	51	76	52	22	57

Degrees 78 · 79 · 80

M i n .	78 RA°	78 RA'	78 Dec°	78 Dec'	79 RA°	79 RA'	79 Dec°	79 Dec'	80 RA°	80 RA'	80 Dec°	80 Dec'
0	76	57	22	58	78	2	23	3	79	7	23	7
5	77	2	22	58	78	7	23	3	79	12	23	8
1 0	77	8	22	58	78	13	23	3	79	18	23	8
1 5	77	13	22	59	78	18	23	4	79	23	23	8
2 0	77	18	22	59	78	24	23	4	79	29	23	9
2 5	77	24	23	0	78	29	23	5	79	34	23	9
3 0	77	29	23	0	78	34	23	5	79	39	23	9

M												
i												
n	78	78	78	78	79	79	79	79	80	80	80	80
.	RA°	RA'	Dec°	Dec'	RA°	RA'	Dec°	Dec'	RA°	RA'	Dec°	Dec'
3	77	35	23	0	78	40	23	5	79	45	23	10
5												
4	77	40	23	1	78	45	23	6	79	50	23	10
0												
4	77	45	23	1	78	51	23	6	79	56	23	11
5												
5	77	51	23	2	78	56	23	7	80	1	23	11
0												
5	77	56	23	2	79	1	23	7	80	6	23	11
5												

Foot of folio 399:

The quadrant table has reached 80° at the foot of folio 399; the remaining degrees (81°–90°) would fall on the next folio (400), which is not present in this stretch — see the report below.

Folio "398" (repeated) — duplicate scan

The fourth page image is a **duplicate scan of folio 398** (degrees 63–71), identical in header and in every value to the folio 398 already transcribed above. It is not re-transcribed.

Right Ascensions and Declinations of one quadrant of the ecliptic, per five minutes [ASCENSIONES RECTAE ET DECLINATIONES VNIVS quadrantis Eclipticae per quina minuta]

(Folio 399 — degrees 72°–80°. This leaf repeats the closing degrees already tabulated at the end of the preceding stretch; see the note under Numbering anomalies. In each block: "asc. rect." = right ascension in degrees [G] and minutes [M]; "Declin." = declination in degrees [G] and minutes [M]; "Min." = the minutes of ecliptic longitude within the whole degree named in the block heading.)

Degrees 72 · 73 · 74

M i n .	72 a.r.°	72 a.r.′	72 dec. °	72 dec.′	73 a.r.°	73 a.r.′	73 dec. °	73 dec.′	74 a.r.°	74 a.r.′	74 dec. °	74 dec.′
0	70	30	22	17	71	34	22	25	72	38	22	32
5	70	35	22	18	71	39	22	26	72	43	22	33
10	70	40	22	18	71	44	22	26	72	49	22	33
15	70	45	22	19	71	50	22	27	72	54	22	34
20	70	50	22	20	71	55	22	27	72	59	22	35
25	70	56	22	20	72	1	22	28	73	5	22	35
30	71	2	22	21	72	6	22	29	73	10	22	36
35	71	7	22	22	72	11	22	29	73	16	22	36
40	71	12	22	22	72	16	22	30	73	21	22	37
45	71	18	22	23	72	22	22	30	73	27	22	37
50	71	23	22	23	72	27	22	31	73	32	22	37
55	71	28	22	24	72	33	22	31	73	37	22	38

Degrees 75 · 76 · 77

Min.	75 a.r. °	75 a.r.′	75 dec. °	75 dec.′	76 a.r. °	76 a.r.′	76 dec. °	76 dec.′	77 a.r. °	77 a.r.′	77 dec. °	77 dec.′
0	73	43	22	39	74	47	22	46	75	52	22	52
5	73	49	22	39	74	53	22	46	75	58	22	52
10	73	53	22	40	74	58	22	47	76	3	22	53
15	73	59	22	40	75	3	22	47	76	8	22	53

Min.	75 a.r. °	75 a.r.'	75 dec .°	75 dec. '	76 a.r. °	76 a.r.'	76 dec .°	76 dec. '	77 a.r. °	77 a.r.'	77 dec .°	77 dec. '
20	74	4	22	41	75	9	22	48	76	13	22	54
25	74	9	22	41	75	14	22	48	76	19	22	54
30	74	15	22	42	75	20	22	49	76	25	22	55
35	74	20	22	42	75	25	22	49	76	30	22	55
40	74	26	22	43	75	30	22	50	76	35	22	56
45 [recte; printed "35"]	74	31	22	43	75	36	22	50	76	41	22	56
50	74	36	22	44	75	41	22	51	76	46	22	57
55	74	42	22	45	75	47	22	51	76	52	22	57

Degrees 78 · 79 · 80

M i n	78 a.r.°	78 a.r.'	78 dec. °	78 dec.' '	79 a.r.°	79 a.r.'	79 dec. °	79 dec.' '	80 a.r.°	80 a.r.'	80 dec. °	80 dec.' '
0	76	57	22	58	78	2	23	3	79	7	23	7
5	77	2	22	58	78	7	23	3	79	12	23	8
10	77	8	22	58	78	13	23	3	79	18	23	8
15	77	13	22	59	78	18	23	4	79	23	23	8
20	77	18	22	59	78	24	23	4	79	29	23	9
25	77	24	23	0	78	29	23	5	79	34	23	9
30	77	29	23	0	78	34	23	5	79	39	23	9
35	77	35	23	0	78	40	23	5	79	45	23	10
40	77	40	23	1	78	45	23	6	79	50	23	10

M i n .	78 a.r.°	78 a.r.′	78 dec. °	78 dec.′	79 a.r.°	79 a.r.′	79 dec. °	79 dec.′	80 a.r.°	80 a.r.′	80 dec. °	80 dec.′
4 5	77	45	23	1	78	51	23	6	79	56	23	11
5 0	77	51	23	2	78	56	23	7	80	1	23	11
5 5	77	56	23	2	79	1	23	7	80	6	23	11

Right Ascensions and Declinations of one quadrant of the ecliptic, per five minutes [ASCENSIONES RECTAE ET DECLINATIONES VNIVS quadrantis Eclipticae per quina minuta] (continued)

(Folio 400 — degrees 81°–89°. This is the tail of the quadrant table that was missing from the scan at the end of the preceding stretch, now present. The argument runs to 89°55′; the trivial endpoint at 90° — where declination equals the obliquity, 23°30′ — is not set as a separate block.)

Degrees 81 · 82 · 83

M i n .	81 a.r.°	81 a.r.′	81 dec. °	81 dec.′	82 a.r.°	82 a.r.′	82 dec. °	82 dec.′	83 a.r.°	83 a.r.′	83 dec. °	83 dec.′
0	80	12	23	12	81	18	23	15	82	22	23	19
5	80	17	23	12	81	23	23	16	82	28	23	19
1 0	80	23	23	12	81	28	23	16	82	33	23	19
1 5	80	28	23	13	81	34	23	16	82	38	23	10 [recte: 20]
2 0	80	33	23	13	81	39	23	16	82	44	23	10 [recte: 20]

M i n .	81 a.r.°	81 a.r.′	81 dec. °	81 dec.′	82 a.r.°	82 a.r.′	82 dec. °	82 dec.′	83 a.r.°	83 a.r.′	83 dec. °	83 dec.′
2 5	80	39	23	13	81	44	23	17	82	49	23	10 [recte: 20]
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Degrees 84 · 85 · 86

M i n .	84 a.r.°	84 a.r.′	84 dec. °	84 dec.′	85 a.r.°	85 a.r.′	85 dec. °	85 dec.′	86 a.r.°	86 a.r.′	86 dec. °	86 dec.′
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1 0	83	38	23	22	84	44	23	25	85	49	23	27
1 5	83	44	23	22	84	49	23	25	85	54	23	27
2 0	83	49	23	23	84	55	23	25	86	0	23	27
2 5	83	55	23	23	85	0	23	25	86	6	23	27
3	84	0	23	23	85	6	23	25	86	11	23	27

M i n .	84 a.r.°	84 a.r.′	84 dec. °	84 dec.′	85 a.r.°	85 a.r.′	85 dec. °	85 dec.′	86 a.r.°	86 a.r.′	86 dec. °	86 dec.′
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5 0	84	22	23	24	85	27	23	26	86	33	23	28
5 5	84	28	23	24	85	33	23	26	86	38	23	28

Degrees 87 · 88 · 89

M i n .	87 a.r.°	87 a.r.′	87 dec. °	87 dec.′	88 a.r.°	88 a.r.′	88 dec. °	88 dec.′	89 a.r.°	89 a.r.′	89 dec. °	89 dec.′
0	86	44	23	28	87	49	23	29	88	54	23	30
5	86	49	23	28	87	55	23	29	89	0	23	30
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20	87	6	23	28	88	11	23	29	89	16	23	30
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[End of Book III]

You have already been shown above how this Table is to be used for our present purpose. And these are the Demonstrations by which Father Grienberger established beyond doubt that Practice which he himself chose to call the "Royal" one — and with it we too bring this book to a close, to the greater glory of God Most Good and of Christ, the eternal King.

(The verso of this leaf is blank. The Book IV display-title and Summarium are not on these pages; they begin on the following leaf.)

ROSA URSINA, OR THE SUN — BOOK FOUR

Rosa Ursina, or the Sun — Book Four

[ROSAE VRSINAE SIVE SOLIS LIBER QVARTVS]

In Book One the Rosa Ursina sent down its roots; in Book Two it grew up into a rough and thorny shrub; in Book Three it put out green leaves and — through the Images of the Observations — calyxes and blossoms still, as it were, half-closed. Now, therefore, in Book Four it opens itself fully: it offers to the earth, for viewing, its natural beauty, hitherto hidden and known only to the sky above, and it scatters the fragrance of its scent far and wide throughout the whole Universe.

In this Fourth Book, then, I investigate the nature of the solar phenomenon from the observations set out in the third book. I divide the book into two parts: in the first I pursue the properties of the phenomenon itself; in the second I present its Theory and draw out the further conclusions that follow both from this and from the phenomenon.

Summary of the First Part

[Summa Partis Primae]

[The page carries two parallel columns, headed with the cross-reference apparatus numerals "I." (left) and "II." (right), the latter with per-column line-numbers marked in fives (5, 10, 15 ... 50) in the gutter. Column I is the Summary; column II is the Prologue and the opening of the treatise.]

[Margin: The order and sequence of the matters to be treated (*Tractandorum ordo & sequela*).]

The chief aim of the First Part is to track down the true position [*locus*] of the solar phenomenon; for once this is known with certainty, one can arrive at sure knowledge of other things — otherwise not at all. But the true position cannot be had except through the known true motion, and this in turn is acquired only from the apparent motion. Hence it is necessary to argue about the apparent motion of the Spots and Faculae [*Apparente Macularum & Facularum Motu*], which was produced and established in the Third Book. And since local motion is not perceived by sight except when the moving body is seen, while the moving body is discerned only through colours and light, we must inquire into the light and darkness of our phenomenon. And because we see these [spots] not only move in place, but also vary in magnitude, change in shape — indeed vanish altogether and be born anew — in the First Part we treat all these matters thoroughly: motion with respect to Place, to Quantity, to Quality; where we discuss the Figure, the Light, the Darkness, the Colour, and the Opacity of the phenomenon; its Rising and Setting; its substantial Generation and Corruption; and finally we determine its true Place by summarily gathering many arguments, we show this same place in relation to the observed Sun, and from that we define the absolute magnitude of the Spots and Faculae.

You have now heard the summary, kind Reader; but think of this same summary as a Rose still closed within its covering. Handle it a little with your hand, warm it, chafe it a little; read, I say, what follows — perhaps a fragrance not unwelcome will breathe upon you. For this Rose delights in perpetual Spring, and continually

supplies fresh growth beneath its falling petals. If, then, you are captivated by its lovely appearance, give thanks to God the Maker of all things, who planted it with his own hand; and if you find it badly handled by me — perhaps against my own intention — do not take offence: I am a man, and the works of God are never handled well enough by man. This wondrous Rose would not be divine and heavenly, if the slenderness of my talent and style could match it.

Prologue

[PROLOGVS]

[Margin: From the observations adduced in the previous book, the doctrine that follows will be deduced (*Ex obseruatis priore libro allatis doctrina sequens deducetur*).]

About to explain the Rosa Ursina — established by long lapse of time, by persistence in observing, and by diligence — I proceed to further matters, taking as known, granted, and beyond doubt the things I have faithfully brought forward and handed down in the earlier books. To make this the more secure, I here set out all at once — but concisely — everything about the apparent motion of the phenomenon that I have established piecemeal before the reader's eyes. And I give this advance warning: although, by the term "this phenomenon," while I deal with apparent motion in general, I mean and comprehend everything seen on the Sun regarding both primary and secondary Spots and Faculae, [Margin: What will be said about the primary Spots can ordinarily be applied to the other parts of the phenomenon as well (*Quae de Maculis primarijs dicetur, poterunt ordinarie etiam alijs Phaenomeni partibus applicari*).] nevertheless, because the Spots — especially the primary ones — most of all meet the eye of the Heliopic observer [*in oculos Heliopici*], I shall so treat of them that most of what I say can be applied to the other solar appearances as well. For the Faculae appear to move neither less nor otherwise than the Spots; and neither less nor otherwise do the Umbrae and Luculae [the shadows and little lights, *Vmbrae & Luculae*] than both of these — except that a greater instability and shorter duration are found in them than in the primary Spots.

[Margin: The threefold kind of motion (*Triplex Motus species*).]

According to the Philosopher [Aristotle], motion is of three kinds: local, of growth, and of alteration. We shall treat of each in turn, with the brevity we have set ourselves.

On the Apparent Local Motion of the Sunspots

[De Motu Macularum locali apparente]

[Margin: True and apparent motion — what each is (*Motus verus & apparens, quis*).]

Local motion is divided into true and apparent. True motion is that which, just as it appears, is also actually present on the side of the moving thing itself; apparent motion is that which sight attributes to the moving body, whether or not it is really present in the thing. Hence it comes about that every true local motion can be, and be called, apparent — insofar, that is, as it can be perceived by sense by reason of the moving subject — yet not every apparent motion is necessarily, or is called, true. I said "by reason of the movable," because if it should happen that there are movable things falling under no sense at all, then their motion will be perceived as neither apparent nor true.

[Margin: Motion merely apparent, while the moving thing is at rest (*Motus merè apparens, quiescente mobili*).]

A ship sails on the sea; the people move along with it and in it, and they see the shores standing on either side — and, together with the shores, the lands, woods, mountains, towers, and the rest — moving in the opposite direction: by a motion, to be sure, that is not true but merely apparent.

[Margin: Motion both apparent and true (*Motus apparens & verus*).]

I see a horse running in the racecourse, and I judge it to be running at the very place where I see it running: here the motion is both apparent and true.

Therefore, to serve the brevity I have set myself, I shall pursue whatever pertains to the apparent motion of the Spots through definite propositions drawn from the observations.

FIRST PROPOSITION

[PRONVNCIATVM PRIMVM]

[Margin: The daily rising and setting of the Spots (*Ortus, & occasus Macularum quotidianus*).]

All the Spots (for as long as they last, and provided they are not turned by their own motion toward the far side of the Sun) rise apparently each morning together with the Sun, are carried round with it throughout the whole day, and set in the evening;

nor do they desert the Sun, being observed in any part of the terrestrial globe. Indeed, at one and the same time they are seen everywhere by the most widely separated observers, at the same locations on the Solar disc, with progressions that are perfectly uniform, and with distances from the centre and from the margins that are either equal or proportional.

CHAPTER I

[CAP. I.]

This proposition has been sufficiently proved throughout the previous book, from the many observations adduced from different places and astronomers, which teach that the Spots are observed at the same — or at proportional — places on the Sun, rise with it from day to day, and are carried across the meridian toward setting. Indeed it needs no further proof than mere inspection, which anyone can perform on any day. And although among astronomers this matter is free of every suspicion of falsehood, yet among those who either do not know the phenomenon, or shrink from the force of the consequences drawn from it, some difficulty might have lurked. For that reason, in the foregoing book I brought forward a proof so frequent and so solid, drawn from others' observations.

[Margin: The Spots are infallibly carried above the Moon (*Maculae supra Lunam euehuntur infallibiliter*).]

For from this single point — namely, that all and each of the Spots, from whatever part of the globe, are seen to rise, culminate, and set together with the Sun, at the same place beneath the Sun, at a proportionally identical time, and so forth — from this one point, I say, even if no others were available (whereas very many are), all the Spots are irrefutably raised above the Moon and above the whole sphere of the Moon. This is demonstrated most evidently, and by the fact itself, from any eclipse of the Sun. For since an eclipse is nothing else than an occultation of the solar rays by the interposition of the Moon, it is certain that, by the opposition of the Spots as well between us and the Sun, nothing else occurs than various intercepting cuts of the Sun's own rays. Hence, just as no solar eclipse caused by the interposition of the Moon is seen at the same place of the Sun simultaneously from different regions of the earth, nor from every tract of the terrestrial hemisphere lying beneath the two luminaries in conjunction [?], so too, if the Spots were set even upon the very thickness of the Moon's sphere — in whatever way that be done — they would be seen neither at the same place of the Sun, nor simultaneously from any opposite region of the earth. Rather, to those who are farthest east the solar Spots would appear more westerly; to those who

are farthest west the same Spots would become more easterly; those who are southerly with respect to the Sun would see them more northerly; and those in the middle, at the middle place of the Sun — just as happens in a total eclipse of the Sun, which those alone see whole who stand within the conical surface of the shadow, while all the rest do not perceive the total obscuration of the Sun, but a part of the Sun toward its top free from all occultation, more or less according as, upon the earth, they are farther from or nearer to the [central] place of the Sun. On which topic more will be said expressly below.

For the present let it suffice that the solar Spots, seen and recorded at practically the same time in various and very widely separated Provinces, were entirely free of any perceptible difference of aspect.

[Margin: Spots placed at the Moon would suffer a perceptible parallax (*Maculae apud Lunam positae, paterentur sensibilem parallaxin*).]

To this I could cite very many witnesses, with whom I have had communication both formerly and now. [Margin: The Spots lack all perceptible parallax (*Maculae carent omni sensibili parallaxi*).] Certainly the Spots observed in Italy, Germany, Poland, the Low Countries, France, Spain, the New World, and elsewhere, when compared with one another, reject absolutely all Parallax. This I have not only frequently established by so many individual instances, and made plain by the many adduced in the earlier book, but others too have repeatedly done the same elsewhere, and all have found among the Spots a very close agreement and likeness as to their figure and their apparent place on the Sun; and they have left this attested in both private and public writings. See Galileo [Galilaeus] in the history *Delle Macchie* [the *Istoria e Dimostrazioni intorno alle Macchie Solari*], in the Letter written to Marcus Welser [*Marcum Vellerum*] on 14 August 1612, page 45, and elsewhere throughout both this and the following letter, etc. [See also] Father Adam Tanner [*Adamum Tannerum*], who in his *Dissertation on the Heavens* [*Dissertatio de Caelis*], Question 7, § 5, page 152, has the following to say about the solar Spots:

[The following continues the quotation (from Adam Tanner, *Dissertatio de Caelis*) that was introduced at the foot of printed p. 405.]

"As for the third point — the sunspots — I confess, first of all, that they really do exist and that they are higher than the Moon. This holds even though many, for a long time, either denied them outright — reckoning them to be defects of the telescope or of the eyes, and spots not belonging to the Sun — or at any rate judged that they are not higher than the

Moon. Both opinions are refuted. Not only were the spots seen at different times by the same observers, and over a fairly long span (a period of about twelve or fourteen days); they were also seen at the same time, in the most widely separated and remote places, by different observers, under the same position of the Sun — except insofar as the proportional advance of their motion, or the distance between the places, altered it — with great uniformity of proportions, constantly; and they are still seen so even now."

What I stated in the Pronouncement therefore stands firm, proved both by the observations set out in the previous book and by the authority of many others. Moreover, the spots are seen to be carried around, day after day without interruption, together with the Sun by the motion of the primum mobile [motu primi Mobilis], and to linger perceptibly in the same position of the Sun, from whatever point on the orb they are finally viewed. From this it is clear and established that none of them is carried about below the Moon in the air, nor with the Moon, nor around the Moon in the aether, but far higher, in those celestial regions. This was the thing to be demonstrated, and it is now commonly accepted by all — a matter we shall nevertheless treat more fully below.

[Margin: The spots rise above the perigees of Venus and Mercury.]

COROLLARY.

By this same mode of argument, the spots will be raised above the circles of the perigees of Venus and Mercury. For there is no doubt that in those positions these planets undergo some perceptible parallax with respect to the Sun — as will be firmly shown below. Hence, if the spots were located in the seats of those planets, their apparent courses would without doubt be thrown off within the observational circle in proportion to the difference of aspect, so that when observed in different places, or in the same place at different times, they would be seen against different and unrelated positions of the Sun. But this does not happen. It therefore remains beyond controversy that the spots are not to be fastened down there, but must be looked up to upon a loftier throne.

PRONOUNCEMENT THE SECOND

All the spots, none excepted, appear always to move from the eastern quarter of the Sun into the western quarter of the same.

CHAPTER II.

For this pronouncement to be rightly understood, one must know, first, that we are here no longer dealing with the common and daily motion of the spots — the motion they undergo incidentally by reason of the *primum mobile* — but with their own particular advance, relative to the solar disk, by which they move forward step by step across the Sun, from one place on the Sun to another place on the same, until they have traversed the whole of it, at fixed intervals of days.

[Margin: First point to be noted.]

One must know, secondly, that the center of the Sun always lies on the ecliptic, and that the Sun is therefore cut by it into two hemispheres. One of these — the one that at midday is raised higher toward the zenith — is called the northern [Aquilonare]; the other — the one that at midday faces the horizon and lies lower — is called the southern, or austral [Meridionale]. Now if, upon the said ecliptic (a circle or plane passing through the center of the Sun), and through the poles and the axis of the ecliptic, another plane or circle be erected at right angles, the Sun will again be cut into two equal hemispheres. Of these, the one that faces east I name eastern, and the one that faces west, western. With these things premised:

[Margin: Second point to be noted.]

[Margin: The various division of the solar disk by certain sections of circles.]

Since, from the observations made thus far and from the many Images of the spots' Courses adduced throughout the previous book, it is abundantly clear that all the spots are always and most constantly carried from the eastern quarter of the Sun into the western, the credibility and force of this pronouncement stand established. For according to sound logic, from a thing's being follows its being said [ad esse, sequitur dici]: therefore, since the apparent motion of all the spots is perpetually from the rising horizon of the Sun to the setting horizon of the same, their apparent motion is rightly and deservedly reported to be of this kind. And it is confirmed by the unanimous practice and consensus of all astronomers, who have defined the apparent motions of all the stars and all the comets, and their tendencies, not from the hidden hemisphere but from the visible hemisphere of the moving bodies. Hence the Sun and all the stars are said to rise each morning, to set each evening, and to complete their daily course from rising to setting...

[Margin: That the spot should be said to be carried from rising to setting.]

[Margin: Rising and setting are named from the visible hemisphere.]

Rosa Ursina — Book IV, Part I (continued)

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(continuing the sentence broken off at the previous catchword, "perfi-")

are said to complete their courses, precisely because they traverse the visible hemisphere. Here again both the Sun and the planets, and likewise all the fixed stars, are believed to complete their own proper periods from west to east, for no other reason than that such revolutions are observed to be carried out in the visible hemisphere. Since, then, the solar spots [*Maculae solares*] are carried across the visible face of the Sun — when the Sun stands above our horizon — always from the eastern region of the Sun toward its western region, whereas on the far side they can be perceived by reasoning alone and by no sense at all, it would be ridiculous, in defiance of sense, reason, and the authority of the ancients, to try to determine their periods from the upper and hidden hemisphere of the Sun that has already run its course — that is, to say that the spots rise when they emerge onto the Sun and set when they enter upon it — especially while the very question of their motion above the Sun is still under debate.

[Margin: An objection drawn from the designation of the epicycles is answered.]

But suppose someone objects with the epicycles of the planets and says that the motions of those epicycles are defined from the upper parts of their circles, and that the same must therefore be laid down for the motion of the spots, since they revolve about the Sun in the manner of epicycles.

I reply. Whether, and in what way, the spots turn about the center of the Sun — whether homocentrically or eccentrically, whether they circulate in epicycles or otherwise — is not now at issue and must be discussed later. This much is certain.

First: no planet is held by astronomers to move from east to west, or from west to east, except in the visible hemisphere and above the horizon under consideration.

Second: a planet carried on an epicycle is not said to be revolved either from the upper part of its sphere alone or from the lower part alone, but from both. And this is because, in the open hemisphere, the planet appears equally mobile in the upper and in the lower part of its epicycle. Hence astronomers had no greater

reason to define that motion as from east to west than as from west to east; and so, most prudently, they defined it from each toward each, separately. Accordingly, if this argument achieves much, it will secure this one point: that the spots are said to be carried below the Sun from east to west, and above it from west to east. Yet if their motion had to be named simply from the motion of those same bodies,

it would be said to be from east to west, because this hemisphere is always visible, the other never. And let these things be said as true, and by my own Apelles.

From this perpetual constancy of motion, then — from the invariable regularity of rising and setting — one ought gradually to lift up the mind, to suspect something great about this phenomenon [*Phaenomenon*], and not to reckon it among cheap and chance meteors, but to ascribe it to the celestial and solemn portents. For if the spots fluctuated about the Sun like clouds — as some such notion may seem able to suggest to the mind — just as we daily see clouds churning about the earth in the atmosphere, who does not see that it would rightly seem incredible, not to say impossible, that they should never at some time be borne by a contrary impulse from west to east? Who would deny that they must sometimes be driven from south to north, or from there toward the southern shore, as our clouds are wont to do? Since these things never happen, the cause of the spots must be far other — more certain and more divine — one that draws them by this constant law from east to west, while all the while they do not lack diffusions of their own within their orbit.

[Margin: The perpetual and self-same direction of the spots, both in rising and in setting, argues something great.]

Furthermore, there are many who think they can sufficiently explain the spectacle of the spots — visible beneath the Sun by their perpetual passage — through the perpetual and most orderly interposition of the celestial orbs placed beneath the Sun; so that the spots and faculae [*Maculae & Faculae*] seen beneath the Sun would be nothing but heterogeneous particles of the celestial orbs, more or less penetrable to, or illuminated by, the solar rays. Although this belief can be refuted by many and evident reasons, and already lies utterly prostrate on the strength of the earlier pronouncement, nevertheless, for the sake of those who pursue sincere truth, let us show *that from this alone — that the fixed course of the spots tends from the eastern region of the Sun toward the western — it cannot be attributed to any motion or arrangement of the subsolar spheres*; granting

meanwhile, though not conceding, that those orbs really exist just as these thinkers wrongly imagine.

Now the orbs of three heavens are, in the view — widely current in these times — of certain persons, placed below the Sun: those of the Moon, of Venus, and of Mercury. I shall treat of each briefly.

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FROM PRONOUNCEMENT II *it is shown that no sphere of the lunar heaven can cause the appearance of any spots upon the Sun.*

CHAPTER III

[Margin: The spots cannot be caused by the interposition of the orbs of the lunar heaven.]

According to those architects of the heavens, five orbs constitute the sphere of the Moon, one of which — the simple eccentric — always moves from west to east. If, therefore, by its own interposition it caused the spots, they would proceed beneath the Sun from west to east, which is contrary to the phenomenon.

The epicycle of the Moon moves in its upper part from east to west, and in its lower part from west to east. If, therefore, the spots appeared through its interposition, they would go partly from east to west and partly from west to east, and that at the same time — which is contrary to the phenomenon.

The two orbs that carry the apogee [*augem*] of the eccentric do indeed move from east to west, but so swiftly that each spot would scarcely remain on the Sun beyond a single hour — which is contrary to the phenomenon.

That any spot caused by this sphere and brought onto the Sun would scarcely remain on the Sun beyond one hour, I demonstrate as follows.

The whole revolution of these orbs is completed in 32 days, 3 hours, 5 minutes. Reckoned altogether, if the days are resolved into hours, this comes to 771 hours 5 minutes. If the resolution is carried down to minutes, the sum becomes 46,265'. Hence, if it be set up that 46,265' — that is, the whole periodic time — is to 21,600' (the whole circumference of the circle reduced to arcminutes) as 60' of time — that is, one hour — is to another quantity: then, the operation performed, there results 28' [followed by a stacked sexagesimal fraction: [?]], that is, 28 arcminutes and 3 seconds, which each point of the orb carrying [the epicycle], placed beneath the Sun, traverses in one hour, from east to west. But since the mean

diameter of the Sun is reckoned at 31', and the Sun, by its own hourly motion tending against the motion of these imaginary spheres, accomplishes about two minutes, it comes about that the aforesaid orbs traverse almost the whole solar diameter in one hour. For those two minutes added to the 28' make a sum of

30' — such an arc as those orbs complete, in the circle placed beneath the Sun, in about a single hour. And so it stands demonstrated, as I had assumed.

But the orb that carries the head of the Dragon [ascending node] completes its revolution in 18 Egyptian years, 7 months, 12 days, and each day advances from east to west by 3 minutes 10 seconds (as our Father Giuseppe Biancani [Giuseppe Biancani] would have it, in his *Sphaera Mundi*, chapter 2, page 139), or by 3' 11" (as Tycho [Brahe] would have it, *Progymnasmata*, book 1, page 026). The Sun, meanwhile, by its own proper motion in longitude from west to east, accomplishes — according to the same Biancani (book cited, chapter 4, page 207) — 59' 8" 19". If (neglecting the 19" this once) the courses of both are reduced to seconds, there result 190" for the motion of the lunar orb [node] and 3548" for the solar motion, per single day beneath the ecliptic. Added together, these give the daily arc of the ecliptic, 3738", run through in one day. Hence, since the Sun and any point of the said lunar orb traverse, by their mutual passages, 3738" of the ecliptic arc in 24 hours, how many hours will they spend in passing through the solar diameter of 31', or 1860"? It will take not quite 12 hours. But if the Sun stood still while the orb of the Moon moved beneath it, that orb would traverse some assigned point within it — the solar diameter — in 9 days and about 15 hours, more or less. Yet neither does this course agree with the spots. It is therefore impossible that the spots should be brought onto the Sun by any sphere of the lunar heaven — which was to be shown, for the satisfaction of the natural philosophers.

Furthermore, these motions are excluded from every simple subsolar planetary orb whatsoever, once we call to mind that the spots exhibit not only the said tendency of motion from east to west, but also a deviation now toward the south, now toward the north — and this with a shape and a duration of motion of such a kind as never has agreed with, nor can agree with, any of the said orbs. For these motions of the spots overturn every law by which the planets proceed. Finally, a certain peculiar dilation and spreading-out of the spots into every difference of place cannot be reconciled with the supposed adamantine hardness and inflexibility of the planetary orbs. But of these matters more fully elsewhere; here I wished only to touch on them, for it was chiefly from the sole east-to-west

tendency that I wished now to accomplish my intended point — namely, that the supposed

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orbs of the planets, admitted about the solar globe on hypothesis alone, can never cause upon the Sun any spots that would correspond, even in the least degree, to the motion of the solar spots. For contrary, or wholly other, things would both come to pass and appear. And so it stands shown — the very thing I had proposed to prove.

FROM THE SAME PRONOUNCEMENT II *it is shown that no orb of the Mercurial sphere can cause any spot upon the Sun by its passage.*

CHAPTER IV

[Margin: The spots cannot be caused by the fictitious orbs of the Mercurial heaven passing beneath the Sun.]

The sphere of Mercury is imagined to be composed of six orbs and two circles.

The two orbs carrying the apogee [*augem*] of the equant move from west to east; therefore they cause no spot, since the spots always go from east to west.

The eccentric carrying the epicycle tends from west to east; therefore it carries no spots, since these always go from east to west.

The epicycle proceeds from west to east in its upper part, and from east to west in its

lower part: therefore it draws no spots with it, which always and only travel from east to west — whereas here both directions would occur.

The equant circle tends from west to east; therefore it hinders nothing, since the spots tend from east to west.

The two orbs carrying the apogee of the eccentric tend from east to west, but neither hinder nor effect anything, because they complete the whole period in 365 days and 5 hours 49 minutes; whence each day some point of theirs advances about one degree. But the Sun advances by nearly as much from west to east by its own proper motion. Therefore, from these motions combined, any Mercurial spot would traverse the Sun in about five hours — which is repugnant to the phenomenon, as was shown in the first Pronouncement. And if, the Sun's proper

motion standing still, that sphere of Mercury were advanced, it would take about twelve hours — which again is repugnant to the phenomenon.

The small circle, describing a similar motion, will be dealt with by a similar reasoning.

Therefore, even were the fictitious orbs of the Mercurial sphere granted, no spots would be introduced onto the Sun by them. Which was the thing to be shown.

[The remainder of the leaf is blank; the whole lower portion carries heavy mirror-reversed show-through from the verso (printed p. 410 — itself absent from this scan), which includes a geometric discussion with point-letters G K M N O P. Not transcribed — bleed-through, [?].]

the orbs assigned to the planets around the solar globe—admitted only as a hypothesis—can never cause on the Sun any spots that would correspond, even minimally, to the motion of the solar spots. For otherwise everything would both happen and appear the other way round. And so what I set out to prove stands demonstrated.

EX EODEM II. PRONVNCIATO

It is shown that no orb of the Mercurial sphere can, by its own passage, cause any spot on the Sun.

CAP. IV.

The sphere of Mercury is imagined as composed of six orbs and two circles.

The two orbs that carry the aux of the equant [Augem Aequantis] move from west to east; therefore they cause no spot, since the spots always travel from east to west.

The eccentric that carries the epicycle tends from west to east; therefore it carries no spots, since these always travel from east to west.

The epicycle advances from west to east in its upper part, and from east to west in its lower part. It therefore drags along with it no spots—spots that always and only travel from east to west—whereas here both directions would occur.

The equant circle [Circulus Aequans] tends from west to east; therefore it does nothing, since the spots tend from east to west.

The two orbs carrying the aux of the eccentric tend from east to west, but they neither hinder nor produce anything, because they complete their whole period

in 365 days and 5 hours 49 minutes; hence on any given day they advance any one of their points by about one degree. But the Sun advances by nearly the same amount from west to east by its own motion; therefore, from these motions compounded, any Mercurial spot would traverse the Sun in about five hours—which contradicts the phenomenon, as was shown in the First Pronouncement. And if, with the Sun's own motion at rest, that Mercurial sphere were set in motion, it would happen in about twelve hours—which again contradicts the phenomenon.

The small circle, which describes a similar motion, will be dealt with by the same reasoning.

Therefore, even if the fictitious orbs of the Mercurial sphere were granted, no spots would be introduced onto the Sun by them. Which was to be shown.

[Margin: "Spots cannot be caused by the fictitious orbs of the Mercurial heaven passing beneath the Sun."]

EX EODEM II. PRONVNCIATO

No orb that is imagined to constitute the sphere of Venus can, by its interposition, cast any spot on the Sun before the sight.

CAP. V.

For the heaven of Venus they construct four orbs: two carrying the aux of the eccentric, the eccentric itself, and the epicycle; and they conceive besides one equant circle. But that none of these, by its interposition, makes the Sun variegated with spots or faculae, I show clearly from the very theory of Venus set before the eyes. In it: A, the center of the world; B, the center of the eccentric CS; C, the center of the epicycle IK; D, the center of the equant circle SR; E, the planet Venus. F is the East [Oriens]; G, the South [Meridies] and the point of the aux [apogee]; H, the West [Occidens]. EGIK is the epicycle carrying Venus E: from E, the west, through G, the south, to the east I, in the upper semicircle; in the lower one, IKE, from I, the east, through K, the south, into the west G. All the rest—namely the two eccentrics "in a certain respect" [secundum quid], D the inner and FLNH the outer, and likewise the eccentric properly speaking [simpliciter] GKMNOP—move from the west H, O, and P, through the south G and K, to the east F, M, and Q. Likewise the equant circle RMSO proceeds from the west O, through the south R, to the east M. Hence it is impossible that, through their crossing, any phases of spots or faculae on the Sun should be presented to an eye placed at A. For all spots advance from east to west, whereas here the contrary motion of

theirs would follow, from west to east; indeed, because of the interposed epicycle, both would follow: for the upper part EGI would present spots from west to east, the lower from east to west—all of which contradict the phenomenon. Therefore no orb, no circle of Venus can cause any spot on the Sun. This was what had to be demonstrated—and I have gladly demonstrated it for the sake of those who eagerly await this truth from this phenomenon. For among the mathematicians these matters are cheap and well-worn, since Venus herself, with her own horns [i.e. crescent phases], has long since leveled to the ground those hovels [casae] by which, as by certain prisons, she had until now been held confined by some, and has thrown open for herself the free heavenly plain...

around the Sun, in which she might range abroad, opening it for herself, while Mercury is confined between her and the Sun in narrower circuits. That Mercury too, therefore, frequently assumes horns is not to be doubted; yet armed with these same horns I judge that he is seen only with the greatest difficulty—partly because he makes but small departures from the Sun, partly because he is small, and not of so vivid a light as Venus. And if to this the attenuation of his horns should be added as they wax, it is no wonder that Mercury so rarely comes into view.

[Margin: "Mercuriū etiam cornutum fieri, quàm est." — That Mercury too becomes horned [crescent-shaped] [?].]

You will say that the demonstrations brought forward hold only against false suppositions, and proceed *ad hominem*, but do not absolutely establish that spots are not produced by other interpositions of orbs. For since it is certain that Venus at perigee moves below Mercury and the Sun, after the Moon, and at apogee above the Sun and Mercury—just as Plato in the *Timaeus* and Aristotle in Book 2 of *On the Heavens*, together with many of the ancients, once likewise placed these two planets absolutely above the Sun—someone might persuade himself that spots are introduced by the interposition of those new orbs, in which Venus and Mercury are carried around the Sun into the visible disk of the Sun.

[Margin: Objection: that spots can be introduced into the Sun by the interposition of new orbs.]

I answer, first: to restore antiquated fictions with new ones, and to wash mud with mud, is not advisable.

I answer, second: that the eccentric of the Sun—both the simple one and the two "in a certain respect" [secundum quid], hitherto held by others as true—does not, in their own hypothesis, admit these guests without penetration or destruction.

And if anyone should insist that new ones be built, the eccentric would of course have to be enlarged, and they would have to be intruded within its thickness.

[Margin: Solution of the objection.]

I answer, third: if the ancient architects of those orbs are now manifestly caught having been deceived, who would deny that new ones can deceive and be deceived by fabrication?—especially since men attempt to assert these things not because they are so, or know them to be so, or affirm them on any probable ground, but because they have brought themselves to believe that it can be so, and do not believe the contrary can be proved in any way; and they persuade themselves that this manner of affirming has strength enough for positing those orbs, provided they show them to be possible with some plausibility. But how weak this way of philosophizing is, is sufficiently plain of itself, even to one who considers it only in passing.

[Margin: "To fashion new orbs in the heaven without solid foundations is not to philosophize soundly."]

[Margin: Solar spots could not be induced in the Sun by the fictitious orbs of Venus, even if they were granted.]

[Margin: These things are brought forward for the sake of the physicists.]

Diagram. A large geometric schema of the Ptolemaic-style theory of Venus (the "Veneris Theoria" referred to in Cap. V), set within a square border at the head of the page. It consists of a set of concentric and eccentric circles about a central point, with two shaded (stippled) annular rings representing the thicknesses of the deferent/eccentric orbs, a small epicycle in the upper region carrying the planet, a vertical diameter and a horizontal diameter crossing at the world-center, and lettered points around the figure. Readable labels :

- R — top of the vertical diameter, on the outermost circle
- G — on the vertical axis just below R (identified in the text as the South/meridian and the point of the aux)
- I — left end of the epicycle's small horizontal diameter, upper region
- C — center of the small upper epicycle
- E — just right of C on the epicycle, marked with the planetary symbol ♀ (the planet Venus)
- K — on the vertical axis below C
- D — on the vertical axis below K
- B — on the vertical axis below D

- A — the central crossing point of the two diameters (the center of the world)
- F — left end of the main horizontal diameter (East / Oriens)
- M — on the horizontal diameter, between F and Q
- Q — on the horizontal diameter, left of A
- P — on the horizontal diameter, right of A
- O — on the horizontal diameter, between P and H
- H — right end of the main horizontal diameter (West / Occidens)
- S — on the vertical axis below A
- N — on the vertical axis below S
- L — bottom of the vertical diameter, on the outermost circle

I answer, fourth: not even if newly fabricated orbs of this kind were admitted would spots be introduced onto the Sun by them in any way. For although this would not be precisely overturned on the ground that the spots tend from east to west (since the progression of those orbs too would be from east to west, below the Sun), nevertheless that it cannot be brought about on other grounds will be shown more clearly than the Sun in the following Pronouncements, and is now demonstrated from the very discrepancy between the motion of those planets and the motion of the spots. This is what makes it so that from their orbs too you can obtain nothing for the present business. The epicycle, then—that is, the deferent of Venus ♀—the earlier System being abolished, remains as it were alone around the Sun, and completes its period in 583 days, 22 hours, 12 minutes...

all of which make up a sum of 837472 minutes of time. If, then, one sets up the proportion: as 837472' is to 21600, the arc-minutes of one whole circle, so 1440', the time-minutes of one whole day—that is, of 24 hours—is to a fourth term: when the calculation is completed, there will result 37' for the motion of one day. Now if again one sets up: as the 37' of one day is to 24 hours, so 31', the minutes of the solar diameter, is to a fourth term: there will result 20 hours. Therefore, if we suppose that spots are introduced onto the Sun from the lower part of Venus's epicycle, they would traverse the Sun in about 20 hours—which contradicts the solar phenomenon; for the spots consume, in their transit across the Sun, 12, 13, 14 days and more. Hence it is impossible that the heaven of Venus should cause them by its interposition. Which [was to be demonstrated].

[Margin: Even though the fictitious new orbs be granted (but not conceded), nonetheless a spot cannot be induced onto the Sun by their interposition.]

[Margin: From the motion of Venus it is demonstrated that spots cannot proceed from its orb.]

[Margin: The motion of Venus does not agree with the motion of the spots.]

which was to be demonstrated.

IDEM DEMONSTRATVR DE MERCVRIO

By similar reasoning: since Mercury, having lost his own—or rather his supposed—lodging, enjoys the solar palace, and dutifully surrounds it with his epicycle and cherishes it in his bosom—even if we allow that epicycle itself to be solid, and set it moving from east to west in its lower part—I nonetheless say that, by its interposition between us and the Sun, no spot can be sprinkled on the Sun.

For its epicycle, that is, its deferent, completes its period in 115 days, 21 hours, 5 minutes; all of which, reduced to time-minutes or scruples, will yield a sum of 166865 scruples. Therefore, if by the Rule of Three one sets up: as 166865 is to 21600, the circumference of the circle, so 1440—the 24 hours—is to a fourth term: there will result 186' [followed by a stacked fractional remainder printed as a small column of fractions — reading uncertain [?]], that is, 3 degrees 6' 24", and so on, for the diurnal motion. Hence if again (neglecting the 24", which are of no consequence to the present matter) one sets up: as 186' is to 24 hours, so 31', the Sun's diameter, is to a fourth term: there will result precisely 4 hours, in which some spot of the Mercurial heaven would run across the whole Sun. Since this is opposed to the phenomenon (for the spots linger beneath the Sun, according to the varying reckoning of the year, 12, 13, 14, and 15 days), it is impossible that spots struck off from the heaven of Mercury should be thrust onto the Sun. Therefore, since from the arbitrary solidity of those subsolar heavens, and from the motion of the planets themselves, and also from parallax and the true appearance of the spots' motion, it has been shown that the spots conspicuous beneath the Sun cannot be in them or belong to them, we must now look to the higher and nobler dwelling-place of those spots. But before I do so, the place and the occasion advise that I insert here what the illustrious and noble lord, Lord Johann Nikolaus von Smogulecz [Jan Mikołaj Smogulecki], of Smogulec, discusses—briefly indeed, but learnedly, in his *Sol Illustratus*—concerning Mercury and Venus received into the Palace of the Sun; for these things contribute not a little to the understanding of what has been said.

[Margin: The orbs of Mercury can induce no spot on the Sun.]

[Margin: The motion of Mercury does not agree with the motion of the spots.]

[Margin: The sum of what has been said.]

CAP. VI.

THEORIA ☿ ET ☉ CIRCA SOLEM

[The theory of Mercury and the Sun about the Sun.] In Theorem V, page 25, therefore, he speaks thus. Mercury:

"Mercury, joined to the Sun in undivided fellowship, is the nearest of the planets; it encircles the Sun and crowns it with its yearly course, and appears for nearly half the time above and, at the mean, below the Sun. For, as is clear from the well-proven discoveries of Copernicus and Tycho [Brahe], Mercury—not below the Sun, as Ptolemy supposed, but around the Sun—is revolved in its orbit; and, when it is nearest the Earth, it is distant by 585 semidiameters of the Earth, and when it is farthest, by about 1700 semidiameters. Yet it circles the Sun in such a way that it does not have the Sun exactly and precisely for its center, but chooses for itself another center near the Sun, distant from it by as much as the eccentricity of Mercury—namely 108 semidiameters of the Earth, as discovered by Copernicus (Book 5, ch. 27).

Therefore, so that the place of Mercury in the heaven of the Sun may appear, let the eccentricity of the Sun (in the smaller adjoining figure) be A, B, of 41 semidiameters of the Earth; the greatest distance of the Sun from the Earth, AE, of 1182 semidiameters of the Earth and 56 minutes [1182;56]; the semidiameter of the Sun's eccentric, B, E; and the eccentric SS—to which we now assign a certain latitude [breadth], greater, however, than geometric proportion would require, so that it may be better distinguished from the other two orbs carrying the aux, K and I, and its motion may be considered; though the mean circular line of the eccentric, E T, keeps its own proportion in distance. From the Sun's apogee E, therefore, upward, as far as C, let there be counted the eccentricity of Mercury, 108 semidiameters of the Earth, of the same units of which A B is 41; and likewise from the Sun's perigee T, inward toward the center, as far as M; and from M and C let there be described an epicycle whose semidiameter is equal to the semidiameter of Mercury's epicycle, that is, 480 semidiameters of the Earth. There will appear the place of Mercury in the heaven of the Sun, which it traverses in its course; and when Mercury is at G, it will have its greatest [elongation]; but when it is..."

[Margin: Mercury around the Sun.]

when it is at H, it will have the smallest distance from the center of the Earth A that it can ever have. For its greatest distance A G is composed of the epicycle radius C G — 408 Earth-radii — the eccentricity C E — 108 Earth-radii — and the greatest distance of the Sun A E — 1183 Earth-radii; which, added together, make 1693, or very nearly 1700 Earth-radii, as we assigned. Its least distance A E is obtained if, from the least distance of the Sun at perigee A T (1101 Earth-radii), one subtracts the eccentricity of Mercury M T together with its radius H M: there will remain 585 Earth-radii. For that is the least distance Mercury can ever have, namely when it is at perigee and closest to the Earth. From this I deduce the following.

Corollary I

If the epicycle C G is solid, then the heaven of the Sun is larger than we posited above, following the tenets of those astronomers who frame the solid spheres, and it is made equal to the circle O N — in such a way that, as regards its convex surface, its minimum distance from the center of the Earth is exactly as great as the greatest distance of Mercury A G from the center of the Earth, that is, 100 [?] Earth-radii.

Corollary II

Likewise the orbs of the Sun — the eccentric taken simply, the eccentric in a certain respect, and the eccentric-of-the-eccentric (if there are any) — do not complete whole circles, but each and all of them are interrupted by the epicycle passing through, as the geometrically drawn figure shows.

Venus

Next after Mercury among the planets that surround the Sun is Venus, which likewise — now higher than the Sun, now lower — encloses it by its own period and encompasses it with a much larger circle. For the radius of its epicycle is 823 Earth-radii; its eccentricity, 24 [Earth-radii]; its greatest distance from the Earth, 2029, its least, 255 — following Copernicus [Nicolaus Copernicus] (*De Revolutionibus* V.21), with whom Tycho [Tycho Brahe] very nearly agrees, although Copernicus in other passages asserts the same value in [other] parts rather than in Earth-radii; yet if you reduce those parts to Earth-radii, you will find just as many as we assigned.

Diagram. The upper (smaller) of two circular schematics on the page, showing the arrangement of Mercury within the heaven of the Sun. The printed caption, set between the two figures, reads "Mercurius et Ven[us] in Cælo ☉" ("Mercury

and Venus in the Heaven of the Sun"). A large outer circle carries the label O at the left end and N at the right end of its horizontal diameter. Within it lies a shaded eccentric ring (the deferent band), marked S on the left and S on the right. A vertical diameter runs through the whole figure.

- G (top, on the outer circle): apex of the vertical diameter
- C (upper small circle / epicycle, top):
- E (upper small circle, middle; crossed by a dashed line):
- ♀ (?) (just below E): planetary symbol
- B (center, upper):
- A (center): Earth
- O (left end of horizontal diameter):
- N (right end of horizontal diameter):
- S (left, on the shaded band):
- S (right, on the shaded band):
- H (lower small circle / epicycle, top):
- M (lower small circle, middle; dashed line):
- T (lower small circle, lower):
- ♀ (?) (lowest point): planetary symbol

Diagram. The lower (larger) of the two schematics — "the larger figure" referred to in the text — showing the path of Venus through the heaven of the Sun. It consists of several concentric circles about a common vertical diameter, with a shaded eccentric band.

- G (top): apex of the vertical diameter
- C (upper small circle, top):
- E (upper small circle, middle; dashed line):
- ♀ (?) (below E): planetary symbol
- B (center, upper):
- A (center): Earth
- P (below A):
- H (lower small circle, top):
- M (lower small circle, middle; dashed line):
- T (lower small circle, lower):
- ♀ (?) (lowest point): planetary symbol
- S (left, on the shaded band):
- S (right, on the shaded band):

- N (right, on the outermost circle):

[Margin: Diagram of the theory of Venus (*Schema Theoricum Veneris*).]

For Copernicus, and likewise Tycho, supposes the eccentric of Mercury and of Venus B E to be also the eccentric of the Sun, whose radius is 1142 Earth-radii — or, as we said above, 1150; thus Tycho, *De nova stella*, book 1, fol. 475. On these suppositions we again constructed the adjacent figure, from which the path of Venus through the heaven of the Sun may appear. For, once the eccentricity of the Sun A B has been assigned, together with its greatest distance A E and the radius of the eccentric B C, let there be counted (in the larger figure) upward from E the eccentricity of Venus, 24 Earth-radii — that is, 24 such parts as B A is 41; and from T inward, the same eccentricity as far as M. From M and E let a circle be described whose radius equals the radius of the epicycle of Venus, namely 822 Earth-radii. For that circle will represent the epicycle of Venus, in which it revolves about the Sun E, and it will mark out the greatest distance of Venus from the Earth A at G, and the least at P — because the greatest is composed of the greatest distance of the Sun A E, 1183; the eccentricity of Venus E C, 24; and the radius of the epicycle C G, 822 Earth-radii, which added together give 2029, the greatest distance Venus can ever have. Likewise, if you subtract the radius of the epicycle of Venus M P, together with its eccentricity M T, from the least distance of the Sun A T, there will remain the least distance of Venus A P, 255. From these things it is deduced as follows.

Corollary I

If Venus moves in a solid epicycle C G or M P, then the heaven of the Sun is much larger than we assigned above; for it must be at least as great as the circle O N, or the greatest distance of Venus from the Earth A G — that is, 2029 Earth-radii — at the minimum. For if the heaven of the Sun were not that great, but smaller, then the solid epicycle would enter into the heaven of Mars, which immediately surrounds the heaven of the Sun. But this can in no way happen — that part of the epicycle should lie in the heaven of the Sun and part in the heaven of Mars — since the heaven of the Sun moves faster while the heaven of Mars moves twice as slowly, and consequently that part of the epicycle carried with the heaven of the Sun would reach its terminus twice as fast as the part carried with the heaven of Mars, and so it would necessarily be torn apart, which is absurd.

Corollary II

Likewise the deferents of the apogee and perigee, K and I, and also the eccentric taken simply, S, cannot, in a solid heaven, be whole orbs completing their entire

circuit, but are interrupted on one side by the epicycle of Venus, as the figure, clearly drawn according to its geometric dimension, demonstrates.

So says he [the author here quoted], learnedly indeed and vigorously, according to the mind of Copernicus and Tycho and the common understanding of the learned of this age — arguments which I have brought forward because they are plain, and because they set before the eyes those orbs, otherwise exceedingly hard to picture, by a beautiful and easy method — a thing I have seen done in this way by no one — and also so that what has been said, and what is to be said below, may be better grasped. For these arguments, by which I have set forth the spots as being above the heavens — or better, as the subsolar courses of these three Wanderers [Errones], namely the Moon, Venus, and Mercury — are neither the only ones nor the chief ones, nor are they fully explained; all of which will be treated in their proper places in due course. Now let us return to the appearances of the phenomenon.

Third Pronouncement

No spot, and no facula, whether primary or secondary, ever appears outside the visible orb of the Sun — that is, outside its visible horizon.

Cap. VII.

[Margin: What is the solar horizon? (*Horizon Solaris quis?*)]

The visible horizon of the Sun is a circle determined by the visual rays that touch the globe of the Sun: namely, the common section of the plane and the solar globe, bounded by the contacts of the tangent rays, at right angles to the axis of the visual cone — the boundary of all those things that are seen on the Sun, dividing the Sun into two spherical segments, the exposed and the hidden. Of these, the former is shown to be greater than a hemisphere and the latter smaller, though the difference is imperceptible to the senses; hence the visual circle of the Sun is commonly taken for a great circle, since in fact it introduces scarcely any perceptible inconvenience — but wherever it does matter, I shall give warning.

[Margin: Synonyms of the apparent solar hemisphere (*Hemisphaerii Solaris apparentis Synonyma*).]

Now the rays, observed from the outermost and marginal contact of the Sun, are concentrated into a convex observing lens; and from there, an intersection gradually being made, they are drawn out into an inverted cone, and its radiant base, behind the concave lens, they project onto paper and there paint a bright

circle. This visible circle of the Sun, then — which is everywhere called the disk, the orb, the surface, the face, or the visible countenance of the Sun — is by me, for the purpose of my design, named the Solar Horizon, inasmuch as it embraces in its own bosom everything that is to be seen on the Sun, while whatever lies outside it is not seen on the Sun at all.

[Margin: The functions of the solar horizon (*Officia Horizontis solaris*).]

Further, [it is so named] because by it the rising and setting of the spots is determined; and finally, because in it all things are in a manner seen — for all things are projected onto it and examined in its plane, and so forth. Hence it has deservedly claimed for itself the name of horizon and Finitor [boundary-marker].

Now this Pronouncement has been sufficiently proved and established by so many years of most diligent investigation, by so many accurate observations adduced in the earlier book, and finally by so many concurring opinions of astronomers. For since some, having wrongly understood my *Apelles* from a reading of it, had persuaded themselves that the Sun's spots had been observed by me as though they were little moons [lunulae] outside the Sun, and that this had been asserted by me, they all strained their sinews in observing, to catch me out by experiment. When they could not manage this, they testified in their writings that outside the Sun nothing at all had been noticed concerning this phenomenon — which I never doubted. But if I disputed anything about the spots as though carried around outside the Sun, I did not do so on the ground that I saw them outside the Sun with my eyes, but because, from the apparent inequality of their motion detected on other grounds, I brought forward certain arguments in the manner of one doubting rather than one firmly affirming. Hence, if from the spots I made bright little moons by the reflection of solar light, this was done upon a supposition (namely, that they are carried outside the Sun) and was not asserted by me absolutely.

[Margin: *Apelles*, wrongly understood, engendered in certain people a false suspicion about its author.]

Now, while I treat this phenomenon and examine the observations, I was most singularly attentive to this matter — [to see] whether by any means at all possible I might catch sight of some notable spot or facula, whether rising or setting, outside the perimeter of the horizon. And although the Moon eclipsing the Sun rather broke my effort concerning the spots — because of the Moon, insofar as it does not stand beneath the Sun, nothing at all falls within view, just as I once investigated most carefully at Ingolstadt while [the Moon] was eclipsing the Sun

— nevertheless the appearance of faculae, at least of the larger and more notable ones, could not, if they were elongated to some extent beyond the surface of the Sun, escape the sharpness of the eyes and the power of the telescopes; especially when, on the horizon — so brilliant, and as if cut off at the perimeter — they took up whole days in ascending and descending. For since bodies placed against the brighter [part] of the Sun's body shine out and are seen, it is evident that the same bodies, placed against a less bright [background], will be seen still more. And it is certain that the aether poured around the Sun is less bright than the Sun itself; therefore, if some facula is discerned by sight in the middle of the Sun, how much more so if it moves next to the Sun in the less brilliant aether?

[Margin: A portion of the Moon projecting beyond the eclipsed Sun is not seen.]

[Margin: If faculae were to project beyond the solar horizon, they would also be seen outside it.]

You will object: Venus at apogee, Mars, and Jupiter, when they are to be conjoined with the Sun, lie hidden in its rays; and yet it ought to be doubtful to no one that the brilliance of Venus, the fires of Mars, and the lightnings of Jupiter are far more brilliant than the splendors of the faculae. Therefore, just as the said planets, brighter than the faculae, grow dark [*noctescunt*] in the presence of the Sun, so it ought to be a wonder to no one if the faculae too, placed outside and next to the Sun in the clear aether, do not shine.

[Margin: An objection from the conjunctions of the superior planets with the Sun.]

I answer: All the superior planets near the Sun are indeed most intensely illuminated in themselves, yet are darkened to us because of the presence of the Sun, which by the abundance of its light so occupies our sight that the sensation of their light cannot reach us — not because their images do not, even at midday, reach us or are not admitted into our eyes, but because the presence of the more intense light (namely the daylight) obscures all the radiant presence of those stars, so that it is not within the power of the visual faculty to apprehend them distinctly. But that the stars and planets do send down their rays into our sight equally whether the Sun is present or absent —

[Margin: Solution of the objection.]

[Margin: The planets shine even by day, but are not perceived.]

— is clear from this: that the effusions of images necessarily occur, provided that light does not impede light in its flowing, and no other opaque body comes

between. Indeed, the experience of many establishes this — of those who have seen the planets with the naked eye at midday. From their number I do not exclude myself: for once, while I devoted myself to Philosophy at Ingolstadt, I often looked at Jupiter with many companions almost at the meridian, and showed it to others. And so there is no doubt that the visible images of the planets always stream forth, and indeed flow into the open and opposed eye; but I say that they are not perceived, because of the efficacy of the greater light. This [greater] light, however, is not that most brilliant light which surrounds the Sun, the planets, and the other heavenly bodies, blazing in that most fluid aether, but our own daylight, which besieges the sight here below. This is proved by daily experiments: for when the twilight darkness vanishes in the morning, the stars too are extinguished; and when it comes on in the evening, they are kindled. And these things do not happen because that upper air [aura] is illuminated or darkened, but because our neighboring air is darkened in the evening by the interposition of the Earth's shadow, and illuminated in the morning by the shadow's withdrawal; and thus the present daylight takes away the sight of the planets nearer the Sun, and its absence restores it.

[Margin: Daylight takes away the daytime sight of the planets and of the stars.]

The same is proved by experience in another way. For if through a telescope you wish to trace onto paper any of the brighter planets shining by night, you will indeed accomplish it, but not without darkness surrounding the eye; otherwise, if even a little light invades the paper or the eye, it will strike out the image [species] of the planet caught on the paper — not because its image is truly removed from the paper, but because the eye, flooded with greater light, is unable to perceive the weaker one. Something similar will happen if you wish to hunt down the magnitude of the Sun admitted through a very small aperture: for that image of the Sun is impatient of any other light let into that place, since any [light] that enters diminishes the image of the Sun; and this comes about for no other reason than that the presence of a brighter [light] strikes out, in the eye, the [image] shining less around its edges; and so it appears smaller in the presence of foreign light than it would otherwise have been by itself. This experience, incredible to many, I have demonstrated by the fact itself. For when I had admitted the Sun through an aperture so small that it almost escaped the sharpness of even the best eye, and had excluded from the chamber all other light, we saw the image of the Sun presented on the paper set before it in its due magnitude; but as soon as, from any place whatever, we ad-

[Margin: It is proved by experiments that the presence of light extinguishes the perception of the images [species].]

[Margin: The admission of the Sun through a very small aperture.]

mitted a little external light, at once the aforesaid image of the Sun perceptibly diminished in everyone's eyes; nor was it possible to restore that diminution except by again excluding the admitted light. From this we concluded that, by the presence of a greater light, the sensation of a lesser one in the organ of vision is obliterated. But concerning this experiment of the solar image I shall give more, and more exact, particulars below, where, at the end of this part, I shall inquire into the absolute magnitude of the spots and faculae.

[Margin: When the Sun is totally eclipsed, the stars appear.]

But the greatest of all, and the experiment proper to this matter, is a total eclipse of the Sun, such as occurred in the year of the Lord 1560 and was seen in Lusitania [Portugal], to such a degree that the stars of the firmament appeared most clearly — just as Christophorus Clavius [Christoph Clavius], in Chapter 4 of his commentary *On the Sphere [In Sphaeram]*, p. 594 of the Roman edition of 1606, has left attested in these words:

"And, to bring forward publicly what we too once observed in this matter, I shall recount two notable eclipses of the Sun that happened in my time, not so long ago. One of them I observed in the year 1560, at Coimbra [Conimbrica] in Lusitania, around midday: in it the Moon was interposed directly between the sight and the Sun, so that it covered the whole Sun for no small interval of time, and the darkness was somehow greater than that of night. For one could not see where to set one's foot, and the stars appeared most clearly in the sky; and — what was marvelous — birds fell out of the air to the ground, out of dread of so foul a darkness." So says he. This same eclipse Father Emmanuel Vega [Emmanuel de Vega], a Portuguese of our Society, still living and an eyewitness, now residing at Rome these many years, confirmed to me as I was writing this. He said that, while a midday meal was being taken, it so increased that darkness — to the dread of many — that at midday it was necessary to light lamps; and that the whole duration of the eclipse was extended beyond three hours, while the concealment of the whole Sun and the sight of the stars matched the space of an hour at the very least. Meanwhile the female sex, ignorant of astronomical matters, running through the crossroads and streets, bewailed with tears and pitiable wailing that the Last Day of Judgment was at hand. He added, moreover, that those shadows were so intense that he beheld the stars throughout the whole

sky as bright as he never [saw them] otherwise in his whole life. A similar eclipse was seen in Spain in the year of the Lord 719, as is com-[memorated] in its Annals... ..which I read in these manuscript compendia in recent days. And so, besides many other prodigies seen in the heavens, they record the following. The Sun was especially so robbed of its light that throughout all Spain the stars were seen for two hours, as if in the dead of night, the Moon giving no light.

[Margin: Examples of stars seen during solar eclipses.]

In agreement with these are the *Annals of Constantinople*, by the author George Kedrenos [Georgios Kedrenos], in the 9th year of Justinian, who was the son of Constantine Pogonatus: "So great," he says, "was the eclipse of the Sun that the stars were seen." The same author, on p. 489, in the 2nd year of Leo, who was the son of Basil: about the same time, the Sun was so eclipsed at the sixth hour of the day that the stars were seen. The same, p. 544, in the 4th year of Nicephorus, on the 22nd day of the month of December, at the 3rd hour: so great, he says, was the eclipse of the Sun that the stars too appeared. The same, p. 572, under the brothers Basil and Constantine, the Sun was eclipsed even at midday, and the stars were seen.

[Margin: From the Annals of Constantinople.]

From the Library of Pierre Pithou [Petrus Pithoeus], jurisconsult, the *Annals of the Franks*, Paris edition of 1588, p. 43 of the first part. In the year of the Lord 839, under the Emperor Louis [the Pious]: "On the very eve of the Lord's Ascension," he says, "that is, on the 4th day before the Ides of May, an eclipse of the Sun occurred around the 7th and 8th hour of the day, so severe that the stars too were seen on account of the Sun's darkness, and the color of things upon the earth was changed." The same, p. 134, part I, in the year of Christ 878: the Sun likewise, on the 4th day before the Kalends of November, after the 9th hour, was so darkened for half an hour that the stars appeared in the sky, and all thought that night was upon them. Ibid., p. 281, in the *Life of the Emperor Louis the Pious*: "At which time," he says, "an eclipse of the Sun occurred, on the third day of the greater Litany, in an unusual manner. For at the threefold withdrawal of the light, darkness so prevailed that nothing seemed to differ from true night. For the fixed order of the stars was so clearly discerned that no star suffered any dimming from the solar light: rather the Moon, which had set itself opposite the Sun, gradually seeking the east, restored to it its light little by little in a crescent shape from the western side—in its usual manner, as when it is first seen new or on its second day—and thus through increments recovered its full beauty, until the whole disk of the Sun was restored."

[Margin: From the Annals of the Franks.]

I have it from a Spaniard, a most learned man wholly worthy of trust, that in the year 1601, on the 24th day of December, when he had seen an eclipse of the Sun at Villa Regia [Villarreal?] in Spain, he at the same time beheld the stars of the Firmament together with the others. He added that in Spain it is common knowledge that in deep wells, with the sky open above, one sees even the stars shining in them by reflection,

[Margin: Other ways of viewing the stars by day.]

as if from a most sharply defined mirror, and sees them even at midday, and men claim to have contemplated them frequently. The Coimbrans [Conimbricenses], and others, affirm that they are seen from a deep well. These experiences are not to be neglected by the astronomer, since they can be of the greatest use. Therefore, from the examples adduced—the day snatched away by the lunar opposition, the Sun removed, night brought on, and the stars standing everywhere in view—the following consequences follow.

It follows, first: that the conjunction of the stars with the Sun, considered precisely, is not the cause why a star is not seen when it is joined with the Sun—unless that conjunction be a bodily one. Otherwise, not even in these eclipses would the stars near the Sun have been seen; but the contrary occurred. Therefore, when the superior planets are joined with the Sun, they do not escape sight for the reason that they are conjoined with the Sun, since in a like case they could be at once conjoined and at once visible.

[Margin: The lateral proximity of the stars to the Sun is not the cause why they are not seen by us.]

It follows, second: that those most splendid celestial shores and breezes, glowing white with solar radiance, are not the cause why the planets conjoined with the Sun do not reach our sight perceptibly—as though that aura, dazzling our sight with its own brilliance, thereby barred our eyes from the sight of the planets. I say this is not the cause; because in these total eclipses of the Sun, apart from the body of the Sun, that region was left almost wholly uncovered by the Moon; and around the Moon a most free field lay open on every side for the eye to range over; and moreover that whole superlunary region was surveyed by the solar light equally within the eclipse as outside it, and lay open to the eye everywhere except at the Moon. And yet, these things notwithstanding, the fixed stars of the firmament and the planets moving above the horizon shone out bright as at

midnight. That ethereal region, therefore, however imbued with splendors, is not the cause why stars near the Sun should be snatched from our sight.

[Margin: The most brilliant aether does not take away the visibility of planets laterally conjoined to the Sun.]

It follows, third: as to why the planets and other stars near the Sun disappear from our eyes, no other cause is to be found than the daylight received into our neighboring air and into the eye. And this is proved thus: that which, when removed, takes away an effect, and when restored, restores it, is the bringer of the cause; now daylight, when removed, takes away the disappearance of the stars, and when restored, restores it: therefore daylight is the bringer of the cause of the disappearance of the stars. The major premise is well known; the minor is clear from the eclipse and from the other experiments adduced. The conclusion therefore stands. Our atmosphere, then, pervaded by the solar light and found above our hemisphere, striking upon the eyes, [makes] the weaker

[Margin: Daylight alone makes the stars joined to the Sun disappear.]

radiations of the stars fail—not physically, but optically. It fails them in the one way because the images of all the stars are present even when the Sun is present; and in the other way because, through the excellence of daylight, the radiant images of the stars, being dulled, cannot be perceived. Hence, when darkness succeeds the daylight—whether this comes about by the earth (as happens each night) or by the interposition of the Moon in solar eclipses—once the tyranny of the stronger light is removed, the weaker luminous cones of the planets and stars exercise their rights upon our sight. And so, since the solar faculae, beneath the Sun, on any clear day, throughout the whole year, in summer as in winter, hurl their brightness and their most luminous fires into our eyes,

[Margin: The light of the solar faculae surpasses daylight.]

I conclude, first: that the light of the faculae is stronger than daylight; otherwise, if daylight were stronger, it would prevail in the eye and would smother the image of the faculae received on paper—the contrary of which happens; for many faculae shine out even when the observation is set up under the open sky.

I conclude, second: that the light of the faculae is stronger than the rest of the light of the solar globe; otherwise the faculae would not shine forth out of that common light of the Sun.

[Margin: The light of the solar faculae is stronger than the common light of the Sun.]

I conclude, third: that the light of the faculae is stronger than any light whatever of a body surrounding the Sun, in the order of sight. For if it is stronger than daylight for sight, and stronger than the solar light, then it is assuredly more vigorous than a surrounding light as well—because the light encircling the Sun comes only from the Sun, and is in a most thin and rarefied body, and for that reason much weaker for acting. Therefore, arguing from the stronger case: if the solar faculae, by the excellence of their light, outstrip the common and uniform light of the Sun, how much more will they surpass a fainter one.

[Margin: The light of the faculae is more intense than the light of the celestial aura.]

I conclude, fourth: that the light of the planets combined with the light of the faculae is of less strength than if it be compared with the common light of the Sun; for the light of the faculae is more intense than the common solar light, and therefore much more intense than the light of the planets.

Hence the objection made at the outset from the planets comes to nothing.

[Margin: The light of the faculae surpasses the light of the planets, more than the Sun stripped of its faculae does.]

[Margin: The objection made at the outset vanishes.]

I conclude, fifth: if the faculae move in the celestial aether next to the Sun, on any side whatever, they will necessarily be seen.

It is proved, first: the Sun will be seen in any region of the aether; therefore the solar faculae, moving next to it, would also be seen, for they are, as has been proved, brighter than the Sun. But I suppose the faculae to be of their usual magni-

[Margin: If the solar faculae are outside the Sun, they will be seen outside, at the sides.]

tude; for a facula could be assumed to be so small that it would escape the sharpness of sight by the smallness of its body, not by any faintness of its light.

It is proved, second: some portion of the Sun, as large as some great facula, placed next to the Sun, would shine; therefore a facula would do the same, since a facula is brighter than a common portion of the solar body.

It is proved, third: the faculae shine upon us from the Sun, as experience makes clear; therefore they would shine much more amply next to the Sun in the aether

—since what radiates from a brighter source shines more amply than what radiates from a less bright one; but the aether shines less than the globe of the solar body, as is self-evident.

It is proved, fourth: the causes why the solar faculae should not shine would be either the aether surrounding the Sun, or our air, or the Sun itself. But from none of these can any reason be assigned why the faculae should shine any the less when placed in the aether outside the Sun: therefore, if they go forth thither, they will shine. The consequence of the major is proved: because, apart from those three causes, none can be devised why faculae placed in the aether would not shine. The minor is proved: because in fact the aether surrounding the Sun does not hinder the stars from reaching us with their splendor in a total eclipse of the Sun, as has been proved; therefore much less does it hinder the faculae. Indeed, they daily surpass in splendor our daytime air and the Sun itself, as experience witnesses. The minor therefore stands proved.

I conclude, sixth: the solar faculae are not distant from the Sun, nor do they go out beyond its surface, nor do they perceptibly project, but they are within it as parts. It is proved thus: because if they were distant, this would be perceived around the limb; the same would happen if they went out from its surface or perceptibly projected. But none of these occurs. Hence it is concluded that they are brighter parts of the Sun, from the fact that they at times, as it were, alternately settle upon the Sun and make it whole, and that, if they were removed from it in thought, the whole Sun would be a mere secondary spot [*Macula secundaria*]. That the secondary faculae settle here and there upon the secondary solar surface, among the secondary spots, has been shown sufficiently from the observations and their Notes in the earlier book, and especially in the last Image of the Observations, or the Meditullium [core] of the Sun, in which the whole face of the apparent Sun is set forth and explained according to plan.

[Margin: The solar faculae are parts of the Sun.]

This argument, though for the most part physical and less geometrical, is nevertheless to a certain extent optical; and it is of such force that it seems altogether to prove its point.

COROLLARY I

Hence it also follows that the spots are contained within the physical surface of the Sun, because the apparent motion of the spots is the same as that of the

faculae—which would not be so if the spots receded from the center of the Sun any more, at least perceptibly, than the faculae do.

[Margin: Spots, like faculae, are within the Sun.]

COROLLARY II

The rotation of the Sun follows directly from this same head, especially if the spots and the secondary faculae are called in as aids. For since these compose, as it were, the whole Sun, and are moved uniformly with a non-uniform motion, yet do not leave the Sun, it is necessary either that the Sun rotate, or that no Sun be seen at all: for that which shines from the Sun and is seen, rotates.

[Margin: The Sun rotates about its own center.]

To all this Galileo [Galilaeus] gives his assent, in his *History, Delle Macchie [Solari]*, last letter, p. 132, in these words:

[Italian:] "I hope that from what I have said thus far, Apelles will be left satisfied, especially by my adding what I wrote in the second letter; and I shall believe that it will present no difficulty to him—not only concerning the very great nearness of the spots to the solar globe, but also concerning its revolution upon itself; in confirmation of which I can add, to the reasons that I wrote in the second letter to Your Lordship, that on the same face of the Sun there are sometimes seen certain little patches brighter than the rest, in which, carefully observed, one sees the same motion as in the spots; and that these are on the very surface of the Sun, I do not believe can remain in doubt for anyone, since it is in no way credible that any substance more resplendent than the Sun itself should be found outside the Sun; and if this is so, it does not seem to me that there remains any room to doubt the revolution of the solar globe upon itself. And such is the connection of these truths, that from it there then correspondingly follows the contiguity of the spots to the surface of the Sun, and their being carried around by its revolution—no [spot] appearing by any

probable reason [to move otherwise], as they would if, being separated from the Sun by a great space, they had to follow its revolution."

This is what he says, which I understand in Latin as follows:

[Scheiner's Latin rendering:] I hope that Apelles will be satisfied by what has been said thus far, especially if he joins to these the things I wrote in the second letter; and I trust that there will be no difficulty for him—not only concerning the nearness of the spots to the Sun, but not even concerning the revolution of the

Sun itself. In confirmation of this, besides the reasons already adduced and stated in the said letter to Your Lordship, I can add this too: that on the very face of the Sun there sometimes appear patches brighter than the rest, in which, diligently observed, the same motion is found as in the spots; but that these adhere to the solar surface, I do not think can be called into doubt by anyone, since it is in no way credible that any substance more resplendent than the Sun itself should be found outside the Sun—which being granted, I do not see how it can come about that the Sun should not revolve upon itself. And this is the connection of the truth, from which there then follows a fitting contiguity of the spots with the Sun, and a corresponding circulation; whereas, on the contrary (if they were separated from the Sun by a great space), no probable reason would be at hand by which they should conform to the solar motion.

This is what Galileo says, concerning my Apelles [Scheiner's own earlier pseudonym]. Here note that I, from the really unequal motion of the spots, had raised a doubt and inquired whether the spots might not recede somewhat from the Sun, and unequally. Since Galileo held the contrary of this, he proved, from the faculae adhering to the Sun, that the spots too are within it, on the ground that the motion of both is one and the same.

What Galileo inferred is true, but he inferred it less solidly, since he proved that the same reasoning holds in the case of the faculae and of the spots—namely, that in the faculae, diligently observed, the same motion is found as in the spots—whereas he himself observed that motion so carelessly that he supposed the motion of all of them to be constantly rectilinear and parallel to the ecliptic, and, moreover, that their tarrying above the solar horizon was equal: things that have been demonstrated to be expressly false in Books 1 and 3. Wherefore, if the motion of the spots had been curvilinear—as perceptibly it almost always is—but that of the faculae rectilinear, as he himself asserts, there would have been an open discrepancy leading to opposite conclusions, and he himself would, from the deception, have inferred the same [wrong result]. Moreover, the means by which he proves the faculae to be within the Sun is something physically probable,

which I likewise indeed employ, but fortified with the firmer safeguards of observations and reasonings, of which he is wholly destitute. For when he had, in the second letter, p. 49, at the end, called this very rotation of the Sun into doubt, he makes it probable from this single conjecture, founded thereon: that so constant and regular a motion as is discerned in the spots could not have its root and primary foundation in a fluid substance, and therefore one easily disturbed

by accidental motions; yet he places the spots there in the surrounding [medium], or at most contiguous to the solar body. Their constant motion he wrongly took to be an always uniform one, and meanwhile ignored the annual motion, which he would much more probably have attributed, together with the other, to the solar body itself.

COROLLARY III

Eccentrics and epicycles are utterly banished; for if the center of the Sun always remains in the line of the ecliptic, and if the spots and faculae never go out beyond the physical surface of the Sun, then it is clear that the epicycles and eccentrics of the spots about the Sun—which it has pleased some, who pervert this phenomenon, to fabricate—cannot exist.

[Margin: Eccentrics and epicycles are excluded by this phenomenon.]

COROLLARY IV

From the same source, neither the spots nor the faculae can be reckoned in the number of the stars—unless one should wish to assert that the solar globe is nothing else than an infinite and randomly heaped-up mass of little stars, which is solidly refuted on other grounds.

[Margin: Faculae and spots are not stars.]

You will say that the argument made from the moving faculae for the rotation of the Sun holds good only if the solar faculae are supposed to be some luminous body, suffused with an internal and permanent light; but that, for the rest, if anyone should say that the solar faculae are a certain appearance of brightness, generated either from reflection or from refraction, the whole argument would be rendered feeble.

[Margin: An objection drawn from refraction and reflection.]

I answer, without qualification: that the faculae both exist, and—both as things already proved and as things yet to be proved—are supposed to be a body intrinsically luminous, and not to arise from reflection or refraction. This will be shown in its proper place below, where the origin and destruction of them is discussed.

[Margin: Reply.]

THE FOURTH PRONOUNCEMENT

No spot has been seen, in all these years now, either to stand still upon the Sun, or to move backward, or to be hurled downward.

CAP. VIII

This pronouncement is true of all and each of the spots, and is proved from all the courses—whether of many spots or of single ones—already adduced and yet to be adduced, all of which proceed in a manner and motion perceptibly proportional and uniform, as is clear from the images of the observations already adduced, and will be discussed more fully in their proper places. For this matter needs no other proof than the explanation of its terms. Therefore, when I say of the Sun, "No spot has been seen to stand still," the sense is: that at a notably different time, any given spot has held, and holds, or will hold, a notably different place, by advancing from east to west [ab ortu in occasum]. Now a notably different time is, in the middle of the Sun, about one hour, and around the margins two or more, according as you have used a large or a small observing circle; for at such intervals of time the progression of the spots from east to west, at the said places, will be observed by an accurate observer equipped with good instruments, in large Observation-Circles.

[Margin: Explanation and proof of the Pronouncement from the observations.]

When I say that none has been observed to move backward, I mean it of the proper motion of the spots, not of the common, everyday, diurnal one; for that they become stationary, retrograde, and progressive as a result of this [diurnal motion] was shown in the preceding book, and the manner and reasons of that motion have been amply set forth. But that station, regression, and progression does not affect the proper motion of the spots, which is carried forward about its own axis, in its own parallel, just as if those appearances never occurred at all.

When I say that no spot has been noted to be hurled downward, I do not compare the motions of single spots with the motions of all, or of single ones, or vice versa; but the motion of each to itself. So that the sense of the pronouncement is this: that a spot, while it tends from east to west, has not been seen to be carried unsteadily or by fits and starts, so as to be now swift, now slow, and again swift, ...nor, being swift, does any spot lay out its course with an erratic back-and-forth motion. But if some spots have been observed to be faster than others, these have kept their own speed, and the slower ones their slowness. This is not contradicted by the apparent crowding-together of the spots toward the edges of

the Sun, nor by the proportional and fixed contraction of their daily intervals, which arises from the rising and falling gradients of their courses. Once explained in this way, this needs no further proof, as I have said; for observations cannot be established except by honest statement and true explanation. And whoever demands more from a faithful observer ought to make himself an observer. Yet such a person, just as he will fail everyone else, will not satisfy even himself, not even in that way; for to convince himself he will produce nothing beyond his own bare observations.

Either, then, the whole phenomenon must be denied, farewell must be bid to the whole of astronomy, and all knowledge derived from the senses must be utterly destroyed — against all sense, against reason, and against the practice of true philosophy — or else, what is most true, we must at last take our stand on certain first observations. If you do not recognize mine as such, then let us have yours; and if these have been worked out with the care and fidelity that are due, I should scarcely believe they would diverge from mine. If they do diverge, you will not take it ill that I trust mine more than yours; for whatever a person does to others so that the same may be done to him, by that very act he recommends it. [Margin: Trust must at last be placed in observations.]

From this pronouncement the following corollaries follow.

COROLLARIUM I.

[Margin: Eccentric orbs below the Sun are excluded from this phenomenon by the pronouncement.]

The spots are not carried in eccentric orbs below the Sun; otherwise they would sometimes be retrograde, which does not happen. That they would be retrograde is clear from this: in apparent latitude they do not go beyond the Sun, but are confined within a fixed band. And further from this: over some appreciable span of time they are carried along a nearly straight path, so far as the senses can tell. From this it follows that their plane is not much inclined, but stands almost upright with respect to the solar circle, so that the axis of the eye and the parallel of the spot lie, as it were, in the same plane, at right angles to the solar horizon. Hence, when such a spot is carried in the upper part of its circle, it will not pass beyond the Sun toward the north or the south, and so it would appear retrograde below the Sun — which, however, is false. Therefore the spots are not carried below the Sun in eccentric orbs, which was what was proposed.

COROLLARIVM II.

[Margin: Epicycles, like eccentrics, play no part in this phenomenon.]

The spots are not carried in any epicyclic orbs, whether below the Sun or around the Sun, and this whether in eccentric or in homocentric ones. For they would undergo, even more severely, the same effects that we have just now explained and cleared away in the preceding corollary. For these epicycles would be carried around within certain other circles below the Sun, or around it — whether homocentric, or eccentric, or any circles whatever — and these epicycles below the Sun would often twist the spots back toward the east, and so on. Since this conflicts with the phenomenon, it must not be asserted. Therefore the spots are not carried around in any epicyclic orbs, whether below the Sun or around the Sun — which was to be demonstrated.

PRONVNCIATVM QVINTVM.

The paths of all the spots appear, at the same time, to be of the same kind and the same position, other things being equal.

CAP. IX.

[Margin: The sense of the pronouncement is explained.]

I mean that if the path of one spot is rectilinear, the paths of the others are so as well at the same time; and if one is curvilinear, the others are curvilinear too at the same time. I add "other things being equal" because there are certain factors that introduce some disparity, as the kindly reader will understand well enough as we proceed, when I point them out in their proper places.

By "the same time" one should not understand the whole course of one spot as coinciding, at some point and place, with the whole course of another. Rather, the word "time" must be understood in a wholly strict and rigid sense: according to the days, and with observation made at a perceptibly identical time — so that on whatever day and at whatever time any spot marked on the Sun and on the observing circle has proceeded along a rectilinear path, on that same day and time all the others describe similar paths; and none advances along a bent track while others go straight, nor along a straight one while others complete a curved one.

By "the same position" I mean the relation of the path-lines to the regions or poles of the solar globe: so that the curvilinear paths of the spots are all concave toward

the same region at once, and convex toward the same region at once; and if they are rectilinear, they keep a roughly similar orientation and a nearly equal inclination to the ecliptic [Ecliptica]. They must also be taken in the same region of the solar circle, whether the eastern or the western.

This pronouncement, explained in the manner stated, is established by the whole of the previous book and by the constant experience of so many years now, so that nothing more is needed than to refer the reader to the pictures and to the particular notes of the observations; for there he will see this property of the courses recurring again and again and being driven home.

From this pronouncement it follows that the subject of this universal motion common to all the spots — that is, its moving cause — must be one and common to all the spots. And so, either there will be some single sphere that carries around with it both the spots and the faculae embedded in it, or one that whirls them around as they cling to it. That this very sphere is the solar globe itself has been proved partly by the preceding pronouncement, and will partly be shown from what follows. [Margin: The common subject of the spots' motion is the Sun.]

Note: if it ever happens — as it usually does — that while some spots, whether northern or southern, curve somewhat, others leave behind them rectilinear traces of their paths, this comes about from the refraction of the lenses [lenticum refractione]; and further, it is so slight that it detracts little or nothing from the straightness, so far as the senses can tell. And therefore nothing should be subtracted from the pronouncement on that account, for we are speaking of perceptible appearances. [Margin: A caution.]

PRONVNCIATVM SEXTVM.

All the paths of the spots described year by year from the same parallels are, to the senses, similar to one another, and for the most part equal in time.

CAP. X.

[Margin: The sense of the pronouncement is set out.]

This pronouncement can have a twofold sense. One is that the motion of any given parallel described in a single year — the motion along which the spots proceed — is annual, and is similar and equal to the annual motion of any other year; and this sense I do not intend. For although — as will be seen in the proper places — there is an annual motion of the whole Sun and of each of its points

about the pole of the solar ecliptic, and so on, still I am not inquiring into that here.

The other sense of the pronouncement, then, is this: that any given solar parallel, at like times of the year, describes similar and equal courses of the spots. For example: whatever motions of the spots are described on the Sun this year, 1627, this month of August, this 22nd day of the same month — such motions, at least in general kind, were described in past years, and such we expect in future ones, at this same time, from the same parallels and the same points of those parallels. And this is the genuine sense of the pronouncement; and what I say about this time in August I want understood in the same way for the time of any month whatever. And how do I know this? From the very spots and faculae falling year by year onto the same parallels — which happens frequently — and whenever it happens, the motions always turn out, to the senses, similar and nearly equal. Consult, among other things, the pictures of the observations presented for this purpose in the previous book, and you will see how constant this truth is.
[Margin: The genuine sense of the pronouncement.]

From this I again infer that the cause and subject of a motion so constant must be something single and universal.

I infer, secondly, that a certain motion common to all the spots is annual, since the individual motions of the spots, run through year by year on the same parallels and compared with one another, are similar and equal, and so on.
[Margin: The common subject of the spots' motion, and the annual motion.[?]]

I have said that the motions are, to the senses, similar in general,

CAP. XI.

and for the most part equal, because it could happen that, on the part of the thing itself, some small dissimilarity might intervene; just as it is certain, from the observations and their notes, that some discrepancy in the motion does sometimes occur. [Margin: Although the motion is annual, the spots are not therefore annual.]

I said that similar and equal motions return year by year, and that this is known from the spots falling onto the same parallels. But note: those spots are not on that account annual and recurring, for this does not happen, since few of them return even once. Rather, because some succeed others, they describe similar paths on the same parallels — because the principal moving body, the Sun in which they reside, completes fixed revolutions: just as in a wheel, if another nail

is set in place of a lost one, it will describe around the axle the same circuits that the earlier one used to, and so on.

PRONVNCIATVM SEPTIMVM.

All spots carried on equal parallels and separated from one another by a six-month interval of time do indeed produce motions that are, as a rule, similar and equal, yet subcontrary in position and orientation.

[Margin: The common subject of the spots' motion.]

Examples of this are everywhere in the whole previous book, and were presented in particular near its end, where I compared the subcontrary motions month by month over two years. By "equal parallels" I always mean two placed beyond and short of the greatest one, at an equal interval of latitude from it.

From these things it again follows that the subject and universal moving body — in which, by which, and according to which the spots are carried — is something single, stable, perpetual, and utterly regular; otherwise the mind cannot grasp how such great uniformity and likeness would always intervene and recur every six months.

PRONVNCIATVM OCTAVVM.

The paths of all the spots and faculae become rectilinear, to the senses, twice a year: once around the end of November and the beginning of December, and once between the end of May and the beginning of June.

CAP. XII.

[Margin: The agreement of the rectilinear motions.]

This pronouncement is evident from the pictures of the observations — both my own and others' — drawn in the previous book for the months mentioned; and it cannot be established otherwise than by observation.

These rectilinear motions agree in the following respects. First: all the courses, one and all, ordinarily produce lingerings across the Sun that are, to the senses, equal. Second: all the paths are oblique to the ecliptic, and none is ever parallel to it. Third: all the angles that these paths make with the ecliptic are nearly equal to one another, and lie between six and eight degrees. Fourth: the time during which this motion lasts as, to the senses, nearly rectilinear extends to about two

weeks. Fifth: all these courses that cut the ecliptic are both northern and southern; those that do not cut it are either wholly northern or wholly southern.

These rectilinear motions differ, however, in the following respects. [Margin: The difference among the rectilinear motions.] First: all the winter ones run from the rising south toward the setting north; while all the summer ones run from the northern rising toward the southern setting. Second: the winter ones gradually draw in toward the ecliptic, both on the southern side at their rising and on the northern side near their setting; while the summer ones tend toward the ecliptic from the north near their rising, and from the south near their setting.

The orientation of the spots' motion is judged chiefly by the rising and setting points; likewise by the chord joining those points, and by its position relative to the ecliptic, and also by the angle it makes with it. And two angles are found, which are made with the ecliptic: one, formed by the arc of the path projected onto the observing plane from the center of the spot, is mixtilinear [mixtilineus] with the ecliptic; the other, formed by the chord joining the rising and setting points, is rectilinear with the same ecliptic. So, as this rectilinear angle decreases, the other increases; as it increases, the other decreases; and when the former is at its greatest, at the balance points [in æquilibrijs], the latter is nothing; when the rectilinear one is greatest, that mixtilinear one is nothing — but the arc, to the senses, coincides optically with the chord, just as the chord, at the balance points, runs together with the ecliptic, or at least parallel to it. These things one must know well in order to understand the orientation of the spots properly.

COROLLARIVM I.

[Margin: These motions cannot occur in any planetary orbs.]

From these things I conclude, first, that this motion cannot exist in any of the fictitious planetary orbs, because they themselves do not possess such motions at these fixed times. Let anyone who wishes examine all the planetary theories, and he will find that the matter stands so. For neither time and paper, nor the just distaste of the learned, permit me here to set out all these trifles and refute them to no purpose.

COROLLARIVM II.

[Margin: The rectilinear motions cannot occur in orbs placed around the Sun.]

I conclude, secondly, that this motion does not reside in any external orb that is either eccentric or homocentric with respect to the solar globe. For I proved in

earlier passages that the periodic revolution of this whole motion is not completed below the Sun. Otherwise the spots below the Sun would necessarily go backward at the same time that they are carried forward by this rectilinear motion, because the planes drawn through the parallels of this motion stand almost upright to the circle of the Sun and lie for a while along the visual axis of the eye. Hence the circles along which the spots turn, however large one imagines them, since they lack the necessary inclination above the plane of the horizon, therefore in no part of themselves pass beyond the latitude of the Sun toward the north or the south. From this it follows that, if the whole solar phenomenon wandered below the Sun, it would have to have been seen going backward in the apogeal part. But since this never happens, from this single appearance of rectilinear motion alone it follows that the spots do not describe their whole period below the Sun. [Margin: The spots' motion is neither wholly below nor wholly above the Sun.]

But neither do they describe it wholly above the Sun, for then they would not be seen at all, because of the interposition of the Sun. It must therefore be judged that they are driven around it — a point that will nevertheless be demonstrated later by other, far more solid arguments. And this being granted, I say that they are not carried on any circle appreciably larger than the solar globe. For either that circle or sphere will be homocentric with the Sun or heterocentric; but neither the first nor the second holds, and there is no third possibility. Therefore that sphere is not appreciably larger than the solar globe. [Margin: The solar spots go around the Sun, but in no sphere outside it.]

The major premise is now proved point by point.

That the sphere in which the spots are imagined to revolve about the Sun is not larger than the Sun, and is homocentric with it.

CAP. XIII.

[Margin: Explanation of the proposition.]

In the title of this chapter and of those that follow, I absolutely deny any greater size, because it must be absolutely denied — as I shall prove expressly below, showing that the spots and faculae are on the Sun itself. Yet, in keeping with the promise made at the end of the preceding chapter, here I reject only a perceptible greater size.

Let the globe of the Sun, a b c d e, be imagined as drawn in the first figure, from the center as a pole; and since the spots are supposed to be carried around it

homocentrically, the axis about which they turn will pass through the center of the Sun, *a*, and let it be *e c*. And since the motion of the spots is taken to be rectilinear, the axis *e c* will lie — to the senses at least — in the plane of the solar circle *b c d e*. And since the primary solar spots and faculae occupy a large zone of latitude on the Sun, while the secondary ones occupy the whole Sun — as is established from the observations presented in the previous book — I therefore take as an example three parallels: the greatest, *b d*, and two smaller ones, one northern, *f g*, the other southern, *h i*, on which any spots and faculae whatever may turn. Since their paths are completed, other things being equal, in a time that is to the senses equal, I say that it cannot happen that they are completed on appreciably larger spheres surrounding the Sun concentrically.

Book IV, Part I — Cap. XIII (continued)

A Caution [Admonitio]

Even though the motion of the spots is, in the nature of the case, always in fact curvilinear — so that it does not trace the line *b a d*, or *f x g*, as a perfectly straight one, exactly as the figure represents — nevertheless, because this deviation from straightness, such as it is, introduces around the aforementioned times no perceptible unevenness into the lengths of the transits, as is established from the observations, the argument still keeps its sinew, which is drawn chiefly from the equal duration above the horizon. As for how great a distance of the homocentrics beyond the Sun would have to be assumed for it to be perceptible to a first observer, I do not determine that here; this much is certain, that it would be a matter of a few minutes — not to say a single one — and would be perceptible. The argument rests on this foundation: that circles of different size do not touch one another except at a single point, and so portions of their arcs cannot be made to coincide with each other, and so forth. With these things premised—

[Margin: Proof.]

Let there be assumed, if it can be done, some sphere *K l m n*, in accordance with what has been said, and let its radius *a K* be double the solar radius *a b*; and let the axis be drawn out on both sides into the poles *l*, the arctic, and *n*, the southern, about which the spots and faculae revolve in the parallels *o p* and *q r*, at the stated times with a motion sensibly rectilinear, and thereby such as they are wont to keep sensibly regular. And let there be some circle *l b n* of latitude, lying on the surface of the said sphere, passing through the poles *l*, *n*, and

touching the Sun at *b* — apparently, or optically, with respect to an eye set on the earth — and let it carry along with it two spots *b*, *f*, and one southern facula, *t*. Therefore, when the said circle touches the Sun at *b*, it is evident that the whole remaining arc *b f l*, and *b t n*, lies outside the periphery of the Sun *b f c*, *b h e*; for it is the semicircle of a greater circle projected onto an elliptical arc. And so, when the spot *b* begins to rise upon the Sun, the spot *f* and the facula *t* still wander far outside the Sun; and conversely, when the spot *f* has been carried to *f* and the facula *t* to *h*, to the point of contact with the solar horizon, then the circle carrying the spots and faculae, having advanced, will cut the Sun at *f* and *h*, and thus [will trace] the whole arc *f h*, and conse-

[Margin: The sphere homocentric about the Sun is shaken out.]

-quently the spot *f* will present itself within the Sun, drawn in at the point *u*. Hence, when the spot *f* and the facula *h* pass beneath the solar horizon, the spot *b* has advanced onto the Sun to the point *u*, by the notable interval *b u*. Again, when the circle *l u h n* reaches its highest point on the Sun, it will be projected onto the straight line *l c a n*, and the spots will culminate — *b* indeed at *a*, *f* at *x*, and the facula *t* at *y*.

And hence again, when the circle carrying the spots runs down to *g*, the common intersection of the horizon and the parallel *o p*, the spot *f* and the facula *t* will set at *g* and *i*, but the spot *b* will still linger above the horizon at the point *Z*. Finally, when the spot *b* sets at *d*, then the circle of latitude has carried the spot *f* up to α and the facula *t* to β . Therefore, if a sphere sensibly larger [than the Sun], carrying the spots and faculae, be revolved about the Sun, these spots and faculae, advanced upon the Sun with rectilinear motion, will never make sensibly equal delays. Since this is false and contrary to the phenomenon, the premises from which these consequences follow must also be false. And so, the truth of the phenomenon standing firm, these homocentric orbs must collapse.

[Margin: The conclusion from the foregoing.]

But if this tiny little orb *K l m n*, set around the Sun and exceeding the Sun's circumference by not fully eight minutes, introduces so great a discrepancy into the rectilinear motions of the spots, what will those men do who assume [spheres] greater not by solar radii but by whole degrees — and those indeed many? Surely such absurd consequences follow, so unworthy of this learned age, that one would be loath to foul the ears of others [with them].

[Margin: Great absurdities follow for large orbs circumscribed about the Sun, in which the spots would be carried.]

But lest we sing the triumph before the victory, let us see whether we can eliminate the heterocentrics with the same ease.

That the sphere in which the spots are thought to revolve about the Sun is not larger than the Sun, and is not heterocentric — CAP. XIV.

[Margin: The various cases of a sphere eccentric about the Sun.]

By three principal ways can the eccentricity of a sphere set around the Sun be posited: either according to longitude, along the line K m, in the same first figure, on this side and on that; or according to latitude, along the line l n, above and below; or, finally, according to depth, along the line of distance running straight from the eye, which in the given figure settles onto the point a. Let us begin with this last one.

[Margin: If, for a surrounding sphere, the eccentricity remains in the visual axis, the demonstration differs in nothing from the earlier ones.]

So then, whether the sphere K l m n, in the still-first figure, approaches the eye perpendicularly at point a while [the eye] rests there, or recedes from it, right up to contact with the Sun at the surface-point a — provided that the visual axis, together with the center of the Sun and of the sphere, settle into a single point a, and so on — then the same things will always happen that have just been described; for the species of the Sun comes to us in the manner of a cylinder, or of a cone, at whose apex, or at whose outermost base, the eye is placed. Hence the spots and faculae, that is, their traced paths, will always cut the Sun and its apparent circle in the same way: as has just been demonstrated.

A scholium worthy of attention [Scholium animadversione dignum]

[Margin: A concise foundation of the demonstration.]

The demonstration here indicated depends on the common section of the sphere and the cylinder — or the visual cone — which section is always a segment of a spherical surface bounded by the circumference of a circle, projected optically onto the apparent solar circle b f g i h. For if the eye stays in the same place, the section will be in a cone; if one imagines the visual axis carried perpendicular to each single point of the solar circle, it will become a cylinder, and the section a

cylindrical one, and so on. And let these things stand as what has been set out concerning Eccentricity according to direction.

Eccentricity according to longitude [Excentricitas secundum longitudinem]

[Margin: First case.]

For example, if a sphere a b c d e, in the second figure — described from one of the Sun's [points] a b, that is, from the contact a as from a center, at the interval of the contact b — carries the spots b f g about the axis and poles c e: when b rises, f and g will stick outside the Sun; and when these rise at h and i, b has advanced to K; and finally, when h and i set at l and m, the spot K is situated at n; and when this sets at a, the rest are situated at o and p, outside the Sun, and so on.

[Margin: Spheres eccentric about the Sun according to longitude are shaken out.]

In the same way, if the center of the eccentric q a r becomes b, and the spots b f t revolve about the axis and poles q r, the spot b will rise first and will set last at a, while the rest rise later at h and i; and while b lingers at u and sets sooner at l and m, b still wanders at x.

[Margin: Second case.]

All of which are contrary to the phenomenon. For the spots, borne with a sensibly rectilinear motion, ordinarily make sensibly equal delays upon the Sun, as I have shown at fullest length from the observations, everywhere in the earlier [books].

But if someone more devoted to contention than to Truth should press that it follows from this that at least those spots whose transit does not agree with the transits of the others in respect of delay above the horizon could be far removed from the Sun, and that thus this argument does not hold conclusively for all of them — I answer that the argument proceeds primarily from the equality of delay, and that, since the inequality found in the transits of certain spots is neither so great nor of such a kind as that which is found in these and similar eccentricities, the force of the argument is secondarily carried over to those [others] as well. It would be enough for me in this place if it were proved of some of them that they cannot be torn away from the Sun; for that where one is, there all the others also are situated, is solidly established from other headings in this treatise.

Scholium [Scholium]

But if someone wanted to compound these eccentricities out of the sphere's eccentric approach to us, or its recession from us, he will not escape, but rather will entangle himself the more, as will be plain to anyone who considers it. For in the sections, whether cylindrical or conical, when they share a common surface with the eccentric

sphere, the same things will happen that I have just described.

Eccentricity according to latitude [Excentricitas secundum latitudinem]

[Margin: First case.]

This is represented in the third figure, in which the center of the eccentric $\beta \gamma \beta$ [?] is α , and the axis about which $\beta \gamma$ turns is at the poles β and γ . [The sphere] touching the Sun $\alpha \gamma \delta$ [?] with its concave sur-

-face at γ , the fixed southern pole. When, therefore, three spots δ, ζ, ξ [?] are carried on a single circle of latitude $\gamma \delta \beta$, the first of all will reach the horizon at δ , the rest being placed far outside. When ϵ reaches the horizon, at κ , then δ has advanced to θ , and ξ sticks outside at ι ; when at last, the circle of latitude $\beta \kappa \gamma$ having been advanced, the spot ι passes beneath the horizon at κ , the remaining two have advanced to λ and ν . All of them—

[Margin: Spheres eccentric about the Sun according to latitude are shaken out.]

Diagrams on folio 427

The recto is dominated by a single engraved plate carrying four numbered geometric figures (1–4), the first two being projections of a spot-carrying sphere onto the apparent solar disk, the last two full spheres with meridian-and-parallel grids. The labels are numerous, small, and largely Greek; each figure is flagged as a Two heraldic rose ornaments and a Jesuit sunburst device are interspersed as decoration.

Diagram 1. The first figure: the projection of a spot-carrying sphere onto the apparent solar disk (the homocentric / apogee–perigee case). A large circle (the carrying sphere) is drawn with an inscribed pointed oval and semicircular arcs representing the Sun's disk and the projected spot-paths, the pole l at the top apex and n at the bottom apex, with a vertical axis $l-x-a-y-e-n$. Readable labels:

- l (top apex, pole)
- o (left end of the upper horizontal), p (right end)
- s, f (on the upper horizontal, left of center), x (center), α (right of center), g (right of center)
- k (far left), q (far left, below k)
- b, u (left, on the mid horizontal), a (center), z, d (right of center), m (right end)
- t, h (left, on the lower horizontal), i, β (right)
- y (below center)
- e (lower center, on the axis)
- n (bottom apex, pole)

Additional small labels on the intersecting arcs are not individually resolvable at this resolution. (many labels [?]).

Diagram 2. The second figure: the longitude-eccentricity case. A large circle (the Sun's disk / carrying sphere) with two upper apices q (left) and c (right), two lower apices r (left) and e (right), crossed by intersecting spot-circle arcs.

Readable labels:

- q (upper-left apex), c (upper-right apex)
- f, h (left of center on the upper horizontal), s (below them), l, o (right of center)
- b, u (left, on the mid horizontal), K (below b), n, x (center-right), a (right), d (far-right end)
- t, g (left, on the lower horizontal), i, m, p (right)
- r (lower-left apex), e (lower-right apex)

(many labels [?]).

Diagram 3. The third figure: a full sphere ruled with meridians and parallels (the latitude-eccentricity case), with a fixed southern pole at the bottom. The grid intersections are labelled with a mix of Latin and Greek letters. Readable labels (top to bottom):

- a, a (two points on the uppermost parallel)
- c, c (next parallel)
- b, b (next parallel)
- α (near center-upper)
- ζ [?], ι , x, π , ν , ω (on a parallel through the middle)

- ν (center)
- $\epsilon, H, \lambda, \xi, \rho, \tau, \psi$ (lower parallels) [several [?]]
- δ [?], m, σ, ϕ, χ, o (lowest parallel)
- γ (bottom pole)

Many peripheral Greek labels are only partly resolvable.

Diagram 4. The fourth figure: a full sphere ruled with meridians and parallels, with an inscribed off-center circle (the eccentric/mixed case), poles at top and bottom (e at the lower pole). Densely labelled in Latin and Greek. Readable labels (roughly top to bottom):

- ϵ, θ (near the top apex), γ, λ, ν, o (upper parallel)
- $\zeta, H, \alpha, \kappa, m, \pi$ (next parallel)
- b, q, r (left), h, δ, a, Z (center), ι, ξ, d (right) — on the main horizontal
- o, s, f (left), g [?], X, n (right) — next parallel
- t (left), i, p, u, y (center), l (right)
- e (bottom pole)

Many interior and peripheral labels are only partly resolvable.

Book IV, Part I — Cap. XIV (conclusion) and Cap. XV

—[all of them] then culminate together, at ν ; ζ, o . Afterwards, the one which entered the Sun last, at η , exits first at π , while the rest stick at ρ and σ . Then, when the spot ρ sets at τ , the other two linger, at ν, ϕ . Last of all, when the spot ϕ reaches the western horizon at χ , the remaining two wander on outside at ψ and ω . And so in this case all the northern spots — of which kind are ζ, ι, κ , and so on — would make the shortest delays on the Sun, the southern ones δ, θ, μ the longest, and the middle ones ζ, η, λ intermediate delays. Yet all these are utterly far from the truth of the solar phenomenon. Therefore heterocentric spheres of this kind are not to be asserted.

[Margin: A true conclusion, from a false hypothesis.]

The contrary of these will happen in position, if the eccentric sphere touches the Sun at β , the fixed northern pole; for then the arctic spot a will remain longest on the Sun, the southern b shortest, and c , the middle one, will behave in an intermediate way. Which again are all false, because they run contrary to the

apparent rectilinear motion of the phenomenon — even that motion which departs somewhat in its duration from the ordinary ones.

And so in these three figures you have set out the six primary cases of the Eccentricities, according to the six primary points of the solar globe expressed on its spherical surface. Of these, two are the greatest apogee and the greatest perigee, designated along the visual axis and expressed by the single character a , in the first figure. So whether the center of the eccentric sphere be conceived as placed at the apogeal point or set at the perigeal, a , the same things will always happen that were shown in the first figure.

[Margin: The eccentricities are set around the Sun according to the six positions of place: Before, Behind, Right, Left, Above, Below.]

Two other points of the solar globe are b and d , which comprehend its longitude; and in these the eccentric sphere fixes its center, in the second scheme. In the third diagram, the center of the eccentric α plays the part of two points — namely c and e — in the solar globe described according to the first figure; of these c is northern, e most southern; and c indeed is compensated by α , with respect to the Sun $\alpha \gamma$, and e with respect to the Sun $\alpha \beta$.

Therefore, since in these six primary and simple positions of the Eccentricities the rectilinear motion of the spots — insofar as it appears uniform and regular up to now — can have no place, anyone sensible will readily understand that much

less place still will there be [for it] in the eccentricities which are compounded out of these. For those compositions produce far greater aberrations, and windings of error, than these earlier simple ones. And that this may be plain to the eye, here for you is the fourth figure, in which I display the matter in a twofold way.

Mixed eccentricity [Excentricitas mixta]

That the sphere in which the spots are thought to revolve about the Sun is not larger than the Sun, and [is not one] of mixed eccentricity — CAP. XV.

[Margin: What mixed eccentricity is.]

I call that eccentricity *mixed* which has something of longitude and something of latitude joined together, or even [something] of depth — which is difficult to present. The mixture of length and breadth I display here, referring to the fourth figure at the point a. Since a is the center of the sphere a b c d e, that sphere, with respect to the Sun a f, will be eccentric — and indeed according to latitude, northward, g a, and according to longitude, westward, h a.

[Margin: First case of Mixed Eccentricity.]

Now since a, the center of the sphere, lies at the contact of the Sun, and the diameter of the sphere is set as double the solar diameter, a i, it is plain that at i there is the contact of the two spheres — namely of the Sun, a r i x, and of the surrounding sphere, c i d. Hence it is necessary that, if some spots be carried in the parallels i t l, b h d, m f n, from one circle of latitude c b i e, about the axis c a e, at the eccentric poles c and e, the spot i will rise while the other two, m and b, still wander outside beyond the horizon; then, when one has arrived from m at o, that the spot i has advanced to p, while b sticks outside at q. But when q rises at r, then o and p are at s and t; and at the same time r and t set — r indeed at a, t at u; at which time the spot f will stick within the Sun at g, and when this sets at x, u will remain at y, and a at z, outside the Sun f.

[Margin: The mixed eccentricity of spheres about the Sun is shaken out.]

In this position, therefore, of oblique eccentricity, the spot i enters first and first exits the Sun at u, together with a; b enters last and exits first, together with i; m enters the Sun after i, before b, and after both exits at x.

Diagram. A full-page geometric plate on folio 429 containing four numbered figures (1, 2 in the top row; 3, 4 in the bottom row), illustrating the spot-paths under the eccentric hypotheses of Cap. XV. Between the two rows, at center, sits a radiant Jesuit **IHS** emblem (with cross and three nails), flanked left and right by two Orsini rose woodcuts. Every figure is a large circle (the Sun's disk/sphere) crossed by chords, arcs, and — in the lower pair — a grid of parallels and curved meridian-like arcs; each is densely lettered with small Latin and Greek minuscule point-labels. Because of the number and small size of these labels, many cannot be individually resolved at this resolution; the readable ones are listed, and the whole plate is a

- **Figure 1** (top left): outer circle with apex **l** at top and an inscribed pointed oval (vesica) whose lower vertex is **n**; central point **x**; the figure-numeral **1** (printed as "I") at center. Readable labels along the horizontal chords and periphery: l, o, s, f, x, α, p (upper chord); K, b, u, a, ζ, d, m (middle chord); q,

t, h, ι, γ, β, r (lower chord); e (foot of the oval); n (bottom vertex). Several Greek minuscules uncertain [?].

- **Figure 2** (top right): outer circle with upper points **q** (left) and **c** (right) from which arcs cross; figure-numeral 2 at center. Readable labels: f, h, l, o (upper chord); b, u, n, x, a (middle chord); r, e (lower vertices); s, p, m, d on the margins. Several labels uncertain [?].
- **Figure 3** (bottom left): circle ruled with horizontal parallels and curved meridian arcs converging at poles **β** (top) and **γ** (bottom); figure-numeral 3 at center; symmetric point-pairs a...a and c...c near the top. Readable Greek/Latin labels in the lower half: α, ν (center); ζ, ι, x, π, υ, ω; λ, ξ, ς, τ; ε, H, θ, m, σ, φ, χ. Many labels uncertain [?].
- **Figure 4** (bottom right): circle ruled with parallels and meridian arcs plus an inner circle, poles **c** (top) and **e** (bottom); figure-numeral 4 at center. Readable labels (upper to lower): γ, ε, θ, λ, υ, ο; β, ζ, H, α, κ, m, π; b, q, r, h, Ω, a, Z, ι, ξ, d; m, o, s, f, g, X, n; ι, p, t, u, y, l. Many labels uncertain [?].

And so this mixed or oblique eccentricity involves far more anomaly and irregularity than the earlier, simple cases. All of this accords far less with the orderly and regular motion of the sunspots than the earlier arrangements did — and can therefore be tolerated far less.

[Margin: The second case of mixed eccentricity.]

These same irregularities occur in the opposite way if the Sun is at α; for among the spots β, γ, δ, the first to rise will be β; then, as γ and δ rise together at ξ and a [?], β will be at [?]. Once these have advanced through Z, ν, θ, the first of all to set will be the southern Z, at [?], while ν and λ [?] occupy the deep part of the Sun. Next ν will follow to its setting at μ; together with λ it will cling to the Sun at ν, while [?] passes outside at ξ; finally, as ν sets at ο, μ will settle at π, and [?] at d. And in this way the first [?]

[Note: this spot-succession passage is densely lettered with small Greek/symbol point-labels; several glyphs are not individually resolvable and are flagged [?].]

ROSAE VRSINAE LIB. IV — folio 430 of all to have risen, β , set in the second place at μ ; and of those rising together, a and ς [?], the southern one, a , set first, and the northern one, ς [?], last.

[Margin: A true conclusion, from a false hypothesis.]

But all of this is irregular, and contrary to the everyday nature and appearance of the phenomenon; and therefore it is by no means to be maintained.

SCHOLIVM

[Margin: All cases of eccentricity can be reduced to one of those already stated, or explained in like manner.]

Although the possible positions of eccentricity are infinite, they all seem nonetheless to be contained within the general cases stated above. Accordingly, none at all appear that can be assigned which do not offend against some one of the points mentioned, or which agree entirely with the rectilinear motion of the spots.

The reason is compelling: whenever the center of motion is changed, its quantity or its quality — and so on — must also be changed.

Note also this: the centers of all these eccentricities have been assumed to lie on the surface of the Sun; yet everything would come out proportionally the same whether the center be assumed outside or inside the Sun.

Furthermore, things similar to these but with opposite locations would result if the eccentricities were assumed at the point r on the Sun's surface, at f and ς , and at the southern point of the Sun's periphery, α .

COROLLARIVM I

[Margin: The absurdities introduced into the motion of the solar phenomenon by the arbitrary fabrications of others.]

From this it follows, first: if an eccentricity taken equal to the Sun's semidiameter produces so great a variation in the paths, what would one, two, or more degrees not produce?

Secondly: if eccentricity alone stirs up such great anomalies, what will added epicycles not produce?

Thirdly: still more discordant consequences would follow if these spheres were assumed so as to cut the Sun. For then there would arise not only a monstrous anomaly of motions contrary to the phenomenon, but also an interpenetration of bodies, repugnant to true philosophy; and finally the spots and faculae would set astronomically before their setting, and rise astronomically after their rising, in the middle of the Sun and out of the middle of it — all of which is portentous and false.

Fourthly: lest anyone suppose that these things happen only in so great a sphere, let him know that the same absurdities would occur proportionally in any smaller sphere too, provided it sensibly exceeds the Sun. I have assumed one this large only so that the matter might be plain to the eye.

COROLLARIVM II

[Margin: In the curvilinear motions of the spots, the same and even greater absurdities will be found, given false hypotheses.]

These same irregularities of the motions would be introduced — and much more so — into curvilinear paths of the spots. I forbear to represent them: any ingenious lover of these matters will discover of his own accord that what I say is true. What I here merely hint at will often be displayed and proved elsewhere, by one argument after another.

COROLLARIVM III

[Margin: The Sun itself is the common source and subject of the motion of the spots.]

Hence it is again concluded that, once the spheres surrounding the Sun are excluded, the Sun itself is the common source and subject of the motion of the spots.

PRONVNCIATVM NONVM

All the paths of the spots, sensibly rectilinear, gradually pass into curvilinear ones, so that out of the winter straightness they swell little by little toward the north, the curvature increasing continuously through three months — December, January, February. Then through three further months in the same way —

namely March, April, and May, up to the beginning of June — the said curvature decreases, and the spots' path-traces return to their summer straightness.

CAP. XVI

This pronouncement is established from the whole of the preceding book, and from so many observational images — both my own and others' — gathered and worked out there. Here the following properties are to be noted.

First. All the courses of the spots from December to the end of May are curvilinear; but the curvature, from the beginning of December to its middle, and from the middle of May to its end, is not perceptible enough to make the durations of the whole courses — other things being equal — or the angles that the chords subtending the courses form with the ecliptic, sensibly unequal.

PARS I. Cap. XVI — folio 431

[Margin: The six-month curvature of the spots' motion and its properties, from December to May.]

Although I am not unaware that during this time the movable axis, on account of its ascent or descent in the small polar circle, draws the spots' paths quite far from straightness — as though [that axis were] fixed — nevertheless, as to why this is not at once noticed in telescopic observations, the chief cause, among others, is usually the business of refraction, which the lenses cause (as will be said below in its proper place). But in the intermediate time this variation of curvature is most notable, especially if whole courses are taken, extended from the rising horizon to the setting horizon.

Second. All these courses, completed in the said six months, are convex toward the north and concave toward the south.

Third. The greatest convexity is reached within a span of three months, which falls around the eighth day of March, more or less. So I pronounce from observations.

Fourth. The inclination which the parallels of the spots keep, at the time of this greatest convexity, to the plane of the ecliptic — or, what springs from the same sources, the elevation of the movable pole above the plane of the horizon — I have always found sensibly equal to the maximum declination of the spots from the ecliptic, measured on the greatest parallel.

[Margin: The vernal equilibrium of the spots and of their motion.]

Fifth. When the spots attain their greatest convexity, then their rising and setting are found to be sensibly equidistant on either side from the ecliptic; and therefore the chords that join the point of rising with the point of setting either lie equidistant from the ecliptic or coincide with it. For this reason I call this state of the courses the *vernal equilibrium*, because the rising and setting of the spots regard the ecliptic equally, and the itinerary tendency of the spots comes to rest, as it were, at a mean; and the chord connecting any two itinerary points equally remote from the center of the observation-circle does not, in the ordinary way, cut the ecliptic — at least not sensibly — which is enough for my purpose.

[Margin: By what is the tendency of the spots to be judged?]

Sixth. The tendency of the spots, or of the courses they make, is usually judged by two things: namely, either from the actual track itself, obtained by connecting lines through orderly observations of the stations; or from the chord drawn through two itinerary points equally distant from the center [and] carried across.

So long, then, as the curvilinear path of some spot is so disposed that its rising and setting are unequally distant from the poles of the ecliptic, the tendency of the spots will thence be known and named. In our present case, then, since the eastern point of any spot clings nearer to the southern pole of the ecliptic than the western point does, from the month of December to March — or, what comes to the same thing, since the rising of any spot is more remote from the northern pole of the ecliptic than its setting — I call the tendency of the spots for this quarter *oblique*, from the southern east toward the northern west.

[Margin: The tendency of the motions from the southern east toward the northern west.]

Likewise, since the chord through the point of rising and setting of any spot — or the chord drawn in the said manner through two itinerary points — is oblique to the ecliptic, and passes across it from the southern rising to the northern setting, so long as this happens, the tendency of the spots is said to be from south to north.

[Margin: In equilibrium the spots do not linger.]

Seventh. But after the spots have, in their course, reached the vernal equilibrium, they do not sensibly cling long in the same state as regards declination and the change of the rising and setting points; for they retain the same curvature perceptibly for a long time — just as on a rectilinear path, on

which they persist for many days without any notable variation, at least of declination and of the eastern and western places. Indeed, they do not so quickly fall away even from sensible straightness; but of equilibrium they are most impatient, and from it, within the space of a single day — as far as I have hitherto been able to observe — they cast themselves out. Thereafter they direct their course continuously from the northern east into the south, from about the eighth of March, through three months, to about the eighth of June, decreasing from curvature into summer straightness in exactly the same way as they had been twisted from winter straightness into vernal curvature.

[Margin: At the time of equilibrium the tendency of the spots changes.]

These increases and decreases occur at intervals and times that are not equal but unequal, yet regular and, sensibly, proportional. And so, under arcs of one and the same kind, toward the same regions and poles in situation and disposition — namely, while all the courses are convex toward the north and concave toward the south — they set up two subcontrary tendencies: one

[Margin: The subcontrary tendencies of the motions.]

ROSAE VRSINAE LIB. IV — folio 432

[Margin: Equilibrium is the common boundary of the opposite tendencies.]

from south to north for three months, the other from north to south likewise for three months — like and equal to the former, other things being equal, and if homologous parts be compared with homologous. Equilibrium, then, is the common boundary of these two directions, and their common midpoint.

Eighth. Spots established at the same time and in the same place of the Sun are not carried along according to different tendencies, but all follow one and the same. I said "in the same place," because if some are situated at their rising, others near their setting, they can — and usually do — fall into different tendencies.

Ninth. The arced courses of the spots, run at the same time under different parallels, have apparent curvatures that differ: smaller for those that are more northern, larger for those that are more southern. These things are established from observations. They hold true from December to May; from here to December the contraries occur.

Tenth. The curvilinear paths of the spots, apparently described at the same time under different parallels, are unequal, and smaller in proportion to their own circles the more northern they are, larger the more southern they are. I said "proportionally," that is, if they be considered in order relative to their own respective circles as compared: for although some itinerary arc described on the most southern parallel may be smaller than another arc more extended toward the north, this one is nonetheless always a larger portion of its own circle than that one is of its own. The truth of these things is established from observations.

Eleventh. The apparent whole segments of the itinerary arcs, reaching from rising to setting, described at the same time under different parallels — the more southern ones are larger than the northern ones, too much so for them to be alike. This matter needs no other proof than the examination and comparison of the observed courses; or, if you prefer, your own but accurate observation.

Twelfth. The whole curvilinear segments of the itinerary arcs, described by the spots at the same time over equal parallels during this southern six-month period, are unequal — the southern larger, the northern smaller — yet not alike among themselves. This is evident from constant and long-continued observing practice, and from careful examination by observers.

I take "the same time" here morally, not mathematically — so that two courses have in common more than half the time spent above the Sun's horizon.

Thirteenth. Curvilinear arcs run at the same time by spots under different parallels are ordinarily completed in unequal times — greater indeed for those that are more southern, smaller for those more northern. The contraries then occur in the boreal or summer half-year. In a word: as arc is to arc, so for the most part do their delays and durations stand to one another. I said "ordinarily" and "for the most part," because many spots too, newly arisen, accelerate their courses more than can be brought under the ordinary delays, even though they undergo regular and not disproportionate velocities. Observations prove what I have said.

Fourteenth. The curvatures of arcs described by spots on the same parallel, at a similar time in the year, are sensibly alike and equal. This is evident from experience of observations, provided the rest be taken equal.

Fifteenth. The curvatures of arcs described by spots that occupy equal parallels at the same time are unequal — greater for the southern, smaller for the northern. This is evident from observations. I always mean the winter half-year: for in the summer one, like things happen in the contrary way.

Sixteenth. The itinerary arcs of all the more southern spots, described at the same time, become more curved than those of the northern ones. This is evident from observations.

Seventeenth. The curvilinear paths of all the spots, spread out from rising to setting, take on an *elliptical* curvature. They certainly never present a circular one. It is a spiral, compounded ordinarily of the annual motion and of the motion of 26 or 27 days. This is evident from observations aptly arranged; or, if you do not believe me, from your own — duly to be observed and set out.

Eighteenth. The courses of any spots whatever, carried successively over one and the same parallel during a notable time in this half-year, always cut one another in the plane of the solar horizon. This is established from observations. The annual ones, however, coincide.

Nineteenth. The apparent course of any returning spot [cuts?] the earlier apparent

[The nineteenth property, begun in the preceding pages, concludes:] ...cuts its parent. This is clear from what has been observed.

Twentieth. The courses of any spots whatever, borne along in any parallels, if they occur at different times within the space of a half-year, never come out parallel to one another. Daily experience [confirms it].

Twenty-first. The courses of any spots whatever, borne in any parallels at the same time, are sometimes parallel to one another, sometimes diverge from one another, and often even tend toward a meeting. Experience [confirms it].

Twenty-second. Many of the spots' path-arcs are wholly northern, many wholly southern, many southern-and-northern, many northern-and-southern; many bend from south into north and then back again into south — and those of this kind cut the Ecliptic twice, the rest only once.

Twenty-third. All the southern spots of this half-year ordinarily make longer stays on the Sun than the rectilinear ones; the northern ones make shorter stays than these. I said "ordinarily" because of an occasionally contrary outcome. Experience readily met with in observations [confirms it].

Twenty-fourth. Although all spots move more slowly near the horizons and more swiftly in the middle of the Sun, nevertheless those that proceed by a curved path move more slowly than the rectilinear ones near the horizon, and

more swiftly at the culminations. The truth of this appearance is established from observations.

Twenty-fifth. Among the curved motions themselves, a greater slowness near the horizon is observed in the southern spots, and a lesser one in the northern at the same time, other things being equal. But around the middle there is, for the most part, greater speed in the northern than in the southern. The matter is certain from observations.

Twenty-sixth. The greatest slowness of the spots near the horizon in this half-year is found in the most southerly ones at the time of the Equilibrium; the greatest speed — and indeed the greatest of all — at the time of rectilinear advance. All these things are manifest from what has been observed.

Twenty-seventh. The daily intervals of all the spots — taken between two stationary or observational points, in the same course — are always greatest around the middle and always least at the horizon, other things being equal. Hence, ascending toward the middle, they always increase most regularly (to the senses) and proportionally; but descending from the middle, they decrease with the same regularity and proportionality. This truth is proved in no other way than by constant and sure observational practice, as is established from the whole preceding book.

Twenty-eighth. For spots borne in the same parallel, the daily intervals of curved motion are shorter than those of rectilinear motion. I assume, however, that from the same parallel both the rectilinear motions (to the senses) and the curved ones are described, each in its own time — which is most certain from the phenomenon. This assertion is clear from what has been observed.

Twenty-ninth. Spots borne in the greatest parallels make, other things being equal, larger daily spaces than those carried around in the smaller parallels; and so the most northerly or most southerly spots fill out the smallest daily spaces.

Thirtieth. The daily spaces of spots borne in the same parallel change gradually: into longer ones with a straighter motion, into shorter ones with a more curved motion; they become shortest with the most curved motion under the equilibrium, and longest under the winter-solstice station when the motion is straight, and so on. These things are established from observations.

Thirty-first. The greatest number of daily gaps between the spots is afforded by the curved courses described by the smallest southern parallels; the fewest by

those that occur along the smallest northern parallels; while those that occur in the greatest parallels behave in an intermediate way.

Thirty-second. At the time of rectilinear motion, spots that rise together set almost together. This is clear from observational practice.

Thirty-third. At the time of notably curved motion, spots that rise together scarcely ever set together; and those that set together very rarely rose together.

Thirty-fourth. It sometimes happens that a spot which rises after another also sets before that same one.

This is had from observations.

Cap. XVII. — What can be gathered from the properties of the spots' motion already set forth

From these properties of the spots' motion which I have just set out — properties noticed from the very beginning of this phenomenon, as they crowded in on me in troops — I at once began to sharpen my mind's attention and to get wind of what the truth actually was: some mixed motion that was nonetheless, to the senses, regular and orderly. This was especially so when, in June of 1612, I first found that the spots returned from a curved motion to a rectilinear one, and then discovered by trial that they gradually passed from this back again into a curved one. Through the following years I learned this by steady experiment, always finding the same result: that the motion from December to May came out similar — in its reversed orientation — to the motion from June to December, and equal to it in time, so that at last the cycle came round again. [Margin: A mixed motion, inferred from the reciprocal curvature of the paths.]

And so the very curved advance of the spots showed that, on the side toward which the concavity faced, some pole and a common axis was raised above the plane of the Sun, about which the spots would describe their circuits — especially since I saw that they all revolved by one common principle. I was further confirmed in this view when I perceived that the spots' progression itself, together with the bendings of their paths, changed in position and shape with a certain concordant and regular — if I may put it so — "irregularity": so that from a southern declination they were gradually turned into a northern one, and from this back again into a southern; and thus in any given year they produced twice over rectilinear tracks (to the senses), and in between, on either side, curved ones — but opposite in orientation. From this I concluded that beneath so regular and uniform a motion there must lie some axis and common poles, in and about

which such a revolution was brought about. [Margin: The apparent curvature of the spots' motion is uniform in a nonuniform way.]

Moreover, when the spots' rectilinear motion ran from south to north, the axis about which such a motion would be described necessarily lay in the Sun's disc, perpendicular to that motion and to the parallel along which the spot, carried round, marked out the axis itself; and when that rectilinear motion ran from north to south, the axis of that motion necessarily lay stretched from south to north, set at right angles to the motion itself. [Margin: The axis is inferred from the spots' apparent orderly motion.]

These indeed were the first rudiments and cradle-beginnings of establishing the axis, the pole, and the annual circlet — beginnings toward which I was led by the phenomenon itself and, as it were, dragged unwillingly, fearing that some deception might lie hidden by which, misled into error, I might impose on others. And so it came about that I hesitated over settling the theory of the circlet, since from it the full understanding of the whole phenomenon had to be drawn; and because this could not be done without many, constant, long-continued, and thoroughly tested observations, I always cautiously deferred it to a later point in my *Apelles*. Nevertheless, whenever I surveyed my observations even in passing, and weighed somewhat more exactly the conditions of the apparent motion, I always necessarily found an axis and common poles over which the spots were turned in their parallels. [Margin: The first beginnings of the Mobile Poles and of the little circles described by them.]

For from finding that the rectilinear courses, completed together and in like manner (to the senses), all ordinarily had the same duration and daily spaces proportional to one another, I concluded — not unreasonably — that the axis of the spots passes through the center of the Sun. [Margin: The axis of the spots passes through the center of the Sun.] [Margin: From what was the motion of the spots about the Sun first concluded?]

And from the fact that the spots were carried most swiftly in the middle but always more slowly toward the edges, and that with due proportion; likewise that their daily spaces appeared greatest in the middle, least near the edges, and intermediate between these, and this most regularly to the senses; and that all the spots ran from east to west, none the reverse — from this I determined that this motion necessarily takes place about the Sun. [Margin: Whence the mobile axis and poles?]

From the fact that this motion gradually passed from straight into curved — and that with the utmost proportion of increase over three months and a like decrease over three, until the curved was restored to straight — I gathered that this axis is mobile, and that it is raised above the plane of the Sun by one of its halves just as much as the spots' course was bent toward the other pole and axis. This I tested by means of the chords joining the end points of the completed courses; for these chords represent, up to a point, the common section of the parallel occupied by the spot with the circle or solar horizon —

that section to which the section of the plane drawn through the mobile axis, at right angles to the Sun's circle, is perpendicular; and it is onto this very line that the raised axis is always projected. [Margin: The visible and the hidden half of the axis.]

From the fact that the spots' course in the other half-year produces bendings contrary and opposite to the earlier ones — yet in all respects similar and proportional (as will be shown shortly) — it is clear that the southern half of the axis is depressed below the horizon, while the other, northern half is raised above it. [Margin: The motion of the exposed pole and axis from west to east — on what grounds?]

But from the fact that the common sections of the parallels with the solar horizon (which the chords drawn through the extremes of the completed courses reveal, more or less) ascend on the eastern side from the south toward the northern pole, and on the western side descend from the northern pole toward the south — in whatever region the spots with their courses happen to lie, and this for six continuous months; and that indeed in the third month the spots' courses stand at the Equilibrium, and their chords coincide with the Ecliptic if they are the greatest ones, while, if not the greatest, they are for the most part all parallel, other things being equal — from this I concluded, first, that the axis about which these motions occur is carried from west to east, contrary to the spots' own ordinary tendency; otherwise the section of that same common parallel with the horizontal arc would not, at rising, ascend toward the arctic pole, nor, at setting, descend just as much toward the south. I concluded, second, that it culminates after a three-month ascent, from the fact that the path-arcs were then most highly curved, and their chords not inclined or oblique to the Ecliptic. [Margin: The rising, highest elevation, and descent of the exposed southern pole and axis — on what grounds?]

I concluded, third, that the same axis, over the remaining three months, again descends within its semicircle down to the Horizon, and there establishes the

spots' rectilinear course. And since this rectilinear motion was observed, gradually and after some days (as we shall now see), to swell toward the southern pole and to be hollowed out toward the northern, and so forth, I conjectured on the same grounds that the northern pole, together with its half of the axis, is raised, and the opposite southern portion depressed — in the very region where I had earlier noted that the southern had been raised and the northern depressed. And this alternate rising and descent of the halves of the axis with their poles [Margin: The rising, highest elevation, and descent of the exposed northern pole and axis — on what grounds?] introduces into the spots' motion all that variety, as will be perfectly clear to anyone who considers and tests it. For just as all the variety in the motion springs from this source, so it is at once explained by a most evident principle. This holds notwithstanding that some anomalies are occasionally noted — small ones, though — arising from natural alteration, about which I shall speak elsewhere. [Margin: The mobility of the poles and axis causes all the variety in the phenomenon's motion.]

For the fact that the spots linger longer near the horizon in curved motion than in rectilinear is caused by the inclination of the parallels to the Ecliptic; that unequal courses are described in unequal times arises from the same cause; nor does the appearance of unequal daily intervals draw its origin from anywhere else. And six hundred other matters — set out, or still to be set out, in their proper places, all deriving their origin from this single System — will be resolved sooner than said.

Let this, then, stand as the general discovery and rough description of the mobile axis with its poles, of the annual motion from west to east, and of the polar circlets. Meanwhile, however, how large these circlets are, and about which poles and axes they are described, has not yet become clear from these considerations — and this is the task, this the toil. [Virgil, *Aeneid* VI.129]

The mobile axis with its poles we shall, for brevity, call the axis of the spots, the mobile axis, the axis of the parallels (for it is perpendicular to them), and the axis of the proper motion. In the same way we shall name the poles of this axis the poles of the spots, the mobile poles, the poles of the parallels, and the poles of the proper motion. [Margin: Synonyms for the Axis and Poles.]

But the axis about which the polar circlet is described — whatever it may finally be — we shall call the fixed axis, the stable axis, the axis of the annual motion, the axis of the common motion; and the oblique axis, with respect to the parallels in which the spots are borne. [Margin: The names of the fixed axis and poles.]

The circlets described by the mobile poles we shall call polar, stable, annual, [circlets] of the common motion, and oblique with respect to the mobile parallels. [Margin: The polar circlets.]

The parallels themselves in which the spots are borne we name mobile parallels, parallels of the spots, and parallels of the proper motion; these we then subdivide into southern and northern, on this side of and beyond the greatest parallel. [Margin: The names of the parallels.]

And these things, indeed, we do not put forward as devised by us from some arbitrary or merely convenient hypothesis; rather, we present them as truths laid open by the phenomenon itself as we observed it, and drawn by evident reasoning from an effect already known; and things whose causes we were formerly ignorant of, we make manifest once these have been brought to light.

Corollary

From these things, well weighed, it is once more evident that the spots cannot be parts of any planetary heaven below the Sun, even if those orbs were supposed to be fictitious — or even if we should imagine within those orbs some further fictitious orb, I know not what. [Margin: The planetary orbs below the Sun are unsuited to this phenomenon.] For the spots go around the Sun; the Moon is therefore excluded from this phenomenon, along with the whole apparatus of her heavens devised by men. Venus and Mercury do not produce this phenomenon by their epicycles — if they have any — on the eccentrics with which they crown the Sun; for those bodies are entirely outside the Sun, do not embrace it in their bosom, and for much of their revolution's time move above the Sun. So then nothing of this phenomenon would appear on the Sun — which is false, since the Sun is never free of it, especially if we speak also of the secondary spots and faculae.

Moreover, the eccentric of this planet, encircling the Sun — which others call an epicycle — in no way undergoes those fixed vicissitudes of the spots about their motion. Therefore, from these considerations too, over and above what was said above, Venus is utterly banished from this phenomenon, together with all her palaces, now fallen to ruin with age.

Nor will Mercury filch anything for himself from this, even if we suppose his two orbs — those carrying the apogee of the eccentric — to be moved from east to west in 365 days, and that about the Sun: what then? Who does not see that the spots, if they were to be depicted on the Sun by Mercury, would have to be driven by a motion far different from the one that now appears? For the spots complete

their course within 26 or 27 days, more or less, as has been seen; all the rest travel from west to east, and by this very fact do not carry the spots around. Therefore let Mercury too be wholly rejected from this phenomenon.

This is further confirmed by the fact that the orbs of those two planets — Venus, I mean, and Mercury — would not produce those fixed deviations of the spots, made at set times in their course: the deviations, wanderings, straightenings, bendings, and curvatures; the velocities of the courses around the middle, the delays at the outermost edges. For no such motion belongs to any orb of those planets. Therefore, simply speaking, it is impossible that these spots should arise on the Sun through any interposition of such an orb between us and the Sun. There is the further point of each spot's own dilation with every difference of position, then its contraction at the margin, and many similar things — which could in no way hold together without a physical tearing apart of the orbs. For which reason, since these things are so — since the solar spots are neither clouds in the Air, nor, in the Lunar region or those of Venus or Mercury, any denser or rarer particles of that breathable atmosphere — it remains that all those who, hitherto wrapped up in these imaginings, held as settled things that could not be, should turn their minds elsewhere. But now, having begun our web, let us weave it to the end.

Tenth Pronouncement

The paths of all the spots — straight around or a little after the beginning of June — are gradually bent into curved ones, more and more arched, until, a little after the beginning of September, they have become most convex toward the South and have been set at the Equilibrium. From that point, again over three months — namely September, October, and November, up to the beginning of December — they gradually diminish and return to their annual straightness.

Now these curvatures, other things being equal — those of this summer-autumn half-year and those of the other, winter-spring half-year — are alike in their manner of increasing and decreasing, and likewise in shape, and equal in magnitude as well as in duration; yet opposite in orientation. For the convexity of the path-arcs always inclines toward the South, the concavity always toward the North; and everything else shown in the earlier half-year happens here too, but with opposite orientation.

Cap. XVIII.

What I say here needs no other proof than the eyes of the Reader, the hand of the Writer, and the practice of the Observer. [Margin: The Pronouncement is proved

from observations.] Survey the whole of the earlier book; consider all the observation-images, and each one, from June to December. Weigh the courses of these final labors — separated by half-year intervals, compared with one another, and set out under a single view — from Observation-image LXV, page 321, to LXX, and you will see that the truth of the Pronouncement holds constant for itself month by month. Read the individual notes there, run through what I shall add here shortly; and, if you please, set your hand to the plow: observe, sort, compare, and you will find things twinned with mine, you will judge them equal, and you will speak and write the same.

[Margin: Observation-images for the rectilinear motion.]

That the sunspots make motions perceptibly rectilinear each year around the end of May and the beginning of June, you have from Observation-image XXV, p. 215, for the year 1625, in the Roman course, Sunspots *a* and *h*; likewise from Observation-image XXVI, p. 217, in the Ingolstadt courses of Table 7, Sunspot *b*, which is the same as the Roman *a*; and Table 8, Sunspot *a*, which in the Roman course was *h*. These repeated courses you have in the Appendix to Image XXVI, p. 223, Table 8, from the 1st to the 9th of June under the letter *b*, and in the last table, from the 6th to the 17th of June, under the letter *d* — so that you may see my candor in handling these matters, and the ever self-consistent tenor of the truth.

You will find things akin to these in Image XXVII, p. 229, the Table for June, for the courses of Sunspots *a* and *b*, observed at Freiburg im Breisgau [Friburgi Brisgoiæ] in the year 1622.

You will find May and June of the year 1626 rectilinear in the same way as the year 1625 had been, from Observation-image LXIV, p. 315, in the courses of the sunspots there depicted.

You have the same months, likewise perceptibly rectilinear, in Image LXX, p. 341, for the year 1627, where one may at the same time discern the course — though not complete, owing to a gap in the sunspot [defectu Maculæ] — a rectilinear one subaltern to it, of November of the year 1626, six months apart, equally inclined to the ecliptic AB, along the lines KL and EF, or the lines OB and IB parallel to them, which together with the ecliptic AB enclose equal angles ABO and ABI. The angles of other years too turn out perceptibly equal to these. These angles, however, are not measured by the arcs AI or AO, but by the arcs [drawn] from the angles at B, up to the inter-

[Margin: Arcs that measure the rectilinear angles which the straight paths enclose with the ecliptic.]

-val of the semidiameter of the solar circle BP described. Consult the images already cited, and the others.

[Margin: Explanation and application of certain things from Image LXX.]

I establish this appearance of rectilinear motion so fully and so solidly because from it both polar circlets [Circellus polaris] and their magnitude are derived no less than from the curvilinear motion. For suppose Sunspot *b*, in the course KL, advancing from K toward L, left behind it a track perceptibly rectilinear; suppose this deviated maximally from the ecliptic AB; and suppose the axis about which the parallel KL was turned — namely MN — lay perceptibly in the plane of the solar circle, or at least that the section of the plane drawn through it and through the axis of the solar cone did not perceptibly shift its seat. Then it is clear that this same axis is as far from the fixed axis of the ecliptic, CD, as the line drawn parallel to KL through the center P of the observatory-circle is understood to be from the ecliptic. In the same way the axis GH, at right angles to the straight line EF, will stand off from the axis CD by as much as the line IB — drawn parallel through the center P — departs from the ecliptic AB. And since these rectilinear courses are known, from observations and the reasonings drawn from them, to be at their maximum declination from the ecliptic — for hereafter the approach of the chords toward the ecliptic occurs, as I shall show shortly — it is clear that the mobile axes MN and GH cannot come to a greater divergence from the fixed axis CD, but that a similar optical approach must occur, of the same kind as happens with the chords toward the ecliptic.

[Margin: From the rectilinear paths the polar circlets are obtained.] [Margin: From the observation-images the assertions are proved.]

This is evident in Image LXV, p. 321, in which you have displayed the course of Sunspot *a*, now somewhat recurved toward the southern pole D; and its chord FG — [derived] from the line parallel to KB and the angle KBA — you see is somewhat more inclined to the ecliptic AB than the straight line OB had been in the earlier figure. So too you discern the projected axis of this course, MN, nearer to the stable pole and axis CD; and its one half, ME, I have drawn with a solid line, to indicate that it is engaged above the horizon, on high, by as great an arc of altitude as is the one that measures the curvature of the course FaG. The other half, EN, is presented as a broken line, so that you may understand it depressed

and hidden below the horizon. The same you will see, in the opposite situation, in the chord HI of Sunspot *b*, in the month

[Margin: As the chord of the courses approaches the ecliptic, so the projection of the mobile axis approaches the fixed axis.] [Margin: Application of Image LXV.]

of December, wrapped about the mobile axis PO. I know that these axes and chords are in perpetual variation, but for the sake of demonstration they must be taken as fixed, as is usually done with the solar parallels which the Sun describes daily — which nevertheless are not truly parallel, and so on; the like is done here.

[Margin: Application of Image LXVI.]

Now in Image LXVI, p. 325: as the chords FG of the courses *a* and *b* — that is, AK, LM, or AP — are more inclined to the ecliptic AB, so you will discern the projected mobile axes HI and NO nearer to the fixed axis CD, the angles being found equal on both sides and in both directions.

[Margin: Explanation and application of Image LXVII.]

In Image LXVII, p. 329, you have the opposite months: August of the year 1626, and in it the course of Sunspot *a*; and February of the year 1627, and three courses of it, *b*, *c*, *d* — some of which strayed somewhat, as rather often happens with this phenomenon. Nonetheless the approach of the chords GH, IK, LM has always taken place, and in the same way the approach of the mobile axes toward the fixed one.

[Margin: Images of the equilibria.]

As to whether peculiar axes are to be assigned at once to deviations of this kind, or whether other causes are to be substituted, will be said elsewhere.

Nevertheless, so that the extravagant divergence might be marked, I have set its own axis to each. Meanwhile the axes PQ and RS, owed to the courses FaG and LdM, approach the fixed axis CD with equal step — which is enough for my purpose.

[Margin: Explanation and application of Image LXVIII.]

Observation-image LXVIII, p. 333, exhibits both equilibria: the autumnal one of Sunspots *a*, *b*, and *c*, within August and September of the year 1626; and likewise the opposite, vernal one, of Sunspots *d* and *e*, at about the 8th of March of the year 1627.

Yet here one may again observe some separation of Sunspots *b* and *c* from one another. Meanwhile the courses HcI, IeH, and FdG are perceptibly and perfectly in equilibrium, and look toward a single axis CD.

[Margin: The motion of the sunspots revolves annually from rectilinear into rectilinear.]

By ocular experiment, then, brought in from things observed and geometrically arranged, it is established that the sunspots — from the rectilinear motion set out at the end of May and the beginning of June — are, over the course of three months, brought to maximum curvature; and thence again, over the space of three further months, are rolled back by that same [motion] into their former, annual straightness, just as in the earlier book,

from Image XXXIX, p. 253, to LI, I showed most fully and most clearly; and, if it were needed, I could teach it further by extending the courses. But lest, together with the sunspots wheeled about in a circular circuit from year to year, we forever cling to the same place and, shaken without end and without beginning, seem driven into a stupid vertigo of the mind — and lest I seem to wish to overwhelm the reader by the sheer multitude of observations — I think the observations should here be closed, and that, setting aside for a while the sight of the eyes, the gaze of the mind should be fixed somewhat more keenly upon this splendid phenomenon.

[Margin: Once the observations are extended enough, an end must at last be set.]

For consider whoever weighs the chords over these three months — from the eastern side a regular descent from north to south, which has a like ascent of the same in the west; whoever considers the growing curvatures of the courses in like proportion, and finds their measures equal to the highest declinations of the greatest parallel [paralleli maximi]; whoever finds the same courses subcontrarily alike and equal in the opposite half-years, and discovers that at annual periods they return in the same parallels, equally productive of sunspots and faculae [Macularum & Facularum]. Such a one, I believe, will readily acknowledge along with me a mobile axis and poles about the fixed axis of the ecliptic.

[Margin: Why the mobile poles and axes are to be recognized from the observations.]

But someone will ask: why, and how do we know, that these motions occur about the axis of the ecliptic?

First. From the two rectilinear motions, separated by an interval of half a year in time, which, as I showed, take the ecliptic into their midst; whence the mobile axes too must present the same on both sides about the stable axis of the ecliptic — since the mobile axes always stand a quadrant of a circle away from the diameter of the greatest parallel, itself likewise mobile, which is the measure or limit of the greatest declination.

[Margin: Why the mobile axis and poles are held to turn about the axis of the ecliptic.]

Second. From the equilibria and their highest arcuations, the same is elicited.

For since these regular protuberances of the courses cannot arise perceptibly except from some perceptibly regular motion, and that carried out about some one axis; and since the maximum apparent curvature of this motion occurs precisely when its diameter either coincides with the greatest of the parallels of the ecliptic, or, existing parallel [to it] in parallels that are not the greatest, its measure moreover [is equal] to the highest declination

perceptibly; and further, since the highest apices of those curvatures are equally distant from the center of the observatory-circle, and so stand off from the ecliptic, and take the same into their midst, with the positions of the arcs opposite, in any half-year interval whatever — it follows entirely that this motion is carried about the axis of the ecliptic, in that it culminates twice in the year, when the mobile axis optically coincides with the axis of the ecliptic, but geometrically, raised to the highest point at the solar circle, makes the maximum angle of inclination. And likewise, as was said a little before, it twice makes its greatest elongations from that same fixed axis — one in the eastern region, the other in the western — each of which nevertheless is equal to the greatest elevation and depression of the mobile pole.

To establish these things, then, since I am led by the hand by the phenomenon itself, and no other convenient and fitting way appears, I hope that the learned reader, from the appearances thus far produced, will not unwillingly concede and embrace this view: not only the proper Motion of the sunspots from east to west, which we see with our eyes, completed in 14, 13, 12 days beneath the Sun, and fewer; but also the annual one, which by reasoning we behold — from the curvature and admirably ordered tendency — from west to east; a motion which no single immediate observation, but many observations digested into one course, and many courses compared with one another through monthly and yearly spans, present to the mind and eyes. The former, namely the proper one, is

effected about the mobile axis and poles; the latter about the axis of the ecliptic and its fixed poles.

[Margin: Two motions of the Sun make one mixed motion.]

Yet I would not have you think that these two motions of the sunspots are found there as separate; rather there is one spiral motion composed of these two — as will be discussed in its own place — which nevertheless resolve into two simple ones. And this annual motion, carrying around the axis and poles of the proper motion, imports nearly the whole diversity in the courses of the sunspots.

The foundations of the annual motion, I think, have been laid out fully and solidly from the apparent journeys of the sunspots. Now let us go further, and look more deeply into the particular apparent motions of the sunspots.

PRONVNCIATVM VNDECIMVM [Eleventh Pronouncement]

The daily itinerary intervals of all the courses that the sunspots describe appear larger near the horizon, and smaller near the middle, than would be consistent with their being regular — on the supposition that the sunspots are carried regularly on the surface of the Sun, as will be proved in this chapter concerning the rectilinear ones.

CAP. XIX.

Animadversio, & elucidatio Pronunciati. [Remark and elucidation of the Pronouncement.]

I have often said in what precedes that the apparent Motion of the sunspots is regular — a motion which, together with the sunspots, I began to bring onto the physical surface of the Sun, and which I shall introduce further in what follows. Yet both reason and experience seem to run counter to this doctrine. Reason, indeed, [is] deduced from the asserted Pronouncements and from the very nature of regular motion. For by the astronomers' determination, Regular Motion is defined as that which accomplishes equal spaces in equal times, or which is always uniform, or equally swift. But this cannot be attributed to the Motion of the sunspots as established by us in the earlier Pronouncements, since it is not simple but composed of two — an annual and a nearly monthly one. Since these are carried from opposite regions toward opposite parts, as has been rightly explained, [regularity] cannot be understood [of it]; by what means, then, could regularity and uniformity be preserved in the motion that is composed of them? For each is made about diverse poles and axes.

[Margin: What is Regular Motion?]

To this subtle objection I reply that the two motions themselves — the annual one of the polar circlets, and the one that is proper and nearly monthly to each individual sunspot — are entirely most regular, especially if their prime subject, which is the Sun, be regarded; and that, if taken singly, they run through equal intervals in equal times. But the motion that is fused from them, without doubt, on the side of the reality, draws some deformity at least to appearance — which nevertheless, as I have hitherto diligently investigated, in the things observed, perceptibly, and rightly

[Margin: The first objection is satisfied.]

set out, for a single circuit, I have not detected; which happens for these reasons.

First. Because the polar circlet [Circellus polaris], which imports some inequality into the proper Motion, is very small.

Second. Because in one whole year it is traversed only once, while the periodic journeys — the revolutions of the sunspots about the Sun — are completed more than 13 times.

Third. Because that inequality is dispensed over the individual days in nearly the same proportion, and with a difference almost imperceptible.

Fourth. Because the conversions of the sunspots are described in the royal road of the Sun [Regia Solis via], or the torrid zone, into which the mobile axes accordingly introduce little change — especially if the sunspots proceed along parallels near the greatest. For the Greatest of the parallels feels no anomaly at all in its motion with respect to longitude, but in equal times traverses geometrically equal spaces, since it always has one semicircle below and the other semicircle above the horizon. The rest [do so] perceptibly — which suffices for my purpose.

But you will insist that the annual Motion with respect to latitude is very notable in the courses of the sunspots, and so on. I reply that in many courses a diversity is at length perceived; but in a single course, comparing day with day, there is no perceptible difference, in that the individual [days] in their daily spans somehow gain equal moments from the annual motion. Indeed, [because] in that same annual [motion], and to like points, one returns from any parallel whatever at each half-year, and the same parallel completes its conversion always in equal time, and so on — these are the things that commend the regularity of this motion.

Fifth. That definition chiefly touches the regularity of a simple motion; for composite motions too are not on that account irregular, because they introduce certain anomalies, provided they do so by fixed laws and times, and so on.

[Margin: Another objection, on account of the irregularity.]

Another argument of irregularity — and indeed a very perceptible one — is brought forward from the very observations of the sunspots, and from the courses digested and ordered from them. For, granting that the sunspots wander over the surface of the Sun, granting that they move re-

-gularly, the very opposite seems to be shown from the courses themselves; nay, the present Pronouncement XI, in its terms, states nothing else than that all the courses of the sunspots, if the sunspots be thrust onto the Sun, appear anomalous and unequal. Whence neither the sunspots on the Sun, nor their Motion, seems to be posited in any way — even perceptibly — as Regular and ordered.

[Margin: Reply.]

I reply: if the sunspots are on the Sun, they will be moved perceptibly regularly; and if they are to be reckoned to move regularly, they are to be located on the Sun and nowhere else — which, from what precedes and what follows, on the supposition of their apparent Motion, will have been and is to be clearly proved. But lest any obstacle arise to the Truth, or any insuperable scruple to anyone, I lay down this Pronouncement XI, and on its occasion I remove all difficulties and stabilize the truths asserted in the earlier [pronouncements].

[Margin: Sight alone, from the apparent Motion of the sunspots gathered onto the solar disk, cannot discern regularity.]

But the truth of this pronouncement cannot be elicited or discerned immediately from the apparent motion of the sunspots set before the eyes. For sight indeed sees the distances of the daily stations, and distinguishes some as larger, others as smaller; but whether they hold a due proportion of their magnitudes to the surface, or even to the Circle of the Sun, among themselves, the eye does not see by mere inspection — rather it is necessary to investigate it by some other geometric examination. For, supposing the sunspots to cling to the surface of the Sun, and to be carried around by a uniform circular motion about an axis passing through the center of the solar globe, it is necessary that each in equal times traverse equal intervals in its own circle, and unequal intervals in unequal times; so that, as time [corresponds] to times, so the intervals correspond to the intervals by a mutual likeness of proportions.

Next, since the Sun is posited to be spherical, the itinerary tracks of the sunspots are considered as seen — toward our gaze — as if in a plane, and as projected onto the Solar circle by perpendicular visual lines; for on account of the excessive distance, and the smallness of the angle under which the Sun is comprehended, astronomers commonly assume perpendicular rays. And although, on the side of the reality, the visual circle of the Sun — onto which the sunspots are projected — [differs] from the rational [circle], which divides the Sun in two, in magni-

[continues into the next opening]

they differ in altitude, as will be seen in its place; but this discrepancy is not so great as to introduce any perceptible distinction that would cause the least trouble to the present treatment. I therefore take the perceptible and the true horizon of the Sun to be one and the same. The perceptible circle of the Sun is supplied by the paper, and by the observatory circle drawn on it and lit up by the Sun.

[Margin: Examination of the daily intervals from the rectilinear courses of the spots.]

Once this is understood, then—to bring out what I have said—one must take the plotted course of any given spot and compare the day-by-day distances of its travel with one another; the excesses and deficits will then come out into the open. How the courses of the spots are to be assembled I have taught in the earlier books, and so on.

The courses of the spots, then, are either rectilinear or curvilinear. If the courses are rectilinear, the procedure will be easy. For at an interval equal to half the course, a semicircle is drawn from its midpoint, and onto the perimeter of that semicircle perpendiculars are dropped from the centers of the spot marked at its several stations. Where those lines cut the semicircle, they mark off the daily intervals of the traversed arcs—the distance covered each day—and in that way they display to the eye, just as is stated in the Pronouncement, that these are unequal.

You have an example of this in Image LXX, Book Three, p. 341, both for spot *a* of the month of November and for spot *b* of May and June. There, in the semicircle E–x–F drawn to match the course of spot *a*, you have the daily intervals *r s*, *s t*, *t u*, *u x*, *x y*, *y z*. And although the arcs *x y* and *y z* are traversed near the middle of the course—that is, with the spot at its culmination—and take up more time than the arcs *r s* or *s t* (as will be plain to anyone who inspects the table), nevertheless the arc *r s* (or *s t*) is larger than the arc *x y* (or *y x*). Yet this ought not to happen if

the spots run along the Sun's surface with a uniform and regular motion, as I suppose; rather xy (or yz) ought to be larger than rs , st . For xy , from 8 $\frac{7}{8}$ o'clock on the 27th of November, took until 9 $\frac{3}{8}$ o'clock on the 28th of the same month—24 and a half hours. But the arc rs took, from the 23rd to the 24th, 24 and $\frac{1}{8}$ hours; it therefore fell short in time of the arc xy by $\frac{3}{8}$ —that is, by a quarter of an hour and a half [of a quarter].

In less time, then, the traversal of arc rs ought to have been smaller, and in more time the arc xy larger, since arc is to arc as time is to time. But the contrary occurs: in the greater time the much smaller arc xy is completed, and in the smaller time the much larger arc rs is finished. It is therefore established from observation that, if the spots are supposed to be carried around on the Sun's surface with an ordered motion, the daily spaces near the horizon are larger than those in the middle, and so forth.

[Margin: The inequality of arcs traversed in equal time is confirmed by practical examples.]

You will find the same thing, and much more strikingly, in the semicircle $K-i-n-L$ for spot b . There the arcs on either side—whether ce and df at rising, or no and op at setting—will be larger than the middle arcs iK , Kl , lm ; even though, through the engraver's carelessness, the arc op has been made somewhat smaller, and ec a little larger than it should be.

But these things notwithstanding, what I said in the Pronouncement is nonetheless plainly discernible. What I have here shown for the sake of example in the two spots a and b , you may know to be true of all spots that describe a perceptibly rectilinear path, in any year and at any season. For spot a belongs to November of the year 1626, and spot b to May and June of the year 1627. And what I have found in these two, I have found in all the past years—together with others alongside me, though they did not notice it; for the same features belong to any rectilinear course whatever, when correctly observed through the telescope [Telioscopium]. Diligent observers will detect the same in times to come.

[Margin: All spots that describe rectilinear paths always exhibit the same inequality.]

Now let us turn our mind and pen to the curved courses, and see from the observations whether they are endowed with the same character.

THE APPARENT IRREGULARITY IS SHOWN ALSO IN CURVILINEAR MOTIONS

CAP. XX.

In the rectilinear course I showed the inequality of the apparent motions described by the spots in equal time, by means of unequal chords and arcs cut off by parallel lines—lines that I drew from the apparent positions of the spots onto the perimeter of the spot's own parallel. Now such a parallel, if it runs off-center, is always smaller than the greatest circle. But it ought to have been the case that, if the spots ran along their parallels on the Sun's surface with a regular motion, then in equal times both equal arcs and equal chords subtending those arcs would be intercepted. That this does not in fact appear to happen has just been shown.

We shall now show that the same thing occurs in curvilinear motions, but by a somewhat different route. For since the seen positions of the spots on the observatory (or solar) circle do not fall on the chord joining the extreme points of the apparent course, but deviate from it in a certain curved bend, we cannot take that chord as the diameter of the spots' parallel, nor emit the parallels with some uniform placement onto an unknown perimeter, nor describe that perimeter with such easy effort. Therefore, in order to elicit from the observed and seen distances and daily progressions of the spots the positions *not* seen on the Sun's surface but corresponding to the seen ones, I had to proceed by a more general investigation, better suited to my purpose. I lay down the following.

[Margin: A different examination must be applied to the curvilinear motions.]

First. From any given point of a sphere on its surface, to any other given point on the same surface, a circle can be drawn on the sphere.

Second. Through any two points on a sphere's surface not taken in diametrically opposite position, one greatest circle—and infinitely many non-greatest circles—can be drawn on that same spherical surface.

Third. The straight line joining those two points is the common subtense of all the intervening arcs of the circles that can be drawn through those points; that is, it is the common section of all the circles that can be designated through those same points.

[Margin: Premises to be assumed.]

I add, besides, two Lemmas by which what is to be said may be secured.

Diagram. The first lemma-figure (labeled "Lem. I."). It shows a plane figure folded along the line E–F: the outer frame runs from G (top-left) across to H (top-right); below, a slanted quadrilateral B C E F represents the raised portion, while the lower portion E F A D lies flat in the ground plane, with A at the lower-left and D at the lower-right. The construction illustrates the plane ABCD divided into part BCEF (in the raised position) and part EFAD (in the underlying plane AH).

- G (top-left corner)
- H (top-right corner)
- B (upper interior, left)
- C (upper right)
- F (mid-left, fold point)
- E (mid-right, fold point)
- A (lower-left corner)
- D (lower-right corner)

Diagram. The second lemma-figure (labeled "Lem. 2."). A square B E F A with its diagonals drawn, crossing at the central point G. B is at the top-left and E at the top-right; A is at the lower-left, C at the bottom-middle, and F at the lower-right; D stands near the top-middle, forming with A and C the triangle referred to in the proof. The figure illustrates the two parallel lines AB and CD, the triangle ABC lying in one plane, and the triangle ACD split into the part AGC and the part CGD.

- B (top-left)
- E (top-right)
- D (upper middle)
- G (center, intersection of diagonals)
- A (lower-left)
- C (bottom middle)
- F (lower-right)

LEMMA I.

It is not the case that one part of a plane lies in the underlying plane while another part lies raised above it.

[Margin: Explanation.]

Suppose, if it can be done, that of the plane ABCD the part BCEF lies raised, while the part EFAD lies in the underlying plane AH—so that all the lines FA, ED, etc. of

the part FD lie in the plane HA, while of the part BE all the lines FB, EC, etc. stand above or below that same plane.

[Margin: Demonstration.]

Given this: since the part FC lies wholly outside the plane AH, the line FB (or EC, etc.) will also lie outside it; and since the part FD lies wholly within the plane HA, the line FA (or ED, etc.) will lie in that same plane. But the whole line AFB is one straight line, and DEC is one straight line, for each lies in the single plane ABCD. Therefore of the straight line AB (etc.), one part lies in the underlying plane and another part lies raised above—which is impossible, by Elements XI.1. Therefore it is not the case that one part of the plane lies in the underlying plane while another part lies raised above it. Which was to be demonstrated.

LEMMA II.

Two parallel straight lines lie in one plane.

Let AB and CD be two parallel straight lines; I say that both lie in one plane. For, joining the straight lines AC, BC, DA, the triangle ABC will lie in one plane ABEF, by Elements XI.2. And if the straight line CD does not lie in this plane, then one part of the triangle ACD, namely AGC, will lie in the underlying plane...

AE, while the other part CGD will lie raised above—which is absurd by the preceding lemma. Therefore two parallel straight lines lie in one plane. Which was to be demonstrated.

PROBLEM.

From the apparent distance—seen on the observatory circle—of two spots at once (or from two positions of a single spot, seen successively on the same circle and correctly ordered), to assign the distance, or the positions, that would belong to those spots if they had been set and moved on the Sun's surface.

[Margin: The method of finding the true distances from the distances seen between two given apparent spots, or between two positions of one spot.]

In the adjoined diagram ABC, let ADBE be the observatory circle, and let two spots have been observed in it at two positions, 15 and τ , both on the 15th of August, at the same morning hour of 8, as may be seen in Observation Image XXXVII, p. 249, where you have the full arrangement of these spots. The spot numbered 15 there is called *a*, while the one lettered τ is *b*. Here, however, I have transferred merely their central points—and thus their apparent distance τ -15—

projected onto the Sun's circle, which is the same as the observatory circle. The distance $15-\tau$, then, is the one that I found by accurate observation on that day on the circle ADBC; it is called the *apparent* distance, because it was by so great an interval that those spots appeared to be separated, when cast onto the plane of the solar circle.

[Margin: The demonstration.]

Now, what corresponds to this seen distance on the Sun's surface—on the supposition that the spots dwelt there—we shall find in this way.

[Margin: This figure is taken over from Observation Image XXXVII.]

From the center C, draw straight lines to τ and 15, the centers of the spots; and then from τ and 15 raise two perpendiculars, terminated on either side at the perimeter of the horizon, and let these be $\tau-\epsilon-v$ and $15-K$. Since these are halves of chords—that is, sines of the arcs $\epsilon-v$, $o-i$, and $o-v$, K —they will stand for the quadrants $\tau-\epsilon-v$ and $15-K$ of the spherical circles, drawn from the poles $o-i$ and $o-v$ at the intervals $o-i$, $\epsilon-v$, $o-v$, K , which lie wholly along the straight lines $\tau-\epsilon-v$ and $15-K$. Hence, if you imagine the semidiameters $\tau-\epsilon-v$ and $15-K$ raised, about the axes $C-o-i$ and $C-o-v$, above the plane ADB...

until they stand perpendicular to it, they will always carry their extreme points v and K around in the perimeters of their own circles, and consequently on the Sun's surface. For these circles are drawn on the Sun's surface. And since these diameters are drawn to the said solar circle ADB, they will be parallel to one another (by Elements XI.6); therefore, by the preceding second lemma, they lie in the same plane, which is represented by the straight line $\tau-15$. The parallels $\tau-\epsilon-v$ and $15-K$ are represented by the points τ and 15, onto which they fall perpendicularly.

Now imagine that plane rolled about the line $15-\tau$ as an axis, until it reclines into the plane of the circle ADBE; the figure $\tau-15-v-\rho$ will be the same quadrilateral that, while it stood upright, had fallen onto the line $\tau-15$. And so the straight line $\tau-\rho$ is equal to the straight line $\tau-\epsilon-v$, and the straight line $15-v$ is equal to the straight line $15-K$; and thus the points ρ and v are those which stood raised on the surface of the solar sphere or globe. Hence, since the trapezium $\tau-15-v-\rho$, once reclined, is the same as it had been when upright, the distance $v-\rho$ must be the one that, in the raised position, corresponded to the seen distance $\tau-15$. The straight line $\rho-v$, therefore, is the chord of the given spots ρ and v —on the hypothesis that they subsist on the solar surface—joining their centers and subtending an arc of the greatest circle, such as ADBE.

[Margin: To assign, from the seen distance, the true distance in degrees and minutes.]

Hence, if this chord is applied to that same circle, the arc it subtends will show the distance of the seen spots in degrees and minutes—the distance owed to the apparent distance $\tau-15$. And thus, from the apparent distance of the two spots, we have found the one that corresponds to it on the solar surface. Which was to be done.

By the same device you will supply the chord $\psi-\alpha$, owed in the raised position to the same two spots X and 19 on the 19th day; and likewise, on the twelfth day, from the seen distance $12-\alpha-l$, you will assign the surface distance $\alpha-v$, $\epsilon-l$. And this is one case: when two spots are seen at once. In this case it is not necessary that their situation and position relative to the ecliptic, or to the vertical perpendicular, be had; it suffices only that their position on the solar (or observatory) circle be given from observation, without any other information, whether of time or of place. The reason for this is that from the mere radius from the centers of the spots and of the solar circle, and from the seen...

[Margin: The true distance of two spots is obtained, without any other datum, from the apparent distance alone.]

distance of them, one may proceed. This procedure, easy as it is in itself, brings the greatest weight to my case; for from this single head alone the spots are proved to be on the Sun, as will be seen later. By this examination any spots whatever can be sifted, and their mutual distances, and their motions—whether conforming or differing—can be discovered.

[Margin: By this most comprehensive method of examination, a spot is found to be on the Sun.]

But when only the itinerary account of a single spot is investigated, and the daily intervals are weighed against one another by mutual comparisons, one must first lay out its path—which is not done without drawing in the perpendicular and the ecliptic. Once the track is set in order, the daily seats are compared with one another, and from the apparent positions the position on the Sun's surface is obtained in the same way. As in the example: suppose you wish to compare the seen positions of days 12 and 13 with the seen positions of any other days—for spot *a*, which completed its course from the 6th to the 19th of August, and is here expressed in the same diagram by the day-numbers alone, from day 6 to 19—you will elicit from the seen positions the positions on the Sun's surface, and from these compared with one another you will understand their proportions.

[Margin: How the daily paths of a single spot are to be compared with one another.]

From the center C, then, you will draw the straight line C-12; from 12 you will drop the perpendicular 12-g to the perimeter; in the same way you will draw the straight line c-13, and from this the perpendicular 13-h. Then to the line 12-13 you will draw two lines from those same points 12 and 13—call them 12-ç and 13-f—parallel to each other and perpendicular to the line 12-13; and let 13-f equal the perpendicular 13-h, and 12-ç the perpendicular 12-g. This done, if the extreme points ç and f are joined by a straight line, this will be the chord connecting the two stations of the spot as it moves on the Sun's surface; and the arc it subtends in the perimeter of the observatory circle will show the true magnitude, in degrees and minutes, of the seen distance 12-13.

[Margin: A practical example of the comparison of daily paths.]

You see this done by me for each of the several days on which this spot traversed the Sun. And so, in the trapezia set out—6 7 r q, 7 8 t s, and so on—the transverse line joining the parallels at unequal angles is always the chord sought, carried through the true positions of the spot on the Sun's surface (on the supposition that the spots inhere in it, which will be discussed more fully later). The line q r, then, answers to the straight interval 6, 7; and s t to the interval 7, 8; while u x...

is owed to the seen distance 8, 9; and to the following interval 9, 10 the chord y z is assigned; and so the rest to the rest, right to the end. In the same way any given courses can be, and usually are, set out.

COROLLARY I.

From these things it is easy to show the truth of the Pronouncement also in the curvilinear travels of the spots—namely, that in equal time more is traversed near the horizon than in the middle. For the distance q r on the eastern side, and ρ-σ on the western, is greater than the middle one, y-δ; yet this middle distance was traversed in one day, one hour, and five-sevenths of an hour, whereas the eastern q r was completed in one day and one-sixth of an hour.

[Margin: The truth of the Pronouncement is made solid by the adduced examples.]

Thus the spot, near its rising, from the sixth day to the seventh, traverses more space in 24 $\frac{1}{6}$ hours than it does from the 11th to the 12th in 25 $\frac{5}{7}$ hours. In the same way, near its setting, in 23 $\frac{4}{5}$ [?] hours a greater distance ρ-σ was covered than near the middle in 25 $\frac{5}{7}$ hours. Much more, therefore, did they accomplish

[near the limb] than near the middle from day 10 to 11, or from 13 to 14, in a roughly equal time. This is plain, for the chords $\alpha\text{--}\beta$ and $\alpha\text{--}\delta$ are much smaller than the marginal chords $q\text{--}r$ and $\rho\text{--}\sigma$. The truth of the Pronouncement therefore stands: if the spots are supposed to be carried on the Sun's surface, then even in curvilinear courses the daily intervals near the margins are traversed larger than near the middle. And this is true not only in this course of the spots, adduced for the sake of example, but in all others (other things being equal). I have tested and proved this constant, ever self-consistent appearance (other things being equal); through a thousand ways and occasions it is perennial, irrefragable, beyond doubt. I have found the same in all the courses of others, when correctly worked out.

[Margin: This truth is to be found also in the observations of others.]

COROLLARY II.

Indeed, this same appearance holds also for two spots weighed against each other near the rising, the middle, and the setting. Look in the diagram at the spots of the twelfth day, $\alpha\text{--}\iota$ and 12; and from the apparent distance $\alpha\text{--}\iota\text{--}12$, consider the surface distance $\alpha\text{--}\nu$, $\varepsilon\text{--}\iota$; and compare this with the middle distance of day 15, and you will see that the chord $\alpha\text{--}\nu$, $\varepsilon\text{--}\iota$ is larger than $\rho\text{--}\nu$ is, from $\tau\text{--}15$...

Diagram. A full-page geometric projection of the Sun's disk showing the daily path of a sunspot across the solar face over successive days, 6–19 August 1625. The figure is a large circle; a horizontal diameter runs from **A** (left limb) through **C** (an interior point toward the center-right) to **B** (right limb, with the small labels π and ς beside it). **E** is marked at the top of the circle and **D** at the very bottom, beneath the arc and the table of times. An arc of numbered points — **6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19** — traces the spot's position on each successive day, with solid and dashed straight lines (sight-lines / chords) drawn from these points to the limbs and interior. A dense fringe of small Greek and Latin minuscule labels runs around the circumference (including ϕ , a, b, c, d, e, f, h, l, m, and interior/lower letters such as r, s, t, u, x, and Greek ω , ψ , ρ , σ , ξ , o, and a lower row z, α , β , γ , δ , ε , ζ , η , θ , ι , κ , λ , ν). Many of these peripheral letters are partly obscured by mirror-reversed verso bleed-through and cannot be individually resolved — flagged [?] below. The four corners carry engraved emblems: a radiant **IHS** Jesuit monogram (top left), a radiant **MRA** Marian monogram (top right), and a heraldic rose (the Orsini device) at the lower left and lower right. Inscribed within the lower arc: "Anno Iubilaeo M.DC.XXV." (lower left) and "à die 6. ad 19. Augusti" ("from the 6th to the 19th of August," lower right).

- A (left end of the horizontal diameter): A
- B (right end of the horizontal diameter): B (with π , ς adjacent)
- C (interior point on the horizontal diameter, center-right): C
- D (foot of the figure, below the arc): D
- E (top of the circle): E
- 6–19 (numbered daily spot positions along an arc): 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19
- Peripheral minuscule ring (numerous small Greek/Latin point-letters, several obscured by verso show-through): φ , a, b, c, d, e, f, h, l, m, r, s, t, u, x, ω , ψ , ρ , σ , ξ , o, z, α , β , γ , δ , ε , ζ , η , θ , ι , κ , λ , ν [several [?]] — see note]
- Corner emblems: IHS (Jesuit monogram, top left); MRA (Marian monogram, top right); heraldic rose (lower left and lower right)
- Inscription (lower left): Anno Iubilaeo M.DC.XXV. [In the Jubilee Year 1625]
- Inscription (lower right): à die 6. ad 19. Augusti [from the 6th to the 19th of August]

More than two peripheral labels are unresolvable against the verso bleed-through — this diagram is a

Table of observation times embedded at the foot of the figure (heading "D — H." = *Dies — Hora*, Day — Hour; "m." and "u." are the printed period-abbreviations, transcribed verbatim):

Da y	Hour	Da y	Hour	Da y	Hour
6	m. 7½	11	m. 7¾ [?]	16	m. 7 [?]
7	m. 7⅔ [?]	12	m. 9	17	m. 9 5/11 [?]
8	m. 7½	13	m. 7¼	18	m. 8
9	m. 7 4/9 [?]	14	m. 7¾ [?]	19	m. 7 5/8 [?]
10	m. 7½	15	m. 8	19	u. 4⅓ [?]

derived. And by this same procedure you will find — for the spot x, on the 19th — that the western chord is again the larger, indeed equal to the eastern one, as is evident. Cases like this occur a thousand times throughout the preceding book. In fact, I have found matching instances in the Galilean Observations: examine the distance of spot y and of the one lying just beneath it (which carries no letter) — examine, I say, their distance — on 26 June, on the 27th [and 28th]; likewise on 1, 3, 4, 5, and 6 July, and you will see that their distances at the margin are found to be greater than those at mid-disk. In one or another middle observation the point

may not agree; but I know that this arises not from the true intervals of the spots, but from human inattention, since in marking down a position it is easy to deviate somewhat.

[Margin: The same conclusions are confirmed from the Galilean observations.]

Corollary III

[Margin: To derive the parallel courses of the spots — or conversely, their convergences.]

From this you may learn the method and the principle for detecting the parallel tracks of the spots, their convergences and divergences toward one another, and the differences among the individual spots.

Scholium

These excesses at the margin are neither equal nor alike; rather, according as the parallels of the spots are large or small, inclined or perpendicular to the horizon, so is there more or less share in this appearance. The same holds according to how the telescopes are applied to the observing.

The difficulties arising from this appearance are weighed and removed

Chapter XXI

[Margin: This appearance conflicts with the regularity of the spots' motion.]

The very first difficulty that occurs to anyone is this: that by this appearance — which is nonetheless perfectly certain — the regular uniformity of the solar phenomenon in its motion is destroyed. For from this appearance, all the courses of the spots become faster at their rising and setting than they are at mid-disk, as has been shown more than sufficiently up to now, since in an equal time larger arcs are traversed. Therefore the motion at the beginning and at the end is always accelerated [*praecipitatur*]; and any acceleration in a motion destroys the uniformity of its progress. Hence it seems downright impossible that the regular uniformity of the spots' motion can stand together with this appearance.

This is confirmed by the fact that this acceleration behaves differently in different parallels — one way in rectilinear tracks, another in curvilinear ones.

[Margin: Reply to the arguments.]

I answer that this difficulty raises more of appearance than of substance. For, **first**: if it proved anything, it would also overthrow the annual revolution of the spots — a motion always uniformly deformed [i.e. rendered non-uniform], with courses now rectilinear, now curvilinear, carrying them into contrary positions. It would overturn the regression, station, and progression of the spots, for all these seem to be at odds with a regular, uniform motion. But if these appearances exist and stand together with the order of a uniform motion, then this apparent acceleration will likewise stand — especially since not even in it is any stable order lacking: for a motion completed in the same parallel is accelerated in the same way, other things being equal. Therefore there must underlie this effect a certain necessary, not accidental, cause.

And so, **secondly**: it is denied that this acceleration cannot stand together with a uniform motion; for it is not inherent in the motion itself, as will be clear later.

Indeed, **thirdly**, I affirm that a uniform and regular motion of the spots cannot stand together with this manner of observing *without* this acceleration of the motion.

And finally, **fourthly**: if the motion of the spots, discovered by this manner of observing, were to lack this acceleration, the result would be that it was not regular, not uniform. All of this will become clear in its proper place below; for now we assume it by way of reply. And so let the first difficulty be, on this reckoning, easily dispatched.

Difficulty II

[Margin: This appearance seems to tear the spots away from the surface of the Sun.]

This appearance seems not to be consistent with the supposition that had been laid down, by which the spots were established to be part of the solar surface. For if the surface of the Sun is continuous in spherical fashion, how is it possible that, when one part of it moves, every other part is not likewise set in motion? Therefore, if the spots are carried swiftly in it and along with it at their rising or setting, it is necessary that they be driven with a like speed around mid-disk as well.

Hence, either the spots together with their motion are not to be thrust into the solar surface, or, if this appearance holds, the surface of the Sun must be twisted and torn apart in a manner that is astonishing — not to say pitiable. For when the eastern spots are hurrying while the middle ones stand still, the surface portion

of the Sun between them will be wrinkled up; and when the western ones prevail while the middle ones do not keep pace, the portion of surface between them will be most violently rent apart. But these things are monstrous even to think of,

let alone to speak of. Therefore this appearance does not stand together with the spots being carried on the Sun.

[Margin: Reply to the arguments.]

I answer, as before, that more of imagination and of words underlies this difficulty than of fact. For, **first**, by the same reasoning it will be proved that ships are not part of the sea's or a river's surface, seeing that vessels heading the same way are carried, some faster than others. Hence it can very well happen that something existing upon another body's surface is moved unevenly, without any great disturbance to that surface. But whether, and how, the spots are carried around upon the Sun unharmed will be told in its proper place. For the moment it is enough to show that the reasoning is not compelling and that the argument in no way forces the conclusion.

Second, so far is it from being the case that this appearance removes the spots from the Sun, that it much more firmly plants them in it.

For, **third**, if the solar spots are not part of the Sun, then the eastern and western acceleration — as will be demonstrated shortly — does not exist.

And, **fourth**, if the rising and setting acceleration of the spots is granted, as it has been shown to be, it is necessary that the spots be part of the Sun; for if they are supposed not to be part of it, then at once there is no acceleration, given a regular motion. And yet, even if these things are so and are granted to occur, no wrinkling of that surface, and no violent tearing, will follow from this apparent motion. On the contrary, even if all the spots were fixed in the Sun like nails, that acceleration, both rising and setting, would still occur — as will be plainly established from what is to be asserted below. So this difficulty carries little force. But how this enlargement of the Sun and of the spots comes about, while the motion remains regular and the spots stay fixed in the Sun, will be taught a little later, in its place.

Difficulty III

[Margin: This appearance seems to establish a parallax of the spots relative to the Sun.]

Of all the appearances in the whole solar phenomenon, none so plausibly insinuates, none so persuasively urges, a parallax of the spots relative to the Sun as this one does. For everything that ought to occur in a case of parallax may perhaps seem to occur here; certainly the things that happen here fit a parallax most beautifully. For if there were a parallax of the spots in this business, it would surely always be greatest near the horizon and least near culmination, and it would diminish on receding from the horizon and increase on approaching it. Now all of these features are present in this appearance: for the daily horizontal arcs and intervals toward the east are greatest, then gradually decrease toward the highest, or mid-heaven, Sun, and at the summit near the center are least, and then again decrease toward the western horizon. Therefore anyone who is ignorant of a deeper knowledge of both matters, or who shirks acquiring it, may easily persuade himself that this appearance is to be referred to parallax.

But in truth, whoever has more intimately examined the nature of this phenomenon, and more carefully weighed the theory of parallax, will go off into anything else rather than admit this appearance we are discussing into the account of parallax.

[Margin: Reply to the arguments, and parallax is sent far away.]

For, **first**: where parallax intervenes, there a thing subject to parallax, viewed at one and the same time from different regions, appears in different places of the sky; and the same spot, whatever region of the Sun it occupies, will appear more western to more eastern observers and more eastern to more western ones. But this never happens here; rather, all observers over the whole world always contemplate the same spot, at the same time, in the same place on the Sun. Therefore this appearance is not to be reckoned among the parallaxes.

Second: if this appearance were parallax, one and the same observer from the same place would find the same spot more eastern near sunrise and more western near sunset than a regular and ordinary motion would allow; but this never happens in this phenomenon, as experience testifies. Therefore this appearance is not parallax.

The consequence in the major case is evident, since, at sunrise, the observer's location is at its most western, so that a spot subject to parallax would be thrown back into the east, beneath the Sun, more than is fair; while at sunset the same location becomes, with respect to that same Sun, the most eastern, so that the spot as seen, if it were subject to parallax, would be projected toward the western

parts of the Sun more than usual. Since neither of these happens, it is clear that no parallax intervenes here. Similar things could

be brought forward concerning parallax in latitude.

Third: if parallax is inherent in this phenomenon, it is always present in every manner of observing, and so on. But this appearance is not always present in every manner of observing. Therefore this appearance is not parallax. The major premise is clear and self-evident; the minor is proved by reflection and by a bare aperture: if the Sun is observed reflected from a plane mirror, the spots do not undergo this acceleration; and they are free of it if the matter is carried out with a bare admission-aperture [pinhole]. Experience will attest both to the diligent investigator — an example of which I shall give later.

Fourth: the very truth, and the genuine cause of this effect — to be brought forward a little later — plainly proves that this experiment can in no way be counted among the parallaxes. This appearance, therefore, has nothing in common with parallax.

Difficulty IV

Whether, on the occasion of this appearance, epicycles ought to be introduced into the solar phenomenon; on which occasion these same epicycles are also entirely rejected on the same ground.

Chapter XXII

[Margin: This appearance seems to establish epicycles around the Sun, in which the spots move.]

If there is anything in this solar phenomenon that could furnish an occasion for fashioning epicycles — that is, small circles, wholly outside but around the Sun, in which the spots roll — it could surely be drawn from this appearance. For suppose that a rising spot is understood to be at its aphelion, that is, at the apogee [*Auge*] of the epicycle, and that in the lower semicircle of the epicycle it turns from east to west, and in the upper from west to east; and suppose it turns once while it passes beneath the Sun and once while it passes above it. Then we should perhaps have that hurrying of the spots in their motion around the solar margins, and we should have the slowness around mid-disk. Now there are those to whom it is a pleasure to waste time uselessly on trifles of this sort and to feed the mind on empty amusements — with their showy devices (as they suppose), but really, with laughable contrivances and childish rattles, deceiving both themselves and

others. So that these people may not, I have thought it worthwhile to work this very contentious saw back and forth here to good purpose — otherwise I would readily have neglected the matter and left each to his own opinion, if they would let it be: for, not content to lay their own rubbish about this subject before the grave gaze of the most learned men, they further promise themselves public sanctions besides, whereby they alone should be wise and others nothing; so that these leaders alone may lead others in triumph, in fetters of hand and foot, along with truth itself. That this may not happen, so be it.

First assertion. *It is impossible that the apparent acceleration of the spots around their rising and setting should be defended by epicycles, on account of their regular and perpetual narrowing toward the said regions.* That the spots and faculae — and whatever else there is in the Sun — are always and constantly contracted around the solar horizon, and much more so upon it, and are thereby drawn out into a certain apparent elongation: this is, from the phenomenon itself, and indeed from the whole of the preceding book, and from the continuous experience of so many years, too well established to need to be shored up by further proofs. Nor do I think anyone will find any difficulty on this point in any way, on account of its very great certainty — so much so that no spot has ever been exempt from this condition, for they all grow narrow.

[Margin: The horizontal acceleration of the spots cannot be defended by epicycles, on account of their narrowing.]

This being laid down, it cannot possibly be that the spots, in order to safeguard the appearance we have so far been treating, are carried around on their own epicycles, whether in the stated way or in any other whatsoever. For, granting this, in the eastern and western regions near the horizon they would be, by what has been posited, most remote from the Sun, and for this reason free from that perceptible and customary contraction — which is false and perpetually contrary to the tenor of the phenomenon.

[Margin: Proof of the assertion.]

That the spots near the horizon would be free of that perceptible narrowing follows from this: that, being far from the Sun — separated, that is, by the whole diameter of the epicycle — they would not have any great inclination, which alone (other things being equal) causes an oblique position and aspect to the eye, and hence the apparent narrowing. This, therefore, since through the cir-

once these epicyclic circles are removed, even at the level of sense-perception, it is clear that they cannot be granted to maintain this appearance.

[Margin: The anomaly of motion that would follow refutes the epicycles.]

Second Assertion. *It is impossible to account for this appearance of the spots by means of epicycles, because of the inevitable asymmetry that would then follow in the motions corresponding to the solar disc — an asymmetry which, once the spots are placed on the Sun itself, is established by what precedes, and will be confirmed by what follows, to be entirely absent.* But if these epicycles are introduced, it is certain that such asymmetry will arise, on account of the spots' perceptible removal from the Sun — for they will stand off from it by their own diameter — and this revolution, passing through the center of the Sun and of the spot borne along, will introduce the greatest diversity into the motion.

Now all of this conflicts with the phenomenon; therefore the epicycles too, which are its cause, conflict with it. And if we imagine some facula being carried around in place of a spot, then, because of the difficulties just stated, it too would be seen outside the Sun — which likewise contradicts the phenomenon.

[Margin: The shape of the spots, and their ever-similar posture, rejects the epicycles.]

Third Assertion. *It is impossible to defend the aforesaid appearance of the spots by epicycles, because the shape and position of every spot is always turned toward the same part of the Sun.* For it is certain that, if the said revolution of the epicycles were attributed to any spot, the position of every spot would be changed — so that its western part would become eastern, and the part that had faced east would be the first to incline westward, and so on, because of the epicycle's revolution. From this there would then arise noticeable and rapid changes of shape, since the spots are not spherically round.

[Margin: The spots do not rotate about their own centers.]

But that none of this occurs is established from the observations recorded in the previous book. That the part of a spot which faced the Sun's setting at its rising is the first to set, and the part that rose last is the last to set, is taught by unbroken experience; the nuclei of the spots prove it; the faculae clinging to the spots, whether ahead of them or behind, demonstrate it infallibly; the spots associated with other spots show it plainly — for none that went before ever followed after, and none following behind ever went in front. The tips and tails of the spots too attest the same beyond dispute: for as long as they last, they cling to the spots toward the same quarter. Therefore, since the position of every spot is thus shown to be unvarying, it is evident that these epicycles are fashioned to no purpose.

[Margin: The contrariety of motion that would follow overturns the epicycles.]

Fourth Assertion. *It is impossible to defend the aforesaid appearance by epicycles, because there would then be motions of the spots, in one and the same epicycle, simultaneously from east to west and from west to east.* But these are monstrous suppositions, utterly foreign to this phenomenon. I assume, moreover, spots of this kind lying near one another — distant indeed from the Sun on the adversary's hypothesis, but equally so; for if they were perceptibly unequal in their distances, this would become known from the apparent motion itself, which, however, does not happen. Once these points are grasped and granted, what the assertion states becomes at once clear. For very often spots on the same parallel follow one another closely in a shared track, at so great, or so slight, a distance from each other that they must necessarily be enclosed within the same epicycle. Granting this, some of them will necessarily be opposed to others in motion just as in position, since they stand and turn about the same center of the same epicycle. For those in the outer semicircle will go westward, and those in the inner will go eastward; and so, in the same epicycle, about the same center, and with a like motion, some spots will be carried toward the east and others toward the west, and there will occur mutual conjunctions, anticipations, and postpositions among them, and so on — all of which, however, are false and contrary to the truth of the phenomenon.

[Margin: The uniting and separating of the spots removes the epicycles.]

Fifth Assertion. *It is impossible to save the aforesaid appearance of the spots by epicycles, because of the mutual coalescences and separations of the spots that the epicycles would have to produce, if several spots are placed in the same epicycle — as I proved earlier that the adversaries must place them.* For two spots at their rising, for example, somewhat separated from each other, would, as they advanced from the horizon toward the middle, draw ever closer together until they were wholly united; then, in the inner (or perihelial) semicircle of the epicycle, they would in turn be separated again. Every epicycle would do this twice for every spot. Since these consequences are utterly false, anyone who reckons epicycles among true things embraces errors in place of truth.

[Margin: The penetration of bodies, and the mutual entanglement of the epicycles that follows, overturns the epicycles.]

Sixth Assertion. *It is impossible to uphold the aforesaid appearance of the spots by epicycles, because of the mutual entanglements of the epicycles and of the motions.* For since the whole Sun is completely filled with spots and faculae in

alternation — secondary bodies equally distant from the Sun's center (which here, just as in the Fourth Assertion, I assume from what has been proved elsewhere concerning the Meditullium) and immediately adjoining one another — either each single one will have its own epicycle, or none will. For there is no greater reason why an epicycle should be granted to this one and denied to that, since, other things being equal, all and each have the same motion in common, the same duration, a similar course, and so on.

Next, their ordinary shapes are oblong, and these cannot be fitted into an epicycle without cutting into the ones adjoining them. And if you enclose two or more within a single epicycle, there is no greater reason why you should link each particular one with this neighbor rather than with any other joined to it. Finally, there would result empty spaces between the epicycles, and at the same time an entanglement of the epicycles. But neither of these can be admitted as true. The proposed assertion therefore stands.

Thus, if epicycles are assigned to none, I have what I aim at; if to each, you get mutual interweavings of bodies and of motions, and hence penetration, and obstructions of their courses, and so on. But these things are impossible; therefore the epicycles are impossible too.

[Margin: Different distances of the spots from the Sun entangle matters still more.]

You will say that all this can be avoided by supposing a greater and a lesser distance of the spots from the Sun's center. I reply that mud is not washed away with mud, nor is an absurdity well defended by a still more absurd invention. For, in the first place, on what grounds does so confident an assertion rest — namely, that one spot is farther from the Sun's center than another, and that outside the Sun? By what reasoning, by what experiment, pray tell, do you build this up? "I assume it," you say; and on that assumption I prove what I wish, and defend what you would not have defended. Really? And because you make an assumption, do you demand my assent on that alone? By this way of philosophizing, what falsehood will you not establish? What truth will you not tear down? You want false suppositions to be believed, yet you place no faith in true phenomena confirmed by so many arguments and so many experiments.

But let us grant meanwhile, for your sake, various distances of the spots and faculae from the Sun, so that there may be room for so great a heap of epicycles, if you so wish; and let us see what will come of this. This, I think: that we shall behold the Sun as anything but round.

[Margin: The faculae, contrary to the phenomenon's appearance, would overstep the Sun.]

For the faculae, at their rising and setting, would overstep the Sun's limb by exactly as much as they are removed from the Sun by the epicycles. But that this is false, the phenomenon itself and the whole preceding book show.

Besides, if that fictitious diversity of distances outside the Sun had any place — even the appearance, for whose defense these things are invented — a notable diversity would be observed in the daily intervals; but this does not happen, as is clear from the observations already made, and will be clear from those still to be made, provided that other things are taken as equal, and so on. Therefore this appearance cannot in any way be defended by those fabricated epicycles, nor these epicycles by arbitrary and impossible departures of the spots from the Sun — not, at least, while the truth of the phenomenon stands, and not without mutual penetrations of bodies and entanglements of motions.

I pass over now other arguments against the perceptible withdrawals of the spots from the Sun such as would necessarily occur here — arguments set out fully elsewhere; and I pass over still others, to be set out elsewhere.

[Margin: Observations made without a telescope do not exhibit this appearance at all; hence the epicycles are groundless.]

Seventh Assertion. *That this appearance is defended by epicycles in vain becomes plain even from this: that if the spots were carried on epicycles, and if because of the epicycles those accelerations occurred, this ought always to happen.* But it is certain that this appearance occurs neither in reflected observations nor in direct ones made through a bare aperture; therefore it ought not to be ascribed to epicycles. And it is confirmed thus: otherwise two contradictories would occur at one and the same time. For whoever records the spots as admitted through a telescope [Telioscopium] will infallibly find the aforesaid anomaly of the daily intervals; but whoever notes them as received through a mere aperture will observe none of this at all. Therefore the same spot would at once be carried on an epicycle, according to the telescopic observation, and at the same time not be carried on it, according to the observation through the bare aperture — which cannot be. But a bare aperture does not alter the object; it transmits it as it is. Therefore, if the epicycles were the cause of this appearance, applying an aperture would not take it away.

Eighth Assertion. *That this appearance can in no way be defended — indeed upheld — gratuitously by contrived epicycles, under even some shadow of*

probability, will become clearer than the Sun itself, once the true and genuine cause and explanation of it is brought forward. For this cause, like the Sun scattering the mists, will at once disperse all the dregs of empty invention.

Accordingly, so as not to detain the studious reader's attention any longer, we come to the matter itself and honestly uncover the very truth.

Twelfth Pronouncement

The aforesaid appearance — that is, the greater-than-due magnification of the daily intervals near the horizon and the lesser magnification near the middle, and hence the [Latin: flata (?)] inequality of the daily distances in the courses which the spots complete, an inequality detected when other things are equal — arises solely from the inequality of refraction which the lenses of the telescope introduce into the transmitted image of the Sun.

Cap. XXIII.

[Margin: The telescope is commended by its outstanding effects.]

This is the one matter that creates no small labor and trouble for the skillful investigator of the solar phenomenon: for however much the use and effect of the optical tube is everywhere obvious, just so much do its manner, principle, and cause seem abstruse and remote from the ordinary understanding of men. It is certain that two very great benefits are afforded to mortals by the telescope. The one is that small things are brought into view at a very great magnitude; the other, that the same things, previously seen only dimly, are perceived distinctly and sharply. And what further recommends the instrument's superiority is this: whereas the other kinds of eyeglass serve either only the near-sighted or only the far-sighted, and each one serves practically only its own particular user, this glass is so constituted that it can be usefully fitted to every eye — provided it is sound — and applied to every object, near or far, whether the eye is furnished with a broad pupil or a globular one;

[Margin: It serves every sound eye, for any object whatever.]

and this by mere contraction and extension. For the near-sighted contract the telescope where the far-sighted extend it, and both distinguish the same object sharply. For near objects both extend it, while for distant ones the same persons contract it, each according to his own constitution; and in seeing a thing well, all attain their wish. They rejoice, as it were, to handle with the hand a thing set before them, which with the unaided sight they had not even been able to reach.

All this, I say, everyone experiences, and they are well aware that it is accomplished by the lenses of the telescope through some wonderful contrivance; and they see that various effects come about by drawing it in and drawing it out. Yet they suspect the inner cause and manner rather than see through to it. That it resides in the lenses is agreed among all; but the manner, and the ingenious composition of art with nature, escapes most people. On this subject, although I have treated it at length in the Second Book, and in the *Sol Ellipticus*, as well as in the *Refractiones Caelestes*, here nonetheless I shall set a few points before the reader's eyes in summary, so as to comply somewhat with his ardent desire.

I therefore assume, from optics, the following principles

— *to be effectively proved, against any objector, either from the solar phenomenon itself, or from the telescopic lenses and their marvelous effects.*

First. Every point of a visible thing emits a sphere of rays. This is clear from any spot whatever, which is seen from every direction at once. This would not happen unless it radiated every which way.

Second. Every ray of the radiant sphere is rectilinear. Otherwise an object would not be hidden by directly interposing an opaque body, for it could be seen by a curved ray admitted from the side, and the spots would then be seen on the averted quarter of the Sun, and so on — which does not happen.

Third. Every visual ray that is to emanate from a visible object requires a transparent medium; for where there is no transparency, there is no flow of rays. This is clear from the sunspots, which, in the part where they occupy the Sun, intercept the luminous ray, because they are not transparent. In the same way we do not see the interior of a wall, a tree, or an animal, because the ray cannot pass out on account of the opaque obstacle. So too the interior of crystal, of water, of fire ...

that the shadow of a mere semblance can in no way prevail will become clearer than the Sun itself, once the true and genuine cause and rationale of it is brought forward. For this, just as the Sun disperses the mists, will at once dissipate all the dregs of vanity.

Therefore, so as not to detain the studious reader's attention any longer, we come to the matter and lay bare the very truth itself with sincerity.

[Margin: Truth will make manifest the vanity of the epicycles.]

TWELFTH PRONOUNCEMENT

The appearance described above — that is, the greater-than-due amplification of the daily intervals near the horizon and the smaller amplification near the meridian, and consequently the established inequality [stata inaequalitas [?]] among the daily distances in the courses which the sunspots [maculae] trace out (all other things being equal, once this is grasped) — arises solely from that inequality of refraction which the lenses of the telescope introduce into the transmitted image [species] of the Sun.

CAP. XXIII.

This is one matter that creates no small labor and trouble for the careful investigator of the solar phenomenon. For however commonly the use and effect of the optical tube [Tubus Opticus] present themselves everywhere, just so much the more is its manner, rationale, and cause hidden and seemingly remote from the common understanding of men. It is certain that two very great benefits are afforded to mortals by the telescope: the one, that small things are brought into view under a very great magnitude; the other, that those same things, previously seen but faintly, are discerned distinctly and sharply. And what commends the instrument's prerogative still more is this: whereas the other eyeglasses serve only the near-sighted [myopes], or only the far-sighted [presbytae], and each is generally suited to a single individual, this glass [specillum] is so contrived that it can be usefully fitted to every eye — provided the eye is sound — and applied to every object,

[Margin: The telescope is commended by its own outstanding effects.]

whether near or far, and to a pupil whether flat or globular; and this by contraction and dilation alone. For the near-sighted contract the telescope where the far-sighted draw it out, and both distinguish the same object sharply. For near objects

[Margin: It serves every sound eye, for any object whatever.]

both draw it out, while for distant ones the same persons contract it, each according to his own disposition; and in seeing a thing well they all attain their wish, and rejoice to handle the thing as though present, which by unaided sight they had not been able to reach. All men, I say, experience this, and are well aware that it is accomplished by the lenses of the telescope through some wondrous artifice, and they see that it comes about variously by shortening and lengthening the tube; yet they suspect the cause and the innermost manner rather than perceive them. And while it is agreed by all that it resides in the

lenses, still the manner, and the ingenious composition of art with nature, escapes most people. Although I have treated this at length in Book Two, and in the *Sol Ellipticus* [1615], and also in the *Refractiones Caelestes* [1617], nevertheless I shall here set out a few points in summary, so as in some measure to comply with the reader's ardent desire.

I therefore assume from optics the following principles — to be proved effectively, whether from the solar phenomenon itself, or from telescopic lenses and their marvelous effects, against any quibbler [refractarius] whatever.

First. Every point of a visible thing emits a radiant sphere. This is evident from any sunspot, which is seen simultaneously from every side; which would not happen unless it radiated in every direction.

Second. Every ray of a radiant sphere is rectilinear. Otherwise, when an opaque body was set directly in the way, the object would not be hidden, for it could be seen by a curved ray admitted from the side, and the sunspots would appear on the averted region of the Sun, and so forth; which does not happen.

Third. Every visual ray about to emanate from a visible object requires a transparent medium; for where there is no transparent medium, there the flow of rays is nil. This is evident from the sunspots, which, in the part where they occupy the Sun, intercept the luminous ray, because they are not transparent. So too we do not see the interior of a wall, a tree, or an animal, because the ray cannot pass out on account of the opaque obstacle. So too [we see the inner parts] of crystal, of water,

of fire, and so forth — we survey their every inmost part, because, being transparent, they afford a passage to the visible images toward the sight.

Fourth. Of transparent bodies some are rarer than others — as air is rarer than water; and some are denser than others — as water is denser than air. Crystal and glass commonly possess a density like that of water. So the authorities and experience teach.

Fifth. A visual ray from an object, falling perpendicularly upon transparent bodies of whatever number and kind, passes on and through unrefracted.

Sixth. Any visual ray whatever, gliding obliquely from any object out of one medium into another, is broken: that is, it deflects from the straightness of its prior course. And although it continues its path along a straight line, still the traversed path taken in the second medium does not lie in a straight line with the trace of the path described in the first medium; but these two rays, since both are

rectilinear, meet at an angle at the boundary of the two media. Whenever, therefore, this happens, the ray is said to be refracted — which always happens when the ray passes obliquely, or falls at unequal angles, from the first medium into the second.

Hence I deduce that refraction does not occur precisely from the fact that the visual ray falls into a medium of another ratio [density], but from this, that it meets another medium obliquely.

[Margin: The obliquity of incidence produces the refraction.]

Seventh. A ray falling obliquely from a rarer into a denser medium is broken toward the perpendicular. Now the perpendicular, to which or from which the refraction takes place, is the line which, from the point of incidence, stands at right or equal angles upon the surface of the second medium or transparent body.

Hence it follows that the rays from the Sun and from the sunspots, gliding into the lenses, are refracted within the thickness of the lenses toward the perpendiculars, because they are carried from a rarer medium — namely air — into a denser one, which is the very transparent substance of the lenses. And this is true not only of a convex lens but also of a concave one — although the latter receives the Sun's rays mediately from the convex

[Margin: The rays of the sunspots are refracted in the lenses toward the perpendicular.]

lens.

Now by the name "second medium" I do not mean only that which is simply second, but that which is called second by comparison with that which immediately preceded it. Thus it can happen that any medium which is neither simply first nor simply last both is and is called first and second: for with respect to the following medium it is called first or antecedent, while with respect to the preceding one, or the first, it is called second or consequent. Air, therefore, before the convex lens, in our business, is the first medium absolutely; the convex lens in the telescope, aimed directly at the Sun, is the second medium — which, with respect to the interior air that follows it, can in turn take on the character of the first or antecedent medium; and the following air, which absolutely would be the third medium, takes on the office of the second, indeed even of the first, medium, with respect to the following concave lens, and so on. These things I have thought worth stating in advance, to avoid errors and guard against confusions.

[Margin: By "second medium" is understood any medium subsequent to a preceding one.]

Eighth. A ray passing obliquely from a denser transparent body into a rarer one is always refracted away from the perpendicular. Hence it follows that the rays of the Sun or of the sunspots, issuing from the lenses, are refracted away from the perpendicular which stands at right angles to the surface of the air through the point of incidence. And since this air is rarer than the substance of the lenses, the refraction must necessarily take place away from the perpendicular.

[Margin: Refraction away from the perpendicular.]

Ninth. The point of incidence is that upon which the ray, [passing] from the antecedent medium into the following medium, first falls. Hence it follows that the points of incidence are to be taken at the surface lying between the extremity of the antecedent medium and the beginning of the following medium, because it is upon that surface that the ray falls first of all.

[Margin: The point of incidence.]

Tenth. Only the first ray departing from the object into another medium is the direct ray of incidence; all the rest after it are at once rays of incidence and refracted rays. The last, arriving at the terminating medium, may be called the ray of settling [radius consistentiae], which nevertheless is always the last of the refracted rays.

Eleventh. Just as an oblique incidence into a diverse transparent body is the true, genuine,

and sole cause of refraction, so a more oblique incidence produces a greater refraction, a less oblique one a smaller, and a perpendicular incidence produces none at all.

Hence there follows, first: all else being equal, the figure of a lens — whether convex or concave — in eccentric irradiations at least, for the most part produces a greater refraction than a plane surface would, because in it the obliquity of incidence is greater, and so on.

There follows, secondly: all else being posited equal, a greater refraction is produced by lenses which are segments of smaller spheres than by segments of larger spheres, because in the former the incidence is more oblique than in the latter.

There follows, thirdly: a greater refraction is produced by those rays which are farther from the axis (or from the perpendicularly incident ray) than by those which are nearer. For the farther they are, the more obliquely, and the nearer, the more directly, do they strike the surface of incidence.

Twelfth. The surface of incidence is the surface of the following medium or transparent body upon which the rays of incidence flow; and it is always simultaneous with the last surface of the antecedent medium — though not one and the same, but altogether distinct, for the refracting media are ordinarily not continuous but for the most part contiguous. I add this qualification on account of the wavy streaks [*tractus undosi*] found in the material of the lenses (which is indeed everywhere continuous), and many other experiences, by no means to be aired here.

[Margin: The surface of incidence.]

[Margin: A caution.]

Thirteenth. The surface or plane of refraction is that in which are contained the ray of incidence, the perpendicular of incidence, the line of refraction, and the Cathetus drawn from the visible point onto the surface of the second transparent body. This plane of refraction is not a surface actually reduced to act, so as to exist as something discrete like the surface of incidence, but is a connecting and coupling surface, grasped by the understanding and immersed in the lens and the other media, yet known by its nature.

[Margin: The plane or surface of refraction.]

Fourteenth. The surface or plane of refraction, in our case, always passes through the greatest circle of that sphere of which the lens is a segment; or, perhaps more clearly: the common section of the lens and the plane of refraction is a segment of the greatest circle of that sphere from which the lens was taken. And this is evident from the fact that the plane of refraction is always erected perpendicular to the spherical surface of the lens, because in it there always lies both the perpendicular line to which or from which the refraction takes place, and the aforesaid Cathetus, and so on.

Fifteenth. The point from which the Cathetus is drawn onto the surface of the second medium is the very first and immediate point of the visible object; but in the second medium and the following ones, if a continuation of them takes place, the Cathetus takes its beginning from the point of incidence or refraction, and

proceeds to the following medium, and so on always, until the last point of incidence is reached.

These things having been premised and understood from the unanimous doctrine of the opticians — although it is neither my intention nor does the time now permit to treat of refraction by design, and many things have already been said in the earlier books — nevertheless I have thought it necessary to append here a few points drawn from practice rather than from theory.

I say, then, first: In the telescope the enlargement of the visible images in the observing circle comes about by the refraction of the inserted lenses. This is agreed by the perception and consent of all.

[Margin: The image is enlarged by refraction.]

I say, secondly: In the telescope the refraction is compounded of two lenses; and the refraction of the one which faces the object never reaches the paper [charta], but only the last refraction does — which nevertheless further refracts and enlarges the image already refracted by the first lens. This is established by experience; for if you take away the concave lens, you will have, all else unchanged, a much smaller picture than if you add the same.

[Margin: The refraction is compounded of both lenses.]

I say, thirdly: In each lens the planes of refraction are drawn through the axis of both lenses and through the several points of the circumference of the base; and in accordance with these planes the sunspots and the several points of the Sun depart by refraction from the center of the Sun's disk as legitimately presented on the paper, and project the Sun not only larger than it would have shone by the natural radiant cone, but also of unequal

[Margin: By refraction the Sun's bright disk grows unequally — least near the center, always more toward the margins.]

magnitude — the parts of the solar disk toward the limb being spread apart by refraction more than those which are nearer the center; provided indeed that the base of the solar disk coincides in every respect with the observing circle. Otherwise those parts, as will be seen, do not increase in this necessary manner, but in a different one.

I say, fourthly: In the planes of refraction all points of the Sun equally distant from the axis of the lenses and from the solar cone are equally refracted. For those which are equally distant glide equally obliquely upon the surface of the

lenses and make equal angles of incidence, from which it necessarily follows that equal refractions occur. Hence it follows that the sunspots equally distant from the center of the observing circle have been equally refracted. For from the equal distance of the sunspots from the center of the observing circle there follows an equal removal of the points of incidence from the axis of the lens on the surface of refraction.

[Margin: Every bright point of the base, equally distant from the center, is equally refracted.]

I say, fifthly: In the planes of refraction all points of the Sun unequally distant from the axis of the lens are unequally refracted — the less distant less, the more distant more. For the angles of the incidences become unequal, and less oblique those which are near the axis, more oblique those which are far from the axis; hence more refraction is felt from the latter, less from the former. It follows from this that the sunspots nearer the center of the observing circle undergo a smaller refraction than those which are farther off.

[Margin: An unequal distance of the bright points from the center causes an unequal refraction.]

I say, sixthly: Refraction does not proceed in proportion to the angles of incidence and to the obliquities of the incidences. This is common to all the opticians, and established by countless experiences of this phenomenon as well, so that there is no room to doubt the truth of this assertion. But to investigate the special causes and manners of this effect belongs to the proper doctrines of refraction, which

it would be beyond my design, and tedious for the reader, to expound here more minutely.

I say, seventhly: The refractions in the planes of refraction, taken from the axis and center of the observing circle up to about a fourth or a third part of the ray or semidiameter, differ perceptibly little or not at all among themselves, so that they proceed at an almost even pace. The reason for this is drawn from the fact that the incidences near the axis are more like right angles than oblique ones, and their discrepancy scarcely falls within the range of sense. And it is confirmed by various experiences, as we shall presently see.

[Margin: The refractions near the center are among themselves, to the senses, nearly equal.]

I say, eighthly: The refractions in the planes of refraction, proceeding toward the margin beyond the third or fourth part of the semidiameter from the center of the observing circle, are perceptibly increased — with an increment by no means proportional to the angles of incidence; rather, the more you approach the periphery, the more you will feel these differences of increment growing steeply. The reason for this is drawn from the fact that the angles of incidence do not advance in the same proportion as the angles of refraction, but the latter, given a greater obliquity, grow more than so as to remain similar to the former; as the common doctrine and daily experience teach.

[Margin: The refractions toward the margins increase vehemently.]

COROLLARY I.

From what has been said, all the difficulties concerning the long-debated appearances that have been adduced are resolved. For from the fact that the sunspots around the middle of the Sun are refracted minimally and, as it were, uniformly, it immediately follows that the spaces traversed by the sunspots in the observing circle in equal times will be, to the senses, equal among themselves, and smaller than those spaces which, in a time that is likewise equal, are completed around the extremities of the Sun under greater refractions that are least equable among themselves — provided the other things are posited equal: that is, provided not only that equal times are assumed, but also that the motion of the sunspot itself around the Sun is regular and uniform, and that the Sun's image agrees perfectly with the observing circle, and the telescope is kept fixed at one and the same setting, and so on.

[Margin: The appearances hitherto debated are most beautifully accounted for by the inequality of refraction.]

Conversely it also follows that the apparent intervals traversed by the sunspots around the horizon in equal times will be optically larger than those around the middle, on account of the greater refraction toward the extremities than is wont to occur around the middle. I have said "the intervals traversed by the sunspots

[The two columns on each of these pages are labelled with centered apparatus numerals "I." (left) and "II." (right), and each column carries an independent 5-line marginal line-count; both are cross-reference apparatus, not structural divisions, and are not reproduced here. The text is read left column, then right column, and flows continuously across the page and column breaks.]

(Continuing Corollary I from the previous folio.)

[Margin: The genuine and truest Appearance, and the solution of the difficulties arising from it.]

described on the observational circle are optically larger by refraction, because when measured geometrically according to the visual angles they are much smaller; whereas if they are considered optically — that is, as they go around the Sun by their circular motion, rising near the east and setting near the west, and are drawn up into a like shape, just as I taught earlier — you will find that the chords owed to the apparent marginal intervals subtend far larger arcs than the central chords usually do; and conversely, that both the arcs and the chords derived from the central daily intervals will always and necessarily be optically smaller than the marginal ones.

COROLLARY II.

From this it follows, firstly: if the spots go around on the surface of the Sun, then the perimeter of the parallel that has been found must necessarily be reckoned — when measured by an arc corresponding to the central interval, or by the chord subtending that arc — to come out proportionally larger, so that the said arc or chord is repeated within it more often than the time owed to the observations and to the spot's course would allow. This happens because the inequality of refraction shows the Sun's circle larger than it should be at the extremes, but at the middle shows the distances smaller than would satisfy that circle. Now if I measure a circumference that is larger than it should be by an arc that is too small — which is exactly what is done in the present case — it necessarily follows that the arc is found within that circumference more often than it should be, and consequently that the proper time is overshot. Since all these things do occur, and experimental truth always most beautifully supports this reasoning, who does not see that the spots must be placed on the Sun? For as soon as the said disparity is removed from the motion, a regular and ordered motion of the spots placed on the Sun follows.

COROLLARY III.

It follows, secondly: if, the same things being posited, the parallel found for some spot

[Margin: The periodic revolution of the course, when measured by an arc corresponding to the central daily distance, comes out larger than it should.]

is measured by an arc corresponding to the marginal interval, its perimeter will be found duly smaller than the said measure, and the course found by the

observations will fall short of the time. And this will happen because that measure, presented through marginal refraction, is larger than the circle of the parallel found requires; whereas a measure that is too large is repeated too few times within the thing measured. The time is therefore cut short.

[Margin: The periodic revolution of the course, when measured by an arc answering to the marginal daily distance, comes out smaller than it should.]

Therefore, since these things follow from that reasoning, are established for the spots on the Sun, and are confirmed by the most constant experience, there is no doubt that the spots are on the Sun.

It follows, thirdly: that if, to obtain correctly from refraction the apparent periphery of the solar circle, the measure of the daily spaces to be applied must be larger at the apparent central intervals and smaller at the marginal ones; and that the true measure, or one very close to the true, will be obtained once the inequality of refraction has been removed or made equal.

The inequality of refraction places the spots on the Sun.

PROPOSITION I.

If, with the spots posited outside the Sun, the appearance of unequal refraction vanishes once the motion of those same spots is found outside the Sun: the spots are not outside the Sun.

CHAPTER XXIV.

Let us suppose that the solar spots are carried outside the Sun, and that by this very fact — in a course laid out outside the Sun — the appearance of refraction so long discussed vanishes; I say that by this very fact the solar spots are not outside the Sun. I prove it as follows. The false never follows except from the false; but if, with the spots posited outside the Sun, the appearance of refraction is removed, then it follows that from the spots posited outside the Sun something manifestly false results; therefore the very placing of the spots outside the Sun is false. And that something manifestly false does follow, if the appearance of refraction discussed up to now is removed, is proved

in this way. If the said appearance of refraction is removed, then it follows that the refraction produced through telescopic lenses is not non-uniform but uniform — which is evidently false; and it follows that refractions, under any incidences whatsoever and any angles and obliquities, are always equal — which is false, and so on. But these consequences are repugnant to all sense, all experience, and

all the authority and teaching of the writers on optics, and they shake the very foundations of the science of Optics. Therefore it stands proved: *if, with the spots posited outside the Sun, the appearance of refraction is removed, the spots are not outside the Sun.*

[Margin: The conclusion demonstrated.]

For if, from their being posited outside, the appearance of refraction is removed, the aforesaid false consequences at once follow, whereby their placement outside the Sun is convicted of being false; and so, by this very fact — because they are placed outside — they are shown to be incapable of being placed or existing outside. Which was to be demonstrated.

PROPOSITION II.

Spots placed outside the Sun, even by a little, remove all appearance of inequality in refraction.

CHAPTER XXV.

[Margin: The sense of the Proposition.]

The discussion concerns the spots observed through the telescope and correctly arranged in their course. I have shown up to now — and it will shortly be demonstrated more fully — that if all these spots are supposed to be carried around on the Sun, they present courses hurried by refraction near the beginning and the end. But now I say: if someone were to raise them a little outside the Sun's surface and carry them around on a sphere concentric with the Sun,

[Margin: The spots cannot be separated from the Sun by twenty seconds.]

whose radius exceeds the radius of the observational circle by only a twentieth, thirtieth, or fortieth part — that is, not by one whole first minute, but by forty, thirty, or twenty seconds, the Sun's visual size being assumed at about 32 first minutes, of which more will be said in its proper place — if, I say, someone were to separate the spots by so tiny a distance from the Sun and carry them around on a concentric sphere, I assert that all this appearance of inequality produced by re-

fraction would be removed, and that everywhere equal arcs would be subtended by the chords which correspond to the intervals of the observations. This matter needs no proof other than a careful examination and demonstrative practice

drawn from my observed courses, in accordance with what has been said and taught.

[Margin: Proof of the Proposition in practical examples.]

Take as an example the courses set out in Figure LXX, Book Three, page 341, and you will see the truth of what has been said. Take others, examine them carefully, draw the circumferences a little larger — you will always find what I have said. I myself have made almost countless trials of this matter, and I have always found what I say; the proposition therefore stands proved from the observations. And so, since by this positing something is introduced into the course of the spots — namely, in equal times an equality also of the corresponding motions, which nevertheless, by this method of observing through lenses, neither ought to nor can occur — it is clear that the spots cannot be placed even the tiniest bit outside the Sun.

[Margin: From this too the spots cannot be torn away from the Sun.]

PROPOSITION III.

If the spots are placed outside the Sun at such a distance that, for the observational intervals run through in equal times, equal arcs correspond in the assumed circle of their course, then their periodic revolution turns out larger than it should. And by this very fact they cannot be placed outside.

CHAPTER XXVI.

Because, if in equal times equal arcs correspond while the circle on which the spots are supposed to travel is outside the Sun, the point of rising and of setting will not be bounded by rays tangent on both sides, but by rays cutting across their course. Hence whatever remains over of the periphery on either side up to the true horizon — and just as much again in the other hemisphere — will be added on top of the periodic motion of the spots that are otherwise placed on the Sun; because, since [it corresponds] to the central arc, the smallest of all, all the rest — on account of the withdrawal of the circle from the Sun, and likewise on account of the hypothesis of the proposition and the obliqui-

ty diminished, which they acquire between the parallels by which the intervals of the daily motions are distinguished — as they issue into a circle outside the Sun, become equal by decreasing (for otherwise they were larger, with the spots posited on the Sun) — it is necessary that that arc be found more often in the larger circle, such as the one now assumed outside the Sun, than in the smaller

one contained within the Sun's surface. It is therefore necessary that more time too be spent in the former than in the latter, for there are several arcs each equal to one another, and so, because of the regularity of the motion, just as many equal times are owed to them. (Here I assume, partly from what has been demonstrated and partly from what is to be demonstrated below — especially from the return of the spots — that the true motion of the spots is carried out on the Sun's surface.) Therefore, since the whole periodic revolution consists of more arcs and times than it should, if in equal intervals of time equal arcs should correspond in the circle assumed outside — since, I say, this falsehood follows from the spots posited outside the Sun by the said reasoning — it is clear that the spots are by no means to be placed outside the Sun, but inside.

PROPOSITION IV.

If the spots are allowed to run around outside the Sun at one, two, three, or more minutes — of which the Sun's radius is set at about 16 or 17 — then, among all the arcs which the parallel lines, issuing from the daily places of observation into the periphery of the circle assumed outside, intercept, the one that answers to the daily central path of the solar arc is the largest of all; each of the rest, toward the horizon on both sides, is always smaller the higher it lies and larger the lower, and the smallest of all is the one nearest the horizon. I assume, moreover: first, that the itinerary points of the spots are arranged in a sensibly straight line, separated by equal times; second, that the apparent motion observed by aid of the telescope, and therefore liable to refraction; third, that the motion of the spots considered in itself, is regular. These things being so,

the spots outside the Sun will by no means travel to the said distances, but are necessarily proved to lie nearer to it.

CHAPTER XXVII.

This matter is immediately evident to the eye from the observations, once a practical examination is applied. For if from the center of any observational circle you describe another circle at some one of the said distances — say of 18, 19, 20[?], or more minutes in the radius — and then, by parallels legitimately drawn from the apparent places of the spots, you explore in the circle assumed outside the chords and arcs owed to the observational intervals, you will always find the arcs corresponding to the central intervals to be the largest of all, the horizontal ones the smallest, and the intermediate ones larger toward the middle and smaller toward the extreme. But since these things, in the regular and ordered motion of the solar spots (which I always assume from what has been

proved elsewhere and what is to be proved), are simply impossible — because they overturn all uniformity of motion — it is clear that the itinerary circles of the spots are not to be assumed outside the Sun. And that the arcs of the middle paths assumed outside the Sun exceed the remaining, steeper ones does not happen because these middle ones increase, but because those others decrease, on account of the deficient obliquity between the same parallels — an obliquity which always decreases as the displayed circle increases, and increases as it decreases.

[Margin: The aforesaid Propositions are shown in a figure.]

It is well to set almost everything said up to now before the eyes in the displayed diagram. From the center A, then, at the interval A B, let a semicircle of the observational Sun, B C D, be understood to be described, and on it let the spot B, from the east B, be moved to the west D, following the apparent rectilinear advance B A D; and let the spot B have made the daily itinerary spaces — run through in equal times — E F, F G, G H, H I, I A, A K, K L, L M, M N, N O; for the residual spaces B E and O D are smaller than the daily ones, as is clear in the arcs P B and a D. Hence from E I begin to count at the rising, and at O I end, at the setting. Now, if the spots on the solar surface B C D

were rotated regularly about the center A — if this was done and observed without any refraction, or with a uniform refraction (whose possibility I no longer dispute) — it is certain that if, from the observation points E, F, G, H, etc., perpendiculars E P, F Q, G R, H S, etc., are dropped onto the perimeter of the Sun B C D, those cut-off pieces — the arcs P Q, Q R, R S, etc. — are equal to one another, a regular and uniform motion being assumed. For as the time of the interval E F is to the time of the interval F G, and so on, so is the arc P Q to the arc Q R, and so on; but the times E F, F G are equal; therefore the arcs P Q, Q R are likewise equal to one another. And this is the first point.

[Margin: From the hypothesis of a regular and uniform motion, equal arcs follow in equal times.]

It is certain, next, that if — with the spots placed on the Sun and carried regularly around — the daily intervals E F, F G, G H are marked off (the Sun being transmitted through the lenses), the arcs P Q, Q R, R S, etc., corresponding to them will be unequal to one another through refraction: P Q larger than Q R, and this larger than R S, up to the arc T C and C V; and from there each earlier one is always larger than the later, down to Z α . And this is so because, if without refraction they had been equal, then when the unequal arcs of refraction are

added, the wholes become unequal to one another; and since, on account of the more oblique incidences, the arcs P Q and O a are more strongly refracted, and so on, this too is evident — which is the second point.

[Margin: Observation of the regular motion, made through lenses, presents unequal arcs on the Sun.]

made through lenses; therefore, if the unequal arcs of the refractions are subtracted from those equal composites, the remainders will be unequal — smaller for d e, e f, etc., larger for h i, i K — because from the former, larger amounts are taken away, and from the latter, smaller ones. The residual and true motion of the spots will therefore be unequal, and so irregular; and because the spot rises at c and sets at p, the averted arc will be much larger than the one that turns toward us, and so on. And this is the third point.

Finally, it is certain that if the spots are still in larger circles — such as q r t y (which occupies a distance of one minute, B q, from the Sun); z α β [?], of two; γ δ ε [?], of three; ζ η θ [?], which is four minutes distant from the Sun — if, I say, the spots are understood to rotate in circles of this kind, then the horizontal arcs r ζ [?], ζ κ [?], λ μ, ν ξ [?], answering to the apparent horizontal path E F, will always decrease, while the middle ones — ο τ, π ρ [?], ς δ [?], σ κ [?] — will always increase with respect to these (although absolutely they too always fall short); therefore, if those horizontal arcs ν ξ [?], etc., together with those arcs of refraction conjoined to them, are nonetheless smaller than the middle ones σ ν [?], etc., how much smaller will the former be than the latter if the arcs of refraction are removed from both sides — larger there, smaller here? Hence the fourth point is evident: that from just this so tiny a removal of the spots from the Sun, an intolerable irregularity, and an inequality of motion correctable by no efforts, is introduced into this otherwise most orderly Phenomenon.

But this inequality arises for the following reason: the farther from the center A the circles are assumed, the more the arcs of those circles, intercepted between the parallels, are stretched out into straightness, and the less transverse space they occupy, as is clear to anyone who considers it. And since all these drawbacks are most fully and most plainly avoided by the single and unique placing of the solar spots upon the Sun, I judge that there will be no doubt whatever, to anyone in the future, that the spots are on it.

Rosa Ursina, Book IV — Part I, Cap. XXVII (Scholium and Summary)

Diagram. A large semicircular geometric construction filling the top of the page — the refraction demonstration belonging to Cap. XXVII (the figure referenced by the arc- and point-labels PQ, QR, RS, ... and the solar perimeter BCD in the surrounding text). A horizontal diameter forms the baseline; on it, at the center, sits point **A**, the common center of a family of concentric arcs (circles) that rise over the baseline. A dense array of vertical lines (perpendiculars) is dropped from the arcs to the baseline, and the baseline carries a graduated scale of tick numbers. The construction is symmetrical about the vertical through **A**. Readable labels:

- Baseline, left → right: numeric ticks **21**, **20** (far left), **15** (near **F**), **10** (between **G** and **H**), **5** (near **I**). Capital point-letters along the diameter: **B**, **F**, **G**, **H**, **I**, **A** (center), **K**, **L**, **M**, **N**, **O**, **D**.
- Just to the right of **D**, extreme lower-right, a run of small Greek minuscule tick-labels: **γ**, **β**, **ε**, **θ** [?].
- Just to the left of **B**, extreme lower-left, small labels including **z**, **9**, **b** and further Greek minuscules [?].
- Left ascending arm (bottom → top, on/near the perpendiculars): **E**, **P** and lowercase **c**, **d**, **r**, **e**, **s**, **t**, with Greek **λ**, **ν**, **ξ** [?]; higher up **Q**, **R**, **S** and small **m**, **x**, **f**.
- Near the apex, on the upper arcs: **T**, **C**, **V**, with Greek minuscules **σ**, **π**, **ο**, **h** and one further Greek letter [?].
- Right descending arm (top → bottom): **X**, **Y**, **Z** (each with a small adjacent letter, **m** / **n** [?]), then **x**, **o**, **P**, **a**, down to **O** on the baseline.

[The figure carries a great many small Greek-minuscule point-labels at the extreme left and right and along the upper arcs; more than two are not securely resolvable at this resolution]

Scholium

[Column-apparatus numeral I.]

Since it has now been shown clearly enough, from the true, genuine, and regular motion of the spots, that they cannot be drawn away from the Sun by even a few seconds of arc, let the prudent Reader now weigh for himself how much credence and authority he should grant to those men who — working from scanty and

badly made observations (and observations begged from others at that), with no prior solid tests, spurred more by personal inclination and by prejudice than by any love of truth — laid violent hands on this phenomenon and tore the spots and faculae away from the Sun: not by one minute of arc, not merely by one degree, but by many. It is not worth the trouble to refute them one by one. The phenomenon itself chastises them well enough, rebuking their errors by its own daily, ordered, and regular march.

Epitome dictorum [Summary of what has been said]

[Column-apparatus numeral II.]

First. Suppose the course of the spots is free — or that the anomaly of Refraction is removed, or reduced to uniformity — and that on this basis parallel lines are drawn to the circumference of some circle, so that equal arcs are cut off, equal both among themselves and in the observed times. If, I say, this is actually carried out: then the circles on which this equality of intersections occurs are always found to lie precisely on the surface of the Sun. And I have this from practice and from the ordered digest of the observations. Hence I do not assume, but infer: if the course of the spots is regular, then on the evidence of the observations it must be placed on the Sun.

Second. But if instead one proceeds from observations carried out through lenses — and therefore liable to unequal Refractions — then no regular course, one agreeing with refraction, will ever be found outside the Sun's circle. As I have proved at length.

LIB. IV — PARS I

Cap. XXVIII

Proposition V, Problem I

To exhibit, by a clear practical experiment, the inequality of refraction hitherto discussed and redounding upon the Observations.

[Margin: Why experiments are adduced for establishing [the doctrine of] refraction.]

Although the evidence for this matter shines out abundantly from the foregoing doctrines — so much so that among those skilled in optics I judge scarcely a scruple will remain — nevertheless, since among less-trained people the things

presented to the senses carry more weight and instruct the mind more agreeably, and since such things commonly delight even the learned very much; and since this matter contributes greatly not only to my own purpose but also, in itself, to the whole nature of refraction: I have not thought I should refrain from bringing forward several notable experiments — none of them, I believe, put forward by anyone else — devised by me with particular zeal for the sake of establishing this truth. Let the first of them be this.

[Margin: Description of the experimental apparatus.]

On some rather thick and rigid sheet of paper, or on some thin metal plate, draw a very small circle, and divide its circumference into equal portions, equal in number — say, twelve. Then, drawing through opposite division-points two diameters that cut one another at right angles at the center, join the remaining points, equally distant from these [diameters], with parallel lines that everywhere cut one another at right angles. Next, with a fine needle, pierce all the division-points on the circle's perimeter and [all] the points of the intersections made within the circle upon the straight lines. Afterwards take a lens convex on both sides — a segment of a small sphere — and likewise a concave portion, also of a small sphere, but of ample hollow, so that it may gather all at once the images transmitted from the convex [lens].

[Margin: Application to use.]

Arrange these lenses properly in a tube, and set the perforated circle, at a proportionate distance, in front of the convex lens. Once this is done, admit the Sun through those little holes into the lenses, and receive it, through these, onto a sheet of paper placed opposite at a suitable distance. You will see all the little holes shining through like tiny stars, thrust out onto the periphery of a very great circle; and all the points which on the pierced paper had been arranged along a straight line come onto the other, ray-receiving sheet along curved lines — convex toward the center, concave toward the perimeter. That this happens only by the refraction of the lenses, I prove as follows.

[Margin: From this experiment refraction is proved.]

First: if I receive the Sun onto the paper through the bare holes, both lenses removed, it shines onto the paper — through the little holes set in a straight line — as tiny stars arranged along straight lines, and that within a much smaller circle. Therefore, that those holes are spread out into a larger circle, and pass from a rectilinear arrangement into a curvilinear one, all this comes about from refraction.

Second: if I employ other tubes, longer or shorter, with the perforated circle set in front, the curvatures become greater or smaller, even though I transmit the Sun through the same holes.

Third: if I try the same things with a lighted candle, similar and proportional results occur — but always in different ways, according to the arrangement and the distances. Yet when transmitted nakedly [without a lens], the things set in straight lines are always enlarged along straight lines, although this enlargement does not equal the one produced through a lens.

[Margin: Why is a short tube employed for the experiment?]

That I describe and require so short a tube is not because long ones would fail to accomplish the same, but because they can be brought into practical experiment only with the greatest difficulty. For the circle perforated in the paper or plate, which is to be set toward the Sun in front of the convex lens, must stand at such a distance from the convex lens that each little hole conveys the Sun distinctly, not confusedly; and because of the excessive distance this can scarcely be reduced to practice in long tubes, whereas in short ones it is more convenient. For this reason I have described the whole procedure by means of a short telescope [Telioscopium].

[Margin: Explanation of the example set out in the figure.]

You have an example in the figure appended, in which — taking a as the assumed center — you see, at the interval a b, a small circle b c d e h l described, whose entire circumference is divided by the points b, c, d, and so on, into twelve equal parts. These [parts], then, being equally distant on either side from the four principal [points] b, e, h, and l, are joined by parallel straight lines c g, d f, n i, m K; likewise n c, m d, K f, i g. These straight lines intersect one another at the points o, p, q, r, s, t, u, x, y, z, ω [?], and there arise square spaces and rectangles longer on one side. But that little circle must be taken smaller than the convex lens, and much more so than the concave one; otherwise the image of the holes would exceed it.

Diagram. A large full-page circular geometric construction illustrating the refraction experiment described in the text. The great circle is quartered by a horizontal and a vertical diameter through its center; a dense grid of chords, perpendiculars, and dotted refracted-ray curves fills the interior, and the outer arc is graduated by numbered stations. Set into the field are four engraved emblems: a radiant "IHS" sun-monogram (upper center), a radiant "MRA" (Maria) monogram (lower center), and a Tudor-style rose ornament at the left-center and

right-center (the Orsini rose device of the title). Near the center is a small inset circle — the *circellum* of twelve divisions described in the text — lettered internally with a, b, c, d, e, f, g, h, i, K, l, m, n, o, p, q, r, s, t, u, x, z. The internal engraved title reads "EXPERIENTIA LVCVLENTA DE Refractione contingente, per lentes Telioscopii" ("A clear experiment concerning the refraction occurring through the lenses of a telescope").

Readable labels (positions approximate):

- β (top of the circle, on the vertical axis)
- λ (left end of the horizontal axis)
- ε (right end of the horizontal axis)
- θ (bottom of the circle, on the vertical axis)
- π (upper-left region, on the vertical grid)
- σ (left, on the horizontal axis near the left rose)
- τ (center-left, on the horizontal axis)
- ν, ς (center, on the horizontal axis, near the origin)
- φ (right-center, on the horizontal axis, near the right rose)
- ψ, ω (lower-center region)
- $\omicron$ (upper-center region) [?]
- μ (upper-left region) [?]
- Perimeter / interior numeral stations: 1, 2, 3, 4, 5, 6, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17 (several partly obscured by grid lines) [?]
- Inset *circellum* letters a–z as listed above [several of the smallest interior letters uncertain]

[Many of the peripheral Greek point-labels and the small inset-circle letters are at or below legible size on this scan and could not all be resolved with confidence; the figure carries far more than two uncertain labels and is a]

Accordingly, I pierced each one of those division- and intersection-points with a very fine needle, and, through a telescope suitably assembled, I caught the Sun, shining translucently, upon the paper; and I found points corresponding to the divisions and intersections — on the perimeter indeed $\beta, \gamma, \delta, \varepsilon, \zeta, \eta, \theta, \iota, \kappa, \lambda, \mu, \nu$; but in the interior area $\xi, \omicron, \pi, \rho, \sigma, \tau, \nu, \varphi, \chi, \psi, \omega, \varsigma$. These, since they lie — as is plain — in curved lines, whereas they had proceeded from points set out in a straight row, make it clear that they have been cast out, by refraction, into places proportional [to their positions].

For although all the outermost points meet on the circle's perimeter, and stand apart from one another by equal intervals, so as to enclose the complete area of the circle, the intermediate points nevertheless do not advance in a like proportion. Rather, those near the center increase, as it were, with an even pace of refraction, and so only a slight difference of curvature is seen; whereas those that proceed farther from the center spread out dissimilarly. For ρ has, by refraction, departed farther from the center than v , and γ more than ρ , and so on. Hence we see the lines γ , ρ , v , ω , η , etc., come out curved — lines which nonetheless, by the law of an equal and uniform refraction (a law which we oppose, and which from this very experiment we set down as unequal and non-uniform), if any such were granted, or supposed given, would have to be straight, and the point ρ , and likewise γ , would have to lie on the straight line v , ι .

[Margin: The outermost circle is subject to non-uniform refraction.]

Hence I conclude, first: that the circle β , ϵ , θ , λ , generated by refraction, is larger than would correspond to a uniform and even refraction. Otherwise the points v , ϕ of the apparent motion, made on the diameter a ϵ , would have to correspond to the points γ , δ — which does not happen. For the perpendiculars v 1, ϕ 2 cut off the arcs β 1, β 2, [which are] smaller than β γ , β δ are, as is evident. The cause, as I have always said, is that a v is nearer to the center a than a ϕ is, and this [a ϕ] nearer than a ϵ — that is, than a δ and a γ . Hence, even if all these supposed spots or faculae η , ω , v , ρ , γ , or ζ , ϕ , δ , should exist on one and the same solar parallel — whose diameter is 1, 3, or 2, 4 — nevertheless, because of the incidence upon the telescopic lens or lenses (differing in position and obliquity), the refraction will leap onto the paper outside the straight line, and will be carried along a curve; notwithstanding that the incidence upon the convex or concave lens itself is along a plane surface, which we call the plane of refraction.

I conclude, second: that the place 1, marked by the perpendicular v 1, is not the true one, that is, the one owed to refraction, but is in truth smaller. For otherwise, since v is [a spot] and is posited on the arc of the circle a ϵ toward the observational circle β , γ , ϵ set erect: if that circle a ϵ be conceived to be gradually lowered until v reaches the horizon β , ϵ , then v would fall not on γ but on 1, and thus the non-uniformity of refraction would cease. All of which is false and contrary to this experiment, for v comes, through ρ , onto γ .

But as to why the point v on the spherical surface of the Sun — carried gradually about the unchanging axis a ϵ , in the same plane, through 1, v , 3, and, set erect toward the solar circle, etc., descending — does not remain on the line v 1 but spreads out to ρ , and, when it reaches the horizon, appears at γ : the reason is that

the farther the spot v (for example) recedes from the Sun's center, the more the ray sent out from it into the lenses departs from the axis of those [lenses], and the more oblique an incidence it produces; and this yields greater refractions, and always larger solar circles, which consequently also enlarge the places of the spots. And hence it is that the place 1, shown by the perpendicular v 1, is smaller than can correspond to the place γ made by refraction. From this, in turn, a clear reason is given why the measure a v — or a similar one assumed in the observations — is too small for the periphery β , ϵ , θ , and would yield more days or hours for the true course than the matter allows. For it is taken as [answering] to the perimeter β , γ , ϵ , θ , [which is] greater by refraction than to be similar or equal to that circle which underlies the refraction touching about the center — a circle always smaller than the horizontal circle.

I conclude, third: that the measure 2, ϵ (or ϵ , 2), taken as corresponding from the arc of the straight line ϕ , ϵ , is too great. This is evident from the previous [conclusion]. Because a ϕ gives the perpendicular ϕ 2, which cuts off the arc β 2, [an arc] too small, and the point 2 is not the true place; therefore its complement 2, ϵ is too great an arc. And it is proved, as before: if ρ be conceived to be moved from on high toward 2, and so on, it will fall on δ , and so on, by refraction.

I conclude, fourth: that the places γ and δ ought to fall after 1 and 2, toward ϵ , because the arcs β 1 and β 2 are smaller than the true ones; the true ones therefore ought to be larger — namely those [given] by experiment, β γ and β δ .

I conclude, fifth: that the arcs β γ , γ δ , δ ϵ ought to be equal to one another, because they answer to the arcs b c , c d , d e , which are likewise equal. But of the refractions...

[Continues onto the following folio.]

Book IV, Part I, Cap. XXVIII (continued)

Diagram. A large circle nearly filling the page, carrying the geometric construction on which the proofs of this chapter depend. At its center is a decorative cartouche reading **EXPERIENTIA LUCULENTA DE Refractione contingente, per lentes Telioscopii** ("A Luculent [clear] Experiment on the Refraction occurring through the lenses of the Telescope"). The cartouche is flanked by Jesuit devices — an **IHS** sunburst monogram above and an **MRA** (Maria) sunburst monogram below — and by several rose ornaments (the Orsini rose device) at left, right, and center. Within and around the circle runs an inscribed rectilinear construction (a square/rectangle with radii and dashed

perpendiculars) bearing numbered points and letters keyed to the text: legible numerals around the perimeter include 14, 8, 12, 7, 2, 15, 5, 6, 10, and a point marked H at the right, together with lettered points (a, b, and Greek minuscules). Most of the small peripheral point-labels do not resolve cleanly at this resolution.

- Central caption: "EXPERIENTIA LVCVLENTA DE Refractione contingente, per lentes Telioscopii"
- Top emblem: IHS (sunburst)
- Bottom emblem: MRA (sunburst)
- Perimeter numerals (partial, legible): 14, 8, 12, 7, 2, 15, 5, 6, 10 [remaining point-labels [?]]

and the primary planes are only those which have within them the center **a** of the lens, together with the radii **a b**, **a γ**, **a δ**, **a ε**, and so on, and which have the axis of the solar cone passing through the center **a** perpendicular to the lens. Since, therefore, all the angles of incidence are equal, and so forth, a similar and equal refraction necessarily arises.

Sixth conclusion. If from **γ** and **δ** the lines **γ a** and **δ a** are drawn, and likewise the perpendiculars **γ 5**, **δ 6**, we shall have the difference by which the apparent place **v** is exceeded, through refraction, above the refracted place **γ**. So if we set it up that as **5 a** is to **v a**, so **ε a** — that is, **γ a** — is to another line, the diameter **7 a** will be obtained, and the place toward **7** will answer to the top of the Sun, provided we conceive the triangle **a v 7** as erected upon the horizon, with the outermost circle **8, 7, 9, 10** — no otherwise than if...

[Margin: To assign the true place from the difference by which the horizontal refraction exceeds that which lies near the center.]

a uniform and even refraction had preceded through the glass (which otherwise, so far as the thing itself goes, does not happen); and all the intervals **8,7; 7,9; 9,10** are equal among themselves, while the arcs **β, γ, δ, ε** are similar and proportional. This is proved as follows. In the triangle **a γ 5**, the lines **5 γ** and **v 7** are parallel; therefore as **v 5** is to the difference **v a**, so is **7 γ** to **7 a**, and so forth.

[Margin: The same, by another example.] In the same way, from the difference **φ σ** already obtained, taken between **a φ** and **a σ**, the place **11** will be found, where the perpendicular **φ 2** and the radius **a δ** intersect one another; and a circle drawn from **a** through this point, at the interval **a, 11**, will give the remaining places, and among them equal motions **11, 13** and **13, 14** — namely there, where it cuts the radii **a β, a γ, a ε**, and so forth.

The same rule is to be applied to the differences of refractions found from observations, by means of transits across the solar circle; concerning which, in their proper places.

Now if the Sun, refracted at **v** according to this refraction, had (per impossibile) proceeded evenly through the rest, the circle of this whole even refraction would have been **8, 7, 9, 10**, and the true places would have stood as the same points **8, 7, 9, 10**, set on the surface of the Sun uniformly refracted. But the places of the apparent motion that then follows, [Margin: The way of reducing the inequality of the refraction to a proportioned evenness, by the benefit of the known difference, etc.] leaning toward the radius **a ε**, upon the plane of the solar circle raised from the circle **8, 7, 9, 10** and standing perpendicularly over it, would have been marked out by **a, v, 15, 10**, with the perpendiculars **9, 15; 7 v; and 8 a**. And the apparent places **a, v, 15, 10** would have been similar and in all respects proportional to the incident places **a, u, x, e**; and the apparent motions **a, v, v, 15; 15, 10** proportional to the unrefracted motions incident upon the lenses, **a u, u x, x e**. Likewise the arcs **8,7; 7,9; 9,12** [?], created by even refraction, would be similar and proportional to the unrefracted arcs **b c, c d, d e**; so that, finally, the rectangles **v 16** and **15, 17** would be proportional to the rectangles **u o** and **x r**, and the squares **v π, v ω** [?] to the squares **u z**. Lastly the point **7** is the point of the true motion and place, such as it could have been had at the Sun through the lens, refracted to **v**. In the same way the point **11** will be given, together with all and each of the homologous and corresponding arcs, lines, and areas in the circle **14, 13, 11, 12**. And the true places will be, according as they lie beneath the unequal...

refraction of the points **v, φ, and ε** [?] — **7, 11, o** [?] — through which the curvilinear arc, as it advances, will be the motion, caused by the refraction of the glass; a refraction which draws the spherical figure of the Sun into a lenticular one, and makes the Sun appear broader than it is high, as will be plain to anyone who considers it.

But if we consider the true places according to the intervening equation, they will be either **γ, δ, ε** on the greatest circle; or **14, 13, 11, 12** on the middle circle, sprung from the apparent place **φ**; or **8, 7, 9, 10**, born from **v** — and all of them will always exist on the outermost surface of the Sun, if the Sun be supposed uniformly refracted. And although no uniform refraction of the Sun actually occurs, yet by this method one arrives at the knowledge of the true places, and it is known that the sunspots [maculae] do not pass outside the surface of the Sun, on the supposition of a regular motion.

[Margin: An objection against the said reduction to evenness.] You will object: a uniform refraction, through the said lenses of the telescope [Telioscopium] and by the doctrine set out above, is impossible; therefore no even refraction, made or to be made, can be supposed. [Margin: It is answered.] I reply that it is true no such refraction is given as would of its own accord proceed so as to conform to some fixed law of the ratio of sines, tangents, and secants, or to be known of itself by some regular and proportional progression; but that there are nevertheless certain practical methods by which it may be reduced altogether to at least a perceptible equality, so that the true place and motion may then be had, no otherwise than if no refraction, or an even one, had intervened.

[Margin: A fundamental doctrine, most worthy of note.] For just as it is certain that refraction near the middle takes place without any great or notable variety of difference — because the incidences there are, to the senses, perpendicular, so that scarcely any perceptible distinction between them is noticed — so it is certain that those limits, as though liable to no refraction, can be compared, by observation, with the natural courses of the sunspots known apart from refraction, and can be assumed in the examinations. For between the natural motion of the spots, free from all refraction, and the motion affected by refraction, a regular comparison can nonetheless be instituted, notwithstanding that the moving thing subject to refraction is increased; this ratio, I say, is not one of disproportion — for the motions and moving bodies increased by refraction about the center are, at least to the senses (which suffices me), not...

Book IV, Part I, Cap. XXVIII (continued)

proportional to the unrefracted motions and moving bodies. But for that very reason the refracted motions and moving bodies cannot be compared with the unrefracted ones, because the refractions are irregular and increase without any fixed and known rule of proportion. Hence, so that something certain and solid may be established, this inequality is to be reduced to a certain evenness, by the methods already stated and to be stated, through the differences discovered: namely, if from the known difference between the middle and the extreme refractions, and by a diminution or an augmentation of the diameters or perimeters made proportional and drawn out, one comes to some mean. But how the differences are to be drawn out, and how one is then to proceed from them, will be shown gradually and more fully, beyond what has been said.

Application of the Adduced Experiment to the Solar Phenomenon

[Margin: Application of the aforesaid refraction experiment to the sunspots.] These matters now being thus dispatched, I turn to my own observations of the sunspots and to my expositions of the observations, and I say that the situation there is in every respect exactly the same as with the experiment brought forward and explained. For, just as the Sun and the parts of the Sun are transmitted through those tiny apertures, admitted into the glass lenses, and refracted by their agency — this is what happens in the very phenomenon observed through the telescope with the sunspots and faculae [faculae] of the Sun: for they are broken in the selfsame manner in the selfsame lenses. And what the apertures do at one and the same time, in a single view, the spots and faculae do and undergo successively. For whatever refraction a single spot suffers from the telescope as it gradually traverses the Sun, this it would sustain from the same instrument if, at one and the same moment, either that spot itself, or other like spots, were placed in the several successive positions to be occupied — since the lenses are assumed to be the same, and their arrangement in the telescope to be similar and correct, and the due application of the telescope to be supposed.

[Margin: A doctrine worthy of attention.] [Margin: Why the eastern or western sunspots are refracted more than the central ones.] A spot moving across the Sun undergoes a greater or lesser refraction, not precisely because it clings to this or that part of the Sun, but because it passes to and fro across the refracting radius of the plane, placed near to or far from the center or axis of the lenses. And since, by the usual and correct order of observing, the Sun's circle is made not only equal but perfectly congruent with the observation circle, hence it comes about that the eastern and western spots...

are refracted more than the central ones; namely because the eastern spots on the Sun are set in the eastern and marginal region of the observation circle, and the western ones in the western; and by this they are placed under more oblique rays of incidence than the central ones. But if these same spots, when rising or setting on the Sun, occupy the middle rays of the observation circle, they will be refracted less than those which are set in the middle of the Sun and placed at the extremes of the observation circle: because it is not the spot's situation on the Sun that determines the greater or lesser refraction of the spots, but its situation on the lenses and on the refracting planes of the lenses and of the rays whose incidences they strike — the force and nature of which rays, the situation of the lenses being unchanged, are themselves unchangeable, whereas they alter the

solar image, as it falls now in this situation, now in that, in a wonderful way. And this is one of the things that must be singularly noted.

[Margin: The situation of the spots on the Sun does nothing toward the refraction, but rather their situation with respect to the lenses, etc.]

In this too the observations agree with the said experiment: that always, if I measure the whole semicircle, or a quadrant of it, along the arc of the observation circle answering to the central segment of the diurnal path, I find more time (as I have said several times) and more delay than ought, from the nature of the thing, to be found; whereas if I do the same along the arc nearest the horizon, I obtain less. Why? Because the smaller diurnal arc is more often found in the same observation circle than the greater diurnal arc. And from the difference of the arcs the inequality of the refraction is inferred, and the difference of the refractions is obtained.

[Margin: The diurnal arcs and the itinerary intervals. What are they?]

By diurnal arcs I mean such arcs as are traversed in the space of twenty-four hours by a spot on the surface of the Sun, and which correspond, in the observation circle, to the itinerary interval of so much time, after the observations have been legitimately reduced. The diurnal itinerary interval, in turn, is the apparent, diurnal distance or progress of the center of a spot within the observation circle, marked out over the time of twenty-four hours, and, by legitimate expositions, reduced to the chords of the diurnal arcs — reductions about which I have now here and there discoursed in the foregoing parts.

PROPOSITIO VI. PROBLEMA II.

To exhibit the inequality of the solar refraction by another practical experiment.

CAP. XXIX.

[Margin: The Sun, by its natural diurnal motion, reveals the inequality of the refraction.] There is no need to run off elsewhere: what is fetched from abroad with so much effort offers itself freely at home. The Sun itself, and the observing tube, in the observation circle, by means of a spot — however unequally the tube may refract — always show most luculently and at once the force and nature of the lenses. And the method is this.

Take any spot whatever, standing anywhere on the Sun, and place it, together with the Sun's image, on the eastern horizon of the observation circle; mark that point; then, with the observing instrument left unmoved, allow the Sun its

diurnal course, and at fixed intervals prick down the center of the spot on the paper, until it reaches the west, whose marginal point mark carefully. Now either the spot passes through the center of the observation circle, or it does not. If the first, you will always have a rectilinear trace of its passage, and from it you will gather nothing to this purpose. If the second, there will always indeed be described, on the side toward the thing, a curvilinear path — but one that, near the center, is not much curved and is scarcely perceptible, while away from the center it is bent more and perceptibly. The convex face of the curvature will always be turned toward the center; the concave will be turned away from it. This experiment is sure and safe, and liable to no cavil; and I have made very many trials of it. By this experiment you will test, first, the correct setting of the tube upon its mounting [feretrum], then the setting of the lenses upon the tube; and besides this, the good or bad figure of the lenses themselves. For if all these are correctly disposed, two courses that are parallel and equally distant on either side from the center must be equally curved; if this does not happen, either something of the aforesaid is deficient, or the observer has erred.

[Margin: A safe experiment, by which many other things can be had.] By this experiment you will further learn how much, at any assumed distance from the center, the lenses of the tube exceed in refracting toward the margins, and how much they fall short toward the center. For the straight line that joins the horizontal points marked at rising and setting will give, at the middle of the curved path, the difference sought, and so forth. This rule is of great moment, and yet very easy. [Margin: The difference of the refractions is learned.]

Besides, you will compare the several different tubes with one another, and from the greater or lesser curvature, other things being equal, you will learn their powers and their differences in refracting. [Margin: To investigate the difference of the tubes in refracting.]

You have here too the reason why, in the rectilinear courses of the spots, I have almost always added that they are, to the senses, equal or similar: because even if the annual motion contributed nothing to the curvature, and even if the axis of the spots lay most flatly upon the solar horizon, yet this manner of observing would bend the rectilinear course of the spots somewhat, more or less, by refraction — according to the quality of the tube, and to the great or small departure of the parallel from the center of the observation circle. [Margin: Curvature from refraction overflows into the paths of the spots.]

COROLLARIVM I.

Hence it follows that the curvilinear courses of the spots — those concave toward the center — become, on account of this very appearance resisting them, somewhat straighter; while the convex ones, on account of the appearance seconding them, become somewhat more curved.

COROLLARIVM II.

Likewise, that it can happen that some courses truly curvilinear turn out rectilinear, and those that are truly rectilinear are bent into curves.

COROLLARIVM III.

Moreover, courses truly parallel diverge from one another, or converge; and those truly diverging appear to be parallel, and so forth. [Margin: Convergence and divergence can arise from refraction.]

These things, I say, and others equal to them, happen and can happen from this appearance of refraction; and although in many cases they introduce no notable difference to the senses, nevertheless a prudent observer must know them, lest he impute to himself, or to the nature of the phenomenon, what happens by refraction — and lest, in the minute apparent motions... [Margin: A warning to prudent astronomers.]

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someone finicky and overly scrupulous in fault-finding, who would gratuitously insist on geometric or arithmetical rigour — down to seconds, thirds, and fourths — to which, given that refraction resists and remains uncorrected, those tiny quantities can in no way be reduced. We have no need at all of such scrupulousness, since we are equipped with so many and so evident arguments — as I shall show later in its proper place — as many and as weighty as no celestial phenomenon has ever been produced or established with.

[Margin: Objection against the curvature — that it arises from refraction — drawn from the parallel diurnal circles of the Sun.]

You will say that the parallel circles the Sun daily describes outside the equinoxes are, with respect to us, not concentric, nor are they great circles; and that for this reason they cannot be projected onto the paper along a straight line, but must

necessarily be curved, etc.; and hence that this apparent curvature could arise from the circles themselves.

[Margin: The objection is answered.]

I reply that the argument seems too finicky. For if we choose to reason from truth and principle, the Sun never describes any parallel at all, but winds along a spiral line, and so we stand at the centre of no parallel.

I reply, secondly, that circles near the equator may be admitted into the reckoning as such.

I reply, thirdly, that the Sun's diameter is not so great that the arc of any parallel extended through the Sun's centre produces any perceptible curvature to us. Hence it is perfectly evident that all this curvature — produced by a spot traversing the observatory circle — comes from the refraction of the lenses alone. This is confirmed by the fact that the same spot, when it has passed on both sides of the centre of the Sun's image, describes tracks with their convexities turned toward each other and their concavities turned away — and the like; whereas if the spot passes through the centre, its path is entirely straight. Therefore this curvature comes from refraction alone.

[Margin: The curvature is proved to arise from refraction alone, by a clear experiment.]

COROLLARY

From this it is clear that the spot's path through the centre may be taken for the equinoctial itself, whose declination from the ecliptic will give the ecliptic to be inscribed.

I have proved this procedure by many examples and have found it reliable and very easy to carry out. And so, among the many other good things that the inquiry into refraction has brought,

it has yielded this convenience too: that the ecliptic can be set into the observatory circle without any use of a vertical plumb-line, and without any tiresome and finicky computation of triangles, from the gnomonic tracing of the zodiac's rays alone, and from the practical discovery of this line. You will have it if — when the centre of a given spot occupies the eastern and western margins of the observatory circle as the Sun runs its course of its own accord — you carefully note those points and join them by a straight line. For if you draw another line parallel to this one through the centre of the observatory circle, that

line will be the one that, at the centre of the observatory circle, encloses together with the ecliptic the angle which the ray of the zodiac shows for that day in the drawn figure. I have treated this matter more fully at the end of Book Three.

[Margin: A new and very easy inscription of the ecliptic into the observatory circle.]

PROPOSITION VII. PROBLEM III.

To demonstrate the inequality of solar refraction through telescopic lenses by another irrefutable experiment.

CAP. XXX.

That the boundary of shadow and light — cast onto some flat surface set directly opposite a luminous body — is bounded by a line resembling the edge of the opaque body, is certain and confirmed by daily experience. This is why the shadow of the earth projected onto the Moon appears round: because the earth is spherical. Opaque rectilinear bodies also bound their shadows with straight lines. These things being assumed:

Choose the side of a wall that is set up perpendicular and smoothly plastered, on which the Sun shines partly, while it is partly hidden behind the wall. It is certain that the shadow of that edge falls in a plane at right angles onto the telescope and its lenses. Yet it is also certain — experience being the witness — that the shadow of this edge, after passing the lenses, will fall onto the paper along a curved line, both at once and at a single fixed position and view, which you will accordingly mark with points at will. And that this curvature comes from refraction becomes evident from what follows.

[Margin: The inequality of refraction is shown by another natural experiment.]

[Margin: Proof of the assertion.]

For if the boundary of this shadow runs through the centre of the observatory circle, it is a straight line; but if you catch this shadow anywhere off-centre, it will always appear with its curvature convex toward the centre and concave toward the margin — with a smaller [curvature] the closer it lies, a larger one the farther it is from the centre. You will test this truth all around; nor is it necessary that the shadow lie in a vertical plane. It is required, however, that there be a great distance from the telescope's aperture to the shadow-casting body. And it is confirmed most strongly by removing the lenses from the tube: for then the shadow always falls onto the paper as a straight line. Therefore the inserted

lenses are what cause the curvature, etc. I made this test at Rome very frequently, and, other things being equal, I found the shadow's curvature to be the same as that produced by a spot running across the observatory circle at the same distance from the centre. From this you will be able very easily to ferret out the variety and power of tubes in refracting, etc. If you have no wall of a house, no tower, no upright column, set up a beam, a joist, or a planed tree-trunk; hang or stretch a cord or a rope, etc., and you will have your wish.

PROPOSITION VIII. PROBLEM IV.

To make the inequality of solar refraction manifest, through any given spot on the Sun, by another experiment.

[Margin: The inequality of refraction is proved by the artificial conveyance of the spots within the observatory circle.]

CAP. XXXI.

You will proceed as follows. With the Sun's image perfectly fitted to the observatory circle, you will observe the centre of a spot, and mark that place of the spot; you will join the marked place by a line drawn through it and through the centre of the observatory circle — a blind diameter — drawn so that the eye can clearly distinguish it. Then you will move the instrument so gently that the spot comes over into the other part of the blind diameter, across the centre, and so that the centre of the observatory circle stands at a place roughly midway between the spot and the bright solar margin. This done, you will again mark on the blind

diameter the spot's place; then, with the spot retained in the marked place, you will mark the intersection of the solar limb with the blind diameter.

For when a solar spot is moved over the observatory circle, the whole bright solar circle must also move, and become eccentric to the observatory circle.

If, then, you have operated accurately, you will always find this distance — of the spot and of the solar margin, discovered on the blind diameter about the centre of the observatory circle — smaller than the one found at the outset between the spot and the limb when the Sun agreed homocentrically with the observatory circle; yet with this difference: that the nearer the spot is to the Sun's centre, the smaller this difference will be found, and the farther off, the greater the difference will arise. The reason for both is physical and optical. Because the spot and the solar edge, when carried over to the central regions of the observatory circle, are placed under rays of incidence that are less oblique than those they

have when the circles agree perfectly with each other; hence it is necessary that they be refracted less in the middle and more at the extreme. And if the spot is near the margin, it is clear that both spot and margin are strongly refracted, because both lie under very oblique rays of incidence; but when they are carried to the centre, on account of nearly perpendicular incidences, much less refraction occurs. From this the greatest difference between the central and the extreme positions arises.

Nearly the same thing will happen if you place the spot not beyond, but only at, the centre of the observatory circle. For the distance which, between some spot and the bright solar margin, is found while both have been carried near the centre of the observatory circle, will always be found smaller than if the same spot were compared with the same bright limb of the solar circle while the whole coincided with the observatory circle. For this marginal distance will be found always greater than that central one; and no reason underlies this except the unequal refraction of the lenses alone, produced by unequal incidence, etc.

COROLLARY I.

From these things it is established that, if a larger

[Margin: When does a larger observatory circle produce greater refraction?]

observatory circle is assumed, the refractions become greater about its margins than if a smaller one is assumed — the same distance of the paper from the concave lens being kept, and the same lenses being duly fitted. For, things being thus, the solar cone occupies more of the concave lens, and consequently the outermost rays fall more obliquely. I said "the same distance of the paper from the concave lens being kept"; for if this distance alone is assumed greater, it enlarges the observatory circle, [but] the refraction is not, on this account, necessarily and appreciably changed.

COROLLARY II.

[Margin: Other things being equal, refraction is greater in winter than in summer.]

With the same size of observatory circle kept, and likewise the same telescope and the same lenses, greater refractions occur about the margins in winter than in summer. Because in winter the solar cone occupies more of the concave lens than in summer, and so it arrives under more oblique lines of incidence: therefore more refraction intervenes. But this discrepancy escapes the senses, etc.

[Margin: Objection against the artificial conveyance of the spots.]

You will say, first, that this conveyance of solar spots seems suspect, and that it does not rest on true practice.

For, secondly, it is impossible that by the motion of the tube alone any spot should be carried from the intermediate parts of the Sun to its edge.

Then, thirdly: we do indeed see, with the instrument at rest, that the Sun together with its spots gradually approaches and recedes from the observatory circle drawn on the paper; but not on that account should the spot, and its refraction, be said to be transferred, and to be such as it would be if it were to enter that part of the glass from which it is refracted onto the same solar circle that the outermost solar orbit produces.

Furthermore, fourthly: when the instrument is moved, the refracted cone is not changed, but in the bright circle projected onto the paper the spot is always found to hold, as it were, the same relation to the centre of the cone and to the circumference — which is a manifest sign that the spot has not been transferred.

[Margin: The objection is answered.]

I reply, first: if this conveyance does not rest on true practice, then the two earlier natural experiments adduced are false, and

at last the whole method of coming to know refraction is cut off.

For this practice agrees in everything with the earlier experiments, as I have tested a thousand times and more. Now if the Sun, with the telescope at rest, carries some spot across the observatory circle by its own diurnal motion, and in carrying it into ever different parts of the concave lens makes its path liable — on account of the different obliquities of incidence — to different refractions: why then will the same not happen if the hand intervenes and, by moving the instrument, compensates for the Sun's very motion? Why will this practice be suspect, when the same motion occurs and the same effect follows? So that you may palpably grasp this with your hands, if you decline to see it with your eyes, here it is for you. Draw any diameter through the observatory circle with a blind line; then choose any spot situated anywhere on the Sun. While you carry this spot along the drawn diameter, mark the course of another spot lying outside this line, going from one margin of the observatory circle to the opposite margin. This done, you will have the track of that spot in the observatory circle, and it will be curvilinear; and if the Sun does not of its own accord describe a similar and equal one, when it has carried the spot across at an equal distance from the centre of

the observatory circle, let me be found guilty. Therefore, if ingenious art imitates to a hair what nature does, will this on that account be suspect, because it proceeds from art — or will nature itself be ruined together with art? Away, then, in a matter so clear and so well-proved, with these suspicious and arbitrary quibbles. And that they may be still further removed, here is another experiment.

[Margin: Another clear method of artificial conveyance.]

[Margin: The Sun of its own accord describes similar tracks.]

Choose some spot on the solar edge, nearer the margin than the centre; observe its place in the observatory circle, through which draw a diameter in the observatory circle, and to this another diameter at right angles, which will be the directrix of the conveying observation. For if you carry the perimeter of the bright solar circle along this line, at the point of contact, across the observatory circle, and meanwhile mark the track of the aforesaid spot from one margin of the observatory circle to the opposite margin of it, that repeated marking of the spot by frequent points will complete the

[Margin: Another striking experiment of conveyance.]

track — a curved line, and indeed just such a one as the Sun would describe if left to its own reins at the same distance from the centre. Can anything more solid be brought to bear on the truth?

[Margin: The alleged fact does not damage the argument.]

I reply, secondly, to what is alleged — that by the motion of the optical tube or of the instrument no spot on the Sun is carried from its seat into another, much less from the middle into the extremes — that this indeed is true, but that it does not damage in the least our view about the translation of the spots. For the conveyance of the spots does not consist in this, that the spots change their position and place on the Sun (to think this, let alone to attempt it, would be frivolous), but in this, that they change their position and place in the observatory circle on the paper. And I show that this can happen from the fact that the Sun itself, with no one managing it, does this continually, since it always deflects the circle of its luminous cone to a different place in the observatory circle. What the Sun does, then, while the observing apparatus stands still, I say that I can do, moving it in whatever direction by the same [amount]. Hence.

[Margin: In what does the conveyance of the spots and of the Sun consist?]

I reply, thirdly, to the third [objection]. When it is objected that if the Sun, with the instrument at rest, runs through the observatory circle with its cone and bright base, and carries some spot to the centre of it and again removes it, this should not be called a translation of the spot — I reply, I say, by denying what is asserted; for this is that conveyance of the spot which I claim, and no other, since it is granted by the very confession of the objection, and indeed by nature's own doing. What forbids calling it so? Surely, according to true philosophy, from being it follows that a thing be said [to be]. The spot, on the Sun and together with the Sun, passes from the eastern side of the observatory circle through the middle to the western side of it, and that at every single moment while the eye watches; and what the eye sees, no one will forbid the tongue to utter. But you press: even if the spot has passed over — whether of its own accord or by the observer's hand — etc., yet the refraction has not been transferred;

[Margin: Reply to the third objection.]

[Margin: Whether and when refraction is said to be transferred.]

[of the] observatory [circles] are not changed — that is true, but this does not tell against my view and practice; rather, it is presupposed by it. The other sense is this: "the refraction is not transferred," that is, the spot, in passing across the observatory circle — or better, the spot, in coming under one line of incidence of the concave lens after another — does not undergo one refraction after another. If this sense is intended in the objection, it is false. Furthermore, I do not say that the refraction is transferred, but that by the conveyance of the spot the refraction of that same spot is changed; for the refraction, at the same place of the observatory circle or of the lens, is always the same. But the spot acquires a different one, because it enters different places of the lens. But you insist: a spot at least transferred in this way is not refracted in the same manner as it would be refracted if it came to this place of the glass by its natural motion around the Sun. I reply that a spot on the Sun, taken at whatever place, if it comes into the same line of incidence, will be refracted in the same manner, by whatever route it is finally carried there — whether this happens by the spots' own motion around the Sun, or by the daily [diurnal] motion, or finally by the observer's hand; and whether at the same time or a different one, quickly or slowly. For all these things make no difference to the matter; because the planes of the refractions do not regard the solar cone or circle, but the one understood to be described about the axis of the lenses, whose base is the observatory circle. And it is with respect to these that the spots are transferred, and are said to be transferred, and by that very translation they change the refraction. And so the assumption is denied.

[Margin: The refraction of a spot translated by art and of one carried by natural motion is the same, at the same place of the same lenses, etc.]

To the fourth, where it is said that, with the instrument moved, the Sun's refracted cone is not changed, but the same spot always keeps the same distance from the centres of the cone and of the luminous base, etc., and that therefore it is a manifest sign that the spot is not transferred:

[Margin: Reply to the fourth objection.]

I reply, first: granting, but not conceding, the antecedent, I deny the consequence. For the argument always takes and supposes that the translation of which I speak must be made with reference to the Sun and to the base of the solar cone, so that the spot changes its place and position on the Sun — which is otherwise. For I understand by translation, as I have often said, that by which the spot, locally, from one [place] of the cone

of the cone and of the plane refractor passes from one part into another. But this plane, and this cone, are not the luminous cone of the Sun. And so, whether the spot occupies the same place on the Sun or not, it makes no difference to the matter. Indeed, if in thought we separate the whole Sun from the spot and imagine the spot alone conveyed through the lenses, that same spot will still be subject to the very variation of refraction to which it is now in fact subject. Therefore the relation of the spot to the Sun makes no difference to the matter, and the consequence drawn from it is deservedly rejected as useless. For from the traverse [traiectio] of the spot I conclude — and I show both practically and theoretically — that the spot is refracted less in the middle and more at the edge of the observatory circle, whether or not it undergoes any change on the Sun itself.

I reply, secondly, that the antecedent is false. For when the instrument is changed, the whole luminous refracted cone of the Sun is at once changed, on account of the altered incidences upon the concave lens. It is also false that the spot keeps the same distance from the points of incidence to the centres of the cone and of the solar circle. These claims, I say, are false, and cry out against manifest truth and daily experience. Hence whatever has been deduced from them lacks any foundation. Nor, from this planar traverse, do the planes of the solar circle, of the observatory, and of the lenses come out oblique to one another; rather, every variety that arises from this is to be ascribed to the inequality of refraction, on account of the varying obliquity of the incident rays.

PROPOSITIO IX. — PROBLEMA V.

To hunt out the inequality of refraction from the mutual distance of two spots.
[Inæqualitatem Refractionis è duarum Macularum inter se distantia venari.]

Cap. XXXII.

[Margin: Modus primus. — "The first method."]

There can be various cases and methods for two spots. One is this: if through two given spots on the Sun and the centre of the observatory circle you draw a hidden straight line, and set up another diameter orthogonal to it, this latter will be the guide-line [directrix] of the conveyance. For if you carry one of the two spots across along it, the other will describe a curved line, which will reveal the inequality of refraction.

[Margin: Alius Modus. — "Another method."]

Another method is this: if you bring the two aforesaid spots under the marginal rays of incidence of the observatory circle — or only one of them, while the other stays inside — you will obtain a greater distance than if you convey them under the central parts, so that one of them is conjoined with the centre of the observatory circle, or the centre is set midway between them. For this central distance will be smaller than the previous marginal distance — which is the greatest of all that those two spots can have within the breadth of the observatory circle — while the central distance is the smallest of all, assuming that the spots keep their true mutual distance unchanged while crossing the Sun. For if that true distance changes, the apparent distance must change too; but the apparent distance changing does not immediately entail that the true one changes as well, since at the same time, by the refraction of the glass, the apparent distance of those spots is altered merely by the shifting of their place and position into different parts of the glass. Yet it is evident that on the Sun the spots have not changed their true distance in this case.

There is likewise another case: if two spots are taken that keep the same distance of latitude between them on the Sun — the kind that occur frequently, rising together and setting together (which sometimes happens around the times of rectilinear motion) — you will see their apparent distance, eastern and western, equal to each other, but the central distance always smaller than either. This comes from nothing other than the refraction caused by the lenses. But if you wish to know whether two spots that came together on the Sun at the same time (that is, which arose together or nearly together, or reached the middle together,

or set together in some fashion) have kept the same constant distance between them, compare their apparent distances at rising, at setting, and in the middle. If the two extreme distances — the eastern, that is, and the western — are found equal to each other, and each greater than the middle one, you will find their intervals to be truly equal in every respect.

And this indeed you will know after the transit is completed. But if you wish to test something before the transit is finished, convey both spots to the eastern and western margins, and also to the centre of the observatory circle, and note these distances. For if, once the transit is complete, they have kept similar distances at the middle and at the edge, you may be confident that the same interval has been preserved across the whole Sun. If they have varied at all in appearance, you will not find the true distance the same everywhere either. For true distances follow apparent ones, other things being equal — that is, provided we abstract from refraction, and provided no error has been admitted in observing and in reducing the observations.

PROPOSITIO X. — PROBLEMA VI.

To demonstrate the unequal appearance of refraction from the absence of any apparent refraction. [Refractionis apparentiam inæqualem, ex nulla refractionis apparentia demonstrare.]

Cap. XXXIII.

[Margin: Sola Refractionis inæqualitas à lentibus caussata, parit inæqualem motus apparentiam, &c. — "The inequality of refraction alone, caused by the lenses, produces an unequal appearance of motion, etc."]

By many arguments hitherto, and by clear reasons and experiences, I have in my judgment proved plainly enough that the unequal appearance of the spots' motion — around the middle and at the edge — arises from the inequality of refraction alone, which springs from the lenses inserted in the optical tube [telescope]. That this is so I now prove, besides what I have already brought forward, by a single irrefutable practical argument, whose sinew no obstinacy of any kind can in the end break.

I have touched on this argument several times in earlier passages, and indicated its force theoretically; now I bring it forward by the very fact, and set the truth before the eyes to be looked at. I present, I say, the transit of spot *a*, which I observed at Rome in the year 1626, from the 17th of September to the 30th of the same month, with all the diligence one can demand of a man, and with truly

inexpressible labour. For the subtlety of this procedure seems almost to surpass the dexterity of human skill — as anyone will find who is a keen investigator of this truth and a diligent imitator of the exercise I have established.

[Margin: *Cursuum absq; Telioscopio excipiendorum, praxis laboriosissima.* — "The practice of catching the transits without a telescope is exceedingly laborious."]

Indeed, I received the admitted Sun through a bare little hole, without any other transparent medium interposed, so that its radiant cone, directed orthogonally onto the paper placed opposite, would shine through the air alone without any refraction, and would cast the shadows of the spots without any adventitious enlargement. I took the distance from the hole to be variable, as the case required — sometimes 15 paces [passus], sometimes 20, occasionally 30 and more. And although I observed the transits of more spots than this one, and likewise recorded a forenoon transit similar to this very one, no less exact, I judged this one alone sufficient, so as to spare time, labour, and expense. For a sensible man will not demand more — indeed, he will add his own experiment; whereas a fool, who once contradicts a single experiment, who once spurns authority, will fight against a thousand, and will always despise them. "Against a single true experience," says the Philosopher [Aristotle], "the quibbles of a thousand arguments avail nothing."

[Margin: *Plures eiusmodi cursus obseruati.* — "Several transits of this kind observed."]

[Margin: *Vna vera experientia æquiualeat mille.* — "One true experiment is worth a thousand."]

For this reason, in the adjoining figure, the circle ABCD is not the observatory circle but an illustrative one, because I did not admit the Sun under so large a figure, but under smaller and various magnitudes; to this one, however, I enlarged the individual images, so that I might afterwards compare this natural admission of light with the telescopic transmission. For at the same time I always caught the Sun through the telescope as well, whose observatory circle was exactly equal to this ABCD; and therefore I had to make this illustrative circle equal to that one.

[Margin: *Eodem tempore, eadem Macula est etiam per Telioscopium obseruata.* — "At the same time, the same spot was also observed through the telescope."]

AB, then, is the ecliptic; CD, its axis. Spot *a* was first sighted on the 17th, at 4¼ in the evening; for in the morning I did not notice it, since it was then moving about on the horizon. For this reason I bring forward the evening transit, not the morning one — because the morning transit closely approaches the horizon on both sides, notwithstanding that the evening one proved fuller in the middle, from several observations. You have the hours noted for each day in the daily Table of Observations inscribed below the Image; and I proceed by hours and fractions of hours, because I argue from time to motion. For I have often said above: as time is to time, so is the arc corresponding to the apparent temporal motion to the arc corresponding to the time; or, as time is to time, so is the path along a parallel to the path along the same parallel...

traversed in the corresponding time, and so forth. Then the spots must necessarily be adhering to the Sun; and this will be manifestly detected if the spots are observed without lenses. Since this is done here, and is found as I predicted, the argument keeps its force.

[Margin: Explicantur & ostenduntur dicta in exemplo practico. — "The things said are explained and shown in a practical example."]

Consider, in the adjoining figure, the trapezia for one day, two days, three days, and four days: they will be to one another as the times owed to them are to one another. Let us begin with the daily ones. They are: *a-b-c-a* [?], *a-d-e-a*, *a-e-f-a*, *a-g-h-a*, *a-i-K-a*, owed to days 25, 26, 27, 28, 29, 30; and the chords *b c*, *d e*, *e f*, *g h*, *i K* correspond to the temporal intervals of the apparent motions *a-a*. Since their times are in some way equal, I found the chords themselves also to be, at least sensibly, equal to one another; and I find the arcs subtended by them likewise equal. Thus the chords of two days, *l m* (from the 17th to the 19th) and *n o* (from the 19th to the 11th [recte: 21]), are equal to each other, and subtend equal arcs, [equal] to any two-day arcs subtended on the Sun's surface, and so on. Thus the arcs of three days, subtended by the chords *p q*, *r s*, *t u*, *x y*, are equal to one another and to any assumed three-day arcs. Why so? Because they were traversed in equal times. Thus if the chord *z α* is taken, owed to the time-interval 17–21, that is, of four days, its arc will be equalized to any four-day arcs reckoned by any daily chord *g h*, or by the two-day chord *n o*, and so on. And what has been said and taught, by way of example, about the chord of one day, of two, of three, and of four, should be understood also of five, six, seven, and more.

Note first: when arcs are compared with arcs, they must be taken from the same circle — either the great circle ABC or a parallel — about the finding of which I shall speak a little later.

[Margin: Cautela. — "A caution."]

Note secondly: I have said that the chords, and the arcs corresponding to them, are sensibly or quasi-equal, on account of the small difference of hours; for in strictness a geometrical equality of lines cannot indeed be established where there is no [equality] of time. Yet since, between the diurnal time and $\frac{1}{4}$, $\frac{1}{3}$, $\frac{1}{2}$, $\frac{1}{8}$ [?] etc. of one hour — within so tiny an interval of apparent motion — it is scarcely sensibly noticeable, I call these things at least sensibly equal, which is enough for my purpose.

Note thirdly: when I say "as time is to time, so chord is to chord," this is true only when equal time is referred to equal time. But when unequal time is taken to unequal time, then it is the arcs subtended by the chords that correspond, once the times are assumed.

From this equality of Times and Motions, then, drawn out by this method of observing, it is clear that every other inequality introduced into the observations by the telescope arises from the refraction of the lenses alone — which was to be proved.

[Margin: Conclusio. — "Conclusion."]

It is clear, secondly, that the spots cannot be placed outside the Sun once the regularity of motion is assumed; for as soon as that is done, either an irregular motion (contrary to the phenomenon) or a dissonance of the times with the motions will be introduced.

The same things are demonstrated together from the perfectly equal distance of the spots from their own mobile pole, in the same figure. [Eadem commonstrantur ex æqualissima Macularum à polo suo Mobili distantia, in schemate eodem.]

Refraction through the lenses also introduces some little inequality into the distance of the spots from their mobile pole, as will appear in the examples to be brought forward. This same inequality wholly ceases in the present kind of observing. Now the mobile pole lies on the little polar circle [circellus polaris], which little circle is obtained thus.

[Margin: Ex Circello polari Maculæ in Sole esse demonstrantur. — "From the little polar circle the spots are demonstrated to be on the Sun."]

When the spots move in a rectilinear course, the little circle is described at the greatest declination of the greatest parallel from the ecliptic — which I have almost always found to be about 7 degrees from it. When the spots move in a

maximally curvilinear motion, by the benefit of the greatest curvature the same quantity, or nearly the same, is found. And because in the present transit there has not been much departure from equilibrium, the same seven degrees were found, nearly, in this way.

[Margin: Quomodo Circellus polaris inueniatur, & describatur. — "How the little polar circle is to be found and described."]

The greatest chord of this transit is drawn from the point of rising of spot *a* to its setting — the line, namely, 17–30. Then to this, through the centre E, another line is drawn at right angles, FEG, which, since it represents the plane mobile axis, will cut the chord of the middle transit...

it will cut the chord 17–30 in two at H, and the trace of the transit at I; and through HI the semidiameter of the little polar circle $\beta\gamma\alpha$ will be obtained, sensibly — which is $\beta\zeta$ [?] or $\zeta\alpha$ [?], namely the sine of the arc C β or C α , of about seven degrees. And since this transit has not departed much from equilibrium, it has sensibly relaxed almost nothing of its curvature.

And since at the middle of the transit the section of the plane through the axis is E I H ν [?], at the beginning of the transit — that is, on the 17th — this section passed through the centre E and reached θ ; for there the mobile pole falls forward, from ι . That on 17 September the mobile pole was at ι is proved from the fact that around 8 September the equilibrium regularly occurs, and the axis is found at γ , as was shown at length from the observations of the earlier book, and can be abundantly established from this very observation. Now, once the apparent place both of the mobile pole and of the spot has been obtained, the true place of each on the Sun's surface, and the true distance between them, will consequently be had, by the benefit of the little circle, in this way. On the 17th the seen and apparent place of the spot was at rising, at *a*; the straight line $\iota\lambda$, parallel to the line $\gamma\iota$, designates the apparent place of the pole. For where $\iota\lambda$ cuts the semidiameter at the point θ , there is the seat of the mobile pole ι ...

[Margin: Ex locis apparentibus, distantia vera inquiritur in Solis superficie. — "From the apparent places, the true distance is sought on the Sun's surface."]

there, I say, is the seat of the mobile pole ι , projected from its original place onto the point θ of the solar circle and onto the diameter $\theta\beta$ [?]. For since that pole always circulates on the polar circle throughout the whole year, it cannot be projected analematically elsewhere than onto the diameter $\beta\iota\alpha$ [?], because this alone is the common section of the solar circle ABCD and of the little polar circle $\beta\gamma\alpha$. Hence the apparent place of the mobile pole must always be sought on

this diameter, and the true place always on the periphery of this circle, as drawn on the globe. But since here everything must be carried out in a plane, the procedure must be set up a little differently, so that the true distance of the true places may be obtained from the apparent ones.

[Margin: Polus mobilis è perimetro Circelli in solam eiusdem diametrum projicitur, &c. — "The mobile pole is projected from the perimeter of the little circle onto its diameter alone, etc."]

Therefore, as I said: to the apparent place of the spot, a , taken on the 17th, and likewise to the apparent place of the pole, θ , found from the observations on the same day, apply a ruler and join the two apparent places θ and a by the straight line $a\theta$. Then from a and from θ draw perpendiculars — both to some one and the same side, as far as is enough. And from the apparent pole θ you will cut off $\theta\lambda$ [?], equal to $\theta\iota$; but from a you will cut off av , equal to $a\zeta$ [?], which is the perpendicular sent out from a — the seen place of the spot — onto the Sun's surface. It is obtained if it is sent out at right angles onto the perimeter of the observatory circle relative to the radius Ea (drawn out from the Sun's centre from the apparent place of the spot); and it is always the right sine [sinus rectus], etc. This radius I have not drawn here, to avoid confusion; but it is seen here and there in other figures.

The point λ [?], then, and the point v , are indeed the points of the true places, deduced from the apparent places, since the straight lines $\theta\lambda$ and av are not only equal to the straight lines $\theta\iota$ and $a\zeta$ [?], but are also perpendicular to the straight line θa and parallel to each other. Yet they do not lie at the true places; rather, they exhibit exactly the true distance λv of the true places.

[Margin: Puncta locorum verorum, & distantiae veræ situs verus, quomodo concipiatur? — "The points of the true places, and the true situation of the true distance — how are they to be conceived?"]

Hence, if the trapezium $a\theta\lambda v$ is imagined to be raised up on high about the fixed line $a\theta$, until the straight lines av and $\theta\lambda$ stand perpendicular to the circle $ABCD$, then the points λ and v will stand aloft and will occupy the true places on the globular surface of the Sun, and the true distance will be the same λv . Since, therefore, in the plane these cannot be fitted to their elevated places, they are usually, in the manner described, reclined onto the plane of the observatory circle, onto perpendicular and parallel lines carefully found from the apparent places; and the apparent places are obtained from the observations alone.

For this reason, if the solar spots accomplish their path on the Sun's surface with a regular and uniform motion about the mobile axis and poles, and if the mobile axis and poles are carried, with a uniform annual motion, about the fixed axis and poles of the ecliptic, then the spot must always be equidistant from its mobile poles. And if it is equidistant, it must certainly have moved regularly on the Sun's surface.

[Margin: *Aequalis Maculae à polo suo mobili distantia vera, arguit Maculam in Sole esse motam.* — "The equal true distance of the spot from its own mobile pole proves that the spot has moved on the Sun."]

That the true distances of this spot *a* from the mobile pole are, among themselves, most perfectly and to a hair's breadth equal throughout the whole transit, is clear to the eye from the straight lines $\theta \pi$, $\varrho \sigma$ [?], $\tau \upsilon$ [?], $\phi \chi$, $\psi \omega$, *a b*, *c d*, *e f*, *g h*, *i K*; for all these are equal to one another, and present the truest distances of the true places, deduced with the utmost fidelity from the apparent places — as may be seen from the trapezium *a v* $\phi \chi$ [?], owed to the 24th day. And if it were raised up upon the straight line *a v* — namely the apparent distance, between the apparent place...

Diagram. A large full-page geometric engraving occupying the upper two-thirds of the folio, illustrating the pinhole projection of sunspot *a* across the sky from 17 to 30 September (Rome, 1626). The construction is a great enclosing circle (the diurnal / celestial circle) with a horizontal diameter running left–right, its ends lettered **A** (left) and **B** (right). A second, smaller circle sits at the top center — the aperture/Sun region — from which a dense pencil of solid and dashed rays (the pinhole projections) fans downward and to the right across the whole figure. A central vertical line descends from the small top circle through the interior points **H**, **I**, **E** (top to bottom). Along the right-hand descending arc runs a dashed curve carrying the successive daily positions of the spot, labelled with the September dates **24**, **25**, **26**, **27**, **28**, **30** (with the ascending dates **17**, **19**, **21** on the left limb near points to the left of **A**). The projected spot-images are marked with repeated small **a**-points (with tick-dots) along the ray-bundle.

Engraved emblems: a sunburst medallion enclosing **IHS** with a cross (the Jesuit Christogram) at the upper left; a matching sunburst medallion enclosing **MRA** (a Marian monogram, surmounted by a Libra sign $\underline{\omega}$) at the upper right; and heraldic rose ornaments at the lower left and lower right corners (the "Rosa" device of the *Rosa Ursina*).

Readable point-labels and lettering (only those legible under magnification are committed):

- Small top circle (aperture/Sun): **G, C** (adjacent, just inside the top of the circle); **λ, ε** at its apex; a cluster of Greek letters around and below it — **β, φ, ψ, τ, ξ, κ** [several only partially resolvable].
- **p** (upper left, on a near-horizontal line running to the small circle); a second **p** at the far right near **B**.
- **b, q** (top, right of the small circle); **r** (immediately left of b).
- **o, α** (upper-left region); **m, n** (left side, upper-middle).
- Left diameter end **A**; right diameter end **B**.
- Central descending points **H, I, E**.
- Right-hand periphery and descending rays: **c, d, e, f, s, x, h, u, t, g, y, K, l** (with the dashed day-curve 24–30 and repeated **a**-points).
- Lower periphery: **s, t, l, m, n, o**.

Engraved caption beneath the figure: *"From the course of spot a — observed through a bare pinhole, without refraction, from the 17th to the 30th of September — the apparent inequality of refraction [seen] through the telescope, and the true place of the spots on the physical surface of the Sun, is clearly shown."* Beneath the caption is the observation table (below), and the imprint **"At Rome, in the Roman College of the Society [of Jesus]."**

Table of observations (engraved on the plate, headed **SEPTEMB.**):

D	H	D	H	D	H
17	4¼	24	5	28	4½
19	4	25	4	29	4¼
21	4¼	26	4¾	30	4⅛
22	3⅓ [?]	27	4¼		
D	F				

[The demonstration continues from the preceding folio, resolving the true places of the pole and the spot onto the Sun's surface.]

[Margin: The true position and the true distance on the Sun's surface.]

concerning the apparent [place of] spot *a* and the apparent pole *★*, it is certain that the true place of the pole *φ*, and the true place of spot *χ*, will stand directly above their apparent places, on the very surface of the Sun. For the line *a χ* is

equal to the line $a l$, and the line $\bullet \phi$ is equal to the line $\bullet \mu$; and both of these lines have their own points — μ and l — on the surface of the Sun, if they are erected [drawn perpendicular]. Therefore the lines $\chi \bullet \phi$, and $a \chi$ as well, if erected, will place the points χ and ϕ on the surface of the Sun. And this will be demonstrated for all the remaining cases in precisely the same way, and so on.

COROLLARY

From these things it is again established that the inequalities apparent through the telescope are the purest

—workings of refraction. Next, it is established that the polar circlet [*circellus polaris*], together with the annual motion of the pole within it — running counter to the drift of the spots — is no arbitrary position or ingenious fiction, but lies wholly in the nature of the thing, and in the turning of the Sun and of the spots' axis, which is mobile along with the Sun itself. (For we conclude that the whole Sun moves proportionally in this way, since the spots have been shown to belong to the Sun — both the primary spots and faculae, which are original to it, and the secondary ones, which everywhere pervade it and are wound about its center in the same rotation as the primary spots.) This is so intimately rooted [in the Sun's nature] that without it the apparent motion of the spots cannot conveniently be accounted for.

[Margin: The polar circlet is derived from the nature of the thing.]

[Margin: It is the refraction of the lenses alone that produces the apparent inequalities of the diurnal motions.]

The same things are demonstrated from the true parallel that spot a described — from its delineation, from its periodic revolution, and from the exhibition of its diameter.

If sunspots inhering in the solar surface are carried in orderly fashion about a pole raised above the plane of the solar circle, then necessarily those spots that advance toward the region of the elevated pole must spend not only [more] time, but must also occupy more than half of the circle that lies above the horizon. It follows that the diameter of the parallel must be greater than the chord which joins the [point of] rising to the apparent [point of] setting; and that the concealed part of the parallel must be smaller than the exposed part, and so on. All of this holds true in the parallel of spot a , whose semicircle $u x q$ — that is, $e x y$ — you have described from its center. Its construction is carried out as follows.

[Margin: From the conditions of the parallel described by the spot, the spot is proved to lie on the Sun.]

Having found the spot's true distance from the pole about which it turns — call it $\star v$, or $o v$, or whatever it may be — take any point **C** of a great circle at your choice, and from it mark off on either side the points **u** and **q**; then join the straight line **u q**, which will be the diameter of the parallel **e x y** — described as though about its own center — of which I here exhibit only the semicircle **u x q**. That this diameter **u q** is greater than the chord 17, 30 is clear from experience and is proved as follows: for if you set one leg of a compass at **C** [or **G**], and extend the other according to the true distance of the spot from the mobile pole, and carry it around the circumference, it will pass — here through the rising point 17, there through the setting point 30 — which also

[Margin: The curvilinear motion of the spots in the region of the elevated pole is greater than a semicircle, [subtended] by a chord smaller than the diameter.]

is evident from the arc 30, q, which is greater than the arc 17, u. From this it follows that the arc **u C q** is greater than the arc 17, C, 30 — a thing that also comes to light in the line **E y** being shorter than **E H**. But these things need not be established, nor proved, from practice: rather, they are known by this evident and prior line of reasoning. From the fact that in the circlet **$\beta \gamma \delta$** the mobile pole is raised above the horizon, it is clear that the apparent path of spot *a* is a portion greater than a semicircle. Hence the chord 17, 30, drawn out from rising to setting, must necessarily be smaller than the diameter, since by hypothesis it subtends the greater portion of the circle. Therefore the diameter **u q** is greater than the chord 17, 30. And since this evident reasoning goes first, and is then followed by clear, palpable experience — who does not see the most beautiful harmony of truth? Who would not gladly grant it the palm? For this truth would not stand if the spots were placed outside the Sun, or even a single second [of arc] beyond it. For never will [the spot] appear as more than a semicircle above the horizon, but always as less. And this is one point.

[Margin: From the greater diameter — found by observation and demonstrated by reasoning — the spot is shown to be within the Sun.]

The other point, which I mentioned, is that the spot must linger longer above the horizon than half a periodic revolution requires. This becomes plain in the designated semicircle **q x u**, in which — according to the daily arcs found, taken over two- or three-day intervals, **i K**, **n o**, **t u** — thirteen days are found, plus or

minus six hours, whereas the spot in fact spent above the horizon a minimum of 13 days, 18 hours.

[Margin: From the time of the course, and from the larger apparent segment, the spot is placed within the Sun.]

This truth does not stand under any other arrangement or regular motion of the spots outside the Sun. And so, from this head too, the spots must necessarily be received into the bosom of the Sun. This always happens when the spots run their course in the region of the exposed pole; the contrary occurs when they complete their periods in the parts of the hidden pole — for there the lingering above the horizon never attains half of the periodic revolution. Yet this must be noted: that excess, or this defect, is not the same in all the spots' courses, but greater or smaller in proportion to the distance which the spot's parallel has from the greatest of the parallels [the solar equator]; for the farther apart they are, the more the differ—

[Margin: The half-quantity of the period.]

[Margin: The differing inequalities of the apparent courses, etc.]

Diagram. This folio carries the identical engraved Plate XXVI already described at fig-p629-1: the same great circle with diameter **A–B**, the same aperture circle with **G, C, λ, ε** and the Greek cluster (**β, φ, ψ, τ, ξ, κ**), the same central points **H, I, E**, the same right-hand dashed day-curve (24–30) with points **c, d, e, f, s, x, h, u, g, y, K, l**, the same **IHS** and **MRA** ($\triangle$) sunburst medallions and corner roses, and the same caption, observation table, and Roman-College imprint. See fig-p629-1 for the full description and the table. [The same plate appearing on two different letterpress pages (475 and 477) is flagged in QA.]

[The demonstration continues from the foot of the preceding folio.]

—ences [between courses] become more notable; the less [distant], the smaller these are. The greater or smaller curvilinear advance of the spots also assists this effect; likewise their own [greater] velocity or slowness. And this was the second point.

The concealed part comes to light if the part which appeared above the horizon is subtracted from the whole period; and the whole period, in turn, emerges from doubling the semicircular arc that was found. Thus, since the semicircular arc **u x q** was found to be 13 days, 6 hours, the whole period will be 26 days, 12 hours; and if from these there be taken the 13 days, 18 hours of the exposed course, there will remain 12 days, 18 hours for the hidden course.

[Margin: The whole periodic revolution.]

[Margin: The quantity of the exposed and the hidden course, and their difference.]

—And so between the appearing segment and the hidden one there will fall a difference of one day; a thing which, other things being equal, I find generally to hold from the other courses as well. The circles of the returning spots also agree with these results, as we shall see more precisely later, in their proper places. Meanwhile I offer the Reader a certain foretaste of these matters, lest I seem to want to approach so great a subject as if abruptly and unprepared, or to drag others into it; for I have no doubt that anyone, once he has weighed the force of our arguments, will of his own accord surrender his hand to the truth, given so great a convergence of all the considerations, reasonings, experiments, and testimonies of the senses.

[Margin: The courses of the returning spots agree closely with this.]

ON THE REGULARITY of the Motion of the Spots, etc.

CHAPTER XXXIV.

Since throughout this whole treatise I so often insist upon, and so often repeat, the Regularity of the Motion of the Spots — in these or similar words, "*the Regularity of the Motion being supposed*," and so on — I have thought it worth my while (lest anyone twist the sense of my words into something perverse, and from that fall into error or false suspicions, as though I did not derive the Regular Motion of the solar spots from observations, but rather read it into the observations from a presupposed conviction, and so shored up my doctrine unsoundly) to explain the matter here somewhat more fully, as it truly stands — especially since those who, with unclouded judgment, have judged it needful to come to the aid of the well-disposed Reader's efforts and prudently to forestall difficulties, request it of me.

[Margin: That the celestial motions are regular, everyone is persuaded.]

And so it is implanted in all men by nature, and they are persuaded, to believe that those things which are and come to pass in the heavens are utterly ordered and utterly regular — especially with the added testimony of divine Scripture, that God founded all things in number, weight, and measure. Since, I say, both the sacred page declares this and common reason persuades of it, astronomers have most firmly held that this holds above all in the motions of the heavenly

bodies. Hence they have always striven to recall any apparent motions whatever, however irregular they might seem, back to regularity. They suppose, that is, that the motions are in themselves most regular, but become irregular and appear so to us through the concurrence and combination of several; and so, catching these composite motions, they resolve them into simple and regular ones with what skill they can. This drove Ptolemy to Eccentrics and Epicycles — not orbs, but circles — by which he might defend the regularity of the celestial motions of which he was persuaded. This held Aristotle to his Homocentrics. And so all have always judged that a certain most regular proportion is present in the celestial motions, and for that reason have sought it with the utmost zeal, and that under the most diverse suppositions. And the more closely each one came, in framing his own Hypotheses, to defending the regularity of the Motions, the truer his teachings have been reckoned.

No one, therefore, will wonder if he sees me too aspiring — on the basis of the discovered and apparent motions of the solar Phenomenon — toward some regularity, following the rule common to and accepted by all. For if, on the Apostle's testimony, the things that are from God are ordered, then it can scarcely be doubted that in the revolutions of this Phenomenon above all the highest order prevails — seeing that the very moving body in which it is found to reside is the most principal of all the heavenly bodies: namely the Sun, the Ruler and Governor of the whole Universe.

[Margin: Erratic, random-moving bodies do not fall under astronomical consideration.]

When, therefore, I observe the motion proceeding from that body itself, and find it to be variable from legitimate appearances and observations, the first doubt that arises for the astronomer is this: whether that apparent motion is regular and ordered, or not? For if he perceives a disorderly and, as it were, chance jostling of moving bodies, one that can be reduced to no order, he lets go the superfluous care of ordering it; but if he has caught some indications of regularity, he presses on, searching them out, and advances as far as the powers of his mind and the manifestation of the proposed Phenomenon allow.

In the present Phenomenon, then, although at its very first discov—

[Continuation of Cap. XXXIV, "On the Regularity of the Motion of the Spots."]

[Margin: Signs of irregularity in the solar phenomenon.]...many things presented themselves that could have drawn the observer's mind away from any settled certainty of regularity, or at least held it in suspense. Such were the various and,

as it were, sudden coalescences of the spots; their abrupt separations; their disorderly deviations; the endless transformations of their figures; the new and unforeseen births of spots in the middle of the Sun, and, conversely, the deaths of old ones; their prodigious growths, or, in the opposite direction, their prodigious shrinkings; the incredible varieties of the faculae; and, above all these, the immense abundance and instability of the secondary phenomenon. Yet even though — I say — these phases and appearances could have turned a prudent astronomer away from hoping for, still less from grasping, any probable regularity in this phenomenon, nevertheless from other, most conspicuous signs of regularity I have been led by the phenomenon itself in the contrary direction, so that I have no doubt whatever about the admirable harmony and most elegant proportion of the motions.

[Margin: Manifest signs of regularity.] Now the signs of the hidden regularity that were delivered into my hands from the apparent motion are these.

First. The constant and perpetual progression of the spots from the eastern region of the Sun toward the western.

Second. The constant swiftness of the spots in the middle of the Sun, and their slowness near the extremities.

Third. When two or more spots are separated from one another along the length, their coming together near the extremities and their parting near the middle, in proportion to the interval and the time.

Fourth. The narrowness of the paths they travel near the Sun's limb, and their breadth near the middle.

Fifth. The slenderness of all the spots near the solar margins, and their widening near the middle.

Sixth. The fixed, similar, and annual return of the apparent motions along the same parallels.

Seventh. Their apparent rectilinear tendency in each half-year.

Eighth. Their admirable and uniformly non-uniform curvature, increasing and decreasing over the half-year, slanted toward the south through half the year and toward the north [Aquilo] through the other half.

Ninth. Their inequality within the Sun's apparent hemisphere, and likewise their duration, unequal not by chance but with the highest regularity.

Tenth. The delay, sensibly equal, of the daily intervals traversed by a single spot, even though the apparent intervals are equal.

Eleventh. The equal delays of the rectilinear motions above the horizon.

Twelfth. The periodic returning courses of the returning spots, answering to their apparent motions.

Thirteenth. The figures of the curvilinear courses, differing only slightly from ellipses.

Fourteenth. The long delays of the durable spots clinging at the limb.

These and similar arguments from the apparent motions cried out all too plainly that some admirable beauty of order lay hidden within, and pointed to it openly, as if with an outstretched finger. They declared that this phenomenon is not rash, not casual or fortuitous, not aerial or sublunary, but celestial, solar, and therefore regular.

Equipped, then, with these supports — namely with a certain most universal perception and conception — [I reasoned] that if this phenomenon is something celestial, there must underlie it some most beautiful symmetry in its motion; and further, once the phenomenon's own settled and regular apparitions had been observed over the passing of so many years, I long ago brought to the settled opinion of an inherent regularity a mind already made firm, and, through countless experiments, I found that very regularity so completely confirmed that nothing else can be decided while saving the phenomenon. Hence:

[Margin: Regularity cannot be attributed to the true motion of the spots unless the spots are carried into the Sun.] *I say, first.* If any regularity belongs to the true — not the apparent — motion of the solar phenomenon, and is to be attributed to it by astronomers on the basis of the apparent motion and common sense, because of so many prior indications, then it is to be attributed to the spots carried into the Sun. But some regularity does belong to the true motion of the solar phenomenon (whatever that motion may finally be — for it is being investigated, not assumed) and is to be attributed to it by astronomers on the basis of the apparent motion and common sense, because of so many prior indications. Therefore that regularity is to be derived from the spots carried into the Sun.

The consequence of the major premise — which, for brevity and clarity, is this: *If regularity belongs to the true motion of the spots, the spots are in the Sun* — this consequence, I say, has been most fully proved thus far, throughout the whole first part of this book, both directly and by reduction to various absurdities,

against the phenomenon itself and its apparent motion. The major premise is therefore plain.

The minor premise is plain both from the instinct implanted by nature in all men — that better things are always to be preferred to worse, and that the regular and ordered are preferable to the anomalous and disturbed, if they can be had — and from the apparent motion itself, which it is utterly impossible should always return in such a form without a most certain proportion of order, and which we cannot defend without some regularity having been discovered. Indeed, if astronomers can reduce it to some convenient regularity, they are eager to do so with the readiest minds. How much more, then, when the phenomenon itself not only calls out for the proposed regularity, but rejects any other regularity forced upon it?

The major and minor premises being proved, the conclusion follows: namely, that the regularity of the spots' motion is to be derived from the spots carried into the Sun.

[Margin: Spots placed into the Sun produce a regular motion.] *I say, second.* If the solar spots are introduced into the Sun, their true and proper motion is always found to be regular. This proposition has been demonstrated everywhere in the earlier parts, and needs nothing but a diligent eye and a sharp intelligence on the reader's part; but it will also be shown effectively in what follows, from arguments collected in summary.

[Margin: Spots drawn out of the Sun will never describe regular motions; they always resist the appearances of the phenomenon, etc.] *I say, third.* If the solar spots are taken out of the Sun, their true motion will never be found regular, but always anomalous and opposed to the very apparent motions of the spots. All this has been proved and shown in various ways in the earlier parts. The spots, when brought back alone, reveal most evidently what I say. [Margin: Spots are borne regularly in the Sun.] Hence let it again be concluded: if the solar spots are in the Sun, their true motion is regular, and it cannot be otherwise; and if the true motion of the spots is regular, they are in the Sun, and it cannot be otherwise.

But the solar spots are in the Sun, as has been proved by several means which I shall gather below; and their motion is regular, as is held from the admirable consensus of the whole phenomenon. Therefore they are both in the Sun, and their true motion is regular. For these two, sufficiently proved from other grounds, mutually imply each other.

Apparent Increase and Decrease of the Solar Spots [Apparens Macularum Solarium Augmentatio, & Diminutio]

Cap. XXXV.

[Margin: The apparent increase and decrease of the spots.] Now that the local, apparent motion of the spots has been explained, we must take up the one who deals with the quantity of that same movable body in place. I call it *apparent* not because it is not real, but because it so appears to the eye, whether it is now real or merely apparent. For it can happen, and often does, that some thing seems to the eyes to be enlarged which yet grows not at all — indeed perhaps even shrinks — and it can happen that a thing which has grown is thought to have diminished.

That the solar spots and faculae — and hence the whole Sun — apparently grow and shrink to the sight of the eye is too certain for even the least doubt about it to arise in anyone hereafter who has inspected this phenomenon even in passing. And this whole matter is everywhere too plainly evident throughout the entire prior book, through all the images of the observations, in which the enormous growths of the spots and faculae, and likewise their diminutions, are seen throughout and explained in the notes.

[Margin: A twofold increase of things: physical and optical.] But now the question is a different one — not whether the spots and faculae *appear* to our sight to grow and diminish, but whether they truly, really, and physically increase, and not merely apparently. To settle this clearly, one must understand that the physical augmentation of a thing is one thing, its optical augmentation another: the former makes the thing greater or smaller in itself, the latter only stops at appearance. Something must be said of both, with reference to the spots. And whatever is argued about augmentation holds also and must be applied to diminution.

The apparent optical increase of the solar spots, and likewise of the faculae [Macularum solarium, vti, & Facularum augmentatio apparens optica]

[Margin: Optical augmentation through the tube.] *First assertion.* All the spots and faculae, and thus the whole Sun, are enlarged in a merely optical way by the benefit of the telescope [Telioscopium] and the helioscope. This is plain from the daily use and experience of the optical tube, which, when it magnifies the received image of the Sun by refraction, is said to enlarge it — even though the

Sun itself, together with the spots, remains entirely the same. And so this augmentation is not physical, of the object, but merely optical, accomplished by the spreading out of the visible images.

[Margin: The apparent [augmentation] around the margin of the observing circle. The separation of the spots. Etc.] *Second assertion.* All the solar spots existing at the same time at the margin of the Sun and of the observing circle are enlarged in a merely optical way. Because, as was shown above, by an excess of refraction they are stretched more than is fair, more so than in the middle of the Sun and of the observing circle at once. This is proved in two ways.

First: if spots at the margin of the Sun are led across from the edge of the observing circle to its middle, you will see that same spot, when in its central position, about a third part slenderer than it appears at the extremity of that circle. There, always, it is drawn out, separated into a kind of ill-defined mist; and whether this is refraction proper, or rather some effect of refraction, is rightly doubted — for it seems to be rather a standing apart beyond the common base and a mutual divergence of the rays from one another than refraction, etc.

Second: if solar spots situated anywhere outside the limb of the observing circle are carried into that limb, they always appear larger than in the middle — a constant experience about which I have said much in the earlier parts.

[Margin: How is the magnitude of two spots to be compared with each other?] From this it follows that if you wish to know the proportion of the visual magnitude of some spot situated in the middle of the Sun to that of another which is at the margin, you must not take it as the spot appears when the Sun coincides with the observing circle; for in that case the marginal spot will appear larger than can be legitimately compared with the central one, and the central one will appear so much smaller than can be compared with it. Therefore, in order that a fitting ratio of the magnitudes may be reached, some equality of refraction must intervene. This will happen if you either lead the marginal spot into the place of the central, or the central into the place of the marginal, and compare the magnitudes of both, noted on each side — central with central, marginal with marginal. For thus the true proportions will be found most nearly, because, being carried under the same lines of incidence, they are refracted in the same way and grow apparently to the same degree.

[Margin: How is the visual magnitude of the same spot, central and marginal, to be compared with each other?] And if you please to investigate the proportion of a single spot by a like method: while it is in the middle of the Sun, you will

observe its apparent magnitude in the middle of the observing circle; then you will lead it out to the margin of that same circle and note its enlarged appearance. Next, when after some days the same spot has descended toward the Sun's horizon, you will note its visual breadth at the limb of that same observing circle; then you will do the same by carrying it into the middle. And thus you will compare middle aspects with middle, previously noted, and extreme with extreme likewise noted, attending only to this one point: whether the spot, as it goes from the middle to the extremity or from the extremity to the middle, has remained in its state and has not notably varied its physical magnitude. For if that had happened, the proportions could not be established so exactly. You will know that the spots remain in the same state of magnitude when the diameter of the breadth — which is most frequent — is found the same. What diameter of the breadth is meant, I shall explain shortly.

[Margin: The apparent increase and decrease of the spots from the approach of the Sun.] *Third assertion.* Granted, but not conceded, that the solar spots are perennial and unchangeable — nevertheless they themselves would be enlarged and diminished optically by their approach to us and their recession from us. For through half the year, together with the Sun, from Cancer [♋] to Capricorn, they will approach us, and, just as the Sun itself does, so they too would appear proportionally larger; through the other half of the year, by the same reasoning, by receding from us, they would be diminished. That they walk toward us and away from us together with the Sun is evident, because they always complete the same periods around the Sun, with the same arcings of their paths and the same intervals of days,

as I have shown most fully in the prior book; and because they are in the very Sun, as I have just taught and will show a little more fully. The assertion therefore stands. Furthermore, these increases and decreases of a single spot would not easily be perceived, because their stay beneath [i.e., within view of] the Sun is at most, ordinarily, fourteen days. And just as the Sun does not visually grow or shrink within fourteen days, so neither do the spots seen upon it, from so small an approach or recession of the Sun. Yet because, on the hypothesis, they would be perennial and would consequently often return, they would be seen under one magnitude and another; but whether they would then be so easily recognized is not so certain, on account of the various causes that could intervene.

[Margin: The apparent increase and decrease of the spots from their own proper motion.] *Fourth assertion.* Granted, but not conceded, that the spots are perennial, and that the Sun neither approaches us nor recedes at all from us —

nevertheless the spots would be enlarged by their mere approach to us and diminished by their recession.

Because, while they go around the Sun, from rising to the middle they draw near to us by the solar semidiameter, and are consequently enlarged optically; from the middle to setting they withdraw from us by just as much, and therefore appear smaller. But this increase and decrease is perceived by reasoning, not by sense, because this approach takes place along the semidiameter of the Sun, which, relative to our distance from it, is at the least as 1 to 125, or, according to others, as 1 to 100, etc. — for on this point the authors do not agree. In any case this approach or recession is noted by no sense; and it is plain from experience, for central spots are not broader than marginal ones, other things being equal, nor is the Sun's own approach toward us noted, to the extent of its semidiameter, by sense, etc.

[Margin: The decreases, or thinness, of the spots around the horizon; their increases in the middle.] *Fifth assertion.* Granted, but not conceded, that the spots are perennial and unchangeable — nevertheless all of them, and each singly, are slender and oblong at their rising and setting; and, proceeding from the rising toward the meridian, they always grow, spreading themselves into some rounded form; from the meridian all the way to setting they continuously decrease — optically. This increase and decrease occurs [Margin: What is the length and breadth of the spots?] chiefly along the length of the spot, not the breadth. Now I consider the length of the spot along its diameter, by which it extends from east to west; its breadth, indeed, by which it stretches out from south to north, or vice versa. And this, to be sure, in a rough-and-ready way [pingui Minerva]: for if we weigh this increase and diminution in strict geometric rigor, it will occur, other things being equal, along the radius extended from the center of the solar circle through the center of the spot. But since the spot's motion in its own parallel seems to bend that radius somewhat according to its own drift, it therefore appears from the spot's very position that something is shared from the struggle of both. For that reason I said "chiefly." For that a ray sent from the center of the Sun — or rather an arc of a great circle passing through the centers of the Sun and the spot, and the said advancing ray — should measure the spot's slenderness, its augmentation, and its diminution, is strongly argued by this: that, other things being equal, the spots, especially near the horizon, accommodate themselves more to the radius of the solar circle than to the radius of the parallel circle. For it has been found by constant observing practice that all the spots, except certain extraordinary ones and in those same rare cases, near the horizon shape their outermost line — by which they are closed off toward the horizon —

into something in a way parallel to the perimeter of the shining circle, so that it is apparently a segment of the circumference of a circle described from one and the same center of the Sun. This is what causes a ray drawn from the center of the Sun through the center of the spot to be perpendicular to the outermost arc of the spot and to the chord subtended to it, which is the breadth of the spot. Although it could also be so, with respect to a spot that is in any way humped toward its extremities, etc.

And if a spot's transverse configuration drawn out lengthwise, or its coalescence with other spots, or a distorted form of the nuclei and their concurrence, sometimes present a different extremity, this in no way prejudices this general doctrine, which is derived from the ordinary appearances.

From this appearance it is established, first, that the outermost surface of the spots, turned from the Sun toward us, differs by its roundness sensibly little from the solar surface; otherwise, if it presented any prominences or humps or inequalities before it, then altogether, in the lateral view near the hori-

so that it would make [this] plainly evident near the horizon.

It is established, secondly, that the outer surface of the spots projects above the solar surface either little or not at all; otherwise they could not be reduced to so slender an appearance.

It is established, thirdly, that the substance of the spots is necessarily immersed in the Sun, at least in part. To make this clear, one should know that I have for the most part rendered the lateral spots in the images of the observations just as they presented themselves to sight in the observing circle through the telescope [Telioscopium] — that is, thicker near the margin than they would appear without that same [refraction] — while indicating this by carrying them across to the center. Nonetheless I also, with the greatest care, carried not a few others across to the center, and having there examined and observed their central slenderness, marked it down at the margins, as may be seen in Book 3, image IIX, p. 177, spot b; image XXV, 265, spot h; XXVIII, 231, n; XXXIII, 241, a; XXXVI, 247, o; XXXVII, 249, a; XXXIX, 253, a and c; XLVI, 273, c; LIII, 289, e; LVII, 297, a; LXI, 307, a; LXII, 311, d; and in many others — for there is no need to rehearse every instance.

Now, so that you may test for yourself that the spots move upon the Sun, I offer two practical rules, drawn from and confirmed by very many trials.

Rule I. For marginal spots, affected by marginal refraction.

If in a marginal spot you remove more than a third part from the apparent diameter of slenderness, the remaining diameter of slenderness will display the true expansion of the contracted spot, equal — other things being equal — to the perception of the central [spot]. For that part removed strips away the excess by which the marginal refraction makes the spot appear larger than the same spot would appear when placed near the middle of the observing circle; and so, once that excess is removed, it makes the central magnitude of the spot equal to the one under lateral refraction.

Rule II. For marginal spots, reduced to the center.

From the versed sine [sinus versus] that the slenderness of a lateral spot displays when carried into the middle

of the solar circle, you will always obtain the full amplitude of the spot, equal to the perception of the central [spot].

From this it is evident that a spot is thinned toward the margin simply by the tilt [decliuitas] it undergoes on the solar surface; for if it stood proud of the Sun, no such contraction of the spot would follow at all.

Consider the examples in the images cited, in which the marginal spots — especially those close to the horizon in aspect — become so fine that some of them are, relative to the visual semidiameter of the Sun, under a hundredth, some a two-hundredth, and some even a three-hundredth part, that is, thinner than any silk thread, so that their versed sine is only 3" 36''' [sexagesimal marks as printed; reading uncertain], the Sun's semidiameter being set at 18' [?].

[Margin: Objection.]

You will say, first: even granting that the spots grow so slender in appearance that the arc on the Sun's surface corresponding to their slenderness is, to perception, almost equal to that which is commensurate with the whole amplitude of the spot (whether in breadth or in length) at mid-course, it still does not follow from this apparent diminution that the spots must be thrust into the Sun; for that apparent thinning of the spots may arise from the Sun's lateral irradiation. When the eye, with the spot toward the horizon, meets that irradiation, the surface, viewed obliquely, is diminished to the sight even though the spot passes outside the Sun, and so on.

[Margin: Reply.]

To this specious objection I reply, first: wherever the spot may be, if it circulates about the Sun with other conditions equal, then — because the face turned toward the Sun is fully illuminated — the unilluminated opposite part is neither diminished nor enlarged. That part, as I said, other things being equal, does not become smaller when the spot is near the horizon nor larger when it is near the culmination, but remains of one unvaried magnitude; nor does the part turned toward the Sun turn out larger or smaller at midday than at rising or setting. Rather, the unilluminated part is varied to our sight, not by any real increase or decrease but by an apparent one, and this because the spot is carried about the Sun's center concentrically [homocentricè]. By this rotation alone it comes about that the spot appears smaller at the horizon, and beyond that, in respect of the part turned away from the Sun:

whether the part illuminated toward the Sun ought to come to view larger or smaller — which is also what the objection maintains — is uncertain; indeed experience drawn from the phenomenon itself, which otherwise would have to be brought forward, lends no support to this voluntary supposition. Sound reasoning does establish for certain that the part of the spot set directly opposite the Sun must be illuminated, if the spot exists detached from the Sun, as the adversary supposes; but that it must be viewed or discerned by our eye as bright is altogether uncertain.

First: because if the spot's surface turned toward the Sun is concave, it is evident that it will not be seen.

Secondly: if it is flat, again it will not be visible.

Thirdly: if it is much compressed, it will scarcely be discerned.

Fourthly: even if it is hemispherical, by the force of the objector's own argument it will not necessarily strike the eyes, as is clear from the example of the Moon, whose luminous hemisphere never appears at conjunction.

Fifthly: even if that illuminated part were seen, either it would not be distinguished by the eye as something distinct from the Sun, or rather it would appear somewhat darker than the Sun itself. But this does not bring it about that what is dark and slender on the averted part of the spot should be slender precisely because this part turned toward the Sun is illuminated.

Sixthly: because if the spot's surface turned away from the Sun be supposed spherically round, such a surface will appear so near the horizon; for it will present a semicircle to the sight — from which, once more and finally, it is

established that the part which faces the Sun contributes nothing at all to the slenderness. Therefore the spot's outer surface, greatly compressed and nearly flat, together with the oblique aspect and position of the spot, produces this apparent contraction.

COROLLARY

From this it is established that the spots are carried about the Sun's center, not rotated [on their own axis], but held fixed with respect to their own center; otherwise they would sometimes be seen broad at the solar horizon, and not always contracted.

[Margin: The apparent slenderness of the spots arises from their slight depth or thickness, and from their position oblique to the sight near the horizon.]

[Margin: Objection II.]

You will say, secondly: the spots physically grow and shrink; therefore the slenderness of the spots is not to be attributed to the Sun on account of their position relative to the aspect, but much rather to their native increase or decrease.

[Margin: Reply.]

I reply, first: that the spots do indeed physically grow and shrink is plain from the phenomenon itself, and consequently there is no doubt that they may accrue or diminish on this very account. But from this the slenderness we are discussing acquires nothing peculiar; for the physical increase and decrease of the spots occurs at every difference of place, as we shall show shortly from the phenomenon itself. Hence, if a spot at the horizon grows physically slender, it is physically shortened also in its other latitudinal dimensions; and in like manner, if its slenderness increases, its other extensions increase as well. From this a valid argument is drawn: if the latitude of some spot situated at the horizon is found to be the same as it was at mid-Sun (which must be judged from the observations), then the spot has, to perception, been neither physically enlarged nor diminished, and so has remained in one state; and therefore the reasoning drawn from the line of slenderness retains its force. It is chiefly for this reason that in the earlier assertions I always added the words "other things being equal" — which holds to perception if the spots remain in a state such as commonly persists, in nucleate spots, for 6, 8, 10, or more days; and so on. Thus very many pass from the horizon to the middle, or the reverse, in a state of magnitude unvaried to perception — which is enough for my purpose. For whatever is soundly demonstrated of some

spots from their thinning could without doubt be applied to each and every one, unless they failed entirely before reaching the horizon.

But if, as I said, the slenderness of a spot has received help from physical diminution, this will become clear by the following means.

[Margin: The state or magnitude of the spot being the same — how is it to be recognized?]

First: a spot whose latitudinal diameter appears shorter at the horizon than at mid-course was, without doubt, physically smaller there than here; and consequently the diameter of its depth — and so of its slenderness — was smaller at the horizon than at mid-Sun. Yet here one must apply care-

[Margin: —and how the slenderness of the spots is helped by physical diminution?]

ful attention as an observer, lest one be deceived in this matter; for the spots tending toward the solar margin and growing slender ordinarily seem so enveloped and absorbed by a kind of misty veil that, even to an eagle eye, they are discerned only with great difficulty. Hence it could happen that a spot might be thought to appear more thinned because it had physically lost something of its magnitude as well, and thereupon the force of the argument would be nullified. To prevent this, nature herself, together with art, has most beautifully provided a remedy. For if you carefully mark off a marginal spot under the perimeter of the observing circle, and then, carrying it to the center of the same, you will behold it pure and clear.

Secondly: a spot whose latitudinal diameter at the solar horizon exceeded the one that appeared at mid-Sun was physically larger at the horizon than at mid-course, and consequently grew less slender.

Thirdly: a spot that displays equal latitudinal diameters at the margin and at mid-Sun surely did not appreciably vary its physical magnitude, and consequently did not vary its depth — and so its marginal slenderness — by any physical increase or decrease; and the objection brought against [this] obtains nothing.

For if a physical increase or diminution introduces anything into the slenderness, this is known from the latitudinal diameter: if the spot be taken by this measure, and we reason from what is assumed, the degrees due to the apparent slenderness will again be found, and the spots will be found on the Sun just as before.

I reply, secondly: that no spots hitherto placed outside the solar horizon toward the center have been seen to grow slender at mid-Sun, or to be dilated from a slender state, even though they are physically enlarged and diminished from day to day. From this it is a manifest sign that that contraction of the spots is not the effect of physical increase or diminution, but only of position relative to the aspect, which the revolution about the Sun produces. I do not deny that some spots are here and there longer and more elongated on one side; but they have that elongation either from birth, or from the addition of others, or from alteration — not, however, from a greater to a smaller

thinning, and so on, and [not] in that regular and orderly manner in which it happens near the horizon.

You will say, thirdly: from the phenomenon itself it is established that the slenderness of the spots is not always of the same tenor, but is unequal even among equal spots, so that its diameter is at one time the versed sine of two degrees, at another of three, of four, five, or six or more degrees. Therefore it is a sign that the spots need not be located on the Sun, but should be placed outside it.

I reply that this is true, and is established by the most accurate observations: that the slenderness even of equal spots, all refraction set aside, has been found to differ, and without doubt will be found so in the future. Yet nothing more is obtained from this than that the spots themselves have some depth in their mass, and then a protrusion above the solar surface — which I would never have denied them on the surface turned away from the Sun. But this does not draw them wholly outside the Sun, into which they have the other portion of themselves immersed. For it must not be supposed that all the spots and faculae are so distant from the Sun's center that they have attained one and the same indivisible geometrical distance; rather, they differ somewhat one from another, as in mass, so in recession. The phenomenon itself supplies the arguments for this — both from what has been adduced, and from the fact that many spots seem buried in the solar light and do not reach the horizon, and so on. Of very many secondary spots and faculae I hold this for certain. For this reason I say that the spots move upon the physical surface of the Sun, which is not a mathematical indivisible, but endowed with a perceptible latitude. Just as we say and see that ships and birds float on the surface of the sea. The nature of trees, certainly, is such that some ride upon the water raised by more than half their thickness, some by half, and others at last are submerged right up to their top; such, it is reasonable to judge from what has been said, is the state of the spots on the Sun's physical surface.

[Margin: How the spots reside in the Sun's physical surface — a noteworthy teaching.]

You will say, fourthly: if the spots rotate about their own center and are imagined to be thin like a disc, they will present slenderness by their own circuit without being brought into

the Sun, or into so close a neighborhood of it.

I reply, first: that from this hypothesis the slenderness of the spots would indeed follow, but a slenderness inconsistent with the phenomenon; for the spots would grow slender even at mid-Sun, and near the margins would frequently be spread out at their fullest — which is contrary to the phenomenon.

I reply, secondly: if we wished to fashion physics and the natures of things out of our own fictions, destitute of reason and experience, the result would be that we should lay down whatever we please, assert whatever we please, and stuff the world into the "Quodlibetical" volumes. For to invent is not to draw out the causes of things from the effects of natural things, but to bring to birth monsters of things out of arbitrary imagination, after the manner of dreamers. That the spots are not rotated about their own center is most evident from the following.

[Margin: Arguments by which it is proved that the spots do not rotate about their own center.]

First: because no spot grows slender near the center, which nevertheless ought to happen.

Secondly: because none is seen with full amplitude near the horizon, which nevertheless would sometimes necessarily occur.

Thirdly: because none ever turns its western part into the east, or the reverse, but remains constantly in the same position with respect to the ecliptic and its own parallel — as is most evidently established from the observed figures of the spots, their nuclei, and other attendant features.

Fourthly: because, when it was extremely slender, it would even lose its latitudinal diameter; for since, by the hypothesis, they are shaped into the form of a disc, when they grow slender the perimeter of this disc will be illuminated by the solar rays, and thus the latitudinal diameter of the spot would be absorbed almost entirely. These and the like impossibilities would occur contrary to the phenomenon — to say nothing of the faculae, which utterly overthrow this opinion, and so on.

But in a physical matter, where we ought to follow the dictate of nature and not to run ahead with blind partiality, to assert such things without any prior trial of the senses, out of mere pleasure or some sickness of mind I know not what, is the mark not of one seeking the truth but of one rashly obtruding vanity,

[Margin: The phenomenon must be followed, not violently dragged to premature dogmas.]

and — to put it in a word — of one raving with method.

COROLLARIES

First. Every spot, other things being equal, is optically smallest at the solar horizon and largest at mid-course. For at the horizon it is viewed according to its lateral thickness, and so [appears] slender; at the middle, according to its whole amplitude. I said "other things being equal" because it could happen that a rising spot (as often occurs) should begin to decrease physically, and then it might come about that the eastern magnitude — especially with refraction coming into play — should equal the middle one; or, conversely, that a spot risen at the middle should physically increase (which too is frequent), and then it might again happen that as it sets it should equal or exceed the middle magnitude — which happens rather often. Here, however, I am speaking of visual magnitude.

[Margin: The smallest and largest optical magnitude of the spots.]

Second. Every spot, other things being equal, increases optically as it advances from the horizon toward the middle. This happens because it carries its shadowed surface ever more from an oblique into a direct position with respect to the aspect.

[Margin: The optical increase occurs toward the middle of the Sun.]

Third. Every spot, other things being equal, declining from the middle toward the setting becomes optically smaller. For because of its oblique position relative to the eye, the visual angle becomes smaller; and even if the spot's thickness be perhaps added to it, they are not compensated from that quarter for what is lost here.

[Margin: The optical decrease occurs from the middle of the Sun.]

Fourth. On account of the physical increase of the spots, it often happens that their optical decrease is compensated, or sometimes exceeded; and on account of physical diminution, that the optical increase is absorbed. Both are clear from daily experiments, everywhere to be met with in the images of the observations.

[Margin: Physical increase varies the optical, etc.]

Fifth. Other things being equal, the optical increase of the spots occurs continuously and gradually, and in the same way their diminution. For their circuit is continuous, and always, while they ascend they increase, and while they descend they diminish.

[Margin: The optical increase occurs successively.]

Sixth. Other things being equal, the optical increase of the spots is like, and equal,

Diagram. A large geometric construction filling the upper part of the folio. At the top runs a horizontal diameter line stretching across the page; from it a semicircle sweeps down and around, so that the whole figure is a great half-circle. On the top diameter, from the far left: **b**, then **z** and **n** (just left of center); at the center is a small eight-rayed "compass-rose" star whose hub is lettered **d**; toward the right end of the diameter are **x** and **α**, and at the far right **f**, with **e** just below it. The eight rays of the central star carry Greek point-letters marking the successive positions of the rotating central spot's diameter: reading around, **β** (upper), **ζ** (upper right), **θ** (right), **ε** (lower right), **γ** (lower), **κ** (lower left), **η** (left), and an upper-left label that is faint and ambiguous [Greek letter, **α** or **Ω**: ?]. Down the left-hand arc: **c**, then **g** and **p**, then **h**. Along the bottom horizontal (a lower diameter/base): **i**, **d**, **K**, with **r** just above and **s** just below. Down the right-hand arc: **l** and **m**, running up to **e/f**. Dotted vertical lines drop from the upper diameter to the base and below it, reaching **o** and **q** on the left, and **u** and **y** on the right. The figure illustrates the demonstration of Cap. XXXVI (a spot carried around the Sun's center presenting the same aspect as one rotated about its own center at the solar center). The same figure is reprinted on the following opening. [Several of the small Greek ray-labels are near the resolution floor and overlaid by verso show-through for label verification.]

[The upper two-thirds of this page is occupied by the diagram; behind it is faint mirror-reversed show-through from the verso, not transcribed. The letterpress text is at the foot of the page, in two columns (I. left, II. right), reading left column then right.]

[is] equal to the diminution. This is established by experience and proved by reason, on account of the equal distance from the Sun's center and of the ordered motion about that center.

PROPOSITIO. The sole proposition.

Cap. XXXVI.

Round sunspots, carried around the Sun [by its rotation], present to the eye — on the Sun's apparent hemisphere — the very same relationship of aspect that they would exhibit if they were rotated in the same way about their own center joined with the center of the Sun.

About the center **a**, describe the circle **b c d e f**, representing the Sun turned toward us. On its surface, at its perimeter, let the length-diameter of some spot, as it rises, be **b c**; this then by its ascent reaches **g h**, thence [passes] to the middle **i K**, whence descending again it reaches **l m**, and thence at last attains its setting **e f**. I say, then, that if such a spot is carried around the solar center **a** along the perimeter **b d e** — physically and to sense unchanged and round — its position and aspect, to an eye set on the earth, will be exactly the same as the same [spot], or one...

equal [to it], would have exhibited if placed at the center of the Sun **a** and rotated about the same — that is, its own — center with a proportional motion.

[Margin: Suppositions.]

To show this, I assume, from the established practice of the Astronomers, that the rays proceeding from the individual points of the solar circle to our sight are to be reckoned as parallel, and as perpendicular to the plane of the Sun, the boundary of the visible hemisphere, because of the extreme smallness of the visual angle. I assume next that the Sun's semidiameter **d a**, relative to the distance that lies between us and the Sun, is optically imperceptible — so much so that if some spot were placed at the center of the Sun **a**, it would not appear smaller than if it were seen on the Sun's surface at **d**. For the solar distance is so great that not even the Sun itself, brought nearer to us by the semidiameter **a d** and so viewed, would perceptibly grow larger — how much less, then, one single spot so much smaller than the Sun? These things assumed, let us take the apparent path of the spot to be rectilinear in the greatest circle **b d f**; and for this reason it will lie in the same plane as the eye. To that eye, from the center of the spot **n, p, r, t, x**, let the rays **n o, p q, r s, t u, x y** go out, parallel to one another and perpendicular [recti] to the solar circle, which the straight line **z e** represents.

[Margin: Proof.]

The eye, therefore, is understood to be **o, q, s, u, y**, and the optical axes carried to the center of the spot are **o n, q p, s r, u t, y x**. From the incidence of these upon the length-diameter of the spot — **b c, g h, i K**, and so on — the position of the spot relative to sight, whether direct or oblique, is inferred. Now the length-diameter of the spot is the chord **b c, g h, i K, l m, e f**. Let there be, at the center of the Sun

a, the spot **b c**, and an equal and similarly placed spot **β γ**; and let the centers of the two spots, **n** and **a**, be joined by the straight line **a n**. Since this falls upon the parallel rays **n o**, **a s**, it makes the alternate angles **o n a**, **s a x** (with **n a** produced to **x**) equal to one another. But the angle **o n a** is right, by the third [proposition] of [Book] III [*Elements* III.3], because the chord **b c** is bisected at **n**; therefore **s a x** too [is right], and its adjacent **s a n** is likewise right, and so on. The optical axes, then — both **o n** and **s a** — are in a straight line with the diameters **b c** and **β γ**, and so contain no angle; and thus the aspect of each of the two spots is held to be similar and equal on both sides to the sight, [namely to] **o** and **s**.

Now, since the motion of each is proportional: if the line of motion **a n** has carried the spot **b c** to **p**, so that its diameter is **g h** — since the spot **β γ** is supposed to move proportionally about its own and the Sun's center **a** — then, while the line **a n** has advanced to **p**, the diameter of the central spot **β γ** has passed from **γ** into **ζ**, and the angle **γ a ζ** is equal to the angle **n a p**. Adding the common angle **p a γ**, the angles **p a ζ** and **γ a n** become equal. But **γ a n** is right, as was shown; therefore **p a ζ** is also right. But **g p a** too is right, because **a p** bisects the diameter **g h** at **p**. Therefore the diameters **α ζ** and **g h** are parallel to one another; and **p a** produced to **l** makes the angles **q p l**, **s a l** equal to one another, from which, the right angles **h p l** and **s a l** being taken away, there remain equal to one another **q p h** and **s a l**. Consequently the relation of the spot **g h** to the eye **q** is the same as that of the spot **α ζ** to the eye **s**; for the positions and aspects are similar. So too, when the spot **i K** has reached the middle, the spot **α ζ** will have its advanced diameter **κ θ** parallel to the diameter **i K** — because, on account of the similar motion, while the line **a p** ascends from **p** into **r**, the diameter **α ζ** has passed from **ζ** into **θ**, so that the angle **ζ a θ** is equal to the angle **p a r**; and adding the common **r a**, the two become equal, **p a r** and **ζ a θ**. And since this [angle], because the axis **s a** is right to **z ε**, is right, and **i r a** is right as well, it is clear that the diameters **θ ε** and **i K** are parallel to one another, and hence that once more all the angles — **s r K** and **s a θ**, and **s r i** and **s a ε**, and so on — are equal to one another, and thus that the position of each of the two spots, **ε a θ** and **i r K**, to the eye **s** is similar and the same. In the same way it will be proved that the angle **ε a s** is equal to the angle **l t u**, and consequently that the position and aspect of the spots **ε a θ** and **l t m**, at **s** and **u**, are similar. The same will happen once the spot **e x f** has reached the western horizon; for the same aspect of this spot and of the spot **β γ** will occur, namely a wholly lateral one. And so the proposition set out at the beginning stands demonstrated.

For which reason I wished to demonstrate it.

First: that it might be evident that any spot, as it tends from rising to setting, is turned almost wholly toward our view — as is plainly observed in the spot **a** with diameter **β γ**. For the point **γ** passes into **ζ** and **β** into...

Diagram. The same geometric construction as reprinted here at the head of the opening so it stands before the eye while the demonstration continues : the great semicircle with its top diameter (labels **b, z, n** at the left, the eight-rayed central star with hub **d** and Greek ray-letters **β, ζ, θ, ε, γ, κ, η** and the faint upper-left label [Greek letter, α or Ω: ?], and **x, α, f, e** at the right), the left-hand arc labels **c, g, p, h**, the base labels **i, d, K, r, s**, the right-hand arc labels **l, m**, and the dotted verticals dropping to **o, q, u, y**. See the fuller description at fig-p641-1. [Same figure — Greek ray-labels near the resolution floor for label verification.]

[Again the diagram fills the upper part of the page over faint verso show-through, which is not transcribed; the letterpress is at the foot, in two columns.]

into **δ**; again from **ζ** into **β**, and that [endpoint] from **α** into **η** — in which position the full face of the spot, turned away from the Sun, is seen. Afterwards the point **β** proceeds from **η** into **κ**, and **γ** from **θ** into **ζ**; and finally from this, the point **γ** comes to rest in **β**, and **β** [passes] from **κ** into **γ** — in which position the whole eastern side of the spot is laid open, just as in the first, eastern, position the whole western side [was], and likewise the thickness on that side, and the convexity of the outer surface, if there is any. For the inner boundary, immersed in the Sun and set aflame, does not seem able to be distinguished by the eye, because of the intensity of the solar brilliance and its resemblance to the kindled part.

Second: that it might be established what would follow, on optical and geometrical principles, for the aspect of each spot, if they were perennial and unchanging — for they would then return by the same middle course, and so on. But now, because they are subject to a perpetual alteration, all these things can indeed be tried out — though not perfectly — in a few cases, namely in those spots which describe circles very close to the greatest [circle]. For the physical increase and diminution of these spots, and their alteration and change of figure, introduces beyond measure a dissimilarity of aspect; and this it is that we now proceed to explain.

COROLLARIUM.

From this it is established that the surface of the spots and faculae which lies open to sight at rising is on the side [hidden] at setting; and that the surface which lies open at setting was concealed at rising.

The physical augmentation and diminution of sunspots. [*Macularum solarium Augmentatio et diminutio Physica.*]

Cap. XXXVII.

How sunspots increase or decrease optically — whether from refraction, or from their situation and varied position relative to our view — has been sufficiently stated and understood. Now it must be examined whether, besides those common variations of apparent magnitude, there also exist others arising from the thing itself, which we call physical.

[Margin: All spots undergo physical increase and decrease.]

I say, first: Just as all natural things grow up from small beginnings into great ones, and then for some while maintain themselves in the state they have acquired, and at length once more decline — so this holds most regularly for each and every sunspot. For out of the many thousands of them which I have hitherto observed with the greatest diligence over many years, not one has been found that did not at least increase somewhat, and not one that did not decline. Every spot, therefore, has a threefold time: of augmentation, of stability [status], and of decrease. These matters need no other proof than careful observation, or at least the inspection of my own observations.

[Margin: The initial magnitudes of the spots are unequal.]

I say, second: Since nothing is increased that is not [already] a quantity, all the spots are indeed endowed with some perceptible magnitude that is to increase — a magnitude not, at the outset, very great, yet to sense not equal [among them]; for some are larger than others. This is evident from the phenomenon.

[Margin: The successive augmentation of the spots is various.]

I say, third: The augmentation of individual spots takes place continuously and gradually; for some spots increase more quickly, others more slowly. This is evident from experiment and from the practice of observations, drawn from the phenomenon itself.

[Margin: The stability of the spots is proportioned to the time of their augmentation, etc.]

I say, fourth: The stability of the spots is unequal, and for the most part proportioned to the time of their augmentation; for those that increase quickly do not cling long in their state, but even endure only briefly — according to the proverb, "what is quickly made quickly perishes." I said "for the most part,"

because sometimes it happens that one growing slowly, and long persisting, quickly fails; or that one quickly coming to birth stands for a long time, and then slowly and gradually declines. This is evident from the continuous treatment of the phenomenon itself.

[Margin: The decrease of the spots is proportioned to their augmentation.]

I say, fifth: The physical decrease of the spots takes place continuously and successively, but unequally. For certain spots are diminished quickly, certain very slowly; and for the most part the tenor of their failing is the twin of the manner of their growth. This is evident from observations everywhere.

[Margin: The augmentations and decreases of the primary spots are not bound to fixed regions of the Sun, but claim for themselves the whole royal course; those of the secondary spots [are owed] wholly to the Sun.]

I say, sixth: Both the augmentation and the decrease of the spots, [when] physical, are not bound to one fixed region of the Sun — as the optical dilation and contraction of the same are — but they are seen to occur in every observed royal place, in the accustomed courses of the spots: whether at rising, or at setting, or finally in between; and this now in the southern region, now in the northern. And so it comes about that, in the same place of the Sun, after some spot has been augmented, a little later another succeeds which there fails: whereas the contrary happens in optical augmentation, which is bound to place — for from rising toward the middle all [spots] increase, and from the middle toward setting all diminish. Physical augmentation and diminution has abolished this law: for it augments very many spots at setting, wears very many down at rising, and utterly extinguishes [them] in the middle — although the contrary also frequently occurs.

These things cannot, and are not wont, and ought not to be proved otherwise than from the phenomenon itself and from accurate observations of it, which you may inspect throughout the whole earlier book. And this indeed concerns the primary spots; for the secondary ones, the whole Sun is answerable.

[Margin: In the same place and at the same time, some spots grow, others decrease, physically.]

I say, seventh: At the same time, and in the same region of the Sun, it is often possible to discern some spots physically growing and others decreasing. This is evident from the phenomenon and from daily experience.

(Continuation of Cap. XXXVII, the sequence of "Dicendum" points on the physical increase and diminution of the spots.)

In the eighth place. [Margin: The time in which any given spot grows, holds steady, and fades is roughly the same.] For any one spot, the times in which it physically grows, in which it holds steady, and in which it shrinks are, to ordinary perception, equal to one another. This has been established from the approved observations of the phenomenon.

In the ninth place. [Margin: The times of growth, of steadiness, and of fading of different spots are unequal to one another.] The times in which different spots grow, hold steady, and diminish are often unequal to one another. Some reach roughly fourteen days, some eight, some fewer; and a few are confined within a span of hours. This is clear from the phenomenon itself.

In the tenth place. [Margin: The increases of the spots are not proportional to their times.] The increases of the solar spots are not proportional to the times taken up in growing, and so forth. For some grow little over a long time, and others grow much over a short time. This is clear from the observations.

In the eleventh place. [Margin: Spots first seen as a mere diameter grow to various and great ratios.] The increases and decreases of the spots often reach the ratio of the first diameter doubled, tripled, and more — indeed there have been some that exceeded sixfold. Look at spots a, b, c in the sixty-fourth Image of observations, page 315, in Book Three, and you will see incredible increases. Look at spot b in Image XXIX, page 233, of Book Three, and examine carefully the marks both of these spots and of the others. Yet take this as generally established: in my study of the spots I have never made their initial sizes smaller, nor their increases greater, than they actually appeared in proportion to the solar disk — so that the force of the truth might come out more certain and more compelling. I pass over the fact that the spots, of themselves, always appear more spread out by refraction when near the horizon than when at mid-heaven. Thus about the magnitude of this increase there is no room whatever for doubt, since I am entirely certain that some of them extended to as much as ten times the ratio of their first diameter. [recte: *decuplam*; the page prints *deculpam*]

In the twelfth place. [Margin: The increases of the spots proceed from their middle toward every point of location.] The physical increase of an individual spot usually takes place toward every point of location, proceeding from the spot's center toward its perimeter. This is clear from experience, and it is confirmed by aligning the spot to the ecliptic, from which the center of the spot

will always be at a fixed distance — the center lying on the path-line, while the remaining parts spill over on both sides. It is further clear from investigating the true positions of the spots, which must always be taken with reference to the spots' centers, and likewise from their nuclei and whatever else holds the middle, and so on.

In the thirteenth place. [Margin: The decreases of the spots take place from every point of location toward their middle.] The physical decrease of an individual spot usually takes place from every point of location, proceeding from the perimeter toward the spot's center. This is clear from physical experience and from the practice of observing, and with the center held fixed in position upon the path-arc; for whatever remains of a diminished spot stays always at an equal distance from the pole about which it moves, as I have learned from the observations.

In the fourteenth place. [Margin: The increase and diminution of the spots by aggregation, or by the dissolution of several, and so forth.] From the growth of many small spots close to one another, a single spot often emerges; and conversely, from the diminution of a single one, many small spots are often left behind. In this case one spot is an aggregate of many, and vice versa — something frequent in this phenomenon.

Closely related to this is the fact that lateral shadows, or new companion spots, approach the spots not by local motion but by physical origin and alteration, and again withdraw by physical decay or alteration. For then the spots will appear to grow not from the center, or to shrink toward it, but from some particular side. When this happens, it nonetheless does no harm to the general doctrine, since this is not an increase proper to the spot but the coalescence of two of them — a thing of which countless examples are seen in the observations.

The various modes of physical increase and diminution are set forth.

Cap. XXXIIX.

[Margin: The modes of physical increase.] Every increase of an extended thing comes about either by rarefaction alone — as when the same quantity of moisture or air, through thinning, comes to occupy more room; or by alteration alone — as when some rusty part of iron infects the part next to it, and the rust is said to grow; or by both together — as when fire falls into gunpowder; or by change of shape alone — as when moisture from a round drop is [poured]

—[a spherical drop] is spilled onto the flat bottom of a very wide vessel, and the water is increased in surface but not in bulk; or as when a Hungarian gold ducat is drawn out by hammering into the thinnest leaves, so that its surface grows while its matter and the quantity of the solid remain the same. Or by a similar accession — as when torrents and rivers swell with falling rain. Or by adjoined growth — as when a plant grows. Or by substantial generation — as when a fire grows from a supply of fuel, and so on.

[Margin: The spots must necessarily grow by some one of the modes named.] Beyond these physical modes of growth just named, no others seem naturally intelligible or possible. Since, then, the physical increases and decreases of the spots present themselves daily before our eyes, it is altogether necessary that they grow by one or several of these modes.

[Margin: A spot is not increased by rarefaction alone.] **First conclusion.** That the solar spots grow by rarefaction alone is in no way probable. For whenever a spot grows, its darkness too is always intensified, and for the most part a perceptible core is acquired at its middle — whereas the contrary ought to happen.

Rarefaction does not occur without a local pulling-apart of the parts from one another, which accordingly produces transparency or brightness, not greater opacity — especially if between the eye and the luminous body to be rarefied something intervenes, as happens in our case: for between the Sun and the eye any given spot is interposed, and so the Sun will penetrate the rarefied spot the more. This can be confirmed by countless physical examples — from vapors, from mists, from clouds, from thinner smokes, which the more they are rarefied, the more passable they become to the Sun's rays. Further, if the spots grow by rarefaction alone, then they must shrink by condensation alone — the contrary of which is shown by ocular experience: for the smaller the spots become, the brighter, and consequently the rarer, they appear.

[Margin: The spots do not grow by local extension of their surfaces alone.] **Second conclusion.** That the solar spots grow by extension of their surfaces alone — like poured-out water, like a beaten-out sheet of metal — is in no way probable.

First: because the more they grow in their outermost surface, the thicker they become in depth, as is evident when they lie near the horizon.

Second: because at their middle they are less transparent.

Third: because their diminution would be a contraction of surfaces, and consequently an increase of solidity — which, however, is false, and so on.

[Margin: A spot is not increased by alteration alone.] **Third conclusion.** The solar spots do not grow by physical alteration alone.

It is proved, first. Because through an alteration of this kind the solar ray would have to be variously blocked from the sight, according to what the phenomenon requires — which cannot happen except by a variously arranged interposition of an opaque or non-transparent [*adiaphani*] body, one accordingly bounded by colors, by which the passage of the light of the Sun's images is inhibited. But such a varied interposition of a body of this kind, as the phenomenon requires, cannot be had by physical alteration alone. Therefore the solar spots do not grow by physical alteration alone. The major premise carries its own proof with it, from what has already been declared.

The minor premise is proved. Because if no accession of new matter occurs in the growth of the spots, but the matter that began to be formed into a spot is always to be altered by the action of the Sun — by the same agent, acting on the same passive matter, everywhere alike disposed and alike applied — then no diversity would arise in such matter; yet we plainly experience such diversity, when what was before a uniform shadow, the trace of a spot, acquires a nucleus at its middle, so darkened to perception as to be far blacker than the rest of the surrounding body.

It is proved, second. Because if alteration alone is what generates the spots, alone increases them, and adds the nucleus, it plainly follows that, with the same agent applied to that matter and altering or to be altered by it by no other motion than that of such alteration, the spots, once produced and increased by it, would never fade away — but this is expressly against the phenomenon.

[Margin: The increase and diminution of the spots does not come about by local motion of like matter alone.] **Fourth conclusion.** That the spots are generated and increased by local motion alone, and by the running-together of like matter to like according to the various rotations of smaller bodies, and likewise are diminished and cease by such motion alone, is not probable.

It is proved—

[Margin: First proof.] *It is proved, first.* Because from the very manner in which a spot comes to be and grows — as observed so often and so accurately in this phenomenon — the exact opposite is plainly gathered. For it is not always the case that the spots which grow slowly also dissipate slowly, and conversely — though, as I have noted, this happens more often, and it has its cause in matter that is alterable now one way, now another. Moreover, the nucleus is acquired at

the middle, and there it grows and appears blacker than the shadowy mantle surrounding the nucleus, though that mantle is not similarly compacted and darkened — as ought to happen if, through various rotations, such smaller bodies drew nearer to the whole spot from elsewhere; nor is it more rarefied and dispersed, as would happen if bodies ran toward the middle out of that mantle in order to form or increase the nucleus with greater darkening.

[Margin: Second proof.] Again, a spot often set in the midst of others grows in bulk and opacity, while the others placed around it likewise grow proportionally, one by one, in a ring, and appear blacker; you have many examples in the observations already presented. This is a sign that their corpuscles, though nearer to the middle than the rest, do not run together to increase that central spot by such a motion, and that it accordingly grows in this way while matter boils up from elsewhere — matter that, through some alteration, has taken on a principle of flowing together in another place and in another way than before.

[Margin: Third proof.] Add that the matter immediately surrounding a growing or shrinking spot is very often plainly dreggy, and therefore utterly unfit either to increase that spot's blackish opacity in this way, or to arise from it when dispersed by local motion alone. To this belong the bays of the spots that creep in with their various windings; for these mostly shine out with bright faculae, while meanwhile the spots ordinarily fade — the opposite of which ought to happen, if the spots grew or shrank by local motion alone and by the apposition of like matter.

[Margin: Fourth proof.] Notice likewise that, when the spots around it are shrinking, the black spot in the middle does not grow; and conversely, when the central one is diminished, the spots placed around it are not increased. Yet this would happen if the corpuscles, running together through their own circuits to a single place, constituted and increased the spot, and, departing from that same place this way and that, diminished and dispersed it.

[Margin: Fifth proof.] Furthermore, the ordinary increase of the spots is spherical on every side toward their center, from every point of location, and their decrease is in every direction around, from their core; and as the nucleus diminishes, the surrounding vaporous mantle likewise is thinned in color and falls short in magnitude. But such a motion of rotations in these smaller bodies — if any there be — for aggregating or dissolving them in this way is incompatible not only with the rest of the heaven but also with the hardness of the solar body. Let those attend well to this who compose the spots out of the confluence of who-

knows-what little stars; for if they assign separate orbs to each, they will be driven into infinite absurdities.

[Margin: First confirmation of what has been said.] And what has been argued thus far is most forcibly confirmed by this: that the core of the spots is usually denser and blacker, with the parts thinning toward the extremities. For if, as the adversary supposes, that blackness of the middle matter arose from the mere heaping-up, by local motion, of particles piled on from outside, then the nuclei of the more prominent spots would have to be sharpened toward our line of sight in the manner of a spinning-top — which the phenomenon manifestly contradicts. For that top-shaped surface, when the spots lying near the horizon are viewed from the side, would appear under the figure of an isosceles triangle, or something similar. But we have shown up to now, from the very practice of the phenomenon, that the globular surface of the spots facing us scarcely projects as far as is enough to raise it a little above the spherical extremity of the Sun. From this it necessarily follows that, if that local motion of corpuscles from outside is assumed, the spots are by no means sufficiently increased, but recourse must be had to supports drawn from within as well; and that the matter serving the increase of the spots is driven outward from the very inner parts of the solar globe by a certain local rolling-together, with many physical alterations preceding and accompanying it, and that thus at last those balled-up parts are compacted into a mass—

—that more durable mass. This truth is favored by the divergence of the spots that sometimes occurs in their motion, and by their convergence — phenomena otherwise quite difficult to defend and explain, and so on.

[Margin: Second confirmation.] This is further made solid by the following. Those wandering corpuscles cannot increase the spots either moving freely or borne about in spheres. Not this way — because single spheres would have to be owed to the single corpuscles, on account of the diverse motions of each; from which an infinite number of spheres, and their mutual entanglements, and their necessary interpenetrations with one another and with the Sun, would arise, since all of them would make their common conjunctions and intersections within the spot; and so on. Nor that way — because the running-together of those corpuscles would be either natural or not. If natural, then, once they had flowed together into a spot, they would all cling there and cease from their own motions; for the motion that a spot performs around the Sun is common to all those corpuscles, proper to none, and consequently not natural. If, then, in the assembled spot as in their natural place they ceased from their proper motion, they would rest there

and would not dissolve, since there would be no agent to scatter them except the Sun — and the Sun, being on the adversary's hypothesis always like itself and of the same action, if it scattered the corpuscles gathered into the spot, would have hindered them from being gathered by the same force. But if the place of the spot is not natural to those corpuscles, who holds them collected there for so long? Not the Sun; for it would hold them always. No other agent; for besides the Sun there is none, nor can any be imagined. Therefore those bodies, once gathered into the spot, will rest there held from some other source, not retained by their own nature; and since there is nothing to retain them except the Sun, it will always hold them bound fast and constrained by perpetual chains. The spots, therefore, will be everlasting — which is against the phenomenon.

But if a spot comes to be and grows by the natural motion of those bodies, it must dissolve again by the same motion; those single bodies will then proceed according to their tendencies, and so very many of them — indeed the greatest part — will penetrate the Sun itself. Nor can it be said that they turn back; for that motion, contrary to the former, would be violent, and no efficient cause suitable to it is found.

Now if this confluence is not natural but either violent or contrary to nature, it is necessary that it be imparted to those bodies by the Sun; and hence they must be drawn. And since the Sun, on the adversary's supposition, is everywhere homogeneous and of equal activity, it would be impossible for these corpuscles to be drawn by it except along the shortest straight line — for this surpasses all others in efficacy. Any body whatever, therefore, would have approached the Sun along a perpendicular line, and so no spot would ever have come into being, because those corpuscles would not have come together: while singly they escape our sight, and so no spot fit to be seen would have been assembled.

Add that our mind cannot grasp how a corpuscle of this kind, standing over the central place of the spot before it arrives at the spot, could go around together with the spot itself without any deviation or departure from the perpendicular line — since nevertheless every spot is always driven by two motions.

Finally, if, as the corpuscles go off into various quarters, dissociated according to their particular rotations, the nucleus of the spot were varied, then necessarily, failing in opacity, it would grow in bulk, and the vapor surrounding it would be darkened and grow — which is plainly against the phenomenon.

Lastly, from the way in which the faculae occupy the place of the spots, it is clearly gathered that the spots did not fade away by the mere dissociation of the

smaller bodies from whose union they were formed, which tend in different directions. For the faculae are not mere parts of the Sun previously hidden by the interposition of the spots and, once those were dispersed, shining out to us — as is clearly proved. Therefore the spots are not generated by local motion alone and by the running-together of like matter to like, and so on — which was to be proved.

These, then, and countless absurdities like them, arise if we generate the spots out of matter drawn into the Sun; all of which are avoided if we derive them from an internal welling-up. For this agrees better both with reason and with the experience deduced from the phenomenon, since on this account we carry the spots around together with the Sun without any disturbance; on this account we very easily account for the misty spots suffused with an ambiguous light; on this account a recent—

[continues the close of Chapter XXXVIII, folio 495 recto]

we resolve with the greatest ease the great excursions of newly-formed spots, together with many other matters that would otherwise be difficult to defend and to explain, and so on.

The Alterative Motion of the Solar Spots

(Macularum solarium Motus alterativus.)

That the solar spots undergo various alterations in their appearance is beyond dispute, and it is at once evident to anyone who greets this phenomenon even from afar and, as they say, on its very threshold. I shall begin from what is best known and most obvious.

Chapter XXXIX

The variable darkness and brightness of the solar spots. (Macularum solarium variabilis obscuritas & claritas.)

If one spot surpassed another in darkness or brightness, yet each retained whatever quality it had once acquired, then alteration on this score would have no place. But as things stand, since one and the same spot is seen now darker, now brighter, it is rightly asked whether this is real, or merely an apparent show.

[Margin: Why the appearance of bright and dark is treated first.]

I take up, first of all, this apparent quality of darkness and brightness, because these two are, among visible things, both the first and the last to strike the sense.

For anything ill-seen casts a kind of shadowy image upon the eye. It is established by daily experience that any objects that are not themselves luminous, when placed within or beside the rays of a bright body, are made out only with great difficulty and are presented to the sight as though they were shadows. The reason is that the intensely radiant image of the bright body somehow smothers, by its own force, the image of the darker object in our sight, so that the power of vision is carried off by that image which, in presenting itself, prevails with the greater force.

[Margin: Less bright things are darkened by brighter ones, and why.]

Thus we see that the otherwise skilful pictures on the highest altars are always less well made out when they are set somewhat behind the side windows; and if the face of a person standing beside a lamp at night is not lit up by its rays, you will take it for a shadow, and so on.

What wonder, then, if we also note those bodies, which we behold as if walking about upon the Sun, to be tinged with no other color than that of shadows? This too is why we gave them the name of "spots" (although one author reckons that we did so belatedly, and not well). They feel an adversary altogether too overpowering, so that in the face of the Sun's blaze they are forced to hide whatever native color they have under perpetual darkness. Yet from these very spots, taken as our phenomenon, we can strike out no small light, if — with the sense going before by way of trial and affording some chink of light — we bend upon them the eyes of reason.

*The ordinary spots are of two kinds, in respect of brightness and darkness.
(Macularum ordinariarum, ratione claritatis & obscuritatis duplex genus.)*

The ordinary or primary spots are one thing; the secondary spots or shadows are another. Here I am dealing with the former. Every spot on the Sun, then, either has a nucleus or has not.

[Margin: Division of the ordinary spots.]

Of those that lack a nucleus, again a twofold class is found. Some are of a brightness and darkness that is even and uniform over the whole body and throughout the Sun's course; others are of an uneven and irregular kind, and these agree in every respect with the nucleated spots, with this single exception, that they are deprived of a nucleus.

The uniform spots. (Maculae æquabiles.)

The uniform spots have an apparent darkness, tinged everywhere with an equal, faint light, of an ashen color as it were; they do not much exceed in darkness the shadows or secondary spots; in duration they match other spots, for some are of long stay, some of brief, like the rest; and they vary their size, in the common manner, as they do their shape.

[Margin: Description of the uniform spots.]

Imagine that over some part of the solar surface a thin veil is drawn, or that something is painted on such as breath made visible by winter's cold, or that a thin mist or smoke clings there — and in imagination you will grasp the appearance of their color and darkness. And although each of them keeps its own tenor of darkness sensibly the same, still some appear darker and brighter than others; toward the margins they are more rarely seen, because

either they pass off into faculae, or by their excessive thinness escape the sight, or else present the look of the secondary shadows, or are hidden by the murky parts of the Sun. Yet there are also some that show themselves right up to the outermost margins.

Spots pregnant with nuclei. (Maculae nucleis foetae.)

[Margin: Properties of spots pregnant with nuclei.]

First: every spot endowed with a nucleus is clothed about by some other body, less dark, brighter, and thinner than the nucleus itself. This is established from the phenomenon.

Second: this little mantle thrown around the nucleus is almost always less dark toward the margins, and, toward the nucleus, nearly always less bright.

Third: the darkness and brightness of this body encircling the nucleus is not always alike, even at the same time and with all else taken as equal; for very often one part is deeply dark, another on the contrary strongly illuminated, and this unstably, for they pass through changeable appearances.

Fourth: the nucleus is sometimes so gradually fitted to its own body at their common boundary that, through a proportioned blending of the dark and the bright, the two seem to make one continuous body, tapering by degrees from a dark core into brighter margins; but sometimes it sits within margins so sharply marked off by darkness that one may well doubt whether the nucleus is continuous with, or merely contiguous to, the body surrounding it.

Fifth: every nucleated spot, as it grows, increases its darkness, ordinarily both in the body and in the nucleus. This is an experience always at hand.

Sixth: every nucleated spot, as it wanes, grows brighter both in nucleus and in the surrounding mass. This is plain from the proven observations of the phenomenon.

Seventh: every nucleated spot, all else being equal, appears more deeply tinged with light near the Sun's horizon than when far from it — though sometimes, by accident, it happens otherwise. This same property has been remarked by others as well.

Eighth: every nucleated spot, near the eastern and western region of the Sun, presents its nucleus confusedly mingled with the rest of its mass, and both, owing to the faint light, appear like a cloud. This is a familiar experience.

Ninth: many spots appear so overspread with some light, and as it were buried under it, that their whitish body is made out only with great difficulty and not sharply. This befalls many near their rising, many near their setting, many in mid-course, many throughout the whole passage — while yet others, meanwhile, suffer nothing of the kind, but complete their course clear enough and well-defined.

Tenth: at the same time, some spots on the Sun grow bright while others darken, whether they lie far apart from one another or near; indeed the very same spots, when joined, frequently undergo similar alternations, and so too does one and the same spot, as I have suggested before, when one part of it is darkened while another is lit up, and the reverse.

Eleventh: it very often happens that two spots heavy with nuclei, lying near each other, so utterly extinguish to the sight the rest of their bodies in those parts where the nuclei face one another, and light them up with brilliant faculae — although this does not always occur, but sometimes the common sections of those bodies are, on the contrary, made darker by their mutual conjunction. Instances are supplied everywhere from the phenomenon itself.

Spots without nuclei, yet of uneven darkness. (Maculae sine nucleis, & tamen obscuritatis inæqualis.)

[Margin: Spots uneven in light, without nuclei.]

Many spots arise, endure, and set without any distinct nucleus; they grow and shrink, turn darker and brighter, and show their middle less bright than their

edges. Since in all these respects — except for the nuclei — they agree with the nucleated spots, there is no need here to weave many new catalogues.

For the rest, since the nuclei present much worth knowing, these must be run through here briefly.

Chapter XL

The nucleus of the solar spots. (NUCLEUS MACULARUM solarium.)

[Margin: Description of the nucleus.]

Not all, but certain — and a fair number of — solar spots, especially the larger, grow dark at their very core in a peculiar way of their own, so that in their blackness they sometimes seem, as it were, to gleam.

This blackness — or rather the mass steeped in this blackness — I call the Nucleus of the spot, because it usually arises at its center. For the better understanding of it, the following are to be noted.

[Margin: Properties of the nuclei.]

First: many spots, as I said before, pass across the whole Sun without any nucleus, and are of varying murkiness, in keeping with what I said a little earlier.

Second: many enter the Sun together with their nucleus, traverse it, and leave it together with the same. And when this is so, the nucleus, at the solar horizon, grows slender along with the rest of the spot's body; indeed it is almost the only thing seen, while the remaining thinner body of surrounding light somewhat fades away in its abundance.

Third: many spots first acquire a nucleus on the Sun after they have crossed the horizon, and carry it up.

Fourth: many spots on the Sun lose the nucleus once carried above the horizon, before they reach their setting.

Fifth: many spots that have risen astronomically without a nucleus acquire one on the Sun, then lose it again, and set once more astronomically without it.

Sixth: many spots that have risen physically on the Sun without a nucleus carry off a nucleus they have acquired.

Seventh: many spots, once carried astronomically onto the Sun together with a nucleus, set physically.

Eighth: many spots rise and set physically on the Sun together with their own nucleus.

Ninth: I have as yet observed no nucleus coming to be physically at the same instant as the spot, but always something

precedes it. For I have found the spot, and never caught a spot setting physically without the nucleus having gradually failed first.

Tenth: some spots, from their very birth and while still small, at once produce nuclei, others when already large and grown enough.

Eleventh: although it is not easy to see any large spot without a nucleus, nevertheless this feature is not so proper to the large spots that the small ones are altogether without them. And so small spots are very often uniform and lack nuclei, yet many of them do nonetheless, again and again, bear and carry about their own tiny nuclei.

Twelfth: nuclei are various in size; a large spot sometimes has a small one, and a small spot one large enough.

Thirteenth: nuclei become large from small by degrees, and in the same way small from large. Yet one grows and shrinks faster than another, according to the duration and increase of the spot; for generally those that do not last long swell and diminish very quickly, while those that grow gradually last longer as well.

[Margin: The growth and diminution of the nuclei.]

Fourteenth: the apparent intensity of the nuclei in darkness is various. For some show a most intense blackness, almost the sootiness of a coal; others display something of a white or ashen color sprinkled in.

Fifteenth: black nuclei generally appear so marked off from the surrounding murk that they present, as it were, distinct margins; but those that are whitish gradually release their color, so that they are softly blended and conformed with the surrounding matter, and appear continuous rather than merely contiguous — a matter of which I also gave warning above.

Sixteenth: nuclei do not always stand precisely in the middle of their spot, as I have also said before, but at times lean toward the sides, and are wont to run ahead of the remaining mass of the larger spots almost always toward the setting, by the western part of their perimeter, dragging after them, as it were, the remaining brighter mass of the spot — which Father Schönberger, in his observations, is accustomed, not ineptly, to call a "cloud" [Nebula];

for it does indeed present something of the sort.

[Margin: The various modes by which nuclei come to be.]

Seventeenth: nuclei come into being in different ways. For some spots at their outset, as though from the depth of the Sun, show only some scanty and very slight tokens of themselves, with a diluted light; then, from day to day, they grow both in mass and in darkness, and as soon as they have been shaped into some spot, they begin to grow darker even in the middle and to become the seeds of a nucleus; these then swell along with the spot itself, and in the same way pass away again into nothing. And this mode of coming-to-be and passing-away is the ordinary one — at least, so far as I have hitherto observed, the most frequent.

Eighteenth: another mode of producing nuclei is when many small spots, neighbouring one another and often keeping company for a long while, gradually — indeed sometimes quickly enough — coalesce into one, and at once also produce a nucleus in the middle. Here note that this coalescence of small spots very rarely takes place toward some side or lateral spot, but ordinarily toward the midpoint of them all. Note secondly, that it is ordinarily so consolidated that the mixture and true union of the spots appears, to the sense, complete, and endures. Note thirdly, that the space of the coalesced spots is a little less than that which the separate ones had occupied. Note fourthly, that this coadunation is fairly frequent along the length of their path. Imagine bubbles of water coming together into one larger bubble.

Nineteenth: the mode of engendering a nucleus is this: when many simple and uniform spots are drawn together into one large spot, but not the intervening spaces — the sites and places do not change; rather, some new spot or shadow supervening thus occupies all of them and the intervening spaces, even the very brightest, and fills them after the manner of a cloud or mist, so that out of them all there results one spot, though a misshapen one. When this happens, either those several earlier ones, or new ones as well, acquire nuclei, which then grow, endure, increase, fail, and pass away, according as the whole spot itself behaves in its growing or its shrinking. And this mode of engendering spots and nuclei is nearly the most usual of all.

Twentieth: a fourth mode of forming nuclei, and one often in use, is when some formless and thin spot or shadow — long enough, slender in one place, in another broad, and of no regular shape, scattered after the manner of smoke or cloud — is either drawn together into one denser spot, or, by a new spot or shadow

physically arisen there on the spot, is gradually shaped up better, and so acquires a stable nucleus or nuclei, in proportion to the spot itself.

[Margin: The shape of the nuclei.]

Twenty-first: ordinarily the shape of the nucleus is like the shape of the spot set around it.

Twenty-second: ordinarily, when the shape of the spot changes, that of the nucleus changes too, and the reverse.

Twenty-third: ordinarily, when the spot grows physically, the nucleus grows too; when the spot diminishes, the nucleus wanes as well, and the reverse — though this is not always so.

Twenty-fourth: ordinarily the growth of the spot, and its diminution, takes place on every side, in every difference of place; and so too for the nucleus.

[Margin: The growth of the nuclei.]

Twenty-fifth: out of the many separate nuclei of a single large spot, very often one nucleus is made — not by a coming-together or local conjunction of them, since their centers keep the same distance among themselves, but by a new filling-in of the interposed spaces with matter of like kind, or by some other extension of an alterative sort.

Twenty-sixth: out of one large nucleus, two, three, or more often come to be — not by a local pulling-apart of its parts, but by some emptying (I know not what) of the intervals; for their centers remain equally distant from one another.

Twenty-seventh: yet conversely too, one nucleus often becomes many, and these again become one, and so on.

Twenty-eighth: they do not change the position of the nucleus, nor of the spot, in a local sense; but the part they turn to the north they do not remove, and the part turned to the south they do not divert; they do not make an eastern part western, nor the reverse — except insofar as the semicircular turning around the Sun assigns this to them; and a partial change of shape does not change the position of the whole.

Rosa Ursina, Book IV, Part I — Chapters XLI–XLIV (folios 499–502)

(continuation of Cap. XL — the properties of the nucleus)

Twenty-ninth. Separate nuclei, at their ingress and egress, often merge together optically, though they remain physically separate; and they frequently eliminate the bright intervals between them, either partly or wholly.

Thirtieth. The nuclei, together with the spots, ordinarily whiten somewhat at the margins and swell up in the manner of a cloud; and that apparent swelling perceptibly diminishes their slenderness.

Thirty-first. Two or more nuclei touching one another optically at the margin appear to make a single, darker one, and turn a thin one into a thick one — which sometimes happens.

[Margin: The appearance of a physical alteration is certain.]

From all this — which has so far been summarily set out concerning the spots and their nuclei, and observed and noted in the earlier book — it is clear that no one can reasonably doubt the apparent variation of the spots in respect of their darkness and their brightness. For it is entirely certain that the spots appear darker and less dark, and likewise more and less bright. But it does not immediately follow that these changes occur through real physical alterations. The Earth's shadow certainly darkens the Moon, more and less, yet does not physically alter it. And so before anything else we must examine whether, in keeping with the phenomenon, the darkness of the spots is some real and physical quality.

Next, whether it inheres in the spots; and then whether it is drawn out of the potentiality of that matter by an altering action, and in what way. The like must be investigated and established regarding the brightness of the spots — what it is, where it comes from, and how it arises.

DOUBT I.

Whether the apparent darkness of the sunspots is mere shadow?

CAP. XLI.

That shadow is a mere privation of light in a suitable subject, no one fails to know. Hence it follows that every shadowed subject is in proximate potency luminous, so that no other disposition is needed than the presence of something bright.

Therefore, just as light pervades a transparent body that is unbounded throughout its whole depth, but pervades a bounded one only at its outer physical surface, so too we see the same thing happen with shadow.

And just as rays [proceed] from a bright body, so we find that shadows in their own way proceed from an opaque one; for they are extended in a straight line, following the flow of the luminous rays, since they are nothing other than the cutting-off of those rays by the interposition of an opaque body.

Since, then, we see with our own eyes every day that the uniform splendor of the Sun's face is stained by sunspots and, as it were, disfigured by shadows scattered across it, the question now is whether these shadows are cast onto the solar surface from outside, as the Earth's shadow is cast onto the Moon.

Conclusion. It is impossible for any shadow to be introduced into the Sun from elsewhere, to be bounded there, and to become visible. For no shadow falls upon a bright body so as to be perceived; indeed every shadow is driven off by a bright body, especially the Sun. Next, no agent so brilliant is found in the whole of nature that it could in any way cast a shadow toward the Sun. Finally, neither is any opaque body of such a kind found from which a shadow could be carried onto the Sun. Therefore, on this ground and in this way, it is simply impossible for the spots to be introduced onto the Sun; and so the spots are not to be reckoned in the category of mere shadows, etc.

[Margin: It is impossible that the spots are shadows cast onto the Sun.]

DOUBT II.

Whether the apparent darkness of the sunspots is the merely apparent opacity of a transparent body.

CAP. XLII.

That solid, non-transparent, colored bodies truly are, and are called, opaque is certain and admitted by everyone. But that transparent bodies, like air, are often not opaque but only appear so, is likewise confirmed by daily experience. For example, if someone looks from a distance through the open windows of a dwelling opposite, he will imagine nothing but dark night; he will detect, by no indication whatever, the shapes of the things placed within or of the people walking about — even though it is certain that the appearances and colors of all the things inside, and of the room itself, are very brightly lit by broad daylight. The question, then, is whether the apparent darkness of the sunspots, and its variation, can be defined and settled by some similar kind of appearance.

[Margin: A pure and truly transparent thing appears opaque.]

[Margin: The state of the question.]

Conclusion. It is impossible that the apparent and variable darkness of the sunspots is a merely apparent opacity. For this merely apparent opacity is either in the depth of the Sun or around its edges.

[Margin: It is impossible that the spots are a merely apparent opacity.]

Not the first: for there would then be dark, variable gaps in the Sun. But that there are no such gaps producing a merely apparent darkness in the Sun, I prove as follows.

The surface of the gaping Sun that surrounds that gap — the surface at which the gap terminates — is either as bright as the rest of the Sun's surface, or it is not. If the former, that chasm will appear just as bright as any other part of the Sun, and so will present no spot, nor any variable darkness — contrary to the hypothesis and to the truth of the phenomenon. If the latter, then that variable darkness will not be merely apparent, but a true opacity — namely, a darker part of the Sun's surface at which vision terminates; but we were supposing a merely apparent opacity.

In the same way it is proved that this merely apparent opacity cannot occur around the Sun's edges. For that surface of the Sun which corresponds to this

apparent opacity is either as bright as the rest, or not. If the former, it will illuminate that merely apparent opacity, since a body that is not truly but only apparently opaque — as we are supposing — ceases to be opaque in the presence of something bright. If the latter, then the darker surface of the Sun will be an object truly, not apparently, opaque — contrary to the hypothesis.

DOUBT III.

Whether the apparent darkness of the spots arises from the interposition of a truly opaque body?

CAP. XLIII.

I am well aware that transparent bodies can be so shaped that, by their very figure and position, the solar rays are diverted elsewhere, so that, interposed between the eye and the Sun, they take away the sight of the Sun and cast back shadows, as is demonstrated in optics. Now such a transparent body can be conceived in two ways: either as invested with definite, regular, and highly polished figures, or with irregular ones — neither regular nor polished, but loosely converging into a single unpolished and rough surface. Since, then, experience teaches that in both of these ways shadows are cast by bodies otherwise internally transparent, someone might suppose that something similar happens with the sunspots too. But that it turns out otherwise, the following will show. Some of these arguments attack both modes of figuring, others reject now this one, now that, in a determinate way.

For, first, the case as proposed supposes that the body set between the eye and the Sun is perfectly transparent throughout its depth, and hence that this shadow is caused by the external surface alone.

But since the interior parts of most sunspots — immersed within their very depth, as I often demonstrate, by their situation and their more diffuse, thinner mass — are either black nuclei or denser parts, it is clear that their darkness does not come from an external shape.

Secondly, that this surface is neither regular nor smoothly polished nor stable is shown by its perpetual increase and decrease, the variation of its figure, the roughening of its perimeter, and the continual change of its position relative to our view.

There is added, thirdly, the new generation or ceasing of nuclei, which — since they are of a more intense blackness than the mist spread around them — clearly

do not arise from a mere variety of external surfaces. For, as is established from the phenomenon and from what has been said, the figures of the nuclei and of the surrounding mist are for the most part similar and similarly positioned; although often the figure of the nuclei varies while their blackness remains unchanged.

Fourthly, the spots gradually pass over into bright faculae, more brilliant than the ordinary bright surface of the Sun itself — something that can be ascribed neither to position nor to a change of surface.

Fifthly, the spots would endure and would return to their former shape, if they suffered that darkness from position alone; for other changes are thereby excluded.

Sixthly, from a proportional increase of some spot there would follow a greater brightness of it, and from its diminution a greater darkness — whereas the contrary happens.

Seventhly, the spots ought to appear darker near the [Sun's] edge than near the middle, because, owing to the oblique view that occurs at the edge, more of the surface comes under a very small angle.

Eighthly, in the middle of the Sun too, the solar rays perpendicular to the spot's surface would easily penetrate to our sight, especially given a polished surface.

Ninthly, uniform spots on the Sun change both their position and their figure, while their darkness always stays the same. Therefore this darkness of the spots does not come from a change in the spots' position and figure.

Tenthly, very many spots, keeping the same figure, change their darkness — either to something more intense or more remitted, or into a facula — and that either wholly or partly. Therefore the surface surrounding the spot contributes nothing to this. Hence the varied configuration of the spot alone, together with a diverse position, or the unevenness of the surface surrounding the spot, does not sufficiently account for its apparent darkness.

For, although I do not deny that hard, perfectly transparent bodies, if clothed with an unpolished surface, present some darkness, yet that they present such a darkness as the spots usually do is always false. For a fuller understanding of these matters I add the following.

First, if — assuming the perfect transparency of the spots — only an uneven outer surface were interposed toward us, it would not happen that as the spot grew the

blackness intensified and as it waned it remitted; because a surface equally rough would yield a similar effect in small and large ones alike.

Secondly, the spots would blacken most at the edge and whiten most in the middle, because there many folded rough parts of the surface would ward off the bright rays, and here fewer — which, however, is contrary to the phenomenon.

Thirdly, [it would follow] that no spot would ever acquire a nucleus which — as I said — is immersed deep within the substance of the spot, as is sufficiently shown by the horizontal phases, of many spots at least, when a thinner mist surrounds the nucleus.

Fourthly, because it is evident that every horizontal spot pregnant with a nucleus turns toward the viewer that subtle halo, whose surface, interposed between us and the nucleus, is not distinguished from the black bulk of the nucleus, except when, in ascending, the spot optically expands and opens out its length. From this it is clear that the apparent variation of color comes not from the external surface of the spot but from internal alterations.

Conclusion. The apparent darkness of the sunspots is a true, real, and physical quality of an opaque body.

Proved first. Every visible darkness is either a shadow, or the merely apparent opacity of a transparent body, or a true opacity — for there is no other possibility. But the apparent darkness of the sunspots is not a shadow, as proved; it is not a merely apparent opacity, as demonstrated; therefore it is a true opacity, and hence a real and physical quality.

[Margin: The darkness of the sunspots is a true opacity.]

Proved secondly. That which blocks the passage of the solar ray to sight is not nothing, nor a mere negation of light, but something physical and real. But the apparent darkness of the spots blocks the passage of the solar ray to sight; therefore it is not nothing, but something physical and real.

You will say: a certain configuration of any transparent body whatever, and its interposition among what is bright, and even a ray, can prevent [the ray] from passing through, as was said a little earlier; and yet in this case all other qualities are absent; therefore the argument is not sound.

I answer: that those figures of a transparent body — by whose arrangement and opposition the solar ray is turned aside — are insufficient to perform this office in our phenomenon is already established from what has been said. Yet even if they

were admitted for the sake of argument, it would still be clear that they are qualities, and indeed qualities variable according to the phenomenon; and since they are not introduced into a subject without very great prior dispositions, it is evident that on their account the subject is altered beyond measure. This is further confirmed because, since the subject of the spots continually either grows or diminishes, and likewise increases and decreases its darkness, it is absolutely necessary that the figures too be changed — not only in position, but far more in magnitude; and that not merely superficially, but throughout the whole depth of the spot, as is evident in the nuclei corporeally enclosed within the spots. But for this to happen without alteration is utterly impossible. Therefore, from the changeable apparent darkness, it must be entirely admitted — by anyone who has not stopped his ears to the truth — that changeable qualities and alterations too are present in the sunspots.

[Margin: The darkness of the spots is a true opacity.]

Proved thirdly. True opacity is a physical quality; the apparent darkness of the spots is a true opacity; therefore it is a physical quality. The major is clear from the very nature of a truly opaque thing, which consists in this: that it is impervious to visible species. And who does not see that this quality is a true physical affection of an opaque body? Otherwise all bodies would be penetrable by light and color, and no body would be non-transparent — which is plainly false. The minor was proved in what precedes. Therefore [the conclusion follows].

Proved fourthly. Every proper object of sight is a true quality; the apparent darkness of the spots is a proper object of sight; therefore it is a true quality. The major is certain; the minor is proved. For the darkness is not a common object of sight, and it is not an object of sight per accidens — such as a shadow is, which is seen only by the benefit of light and yet is seen, as is clear from daily observations; and a little earlier I showed that the spots are not a shadow, etc. Therefore it is a proper object of sight, and the conclusion is clear.

DOUBT IV.

What kind of quality, specifically, the apparent darkness of the sunspots is? [reads "sit in in specie Qualitas" — dittographic "in", see anomaly a]

CAP. XLIV.

Conclusion. The apparent darkness of the sunspots is a true color.

[Margin: The darkness of the sunspots is a true color.]

Proved first. The apparent darkness of the spots is a true and proper object of sight, as is proved; and it is not light; therefore it is a true color. For every true and proper object of sight is either light or color.

Proved secondly. The opacity of a bounded transparent body is nothing else, on the side of the thing, than color; but all apparent darkness of the sunspots is the opacity of a bounded transparent body; therefore the apparent darkness of the sunspots is color.

[Margin: True opacity is nothing but color.]

The major is proved because, if you take color away from a bounded transparent body, it at once becomes an unbounded transparent body, and so pervious to light and to visible species. The minor has been proved thus far, and is clear to the eye, because the spot's substance alone excludes the ray of the Sun. Therefore the conclusion follows.

It is confirmed thus: when we look at a person next to or in front of a burning lamp, with his face not illuminated, etc., we seem to perceive something like a shadow; and yet we everywhere look upon true colors, but do not distinguish them, because of the light's intensity in the eye, which dulls the species of the colors. Likewise the Moon eclipsing the Sun is seen — whether on paper, or directly through a covered helioscope — under the same color as the spots; yet what is seen of the Moon is not a mere shadow, but is the color of the Moon. But also... ..and clouds, and any objects whatever — trees, for example, towers, columns, the gilded globes atop towers — if they are projected onto paper from the Sun through the telescope [Telioscopium], do indeed cast black shadows, with no distinction of their own colors, just like the sunspots [Maculae]. Yet in those objects there are no mere shadows; rather, the appearances [species] of their true colors are carried onto the paper — as both reason and the eye attest. This is

plain from the images admitted through a small aperture or a convex lens into a darkened chamber: they are dimmed by the presence of too much light, but when that light alone is let in they present a most beautiful picture of the objects standing outside. Therefore, since everything else about the spots turns out in the same way, there is no room for doubt: their apparent darkness must be counted among true colors.

DUBIUM V.

What is the color of the sunspots? [QVISNAM MACVLARVM Solarium sit color.]

CAP. XLV.

[Margin: The apparent darkness of the spots does not necessarily prove them to possess a true blackness.]

First conclusion. Since all colored things, once they too have passed through the telescope [Telioscopium] onto the paper together with the Sun, take on the likeness of the spots — that is, of shadows — whatever their color may finally be, it is certain that from this appearance of darkness or blackness one cannot establish with any certainty that the spots' color is black. For white things quite as much as black ones appear of a similar and identical color.

[Margin: The apparent color of the spots is probably blackness, etc.]

Second conclusion. It is nonetheless probable that the apparent color of the spots is black, or close to black. The helioscope [Helioscopium] furnishes signs of this, for it displays the spots blacker to the eye than the telescope does on paper — whereas, if they were not black, it ought to show them more diluted, since their parts are more widely spread out when a more powerful tube [Tubus] is used; just as happens in a lunar eclipse, which is offered blacker on paper than when seen through the telescope, and blacker through a smaller tube than through a large one. Likewise a cloud drawn through the tube onto paper looks blacker than when viewed through the telescope; the tube does the opposite with the color of the spots, for they are seen blacker through the tube by the eye than when they have fallen onto the paper.

Some offer another and quite pressing argument drawn from certain nuclei [Nuclei] of the spots that are exceedingly black and dense. Since these look as black as any mountain or the most tightly packed mass, the apparent blackness of the nuclei seems not to be caused by the mere coloring of an opaque body —

compact though it be — of any sort whatever, but by an outstanding blackness [ater] rooted in the nuclei themselves. This view is supported by the physical origin of the spots and nuclei, and by their eventual transformation into faculae [Faculae], of which more hereafter.

COROLLARY [COROLLARIUM]

From what has been argued so far, I judge it plain that in the spots there are found not only alterable physical qualities, but that these are in fact altered daily. For no one will say that the daily growth and diminution of the spots occurs without prior alterations; and colors are not usually generated, and again destroyed, without a physical alteration.

[Margin: From what has been said, a true alteration is inferred.]

But since these same blacknesses of the spots increase not only in extent but also in intensity, there now arises the following question.

DUBIUM VI.

Whether the sunspots blacken through condensation, and whiten or brighten through rarefaction. [AN MACVLAE SOLARES nigrescant ex condensazione, ablescant seu clarescant ex rarefactione.]

CAP. XLVI.

[Margin: First point to note: How do intensification and remission differ from condensation and rarefaction?]

Note first: intensification and remission of a quality in a subject are one thing; condensation and rarefaction are another. Intensification and remission concern a quality's being more or less such in one and the same subject; condensation concerns much subject-matter with little extension, rarefaction little subject-matter with much extension — or else, condensation presents the same matter as smaller, rarefaction as larger, and so on, all else being equal.

[Margin: Second point to note: the distinction of condensation and *rarefaction*. (The margin prints *Refractionis*, evidently a slip for *Rarefactionis*.)]

Note second: there is another kind of condensation and rarefaction, namely when the continuity of a body is broken up by the intermixing of the parts of another body or appearance; and yet another, when the continuum of one and the same appearance grows rarer or denser. Thus in the first way we call rare a

pumice, a porous sponge, dust, foam, when they have many large pores lying between; and we call dense or thick a fog, a cloud, a vapor, when it occupies small and narrow pores. But this notion of condensation is more popular than philosophical.

[Margin: Third point to note.]

Note third: the black and the luminous are not opposed as contraries; rather, the black is opposed to the white, the luminous to the dark.

[Margin: Fourth point to note.]

Note fourth: if a faint colored thing is laid over another likewise faintly colored, then what results from them will appear more strongly such; if the superimposed thing is taken away, it will appear less such. Similarly if a luminous thing is laid over a luminous, or a dark over a dark, and so on.

[Margin: That the blackness of the sunspots is intensified, in the strict sense, by condensation is not certain.]

First conclusion. That the blackness of the sunspots is intensified by condensation, strictly so called, is not certain.

First, because condensation and rarefaction, strictly so called, are not suited to inducing or expelling color. For we see that the purest air is condensed and rarefied without any acquisition or loss of color; indeed winter air, denser and more compact, is more transparent than the thinned-out summer air — the eye itself being witness.

Second, blackness is induced in charcoal even while the subject is not condensed; and the whiteness of lime is acquired by rarefaction — lime, when water is poured over it, is rarefied and whitens further. So too air, when its rays are concentrated by refraction or reflection and sharpened into a bright cone, becomes bright, and the more it shines the more it is rarefied [?]. The lamp-wick [Elychnium] certainly, in the middle of the flame, while it blackens or reddens, is rather rarefied.

Therefore, from experiences of this kind the conclusion is plain: namely, even though the blackness of the spots, whether intense or remiss, passes daily before our eyes, it does not on that account necessarily follow that they are intensified by a condensation of the subject, since the intensification of a quality frequently occurs while the subject is being rarefied.

Although I do not deny that, if a subject is condensed, its qualities do also ordinarily thereby become more perceptible.

[Margin: The intensification of the spots comes from the addition of similar material.]

Second conclusion. The phenomenon indicates that the blackness of the sunspots is intensified by the heaping-on of material similar [to their own].

First, whenever the spots grow in blackness, they also always grow in size on every side; this is therefore a sign that it comes about by an influx of material.

Second, when they begin to shrink, they brighten in the same proportion.

Third, in the middle they are ordinarily blacker, and gradually clearer toward their edges; this is therefore a sign that it comes about from deeper material in the middle and thinner toward the extremes — otherwise the Sun would shine through equally, since it would be tinged equally throughout a substance equally thin.

Fourth, this is most evident from their side-on aspect, when they draw near the horizon: for the blacker ones are ordinarily seen to be thicker, and so on.

[Margin: The true intensification of the spots in respect of color is argued from the nuclei.]

Third conclusion. That the material of the spots — especially of the more notable ones — is in some places more compact than in others, and that their blackness is produced and intensified not merely by the addition of similar material but by a true physical action of a different material, is what the nuclei persuade us of, and in a manner even prove. For although the nuclei are not so very deep as the rest of the body surrounding the spot — as is clear from viewing them at their rising and setting toward the Sun's edges — they are nonetheless endowed with so intense a color that they yield not even the least passage to the solar brightness, as the surrounding parts do. Now if the nucleus of a spot arose merely from an over-pouring of similar material, then that surrounding mass ought at least proportionally to be blackened too; the boundary between the nucleus and the mass ought to share in something intermediate on either side — yet ordinarily this does not happen; nor meanwhile does the nucleus grow in depth in proportion to the blackness it displays. From this a most powerful argument is drawn for condensation, or intensification, strictly so called.

Second, many exceedingly minute spots persuade us of the same, spots so black that they surpass many others fifty times as broad both in blackness and in duration.

Third,

many frequent gaps between the spots and the nuclei persuade us of it: gaps which, the nuclei mostly remaining unharmed, consume the other, thinner adjacent material — whence a most valid argument is drawn, that the nucleus differs greatly from that thin mantle.

Fourth, and finally, the ordinary resolution of the spots into shadows, and of the shadows into faculae, clearly proves the things I have said. For into the place of the spots, even the smallest, shadows usually succeed, and much larger faculae take up these in turn. Since all this could not happen without prior dispositions, alterations, and rarefactions, it is a matter of general agreement that the solar phenomenon is subject, to the greatest possible degree, to the motion of alteration.

OF THE NUCLEI OF THE SUNSPOTS: SEVERAL PARTICULAR QUESTIONS [DE NVCLEIS MACVLARVM Solarium; aliquot singulares Quaestiones]

CAP. XLVII.

You will not take it amiss, kind Reader, if here I raise some questions about the nuclei of the spots on their own account — questions I touched perhaps piecemeal in the earlier chapters, when I was treating of the spots, as occasion offered and almost in passing. But since the matter of the nuclei is deservedly reckoned among the noblest parts of this phenomenon, you will grant me pardon, I trust, if here of set purpose I recall the same, as it were, to the anvil. In this task, however, I will so regulate myself that, if I revive the earlier questions, I shall not bring back the earlier solutions, or at any rate I shall be seen to treat them in some other way.

QUAESTIO I.

Whether the apparent blackness of the nuclei is a mere privation of light, or rather a positive color. [Vtrum apparens Nucleorum nigredo sit mera lucis priuatio, an vero color posituius.]

First conclusion. The apparent color or blackness of the nuclei is not a mere privation of light.

[Margin: Various proofs of the conclusion.]

Proof. Because a mere privation of light exists only in a purely diaphanous body. Therefore, if the blackness of the nucleus be held to be a pure privation of light, the space the nucleus occupies, being deprived of light, will be a part of a purely diaphanous medium, nowhere bounded; but every purely diaphanous thing set between the seer and a luminous body is perfectly illuminated by the luminous body. The nucleus, then, interposed between the seer and the Sun, will shine — since the Sun is, and is here posited as, luminous. But that the nucleus should shine is false and contrary to the phenomenon: for then all the nuclei-bearing spots would be conspicuous in the midst of the faculae. Therefore the nucleus's color is not a mere privation of light.

Otherwise. Every mere privation of light ceases in a diaphanous medium in the presence of light; the nucleus's color, in the presence of light — namely of the Sun — does not cease; therefore the nucleus's color is not a mere privation of light.

Otherwise. It is impossible that a mere privation of light should cut off from the eye a present and direct ray of light; but the apparent blackness of the nucleus does cut off from the eye the present ray of solar light; therefore it is impossible that the apparent blackness of the nucleus should be a mere privation of light. The major is evident, for otherwise darkness would never be driven off by light present to it, and darkness would be positively contrary to light — contrary to all truth and experience. The minor is proved: for if the nucleus's color be set aside, whether in reality or in thought, from that part of the Sun, the Sun will at once send its ray to the eye — a ray that is always present and ready to shine, and indeed to shine into the eye, since the nucleus alone is, and is posited to be, between the seer and the Sun. The conclusion therefore stands.

Otherwise. If the nucleus's blackness is a mere privation of light, then that medium, deprived of light, will reach as far as the Sun; therefore that common contact of the Sun and the medium will be deprived of light. For if it is luminous, the diaphanous medium in which the nucleus is,

being bounded by the luminous, or bordering upon the luminous, is illuminated, and so on.

SCHOLIUM [SCHOLIVM]

The earlier things proved of the spots can be carried over to the nuclei as well; and these things about the nuclei can be accommodated to the spots.

[Margin: The blackness of the nuclei is a true color.]

Second conclusion. The apparent blackness of the nuclei is a true and positive color.

Proof first. Everything that prevents the passage of light to the sight in a semicircular position is a color, or a colored thing; the blackness of the nuclei prevents the passage of light to the sight in a position semicircular with respect to the Sun; therefore the blackness of the nuclei is a color, or a colored thing. The major has been sufficiently established in the earlier chapters. The minor is settled by experience: for the nucleus, advancing from its entry to its exit, runs through as it were a semicircle of the Sun, and yet all the while blocks its light.

Proof second. Every proper visible object is either light, or color, or a privation of light per accidens, that is, an opaque thing, and so on. The nucleus of the spots is not opaque, nor a privation of light — as was proved in the first conclusion — and it is not light, experience being witness; therefore it is a color.

QUAESTIO II.

Of what sort is the color of the apparent blackness of the nuclei? [Qualis apparens Nucleorum nigredo sit color.]

First conclusion. It cannot be known for certain what the color of the nuclei is. For everything colored that is set between the seer and the light appears black (unless it be illuminated from some other quarter); and every lamp-flame [lychnus] from the fire of a candle, seen from afar, mostly appears black; and the Moon, placed beneath the Sun, appears black.

Second conclusion. It is nonetheless more probable that that color of the nuclei is black. The reason for this will be given where the generation of the nuclei is treated.

QUAESTIO III.

Whether the blackness of the nuclei is merely superficial, or lies in the depth. [Vtrum Nigredo Nucleorum sit tantum superficialis an in profundo.]

Conclusion. The nuclei of the spots are deep.

First, because their varied and intense blackness indicates this well enough.

Second, because two nuclei, from a side-on view alone, often touch each other optically, and take away from view the space lying between.

Third, because around the Sun's edges they still show some thickness, and that observed thickness pertains to their depth — apart from the fact that, when immersed in the Sun, it gleams [?] and deceives the sight.

Fourth, because on whichever side they look toward the Sun they are somewhat cut into, and of this we have an evident experiment from that light which, intercepted between two nuclei, diminishes them somewhat. And so it is certain that the nuclei are deeper than they appear at the limb.

QUAESTIO IV.

Whether the nuclei are bodies denser than the darkness [caligo] and facula surrounding them. [Vtrum Nuclei sint corpora densiora, quam illas circumstans caligo & Facula.]

Conclusion. The nuclei are denser than the surrounding darkness, and this darkness denser than the facula.

[Margin: The nuclei of the spots are denser than the spots and the faculae.]

First. Because the Sun's ray penetrates rare bodies more quickly than dense ones, and dense bodies with more difficulty than rare ones, it is a sign that the nucleus is densest, being one that is never broken through by the solar ray; that the mass set around it is rarer, since more light is taken into it; and finally, rarest of all, after these, is the facula, full of light to the very degree of a flame.

Second. Because as the surrounding spot grows, the nucleus grows and is intensified, and as it shrinks the nucleus shrinks and is remitted; this is therefore a sign that it comes about also by an accession of material, which condensation for the most part accompanies or follows. And if anyone should contend that it is not condensation strictly so called, it is at any rate a great heaping-up of similar material — which suffi-[ces]

[this] is sufficient for my purpose in this whole disputation. But this point too has been treated in the earlier parts.

Third: because from spots that have dissolved there usually result both umbrae and faculae, occupying a far more ample place and a greater space; therefore the material of the spots had been rarefied, and so on.

Fourth: because spots are prolific in nuclei, which are always larger, more brilliant, and more long-lasting, and which for the most part carry faculae round about them on every side. This is therefore a clear sign that the nuclei are very compact.

QUAESTIO V.

Whether the nuclei, besides their revolution about the Sun, also turn about their own proper center?

Conclusion. The nuclei do not turn about their own center.

[Margin: The nuclei do not turn about their own center.]

First: because they do not change their position in any way proportionate to a rotation, which nonetheless would necessarily happen [if they did rotate].

Second: if they turned together with the spots, these too would change their position, which does not occur; but if the nuclei alone turned while the rest of the body of the spots did not, they would take on a position and figure unlike that of the spots — which is ordinarily contrary to the phenomenon.

Third: because the penetration of bodies would not be avoided, if such irregular bodies were granted rotations and the Sun, the nuclei, the spots, and the faculae were posited as hard bodies.

Fourth: because the continuity between the nucleus and the surrounding murk [caligo] would be broken, which conflicts with the phenomenon; secondly, because the nucleus is not spherical — indeed it ordinarily has unequal dimensions among themselves of length, breadth, and depth.

QUAESTIO VI.

Whether the nuclei are carried about on epicycles and eccentrics.

Conclusion. It is impossible that the nuclei are carried on epicycles and eccentrics.

[Margin: The nuclei are not carried on eccentrics or epicycles.]

First: because, once all [the required] hard bodies are supposed, the penetration of bodies would not be avoided — whether the nucleus be placed on its own epicycle or not. For the nucleus can project beyond the visible surface of the Sun only by its own depth, and not even by the whole of that, as is established most

clearly from observations and is shown at length elsewhere; and this [depth] is much smaller than the breadth. But the epicyclic orb ought to extend itself so as to take in the whole latitude of the nucleus; therefore it will enter far into the body of the Sun, and so on.

Second: because it would change its position in an extraordinary way, which is contrary to the foregoing.

Third: it would often appear slender in the middle [of the disc] and broad at the horizon [edge] — which is false.

Fourth: it would become swift, slow, direct, retrograde, and so on — which is false.

Fifth: at fixed monthly and yearly intervals it would return, which is false.

Sixth: the very ways in which the nuclei are generated and perish will in no way permit eccentrics and epicycles.

Seventh: their increase and decrease likewise overturns those [hypotheses] from the ground up.

Eighth: the nuclei are enclosed within that nebulous body; therefore, once everything is posited as hard, the nucleus by itself cannot rotate on an epicycle without some associated parts of that mass — which nonetheless conflicts with the phenomenon, and so on.

QUAESTIO VII.

Why do the nuclei whiten somewhat around their margins, while about their middle they often blacken like charcoal?

Because the nuclei in the middle of the Sun reach the sight through fewer and shorter portions of the Sun, as it were atmospheric ones, but through far more of them at the edges; and since these [portions] are somewhat luminous, they tinge the nucleus with their own whiteness and diminish it. From this it is evident that the nucleus lies to some extent within the solar surface. And this indeed is the general reason; but the special one is that the mass surrounding the nucleus meets the sight before the nucleus does, and this mass is suffused with light, and so on.

[Margin: Reasons are given why the nuclei are tinged with a certain whiteness about their extremities.]

There is added another, optical reason: that the rays of the Sun, [with the mass] revolving about the middle of the nucleus...

revolving, once received into that murky mass, cannot be perceived in that straight [central] position of the spot, but can be perceived in a lateral one. Furthermore, between us and the nucleus not much of that material is found, for the reason that the Sun's rotation somehow wipes away the copious redundance of that murk. And finally, because the excessive splendor of the mid-Sun smothers the less luminous things, so that they do not appear distinctly. The faculae prove this, for they shine far more brilliantly toward the edges than in the middle. So too that cloud [nebula] which encircles the nucleus, when it is interposed between us and the nucleus near the limb: being suffused with light, it appears to the eye, which thereupon indicates the blackness of the nucleus as, on this account, less dark, and so on — because the colors of intervening objects are attributed by the sight to the more remote objects.

QUAESTIO VIII.

Why do the nuclei, as also the spots, swell into the form of little clouds toward the margin of the observing circle, and shrink toward the center?

This comes about from the refraction of the lenses alone, which enlarge the spots and nuclei that have been carried onto the oblique lines of incidence, whereas in the middle, under lines of incidence that are nearly perpendicular, they suffer little, and so on. But of these matters let it be treated under the slenderness of the spots.

ON THE LIGHT OR BRIGHTNESS of the sunspots.

CAP. XLVIII.

Since the occasion itself prompts that, after the obscurities have been discussed, we should say something about the brightness of the sunspots, I do not wish to leave that [topic] empty; and I will dispatch the matter briefly with at least a single Question, because it also bears on the point of Alteration. So let it be, then.

QUAESTIO UNICA.

Whether the light or brightness that is discerned to be present in the murky mass of the spots is fixed, permanent, and inherent — such as is present in the Moon, the

stars, and so on; or rather transient, such as is present in the air, so that the Sun merely shines through the spots to us?

To this question no better answer can be given than from the phenomenon itself, once its exquisite observations are supposed. The question, then, is this: whether the Sun's light inheres in the spots permanently, as it does in the Moon and the stars; or rather transiently, as in the air, so that the Sun is shining-through [*tralucens*] and not the spot shining-back [*allucens*].

[Margin: The status of the question is explained.]

I suppose that the Sun appears much more luminous in the middle [of the disc] than at the edges, as is established to the senses by very many experiences. And although in the *Treatise on the Translucence of the Faculae* the truth of this resolution will be plainly established, still it is not out of place to show the same thing here in passing, so that the true alteration of the spotted subject may thereby become clear.

[Margin: The Sun is brighter in the middle, duller at the edges.]

Conclusion. The brightness of the sunspots comes from a light inherent in them, and not from a Sun shining through them.

[Margin: Its own light inheres in the spots permanently.]

Proved first. Because most spots whiten more about the horizon [i.e., the limb] than in the middle, which ought not to happen if their whiteness arose from mere translucence, since the Sun in the middle, being strongest, casts out brighter and more powerful blazes, whereas from the edges it emits rays dull enough. How, then, can it come about that with a duller light, such as is the marginal light, [a spot] should glow more than with a purer one, such as is the central? And this is most strongly confirmed from a double head. Of these, the first is drawn from the nucleus itself, which in the middle of the Sun is for the most part constantly black, but at the horizon [limb] appears with its blackness diluted and suffused with light. This is certainly not produced by translucence, since the nuclei — especially the larger ones — are utterly destitute of light. That light, therefore, lying upon the nuclei at the margin of the Sun, is from the whitening [material], from the very murk [*caligo*] of the nucleus — as is clearly evident from the apices running out above and below the nucleus, toward the north and the south, which likewise whiten. The other [head] is drawn from the...

depth of the spots — which yields by many parts to the length or the breadth (as has been said for the most part above, and will be more fully proved a little later

below). Therefore, if the mid-Sun with its most robust light does not penetrate the small depth of the spots, how does it come about that the marginal and oblique rays should break clean through the whole length crosswise, both through the spot and through its nucleus?

[Margin: A most efficacious argument.]

Assuredly the mind and reason cannot reconcile this matter with mere translucence of the rays.

Objection. You will say that from other chapters this whitening of the spots toward the horizon can be defended.

[Margin: Objection.]

For [you will say] this comes about from the figure of the lenses, which, by refraction, apparently rarefy the distended spots and so present them as less black to the sight; and this is confirmed from the fact that spots carried from the margin of the observing circle to its middle appear smaller indeed, but more sharply defined and blacker; and, conversely, from the fact that those spots which, while dwelling in the middle of the Sun and holding the middle of the observing circle, appear clean, black, and distinct, are, when carried to the margins of that circle by the motion of the instrument, at once seen more confused and less black. Whence it does not necessarily follow that the apparent whiteness arising toward the margins is something implanted in the spots, since it can come to them from without in the said manner.

[Margin: The experiment of carrying the spots to the center, and from the center to the limb.]

Reply. I answer that spots at the margins of the Sun — carried, at length, wherever, even to the middle of the observing circle — are less foul and more diluted in light than they had earlier been, while they moved along spread out in the middle of the Sun; and that those which are spread out in the middle of the Sun, if then carried by the motion of the instrument toward the margin, will indeed be somewhat larger through refraction and somewhat brighter, yet will not appear so diluted in light as they do become when, by their own spontaneous motion, they approach the solar horizon [limb]. Whence, although I grant refraction its due, still it by no means produces of itself all those things which the phenomenon displays with respect to brightness, nor does it satisfy experience. And so the strength of the argument and the sinew of truth remain. Now for this

purpose I performed, in order to clear up this doubt, innumerable experiments; and that which I have just now delivered I always...

[Margin: The refraction of the spots at the margin is not the adequate cause of the whitening of the spots.]

found true [in them]. Whence it is necessary that the brightness of the spots inhere in them durably.

Proved second. From the facula-bearing inter-luminosities [*interlustres*] of the nuclei and spots, which, although they are rather frequently smaller than the nuclei themselves, are nonetheless seen all the way to the exit [from the disc]; which would not happen if that matter came about through translucence alone, because [such an inter-space] would be less far from the Sun's center than the nuclei or the spots, and so, from the aspect of the slope [*dechui* (?)] of the nuclei, would be cancelled out by their mutual optical contact. And it is confirmed, because, when those intervals are so illumined by the faculae, that mass flowing round the nuclei, on that side where the nuclei mutually face each other, grows utterly bright; whereas, if [the effect] is ascribed to translucence alone, why does the Sun not shine through round the whole nucleus in like manner? For all things are everywhere equal: the surrounding material is everywhere equally rare, equally soft, the underlying Sun of the same brilliance and activity. Why, then, does it not translucent equally through things equally thin? A clear sign, therefore, that that inter-luminosity of the nucleus and of the spot adheres to the body at the summit of the Sun, and hence that the Sun does not shine through.

Proved third. Because very many spots are seen suffused with light on every side, which cannot come from translucence. For that light is between the eye and the spot.

[Margin: Light clothes the spots round about.]

Proved fourth. Because certain spots have about themselves peculiar most-beautiful nimbi or *areae*, after the fashion of a halo [*halos*] — sometimes over their whole [extent], at other times over parts, and over many days; and these nimbi are variegated with a most beautiful mixture of colors — white, pale-yellow, greenish, and dusky [*furui*]. Now that this comely blending of colors among themselves is not from the telescopic [*Telioscopicis*] lenses is proved: because [the lenses] ought always to exhibit like effects in like spots; and that it is not from the light of the Sun [is proved], because [the Sun] ought always to produce like effects about like spots. Therefore such things must be ascribed to the brightness inherent in and adhering to the spot itself, and so on. And it is

solidly confirmed from the fact that Father Georg Schönberger [P. Georgius Schönberger] observed and noted these same affections of the spotted light also at Ingolstadt — just as I too have faithfully set forth the same things in the Notes to the Observa-...

[Margin: The colored nimbi of the spots.]

-tions. But on this matter more will be said below, where the solar faculae and the translucence of the solar body will be treated professedly, when the rising and setting of this phenomenon is disputed.

THE FIGURE OF THE SUNSPOTS.

CAP. XLIX.

Figure is a quality of finite quantity. Of figures, one kind is of a surface, another of a body. For lines and angles do not have completed fissures [i.e., closed boundaries]; yet they do have the beginnings of them. And of figures — both superficial and solid, that is, corporeal — one kind is absolute, another relative, namely from position and aspect. For a figure, for example that of a sphere as solid, absolutely and simply, is a globular body, comprehended by a single surface everywhere equally distant from the center; but if optically you consider the same sphere from some fixed distance, you will say it is a circle or a disc, and so on. Thus a cylinder, viewed by an eye set on its axis, will be a circle; [viewed] in a straight line bisecting the axis at right angles [i.e., perpendicular], a rectangle; [viewed] in a line oblique to the axis, it will present yet another figure; and proportionally for other bodies, and so on.

In the same way the sunspots can be considered.

For, First: all of them, none excepted, grow slender when near the horizon [limb].

Second: about the middle they are all displayed after the manner of surfaces; whence a doubt may deservedly arise for someone: whether this is from position, or from a proper figure, or from something else?

It must be said, first: the horizontal slenderness of the spots is not the absolute figure of those spots. For all of them, none excepted, the more they descend from the horizon [limb], the more they grow large; and the more they approach it, the more, again, they grow slender.

[Margin: The figure of the slenderness is relative.]

But at a middle distance from the horizon [limb] they all appear in their maximum breadth, variously terminated, as will presently be said.

It must be said, second: the slenderness of the spots is partly from their position relative to the eye, partly from the interposition of the solar light.

[Margin: Whence the slenderness arises.]

It is clear, first: because if they are near the horizon [limb], we look at them from the side and obliquely, as at a disc oblique to the eye.

It is clear, second: the Sun's light greatly obliterates, on every side, [the spots] with its own rays, and so on. And that this may be solidly known:

It must be said, third: the solidity of the spots is not pits, fissures, hollows, or dark chasms in the Sun.

[Margin: The solidity of the spots is not a pit, etc.]

First: because the surrounding bright parts would obliterate them, just as we see black obliterated by white, dark by bright.

Second: because those pits would not take on color, nor bear haloes about themselves.

Third: because they would not draw the faculae after, but above, themselves.

Fourth: because they would always be wholly covered before the exit [from the disc], and would first be uncovered after the entry. For the bright parts would absorb them in the sight, as daily experience testifies — yet these things do not happen.

And Fifth: they themselves would not cover even the smallest bright interval; which nonetheless does occur.

Sixth: they would not recede from or approach one another mutually, as in fact happens.

It must be said, fourth: the figures of the spots are not certain superficial blemishes or stainings [*labes ... seu infectiones*] spread out only over the outermost part of the Sun.

[Margin: The solidity of the spots is not a blemish.]

First: because these marks would never cover over the bright interstices near the horizon [limb], which nonetheless they often do.

Second: because at the horizon [limb], toward the center, they would not make a wound into the Sun, which nonetheless frequently happens.

Third: because small spots would not be seen in the vicinity of the horizon [limb], which nonetheless very frequently occurs.

It must be said, fifth: the solidity of the sunspots is compounded of a solid, opaque body, dark and non-transparent [*adiaphano*], and one that mostly protrudes beyond the bright solar surface according to some portion of itself.

[Margin: The solidity of the spots is from an opaque body.]

That it is from a body — the compact solidity of the spots is established from the fact that...

it has a threefold dimension; and as regards its length and breadth there is daily observation and experiment, while as regards its depth — at least some depth — it is proved as follows.

First, because in the nature of things no purely mathematical surface is ever given.

Second, even if someone wished to insist that such a mere surface is what is found in the spots, still from that very supposition these consequences would follow:

First, that all the spots would be of equal thinness and of no density — which is false.

Second, that no spot would be noticed on the Sun at all; for just as a point takes on no color, so neither does a surface, by reason of the depth which it wholly lacks. And just as the thinnest little cloud passing before the Sun induces no perceptible spot — as experience testifies — so neither would such a surface produce any effect.

Third, the spots would have no nuclei.

Fourth, the spots would not touch one another at their sloping edges [declives].

Fifth, they would appear blacker.

Sixth, the bright gaps between them would cast no shadow.

Seventh, at the limb they would show no depth, and so on — all of which, however, is false and contrary to the experience of the phenomenon.

It therefore stands firm that the solidity of the spots consists of a body perceptibly of three dimensions.

That this body is opaque, dark, and non-transparent [adiaphanum] is manifest from daily experiment. For since it lies right at the very source of light — the Sun, I mean — if that body were transparent, it would not present a shadow to us by its interposition, nor would it interrupt the flow of the Sun's light; and it does so more or less, according as the spots themselves are large or small, dense or rare.

Finally, that they generally protrude at least somewhat above the Sun is established from this: that around their edges they frequently, by their mutual approaches, squeeze out the bright gaps between them, and so join together, so that two, three, or more spots appear as one. This would be simply impossible unless the spots rose somewhat above the outermost surface of the Sun — assuming them to be at an equal distance from the Sun's center, at least to sense, as we prove elsewhere.

For if some approached nearer to the center and others less so, and that perceptibly, it would not be necessary for them to project beyond the Sun in order that they should hide one another around the edges, and so on.

I said "generally," because it not rarely happens that large sunspots, before they reach the horizon, are suddenly so overwhelmed by light that they cannot be seen at all. And in such cases arguments to the contrary can carry great weight. For it is scarcely credible that they always physically perish; and so it seems entirely probable — indeed almost necessary — that they are buried under an excess of overspreading light. That such spots sink into the Sun, or that light floods over them, can be in no doubt.

Sixth. The figure of the spots seen head-on [ex oppositione visus directæ], when they are viewed in the middle of the Sun, is not the absolute figure of the body that we are seeking, but a superficial one — to be counted among those figures that depend on position and viewing-angle, in the case of very distant objects. So, since the sunspots are very far from us, we cannot, from a direct view of them, establish anything indubitable about their true and solid configuration. [Margin: The solid figure of the spots is not obtained from a direct view.] For as is demonstrated in optics, a sphere seen from afar appears as a circle, a cylinder as a rectangle or something else, and in short all solids appear flat, and many appear as one, and indeed such as are bounded by the outlines under which they are seen. Hence, even if the sunspots appear, from a middle or direct viewpoint,

round, or elliptical, or angular, and so on, their solidity or bodily bulk is not on that account known or inferred from these appearances.

Seventh. The superficial figure of simple spots, seen head-on, ordinarily appears somewhat round, or an imitation of round. This is clear from daily experience, drawn from the phenomenon itself over so many years. [Margin: The perimeter of the spots is curvilinear.] For the perimeter of simple spots always presents a curved line returning upon itself, and sometimes exactly circular. See the Figures.

Eighth. The figure of compound spots is composed of many round ones.

This too is clear from the same experience of so many years. I call spots "compound" when two or more fully formed spots are so close together that they make up, as it were, one continuous body. This is shown most clearly by their several distinct nuclei — either by a preceding separation, which is frequently the case, or by a following one.

Ninth. A figure composed of shapeless spots, or of umbrae, or of a mixture, is itself shapeless, unstable, mixed, and uncertain. [Margin: The figure of shapeless spots.] This too is clear from daily experience, and lies before the eyes in the diagrams presented. I call "shapeless" those spots which, not being round but of many forms, also usually lack nuclei. [Margin: Shapeless spots and umbrae.] I call "umbrae" those which mark the beginning of spots, or preserve, as remnants, their end, or act as the boundaries and guardians of the faculae, or stain the Sun as if through a lattice [per transennam]. The Figures of the Observations are full of these things.

The whole Sun, throughout the year and always, is utterly full of them, like an ocean with its rippling waves; but on account of their multitude and continual variation they cannot be observed except with the very finest telescopes, because the extreme faintness of these umbrae eludes the sight — a difficulty greatly relieved by an excellent telescope [Telioscopium] and a darkened place.

Tenth. The true, absolute, and solid figure of the spots — which is what we are seeking here — cannot be known and reported except from every possible position and aspect of them relative to the eye. [Margin: The solid figure of the spots is known from the aspect and position of all their outlines.] This is clear from experience and from the induction of all visible things. For position and aspect reveal the outlines of bodies in every situation, and from these the geometer, the astronomer, or the optician pronounces upon solid figures. Therefore, unless we can view the spots from every position all around, we cannot establish anything certain about their absolute and total figure.

Eleventh. We cannot obtain every situation, position, and aspect of the spots. [Margin: Not every position and aspect of the spots can be had.] This is clear from the fact that a different situation of the thing to be viewed is not obtained unless either the thing is moved before the eye, or the eye before the thing, through every difference of place.

Our eye neither moves nor can be moved around the spots; for the whole breadth of the earth yields no diversity of aspect toward the spots whatever, even if you were to pass from one extreme to the other in an instant, and so on. Although the spots do move before the eye around the center of the Sun, still — because, owing to the interposition of the Sun, they are not seen in the hidden hemisphere; and likewise because they wander little in latitude, and sometimes not at all, namely in December and June, especially when they are carried along in the higher parallels — for these reasons it is impossible to view their configuration in every possible position; and therefore it is impossible perfectly to hunt out their absolute and solid figure.

Twelfth. Nevertheless, the character of the solid and absolute figure of the sunspots can be known with fair certainty from their eastern, meridian, and western position and aspect. [Margin: Concerning the solid figure of the spots, a fair amount is known.] For the rising and setting aspects give a view of diametrically opposite sides, and the meridian gives the surface intercepted between them. From this it is at least evidently established that the spots are bodies in some way perceptibly deep; and in a matter so remote, so abstruse, so subtle, it would be enough to hold this even by probable conjecture — but if in fact so much is obtained with such certainty, it is altogether to be prized. Indeed, if the spots decline or lean toward the south or toward the north, much of them is also seen from those sides.

Thirteenth. The sunspots are thicker than they commonly appear at the limb.

This is proved, first, because it is certain that on the side by which they face the Sun their thickness is much diminished by the incidence of the Sun's light.

Second, because it is certain, as observational experience attests, that the spots fall short in their other dimensions too — not in reality, but through the force and abundance of the light surrounding them on every side.

Third, because when they come to the extremes, so as to begin to reach the limb, what they stretch out beyond it cannot be perceived.

Fourth, because as long as they are within the disk, they are always diminished to the view by the surrounding solar light. We have countless daily examples of this in physics. From these I draw the conclusion:

that the absolute magnitude of the sunspots is greater than the magnitude presented to our sight.

First, because a non-luminous body placed among luminous ones always appears smaller.

Second, because the surrounding Sun illuminates more than half of any given spot.

Third, because we do not know how great a portion of the spot is submerged within the Sun — a portion which the sight does not distinguish from the rest of the Sun's bright body.

Fourteenth. The apparent thickness or depth of the spots is not as great as either their breadth or their length. This is established by daily experiments and observations, and is proved thus: that depth would appear most of all near the limb; for if the middle and brightest light of the Sun, surrounding a spot at the center, cannot absorb it, much less would the weaker light at the limb do so. And this is taught by the outermost line bounding them, which appears little curved, but almost straight, and so on.

Corollary. From this it follows that, if we set aside the part which is submerged in the Sun and luminous, the remaining, shadowy body of the spot is in a certain way of a lens-shaped [lenticular] figure.

Fifteenth. The solid figure of the spots is always physically altered. [Margin: The solid figure of the spots always varies.]

This is proved, first, because it is always increased or diminished; and these things do not happen in the present matter without preceding, accompanying, and following alterations.

Second, because they are continually condensed and rarefied.

Third, because in their inherent blackness and light they are intensified and remitted.

And these belong to the class of physical alterations.

Fourth, because they continually change their outermost surfaces.

Fifth, because the nuclei vary most of all; and since these are enclosed in the very inward parts of the spots, they prove the alteration most decisively.

Sixteenth. The surface, turned toward us, of the spots as they move around the center of the Sun is bounded by a curvilinear perimeter and is convex toward us with a bulge [gibbosity]; in the round ones it is spherical, to sense, and in the non-round ones it varies. [Margin: The surface of the spots is curvilinear, and is convex toward us.] That they are surfaces bounded by circular or various lines is shown by the perimeter while they occupy the middle of the Sun; that they are convex toward us is clear from their position at the limb.

Seventeenth. The superficial figure of each spot is inconstant, as I hinted a little earlier, both in quantity and in quality; for it increases and diminishes, and is transformed into various shapes. [Margin: The superficial figure of the spots is altered.] There is no need to prove by many arguments a thing met with daily. Look at the figures of the observations, and read through the notes.

And these are either physical alterations, or do not occur without physical alterations.

Eighteenth. The perimeter that determines the superficial figure of the spots is neither constant, nor self-similar, nor even, nor sharply cut; but varied, rough, pitted, and softly fading where it meets the brighter surface of the Sun — flocculent [floccidus], arising from the reciprocal mingling of light and shadows. [Margin: The boundary of the superficial figure of the spots is always variable.] This doctrine needs no other proof than the use of the eye and the reasoning of the mind. For an injury is done to nature if we try to prop up, with arguments hunted from elsewhere as though the matter were uncertain, things that are plain to undoubted sense. It is indeed true that spots sometimes occur whose circumference remains constant and self-similar all across the Sun — as happens with certain round ones, their own optical appearance teaching this; but since this is rather rare, and holds true only in the particular state of some spots,

the assertion proceeds from what generally happens. For the tearing of the edges, and the winding encounter of the luminous with the dark, is so familiar to this phenomenon that from day to day, and almost from hour to hour, now new angles of shadow, now new bays of light, arise. Meanwhile this remains the constant rule: whatever kinds of boundary-circuits and outlines finally come to be — whether curved, or straight, or, in the end, mixed — they never appear clean, sharp, or drawn out along an even thread, but always rough, toothed,

serrated, and sprinkled with certain little fibers; and this itself is never in the same manner, position, and state, but always joined with the utmost variety.

The alteration of the solar phenomenon is proved also from other appearances

Cap. L.

Whatever has so far been discussed concerning the primary spots will, I think, sufficiently persuade the lover of truth of their alteration; and although most of it can be applied to the secondary spots and to the faculae themselves that are associated with them, still I have thought it well to open up here, in passing, certain general sources of alteration, so that anyone bound by the zeal for investigating the truth may have a point from which to proceed further.

The various sources of alteration.

The first, then, is that the whole Sun is found crammed with umbrae — that is, secondary spots — and with "luculi," that is, secondary faculae, and these ever changeable. [Margin: The first source of alteration: from umbrae and luculi.] For not only do they change from day to day in place, in bulk, in figure, and in brightness and darkness, but they are mutually converted into one another. Hence it is utterly impossible that they should not be altered. See the *Meditullium*, with its Notes, in the earlier book.

The second source from which alterations flow is this: that around the poles of the parallels described by the spots one sees fairly ample spaces of the solar surface, entirely bereft of primary and secondary spots and faculae, overspread with the tranquil splendor of the Sun and with an evenly shining, gleaming surface. [Margin: The second source of physical alteration: from the ample, tranquil, and homogeneous tracts of the solar surface.] Yet these very spaces are not constant to themselves in extent, in figure, or in time, but vary, and are very often sprinkled with secondary spots and luculi; just as, conversely, other regions crammed with spots or faculae are cleared out and calmed into a uniform appearance. Indeed — what you may wonder at more — such portions of the solar surface, quiet and calm, empty of every deformity of any spot or facula, whether primary or secondary, are sometimes carried into the very Torrid Zone, that is, the royal highway of the spots, and are advanced along with them in the manner of the spots. And these vicissitudes assuredly cannot occur without a true alteration.

A third source of alteration is gathered from this: that the whole Sun is often, for many days together, free of every primary spot — which does not happen without the greatest alteration. [Margin: The third source of physical alteration: from the absence of spots and faculae.] The same must sometimes be held of the primary faculae as well.

A fourth source of alteration — and an evident one — breaks out from this: that the purest faculae are kindled on the Sun and again extinguished, the space they had occupied being turned back into the earlier, less bright form of the solar surface. [Margin: The fourth source of physical alteration: from the kindling and extinction of pure faculae.] In this case an alteration must necessarily intervene. For that this change cannot be ascribed to a translucency of the Sun is proved also from this: that faculae of this bright kind extend to the outermost surface of the visible Sun, since at their rising and setting they sit upon the perimeter of the horizon — as the most frequent experience and continual practice of observing testify (though I shall treat these more fully below, in the discussion of generation). Whence it is necessary that, both when such a facula is born and when it dies, the physical and visible substance of the Sun itself, which is plain to view, has been altered; for

[Conclusion of Cap. L — the fifth and sixth physical sources of alteration.]

[Margin: The fifth physical source of alteration: spots converted into faculae, etc.]

for a facula has taken its place, and the spot in turn steps into the place of the facula — not the same individual, but the same kind.

A fifth and most abundant source of alteration wells up here: nearly all the spots so far observed have been seen to pass off into faculae, and in the midst of the faculae themselves spots sometimes emerge. This metamorphosis undoubtedly carries with it a vast crop of alterations — especially if we reckon into this fountainhead, as we should, those faculae that the spots carry along in their own train. For they come to birth on every side and on every side are done away with, and they display countless variations, seen not from an oblique, sidelong optical view but from a direct and full one.

[Margin: The sixth physical source of alteration.]

A sixth source of alteration bubbles up — and this the most beautiful. Just as on the solar surface bright, quiet spaces, and the like, are seen for several days at a time near the poles and occasionally in the middle (as I set out under the Third source), so, conversely, on that same solar surface there often rise up certain

broad tracts, spread over the Sun with an even and delicate sort of haze, in the manner of clinging smoke or a slow-moving mist, or of small clouds laid over the brighter parts. Appearances of this kind differ from the primary spots in that they are of a much thinner and more delicate shadow, greater in size, shorter in duration, and are not easily transformed into spots. They differ from the secondary shadows in that they are darker, more constant, and larger, and are ordinarily detected with an observing telescope [Telioscopio]. Outpourings of such sootiness not rarely occupy the largest parts of the Sun. In the end they are consumed and restore the Sun to its common brightness. If all of this does not prove alterations, then I do not know what alteration is.

These sources, and others like them, I ought indeed to have set out more fully; but the constraints of time did not permit it, and something too had to be entrusted to your own effort, fair Reader, and to my later labors.

On the Rising and Setting of the Solar Phenomenon [De Phaenomeni Solaris Ortu, & Interitu]

From the observed phenomenon of the Sun there are briefly brought forward and weighed those matters that bear on the physical rising and setting of the spots and faculae.

Cap. LI.

Concerning the local motion, the increase and decrease, and the alteration of the spots and faculae, I have already, as I think, drawn arguments from the phenomenon itself effectively enough. These points, of themselves, indicate clearly enough — and lead the observer, as it were, by the hand — that it cannot be that in bodies so great, changes so great and so sudden should occur without the accompanying or attendant passing-away or coming-to-be of the moving subjects. Yet because to many this outcome may perhaps have seemed either incredible or unexpected, one must bring forward evidence proper to the matter, and only then the argument — and this for the sake of the truth, and of those who burn with desire for it, whom I have always striven with every effort and duty to serve alone. Bear with me patiently, dear Reader, while I lead you step by step into the innermost recesses of this rather hidden inquiry.

That spots and faculae are born and pass away: a first indication, drawn from their appearance and disappearance on the visible disk of the Sun.

The greatest part of the spots come newly into being directly on the open face of the Sun, grow, advance, and set astronomically; again, a great number of them rise astronomically, but fail entirely before they reach their setting; many too there are that undergo neither an astronomical rising nor an astronomical setting, but begin and cease to exist between the two, on the Sun; and finally many there are that endure through the whole Sun turned toward us, from rising all the way to setting. Thus we find a fourfold class of spots: some set without any prior astronomical rising; some rise

[Margin: The physical rising and setting of spots is a strong indication of generation, etc.]

with no ensuing setting; some enjoy neither; some enjoy both. As for the last, the argument I have in hand does not bear on it directly; by design it looks to the earlier ones.

Spots without [astronomical] rising, but with astronomical setting.

[Margin: Spots that come to birth on the Sun by a merely physical rising, not an astronomical one, prove generation.]

That spots which appear on the Sun suddenly and abruptly, and then advance by the ordinary path together with the rest, are there generated anew — of this the following are the evidence. They begin under the least size and with a faint darkness, and grow gradually in both respects. Certainly no spot of great size or of intense blackness has ever yet appeared at its first showing; therefore they did not exist before, otherwise they would not have escaped the eye. For it was proved above that, from the meeting of several bodies running into one another this way and that through their revolutions, these spots do not appear as some newly more perceptible aggregate, nor, when the bodies again move off elsewhere, do they disappear. And it will be shown determinately below that it is impossible for solar spots to arise from the concurrence of opaque parts, from hard risings turned around the Sun in perpetual rotation. And since neither the other explanation seems sufficient either — especially for the forming of the nuclei and the faculae — it remains that we take refuge in generation.

Spots without setting, but with astronomical rising.

[Margin: Spots that set on the Sun by a physical, not an astronomical, setting suggest their corruption.]

In the same way, very many climb above the eastern solar horizon, but fail gradually before they attain their setting. They fail both in size and in darkness,

so that nothing at all like them remains, but only the common surface of the Sun, [nothing?] brighter than it [?]. Since, then, they are so consumed that no perceptible accident belonging to them is left over, it is strongly suggested that they perish. And this is confirmed, because they are not sufficiently explained by dispersion through local motion, nor by rarefaction or alteration; hence it accords with the truth that corruption intervenes — especially when, in the very bosoms of the spots,

large nuclei pass off into blazing faculae — which happens not rarely, whether wholly or in part.

Spots lacking both astronomical rising and setting.

[Margin: Spots are physically born and physically die on the Sun itself, without any astronomical rising and setting; from which generation and corruption are proved.]

Spots of this kind, ignorant of astronomical rising and setting, are very frequent; and rarely is there some large spot which does not, at least for some little while, enjoy a similar temporary retinue. They sometimes go before it, but more often follow behind, or gird its flanks — now on the north, now on the south, now separately, now on both sides at once. Yet the service they render is neither long-lasting nor faithful: for some do not last a day, some last two days, a few last three and even longer, but they withdraw themselves from attendance with the same fickleness by which they crept in, stealthily and unnoticed. Small and whitish they mostly come; small and pale they ordinarily depart; they grow quickly and shrink quickly. If, then, you infer that all these spots — and any others — are generated and corrupted, from the fact that nothing seems lacking to them for the nature of rising and passing-away (as will be shown more distinctly below), provided that whatever happens in the phenomenon be well weighed [you will judge rightly]. Here too belong the temporary flashes of light [interlustra temporaria] that supply torches to the spots, the many-colored bright clouds [nimbi diuersicolores], and whatever similar appearances step onto the stage.

[Margin: Separate faculae: indications of generation.]

What I have said of the spots must be applied to the separate faculae as well, for they behave in a like manner as to rising and setting. For many are born anew before setting, many perish after rising; there are also some — but rarer and harder to observe — which, in the middle of the Sun, come forward as onto a stage, and dart out before they reach the western horizon. That these are truly

and properly generated, no one will deny who reflects that they possess, from their own nature, an internal source of light greater than the rest of the body of the Sun and innate to them — of which more shortly, in its place.

That spots and faculae are generated and corrupted: a second ground, from the fact that they do not return.

[Margin: The generation and corruption of spots is suggested by the fact that they do not return, and by the fact that the Sun is not rarely entirely free of them.]

If the spots did not perish, they ought to return in a span of about 27 days, as is established from the return of some of them and from many other arguments. But they do not return, as daily and unbroken experience testifies. Therefore they perish. And therefore they are also generated — since what cannot be generated cannot perish. Up to now, certainly, no spot and no facula has lasted forever. That they ought to return is established from the fact that they abide on the Sun, as will again be proved distinctly below.

To this belongs the perpetual change of the secondary spots and faculae.

Likewise, the fact that the Sun is sometimes free of primary spots for nearly a month's span.

Therefore all those that had earlier run across its open face must then have perished.

That spots and faculae are generated and corrupted: the decisive argument [Argumentum palmarium], from the fact that out of spots faculae come to be; and to strengthen this argument, the production of faculae by translucency is expressly refuted.

Cap. LII.

[Margin: Spots are truly generated into faculae.]

The greater number of the spots degenerate into faculae, as experience testifies; and that this should happen without a coming-to-be and a passing-away is not credible. For the spots, by the very fact that they are such, are colored and opaque — especially if we attend to the nuclei; and that all this should be converted into a substance brighter than the Sun itself, by rarefaction alone, without any consequent generation, is altogether impossible, nor is it easy to find an example of such a thing.

[Margin: Rarefaction is refuted.]

For rarefaction, of its own nature, does not tend toward the luminous; on the contrary, the rarer the fire, the less bright and the more transparent it appears. From the fact, then, that the solar spots rarefy, it does not necessarily follow that they will become brighter.

You will say that this follows in the underlying matter: that the spots eclipse the Sun, and that when they are dispersed and rarefied and consumed by the Sun's activity, the obstacle being removed, the Sun itself shines out from that place purer and clearer, and that this surpassing splendor is thereupon reckoned a facula.

[Margin: By the Sun's translucency, faculae are not generated.]

I reply that this objection coincides with the translucency [tralucentia] of the Sun, which we showed from the phenomenon itself to be impossible in what came before. Still, it is worth recalling something here, and treating the same argument more distinctly, so that this empty escape may be shut off entirely.

For, on the contrary, there is the fact that countless faculae shine most limpidly on the horizon — now the eastern, now the western — onto which they could never be projected by translucency alone. For that translucency (as the adverse opinion would have it) holds the Sun — most clean, most polished, equally bright everywhere — shut in, as in a cage, within a surrounding spherical surface-crust, and lets through to us just so much clear light as the Sun bores through, with its own most piercing darts, from the walls of that prison; and yet those very fissures are, by I know not what Vulcan, stopped up again and again, lest poor Phoebus should cheer us more freely with that countenance "*with which he clears the sky and the storms*" [Virgil, *Aeneid* I.255]. Therefore, granting and admitting translucency, no facula will ever appear on the horizon. Which I demonstrate as follows.

In the following figure, let the semicircle BCD, described from A, be the apparent hemisphere of the Sun; and around it let there be a translucent sphere, the regulator of the solar rays — let it be BED, concentric with the Sun, bounded by two surfaces, the inner BCD and the outer FEG. And let this be that sphere which, by its variety and mutability, is supposed to introduce into the Sun all the apparent, unstable diversity around the spots and faculae, as it pleases the adversary. These things being posited, suppose there is some spot EH, and that it, transmuted by rarefaction and consumption, has by translucency alone [passed] into a brilliant facula CK, no part of which enters the surrounding thickness of

the sphere, CH or HK, but which is wholly bounded by the most brilliant and polished surface of the Sun, CK —

CK, and thence [passes] into the eye LM, which lies in the same plane — one passing through a parallel of the facula BCD; let it shine with the rays CL, KM. These things being posited:

I say first: from the facula CK — even if it should persist and remain in its full vigor, and reach the horizon B in its liveliest state — not even a spark of light will reach the eye N.

Let the facula CK, then, have arrived at the horizon B, and let it be BO, and let it shine to the eye N by the nearest ray ON, which proceeds from the last point O of the facula and cuts the outer surface FE of the surrounding sphere at point P; and to that point let the straight line AP, drawn out, divide the common surface of the sphere and the Sun, BOK, at point Q; and when the chord OQ is joined, let the triangle OPQ be formed. Now since the angle AQO is less than a right angle — for it is less than the mixtilinear angle OQA, which is the internal right angle at the circumference of the circle, and so is itself less than a rectilinear right angle — it follows that the rectilinear angle OQP, adjacent to angle OQA, is greater than a right angle, since the two together are equal to two right angles. Therefore QOP, in the same triangle OPQ, is less than a right angle, and consequently much less than OQP. Therefore the straight line PQ, subtending the smaller angle O, is smaller than the straight line OP, which in the same triangle OPQ subtends the greater angle PQO. Hence, if the point of the Sun Q — being equally powerful as the point O — cannot with its own direct and shorter ray QP penetrate the perpendicular thickness PQ of the surrounding sphere (as the adversary wishes and supposes, and as in fact it does not penetrate, the very phenomenon of the faculae and spots bearing witness), how will the ray OP, oblique and much longer, cross the same oblique breadth of the interposed sphere? It remains true, therefore, that from the facula CK, or BO, nothing will reach the eye N — that is, if they reach us out of the rarefied sphere by translucency alone; which was to be demonstrated. And this is one [argument].

And since the continuous nature of the phenomenon cries out against it — for the faculae resting on the horizon are almost infinite in number — it is manifest that this too is false and impossible. It is not, then, from mere

translucency that the faculae arise, but from a true change of that matter of theirs. Or thus: if the point of the Sun O shines through unharmed to P along the longer line OP, then the point Q will shine through to the same P along a shorter

line; and so of each of the points of the solar surface. Therefore the Sun will shine through everywhere equally — which again is false, and contrary to the daily custom of the phenomenon. And what I have proved of the facula-point O will be demonstrated likewise of the point B, and of any point interposed between B and O.

[Margin: An objection on behalf of translucency.]

But the adversary will say that this demonstration does not conclude unless a uniform arrangement of the surrounding sphere BPK, in rarity and density, is assumed. For suppose someone denies that the part BRQ has the same temper while the facula B rests on the horizon as it had while that same facula occupied the middle of the Sun at CK, but instead asserts that, with the facula B situated around the horizon, the portion BRPQ is rarer, and thus made passable to the ray OP of the facula BO by its translucency — and that this happens of necessity, by the nature of the Sun and the demand of this phenomenon, in such a position of faculae situated around the horizon: if, I say, someone should stubbornly urge this, the demonstration set out above does not compel such an obstinate opponent. For the longer ray OP will shine through along a longer but rarer tract, while meanwhile the shorter ray QP cannot break through the shorter but denser gap of the surrounding sphere. And so the demonstration brought forward is enfeebled, not overthrown; rather, the Sun's translucency remains the more strongly established.

[Margin: General reply.]

I reply that it is indeed true that the demonstration brought forward proceeds and has force, among other cases, when the affection of the body surrounding the Sun is equally dense or equally rare. Nonetheless, whether these things — arbitrarily thrust in — rest on any reasoning, or are consistent with the assumed hypothesis and the truth of the phenomenon, must be examined more inwardly and considered more carefully.

[Margin: Assumptions granted for the sake of argument [ad hominem].]

Now the hypothesis is this. First, that the Sun ABCD is most perfectly spherical, homogeneous, uniform, equally luminous, by nature incorruptible, rigid with a hardness more than adamantine. Secondly,

Diagram. A geometric construction filling the upper part of the page, illustrating the "visible Sun" and the translucent sphere supposed to surround the Sun's globe. The figure is partly obscured by heavy verso show-through, so several

small labels are uncertain. Its overall structure: a large arc (the semicircle **A G H F**, the "visible Sun") sweeping from an apex at upper right down the left side; the Sun's own globe **F K G** set within it; and the ambient sphere lying between the external horizon **G H F** and the internal horizon **D K B**. Sight-lines run to the eye at the bottom.

- A (apex, upper right of the arc): vertex of the semicircle representing the visible Sun; dashed lines run from A downward.
- B, F (upper right, near the top of the vertical diameter): points on the horizon; a small quadrilateral **O–R** is drawn just below B–F.
- Q, P (below O and R): points on the sight-line / horizon OP.
- G, D (top of the left arc): the external and internal horizon points on the eastern side.
- V, S [?]; X, m [?]; β , γ [?]; C — a descending sequence of labels along the left arc marking successive faculae/portions.
- C, K (mid-right, small box): the meridian portion CK of the Sun.
- H, E (right, small box below CK): interior points of the sphere near CK.
- L, M (foot of two vertical lines at the bottom).
- N (bottom center): the eye [oculus].
- α , z [?] (near the foot of the left arc).

Secondly: this same Sun is more luminous than any other naturally luminous body.

Thirdly: this very globe of the Sun is smaller than the body **F K G** that surrounds it.

Fourthly: the sphere thrown around the solar globe is larger than the globe by exactly as much thickness as the depth of any of the spots [maculae], together with their nuclei, requires.

Fifthly: this envelope of the Sun is by its own nature denser than the celestial aether — opaque, indeed, yet endowed with some light — and it comes into view on the side where it projects beyond the Sun's body. (As for the case in which the excess does not fall within view, I shall treat of it later, in its proper place, at the end of this demonstration; meanwhile I pursue my aim, assuming from the hypothesis that a sphere larger than the Sun appears as one thing together with it, and that on every side, even where it passes beyond the Sun, it bounds our sight.)

Sixthly: the nature of this sphere is fluid, mobile, and changeable in every way; and therefore every variation in the Sun arises from it.

Seventhly: the solar faculae [faculae], however, are not in this sphere, but on the surface of the Sun, and they shine through it only where, by rarefaction or some other change, it has opened up transparent windows for the light to pass — the very windows the adversary always insists on finding in a horizontal facula.

With all this supposed, then, let us see whether the objections that the opposing side heaps up with so much effort — on behalf of a fictitious translucency [tralucentia], against the demonstration already made — are consistent with reason and compatible with the assumed appearances of the solar phenomenon [Phaenomenon solare]. For the sake of greater clarity, to avoid every ambiguity and cut off every handle for error, I call "the visible Sun" [Sol aspectabilis] that whole luminous mass which daily rises above our horizon and again sinks below it, and in which all the variety of this phenomenon has so far been shown to reside; and it is represented by the semicircle **A G H F** — whether that mass be one continuous sphere, or, as the adversary would have it, be compounded

out of the Sun's enclosed body **A D K B** and the mass **D H B** of the sphere poured around it. Let us call the outermost perimeter of this mass the *external horizon* of the visible Sun, or the horizon of the spots — such as **G H F** is. And the perimeter of the enclosed Sun [Sol inclusus], **D K B**, let us call the *internal horizon*, or the horizon of the faculae.

[Margin: *Responsiones particulares* — "Particular replies."] These things being premised, I say it cannot be that the appearances of the solar faculae are saved by a horizontal translucency **O P**, on whatever grounds they may at last be defended — and this because of the following absurdities.

First. No solar facula would ever be seen to rise or set on the external horizon of the Sun; that is, no facula **D** would rise at the point **G**, and none, **B**, would set at **F**. But this is false, and perpetually contrary to the constant tenor of the solar phenomenon — as I have shown from many thousands of observations and their expositions in the third book, and so on. For the facula **B O** does not shine through from **O**, along **O P**, to the eye **N**; rather, if it is truly viewed from the eye **N**, it stands at **P**. Otherwise, as I said, sinking toward the west, it would not be found on the outermost surface of the visible Sun, at the point **F** — which nevertheless always happens, the solar phenomenon being preserved. Here, however, note that I do not say all faculae reach the setting-point of the solar horizon, for some are extinguished earlier, in one way or another; I say only this:

on the plane of the solar horizon I have noted no facula, by the various rules of exposition and examination, that I did not also find on the outer horizon.

Second. No facula has ever been detected by me either rising or setting on the Sun's internal horizon — which nevertheless ought to happen if one assumes the Sun's translucency through the larger surrounding sphere. For since the enclosed Sun is bounded by the horizon **B C D**, a rising facula would stand at **D** and a setting one at **B**; and so, within the visible Sun, every facula would necessarily rise, namely at the point **D**, and within the same would set, namely at **B**. Since the perennial tenor of the phenomenon is diametrically opposed to this, judge for yourself whether that translucency is real.

Third. Every facula at its rising or setting would be longer than at midday — because at setting it would shine through along the whole line **B O P**, [showing] the Sun's part **B O Q**, as will be proved later; whereas at midday it shone through only along the line **C K**. But these things run counter to the phenomenon, since the faculae in fact grow slender near the horizons.

Fourth. Every eastern or western facula would be accompanied within the Sun by a dark gap as great as the line **G D** or **B F**. But this contradicts the phenomenon.

Fifth. The eastern facula **D S**, since it would shine through the whole space **D S β**, would also appear in the middle larger — by just that much space — than experience of the phenomenon allows; which will be confirmed below, once the various evasions have been shut off.

Sixth. No courses of faculae would be lawfully joined with the courses of their own spots; none would be placed on the outermost surface of the visible Sun; all would be found irregular and disordered — against the whole tenor of the phenomenon, against the practice proven by earlier observers, against so many adduced expositions and demonstrations.

Seventh and last, that we may reason on physical grounds as well: the facula **B O** shines through the part **O P** either because its position is oblique, or from some other cause ordained by the Sun, or by chance. If the first, there will be no spots on the horizon, on account of the oblique position, and the whole Sun round about will shine through — for everywhere the ratio of an oblique or sloping position is the same.

If the second, that cause which rarefies the surrounding sphere so that the Sun shines through is either the Sun's rotation, or light, or some other quality in the Sun endowed with the power of rarefying. Not the first: because that sphere is

carried around with the Sun, like a garment with the clothed body — for the motion of both is as the motion of one, as is quite clear from the observations. It does not appear, then, why the Sun's rotation should not condense that sphere as much as it dissipates it — especially since the spots are condensed in those same parts where the motion runs hot, whereas around the poles, where there is great rest, neither spots nor primary faculae arise. Motion, then, or rest, contribute little here. Yet, granting that it must be ascribed to motion — since in the middle the Sun's rotation is equally

Diagram. The same construction as fig-p673-1 (semicircle **A G H F** = the visible Sun; the globe **F K G**; the horizons **G H F** and **D K B**; faculae and portions at **B, O, R, Q, P, D, S, β, γ, C**; the interior points **C K, H, E**; the eye **N**; the feet **L, M**), reprinted here at the head of the recto so that it stands beside the continuing text. Reading of the smaller peripheral labels is again limited by verso show-through.

swift as at the horizontal extremes, there is no greater reason why the solar motion should not dissipate the sphere around the Sun's middle as well, but should dissipate it only around the extremes: therefore [it acts] either everywhere or nowhere.

But for the same reason it follows that the Sun's light cannot be invoked to produce this rarefaction. For since, by hypothesis, that light exists everywhere with equal power, what reason could there finally be why it should thin the surrounding sphere in the neighborhood of the horizon but not in the middle? The power to act is the same everywhere, the patient the same and applied in the same way; and yet the Sun's part **C K** cannot act on the points **H** and **E** of the sphere, which lie near it, while the facula revolves in the high Sun — whereas that same part **C K** of the Sun and facula can act on those same parts when it has descended into the low Sun, at **B O** and **F K**. For on this translucency hypothesis a facula is nothing but some fixed uncovered part of the Sun laid bare — such as **C K** is in the example. This part **C K** of the Sun, then, by its own light drives off the portion **R O P** of the surrounding sphere near the horizon at **B O**, but does not disperse

it at **C K** — even though the necessary agent be present and all else be set simply equal: a luminous Sun as agent, the sphere carried round as patient, the acting power one and the same in number (namely light), the application the same, the contact of Sun and sphere immediate. The only difference lies in this, that time and position intervene; but these, in this case of orderly rarefaction as it usually occurs here, neither help nor hinder — because at its rising the same facula **D S** had already, by rarefying, worked upon the parts **S β**, and therefore ought, in the

manner stated, to have continued the same in the middle as well, and to have renewed it at the extreme, near **B O**. And so this philosophy I have neither learned nor understand — a philosophy which, springing from the assumed translucency of an imprisoned Sun, embraces that very translucency, to which vanities against the manifest truth are pleasing. For my part, with these reasons standing in the way, I cannot go blind against the light of noon.

There is a further point. If the facula **B O** shines through by the bright ray **O P**, the part **O R P** must be made pervious to light; and therefore also the part **O P Q** — otherwise the Sun's luminous part **O Q** would have overtaken the

remote portion **O R P** and would not have overtaken the neighboring **O P Q**, which is absurd: therefore the whole portion **R Q** shines through. And so, if the western part of the Sun can do this, the same midday part can do it too. Since it does not do so at midday, by the witness of experience, neither does it at setting. The translucency of the ray **O P** is therefore fictitious, and idly contrived. These considerations, then, do effectively take this cause away from the light.

But the same reasons will produce entirely the same result against any rarefying power whatever. For either it will belong alike to the whole Sun, or to certain parts. If to the whole, the same arguments are taken up again that told against the light. If to certain parts, there is no greater reason why that power should open that sphere in the stated orderly way near the horizon than around the middle — since it is one and the same in number, and the rest is identical in the individual case; and if it opened elsewhere in another way, there stand against it the things we set down a little earlier, absolutely, against translucency.

Finally, every part of the enclosed Sun that answers to the horizon lies within the concave surface of the ambient sphere; but no apparent facula is within the concave surface of the ambient sphere — rather, [it lies] outside, on the convex surface — since it reaches [radiat] the visible horizon of the Sun, both at rising and at setting, no less than a spot does; therefore no apparent facula is a part of the enclosed Sun. Therefore the enclosed Sun, even if it were granted to be transparent, will not produce faculae for us by translucency. This translucency, then, is fictitious, and the first demonstration stands in its own strength.

Or thus: if the faculae are translucent parts of the Sun, then either the Sun is uneven, or the sphere that dims the Sun penetrates it — because all the horizontal faculae lie in the visible surface of that same Sun. But the adversary will grant neither. Let him therefore, not unwillingly, dismiss a translucency gratuitously fabricated and destructive of the solar phenomenon and of the *Rosa*

Ursina, and gladly yield the palm to experience, to reason, and to most powerful truth.

[Margin: *Sphaera ambientis tenuitas invisibilis refellitur* — "The invisible tenuity of the ambient sphere is refuted."]

[Margin: *Refutatur casus ille, quo sphaera Soli circumducta ita subtilis asseritur, ut id quod ex ipsa Solem excedit, in visum prae tenuitate non cadat* — "That case is refuted in which the sphere carried around the Sun is asserted to be so fine that what of it projects beyond the Sun does not, on account of its thinness, fall within sight."]

I come now to that case in which the obstinate objector [refractarius] does indeed carry the sphere **F K G** around the Sun **A B C D**, but so conditioned that on the side where it covers the Sun it dims it, while on the side where it falls outside it does not strike the eye. From this he wants it to follow that, of the portions **D β G** (at rising) and **B P F** (at setting) which fall outside the Sun, the eye perceives nothing: for in that region either there are spots, and these by their opacity escape sight; or else [what is there is] the very substance of the ambient sphere, and this, by its thinness, draws so little light from the Sun that it throws none back to view, and therefore remains dark. And so, along this portion of the sphere set beneath the Sun, everything that physically occurs in the sphere will be transcribed onto the Sun itself — just as, conversely, the Sun's own light passing through the sphere will be attributed to the sphere, when in reality it comes about by mere translucency. By this plausible discourse the stubborn man hopes he has fortified and defended himself as with an insuperable rampart — but how idly, will soon appear.

For, the solar phenomenon standing firm, my own observations and others' standing firm, the expounded courses of the spots standing firm, the true place of the spots and faculae standing firm — a thing demonstrated in so many ways and by so many means — it is impossible that this position and explanation of a sphere set around the Sun should stand. For indeed:

First. From the observed and expounded courses of the phenomenon, all the spots have their centers placed on the sensible surface of the Sun, **D C B**; but on this refractive fancy, no spots have anything of themselves on the Sun.

Second. From the observed and demonstrated courses of the spots, one and the same regular course is formed and continued, both as a spot passes into the place of a facula and as a facula succeeds into the place of a spot — as I have made plain by very frequent examples, and could show by countless more. But on this

obstinate man's contention it is impossible that the course of any spot be combined with the course of any facula, because the faculae would always be parts of the Sun while the spots are outside it; and so the courses of the former would be nearer the Sun's center **A** than the courses of the latter, and therefore smaller than these.

Third. From my observations and their

Diagram. A schematic geometric figure spanning the top of the page across both columns, illustrating the refutation of the "translucency" hypothesis. A large curved line (the Sun's visible surface DCB) sweeps from the upper left down to a low central point and up again to the right; an outer boundary and a stepped "staircase" of short segments on the left represent the promontories and valleys of the surrounding, supposedly translucent, sphere GHF. Dashed lines run from the apex **A** down toward the left-hand stepped figure and toward the right. Vertical drop-lines descend from the central points to the base line. Readable point-labels, by position:

- **G, D** (top left corner)
- **A** (apex, top center; dashed rays converge here)
- **B, F** (top right corner)
- **V, S** (left, upper step of the stepped figure)
- **m** (left, next step down)
- **X, β** (left, lower steps)
- **O, R** (right side, below **B F**)
- **Q, P** (right side, below **O R**)
- **C, K** (center, at a small dotted rectangle)
- **H, E** (center, just below **C K**)
- **L, M** (base line, left of center)
- **N** (base line, center-right)

[Additional small letters near the left-hand stepped figure — the text references points **T** and **Y** in this region — cannot be resolved with certainty on the scan.]

[Column I]

and once these have been demonstrated, reviewed, and duly approved as valid expositions, every sunspot [*Macula*] displayed on the Sun's surface — such as DCB — exhibits the utmost regularity of motion; but outside [that surface], where the advocate of refraction [*refractarius*] would have it, on the surface GHF, it

preserves none: because, in being projected, it is assumed onto a fictitious larger path, with DB as the smaller diameter, and so on.

Fourthly. In my observations and in the courses I have set out, countless courses of spots are found running from D, the eastern rising point of the solar horizon, to B, its western setting point — not only crossing optically, but, day by day, advancing in the most orderly fashion across the whole semicircular arc over the solar surface. On the adversary's imagined scheme, however, none of this is ever possible, because any spot that appears optically at D really rises near β and sets close to P — since it is posited by the adversary to run its course along the greater perimeter G β P.

Fifthly. According to what I have observed, set out, demonstrated, and duly approved, the curvilinear courses of the spots are not very unlike segments of ellipses; the spots linger long at the horizon; there they grow markedly thinner; and the apparent segments of their tracks sometimes reach half of the ellipse, sometimes grow beyond half. All these things —

[Column II]

— because of the course assumed outside the Sun, as I demonstrated earlier, cannot hold together.

Sixthly. According to observation and the truth of the phenomenon, all the courses of the spots of the apparent solar hemisphere — those contained within the quadrant that the elevated pole and the greatest of the parallels define — are equal to or greater than the hidden ones; but on this [adversary's] position — because on the horizontal line DB the spots would neither rise nor set, but would rise long afterward at β and set long before at P — this does not happen.

Seventhly. On this position the returning spots are not accounted for, because their visible courses are too short to correspond to the hidden ones, and the times are in no way proportional to the [other] times.

Eighthly. On this position, while facula D, for example, is rising, spot G — standing directly above it — is still ranging far outside the point of rising; and when it reaches that point near β , facula D has ascended to γ and has passed beyond the arc D γ ; again, when the same spot from β arrives at ϵ , facula γ has ascended to δ ; but when that same facula reaches CK, the middle of the Sun, the spot will stand directly above it at HE — (I am assuming, in accordance with the phe-

[Column I]

—nomenon, that both move on the same parallel in like proportion.) Then, when the facula has been carried to Q, the spot will set at P; but when the facula sets at B, the spot will still be ranging far outside the horizon at F. And so the same facula will both precede and follow the same spot, in both time and place, on the Sun's apparent disc. Since these consequences openly clash with the solar phenomenon, being unheard-of and monstrous, they cannot and must not be admitted. Hence the opinion from which they follow — the aforesaid translucency of the Sun — must be held for certain to be false.

Positive arguments, to be drawn from observations, against the aforesaid fantasies of translucency

Firstly. Many faculae adjoining spots — whether toward the north or toward the south — settle together on the eastern horizon; then, cohering with one another in the same way, they advance for many days until one or the other is consumed. Many again, in the same steady manner, proceed together from the middle of the Sun all the way to setting, and reach contact with the horizon together. But this would be impossible if the spots existed on a different surface than the faculae. For the horizon on which a facula exists is the outermost limit of the solar globe, which the spot would long since have crossed if it moved on a different and more remote surface from the Sun's center than the facula does — as you will plainly recognize by recalling what was said a little earlier at number 8. And since they are always mutually linked to one another within the Sun and at its edge, that conjunction is not merely optical but physical. This argument, well weighed, admits of no escape.

Secondly. Many nuclei of spots are cleft, and through that slight interstice [of light] they have nourished a bright facula right up to the horizon — which they would have overspread much sooner if they themselves had been correspondingly higher, as the opposing side maintains. As is likewise gathered at number 8.

Thirdly. Many spots at the horizon are so overwhelmed by the brilliance of the faculae that they can scarcely be distinguished, except very grudgingly [with great difficulty]: an evident sign, therefore, that such spots are in some way enveloped by the faculae.

Fourthly. The centers of faculae that have grown out of spots are found on the same parallel and the same surface of the Sun on which —

[Column II]

— the centers of the spots were found, by the most rigorous examination, down to the fineness of a single hair. Of this I have given very many specimens.

Therefore, if spots and faculae move on the same bright and visible surface of the Sun and keep the same perceptible distance from the center, it is clear that the Sun's translucency is banished, and that they come to be through mutual alterations. But if anyone should nonetheless wish that, enclosed within this physical and alterable surface of the Sun, there be an unchangeable — yet never visible — globe of the solar body, a fount of perennial light, he is free, for all I care, to imagine whatever he likes for himself; provided it be established from what has been said that the solar faculae neither are, nor can be, nor can in any way be called or imagined to be parts of the said Sun as though it were translucent, without doing violence to the solar phenomenon. Now let us return to weaving our web.

I say, second: that no spot, whether rising or setting, will be converted into a facula visible to us.

For suppose — if it can happen — that the setting spot FR is converted into the facula OB, which shines into the eye N along the ray OPN. Since, then, the facula is seen under the ray ON — the sphere being OPK — it will be transparent along the longer segment OP, which nevertheless was not and is not transparent along the shorter segment PQ, notwithstanding that point Q shines directly and point Q [?] shines obliquely. But this is absurd. Therefore the facula BO does not shine through in consequence of the departure of the spot FR. It remains, then, that no rising or setting spot, as it vanishes, will leave behind it a facula there visible to the eye N, etc. — which was to be demonstrated. For what I have demonstrated of the western side holds equally of the eastern, GV, etc. And this is the second point.

Since the phenomenon opposes this consequence with unbroken constancy — for six hundred spots and more, around rising and setting, have been converted into most brilliant faculae, and are converted daily — it is evident that even the hypothesis from which these falsehoods follow is itself false. False, therefore, is the Sun's translucency; and, from the very appearance of the faculae, false and fabricated is the sphere placed around the Sun by our adversaries — whereas true is our own account, the production of faculae out of spots.

I say, third: that separate faculae, around the solar horizon both morning and evening, will never optically coalesce into a single —

Diagram. The same geometric construction as fig-p677-1, reprinted at the top of this page across both columns. The large curve (the Sun's visible surface DCB)

descends from the upper left to a low central point and rises again to the right; the left-hand stepped figure and outer boundary represent the promontories/valleys of the surrounding sphere; dashed rays converge on the apex A; vertical lines drop from the central points to the base. Readable point-labels, by position:

- G, D (top left)
- A (apex, top center)
- B, F (top right)
- V, S (left, upper step)
- m (left, next step)
- X, β (left, lower steps)
- O, R (right, below B F)
- Q, P (right, below O R)
- C, K (center)
- H, E (center, below C K)
- L, M (base, left of center)
- N (base, center-right)

[Small letters near the left-hand stepped figure (the text names T and Y here) are not resolvable with certainty.]

[Column I]

[Margin: By this fictitious transparency of the Sun, the optical coalescence of horizontal faculae is destroyed.]

— facula. Let there be two eastern faculae, S and T. Since, then, S does not reach the eye Z along the ray SZ, being blocked by the portion of the sphere VX, while T does not reach the eye α , being obstructed by the part TY, it is clear that neither facula will be seen; for they lie hidden, like valleys sunk into the Sun's surface DST, between the high promontories of the surrounding sphere — the projections VX and T β Y. The faculae shine forth only along a direct line, through the gaps VG and β X opened by rarefaction, on the adversary's arbitrary [assumption of] transparency. Therefore, since two or more horizontal faculae would lie hidden entirely, as though behind sedge, it is clear that they will not optically coalesce into one — which was to be demonstrated. And since the phenomenon repeatedly shows us the opposite, it is manifest that this hypothesis, convicted of falsehood, must be hissed off the stage, while any sensible man must subscribe to our own doctrine — which was the third point.

I say, fourth: From this hypothesis —

[Column II]

[Margin: The invented transparency of the Sun does not square with the apparent horizontal breadth of the faculae.]

— any horizontal facula, even the largest, will be seen as much smaller than it ought to be, [as is clear] from the use and practice of the phenomenon.

For faculae at the horizon do not always thin out and settle in the same way as spots do; rather, very often they appear quite broad and brilliant — the contrary of which would always and necessarily happen if faculae arose from translucency alone.

For let us suppose that the whole interval corresponding to the arc DSTy is opened by rarefaction into a facula: it will appear no larger than the distance comprised between the two rays DZ and Tα. But this contradicts the truth of the phenomenon. The emptiness of this fiction must therefore be rejected, and our own view embraced.

I say, fifth: that all spots will be farther from, and all faculae nearer to, the Sun's center A.

For on this supposition of translucency, all spots move in the sphere set around the Sun, and no —

[Column I]

— faculae ever pass beyond the Sun's surface DCB; but the whole sphere is farther from the center A than the Sun's surface is. The proposition is therefore clear — which was the thing to be demonstrated in the fifth place.

But that this is false is established from nearly the whole of the previous book. False, therefore, is also that from which it follows; and true is the contrary, which we assert.

Here, however, note that we do not assert that all faculae and all spots are always at the same invariable and indivisible distance from the Sun's center — this we do not assert. Rather we say this: that every spot which is converted into a facula, or every facula out of which a spot arises, is no more and no less distant from the Sun's center than the very facula or spot produced from it. But that different spots and faculae sometimes have different distances from the Sun's center — within the breadth or thickness of the physical solar surface — can scarcely be

doubted, since the phenomenon itself seems at times to indicate this well enough, especially if we care to examine secondary spots and faculae.

[Margin: The imaginary translucency of the Sun does away with the rising and setting of spots together with faculae.]

I say, sixth: that, on the supposed translucency, no facula would ever rise or set together with a spot; likewise, no spot would be seen in the midst of faculae, or vice versa. This is clear enough from what has been said and demonstrated earlier. How false it is, anyone will find who has gained even a little practice with this phenomenon.

[Margin: The contrived transparency of the Sun transfers spots to a place on the Sun not their own.]

I say, seventh: that no spot, with respect to the solar surface DCB, will be seen in its own place, but always in a place not its own — except when the spot culminates, that is, holds, to sense, the middle of the Sun; for the rest, all will be involved in perpetual parallax. And this is true and perceptible even if the sphere surrounding the Sun reaches, in its thickness, only a fourth or a sixth part of one minute. So that this may be rightly understood, it must be noted that the parallax of the spots, with respect to the Sun, can be detected in three ways.

The first and ordinary way is when, from the different positions of observers on the earth, one and the same spot is observed at the same time and is found in either a different or the same place on the Sun; then that spot is said either to lack diversity of aspect — that is, parallax — or to possess it. For example, if the Sun rises for one observer and sets for another, these will be separated by [half] the terrestrial hemisphere; and if they see a spot or facula at the same time in the same place on the Sun, they will absolve it of parallax — as I have shown to be done, throughout the previous book, in the Images of the Observations and their accompanying Notes.

[Column II]

The second way of detecting parallax depends on the Sun's daily motion, with the same place on earth but a different time — as when I observe a spot on the Sun in the morning and again in the evening. If it is not on the Sun, and is sensibly distant from it, in the evening it will have to be seen in a different place, once the proper subtractions or additions are made that belong to it from its own motion over a single day. But this parallax too has been dealt with above.

The third way — and perhaps one not so well known — is that drawn from the spots' own proper motion around the Sun. In this case, since the true place and the seen place of the spots are investigated in relation to the Sun, the seen place will be the one that the visual ray, passing through the eye and the center of the spot, marks out on the Sun's surface; the true place will be the one that the Sun's semidiameter, drawn through the center of the spot, shows on the Sun's surface.

Thus spot Y will have T as its seen place and γ as its true place; and spot P will have O as its seen place and Q as its true place. From this it is clear how, given that sphere, a diversity of aspect always arises with respect to the solar surface BCD. What further absurdities, and how great, would thereby be introduced into the motion itself — otherwise found to be ordered and regular — it is not worth the trouble to unravel, since they have been sufficiently set forth earlier.

But if anyone, to escape these absurdities, should want to turn aside so as to say that the faculae are found now in the surrounding sphere, now enclosed in the Sun itself, he will involve himself in far greater difficulties, as will be plain to anyone who considers what has already been said; or else he will differ from me in name only, etc.

For the rest, in order that this sphere drawn around the Sun — besides the geometrical arguments already brought forward —

Diagram. A large geometric construction printed across the top of the page, above both text columns (the same class of translucency/refraction figure carried on the preceding folios). It shows a quadrant-like arc sweeping down from the upper corners to a low point at the bottom, crossed by vertical construction lines and radial/oblique lines (some dotted), with two small squared insets at the upper-left and upper-right corners. Much of the figure is overlaid by heavy verso show-through, which obscures the finer line-work. Readable point-letters, by position:

- A (top center): apex of the construction
- G, D (upper-left corner, adjacent): heads of the left vertical
- V, S (just below D): points on the left vertical
- X, m (below V/S): points on the left vertical / inner line
- β , η , ϵ (Greek beta, eta, epsilon; descending the left curve toward its foot)
- B, F (upper-right corner, adjacent): heads of the right vertical
- O, R (just below B/F)
- Q, P (below O/R, on the right descending line)
- C, K (mid-left, at the level where the arc turns)

- H (just below C/K)
- M (lower center-left), N (lower center)
- I [?] (a further letter near M/N at the foot, not cleanly separable from the column-apparatus numeral "I")

[Cap. LII, continued from the preceding folio.]

[by geo]metric [reasoning], and even by what is virtually physical reasoning, I shall utterly overturn it.

I say, eighth: *From this very fact — that this sphere is posited — it necessarily follows that it is done away with.* For these spheres clothe the Sun round about with just this purpose: to defend it from every injury (as they suppose), and so to preserve it mathematically spherical, most smoothly polished, most brilliantly shining, harder than diamond, purer than crystal — one, the same, uniform, homogeneous, forever like itself.

Let us grant, then, that it is so; let us say, write, and think the same. Now if the globe of the Sun D C B is of equal power and activity everywhere; if against that sphere — by which it is held bound as by a band — it has waged relentless war from its very first rising; if it dissipates that sphere by every means it can, tears it apart often in many ways, and opens gaping windows toward us — then many weighty, and perhaps not readily resolved, questions arise.

For it is certain, **first**, that the Sun is a natural and necessary — not a free — agent; and so it exerts upon the subjacent material of the surrounding sphere all the power of acting that nature gave it.

It is certain, **second**, that nothing corrupts itself. Hence we must hold that the dissipation of that sphere, if it should occur, would come not from the sphere itself but from the Sun as the efficient cause.

It is certain, **third**, that the spots [*maculae*, sunspots] are denser than the rest of the surrounding material of that sphere; otherwise the Sun's rays would be intercepted by them no more than by the surrounding parts of the sphere itself.

It is certain, **fourth**, that many regions in the visible hemisphere of the Sun are often found empty of every spot or facula [*facula*], even and uniform in tenor throughout. These things being established:

Questions not so easily solved are put to the adversaries.

It is asked, first: Why do no notable faculae arise near the poles? For the Sun's power of dissipating that sphere is everywhere the same; and it is further certain, from the observations, that the polar parts of the Sun are purer of spots than the rest. Therefore the Sun will more easily thin those parts out so as to become translucent, and so faculae should shine forth there more frequently and more brightly.

You will answer that at the poles the Sun's motion is weaker, and therefore the rarefaction of the sphere is less. From this answer, then:

It is asked, second: Why toward the polar parts of the Sun are no primary spots ever seen or gathered — especially since the cause that dissipates spots, and consequently creates faculae, does not prevail there?

It is asked, third: How does the Sun's rotation, however violent, arrange the uniform sphere in so contrary a manner in its several parts — so that in one place it is condensed so powerfully, and in another wholly dissipated — with no observed sign of the turbulent agitation of the parts gathered into spots, or of the regions opened out into faculae?

It is asked, fourth: Who produces the spots? Not the Sun; for by what power would the Sun gather spots? Not by light; not by local motion. We must therefore take refuge in some occult quality or other — one that can be assailed on these very grounds. For if the Sun by its power compels the spots [to form], who in the end dissipates them? Does the same unchangeable Sun at once gather and scatter them? For if the Sun has the power of dissipating spots anywhere, it has it everywhere; if it has it once, it has it always; and since it acts by necessity, it will always dissipate any given spot — yet it will also always gather it, if indeed the power of gathering spots resides in the Sun. Thus the Sun would at one and the same time both gather and scatter the same spot; and if it scatters, it does not gather; therefore it would at once gather and not gather — which is impossible. The power of compelling the spots, then, is not to be attributed to the Sun on these grounds; it will therefore be ascribed to the surrounding sphere. Whence:

It is asked, fifth: Why does the Sun not prevent the surrounding sphere from heaping up spots one after another? For by the same faculty by which it dissolves those already formed, it could hinder new ones from coalescing — especially since no agent disposing the matter in the contrary way is sufficiently present there.

Sixth: Why does the Sun, by thinning them, reduce the densest nuclei [*nuclei*] of the spots to nothing, yet disperses the thinner mass less? Can it be that one able to

do the greater cannot do the lesser — that one who dissipates opaque bodies does not know how to scatter thin vapors? The power is the same; the action is not free; therefore it will act.

Seventh: Why does the Sun convert the larger and denser spots into faculae, yet at the same time leave the neighboring, contiguous, adhering ones — smaller and rarer — unharmed, indeed often growing? The Sun's efficacy is everywhere the same; therefore the smaller and thinner spots ought to be reduced to faculae the sooner.

Eighth: Why does the Sun thin the opaque spots into faculae, yet does not transmute the surrounding, thinner material of the sphere into the same? The efficient cause is applied everywhere in the same way, and the patient material is (as the adversaries explain) better disposed to the appearance of faculae; therefore the effect ought to follow.

Ninth: Why does the Sun fit one part of the same spot into a facula, yet leave another portion of it untouched — when the Sun's action, and the application of agent to patient, are the same?

Tenth: Why does the Sun not keep the place of a once-dissipated spot forever open, and translucent as a facula? Is it more powerless in guarding what it has gained than in acquiring it? Yet it is endowed with a sinew of ever-equal strength; therefore it ought to preserve forever the faculae once obtained.

Eleventh: Why does the Sun transmit to us faculae bright with unequal light? Can it be that in one place it was able to remove all obstacles, in another it could not? Yet everywhere it possesses an equally potent vigor. So then — will one that drives off the denser shadows and opacities put up with the rarer ones? And will one that in some places purges the medium to the purest transparency [*diaphanitas*], in others — though endowed with the same activity — fail to do the same? Surely not: for the Sun is a necessary agent.

Twelfth: Why does the Sun, in an even region of the surrounding sphere, raise up some facula here, and not there or elsewhere — when the sphere is disposed in the same way and the Sun is affected in the same way? Either, then, faculae will appear everywhere, or nowhere.

Thirteenth: Why does the Sun so blot out the primary spots that sometimes it comes out entirely free and clear of them all, yet never so of the secondary ones? Is it overcome by a weak enemy — it that laid low a far more powerful one?

These and similar questions — of which countless can be raised from the phenomenon [*phaenomenon*] — must be answered by anyone who dims the Sun's most dazzling splendor with a filthy cloak of surrounding sphere. Since this can never plausibly happen (as will appear far more clearly than the Sun itself to anyone who weighs all the moments of the matter in an even balance), it remains that — abandoning mere Transparency and rejecting that fictitious sphere — we should turn our mind to true and solid thoughts worthy of a philosopher, and recognize the true generation of spots and faculae, with the phenomenon leading and so teaching. And this anyone is bound to recognize, from the arguments we brought forward at the outset, even if he should wish to abstain from solving these physical questions, or should suppose them solved by himself under the guise of probability. And that he may do so the more willingly, I have judged it worthwhile to reject, from the generation and death of the spots (as we promised earlier), that manner in which some strive to explain them: by dissimilar parts of the surrounding spheres, gathered and dispersed according to their various encounters.

IMPOSSIBILE EST MACVLAS Solares fieri ex concursu partium opacarum, orbibus duris circa Solem statutis, & perenni rotatione conuersis.

[It is impossible for the solar spots to arise from the concurrence of opaque parts, given that hard orbs are set around the Sun and turned in perpetual rotation.]

CAP. LIII.

There are those who, to defend the rigid and unchangeable substance of the heavens [*caelum*], leave no stone unturned, so as by every possible means either to break down or to elude the phenomenon of the solar spots and faculae, which presses upon them most forcibly. And so, since the unstable and ever-new variety of these presses daily upon their very eyes — inasmuch as they can in no way sustain the motion of the spots through the orbs of the planets (orbs which they, against the opinion of Ptolemy and the common view of the astronomers, posit as hard), nor the varying density and rarity of the intervening [material], as I have effectively shown up to this point — they whet their wits for new contrivances. Around the solar globe — uniform, unchangeable, compacted with a bronze-like and adamantine hardness — they lead about a virtually infinite number of spheres, likewise hard and incorruptible, variegated with a transparency and opacity that is not uniform but multiform; so that, by the varied intervening passage of these spheres and by the meeting of the opaque parts, the spots are

created — and by the meeting of the transparent parts, the faculae — by local motion alone, without any other intervening change. For they think it can come about thus: that spots arise from the underpassing of several opaque bodies, but faculae from that of several transparent or luminous ones.

[Margin: The opinion of the opposing side is set out.]

But that the emptiness of these fancies may become clear, I lay down the following — drawn from the observed spots, from the images of the observations digested from them, from the courses of the spots set out and variously discussed, and from their investigated locations:

[Margin: Assumptions drawn from the observations, and explained in the earlier book.]

First: that the centers of all spots and faculae stand at the same sensible distance from the center of the Sun, as is clear from the investigated true positions of them.

Second: that every spot, if it grows, almost always grows in every direction of place, from its middle toward its extremities; and that as it grows, it always deepens at the middle in apparent blackness. And conversely, that every spot ordinarily wanes on all sides in every direction of place, proceeding from its outer edges toward the middle; and that as it wanes, its blackness always slackens. This is clear from the observations, and from examining their true positions.

Third: that many spots — especially small ones — cross the Sun without notable growth or diminution; and that those which are at a standstill persist for many days sensibly unchanged.

Fourth: that many spots are surrounded on every side by faculae, and at the same time often grow on all sides, often shrink, often — while one grows — the other diminishes, and vice versa; and often both stand still for a long time. Similar things are asserted of the faculae on the flanks of the spots.

Fifth: that many faculae are frequently kindled in the midst of the spots and their nuclei, and that not seldom with both growing, or both shrinking, or alternately, and so on.

Sixth: that neither the spots nor the faculae grow or shrink equally fast, nor stand still equally long; but some more slowly than others, some more quickly, some longer, some more briefly. These things are established from daily practice.

Seventh: that while some spots grow or stand still, others shrink; the same is to be judged of the faculae.

Eighth: although the polar regions are for the most part free of very notable changes — since they do not engender notable or primary spots or faculae — nevertheless, in enlarging or contracting their limits of rest, they undergo great increases or decreases in a short time, indeed even within a half-day.

Ninth: but the secondary spots and faculae undergo far more numerous and more rapid changes of magnitude and figure, so that they vary almost by the day and hour, and so on.

Tenth: the middle, or center, of any spot is the first thing to be born and the last ordinarily to fail. The experience [of this] is steadfast.

Eleventh: no spot or facula lasts forever, but all simply vanish in the end; and the whole Sun is quite often stripped of every primary spot.

These things being thus laid down in advance:

Since all spots agree in their manner of growing and shrinking — namely, that all grow from the center toward the extremities, and from these fail back toward the middle — the principle from which these things proceed must be universal and the same in all. Hence, in the view of those who attribute all this to local motion, it must happen in the same way in all spots. But no other manner can be conceived or can exist than that the parts constituting the spot are carried toward the center of that same spot by means of the hard, movable orbs in which they reside.

Furthermore, whether — and by what means — these constitutive parts of the spots become sensible must be examined before all else. For that the local motion of them, when separate, is not perceived is certain: when joined they are seen; when separate they are not.

DE MACVLARVM SOLARIVM partibus.

[On the parts of the solar spots.]

The parts of the solar spots, according to this view, are either simple or compound.

[Margin: What are the simple and the compound parts of the spots?]

A *simple* part of a given spot is one which, by itself alone, is not so opaque as to fall under our sight, but which — when a similar part, or similar parts, is added — becomes sensible; and this latter I call *compound*.

From this it follows that, to constitute any least part of some spot and bring it under sense, at least two spheres are required, by whose mutual overpassing the individual spheres — otherwise imperceptible — may be seen as one.

DE CENTRI MACVLAE CVIVSQ. generatione sensibili.

[On the sensible generation of the center of each spot.]

The center of each spot, on this view, considered in itself and absolutely, always exists, since it stands out in the simple parts; but it comes forth by a sensible generation when two such imperceptible particles concur into a single visual ray, for then they begin to lie open to view. But since the daily experience of the phenomenon teaches that the center of any spot is ordinarily the first and the last thing sensible — according to Supposition 11 — it is doubted how, in a given place of the Sun, such a central part of the spot can endure.

[Margin: How does the center of each spot endure?]

For it is certain, from the phenomenon, that the middle or central part of the spot remains unharmed through its whole course — that is, for 13 days and more. It is also certain that, as the spot grows, its blackness apparently deepens — although on this supposition no true intensification occurs, since the color increases by the positioning of part upon part. And it is certain, finally, that when the spot is stationary, its center too keeps its state as regards opacity.

But the center must remain by one of two ways: either by the rest of the simple parts of which it consists, or — if these do not rest — by a continual succession of similar ones. If the first, then it is also necessary that the spheres by which those simple parts are carried [remain] around the Sun in the station of the spot... ..the spot must be at rest. Therefore all those spheres too — the ones that hold the agglomerated parts heaped over the center, and thereby make that center darker — will likewise stand still. And so a contiguous mass of spheres will stand motionless, as deep as the given spot's depth or thickness. That thickness is inferred chiefly from the greater or lesser apparent blackness, which is produced solely by the piling of parts upon parts through local motion. A greater blackness therefore implies a greater superposition, and a greater heaping-up of parts carries with it a thicker series of spheres packed close about the center. Then,

when the spot begins to shrink and its center or middle gradually loses its blackness, these spheres — stable until then — must move again.

We must reason in the same way about the perceptible generation of the center in every spot, one by one. Since the pattern of growth and decay is the same in all, it is rightly concluded that the origin of all of them is just like the origin of any one. Hence, since while some spots stay put others grow and others fade, it follows on this hypothesis that each spot claims its own spheres, because motion and rest cannot belong to the same sphere at once, and so on.

But if that same perceptible center is to be maintained not by rest but by a continuous succession of simple parts, then the spheres that carry those parts must move in such a way that their motions are not random or accidental, but ordered and regular. This is sufficiently gathered from the orderly and uniform coloring, condensation, and rarefaction of the centers, and likewise from the growth and diminution of the spots. From this various doubts arise. What sort of motion do those spheres have that carry the central parts? About which poles, and along which circles — great circles or not? How fast is that motion? I assume, along with those who devise these spheres and motions, that the motion of the whole sphere carrying such a particle is homocentric with the Sun; and this is also proved by the observed phenomenon itself. For otherwise many anomalies would occur contrary to observation — above all this, that very many spots would arise not only at an unequal distance from the Sun's center, but at an excessively great one — though their true position contradicts this.

Moreover, that very many spots would arise at too great a distance from the Sun's center follows, given a single spot's perceptible eccentricity, from the fact that the entire sphere of an eccentric spot is eccentric and impenetrable. So, granting that a given spot lies at perihelion — that is, at the point nearest the Sun — some other spot lying at aphelion, or the opposite point (which happens very often, when one is rising while another is near setting), must move too far from the Sun. For once one eccentric sphere is granted, all the rest around it will be eccentric too, barring the interpenetration of bodies, and so forth. And on this view we must concede that in different spheres not only whole spots but even their individual parts are carried. That this motion of the central parts follows great circles is made probable by the proportional growth of the spot about its center, and conversely its shrinking; but how large and how swift it is must be guessed at rather than settled. For no perceptible portion outside the spot is ever seen departing from it or approaching it, as observation attests; so whatever approaches or recedes by local motion must all be simple and below perception.

Yet it must be continuous, moving along its own circle through the spot's center; and since another circle likewise passes through it, carrying around a simple portion of its own, their common intersection — or rather meeting — at the spot's center always makes a composite and visible part. The makeup of the visible central part, then, is the joint placing there, by local motion, of two or more parts that are not individually visible but simple, so that one added to another increases the opacity and makes it visible to the eye. And because these simple parts are supposed to be in perpetual passage through local motion, the center of any spot must indeed remain the same in site and position with respect to the Sun — but not the thing which occupies the spot's center as through a lattice; rather, it is always some fresh matter and then more. Since these are all of the same density, they always yield a like intensity at the common section.

Next, in the more durable spots — such as the recurring ones especially are — the succession of such parts must have been greater, since over a longer time the motion is greater and more moving bodies are transported, if the motion is assumed uniform. Hence it could happen that the very same simple parts returned, and so on.

But since two great circles on a sphere necessarily bisect each other at opposite points, in such cases it ought to happen that at the opposite section of the center a central part of a spot would also exist and fall into view. The same would occur wherever the circles and the segments of the central circles of different spots ran into one another. For a simple portion of a center, meeting equally with another simple portion or portions, makes a composite and hence visible portion.

What I have said about the makeup of the visible center must be applied, in like proportion, to the composition of the other parts that stand around the center. For each of them must be constituted either by a similar rest or by a similar local motion, through the common apparent intersection of the circles that carry those parts.

With these rough first principles laid down, we must now go further and disclose what can be brought forward, as true, toward the inquiry we have proposed.

First conclusion. *The said central composition of spots does not agree with the solar phenomenon, whether it be supposed to be acquired and maintained by motion or by rest.*

The reason: as is sufficiently clear from what has been said, individual spheres would have to be assigned to individual visible parts, at the very least, in order to avoid the entanglement of the motions and the interpenetration of bodies. And so

each spot would, as a whole, be either nearer to or farther from the Sun's center than every other — something that would certainly be perceptible, especially in the great multitude of sunspots, which sometimes together exceeds the number sixty. Since, therefore, the center of each lies in its own sphere, the two extremes must differ from each other by as much as all the intervening intervals occupy — which is certainly a very large space, even though the individual gaps somehow escape perception one by one. But so great a separation of the centers from one another and from the Sun's center — not in length or breadth, but in depth — is simply impossible for the phenomenon as it stands. And if the bare, simple positioning of the centers cannot bear this fiction, what will happen when we consider the manifold heaping-up of individual parts and their agglomeration through the whole depth of the spot? There will surely rise up on the Sun masses of unwonted depth; the marginal thinness of the spots will collapse; irregular motions will spring up; spot will cover spot, now going ahead of it, now following. In a word, countless falsehoods will result contrary to observation, and so on.

Second conclusion. *This same composition of the central parts cannot agree with the solar phenomenon by means of the said hard spheres, because of the incompatibility of the motions and of the moving bodies.*

For while some parts come to be, others fade, others hold their state, others intensify, and so on. All these, each and every one, require different motions, circles, and spheres; and so we fall back into perceptibly different distances from the center — which in truth do not occur in the phenomenon.

Third conclusion. *One runs into the same impossibility if the parts of the spots surrounding the center are considered; for since the motion of each is either toward the center or away from it, each part too will claim its own single sphere.*

For these motions are incompatible within one hard sphere. When one part of a rigid sphere is moved, all are moved; so if one of its points approaches the center of a given spot, the other parts standing across from it will recede — whereas the contrary ought to happen according to observation, since the spot grows about its center everywhere proportionally at once. The parts, then, approach by local motion, on the hypothesis; and since this motion cannot occur within one sphere, one must admit as many spheres as there are least perceptible parts. And so once again the multitude and height of the various spheres grows, and the earlier argument about the spots' perceptible approach to and recession from the Sun's center still stands.

Fourth conclusion. *This gathering of sunspots by hard spheres moving about the Sun is shown to disagree with the phenomenon, from their unequal congregating, unequal standing, and unequal dispersing.*

For some grow very fast and are greatly enlarged, some slowly and not much, and some stay, as it were, constant to themselves, and so on. But fast and slow motions do not belong to the same sphere, other things being equal. Hence different spots come to be gathered by different spheres, and so, taken as wholes, they will stand off from the Sun's center in different ways — which again the practice and experience of observation does not allow.

Fifth conclusion. *This local gathering and dispersing of spots does not hold up, because their intensification occurs together with their extension, and their fading together with their diminution.*

For it is certain, from constant practice in observing the phenomenon, that spots grow as they darken and shrink as they whiten. But if they came to be by the said carrying-together of particles, then it is certain that they would be enlarged as their blackness decreased, and — though the bulk of the body appears to grow — reduced as their blackness increased. Since these consequences are false, that belief cannot be true. But this argument has been treated elsewhere as well.

Sixth conclusion. *If spots come to be and grow from the alleged concurrence of parts, they ought to form equally around the north and the south as around the east (their rising) and the west (their setting).*

For their growth and diminution in every direction of place requires spheres and circles movable every which way, and consequently, everywhere, spot-forming concurrences of simple parts. But since this does not happen, it is clear that those motions do not occur through such spheres.

Seventh conclusion. *If such a generation of spots by surrounding movable hard orbs were granted, then a generation of faculae by the mere shining-through of the Sun would have to be granted as well.*

For just as spots are begotten by the interposition and confluence of dense parts, so faculae are born from the meeting of rare ones. But that this is impossible I demonstrated earlier by means of the fluid sphere surrounding the Sun, from which all the arguments apply here with much greater force. And this single argument would be more than enough to overturn the said spheres.

Eighth conclusion. *Because spots are born in the midst of faculae and grow both in apparent intensity and in extent, and because the surrounding shining faculae grow at the same time, these things cannot come about by local motion.*

For the spot-forming parts would have had to be transported across the regions bright with faculae — which is false, since they would then have been noticed. Or they descended from above, enclosed within the margins of the spot — but not this either, because the orbs carrying these parts would be neither homocentric with the Sun nor wholly outside it, but would enter by penetrating it. Or, finally, enclosed from the center of the spot, a local spreading-out of the parts would take place in every direction — and not this either, because that manner of growth conflicts with observation. For this unfolding of the spot would thin and rarefy its very middle, whereas the opposite always happens: as the spot's breadth grows, its opacity always grows too, as observation attests. I say nothing now of the fact that these motions would call for different spheres, as it were infinite in number, which would make the spot's height or depth intolerable to observation. From this, then, it is clear that an appearance of this kind cannot be defended by local motion. This becomes still clearer from the enlargement of the surrounding faculae themselves, both in place and in light; for neither reason nor mind can grasp from where the transparent parts would be carried there by local motion, or to where the spot-forming ones would go. The same is confirmed by the large black nuclei that are born and grow within their own whitish spots. Their opaque matter could not be carried to the middle from every side without passing through the outermost edges — which, however, observation contradicts, since those edges would then have been stained with some perceptible blackness. Indeed, since the nuclei are surrounded on every side by that thinner mass, which flows around them even on the side facing us, it does not appear how it could grow, if the interpenetration of bodies is not allowed. Therefore these things do not happen by local motion alone and the surrounding placement of hard spheres.

Ninth conclusion. *Because faculae suddenly flash out in the midst of spots or nuclei and persist through continuous courses, this same hypothesis of movable hard spheres has no place.*

For where, and by what motion, did that black portion in the middle go? And from where, and by what motion, did that transparent part take its place?

Tenth conclusion. *Since, throughout the solar phenomenon, faculae near the Sun's edge or horizon optically merge everywhere into one continuous whole while the*

umbrae between them vanish, those umbrae must be somewhat nearer to the Sun's center than the faculae themselves.

It is therefore impossible that such faculae shone out through the Sun's transparency; for on this supposition of hard spheres every facula must be interior, and every spot too — even a secondary one, or umbra — exterior. Yet the actual practice of observation gives the opposite.

Finally, eleventh and last: even granting — though not conceding — that by hard spheres of this kind, through the concurrences of invisible parts, the appearances of the spots could to some extent be defended (which nevertheless, given the appearances of the phenomenon, is utterly self-contradictory) — let anyone who seeks the truth consider whether this way of philosophizing is sound.

[Margin: A <Elubis[?]> manner of philosophizing — arguing from "it can be" to "it is."]

For neither any sense nor any probable reason leads one on; one builds up what one pleases merely because it is not demolished by evident arguments from the opposing side, or because it is not effectively proved that it can come to be or exist under some appearance of likelihood, but is merely asserted brazenly [proterue[?]] — the contrary truths being ordered off far away, whether you prove them by evident reasons, by probable experiments, or by authorities beyond all exception, or not. This way of philosophizing, I say, is worthless by the precepts of logic: "it can be, therefore it is; therefore it must be held and laid down" — even though reason, sense, and every authority fight against it. But I break off [abiungo[?]], and I stop refuting trifles in earnest, lest I too be judged a trifler by the prudent reader.

I have pursued these matters at somewhat greater length, not because the dignity of the subject or the weight of the argument demands it, but because the unfairness of the times and the condition of the ignorant require it. For there are those who, from this refuge of ignorance, violently attack both the truth and this solar phenomenon, imagining that they have laid the truth bare if only they have found safe hiding-places for their fabrications. These trifles, then, had to be treated and refuted by me in earnest — so as to wrench their toys from their hands like childish rattles, and to take diligent care that those ignorant of this phenomenon should not be deceived by men who are unskilled yet overbold.

MACULAS ET FACULAS generari & corrumpi, confirmatur ex ipso incipiendi & desinendi ipsarum modo.

That spots and faculae are generated and destroyed is confirmed from the very manner of their beginning and ceasing.

Cap. LIV.

Although this matter has often been driven home in actual practice throughout the previous book, in the images of the observations and their explanations, I nevertheless bring it forward here briefly gathered together, to give the studious reader occasion to inquire more ardently into this phenomenon.

Whoever devotes his effort to the diligent investigation of this phenomenon will, without any doubt, often gaze in wonder at spots and faculae that appear suddenly and were not foreseen; and he will observe them not at the eastern or western limb, but around the middle of the Sun.

[Margin: The beginnings of sunspots are difficult to observe.]

And so he will ask himself from where, or how, such foreign guests came here in such numbers, with no sign of their entrance given beforehand. This thought long and often held me in suspense; and once I had come to know well how very hard their beginnings are to trace — since the Sun, crammed with secondary spots or thin umbrae, offered no sure sign of the spots — I took another way. And because from daily observations I learned that in the end all spots resolve into umbrae and faculae, I began most carefully to study their endings and deaths, so that from these I might perhaps find their beginnings and birth to be similar... ..so that I might detect it. And indeed, my strenuous effort and toil met with a very kind success. For from the manner in which the spots fade away, I came clearly enough to understand how the same ones begin, and I learned to anticipate their coming births from signs that are far from obscure. The ways in which they disappear are these.

[Margin: The various ways in which spots come to an end are explained.]

Some spots, as they shrink in bulk, are at the same time thinned into an extremely faint shadow, so that at last you cannot distinguish it from the rest of the Sun's surface except by shaking the instrument. Such a shadowy trace sometimes lasts one or more days, sometimes quickly vanishes altogether; and sometimes these faculae appear alongside it or follow after it, sometimes without any facula at all. Indeed, unless you had known for certain that a spot had gone

before, and that this was the trace of the one now past, you would scarcely dare to declare it with confidence.

Some spots, when they have been thinned into a faint, even shadow, then dissolve that very shadow into tiny, scattered spots, like points, so that the spaces of the remaining solar surface shine out between them. And once this separation into little spots has taken place, they nonetheless advance in their own order, over one or sometimes several days, and do so in various ways. For often they all gradually pass away afterward, in the manner of the others, into faculae or into the Sun's ordinary surface; often some sooner, some later, degenerate one into the other; often they leave behind a certain bright track; and sometimes they leave a shadowy, shapeless remnant behind, with no notable facula.

It also happens that, spreading out, they return into a single continuous shadow for a day or two, and then, separating once more, they pass away in the ways just described. It even happens that, while some are vanishing, certain of them revive and grow into new spots. Indeed, the same spot sometimes, after being gone for a day or two, appears again, so that they seem, as it were, reciprocal and in a way [*luctae* — join at column break; reading uncertain]; since there is nothing in nature that does not strive to preserve itself in its own state, nothing that does not shrink from destruction.

Nevertheless, in the end all spots come to an end — either into faculae, or into the Sun's common surface, or at least into certain dim traces of shadow, which themselves finally also vanish and are converted either into faculae or into the Sun's common surface, unless you prefer that they be dispersed into the surrounding aether.

[Margin: Spots absorbed by the light of the faculae.]

Some spots, finally, seem to be gradually overwhelmed, as it were, by a brighter material on every side, and as that material grows, the spots themselves shrink, until from something dark nothing further remains, but a brilliant facula blazes — sometimes pure, sometimes hedged about, on all sides or in part, by certain hazy traces. Endings of spots of this kind are frequent enough, and they differ from the earlier ones in this: that those earlier spots are not suffused with this malign light, but fail while the pure blackness of the spot, and one always growing fainter, remains; whereas these latter spots — even ones still teeming with nuclei and quite substantial — are, once flooded with light, taken from sight, until, all the opaque matter being gradually absorbed, they pass over into bright faculae.

And so that no one might ascribe this transformation to the spots' position relative to sight, I took particular pains to inquire whether this happened only near the horizon, or in other places of the solar disk as well; and after a careful investigation I found that it occurs indifferently in any part of the Sun. I therefore concluded within myself that this must be attributed peculiarly to the way spots end. And thus it seems shown, from this very vanishing of the spots, that in the end all spots are converted, immediately, either into faculae, or into the Sun's ordinary surface, or into the shadowy traces of spots — and these last at length into the Sun's surface, or certainly into the surrounding medium.

Now that these things were known, I turned my mind to investigating their beginnings, and I found the entrances plainly similar to the exits.

[Margin: A method for recognizing the faint, shadowy beginnings of spots.]

For I observed that many spots, as they rose, had as their heralds, so to speak, extremely faint shadows, spread out over the Sun's surface like a spider's web, noticeable only by moving the instrument. These, in the course of time and days, gradually became denser, and, drawn together into spots, presented a stable appearance. For this reason, at the start of each observation I survey the whole Sun within the observing circle and thoroughly test it by moving the instrument. If I notice any new shadow and come to hope for a spot that will follow, I record its place and size and shape, and note down in writing its rarity and density, its uniformity or non-uniformity. By this method I have traced the first origins of many spots — though I do not deny that mere shadows too have often been detected by me, which accordingly, in coming to be and passing away, go before the primary spots; for they do not cling long with any stable duration.

Afterward, in the same way, I found the smallest spots bubbling up separately from one another, and, gradually spreading, making a single continuous one, growing, standing still, diminishing again, and failing by a like process, and so on. At last I saw very many rise up with much light in any place whatever of the Sun along the royal path, so that at the outset I would often note the purest faculae along with doubtful shadows, and so on. And so by settled experience I found that the physical rising of spots is twin to their setting; and just as faculae succeed into the place of consumed spots, so from the midst of faculae spots come forth — this I learned by frequent practice. Examples occur everywhere in the observations and in the observers' notes in the earlier Book.

But if to anyone these things seem the stuff of fable, let him observe, and he will attain the truth — he who was unwilling to trust me when I asserted it.

Note, first: all the seeds of these generations are, at the very beginning, exceedingly small, both in extension and in intensity, so that they nearly escape sight.

Note, second: their increases, both in extension and in intensity, are indeed continuous and successive, but of varying speed; for some indications of spots ripen over days, some grow within hours, and within the space of half a day or less are formed into spots.

Note, third: just as the faculae are far more unstable than the spots, and harder to detect, so, if the faculae are pure, their origins can scarcely be foreseen — as a rule they are not; they are noticed only when they already shine. And their endings too are not discerned as the spots' endings are. The reason is that, since the spots always carry something dark about them, they are more easily distinguished from what is bright than one bright thing is from another, on account of the likeness of quality.

Note, fourth: faculae created from spots are for the most part larger than their own spots, though they sometimes appear smaller.

Note, fifth: these reciprocal and, as it were, circular generations of spots and faculae are not to be understood as if they were linked in a continuous course and by a perpetual chain, as it were — so that, when from some one spot a facula arises, from this facula so produced a new spot again emerges, which in turn gives birth to another facula, and so on to infinity. That, I say, is not the meaning, nor is such the reciprocation of the generation; otherwise the Sun's royal path would be nothing else than a continuous heaped-up jumble of primary spots and faculae. Rather, this is the meaning of what has been said: when some spot passes into a facula, that facula lasts as long as the constitution of the underlying matter allows; and when that is used up, it withdraws into the common form of the solar surface — or else (which I judge can happen sometimes, though more rarely) it is carried over into the nature of another facula or spot, with new matter or disposition supervening, and so forth; or it is dispersed into the surrounding medium.

From what has been explained thus far, I judge that any sound-minded man, a lover of the celestial physics, understands well enough and more that these so great alternations of change cannot come from local motion alone, from condensation and rarefaction alone, or from any other alteration, but that further resources of change must be admitted in order to maintain a sufficient appearance of the phenomenon — especially since it is established for certain

that in matter which, having formerly been spotted, has passed over into a broader facula, an internal principle of light has been acquired, and indeed of a greater light than there is in the rest of the Sun.

ON THE TRUE PLACE OF THE SOLAR PHENOMENON

From what has been observed and shown thus far concerning the solar phenomenon, the strongest arguments are gathered into a single view, by which the true place of the solar spots and faculae in the Sun is proved.

CAP. LV.

FIRST ARGUMENT, FROM THE ABSENCE OF PARALLAX.

If the solar spots, with respect to the Sun, are free of every difference of aspect, they will surely be reckoned to lie within the Sun. But that they are free, with respect to the Sun, of every difference of aspect is established from the observations of various men, in regions different and far apart from one another — some set out in the preceding Book, some to be indicated here.

For, first, in different places differing by, say, seven or eight degrees of latitude, the courses of the same spots are the same, exposed with no difference of declination toward the south or the north. Second, in different places, however far apart in longitude, the horizontal spots — at the hours when, by the nature of their course along the Sun's longitude, they are to the senses virtually stationary — are observed and found in exactly the same place. Third, in the same places some observations have been made that fall at the same time and the same place of the Sun. Fourth — and this is the case with very many — although they differ in the hours, yet in the laying-out of the whole course upon the observing disk of the Sun, according to each person's most exact reckoning, they undergo no perceptible variation, but are set in an entirely proportionate place.

It therefore stands proved — the very thing that had been asserted in the Minor [premise]. Therefore the spots must be reckoned to lie within the Sun. And it is confirmed *a fortiori*: because by this very fact — that some new star is demonstrated to be free of all parallax with respect to the firmament — it is placed as lying within the firmament, with the practice and judgment of all astronomers agreeing.

[Margin: Objection.] You will say that from this argument no more is proved than that the spots are not so far distant from the Sun as to produce any perceptible parallax; and that from this no more can be inferred than that the spots are not

perceptibly absent from the Sun, with respect to us who are placed on the Earth — even though it could happen that in reality they are far distant from the Sun in part, yet this cannot be perceived, on account of the imperceptibility of the Earth's diameter in comparison with the greatest distance of the Sun.

[Margin: Solution.] I reply. It is not to be denied that the force of this objection is not empty or to be dissembled. Nevertheless, from the fact that the spots, with respect to the Sun — whether at its apogee, or at its mean distance, or at its perigee — always lack all perceptible parallax, I have this: that the spots cannot be as far from the Sun as the Moon is from it, or as Venus and Mercury are at perigee.

For since Venus at perigee, according to Tycho [Brahe] — whom I here follow before the rest — is distant from the Earth by 255 semidiameters of the Earth, her horizontal parallax is 13' 29". The distance of Mercury at perigee is 585 semidiameters of the Earth; its horizontal parallax, 5' 53". The Moon at apogee is distant from the Earth by 61 semidiameters, and undergoes a horizontal parallax of 56' 21". The distance of the Sun at apogee from the Earth is 1,182. 56. terrestrial semidiameters [numeral as printed — see note], and its horizontal parallax 2' 55".

Therefore, if from these parallaxes we subtract the parallax of the Sun at apogee, there will remain, between the solar horizontal parallax and that of Mercury at perigee, a difference of 2' 58"; that of Venus at perigee, 10' 34"; that of the Moon at apogee, 53' 26".

From this it manifestly follows that, if we suppose the solar spots to dwell in some one of the said places, then, seen upon the Sun as it rises or sets, they would undergo a like parallax; and so it would come about that their true place would not be that in which I see them on the Sun, but a far different one — namely, that upon which a line drawn from the center of the Earth through the center of the spot would fall. And in such a case, a spot placed in the heaven of Mercury would be thrown from its own place by about a fifth part of the solar semidiameter — which, in the observing circle, if the spot be understood to dwell on the solar horizon, would make of the ordinary course three whole days; at the middle [of the disk], one and a third; and in the intermediate spaces, an interval of two days would be taken up, more or less, according as the spot were more or less distant from the horizon in the solar circle.

A like spot set in the perigee of Venus would be thrown from its true place by about six days, when seen on the Sun's horizon; and its true place would be about the middle of the Sun. But if it were set at the Moon's apogee — if it were found

by me anywhere at all on the Sun, near the rising or the setting Sun — it would have its true place entirely outside the Sun, because the parallax of the Moon at apogee differs from the parallax of the Sun at apogee by 53 minutes, 26 seconds, which make one solar diameter and 23' 26", if that diameter be put at thirty minutes.

And in this position a discrepancy of twenty-three days would occur, according to the usual rate at which the spots run. And so, whoever had the spot at his zenith, while I was seeing it at the rising or setting of the Sun in the horizontal region of that same [Sun], would see nothing of it at all upon the Sun; and if he wished to find it in a similar place of the Sun, this had to happen three weeks earlier. And likewise it would have had to be seen by me, that much time earlier, at midday, where the parallax for the most part ceases, and so forth.

But you will perhaps object that these things do indeed follow from those distances of the planets from the Earth, if we place the spots together with them; yet it is not established from the observations that no parallaxes of the spots occur in places distant by a terrestrial semidiameter or more. And that it could happen that, even if in the neighborhood of the places no parallax is found, yet at the greatest distances of lands some parallax altogether is found. For whence is it established that the spots of the Sun are seen, at one and the same moment, in the same place of the Sun always, everywhere on Earth? Who has observed this across such great intervals of the lands?

I reply, first: even if from very widely separated places no observations could be produced, the nearer ones would nonetheless persuade sufficiently that the spots, in remote places too, most probably lack all parallax — since in places less remote, yet remote enough, no indication of their parallaxes would be afforded; which is what happens in the present case.

For Freiburg im Breisgau, for example, is not far distant from Rome — namely by eight degrees, fifty minutes, more or less. And yet if we consider that, on a great circle drawn through the zenith of both places, something existing in the heavens on high, in the heaven of the Moon, is observed at the same time, that distance of the seen object from the lands will vary the seen places by eight minutes and more. This difference of aspect is great, given so small an interval of places and given the seen object at so great an altitude above the horizon — one that would be about eighty-six degrees. Now eight minutes in the observing circle take away, at the very least, half of the solar semidiameter, and, around the outermost margins, cut off four days from the courses of the spots, and around the middle more than two.

But if a difference of aspect of eight minutes, arising from an interval of eight degrees, brings so much discrepancy into the place of some spot, then surely greater distances of places — such as that between Ingolstadt and Coimbra, namely of 20 degrees and 20 minutes, more or less — would produce still more. And since this happens neither there nor in any other places of Europe, it is not credible that in other parts of the whole globe even so little parallax should occur. That it certainly does not occur in the said planetary orbs is certain, because that difference, even in Europe... ..Europe — though not with so great an excess or deficiency, because the intervals between the places were smaller — it would certainly have been detected. And lest I seem to want to argue about the Sun from mere conjectures:

You should know that faithful observations of the solar spots [*maculae solares*] have been sent to me from both the Indies, East and West, from places more than a quadrant of a circle distant from Ingolstadt. Among these observations, not the least place is held by those of Father Gaspar Ruess, of pious memory — once my pupil in mathematics at Ingolstadt — whom, when he was about to depart for the West Indies to convert the unbelievers, I equipped for the task with singular care, together with a telescope [*telescopium*] and observing lenses. He, having admirably discharged this office of friendship, sent from the New World a good many observations, both to me and to Father Paul Guldin [Paul Guldin], likewise a mathematician of our Society. When I compared these carefully with my own and with those made by others in Europe at the same time, I found that they agreed to a nicety. I would have made you a partaker of them, kind reader, had they been at hand; but since the autograph records are kept in Germany, and I did not wish to summon them here at the risk of losing them, you will patiently bear with me until, on some perhaps more favorable occasion, I may one day oblige you with more of them along with others.

Nor am I the only one to have collected various observations of the spots; others have done the like, in order to confirm or reject the parallax from them. Among the rest, Father Charles Malapert [Charles Malapert] writes to me thus from Douai, on 3 April 1625:

"I likewise have observations made at Coimbra by Father William Wely [Wilhelm Wely], from the year 1620 to 1623, which he communicated to me. I have compared very many of them with my own, and they agree most exactly; just as, some years ago, I received others at Kalisz in Poland, which likewise agreed. I keep all these observations, now spanning many years, and also those I received from friends." Thus he.

Furthermore, I myself taught Father William Wely the method of observing at Ingolstadt when he was about to leave for Portugal, and asked him to inquire diligently into the parallax, so that he might produce reliable observations — as, in fact, he did, as you have now sufficiently perceived from an eyewitness.

Galileo Galilei, in his letter written to Marcus Welser [Marcus Welser] on 14 August 1612, confirms the same from his own and others' observations on page 56 of his *History* [*Istoria e Dimostrazioni intorno alle Macchie Solari*]: to which reader I refer you.

But you have very many domestic examples brought forward in the Third Book, among the Images of the Observations:

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Likewise in the two Appendices to Images XXIII and XXIV, page 227.

In these Images, then, and in many others not cited, you will find not only Spots but also Faculae [*faculae*] observed to agree with one another in different places.

Read my Notes, and you will find times compared with times, and hours with hours, agreeing well.

And if some discrepancy occasionally arises in the longitudes, know that some of it is to be charged to the engraver, some to the type and paper, some to the inattention of the observers — or rather to the difficulties of observing. For in longitude there is always more deviation than in latitude, on account of the speed of the daily motion, which is closely akin to the motion of the Spots in longitude.

I answer, secondly. The said parallaxes would likewise be perceived most of all in one and the same place — morning, noon, and evening — and would introduce into the ordinary and daily motion of the Spots only as much discrepancy as the Earth's semidiameter carries with it in the said distances of the planets; and to perceive this, I suppose nothing more...

than the said distances of the planets, and the daily observation of the Spots under the Sun's aspect: to which end the Spots near the solar horizon contribute not a little, for there they appear to stand still. Therefore, since the solar spots observed at the three said times from the same place do not suffer the said differences of aspect on the Sun — indeed, they present not even any indication of that difference — it follows that they are exalted far above the Moon, Venus, and Mercury, all of them.

The Sun at perigee differs from the Sun at apogee in horizontal parallax [*parallaxis horizontalis*] by 13", reckoned on the arc of the eccentric circle; but in the observatory circle these are reduced to an arc of 50', of which one degree is 60'. The reduction is done as follows. Let the visible semidiameter of the Sun subtend an arc of 15'. Multiplied by 60, this gives 900". And since this arc does not sensibly differ from a straight line, it can be taken as the whole sine [the radius] of the quadrant of the observatory circle. If, then, we set up the proportion — as 900" is to 10000000 (the whole sine), so 13" is to another number — the resulting sine will be 144444, whose arc is 50', reckoned on the perimeter of the observatory circle. These 50 minutes, moreover, are perceptible. For the right sine of these 50', at the middle of the Sun, from the track of the journey of some Spot, occupies the space and course of about two hours, near the limb, at midday. Since this difference does not in fact occur, the Spots must, while the Sun sits at apogee, be higher than the place the Sun holds when it is nearest to the Earth. And hence, by force of parallax, the Spots are necessarily raised into the heaven of the Sun. And this parallax, by which the Sun at perigee differs from that at apogee, is doubled at the same moment in places separated by the whole diameter of the Earth; for to one observer the Sun will rise, to the other it will set,

so that the composite parallax would be 26", and would thus produce a horizontal parallax of the Spots amounting to nearly a full day. But such things fall under perception most readily; and since they do not occur, it is evident that the Spots are nearer to the Sun than perigee is to apogee. The same will hold in the same place at a different time — namely morning and evening — of one and the same day, and so on.

[Margin: The Spots, because of the absence of any parallax, are carried up into the heaven of the Sun.]

I say further, that even the Spots near the Sun...

are nearer to it than it is to its own apogee, at the mean distance; and its parallax [there] differs from the parallax at apogee by about 6", and these present in the observatory circle a sine of 23 minutes. It is most certain, moreover, that a parallax of so great a magnitude would be noticed in my journeys of the Spots, for they are doubled together if the Sun is observed at points of the Earth diametrically opposite, or in the same place morning and evening. Whence, from such a parallax of 20 minutes, it would result that some Spot seen on the solar horizon would earlier have crossed the same [meridian], and toward midday, and even evening, would notably accelerate its course; likewise that some Spot near the solar horizon, as the Sun tended toward its setting, would suddenly pass out beyond it. Yet none of these things ever happens: whence it is necessary that the Spots approach very closely to the mean elongation of the Sun from apogee.

Nay more, I would hold for certain that fewer than 5 minutes of the Ecliptic are involved in the journeys of the Spots — a matter greatly helped if the observatory circle is much enlarged, and long tubes, or convex glasses of larger spheres, are applied; for by these it will come about that, on account of the magnitude of the circle, even one perceptible second of arc of the Ecliptic will occupy a [measurable] interval in the semidiameter of the observatory circle. This property, being peculiar and proper to this instrument, can never be praised enough, for it brings incredible usefulness to astronomical work: I speak from experience. But for this practice, patience, dexterity, and no ordinary industry are required.

[Margin: By what means a few seconds of arc of the solar sky may be perceived in the observatory circle.]

And thus far, indeed, the force and inquiry of parallax extends securely — which I have carried out the more fully for this reason: that I might place solid foundations in the hands of the philosophers who ask it of me, by which they

might know the Spots to be raised, by force of parallax, above the Moon, above Venus and Mercury at perigee, right up to the heaven of the Sun, to its Court and royal seat; and might not seek them in the sublunary, or even the subsolar, regions, but in the very bosom and lap of the Sun; and might raise worthy questions about them for the sake of celestial physics and truth.

[Margin: The Spots must henceforth be sought by the philosophers above the planets Moon, Venus, and Mercury — near the Sun.]

For the rest, having thus far disputed the absence of parallax in this Phenomenon [*phaenomenon*], it is...

[Margin: That the Spots have no parallax is confirmed by other experiments.]
also confirmed by what follows.

First. When the Sun is stripped of all Spots, this happens everywhere in the whole world at exactly the same time — which would in no way happen if parallaxes of the Spots occurred with respect to the Sun.

Second. When new Spots arise, this happens everywhere at the same time and at the same place of the Sun.

Third. When some Spot occupies the center of the Sun or the Ecliptic, this happens everywhere at the same time.

Fourth. If the courses of the Spots, drawn from the observations, are arranged in order, they always turn out alike, even in different years — provided they are taken at similar times and in the same parallels.

Fifth. Never has anyone noted, in any Spot beneath the Sun, a deviation in latitude — which nevertheless ought to happen daily in any Spot around midday, and especially at the time when the Sun's place bisects the Ecliptic above the horizon. For then all the Spots in our northern climes would be thrown back toward the southern regions of the Sun, and in southern climes toward the northern: but none of this happens.

SECOND ARGUMENT [Argumentum Secundum]

For fixing the seat of the Spots in the very body of the Sun, drawn from the apparent inequality of refraction itself, introduced into the motion of the Spots observed through observing lenses.

Cap. LVI.

I have pursued the force of this argument at length above, where I showed it:

First. That the apparent inequality in the motion of the Spots is nothing but what is caused by refraction through the observing lenses — and this by many efficacious arguments. Among these, one refutes the stubborn objector conclusively: namely, an observation made perfectly without lenses, in which, since that inequality does not occur, it is clear that the apparent anomaly is induced by the [observing] lenses.

Second. I showed that, once that anomaly is removed — either by projection [*expositio*], or corrected and brought back to a uniformity congruent with the time and the appearances — the motions come forth ordered and uniform on the surface of the Sun, such indeed as the periodic revolution of the Spots requires, exhibited also by the returning Spots.

Third. I showed that, under whatever other position and hypothesis of the Spots running outside and around the Sun is assumed, their courses, fitted to the time of the observations, are always irregular and would be unduly greater, and so could never be reduced to any fixed order.

Further, since astronomers, through the apparent motions they discover, always inquire into the proper motions [and try to] order them, and — if they can — by any means recall them to equality and regularity, and readily embrace with both hands the method found for this: I do not see what difficulty there will be in this opinion of ours, seeing that with the Spots placed in the Sun, and the flaw of refraction removed, the motion is always found ordered and regular; whereas with the Spots placed outside the Sun, and the anomaly of refraction removed, the courses always follow as anomalous and disordered. And conversely, supposing some regularity of motion — to which the Phenomenon plainly leads by so many mutually corresponding signs — the Spots must necessarily be placed in the Sun, for outside it such regularity will never be obtained.

This argument has great force in astronomical matters. For who would believe that a false assumed hypothesis would always answer, to a nicety, all the appearances — as does our placing of the Spots in the Sun? And that a true assumed hypothesis would never answer the observed phenomena? — which is precisely what happens under any assumed hypothesis of the Spots being placed outside the Sun.

This Hypothesis, therefore, into which the Phenomenon itself has led me by the hand, I judge to be altogether true, and destined to be accepted and embraced by all.

THIRD ARGUMENT [Argumentum Tertium]

The Spots are placed in the Sun by the benefit of the Faculae.

Cap. LVII.

That the solar faculae are not carried outside the Sun has been proved everywhere by many clear reasons; and if these convince — as it is right they should convince a sound intellect — it follows at once that the Spots too do not go outside the Sun. For from the observed courses of the Spots and Faculae, carried in the same parallel at the same time, the Motion has been found to be one and the same and equal — which would never happen if the Spots departed even the least bit outside the Sun's surface.

For the Faculae, being the brighter parts of the Sun, never leave it — throughout the phenomenon of so many years.

Whence I frame this syllogism:

If the Faculae are in the Sun, the Spots are equally in it. But the Faculae are in the Sun. Therefore the Spots too are in it.

The consequence of the Major is proved from the identity of motion of both; likewise from the fact that they succeed one another into mutually altered and changed places, and mutually conceal one another, and so on. The Minor is proved from the observations and from the reasons drawn from them. The Conclusion therefore stands.

[Margin: An efficacious argument for placing the Spots in the Sun.]

FOURTH ARGUMENT [Argumentum Quartum]

The usual slenderness of the Spots around the horizon places them in the Sun.

Cap. LVIII.

This argument holds more force in reserve than it shows at first sight — as will become manifest to anyone who weighs it well, if he considers the breadth of the Spots appearing around the center of the Sun, and the incredible thinness of

those moving around the horizon: to such a degree that the outermost surface of them, let alone...

their central point, can scarcely be distinguished and freed from the very edge of the Sun. This slenderness agrees with the drawing-out of the very figure of the slender Spot into a thin line, to the eye; then with its long-lasting delay there on the solar horizon; and finally with the corresponding versed sine, and with the arc corresponding to the versed sine, assumed in the Sun's observatory circle. For all these things (refraction being subtracted) force upon us a motion on the surface of the Sun; since they render the outermost arcs, to the eye, equal to the middle ones, and so on, if the rest be taken as equal — as has been copiously proved above.

[Margin: The slenderness of the Spots does not permit them to be removed from the Sun.]

It does not seem possible to satisfy this argument by casting the Spots outside the Sun. For whatever is said, one runs into some appearance contrary to the Phenomenon.

FIFTH ARGUMENT [Argumentum Quintum]

The Spots, through examination of the intervals of two Spots, or of a single Spot advancing day by day, are found on the surface of the Sun.

Cap. LIX.

Whether these intervals be taken lengthwise, or breadthwise, or mixed, the Spots are always found to lie on the surface of the Sun — which could by no means happen if they clung to another sphere surrounding the Sun and were moved in it with a regular motion around the Sun. I have made a great many trials of this kind, and adduced many examples in the preceding parts.

This argument seems altogether conclusive. Its foundation is in Clavius [Christoph Clavius], *On the Sphere [In Sphaeram]*, chapter 2, page 353 of the Roman edition, in the year 1606, *ex Maurobyco* [?], and so on.

SIXTH ARGUMENT [Argumentum Sextum]

The Spots, advancing in a rectilinear course along parallels erected from the observed places into the Sun's surface, are found to move within that same surface, with intervals proportional to the times and to the motions.

Rosa Ursina, Book IV, Part I — Cap. LX–LXV (folios 543–546)

CAP. LX.

[Margin: That the spots are in the Sun, proved from the rectilinear motion of the spots.]

But this could in no way happen if the spots were to move outside the Sun while preserving their proportion of times and paths. And, conversely, since they preserve this harmony when carried along the Sun's moving surface, it cannot be that they should be placed outside it. This argument has been demonstrated throughout by many observed examples, and it could be shown by still more — as perhaps I shall do.

The force of this argument, once the regularity of the spots' motion is assumed (as the senses attest), reaches its conclusion.

[Margin: The argument reduced to syllogistic form.]

The argument, reduced to a syllogism, is this:

If the spots were to move regularly in a straight line outside the Sun's surface, then it would be impossible for them to preserve, on the exposed surface of the Sun, the regularity of their rectilinear motion. But they do preserve it. Therefore they do not move regularly outside, and so on.

ITEM.

If the spots on the Sun's surface preserve a regular rectilinear motion (as the senses attest), they cannot be placed outside the Sun with that same regular motion. But they do preserve a regular rectilinear motion on the Sun's surface (as the senses attest). Therefore they cannot be placed outside the Sun with that same motion.

ARGVMENTVM SEPTIMVM.

That the solar spots are in the Sun, proved from their curvilinear, quasi-elliptical path.

CAP. LXI.

If the pole that carries the axis of the spots always stayed fixed at the point of equilibrium [Aequilibrium], that is, at the point of greatest altitude, and if the spots circled about on the Sun's surface, then it is clear that the trace each one left in the solar circle would be a truly elliptical arc. But now, because the axis is twisted back yearly from west to east, describing a little circle [circellus] with its pole — of which I shall treat shortly — it comes about that the path-traces of the spots do indeed deviate somewhat from an ellipse in reality,

[column II]

yet so slightly that the difference from an elliptical curvature cannot be discerned by the senses; it is known, however, by reasoning and by comparing the succession of several courses. That this quasi-elliptical curvature of the paths should be projected onto the solar circle by spots placed outside the Sun in just the same way as if it arose from a circle described and situated on the Sun's surface — this is simply impossible.

Moreover, these arcs, at the points of equilibrium, and especially on the side of the apparent pole, are always greater than half an ellipse, and so on — which is impossible for the course of any spot placed outside the Sun to agree with. Hence, given this established experience, it is impossible that the spots should be carried outside the Sun.

[Margin: Argument from the magnitude of the apparent path-arc.]

For no circle greater than the greatest circle of the solar globe can project onto that same globe any arc of an ellipse equal to half of it in length — because the diameter of a circle greater than the solar circle is greater than the diameter of the solar circle, and so on.

This argument cannot be evaded.

ARGVMENTVM OCTAVVM

From the properties of the curvilinear path-arcs described by the spots, it is proved that the spots are in the Sun.

CAP. LXII.

The curved segments of the courses described by the spots over a single half-year proceed, increase, diminish, curve, and are again straightened out with such an

order and proportion, and are so intersected by the solar circle, that they cannot possibly be fitted to any sphere other than the solar one. From this it plainly follows that the spots are in no way carried outside the Sun. For if they were carried outside, their paths would fit some sphere other than the solar one — indeed, they could not be fitted to the Sun at all. And so, from this argument too, it cannot be that the spots should be held to revolve outside the Sun. I do not argue the point in detail here, but only intimate it, because it has been fully and minutely explained above.

This argument too, once the observations are granted, brings an irresistible force to any sound understanding.

ARGUMENTVM NONVM.

From the daily intervals of a single curvilinear course, compared with one another and found uniform (as the senses attest) on the Sun's surface, it is proved that the spots are in it.

CAP. LXIII.

Because, if they were not in it, the daily intervals would not be equal to one another; but they are equal. Therefore the spots are in the Sun.

The consequence of the major premise has been shown in what precedes; the minor is established from the observed courses of the spots, met with everywhere — whether observed by me, or, if you prefer, to be observed and duly ordered by you, and so on. Therefore the conclusion follows.

ARGUMENTVM DECIMVM.

By means of the small polar circle [Circellus polaris], the solar spots are proved to be in the Sun.

CAP. LXIV.

[Margin: From their equal distance from their mobile poles, the spots are necessarily inferred to be in the Sun.]

If the solar spots are in the Sun, and if in the Sun they are twisted around some fixed axis and pole, along some definite circle at the rim of the solar globe, in whatever time and with whatever speed or slowness — then it is certain that a spot rotated by such a gyration always stands at an equal distance from the pole of its circle. For it is supposed to complete its period on a fixed circle around the

axis, described from the pole of the axis. But since it is established from observation that the gyres which the spots describe with their circles, when projected onto the plane of the solar circle, do not present fully elliptical lines but ones somewhat deviating from an ellipse, it necessarily follows that the circle on which the spot ran about — and consequently the axis and the poles too — is mobile. Therefore, once the little circle [Circellus] is known, along which each pole of the mobile axis runs, and once the apparent position of the mobile pole is found, and this from day to day (for each day a different position

[column II]

of the mobile poles settles into the solar circle and into the observatory) is obtained for a given day and time of day — the apparent distance of the spot and the pole in the plane of the solar circle. Then, from this discovered apparent, or seen, distance, is derived the true and unseen distance which those same two points occupy on the round, or spherical, surface of the Sun. From which I form a syllogism of this kind:

[Margin: The argument in syllogistic form.]

If the spots exposed on the Sun's surface always preserve, for each course, the same and an equal distance from their mobile poles, then they most certainly describe their true motions on that same solar surface, and are to be admitted by astronomers onto that same surface.

But the spots exposed on the Sun's surface do always preserve, for each course, the same distance from the mobile poles.

Therefore they describe their true motions on that same solar surface, and are to be admitted onto it by astronomers.

The consequence of the major premise is clear.

The minor is proved from observations faithfully examined.

Therefore the conclusion follows.

But to the contrary, thus:

If the spots, once circles outside the Sun are assumed, obtain unequal distances from the poles and acquire irregular motions in longitude, then they are not to be placed outside the Sun. The former is the case. Therefore the latter is not to be done.

I have examined each month of the whole year, and I have always found regularity of the courses when the spots are placed in the Sun; when they are placed outside, anomalies have always followed.

ARGUMENTVM XI.

From their periodic return, the spots are proved to move in the Sun.

CAP. LXV.

[Margin: A sophistical argument against placing the spots in the Sun.]

If the solar spots were on the Sun's surface, and were to gyrate about its center, they would certainly return; but they do not return: therefore they do not gyrate on the Sun's surface.

Thus many argue everywhere, and by this reasoning

they knot up certain Gordian knots — I know not which — for the incautious, as with a rope of contention; in which they entangle no one more than themselves, and with blind impulse they carry off the spots and faculae themselves as far as possible from the Sun, hiding them away in the hollow, blind orbs of eccentrics and epicycles alike, so that in this way the spots may either never, or only very late — after perhaps the end of the world — return beneath the Sun; and even if they should chance to return, they could not easily be caught sight of or recognized, especially on account of the shape being meanwhile disturbed by the varied motion of the little bodies of which they are composed. And by this device they preserve, in their own opinion, spots and faculae that are everlasting — but how well and for how long, will presently be apparent.

[Margin: The fallacy of the argument is exposed.]

For when they say that the spots carried around on the Sun's surface will return, it does not follow — unless they add that the spots carried around on the Sun's surface are incorruptible. For otherwise, if they are generated and corrupted, it is not necessary that they return, since they may have perished on the other side of the Sun; and no one who has more deeply penetrated the nature of this phenomenon can doubt that this most often happens. And so, for the consequence of the major premise to gain force, it would have to be framed thus:

If the solar spots on the Sun's surface, and about its center, were to gyrate as everlasting, or at least as long-lasting, then they would certainly return. If, I say, the major proposition were formed in such a way, something might be granted to

the consequence — the necessary suppositions being supposed from the phenomenon itself: namely, that the spots are carried only in longitude, with some small variation in latitude; likewise that they are never wont to exceed the Sun's whole breadth as circumscribed by a certain middle zone, and so on. Fortified with these and similar circumstances drawn from the phenomenon itself, the major stands firm. Now to the minor; but the spots do not return.

This minor proposition, to conclude anything, must be universal, in this manner: No spots return. Granting this for the moment, though not conceding it, what follows? Therefore no spots gyrate on the Sun's surface, and about its center, as everlasting or at least long-lasting.

This conclusion, admitted from the given premises, whom does it strike? No one at all. For it proves no more than that the spots on the Sun's surface are not everlasting or

[column II]

long-lasting — which we willingly concede to our adversaries; indeed, we have by our very design urged it as proved thus far. But then to infer: "Therefore the solar spots absolutely do not gyrate on the Sun's surface" — this is a fallacy from the qualified-in-a-certain-respect to the absolute [ex adiacente secundo, ad absolutum]. "The solar spots are not, or do not gyrate on the Sun's surface, as everlasting or at least long-lasting; therefore they absolutely are not, or do not gyrate on the Sun's surface."

Once the antecedent is conceded, the consequence is denied: for it is a manifest and sophistical fallacy — and much more so is the violent migration of the spots and faculae into foreign regions that is deduced from it. For unless you have proved that the spots and faculae are stable or everlasting in the Sun itself, unless you have proved that the spots and faculae cannot, or are not wont to, come into being and perish, you accomplish nothing, but are deceived and deceive; the argument does not bind. And so in vain do you set those same spots free from the Sun, in vain do you cram them, outside the Sun, into the trifling workhouses of the orbs of eccentrics and epicycles, an asylum of ignorance.

[Margin: The adversaries' minor proposition is false; for the spots do return.]

For even if they are in the Sun, it can happen — and in fact does happen — that when dissolved they do not return. It is therefore not necessary to cloak their non-return by a fabricated separation from the Sun, propped up by no experiment, no sense-evidence, no reasoning, but forced in by mere prejudice;

nor to impose false persuasions on the inexperienced. And so that this may shine forth much more clearly than the Sun itself, I take up the minor again, and, its mask torn away, I inspect its face thoroughly. It was this:

"But no spots return." This minor, I say, is denied. And it is convicted of manifest falsity from the phenomenon itself. The solar phenomenon itself is so fruitful, so powerful, so clear, so ready and open, that to those who inquire willingly and of their own accord it pours forth truth with open bosom, most generously, as from a horn of plenty. Had these men been willing to embrace it seriously, they could certainly have unearthed it long ago; but it seems to lie close to their hearts, not so much to confirm the truth of the phenomenon as to confirm an erroneous, prejudiced conviction — as they themselves do not conceal, but indicate openly enough, being ready to embrace and devise any plausible fictions whatever rather than depart a nail's breadth from their own thesis. And if

they have thus far been unable to draw out the truth lying hidden in the phenomenon, let them acknowledge the insufficiency of their observations for this matter — otherwise slippery — and from this let them more cautiously decide, or let them acknowledge their own inexperience in handling these things; and if they are content to err, let them not wish to draw others into error along with themselves.

For my own part, to say the matter as it is: from the very beginning of this phenomenon that I discovered, I was always confident of the return of at least some of the spots. For, given their great nearness to the Sun — as far as I could clearly see and set forth in my *Apelles* — reason always pressed upon me that it could not but be that at least some should sometimes return, notwithstanding their natural and physical destruction.

[Margin: An expectation consistent with the return of the spots.]

For just as many were remaining almost unchanged across the whole face of the Sun, so it followed as a consequence that some should persist in concealment and return to us after a like interval of time. But while this reasoning pressed hard upon me, I saw, on the other hand, that even if the spots should perhaps return, this could not be known or denied for certain, so long as their apparent motion was not yet clearly established.

[Margin: The return or non-return of the spots is difficult to know — and why?]

For if this is not known, the return of the spots is investigated in vain: because, even if you have obtained one that has truly returned, you dare not assert that it

has or has not returned, unless the apparent motion of it is established for you — where the given spot departed, where and when it ought to return, with what course it moves, whether rectilinear or curvilinear, and whether parallel or oblique to the ecliptic.

Since I held these matters clearly in view, I suspended my judgment, and I always prudently deferred to future observations and discussions. And when I was often pressed by many to affirm or deny at last the return of the spots, I always replied that the apparent motion must be most exactly foreknown for deciding this question; and that for this task very many observations were needed — continuous, most keenly examined, and arranged in order of path — which, since through my occupations I had not yet worked through them, let them patiently bear with my delay; that it was better to bring forward late and

[column II]

once a true opinion, than a premature and always false one. A word once uttered is irrevocable, and a reputation once lost is never restored.

And so it came about that, just as through so many elapsed years I did not assert that the spots return, so neither did I in any way pronounce that not a single one ever returns; but, always doubtful, I observed diligently, so that even on this account I might arrive at some certain goal. And I judge that I have at last attained it, caring little what others, by affirming or denying without consulting the phenomenon, may have blurted out against the truth from mere partisanship — things now shameful to swallow back, and impossible to defend.

Therefore, after I had reduced almost all the observations to order, and had with the greatest care fitted together the courses of the individual spots, I began at last to discern whether any spots returned in agreement with their courses and little circles [Circelli], or not. And indeed I found the evidences of quite a number to be clear enough; but I was unwilling to mix anything doubtful into what I published, nor yet to bring forward everything certain, so as to keep nothing wholly hidden for myself.

From those spots, then, which I found at Rome to be returners, I bring forward four, at intervals of no great length of time; and they are these.

Spot I, southern, returning, from March to May, in the Jubilee Year 1625.

In Image XV, page 191, of the year 1625, you have the course of spot **c**, from the 22nd day of the month of March, at the morning hour of 8½ [?], to the 4th of April, at the evening hour of 1½ [?]. That this same spot, in Image XXI, page 207,

under the letter **a**, has returned, is urged by the same place, time, motion, and parallel. The course on both occasions was wholly southern, but the earlier one, under the letter **c**, was more curved back toward the ecliptic **A B** than the later one under the letter **a**. The cause of both is that the little course **c** stood nearer to the vernal equilibrium [Aequilibrium], and had its southern pole, on the small polar circle, more elevated above the plane of the solar circle than the later course **a**. In the first course, **c**, this spot grew; in the last

Rosa Ursina sive Sol — Book IV, Part I (folios 547–550)

(left column, continuing from the previous folio's catchword "mo")

—o. Spot a waned, and it came to rest in the middle of the hidden hemisphere. Consult the cited Images of the Observations, and the notes upon them.

MACULA II.

Boreo-austral [north–south] spot on its return, observed in the same year 1625, from 11 May to 18 June.

[Margin: The spot on its return.]

You will find this spot described in Image XXIII of the Observations, on page 211, from the 11th to the 23rd in the morning — where it indeed no longer appeared, though a little before it had entirely set, the faculae lighting up its horizon revealed it, and I marked it with the letter **a**. After it had completed its course in the hidden hemisphere, it returned on 6 June and remained above our horizon until 18 June; after which it set completely at night, and so on the morning of the 19th nothing more of it was seen. You will find it depicted most fully in this second course, in Image XXV, page 215, under the letter **h**. Each of its two courses was very nearly rectilinear, as is plain on inspection, though the later one in June was somewhat straighter than the earlier one in May, because this later course stood a little farther from the summer solstitial turning-point [conuersione seu statione Tropica æstiuæ] than that of June did. Each course also shared something of both regions — the northern and the southern — yet less of the north than of the south. The whole course **a** looked back toward the southern pole **N**, which still in some manner overhung the horizon and was soon to set — something the wavering course itself, as it were, hinted at. The whole course **h** thereafter looked back toward the northern pole **Z**, newly risen. But the intermediate course, which

the same spot completed on the far side of the Sun, from 23 May to 6 June, shared in both poles, so that its apparent advance, projected onto the plane of the solar circle, must have been the straightest of all.

For the rest, that both courses of this spot were completed in one and the same parallel is clearly indicated by the same very short distance of each from the center C — a distance which, on account of the straightness of the courses, fixes its latitude at five degrees on either side, more or less.

(right column)

Therefore anyone who weighs the places, times, intervals, sections of the ecliptic, declinations from it, and the resemblance of the spot at full and at waning, and who balances everything in an equal scale, will — together with me — establish beyond any doubt that this spot returned into our view.

COROLLARY.

From the mutual comparison of these two courses you will grasp how true is what I have often said: that the rectilinear traces of the spots at rising and setting yield differences that are scarcely perceptible. For their rising and setting occurred at nearly the same places, with so great a lapse of time between; the reason being that, since the axis and pole ascend from the horizon within the polar circle [circello polari] over so long a time, the optical approach to the fixed axis scarcely varies perceptibly, and so the declination remains, as it were, the same. Now from 10 May to 18 June there intervene 39 days. You therefore have, by a practical example, the truth I have so often asserted.

Yet by this I mean to detract nothing from the curvature of the middle of the course, which always follows the inclination that the moving axis makes to the plane of the ecliptic, and so forth.

The risings and settings of the chords connecting the [course's] points, however, relative to the ecliptic line and its inclination, introduce no perceptible variety over many days. Just as, conversely, when the greatest curvatures occur in the courses the spots are traversing, then in these there is no perceptible change over many days, whereas the change is swift and great in the chords and in the angles of the chords with the ecliptic.

Since the curvature of the course follows the inclination and elevation of the moving axis and pole, which stands in near-equilibrium — while the declination of the chords, in turn, follows the optical declination of the moving axis from the fixed axis, which at those times is swift and greatest.

(left column)

MACULA III.

In the same year 1625, on its return from 8 June to 15 July, from north into south.

[Margin: The spot on its return.]

In Image XXVIII, page 231, a single composite spot k arose, from 8 June, emerging from faculae by minute signs and swelling with continuous growth until, sufficiently large and compact, on the 19th it went out — in that state, or rather still growing — and, having traversed only at its surface the region of the Sun opposite [to us], after thirteen days, in the month of July, on the third day, at the 8th morning hour, it halted again. In Image XXXIII, page 241, having crossed the horizon, I marked it with the letter a. Its earlier course was a little straighter than this later one, because the pole toward Z stood lower there and higher here; for it ascends within the polar circle toward the equilibrium [point], though on both sides in the same parallel. The spot advanced through a latitude of only four degrees, and so completed a circle distant 94 degrees from its own moving pole appearing as Arctic, or 86 degrees from the hidden Antarctic pole; and thus it was not far from the greatest of the parallels, and therefore only a slight difference separates the apparent from the hidden course. For the greatest parallel makes both courses always equal throughout the year — the hidden to the visible, and this to that. But as for the remaining parallels: the nearer they are to this [greatest one], the more alike [the courses]; the more remote, the more dissimilar the apparent courses they describe on the oblique sphere of the Sun. On the right [sphere], which happens perceptibly twice a year, all the apparent courses too, of whatever parallels, are among themselves — other things being equal — nearly alike and equal in duration, that is, in time above the horizon.

The track of this spot was curvilinear, almost entirely southern, as is evident; near the east it cut off some portion from the ecliptic. Its whole periodic motion did not quite reach 27 days.

See the cited Images of the observations, XXVIII page 231 and XXXIII page 241. This spot, in its later course, was also observed by Father Christoph Grienberger, and he set it forth as you have it in Image XXXIV, page 243.

(right column)

MACULA IV.

On its return in the year 1625, from 12 July to 19 August.

[Margin: The spot on its return.]

In Image XXXV of the Observations, page 245, there appears the northern course o of spot o, gradually born in the Sun from faculae on 12 and 13 July, which with great growth reached the horizon on the 24th of the same month; then, having traversed the hidden surface of the Sun on the far side, it revisited us in the east on 6 August, at 7½ in the morning, from which it again came to the western horizon on the 19th, at 4⅓ [4⅓] in the afternoon, in Image XXXVII, page 249.

That this spot is the very same one that in July, at the said place and days, occupied the Sun — all the conditions the matter requires persuade us; and for the reader's sake, by way of example, I am glad to set them out.

Arguments persuading the return of the spot. From place.

First. Place: because the place of rising in August, at the ecliptic point A, was so much nearer than it would have been in July, had the spot [then] held the horizon, as the annual motion of the pole in the little circle [circello] required; and by the same reasoning the point of setting in August receded from the ecliptic B just so far beyond the setting-point in July as was owed to the same little circle. Furthermore, the itinerary points of the spot midway in course o are more distant from the center of the solar or observational circle than the points of course a in August; and the difference of the distances answers beautifully to the journey meanwhile completed in the polar circle. Besides, the several assumed points of both courses — both o and a — examined on the surface of the Sun from the moving pole, are distant by equal arcs, which are taken on the greatest circle of the Sun, or on the perimeter of the observational circle: and in the said courses they amount to 68 degrees 20 minutes. Whence there arises—

Second. The same [spot] is, in both courses, parallel — which the same latitude gives, the latitude obtained from the same distance of each circle, found from the moving pole, which I said to be 68 degrees 20 minutes. [Margin: From one and the same parallel.]

(left column)

This [latitude], subtracted from 90 degrees, leaves the latitude of the parallel described by the spot on both sides, which recedes from the greatest of the parallels by 21 degrees 40 minutes toward the north. Therefore one and the same parallel, carrying the spot by number to a suitable place, adds the greatest weight to the present business.

From the quality of the apparent courses.

Third. The situation and configuration-quality of both courses. For the July course is straighter, and at rising departs more from the ecliptic, at setting less, than the more curved August course — and so it had to be, if the same spot had returned, on account of the polar circle, in which lies the governance of this anomaly.

From time.

Fourth. Time agrees in every way upon one and the same spot. For this spot, in course o, on 24 July, at the 8th morning hour (as is clear from inspection of the autograph records), was seen to occupy the western horizon for the last time; then, returning in the month of August, it obtained the same [horizon], being last seen on the 19th at the 6th evening hour; and thus, for one whole revolution — from the contact of the western horizon to the [next] contact with the same — it took up 26 days 10 hours, more or less. Now if we reckon the same time by parts: from the setting on 24 July to the rising on 6 August, we shall have, for the segment of the hidden course, 12 days 16 hours; and if to this we add the visible course, from 6 August to the 19th of the same month, namely 13 days 18 hours, the whole sum of the periodic course will be 26 days 10 hours, more or less. For here I am not concerned to bind this most subtle matter to hours and minutes with geometric rigor — from which it would be a crime to depart — but it suffices for my purpose to state the perceptible quantity of the periodic motion to the day and hour, as far as it can be had from sober observations, more or less. For the ultimate and individual precision, more years and observations — and, I add, under larger observational circles — are required.

(right column)

To this end — that I may show either that the same spot returned, or that it completed its course on the surface of the Sun — that most exact reckoning of time is not necessary. It would indeed serve wonderfully, if it were had; but while we are investigating it, in order to confirm [our claim], we ought not to presuppose it, but to prove it from observations.

We shall therefore find it the same by comparing among themselves the culminations of the spot, on 16 July and 12 August — where note that, among the spots marked on the 16th, the more eastern are to be taken; for these, with the succession of days, grew into this spot, and they took the same time in returning, namely 26 days 10 hours, more or less.

The same time will emerge if the daily intervals of the apparent motion a a a are raised to the surface of the Sun and investigated there, as you see was done in the

earlier cases. For if, about the apparent course a a a, you describe a circle whose diameter is the latitude of the spot — which it presents as 21 degrees 40 minutes — a circle equal to the periodic revolution of the spot, and on its circumference you lay off repeatedly the daily space near the center, you will find about 28 days; but if you apply some horizontal daily space to the same periphery as many times as it will go, you will find about 25 days; and if finally you take the day's course that lies midway between the central and the marginal, and traverse it in measuring the perimeter of the same found circle, you will obtain altogether 26 days and 10 hours, more or less. And hence it is plain — what I have so often driven home — that this inequality of defect and excess arises solely from the inequality of refraction.

The remaining arguments for the return you have noted in the cited Images of the Observations themselves. [Margin: There are more arguments in the annotations to the observations.]

In the same way I have compared the circuits of other returned spots with the apparent ones, and found similar agreements, and always found the conversion turning between 26 and 27 days, more or less.

But whether they can, or are wont, sometimes to exceed, or to fall short below the said number, I have no means at present to affirm; for I follow the phenomenon, I do not go before it; I record, I do not prescribe. Meanwhile I cannot conceal these beautiful harmonies of numbers.

(left column)

If it is set up so that the whole periodic time of the course of spot a — that is, 26 days 10 or 12 hours — is [set] against the perimeter of the whole circle, which is 360 degrees, and likewise one day, or 24 hours, [is set] against another [term], there will come out 13 [+ compound fraction, small figures read as roughly $\frac{3}{6} \frac{7}{3} \frac{2}{6}$, reading uncertain [?]] for the stretch of one day which the spot completes by its own course in its parallel, more or less.

Again, if it is set up so that 636 hours is to one revolution as 8820 — that is, the days of a year, 365 — is to another, there will come out revolutions of one year, 13 [+ compound fraction, small figures read as roughly $\frac{5}{6} \frac{5}{3} \frac{2}{6}$, reading uncertain [?]]. But if we allow 27 days to one revolution — which sometimes happens — there will come out revolutions in one year, $13\frac{1}{2} \frac{4}{7}$.

In the same way, since the poles of the spots, by their annual motion in the little circle, daily advance from setting to rising by about one degree, while the mean

period of the spot is being completed the pole will run through, in the little circle, thirteen and a half degrees, more or less.

And so each spot, by its own daily motion, completes as many degrees of its parallel as there are periodic revolutions occurring in one year; as many days as the mean period takes up; as many degrees in the little circle as the moving pole [runs through], and so on. But let these things be indicated with a light hand and a rough sketch [pingui Minerua], rather than discussed.

Examples of the practical exposition, for establishing the truth so far asserted, will be brought forward a little later, in the second part of this book; which accordingly you will examine and consider.

This argument, for placing the spots in the Sun, seems to remove all doubt and evasion. But I leave the judgment to the wise reader, and I do not wish reasons to have more force than they are worth.

(right column)

ARGUMENTUM Duodecimum.

The spots are proved to be in the Sun from the secondary phases of this phenomenon.

CAP. LXVI.

I showed at length in the previous book, on page 345, when I explained the observations of the solar meditullium [Meditullij solaris], that scattered over the whole Sun there are secondary spots and faculae, alternating; that they are even and quiet parts, especially near the poles and the polar circles. I showed that these things have not only a perpetual variation, but also the very same motion that belongs to the primary spots and faculae. And since all these, taken together, constitute and make up the visible surface of the Sun, it is plain that they are in the Sun itself — otherwise we would never see anything of the Sun. [Margin: Either the shining Sun is not the Sun, or the secondary spots and faculae are in the Sun; or the Sun itself passes beyond itself.]

And these are the twelve arguments by which it is effectively urged that the spots and faculae are present in the physical surface of the Sun. Scattered here and there throughout the whole work, I wished to present them, collected briefly here, to the reader as if at a single glance. I could bring forward more; but if these do not prevail, the rest will perhaps accomplish no more — for who will wring

assent from one who is unwilling, and who neither weighs nor scorns the weight of reasons?

For, as the proverb has it, one fool can deny more than ten wise men can prove.

I, therefore, will not be the man who, against those who deny principles and trample sure and palpable observations and experiences, would wish to take up war. Let him keep to himself, who so wishes, his own ravings; for all I care, let him — lowly and obscure — pursue the darkness with the moles. My concern is with the philosopher and the lover of truth: under the open sky, in the clear aether, with the Sun itself, conscious of all, as witness, we dig out the light of truth and put to flight the darkness of falsehood. Here there is nothing painted, feigned, forced, or smacking of private bias; I put forward nothing of my own, but what

Rosa Ursina sive Sol — Book IV

Part I, Cap. LXVI (conclusion) — end of Part I

[The two text columns on this page are labeled with the cross-reference numerals "I." (left) and "II." (right); they read continuously, the left column running on into the right. The small marginal numbers 1, 5, 10 are the page's line-count apparatus.]

which, marveling, I observed bearing its torch in the Sun, I have faithfully brought to light. Yet I have not thrust the spots into it so far that I would want them always wholly immersed, for some can project or sink in more, others less, just as we see one ship stick more deeply than another in the open sea. This is why I always say that the spots adhere in the *physical* surface of the Sun — which is not to be conceived in the mathematical manner, devoid of all thickness, but in the physical manner, endowed of course with sufficient depth: with which, and in which, the solar spots are whirled about the Sun.

And let these things be taken as truly established regarding the location of the solar spots and faculae [*maculae Facularumque solarium*]. Content with them, now that they have been placed in the Sun, I rest, and I set an end to the first part of this Book, for the Glory of the Triune and one God, who alone does wondrous things in Heaven and on earth.

ROSAE VRSINAE SIVE SOLIS — Book Four, Part Two and Last

ROSA URSINA, or THE SUN

Book Four, Part Two and Last

Summary [Summarium]

; foliate ground.]

This last part of Book Four — and of my whole work — presents the following.

First, a theory of the motion of the solar spots and faculae — rough, admittedly, in its wording, yet solid and grounded in fact, and drawn from the very motions of the phenomenon itself; for a serious observer must follow nature, not run ahead of it.

Second, it surveys the Royal Zone, or path, of the spots, and points out its causes.

Third, it discloses the apparent arc of the Sun within the Sun's own greatest circle, and by how much it is smaller than the hidden arc; and concerning the magnitude of the solar diameter — both as seen and as true — which is to be investigated and determined, it offers throughout much that is new and worth knowing.

Fourth, it displays the marvelous nature of the solar phenomenon, its perennial age, its noble causes and effects, and from these, exceptional truths and outstanding uses.

Fifth, on the light and color of this phenomenon it brings forward select records, hitherto untouched, together with experiments.

Sixth, it teaches what may be concluded from these and other celestial novelties — by some, concerning the fiery nature of the Sun, the stars, and the heaven; by others, concerning their corruptibility; and finally, concerning the fluid substance of the heaven — according to the mind of the Holy Fathers [Sanctorum Patrum], in conformity with Scripture and the sacred interpreters, and following every kind of learned doctrine. For this purpose, then, and for your benefit too, friendly Reader, I set forth these same authorities — laboriously collected and arranged in order — faithfully, word for word, from the sources themselves. And so at last I finish my work, and hand over to your eyes, hands, and nose this Ursine Rose [Rosam Ursinam], brought forth at last after a difficult and drawn-out labor: you

will examine it, handle it, and smell it as you judge best. And if you find little pleasure in my cultivation of it, you will assuredly find a great deal in the admirable handiwork of God within this rose-garden [Roseto] of graces and delights. At Rome, in the Professed House, the day before the Ides of November, 1628 [MDCXXVIII].

PHAENOMENI SOLARIS SEV ROSAE VRSINAE THEORIA

THE THEORY OF THE SOLAR PHENOMENON, or of the URSINE ROSE

Cap. I

[The text again runs in two columns marked "I." (left) and "II." (right), read continuously left-into-right; the marginal numbers 10, 15, 20, 25, 30, 35 are the line-count apparatus.]

I do not lay down or invent the theory of this phenomenon at will. Rather, having followed nature herself — explored by so many and such varied paths — I describe it a posteriori, after the manner of those who first dared to define the motions of the stars; and I put forward a kind of history — a "Theory," so to speak — better perhaps than the Censor Apelles did, yet briefly, and therefore perhaps less worthily, because, pressed by shortage of time, I cannot spread wider sails to the winds. It may be that, once granted more ample leisure, I shall do so. For the present I set before your eyes a compact account of the whole constitution of this Appearance and inquiry — an account made by nature, implanted by God, not fabricated by me nor devised hypothetically, but drawn out of observations.

For it is established from what has been observed and already often said, that the apparent Motion of the spots about the center of the Sun is twofold, regular and fixed: the one annual, the other roughly monthly. [Margin: The rectilinear motion of the spots. (*Motus Macularum rectilineus.*)] Since this motion varies its aspect toward us, and twice a year — at opposite six-month intervals, namely in June and December — becomes, to the senses, rectilinear, it is altogether necessary that at those times the axis about which the spots revolve lies in the apparent circle of the Sun; and because in the remaining, intermediate months that motion [continues in col. II] passes from rectilinear into curvilinear, [Margin: The same becomes curvilinear. (*Idem curvilineus.*)] and this in opposite directions — so that at one mid-year the convex curvature faces north, at the other mid-point south, and each curvature gradually swells and gradually subsides, the proportion of

times and of curvatures being kept uniform, and so forth — it must be that the said axis, together with the poles in which and about which the spots revolve, at one mid-year raises one of its halves above the plane of the solar circle [Margin: The axis is movable: one half of it is below, the other above the solar horizon. (*Axis mobilis: altera medietas infra, altera supra horizontem solarem existit.*)] and lowers the other by as much; and because the apparent curvature of the spots, from the month of December — as has been said sufficiently — increases to its maximum over three months, then over another three decreases again, and afterward the same happens in the opposite region of the Sun: the axis about which the spots are carried by their own motion must revolve annually, and from its poles two circlets [circellos duos] must be described on the Sun's surface, both toward the south and toward the north; [Margin: The origin and description of the polar circlets. (*Circellorum polarium origo & descriptio.*)] and of each of these, one half lies exposed in the visible hemisphere, the other lies hidden in the concealed one. Their poles lie on the perimeter of the solar circle, removed from the solar Ecliptic by a quadrant of the circle, the axis cutting that same Ecliptic, through the center of the Sun, at right angles.

For if that annual revolution of the axis that carries the spots did not occur, the spots' proper motion would always be either rectilinear or curvilinear, and perfectly similar to itself and uniform as seen by us. But as it is, because the axis of the spots is engaged in a perpetual change of position — and, by the annual revolution of the poles and circlet, now lies in the plane of the solar circle — that [motion]...

[continued from the opening of Cap. I]

toward the eastern or the western region of the Sun; and now it is raised above that [region], and this happens either in the exposed or in the hidden hemisphere of the Sun. From this arises almost all that remarkable variety of apparent motions in the solar spots. Since, therefore, the annual circlet — carrying about the axis and the poles of the axis — is the greatest and almost the only cause of these variations, something must be said about the method of finding and establishing it. And so that the matter may be more orderly, we shall proceed by way of little questions [*Quaestiunculae*].

Quaestiuncula I.

How many circlets are there?

I say there are two, on opposite parts of the Sun. For since the axis of the circlets — which is also the fixed axis of the ecliptic — passes through the center of the

Sun, it strikes the surface of the Sun on opposite parts; and these points are the poles from which the circlets are described.

Quaestiuncula II.

Where do the poles of these circlets lie with respect to the solar ecliptic [Ecliptica Solaris]?

The solar ecliptic is the common section of the plane of the celestial ecliptic and of the exposed solar circle, that is, the solar horizon. I therefore say that the poles of the circlets are removed equally on both sides from that same ecliptic, and so lie midway — such that between the extreme points of the ecliptic line (the eastern and western points of the solar region) and either pole, a quadrant of the solar circle lies within the perimeter of the horizon. This is established:

First, from the greatest curvature of the apparent motion of any spot at the time of equilibrium [tempore aequilibrii]; whereby the chord joining rising to setting along the arc of the path either coincides with the ecliptic or is parallel to it.

Second, from the greatest declination of two equal parallels, equally distant on either side from the center of the Sun toward the north and toward the south; for those declinations are equally distant from the ecliptic. This declination occurs most of all in the rectilinear courses of the spots, etc.

Third, from the greatest declination — both southern and northern — of the greatest parallel, taking each in the east or in the west. For just as the greatest parallel recedes perpendicular to the horizon from the ecliptic, so its axis and pole recede from the axis and poles of the ecliptic. And the greatest parallel recedes equally from the ecliptic on both sides; therefore the axis likewise recedes from the axis in the same way.

Much can be applied here that was said at the end of Book Three, etc., to which I refer the reader.

Corollarium.

From what has been said it is clear that the poles of the circlets are also the poles of the solar ecliptic.

Quaestiuncula III.

Are the two circlets, the northern and the southern, equal to each other?

I say they are — at least those referred to a single course; for if several courses are considered, they are found ordinarily and to the senses to be equal, of which more later. For both the declinations and the inclinations of the apparent motions, taken over equal parallels described in different regions, are ordinarily and to the senses equal to each other.

Quaestiuncula IV.

What is the axis of the circlets?

It is the diameter of the Sun that cuts the line of the solar ecliptic through the center at right angles. Each day it coincides with the common section of the vertical and of the solar circle, which occurs when the place of the Sun bisects the celestial ecliptic above the horizon — that is, when it is a quadrant of the ecliptic distant from the horizon on either side.

Quaestiuncula V.

How large is the circlet?

I ask not about the area, nor about the perimeter, but about the diameter, or the semidiameter: namely, by how many degrees — counted on the solar circle, or observation-disk — the perimeter of the circlet is distant from its pole; or how large is the arc, taken on the solar circle, which the diameter of the circlet subtends as a chord, or half of which the semidiameter of the circlet subtends as a sine; to what interval of arc, finally, the circlet is described on the globe? And in the plane, to the interval of the sine subtending that arc?

[Margin: The state of the question is set forth.]

I say that the definition of this matter, and sure knowledge of it, is one of the chief and cardinal points in this phenomenon. Hence all my industry has always striven toward this: that in this matter I might arrive at some firm and solid certainty. I have found the circlet sometimes to correspond to a semidiameter of 6 degrees, never (so far as I know) below that; sometimes eight, and no more; but for the most part seven, or seven and a half. Hence I have adopted it in my expositions as ordinarily seven degrees, of the kind of which the periphery of the solar circle is 360.

Yet I would not have this matter so decided or fixed that, if it should be found otherwise by anyone (which, however, I hardly think), I would be unwilling or unable to agree. For half a degree of these solar degrees, more or less, added or

taken away, scarcely introduces a perceptible difference, as I have proved by many examples.

[Margin: The ordinary magnitude of the circlet appears to be 7 degrees.]

I chose seven so as to proceed by a middle path; and then because I found seven degrees more frequently — and most of all when I investigated this matter with more than ordinary care — and I suspect that that excess or defect can be introduced from elsewhere, as I shall suggest below.

Quaestiuncula VI.

By what reasoning above all was the magnitude of the circlet investigated?

First. When the solar spots present a rectilinear apparent course, the axis of their motion must lie, to the senses, in the plane of the solar circle; and therefore its extreme points — which are also called the mobile poles — must be situated, at the circlet's greatest elongations to our sight, at the extremity of the chord, or transverse diameter, and must produce the greatest visual distance from the fixed axis of the ecliptic. But since the rectilinear path that any spot makes is perpendicular to its own axis, if a line parallel to it be conceived — for any such given path, projected onto the circle of the Sun — to pass through the center of the Sun, that line will decline from the ecliptic by just as much as the mobile axis of the spots recedes from the fixed axis of the circlet. Given, therefore, the rectilinear course of any spot, the greatest distance of the mobile axis from the fixed axis of the circlet is also given; and this axis of the ecliptic is the same as that of the circlet. And by means of the found apparent greatest distance of those axes, the sought amplitude of the circlet is likewise obtained — which is nothing other than the half of the chord subtending the arc intercepted, out of the solar circle, between the said most-distant axes; or the arc subtended by that half.

[Margin: From the highly curvilinear motion of the spots.]

Second. When the apparent course of the spots is highly curvilinear — which happens at the equilibria, the chord connecting the horizontal eastern and western extremities of the paths being parallel to the ecliptic, and not much distant from it, or wholly coincident — then the arc out of the solar perimeter, or horizon, intercepted between that chord and the tangent at the mid-point of the course, is the magnitude of the circlet. For in this case the mobile axis has its greatest inclination to the solar circle, and the apparent pole of the mobile axis has its greatest altitude above the horizon; and both the axis and the mobile pole coincide optically with the fixed axis of the circlet — or, what is the same, are

projected onto it — and the pole of the mobile axis is as far distant on the sphere from the fixed pole of the circlet as the line touching the mid-summit of the given course is from the chord connecting the extremities of the course. Since, therefore, the course is given by observations, together with its distance from the chord, the magnitude of the circlet is also given by means of the drawn tangent — found ordinarily to be seven degrees, or a little more or less.

[Margin: From the practice of projection.]

Third. Practice, or the experience of projection, best shows the fitting magnitude of the circlet. Since, then, from the poles of each circlet described at seven degrees I have set out the courses of the spots through all the months of the whole year, and have found the greatest agreement of places, its soundness can scarcely, it seems, be called into doubt.

Quaestiuncula VII.

Why is the magnitude of the polar circlet found sometimes greater, sometimes less than seven degrees?

First. Because the spots, on account of the continual variation of their magnitude and their natural alteration, can easily deviate somewhat this way and that, and so add something to, or take something from, the curvature of their path — a thing that at once adds something to, or takes something from, the magnitude of the circlet.

Second. Because the same can come about through local motion or thrusting, or through the agitation of the spots, whose manifold causes may underlie it and be assigned to it — which for now I leave to the physicists to consider.

Through these things, however, nothing at all is taken from the first and primary mobile itself, which is the sphere of the solar body, moved most regularly. I shall bring forward the causes in their own time, if it please God.

Quaestiuncula VIII.

In how much time does the circlet complete its period?

[Margin: The periodic revolution of the circlets is completed in one year.]

Thus far I have found it to be a year — so that, just as the axis and poles of the celestial ecliptic run through the polar circles on the sphere in the course of a whole year, so the mobile poles of the axis of the spots run through the two polar circlets on the Sun, completing about one degree of each daily. But whether this

motion is so precise and stable that nothing is ever lacking or in excess, in advance or behind, or that nothing will ever be deficient or superabundant — this still escapes me. The matter is subtle, and requires observation, practice, and the collation of many years. I, the first investigator of these things, open the door, and I faithfully report what I perceive to the senses.

Certainly the observations and their practical applications agree well enough to the senses, and incline toward a revolution of one year. Consider the Images of Observations LXV, page 321; LXVI, page 325; up to LXX, page 341; and you will understand the truth of what I write — for it was for this reason that I brought them forward.

Quaestiuncula IX.

Whence, whither, and of what kind is the motion of the circlet — that is, of the mobile axis — within the circlet?

From the western region of the Sun to the eastern region of the same, against the daily tendency of the spots, yet not over their poles, but about the stable axis and over the fixed poles of the ecliptic. The annual circulation of the mobile axis is uniformly non-uniform, and its poles move most greatly and most swiftly; the mid-point at the center of the Sun is at rest; the parts near the center move less, those nearer the poles more, according to the ratio of the annual cone formed by the motion of the axis — of which two are made, at vertices opposite one another at the center of the Sun.

Quaestiuncula X.

With what speed is the pole of the mobile axis carried, in one day, in one hour, in Roman miles and paces?

A thousand paces make one Roman mile. Now the greatest circle of the Sun, according to Tycho [Brahe], contains in its circuit 153,715,000 paces, of which the quadrant will be 38,428,750. Setting therefore the whole sine at 10,000,000, the sine of an arc of 7 degrees will correspond to 1,218,693 paces. So if it be made — as the whole sine, 10,000,000, is to 38,428,750, so is 1,218,693 to another — there will result 4,683,284 paces for the quadrant of the circlet. In this, since the pole of the axis advances one degree in one day, there will come out about 52,036½ paces for one day; for one hour, 2,172⅓ paces — that is, two Roman miles and 172⅓ paces. But since the Sun is much larger than Tycho Brahe himself makes it, the truth of what has been said is all the more apparent.

The spots, advancing by their own motion from the eastern region of the Sun to the western, advance in one day, on the greatest circle of the Sun, 5,693,148 paces — that is, 5,693 Roman miles and 149 paces. By "day" I understand 24 hours. In one hour they proceed 237,214 paces over the surface of the Sun, that is, 237 Roman miles and 214 paces, which make $59\frac{1}{2}$ German miles, reckoning one German mile for four Roman [miles] in the computation. This speed is like that of a ball shot from a cannon, which, in flying over one German mile, consumes about one sixtieth part [scruple] of an hour, more or less. This speed would suffice for the balling-together of a body, even if the material were otherwise less consistent, thus revolved about its own center. Here various questions might be raised: What does this motion contribute to the Sun? What to the Earth? What to the planets? What to the stars? For that it is not there to no purpose is most certain. But these things I omit for now, for brevity's sake.

Quaestiuncula XI.

Whence is the beginning of this motion to be made?

From some one of the cardinal points: namely, when the poles carrying the axis either lie in the solar circle, or are raised to the utmost above it. Now the poles lie in the plane of the solar circle (but only to the senses, for in point of fact they never rest there) when the path of the spots is rectilinear; they attain their greatest elevation when the greatest curvature of the paths occurs. These points on the circlet are a quadrant of the circle distant from one another, each of which is traversed by the mobile pole in a space of three months. See what has been said on these matters in Book 3.

Quaestiuncula XII.

At what time of the year — month, day, hour — is the beginning of this annual motion to be taken?

[Margin: The difficulties of setting the beginning, from the rectilinear motion, are recounted.]

The resolution of this question is the more difficult, as both the proneness to error is the greater and the harm of an error admitted is the more damaging. The danger of erring threatens greatest from this: that if I set the beginning of the motion from the point at which the apparent pole reaches the solar horizon — which must be done in rectilinear motion — it is most difficult to reach this point and moment of contact with true precision. For the rectilinear motion of the spots remains, to the senses, unvarying for quite a long while about the horizon, on

account of the almost straight ascent or descent of the mobile pole in the circlet; from which it comes about that scarcely any difference of declination is perceived on the Sun's perimeter over a great span of time — just as happens at the tropical turnings of the Sun, where the declination varies almost not at all. Therefore, since the rectilinear motion of the spots is such, there is hardly a way of knowing the true conjunction of the pole with the horizon; and hence the reckoning of when to begin the motion is most difficult, for several days are, without any trouble, either anticipated or postponed. And if this happens, the fault of this lapse spreads into the whole annual course of the circlet; and so, consequently, error is committed in the courses and expositions of the individual spots; and then at once it is imputed to the phenomenon or to the theory — an error that arises from the fault of this positioning.

[Margin: The difficulties of setting the beginning, from the curvilinear motion.]

But if I apply my mind to the other cardinal point — namely, when the mobile pole is highest and the axis is least inclined and as much as possible elevated to the plane of the solar circle — intending to take the beginning from there, I again find the greatest slipperiness. For in this case one must have the most exact horizontal rising and setting of the spot, or nearly so, in order to know whether the chord proceeds parallel to the ecliptic or not; but this condition is rare, for spots sitting on the horizon do not readily show themselves. Then their very marking-down is very slippery; and finally, of all, the greatest labor is in the middle, about the center. Add to this that, around these times, the spots change their daily declinations quickly and strongly, a thing which continually moves the chord, in the space of a day, from its parallel state, etc.

[Margin: The beginning of the course, approximately.]

And so, since this approach is beset with so many difficulties on every side — and yet on it the chief hinge of the matter turns — I have attacked the problem not in one simple way, but in all; and through all the cardinal points, indeed through all the months of the year, I made trial to which time, month, and day the true position of the spots would correspond. And after very many labors, I found it around the end of November and the beginning of December; likewise around the end of May and the beginning of June; also around the end of February and the beginning of March; and moreover around the close of August and the entrance of September — so that we may say the contact of the eastern southern pole occurs in the month of December, and on a day of the month approximately [...]

PARS II — Cap. I (continued)

(Folio 559. Two-column page; the columns run in sequence — the left column continues into the right. The centered "I." / "II." above the columns and the marginal 5-line numbers are the cross-reference apparatus, not section divisions.)

the first; or in the month of November, on about the 28th day. And then let us proceed around the circlet in the order of the months and the signs of the Zodiac, inscribing those same months and signs upon the perimeter of the circlet, so that from a given date we may determine the pole and the ordinary axis about which the spots run.

I say the *ordinary* axis, because I have found that the courses of most spots agree with this root and key — even though I am well aware that some are erratic, as will be explained a little later. I therefore conjecture, from the observations, that the beginning — the root and key of the pole and of the mobile axis — falls on about the first of December, in the western region of the southern horizon; for from there the circlet strives eastward, against the tendency of the spots. From that point I advance this same pole daily by roughly one degree along the periphery of that circlet. And since every spot moves in its own parallel about the mobile axis, it follows that the spots move not by a single simple motion about that axis, but by a variously compounded one. For the periphery of the circlet, lying on the surface of the globe, rises from the horizon partly toward the north and partly toward the east; hence it is clear that all the spots situated toward this pole, while they tend from east to west, are at the same time carried from west to east and from north to south, and that those which face the opposite pole do and undergo the contrary.

QVAESTIVNCVLA XIII.

Whether all the spots have regard to the same axis and to the mobile poles carried out of and into the circlet?

[Margin: The spots are carried around about the same axis, in the same direction.]

The answer, established from the phenomenon up to now, is that most spots are carried by their ordinary course about the same axis in the same direction. Nevertheless it has sometimes been observed that a few deviate somewhat in their apparent motion, because at other times they run ahead by the speed of their own motion. On this matter consult the Images of the observations and their Notes. These deviating spots are nonetheless carried while the poles of their axis

are still kept on the perimeter of the circlet; this is evident when their course is laid out from those poles, once these are given or posited, for everything will agree in no other way than if you had kept to the fixed times and places.

But the business of refraction too, worked out from observational lenses, can and usually does contribute something to these excesses or defects.

Whether this deviation proceeds from some other principle proper to it, or rather from one common to all; or from the mutual running-together and clashing of contrary motions, or from a lateral impulse upon the spots, and so forth — I cannot say. This much, meanwhile, is certain: that even the wanderings of these spots are regular, that their axes are bound to the circlet, and that the spots themselves are fastened to the Sun's surface. From this phenomenon a very strong argument is drawn for the fluidity of the solar surface, and so on.

QVAESTIVNCVLA XIV.

Whether the proper rotations of the spots are all equal to one another in duration of time, and how great they are?

[Margin: The duration of the spots' rotation is unequal.]

The answer, drawn from the apparent courses observed and carefully examined, is that they are not equal. For many well-explored courses scarcely exceed 25 days; many reach 27; and some seem to aspire to 28. These conclusions are clearly deduced from the true places and motions, investigated by means of the given apparent ones. Consult the Images of the observations and the Notes on them presented in Book 3.

Systema Generale Motus Phænomeni Solaris

CAPVT II

(Folio 560. Two-column page; the columns run in sequence.)

What has been said thus far will be better understood if the matter is set before the eyes.

In the accompanying diagram, then, let the drawn circle ABCD represent the Sun, whose center is E, and let the line of the solar ecliptic be AB. By "solar ecliptic" I mean that portion which the plane of the ecliptic has in common with the Sun; it is a great circle on the Sun. Its intersection with the apparent disk of the Sun is

the line AB, called the ecliptic, whose axis is CD, having the poles C (the northern) and D (the southern), taken on the perimeter CADB of the solar circle.

And although both the solar circle ACBD — which I also call the sensible horizon — and the axis CD, or the ecliptic AB, are not strictly diameters or great circles, they are nonetheless treated as greatest, because in this matter they introduce no perceptible difference of magnitude, owing to the Sun's very great distance from the eye. On this I shall speak deliberately later, in Chapter 3.

Now suppose that on either side of the fixed poles C and D, arcs of seven degrees are cut off on the periphery — to G and O, and to F and P — degrees of which the whole circumference ACBD contains 360; and let the points of these cut-offs be joined by the straight lines GO and FP, which cut the axis CD at a and b; and from these points as centers let the circlets cF dP and eG fO be described, with radii aO and bP. These will be the very circlets on which the annual motion is completed, and through which that great variety of motions is introduced into this solar phenomenon.

[Margin: Explanation and description of the polar circlets.]

Let the circlet cF dP be called the southern, or Antarctic, because when the Sun holds the meridian of the place it lies in the southern region toward the Antarctic pole; and let the other, eG fO, on account of its opposite situation and region, be called the northern or Arctic.

These circlets are to be conceived as erected perpendicular to the plane of the solar circle ACBD. Both of them, on the spherical surface of the Sun, are described from the fixed ecliptic poles C and D by an annual motion — that is, by the mobile poles O, P or F, G — while the mobile axis OP or FG revolves about the fixed axis CD with a motion that, so far as the observations hitherto establish, is steady and uniform.

And these same mobile poles carry the said Mobile axis of the solar spots by poles diametrically opposite — such as F and G (axis FG), or O and P (axis OP), or g and k (axis gk), or d and f (axis df). Thus while the pole O, and the half of the axis OE, in the upper hemisphere traverses the exposed semicircle OfG of the northern circlet — from its rising at O to its setting at G — meanwhile the other portion of the axis, EP, in the hidden portion of the Sun, describes, with the opposite depressed pole P, the hidden semicircle PdF of the southern circlet, from its rising at P to its setting at F.

The root, or beginning of the motion, may be taken in the southern circlet D at the point F, and in the northern circlet C at the point G, and that around the beginning of December. At this time the parallels in which the spots are rolled by their proper motion from east to west — that is, from A toward B — are oblique to the ecliptic AB; and the greatest of them, HEI, makes its greatest declination — AH southern, or IB northern — equal to the magnitude of the circlet, that is, to the arc CG or DF.

The smaller circles are parallels — for example KL, the northern, and MN, the southern. Because at this time the poles F and G rest, to the senses, in the plane of the solar circle, and the declination of the axis FG does not perceptibly vary, their courses coincide entirely with the diameters (or chords) HI, KL, and MN. Hence the courses of the spots that occur on these parallels become sensibly rectilinear for as long as the poles F and G do not apparently or perceptibly recede from those same horizon-points F and G. This at last happens only when perpendiculars dropped from the position of the mobile pole onto the diameter of the circlet, FP or GO, cut off a notable portion of it — which scarcely happens perceptibly before 24 November and after 8 December.

Although I am not unaware of the inclination of the mobile axis above the plane of the horizon...

(Folio 561. A full-page engraved plate occupies the whole leaf; there is no letterpress body text — the faint, mirror-reversed lettering across the leaf is show-through from the adjoining pages, not transcribed. The text flows directly from folio 560 to folio 562.)

Diagram. A full-page engraved geometric construction titled, in large capitals spread across the plate, **SYSTEMA THEORICVM VNIVERSALE DE MOTV MACVLARVM SOLARIVM** ("Universal Theoretical System of the Motion of the Solar Spots"). At the upper left is a radiant medallion bearing the Jesuit monogram **IHS** (with cross and three nails); at the upper right a matching radiant medallion bearing the Marian monogram **MRA**. Two Orsini rose emblems (the dedicatee's device) are set in the lower field, one to each side of the vertical axis.

The construction shows the great solar circle (the disk ACBD) with its center E, from which numerous straight rays fan out to labelled points on the rim; a small polar circlet is drawn at the top (the northern/Arctic circlet) and another at the bottom (the southern/Antarctic circlet), each with an internal cluster of small italic and Greek point-letters.

Clearly legible labels:

- E (center of the great circle)
- Left rim, top to bottom: R, K, A, H, M
- Right rim, top to bottom: L, I, X, B, N, Q
- Top circlet (northern), across its horizontal diameter: G (left), C (top-center), O (right)
- Bottom circlet (southern), across its horizontal diameter: P (left), D (center), F (right); c at the bottom

Small interior/adjacent labels, only partially resolvable at this resolution:

- Near A and along the dotted line beside it (left): small italic/Greek letters, ϕ , ρ , τ [?] and further small marks [?]
- Near I and X (right): a small "m" and "ς" [?]; near N a "λ" [?]
- Top circlet interior: small letters reading approximately q, a, α [?], with p, f, z and H [?] below
- Bottom circlet interior: d (top), and a cluster reading approximately x, ς , n, ϵ , ζ , y, b, τ , o, h, S [?]

[Because more than two interior labels cannot be resolved with confidence, this plate is marked a]

(Folio 562. Two-column page; the columns run in sequence, resuming the sentence broken off on folio 560.)

[Margin: The path of the mobile pole.]

the horizon, and that from it some curvature of the paths arises around the middle. This, however, will not move anyone ignorant of the sense of these speculations to attribute the curvature to the phenomenon itself rather than to the observer or to refraction — unless continual practice and theory teach him so.

In the month of January the southern pole (which must now be imagined raised, together with its semicircle FdP, just as GfO is depressed) has its lodging at g; and the northern pole G [lodges] at K, the point of the hidden semicircle. Of these, the one is projected onto r, the other onto h. And because the axis FG — that is, gk — is advanced by a double motion (one from the Sun's western region B toward the eastern A, against the succession of the spots; the other from the southern region D, ascending toward the northern C, namely while the pole is raised from F above the horizontal plane toward g), therefore the first motion — by which F and the half-axis FE approach the fixed axis DE — is followed exactly by the diameter of the parallel HI, which passes from H into l and, from the opposite point I, into m,

toward the ecliptic AB. This diameter HI, or lm, is imitated in like manner by all the sections of the remaining smaller parallels, which are always, to the senses, parallel to the section that the greatest of the parallels has in common with the solar circle ACBD.

But the motion of inclination — or of altitude above the plane of the horizon — from F to g is not followed by the section of the parallel and of the solar circle HI in the horizon, but rather by the itinerary arc of that same circle, described on the spherical surface of the Sun and projected from the center of the spot onto the plane of the solar horizon. This arc, around the middle of the journey (that is, of the Sun), recedes from E toward k by just as much as the mobile pole recedes from F toward g. And from this arises the curvature of the spots' paths.

By the same reasoning, while the same axis gk advances throughout the whole of January to n and p, the common section of the greatest parallel, lm — that is, the diameter subtended by its semicircular arc — has advanced from l and m, keeping pace, to r and s; and similarly the common sections of the remaining smaller parallels with the horizon, or the chords of the arcs, have made like advances. And the summit of the itinerary arc — which passes through the three points r, t, s — equals the altitude of the southern pole n, or the depression of the arctic pole p, which the perpendicular no or pq marks at the points o and q; although from that arc I have expressed nothing beyond the three points.

The complement of the inclination, bo, which is lacking to this altitude for completing the seven degrees on the arc FD, always corresponds to the declination of the greatest parallel from the ecliptic AB, which in the present case is the arc rA.

About the beginning of March, the mobile axis df occupies the highest or middle point of the southern circlet, d, and the lowest point of the northern, f. The latter lies hidden in the opposite hemisphere, the former is exposed in the near one. And the inclination of the greatest parallel AuB above the plane of the solar ecliptic — the greatest inclination Eu, expressed on the meridian df — is equal to the semidiameter bd of the circlet, or to the greatest declination AH or AK. But on this day the declination is nil: rather, the diameter of the greatest parallel coincides with the ecliptic AB, and the axis df with the axis DC of the ecliptic.

This station is called the *inclinatory equilibrium* [Aequilibrium inclinatorium].

Now all the inclinations of the smaller parallels above the planes of the ecliptic's parallel circles are in reality equal to the inclination of the greatest parallel, though they do not appear so; and likewise the declinations.

From this time the axis dE, with its pole, begins to descend again toward the eastern parts P — for hitherto it had been ascending from F, the western region — and it ascends on the opposite circlet C, until, by descending, it reaches X there and, by ascending, Z here, at the beginning of April. There the meridian inclination is E β , marked on the axis ZX at the point β , equal to the perpendicular line xy, whose complement to 7 [degrees] is the arc of the sine, or of the straight line by, equal to the declination Ay or B δ . From this time on, the mobile axis df begins to pass into the eastern parts, from d toward x; the diameter of the greatest parallel, in that same eastern region, ascends northward across the ecliptic, and in the west descends southward — as is clear from E δ and Ey, the two halves of the same line. The smaller parallels do the like, if they are neighbors of the greatest parallel; those that are not neighbors do not indeed cut the ecliptic, yet they exhibit departures and approaches from region to region, proportional, by their chords, to the diameter of the greatest parallel.

Rosa Ursina, Book IV, Part II (the *Theoria*), Cap. II — folios 563–566

Folio 563 — full-page engraved plate

Diagram. A full-page engraved plate, the "Universal Theoretical System of the Motion of the Solar Spots," printed over the show-through of the text leaf. An octagonal border frames a large circle (the solar disk / celestial sphere in projection) centered on the point E. The engraved title is set across the middle of the plate in four blocks flanking the central figure: at upper left **SYSTEMA / VNIVE-**, at upper right **THEORICVM / RSALE**, at lower left **DE MOTV / SOLA-**, at lower right **MACVLARVM / RIVM**. Between the upper title-blocks sit two radiant emblematic medallions — a sunburst **IHS** (the Jesuit Christogram, left) and a sunburst **MRA** (the Marian monogram, right); two Orsini heraldic roses occupy the lower quarter, one on each side (the *Rosa Ursina* device). A dense pencil of straight lines runs from the two small polar circlets (top and bottom) to and through the central point E, representing the sightlines / axis positions across the year.

Readable labels (capitals confidently read; small interior Greek minuscules flagged):

- Center: E
- Top circlet (arctic), outer letters left→right: G, C, O

- Top circlet interior row of small letters: ι , η , α , κ , θ [?]; with **K** at its left edge and, below, **P**, **f**, **z**, ς [?]
- Left side of the main circle, top→bottom: **R**, **K**, γ [?], **A**, then a small cluster ϕ , ρ , τ [?], **H**, **M**
- Right side of the main circle, top→bottom: **L**, **I**, small **m**, ς [?], **X**, **B**, a small letter [?], λ , **N**, **Q**
- Bottom circlet (antarctic), outer letters left→right: **P**, **D**, **F**
- Bottom circlet interior: **x**, ς , **n** [?]; **y**, τ , **o**, **h**, g [?]; **c** at the very bottom

[The plate is repeated on folio 565; see fig-p719-1.]

Folio 564 — text

When the poles of the axis, carried from **X** and **Z**, have been brought to σ [?] and ω [?], the month of May comes round, and the meridian $\sigma\omega$ raises up the greatest arc of the spots, namely **E** σ , equal to the perpendicular **e** σ ; and the complement of this arc to seven degrees is the sine-arc **b** σ , equal to the declination **A** ω , or **BA**. Similar things happen in the smaller parallels.

From here the axis, running from σ to **P** and from ω to **O**, once again settles upon the horizon — which is the Sun's circle **ABCD** — and this around the beginning of June, when the pole **P** sets and the southern axis **PE** sets with it, while by contrast the northern axis **EO** rises, together with the pole **O**. At that moment the greatest parallel again has no inclination; and so its complement **PD** — that is, **AK** or **BN** — attains its greatest declination. Once more the arcs of the spots coincide with their diameters and chords **KN**, **HQ**, **RI**, and therefore trace out straight-line paths. Thus is completed the six-month course of the visible southern circlet **FdP**; by whose agency all the spots have moved along a curved track — convex toward **C**, the arctic pole, and concave toward **D**, the antarctic pole.

Now let us follow the other, northern circlet **OfG**. We must imagine the circlet **OfG** raised above the horizon, and **PdF** sunk below it.

So the northern pole **O**, together with its axis **OE**, rises around the first of June, and the spots trace their paths in the greatest parallel **KEN** as nearly straight lines: in the middle portion **KE**, northern; in the other middle portion **EN**, southern; and in the remaining smaller parallels, either wholly southern — as in the line **HQ**, which runs entirely outside the ecliptic **AB** — or wholly northern, such as **RI**; or, finally, mixed to a greater or lesser degree, according to their greater or smaller distance from the poles or from the center **E**. Yet all of them,

without exception, come out oblique to the ecliptic, following the obliquity of the axis **OP**.

In the month of July, while the upper pole reaches **H** and the lower reaches **σ**, the inclination of the itinerary arc in the greatest parallel is **Eω**, and the declination of that same greatest parallel is **ωA** or **λB**. In the smaller parallels, proportional values occur.

At the beginning of August, the poles and axis **ZX** produce the meridian inclination **Ev** and the declination **γA** or **λB**.

At the beginning of September the spots once more produce the Inclinary Equilibrium — the autumnal, or northern, equilibrium — and the diameters and chords are wholly free of declination: they either coincide with the ecliptic or lie parallel to it. The parallels, however, and the planes lying in the parallels, make their greatest inclinations with the solar circle.

After this time the chords of the parallels change their obliquities to the ecliptic into their opposites — just as the visible axis **OE**, once it has reached **f**, the highest point of the circlet, turns from western to eastern; and some chords change from arctic to antarctic, and vice versa, though all remain oblique to the ecliptic, and so on. The opposite happens in the hidden half of the axis, **EP** and **Ed**, and so on.

So the poles **p**, **n**, at the beginning of October, display the greatest apparent curvature of the spots in the greatest parallel, **Eo**; and the declination **Al** (southern), **Bm** (northern); similar things occur in the smaller parallels.

The beginning of November presents the poles and axis at **K** and **g**; the altitude **Eπ**; the declination **Ar** (southern), **Bs** (northern); and the smaller parallels do likewise in their own proportion.

After this, at the beginning of December, the northern pole comes to **G** and the southern to **F**, and the whole axis **GF** lies, to the senses, in the horizon. After that time the pole **G** sets, and the northern axis **GE**, in the east; while the pole **F** rises, and the meridian axis **EF**, in the west. In the same manner it completes its journey and its task, just as in the previous year. And so the ordinary courses of the spots continue perpetually — even though the spots themselves do not much exceed a month's age, even when they last a long while. It is like the same road, trodden by one traveler after another; the riverbed stays the same, but different waters occupy it, and so on.

This theoretical account of the phenomenon — its constitution and explanation — I have not fabricated at my own discretion; rather, as I warned earlier, I have

drawn it from the very entrails of the thing itself, and from the most faithful observations, produced and arranged throughout —

Folio 565 — full-page engraved plate (repeat)

Diagram. The same full-page plate as on folio 563 is printed again here, from the same engraving (identical octagonal frame, central circle on **E**, **IHS** and **MRA** sunburst emblems, two Orsini roses, four engraved title-blocks, and the same pencil of axis-lines through the polar circlets). The plate is deliberately repeated so that it faces the text on folio 564. For the full label inventory see fig-p717-1; the same capital labels **G C O / R K A H M / L I B N Q / P D F** and center **E** are present, with the same small Greek-minuscule interior labels [several [?]].

Folio 566 — text

— for I found all these things in the observations themselves, by the effect itself; and here I make public to the whole world the cause that lies hidden within them, now at last brought to light.

Hence it would be impossible for each and every detail to correspond with the others in this way, if this theory did not, on the side of the reality itself, hold true. For from it the following becomes at once evident to the eye:

First. Why do the spots' paths become sensibly straight only twice a year — and that in a position oblique to the ecliptic, and crosswise opposed?

[Margin: Why the courses of the spots are sensibly straight only twice a year.]

The reason is that the planes of the parallels follow the spots' axis — which is mobile within the polar circlets — as regards inclination (that is, the apparent motion in latitude); and the chords, or subtenses, of the arcs follow it as regards declination. Since, then, the mobile axis is the axis of the parallels, by that very fact it stands perpendicular to all the parallel circles. Therefore, since this same axis lies in the solar circle only twice a year — namely in **FG** and **OP** — it necessarily follows that all its parallels, mobile along with it, likewise stand at right angles to the solar circle only twice a year, and so place both their arcs and their chords (or the diameters of the arcs) in one common section on their horizon. By the same reasoning: since this same axis **GF** and **OP** is oblique to the immobile axis of the ecliptic **CD** — and that crosswise and equally, because the poles **C** and **D** of the axis **CD** are also the poles of the circlets **GfO** and **FdP**, which carry the mobile axis of the spots **FG** — it follows again that the position of the

greatest parallel relative to the ecliptic behaves in like manner, and the smaller parallels in proportional measure.

Second. Why does the declination of the greatest parallel always follow the complement of the axis's altitude? And so on.

Because that complement arises from the axis projected onto the solar circle, which is the common section of the horizon and of the plane drawn through the axis and the eye positioned upon the earth. Now this plane is always perpendicular to the solar horizon. Therefore, since the axis is perpendicular to the plane of the greatest parallel, it must also be perpendicular to any line drawn out from **E** in that same plane of the greatest parallel; and thus the chord of the greatest parallel will always be at right angles to the common section of the horizon and of the plane carrying the axis. Therefore, just as that section stands to the axis of the ecliptic **CD**, so the chord of the greatest parallel — a quadrant distant — stands to the ecliptic **AB**, in the horizon's plane **ACBD**.

Third. Why does the meridian altitude of the greatest parallel follow the altitude of the mobile pole in the circlet?

Because these points are a whole quadrant apart. Hence, if I move the pole **F** up from the horizon, raising it to **g**, then necessarily **f** is moved forward by just as much from **E** — **f** being the common section of two arcs of great circles, namely the greatest parallel and the circle of the axis, or meridian; for in this meridian there always lies the midpoint of the parallel standing above the horizon. From this I deduce a few consequences.

COROLLARIES [Corollaria]

FIRST. The zone which the greatest parallel wanders through in one year is equal in width to the diameter of any circlet that carries the axis.

[Margin: The zone of the greatest parallel.]

From this it follows that one and the same spot, carried around in the greatest parallel — even if it lasted forever — would nevertheless neither rise a second time in the place where it first rose, nor set in the same seats, except after a year; and in one year it would undergo every variation that belongs to this zone by reason of its situation and position. The same is asserted proportionally of the smaller parallels.

[Margin: The zone of the non-greatest parallels.]

For just as, in the zone of the greatest parallel **HKIN**, some durable spot would produce the annual vicissitudes, so if some spot had been in the parallel **MN** while the pole was turning at **F**, it would by the same annual revolution have exhausted the zone due to it, **MHNQ**; and one opposite to it, **KL**, the zone **KRLI**, and so on.

From these zones is composed the Sun's middle zone — that is, the ordinary path of the spots and faculae — which we may call the Royal Zone, or, if one prefers, the Torrid Zone, on account of the constant blaze of faculae within it; of which I shall treat at greater length a little later.

SECOND. Any apparent itinerary arc of the spots, continued from the rising horizon to the setting, is a little higher than a simple circular one.

I.

For I have found all these things in the spots by the very effect itself, whose cause — hidden within them, and only now unearthed — I here disclose to the whole world. It would therefore be impossible for everything, item by item, to correspond to one another in this way, if this theory did not answer to how things really are. For from this it is at once obvious, plain to the eye:

First: why do the paths of the spots become, to the senses, rectilinear only twice a year — and that in a position oblique to the ecliptic, and set crosswise-opposite?

[Margin: Why the paths of the spots are rectilinear to the senses only twice a year.]

Because the planes of the parallels follow the axis of the spots — which is movable within the polar circlets — with respect to inclination, that is, the apparent motion in latitude; while the chords, or subtenses, of the arcs follow that axis with respect to declination. Since, then, the movable axis is the axis of the parallels, it will for that very reason stand perpendicular upon all the parallel circles. And since this same axis lies in the solar circle only twice a year — namely at **FG** and **OP** — all its parallels, which move along with it, must likewise stand at right angles to the solar circle only twice a year, and so must place both the arcs and the chords (or diameters) of those arcs in a single section common to them and the horizon. By the same reasoning: this same axis **GF** and **OP** is oblique to the immovable axis of the ecliptic **CD** — and that crosswise and equally, because the poles **C** and **D** of that axis **CD** are also the poles of the circlets **GfO** and **FdP** that carry the movable axis of the spots **FG**. From this it follows in turn that

the greatest parallel stands to the ecliptic in the same way, and the lesser parallels in proportional ratio.

Second: why does the declination of the greatest parallel always follow the complement of the altitude of the axis? And so forth.

Because that complement arises from the axis projected onto the solar circle, which is the section common to the horizon and to the plane drawn through the axis and through the eye situated on the earth. But this plane is always perpendicular to the solar horizon. Therefore, since the axis is perpendicular to the plane of the greatest parallel, it must also be perpendicular to any line drawn out from E in that same plane of the greatest parallel; and so the chord of the greatest parallel will always be at right angles to the section common to the horizon and to the plane that carries the axis. Therefore, as that section stands to the axis of the ecliptic CD, so the chord of the greatest parallel — a quadrant away — stands to the ecliptic AB, in the plane of the horizon ACBD.

II.

Third: why does the meridian altitude of the greatest parallel follow the altitude of the movable pole on the circlet?

Because these points are a whole quadrant apart. Hence, if I advance the pole F up from the horizon, raising it to g, then necessarily f is advanced by the same amount from E — f being the section common to two arcs of great circles, namely the greatest parallel and the circle of the axis, that is, the meridian; for in this circle there always lies the midpoint of the parallel that stands above the horizon. From this I deduce the following.

COROLLARIA

FIRST. The zone that the greatest parallel traverses in the course of one year is equal in breadth to the diameter of any one of the circlets that carry the axis.

[Margin: The zone of the greatest parallel.]

From this it follows that one and the same spot, carried around on the greatest parallel — even if it were to last forever — would nonetheless not rise a second time at the place where it first rose, nor set in the same seat, except after a year; and in the course of one year it would pass through all the variation that belongs to this zone by reason of its situation and position. The same may be asserted, proportionally, of the lesser parallels.

[Margin: The zone of the parallels that are not the greatest.]

For just as, in the zone HKIN of the greatest parallel, some enduring spot would produce the annual cycles, so too, if some spot on the parallel MN had existed while the pole lay at F, that same spot would, by the annual revolution, have exhausted the zone owed to it, MHNQ, while its opposite KL would have exhausted the zone KRLI, and so on.

Out of these zones is composed the Sun's middle zone — that is, the ordinary highway of the spots and faculae — which we may call the Royal zone, or, if one prefers, the torrid zone, on account of the constant blaze of faculae within it; I shall treat of this more fully a little later.

SECOND. Any apparent path-arc of the spots, continued from the point of rising on the horizon to the point of setting, is a little higher than a simple circular arc.

Folio 567 — full-page engraved plate

Diagram. A full-page engraved schematic titled, in four blocks of display capitals arranged around the figure, **SYSTEMA VNIVERSALE THEORICVM DE MOTV MACVLARVM SOLARIVM** ("A Universal Theoretical System of the Motion of Sunspots"). The construction is a large circle (the projected solar globe) with a dense sheaf of straight lines converging on the central point E. Point-letters run down each side of the circle and cluster at a small circlet at the top and another small circle at the bottom. Two radiant emblem-roundels and two Orsini roses are engraved within the figure (see below). The plate corresponds to the geometry argued on folios 566 and 568 (axis FG/OP, poles C and D, the greatest parallel, and the sunspot zone).

Readable capital point-letters (confidently legible):

- C (top, at the upper circlet), with G to its left and O to its right — the small polar circlet carrying the axis; several small interior letters (Greek/lowercase, e.g. an *a* and an *α*) are present but not securely legible [?].
- Left side, descending: R, K, A, H, M.
- Right side, descending: L, I, B, N, Q (with a small **x** marked between I and B).
- E (center) — the point of convergence of the radiating lines; small marks (*y*, *τ*) beside it [?].

- Bottom small circle: P (left), D (bottom center), F (right), and c (at the very bottom); its interior carries several small letters (among them *d* at top, *x*, *n*, and others) that are only partly legible [?].

Emblems within the plate:

- Upper left of center: a radiant sun-disc enclosing the Jesuit monogram **IHS** with a cross.
- Upper right of center: a radiant sun-disc enclosing a crowned Marian monogram **MRA** (for *Maria*).
- Lower left and lower right: two heraldic roses (the Orsini rose device of the dedicatee).

I.

Because a spot, once risen, does not set at the point to which the arc of that day extends on the western horizon, but at the point it reaches on its final day of setting. For example: let some spot have risen at *r*, the point of rising of the greatest parallel; the meridian point of that day will be *t*, and the western point *s*. After some 14 days, more or less — during which the spot has moved above the horizon — the poles of the movable axis come to rest on the circlets at the points ρ and σ ; and the perpendicular dropped, $\rho\tau$, will be the meridian altitude of that day on the path-arc of the greatest parallel, while the declination from the ecliptic on that day will be *Ap* at rising and *Bx* at setting. Therefore, if *r* — the first point of this path in the east — is joined with the last point *x* in the west, the chord of the path will fall below the center *E*, and the meridian altitude will become greater than the simple circular one, by the excess of the small line [symbol ?]*E*. So that no error arise, one should evidently proceed by a middle way between *r* and ρ , and between *s* and *x*, and so forth.

THE ZONE OF THE SUNSPOTS

It is that region of the Sun within which the primary sunspots appear to be confined and to complete their journeys. Conceived along its length, it is parallel to the ecliptic; it stretches across the Sun's visible hemisphere from the eastern horizon all the way to the western, and from there, through the hidden hemisphere, returns into itself as far as the east — so that it girdles the middle of the Sun like a single band. In breadth it runs out on both sides from the ecliptic toward its poles. Although no wholly fixed and precise limit of this outrunning can be assigned, nonetheless, from the observations gathered over so many years, it does not so far appear to have exceeded thirty degrees of latitude to

either side, that is, toward the same pole — although, if one considers the faculae and the secondary shadows, it is often not far from the poles themselves. See, among the observation-plates: the seventh for February, p. 185; the third for March, p. 191; that for July from the 12th to the 22nd, p. 231; the first for November, p. 273, and the one from the 6th to the 22nd, p. 275; likewise all those for December, from the 15th, of the year 1625, p. 277; and finally the one running from 24 February to 15 March of the year 1626, p. 187.

II.

When I said that the zone is parallel to the ecliptic, this is to be understood of the circles drawn parallel to it through the greatest declination of the spots that are most remote from the ecliptic; and this is, as it were, a boundary and border-field of the zone. But if we speak of the zone itself, formally, and of the track that the spots and faculae mark out, then it is composed of innumerable path-traces of the spots, entangled among themselves in inextricable bends and spirals; and it is never equidistant from the ecliptic, but always cuts it — twice a year in a quasi-rectilinear position, when it crosses itself upon the ecliptic crosswise, namely in December and June; whereas in a curvilinear position, inclined to the ecliptic, it proceeds in March and September — according, of course, to the variety of the spots' monthly motion, and so forth.

[Margin: The division of the Sun's surface into five zones.]

On the occasion of this zone, the Sun may, not unfittingly, be divided into five zones or climes. For the principal and middle zone — the royal highway of the spots, which we are treating here — may be called torrid, on account of the very great abundance of faculae; and stormy, on account of the vehemence and violence of the motions; and indeed, on account of the perpetual changing of spots, faculae, and shadows, it may be called tumultuous, restless, and turbulent. Two others, lying next to this one on either side toward both poles, are quiet and peaceful zones, whose boundaries are the middle zone just explained and the two polar zones. The breadth of each of these intermediate zones is 53 degrees. They rarely have primary spots or faculae, but almost always teem with secondary ones. The two outermost zones, enclosed between the poles of the ecliptic and the polar circles — and therefore to be called polar — have a breadth of seven degrees. Their surfaces appear almost always even, uniform, and quiet, because there the rest of the solar globe is fairly great; for the axis of the spots, straining by its annual motion against the Sun's diurnal motion, does not much disturb it, as was shown above, and the diurnal motion is there much slower than at the middle of the Sun. And so the Sun appears ordinarily peaceful in the polar zone; a

little more disturbed in the lateral zone; and in the middle zone it is seen as extremely varied and turbulent — although even entire [zones now and again...]

Diagram. Full-page engraved fold-out plate, printed on folio 569 and here folded over the underlying letterpress (the surrounding faint, part-reversed text is verso show-through and is not transcribed). The plate is titled, in four parts arranged around the figure: **SYSTEMA** (upper left) — **THEORICVM** (upper right) / **VNIVE=RSALE** (below) — **DE MOTV** (lower left) — **MACVLARVM** (lower right) / **SOLA=RIVM** (bottom). ["Universal Theoretical System of the Motion of Sunspots."] This is the same plate catalogued in the prior folios as fig-p721-1 and is very probably the duplicate/out-of-order scan of it noted there.

At the upper center are two radiant sun-emblems: a Jesuit Christogram **IHS** (with cross above and three nails below) on the left, and a Marian monogram **MRA** on the right. Two heraldic roses (the Orsini rose device) sit at the lower center.

The geometric construction is a large octagonal/lozenge frame enclosing a great circle (the ecliptic / solar great circle) crossed by a vertical axis and by numerous straight rays converging on a central point. Principal readable labels:

- Central convergence point: **E**, surrounded by small Greek letters (β , η , ι above; ε , π below; ψ , γ at the sides) [several partly illegible — [?]]
- Left arc (top to bottom): **R, K, A, H, M**, with small Greek minuscules (φ , ζ , ι) beside A and H
- Right arc (top to bottom): **L, I, x, B, N, Q**, with small minuscules beside I and B [partly illegible — [?]]
- Small circle at the top of the axis: apex **e**; a horizontal line **G** (left) — **C** (center) — **O** (right); interior points along the diameter 1, 9, a, c, 8; **K, H** at the sides; **z** center; **p, f** below
- Small circle at the foot of the axis: **d** at top; interior points x, n, y, b, o, h with Greek ε , ξ , ς [τ [?]]; base line **P — D — v — F**; apex **c** at the bottom

[Numerous small peripheral minuscule and Greek labels on this dense plate cannot be resolved cell-by-cell at this scan resolution]

and thereupon to keep holiday and to shine upon us with a gentler, more even face, and, as it were, to smile on us.

By how much the sensible horizon of the Sun differs from the true horizon; that is, how much the apparent circle of the Sun differs from its greatest [true] circle.

CAP. III.

Since it is certain that the Sun is larger than the eye, and certain too that less than half of the Sun is seen, it follows with equal certainty that the perimeter which is circumscribed on the Sun by the power of vision is smaller than the perimeter of the greatest solar circle. And although, on account of the eye's very great distance from the Sun, the difference in size between those two circles all but vanishes, nevertheless — because I promised to treat this matter at the beginning of the second chapter, and because it involves a doctrine of very useful things — I could not pass it over without redeeming my pledged word. To do this the more effectively, take what follows.

LEMMA.

If, upon the diameter of a given circle produced to any length, a point be taken anywhere outside the circle; and from that point a tangent to the circle be drawn; and to the produced tangent a second diameter be carried out, perpendicular to the first; and likewise from the point of contact a radius be drawn to the center; and if, upon the point common to the first-produced diameter and to the tangent, a larger circle be described about the center of the given circle — then both the sides of the triangles and the perimeters of the circles will be cut proportionally.

[Margin: Construction of the proposition.]

In the accompanying figure let there be given the circle $abcd$, and through its center a let the diameter bd be produced to any length as far as e ; from this point e let a tangent to the given circle then be drawn, which meets the other diameter ca — perpendicular to the first, bd — when it too is produced, at the point g ; then from the point of contact f let fa be drawn; and at the interval ae let the circle $h ai$ be described about e . These things being posited:

I say that the two triangles efa and afg are similar right triangles, and that the tangent eg is cut in mean proportion at f ; and likewise that, as the whole circumference $h ai$ of the greater circle is to the whole dfb of the lesser, so the segment (or arc) ka is to the segment (or arc) fl . This I demonstrate thus.

The angle eag is right by hypothesis; the angle efa is right by the tangency. Therefore the two triangles eag and efa are right triangles and have the angle at e in common; hence the remaining angle ega is equal to the remaining angle eaf . Again, the two triangles efa and afg have their two angles at the contact f right, and the two angles ega and eaf equal, as was just proved; therefore the remaining angle aef is also equal to the remaining gaf . The triangles efa and afg

g are therefore similar, and the sides opposite equal angles are homologous. Hence, as ef is to fa , so is af to fg ; and thus the line eg is cut at the point f in mean proportion by fa .

Again, since the angles $ae f$ and $fa g$ have been proved equal, the arcs subtended by them — ak of the greater circle and fl of the lesser — are similar. Therefore, as the whole circumference of the greater circle is to the whole of the lesser, so is the arc ak to the arc fl . And these were the things to be demonstrated.

From what has been demonstrated, the question is easily answered. For if we take the circle $bmdf$ to be the Sun, and $h a i$ the Ecliptic, and e the place from which the Sun is observed from the earth: I say that what remains, from the open solar arc mdf up to the midpoint l and c — namely the arcs fl and mc together — is to the perimeter of the Sun as the arc of the Ecliptic that the visual diameter of the Sun fm opens up; which arc $na k$ is intercepted by the two tangents, or extreme visual rays, em and ef , at the points n and k .

Once, therefore, the visual angle fem is known through careful observations — that is, the visual diameter of the Sun fm — the arc $k a n$ on the Ecliptic will also be had. Whence a new question arises.

Diagram. Geometric figure at the head of the page (the "accompanying figure" of the Lemma above). A circle with **b** at the top and **d** at the bottom, crossed by a horizontal diameter through **c** (left) and the center **a**, and by a vertical axis $b-a-d$. From an eye-point **e** far below, straight lines (visual rays / tangents) rise to the circle, touching it near **f** on the right; a tangent runs out to **g** (right, outside the circle), with **K** beside it (marked with a small "1"). At the left, below center, a small cluster of points **h**, **n**, **m** marks the intersections of the rays with the near side. Readable labels: **b** (top), **c** (left), **a** (center), **h**, **n**, **m** (left cluster), **d** (foot of circle), **e** (eye-point below), **f** (right, on circle), **g** (right, on the tangent, outside), **K** (right, near **f**). [The point where the horizontal meets the right side of the circle, and one or two adjacent minuscules, are obscured by show-through and not securely read — [?].]

How great is the visible diameter of the Sun, in minutes of the Ecliptic?

Passing over many things — treated elsewhere, or still to be treated — I state, against the common opinion of astronomers, that the visual Sun is much larger than they themselves reckon. For, as will later be set out at length, it is established that its apparent diameter, while it lingers in Cancer [♋], presents itself at 46' at the least. But, for the sake of greater certainty, let us grant it only 32', following Tycho's [Brahe's] view. Then, for us to discern half of the Sun, no

more is lacking in the solar circle — by what has just been demonstrated — than 32 first minutes of one degree, of which degrees the whole circumference of the Sun is 360, that is, 21,600 first minutes. Now if we divide this number in two, we shall have 10,800 for the greatest semicircle of the Sun; and if from that number 32' be subtracted, there will remain 10,768' for the open (patent) solar arc; if they be added, there arise 10,832' for the greatest hidden (latent) arc of the same. Therefore, if we should have some course of some spot along the open arc of days — for example, of 13 days and 12 hours, that is, of 324 hours — the rule of proportion will give us, for the latent arc, 325 hours and 55 horary scruples [minutes]. Hence the latent arc will exceed the patent arc by 1 hour and 55 first horary scruples. And thus some one spot, carried along the greatest circle of the Sun, would linger in the hidden hemisphere of the same one hour and fifty-five scruples [minutes] longer than in the visible one. The 32' by which the apparent arc differs from the hidden one make, on the greatest circle of the Sun, 175,087 paces — 175 Roman miles, $43\frac{3}{4}$ German. Therefore, according to this Tychonic hypothesis, the space which, round about, remains from any point of a tangent ray up to the midpoint of the Sun — reckoned on the arc of the greatest circle — will comprise $87,543\frac{1}{2}$ paces, that is 87 Roman miles with $543\frac{1}{2}$ paces; 21 German miles with $3,543\frac{1}{2}$ paces. Whence, if the Lord God were to place some damned soul, or Lucifer himself,

at the point *e*, and were to command it to walk along the line *b e*, infinitely produced on the side of *e*, until the visual rays *e f* and *e m* should reach the mid-points of the Sun, *c* and *l* — even if that spirit should walk for all eternity, even if it were borne along with infinite speed — nevertheless the visual rays would never reach the mid-points of the Sun *c* and *l*, notwithstanding that they always draw nearer and nearer, and that ever more of the Sun would be seen than was seen before. Yet the middle of the Sun would, to all eternity, never be seen, not even by an eye of infinite power.

Again, on withdrawing, more of the Sun will be seen, but it will appear smaller, because the angle *m e f* is always diminished; on approach, less of the Sun will be discerned, but it will appear larger, because the visual angle *f e m* is enlarged. I suppose, however, that the spectator's eye at the point *e* is smaller than the Sun.

This Lemma has an incredible use in matters optical and astronomical; for if an eye, from the center of a circle, looks at another circle set outside it, one may know from the visual angle how great is the portion of the beheld circle's arc that is in view. In the same way, one may know how great is the portion that appears of a beheld sphere, or of a beheld cylinder.

The same things may be transferred to the apparent globes of the stars. Many other matters I leave to the ingenious Reader to consider by his own study.

On Finding the Apparent or Visual Diameter of the Sun — An Inquiry. Chapter IV.

Now that the true location of the solar spots [*maculae*] and faculae [*faculae*] has been discovered and established — namely, the very surface of the Sun — it follows that we should reach some conclusion about their magnitude. For since observation gives us the ratio of the spots' size to the Sun's disk, it is clear that if the Sun's absolute magnitude is given, the magnitude of the spots will be given too.

[Margin: The visual diameter of the Sun is not yet fully known.]

And yet, although among all the things God created for human use nothing is better known than the Sun, its absolute magnitude has nevertheless not been perfectly known from the creation of the world down to the present. To this very hour astronomers labor to ascertain and define its visual diameter, without which it is impossible to arrive at its true quantity. Then, too, great effort is expended in assigning its distance from the Earth, without which, again, we cannot pronounce upon its true magnitude. These, then, are the things that make the true and absolute magnitude of the spots as well difficult to know and to express in any fixed measure. Yet much that is excellent could be said and settled about it, if some definite measure of the solar globe were known; and since we are without that, we shall discuss the matter on the basis of what is handed down by others.

Now, so that we may contribute something of our own as well, we shall set out a method for investigating the visual diameter of the Sun — not with the intention of settling the question by it, nor of establishing here and now the visible diameter as certain and beyond doubt down to precise minutes, but so that we may hear the judgment and opinion of experts on the matter, and offer some solid means of drawing out the truth and of driving off many errors. For if the method I use is free of fallacy, it is evident that a sure door stands open for laying bare things in astronomy that seem incredible; but if — though I myself do not see it — some hidden deception, or some natural power hitherto concealed from the opticians, should lurk in this procedure, I shall be grateful to whoever brings

the hidden truth to light and cuts off the occasion of error both for me and for others.

[Margin: An easy method of investigating the visual diameter of the Sun.]

In a wooden beam, shaped as a parallelepiped after the present figure a b c d e f, planed straight and smooth, of a length of 10, 20, or 30 feet, let the line g h — the middle line of the surface a b e f — be divided into equal parts: a thousand, or ten thousand, or, what is preferable, a hundred thousand or more. For the purpose of the present business, however, there is no need to divide the whole line into so many particles; it suffices to have about a hundred such parts as make up the whole thousand, or two hundred such as make up the whole ten thousand, and so on. So, with the straight line g h divided in this way, let a square metal plate a b i k be raised perpendicular to the beam, pierced at the point l with an aperture [*foramen*] as physically small as can be made. Then at the other end of the beam let a small paper-bearing board m n e f be set up, likewise at right angles, to which a paper o p q r is fastened. Once these are in position, the observing instrument for finding the visual diameter of the Sun will be ready.

[Margin: Use, or practice.]

Within a room closed on every side, so that no light at all enters anywhere, set the instrument's plate a i opposite the Sun s t u, in such a way that through the single aperture l the light shines through onto the paper q o and there paints a bright circular image of itself, x y z. When this is done, if with an opened compass you take its diameter x z, and measure it on the line g h in terms of the marked parts, you will by their means arrive at knowledge of the solar visual diameter, grasped in determined parts of minutes, as you will be taught shortly.

Demonstration.

[Margin: Demonstration of the aforesaid practice.]

The Sun's rays u x and s z are rectilinear, by the nature of emanating light and by the common doctrine of the opticians; and because the aperture l is made as small as it can possibly be — assumed indeed much smaller than it is drawn here — the said rays will intersect one another at that same point, and it will become the common vertex of the two cones of solar rays l u s and l x z. The cone l u s will be in the upright position, l x z in the inverted position; and the base of the former will be the apparent circle of the Sun, u s u, while the base of the latter will be the projected image of the Sun, x z x. Since the axis t l y, passing through the centers t and y of both cones and through the vertex l, is assumed — from

good observational practice — parallel to the straight line gh , and since gh is at right angles both to the plane $hemf$ and to the plate $gbik$ at the points g and h , the axis tl will likewise be at right angles to them at the points t and y , by [Euclid] Book XI [prop. 8]. And because the same axis stands perpendicular to the Sun's circle usu at the point t , that circle of the Sun will be parallel to the plate ia and to the paper-board fn , by Book XI [prop.] 14. Therefore the plane through the axis tl will make the sections us and xz parallel in the bases of the cones, by Book XI [prop.] 16. Hence the alternate angles at s and z , and likewise at u and x , will be equal to one another; and the vertical angles at l , opposite each other, are also equal; therefore the two triangles lus and lxz are equiangular. Consequently their corresponding sides are proportional to one another — namely side zl to side ls , xl to lu , and the base xz to the base us . Now xz is the diameter of the solar disk xzx projected onto the paper $opqr$, just as us is the diameter of the same original in the Sun itself.

[Margin: Rule for finding how many minutes the observed solar diameter contains.]

Therefore, once the diameter xz is known in the parts of the line gh , it will be known in us as well, since they are proportional. The ratio of the diameter xz to the line $x[l]$ — or lz — is found if you inquire with the compass how many times the diameter is contained in either of the said lines; or if you square half of the said diameter, add the product to the square of the axis ly , and then extract the square root of the whole: for that will be the straight line lz , or lx .

You will obtain the angle xlz if you set the axis ly in the assigned parts of the line gh — which is always equal to the axis — [take] the whole sine [*sinus totus*], and make the parts of the line xy or zy (known from the practice of observing and from the doctrine already delivered) the half-chord. Then, if you set it up so that as the axis ly is to the whole sine, so is yx or yz to a fourth term, and work it out according to the intended parts of the line gh , the required sine will result; and the arc corresponding to it will give the angle xly , which is the magnitude of the solar visual semidiameter subtending half of the sought angle xlz . Its double will exhibit the whole angle, and so on. Of this I shall later give several examples.

[Margin: Properties of the bright solar circle admitted through the aperture l , many of which are also explained more fully below, where the color of the Sun is treated.]

First. The light of this solar image yzx is not everywhere equally intense, but bright in the middle, while toward the edges — for about a quarter of the

semidiameter — it is very weak and dim: which will be set out more fully elsewhere.

[Margin: Properties of the admitted solar image.]

Second. Nor does its falling-off seem uniform, but uneven; for in the middle it glows with a nearly even brightness over a large space, then falls off sharply toward the extremes, into a color mixed of red and dusky.

Third. The whole light is seen continuous from the center to the edges, nowhere interrupted.

Fourth. This tempering of the light is found in the image of the Sun always, at every season of the year, at any hour of the day, under any altitude of the Sun, provided you observe with the same aperture at the same distance of the paper.

Fifth. If, keeping the same aperture *l*, you move the paper *n p i* nearer, the bright circle will shrink, and the less-bright edges too will be drawn in more tightly toward the center *y*; if you move the paper away, everything will be enlarged.

Sixth. This image of the Sun, when the aperture is round, is always circular — except when the Sun near the horizon is contracted by vapors.

Seventh. When the Sun is seen above the horizon, before the Sun itself is bodily seen and casting its rays, nothing of this image appears on the paper at all —

Diagram. An engraved schematic of the observing instrument (the *observatorium*), framed at the head of the table. It shows a long parallelepiped beam (the *tigillum / pertica*) drawn in perspective, lying horizontally. At the left end the Sun's converging rays enter through a small circular tube; at the right end stand the pierced aperture-plate and, beyond it, the projection-screen board carrying the projected solar image. A graduated scale runs along the beam's near lower edge.

- *s* (upper left, entering ray): endpoint of the solar cone
- *t* (lower left, at the small circle): center of the entering beam / Sun's ray
- Scale along the beam (left → right): 1000, 2000, 3000, 4000, 5000, 6000, 7000, 8000, 9000, 10000
- *l* (right, on the upright plate): the aperture [*foramen*]
- *k* (top of the upright aperture-plate)
- *m* (top of the projection-screen board, far right)
- *o* (screen, upper): corner of the paper

- n [?] (screen): board corner
- p (screen, right): corner of the paper
- y (center of the projected circle): center of the solar image
- x (top of the projected circle) / z (bottom): the projected diameter endpoints
- f (screen, lower left) · h (screen, lower right) · q [?] (screen): board/paper corners
- b, c, d (lower corner of the screen board): base points

Prose labels legible; two peripheral letters (n, q) flagged [?].

Observations of the Visual Diameters of the Sun, in the years 1625, 1626, 1627, at Rome.

AB, a line of two hundred and ten particles, of which the whole distance of the aperture from the paper was 10000.

Scale $A \rightarrow B$ (upper ticks): 10 · 30 · 50 · 70 · 90 · 110 · 130 · 150 · 170 · 190 — (lower ticks): 20 · 40 · 60 · 80 · 100 · 120 · 140 · 160 · 180 · 200 · 10

Ann us	Mensis	Dies	Diametri visuales observatæ (letter·upper/lower, printed left→right)	per Foramen
1625	Octob.	15.	d·39/114 · c·47/137 · b·51/150	Minimum.
1625	Nouem b.	23.	e·35/100 · d·39/115 · c·41/120 · b·45/130	Minimum.
1625	Nouem b.	28.	d·38/110 · c·45/130 · b·49/143	Minimum.
1625	Deceb.	25.	f·37/106 · e·40/117 · d·43/125 · c·37[?]/136	Minimum.
1626	Mart.	23.	e·39/115 · d·42/122 · c·47/136 · b·53/155	Minimum.
1626	Iulij	14.	e·36/103 · d·41/119 · c·43/125 · b·47/137	Minimum.
1626	Octob.	19.	c·43/125 · b·55/160	Minimum.
1626	Octob.	21.	d·32/95 · c·38/110 · b·48/138	Minimum.
1626	Octob.	22.	e·30/87 · d·37/107 · c·42/122 · b·48/140	Minimum.
1626	Deceb.	27.[?]	e·31/90 · d·38/112 · c·47/136 ·	1. Minimum.

Ann us	Mensis	Dies	Diametri visuales observatae (letter·upper/lower, printed left→right)	per Foramen
			b·56/165	
1626	Deceb.	27.[?]	b·55/160	2. Maius.
1626	Deceb.	27.	e·30/85 · d·36/104 · c·41/120 · b·50/144	3. Amplius priore.
1626	Deceb.	27.	d·29/83 · c·32/93 · b·39/114	4. Maius priore.
1626	Deceb.	27.	d·29/84 · c·33/95 · b·37/105	5. Maximum.
1627	Iunij	21.	e·33/95 · d·38/110 · c·48/140 · b·57/155	Minimum.
1627	Sept.	27.	e·37/108 · d·45/130 · c·49/142 · b·56/162	Minimum.

(Table complete on this page; the aperture legend and instrument are explained in Cap. V below.)

— appears, even if the reddest dawn or the most brilliant radiance of a clear sky runs ahead of the neighboring Sun; but as soon as the Sun flashes out at its first stroke, the beginning of this image gleams on the paper — though in inverted position — and it grows in proportion to the emergence of the solar body; but at the very point at which the Sun clears the whole horizon, this image completes its circle, and not before.

Eighth. The like happens when the Sun is descending below the horizon; for at the moment the Sun reaches the boundary [horizon], this image begins to be cut by its own circle, which is wholly extinguished on the paper when the Sun hides its last ray; it is rekindled —

— if, as often happens, the Sun springs back up. After the setting of the Sun, although the sky may blaze and glow most brightly in its vicinity with fires, yet nothing but the deepest darkness settles on the paper, and no indication of any light is given.

Ninth. I tried the same thing around midday, when the Sun at its highest most vehemently illuminates the surrounding ether. So, when it had hidden itself after [passing] a wall set some way off, I caught it as it came forth; and in turn, when it had withdrawn behind another wall, I observed it departing; and nothing before it, nothing after it, but only in its presence did I perceive the paper illuminated with a bright circle — whole or broken, according as the Sun appeared whole or

cut. And lest any shadow of even the slightest doubt remain to me or to others, I appointed men who would at the same time observe the Sun as it approached or departed — with free sight, with the Helioscope, and with the Telioscope — upon the paper; and I forbade them all to warn one another about the first or last disappearance of the Sun, but to leave this task to me. So, intent upon my own image, when the Sun held its last point on the eastern horizon, or its first and last on the western, I gave the signal from the aspect of my image alone; and just as I did on the paper, so they experienced it with free sight, with the Helioscope and the Telioscope; and the same we experienced around midday. And all these experiences I found most true in the very doing, at Rome, and formerly elsewhere too.

Tenth. The periphery of this solar image is not cleanly cut, but softly torn and rough, so that it is discerned only with difficulty from the neighboring darkness — especially if a nearby eye strains at it; for if the eye stands off a little, it will attain a sharper distinction of the boundary between light and darkness: which is familiar also with other shadows cast by the Sun.

Eleventh. This image, all else being equal, is smallest when the Sun occupies its apogee, largest at perigee, intermediate at intermediate distance. Yet the excess of the greatest over the least, or the latter's shortfall from the former, can scarcely be obtained, because of the tenuity of the marginal light and the unequal precision of the perimeter.

Twelfth. In this mode of observing, this perpetual and constant property is found: that the less the aperture used, all else being equal, the bright solar circle turns out larger in extent but smaller in intensity of light; when a larger aperture intervenes, the extent of the luminous circle is diminished but its intensity is increased — yet this within a certain magnitude as the true limit, as use and experience will readily show the diligent observer. For if you use an aperture of notable size, the figure of the Sun will turn out larger than through a smaller aperture, and so on.

[Margin: The observing instrument, and the observed visual diameters, are set before the eyes and explained.]

Chapter V.

The beam or rod, a parallelepiped *c f*, well planed and rigidly extended, together with its little boards *b K* and *e m*, and the Sun *t* and its received image *y* — all this

you have sufficiently explained in the described method and practice and their demonstration; now I set forth the rest of this Table, as the matter requires.

The title at the top, after the design of the observing instrument, shows that these observations of diameters were made at Rome in three years — namely the twenty-fifth, sixth, and seventh above one thousand six hundred [1625, 1626, 1627]; but where, and in what month or on what day, by what witnesses, and with what accuracy, or to what end they were carried out, it does not indicate. Some of these things, then, are signified in the diagram itself — such as the time, the parts of the recorded diameters, and the apertures assumed — about which I shall write more fully later; some things are passed over in silence in this diagram, about which the Reader must now be advised one by one.

[Margin: The purpose of these observations.]

This [purpose] is not the one that a burning inquirer into these matters might perhaps imagine for himself — namely, a precise determination of the Sun's visual diameters. That, I say, is not the end I intended through these observations; for I did not [set out to promise] so great a thing, one that is new and unheard-of even to the astronomers themselves —

PARS II. Cap. V.

(Folio 577 — Book IV, Part II, *Theoria*)

Diagram. A schematic of the observing instrument (the "Observatorium for capturing the visual diameter of the Sun") heads the table. It is drawn as a long horizontal box or tube seen in perspective, tapering from a small aperture-end at the left to a broad screen-panel at the right. Along the floor of the box runs the graduated baseline marked in thousands (1000, 2000, 3000, 4000, 5000, 6000, 7000, 8000, 9000, 10000), with a hatched bar (the rod / *pertica* g–h) beneath it. The Sun's rays enter through the aperture at left and project a disk onto the screen at right.

- s (top, left/aperture end): label
- t (middle, left end): label at the small aperture circle (the *foramen* l through which the Sun is admitted)
- u (bottom, left end): label
- m (top, right screen): label
- o (upper right screen): label
- n (top-right corner of screen) [?]

- p (right edge of screen): label
- x, y, z (inside the projected-disk circle on the screen): labels of the Sun's image
- f (mid-left of screen): label
- g, h, i, k (foot of the right end / baseline): labels
- Baseline scale: 1000 ... 10000 (the distance of the aperture from the chart)

Observations of the Visual Diameters of the Sun, made at Rome in the years 1625, 1626, 1627.

AB is a line of two hundred and ten little parts, of the size that the whole distance of the aperture from the chart amounted to, namely 10000.

Scale line (as engraved above the table): A |10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200| 10 |B (i.e. 200 + 10 = 210 parts).

Ann us	Mens is	Di es	Diametri visuales observatae	per Foramen
162 5	Octob .	15.	d 39/114 · c 47/137 · b 51/150	Minimum
162 5	Noue b.	23.	e 35/100 · d 39/115 · c 41/120 · b 45/130	Minimum
162 5	Noue b.	28.	d 38/110 · c 45/130 · b 49/143	Minimum
162 5	Dece b.	25.	f 37/106 · e 40/117 · d 43/125 · c 37[recte: ?]/136	Minimum
162 6	Mart.	27.	e 39/115 · d 42/122 · c 47/136 · b 53/155	Minimum
162 6	Iulij.	14.	e 36/103 · d 41/119 · c 43/125 · b 47/137	Minimum
162 6	Octob .	19.	c 43/125 · b 55/160	Minimum
162 6	Octob .	21.	d 32/93 · c 38/110 · b 48/138	Minimum
162 6	Octob .	22.	e 30/87 · d 37/107 · c 42/122 · b 48/140	Minimum
162 6	Dece b.	27.	e 31/90 · d 38/112 · c 47/136 · b 56/165	1. Minimum

Ann us	Mens is	Di es	Diametri visuales observatae	per Foramen
162 6	Dece b.	27.	b 55/160	2. Maius (Larger)
162 6	Dece b.	27.	e 30/85 · d 36/104 · c 41/120 · b 50/144	3. Amplius priore (Wider than the last)
162 6	Dece b.	27.	d 29/83 · c 32/93 · b 39/114	4. Maius priore (Larger than the last)
162 6	Dece b.	27.	d 29/84 · c 33/95 · b 37/105	5. Maximum
162 7	Iunij.	21.	e 33/95 · d 38/110 · c 48/140 · b 53/155	Minimum
162 7	Sept.	27.	e 37/108 · d 45/130 · c 49/142 · b 56/162	Minimum

(Foot of folio 577, two columns, continuing the discourse of Cap. V:)

I. ...one that I might venture, uninvited and without consulting the Senate of the Experts, to bring before the public as though it were certain — paradoxical and perhaps suspect as it is. My purpose in these labors of mine was therefore this:

First, to set before men versed in this field my method of observing, to teach them its effect, and to hear their judgment — which is what I am doing even now.

II. Second, to give occasion, if the method is sound, for embracing and adopting it, and, once that is done, for putting to the test the things I here bring forward, so that the truth may be the more firmly established; or, if the method is infected with some hidden fault, to expose that very fault, for the public good.

Third, on the supposition that this manner of observing is legitimate, just as...
[text continues on folio 578]

ROSAE VRSINAE LIB. IV.

(Folio 578)

I. ...I am wholly convinced that it is, to show in a general way, from these observations, that the visible diameter of the Sun is far greater than has hitherto been believed, and to offer astronomers a handle for investigating that diameter in particular by this easy and readily available method. If they do so, they will find that I did not sound the alarm for nothing.

[Margin: The just (true) diameter of the Sun has always been taken too small, and that deliberately.] For in these observations I have, with the greatest care, held back from the largest solar disk that the eye beheld, so that the argument to be drawn for its magnitude might carry the greater force. For if the apparent diameter — assumed smaller than it shone — already far exceeds in length all those hitherto assigned, then the largest of the apparent diameters would exceed them by much more still.

[Margin: The visual diameter of the Sun is much larger than is supposed.] My aim, then, in presenting these things, is to make plain in a general way that the visible diameter of the Sun is much larger than long-standing opinion holds; but just how much larger it is will become clear in due time, once the verdict of the wise astronomers has been heard.

Other circumstances concerning these observations.

Some of them were made in our Professed House, most in our Roman College [Collegio Romano], before prudent men who watched with their own eyes what I here set down. I did the like earlier in Germany — at Ingolstadt, Innsbruck [Oeniponti], Freiburg [Fryburgi], Vienna, and Prague — and I always found the same effects of the apertures, and magnitudes greater than those received up to now.

Explanations of the remaining items comprised in the Table.

[Margin: The true little parts of the line by which these diameters were observed and measured.] AB is a line divided into two hundred and ten parts, of the true magnitude they had on the rod itself and on its line g h. From this you can derive the whole length of the rod: for if you lay the line A 200 end to end five times, you obtain a tenth part of the beam g h, and from that you may easily estimate the whole extension of the rod, and so on.

It is not, however, for this reason alone that I set this line before the eyes, but much more so that from it you may measure the reported diameters in parts of the line, and from those derive, in practice, the visual angle — as I shall say a little later.

The remaining part of the figure is divided into five descending series or columns, over each of which, at the top, stand headings indicating what is contained in each column of any given series. The first heading, at the left, contains the year; the second, the month; the third, the days on which the observation was made; the fourth, the observed diameters themselves, with the numbers of parts and of

minutes; the fifth and last denotes the size of the aperture l through which the Sun was admitted — if indeed it is to be called large, seeing that by its narrowness it escapes even good eyesight.

You have here, then, the reported observations: those of the year 1625, carried out in the months of October, November, and December, on the days noted; those of 1626, completed in the months of March, July, October, and December; and those of 1627, finished in the months of June and September — with the corresponding days in the third column.

Explanation of the diameters.

[Margin: The diameters are explained.] The visual diameters are marked with alphabetical characters, a, b, c, d, and so on; and each of them denotes as many observations and observed diameters as it has letters set beside the numbers. In the example, the diameter a b, observed on 15 October in the year 1625, has beside its numbers the letters b, c, and d: a sign that three diameters were taken from the admitted image of the Sun — namely a b, one; a c, another and smaller; and finally a d, a third and smallest, in this observation.

Now if you wish to know how many parts a b amounted to — parts such as are laid out in the line A B — look at the number written immediately beneath b, and you will find 150; while immediately above it there answer 51 first-minutes.

In the same way, to the diameter a c there will answer 137 parts below and 47 minutes above.

Likewise, to the visual diameter a d there will be assigned 114 little parts and 39 first-minutes.

PARS II. Cap. V.

(Folio 579)

The head of this folio reprints, identically, the instrument schematic and the full observation table already given on folio 577 above — same "Observatorium" diagram, same title block ("Observations of the Visual Diameters of the Sun, made at Rome in the years 1625, 1626, 1627"), same AB scale line, and the same sixteen data rows cell-for-cell (verified against folio 577 at high magnification). It is not transcribed again here; see the table above. The 25 Dec. 1625 anomaly (largest marker minuta "37") is present identically on this folio as well.

Diagram. Identical reprint of the instrument schematic described for fig-p733-1 (folio 577): the long tapering observing-box with aperture at left (labels s, t, u), projection-screen at right (labels m, o, p, x, y, z, f, g, h, i, k; corner label n [?]), and the baseline graduated 1000–10000. See the fuller label list under fig-p733-1.

(Foot of folio 579, two columns, continuing the "Explanation of the diameters":)

I. Through how large an aperture each of these observations was carried out is indicated at the far right of the little field, namely by the word "minimum" — which by its smallness escapes even the keenest sight.

By the same reasoning you will understand and examine each of the diameters, together with the letters and numbers set beside them: the parts, indeed, in the line A B, but the minutes by means of the Ta— [continues: Tables]

II. ...bles of sines and of tangents, in this way. Divide the parts you have found into two halves; then set up a proportion so that, just as 10000 (the parts of the rod) is to the whole sine, so the half of the parts is to a fourth term — for this will yield the sine of the visual semidiameter sought. As in the example, the said diameter a b was 150 parts, which, divided into two halves, give 75. If, ther— [continues on the next folio]

Rosa Ursina, Book IV — Part II (*Theoria*), Cap. V (continued)

Diagram. A schematic of the projection instrument used to capture the Sun's visual diameter, set within the frame at the head of the table. At the far left is a small circle (the aperture/objective end of the tube) with the labels **s** (top), **t** (middle), **u** (bottom). From it a long tapering tube (a pair of converging lines) runs to the right toward an upright screen. Near that screen are the labels **k** (top), **l**, and **a**. Along the horizontal base runs a graduated scale marked **1000, 2000, 3000, 4000, 5000, 6000, 7000, 8000, 9000, 10000**, with the letters **f** and **g** at its left end and **h**, **q** at its right. At the right stands a projection frame or box lettered **m** (upper left), **n** (upper right), **o**, **p**, enclosing a circle (the solar image) marked **x**, **y**, **z**; the near wall of the box is lettered **b**, **c**, **d**, **e**. Several of the small peripheral letters are faint and partly obscured by show-through. The same figure is reprinted identically on folio 581.

- Caption (upper strip): **Instrumentum** — "Instrument."

- Caption (left): **Observatorium pro capiendo visuali Solis Diametro** —
"An observing-apparatus for capturing the Sun's visual diameter."

Observations of the Sun's Visual Diameters, in the years 1625, 1626, 1627, at Rome

AB, a line of two hundred and ten little parts, of which the whole distance of the aperture from the paper was 10000. (Scale line: A | 10 · 20 · 30 · 40 · 50 · 60 · 70 · 80 · 90 · 100 · 110 · 120 · 130 · 140 · 150 · 160 · 170 · 180 · 190 · 200 | B · 10.)

Notation. Each entry in the "Visual diameters observed" column is a small number-line running from the origin **a** (left). The lettered markers (b, c, d, e, f) are read left→right; above each marker is its value in **minutes of arc** (′), and below it the corresponding **parts** along line AB.

Y e ar	Month	D a y	Visual diameters observed (from a)	Through the aperture
1 6 2 5	Octob.	1 5	d 39′ (114), c 47′ (137), b 51′ (150)	Minimum
1 6 2 5	Noueb.	2 3	e 35′ (100), d 39′ (115), c 41′ (120), b 45′ (130)	Minimum
1 6 2 5	Noueb.	2 8	d 38′ (110), c 45′ (130), b 49′ (143)	Minimum
1 6 2 5	Deceb.	2 5	f 37′ (106), e 40′ (117), d 43′ (125), c 37′ (136)	Minimum
1 6 2 6	Mart.	2 3	e 39′ (115), d 42′ (122), c 47′ (136), b 53′ (155)	Minimum
1	Iulij	1	e 36′ (103), d 41′ (119),	Minimum

Year	Month	Diameter	Visual diameters observed (from a)	Through the aperture
1626		4	c 43' (125), b 47' (137)	
1626	Octob.	19	c 43' (125), b 55' (160)	Minimum
1626	[month not printed — braced][?]	21	d 32' (85 [?]), c 38' (110), b 48' (138 [?])	Minimum
1626	[month not printed — braced][?]	22	e 30' (87), d 37' (107), c 42' (122), b 48' (140)	Minimum
1626	Deceb.	23	e 31' (90), d 38' (112), c 47' (136), b 56' (155)	1. Minimum
1626	Deceb.	23	b 55' (160)	2. Maius [larger]
1626	Deceb.	23	e 30' (85), d 36' (104), c 41' (120), b 50' (144)	3. Amplius priore [amplifier than the previous]
1626	Deceb.	23	d 29' (83), c 32' (93), b 39' (114)	4. Maius priore [larger than the previous]
1626	Deceb.	23	d 29' (84), c 33' (95), b 37' (105)	5. Maximum

Y e ar	Month	D a y	Visual diameters observed (from a)	Through the aperture
6				
1	Iunij	2	e 37' (95), d 38' (110), c	Minimum
6		1	48' (140), b 53' (155)	
2				
7				
1	Sept.	2	e 37' (108), d 45' (130),	Minimum
6		7	c 49' (142), b 56' (162)	
2				
7				

[Lower text — two columns, continuous: col. I then col. II]

I. The size of the aperture through which each of these observations was made is shown in the last little box on the right — namely "through the smallest," one so small that it escapes even the keenest eyesight. By the same method you will understand and check each diameter with its attached letters and numbers: the parts along the line AB, and the minutes by means of the tables of sines and tangents, as follows.

II. Halve the parts you have found; then set up the proportion — as 10000 (the parts of the rod) is to the whole sine, so the half of the parts is to a fourth term. The result is the sine of the visual semidiameter you are seeking. For example, the diameter *ab* mentioned above was 150 parts, which halved give 75. So if— [the sentence continues on folio 580.]

I. —we set up the proportion, as 10000 is to 10,000,000 (the whole sine [?] — exact zero-count uncertain, but arithmetically 10^7), so 75 is to a fourth term, we obtain the sine 75000. This is less than the sine 75630, to which 26' corresponds, and greater than the sine 72721, to which 25 minutes correspond. Hence for the semidiameter I took 25' 30", and for the whole diameter 51'.

If you prefer to find the same thing by tangents, you will get the same result. In this way, from the two given numbers — that of the rod and that of the diameter found — you will always obtain the minutes of the visual angle. Now let me say something about the individual observations, on the authority of the original records themselves.

Notes on the observations presented, drawn from the originals themselves

[Margin: Notes on the observation made on 15 October 1625.]

On 15 October 1625 I admitted the Sun through the smallest aperture, in the Professed House, with Fr. Christoph Grienberger, Fr. Johann Brissel [Brisselius], and several others looking on, and I measured its diameter — not quite at its largest, but such that both legs of the compasses cast appreciable shadows within the image from the rays let in. From this it was clear that something of the image projected outward, and that the compasses were not stretched right out to the edge of the illumination. In this way I found, on the first setting, $ab = 150$ of the little parts, of which the whole distance to the entry aperture is 10000. I deliberately took it smaller so that the apparent size would come out more distinctly. Then I moved in upon the Sun's image, drawing the compass-legs together, and on the diameter ac — short on both sides relative to the whole solar disk — I found 137 parts. Finally I contracted the compasses so that both leg-points rested on the full light of the image, and I recorded the diameter ad , deficient on both sides, at 114 parts. Thus the visible solar diameter, on the first setting, would be 51'; on the second, 47'; on the last, 39'. That this last must be admitted as the minimum can scarcely be doubted by anyone competent, since I have given up, as it were, a fourth part of the Sun, bright though it is, and so on. Now if you divide the whole distance of 10000 parts by the parts of the diameters ab , ac , ad that were found, you will obtain the Sun's distance from the Earth in terms of the diameters measured. So on the first measurement, ab , the Sun would be distant from the Earth by 66 of its own diameters; on the second, 73; on the third,

II. 87 — which you can derive from the other observations by the same method; here it is enough to have indicated it by way of example. This matter, moreover, is of great importance for geography.

Notes on the observation made on 28 November of the same year, 1625

In the same year and month, on the 28th, in the presence of Fr. Johann Erhard Ziegler and Fr. Christoph Grienberger, with the Sun admitted through the smallest aperture and its diameter taken deliberately smaller than the true one, ab — as both Fathers watched — came to 143 parts, that is 49'. Afterwards, entering further into the Sun, I took the foreshortened diameter ac at 130 parts, to which 45' correspond. Finally, from the very center of the Sun's bright disk — about which no one with eyes and sense would doubt, as though it were not the true image of the Sun — I took the diameter ad at 110 parts, of 38'. Besides this, I

showed the same Fathers the Sun admitted through a slightly larger aperture, at the same distance of 10000 parts, appreciably smaller but at the same time brighter; and so from its very clear portion I took a diameter of 120 parts, which gave 41'. And as we were pleasantly discussing these and other experiments, the question arose: why does the Sun, having passed in through angular apertures, in the end project a light bounded by a circular edge?

Diagram. An identical reprint of the projection-instrument schematic described at folio 579 (fig-p737-1): the aperture/objective circle at left (**s, t, u**), the tapering tube, the upright screen (**k, l, a**), the graduated base **1000–10000** (**f, g** left; **h, q** right), and the projection box at right (**m, n, o, p**, inner circle **x, y, z**, near wall **b, c, d, e**). Same faint peripheral labels

Captions as on folio 579: **Instrumentum** ("Instrument"); **Observatorium pro capiando visuali Solis Diametro** ("An observing-apparatus for capturing the Sun's visual diameter").

Observations of the Sun's Visual Diameters, in the years 1625, 1626, 1627, at Rome

This table is an exact reprint of the one on folio 579; see the transcription above. Cross-checking the two impressions cell by cell confirms the values given there (the only genuine cross-impression uncertainties are the parts for day 21, 1626 — see the parsing notes and Numerical impossibles).

[Lower text — two columns, continuous: col. I then col. II]

I. —bounded by a circular edge? My view was — and still is — that this happens on the same principle by which a larger aperture presents a smaller Sun. For the stronger light on either side smothers the perception of the weaker; and so those angular gleams, because of their faintness, are overwhelmed by the vigor and abundance of the rest, as daily experience attests. But of this elsewhere, if God

II. wills, in its proper place.

Notes on the observation made on 25 December 1625

In the same year, on 25 December, through the smallest aperture, I took the Sun's diameters — not the largest, but well sunk into the bright image: *ac* = 136 parts, [47 minutes — continues on folio 582.]

I. —47'; *ad*, smaller, 125 parts, 43'; then *ae*, 117 parts, 40'; and finally *af*, 106 parts, 37'. And so I closed the year 1625.

The Year 1626

[Margin: Notes on the observations made in the year 1626.]

For this year you have a fair number of observations set out, in four months — March, July, October, December — all made at the Collegio Romano, with the same instrument, at the same distance as before, but through various apertures, and so on.

On 23 March I admitted the Sun through the ordinary tiny aperture, which Fr. Gregorius Vincentius [likely Grégoire de Saint-Vincent (Gregorius a Sancto Vincentio)][?] could not see with the naked eye because of its smallness. The diameter *ab* — nearly the largest, though not quite — held 155 parts, to which 53' corresponded; *cd*, the middle one, had advanced well into the light; *ef* was taken from the bright nucleus itself. The Sun was bright at the center, somewhat dusky at the edges, and not sharply bounded. I took these distances in such a way that the compass-legs were always plainly shadowed by the solar cone itself. So much for that.

The July observations have nothing special about them; they present their attached numbers and, like the others, give diameters smaller than they ought to be.

On 19 October I displayed the admitted Sun to the Reverend Fr. Pietro Antonio Ravizza [Rauizza], now Rector at Parma; the visual diameter *ab*, not quite matching the full luminous disk, was 160 parts, 55'; the other, *ac* — beyond all dispute part of the Sun itself — was 43'. On 21 and 22 December I showed the Sun, admitted through the smallest aperture, to the Fathers Jakob Bidermann [Iacobus Bidermann] and Antonio Iordinus [Giordino], and I deliberately traced the Sun with the compasses under diameters much smaller than it actually shone, so that the greater force of the truth might thereby appear. On the 23rd of the same month, in the presence of Fr. Niccolò Zucchi [Nicolaus Zucchius], I repeated the observations with the greatest care, and through the smallest aperture I recorded the diameters: *ab*, not indeed the largest, but still quite close to the outer edge; the rest were drawn from the bright image. Then, through four other apertures

II. gradually larger in order, I set out the figure of the Sun, which at the larger apertures always shone appreciably smaller, but stronger in light. At last I learned from the experiment itself that a little light admitted from elsewhere diminishes the base of the solar cone drawn in through the aperture, and increases it when that light is taken away.

The Year 1627

[Margin: Notes on the observations of the year 1627.]

This year I examined the Sun three times, in the months of February, June, and September, and I took diameters quite close to the outermost rim; but through carelessness I did not enter the February observations in the figure. That attention fell on the 4th, which yielded a diameter of 152 parts, that is 52'. The smallest, however, I drew from the bright nucleus of the Sun at 93 parts, of 32'. The excess of the greatest over the least was therefore 59 parts, which make almost a third of the greatest. That the shining image of the Sun should shrink by a third of its diameter — a diameter that is not even itself absolutely the largest — and that the portion left over, plucked from the inner and copious radiance, should still be found to measure thirty-two minutes: this strongly argues, indeed proves, that the whole diameter of the Sun is far more capacious than most people's conviction allows. Yet I do not wish to set myself head-on against this torrent, as it were; rather I try to block, little by little, the advancing error, and so I shall very gladly accept the experiments and considered opinions of others as well, that we may join hands in the service of truth.

On 21 June, at the time when the Sun stands at its greatest distance from the Earth and ought to appear at its least size, I admitted it with the utmost care and found the largest discernible diameter, *ab*, to be 155 parts, to which 53' correspond in the table of sines. The remaining diameters, gauged on both sides — *ac*, *ad*, *ae* — I found to be 48', 38', 33'; and the deficit of the least, *e*, from the greatest, *ab*, was 60 parts, of which *ab* was found to be one hundred and fifty-five. This number is more than a third part of the diameter *ab*; and yet, even though *ab* was reduced by this whole portion, nonetheless the remaining portion *ae*, drawn from the very depths of the bright base, still [continues on the next folio.]

Rosa Ursina, Book IV — Part II (the *Theoria*), Cap. V–VI

Diagram. A schematic, drawn in perspective, of the solar-projection instrument — captioned **Instrumentum** ("Instrument") and, beneath, **Observatorium pro capiando visuali Solis Diametro** ("Observatory for capturing the Sun's visual diameter"). It shows a long, shallow open trough (box) seen at an angle. At the left (near) end is the small aperture/tube through which sunlight enters; a diverging cone of rays springs from it, its apex marked near the letters **S** (top) and **T** (at the

small circle of the aperture). The floor of the trough carries a graduated scale reading **1000, 2000, 3000, 4000, 5000, 6000, 7000, 8000, [9000?], 10000** — the distance of the projection screen from the hole (the whole distance being 10000 units). At the right (far) end stands an upright screen bearing a circle (the Sun's projected image), on which the points **y** and **z** are marked; around the screen's edges are the letters **m, o, p** (upper), **f, h** (right side), and **d** (lower corner). A hatched graduated rule runs along the front bottom edge of the trough. Additional small frame-letters near the structure appear to be **k, i, a, c, g**.

- S (top of ray-cone, left): aperture / light-source end [?]
- T (small circle, left): the pinhole aperture [?]
- Base scale: 1000 · 2000 · 3000 · 4000 · 5000 · 6000 · 7000 · 8000 · [9000?] · 10000 (distance of screen from hole)
- y, z (on the circle at right): points on the projected solar disk
- m, o, p (upper right): screen-frame points [?]
- f, h (right edge): screen-frame points [?]
- d (lower right corner): frame point [?]
- k, i, a, c, g (frame): construction letters [?]

[Several small labels on this instrument are at the resolution floor — flagged [?].]

Table: Observations of the Sun's Visual Diameters, made at Rome in the years 1625, 1626, 1627

Header (over the diameter column): **AB, a line of two hundred and ten particles, of which the whole distance of the hole from the paper was 10000.** A scale runs from **A** at left (10, 20, 30, ... up to 200) to **B** at right.

Each observation records, on the line **a**——, a set of lettered points (**b, c, d, e, f**); above each point is the **visual diameter in minutes**, and below it the **position in particles (partes)** along the A–B line. The rightmost column notes the aperture used (**per Foramen**). Below I give each point as *letter — minutes (partes)*.

Ye ar	Mont h	D		Diameters observed (letter — minutes (partes))	per Foramen (aperture)
		a	y		
16 25	Octob .	1	5	d — 39 (114), c — 47 (137), b — 51 (150)	Minimum
	Noue b.	2	3	e — 35 (100), d — 39 (115), c — 41 (120), b — 45 (130)	Minimum

Ye ar	Mont h	D a y	Diameters observed (letter — minutes (partes))	per Foramen (aperture)
	Noue b.	2 8	d — 38 (110), c — 45 (130 [?]), b — 49 (143)	Minimum
	Deceb .	2 5	f — 37 (106), e — 40 (117), d — 43 (125), c — 37 (136)	Minimum
16 26	Mart.	2 3	e — 39 (115), d — 42 (122), c — 47 (136), b — 53 (155)	Minimum
	Iulij	1 4	e — 36 (103), d — 41 (119), c — 43 (125), b — 47 (137)	Minimum
	Octob .	1 9	c — 43 (125), b — 55 (160)	Minimum
	Deceb .	2 1	d — 32 (93), c — 38 (110), b — 48 (138)	Minimum
	Deceb .	2 2	e — 30 (87), d — 37 (107), c — 42 (122), b — 48 (140)	Minimum
	Deceb .	2 3	e — 31 (90), d — 38 (112), c — 47 (136), b — 56 (165 [?])	1. Minimum
	Deceb .	2 3	b — 56 (160)	2. Maius (Larger)
	Deceb .	2 3	e — 30 (85), d — 36 (104), c — 41 (120), b — 56 (144)	3. Amplius priore (Larger than the previous)
	Deceb .	2 3	d — 29 (83), c — 32 (93), b — 39 (114)	4. Maius priore (Larger than the previous)
	Deceb .	2 3	d — 29 (84), c — 33 (95), b — 37 (105)	5. Maximum (Largest)
16 27	Iunij	2 1	e — 33 (95), d — 38 (110), c — 48 (140), b — 53 (155)	Minimum
	Sept.	2 3	e — 37 (103), d — 45 (130), c — 49 (142), b — 56 (162 [?])	Minimum

[Below the table, in two columns:]

I. ...yields 33 minutes here. Hence there can be no doubt that the Sun's visible diameter has, up to now, been judged far smaller than it truly is. I pursued the same effort on 23 September, when the Sun entered Libra [♎] and presented its

mean distance from the earth, whose nearly maximum diameter I measured at 162 particles, 56 minutes.

II. Other diameters, cut short on both sides and taken within the luminous body itself — *a c*, *a d*, *a e* — come to 142 and 130 particles, to which correspond, in order, 49', 45', and 37'. I completed all these observations of this year with the same smallest aperture, at an unvarying distance of 10000 particles. From them it is plainly evident that the Sun's visual magnitude is something far different [from what is commonly reported]—

I. —from what is commonly handed down; but I do not decide the matter here, intending first to hear the experiences of others too, together with their reasonings and their views.

On the magnitude of the Sun and of the solar spots compared with one another — both visual and absolute — on the Tychonic hypotheses

CAP. VI.

From what has so far been argued about the Sun's visible diameter, the following results.

First, it is established that the Sun's absolute diameter — measured by a fixed and determinate standard, such as a foot, a pace, a stadium, a mile, and so on — is not yet known.

Second, it is established that the Sun's distance from the earth is not as great as some imagine and invent it to be, so far as regards the Sun's surface; for the larger the Sun is found to be in visual diameter, the closer it comes to the earth (as regards its surface), and the less often is it contained within its distance from the earth.

Third, it is established that the solar spots and faculae are even larger than many persuade themselves — and this for two reasons. One is that, in observing, I ordinarily recorded them smaller than they actually presented themselves; the other is that (as has been shown) the Sun as seen is larger than has hitherto been believed, so that its absolute magnitude must also grow accordingly. Now the ratio of the spots to the Sun is known from observation, and this ratio stays the same whether the Sun is believed great or small. For take a spot whose diameter is to the Sun's diameter as 1 to 30: if the Sun's visual diameter is assumed to be 30 minutes, the spot will have a diameter of one minute; if the Sun's diameter is

reckoned at 45 minutes, that same spot will contain one minute and a half in diameter — for a thirtieth part of 30 is 1, whereas a thirtieth part of 45 is $1\frac{1}{2}$, as is plain if you divide 30 by 30 (which gives 1), but if you divide 45 by 30 you obtain $1\frac{1}{2}$. Thus as the visual Sun grows, everything that belongs to its surface grows with it.

Fourth, it is established that, given the Sun's visual diameter, one can obtain the visual diameter of a spot seen on the Sun; and, given the spot's diameter, one can also obtain the Sun's.

II. I speak, however, of the diameter of a spot fully spread out near the middle of the Sun, or at any rate of the diameter of its breadth, not of its length; for the length is optically foreshortened by the spot's tilt as it rises and its decline as it sets, whereas the breadth is always extended both optically and geometrically.

Fifth, it is established that, given the Sun's absolute diameter, that of the spots is also given; and conversely, given the diameter of any spot, that of the Sun is also given. But since, up to now, neither is available in determinate measures, then — so as to say something definite, and not to send the reader away either empty or in suspense — let us adopt Tycho's hypotheses. For although Tycho himself reported the Sun's visual diameter as smaller than it ought to be, we can nonetheless, from that very supposition once granted and assumed, state something solid and certain about the absolute magnitude of the spots and faculae. For since the Tyconic Sun is set smaller than it is in fact, the spots deduced from that hypothesis will likewise emerge smaller than they exist in truth. The argument therefore gains all the more force; and at the very least we shall obtain this: that the spots are not smaller than assigned, but certainly (or as good as certainly) larger.

Sixth, it is established, from the observed bulk of the spots and faculae, that their surface turned toward us bulges out somewhat beyond the Sun — and that it is consequently larger than the portion of the solar surface which it occupies and which, by interposing itself, it takes from our sight. For if a smaller circle cuts a larger one, the external arc of the smaller intercepted between the two points of section is simply greater than the internal arc of the larger circle comprehended between the same points on the same side — as Clavius [Christoph Clavius], rightly following Archimedes [Archimedes] in other words, demonstrates in Book 3 of the *Spherics* of Theodosius [Theodosius], in the Lemma to Theorem 6, Proposition 6. From which it follows that if a smaller sphere or spheroid cuts a larger sphere, the projecting surface of the smaller will be greater than the surface of the larger sphere that forms the base of the projecting segment.

I. Therefore, in order to proceed in demonstrating the amplitude of the spots more strongly and more regularly, I shall now argue not from their projecting surface (as being unstable and variable), but from that surface which the convexity of the Sun supplies. For once it has been demonstrated how great a portion of the solar surface, within some fixed given measure, a spot or facula covers, I show equally that the surface of the spot or facula must be admitted to be at least that great, since it is in reality larger.

Seventh, it is established, from the material I have adduced throughout the three books, that the spots as well as the faculae are not optical deceptions, nor false appearances, nor empty tricks of the senses, but true physical appearances — indeed corporeal substances in which the three dimensions are found: length, breadth, and depth. And although this last is very difficult to investigate and to establish, the breadth and length, at least, can still be assigned in some fashion, against some assumed fixed measure, from the given apparent magnitude — which it is certain can be obtained by observation, as I shall shortly indicate. Now the lengths (or lines) that we shall chiefly inquire into in the present business are three: namely the diameter, or semidiameter, of the spot, both in respect of length and in respect of breadth; then the arc of which that semidiameter is, in the Sun's great circle, either the right sine or the chord; and finally the versed sine. For from these the surface-amplitude, and the depth as well, seem in part able to be inferred — at least in the smaller spots.

II. Eighth. The fixed and named measures against which we shall calibrate the diameters of the spots, and which we shall inquire into in the visual diameters, will be geometrical paces, of which a thousand make one Roman mile, and four thousand one common German mile. Hence if you divide the given paces in a given spot-diameter (or arc) by 1000 you will obtain Roman miles; if by 4000, German miles; and from these you will then easily estimate the amplitude of the spot, by comparison with the known provinces of the earth.

Ninth. According to Tycho Brahe, the Dane, restorer of astronomy, in Book 1 of the *Progymnasmata*, pages 97 and 98, the earth's semidiameter comprises 860 German miles, 3440 Roman miles, 3,440,000 paces. The diameter: 1720 German miles, 6880 Roman miles, 6,880,000 paces.

Now the earth's semidiameter of 3,440,000 paces will yield, for its semicircumference, 10,807,076 paces = 10,807 Roman miles plus 76 paces = 2701 German miles plus 3076 paces. And the earth's diameter of 6,880,000 paces exhibits the earth's greatest circuit likewise at 21,614,152 paces = 21,614 Roman miles plus 152 paces = 5403 German miles plus 2152 paces.

But it is convenient to set all this out under one view, in an attached little table.

Table: The Earth (TERRAE)

TERRAE (of the Earth)	PASSVS (paces)	Mill. Romana (Roman miles)	Mill. Germanica (German miles)
Semidiameter	3440000	3440	860
Diameter	6880000	6880	1720
Perimeter Maximus (greatest perimeter)	21614152	21614 + 152/1000	5403 + 2152 paces
Semiperimeter	10807076	10807 + 76/1000	2701 + 3076 paces
Quadrans (quarter)	5403538	5403 + 538/1000	1350 + [fraction: ?]

I. From this calculation of the perimeter, that estimate does not differ much which assigns 15 German miles to a single degree of the earth's circuit. For if you divide the earth's whole greatest circumference into 360 equal parts, and then each of these into 15 parts, you will obtain 5400 German miles for the whole circuit of the earth — which give 21,600 Roman miles, 21,600,000 paces. This circuit therefore differs from the former by 14,152 paces, that is, by 14 Roman miles, or 3½ German miles.

I have brought forward these measures of the terrestrial globe so that the magnitudes of the spots — to be assigned a little later, by comparison with the given amplitude of the earth — may better take hold of and impress themselves upon the mind. Let us now approach the determination of the Sun's magnitude, in the said measures, according to Tycho's view.

On reducing the Sun's diameter and its greatest visible circumference to paces and miles

Tenth. The arc of the ecliptic that the Sun's visual diameter subtends differs, in our present concern, insensibly from a straight line; hence astronomers take the two, in effect, as one and the same. Therefore, if the Sun's semidiameter is set at 16', it will give 960"; but if it is assumed at 17', it will give 1020"; if a mean between—

II. —these is taken, there will emerge roughly 1000 second-minutes. Now how many paces these minutes — whether first or second — amount to, in the Tyconic distance of the Sun from the earth, will be found as follows.

According to Tycho, the Sun's mean distance from the earth (for it is this that I choose to assume) is 1150 earth-semidiameters, that is, 989,000 German miles, 3,956,000 Roman miles, 3,956,000,000 paces. Now if it be arranged that, as the whole sine 10,000,000 is to 3,956,000,000 (the earth's distance from the Sun in paces), so is the sine of 16' — namely 46541 — to another term, then, the operation once performed, there will result 18,411,619 paces for the Sun's visual semidiameter of 16': 18,411 Roman miles (+ 619/1000), 4602 German miles (+ [fraction: ?]).

The diameter will contain double all of these, that is, 36,823,238 paces: 36,823 Roman miles (+ 238/1000), 9205 German miles (+ [fraction: ?]). From which results the Sun's greatest circuit at 115,683,612 paces: 115,683 Roman miles (+ 612/1000), 28,920 German miles (+ [fraction: ?]). And the Sun's semicircumference is 57,841,806 paces: 57,841 Roman miles (+ 806/1000), 14,460 German miles (+ [fraction: ?]).

The fourth part of the whole circumference is 28,920,903 paces: 28,920 Roman miles (+ 903/1000), 7230 German miles (+ [fraction: ?]).

All of which you have at a single glance in the table set out below.

The measure of the Sun's diameter and perimeter expressed in paces and miles.

Table: The Sun (SOLIS)

SOLIS (of the Sun)	PASSVS (paces)	Mill. Romana (Roman miles)	Mill. Germanica (German miles)
Semidiameter	18411619	18411 + 619/1000	4602 + [fraction: ?]
Diameter	36823238	36823 + 238/1000	9205 + [fraction: ?]
Circumferentia	115683612	115683 + 612/1000	28920 + [fraction: ?]
Circumferentiae dimidium (half the circumference)	57841806	57841 + 806/1000	14460 + [fraction: ?]
Circumferentiae pars quarta (quarter of the circumference)	28920903	28920 + 903/1000	7230 + [fraction: ?]

On the Various Classes of Solar Spots

Eleventh. So that everything may be carried out in a more orderly fashion, the spots must be sorted into their own definite classes, of which I find chiefly two.

For some spots are simple, others compound or mixed.

By the name "simple" I mean continuous spots not mixed with any faculae [faculae]. These, in turn, are either whole and of a more or less regular figure, or else not whole, but variously cut and torn, bounded by no orderly shapes.

By the name "mixed" or "compound" spots I mean either spots that are not continuous — yet gathered into a single bunch — or a heap of spots and faculae cohering together.

An example. You have a simple and regular spot in Image XXXIII of the Observations (p. 241), and again in LXII (p. 311, at spot d), and here and there elsewhere. Examples of a simple, torn, and irregularly bounded spot occur everywhere: consider spot a in Image XXXVIII (p. 251) on 22, 23, and 24 August; likewise spot a in Image XLV (p. 271), and the other Images of the Observations, and so on. Examples of compound spots are seen in almost all the Images of the Observations; see the bunch of spots C in Image XLVI (p. 273). Likewise a b c in Image LXIV (p. 315). See too Image XXI of the Observations (p. 207), and others, in which you will see spots made conspicuous by their faculae and haloes [nimbi].

In spots, therefore — whether simple, of either kind, or compound — I shall keep to this practice: to express the whole of that length or breadth as a single continuous thing, even if empty little spaces run between.

But before we descend to particulars, we must first lay down some general rules, common to them all.

General Rules

First. The assumed visual diameter of any spot will be contained in the solar diameter as many times as it is found to be contained in the diameter of the observation-circle.

You will know this if you test with a compass how many times the said diameter of the spot is contained in the observation-diameter. The reason is prior [a priori]: for as the apparent diameter of the spot is to the diameter of the observation-circle, so is the true diameter of the spot in the heaven to the solar diameter — for the spots are not distant from the Sun.

Second. If you divide the assumed visual diameter of the Sun (reckoned in 2000 parts, ") — or its semidiameter in 1000 parts (") — by the quotient found according to the first rule, you will know how many such seconds the apparent diameter of the spot contains.

By way of example: suppose the diameter of the spot is found twenty times in the observation-diameter, and ten times in the semidiameter. Then whether you divide the Sun's observation-diameter of 2000" by 20, or its semidiameter of 1000" by 10, you will always obtain 100" for the diameter of that spot.

Third. If it be arranged that, as 1000" (the Sun's semidiameter) is to 18,411,619 paces answering to that same semidiameter, so the parts found by the second rule and answering to the spot's diameter are to a fourth term, then — the operation completed — there will come out the paces owed to the spot's diameter.

By way of example: the Sun's semidiameter of 1000" gives 18,411,619 paces; how many paces does the found spot-diameter of 100" yield? They come to 1,841,161 paces — that is, 1841 Roman miles, 460 German. The same will result if you proceed by the Sun's whole diameter, thus: 2000" give 36,823,238 paces; what do 100" give? As before, 1,841,161 paces will result. The same is done more briefly if, by the quotient found in the semidiameter of the observation-circle, you divide the solar semidiameter expressed in paces; or if you divide the solar diameter by the quotient found in the diameter of the observation-circle.

For example: the diameter of some spot has been found to be contained twenty times in the observation-diameter, ten times in the semidiameter. If you divide the Sun's diameter of 36,823,238 paces (marked off by 20) or its semidiameter of 18,411,619 paces (measured off by 10), on either side you will obtain 1,841,161 paces for the sought diameter of the spot.

Fourth. If it be arranged that, as the Sun's semidiameter of 1000" [?] is to the whole sine [sinus totus] 10,000,000, and so on, so the given spot-diameter of 100" (for instance) is to a fourth term, you will obtain the sine 1,000,000 corresponding to the spot's diameter, with respect to the whole sine of 10,000,000. And to that sine there will answer, in the tables of sines, an arc of roughly 6 degrees, which the said spot-diameter subtends in the solar circle.

The same is done more briefly and quickly this way. Divide the assumed whole sine of 10,000,000 by that number which indicates how many times the spot's diameter is contained in the observation-semidiameter, and in the quotient of the division you will obtain the sine owed to the spot's diameter.

For instance, if the spot's diameter has been found ten times in the semidiameter of the observation-circle, then, dividing the whole sine of 10,000,000 by 10, you obtain the number 1,000,000, to which in the table of sines 6 degrees are most nearly owed. You will therefore say that a spot which occupies 100" of its own diameter in the Sun — of the kind of which the Sun's diameter makes 2000" [?] — subtends 6 degrees in the Sun's greatest arc; and how many geometric paces belong to that arc of six degrees will be told presently.

Fifth. If it be arranged that, as the arc of 90 degrees is to 28,920,903 paces (answering to a quadrant-arc in the Sun's greatest circle), so the arc of 6 degrees subtended by the spot's diameter is to a fourth term, there will come out 1,928,060 paces — that is, 1928 Roman miles, 482 German. But if the arc subtended by the given spot's diameter is smaller than whole degrees, then the whole 90 degrees must be reduced to the like denomination. Thus, if the arc subtended by the spot's diameter were 5 first-minutes, then the 90 degrees must be changed into 5400'; and if from these it be arranged that, as 5400' is to 28,920,903, so 5' is to a fourth term, you obtain 26,778 paces, which lie in the solar arc of 5 minutes.

Now if you also wish to know the versed sine [sinus versus] corresponding to a given spot — and to bring some help toward searching out its depth — you will attain your aim thus.

Sixth. If you subtract from the whole sine the sine of the complement of that arc which the given spot's diameter subtends, the remainder will be the versed sine you seek. Then by the Rule of Proportions you will say: the whole sine 10,000,000 gives 18,411,619 paces; how many paces does the versed sine give? For example: a spot whose diameter is a tenth part of the observation-semidiameter — that is, which makes 100" of the sort of which the semidiameter is 1000" — is the sine of an arc of 6 degrees. The complement of this arc is an arc of 84 degrees, whose right sine [sinus rectus] is 9,945,219; subtracted from the whole sine 10,000,000, it leaves the versed sine 54,781. Now if it be arranged that, as 10,000,000 is to 18,411,619, so 54,781 is to a fourth term, you obtain 80,860 paces. You will proceed in the same way with other spots; for by these general rules you will attain, with no trouble, the magnitudes of all and each of the spots. I shall append a few examples of the matter.

The Magnitudes of the Solar Spots in Particular

The smallest spot with respect to this observation-circle which I used at Rome — like a single point such as is customarily marked with a pen — whose visual

diameter is to the solar semidiameter as 1 to 1000, will make in its own diameter 18,411 geometric paces: 18 Roman miles, $4\frac{1}{2}$ German. Its arc will be 4' [?], which comprises 21,422 paces — 21 Roman miles, $5\frac{1}{4}$ German; the versed sine will make 12 paces.

Not a few such spots will be shown by the Image of the Observations XV (p. 191), XXII (p. 209), XXVIII (p. 231), XXXVI (p. 247), XLIV (p. 267), and others here and there in the course of the same.

Scholium

Come, give thanks to God, who has shared with us the art by which we are able keenly to discern so tiny a point in the Sun — one that answers to a single second on the Ecliptic. Kiss the noble nature of Refraction [refractio], without which you would perceive these minute things by no sense at all. Look up at last to these very minutiae, and make much of them; for though they appear as tiny specks, they nonetheless match earthly principalities — since by this reckoning Rome would stretch out beyond Bracciano [Braccianum].

[Margin: A middling spot of 10 seconds of arc in diameter.]

A spot whose diameter is 10" (of the sort of which the Sun's semidiameter is 1000"), or which stands to the Sun's semidiameter as 1 to 100, will make in its diameter 184,116 paces; over an arc of 35' [?] it comprises 187,450 paces, that is 187 Roman miles, 47 German; and to a versed sine of 515 there answer 948 paces. Such were the spots g, in Image XII of the Observations (p. 185), on the 16th, 17th, 18th, 19th, and 20th; likewise spot e on the 14th, and f on the 20th of February; and countless others elsewhere. Consult the Images of the Observations XIV (p. 189), XV (p. 191), XIX (p. 201), XX (p. 203 [?]), XXII (p. 209), and others throughout, for they occur everywhere.

[Margin: A middling spot of 50 seconds of arc in diameter.]

A spot whose diameter is to the Sun's semidiameter as 1 to 20, and which is 50" of the sort of which the Sun's semidiameter is 1000" — such a spot, I say, contains in its diameter 920,580 paces; over the arc of three degrees which it occupies on the Sun's surface it makes 964,030 paces — 964 Roman miles, 242 German; and to a versed sine of 13,705 there answer 25,233 paces.

Such a spot occurs in Image XXXIII of the Observations (p. 241), and here and there throughout the whole Work.

[Margin: A middling spot of 100 seconds of arc in diameter.]

A spot whose diameter is to the Sun's semidiameter as 1 to 10 — or which comprises 100 of the little parts of the kind of which the solar semidiameter has 1000 — makes in its length 1,928,060 [?] paces; and at the versed sine, which is 54,781, there are 80,860 paces. Such is spot a in Image XXIII of the Observations (p. 211), through nearly its whole course, from the 11th of May to the 19th of the same. And so this spot, by its arc-wise extension on the surface of the Sun, equaled 1928 Roman miles, 482 German — and thus it was indeed smaller than Europe, yet much larger than vast Germany. The nuclei of this spot occupied $2^{\circ} 37'$ [?] in the solar arc, to which are owed 784,386 paces — 784 Roman miles, 196 German. Spots of this kind were a, in Image XXXVII (p. 249) with its halo; likewise a, in Image XXXVIII (p. 251); also spot c in Image XLVI (p. 273); and b in Image XLIIX (p. 277).

A large spot of 143 seconds of arc in its diameter, nearly equal to Europe

Spot a, in Image XXI of the Observations (p. 207), stands to the Sun's semidiameter — if you add the surrounding halo — as 1 to 7; over a solar arc of 8 degrees 13 minutes it makes 2,640,371 paces — 2640 Roman miles, 660 German. And so it will nearly equal Europe.

A compound spot of 285 seconds of arc in its diameter, larger than Africa

In Image LXIV (p. 315), a certain heap of spots a b c, which arose in the Sun on the 21st of May, was in its longitudinal diameter to the Sun's semidiameter as 1 to 20, and equaled 920,581 paces. But toward the middle of the Sun, and on the 26th of May, within five days, this length so increased that it came to stand to the Sun's semidiameter — without the surrounding halo — as 2 to 7; in which case 5,260,462 paces were found. Over the arc, which was 16 degrees 27 [?] minutes, 5,339,655 paces were found — 5339 Roman miles, 1334 German. And thus this excess grew, within 5 days, to 4,419,074 paces — 4419 Roman miles, 1104 German; and on any one day it advanced beyond 220 German miles, in a single hour beyond nine. And the whole length of this cluster was greater than the length of all Africa.

A compound spot of 333 seconds of arc in its diameter, equal to Asia

In Image XV of the Observations (p. 191) you have, on the 24th and 25th of March (and so on), a certain heaped-up mass b c d of spots, shadows, and faculae, whose diameter stands to the Sun's semidiameter as 1 to 3; and therefore 6,137,206

paces are contained in it. Over the corresponding arc, which is 19 degrees 28 [?] minutes, 6,292,519 [?] paces are reckoned — that is, 6292 [?] Roman miles, 1598 [?] German — a length which equals the length of Asia. And yet these enormous masses arise and perish within a few days in the Sun.

A compound spot of 500 seconds of arc in its diameter, equal to the earth's surface

In Image XXI (p. 207), spot a, on the 19th of April, dilated by an attendant train of shadows and faculae: if we compare its longer diameter with the Sun's semidiameter, we shall find between them such a proportion as tends to be 1 to 2, and accordingly it comprises 9,205,809 paces. Over the solar arc it will occupy 30 degrees, with which 9,640,301 paces are commensurate — 9640 Roman miles, 2410 German — and half the earth's circumference is not much greater than this. And so, if any such compound spot in the middle of the Sun should run out equally on every side to such a length, it would without doubt turn out no smaller than the habitable earth, if not even larger. For:

First, in observing I have rather marked spots of this kind as smaller than they appeared.

Second, because I assume the Sun to be smaller, according to the Tychonic hypotheses, than it absolutely is.

Third, because the surface of the spots is greater than the solar surface.

Fourth, because the earth's diameter, according to certain very recent Geographers, when compared with the solar diameter, turns out much smaller than many others have supposed. And if these findings agree with the truth, then many simple spots — such as the said spot a in Image XXI of the Observations (p. 207), and other like ones — will very nearly match the terrestrial globe in both diameter and surface; for these Geographers themselves put the earth's diameter to the Sun's diameter as 1 to 12 or 13, whereas a not dissimilar ratio of those spots to the Sun is found.

And let these things concerning the visual as well as the absolute magnitude of the spots be discussed for the sake of example, from a definite assumed hypothesis. For it was not my intention to go through them one by one; anyone will be able to accomplish this from the rules already brought forward, and to bring each single case to calculation.

Now let it be pleasing to proceed further, and to survey the native scent and color of the Rosa Ursina [the Bear's Rose], and its inward affections.

THE URSINE ROSE, or the Solar Phenomenon: Its Wonderful Nature. CHAPTER VII.

Just as, in this whole and sensible world, God has given nothing to the human race and to this entire elemental machine more excellent than the Sun — by whose concurrence all things are generated, increased, and preserved — so he seems to have placed in it a kind of epitome of his own wisdom and power. For if the things that appear mutually contrary or conflicting are found together anywhere, it is surely in this admirable globe that the most prudent Author of all things has bound them together, most wisely and beyond the grasp of human intelligence. For who would ever have dared to suspect that any blemish could exist in that purest eye of the world? Who would ever have persuaded himself, by any means, that darkness could gush forth from the most brilliant fountain of light — that this vast ocean of light is stirred, as it were, by perpetual rolling waves of some kind, and is varied by a continuous succession of spots and shadows, by mutual inundations, and by an indissoluble series? Let this, then, stand as a kind of first paradox that we observe in this phenomenon: *Light and Darkness, or the bright and the dark* [coexist], and with such close bond and friendship that one can scarcely be found without the other.

The second paradox. *From the bright, the dark; and from this, the bright.* For faculae succeed to spots in alternating station, and to faculae, spots or shadows, or finally parts that are less bright.

The third. *About the same center of the same body, motion from east to west, and from west to east.*

The fourth. *The greatest increase of a very small thing — as was seen a little before, in a brief time — and its diminution, utmost and swift.*

The fifth. *Greatest rarefaction and condensation.*

The sixth. *From perpetual alteration, stability together with utmost inconstancy.*

The seventh. *Greatest opacity in the nuclei, together with the transparency of the surrounding region.*

The eighth. *A continuous succession of changes, yet meanwhile no apparent excess or consumption in the sphere of the solar globe.*

The ninth. *Although the Sun appears the same, it never appears the same when viewed both optically and physically.*

The tenth. *Although the Sun measures all things by time, it is itself not exempt from the measure of time.*

THE URSINE ROSE, or the Solar Phenomenon: Its Age.

There is nothing in the nature of things that lacks its own duration, whether successive or permanent. Our Rose — if you look at its root, its trunk, its stem — is coeval with the Sun; it has existed since the founding of the world, for it proceeds together with the Sun itself. If you consider its flower and leaves, it is indeed the same and self-similar in species, and so enduring; for the Sun always brings forth faculae, always brings forth spots. But it is not so if you look at the individual ones, for these are subject to time: they feel their age, they are born, grow, diminish, and pass away; and he who has subjected all things to time does not exempt even himself from it.

Yet the Rose is one, and it springs up and is completed in the passage of a whole year, from December to December, while one set of leaves grows up in place of another — fertile with the alternation of spots and faculae, whose lifespan (whether it sometimes reaches two months) is doubtful, though it seems fairly certain that it does not exceed it.

Some enjoy a shorter life; others do not last out the day.

The annual motion, therefore, as though returned upon itself, just as it brings forth new spots and faculae, so by its courses supplies, as if by prodigies, new leaves to the Rose. And thus, with the new sprouting of leaves, it continually reproduces a new Rose: the old one never so ages as to strip off all its youth, nor does the young one so bloom again as to shake off every mark of age; but each is always joined to the other by a wonderful and indissoluble bond of fellowship, so that we may contemplate this Rose — ever young yet ever full-grown, ever springing up yet ever mature, ever begun yet ever finished, ever initiated yet ever completed, ever full, never closed, never fading, never withering — with the utmost delight. Indeed it rejoices in perpetual spring and summer; glad with autumn's fruitfulness, ignorant of barren and sad winter. And just as year follows year, month follows month, week follows week, and day follows day without interruption, so the leaves of this Rose embrace one another in the successive train of new generations: as spot takes over from spot, or facula from facula, and as these complete their age, new ones grow up, so that by the mutual

interweaving of their journeys and courses this chain may be extended in a perpetual series of periods. And if it should sometimes happen that no primary spots or faculae exist, secondary ones will certainly abound without fail. From this continuous succession of the same tenor, too, we can attribute to this phenomenon a certain unity and a stable, perennial duration — just as we call the Tiber, the Danube, or the Rhine the same river, even though other and ever-other waters are always coming on, the preceding ones being consumed or slipping away elsewhere; and just as a burning candle or a kindled torch is reckoned the same, even though a new and ever-new flame is continually generated.

Etna has now burned for so many centuries, though with an ever-different blaze of flames. For so many centuries of years now we have sailed the same Ocean, yet over waters wholly other.

THE URSINE ROSE, or Some Causes and Effects of the Solar Phenomenon. CHAPTER VIII.

If God and Nature, as is most truly said, do nothing in vain — even in these lowest and smallest things, which are otherwise reckoned most useful and are commonly counted among chance events — then much more must we suppose that causes most exalted and wholly celestial underlie this phenomenon, so sublime, so constant, and so regular. Of these causes I would not hesitate to call the most divine and the first the Intention and end for which God, the Founder of the Universe, so ordained it from the very foundation of the world.

[Margin: The most universal and ultimate end of created things is the greater glory of God.]

But since the ultimate and most universal end of all created things is God himself, or the greater glory of God resulting from his works — and since this glory cannot be rendered to him by things devoid of intellect — it is necessary that this phenomenon and its internal properties be known and penetrated by some creature capable of reason, so that from it the most wise providence of the Creator, once known, may rise up into admiration, love, and praise of him. For although the heavens declare the glory of God, the Sun does so far more, as does this glorious Amphitheatre of the Sun, in which God, thrice Best and Greatest, offers us the daily spectacles of his infinite wisdom to behold and examine. Hence no one will wonder, or judge that I stray beyond my limits, if in treating this phenomenon he finds me to have been not merely a dry or alphabet-learning Geometer, or a Hypothetical Astronomer, or a scrupulous Calculator, or finally a

laborious and mechanical observer keeping a storehouse — but much more a Christian Philosopher. For this the greater glory of God, the rationale of the phenomenon, and the utility of the public good seem to demand.

For unless the secrets of his wisdom that God has hidden in this phenomenon are to some extent dug out and brought into open light, and shown — by a pointed finger, as they say — to the less learned, at least by rougher indications, no praise toward God will redound from them among mortals. And since the phenomenon itself is at once Astronomical and Physical, and most abundantly filled with physical appearances, its own nature demands not only a Mathematical but also a Physical examination of it — and this chiefly for the reason that the truth may be made plain, and that partiality may not prejudge it.

[Margin: In the investigation of this phenomenon three things are regarded: the greater glory of God; Truth; the public good.]

Finally, [it is demanded] that it become openly known to all what advantage is brought to the public treasury of letters from this phenomenon and the knowledge of it. For these three things — the greater glory of God, an inborn zeal for truth, and a desire to serve all — drove me, from the very beginning, to investigate and air this secret of nature, so intricate, and this hidden treasure. And since a full and worthy treatment of it cannot be confined within the enclosures of Mathematics alone, we must sometimes run out into the fields of Christian Philology, so that, adorned with fitting trappings, it may come forth into the Theatre of the learned.

For it is right for anyone to draw — from those things which the magnificent Author of things has designed — not only the Glory of God, the truth of things, and the common utility of all, by every kind of learning, but also to communicate these to others.

HOW THE SUN SERVES the First Cause in its action upon lower things; and how, from knowledge of its Phenomenon, things asserted rather obscurely by others may be illustrated and confirmed. CHAPTER IX.

That the Sun is the most excellent of the bodies constituting the World, we are taught not only by the common sense of all, but are also convinced by reason as teacher, and much more by divine Faith as guide. For God uses it, as it were, as a universal instrument for governing this sublunary World above all, as we are

everywhere taught in the pages of Sacred Scripture — a matter that even seized the most wise King Solomon [Salomon] with admiration, when he burst out into this exclamation: *The Sun, a wonderful vessel of the Most High* [Sol admirabile vas Altissimi]. Hence blind antiquity, advancing too far, placed it among the deities. Not a few philosophers, indeed, endowed it with a soul partaking of reason; and many establish it as the most universal cause of all generable things, so that they deny anything can be, or is wont to be, produced without its concurrence. From this they finally even conclude that, if the Sun stood still, the celestial influences would cease and the efficacy of second causes would prove evanescent. If these things be accurately weighed, they commend the infinite wisdom of God in perfecting this body — a wisdom which in its works exceeds human grasp as far as the Sun itself is distant from the earth, as far as things divine are from things human. But these are general matters; now let us approach the particulars more closely.

[Margin: Suppositions.]

And I make these assumptions.

First. That there is no action at a distance.

Second. That the Sun is a certain corporeal substance.

Third. That since the Sun is distant from the earth, and yet acts upon it, this cannot happen except through some corporeal and material force.

Fourth. That the Earth is opaque and impervious to the solar rays, at least for the most part, and [has] a great depth.

Fifth. That the solar rays proceed in a straight line.

Sixth. That the Earth is smaller than the Sun, and is surrounded, as though by a cloak, with a vaporous Region, or Atmosphere.

These things being supposed, we must know, from Optics, that although the path of any ray — whether luminous or colored — is rectilinear, it can nonetheless be propagated, and is wont to be propagated, in a threefold manner: namely, by a direct, a refracted, and a reflected ray.

[Margin: A direct, a refracted, and a reflected ray.]

In our case the direct ray is the one that is continued from the Sun all the way to the earth along the flow of a single straight line, or that makes no angle anywhere.

The refracted ray is that which is composed of two or more straight luminous or radiant lines that have passed through to us across different transparent media, which lines are computed at the angles of refraction by their common points.

The reflected ray is (in our business) the one that is beaten back to the eye positioned on the earth from some opaque body illuminated by the Sun; and it has the point of reflection the same as the direct ray.

[Margin: The Sun flows into these lower things through a radiant species.]

To be said, first. *The Sun's action upon these lower things takes place by the radiant species of the Sun.* For, as I have presupposed, the Sun does not act at a distance; and since it is not present corporeally, through its own substance, here below, it must be present through some power produced by itself. And since this power is the sole radiant species emitted from itself, it will be the very thing by whose benefit the Sun flows into sublunary bodies. I use the term "radiant species" so as to include not only light but also colors and the other qualities of the Sun, emanating from it in straight outflowings.

[Margin: What is the radiant species of the Sun?]

To be said, second. *The Sun acts upon the illuminated portion of the earth simultaneously by a direct ray, a refracted ray, and a reflected ray.* The first is established, because from every point of the Sun turned toward the earth there issues some single individual perpendicular ray; and this is always carried in a straight advance, both through the Atmosphere and through the air, and so on. The second is established from a certain incidence of the solar species upon the Atmosphere, which brings refracted rays down to the earth. The third is plain, because the Sun illuminates all the stars existing above the horizon; and these, in turn, [shed(?) — the verb continues past the page break] onto the earth also the light received from the Sun, [themselves] shin-

[Margin: The Sun acts upon the earth always by a threefold ray: direct, refracted, reflected.]

they pour back [reflect] while the Sun shines. Nor is it any objection that we fail to see the reflected rays because the daylight blocks them; for the earth and terrestrial natures do sense those rays, even though they do not perceive them by sight.

Third statement. *The Sun's action is strongest when it takes place by a direct species [specie directa]; less strong when by a refracted species; and least of all when by a reflected one.*

[Margin: How great is the force of the Sun's actions?]

The first point is clear from this: that all rays fall without any hindrance onto the earth's surface. It is confirmed as well by the right sphere, in which the Sun at the meridian shines down from the zenith. [Margin: Proved first.]

The second is clear from the fact that solar rays, in passing through the atmosphere [Atmosphaera], are blunted by refraction — and the more so, the further they depart from perpendicular incidence, as is evident from the situation of the oblique and the parallel sphere, and likewise from the Sun's daily rising and setting. [Margin: Proved second.]

The third becomes clear from this: that the stars, which reflect the Sun's rays, send back very feeble species — because of their enormous distance and the apparent smallness of their bulk, and also because they absorb most of the light into themselves or scatter it elsewhere. This may be seen on any clear night, especially a moonless one. But all this is to be understood of illumination as it proceeds from the Sun and as that ray acts; for as to the power of a solar ray once received by a star, I do not now dispute, and so on. [Margin: Proved third.]

Fourth statement. *The whole Sun acts upon the illuminated hemisphere of the earth, but in different ways.* For it exercises its direct and refracted action from the hemisphere of its globe turned toward us; but its reflected action it exercises from the averted hemisphere, by which it illuminates the stars standing above the horizon, and they hurl back into the earth the sunlight they have absorbed. [Margin: The Sun's action upon the same hemisphere of the earth is varied.]

Corollary.

From this it follows that the earth's exposed hemisphere is illuminated by the whole Sun, and hence its hidden hemisphere too is illuminated even by day.

Fifth statement. *The Sun's hemisphere that appears to us acts upon the hidden and averted portion of the earth by reflection alone; and that part of the earth receives nothing from the Sun beyond this solar influence.* And it is proved thus. Since the earth is non-transparent [adiaphana], as I have supposed, and the Sun's rays travel in a straight line, the whole earth is therefore never looked upon at once by the whole Sun with direct rays. For all the rays from the averted side of the Sun are stretched out toward the heaven raised above us, while the refracted rays arise from those rays of the Sun which, from the Sun's opposite face, fall into the terrestrial atmosphere...

and these same rays never strike the averted region of the earth. It remains, then, that if any rays of the Sun are carried into the hidden part of the earth, they are rays reflected from the stars — rays which those stars received from the Sun's hemisphere that is exposed to us. For the rays that proceed from the hidden hemisphere fall upon the daytime stars, whereas the stars that receive the nighttime rays reflect them back onto the nighttime earth; and these set out from the region of the Sun that is shining upon the earth — as will be evident to anyone who considers it. Nor, in so clear a matter, is any other proof needed. [Margin: The varied manner of the Sun's acting upon the earth — where does it arise from?]

Corollary.

From this it is clear that the whole circuit of the earth is irradiated at once by the exposed hemisphere of the Sun turned toward the earth; but that by the Sun's entire circuit only so much of the earth is lit as is exposed and turned toward the Sun.

Sixth statement. *The varied power by which the Sun acts upon the surface of the terrestrial globe — a power it exercises upon the whole illuminated surface at once, not successively, in this present state of the world — does not arise on the Sun's part. It is not because the Sun, toward the outermost parts of the illuminated earth, emits rays that are fewer, or of themselves weaker, or otherwise configured; nor because, the earth being round, it is less able to receive those rays; nor because the Sun projects a longer cone to its point of contact with the earth, and to the parts near that contact, than to the place lying beneath the vertex. Rather, it is from this cause almost alone: that the atmosphere blunts the Sun's rays directed at the earth, not only by refraction but far more by their long passage, and so weakens them that, compared with the direct rays, they have very little strength.* [Margin: The statement is explained.]

That the earth is illuminated by the Sun all at once, so that the illuminated extent of the earth is a segment of the spherical surface larger than the part not illuminated — this follows from the fact that the Sun is larger than the earth, as everyone knows. That this same surface, bathed in the Sun's light, is illuminated unequally — most intensely at the center, most weakly at the edges, and in an intermediate way between the two — is agreed among all who are even moderately skilled in physical and mathematical matters, and can be seen from daily experience. For the light of the rising or setting Sun is the faintest of the whole day; the noon light the most intense; that of the middle times, intermediate. Likewise the Sun beneath the horizon is variously colored and

shaped, and is seen enlarged and diminished, differently than at midday. From this tempering of the solar light through its various positions, then, I hold that the Sun's power of acting is likewise to be reckoned commensurate. [?] [Margin: How one and the same radiant cone of the Sun affects the earth in different ways.]

In proportion to the solar light, then, I say that the solar power of acting is also to be measured. Hence, whoever wishes to know the cause of the varying activity must investigate the illumination and the other accidents; and this I now carry out through several members. Of these:

The first is: *That the Sun's varied power of acting upon the different parts of the illuminated earth does not arise from the Sun's failing on its own part in illuminating — that is, from its sending there rays fewer, or weaker, or formed and fixed in another way. Rather, I say that these rays behave in exactly the same manner everywhere, so far as it depends on the Sun.* [Margin: The varied mode of illumination causes the varied power of acting.] [Margin: The first member of the sixth statement is proved.]

To prove this, we must separate off in thought all the other things that can introduce any disparity, and conceive by imagination a single uniform transparent medium [diaphanum] between the Sun and the earth. Once this is posited, the truth of the statement is at once evident. For toward any assignable point of the illuminated earth there will terminate a cone of solar rays, similar and equal to every other; the base of this cone will be the Sun's surface itself, and its vertex the point marked out and illuminated on the earth. [Margin: Between the Sun and the earth a medium everywhere alike and uniform must be assumed, for the sake of what is to be proved.] The conical surface of the ray, from the assigned vertex on the earth, touches the Sun in a circle. And since as many such radiant cones can be had as there are assignable points on the illuminated earth, and since all of them are, to the senses, similar in figure and equal in magnitude and in illuminating power (or, as they say, in extension and intensity), and all are formed of purely direct, unrefracted rays, as is supposed — it is clear that the power of acting of each will be equal, because they will have rays equal in number, equal in magnitude, and alike in efficacy of acting. Since, then, the illumination of any terrestrial point is equal to the illumination of any other, it is clear that an equal effect must also be produced in each by the illumination. Therefore the disparity of acting does not, on this side, come from the Sun onto the earth — which is what was to be proved first.

The second member: *That the disparity of acting — or rather the inequality in receiving the solar power — must be dissociated from the earth [i.e. is not due to*

the earth's shape]. [?] [Margin: The second member of the sixth statement is proved.] For someone might imagine that this arises from the fact that the solar rays fall obliquely upon the round surface of the earth — since we everywhere find, in the case of things borne in straight motion, that if they strike straight against an opposing mass they hit more forcefully, and less forcefully if they graze it obliquely. And it is confirmed by the angle of rebound, which is made equal to the angle of impact — there is no doubt of this. But when the assault happens in such a way that it grazes the facing body lightly and obliquely, then the moving thing, with almost no hindrance, completes the course it has begun, without any perceptible change of its straightness, until it reaches the place it aims at. In the same way, then, the tending of light issuing from the Sun, since it is advanced by a rectilinear flux (as we have supposed), will, where it touches the earth, not be halted, but will proceed further without any deviation of direction — because the angle of contingency neither halts, nor breaks, nor drives back a rectilinear ray. Consequently, the Sun, at the point of contact or in the vicinity of contact, either does not illuminate the earth at all, or illuminates it in places near the contact less than in remote places and in those nearer to perpendicular illumination. [Margin: Whether the straight flux of light behaves toward the object to be illuminated as the straight motion of a moving body behaves toward an obstructing body?]

To this elegant piece of philosophy I answer: it is indeed true that the emanation of light is propagated along a straight line, and that perhaps some sinew of the argument would remain, if the earth were either transparent, or geometrically spherical and so clothed with a most polished and even surface. For thus the light, falling more directly, would penetrate into it more deeply and take root more thoroughly than around the edges. But in fact, since the earth is opaque and not mathematically spherical but uneven and rough; since light, moreover, is not a substance but an accident, and proceeds in a straight line not by local motion but by alteration, and is not itself something mobile but the term of motion or of illumination; and since, besides, we are here disputing about physical contact — I say that the terrestrial parts subject or near to the outermost illumination are for the most part illuminated no less by the bright cone of the Sun than the middle parts, provided we suppose a uniform medium. [Margin: The disparity between the illuminating light and the moving body with respect to their straight tendency.] For the solar cone falls upon the bodies set on the terrestrial surface at right angles; the rising or setting Sun, indeed, stands distant from the vertex of each place at which it rises or sets by a whole quadrant of the circle. The rays, therefore, of the rising or setting Sun — and hence the solar cone — are at right

angles to the vertical line of the said place. And because the mountains of the earth are raised along the vertical line, and plants likewise rise up...

toward the zenith of the place; men too and beasts stand perpendicular to the horizon, even though they are raised along the vertical line. So all these things are erected to the plane of the horizon, just as are the walls of towers, palaces, temples, and houses, and also the pyramids, columns, and colossi raised by the plumb-line, and likewise ships and ships' masts, and the sails hung from them, and so on. It is clear that their sides, turned toward the face of the rising or setting Sun, are illuminated by the Sun's rays directly, not obliquely. For the solar rays lie in the plane of the horizon, while the surfaces of the heights of those illuminated bodies stand in vertical planes. The Sun, therefore, whether rising or setting, if it shines through a single and purely transparent medium, will illuminate them most forcefully of all. A man, for example, here at Rome, standing in the open and receiving the rising or setting Sun, will find it just as bright, just as forceful — indeed more fervent — as he is accustomed to feel the noonday Sun itself in high summer. The reason is that the meridian Sun is oblique to an upright man in an oblique sphere, whereas the eastern or western Sun is always at right angles. Therefore, all else being equal — apart, of course, from the vaporous region of the sky — the one acts more here than the other. And thus the second member too is made clear: namely, that the Sun's unequal power in illuminating and quickening the earth — a power decreasing toward the lower and more remote parts — does not arise on account of the round configuration of that same earth as it is now constituted, and on account of the parts unfit, by their slope, to receive the light.

And it is confirmed, first, by the most manifest experiences of the Moon — new, half, and full alike. [Margin: What has been said is confirmed by an example drawn from the Moon.] For we see that in the new and waxing Moon, or conversely in the old and waning, the ridges of the lunar mountains, bathed in the sunlight, shine most brilliantly, even though the Sun touches them only with the outermost rays of its illumination; whereas in the full Moon we behold the edges as bright as the central fields. All of which would doubtless happen in the illumination of the earthly globe, if the solar cones fell upon it from the Sun through an everywhere-uniform medium.

It is confirmed, second, from the unequal position of the terrestrial surface and of its individual parts, as has been said; for this makes the Sun's ray find, as it were, always a direct incidence — and hence one most suited to acting — even in a sloping situation. And thus the second member stands proved.

For the better understanding of this, and to meet objections, it must be noted, first, that I do not deny that a solar ray falling upon a perfectly round and polished sphere acts more forcefully at direct incidence than at oblique; this is certain to everyone. I affirm only this: that this difference — even if the earth's globe were geometrically spherical and optically polished like a mirror — does not derive from the incident ray precisely considered in itself. For if we abstract from the point of incidence and from the reflected ray, all direct rays will be found of equal power. But whether the point of reflection, or the manner of reflecting, or finally the reflected ray, produces the difference of this operation — this I do not examine here; for in optics such matters are usually discussed. Hence:

It must be noted nonetheless, second, that the dullness in shining and the weakness in heating which the horizontal Sun now displays — even if in thought we suppose the earth mathematically smooth — does not on that account mean that the Sun would be brighter to the human eye; for the effect of the atmosphere does not depend on the incidence of the solar ray in any way whatever. Although in this case one must grant that the earth would have to be altered otherwise than it now is by the Sun's action, yet my question does not require this; for I press only this one point: that the obscurations of the horizontal Sun, which occur in this present state of the earth, are not due to the solar incidence. And to make this further evident:

It must be noted, third, that I prove this from the earth as it is now roughened, on account of the incidence at morning, noon, and evening being nearly alike. For the sea, though not indeed so rough, is nevertheless translucent, and so, by absorbing the oblique and lateral rays more deeply at the extremes than around the middle, can compensate much in the matter of light. Hence it is rightly said that, if — the earth being as it now is — we were to remove the atmosphere, the rising or setting Sun...

would be just as forceful as it now is at noon, wherever it might be. From which it is clear that those differences of the horizontal Sun are to be ascribed to the atmosphere alone, in the manner explained.

The third member was: *That the weakness of the solar rays and their unequal power of acting do not arise from the unequal length of the solar cones.* [Margin: The third member of the sixth statement is proved.] That this may be rightly understood, one must know that the whole apparent Sun sends to every point of the terrestrial surface facing it a single cone of illumination, whose base is the apparent circle of the Sun, and whose vertex is each illuminated point of the

earth. Since, then, the earth is a globe, it follows that the cones which come to a point at the more elevated points of the earth's surface are shorter than those which end at the lower points. For if from the Sun's center a ray is dropped to the center of the illuminated terrestrial surface — a ray through which an arc of a great circle on the earth's surface is understood to pass — and if other rays then descend from the Sun's center onto this greatest arc, that ray will be the shortest which lies between the Sun's center and the earth's diameter, [Margin: Euclid, Book 3, Proposition 8.] while of the others the nearer one will always be smaller than the more remote, and so on.

And since rays of this kind belonging to the solar cones I am discussing are the axes of those cones, it is certain that the cones are of unequal height, inasmuch as their axes measure unequal lengths among themselves. The longest cones will be those whose axes graze the earth, the shortest those which fall perpendicularly upon it; and the difference of the heights will, at most, be a little greater than the earth's semidiameter.

But that this discrepancy of heights or lengths contributes nothing at all to the present matter is clear from this: that the perigee Sun [perigaeus] is nearer the earth by 80 earth-radii than the apogee Sun [apogaeus]; and yet, if the height or lowness of the cones were sensible in making the Sun more or less effective, this would have to be felt most of all in the perigee and apogee positions of the Sun — which, however, does not happen. Since the winter Sun is nearer to us by 80 earth-radii than the summer Sun, and appears to the senses larger than in summer, and yet we do not perceptibly experience it to be more luminous or more active...

all else being equal. If, then, so great a difference of the radiant cones does not introduce a sensibly different activity of the Sun upon the earth, how much less will a single earth-radius [semidiameter terrae] do so — which in this business is plainly imperceptible? For since the perigee Sun is distant from the earth by 1101 semidiameters of that same earth, if we add or subtract one at this distance, who will perceive it by sense? Much less is a unit, against 1182, perceptible to sense — which is what happens with the apogee solar cones. And thus the third member too stands demonstrated: *namely, that the differing length of the solar cones falling upon the individual points of the earth does not cause any difference in the Sun's power to illuminate and alter the earth.*

Therefore there remains the fourth member, which was: *That the whole non-uniformity which the solar ray undergoes in illuminating the earth exists from the vaporous region alone — that is, from the atmosphere, which clothes the earth as*

with a delicate garment and so shields it from the darts of Phoebus [the Sun] that it variously blunts their more forceful impact, according as they come more or less obliquely, and according as the atmosphere itself proves denser or rarer, deeper or thinner. [Margin: The fourth member of the sixth statement, in which the whole cause of the diversity is thrown upon the atmosphere.] For it is most certain that the atmosphere is itself in perpetual variation as well. The solar rays, therefore, propagated through it onto the earth's surface, are both blunted and refracted in different ways — both of which effects I have discussed at length in my *Sol Ellipticus* and my *Refractiones Caelestes*. That these two effects — refraction, namely, and the dulling of light — are distinct from one another is clear from their distinct causes: for refraction follows the density or rarity of the transparent medium, which subsists without any necessary coloring or opacity; whereas the dulling of light draws its chief origin from opacity or coloring.

Hence, since both are found in the atmosphere — density, and an opacity quite notable from its inherent colors — it is no wonder that it exercises so much authority over the bright cone of the Sun, especially when an oblique position is added, which makes the solar ray, when near the horizon, pursue a long path in that atmosphere, and so lose very much of its light and vigor. Just as daily experience...

(Continuing Cap. IX, from the "quotidia-/quotidiana" catchword of the previous folio.)

as daily experience makes plain in the look of the rising and setting Sun — which the unaided eye endures without harm — whereas at midday it does not.

Now the effects we have discussed up to this point concerning the illuminated earth arise from the very nature of illumination, considering the Sun without local motion, at a fixed standstill; for they follow from this alone, that the Sun lights the earth through such a medium. From this it follows that, if the Sun were not carried around the earth, then in those places over whose zeniths it stood fixed and overhead there would be a most savage and scorching summer; in the more sloping regions, a milder temperateness; at the outermost edges of the illuminated tract, great cold; and in the regions of the earth opposite [the Sun], perpetual night and a most savage winter.

Whence Arise Several Doubts to Be Resolved [Vnde Nascvntvr Nonnvlla Resolvenda Dvbia]

Cap. X.

First Doubt [Dubium Primum]

If the Sun, the Moon, the other planets and the fixed stars stood still, would there be any atmosphere about the earth, and of what kind would it be?

That the atmosphere is stirred up out of terrestrial exhalations and watery vapors by the action of the Sun and the other heavenly bodies is agreed among the learned. It is likewise beyond doubt among them that this same atmosphere is variously changed and tempered by the revolutions of the Sun and the other stars.

If, then, the revolutions of both the Sun and the stars about the earth were to cease, it is rightly debated among the learned whether the atmosphere too would cease; or, if it did not stop, what sort it would then be.

To settle this question one must first note that the productive cause of the atmosphere is not the Sun's motion about the earth, taken precisely, but the Sun's power, which it exerts upon the earth through illumination — whereas the Sun's motion is that by which this power is carried about and variously applied now to one part of the earth, now to another.

[Margin: The Sun, though standing still, nevertheless shines.]

I answer, then, first: even if the Sun and the other heavenly bodies, whether fixed or wandering, stood still, the power of illuminating the earth — and, following from it, the power of acting — would nonetheless not be taken away from the Sun or from the standing stars; and consequently the atmosphere would still be produced through the drawing-up of vapors. We have an example of the Sun standing still and yet shining in Holy Scripture.

I answer, secondly: that this atmosphere, produced while the Sun stood still, would be very unlike the one that now exists, because of the unlike application of the producing cause. For the Sun, resting perpendicularly over the part of the earth set directly beneath it, would act most vehemently; toward the flanks, more weakly; but upon the night side only indirectly, by rays reflected from the stars — that is, with the feeblest light and heat. From all this it is easy to judge that the

constitution of the atmosphere would be irregular beyond measure, and very unlike the one that now is.

Whether this same atmosphere would, in this irregularity of its, ever come to be quiet and stable, I leave partly to be thrashed out by the philosophers, and partly trust will be understood, so far as may be, from what is to be said.

Second Doubt [Dubium Secundum]

Whether, and how, with the Sun and the Moon (etc.) standing still, the Sun would nonetheless — through the motions proper to this Phenomenon — perpetuate and direct the vicissitudes of generation and corruption?

A philosophy has been received among many that nothing happens in this sublunary world without the universal concurrence and influence of the mobile Sun; whence they generally conclude that, with the Sun standing still, actions and the productions of things would in some manner cease.

But this opinion — once the Phenomenon itself teaches that even the standing Sun is revolved about its own center and variously altered — must grant that the power of that same Sun, even at a standstill, is repeatedly changed over the whole globe of the earth; and hence it is not clear that generation would cease altogether.

This much seems certain: that were the Sun to stand still, the governance of this earthly world would prove far

otherwise, and in a turbulent state; nor would the globe of the earth be everywhere habitable, as we now find it — and this because of the absence of the Sun, which is beneficial and quickens and preserves all things.

From these matters the bountiful goodness of divine providence has shone forth, in that it assigned to this heavenly body [the Sun] the daily motion of longitude and the yearly motion of latitude, together with its eccentric [motion]; for thus the atmosphere is arranged into an even moderation and a temperateness suited to human uses; thus we have the vicissitudes of the seasons — of Winter and Summer, of Autumn and Spring; thus we pass through the courses of years, of months, of weeks, and also of days — the vicissitudes and diversities of which one and the same Sun brings about by its presence and its absence.

The Sun's power, therefore, is imparted to the earthly globe by divine providence through the local motion, daily and yearly, which is the bearer of that power.

Next, [it is imparted] through the Moon [revolving] about the earth, and the planets turned about the Sun as their center, which pour back upon the earth the rays they have received from the Sun.

And since their bodies drink in the Sun's radiance not merely superficially but bodily into themselves, and tinge it with their own native property, they therefore send it back to the earth far otherwise affected.

[Margin: The differing colors of the stars are not from the Sun.]

That this tincture is indeed so is plain from their very differently colored lights; and that this variety of colors is not from the Sun's light is established thus: if [the colors] came from the Sun, all the planets would be steeped in a similar color at the same time, and if the color of one changed, the same would happen to all. By like reasoning it is plain that their colors do not come from the medium either, because each keeps its own tinctures in every place, position, and time. Hence one must wholly admit that the Sun's incoming light is dyed by the colors innate in [the stars], and thence reverberated to the earth together with their qualities, and so is affected in that same diverse manner.

This influence of theirs upon the earth varies with their approach and their withdrawal — both toward the Sun and toward the earth — and also with varying position.

For just as the radiant cones of the Sun itself are variously dulled by the intervening atmosphere, so there is no doubt that the rays of any planet, once they have reached the earth, are affected differently and differently according as their passage through it [the atmosphere] is direct or oblique.

For that a planet near the horizon shines more dully than one close to the point directly overhead [Vertex], daily experience confirms; and the sole cause of this difference is the atmosphere. Through it a planet near the zenith transmits its ray more directly, and therefore over a shorter space, more vigorous; whereas from the horizon, because of its slanting passage across, [the planet] loses much of the liveliness of its light. This the very twinkling of the stars most plainly shows: for near the point overhead it is calm, but near the horizon very restless. Why? Because more vapors come between toward the horizon, fewer toward the zenith. These alone produce the trembling that appears in the stars, by the interruption of the stellar radiations.

The fixed stars, too, modify the Sun's rays that they receive according to the condition of their own nature, and, pouring them back, impart their own powers

to the earthly body. For all the light they render to the earth they owe to the Sun; yet they send it back not like a clean and polished mirror, but as the Moon does, as Venus, as other pitted bodies illuminated by the Sun. And so it is clear that all heavenly light — imparted in whatever manner, at last, to the whole earthly world out of the entire universe — is solar: either immediate, from the Sun itself, or mediate, through the stars. And this [mediate light], though in respect of light much feebler than the other, yet in respect of active power carries off with it, it seems fairly certain, something peculiar of its own, drawn from the star's property. And from this some wellspring of the heavenly influences flows.

[Margin: All light fallen from heaven to the earth comes from the Sun alone.]

For the rest, most of what has been said so far commends the admirable order and wisdom of the divine disposition, [drawn] from the things concerning the Sun and its motions that have been learned and taught by astronomers; yet from these the full governance of the mundane world is not sufficiently recognized —

because these motions are not proper to the solar body but accidental to it, whereas our Phenomenon teaches [that there are] other motions, connate to the solar globe from its first foundation.

The Sun's Rotation [*Solis Gyratio*]

The first motion is local: by it the Sun completes one revolution about its own center roughly every twenty-seven days. By the benefit of this turning it pours out, most abundantly and in succession, whatever light and whatever radiant power it holds — onto the earth, onto the whole heaven, and so onto each of the stars. That this circuit of the Sun was implanted in it by the Creator especially for the earth's sake seems clear from the following: the motion is not simple but compound, arising from the annual carrying-around of a movable axis about which the prior motion is traced. Hence it comes about that the Sun — about its northern summit and its southern dip — nods toward the earth for six months and turns away from it for the other six, with an alternating appearance of the poles and movable axes above the solar horizon and their concealment below it, as has been shown well enough from the observed phenomenon throughout, and in particular in the *Theoria*.

[Margin: The local motion, proper to the Sun and newly discovered, is the origin of the changes in things below.]

That this dizzying libration of the Sun, achieved by means of the little polar circles, is also for the benefit of the terrestrial mass, I think will scarcely be

disputed among experts. For if we divide the three hundred sixty days of one year by 27, we find that the solar sweeps over the whole universe will number thirteen and a half in a single year. And since on this account the earth's surface will always be irrigated with one solar light after another, so too it will without doubt be steeped in one solar power after another.

[Margin: In one year the Sun revolves about its own center thirteen times.]

Should anyone maintain that this motion was assigned to the Sun by God its Author chiefly for the Sun's own preservation, and is in a manner natural to it, I nonetheless tug his ear and remind him that the Sun itself was made also for the sake of the earth — to light it, to quicken it, and as it were to animate it. From which it follows that whatever exists for the Sun's sake exists also for the earth's; and from this the marvelous excellence of this Phenomenon emerges.

Divine providence could indeed easily preserve the Sun without this rotation of its; yet it cannot turn its direct rays, and the immediate power of the averted solar hemisphere, toward us without such a motion.

The Motion with respect to Quantity [*Motus ad Quantitatem*]

The second motion of the Sun — or rather of the solar Phenomenon — is increase and decrease; indeed, the appearances and disappearances of new spots [*Maculae*], umbrae, and faculae, together with the perpetual variations of their figures, and their mutual conjunctions and separations. Who does not see that by these things the aspect of the Sun is incredibly varied? And if Astrologers and natural philosophers [*Physici*] attribute so much to the aspects and conjunctions of the planets and to the eclipses of the Moon and Sun, what then is it fitting to think of this Phenomenon — by whose working the Sun sometimes undergoes at once fifty or sixty eclipses of its more notable spots? Spots that often equal the Moon in size, and sometimes surpass it. What shall we say of the perpetual dispersion of secondary spots over the whole Sun? Or of the fact that the greatest part of the Sun is quite often lit up with brilliant faculae — and those the largest, exceeding the hemispherical surface of the earth? And finally that often, even without these, the Sun shines forth with an even and placid face? Surely reason and true philosophy teach that these things act upon the earth in diverse ways and produce dissimilar effects. For they vary the Sun's very light — they impede or promote it, they increase or diminish it.

[Margin: The motion of quantity that is found in the Sun changes things below.]

The Motion of Alteration [*Motus Alterationis*]

The third motion is the continual alteration of the solar surface, as spots, umbrae, and faculae are transmuted into one another by mutual actions — and this over practically the whole visible surface of the solar globe. Since the Sun's chief action upon the earth flows out from that surface, it is clear that, as the surface is continually changed, the solar influx upon the lands and upon the sublunary world is likewise continually changed.

[Margin: The motion of alteration observed in the Sun has great power over sublunary things.]

From these three perennial wellsprings of the solar Phenomenon, then, let it be briefly indicated — rather than fully stated — that the inscrutable wisdom of the divine Majesty in governing this earthly world can to some degree be drawn out. Every wise man will dig out for himself here the material for a fuller and truer speculation. For me it is enough to open the door and to show the way by which, from this Phenomenon, the Lover of Truth may enter into the wonderful treasures of eternal Providence and contemplate them. For I judge it better to leave the more numerous and more excellent matters to be examined and ruminated upon by sharper minds, than to wear down the magnificent works of the most wise Creator with my empty words rather than to celebrate them with the praises they deserve, as befits the dignity of His Majesty. From the praise of God, then, insinuated by these appearances, I betake myself to the springs of truth — some already open, some yet to be opened; and this itself affords no small support toward the amplifying of God's glory.

[Margin: The zeal for attaining and uncovering truth is what wove together these studies.]

Cap. XI.

From the Solar Phenomenon, Truth is laid open and Falsehood vanishes [*Ex Phaenomeno Solari, Veritas patescit, evanescit Falsitas*].

I frankly confess this: that — after the greater glory of God, thrice best and greatest, which above all else I have always kept before my eyes in bringing this Phenomenon to light, and which has held me fixed to it through so many years now of such relentless and stubborn labor — my one aim was the purest and most sincere zeal for finding the Truth, and, if it should one day please God and my Superiors, for making public, for the common good, what I had found. This zeal blazed the more in my mind the more I saw others committing vanities, in

truly unworthy ways, about this same most sublime Phenomenon. For although even then, from the observations begun and continued at Ingolstadt by me and my pupils, I was for my own part quite certain of most of the things I here set down — whether in general or in particular — the interruptions that kept intervening had prevented me, as the matter required, from making the necessary arrangements of the observations needed to prove solidly the things I had come to know were present in the Phenomenon; while from another quarter the fabrications of many who handle this Phenomenon badly were coming out. At last I counted it a matter of conscience to dissemble any longer, and to bear with an even mind that so great a matter should be treated so ruinously, and that Truth should be left to be most unworthily trodden down by Falsehood.

Deprived, moreover, of resources long since made ready — and relying on no probable hope of securely recovering them, given the great distance of the places and the injury of time — I brought my mind to forge fresh supplies by observing anew, from which to draw up my battle line; and to these I opportunely joined suitable reinforcements gathered from friends elsewhere. Once these had, with the utmost labor, study, and candor, been marshalled into the order and apparent course set out in the previous book, I have at last brought forth the following Truths for the true Lovers of Wisdom.

[Margin: Suitable resources — of what kind, and from where obtained?]

From the Solar Phenomenon: Truths for Astronomy [*Ex Phaenomeno Solari, Veritates pro Astronomia*]

The astronomer, on Ptolemy's testimony (*Almagest* I.1), considers the Quantity of the heavenly bodies — namely that quantity which Aristotle himself expounds in the *Categories* [*Praedicamentum*], and which he teaches in his physical works to be considered by both the natural philosopher and the mathematician, though in different ways — together with the things annexed to it. His entry upon their investigation he ordinarily prepares for himself through the observed apparent Motion, since other infallible means are usually wanting. Now the apparent Motion of this Phenomenon, accurately observed and duly ordered, I set forth in the whole of the previous book. In the present book, however, from the qualities of the Apparent Motion weighed with right judgment, you have — drawn out and made firm — the True place of the spots and faculae; their true Motion; their visual Magnitudes, figures, durations, increases, and decreases; and the appearances of their light and, no less, of their colors, both true and deceptive, and so forth. And so let this stand:

The First Astronomical Truth: the true place in the heaven of the solar spots and faculae — both the primary and the secondary — is the very luminous and physical surface of the Sun. This Truth has been proved at length in the first part of this Book.

[Margin: The true location of the spots is on the surface of the Sun.]

From this Truth it becomes plain — and the vanity of the following goes up in smoke: of those who located this Phenomenon in the air below the Moon; of those who, outside the Sun, packed it into hard orbs or spheres of its own; and of those who shut it up, as in a perpetual prison, between the Sun and another luminous sphere thrown around the Sun which nevertheless would not exceed the visible body of the Sun itself.

[Margin: The motion of the spots is composite.]

Second Astronomical Truth. The true motion of the solar spots and faculae, as traced on the surface of the Sun, is not circular or simple, but compounded of two circular motions—in the manner of a certain quadratrix line, or a spiral bend—not deviating much from an elliptical curvature.

Of the simple motions into which it resolves, one is the annual circular motion: about the fixed axis on the poles of the solar ecliptic, perpendicular to the plane of the solar circle, running from west to east across the exposed half of the Sun and from east to west across the hidden half. The other runs from east to west, about a movable axis and movable poles, always oblique to the ecliptic; and it completes its course within about 27 days, more or less, as it is now compounded with the annual motion. Were it to revolve on its own, without this, it would finish that much sooner—by as much as the annual motion, running counter to it, subtracts over the 27 days, which appears to exceed the arc of two days. So this simple motion, if it stood alone, would perhaps not much exceed 24 days. If its axis lay in the plane of the ecliptic it would always be rectilinear; if outside that plane, always curvilinear; and even so it would never be parallel to the ecliptic. All this has been proved in the *Theoria*, and here and there in the earlier parts.

From this Truth, as from a most abundant spring, very many others gush forth—some touched on elsewhere, some left for the ingenious reader to dig out for himself. Hence the error becomes plain of those who confined this motion within an interval of three or four days, or stretched it out to 29 days or more, or finally made it always rectilinear, always parallel to the ecliptic, and alike or equal in every spot. Anyone who has examined the Censor's *History of the solar spots* [Galileo, *Istoria e Dimostrazioni intorno alle Macchie Solari*] and my own first

Book will see clearly enough that the Censor of Apelles [Galileo] is liable to these errors.

[Margin: The Sun rotates about its own center.]

Third Truth. The Sun, by the same motions as the spots and faculae, revolves about its own proper center. This Truth has hitherto been unknown to most, doubtful to many, asserted rather than solidly proved by some, and finally denied by most.

But now the location and the true motion of the solar phenomenon prove this same thing more plainly than the Sun itself. For the whole solar phenomenon is the Sun's own apparent physical surface; but that phenomenon moves around the Sun's center; therefore the physical surface of the Sun also moves around that same center. And if the physical surface of the Sun is turned round, the Sun itself must necessarily be turned round too. Therefore.

Hence it is plain that all the other motions which were hitherto thought to be the Sun's own are merely accidental to it, and so forth. It is plain, moreover, that it is *not* true that several motions cannot belong to one body at once; nor that from a plurality of celestial motions a plurality of moving bodies must be inferred; nor that from a single star's differing observed motion a distinction of separate heavens must necessarily be concluded; nor that circular motion is owed only to a simple body revolving about the earth as its center; nor that the stars must be supposed immovably fixed in their spheres—and so on.

Hence too a very strong conjecture is drawn: that the sphere of the solar body itself is turned about its center, by its own simple motion, in precisely twenty-four days—a truly elegant harmony, in that just as the Sun in one natural day and one revolution about the earth spends 24 hours, so in one natural revolution about its own center it uses up 24 natural days. That the spots and faculae do not exactly attain this number can be ascribed, among the other causes touched on elsewhere, to their own particular constitution and resistance, as we constantly find in natural things, and so forth.

[Margin: The Sun is spherically round.]

Fourth Truth. The Sun is spherically globular. This follows from the preceding: for if it rotates and always appears circular, it is necessarily spherical. This Truth has hitherto been held by everyone as beyond doubt, yet—so far as I know—has been sufficiently proved by no one. But from this phenomenon, as is clear in Book Three and was said a little earlier, it is sufficiently established.

[Margin: The surface size of certain spots perhaps equals the terrestrial hemisphere.]

Fifth Truth. From the assumed or foreknown size of the solar disc, it is shown with certainty that many spots—in their surface extent, when turned toward us at the middle of the Sun—are not smaller than the Moon; indeed larger; and that some perhaps rival the hemispherical surface of the earth. And there is no doubt that this hemispherical measure is often exceeded by many bright primary faculae and by secondary spots and faculae.

But whether, and how far, the depth of each of them extends inward toward the center of the Sun, is not yet clearly settled for me.

[Margin: The spots do not rotate about their own centers.]

Sixth Truth. A perpetual variety of shapes and sizes occurs, both in the spots and in the faculae. The spots and faculae, however, do not rotate about their own centers. All this has already been demonstrated most fully and clearly in the preceding parts, and needs no more attention than the reading of my own writings or the eyewitness inspection of one's own observations.

[Margin: The surface of the Sun is gently ruffled.]

Seventh Truth. The apparent surface of the Sun is not geometrically even, nor optically smooth or polished, but astronomically spherical—like a heaving sea, and rugged with mountains and valleys like the earth and the Moon. This Truth is obvious to anyone from what has so far been adduced and argued about the surface of the Sun.

[Margin: Sarsi. Clavius.]

With this Sarsi concurs, in his *Libra Astronomica ac Philosophica* [Lothario Sarsi = Orazio Grassi, *Libra astronomica ac philosophica*, 1619], p. 45; and, concerning the Moon, Clavius in his commentary *on the Sphere* [*In Sphaeram Ioannis de Sacro Bosco*], vol. 3, p. 75, who says that "he cannot sufficiently marvel that such great irregularities exist in the lunar body."

Eighth [Truth]. There is no force of the Sun that, by its rotation, drives the other planets around in their circuit—because their revolutions run in contrary directions and are not performed in proportional times.

Some, therefore, waste both their oil and their labor in trying to explain these things; for they are false, and contrary to the truth of this phenomenon.

From the Solar Phenomenon: Truths Bearing on Astrology

The astrologer, from the celestial motions and from the stars' varying relation, situation, and aspect toward the Sun—among which the conjunctions are reckoned the most important—predicts, among other things, various effects and the future outcomes of sublunary affairs, and so on. But how truly and how well he does so is shown by this single solar phenomenon alone.

From this, although by going through them one by one I could bring forward manifold Truths, yet, because I am sparing of time, aim at brevity, and leave much to the talent and shrewdness of the studious reader, I here put forward, in place of all the rest, only one Truth, namely:

[Margin: Judicial astrology is refuted by this phenomenon.]

From this solar phenomenon the vanity of judicial astrology is most clearly exposed. For since a perpetual variation of the Sun arises from this phenomenon, all the influences of the stars must likewise be altered. The condition of the atmosphere, too—which they treat little or not at all—utterly demolishes their trifling foundations, arbitrarily deduced from the aspects and dignities of the planets.

Hear how learnedly Ottavio Farnese [Octavius Farnesius] argues on this matter, in his *Philosophical Questions*, Book 2, *On Natural Philosophy*, chapter 13, page 117, in the numbers (or theses) 756, 757, and 758:

"There is," he says, "some indirect action of the heavens upon a man, insofar as his bodily organs are in better or worse condition; but there is no direct action upon the soul itself. That diviner, then, called Astrology is a liar; and the casters of nativities are deservedly driven out from the company of mortals—men who profess to divine future contingents from the course and situation of the stars, which they cannot know. They are dreams that read off future events in the arrangement of the stars, as if in a composition of the elements; and it is no wonder if, when they have told many lies, something true occasionally comes to pass—just as it happens by chance that something true issues from the portents of dreams. It has been believed until now that these very diviners could easily note under what star and under what celestial state each person was conceived, and under what horoscope born, and it was even granted them to draw from this a conjecture about a person's bodily habit and complexion. But how uncertain must these very things now be judged to be, now that stars have been added by means of new instruments, and now that so many spots have been detected on

the Sun, wandering through that immense field of light under no fixed law that could hitherto be observed?"

Thus far he—and rightly indeed. For if to the ecliptic nodes—to the Head, I mean, and the Tail of the Dragon—and indeed to lunar and solar eclipses they attribute a great power and prerogative, buttressed (as they say) by the experience of the ancients, then surely they would defer far more to the more conspicuous of the solar spots. For:

these spots too eclipse the Sun; and although they do not hide so great a portion of it from our sight, they nonetheless bring that eclipse to the whole world—something the Moon never does. Furthermore, the interposition of any given spot between us and the Sun does not last a mere three or four hours, but usually many days. But just as the generations of the spots and faculae cannot be foreknown, so neither can any special operations and influxes of the Sun be foretold from them.

Gnomonic and Cosmographical Truths, to be Drawn Out from this Solar Phenomenon

[Margin: The visual magnitude of the Sun and of the remaining planets is obtained.]

First. The visual magnitude of the Sun—a matter of the highest importance among astronomers—can be obtained by the method of observing this phenomenon, as I have taught more than sufficiently, from the Sun admitted through a bare aperture and likewise transmitted through a tube.

And although I have not determined in particular how great the Sun's visual diameter is, I nevertheless hold it beyond doubt—from the experiments and arguments I have produced—that it is much greater than the value Tycho Brahe [printed *Tycho Prahe*] or others assign. Yet I shall not be reluctant to hear the judgments of experts on this matter. Once, before me, Johannes Kepler [*Ioannes Keplerus*] had set out on a not dissimilar path in his *Paralipomena*, in investigating the visual magnitude of each luminary; but, deterred by the excess of it, he abandoned and rejected those less-trodden ways as suspect—more rashly than cautiously.

I still keep to those ways, because I do not yet detect any fallacy in them. I praise the Tychonic reed [sighting-rod, *arundo*], but I am ready to bring forward clear reasons why it presented the Sun as smaller than it should.

Given this truth, then, several others will follow, and varied ones at that. Namely: the earth, compared with the Sun, is far smaller; the Sun, measured against the earth, is much larger. Likewise Venus, in relation to the Sun, will stand differently in magnitude than many suppose, for it will be increased. For suppose, by way of example, that Venus's visual diameter to the Sun's visual diameter is found to be as 1 to 30; if we now

assign the solar diameter an absolute 30 minutes, it is certain that Venus's absolute diameter will be one minute; but if we attribute to the Sun's absolute diameter 45 minutes, it is certain that Venus's diameter will come to one minute and a half. And thus what I asserted is plain—and I mean the same to be said of the other planets. For since their visual proportion to the Sun is fixed, if the Sun is found larger than supposed, it is only fair that the planets themselves grow too.

And by the same reasoning the solar spots and faculae will far exceed the magnitude assigned to them—the magnitude that follows from the Tychonic hypotheses.

Secondly. The visual magnitude of the luminaries, compared with one another, is obtained if, under the same aperture of the tube, the Moon is recorded just as the Sun is admitted. And the larger planets, too, can sometimes be acquired in a like manner. This practice and truth is of the greatest importance: for from it will be known with certainty whether, when, how, and by how much the full Moon exceeds, in visual diameter, both the new Moon and the Sun itself; and not a few astronomical controversies will be settled. For the telescope [*Telioscopium*] does not deceive in this respect, as regards the diameter measured lengthwise, which in any position of the sky does not vary within a single day—even though the luminaries, from their differing elevation above the horizon, do vary the altitude-diameter on account of refraction.

Thirdly. On the occasion of this phenomenon, the refraction of telescopic lenses, with respect to the Sun or to the shining Moon, is obtained in this way. Through a given convex lens, transmit the Sun onto a paper duly set in place, and carefully mark the size of the solar circle. Then, with everything left unchanged, remove the lens and in its place insert a thin plate of paper, wood, or metal pierced with a narrow hole; note the size of the Sun that has entered through it and fallen onto the paper. The shortfall, then, of this solar circle from the former one will reveal the lens's refraction, in the diameters of the circles. I said "with respect to the Sun or the Moon" because the notably varied distances of the celestial objects also vary the amount of the refraction.

In exactly the same way you will estimate the refraction of two lenses combined in a tube. For always, in the place which

the lens that had directly faced the Sun occupied, the plate is put—opened with a single small hole, with all the lenses removed—and so forth. In the same way the force of refraction will be taken from terrestrial objects placed nearby, and so on.

I said that the hole made in the plate ought to be small; and this is done so that the Sun's native magnitude may be shown without deception. But if you wish to apply a convex lens to that same hole and to explore the Sun's magnitude enlarged by refraction, you can certainly do so; for a larger hole will give, through the glass, an image not appreciably larger but clearer, as I have often said elsewhere, and so forth.

[Margin: The construction of [solar] clocks is less convenient.]

Fourthly. If a large observing circle is taken, and throughout the whole day the spots are observed on a chart kept unmoved against one and the same plumb-line, each spot will trace, as it were, its own diurnal arc about the center of the observing circle. By their aid there is no doubt that telescopic clocks could be made, in which the individual spots would mark the hours of the day by their passage. Yet because throughout the whole summer, from Aries to Libra, the stations and retrogressions of the spots disturb the continuous progression of their course, I have left this labor itself—otherwise a truly beautiful one—unfinished. I wished nonetheless to hint at it, since during the winter half-year at least there is a continuous progression of the spots, without any interruption by retrogression.

[Margin: The approach and recession of the Sun.]

Fifthly. The Sun's approach to the earth, and its recession from it, is also obtained, and that in two ways. The first, if the observing circle on the paper is always kept the same: for then, when the Sun is at apogee the tube must be shortened, which yields the Sun's greater distance; when it is at perigee the tube must be drawn out, which proves the Sun nearer. This is because nearer objects require the same tube longer, more distant ones shorter. The second, if the tube's aperture and its distance from the paper are kept the same: for then the Sun at apogee casts a smaller circle onto it, and at perigee a larger one; and the larger plainly proves the Sun nearer, the smaller farther.

[Margin: The longitudes of places can be found fairly easily.]

Fifthly. This phenomenon brings the very greatest importance to Geography: for by its benefit the longitudes of places

over the whole globe can be acquired with certainty and—in my judgment at least—easily and quickly. This is done if, in different parts of the world, different astronomers observe some one and the same spot passing through the center of the observing circle, or cutting the ecliptic, or [reaching] the midpoint of its course, or the like—as they shall have agreed among themselves, and so on. For thus, from the difference of times, they will obtain the longitudes of the places. But I run through these matters briefly here. There will be a time when, God granting, I shall unfold the same more fully and more exactly.

Toward a Celestial Physiology, Very Many Truths are Opened Up from the Solar Phenomenon

Cap. XII.

In matters of natural science, concerning the things that happen in the heavens, very much is unknown; few things are known for certain; most are doubtful; many falsehoods are asserted; very many truths are denied. And no wonder: for God and nature have entangled these lofty matters in so many difficulties that a sure access to understanding them scarcely lies open to human wit—so all the ways have hitherto been walled off by the immense interval of the distances. For it comes about from this that, apart from the bright globes of the stars and a few occasional eclipses of the luminaries, we perceived almost nothing at all in the heavens.

But now, with the telescope [*Telioscopium*] invented and its use laid open, we are permitted to approach more nearly those ethereal regions and divine halls, to enter the very Palace of the Sun—until now inaccessible—and thence not only to gaze upon the hidden treasures of celestial philosophy, now unlocked, but even to carry them off, and to bring to the whole terrestrial world the Truth so long hidden from it.

Whoever earnestly longs to investigate and embrace that Truth with an open mind will, under the guidance of this phenomenon, attain it in many respects most plainly and without any obstacle. I myself, at the request of many, merely point a finger, and briefly pursue a few chief heads of the matter.

Rosa Ursina, Book IV — Part II (the *Theoria*)

Chapter XII (continued)

Physical truths made manifest through this phenomenon from the proper motion of the Sun [*Ex motu Solis proprio per hoc Phaenomenon patefacto, Veritates Physicae*]

In natural philosophy one may ask:

First, whether the stars of heaven (among which the luminaries too are reckoned) are fixed in celestial orbs, like a knot in a plank or a nail in a wheel. **Second**, whether from the motion of the stars the multitude or the simplicity of the heavens is rightly inferred. **Third**, whether the motion of the solar heaven around the earth belongs to that heaven as its own, or rather comes from elsewhere. **Fourth**, whether the motion of the Sun, which by hypothesis it shares from its own heaven — whether the daily motion from east to west, or the yearly one from west to east — belongs to the solar globe of itself, or from elsewhere. **Fifth**, whether the motion that some spot or facula on the Sun, and together with the Sun, describes around the Sun's center — whether from the solar east to west, or from that same west to that same east — belongs to the spot or facula of itself, or from elsewhere. **Sixth**, whether the motion of the Sun about its own center is the Sun's own, and not communicated from some other orb. **Seventh**, whether the motion of a spot, both of increase and of deviation (as sometimes happens), is the spot's own and belongs to the Sun only accidentally. **Eighth**, whether the local motion of the celestial bodies that the astronomer considers is the same one that the natural philosopher [*Physicus*] investigates and examines. **Ninth**, whether several diverse motions can be present at once in one and the same celestial movable body. **Tenth**, whether the Sun's motion around the earth is simple. **Eleventh**, whether, if the whole heaven of the Sun were such a body as the Sun is, and moved homocentrically around the earth, a motion of this kind would be simple. **Twelfth**, whether from a simple motion of this kind, once granted, around the earth, the simplicity of the movable body would be effectively inferred. **Thirteenth**, whether, granting (though not conceding) a homocentric motion of the Sun around the earth, the simplicity of the solar globe would thence be inferred. **Fourteenth**, whether the motion of the whole solar heaven, homocentric with the earth, belongs to it of itself or from another. **Fifteenth**, whether from that motion the simplicity of that heaven rightly and necessarily follows. **Sixteenth**, whether, if either of the two motions of the solar globe were brought to a halt, the other would be simple. **Seventeenth**, whether this mixed

motion of the Sun is for the sake of the Sun itself, or of the earth, or of the good of the universe. **Eighteenth**, whether this motion of the Sun is natural to the Sun, or violent, or contrary to nature [*praeter naturam*]. **Nineteenth**, what its principle is, or who is its mover. **Twentieth**, who moves the spots, faculae, and umbrae, and so on.

These and similar questions are raised within celestial physics on the occasion of this phenomenon. Whoever wishes to answer them all truly and solidly, without deceit and trickery, will run back to the Sun, and thence will draw out better responses than those the Delphic tripod would give from Apollo himself. As for setting these out one by one, I now prudently forbear, lest I should seem to others to want to snatch away all the material for disputation about this matter. I am content with this one point of knowledge: that these questions, raised from the newly discovered and adduced motion of the Sun, can be excellently decided; and that this motion is so proper to the Sun that it is shared by no other part of the solar heaven, neither of itself nor accidentally. For around the center of the Sun the heaven of the Sun rotates neither wholly nor in part; rather, the Sun alone, with its spots and faculae, wheels about that center.

These things, however, I now touch on only briefly — for the wise, a few words suffice. And if I perceive that they find favor, they will add spirit and a spur to bring out more.

[Margin: The decision of these and similar physical questions, raised from this solar phenomenon, is deferred to the natural philosophers.]

Physical truths known from the variety and variability of the solar surface through the spots and faculae [*Ex solaris superficiei Varietate et Variabilitate per Mac. et Faculas cognita Veritates Physicae*]

Again, in natural philosophy it is customary to ask:

1. Whether the heaven and the stars set within the heaven consist of matter.
2. Whether that matter of which the stars consist is of the same kind as the matter of the heaven.
3. Whether the matter of the stars is, for all of them, of the same kind.
4. Whether the matter of the celestial bodies is of the same kind as elementary matter.
5. Whether all the stars are simple bodies.
6. Whether the Sun is a homogeneous or a heterogeneous body.
7. Whether the Sun has anything mixed in it.
8. Whether celestial matter is ingenerable and incorruptible.
9. Whether in those ethereal regions any changes occur, in their qualities and substances.
10. Whether — and what — colors are in

the Sun. 11. What the light in the Sun is like: pure or mixed? equally intense everywhere, or unequally? whether it is in the Sun's outermost surface only, or in the Sun's depth? 12. What the Sun's surface is like: even or pitted? stable or fluctuating? polished or rough?

All these and similar questions are resolved from the very phenomenon of the Sun.

For it is the Sun itself that, for dispelling the shadows of errors and for spreading abroad the light of truth, holds up not one torch but countless ones, and not once but always; and lest perhaps someone go blind, when the others are extinguished it kindles new ones again and again. There is therefore no other task than to open one's eyes and to admit the shining brightness of Truth. And if the Sun is not exempt from the common law of vicissitudes, we must not reckon the heaven itself, nor the remaining stars, to be any better than the Sun.

Truths for Sacred Scripture and Theology [*Veritates pro Sacra Scriptura, et Theologia*]

Although it is certain that in doubtful matters the natural sciences ought rather to accommodate themselves to the common sense of Scripture and of the theologians, nevertheless this too is admitted by all: that those points which are controverted either in Scripture or among theologians concerning matters of nature — if some natural evidence comes to bear — one may stand by, on behalf of that same Theology as much as of Sacred Scripture. For we know that neither Sacred Scripture nor Theology ever pronounces against the truths of nature. Therefore, since from this phenomenon very many natural truths about the Sun and the celestial bodies have already been drawn out — and more are to be drawn out in the future — I judge that, with the help of this phenomenon, not a few questions debated among the sacred writers concerning the first chapter of Genesis, on the creation of Light and of the Sun, can be sufficiently clarified. This, in its own time, God granting, will perhaps be shown more fully; for now I have thought it enough to mark the source itself from afar and to salute it at a distance — especially since, as the Work proceeds and as opportunity of time is offered, many things may be explained more copiously.

PHÆNOMENI SOLARIS UTILITATES — The Utilities of the Solar Phenomenon. CHAPTER XIII.

I do not pursue the benefits to the nature of the universe that flow from this phenomenon: for whatever pleasant thing, whatever useful thing we have, feel,

and enjoy in this world proceeds from this phenomenon — from the solar faculae, I say. Take the faculae away from the Sun, and you have brought darkness upon the whole world. But these things I do not now examine, since they are found scattered among the matters I explained above.

Now I shall briefly touch on what benefit, beyond what has been said, results to learning or to human use from the knowledge of this phenomenon. And indeed the first and greatest utility for the man of letters is to be freed from error, stripped of the shadows of ignorance, and not circumvented by false opinions; for the first method of attaining the truth is to know what is false and to enter upon the straight path, not swerving into byways. In what obscurities, moreover, and in what clashings of opinions the physiology of celestial things has until now been engaged, all the books of approved authors declare. Much, therefore, do we owe to this phenomenon, which by its spots banishes from our understanding the night of ignorance, and by the benefit of its faculae brings in the day of Truth.

[Margin: The first utility of the solar phenomenon: the dispelling of ignorance.]

For the next thing that follows upon the error once recognized is the clear apprehension of Truth itself in our minds; suffused by whose illumination, the human mind makes wondrous progress, and from one spring draws off countless streams of truth.

[Margin: The second utility: the knowledge of Truth.]

Hence, once it has come to know the solar spots and faculae on the Sun itself, and known them to be subject to rising and setting, from these very discoveries it brings no small light out of its darkness to the obscure monuments of the ancients.

For we read many things here and there in [ancient] writers that might seem either fabulously fabricated or hyperbolically amplified; yet by this phenomenon one may easily persuade oneself that they are quite true.

[Margin: From the darkness of the solar phenomenon the light of the truth of history shines forth.]

From the Frankish Annals, in the Library of Pierre Pithou [*Petri Pithæi*], published at Paris in the year of Christ 1588, in the Life of Charlemagne [*vita Caroli Magni*], p. 62 of the latter part, these things are recorded: "In this year, that is, from the Incarnation of the Lord 807, on the fourth day before the Kalends of March, there was an eclipse of the Moon, and battle-lines [*acies*] of wondrous size appeared that same night; and the Sun stood in the 11th degree of Pisces, and the

Moon in the 11th degree of Virgo; and the star of Mercury, on the sixteenth day before the Kalends of April, was seen upon the Sun, like a small black spot, though a little above the middle of the center of that same star [the Sun]; and it was observed by the Franks for eight days. But when it first entered or departed could by no means be noted, because clouds interfered."

Joseph Scaliger [*Iosephus Scaliger*] says the same about himself [i.e., about the same matter], in Exercitatio 72 against Cardano [*Cardanum*, Girolamo Cardano].

The same, about himself, [says] Johannes Kepler [*Ioannes Keplerus*], in the year 1607, on 28 May. But that this spot appearing beneath the Sun was not Mercury, but a true spot of the Sun — and a very large and very dark one — cannot be doubted, for this reason: that it is written to have been observed not by one person only but indifferently by the Franks; and that it moved on the Sun is clear from this, that the writer of the Annals says its entry and exit could not be observed because of the intervening clouds.

[Margin: Mercury observed beneath the Sun was not Mercury but a spot.]

Nor is it in any way probable that Scaliger or Kepler saw anything other than a true spot — as Galileo [*Galilæus*] too rightly warns, in his *History of the Sunspots* [*Macularum Historia*], p. 54.

George Kedrenos [*Georgius Kedrenos*], in the Constantinopolitan Annals, published at Basel, under the 7th year of Justinian the Great [*Iustiniani Magni*], p. 304, line 60, has this: "That whole year the Sun, like the Moon, gave a mournful light without rays, for the most part resembling one undergoing eclipse."

The same author, on p. 389, in the 7th year of Constantine [*Constantini*], which was the year of Christ 786 according to this author: "In the 7th year (he himself says), the Emperor came with his Mother to Pusa, to the baths. And when, a few days later, a son was born to him (to whom he himself gave the name Leo), on receiving the news he left his Mother with the whole imperial retinue and hurried back to the City (Constantinople). There Irene (the Mother), having gained her opportunity, corrupted all the leading men of the several orders, that they should strip her son of the empire and let her rule alone. And so, when Constantine came into her palace in his Mother's absence, the nobles, by Irene's decision, shut him up in the Porphyra [the porphyry chamber], where he had been born, and gouged out his eyes so thoroughly that no room was left for medicine. *The Sun was then darkened for 17 days, sending forth no rays; and people commonly said this had happened on account of the blinding of the Emperor. So great was the darkness that ships too strayed from their course.*"

[Margin: The Sun failing for seventeen days.]

But here consider the inscrutable judgments of God. For it can be reckoned that, five years [a quinquennium] from the day on which the Emperor tore out the eyes of his uncles, on the very same day of the year and month he himself too was punished in his eyes.

Gaius Pliny [*C. Plinius*, Pliny the Elder], *Natural History* [*Historia Mundi*], Book 2, ch. 30: "There occur," he says, "portentous and unusually long failings of the Sun, such as the one when the Dictator Caesar was slain, and, during the Antonian war, with an almost year-long continuous paleness," and so on.

A similar prodigy, Xiphilinus [*Xiphilinus*] noted, happened under Augustus. Tertullian [*Tertullianus*], to Scapula, writes thus: "For that Sun too, in the assembly of Utica [*in Conventu Uticensi*], with its light nearly extinguished, was so great a portent that it could not have suffered this from an ordinary eclipse, placed as it was in its exaltation [*hypsoma*] and domicile [*domicilium*]. There you have the astrologers."

These and similar portentous symptoms of the Sun, a Batavian [Dutch] disputant [*Dissertator Batavus*] attributes to the faculae of the Sun. What sort of [explanation] this is, I do not argue; but this I do say: that many things are found in [ancient] authors, of doubtful or suspect credibility, which by the help of this phenomenon come out plain and can be most conveniently defended; and many which, without assuming this phenomenon, could not be given any color of probability at all.

[Margin: In [his] short dissertation, in the year 1612, pp. 12–13.]

Certainly this — which is described in these words from the Library of P. Pithou, in the Frankish Annals, in the latter part of the book, p. 414, in the 3rd year of King Lothair [*Lotharii Regis*], of the Lord's Incarnation 955: "The Moon was turned into blood, and in the same year, in the month of June, a marvelous sign appeared in the sky, namely a great Dragon without a head; and a little later, in the same year, an eclipse of the Sun occurred on the 15th day before the Kalends of January, and stars appeared from the first hour up to the third hour." This, I say — on account of so long-lasting an appearance of the stars during a solar eclipse — might seem to someone highly suspect; yet, on the other hand, since the author of these Annals appears most trustworthy, he does not seem deserving of the brand of such frivolity. One must therefore take refuge either in the earth's atmosphere or in the solar phenomenon.

[Margin: Through the solar phenomenon the credibility of many portents is preserved.]

Into the earth's atmosphere this darkness that dulled the Sun's radiance cannot be transferred; for if it had been great enough to blunt the Sun's vigor — so that the Sun would not, by its surpassing brilliance, snatch away the sight of the stars — it would have utterly blotted out the splendor of the stars themselves, which is of itself very feeble. But since those stars shone for about three hours, the sky must have been very clear, and therefore the cause of this must not be thrown back upon the earthly atmosphere.

It remains, then, either that the chronologer was hallucinating — which is hard to believe, since he would have been refuted by the writers of his own time — or, what is more probable, that the Sun suffered some dulling of its brightness from the dark

material of the spots. For it so happened that its bright segments, even when turned toward our sight, nevertheless gave so faint a light that they did not smother the reflected light of the stars.

The eclipse of the Sun that occurred while Christ, our Lord and God, was suffering — if it spread over the whole world — earns easy credence and explanation from this phenomenon; without it, it demands new and unheard-of miracles of God.

[Margin: The eclipse of the Sun while Christ suffered is conveniently defended by means of this phenomenon.]

For the Moon, placed beneath the Sun (as St. Dionysius [*S. Dionysius*, Dionysius the Areopagite] attests he himself saw at Heliopolis in Egypt) and eclipsing the whole Sun, does not extend the diameter of its shadow upon the earth beyond 70 German miles, or 350 Italian ones (reckoning, of course, 5 [Italian] for 1 [German]).

[Margin: In the letter to Apollophanes and Polycarp.]

That this failing of the Sun was universal over the whole earth, the Evangelists indicate clearly enough: Mark, ch. 15, v. 33; Luke, ch. 23, v. 44; Matthew, ch. 27, v. 45. Hear what George Kedrenos writes in his Constantinopolitan Annals, around the 19th year of the Emperor Tiberius, p. 155 of the Basel edition:

[Margin: George Kedrenos.]

"Our Lord (he himself says), Jesus Christ, underwent his punishment, just as the prophets had foretold. What was noted in the Greek commentaries at that time we shall report in their very words: [Greek: Ἐγένετο ἔκλειψις ἡλίου μεγίστη τῶν ἐγνωσμένων πρότερον, καὶ νύξ ὥρα ἕκτη τῆς ἡμέρας ἐγένετο, ὡς καὶ ἀστέρας ἐν οὐρανῷ φανῆναι· σεισμό. στε μέγας κατὰ Βιθυνίαν γενόμενος, τὰ πολλὰ τῆς Νικαίας κατεστρέψατο· ταῦτα Φλέγων φησί. — Phlegon's account of the eclipse; a few breathings/accents uncertain [?]; the author's own Latin rendering follows]. Which are thus rendered by the translator: 'There occurred a failing of the Sun greater than all previous ones, and night arose at the sixth hour of the day, so that the stars too were seen in the sky. There was also a huge earthquake in Bithynia, which overthrew a great part of Nicaea.' So Phlegon. Africanus [*Africanus*, Julius Africanus] too narrates that, on the day Christ was subjected to punishment, an exceedingly terrible darkness arose over the whole world, that by an earthquake the rocks were split, and much of the earth was leveled. This darkness the Jews call a failing of the Sun — absurdly, in my judgment, and against nature. For the Hebrews arrange their Passover according to the motion of the Moon; and it was on the day before the Passover that Christ suffered his punishment on the Cross. Now a failing of the Sun does not occur except when the Moon passes under

it, nor can it happen except at New Moon, when the luminaries meet, or nearly so. How then could that darkness have been a failing of the Sun, since at that time the Moon was nearly in the region opposite the Sun? But be it so, nevertheless — the thing that was accepted by many — and let us reckon it, together with the error of the eyesight, as a failing of the Sun, darkness cast, as it were, over the whole world," and so on. Thus Kedrenos, who also appeals to the Consular Fasti.

Eusebius [*Euseb.*], in his *Chronicle*, at the year 33 of Christ, adduces similar things. "Phlegon too wrote about these matters," he says — "an outstanding reckoner of the Olympiads — in Book 14, saying thus: In the fourth year of the two hundred and second Olympiad, a failing of the Sun occurred, great and outstanding beyond all that had happened before it: the day was so turned into dark night at the sixth hour that the stars of heaven were seen; and an earthquake in Bithynia overthrew many buildings of the city of Nicaea [*urbis* [?] — printed form uncertain]."

Origen [*Origenes*], in Book 2 against Celsus, argues from this eclipse. Tertullian too appeals to the archives of the Romans — Tertullian, *Apology*, ch. 21.

Lucian the Martyr [*Lucianus Martyr*, Lucian of Antioch] casts this same failing of the Sun in the teeth of the pagans, out of their own records, in the acts of his

martyrdom. Orosius [*Orosius*] too testifies, in Book 7, ch. 4, that some Greek books recall this eclipse.

St. Dionysius the Areopagite [*S. Dionysius Areopagita*], at any rate, after he had long labored in vain, with many arguments, to convert to Christ the stubborn soul of Apollophanes [*Apollophanis*] the pagan Sophist, at last — by recalling this very eclipse to memory through St. Polycarp [*S. Polycarpum*] — softened him, and on the very night of this eclipse drove away from his understanding a darkness more than Cimmerian. Read the 7th letter, which is to Polycarp; it confesses this very thing. The holy bishop [*Antistes*], in his letter of congratulation to the converted Apollophanes — in which he most vividly describes the marvelous manner of this eclipse, far exceeding the powers of nature — [writes] in these words: "But when the supernal light of the Father's glory, by its own will, ordained that its splendor should shine into the darkness of your mind, it straightway poured into the depths of my heart [the resolve] that I should set before your eyes a most devout remembrance and a monument of what had happened."

namely, that at Heliopolis you—almost exactly my own age—and I, unrolling a span of nearly twenty-five years, had been staying together, when on a certain sixth day of the week, and at very nearly the sixth hour too, the Sun was suddenly overspread with dreadful darkness, the Moon passing across it; for the Moon, being not God but a creature of God, could not shine at the setting of that true light. And a little further on:

For we ourselves were enveloped in the darkness, a gloom seizing the disk of the Sun on every side and evenly; and after a cleansing and restoration had taken place, the Moon, turned back toward the Sun's diameter, slipped away. And then too we took up the Canon of Philip Arrhidæus [*Regula Philippi Aridaei*]; and when we had found—what was indeed very well known—that at that time the Sun ought by no means to have suffered the troubles and toils of an eclipse, and that nonetheless the Moon had drawn dark, blackening veils over the Sun's brightness from the east, though it usually enters upon the Sun from the western side; and that then, ranging even to the western bounds of the Sun, it had (so we supposed) hidden the treasures of the Creator's [opificis [?]] light beneath the mists it had itself begotten—even though this was not the Moon's proper time for it, nor was any conjunction known to be near at hand. And a little later:

Finally, having carefully noted the day of the week and the year, and having found by experience that the celestial signs agreed and harmonized with the proclamation which holy Paul had poured into our attentive ears, I submitted my hands to the truth and was set free from the bonds of falsehood. This truth I proclaim with wonder, and I share it with you as well. So far that passage, etc.

And so, just as God, being born at midnight, scattered the darkness from the minds of the Magi by the brightness of a new star, so the same God, dying in broad daylight, divinely enlightened the minds of these philosophers—minds clouded over by the gloom of error—through a darkness that was miraculous and stirred up against the course and powers of nature.

That this darkness clothed the whole globe in mourning is sufficiently clear: first, from the manner of speaking of the Evangelists; second, from the authorities just cited. For from Phlegon it is evident that this eclipse of the Sun was most complete—both because he reports that night came on and stars were seen, and because he presents it as the greatest of the eclipses observed up to that time. And it is certain that in earlier ages total eclipses, and stars becoming visible, have often occurred.

But that it was total in Judaea as well is firmly drawn from the text of the Gospels; and for Egypt, the eyewitness Dionysius, already cited, bears witness. Since, then, in these three provinces the Sun was wholly darkened, and this entire [darkening] cannot be attributed to the interposition of the Moon—for a total failing of the Sun does not exceed 70 German miles in the diameter of the shadow as bounded on the earth's surface—it is clear that this darkness proceeded from another cause as well. The same cause, therefore, took the Sun's ray from Africa and Asia as it did from Europe.

This is confirmed too by the express testimony of other, non-Christian historians. "In other pagan commentaries," says Eusebius, "I found this written, word for word:

A failing of the Sun took place, and darkness over the whole earth. Bithynia was shaken by an earthquake, and in the city of Nicaea very many buildings collapsed."

Third, there is added the common consensus and authority of the learned. Read Baronius [Baronium], vol. 1; Jakob Gretser [Iacobum Gretserum], in his volume *On the Holy Cross* (Book 1, ch. 31, p. 102); Barradas [Barradium], *On the Gospels*

(Book 7, ch. 19); Jansenius [Iansen.], on the *Concordance of the Gospels* (ch. 143); and so on.

As for why the Lord made use of the ministry of the Moon for this failing—which nonetheless did not by itself suffice—among the other reasons may be these. First, that men might be the more stirred, by this extraordinary motion of the Moon, to take notice of the miracle and to look up in awe at its greatness; and that this did happen is established from the sacred Gospels, from the mentioned Epistles of St. Dionysius, and also from the cited writings of outsiders. Next, that it might be established that Christ is Monarch of both Heaven and Earth. Finally, that from the obstinate Jews every occasion for evasion might be cut off, since they saw the Moon passing beneath the Sun against the laws of nature.

Now the manner of this darkening is best and most reasonably explained through our Solar Phenomenon: namely, by the massing together of spot-matter so abundant and so dense that it would snatch the whole Sun, as though it were a single spot, from the sight of mortals. For from the atmosphere of the earth ...

[Margin (right column): The eclipse at the Lord's suffering was universal, throughout the whole world.]

that this did not come about from the earth's atmosphere is clear from this very point: that everywhere the sky was serene; otherwise neither the stars, nor the Moon as it approached the Sun and then receded from it, would have been observed, and so on. And St. Dionysius himself seems to indicate this very mode sufficiently, when he says that the light of the Sun was veiled by a mist which, in their opinion, the Moon had generated. That mist, then, appeared to them to have been produced at the Moon—though it is more fittingly ascribed to the solar Phenomenon, the knowledge of which they lacked. For in this way it at once becomes clear how this night, so foul and frightful and yet occurring at midday, was drawn over the whole world at once. On this the following points should be noted.

First, that the whole Moon was stripped of all solar brightness.

Second, that all the stars of the hidden hemisphere were deprived of their own light—which they have from the Sun alone—because the face of the Sun turned toward them, wrapped in the dark spot-matter and enveloped in thick shadow, cut off from them every ray of light.

I have treated these matters at some length so that it might become clear in what way this Phenomenon is fitted to the historical accounts, and the accounts in turn to the Phenomenon.

The Idolatrous Errors Committed Concerning the Sun Are Corrected by This Phenomenon

[Margin: Isaiah ch. 38; 2 Kings (4 Regum) ch. 20.]

We read everywhere, both in antiquity and in modern times, that the Sun has been worshiped as a deity by many nations. The Persians—from the fact that the prophet Isaiah called the Sun back for King Hezekiah by ten lines, that is, by 10 hours (as St. Dionysius holds, Epistle 7, to Polycarp)—instituted, in honor of the Sun as a god, a feast day called the "Triplicity," because the Sun by its motion had made, as it were, a threefold artificial day. For it had advanced by ten lines, and so was heading toward its setting, with the afternoon shadows [lengthening (?) — *(de)scentibus umbris pomeridianis*]; then, at the prophet's command, it went back by the same number of hours; and finally it advanced again through those same hours. And thus, above one and the same horizon of Judaea, the Sun—by proceeding from its rising to its setting, then from the setting heading back again toward the rising, and from there going once more to the setting—used up thirty-two hours; Pachymeres [Pachymerio] confirms this very thing, on the same passage.

And, terrified by this monstrous motion of the Sun, the Persians made peace with Hezekiah, and, sending great gifts, honored him splendidly; yet this miracle, by which they ought to have come to know the true God, they impiously repudiated, and to the Sun itself, on account of this threefold motion, they decreed divine honors year by year. Other nations too fell into similar follies, and so on. All of which can be convicted of sacrilegious error by this single Solar Phenomenon.

For God is light, and there is no darkness at all in him; but in our Sun there are shadows; therefore our Sun is not God. Likewise, with God the Father of lights there is no change, nor any shadow of alteration; but in our Sun there exists continual change and shadow of alteration; therefore our Sun is not God. And the varieties of these alterations can be shown to the eye of anyone, provided only that he has at hand a telescope [Telescopium] set up for observing, and so on.

Comets Seem to Owe Their Birth to This Phenomenon

[Margin: Comets are not unlike the solar spots and faculae.]

It is also worth considering that ordinary comets for the most part arise and become visible in the vicinity of the Sun, gradually receding from it; that many are born out of the Sun's bearded or tailed rays, their head lying hidden near the Sun; that most exhibit durations equal to those of the solar spots [Maculae Solares]; indeed, that they display a similar course in their manner of growing, expanding, and diminishing, and present the very same properties. This is clear from the comet of the year 1618, which I too observed at Innsbruck [Aeniponti] with a telescope, and which our Father Cysat [Cysatus] beautifully displayed in his publications. For it exhibited such changes and varieties of its nuclei as spots regularly do. Is it, then, that a similar matter frees itself from the Sun and, kindled thereafter into a comet, wanders through the aether? That this comet certainly traversed the entire celestial regions, from the Antarctic to the Arctic pole—and indeed by a transverse path—is the agreed and true teaching of all the better astronomers, a teaching which the Roman College of the Society of Jesus [Collegium Romanum Societatis Iesu] also received, with its own calculation and applause, in its Disput[at]ions...

in an astronomical [disputa]tion held in 1619 by one of our confreres concerning this comet, who on page 10, in the second assertion, writes as follows:

"Secondly, it seems that on no account should it be said that this same thing (the phenomenon) was sublunary — a point he afterwards proves at length. And on page 14 he places it between the Sun and the Moon, in these words: 'So that we may now fix the comet's position close to the true one, we say that it can probably be placed between the Sun and the Moon,' and so on."

Lothario Sarsi [Lotario Sarsi, pseudonym of Orazio Grassi] confirms the same in the *Libra Astronomica* [*Libra astronomica ac philosophica*], published at Perugia in that same year 1619, on pages 20 and 32; and at page 27 he speaks thus:

"Galileo [Galilæus] asserts, moreover, that the matter of the comet does not differ from the matter of those little bodies which move about the Sun in a fixed revolution and are commonly called sunspots [solares Maculæ]. I do not deny it — indeed, I add this: during the whole month in which the comet was visible, not a single blemish of this kind was seen [on the Sun], and only very rarely afterward were such blemishes observed on it."

DE SOLIS COLORE EX Phænomeno solari per Telioscopium patefacto. CAP. XIV.

On the Color of the Sun, as Disclosed by the Solar Phenomenon through the Telioscope. Chapter XIV.

The Sun's color is twofold: the one it presents from its light, and the one it presents from its shadows, that is, from the sunspots [Maculæ]. The former is considered in various ways, either with the unaided eye or through the telioscope [Telioscopium]. If it is examined with the naked eye, the color always reaches our sight mixed or confused, on the side of the object itself — never pure and unadulterated — both because of the interposition of the vapor-laden region, which colors the Sun's light in various ways (as experience attests), and because of the admixture of the appearances [species] streaming from the shadows or the sunspots. Yet the eye perceives all this under the aspect of a single luminous appearance, discerning no variation of light among the Sun's parts, since the light of course prevails and smothers the shadow-casting images of the spots.

And so the Sun, viewed with the naked eye, ordinarily presents nothing to the senses beyond a luminous mass; for the fact that very large spots are sometimes seen cannot with certainty be referred to the Sun on the basis of naked-eye observation alone.

Therefore, so that we may see — and judge that we see — some color in the Sun other than that of pure light, and so that we may prevail against the stubborn objector, we must employ, over and above the natural eye, the artificial eye of the optical tube [Tubus Opticus] as well: whether one prefers to gaze directly at this luminous star with a helioscope [Helioscopium], or to project it onto paper with a telioscope, or finally to contemplate it by other means, as I have taught elsewhere.

With these artificial eyes of the telioscope, then, you will acquire not only the colors of the Sun's luminous parts, kept distinct from the colors of the non-luminous parts, but also the several colors of the opaque parts as they variously differ among themselves. And you will acquire them all, each one ordered, unconfused, and unmixed with the others — provided that the due arrangement of the lenses is used, and that the Sun is consulted while raised so high above the horizon that it does not suffer the refraction and tincture of the earthly atmosphere [Atmosphæra]. By this latter, artificial mode of viewing the Sun, then, we obtain distinct views of both of the Sun's colors — the bright, that is, and the

dark — so that from their differing qualities we may render a philosophical judgment.

When the optical tube, therefore, is applied to the Sun, the spots present the likeness of an opaque body, of a color almost black; the faculae [Faculæ], the color of a purified, whitish flame; while the remaining portion of the Sun displays a certain intermediate color, gleaming with a light not entirely pure, but still glowing as it were with a dreggy dullness, of the sort seen in molten tin or lead.

[Margin: Quales diuersarum Solis partiū colores cernantur? — What colors of the Sun's various parts are perceived?]

Between this color and that of the spots there is a middle color, that of the secondary spots, or solar umbrae [Vmbrae solares]. And all these colors are ordinarily discerned in the Sun at the same time, but each in a different part: for in one place there are spots, in another faculae, in another umbrae, in another uniform tracts of the Sun, and so forth. There also exist, and are sometimes seen in the same Sun, certain other extraordinary colors — whether of areas [areae], or partly of rainbow-hues [Irides], or finally variegated ones — of which I gave notice in the Observations. And since these too have been noticed elsewhere at the same time and place on the Sun, it is certain that they must be reckoned not a deception but a true appearance arising from the object.

Now, since many of the Holy Fathers, and modern theologians too, have taught and still teach that the light created on the first day lacked any material or inherent subject, and that it thus ran its course through three whole days and spread its radiance [lumen] over the orb — one might with good reason wonder whether such a light of the Sun, if it were or had been given in the abstract, would fall within the range of sight. Since knowledge of this question does not seem to lie outside our present subject, and since it supplies the foundations for penetrating many other matters concerning the light and color of the heavenly bodies, it must here be run through by way of a few general doubts, as if through a lattice-window.

De luce in abstracto, seu sine ullo materiali subiecto considerata;
Dubia Nonnulla.

On Light Considered in the Abstract, or without any Material Subject;
A Few Doubts.

[Margin: An lux in abstracto oculis pateat? — Whether light in the abstract is visible to the eye?]

One might doubt, first: *Is light [lux], considered in its own nature — that is, in the abstract, and without any subject of inherence — visible?* That it is visible would seem to follow from this: that light is of itself and primarily the object of sight, while luminous things are its object through the light. It is further clear from the same consideration in the case of colors, which are evidently seen in the abstract — as is plain from the mystery of the Most Holy Eucharist. St. Basil [D. Basilius] expressly held that the primeval light created by God on the first day traveled about and illuminated the universe for three days in the abstract; and many of the weightiest Doctors, both ancient and more recent, follow him. Finally, the common doctrine of the writers on optics is that light is a certain species of color, and therefore of itself, by its own nature, capable of being seen.

Ptolemy [Ptolomæus] too, in the second book of the *Optics* [*Optica* II], from the manuscript: "We say, therefore," he says, "that sight recognizes body, magnitude, color, figure, position, motion, and rest."

But sight recognizes none of these without something luminous, and something that in any way hinders penetration. Those things, then, that are truly seen are luminous and dense. For the objects presented to sight must be in some way luminous — whether of themselves or from elsewhere — since this is proper to the visible in relation to the sense; and they must be dense enough in substance to arrest the sight, so that the sight may penetrate them and not pass through without an effect of incidence. Hence it is impossible for anything to be seen without both of these together, since the one cannot truly be seen without the other.

To the contrary, however, this argues: that we evidently know the heavenly regions to be always most brilliant with the Sun's light, and yet not a mote of that light is perceived by us — scattered abroad through those immense spaces — on clear nights or during total eclipses of the Sun. Likewise, that the philosophers say the element of fire dwells beneath the concave [of the Moon's orb], and yet no one has ever seen its light.

We must say, therefore, that light [lux] is one thing, and radiated light [lumen] — propagated from the light through a medium — is another; for light stands to radiance as color stands to the species of color, since radiance is a species of light. And just as we do not perceive the species of colors present in the air, so we do not see, in a perfectly transparent medium, the species of light, which is radiance. And just as we would argue badly if, from whiteness not being seen as a species in the air, we concluded that whiteness is of itself not visible — so it is not rightly concluded, from the fact that radiance is not seen in a pure medium, that light is

by its nature invisible. Light in the abstract, therefore, without a subject, can by its own nature be visible, even though, once propagated into a perfect transparent medium, it cannot be discerned.

[Margin: Lumen est lucis species. — Radiance (lumen) is a species of light (lux).]

[Margin: Lux in abstracto videtur. — Light in the abstract is [nonetheless] seen.]

Whether, and in what way, the species of light — the radiance propagated from the light — falls upon our sight, I have no leisure now to pursue. This much is certain, in my judgment: that the Sun's radiance, striking the bodies of the stars, becomes visible.

[Margin: An lux Solis sit eiusdem speciei cū luce sublunari quavis? — Whether the Sun's light is of the same species as any sublunar light whatever?]

One might doubt, second: *Is the Sun's light of the same kind, in any respect or species, as any other light?* The Coimbra commentators [Conimbricenses] rightly affirm it, in book 2 of the *De Caelo*, chapter 7 (Conimbricenses, *In De Caelo* II.7). And they prove it from this: that by the mutual conjunctions of these lights the whole compound turns out brighter. Now, so that the certainty of this argument may come out still greater, take the following experiment.

[Margin: Affirmatur & probatur experimento. — It is affirmed and proved by experiment.]

Through a very narrow aperture let the Sun enter upon any surface whatever, held in any way whatever, so that on its surface the Sun's splendor shines back; and the place must be as dark as possible. This done, from another place, likewise darkened and empty of any extraneous light, transmit through a slender chink the faint gleam of a lighted lamp or of any torch you please, in such a way that the ray of this gleam falls, in the manner of a solar ray, somewhere upon the surface of the spread-out board or paper that receives the solar image.

For you will see that the common concurrence of the solar image and the candle's is brighter than either the Sun's alone or the facula's alone. And this will always happen, whatever flame you finally kindle and bring together with the Sun's image. Therefore, since any light whatever intensifies the Sun's light, it is manifest that its species is in all cases one and the same.

COROLLARIUM.

Corollary.

From this it is plain that like can be, and usually is, intensified by like, and a thing more of such a kind by a thing less of such a kind.

[Margin: An lux sit colorata? — Whether light is colored?]

One might doubt, third: *Does the primeval light, in the abstract, present a color — and which one? Does more intense light intensify the color of the light, and less intense light remit it?* The resolution of this doubt is difficult. For who has seen light in the abstract? Yet that light is of itself visible can hardly be doubted; but under precisely what color, this is not so clear — because light in a subject shares in the affections of the bodies in which it inheres, and by their colors it is corrupted, as will be seen later. In the meantime, however, if we estimate the color of light from the Sun, it seems it must be laid down that the native color of abstract light lies between white and

[Margin: Lux natiuū quendam colorem præsefert. — Light exhibits a certain native color.]

yellow — which the flame of fire, too, suggests. That the color of concrete light is intensified and remitted together with the light is established by everyday experiment. These points are confirmed by lightning-flashes and nocturnal heat-lightning [chaumata], whose light whitens greatly. And because this light resides in a thin subject that is, as it were, void of color, it displays its own quasi-native color.

[Margin: Lux in subiecto simpliciter diaphano natiuū colorē non mutat. — Light in a simply transparent subject does not change its native color.]

One might doubt, fourth: *Does the primeval light, when placed in a simply transparent subject, change its native color?* The answer is that it does not change it. For that subject is, by hypothesis, a bodily substance simply transparent; therefore it contributes nothing to the light in the way of color. For if it did contribute anything, this would come either from light or from color; but from neither — because, if it came about from either of these, that subject would not have been simply transparent, since both light and color are by their nature visible, and therefore bound the subject, and so forth.

One might doubt, fifth: *Does light placed in a simplest body change its native color?* The answer is: if the body

is perfectly transparent, then the light, in accordance with the fourth doubt, will not change its color; but if the simplest body is not simply transparent, the primeval light placed in such a simplest body must change its native color. But if that simple body had been affected only by light, then any light superadded would of course change its color — not in species, but in intensity.

[Margin: Lux abstracta in corpore simplicissimo posita, suum colorem non mutat. — Abstract light placed in a simplest body does not change its color.]

One might doubt, sixth: *Does the primeval light, placed in a mixed body, change its color?* If the mixed body is transparent throughout and homogeneous, and tinged by no light, it does not change it — as was just said of light and its color. If it is non-transparent, or affected by some light, it does change it. This is established by reason and by experiments: because light supervening upon light or color is to some extent assimilated to their qualities, and experiences of this kind are given without number.

[Margin: Lux in mixto posita, eius coloribus sese accommodat. — Light placed in a mixed body accommodates itself to its colors.]

One might doubt, seventh: *Does the primeval light, all else being equal, shine less in a perfectly transparent or a simple rare body than in the same perfectly simple or dense transparent body?* Suppose, for instance, there is a light of one cubic palm, of intensity four, and it occupies a cubic palm in a rare body, and that then the same light in a dense body of the same ratio occupies likewise one cubic palm: it is asked whether it will have changed its inherent color, and whether it will appear brighter in the dense than in the rare?

The resolution of this doubt depends on this: whether a simple, or perfectly transparent, body, if it is condensed, loses anything of its perspicuity. And the answer is that the terminus of condensation is not color, and that a simple and perfectly transparent body, even if it were condensed to infinity, will not on this precise account become opaque or less transparent. Hence, in reply to the doubt raised, we answer that the primeval light,

[Margin: Resolutio Dubij. Lux eodem modo se habebit. — Resolution of the doubt: the light will behave in the same way.]

equally extended and intense, will not be changed when placed in the rare instead of the dense, nor in the dense instead of the rare, all else being equal.

One might doubt, eighth: *Is the primeval light, placed in any subject whatever, changed when the subject is condensed or rarefied, all else being equal?* Suppose, for example, the subject were luminous,

of four cubic palms, and it is condensed into two, or from three is rarefied into six cubic palms: the question is whether the change of the light will affect its color. I answer that it will; for that condensation is in some way equivalent to an intensification of the light, and the rarefaction to a remission of it.

[Margin: Resolutio dubij. — Resolution of the doubt.]

One might doubt, ninth: *If the abstract and extended light, all else being equal, is contracted into a smaller space, is it to be intensified? And if, when contracted, it is extended, is it to be remitted?* The answer is: if the parts to be contracted penetrate one another, the light will be intensified; if the parts to be drawn apart migrate outward, it will be remitted; if otherwise, there will be neither intensification nor remission.

[Margin: Resolutio dubij. — Resolution of the doubt.]

From the resolution of these doubts a prudent natural philosopher [physiologus] will unravel much concerning the light, color, and matter of the sunspots and solar faculae; much concerning the color, light, matter, simplicity, and composition of the stars; and finally much concerning the light, color, and matter of the heavens. To have now indicated the foundations of these matters is enough: for these things are wont to be, and can be, treated more fully by design in works on optics.

Now, leaving aside the doubts concerning abstract light, let us turn to the Sun's own color, and see whether — and what — can be decided from it regarding our Phenomenon.

First conclusion. The color of the Sun's light, viewed with the unaided eye, does not supply a necessary argument for persuading us that a fiery Nature is present in the Phenomenon itself. For that color always appears to the naked sight stable, uniform, unchanging, and — with a fiery splendor of the kind observed among us in fire — much more vehement and more noble. I said that no *necessary* argument can be drawn from it; for certain persons took it as a *probable* one, and confirmed it from the color of the lightning-fire, which rivals the Sun's in many properties, as will be seen later from St. John Chrysostom [S. Ioannes Chrysostomus] and others.

Second conclusion. The color of the Sun, apprehended both by the helioscope and by the telioscope, furnishes such indications that many, on their basis, judge that a fiery Nature must be attributed to the solar Phenomenon. And the indications are these.

First. Because the tube shows that the color of the solar Phenomenon is condensed and rarefied; and these things are not wont to happen without color; nor does any physical experience allow that similar effects are exhibited without the intervention of similar qualities — so they judge.

Second. Because the tube shows that intensification and remission occur in the parts of the solar Phenomenon, both bright (that is, luminous) and dark (that is, opaque); and these, they keep insisting, do not occur among us without the intervention of heat.

Third. Because the tube shows the sunspots and the Sun's faculae to increase and diminish, which again are not wont to happen without a resolution of the parts and some varying alteration supervening. And these effects, they themselves say, do not occur in other things without heat.

Fourth. Because by the aid of the same tube the spots and faculae are seen to be born anew and to perish on the outermost surface of the Sun — and that gradually, in the manner of generation and consumption; and they contend that this cannot happen without the help of heat.

Fifth. Because we see faculae generated from spots, whose likeness to flames is of itself sufficiently obvious to the eyes; and since changes of this kind are not wont to occur without heat, they think they have solidly concluded this opinion of theirs from it.

Sixth. How wonderfully, they say, it is confirmed by the various and admirable birth of the nuclei [Nuclei] and their perpetual perishing.

Seventh. There strongly attest to it, moreover, the luminous halos [Nimbi luminosi] poured about the larger spots, and the extraordinary colors — yellow, reddish, greenish, and also blue — adhering [to them], just as others in Germany, too, observed and noted; as was sufficiently said and taught in Book 3.

Eighth. Finally, they say that this doctrine, drawn from the conceded Phenomenon, does not appear to be against the mind of the Philosopher [Aristotle]; for if he denied that changes of this kind exist in the heavens, he asserted this consistently with his own principles, since he believed that only change of place belongs to the heaven — because he noticed no others. And had

he noticed those changes which are now daily perceived by the aid of the optical tube, they suppose he would in all likelihood have pronounced differently about those movable [heavens]. And this

It is in just this way that very many of the moderns, as I have said, philosophize about these matters, guided by the appearances just surveyed.

On Other Experiments with the Solar Ray, and Those Most Thoroughly Proven. Chapter XV.

(De aliis radii solaris experientiis, iisque probatissimis. Cap. XV.)

[Margin: What is meant by a solar ray? (*Quid per radium solare intelligatur?*)]

By "solar ray" I do not mean merely the straight, linear projection of some single luminous point of the Sun. I mean also the splendor of the whole surface — and indeed of the deep, or bodily, light — spread out beyond the Sun. It is from all of these together that the matter proposed is investigated, and I embrace them all under the name of the solar ray.

First experiment, by means of a bare admission-hole, which was set out earlier in connection with the Magnitude of the Sun; here I repeat and expound it for my present purpose.

If the Sun is admitted through a very tiny hole, at a distance of 10, 20, or more palms, you will catch its image on a clean sheet of paper — an image possessing the following properties.

[Margin: The admission of the solar ray through a very tiny hole. (*Radii solaris per minutissimum foramen intromissio.*)]

First, the whole image of the Sun will be of very faint and dull light.

[Margin: Properties of the admitted solar ray. (*Radii solaris immissi proprietates.*)]

Second, the whole light will be uneven in brightness — more intense at the center, weaker at the edge. This unevenness does not increase uniformly or proportionally: rather, out to about a third of the diameter, for example, it extends around the center with a fairly great and nearly even brilliance, and only then does it begin, quite abruptly, to darken and grow murky [*turvescere*, i.e. *torvescere*].

Third, the shape of this image is always round — unless either the hole is not round and the receiving plane is not at the proper distance, or the Sun is contracted amid vapors.

Fourth, the edge of this figure is never sharp or clean, but softly ragged — as if one were looking at a snowflake, or at wool spread out in a circle; or (perhaps a better comparison) such as the outline of a thin, wispy white cloud tends to be, or the tip of a flame in a quietly burning lamp. If you imagine that flame-tip set all around the margin of the circle, stretched from the center outward, you will have some likeness of the solar image with respect to its roughened edge. We experience something of this roughening at the boundary between the light and the shadow caused by the Sun and an opaque body: that boundary always wavers, and never shows an edge ending in any clean line. The trembling image of the Sun, admitted onto paper through a telioscope [helioscope-projection instrument] and broken up by vapors, presents something similar.

Fifth, this image becomes noticeably larger, but darker, from a smaller hole; smaller, but brighter, from a larger hole.

Sixth, the larger the hole, the cleaner the edge becomes; the smaller it is, the more uneven.

Seventh, if the place is entirely closed off, so that none of any foreign or external light gets in at all, and the hole is physically very tiny, the image of the Sun will appear at the greatest size it can attain; but if even a little other light enters that chamber, something will be lost from the size of the image.

This experiment is entirely reliable. Over very many years now I have found it — other things being equal — always to hold consistently, and I have shown it to many most learned men. We now seek the causes of what we observe through it.

[Margin: The cause of this appearance is investigated. (*Causa huius apparentiae inquiritur.*)]

First: Why does the Sun, admitted through a smaller hole, appear darker than when transmitted through a larger one? For is not the whole Sun passed through even the smallest hole? If the whole, then the light of the whole passes; and so it should be equally bright through a small hole as through a large one.

But the matter stands otherwise if it is weighed correctly by optics. It is certain that the whole Sun falls upon any point whatever assigned anywhere on the earth; but it is equally certain that to a given point only one straight line can be drawn from any given point of the Sun. Hence it is certain that from any point of

the Sun to any other given point only a single ray can arrive. So when the argument runs from the whole Sun, passed through a given hole, to the light of the whole, the antecedent may be granted while the consequence is denied. For there is a fallacy in passing from the quantity represented to the representing quality.

The quality of the Sun that represents its quantity is the bright solar ray, directed from each point of the Sun onto a single point of the plate. By this radiant, rectilinear, bright quality of the Sun — which by another name we call the *species* or image of the Sun — the whole quantity of the Sun glides together by conradiation onto that point. And if that point be made physically pervious by the smallest little hole, that radiant cone, intersected at that point, will pass through onto the paper set opposite, and will represent the magnitude of the whole luminous Sun. Now because, on account of the smallness of the hole, only a single ray passes through from the radiant sphere of each point in the luminous Sun (for every luminous point radiates spherically), and consequently from the several points of the Sun only single rays are coordinated into the radiant cone of the Sun — for this reason it comes about that the whole Sun is presented to the sight as a rather dark luminous cone, and the inference from a partial quality to the whole quantity, or the reverse, does not hold. For the whole surface-quantity of the Sun can be represented by a cone that is either more or less bright; but the cause of the cone's being more or less bright is not the magnitude of the Sun represented, but the representing solar ray. If much of it is admitted, it will increase the brightness; if little, it will diminish it. So through the smallest physical hole it will carry through only the least little bit of light, namely a single ray from each point of the Sun, because the infinitely many others are excluded by the narrowness of the hole.

[Margin: The narrowness [?] of the hole. (*Foraminis exi[?]tas — an ink-blot obscures the middle of the word; likely exilitas or exiguitas*.*)*]

But when the hole is enlarged, even by as much as a single atom, the light of the admitted cone at once brightens perceptibly. Why? Because through the larger hole more rays, from the radiant sphere of each shining point of the Sun, shine together into the base of the solar cone. Now I took a hole that was physically almost minimal — so small that even in a brass [*orichalcea*] plate it escaped a keen eye, such as I judge mine to be. I showed the plate to many; I told them a very fine hole was in it; and they could not find it except by turning the plate toward the light. So the Sun, passed through such holes into a very dark place,

shows its figure with the faintest brilliance; but through larger holes it at once comes out brighter, and so on.

[Margin: The cause of the difference between brightness and darkness is investigated. (*Claritatis & obscuritatis differentiae caussa inuestigatur.*)]

Second: Why is the solar cone, admitted through a very small hole, brighter in the middle and darker toward the edges? Why does a large part of the middle shine with an almost even brightness, while around the edges there is such an unevenness of darkness?

These doubts must be resolved by way of other doubts resolved first.

[Margin: First doubt. — Resolution.]

The first of them is: *Does one and the same luminous point of the Sun emit rays equally bright in every direction, other things being equal?* The answer is that no cause can be found why the same point should not shine equally toward every difference of place, other things being equal. For since it is a point, equally bright in itself, and acts not by choice but by necessity, it will emit equally bright rays in every direction; and from that common principle, "things equally bright radiate equally." And what is more equally bright than a thing identical with itself? From this it follows that a lateral or marginal point of the Sun ought — if the rest be taken as equal — to produce a ray just as powerful as a central point. For from one and the same point of the Sun some rays go out perpendicular to the Sun's surface, others oblique.

[Margin: Second doubt.]

Second doubt: Does the differing distance of the Sun's luminous points from us create this difference of brightness? It is certain that a luminous point of the Sun coming from the margin of the visible solar circle is farther from us than a point on the radiant axis descending to us from the middle summit of the Sun; for the latter is nearer to us than the former by one solar semidiameter. Whether, then, other things being equal, this distance causes so great a difference of brilliance — that is the question.

[Margin: Resolution.]

The answer is that this is not the cause of the difference in brightness either. For the Sun at apogee recedes from us by many whole solar diameters, and at perigee approaches by many; yet the rays — the lateral ones do not change their darkness, nor the middle ones their brightness, perceptibly, as in our case, but

behave in the very same way. Therefore the distance of a single semidiameter does not change the brightness of the ray, other things being equal.

Hence I infer that the darkness of the ray, or solar image, toward the edges, and its brightness toward the middle, must come from some other source. To dig this out from its foundations, the inquiry is pressed further, and set down as follows.

[Margin: Third doubt.]

Third doubt: Supposing the Sun to be non-translucent, will two radiant points equally bright, placed anywhere at all on the solar surface, shoot out equal rays toward us? — all else being posited as equal.

[Margin: The sense of the doubt is explained and its solution given. (*Sensus dubii explicatur, & solutio redditur.*)]

Let there be two surface points of the Sun, equally bright — one marginal, the other central — and let the Sun be posited as non-translucent in respect of its depth. The question is whether these two points will emit equal light to us. I answer: entirely so, other things being equal — and this is clear from what precedes. For each radiant point emits rays equally bright in every direction. Therefore, of two equally bright points, all the rays will be equally bright. From this I infer: if the Sun shone toward us only at its surface, this experimental result — the diversity of light — would not occur. So, to account for it, we must come to other causes.

[Margin: Fourth doubt.]

Fourth doubt: If the Sun be posited as luminous throughout its depth and uniformly translucent, will this experimental result still hold?

[Margin: First reply.]

I reply, first: If all and each of the Sun's points, even in the depth, are posited as luminous, equally luminous and equally translucent, this experimental result is not in every respect preserved. For although it is true that, if bright be added to bright, a brighter ray is cast, nevertheless — with the Sun's luminous points posited everywhere of the same intensity and likewise equally translucent, which is exactly what is here supposed — it is impossible that this result should hold in the Sun, on two counts. For this experiment barely shows that portion of the solar disc which answers to a third part of the diameter to be evenly bright compared with the rest; the other portion, spread around it, it shows differing vehemently and unevenly from the central light. But if we posit that equivalence of luminous

and translucent points, the brightness of the solar base [the projected image] will behave somewhat as strings to strings; and thus at the edges it will scarcely darken at last, and not as much as we see — which, however, plainly conflicts with the experiment itself. On the other count, that equivalence of bright and translucent parts is inconsistent with the manner in which the brightness fails and the darkness increases. For, according to the experiment, the middle parts are fairly and almost evenly bright; then, once they grow darker, they fall away from the light vehemently and not gradually. This would not happen if the Sun's points, all and each, were equally bright. (By a "luminous point" I mean a physically least particle, or nearly so, from which exactly one bright ray can proceed straight to us.)

That, on this posited equivalence, the image of the Sun would not exhibit so great an unevenness of brightness and darkness, is clear. For since the whole Sun is posited as equally bright throughout its whole body, at every point, and each point equally translucent, then — until one reaches the margins in the solar image — there will always be many points intensifying one another through the translucency, as is evident on reflection. On this way of proceeding, then, the experiment — otherwise perfectly true — is not upheld. But still less will the truth be upheld this way if someone should hold that the middle of the Sun is opaque and non-transparent [*adiaphanum* — Greek-derived, "non-transparent"], like an enclosed kernel, while the rest is equally large, equally bright, and translucent. For in that case the marginal parts would easily equal the middle parts in abundance of light — indeed would rather surpass them — which is false, since it is contrary to experiment.

[Margin: Second reply. The true cause of the unevenness in the light is given. (*Responsio secunda. Difformitatis in luce vera caussa redditur.*)]

I reply, then, secondly: if the Sun's luminous points are understood to be so arranged that, going inward from the outermost surface toward the center, they show themselves ever brighter and purer, and going from the center out toward that same surface, ever darker and more turbid — then the image of the Sun projected onto paper will be very well accounted for; otherwise it can in no way be saved, given the following experiment. And it is proved thus: a weaker ray flowing from the Sun onto the paper, if it is not dulled from some other cause, necessarily flows from a less luminous point, and a stronger one from a more brilliant point. Now here, in this experiment, the rays around the middle are always stronger and render a brighter image, and the outermost are always weaker — because they are not dulled from any other cause, as I suppose in this

case and as the experiment establishes; for it always appears so. And if something else were darkening it, the middle rays too would feel this proportionally and would present the whole image of the Sun darker, on account of the Sun's apparent smallness — which, however, does not happen. And from this same supposition there at once appears the uneven darkness of the parts near the solar limb; because

these turbid parts darken one another the more, owing to the ray's longer, transverse passage; whereas in the middle their opposition to us is short and direct, and the shining-through of the bright parts leaves the solar image more brilliant there — just as we see happen in a burning pyre, whose flames, struggling upward, are dulled into dark exhalations. That the whole Sun is clothed round with this darker massing of parts is shown by the very base of the solar cone projected onto the paper, dark on every side toward the margins; and the reasoning brought forward, together with experiment, proves it — namely, that the Sun rotates, and yet always, everywhere, projects an image like itself and similarly disposed. And so toward us too such shadowy exhalations extend, even though — because the inner central brilliance prevails — they are not perceived.

Just so we see a certain thin halo clinging like a mist to a burning candle or lamp; yet from a direct view we observe nothing of it at all, though it is nonetheless certain that it surrounds the whole inner flame on every side. This is clear if you either turn a lit candle around while it stays in its place, or yourself walk around it while it stays still: for from every position you will always see that halo, and hence it must be wrapped all around it everywhere. But I speak of the halo that truly encircles the candle's inner flame, not of the one that sometimes exists only apparently, in the eye, through refraction and a confusion of light. But you will say that from this very example another — and perhaps better — way of defending the reported result can be drawn out. For sight makes plain that the halo cast around the candle is a rarer and more transparent flame than the middle one; so if someone maintains that the Sun's outer parts are rarer than its inner, those outer parts will also have a fainter light, from which it likewise follows that the bright image of the Sun caught on the paper is brighter in the middle and darker at the edges. I reply: if the experiment in question turned only on the ratio of greater or lesser brightness, perhaps it could be satisfied by the adduced density and rarity of light alone. But if color is considered, and its range in the Sun, then rarer light alone does not suffice; for it will never show those fiery colors that both this and the following experiment attest. For if a burning candle were surrounded by such a halo as is the topmost sooty tip of a flame, then the example would agree in every respect with the reported experiment.

Such it would be if one were to look at a fire at the center of the earth: for from it those turbid flames, struggling up equally on every side toward the heights, would present darker margins to the sight than the middle parts, for the reasons given. Such too will probably be the aspect of the conflagration on the last day of the World: whoever looks down upon that flame from heaven [*qui è caelo co[r]ruebitur*; the verb is ill-set — reading uncertain [?]] will, without doubt, see it brighter in the middle and sootier toward the edges, notwithstanding that the whole conflagration is surrounded on every side by those impure flames.

From these, then, and from similar appearances and experiments, Johann Kepler [Iohannes Keplerus], Galileo Galilei [Galilaeus Galilaei], and other astronomers have brought forward their conjecture and doctrine of celestial fires — although they by no means seem to have worked out every detail so accurately. But let us now return to finish weaving our web.

[Margin: The cause of the roundness is given. (*Rotunditatis caussa redditur.*)]

Third: Why is the shape of the solar image round? Because the Sun is spherical — which is known from the fact that, when rotated, it always settles into a circle. Otherwise it would not fall onto the paper as a circle, even though the hole were perfectly round. This is proved by the oblong flame of a candle, which, transmitted through a circular hole, will always give a somewhat elongated image, unless you take a disproportionate distance. It is clear too from the crescent Moon admitted through a round hole: for it appears as a crescent, and so on.

[Margin: The reason for the ill-defined perimeter. (*Perimetri male praecisa ratio.*)]

Fourth: Why is the perimeter of this solar figure not even, but rough and ill-defined? I reply that this comes from the luminous edge of the solar body itself, which renders a perimeter like the one nature has set around it.

[Margin: The reason why a larger appearance comes through a smaller hole, and a smaller through a larger. (*Maioris apparentia per minus foramen, minoris per maius ratio.*)]

Fifth: Why does a smaller hole present a larger image of the Sun, and a larger hole a smaller one? This experiment has hitherto wearied the wits of many, for I have shown it to many highly expert mathematicians; yet it is very easy for anyone to try. But all else must be equal: the distance of the hole from the paper, a wholly darkened place, and the greatest clearness of the sky.

Johann Kepler, the Imperial Mathematician, in his *Paralipomena to Optics* [Kepler, *Ad Vitellionem Paralipomena, quibus Astronomiae Pars Optica traditur*, 1604], brings forward the same experiment; but because from it he found the visual diameter of the Sun, in his opinion, too large, therefore

and he therefore places around the Sun, in the aether, a fiery sphere, as it were — one that is not stable or perpetual, but temporary. But whether he is right to reject, on so slight a persuasion, a truth found out by careful labor, let him look to that himself. For my part, I judge that Astraea [the goddess of justice, here truth], having descended to us from heaven, should be treated more generously, received with liberal hospitality, and not driven off rashly.

Setting aside the many opinions that bear not at all on the matter, I gave the true and genuine cause in what went before, where I discussed the daily light of the faculae [faculae]; and I now repeat it, and perhaps establish it more clearly and firmly, with more instances, reasons, and experiments.

[Margin: The genuine cause is assigned.] I say, then, that the Sun exhibits to the sight a larger image of itself on paper set to receive it [the projected image] through a very small aperture than through a larger one. The reason is that the image of the Sun, having entered through the smallest aperture, is composed of simple and well-ordered rays, each of which has fallen to it from a single point of the Sun; and because each shines with a faint light — and with differing intensity (for the middle rays are strong with the greatest brightness, the outermost with the least) — and the brighter middle ones fall onto the paper unmixed and interspersed among the others, therefore [the whole] does not have so great a brilliance as to keep the very faint lights of the outermost rays from the sense of sight. But if the opening of the aperture is made a little larger, at once more rays of the solar cone [conus solaris] enter and present the base of the radiant solar cone as more intense in light, indeed, but less extended in quantity — not because this image becomes smaller in reality than it was before, but because the sight perceives it as smaller than it truly is: for, [Margin: A doctrine well worth noting, from which countless difficulties in physics and optics are resolved, following what precedes.] steeped in the presence of the greater light, it does not sense the lesser one, however present it is and however much it occupies the edges of the bright circle. And that this is a true and not a fanciful philosophy, I show, confirmed by yet another and most certain experiment. [Margin: The claims are confirmed by another, palpable experiment.] The Sun's image caught under the smallest aperture you will see as large as it [really] is, in a place everywhere free from external light. To prove this, take its diameter with a compass; then, with

everything else unchanged, admit even the least gleam of daylight, and with the help of the compass measure the same image of the Sun: you will find its diameter perceptibly smaller than before. And from what does this come? Did anything depart from the image with the accession of daylight? Not in the least. Rather, the sight, occupied by the splendor of the other gleam of light, could not discern the very faint earlier light. And I have shown this striking experiment to other most expert men as well. Here is another, twin to it. [Margin: Another experiment in confirmation of the foregoing.] I attempted to catch the crescent [corniculate] Venus on paper by means of the telescope [telescopium], and I did project it; but if I shaded the paper-bearing little board so that it was free from twilight and wholly dark, I saw Venus's star clearly on the shadowed paper. If, however, I let in even a little of that otherwise dim light, I saw Venus's image either not at all, or only very grudgingly. The greater light in the eye struck out the sensation of the lesser. Take now another, most celebrated experiment.

[Margin: Another experiment, from a lunar eclipse.] On the past 21 January there was an eclipse of the Moon (but here at Rome it could not be properly observed, owing to the restless passage of the clouds). There was nonetheless an eclipse, which I examined, so far as I could, through the clear intervals with a telescope. When, therefore, the whole Moon lay hidden in shadow — though not in its central part — it appeared very ruddy, like glowing iron. When it began to be restored to its own light, that earlier brightness of glowing iron, suddenly changed, appeared as a dismal, somewhat dark, rusty [ferruginous] color much weaker than before. And this from no other cause than that the bright portion of the Moon, illuminated by the Sun with direct rays, separated the less bright part from perception. [Margin: Another example.] Another example. We know that famous artificial and luminous stone which, if it is exposed to the open daylight, glows in the dark once it has taken in light; but if even a speck of daylight occupies the spot, the eye is blinded to that absorbed light. Why so? Because the presence of the greater light so occupies the sense that the lesser cannot be perceived. I refrain from adducing further experiments — which I would not lack — since those already brought forward convince any sound understanding.

The Sun's image, then, caught through a smaller aperture, is not larger, but appears larger to the sight; and admitted through a larger aperture, it appears smaller, though it is not. This is because the brighter light obscures the very faint marginal radiations of the less bright part; and so, these going unperceived, in the brighter image a smaller portion is seen, in the less bright a larger — because, owing to the absence of more abundant light, the sense grasps whatever shines

within it. Sixth: why, under a larger aperture, does the perimeter of the solar figure appear cleaner, and under a smaller one more ragged? Because the larger aperture admits more of the Sun, whereby it comes about

that the more intense and stronger light removes from the sense of sight those outermost rays that terminate the Sun unevenly, while it steadily sustains the others, which are strong with a vigorous and lively light; and from this even vigor there must result an even and sharply defined limb [limbus] of the solar disc. But when the smallest aperture is used, the outermost rays of the Sun always force their way in; and since these come from the Sun poorly terminated, it is likewise necessary that they present poorly defined margins to the eye.

Let these, then, be what we have discussed concerning the Image of the Sun and drawn from the Image; now let us approach the Sun itself, and test whether similar things are discerned in it by direct gaze.

SECOND EXPERIMENT, directed at the Sun through Telescope and Helioscope. — CAP. XVI.

[Margin: Explanation of the experiment.] If you so cover the convex glass of a good optical tube with an opaque plate of any kind laid over it that in the middle you open a small hole with some rather large needle, and then look at the Sun through it — everything else being duly arranged, under such an aperture as the Sun requires, with the eye applied to the concave lens — you will see the Sun's body very bright in the middle, its light verging on a silvery color, provided you use a telescope. But if you use a helioscope [helioscopium], the Sun's color will be somewhat affected by it. The outermost limb of the solar disc, however — for about a quarter of the solar semidiameter — will be seen all around with a much weaker light, and that light passing into a red or fiery color, like a pointed, flickering flame. And that light appears everywhere most closely continuous and joined with the central light; yet toward the outer parts it is greatly attenuated, and, furrowed with various little points, it plainly shows a roughened perimeter all around. [Margin: The appearance is not from any fallacy of optics, but is a true presentation of the object being such.] That this experiment is no illusion or any deception is proved by the eyes of different observers; by lenses of every kind, whether colored or not; whether simple, such as a single convex, or compound — convex with concave, or finally convex with convex; with the Sun's position upright or inverted; at any place in the sky, eastern, southern, western, or intermediate; at any time of year; in any region of the earth. The Sun, then, always appears

such — even through thin clouds or mists, even through a subtle yet serene and purified atmosphere. But the observer must admit his eye to this spectacle gradually and slowly, beginning from the margins of the Sun, lest, struck by the vigor of the solar rays, it shudder or grow dull — for they are strong enough. Then one must lead the sight out to the very object, the Sun, and not linger on the illuminated convex lens, nor dwell on the little shadows and gleams flitting before it, or the ray-like lines, or other phantasms, about the avoidance of which I have said enough in my *Oculus* [1619]. [Margin: The eye is to be admitted to the Sun cautiously.] For these are effects not of the Sun but of the eye and the lenses, arising from abundant and variously affected or affecting light, and so on.

That the aforesaid appearance of the solar color is not produced by the lenses through any refraction is clear, because the margin, or solar limb, appears such even when considered at the center and axis of the lenses; and the middle portion of the Sun, viewed at the edges of the lens, appears no differently than at its center. Therefore this coloration of the solar image cannot be attributed to an oblique incidence of the rays upon the lens. And what obliquity, after all, could be found in so tiny an exposed portion of the lens? It pre-exists, therefore, on the side of the thing, in the object itself. And the more powerful the tube employed, the clearer this experiment becomes. Meanwhile, however, I warn that the sight which is to grasp the perception of this experiment must be good enough and tolerant of light. Then I add this too: that in this method of viewing the Sun no spot [macula], no facula, could be discerned by me; and the reason is that, owing to the smallness of the aperture, everything is too greatly attenuated, so that apart from the form of the light nothing else can be distinguished. And it is confirmed by another, similar experiment concerning the viewing of the Moon. For if one surveys the Moon with a shorter tube, he will distinguish its old spots well; but if you approach the same Moon with a longer and more powerful telescope, those images of the spots — enlarged by the refraction proceeding from the lenses, and apparently rarefied — will not so easily be seen distinctly, but will tire the sight. In lunar eclipses the extremities of the earth's shadow undergo the same thing: for they are not precisely distinguished from the illuminated parts by powerful telescopes, but best by weak or short ones.

But that this appearance cannot be attributed to the eye either — beyond what was said a little above — I now add these reasons as well.

First: because if this were from the eye and in the eye, it would appear even when the tube is turned toward the middle of the Sun, when it touches none of its margins; yet this does not happen.

Second: it would appear also when the tube is held toward the Moon; yet I have not found this to happen.

Third: because when the Sun is near the horizon and settles into an ellipse [i.e. appears flattened], this appearance is likewise contracted — which would not happen if it resided in the eye alone, for the shape of the eye and the crystalline humor are not compressed at that time, and so on.

Fourth: because things similar to these are represented in the image of the Sun transmitted onto paper through a bare aperture; and since there the eye contributes nothing, but everything happens under nature's guidance, it is clear that both experiments are free from any deception of sight, and that each is most firmly established by the other.

[Margin: The Sun is brighter toward its central parts.] From this experiment two things are clearly drawn out by the immediate view of the Sun itself. The first is that the Sun is brighter in the deeper parts toward the center than it is in the parts near the solar edge. This is proved as follows: if it were equally bright in these marginal parts as in the middle ones, it would also appear equally bright to the eye; but it does not appear equally so, but less bright, by this very irrefutable experiment. Therefore the Sun is brighter in the middle parts surrounding the center than in the outermost parts adhering to the edge — and this is one point.

[Margin: The color of the Sun's edge is reddish.] The other is that the parts of the Sun adjacent to the perimeter appear, and are, tinged with such a color as we see in fire — reddish, ending in a dark tawny but poorly defined [edge]; which I prove by the same reasoning. For if that color were not truly and really in the Sun in the aforesaid ways, it would not appear such in the eye through the telescope; but it does appear, as experience testifies: therefore it is truly and really such. The consequence of the major premise is proved thus: if it were not truly and really present in the Sun, the Sun could not present it to the visual power, since what the Sun does not have it cannot present; nor is that color presented by anything else, on account of which it might be transcribed to the Sun by error.

[Margin: The presentation of the solar color is not from the eye, the tube, or the medium; therefore from the Sun.] For, as I have shown, the presentation of this color cannot proceed from the eye, nor from the lenses inserted in the tube, nor yet from the medium — for that would be the atmosphere and whatever else lies between, up to the Sun. But that this color is not present in this medium is clear from the fact that the Sun exhibits this marginal coloring uniformly in every position of the sky — whether it is viewed at the horizon, at the zenith [vertex], or

between the two — and at any time. But that the medium is everywhere and always imbued with an equal tinge of this kind is simply false and impossible. Again, if all the mathematicians everywhere were to look at the Sun in the said manner at the same time, they would find it growing tawny, just as I have described; hence that appearance cannot come from the interposed medium. Furthermore, the Moon would induce that affection of the medium much more than the Sun does, yet this does not happen. I would maintain the same of Venus and Jupiter and the other planets. Finally, if that color were induced into the Sun by the medium, not only the limb of the Sun but the whole Sun would be equally discolored over its entire disc; yet this does not happen. Therefore it is impossible that anything be introduced into the Sun, by any deception on the medium's part, on the basis of this color.

[Margin: Kepler's opinion about the inflamed aether is refuted.] Johannes Kepler [Kepler], in his *Paralipomena* [*Ad Vitellionem Paralipomena*, 1604], as I intimated earlier, judges that this tinge of the Sun comes about not from the medium, but that the surrounding and adhering aether [aether] is set aflame by the Sun itself, which is fiery in any case; and that thus the Sun is seen at its extremities as less bright, but girt about with a dark-tawny redness, this light being continuous, to the senses, with the rest of the Sun. But the following considerations stand against this kindling. First: that this appearance is perpetual in the same tenor, whereas Kepler would not have that inflammation of the adhering aether be regular, but temporary and rather rare. Second: that it persists always at the same perceptible magnitude, whereas in the said inflammation this would certainly turn out otherwise from time to time. Third: that of that burning there is absolutely no indication or trace outside the visible body of the Sun — for as soon as the Sun has set, the whole image of the Sun is obliterated, whether on paper by intromission or in the tube by emission.

But since the burning of the neighboring aether is seen for a long time by the free, unaided eye before the Sun's rising and after its setting, it is truly remarkable

that nothing at all can be noted [of it] by intromission or by inspection through the telescope — since in the Sun's absence it ought all the more to convey its presence. For what depicts itself on the paper together with the Sun could do so far more readily when the Sun is absent. I pass over for now many other arguments by which the impossibility of this opinion is sufficiently shown. For this matter is discussed elsewhere as well, and perhaps in its own time will be treated more fully.

[Margin: The consequence to be drawn from the adduced experiments concerning the Sun's nature is deferred to other places.] Now, therefore, since we see the Sun to be unevenly bright — more in the middle, less at the extremities — and, besides, somewhat tawny, and not cleanly terminated: from these headings too we have obtained a great occasion for philosophizing about its nature.

WHAT IS USUALLY DEDUCED, FROM OUR OWN AND other modern phenomena, concerning celestial matters. — CAP. XVII.

There are those who say that, from the principles we have adduced thus far and from similar appearances, one can infer — and who in fact do infer — a fiery nature of the Sun, the stars, and the heaven; or their corruptibility; or, finally, a fluid substance. And in order to prove this further, and to avoid the odium of novelty, besides the reasons drawn and deduced from the very heart of the appearances and experiments, they seek out supports from the Holy Fathers, from Sacred Scripture and its interpreters, and finally from men distinguished by various kinds of learning. For their sake, therefore, I faithfully append here for the kindly reader a number of such authorities, gathered into a summary from the very sources I was able to obtain.

On the Fiery Nature of the Heaven and the Stars — According to the Authorities of the Holy Fathers

DE CAELI ET SYDERUM NATURA IGNEA, AD AUCTORITATES SANCTORUM PATRUM. De Natura Caelestium. PROLOGUS GENERALIS.

[On the Fiery Nature of the Heaven and the Stars, According to the Authorities of the Holy Fathers, On the Nature of Celestial Bodies. General Prologue.]

*(folio 625 / *

Magnus Aurelius Cassiodorus [Cassiodorus], who from Senator and Consul of the City became a Monk. From *On the Instruction for Reading Sacred Scripture* [De

Institutione Sacrae Scripturae], from the Preface to Book I. This great man flourished around the year of Christ 575.

The passage below is set off throughout the left margin with quotation marks:

It is not my own teaching, but that of the ancients, that I speak — teaching which it is right for later generations to praise, and glorious to proclaim; for whatever is said of the ancients in praise of the Lord is not counted as odious boasting. [*And, a few words further on:*] Therefore, most beloved brethren, let us without hesitation ascend to the divine Scripture through the probable expositions of the Fathers, as by a kind of ladder of vision, so that, carried upward by their understandings, we may deserve to arrive effectively at the contemplation of the Lord.

Pro Natura Solis, Astrorum, & Caeli Ignea, Auctoritates Sanctorum Patrum.

[Authorities of the Holy Fathers for the Fiery Nature of the Sun, the Stars, and the Heaven.]

*(folio 626 / *

[The page is set in two columns headed with the cross-reference numerals I. (left) and II. (right); the text runs down column I, then continues in column II. Each column also carries printed every-5-line reference numbers in the gutter — a citation apparatus, not reproduced inline.]

[Col. I]

[Margin: Caution 1.] It should be noted that not all the testimonies, nor each single one, are brought forward to serve for all cases or for each single case. For some are suited to all — that is, to the heaven, the stars, and the Sun — while some are assigned to particular things only; and this the prudent Reader will easily perceive from the very context of the words.

[Margin: Caution 2.] It should further be noted that not all the Fathers to be cited are entered in the Catalogue of the Saints, though their title of honor is one attributed to them by many.

AVCTORITAS ECCLESIAE.

[The Authority of the Church.]

Now, what the mind of Holy Mother the Catholic Church is on this matter can be gathered clearly enough from her own daily sacred Hymns, in which she celebrates the deeds of God. For thus at the sixth hour [Sext] she sings each day:

Mighty Ruler, God of truth, who govern the changes of things, you
furnish the morning with splendor, and midday with fires. etc.

Here you see that "morning," or the matutinal time, is celebrated under the word "splendor" on account of the dawn glimmering forth, whereas "midday" is named from the fiery Sun on account of the abundance of light and heat. And that this is said properly, not poetically, is gathered from the fact that by the holy Fathers who composed these hymns the Sun was believed and taught to be truly fiery — both because they declared the same openly in other Hymns, and finally because the Theologians so explain them.

[Margin: On the fiery Sun, the mind of the Church, etc.]

Feria 2. ad Vesperas. [*Monday, at Vespers*]

Immeasurable Maker of heaven, who, lest the mingled [waters] should
be confounded, dividing the streams of the waters, gave the sky [caelum
[?] — first word ink-blotted] as their boundary: fixing a place for the
heavenly [waters] and likewise for the earth's streams,

[Col. II]

that the wave may temper the flames, and not break up the soil of the
earth.

[Margin: Why are the waters above the fiery heaven?] Here you see, according to the mind of the Church, that the waters were raised above the heavens in order to restrain the burning of the Sun and of the other stars, and thus to keep the earth unharmed.

But let us hear more.

Feria 4. ad Vesperas. [*Wednesday, at Vespers*]

Most holy God of heaven, who paint the shining center of the pole with
fiery whiteness, augmenting it with comely light. On the fourth day, you

who, setting the flaming wheel of the Sun, appoint the ministering order of the Moon. etc.

Here it is clear that both the light of the first day and the Sun of the fourth day are reckoned to be of a fiery nature.

Sabbatho ad Vesperas. [*Saturday, at Vespers*]

O blessed light, O Trinity, and sovereign Unity, now the fiery Sun withdraws,

This is the Church, spread throughout the whole world. Now let us attend to the Fathers of the Church — but first let us consider whether, and how far, both she and they are to be heeded in such matters, once we have heard it from the orthodox profession of faith of the holy Roman Church herself, according to the decree of the Council of Trent. For in it, among the other words, every good Christian is accustomed to swear as follows:

Likewise I accept Sacred Scripture according to that sense which Holy Mother Church has held and holds — she to whom it belongs to judge of the true sense and interpretation of the Sacred Scriptures — nor will I ever accept or interpret it otherwise than according to the unanimous consent of the Fathers. Etc.

This most solid foundation having thus been laid, let us be pleased to hear the holy Fathers — what they have thought, from Scriptu-

PARS II. LIB. IV. Cap. XVII.

*(folio 627 / *

[*Two columns, headed I. (left) and II. (right), continuing from the previous page.*]

[Col. I]

—re, about the doubtful questions proposed. Among these, those who expressly taught that the Sun is fire, or of a fiery nature, are the following: Tertullian; St. Basil [Basil], Justin [Justin Martyr], Ambrose, Cyril of Jerusalem [Cyril of Jerusalem], Augustine, Caesarius, Theodoret, Chrysostom [John Chrysostom], Gregory of Nyssa [Gregory of Nyssa], Procopius [Procopius of Gaza], Anastasius Sinaita [Anastasius of Sinai], Arnobius, Lactantius, Anselm of Canterbury [Anselm of Canterbury], Alcuin, Bede, Isidore [Isidore of Seville], Hugh of St. Victor [Hugh of St. Victor], [John] Damascene [John of Damascus], Athanasius, Claudius Marius Victor, Dracontius, Junilius, Peter Damian [Peter Damian].

To these are added, from more recent writers, Augustinus Steuchus [Agostino Steuco] in his *Cosmopoeia* [*Cosmopaeia*], Ascanius Martinengus [Ascanio Martinengo [?]] in his *Great Gloss on Genesis*, and others, to be cited later.

I think it will not be unwelcome to the Reader if I first make the beginning of citing the holy Fathers from the *Ecclesiastical Annals of the Old Testament* of Fr. Jacobus Salianus [Jacques Salián] of the Society of Jesus, published at Paris in 1619, Vol. I, on the fourth day of Genesis, no. iv, page 78 and following. For thus he says:

Those who have said that the heavens are watery generally also attribute a fiery nature to the stars, and separate them from their own orbs in kind and in nature. It is in accordance with their mind that Alexander of Hales [Alexander Halensis] seems to have spoken [Margin: Alexander of Hales], when he says: "It seems rightly said that the luminaries are *finished in* the firmament, not *out of* the firmament — as is stated in what follows, 'let the waters bring forth,' 'let the earth bring forth.' And this is a manner of speaking such as if a precious gem were set in a ring for the ring's adornment, whence it follows below, 'and he placed them in the Firmament of heaven.'" Thus he himself. Yet this seems to have been said by Scripture in a popular way, adapted to the grasp of the common people — but I proceed. And to pass over the more ancient Philosophers, who called the Sun and the Moon and the remaining stars now fiery clouds, now glowing iron, now stones, [now] things kindled by flame, and named them by other names of this kind — as Theodoret relates more fully — I will also pass over the poets, who celebrate that same teaching in their songs with great consent: the Gentiles, I say, and the Christians, with whom the Church [agrees].

"On the fourth day, you who, setting the flaming wheel of the Sun," etc.

[Col. II]

Certainly Tertullian: "The Sun," he says, "is a body, if indeed it is Fire — but a fire such that the eagle may acknowledge it, while the owl denies it." [Margin: Tertullian]

St. Basil says that the opinions of those who deny that the Sun is hot are "silly and old-womanish," and that the view of those who deny the Sun to be endowed with a fiery nature is not true — where he seems to censure the Peripatetics; just as Justin does in his refutation of Aristotle. [Margin: St. Basil; Justin; Ambrose] Ambrose, after his custom, follows Basil.

But remarkable is the opinion of Cyril of Jerusalem [Margin: Cyril of Jerusalem]: "The heaven is water, and in it the Sun is fiery, and the Moon, and the Stars — and how do fiery things run their course in water? But if anyone doubts about this on account of the contrary natures, let him recall that fire which ran forth amid the hail in Egypt in the time of Moses, and let him consider the most wise workmanship of God."

Add Caesarius [Margin: Caesarius]: "Since I have said that the Firmament is of crystal, it was to receive the splendor of the luminaries set beneath it — the Sun, I mean, and the Moon, and the rest of the assembly of the stars, which have their nature from fire. Therefore, lest what is fixed should be dissolved by their burning, on account of this He separated off from it that boundless water, set as it were upon its shoulders, to cool their blaze and to smooth their rotation, so that, made denser by that moisture, it might resist the fire of the luminaries. And because he perceived that these things exceed the powers of nature, in question 69 he asks: How can it come about that ice resists fire — ice which in no way endures the nearness of fire, nor the touch of a hand, nor warmer air, nor to be covered with a garment? And he answered: But those supramundane things are not to be subjected in every respect to earthly ones; for the divine power dispenses and governs all things otherwise than [it would] for our weakness, etc. Yet next he renders this probable by examples drawn from nature, and by miracles taken from Scripture."

Theodoret: "God divided the nature of all the waters in two, and set some of them above, which by their fluid and their cold would not allow the firmament to be corrupted by the fire of the luminaries." [Margin: Theodoret] And in his first Sermon on Providence: "For this reason, then, since so great a fire revolves about this heaven — namely that of the Sun, of the Moon, and of the remaining stars — yet through the revolutions of so many years it is neither melted and poured out, nor dried up, nor set alight and burning. [*And further on:*]

ROSAE VRSINAE LIB. IV.

*(folio 628 / *

[Two columns, headed I. (left) and II. (right), continuing from the previous page.]

[Col. I]

Nor does the abundance of the waters extinguish the nature of the fire, nor does that icy — or airy and cloudy — body of the heaven melt or perish from that excessive and burning heat of fire; but although they dwell side by side as neighbors, they nevertheless conceal their hostile forces, and, persuaded by the word of their Creator, they have ratified a perpetual friendship." Thus far he. You will read things similar to these on Psalm 148.

St. Chrysostom [Margin: St. Chrysostom] calls the Sun an "Element," and attributes to it the properties of fire — heating, drying, hardening [*durendi* — reading uncertain [?]], and many others. Still more clearly, when he reviews the various differences among fires, he says there is one fire in the Sun, another in the Moon, another in lightning, another in the air, another which comes from wood, and so on. And again, comparing the Just to the stars, he says: "Theirs is the fiery nature of the stars, and these (the earthly stars, that is) are taught to obtain a fiery nature. But there [it is] the fire which human sense discovers, whereas here [it is] the fire which the secret things of the mind reveal."

Gregory of Nyssa [Margin: Gregory of Nyssa], in his account of the six days [*Hexaemeron*], teaches that the stars are of a fiery nature — and indeed from that which in fire is most subtle and lightest.

Procopius [Margin: Procopius]: "God arranged the light, the Sun, the Moon, and the stars — the substance of all of which is fiery — in such a way that they should carry out their motion in the Firmament. But fire is of such a nature that it powerfully scatters and dissolves things congealed [*congelata* [?]] and concreted out of the waters. Therefore, lest this should perhaps happen to the heaven, He of necessity placed so great an abundance of waters in the upper region, which would keep the heaven unharmed and inviolate from the burning of the fire."

Anastasius Sinaita [Margin: Anastasius of Sinai]: "For He who," he says, "made the heaven firm out of the waters, and suspended the earth upon the waters, could also — even without water — keep the firmament indissoluble, even from the fire of the Sun."

Arnobius [Margin: Arnobius] indicates that the stars are fiery — and so does

[Col. II]

Lactantius. [Margin: Lactantius] Now, how contradictory and absurd is this: that while they affirm the heavenly fires and the other elements of the world to be gods, they likewise call the world itself God.

Anselm of Canterbury [Margin: Anselm] affirms that the Sun, the Moon, and the stars are by nature fiery.

Likewise Alcuin and Bede. [Margin: Alcuin, Bede, Isidore] Isidore asserts this of the Sun, but is silent about the rest.

Hugh of St. Victor [Margin: Hugh] makes the Sun fiery, but the other stars airy.

In so great a consensus of the ancient Fathers, then [Margin: Fr. Salian], what forbids us — just as we confess with them that the heavenly orbs are made from water, yet dissoluble by no force except the divine, thanks to the form implanted in them by their author — to confess likewise, as probable and out of regard for venerable antiquity, that the stars too were begotten by God's craftsmanship from the substance of fire?

SENTENTIA D. AVGVSTINI.

[The Judgment of St. Augustine.]

Now I cannot pass over the notable testimonies of St. Augustine. [Margin: Clear testimonies of St. Augustine for the fiery Sun.] In his first Sermon *On the Words of the Apostle* he argues thus:

How is the divinity distinguished from itself, when the splendor of its light or the heat of its Sun is in no way separated [from it]? For behold, just as we see, in the Sun there are three things, and they cannot be separated at all. Let us see what the three are: course, splendor, and heat. For we see the Sun running in the sky, shining, and giving heat. [Margin: Formal heat in the Sun.] Divide, then, if you can, O Arian, the Sun — and only then divide the Trinity. But perhaps the reasoning about distinguishing the Sun is difficult, because it is in the sky and set far from us. Behold, we propose another element, which is smaller and is here on earth with us: I mean Fire, which is held in our hands, and yet is not divided. For Fire, too, has three things and cannot be divided — that is, Motion, Light, and Heat. [Margin: St. Augustine makes the properties of the Sun and of Fire the same.] If, then, O wicked heretic, you cannot divide the created Sun and Fire, how can you divide God, the Creator of all?

The same [Augustine], in his first Sermon, on the Sunday nearest before the Lord's Nativity: [Margin: Another testimony of St. Augustine.] "Behold— [Margin: "Formal heat in the Sun." (*Calor formalis in Sole.*)]

[Augustine, continuing:] "See once more another instance in the Sun. Heat and splendor are present in a single ray; yet heat dries, splendor illuminates: heat performs one office, splendor another. And although heat and splendor cannot be separated from each other, splendor takes on the act of illuminating, not of burning, while heat takes on burning, not illuminating. They act partly together, partly each on its own, and yet are never separated from one another. So too the Son took on flesh and did not abandon the Father, and so on."

[Margin: "Another testimony of St. Augustine." (*Aliud D. Augustini Testimonium.*)]
[Margin: "The Sun is formally hot." (*Sol formaliter calet.*)]

"The same, in the *Appendix*, Sermon LIX: Through the creature the Creator is understood, by these comparisons and by a great many others. Sun, brightness, and heat: there are three words, and the three are one. What shines is hot, and what is hot shines: these three words are recognized as one single reality. So the Father, the Son, and the Holy Spirit—three persons—are one in the Godhead, and are rightly believed to be an indivisible unity."

So the holy Doctor. And do not say that he used these examples merely for the sake of teaching, without supposing that the matter really stands so in nature. For that would be to fasten a grave reproach upon the most holy Father—as if, employing figments he knew to be such, he wished to illustrate the hidden articles of our faith and to stop the mouths of heretics with empty inventions—whereas he himself expressly declares that he brings these things forward precisely so that through created things the Creator may be understood. It is therefore clear that St. Augustine [Augustine] and the men of his age held it for undoubted truth that the Sun is as hot as they saw it to be bright and mobile; and hot indeed not merely effectively but formally [*non effective tantum sed formaliter*], and thus that it is fire.

Blessed Peter Damian [Peter Damian], who flourished in the year of the Lord 1080, writes as follows in Sermon 1 *On the Epiphany of the Lord* (vol. 2, p. 2, of the Roman edition, 1606):

"In a star, brethren, four things are chiefly displayed. For a star is of fiery nature; a star is in itself bright and clear; a star sends forth a ray from itself; a star shines in the night, and so on. A star, as we have said, is of fiery nature."

So he. If, according to this Father, a star is of fiery nature—and he asserts this generally of any star whatever—then surely it must be understood much more of the Sun. And this Sun, when he pronounces it free from every spot [*ab omni Macula immunem*], must certainly be taken as it was known to those times by unaided sight and observation.

In favor of the fiery nature of the Sun, there are also cited those writers who assert that the Sun was created on the fourth day out of a fiery or luminous cloud.

CAP. XVIII

Furthermore: since there are many who, though they did not write in express words that the Sun is fire or fiery, nevertheless said that on the fourth day it was made—or perfected, or augmented—out of that light which they acknowledged to have been created on the first day as either fire, or a fiery quality, or a cloud, or a substance or form of that kind; for this reason these authors too, as not unlike the first opinion, ought to be brought in here. For whoever says that the primeval Light created by God was fire, or of fiery nature, or a fiery cloud or luminous nature, or a similar body, and then out of it, once purified, forms the Sun, and so on—he certainly transfers into the Sun that which most belongs to the nature of fire. And this is what most of the cited authors did, along with many others soon to be mentioned. And conversely, whoever recognizes the Sun as fiery by nature, and admits no other heavenly primeval light besides it, will surely not exclude from the Sun and from the nature of fire that light which on the first day illumined the world.

[Margin: "To the authors who expressly taught that the Sun is fiery must be added also those who wrote that the Sun was formed on the fourth day out of a fiery cloud, etc."]

Therefore, besides the authors named a little earlier, those who handed down that the Sun was made by the Creator out of a fiery or luminous cloud—in agreement (as they claim) with sacred Scripture—are these:

- The Master of the Sentences [Peter Lombard].
- [Peter] Comestor [Peter Comestor].
- Alexander of Hales [Alexander Halensis].
- Bonaventure.
- Lyranus [Nicholas of Lyra].
- Tostatus [Alonso Tostado].
- Didymus [Didymus the Blind].

- Apollinarius [Apollinaris].
- Jacobus Billius Prunaeus [Jacques de Billy].
- St. Thomas is favorable.
- Juvenicus the Presbyter.

And although it does not escape me that some among these writers nonetheless held the Sun to be incorruptible, even though they had formed it out of a luminous cloud—still, if they wished to keep consistently to Peripatetic philosophy and Thomistic doctrine,

they would by no means proceed by these lines of argument. For, according to the mind of St. Thomas (Part 1, q. 67, art. ult., *ad secundum*): if the Sun was made from a luminous cloud, then the Sun's body is of the nature of the four Elements, and consequently, above all, of the nature of fire. Thus [Paul of] Burgos [Paul of Burgos] explains and defends St. Thomas against Lyranus, in his seventh Addition.

[Margin: "The teaching of St. Thomas, drawn from Burgensis, as given in Martinengus, Part 7, p. 863."]

"Saint Thomas," he himself says, "does not disprove the third position—which says that the Sun was made from that luminous cloud—on the ground that in the first production of things one ought not to say that anything was produced only to be corrupted quite soon, as the Postillator [Lyra] imputes to him; rather, the holy Doctor disproves this position by another means, conditionally—namely, if the Sun's body be supposed incorruptible by nature: because on that supposition its matter could not have existed under any form distinct from the form of the Sun which it now has, etc."

[Margin: "The words of St. Thomas."]

St. Thomas, in Part 1, q. 67, art. 4, writes thus:

"And so others say that the Sun's body was formed out of that cloud. But this too cannot be said, if the Sun's body be supposed not to be of the nature of the four Elements but to be incorruptible by nature: since on that supposition its matter cannot exist under another form; and therefore it must be said, etc."

[Margin: "A doctrine of St. Thomas to be noted."]

Therefore, according to the mind of St. Thomas and Aristotle: if the Sun is endowed with an incorruptible nature, then it could not have been made from any luminous cloud. And if it was formed from some pre-existing luminous cloud,

then it consists of elemental matter, and consequently turns out to be corruptible and fiery in nature.

[Margin: "St. Thomas also admits the opinion that the Sun is of fiery nature."]

Hence, on the interpretation of Burgensis and of St. Thomas himself, St. Thomas does not absolutely reject as false the opinion that makes the Sun of fiery nature; indeed he even admits it. He rejects it only conditionally [*tantum conditionaliter* [?]]—namely, if one should wish to follow the positions of Aristotle, etc.

[Margin: "St. Bonaventure judges that deference is owed to the holy Fathers."]

St. Bonaventure certainly, in Book 2, dist. 14, part 2, doubt 3—where he argues many things admirably on both sides concerning the Moon and its light, and inquires whether it is of fiery nature, etc.—expressly approves the opinion of the holy Fathers, who say that the Moon and the Sun were made as luminaries out of that primeval light.

"Maintaining this manner, then," he says, "out of reverence for the Saints, and because in this matter it is safer to rely upon their words—a matter in which one proceeds more by conjecture than by sure reasoning—we must say that the luminaries, in so far as they are constituted from their orbs by aggregation, have more fitness for receiving than for diffusing [light]; but that they shine, this they have from the perfection of the light first created. And therefore that luminary to which God gave much of that light shines the most, as this Sun does; that to which He gave less shines less, and that to which He gave least shines least of itself: yet if it shines, this is by its reception of the solar influence, etc."

[Margin: "St. Bonaventure teaches that it is safer to rely upon the opinions of the holy Fathers."] [Margin: "The primeval light was distributed among the luminaries."]

The same holy Doctor, in Book 2 of the *Sentences*, dist. 13, art. 1, q. 11, *ad* 5, has this:

"To the objection that it was superfluous to make the Sun, we must say that it is false; for even though that light illuminated perfectly and made the day, as far as sufficed for that time, for the distinction of days, it nevertheless pleased God—once things had been brought forth to a greater perfection, namely for adornment—to make a fuller light, one that would also make the day brighter; and on this account, from that very light, or luminous cloud, He made the Sun in a greater light, as will be said afterward. And by this is answered the last

objection, namely that that light ought to have remained; for we must say it is true that it remains according to form and nature: but it need not remain in that state in which it was first formed. It remains, however, in the Sun, which was formed from it, as the expositors intimate, and as appears better upon the [scriptural] letter."

[Margin: "The Sun was made out of a luminous cloud."]

Therefore these holy Doctors, Bonaventure and St. Thomas, do not absolutely repudiate that opinion concerning the corruptibility of the Sun, but only conditionally—if one should wish to insist on the philosophy of the Stagirite [Aristotle], etc. For the rest, Hugh too will readily admit—says Ascanius Martinengus [Ascanio Martinengo]—that the solar body is compounded of fire, or of the Elements, and could therefore have been made out of that shining cloud; and to this opinion of Hugh's nearly all the Fathers assent. Nor does St. Thomas himself

[Margin: "Part 2, the *Glossa Magna* on Genesis, p. 863."]

dare to attack it, except upon the concessions and subscriptions of the Peripatetics, who maintain that the stars are not liable to corruption. So Martinengus. Now it is worth approaching the ancients themselves once more and hearing them more fully; for, as the proverb has it:

The waters are better drunk from the spring itself.

Here note that, although I cite many authors from Ascanius, nevertheless all that I could obtain have been seen and examined by me in the sources themselves, so that no difficulty concerning the accuracy of the passages cited need creep upon anyone.

[Margin: "St. Gregory of Nyssa."]

Gregory of Nyssa [Gregory of Nyssa], in the *Hexaemeron*, or *History of the Six Days*:

"I do not think our view will stray from what is probable and fitting, if we suppose Moses [Moses] to have meant this: that in the beginning, indeed, the whole illuminating power, heaped up and gathered into itself, became light; but since a certain great difference—in respect of greater and lesser—was discerned in that subtle and nimble [substance] within the nature of the universe of things, a span of three days sufficed for each of these to be discerned, and, without confusion, for the one to be drawn off and separated from the other: so that

whatever, from its fiery nature, was subtle and light and wholly free of matter should dwell in the highest place, [a place] falling under the perception of sensible nature; and this part the nature that is discerned by the mind and is incorporeal receives. But whatever was sluggish and inert would come together within the embrace of that thin and light [substance] about itself; and this, again, would be divided—according to the difference of its innate property—into seven parts, all the particles of light that were equal and of the same nature coalescing with one another by kinship, and being separated and parted from those of another kind. Thus, then, whatever was interspersed through the illuminating solar nature—when all these particles had run together, one to another—became one great light.

[Margin: "The origin (*genesis*) of the seven Planets from fire."]

"In the same way, too, in the Moon, and in each of the rest—both the wandering stars and the non-wandering fixed stars—the running-together of each one's particles toward things of its own kind produces some one thing of those that appear in the heaven; and thus all things were made. And it was enough for the great Moses, when he had named only the most notable among these—the greater luminary and the lesser—

to call all the rest generally by the name of stars, etc."

Claudius Marius Victor [Claudius Marius Victor], the orator of Marseilles, in Book 1 of his *Commentaries on Genesis*:

Now that three [days] were completed, kindled [*succensa* (?)] by swift motion, the Sun's first day—bidden to gather itself into flames and a globe of fire— and the founded seeds of light scattered their ruddy tresses with rosy kindling.

From these lines Claudius Marius Victor is seen to have thought the Sun nothing other than a flame and a globe of fire, by a definition conformable to that of the Nyssene [Gregory of Nyssa], etc.

[Margin: "Hugh of St. Victor."]

Hugh of St. Victor [Hugh of St. Victor], in his annotations on Genesis, chapter 6, expressly taught this: "On the fourth day, out of the aforesaid light or fire, by improving it with form and splendor, He made the Sun." From this we conjecture that the Sun was made from the fire mentioned above. And a little later: "The Sun alone has its own light, and it alone was made from fire; but all the stars, like the

Moon, were made from airy matter, and only reflect light, and do not shine of themselves."

[Margin: "The Master of the Sentences [Peter Lombard]."]

The Master of the Sentences, in Book 2, dist. 13, as we reported above: "But if it is asked what became of that light, since it now does not appear: it can be said either that the Sun's body was formed from it, or that it is in that part of the heaven where the Sun is—not that it is itself the Sun, but that it is so united to it that it cannot be distinguished."

[Margin: "Peter Comestor."]

Peter Comestor, in the *Scholastic History*, chapter 6, when he enumerates the outcomes of the first, primordial [*ordialis* (?)] light, did not omit this. Concerning that luminous cloud spoken of above, it is handed down in the following way: that either it returned into the matter from which it had been made—like the star that appeared to the Magi, and the dove in which the Holy Spirit was seen; or that it always accompanies the Sun; or that from it the solar body was made.

[Margin: "Alexander of Hales."]

Alexander of Hales, [Part] two, question fifty-one: "To this it is relevant that the light which was made on the first day did not cease to be; for it rather appears to have been turned into the luminaries, inasmuch as that which formerly distinguished day and night was then, in a fuller manner, accommodated to sight, and in a more perfect manner too, because in it [the Sun] the light is more perfect and more distinct."

[Margin: "St. Bonaventure."]

St. Bonaventure, in the Commentaries on the distinction cited above, etc.: "Hence there is a third manner of speaking—that the Sun was made from it [the light], and is preserved in it as in a thing of the same kind. But since Scripture does not seem to express

that after the first day God produced a new light, but only distinguished the luminaries: therefore there is a fourth opinion, that from that light the luminous bodies were made, among which the Sun holds the primacy; and there was no violence there, because each creature received that place which the Lord had by nature assigned to it. And thus the objections are answered, since there was neither a corruption of that light nor any violence, but rather a certain greater perfection and distinction."

[Margin: "Nicholas of Lyra."]

Lyranus [Nicholas of Lyra], in the *Postils*, in the second exposition: "Here is described the work of the Fourth Day, and here is understood the making of the luminaries as regards their specific substantial forms; and according to this exposition, the Sun was made out of that aforesaid luminous cloud, which during the three preceding days made the day and the night by its diurnal motion."

[Margin: "Tostatus."]

Tostatus [Alonso Tostado], on Genesis: "On the fourth day the Sun was made, which circled in a nobler manner than that light did. Hence it is believed to have been made from that little cloud, having advanced [*profectum* (?)] substantially into another species, and accidentally in its brightness and in its power of exerting influence." So much, from these authors, concerning the luminous cloud.

[Margin: "St. Basil."]

St. Basil [Basil], in the *Hexaemeron*, Homily 6, sets this out more eloquently and more clearly, and reports that on this day the globes were heaped together as vehicles of the first-created light:

"These things certainly do not conflict with what was said about light: for then the very nature of light was produced, whereas now this body of the Sun was founded for this purpose—that it might be a vehicle for that first-born light. For just as fire and a lamp are distinct and different things, and not the same—fire indeed possessing the power of illuminating, while a lamp was made for this, that it may furnish at least a moderate light to those who need it—so too, for that most pure, unmixed, and immaterial light, the luminaries themselves have now been built up as a vehicle, so to speak, etc."

Furthermore, since St. Basil proves most copiously and of set purpose [*ex instituto*] that the Sun itself is fiery, against certain ancient philosophers who deny it—and derides them as madmen, as he himself calls them (*Hexaemeron*, Homily 3)—it must follow that this abstracted light was recognized by him as nothing other than the light of fire; which he sufficiently proves by many examples drawn from Scripture, etc. Basil's words are these:

"Although not even they concede that the Sun is hot. So greatly do these men, with their abundance of leisure, run to excess in crazy and old-womanish trifles, etc."

[Margin: "Didymus."]

Didymus [Didymus the Blind], as [given] in the *Catena* of Lippomanus [Luigi Lippomano]: "And just as the water first spread over the face of the earth God afterward, on the third day, gathered into one—whence the seas and rivers and wells arose—so also that first light, spread over the whole heaven, He gathered into one on the fourth day and formed into the Sun, the Moon, and the stars; so that the Sun is nothing other than the day."

[Margin: "Apollinarius."]

Apollinaris [Apollinaris], with Steuchus [Agostino Steuco] as translator: "From the first-born light He selected into the Sun whatever was purest, and assigned the remainder to the Moon and the stars."

[Margin: "Damascenus."]

John of Damascus [John of Damascus], *On the Orthodox Faith*, Book 2, chapter 7: "Into these luminaries the Maker implanted the primeval light—not as though needing another light, but lest that light should remain idle and unemployed; for a luminary is not the light itself, but the receptacle of light." But of what kind that light was, hear from the same holy Father, as reported thus in the *Glossa Magna* of the same Ascanius, part 1, p. 471: "Fire is one of the four Elements, the lightest of the rest and most swiftly flashing upward, capable of burning and of illuminating, created on the first day by the Maker of things. For the divine Scripture says: *And God said, Let there be Light, and Light was made.* For fire is nothing other than Light, etc."

Nor is this contradicted by what the same holy Father says in the cited Book 2, chapter 7: "This too," he says, "is manifest: that the Sun, the Moon, and the stars, being composite, are subject to corruption according to their own nature; but what their nature is, we do not know." This, I say, does not contradict the former; for the Sun can nonetheless be [shown to be] of fiery nature [text prints *prohiberi potest*; sense requires *probari potest*, "can be proved" [?]], even though it is not known what its nature is as an individual. The Damascene, says Benedict Pererius [Benito Pereira] (vol. 1, Book 1, on Genesis, p. 46), "seems to have thought that that light was the element of fire, etc." And since God, according to the mind of this holy Father, transferred it into the Sun, unchanged in its substance, etc.—

It is evident that, according to the mind of this holy Father, there is fire in the Sun. Although what sort

[Continues in the following chapter's material.]

confesses that he does not know what its nature is in its lowest species.

[Margin: Theodoret.] Theodoret, in Question 14 on Genesis, relates as follows that God fashioned the luminaries on the fourth day out of the first light:

"And so he created light too, just as it pleased him. And just as by the firmament he separated the nature of the waters — placing some above and leaving the rest below — so, dividing that light according to his own will, he made the luminaries, both great and small. But since it is clear from another passage of the same author that the Sun is fire, it is evident that this light, being received from it, [has] the property of fire," etc.

[Margin: Anast. Syn.] Anastasius Sinaita [Anastasius of Sinai], in his Commentary on Genesis, book 4: "The light of the three preceding days," he says, "spread out and dispersed throughout the whole universe, showed that the light of the uncreated Trinity reaches everywhere and leaves no place empty of it. But when on the fourth day the orb of the Sun is fashioned, and that light which is everywhere present is placed within it," etc.

And since he recognizes the Sun to be fire — as was seen earlier from Salianus — it is plain that this light of the Sun, bestowed by it, is a Quality of fire, etc.

[Margin: S. Athan.] Athanasius, in Question 83 on Genesis: "And God said, Let there be light, and there was light." And a little later: "Since this light was great and most splendid, God divided it into those luminaries — the Sun and the Moon and the rest." And afterward, in Question 85: "That great light which God had made, he divided into the luminaries. This light, scattered here and there, was to some extent diminished; and had this not been done, the animals could not have borne the great blaze and radiance of so great a fire. Indeed it was for this very reason that the animals were created after the Sun and the Moon, so that they might be able to endure the splendor of that fire." [Margin: The Sun made out of fire.] In Question 74 the same Father has these words: "God divided that great light which he had made into the luminaries."

[Margin: Procopius.] Procopius agreed wonderfully with Basil in his Commentaries on Genesis, chapter one — passages that may be seen either in the author himself or in Martinengo; I transcribe only a few.

"God," he says, "taking the purest part [of the primeval light], transferred it into the Sun; the remaining part he distributed among the Moon and the other stars. Just as God gathered all the water that formerly flooded the whole earth into one receptacle, as it were — namely into the seas, rivers, and wells — so he drew

together into one the light that had been abundantly diffused into all things: the Sun, the Moon, and the stars; and from these he shed light abroad."

[Margin: Bonaventura.] Bonaventure, in the second book of the *Sentences*, distinction fourteen, approves this opinion. He does not, however, admit the corruptibility of the Sun, etc.

Then, having reviewed all the authors in order, together with the rich texts that Fr. Salianus cites, Ascanius adduces more from others. [Margin: Iuuenus.] Juvenius the Presbyter, in the Prologue to book 1 of his *Evangelical History*, twice calls the stars fiery:

Nothing immortal is held within the frame of the world: not the sphere, not the realms of men, not golden Rome, not the sea, not the earth, not the fiery stars of heaven. For the Begetter of things has appointed an irrevocable time, when a final rushing flame shall seize the whole world.

[Margin: Alcuinus.] Alcuin — or Albinus Flaccus — the teacher of Charlemagne, in his *Questions on Genesis*. To the question, "Which creatures were made from nothing?" he answers: "Heaven, Earth, the Angels, Light, Air, Water. The soul of man." "Of how many elements does the world consist?" "Four: fire, air, water, earth." "Of what nature is heaven said to be?" "Fiery, round, and revolving."

[Margin: S. Beda.] Bede, in the book *On the Nature of Things*, chapter 5: "Heaven is of a subtle and fiery nature, gathered together on every side at equal distances from the center of the earth." And chapter 19: "They say that the fire of the Sun is nourished by water," and: "Since it is fiery by nature, by its excessive motion it also increases its heat."

[Margin: Anselmus.] Anselm of Canterbury, *On the Image of the World*, book 1, chapter 23: "The Sun (Sol) is so called because it alone shines (*solus lucet*) when the other stars are darkened, or because it shines above all things; spherical in shape, fiery in nature.

"And the body of the Moon is spherical, fiery in nature but mixed with water. And concerning the stars, in chapter 20: All the stars are round and fiery, and their arrangement is known to God alone."

[Margin: S. Isidorus.] Isidore, *Etymologies*, book 3, chapter 48: "Since the Sun is fiery, it grows still hotter from the excessive motion of its revolution; and the philosophers say that its fire is nourished by water, and that it receives its power of light and heat from the opposite element."

[Margin: Mag. Sententiarum. (Master of the Sentences)] The Master of the Sentences, in the second book, distinction 14, ascribes this to Augustine: "Some, however, say that the heaven which lies beyond the regions of the air is of a fiery nature, maintaining that above the air there is pure fire, which is called heaven; and they conjecture that the stars and luminaries were made from this fire. With whom Augustine seems to agree." (*On Genesis, Literally*, book 2, chapter 3, etc.)

Augustine certainly never disapproved of this opinion; rather, he admitted it as at least probable, as will be shown from that same passage of his — indeed he expressly taught that the Sun is formally hot, as was demonstrated a little earlier from his own words.

[Margin: Iunilius.] Junilius, the African bishop, who according to Bellarmine (*On Ecclesiastical Writers*) flourished around the year of the Lord 545, in his little book *On the Parts of the Divine Law* holds views consistent with these. For he says that the heaven made on the first day was air, and he deduces this from Scripture: "And let there be a firmament."

[Margin: A fluid firmament.] "Assuredly," he says himself, "this signifies that there was something fluid and liquid — that is, waters," etc.

"And again, he called the luminaries 'derivative,' which were made on the fourth day, so as to show that they were made from the light produced on the first day. But among the things made on the first day, it is nowhere declared, either openly or by any subtle expression, that one was made from another."

In the same place he appends, to the questions of the Disciple (Δ), the answers of the Master (M), as follows:

Disciple (Δ): The things that were made from something — how many materials did they have?

Master (M): Six: Earth; Waters; Air; Fire; Light; the Rib.

Disciple (Δ): Give the origins of each individually.

Master (M): From earth: green things, plants, and animals. From the waters: the firmament, the sea, swimming and flying creatures. And at the same time from earth, water, fire, and air: all the things that are renewed by succession. From Light: the luminaries. From the rib: Eve. [Margin: The firmament made from the waters.]

Disciple (Δ): How is it proved that fire was made? Or from what? Or in what way?

Master (M): That it was made we can confirm from Scripture in a general way, since it is said of God, "Who made heaven and earth, the sea and all that is in them" — for fire too is certainly among them. From an explicit statement: "Praise the Lord from the earth, you dragons and all deeps; fire, hail, snow, ice, stormy winds" — of which he had said before, "For he himself spoke, and they were made." And again: "Bless the Lord, all you works of the Lord," and he added, "Bless the Lord, fire and heat." But whether it was made from nothing, like the other things, or from something, is doubtful. For many hold that it is a particle of the heavenly luminaries; indeed even now we frequently see men borrow fire in a certain manner from the rays of the Sun. If that is so, it was made on the first day. But Scripture more wisely called it "light" rather than "fire," so that it might take its name from the better use. [Margin: Our fire is a particle of the solar fire — according to the probable opinion of this and other authors.]

From this it is clear that this most learned Father acknowledges the greater luminary to have been made from the first light, and admits that the Sun is fiery; and that the fire created on the first day was called "light," by a more illustrious term on account of the nobler use of shining — indeed also on account of the purpose and intent of God the Maker: for God had intended to dispel the darkness, and therefore he named the fire created on the first day "light," and called its effect "day."

[Margin: S. Bruno.] St Bruno, patriarch of the Carthusians, distinguished in the eyes of the Supreme Pontiffs as much for the holiness of his life as for his reputation for learning, in his Commentaries on Psalm 148, on those words ["Praise him, Sun and Moon; praise him, all stars and light," etc.]: "You faithful," he says, "praise him" (namely God) "through the contemplation of all these things" (that is, of the Sun, the Moon, the stars, all the heavens

and the supercelestial waters) — because he himself spoke, that is, established, willed, arranged; and from nothing were made the four elements, which were the material of all these things. He afterward gave the command within that same arrangement of his, and all these things were created — that is, formed out of these four elements." [Margin: All things formed out of the four elements.]

In this Patriarch's view, then, the predominance of fire must certainly prevail in the Sun. And in a word, all who acknowledge that the Sun was created and formed out of the elements deserve to be enrolled in this Father's company; for they could in no way free the Sun from a fiery nature.

[Margin: Rupertus Tuitiensis.] Rupert, abbot of Deutz, in book 1 on Genesis, chapter 41, speaks thus: "Here we must not pass over what the natural philosophers elegantly declare about this great governor (the Sun) of this heaven — that it is the source of the ethereal fire, the heart or mind of heaven, and the tempering of the world."

The same Father gives us a clearer sense of this teaching in chapter 46, in these words:

"This world, then, these luminaries alone illuminate. Concerning them, this too must not be passed over: that it was chiefly for their sake that the firmament had to be revolving — namely, so that the Sun, which is of such great heat that (as was said above) it has been called the source of the ethereal fire, and was made for this very purpose, might provide not only illumination but also a frequent tempering of the world, being present to all its parts; and so that the notable order of the stars, wheeling round so often, might become better known. For it is now much better, since the burning Sun is present briefly indeed, but frequently." [Margin: Solferuidus (the burning Sun).]

From this it is clear that in the time of this Abbot — that is, nearly 500 years ago — the Sun was held by the natural philosophers to be of a fiery nature.

The Authorities of St Dionysius for an Ignited Sun, and for a Fluid and Corruptible Heaven

Nor does St Dionysius the Areopagite seem to have been a stranger to this opinion or teaching about a fiery Sun — a witness whom I ought otherwise to have brought forward long ago. But because he does not set this opinion forth so clearly that others might not doubt it or lean toward the contrary, I have deliberately deferred it to this last place, as it were, to be aired here and settled by the judgment of the greatest men.

The arguments, then, by which St Dionysius assigned the Sun to a fiery nature are these. [Margin: The arguments from which St Dionysius's mind, in favor of an ignited Sun, is gathered.]

First: because he expressly teaches that the light of the first three days was transformed into the Sun on the fourth day — which, as we saw a little earlier from his own words, St Thomas denies can happen generally and absolutely, if one supposes that the body of the Sun is not of the nature of the four elements, but is incorruptible by nature, etc.

Second: because he holds that the first light was carried around without any subject and without a fixed shape — men distinguished partly for holiness, partly for learning, so explaining him, as will soon be seen. Hence they even openly declare that on this matter he agreed with St Basil; and it is established, according to St Basil, that the Sun, fire, and that first-born light are one and the same.

Third: modern theologians also come forward who judge that St Dionysius thought otherwise than many Scholastics interpret him.

So that all this may be plainly established, here are the very words of St Dionysius and of the commentators just praised.

[Margin: S. Dionysius.] St Dionysius the Areopagite, chapter 4 of *On the Divine Names*, page 187 of the Paris edition, from the translation of Fr. Petrus Lansellius, 1615, which runs as follows:

"Moreover — a point that had slipped from us in the middle of our discourse — the cause of the heavenly beginnings and endings is the highest Good, whose essence and nature can neither increase nor diminish nor be changed in any part; the cause too of the motions which, without sound (for so one must speak), are borne along in the vast course of the heaven, and of the configurations of the stars, of their beauties and lights and steadfastnesses, and of the manifold motion by which certain stars are carried, and of the two luminaries which the divine Scriptures call 'great' — [carrying them] from the same places back to the same, by a recall and return which is borne round in a circle, by which our days and nights are determined, and the months

and the years — the measure of comprehended time and of those changes which occur in time; and they define, number, regulate, and contain them.

"What might one say of the very ray of the Sun taken in itself?" And, after much more: "For this is that light — even though it then lacked the form of a definite body — which the divine Moses records to have marked off and distinguished even those first three of our days."

So says Dionysius, in whom the reader will find wondrous praises of the Sun — whose light, he says, is desired by all, both those that possess reason and sense and those that lack them. I cannot refrain from excerpting a few small passages for the benefit of those who perhaps have no access to this author. So then this great Father says, in the same place:

"For from the Good itself comes light, and it is an image of goodness. And so the Good itself is celebrated under the name of light, as the original pattern

expressed in an image. For just as the goodness of the divinity that surpasses all things reaches from the highest and worthiest natures down to the lowest, and yet excels them all — so that neither do the higher attain to its excellence nor do the lower pass beyond its grasp — but it illumines all that exists, and makes and quickens and contains and perfects them, and is, of the things that are, their measure, eternity, number, order, connection, cause, and end: so too this great Sun, which is a clear and express image of the divine goodness, wholly shining and ever splendid, in the least likeness of that Good, shines upon all things that can receive its light, and has a light diffused through all things, unfolding in every way that we perceive the splendor of its rays, both upward and downward. And if there is anything that does not share in them, that is not to be attributed to any thinness or smallness of its diffused light, but to those things which, because they are not fit to receive the light, are not opened up to receive it." Thus far he.

St Maximus of Constantinople — of noble birth, then a monk and martyr, most celebrated for his learning and the great number of his writings in defense of the Faith, who flourished in the year of Christ 657, as Possevino's *Apparatus* has it, but, as Bellarmine reports (*On Ecclesiastical Writers*, from the 8th volume of Baronius), in the year 660 — whose tongue and hand the heretical Emperor Constans cut off (in the 16th year of his reign, as Kedrenos reports, which was the year of Christ 656) because he could not draw him into fellowship with his wicked opinion.

This great and noble Martyr, then, interprets the cited passages of St Dionysius as follows (in our Lansellius's rendering):

"He says that the heavenly essence neither grows nor diminishes, as having attained its end perfectly and sufficiently; and therefore he called it unchangeable from the moment it was made, not perverted. For that is perfect which neither grows nor is diminished. These motions, moreover, he called ὑποπερατώσεις [Greek: hypoperatōseis, roughly "relative boundings / roundings-off" [?]], not ἀποπερατώσεις [Greek: apoperatōseis, roughly "absolute terminations" [?]], because the motion is circular: for it has a terminus, but improperly so — rather a quasi-terminus — being a motion that runs back to the same (point), as from some beginning to something like a terminus, e.g. toward the east." [Margin: St Maximus, the Greek commentator on St Dionysius, page 130.]

Note that he says the heavens move without sound and without sensation.

"But this — 'the manifold motion by which certain stars are carried' — he says of the planets." [Margin: St Dionysius, from the interpretation of St Maximus: that the planets alone are moved, without any motion of the heaven — certainly in a fluid [heaven] [?].]

Note further this: that he admits only the planets to move.

Observe also from what source the reckonings of time come. These things are from St Maximus, page 130, letter D.

The same St Maximus, page 134, letter D, has these remarks upon the words "For it is itself light":

Note that the Sun, even while it lacked shape, illumined the three days that preceded its creation, and that the light which was first produced was transformed into the Sun on the fourth day, and that he speaks of a triad of days, as the Great Basil also plainly says in the *Hexaemeron*. But do not overlook this: namely, that the things said before are spoken not of the Sun, but of the first-created light, which was transmuted into the Sun. Thus far St Maximus — from whom anyone will recognize beyond doubt both that the Sun is fiery and that the heaven is fluid, and moreover corruptible by its own nature.

Georgius Pachymerius [George Pachymeres], likewise a Greek and an interpreter of St. Dionysius — who, as Possevinus [Antonio Possevino] reports, wrote on these same passages in the time of Michael Palaeologus, around the year of Christ 1266 — after saying the same things about the substance of the heaven that St. Maximus [the Confessor] had said, comments as follows:

"That passage about 'the manifold revolution of the motion of certain stars,' he says, he understands of the planets; for he admits that they alone are moved" (p. 106, near the end).

And later, on p. 107, he says, together with St. Dionysius, that that primeval light was solar, and he proves it from Moses, on the ground that it measured out the first three days.

Likewise, from the seventh letter of St. Dionysius (pp. 266 and 267), he indicates in two places in his commentaries that, in Dionysius's view, the Sun ranges freely in the heaven, and so on.

I have chosen to bring forward these two authors so that, from the mouth of these two, the wording, mind, and meaning of St. Dionysius might stand more surely and reliably established for us than it would from certain moderns who

drag the divine Dionysius to their own side against his will. For those men who (as Lansselius [Lanssel] rightly notes)—

[Margin: The explanation of the primeval light, according to the mind of St. Dionysius.]

"—were born in Greece and stood nearer the source and closer to the fountainhead, and so could drink in the force and sound of Dionysius's discourse more purely—to these, we judge, more credence should be given."

That three-day light, then, whose great praises and properties St. Dionysius celebrates, was not weak or imperfect but most brilliant; yet it was called ἀσχημάτιστος [Greek: aschēmatistos, "unfigured," without determinate shape] by St. Dionysius, in the manner of mathematicians. For when they want to express a line of uncertain measure, they call it "unbounded," "indefinite," or even "infinite," or "of free length"; a plane surface not restricted to any fixed figure they call "any plane whatever," under the name of a "vague individual"; and finally a body not endowed with magnitude or a fixed shape they designate by an indefinite name, "any solid whatever." So too, then, St. Dionysius called that three-day light — still fluctuating and, like a cloud, taking on various shapes through its extremely swift revolution — "unformed," because it truly lacked a fixed and determinate figure; but it does not follow that it lacked all material substrate. Now just as that light, on the first day, circled about in that air or spirit which was borne [col. II] over the waters, so too, having been raised up in a portion of the waters above the firmament, it completed its course on the second day, enclosed in the same airy or spirit-like place between the upper and lower waters — the place celebrated in Genesis under the name of the "firmament" and "second heaven" — during which whole day the earth was still not directly irradiated, since it was still bound up, wrapped round by the lower waters as if by infant's swaddling-bands. Finally, on the third day, when the waters had been gathered into the seas, it shone freely upon the now-visible earth. From this three-day light of unstable shape, then, astronomers draw in their judgment an unanswerable argument for a fiery Sun and a fluid heaven. For it is certain that this light was carried around in the heaven, since otherwise night would not have succeeded day; but if it had been endowed with a stable shape, St. Dionysius would have called it ἀσχημάτιστον — that is, on the testimony of St. Maximus, "without shape" — in vain, and other writers would in vain have called it a fiery or luminous cloud. And this same point is further clear from Dionysius, in that he allows all the planets to be free in the heaven and to move of themselves — which

indeed they obtained by the grace of this light. Likewise from the fact that St. Maximus says it was transmuted into the Sun: from which, they say, it is evident that St. Dionysius was never of a contrary opinion regarding the matter of the heaven or the Sun. But on this matter it is worth hearing also two of our own theologians, Del Rio and Salianus.

From the *Pharus* of Fr. Martín Antonio Del Rio [Martín Antonio Delrío], *On Genesis*, ch. 1, pp. 54 and 55:

"It is a hard question: of what kind, and what, was that light created on the first day? Two opinions are nobler and more probable than the rest, for nothing certain presents itself. One is that of those who hold it was a certain accident, corporeal and luminous, produced miraculously, immediately, and without a subject, which by God's command — in a certain part of this mass of waters, starting from the space where it was created — soon began to be diffused through an entire hemisphere in a uniformly-yet-unevenly manner [uniformiter difformiter], and to illuminate it, in the same way the Sun would later do: running from that region of the world which was soon to be East, and hastening into that which was to be West, and completing its course in a span equal to 24 hours—

—completing it, I say. This accident, they hold, existed without a subject: two Fathers who were like brothers and friends, Fathers of the greatest weight — Basil the Great (Hexaemeron, Homily 6) and Gregory Nazianzen (Oration on Low Sunday) — who, inasmuch as they seem to deny that it is corporeal, do not speak of its essence, as though it were something spiritual, but deny that it inhered in any subject or was enclosed in any substance as in a vessel, as Nicetas explained. The same was held by other Greek Fathers: Theodoret (qq. 14 and 16), Athanasius (q. 74), Anastasius of Antioch (Hexaemeron, bk. 4), Procopius (here), and [John] Damascene (On the Orthodox Faith, bk. 2, ch. 7), Didymus and Apollinaris in the Catena. All these hold that this light was on the fourth day placed into the luminaries of heaven; and if you maintain this, it must plainly be said — or rather, it must be said that on the fourth day, being no longer necessary, it vanished, which, of a mere quality, is by no means absurd to say. This opinion is learnedly upheld by Paul of Santa Maria, commonly called 'the Burgensis' [Paul of Burgos], and by Luis de Molina (On the Work of the Six Days, disp. 7, comm. on Part 1 of St. Thomas). And I should believe that this light shone forth beforehand in the shape of a cloud, perhaps formed into a column. For Holy Scripture

teaches that it is God's regular practice, whenever He willed to use some ordinary light other than that of the Sun and stars, to use a luminous cloud — as when He led the sons of Israel to the land of promise (Exodus 14:19; Deuteronomy 1:33, etc.; Isaiah 4:5, etc.; Ezekiel 1:4, etc.)."

"The other opinion is that of St. Thomas, and more common in the Schools: that this light was the Sun itself, still unformed and imperfect. This they support by the authority of St. Dionysius the Areopagite (On the Divine Names, ch. 4)—

[Margin: St. Maximus understands and explains Dionysius against St. Thomas.]

—where, however, St. Maximus in his Scholia holds that this light, first formed on the [first] day, was, in Dionysius's mind, on the fourth day transformed into the Sun — καὶ ὅτι τὸ πρωτόκτιστον [?] φῶς τῇ τετάρτῃ ἡμέρᾳ μετασχηματισθῇ [?]ς ἥλιον [Greek: "and that the first-created [?] light on the fourth day was transformed into the Sun"] — and he judges that this was more clearly explained by St. Basil, not so much concerning the Sun itself as concerning the forming of this light, first created, into the Sun—

[Margin: Del Rio hesitates over the interpretation of the Latins.]

—so that I am in doubt whether St. Dionysius meant this — and that his having meant it [col. II] is what the Latin Scholastics suppose — or whether truly he meant only that this light was the very thing by which the Sun afterwards shone, as St. Nazianzen and those other Fathers held, drawing an argument also from the word 'luminary,' which they call φωστῆρα [Greek: phōstēra, 'luminary']."

Salianus [Jacques Salian], in his *Annals* (vol. 1, on the first day, on Genesis, p. 45), also concedes this opinion, that St. Dionysius acknowledged the light created on the first day to be abstract [i.e., without a subject]; for after adducing this opinion of St. Basil, he adds the following:

[Margin: Salian's opinion agrees with St. Basil's regarding Dionysius's meaning.]

"These things and more to the same effect St. Basil held — which same view, I judge, the divine Areopagite held and wrote long before. For that light, he says, though it lacked the shape of a fixed body, is what that divine Moses records as having defined and marked off those first three days of ours."

"When he calls the light ἀσχημάτιστον [unfigured], he certainly put 'shape' in place of 'subject'; for how could a shape be called shapeless, or matter immaterial, or goodness wicked, or reason devoid of reason?"

"Thus ἀσχημάτιστον is nearly the same as ἄϋλον [Greek: aūlon, 'immaterial'] or ἀνυπόστατον [Greek: anypostaton, 'without subsistence'] — 'lacking matter or subject,' if one is pleased to use the words so. For when he was there treating of the Sun, he meant to signify that this light had not yet clung to that body as to its own proper subject. Unless perhaps you prefer that 'unfigured light' [φῶς ἀσχημάτιστον] means 'shaping nothing' [μηδὲν σχηματίζον (?)], informing no body as its own and permanent subject."

"And in the Scholia, p. 48, the words of St. Dionysius, should anyone require them, are these:"

αὐτὸ γὰρ ἐστὶ τὸ φῶς, ὃ καὶ τότε ἀσχημάτιστον ἦν, ὅπερ ὁ θεῖος (?) ἔφη Μωσῆς, καὶ αὐτὸν ἐκείνην ὀρίσται τὴν πρώτην τῶν καθ' ἡμᾶς ἡμερῶν τριάδα. [Greek: "For it is the light itself, which even then was unfigured, of which the divine (?) Moses spoke; and he defines that very first triad of the days as reckoned among us."]

"He certainly means that the light was then a separate accident, one that was not the shape of any body; and so our Lansselius understood it, and so explained it in his notes on Dionysius: 'The light was diffused,' he says, 'informing no determinate body as its own proper matter.'"

"Therefore he rendered it thus: even though it then lacked the shape of a fixed body — or, if you prefer, there was no shape of a fixed body. For a shape is not, properly speaking, without shape, since it is itself shape and gives shape to a body; it does not take shape from the body, so as to be said to lack the shape of a fixed body. And perhaps St. Dionysius used the word ἀσχημάτιστον for want of a term, to signify 'lacking a subject.'"

"For neither does ἄϋλον [immaterial] signify it conveniently enough, but rather 'that which lacks matter,' like spiritual things; and ἀνυπόστατον [without subsistence] is 'that which does not subsist,' but not 'that which subsists through itself'; ἀνυποκείμενον is likewise 'that which is not made subject,' but not 'that which lacks a subject.' But enough of these."

Whoever considers that St. Dionysius was a distinguished mathematician (for it was to this end that he had set out for Heliopolis, that he might be trained in these studies) will draw from his very manner of speaking nothing other than

that this light lacked a fixed figure — which the Greek interpreter, St. Maximus, clearly indicates.

[Margin: Dionysius is explained according to the sense of the mathematicians.]

That light, then, was nothing other than the primeval fire, wheeled about by a tumultuous conglobation throughout the first three days of the world; and because, during that three-day revolution, it kept changing its shape through the continual conglomerations of its flames, St. Dionysius called it ἀσχημάτιστον, in the customary manner of mathematical speech. Yet if anyone should wish it to have been an abstract light without a material subject, he nonetheless falls back into the same metamorphosis of figure that I described before; for figures accrue even to abstracted accidents and to separated substantial forms, since neither substantial forms — especially material ones — nor abstracted accidents lack extension and a figure circumscribed to a place, as is clear in the accidents of the Eucharist.

[Margin: From this passage of St. Dionysius the fifth essence is wrongly argued.]

Furthermore, from the fact that this same St. Dionysius says the heavenly essence neither grows nor diminishes, and is therefore immutable, it in no way follows that St. Dionysius asserted the "fifth essence" [quintessence] of certain thinkers; rather, as the cited interpreters show, he merely established its perfection and a state like that in which it was produced by God. Otherwise it would necessarily follow that all those who follow Plato and the ancients — or who say that the matter of the heavenly and of the sublunary is the same, and subject all natural things to destruction — all these, I say, would necessarily be, against their own will and doctrine, defenders of the fifth essence.

For these men, with one voice, together with St. Dionysius have hitherto asserted that the essence of the heaven neither increases nor diminishes, but remains immutable in the same state — notwithstanding that it exists as corruptible by its own nature. For the astronomers too assert this very thing, but with respect to sense [i.e., to appearance]. And if Aristotle, or the ancient Fathers, or finally the more recent theologians had perceived any knowledge or observation of new appearances in the heaven — or, in short, of this very solar phenomenon — as evident as we now have, the prudent reader will judge what they would have asserted about that fifth essence or about total immutability.

PRO NATURA SOLIS — For the Fiery Nature of the Sun, the Stars, and the Heaven: the Authorities of Recent Doctors.

CAP. XIX.

Augustinus Steuchus [Agostino Steuco] in his *Cosmopoeia*:

[Margin: Agostino Steuco of Gubbio.]

"The first thing, then, generated from water was a luminous substance. That this was the Sun, one consideration alone deters us; but many others invite us and persuade us to affirm it with reasons. What deters us is that the Theologian [Moses] seems to say the Sun, Moon, and stars were sown [created] on the fourth day. But the reasons that draw us toward the contrary — all but clamoring aloud — are chiefly these: that the Sun alone (so called because it alone shines) is the begetter of corporeal light. It alone is the heavenly fire, the one lamp of the earthly world, which God set upon the candelabrum of the world so that it might be seen by all, etc." And afterward:

"The Author [God] had to bring this forth first from the heap, and His prudence is seen to have been intent on this: that before the particular effects He might devise the universal causes. And just as, in order to have that from which He might draw forth all things, He first cast down the earth and the waters, so, in order to have that from which the air—"

[completing it]. This accident, they hold, existed without a subject — those two Fathers of the greatest weight, like brothers and friends: Basil the Great [Basil] (*Homily 6 on the Hexaemeron*) and Gregory Nazianzen [Gregory of Nazianzus] (*Oration on the New Sunday*). When these seem to deny that it was corporeal, they are not speaking about its essence, as though it were something spiritual; rather, they deny that it inhered in any subject, or was enclosed in any substance as in a vessel — as Nicetas explained. The same view was held by other Greek Fathers: Theodoret (questions 14 and 16), Athanasius (question 74), Anastasius of Antioch (*on the Hexaemeron*, book 4), Procopius (here), and Damascene [John of Damascus] (*On the Orthodox Faith*, book 2, chapter 7), and Didymus and Apollinaris (in the *Catena*). All of these hold that this light was implanted in the luminaries of heaven on the fourth day. And if you maintain this, it must plainly be said — or rather, that on the fourth day, being no longer necessary, it vanished; and to say this of a mere quality is not at all absurd. This opinion is learnedly defended by Paul of Santa Maria, commonly here called "the

Burgensis," and by Luis de Molina [Luis de Molina] (*On the Work of the Six Days*, disputation 7, commentary on part 1 of St Thomas). And I would believe that this light shone forth beforehand in the form of a cloud, perhaps shaped into a column. For the Sacred Scriptures teach that it is God's regular practice, whenever he wished to use some light other than the ordinary light of the Sun and stars, to use a bright cloud — as when he led the sons of Israel to the land of promise (Exodus 14, 19; Deuteronomy 1, 33, etc.; Isaiah 4, 5, etc.; Ezekiel 1, 4, etc.).

The other opinion is that of St Thomas [Aquinas], and the more common one in the Schools: that this light was the Sun itself, still formless and imperfect. They prove this by the authority of St Dionysius the Areopagite [Dionysius the Areopagite] (*On the Divine Names*, chapter 4). Yet there St Maximus [Maximus the Confessor], in the *Scholia*, holds that this light, first formed on the [first] day, was — according to the mind of Dionysius — transformed into the Sun on the fourth day: καὶ ὅτι τὸ πρωτόκτιστον [?] φῶς τῇ τετάρτῃ ἡμέρᾳ μετασχηματίσθη εἰς ἥλιον [Greek: kai hoti to prōtoktiston phōs tē tetartē hēmera metaschēmatisthē eis hēlion, "and that the first-created light was transformed on the fourth day into the Sun"]. And he judges that this was more lucidly explained by St Basil — not so much about the Sun itself as about the first shaping of this light into the Sun — so that I am left in doubt whether St Dionysius meant what...

[Margin: St Maximus understands and explains Dionysius against St Thomas.]

[Margin: Del Rio [Martín del Río] is uncertain about the explanation of the Latins.]

the Latin Scholastics suppose him to have thought; or rather only that this light was the very thing by which the Sun afterward shone, just as St Nazianzen and those other Fathers held — drawing their argument also from the very word "luminary," which they call φωστῆρα [Greek: phōstēra, "light-giver, luminary"].

Salian [Jacques Salian], in his *Annals* (volume 1, on the first day, on Genesis, page 45), also concedes this opinion: that St Dionysius acknowledged the light created on the first day to be abstract [i.e., subsisting without a subject]. For after bringing forward this opinion of St Basil, he adds the following:

"These things, and more to the same effect, St Basil [said] — the very same things which I judge the Areopagite to have thought and written much earlier. For that light, he says, even though it then lacked the form of a determinate body, is the light which the divine Moses records as having bounded and distinguished those first three of our days.

"When he calls that light ἀσχημάτιστον [Greek: aschēmatiston, "unfigured, without shape"], he has certainly put 'form' in place of 'subject'; for how could form be called formless, or matter immaterial, or probity improbe, or reason devoid of reason?

"Thus ἀσχημάτιστον is almost the same as ἄνυλον [Greek: aylon, "immaterial"], or ἀνυπόστατον [Greek: anypostaton, "without subsistence"] — lacking matter or subject, if one may so use these words. For since he was there treating of the Sun, he meant that this light had not yet adhered to that body as to its own proper subject. Unless perhaps you prefer it to be φῶς ἀσχημάτιστον [unfigured light], μηδὲν σχηματίζον [Greek: mēden schēmatizon, "shaping nothing"] — that is, informing no body as its own and perpetual [subject].

"And in the *Scholia* (page 48): the words of St Dionysius, should anyone seek them, are these:

Αὐτὸ γὰρ ἐστὶ τὸ φῶς, [?] καὶ τότε ἀσχημάτιστον ἦν, ὅπερ ὁ θεῖος ἔφη Μωσῆς, καὶ αὐτὸν ἐκείνην ὀρίσται τὴν πρώτην, τῶν καθ' ἡμᾶς ἡμερῶν τριάδα. [Greek: "For it is the light itself, which even then was unfigured, of which the divine Moses spoke; and he defines that very first triad of the days that are ours."]

"He certainly means that the light was then a separate accident, one that was not the form of any body; and so our Lansselius [Pierre Lanssel] understood it, and explained it in his notes on Dionysius. 'The light,' he says, 'was diffuse, informing no determinate body as its proper matter.'"

"So it turned [i.e., it came about] that, even though it then lacked the form of a determinate body — or, if you prefer, there was no form of a determinate body. For form does not, properly speaking, lack form, since it is form itself, and gives form to the body without taking form from the body — such that it should be said to lack the form of a determinate body. And perhaps blessed Dionysius used the word ἀσχημάτιστον [unfigured] for want of a [proper] term, one that would signify 'lacking a subject.'

"For neither does ἄνυλον [immaterial] signify it aptly, but rather what lacks matter, as spiritual things do; and ἀνυπόστατον [without subsistence] is what does not subsist, but not what subsists through itself; ἀνυποκείμενον [Greek: "not-underlying, not made a subject"] too is what is not made a subject, but not what lacks a subject. But enough of these matters."

[Margin: St Dionysius is explained according to the sense of the Mathematicians.]

Whoever considers that St Dionysius was a distinguished mathematician — for it was precisely to be trained in these studies that he had gone to Heliopolis — will draw from his very manner of speaking nothing other than that this light lacked a determinate figure, which the Greek interpreter St Maximus clearly indicates. That light, therefore, was nothing other than the primeval fire, wrapped about in a tumultuous rolling-together during the world's first three days; and because throughout that three-day revolution it changed its figure by the constant heaping-up of flames, St Dionysius called it ἀσχημάτιστον [unfigured], in the manner of speaking customary to mathematicians. Yet if anyone should wish the light to have been abstract, without a material subject, he will nonetheless fall back into the same Metamorphosis of figure that I mentioned above. For even when accidents are abstracted and substantial forms separated, figures nonetheless belong to them; nor indeed do substantial forms — especially material ones — or abstracted accidents lack the extension and figure that circumscribe a place, as is evident in the Eucharistic accidents.

[Margin: From the passage of St Dionysius the Fifth essence is not rightly argued.]

Furthermore, as to the fact that the same St Dionysius says the celestial essence neither grows nor diminishes, and is therefore immutable — it in no way follows from this that St Dionysius asserted the Fifth essence of certain [philosophers]. Rather, by the interpreters cited, he only established its perfection and a stable condition, in accordance with the state in which it was produced by God. Otherwise it would be necessary that all those who follow Plato and the ancients — or who say that the matter of celestial and sublunary things is one and the same, and subject all the things of nature to destruction — it would be necessary, I say, that all these, against their own will and doctrine, be asserters of the Fifth essence.

For these men have with one voice, together with St Dionysius, hitherto affirmed that the essence of the heaven neither increases nor diminishes, but remains immutable in the same state — notwithstanding that it exists corruptible by its own nature. For the astronomers too assert this very thing, but with respect to sense-perception. But if either Aristotle, or the ancient Fathers, or finally the more recent theologians had gained any knowledge or sense — as evident as we now possess — of the new appearances in the heaven, or indeed of this very solar phenomenon [phaenomenon], a prudent man will judge what they would then have asserted about that Fifth essence, or about complete immutability.

Cap. XIX. — For the fiery nature of the Sun, the stars, and the heaven: the authorities of recent scholars

Augustine Steuchus [Agostino Steuco], in his *Cosmopoeia*.

[Margin: Augustinus Steuchus of Gubbio.]

"The first thing generated from water, then, was a luminous substance. That this was the Sun, one consideration alone deters us, but several others invite us and persuade us to affirm it with reason. What deters us is that the theologian [Moses] seems to say that the Sun, Moon, and stars were made on the fourth day. But as for the reasons that draw us in the contrary direction — almost with a great outcry — these are foremost: that the Sun alone (so called because it alone shines) is the begetter of corporeal light. It alone is the celestial fire, the one lamp of the earthly world, which God set upon the candelabrum of the world, that it might be seen by all, and so on. And afterward:

"The Author [God] had to produce this first out of the heap; and his prudence is seen to have bent upon this — that before the particular effects he might devise the universal causes. And just as, in order to bring forth all things, he first cast down the earth and the primal waters, so, in order that [he might make] air,...

"...animals, and plants, he sent ahead the Sun as the Begetter of those things. God, the Sun, and man beget man. And afterward: Now in the theology of Moses, the name and the effect of the Sun and of light are one and the same; for when he writes of the Sun, that it should shine upon the earth, he uses the same word as when he brings forward that light existed first. There [in the one place]: 'Let there be Or' [Hebrew אור, "light"] — that is, Light; here [in the other]: 'Lehair' [?] [Hebrew לְהַאִיר, "to give light"] — to give light, or that they may shine. And afterward: That among Moses, and among the other nations too, light and Sun are the same, the usage of speech teaches abundantly. The Latins call light 'day' [lux/dies], so as to show that day and light are produced by the same thing. But Moses — and this is the strongest argument that that first-begotten light was the Sun — attributes to this first-begotten thing the same office as to that which was created on the fourth day. To each is given the office of putting the darkness to flight; each is created for making the day; by each the day is separated from the night.

"And afterward: What of the fact that in other places of Scripture the Sun is called 'light'? As in Jeremiah, chapter 4: 'I looked at the heavens, and there was no light in them.' And afterward: By this too it is proved that corporeal light — that is, the

Sun — is to be understood here as first created, since all the Prophets who have spoken of creation, or have named created things, have expressed the Sun by 'light.' In Psalm 148, having listed the Angels, he says: 'Praise him, Sun and Moon.' At last he concludes thus:

"But although this light of ours proceeds from fire, from clashing clouds, from the stars, from the Moon — yet the chief of visible things is the Sun, the ruling one [ἡγεμονικόν] [Greek: hēgemonikon, "the governing/ruling principle"]."

From these things it is sufficiently clear that the Sun is judged by this Author to be fiery by nature — a point which he elsewhere too inculcates frequently and far more clearly.

[Margin: The Sun, from Scripture, is the same as Light.]

"For in the seventh book, *On the Perennial Philosophy*, chapter 4: The ancients likewise, he says, gave to Heaven the name 'aether' — not from its eternal course (although Plato asserts this in the *Cratylus*), but from its brightness, its burning, and its light. Its substance is luminous and pure, and shining it kindles into flame, and pours vital heat into the lands — the whole designated by the name of Aether. Hence one of the seven wandering stars, Mars, is called 'burning' by them, Aethon; and although the Sun's horses are four, the name was given, with one exception, to the rest from their burning: Pyroïs, Phlegon — that is, 'fiery' and 'burning'; and the reason of the name, that it burns, designates it to be celestial fire, generated from the purity of the elements.

"For the most ancient Trismegistus [Hermes Trismegistus] hands down — a thing which you may see among other authorities of greater standing too, and in which Plutarch [Plutarch] writes that many philosophers of Greece agree — that the aether and the orb of the Sun were made out of the most limpid and purest substance of water, just as the purest clouds are made, and torches, and lofty flames; and watery clouds, when clashed together and set aflame, illuminate a long tract of the air. These things they said, that I may show — and it is exceedingly agreeable to reason, since we see many luminous things arising out of water, of the same force and substance, which is varied incredibly into all the most beautiful and admirable species — as gold, crystal, air, clouds, fires, the varieties of colors, luminous clouds, even in the middle of the night. Thus by the most wise Craftsman the most fluid substance of Air could be separated and selected out of the waters.

"Plutarch, then, is the authority that Empedocles [Empedocles] believed the heaven to be [made] out of air condensed by fire after the manner of crystal, in

which there is something fiery and something airy; [Margin: The philosophers according to Plutarch] that Aristotle [held it made] out of a fifth body, or out of a tempering of hot and cold; that Anaximander [held] the Sun to be full of fire; Xenophanes, [made] of gathered little fires; the Stoics, understanding a kindling out of the sea; Plato, out of very much fire; Anaxagoras, a fiery stone; Philolaus, taking a glassy [heaven] out of the world's fire. From all of which it appears that the ancients named the aether not from a perennial course, but from burning and fire.

[Margin: Other arguments, from etymology, etc.]

"The same, in the *Cosmopoeia*: And this is most true, and asserted by the most ancient theologians too — that by the same reasoning the aetherial substance was drawn out of the waters, and heaven itself, and the celestial exhalations. For we see water changed into air, into clouds, into torches, into fiery vapors."

[The scan pages of this opening are out of order and one is duplicated; the translation below follows the book's own reading order — folio 640, then 641, then 642 — across which the quoted text runs continuously.]

Cap. XIX (conclusion)

[The extended quotation from Agostino Steuco continues.]

...to found the animals and the plants, He set the Sun before them as the begetter of these things. God, the Sun, and man beget man. And later: Now in the theology of Moses the name and the effect of the Sun and of light are one and the same; for when he writes of the Sun, that it should shine over the earth, he uses the very same word as when he reports that light first came to be. In the one place, *fiat Or* — that is, "Let there be Light" ["Or", Hebrew אור, "light"]; in the other, *Lehair* ["Lehair", Hebrew להאיר, "to give light"] — for giving light, or that they may shine. And later still: That the two are the same, both in Moses and among the other nations, ordinary usage teaches abundantly. The Latins call the daylight *lux* [light], so as to show that light and day are produced from one and the same source [?]. And Moses — this being the strongest argument that that first-born light was the Sun — assigned the same office both to this first-born thing and to the one created on the fourth day. To each is given the task of driving away the darkness; each is created to make the day; by each, day is separated from night.

[Margin: The Sun is, from Scripture, the same as Light.]

And later: What of the fact that in other places of Scripture the Sun is called "light"? — as in Jeremiah, chapter 4: "I looked upon the heavens, and there was no light in them." And later: This too proves that the corporeal light — that is, the Sun — is to be understood as created here, on the first day: for all the Prophets who spoke of the creation, or named created things, expressed the Sun by the word "light." In Psalm 148, after mentioning the Angels, it says: "Praise Him, Sun and Moon." At last he concludes thus: But since this light of ours comes [?] from fire, from clashing clouds, from the stars, from the Moon — the chief of visible things is nevertheless the Sun, the ruling principle [Greek: ἡγεμονικόν (hēgemonikon), "the governing part"].

From all this it is sufficiently clear that, for this author, the Sun is reckoned fiery by nature — a point he drives home elsewhere too, frequently and far more plainly.

[Margin: Further arguments from etymology, etc.]

For in Book VII of the *De perenni philosophia*, chapter 4: "The ancients, likewise," he says, "gave the heaven the name *Aether* not from its eternal course — though Plato asserts this in the *Cratylus* — but from its brightness, its blaze, its light. Its substance is luminous and pure, and, shining, it glows, and pours life-giving warmth into the earth — the whole of it designated by the name *Aether*. Hence one of the seven wanderers, Mars, is called by them *Aethon* [Greek: Αἶθων, "blazing"]; and since the Sun's horses are four, a name drawn from burning was given — with one exception — to the rest: *Pyrois* [Greek: Πυρόεις, "fiery"], *Phlegon* [Greek: Φλέγων, "burning"] — that is, 'fiery' and 'burning'; and the sense of the name, that it burns, marks it out as a celestial fire, generated from the purity of the elements.

"For the most ancient Trismegistus [Hermes Trismegistus] reports — a view you may find in other early authors too, and one in which Plutarch writes that many philosophers of Greece concur — that the aether and the Sun's orb were made from the clearest and purest substance of water, just as the purest clouds, and torches, and lofty flames come to be, and watery clouds, clashing and bursting into flame, light up a long tract of the air. This is what they said; and — to make my point — it is thoroughly consonant with reason, since we see many luminous things arise from water, of that same power and substance, water which is varied incredibly into every most beautiful and wondrous form: as gold,

crystal, air, clouds, fires, the varieties of colors, luminous clouds even in the dead of night. In this way the most fluid substance of the air could be separated out and selected from the waters by the most wise Craftsman.

"Plutarch, then, is the authority that Empedocles believed the heaven to be [made] of air condensed by fire like crystal, in which both the fiery and the airy are present; [Margin: The philosophers, according to Plutarch.] that Aristotle [held it to be] of a fifth body, or of a tempering of hot and cold; Anaximander, that the Sun is full of fire; Xenophanes, that it is of little fires gathered together; the Stoics, an intelligent kindling drawn from the sea; Plato, of the greatest amount of fire; Anaxagoras, a fiery stone; Philolaus, glass-like, taking [its fire] from the world-fire. From all of which it appears that the ancients named the *aether* not from its perpetual course but from its blaze and fire.

"The same, in the *Cosmopoeia*: And this is most true, and asserted by the most ancient theologians as well, that by the same process the aetherial substance was drawn out of the waters — and the heaven itself, and the celestial exhalations. For we see water changed into air, into clouds, into torches, into fiery va[pors —

[Margin: How the fiery Sun comes to be.]

— chan]ged. And so we must suppose it was done at that very time when the wisdom and craft of God moved over the waters and drew out of them the purer substances — the Sun first of all, whose laborious magnitude and beauty surpasses everything, celestial and terrestrial alike. Stirring, therefore, and shaking the waters He had created, He brought them to the boil and kindled them with fire, [making] the purest lights and refined materials — as of mirrors and of clouds — so that they should be both luminous and very light, like the brightest clouds, which, the purer they are, the higher the seats they seek; and fire itself — that is, flame — is nothing other than kindled air."

[Margin: Ascanio Martinengo.]

Ascanio Martinengo [Ascanius Martinengus], in the first volume of his commentary on Genesis, on the words "Let there be great lights" (p. 875), reasons as follows, among much else:

"The daily experience compels me more forcibly — the experience by which we continually find that the stars, and the Sun above all, illuminate, warm, and scorch. Nor does that distinction of the

Peripatetics about a twofold 'hot' — by which they say the Sun heats us not formally but virtually, or effectively — seem to me to hold up much; rather, it seems to totter. For no other way is left to us by which we might determine that any body is hot properly and, as they say, formally, except its effect as perceived by the judgment of sense. Since, then, we feel not only the air and other bodies but our very selves grow warm under the Sun's rays, what is there to make us doubt the Sun's blazing heat? But if the judgment of the senses does not suffice concerning the Sun, then neither, we shall have to grant, does it suffice concerning fire. And since we experience ourselves warmed by the Sun in no other way than by fire, we shall assert that fire too is not hot formally but only effectively, since the reasoning is the same," and so on.

[Margin: Jacques Salián.]

Fr. Jacques Salián [Iacobus Saliánus] — as we saw in chapter 17 — after reviewing a large catalogue of the holy Fathers to this same effect, out of deference to venerable antiquity says it is probable that the stars were generated from the substance of fire by the craftsmanship of God.

In favor of the fiery nature of the Sun, the stars, and the heaven the arguments contend — the very arguments on account of which the holy Fathers, moved by the authority of sacred Scripture, testified that true elementary waters lie above the Firmament.

Cap. XX.

That true, natural, and therefore elementary waters were raised by God, thrice best and greatest, above the Firmament — this, they say, is so clear from sacred Scripture that even not a few of those who defend Aristotle's fifth essence tooth and nail dare not resist the unanimous consensus of the Fathers (which I shall present later); and certainly this opinion thrives everywhere among the learned, though by differing routes.

For not all assign the same causes, nor derive similar effects from them. There are some who acknowledge the divine deed but confess that they do not know its rationale.

I shall present the authors together with their arguments — not to approve or to reject them, but to show clearly from them either that the Sun, in their view, is fiery by nature, or else that these arguments were adduced without warrant by

those ancient Fathers and holy authors, who did not [themselves] acknowledge the heaven or the Sun to be fiery.

From Martinengo, Part 1, p. 637 and following.

[Margin: St. Hilary.]

Hilary, *Commentary on Psalm 137*:

"For by raising up the waters He tempered the very nature of the first heaven — a nature which, kindled by the power of the God on high, would in no way be bearable [?] by the lower natures. But the lower heaven He stretched out not as uniform but as manifold; and, calling the whole of it 'Firmament,' He made it solid with a strength powerful enough to sustain the upper waters and to temper our air."

[Margin: St. Basil.]

Basil, *Hexaemeron*, homily 3. He conducts a lengthy discussion of the immense abundance of waters — waters necessary, both above and below the Firmament, for restraining the force of the seething fire; and, having rejected the opinions of Origen and Apollinaris, he adds the following:

"Let us take the water as water — literally — and understand the separation of the moist elements from the Firmament to have been made for the cause we have assigned. And even if the waters set above the heavens are sometimes said to praise the common Lord of all, we do not on that account judge them to be natures endowed with reason.

And later: For the water standing above the heavens does not, merely because it surpasses the lower [waters] in some preeminent dignity of honor, fulfill its divine praise on account of some extraordinary and remarkable prerogative of its own power alone. Rather, 'Praise Him,' it says, 'you also that are of the earth, you dragons and all deeps.' From this same Father you will see clearer things a little further on."

[Margin: St. Ambrose.]

St. Ambrose, after Basil (in the same Martinengo, p. 639), for the same reasons makes those same true, elementary waters hang suspended above the Firmament; and this he proves at great length, chiefly from the Word of God, against those who argued that the waters had to be poured out.

[Margin: Caesarius.]

Caesarius, in the *Dialogues*, Question 71 [?]:

"When, therefore, the heavenly waters fail," he says, "all things will at once dissolve [?] in an abundance of fire; for the stars will fall, as leaves from the vine."

See how this Father acknowledges both that the waters are to be consumed, and that the celestial fire grows and at last devours all things.

From Martinengo, Part 1, p. 661.

[Margin: Procopius.]

Procopius, *Commentary on Genesis*:

"A question nevertheless arises: Why was half of the waters carried up above the Firmament? But this cause will be given. God arranged the Light, the Sun, the Moon, and the stars — the substance of all of which is fiery — in such a way that they should carry out their motion in the Firmament; but fire is of such a nature that it powerfully scatters and dissolves what has been frozen and congealed out of water. Lest, then, this should perchance befall the Heaven, He necessarily placed so great an affluence of waters in the upper region, to keep the heaven unharmed and inviolate from the fire's blaze. But in this way it pleased God to protect the highest heaven, although His will alone could have granted it safety and preservation," and so on.

[Margin: St. John Damascene.]

John Damascene [Ioannes Damascenus], *On the Orthodox Faith*, chapter 9:

"For whose sake did God place water above the Firmament? Because of the most fervent heat of the Sun and of the aether. For immediately beyond the Firmament the Aether is drawn up, whereas the Sun, together with the Moon and the stars, is in the Firmament. And had the water not been set above, we must suppose that from that immense heat the Firmament would already have burst into flame, and the abyss [dissolved] into flames [?]."

[Margin: St. Bede.]

Bede, *On the Nature of Things*, chapter 8:

"The waters placed above the Firmament — lower, indeed, than the spiritual heavens, yet higher than every corporeal creature — some

affirm were kept for the cleansing of the Flood, while others, more correctly, [affirm they were] suspended there for tempering the fire of the stars."

[Margin: St. Justin.]

Justin, *Questions to the Orthodox*, question 93:

"Nor indeed is this the only reason why there are waters in the hidden [back] parts of the heaven — namely, that the underlying flame of the stars may stand unconquered [?] — but also because the mass of the waters that are in that hidden region presses downward by its force and abundance, and is not stirred by the rush of the winds; and because the greatest cold is sent down from them, and when this is mixed with the greatest heat of the Sun, a favorable tempering of the air is produced, for the perpetuity of the animals and of the things the earth brings forth of itself."

[Margin: Justin again.]

The same Justin, in the same place:

"Although the stars are below the heaven," he says, "the motion of their activity — [stars] which imitate the nature of fire in their essence — naturally tends toward the higher regions."

And so those brought forward the true cause who said that, for the stability and constancy of the Firmament, the upper parts of the Heaven are weighed down by the waters.

[Margin: Procopius again.]

Procopius, in the passage cited, brings forward much the same about the rays of the Sun and of the stars:

"The waters set above the Firmament," he says, "not only guard the safety of the first heaven, but also have another advantage — namely, that they drive the rays of the Sun and Moon down[ward...]

[The catena of authorities on the waters above the firmament continues from Cap. XX. The opening paragraph completes a quotation carried over from the previous page.]

drive it down, so that they may supply light to the globe of the earth. For if the heaven were transparent, all its splendor would strain toward the highest region

— since fire by its own nature tends upward. And so water is joined to the highest heaven, in order to force the splendor down to the lowest parts.

[Margin: Again, St. Bede.]

Bede, in *On the Nature of Things*, chapter 7: "The heaven of the upper circle, etc. God tempered it with icy waters, lest it should set the lower elements ablaze," etc. And the Cabalists, on the testimony of Vielmus, Lecture 14, do not reject this view.

[Margin: Again, St. Basil.]

Basil, *Hexaemeron*, Homily 3: "The diffusion of the waters was, as it seems, boundless — flooding the earth on every side and so occupying its surface on high that, compared with the other elements, they seemed by their proportion to surpass them. This is why it was also said earlier that the abyss surrounds the earth on every side. But the cause of so great an abundance of moisture we must assign in what will be said next." And later: "What necessity, then, was there that the nature of water should abound in such — indeed inexplicable — profusion? For the essence of fire is necessary to the universe, not only for the governance of terrestrial things but also for completing the integrity of the whole universe itself — for it would be mutilated if it were deprived of this one element, the most serviceable of all. Yet fire and water are mutually opposed, and each is destructive of the other. Fire, when it exceeds water, overcomes it by force; but water, when it surpasses fire in quantity, overcomes it. So there had to be neither strife between them nor any cause arising from the failure of one, by which the universe would be dissolved and perish. God, who arranged all things, prepared and stored up so great a nature of moisture that — though it is gradually consumed by the forces of fire — it might be able to resist that fire right up to the appointed limits of the world's constitution. Indeed, he who arranged all things by weight and measure (for according to Job even the raindrops are numbered by him) knew perfectly how much time he had prescribed for the world's duration, and was not ignorant of how much expenditure and fuel he had to store up for the fire. This is the reason for the abundant and copious water at the creation."

Moreover, Basil discusses at length the necessity of fire, which he shows to be serviceable and necessary not only for the structure of those things that are fashioned by art, but also for generating, nourishing, and sustaining the life of all things.

[Margin: St. Ambrose.]

Ambrose, in the second book of the *Hexaemeron*, chapter 3, as an interpreter repeats almost all these matters that Basil had examined (as is his custom). He adds, too, that God created an immense abundance of waters, so that they might be able to resist the fiery power seething both in the stars, and in the aether, and in these lower parts of the world.

[Margin: Procopius again.]

Procopius, *Commentary on Genesis*, chapter 1: "Since this universe needed a fiery element that would resist water, consume the other element, and give occasion for the destruction of the universe, provident God substituted so great a force of water that, remaining within the prescribed limits of this elaborate machine, it could struggle against the element of fire, lest it be wholly consumed by it."

[Margin: St. Bede.]

Bede teaches the same, besides the passages already cited, also in his book *On the Creation of the Six Days*.

[Margin: St. Thomas.]

St. Thomas, in the *Postil on Genesis* ascribed to him, seems to agree, when he says: "But as to why those waters are placed there, I believe it is for the purpose of tempering the heat generated by the celestial heat and by the warm influence from the stars and planets."

[Margin: Claudius Marius.]

Claudius Marius Victor sings the same, etc., in his *Commentary on Genesis*.

St. Augustine, *On Genesis according to the letter*, book two, chapter 5; and *On the incomplete [commentary on] Genesis*, chapter 8; and Bede in his *Questions on Genesis*, among other reasons adduce this one: that the star Saturn may be cooled, etc.

I deliberately refrain from adducing more authorities and more testimonies from these authors, because I judge these to be sufficient for my purpose — namely, to show that the ancient ecclesiastical writers, by the very reasons they brought forward as to why (both in agreement with Scripture and drawing from Sacred Scripture) they asserted that God placed elementary waters above the Firmament,

by those same reasons consequently also prove the Sun itself to be hot and of a fiery nature. And this is something that any judicious reader will perceive most

clearly and without any doubt — if he either rightly weighs these very testimonies here adduced, or (as I should prefer) consults the holy Fathers themselves, as I have done in most cases — so that there is no need to hold a torch to the daylight itself and to draw the point out by inferences, since it is self-evident to anyone who looks. Whether all the reasons they gave for the waters being placed above the Firmament are true matters little to me; what bears on the case is that they be such that from them it is clear, without any evasion, that the Fathers counted the Sun among their number — that is, among bodies which received a hot and fiery nature from God the Creator, and which therefore require so great an abundance of waters to blunt the force of their heat.

More authorities for this view will come up later, where the corruptibility and fluidity of the heaven will be treated. For these subjects are interwoven and draw one another along.

Authorities who placed elementary waters above the Firmament, without asserting that the Heaven is of a fiery nature.

Chapter XXI.

Setting aside the aforesaid reasons, most of the more recent commentators on Sacred Scripture, together with the ancients, moved by the authority of Sacred Scripture, nevertheless raise real and elementary waters above the Firmament itself; and I judge it will not be out of place to set some of them before your eyes.

[Margin: Cardinal Bellarmine's waters above the firmament.]

The most illustrious Cardinal of the Holy Roman Church, Robert Bellarmine [Robert Bellarmine], on Psalm 103, on those words, "Who coverest the higher parts thereof with waters": "It is a second point," he says, "that God by a wondrous artifice placed waters above the heaven, as it were waters upon fire; and yet neither do the waters extinguish the fire nor does the fire consume the waters. About these waters the Scholastics dispute much; but the common opinion of the Fathers seems to be that the waters are above the aethereal heaven, which is called the Firmament, and not above the airy heaven. See, among others, Basil, Homily 3 of the *Hexaemeron*; Chrysostom, Homily 4 on Genesis; Ambrose, book 2 on Genesis, chapter 4; Augustine, book 2 on Genesis,

chapter 4, and on this Psalm 103; Eucherius, book 1 on Genesis, chapter 3; etc. Thus far his words there.

But on Psalm 101 the same author says that the heavens will be changed and consumed as to their manner and external form: "The heavens will be changed," he says, "in the way a man is changed when he changes his garments — as to their outward face, etc."

From this you may easily gather that this author admits supercelestial waters — a view for which he is also cited by Lorinus, on Psalm 148. Moreover, that he does not seem averse to a fiery nature of the heaven, both because he implies that the waters are placed above fire, and because he everywhere honors the Heaven of the Firmament with the name of aether, and has acknowledged and taught a fluid heaven — as the illustrious and noble lord Johannes Nicolaus à Smogulecz Smogulecki [Jan Mikołaj Smogulecki] reports in his *Sol illustratus*, etc.; and Father Johannes Ziegler [Johann Ziegler] himself often related the same thing to me. Indeed, in a certain letter written from Rome to Father Sebastian Heiss at Ingolstadt, the most illustrious Cardinal himself indicated it — a letter which I too have read.

[Margin: Martin Becanus.]

To this same doctrine — that the waters are placed above the starry Firmament — Martin Becanus [Martin Becanus], a theologian of our Society, firmly subscribes, in the first part of his *Scholastic Theology*, in the fourth Tractate on the Works of the Six Days, chapter 2, number 6, second Conclusion, page 396, first column, of the Mainz edition of the year 1612; and passim throughout that Tractate, as will be seen a little later in the question on the corruptibility of the Heaven, to which I refer the reader.

That there are real waters above the Firmament.

From the *Pharus* of Martín Del Río [Martín Del Río], on Genesis chapter 1, page 58, on the words, "and he divided the waters," etc.

[Margin: Martín Del Río.]

"That these waters are real and homogeneous with the lower ones has been handed down by so many and such weighty authorities that it seems to me to amount to the decree and consensus of a kind of Ecumenical council. I shall enumerate the Greeks and Latins, each in his order, whom I know. This is the view of Clement of Rome, book 1 of the *Recognitions*; Justin [Justin Martyr], Question 93 *To the Orthodox*; Basil, Homily 3; Epiphanius, in his *Letter to John of*

Jerusalem; Chrysostom, Homily 4, and on Psalm 148; Cyril of Jerusalem, Catechesis 9; Theodoret, here, Question 11; Procopius, here; Hippolytus and Severian [Severian of Gabala], in the Catechesis; Euthymius [Euthymius Zigabenus], on Psalm 103.

"Of our own Latins: Tertullian, in the said chapter 8; Hilary, on Psalm 135; Ambrose, book 2 of the *Hexaemeron*, chapters 3 and 4; Jerome, in the said letter to Oceanus; Augustine, book 2 *On Genesis according to the letter*, chapter 5, book 11 of the *City of God*, last chapter, and on the said Psalm 103, and there Cassiodorus; Haymo [Haymo of Auxerre], Bruno, Lombard [Peter Lombard], Richard of Pamplona [?], as well as Eucherius, Rupert [Rupert of Deutz], Hugh of St. Victor, Bede, and Strabus [Walafrid Strabo] here; Anselm of Canterbury, in the said place, chapters 25 and 28; Richard of St. Victor, book 2, *Exceptions*, chapter 7; and the ancient Christian bards, Dracontius the Spaniard and Marius Victor, *On the Work of the Six Days*, and Drepanius Florus [Florus of Lyon] in the *Hymn of the Three Children*.

[Margin: More recent authorities.]

"There are many councils to which not so many Fathers subscribed. Nor are there lacking more recent writers who defend what we have said — such as Antonio de Honcala, and Oleaster [Jerónimo de Oleastro] here; Vielmus, *On the Work of the Six Days*, Lecture 14; Luis de Molina [Luis de Molina], in the same treatise, question 10; and, discoursing most copiously, Ascanio Martinengo, in volume 1 of the *Great Chain on Genesis*, from folio 648. This opinion, therefore, is not repugnant to common sense.

"But it appears most credible above all because it is most in agreement with the words of Sacred Scripture taken plainly and simply,

[Margin: Very clear passages of Sacred Scripture.]

which those who hold the contrary are forced to take figuratively. For there are (in my judgment) very clear passages of Sacred Scripture — besides this one of ours, three others. In Psalm 103:3 you have: 'stretching out the heaven like a skin, who coverest its higher parts with waters.' Psalm 148: 'the waters that are above the heaven,' etc. Daniel 3:59: 'Bless the Lord, all you waters that are above the heavens.' And it is equally probable, if you look to the reasoning. For none of the objections usually raised presses upon us.

"I confess that these waters are by their own nature corruptible; that they will actually be corrupted, I deny." And a little later: "The purpose for which they

were placed there is known to him who placed, created, and separated them: I was not his counselor; but I am certain that whatever was done by him was done most wisely and for the best end." And a little later:

[Margin: He confirms it from St. Augustine.]

"I conclude with Blessed Augustine: In whatever manner and of whatever kind the waters there may be, that they are there is not in the least to be doubted; for the authority of this Scripture is greater than the whole capacity of human wit."

On this same matter it will not be amiss to set before your eyes the luminous testimony of Luis de Molina. Although in his philosophical works — book 1 *On the Heaven*, chapter 3, question 21 — he had once taught that the matter of the heaven is of a different species from the matter of lower things, now here, in his fifth Disputation, he expressly teaches the contrary; and the objection he had raised against himself out of his own earlier position he dissolves by explaining that, whereas he had once philosophized to please others, he is now bound, by the weight of reasons and by the authority of Sacred Scripture and the Fathers, to think otherwise. That he was very greatly impelled to this by the [scriptural] inundation of the supercelestial waters, anyone who reads him will scarcely doubt. But let us hear the man himself, drawing his case with great force from Sacred Scripture.

That there are elementary waters above the heavens.

From Luis de Molina, *On the Work of the Six Days*, Disputation 10, page 724, letter D.

[Margin: Luis de Molina.]

"By these arguments, weighty though they are," he says, "we are not led to the proposed opinion. For the context of Scripture in Genesis 1 plainly sounds the contrary, unless we choose to twist it by violent expositions unworthy of the sincerity of Sacred Scripture — as is self-evident, and as we have already shown in Disputations 2 and 3. The other Scriptural testimonies which we adduced in that same place sound the same, namely that in the midst of the elementary waters — which occupied the whole interval that lies between the earth and the empyrean heaven — God on the second day made the firmament out of the matter of those same waters, and by that firmament divided those truly elementary waters, which remained above the space in which it was made, from the lower waters. And what Sacred Scripture plainly sounds I judge must be established as the rule by which men's thoughts are to be measured, whether

they are true or false. Nor do I think that any violence should be done to Sacred Scripture on account of the deceptive opinions of men.

"Hence St. Augustine, on Genesis according to the letter, book 2, chapter 5, after relating some things by which certain people tried to prove that above the heavens there are elementary waters — no longer of a vaporous thinness, as the waters of the clouds are, but of a glacial solidity — adds:

[Margin: The cited authority of Augustine.]

'But in whatever manner and of whatever kind the waters there may be, let us not in the least doubt that they are there; for the authority of this Scripture is greater than the whole capacity of human wit.'

He appends more things in favor of this view, worthy of reading, drawn from reason and the authority of others, etc.

The same, Disputation 2, page 705, B 1: "It also comes about," he says, "that the firmament was not made from nothing, and therefore not by creation strictly taken,

but from the matter of the waters, which previously occupied the space in which it was fashioned out of them, and which were created together with the empyrean heaven and the earth." He then cites, for this view, Clement, book 1 of the *Recognitions*.

[Margin: Jacques Bonfrère.]

Jacques Bonfrère [Jacques Bonfrère], of our Society, in his *Commentaries on Genesis* published in the year 1625, on chapter 1, on those words, "And he divided the waters that were under the firmament from those that were above the firmament": "I understand these words properly," he says, "as St. Clement too (book 2 of the *Recognitions*) and all the holy Fathers understood them, and as the words of Scripture here actually sound, unless someone wishes (note this, reader) to twist them beyond measure. Other passages of Scripture indicate the same: Psalm 103, 'stretching out the heaven like a skin, who coverest its higher parts with waters'; Psalm 148, 'the waters that are above the heavens'; and in the Canticle of the Three Children, Daniel 3. And afterward: Nowhere will the word 'Firmament,' or the Greek word στερέωμα [Greek: στερέωμα (stereōma, "firmament, solid expanse")], or the Hebrew ירקיע, *Raqia* [raqia, "firmament, expanse"], be found used for the air, etc."

The same, page 101:

[Margin: The supercelestial waters are elementary.]

"But here I understand elementary waters, of the same species as our own waters." And a little later: "Hence one comes to wonder that there are some who say these supercelestial waters differ in species from these sublunary ones." And afterward, giving some reason for their having been placed in the heavens: "Let us say — so long as nothing better presents itself — that they are there in order to withhold from us the sight of the empyrean heaven, which is most brilliant on every side."

[Margin: Pedro Hurtado.]

Pedro Hurtado de Mendoza [Pedro Hurtado de Mendoza], of the Society of Jesus, in his *Philosophy* published in the year 1624, *On the Work of the Six Days*, Disputation 3, Section 3, §§ 43, 44, 45, 46, 47, 48, writes as follows about the waters placed by God above the firmament, page 381: "Therefore by the word 'waters' understand what Scripture plainly sounds, namely elementary waters, in and beneath the heaven. Since there are elementary waters above the Firmament, it cannot..."

[The following continues the extended quotation begun on the previous page — Hurtado de Mendoza reviewing the opinions on the firmament and the supracelestial waters.]

that by the name "firmament" the air is understood, above which there are no waters. Others, following Father Pereira [Benedictus Pererius] and Molina [Luis de Molina], understand by "firmament" the eighth sphere of the heaven, which separates the ninth heaven — the one called "glacial" — and the watery heaven from the elementary waters. [Margin: He refutes the ninth, glacial heaven.] Father Pereira more truly says that to understand *the heavens* by *the waters* is far too unusual and repugnant to Scripture; nor is it credible that "water" should be taken so ambiguously within one and the same phrase and narrative. Molina likewise says that this heaven was known to none of the ancients, not even to Aristotle himself, but is an invention of certain Catholic writers, by which they might answer the argument drawn from this passage to prove that there are waters above the heaven. And afterward:

"The firmament, then, is the aggregate of the intervening bodies placed between the terrestrial and the celestial waters, which are contiguous to the empyrean heaven. [Margin: Whatever lies between the celestial and the terrestrial waters is understood under the name of "firmament."] This aggregate includes all the mobile heavens and the air. This is the more common exposition, which Molina

staunchly defends, which Pereira too admits, and which our Martín del Río [Martín del Río], the celebrated interpreter of the Sacred Scriptures, has most recently defended.

"It is proved thus: because they do not fit either the heaven alone or the air alone — the things said in this first chapter about the firmament. For birds do not fly in the heaven but in the air; nor does the heaven divide the sublunary waters, but the air does; while the stars and planets are not in the air, but in the eight parts of the starry heaven.

"Again, the firmament, taken as the outermost convex surface of the starry heaven, contiguous to the upper waters, intersects both and divides them.

"And this openly commends the said exposition, since it sets forth the sacred text plainly and clearly, without any manufacturing of chimeras.

"And so on the first day were created the empyrean heaven and the earth, between which two bodies was created the abyss, filling the entire gap between heaven and earth; for there was no empty place.

"On the second day God created the starry heaven, distant from the empyrean; and between these two heavens he left a good portion of the waters. He likewise created fire and air, below which were, on that second day, the sublunary waters, and beneath these the earth. But the waters that occupied the space of the firmament were not annihilated — for God has annihilated nothing as yet — rather they were converted into the firmament, which was made out of the waters. [Margin: The firmament was made out of the elementary waters.]

"And so the matter of the heaven, of fire, and of air was previously the matter of water; and the starry heaven was produced from the privation of that matter and generated from it, and so forth." And shortly after: "And so the matter of the starry heaven and of the sublunary world are of the same species. [Margin: The matter of the heaven and of the sublunary world is of the same species.] So say Molina and del Río, who holds that the mobile heavens are of their own nature corruptible," and so on. And afterward:

"That there are waters above the heavens — besides these testimonies, there are many others. First, since the sacred writers repeat this so often, yet none of them ever explains the proposition away, but they all leave it as it stands. [Margin: He proves it by various arguments.] Again, God was able to place them there; but whether he in fact did so depends on his will alone, which we must investigate from his testimony rather than from anything else. Now if God had done this and

wished to attest it, in what plainer and clearer language could he have done so? Add Psalm 103:3, *Stretching out the heaven like a skin, who coverest with waters the upper parts thereof* — where "heaven" is not taken for the air, whose upper part is not covered by water, not even by rain-water, since the clouds are held not in the outermost region of the air but in its middle region, while the upper reaches of the air are covered not by waters but by fire, to which the air is contiguous," and so on. And afterward:

"This I confirm from the Canticle of the Three Youths, which seems to be a gloss on this psalm (namely Psalm 148)," and so on.

"But you ask, to what purpose do the waters serve there? Yet why do you ask me? Ask him who willed them to be there — who, had he so willed, would surely not lack an honorable and excellent purpose. For my part I was not his counselor, nor do I know the mind of the Lord. But you object: we do not know in what manner they are there. Yet he knows who placed them"

"there. For we ought not to measure Scripture by our own capacity; rather Scripture ought to take our mind captive and reduce it to obedience. [Margin: N.B. The human intellect is to be taken captive into obedience to Sacred Scripture.] He who preserves bodies without food in the heavens, and who does not suffer limbs scorched by eternal fires to be consumed — will he not be able to keep the waters unharmed from heat?" and so on. Thus far Hurtado.

Let this suffice for what has been said on this occasion — namely, in proving from the celestial waters, on behalf of a fiery Sun, from the peaceful teachings of the ancients, concerning the elementary waters carried up into the heaven. Now I return to my own purpose and say: even if the solar phenomenon should show the Sun itself to be burning, flaming, and seething, this still would be nothing new, but something long since recognized and unanimously asserted by the ancients — who nonetheless were ignorant of, and did not so much as catch from afar the scent of, the ROSA URSINA. For the ROSA URSINA had not yet arisen, still less been cultivated.

Sense and reason have led our external witnesses — and Sacred Scripture and Reason have led our own — to this view. I have everywhere woven in the authorities of those outside our fold: you will find them more copiously in Plutarch, *On the Opinions of the Philosophers*, and in Seneca, Pliny, Cicero, Plato, Aristotle, Kedrenos [George Kedrenos], the Conimbricenses [the Coimbra commentators], and others. Of our own writers you have seen the greater part in

the authorities already produced, and you will see more shortly in the following Propositions concerning the corruptibility and fluidity of the heaven.

At this point I cannot fail to set forth the opinion of Girolamo Vielmi [Girolamo Vielmi] of the Order of St. Dominic, Bishop of Aemonia [Cittanova] and Professor at Venice — an opinion he states, as accurately and vigorously as anyone, in his theological *Lectures on the Six Days*. [Margin: Girolamo Vielmi, a Dominican, contends for the supracelestial waters.] For in Lecture 13, page 161 of the Venice edition of 1575, upon the words *And God said, Let there be a firmament*, and so on — after citing Severian [Severian of Gabala], Theodoret, and William of Auxerre [William of Auxerre] — he says:

"There follow, among the more recent writers, in holding this opinion, Jerome of Oleaster [Jerónimo de Azambuja] in this passage, and Francisco Foreiro [Francisco Foreiro] on Isaiah chapter 40; and to establish it they bring forward the words of St. Peter, in his second epistle, chapter 3, which are these: *For this they willingly ignore, that the heavens existed long ago, and the earth was formed out of water and through water by the word of God* [2 Peter 3:5] — words which certainly seem too clear to be obscured by any glosses. [Margin: Francisco Foreiro.]

"An argument can also be brought for this view from the etymology of the Hebrew name. [Margin: A scriptural passage effective, in Vielmi's judgment.] For (if we may believe Rabbi Joseph Kimhi [Joseph Kimhi], the divine Jerome on the word *Oceanus*, and Agostino Steuco [Agostino Steuco]) *Schamaijm* [Hebrew *shamayim*, "the heavens"] means for them the very same as "waters there" does for us. It is therefore of waters that the firmament consists. [Margin: An argument from etymology.]

"Now as regards those supracelestial waters, by a remarkable consensus (with one or two exceptions) the authorities hold that they are elementary and properly so called — that is, entirely akin to our own — since God said, *Let there be a firmament in the midst of the waters, and let it divide the waters from the waters*. [Genesis 1:6] That division, then, was the partitioning of a single homogeneous body and its separation into two parts; and so both parts are of one nature. Now this part, the subcelestial, is true elementary water; therefore that other part, the supracelestial, is likewise true elementary water. [Margin: The supracelestial waters are true elementary water.]

"And afterward, on page 163: What forbids us, I ask, to hold that this quality of cold depends upon those supracelestial waters and is preserved by them, and that

they were placed there for that very purpose? Likewise on page 164 he says that under the name of "firmament" the whole mass of the celestial bodies is contained: *For too resplendent, he says, are the Scriptures they adduce to be obscured by any mist of figurative interpretation — which some nonetheless attempt.*

"On page 165: But whether that mass in which the stars are set was, as it were, a kind of crystal compacted or frozen out of water, is a most doubtful and intractable problem. [Margin: Scriptural passages adduced for the supracelestial waters cannot be obscured.]

"(For, as he says on page 166,) this opinion so displeased St. Basil [Basil] that he called it the vulgar one, and one that is childish and of a rather simple wit. See in what place St. Basil holds the opinion of the hardness of the heaven produced from the freezing of the waters after creation —" [Margin: St. Basil laughs at a heaven frozen out of water.]

"— he calls that opinion, once introduced, childish and of a simple wit; so Vielmi testifies.

"On pages 174 and 175, Lecture 14: This assumption, however — namely, that there are no true and elementary waters above the heavens — St. Thomas [Aquinas] and Durandus [Durandus of Saint-Pourçain], Book 2, distinction 14, prove as follows. [Margin: The contrary opinion of St. Thomas and Durandus.] If the elementary waters were between the two celestial globes, they could also be heated and rarefied by the motion of those globes, beyond what even their own forms would allow, and so could be corrupted, and thereupon air or fire could arise from them — which nevertheless the philosophers, by broad consensus, deny. But this opinion, which denies in general that elementary waters proper to themselves are set above the heavens and the stars, seems to me so to conflict with the word of God that I cannot cease to marvel how it can have crept into the minds of such great Doctors. Wherefore, with a prefatory word and with the reverence I owe these great Doctors, I argue against them thus." [Margin: Vielmi champions the supracelestial waters from the word of God, and answers the arguments.]

And he sets out eight arguments in order for the supracelestial waters — which, for brevity's sake, are not to be inserted here. After them he resolves the contrary reasonings made by his opponents, and at last, on pages 176 and 177, concludes:

"Therefore, with Denis the Carthusian [Denis the Carthusian], I judge that these waters were so disposed and consolidated there by God that they cannot be

altered or dispersed for as long as they are to serve the use of the world. But I shall treat this matter more fully hereafter; that opinion, accordingly, does not please me."

This is the opinion, of course, that denies true elementary waters can be set above the heavens.

"For (as he says in the sixth argument, page 176) the whole chorus of the Greek and Latin Fathers stands against the exposition of these men (who deny the waters); and they (the Greek and Latin Fathers) held them to be true and natural waters," and so on. [Margin: All the Fathers, Greek and Latin, stand for true, natural waters.]

"On page 179 the same author proceeds thus: But although this opinion seems to me quite plausible, and in part even true (namely, that under the name of "firmament" the sublunary air is understood), and such that, if there were no other passages of the Sacred Scriptures besides the one we are examining, it could not easily be rejected — nevertheless I feel that the Holy Spirit has here set before us something other [Margin: The sublunary air alone cannot be understood under the name of "firmament."] and further, than merely this that has been said about the air; and that it is something far more wonderful, and something he willed in order to build our faith by this marvel of the air which has been set forth and which we so frequently observe. Hence there is no one who cannot easily reason and run through the argument thus:

"If the air — a rare and permeable body — by God's command strongly sustains waters that are by nature heavy and flowing, so that they do not rashly fall or slip away, why should the heaven not be able, by the same command, to sustain waters for as long as he shall see fit, even though those waters be of a nature different from the elements — provided the waters are heavy and of one kind with our own? This, this is the thing that surpasses all thought and by its magnitude exceeds all understanding: that the Maker should have set, above the true and highest heavens, waters of our own kind — a thing that was surely as easy for him as all those other things that seem to us most easy. And this too I judge Moses to be expounding to us, together with what has thus far been said about the air, so that his words may bear this sense: *Let the whole mass of bodies, from the Primum Mobile down to the Ocean and the earth, be made solid and vigorous — and indeed in such a way that it touches the waters on both sides, on its convex and on its concave part; that is, that it be surrounded by the waters above and itself likewise surround the waters below, and never in the meantime give way.* [Margin: Vielmi lays open foundations for a liquid heaven, and indicates its

liquidity in words far from obscure. For he asserts the heaven to be like air, and this air to be like that heaven — hard; and he refers it to a miracle of God that both the air and the firmament bear waters above themselves, and so on. But it would not be a miracle of God if the heaven, being formally hard, bore waters above itself, and so on.]

"Further, let this lowest portion of it too, which is the air, be so solid that, as a kind of interstice and partition, it may bear above some part of itself waters for the benefit of the lands and of living things, and may embrace the seas below, and yet never flow away. For I judge that the Holy Spirit has in the present passage set forth both as a miracle; yet the aforesaid Doctors, it seems to me, thought of neither of the two. [Margin: In what way the air is solid.]

"And on page 181: But you ask why God placed the waters above the heavens, and say the cause is hidden — all of which I not only confess but teach and contend: that this may stand out among the marvels, this wonder, from those familiar" [Margin: The cause of these waters is hidden from us.]

"marvels — though I do not doubt that this too, no less than all the rest, is for the benefit of mankind and the adornment of the universe," and so on.

"For although Scripture has expounded to us plainly (provided it be weighed seriously and diligently) that there are true waters there (as I indeed hold), it nevertheless does not explain of what kind they are — that is, whether flowing or congealed, thin or thick — nor to what use or end they were placed there.

"Page 182: It is therefore more fitting candidly to accuse our human darkness and our ignorance than, in order to press this view, to bring forward empty reasonings. For all understand it in this way: that we rest upon the authority of God speaking alone," and so on. [Margin: We must rest upon the authority of God speaking alone.]

"And afterward: I pursue these things at greater length than I am accustomed, in order that from them, as from most certain reasonings, I may demonstrate that those men are greatly in the dark and deceived who reason thus: *It does not appear to what use the elementary waters were placed above the heavens; moreover, the nature of things does not permit it; therefore this position is a fiction.*

"These things would indeed be rightly said, and the inference would be plausible, as he puts it, were it not that the word of God stands against them — especially as understood by the ancient holy Interpreters, who understood (as I am compelled often to repeat) that waters of one kinship and nature with our own are set and

exist above the heavens, in these words: *And God made the firmament in the midst of the waters, and divided the waters from the waters.* [Margin: From the word of God, understood according to the ancient holy interpreters, true supracestrial waters are asserted.] But we Christians are in this calamity at the present time, that many of our own (if indeed they deserve to be called ours) grow accustomed, from the first bloom of youth, not to shrink from holy antiquity," and so on. [Margin: He grieves at the neglect of antiquity.]

And after he had said that this truth is above all established from Psalm 148 and the Canticle of the Three Youths, he proceeds thus on page 183:

"Therefore, when the three Youths say simply, *Bless the Lord, you heavens* [Daniel 3], either the utterance is emphatic — so that the sense is, Bless him, you heavens, namely the amplest and most eminent, which David called the heavens of heavens — or else it is extended without distinction to all the heavens of the discourse.

"*And let all the waters that are above the heavens praise the name of the Lord.* [Psalm 148:4] Who does not see that the Prophet, as the Maker, explains above which heavens the waters were placed? The context certainly, and the very sequence of the words, compels us to understand that he said they were placed above those heavens which he had just now called the heavens of heavens — that is, higher and more sublime than the rest. The waters, then, are not set above the air alone, as Abraham Ibn Ezra [Abraham Ibn Ezra] and the rest suppose, but above the very highest heavens as well. [Margin: From the context and sequence of Scripture he proves the supracestrial waters.]

"And this verse of David is truly a striking commentary on the words of God which we are weighing, *Let there be a firmament in the midst of the waters* — so that it seems to me the mark of a contentious and headstrong mind, or at least of one little fitted to grasp the divine meanings, to affirm that here, in the Prophet, the air comes under the name of the heavens of heavens. [Margin: He censures the violent glossators of Scripture.] Besides, one must remember that David is now in the heights — that is, in the upper part — whereas the air is set in the lower part; and he called it "of the heavens" in the heading. And on page 184:

"And thus far David's testimony could indeed have sufficed for sober and pious minds; but the Holy Spirit willed that this matter which we are investigating should be opened more powerfully and more fully — on account of contentious people — again in what follows, by this same Prophet: *Praise the Lord from the earth*, and so on: *hail, snow, ice, storm winds*, and so on. Behold, you hear that the

waters which are made in the heaven — that is, in the air — namely hail and snow (and understand together with these the dew, hoarfrost, rains, and clouds, and so on) — Therefore those waters which are above the heavens of heavens are other than these, which, set in the air, hang over us.

"But, to draw together what I have said, let me now contract it into an Epilogue: this indeed, and the distribution of the creatures which David makes, and the general names of the waters, and the particular names of hail and snow, so powerfully make it manifest that I judge it superfluous to dwell longer on this matter; and, for those whom these things do not persuade, I do not doubt that neither my discourse nor another's could easily persuade them.

"Wherefore this received and widely accepted"

[The opinion] widespread in our time among the Innovators — that only the waters of the air are called supercelestial — is thereby proved false.

For the Fiery Nature of the Sun: Authorities Drawn from Sacred Scripture and from Hebrew Sources

Chapter XXII

Sacred Scripture strongly supports the numerous phalanx of venerable antiquity that contends for a fiery Sun.

Psalms 18[5–7]: "In the Sun he has set his tabernacle, and he himself, like a bridegroom coming forth from his chamber, has rejoiced as a giant to run his course. His going forth is from the highest heaven, and his circuit reaches to its summit; *nor is there anyone who can hide himself from his heat.*"

Ecclesiastes, ch. 1, v. 5[–6]: "The Sun rises and sets, and returns to its place; and there, being born again, it wheels through the south and bends toward the north. *Surveying all things in its circuit, the wind advances and turns back upon its own circles.*"

Ecclesiasticus, ch. 17, v. 31: "What is brighter than the Sun? *Yet even this shall fail.*"

The same book, ch. 43, v. 2: "The firmament on high is his beauty, the appearance of heaven in a vision of glory. The Sun, at its appearing, announcing as it goes forth — a marvelous vessel, the work of the Most High. At noon it scorches the earth, and *in the sight of its blazing heat, who shall be able to endure?* It keeps a furnace at its works of burning. Threefold the Sun, scorching the mountains,

breathing forth fiery rays, and, blazing with its beams, blinds the eyes. Great is the Lord who made it," and so on.

From these and similar passages of Scripture the sacred interpreters prove that the Sun is formally hot, of a fiery nature, that it moves freely and of itself in the heaven, and, finally, that it is not exempt from decay. Since the Moderns see that these things agree very closely with the solar phenomenon, they hold that they are to be taken properly and without any metaphor, and they deny that there is any reason why the Sacred text should be forced into metaphorical and distorted senses. For when Scripture calls the Sun itself a "spirit" surveying all things and returning upon its own circles, it points its finger, as it were, at the fiery and kindled abundance of its exhalations — that is, of the Spots and Faculae.

Hebrew Sources, and the Names of the Sun

The Hebrew sources, indeed, and the very words for the Sun, breathe nothing but flame, dryness, and burning heat.

For אור, *Or*, among the Hebrews — as Pagninus [Sanctes Pagninus] attests in his *Thesaurus Linguae Sanctae* — means to shine, to grow bright, to be illumined, to kindle; whence the Greek ὁρᾶν [Greek: horan, "to see"], οὐρανός [Greek: ouranos, "heaven"]. And the same word is also a noun, which in Sacred Scripture is used for Light, the Sun, Flame, the light of fire, and the light of a cloud; for each of these, seek the clear scriptural testimonies in the same author, fol. 46–47. Therefore, from the word *Or*, Light, is derived *Luminare* (luminary), *Maor*. Genesis 1:16; Psalm 74:16.

That the same word *Or* signifies the flame of fire, you have in Isaiah 31:9 and 47:14, likewise Genesis 15:7: "I am the Lord, who led you out of *Ur*" — that is, out of the *Fire* of the Chaldeans — as Father Cornelius a Lapide, together with others, explains (Commentary on Genesis, ch. 11, p. 148). Whence Benedict Pererius [Benedictus Pererius], book 1 on Genesis, vol. 1, p. 50:

[Margin: Cornelius a Lapide.]

"The word 'light,' used absolutely," he says, "usually designates the light of the Sun, which, on account of its abundance and beauty and efficacy, is simply called 'light.' For very often divine Scripture uses the word 'light' for the light of the Sun, as in Isaiah ch. 60: *The Sun shall no longer be to you a light by day.*' For 'to give light,' in Hebrew, is *Laor*, that is, 'for light'; for even the light made on the first day is here called *Or*.

"And Jeremiah, ch. 4: 'I looked at the earth, and behold, it was empty and nothing; and [I looked at] the heavens, *and there was no light in them.*' And not only in Sacred Scripture, but also in Latin and common speech, it is frequent to put 'light' simply for the light of the Sun, or for the day that is made by the Sun; thus one says 'by today's light,' and 'it has not yet grown light,' and so on."

Since, therefore, Light, created on the first day, signifies among the Hebrews fire, light, and the Sun, what wonder is it that the Holy Fathers said the Sun is fire?

[Margin: An argument from the imposition of the name.]

Another word for the Sun is חַמָּה, *Chammah*, from the root *Chamam*: to grow warm, to grow hot, to be warmed, to be hot, to be warm, to seethe with heat. Exodus 16:21, וַחֲמָה *Vecham*, "and the Sun grew hot." This indeed is a verb; but if the same word is used as a noun, it will signify "heat." See Pagninus, p. 72. These usages certainly indicate that the Sun is hot formally, and not merely effectively; for "to seethe, to be hot, to be warmed," and so on, by no grammar means the same as "to make hot" (*calefacere*), and so on.

[Margin: That the Sun is formally hot — another compelling argument, drawn from its very name.]

[Margin: The fiery nature of the Sun, from Hebrew etymologies.]

There is also among the Hebrews another word for the Sun, חֶרֶס *Cheres*, which impresses on the mind burning heat and drying-up, as Pagninus attests, p. 804.

[Margin: An argument from another word for the Sun.]

But the very name of heaven, which the mouth of the Lord named, also indicates — according to the Hebrew etymology of the ancient Rabbis — that the Sun is by nature fiery. For God called the Firmament "Heaven," which in Hebrew is שָׁמַיִם *Schamaijm*, from שָׁם and מַיִם, *scha* and *Maijm*, that is, "There [are] Waters"; and from this etymology writers prove the supercelestial waters. Or, according to the Rabbis, [it is] from שָׂח and מַיִם, from *Esch* and *Maijm*, that is, from Fire and Water — because the Firmament, made from the waters and standing in a middle place between the upper and lower Waters, contains within itself fire, namely the Sun. For Scripture says: "And God made two great luminaries, and set them in the Firmament of Heaven." And since God himself imposed this name *Schamaijm* upon the Firmament, this is assuredly its name, and at the same time it explains, by its very meaning, its nature and essence in the best possible way. For if, as Scripture attests, God brought the animals to Adam that he might see what he

would call them, and Adam, from the natures of those animals — seen and known through the knowledge infused by God — imposed on each the names fitting them and indicating their essence (so that Scripture testifies that the name of each beast is the one Adam gave it), how much more shall we suppose that God, thrice best and greatest, would impose upon the Firmament a name most proper to it, and consequently that, by the force of the word and through his own omnipotent utterance, he would join there water and Fire in an indissoluble harmony? Just so, by the name of our Savior JESUS, which he himself imposed, he wished us to understand that he would be the Savior of the whole World.

[Margin: From the etymology of the Firmament, both water and fire in heaven are argued.]

Finally, another name for the Sun is שמש *Schemesch*, so called because the Sun dispenses light, as Pagninus teaches at length, p. 3049. That sound arguments can be, and usually are, drawn from the true etymologies of names is admitted by all — especially with so great a foundation added as we have in the present case: namely, that in the Sacred language words were imposed on things not at the arbitrary will of men, as mere sounds, but as signifying of themselves, and as declaring the natures and properties of the things they were adopted to signify. Now, if you please, let us apply one or two arguments to our Phenomenon, drawing on the very mind of those who press and champion these points, and let us see what sinew there is in them.

That the Solar Faculae Are in the Sun, and Are Parts of the Sun, Is Proved by Conclusions Deduced from Sacred Scripture

Nothing is brighter than the Sun, as we have in Ecclesiasticus 17:31, where it is said: "What is brighter than the Sun?" — as if to say, nothing. But it is clear that the solar Faculae themselves, both primary and secondary, are brighter than the rest of the Sun. Therefore, if they are in the Sun yet are not parts of the Sun, it follows that something is brighter than the Sun — contrary to Sacred Scripture, which is absurd. The Faculae of the Sun, therefore, are parts of the Sun.

[Margin: It is shown that the solar Faculae are parts of the Sun, by an argument deduced from Scripture.]

Likewise, if the Faculae of the Sun are not in the Sun, nor parts of the Sun, then not only is something granted that is brighter than the Sun, but the Sun itself will be somewhat dark, and will not be seen at all — which, again, is contrary to Sacred Scripture. The consequence is proved: because the entire bright surface of the Sun is nothing but mere secondary Faculae, as I have most fully

demonstrated from the phenomenon itself in the third book and in the first part of this fourth book. Therefore, lest we fall into those absurdities against Sacred Scripture, we cannot deny that the solar Faculae are parts of the Sun.

[Margin: Another [argument].]

Likewise, from Sacred Scripture it is certain that the Sun was created by God to illuminate the earth and to dispense light; but it is most certain, from the Sun's own Phenomenon, that this function is fulfilled by the solar Faculae alone. For if we separate them from the Sun in thought, the Sun will have no residual light left except that which resides in the Spots and shadows, as I have shown at length in the preceding [books]. Therefore, if the solar Faculae are not admitted into the reckoning of the solar parts, then something [other than the Sun] will dispense light to us and to the earthly globe and will perform the other offices of the Sun — which the Sun does not. But since this cannot even be conceived, much less affirmed, without going against God's ordinance and Sacred Scripture, it is clear that the solar Faculae are parts of the solar body.

[Margin: Another.]

By the same reasoning, from that passage of Ecclesiastes — "surveying all things in its circuit, the Spirit advances, and turns back upon its own circles" — they draw an argument for the fiery nature of the Sun. For on account of that predominant fiery power of the Sun, Scripture calls the whole Sun a "spirit"; just as the Empirics call "spirit" that finer and more vigorous substance drawn off by distillation; so we call strong wine "spirituous," and we call the hottest and most refined blood by the name of "spirits." The Sun, therefore, because it excels supremely in fiery nature, is proclaimed a "spirit" in the Sacred writings, according to these men.

[Margin: That the Sun is fiery.]

For the circumstances do not seem to permit that "aether," or much less "air," be understood there.

Again: if the Sun were not of a fiery nature, that etymology bestowed on the Firmament, *Schamajm*, would be gratuitous. For the Firmament is called "Fire" only by reason of the Sun; for if the Sun be removed, there will be no fire in the Firmament. Either, then, the origin of the word is not from fire and Water, or — as they say — the Sun must be acknowledged to be fiery.

[Margin: In another way.]

The authorities of the other Doctors, and especially of the Theologians, you now have partly among those already adduced, partly among those still to be adduced, in chapter 24 and those following. For they themselves do not, of set purpose, press this question very hard, inasmuch as it is more a Natural than a Theological one, since neither Sacred Scripture nor any fixed dogma of the Church has determined it.

For the Fiery Nature of the Sun: Philosophical Authorities Are Introduced, and Objections Are Resolved

Chapter XXIII

There were once many sects of Philosophers, and all of them, except Aristotle, admitted that the nature of heaven and of the heavenly bodies is fiery, though in different ways. On this matter, consult Plutarch in the *Placita Philosophorum*, Seneca, Pliny, Cicero's *On the Nature of the Gods* and *On the Universe*, Plato, Aristotle, Kedrenos [George Kedrenos], and others — especially Martinengus [?] in his great Gloss.

The Mathematicians, certainly, both Ancient and Recent, have held this view — most of the better and older ones. And lest you think, friendly Reader, that words are being palmed off on you, and that I impose this out of partiality, bear with me patiently, and in the propositions that follow I will produce witnesses, and by the deed I will lend credit to my words. For at the present time, all Mathematicians either follow the Tychonic Hypotheses, or the Copernican, or perhaps devise new ones. Those who follow the Copernican, all without doubt or difficulty acknowledge the fiery nature of the Sun, and say that the Sun is in the Universe as the heart is in an animal, and so on. Those who are devoted to Tycho [Tycho Brahe] all embrace a celestial substance of purified fire.

But, as I said, I break off now, because I will bring forward the passages, together with their authors, of set purpose in the following chapters, as much as is sufficient. For these matters are so closely akin to one another that one can scarcely be treated, proved, or rejected without the other. This too I warn: that many arguments which could be brought forward for this view are deliberately omitted, in order to avoid prolixity and tedium. But these seem sufficient to ward off the odium of novelty; for it is chiefly to this end that they have been adduced. Now let us hear some objections and clear them away.

What the Astronomers Are Accustomed to Reply to the Objections Which Seem to Militate Against the View Comprised in the Authorities Adduced

Various objections and difficulties can, and usually do, arise and be raised, which might drive someone far from that view, so that he does not, with the authors adduced, believe the Sun to be fire, or something fiery. For:

[Margin: Objection 1.]

First: since it is established, from the Spots and Faculae themselves, that the Sun is engaged in a perpetual consuming of its own self, how can it come about that it is not at last either perceptibly diminished, or entirely consumed, or, finally, extinguished when its combustible matter has been eaten away?

[Margin: Solution 1.]

They reply, first, that by this same argument many things which, from the foundation of the world down to now, stand indubitable before our eyes could — though wrongly — be called into controversy and doubt. For from the founding of the world, from the time when the earth, drawn out of the waters, appeared, and the ridges of the mountains were stretched up into the air, the individual mountains themselves have gradually worn down, worn away over the years by the vicissitudes of the seasons and by the opposing and alternating conflicts of heat and cold, moisture and dryness; the valleys have swelled up; the yawning caverns of the Ocean have begun to be filled by the inflow of earthly sediment. Yet who, over so many ages now, has any such perception of these diminutions or accretions as could warn an observer from afar? Who could introduce any perceptible proportion of difference in the height of the mountains or the depth of the valleys?

The loftiest ridges of the Alps stand, and are not lowered, even though every year whole mountains, from their frozen and crumbled summits, are carried down by the force of the rain-waters to the thickness of a palm's-breadth or two; nor are the valleys below thereby filled to overflowing, nor do they aspire to the height of the neighboring ridges; and the sea itself, from the quantity of earth carried into it, neither swells nor overtops its shores — at least not with any notable flooding perceptible to an eye looking down from on high, far off.

By a similar reasoning, therefore, even if the Sun were fed by the consuming of its own parts, nothing would have been observed by us, so far distant, down to this day. Hence the adversary accomplishes nothing against this view with this

weapon, but he must furnish other arms from elsewhere, if he wishes to accomplish anything.

[Margin: Solution 2.]

They reply, second: that Mount Vesuvius, Aetna, and many others on earth, burning with everlasting fire, have not yet suffered any perceptible loss of their bulk, although the voracious flame prepares for itself a continual banquet out of their very entrails. Now imagine the whole globe of the earth to consist of a continuous series of similar mountains: would not such an inflamed globe present, to some celestial spectator, something like a lesser Sun, without any perceptible diminution of itself, even though the nourishment of the entire fire were drawn from every single part of the burning globe itself? But what fraction is the height of Aetna in relation to the semidiameter of the earth? And that very matter by which that fire is fed — how great do you suppose it is? Smaller, certainly, than Aetna itself, without doubt, it must be.

And the semidiameter of the whole earth in relation to the semidiameter of the Sun — how great do we judge it to be? Therefore, if we see one mountain of the earth burning for so many ages and yet not consumed, nor perceptibly seen to be diminished at the said proportion of distance; if we sufficiently understand that the earth itself would remain in its full magnitude under a like conflagration — what reason is there that we should deny that something similar could happen, or has happened, in the case of a supposed burning Sun, when we daily see it happen thus, with our very eyes, in these sublunary things?

The same Creator God, therefore, who fashioned Aetna blazing without the said diminution of itself, could also create a fiery Sun without any decrease at all. But whether he did so, or otherwise, must be sought elsewhere.

[Margin: Solution 3.]

They reply, third: If human ingenuity — which many concede, and think has actually been done, and certainly grant to be possible — can kindle a perpetual artificial fire on earth, will the wisdom of God not be able to light and perpetuate a natural one in heaven? Human art, to be sure, will maintain from fire a fuel, and from fuel a fire; and shall the same [God] not be able [to do so] in... ..in the heaven, if it should so please the creative Wisdom of God. And that it has so pleased, these men [the defenders of a fiery Sun] both maintain and argue from the new phenomena brought forward, reinforcing their case with the authority of the ancient holy Fathers drawn from Sacred Scripture.

[Margin: Solution 4.]

They answer, fourthly. If fired gold is not diminished, even though it glow perpetually in the flames — but why do I speak of gold? Many hold the same of water, even a small quantity, which, when enclosed in a glass vessel and subjected to the fiercest and most prolonged action of fire (though it be dissolved into a most tenuous, as it were burning, vapor), nevertheless, if the mouth of the glass tube is left open, drips back drop by drop into exactly the same measure, so far as observation can determine. If, then, molten gold, or water once set on fire, is not consumed even by a continuous, tormenting flame, it does not follow from the Sun's burning that it must necessarily be used up. And if it does gain or lose anything, that happens only incidentally.

These points are confirmed still more fully from the various kinds of coal-dust: for although these are most readily kindled and reduced to ashes, they can nonetheless — and regularly do — be enclosed by a certain art in an earthen shell and set alight without any loss to themselves, even if that fiercest combustion is kept up for days and years on end. I report this not from hearsay but as something seen and actually done; nor do these experiments lack a philosophical explanation.

[Margin: Solution 5.]

They answer, fifthly. From the solar phenomenon it is entirely certain that the spots of the Sun [Maculae Solis] come to be and pass away, grow larger and smaller, brighten and darken, condense and rarefy, and finally pass off into bright faculae [faculae], brighter than the rest of the Sun.

These facts, then — which, they say, must either be denied (though because of the evident testimony of experience and of the solar phenomenon they can never be denied, buttressed as they are by observations and testimonies so many, so great, and from so many observers), or else one must at last yield up both one's own place to the truth and the phenomenon its own course — these acute minds will readily see through, and where the argument tends. They themselves are certainly convinced by what has been brought forward that it tends this way, and they have no doubt that others too will be convinced, once the weight of the reasons is well pondered.

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OBJECTION II.

Since such great changes take place in the Sun that its parts are by turns bright and by turns shadowed, and the primary spots often equal in some fashion, indeed exceed, a third or half of the whole terrestrial globe, and so forth — how is it that a sound, unimpeded eye does not notice this? For reason seems to argue that there ought to be some sense-perception of the matter, if things really stood so.

[Margin: An objection drawn from the fact that the spots are not seen with the naked eye.]

The reply is that no sense-perception of this occurs because the species [visual images] of bright objects always overwhelm the species of objects that are not bright, even when the two are set side by side, and even when the non-bright bodies are equal to the bright ones or much larger. For bright bodies have this from their nature, that they emit a livelier image into the sight than non-bright bodies do; and so the latter are suffocated by the former.

[Margin: Solution.]

There are very many experiments bearing on this, not a few of which you will find in my *Oculus* [1619]. If some spots have at times been seen with the naked eye on account of their excessive size, they were nonetheless not taken as a display [ostentum] of spots, because at that period this phenomenon was unknown, and so on.

OBJECTION III.

If the Sun were fire or something fiery, it could be looked at by a sound eye with unimpeded gaze and without hindrance; but the Sun cannot be looked at by a sound eye with unimpeded gaze and without hindrance; therefore the Sun is not fire or anything fiery.

[Margin: An objection drawn from the fact that the unaided eye cannot bear the sight of the Sun.]

This objection might perhaps render an incautious mind, one less versed in matters of this kind, doubtful about the truth of what has thus far been said and deduced from the phenomenon, because the objection itself appears in some way plausible and suited to the grasp of the common people. For it is not easy to find,

among sublunary natural things, a fire so intense that a healthy sense of sight cannot bear it; and so the argument wears the look of a triumphant one, and so forth.

Yet in fact, once the matter has been looked into and examined more thoroughly, it all vanishes like children's rattles.

[Margin: Solution.]

I therefore reply to the argument in its [syllogistic] form. When it is said that the Sun, if it were fire, ought to be able to be seen without injury by a sound eye with unimpeded gaze — the answer is that, if the proposition is understood universally and of every mode of seeing, the inference is false. For there can be a fire, or even a light from fire, so intense that even the soundest eye cannot bear its violence.

Examples (to say nothing of the intolerable dazzlings gathered by optical devices) occur among the natural flashes and thunderbolts, whose power grievously injures even a sound eye.

Hear what St. John Chrysostom [Chrysostom] writes about this in his Homily on Psalm 134, on the words *He made lightnings for the rain*:

Consider yet another marvel, and diverse natures brought into agreement. For nothing is more fiery than lightning, and nothing colder than water; yet these are mingled, and neither confounded nor blended together, but each preserves its own bounds. For while the fire remains in the water, and the water in the fire, neither did the one dry up the other, nor the other extinguish it.

And lightning is sharper than the Sun's fire, and more splendid, and the more it cuts and divides. To this the sight bears witness, which constantly meets with the rays of the Sun, yet cannot bear even the slightest assault of the lightning. And the Sun indeed runs through the whole sky in a whole day, whereas the lightning [runs through] the whole globe of the earth in the least moment of time, as Christ too testifies, and so forth.

So [says] that great and holy Theologian.

But if the proposition is only particular, so that the sense is that the Sun, if it be fire, ought to be endured by at least some sound eye, then the inference may be granted — at least materially, as they say, but not formally: because from the Sun's being fiery it does not necessarily follow that it must be able to be looked at

without harm by any eye whatever, since it is certain that the splendor of that fire too can be intensified without limit. Therefore it does not necessarily follow that it will be proportioned to the sight; but, as I said, grant that it must be seen: the major premise being conceded, then, the minor is denied. And it is said that many are found who behold the Sun with an unharmed eye —

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— of whom I myself know several. And if we consider the manner of looking at the Sun, it is again most clearly plain that the inference of the major wavers less than that of the minor. For if the Sun's brightness were absolute and thus great in itself, and not rather [a matter of] magnitude and of a certain depth of a translucent bright body of that kind that made it intolerable to the sight, then indeed any particle of it whatever would turn the eye away from looking upon it, since its flame is posited to be of the same character. But that a particle of it does not bar the sight from beholding it is shown by the Moon eclipsing the Sun. For the crescent-shaped, uneclipsed portion of the Sun lets the eye look on unharmed all the while that the Moon takes away the greater remaining part — as my own experience too attests; and also because the conspicuous stars of the sky become visible, notwithstanding that exposed particle of solar light: just as I have made plain in earlier passages by many examples from the historians.

It is evident, then, that such a segment of the Sun does not much surpass — or perhaps does not equal — the brightness of the full Moon itself in respect of the power of seeing, since it is established that at full moon the stars of the sky grow dim enough, and so forth.

Now, of whatever character one crescent-shaped bright particle of the Sun is, it is not wholly unlike the whole as well. Yet the one particle can be seen without harm to the eye; therefore the several particles too can be seen, presented successively and separately in no great portion, and not rushing upon the eye all at once.

That the eye does not bear the whole at once, or look on the Sun with impunity, arises from its excessive magnitude and its distance from the eye. By reason of this, more of its bright hemisphere is seen; and, the non-bright species of the spots being suffocated, its bright parts are as it were optically condensed, viewed under a very acute angle, so that they strike the more forcibly, formally speaking, the organ of vision set in the concave floor of the retina [Retina] — to which the globular shape of the crystalline humor greatly contributes, as the everyday experience of the convex lens teaches, and so forth.

OBJECTION IV.

No fire seems able to have splendor enough to produce day; therefore it does not appear probable that the Sun is fire. This objection is akin to the previous one, and does not differ much from it in substance. For there the argument was taken in relation to the Sun's power over the sight — which bears any sublunary fire whatever, but by no means [bears] the Sun; whereas here the Sun is considered in relation to the sublunary world, in illuminating which it produces day: an effect that seems unable to be ascribed to fire.

[Margin: Solution.]

But the reply is to deny the antecedent. For a great fire gathered into one can do this. And that the splendor of the Sun is not great enough to produce clear day unless it flows down here from the whole Sun is plain from solar eclipses, which, in proportion to the Sun's being shadowed, likewise diminish the brightness of the day — as I said before, and as can be shown by countless examples. And I am quite convinced that if some solar facula or bright portion were set beside an equal fire, so that it were viewed from here, it would present an equal splendor. But lest I be judged to be putting these things forward on rash imaginings, here is an example in which a sublunary fire —

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— turned night into the brightness of noon, and that at Naples in Italy; as is reported in the *Chronicle* which appeared at Naples in the year 1626, published by Antonio Caracciolo from a manuscript of the Monte Cassino codex; he entitled the book *Four Ancient Chronologists* [*Antiqui Chronologi quattuor*], and so on. He narrates it thus:

[Margin: A sublunary fire produces day.]

In the year of the Lord's Incarnation 1388, in the eleventh indiction, in the month of January, on the eighth day, at the late hour of half past one, there were seen from the west stars going through the sky with a horrifying sound toward Naples and Gaeta; which stars indeed were dazzling in their brightness, and of such splendor that, when their coursing took place, it seemed to be as it were mid-day. In size they were indistinct: for some of them were seen to be of such magnitude as if they were great fiery beams, and so on.

You have here, then, day produced by a sublunary fire in the night-time.

Other objections — common ones, drawn from the crossroads and by now worn threadbare everywhere in the writings of others, or such as anyone can resolve by his own effort — I do not bring forward, so as to spare both time and the diligent reader. Much, too, is met everywhere by what has been said and what remains to be said, [answered] by the very authors who are cited.

ON THE NATURAL CORRUPTIBILITY OF THE HEAVEN AND THE STARS

In support of the corruptible nature of the Sun, the stars, and the heaven,

CAP. XXIII.

Authorities from Sacred Scripture.

The Authorities of Sacred Scripture which the holy Fathers, the Doctors of the Church, and the Expositors of the sacred volumes commonly use to assert the corruptibility of the celestial bodies are so many that it would not be worth the labor to heap them all into one; it will be enough, then, to set forth in the open the more familiar and well-worn ones, for the more recondite will readily occur to the diligent reader in the course of reading Scripture and the Authors.

[Margin: Passages of Sacred Scripture in support of the corruptible heaven.]

Genesis c. 1. v. 6. And God also said: Let there be a firmament in the midst of the waters, and let it divide the waters from the waters. And God made the firmament, and divided the waters that were under the firmament from those that were above the firmament. And it was so done; and God called the firmament Heaven.

Genesis cap. 7. v. 11. All the fountains of the great deep were broken up, and the floodgates of heaven were opened.

Psal. 101. In the beginning, O Lord, thou didst found the earth; and the heavens are the works of thy hands. They shall perish, but thou remainest: and all of them shall grow old like a garment. And as a vesture thou shalt change them, and they shall be changed.

Psal. 103. v. 3. Who stretchest out the heaven like a skin, who coverest its higher parts with the waters.

Psal. 148. v. 4. Praise him, ye heavens of heavens: and let the waters that are above the heavens praise the name of the Lord.

Danielis c. 3. v. 60. O all ye powers of the Lord, bless the Lord: bless the Lord, all ye virtues of the Lord.

Isaiae c. 34. v. 4. And all the host of the heavens shall languish, and the heavens shall be folded together like a book: and all their host shall fall down, as the leaf falleth from the vine and from the fig tree.

Isaiae cap. 51, v. 6. Lift up your eyes to heaven, and look down to the earth beneath: for the heavens shall melt away like smoke, and the earth shall be worn away like a garment, and the inhabitants thereof shall perish in like manner: but my salvation shall be for ever.

Isaiae 55. v. 17. For behold I create new heavens and a new earth: and the former things shall not be in remembrance, and they shall not come upon the heart.

Eiusdem, c. 66. v. 22. For as the new heavens and the new earth, which I make to stand before me, saith the Lord, so shall your seed stand, and so forth.

Iob 14. v. 12. Man, when he is fallen asleep, shall not rise again, till the heaven be broken; he shall not awake, nor rise up out of his sleep.

[Continuation of the scriptural catena in Cap. XXIV, Part II — authorities from Sacred Scripture for the natural corruptibility of the heaven and the stars.]

Proverbs, chapter 8, verses 27 and 28: "When he prepared the heavens I was present; when with a fixed law and a circle he enclosed the depths, when he made firm the sky above, and poised the fountains of the waters."

Ecclesiasticus, chapter 17, v. 30: "What is brighter than the sun? Yet even this will fail."

Matthew, chapter 24, v. 29: "Immediately after the tribulation of those days the sun will be darkened, and the moon will not give her light, and the stars will fall from heaven, and the powers of the heavens will be shaken."

The same is found in Mark, chapter 13, v. 25, and in Luke, chapter 21, v. 25.

Apocalypse, chapter 6, verse 13: "The sun became black as sackcloth of hair, and the whole moon became as blood; and the stars fell from heaven upon the earth, as a fig tree casts its unripe figs when it is shaken by a great wind; and the heaven withdrew as a scroll rolled up."

Matthew, chapter 24, v. 35; Mark 13, v. 31; Luke, chapter 21, v. 33: "Heaven and earth will pass away, but my words will not pass away."

1 Corinthians 7, v. 31: "For the figure of this world passes away."

Apocalypse, chapter 20, v. 11: "Earth and heaven fled away, and no place was found for them."

Romans, chapter 8, v. 20: "For the creature was made subject to vanity."

The Second Epistle of Peter, chapter 3: "In the last days there will come deceivers walking after their own concupiscences, saying: Where is the promise or his coming? For since the fathers fell asleep, all things continue thus from the beginning of creation. For they are willingly ignorant of this, that the heavens were before, and the earth standing out of water and consisting through water by the word of God: whereby that world of old, being flooded with water, perished. But the heavens which now are, and the earth, by the same word are kept in store, reserved unto fire against the day of judgment and the destruction of ungodly men." And a little later: "But the day of the Lord will come as a thief, in which the heavens will pass away with great violence, and the elements will be dissolved with heat, and the earth and the works that are in it will be burnt up.

"Seeing then that all these things are to be dissolved, what manner of persons ought you to be in holy conduct and godliness, awaiting and hastening toward the coming of the day of the Lord, by which the burning heavens will be dissolved and the elements will melt with the heat of fire? But we look for new heavens and a new earth according to his promises."

Apocalypse, chapter 21, v. 1: "I saw a new heaven and a new earth. For the first heaven and the first earth passed away, and the sea is now no more."

Ibid., v. 5: "And he that sat on the throne said: Behold, I make all things new. And he said to me: Write, for these words are most faithful and true."

From these and other similar testimonies of Sacred Scripture — understood properly and to the letter — the Holy Fathers and other standard writers judge the nature of the heavenly bodies to be shown so clearly liable to corruption that the matter needs no further proof, and no room for evasion to the contrary remains.

But should some think one must take refuge in metaphorical or allegorical expressions, [these authors] say this ought not to be done without necessity; rather, one must hold to the proper sense of the words so long as the subject matter and the literal sense allow it without notable prejudice. Nor, for the sake of anyone who thinks otherwise, should anything be conceded against the plain

and express text of Scripture — as you will clearly perceive, from the authors' own words, as the work proceeds.

How many, and how weighty, are the Fathers who stand behind the passages cited can be seen partly in the earlier authorities brought forward for the fiery nature of the heavenly bodies, and partly from those which will shortly be adduced concerning their fluid substance. For these subjects — the fiery, the corruptible, and the fluid nature of the heaven — are so bound up with one another that one can scarcely be treated apart from the others. The passages cited on both sides, therefore, must be examined by the student of these matters and weighed carefully. For all who embrace the fiery nature of the heavenly bodies undoubtedly, every one of them, subscribe to their cor-

[ruptibility]; and to these are rightly to be added those who compose the whole universe out of the four elements; who attribute the same prime matter to all things that consist in the sensible world, if they wish to philosophize consistently in the Aristotelian way; who teach that the heaven was made from elemental waters; who maintain a crystalline or truly frozen heaven; and finally those who acknowledge an airy heaven, or one compounded of a mixture of several elements.

I am readily convinced that the number of those whom I have brought into the field on behalf of the Sun and a fiery heaven (leaving aside the philosophers, omitting the mathematicians, and setting last the natural philosophers, of whom there is a vast harvest) will reach fifty. Now, for our purpose, we shall hear speaking on corruptibility, from their own writings, not all of them, but only a few by way of example; for they are exceedingly many, and all their books are full of these matters.

For the Corruptible Nature of the Heaven and the Stars: Authorities of the Holy Fathers and Doctors of the Church.

According to John Chrysostom, all the bodies of the world are corruptible.

St. John Chrysostom [John of Chrysostom], vol. 2, on Matthew chapter 9, homily 32, p. 251: "All these things which we see," he says, "since they are perishable and unstable, never remain the same; for all things will be transfigured — *heaven, and earth, and seas.*"

The same, on Matthew chapter 5, same volume, homily 40, p. 696: "For unless these things had come to pass — (the Nativity, life, passion, and death of Christ, the descent to hell, the Resurrection, the Ascension to the Heavens, etc.) — now, however, all [the prophecies] have been fulfilled, *and will yet be fulfilled, when the stars shall have fallen, when the Sun shall have been darkened, when the heaven shall have been folded up like a book.*"

The same — or rather, in the same volume, p. 943, on Matthew chapter 24, the Author of the *Opus Imperfectum* [Opus Imperfectum in Matthaeum], upon the words: "Hea-

ven and earth will pass away, but my words will not pass away." "Because heaven and earth were created for your service, but my words are ordained for your governance. *Heaven and earth are made subject to vanity*, as the Apostle says, Romans 8: *for the creature was made subject to vanity*. But by nature Truth cannot lie, nor can it ever perish."

The same, vol. 3, p. 792, in the sermon on Pentecost, concerning the Holy Spirit: "And how, consequently, is not every pure mind among Christians proved to be a pure heaven — nay, even more precious than heaven? *For the heavens will perish*, but the faithful remain for ever, as many as bear and behold God within themselves."

From volume four, p. 142, on the Epistle to the Romans chapter 8: "If these parts of this heaven," he says, "which you see turned toward us, are nevertheless of such great beauty and such delight, what then can those higher parts be like, and what must the very heaven of heaven be? But since we are not permitted to behold this now with bodily eyes, ascend in thought, and standing above this heaven, turn your eyes to that heaven higher than this of ours, to that altitude bounded by no limit, to that awe-filled light, to those peoples of the Angels, to those immense nations of the Archangels, to those other incorporeal powers." And afterward: "*For the powers of the heavens will be shaken*; for then the whole heaven is opened, then the doors of those vaulted spaces are loosed," etc.

From the same volume 4, p. 244, on the same epistle, chapter 15: "For concerning things to come," he says, "the songs of David will discourse to you, and concerning things invisible, and the invisible creation, and concerning Heaven itself. *Do you wish to learn whether Heaven will remain in this state, or will at some time be changed? He will openly answer and tell you: For the heavens shall grow old like a garment, and as a cloak you shall fold them up, and they shall be changed.* Psalm

101. And concerning the figure and form of heaven, if you will hear, you will hear all: *Who stretches out heaven*, he says, *like a skin*. And if concerning the higher parts you wish to know more, and about its surface, he will tell you again: *Who covers its higher parts with waters*. And he does not stop even here, but discourses also on its breadth and its height, showing that in both the measure is one and equal. *As far as the east is distant from the west*, he says, *so far has he removed our iniquities from us; according to the height of heaven from the earth, the Lord has strengthened his mercy toward those who fear him*."

From the same, p. 133, on the Epistle to the Romans chapter 8, homily 14: "'For the creature,' he says, 'is subject to vanity, not willingly, but by reason of him who made it subject.' What does this mean, that *the creature is subject to vanity*? *It has been made corruptible*. By what name, and for what reason? For your sake, O man. For since you received a mortal and passible body, therefore the earth too received a curse, and bore thorns and thistles. *But that heaven, growing old together with the earth, will be changed, ending in something better* — hear the Prophet saying: 'In the beginning, O Lord, you founded the earth, and the heavens are the works of your hands. They shall perish, but you remain; and they shall all grow old as a garment, and as a cloak you shall roll them up, and they shall be changed.'

"And Isaiah, chapter 51, making these things plain likewise, said: 'Look up to the heaven above, and to the earth beneath: *for the heaven is established like smoke, and the earth will grow old like a garment, and its inhabitants will perish like these things*.'

"*Do you see how the creature has served vanity? And in what way it is freed from corruption?* For the one [David] says: 'as a cloak you shall roll them up, and they shall be changed.' But Isaiah: '*its inhabitants shall perish like these things*' — *not meaning an utter destruction, for its inhabitants, that is, men themselves, will not suffer such a destruction, but a temporal one, and through it they will be transmuted to immortality, just as the creature also*. All of which he signified by these words, as [in these]; just as Paul too says in what follows.

"But now he dis-

putes concerning its servitude, and shows for what cause it was made such. And he sets us ourselves as the cause. What then — was any injury done to it, since it suffered these things on account of another? By no means; for it was made for my sake. How then can that which was made for my sake be treated with injustice, if it happens to suffer these things for my correction? But otherwise, whenever

account is taken of the just and the unjust, it ought not to move me if anyone raises objection to me concerning things inanimate and lacking sensation.

"But Paul, since he introduced [creation] by personification, used none of these arguments which I have mentioned, but strove instead to console the hearer beyond measure by a certain other one — of what kind, I ask?

"*'What do you say?' he asks — 'it was ill-affected for your sake, and made corruptible.'* Yet not even so did it receive any injury; for the same creation, for your same sake again, will be immortal. For this is what that phrase 'in hope' conveys. And when he says *'it is subject not willingly,'* he says this not to show it to be mistress of the decision, but that you may understand the whole affair to have been the care of Christ, not a merit of the creature itself. And say this too — and with what hope? *Because the creature itself also will be delivered.*

"What does this word *'itself also'* mean? Not you alone, but also that which is beneath you, and which has no share either of thought or of sensation — even this very thing will have communion of the good things with you.

"*'For it will be delivered,'* he says, *'from the servitude of corruption.'* That is, it will no longer be corruptible, but will follow the beauty of your body. For just as, when you were made corruptible, it too was made corruptible, so when you are made incorruptible, it too will follow, and will be your companion — which, to make it clear, he added: *'into the liberty of the sons of God,'* that is, for the sake of liberty." And a little later he confirms these same things from another passage of the Pauline epistle, 1 Corinthians chapter 7, thus:

"But further, when he was showing that, together with the destruction of the body, the state of human affairs likewise vanishes and perishes, he wrote again in another pas-

sage: *'The figure of this world passes away.'*

[Margin: The destruction of the stars.]

From volume five, p. 618, the *Homily to the Neophytes*: "*Those [the stars of heaven] perish in the confounding of the ages, while these [the earthly stars, the just] show themselves brighter at the end of time. For of the former it is said, That the stars will fall from heaven, as leaves fall from the vine; but of the latter he says, the just will shine like the stars of heaven.* What does he mean by saying: *as leaves fall from the vine, so the stars will fall from heaven?* For just as vines, when they are weighed down with the fruit of the grapes, demand the necessary aid of their leaves that [the fruit] may be protected, but when they have laid down their fruit

must needs be stripped of their leaves: *so it is with this age; as long as it holds the human race within it, the heaven too will hold its stars, just as the vine holds its leaves. For when the night ends, without doubt the usefulness of the stars will fail together with the night.*"

[Margin: The fiery nature of the stars.]

"Fiery is the nature of those stars, and they are taught to have obtained a fiery nature. But there [above] indeed is a fire which human sense discovers; here [below], one which the hidden depths of the mind reveal." And soon after: "The names of those stars are these:

Orion, Mazzaroth [Mezaroth], Arcturus, the Evening Star, the Morning Star."

[Margin: The stars will truly fall from heaven.]

From which it appears, according to this holy Father, that it is the true stars of the firmament that will fall from heaven — not certain fabricated "meteors" or the like, which are to fall from the air, etc.

From the same, p. 976, *On the Incomprehensible Nature of God*, homily 3: "We know that this heaven bears the form of a vault — and this not by our own ingenuity and reason, but by the divine declaration of Scripture; and we are not ignorant that it likewise encompasses the whole earth — this too we have drawn from the same divine source.

[Margin: The substance of heaven is unknown in its kind.]

"But of what substance it consists we do not know. Let anyone who contends, and affirms that he has known, say what the substance of heaven is: Is it some moisture congealed into ice? Is it a condensed cloud, drawn over into a thicker substance? Is it thick and heavier air? Surely no one can plainly explain what it is. And if this is so, who besides would de-

mand an argument by which to grasp the madness and frenzy of those who claim to know what God is? You cannot give an account of the nature of the heaven, which you behold daily, and yet you profess without doubt to know the substance of the invisible God?"

From the same, p. 376, *To the People of Antioch*, homily 69: "Do not think this — that he returns here no more — but rather that not even these things which are seen remain as they are, but they too are transformed. For indeed heaven, and earth, and sea, and all things are transmuted; then it is that you will receive your son with greater glory."

[Margin: Heaven, earth, and seas are transmuted.]

From the same, pp. 845 and 846, in the *Exhortation to Theodore the Fallen*, epistle five: "Then," he says, "the gates of the heavenly summits will be opened; nay, this very heaven will be withdrawn out of the midst, no otherwise than the hides of a stage-set, and the curtain is drawn away from the midst, that it may be changed for the better."

Thus far this great Doctor of the Church, who everywhere brings forward from Scripture the corruptibility of the heaven as an undoubted fact: its total abolition he indeed denies, but a physical change he undoubtedly maintains; only a mere cessation from local motion does he wholly pass over — a cessation which physically adds nothing better to the heaven, for otherwise, through its motion, the heaven would have turned out worse.

According to St. Basil, the Sun and Heaven are corruptible.

[Margin: St. Basil teaches the same.]

St. Basil, in homily 6 of the *Hexaemeron*, volume one, p. 69, letter C, of the Paris edition of the year 1618, writes thus: "If the magnitude of the heaven exceeds the human mind's power of measuring, what mind, what intellect, I ask, could investigate the nature of eternal things?"

[Margin: This sun is corruptible.]

"If this Sun, subject to corruption, is so beautiful, so great, most swift indeed in its motion, yet performing its periods in a most seemly order, endowed with a magnitude duly proportioned to the universe, so that in no way [does it exceed] the proportion to the whole rest of the ma-

The following continues the patristic catena on the corruptibility of the heavens (Book IV, Part II, Cap. XXIV), begun in the preceding pages with St Basil.

...may pass over to the measured limit; but in the beauty of nature [the Sun is] like a certain splendid eye adorning creation itself. And if the sight of it is insatiable, what kind of Sun of Righteousness ought we to judge Him to be?

He writes as follows in the same volume, p. 249, on Psalm 44, letter C:

"It is sown," says the Apostle, "in corruption; it rises in incorruption." Do you see the change?

It is sown in weakness, it rises in power. An animal body is sown, a spiritual body rises.

Do you see this change? It will, moreover, come about when the whole bodily creation is transformed together with us. For the heavens themselves too will grow old like a garment, and God will change them like a covering, and they will be changed. Then the Sun will be sevenfold greater, as Isaiah says, and the Moon will be as large as the Sun now is in magnitude. For it must be (says the same holy Father, Homily 1 on the Hexaemeron, p. 6, letter C) that you believe this world must be changed — if only you do not doubt that the state of souls is to be reformed and transformed into a far different kind of life.

For just as this temporal life has obtained a kindred nature, conformed to this world, so too the ordering of the life to come will take up a lot and condition most fittingly answering to the state of our souls.

But those men — the Philosophers — are so far from turning their minds to these most true doctrines that, whenever we discuss with them the consummation of the world and the regeneration of the age, they dissolve into the most unrestrained laughter, and tear at us with ridiculous jeers as though we were madmen, and harass us.

And a little before, on p. 5:

Likewise you too, through this — that these bodies which are set going by a circular motion — understand them to turn upon themselves as if by mutual conspiracy and concordant assent.

[Margin: A weighty admonition of St Basil concerning the incorruptibility of the World, etc.]

Look carefully, lest their very uniform motion, interrupted by no intervening pause at all, instill error into your mind or leave it implanted there — whereby, ill-persuaded, you might believe that this world, as it once received no beginning, so also is never at any time to be brought to an end. For the fashion of this world passes away. And heaven and earth shall pass away. [Margin: 1 Cor 7; Matt 24.] Each of these teachings, surely foretelling the coming consummation and the renewal by which the world is to be changed for the better, embraces the very same things which here too, in a brief compendium of words, Moses hands down for the instruction of us all — an instruction of whatever sort, namely an elementary one — a doctrine divinely breathed into him, saying: (In the

beginning God made). Things that took their beginning from time must absolutely also be such as one day to cease and be brought to an end. For if they were allotted a beginning in time, do not doubt about their end.

Note well, reader, the words of so great a Father and Philosopher. The many things this holy Doctor brings forward from the sacred Scriptures about the corruptibility of the heaven occur throughout his work; and it is not my intention to heap them all together here, since not a few have already been cited above, where I treat of the fiery nature of the heaven, and further below excellent testimonies from him in favour of this view are still to be produced concerning the fluid substance of the heaven. For these subjects are so closely related to one another that they can scarcely be treated separately — a thing I often point out — so do not be surprised if I also gather testimonies together in mixed fashion.

According to St Ambrose, the Sun, a star, and the heaven are subject to corruption

From St Ambrose, Hexaemeron book 1, chapter 6, the following are found.
[Margin: St Ambrose most strongly supports the same views.]

It is enough, he says, for the present assertion, that in the beginning He made the heaven, whence comes the cause of generation, and the earth, in which the substance of generation might reside.

For in these the elements were created, from which are generated all those things that belong to the world. And the elements are four — air, fire, water, and earth — which are mingled with one another in all things. [Margin: All things are from the four elements, and these are in all things.]

Indeed, even in earth you will find fire, which is frequently struck out from stones and iron; and in heaven — since the pole is fiery and glitters with shining stars — water may be understood to be present: either the water that is above the heaven, or the water that is sent down from that higher place to the earth in frequent and abundant rain. — And later: — But concerning the nature and quality of the substance of the heaven, why should I enumerate the things the philosophers have woven together in their disputations? For some assert that the heaven is composed of the four elements, while others bring in a certain fifth nature of body to account for its constitution, and imagine it to be an ethereal body with which neither fire is mingled, nor air, nor water, nor earth — [arguing] that elements of this kind have a certain course of

their own, and a use and natural motion, so that the heavier ones sink and are carried downward, while the empty and light raise themselves upward. For each thing has its own proper motion. [Margin: He vividly describes the philosophers' opinion in favour of a fifth essence of the heaven.] But in the revolution of a sphere these motions are confounded and lose the force of their own course, since the sphere is rolled about in its orbit, and the upper parts are changed into the lower, and the lower likewise into the upper.

And of those things whose natural motions have been changed, they hold that the qualities of their substances too are necessarily wont to be changed. Why, then, do we maintain that there is an ethereal body, lest the heaven should seem subject to corruption? For whatever is composed of corruptible elements must necessarily be dissolved. For by the very fact that the elements are of different natures, they cannot have a simple and inviolable motion, since the differing motion of the elements fights against itself. For one motion cannot be suited to all, nor agree with elements that stand apart; for a motion accommodated to the light becomes ill-suited to the heavier. And so, when a motion toward the higher regions is required, it is weighed down by the earthy elements; when a descent to the lower is sought, that fiery vigour is violently drawn along. For it is indeed forced downward against the use of its own nature. And everything that is forced into its contrary, serving not nature but necessity, is quickly dissolved and split apart into those things of which it seems composed, each returning to its own region.

Considering these things, therefore, and judging that they could not be stable, [the philosophers] reckoned the body of the heaven and of the stars to be ethereal, introducing a certain fifth nature of body, so that they might think the substance of the heaven to be long-enduring. [Margin: To preserve an everlasting substance for the heaven, they introduced a fifth essence.] But this opinion could not withstand the prophetic judgement, which the divine majesty of our Lord Jesus Christ and of our God also confirmed in the Gospel. For David said: In the beginning you founded the earth, O Lord, and the heavens are the works of your hands. They shall perish, but you remain; and all shall grow old like a garment, and like a cloak you shall change them, and they shall be changed; but you yourself are the same, and your years shall not fail. This the Lord so confirmed in the Gospel that He said (Matt 24): Heaven and earth shall pass away, but my words shall not pass away. Therefore they accomplish nothing who, in order to assert the perpetuity of the

heaven, thought that a fifth ethereal body must be introduced — since they equally see that a portion of a single member, joined on and unlike the rest, is wont rather to bring decay upon the body.

Note this at the same time: that the prophet David, when he named the earth first and the heaven afterward, believed it was a work of the Lord that needed to be declared — lest the heaven should seem, even by the prerogative of primogeniture, to be adjudged part of the divine substance, whereas it should rather be esteemed [only] with the privilege of a firstborn creature. When, therefore, He said, "and they were made," He indicated that both were made at once. It matters nothing, then, which you name first, since it is written: He who lives forever created all things together.

So let us leave those men to their own quarrels, who refute one another by mutual disputations.

For us, what suffices for salvation is not the controversy of disputations but the truth of the commandments; not the cleverness of argument but the faith of the mind, so that we may serve the Creator rather than the creature.

From the same, *On Abraham*, book 2, chapter 8, p. 125:

Hence the Philosophers too hold that the higher substance of this world, which they call ether, consists not of an admixture of the other elements, but assert that it is splendid and shines much with light, receiving nothing of the filth of earth, nor of the moisture of the waters, nor of the mistiness of the air, nor even any of the ruddiness of fire itself, and that it is of a certain fifth essence [*usia* = οὐσία, *ousia*]; and [they hold it] to be, as it were, the swift mind of this world, more rapid and purer than the other parts — for the others are mixed and concreted together. [Margin: He again reviews and refutes the philosophers' opinion. Therefore he did not derive his own view from them.] But we consider nothing to be exempt from and free of material composition, save that one substance alone of the venerable Trinity, which is truly of a pure and simple, sincere and unmixed nature.

From the same author, volume 5, p. 233, Commentary on Apocalypse chapter 21:

And I saw a new heaven and a new earth. For the first heaven and the first earth had passed away, and the sea is now no more. [Margin: The heavens and earth will be burned up.] The heaven and the earth and the

other elements which we now see will be consumed by fire — not so as to be utterly destroyed, but so that, as we have already said above, they may be restored into a better state by fire, as the Psalmist indicates, saying: They shall perish, but you shall remain; and all shall grow old like a garment, and like a cloak you shall change them, and they shall be changed. In saying that the first heaven and the first earth passed away, he shows that the outward form of such a heaven and earth is to pass away. For it is their form, not their essence, that will pass away, when they are changed into a better state. [Margin: He thinks the sea will be wholly abolished.] But as for his adding, "and the sea is now no more," we may understand it according to the letter, that the sea will be utterly destroyed.

He says almost the same, volume 2, p. 295, book 1 on Job, chapter 7, upon these words: "But when a man has fallen asleep, he shall not rise again until the heaven is worn away."

From the same author's volume 5, p. 141, of the *Letters*, book 5, the Letter to Bishop Horontianus:

But since even the heavenly creature is subject to vanity — though this be in hope — the piety of truth and the redemption of the whole universe will bring it about that even the treachery and drunkenness of these, fallen through the vanity of this world, should pertain to pardon.

Therefore, to conclude: both that great and glorious Sun, and that Moon which the darkness of night does not cover, and those stars which are the ornaments of the heaven, now bear the servitude of corruption, because every body is corruptible. [Margin: Sun, Moon, star, and heaven are corruptible, and will perish like the earth.] For indeed the heavens too shall perish, and heaven and earth shall pass away. But afterward the Sun, and the Moon, and the other lights of the stars shall come to rest unto the glory of the Sons of God, when God shall be all in all — who may be in you and in us through His fullness and mercy.

The same, volume 2, p. 461, on those words of Psalm 118: "Forever, O Lord, your Word remains in heaven." He says that the old heaven will pass away, and a new one will come to be, etc.

Notes on St Ambrose

From these passages you have: first, that this holy Father learned his doctrine of the corruptibility of the heaven from Sacred Scripture, and not from the unbelieving Philosophers, whom he refutes. Second, that he is wrongly understood and cited by some in support of the contrary opinion. Third, that the heaven is to be changed not by the cessation of local motion alone; but, fourth, by a true physical alteration, like the earth; and therefore, fifth, that it is to be burned up by fire; and thus, sixth, that it is to be restored into a more elegant form and adorned with nobler qualities; and not, seventh, as some supposed, to be reduced to nothing — but rather that, just as the earth and our own corrupted bodies are to be repaired, so too the heavens, laid waste by fire, are to be repaired, etc.

According to St Jerome, the Sun, the stars, and the heavens are corruptible — from the Paris edition of 1609

St Jerome, volume 2, p. 349, on Isaiah chapter 51, upon these words, "Lift up your eyes to the heavens, and look down beneath the earth, for the heavens shall vanish like smoke," etc. [Margin: St Jerome supports what has been said.]

This is what the Lord says in the Gospel, Matt 24: Heaven and earth shall pass away, but my words shall not pass away. And David sings in Psalm 101: In the beginning, O Lord, you founded the earth, and the heavens are the works of your hands. They shall perish, but you remain; and all shall grow old like a garment. [Margin: Matt 24; Ps 101.] And like a mantle you shall roll them up, and they shall be changed. From this it is shown that the destruction of the heavens signifies not annihilation, but a change for the better. Of these it is said: there shall be a new heaven and a new earth, which I will make to abide in my sight.

For if it is written of the saints, "We shall not all sleep, but we shall all be changed," and if in the titles of four psalms one reads, "For those who shall be changed," how much more must this be believed of the heaven, and of the Sun and the stars? — when the Moon shall receive the Sun's light, and the Sun shall glow with sevenfold brightness. Hence too every creature groans together and is in travail, awaiting the revelation of the sons of God, that it may be changed for the better; and that not only the souls of men, which are immortal, but their bodies too may be changed into a glorified substance.

For this corruptible must put on incorruption, and this mortal must put on immortality.

[Margin: From the destruction of the heavens he argues to the death of men.]

But since the heaven grows old, and the earth as well, consequently also the things contained within the circle of the heaven, and the men who are the inhabitants of the earth: just as these shall die, it will be not unto their own annihilation, but unto the abolition of their old worthlessness and the renewal of a glory to come — when the just shall shine like the Sun, and, once the past and ancient things have gone away, all things shall be made new.

Some take "to perish" and "to grow old" as meaning abolition and death, according to what we read in the Catholic epistle: The heavens that now are, and the earth, are by the same word reserved unto fire. And again: The burning elements shall be dissolved. This indeed is also the opinion of the Philosophers of the World — that all things we behold will perish by fire; whence the Apostle too says: The fashion of this world passes away, as we contemplate not the things that are seen, but the things that are not seen.

For the things that are seen are temporal, but the things that are not seen are eternal. Something similar the Apostle John also writes (1 John 2:6): The world passes away, and the desire of it. [Margin: 1 John 2:6.] And in the Hebrew it says: The heavens shall vanish like smoke. Or, according to Aquila and Symmachus: They shall be crushed to nothing, and shall be ground down after the manner of salt, and shall vanish away — of whom the former [Aquila] said μειωθήσονται [Greek: meīōthēsontai, "they will be diminished"], and the latter ἁλιώσονται [Greek: haliōsontai ?], apparently "they will be turned to salt / dissolved," from ἅλς, "salt", which clearly draws its etymology [ἐτυμολογίαν, etymologian] from the crushing and melting away of salt. On which account I wonder what the Seventy [the Septuagint translators] intended by ὁ οὐρανὸς ὡς καπνὸς ἐστερεώθη [Greek: ho ouranos hōs kapnos estereōthē, "the heaven was made firm like smoke"] — that is, "the heaven has been made firm like smoke." For if firmness is taken to mean strength, how is that which is firm compared to smoke? — unless perhaps we can say this: that all the firmness and strength and might of the heavens is put on a level with the emptiest wind and with smoke that dissolves into thin air, as in Ecclesiastes chapter 1: Vanity of vanities, and all is vanity.

And this too must be said: that if the heaven and the earth shall perish and grow old, by what logic would their inhabitants likewise die and utterly perish — since we know that souls are everlasting and that bodies shall rise again? From which it is plain that the heaven and the earth do not perish and get reduced to nothing, but are changed for the better.

[Margin: As human bodies perish and rise again, so too the heavens.]

From this passage it is established: first, that by this holy Doctor the change of the heaven and earth for the better cannot be understood as the cessation of local motion alone, since the heaven and the earth are to be changed on a like principle — yet the earth will not cease from motion, seeing that it has always lacked motion. Second, that a physical alteration or change of the heaven, as of the earth, will necessarily come to pass. Third, that only a total and permanent destruction or abolition — or, as he himself calls it, a reduction to nothing, which some had asserted — is denied. Fourth, that the corruptibility of the heaven is admitted no less than that of the earth, and of man himself as well. That man and earth are corruptible, daily experience teaches; nor is it an objection that the human soul is immortal. For the whole is said to be corrupted even if the constituent parts of the whole are unchangeable — for prime matter is indeed incorruptible; [the whole is corrupted] by reason of the dissolution of the whole composite, etc.

The same holy Father, in the same volume, p. 469, on Isaiah chapter 65, upon these words: "For behold, I create new heavens, and a new ear[th]..."

(Continuing Cap. XXIV, Book IV, Part II — the patristic catena on the corruptibility of the heaven and stars. The page opens mid-quotation, within the Jerome excerpt begun in the preceding pages.)

a new earth; and the former things shall not be remembered, nor shall they come up into the heart, etc."]

[Margin: 2 Cor. 4.] "'A new heaven,' he says, 'and a new earth' — those who suppose that everything we behold will perish interpret this by the testimony of the Gospel: 'Heaven and earth shall pass away.' And by that of the Apostle Paul: 'For the things that are seen are temporal, but the things that are not seen are eternal.' [Margin: He disproves a total destruction of the heaven.] Moreover, those who hold that what is meant is newness and change for the better, and not the destruction of the elements, make use of this example: 'In the beginning you, Lord, founded the earth, and the heavens are the works of your hands. They shall perish, but you remain; and they shall all grow old like a garment, and like a

cloak you shall fold them up, and they shall be changed.' In this it is plainly shown that the words signify loss and destruction — not annihilation into nothing, but change for the better. [Margin: Isa. 30.] For neither does that which is written elsewhere — 'The moon shall shine like the sun, and the sun shall receive sevenfold light' — signify the destruction of the former things, but their change for the better. And afterward: 'Understanding this, Paul the Apostle too spoke as he did. For the fashion of this world passes away.' [Margin: 1 Cor. 7.] Let us consider what he said: it is the fashion that passes, not the substance.

"Peter signifies this same thing: 'They are willingly ignorant of this: that the heavens were of old, and the earth, standing out of water and through water, subsisted by the word of God; through which the former world was flooded and perished by the deluge. But the heavens which are now, and the earth, are by the same word kept in store, reserved for fire' — in what sense this is to be taken, he teaches afterward. 'But we shall see new heavens and a new earth, and his promise' — he did not say 'we shall see other heavens and another earth,' but the old and ancient ones changed for the better.

"From the same volume and chapter, p. 489, on the words, 'For as the new heavens and the new earth which I make stand before me, etc.': But how there will be a new heaven and a new earth, and a new Jerusalem, so that it may by no means be said, 'Heaven and earth shall pass away' — and again, 'The heaven shall be rolled up like a book, and the earth shall be dissipated by corruption' — so, in all new things,

the people of God too will be made new: as Scripture says, 'The old things have passed away; behold, all things have been made new,' etc."

NOTAE.

NOTES.

From this it clearly follows, according to the mind of this holy Doctor, that a merely hypothetical corruptibility and destruction of the heaven does not hold. [Margin: A hypothetical or conditional corruptibility of the heavens does not hold.] For it always has a place even after the consummation of the World, and even in the case of a created substance of any kind whatever — even one of incorruptible nature. For it will always be true to say, if God so wills, that heaven, man, mind, and angel will not be [?]; it will always be true that any one of these will perish sooner than the word of God, etc. And yet Jerome says that after the last day of the World's renewal, after a new heaven has been made, a new earth and a new Jerusalem founded, it will by no means any longer be said, 'Heaven

and earth shall pass away.' Yet this would always be true, if that hypothetical sense were the one intended in the Scriptures. Therefore it is not this hypothetical sense, but a physical change of the heaven, that must necessarily be embraced, etc.

CAELORVM CORRVPIBILITATI subscribit etiam S. Hilarius, magnum Ecclesiae Lumen.

To the corruptibility of the heavens St. Hilary [Hilary of Poitiers], a great Light of the Church, also subscribes.

[Margin: S. Hilary.] St. Hilary, Bishop of Poitiers, on Psalm 122, Paris edition, p. 986, writes thus: "This heaven, which by its matter lies subject to our sight, which — as though solidified smoke — received both the nature and the name of the Firmament, shall pass away and shall be no more; but the seat of the Lord abides forever."

The same, on Psalm 135, p. 1082, places the waters above the heavens for the cooling and tempering of the lower heavens and of our air. He therefore acknowledges them to be hot and corruptible. [Margin: The Firmament and the earth are not established for ever and ever.]

The same, on Psalm 148, p. 1189, writes thus: "It must be observed that, among these creatures which are established for ever and ever, neither this heaven which is called the Firmament, nor the earth which is called the dry land, is mentioned as having been recorded — since it is also said in the Prophets: 'Behold, I make a new heaven and a new earth.' And the Lord said in the Gospel: 'Heaven and earth shall pass away, but my words shall not pass away.'" And, after much else, p. 1191:

"For then there will be a new heaven and a new earth, when, these present ones being dissolved, those new and eternal ones succeed; and so his praise will be rendered above heaven and earth — because the seat of that blessed kingdom is established not in this age, nor in this air, but in the higher places."

CAELORVM CORRVTIBILItatem ex Sanctis Scripturis asserit Sanctus Epiphanius.

The corruptibility of the heavens St. Epiphanius asserts from the Sacred Scriptures.

[Margin: S. Epiphanius.] St. Epiphanius, vol. 1, book 2 *Against Heresies*, p. 553, letter D, Paris edition 1622: "This whole World," he says, "so that it may be purged and restored, will be set ablaze by overflowing flames in a conflagration; yet it will not utterly perish and be corrupted." [Margin: The whole World will be burned up.] And a little later: "With whom Paul too plainly agrees, when he speaks thus: 'For the expectation of the creature waits for the revelation of the sons of God. For the creature was made subject to vanity, not willingly, but by reason of him who subjected it in hope: because the creature itself also shall be delivered from the bondage of corruption into the liberty of the glory of the sons of God. For indeed the creature was made subject to vanity,' he says." He expects, moreover, that the creature is to be freed from this bondage — by which name he meant to signify this World. [Margin: By the name "creature," this visible World is here understood.] "For it is not the things that cannot be seen, but these visible things, that serve corruption. Therefore the creature remains, renewed into a better and more seemly state, rejoicing and exulting in the resurrection for the sake of the sons of God — for whose sake it now groans and travails, awaiting our redemption from the very corruption of the body: so that when we have been raised from the dead and have shaken off the mortality of the flesh — as it is written, 'Shake off the dust, and arise, sit, Jerusalem' — and when we have been freed from sin, it too may be freed from corruption itself, and no longer serve vanity, but justice. And after: So too Isaiah [Margin: Isa. ch. 66.] likewise: 'For as,' he says, 'the new heaven and the new earth which I make remain before me, says the Lord, so shall your seed and your name be.' And again: 'Thus says the Lord [Margin: The same, ch. 46.], who made heaven — he who founded the earth

and made it, he himself established it, not in vain, but that it might be inhabited.' And after: 'Whence it is necessary that both earth and heaven exist after that conflagration and burning of all things.' And after: But adversaries will object: If this whole universe by no means perishes, why does the Lord say that heaven and earth are to pass away? And why does the Prophet say that the heaven is to perish like smoke [Margin: He denies a destruction of the heavens of every kind.], and the earth to grow old like a garment? But to this we shall answer that it is the Scripture's manner of speech to call the restoration of the world, and its change to something better and more excellent, a 'destruction' — inasmuch as the prior

form perishes in that conversion into a more delightful state. [Margin: A physical transmutation of the form of the world.] For nothing in the sacred Writings is contrary to this or absurd. For it is 'the fashion of this world' that passes away; he did not say the World itself. So it is most usual for the Scriptures to call the change of the antecedent form into what is better and more beautiful a 'destruction.'"

The same St. Epiphanius, vol. 2, Paris edition, year 1622, p. 179, *On Measures and Weights*, reckons the Heaven among the elements from which the others were produced; and he asserts that the Firmament is set in the midst of the waters; and he says that a spirit is present within all created things, which heaven and earth embrace.

Therefore this holy Father here expressly teaches a physical conflagration of the heaven, and thereby a physical restoration of it to something better. Hence it is necessary that, according to him, the heaven is by its own nature corruptible.

A CORRVPTIBILITATE Caelorum stat etiam S. Ephraem.

By the corruptibility of the Heavens St. Ephraem also stands.

[Margin: S. Ephraem.] St. Ephraem accords with these, in his *Exhortation on the Second Coming of the Lord*: "Who, then, will endure at that time, when he beholds those wonderful and astounding signs? When you will see the powers of the heavens shaken? When you will see the elements dissolved? [Margin: Matt. 24. Luke 21. Rev. 6.] When you will behold the heaven rolled up like a book, the Sun darkened, the Moon turned to blood, the stars falling from heaven like leaves from a fig tree? The earth burned up, and all the works that are in it? When you hear the trumpet from heaven

resounding horribly, and rousing those who from of old have fallen asleep? When you have contemplated the heavens being torn apart, and God revealed with great fury over sinners?" But that all these things are to be understood just as they sound in this holy Father, anyone who reads him will see — both in this and in his other sermons, etc.

NATVRALEM CAELORVM corruptibilitatem S. Irenaeus è Sacris Scripturis contra negantes ostendit.

The natural corruptibility of the heavens St. Irenaeus [Irenaeus of Lyons], from the Sacred Scriptures, demonstrates against those who deny it.

[Margin: S. Irenaeus.] St. Irenaeus, *Against Heresies*, book 4, chapter 6, writes thus: "Since those who slander us say — 'if indeed heaven is the throne of God and earth his footstool, and it is said that heaven and earth are to pass away, then, when these pass away, this God who is seated above them must also pass away; and therefore he is not the God who is over all' — first of all, they do not know what 'heaven the throne' and 'earth the footstool' mean. Nor indeed do they know what God is, but suppose that he sits and is contained after the manner of a man, and does not himself contain; and further, they are ignorant of the passing of heaven and earth. But Paul was not ignorant, saying: 'For the fashion of this world passes away.' Then David resolves their question. For, while the fashion of this world passes, he says that not only God endures, but also his servants, saying thus in the hundred-and-first Psalm: 'In the beginning you founded the earth, Lord, and the heavens are the works of your hands. They shall perish, but you shall endure; and they shall all grow old like a garment, and like a covering you shall change them, and they shall be changed. But you are the same, and your years shall not fail. The children of your servants shall dwell here, and their seed shall be directed forever' — plainly showing what things they are that shall pass away, and who it is that endures forever, namely God, with his saints. And Isaiah likewise: 'Lift up,' he says, 'your eyes to heaven, and look down upon the earth beneath; for the heaven is made firm like smoke, and the earth

shall grow old like a garment; but those who dwell in them shall die even as it does; but my salvation shall be forever.' If it is natural for men to die, it is natural for the heavens to be corrupted; for as the heavens are corrupted, so men die, etc."

INGENITAM CAELI CORruptibilitatem ex eloquio diuino docet Sanctus Cyrillus Alexandrinus.

The inborn corruptibility of the heaven, from the divine utterance, St. Cyril of Alexandria teaches.

[Margin: S. Cyril of Alexandria.] St. Cyril of Alexandria, vol. 1, Paris edition, p. 339, book 4 *on Isaiah*, ch. 51, on those words, "Lift up your eyes to heaven, and look upon the earth beneath, for the heaven is made firm like smoke, etc.": "When therefore," he says, "you shall marvel at the firmly-set heaven, and gaze upon it as upon the appearance of smoke, know also," he says, "that the things which were produced in order to exist shall again be dissolved. For those things which have a beginning of birth shall someday cease again into that which is not. Through age, therefore," he says, "the earth shall be consumed, that is, abolished; and those who inhabit the earth shall die even as it does." He names, properly [Margin: From the destruction of the heaven, the death of men follows.] and aptly, the death of the elements a change for the better.

"As Paul too says: 'The creature itself also shall be freed from the bondage of corruption, into the liberty of the glory of the Sons of God.' In what manner it shall be freed, the disciple of Christ will show, saying: [Margin: 2 Pet. 3.] 'For the day of the Lord shall come like a thief, in which the heavens shall pass away with a tempest, and the burning elements shall be dissolved, and the earth and all the works that are in it shall be burned up. [Margin: The heavens shall be burned up.] But we look for new heavens and a new earth, and his promises.' Therefore he says that the renewal of the creature will be, as it were, a resurrection from the dead, just as in human bodies. And after: How great the difference is between the maker and the creature, between the fashioner and the thing fashioned, he makes plain by these words, saying: [Margin: The heaven is not a stranger to corruption.] 'Through age the creature too shall be consumed; and as it was produced from that which was not into that which is, so it shall not be a stranger to corruption. But the Creator and Artificer of all things, God the Word, through whom are all things and in whom are all things, shall be forever, and shall not fail;

which the divine Lyric-Poet [David] also teaches, when he says: 'In the beginning you, Lord, founded the earth, and the heavens are the works of your hands; they shall perish, but you shall remain,' etc." [Margin: Psalm 101.]

The same holy Father, vol. 2, p. 580, col. 2, line 3, *Against Julian the Apostate*, expressly proves that the heaven is by its own nature corruptible; and he asserts

that it will one day be dissolved, even on the authority of Plato. "In what way, then," he says, "is that which is dissolved immortal by nature? And how is that without destruction which has obtained incorruption by the will of the Maker alone?" etc. [Margin: The heaven is not immortal by nature.]

SOLIS, CAELI ET ASTRORVM naturam corruptioni obnoxiam expresse confitetur S. Ioannes Damascenus.

That the nature of the Sun, the Heaven, and the Stars is subject to corruption, St. John Damascene expressly confesses.

[Margin: S. John Damascene.] St. John Damascene, *On the Orthodox Faith*, book 2, ch. 6, Paris edition, year 1577, p. 200, writes thus: "Now indeed, since all other things which had a beginning are, according to the order of nature, subject to corruption, so too are the heavens themselves — even though by God's grace they are held together and preserved." And after: "For this reason too Scripture says, 'They shall perish, but you remain' — although the heavens shall not utterly perish. For they shall grow old, and shall be rolled up like a covering, and shall be changed; and there shall be a new heaven and a new earth."

The same, book 2, ch. 7, has this: "It is also manifest," he says, "and this because the Sun, Moon, and Stars are composite, that they are subject to corruption according to their own proper nature."

IN EANDEM CONCEDIT SENTentiam Andreas Caesarensis.

To the same opinion Andreas of Caesarea concedes.

[Margin: Andreas, Archbishop of Caesarea.] Andreas, Archbishop of Caesarea in Cappadocia — who lived about the year of Christ 500, but was first brought to light in the year of Christ 1596 — in his Commentary on the Apocalypse of John, ch. 64, sermon 22, on those words, "From whose sight the earth and the heaven fled, and no place was found for them,"] writes thus: "The flight of heaven and earth signifies

their transition and change for the better. Consequently, no further place for conversion or change will afterward be found in them. For if, for our sake, according to the Apostle's teaching, the creature was made subject to change and corruption, then — we being changed and translated into the liberty of the glory of the sons of God — it too shall likewise be renewed and transformed into a happier form. But it shall not be turned into destruction; nor, as Irenaeus, Antipater, and other holy men rightly taught, shall it be wholly corrupted. The

words of Irenaeus run thus: [Margin: He cites the words of St. Irenaeus.] 'The substance and essence of the creature shall by no means perish; for he who formed and founded it is true and stable; but that species and part of the world in which transgression occurred, and in which man has grown old, shall pass away.' [Margin: The whole visible world is changeable.] For indeed, since God foreknew the fall of man, he willed that part of the universe which was to serve the uses of humanity for a time to be temporary, and altogether of such a kind as could someday be changed into a better and more stable state. And the great Patriarch Methodius, in his sermon *On the Resurrection*, discourses about these matters thus: [Margin: St. Methodius openly confirms the same.] 'It does not please me, what some assert — namely, that the whole totality of things will perish all at once, and that heaven and earth and air will no longer be, the rest not destined to exist. The whole world will indeed be set ablaze for its purgation, flooded with fire as by a kind of deluge; yet it will not pass into a destruction of every kind, nor into utter nothingness.' [Margin: The burning up of the whole world.] And again, further below: 'And Paul too plainly testifies, saying: The expectation of the creature waits for the revelation of the sons of God; for the creature was made subject to vanity, not willingly, but by reason of him who subjected it in hope: because the creature itself also shall be freed from the bondage of corruption, into the liberty of the glory of the sons of God.' And what follows. And before these Saints, blessed David too, when he wished to praise the Lord, spoke thus: 'You shall send forth your Spirit, and they shall be created, and you shall renew the face of the earth.' To which is akin that saying of Isaiah: 'Behold, I create new heavens and a new earth, and the former things shall not be

(The page breaks here, mid-quotation; the sentence continues on the following page: "...shall not be held in memory.")

[Margin: The coming renewal of man and of the heaven is alike, etc.]

the former things; they shall no longer come up into the heart. But you shall be glad and rejoice forever in the things that I create, and so on; and further on. Their opinion, therefore, is consonant with reason: they hold that the creature which was made for our sake will indeed undergo a change, together with us, into a better state, but will by no means pass away into nothing — just as we ourselves, after death, shall not pass over into that which is not.

These things are so clear that they need no explanation. Anyone who reads them and understands the words cannot fail to see that, according to these holy men, the heaven was made by God as corruptible in its nature.

For the corruptible nature of the Sun, of the stars, and of the heaven: the authorities of Saint Augustine

[Margin: Saint Augustine's teaching on the corruptible heaven.]

Saint Thomas [Aquinas], in the second book of the *Sentences*, distinction 14, article 2, expressed clearly, in these words, what Saint Augustine held on this matter:

"The expositors of Sacred Scripture have differed on this point according to the various philosophers whose followers they were and by whom they were trained in philosophical questions. For Basil and Augustine and many of the saints follow, in philosophical matters that do not bear on the faith, the opinions of Plato, and therefore they hold the heaven to be of the nature of the elements."

Father Adam Tanner [Adamus Tannerus] confirms this teaching of Saint Thomas in his *Dissertation on the Heavens*, question 3, page 55.

Likewise, in the same question, page 40, in these words: "But Augustine too, holding fast to the same tenets of the Stoics and of Plato, indicates in many passages that the heaven and the stars consist of a fiery nature — as the Master [Peter Lombard] also noted, book 2, distinction 14."

"For in his book *On Genesis, according to the Letter*, chapter 4 (a passage we cited in the preceding question, conclusion 2) — since Augustine recognizes only four simple bodies out of which this whole world is compacted, namely earth, water, air, and fire — he assigns this last one especially to the heaven and the stars."

"And in book 2 *On Genesis, according to the Letter*, chapter 3, he says: 'And so above the air the heaven is said to be pure fire, from which the stars too, and the luminaries, are conjectured to have been made — that is, of that fiery light, which by a coalescing and disposing nature was gathered into those forms which we see in the heaven.'"

"The same author, in question 2, page 24, states this: On this matter Augustine, among others, treats best in his book *On Genesis, according to the Letter*, chapter 4:"

"Nor should it be thought in any way that in this passage of Scripture any element of this world was passed over. For since it is agreed that the world consists of the four most familiar elements, it seems here to mention heaven, water, and earth, but to be silent about air. Indeed it is the custom of our Scriptures either to call the world by the name of heaven and earth, or sometimes

to add "and the sea." And so air too is understood to belong to heaven, insofar as there are in its regions the most tranquil and most peaceful spaces; or to belong to earth, on account of this turbulent and murky place [the lower air], which grows dense with moist exhalation — although the air itself is more often called by the name of heaven." So far from Tanner.

"Saint Augustine, *On Free Will*, book 2, chapter 5, volume 1: 'Among bodies,' he says, 'light holds the first place.'"

"The same, *On Genesis, according to the Letter*, book 7, chapter 19, volume 3: 'The soul,' he says, 'excels all corporeal matter in the dignity of its nature; yet it administers the body by means of light and air, which are the most excellent bodies in the world.'"

"The same, in the third letter to Volusianus, volume 2: 'This,' he says, 'is the way men perceive: they can think of nothing but bodies — whether these are grosser, such as moisture or earth, or subtler, such as air and light, but still bodies.'"

"Saint Bonaventure, *Sentences* book 2, distinction 13, article 2, question 1, in the conclusion, says that Saint Augustine understands fire by the word 'light.' 'For there,' he says, 'he calls "light" what we call "fire"' — as is expressly gathered from Augustine's own words."

"From the same Saint Bonaventure, *Sentences* book 2, distinction 14, question 1, part 1, article 1, in the second objection, this is found. Augustine, *On Genesis according to the Letter*, book 3, chapter 10, and in his book *On the City of...*"

[Margin: The firmament is of the nature of fire, according to Augustine.]

"...of God, says that there are only four bodies of the world, namely Moisture and Soil, Air, and Light. If, then, the firmament is one of the bodies, and is not earth, nor water, nor air, then it is fire." But later, from Vielmi, we shall hear more concerning the mind of Saint Bonaventure; for now let us adduce certain passages of Saint Augustine himself. In one book, then, *On Genesis, according to the Letter*, chapter 4, he speaks thus:

[Margin: By the name "heaven" Augustine understands the element of fire.]

"A third opinion can arise concerning this 'spirit,' namely that by the name 'spirit' the element of air is meant — so that the four elements should be intimated, by which this visible world is contained: heaven, that is, and earth, and water, and air; not because they were already distinct and set in order, but because in the material of that world — however formless its confusion — they were

nonetheless prefigured, destined to arise: which formless confusion is designated by the name of darkness and abyss."

[Margin: Great foundations and testimonies from Saint Augustine for a fiery, corruptible, and fluid substance of the heaven.]

The same holy Doctor, in book 3 *On Genesis according to the Letter*, chapter 6, writes thus: "He [Moses] was therefore not ignorant of the natures of the elements and their order. When he was introducing the constitution of the visible things that are moved within the world in the elements according to their nature, he narrated first the celestial luminaries, then the living creatures of the waters, and the creatures of the land last of all. This was not because he passed over the air, but because the spaces of the purest and most quiet air — where the birds are said to be unable to fly, if there are any such — are joined to the higher heaven, and in Scripture, by the designation 'heaven,' are understood to belong to the higher part of the world. Thus by the name of 'earth' this whole lower region is signified universally: the region from which, going downward, there begin fire, hail, snow, ice, the spirit of the tempest, and all the depths, until one reaches the dry land, which is called by its proper name 'earth.' And so that higher air — whether because it belongs to the celestial part of the world, or because it has no visible inhabitant, of which last there is now discussion in the narrative — was neither passed over (since 'heaven' was named), nor counted among the creatures in the creating of the animals; whereas that lower air, and so on." In this he shows well enough, throughout the whole of chapter 7,

"...that the firmament, in which the luminaries are..."

[Margin: The firmament is composed of air and of sidereal fire.]

"...set, is contained partly of the higher air and partly of sidereal fire." This shines out yet more in chapters 9 and 10, where he writes thus: "Because in them the element (of air) prevails, which is more apt for acting than for being acted upon — two [elements] being set beneath, namely water and earth, and one set above, that is, sidereal fire. For the elements are distributed for being acted upon into two, moisture and soil; and for acting into another two, air and fire." And further: "But the air reaches from the boundary of the luminous heaven down to the fluid of the waters and the bare surface of the lands."

"Yet the moist exhalations do not darken the whole of its space, but only up to that limit from which it now begins to be named 'earth' — according to that Psalm 148, where it is said: 'Praise the Lord from the earth.'"

[Margin: Psalm 148.]

"But the higher part of the air, on account of its pure tranquillity, is joined in a common peace to the heaven with which it borders, and is called by its name."

[Margin: The fiery heaven; the air beneath it is added to it, etc.]

Then the same holy Father, in this same chapter, holds that the demons are aerial animals, since they flourish with the nature of aerial bodies. He therefore supposes that before their fall they dwelt either in the highest and quiet air, or in the higher fiery element; but that after their fall they were thrust down into this lowest and turbulent region of the air. Hence: "If those transgressing Angels," he says, "were bearing celestial bodies before they transgressed, it is no wonder if, by way of punishment, they were converted into the aerial quality, so that they might now be able to suffer something from fire — that is, from the element of a higher nature. Nor were they permitted to hold even the higher and purer spaces of the air, but those murky ones, which for their kind are, as it were, a prison for them, until the time of judgment." And at the beginning of the ninth chapter, he says that the celestial animals are called partly luminaries, partly Angels.

Corollary

When all these things have been well weighed, it is clear that, according to Saint Augustine, the heaven has been held to be fiery in nature, corruptible in its nature, and fluid in its substance. Many more testimonies of this holy Father could be adduced, but these seem sufficient.

For a corruptible heaven: the view of Vielmi

[Margin: Girolamo Vielmi.]

Girolamo Vielmi [Hieronymus Vielmus], in his eighteenth Lecture, upon the Question "Whether the luminaries are fixed to their own orbs," after he had cited many authors and passages of Scripture for the negative side:

"For first," he says, "this must be investigated: whether these bodies are composed of the elements, or are rather so simple that they are in no way constituted out of other bodies."

[Margin: The question: whether the celestial bodies are composed of elements.]

"And here indeed the business shows itself greater and more difficult for us. For the more eminent Fathers are almost all of the opinion that the luminaries and

the heavens were constituted out of the four elements, since they are corruptible in nature — indeed, that at an appointed time, on account of Adam's sin, as some of them think, they will be dissolved. For Saint John Chrysostom brings forward this reason, and judges that David held this view in Psalm 101, when he says: 'In the beginning, O Lord, you founded the earth, and the heavens are the works of your hands. They shall perish, but you remain; and they shall all grow old like a garment, and like a covering you shall change them, and they shall be changed.'"

[Margin: He confirms the Fathers from Scripture.]

"This passage seems to some to be most powerful, and not to have been met adequately by more recent writers when they suppose it was said for this reason: that when the Lord comes to judgment, the heavens shall cease to move. For it is said not of their motion but of themselves that they 'shall perish'; and again, 'like a garment' — or, as Felix Pratensis [Faelix Pratensis] renders it, 'like a cloth' — 'they shall grow old.' For assuredly all these expressions..."

[Margin: The perishing that is foretold concerns the substance of the heavens, not their local motion.]

"...seem to have regard to their constitution and substance."

"Again, Isaiah 51: 'Look up to the heaven,' he says, 'and look down, for the heaven shall pass away like smoke' — or, as more recent writers read it, 'For the heavens shall be corrupted like smoke.'"

"To this the Lord adds, in Matthew 11 [recte 24]: 'Heaven and earth shall pass away, but my words shall not pass away.'"

"Finally, Saint Peter, in his second Epistle, chapter 3, writes thus:"

"'But the heavens which now are, and the earth, are by the same word kept in store, reserved unto fire against the day of Judgment and of the perdition of ungodly men.' These and testimonies of this kind, those Fathers understood, signify a change to come in the heavens greater than that they should merely cease to move."

"And because whatever is liable to corruption is constituted of contraries, they believed for this reason that [the heavens] consist of the elements, and that Scripture, by a certain sequence of reasoning, sets this forth to us."

[Margin: A noteworthy observation. The holy Fathers compose the heavens out of elements because they learned from Scripture that the heavens are corruptible.]

"Therefore observe diligently that the Fathers did not thence infer that the heavens will perish because they are constituted of elements. For they understood that our own bodies too, after the day of judgment — though composed of contrary elements — will, by the will of God, who is to bestow great endowments upon them, be incorruptible in the future; but from the ceasing granted to them [i.e., of the heavens], which the Scriptures everywhere seemed to them to attest, they concluded (and rightly indeed) that the heaven consists of contrary elements."

"But Pseudo-Dionysius [Divus Dionysius] holds the contrary, in *On the Divine Names*, chapter 4; Saint Thomas, part 1, question 66; and nearly all the Scholastics, on book 2, distinction 14. For, following Aristotle, they judge those bodies to be both simple and entirely exempt from generation and corruption; and they prove this on the ground that their natural motion is simple and wholly different from the motion of the elements. And since these matters are worn and commonplace among you, I shall now refrain from expounding them at greater length."

"And so we see the sons, as though having joined hands in turn, departing from the Fathers and..."

[Margin: He modestly refutes Saint Bonaventure.]

"...forefathers. And since this seemed to Saint Bonaventure to be a fault, he judged, in [book] 2, distinction 14, that the ancients did not really think so, but said that the heavens and luminaries are composed of elements only because they have in common with certain elements a transparency and rarity."

"But this response must be granted either to the piety, or to the reverence, which the Seraphic Doctor [Bonaventure] everywhere showed toward our elders, or certainly to the fact that he unfolded their records less accurately. Accordingly Saint Thomas, in the same distinction 14, question 1, said that they [the Fathers] brought this opinion into the Church from the Academy; and that therefore less weight should be given to them in this matter — that is, that here they have no more authority than Plato, whose teaching they were following. For Plato taught these same things earlier in the *Timaeus*; and so did Plotinus, in book 1, *Ennead* 2, chapter 7, whose arguments Sebastián Fox Morcillo [Sebastianus Faxius], a recent and learned interpreter of that author, gathered together and set forth there quite fully in [his commentary on] the *Timaeus*; and it was the opinion of all the philosophers who preceded Aristotle."

[Margin: Vielmi defends and follows the holy Fathers.]

"But shall I say what I think, my hearers, or shall I keep silent out of reverence for so great a Doctor [Thomas]? I shall certainly speak, and, as befits us, I shall prefer the truth; and this, I judge, is the truth: that this response of Saint Thomas does not remove every scruple. For although it is true that the opinions of our elders, which they drew from the schools of the philosophers, make an extraneous argument in Theology — just as do the authorities and reasonings of the philosophers, as [Thomas] himself teaches most weightily in part 1, question 1, article 8 — nonetheless, since they profess to draw and teach these opinions from the Scriptures, and that with a certain great agreement, I..."

[Margin: If the nature of the heaven had ever had to be decided, judgment would have been given according to the Fathers.]

"...never doubt that it would have been defined according to the doctrine of the Fathers, without any hesitation. For this is the solemn and perpetual custom of the holy Councils: to settle the controversies laid before them in accordance with the Doctrine of the saints."

"And perhaps even now this would be done. For although the authorities of the weightiest doctors seem to stand on the other side, and this seems to be the common opinion of the theologians of our own time, and although it is certain that in no age is the Church destitute of the promises of Christ the Lord, and therefore that it can never at any time err in the faith — nonetheless, since (so far as it seems to me) no one of the Recent writers has professed to establish it [the incorruptibility view] from Scripture, and all follow it merely as an opinion, whereas the opposite view (which is drawn from reasons taken from the nature of things) is more probable: perhaps the view of the Church would even in the present case fall on the side of the Fathers — because, as I was saying, they [the Fathers] would say that they held that understanding from the Scriptures, as may be seen in Saint Ambrose, *Hexaemeron* book 1, chapter 6; in Saint Basil in this place; in Gregory of Nyssa [Gregorius Nyssenus]; in John Damascene, book 2, chapter 6; in Saint John Chrysostom, homily 14 on [the Epistle to the] Romans, and elsewhere — to say nothing meanwhile of Denis the Carthusian [Dionysius Carthusianus], on [book] 2, distinction 14; Ambrogio Catarino [Ambrosius Catherinus] in his Commentary on Genesis and elsewhere; Jerónimo de Oleastro the Portuguese [Hieronymus de Oleastro Lusitanus], and certain other Recent men, learned and especially distinguished, who have come over to the opinion of the Fathers." Thus far Vielmi.

Scholia on the Discourse of Vielmi

[Margin: If the nature of the heavens had even now to be decided, the Ecumenical Councils would stand with the holy Fathers.]

If the opinions of the holy Fathers concerning the nature of the heavens are to be judged of less weight for this reason — that they introduced them into the Church as received from Plato, and therefore they are worth only as much as Plato — then the partisans of the Fathers argue on equal terms, and say that the fifth essence of the heaven [the quintessence], and the contrivance of it that opposes the holy Fathers, obtain no more authority in the Church than...

deserves no more of it than Aristotle himself, its Architect, deserves.

And as for how much he deserves — they say it is clear enough from his premises, which are false and at war with the Catholic faith, from his merely dialectical arguments, and from the fact that his own followers everywhere reject them.

As for what concerns the holy Fathers: by their very deed — in the actual exercise of it, as the phrase goes — they profess the contrary of what is ascribed to them. For in support of their teaching about the corruptibility of the heaven they bring forward only the instruction of the Catholic faith and the testimonies of sacred Scripture; and on that same ground they attack, without distinction, all philosophical opinions — as is abundantly plain from the authorities already cited and those still to be cited. And this they then perform vigorously in the actual, express exercise of it, as they say. For, to give some examples, I will produce a few.

Basil the Great, *Hexaemeron*, Homily 3:

[Margin: Basil.]

"We are not pleased to assert," he says, "that the Firmament is either made of one of the simple bodies or a mixture of them all" (although Basil firmly holds and teaches, from philosophy, that all things are present in all things, he nevertheless does not dare to fix the composition of the firmament to this or that matter, inasmuch as) "we who have been so schooled by the divine Scripture itself" (note: from Scripture, not from the Academy) "that we allow our mind to imagine nothing beyond what has been granted us, and so forth."

[Margin: The Damascene confirms Basil.]

The same Basil (says St. John of Damascus [John of Damascus], *On the Orthodox Faith* II.6) teaches that the nature of the heaven is thin and subtle like smoke — taught this, of course, by the divine Scripture.

[Margin: Ambrose.]

"We, however," says St. Ambrose (*Hexaemeron* II.3), "follow the sequence and order of the Scriptures, and by contemplation we take the measure of the work of its Author" — of God, that is, not by the opinion of Plato.

Ambrose declares that in defining the nature of the heaven he follows the Scriptures, not philosophical subtleties.

[Margin: Chrysostom.]

St. Chrysostom, *On the Incomprehensible Nature of God*, Homily 3: "We know," he says, "that this heaven bears indeed the form of a vault, and this not by our own wit and reason, but by the judgment of the divine Scripture; and we are not ignorant that it embraces the whole earth — which too we have drawn from the same divine source."

"From Scripture," he says, "and from the divine source I draw my teachings, not from human wit or philosophical reasoning."

Here note, in passing, that he acknowledges that the heaven embraces the whole earth.

[Margin: The Damascene.]

St. John of Damascus, *On the Orthodox Faith* II.6: "Those among the outsiders," he says, "who flourished in the praise of wisdom, claiming the doctrines of Moses for themselves, call [the heaven] the sphere devoid of stars."

And St. Justin Martyr, a most learned philosopher, who flourished in the year of Christ 153, attests the same everywhere concerning Plato and others, and makes it plain by many examples: *Apology for the Christians* II, p. 72, line 25, column 1, in the edition of Hieronymus Commelinus [Jerome Commelin], of the year 1594, where he says that Plato learned the creation of the world from Moses; the same *Apology*, pp. 63 and 64, first line and following; likewise the first *Exhortation to the Greeks*, p. 22, line 15 and following, p. 23, line 30, and p. 24, line 35. These passages, most apt to the present matter, he handed down to posterity.

[Margin: Justin Martyr.]

"From what source, then, did the learned Plato learn that time was created together with the heaven? For he wrote thus: *Time therefore came into being with the heaven, so that, having arisen together, they might also be dissolved together, whenever the moment of their dissolution should come.* Did he not understand this from the divine writings of Moses?" And a little later: "And from what source did he write as he did, having conceived the opinion of the dissolution of the heaven as well? Did he not perceive this too from the sacred Prophets, and judge that it had been so stated by them?"

And so Plato learned the corruptibility of the heaven and the perishing of the world from the reading of the sacred Scriptures. But the holy Fathers, full of God and divinely

inspired, could not attain this from the divine oracles, but had need of Platonic tutelage — so that their philosophy of the heaven, though sprung from the written word of God, must be reckoned to have been drawn not from the very founts of the divine utterance, but from the impure cisterns of the Academy! This is something that strongly displeases Vielmi [Girolamo Vielmi] and other expositors of sacred Scripture and defenders of the Fathers.

[Margin: Plato learned his better doctrines from Sacred Scripture; how then did the holy Fathers draw theirs rather from him than from it?]

But let us listen further to St. Justin, who, in his *Response to the Christian Question* 94, p. 349, line 1 and following, says:

[Margin: Justin's clear opinion on the corruptibility of the heaven.]

"The Holy Scriptures," he says, "have represented its (the Firmament's) dissolution by comparison — sometimes to a book that is rolled up, sometimes to an element that is dissolved by fire, as the Apostle Peter says in his second Catholic and universal epistle, and sometimes to a garment growing old. For with the bringing-in of a better heaven, newly made, the Firmament must of necessity be taken away, as being of no thing or use to that [new] constitution — so that by its very perishing it may at last be proved empty: the dogma of those men, current among them, who declared the heaven to be unbegotten and eternal and without end, and to be exempt both from generation and from corruptibility."

These things the holy Martyr said and wrote at Rome, in the Amphitheatre of the world; to them I add not a word, lest I diminish their weight.

But as for how much St. Augustine deferred to the sacred Scriptures, and how little to profane ones; how ill he bore it when Christians investigated the

philosophy of the heaven from foreign books rather than from their own, divine ones; how ready he always was to admit the true demonstrations of the mathematicians and the physical and astronomical findings, and always prepared to lay aside a contrary opinion; and, on the other hand, how angry he was at those who, to prop up their own opinions, did violence to both truth and Scripture, and how hard he labored to show that all the discovered and manifest astronomical truths are either contained in sacred Scripture or at least are not against Scripture but in accord with it — all this, I say, and things like it, is better heard from the man himself. For thus he speaks.

St. Augustine's cautions in bringing forward sacred Scripture in connection with natural questions about the heaven, etc.

St. Augustine, *On Genesis to the Letter* [*De Genesi ad litteram*] I, chapters 18 and 19, gives this most weighty warning:

"In matters obscure and far removed from our eyes, if we read anything — even in the divine writings — that can, while keeping the faith with which we are imbued, give rise to various differing interpretations, let us not throw ourselves headlong into any one of them by rash assertion, so that, if a more careful examination of the truth should rightly overthrow it, we fall with it — fighting not for the meaning of the divine Scriptures, but for our own, wishing that the meaning which is ours be the Scriptures', when rather we ought to wish that the meaning which is the Scriptures' be ours.

[Margin: How is sacred Scripture to be handled in the matter of the heavens?]

"For let us suppose, in that which is written — *God said, Let there be light, and there was light* — that one person has understood a corporeal light to have been made, and another that it is a spiritual light in the spiritual creation, which our faith does not doubt. But that there is a corporeal, celestial light — even above the heaven or before the heaven — upon which night could follow, is not against the faith so long as it is not refuted by the most certain truth. And if that should happen, it was not the divine Scripture that held this, but human ignorance that had so understood it. But if a sure argument demonstrates this to be true, it will still be uncertain whether the writer of the holy books meant it to be understood so in those words, or something else no less true. And if the rest of the context of the discourse proves that he did not mean this, that which he himself wished to be understood will not on that account be false, but will be both true and more useful to know. But if the context of Scripture does not oppose our understanding the writer to have meant this, it will still remain to ask whether he might not

also have meant something else. And if we find that he could indeed have meant something else, it will be uncertain which of the two he meant; and it is not unreasonably believed that he wished to mean both, if a definite circumstance supports each interpretation.

[Margin: Even non-Christians can, and commonly do, know natural things by reason or by sure experience.]

"For it often happens that even a non-Christian knows something about the earth, the heaven, the other elements of this world, the motion and revolution or even the magnitude and distances of the stars, the fixed eclipses of the Sun and Moon, the cycles of years and seasons, the natures of animals, shrubs, and stones, and other such things, and holds it by the most certain reasoning or experience. Now it is exceedingly disgraceful and pernicious, and above all to be guarded against, that any unbeliever should hear a Christian speaking of these things — as though according to the Christian writings — rave so absurdly that, seeing him (as the saying goes) err by the whole width of the heaven, he can scarcely keep from laughing. And it is not so much that the erring man is ridiculed, but that our own authors are believed by those outside to have held such views, and — to the great ruin of those whose salvation we are laboring for — are censured and cast aside as unlearned.

"For when they have caught anyone from among the Christians erring in a matter which they themselves know best, and asserting his empty opinion as [drawn] from our books, on what terms will they ever trust those books concerning the resurrection of the dead and the hope of eternal life and the kingdom of heaven, when they have concluded that the books were falsely written about those very things which they have already been able to test by experience or by indubitable calculations?

"How much trouble and grief rash, presumptuous people heap upon prudent brethren cannot be said adequately. For whenever they begin to be rebuked and refuted for their perverse and false opinion by those who are not bound by the authority of our books, then, to defend what they have said with the flimsiest rashness and the most manifest falsehood, they try to bring forward those same holy books as proof; or they even recite from memory many words which they suppose to carry weight as testimony, understanding neither what they

are saying nor the things about which they make assertions.

"For it was to have this considered and observed that I unfolded the book of Genesis in many ways, as far as I could, and set forth various interpretations of

words obscurely placed for our exercise, not rashly affirming any single one to the prejudice of another, and perhaps better, exposition — so that each may choose, according to his own measure, what he can grasp; and where he cannot understand something, let him give honor to the Scripture of God, and fear to himself. But since the words of Scripture which we have treated can be expounded with so many outcomes, let those at last restrain themselves who, puffed up with secular learning, harass — as though it were something clumsy and unpolished — these words that are so set down as to nourish all pious hearts, creeping on the ground without wings, and mocking the nests of birds that are about to fly. But more dangerously do certain weak brethren err who, when they hear those impious men discoursing subtly and copiously about the numbers of the celestial bodies, or about any Questions whatever concerning the elements of this world, lose heart; and, sighing as they set those men above themselves and think them great, they return with disgust to the books of most wholesome piety, and can scarcely bring themselves patiently to touch those things which they ought to drink in sweetly — shrinking from the roughness of the cornfield, and gaping after the blossoms of thorns.

"For they have no leisure to see how sweet the Lord is, nor do they hunger on the Sabbath, and so they are too lazy — with the power received from the Lord of the Sabbath — to pluck the ears of grain, to keep turning them in their hands and rub and cleanse them until they come to food. Someone will say: What, by all this threshing of yours in this dispute, have you stripped from the grain, what have you winnowed? Why does almost everything still lie hidden among open questions? Affirm one of those many things which you argued could be understood. To him I answer that I myself have come sweetly to this very food — namely, that I have learned that a man does not get stuck in answering, according to the faith, what must be answered to those men who set their heart on slandering the books of our salvation: namely, that whatever they

[Margin: Augustine raises an objection against himself and answers it.]

can demonstrate by truthful evidence about the nature of things, we may show is not contrary to our writings.

[Margin: Doctrines contrary to the Scriptures are false.]

[Margin: The Scriptures expose the loquacity of false philosophy, etc.]

"But whatever they bring forth, from any of their volumes, contrary to these our writings — that is, contrary to the Catholic faith — let us either show, by whatever means we can, [that it is false], or believe without any doubt that it is

utterly false; and let us so hold to our Mediator, in whom are hidden all the treasures of wisdom and knowledge, that we may neither be seduced by the loquacity of false philosophy, nor terrified by the superstition of false religion.

"And when we read the divine books amid so great a multitude of true meanings that are drawn out from a few words and are fortified by the soundness of the Catholic faith, let us choose above all that meaning which appears certain to have been the sense of the author we are reading. But if that is hidden, then at least that meaning which the context of Scripture does not forbid and which agrees with sound faith. And if even the context of Scripture cannot be examined and discussed, then at least only that which sound faith prescribes.

"For it is one thing not to discern what the writer chiefly meant, and another to stray from the rule of piety. If both are avoided, the reader's fruit is complete; but if both cannot be avoided, then, even though the writer's intention be uncertain, it is not useless to have held an interpretation agreeable to sound faith."

The same holy Doctor of the Church, *On Genesis to the Letter II*, chapter 18 and the last, has this:

"It is also commonly asked whether these luminaries of the heaven are conspicuous bodies only, or whether they have certain governing spirits of their own; and, if they have them, whether they are also vitally animated by them, as flesh is animated by the souls of animals, or [are governed] by their presence alone, without any admixture.

"Although this cannot easily be grasped at present, I think nevertheless that in the course of treating the Scriptures more suitable passages may occur, where, concerning this matter, according to the rules of holy authority, it will be permitted us — even if not to demonstrate anything certain — at least to believe according to the rules of holy authority; and even if not to demonstrate anything certain, we shall nevertheless be permitted to believe.

"But for now, always keeping the moderation of pious gravity, we ought to believe nothing rashly about an obscure matter, lest perhaps something which the truth may afterward reveal — although it could in no way be contrary to the holy books, whether of the Old Testament or the New — we should nevertheless come to hate out of love for our own error."

Annotations on the passages of St. Augustine cited.

From these passages it becomes clear, first, that all the opinions which St. Augustine brings forward on the words of Genesis, and does not reject, are held by him as probable, and are adduced only as probable, until a contrary truth is brought forth.

Second, that he leaves each person free to follow the one he has judged most to be followed, so long as an express truth does not become plain from some other source.

Third, that philosophical opinions ought to be handmaid to holy Scripture, and not Scripture to philosophical opinions.

Fourth, that Christian philosophy is to be sought rather from the Sacred Books than from profane writers.

Fifth, that in obscure and difficult matters one must have recourse to the rules of holy authority; if nothing certain can be had, one's judgment must be suspended and not rashly precipitated into either side of the contradiction as though it were certain, but, while the matter is doubtful, the opinion must be held as doubtful, and its place left to probability.

Sixth, that one must prudently yield to the established truths and experiments of the mathematicians, and the Scriptures must not be rashly wrenched, against their will, to the contrary, and brought forward to the spiritual harm of hearers.

(Book IV, Part II, Cap. XXIV, continued. The page carries two text columns of continuous prose, labelled "I." and "II." for cross-reference; the reading runs down the left column, then the right, and on across the following pages. These column labels and the five-line marginal reference-numbers are citation apparatus, not textual divisions, and are not reproduced as headings.)

St. Gregory the Great, together with the other holy Fathers, sides for a corruptible Heaven

[Margin: St. Gregory.]

For in book 17 [of the *Moralia*], on Job chapter 24, volume 2, page 435, chapter 5, he writes as follows:

"But the question may be raised: since it is said through Solomon, *One generation passes away, and another generation comes, but the earth stands forever*, why does blessed Job assert that all things are humbled

and taken away? Yet we settle this easily, if we distinguish both how the earth and the heaven pass away, and how they endure.

"For both of these pass away as regards the appearance they now have, and yet they subsist in their essence without end. Hence it is said through Paul: *For the figure of this world passes away*. Hence Truth declares through itself: *Heaven and earth shall pass away, but my words shall not pass away*. Hence it is proclaimed to John by the angelic voice: *There shall be a new heaven and earth*. These indeed are not to be created as other [heavens and earth], but these very ones are renewed.

"Heaven, therefore, and earth both pass away and shall be: for from the form it now has [the heaven] is cleansed by fire, and yet is always preserved in its own nature. Hence it is said through the Psalmist: *You shall change them, and they shall be changed*. And this, their last transformation, the very vicissitudes now announce to us, by which they unceasingly alternate for our uses."

Heaven, then, is corruptible just as the earth is, according to the mind of St. Gregory.

[Margin: St. Paterius holds the same.]

To this, word for word, St. Paterius [Paterius] subscribes — Notary of the Roman Church, contemporary with St. Gregory — in book 3 on the Apocalypse, page 219, of the Roman edition of 1553.

[Margin: St. Macarius teaches the same.]

St. Macarius, in Homily 32, writes thus: "It has been foreordained by God that this creation be dissolved, and that heaven and earth pass away."

This Saint flourished in the year of the Lord 350. He was first published in Latin at Frankfurt, in 1594.

St. Gregentius [Gregentius], Archbishop of Taphar, in the kingdom of the Homerites in Ethiopia, after he had disputed with the Jews for a good many days, at last, in his prayer — by which he obtained from the Father that Christ should be shown miraculously from heaven to the unbelieving Jews — addresses God thus: "You (God the Father), who through him (your Son) have made firm the heaven and the earth, and by your Holy Spirit have founded [them], and have covered [them] over above the waters on either side," and so on. He flourished around the year of Christ 390, in the time of Palladius, who noted down this disputation as an eyewitness; it appeared at Paris in 1586.

[Margin: St. Gregentius places the waters above the Firmament.]

The divine Basil, Bishop of Seleucia [Basil of Seleucia], in his first Oration, from the second page to the sixth, openly acknowledges this sixfold composition of the world out of the elements, since he fills all things with water, from the earth up to the Empyrean heaven. "Then," he says, "God stretched out the Firmament within the waters, into a circle, like a paneling most fit for painting." He flourished in the year of Christ 650. He was first published in the year 1604.

[Margin: St. Basil, Bishop of Seleucia.]

Zacharias the Christian Philosopher proves the heaven to be by nature corruptible

Zacharias Scholasticus the Christian, afterwards Bishop of Mytilene [Zacharias of Mytilene], in his learned disputation which he composed *On the Making of the World* against the Philosophers, both Platonists and Aristotelians, most forcefully and expressly champions the corruptibility of the heaven and the stars.

He flourished around the year 518; translated into Latin, he appeared at Paris in the year of Christ 1618. He speaks thus, on page 519:

"The World, then, was made; and if made, it will also be corrupted: since it has these two joined and associated with it by nature — an origin and a corruption."

And on page 535:

"The place had to be suited and fitting for its future inhabitants, and the dwelling ought not to differ much from those who were to live in it.

"It was necessary, therefore — since we are corruptible and daily flow away and slip — that the things surrounding us be such; but on the contrary, as we pass over to immortality, [that these things be conformed] to us. Does it not seem to you that like rejoices in like, and is friend and companion [to like]?" and so on.

[Margin: The Sun, Moon, planets, and the heaven itself are by nature corruptible.]

And further on, page 537:

"By what means would mortal eyes have caught sight of them, and [how] would the heaven and the things revolved by the heaven's motion have been capable of [the perception of] the other senses, if they had been

immortal and incorrupt and exempt from perishing? For that like joins with like, reason, the wisdom of the ancients, and the fact itself show and teach. But since by the providence and kindness of the Craftsman we shall come back to life, and shall receive these bodies — with which we have discharged the office of life, in which we have dwelt and come into this life — as immortal and beyond every hazard of change: for the Good One did not condemn us, creatures endowed with reason, utterly and to perpetual corruption. In turn it was fitting that the things pertaining to us be such as our bodies [will be]: full of glory and immortality, and finally free from all change, so that like may approach and draw near to like.

"This, O good [friend], is the reason why God did not from the beginning make this universe immortal and incorrupt." And on page 544:

"Yet they affirm that the Sun and Moon — and, in a word, the seven they call planets — and the heaven itself are gods, and are the causes of each and every thing that happens, [beings] which are by nature corruptible." And on page 545:

"We know the world to be corruptible by nature, for it was made. Yet we say it is corrupted not utterly or forever — and this because of the Craftsman's goodness — but that it puts on another, better form, and together with our bodies becomes immortal, after the general consummation of the Universe," and so on.

And when he had said that the cause of corruptibility was the fall of the first man, after much [discussion] he resolves a certain objection, on page 549:

"How, since the contempt of the law — which you say is the cause of destruction — was later than the making of the world, did that [contempt], going before, make the world corruptible?"

To this objection he replies thus:

"The Craftsman knew, O good [friend], by his power of foreknowledge, that man would despise his law and would become mortal; anticipating this, he established for him the World, [itself] mortal, as his proper dwelling."

[Margin: Why did God make the World corruptible?]

Thus far this author. These [words] plainly declare what he himself thought about the corruptibility of the Heaven, the Sun, and the stars.

Nor did Philip the Solitary [Philippos Monotropos] think otherwise, in his *Dioptra*, which our Father Jakob Pontanus [Jakob Pontanus], having rendered it into Latin, published at Ingolstadt in the year 1604. This Philip lived in the year of the Lord 1105. In book 3, chapter 6 of his *Dioptra* he expressly teaches that Heaven and Earth are to be dissolved by heat. Then, in chapter 7, he adduces from St. Chrysostom the same passages we [cited] above, to confirm his own view; and finally, on page 125, he appends these words of his own:

[Margin: Philip the Solitary declares the same opinion.]

"Nor will those four and first of all bodies — the elements, namely water, earth, air, and aether or fire, in which and through which the whole machine of the World subsists — remain: [the elements] of things visible, sensible, animate, and vegetative, of what are called [Greek: ζώοφυτα (zōophyta, "zoophytes" — plant-animals)], and of plants, of inanimate and insensible things.

"For all things consist of these four. If, then, along with the rest these too shall pass away — the very things by which, as by first principles, all things are contained — from where shall I find a body to rise again?" and so on.

Ascanius Martinengus everywhere subscribes to this opinion in his Gloss

Turn to Ascanius Martinengus [Ascanio Martinengo], in the first volume of the *Great Gloss on Genesis*, page 592 and following, on the words *Let there be a Firmament*.] "Besides all the philosophers before Aristotle, you will readily find some thirty classical authors who held that the heaven is composed either of one or of several elements, whose clear testimonies a diligent Reader can inspect in his work. One passage of this Writer I certainly cannot pass over."

[Margin: Several classical authors hold this opinion.]

He, then, having cited the words of St. Ambrose on the corruptibility of the World that I adduced above, offers this admonition in his first volume, page 605:

"Let recent teachers, I beg, weigh well from this doctrine of Ambrose — those who,

"disregarding the authority of all the ancient Fathers (for I shall show, in a more fitting place, that Dionysius too — with the leave of St. Thomas [Aquinas] — marches with the rest), everywhere and tenaciously defend

that the heaven is a fifth essence, and prefer to twist the scriptures into strange and novel interpretations rather than not approve this Aristotelian invention of a fifth essence of the heaven.

"Let them consider, I say, whether they have seen through the cunning of Aristotle — Aristotle, I say, the bitterest enemy of the Church's teachings — who, in order to build up an eternal World to the mockery and reproach of our faith, brings in a Fifth essence. And let them consider, and beware, lest we — who believe that the created World, and the heavens (if not dissoluble, at least to be restored, or to be held back from their motion), while we strive to profess with Aristotle that the heavens are compacted of a Fifth essence — turn our own weapons against ourselves."

So Ascanius.

[Margin: St. Dionysius nowhere asserted that the Heaven is by nature incorruptible.]

What he asserts about St. Dionysius [Pseudo-Dionysius the Areopagite] agrees with what we reported above from St. Maximus and other commentators. And indeed, that most divine Theologian held nothing else than that the heaven is something highly perfect and complete in all its parts — even though it is not exempt from the reckoning of the elements; and other disciples of the Apostles urge the same.

[Margin: Hermas, a disciple of St. Paul, subjects the Heaven to corruption.]

Indeed Hermas, a disciple of St. Paul, in his Book which he entitles *The Shepherd*, is openly taught this opinion by the Church in the first Vision, in these words:

"Behold, the God of hosts, who by his invisible power and great wisdom founded the World, and by his honorable counsel surrounded his creation with beauty, and by his most mighty word fastened the heaven and founded the earth upon the waters, and by his powerful strength founded his Holy Church, which he blessed: behold, he will remove the heavens and the mountains, the hills and the seas, and all things shall be made full for those his elect, that he may render to them the reward he promised, with much honor and joy, if they have kept

"the ordinances of God, which they received in great faith."

And in the third Vision: "For the World too," he says, "is held together through four elements."

This Book, says our Cornelius [a Lapide], on the Epistle to the Romans, chapter 16, verse 14, was held in great authority among the ancients. For, as Bellarmine [Robert Bellarmine] shows in book 1, *On the Word of God*, chapter 20, many of the Fathers cited it almost as Canonical Scripture; and Baronius [Cesare Baronio] too, in volume 2, at the year of Christ 159, brings forward agreeing testimonies from Eusebius, Irenaeus, Origen, Clement of Alexandria, Athanasius, and Jerome. "As for the Latins," he says, "the book became known to them in such a way that they nonetheless numbered it among their classes of Apocrypha — [books] which may be read in the Church, but ought not to be cited to establish the Catholic faith."

[Margin: Cornelius.]

[Margin: Bellarmine.]

[Margin: Baronius.]

Tertullian affirms that it was marked with this censure by our forebears — and later [writers do so too]; and from their judgment more recent [authors] have by no means departed. For Rufinus [Rufinus of Aquileia], treating of the same [book] in his exposition of the Apostles' Creed, says this: "In the New Testament, the little book called *of the Shepherd*, or *of Hermas*, which is [also] called *The Two Ways*, or *The Judgment of Peter* (for it has been called by so many names by different [writers]) — all these they indeed willed to be read in the Churches, yet not to be brought forward to establish the authority of the Faith from them." So Rufinus. All of which is most fully confirmed by St. Athanasius, from his thirty-ninth Festal Epistle, in volume 2 of the Commelinian Edition, [printed] in the year 1600, page 45, letter C. You will also find it in our Francisco Turriano [Francisco Torres], in the Preface to the *Constitutions* of Clement. So then the Paraphrast [renders] from the Greek:

[Margin: St. Athanasius.]

"But for the sake of greater clarity," he says, "I will necessarily add this also, knowing that there are still other books besides those here enumerated (namely, the Canonical ones), which do not indeed constitute the Canon, but were appointed by the Fathers to be read by those who newly come [to the faith] and simply wish to be taught the word of piety:

"the Wisdom of Solomon, and the Wisdom of Sirach, Esther, and Judith, and Tobias, and the Teaching that is called [the Teaching] of the Apostles, and *The Shepherd*."

"And yet, beloved, under those [books] entered in the Canon, and these [appointed] for reading, no mention at all is made of the Apocrypha."

And so, in St. Athanasius's time, this book was not held to be Canonical, but next to the sacred books. When some tried to force it into the Canon, and Heretics abused it for their own treachery, at length — as Sixtus Senensis [Sixtus of Siena] says in his *Holy Library*, book 2 — it was rejected by Gelasius among the scriptures of doubtful faith, in order, as I judge, to overthrow the Heretics — not the Arians indeed, etc., but the Novatians, to whom it seems to have given a beginning [i.e. occasion], etc. Hence the scholia — in the volume of the *Library of the Fathers*, Paris edition of 1610 — advise that it be read cautiously as regards [its teaching on] a single [i.e. one-time] repentance; and Bellarmine gives the same warning in his *On Ecclesiastical Writers*.

By the decree of Gelasius, therefore, the book was stripped of Canonical authority — a book otherwise, as St. Jerome testifies, truly useful, whose testimonies Writers still frequently praise and cite, especially those who treat of morals and of rightly ordering one's life. Our Cornelius a Lapide, on Ecclesiasticus [Sirach], chapter 30, verse 26, on the words *Envy and anger shorten one's days*,] "It is memorable," he says, "what Hermas, a disciple of St. Paul, writes from the mouth of God, in book 2 of *The Shepherd*, at the third Mandate." Namely, that anger and impatience darken and extinguish the Holy Spirit within us, etc. Other more recent [writers] also cite this same author. See the *Panarium* of Busaeus [Johannes Busaeus]; likewise the *Works* of Father Álvarez de Paz [Diego Álvarez de Paz], etc. St. Gelasius, then, did not wish this book to carry infallible authority.

But since the [passages] adduced from it agree with the very text of Holy Scripture and with the interpretations of the Fathers, they will certainly not lack their own weight — seeing that, in the earliest times of the Church, they were customarily read aloud in the said manner to the Catechumens themselves, with the approval of the Presidents of the Churches. This is especially so since St. Clement too, in the books of the *Recognitions*,

as will be seen a little later, expressly teaches this corruptibility of the heaven; and the Apostle Peter himself — both there and in his second epistle, chapter 3 — clearly proclaimed the same dissolution of the heavens, against those who assert the eternity of the world, as the authors of this opinion and the Interpreters of St. Peter everywhere testify.

The argument: In support of the corruptible nature of the Heavens, the Epistle of St. Peter is brought forward and explained from the Commentaries of more

recent [writers]. At the same time, St. Clement's teaching on this controversy is reviewed from the Books of the *Recognitions*, and is confirmed by Mathematical arguments drawn from the waters of the Ocean; and finally, not a few authorities of modern Theologians are produced.

CAP. XXV.

For when the Apostles had preached that a Universal regeneration of the World would come at the time of the Last Judgment, many resisted the Apostles (as is gathered from the text and its Interpreters, and from the Books of the *Recognitions* of Clement), on the basis of an opinion they had drunk in concerning the incorruptibility and necessary eternity of the Heaven. Hence they denied that any future destruction of the World would come, on account of its natural immutability — which they argued from its very same and unvarying course. But the Apostle, in order more effectively to convince the false-speakers [Pseudologoi] both of his own time and of the future of the coming dissolution of the heaven by a universal conflagration, points to its past destruction through the universal flooding of the Waters at the time of the deluge. For he says that the heavens themselves — dissolved by the fall of the waters, and afterwards restored by the Word of God — are being reserved for a final conflagration. But it is better to hear the Apostle himself thus forewarning:

[Margin: Peter, Epistle 2, chapter 3.]

"In the last days there shall come deceiving mockers, walking after their own lusts, saying: *Where is the promise, or his coming? For since the Fathers fell asleep, all things continue thus, as they were from the beginning of creation.*"

[Margin: The Epistle of St. Peter the second, chapter 3.] For this they willingly fail to know: that the heavens existed of old, and the earth standing out of the water and holding together through the water, by the Word of God; *through which waters the world that then was, being flooded, perished. But the heavens which now are, and the earth, by the same Word are kept in store*, reserved for fire against the day of judgment and of the perdition of ungodly men. And a little further on: But the day of the Lord will come as a thief, in which the heavens will pass away with a great rushing, and the elements will be dissolved by heat, and the earth and the works that are in it will be burned up. Since, therefore, all these things are to be dissolved, what manner of persons ought you to be in holy conduct and acts of piety, awaiting and hastening toward the coming of the day of the Lord, *through which the burning heavens will be dissolved, and the elements will melt away in the*

blaze of fire. But we look for new heavens and a new earth, according to his promise, in which righteousness dwells. So far Saint Peter [2 Peter 3:5–13].

From these words the interpreters reason yet further as follows. Since by the "heavens laid up and reserved for fire" the Apostle understands the heavens properly so called, that is, the Firmament, it must be that these same heavens were the ones destroyed by the waters of the flood. And that by "the heavens laid up" he means the heavens properly so called, and hence the Firmament, is established from this: that he asserts them to have been laid up again by the same Word of God by which they had first been set in place at creation. Now it is certain that, after the first heaven, nothing was set in place by the Word of God except the Firmament — for *by the Word of the Lord the heavens were established, and all their power by the breath of his mouth.* The Firmament, therefore, was both set in place first, in Genesis, and set in place again, secondly, after the flood, and will be burned, thirdly, at the Last Judgment. There is thus nothing new in something being physically altered and changed in the heaven, if the whole heaven was once disturbed and altered by a flood of waters.

And this line of reasoning is further confirmed from the antithesis in the wording: *that the heavens existed before*, holding together of water and through water by the Word of God; *but the heavens that now are*, by the same Word of God, have been laid up, reserved for fire.

It is as if he meant to say: first, as is clear from Genesis, the Firmament was raised up by the Word of God in the midst of the Waters, and like a wall it held back the upper Waters lest they fall — which Firmament, in the universal flood, was broken apart when the floodgates of heaven were opened to submerge the earth, and had to be restored by the same Word of God by which it had once been founded at the beginning. And so the Firmament was indeed restored; but neither it nor the earth perishes any longer by an overflow of waters, God having so promised — yet both the earth and the Firmament will be consumed in the final conflagration. And that no one may think this conflagration of the heavens by fire incredible, let him consider that the same firmament's dissolution, [carried out] by sending down the waters, was already made once before, at the time of the earthly inundation. Nor let them dissemble in this out of willfulness; for their affected ignorance will not absolve them from the guilt of denying the Truth. That this is the mind, meaning, and doctrine of Saint Peter in the cited text, they undertake to prove — from no source other than Saint Peter himself and his disciple Saint Clement, in the most express words — so that no room is left for turning the matter aside to anything else. Saint Clement writes as follows, in Book

2 of the *Recognitions*, page 45 (Cologne edition, 1569), from the colloquy that Saint Peter held with Simon Magus.

[Margin: St. Clement, Pope.]

To this Simon [Magus] says: "It seems better to me to believe quite simply that this alone which we see is the heaven in the whole Universe." And Peter: "Not so," he says, "but one must indeed confess one God, who truly is. And that there are heavens which were made by him, as the Law also says: of which one heaven is the higher, which contains also the visible Firmament, and that this higher one is perpetual and eternal, together with those who dwell there. But this visible one is to be dissolved and pass away at the consummation of the age."

[Margin: St. Peter says the Firmament in which the stars are will perish.]

The same, in Book 3, *Recognitions*, page 53: "And then (when the number of the predestined has been fulfilled) this visible heaven would be rolled back like a scroll [*vt Liber*], and that which is above would appear; and the souls of the blessed, restored to their own bodies, would be led forth into the light.

But the souls of the impious, wrapped for their unclean deeds in a fiery spirit, would be plunged into the depth of the inextinguishable fire, there to pay their penalties through the age. That these things are truly so, the Prophet has borne witness to us." In the same place, a little further on: "But Simon, and so on, says: 'To the things I wish, answer me and tell me: if this visible heaven, as you say, is *to be dissolved*, why was it made from the beginning?' Peter answered:

[Margin: St. Peter repeats the same, and says he has this from Christ.]

'For the sake of the present life of men it was made, that there might be a certain intervening space and division, lest anyone unworthy should happen to see the dwelling of the heavenly ones and the very seat of God, which are prepared to be seen only by those who are pure in heart.

[Margin: Why the Firmament was made.]

But for the present — that is, in the time of the contest — it has pleased [him] that those things be invisible which are destined as a prize for those who overcome.' And Simon says: 'If the Maker is good, and the World is good, how will the good one dissolve good things at some point? But if he dissolves and destroys it as though it were evil, how will he not seem evil, who made an evil thing?' Peter to this: 'Since,' he says, 'we have pledged to you not to flee from you as you blaspheme — for you yourself will render an account for the things you say — we

bear it patiently. Hear, then, now: *this heaven which is visible, and passes away*, if indeed it had been made for its own sake, would perhaps have some reason for what you say, since it ought by no means to be dissolved. But if it was made for the sake of something else, and not for itself, *it will necessarily be dissolved, so that that for which it was made may appear*.

[Margin: He repeats the same, and proves it by an elegant simile.]

As, for the sake of an example, I might say: the shell of eggs, however beautifully made and carefully formed it may seem, must nevertheless be broken and dissolved, so that the chick may come forth from it, and that for which the whole form of the egg is expressed may appear. So too, then, must the condition of this World pass away, that that loftier state of the heavenly kingdom may shine forth.' And Simon: 'It does not seem to me that a heaven which was made by God can be dissolved. For from the eternal, eternal things arise; from the corruptible, temporal and perishable things.' And Peter: 'It is not so, but from mortal

[Margin: St. Peter repeats the same, and proves it by an elegant simile.]

things indeed all sorts of corruptible and temporal things arise; yet from the eternal, things are not always corruptible, nor always incorruptible, but as the Creator God shall have willed, so also will be the things he creates. For the power of God is not under law, but the law for his creatures is his Will.' " Saint Peter asserts things of the same kind, in book 1, p. 9.

Thus far we have heard the Apostle Peter, from the pen of Saint Clement, speaking on his own behalf and explaining the meaning of his Epistle. Now, if it please, let us take in Clement himself as well. He therefore writes as follows, in the index of the Books sent to Saint James and the summary of each one, toward the end of this third Book:

"The Fifth (Book contains:) That there are two heavens: of which one is this visible firmament, *which will also pass away*; but the other is eternal and invisible."

[Margin: St. Clement says the same things which, in the earlier passages, he wrote that St. Peter had said.]

Moreover, lest anyone should say, with Bellarmine [Robert Bellarmine] in his *On Ecclesiastical Writers*, that these Books of the *Recognitions* are apocryphal, I set against him the fact that their authority — in this matter especially, which contains nothing apocryphal — is everywhere employed by the Scholastics, as Fr. Tanner, Fr. Cornelius a Lapide, Suárez, and others do; to say nothing of the fact

that these things are closely akin to what is said in Peter's own Canonical Epistle itself.

But Bellarmine himself, in a similar objection made against introducing the Office of Saint Joachim, replies in these words in a letter written in his own hand, from which I have excerpted the following:

"It is true that the objection drawn from Saint Augustine, *Against Faustus*, book 23, ch. 9, says that it is from apocryphal Scripture that Joachim was the father of the Blessed Virgin. But the answer is that it is true this is not found in canonical Scripture, yet it is not therefore false. For in the Apocrypha there are many true things, as in the third book of Esdras and the Third of Maccabees, and so on; and Saint Augustine does not reject this testimony except in the one point which Faustus was asserting, that Joachim was of the tribe of Levi. And Saint Augustine [holds] that he could have been of the tribe of Judah and of Levi at once. In the same way, therefore, together with Bellarmine himself, it can be

answered that, if some parts of the *Recognitions* are apocryphal, many parts in them are, by contrast, true and uncorrupted." And since Theologians of the greatest weight employ these authorities concerning the heaven, no one, I think, will deny that they can be recognized as legitimate.

Now, since Saint Peter, in these cited passages, expressly teaches that the Firmament is the second heaven, and that no more heavens were made by God than two, and that of these two heavens it is the second, not the first, that is to be destroyed on the last day — from this they infer that, under the name of "Heaven" or "Firmament" that is to be burned up at the end, one cannot understand, in Saint Peter's mind, the lowest region of the air, nor any sublunary element, nor, finally, the very space in which the Planets wander. For once all these have been taken away, there would still stand the second heaven, that is, the Firmament — which nevertheless, in the mind of the divine Peter, is to be removed. And so that reason too may be brought forward on behalf of this doctrine, a few foundations must be touched upon.

ARGUMENTS DRAWN FROM THE WATERS OF THE OCEAN AND THE FLOOD, ETC.

[Margin: St. Peter's view is confirmed by mathematical arguments.]

First. It is established from Genesis that the lower waters are the Seas, shut up in the caverns of the earth, and the clouds flying here and there in the air, and so on.

Second. It is certain that from these pits of the earth the mountains rose up when they were taken out. Hence the waters do not occupy more room than the mountains had occupied in the rounded earth.

Third. It is established from Geographers that the surface areas of the earth occupied by the bases of the mountains are far smaller than are those which the plains lying between the mountains occupy.

Fourth. It is established that the Levels of the Waters, considered according to their uppermost surface, are in a certain way equal to the surfaces of the land that stands out.

Fifth. Cosmographers teach, from nautical experiments, that the depth of the Sea for the most part does not exceed a half of a Roman mile, that is, five hundred paces.

Sixth. By various experiments of mathematicians and narratives of historians, let it be taken as plain that the summit of the highest mountain, raised perpendicularly above the level of the Ocean, easily rises to two Italian miles by the perpendicular. But one must also take into account that the bases of mountains are broadened, and their summits shortened by the continual slippage of material.

Seventh. From Sacred Scripture we know, moreover, that the waters of the flood exceeded the highest mountain of the whole globe by fifteen cubits.

These things being supposed, then, it becomes clear at once, without any calculation, that the waters of the flood comprised within themselves at least eight Oceans — indeed, easily reached up to twelve. From which it becomes clear that those authors who, along with Sacred Scripture, brought the supercelestial waters down are not so ridiculous as they appear to some who have perhaps not weighed the matter sufficiently. Among these, in the cited passages, are named Epiphanius, Cyril, Haymo, Richardus Pampolitanus [?], Hieronymus Oleaster, Cassiodorus, and Josephus [?] of Gubbio [Eugubinus], as cited in Giustiniani [Iustinianum], and so on. These say that the supercelestial waters rained down either at the flood or on other occasions, and so on. Nor do Saint Basil, Ambrose, Augustine, and many others of their followers seem to have departed much from the teaching of these men — men who expressly teach that the Sun and stars are nourished from the supercelestial waters; and this cannot happen without a change either in that which nourishes or in that which is nourished.

They strengthen their opinion, finally, by daily experience: that when waters are resolved by heat into vapors or into air, the result is that they require a much larger space. And so they ask: whence, or how, in the flood did so great a mass of waters — which equaled ten and more Oceans — rain down from the sky? Was it by the condensation of the air, or by the changing of air into water? But all the air, even if turned into water, would scarcely have sufficed. What meanwhile took the place of the air [that vanished]? Not a vacuum, not some other body that would fill so great an emptiness. And, conversely, where were so many Oceans carried off to after the flood? "By the same Word of God," says Peter, "the heavens which now are have been laid up, reserved for fire." We see how many mists and clouds the dewy surface of the earth, or the edge of a river's wave, supplies; how great a whirl of murky vapor the

effervescing water sends up; how much the hot flint, sprinkled with a little moisture, [gives off]; what storms of vapors and whirlwinds of winds a bronze aeolipile [*Aeolipila*] full of water breathes out through the tiniest opening. Surely a single drop of water, evaporated in this way, comes to occupy a hundred times and more a greater space. Where, then, do so many and so vast seas roam after the flood?

[Margin: The multiplication of air produced from water.]

To this point belongs what Willebrord [Snell] writes concerning the tails of Comets, in Mersenne [Marin Mersenne], Question 7, art. 9, p. 829: he says that it ought not to seem surprising that so great a tail is spread abroad from so great a head, seeing that a grain of gunpowder, scarcely filling a two-hundredth part of a Roman foot, when kindled scatters from itself a flame in a sphere whose diameter equals a quarter of that same foot — so that the diameter of the body is to the diameter of the flame less than one to fifty, and that kindled little globe has to its own source the ratio of 125,000 to 1; and thus the flame comes to be a hundred and twenty-five thousand five hundred times greater than its own tinder.

[Margin: The augmentation of fire produced from earth.]

If, then, a flame produced from earthly matter exceeds its own seed a hundred thousand times in magnitude, he will by no means stray from the truth who supposes that air, made from water, is twelve thousand times larger than its own watery source, and so on. But now let us hear the interpreters of Saint Peter themselves, at least speaking in part.

FROM FR. ALFONSO SALMERÓN — who was distinguished in virtue and learning among the first ten companions of Saint Ignatius, and who greatly illuminated the Society by his writings — Volume 16, Disputation 4, on chapter 3 of the latter Epistle of Blessed Peter, on the destruction of the World, etc., page 173.

"Likewise it is established that Aristotle, by that principle 'From nothing, nothing comes,' denied the creation of the world and posited the eternity of the world, and, by certain reasons and demonstrations, as he himself supposed, made it good; and that concerning the immortality of the soul too he wavered, in agreement with the view of many of the Greek Fathers."

[Margin: Salmerón's teaching against certain philosophers is to be noted.]

"But what would you expect from a philosopher of this sort, who utterly denies doctrines so clear and so open? Certainly, to confess the truth, I cannot bear it with a patient enough mind, when I see some men so superstitiously and stubbornly defending Aristotle's dogmas that they would rather twist many texts of Scripture by violent glosses and senses than have Aristotle collide with a single one. For more must be attributed to one passage of Scripture, through which the Holy Spirit speaks, than to

[Margin: More is to be attributed to one passage of Scripture than to all the Philosophers, etc.]

all the philosophers together saying one and the same thing consistently."

Afterward he proves the same points against Aristotle from the Sibylline Oracles, from Lucretius, Ovid, Lucan, Plato, Seneca, Pliny, Eusebius, Clement of Rome, and others, and likewise from Sacred Scripture elsewhere, and so on. Then, on page 175, he adduces from Saint Jerome many passages of Scripture to prove the destruction of the heavens.

The same, in the same place: "This too is brought forward, beyond controversy and even against Aristotle: that the heavens and the earth, together with the lower things and the elements, are of altogether the same matter; because Peter said openly that the heavens and the earth are of water and hold together through water.

[Margin: The matter of heavenly and earthly things is the same.]

Hence, too, fire is given by the same Apostle the power to act upon the heavens themselves, and there is no need to add any further power to fire anew that it may be able to act. For if fire could not [do so], then we would be granting that it could act as an instrument of God."

"Nor is it of any force," he says, "if anyone should say that the heavens, according to Aristotle's doctrine, are ingenerable and incorruptible — the opposite of which, nevertheless, Plato held in the *Timaeus*, where he makes them generable and corruptible.

[Margin: St. Peter, in his second Epistle, ch. 3, wished to overturn Aristotle's view.]

Peter, too, seems to have said these things with a view to overturning Aristotle's opinion."

These few things out of his many I have thought it good to adduce; a whole forest of them the reader will find in [Salmerón] himself.

(Book IV, Part II — the catena of authorities in favor of a corruptible and fiery heaven, continued. On these facing pages the text runs in two columns, and Column I flows continuously into Column II. The centered numerals "I."/"II." at the head of each column and the five-line marginal numbers are the printer's cross-reference apparatus, not structural divisions, and are not reproduced as body text.)

In favor of a corruptible and fiery heaven stands Giovanni Battista Lauro [Giovanni Battista Lauro] of Perugia.

[Margin: Giovanni Battista Lauro of Perugia.]

Giovanni Battista Lauro of Perugia, a Privy Chamberlain of Our Most Holy Lord Pope Urban VIII, is a living witness here at Rome to a heaven at once corruptible and fiery. In the sixth of his *Select Letters*, to Alessandro degli Angeli [Alessandro degli Angeli], a theologian of our Society, he writes as follows:

"I cannot help exclaiming: O hospitable house of Scorpio! in which two Comets have splendidly begun their banquet. And, so that some starry torch might blaze out from the lamp for the guests as they dine, this one — struck from Mercury's flint — has shone more brightly than the other fires of Heaven, and to gaze at it people stream together in crowds. I too, to contemplate it, rise from my bed far into the night, clad in a fur-lined cloak while the North Wind blows sharply, and from the highest little turret of our house I clearly behold, with straining eyes, the comet hurling its train far out. [Margin: A comet begotten of Mars or Mercury.] In my notebook I sketch the appearance of its heavenly course; and, using the

optical tube, I revere that most beautiful Comet, glowing without any doubt between the lodgings of the Sun and of the Moon. Yet as to its parentage — whether it was truly begotten of Mercury or rather of Mars — today after luncheon, when I come to you, most excellent Alexander, I long to hear your opinion; and do not keep silent about the connected sequence of future events, for Heaven does not love to be silenced, since with so many torches, as if with tongues, it now speaks out more openly than ever before. From our house, on the third day before the Kalends of December [29 November], 1618."

In Letter 24, to Feliciano de Penna, Procurator General of the Servites, he writes about the middle of the letter:

"You will be amazed at how many and what sort of predictions of disastrous events a certain Frenchman has slipped into on the basis of the common contemplation of the Comet — predictions to which not even any Chaldean, however superstitious, would subscribe, still less the more sober Ptolemy [Ptolemy]. And yet concerning the Turkish affairs, and likewise the upheavals of Germany, he played the diviner more than would be good for any German —

(Column II) — regarding the month of August, take care not to teach anyone, once the danger itself has come to pass, what deadly evil or what contagion may have overrun the City; but while you are still hale and strong, warn us of what is to happen, so that we may leave this place and withdraw to a healthier region for this stretch of the summer. Although, for my part, I long ago learned from the Comet that was seen in July 1596 — and from another, a full decade later, at the beginning of October — how much the observations of the Mathematicians tend to waver; at which time it was not so much that the insolence of those who make predictions had grown, as that confidence in them had diminished. And truly from this we came to understand that Heaven, by these fires arising at intervals, meant only to show us that it is by no means to be charged with barrenness; [Margin: Heaven is able to generate stars.] and that it can, day by day, bring forth far more beautiful stars, since at its very beginning it produced the most beautiful ones."

You see how in the earlier letter he calls the Comet a torch and a fire, kindled by Mercury or Mars; you see how he now says that Heaven lays bare its own nature by these corruptible fires arising within it. The other letter refutes the fabrications of certain men who wanted these fires to be produced there not by any natural but by some divine power, and who from them prophesied I know not what; whereas he himself says that Heaven, by this and by other Comets,

meant only to show that it is by no means to be charged with barrenness, and that it can, day by day, bring forth far more beautiful stars.

Juan Maldonado [Juan Maldonado], *Commentary on Matthew*, on the words "And the stars shall fall from Heaven," p. 552.

[Margin: Maldonado.]

"Many are of the opinion that they will not truly fall, but that, because they will not shine, they will seem to fall — a view I can in no way bring myself to accept. For Christ would have said, as he had said of the Sun and Moon, that they would fail to give light; but now, when he says that they will fall, he surely meant to signify something greater. And so I gladly agree with Chrysostom [Chrysostom] and Euthymius [Euthymius Zigabenus], who think the stars will truly fall; [Margin: Christ is to be believed rather than Aristotle.] for I judge that we ought to believe Christ, who affirms it, rather than Aristotle [Aristotle], who denies (Page 688) it can happen."

Luis de Molina [Luis de Molina], in Disputation 5, expressly teaches that the matter of the heaven is of the same species as the matter of things below — although he says that formerly, in book 1 *On the Heaven*, chapter 3, second question, he had, to please certain people, defended the contrary.

[Margin: According to the Scriptures, the heavens will come to be of another species.]

The same author, Disputation 3, p. 707: "For my part," he says, "I judge it more consonant with the testimonies of Holy Scripture if we say that even the starry heavens are to be renewed, restored, and perfected on the day of judgment, and that this will come about through the advent of a new substantial form, only the original matter being retained. Therefore the heavens will remain, but not the same in species as those that now exist — rather, others far more excellent and beautiful."

[Margin: Cornelius a Lapide.]

Cornelius a Lapide [Cornelius a Lapide], *Commentary on 2 Peter*, chapter 3, on the words "[All things continue thus from the beginning]": Thus, he says, Aristotle, in *On the Heaven* book 1, infers that the heaven is incorruptible from the fact that no change has ever been seen in it. But they reason fallaciously and err (namely, those against whom Peter argues), both because in the World the changes of things are frequent — indeed perpetual — motions, generations, corruptions,

alterations, and so on, as St. Peter adds; and because the Deity — that is, God, the governor, judge, and avenger — is most fully demonstrated from this World's inconstant constancy and constant inconstancy. And afterward, on the words "[The heavens were of old, etc.]": "Take 'heavens and earth' properly, and not as prime matter, as St. Augustine [Augustine] seems to wish (*On Genesis against the Manicheans*, book 1, chapter 7); for prime matter was not created formless, but together with the form of the heavens and the earth. Again, 'heavens' signify not only the air, as Bede [Bede] and others hold, but also the true heavens." The same, on the words "[Consisting of water and by water]": "Finally, our Lessius [Leonardus Lessius], *On the Divine Attributes*, book 13, chapter 20, refers the phrase 'of water' to the heavens, but 'by water' to the Earth, and explains it of the division of the waters above from those below." Genesis 1:

(*Column II*) 6 — "as if he said: The Heavens were constituted out of the Waters, because God, at the beginning of the World, established and made the Firmament (that is, the heaven) so that it should stand in the middle and divide the waters above from those below, so that it should stand out from both and exist separately from both. The earth, on the other hand, was constituted by water, when he gathered into one place the waters that were beneath the Firmament, and through the midst of the waters the dry land appeared. A similar Hebrew transposition [hyperbaton] occurs in Psalm 67:9 and Psalm 112, verses 5 and 6, and elsewhere.

[Margin: He proves it from the authority of St. Clement, *Recognitions* book 1.]

The same interpretation is fitted to this passage, and it signifies that the heavens not only stand out from the waters but were also made from them, as St. Clement [Clement of Rome] explains in *Recognitions* book 1, who asserts that he received this from the mouth of St. Peter.

Hence this exposition seems clearly to accord with the mind of St. Peter, and to be genuine, so that you should expound the phrase 'of water' by referring it to the heavens, and 'by water' by referring it to the earth — that is to say: [Margin: The heaven of the Firmament was produced from water.] The heavens, originally [primitus] created out of water by God, subsist by the Word of God; but the earth, through the water mingled with it, stands firm by the same Word of God.

The same, on the words "[through which]": the heavens and the earth, yielding up the waters of the flood, which would seek again their ancient seats (namely by occupying and covering the whole earth once more), from which they had withdrawn at the Lord's command (Genesis 1:9) — they would seek them again, I

say, by a new miracle, to avenge the crimes of the impious earth-born. For he answers the objection of the scoffers, who say (verse 4) that all things continue thus, just as they were created from the beginning, and that therefore there is not, nor will there be, any judge and avenger of crimes. This he refutes, saying that God was the avenger of the impious when he drowned and destroyed them all in the waters of the flood; but this, he says, is hidden from them, because they do not know it, or do not wish to know it.

[Margin: The ancient heavens perished when the world perished, at the time of the flood.]

The same, on the words "[But the heavens which now are, etc.]": there is an Antithesis that fills out the force of the argument. For over against the earth and the heavens that existed before — in Greek ἑκπαλαί [Greek: ἑκπαλαί (ekpalai, "of old, from ancient times")], that is, the primeval, the bygone, the ancient — he sets the earth and the heavens that now are, namely the modern ones; for just as those former ones perished when the world perished

(Page 689) — in the common flood of waters, so these will perish in the flood of fire, in the conflagration, when God avenges the crimes of men by fire, just as he once avenged them by water.

And conversely: just as at the end of the World they will perish by fire, so in the flood, when the cataracts were burst open, they were destroyed by waters. For this must be admitted by anyone who wishes to follow the genuine meaning of Peter, both here and in the books of the *Recognitions*.

[Margin: Very many authors of this opinion are cited.]

The same, on the words "[in which the heavens with great violence, etc.]": the same view — namely, that the starry heavens will perish and be consumed by fire — was held (besides Basil [Basil], already cited) by St. Justin [Justin Martyr], St. Jerome [Jerome], Theodoret [Theodoret], St. Ambrose [Ambrose], Gregory of Nyssa [Gregory of Nyssa], Hilary [Hilary of Poitiers], and Oecumenius [Oecumenius]; and among the Moderns, by Catharinus [Ambrogio Catarino], Salmerón [Alfonso Salmerón], and Serarius [Nicolaus Serarius] (who vigorously proves it here), Girolamo Maggi [Girolamo Maggi], Francisco Valles [Francisco Valles], Luis de Molina, and others, whom I cited on Isaiah 34:4, where I said more about this matter.

The same, in his *Commentaries on the Prophet Isaiah*, p. 294, on the words of chapter 34, "The heavens shall be folded up like a scroll":

[Margin: Philosophy ought to follow Sacred Scripture.]

Nevertheless many Fathers, and more recent writers — those who hold that philosophy must be brought into line with the sacred writings, and not the reverse — hold that heaven and earth will perish, even as to their substance, and will be changed into another, new heaven and another, new earth.

For this seems to be stated most clearly here and elsewhere, as in Isaiah 51:6 and 65:17; Apocalypse 6:14 and 21:1; Ecclesiasticus 17:30; Psalm 101:27; Matthew 24:35; and 2 Peter 3:7 and 12.

[Margin: The heavens will be changed substantially, and more than human bodies are.]

Here note that Sacred Scripture speaks far more forcefully of the change of the heavens and the elements than of the change of the bodies of the Blessed at the Resurrection, and plainly indicates that the change of the former will be far greater than that of the latter — because the former will be substantial, the latter only accidental.

There is the further point that the Heavens were made from the Abyss and from the waters, as Genesis 1:8 taught; therefore they are not wholly incorruptible with respect to their form, but only with respect to their prime matter, according to which they are said to be destined to remain forever.

[Margin: A new change in the heavens.]

This very point is confirmed by the fact that

(*Column II*) in 1572 a new star was seen in Cassiopeia, which disappeared after two years. Modern Astronomers have noted several such changes in the heavens; and so some, convinced by these phenomena, judge that the heavens are not solid and hard, but that they yield, change, and can be cut and divided like the air — although they surpass the air in subtlety and excellence; for the heavens are ethereal, not airy, and are the aether itself. [Margin: The heavens are not hard but fluid.] But this belongs to another question and another place.

Again, since light flows forth, as it were naturally, from the essence of the heavens, and since that light will then be far greater and nobler, it likewise seems that it will emanate from another, nobler substantial form. [Margin: Another argument for the corruptibility of the heavens, drawn from light.] For light so great as it will then be is not connatural to the form of the Sun as it now is.

This is the view of St. Chrysostom, homily 14 on the Epistle to the Romans, and after him Theodoret and Oecumenius; Justin, Question 93; Ambrose, *Hexaemeron* book 1, chapter 6; Basil, homily 3 of the *Hexaemeron*; Gregory of Nyssa, *On the Creation of Man*, chapter 24; Clement, *Recognitions* books 2 and 3; and the Sibyl, in St. Augustine, *City of God* XVIII[.3], when she sings:

[Margin: The prophecies of the Sibyl.]

The seasons will grow numb; widowed will be all the seeds of the World; Air, earth, sea, the light, the burning fire of heaven, the pole, day, and nights — all will collapse [?] into fire; and the face of things will become utterly desolate. [Margin: All the stars will fall from heaven.] For all the shining stars will fall from heaven.

The same is taught at length by Girolamo Maggi, *On the Burning of the World*, book 2, chapters 6 and 7; and Francisco Valles, *Sacred Philosophy*, chapter 89; and our Molina, *Treatise on the Work of the Six Days*, disputation 3, and so on. And shortly after, he meets an objection drawn from a contrary scriptural passage, continuing thus:

"Moreover, the fact that Scripture says elsewhere that heaven and earth will stand forever does not conflict with this view. For the same earth will remain, the same Sun, and the same heavens generically; for the Earth

(Page 690) will retain the form of earth, and the heavens the generic form of heavens, even though they receive another, specifically different, form — and one more excellent.

For there will then be a renewal, a reformation, and a re-creation of the whole World." And a little later: "To this and similar passages of Scripture, which seem to say the contrary, those Philosophers and Theologians who hold the opposite view give three responses.

[Margin: The responses of the opposing party to the Scriptures adduced in favor of a corruptible heaven.]

The first is: they say that some passages speak hypothetically and comparatively, like that saying of Christ, 'Heaven and earth shall pass away, but my words shall not pass away' — the meaning being, as it were: 'sooner shall heaven and earth pass away than my words pass away and my promises prove false.'

The second is: that by 'heavens' the air is understood. For thus the 'birds of heaven' are so called — that is, of the air. And thus they understand that passage

of St. Peter (2nd epistle, chapter 3, verse 7), 'But the heavens which now are, etc.': that by the same Word (by which, at God's command, they were overwhelmed by the waters of the flood, as was said before) they are stored up, reserved for fire against the day of judgment.

[Margin: He rejects the response of the opposing party.]

This is well said; but this exposition does not accord well with verses 10 and 12, where he sets the heavens over against the elements — so that by 'heavens' he understands not the airy ones but the starry ones. For he says, 'The heavens shall pass away with great violence, but the elements shall be dissolved by heat.' And still more forcibly, verse 12: 'The burning heavens shall be dissolved, and the elements shall melt with the heat of fire' — where they are forced to take 'heavens' as the uppermost air, and 'elements' as the air, water, and fire that are in or around the earth.

The third response is drawn from what St. Peter adds there, and from Scripture elsewhere: 'But we look for new heavens and a new earth according to his promises.' They say this renewal will be not substantial but accidental — namely, because the Sun, Moon, and heavens will be adorned with greater light and will shine more brightly, so as to share something of the glory of the Blessed, whom they served in this life.

[Margin: The opinion of Father Cornelius: according to Scripture the heavens are rather corruptible; according to Aristotle, incorruptible.]

Both opinions are probable and have weighty authors: the former is more conformable to Sacred Scripture, the latter to Aristotelian Philosophy. Which of the two is the truer will be treated elsewhere."

(Column II) Thus far Father Cornelius. According to him, the solar phenomenon — and any doctrine of the heaven's corruptibility that one might derive from it — has as its patrons Sacred Scripture, the holy Fathers, and many Theologians, and finally Cornelius himself; and it is reckoned at least among the probable opinions.

[Margin: Francisco Suárez.]

Francisco Suárez [Francisco Suárez], on the Third Part of St. Thomas [Thomas Aquinas], volume 2, question 59, article 6, disputation 58, section 2, pp. 691–692, brings forward still more authorities — from Scripture, the Fathers, and other writers — in favor of the corruptibility of the heaven and of a substantial renewal of the heavens at the end of the World; and although he himself holds the contrary opinion, he nevertheless admits this one as probable. For he says thus:

"Furthermore, although concerning the other heavens it may in some way be probable, on account of certain testimonies of the Scriptures, that they are to be corrupted, nevertheless concerning this heaven it is not likely. And in stating the third point—"

"Thirdly, it must be said that the remaining celestial bodies are indeed to be renewed and changed in respect of certain accidents, but that they will remain numerically the same in respect of substance."

"I set down this assertion only as the more probable, not as certain."

"For the former opinion, though it may seem rejected by the Schools, cannot be denied all probability, since it has an evident foundation in Sacred Scripture, and on that account seems to have been approved by many of the holy Fathers, and so on."

[Margin: Probability cannot be denied to the opinion of the heaven's corruptibility.]

León de Castro [León de Castro], on Isaiah chapter 51, on the words "The heavens shall vanish away like smoke, and the earth shall wear out like a garment, and its inhabitants shall perish in like manner." [Margin: León de Castro teaches the same.] From the holy Fathers — Chrysostom, Epiphanius [Epiphanius], Irenaeus [Irenaeus], and Jerome — he proves the true corruptibility of the starry heaven.

Agostino Steuco of Gubbio [Agostino Steuco], in his *Commentary on the 2nd Epistle of St. Peter*, chapter 3, and likewise in his *Commentary on the Epistle to the Hebrews*, chapter 1, and so on, is the keenest champion of this opinion — as attested by Francisco Feuardent [François Feuardent], *Commentary on chapter 6 of book 4 of St. Irenaeus*. There he says, following St. Chrysostom and Ambrose (who from Sacred Scripture — Isaiah 51, Psalm 101, Luke 21, etc. — make the heaven fluid and corruptible), that almost all the Greek Fathers

[Margin: Agostino Steuco of Gubbio.]

that the Fathers agree — as can be sufficiently established from the authorities of theirs already cited.

He gathers still more in support of this view. The same most distinguished man cited above at p. 687 — Giovanni Battista Lauro [Ioannes Baptista Laurus], private chamberlain to His Holiness and secretary of the Sacred College of Cardinals — in his *Orchestra of the Roman Theatre* [Theatri Romani Orchestra], which he wrote at Rome in the year of our Lord 1618 and which Riquius the

Belgian [Riquius Belga] published in print in 1625, *On Comets Generated in the Aethereal Heaven*, pp. 40, 41, 42, 43, speaks as follows: [There is also Orazio Grassi [Horatius Grassius], who — to use a Persian expression — chastised by his own balance the reckless examination of others concerning comets. Through him, then, and through Giovanni Antonio Roffeno [Ioannes Antonius Roffenus], Antonio Luciani [Antonius Lucianus], Alberto Rutilense [Albertus Rutilensis], Michele Pietro [Michaël Petrus], and Giovanni Alvarez [Ioannes Aluarez], we at last attain what Seneca had written — that it would one day be brought to light by the diligence of a longer age; and we now marvel that our forebears were so openly ignorant of it, etc.]

[Margin: Fr. Salian contends for the corruptibility of the heaven.]

Jacques Salian [Iacobus Salianus], whom I have also cited above for the fiery nature of the Sun, writes as follows concerning the corruptible heaven, on the Fourth Day of Genesis, in the passage cited, in the first volume of his *Annals*:

[If we believe that the heavens are to be dissolved by the burning of fire on the Day of Judgment, it is right to understand the same of the stars as well, and therefore that they too are dissoluble by divine power, so as to be changed for the better. *What is brighter than the Sun? Yet this too shall fail. The stars shall fall from heaven.* As for the fact that many refer these words to an incidental change of the elements — taking "heavens" to mean the region in which clouds and birds are carried about in wandering course — they seem to do violence to the words of St. Peter. For the Apostle clearly distinguishes the heavens from the elements: *But the day of the Lord shall come as a thief, in which the heavens shall pass away with great violence* — these things must be understood of the true heavens; for there follows, *and the elements shall be dissolved with heat; and the earth, and the works that are in it, shall be burned up.*

[Margin: Eccl. 17. v. 30; Luke 21.]

[Margin: Violence is done to St. Peter's words, wresting them to a contrary meaning.]

Since therefore all these things — namely the heavens and the elements, of which he had just spoken — are to be dissolved, *what manner of persons ought you to be in holy conversation and godliness, looking for and hastening to the coming of the day of the Lord, by which the burning heavens shall be dissolved, and the elements shall melt with the heat of fire?* Behold, here again he sets the heavens apart from the elements; but *new heavens, and a new earth, according to His promise, we look for*, etc.

Who, moreover, does not see that the interpretation is forced — that "the burning heavens shall be dissolved" means "the heavens shall liquefy like smoke; the heavens shall pass away with great force; the heavens shall perish," that is, "they shall be purified, shall grow bright, and shall be wiped clean as if of rust"? But who does not know that water which goes off into smoke passes into another substance? just as wood too, dissolved by burning, goes off into ashes? Nor can things be fittingly said to "perish" which remain the same in matter and form. Who would not admit that this exposition is harsh — that "you shall change them, and they shall be changed" means "you shall purge them and renew them" — especially since no defilement is contracted by the heavens? And that it is fitting that the heavens, which serve the perpetual alterations of sublunary things, should thus be freed from that servitude, so that, with the greatest increase of glory, they may be objects endowed with the glory of the [risen] bodies — an increase multiplied sevenfold, as the great Isaiah affirms, lest it be forever violent — must proceed from a new form suited to so great a light, as we said above with Molina, and as Cornelius [a Lapide] confirms, on the fourth day.

Notes on the Fourth Day, by the same Salian.

To this view, concerning the true dissolution of the heavens, Manuel de Sá [Emanuel Sà] strongly inclines, in his *Notes on the Epistle of St. Peter*; for on the words *the burning heavens shall be dissolved* he says: "the aerial [heavens], perhaps indeed the higher ones too — as is also indicated by that saying of Christ, *Heaven and earth shall pass away*; and here little heed need be paid to what the Philosophers say." So he.

[Margin: Manuel de Sá.]

Add Caesarius, in the *Dialogue*, question 7.1: "What then," he says, "will the heavens never be abolished, nor will there be a destruction of their luminaries?"

[Margin: Caesarius.]

He answers: "There will indeed be a dissolution of the creature, yet not a total removal, but a change for the better — as we learn from David, the divine bard, who sings in this manner: *In the beginning, O Lord, you founded the earth, and the heavens are the works of your hands: they shall perish, but you remain*. And again, adding [a word] about the regeneration, he says: *And they shall all grow old like a garment, and like a cloak you shall roll them up, and they shall be changed*. [When therefore the supra-celestial waters fail, all things at once shall liquefy through an abundance of fire; for the stars shall fall like leaves from the vine, as that

eminent one among the Prophets, Isaiah, says. And in the Catholic Epistles Peter says, *The seething elements shall be dissolved.*]

[Margin: Caesarius.]

But that they must be restored for the better, and to a state that will thereafter no longer fail — this the divine Prophet, speaking of things both present and future, teaches in these words: *You shall send forth your Spirit, and they shall be created; and you shall renew the face of the earth.*"

Thus far Caesarius, acknowledging a dissolution of the heavens and the heavenly bodies, just as we see metals dissolved by the burning of fire; and thereafter their restoration for the better by their Creator, namely through a new form, whereby new heavens and a new earth may come to be, as the Apostles and Prophets have said.

[Margin: A new form to be introduced into the heavens.]

But on this whole Question see Serarius, on the Second Epistle of St. Peter, chapter 3. See also Book 3 of the *Recognitions*, p. 53. Basil, in Homily 6, calls the Sun [Greek: τῇ φθορᾷ ὑποκείμενον (tē phthora hypokeimenon, "subject to corruption")], subject to corruption. And thus far Salian.

[Margin: The Sun subject to corruption.]

The authority of Nicolas Serarius for a corruptible heaven.

Now, if you please, let us also hear for a little while Father Nicolas Serarius [Nicolaus Serarius] of our Society, on chapter 3 of the Second Epistle of St. Peter. ["To me," he says, "at p. 50, column 2, there seem to be four [points]. The first — that 'heavens' is to be taken properly — Catharinus proves, etc.

[Margin: Nicolas Serarius agrees on every point.]

I prove it, first, from the propriety of the word, which is to be retained unless something stands in the way.

Second, because the Apostle meant to speak of the principal and, as it were, outermost parts of this World, so that through them he might imply a certain change of the whole World.

Third, because in verse 10 the elements are placed between the heavens and the earth, by which are understood fire and air. Then he refutes Suárez [Soarez], etc.

The same, in the first little question — whether that fire is to be taken properly — answers that it is to be taken properly, and that from common [usage].

The same, in the same place, in the second little question — whether the whole World, and as to its essence, or only some of its parts and in some respect, will perish — answers that there are two opinions. The former, which says the whole will perish, he supports, and to it he also cites Father Alfonso Salmerón [Alphonsus Salmeron], Prolegomenon 8. He himself writes thus:

*First Proposition. The four principal parts of this lower world will be burned as to their substance: first, [the part] of the starry heaven; second, Air; third, Water; fourth, Earth. It is proved, first: the propriety of the words says this most plainly. For, first, [Greek: λύεσθαι (lyesthai, "to be loosed / dissolved")], when there is no mention of bonds, signifies the being loosed of that which had been compacted, the being destroyed of that which had been constructed — so that [Greek: καθίστασθαι(?) (kathistasthai, "to be set / established")] is opposed to it at verse 5, as in John 2:19, *Destroy this temple*; and Ephesians 2:14; 1 John 3:8; nor can there be any other violent alteration than that which Suárez [Soarez] means to be signified by that word, in Conclusion 4, at the passage cited. Second: to pass away, as above, namely from being to non-being. Third: to catch fire. Fourth: to burn. Fifth: to melt or waste away. But from the very propriety of the words, as the common rule holds, one must not depart unless a grave cause presses — and here there is none, but only an anticipated opinion of certain Aristotelian arguments, which can easily be resolved.*

[Margin: An anticipated opinion of certain Aristotelian arguments is not a sufficient cause for departing from the propriety of the divine words.]

It is proved, second: if the Apostle had wished to hand down the contrary view, he could very easily have used other words, which would have had either no ambiguity or less. But if he wished [to convey] our view, then, in common speech, he could not and ought not to have used others, or clearer ones.

[Margin: Proof 2.]

Third: the subjects of this proposition are to be taken properly, as I have shown. But the contrary opinion also takes the predicates properly. This is confirmed from Suárez, lecture 3, etc.

[Margin: Proof 3.]

It is proved, fourth: from the Fathers cited above, to whom may be added St. Hippolytus [Hippolytus], in his book *On the Consummation of the Age*;

Oecumenius here; the Sibyl at the passage cited. Jerome also adds Irenaeus; Proclus, in Epiphanius; indeed even Augustine, *City of God* XX, chapter 26.

[Margin: Proof 4.]

It is proved, fifth: *There shall be a new earth, and new heavens, verse 23. Therefore the old ones shall have ceased, etc.*]

Fabrizio Paolucci makes the heavens corruptible by nature.

[Margin: Fabrizio Paolucci.]

Fabrizio Paolucci [Fabritius Paulutius] of Forlì, first Bishop of Città della Pieve, in the Commentaries on Genesis which he published at Rome in 1625, chapter 1, on the first day, proves at length from Sacred Scripture that all bodies in the whole universe were made by God out of one and the same prime matter — even the Empyrean heaven. He likewise places the elemental and flowing waters above the Firmament. [*"We cannot," he says, "at p. 11, col. 2, be ignorant, since Scripture clearly says, that the waters placed above the Firmament were not true and elemental waters, such as those that remained beneath the Firmament."* And a little later: *"Hence those are true and elemental waters, not changed into others — which Scripture does not say; nor can we ground novelties."*]

The same, in the Commentaries likewise published at Rome in 1629 on the Second Epistle of Peter, chapter 3, p. 538, column 1, has this: [*The heavens shall pass away with great violence.* Whether all the heavens, or only the aerial one? A great difficulty. Peter seems to understand it of the aerial heavens, because water touched only those, which he says are reserved for fire. But it seems to the contrary that, since all the heavens were formed from prime matter (from which the four elements too were compacted): Genesis 1; and all the elements are to be dissolved by heat, among them the waters which are above the convex of the Firmament, Genesis 1, below the Empyrean; and every creature awaits its renewal, Romans 8; and this comes about in man, who is compacted of the same elements, more excellent than any heavens, and they too shall pass away and be dissolved. And Job 14:13: *So man, when he has fallen asleep, shall not rise until the heaven is worn away; he shall not awake, nor rise from his sleep.* And David: *They shall perish, but you remain; and they shall all grow old like a garment, and like a covering you shall change them, and they shall be changed* — thus Augustine, *City of God*, Book 21, chapter 24. And *if there shall be signs in the Sun, the Moon, and the Stars; if the powers of the heavens shall be shaken; if the heaven is to be folded up like a book; if the heavens shall not exert their influence — then these too are to suffer, and consequently to be renewed, to pass away, to be dissolved by*

fire; yet you may say that the substance of all the heavens and of the elements will remain, as others here commonly [hold], and Rupert the Abbot [Rupertus Abbas], on Genesis, Book 1, chapter 28 — just as also in the raising up of man, etc.

Mersenne assents to the corruptibility of the heaven.

[Margin: Marin Mersenne.]

Father Marin Mersenne [Marinus Mersennus], who published a *Work on Genesis* at Paris in the year 1623, in Problem 4 (*Veneti*), has among other things this, at p. 12, column 2:

[But that I may freely confess what I think: there is no argument for this or the other view that does not admit of an easy solution, since the incorruption of the heavens can be defended otherwise; nor do I yet consider it certain by what reasoning the incorruptibility of the heavens can be defended — whether absolutely as to all and each of the parts, or as to the whole; nor how the elements can be called incorruptible; nor do I yet see that it has been decreed by the Church, or know how that passage of St. Peter, in which he says the heavens are to be consumed by fire, is to be understood — namely, whether they are to be dissolved by the burning of fire according to their qualities, or even according to their substance.

Add that there are not lacking certain experiences of the Astrologers which seem to establish the corruptibility of the heavens — of which we have treated expressly elsewhere.]

Salazar raises the natural waters above the Firmament.

[Margin: Fernando de Salazar.]

Fernando Quirino de Salazar [Ferdinandus Quirinus de Salazar] of our Society, in the Commentaries on the Proverbs of Solomon, at chapter 8, verse 27, p. 673, in the year 1619, number 344, letter D, on these words —

When he prepared the heavens I was present; when by a fixed law and compass he encircled the depths —

adduces the reading of the Septuagint translators, which is as follows:

When he set apart his seat above the winds.

[*"These words," he says, "are indeed difficult to explain, in which the Seventy, being concerned more with the sense than with the individual words, expressed their meaning. Yet, so far as I can attain by conjecture, I think they call the seat of God*

the Empyrean heaven. And they seem to have followed that opinion which defends waters above the heavens, and above waters of this kind [places] the Empyrean heaven, which they say is fixed as the seat of God and of the Blessed. And indeed — that I may say what I think — although against this opinion, which very many testimonies of Scripture render robust (Genesis 1, And God made the Firmament, and he divided the waters that were under the Firmament from those that were above the Firmament; and Psalm 148, And let the waters that are above the heavens praise the name of the Lord), which many of the Fathers too confirm by their vote and reckoning, and against which the Astrologers and Philosophers have heaped up many arguments, teaching that it is repugnant to the natures of things — yet I think that, without any injury to nature and with the greatest honor to the Sacred Scriptures, it can be defended, and vindicated from the injuries of the Philosophers. This our Luis de Molina [Ludouicus de Molina] once accomplished, on the First Part of St. Thomas [Aquinas], etc."

[Margin: He says that the opinion which sets the waters above the Firmament can, in accordance with nature and with Scripture, be vindicated from the injuries of the philosophers.]

So Salazar, who then proves at length that waters of this kind must necessarily be interposed between the Prime Mobile and the Empyrean heaven, lest the Empyrean heaven, being contiguous to the Prime Mobile, be swept along with it. And thus all the readings of Scripture — from the Hebrew, from Cajetan [Caietanus], from Rudolph [Rodulphus], from the Tigurine [Zurich] version, from the Septuagint, from Aquila, and from Symmachus — agree, etc.

Folenghius, approved and published at Rome, asserts from the Scriptures the substantial perishing of the heavens.

Giovanni Battista Folengo [Ioannes Baptista Folenghius] of Mantua, a Cassinese monk, in his Commentary on the Psalms published at Rome in 1585 by order of Gregory XIII [Gregorius XIII], on Psalm 101, upon the words —

[Margin: Giovanni Battista Folengo.]

They shall perish, but you remain; and they shall all grow old like a garment, and like a covering you shall change them, and they shall be changed — discourses thus:

"Like a garment and a cloak you shall change them" — so they render it from the Hebrew — *"and they shall be changed."* Here it is plainly affirmed by the [Holy] Spirit that, as the old [heaven] withers and passes away, the heaven must be

recast anew — that is, the whole machine of the elements, and whatever is set above the elements.

[Margin: The whole Machine of the World shall be dissolved.]

For it is altogether necessary that the fabric of this World perish, so that it may take on a new form [Latin: *nonam* imaginem, likely a misprint for *nouam*, "new"]; otherwise Isaiah would not have said *that the heaven shall vanish like smoke, and the earth shall grow old like a garment*. And what grows old, Paul said, is near to perishing.

Did anyone ever say that a garment is changed by someone unless, the former being cast off, he has put on another? Behold, he says, *I create new heavens, and a new earth, and there shall be no more remembrance of the former things*.

Until, says Job, the heaven be worn away, man shall not rise when he has fallen asleep. But if the heaven were certainly not to be worn away and utterly dispersed, we should not be compelled to affirm that man will rise again.

All the heavens, therefore — namely the most noble workmanship of God — shall perish, and the whole world shall take on a new face. So he.

[Margin: All the heavens shall perish substantially.]

This author, moreover, was approved at Rome by the Master of the Sacred Apostolic Palace.

PARS II. Cap. XXV.

[The page is set in two columns. The centered numerals "I." (left column) and "II." (right column) are apparatus markers keyed to the five-line marginal numbering that runs down column II; they are not section divisions. Each column is given below in reading order, left column first.]

[Column I]

Génébrard teaches that the heavens are corruptible by nature, etc.

[Génébrardvs caelos natura corruptibiles docet, &c.]

[Margin: Génébrard]

Génébrard [Gilbert Génébrard], on Psalm 101, in the Lyons edition of 1600, on the words "They themselves shall perish":

"The heavens, he says, will withdraw from their present state, and all will grow old like a garment; and when it has been worn away through age, it must be renewed. For so too the heavens, when they reach the consummation of the age, will be transformed into the newness of a greater glory.

For there is to be a *change* of both the heavens and the earth, *not a total abolition* — so that they *cast off the garment of corruption* (2 Peter 3, verse 13; Romans 8, verses 20 and 21) *and put on the new garment of incorruption*, etc.

And on Psalm 148: The heavenly bodies will be altered, or rather *renewed*, only in respect of their qualities (that is, physically, not merely locally) by the fire of the conflagration. For indeed, as he says a little later, *it is not natural to the heavens that they should abide forever, but this is bestowed on them by the goodness of God*, etc."

[Margin: The heavens will be burned up (*Caeli conflagrabit*).]

Martin Becanus acknowledged and taught that the heaven is by nature corruptible and destined to be destroyed.

[Caelvm natvra corruptibile, & corrumpendum agnouit, & docuit Martinus Becanus.]

[Margin: Martin Becanus]

Martin Becanus [Martinus Becanus], of our Society, in the first part of his *Scholastic Theology* — which he issued for the public benefit at Mainz in the year 1612 — in his treatment of the work of the six days, in the Work of the Second Day, on pages 403, 404, and 405, philosophizes as follows.

"Second Conclusion. By the Firmament must be understood an aggregate composed of air, fire, and all the mobile heavens, etc.

Third Conclusion. All these things that are understood under the name of the Firmament were made out of water, which formerly filled the whole space, from the earth up to the empyrean heaven, etc."

[Margin: A threefold objection.]

"You will say: if the heavens are produced from water, three absurdities follow."

[Column II]

"First, that they have matter of the same species as these lower things.

Second, that they are corruptible.

Third, that they were not created but produced out of matter.

I reply: none of these is absurd.

Not the first, because many philosophers hold that the matter of the heavens and of sublunary things is of the same species.

Nor the second; because although the heavens cannot be corrupted by a natural agent — and for this reason are commonly said to be by their own nature incorruptible — nevertheless they can be corrupted by God, and in fact will be corrupted, as is clear from the Scriptures. Psalm 101, verse 26; Isaiah 51, verse 6: *The heavens shall melt away like smoke.* 2 Peter 3, verse 10: *The heavens shall pass away with a great rush. The heavens, burning, shall be dissolved.*"

[Margin: The heavens will be corrupted (*Caeli corrumpentur*).]

"Nor the third, because many of the Fathers teach it, and no contradiction appears.

Sixth Conclusion. By the waters that are above the Firmament must be understood true waters, and of the same species as these lower ones.

So hold most of the Fathers, in Molina [Luis de Molina], disputation 10. And it is proved because this is more in conformity with Scripture, which asserts openly — not in one place but in many — that there are waters above the heaven.

And nothing prevents this from being understood in a proper sense; indeed it must be understood properly, as is clear from the narrative of Moses. For the waters on the first day were not divided but joined together, and without doubt of the same species: therefore, once they were divided, they could not become of a different species, because the specific nature is not changed by mere local separation."

[Margin: Objection.]

"You will say: elemental waters are by their own nature corruptible, and they actually are corrupted whenever some natural agent is present that can corrupt them. But the sun's rays reach all the way to the supercelestial waters, and they have the power of corrupting elemental waters. Therefore, if those supercelestial

waters are elemental, they will be corrupted by the sun's rays. But it is absurd to admit corruption of this kind above the heavens: therefore also —"

[Column I]

"— it is also absurd to grant that there are elemental waters above the heavens."

[Margin: Solution.]

"I reply: those supercelestial waters are indeed corruptible, yet they are not actually corrupted — either because of a preserving quality of their place, or because of an utmost resistance, or because of some quality impressed upon them (such as the glorified bodies and the bodies of the damned also possess), or finally because God withholds his concurrence from every alteration by which they could be corrupted."

Concerning the Work of the Fourth Day, that is, concerning the Stars, on page 409 he writes as follows.

"First Conclusion. It is probable that God on the fourth day produced the stars both as to their substance and as to their accidents — which I explain thus. On the second day God produced the celestial orbs out of the waters in a uniform variety and density; on the fourth day he made certain parts rarer and others denser, and to the denser parts he gave new substantial forms, a round figure, light, and motion.

Since, therefore, those denser parts are the stars, it follows that the stars were produced on the fourth day according to their substantial forms and according to the accidents already mentioned. This conclusion is proved because Scripture speaks no differently about the production of other things: but other things were produced not only as to their accidents but also as to their substance: therefore the stars too."

[Margin: The stars are specifically distinct from their orbs.]

"You will say: this opinion supposes that the stars have substantial forms distinct from the forms of their orbs, and consequently that they are specifically distinct from their orbs.

I reply: so it is. And it is proved, first, because what is of its own nature luminous differs in species from what is of its own nature not luminous: but it is probable that the Sun is of its own nature luminous, whereas the orb of the Sun is not: therefore it is probable that the Sun differs in species from its own orb.

I say the same of the other stars, except the Moon, which of its own nature is not luminous but is illuminated by the Sun." Thus far Becanus.

[Column II]

In favor of a corruptible Heaven: the Authority of Father Juan Luis de la Cerda.

[Pro caelo corrvtibili, Patris Ioannis Ludouici de La Cerda Auctoritas.]

[Margin: Juan Luis de la Cerda]

Juan Luis de la Cerda [Ioannes Ludouicus de La Cerda], of our Society, in his work *Adversaria Sacra*, which he brought to light at Lyons in the year 1626, in chapter 154, page 380, number 21, column one, argues weightily in favor of the heaven's native corruptibility in the following words:

"That the heavens are by their own nature corruptible, very many of the Fathers strive to prove from Scripture — note, Reader: from Scripture, not from Plato's Academy. Ambrose, in the first book of the *Hexaemeron*, chapter 6, where he mocks those who say, with Aristotle, that the heaven is a Fifth Essence, not of the nature of the elements. Cassiodorus, on Psalm 101: *The heavens are the works of your hands; they shall perish, but you remain.*"

[Margin: St. Ambrose mocks the fifth essence of the heaven.]

[Margin: Opinion in favor of a corruptible Heaven.]

"In the same place, Euthymius, and [John] Damascene, *On the Orthodox Faith*, book 2, chapter 6; Gregory of Nyssa, *On the Creation of Man*, chapter 24; Chrysostom, Homily 10 *to the People*; Theodoret, on Romans 8, on the passage *Creation shall be freed from the bondage of Corruption*; Justin Martyr, in Responses 93, 94, and 95 to the *Questions of the Orthodox*.

The other opinion holds that the heavens are incorruptible, and are of a certain essence removed from the elements — the view Aristotle maintained, and which St. Thomas [Aquinas] follows, together with the common School of Theologians. And to all the Scriptures cited for the first opinion they respond either that by them the air is to be understood, which is commonly called 'heaven'; or, if the heaven is truly meant, that it is understood of the heaven insofar as it has the accidents of motion, of brightness, and other such things — because the Sun will be darkened, and the Moon, and the stars, and the motion of the heavens will

cease — but not insofar as concerns the essence of the heavens, which are incorruptible."

[Margin: Opinion in favor of an incorruptible Heaven.]

[Column I]

"This, then, is each of the two opinions, and it is remarkable how many minds it has exercised. What am I to say amid so great a variety?"

[Margin: De la Cerda holds that the heavens are corruptible.]

"I certainly consider the former opinion to be most true, and that the heavens are altogether corruptible — although, by God's providence, they will not be corrupted. For I do not know what could be answered to these passages: namely, to Job 14,"

[Margin: The strongest scriptural passages for the corruptibility of the heaven.]

"When a man has fallen asleep, he shall not rise again until the heaven is worn away. And of Psalm 101: The works of your hands are the heavens; they themselves shall perish — that is, they will be able to perish. And it is clear that he is speaking of the heaven. Isaiah 34: And all the host of the heavens shall waste away, and they shall be rolled up like the scroll of the heaven. Likewise: And all their host shall fall away. And in chapter 51: The heavens shall melt away like smoke. To these it is difficult to reply.

And let them consult (I beg) Ambrose, in the first book of the *Hexaemeron*, chapter 6 — to whom this opinion seems difficult.

Why the philosophers have labored so hard in proving the incorruptibility of the heaven, I was long puzzled; and, examining it as far as I can, no other consideration moves them than to present Aristotle safe and whole. A fine praise indeed, to set him above so many heavenly things! I have no doubt that he erred, and all who defend his opinion."

[Margin: Aristotle, with his followers, erred concerning this question.]

Thus La Cerda:

"I conclude these authorities on the Heaven's corruptibility with the Church's Vespers Hymn, and with the sacred funeral lament by which the Church seems, every year, solemnly to perform the funeral rites for the heavens themselves, and to foretell their certain perishing."

[Column II]

The Church's Vespers Hymn.

[Hymnus Ecclesiæ Vespertinus.]

"Boundless Creator of the heaven, who, lest things mixed should be confounded, dividing the flowing waters, gave the heaven as their boundary, fixing a place for the celestial waters, and likewise for the earth's streams, that the water might temper the flames, lest they break up the soil of the earth."

Observation.

[Animaduersio.]

Here you have true waters set above the Heaven of the Firmament; you have a hot heaven, and cold supercelestial waters, which by their cold temper that celestial heat, lest by an excess of burning they should consume the earthly mass — and consequently all things by their own nature subject to corruption. And this according to the mind and sense of the most holy Church, and of the ecclesiastical Hymn, in praise of this divine Work accomplished on the second day: a praise that would be slight, were these things not held to be true.

We have heard the Hymn of Vespers; let us also consider, if it is not burdensome, the funeral Sequences of the Sacred Matins — that is, the verses of the Mass of the Dead — and let us, together with the whole Church, perform funeral rites over this perishable World with mournful rite and chant.

The Church's Matins Hymn.

[Hymnus Ecclesiæ Matutinus.]

"Day of wrath, that day, shall dissolve the world into ash; as David testifies, with the Sibyl. Etc.

So shall the fabric of the world fall in ruin; I add no further word."

[Column I, continuing into Column II]

"These verses, moreover, I judged would prove all the more welcome because they were plucked from that most flourishing and most fragrant Rose-garden of the Orsini itself. For, on the testimony of Abraham Bzovius [Abraham Bzowski], in volume 13 of the *Annales*, under the year of Christ 1294, numbers 37 and 39: Brother Latino [Latino Malabranca Orsini], Bishop of Ostia — his father a

Frangipani, his mother an Orsini — was adopted as a son into the Orsini Family by Nicholas III, Supreme Pontiff, his uncle and himself an Orsini, and was created Cardinal from the Order of Preachers. He composed these sacred laments — monuments of his learning and piety that will never perish — which the universal Church, together with a few hymns of the same kind, took up as a part of the Divine Office for the Dead, so that he himself might live forever, while the death of others is mourned in doleful song until the setting of the World."

But let all these things be said without prejudice to the other side, and with the sense of Holy Church preserved.

DE CAELI LIQUIDA SUBSTANTIA.

PRO NATURA CAELI LIQUIDA. CAP. XXVI.

Authorities from Sacred Scripture [Auctoritates ex Sacra Scriptura]

(On the liquid substance of the heaven. For the liquid nature of the heaven. Chapter XXVI.)

[Margin: The liquidity of the heavens is asserted: First, from etymology.]

The first authority is drawn from the etymologies of the Hebrew names, whose meaning — imposed upon them by the Lord God himself — seems to lead the hearer, as though by the very hand, into the opinion of a fluid heaven. On this matter much has been said in the place where we discussed the fiery nature of the heaven on the authority of others, and to that place we also refer the reader.

[Margin: Second, from the liquid nature of the elements, of which the heavenly bodies consist.]

The second authority is drawn from those passages of Scripture in which the heaven is indicated to be either fiery, or airy, or watery. Very many such passages are brought forward by the holy Fathers, as may be sufficiently seen throughout this whole treatise. In Isaiah, chapter 40, the heaven is compared to NOTHING; in chapter 51 of the same prophet, to SMOKE — certainly on account of its most liquid thinness, or its most tenuous liquidity, as the holy Fathers explain.

The third authority is taken from those passages in which sacred Scripture attributes motion not to the heaven but to the planets themselves — which same

[motion] the Fathers have understood also of the standing-still [of the heavenly bodies]: Joshua 10; Ecclesiastes 1; Psalms 18 and 104; Job 38; Isaiah 10; Habakkuk 3; and so forth.

[Margin: Third, from the free motion of the planets.]

That these passages are so understood by the Fathers will be shown by the authorities to be adduced from them.

[Margin: Fourth, from the number of the heavens and the varied motion of the celestial bodies.]

Fourth: the authority for a liquid heaven is most forcefully pressed from Scripture by the holy Fathers on this ground — that the multitude of heavens which the variety of celestial motions would require was nowhere expressed by Moses and the other canonical writers, even though both the heavens and all their adornment were sufficiently expressed. And since the Fathers know of no more than three heavens from Scripture; and since in the first (or Empyrean) heaven and in the last (or aerial) heaven no stars either exist or move, but all exist in the middle heaven — which, on the testimony of Scripture, is the Firmament: therefore, in order that the interpenetration of bodies be avoided, that Firmament, since the stars move through it in various ways, must be granted to be penetrable, and so flexible and yielding — as the Holy Fathers contend with all sail and oar, from Scripture itself, to be argued below in their proper places together with their testimonies.

[Margin: Fifth, from Scripture's silence about a hard heaven.]

The fifth authority is derived from the fact that Sacred Scripture nowhere makes mention of a hard heaven. For that passage of Job, chapter 37, verse 18 — "Perhaps you fashioned the heavens together with him, which are most solid, as though cast of bronze" — the Peripatetics themselves explain in favor of the liquidity of the heaven, against that adamant hardness. Fr. Marin Mersenne [Marin Mersenne], pages 836, 837, 838, 840: "Just as (he says, together with our Pineda [Juan de Pineda]) there is no need to conceive the Firmament as hard, like a stone, so neither [need one so conceive] the heavens — which proclaim the divine power in this, that although they are of a fluid and slippery nature, their duration is nonetheless no less perpetual than if they were most firm and, as it were, cast of bronze." Then, from the Rabbis, he proves from this passage that the heaven is thin air. And afterward: this passage (he says) Vatablus [François Vatable] — corrected by order of the Holy Inquisition and published at

Salamanca in the year 1584 — renders thus: "Did you, together with him, stretch out the aether, so solid that it seems a molten thing?"

[Margin: Vatablus's version.]

Then, after prefacing many translations, he adds: "I do not think this passage so favors the solidity and hardness of the heavens that we cannot admit their liquidity and fluid nature, etc. — since indeed the true aim and sense of this passage is that we should look up to and venerate the infinite power of the divine Majesty, which is most clearly seen in this: that a fluid nature, such as the airy, the ethereal, and the watery, persists so firmly in its place as if it were forged from the strongest crystal, or from some other very hard material." And at length, after much more.

"Take note," he says, "that nothing is to be inferred from that passage of Job, because it is not Job, nor God, who speaks, but Elihu — who speaks continuously from chapter 35 up to 38 — all of whose sayings we are not bound to prove as true."

And thus, by the very admission of the Peripatetics, the strongest passage of Scripture — as will be seen elsewhere too — works against them, in favor of a liquid heaven.

[Margin: Sixth, from the very natural and material genesis of the heavens.]

The sixth scriptural authority is brought forward from the very genesis of a liquid, not a hard, heaven: Genesis chapter 1, at the very beginning, and Proverbs chapter 8. These passages, being weighty, will later be quoted verbatim at the close of this treatise on the liquidity of the heavens. Whoever wishes fuller and richer material should consult the *Sol Illustratus* of the illustrious and noble lord, Sir Jan Mikołaj Smogulecki of Smogulec [Jan Mikołaj Smogulecki], etc., pages 53, 54, 55. Now let us hear the holy Fathers themselves declaring their opinion.

[Margin: Seventh, from Ezra.]

Seventh: to this may be recalled Ezra, who in book 4, chapter 6, verse 41 [4 Ezra 6:41], sets forth the same opinion of a liquid heaven quite clearly, in these words: "And on the second day you created the spirit of the Firmament, and commanded it to divide, and to make a division between the waters, so that one part might withdraw upward and the other remain below." So he says. Then he adds that on the third day a seventh part of the lower waters was gathered into seas, while the other six parts were dried up into the height [as dry land]. Now, by "the spirit of the Firmament" — by which the celestial waters are said to be separated from the

terrestrial — nothing can be understood except air or fire; and each of these is by nature liquid. Moreover, the authority of this man is reckoned by theologians to be next to canonical Scripture.

PARS II. Cap. XXVI.

For the liquid substance of the heaven: the Authorities of the holy Fathers [Pro Caeli liquida substantia Auctoritates sanctorum Patrum]

That this question — concerning a heaven hard or not hard, fluid or not fluid — is not new, but has been debated among the learned since antiquity and settled one way or another, will be sufficiently clear from what the holy Fathers handed down to posterity in their writings, as will presently be recounted in their own words.

For a liquid heaven: the authority of Saint Augustine [Pro caelo liquido. Auctoritas sancti Augustini]

[Margin: St. Augustine.]

For Saint Augustine [Augustine], in book 2 of *On Genesis, Literally Interpreted* [De Genesi ad litteram], chapters 1, 2, 3, 4, and 5, on those words — "Let there be a Firmament in the midst of the waters, and let it divide the waters from the waters: and so it was done; and God made the Firmament, and God divided the waters that were under the Firmament from the waters that were above the Firmament; and God called the Firmament heaven" — writes thus:

[Margin: Whether the Firmament is air, or is above the air.]

"Whether now that heaven is meant which exceeds all the spaces of the air and its whole height — where too the luminaries and the stars are set in place on the fourth day — or whether the air itself is called the Firmament, may reasonably be asked. For many assert that the nature of those waters cannot be above the starry heaven, since they have their weight so ordered that they either float upon the earth, or are borne as vapor in the air nearest to the earth.

"Nor ought anyone to refute these men by saying that, according to the omnipotence of God — for whom all things are possible — we must

believe that waters even as heavy as those we know and perceive are poured over the heavenly body in which the stars are.

[Margin: Here the holy Doctor excludes God's miraculous power.]

"For now it is fitting for us to inquire, according to his Scriptures, in what way God established the natures of things — not what, in them or from them, he might will [to do] for a miracle of his power.

[Margin: Here the holy Doctor teaches that the natures of things are to be investigated according to the Scriptures, not according to the doctrines of Plato, etc.]

"For even if God willed that oil should at some time remain beneath water, it would not fail to happen; yet the nature of oil would not on that account be unknown to us — namely, that it is so made that, seeking its own place, even if it has been poured underneath, it will break through the waters and set itself above them.

"Now, therefore, we ask: 'Whether the Creator of things — who arranged all things in measure and number and weight — assigned not [merely] one proper place to the weight of the waters around the earth, but also one above the heaven, which, beyond the boundary of the air, is spread around and made solid?' Those who deny that this is to be believed argue from the weights of the elements, denying that the heaven is in any way solid — as though [it were] a kind of pavement — such that it could sustain the weights of the waters; because such solidity could belong only to earth, and whatever is of that kind would be not heaven but earth. For the elements are distinguished not only by their places but also by their proper qualities, so that, in accordance with their proper qualities, they might obtain also their proper places."

[Margin: Wisdom 11:21.]

[Margin: The state of the question.]

[Margin: Those who argue from the weights of the elements take rigid solidity away from the heaven, and grant it to earth alone.]

This they prove there, in order — from earth to water, from water to air, from air to fire, and so up to the heaven. After all this, the divine Augustine again continues thus:

"Therefore they conclude that there can be far less room for the waters [above that fiery heaven], since there even the air — being much lighter than water — could not remain."

[Margin: In Augustine's time it was believed that above the air there is a fiery heaven; and Augustine himself was of the same view, as was seen earlier.]

Yielding laudably to such disputations of theirs, a certain person attempted to demonstrate that there are waters above the heavens, so that from these very visible and conspicuous natures he might uphold the trustworthiness of Scripture. And when he had proved from various passages of Scripture that the air is called "heaven," and that the clouds are rolled above the air, Saint Augustine adds:

"Therefore, from the air — which is among the moist vapors, from which higher up the clouds are massed together, with the seas poured between

—

he wished to show that there is a heaven between the waters [above] and the waters [below]. This diligence and consideration, then, I judge most worthy of praise; for what he said is not against faith, and can be believed on the evidence that lies ready at hand.

"Although it may seem that the proper weights of the elements are no obstacle — [the question being] how there could be waters even above that lofty heaven, by those minute particles by which they were able to exist even above this space of air. For the air, though heavier and lower, lies beneath the highest heaven, and is without doubt lighter than water; and yet those vapors are prevented by no weight from being above it. So, then, above that heaven too a lighter exhalation of moisture, in smaller droplets, can be spread out — one that is not forced by its weight to fall.

"For they [the philosophers] persuade, by the subtlest reasoning, that there is no corpuscle, however tiny, in which division comes to an end, but that all things are divided to infinity — since every part of a body is a body, and every body must have a half of its quantity. And through this: if water can, as we see, reach such minuteness of droplets that it is borne as vapor above this air (which is by nature lighter than water), why could it not also flow forth above that lighter heaven, in still smaller droplets and lighter vapors?

"Some of our own [writers] too endeavor to refute — from the qualities and motions of the stars themselves — those who deny, on account of the weights of the elements, that waters can exist above the starry heaven.

[Margin: An argument from the quality and course of Saturn.]

"For these same men assert that the star which they call Saturn is the coldest, and that it completes the zodiacal circle over thirty years, because it travels in a higher — and therefore wider — orbit. For the Sun completes the same circle in a year, and the Moon in a month: as much more quickly, they say, as it is lower, so that the span of time may match the span of place.

"And so it is asked of them: how that star can be cold, which ought to be the hotter, the loftier the heaven in which it is swept along.

"For without doubt, when a round mass is driven in circular motion, its inner parts go more slowly and its outer parts more swiftly, so that the greater distances, together with the shorter, come round alike to the same revolutions; and those parts that move more swiftly are certainly the hotter.

"Accordingly, the aforesaid star ought to have been hot rather than cold. For although by its own motion — since the space is vast — it traverses the whole circuit in thirty years, yet, being whirled the more swiftly by the contrary motion of the heaven (which it must undergo daily, since, as they say, the single revolutions of the heaven mark out single days), it ought to have taken on a greater heat from the more rapidly driven heaven.

"Surely, then, what makes it cold is that nearness of the waters set above the heaven — which those who dispute about the motion of the heaven and the stars, in the terms I have briefly stated, refuse to believe. With these conjectures some of our own writers proceed against those who refuse to believe that there are waters above the heavens, and who hold that the star which circles next to the highest heaven is cold — so that from this they may be compelled to believe that the nature of the waters hangs there no longer in vaporous thinness, but in glacial solidity.

"But in whatever manner, and of whatever kind, the waters there may be, let us by no means doubt that they are there; for the authority of this Scripture is greater than the whole capacity of the human mind."

The same Saint Augustine, in book 11 of *The City of God* [De Civitate Dei], chapter 34, writes as follows concerning these supercelestial waters:

"But those who wish 'the waters that are above the heavens' to be understood as Angels are moved by the weights of the elements, and therefore do not think that the fluid and heavy nature of water could have been established in the upper regions of the world. According to their own reasoning, if they themselves could make a man, they would not place in his head the phlegm — what in Greek is called *phlegma* [Greek: *phlegma*, "phlegm" — the term is printed in Latin letters, not Greek script] — which, among the elements of our body, holds, as it were, the place of water; for there [in the head] is the seat of phlegm, most fittingly according to God's work. But according to the conjecture of those men it is placed so absurdly that, if we did not know this, and it were likewise written in this book that God placed a fluid and cold — and therefore heavy — humor in the highest part of the human body, above all the rest, these weighers of the elements would by no means believe it. And if they were subject to the authority of the same Scripture, they would judge that something else must be understood from this."

[Margin: Against the weighers of the elements, the divine Augustine sets the fabric of the human body.]

SCHOLIA on the Cited Passages, and Corollaries

From these it is clear that in Saint Augustine's [Augustine] time this question of the hardness of the heaven [caelum] was not unknown, but sharply debated, and treated by everyone as though settled — settled, moreover, on the negative side: namely, that no hardness whatever is to be found in the heaven. For he writes in plain words that it has been denied that the heaven is in any way made solid overhead, like a kind of pavement, so as to be able to bear up the weight of the waters. And he gives the reason for this denial: that hardness of this kind is a property of earth alone, not of the heaven. Hence, upon this denied hardness of the heaven and the opposite fluidity assumed in its place, they built their arguments drawn from the weight of the elements — arguments that would surely have had no force or weight at all, if either they themselves or their opponents had recognized that adamantine firmness of the heaven which the moderns [Neoterici] now urge.

For they would either have been ranting madly against their own position, if — granting a hard heaven of their own admission — they had feared that the waters

might fall down, or urged that they might rise up; or else they would, in a vain effort, have been forcing this very argument upon their adversaries, if against those who assert a hard heaven they had deployed weapons so inept. For who does not see that all their efforts, deduced from the weights of the elements, could have been shattered and reduced to nothing simply by opposing the hardness of the heaven? Since Saint Augustine did not do this, but says further that their disputations were commendably yielded to and given room, it is plain that the fluid nature of the heaven was admitted on both sides and taken as granted.

And hence it came about that, since the waters had to be placed above the firmament [firmamentum] of the stars by force of Sacred Scripture, they — in order not to be compelled to admit that these waters would fall down by their natural weight — drew them down below the Moon and the sphere of fire, and confined them above the air, once it had been reduced to clouds or vapors, substituting the air itself in the place of the heaven and firmament by their exposition of Scripture. Hence too Saint Augustine himself, drawing on the very principles of those mathematicians, says that these same natural and heavy waters — whether thinned by heat into the subtlest vapors, or condensed by cold into icy stiffness — can be held suspended and free from falling in the highest regions of the world, beyond Saturn. The holy Father would say this in vain, unless he supposed that waters not compacted, or not firm, are liable to slip downward. From which it at once shines out that the heaven lying beneath these waters was held by him to be by no means hard, but liquid and yielding.

Otherwise, there would have been no need to restrict the waters — which were not going to fall — to these two cases; rather, he could have said outright that the waters would in no way flow down, even if they had been wholly liquefied and gathered together into a single sea, since the insuperable firmness of a heaven of bronze or adamant, or finally of crystal, would have entirely prevented their falling.

Saint Augustine, therefore, in no way acknowledged a rigid solidity of the heaven. This is further established by the following: against those who — pressed by the force of the mathematicians' arguments and turning aside to metaphorical expressions — interpreted the supercelestial waters as Angels, he did not oppose an unyielding hardness of the heaven, which he certainly ought to have done had he judged the heaven to be rigid. Instead he opposed the phlegm of the human brain — which, once again, would be poorly applied here by Augustine if he had believed the boundary between the celestial and terrestrial waters to be so firm that neither could the latter evaporate above it, nor the former, dissolved into

larger drops, distill down below it. In vain, I say, would he allege the temperament of the human body against those weighers of the elements, since there would be no basis whatever for the comparison.

[Margin: Saint Augustine would raise the objection of the moisture of the human brain to no purpose, if he acknowledged a hard heaven.]

Those very inventors of these allegorical senses, too, would have no ground for excusing themselves; for if a hard heaven were either posited or acknowledged, they could have extricated themselves without any trouble from the modest scales and balancings of the mathematicians, by saying that the waters — heavy and elemental though they be — are held up above by the hard substance of the heaven, once placed there by God.

Since none of them advanced these points, it is plain that a hard heaven was proved by no one, but that a fluid heaven was held and assumed — as will be shown more fully a little later.

[Margin: A question debated in Saint Augustine's time: whether the firmament stands still.]

For the same Saint Augustine, in *On the Literal Meaning of Genesis*, book 2, chapter 10 (*De Genesi ad litteram* II.10), is vexed with those who, beyond their proper business, press such questions too importunately or too inquisitively.

["Concerning the motion of the heaven, too," he says, "some of the Brethren raise the question, whether it stands still or moves. For if it moves, they say, how is it a firmament? But if it stands still, how do the stars, which are believed to be fixed in it, travel round from east to west, the northern ones completing shorter circuits near the pole — so that the heaven, if there is another pole hidden from us at the opposite vertex, seems to rotate like a sphere, but if there is no other pole, seems to rotate like a disc? To these I reply that such matters are investigated by very subtle and laborious reasonings, in order truly to grasp whether it is so or not so; and for entering upon and handling these I have no time, nor ought those to have time whom we desire to instruct for their own salvation and for the necessary benefit of the holy Church.

[Margin: The reply of Saint Augustine.]

Let them at least be aware of this: that the name 'firmament' does not compel us to suppose that the heaven stands still. For we may understand the firmament to be so called not because it stands still, but because of its firmness, or because of the crossing of the boundary between the upper and lower waters. Nor, even if

truth should convince us that the heaven stands still, are we hindered by the circuit of the stars from being able to understand this; indeed, it has been discovered by those very men who investigated this most curiously and most idly, that even with the heaven unmoved, if the stars alone revolved, all those things could have come to pass which are observed and comprehended in the revolutions of the stars themselves."]

[Margin: The cited passage is explained.]

From this passage of Saint Augustine it is clear that the name "firmament" may seem to have been given to the heaven, first, on account of its standing still — because it would remain unmoved while the stars move. Concerning this opinion the holy Father says two things: first, that this does not necessarily follow from the meaning of the word itself, since by the name "firmament" one may understand either the firmness of the material or the stable separation of the waters; second, that if by some chance the truth were nevertheless brought out, so that it should be established that the stars revolve while the heaven is unmoved, astronomers have nonetheless found ways by which all the phenomena [Phaenomena] of the Sun [Sol] could be defended by the circuits of the stars themselves.

And this indeed could be the first sense of the word — namely, the unmoved standing of the heaven; and if truth should approve it, says Augustine, it will nonetheless in no way stand in the way of the revolutions of the stars and the celestial appearances; for the courses of the stars remain free, and everything that depends on them can conveniently be defended, even if the firmament stands still while they move.

And these things, says Saint Augustine, he is accustomed to reply to the Brethren — that is, to the Christians who are wont to ask him such questions. And although he does not specify which particular discovery it was, made by those who investigated these matters most curiously and most idly, whereby all the phenomena of the heaven might be defended with the firmament standing still and the stars moving, he nevertheless indicates it plainly enough when, in this same second book, chapter 4 (*De Genesi ad litteram* II.4), he says most openly, against those who denied that there are waters above the firmament, that these waters can by their vaporous thinness naturally ascend up there, above that lighter and fiery heaven of the firmament.

[Margin: The fiery heaven, according to Saint Augustine.]

Just as, therefore, waters can ascend above the firmament by their vaporous thinness, according to Saint Augustine's view, so too the stars can revolve within the firmament and beneath the firmament, according to the astronomers' opinion — whether they be placed in the eighth sphere [sphaera octava] or in the lower spheres.

What that discovery was is not hard to guess. For if the stars move while the heaven stands still, the heaven must be yielding — assuming, that is, that it is a body and that one wishes to avoid the interpenetration of bodies.

[Margin: To say that the firmament is fluid is not rash.]

Whence they conclude that to deny, in the Church of God, that the firmament of the heaven is hard, or to hold or say that the firmament is a soft and fluid body — this is not rash, but is put forward by Saint Augustine himself as sound and free from any suspicion of error, and is customarily handed down by him to the faithful of Christ, not as an article of Faith, but as an indifferent and astronomical teaching, disapproved neither by him nor by others, but rather admitted.

They next infer that a second reason is brought forward by the holy Doctor as to why the heaven is called "firmament" — namely, on account of its firmness. Yet he does not specify what that firmness is: whether as of something solid and rigid, or as of something condensed, or as of something endowed with wondrous qualities for acting. Accordingly, seeming himself to place little weight on this firmness, he at once passes on to the third reason for this name, and says that the starry heaven is called "firmament" because it is the boundary established by God, impassable to the upper and lower waters.

[Margin: What sort of firmness the heaven has, according to Saint Augustine.]

Moreover, from the fact that the holy Father says — "If the truth should convince us that, with the firmament standing still, the stars move, ways have been found by the treaters of these matters for nonetheless defending all the phenomena of the heaven" — he plainly signifies that it belongs to the mathematicians to investigate these truths, and that the ecclesiastical writers did not disdain to accept from them the things that were not clearly found in Scripture. Among these, this very controversy about the motion of the heaven and the stars is doubtless to be counted; and this liberty of investigating the truth was never taken away from the mathematicians, nor curtailed, by the theologians, in those questions which were not decided by the authority of Faith or by the definition of the Church. On the contrary, as was seen earlier, he strongly exhorts learned

Christians to the sacred books for the investigation of such matters. From what has been said, therefore, the following argument is framed:

If, in Saint Augustine's time, the firmament had been recognized as hard and impermeable, the holy Father would surely not have labored so hard, against the objections of the unbelieving philosophers, to draw the waters up there — naturally, by their vaporous thinness, without any miracle of God — above the air, above the fiery and ethereal heaven, and, once carried up there, to keep them from falling, whether made subtle by the same rarefaction or bound together by icy condensation. If, I say, Saint Augustine had known that in his own day that opinion about the adamant hardness of the heaven, which many now assert, held sway in the Church of God under any semblance of probability, he would not have defended himself against those philosophers by this ascent of the waters; rather, he would have answered in a single word: that the waters were placed above the solid and hard firmament, in the first creation, by the word of God, and are held above it lest they fall, by the impassable and incorruptible hardness of that same firmament. Since the holy Father did not answer this, but rather conceded that this air extends up to the fiery and ethereal heaven, and that the higher regions are always by nature more subtle and lighter, yet that the rarefied waters can nonetheless ascend above them and remain there by a natural power, with no violence or miracle of God intervening — since, I say, he granted these things to his adversaries, who were arguing against Scripture, and freely allowed that that whole fiery and ethereal space is taken by Scripture under the name of "firmament" — it is evident that the firmament was held by Augustine to be not hard, but soft and permeable. And this is the first point.

[Margin: Another argument.]

Next: if Saint Augustine acknowledged a hard firmament, he would not say that the stars can move while the firmament stands still; but he does say the latter; therefore he does not acknowledge the former. The inference is proved: without the interpenetration of bodies it cannot be said that, with the firmament standing still, the stars move within it, as the mathematicians amply demonstrate. But for the holy Father to hold this — that a natural interpenetration of bodies is granted — is altogether foreign to truth and to the learning of so great a Father.

[Margin: Another passage of Saint Augustine.]

In the same book 2, chapter 9 (*De Genesi ad litteram* II.9), the same holy Father discusses the shape of the firmament. For he says: "It is also customarily asked, what form and shape of the heaven ought to be believed according to our

Scriptures?" And after discussing many things, he says that according to our Scriptures the shape of the heaven is described as "stretched out like a skin" with respect to a plane, or "like a vault" with respect to an arch — whence he doubts whether the heaven is flat, or hemispherical, or a complete sphere. "And indeed," he says, "that likeness of a vault, even taken according to the letter, does not among us hinder those who say that the heaven is a sphere. For it is rightly believed that Scripture meant to speak of the shape of the heaven with respect to that part which is above us. If, therefore, it is a sphere, it is a vault on that one side on which the heaven covers the earth; but if it is a sphere, it is a vault on every side. But that which is said about the 'skin' presses harder, lest it be opposed not to a sphere — which is perhaps a human fabrication — but to our very vault. What I have understood allegorically from this, the thirteenth book of our *Confessions* contains (*Confessions* XIII). Whether, therefore, it is to be understood as I set it down there, or in some other way — the heaven 'stretched out like a skin' — on account of those troublesome and excessive exactors of the literal exposition, this I say, which, as I think, is plain to everyone's senses: for perhaps both — that is, both the skin and the vault — can be understood figuratively; but how each can be understood literally must be examined. For if a vault is rightly called not only curved but also flat, then surely a skin too is stretched out not only into a plane, but also into a round fold [sinum [?]]. For both a wineskin and a bladder are of skin." Thus far he.

[Margin: Saint Augustine did not acknowledge a hard firmament, etc.]

Since, therefore, from these things it is clear that Saint Augustine doubted whether the firmament is spherical, but from Scripture more probably held that it is stretched out over the habitable earth like a hemisphere, or in the shape of a disc, as he himself says in the same place — it is also clear that the firmament could not be set down by Augustine as of impenetrable solidity. For otherwise, either the stars would not have been set in motion as placed in the firmament; or the firmament itself, together with the stars, would have gone off to the opposite side, and thus the earth would have been stripped of the covering of the heaven — not to mention that a flat or hemispherical shape cannot be moved around the earth without countless absurdities. But to attribute these incongruities to so great a light of the Church, I do not think fitting.

Whence it is certain that Saint Augustine did not acknowledge a hardness of the firmament. And therefore those who, along with Saint Augustine, do not accept a hard heaven, or at least doubt about the hardness of the heaven, are certainly not rash on this score — even though it is written in Job that the heavens are "most

solid, as though cast of bronze" (Job 37:18). For who doubts that this passage of Scripture was well known to Saint Augustine? And yet, notwithstanding it, he says that for the heaven to be spherical may perhaps seem a human invention. These are the words of Saint Augustine himself.

To the passage of Job, moreover, reply is made expressly elsewhere — not so much by the astronomers as by the scriptural commentators, and by the Peripatetic philosophers themselves, who clearly say and teach that the discourse there is only about the sublunary air, and by no means about the higher heaven endowed with the quality of hardness. So that the adversaries press this text to no purpose, since it militates against their very selves, and so forth.

FOR THE LIQUID HEAVEN: The Authority of Saint Basil

[Margin: Saint Basil.]

Saint Basil [Basil], older than Augustine — although in the third homily of the *Hexaemeron* (Basil, *Hexaemeron*, homily 3) he acknowledges the firmament to be, both in name and in function, distinct from the first heaven or Empyrean [Empyreum], and thus of a comparatively more solid nature — nevertheless by no means admitted a solidity that is impermeable or in no way yielding. For he himself says:

"[If the body of the firmament is spherical, as its very appearance shows, and if water, being by its own nature fluid, is wont and bound to slip down from a lofty star, how could it have remained solidly and stably on the curved and upper circumference of the firmament?]"

After he had answered this objection from the shape and nature of the firmament, he assigns the reason for the waters raised above the firmament: to temper and moderate the heat of the fiery ether, and to nourish the Sun until the end of the world.

[Margin: Saint Basil says that the waters placed above the firmament are the fuel of the solar fire.]

"[For indeed," he says, "He who arranged all things by weight and measure — for even the drops of rain, according to Job, are numbered by Him (cf. Job 36:27) — clearly knew how much time He had prescribed for the world's duration; and He was not ignorant of how much expenditure and fuel He had to store up for the fire. This is the reason for the abundant and copious water at the creation.]" And long after...

Further on: "Let us understand water as water, and let us take the separation of the fluids from the Firmament in the sense we have assigned. And even if at some time those waters which are placed above the heavens are said to praise the common Lord of all, we do not on that account judge them to be natures endowed with reason." And later: "For the water resting above the heavens does not fulfill the divine praise merely because, in the dignity of first honor, it precedes the lower waters — solely on account of the exceptional and signal prerogative of its own virtue, etc."

Saint Basil, then — as is most evident from these and many other passages, indeed from this whole Homily — affirms, taught not by Plato but by Sacred Scripture, that real waters (corporeal, elemental, corruptible, heavy, cold, clear, unfrozen) are placed above the Firmament itself, so that they may temper the world and blunt the Sun's vehemence, and that they settle, like nourishment, upon its insatiable voracity right down to the very last day. Since these things are most certain from the Holy Father's teaching, I construct from them the following syllogism.

[Margin: An argument from the teaching of St. Basil [Basil] against the hardness of the heaven.]

If the Sun gradually draws off, to its own feeding, the waters placed above the Firmament by God the Creator, and converts them into a substance either of its own kind or of the fiery ether — then the Firmament, which holds those waters above its own upper surface, is not hard or impassable. But the Sun, according to Basil's view (as is evidently established from the passages of Homily 3, both those cited and those not cited), does gradually draw off, to its own feeding, the waters placed above the Firmament by God the Creator, and converts them into a substance either of its own kind or of the fiery ether. Therefore, according to Basil's view, the Firmament which holds those waters above its own upper surface is not hard or impassable. The major premise is clear; the minor is clearer still, from the Holy Father's own Homily; the conclusion, therefore, is clearest of all — and this by reasoning founded on the Firmament itself as more solid ground.

[Margin: St. Basil's view of the Firmament, from Sacred Scripture.]

But let us now hear again the Holy Father himself, disclosing his opinion in plain words. (Homily 1 on the Hexaemeron.)

"As for the substance of the heaven, those things satisfy us which were spoken by the prophet Isaiah [Isaiah], who in ordinary words opened up for us a fitting

understanding of its nature when he said: *He who made the heaven firm like smoke* — that is, he who made its nature thin, not solid, and not thick, for constituting the substance of the heaven."

[Margin: Isaiah 51:6 and 40:22.]

What could be clearer than these words? The same, in Homily 3: "Outsiders call that a firm body which is, as it were, solid, dense, and full, so as to distinguish it from a mathematical body. Now a mathematical body is one that consists in dimensions alone — that is to say, in breadth, length, and depth."

[Margin: Definition of "firm" according to Basil, following the mind of the philosophers. // According to the mind of Sacred Scripture.]

"But the firm and solid is that which, together with its dimensions, can also strain and resist. [?] Sacred Scripture, however, is accustomed to call *firmament* everything that is very robust and does not yield — so much so that it seems generally to use this very word even of condensed air, as when it says, *He who makes the thunder firm*. For Scripture named the solidity and resistance of that spirit which is shut up within the hollow confines of the clouds — and which, through its violent eruption from there, produces those sounds and crashes we call thunder — the *firmness of thunder*. Here too, therefore, we judge that this word was ordained by Scripture for a certain firm and solid nature, fit for holding in and confining the waters, which of their own nature slip away and very easily dissolve."

"Yet the Firmament itself is not to be thought similar (although, according to the common and popular understanding, it seems to have taken its origin from water, or from water congealed into ice, or from some such matter that draws the beginning of its origin from percolated moisture) to the nature of crystal-stone — which, they assert, is transmuted, through the excess of the water's congelation, into the essence it now possesses — nor to the nature of the specular stone, of the sort generated among the metals.

[Margin: He removes from the Firmament the hardness that comes from freezing.]

And indeed this transparent stone, and

translucent one, shining with a peculiar and most pure clearness — so that, if it answers to all the requirements of its own nature, and is neither eaten away by any rot, nor broken through to the bottom, nor perforated with cracks, it vies with air, and seems to be almost similar to it in transparency.

From these considerations, then, we judge that the Firmament is like none of these. For it is indeed the mark of a childish and simple mind to hold such opinions about the heavenly bodies.

[Margin: That the Firmament is frozen — this, he says, must be reckoned among children's imaginings.]

And yet, granted that all things are present in all — fire in air, air in water, and one of the rest present in another, and that none at all of the things falling under sense is a pure element free of mixture, so as not to partake of an intermediate or of its opposite — it does not on that account please us to assert that the Firmament is either made of one of the simple bodies or mixed from them all; for by the divine Scripture itself we have now been so instructed that we allow our mind to imagine nothing beyond what has been granted, etc."

Now, lest anyone should on this account falsely imagine that Saint Basil ascribed to the heaven some sort of Fifth essence and an incorruptible nature, hear the same Father explaining his own words more clearly, as it were, in the same third homily. "Since these things are so," says the great Father, "shake off that infatuated wisdom (the wisdom of those philosophers who deny and mock the supercelestial waters, and who are wont to hold that such waters are consumed by the Sun's heat), and take up with us the teaching of truth — unskilled indeed in expression, but stable and firm in knowledge. Therefore: *Let there be a Firmament in the midst of the waters, and let it divide between water and water.* We have said what meaning the name *Firmament* has in Scripture. It certainly suggests a nature in no way reluctant or solid, nor one that is heavy or resistant by its own weight. It is not of that kind that he says the Firmament is. Otherwise, if you understand its nature to be heavy in mass in this way, the earth would more nearly and more justly have claimed for itself the name of firmament. But because the nature of the things that tower above us and are sublime is exceedingly thin and rare, and cannot be perceived by any sense,

[Margin: To the Firmament he attributes the power of separating the waters, etc.]

it is this that Moses [Moses] called the Firmament — by comparison with the bodies that are most thin and that are easily grasped by sense. Now imagine for me some one place endowed with the faculty of separating moisture, which passes the thin, filtered moisture over to the upper regions, but sends the thickest, earth-mingled part down to the lower regions, so that from beginning to end one and the same temperature is preserved throughout the universe, the heat gradually consuming the substance of the moisture.

You, for your part, do not believe that the abundance of the waters is so great; but you fail to consider that the abundance of heat is likewise so great — heat which, though small in magnitude, can nevertheless consume much moisture by its native force.

[Margin: To the heavenly fire he transfers the power of consuming the waters.]

For it draws to itself the moisture that lies near it, as the physicians' cupping-glasses show, and once drawn it consumes it, just as happens in the flame of a lamp, which quickly burns up the neighboring fuel drawn to it through the wick, once that fuel has been transformed."

From these words you plainly have the Holy Father's mind: that he in no way wishes the nature of the Firmament to be hard, rigid, and resistant, but soft, yielding, and permeable.

Next, that it is not impure or mixed from the elements, but something most subtle and, out of the elements themselves, most thoroughly refined; for he mocks Aristotle's [Aristotle] Fifth essence as fabricated and trifling, in these words:

"(Homily 1.) Certain men," he says, "having set aside, as improbable, and rejected the opinion that the heaven is composed of the four elements, introduced a certain Fifth nature of body for constituting the heaven — a nature fabricated by their own contrivance and out of themselves, and devised to suit the occasion. And when he had brought forward the arguments for this view copiously and vividly, what do you suppose the Holy Father concluded? that he approved it? Hear him:

Owing therefore to these necessities of reasoning (as they say), and having rejected the arguments of their predecessors, they had need to prop up their opinion by a certain private and peculiar supposition — men who postulated a certain essence of body for constituting the generation of the heaven and its stars.

And on the other side, another one of them — men who through their age had trained themselves in arguments of the persuasive kind — attacking these first men, both set their claims in order and then straightway dissolved them; nor did he only do this, but by his own contrivance he brought in an opinion peculiarly his own."

[Margin: D. Basilius / St. Basil.]

You have heard these philosophers cross swords among themselves. On which side would you reckon that Great Basil will take his stand? Let us see.

"If we now undertake to speak about these matters," he continues, "we shall fall into trifles just as they did. Therefore, leaving them aside — that they may destroy one another in the mutual sword-play of their controversies — and likewise setting aside the discourse about essence, let us keep faith with Moses."

[Margin: He says faith is to be kept with Moses, not with the philosophers.]

From these words, then, it is most clear that Saint Basil in no way assigned the heaven to a Fifth essence; otherwise he would have enrolled himself too in the census of the triflers. And the fact that he says it does not please him to assert that the heaven is mixed from one or several elements does nothing at all for the opposing side, nor will they ever prove from it that Saint Basil admitted a Fifth essence in the heaven, or that he excluded the heaven entirely from the nature of the elements. For from the very context and force of the argument here, and elsewhere in other passages, it is manifest that the Holy Doctor wished nothing more than this: that the heaven is not composed of impure or half-mixed elements, but is something most pure, most simple, and most thoroughly refined.

Nor does the text adduced according to Eustathius's [Eustathius] version help the opposing side at all. For neither is that translation genuine, nor is it Basil's opinion; rather, Basil brings it forward out of the mind of those who champion the Fifth essence, adducing it against others. But I prefer to bring forward the Greek words themselves, lest I seem unjust toward Eustathius:

ἀλλὰ μὴν οὐδὲ ἐκ τῶν πρώτων σωμάτων ἃ δὴ στοιχεῖα καλοῦμεν, σύνθετον εἶναι δυνατὸν ἡμῶν ὑποθέσθαι τὸν οὐρανόν, &c. τῷ τὰ ἐκ διαφόρων [Greek: "But indeed neither is it possible for us to suppose that the heaven is compounded out of the primary bodies which we call elements, etc.... to that which [is made] of different things"].

These words, in the first volume of the Greek-Latin Basil published at Paris in 1618 (from which I transcribed all of this), are on page 14 rendered thus, in the best of faith:

"But neither can we suppose that the heaven consists of the primary bodies, which we also call elements, for the reason that, etc." — *this is the genuine rendering*. Eustathius, however, translated these same words thus: "Nor is it possible for us to believe that the heaven was composed of those principal bodies which are called elements, etc."

[Margin: Eustathius's version.]

I leave it to the reader's judgment whether he thinks this version genuine. The opinion itself is certainly ascribed to the Holy Father in bad faith when it is brought forward by the champions of the Fifth essence as a member of Basil's argument — whereas in fact Basil brings it forward not as his own but as belonging to others, and then rejects it as false;

[Margin: St. Basil adduced the quoted words not in his own sense, but in that of his adversaries.]

a thing clearer than the Sun, both from the context itself and from the words of Basil himself, who subscribes thus at the end of the arguments: "Owing therefore to these necessities of reasoning (as they say), they had need [of such a device]."

Undeservedly, then, are there ascribed to Saint Basil the fabricated opinions of outsiders or pagans about the heaven's Fifth essence — opinions which he himself calls, and refutes as, trifles. Rather, it stands firm from his very own judgment that the Firmament is neither rigid with adamant hardness, nor foul with the dreggy filth of the elements, but tender in its most purified subtlety, soft, tractable, and indeed permeable to the waters both above and below. And if you say that the Holy Father himself declared the nature of the heaven to be unknown, that must be referred to its lowest species, not to its genus; for he acknowledged that the Firmament is a fluid body, even though he might disavow knowing what precisely it is in its species. Yet from this you will not wring a Fifth essence out of him — otherwise you will also be enrolling the earth itself in the catalogue of the Fifth essence, since he asserts that the ultimate specific essence of the earth too is inscrutable, and therefore strongly dissuades Christians from the vain attempt to search it out.

"For you will end up in utter nothingness," he himself says, "if you try, by reasoning, to strip away one by one the qualities that the earth possesses." And later: "For in this way the mind, as if seized with vertigo, will be thrown into confusion, since your reasoning proceeds to no fixed end at all." And later: "These same things we may say also about the nature of the heaven: for

whatever intellect there be" — he says at the end of Homily 1 — "it is not adequate to expound and explain, according to the dignity of the subject, even the tiniest of the things that are in the world."

PRO CAELO LIQVIDO — Auctoritas Sancti Ambrosii

For the Liquid Heaven: the Authority of Saint Ambrose

Saint Ambrose [Ambrose] — as in most other parts of his *Commentary on the Six Days*, so also here, on the nature of the heaven and the Firmament — is not unlike Great Basil: he acknowledges neither a Fifth essence nor a rigid consistency of the heaven. For in the *Hexaemeron*, Book 1, chapter 6: "From the elements," he says, "are generated all these things that belong to the world. Now the elements are four — air, fire, water, and earth — which in all things are mixed with one another. Indeed, even in earth you will find fire, which is frequently struck out from stones and iron;

[Margin: The heaven fiery.]

and in the heaven — though the vault is fiery and glittering with shining stars — water can be understood to be present: water which is either above the heaven, or which is frequently sent down from that upper place to the earth in abundant rain."

[Margin: Water above the heaven.]

And later: "Concerning the quality and substance of the heaven, then, it is enough to bring forward what we find in the writings of Isaiah, who expressed the quality of the heavenly nature in ordinary and familiar words when he said that *He made the heaven firm like smoke* — wishing to declare its nature to be subtle, and not solid."

[Margin: Isaiah 51.] [Margin: The substance of the heaven subtle, not solid.]

And in Book 2 of the *Hexaemeron*, chapter 3: "But we," he says, "follow the sequence and order of the Scriptures — not philosophy (the Platonic kind, as some falsely father upon the Fathers) — and we weigh the work by contemplation of its Author; we ask what has been said, and who said it, and to whom he said it. *Let there be a Firmament in the midst of the water*, he says, *and let it divide between the waters*. I hear that the Firmament is made by a command, by which the water was to be divided, and the upper separated from the lower. What could be more manifest than this? He who commanded the water to be divided by a firmament set in the middle also provided how it might remain divided and distinct.

The word of God is the power of nature and the substance of its endurance — for as long as He who established it wishes it to remain; as it is written: *He*

established them for ever and ever; He set an ordinance, and it shall not pass away. And that you may know he said this about those very waters which you deny can be in the upper regions of the heaven, hear what precedes: *Praise Him, you heavens of heavens, and let the waters that are above the heavens praise the name of the Lord.* Did He not, as though to you who object, say: *For He spoke, and they were made; He commanded, and they were created. He established them for ever and ever; He set an ordinance, and it shall not pass away?* Does He not seem to you a competent authority, to give a law to His own work?"

And later: "When you hear these things, why do you wonder if, above the Firmament of the heaven, the water could — by the working of so great a Majesty — be held suspended?"

Next he proves that this is not impossible for God: from the waters of the Red Sea and of the Jordan, divided and held suspended with air set between them; likewise from the mutual ascent and descent of the waters; and from the stationing of the earth itself.

"For by whatever principle," says the Holy Father, "they say that the earth hangs suspended in the middle and remains immovable — although it is certainly heavier than water — by that same principle they can say that the water which is above the heavens is not flung down by the revolution of that celestial sphere.

[Margin: An argument from the earth balanced in the air.]

For just as the earth is suspended in the void, or, with its weight balanced, persists immovable on every side, so too the water is held in balance by weights either heavier than, or equal to, those of the earth."

And later: "Then, since they themselves say that the sphere of the heaven, gleaming with blazing stars, revolves — did not divine providence necessarily foresee that water should abound within the sphere of the heaven, and above the sphere, to temper those fires of the burning axis? For this reason: because fire overflows and boils, water too has overflowed upon the lands, lest the heat of the rising Sun and of the glittering stars should burn them up, etc."

Then, toward the end of this chapter, he says that the ether is fiery, and that the hot Sun within it — inasmuch as, against the ancients, he proves most fully that it is burning — draws coolness and nourishment from the supercelestial waters. But in the fourth chapter he says that the Firmament is so named from firmness — yet not with such a firmness as belongs to a rigid body, but with such as belongs to the lightning-spirit shut up within the bosom of the clouds. For

Scripture says [that God makes the thunder firm], and so the Firmament too is "made firm" and so called; either because it has been made firm by divine power, as Scripture [

[Margin: The firmness of the heaven is not rigid but robust — by the will of God.]

he teaches us: "Praise him in the firmament of his power."]

And so, in the mind of St. Ambrose, the firmament would be firm not by the firmness of the work, but by the firmness of God who works it. In itself, then, it is not solid, not firm, but soft, flexible, and flowing — least of all hard or resistant, but yielding and permeable — and yet it would hold the stars and the waters [in place].

Hence, from what has been adduced in support of St. Ambrose's view, we may draw the following argument for the fluidity of the Heaven and the Firmament.

[Margin: From the teaching of St. Ambrose, an argument for the fluidity of the heaven.]

If St. Ambrose had recognized an adamant hardness of the heaven — whether arising from a fifth essence [quintessence] or from some other source — he would not have denied that the substance of the heaven is solid; he would not have asserted that the firmness of the Firmament belongs to God's power alone; he would not have granted that the waters can ascend above it and descend below it, that these same waters are taken up as fuel by the Sun and the stars and by the whole kindled aether and substantially transformed, and that the balance of the whole universe is preserved by them; and he would not have defended himself in such laborious ways against the troublesome objections of the unbelievers of old. Instead, he would simply have set up the hardness of the Heaven like the shield of Ajax, and, secure and unharmed behind it, would have guarded himself without any difficulty against every blow of his adversaries. But he did not do this. Rather — as is fully and plainly clear from the scriptural passages cited and from many others omitted for brevity's sake — he did indeed admit [their objections], yet he kept himself unharmed by means of sacred Scripture against the darts the unbelievers hurled.

Therefore St. Ambrose in no way acknowledged a hardness of the Heaven; he judged it to be liquid, and from this he celebrated the mighty Majesty of God all the more. "By the word of the Lord the heavens were established, and all their power by the breath of his mouth." But in a matter so clear there is no need to linger long. Let the holy Fathers be read, and the truth will appear.

The following Fathers seem to belong to this same company of Basil and Ambrose.

PRO LIQUIDA CAELI SVBstantia auctoritates aliorum sanctorum Patrum.

[In support of the LIQUID SUBSTANCE OF THE HEAVEN: the authorities of other holy Fathers.]

[Margin: St. Epiphanius.]

St. Epiphanius [Epiphanius of Salamis], in his Letter to John, Bishop of Jerusalem — translated by St. Jerome — against the opinions of Origen. [Origen says that the waters which are above the Firmament are not waters, but certain powers of an angelic authority; and again, that the waters which are above the earth — that is, below the Firmament — are contrary powers, that is, demons. *And how then do we read that in the flood the floodgates of Heaven were opened and the waters of the deluge poured over [the world]? How were the fountains of the abyss opened, and the whole World covered with waters?]

According to Epiphanius's view, then, the Heaven is not hard; otherwise it would not have given passage to the waters of the flood. That he is speaking of waters set above the Firmament is clear from this: otherwise he would have achieved nothing against Origen. And lest anyone imagine that certain openings were made through a hard Heaven, this stands against it — that the water of the flood fell at the same moment from the sky on every side.

[Margin: St. Cyril.]

St. Cyril of Jerusalem, in his ninth Catechesis. [What indeed do they find to fault in this greatest work of God? At the sight of the vaults of the heavens they ought to be struck with wonder, and to adore him who set the heaven up like an arch — who, out of the flowing nature of the waters, constituted the firm and stable nature of the heaven. For God said, Let there be a Firmament in the midst of the water. *For God spoke once, and it stood fast; the water does not fall, nor does the Heaven, and the fiery bodies within it — the Sun and the Moon and the stars.

And by what means do the fiery bodies run their course in water? But if anyone, on account of the contrary natures of fire and water, is in doubt, let him remember the fire that in the time of Moses poured out flames amid the hail in Egypt, and let him behold God's workmanship, most wise in every part. *For since there would be need of waters for the earth that was thereafter to be cultivated,

he prepared on high a watery Heaven, so that when the region of the earth had need of the moistening of showers,

[Margin: The supracestrial waters, for the use of the rains.]

the heaven should be ready and prompt for that purpose.

From all this it is evident that this holy Father held the Firmament to be stable indeed in itself, yet passable — with the stars moving within it and the celestial waters descending to the earth for human uses. For it is certain that he is speaking of the supracestrial [waters], as will be clear to the reader, and so on.

[Margin: Eucherius.]

EUCHERIUS [Eucherius of Lyon], Commentary on Genesis, book 1, chapter 3, as found in Martinengus. [Here one may ask: how can the element of water be above the heavens? For water yields to earth, air yields to water, and fire yields to air. Hence it seems impossible that the second element, which is water, should be above the fourth, which is fire. In what manner and of what kind those waters are which Scripture says are above the heavens, we have no doubt at all that they are there: they seem to be above the heavens not by the location of their place, but by the dignity of their nature. *For just as those clouds which are everywhere are borne above the air, which is the third element, so I judge it can happen that thin and subtle waters are borne above the heaven. For it is from this weight of the elements that many of the philosophers, mocking the resurrection of the flesh, say it cannot happen that a man, who was certainly made from earth, should be in heaven. But the truth refutes them — the truth that makes many earthly animals fly about in the air, and water be above the air, and fire (which is surely the fourth element) be in the earth. Therefore the power of God, which is proved to do these things, brings it about that both man and water may be above the heaven.] If the Heaven were adamantine, this Father would be philosophizing to no purpose in this way. He therefore supposed it soft and permeable — indeed, he treated it the same as fire.

[Margin: Junilius.]

JUNILIUS [Junilius Africanus], on the Hexaemeron. [He who below the Heaven binds the waters — for a time, when he wills, so that they may not all fall together, waters sustained by no ledge of firmer substance but held only by the vapors of the clouds — was himself able to suspend the waters above the round sphere of the heaven, so that they might never slip down, not by a vaporous thinness but by an icy solidity. *But even if he willed to make liquid waters stand

still there, is this any greater a miracle than that he hangs the very mass of the earth

(as Scripture says) upon nothing?]

These arguments have no place if the Firmament is said to be hard.

[Margin: The Ordinary Gloss.]

The Ordinary Gloss on Bede has similar things, as found in Martinengus, part one, page 643.

[Margin: St. Bede.]

St. BEDE, in his Questions on Genesis. He has almost the same, word for word, as we recited above from Eucherius, and he says that the waters set above the Firmament do not fall for this reason: that they are held frozen together by an icy solidity. He acknowledges, therefore, that they would fall if they were melted — from which it must follow that he acknowledges the Firmament to be not hard.

[Margin: Haymo.]

HAYMO [Haymo of Auxerre] on Psalm 148. [And all the waters that are above the heavens, and so on. The waters which in very truth are above the Heavens (from which the rains come down to us through the floodgates of Heaven) — let them praise the name of the Lord: that is, let them be for us matter for praising God, considering, among other things, that since those waters, which are of a dense body, are held up by the most subtle body of the heaven, we may greatly marvel and ought not to cease from the praise of God.]

If this Father had acknowledged the philosophers' hardness of the heaven, he would not marvel how dense waters are held up above the most subtle heavens; nor would he draw from this a singular occasion for praising God; nor would he truly derive from Scripture that those waters are brought down to the earth as rain through the floodgates of heaven. Therefore he acknowledged the Heaven to be liquid, not hard.

[Margin: Richardus Pampolitanus.]

RICHARD Pampolitanus [Richard Rolle of Hampole?] on Psalm 148. [And let all the waters that are above the heavens — [set there] to complete the harmony of the elements — praise the name of the Lord. It is a great praise that the thinness of the heavens both stands firm and holds up waters that are heavy: waters

which do not flow down except when sent, by rains.] So either I am blind, or this great Theologian established the heaven to be not hard, but fluid.

PRO CAELO LIQVIDO Auctoritas Magistri Sententiarum.

[In support of the LIQUID HEAVEN: the authority of the Master of the Sentences.]

[Margin: Master of the Sentences.]

The Master of the Sentences [Peter Lombard], in Book 2 of the Sentences, distinction 14. [Let there be a firmament in the midst of the waters, and let it divide the waters from the waters. And he divided the waters that were under the firmament from those that were above the firmament. *It should be known that the creation described here is that of the heaven — as Bede says on Genesis — in which the stars are fixed, beneath which the waters are placed, in the air and in the earth, and above which are placed other [waters], of which it is said: You who cover its upper parts with waters. In the middle, then, is the firmament, that is, the starry heaven, which may be believed to have been made from waters. For crystalline stone, which has great firmness and transparency, was made from waters. But if it troubles anyone how waters — fluid by nature and prone to slip to the lowest place — can hold together above the heaven, let him remember that it is written of God that he binds the waters in his clouds. *For he who below the heaven binds the waters, held for a time by the vapors of the clouds, can also suspend the waters above the sphere of the heaven, so that they do not slip away — not by a vaporous thinness, but by an icy solidity. And afterward: *Behold, it has been shown by these words that the heaven was made — namely, that heaven in which the stars are fixed, that is, the one that lies beyond the air — and from what matter, namely from waters. And afterward:

[Margin: He cites St. Augustine in his own support and explains him.]

But some say that the heaven which lies beyond the region of the air is of a fiery nature, asserting that above the air there is pure fire, which is called heaven; and they conjecture that from this fire the stars and luminaries were made. Augustine seems to agree with them. But whether, by the name "Firmament," one should understand the heaven that lies beyond the air, or the air itself, Augustine asks and does not resolve. Yet he seems rather to approve that the heaven meant here is the one that lies beyond the region of the air. As for the waters that are above that heaven, he says they are drawn up in the manner of vapor and suspended in the finest droplets — just as this misty air draws up waters in the manner of vapor by the exhalation of the earth, suspends them in fine particles, and

afterward, when they have gathered more thickly, pours them back down as rain. If, then,

water can, as we see, reach such fine particles that it is borne up in the manner of vapor above the air, which is naturally lighter than water — why should we not believe that above that lighter heaven, too, [waters] issue forth in still finer droplets and lighter vapors? But in whatever way they are there, we do not doubt that they are there.] And afterward: [It is also asked whether the heaven stands still or moves. If it moves, they say, how is it a Firmament? If it stands still, how do the fixed stars go around within it? But it can be called a firmament not on account of its standing still, but on account of its firmness — or as the boundary of the waters that cannot be crossed. If, however, it does stand still, nothing prevents the stars from moving and going around.]

[Margin: Even with the Firmament standing still, the motion of the stars is defended.]

These are the words of the Master of the Sentences, which come out more briefly indeed, but almost more clearly, on Psalm 148. [And let the waters, he says, that are above the heavens — divided from those that are below the firmament — praise the name of the Lord; and so both the heavens and the waters do. *For it is exceeding praise that the thinness of the heavens both stands firm and holds up the waters that are heavier: waters which do not flow down unless bidden, by rains, which (as it is said) are sent through the opened floodgates of heaven by the rain.]

From this you have St. Augustine — placed at the head of this array — both explained and confirmed, and my arguments, drawn from him, thoroughly established. To give them still greater firmness, I reason as follows.

[Margin: From the cited teaching of the Master of the Sentences, in support of the fluid heaven: first argument.]

First. If the heaven, according to the Master of the Sentences, were solid — that is, hardened with an unbending, inflexible rigidity — he would ask in vain by what means waters heavier than it hold together above it; and he would idly say that it detains them there, either congealed by cold or attenuated by heat, so that they may not slip down. For even when melted into flowing moisture they could not descend, being held back by that hardness of the heaven, harder than bronze. Therefore it is impossible that he acknowledged a hard heaven; otherwise that philosophy of his would be utterly empty and ridiculous.

[Margin: Second argument.]

Second. If the Firmament, he says, stands still, nothing prevents the stars from moving and going around. But the hardness of the Firmament prevents the stars from moving and going around, if the firma-

ment stands still. Therefore the Master of the Sentences in no way acknowledged a hardness of the Firmament.

[Margin: Argument 3.]

Third. It is exceeding praise, he says, that the thinness of the heavens is firm and holds up the heavier waters. But if that firmness of the heavens consisted in an adamantine hardness, it would be no praise that it holds up the waters, for this would follow naturally: it is no wonder that a vault set above holds up masses of water, when it also bears the heavier masses of the lands. Therefore that firmness does not consist in hardness, and so on.

[Margin: Argument 4.]

Fourth. Those waters descend all the way down to us as rain. And so it is clear, on the mind of the Master of the Sentences, that the Heaven is not hard, but soft and permeable.

[Margin: The Master of the Scholastic History.]

The Master of the Scholastic History [Peter Comestor] favors the Master of the Sentences, chapter 4. [Why in truth they are there (the waters above the firmament), God knows, he says — unless it be, as some suppose, that dew descends from there in summer.] Here too, then, [we have] the liquidity of the Heaven.

PRO CAELO LIQVIDO depugnat Oleaster & alii.

[In support of the LIQUID HEAVEN, Oleaster and others contend.]

[Margin: Jerome of Oleaster.]

Jerome of Oleaster [Hieronymus ab Oleastro], on Genesis, upon those words, There shall be a firmament, or an expanse, in the midst of the waters, and there shall be a division between the waters and the waters. [Here some dispute, he says, whether there truly are waters above the Firmament, or the expanse; and although Scripture everywhere cries out that they are there, many Theologians prefer to follow blind Philosophers rather than the authority of Scripture. For in

the Psalm we read: Let the waters that are above the heavens praise the name of the Lord. Below, too, in chapter 7, it is found — where the flood is spoken of — that on that day the fountains of the great deep were broken up and the windows of Heaven were opened. And in Daniel 3: Bless the Lord, you waters that are above the Heavens. I would therefore rather err with Scripture (if it could err) than speak the truth with the Philosophers. But why there are waters there, above the expanse, I do not wish to determine.

Yet I think they are elemental, and of the same nature as those below. For beforehand, as is clear from the text, they were continuous with the lower [waters]; and once the firmament, or division, was made, they do not seem to have changed their nature. Moreover, in the time of the flood they came down, as has been cited, just like the other waters.]

From this it is evident that this Theologian did not acknowledge that adamant hardness of the heaven, nor the intricate machinery of the Planetary orbs; otherwise he would not have granted them a descent in the flood, and so on.

[Margin: The same Lusitanian.]

In his Commentary on the 7th chapter of Genesis, expounding the words The floodgates of Heaven were broken up: [I cannot understand it otherwise, he says, than as the letter [of the text] has it. For it supposes that there are true and elemental waters above the Firmament, as both Basil and Chrysostom hold: it is no wonder if the Lord broke open windows in the Firmament, so that those waters might descend; nor do I think there is room here for metaphors.

[Margin: The supracelestial waters descended in the time of the flood.]

St. Thomas [Aquinas], however, says it must be wholly admitted that there will be waters there, though it remains in doubt of what kind they are — whether, that is, elemental, or rather dense after the manner of crystal. Those, therefore, are to be censured who would rather subject sacred Scripture to the Rules of Philosophy than — as is more fitting — make Philosophy serve it as its handmaid.]

[Margin: Philosophy ought to serve Scripture.]

If the waters were able to descend through a hard firmament, it is credible that the Lusitanian [Oleaster] believed the heaven to be hard and impenetrable. But the waters descended everywhere at the same time; therefore the floodgates of Heaven were opened on every side.

[Margin: Cassiodorus.]

CASSIODORUS on Psalm 148. [There is no doubt that the waters which are above the Heavens are those which rain down: Genesis being witness — The floodgates of Heaven were opened, and rain fell upon the earth for forty days, and so on.]

If in the time of the Flood the waters were able to descend through an adamantine Heaven, then they will surely be hard, according to Cassiodorus. But that he understands, by "Heaven," the firmament in which the stars are, and that he means the waters placed above it to rain down — this is clear to the reader.

[Margin: Josephus]

Josephus [Iosephus], in Book 1 of the *Antiquities* [*Antiquitates*], seems to be of the same mind. For in chapter 1 he says this:

[After this, on the second day, God set the heaven over the whole of creation, separated from the rest and placed on high by itself, packed round with ice, and duly tempered with a moist and rainy nature so that it might serve the earth by watering it, etc.]

In favor of a fluid heaven — the authority of the Abbot of Deutz [Pro caelo fluido, auctoritas Abbatis Tuitiensis]

[Margin: Rupert of Deutz]

Rupert, Abbot of Deutz [Rupertus Abbas Tuitiensis], a man radiant with much learning, around the year of the Lord 1124, in Book 1 on Genesis, chapter 22, professes this opinion concerning the fluidity of the heaven most openly, in the words that follow — although he is wrongly cited by some to the contrary effect.

First, then, for the sake of the simpler folk, we must speak of what the Firmament is, or from what it arises. *The firmament is not something solid or hard, as is commonly supposed, but is air that has been stretched out and so far rarefied that, although it can be seen, it may nonetheless more correctly be called spirit than body — as Ecclesiastes testifies when he speaks of the luminaries [Margin: Ecclesiastes 1], *which are visibly borne along in it: "the spirit goes on, circling in its circuit, and returns upon its own circles." Since, then, this is not solid, yet neither so corporeal as this lower part of the air, Scripture has nonetheless called it firmament for another reason — namely, because it divides the waters from the waters.]

Next, in chapter 23, he refutes those who wished the "waters placed above the firmament" to be understood as Angels, on the basis of Psalm 148 and the hymn of the three young men. [Assuredly, he says himself, by the term "waters"

Scripture compels us to understand something other than Angels.] And afterwards: [Furthermore, other Doctors hold that by the "waters which are above the firmament" nothing else is to be understood than simply waters. *Their opinion is without doubt more justly and more safely to be preferred, namely, that the sense should not depart from the letter of the Sacred history. Yet we do not so far agree that the waters are above the firmament as to concede also that they are frozen — which some have supposed more by conjecture than by reason.]

And in chapter 24: [But if it be asked of us, in what form, then, are those waters that are above the firmament, if they are not frozen? Let us ask them, in what form they were before the firmament was made?]

[Margin: The waters above the firmament are the same as those that were below.]

And afterwards: [Let us hold this one thing as certain: that the chamber of this world is set in the midst of the waters, since the firmament — which is, as it were, the roof of that same chamber, surrounding it on every side — was, by the authority of Scripture, made in the midst of the waters. For indeed, since God said, "Let there be a firmament in the midst of the waters" — to what end? "That it may divide," He says, "the waters from the waters." And lest this should have too little firmness, once stated, Scripture repeated the very same thing again, saying: "And God made the firmament, and divided the waters that were under the firmament from those that were above the firmament." And likewise, because "in the mouth of two or three witnesses every word shall stand," He added, "and it was so."]

And chapter 25: [And it is indeed a marvelous work of the magnificent God, that the underlying firmament sustains the mass of the waters *— the firmament being subtle in nature. [Margin: The firmament is subtle in nature.] Yet this very wonder is made more tolerable by a present-day example, lest it be incredible to anyone. *For what else sustains the very heavy earth, of which we must speak hereafter, except that same air poured around it on every side — coarser, indeed, and partly flowing around it?]

From these things it is clearer than the sun itself that this author does not understand by the "supercelestial waters" clouds flying in our air, but [waters] resting above the stars themselves — just as Martín del Río [Martinus del Rio] rightly cites him, whereas others wrongly [cite him] for waters of clouds flying in the air. [Margin: Some wrongly cite this Author for clouds of the air.] *For he himself extends the firmament from here up above the very stars, and does not

distinguish it from the air itself except by subtlety alone — after the manner of the learned of this age — and, as he himself besides what has been said sufficiently indicates in the same book, chapter 28: *There are, he says, the higher heavens — namely in the firmament — through which the Sun and Moon are borne [Margin: The Sun and Moon are in the firmament, etc., but a liquid one.], and besides these the five stars which they call planets, that is, the wandering stars. And afterwards: Accordingly there is (as has already been said) a scrupulous dispute among the learned, whether the luminaries themselves, together with the heavens or circles through which they are borne, are to perish. In the same way, when he disputes about the position of the stars and planets in the firmament of the heaven, chapter 43,

he says that the greatest matter of divine praise lies in this: that, since the individual planets occupy and keep their own circles in the firmament of the heaven by the ordinance of God, this is most to be marveled at — that they never stray from the path prescribed for them. But it is better to hear him himself. [*For it is no small matter of divine praise, he says: the firmament — the course of these [stars], which they never exceed, running without cease and bending back into their own circles.] Whence it is evident that Rupert himself supposes the firmament to be liquid; otherwise, if we should hold it hard, it is impossible for the Planets to deflect from their appointed course. Nor, moreover, if they did not stray, would this be a great matter either of divine praise or of human wonder, etc.

From this it is given to understand in what sense the ancients used the names of the circles in this matter — namely, not for discrete solid orbs, but taking them from the imaginary traces of the paths described by the planets. Just as today the sea-tracks of ships are represented by Geographers on maps in nautical practice, etc. But as for the fact that certain people bring in I-know-not-what solid circles, they deviate by the whole heaven from the true teaching of the Mathematicians, who no more acknowledge solid circles than the Physicists acknowledge a "Blictri" [a stock meaningless utterance]. This will be clear from Ptolemy [Ptolemaeus] later on.

In favor of a liquid heaven — the authority of the Damascene [Pro caelo liquido, auctoritas Damasceni]

[Margin: Saint John of Damascus]

Saint John of Damascus [S. Ioannes Damascenus], in Book 2, chapter 6 of *On the Orthodox Faith* [*De fide orthodoxa*], acknowledges the heaven to be liquid, both

from the [teaching] of St. Basil and from Sacred Scripture and the opinion of others. [Its nature, moreover, he says, St. Basil hands down to be thin and subtle, like smoke, being taught this by divine Scripture.] Behold, St. John of Damascus says that St. Basil learned from divine Scripture that the heaven is liquid; the moderns, in order to escape [the charge of] envy, say that St. Basil got this from Plato. Whom should we rather believe — the Damascene or the Neoterics [the moderns]? But let us hear the same holy Father, in the same chapter:

[The earth and the water, they say — being the heavier and lower bodies — hang in the middle [in meditullio], so that they are set opposite one another, downward of course: earth and water (moreover the water surpasses the earth in lightness, and for that reason is also more easily moved than it); but upward, on every side into a sphere, [they place] the air, like a kind of covering, and everywhere around the air the aether; and finally, beyond all these, the heaven spread out into a sphere. *They teach, moreover, that the heaven revolves with a circular motion, and compresses and constrains the things that are within it, and thus keeps them firm and safe from falling.] And afterwards: [All these things were made and established by the divine command, *and they hold the divine will and counsel as their most firm foundation.] And afterwards: [And in the same way he understands, by "the waters which are above the heavens," either the air, or the seven orbs of the firmament, or finally the firmament itself.]

[Margin: How are the stars held fixed in the aether?]

Hugh Carensis [Hugo Carensis; perhaps Hugh of Saint-Cher] [?] agrees with these things in his *Postils* [*Postillae*], published by Martinengo, part 1, page 561.

[Margin: Hugh Carensis]

[And it is called firmament, both because it is firm, and because it is the impassable boundary of the waters that are above it. And below: The aether, according to St. Isidore [S. Isidorus], Book 13 of the *Origins* [*Origines*], chapter 5, and in the book of *Differences* [*Differentiae*], number 82, is fiery air, in which are the stars.]

In favor of the liquid nature of the heaven — the authority of Saint Chrysostom [Pro liquida caeli natura, auctoritas sancti Chrysostomi]

[Margin: St. Chrysostom]

Saint John Chrysostom [Sanctus Ioannes Chrysostomus], in Homily 12 to the people of Antioch, in order to show how the Creator is glorified through heaven and earth and sea:

[Today, he says, having philosophized a little while again upon this matter, we shall pass to another discourse: for He did not merely make the world, but also brought it about that, once made, it should be at work; *neither leaving the whole immovable, nor bidding the whole to move; but the heaven indeed remained unmoved, as the Prophet says: "Who established the heaven like a vault [testudo], and stretched it out like a tent over the earth." *But the Sun, together with the rest of the stars, is daily carried round. [Margin: The heaven unmoved. Psalm 103.] And afterwards: And the heat of the solar splendor is indeed one, but it ripens all things differently, etc.]

Who would not be astounded at this?

The same [Chrysostom], in Homily 14, upon those words of the Apostle to the Hebrews: [We have such a High Priest, who has taken his seat at the right hand of the throne of majesty in the heavens, a Minister of the holy things, and *of the true Tabernacle, which God pitched [fixit] and not man.] "Which God pitched," he says, "and not man." Where are those who say the heaven is moved? Where are those who declare it to be spherical? For both are here done away with.]

[Margin: The heaven unmoved, from the Apostle Paul.]

The same, in Homily 6, upon those words of Genesis: "And God set them in the firmament of the heaven."

[Take note here how great a use of these things too he has declared to us. "He set them," he says, "in the firmament of the heaven." *What is "he set"? Did he perhaps mean, as someone might say, that he "fixed" them? By no means. For we see that they [the stars] pass over a great space in a single moment of time, and never stand still in one place, but accomplish the course that the Lord appointed for them. *What, then, is "he set"? It is "he commanded" — that they should be in the heaven. For this is permitted to be seen from the course of Scripture, since elsewhere it says: *"God set Adam in Paradise" — not that he fixed him in Paradise, but that he commanded him to be in Paradise. [Margin: God fixed the stars in the firmament no otherwise than [He fixed] Adam in Paradise.] Similarly, someone might say of the stars that he commanded them to be in the firmament of the heaven, and to send forth their own light upon the earth.] And a little after, he calls all the stars "elements," and attributes to the arrangement and order of the singular divine will the fact that each keeps within its own bounds and does not wander.

The same, in Homily 4: [But what at last shall we say this firmament to be? Condensed water, or compacted air, or some other essence? Scarcely would any

prudent man rashly assert this. For it behooves us to receive with great modesty and gratitude the things that are told to us, and not to advance beyond our own nature and scrutinize things that are above us; *but to know and hold this alone among ourselves: that the firmament was produced by the command of the Lord, [Margin: He implies that one must pronounce from Scripture alone.] making a separation of the waters, so that it might avail to hold some beneath itself and to bear others upon its back. And God, he says, called the firmament "heaven."] And afterwards: [And God called the firmament "heaven" — this that is seen. *And how do some say that many

heavens were made? They did not learn this from divine Scripture, but are driven to say such things from their own opinions. But the blessed Moses teaches nothing more than these things; for as he said, "In the beginning God made heaven and earth," and then taught the cause why the earth was invisible — namely, because it was covered by darkness and by the waters of the abyss; after the formation of light, using a certain order and sequence, he says, "And God said, Let there be a Firmament." Then, after he had diligently taught the use of the Firmament, and had said that it should distinguish between water and water, this same thing — the Firmament, which made the separation of the waters — he called "heaven." *Who, then, after such great teaching, would endure those who dare, out of their own head and against divine Scripture, to speak of many heavens? Furthermore they say: Behold, the blessed David, offering praise to God, said: "Praise Him, ye heavens of heavens." [Margin: He resolves the Scripture [alleged] against him.] *Be not troubled, beloved, nor think that Sacred Scripture is anywhere contrary to itself; but learn rather the truth, and, holding fast diligently to its teaching, stop your ears to those who say contrary things. And what this is that I wish to say, hear with great attention: that you be not easily moved by those who wish to say violent and alien things. All the divine books of the Old Testament were composed from the beginning in the language of the Hebrews, and in this all agree.] And afterwards.

[*These things I would not narrate to your charity rashly, but that you may know that these books were composed not in this language — our own, I mean — but in Hebrew. Those, therefore, who are skilled in that language say that the word "heaven" is used by the Hebrews in the plural number, which those also confess who know the language of the Syrians. And no one in that language says "heaven" [singular], but "heavens." And therefore, if it is said — as it was said by blessed David — "heavens of heavens," [this is] not because there are many heavens (for blessed Moses did not teach us this), but because it is the custom of the Hebrew language to name a single thing in the plural number: [Margin: He says that the

plurality of the heavens is a Hebraism.] *for if there were many [heavens], the Holy Spirit would not have omitted, through the tongue of the Prophet, to teach us their formation as well. Keep these things diligently, I beseech you, that you may be able to stop the mouths of those who bring forward things contrary to Ecclesiastical teachings. And that you may see the power of those things which are

contained in Scripture; for it is for this reason that you gather frequently here, and we impart a more abundant teaching, that you may be ready to render an account to everyone who asks it of you.] These things that great Light of the Church, Saint Chrysostom, [uttered] with his golden mouth; and they are so clear that they need no further discussion.

For although he was unwilling to decide the specific substance of the heaven itself, nevertheless he evidently removes hardness from it.

First: in that he denies that the stars are fixed in the Firmament, but affirms that they are placed there no otherwise than Adam was placed in Paradise. Now it is certain that Adam walked free in Paradise, and did not go about enclosed within fixed passages, but in free, unfrozen air; it is therefore also certain that the stars move freely in the Firmament, in the soft Aether, not enclosed within hollows and burrows.

Second: in that he takes away from the Heaven — on the basis of the Epistle of Paul to the Hebrews — both the full spherical figure and mobility, but grants [mobility] to the stars.

Third: in that from Sacred Scripture — and not from the Platonic school, but rather against Plato and his followers — he established a single heaven. And since the motions of the heavenly bodies are not one, but most diverse, it is impossible for the stars to be moved while the heaven stands still, [it being] one and not liquid; and this from the doctrine of this Father. Then this too is to be noted: that this holy Father is so far from having acknowledged the heaven to be hard, or mobile, or manifold, or the stars to be mobile together with it or in it, that he rather did not shrink from proclaiming the contrary — that is, to say or hold the firmament to be hard, the stars fixed in it and mobile only together with it — [he did not shrink from proclaiming this] to be an external dogma, alien to the Church and to Scripture. For he says that this is contrary to Ecclesiastical teachings. And these Ecclesiastical teachings the Doctor of the Church — and so great a one — assuredly did not fail to know.

*Hence to say or hold that the firmament is not hard ought in no way to be said or judged rash, etc. For the teaching of the Church is no other now than it was of old, in the time of this holy Doctor.

[Margin: To deny that the firmament is hard is not rash.]

[Margin: St. Justin]

[Saint Justin Martyr [S. Iustinus Martyr], in the *Questions to the Orthodox* [*Quaestiones ad Orthodoxos*], question 57: If [you ask how], regarding the creation of a double heaven for us,

Moses set it forth — how does Scripture teach that they are more than one? — sometimes handing down "the heavens of heavens"; sometimes "the heavens were opened to him"; and "I see the heavens opened"; and "he was caught up into the third heaven." And it did not say "into the third part of the heaven," but absolutely, "up to the third Heaven." Many things similar to these you may find in the Scriptures. How, then, do they not speak things contradictory to themselves, and yet speak truly in both ways?]

Response [Responsio]

[Moses indeed spoke of "heavens," but he handed down no number — neither one, nor two, nor more. *Moreover, divine Scripture is accustomed to name the upper spaces of the regions "heavens": as "the birds of heaven," and "the eagle from heaven," and "the stars of heaven." And from these things that have been said, which are set down, it follows that we should understand the heavens to be, in substance indeed, two, but in [their] spaces, more. And if we take "heavens" in this way, no contradiction will be left in the words. From these things it is evident that this holy Philosopher reckoned the air together with the firmament as one continuous heaven, and consequently made it liquid. The same things are proved from the same question 93; and in question 94 and its response, he says that the firmament, at the end of the world, will be utterly destroyed. [Margin: The firmament will be utterly destroyed, to refute the vanity of the philosophers.] [*So that by its destruction (these are the words of the Martyr) may at last be refuted as vain the dogma of those men which is bruited about concerning the heaven — that it is exempt from generation and corruption — who said that it is unbegotten and eternal and without end.]

Diodorus of Tarsus [Diodorus Tarsensis], in Martinengo, page 1011, from the Catena of Lippomanus [Catena Lippomani]. [Margin: Diodorus] [*Let no one, therefore, when he hears "and he set them in the firmament of the heaven,"

*suppose that the Sun and Moon and stars are fixed in the heaven — thereby introducing a gentile dogma into the Church — nor [suppose] that the heaven is moved. For neither, when it is said "and he set Adam in Paradise," is it to be believed that Adam was fixed there, but [that he was set there] so that he might pass his life there. *Wherefore it must be understood that, just as men [are set] upon the earth, so the luminaries are set in the heaven, accomplishing that lofty journey of theirs.] These things are sufficiently plain regarding the permeability of the firmament, and need no other interpretation.

Book IV, Part II, Cap. XXVI (continued)

[Margin: Eusebius of Emesa]

Eusebius of Emesa [Eusebius Emissenus], in the *Catena* of Martinengo, page 1011, and of Lippomano, page 30:

["The question is asked whether the luminaries and the stars complete their courses at a distance below the heaven, or are fixed in the heaven, or make their journey through the heaven like travelers. If it is said that they run below the heaven, let people hear Homer, in whom the Sun rises from the flowing Ocean to the middle of the sky and then, its course completed, sets. Nor, again, can they be said to be fixed to the heaven, for on that reasoning the one could never be faster than the other — which is nevertheless so evident that it cannot be denied. *Holy and divine Scripture therefore testifies that the heaven is firm and immovable, but that the Sun and Moon move in the heaven and run their course. For in Joshua it is said, 'Let the Sun and Moon stand still' — it does not say, 'Heaven, moving the Moon or the Sun, stand still.' Likewise it was said to Hezekiah, 'Let the Sun go back' — it does not say, 'Let the heaven, moving the Sun, go back.' Blind is the man who does not see from these words that the stars move in a liquid medium."]

[Margin: While the heaven stands still, the stars move.]

[Margin: St. Philastrius]

St. Philastrius [Philastrius], Bishop of Brescia, who was prominent under the Emperor Theodosius in the year of the Lord 380 — whom St. Augustine testifies he himself saw at Milan together with St. Ambrose, in his letter to Quodvultdeus, in the *Catalogue of Heresies*, Heresy 82 — writes thus:

["There is a heresy that supposes the fixed stars to be set within the heaven, and denies that from hidden treasures and places, arranged by God, they come forth

suddenly at evening by divine command, and that at appointed hours they carry out by their own light the course and ministry assigned to them. *This is found to be contrary and foreign to the Catholic Faith; and if anyone holds it, he will be shown to have more fellowship with pagan vanity and with the empty opinion of the philosophers than with Christian knowledge. For Scripture teaches the omnipotence of God in such a way that it declares the stars to run together and course to and fro out of their various treasuries in a moment, and to have been furnished and lent by God partly as an ornament of the heaven and of the night and for the sake of light; and that through the various spaces of the hours they are appointed to return again, as it were, to their own places — so that from the very places they are bidden to leave each day, they may return again to those places, an Angel presiding and driving them on, and can in no way fail to complete their due course, etc."]

Therefore, in the time of this holy Father, throughout the whole Church, both Eastern and Western — as is clear from Augustine, Ambrose, Basil, Chrysostom, and the other holy Fathers and ecclesiastical writers — the opinion regarding the immobility of the heaven was so unanimous and settled that St. Philastrius judged it a doctrine to be held almost as an article of Faith. He therefore condemned as consequently heretical that view which taught the stars to be fixed in the heaven and which would consequently make the heaven move from its place.

The words of the holy Father are understood in this sense — most correctly — by Pererius (book 2 on Genesis, question 9), by Cornelius a Lapide [Cornelius Corneli a Lapide] (on chapter 1 of Genesis), likewise by the marginal Gloss on the text in the *Bibliotheca Patrum* (volume 4, page 41), and by others. Some, by contrast, wrongly wrest the words of that most illustrious holy man, as though nothing could be drawn from them against the solidity and in favor of the liquidity of the heaven. But the holy Father's words are all too clear. This holy Father, moreover, often used the term "heresy" in a broad sense, as is plain to anyone reading him, and there is no doubt he did so here as well.

[Margin: Pererius, Cornelius a Lapide, and others understand Philastrius straightforwardly in this way.]

Lactantius agrees with these statements [DICTIS ASSENTITVR Lactantius]

[Margin: Lactantius]

Lucius Caecilius Lactantius Firmianus [Lactantius] — whom the noble lord Jan Mikołaj Smogulecki [Ioannes Nicolaus à Smogulecz], a Pole of Smogulec, rightly brings forward in his *Sol illustratus* — lived in the times of Jerome and flourished about the year of Christ 320. Arguing against those who affirm the existence of the Antipodes, in book 3 of *De Falsa Sapientia*, chapter 24, he thought and stoutly maintained that the heaven is merely an immovable hemisphere, that it is air in substance, and that the stars roll freely through its spaces. Since he granted that they are animate and admitted that their motions are voluntary, he prevented them from wandering off their fixed path on their journeys — from moving at will across those vast celestial fields — by having the divine laws restrain their liberty, so that they run their courses along fixed tracks, driven not by any inborn impulse but directed by divine reason. But it is better to hear the orator himself for a while, who writes as follows in book 2 of *De Origine Erroris*, chapter 5:

["How, then, do the stars keep their constancy in carrying out their motions?"]
(Understand: if their motions are not voluntary — for he raises against himself the view of his opponents, who held the stars to be animate, and then resolves it.)

["Surely God, the maker of the universe, so arranged them, so contrived them, that by a divine and admirable plan they should run through the spaces of the heaven, to bring about the varied succession of the seasons."] And a little later: ["There is therefore in the stars a plan suited to accomplishing their courses. But this plan is God's — who made and governs all things — not the plan of the stars themselves, which are moved; for if He had willed the Sun to stand still, there would surely be perpetual day, etc."]

[Margin: He moves the stars freely through the spaces of the heaven.]

Now from this, nothing else is proved in favor of this view than that he maintained the heaven to be not solid but liquid, and so that he stands for this view and not for the opposite one; for he always attributed motion to the stars, and says that they run *through the spaces of the heaven*, not *along with the heaven*.

[Margin: Procopius]

Procopius, in his *Commentaries on Genesis*, chapter 1, in Martinengo, part 2, page 1012:

["The question now arises whether those luminaries are carried around fixed to the heaven, or whether — while the heaven remains stable and immovable — they complete their revolutions; and further, whether they set their motions going below this heaven. Some declare that the luminaries wander in the air at a great interval from the heaven, far removed from it. Thus, as appears from what

has been said, they would pour the greater part of their light into the upper region and finally transmit the rest downward to us — and would besides illumine the heavens more than our own region with their brightness. As it seems to me, they move along the surface of the heaven, extending their light to us in every direction. For not in vain does Scripture say: 'He placed them in the firmament.'"]

[Margin: The stars are not fixed in the heaven.]

["Nor is the word 'placed' to be understood, as some would have it, as meaning 'fixed.' This is why Joshua son of Nun also cries, 'Let the Sun stand still' — he did not say 'Let the heaven stand still,' which moves the Sun itself, etc."]

St. Isidore fights for the liquid heaven [PRO CAELO LIQVIDO S. Isidorus depugnat]

[Margin: St. Isidore]

St. Isidore [Isidore of Seville], Bishop of Seville, who flourished in the year of Christ 630, in book 3 of the *Origines* [*Etymologiae*], chapter 30, of the Paris edition of the year 1601:

["The natural philosophers," he says, "said that the heaven is round, revolving, and blazing, etc. In Greek it is called οὐρανός [Greek: ouranos, 'heaven'], ἀπὸ τοῦ ὁρᾶσθαι [Greek: apo tou horasthai, 'from being seen'], that is, from being seen, because the air is transparent and purer for observation."]

[Margin: The heaven is purer air.]

He has the same in book 13, chapter 4. So, according to the mind of this holy Father, the heaven is purer air, and therefore liquid. And lest you think I have foisted this on him from my own understanding, here it is in his own words.

Book 13 of the *Origines*, chapter 5: ["The aether is the place in which the stars are, and it signifies the fire that has been separated off from the whole world into a distinct region. Indeed the aether is the element itself; but the *aethra* is the brightness of the aether, and the word is Greek."]

And in the *Book of Differences*, under the letter C, number 82: "Between *Caelum* and *Aether* the distinction is made thus, that the former is not merely the star-bearing region, but that this air too is called *Caelum*. *The aether, however, is the higher part of the heaven, in which the stars are set. Truly the aether is fiery air, and is the higher; the *aethra* is the light and brightness of the aether."]

[Margin: The aether in which the stars are is fiery air.]

From these passages it is plain that, in this holy Father, *Caelum* and air extend, as it were, equally far, and that the upper part of the heaven is called the *aethra* or fiery air, and the lower part the turbulent air — which I shall shortly prove from book 13 of the *Origines*, chapter 7:

["Air," he says, "is emptiness having more rarity mixed in than the other elements, etc. *But it pertains partly to celestial, partly to earthly matter; for that subtle air, where windy and stormy motions cannot occur, belongs to the celestial part, while this more turbulent air, which takes bodily form through moist exhalations, is assigned to the earth, etc."] He says the same about the heaven in the same book, chapter 4.

[Margin: He disperses air throughout the whole universe.]

Likewise, book 3 of the *Origines*, chapter 4: ["This world," he says, "consists of Heaven, and earth and sea, and all the stars. Which

world is called *Mundus* for this reason, that it is always in motion:"] for no rest is granted to its elements. He repeats the same, and more clearly, in book 13 of the *Origines*, chapter 1. He therefore numbers the Heaven among the elements of the world; and that by the name "Heaven" he understands air and fire, hear what he says in book 13 of the *Origines*, chapter 3: ["The Greeks call the elements στοιχεῖα [Greek: stoicheia, 'elements'], because they agree with one another in a certain concord and fellowship of association. For thus they are said to be joined together among themselves by a certain natural reasoning, now tracing their origin from fire down to earth, now from earth up to fire; so that fire passes off into air, air is condensed into water, water thickens into earth, and again earth is dissolved into water, water is rarefied into air, and air is thinned into fire. Hence it is established that all the elements are present in all; but each of them has taken its name from what it has in greater measure. And they are distributed by divine providence to their proper living creatures: *for the Creator himself has filled the Heaven with Angels, the air with birds, the sea with fish, the earth with men and the other living creatures."] See how he here puts Heaven in the place of fire!

[Margin: Heaven and Fire are the same according to St. Isidore.]

But the Heaven, in the holy Scriptures, he says (in book 13 of the *Origines*, chapter 4), ["is for this reason called the firmament, because it is made firm by the course of the stars and by fixed and settled laws. That its nature is subtle (as he says in the *De Natura Rerum*, chapter 12, along with St. Ambrose) Scripture too shows,

saying that 'He made the heaven firm like smoke.'"] But of what sort these courses of the stars are, he teaches in book 3 of the *Origines*, chapter 62: ["*The stars are either carried along or moved. Those are carried along which are fixed to the Heaven and revolve with the Heaven. But certain ones are moved — such as the planets, that is, the wandering stars, which complete their vagrant courses yet by a fixed rule."] For in book 3 of the *Origines*, chapter 49, and in the *De Natura Rerum*, chapter 17:

[Margin: The Sun moves by itself.]

["*They say that the Sun moves by itself, and is not turned along with the World. For if it remained fixed to the Heaven, all the days and nights would be equal; but since we see that it will set tomorrow in one place, and set yesterday in another, *it appears that it is turned by itself, and not along with the World."]

Eadem — he repeats the same concerning the seven planets in the *De Natura Rerum*, chapter 22, and assigns to them their own portions in the heaven and homocentric circles. So, to conclude with this same holy Father: ["The world," he says in the *De Natura Rerum*, chapter 9, "is the whole totality that consists of Heaven and earth."] And in chapter 11: "The parts of the world are four: Fire, Air, Water, Earth. Their nature is as follows. Fire is thin, sharp, and mobile; Air is mobile, sharp, and thick."] And since in book 13 of the *Origines*, chapter 1, he says, "The world is Heaven, Earth, Sea, and what is in them" — who does not see that St. Isidore embraces both Air and Fire under the name of "Heaven"? And since Air and Fire are mobile and liquid by nature, the Heaven is therefore held by this holy man to be liquid, not hard.

[Margin: Liquid heaven — in which St. Isidore follows St. Ambrose.]

This is further confirmed by the fact that he cites and follows St. Ambrose word for word in the *De Natura Rerum*, chapters 13, 14, 15, 16, and so on. And that, in the mind of St. Ambrose, the Heaven is fluid, is clear from what has been adduced earlier.

Moreover, lest anyone suppose that, because this holy Father assigned spheres or circles to the seven planets, it follows that he acknowledged the heavens to be distinct and hard, the author himself guards against this very fancy when he expressly teaches that the planets are carried in the same heaven according to different regions — the higher and lower ones, that is — and that they move by free and vagrant wanderings, not fixed, contrary to its motion, in that same heaven, etc.

Iunilius celebrates the liquid heaven [CAELVM LIQVIDVM celebrat Iunilius]

[Margin: Iunilius]

Iunilius hands down teachings in harmony with these, in his work on Genesis, on the words "Let there be luminaries in the firmament of Heaven":

["For although," he says, "the night is very often dark and blind for us — the air, which is nearest the earth, being obscured by misty whirlwinds — *yet those upper spaces, which are reckoned by the name of aether and which reach from this turbulent air up to the starry heaven, are always made bright, and shine, on account of the stars that revolve about them."]

[Margin: The aether extends right up to the stars.]

Hence it is plain that the whole space, from the atmosphere —

as it were beginning at the atmosphere, up to the Heaven of the fixed stars — is comprehended under the name of "Firmament," and that it is nothing but liquid aether. This the author himself confirms in what follows, on the words "That they may shine in the firmament of heaven, etc.":

["He indeed always says that the luminaries shine in the Firmament of Heaven, as we have said; and that the places nearest to it are flooded with clear light, but that at opportune times they illumine the earth. From which it is plain that the Sun and Moon are carried in the liquid aether. For on the words 'And God said, Let the waters bring forth the creeping creature of living soul, and the flying thing above the earth, under the firmament of Heaven.'"]

["He says that the elements are joined to the Heaven in this way, because this air is so near to it that it too sometimes takes its name. Just as Scripture calls the flying things 'birds of heaven,' which it is agreed fly in the air."] And afterward: ["Indeed, according to another translation, some are troubled by what is said: 'and the flying things flying according to the firmament,' or 'along the firmament of heaven.'"]

"But it must be understood that the reason it is said that the birds fly 'according to the Firmament of heaven' is *that by this name the aether too is indicated: that is, that upper space of air which reaches, from this turbulent and murky region in which the birds fly, right up to the stars. That this space is wholly tranquil and full of light is not without reason believed. For the seven wandering stars, which are reported to be carried in their vagrant course within this space of aether,

Scripture said were placed in the firmament of heaven. Therefore the birds are rightly said to fly 'according to the firmament of heaven,' because these turbulent spaces of air that sustain the flight of birds are, so to speak, near to the aether."

[Margin: The aether — and the upper air with it — reaches right up to the stars.]

Nor need it be any wonder if the aether is called the firmament of heaven, since air too is called heaven, as we taught above.

[Margin: Aether is the Firmament of heaven.]

From these passages it is evident that the Sun, the Moon, and the rest of the planets are carried in purer air, and so in a liquid heaven, according to Iunilius. And that the stars themselves too are not situated in anything hard, you have proof both here and above from the same Iunilius. Hence it is not rightly cited by others to the contrary.

[Margin: Richard]

Richard of St. Victor [Richard of St Victor], who flourished

about the year of the Lord 1140, in book 2 of the *Exceptiones* [*Liber Exceptionum*], chapter 7, on the words "In the beginning God created the Heaven and the Earth":

["By 'Heaven' he means the three elements — Fire, Air, Water — which had been mingled in one confusion, or confused in one mingling, fluctuating around the fourth, which is earth."] And afterward: ["In the beginning, therefore, were created heaven and earth, that is, the four elements, the simple matter of all things to be made."] And afterward: ["On the fourth day He made the luminaries, which are shown to be fixed in the firmament, except for the seven planets, whose names are these: Moon, Venus, Mercury, Sun, Mars, Jupiter, Saturn."]

[Margin: All things were created from the elements.]

Richard therefore places the seven planets in the firmament as not fixed, but wandering and free; whence, according to him, the Heaven must be not hard but permeable.

But when he says that the firmament, made of the stars fixed above, is revolvable, he is speaking of the upper part of the firmament; and when he denies that it can be known from what matter it was made, he is speaking of the specific matter — namely, that it is unknown whether it was formed of water, air, or fire, though according to him it must have been made of one or several of these.

St. Anselm [Anselm of Canterbury], Archbishop of Canterbury, who died in the year of the Lord 1109, in book 1 of the *De Imagine* [*De Imagine Mundi*], chapter 24:

[Margin: St. Anselm]

["Fire," he says, "which is reckoned the fourth element and is called, as it were, non-generating, *extends from the Moon up to the firmament. It is as much more subtle than air as air is thinner than water, and water rarer than earth. This too is called aether, as it were pure air, and it rejoices in perpetual brightness.

"From this the Angels take on bodies, when they come sent to men. In it the seven stars are carried, each in its own circle, against the world; and because of their vagrant course they are called 'planets,' that is, wandering stars. These are snatched with the immense speed of the firmament from East to West, yet are proved to go by their natural course against the world — just as, if a Fly were carried around on the wheel of a mill, it would nevertheless by its own motion go against the wheel's revolution

Chapter XXVI (continued) — Authorities for a fluid (liquid) heaven

seems to make its way there. And in chapter 25: "But the heaven is of a fine and fiery nature." And afterward: "For the stars are fixed in the firmament and do not fall, since it runs with wondrous speed."

[Margin: Caelum naturae igneae — the heaven is of fiery nature.]

Here, then, you have it: the planetary heaven is liquid, for it is pure fire, and pure fire cannot be hard. Whether he makes the firmament hard on every side is doubtful, and for this reason: he says that the stars fixed in it do not fall because of the incredible speed of its motion — by which he hints that, were the motion to cease, they would fall; and consequently one would have to admit that not even the firmament itself is hard. For when he says it is solidified out of the waters like crystal, this can be attributed to the firmament only by way of denomination — namely, because it is said to be made firm out of the upper waters, congealed. And this explanation is powerfully confirmed by the fact that a little earlier he called the heaven fine and of a fiery nature, which agrees little with the solid density of crystal.

[Margin: Hugo Carensis — Hugh of St Cher.]

Hugh of St Cher [Hugo Carensis], in his *Postils*, as cited in Martinengo, part 2, p. 1014: "Let there be lights — that is, the Sun, Moon, and Stars. (The stars are fixed

in the firmament according to some, or near it according to others; the Sun, Moon, and the other planets are beneath the stars, in the aether.)"

Here at least it is established that the planetary heaven was judged — by those whom he cites without naming — to be not hard but liquid. For the aether, as has been shown, is fiery air; and when the ancients distinguish it from the firmament, they ordinarily take it to be fire, or a purer air of fluid nature, as will be plain enough to anyone who reads and weighs the matter carefully.

[Margin: Theophilactus — Theophylact.]

Theophylact [Theophilactus], Archbishop of Bulgaria, on the Second Epistle to the Corinthians, chapter 12, says that according to Sacred Scripture there are no more than three heavens: the airy heaven, the firmament, and that which was created on the first day together with the earth. And since, on the Epistle to the Hebrews, chapter 8, on the words "of the true Tabernacle, which God fixed and not man," he declares — not only from others' opinion but from his own as well — that the heaven is neither mobile nor circular, it is evident that he could not have held the heaven to be hard; otherwise the stars

[Margin: Caelum immobile — the heaven is immobile.]

could not have moved within it. That he made the heaven immobile from his own conviction, and not merely by way of a bare citation of others' opinion — for this, take the words from the Paris edition, from the Ascensian press, in the year of Christ 1534, published at Rome. The words of Theophylact, translated from Greek into Latin by Brother Christophorus Porsena of Rome, are these: "From this it can be understood — just as Basil too holds — that the heaven is neither mobile nor circular; for when he says 'He fixed it,' he removes both."

Now this translation — since it was the first, made at Rome from the Vatican exemplar, and dedicated to the Pontiff himself — who would doubt to be true and genuine? Hence the corruptions of the more recent editions carry no weight.

Waters nearer to their springs are always the purer. For although it is certain that St Chrysostom teaches the same in his [homilies] on the Epistle to the Hebrews, that St Basil too held the same opinion is nonetheless soundly gathered from Homily 1 on the Hexaemeron, where he writes: "Concerning the shape of the heaven as well, enough are the things that same author (Isaiah) said in recounting the glory of God: 'He who established,' he says, 'the heaven as a vault.'"

[Margin: Isaiah 40:22 — Esa. 40.22.]

Martinengo, in the first part of his *Gloss*, cites Theophylact to this same effect in the very words in which I have adduced him — not from Martinengo, however, but from the autograph codex, as has been indicated.

The same Martinengo, in the same part, p. 609, adduces from Vielmus — for the same immobility of the heaven — **Severian** [Seuerianus] and **Acacius** in the *Catena*, and so forth.

[Margin: Severian; Acacius — Seuerianus. Acacius.]

Euthymius [Euthymius], on Psalm 103, speaks thus: "Isaiah, employing another and elegant rendering, likewise demonstrated the immobility and the shape of the heaven, saying: 'He who set the heaven like a vaulted chamber.' And if you understand 'skin' in place of 'Tabernacle,' we shall say that the shape of the heaven is signified by this expression; for the Tabernacle was in the manner of a vault."

[Margin: Euthymius.]

Procopius of Gaza [Procopius Gazaeus], in his *Commentaries on Genesis*, book one, [adduces] the passage of Isaiah as established: "He who set the heaven as a vault, and stretched it out like a tent over the earth" — he too maintains this view.

[Margin: Procopius.]

Very many, following the prophetic testimony just related, have asserted the form of the heaven to be hemispherical, whereas others affirm its form to be spherical.

But let us hear what the Apostle declares about its state and form, and about the true Tabernacle, which God fixed and not man. Where, then, are those who dare to pronounce the heaven to be swept along in perpetual whirling, and to be spherical? For Paul, by his eloquence, does away with both and most firmly refutes both. Etc.

[Margin: Caelum stans — the heaven stands (is at rest).]

Theodoret [Theodoretus], on Genesis, Question 11: Is there one heaven or two? He answers thus, after much [discussion]: "He who does not believe there is a second heaven strays from the straight path; but he who tries to number more clings to fables, setting aside the teaching of the divine Spirit. The firmament, therefore, expressly teaches that there is only one heaven, and he repeats this very point on Psalm 148. Therefore, according to him, the planets must move freely in it, and so the firmament must be permeable."

[Margin: Theodoretus — Theodoret.]

IN FAVOUR OF A LIQUID HEAVEN — the authority of St Bonaventure

St Bonaventure [D. Bonaventura], on the *Sentences*, book 2, part two, article one, question one, treats and settles this question expressly. I am not reluctant to set down his words — and indeed at length — because some wrongly cite him for the contrary opinion.

[Margin: D. Bonaventura — St Bonaventure.]

Question I. Whether the lights of the heaven are located in one continuous [body].

"Whether all the lights of the heaven are located in one continuous body? That they are seems to follow from the text of Sacred Scripture, which says that all the lights are placed in the firmament: 'Let there be lights,' it says, 'in the firmament of heaven,' etc.

"Likewise this seems [to hold] by reason: whatever bodies are distinguished from one another are distinguished either by form or by surface; but the body of the heaven, from the Moon up to the starry heaven, is uniform, and, again, it is not a body having a bounded surface; therefore it is impossible for it to have plurality or distinction; therefore all the lights are in the same body.

"Likewise, if some bodies are distinct from one another, the motion of one does not follow upon the motion of the other; but the outermost sphere moves everything that is below it from east to west; therefore the whole celestial nature must be one continuous body.

"Likewise, just as the birds were produced for the adornment of the air, so the lights for the adornment of the heaven; but there is one body of air which is adorned by all the birds; therefore, by parity of reasoning, there is one body of the heaven, which is adorned by all the lights.

"First. For the opposite, the argument runs thus. In bodies of the same nature, number arises from the division of a continuum; but the orbs of the planets are said to be seven, both by the natural philosophers and by the mathematicians; therefore they are discontinuous; therefore the lights of the heaven are not in the same continuous body.

"Second. Likewise, it is impossible that two bodies which move with wholly different and disparate motions be continuous throughout their whole extent; but

the orbs of the planets, as the astronomers say, move contrary to the outermost sphere; therefore it is impossible that they be continuous with one another.

"Third. Likewise, [John of] Damascus [Damascenus], in his enumeration of the heavens, distinguishes the heaven of the seven planets from the heaven of the stars; but this would not be so if that body in which the planets and the stars are were continuous; therefore, etc.

"Fourth. Likewise, if all the lights were placed in the firmament, so as to be in one continuous body, then all the stars would be fixed and none wandering; if, then, some are called fixed and others wandering, it seems that they are placed in [distinct] bodies.

CONCLUSION

The lights of the heaven are placed in several orbs, yet in one continuous body, which Scripture calls by the name of the firmament.

Reply to the argument

"For the understanding of what has been said, it must be noted that, according to the common opinion of those who speak on this subject — whether natural philosophers or mathematicians — the lights are located in different orbs. But this distinction, or diversity of orbs, according to those who understand it better, does not arise from a distinction of forms, as air and water are distinguished, nor from a discontinuity of surface, as one stone is distinguished from another; rather, it arises from a diversity of motions.

[Margin: Caelum est unum corpus continuum — the heaven is one continuous body.]

"But a diversity of motions does not destroy continuity in that which is fine and apt for motion, as is plainly seen in water when it is moved in its several parts to different positions, and likewise in air; yet from this it is not made discontinuous. According to this position, then, it must be said that the lights of the heaven are placed in several orbs, yet in one continuous body, which Scripture calls by the name of the firmament; and therefore it says that all the lights are placed in the firmament of heaven. Hence the arguments brought for this side are to be granted.

[Margin: Respondetur ad argumenta contraria — reply to the contrary arguments.]

"First. To the objection that number arises from the division of a continuum, it must be said that this is true of the number by which bodies of the same nature are counted in the genus of beings; but it is not true of the number by which bodies are counted in the genus of movables. For producing this [latter] number, the distinction of motions alone suffices; and so it is in the present case.

"Second. To the objection that the orbs of the planets move with motions contrary to the outermost sphere, and are therefore discontinuous, it must be said that this does not follow; for it holds true only in a solid body. For in a body

[Margin: Caelum est fluidum, sicut Aqua, et Aër — the heaven is fluid, like Water and Air.]

that is fine and rarefied, like water and air, there is a manifest counter-instance. For in such things a distinction can come from the power of the mover while the continuity of the movable is preserved, because it is highly obedient to the mover, and such things do not have a surface bounded as solid bodies do. And this is plainly evident when two opposite winds blow through the air, one above and the other below.

[Margin: Exemplum à ventis contrariis — an example from contrary winds.]

"Third. To the objection drawn from [John of] Damascus, that the heaven of the planets is distinguished from the firmament, it must be said that the distinction of the heavens is regarded more according to a diversity of properties and motions than according to a discontinuity of bodies — though it can be regarded in both ways. Hence Rabanus [Maurus] too, in his distinction of the heavens, comprehends the starry heaven and the planetary heaven under the same heaven.

[Margin: Explicat Damascenum — he explains [John of] Damascus.]

"Fourth. To the objection that, if the planets are in the firmament, then there are no wandering stars, it must be said that this does not follow, because within the same body the contents can be arranged in different ways, so that one is bound inseparably while the other is not at all. And the stars are called fixed, being placed immediately in the eighth sphere, by whose motion they are moved; but the planets are in the lower orbs, which move with another motion; and so they appear to our sight to wander, since they go against the path of the higher orb."

Thus far St Bonaventure, from whom you have:

First, a liquid heaven.

Second, one continuous heaven of the stars and planets.

[Margin: Quid ex D. Bonaventurae doctrina sequatur — what follows from St Bonaventure's teaching.]

Third, that the orbs, spheres, or circles introduced by the mathematicians are to be taken as not real but imaginary.

Fourth, St [John of] Damascus explained, concerning the circles of the seven planets.

In the second question, moreover, he says that the planets move in their imaginary orbs like a nail fixed in a wheel — this according to Aristotle's view, on account of the incorruptibility of the heaven — yet [he holds] that this motion and all the orbs are homocentric with the earth. And although the mathematicians would have those orbs be eccentric, and really distinct in their surfaces, this is nevertheless more truly denied by the natural philosophers on account of Aristotle. Etc.

CONCLUSION

The luminaries of the heaven are placed in several orbs, yet within one continuous body, which Scripture calls by the name of the firmament.

Reply to the Argument

[The following is quoted from St. Bonaventure.]

"For an understanding of the foregoing, note that, according to the common opinion of those who discuss this matter — whether natural philosophers or mathematicians — the luminaries are located in different orbs. But according to those who understand the matter better, this distinction, or diversity of orbs, does not arise from a distinction of forms (as the stars, the air, and water are distinguished), nor from any discontinuity of surface (as one stone is distinguished from another); rather it arises from a diversity of motions.

[Margin: The heaven is one continuous body.]

Now a diversity of motions does not destroy continuity in something that is subtle and apt for motion — as is plainly evident in water, which, when it is moved in its various parts toward various positions, and likewise in air, is nonetheless not thereby made discontinuous. On this account, then, we must say that the luminaries of the heaven are placed in several orbs, yet within one continuous body, which Scripture calls by the name of the firmament; and that is why Scripture says

that all the luminaries are placed in the firmament of the heaven. Hence the arguments brought forward for this position are to be granted.

[Margin: Reply to the contrary arguments.]

First. To the objection that number arises from the division of the continuous, we must say that this is true of the number by which bodies of the same nature are counted within the genus of being, but not of the number by which bodies are counted within the genus of the movable. To produce this latter number, a distinction of motions alone suffices; and so it stands in the case at hand.

Second. *To the objection that the orbs of the planets are moved by motions contrary to that of the outermost sphere, and are therefore discontinuous, we must say that this does not follow. For this holds only in a solid body; but in a body that is*

[Margin: The heaven is fluid, like water and air.]

subtle and rarefied, as water and air are, there is a manifest counter-instance.

For in such bodies a distinction can arise from the power of the mover while the continuity of the movable is preserved — precisely because such a body is most obedient to its mover and does not have a surface so sharply bounded as solid bodies do. This is quite clear when two opposing winds blow through the air, the one above and the other below.

[Margin: An example from contrary winds.]

Third. To the objection drawn from the Damascene, that the heaven of the planets is distinguished from the firmament, we must say that the distinction of the heavens is regarded more in terms of the diversity of their properties and motions than in terms of any discontinuity of bodies — though it can be considered in both ways. Hence Rabanus too, in his distinction of the heavens, includes the starry heaven and the heaven of the planets under one and the same heaven.

[Margin: He explains the Damascene.]

Fourth. To the objection that, if the planets are in the firmament, then there are no wandering stars, we must say that this does not follow. *For in one and the same body things contained may be arranged in different ways, so that one is bound inseparably while another is not so bound at all.* And the fixed stars are said to be fixed immediately in the eighth sphere, by whose motion they are moved; the planets, by contrast, are in the lower orbs, which are moved by another motion.

That is why they appear to our sight as wandering, since they move against the course of the higher orb.]"

Thus far Saint Bonaventure — from whom you have the following.

First, that the heaven is fluid.

Second, that the heaven of the stars and of the planets is one and continuous.

Third, that the orbs, spheres, or circles introduced by the mathematicians are to be taken not as real but as imaginary.

[Margin: What follows from the doctrine of St. Bonaventure.]

Fourth, that the account given by St. John Damascene of the seven circles of the planets is [thus] explained.

But in his second question he says that the planets are moved in their imaginary orbs like a nail fixed in a wheel — and this on the view of Aristotle, on account of the incorruptibility of the heaven — yet that this motion, and all the orbs, are homocentric with the earth.

And although the mathematicians would have those orbs be eccentric and actually distinct in their surfaces, this is nonetheless more truly denied by the natural philosophers, on Aristotle's account, etc.

I judged it worthwhile to report this at length, because this holy Father is wrongly wrenched by others into positions foreign to him. Here belong all those who do not distinguish the heaven of the firmament from the heaven of the planets except by the moving luminous bodies placed in it and by their motions — those who assert that the planetary spheres are not real but only imaginary. Among them is Francis of Meyronnes [Franciscus Mayro], in Book 2 of the *Sentences*, dist. 14, quaest. 3. And there are those who posit only one heaven, or only two, or even three.

[Margin: Francis of Meyronnes, with others, etc.]

Examples of continuous liquids carried by diverse motions we have in the Rhine, which runs through the whole of Lake Acronius [Lake Constance] for many German miles; and likewise in the winds, which very often, at one and the same time, are driven violently from every quarter of the sky, yet at distinct altitudes — as is plainly shown by the clouds they carry along, and as happens frequently in Germany.

[Margin: Origen.]

That ORIGEN [Origenes] held the heaven to be fluid and not hard is attested everywhere by authors, and is sufficiently deduced from his having supposed the Sun and all the stars to be living beings, etc., as is found in him in the first book of *Perì Archōn* [Greek: Περὶ Ἀρχῶν (Peri Archon, "On First Principles")], chap. 7. It is also cited at length in the *Sol Illustratus* of the illustrious and noble Lord Jan Mikołaj Smogulecki [Ioannes Nicolaus à Smogulecz], etc., on pp. 60 and 61. See too his Commentary on John, whose words — not far before the end of his Commentary on the Gospel of John — I am pleased to transcribe, on those words of the Psalm, *By the word of God the heavens were established, and by the spirit of his mouth all their power*:

"[Some (he says) suppose these words to be spoken of the Savior and the Holy Spirit, although they can also bear this sense: that the heavens were established by the reason of God, just as we say that a house was built by reason — which is the art of building houses — and that a ship was framed by that reason which is the art of building ships. So too, saying that the heavens were established by the reason of God: those heavens that attain a more divine body, which for this very reason is also called the Firmament, since it does not have so very much flux, nor that ease of flowing, which the other, lower things have. On account of this

[Margin: The heaven is fluid.]

difference and preeminence, we say also that the heaven was, in an eminent way, established by the divine reason.]"

See how this Father here makes the heaven not hard, but altogether fluid — though less fluid than the things below.

To this class belong many others who held the stars to be animate, etc.

That there were formerly very many such thinkers is clear beyond doubt, both from others and from Cicero's *On the Nature of the Gods* [*De Natura Deorum*]. Among their number very many place Aristotle — indeed, if he is read rightly, he can scarcely be understood otherwise.

[Margin: Origen cited and explained by Fr. Cornelius a Lapide.]

Concerning this same Origen, our Father Cornelius à Lapide [Cornelius a Lapide], in his Commentary on the Apocalypse, chap. 6, p. 129, speaks thus:

"[Origen, in Tract 30 on Matthew, says that the stars 'fell from heaven' — that is, they lost their light when their fuel failed, and whatever earthly element remained in them fell to the earth. For he thinks, following the opinion of Plato in

the *Timaeus*, that the heavens and the stars are composed and fused out of the elements, and therefore need nourishment, like our own fire or a lamp. Hence, as their nourishment gradually fails, at the end of the world the light of the stars too — or whatever is fiery in them — will fail, while whatever is earthly in them will fall back to its own elements and to the earth.

From this it is clear that Origen acknowledged the stars to be of corruptible matter and of a fiery nature, and the heaven to be penetrable.]"

For the Fluid Substance of the Heaven: the Authority of Saint Gregory of Nyssa

[Margin: St. Gregory of Nyssa.]

Saint Gregory of Nyssa [Gregorius Nyssenus], brother of Saint Basil the Great, in his book *On the Hexaemeron*, from the Paris edition of 1615:

"[But let us return to our purpose, and let us see how — once the supreme boundary of sensible nature had been occupied by fire — the Firmament was afterward made, which he says is the boundary between the higher and the lower waters.

[Margin: The heaven is fiery.]

For I hold that the Firmament — whether it be one of the four elements, or something else that embraces them, as the external philosophers have taught — is not a solid and hard body, but that, in comparison with the everlasting and incorporeal and imperceptible-to-touch nature, that outermost region of sensible nature, which fire encircles by its perpetually mobile force, is called the firmament by Scripture.

For who does not know that whatever is solid is condensed by a certain resisting hardness? And that what is dense and hard and resistant does not lack the quality of heaviness? And that what is by nature heavy cannot be carried upward?

But above all sensible things is the Firmament; hence it comes about that nothing crass or corpulent can be conceived in it. Rather, as has been said, in comparison with things that lack body and are grasped by the mind alone, whatever is subject to the senses is called solid and firm — even though the Firmament possesses a nature as subtle as can possibly be conceived.

[Margin: The Firmament possesses a most subtle nature.]

Deservedly, then, that which is encompassed by the circuit of fire — and whatever consists of crass matter is so encompassed — once it has been circumscribed by its own boundaries, on account of the natural crassness of its matter, and in distinction from the higher things, is called the firmament.]"

These things are so clear that they need no fuller explanation. Saint Basil said and wrote almost the same, word for word, as can be sufficiently seen in the texts cited earlier.

For the Fluid Heaven, the Authority of Denis the Carthusian is Adduced, in Which a Summary of What Has Been Said is Contained

[Margin: Denis the Carthusian.]

Denis the Carthusian [Dionysius Carthusianus], on Chapter 1 of Genesis, article 12, on those words *And he set them in the firmament of heaven*, etc., p. 30 of the Cologne edition:

"Here the firmament is taken for the starry heaven, or the eighth sphere — unless perhaps by 'stars' are understood not only the stars called fixed in the firmament, but also the other five planets.

Finally, the stars that are in the eighth sphere, according to Aristotle and his followers, are fixed in it, and do not have their own motion, but are moved by the motion of their orb.

And they are of the nature of that same orb, and each of them is a denser part of it. Hence they are disposed to receive light more brilliantly than the other parts of the orb.

The planets, however, are called wandering stars — that is, not fixed in their own spheres, but having their own motion.

[Margin: The planets are not fixed, but are freely carried by their own motion.]

Nevertheless Plato in the *Timaeus* says that the stars are not fixed in the firmament, but move and lead a dance within it; and in this Ptolemy followed Plato. Hence they say that it is not the heaven, but the stars of the heaven, that are moved and carried around.]" These are his words there.

The same author, in his exposition on the first chapter of Genesis, article 10, on those words *And he divided the waters that were above the firmament*, etc.; *And God called the firmament heaven*, etc.:

"Concerning this text it is asked, first, whether the heavenly bodies are of an elementary nature. And it seems that they are, from the present text, since the Firmament was made in the midst of the waters. Hence it seems to differ from them by division alone; and again, since above it there are waters.

The Doctors on the second book of the *Sentences* discuss this question at length, and commonly follow Aristotle, saying that the heavenly bodies are of a different nature than the elements. Finally there is a special question: whether at least the crystalline or watery Heaven, designated by 'the waters that stand above the firmament,' is truly of the nature and species of water. And it seems that it is, because that passage of Scripture says most openly that above the firmament there are waters, and in the same context uses the word 'water,' so that it seems to speak of water univocally.

This also seems to be plainly urged by other passages of Scripture of the Old Testament — as when it is said in Psalm 103 [Ps 104:2–6]: *Who stretchest out the heaven like a skin, and coverest with waters the higher parts thereof.* And likewise: *Praise him, ye heavens of heavens, and let all the waters that are above the heavens praise the name of the Lord.* And again, in the Cantic of the Three Children: *O all ye waters that are above the heavens, bless the Lord.*"

[The fourth page of this opening is a duplicate scan of the preceding folio 726, repeating the same text from "Hæc ad longum referre..." through "... comparatione sempiternæ & in-". No new content. See QA note.]

and incorporeal, and of a property not perceived by touch — that outermost part of the sensible world, which fire surrounds by the force of its own ever-moving [sphere], is what Scripture calls the "firmament."

For who does not know that whatever is solid is condensed by a certain resisting hardness? And what is dense, hard, and resistant is not free of the heavy quality; whereas what is by nature heavy cannot be borne upward.

But above all sensible things stands the Firmament. Hence nothing thick or corporeal can be conceived in it. Rather, as has been said, in comparison with things that are without body and are grasped by the mind alone, whatever is subject to the senses is called "solid" and "firm" — even though, in its own nature, it is as subtle as anything can possibly be conceived to be.

[Margin: The firmament possesses a most subtle nature. (*Firmamentum naturam maxime subtilem obtinet.*)]

Rightly, therefore, since it is enclosed within the compass of fire — and whatever consists of thick matter is so enclosed — [the firmament], once it has been circumscribed within its own limits, has, on account of the natural thickness of its matter, been called "firmament" to distinguish it from the higher [bodies].]

These things are so clear that they need no fuller explanation. St. Basil said and wrote almost the same, word for word, as can be sufficiently seen in the texts already cited.

In support of the liquid heaven, the authority of Denis the Carthusian is adduced, in which a summary of the [foregoing] statements is contained.
(*PRO CAELO LIQVIDO affertur auctoritas Dionysij Carthusiani, in qua dictorum compendium habetur.*)

[Margin: Denis the Carthusian.]

Denis the Carthusian [Dionysius Carthusianus], on Genesis chapter 1, article 12, on the words "And he placed them in the firmament of heaven," etc., page 30 of the Cologne edition [editionis Coloniensis]:

"Here 'firmament' is taken for the starry heaven, or the eighth sphere [sphaera octava] — unless perhaps by 'stars' we understand not only the stars that are called fixed in the firmament, but also the other five planets.

Finally, the stars that are in the eighth sphere, according to Aristotle and those who follow him, are fixed in it and have no motion of their own, but are moved by the motion of their own sphere. And they are of the nature of that same sphere, and each of them is a denser part of it. Hence they are disposed to receive light more brilliantly than the other parts of the sphere.

The planets, however, are called wandering stars — that is, not fixed in their own spheres, but having their own motion.

[Margin: The planets are not fixed, but are freely driven by their own proper motion. (*Planetæ nō sunt fixi; sed motu proprio liberè aguntur.*)]

Yet Plato in the *Timaeus* says that the stars are not fixed in the firmament, but move and lead a dance within it; and in this Ptolemy followed Plato. Hence they say that it is not the heaven, but the stars of the heaven, that are moved and carried around.] So much there.

The same [author], in his exposition on the first chapter of Genesis, at article ten, on those words: 'And he divided the waters that were above the firmament,' etc.; 'And God called the firmament heaven,' etc.

Concerning this text it is asked, first, whether the heavenly bodies are of elemental nature. And it seems that they are, from the present text, since the Firmament was made in the midst of the waters. Hence it seems to differ from them only by division; and again, because above it there are waters.

The Doctors on the Second [Book] of the Sentences discuss this Question sufficiently, and they commonly follow Aristotle, saying that they are of a different nature than the elements. Finally, there is a special Question: whether at least the crystalline or watery Heaven [Cælum crystallinum seu aqueum], designated by the waters that stand above the firmament, is truly of the nature and species of water. And it seems that it is, because Scripture there says most plainly that above the firmament there are waters, and under the same context it uses the name 'water,' so that it seems to speak of water univocally [de aqua vniuocè loqui].

Other passages of the Old Testament Scripture too seem manifestly to claim this, as when it is said in Psalm 103: 'Who stretchest out the heaven like a skin, and coverest with waters the higher parts thereof.' Likewise: 'Praise him, ye heavens of heavens, and let the waters that are above the heavens praise the name of the Lord.'

And again, in the Canticle of the Three Children [in trium Cantico Puerorum]: 'Bless the Lord, all ye waters that are above the heavens.'

Since, therefore, we ought rather to follow the authority of divine Scripture than the dictate of human reason, it seems we must say without qualification that above the heavens there are truly and properly waters, and that the crystalline heaven is of the nature of water; and further that the Firmament is of elemental nature — namely fiery, as some say, or partly fiery (as regards the stars) and partly watery (as regards its remaining parts).

Finally, the ancient and holy Doctors — Augustine, Basil, Gregory, Ambrose — held this view; and Bede, Strabus [Strabo], Damascene [John of Damascus], the Master of the Sentences [Peter Lombard], the author of the Scholastic History [Peter Comestor], the Gloss, and many others followed them. On the decision of this Question, Bonaventure writes on the Second [Book of the Sentences]: 'In this question, because of the diversity of positions and the weakness of the arguments, scarcely anything certain can be said.' Then, after many words, he inclines to this: that by the waters which are above the heavens is to be understood the ninth sphere, which is called the crystalline heaven — not because of the true nature of water, but because of a likeness in transparency

[diaphaneitas], by which water is not only receptive of light but also in some way retentive of it, as is evident in certain stones that are not visible at night unless they are placed in water.

Then, as if reconciling the Theologians and the Philosophers, he says that St. Augustine and the other Saints held the Firmament to be of the nature of fire — not that it has the substantial form and most specific species of fire, but because it participates in the nature of light by analogy.

And although this is well said, insofar as it seems piously to safeguard the words of the holy Theologians and to accommodate them to men — yet if anyone wishes to be more fully and curiously informed, he will find that, according to the intention and mind of the Fathers just named, the crystalline heaven is truly of the nature of water, and formally cold, especially since they place waters above the Firmament to temper the heat of the Sun and of the other heavenly bodies.

Hence they affirm Jupiter [♃] to be colder than the other planets, although it is moved more swiftly than they, since it is set higher, because of its nearness to those waters.

Hence Thomas writes on the Second [Book of the Sentences]: 'Concerning this question there was among the Philosophers a diversity of position. For all before Aristotle said that the heaven is of the nature of the elements, which Aristotle was the first to disprove, laying down that the heaven is without heaviness and lightness and their other contraries, as is evident in the first [book] of *On the Heavens and the World*. And on account of the efficacy of his arguments, the later philosophers — namely the Peripatetics — agreed with him; hence now all follow his opinion.

Similarly the expositors of Scripture were divided in this matter, according as they were trained in the doctrines of different Philosophers. For Basil, Augustine, and many of the Saints, in matters that concern philosophy and do not pertain to faith, follow the opinions of Plato; and so they hold the heaven to be of elemental nature. Denis, however, almost everywhere in such matters follows Aristotle, as is evident to anyone who carefully examines his books.

In such matters, therefore, the sayings of the Saints are of no greater authority than the philosophers whom they follow, except that they are immune from all suspicion of unbelief.' Thus Thomas. And the sayings of Albert, in the book *On Coeval Things* [de Coæuis], agree with the sayings of Bonaventure.

Finally, Bede says: 'The starry heaven is agreed to be in the midst of the waters, and it can be believed to have been made of the waters. For crystalline stone, which is of great firmness and transparency, is made from water. And, according to the same Bede, the waters are above the heaven like firm and solid ice.' Many similar things are found in the Gloss, and are cited by the Master on the Second [Book] of the Sentences. In the Scholastic History, likewise, it is said: 'God made in the midst of the waters a firmament — that is, a certain outer surface of the World, solid, of waters frozen like crystal, and bright, above which are waters frozen crystal-like, lest they be dissolved by fire.'

With these seems to agree what Josephus says: 'On the second day God set the heaven above all things, and, distinguishing it from the rest, ordained that it be established in itself; and, fastening about it a moist and rainy crystalline [envelope], he fittingly fashioned it for the benefit that comes from the rains upon the earth.'

See how the most learned and ingenious Men, on account of the authority of Scripture, setting aside the doctrine of the Peripatetic Philosophers, hold that the heavens — that is, the stars — are of elemental nature.

Moreover, what St. Ambrose writes in his Hexaemeron against those who think otherwise is evident in that book. I judge, therefore, that on this matter one must speak soberly.

[Margin: Aristotle's arguments are only probable. (*Rationes Arist. sunt tantum probabiles.*)]

Aristotle's arguments too, by which he proves the Heaven to be of another nature, are not demonstrative, but only probable. Namely, what he argues from the specific character of the motion of the heavenly bodies — that they are moved neither toward the center nor from the center, but around the center — what does this prove, since fire too, in its own sphere, is moved around the center, or circularly?

And if it be said that this is per accidens — that is, by the power of the higher sphere that contains it — nevertheless that motion is not violent to fire, nor entirely unnatural. Finally, in the generation of mixed [bodies], the light elements, namely fire and air, naturally move downward, and this motion is natural to them with respect to universal nature.

So one might argue concerning the motion of the Heavenly bodies: that even if they were of elemental nature, it would not follow that they are corruptible, since

the elements themselves are not corruptible in their totality, and other grounds of incorruptibility can be assigned to them.

Hence St. Thomas, on the Second [Book of the Sentences], calls the position of Aristotle an opinion; and in the First Part, question sixty-eight, he speaks very soberly of this matter, saying:

[Margin: St. Thomas leaves both opinions free, and does not bind [us] to Aristotle. (*S. Th. vtrāq. sententiā liberam relinquit, nec ad Arist. alligat.*)]

'[If we say that the Firmament is the starry Heaven, then the waters that are above the Firmament can be said to be of the nature of that heaven. Hence those who say the Heaven is of the nature of the elements can say that those waters are elemental.

But those who assert that the Heaven is of a special nature say that these waters are not of elemental but of celestial nature; and those who place elemental waters above the heaven can say that they are not heavy, but subtle — nor fluid, but like firm and hard ice. Hence by some they are called the crystalline Heaven.]' Thus St. Thomas.

Further, as St. Bonaventure touches on it, on the Second [Book]: 'These say that God, in the order of the universe, attends more to the common good and the usefulness of the end than to the quality and good of a form of a special nature. Therefore, just as in the lesser World [the microcosm] God placed the brain above, to temper the heat of the heart, so above the starry Heaven he placed the watery Heaven, to cool the burning of the aether. And by this they resolve the arguments that are usually raised against these views.

I assert nothing in this matter; nor is it my intention, in this place, to dwell fully on the discussion of these things. But out of reverence for the holy Fathers I have touched on these matters.'

Hence, in the discussion of this matter, St. Bonaventure says: 'This especially must be heeded: that in an uncertain matter nothing be asserted with claimed certainty. For it is better piously to doubt than rashly to define anything.]' Thus far Denis.

[Margin: St. Bruno.]

St. Bruno, Patriarch of the Carthusians [S. BRVNO CARTHVSIAE Patriarcha], on Psalm one hundred forty-eight: '[By "material Heavens," he says, we mean the air

and the aether and the Firmament itself, and also the seven circles of the seven Planets.]" And afterward:

"[Be the theme of his praise, you higher Heavens, encompassers of the lower Heavens. The higher, which surround the lower Heavens, he calls the Firmament and the Aether; the lower, the circles of the planets and the air.]" And afterward:

"[In this the Creator shows himself exceedingly powerful and marvelous: that he created waters not only under the firmament, but also above the firmament," etc.

Hence it follows that this holy Patriarch [Bruno] embraced the liquid Heaven:

First. Because he forms it from aether — that is, as St. Isidore explains, from fiery air; for that this Father took it thus is sufficiently established from the text and from the usage of those times.

Second. Because he attributes to the Planets not orbs but only circles, which are therefore to be reckoned in the class of imaginary things — of which there is no doubt, as has been abundantly gathered from Rupert [of Deutz], St. Bonaventure, and others.

Third. Because he places these same circles below the aether, and thus quite openly transfers them to the airy heaven. But that the ancients, by "aether" or "fire," or by a certain heavenly liquid body, understood [such a thing] — when they spoke of it in such a way as to distinguish it against the Firmament, as this Saint does — anyone will easily see who attentively peruses their records. And so I do not think it necessary to prove this at greater length, with many words.

In Support of the Nature of the Heaven as Either Liquid, or Fiery, or Both — Chapter XXVII

PRO NATVRA CAELI VEL LIQVIDA, VEL IGNEA, VEL VTRAQVE: Authorities of the More Recent Theologians, Philosophers, and Natural Scientists [*Physiologorum*], etc. CAP. XXVII.

The Authority of the Most Illustrious Robert, Cardinal of the Holy Roman Church, Bellarmine [Robert Bellarmine], Reinforced by the Authority of the Most Illustrious and Most Excellent Federico Cesi [Federico Cesi], Prince of Sant'Angelo, etc.

Although elsewhere, in Chapter 21, page 644, I did indeed suggest that the Most Illustrious Cardinal Bellarmine held the opinion of a liquid heaven, and that this had been made public in print by others, nevertheless—since recently, while I

was engaged with this very subject of my work, I was informed, by very good fortune, of a far more certain investigation of the matter and of a testimony beyond every exception, by the Most Excellent Dr. Johann Faber [Johann Faber], physician for the herbal studies [botany] of our Most Holy Lord Urban VIII [Pope Urban VIII], etc.—I could not but insert it here. For he related to me that the Most Illustrious and Most Excellent Prince Federico Cesi, while Bellarmine was still alive, had composed a certain astronomical work, adorned with the title *Caelispicium* [*Caelispicii*, "Sky-Watching"], concerning the recent appearances of the heaven, and that in it he had asserted the liquidity of the heaven. But since, on account of the boundless multitude of his affairs—and also for this further reason—he had given up the task of finishing the work, because he was by no means willing to proceed in the explication of Sacred passages without the vote of a distinguished Theologian, out of the reverence owed to the sacred pages: when the Cardinal learned of this, he was exceedingly glad, and marvelously praised the heroic endeavors of the Most Illustrious Prince, and vehemently urged him to complete what he had begun. For, he said, there was nothing whatever that ought, through any sinister suspicion, to frighten him away from a matter so well begun; for he himself still persisted in the very opinion which he had drawn long ago, thirty years before, from the Holy Fathers and divine Scripture. Accordingly he exhorted him again and again to publish his offspring [i.e., his work]. Having learned these things from the most distinguished Dr. Faber, I insisted that he, out of his kindness, obtain from the Most Illustrious and Most Excellent Prince a fuller acknowledgment of this matter, an undoubted assurance, and permission to publish—which he indeed accomplished, in the manner set down below.

[Margin: *Epistola Illustrissimi Principis Caesii, &c.* — Letter of the Most Illustrious Prince Cesi, etc.]

The letter of Prince Cesi (Italian original)

My most learned Signor Faber:

What I can testify to for the truth is this. Since the late Signor Cardinal Bellarmine, of blessed memory, very much my lord, who bore me a particular affection, often wished to hear from me about my studies and compositions; and when I gave him an account of my work on the Heaven, and in particular that I held it to be fluid—an opinion which seemed to me very well confirmed by Sacred Scripture and by the authority of the Holy Fathers, though I was unwilling to commit myself in the interpretation of sacred passages without the approval of a Theologian of such eminence as was His Most Illustrious Lordship—he showed the greatest joy at it, and told me that he had always held this himself, as being in

conformity with the sacred writings and the interpretations of the Holy Fathers, and that he had no doubt about it; but that he had not pressed to promote it, on account of the opposition commonly raised by the schools, which allege Mathematical demonstrations to the contrary, and in particular that without the solid orbs and their motion it is wholly impossible to save the Appearances [phenomena]. When I replied to this that I had not only fully satisfied the Physical and Mathematical side and all the phenomena, but that, on the contrary, it is entirely impossible to satisfy and to save (as they say) the Appearances by positing the orbs, he took all the greater pleasure in it, and pressed me to complete the work; nor did he ever see me after that conversation without asking me about it and reminding me to finish it, showing great desire for it, and displeasure that my endless household occupations were delaying me. In keeping with which, letters also passed between him and me while I was at Acquasparta. Thus Your Lordship may frankly assert this to whoever has asked you about it, giving him full assurance of it; and with all my heart I kiss Your Lordship's hands.

From my Fortress of Sant'Angelo, this first day of June 1628.

Your Lordship's ever most affectionate, Federico Cesi, Lincean, Prince of Sant'Angelo.

Scheiner's note and the Latin rendering

This letter, then, of the most gracious Prince, written to Dr. Faber and secured with his own hand and seal, Faber himself sent to me and directed that it be at my disposal; and so I carefully preserve it, to give assurance to anyone, and I append it below—rendered into Latin for the reader's benefit.

[The letter of Prince Cesi (Scheiner's Latin translation).]

Most learned Dr. Faber: What I can testify to in truth is this. Since the Most Illustrious Cardinal Bellarmine, of most happy memory, etc., always regarded me with a singular affection of benevolence, he often wished to know in what state my studies and literary commentaries stood. When I had explained to him the work I had in hand on the nature of the Heaven, and had disclosed above all this—that I held its Substance to be Fluid, and held this as ratified and firm from the sacred writings and the monuments of the Holy Fathers, yet was unwilling to take up the very weighty task of interpreting sacred passages without the guidance of some distinguished Theologian such as he was, lest I do so with any mark of presumption—he showed that he took the greatest pleasure in this, and added moreover that he had always been of that opinion; that he had judged it conformable to sacred Scripture and to the interpretations of the Holy Fathers,

and had never had any doubt of its truth; yet that he had pressed it less insistently, because he saw the common opposition in the schools, which allege Mathematical demonstrations to the contrary, especially that without the solid orbs and their motion it would be impossible to save the Phenomena. But when I had replied that I had not only satisfied the arguments drawn from Physics and Mathematics and the Phenomena, but that everything rather militates to the contrary—and indeed that it is impossible to satisfy and to save the Phenomena once the Orbs are posited—he took all the greater delight, and spurred me on to complete the Work. Nor did he ever afterward, after this conversation, see me without inquiring of me about this work and pressing upon me the mention of its completion, showing that he was gripped by a vehement desire to see the thing accomplished, and was affected with the greatest grief that my innumerable household occupations were holding me back from what I had begun. And as further evidence of this matter, letters passed as witnesses between him and me while I was staying at Acquasparta. Therefore Your Lordship will be able boldly to assert this to the one who asked for it, giving him full assurance, etc.

From my citadel of Sant'Angelo, the first day of June 1628.

Your Lordship's ever most devoted, Federico Cesi, Lincean, Prince of Sant'Angelo.

Scheiner's discussion

From these things, then, kind Reader, you have this opinion concerning the liquidity of the Heaven reinforced by the authorities of those two Most Illustrious Princes, whose testimony you will surely reckon most weighty. Of them let this one thing suffice to declare: that such were the views of these Princely men, who grant nothing to favor and nothing to popular applause, but measure a matter by truth and not by feeling. Bellarmine, assuredly, a holy Prince of the Roman Church, renowned for the holiness of his life, remarkable for singular erudition, venerable in his gray hairs, clung wholly to this doctrine as most certain and in no way to be called into doubt—not by human sense but by divine utterance, not by private opinion but with the concurring spirit of the Holy Fathers, not by any sudden impulse, but through the long-lived practice of a scholarly life over very many years—and that against the torrent of the Schools (as he himself judges it), which wrongly drags the reluctant Mathematicians to its own side, though these in fact go off entirely in the opposite direction. But the most distinguished Dr. Johann Faber himself also fully subscribes to this opinion, and he affirmed that many members of the Most Illustrious Academy of the Lynxes [Accademia dei Lincei] embrace it as well.

You will easily discern, even without my saying so, what needs to be done: whether you should side with Bellarmine, so great a Man, who decides that Scripture and the Fathers stand on his side—or, to speak more correctly, who resolves to decide in accordance with the Fathers and Scripture; or whether you think you should cling to certain Novices who wrench Scripture against its will and drag the resisting Fathers along. If Bellarmine was not versed in the Sacred Scriptures, if he misunderstood the Holy Fathers, who will know the former, who will penetrate the latter? But let us hear the man himself.

Bellarmino, *On the Ascent of the Mind to God*, Seventh Step, From the Consideration of the Sun, Chapter I

[A great thing is the Sun, for which God has prepared a most spacious, most beautiful, and most noble palace. For He willed that the Heaven itself should be the Palace of the Sun, in which it might Freely (note this, Reader) walk about and work; and that the Sun itself should be the Palace of the supreme Prince, God.]

[Margin: *Sol libere perambulat in suo caelo.* — The Sun freely walks about in its own heaven.]

From the same Seventh Step, Chapter IV

[We are not unaware, indeed, that there have been those who, from the motion of the stars, defined the nature of the Heaven as a Fifth Essence—simple, incorruptible, and perpetually moved in a circle; but we know too that there have been others who held the Heaven to be the element of fire, which is not moved in a circle, nor is incorruptible in its parts. We, however, seek not opinions, but sure knowledge or the doctrine of Faith, that from it we may build ourselves a solid ladder for coming to know God. Therefore we shall be content with the Moon and the stars, which we see, to raise a ladder with the Prophet, as we did a little earlier from the Sun, which is the light and Prince of the remaining luminaries.]

[Margin: *Fauet caelo Solis igneo.* — He favors a fiery heaven of the Sun.]

Thus far that most eminent Cardinal, who seems sufficiently to hint at a fiery nature of the Heaven, and certainly to presuppose a Liquid one, when he says that the Sun freely walks about in the Heaven as in its own Palace. He does not walk about *freely who, like a knot in a plank or a nail fixed in a wheel, is not moved of himself, but is carried round by his own orb as though shut up in a prison-workhouse—like a little bird in a cage, a bubble or grain of sand in the

thickness of glass, a sick man in a litter, food in a vessel. None of these is moved *freely; but the Sun, according to Bellarmine, as you have heard, is moved *freely in the Heaven. Therefore, according to him, the Heaven of the Sun is liquid. I did not wish these things to remain hidden from you.

The Authority of Vielmi, in Support of a Liquid Heaven

[Margin: *Hieron. Vielm. Dominicanus*. — Hieronymus Vielmus [Girolamo Vielmi], Dominican.]

Although one may sufficiently elicit the liquidity of the Heaven from Girolamo Vielmi [Girolamo Vielmi], where I cited him on pages 649 and 673 concerning its corruptibility, nevertheless, since he brings this out most clearly in speaking of the extension of the firmament, I do not mind transcribing his words for the Reader.

[Things, then, are usually extended in four ways, he says (Lecture 14, pages 185 and 186): by rarefaction, by increase, by pounding, and by expansion, etc. I shall therefore put forward what I have thought out, and what (unless I am mistaken) is more probable. It is this: that this extension came about not by way of pounding or expansion, as it seemed to these Doctors, but rather by way of increase—not of substance (which admits neither more nor less, and is situated in the indivisible), nor of quantity and mass (for those first bodies all came forth already bounded, as we have explained elsewhere, each set in its own place and position), but according to quality and power; not indeed in such a way that the bodies which are called the firmament previously had no qualities and powers, but that, in addition to the earlier ones which they received together with their forms at the beginning, they have today also obtained this one from the Maker, namely that they should be of such solidity and strength that they would not yield to the waters placed above them, and that—without any detriment to the particular nature of those waters—they would not merely support and, as it were, carry those waters (heavy though they be), but would even preserve them, like a deposit entrusted to them, for so long, until the Maker should demand them back, etc.

And on page 187: Nor is this opinion of ours destitute of the support of great authorities: for St Ambrose, when he had weighed the word "Firmament," finally added this reflection: "or because it was made firm by divine power"—indicating, that is, that it was perhaps so named because it received firmness and strength by the power and bounty of

God. And later: For this extension came about above all by an accession of forces—that is, of solidity, firmness, and strength, etc.]

[Margin: *Probatur auctoritate S. Ambrosii.* — Confirmed by the authority of St Ambrose.]

[Margin: *Item Scriptura.* — Likewise, Scripture.]

Hence, as to what we read in Psalm 17, "The Lord is my Firmament," there are those who render it "The Lord is my strength"; others, "The Lord is my crag," or even "my rock." All these things, then, readily come together into one, so that we may accordingly infer that God has today made the air so solid—that is, so strong, and so endowed and enriched with such power—that it can sustain the pressures of the waters with no difficulty; and that He has thus made those most noble heavens so strong, and so rich by His goodness, that they would bear the elemental waters above them, for as long as He willed, without injury—just as, of course, a very hard crag or rock is wont to bear, or even to catch and hold, the waters that hang over it. Wherefore, as St Basil does, so in this place he says: "Sacred Scripture uses this name of Firmament for those things which excel in strength and power."]

[Margin: *D. Basilii.* — St Basil.]

And later: [The upper heavens, therefore, and the air—which is the lower heaven—our people have rightly, and by Metonymy, called the firmament.]

Scholia on Vielmi

Vielmi, then, held the firmament to be fluid just as surely as he refused to acknowledge that the air—which bears up the clouds and mists—is hard. For he declares that both were endowed by God with the same firmness. But it is certain that the firmness of the air does not take away its liquidity; and so it is equally certain that the firmament is not rendered hard by that same firmness. Nor is there any reason for the word "solidity" to trouble anyone; for among the Latins, and especially the Geometers, "solid" is not the same as "hard," and Vielmi himself expressly declares that by the word "solid" he understands not hardness, but a certain force by which the air holds the clouds above itself, and the firmament holds the waters. He proves this further from the extraordinary and, indeed, arbitrary will of God which suspends the waters—a proof that would be pointless if he understood the air and the heaven to be hard; for a hard air and

heaven would necessarily, and without any miracle, hold in the waters floating above them.

[Margin: *Viel. soliditas non est duritia, sed stat cum aëre atque firmamento liquido.*
— Vielmi: solidity is not hardness, but coexists with air and a liquid firmament.]

He further approves the authority of St Ambrose and St Basil, each of whom [held/placed] the heavy waters above a fluid firmament...

he holds it to be fluid. Finally, in plain words, he confirms this very point — that there is one and the same Heaven — in agreement with holy antiquity.

"[*They are therefore all of one mind," he says (Lecture 18, p. 222), "that the body of Heaven is one only, a single mass, not solid and hard but permeable, mobile, and rare — and, as St. Basil [Basil] says, thin like smoke — through which the stars, like so many balls and little spheres, are carried in perpetual revolution, whether by a soul, or by an Angel, or, if you prefer, by an intelligence assigned to them, in a fixed and inviolable order prescribed and appointed to them by God, and so on. [Margin: The Rabbis, cited from Nacchianti.] And that there was no lack of certain ancient Rabbis of the Hebrews who held this to be so, is testified by Jacopo Nacchianti [Jacopo Nacchianti], Bishop of Chioggia, in his *Medulla*, and so on. Moreover, that in the first centuries of the Church this opinion was most widespread and accepted among Catholics I conjecture without much trouble: for Filastrius [Filastrius] — who, on the testimony of St. Augustine [Augustine] in the preface to his book *On Heresies*, was a contemporary of St. Ambrose [Ambrose] — lists among the heresies that opinion which asserts that the stars are fixed to the heaven.]" Thus far Vielmi [Girolamo Vielmi], who at length (p. 226) admits this teaching of the ancient Fathers at the very least as probable.

DE CAELO LIQVIDO stat Folenghius. [Folengo stands for a liquid heaven.]

[Margin: Folengo.] Giovanni Battista Folengo [Giovanni Battista Folengo] of Mantua, a Cassinese monk, in the year 1585 at Rome under Gregory XIII, commenting on Psalm 148, on the verse "Praise him, you heavens of heavens, and let all the waters that are above the heavens" and so on:

"[From the highest fabric of the heavens, he says, the Prophet descends through the airy tracts all the way down to the earth, keeping the order of nature. Indeed, since he had begun from those ethereal minds, and had at once passed over to the heavenly bodies, from these he now goes down to the heavens of heavens — that is, to the places where the seat of fire and of air lies.]" [Margin: Where the seat of fire is, there are the heavens of heavens.] And later: "[Hence it was said,

'and the waters that are above the heavens' — *which the Hebrew expositors take to be understood also of that first firmament created on the second day, and which they call the 'expanse' [expansum].

Moses says, God made the firmament, and divided the waters that were under the firmament from those that were above the firmament — *that is, those rare and thin ones, which for that reason hang aloft on account of their lightness; from the others, with an interval set between them: which others, being heavy and dense, either turn into rains and flow down, or, held back below among the clouds, lie still. There are those who summon here a crystalline heaven, which they would place above the starry one. But there is no need to philosophize further here, especially about matters which, though by their beauty and adornment they can arouse the boundless praises of God, are nonetheless almost hidden (let the philosophers prattle as they please) and unknown, and so on.

*O various and wandering spheres of the heavens! O waters that abide above the very heavens by God's astonishing miracle — Praise the Lord!]" [Margin: The waters hang miraculously above the heavens.]

If the theologian recognized the heavens here as hard, he would not place them there where the seat of fire and of air is — for these elements are not hard; nor would he ascribe to God's astonishing miracle waters hanging above the firmament. For it is no astonishing miracle of God that fluid water, held in check above a hard body, does not fall away but rests still; rather, it would be an astonishing miracle of God if it *did* descend, since that could not happen without interpenetration.

PRO NATVRA CAELI LIQVIDA, Auctoritas Mersenni. [For the liquid nature of the heaven: the authority of Mersenne.]

[Margin: Marin Mersenne.] Friar Marin Mersenne [Marin Mersenne], of the Order of Minims of St. Francis of Paola, in his *Commentaries on Genesis*, published at Paris in 1623, at Question 7, Article 9, First Conclusion, p. 843, argues most brilliantly of all for the liquidity of the heaven among the moderns, as follows.

First Conclusion. "[*That all the heavens in which the stars are seen to move are liquid like air seems to me not improbable — heavens whose parts at once close together again wherever the stars fly across from place to place by their own motion. [Margin: He removes the objections of those who think otherwise.] Since this view is not pressed by as many difficulties as those opposed to it, and is of all the easiest, so that by it we can explain any motions of the stars whatever, their

distances and aspects, the agitations and altitudes of comets, the productions of new stars, and the appearances and productions of all phenomena.

Indeed, since the Peripatetics themselves admit intelligences that move the heavens — from which neither philosophers nor Catholic theologians shrink — why, I ask, do we bind ourselves with the ropes of Eccentrics and Epicycles, by which the mind is so tied down that it can scarcely grasp those fictions, whatever figures, whatever schemata, whatever circles and poles you may describe with a compass to attain the understanding of those circles, or fashion out of wood, paper, and bronze, or even, like Archimedes, enclose in glass? Has this office been committed to the Angels — to carry the stars and the wandering globes here and there, to snatch them along at this speed and at that, by which we see them daily turned about? Do they lack the industry, the wisdom, or the strength to carry out these motions? Let us then grant this much to the Angels, if we concede that the heavens are moved by them — lest, against the philosophers' decree, we multiply beings without any necessity.

Or if you deny that they are present to the heavens, so that the heavenly spheres move themselves by a power first granted to them by God, then attribute the same to the stars: for the stars can possess a power similar to that which you affirm was infused into the heavens by God, whereby they may at one moment become nearer to us and soon slower, or faster, according to God's will and command. For although we cannot impart to a thrown stone that power, so that it should straightway go slower, straightway faster, and continue so through many ages, yet this is most easy for God, who is mighty with infinite power and wisdom.

*Nor indeed can better provision be made for the phenomena than that we constitute the heavens to be of an ethereal nature; for in them the stars and comets will accomplish all their courses with the greatest ease — which... [I add,] that the demonstrations of the opticians and astronomers compel us, even against our will, to assert it, as may be seen in them, those] who have treated of new stars and of the very latest comets." And, a little further on:

"[*There is therefore no reason for anyone to complain if the solidity of the heavens is taken away, or even their number, since it is more than enough that so deep an ethereal region should afford free passage, so that here and there the Sun, Moon, and Stars, as God established them from the beginning, may range abroad, whether by Angels or by their own power granted them at creation, carrying out their motions. Indeed, it is far easier to understand their courses once solidity is removed, since so great a multitude of Epicycles and Eccentrics is not in the least necessary.

It can also be more easily explained how new stars can appear in the heavens — such as were nine, of which one was detected by Hipparchus [Hipparchus] about 125 years before the birth of Christ.

The second: in the time of the Emperor Hadrian.

The third: in the age of Otto I, the first emperor, in Cassiopeia, on the testimony of Cyprian Leowitz [Cyprian Leowitz] as cited in Baranzano [Redento Baranzano].

The fourth: near the same Cassiopeia, in the year 1264.

The fifth: in the same constellation, in the 7th degree of [symbol: ♄?], in the year 1542. [Margin: Nine new stars are enumerated.]

The sixth: in the year 1577, which appeared for ten weeks.

The seventh: in the year 1600, in the breast of the Swan [Cygnus], in the 17th degree of Aquarius.

The eighth: in the 18th degree of [symbol: ♏?], and in the constellation of Serpentarius [Ophiuchus], in the year 1604.

Another too, before the fall of Troy — namely the seventh of the Pleiades — is said to have appeared brighter than the rest. And since these were seen at the same altitude as the other stars, far more must be contrived to explain those new stars and their courses if the heavens are solid, than if, being fluid like air, they are easily passable, and so on.

*Finally, there is no phenomenon (he says at the end of Art. 8, p. 842) which cannot be conceived, saved, and explained far more easily on the supposition of the tenuity or liquidity of the heaven, than if we suppose the heavenly spheres to be hard and adamantine. For it is no more difficult (he says a little before) for a star to move, or be moved, through the ether, than for the sphere itself to complete its own revolutions; and so we readily deny that as many heavenly spheres must be posited as there are stars — "which stars can be set in motion, if not by κυλίσει [Greek: kylisei (?), "rolling"] or by δινήσει [Greek: dinēsei (?), "whirling"] — that is, by rolling or gyration — at least by προνεύσει [Greek: proneusei (?), "forward inclination"], that is, by progression or advance. Now the reasons he brings forward for this fluid nature of the heaven, in Article 1, p. 811, and following, are these:

[Margin: The first reason.] "*The first reason is drawn from Optics, which Pena [Jean Pena] deduces at length in his preface to the *Optics* addressed to Charles, Cardinal of Lorraine [Charles de Lorraine]. If the heaven is a body distinct from

the air, and has as many parts contiguous among themselves as there are globes of wandering stars, and is solid and hard, many absurdities follow. For the fixed stars, and others, poured so widely through so many media, distinguished by so many surfaces, would be seen elsewhere than at the pole of the horizon, and would never be discerned in their true place, and so on. If these things were to happen, farewell Astronomy! Farewell the observations of Hipparchus! Let those of Ptolemy [Ptolemy] be torn to shreds, and so on.

[Margin: The second reason.] The second reason is taken both from comets and from stars newly appearing. For how can it be that comets run here and there through the spaces of the heaven, and are carried up as far as the altitude of Venus, or even higher, unless the heavens are constituted fluid like air? And the astronomers testify that comets rise up that far: concerning the comet of the year 1577, which at the beginning of its rising they judged to be distant 210 earth-radii from the eye of those observing — even though it was then at its nearest — that is, 180,690 German miles (each of which contains 4,000 paces). From which it follows that this comet was three times higher than the lunar sphere; since indeed, according to Copernicus's [Copernicus] view, the vault of the Moon is distant from the center of the earth only 52 earth-diameters, or 44,720 German miles. But if we follow the Ptolemaic measure — which admits the Moon's distance from the center of the earth to be only 33 radii — the comet must be placed six times higher than the Moon, and by a third part of one radius, and a little more. And that the very latest comet, of the year 1618, was no lower, Fromondus [Libert Froidmont] judged, in his *Treatise on that Comet*, chapter 7. Indeed, if according to Tycho [Tycho Brahe] the Sun's greatest distance is only 1,179 radii, then that comet must certainly have exceeded the altitude of the Sun, as well as its distance, which Clavius [Clavius] reports in the first chapter of the *Sphere* concerning the convex of the solar orb — or rather finds from Maurolico [Maurolico] — namely 1,216 earth-radii, together with a twelfth part of one radius.

[Margin: The third reason.] The third reason is taken from physics: since things seem to be more noble the less dense and solid they are, and the thinner and more subtle, as is clear from the enumeration of the parts of the whole universe, and so on.

[Margin: The fourth reason.] The fourth reason is sought from the Hebrew names themselves, which signify that the heaven is fluid like air or water, and so on.

[Margin: The fifth reason.] The fifth reason is taken from the authority of many Fathers of the Church, and so on.

[Margin: The sixth reason.] The sixth: to all these add, if you please, very many of the most excellent astronomers of this age, and the philosophers who are patrons of this view — so that the solidity of the heavens has begun to be laughed at in the schools. For it is far easier to explain all celestial phenomena from the hypothesis of fluid heavens than while solid ones are supposed; seeing that, if they are fluid and as it were airy, we do not need so many Epicycles and Eccentrics. For what is easier — nay, what at the same time can be more probable — than that an Angel was assigned to each star by God the moment they were created, to move them at God's command until the end of the world?

[Margin: The seventh reason, from the more recent phenomena of the planets.] The seventh: he enumerates these recent phenomena in the planets, at Art. 9, p. 846.

First: that the Moon is horned, uneven, rough, and everywhere beset with hollows and valleys.

Second: that comets are higher than the Moon — that all of them were sublunary Tycho denies, in Book 2 of *On the Recent Phenomena of the Etherial World*, chapter 10, section 1, p. 246; and in his letter to Rothmann [Rothmann] of 14 January 1595 he says that those must be held for stupid and insipid who should in future maintain that comets are sublunary.

Third: sunspots [maculas solares], which even in the middle of the Sun's disk often vanish or are newly caught sight of, to which they add the faculae [faculae], which variously set and rise.

Fourth: the stars ♿ [Mercury] and ♀ [Venus] are seen horned and full, and they carry out their circuits around the Sun as around a center; and Mars [♂] itself cuts across the Sun's heaven [☉] by a great interval.

Fifth: the 4 Jovian planets [♃], going around by their own motion, and the two Companions of Saturn, encircling it like satellites, have newly been seen — *all of which the more recent astronomers think cannot be explained unless we hold the heavens to be both liquid and liable to change, generation, and corruption.

[Margin: The passage from St. Job usually cited is explained.] The eighth: he takes his argument from the easy and plain solution of the arguments brought forward for the solidity of the heaven. Among these he expounds at length the passage of Job, chapter 37, verse 18, and among other things says this:

"[Since the true sense and aim of this passage is that we should look up to and revere the infinite power of the divine Majesty — which is most clearly seen in

this, that a flowing nature such as the airy, the etherial, and the watery persists so firmly in its place, as if it were forged of the strongest crystal or some other very hard material — *I do not think that it favors the solidity and hardness of the heavens in such a way as to prevent our admitting their liquidity and fluid nature.

Which I confirm the more, from the fact that the various translations — indeed the Hebrew text and the Vulgate — seem to have in view that beauty which is diffused through the heavens by the benefit of light, when they compare the heavens to a mirror.

And on p. 840: [Let us proceed, he says, to the other arguments — provided, however, that you first note, from that passage of Job, that nothing is to be inferred; because it is not Job or God who speaks, but Elihu, who speaks continuously from chapter 35 to 38, and whose sayings we are not bound to prove as true.] Let those note this well who press this passage too importunately. Consult chapter 30, the second Objection.]"

RATIONES A MERSENNO PRO Caeli liquiditate recensitae, ex mente & sensu Astronomorum roborantur & augentur. [The reasons reviewed by Mersenne for the liquidity of the heaven are strengthened and enlarged from the mind and judgment of the astronomers.]

EX OPTICA. [From Optics.]

First: light suits the heaven, not because [it is] either corruptible or incorruptible, but because the body is capable of this accident. Thus the properties of light — to be reflected and refracted — belong not to a corruptible or incorruptible body, but to a bounded or unbounded body, transparent or non-transparent, dense or rare, polished or rough.

For light is not reflected to us from the Moon because the Moon is by its nature incorruptible, but because it is opaque, and so on; and the same must be said of refraction. For a transparent body does not refract received light because it is corruptible or incorruptible, but because, being either denser or rarer, it turns the obliquely received ray in another direction. [Margin: An example of refraction from the Moon.]

From this most solid foundation — to be demonstrated, and demonstrated, by the opticians elsewhere — the utterly empty subterfuge of those men is exposed who, to weaken the force brought by Pena for a liquid heaven, say that the heavenly

spheres, because they are incorruptible, do not refract the light they receive, and so on.

Second: supposing, then, refraction to be a property of a transparent body of such-and-such density, such-and-such rarity, so-and-so shaped, polished, and the like — it at once becomes clear by what reasoning the stars, through those adamantine spheres (especially the Epicycles, which differ in density and rarity, as many place them, and so on), at any altitude above the horizon, ought to be refracted, enormously indeed, yet infallibly — apart from that ordinary refraction caused by the Atmosphere, which raises no difficulty for the mathematicians against this matter. It is that extraordinary refraction that Pena presses; for the Moon, for example, turning in its epicycle to the side and shining through it to us, will by the law of refraction display a most certainly perceptible change in itself; so Jupiter in its own, so Venus, so any wanderer in its own; so the Sun and any star, brought down to us through an alien Epicyclic orb, must — if these are hard, if they are distinct — be refracted, as [the wanderers set] on the opposite side [must].

But these things have never happened, nor do they happen now. There is therefore no refraction; therefore no refracting body; therefore no Epicyclic spheres; therefore the heaven [is] not...

not hard, but liquid. With such darts these men press their attack; but I only hint at this in passing, my quiver left open. And let this one point stand on behalf of Pena.

On the apparent unevenness of the Moon

Second. Twin to the preceding is an argument drawn from the Moon's appearances, by the reflection of rays. For it is certain that the globe of the Moon itself turns monthly about its own center — evident from the fact that it always turns the same face toward us and is carried by an epicyclic motion. If, then, the Moon is rough — as the telescope [*tubus opticus*] shows it to be, as many concede, and as not even some of the Peripatetics themselves entirely deny — it is impossible for it to move about its center in its epicyclic orb by any means except one of these: either through a vacuum, which the nature of things does not allow; or through the interpenetration of bodies, which philosophy together with nature rejects; or through an intervening liquid body — which is precisely the point in question.

But suppose the Moon were mathematically polished and geometrically spherical. Then nothing would be seen on it but the image of the Sun reflected to us, forever shifting from place to place; or at the very least that image would always shine out far more brightly than the rest of the Moon's illumination, and would utterly blot out the spots [*maculae*] of the Moon lying beneath it. This is plain in the gilded balls atop towers, in polished marble spheres, in glass flasks filled with water or of various colors, and, in short, in other polished bodies. But since the Sun's image is not in fact reflected back to us from the Moon in the manner described, they deny that the Moon is clothed with a smooth spherical surface, and insist instead that it is furnished with a thoroughly rough and genuinely pitted one.

Now suppose you object that the solar image formed on a smooth lunar surface would not reach us, because of its smallness — as seems probable to Aquilonius [François d'Aguilón] and to some others. Others skilled in optics deny this, on the ground that even small spheres represent the Sun quite perceptibly, and that standing waters reflect it just as large as it appears to direct view; whereas the Moon's roundness is great. But even in an inverted position, and with its rays thrown into confusion, that appearance of the Sun could still be cast across to us — just as happens with the stars, whose minute bodies plainly cannot be [distinctly] made out. At the least, telescopes trained on the Moon would not let that impressed image of the Sun escape their power, for it would reveal smaller and fainter points of light [*luculae*]. Yet this does not happen.

Certain other astronomers, granting that the Sun's image could not reach us from the Moon, nonetheless infer from this that if the Moon were exactly smooth it would not be seen at all; and so, with the same Aguilón, they ascribe to it an unevenness resembling a little cloud or mist. What they say of the Moon, the astronomers want understood of all the stars, since the same reasoning proves the same thing everywhere.

Aristotle, to be sure, having supposed the Moon to be homocentric with the earth, and having concluded — from the fact that the same face of it is always turned toward the earth — that it is itself stationary within its own sphere, said that the same must be laid down for all the planets and stars, as being proved of one. Therefore, since the astronomers demonstrate a lunar and likewise a solar rotation, one must argue similarly, by Aristotle's own judgment and manner of arguing, about all of them.

That the Sun, moreover, is in its heaven neither fixed nor endowed with an even surface, its own appearance and its monthly rotation prove; and Mersenne

[Marin Mersenne] concurs. They argue in like manner about Jupiter, from the unequal circling and light of its satellites [*laterorum* [?]], and so on: for whether you drive them around in a hard heaven or in a liquid one, Jupiter certainly cannot be carried around by each of their several motions. It is therefore not fixed to the aether.

It might perhaps be objected that Jupiter is continuous with the sphere of its innermost satellite. But whether this can reasonably be maintained deserves consideration. For on that view the satellite, the intermediate sphere, and Jupiter itself would be made into one continuous globe. Again, that satellite would hang immovably over Jupiter always at one and the same point — contrary to what the other three would do. And finally, Jupiter would appear in a way to be governed by the satellite rather than the satellite by Jupiter. Yet these are reasonings and conjectures — ingenious, no doubt, but not necessary inferences; and taken all together they do not, in the eyes of fair judges, appear to lack their own weight. They conclude much the same about Saturn.

These considerations, then, and others like them, carry great presumptive weight among the learned in favor of a liquid heaven. Indeed Galileo and Kepler — as reported in Simon Marius [Simon Mayr], *Phaenomenon* 7, and elsewhere — emphatically wrap Jupiter in a liquid atmosphere, and the astronomers vie with one another in agreeing. And Raphael Aversa holds that absolutely all the stars rotate about their own center, and twinkle for that very reason, and so on.

On the head of the superlunary comets

[Margin: An argument for a liquid heaven, drawn from the head of a comet.]

Third. The astronomers bring forward another argument, from the head of a comet situated in the heaven. For since — as is established, by common teaching and by indubitable experience, from the comet of the year 1618 — its head grew larger uniformly all around, in every direction, the astronomers ask: *how could this have come about in a hard heaven, and that by local motion alone, by the converging of denser corpuscles or parts from every quarter toward one center?* There would then have to be infinitely many celestial spheres to heap together each of these denser, invisible portions — by irregular motions, unheard-of, impossible, and hitherto known to no one, neither man nor angel — through which one must concede either the interpenetration of bodies, or the splitting of the adamantine heaven, or else (as the astronomers intend) must embrace fluidity. The astronomers pursue similar questions about the comet's diminution.

The nerve of this argument can be weighed from the growth and shrinking of the sunspots, since the same reasoning holds in both cases.

Much could be argued here, to the present purpose, about the kindling and brilliance of the comet; but I merely point to the astronomers' arguments from a distance, and do not unfold them fully. For that comet of 1618 made a transverse journey from pole to pole through all the heavens — which, if fluidity is denied, could not have happened without a penetration of the heavens.

Fourth. The comet's tail, too, and its beard, seem in the astronomers' judgment to tell very strongly for a fluid heaven. For it is formed out of the solar rays alone, which become visible in that vaporous medium; and its curvature, and its bending into the shape of a scimitar [*acinaces*] — such as the comet of 1618 presented with a fearsome aspect — cannot be defended on a hard heaven, but can be explained most conveniently once a liquid one is granted. They maintain the same about its fluctuating to-and-fro motion, its sudden disappearance, its sudden appearing-together, its lengthening, contraction, enlargement, and constriction, and accidents of this kind. For if all these are supposed to occur in a hard heaven, they will admit only a most difficult explanation, or none at all; but in a liquid heaven they present themselves quite easily, of their own accord, to anyone.

The unusual trembling of the Moon about its edges when it eclipses the Sun

Fifth. *To this belongs the unusual fluctuation of the lunar perimeter when, in solar eclipses, it is placed beneath the Sun — a trembling greater and more violent than that of the Sun's limb — from which the astronomers argue for a lunar atmosphere.*

Hear what a distinguished mathematician writes on this matter, from an eclipse he observed at Barcelona on the very day of the Lord's Nativity, in the past year 1628. [*"Finally, in the same eclipse," he says, "with the Moon placed beneath the Sun, I observed a marvelous thing: namely, the periphery of the Moon fluctuated and trembled very greatly, while the Sun's periphery trembled either not at all or very slightly — exactly as a sea stirred by waves, one wave driving the next. From this I gathered that the globe of the Moon is surrounded by an atmosphere no smaller — and perhaps denser — than that of the earth. Let Your Reverence judge, I beg, whether I have inferred rightly. Certainly I find no other cause why, at the same altitude of the Sun, the Moon's periphery should always have trembled much more than the Sun's, unless this one: that the solar rays were cut off by the vapors surrounding the Moon.* Hence a greater light seems to arise, in the case of the

sunspots and comets, if — just as vapors are exhaled from the globe of the earth and Moon — they are likewise exhaled from the globes of the remaining planets."*] This that learned mathematician, an exact observer, wrote to Rome on 12 January 1629. What fallacy lurks in his shrewd reasoning the astronomers have not yet discovered.

The account of this experience rubs fresh in my memory a certain kindred phenomenon in the Sun, which I have observed ever since I first discovered the solar phenomenon [of sunspots], and it is this: that the Sun, besides its own

marginal trembling — which, however, it does not always afford to be seen — and besides the roughening it frequently exhibits (of which I have often spoken elsewhere), also flashes, as if with a kind of sudden lightning, uniformly in every direction across its whole open hemisphere, exactly as if, swelling with a light conceived within, it were bursting and blazing forth after the manner of a lightning-flash, leaping up with a momentary radiance. Concerning the origin, cause, and manner of this appearance one might reasonably be in doubt: does it proceed from the Sun, or from elsewhere?

Simon Marius, in the preface to the Reader of his *Mundus Iovialis*, thinks it arises from an internal scintillation of the Sun, which he says is a kind of lightning-flash or boiling-up of the solar matter. [Margin: Simon Marius.] [*"For in this way,"* he says, *"I have seen the Sun's surface stirred, exactly as gold melted by intense heat, in whose flux a like agitation and, as it were, lightning arises on the gold's surface, and so forth."*]

Marius here describes the experience correctly — and the Reverend Father Raphael Aversa also agrees with him, as is said in his own passages. But whether all the rest, inferred from this, stands so or otherwise, I leave partly to the astronomers to decide, and partly reserve my own opinion for another time and a more exact inquiry. For I would have nothing asserted rashly or hastily, but everything brought forward well-weighed and mature. The effect I see for certain; that its precise cause remains, in one way or another, wrapped in obscurity, I readily acknowledge. So much in passing: now let us come to Mars.

[Margin: In solar matters one must proceed cautiously.]

Mars, an ancient inhabitant of the Sun's heaven

[Margin: Mars fights for a liquid heaven.]

Sixth. As for Tycho Brahe's having brought Mars into the heaven of the Sun — he did so neither alone nor in any novel way, on the strength of his own observations. For many centuries before him the Prince of Astronomers, Ptolemy — as will later appear (contrary to what Mersenne, swept along by the flood of common opinion, supposed) — from the celestial motions he had detected and defined, [said] that the spheres of the planets are intermingled with one another's spheres (*note this well, Reader*), that circles are interwoven with circles, that axes run across axes, and that poles meet poles — he stated this in express [terms] [?]. [Margin: Ptolemy mingles the paths of the planets.] Yet, when these things came to pass, he extricated [the planet] from every difficulty by the mere mobility of the celestial body and its ease in yielding place — and thus by its liquidity. And so he led the wandering stars [*errones*] — otherwise hard, and unable to give way to one another — around through those most tenuous breezes, quite freely and with no trouble, even though one would from time to time cut transversely across another's circles; for from this, he said, nothing at all absurd is admitted into the nature of things, *since that breathable material affords a most easy passage to those celestial runners.*

See the *Sol Illustratus* of the illustrious and noble lord, Lord Jan Mikołaj Smogulecki of Smogulec [Smogulecki], who cites for this doctrine also Copernicus, Kepler, Sarsi [Orazio Grassi], Rothmann [Christoph Rothmann], and others, and says that it is the common opinion among nearly all astronomers. [*"This is certain,"* he says: *"if the heaven of the Sun is made larger on account of the epicycles of Venus and Mercury — as it necessarily must be, as we have said above and shall say below — then, not only according to Ptolemy but also according to Thebit [Thābit ibn Qurra], al-Battānī [Albategnius], and al-Farghānī [Alfraganus], who came after Ptolemy, Mars infallibly, and indeed deeply, enters the heaven of the Sun."* So he there, and so forth.]

At this point a physical difficulty against the hardness of the heaven could be raised — one that some put forward, arising from the mutual contact of hard bodies. For since any two adamantine celestial spheres — the container and the contained — have their surfaces both convex at once, it seems impossible, both because of the vastness of the spheres and because of the contrarieties of local motions, together with many other drawbacks that would follow, that diverse local motions should take place. But these disputations of many writers, drawn from the nature of surface contacts, I leave for the present to the Reader's own free reflection; there will perhaps be another place for examining them. For now the time bids me continue the web I have taken up from the authority of others.

Pedro Hurtado does not shrink from a liquid heaven

[Margin: Pedro Hurtado's opinion on the heaven.]

Pedro Hurtado de Mendoza of our Society, in his philosophy — which, revised and enlarged, he had reprinted at Lyons in 1624 — in the second Disputation, on the properties of the heavens, section 1, recognizes through various paragraphs only a single heaven in number for all the stars, both fixed and wandering. For on page 368, §9, he writes as follows: [*"The astronomers gather eight heavens from the seven planets and the fixed stars. Now I show this argument to be weak: because in one and the same heaven there can be several planets or wanderers, that is, roving stars. For since the heaven is of broad depth, different regions can be assigned within its single body, where the wanderers may lie; and from their varied revolution through those regions they produce various aspects and conjunctions — no less than if they were in different heavens. Therefore the heavens are not to be multiplied, since in philosophy a multiplicity of things is not admitted without necessity."*] [Margin: He posits a single heaven for the stars, both fixed and wandering.] *"Now all astronomical demonstrations are consistent with a small number of heavens, provided that different regions are assigned to the courses of the planets."*

And afterward, §10: *"Just as the air is divided by us into three parts — the aerial region, which is nearer to us; the Olympian, because it touches the summit of Olympus; and the ethereal, because it is closer to fire — and yet we do not on that account set up three distinct airs: exactly the same holds for the heaven."*

And shortly after, §11: *"The astronomers can point to only eight parts of the heaven — one lowest, the others higher in their order; but that these are divided into eight distinct heavens they do not prove; otherwise six other new heavens would now have to be reckoned in as well (namely, from the six new planets, and so on)"* — which, however, he himself holds to be absurd. Hence he makes the spaces of those new planets either liquid or hollow in any case.

Then, §12, he proves his opinion about three heavens from the holy Fathers, proceeding thus: [*"To this opinion of ours several Fathers openly assent — Chrysostom, in Homily 4 on Genesis, in these words: 'And how do some say that many heavens were made? They did not learn this from divine Scripture, but are driven by their own opinions to say so.' Confirming which, he adds in the same place: 'Who, then, after such teaching, would tolerate those who dare to speak out of their own head and, against divine Scripture, to affirm many heavens?'"*] There he answers the arguments made for a multitude of heavens. And Ambrose, in the

second book of the *Hexaemeron*, chapters 2 and 3, enumerates only three heavens, which we shall admit below.

These Fathers Saint Thomas [Aquinas] expounds in the First Part, Question 68, Article 4, as speaking of a plurality of bodies distinct from those enclosed within the celestial spheres, such that there is no other World besides this one. *But Saint Thomas, out of modesty, adds this interpretation lest he seem openly to depart from these Fathers — against whom such an interpretation is not free of difficulty:* both because Ambrose openly argues against those who assert other Worlds — and, that argument concluded, sets up another concerning the plurality of the heavens and the distinction of the firmament from the heaven which God produced first; and because he affirms that he cannot deny three heavens, since the Apostle says he was caught up to the third, among which [heavens] he counts the air. Therefore Ambrose is not speaking of other Worlds — otherwise he would be establishing three Worlds.

§14. Chrysostom, however, makes no mention of another world, but of a celestial body: for he distinguishes heaven from earth, and treats of the heaven as of a distinct part of the world. (And this against those — even Christians — who, from their own opinions, held that there were many heavens; yet no Christian held that there were many worlds, and so on.)

Add Theodoret, Question 12 on Genesis, saying thus: "Whoever, then, does not believe that there is a second heaven strays from the straight path; but whoever tries to count more clings to fables, setting aside the teaching of the divine Spirit," and so forth.

Basil, moreover, in the *Hexaemeron*, admits two heavens in Homily 1 — indeed even three; and this third, too, at the end of the homily he says to be

the air. Nor does he admit more heavens; indeed he mocks those who assign seven orbs to the seven wandering stars, intermixed and enclosed among one another in the manner of several jars or little vessels. For he reports their whole opinion about the number and the music of the heavens, but rejects it.]

§15. He also proves from Saint Clement (*Recognitions*, book 2) that there are nevertheless two heavens, as Saint Peter teaches, etc.

[Margin: Three heavens: the aerial, the starry, the Empyrean.]

§16. And so there are three heavens according to the sense of these Fathers.

[The first is called the aerial, etc.]

The second heaven is the starry one, containing the stars in its eighth and highest part, which is called by the astronomers the Firmament, or the eighth sphere, or the Aplanes [the starless / fixed-star sphere]; and it holds the Moon at the innermost surface of its concavity, and the other planets in between.

The third is the Empyrean heaven, of which it is said in Genesis 1, "In the beginning God created heaven and earth," as Father Martín del Río [Martinus del Río], and Pereira on the same passage, and Molina in part 1, on the work of the six days, expound; we shall treat of this heaven in disputation 3.

§.17. Ambrose admits these three heavens, and so Father Molina explains Paul's assertion that he was caught up to the third heaven. *Neither in Scripture nor in the Fathers is any basis found for more heavens; and the astronomers must submit themselves to the Fathers. But if the second heaven is sometimes spoken of as several heavens, we should understand several parts of the same heaven, etc.*

For the rest, the astronomers will most gladly accommodate themselves to the holy Fathers — and to Hurtado [Pedro Hurtado de Mendoza] himself as well — following the example of the learned and well-versed Hurtado himself. For once he had sufficiently aired that exotic opinion about the channels of a hard heaven, and had noticed that it was rather harsh and repugnant to more cultivated ears, he clearly subscribed, together with the astronomers, to the unanimous teaching of the holy Fathers concerning a yielding and therefore fluid heaven. For thus he writes in §.24:

[But if these points please less (for they are foreign to the common opinion of the astronomers, and I have proposed them only for the sake of resolving difficulties and arguments), let the Greek Fathers readily extricate themselves, admit-—ting the corruptibility of the heaven and its being cut through by the rotation of the planets [recte: planetarum]. But although they are cleft, it can also be said that they are not corruptible, just as prime matter is incorruptible even though it is divisible. Nor by that cleaving is any part of the matter, or of the celestial form, corrupted; there is only a rejoining of the indivisible continua. As the planet advances, the parts of the heaven close up again, just as the water does when a ship [navi] passes through it.

Hurtado, then, holds that the heaven can be liquid, and not on that account necessarily corruptible, but that it can remain incorruptible — as Bellarmine [Robert Bellarmine] too judged.

In Favor of a Liquid Nature of the Sun — the doctrine of Raphael Aversa [Raffaello Aversa].

The most reverend Father Raphael Aversa of San Severino, General of the Minim Clerics Regular, published at Rome in the year 1627 the Second Volume of his *Philosophy*, in which, at Question 34, page 160, he infers from the phenomenon of the sunspots that the Sun is not solid but fluid; for by this reasoning he thinks that both the reality of the spots and the integrity of the solar body are more than adequately provided for. His marginal notes, set down throughout the whole Ninth Section on the spots, are these:

First: the spots detected in the Sun are variable, irregular, and mobile.

Second: they are not illusions of the eyesight or of the glass [lens].

Third: they are not elemental vapors beneath the heaven.

Fourth: they are not elemental vapors in the heaven.

Fifth: they are not celestial vapors of the Sun itself.

Sixth: they are not opaque parts of the lower orbs.

Seventh: they are not opaque parts, nor stars revolving around the Sun.

Eighth: they appear to exist, and to move, in the Sun itself.

Ninth: they are either opaque parts of the Sun itself, or opacities in the parts [recte: partibus] of the Sun.

That this may be better understood, he reasons as follows, on pages 159 and 160.

So at last one will have to admit that such spots truly and really exist in the Sun itself. And that the Sun itself performs a distinct motion about its own center, by which, in its lower hemisphere, it carries the spots from east toward west over a span of fourteen days.

This can be confirmed further: for when, through the same tube, and in the same image of the Sun caught on the screen, one observes an intense scintillation and, as it were, a boiling of the Sun over its whole circumference, this same effect is found in exactly the same way in all the spots scattered across the whole middle of the Sun. These spots, therefore, are really in the Sun itself, and hence are stirred and moved about together with it.

[Margin: The variety of the solar spots.]

But these spots cannot be established in the Sun as fixed and permanent features of it; for, as we have already related, the same ones are not found to return more

than once, but those that succeed one another are always various and different, as is recognized from their shape and from other circumstances. And at the very time when they are seen to pass across beneath the Sun, they are perceptibly found to vary in shape and in other conditions. These spots, therefore, are entirely formed anew on the Sun, last for a while, then vanish, and yet others succeed them anew.

But as to how this happens, and what in the end is the whole account of these spots, two ways present themselves that can be conceived without prejudice to the substantial integrity of the celestial bodies.

The first is if the Sun be said to be not a solid body but rather a fluid one, contained in its place as in a vessel, and stirred within itself like molten metal; and that within it are found certain opaque and dark parts, which are from time to time brought out to the external face of the Sun and then drawn back again, and which tend to return with a change of shape and of other conditions. In this way all those appearances of theirs reported above could be well saved; and the said motion of the Sun within itself could well be carried out — either because the Sun as such turns absolutely in its own place by the power of a moving intelligence, or because, enclosed within a kind of epicy- [Margin: The Sun made to rotate.] —cle, it is turned round in a circle about its own center by the revolution of that epicycle.

The second way will be if it be said that a certain opacity, obstructive of light, is truly produced anew by the power of celestial causes in some small part of the Sun; and that this lasts for a while and is afterward destroyed, and so is successively renewed over time, occurring with all that variety and variation which has been observed in these spots — and that the Sun rotates within itself along with those spots, in keeping with all their apparent motion. Thus this whole thing would come about through an accidental change alone, with the entire substance of the Sun preserved.

[Margin: The second way: through the production of a new opacity, etc.]

For this accidental variation need not imply a substantial renewal; rather, just as a change of light and darkness occurs in the heavens without any change of substance, so this change of opacity can be understood. Nor even ought it to come about through a variation and a condensing of quantity; it will be enough that there be a certain change in quality, as is gathered from what was said in section 2. But if in the end neither of these ways is satisfactory, nothing else will remain but to confess that the matter is unknown until something better comes to light.]

Notes.

From the teaching of this theologian the following are sufficiently clear.

First: according to him, both the sunspots and the Sun itself are held to be incorruptible, etc.

Second: that the Sun is nonetheless of a transparent, bright, and liquid substance.

Third: that the Sun turns either about its own center or on a proper epicycle, and carries the spots along with it, over roughly a month's span.

Fourth: that the spots truly exist in the body of the Sun, yet are to be regarded not as fixed but as movable parts of that same Sun.

Fifth: that all their variety can be accounted for either by local motion alone — arising from their emergence out of the depth of the Sun and their immersion back into it — or by the generation and corruption of a new opacity, without any injury or physical change to the solar substance.

For the rest, although this author has said much that is excellent about the sunspots in a brief compendium, whether all of it agrees with the truth and with the phenomenon will be easily judged by anyone who examines the *Rosa Ursina*. For in that work he will learn that the spots are carried around in and with the Sun, as it rotates about its center, ordinarily in twenty-six or twenty-seven days; and that their incredible variety, and their regular appearance and disappearance, cannot be accounted for merely by a procession from the inner core of the Sun out to its outermost surface, and from there again a retreat toward the interior. Besides the points that arise of their own accord throughout the whole work, the following also establish this.

[Margin: Difficulties against the emergence and immersion of the spots.]

First: from the fact that the spots floating on the Sun do not rotate on themselves about their own center — as I have proved at length in its place — and likewise that they are not assembled from a chance concurrence of tiny ones (as the author himself rightly proves), and finally that scarcely any appears for long with the same size, shape, and position, but always with a different form and appearance (as I have found from seventeen continuous years of observations): it follows that all the spots, if you set aside a few recurring ones, are distinct from one another.

From which it further follows that, since ever since the Sun's creation there have always been and appeared some spots after others, they would in a way have to be infinite, so that the Sun could by no means now contain them.

Nor should you say that they turn within the Sun and then appear in a different configuration from a changed position; for it stands against this that every spot, in progressing from the rising edge of the Sun to its setting edge, presents to the observer every position of its body, as I have demonstrated. Why, then, would no spot ever appear like a slender line in the middle of the Sun, and not broad at the Sun's edges? — if indeed it is perpetually turning about its own center as it travels across the Sun. Why do they all always display their full breadth in the middle? Why do they show thinness and slenderness only near the Sun's extremities? A fitting answer is lacking. Therefore, if the spots were permanent in the Sun, there would now be so many that in the Sun nothing should appear besides spots; indeed, they would exceed the Sun itself in magnitude.

Second: no reason will be given why no primary spots emerge near the northern and southern solar poles, but confine themselves only within the torrid zone of the Sun.

Third: the first appearance and last disappearance of the spots, explained in the earlier sections, does not hold up through emergence and immersion, as will be clear to the reader.

Fourth: often, while a spot is growing, it is somewhere split; the former would have to happen by emergence, the latter by immersion; so it would at the same time be emerging outside and immersing inside the Sun — which cannot be.

Fifth: often, while some spot is growing, it somewhere blazes up within itself into a facula; these things do not accord with emergence and immersion.

Sixth: spots that are uniform and very thin grow and shrink gradually as they cross, which cannot happen by emergence and submersion, since, because of their thinness, they would all sink at once, etc.

Seventh: spots acquire nuclei after they have grown, and lose them before they perish; which cannot happen by immersion and emergence.

Eighth: many nucleated spots, while they are in a steady state — that is, while they neither grow nor shrink perceptibly — nevertheless remarkably alter the nuclei set within them, both in shape and in blackness; which can in no way be ascribed to immersion or emergence, since the spot is posited as being in a steady state.

Ninth: most spots degenerate into faculae; and the largest spots often leave behind them either none or only small faculae, while the smallest leave behind the largest. These things do not accord with immersion.

Tenth: the secondary spots, with which almost the whole Sun nearly always teems, cannot be explained by these immersions.

Eleventh: the solar faculae, both pure and impure, cannot at all be adequately explained and accounted for by these modes of emerging and submerging, as will be clear to one who considers them.

Twelfth: this emergence and submersion utterly overturns the regular motion of the solar phenomenon, as, to one who consid- —ers, becomes clear. For when the spots emerge outside the Sun, when they abide in a steady state on its outermost surface, and again when they are submerged, they are revolved within it and along with it; but these show an irregular motion, which is contrary to the phenomenon.

Thirteenth: recurring spots clearly overturn this emergence and immersion, for they always remain on the surface of the Sun.

Fourteenth: as for the idea of this emergence and submersion of the sunspots — although it often came into my mind while I was working late by lamplight, I nevertheless made no mention of it, because I never thought that an opinion so absurd in itself would find either a patron or a champion. It was not, indeed, hidden from me that there are some who think the sunspots are certain protuberances on the Sun, like mountains; but since these views proceed from a preconceived disposition of mind and from ignorance of the solar phenomenon, I disregarded them — especially since I have found in the phenomenon itself not the slightest basis or indication for either the one mode or the other. To invent things from mere arbitrary judgment, and to affirm that something is so because I can imagine it to be so, does not seem philosophical, especially in a matter so difficult; otherwise the astronomers too will argue in this way: the emergence and immersion of these spots can be non-existent; therefore it does not exist. Its contrary can be the case; therefore its contrary is the case in the Sun. If this manner of arguing is invalid, so is the other, since it is the same in both cases. It is the mark of a sincere astronomer to follow the phenomenon, not to run ahead of it — to draw the truth from the object accurately observed, not to drag the unwilling object into arbitrary fictions.

I have touched on these things briefly, because I am dealing with prudent men; but if it shall be necessary, I will demonstrate each one individually.

Concerning the opacity of the spots, both real and apparent, I have disputed sufficiently in the earlier parts, which may be consulted.

But what Apelles thought about the spots — and that he never placed them either outside the Sun or in the reckoning of the stars — has been set forth in Book 1.

Moreover, as to the fact that the said author seems to make Protogenes the Venetian equal to, or even earlier than, Apelles in the discovery of the spots: I confess that, apart from those manuscripts which Apelles mentions in his letter dated 25 July 1612, I have seen nothing published in print by Protogenes; and those [manuscripts] had been sent to Welser [Marcus Welser], discovered after, and in addition to, the first published Table of Apelles. But if Raphael knows of older ones, I am astonished that such matters concerning a Venetian should be unknown to the Venetians. Rather, I suspect that this writer is mistaken.

IN SUPPORT OF A LIQUID HEAVEN — The Testimonies of the Ancient Philosophers. CHAPTER XXVIII

(*PRO CAELO LIQVIDO* — *Antiquorum Philosophorum Auctoritates. CAP. XXVIII.*)

I.

[Margin: The ancient philosophers, etc.]

As for the ancient philosophers, they were of one accord — as I have often said — in the view that the heaven [caelum] is composed of some one of the elements, and so of air or fire, and the like. Aristotle himself attests to this in *On the Heavens* [De Caelo], Book 2, text 56, where he says: "What if the bodies of these (that is, of the stars) were carried along, either diffused through the whole in a multitude of air, or of fire, as everyone says, etc.?" So — as Aristotle himself admits — all the others make the heaven liquid.

[Margin: Aristotle's testimony on behalf of the ancient philosophers.]

Cicero agrees, in the second book of *On the Nature of the Gods* [De Natura Deorum], where he says that the whole world was created by God out of nothing, and consists of four elements, of which fire is the highest — from which come the heaven and the aether, in which the stars are fiery living beings.

[Margin: Cicero.]

"And so," he says, "once the divinity of the world is grasped, the same divinity must be attributed to the heavenly bodies, which are generated from the noblest and purest part of the aether, and have no other nature mixed in besides; they are wholly warm and translucent, so that they too may most rightly be said to be living, and to feel and understand. And Cleanthes [Cleanthes] holds that they are indeed wholly fiery, confirmed by the testimony of two senses, touch and sight.

[Margin: Cleanthes.]

For the brightness of the Sun is more brilliant than any fire, since it shines out so far and wide over the immense world; and its touch is such that it not only warms but often even scorches — neither of which it would do were it not fiery, etc." He then says that some are fed by the moisture of the Ocean, and the like. And afterwards he says that "the remaining stars arise in the celestial fire, which is called the aether, or the heaven." And soon after: "It seems absurd to Aristotle that, in that region which is fit for generating —

II.

— the most suitable living beings, no living being should be generated. But the heavenly bodies occupy the aethereal region: and since this is the most rarefied, and is always in motion and vigorous, it necessarily follows that any living being generated in it must likewise be of the keenest sense and the swiftest mobility. Therefore, since the stars are generated in the aether, it is reasonable that there be sensation and intelligence in them." The same, much later.

[Margin: Cicero cites Aristotle in his own support.]

"Nor indeed do those stars which are called fixed [inerrantes] fail to signify the same mind and prudence: theirs is a daily, harmonious, and constant revolution. They do not have aethereal courses, nor do they cling to the heaven, as most people say who are ignorant of physical reasoning. For the nature of the aether is not such that by its own force it should embrace and whirl the stars around: being thin and translucent, and suffused with an even heat, the aether does not seem well suited to containing the stars. The fixed stars therefore have their own sphere, separate and free from any aethereal connection. Their unfailing and perpetual courses, moreover, with their admirable and incredible constancy, declare that there is in them a divine power and mind, etc." And afterward: "The Moon is the lowest of all, and dwells in the region of the earth." The same, much later: "And since there are four kinds of bodies, the continued nature of the world is maintained by their alternation. For from earth comes water, from water arises

air, from air aether; then in reverse, in turn, from aether air, from air water, from water the lowest earth. Thus, as these natures — of which all things are composed — pass up and down and back and forth, the connection of the parts of the world is held together." Thus far there.

[Margin: In Cicero's time the heaven was held to be liquid by the learned, and hard by those ignorant of natural science.]

The same in the *Dream of Scipio* [Somnium Scipionis], from Book 6 of *On the Republic* [De Republica]: "And to these has been given a soul, out of those everlasting fires which we call stars

[Margin: The whole universe consists of four elements.]

I.

— and constellations, which, being spherical and round, and animated by divine minds, complete their circles and orbits with wondrous speed." In the same place he seems also to have recognized that Venus and Mercury revolve around the Sun, for he calls them both companions of the Sun.

The same, concerning the whole system of things, he says: "The whole consists of earth, water, air, and fire, which it encloses within the outermost heaven, and within which it places the stars."

"For these reasons, then," he says, "the stars have come to be, which, passing through the heaven, turn back with a solstitial and a winter return, etc." This from Cicero, a few things out of countless.

IN SUPPORT OF A LIQUID HEAVEN — Testimonies from Seneca.

(*PRO CAELO LIQVIDO — Auctoritates ex Seneca.*)

In Seneca, in Book 7 of the *Natural Questions* [Naturalium Quaestionum], chapters 12, 13, 14, 15. Some of the ancients said that comets are generated from the mutual encounters of the wandering stars; and, to make this the more persuasive, they claimed that not only these five planets range through the aether, but that innumerable others are carried along unseen, and that whenever one comes up against another, the interval between them is lit up and set ablaze, and thus a long trail of fire is produced. All of these men, together with Seneca, suppose the heaven in which those wandering bodies range to be fluid. Against them, nonetheless, Seneca argues in various ways in chapter 15.

"After the death of Demetrius, king of Syria," he says — "whose sons were Demetrius and Antiochus — shortly before the Achaean War, a comet blazed out no smaller than the Sun. At first it was a fiery and ruddy disc, giving off a bright light, enough to overcome the night. Then gradually its magnitude was drawn in, and its brightness faded. Finally it wholly disappeared.

[Margin: The comet seen to equal the Milky Way.]

"How many stars, then, must come together to make up so great a body? You may crowd a thousand into one, and they will never match this appearance of the Sun. In the reign of Attalus, a comet appeared at first of modest size. Then it raised itself up and spread out and came all the way to the equinoctial circle, so that, stretched out to an immense extent, it equalled that tract of the heaven which bears the name of the Milky Way [Lactea].

II.

1 "How many wandering bodies, then, must have converged, to occupy so long a tract of the heaven with continuous fire?"

From these and other matters discussed there at length, it is clear that the substance of the heaven is supposed to be liquid, etc.

Although Artemidorus [Artemidorus] would have its outermost surface be hard, Seneca so demolishes him that he does not judge him even worthy of a reply. "This," he says (chapter 13), "of the falsehoods he tells (about comets, of course) is the slightest: his whole account of the world is a shameless lie. For if we believe him, the outermost surface of the heaven is utterly solid, hardened after the fashion of a roof, and of a deep and dense body, which heaped-up and piled-together atoms have made. Next to this is a surface of fire, so compacted that it cannot be dissolved or damaged. Yet it has certain vents, and, as it were, windows, through which fires flow in from the outer part of the world — not so great as to disturb what is within. And again they slip from the World into the outer regions. And so these things that appear contrary to custom, they have introduced out of that matter lying on either side of the world. To argue such things — what else is it than to flex one's fist and to fling one's arms into the wind?"

Then, however, from set purpose he attacks the hardness of the heaven through nearly the whole of chapter 14. But in favor of a liquid heaven he declares his own opinion throughout, in the whole volume of the *Natural Questions*. For he himself composes this universe out of earth, water, air, and pure fire or aether, in

which, as in a heaven, he locates the stars. Hear the man himself, Book 1, chapter 2:

"In the vicinity of the Sun and the stars," he says, "nothing of the sort can happen" (he is speaking of the region around the Sun) "because there the aether is thin.

"Book 2, chapter 4: The air, as I was saying, coheres both with the heaven and with the earth. In the same book, chapter 10: Its highest part is the driest and hottest, and for this reason also the most rarefied, on account of its nearness to the eternal fires, and to those so many motions of the heavenly bodies, and to the ceaseless revolution of the heaven, etc. For its upper regions feel the heat of the neighboring stars. In the same book, chapter 13: Nothing of the kind happens in the purest fire, in which there is nothing that can be pressed down." And afterward: "The order of things is such, and purified

I.

— fire, having been allotted the outermost margins in its guardianship of the world, most beautifully performs its tasks: from here it cannot depart, nor can it even be forced out from without: for in the aether there is no place for any uncertain body. He confirms the same in Book 6, chapter 16: 'This whole heaven,' he says, 'which the fiery aether, the highest part of the world, encloses — all these stars, whose number cannot be reckoned, this whole assembly of celestial things, and — to pass over other matters — this Sun, driving its course so near to us, and by no small measure larger than the whole compass of the earth: all of these draw their nourishment from the earth's exhalation, and share it among themselves, and are sustained, of course, by nothing else than the exhalation of the lands. This is their nourishment, this their food.'

[Margin: The heaven, or aether, the Sun and the stars are nourished by the earth's exhalation.]

"He drives home the same point in Book 2, chapter 2: 'From here (that is, from the earth) is brought forth that by which so many heavenly bodies are sustained — bodies so active, so eager, by day and by night, in their work as in their feeding. And the nature of all things indeed takes up as much nourishment for itself as is enough; but the world took up as much as it desired for eternity.'

"The same in Book 7, chapter 8: 'Comets, however,' he says, 'we see gliding through the upper regions, mingled with the stars.'

[Margin: He places comets in the heaven.]

"For I do not think,' he says (chapter 22), 'that a comet is a sudden fire, but that it is among the eternal works of nature.' And chapter 23: 'A comet,' he says, 'has its own seat: and therefore it is not quickly driven out, but serves out its own allotted span; nor is it extinguished, but withdraws. If it were a wandering star,' he says, 'it would be in the zodiac. Who sets a single boundary for the stars? Who compels the divine into a narrow space? Surely these very heavenly bodies, which you believe alone to move, have one circle after another. Why then should there not be some bodies which have withdrawn into a course of their own, remote from these? What reason is there why in some region the heaven should not be passable?'

[Margin: He refutes an objection.]

[Margin: The heaven everywhere passable.]

"And chapter 24: 'Consider whether this does not better befit the magnitude of the world — that it be divided into many paths, and not wear down this one track, while the other parts lie idle. There will come one,' he says (chapter 26), 'who will one day show in which regions comets wander, why they go so far apart from the rest, and how great and of what kind they are. We are content with what we have found: let posterity too contribute something to the truth.'" Thus far Seneca — from which

[Margin: He leaves much to be discovered by posterity.]

II.

— you may without doubt recognize the heaven to be liquid.

First, because he openly attacks — indeed derides — the hardness asserted of it by Artemidorus.

Second, because he makes the outermost surface of the universe to be the purest fire, which he calls the aether and the heaven.

Third, because he directly joins this to the air lying immediately beneath it.

Fourth, because he feeds both the heaven and the stars from the exhalation of the earth, carried up through the air.

Fifth, because he places comets in the heaven, wandering at any place and time — though not always visible — and makes it everywhere passable to their journeys, and consequently liquid.

From this, moreover — as I have often noted elsewhere — it is readily understood that the ancient writers, by the word "aether," for the most part signified some thin and fluid substance of the heaven.

Furthermore, if they say that the planets simply move in the heaven, whereas the stars are carried along; that it comes to the same thing; and that these latter are carried around as fixed, but the former travel freely on their own account — this contributes very greatly to the truth and to a sound understanding of the ancient writers, and is most necessary to observe.

[Margin: Pliny.]

PLINY [Pliny the Elder], *Natural History* [Naturalium Historiae], Book 2, chapter 5: "I do not see that there is any doubt about the elements, that they are four: the highest is of fire, whence come all those eyes of the shining stars. Next is Breath [Spiritus], which the Greeks and we alike call by the same word, air." The same, chapter 6: "Between this (the earth) and the heaven, suspended by the same breath, at fixed and separate intervals, hang seven heavenly bodies, which from their going we call the wanderers."

[Margin: Other writers, natural and philosophical.]

I pass over now Plutarch [Plutarch] in *On the Opinions of the Philosophers* [De Placitis Philosophorum], and others in Diogenes Laertius [Diogenes Laertius], Dio [Dio], Kedrenos [George Kedrenos], and many besides. This one thing — and as though it were a paradox — many bring forward and assert: that this doctrine, which is offered on the supposition of the phenomenon, is not repugnant to Aristotle; and that the doctrine which is now defended to the point of hoarseness as Aristotelian, concerning the incorruptibility of the heaven, is not Aristotelian except in name only — and that its advocates do not so much prove it as transcribe it from Aristotle himself.

THE MIND AND TEACHING OF ARISTOTLE on the Corruptibility of the Heaven, or against it.

(*MENS ET DOCTRINA ARISTOTELIS de Caeli corruptibilitate vel contra.*)

I.

[Margin: The mind and text of Aristotle on the corruptible and incorruptible heaven.]

Aristotle, *On the Heavens*, Book 1, text 113: "The corruptible and the incorruptible are treated alike. For either that which formerly was something, but afterward is not, or which admits of not being, we call corruptible — whether it undergoes corruption and change at some time, or not. And there is also that which through corruption admits of not being, which we call corruptible; and yet in another sense, that which is easily corrupted, which one might call easily corruptible.

"The same, text 114. And concerning the incorruptible the reasoning is the same. For either it is that which without corruption sometimes is and sometimes is not — as [in the case of] the things touched themselves, since, though formerly they were without corruption, afterward they are not. Or that which, though existing, is nonetheless capable of not being; or which is also not going to be at some time, but now exists: for you exist, and things touched exist now, but are nonetheless corruptible; because there will be a time when it will be true to say neither that you exist, nor that you touch these things. But most properly [is incorruptible] that which indeed is, but which it is impossible should be corrupted in such a way that, existing now, it should afterward not be, or should admit of not being. Or also that which is not yet corrupted, but admits of afterward not being. And that too is called incorruptible which is not easily corrupted.

"The same, text 121: It is impossible, then, that anything should both always be and be corruptible; and likewise neither generable: for of two terms, if it is impossible for the later to exist without the earlier — if this one is impossible to exist, so too is the later. Therefore, if that which always is does not admit of not being at some time, it is impossible that it should also be generable.

"The same, text 125: The ingenerable and the incorruptible are convertible.

"The same, text 133: It is manifest also in another way, that it is impossible that what is corruptible should not be corrupted at some time, etc.

"The same, text 134: It is possible to consider also in this way — that it is impossible that anything at some time made should be incorruptible —

II.

1 — [that it should] endure, or that what is ingenerable, and always previously existing, should be corrupted."

The same, Book 2 *On the Heavens*, text 1, etc. He subsumes these under the general propositions established, and says that the heaven is neither generable nor corruptible. Then often elsewhere he says that the motion of the heaven is

necessary and from eternity, and that it will never cease. As may be seen throughout the whole of chapter 10 of Book 1 *On the Heavens* — from which I judge it will not be unwelcome to the reader to copy out a few texts. In text 102, then, he writes thus: "To say that the world is generated, yet everlasting, is among the impossibilities." And in the whole of text 103 things very similar to these are reported. Text 104: "As for the assistance which some of them try to bring to themselves, who say that it is indeed incorruptible, but made — this is not true." And text 106: "That it is therefore impossible for it to be at once everlasting and made, is manifest." He asserts things in agreement at text 109. Indeed, in this whole chapter the Philosopher attempts to assert nothing else than that the incorruptibility of the world cannot stand together with its temporal production — a point which he presses most insistently right to the end of Book 1: and to the reading of these [texts] I urge the seeker of truth again and again.

From this it follows, first: If Aristotle, granting belief in God, had believed the heaven to be made by God in time, then according to his own doctrine he would have said outright that it is corruptible, and to be corrupted at some time.

[Margin: According to Aristotle's doctrine, granting the belief that the world was created, the heaven would have been simply corruptible.]

Second: If he had known the phenomenon of the Sun, he certainly would not have made it incorruptible. Hence,

Third: Those who — with Holy Scripture, with the Christian faith, and with so many and so great phenomena presupposed — nonetheless will have the incorruptibility of the heaven kept whole and intact, and this out of regard for and in favor of Aristotle, stray as far from Aristotle and from the truth as the eternal stands apart from the temporal.

For it is evident that Aristotle attributed to the heaven an eternal and necessary incorruptibility, an absolute indestructibility, a being without beginning or end — such as he grants to nothing created, etc. But this in passing: whoever has read Aristotle will see that I speak the truth: in confirmation -mation, greater [...] [?] — the opening word is cut off at the page break (fem. acc., governed by a verb in the preceding page: perhaps "[for their greater esti]mation"). I commend, out of many, a few of them — the foremost supporters and patrons alike of Aristotle and of the Peripatetics.

[Margin: Franciscus Suárez [Francisco Suárez], on Aristotle concerning the founding of the world.]

Francisco Suárez, *De Universo, seu de Opere sex dierum*, book 1, chapter 1, no. 2, pp. 3 and 4: "Many, he says, think that Aristotle consistently held the world not to have been made or produced by another, but to have had being of itself, everlasting. Others, however, believe that he was not unaware of the eternal dependence of the whole universe on God its Author — as on a first principle, from which it flowed, as it were, by a natural emanation." And afterward, p. 4, no. 3: "That principle, *out of nothing nothing comes*, cannot stand together with a true creation, whether one made freely and in time, or one conceived as eternal through a kind of natural emanation. Yet once that principle is granted, it could perhaps be said that Aristotle — either by way of doubt and problematically in disputation — said the principle could be denied, or at least that he denied it as regards natural emanation, even if he admitted it in its other proper operations: but by what usage this could be said, or by what reasoning it could hold up, I do not see."

[Margin: Gabriel Vázquez, on Aristotle's doctrine concerning the creation of the world.]

Gabriel Vázquez, vol. 1, q. 19, disp. 81, ch. 1, no. 3, p. 493, writes as follows: "Since Aristotle, in book 1 of *De Caelo* and book 8 of the *Physics*, holds the world to be eternal and unable to begin in time, he seems to have removed entirely the action of the first cause — or the action through intellect and will — in such a way that either the whole universe, as to its perpetual parts, was from itself, or, if from God, then it proceeded not by will but by the necessity of nature. For if Aristotle had thought the world to exist by God's will, he could easily have seen that it might have begun in time and was not necessarily from eternity. To me it seems highly probable, with Gregory of Rimini [Gregorius Ariminensis] in book 2, distinction 1, question 1, article 1, that Aristotle plainly held the intelligences of the heaven and the elements — and whatever he said to be from eternity — not to have been made by God; for Aristotle thought that *out of nothing nothing comes* (*Physics* 2, text 33), and hence at text 62 he proves that a subject is necessary out of which something may be made, and therefore that ma-[terial]

[Margin: The elements, and the things which Aristotle holds to be from eternity, do not depend on God, according to Aristotle, etc.] ...matter is unbegotten [*materiam esse ingentam*]. Read Gregory of Rimini."

[Margin: Pedro Hurtado de Mendoza, on the errors of Aristotle concerning the creation of the world.]

Pedro Hurtado de Mendoza, *de Opere sex dierum*, Disputation 3, section 1, §2, p. 376, says as follows: "Aristotle erred shamefully concerning God and the creation of the world; for in his physics he established the first cause from the repugnance of an infinity of successive causes, whereas in the book *De Caelo et Mundo* he judged the world to have existed from eternity, with a succession of motions." And a little after: "But that Aristotle asserted the heaven was not made is a madness so celebrated that it needs no refutation; and much less what he said — that God by a fatal necessity so moves the heaven that it cannot cease from motion."

Pererius [Benito Pereira / Benedictus Pererius], book 5, chapter 7, says: "It never entered Aristotle's mind to suppose creation out of nothing to be possible; nay, nothing more contrary to his doctrine can be found than creation, because Aristotle everywhere supposes *out of nothing, nothing comes to be*. And expressly, in *Metaphysics* 2, text 4, he says: *the principles of the things which always are have no cause*, etc. And so, since he held the world to have been from eternity, he seems thereby to have held that the world was necessarily and of itself; for at the same time he says that the world is ingenerable and unbegotten." These things Raphael [Aversa] reports summarily from Pererius, in volume 2, question 31, section 6, p. 18. Benedictus Pererius himself pursues them more fully in the passage cited, *De Communibus rerum naturalium principiis*, book 15, published at Rome in the year 1579 with the privilege of Gregory XIII. Therefore the same Pererius, in the passage cited: "What force, he says, has that argument by which, in book 1 of *De Caelo*, Aristotle refutes the opinion of Plato — who made the heaven born from some beginning but never to perish? *Everything*, he says, *which begins to be will at some time cease to be; for what is of such a kind is made out of matter, and hence corruptible; and what is corruptible will at some time be corrupted*. This argument, I say, what force has it, once creation is admitted? None at all." So Pererius.

Furthermore, these Aristotelian principles, and the eternity of the world understood in this way,

[Margin: The objection is answered.]

are refuted by some on this ground: that otherwise the mortality of the human soul would follow — something that ought not to be imputed to so great a Philosopher.

To this objection Pererius, book 12, chapter 19, p. 338, responds as follows: "Divine Thomas [Aquinas], who holds that even according to Aristotle the

intellect of man is immortal and is one in each individual man, sticks fast in the solution of this difficulty." And later: "For this reason many have dared to say that Aristotle contradicted himself in his two doctrines. For to make the intellect of man immortal, one in individual men, and again to establish the world as eternal, do not cohere with one another — like thread with thread, as the proverb has it; but since this question belongs to the books *De Anima*, let it be passed over here. This much only can be said at present: that by the aforesaid argument any Peripatetic is forced to confess one of these three things — either that Aristotle did not hold our souls to be immortal and severally multiplied according to the multiplication of men; or that he did not consider it absurd that there should be some infinite multitude of things lacking matter and mass, occupying no place; or, finally, that he imprudently and unknowingly contradicted himself. But which of these is to be thought and pronounced concerning Aristotle, it is not for this place to decide." Thus far Pererius.

[Margin: Aristotle falls into one of three absurdities.]

These same difficulties the often-praised Father Raphael Aversa has most recently examined on every side, in his *Philosophy*, vol. 2, question 57, section 5; and when he had brought into the open the various ways of speaking, both his own and others', at last, at the foot of p. 787, first column, he concludes thus:

[Margin: Raphael Aversa writes the same as Pererius.]

"But it is not only from the immortality of our soul, but universally from the succession of things through the whole eternity of the world (on Aristotle's view) that this difficulty arises — namely, how he could have posited the world from eternity and yet denied the infinite; for the multitude of things behaves the same whether it exists simultaneously or passes away successively. Therefore, concerning the infinite itself, at question 24, section 3, we have recited the various ways of speaking, tending either to the censure or to the excuse of Aristotle.

[Margin: Aristotle philosophized incoherently concerning the eternity of the world.]

And indeed anything else at all will be more tolerable than to attribute so execrable an error, concerning the mortality of the soul, to so great a Philosopher. It will be a lesser injury to him if he be said to have philosophized incoherently, by positing the eternity of the world and denying the infinity of things; or to have been ignorant how to satisfy these points, and therefore to have dissembled the difficulty; or to have preferred to allow the repetition of the same things and the

transmigration of souls; or to have gone too far in denying the infinite, while, universally in all things, he seemed to attack every infinite multitude — provided that the immortality of our soul be maintained on his own view, that of Aristotle." Thus far this great champion of Aristotle.

Whence astronomers are needlessly harassed, and are all but branded as architects of new dogmas, if — supposing the Christian Faith — they establish, together with the holy Fathers and on the strength of divine eloquence, that the heaven of the firmament, made by God in time out of another matter, is by its own nature corruptible, and if they further confirm this doctrine of theirs by the authority of Aristotle. For Aristotle, granting that the heaven began in time, at once inferred against Plato (as we heard a little earlier from Pererius) that it would also at some time, and indeed naturally, perish. And that this is Aristotle's serious and genuine philosophy has been sufficiently shown from the weightiest cited Peripatetic authors, and could be demonstrated from very many others as well.

There is therefore no reason for any mathematician to take offense if they acknowledge the heaven, made in time, to be corruptible — since this is Aristotle's own consequence, drawn from the hypothesis *of a heaven produced in time and not from eternity*; and, given this hypothesis, the contrary nature of an incorruptible heaven is utterly foreign to Aristotle.

Many also dispute much concerning the animation of the heavens and the stars, drawing on the mind of Aristotle, and from it try to infer the corruptibility and liquidity of the heaven. How much force or truth this has, I do not now wish to pursue: there will perhaps be another

place for examining these things. This much is most certain: that the liquidity of bodies in no way whatever impairs incorruptibility. For the bodies of the Blessed will possess their own blood, and that not at all corruptible; and the inner parts — of the chest, the lungs, the stomach, the viscera, and so on — will certainly not be empty, but will be filled with a certain heavenly, spirituous body, not perishable but eternal; and the Empyrean heaven itself, according to Divine Thomas [Aquinas] and the common teaching of the theologians, and the whole doctrine of the holy Fathers, will consist of a most subtle but incorruptible spirit.

[Margin: On Raphael Aversa's view, liquidity does not obstruct immutability, etc.]

In the same way, even if the stars moved of themselves in a liquid heaven, and cleaved the parts of the heaven as birds cleave the air and fishes the water, "yet that cleaving and division," (says Father Raphael, q. 32, sect. 6, p. 68) "occurring

part by part, if the heaven were fluid, would in no way prejudice the rest, nor its incorruptibility and immutability." Nay, the same author wants not only the Sun to be liquid and nonetheless incorruptible, as seen before, but attributes this very thing to all and each of the fixed stars, at q. 34, sect. 3, p. 135, where he discourses thus concerning their scintillation:

[Margin: And the Sun and all the stars of the Firmament are, on his view, liquid.]

"But what, after all, if someone should say that the stars are in very truth agitated and fluctuate in themselves, just as appears to sight itself? — namely by saying that they are not solid bodies, but fluid, contained within their own place as in a vessel, and thus flow in this way through the most rapid motion of the heaven itself. And especially that the Sun itself is so disposed, and is seen so manifestly, at all times and places, and above all through the telescope, to boil up, as it were — whereas nothing of the kind is seen, even slightly, in the Moon, which nevertheless we see through the same intermediate air.

[Margin: Raphael strongly inclines toward the nature of a fluid heaven.]

And this, moreover, would contribute not a little to saving the appearances of the Sunspots [*Maculis Solis*], of which we shall speak later in particular. All this, I say, someone could think. And perhaps it could not be refuted so easily as that position which made the heaven itself fluid."

Thus Raphael Aversa; who, although he does not absolutely follow this opinion of a liquid heaven, nevertheless does not utterly reject it, but seems to admit it at least as probable.

Furthermore, from Aristotle such passages are brought forward as, without any liquidity of the heavenly bodies, admit only a difficult explanation. Let some of them be heard.

[Margin: Passages of Aristotle adduced in favor of liquidity.]

"But of them, he says, in the second book of *De Caelo*, text 42: the things which are above — each is carried in its own sphere, so that they themselves are not ignited; but the air, since it exists beneath the sphere of the circularly-moved body, must necessarily grow hot when that body is carried around — and most of all where the Sun is fixed. These are Aristotle's words, to which he brings forward kindred things in book 1 of the *Meteorologica*, chapter 3, where he speaks thus: But for what cause heat arises, since those heavenly bodies are by no means of such a nature of themselves, must now also be stated. We see, then, that motion can separate and kindle the air to such a degree that, quite often, even the things set

in motion appear to be liquefied. Therefore, in order that warmth and heat be generated, the Sun's motion alone is enough to bring it about. For the motion must both be swift and not too far distant. The motion of the stars, accordingly, is swift, but far removed; that of the Moon is indeed downward, yet sluggish. But to the solar motion both of these belong abundantly. Moreover, that heat is generated chiefly together with the Sun itself is consonant with reason, drawn from the likeness of the things that happen here below. For when certain things here are carried by force, the neighboring air becomes most hot — which happens not without reason; for the motion of a solid thing can separate the air in the highest degree. Therefore, both on this account the fervor of heat is wont to press toward this region, and because fire, embracing the air, is by reason of its motion frequently separated and dissipated, and by force carried downward." From these passages of Aristotle, [certain] authors judge that the liquidity of the heaven can be sufficiently elicited. Among them, a certain most learned Scholastic comments thus: "When Aristotle, in book 1 of the *Meteorologica*, had asked why the Sun rather generates heat than the Moon or the stars called fixed, he answers that the body which is moved, or which generates heat, must be nearest and swiftly moved. The fixed stars, indeed, are swiftest, but most remote from the earth; the Moon, on the other hand, nearest, but slowest. But to the Sun these two belong: that it is both nea-[rer] and swifter; and that this is the cau-[se] -se why heat is moved together with the very body of the Sun. Whoever, then, wishes to judge that the Aristotelian hardness of the heavens is the case, let him try to satisfy this passage. I, for my part, find nothing I might answer."

The same Aristotle, book 1 of *De Caelo*, chapter 8, text 96: "Again, he says, in another sense the heaven is called the continuous body (τὸ συνεχὲς σῶμα [Greek: to synechès sōma, 'the continuous body']) at the outermost circumference, in which are the Moon, and the Sun, and certain of the stars; for we say that these are in the heaven." Then, in book 1 of the *Meteorologica*, chapter 4: "For fire, he says, is continuous with the element that is above, and air is continuous with fire." The Philosopher has things like these frequently. In the book *De Mundo* he says: "The substance of the heaven and the stars we call aether" — where many things are said on this matter; so much so that from Aristotle you would find nothing at all solid in favor of a rigid hardness of the heaven, which he does not even mention by so much as an express word; whereas in favor of the liquid, besides these, there are many other passages, perhaps to be explained elsewhere. For as to what fixes the stars firmly in the Firmament, this does not differ from that by which the same philosopher judges the matter of comets to be a slow exhalation tenaciously adhering to the liquid air, and which he nonetheless most

regularly snatches around, together with the air itself, in the first motion. But on these matters, con-[sult] ...consult the *Sol illustratus* [Solem illustratum — apparently a work- or figure-reference [?]], p. 74. Nor does Divine Bonaventure, adduced above, explain Aristotle otherwise, although he is Aristotelian in the highest degree. Albertus Magnus, too, favors it very much, when he interposes a breathable body [*corpus spirabile*] between the celestial spheres.

In Favor of a Liquid Heaven Stand the Egyptian Hieroglyphics

[Body rubric, verbatim: "PRO CAELO LIQVIDO stant Aegyptiorum Hieroglyphica."]

In Pierio Valeriano [Ioannes Pierius Valerianus], in the Lyons edition of 1586, there are two books appended, written by an anonymous but learned man in the year 1567. He, then, in Book 1, describes the Sun in the following words:

[Margin: An anonymous author, indeed, [drawing] from the secret signs of the Egyptians. He makes the heaven liquid.]

"The Sun, he says, they (the Egyptians) painted with a youthful and round face, and set it in a ship which a Crocodile bore. By the vessel they signified its motion in the moist — that is, in the aether, or in the intelligences. For many supposed the aether, too, to be moist, and that so long-lasting a motion could not take place in the dry, and they called the heavens watery. Whence, in the sacred writings, they are so often comprehended by David under the name of celestial waters. And by the Crocodile [they signified] rain-water, the cause of which is attributed to the Sun."

II. In Favor of a Liquid Heaven — The Authorities of the Astronomers. CHAPTER XXIX.

[Display heading, folio 755: "PRO CAELO LIQVIDO Auctoritates Astronomorum. CAP. XXIX." The centered numeral "II." above the title continues the enumeration of the classes of witnesses for a liquid heaven begun in the previous chapter (where the Egyptian hieroglyphics were adduced). Throughout these pages the small centered "I." / "II." and the marginal five-line numbers are the printer's column-and-line cross-reference apparatus, not section divisions, and are not reproduced in the running text.]

From the very beginnings of the cultivation of astronomy, it is beyond dispute that astronomers always held the heaven and the stars to be the most excellent part of the world. Yet the notion of that hardness — which for some centuries past has lodged in many minds on the occasion of the material spheres, the diagrams of the planetary theories, and the manner of speaking of certain astronomers — they always rejected. On the contrary, the astronomers' own monuments, or the documents handed down by others, plainly attest that they embraced a heaven most rarefied, most limpid, most subtle, permeable, yielding, and pervious to breath.

[Margin: The opinion that the heaven is hard is falsely fathered upon Ptolemy.]

Foremost among them I set Ptolemy [Claudius Ptolemy], with full justice, as their standard-bearer on the title-page, and now, as a prudent advocate, I vindicate him from the wrong so long inflicted on him by others. For they have all but crushed this innocent man, so long as these architects of the heavens load upon him — as upon an Atlas — their eccentric-epicyclic constructions of the higher bodies, tangled and undigested masses; and with a pen more bold than learned they set up Ptolemy not merely as the patron but even as the author of their own contrivances — Ptolemy, who thought nothing of the kind and wrote the very opposite. Nor do I trouble myself over what some have written, or said, who either did not read Ptolemy or did not understand him, but, following the common report of hearsay, reinforced in writing the opinion of those men whose error they ought rather to have corrected by sound teaching. Let us, then, free this just man from blame and burden — as much on the testimony of others as on his own most transparent confession.

[Margin: They free Ptolemy from the doctrine of a hard heaven.]

Saint Thomas [Thomas Aquinas], accordingly — a thoroughly fair judge, and one to be believed more than the words of any recent writer — settles this controversy thus, in Part One, Question 70, Article 1, in reply to the third objection: "It must be said that, according to Ptolemy, the luminaries are not fixed in the spheres, but have a motion of their own apart from the motion of the spheres."

[Margin: D. Thomas (Thomas Aquinas).]

So Saint Thomas frees Ptolemy from the hardness of the heaven, and does not force anyone else there to the same view, but disputes the matter as it were problematically, and leaves each free to follow what he wishes. Now let a second judge come forward.

[Margin: Dionysius Carthusianus (Denis the Carthusian).]

Dionysius the Carthusian [Denis the Carthusian], on Genesis chapter 1, article 10, upon the words "Let there be lights made in the firmament of the heaven," etc., writes among other things as follows: "Plato in the *Timaeus* says that the stars are not fixed in the firmament, but move and lead their dance within it, and in this Ptolemy followed Plato. Hence they say that it is not the heaven, but the stars of the heaven, that are moved and carried around." Ptolemy, then, will hereafter bear his burden more lightly, and be pressed no longer by a most hard heaven. Some bring in a third arbiter for us in their commentaries on Genesis, in these words: "That the stars are fed on vapors, whether drawn up out of the Ocean or such as the one draws from the other, was a most celebrated opinion among the ancients. And if the hardness of the heaven were adamantine, this could in no way hold good, since a most solid lunar orb would deny the vapors any passage. But what men do you suppose believed this? The most learned of all antiquity. Indeed John Lorinus [Juan Lorino], on 2 Peter chapter 3, cites Homer, Anacreon, Ptolemy, Virgil, Lucretius, Lucian, Pliny, Manilius — add Seneca, Metrodorus, Heraclitus, all the Stoics, all the Egyptians, and finally nearly all the philosophers, etc."

[Margin: Ioannes Lorinus (Juan Lorino).]

See, then, with how great a retinue and chorus of applauders does Ptolemy plead his cause for a liquid heaven!

Fourthly. Hieronymus Vielmus [Girolamo Vielmi] of Venice, *On the Six Days*, Lecture 20: "It is certain," he says, "that Ptolemy, the prince of astronomers, by no means affirmed the eccentrics and epicycles to be truly real; but

[Margin: Vielmus (Girolamo Vielmi).]

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he said them merely to satisfy — provided they were laid down for the purpose of discerning the effects of the wandering stars." Thus far he.

[Margin: Cornelius à Lapide (Cornelius a Lapide).]

A fifth judge is added, Cornelius a Lapide, who in his commentary on the Second Epistle of Saint Peter, chapter 3, after reviewing very many authors, says that Ptolemy in the *Quadripartitum* [*Tetrabiblos*] and others held that the stars are nourished by vapors, which, being taken away and burnt up at the end of the

world, will themselves perish, etc. But these things cannot stand without the liquidity of the heaven, etc.

But now let Ptolemy himself come forward into the midst and speak for himself. For he is 1498 years old, and, gray with much wisdom, still lives on; and (as he says in the preface to the *Almagest*) "a man's learning is the companion of his understanding, and his advocate among men." And: "He did not die who gave life to knowledge." Let us now hear Ptolemy himself, as, for the sake of winning the reader's confidence and goodwill, he pleads his cause yet further.

FROM CLAUDIUS PTOLEMY, *Almagest* (*Great Composition*), Book 13, Chapter 2

[Greek: Ptolemy, *Almagest* XIII.2. The passage is quoted in full in Greek, beginning:]

Καὶ μηδεὶς τὰς τοιαύτας τῶν ὑποθέσεων ἐργώδεις νομισάτω, σκοπῶν τὸ τῶν παρ' ἡμῖν ἐπιτεχνημάτων κατασκελές. οὐ γὰρ προσήκει παραβάλλειν τὰ ἀνθρώπινα τοῖς θεοῖς, οὐδὲ τὰς περὶ τῶν τηλικούτων πίστεις ἀπὸ τῶν ἀνομοιοτάτων παραδειγμάτων λαμβάνειν. (τί γὰρ ἀνομοιότερον τῶν αἰεὶ καὶ ὡσαύτως ἐχόντων πρὸς τὰ μηδέποτε; καὶ τῶν ὑπὸ παντὸς ἄν κωλυθησομένων, πρὸς τὰ μηδ' ὑφ' αὐτῶν;) ἀλλὰ πειρᾶσθαι μὲν, ὡς ἔνι μάλιστα, τὰς ἀπλουστέρας τῶν ὑποθέσεων ἐφαρμόζειν ταῖς ἐν τῷ οὐρανῷ κινήσεσιν, εἰ δὲ μὴ τι προχωροίη, τὰς ἐνδεχομένας. ἐὰν γὰρ ἅπαξ ἕκαστα τῶν φαινομένων κατὰ τὸ ἀκώλυτον τῶν ὑποθέσεων διασώζηται, τί ἂν ἔτι θαυμαστόν ποτε δοκοίη τὸ δύνασθαι τὰς τοιαύτας συμπλοκάς ταῖς τῶν οὐρανίων κινήσεσι συμβεβηκέναι, μηδεμιᾶς ὑπαρχούσης παρ' αὐτοῖς φύσεως κωλυτικῶς, ἀλλὰ συμμέτρως πρὸς τὸ εἶκιν, καὶ παραχωρεῖν ταῖς κατὰ φύσιν ἐκάστων κινήσεσι, κἂν ἐναντία τυγχάνωσιν, ὡς πάντα διὰ παντὸς ἀπλῶς τῶν χ[υ]μάτων [σχημάτων? [?]] διικνεῖσθαι καὶ διαφαίνεσθαι δύνασθαι· καὶ μὴ μόνον περὶ τοὺς κατὰ μέρος κύκλους τὸ τοιοῦτον διοδεύειν, ἀλλὰ καὶ περὶ τὰς σφαίρας αὐτὰς καὶ τοὺς ἄξονας τῶν περιφορῶν, ὧν καὶ αὐτῶν τὴν ἐν ταῖς διαφόροις κινήσεσι συμπλοκὴν καὶ ἐπαλληλίαν ἐν μὲν ταῖς κατασκευαζομέναις παρ' ἡμῖν εἰκόσιν ὡς ἐργώδη καὶ δυσπαραδείκτον πρὸς τὸ τῶν κινήσεων ἀκώλυτον, ἐν δὲ τῷ οὐρανίῳ μηδαμῇ μηδαμῶς ὑπὸ τῆς τοιαύτης μίξεως ἐμποδιζομένων· μᾶλλον δὲ καὶ αὐτὸ τὸ ἀπλοῦν τῶν οὐρανίων οὐκ ἀπὸ τῶν παρ' ἡμῖν οὕτως ἔχει δοκούντων προσήκει κρίνειν, ὅποτε μηδ' ἐφ' ἡμῶν τὸ αὐτὸ πᾶσιν ὁμοίως ἐστὶν ἀπλοῦν. οὕτω γὰρ σκοποῦσιν οὐδὲν ἂν δόξειε τῶν κατὰ τὸν οὐρανὸν γινομένων ἀπλοῦν, οὐδ' αὐτὸ τὸ τῆς πρώτης φορᾶς ἀμετάστατον· ἐπειδὴ

καὶ τοῦτο αὐτὸ, τὸ πάντα τὸν χρόνον ὡσαύτως ἔχον, ἐφ' ἡμῶν δυσχερές, ὃ
ἐστὶ οὐ δύσκολον μόνον, ἀλλὰ καὶ παντάπασιν ἀδύνατον. οὐκ ἐνθένδε
γοῦν, ἀπὸ δὲ τῆς τῶν ἐν αὐτῷ τῷ οὐρανῷ φύσεων καὶ τῆς τῶν κινήσεων
ἀμεταβλησίας κρίνειν δεῖ· οὕτω γὰρ ἂν πᾶσαι καὶ φανείησαν ἀπλᾶι, καὶ
μᾶλλον ἢ τὰ παρ' ἡμῖν οὕτως ἔχειν δοκοῦντα, μηδενὸς πόνου μηδὲ
δυσχερείας τινὸς περὶ τὰς περιόδους αὐτῶν ὑπονοηθῆναι δυναμένων.]

[Ptolemy's Almagest XIII.2, in Scheiner's facing Latin rendering — the definitive text, here Englished:]

And let no one think hypotheses of this kind laborious or hard to grasp, put off by a certain dryness that seems to attend our discoveries. For it is not fitting that human things be compared with divine, nor that the opinion we hold about divine things be shaped by setting before ourselves human things — utterly unlike them — as patterns or exemplary forms. (For what greater unlikeness could be found than between things that are eternal and remain forever in the same state, and things destitute of both these qualities? and again, between things driven about on every side by others, and things that suffer no hindrance either from others or from themselves?) We must rather strive, so far as we can, to fit hypotheses as simple as possible to the celestial motions; and if this is frustrated of the wished-for success, then we must accept and admit whatever suppositions can be found suitable. For if every single phenomenon is fully saved, according to the assumed hypotheses, without any hindrance, it ought not to seem strange or incredible to anyone that the same combinations may be found in the motions of the heavenly bodies — especially since their nature has no power whatever to resist, but adapts itself with the greatest proportion and ease, and gives place by yielding to motions that follow nature, even if these prove contrary to one another, so that all the fluxes can permeate and pass through any others whatever. And this ease of the moving bodies in passing through the medium belongs not only to the several circles, but also to the spheres themselves and to the axes of the revolutions; and whereas in the models we have devised we see their mutual entanglement and intermixture in diverse motions, and their alternating interchange, to be laborious and hard to determine if the freedom of the motions is to be preserved — yet in the celestial bodies no hindrance at all arises for anything from such intermixture of circles, of spheres, or of axes.

Moreover, that the simplicity of the celestial things is not to be judged from the things that appear such to us is plain from this: that among us there is no like agreement about the simple itself; so that, for those proceeding in that fashion, it would follow that nothing simple could be found in the heaven, nor the

unchangeable revolution of the first motion itself — since to find among us anything that keeps forever the same state is not merely difficult but simply impossible. We must judge, therefore, not from things here, but from the natures existing in the heaven itself, and likewise from the unchangeableness of the motions. For so judged, they will all appear to us simple — and more truly so, indeed, than the things that seem such among us — every suspicion of toil and difficulty about their periodic revolutions, to which they might seem liable, being set far aside.

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[Margin: The fluid Sun renders the stars [fluid], &c. [reading uncertain] [?]]

SCHOLIUM

From these words you have, first, that Ptolemy in express terms denies the substance of the celestial bodies to be hard or resistant, but affirms it to be soft, pliable, flexible, yielding, offering no obstacle to axes, circles, or spheres, and permeable to any moving bodies whatever.

[Margin: A fluid heaven is gathered clearly enough from this [?].]

Secondly, that for this reason it makes no difference even if axes are entangled with axes, circles with circles, spheres with spheres, all together — the celestial motions so requiring it; for not on that account is any motion brought to a standstill [*vel motum ... stitum*, one word uncertain [?]], nor are the celestial bodies penetrated, since the stars, as has been said, are carried without any resistance through those [heavens], which yield of their own accord.

Thirdly, that although in these gross and material sublunary bodies it is difficult for such things to happen, or to be represented, without mutual obstruction, nevertheless — if, once these Ptolemaic hypotheses are found, the celestial bodies correspond to them in their motions — it must not be doubted that there it does so happen. Yet no argument is to be drawn from these material bodies to those celestial ones: for our bodies, on account of their hardness, struggle against and resist one another; but there, in a rarefied matter, all things at once give place to one another without any counter-effort, and so the motions are carried out unharmed, without any penetration of bodies.

Fourthly, that no argument is to be made from these lower natures to those higher ones, he confirms from this: that otherwise the very simplicity of the heaven would be done away with.

Fifthly, let those especially take good note of this who, under the pretext of defending and championing the Ptolemaic system, contrive an inextricable hardness of the heavens; for these men flatly contradict Ptolemy. For Ptolemy does indeed acknowledge the mutual intermixtures of his theories, in the circles, in the axes and poles, and in their motions; yet he rejects any positing of hard celestial bodies, and avoids the retardation of their motions by this alone — that he makes the celestial bodies fluid, and indeed, on account of the subtlety of their nature, wholly without resistance, yielding to the moving stars. And this is to acknowledge a flowing and flexible heaven. Such men, therefore, do not follow Ptolemaic astronomy, but thrust upon us a new structure of the heavens, unknown to the ancient astronomers — the mere fancy, in truth, of their own brain.

Sixthly, it is plain from this that the Tychonic hypotheses are in this respect akin to the Ptolemaic, since Tycho [Tycho Brahe] likewise builds in the entanglements of the celestial motions, yet by liquidity alone avoids all the absurdities.

[Margin: Venus and Mercury revolve around the Sun. [faint and mirror-reversed — likely show-through from the un-imaged folio 758; not committed] [?]]

Seventhly, that Ptolemy, both here and in chapter 1 of the First Book, proclaims the celestial bodies divine and immutable — in this he does the same as Plato and all the Platonists,

[The seventh point breaks off here; it continues on folio 758, which is not present in this scan — see the QA note on the duplicated page below.]

[Margin (inner/left margin, faint printed gloss, largely illegible) [?]]

which, in accordance with nature, yield place to the motions by giving way, even if they are found to be mutually contrary, so that all the currents [*fluxus*] are able to pass through and pass across any of them whatever. And this ease of the moving bodies in overcoming the medium belongs not only to the particular circles, but also to the spheres themselves and to the axes of the revolutions. In their diverse motions we see their mutual and reciprocal interweaving and intermixing — in the models [*imagines*] that we have constructed — to be laborious and difficult to determine, if the freedom of the motions is to be preserved; but in the heavenly bodies no hindrance at all is introduced to any of them from any such intermixing of circles, spheres, or axes.

Furthermore, that the simplicity of the heavenly bodies is not to be judged from the things that appear such to us is clear from this: that among us there is no like

agreement about the simple itself. So, proceeding in this way, it would turn out that nothing simple could be found in the heaven, nor the immutable revolution of the first motion [*prima latio*] itself; since to find among us something that always remains in the same state is not merely difficult but flatly impossible. We must therefore judge not from this, but from the natures existing in the heaven itself, and from the immutability of the motions. For in this way they will all have appeared to us simple — indeed more so than the things that appear such among us — with all suspicion of labor and difficulty concerning their periodic revolutions, to which they might seem liable, set far off.

Scholium.

From these things you have, first: that Ptolemy [Ptolemaeus], in express words, denies that the substance of the heavenly bodies is hard or resistant, but affirms it to be soft, tractable, flexible, yielding, and — without any obstacle — penetrable by axes, circles, spheres, and any moving bodies whatever.

Second: that for this reason it makes no difference even if axes are interwoven with axes, circles with circles, spheres with spheres, all at once, the celestial motions so requiring; yet not for that reason is either the motion halted [*motum [sisti?] [?]*], nor are the heavenly bodies penetrated —

[continues in col. "II."] — since the stars are borne, as has been said, without any resistance, the [heavens] yielding to them of their own accord.

Third: although, in these physical, sublunary, gross and material things, it is difficult for these [interweavings] to happen or be represented without mutual impediments, nevertheless, once these Ptolemaic hypotheses have been found and the heavenly bodies correspond to them in their motions, there must be no doubt that there it does happen so. Yet the argument must not be carried over from these material things to those [celestial ones]; for our things, on account of their hardness, struggle and resist one another, whereas there, in the fine matter, all things at once give way to one another without any resistance, and thus the motions occur unharmed, without any penetration of bodies.

Fourth: that one must not argue from these lower natures to those higher ones, he confirms from this — that otherwise the simplicity of the heaven would also be destroyed.

Fifth: from this too let them observe these things well, especially those who, under the pretext of defending and championing the Ptolemaic system, contrive an inextricable hardness of the heavens; for they are diametrically opposed to

Ptolemy. For Ptolemy does indeed acknowledge the mutual intermixings of his Theorics — in the circles, in the axes and poles, and their motions — yet he rejects the positions of hard heavenly bodies, and thus avoids the retardations of their motions by this alone: that he makes the heavenly bodies fluid, and indeed, because of the subtlety of their nature, yielding to the moving stars without any resistance. But this is to acknowledge a flowing and flexible heaven. These men, therefore, do not follow Ptolemaic astronomy, but obtrude a new structure of the heavens, unknown to the ancient astronomers — the fancy, no doubt, of their own brain.

Sixth: hence it is clear that the Tychonic hypotheses are akin to the Ptolemaic in this respect, since Tycho [Brahe] too builds in the interweavings of the celestial motions, yet by fluidity alone avoids all the absurdities.

Seventh: as for Ptolemy's proclaiming, both here and in chapter 1 of the first Book, that the heavenly bodies are divine and immutable — he does the same as Plato and all the Plato-

—nists, who nonetheless acknowledge that these same [heavens] are made and compounded out of the elements. That Ptolemy was a follower of Plato you have from the witnesses already cited, and from his very own books.

[Margin: This same thing the Peripatetics proclaim concerning Ptolemy.]

To this opinion about Ptolemy a most recent author subscribes: Fr. Raphael Aversa, published at Rome in the year 1627, in volume 2 of his *Philosophy*, question 33, section 1, page 76, where he speaks thus:

[Plato in the *Timaeus* taught that the heaven consists of all four elements, but of the purer parts of them, and that it partakes more of earth and fire. So too Alcinous reports, chapter 12, *On the Doctrine of Plato*. And moreover, among the later Philosophers, he was followed by Plotinus and Ficinus [Marsilio Ficino] on the *Timaeus*; by Philoponus, in his book *On the Eternity of the World against Proclus*; by Pliny, in the second book of the *Natural History*, chapter 8; and by certain others. Furthermore Ptolemy, in book 1 of the *Quadripartite* [*Tetrabiblos*], and other Astronomers seem to hold the same view, that the heavens consist of all the elements.] The truth of what has been said is therefore established even by the Peripatetics themselves — namely, that Ptolemy never acknowledged a Fifth Essence [Quintam essentiam], and so forth.

Opinions in favor of a liquid heaven [Sententiae pro caelo liquido]. Vitruvius adds his assent.

From Marcus Vitruvius [Vitruvius], who dedicated his books to Caesar Augustus, these passages are excerpted, book 9, chapter 4:

[Margin: Venus and Mercury revolve about the Sun.]

[Now the stars of Mercury and Venus, wreathing the Sun itself with their journeyings as though about a center around the Sun's rays, make retrograde returns backward and retardations, and, by that circling motion, they also linger in stations within the spaces of the signs, etc.]

From this you have that the revolutions of Venus and Mercury around the Sun are not new [inventions] [?], nor figments of Tycho, nor contrivances [*inventae*] [?] of Galileo, but the doctrines of the ancient Astronomers. Next the same author goes on to describe the inequality of the apparent motions, the retrogradations, the delays, the swifter accelerations, and so on; the cause of all which he ascribes not to eccentric orbs — which he did not recognize — but to the hot

[continues in col. "II."] traction [*tractio*] of the Sun, in these words:

[Margin: The fiery Sun draws the stars, etc.]

[This account, then, will rather hold good for us: that heat, just as it summons all things and draws them to itself (as we also see the fruits rising up from the earth to a height by warmth, and no less the vapors of water drawn up from the springs to the clouds through arcs), by that same principle the vehement onset of the Sun, extended by its rays in the form of a triangle, draws to itself the stars that follow after, and, reining in and holding back as it were those that run on ahead, does not suffer them to advance, but forces them to move back toward itself and to enter the sign of the next triangle. Perhaps one will want to know why the Sun produces these retentions in these heats rather at the fifth sign from itself than at the second or third, which are nearer. I will set forth how this appears to come about. Its rays are drawn out in the world along lines in the form of a triangle with equal sides; and this is neither more nor less than to the fifth sign from it. Therefore, if the rays, poured through the whole world, wandered in circlings and were not extended in projections to the form of a triangle, the nearer places would blaze up. And this too Euripides, the poet of the Greeks, seems to have observed; for he says that the things that were farther from the Sun burned more vehemently, but the nearer ones were kept more tempered, etc.]

[Margin: A liquid heaven is sufficiently inferred from this.]

Then he gives the reason why the planets nearer the Sun complete their own proper course more quickly, and the more remote ones more slowly:

[Just as, he says, if upon the wheel that potters use seven molds were set, and as many channels made in the wheel, arranged around the center at the bottom, increasing toward the rim, in which these [molds] were compelled to make a circling motion, and the wheel were turned in the other direction, it would be necessary that they, none the less, move against the wheel's rotation along their own paths; and that whichever had the nearer position to the center should travel around more quickly, while whichever ran the outermost circuit of the wheel, even though it moved equally fast, should, because of the magnitude of its circuit, complete its course much more slowly. In like manner the stars, striving against the motion of the World, complete their circuit along their own paths, but by the rotation of the heaven they are carried back in overflows [*redundationes*], in the daily circulation of time.]

From these things it is clear that they [the planets], freely, by their own proper motion, [are] not

fixed and [so] borne along, but he goes on. [That there are temperate stars, others hot, and also cold, this seems to be the cause: that all fire has, in the higher regions, a flame that climbs upward. Therefore the Sun, burning with its rays the aether that is above itself, makes it glowing; and in those regions the star of Mars has its course, and so, being hot, it is made so by the burning of the Sun. But that of Saturn, which is nearest to the outermost edge of the world and touches the frozen regions of the heaven, is exceedingly cold; and from this Jupiter, since it has its course between the circuits of the two, from their cold and heat in the mean, seems to have suitable and most temperate effects. Concerning the Zone of the twelve signs, and of the seven stars, and their contrary working and course — by what principles and numbers they pass from signs into signs and complete their circuit — I have set forth as I received it from my teachers.]

[Margin: Vitruvius reports these things from the tradition of his teachers.]

Notes [Notae].

From this, again, it is given to understand that the ancient Mathematicians judged the seven planets to be not only wandering, but also freely moved in the aether; and that the aether itself, kindled by the burning of the Sun, glowed white-hot as it were; and that, by the solar rays, the remaining planets were held now checked, now driven forward, now drawn back; and that their nature was either cold, or tempered to a mean. And finally, that the outermost parts of the world, beyond the Saturnian region, bristled with frost — this too from their doctrine.

Similar things about the drawing force of the Sun through its rays many of the ancients write, among them Isidore [Isidorus], in the third book of the *Origins* [*Etymologiae*], chapter 22, these lines from some one of the ancient poets:

— The Sun divides the seasons, and changes day with night, and with its potent rays forbids the stars to go, and by a halt delays their wandering courses.

For a liquid heaven [Pro caelo liquido]: the same things are proved from Hyginus.

Gaius Julius Hyginus [Hyginus], a freedman of Augustus, who flourished about the time of Christ's birth, in the first book of his *Poeticon Astronomicon*,

[continues in col. "II."] when he had enumerated in a brief Synopsis the things he had written, [says: Next, we have described in full whether the Sun is turned, fixed together with the World, or whether it is moved by itself; and whether [each of the planets] [?] is moved by itself, and moves against the rising of the 12 signs, so as to rise and set together with the World.]

[Margin: The Sun moves by itself, freely.]

The same author, in the fourth book, *On the Sun and Moon* and the other planets, proves at length that they are moved by themselves, and are not fixed to the heaven as the fixed stars are wont to be. [But as I said before, he says, we will now speak straightway of the Sun's course. For it is necessary that the Sun either be moved by itself, or, turned together with the World, remain in one place. But if it remained, it would necessarily set and rise in the same place from which it had risen the day before, just as the signs always rise and set in the same place. Besides, if it were so, days and nights would necessarily all be equal, so that however long today's day was, just so long it would always be. Likewise the night would, by the same reasoning, always remain equal. Since this is not so, this too is necessary — seeing that we observe the days to be unequal, and the Sun about to set today in one place, and to have set yesterday in another. If, then, it rises and sets in different places, it must necessarily be moved, and not stand still. And that the Sun runs counter to the motion of the World, we can understand as follows;] and so on.

[Margin: According to the ancients, the planets are moved in the heaven, as a sailor in a ship, etc.]

Here he proves at length, both of the Sun and of the Moon and the other five planets, a free motion; and he brings forward the example of a sailor walking

from the prow of a running ship toward the stern. Thus he says that the Sun and the planets, in the heaven turned from east to west, perform their own proper courses in the contrary direction. Here note well that the Holy Fathers often cite the words of this very author, and prove, in the same sense and manner, that the planets are borne in a liquid [medium], etc. From which it is rightly inferred that they held exactly the same, as regards this controversy, since they declared their opinions in the same words.

[Margin: The Holy Fathers often use the words and arguments of Hyginus.]

From the Paraphrase of Aratus [Ex Arati paraphrasi].

The same things are contained in the Fragment of the *Phaenomena* of Aratus, with Germanicus Caesar as translator, in which, upon that verse "From Jove the beginning," etc., he asks why the poet began from Jove, and he answers in these words:

[Crates says that Jupiter is called "heaven," and is rightly invoked, "because in the air and the aether are the stars." And not long before the end, after the last verse, "These same signs the Fishes [Pisces] will give you, not in vain." The Sun, he says, is agreed to move by itself, and not to be turned together with the World, but to traverse its course in the obliquity of the Zodiac circle,]

[continues in col. "II."] as we said a little above. And afterward: [The Sun, meanwhile, since it is fiery, grows still hotter from the excessive motion of its revolution; and its fire, the philosophers say, is nourished by water, and receives the power of its light and heat from the contrary element, etc.] From this author too, many of the Holy Fathers appear to have borrowed their words, and so on.

From Manilius, similar things are sung in favor of a liquid heaven [Ex Manilio similia pro caelo liquido accinuntur].

Marcus Manilius [Manilius] — whom others call Gaius Manilius — who flourished not long before the birth of Christ, sang of the liquidity of the heaven far more elegantly than others, in various places of his *Astronomica*. Not long after the beginning he sings thus:

Page 5:

Fire, on the wing, lifted itself into the aethereal breezes, and, embracing the topmost summits of the starry Heaven, made the ramparts of Nature with a rampart of flames. Next, air came down into thin breezes, and

spread the middle region through the void spaces of the World. The breath of wind feeds the fire, set beneath the neighboring stars, etc.

Page 6:

For unless the earth hung poised by balanced weight, the Sun [Phoebus] would not drive its courses beneath the rising stars toward the west, and would never come back again to the east, nor would it guide its submerged courses through the void. Nor would the Morning-star [Lucifer] shine in the morning hours — the Evening-star [Hesperus], which had given its light to sunken Olympus. Now, because the earth is not cast down into the lowest deep, nor hangs suspended in the middle, all things are passable.

Page 7:

Nor indeed should the nature of the hanging earth seem to you a thing to marvel at, since the World itself hangs and sets its footprints upon no floor; where it might fall, the heaven comes beneath, and it rises up again. This is plain from its very motion, and from the course of the flying [World]: since Phoebus goes suspended, and bends back its course this way and that, and keeps its nimble turning-posts in the aether; since the Moon and the stars flit through the void of the World. The earth too, imitating the airy laws, has hung. The Earth, therefore, is allotted a hollow in the middle of the air, and is suspended equally in the whole deep, not stretched out into open expanses, but formed into a globe, rising up on every side alike, and alike falling away. This is the face of nature.

Book 1, page 15:

There are other stars, fighting against the World in the opposite direction, which hang, flitting, between heaven and earth: those of Saturn, of Jupiter, and of Mars, and of the Sun; beneath these Mercury drives on, set between Venus and the Moon.

PART II, Cap. XXIX (continued)

**

Only do not look for shapes resembling bodily forms, nor for every limb ablaze with an equal color, so that nothing is lacking and no part stands

void of light. The world could not endure such vast conflagrations if all the stars were to burn with their members full. Whatever nature has withdrawn from the flames, she has spared, lest it sink beneath the burden — content only to mark out shapes and to display the constellations by fixed stars. The fiery form marks them out, and fires answer to fires, and so on.

[Citation: Book I, p. 17.]

That the Sun never runs crosswise toward the Bears, nor changes its paths and turns its course toward the east, and never shows a new dawn dawning upon new lands; that the Moon never oversteps the fixed circles of her light, but keeps the measure by which she waxes and by which she wanes; that the stars, hanging in the sky, never fall to the earth, but the constellations, measured out, run their course through their own signs — this is no work of great chance, but the Order of the Godhead. These stars, then, weave with even course, paneling the heaven with their fires into varied forms. Nothing is higher than these; these are the summits of the World.

This author, then, is outstanding: he has embraced everything concerning the Heaven, the Sun, and the stars so clearly, so roundly and so elegantly that no other interpretation is needed. He is unfortunate in this one respect only — that he fell in with that bold and supercilious critic, Joseph Scaliger [Iosephus Scaliger], who, taking on a subject too heavy for his shoulders, passes judgment without competence, condemns what he fails to understand, and, while chastising and cruelly mangling a most learned poet, himself above all deserves the censor's rod. But I say this only in passing, lest others put too much trust in those notes of his. I shall perhaps say something more specific on the point, if God grants me life and time; for it is only fair to honor the ancients who have deserved well of letters, not to tear them to pieces.

FOR THE LIQUID HEAVEN

The same points are adduced from the *Philology* of Martianus Capella.

Martianus Capella — who, according to the Chronology of Giuseppe Biancani [Iosephus Blancanus], flourished a little before the Emperor Heraclius, in the sixth century of the Christian Era, that is, about a thousand years ago — in the eighth book of his *Philology*, in language brief but no less fertile than eloquent, makes the heaven, as regards the thing itself, one and continuous, of pure and

fluid ether; but he says that the circles and imaginary spheres are fashioned by the mathematicians on account of the variety of the motions of the planets that trace them out within it, and so forth. But it is better to hear these things from the Author himself. And so, in his chapter *On the World*, he speaks as follows, bringing in Astraea as the speaker:

Although at the very threshold of building up [my account] I would not disdain to give ear to the natural philosophers — who hold that the delicacy of subtle bodies, drawn around by their own compressions, is not parceled out into certain divided paths and intervals of circles, but that the natures, clinging to their own waves, are diffused on every side, in a globular sweep and in orbs; around whose center — which they have called the *centron* — he records first the swell [*cyma*] of water, next that of air, and third that of fire; and now, by a certain fifth tempering of corporeal substance, the ethereal fires flying about — the region in which the obliquity of the Sun, the Moon, and of the sign-bearing [zodiacal] orb wheels itself around, and so forth; whose tranquil nature also holds that outermost and wider course, which — from the fact that it is marked by no stars — is called ἀναστρος [Greek: *ánastros*, "starless"]. If, then, the whole compass of the revolving [bodies] is found uniform, like itself, no circles can vary the ethereal course.

[Margin: In Capella's time the natural philosophers held the heaven to be one and continuous.]

We, therefore, shall speak of circles not so as to imagine bodily divisions that abandon the [uniform] nature, but so as to demonstrate the ascents and descents of the wandering [stars] toward us. For I will not attribute to the strength of the world's frame either an axis or poles — which mortals have fixed upon the bronze sphere, called the *Circite* [?], as aids to understanding — since there is nothing more solid than the earth that might support it. Then, [it is supposed] that the poles project as though from the hollows of a pierced outer sphere, and that certain gaps and pivots are imagined — which surely, it is agreed, could not befall subtle and ethereal things. [Margin: Only the earth is hard; the heavens are fine.] Wherever, then, for the purpose of understanding and exposition, I shall speak of an axis, or poles, or circles [Margin: Circles, axes, poles are imaginary.], let it be managed by a certain ideal prudence — distinguished not by any diversity of the heaven, but by considerations of the spaces. And so let it be understood [Margin: The heaven is continuous.] when I call the world convex and sloping: since it is uniform

in all its parts, and is raised aloft or lies hidden according to the condition of the horizon and the position of the lands.

[Margin: * Perhaps read "*secum*" (in place of "*secus*").]

SCHOLIUM

From this it is evident that, in this author's opinion, the ether is continuous and of a fiery nature, and is distinguished only by the motions of the planets, not in reality itself. Here note that, when the text says *Linquentes* ["abandoning"], it seems to some a corruption, in place of which one should perhaps read *Liquentis* ["flowing"] — which renders the author's meaning perfectly plain, whereas the former makes it most obscure and the Latin phrasing most difficult.

And in his chapter on the orbs of the Planets he draws this distinction between the fixed stars and the planets: that the former are carried around together with their sphere, while the latter are borne freely by their own motion.

Of these seven [he says, meaning the planets], this above all is the difference to be reckoned between them and the fixed stars: that the fixed stars, adorned with their own station, are moved only by the courses of the heaven, whereas the planets are both swept off by the world's motions and moved by their own courses. For as much as the rotation of day and night carries them back, so much do they strive to make up by their differing periods — that is, either by a month, as the Moon; or by a year, as the Sun; or by thirty years, as Saturn; and by the other periods assigned to each, according to the breadth or the shortness of the spaces they traverse. All these stars, though they seem to move toward the east, nevertheless do not push against the world with a rigid motion, but work their way obliquely, fixed along the Zodiac. Otherwise, given the contrary motion of its parts, the world could not stand firm. Finally, even the doctrine of the Peripatetics maintains that these stars are not driven forward against the world, but are left behind by the speed of the world, which they could not keep pace with. And even granting this to be true, it cannot conflict with my reasonings. [Margin: The retardation [of the planets] was known also to the ancients, and ascribed to the Peripatetics.] For whether Saturn, vying with the World in its great speed, is barely overtaken by [its] slight courses, while the Moon, because it moves more slowly, is passed by the same part of the World within the thirtieth day; or whether, on the view that [the planets] strive against the World, the Moon is faster because it circles its orb in a

shorter compass, and Saturn slower because of the breadth of its outspread orb — whichever you prefer, it does not stand against my rules, since their motion is regulated by these accounts. Yet these seven stars have one motion in common — that they all make for the east; and another [common trait] — that they all vary with the diversities and accidents of the seasons. For of these, five stars undergo stations and retrogradations, while the Sun and Moon are swept along in continuous course. Likewise these two luminaries are hidden by the alternations of the things that darken them [i.e., in eclipse]; but the five stars cannot be shadowed. Three of them, moreover, together with the Sun and Moon, go around the globe of the earth; but Venus and Mercury do not encircle the earth.

And later:

And this must be observed generally of all seven: that although the world is turned by the uniform rotation of one and the same sweep, the planets daily seize both their positions and the varieties of their circles, and so forth.

And later:

For although Venus and Mercury display daily risings and settings, their circles do not encircle the earth at all, but revolve around the Sun in a wider compass. Finally, they set the center of their circles in the Sun, so that at times they are borne above it [Margin: Venus and Mercury move around the Sun.], but for the most part within it, and thus nearer to the earth — while Venus is separated from it [the Sun] by one sign and a half. But when they are above the Sun, Mercury is nearer to the earth; when below the Sun, Venus — inasmuch as it curves in a purer [?] and more diffuse orbit.

And at the end of the book:

But the varieties of their course, and the causes of their [changes of] altitude — of standing still, of retrograding, and of advancing — are brought about, in all the aforesaid [planets], by the shining ray of the Sun, which, striking them, either lifts them on high, or presses them down into the depths, or makes them decline in latitude, or turn retrograde.

From this it is clearer than the Sun itself that this author — a genuinely learned man — recognized no celestial orbs or distinct spheres, such as those mechanical builders of celestial orbs now contrive, but made the sphere of the whole heaven ethereal, subtle, fluid, continuous, and single; and in it he hung the stars and planets suspended, igneous by nature — the former [the fixed stars] indeed stable in their places, but the latter [the planets] wandering with varied motion. Martianus Capella, therefore, agrees with the teaching of St. Bonaventure, who in like manner recognized one continuous, liquid heaven, and so forth.

Cecco d'Ascoli [Cichus Esculanus], professor at the University of Padua, in his *Commentary on the Sphere* (published at Venice in 1519, p. 6): "To the second point," he says, "I say that the orbs (of the planets) are neither continuous nor contiguous, but there is a medium body between them that admits compression, following the opinion of Thebit [Thābit ibn Qurra] and Albertus." And these things were spoken and taught in the public Academy around the year of our Lord 1507.

Michael Scot [Michael Scotus], in his *Questions on the Sphere*, p. 105, on the definition of the sphere: "Note that 'solid' is said in three ways. In one way it is the same as 'hard,' like earth. In another way, 'solid' means the same as 'continuous,' and in this sense the elements and the supercelestial bodies are called solid. In the third way it means that which has three dimensions, and thus it is the same as 'body.'"

Nicolaus Copernicus, and all his followers — of whom he has very many in the arranging of the planetary motions — place the fiery Sun in a liquid heaven.

Their chorus-leader is **Johannes Kepler**, in his *Paralipomena* [to Witelo], in the *Mysterium* [Cosmographicum], in the *Hyperaspistes*, in the *Epitome of Astronomy*, and most fully and by design in his [work] on *Mars*. **Willebrord Snell** [Willebrordus Snellius], in his Batavian dissertation, and in Mersenne [Marin Mersenne], question 7, article 9, p. 829. **Simon Stevin** [Simon Stevinus], in his *Mathematical Memoranda* [Hypomnemata Mathematica]. **Johannes Remus Quietanus**, Doctor of Philosophy and Medicine. **Galileo Galilei** [Galilaeus de Galilaeis], in his [Sidereal] *Messenger*, in his *History* concerning Sunspots, and elsewhere. The **Lynceans** [Lyncei], very many of whom I have known.

Tycho Brahe — on whose authority (says the most recent Raphael Aversa, question 32, section 6) many other more recent writers, not only astronomers but also philosophers and Peripatetics, went over to the same opinion, namely all those who accepted that comets are generated and exist in the heaven and run to

and fro through it. In his volume of *Letters* [Epistolae Astronomicae], disputing with Rothmann, he most strongly defends this opinion of the fluidity of the heaven — although he denies that the heaven is of airy substance, and says rather that it is of a certain nobler, liquid, quasi-fifth-essence; yet not the Aristotelian one, as some wrongly imagine him to mean, but of the sort that the Chemists extract by sublimation from sublunary things, and such as, he says, is generated by the Sun in those sublunary [bodies]. Tycho, therefore, like Martianus Capella, makes the heaven thin and purified in ether, and the Sun igneous by nature and incombustible.

As I said a little before, he is followed at present by most astronomers of any note who do not admit the Copernican motion of the earth, and his System is commonly adopted among our own [countrymen]. For ever since it became forbidden — by the public interdict of the Purpled Senate [the College of Cardinals] — to profess the opinion of Copernicus, they embrace nearly all of that man's hypotheses: about the liquid heaven, about comets being born within it, about Mars penetrating the heaven of the Sun, about Venus and Mercury being brought over into the same [arrangement], and so on; and they vigorously champion them, vying with one another in writings publicly issued on the subject. This has been done by learned men — still living, and themselves living witnesses of these things — in the Low Countries [Belgium], in Italy, in Germany, in France, and elsewhere; to say nothing of the many Theses committed to print.

The same is taught by [Margin: Other astronomers.] Cornelius Gemma; Witich [Witichius]; Michael Mästlin [Maestlinus]; but above all, most forcefully, Christoph Rothmann [Rothmannus], a most noble mathematician, as is clear from many passages of the *Letters* contained in the cited Tychonic codex. Likewise Jean Pena [Ioannes Pena], in his preface to the *Optics* of Euclid; Jerónimo Muñoz [Hieronymus Munosius]; Marcello Squarcialupi [Marcellus Squarcialupus]; Redento Baranzano [Redemptus Baranzanus], in his *Uranoscopia*, epistle 1, doubt 9, member 1; Longomontanus; Origanus [David Origanus].

Nicolaus Reimarus Ursus [Raymarus] of Dithmarschen [Diethmarsus], a pupil of Tycho Brahe, pursues the same view by design in his learned *Astronomical Foundation* [Fundamentum Astronomicum] — whose invention and sharpness of mind even our Clavius celebrates, in his *Astrolabe*, book 1, lemma 53, p. 178. [Margin: Nicolaus Reimarus.] He, then, in his second Astronomical Thesis, states as follows: "The world itself, or the whole System of nature, is divided into air, and the bodies hanging in the air, which are called world-bodies." Thesis 6: "A world-body," he says, "is a substance hanging in the air by its own force — such

as the fixed stars, the planets, the Sun, the Moon, and the Earth together with its water." So he; whoever wishes will find more of this kind in him. He published his *Foundation* in 1588, and dedicated it in parts to various mathematicians, including Clavius himself. He pursues a System of his own, a middle one between the Copernican and the Tychonic.

In the same letters of Tycho one may find the opinion of the Empirics, who teach that the heaven is of an igneous and fluid nature and the Sun fiery — and likewise [it is the opinion of] all the Medical Doctors of our time who are devoted to Chemistry, in whose no small yield our age rejoices; for these men, being vigorous explorers of nature who join experience with reason, seem to bring no small weight to bear on natural philosophy. [Margin: Medical doctors, and especially those given to Chemistry.] For while they seek the art of making gold, they discover wondrous natural experiments, and secrets worthy to be matched with gold — or perhaps even preferred to it. These commonly acknowledge three heavens — the Empyrean, the Sidereal, and the Aerial — all of the same material; and they say that the Sun and the other planets are held suspended in the clear ether by a kind of magnetic force, and that the other planets, like attendants of the Sun, are carried around through the immense spaces of the celestial air. And because they themselves experience the wondrous power of the Fifth [essence] which they extract from the essence of things, they therefore judge that the essence of the heaven and of celestial things differs not at all from that spirit which they draw out of earthly bodies; and on account of the excellence of its nature, and the force and vivacity it displays, they call it the fifth essence, or the celestial [substance].

THE ASTROLOGERS

This same opinion — that the Sun is fiery, that the stars are cold or in some intermediate condition, and likewise that the material of at least the planetary heaven is mobile and flowing — most Astrologers, drawing on Ptolemy, either assume or teach, along with the compilers of Ephemerides; and it is on this basis that they attribute to the stars such wonderful natures, properties, and influences.

Natural philosophers writing on celestial comets.

All those agree in this same doctrine who taught that comets are born in the heaven and are carried above the planets, or along with them. Of this kind — besides some already recounted — are counted: Ficino [Ficinus]; Pliny [Plinius]; Abū Ma'shar [Albusasar]; Cardano [Cardanus]; Hipparchus; Anaxagoras;

Democritus; Hippocrates [Hyppocrates]; Apollonius; and most of the more recent writers. See also, in Raphael Aversa, *Philosophy*, volume 2, question 32, section 6; Antoine Mizauld [Antonius Mizaldus], in his *Planctologia*, chapter 3, and in *Paradox 2, On the Things of the Heaven*.

As for the fact that some, on the basis of certain minutiae neglected in observation or not weighed with sufficient accuracy, go about tearing at Tycho's name and long to see the man's greatness diminished in others' eyes — by this trifling matter they detract neither much from him nor anything from the truth, nor do they gain for themselves anything stable or certain: for *ad hominem* arguments rarely prove anything universally. Tycho did greater things than bring comets into the heaven — these are but corollaries of his labors. He corrected the errors of the celestial wanderers, especially of Mars, which deviates by many degrees; he restored the equinoxes and the reckonings of the seasons; he increased the number of the stars of the Firmament; he set Venus and Mercury around the Sun; and finally he restored the study of Astronomy...

restored it in itself and roused it in others, so that we owe him all the greater thanks the more we return the like. Whoever has learned by his own experience what the labors of observing are, and has tasted the vexations that go with them, will value Tycho's sweat at its true worth — though I do not bring this forward to defend whatever blemishes he may have contracted, but to express, toward one who has deserved so well of astronomy, the mark of a grateful mind. I am provoked by the example of Lucius Annaeus Seneca, who, in book six of the *Natural Questions*, chapter 5 [says]:

[The ancients must be heard with indulgence. Nothing is complete at its beginning — and not only in this matter, the greatest and most involved of all, in which, even when much has been accomplished, every age will still find something to do; rather, in every other undertaking as well, beginnings were always far from perfect. All things were new to those who first attempted them; afterward those same things were refined, and if anything has been discovered, the credit must nonetheless be given to them. It was the work of a great mind to push aside the hidden recesses of nature and, not content with its outward face, to look within and descend into the secrets of the gods. He contributed most to discovery who hoped that it could be found.]

[Margin: The refinements even of later men are to be credited to the first discoverers.]

So says Seneca. I have quoted this on Tycho's behalf, to the credit — or rather the shame — of those who do not scruple to carp at the labors of Tycho and of others as worthless, though they themselves can neither contribute anything to the common store from their own discoveries nor would ever dare to. Clearly it is easier to talk than to act, to snipe at what is praiseworthy than to bring forth what deserves praise. If an earnest effort in great matters deserves commendation, what censure, then, does the man deserve who tears to pieces with abuse what others have rightly discovered?

In any case, whether or not Tycho was sometimes mistaken, it is beyond doubt among astronomers that at least some comets are supralunar. This is now the common and most widely received doctrine among them, and I would not readily believe that the contrary view can be solidly maintained. We have a recent example of this in the comet of the year 1618, which all reputable astronomers placed in the heavens. This opinion — as also the opinion on the fluidity of the heavens — is held in common by the mathematicians of our own age, in Germany, the Low Countries, the Rhineland, France, Italy, Spain, Portugal, and elsewhere all the way to the Far East.

The peoples of China, indeed, though they abound in countless flourishing academies, have in none of them ever taught anything about that crude hardness of the heavens — as is clear from their books published more than two thousand years ago. From this the very ancient opinion of a fluid heaven, implanted as if by a natural light in every nation, is not a little confirmed.

[Margin: The academies among the Chinese have held the heaven to be fluid since antiquity.]

In this the Chinese all persist so immovably that they consider the contrary view utterly foreign to reason; and in their provinces they will not allow this doctrine of the multiplication and hardness of the heavens — which they regard as novel and exotic, and as contrary to their own mathematics confirmed by so many years' experience — to be introduced by newcomers or urged upon them, as those who have returned from among them report.

Fr. Giuseppe Biancani [Iosephus Blancanus], in his *Sphaera* and in his exposition of the Aristotelian passages, on the passage of Aristotle where he teaches that the stars, fixed in the heaven, are revolved [with it]:

[Margin: Giuseppe Biancani.]

[These teachings of Aristotle, he says, are consistent with the observations of the ancient astronomers; but the observations of our own age contradict them — especially those made concerning the wandering stars [the planets], from which it seems we must admit that the heaven, in the part where it contains the planets, is fluid, and that the planets advance through it by their own motion, etc. And he immediately adds: By these observations the moderns attempt to prove that the heaven is fluid and that the planets pass through it — and to these arguments no solution occurs to me.]

Fr. Johann Baptist Cysat [Ioannes Baptista Cysatus], in his work on the comet of the year 1618, says that comets perform their dances in the utterly limpid expanse of the aether — using a Platonic turn of phrase. And by the very fact that he showed that comet, in the region of the heaven, to have had motions so varied that they cannot be attributed to any celestial orbs — spreading itself out to every difference of place — many believe that the heaven was not hard, but necessarily permeable.

Our own Orazio Grassi [Horatius Grassius] assumes and teaches the same, often, in his *Lothario* [i.e. under the pseudonym Lotario Sarsi].

Others in other places have frequently taught the same, in publicly circulated theses or in other writings; but, so as not to be too long, I forbear to cite them. There is one, however, whom I ought to have brought forward long ago, and whom I neither wish nor ought to pass over in silence.

The Judgment of Christoph Clavius on the Novelties in the Heavens.

Christoph Clavius [Christophorus Clavius], that is — a man of most acute judgment — in volume 3 of the Mainz edition, pages 104 and 105, on the first chapter of the *Sphere* of Johannes de Sacrobosco, treating of the new star that appeared in Cassiopeia in the year 1572, after he had disputed much about its place in the heaven, declares as follows what he thinks should be concluded from this concerning comets and the matter of the heaven:

[So, to state briefly what I think: I judge that that star, whatever it was, existed in the firmament, where the fixed stars are. For that it appeared in the aethereal region and not in the elementary one is clear from what we brought forward a little earlier in refuting the third opinion — that of those, namely, who made it a comet existing in the highest region of the air — for the reason that no parallax [aspectus diuersitas] was detected in it. And a little later: Now, to make me believe that that

new star existed in the firmament and not in any other celestial orb, I am led chiefly by this argument: that neither I, nor any astronomer whatsoever, so far as I know, has noticed any motion in it other than the one we observe in the fixed stars. For it kept a constant motion always, and exactly the same position among the other fixed stars, for the whole two years (for it lasted about that long). But if it had been in the orb of some planet — since that orb certainly has a motion different from the fixed stars — the star itself would undoubtedly have had the same motion and course; yet the astronomers found that the matter was otherwise. And this same argument evidently proves that the star was still less in the elementary region, since there it could in no way have kept always the same position and distance from the fixed stars. Since this is so, I am persuaded that that star was then created by God the Best and Greatest [Deus Optimus Maximus] in the eighth heaven, [Cael. octav.] to portend something great (of what kind is still unknown); or at least that comets can be generated in the heaven itself, just as in the air, though this happens there more rarely. This not a few of the ancient philosophers openly acknowledge; and many of the moderns bring forward numerous authorities and histories to persuade us that stars of this kind have often arisen in the heaven at long intervals of time, each to signify something different. If this is true, let the Peripatetics see how they can defend Aristotle's opinion about the matter of the heaven. For it will perhaps have to be said that the heaven is not some fifth essence [quintessence], but a changeable body, though less corruptible than these lower bodies —

[Margin: The heaven is not the fifth essence.]

which indeed, before Aristotle, Plato with many other philosophers held, and, after Christ, not a few — among them St. Ambrose, Basil, Gregory of Nyssa, and nearly all the other lights of the Church — taught not obscurely. And on page 221: The same, he says, must be said of that new star which (as was written to me from Germany) appeared in the year 1600 in Cygnus, next to the one that shines in its breast, and still persists.

[Margin: A new star in Cygnus, and another in Sagittarius, is likewise to be placed in the firmament.]

Likewise of another, first seen in the year 1604, in the month of October, between the 17th and 18th degree of Sagittarius, having a northern latitude of 2 degrees or thereabouts — though now (as I write this) it has so diminished that it scarcely appears. The same, I say, must be said. For each star is to be placed in the firmament for the same reasons, because it was found everywhere at the same distance from the other fixed stars, so that it admitted no parallax, and no motion other than the one we note in the fixed stars was observed in it.]

This, then, is how Clavius philosophized about the matter and corruptibility of the heaven, having seen so many new things in the sky, whether stars or comets. And as time went on afterward, once the new eye of the optical tube [the telescope] had been brought to the world, he — now a veteran and a master mustered out of service with the wooden sword [*rude donatus*] — began to doubt the whole machine of the heaven that he himself had so laboriously constructed of so many orbs, and to rouse astronomers to erect it anew; for he writes as follows in the same volume, page 75:

[I do not wish, however, to leave the reader in the dark at this point:

that not long ago a certain instrument was brought from Belgium [the Low Countries], in the shape of a kind of oblong tube, in whose ends are fitted two glasses or lenses, by which objects far removed from us appear very near, and indeed far larger than they really are. With this instrument very many stars are seen in the firmament that cannot be seen at all without it, etc. The Moon too, when it is crescent or half-full, appears wonderfully broken and rough, so that I cannot wonder enough that such great irregularities exist in the lunar body, etc. And afterward: Among the other things seen with this instrument, this holds no last place — namely, that Venus receives its light from the Sun like the Moon, so that it appears crescent-shaped, now more, now less, according to its distance from the Sun. This I, a member of the Society here, have observed more than once together with others. Then, after he had recounted the two companions of Saturn and the four satellites of Jupiter, he concludes thus: Since this is so, let astronomers see in what way the celestial orbs are to be arranged so that these phenomena can be saved.]

If Clavius, upon seeing these novelties, entertained thoughts of changing the system and the matter of the heaven, what would he not have done had he seen the so great — and continual — variety of the solar phenomenon? Surely he would now, by way of serious exhortation, have impressed upon the students of his own discipline that very thing which he once wrote, in chapter 4 of the *Sphere*, page 300, in the manner of one raising an objection:

If they have a more convenient way, he says, let them show it to us (the astronomers), and we shall be content, and shall give them the greatest thanks. For astronomers aim at nothing else than to account as conveniently as possible for all the phenomena in the heaven, whether this be done through eccentric orbs and epicycles, or in some other way.

Scholium on the Words of Clavius.

Note, reader, that Clavius (as not only his own writings sufficiently attest, but as the living testimony of those still surviving unanimously declares of him) was extremely cautious and circumspect in putting forward an opinion, especially on doubtful and controversial matters. And since he placed the star of the year 1572 in the heaven so assertively [*assueranter*, recte *asseueranter*], one must not suppose that this was done by a man of such acute judgment thoughtlessly and without the most certain and most solid foundations. For he confirmed so great a matter not from another's hearing or sight, but by his own observation, and that a frequent one, as he himself clearly and often testifies of himself.

The arguments by which Clavius assigns the star to the heaven are chiefly two. The first, that in the most widely separated places of Europe it was found by skilled astronomers simultaneously in the same place and position of Cassiopeia; the second, in his words: *that neither I myself have noticed any motion in it other than the one we observe in the fixed stars.*

[Margin: Clavius himself observed the star of 1572 in person.]

For it kept a constant motion always, and exactly the same position among the other fixed stars, for the whole two years (for it lasted about that long). Always, he says, it kept a constant motion; from this constant motion it never departed at any time — not in summer, not in winter, not in spring, not in autumn; not at its rising, not at the meridian, not at its setting, not at midnight; not when highest, not when lowest, not when moderately raised above the horizon. In a word, always, always it displayed the same and constant motion as the fixed stars themselves, with which it was carried in Cassiopeia; and it also kept always exactly the same position with, and toward, the same stars, and it showed this most constantly to Clavius himself as he observed at Rome over the two years. These things are simply impossible if that star underwent any sensible parallax, such as even the Moon's is. For it would necessarily have had a daily motion that was inconstant and different from the stars set in Cassiopeia, and a change of position and configuration altogether perceptible even to the naked eye. And since Clavius, together with the sharpest-eyed astronomers of that time, most constantly denies this, I put more trust in them as they deny it — and, from this fullest agreement, place the star in the heaven — than in any who frivolously hold the contrary.

As Clavius was writing these things at Rome, a little afterward — in the year 1613 of this century, when the wonderful power of the telescope [*Telioscopij*, recte

Telescopii] was stirring the greatest excitement in the minds of the learned — there came the Parma theses, publicly disputed in the university, from which it seemed good to cull the following, as pertinent to our subject.

New Phenomena in the Heaven Render the Old Hypotheses Doubtful.

In book two of *Natural Philosophy*, chapter one, Theses 293 and 294, page 51:

[Astronomy [Astrologia], he says, most attentively investigates the height, position, intervals, figure, and motion of the heavens — or rather of the stars, etc.

Of the stars, I say, rather than of the heavens: for the things that in earlier ages seemed rightly established concerning the number of the celestial orbs — both in respect of their having the same center as the earth and this whole universe of things, and in respect of what are called the eccentrics, and concerning the epicycles — the new stars have called into doubt: both those which come into everyone's view at uncertain intervals of time and then withdraw, and those which the lenses enclosed in a two-cubit tube revealed around Jupiter.

In the same place, Thesis 295: Therefore, let astronomy be about the stars, and about the Sun, the Prince of the stars, by whose light not only the Moon shines with fixed waxings and wanings, but Venus also. And what of the fact that this same Sun is sprinkled with frequent spots [maculae]? Surely something opaque is set before it — so that astronomy becomes still more uncertain, according to the ancient and now-received arrangement of the celestial orbs. But as to the distinction of the heavens, their magnitude, and likewise whether they are solid or fluid, let the astronomers see what they pronounce.

The Matter of the Heaven Is the Same as That of Sublunary Things.

The same author, in book two, chapter thirteen, page 114, Thesis 736: Finally, those too find favor who posit in the heaven a matter of the same nature as ours, etc. Giles of Rome [Aegidius] in his treatise *On the Matter of the Heaven*, Scaliger in Exercise 61, and, older than these, the Nominalists — Ockham, Gabriel [Biel], and several more writers on Sacred Genesis.

In the same place, Thesis 740: Finally, when someone asserts that the celestial matter agrees with the rest — with Scotus as interpreter — he departs for a while from Aristotle in order to approach the truth; for he says that this is truly said,

but not according to the mind of the Philosopher [Aristotle]. But what if that matter, actualized by the celestial form, does not indeed change its nature — so that it might be called homogeneous with the lower matter — but does change the conditions of its nature, and on this account loses the name of matter, so that it may be said not to be matter, or to be less of the same character? I assert it thus, and while I maintain this view I interpret Aristotle accordingly.

In the same place, page 115, Thesis 742: If, however, the other view is preferred — the one to which the new appearances of the new stars, and their new motions, persuade us — there is one matter in the heaven, and that homogeneous, throughout the whole space that extends from the lowest dwelling of the stars up to the highest; and through this fluid and liquid matter the stars are carried, each in the course to which its intelligence has directed it.

In the same place, Thesis 743: And since it is not credible that this motion is violent, it is credible that the stars, which do not keep the same motion, differ from one another in species, and likewise differ from the substance of the heaven, in which they merely have a place, as fish do in the sea.

[Margin: The stars move in the fluid heaven, like fish in the sea.]

In the same place, Thesis 783: Therefore, either the stars or the heavens are moved by the intelligences, as by an external principle.

In the same place, Thesis 788: If you make no division of orbs, but let the stars go through the fluid, I likewise think there is no objection to a chorus, as it were, of several stars being led by a single intelligence.

In the same place, book two, chapter fourteen, Thesis 828: It is a most ancient opinion that there is a very ample place of fire above the air, and that its denser and brighter parts are the stars themselves.

[Margin: The stars are fiery.]

Nor is this opinion wholly obsolete, which — against Aristotle — Aristotle's Interpreter, Philoponus, asserts to be true (Commentary on Book I of the *Meteorologica*).]

Antonio Magini admits a liquid heaven.

Antonio Magini [Giovanni Antonio Magini], the most distinguished mathematician of our age and once the foremost champion and multiplier of the hard heavens, in the end came over to Tycho's [Tycho Brahe] system and opinion as well, and embraced a fluid or breathable heaven.

In short, this view now seems to be the shared and received teaching of all astronomers. Those who hold the contrary they regard with a kind of astonishment, because such men reject—without sufficient cause—a truth that (as it appears to these astronomers) is plain, conformable to Sacred Scripture and the Holy Fathers, established by the firmest reasoning, and equipped with irrefragable experiments. [Margin: The arguments of the astronomers for the hardness of the heaven and for the celestial orbs are hypothetical and directed to the man [ad hominem] rather than absolute.] This is especially so since the mathematicians never admitted the hardness of the heaven except hypothetically—that is, on the supposition that spheres or discrete orbs are to be posited—but with Ptolemy [Ptolemy] put forward only the motions and the imaginary theories of the circles. Yet once it was laid down that the heavens are physically hard, real orbs had necessarily to be established so that the appearances of the motions might be saved; and again, if real, discrete orbs had to be introduced, this could not be done without the hardness of the heaven. Such indeed have always been, and still are, the argumentations of the astronomers against the natural philosophers. If the heaven is hard, then real, discrete eccentrics and epicycles necessarily follow; and conversely, if discrete eccentrics and epicycles are granted, the heaven must be hard. But the former holds according to the natural philosophers; therefore the latter too. However, that the heaven is neither hard, nor that those real orbs can be established, the astronomers show from phenomena so many and so varied—namely, because these things cannot be maintained without a mutual interpenetration of bodies. On this matter our own Blancanus [Giuseppe Biancani], in his *Sphere*, part 3, chapter 4, gives the following warning. [Margin: Giuseppe Biancani.]

"It must be understood, first, that the ancient astronomers—Hipparchus, Ptolemy, and others—said nothing certain about this distinction of the heavens, as may be seen in Ptolemy and others; rather, they spoke hypothetically, that is, on the supposition of such-and-such a division or number of the heavens the appearances and observations are accounted for. Indeed, as may be seen in Ptolemy and Proclus, they called these fabrics of the heavens *hypotheses*, and today the more learned still call them so. This opinion about a real distinction of the heavens was scattered among the people long ago by Eudoxus and Callippus, and later by the half-antique and half-barbarous writers of treatises on the sphere or on the theories of the planets. In order to peddle marvels to the people and to others ignorant of astronomy, these writers published such constructions of the heavens, packed with true and real eccentrics and epicycles, and proclaimed what they used to call the ancient hypotheses as though, in the course of time, they were assertions announced without any evident reason. The simpler

and cruder sort gave them ready credence, so that even a good many philosophers gradually assented to the same. [Margin: The hypotheses of the astronomers posit nothing necessarily real.]

"Once this hypothesis of the heavens had been transformed into an assertion, it also came about that they deduced many heavens to be not only divided from one another but also hard. For while they understood the distinction of the heavens and their offices in carrying the stars, they consequently also philosophized about their solidity. But in truth the most learned of the ancients and of the moderns—such as Ptolemy, Copernicus, Tycho, and others—explained the motions of the planets excellently by lines or circles alone, as may be seen in their works." So far him. [Margin: The authors of the hard heaven.]

A certain distinguished theologian, in his discourse on this subject, says: "The Arabs, especially those who flourished so widely in their empire in Spain, expended much effort and study on Ptolemaic astronomy. And, being barbarous and rustic, what he [Ptolemy] had designated by circles and lines, they declared to consist of solid globes expressed in the heaven—whether because they thought so, or because that way seemed easier for understanding and handing down these matters. As this fiction gradually gained strength, one barbarian following another (as they are wont to follow in the manner of a herd), the hardness of the heaven, confirmed by the authority of nearly all astronomers of that kind and with the crowd applauding, hardened into common belief. [Margin: How the hardness of the heaven was introduced by the Arabs.] Therefore, after Aristotle, Ptolemy, and the good authors escaped out of the hands and tongue of the Arabs into Latin, they carried with them the commentaries of the Arab writers; and to such a degree did those same old tales about the adamantine heaven settle into the minds of our own men

that they could easily have been detected, had not a certain fateful barbarism of those times stood in the way. [Margin: St. Thomas filled the epicyclic space with a divisible—and therefore liquid—body.] To the Scholastics, then, whose single business is to contemplate divine things, it seemed wise in these matters—which do not much pertain to theology—to embrace what was said by the astronomers. Indeed St. Thomas [Thomas Aquinas] somewhere acknowledged, in some part, a breathable heaven, because the astronomers said so. For, to prove that the Empyrean could be liquid and yet incorruptible, he says (in book 2, distinction 2): 'Just as the astronomers place, between two spheres that cannot be cleft, a certain space filled with a divisible body, since in that space there is the motion of the planets in the epicycle.'

"I have chosen to add these remarks about the Scholastics; yet it would not be so absurd or unusual if—just as St. Thomas, in book 2, distinction 14, question 3, rejects the authority of those Fathers who posit a corruptible heaven, on the ground that they held this from Platonic teaching—so too we should reject the testimony of the Scholastics who say the heaven is hard, on the ground that they were forced to say this because Aristotle was then thought to have said it." So far him.

And he then, soon afterward, in Proposition IX, fully and deliberately proves that "the authors of the hard heaven were chiefly the fabulous poets, who, in describing the celestial 'houses,' delighted the crude common folk all the more; then the deceiving Cabalists, who with I know not what colors depict twelve tables of the heaven, fashioned by themselves after the likeness of an area; and finally the superstitious Magi, who inscribe the same with letters and maleficent characters. [Margin: The authors of the hard heaven are fabulous poets and superstitious Cabalists.] From these, both the one sort and the other artfully and fraudulently color their fabrications to bewitch the ignorant. Hence arose, along with many other absurdities, that one above all which paints astronomical images—which the Arabs call *Talismanica*, and the Greeks στοιχεῖα [Greek: στοιχεῖα (stoicheia, 'talismanic figures/celestial images')] [?]. For once they had persuaded themselves that images carved in the heaven were neither idle nor inert, they spread abroad among the crowd that marvelous and prodigious effects could be produced, if someone should carry an engraved stone bearing the same figure with which the heaven was carved." And to this same effect he learnedly argues much against these smoke-sellers—from whose frauds those who acknowledge a fluid heaven have nothing to fear. Now we must resolve one or two objections from the side of those who hold the heaven to be liquid.

The objections against the fluid heaven are resolved, and an end is put to the Book. CHAPTER XXX.

First Objection. From the Name "Firmament."

The heaven is called in Sacred Scripture the "firmament"; therefore it is hard, not liquid. The defenders of the contrary view reply by granting the antecedent and denying the consequence. For the Hebrew word רקיע [Hebrew: רקיע (raqia, 'expanse')] *Rakiah* sounds not "hardness" but "attenuation" and "expansion": for the heaven was made out of water or some other liquid substance by a certain attenuation. The Seventy [Septuagint], moreover, rendered it στερέωμα [Greek: στερέωμα (stereōma, 'firmament / solid expanse')], to declare the threefold dimension of the celestial body; and this, on the testimony of Gellius [Aulus

Gellius] (book 1, chapter 20), is in Latin called *solidum*. For "solid," as Henri Estienne [Henri Estienne] noted from Pliny, is opposed to the empty and the hollow, and denotes the continuation of a threefold dimension. The Holy Fathers, as has been made clear from the passages cited, say that the heaven is called "firmament" not because it is hard, but because it was set up by God as a boundary and impassable limit between the upper and lower waters, and so forth.

Second Objection.

Job, chapter 37, verse 18: *The heavens are said to be most solid, as though cast of bronze*. Therefore they are hard. The authors of the contrary view commonly reply. First: that this statement is not Job's but Elihu's—one of his friends, a Sophist, whom God rebukes: *Who is this that wraps up his opinions in unskilled words?* And so it does not follow that that statement is canonical.

Second: that by "heaven" in this passage is understood the air, as nearly all the Greek and Hebrew interpreters teach—except Levi ben Gershon [Gersonides]. So the Zurich Bible [*Biblia Tigurina*], following the Chaldaic Paraphrase, explains, as does our Father Pineda [Juan de Pineda] and others on this passage. For throughout that whole chapter the discourse is only about the aerial heaven. Elihu marvels that the air can sustain the greatest clouds, no otherwise than if it were of bronze; and indeed the Hebrew word שחק [Hebrew: שחק (shachaq, 'sky / cloud')] *Sachak*, which is read some twenty times in the Sacred Writings, nowhere signifies anything other than air and clouds.

Third: If in this passage the discourse were about the starry heaven, then by this testimony it could most strongly be proved that the starry heaven is breathable and liquid. For what in Hebrew is תרקיט [Hebrew: תרקיט (targia, 'you spread out / beat out')] *Tarkiah*—in Latin, "you have fabricated"—can be turned, according to the sound of the word, into "you have attenuated." And what follows—"most solid, as if cast of bronze"—the Seventy rendered "strong as the appearance of a molten thing"; in the Hebrew, "strong as a molten vision"; from the Greek, "strong as inspections of an infusion or effusion." Yet because that effusion is constant and perpetual, our interpreter therefore compared it to bronze—seeking not hardness in the bronze, but stability. [Margin: Pineda.] "It must be understood, then," says Pineda, "that the power and wisdom of the Creator are much commended in this: that a fluid and unstable thing is no less constant and perpetual than the most solid thing cast of bronze would be," and so forth. And Augustine Tornielli [Agostino Tornielli], in tome 1 of his *Sacred Annals*, folio 32: [Margin: Augustine Tornielli.] "But if the words cited," says St. Job (as

many approved authors have handed down), "ought to be interpreted as though he had meant to say that the heavens, although they appear to be—or are—substances after the manner of air and smoke, fluid, mobile, unstable, very light and very thin, nevertheless are through divine power so durable and perpetual as though they had been cast, compacted, and forged from the hardest and most solid molten bronze: if, I say,

this is the legitimate and true sense of the prophet, then all the aforementioned difficulties cease, and everything is rendered consonant, so that nothing prevents us from saying, with the philosophers, that the stars indeed are denser and more solid than their proper heavens, but that the substance of the heavens (as the cited Fathers gather from the passages of Isaiah, and as is elicited from the aforesaid exposition of the words of St. Job) is most subtle and everywhere passable—as the many and varied motions of the stars, which are carried through it, plainly indicate—yet is no less durable and perpetual than the stars themselves. Whoever wants a fuller solution both of this argument and of the other objections, let him consult Mersenne [Marin Mersenne], at the place cited above, chapter 27 (from whom I have cited a fair amount); let him consult the other Peripatetics, who everywhere agree in this response. Other objections, too, everyone will easily either solve or else adapt to his own understanding. Now I bring forward from Sacred Scripture the authorities for the liquid heaven that I promised in chapter 26, discharge the pledge I gave, and bring the Book to an end.

Genesis, chapter 1, verses 1 and 2: "In the beginning God created heaven and earth. But the earth was void and empty, and darkness was upon the face of the deep, and the Spirit of God moved over the waters. And God said, Let there be light, and light was made." Here you have all things liquid, except the earth, which the abyss of fluid waters surrounds; this the Spirit of the Lord—that is, the air—encompasses, as the Holy Fathers and very many expositors of Scripture, among them Augustine, best interpret. To the air is superadded light, or fire, according to the sense of the same authors; above this stands the empyrean heaven, within whose bosom, or lowest concave surface, all things down to the earth are liquid. Whether some of these, and when, and how, and for what cause they hardened into some adamantine solidity (as some would have it), the Scriptures do not indicate—if we consult the authority of the Fathers, searching the Scriptures, as has seemed right. There is the further point that even those who bite down hard in defense of the heaven's hardness freely grant that the intermediate space of the Empyrean Heaven is full of a certain breathable body, and that all the rest, in the creation of the world, down to the earth

were fluid, and again that such they will be, according to their nature, after the last Day of Judgment, and will so remain for eternity; but that they were hard while this world served the use of men. Therefore the heaven, against its natural inclination, was according to these men hardened for the whole time the world is of use; but when it ceases to serve man, it will return to its fluid nature. Of these things Aristotle dreamed nothing, who taught simply that the heaven is immutable, and so forth.

In tune with the aforesaid text is Solomon, in Proverbs, chapter 8, verses 27 and 28. "When he prepared the heavens (says divine Wisdom) I was present; when with a fixed law and compass he enclosed the depths; when he made firm the ether above." So the Vulgate edition. Pagnini [Sante Pagnini], from the Hebrew, renders it thus: "When he prepared the heavens I was there; when he described with a compass the surface of the abyss; when he made firm the heavens above; when he strengthened the fountains of the abyss." The Seventy, however, speak for a liquid heaven very clearly, thus: "When he made ready the heaven I was present with him, And when he set apart his seat upon the winds, and when he made strong the clouds above." This passage, because it is so strong and clear for a liquid heaven of the Firmament, some try to change into another reading; but the Bible published at Rome in 1588 by order of Sixtus V [Sixtus V] has it exactly as I have cited. Aquila and Symmachus agree: "When he set apart his tower upon the winds." Nor does Arias Montano [Benito Arias Montano] dissent, who renders the Seventy interpreters thus: "When he prepared the heaven I was present with him at once, and When he set apart his seat upon the winds." Cajetan [Cardinal Cajetan], as reported by Fernando Quirino de Salazar [Fernando Quirino de Salazar], interprets those words, *he made firm the ether above*, of the outermost Heaven—namely, either of the *primum mobile* or of the Empyrean Heaven. The Rabbis and many other Doctors side with Cajetan; to string them together laboriously is not necessary. To wish to establish so many authors and such solid authorities by still more would, in my judgment, be to do some injury both to them, as being too weak, and to the reader, as being unteachable. For the rest, "These are the matters (that I may conclude the authorities with the authority of Seneca, in book seven of the *Natural Questions*, chapter 29)

Part II, Cap. XXX (conclusion)

(...*I shall conclude*) — the considerations bearing on comets (as they touch the solar phenomenon), whether they moved others or moved me. Whether these things are true, let those debate it whose business it is to defend them. *For us it is permitted only to probe and to conjecture about such matters in private.* For there

is no shortage of others who take the contrary view, who interpret these authorities differently, and who bring forward still other authorities in support of their own opinion — which I have no leisure to review here. Whoever wishes may consult Tanner [Adam Tanner] in his *Dissertation on the Heavens*.

What I myself think I shall disclose at another time, in a work composed for that purpose, God willing and with my Superiors' approval. For at present, on a matter so weighty and to most people so new, and under such pressure of time, it does not seem prudent to insert my own verdict — to cut off, as it were, every thread of free judgment for others — nor to settle the question in any way. It is better to leave the sensible reader's own mind free to run its course.

For my part, I think I have done enough this time to make the effort worth while, if I have brought a phenomenon — hard to discover on its own — to such ease, and one obscure to handle to such clarity, as anyone versed in these matters could wish; if I have sampled its chief properties, and openly brought its visible effects into the amphitheatre of the City and of the World [Urbis atque Orbis], for the eyes of the learned to behold; if at last I have freed it from the misrepresentations of others. Now I am readier to listen than to be heard, and to gather the contributions of others than to pay out my own. For into the senate of the learned of this most wise age I have brought, by this writing of mine, not decrees but wishes.

Magnus Aurelius Cassiodorus [Cassiodorus], from Senator and Consul of the City turned Monk. In his book On Astronomy.

[Aurelian [Orléans] edition of 1609, p. 1127]

For us (Christians) it is enough to hold concerning this art only so much as is read in the sacred Scriptures; for it is quite unseemly to follow human opinion in a matter where we know that we possess — so far as is expedient for us — divine teaching.

EPILOGUE OF THE WHOLE WORK

Here you have at last, friendly reader, the bosom of the URSINE ROSE spread open — poured out upon all, bountiful, generous, and fruitful toward everyone, sprinkling all with the sweetness of its fragrance. And no wonder: for this Rose, coeval with the Sun, looked upon the light at the same moment as he did, circled the world together with him, and not only surveyed but illuminated both the regions below and those above. It wove the same dances and the same circlings with him, and by the greatness of its scent and beauty it drew the very planets

along with it through those vast fields of aether — and draws them still today — planets which pour the power drawn from it abundantly into these bodies of the sublunary world, so that the Rose proves beneficent not only through itself but through others as well.

And if the Bear [Ursa], borne up into the heavens and having gained the governance of the poles, most faithfully guides the night-wandering courses of men by land and sea, then this Rose, having attained the mid-heaven and the very palace and bosom of the Sun, consoles the daily labors of mortals with its most lovely aspect and most delightful breath, and gently soothes them. And so, just as sailors turn their eyes by night toward the Bear, philosophers will turn the gaze of their mind by day toward this Rose.

From it astronomers will draw ample impulse and support for their System and for the celestial motions. From it the natural philosophers will inquire into the matter of the heavens and into the continuous, breathable substance diffused through them all, and will learn the standard of a solid philosophy from a fluid nature. From it, by contrast, the astrologers [iudiciarii] will unlearn the vanities of their predictions. From it the moral philosopher will turn his soul away from the emptiness of perishable things toward their one unchangeable Author, God alone — since he will find that not even this visible Sun itself is always the same. Through it the theologian will seek light without darkness, brightness without blemish — that is, God himself, and him alone; for what else should shine for a Christian, once he sees that the Sun itself is steeped in native darkness? From it let the vain idolater turn away from his errors — the man who worshipped, as an immortal deity, a Sun subject to so many changes.

But I break off. The most powerful fruits of this Rose, offered and proven to the whole world, I shall never presume to trace out with this pen, nor to enclose within this paper, nor to match with my own talent. It is enough for me to have opened the hiding-places of this treasure and the teeming veins of its richest ore — for the greater glory of God, who dwells in inaccessible light; to the praise of Christ, the Sun of justice; and for the common good of the whole Church, of the world of letters, and of our Society [of Jesus]. Their common prayers I judged I should answer, if for this heavenly treasure I secured heavenly guardians from the heavenly Bears [the Orsini]. If, I say, I placed the glory of the most illustrious and most excellent House of Orsini [Domus Ursina] — a true Sun to us, whether in honoring or in cherishing us — most deservedly in the royal court of the Prince of the stars, a glory whose lights no clouds of envy and no nights of oblivion could obstruct; and finally, for the sake of your own benefit, whoever you are who read

this — a benefit which, if you have gained it, you will repay, together with me, in the thanks due to the immortal God. But if you fall short of your wish, I have, I think, shown more than sufficiently that at least my goodwill, and my ready eagerness to oblige you, were not lacking in this matter.

At Rome, partly in the Roman College of the Society of Jesus, partly in its Professed House, from the close of the year 1624 to the present year 1629, in unwearied five-year study, never once interrupted. On the 20th day of March.

Job, ch. 38, v. 33. — Do you know the order of heaven, and can you set down its reckoning upon the earth?

Psalms 148. — Praise him, Sun and Moon; praise him, all you stars and light. Praise him, you heavens of heavens, and let all the waters that are above the heavens praise the name of the Lord.

May this book too proclaim his praise.

ALL FOR THE GREATER GLORY OF GOD. [Omnia ad maiorem Dei gloriam]

When the whole work was now finished, both in the writing and in the printing, I approached the most illustrious and most excellent Prince Federico Cesi, the Lyncean, Prince of Sant'Angelo, etc., to render him the thanks I owed for the testimony mentioned in chapter 27. While I was doing so, the most gracious Prince not only confirmed everything to me in person, but also declared that his own letters to Bellarmine [Robert Bellarmine] on the matter, and Bellarmine's to him, were still extant and authentic. When I had shown that I was gripped by an incredible longing for them, the excellent Prince granted my wish: on the 3rd of July he sent them to me through the most distinguished Dr. Johannes Faber [Giovanni Faber], physician, himself a Lyncean, and my particular friend. I therefore, without any delay, showed the Cardinal's venerable writing, together with its seal, to our Fathers Johann Brissel [Ioannes Briselius], Giacomo Fuligati [Iacobo Fuligato], and Nicholas Lancicius [Mikołaj Łęczycki]; and they at once, with one voice, kissed it as the true hand of a holy man. I did this not because I had any reason whatever to doubt the genuineness of the letters, but to satisfy the reader's certainty; and for his sake I append both — the Latin letter of Prince Cesi, and the Italian one of Cardinal Bellarmine, to which, however, I add a Latin version. And so to these authorities I add nothing of my own, lest I should seem to want to illumine light with darkness.

A LETTER of Prince FEDERICO CESI, the Lyncean — Prince of Sant'Angelo and of San Polo I, Marquis of Monticelli [Montis Caelii] II, etc., Roman Baron — ON THE UNITY AND TENUITY OF THE HEAVEN, and its diffuse nature, pervious to the motions of the stars, FROM SACRED SCRIPTURE; to the most illustrious and most reverend Lord ROBERT BELLARMINE, most eminent Cardinal of the Holy Roman Church.

[This half-title page is set entirely in letterpress display capitals. Verbatim transcription of the source lines:]

- PRINCIPIIS
- FEDERICI CAESII
- LYNCEI
- Princ. S. Angeli & sancti Poli I. March. M. Cælij II. &c.
- BARONIS ROMANI.
- DE CAELI VNITATE, TENVITATE,
- fusaque & peruia Stellarum motibus Natura.
- EX SACRIS LITTERIS
- Ad Illustriss. & Reuerendiss. D.D.
- ROBERTVM
- BELLARMINVM
- S.R.E. CARD. AMPLISSIMVM
- EPISTOLA.

[The verso of this half-title is blank; it carries only faint mirror-reversed show-through of the half-title on its recto. Nothing on this side to transcribe.]

To the most illustrious and most reverend Lord, Lord ROBERT BELLARMINE [Robert Bellarmine], most eminent Cardinal of the Holy Roman Church — Federico Cesi [Federico Cesi], Lincean, Prince of Sant'Angelo, sends greetings.

Behold: now that I have withdrawn a little from the accumulated press of urban business and civic affairs, I am at last free to devote myself more seriously to the contemplation of the heavens, while my mind enjoys a certain freer air; for it craves nothing more than to range through the vast regions of that higher nature. I have long desired this, but it above all needed seeing to — and especially for your sake, most illustrious Prince, that I might comply with your admonitions

and satisfy them. It was those very admonitions that made me take up the task the more eagerly and boldly. A heavenly province, indeed — one that could not seem difficult to anyone. And to whom would the minds of the natural philosophers [Physiologi] seem more difficult, set as they are within its established laws? To whom the many rumors in the schools arising from the new things discovered by Galileo? One might well say the Olympic contests had been revived — or rather set up in the very midst of the schools. But with you urging me on, nothing is hard, nothing difficult; everything is smooth. When you wished to hear my opinion, you affirmed — and not merely so far as it goes — that the heaven I had proposed is single, tenuous, and permeable [Unicum, Tenue, peruiumque Caelum], and that so many and so tangled masses of orbs and orblets [Orbium & orbiculorum] are to be cleared away from the purity of nature; moreover, you affirmed by your own express wish that this is so, and most consonant with the oracles of the sacred page. Then indeed I burned to complete the work, and then the delays forced upon me by the entanglements of business became most vexing. So much the more does the labor now undertaken delight me, and my retreat to it, here in these Umbrian hills of mine, is the more welcome and pleasant — though it came late, after being kept from me by those troublesome cares. Now some account of the work itself must be rendered to you, most illustrious Lord. And that I may do this in the present letter, what better could I offer?

Shall I set out the very disputes of the natural philosophers, by which — as though by dense and inextricable thickets crowding the road on every side — the approach to the matter is made the rougher? Or shall I rather sketch the varied history of the heaven, according as we find it diversely adorned and wrought by the loftier minds of men? Truly it would be an abuse of that kindness of yours by which — amid those more illustrious labors and higher cares by which you constantly and diligently provide for the good of the whole Christian Commonwealth — you often unbend, so as to satisfy in every way the conversations of those who distract you, however inopportune. And it would be quite unfair to detain you with these matters: it will be enough to look at them more conveniently as they are written out in the work itself. Let me signify only this much for now: the heaven as sought physically and mathematically. The heaven, packed with clouds and plunged in a deeper darkness — not, indeed, a darkness natural to a body shining on every side, nay, natural to the very origin of all this light, but by the winding maze of human reasonings so besprinkled and enveloped that in the very midst of splendor we make darkness for ourselves, and the very thing we seek we hide and conceal from ourselves by our own questioning. Yet I will not deny that a hope of clear sky shines upon me as I seek;

and if to satisfy the dignity — if the magnitude of the object before us — should prove wholly beyond my strength, at least the attempt will be counted to my credit before them all. From the discussion of these lower matters I am swept up to that highest and first truth of the sacred books. From it are drawn testimonies of the fullest authority, which it is sinful to gainsay; from it many confirmations, which it is impious to resist. But since some things are variously interpreted by various people, and are much debated in the schools, my plan is to set these out here — and indeed at length — as matters more worthy of your inspection, most worthy of your judgment; for my explanations could not seem to me settled in every respect unless the examination and authority of some divine Interpreter had intervened. And whose, rather than that of the most illustrious Bellarmine? Therefore, by that goodwill with which you have always attended me, deign to render me this service, most illustrious Prince — I ask and beseech you — that everything may be rightly set forth and aptly placed, the genuine sense of the sacred letters being always preserved; and if anywhere there should be even the least departure from it, recall me to it, I pray, and signify whatever you judge best.

[Margin: Genesis 1, homily 4.] The unity of the heaven I first assume, together with St. Bonaventure, on the first chapter of Genesis, following St. Chrysostom [John Chrysostom] foremost among the standard-bearers — who sharply rebukes the champions of a multitude of heavens as contrary to the truth of the sacred letters. Here I dissolve the objection that in Scripture "heavens" is very often spoken of in the plural: I do so from a property of the Hebrew tongue, and I note that it is not unusual among the Latins either to indicate one thing by a plural, as when we say *Venetiae* (Venice) or *Athenae* (Athens). I observe, too, that this manner of speaking has regard to the magnitude of the thing itself — expanded and diffused far and wide, which by its vastness in some way takes the place of many things, since it can be conceived as divided into many, indeed huge, parts. So [Margin: Genesis.] we commonly call the whole body of the waters "seas" and "waters" in Scripture. But if the Hebrew dual be recognized, I observe that two parts or regions of the physical heaven are expressed, the starry and the aerial, so that a third would be the Heaven of Heavens [*Caelum Caelorum*] — namely the Empyrean [Empyreum], to which St. Paul was caught up; [Margin: [Chrysostom], On Genesis, homilies 2 and 6; homily 3 on Genesis; on Genesis, question 11; in the Catalogue of heresies.] and to this distinction St. John Damascene, St. Basil, Theodoret, and Philastrius give their assent.

I observe that רָקִיעַ [Hebrew: *rāqîa'*, "expanse, firmament"] signifies something expanded, extended, and diffused far and wide, so that the word "Firmament"

[Firmamentum] substituted for it seems to answer it poorly; nor can the adamantine solidity of the orbs be inferred from it in any way. Rather, if from the Greek στερέωμα [Greek: stereōma, "solid frame, firmament"], or from the Latin "Firmament," some notion of firmness is to be retained, it is this: that the swift course in a circuit, and the manifold revolution by the aether, ought to be entirely removed. Of this it is written that He made the aether firm above, and the Tabernacle fixed, [Margin: Chrysostom, To the people of Antioch, homily 12; Proverbs 8; Epistle of St. Paul to the Hebrews 8; Chrysostom, homily 14 To the people of Antioch, homily 12; On Genesis according to the Letter, book 2, chapter 10.] but that motion, whirling, and course are attributed to the very bodies of the stars, of the sun, and of the moon, by the authority of the sacred page — in which motion, whirling, and course are said of the stars themselves, not of any orbs; of which orbs there is in Scripture no mention at all, just as in physical appearances there is no sight of them, no indication. We have too from St. Augustine [Augustine] that it was long ago most diligently observed that whatever appears is best explained by the heaven not being moved, but only the stars themselves; and this has been the more confirmed by recent observations.

Thus [the Fathers] not only acknowledge the heaven immobile, and the stars by no means fixed but coursing through that permeable [heaven], but they determine it for us with the utmost asseveration: [Margin: On Genesis, homilies 6 and 13; To the Antiochenes 12; on question 93, Orthodox [Questions]; on Genesis 1; book 5 Against Celsus; chapter 1 On First Principles [Peri Archōn]; on Genesis 1 and 7; in the Catalogue of heresies.] Chrysostom, Justin Martyr, Diodorus of Tarsus, Eusebius of Emesa, Origen, Procopius of Gaza, Theodoret of Tyre, Theophylact, Lactantius, Philastrius, and others.

Such a nature of the heaven — devoid of any proper motion, and following an uncertain figure — I observe [to be taught], so that the Orbists [Orbistae] must wholly acquiesce in the authority of the holy Fathers, who long ago exploded the spherical ornaments from the sacred letters, and are compelled to abandon their stubborn defense of elegant globes and their multiplicity. For it seems to have been done less rightly and less piously in [Scripture], with no phenomenon and no firm reason to persuade it. You know, most illustrious Lord, how unanimously the same [Margin: homilies 14 and 27; Hexaemeron 1; homily 1 on Genesis; in the epistle to the Hebrews 8; on question 130, Orthodox [Questions]; Divine Institutes 3; 13; Commentary on Genesis.] Chrysostom, Ambrose, Basil, Theophylact, and Justin — and more sharply Lactantius and Procopius of Gaza — rejected this spherical figure. Now, this figure being abolished, apart from the very expansion, dilation, and diffusion expressed pointedly by the single word רקיע [rāqīaʿ], I

would judge that no other [heaven] — determinately known to our uranometers [Vranometrae], or that could be grasped — can be introduced. This alone stands firm: that the heaven is poured out on every side and spread above all things, so that the modes and functions of a Tabernacle, a Vault, a Curtain, a Tent, and a Skin, concerning its stretching-out and spreading-over, are quite fittingly held of it in the sacred [writings].

[Margin: Job 36; Job 38.] It is He who elsewhere more precisely applies its parts — the clouds, I mean — to those very [heavens]. For one may read: "if he will stretch out the clouds as his tent," and: "when I placed a cloud as its garment, and wrapped it in darkness as in the swaddling-clothes of infancy"; and often it is said "to spread out, to cover, to clothe with clouds, mist, and darkness."

Nor does the heaven seem comprehended within any determinate limit — not only as to the magnitude of its mass, but also as to the multitude of the bodies, namely the stars, disposed within it. For the number of one thousand and twenty-two, received in the schools and published in the tables of the astronomers, is fixed with utterly rash daring. It is not defective or mutilated, but scarcely the beginning of any numbering. That multitude is by no means granted to mortal senses, as is held in Scripture and as many of the Fathers teach; and so I see it established by many trials of observation, by which one may descry both countless distinct stars and many indistinct ones, and there are very many indications of very many that lie hidden — so that the multitude is altogether wonderful, [Margin: Genesis 15; Deuteronomy 10; Jeremiah 33.] and is deservedly compared to the sand of the sea and the seed of Abraham. Now the number of the Hebrew soldiers in the time of Moses was six hundred thousand and more. And so the stars, as St. Augustine excellently says, cannot be counted, [Margin: City of God 16.23.] because it is not to be believed that they can all even be seen; for the more keenly each man gazes, the more he sees. For [Margin: Psalm 146:4.] God numbers the multitude of the stars, and calls them all by name. But surely I cannot but lament the malady of many would-be philosophers of our age, who are wont not only to abstain from experiments and observations but even greatly to abhor them. For not a few there are who execrate not only the Telescope, by which the sight of men is raised higher, and Galileo himself — who uncovered so many things in the heaven hidden from the ancients: new Planets for us, new fixed stars, new faces of the heavenly bodies — but who, destitute even of the simple observation of the unaided eye, would rather willingly go blind of their own accord and retreat into the ancient wood of certain of the old writers, bewitched by opinions, than depart even the least bit from them, led by sense and reason, or add or change anything with regard to presumed decrees or rules.

For the rest, from all these — Unity, Immobility, and a Poured-out nature, confined by no solid boundary of figure but yielding and permeable to the manifold motions of the multitude of stars both apparent to us and hidden — matters which also confirm this very proposition and mutually corroborate one another — I judge that it can be gathered from the sacred letters, and most fully, that the heaven is by no means hard after the manner of stone, nor dissected into many orbs differing in kind, motion, and other respects, carrying around the fixed stars by a constant rotation (as has been set forth by many with great applause), but rather that it exists Fluid and Tenuous [Fluidum Tenueque], after the manner of the air itself — which is on that account also given the name of "heaven," and is little distinguished from it, and in almost the same way in which the lower part of any body is usually distinguished from the upper. That it is called in Scripture also by the name of "Firmament," that most learned Pererius [Benedict Pereira] seems to have shown fully; and in that firmament we read that both waters and stars are placed, just as also "in the heaven" we mark both the stars and the birds, and "the way of the eagle."

שמים : שחקים : שחקים : שחקים [Hebrew: rāqîa' ("expanse"); shēḥāqîm ("skies, clouds"); shāmayim ("heavens")] are nearly common words, which no less confirm the proposition and exhibit the marks of the heavenly Nature — their particular significations and origins; and so it is worthwhile to observe them all more minutely in the work itself.

The heaven is expressed as Poured-out and fluid by all [these words], but especially by רָקִיעַ [rāqîa'], which denotes something expanded and extended. For what, I ask, could be more expanded or dilated — so as to be called such by way of excellence — than the most tenuous and rarest thing, something like air? And how could a body constricted by the utmost hardness and density [which would then be something wholly earthy] ever be said to be expanded? We have in Isaiah [Margin: 51:6.] an express likeness of smoke to the heaven, or rather, in its very dissolution, an affinity; whence also, from St. Basil and St. Ambrose and other holy Fathers, the fabric of the aether is held to be nothing other than a certain most tenuous smoke, such as the air is. Its tenuity, too, is set forth — its tenuity and rarity are wonderfully [expressed] in the same Isaiah, in these words: [Margin: 40:22.] "Who stretches out the heavens as nothing" — which, as is plain to the reader, is said of the whole body of the heaven; nor can it in any way be called some corpulent, hard, manifold thing occupying vast spaces, "like nothing." On the contrary, it is excellently likened to nothing, as something attenuated and so drawn apart that it hinders nothing and is almost imperceptible to us. In the same way, indeed, the Ancients called the air itself "void," and in Scripture we

read: [Margin: Job 26:7.] "Who stretches out the North [Aquila] over the void, and hangs the earth upon nothing." Behold, here the air is called by the name of "void" and "nothing," and the earth is hung above it, not upon any solid or hard thing that could sustain it.

And although these things thus set forth leave no room for introducing solidity, yet because some of its Authors — as though creeping in secretly from all these, or vainly hunting for escapes — bring in certain things to impose it, namely in Job: [Margin: 37:18.] "Perhaps you fashioned with him the heavens, which are most solid, as though cast of bronze," and elsewhere: [Margin: 14:12(?)] "until the heaven be worn away" (a great support, in the first place, from the solidity spoken of as of bronze; in another place, the wearing-away noted, which is of two bodies) — to remove this handle of whatever kind, I have thoroughly pondered it by consideration and explanation of the passages, being sure that they in no way contradict what was adduced above. Therefore I consulted the primary reading and the Interpreters themselves.

First I noted that it is variously rendered. By some: "Solidities strong with it in antiquity, like the aspect of a pouring-out." By others: "You shall make firm with it the strong antiquities," and so on. By others: "He made firm the heaven into conversions strong as the aspect of a pouring-out." By others: "You stretched out with it the strong clouds like a clear mirror" — or like the aspect or species of a mirror, or of the Fusible. By others: "He made firm the heaven with a robust framework, like the aspect of a Pouring-out." But the Hebrew words themselves are:

מִשְׁתַּחֲקִים עִמּוֹ לְשַׁחֲקִים חֲזָקִים כְּרָאִי מוֹצֵק [Hebrew (Job 37:18): tarqîa' ("you spread out"), from the same root as rāqîa'; 'immô ("with him"); li-shēḥāqîm ("the skies"); ḥāzāqîm ("strong"); ki-rē'î ("as a mirror"); mûṣāq ("molten, cast") — "Wilt thou with him spread out the skies, strong as a molten mirror?"]

"You spread out with him the strong heavens after the manner of a casting": this the words plainly seem to say — as you, most illustrious Lord, will be best able to weigh and assess.

Once I had considered these things, I judge that any sense of aerial or metallic solidity is sufficiently excluded, and the fusion itself, and the expansion, the more confirmed. Certain of the Hebrews expound it so that the sense is this: "Will you help him to pour out the clouds, and to make them strong, so that they be like a mirror, and from them he may transmit light to the earth?" But I have weighed three things in this context. First: that what others render "to make firm

solidities," "to fabricate," and "to extend," they say from תַּרְקִיעַ [tarqîa'], which is to be traced back to expansion, רָקִיעַ [rāqîa']; and it is no wonder if "to make firm" and the like in this place [are derived] from the verb, just as elsewhere "Firmament" [is derived] from the noun, and not so properly. Next: that "Robust," "Strong," "Violent" — to some "solid," to others "Enduring" — which is most aptly taken from חֲזָקִים [Hebrew: ḥăzāqîm, "strong ones"], should be rendered by "Validity," so that it is understood as strong, sturdy, and persevering in its own purity of nature (as St. Bonaventure takes it), or else of a settled and firm order at any time whatever. Third, as concerns the likeness of poured-out air, or of a mirror, or of the Fusible: that only the appearance, or likeness, or aspect of Pouring is meant. Bronze and Mirror are introduced from it because from the same word רָאָה [Hebrew: rā'āh, "to see"] both the mirror which we see and the vision itself can be derived, as Pineda [Juan de Pineda] excellently notes. Hence, because mirrors are of bronze or of glass, there arose for some a glassy or bronze solidity, conveniently joined to the word of casting; so that, when the word מוֹצֵק [Hebrew: mûṣāq, "molten, cast"] signifies the thing itself as poured and liquid, it was carried over to them as "Fusible" and "Liquefiable" — those to whom, perchance, the adamantine hardness of the heaven itself had clung, harder than their own minds. But if perhaps to someone the likeness of poured-out air or of a mirror has appealed too much, there are those who, setting aside any hardness and density whatever, would refer it more becomingly to a constancy and perennial nature of transparency, brightness, and splendor. Besides these, let this too confirm the matter entirely: that "heavens" here is called שְׁחָקִים [Hebrew: shēḥāqîm]. This word, if I have observed rightly, signifies precisely that part of the firmament where the Meteors are generated — namely the air, and not the highest air; though elsewhere it is often, and in the immediately preceding chapter of Job, rendered "air," and properly "thin, comminuted, subtle things," from שָׁחַק [Hebrew: shāḥaq], which means "to comminute, to pound fine,..."

[Federico Cesi to Robert Bellarmine, *De Caeli Unitate, Tenuitate* — conclusion]

[The centered column numerals "I." (left column) and "II." (right column), together with the marginal 5-line count (5, 10, 15...) beside each column, are the reprint's cross-reference apparatus, not textual divisions; the letter is set as continuous prose and is translated as such. Reading order per page is left column, then right column.]

— and to attenuate it. And so any notion whatever of a hard and solid fabric falls away entirely. Along with me, besides others, these men eminent in learning hold

this: Juan de Pineda [Ioannes Pineda], who wrote most copiously and diligently on Job, and Benito Arias Montano [Benedictus Arias Montanus] in his *Natural History*. The latter reads the passage under discussion thus: "Did you, together with him, stretch out the *Sahhakim* [Hebrew: שְׁחָקִים (sheḥaqim, "the skies / clouds")], enduring like a molten mirror?" But in place of "solidity" he understands "Strong, Mighty, Violent," and applies it to the air. Both explain the passage fully and in the same sense.

Now, as for the "wearing away" [*attritio*] set in the second place — in its stead others speak of consuming, dissolving, growing old, or a change like the wearing out of garments; so that the force of that very word need in no way imply a hard body. Even for the least possible case it could be understood [to mean]: "until the Heaven is worn away." But it has seemed by no means necessary to use these explanations, since in very many [copies] these words — "until it is worn away," or "until it is consumed" — are neither added nor read, as I have observed in Comitulus [Paolo Comitoli], and the Hebrew words themselves:

[Hebrew: וְאִישׁ שָׁכַב וְלֹא יָקוּם עַד בִּלְתִּי שָׁמַיִם — Job 14:12, "and man lies down and does not rise until the heavens are no more"]

"and man has lain down; he will not rise until [there is] no Heaven" — they sound, that is, with the substantive verb understood, "until there be no Heaven," if I perceive rightly. As we read elsewhere: "until the Moon be taken away" [Ps. 71:7, Vulgate], for the Hebrew words meaning only "until [there be] no Moon"; so that the very annihilation, or total consuming, of the Heaven is to be understood, and a resurrection compared to it by the powers of Nature. [Margin, beside "until the Moon be taken away": Ps. 71. 7.] And with all these [considerations], this hardness heaped up [against my position] seems to me sufficiently softened, and its darts so turned back upon my opponents that nothing remains as an objection or hindrance to the most finely diffused fluid of the Aether; rather, [my view] seems to shine forth more and more. But who indeed ever — who at last could they be — who, between us and that blessed Homeland of the Empyrean and the promised and longed-for seats of Glory, would prefer to conceive some eighty walls interposed, harder than iron and of monstrous thickness, and would prefer to augment

and multiply the marvels of penetrating its approaches, its descents and ascents? Will it seem beautiful and fitting to construct wondrous bodies utterly unlike all others — bodies passed over in the sacred pages — and to burden Nature, beyond any necessity, with these many great [structures], and to shut us earth-dwellers in on every side within a kind of bark-like husk, as though in a kernel, wrapped in

manifold covering and a most hard cage? Or could a mind, drawn by no reasoning about motion and by no beauty, have clung to such notions so fast that it would laboriously strive to fit to them the very facts, and the arguments, and the sacred texts, so as in no way to depart from them or be dislodged? I would judge — harshly, to be sure — that one ought to be driven far back from these most rigid positions, so that one could not so much as minimally draw near to them, unless a will otherwise disposed than by the desire of knowing had driven and compelled it, even against its will.

Furthermore, as to the motion of the stars — that is, of the shining bodies themselves, a motion simpler, easier, more harmonious, and more effective than that of orbs, and confirmed by the sacred testimonies — how it is carried out: this is the same question as the one concerning the motion of orbs among the sphere-theorists [*Sphaerologi*]. To me indeed, as I explained to you long ago, most illustrious Lord, this too seems to be found in the sacred writings: that Angels are seated within the stars themselves — movers acknowledged even by the Aristotelians, though these wrongly set them, as if to a treadmill, to turning the orbs. In very many places, therefore, I observe that under the name of "stars" Angels are designated in Scripture, inasmuch as they, being many, have their seats in the stars and move them. Not a few, both of the ancients and of recent [writers], since they did not recognize these to be Angels but only understood the stars themselves to be named, seem to have slipped so far as to assert them to be animate. For these things are said of the moving and attending Angels, to whom they belong; and indeed to these pertain that battle and fall of the Angels: "The Dragon drew a third part of the stars; he himself and his angels fought" [Margin: Apoc. 12.]. To which the "unclean stars" in Job seem also to be referred [Margin: 25. 5.], from which Origen judged the stars capable of Vice and Virtue [Margin: 1. Com. in Iob], as also that passage of Job: "and in his angels he found depravity" [Margin: 4. 18.]. And elsewhere: "From Heaven war was waged against them; the stars, standing in their order and course, fought against Sisera" [Margin: Iudic. 5.] — which authority

the astrologers [*Genethliaci*] are wont to abuse in vain. Hence the "Host of the Heavens" is explained as [the host] of the Stars, and concerning it in Isaiah: "I commanded all the host of the Heavens" [Margin: 45. 12. & 40. 26.] — St Jerome [Hieronymus] expounds it: "I commanded all the stars" [Margin: Comm. [in Isaiam?] 3. [?]]. The praises of the Angels, too. In Job: "when the morning stars praised me, and all the sons of God rejoiced." The guardianships and ministries of the Angels, in Baruch [Margin: 3. 34. [printed "8. 34."]]: "But the stars gave light in their watches, and rejoiced; they were called and said, 'Here we are.'" And finally,

the motion of the stars is ascribed precisely to Angels, in Job: "under whom they are bowed down who bear the Orb" [Margin: & Ps. 146. 4. as above, Job 9. 13.]. For the orbs that are carried along are the stars themselves, which are transferred from place to place; whereas those fictitious orbs are by no means moved from their place, but are only rotated within it as to their parts, according to their proponents. And most plainly in Isaiah: "Lucifer, who did rise in the morning" [Margin: 14. 13.]; and in Ecclesiastes: "The spirit goes whirling and whirling about" — said of the Sun. All of which mutually confirm one another: whence my proposition seems to be gathered most fully, and the opposite [view] to be ever more excluded.

These, most illustrious Prince, are the things I have found in the sacred writings concerning the substance, the number, and the motion of the celestial body; and with them Physics and Mathematics

agree most closely — for I have noted more than once that the phenomena and all the experiments fully correspond. So indeed I have adduced them, so I have explained them. I now anxiously long to learn what you think; if they please [you], I shall reckon that I have done a service of no small worth, and I shall apply myself with greater fervor and spirit to the completion of this labor concerning the heavens, always made more vigorous and ready by your auspices. But if in some part I have satisfied [you] less, admonish me, teach me, help me. I am led by the love of the one Truth, and I always embrace it most gladly; and I have judged that I obtained a sufficiently ample pledge [*arrhabo*] of it in these celestial matters, since I have found you assenting to their purity, tenuity, and simplicity.

Farewell, most illustrious Lord, and go on loving and helping me, devoted to you with every affection of my heart, while I venerate God, the Best and Greatest — that, for the good of his whole Church, he may keep you (born under favorable auspices, a model of integrity and learning to be admired in ages to come) safe and prospering yet very long, and bestow upon you all greater and better things. From Acquasparta [Aquaspartae], 14 August 1618.

All'Illustriss. & Eccellentiss. Sig. il sig Federico Cesi Principe di santo Angelo &c.

[Robert Bellarmine's reply — Italian original]

[Beneath the heading, centered: *Acquasparta*.]

[Italian.] Most illustrious and most excellent Lord,

I have read with great pleasure the paper Your Excellency sent me; it is indeed very learned and very novel, and for the most part in agreement with what I hold to be true. One thing alone leaves me not fully content, and that is the figure of the Heaven, which Your Excellency denies to be round, citing St John Chrysostom [S. Gio. Chrisostomo] and others.

Against this I have the text of Ecclesiasticus at chapter 24, which says *Gyrum Caeli circuivi sola* ["I alone have compassed the circuit of Heaven"]; and we see that the Sun, the Moon, and the Stars turn about the globe of the earth; and Solomon in Ecclesiastes says that the Sun *gyrat per meridiem* ["turns toward the south"], etc.; and finally there is no doubt that the round figure is the most perfect, and we know that *Dei perfecta sunt opera* ["the works of God are perfect"]. But what I wanted from Your Excellency is not to know that Holy Scripture and the holy Fathers hold that the Heaven stands still and the stars move, and also that the Heaven is not hard and impenetrable like iron but soft and most easy to penetrate like air — for these things I already knew. Rather, I wanted to learn from Your Excellency how the motions of the Sun and of the stars are to be accounted for [*saved*], and especially of the fixed stars, which always go together and make their circles larger or smaller according as they are farther from or nearer to the Pole — this being the reason why the philosophers and astronomers assign to the seven Planets seven Heavens, and to all the fixed stars a single Heaven. And above all I wanted to understand how the different motions in one and the same star are to be accounted for, if there is only one Heaven, and that immobile.

When I was young, I tried to account for the motion of the Planets from West to East, contrary to their motion from East to West, by saying that their motion from East to West was not, for all of them, of twenty-four hours, but [that the motion]

of the Sun was of 24 hours, while that of the Moon was of 24 hours and a quarter, so that it seemed the Moon by its own motion had turned somewhat backward, and thus little by little drew away and then drew near again to the Sun. As for the motion of the Planets from south to north, I tried to account for it by saying that the motion of the Planets was not a perfect circle but a spiral, and so little by little they passed from south to north and then returned by the same way. But this device of mine did not satisfy for all the Planets, nor even for the stars of the firmament, which — by making very long motions in the meridian circle — seem clearly to show that they are carried by the Heaven, and therefore in the middle make very long circles and at the extremes very short ones. These and similar things I wanted to learn from Your Excellency, in case you had perhaps made

particular considerations toward accounting for the motions of the stars in such a way that one could at the same time preserve the opinion of the holy Fathers, which sets the Heaven immobile and the stars mobile. But I do not wish to occupy you with these speculations, if you have other occupations of greater moment. Let us strive, my Lord, to live in the holy fear of God in such a way that we may reach Heaven, for there, in an instant, we shall be enlightened about everything. May God keep you in health, and command me. I return Your Excellency's paper, in case you may not have kept a copy for yourself, and lest by chance it be lost among my countless scrap-papers.

From Rome, 25 August 1618.

Your Excellency's

Most affectionate Servant,

Cardinal Bellarmine [Il Cardinale Bellarmino].

**Illustriss. & Excellentiss. Domino D. FEDERICO CAESIO
Principi sancti Angeli.**

[Robert Bellarmine's reply — Latin version]

[Latin.] Most illustrious and most excellent Lord,

I read with great pleasure the writing sent to me by Your Excellency; it is truly most learned and novel, and for the most part in agreement with the opinion that I hold to be true. Only one thing is not fully to my taste: the figure of the Heaven, which Your Excellency denies to be round, citing St Chrysostom and others. Against this I have the scripture of Ecclesiasticus ch. 24, where it is said: "I alone have compassed the circuit of heaven." And we see the Sun, Moon, and Stars turn about the globe of the earth. And Solomon in Ecclesiastes says: "The Sun turning toward the south," etc. Finally there is no doubt that the circular figure is the more perfect, and we know that the works of God are perfect. But what I desired from Your Excellency is not to understand that Holy Scripture and the holy Fathers assert the heaven to be firm and the stars to move, and that the heaven is not hard and impenetrable like iron but soft and most easily penetrable like air — for all these things I knew. Rather, I wished to learn from Your Excellency how the motions of the Sun, and of the Stars — especially the fixed ones, which are always together and complete their circles larger or smaller according as they are farther from or nearer to the pole — are to be accounted for. For this is the reason why the Philosophers and Astronomers give to the seven planets seven

heavens, and to all the fixed stars a single heaven. Above all I desired to understand how the different motions in one and the same star are to be accounted for, if there is only one heaven, and that immobile. When I was young, I tried to account for the motion of the planets from West to East, contrary to the motion of the same from East to West, by saying that their motion from East to West

was not for all of them of 24 hours, but that [the motion] of the Sun was of 24 hours, and that of the Moon of 24 hours and one quarter. And therefore it seemed that the Moon, by its own motion, had receded somewhat, and so gradually drew back and afterward approached the Sun. As for the motion of the planets from south to north, I tried to account for it by saying that the motion of the planets was not a perfect circle but a spiral, and so gradually advanced from south to north and then returned by the same way. But this device of mine did not satisfy for all the planets, nor for the stars of the firmament, which — since they have very long motions in the meridian circle and very short ones toward the poles — seem clearly to demonstrate that they are carried by the heaven, and therefore in the middle make very long circles and at the extremes very short ones. These and similar matters I wished to learn from Your Excellency, in case you had perhaps applied particular considerations toward accounting for the motions of the stars in such a way that at the same time the opinion of the holy Fathers — asserting the heaven immobile and the stars mobile — might be preserved. But I do not wish to occupy you with these speculations, if you are detained by other occupations of greater moment. Let us strive, my Lord, to live in the holy fear of God in such a way that we may reach heaven; for then, in a single instant, we shall understand all things. May God keep you in health, and command me. I return Your Excellency's writing, lest — if perhaps you did not keep a copy for yourself — it should perish among my countless *apsodiae* [i.e. rhapsodies, jumbled papers]. Rome, 25 August 1628. [The Italian version gives 1618.]

Your Excellency's

Most devoted Servant,

Cardinal Bellarmine [Card. Bellarminus].

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In which the Authors are also listed under the heading of Water and of Heaven, as well as under their own initial letter.

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- The Censor makes himself the first inventor of the optical tube [Censor se primum Tubi Optici inuentorem facit], p.31.2.22. & 130.1.47

- The Censor teaches nothing beyond the use of the telescope [Censor praeter Telioscopij usum nil docet], 11.1.55
- When did the Censor not have the Sun enclosed in a circle? [Censor Solem circulo inclusum quando non habuerit?], 14.1.13
- The Censor published his own in 1613, Apelles his in 1612 [Censor sua an.1613. edidit, Apelles sua 1612.], pag.28.1.45
- The Censor's writings [Censoris scripta], p.2.1.50. & p.10.1.42. & p.12.2.15. & p.13.1.52. & p.14.1.41. & p.15.2.12. & p.16.1.27. & p.18.2.23. & p.22.1.12. & p.23.2.50. & p.24.2.20. & p.28.2.1. & p.32.2.10. & p.33.1.25. & col.2.25. & p.34.1.18. & col.2.10. & p.35.1.37. & p.37.2.45. & p.38.2.42. & pag.39.1.10. & vers.42. & vers.53. & p.51.1.12. & 53.1.36. & p.54.2.50. & p.61.2.8. & p.65.1.24. & col.2.30
- A concave sheet better represents the images [Charta concaua melius species repraesentat], 110.2.15
- By agitating the sheet the spots reveal themselves more [Chartae agitatione maculae magis se produnt], 138.4.1
- Christophorus Rothmannus [Christoph Rothmann], for a liquid heaven [pro caelo liquido], 764.1.1. & 741.2.20
- Christophorus Clavius [Clavius], for a liquid heaven [pro caelo liquido], 766.1.10
- St. Chrysostom, for waters above the heavens [s.Chrysostomus pro aquis supra caelos], 645.1.15. & p.716.2.40
- for a corruptible heaven [Pro caelo corruptibili], 660.1.30
- for a fiery heaven [pro caelo igneo], 628.1.15
- for a liquid heaven [pro caelo liquido], 717.1.30
- Ciccus Esculanus [Cecco d'Ascoli], for a fluid heaven [pro caelo fluido], pag.763.1.30

I.

- Cicero, for a fiery heaven [pro caelo igneo], 653.2.15. & 747.1.20
- for a liquid heaven [pro caelo liquido], *ibid.*
- Ash is not consumed in fire [Cinis in igne non consumitur], pag.655.1.25
- On the polar circlets [circelli] in the Sun around which the spots revolve yearly [de Circellis polaribus in Sole circa quos voluuntur Maculae annuè], 554.2.20
- How many circlets there are [Circelli quot sint], 555.1.15
- Where the poles of the circlets lie [vbi Circellorum poli consistent], *ibid.*

- Whether the circlets are equal to one another [an Circelli inter se sint aequales], *ibid.* colum.2.20
- What the axis of the circlets is [Circellorum quis sit axis], *ibid.* col.2.30
- How large the circlet is [Circellus quantus sit], *ibid.* col.2.45
- The size of the circlet ranges between 6 and 8 degrees [Circelli magnitudo inter 6. & 8. gradus versatur], 556.1.15. & col.2.40
- By what reasoning the size of the circlet was investigated [Circelli quantitas quibus rationibus inuestigata sit], 556.1.40
- Why the size of the circlet is sometimes larger, sometimes smaller [Circelli quantitas cur aliquando maior aliquando minor sit], 557.1.1
- In what time the circlet completes its period [Circellus quanto tempore periodum absoluat], 557.1.30
- Whence, whither, and of what kind the motion of the circlet is [Circelli motus vnde, quo, & qualis sit], 557.2.5
- With what speed the circlet is carried, in miles and paces [Circellus quanta celeritate feratur in milliaribus & passibus], 557.2.25
- From where the beginning of the circlet's motion is to be reckoned [Circelli motus initium vnde faciendum], 558.1.15
- When the beginning of the circlet's motion occurs [Circelli motus initium quando fiat], p.558.1.40
- The poles of the circlets [Circellorum poli], 560.1.26
- Small circles are insufficient for observing the phenomenon [Circuli parui ad obseruandum Phaenomenon insufficientes], 208.2.25. & 220.2.1. & vers.19. & p.170.1.35. & 186.2.35. & 258.1.12
- When conditions are equal, equal circles are preferred in observing [Circuli aequales in aequalibus praeferuntur in obseruando], 137.1.25
- Smaller observational circles are not to be wholly rejected [Circuli obseruatorij minores non sunt penitus reiiciendi], 137.3.5
- The use of the circle through the vertex [Circuli per verticem vsus], 147.4.10
- To describe on a sphere a circle equal to one on a plane [Circulo in plano aequalem in sphaera describere], 144.2.1
- It is better that the observational circles come from the same telescope [Circulos obseruatorios ab eodem telioscopio prodire praestat], 137.1.40
- It is better to gather several observations into the same circle [in Circulum eundem plures obseruationes colligere praestat], 137.2.40
- What is called an observational circle [Circulus obseruatorius quis dicatur], 91.2.5

- How the observational circle and the solar circle are distinguished [Circulus obseruatorius & solaris quomodo distinguantur], 136.1.40
- A larger observational circle is preferred to a smaller one [Circulus obseruatorius maior minori praefertur], 136.2.20
- The observational circle is marked out in practice [Circulus obseruatorius practice designatur], 137.4.25
- The annual circle of the spots, after a long[?] time, scarcely becomes perceptible [Circulus annuus macularum post lon[gum?] tempus vix fit perceptibilis], p.440.1.30 (*entry completes at the head of column II; the word at the column break reads "lon-"/"gutu" and is unclear*)

II.

- Claudius Marius Victor, for the supracelestial waters [Claudius Marius Victor pro aquis supracaelestibus], 643.2.40
- Cleanthes, for a fiery heaven [Cleantes pro caelo igneo], 747.1.30
- for a liquid heaven [pro caelo liquido], ibid.
- St. Clement, for waters above the heavens [s.Clemens pro aquis supra caelos], 645.1.15
- for a corruptible heaven [pro caelo corruptibili], 683.2.30
- A less intense color, superimposed on a more intense one, augments it [Color minus intensus intensiori superadditus illum auget], 128.4.53
- A uniform color is not confused [Color vniformis non confunditur], pag.101.1.1
- Color of light [Color lucis]. See "Of light."
- Color of the Sun [Color Solis]. See "Of the Sun."
- Comets, nine[?] in number, seen in the heaven above the Moon [Cometae nouem in caelo supra Lunam visi], 736.2.20. & 737.2.40. & 766.1.10 [? the word "nouem" (nine) may instead be "novè" (newly)]
- Comets seem to have their origin from the Sun's spots [Cometae è Maculis Solis ortum habere videntur], 612.2.30
- The comet of the year 1618 is believed to have been generated by Mars or Mercury [Cometa anni 1618. à Marte aut Mercurio procreatus creditur], pag.687.1.34
- On the cause of comets [de Cometarum caussa], 748.1.20
- When the confusion of images occurs [Confusio specierum quando fiat], 100.1.5. & 116.1.35. & 119.2.2

- Whence the confusion of the image arises [Confusio speciei vnde oriatur], 118.2.35
- The first station of the confusion [Confusionis prima statio], *ibid.* col.1.1
- Copernicus, for a liquid heaven [pro caelo liquido], 741.2.20. & 763.2.40
- Cornelius Gemma, for a liquid heaven [pro caelo liquido], 763.2.55
- Cornelius à Lapide [Cornelius a Lapide], for a corruptible heaven [pro caelo corruptibili], 688.1.20
- Corollaries from the Florentine disputant against Apelles [Corollaria ex disputatore Florentino in Apellem], 3.1.15
- What is corruptible and incorruptible according to Aristotle [Corruptibile, & incorruptibile quid sit secundum Aristotelem], 750.1.1
- All things are corruptible except God [Corruptibilia omnia sunt praeter Deum], 665.1.11
- Crates, for a liquid heaven [pro caelo liquido], 760.1.1
- *On the course of the solar spots* [De Macularum solarium cursu].
- Courses [cursus] nearer the center are smaller, those farther from the ecliptic larger [Cursus centro viciniore minores, ab ecliptica remotiores maiores], p.248.1.47
- Subcontrary courses [Cursus subcontrarij], 331.2.1
- Subcontrary courses in opposite months [Cursus subcontrarij mensibus contrarijs], 320.1.10
- Subcontrary courses of different years [Cursus subcontrarij annorum diuersorum], 334.1.40. & 324.2.40
- Subcontrary courses in the same year and month [Cursus subcontrarij, anno & mense eodem], 328.2.30
- Course from the North to the South [Cursus ab Aquilone in Meridiem], 224.2.47

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- The course or motion of the solar spots, deviating much from the ecliptic [Cursus seu motus Macularum solarium ab Ecliptica multum declinans], 282.2.26
- Thirteen courses of the spots are completed in a year [Cursus Macularum tredecim in anno absoluuntur], 440.1.8
- Courses more convex toward the ecliptic cause a greater delay [Cursus ad Eclipticam magis conuexi maiorem moram causant], pag.296.2.25

- Courses rectilinear to the senses [Cursus ad sensum rectilinei], 208.2.44. & 210.2.20. & 214.1.10. & 220.1.15. & 224.1.27. & 225.1.35. & 230.2.30. & col.1.51. & 262.2.28. & 272.1.5. & 274.2.23. & 276.1.1. & 278.2.13. & pag.286.2.31. & pag.318.col.2.40
- The same rectilinear course returns after six months [Cursus rectilineus idem post sex menses redit], 437.1.16
- Diverse aggregates of data and observations show the courses to be rectilinear to the senses [Cursus ad sensum rectilineos diuersae vniuersitates & obseruationes docent], 220.1.15
- When the courses are most rectilinear [Cursus quando maxime rectilinei], 225.2.22
- Rectilinear courses do not occur in the larger orbs of the Sun [Cursus rectilinei non sunt in orbibus soli maioribus], 424.1.30. & columna 2.15
- Curvilinear courses always exist [Cursus curuilinei semper existunt], 224.2.25. & 290.1.1. & 228.1.45
- The courses of the spots appear rectilinear twice a year [Cursus Macularum bis in anno rectilinei apparent], 423.2.1
- The difference of the rectilinear courses nearly equals a day [Cursuum rectilineorum differentia ferme diem adaequat], pag.288.colum.2.25
- The difference of the rectilinear courses is scarcely a few hours [Cursuum rectilineorum differentia vix aliquot horarum], pag.288.colum.2.20
- Rectilinear courses cover equal spaces in equal times [Cursus rectilinei temporibus aequalibus aequalia conficiunt spatia], pag.318.1.10
- The annual course of the solar spots begins in December [Cursus Macularum solarium annuus in Decembri initium sumit], pag.163.col.1.23
- Some course of the spots is annual [Cursus aliquis Macularum est annuus], 422.2.50
- The total course ranges between 26 and 27 days [Cursus totalis inter 26. & 27. dies versatur], 549.2.45
- Complete courses are of 12, 13, 14, and 15 days [Cursus integri sunt dierum 12. 13. 14. & 15.], p.412.1.32
- The annual, semiannual, and quarterly alternation of the courses is perpetual [Cursuum annua, semestris, & trimestris vicissitudo perpetua est], pag.162.1.11
- From March to September the courses run from north to south, from September to March from south to north [Cursus à Martio ad Septemb. ex

aquilone in austrum, à Septemb. ad Martium ex austro in aquilonem fiunt], 161.2.42

II.

- Courses of different years are alike [Cursus annorum diuersorum similes], p.225.1.35. & 228.1.45
- Courses of the years [Cursus annorum]. See "Of the years."
- The course of the spots in one year is like the course of other years at the same time [Cursui Macularum vnus anni similis est cursus aliorum annorum tempore eodem], 422.2.25
- Courses at different places are alike [Cursus locorum diuersorum similes], p.172.1.25
- Unequal courses [Cursus inaequales], 246.2.5. & 260.2.3. & 335.2.1
- Unequal courses at the same time [Cursus inaequales eodem tempore], 290.1.5. & 330.1.53
- An unequal course in the same parallel [Cursus inaequalis in eodem parallelo], 316.2.50. & 190.1.15. & pag.246.2.25
- The course around the vernal equilibrium exceeds the northern courses by more than a day [Cursus circa aequilibrium vernum superat cursus boreales plusquam die], p.304.1.12
- The course of December [Cursus Decembris]. See "December."
- Course of 13 days [Cursus dierum 13.]. See "Of the days."
- Distances of the courses [Cursuum distantiae]. See "Distances."
- The Douai course [Cursus Duaceni]. See "Douai."
- The Freiburg course [Cursus Friburgani]. See "Freiburg."
- Fragments of the courses [Cursuum fragmenta]. See "Of the days."
- The courses are not unlike elliptical ones [Cursus ellipticis haud absimiles sunt], p.308.2.40. & 260.2.19
- Course at equilibrium [Cursus in aequilibrio], 186.1.1
- Courses beginning at the same point, month, and day will be alike [Cursus incipientes eodem in puncto, mense & die similes erunt], pag.160.1.35
- Between May and June the course always becomes rectilinear, obliquely from north to south [Cursus inter Maium, & Iunium rectilineus fit semper oblique ex Borea in Austrum], 225.2.1
- Between November and December it tends obliquely from south to north [Cursus inter Nouembrem, & Decemb. ex Austro oblique tendit in Boream], 225.2.2

- For three months the courses are convex toward the north, and for another three concave [Cursus mensibus tribus conuexi in Aquilonem & alijs tribus concaui], 161.2.41
- In March, April, and May the courses are concave toward the south [Cursus Martio, Aprili, & Maio concaui sunt in Austrum], *ibid.* vers.42
- In June, July, and August they are convex toward the south [Cursus Iunio, Iulio, & Augusto conuexi sunt in Austrum], 161.2.46
- In September, October, and November they are convex toward the south [Cursus Septem. Octob. & Nouemb. conuexi sunt in Austrum], 162.1.1
- In December, January, and February they are concave toward the setting south, convex toward the rising north [Cursus Decemb. Ian. & Febr. concaui in Austrum occiduum, conuexi in Septentrionem ortium], 162.1.6
- Where, when, and how the courses begin to curve [Cursus vbi, quando, & quomodo curuescere incipiant], 225.1.15
- The winter course becomes rectilinear at the beginning of December [Cursus hyemalis rectilineus fit initio Decemb.], 225.2.25
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- *Cursus macularum, facularum, & vmbrarum idem* — The course of the spots, faculae, and shadows is the same. 225.2.25.& 226.2.30 & 310.2.9
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- *Daemones in aëre habitasse, ait S. Aug.* — Demons dwell in the air, says St. Augustine. 627.2.25
- *Decembri & Nouembri summa macularum ab ecliptica declinatio* — In December and November, the greatest declination of the spots from the ecliptic. 276.1.9
- *Decembri aliquot diebus Sol à maculis vacuus* — In December, for several days, the Sun is free of spots. 163.2.20

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- *Dierum minimum decem omnium macularum cursus* — The course of all the spots, at least ten days. 218.1.1
- *Dierum 10.& horarum 9. cursus* — Course of 10 days and 9 hours. 317.1.10
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- *maior Dierum 12. cursus* — greater, course of 12 days. 175. num. 7.& 190.2.55.& 318.1.19
- *Dierum duodecim & semis cursus* — Course of twelve and a half days. 318.1.45.& 292.1.14
- *Dierum tredecim cursus rarus* — Course of thirteen days, rare. pag. 292.2.10
- *Dierum tredecim cursus* — Course of thirteen days. pag. 298. col. 2.10
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- *Dierum 13.& semis cursus* — Course of 13 and a half days. pag. 318.2.39
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- *vnius Diei faculae & vmbrae* — Faculae and shadows of one day. 238.2.25 & 274.1.19
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- *Dionysius Carthusianus* [Denis the Carthusian] — for waters above the heavens. 727.2.40
- *Distantiae mac. triplo auctae* — Distances of the spots increased threefold. 298.1.15.& 266.2.22
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- *Distantiae macularum aequales quod rarum est* — Equal distances of the spots, which is rare. 312.2.5
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- *Eclipsis Solis facta in passione Domini à maculis solaribus causata fuit* — The eclipse of the Sun at the Lord's Passion was caused by solar spots. 611.2.50
- *plures Solis Eclipses non à Luna* — Several eclipses of the Sun not caused by the Moon. 609.1.20
- *Ecliptica Solis quae dicatur* — What is called the Sun's ecliptic. pag. 154.2.25
- *Eclipticam in circulum obseruatorium inducere* — To draw the ecliptic onto the observatory circle. 149.2.5
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- Why the Sun is brighter at the center. p. 619 col. 1.1
- The translucent Sun is brighter within. 619. 2.30
- Some part of the solar light does not equal the Moon's light. p. 656. column 2.25
- Physical questions arising from the Sun's motion. 607 col. 1.1
- The Sun does not move the planets by its own motion. p. 604.1.31

[column II]

- The Sun's motion with respect to magnitude. p. 601 2.1
- The Sun's motion of alteration. p. 601. col. 2.35
- The Sun is much larger than is believed. 578 1.20. & 584.1.15
- How great the visible diameter of the Sun is. p. 571.1.1
- The Sun's diameter and perimeter expressed in paces and miles. p. 586 1.25

- The margins of the solar disk are reddish and dusky in color. 574.2.30
- The Sun's magnitude has hitherto been uncertain. p. 573.1.20
- The Sun's diameter is investigated with a new instrument. col. 2. 10
- Why the Sun, having entered through angular figures, appears circular. 580.2.55
- Light admitted from elsewhere diminishes the solar base. 582.2.5
- Annotations on the image of the Sun admitted through an aperture. 580
- The Sun is nearer to the Earth than is believed. p. 584.1.25
- The sunspots eclipse the Sun for the whole world. p. 605.1.1
- The Sun's magnitude is obtained through observation of the phenomenon. p. 605. 1.30
- If the Sun is changeable, then the stars and the rest of the heaven will be alike [changeable]. 608.1.10
- How the Sun's perigee and apogee are detected. 606.1.40
- How large a part of the Sun appears. p. 570. 1.5
- St. Isidore [Isidore of Seville] says the Sun by its rays causes the various courses of the planets. p. 759. 1.45
- The Sun is spherical. page 603. column 2.40
- The Sun's surface is rippled. p. 604. col. 1.20
- Simon Marius [Simon Marius] says the Sun twinkles. p. 741.1.15
- The Sun strikes the eye not by its own nature but on account of its magnitude. p. 656. 2.5
- Even if the Sun stood still, generations would still occur. 599.1.55. & col. 2.30
- That the Sun is nearer is not the cause of greater activity. 598.1.6
- The Sun is a corporeal substance. 594.1.47

[column I]

- The Sun is divided into zones. p. 568. col. 1.25
- White spaces interspersed among the spots. p. 276 2.25
- White spaces between the nuclei. 210.2.31. & 256.2.30
- A white space brighter than the rest of the Sun's body. 219.2.15
- Whether a uniform space is always present on the Sun is uncertain. 344.2. 40
- Images pass through the tube without any distinction of colors. p. 503. col 1.5

- That the sphere in which the spots move is not larger than the Sun. p. 428. column 2.15
- Squarcialupus [Squarcialupi] for a fluid heaven. p. 764 1.1.
- The new star in Cassiopeia in the year 1572 was observed by Clavius [Clavius]. p. 766. col 1.20
- Clavius says new stars can be generated in the heaven. col. 2.5
- Clavius places in the heaven a new star seen in Cygnus in the year 1600. column 2.25
- Clavius says there was a new star in Sagittarius in the heaven in the year 1604. p. 766. 2.30
- Nine stars are enumerated which appeared and disappeared in the heaven. 736 2.20
- The star seen in Cassiopeia proves the heaven corruptible. page 689. column 2.1
- Seneca [Seneca] says the stars are nourished by earthly exhalation. 749.1.15
- Ptolemy [Ptolemy] holds the same. p. 756. 1.10
- Vitruvius [Vitruvius] said the stars are kindled by the Sun. 759.1.15
- The stars are of a fiery nature. p. 662. col 1.25
- The stars will truly fall from heaven. line 35. & 689.2.40
- The stars receive all their light from the Sun. 600.2.30
- The stars draw rays from the Sun and, affected by their own property, send them back to the earth. col. 1.30
- The stars have their own influences. 2. 38
- Vapors in the atmosphere cause the twinkling of the stars. line 20

[column II]

- Stars shine at midday, as is evident during solar eclipses. p. 417.1.5. & 418. 1.10
- A method for seeing the stars at midday. 417. 1.53
- The raising of a style at the Sun's margin. p. 72. 2.46
- The Stoics for a fiery heaven. 640.2.35. — for a fluid heaven. 755.2.30
- Strabo [Strabo] for waters above the heavens. p. 645 1.30
- The Sibyl for a corruptible heaven. p. 690. 2.10
- Symmachus [Symmachus] for a fluid heaven. p. 772. 2.35

T

- What the lateral tablets are. p. 216. 1. 50
- Lateral tablets of various places. 199. 217. 229. 257. 281
- What the Tablet of Apelles is. 7.2.15. — why it is so called. col. 1. 25. — when written and published. 56.1.30
- The Tablet was published by Marcus Welser [Marcus Welser]. 7. 1. 36
- What is taught in the Tablet. 15. 1.30. & 17. 2. 22
- The Tablet of Apelles differs greatly from the Censor's *Saggiatore*. 2.2.35
- What is called a telescope [Telioscopium]. p. 131. col. 4.20
- The use of the telescope. 71.1.15. & 130.2.30
- The telescope was first invented in Germany. 68.2.14
- The Censor wished to make himself the inventor of the telescope. 5.1.4
- The material parts of the telescope. 133. col. 3.35
- What the rings of the telescope ought to be like. 133. col. 4.7
- The telescope serves every healthy eye. 451.1.46
- The telescope reveals what escaped the sharpness of the eyes and shows an object more, and more clearly. 451.1.36
- The near-sighted shorten the telescope, the far-sighted extend it. page 451. col. 1.53
- The telescope is shortened for near objects, extended for distant ones. p. 131. col. 4.35. & 135.1.35. & 451.2.1
- One aperture after another is used for the telescope. 137.2.10

[column I]

- The time must be marked at the end of an observation. 149. col. 3.40
- To recognize an unsuitable time for observing. 149. col. 3.10
- A suitable time for observing. 149. col. 4.20. & col. 30.1. & column 31.1. See "Observation."
- The Earth will burn up together with the heaven. 665 1.20. 683.1.5
- How great the magnitude of the Earth is. 585.2.16
- The Earth is opaque, impervious to the Sun's rays. 594.1.53
- The Earth, smaller than the Sun, is surrounded by the region of the atmosphere. 594.2.5
- The Earth and the heaven exist from and through water. 668.1.50
- Tertullian [Tertullian] for waters above the heavens. 645 1.25
- for a fiery heaven. 627.2.1
- Thābit [Thābit ibn Qurra] for a fluid heaven. 763.1.35

- Theodoret [Theodoret] for waters above the heavens. 645.1.30
- for a fiery heaven. p. 627.2.50. & 633. 1.3.
- for a fluid heaven. 724 1.20
- Theologians who defend a fluid heaven. 731
- Theophylact [Theophylact] for a fluid heaven. p. 723. 1.43
- St. Thomas [Thomas Aquinas] interposes a fluid ether between the epicycles. 770.1.10
- The same for waters above the heavens. p. 643. 2. 31
- for a fiery heaven. 630.1.30
- for a fluid heaven. 729. 1.50
- Tostatus [Alfonso Tostado] for the fiery nature of the heaven. p. 632. 1.25
- The use of certain spherical triangles. 371.
- Which tube is better. 136. col. 4.10
- From the tube's aperture the distance of a place is determined. 132.1.5. 131.1.45
- Comparison of the tube with the eye. 114.1. 54. & col. 2.10
- Practical rules of the inverted tube. 114.1.1
- Why a tube drawn out too far accomplishes nothing. 127. col. 4.53
- How and from what material tubes are made. 133. col. 3.45
- The retina is the formal organ of vision. 120.1.50
- Tycho Brahe for a fluid heaven. 741. 1.45. & 763.2.15

[column II]

V

- Vapor around the nuclei. p. 290. 1.40
- Vapor around the spots. p. 298 1.20
- Venus revolves around the Sun. 758. 1.40
- Venus does not cause the spots on the Sun. 410 1.1
- The finding of the vertical of the meridian. p. 149. col. 5.1
- To state the least and greatest inclination of the verticals to the ecliptic for the whole year. 149. col. 29. 1
- Vertical circles. See "Circles."
- Vielmus, a Dominican, Bishop of Aenomia [?], for waters above the heavens. p. 648. 1.40
- for a corruptible heaven. 673. 1.15
- for a fluid heaven. 734. 1. 1

- Virgil [Virgil] for a fluid heaven. 755.2.30
- Vision follows the picture — a clear vision, a clear picture. p. 120.1.47
- Why vision contradicts a picture on paper. 128. col. 3.20
- The visible is whole in the whole and whole in any part. 116.2.50
- The use and adaptation of the lenses. p. 96. 2.40
- A lens that magnifies the object more shows a smaller part of the object. 128. col. 4.28
- Vitruvius for a fluid heaven. 758.1.35.
- A description of the shadows [umbrae]. 157.1.1
- What the secondary shadows are. 346.1.10
- Where the secondary shadows are. *ibid.* line 20
- The secondary shadows move like the primary ones. 346.2.25
- Diverse shadows. 226.2.8
- Shadows lasting three days. 244.1.20
- Shadows at midday. 233.2.2
- Some shadows last several days, some one day, some scarcely exceed an hour. 344.2.50
- A shadow [umbra] blazing with faculae. 272.2.22
- An umbra and a facula, following a spot, precede it at setting. 262.2.20. 246 1.16
- Umbrae are often spots. 246.1.10
- Umbrae are the seed of spots. p. 290. 2.39

[column I]

- Umbrae and spots move. p. 290 2.38
- Umbrae are transformed into spots. 234 2.45. & 270.2.22. 318.1.50
- Umbrae into spots, and these back again into umbrae. 306. 2.40
- An umbra changed into a spot, and this into a facula. 262. 2.10
- An umbra arising physically. 318.2.28
- The umbrae, luculae, and plagae on the Sun are always different. 344.2.45
- A returning umbra. 318.2.20
- Welser [Marcus Welser] testifies that Apelles had not seen the Censor's writings. 21.2.1
- Welser was the first to publish the Tablet of Apelles. 7.1.1 (*entry begins in column I, "Welserus primus Tabulam Apellis in—" and completes at the head of column II with "vulgus dedit"*)

[column II]

- Willebrord Snellius [Willebrord Snel] for a fluid heaven. 763.2.5
- Witichius [Paul Wittich] for a fluid heaven. 764.1.1

X

- Xenophanes [Xenophanes] for a fiery heaven. p. 640.2.35

Z

- Zacharias, a Christian philosopher, Bishop of Mytilene [Zacharias of Mytilene], for a corruptible heaven. 679.2.30

FINIS.

[End of the Index of Principal Subjects, and of the volume. No errata, colophon, or further end-matter follows the FINIS on this page; the remainder of p. 996 is blank.]

Erratorum Correctio (Correction of Errors)

The four leaves following the index's **FINIS** are the volume's **errata list**, headed *Erratorum Correctio*. The physical sequence as imaged is scrambled: two of the four scans duplicate content already captured.

- ** ** — *Erratorum Correctio*, part 1 (opening address + errata for pages 2–427).
- ** ** — the final page of the *Index Praecipuarum Rerum* ending in **FINIS**. This is a ****DUPLICATE image**** (already translated in the prior batch). Flagged for Cat-D dedupe.
- ** ** — *Erratorum Correctio*, part 1 again. This is a ****DUPLICATE image****. Flagged for Cat-D dedupe.
- ** ** — *Erratorum Correctio*, part 2 (errata for pages 428–764), the true verso continuation of p. 997.

Erratorum Correctio

Opening address to the reader (translated):

Since in so large a volume — and especially through my absence — a number of errors have crept in owing to the carelessness of the compositors, I here set them out for correction, beginning with the page-numbers themselves; for unless these are first put right, you will neither find nor be able to correct the other errata.

The true numbers to be substituted for the faulty ones are these. In Book 3, at pages 366 and 367, in place of the numbers 368 and 369, [read them] immediately after the numbers 365 as printed. In Book 4 the true numbers to be restored are these: 511, 512, 513, 514, 519, 520, 521, 522, 527, 528, 529, 530, in place of the false numbers 459, 460, 461, 462, 467, 468, 469, 470, 475, 476, 477, 478, beginning immediately after the number 510. In Book 2, from page 125 onward the numbers are inscribed on one side only — the earlier (recto) face of the page — up to page 149; and for this reason each of those pages has its several columns marked at the head with the numeral-signs I, II, III, IV in fours, according to which the numbering on these pages is set up. On the same principle, from page 149 to the end of the book this single unchanging number 149 is set at the head of each and every page, twelve at a time, while the columns — by which the counting here proceeds — are marked with the numeral-characters from 1 to XLII. Moreover, among the Greek and Latin letters ββ, γ γ, η η, u H, and likewise X and χ, etc., frequent confusion has occurred; of which I warn the Reader, so that if anything has escaped my diligence in noting the errors, he may by his own learning and shrewdness make it good. And so that the places of the errata may be found quickly, at the head [of each column] I set the Page, Column, Line, Error, Correction. Furthermore, among the cited authorities, sometimes what is mine is marked as though produced by others, and what is others' as though it were mine: which the prudent reader will easily tell apart, especially by inspecting the cited sources of the authors themselves. Farewell, and above all make use of the corrected text. If it wearies you to enter the corrections, it has certainly not wearied me to make them for your benefit. Farewell again, kind Reader.

Errata table (transcribed verbatim; each entry gives Page · Column · Line · *error as printed* → *correction*). The list runs in three panels across the page (left, then middle, then right); the internal book-dividers EX LIB. II./III./IV. are preserved. Purely typographic Greek-letter / mathematical-symbol corrections are transcribed to best reading, with [?] where the exact glyph could not be resolved at native resolution.

Panel 1 (left)

Pag.	Col.	Ver.	Errata	Correcta
2	2	4	ad ϝ	ed
2	2	—	in margine sit	fit
3	1	9	imprimis	in primis
3	2	7	vlliq, lesione	vllius laesione

Pag.	Col.	Ver.	Errata	Correcta
3	2	46	constructi	constricti
8	1	26	libbellam	libellam
8	2	22	impastor	impostor
10	2	53	censui	sensui
11	1	42	perpediculi	perpendiculi
12	1	3	multos	multas
14	1	7	suparem	supparem
18	2	18	cronologica	chronologica (uisset)
24	2	12	in marg. nil	nil sci[-]
26	1	3	praessisset	pressisset
26	2	51	summa	summo
28	1	33	1610.	1611 (menō)
30	2	6	Phaenomen.	Phaeno[-]
36	2	7	variabili	iuvariabili
40	2	16	qui est	q est Iunius
40	2	17	diem	diem 6. Iunii
53	1	10	disqtione	disqsitio[ne]
57	2	48	hius	huius (ne)
58	2	17	absolute	absolute
59	2	55	errores	errones
60	1	17	errores	errones
61	1	31	nimis prouide	nimis improuide

EX LIB. II.

Pag.	Col.	Ver.	Errata	Correcta
68	2	43	vsu	visu
69	1	19	obtatu	obtutu
69	1	41	ius	via
69	1	48	maius	mauis
69	2	13	stadium	studium
69	2	21	nūquam frustra	nūquam; frustra

Pag.	Col.	Ver.	Errata	Correcta
69	2	43	Elliptica	Elliptico
71	2	20	Solo	Sole
73	2	7	Sole	Soli
74	1	44	Cap.	Cap. XXIII.
74	2	53	quis	qui
75	1	39	quas	per quas
75	2	46	locis	lucis (mēta)
76	1	30	ipedimētis	impedi[mentis]
76	1	35	Telioscopice	Telio[scopica]
76	1	37	G,H	GH (scopica)
76	1	43	asserere	assere
76	2	18	Num.1.	Num.6.
79	1	41	excipientur Sol	excipietur Sol
79	2	48	occupationes alias	occupationes aliae
89	2	13	diueniri	deueniri
91	2	51	iuestigies	iuestiges
92	1	14	cuiusmodi	cuiusmodi sit
94	2	14	morae	more
94	2	52	colum	colurum
96	2	12	immissio	immisso
97	2	20	inclinatinnes	inclinationes
99	1	19	non esse	non est
99	1	43	qui	quae
101	2	25	qui	quae
103	1	15	otime	optime

Panel 2 (middle)

Pag.	Col.	Ver.	Errata	Correcta
103	1	51	ipsae	ipse
103	2	18	perstinctas	pstrictas
104	1	8	striati	itriati

Pag.	Col.	Ver.	Errata	Correcta
107	1	3	n ξ κ θ	n ∫ κ θ
108	1	46	remotiore	remotio[re]
108	2	5	tamen	tantū (ra)
110	2	50	Anatome à	(adde) quodā Sapientiae Romanae Doctore
110	2	55	Corneam non esse	(adde) consolidatiuae concentricā, sed foras per modū ferme superficiei hyperbolicae, ptuberare. Alterum neruum opticum non esse.
110	2	48	ptrudito	ptruditur
115	1	51	speculari	ipeccillo
115	1	55	proportionata	proportionato
116	1	1	Coroll. I.	Coroll. II.
119	1	38	ex quia	ex qua
120	2	30	intersectio ∫	intersectio g
122	1	22	κ ι	α f
122	2	29	κ ι	α f
122	2	9	est	&
124	2	33	adhibendorom	adhibendorum (ne)
128	2	22	collocat	collocatio[ne]
128	3	31	ingressam	ingressā speciem
129	1	14	IX	& n
129	4	15	psopographicas	psopographicas [?]
129	4	45	connexam	conuexā
131	3	12	quod	quot
136	3	9	inutilis cursibus	mutilis cursibus
136	4	17	portione	portionē
139	2	45	proijciatq;	proijcitq; [?]
139	4	10	vel post	vel post meridiem
141	3	32	perpēdiculū H	perpēdiculū n
141	3	33	sunt H	sunt n

Pag.	Col.	Ver.	Errata	Correcta
141	4	55	Mac. H	Mac. n
144	4	12	PSV	FSV
145	2	2	describere	describe
145	2	6	κ ξ	κ Ϛ
145	3	7	minorē H	minorem n
149	2	9	prestabis	obseruabis

Panel 3 (right)

Pag.	Col.	Ver.	Errata	Correcta
149	11	52	Verticalem A, 30 C.	Verticalē A, 25. C.
149	12	24	collocauerunt	colcauerunt centra
149	12	50	interceptos	intercepto
149	15	40	et ϝ [?]	et σ
149	15	42	ad ϝ [?]	ad σ
149	15	45	vsq. in ϝ	vsq. in σ
149	15	49	A ϝ C	A σ C
149	15	54	ϝ A B	σ A B
149	20	18	φ y ϝ [?]	φ y σ [?]
149	36	47	CAF	GAF
149	36	48	a,b,c	<i>a,b,c</i> (italic)

EX LIB. III.

Pa g.	Col .	Ver .	Errata	Correcta
149	0	9	illaterato	illiterato
156	2	13	immobili	in Mobili
163	2	27	Mic.a	Mac.a
163	2	36	b, in minore	<i>b</i> , in minore (italic)
172	2	40	exhorta	exorta
174	0	3	constat	constant
176	1	24	conuenire	conuenire sit difficillimum
184	1	6	purae	pura

Pa g.	Col .	Ver .	Errata	Correcta
184	1	28	vt	&
185	2	3	arctouum	arctoum
186	2	29	Tobella	Tabella
188	2	35	idoque	ideoque
189	2	3	positionē	positionū
190	2	35	in Eclipticā & chordatū quis	inter Eclipticā & chordas quasuis arcuū
194	1	10	36.	30.
194	2	6	conimntatem	concinnitatem
198	2	10	Macula C	Macule C
200	1	11	rursus	versus
200	1	19	respondet	respōdet
204	1	56	die 16.	Diem 16
204	1	37	ad latus boreales	ad latus boreale
219	2	44	cōphēso	cōprehēso
231	1	6	conformitatis	conformatis
234	1	15	marg. paruae	parae
235	2	2	arctius	arctico
235	2	3	appositas	oppositas
240	1	14	marg. cōtractas	cōtactas
240	2	11	gemina	genuina
244	2	50	ad 10.	ad 16.
250	1	40	duratie	duratio
264	1	33	australis	borealis
255	2	2	multae	multo
290	1	20	Faculam e	Faculāq.
290	1	22	intempories	intemperies
292	2	26	in imaginem	in imagine
296	2	5	neque notandū	beneq. notandum
308	1	3	Macule	Macula

Pa g.	Col .	Ver .	Errata	Correcta
314	2	37	c	c
332	1	37	qui	quae
336	2	47	vnam	vna
338	1	13	in Eclipticam	inter Eclipticam
348	1	9	multos	multas
357	1	28	Ɔ[?]	69 vel LXIX
362	1	52	semicirculi	quadrantis
366	0	13	IR	IE
366	0	22	ZY	in Z, Y;
366	0	16	ad KN	ad HN
366	0	40	QR	QP
367	0	4	BD	ED
368	0	1	BF	OF
368	0	11	MS	M,S,
368	0	14	ipsi KI	ipsi RI
368	0	16	KS	KS
369	0	6	EM, NG	IM, EG
370	0	17	EH	DG
372	0	1	HDO	HBO
374	0	11	declinationes	declinationis
374	0	15	hoc sinus	hoc est sinus
380	0	5	Ga	a, deest in figura
380	0	8	GA	Ga (gur[a])
380	0	16	aequinoctialis	dele punctum, & scripturam cum sequenti versu continua hoc modo: ad puncta aequinoctialis B, C. sunt enim &c.
380	0	30	gh	gH
380	0	44	HE	He
380	0	47	OR, he	gR, He

Pa g.	Col .	Ver .	Errata	Correcta
382	0	43	OR	gR
383	0	6	HI	NI
384	0	5	Ptolematico	Ptolemaico
384	0	35	od	ad
384	0	3	horarios	horarias
385	0	4	FC	FC
385	0	15	NGK	MGK
388	0	19	EG	NG

EX LIB. IV.

Pag.	Col.	Ver.	Errata	Correcta
410	2	9	e que	neque
415	2	33	Mattias	Martios
416	2	17	Clarius	Cluius
424	2	29	Ex à	Exa
424	2	34	ec	deest in figura littera c
425	2	1	Macula f	Maculā b
427	2	2	ϑ, ε, ξ	Λ, ε, f
427	2	4	ϑ	Λ
427	2	6	ad κ	ad κ
427	2	7	et ξ	et f
427	2	10	in λ, μ	in λ μ

Index — final page with FINIS

[DUPLICATE of earlier page — flagged for Cat-D dedupe.] This scan is a second image of the final index page already translated in the prior batch: the tail of the *Index Praecipuarum Rerum* under the letters U/V, W, X, Z, closing with FINIS. Its content (entries from *Vmbrae & Maculae mouentur* through *VVitichius pro caelo liquido*, *Xenophanes pro caelo igneo*, and *Zacharias philosophus Christianus Episcopus Mitilenes pro caelo corruptibili*, then the large centered FINIS.) matches p. 996 and is not re-transcribed here. The lower half of the leaf shows heavy

mirror-reversed show-through from the verso; none of that ghosting is transcribed as text.

Erratorum Correctio

[DUPLICATE — flagged for Cat-D dedupe.] This scan is a second image of the errata part-1 leaf (opening address + errata for pages 2–427, catchword 428), identical to above. Not re-transcribed.

Erratorum Correctio

Errata continuation, running from page 428 to the end of the book (page 764). Three panels (left, middle, right). Same conventions as above.

Panel 1 (left)

Pag .	Col.	Ver .	Errata	Correcta
428	1	2	ad v	ad κ
429	2	3	in ξ	in ζ
429	2	3	per Z, n θ	per Z. n, θ
429	2	5	n	n
442	2	46	recta	rectae
443	1	48	o v	ou
444	1	35	12. o	12. ε
444	1	38	12. o	12. ε
444	2	41	vicibus	vicibus:
446	1	39	sana	sane
446	2	51	inter media	intermedia
462	1	30	a o	a ε
462	2	1	a o	a ε
462	2	2	β o	β ε
462	2	23	loco y	loco γ
462	2	36	o 2	ε ι [?]
462	2	44	si ε	si φ
462	2	48	loca y	loca γ
462	2	49	β	β

Pag .	Col.	Ver .	Errata	Correcta
462	2	51	βy, et ββ	βy, et βΛ
462	2	52	βy, yΛ	βy, yΛ
463	2	6	versus	verus
464	1	11	φ σ, inter a φ, et a σ	φ6 inter a φ, et a 6
464	1	17	a y	a y
464	2	2	11. ε	11. ε
464	2	10	vel y	vel y
465	2	36	refractionem	refractionum

Panel 2 (middle)

Pag .	Col.	Ver .	Errata	Correcta
469	2	12	obnoxia	obnoxium
469	2	13	monendo	mouendo
470	1	25	quiqua versus	qua versus
473	2	54	planum axem	planum, & axem
474	1	28	y ε	y ε
474	1	32	β	β
474	1	36	β	β
474	1	38	βy	βy
474	1	55	θ u	θ n
474	2	12	n	n
Ib.	2	20	n	n
Ib.	2	23	n	n
Ib.	2	24	n	n
Ib.	2	27	n	n
Ib.	2	48	ab,cd,ef,gh ik	ab,cd,ef,gh,ik
475	1	6	v φ	η φ
Ib.	1	7	κ μ	η μ
Ib.	2	1	κ φ	η φ
476	1	14	eodem	eadem

Pag .	Col.	Ver .	Errata	Correcta
Ib.	1	38	e x y	ex y
Ib.	1	45	nectae	necte
Ib.	1	48	uxq	uxq
Ib.	2	16	uq	uq
Ib.	2	31	qxu	qxu
477	2	4	uxq	uxq
479	1	30	perpetuè	perpetua
488	1	32	igitalar inteliigitur	igitur intelligitur
Ib.	2	8	βy, ex y	βy, ex y
Ib.	2	10	y-y	y-y
Ib.	2	11	y-y	y-y
488	2	29	ra;	raε
488	2	32	u θ	η θ
488	2	38	κ a f	κ a f
488	2	44	β-β	β-β [?]
489	1	1	ex ε-	ex ε
489	1	4	ex κ pergit in κ	ex η pergit in κ
489	1	5	y	γ
489	2	4	medio	modo
489	2	5	motationi	mutationi
501	2	23	ablescerent	albescerent:
508	2	51	ablicante	albicante
516	1	28	ortibus	orbibus
518	1	21	est	qui est
521	2	9	rarefact one ordinate	rarefactionem ordinatam
522	2	44	tam	quam
525	1	2	T;	γ ι
525	1	5	T	y
525	1	6	TY	yε
525	1	9	DST	DSy

Pag .	Col.	Ver .	Errata	Correcta
525	1	11	VX, et TβY	VmX, et βγ
525	2	13	D,Tγ	DSmγ
525	2	16	ƒα	yα
526	2	35	γ	ε
526	2	36	T locū verū y	y, locū verū Λ
532	2	26	non esse	non esse pbatur
535	1	14	agitatione. instrum	agitatione instrumenti
535	2	51	ambieno	ambiens
536	2	49	caelestes	caelestis
540	1	9	illius	vllius
540	1	31	istarum	istorum
544	1	5	aequabilis	aequalib9 (aequalibus)
546	1	25	praemeret	premeret

Panel 3 (right)

Pag.	Co l.	Ve r.	Errata	Correcta
562	1	12	K	k
562	2	10	d ι	d f
564	1	32	imaginarij	imaginari
574	1	45	x	xl
580	2	53	discurremus	discurreremus
582	1	46	ex industria	ex industria compresso
583	1	4	iudicatum	iudicatā
610	2	22	vmbris	vrbis
610	2	37	asper & male terminatus?	aspera & male terminata?
643	2	8	demonstraui	demōstrauit
653	2	21	seniores	saniores
659	1	37	illustres	illusores
659	2	21	litteram :intel.	litterā intellectis,
662	1	33	Stellae verè	Stellae verae

Pag.	Co l.	Ve r.	Errata	Correcta
663	1	37	animun nostrarum statu	animarum nostrarum statui
663	1	39	tantam	tantum
666	2	51	incompactibilis-	incompactibilis, compactibilis est,
677	2	36	aspiritate	asperitate
682	2	3	ipsaeq.	ipseq.
691	1	23	aperte	aperta
694	1	36	fuie	fuse
702 & seqq.	—	—	(note)	Stellulae notabilia significanti, quae charactere alio fuissent imprimēda. ["The little stars mark the more noteworthy items, which should have been printed in a different type."]
704	1	37	transgressionem	intransgressibilem
718	1	25	Et	Ex
735	1	31	DE	PRO
738	2	29	configurari	configurati
751	1	27	consuetudine	consecutione
761	1	6	Iosephum	Iulium
764	1	18	Ipsi	Ipse
764	1	31	Copernicarum, & Tyconicarū	Copnicanū & Tyconicanum