### Oklahoma City Astronomy Club tour

History of Science Collections University of Oklahoma Libraries April 14, 2023

Hosted by: Kerry Magruder, Curator kmagruder@ou.edu

# Stro





# astronomy Ancient



## Cuneiform brick ca. 1300 BCE

#### Located in the Foyer

This object looks and feels like any block of old red sandstone one might find in the hillsides of Oklahoma. It's actually the oldest object in the History of Science Collections.



This cuneiform brick comes from the ziggurat of Choga Zanbil, the best preserved ziggurat of antiquity, now a World Heritage site. The ziggurat was faced with baked bricks, some inscribed with dedicatory inscriptions like this one, written in ancient Elamite. This script is a dedication from the Elamite king, beginning:

#### "I, Untash Napirisha, son of Humbanumena..."

From the ziggurats of ancient Mesopotamia, scribes like the one who recorded this dedication created the science of mathematical astronomy, predicting the positions of the planets centuries into the future. Without the Babylonian contributions, later Greek astronomy such as we find in Hipparchos and Ptolemy would have been inconceivable. The Mesopotamian astronomers were the original source of quantitative methods in ancient mathematical astronomy.

"Can you bind the beautiful Pleiades? Can you loose the cords of Orion? Can you bring forth the constellations in their seasons or lead out the Bear with its cubs?

Do you know the laws of the heavens?"

Job 38: 31-33



## Peter Apian, Cosmographicum (1540, 1545)

In this introduction to astronomy and geography, the Moon lies embedded within a solid sphere carrying it around the Earth once a month. The solid sphere explains why the same side of the Moon always faces the Earth.

High overhead the stars appear fixed in the patterns of the constellations, as if they were bright points of light embedded within their own transparent celestial sphere, which rotates around the Earth once each day. Apian's cosmic section illustrates the traditional Aristotelian understanding of the universe.

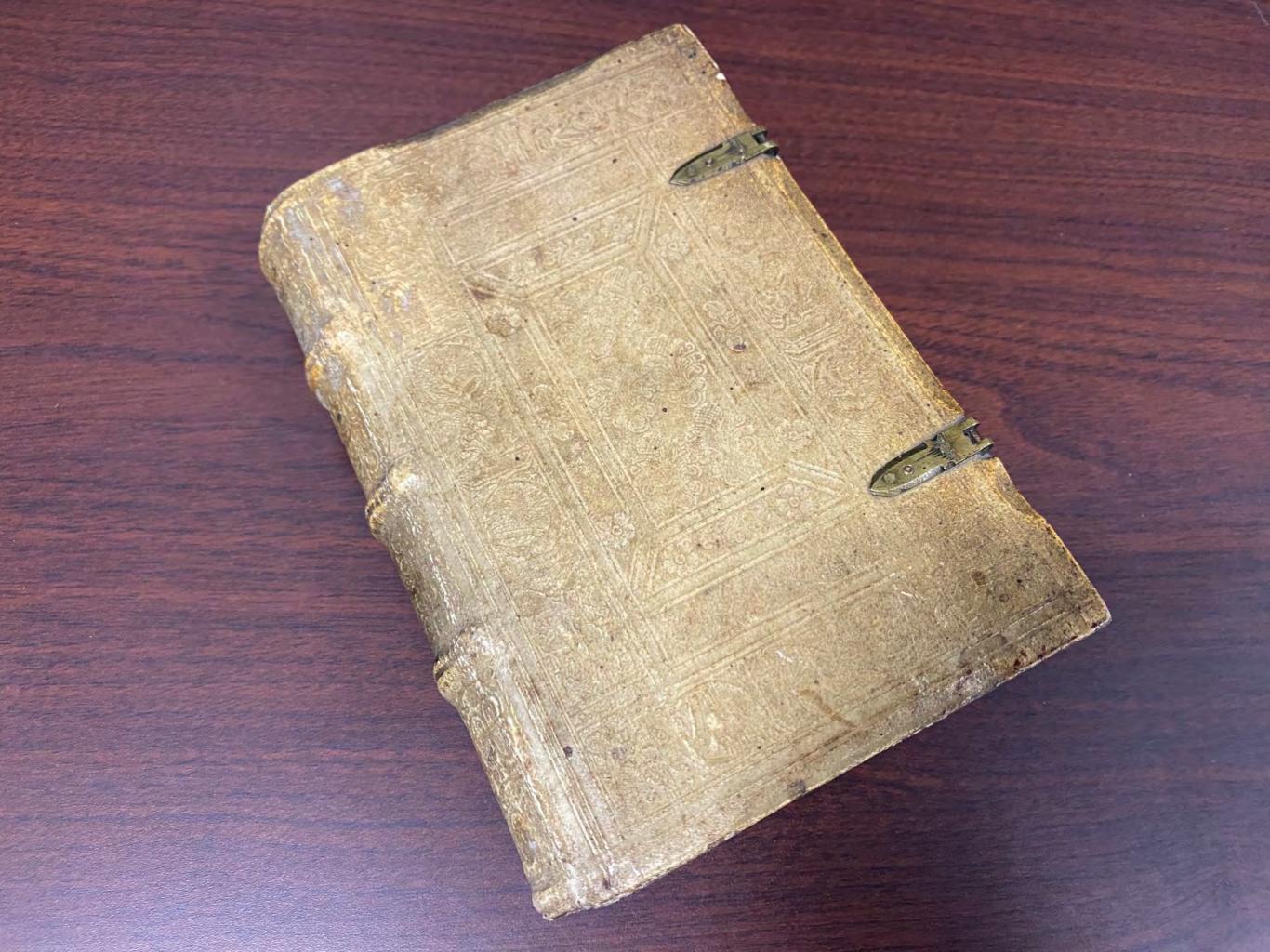
Another woodcut illustration in Apian's textbook shows one of Aristotle's arguments for the sphericity of the Earth: during a lunar eclipse, the Earth's shadow on the Moon is always curved. If the Earth were any other shape, some time or other its shadow would be angular. Therefore, neither Aristotle nor his later readers needed to circumnavigate the globe to know that the Earth is round. The mistaken idea that Columbus faced opposition from flat-earthers is a modern myth.



### Hesiod, Opera "Works" (Frankfurt, 1559)

Ancient star catalogs described the constellations and their meanings. In *Works and Days*, the poet Hesiod, a rough contemporary of Homer, compiled guidelines for living according to the stars. Hesiod explained, for instance, that when Orion rises at sunset, it's time for autumn storms, and time for sailors to bring their ship to land:

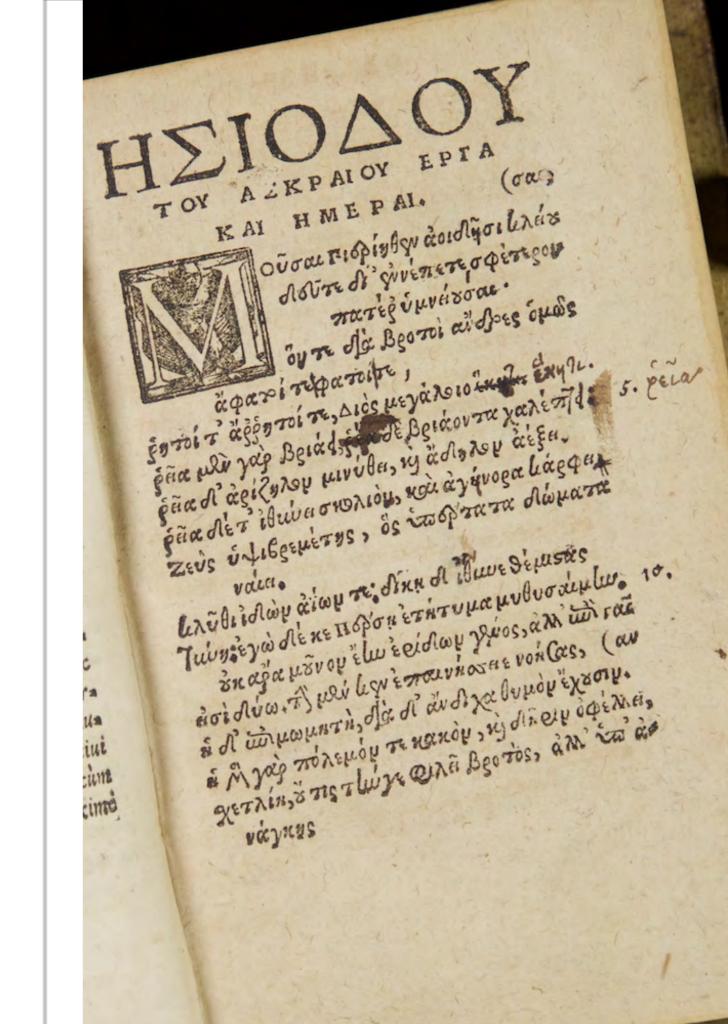
"...then the winds war aloud,
And veil the ocean with a sable cloud:
Then round the bank,
already haul'd on shore,
Lay stones, to fix her when the
tempests roar..."



#### Hesiod

Opera "Works"

(Frankfurt, 1559)

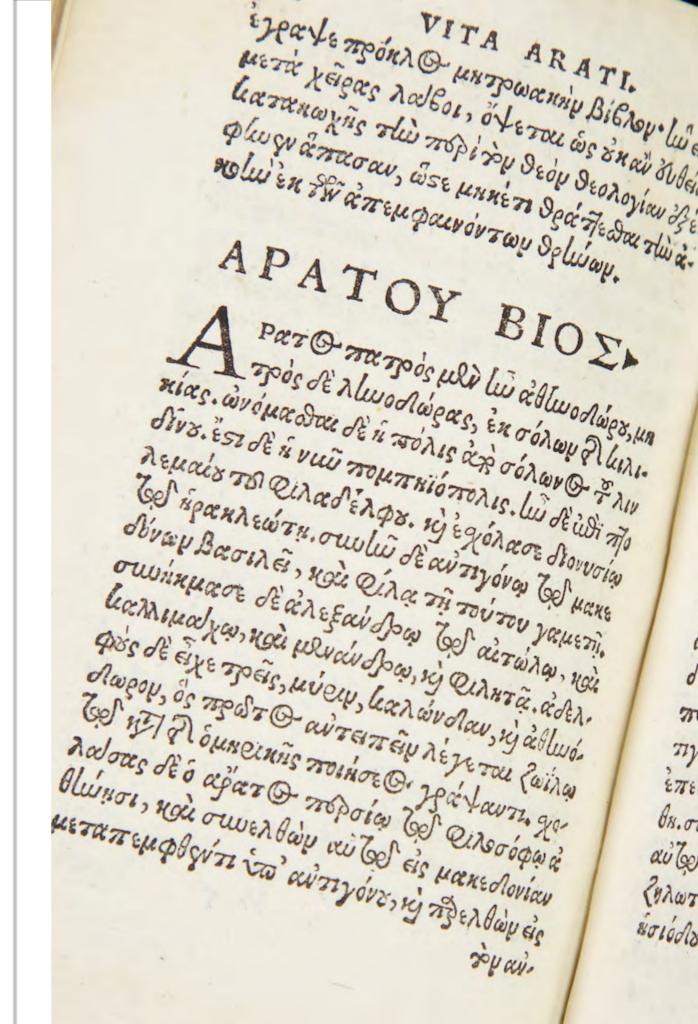


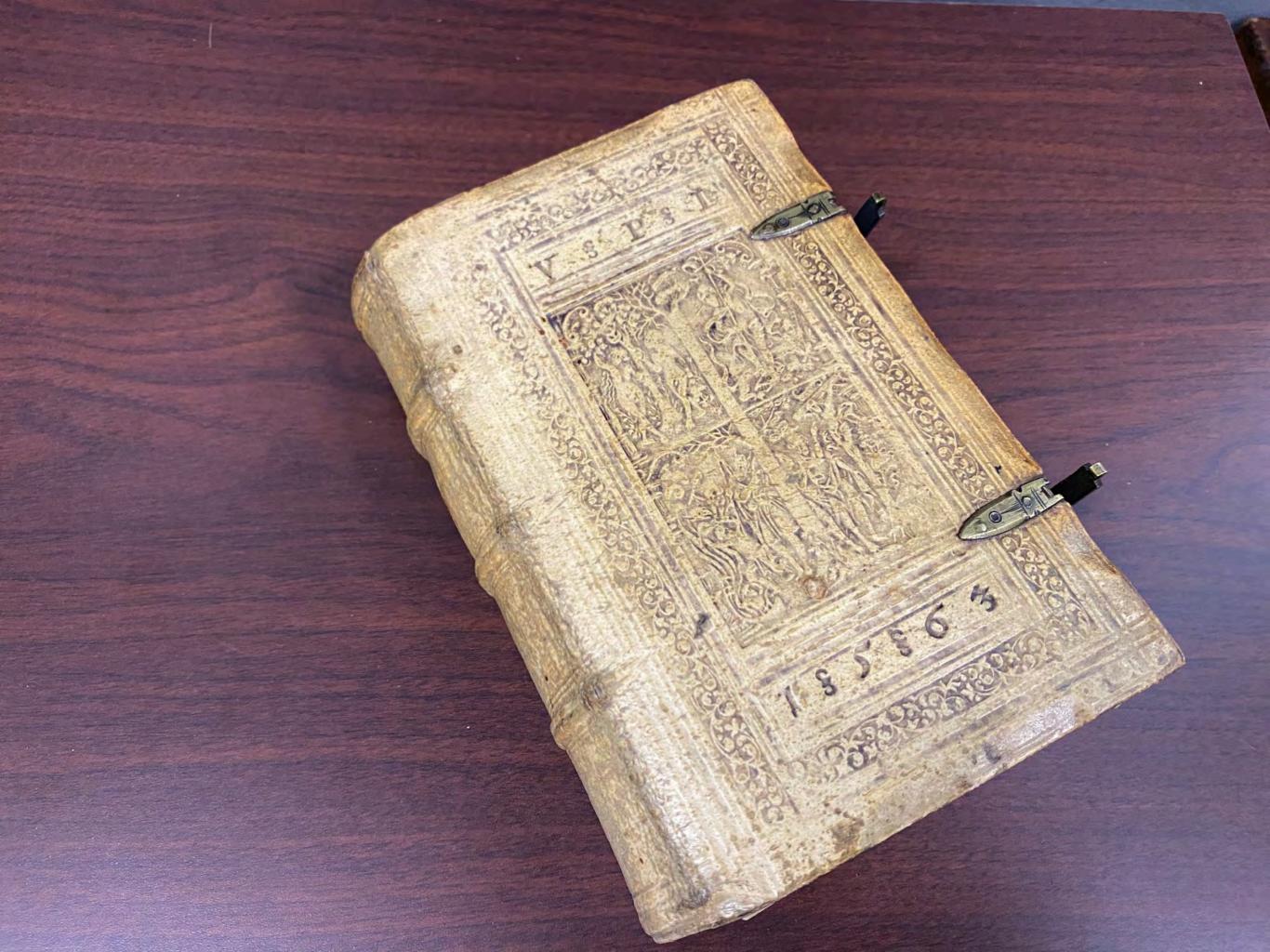
#### Aratos

Phenomena "Appearances of the Sky"

(Basel, 1547))

Aratos, a Greek scientist and poet of the 3rd century B.C.E., offered similar practical advice as Hesiod, based on the seasonal changes heralded in the changing constellations.





### Hyginus, Poeticon astronomicon (Venice, 1485)

Hyginus, a Roman poet, conveyed the practical astronomy of Hesiod and Aratos into Latin in this "Astronomical Poem."

This edition was printed by Erhard Ratdolt, a renowned early printer of works in astronomy and geometry. It contains charming constellation figures... some hand-colored in the OU copy.

Virgo, the goddess of Justice, could not tolerate the anguish of living among unjust people, so she needed wings, as shown here, to escape us and fly up into heaven.



## Ptolemy, Almagest

Ptolemy (Claudius Ptolemaios) lived in Alexandria, Egypt, in the 2nd century.

Ptolemy's technical work on astronomy, originally written in Greek, was titled *Almagest* ("The Greatest") by its Arabic translators.

Ptolemy's *Almagest* represents the culmination of ancient Babylonian and Greek mathematical astronomy. It achieved an unparalleled degree of accuracy in quantitative predictions of the positions of the planets.

"I know that I am mortal and living but a day.

Yet when I search for the numerous turning spirals of the stars,

I no longer have my feet on the Earth,

But am beside Zeus himself,

filling myself with divine nurturing ambrosia."

(anonymous epitaph attributed to Ptolemy)

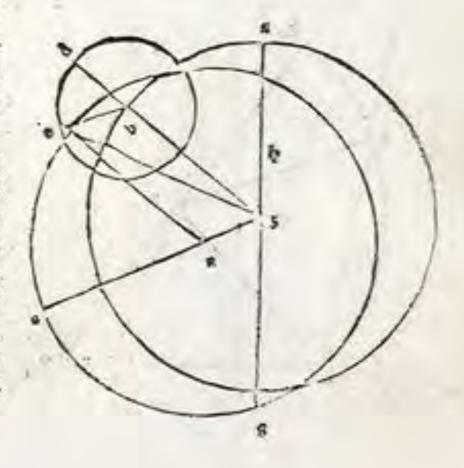
### Ptolemy, Almagest

# Epitome by Regiomontanus

Nuremberg, 1496

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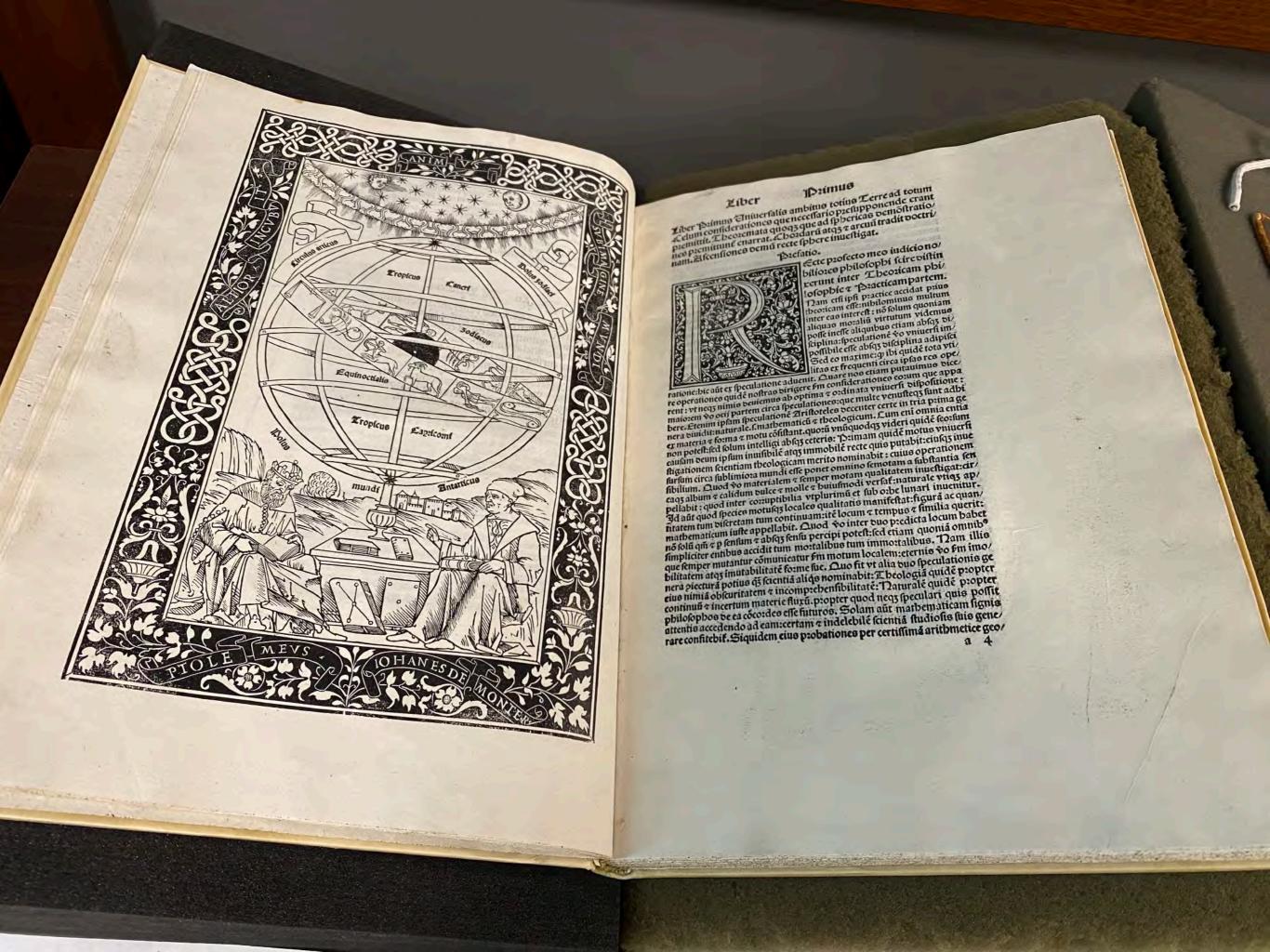


## Regiomontanus, *Epitome* of Ptolemy's *Almagest*

Regiomontanus was the leading European astronomer of the 1400's. This *Epitome* of the *Almagest* by Regiomontanus was the first printed edition of the *Almagest*. It represents state-of-the-art astronomy at the time when Copernicus was a young man.

A magnificent full-page woodcut depicts Ptolemy and Regiomontanus seated beneath an armillary sphere representing the music of the spheres. Ptolemy is wearing a crown, a case of mistaken identity, for he was actually unrelated to the Ptolemy line of Egyptian rulers that came to an end with Cleopatra.

Noel Swerdlow argues that a diagram on page n4r of the *Epitome* provided the major step in the transformation from Ptolemy's Earth-centered system of the world to a Sun-centered model. Here Regiomontanus proved that eccentric models could be used for all of the planets instead of epicycle models, except for retrograde motion. This proof, sought for but not obtained by Ptolemy himself, was included by Regiomontanus in the *Epitome*. Copernicus then took the next step by transposing the Earth and Sun, given the *Epitome*'s demonstration that the geometry would be equivalent.



#### Regiomontanus, Calendarium (Venice, 1476)

#### "Astronomical Calendar"

In this book, Regiomontanus predicted the positions of the Sun and Moon for 40 years. He designed a sundial to work independently of one's latitude, and a volvelle, or circular dial, to locate the position and phase of the Moon according to date and time. Books became observing instruments in their own right.

The Printing Revolution transformed every field of science in part because of a more widespread use of images. But images were not the only visual components of books. As early as 1476, books became instruments, combining paper and metal in "volvelles," circular calculating wheels, and even in portable sundials.

This Calendarium by Regiomontanus, published in Venice by Erhard Ratdolt, is the earliest work to contain a date on the first page.

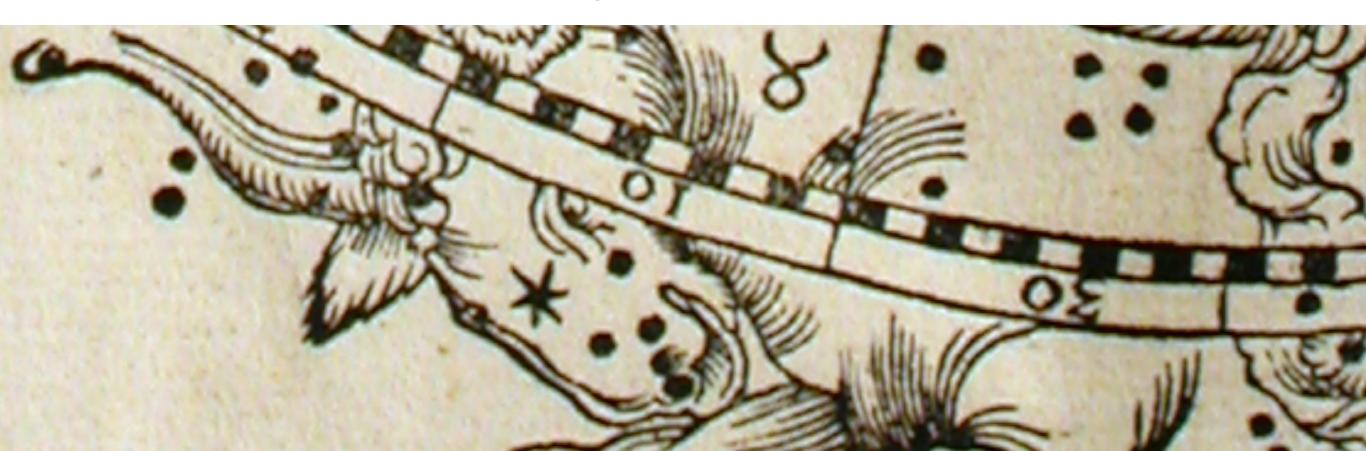
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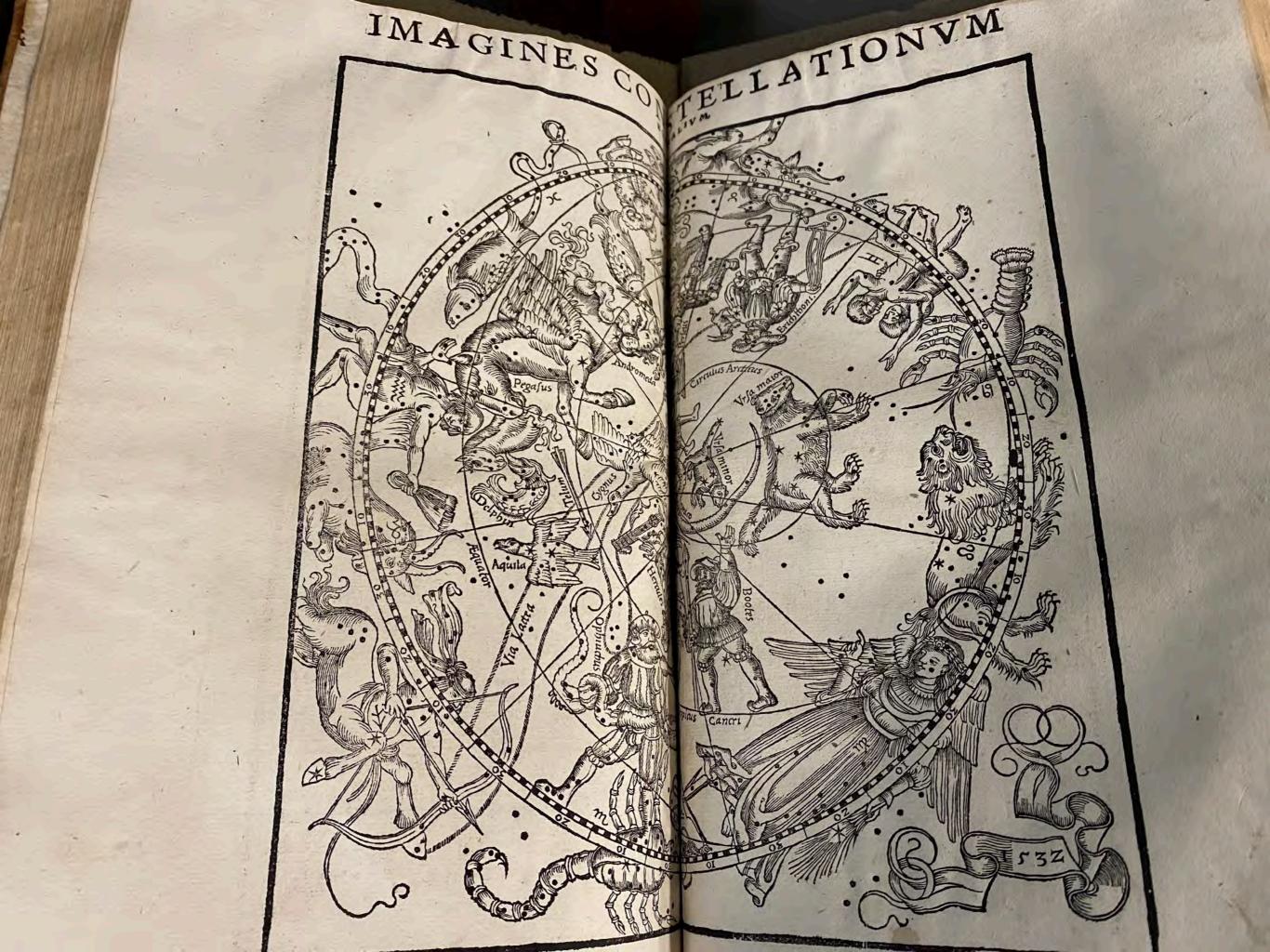
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## Ptolemy, Opera "Collected Works" (Basel, 1541)

In this 1541 edition of Ptolemy, Johann Honter drew constellation figures after the manner of Albrecht Dürer. The figures appear in contemporary dress rather than in a classical style. Although the stars are positioned on a grid, unfortunately the coordinates were misaligned and constellations are shifted by 30°.





#### Aristarchos of Samos, fl. 3rd century BCE

Aristarchos, the Copernicus of antiquity, proposed in the 3rd century B.C.E. that the Sun lies at the center of the universe and that the Earth and other planets revolve around the Sun. That work did not survive.

In this book Aristarchos demonstrated an ingenious method for calculating the sizes and distances of the Sun and the Moon.

This is the first printed edition, *De magnitudinibus et distantiis solis, et lunae* ("On the Sizes and Distances of the Sun and the Moon"; Pesaro, 1572).

### ARIST DE MAG.

Quod faciet sectiones in spharis circulos Expri masphericorum Theodosii Fieri igitur potes c sumatur aliquod pundum

velut K, ita ut H ad autem punctum hoc modo inuenie mus. Ducatur am ea, quae ex centre circuli maioris c

DE, sitá, AD : & ex ipsa AD abscindatur AO aequalisei, College Coll quae ex centro minoris circuli : fiatý, vt DO ad O.A, ita A B ad aliam, quae sit BK. erit enim componendo, re DA ad AO, hoc est ut quae ex centro circuli maioris ad eam que; ex centro minoris, ita AK ad KB.

Recta igitur linea est CFK ] Hoc est si à punto Cad K ducatur recta linea, transibit ea per F. quod nos demonstrauimus in commentarijs in decimam propositionem libri Archimedis de ijs, quae in aqua vehuntur, lemmate primo.

H Sed angulus KFB rectus est, ] Ex 18 terty elementorum.

Ergo & rectus KCA ] Ex 29 primi elementorum.

Ac propterea KC circulum CDE contingit] Er 17 tertij elementorum.

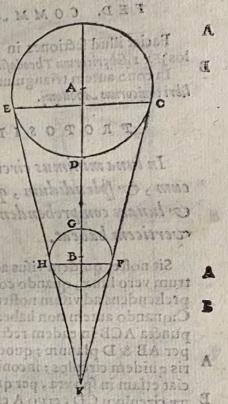
Triangula vero KCL KFM conos efficient ] Ex-18 diffinitione vndecimi libri elementorum.

#### PROPOSITIO. II.

Si sphæra illuminetur à maiori sphera, maior eius pars, quam sit dimidia sphara,il luminabitur, otosande idd haireburg mothogib 16 23 Sphzr2

#### ET DIST. SOL ET LVNAE.

Sphæra enim, cuius centrum Bàma iori sphera, cuius ce tru A illuminetur. Dico partem sphere illuminată, cuius ce trú B dimidia fphæra maiore effe. Qm enim duas inæquales spheras idem conus comprehendit, vertice habes ad minorem fphæram : fit conus sphæras comprehédés; & per axé planum producatur faciet illud sectiones in spheris quide circulos, in cono autem triangulum. Itaq; fa ciat in sphæris circu los CDE FGH; & in cono triagulu CEK. manifestum est portione sphere, quæ est



ad FGH circuferentia, cuius basis circulus circa dia metru FH, parte esse illuminată à portione, quæ est ad circumferentiam CDE, cuius basis circulus circa diametru CE, rectus existes ad ipsam AB. etenim F GH circuferetia à circuferentia CDE illuminatur; quod extremi radij sunt CF EH: atque est in proportione FGH centrum sphæræ B. Quare pars sphę re illuminata, dimidia sphæra maior erit.

FED.

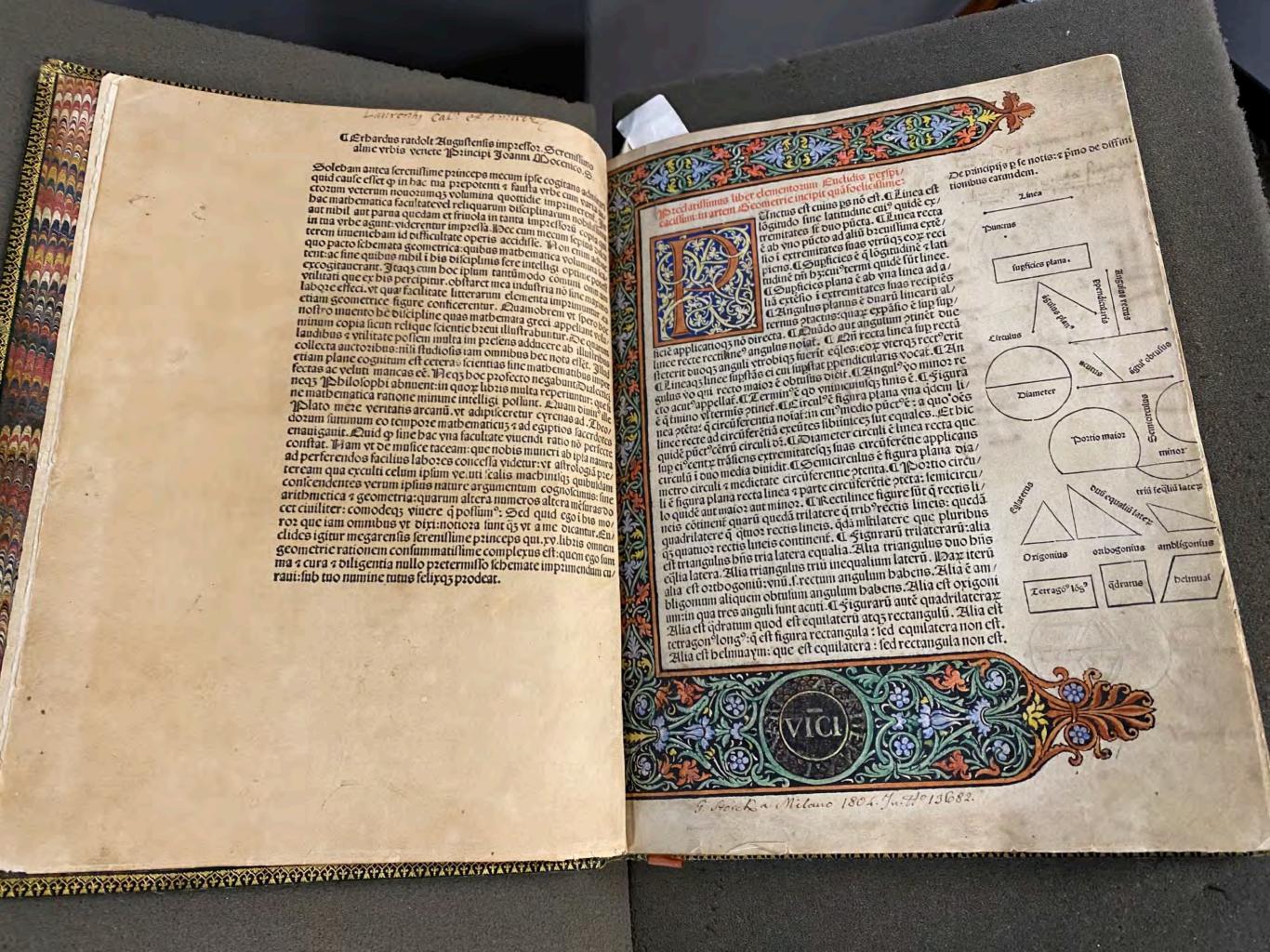
#### Euclid, Preclarissimus liber elementorum (Venice, 1482)

#### "Elements of Geometry"

Euclid was the starting point for astronomy, which was a subfield of geometry. Geometrical circles in motion make up the principles of astronomy. In an analogous way, numbers in motion comprise the principles of music, so astronomy and music were considered sister sciences.

This is the 1st printed edition. The beautiful woodcuts are hand-colored in this copy. The text of the first page was printed in both black and red ink. The geometrical diagrams were a challenge to prepare.

The printer, Erhard Ratdolt, moved south from Germany and set up shop in Venice. To print the many curves and angles required, Ratdolt came up with the idea of forming the diagrams with copper wire, formed around molds. This innovation enabled Ratdolt to print Euclid affordably, and to go on to print the first editions of many notable works in astronomy and geometry.



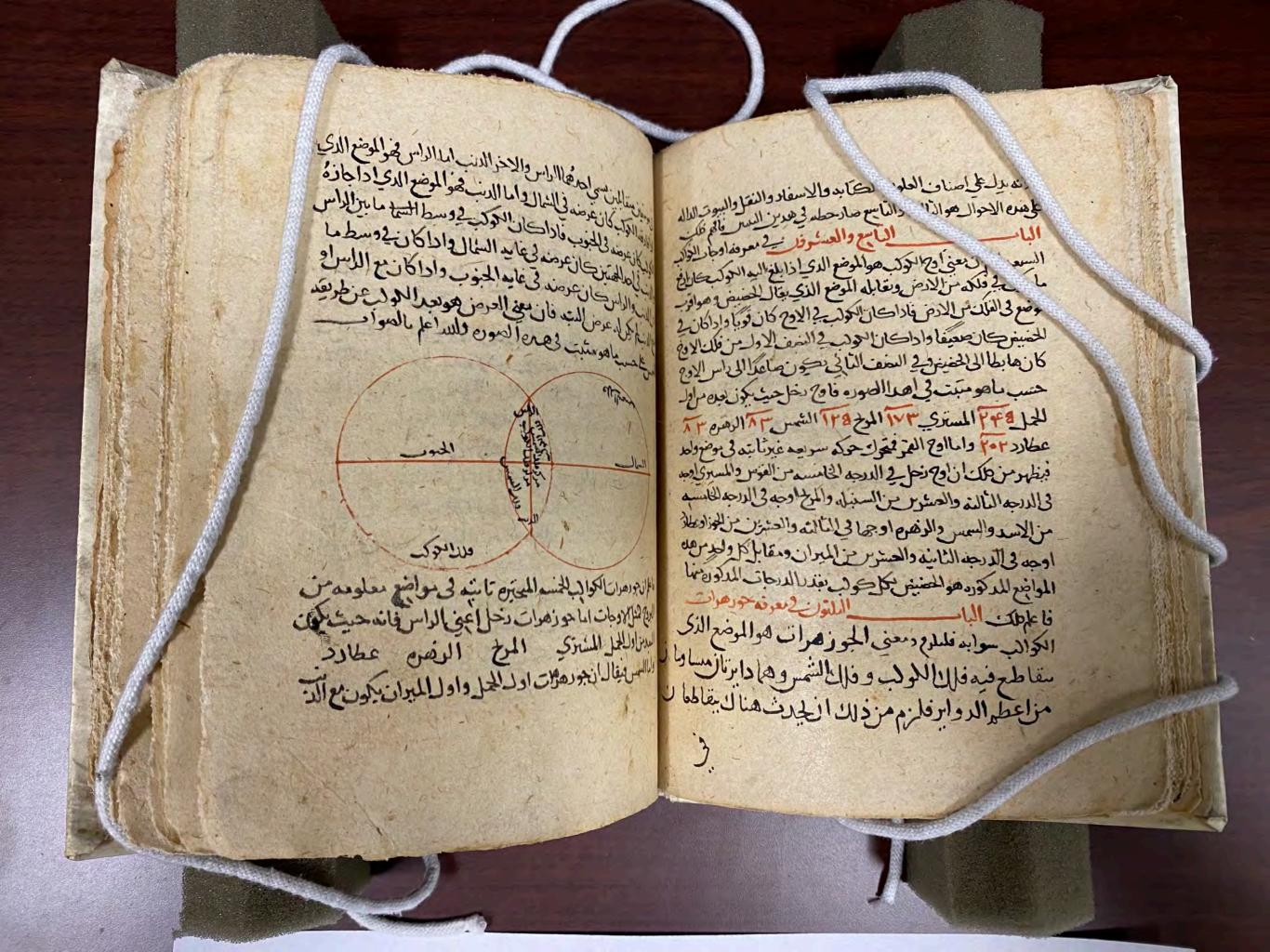
# Slanicate

## Abdul-Hasan Kúshyär ibn Labban ibn Bashahri Daylami, *Principles of Astronomy*

Manuscript on paper. Date unknown. Author and title tentative.

Kūshyār Daylami, as he was known, was born in 971 in Daylam, Iran, and died in 1029 in Baghdad.

This manuscript has been digitized by OU Libraries and will soon be put online to enable scholars around the world to confirm its authorship and contents. (Five other Islamicate manuscripts have been previously digitized and were successfully described by the same process.)



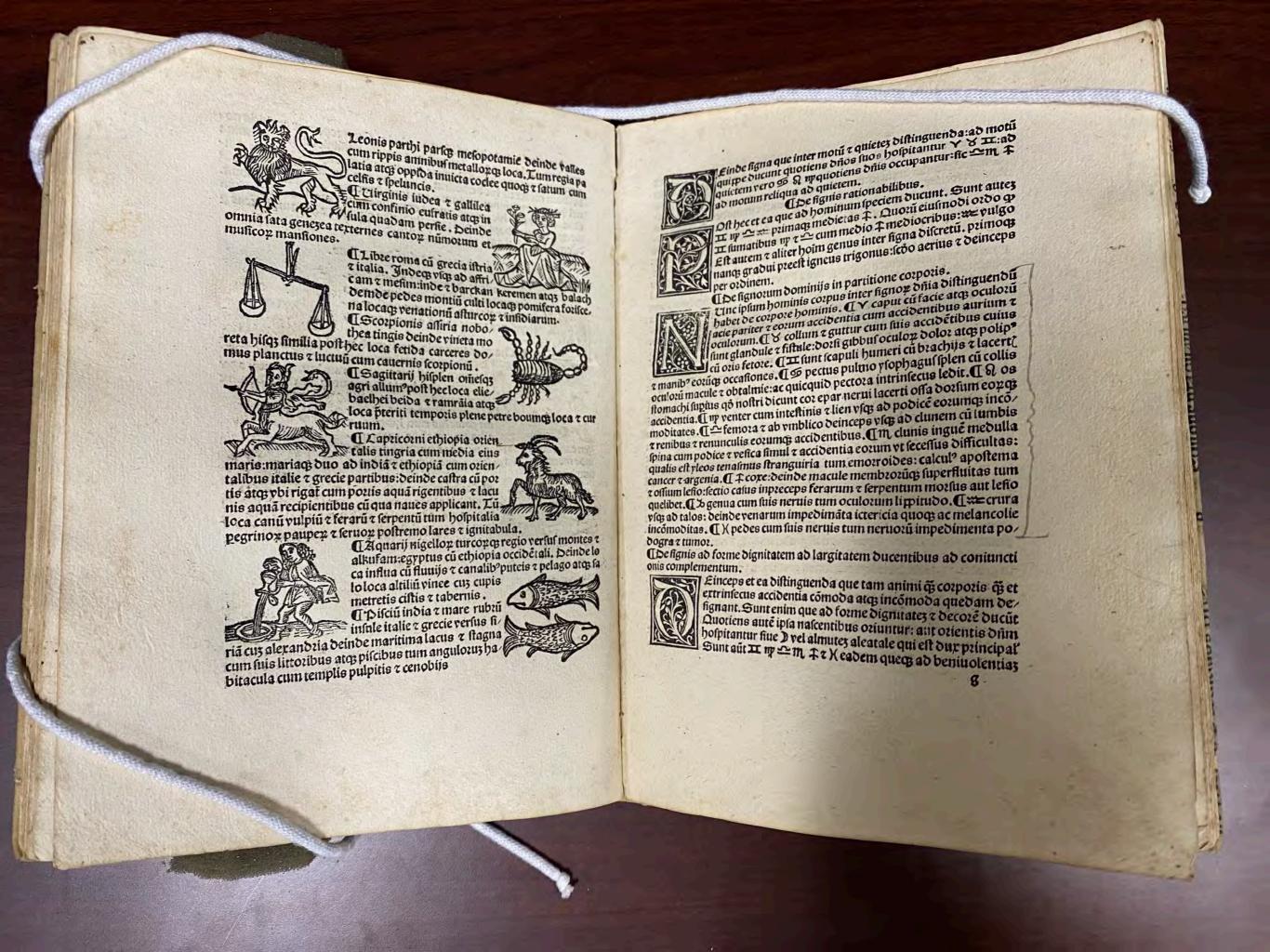
## Abū Ma'shar. *Introductorium in astronomia[m]* (1489)

Abu Ma'shar, an astronomer in 9th century Baghdad, was one of the most prolific writers on astrology during the Middle Ages. This work was cited by Albert the Great, Roger Bacon, Pierre d'Ailly, and Pico della Mirandola, among others.

Constellation figures appear without stars. Or, if stars are shown on the constellation figures, they appear in an impressionistic manner, not as a sky map but rather as an aid to memory.

This 1st edition was printed by Erhard Ratdolt, and the constellation figures appear similar to the ones in Ratdolt's editions of Hyginus.

The OU History of Science Collections holds three works by Abu Ma'shar printed by Ratdolt in 1489, all different. This one is bound in a discarded sheet of medieval music.



#### Astrolabe, Persian, date unknown

The astrolabe, one of the fundamental instruments for observational astronomy, consists of three major parts: the *mater*, or underlying disk; the *climate*, a removable disk adjusted for latitude; and the *rete*, a ring marked with star positions.

How many parts of this astrolabe can you identify?

Astronomers use astrolabes for dozens of astronomical operations including telling time by the Sun or stars and determining the positions of planets relative to fixed stars.





# Nasir ad-Din al-Tusi (pseudo-Tusi), Kitab tahrir usul I-Uqlidus (Rome, 1594)

Euclid, "Elements of Geometry"

This Arabic text of Euclid purportedly came from the circle of the Persian astronomer al-Tusi (13th century). Al-Tusi worked in Baghdad and in the observatory of Maragha, in modern northwestern Iran.

Printing Arabic with moveable type was a technological challenge. This book was not printed in Baghdad or Cairo. Because of widespread European interest in works of Islamic science even as late as the generation of Kepler and Galileo, the Medici established a press to print Arabic works in Rome. This work is one of the first Arabic-language books printed in Europe.

In another work, al-Tusi invented the "Tusi couple," a highly useful device for modeling the motion of the Moon that was later employed by Copernicus to solve a problem pointed out by Regiomontanus in the Epitome of Ptolemy's Almagest (1496).

The History of Science Collections also holds an Arabic geographical text by Idrisi printed at the same Medici press two years earlier.



#### Johann Hevelius, Selenographia (Gdansk, 1647)

Frontispiece photo (the book is displayed in another section)

On the frontispiece of this book, Hevelius celebrates not the triumph of a European "scientific revolution," but a much broader heritage.

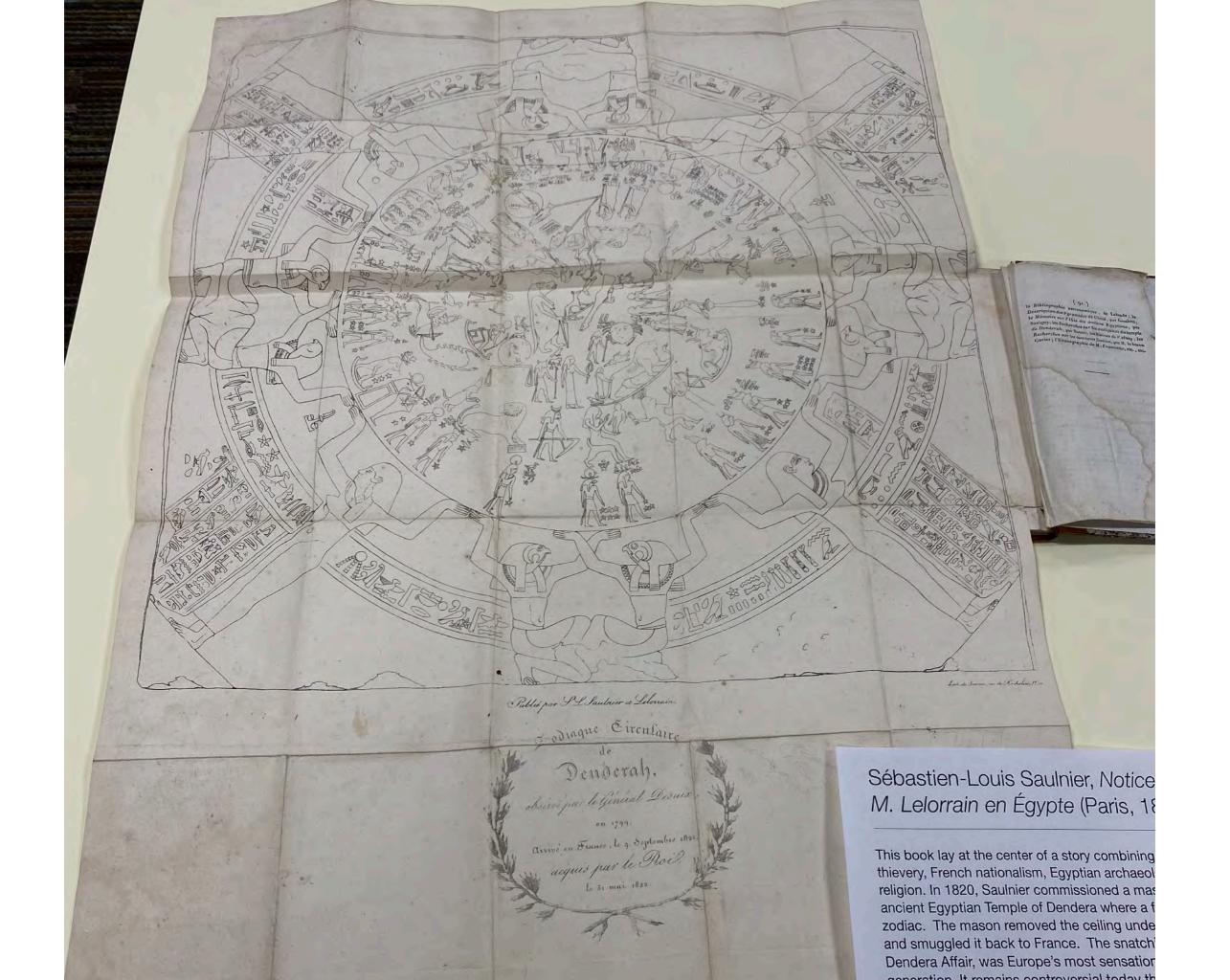
On the left appears Ibn al-Haytham, a leading medieval Islamic astronomer and optical theorist.

On the right, holding a telescope, is Galileo, portrayed in Middle Eastern dress. This frontispiece of Hevelius reminds us that the growth of western science cannot be understood apart from rich and sustained interactions between multiple cultures. It is impossible to separate the European "scientific revolution" from the achievements of the medieval Islamic culture and other civilizations which came before.

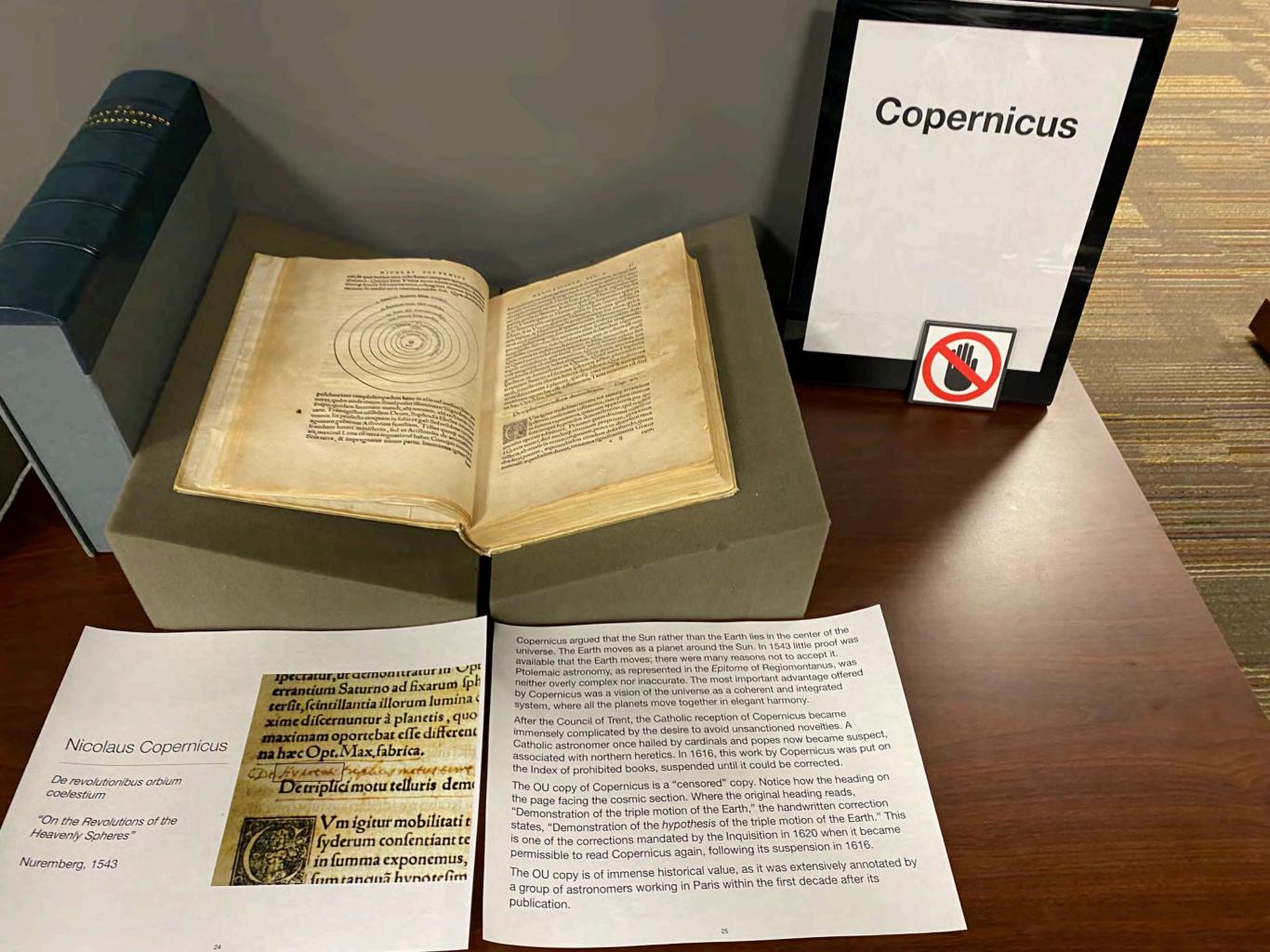


# Sébastien-Louis Saulnier, *Notice sur le voyage de M. Lelorrain en Égypte* (Paris, 1822)

This book lay at the center of a story combining ancient astronomy, intrigue, thievery, French nationalism, Egyptian archaeology, politics, and science and religion. In 1820, Saulnier commissioned a master stonemason to travel to the ancient Egyptian Temple of Dendera where a famous ceiling depicted the zodiac. The mason removed the ceiling under the nose of Egyptian officials and smuggled it back to France. The snatching of the zodiac ceiling, or Dendera Affair, was Europe's most sensational archaeological event for that generation. It remains controversial today that one goes to the Louvre to see the Dendera Zodiac ceiling, but to Egypt to see the roofless temple.



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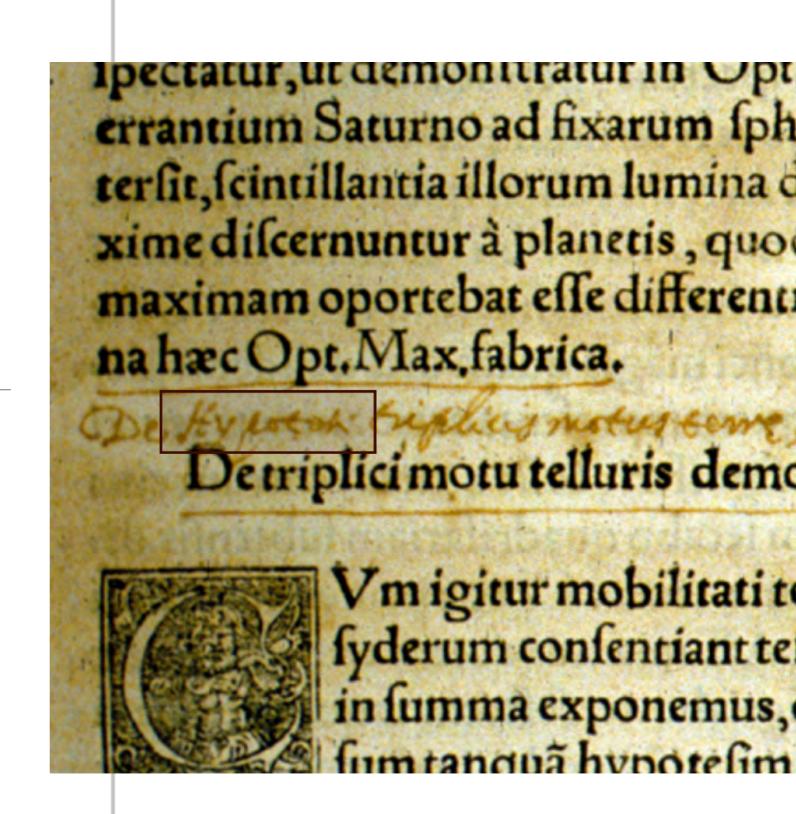


#### Nicolaus Copernicus

De revolutionibus orbium coelestium

"On the Revolutions of the Heavenly Spheres"

Nuremberg, 1543



Copernicus argued that the Sun rather than the Earth lies in the center of the universe. The Earth moves as a planet around the Sun. In 1543 little proof was available that the Earth moves; there were many reasons not to accept it. Ptolemaic astronomy, as represented in the *Epitome* of Regiomontanus, was neither overly complex nor inaccurate. The most important advantage offered by Copernicus was a vision of the universe as a coherent and integrated system, where all the planets move together in elegant harmony.

After the Council of Trent, the Catholic reception of Copernicus became immensely complicated by the desire to avoid unsanctioned novelties. A Catholic astronomer once hailed by cardinals and popes now became suspect, associated with northern heretics. In 1616, this work by Copernicus was put on the Index of prohibited books, suspended until it could be corrected.

The OU copy of Copernicus is a "censored" copy. Notice how the heading on the page facing the cosmic section. Where the original heading reads, "Demonstration of the triple motion of the Earth," the handwritten correction states, "Demonstration of the *hypothesis* of the triple motion of the Earth." This is one of the corrections mandated by the Inquisition in 1620 when it became permissible to read Copernicus again, following its suspension in 1616.

The OU copy is of immense historical value, as it was extensively annotated by a group of astronomers working in Paris within the first decade after its publication.

Leonard Digges, A Prognostication Everlasting of Right Good Effect...; Lately corrected and augmented by Thomas Digges his sonne (London, 1605)

This Sun-centered cosmic section represents the first published defense of Copernicus in England, and it was printed in a work of meteorology.

The Earth carries its meteorological regions of water, air and fire along with it, as a single "globe of mortalitye." The fixed stars, each far larger than the Sun, extend "infinitely up" in a "Pallace of Foelicitye."

Leonard Digges wrote this prognostication in a genre known as "astro-meteorology." Astro-meteorologies were early modern versions of *The Farmer's Almanac*. They attempted to provide annual guidance for agricultural activities and other events on the basis of meteorological and astronomical patterns.

Thomas, his son, published an updated edition in which he substituted the Copernican system for his father's reliance upon the Ptolemaic. An appendix includes the first English translation of Book 1 of Copernicus' *On the Revolutions*.

### TO THE READER.

In the middeft of this Globe of Mortality hangeth this dark flar or ball of the earth and water, balanced and fuffayned in the middest of the thinne ayre onely with what proprietic which the wonderfull workeman hath given at the Creation to the Center of this Globe, with his magnetical force vehemently to draw and hale vnto it selfe all such other Elementall things as retayne the like nature. This ball euerie 24 houres by naturall vniforme, and wonderfull flie & fmooth motion tolleth round, making with his Period our natural day, whereby it feemes to vs that the huge infinite immoueable Globe should sway and turne about.

The Moone Orbe that enuironeth and contayneth this darke flar, and the other mortall, changeable, corruptible Elements and Elementary things, is also turned round every 20 daies. 31. Minutes, 50. feconds, 8. thirds, 9. fourths, and 20. fiftes: and this Period may most aprly be called the month. The rest of the Planets motions appeare by the Picture, and shall more largely be hereafter spoken of.

Herein good Reader, I have waded farther then the vulgar force, Demonstratine & Practice, and God sparing life I meane, though not as Judge to decide, yet at the Mathematical barre in this case to plead, in such sorte, as it shall manisestly appeare to the world, whether it bee possible vpon the Earths stabilitie to deliuer any true or probable Theorick, and then referre the pronouncing of sentence to the grave Senate of indifferent discrecte Mathematicall Readers.

Farewell, and respect my travailes as thou shalt see them tende to the advancement of truth, and discovering the monstrous loathsom shape of error.

Some reason, amount fromemor answer of the star

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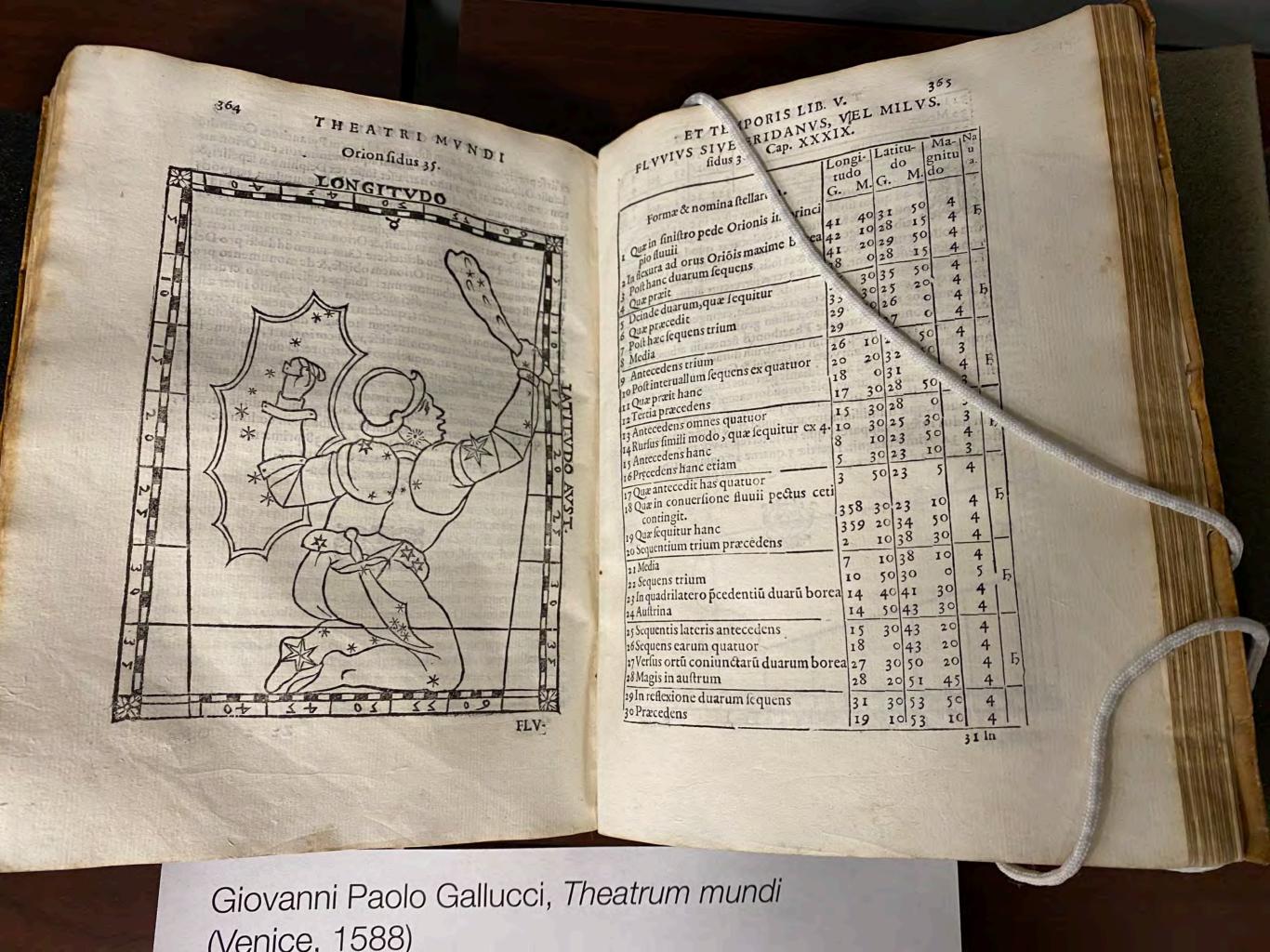
A perfit description of the Coelestiall Orbes, according to the most auncient doctrine of the Pythagoreans, &c. A'PER-

# Giovanni Paolo Gallucci, *Theatrum mundi* (Venice, 1588)

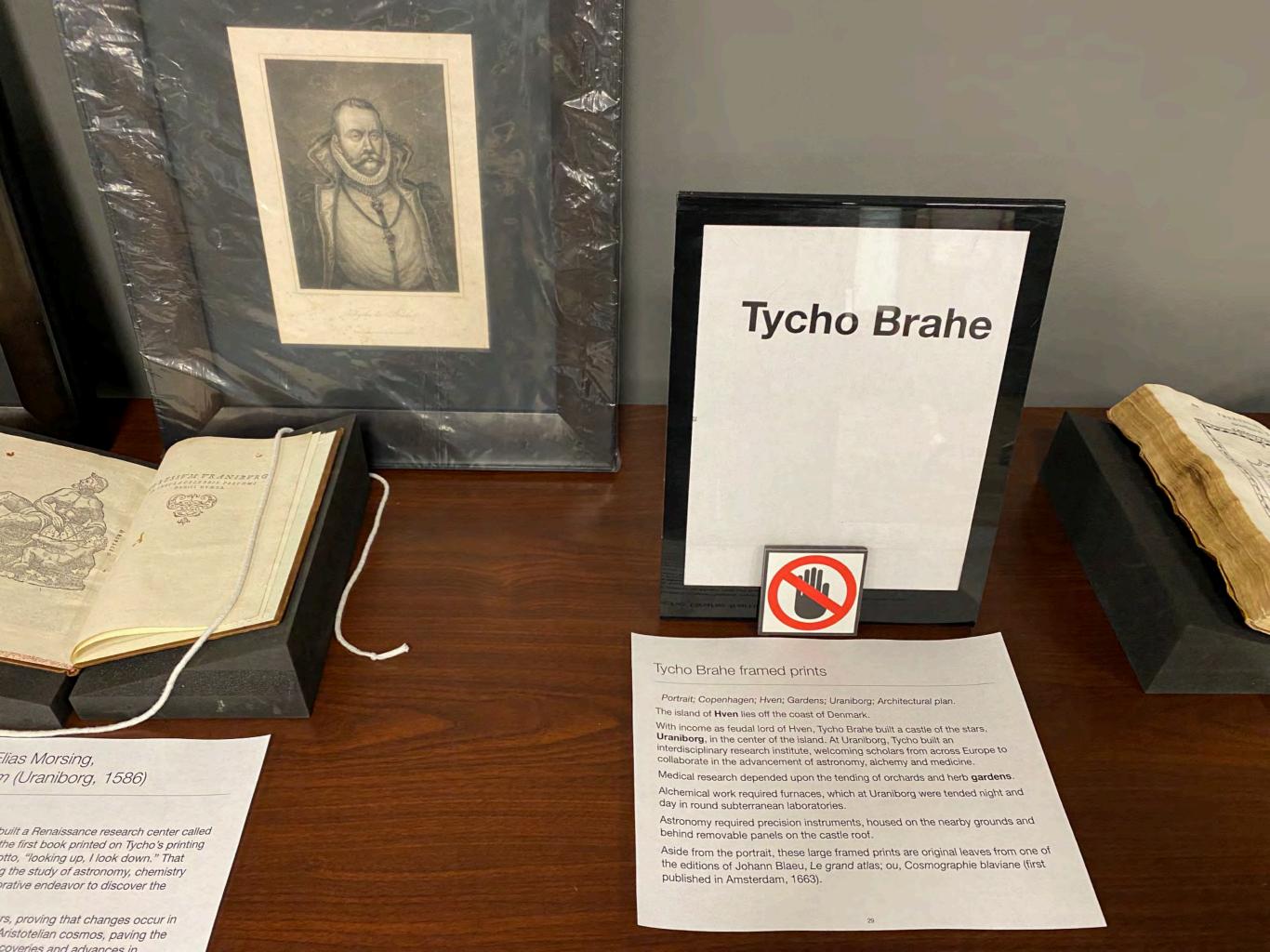
#### "Theater of the World"

Gallucci, a Venetian scholar, was interested in astronomical instruments, both physical and on paper. The "Theater of the World" features a parade of rotating wheels, or "volvelles," descendants of the astrolabe. These were paper instruments used to predict the positions of the Sun, Moon, planets and stars.

Gallucci's star positions, with constellation figures, appear in Book V. Rulers along the borders established a grid for plotting star positions accurately. Gallucci's book was the first star atlas to add such scales in both celestial latitude and longitude. The trapezoidal shape of the grid better accommodates the curved surface of a sphere. Gallucci took his star positions from the star catalog of Copernicus. The constellations are the 48 ancient constellations listed by Ptolemy; today, 88 constellations are officially recognized.



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#### Tycho Brahe framed prints

Portrait; Copenhagen; Hven; Gardens; Uraniborg; Architectural plan.

The island of **Hven** lies off the coast of Denmark.

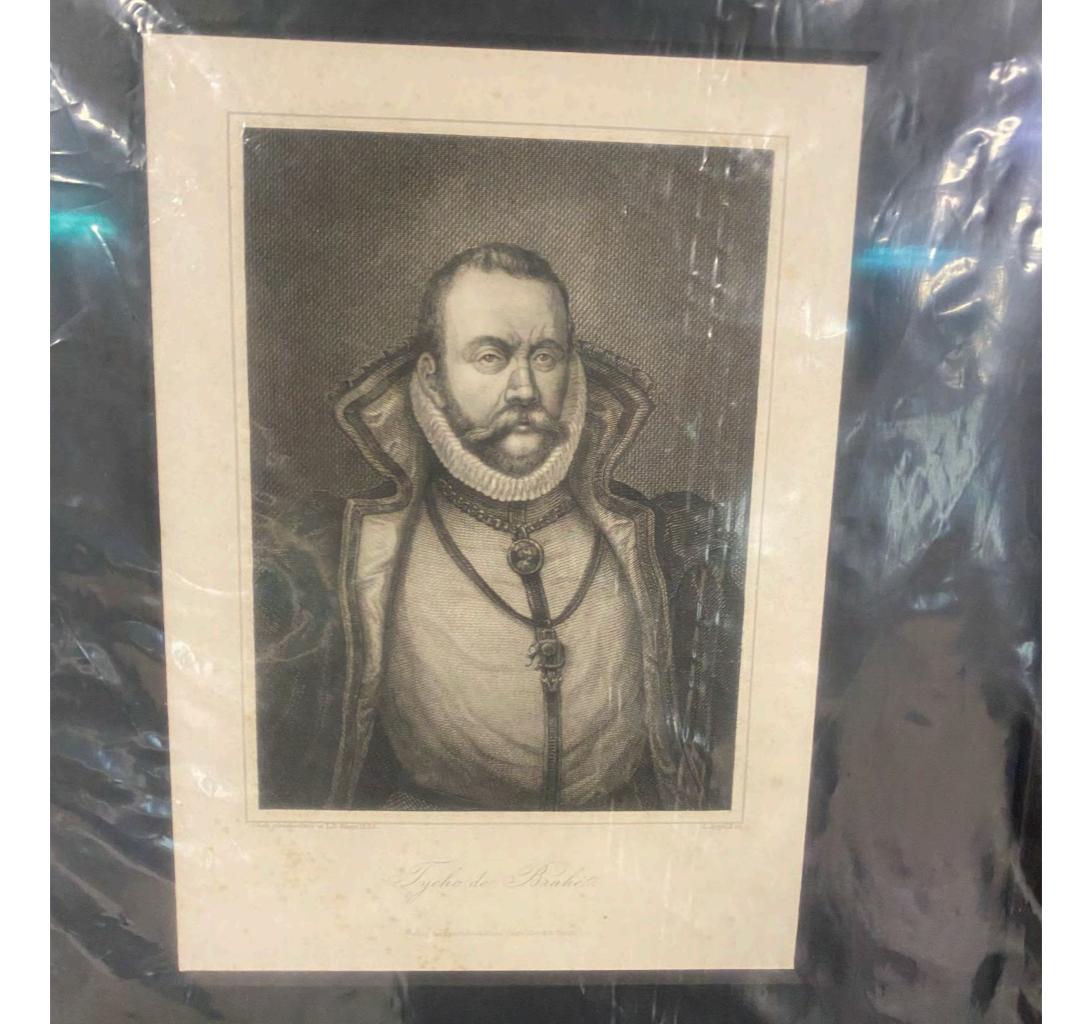
With income as feudal lord of Hven, Tycho Brahe built a castle of the stars, **Uraniborg**, in the center of the island. At Uraniborg, Tycho built an interdisciplinary research institute, welcoming scholars from across Europe to collaborate in the advancement of astronomy, alchemy and medicine.

Medical research depended upon the tending of orchards and herb gardens.

Alchemical work required furnaces, which at Uraniborg were tended night and day in round subterranean laboratories.

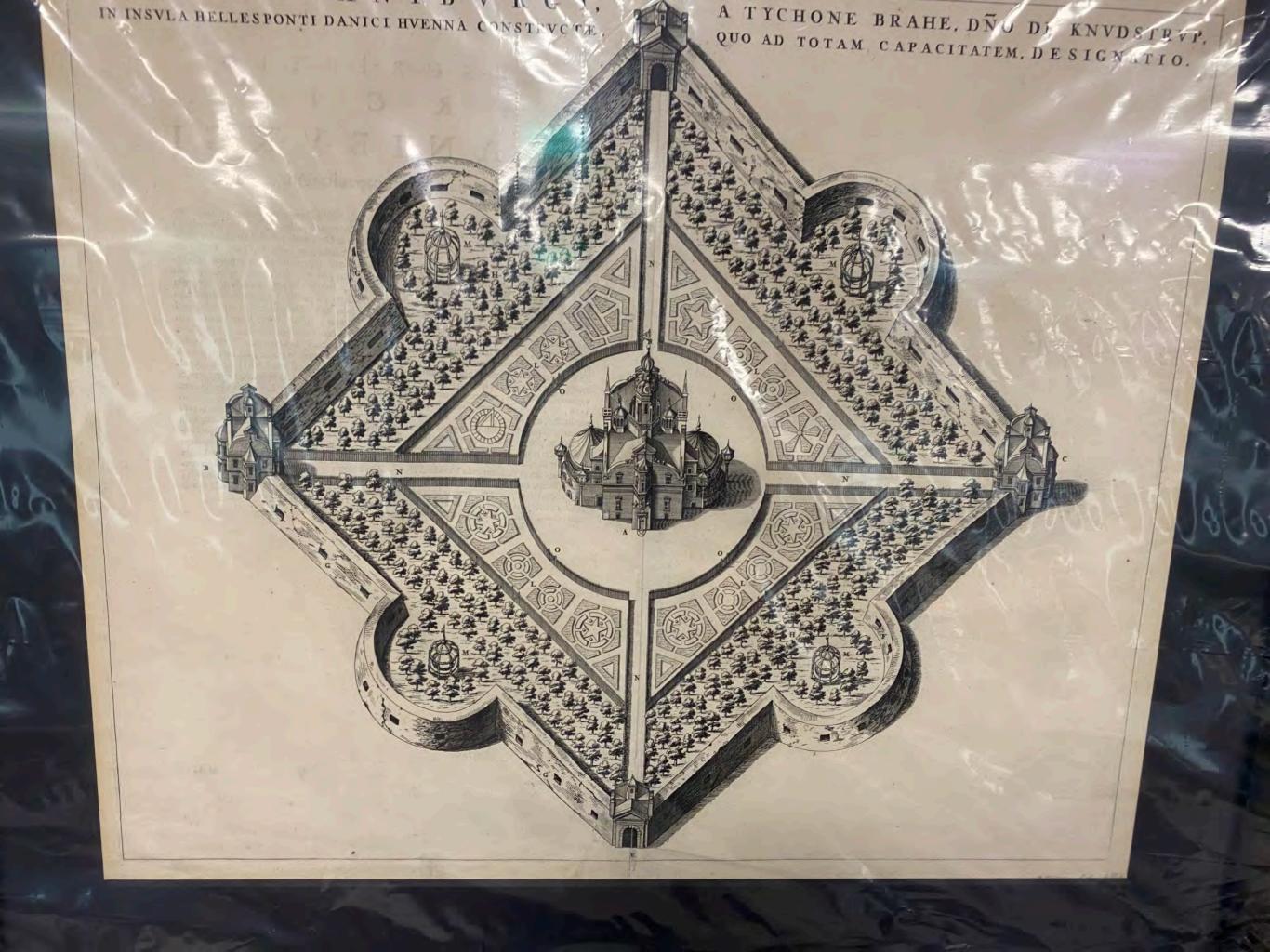
Astronomy required precision instruments, housed on the nearby grounds and behind removable panels on the castle roof.

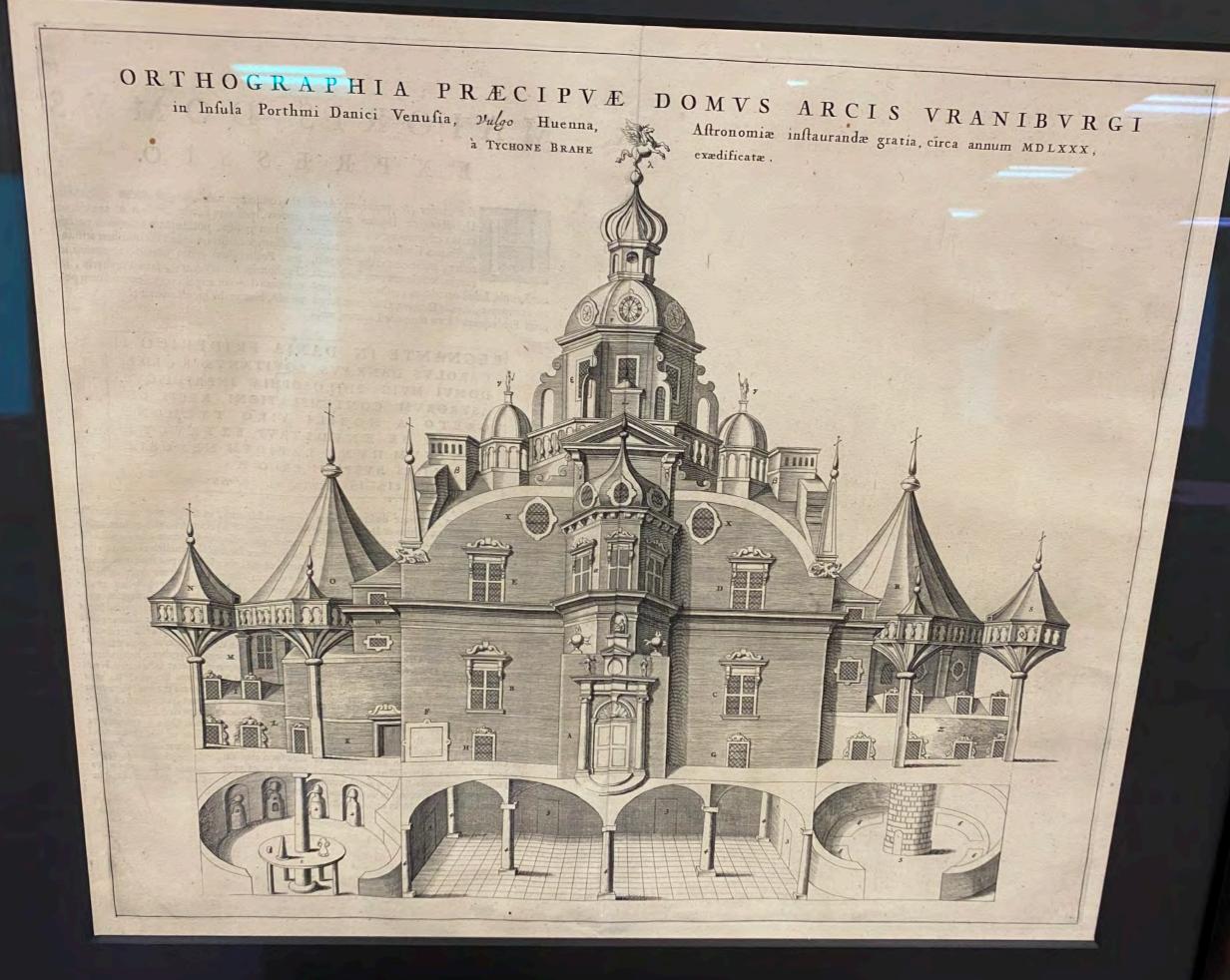
Aside from the portrait, these large framed prints are original leaves from one of the editions of Johann Blaeu, *Le grand atlas; ou, Cosmographie blaviane* (first published in Amsterdam, 1663).













#### Tycho Brahe and Elias Morsing, Diarium astrologicum (Uraniborg, 1586)

#### "Astronomical Journal"

On the Island of Hven, Tycho Brahe built a Renaissance research center called Uraniborg, "City of the Stars." This is the first book printed on Tycho's printing press at Uraniborg, and displays his motto, "looking up, I look down." That motto symbolized his aim of coordinating the study of astronomy, chemistry and medicine in an innovative and collaborative endeavor to discover the secrets of nature.

Tycho's observations of comets and new stars, proving that changes occur in the heavens beyond the Moon, upended the Aristotelian cosmos, paving the way for Galileo's fundamental astronomical discoveries and advances in physics.

In a new world of discovery and innovation, how are we to coordinate the disciplines today? What is nature and how is nature known?



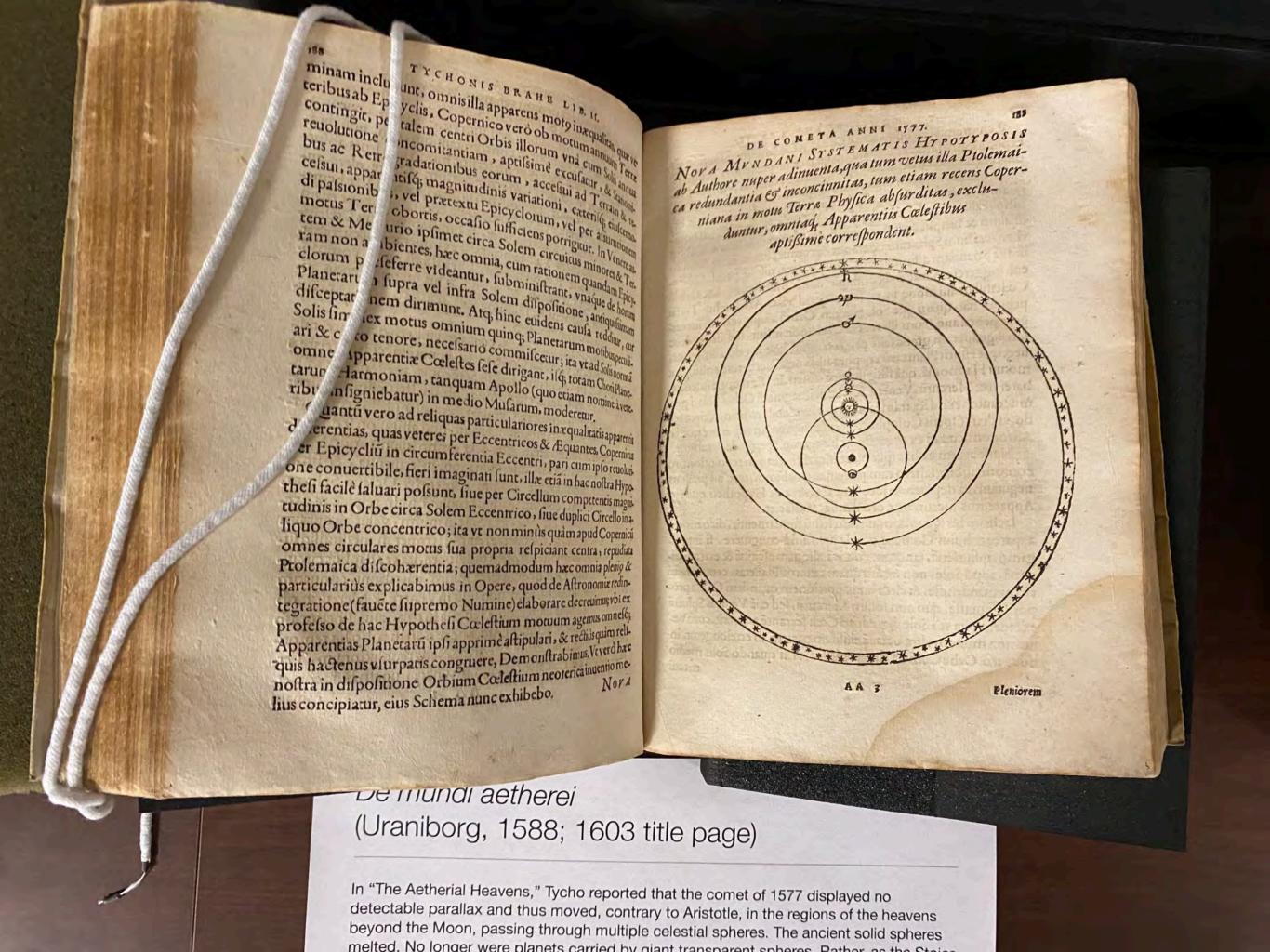
#### De mundi aetherei (Uraniborg, 1588; 1603 title page)

In "The Aetherial Heavens," Tycho reported that the comet of 1577 displayed no detectable parallax and thus moved, contrary to Aristotle, in the regions of the heavens beyond the Moon, passing through multiple celestial spheres. The ancient solid spheres melted. No longer were planets carried by giant transparent spheres. Rather, as the Stoics taught, planets must "swim through fluid heavens as fish swim through the sea."

In the Tychonic system, the Earth lies at the center of the cosmos. The planets revolve around the Sun, while at the same time the Sun revolves around the Earth. Even today, the Tychonic system has been updated to give accurate predictions of the positions of the planets. A mechanical-optical star projector projects the motions of the planets according to an observer-centered system. The engineers who craft such machines are modern-day Tychonic astronomers.

Because in this system the sphere of Mars intersects the sphere of the Sun, the Tychonic system was incompatible with solid celestial spheres. So long as one abandoned solid spheres, the Tychonic system provided all of the mathematical elegance of the Copernican system, consistent with the absence of stellar parallax, but without the arbitrary supposition of unreasonably large stars.

The text block of this copy was printed at Uraniborg on Tycho's own printing press. The title page was printed later in Prague. This was acquired in 2022.



# Tycho Brahe, *Astronomiae instauratae mechanica* (Nuremberg, 1602)

"Instruments for the Restoration of Astronomy"

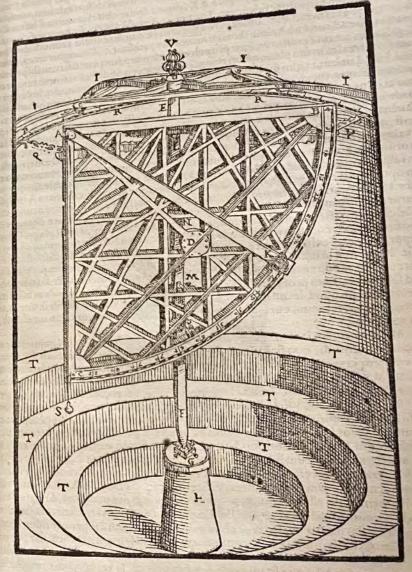
For two decades, Tycho and his assistants at Uraniborg produced thousands of astronomical observations of unprecedented quality. Tycho's large-scale observing instruments, together with sophisticated new error correction techniques, increased observational precision by a factor of twenty. His star positions were accurate to within 1 minute, or 1/60th of a degree. The absence of observable stellar parallax, predicted by Copernicus, became even more puzzling given the increased precision achieved in Tycho's monumental observing program.

EXPLICATIO FABRICAE ET VSVS annos nimirūzcirca ætatis verò suæ annum 14 me in en sus lus Venussa Uraniburga de la comparar reliquam Nobilitatem Aulicam, cribus Regni Senatoribus primaria annos nimiru y circa atatis vero lua annum 14 me inonina venulia Uranibus fecum prater reliquam Nobilitatem Aulicam, cribus Regni Senatoribus prima gubernationi prefuerunt, clementer invifere non est dedignatus, submisse don est dedignatus, submisse don gubernationi pretuerunt, elementer invuere non en demguarus, iummisedono etiamnum confervat. Seremsimus autem Rex Electus, me vicisim torque autem a confervat et a conferv etiamnum contervat, seremisimus autem kex Electus, me viensim torqueaute artificio, qualem gestare tune solebat, pulchrè elaborata & sua estigie decorata artificio, quatem genare tune tolebar, putenre etaborata estua enigie decorata donavit. Supra ipfiam Globum, de quo nune diximus apud literam V Bibliothe liqua pars repræsentatur. Ad Y verò & Z appendent binæ effigies intra rotun liqua pars representatur... Ad i vero & Lappendent una emgles intra rotundu folide efformatæ, quarum una est serenissimi & potentissimi illius Regis Dano Iolide efformatæ, quarum una eft ferentisimi & potentisimi tinus Regis Danourici II. laudzifsimæ memoriæ: altera ferenifsimæ Reginæ Sophiæ, ejus conjusis mæ, qui me mead; studia Regio & clementi savore semper prosecuti sunt. Porto mæ, qui me meaq; itudia kegio & ciementi iavorestempet profecuti mit. Portog teriore pictura cernuntur, primó superius juxta, numeros 1234, sunt aliqua ex list meis ischie depicta. Deinde infra hanc contignationem Musaum exhibetur. Un & 8. mensæ sunt, quibus studiosi mei Astronomici intercalculandum velalia hu tia agendum afsidere foliti. Erantautem in ipfo Musao tales mense 4. Solebam er per ad minimum 6.vel 8.interdum 10.vel 12.tales sustentare studiosos, undecendo per ad minimum 6. vei 8. interdum 10. vei 12. tales intentare itudiolos, undecuno præter pueros & juniores ejufcemodi Discipulos. Intra has mensas cernitura pud 6. columnam, in medio Musai rotundi constitutam, Globus ille maximus Orichalcicin. dum in Diametro, quem posteá suo loco exhibebimus & declarabimus. Tandemi omnia juxta numeros 9.10.11. spectatur laboratorium meum Chymicum, quod totus terraneum & crypticum erat; in quo 16, varii generis & forma adornaram fornar ronomicas". Nam & huic studio impense, ab incunte etiam arate, non minus quanda nomico addictus sui; magnaq; diligentia, nec parvis sumptibus id excolui, lltimojum des meos apud numerum 12, recumbit Canis quidam è nostris venaticus, qui admo dus & sagax erat. Isq; in ea forma & quantitate depictus, qua cernebatur: nontam No tis, quam fagacitaris & fidelitaris hieroglyphicum. Sicq; picturam universam, quatem tam parva forma imitari eam licuit, breviter expositam habes: quam tres divers & core Artifices missi depinxerunt. Effigiem meam Augustanus ille, de quo dixi, pictor, san archives diversaments and supplications of the same and supplications of the sam tectonica ista, & quæ his comprehenduntur, Architectus meus Johannes de Embdas, vvichel esfinxit. Quæ vero supra illa instar descriptionis Regionum & montium, ubite Sol occidere visitur, depicta sunt, Johannes de Antverpia pictor Regius Coronaburge appositit. Quilibet enim ex dictis tribus artificibus in hocipso, quod secerat, praectum celluit. Demum superius juxta R Sest effigiei & totius pictura inscriptio, prout vider

Us us hujus maximi Quadrantis est in rimandis accuratissime Siderumsublinia bus intra sextam unius minuti partem, collimatione facta per aliquod pinnacidiorum mula superiore & inseriore juxta Cylindri utrans; etjam circumserentiam hisceandon & numerando ipsam Altitudinem in superficie Quadrantis exteriore apud positume pinnacidii. Potest etiam momentum transitus per Meridianum una ab utroquelatete pinnacidiorum quam Cylindri haberi intermediantibus horologiis accuratis, dequi ximus. Quomodo verò ex data Altitudine & momento temporis, quo sidus Meridin transit, adhibito motu Solis, ejus locus constet, Astronomis notum est. Confisus sum mum huic quadranti in restituendo motu Solis ex ejus Altitudinibus Meridianis, is

tromissa Cylindri umbra quadrata in interiorem partem alicujus è pinnacidii in quadrata erjam figura umbram illam ad amussim excipiente& comprehendente. Adhibui nihilominus & alios magnos Quadrantes in confilium, ut res tam subtilis omni erroris suspicione vacaret.





EXPLI

# Tycho Brahe, *Epistolarum astronomicarum* (Uraniborg, 1596)

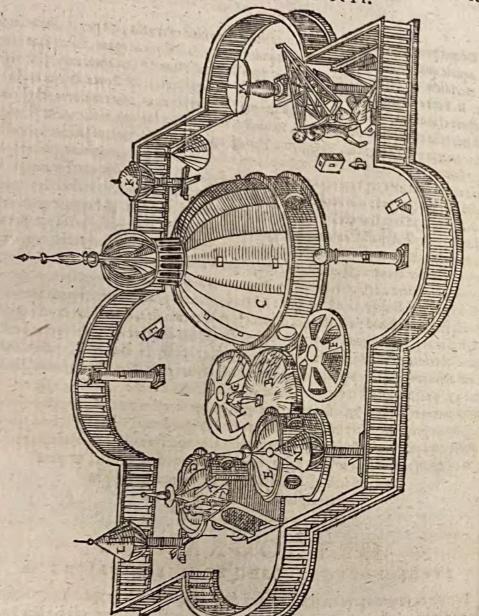
#### "Astronomical Letters"

In this work, Tycho explained two problems posed for Copernicus by the absence of stellar parallax:

- 1. Due to the annual movement of the Earth around the Sun, one would expect to see stars appear to shift in position. This parallax evaded detection, even at Uraniborg.
- 2. Tycho reported precise measurements of the apparent widths of stars, which allowed him to quantify how large they must be as a function of their distance. If stars were mere pinpoints of light, with zero apparent width, there would be no problem for the Copernican system. But if stars show apparent width, then combined with the absence of parallax, there is a problem for Copernicus in that stars that are far enough away to explain the absence of parallax would have to be immense. Indeed, given the observed apparent widths of stars, the diameter of even an ordinary star would have to be no less than twice the distance between the Earth and the Sun. In other words, if the Copernican system were true, then each star must be an incomparably immense body. Indeed, stars would have to be altogether different kinds of bodies than the Sun, far dwarfing the Sun in size, breaking all analogy and proportion with the ordinary course of nature.

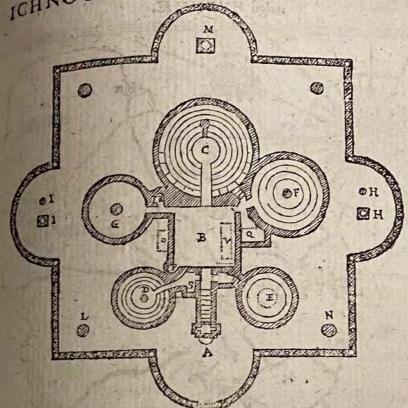
# Brahe, Epistolarum astronomicarun

ORTHOGRAPHIA STELLAEBVRGI EXTRA



Exterius in area hujus capacitatis STELLEBVRGICE columna lapidea HI un tring; ad Ortum & Occasium disposite, quibus tam Regulæ Ptolemaica imponuntur, quam Armillæ minores portatiles, quando requiritur, sufpenduntur. K L NO Globi fulcris suis incumbentes, & in dicta area nonnunquam dispositi, ut ijs Sextantes ad quemcunq; Stellarum situm collimandum reclinentur. M mensa lapidea & rotunda, Quadranti portatili, & alijs minoribus Instrumentis in ea, cum opus fuerit, constituendis, ut observationibus commode in seruiant, destinata. Reliqua oculatus & intelligens considerator per se animaduertet. 1 CHNO

EFISTOLARYM ASTRONOMICARYM. ICHNOGRAPHIA STELLAEBVRGI.



ICHNOGRAPHIÆ HVIVS EXPOSITIO.

Vifibulum quò per gradus Obseruatorium subintratur. B Hypocaustum Quadratum. Ccrypta pro Armillis maximis Æquatorijs. D Pro Quadrante Velubili E Pro Armil= Lodiacalibus. F Pro Quadrante Chalybeo magno habente exterius Quadratum Geome= nametiam Chalybeum. G Pro Sextante Quadricubitali Globo suo conuolubili imposi= HH Columne lapidee ad occiduam plagam disposite. 11 alie Columne lapidee Ori= mintes su locate. KLNT Globi Sextantibus Astronomicis fulciendis extrapositi. M mene stunda saxea. O lectus ipsius TYCHONIS. Q lectus Studiosorum. P fornax. V infa. S initium subterranei meatus infra uallum atg; hortum, in Laboratorium pyro= Michigan Arcis aliquando (D V) deducendi, incoatus enim est, sed non dum absolutus. Extetrarea cum sua Galleria habet in quolibet quadrati laterum quatuor mundi plagas respicie dem pedes 70. Diameter uerò semicirculi medio loco intercepti est pedum 24. In duobus rotune sun. ... Quadratæ areæ uersus Notapelioten & Notolybicum Thecæ quædam Portune sunt, in quibus maius illud Instrumentum semicirculare quo distantiæ Siderum ula uquadrantem capiuntur, tum quoq; Sextantes alij, similiaq; Organa mobilia, quorum ujus Jemper requiritur's sarta tecta conservantur, quemadmodum etiam ad angulos Borrham Hechreuiten TYCHO quædam alsa suo tempore disponere constituit.

Hechreuiter de Structuris hisee Astronomiæ inseruientibus dicta sint: ut uero ipsa In-Asin qua hec proximis aliquot annis non minus laboriose quam sumptuose d TYCHO= translata sunt und conspectui pateat; eius etiam aliqualem designationem subiungemus.

TOPO=

# John Bainbridge, *An astronomicall description of the late Comet* (London, 1619)

Three bright comets visible to the unaided eye appeared in 1618!

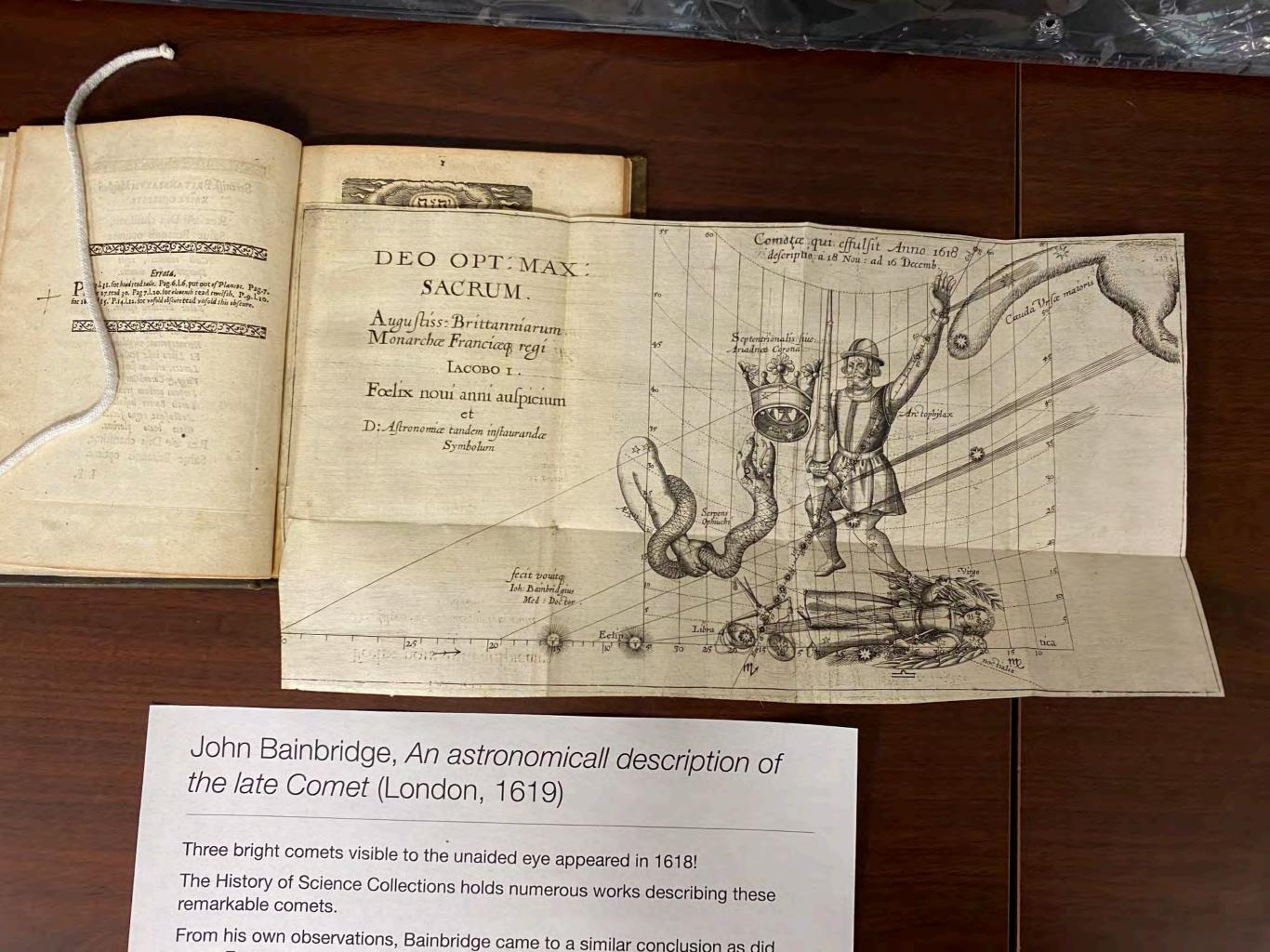
The History of Science Collections holds numerous works describing these remarkable comets.

From his own observations, Bainbridge came to a similar conclusion as did many European astronomers — that the comets of 1618 proved that comets move through the heavens beyond the Moon. This conclusion was consistent with the arguments of Tycho Brahe. Quite surprisingly, Galileo was one of the few astronomers who opposed this conclusion.

This book contains the first telescopic observations published in England and the first recorded use of the word "telescope" in English.

In this work, Bainbridge also rejected the astrological significance of comets.

He later became the first Savilian Chair of Astronomy at Oxford.



# Athanasius Kircher, *Iter exstaticum* (Würzburg, 1660)

"Ecstatic Journey through the Heavens"

Six chief world systems were debated in Galileo's world, some geocentric and some heliocentric. The six systems, as they appeared side-by-side in this book by Athanasius Kircher in 1660, were as follows:

Ptolemaic: Upper left. All planets revolve around the central Earth. Geocentric.

Platonic: Upper right. Like the Ptolemaic, except the positions of Venus and Mercury are switched. Geocentric.

Cappellan or Egyptian: Center left. Venus and Mercury revolve around the Sun. Otherwise geocentric.

Tychonic: Center right. All planets revolve around the Sun. The Sun in turn revolves around the Earth. The Earth and Moon are not planets.

Semi-Tychonic: Lower left. Like the Tychonic, except Jupiter and Saturn revolve around the Earth.

Copernican: Lower right. All planets revolve around the Sun. The Earth is a planet. The Moon is a satellite and not a planet. Heliocentric.



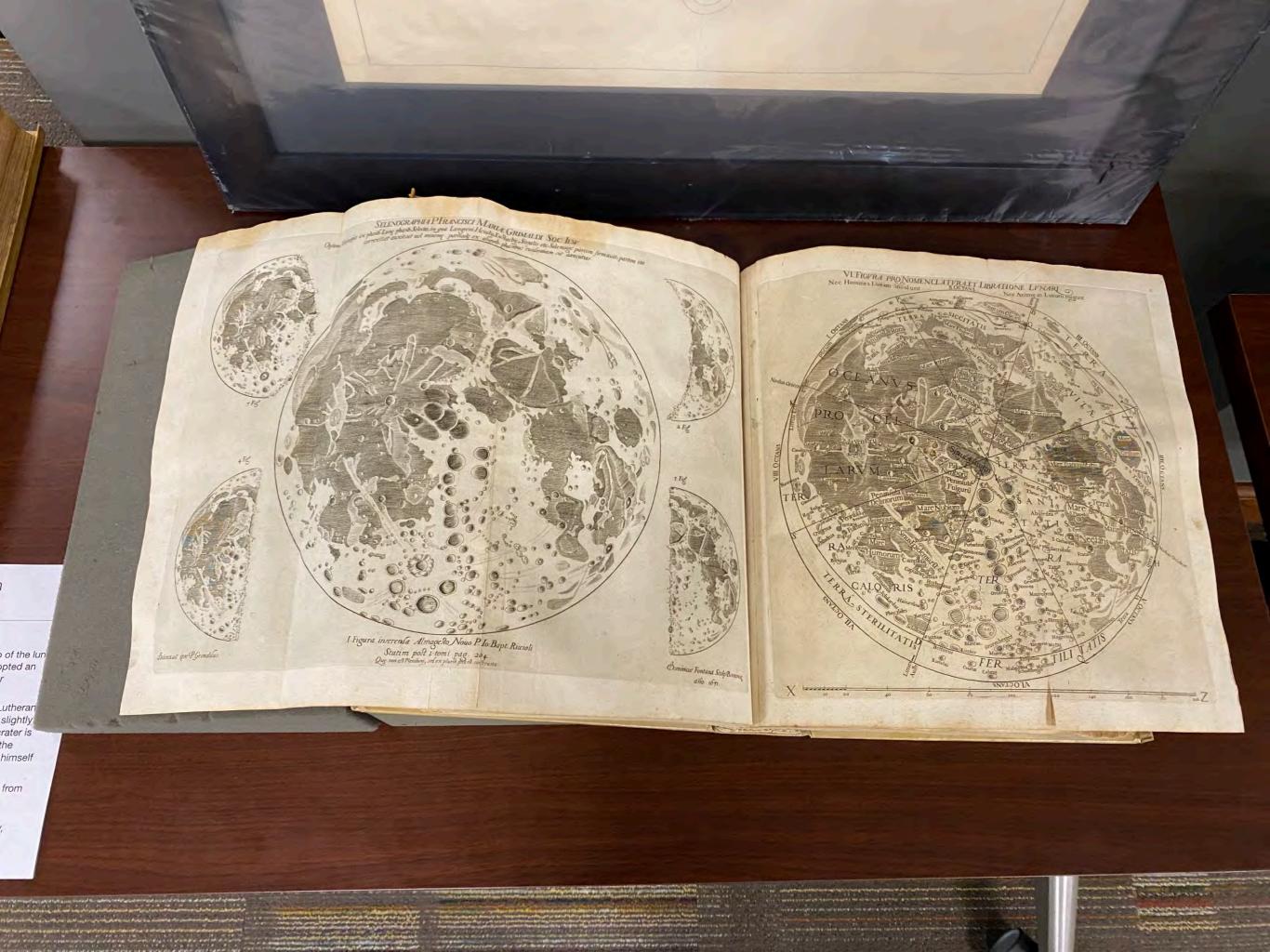
## Giambattista Riccioli, Almagestum novum (Bologna, 1651), Part 1

#### "The New Almagest"

In a massive textbook of astronomy, Riccioli adopted Hevelius' map of the lunar surface, yet he proposed different topographical names. Riccioli adopted an inclusive approach to lunar nomenclature, naming lunar features after astronomers of multiple nationalities and religious affiliations.

For example, Riccioli, a Jesuit, named a crater after Kepler, who was Lutheran rather than Catholic. Galileo lies to the left of Kepler; Hevelius appears slightly below Galileo. Copernicus is in the upper right. In the center, below, a crater is named for Tycho. Above Tycho is Gauricus, named after Luca Guarico, the Pope's own astronomer in the generation of Copernicus. Riccioli placed himself far out on the left margin.

Riccioli's system of naming succeeded because he included astronomers from across Europe and the Middle East, Protestants and Muslims as well as Catholics. Many of Riccioli's names remain in use today. In 1969, Apollo 11 landed on the Moon, establishing "Tranquility Base" in the Sea of Tranquility, named Mare Tranquilitatis by Riccioli.



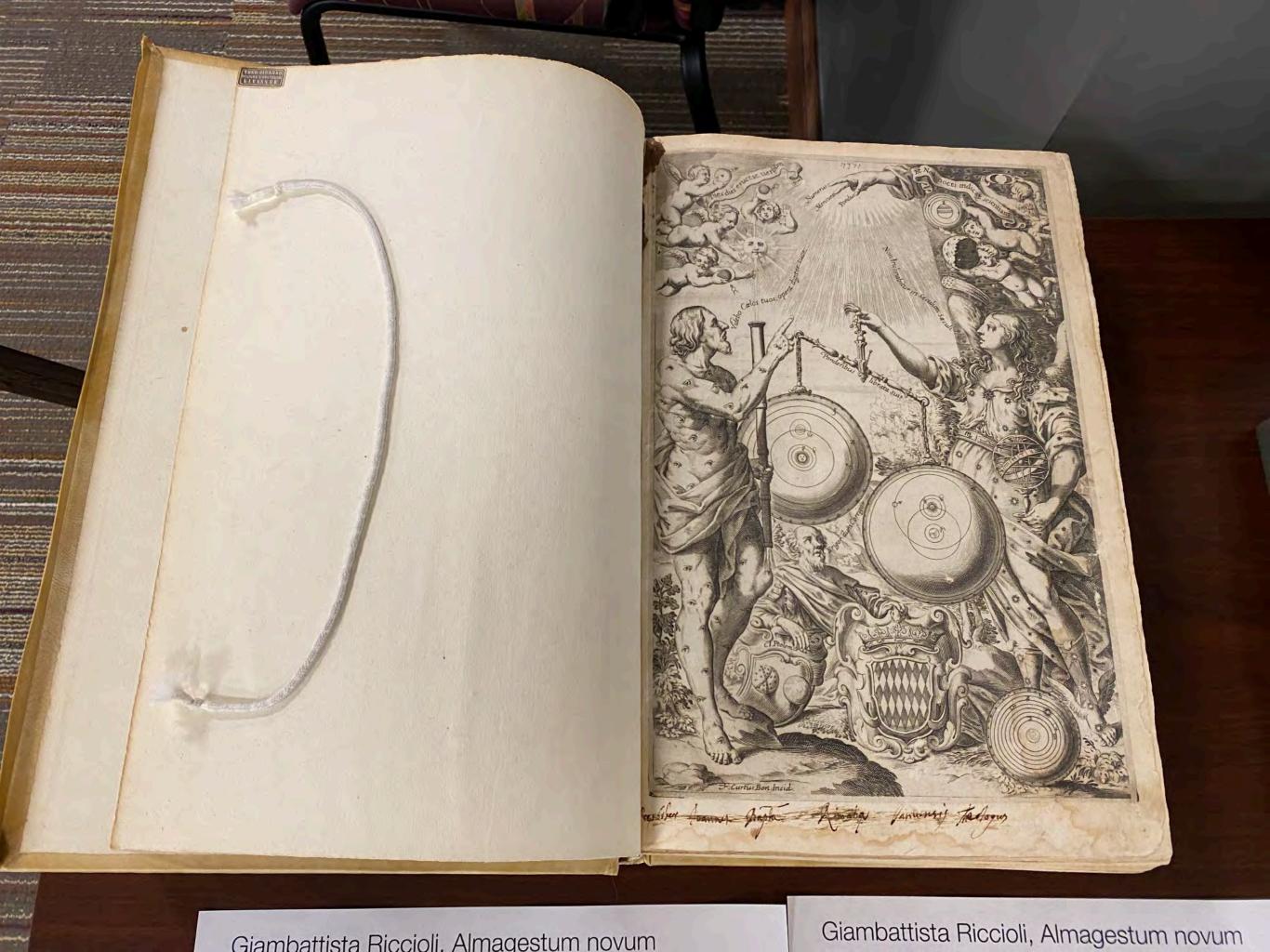
## Giambattista Riccioli, Almagestum novum (Bologna, 1651), Part 2

The frontispiece of Riccioli's treatise depicts not two, but 3 major systems of the world:

- 1. The Ptolemaic system rests discarded (lower right corner) because of the phases of Venus and Mercury (upper left corner). All-seeing Argus looks on, holding a telescope. Urania weighs in a balance the two chief world systems which remain:
- 2. The Copernican system appears as the standard against which alternatives must be measured.
- 3. Riccioli's semi-Tychonic system weighs in as the most warranted.

A comet and several telescopic discoveries (upper right corner) include the banded appearance of Jupiter and the ring of Saturn.

Riccioli's frontispiece indicates that Copernicanism was admired as the standard by which the mathematical aspects of other systems were judged, but alternatives proliferated rapidly as the search for observable distinguishing evidence bogged down. In terms of predicting planetary positions, competing systems were not just empirically similar, but geometrically equivalent.





## 



## Johann Bayer

Uranometria "Measuring the Heavens"

(Ulm, 1661; reprint of 1603 1st ed.)

bound with Johann Bayer, Explicatio characterum (star catalog; Ulm, 1697)



Bayer's star catalog, bound in the OU copy at the front, before the atlas, was based on that of Tycho Brahe.

In the atlas, Bayer's artfully-drawn constellation figures influenced every subsequent star atlas. Each figure is superimposed upon an accurate star map, plotted on a one-degree grid. By fusing science and art, Bayer inaugurated the golden age of the celestial atlas.

Bayer's atlas consists of 51 double-page copperplate engravings.

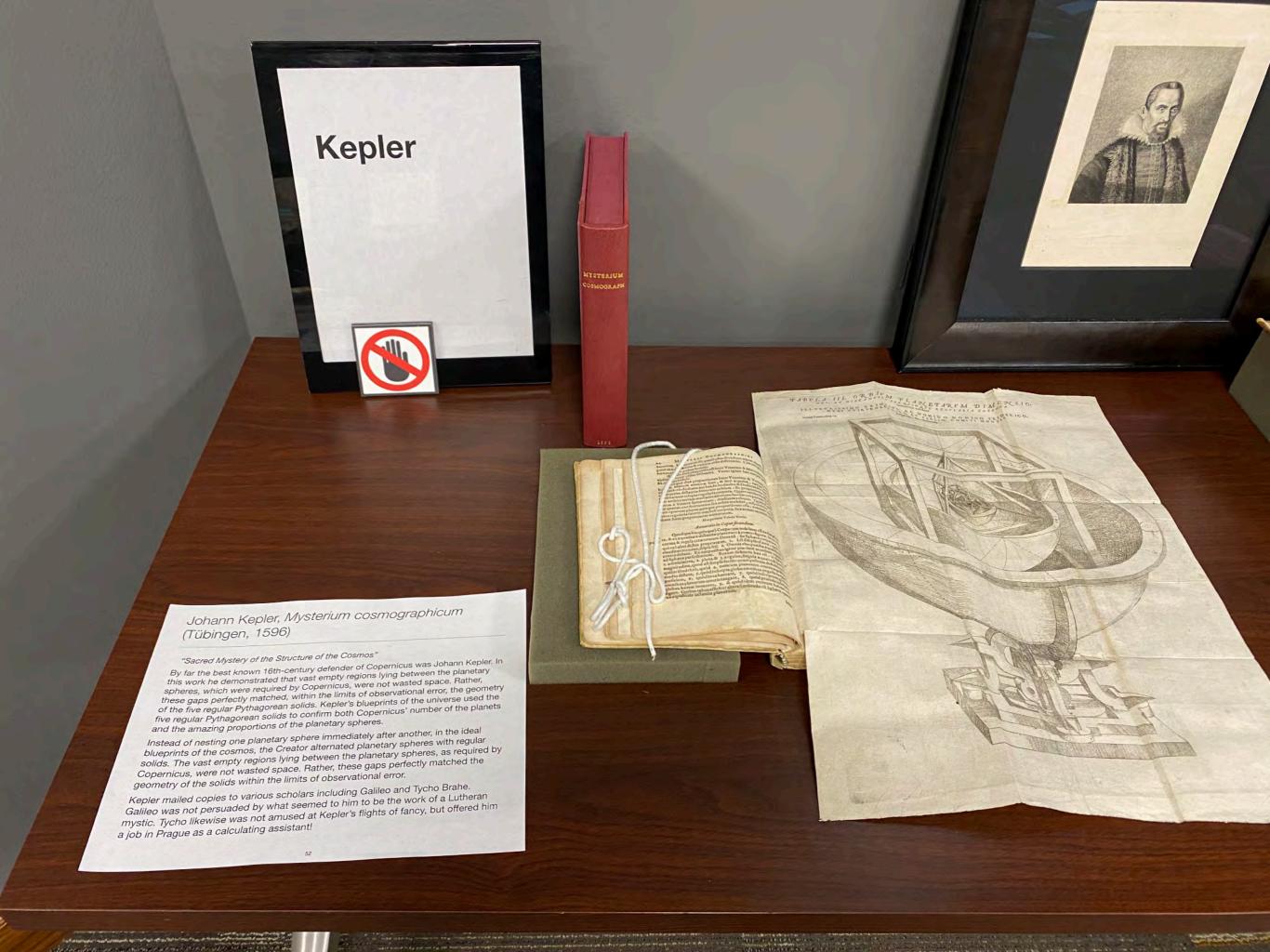
In the constellation of Taurus the Bull, the "ecliptic" runs across the middle of the dark Zodiac band. The Milky Way angles down the left side. Bayer labeled the stars with Greek letters, according to their apparent magnitude, so that the brightest star in Taurus is alpha-Tauri, instituting the convention still used today.

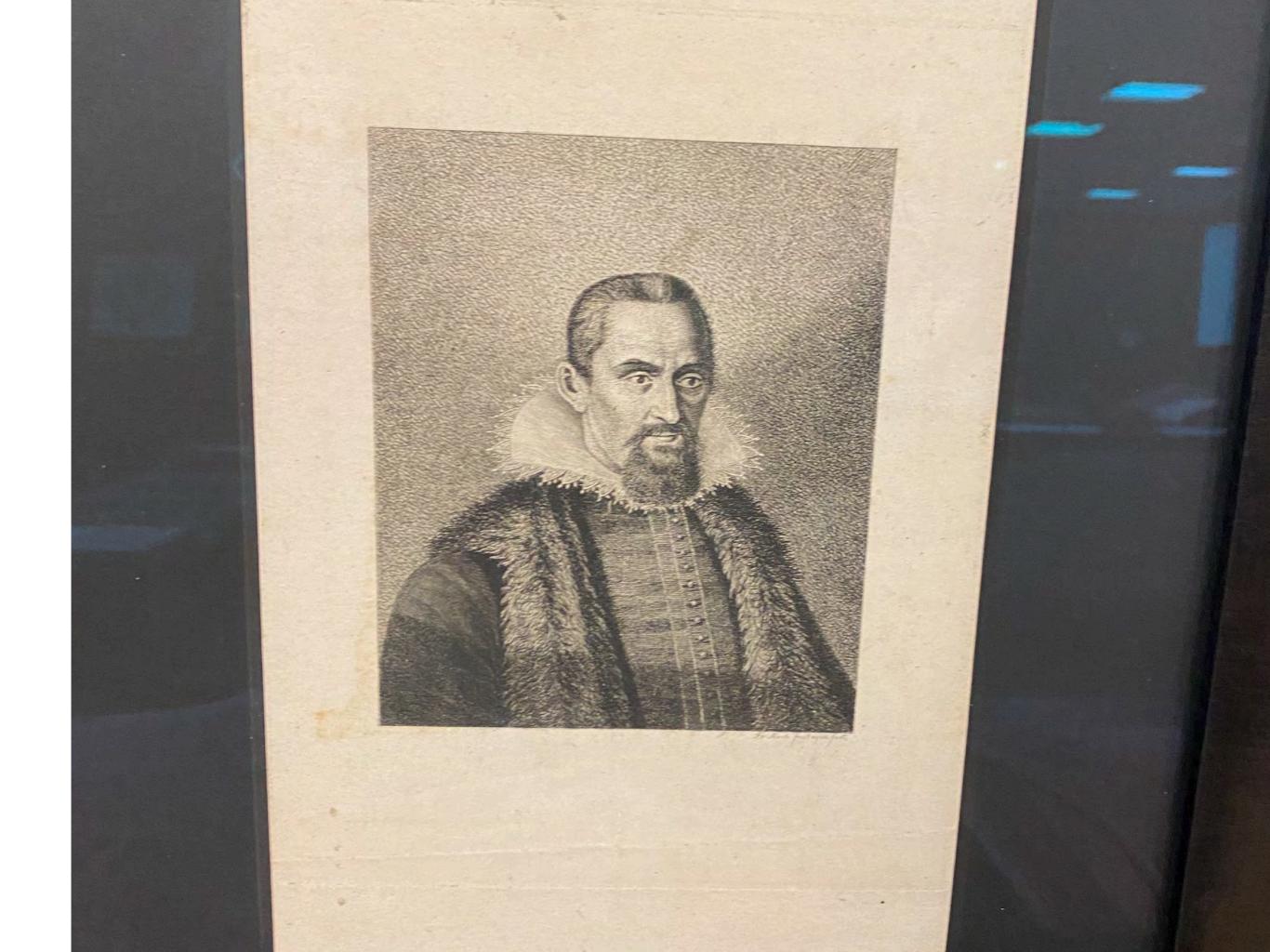
The 1603 1st edition printed both sides of the leaves. In this edition, the absence of printed text on the back side of each leaf prevented type from showing through on the atlas pages. Each double-page atlas leaf is attached to a strip of scrap paper that is bound in the gutter, so that the atlas image itself does not disappear down into the fold.



# 







## Johann Kepler, *Mysterium cosmographicum* (Tübingen, 1596)

"Sacred Mystery of the Structure of the Cosmos"

By far the best known 16th-century defender of Copernicus was Johann Kepler. In this work he demonstrated that vast empty regions lying between the planetary spheres, which were required by Copernicus, were not wasted space. Rather, these gaps perfectly matched, within the limits of observational error, the geometry of the five regular Pythagorean solids. Kepler's blueprints of the universe used the five regular Pythagorean solids to confirm both Copernicus' number of the planets and the amazing proportions of the planetary spheres.

Instead of nesting one planetary sphere immediately after another, in the ideal blueprints of the cosmos, the Creator alternated planetary spheres with regular solids. The vast empty regions lying between the planetary spheres, as required by Copernicus, were not wasted space. Rather, these gaps perfectly matched the geometry of the solids within the limits of observational error.

Kepler mailed copies to various scholars including Galileo and Tycho Brahe. Galileo was not persuaded by what seemed to him to be the work of a Lutheran mystic. Tycho likewise was not amused at Kepler's flights of fancy, but offered him a job in Prague as a calculating assistant!



## Johann Kepler, *De stella nova in pede serpentarii* (Prague, 1606)

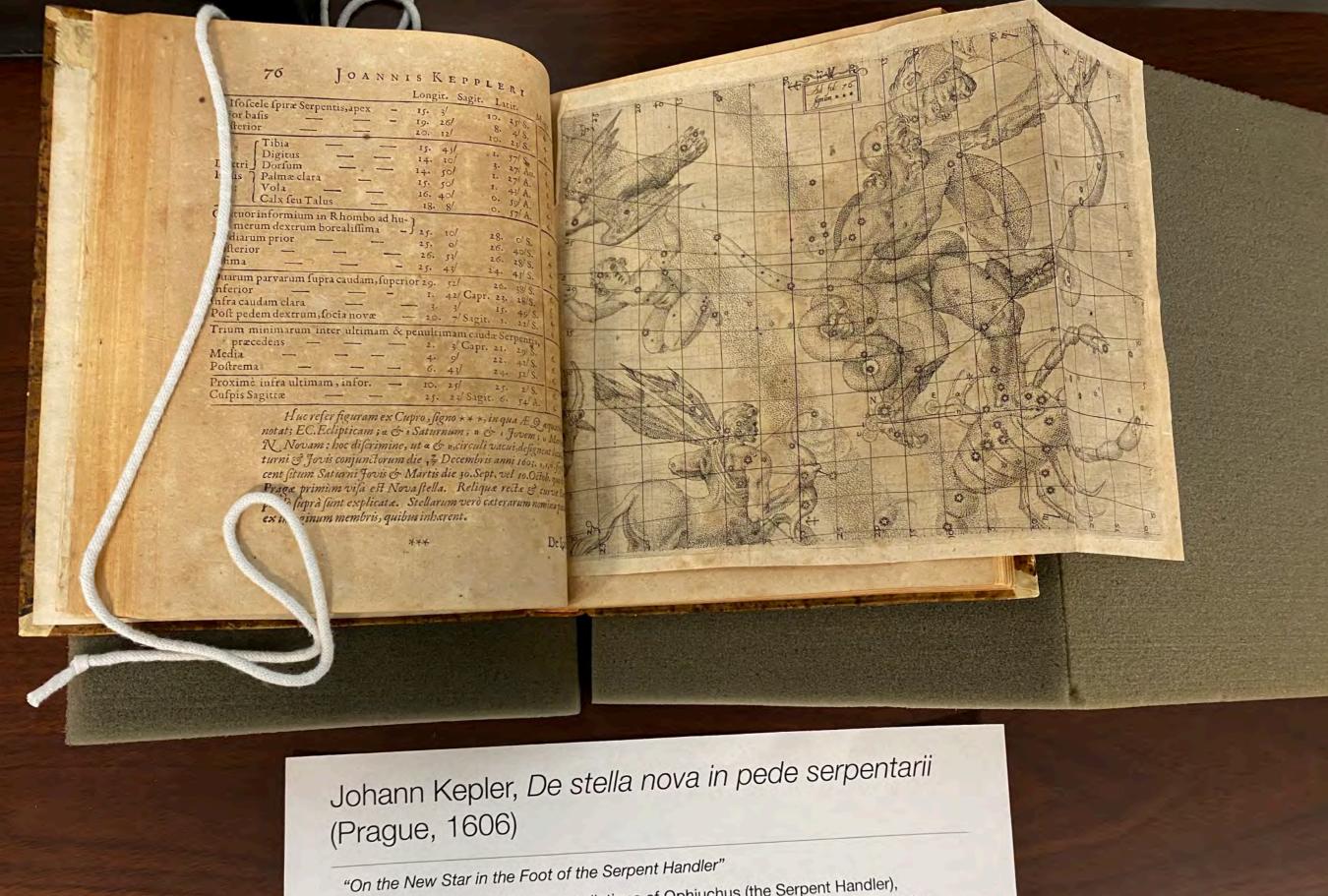
"On the New Star in the Foot of the Serpent Handler"

Kepler's star map shows the constellations of Ophiuchus (the Serpent Handler), Sagittarius and Scorpius. The Milky Way runs diagonally down from the left, and the "ecliptic," or annual path of the Sun, runs horizontally through Sagittarius and Scorpius.

A triple conjunction of Jupiter and Saturn took place in 1603, followed by a planetary massing with Mars in 1604. After the planetary massing, a "Nova" or bright star ("N") suddenly appeared in the ankle of Ophiuchus on October 10, 1604. The new star was no ordinary star; it remained visible even in the daytime sky for over a year. The new star prompted widespread debate about what it might portend and whether the heavens could change. Now called Kepler's nova, it was the second supernova to be observed in a generation, after the supernova in Cassiopeia, described by Tycho, which appeared in 1572.

Kepler's star positions and artistic style show the influence of Tycho and Bayer. Bayer had reversed a number of constellation figures, including Orion and Ophiuchus. In contrast, Kepler's map shows the figure of Ophiuchus facing toward us rather than outward, so that the traditional star names of his feet and shoulders match the orientation of the constellation figure.

In this book, Kepler also discussed mathematical chronology, the date of the birth of Christ, and the nature of the Star of Bethlehem.



Kepler's star map shows the constellations of Ophiuchus (the Serpent Handler), Sagittarius and Scorpius. The Milky Way runs diagonally down from the left, and the "ecliptic," or annual path of the Sun, runs horizontally through Sagittarius and Scorpius.

A triple conjunction of Jupiter and Saturn took place in 1603, followed by a planetary

## William Schickard, *Astroscopium* (Stuttgart, 1698)

"Star Viewer"

William Schickard was a gifted linguist, skilled craftsman, and expert astronomer. He was also a friend of Johann Kepler, and produced some of the illustrations for Kepler's *Epitome of Copernican Astronomy* (1618-1623).

In 1623 Schickard published this *Astroscopium*, which included conical images of the constellations designed to be assembled together. This "paper instrument" was a model intermediate between a planisphere and a celestial globe, and could calculate the positions of the stars for any day and hour of the year. The book itself measures only about 5" tall, but the pages which contain these conical maps of the night sky are considerably larger.

During his lifetime Schickard also created a mechanical calculating machine, produced two textbooks to teach Hebrew, one in Latin and one in German, and also taught astronomy, mathematics, and geodesy. Schickard died in 1635 as the result of a plague outbreak in central Europe.





## Johannes Kepler, *Astronomia nova* (Heidelberg, 1609)

#### "The New Astronomy"

This is Kepler's famous "pretzel diagram," where he focused attention on the paths of planets themselves rather than on the rotating solid spheres believed to carry them. In an Earth-centered system, a planet carried along within its thick, solid sphere would follow some kind of pretzel-like path.

By analyzing Tycho's observations of Mars, Kepler put forward what are now regarded as his first two laws. Just as fundamentally, he changed the paradigm from focusing on orbs, or solid spheres, to orbits, the actual path a planet takes as it moves through space. It is perhaps difficult for us today to recognize that it was necessary to invent the concept of an orbit, of tracking the actual path of a planet through space, to replace the ancient concept of celestial spheres.

Kepler defended Copernicus, ironically, in ways that Copernicus would never have approved. Kepler's first two laws re-introduced ideas which Copernicus had denied. For Kepler there are no perfect circles in the heavens. Instead of moving in uniform motion as seen from the center, for Kepler, planets sweep out equal areas in equal times as seen from a focus located off-center. The empty focus of Kepler's ellipse worked very much like Ptolemy's equant point, which Copernicus rejected.

CAP. I.

Martis, quos p auram atheria ille decurrit ab ano MDLXXX mq ad annum
M D XC VI,
fi verum elt
terram finte, op
Prolemaus &
Braheus volit.
Eos moțus ulterius cócimate perplexum
erat funurum;
nam connexio
infinis eft ns.
quam in fe iplam recurre.
Et nota, quod
cum ranta requiiratur vafiitas orbis Martii, in anguftic
fimo poftea
circello circa A
terram, cjusqi
fpaciolo B, includi fpharas
Solis, Veneris,
Mercurii, Lumz, Ignis, Acris,
Aque, Terre;
atque de hoc iplo fpaciolo uni Veneri cedete portinuculi
portifimam,niDE MOTIB. STELLÆ MARTIS

portione, quam Marti hiccessii detoto hujus schematis spacio.
plectiores, is teura star. Spitarum istatum caussas, ordinem, const tarum singulorum sircumducits, qui motum Solis imitatentur que relinquir, Copernicus uno motu annos relluri attributo.

R v R S v M autem animadversum est, hos uniuscujusque Planetæ spirarum articulos in diversis zodiaci signis esse inæquales; ut alicubi Planeta per longiorem arcum zodiaci retrocederet alicubi per breviorem, jam longiore jam breviore temporis spacio: nec idem perpetuo retrogradi Planetæluminis incrementum. quod sitempora & locainter medios retrocessuum articulos computarentur, neque tempora temporibus neque arcus arcubus erant æquales, neque quæque tempora suis arcubus eadem proportione respondebant. erattamen unicuique Planetæ certum signum zodiaci, a quo signo usque ad oppositum, per utrumque semicirculum, omnia ista successive augebantur.

Ex quibus observationibus intellectum est, duas inæqualitates apud unumquemque Planetam in unum confundi, quarum prior cum reditu Planetæ ad idem zodiaci signum, altera cum reditu Solis ad Planetam restitueretur.

Harum itaque inæqualitatum caussa & mensuræ investigari aliter sol habet una folam inaqualitate inaqualitate inaqualitate respectiu emposis, intra inferiore priendum, quod esse constantior & expeditior; ut cujus exemplum in Solo solveur. Nam qui alteri inaqualitati non erat obnoxius. Vt igitur is motu videbant, qui alteri inaqualitati non erat obnoxius. Vt igitur ab hac prima inaqualitate secundam separarent, aliter non potuere, ab hac prima inaqualitate secundam separarent, aliter non potuere, quam si considerarent Planetas iis noctibus, quarum in principiis oriunde august prase, in infradi-tur occidente Sole; quos inde august appellabant. Nam quia præsentur. tur occidente Sole; quosinde axquivyius appellabant. Nam quia præsen-

tia & conjunctio Solis ipsos præter morem accelerat, oppositio Solis etiam in contrarium ducit; certe ante & post hos articulos multum e suis locis, quos erant repræsentaturi per primam inæqualitatem, emoventur. Inarticulis ergo ipsis conjunctionis & oppositionis cum Sole illa ipsassante in conjunctione vero Solis cum cerni nequeant, relinquitur sola oppositio cum Sole idonea huic rei.

CVM AVTEM alius sit \*medius motus Solis alius apparens, eo quod Soletiam sit obnoxius inæqualitati primæ; igitur quæritur, quisnam ho Soletiam ittopnoxius inæqualitate fecunda, &, utrum Planetæ fint inspium exuat Planetas inæqualitate secunda, &, utrum Planetæ fint inspium occupate
editi de secunda secu rum exuat Manetas in aquantate recumua, vo, in existing an exuat Manetas in aquantate recumua, vo, in existing an lemæus medium motum elegit; quod discrimen, si quod sit interusurpationem medii vel apparentis motus Solis, observationibus censeret deprehendi non posse; fieret vero forma calculi & demonstrationum expedita, usurpato motu Solis medio. Ptolemæum Copernicus & Tycho insuis transsumptionibus sunt secuti. Ego, ut habes in Mysterio meo Cosmographico cap. xv, apparentem locum & ipsum Solis cormeo Cosmographico cap. xv, apparentem locum & ipsum Solis cap. Xv, apparente pus pro meta statuo: idque demonstrationibus, operis parte quarta & quintà sequentibus, evincam.

Prius tamen hac parte prima demonstrabo, quod is, qui pro medio apparentem Solis motum adhibet, omnino aliam Planetæ orbitam in æthere statuat, quamcunque ex celebrioribus opinionibus de mundo sequatur. Quæ demonstratio cum æquipollentiæ hypothesium. innitatur, ab hac incipiemus.

CAPVT II.

De prima & simplici æquipollentia eccentrici & concentrepicyli, & earum causis Physicis.

C INITIO hic amplector illam a Ptolemæo lib. 111. & Copernico lib. 111. cap. xv. demonstratam æquipollentiam hypothesium, quæ pro prima inæqualitate salvanda funt susceptæ; ubi eccentricus paria facit cum epicyclo in concentrico: siquidem linea apsidum in eccentro, & linea per centrum epicycli & Planetam in concentrico, perpetuo maneant paralleli; & hic semidiameter epicycli æquet illic eccentricitatem,

semidiametri vero illic eccentri & hic concentrici sint æquales; moveaturqueillic Planeta in eccentro æquabiliter, sic ut æqualibus temporibus æquales arcus conficiant.

A 3 Sit primo

(Heidelberg, 1609)

... nova

## Johann Kepler, *Dissertatio cum Sidereo* (Frankfurt, 1611)

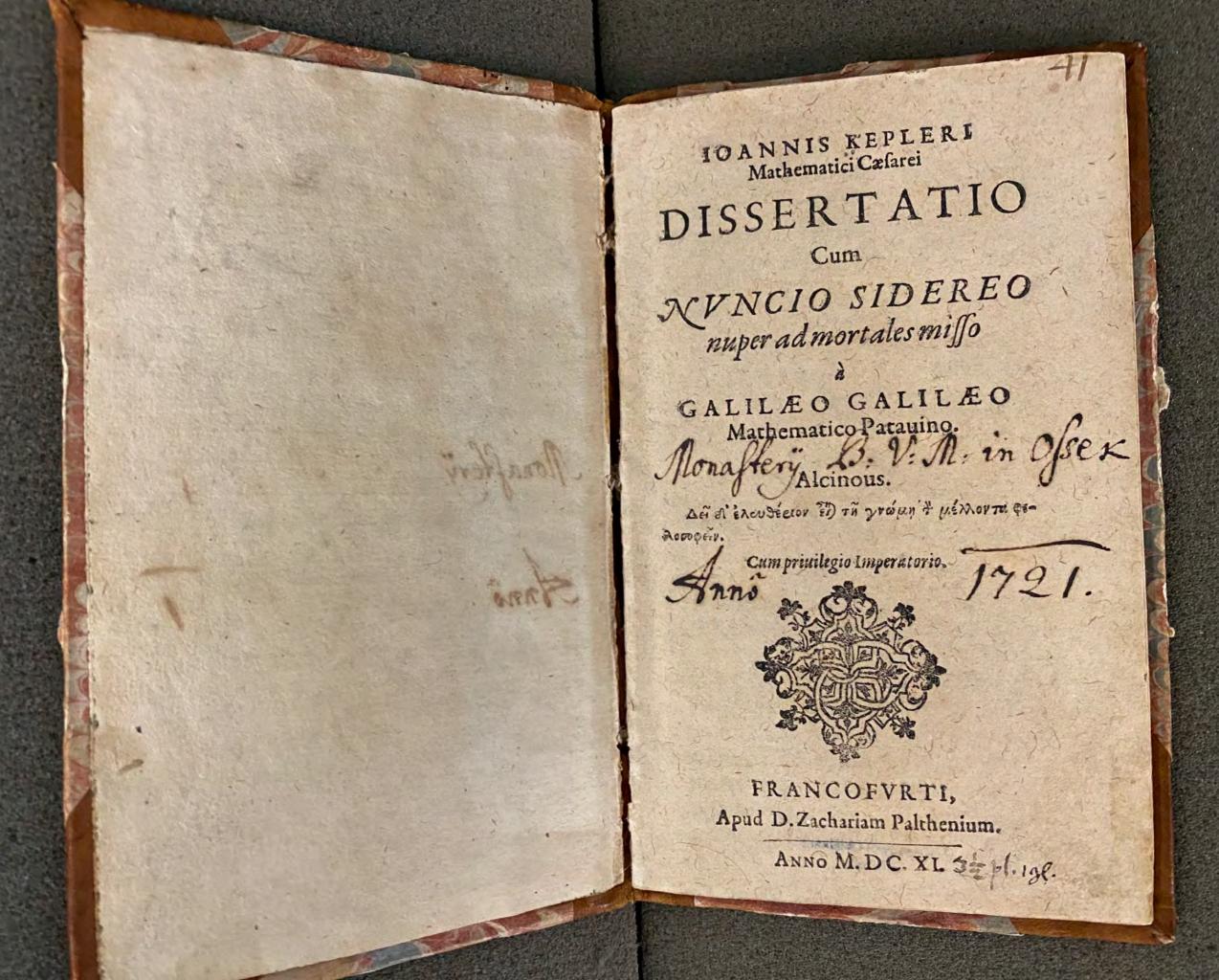
"Conversation on Galileo's Starry Messenger"

"I thank you because you were the first one, and practically the only one, to have complete faith in my assertions." – Galileo

In this public letter, Kepler expressed support for Galileo's telescopic discoveries. But Kepler went further, speculating that the Moon and Jupiter might be inhabited, and that explorers from the Earth might be able to visit them. This is the earliest work by a modern astronomer to entertain the possibility of space travel. These questions, conspicuously absent in Galileo's works, explain why the modern telescope used to search for terrestrial planets was named after Kepler.

This book played a prominent role in the exciting story of the immediate reception of Galileo's Sidereus nuncius, equal to Galileo's visit to Rome to demonstrate his discoveries for the Jesuits. After both Kepler and the Jesuits endorsed his discoveries, opinions quickly consolidated in his favor.

This is the 3d ed., more rare than the 1st (Prague) and pirated 2d (Florence) editions which were both published in 1610. Kepler objected to the pirated Florence edition in a letter to Galileo written in December, 1610. Kepler may have spearheaded the publication of this Frankfurt edition to retaliate against the Florentine one.



#### Johann Kepler, *Harmonices mundi* (Linz, 1619)

#### "Harmony of the Universe"

This is the first work in which all three of what we now call Kepler's laws appear.

In this work, Kepler integrated theoretical astronomy and music, showing that the motions of the planets employ the same numerical ratios as the most harmonious musical scales. Kepler's "harmonic law" still describes how planets and stars and satellites and galaxies revolve around one another in space.

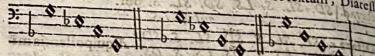
Kepler's integration of theoretical astronomy and music fulfilled an ancient dream. Plato wrote, "As our eyes are framed for astronomy, so our ears are framed for the movements of harmony, and these two sciences are sisters" (Republic, VII 530d). From antiquity, music was a sister science to astronomy, with both subordinated to mathematics.

The beauty of music provided the context for what we now call Kepler's "third law." The story of science reveals creative leaps across disciplinary boundaries; in this case, bringing together music and astronomy. Kepler's vision truly was cosmic, of a cosmic hope and consolation amidst earthly sorrow.

## HARMONICIS LIB. III.

XIV. lie X quaternis primis locis coincidentes cum prioribus, aut Hoc pacto in nostris XIV. specicous com prioribus, aut chan liæ X. quaternis primis locis coincidentes cum prioribus, aut chan liæ X. quaternis primis locis coincidentes cum prioribus, aut chan liæ X. quaternis primis locis coincidentes cum prioribus, aut chan liæ X. quaternis primis locis coincidentes cum prioribus, aut chan liæ X. quaternis primis locis coincidentes cum prioribus, aut chan liæ X. quaternis primis locis coincidentes cum prioribus, aut chan liæ X. quaternis primis locis coincidentes cum prioribus, aut chan liæ X. quaternis primis locis coincidentes cum prioribus, aut chan liæ X. quaternis primis locis coincidentes cum prioribus, aut chan liæ X. quaternis primis locis coincidentes cum prioribus, aut chan liæ X. quaternis primis locis coincidentes cum prioribus, aut chan liæ X. quaternis primis locis coincidentes cum prioribus, aut chan liæ X. quaternis primis locis coincidentes cum prioribus, aut chan liæ X. quaternis primis locis coincidentes cum prioribus, aut chan liæ X. quaternis primis locis coincidentes cum prioribus primis locis cum pri quinis; ubi verò incipiunt differre, præmissa est particula, vel,

Quod si jam accesserir ulcima causa, discriminans Tonos, scilios Toyn & πετ st α ? criplicabitur Numerus, & fient 72. species. Onne enim sceleton Octava; ex omnibus 24, habet & rerriam & quartam on Si ergò hænar. cordantem cum prima, & quintam & fextam. Si ergò ha partes can cupentur, tunc statuna cus potissimum circa quartam & sextam occupentur, tunc statuun fimo loco Diatessaron: Sincirca tertiam & sextam, Diatessaron,



in medio, sin deniqueirea tertiam & quintam, Diaressaron est lon

Hæc autem non ideò dico, quod necessaria sie tam minuta cono sio, cum sciam, plerumq; miscerirernas formas in uno cantu: seduta hoc numero possicijudicium ferri de discriminibo Tonorum, que Mo derni tradunt quæ partim talia sunt, vt mihi videantur illorum toth tui posse, quot sunt omnino cantiones, catera unius Toni. Atsid fervamus hae principia, numerus Tonorum utcunq; magnus, fining tamenest. Insumma, Toni realibus distincti meris & discriminibus non respectu alcitudinis vocis in Organo, sed in ipsaetiam humanavo ce , quæ principium naturalis Systematis à quacunq; voce altavelore funda facere potest, sunt vel z. tantum, vel 14; vel 24, vel 72.

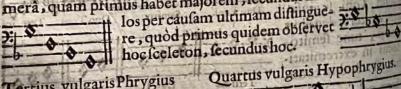
Cum his principijs meis sic ego concilio Tonos octo vulgares quos Ecclesiasticos dicunt: erantq; veteribus, opinione quorundam I. Hypodorius



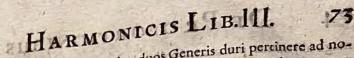
Adam primus Homo.

Noe fecundus.

Hæfuneduæ species Cantus mollis, ex specie octavæ, quæ est mi Prima inter XIV. Nec video aliam differentiam, quam in altitude merà, quam primus habet majorem, secundus minorem; nisi velisi









Et hisimiliter manisestissime scribendi sunt ex f. suntq; generis posito ex duobus

mollis, distinguunturq; altitudine vel sceletis hisce, ex nostra XIII.



Etsi apparet consilium inventorum, quod Primum & Secundum alcendat , sed infra ex d. feribere voluerint, Tertium & Quartum ex c. Quintum & Sextum aut quaria le continear, vel infra radi-

exf. Septimum & Octavum ex G. certumtamen est ex ijs quæ supra disputavimus, etiam hos generis Duricum Primo & Secundo ex eadem clavi G. (cribi debere, quibus ex nostra specie II. competunt hæc sceleta.

Hacigitur applicatione vulgarium octo Tonorum ad meas spe-ticulos vel notas cies Octava I. XI. XIII. II. ego multo evidentius discrimen oftendere hispictaspervadate possum inter hos Tonos, quam Musici nostri, quia comma contem-sus sauch earum diapanunt, Qui enim ex G, scribuntur, omnes quatuor habent consonan- son inferiores Hos tias legitimas, tertia, quarta, quinta, & fexta cum prima. Qui verò ex igt. ses demittes F. & e. consonantis utuntur adulterinis, infrà quarta majori e a. & f bb. possemuscum anti-& quinta majori e bb. & fcc.

Quid igitur cum reliquis decem speciebus, inquies ? cum omnes thentas ustati Toni redigantur ad quatuor? Nimirum ad hoc serviunt, ut sciant Musici, si Systemata principalis Octavæex G, descriptæ, temperemus ut natura suadet; tune nequaquam ita facile & varie transponi posse cantum sine mutatione sinceritatis suz, ut ipsi habent in usu. Liberum igitur illisest, vel rejicere omnes residuas 10., & cum ijs etiam transpostiones suas: vel fateri, quòd plures Formæ Melodiarum, plures nempe Modi vel Toni poslint existere, ijq; differentes ab his positis, alij

modo, utin voce humana criamq; in Organis fi ex G afcedat radix Syfte-\_ matis ing. ubi non iplius radicis cujus-19, ToniinSyftema diapafon Neg,hao

> tur: importat enim permutata Clavi ra dicali Systemaris spectu suz radicalis vis, quâ manenmanet quidem liud quafi schema induit: ut fi non ad Octavam radicis

> > mein fine ad radicem. Itaq; sceleta ifta non fie funtintelligenda,qualiMe lodia omnes ejus ag gios : careros Au

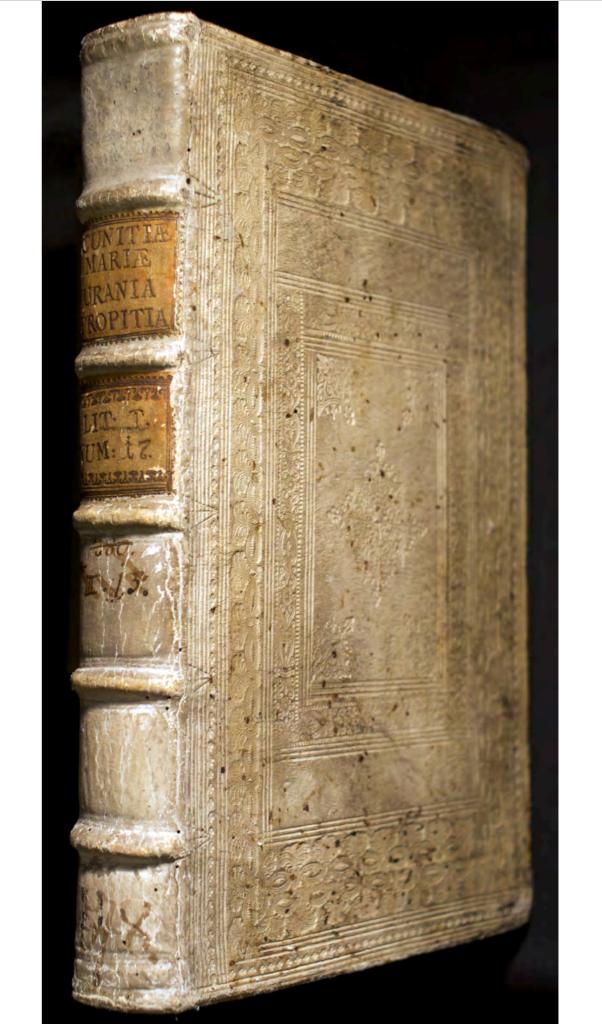
cem lese crebro de-

mittat, rediens t.

#### Maria Cunitz

*Urania propitia*Oels, 1650

This Cunitz volume was acquired in honor of Marilyn B. Ogilvie upon her retirement as Curator in 2008.

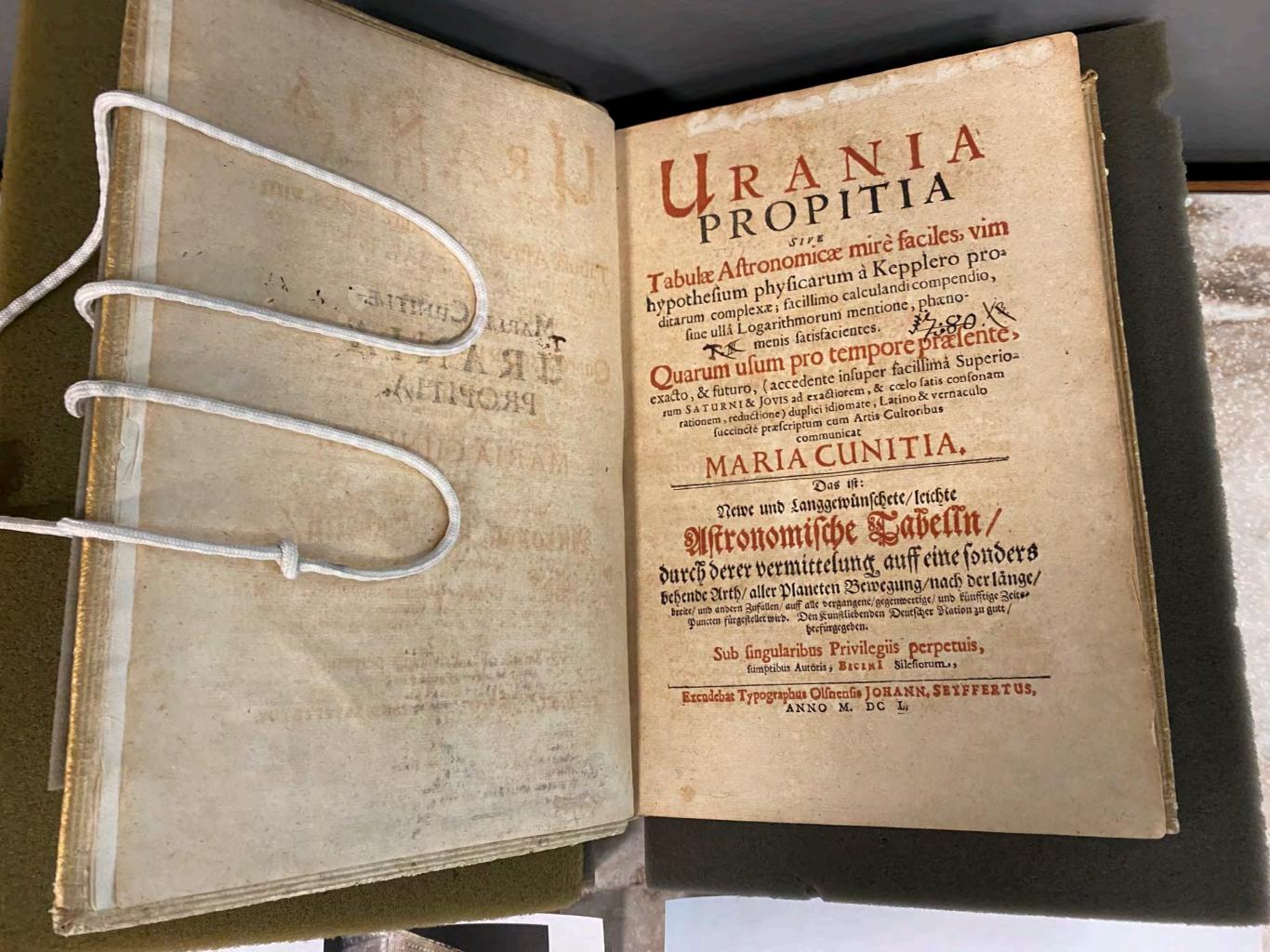


#### Maria Cunitz, *Urania propitia* (Oels, 1650)

"Beneficent Urania" ("The Generous Muse of the Heavens")

Prior to Newton, perhaps half a dozen astronomers accepted Kepler's three laws. Galileo was typical in exhibiting skepticism toward Kepler's accomplishments. Yet this beautiful book is an exception: it clearly demonstrated that Kepler's laws were more accurate than anything that had come before. It was written by Maria Cunitz, one of the first astronomers to endorse Kepler's astronomy. Cunitz recast Kepler's planetary predictions into a form equally accurate but much more convenient and easy to use. Kepler's tables may have been cumbersome, but these were not. Cunitz made Kepler's achievement easy to grasp.

In an age when women were not admitted to European universities, Cunitz corresponded with Johann Hevelius and was well-acquainted with the works of contemporary European astronomers. Historian Noel Swerdlow describes Cunitz as the most accomplished mathematical astronomer of her generation. She was encouraged in her scientific pursuits by her husband, Elias von Löwen. Von Löwen, a physician with a keen interest in astronomy.



Giovanni Domenico Cassini, *Martis Circa Axem Proprium*; *De aliis Romanis observationibus macularum Martis*; and *De Periodo quotidianæ revolutionis Martis* (Bologna, 1666)

"Observations in Bologna of the rotation of Mars around its axis"; "On other Italian observations of the dark patches of Mars"; and "On the period of the daily rotation of Mars"

These 3 broadsheets, issued approximately 2 weeks apart, contain the first detailed illustrations of Mars. Although the patches do not correspond to actual features discernible today, Cassini used them to determine that Mars rotates on its own axis, inclined to the ecliptic, with a period of 24 hours, 40 minutes (only 3 minutes off the present value).

At this time, Cassini was a professor of astronomy at the University of Bologna, using a 17-foot long telescope crafted by Giuseppe Campani. In 1671, he became the founding director of the Paris observatory. In addition to discovering 4 additional moons of Saturn, he discerned the major break in Saturn's ring now known as the Cassini gap.

& littera H lubscriptum dedimus: addita hae inscriptione .

Typus Martis cum insignibus maculis Roma primum visis DD. Fratribus Saluatori, at Francisco de Serris tubo Eustachy Divini palmorum 25. ac subinde 60. à die 24. Marty ad 30. qua die in adibus Illustrifs. D.Cafary Giory hora pradicta, & ipsomet Illustrifs. D. describente tub. p.45. apparuit vt bic exprimitur innerso modo, nigriore inter alias existente macula Orientali: pro situs obseruata variatione eiusdem planeta circa proprium axem reuolutionis periodum indicatura; horis nempecirciter 13.

Quòd hæ maculædiçantur primu visæ Rome, primum à DD. Saluatore, & Francisco de Serris, primum Tubo Eustachij Diuini, primum à die 24. Martij, illis per me licet. Me, qui illorum tergemina confessione à mense Februarijearum obseruator, & præmonstrator sum, nec inanis gloriæaucupium impulit, nec verecundia passa est, vt me primum observatorem dicerem. Locum ergo primum mea incuria vacuum futuris observatoribus, & à me ad observandum vitrò inuitatis volens libensq; concesserim. Illorum ramen ingenuitatem bonarum artium studio copulatam eam esse scio, ve nolint alienam qualécumque laudem sibi, vindicare, & eos boni consulturos me illorum testimonio rei veritatem aperire; ne qui magnificam Typi Eustachiani inscriptionem legerint me silente in errorem inducantur. Quod vero ad huiusmodi observationem attinet illa nostræ illius diei, & hora non conuenir. Tunc enim Bononia habuimus fecundam Martis faciem multò maioribus maculis conspicua, ijsq. semita lucida distinctis, maiore orientali minore occidentali, & qualem supra impressa dedimus, & numero V. repetiuimus directè nobis expositam. At schema primam Martis saciem videtur repræsentare qualem nos in fronte, & iterum n. 4. dedimus, & qualem Romæ die 3. Martij de-scripserat Campanus, quæq; die 30. Martij ex nostra hypothesi hactenus obseruatis respondente non h. 2. noctis sequentis, sed per diem Terræ obuertebatur, nec videri potuit ad eam horam in eo faciei Martis fitu ante diem 10. Aprilis. Quarè cum nil magis observationis huius sidei per me detractum velim, quam quòd collatio recensitarum Epistolarum cum hac inscriptione postulat; Est tantum quòd mirer, quomodo tantæ latitudinis maculas, & inter se adeò vicinas, sed semita lucida distinctas, & tunc in medio Martis disco, Telescopium Eustachianum ostenderit paruas, valde inter se distantes, & procul à medio Martis disco, minoremq; orientalem, quam occidentalem, Magna præterea ingenij celeritatis est ex observationibus dierum 6. Periodum revolutionis horarum circiter 13. diuinasse; Fateorq; me timidum, & cunctantem, qui ex editis observationibus duorum mensium, earumque collatione nondum Periodum concludere ausus suerim, diurna contentus restitutione quocumq; die min. 40. circiter tardiùs quam præcedente, itaut restitutio eiusdem maculæ ad eumdem in Martis sacie apparentem situm spatio dierum 36. (exactius dixerim 37.) ad eamdem proxime horam, restituatur. Vtrum autem semel, an bis vivo die, & min. 40. revolutio complea tur adhuc filui, nondum proditis rem plane determinantibus observationibus. Hinc tamen tutò prædicere possum secundam Martis faciem, qualis à me eo die observata est, ad eamdem horam suturam terræ obversam die 7. Maij, primam verò ad diem 17. eiusdem mensis, vnde his, & circumstantibus diebus commoda erit vtriusque faciei observatio, & inter se comparatio.

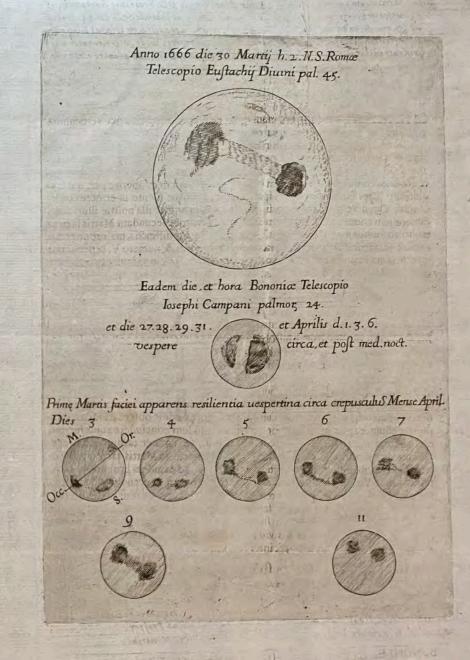
Observationibus nostris frequentissimi adfuere.

Excell. D. Io. Baptista Sanutus Pellicanus. Excell. D. Io. Galeazius Manzius . Excell. D. Geminianus Montanarius. Excell. D. Augustinus Pinchiarius.

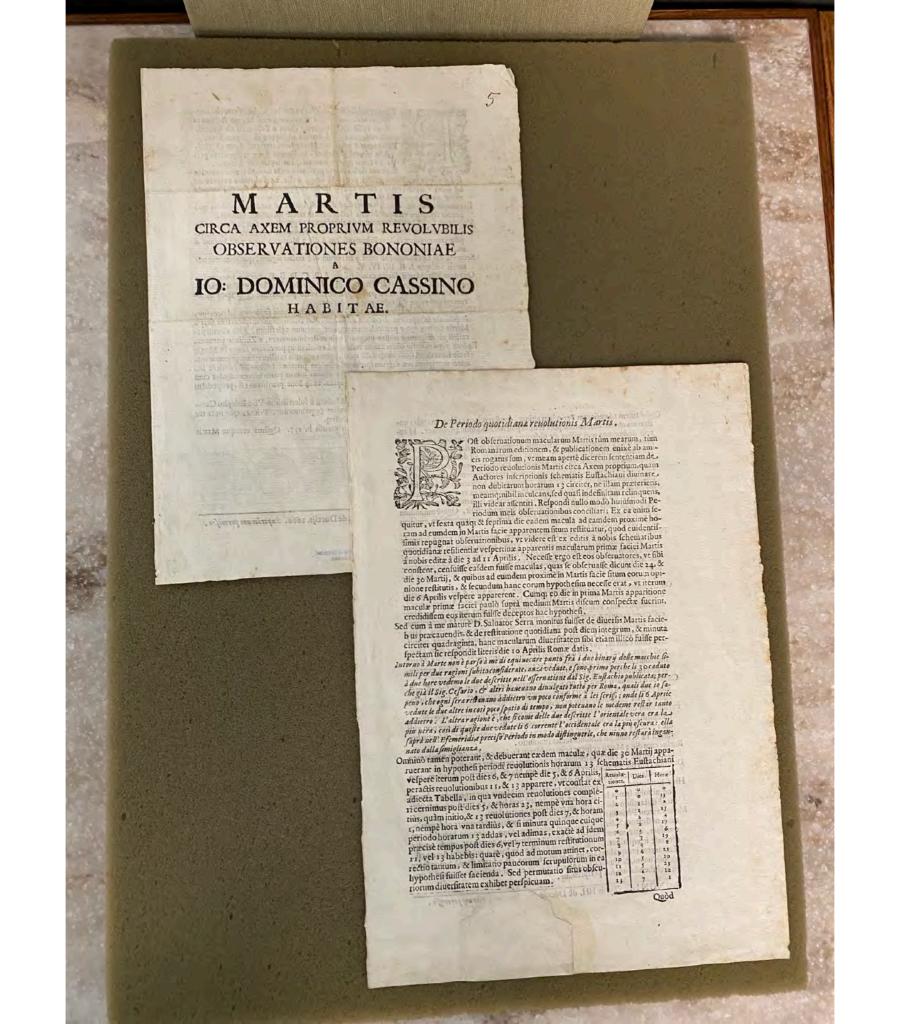
Excell. D. Io. Baptista de Coris.

Illustris. D. March. Iofeph Pallauicinus. Illustrifs. D. Go. Alexander Fontana. Illustrifs. D. Hercules de Zanis. Reu. D. Iacobus Profper. D. Franciscus Monarius.

BONONIÆ, Ex Typographia HH. de Duccijs. 1666. Superiorum permissu.

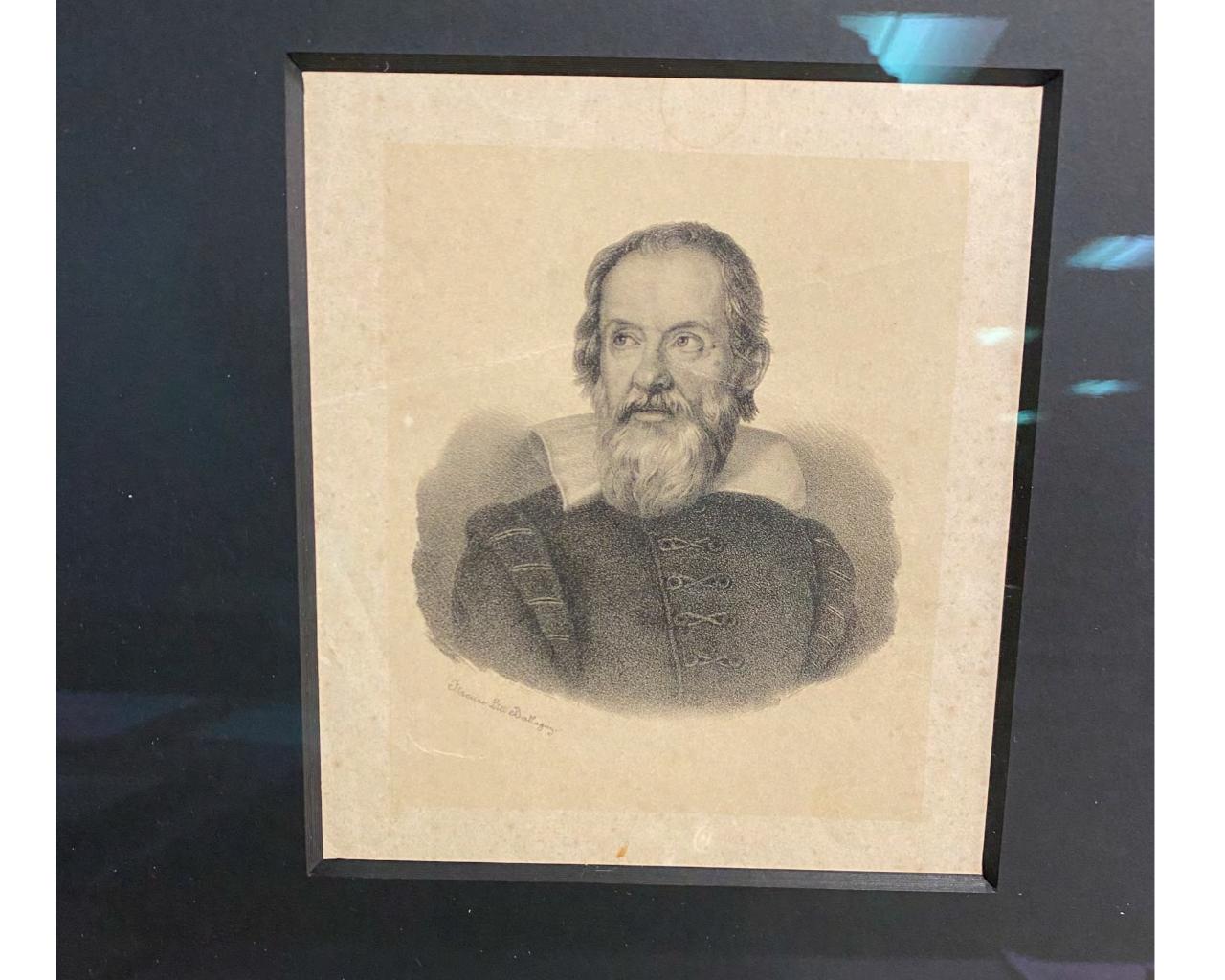


Do allie Romanie



## Galle 6





## Galileo Galilei

Sidereus nuncius "Starry Messenger"

(Venice, 1610)



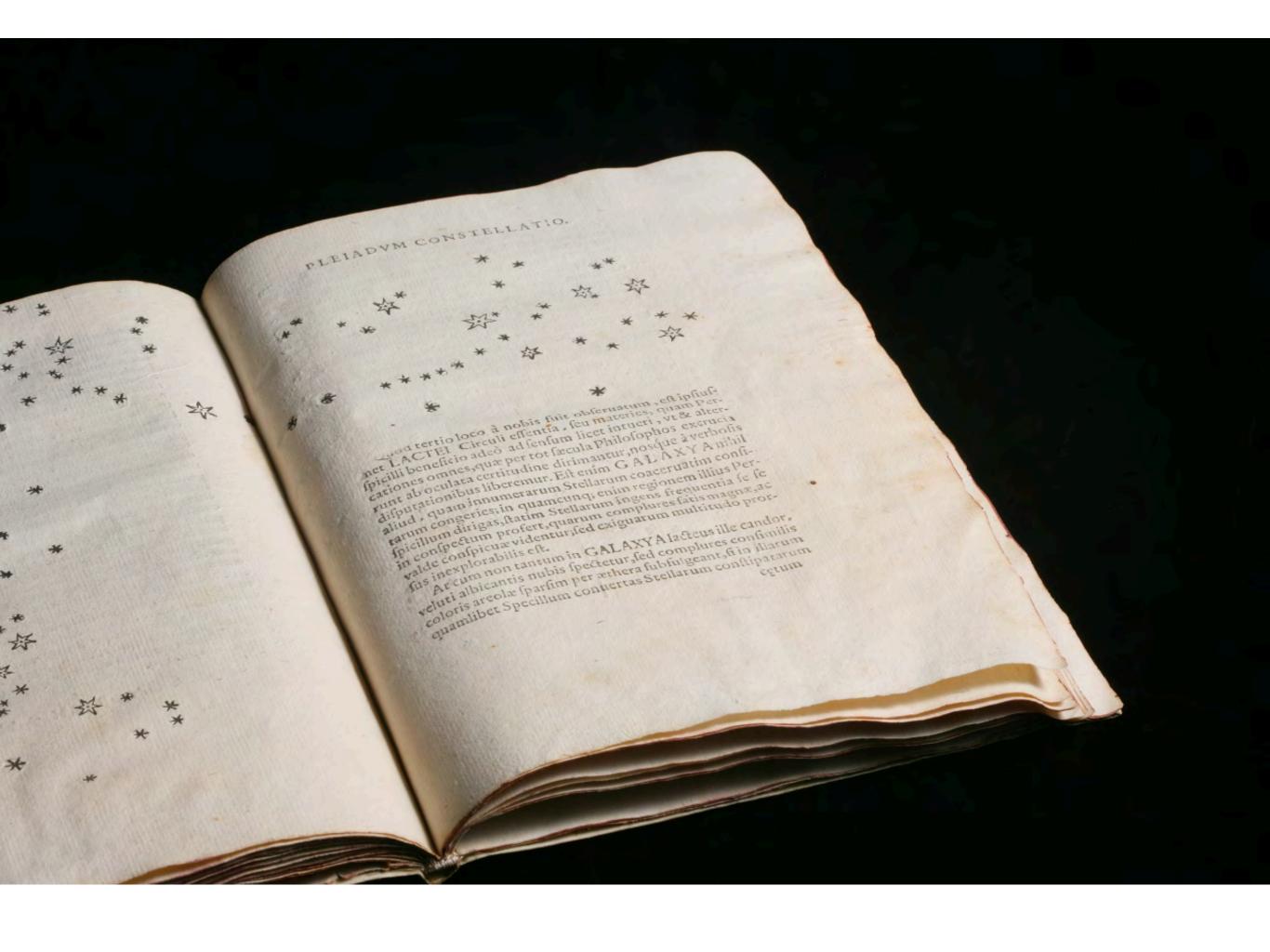
## Galileo, Sidereus nuncius (Venice, 1610)

When Galileo heard news of telescopes invented in the Netherlands he worked out the underlying geometry and crafted one of his own design. In this work, Galileo published the first observations of the heavens made with the telescope. His sensational discoveries included mountains on the Moon, vast numbers of previously undetected stars and four satellites of Jupiter.

On one star chart, Galileo showed 36 new stars around the original six of the Pleiades, and on another, 80 new stars near the belt and sword of Orion.

Galileo printed more than 60 observations of the positions of the satellites of Jupiter from night to night. The satellites of Jupiter removed the anomaly of how the Earth could have its own satellite, unlike any of the other planets. Jupiter was a miniature Copernican system set in the sky as a confirmation of the theory of the leading 16th century Catholic astronomer.

Galileo inscribed the Oklahoma copy to Gabriele Chiabrera, a poet. So here we have a connection between astronomy and literature. Art, literature and astronomy merge in the stories of the night sky.



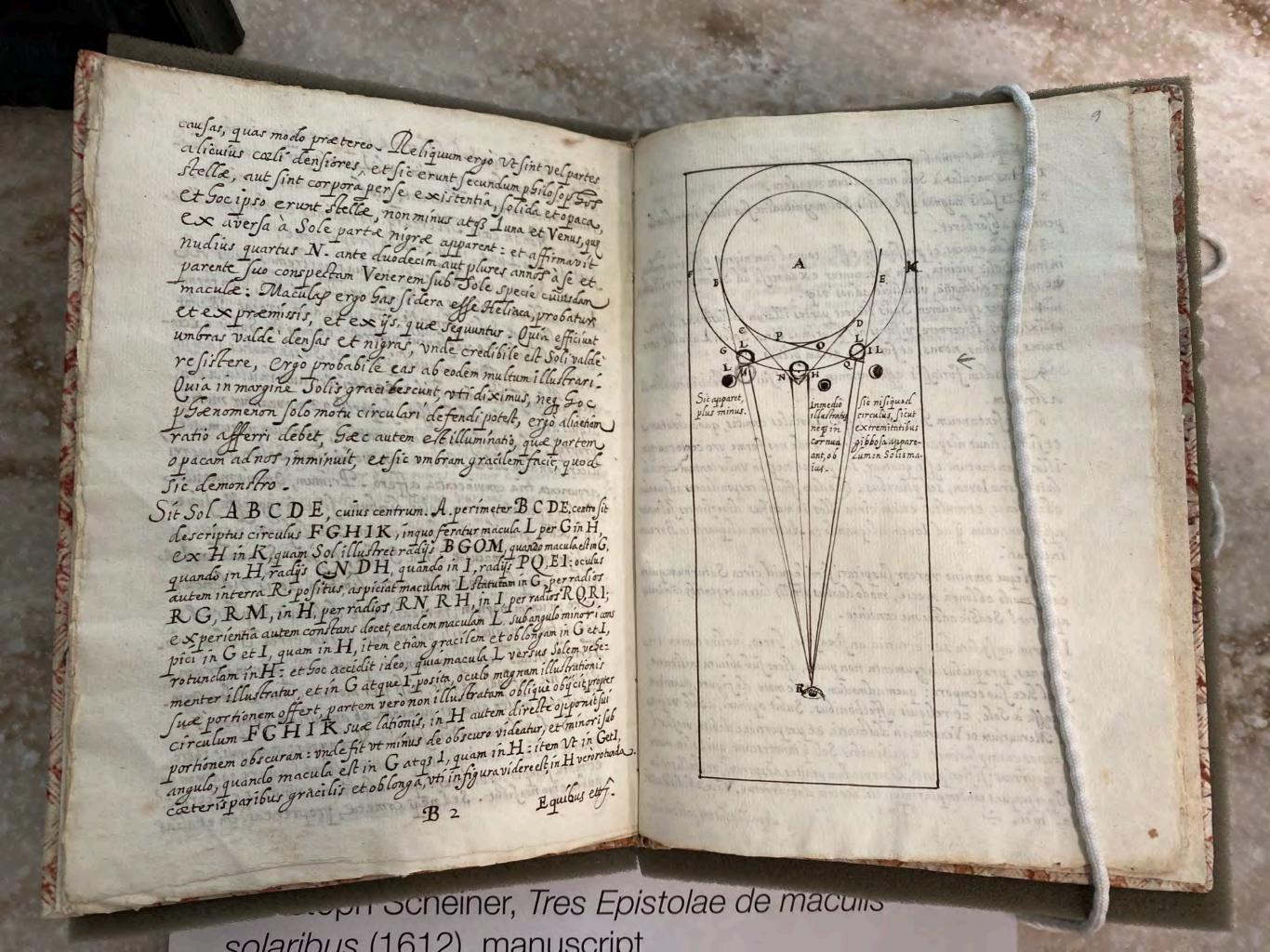
# Christoph Scheiner, *Tres Epistolae de maculis solaribus* (1612), manuscript

### "Three letters on sunspots"

With these three letters, Scheiner, a Jesuit astronomer, announced his discovery of sunspots, which prompted Galileo to study them himself. In his book on sunspots, Galileo took issue with Scheiner's suggestion that they might be little planets orbiting the Sun.

Scheiner eventually published *Rosa Ursina* (1630, also held in the Collections), the definitive work of the 17th century on sunspots, in which Scheiner accepted Galileo's argument that sunspots "move like ships" on the surface of the Sun instead of orbiting around it. Scheiner and Galileo agreed that sunspots counted against the Aristotelian doctrine of celestial incorruptibility. The view that the heavens are corruptible, though contrary to Aristotle, nevertheless had been supported by many Jesuits going back to Robert Bellarmine in 1570 and the discovery of Tycho's nova in Cassiopeia in 1572.

Scheiner became an implacable enemy of Galileo, resentful of Galileo's patronizing invective and jealous of Galileo's priority claims for the discovery of sunspots.



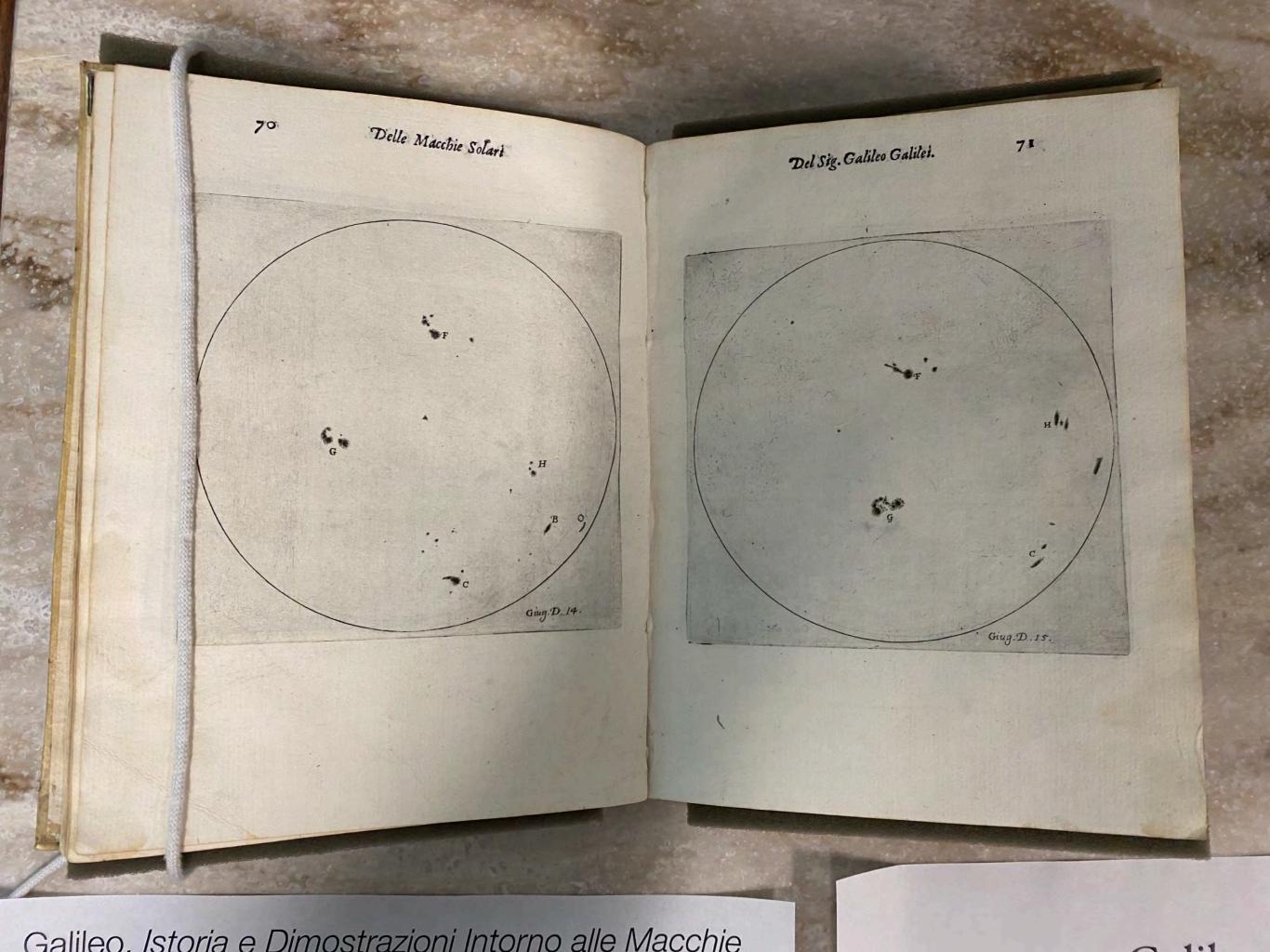
## Galileo, *Istoria e Dimostrazioni Intorno alle Macchie Solari* (Rome, 1613)

## "Letters on Sunspots"

In 1611, the Jesuit astronomer Christoph Scheiner argued that sunspots are little planets circling the Sun like Venus. Galileo answered Scheiner with this book, which inaugurated the era of telescopic solar observation. Galileo's detailed, full-page copperplate engravings proved that sunspots lie on or very near the surface of the Sun, and are not little planets. Sunspots therefore suggest that the Sun and the heavens are corruptible, a tenet contrary to Aristotle but already accepted by some scientists and theologians.

The title page identifies Galileo as a member of the Academy of the Lynx (*Accademia dei Lincei*). Galileo's geometrical compass and telescope adorn the frontispiece. Hereafter, Galileo always signed his name Galileo Galilei Linceo. For the first time in print, Galileo also spoke out decisively in favor of the Copernican system.

An introduction written by someone else strongly supported Galileo's priority in the discovery of sunspots against Scheiner, which led to an unfortunate and prolonged controversy between Galileo and a number of Jesuit astronomers.



## Bernardino Baldi, Nova gnomonices (ca. 1592)

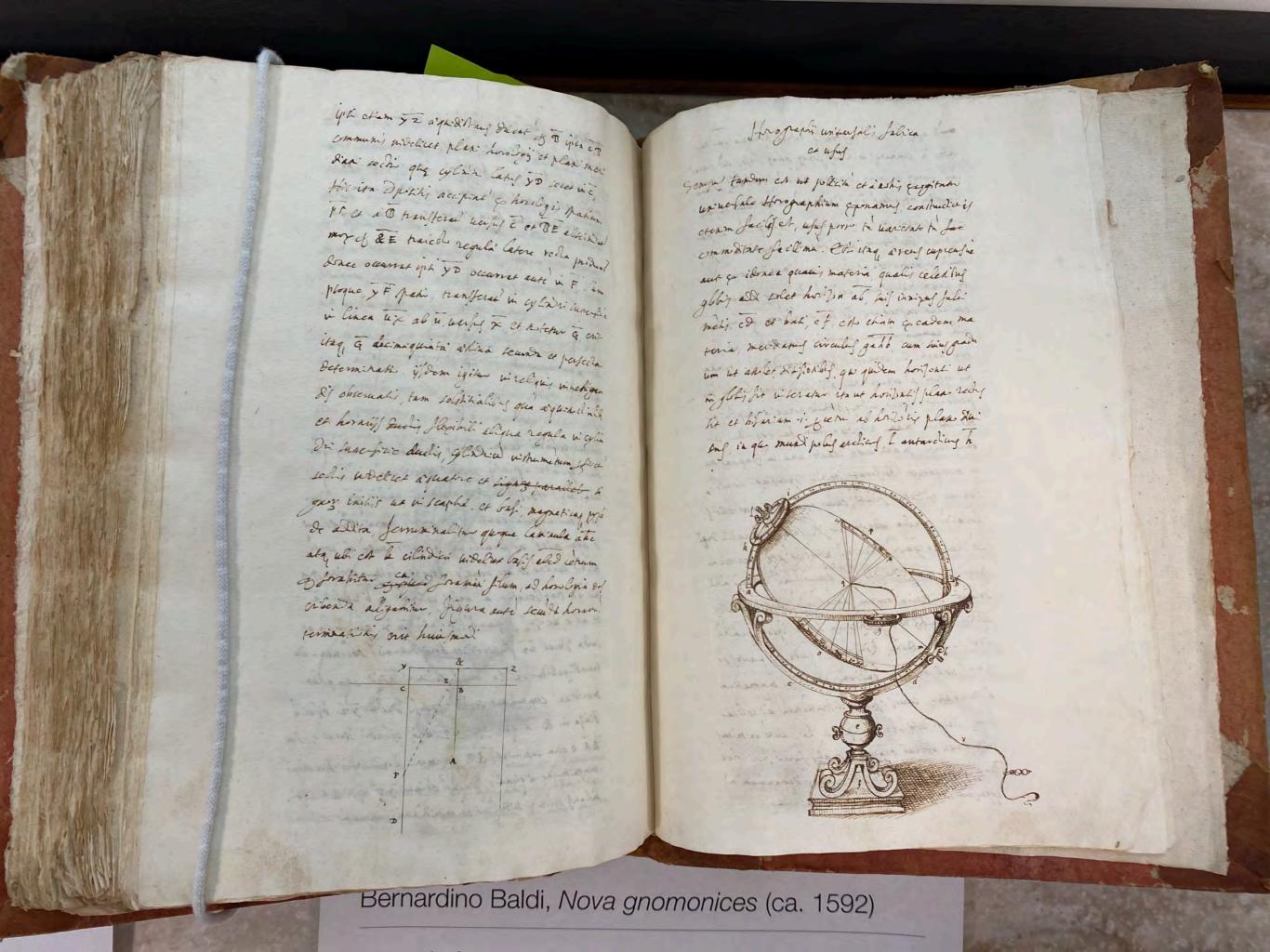
#### "Innovative Sundials"

This manuscript, a never-printed treatise on sundials written in the author's own hand, was lost in the 18th century and believed destroyed in a shipwreck.

Bernardino Baldi, a celebrated Italian mathematician, studied during the 1570s with Federico Commandino, and later with Guidobaldo del Monte, one of Galileo's teachers.

Mordechai Feingold writes,

"The rediscovery of this manuscript offers an important new document for knowledge of Italian mathematics and precision instruments during the first third of Galileo's career."



# Pocket sundial, by David Beringer (Nuremberg, c. 1760)

A sundial consists of a **gnomon**, which casts the Sun's shadow, and a **dial** on which the shadow indicates the time.

The gnomon on this pocket dial is a short length of string which casts a shadow on the vertical dial.

The horizontal **compass** enables the pocket dial to be positioned facing due south.

Sundials have ranged in size from pocket or table-top dials to monumental architecture. A simple portable sundial features a gnomon that can be adjusted according to one's latitude. Obelisks of ancient Egypt functioned as gnomons. Renaissance cathedrals functioned as scientific instruments in their own right, featuring gnomons in windows or near ceilings. From the streets of any older European university one is likely to see a sundial mounted on the side of a nearby building, oftentimes alongside rather than replaced by, a mechanical clock.



# Cube sundial, by David Beringer (Nuremberg, c. 1790)

Polyhedral sundials have a gnomon on every face, with dials aligned to tell the same time on every side. This wooden cube sundial is able to cast a shadow for the correct time on multiple faces simultaneously.

As an object it represents the mathematical artistry that was common among mathematical practitioners in the Renaissance and early modern periods. The sundial has an inset **compass** on the base, useful for aligning the gnomens and base of the dial with respect to North.

The sundial also is able to be adjusted for different **latitudes**, which is accomplished both by a wooden pillar, that supports the sundial, and which pivots at a ball joint, as well as a scale, located on the east vertical dial, that would allow the measurement of the latitude. On this particular face, there is a metal hook that would allow an attached plum-line, which would measure the latitude against the arced scale, as the sundial pivoted.



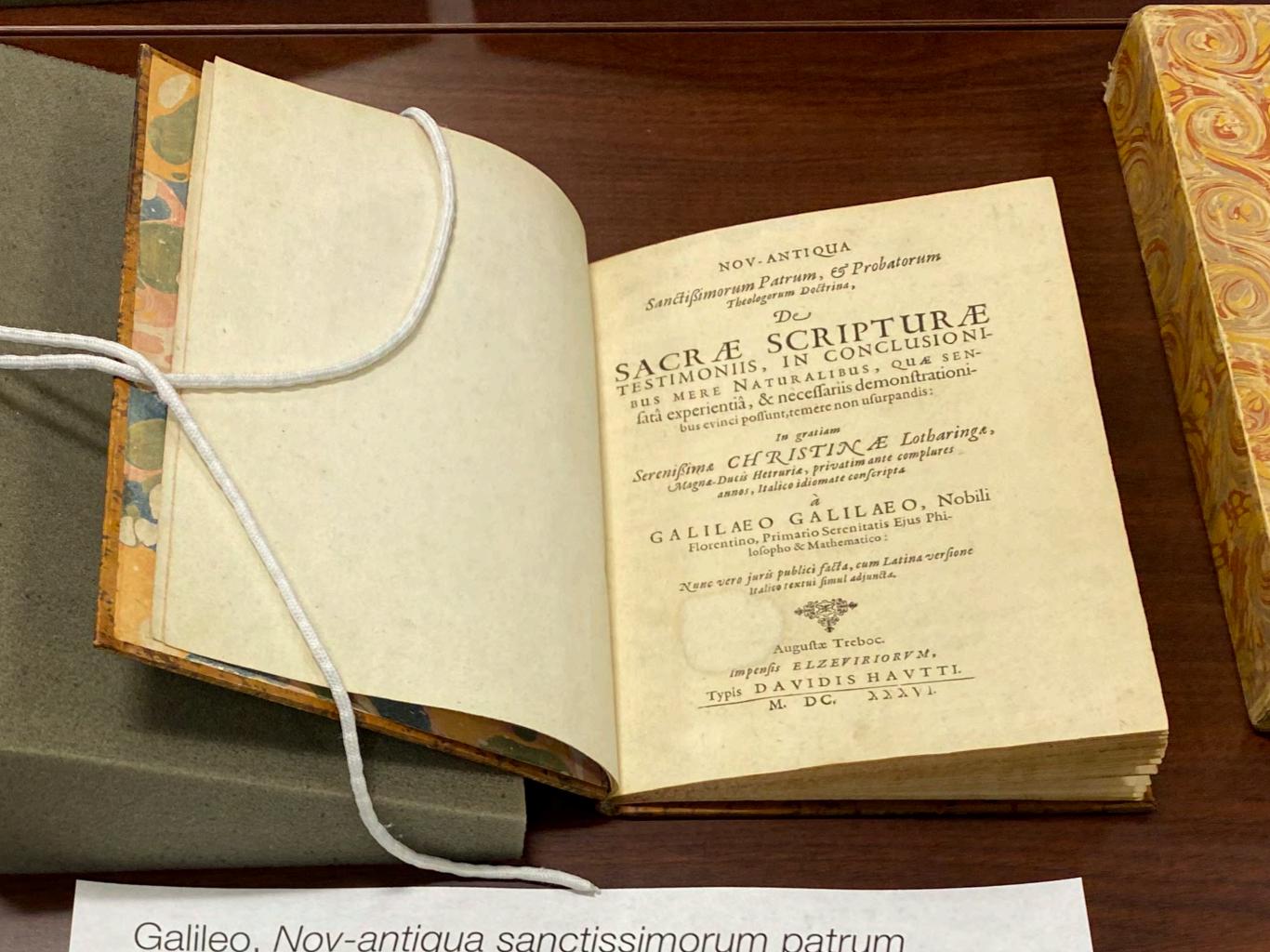
# Galileo, Nov-antiqua sanctissimorum patrum (Strassburg, 1636)

"The Ancient and Modern Doctrines of the Holy Fathers" (Letter to the Grand Duchess Christina)

In response to gathering criticism, Galileo in 1615 wrote a reconciliation of Scripture and Copernicanism which circulated in manuscript as the *Letter to the Grand Duchess Christina*. This is the first printed edition, which appeared in 1636.

Galileo cited Augustine throughout. In theory, nothing would have prevented theologians at the time from accepting the Copernican system, had they rigorously followed their own explicitly formulated principles of interpreting Scripture.

Pope John Paul II used Galilean language to affirm similar hermeneutical principles in 1992. However, no theologian then or now was persuaded by the weakest and most provocative part of Galileo's letter, where he argued that he could prove Copernicanism from scripture.



## Galileo, Lettera Madama Cristina di Lorena (Milan, 1967)

"Letter to Madame Christina of Lorraine" (Letter to the Grand Duchess Christina)

Galileo's Letter to the Grand Duchess Christina provides a modern example of the book arts. The outer case opens to show a smaller case, the size of a miniature version published a century ago. This 1967 edition fits entirely within the circumference of a nickel. A magnifying glass to read it is included in the smaller case, along with one of the plates used to print it. This is no. 27 of 100 copies.

The larger gilt-morocco book-shaped case contains, bound within it, a 75-page preface by Giuseppe Cantamessa which discusses the process of printing.



## Galileo, *Dialogo* (Florence, 1632)

"Dialogue on the Two Chief Systems of the World"

This is Galileo's witty and entertaining dialogue in defense of Copernicus. In the frontispiece, Aristotle and Ptolemy hold an Earth-centered armillary sphere (left). Copernicus holds a Sun-centered model of the universe (right). Just two systems appear in the *Dialogo*; Galileo nowhere mentions the Tychonic system then favored by most astronomers.

Galileo inserted statements about the hypothetical character of the work in the preface and conclusion. Nevertheless, the book as a whole was anything but even-handed, contrary to instructions issued to Galileo in 1616. Once published, Urban VIII gave orders for the *Dialogo* to be recalled and summoned Galileo to Rome for trial.

Galileo placed greatest emphasis upon an argument for Copernicanism from the ebb and flow of the tides. This argument was physical in nature, based on causal explanation, rather than mathematical. It was an attempt to achieve a level of certainty which had proven elusive for mathematical methods alone. Unfortunately, the argument was not persuasive, then or now.

This copy is one of four first editions of Galileo held by OU which contain Galileo's own handwriting.



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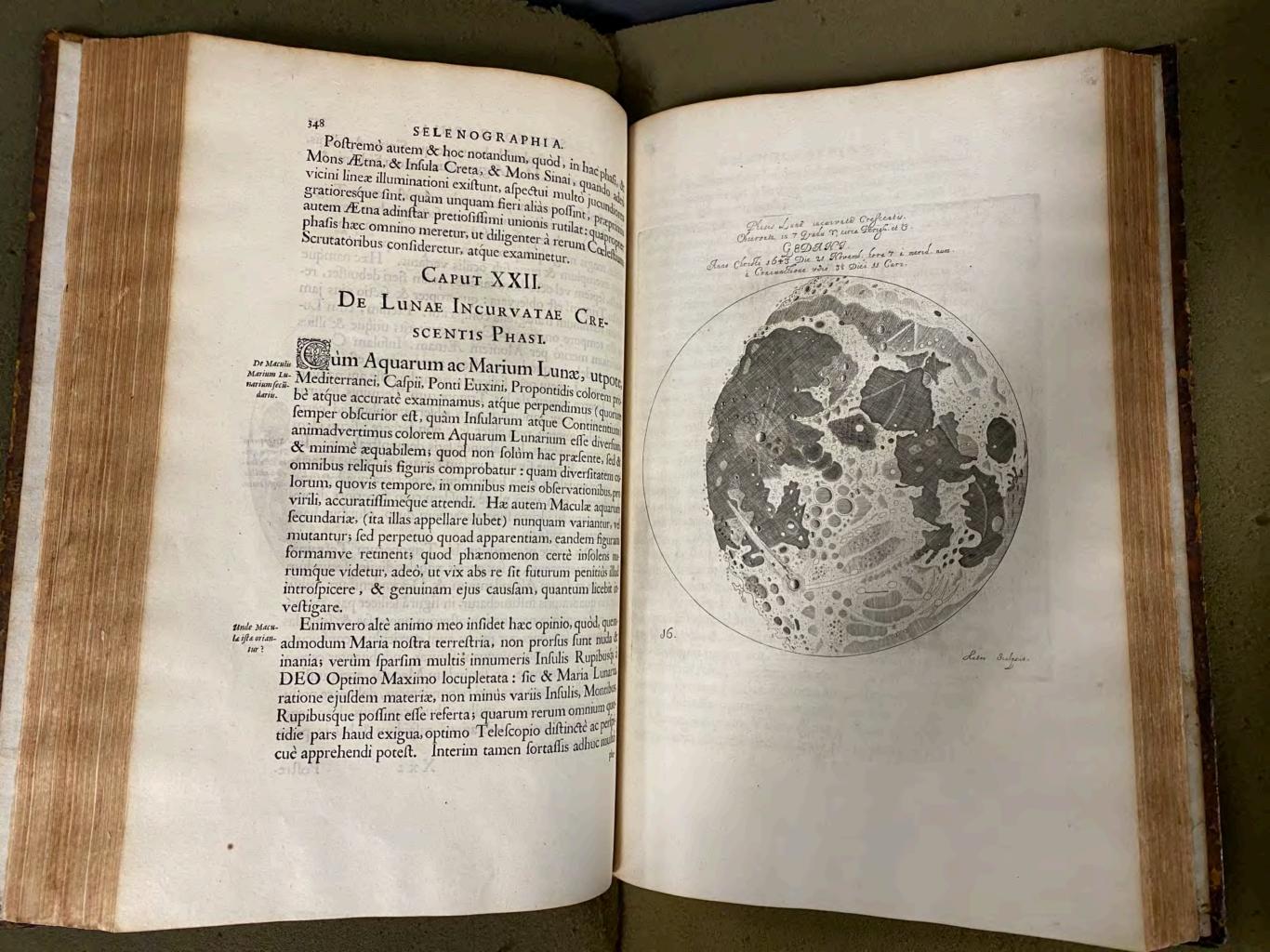
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## Johann Hevelius, Selenographia (Gdansk, 1647)

After Galileo proved that the Moon has a topography that might be mapped, Hevelius accomplished that task by mid-century in this lunar atlas. It set a new standard for precision that remained unmatched for a century. 40 stunning copperplate engravings portray topographical relief along the Moon's shadow-line, or terminator, at every conceivable angle of solar illumination. They represent the appearance of the Moon, along the terminator, over a period of five years.

A double-page plate depicts the entire lunar surface as a summative representation of the individual topographical studies. Rather than comprising a naturalistic portrait of how the Moon actually appears, this map is a composite record of the shadows cast by the passing of light moving back and forth, in both directions, during opposite lunar phases. The lunar map of Hevelius is accurate enough to plot the Apollo lunar landings.

Hevelius named 275 lunar features, but his nomenclature scheme, based on classical terrestrial geography, was not widely adopted. In Gdansk, Hevelius operated the most sophisticated observatory in Europe. With income from the family brewery, he constructed the largest telescopes then known. His telescopes, used for observing the Moon and planets, included one that was 150 feet long.



## Elisabeth and Johann Hevelius, *Firmamentum* Sobiescianum sive Uranographia (Gdansk, 1690)

"The Firmament of King Sobiesci, or Map of the Heavens"

The *Uranographia* of Johann and Elisabeth Hevelius, the most detailed and influential celestial atlas of the 17th century, contains 54 beautiful double-page engraved plates of 73 constellations, and 2 oversized folding plates of planispheres. The OU copy is bound with their star catalog and a *Prodromus*.

Of the 12 constellations they created, 7 are still recognized today. One is the Lynx, in recognition of the far-seeing eyes of astronomers. The new Sextant constellation represented a large instrument which Johann and Elisabeth used to determine star positions. Elisabeth finished the work and saw it through publication after Johann's death in 1685.

Unique among the major star atlases, the Hevelius atlas depicted the star patterns as if from the outside looking in, not as seen when looking up into the night-time sky. Consequently, the Hevelius atlas constellation figures provided an influential model for the production of artfully-designed celestial globes like Coronelli's.

The full title of the *Uranographia* pays tribute to the Polish king, John III Sobiesci. Johann and Elisabeth created a new constellation, Scutum, the "Shield of Sobiesci," representing the king's defense of Europe against the Turks.

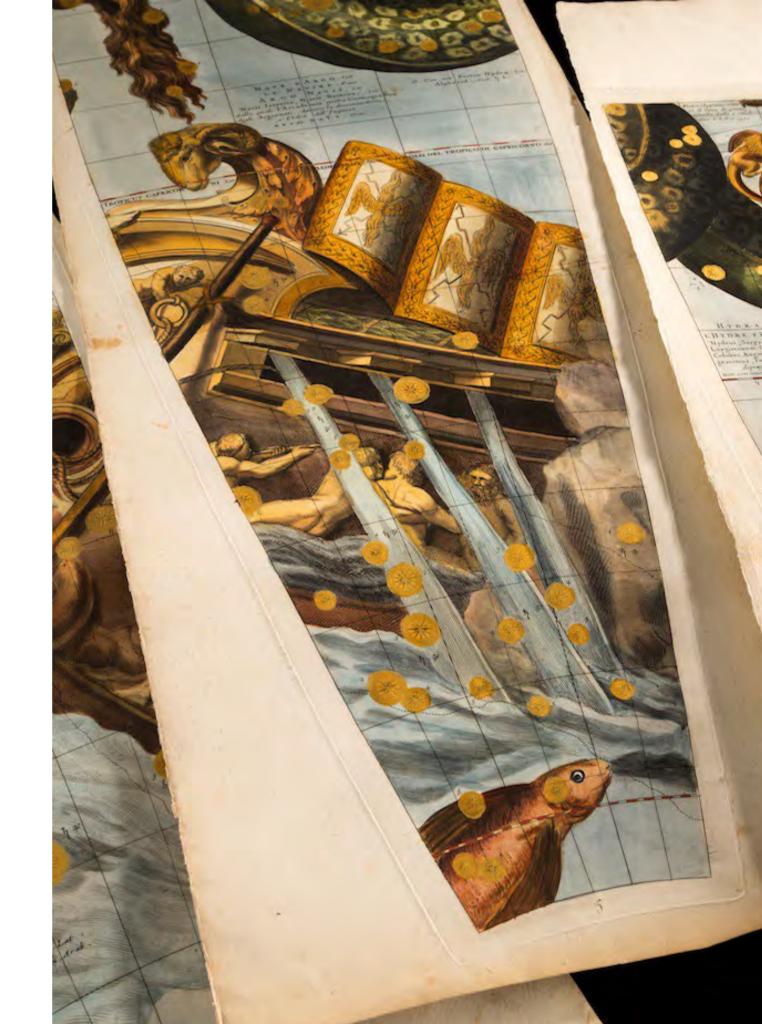


## Vincenzo Coronelli

Celestial Globe Gores (Paris, 1693)

Do any of the gores match up with others side-by-side?

Can you arrange them in order?



## Vincenzo Coronelli, Celestial Globe Gores (Paris, 1693; reprint ca. 1800)

Coronelli, a Franciscan theologian and astronomer who worked in both Italy and France, was an influential maker of celestial and terrestrial maps and globes. To make a globe, craftsmen printed sheets of map sections, called gores, which were then hand-colored, cut out and glued onto a wood and paper-maché base. There was no clear boundary between books and instruments.

These 9 gores were part of an original set produced at the request of Coronelli's Accademia Cosmografica to make a 3.5 foot diameter celestial globe. The copper plates used to make these gores were designed by Arnold Deuvez and engraved by Jean-Baptiste Nolin in 1693 in Paris. These 1693 plates were a revision of those which Coronelli used in 1688 in Venice. At the time, Coronelli's 1688 globe was the largest and most accurate celestial globe in Europe. The Latin and French legends distinguish this 1693 Paris reprint from the 1688 Venetian gores, which were in Italian. The 9 beautiful gores on display are reprints of the Paris reprint; that is, they were printed in 1800 using the actual 1693 Parisian plates. (15 gores are missing out of the original set of 24.)



# 



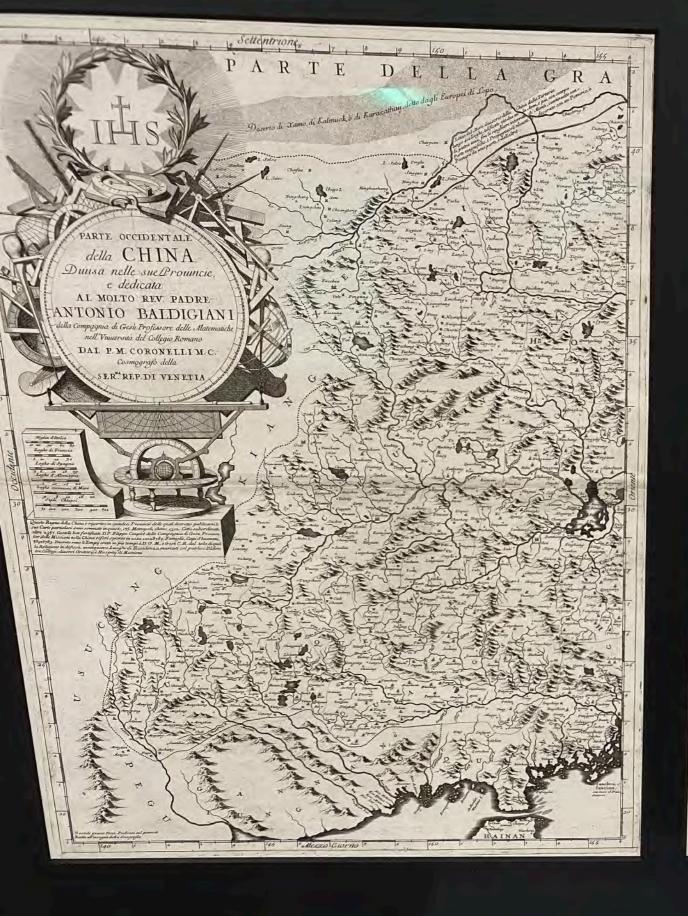
# Vincenzo Coronelli, Parte Occidentale della China... Parte Orientale della China (Venice, 1696)

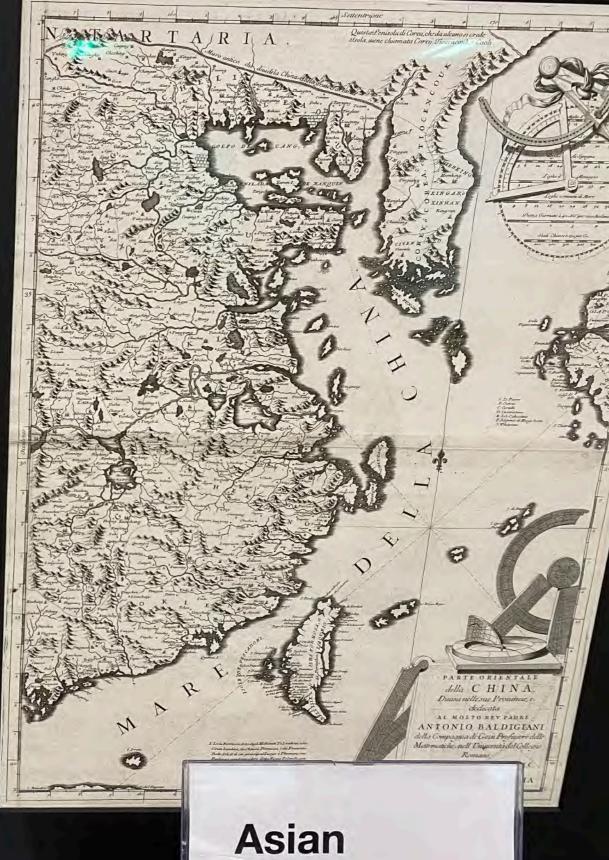
"The Western and Eastern Parts of China divided into their Provinces"

European techniques of map-making, coupled with Chinese skill and knowledge, led to this two-sheet map by Coronelli. Detailed cartouches depict the tools of the surveyor and cartographer.

Can you find the Great Wall, Beijing (Xuntien), Korea, Japan, and Taiwan?

Around 1688, at the instigation of the Emperor Kangxi, about a dozen Jesuits with Chinese collaborators began a 30-year project to map the entirety of China. They plotted longitude and latitude coordinates for more than 600 locations based on the meridian of the Paris Observatory. As a result, both Chinese and European geographers had access to maps constructed from the same geographical data.





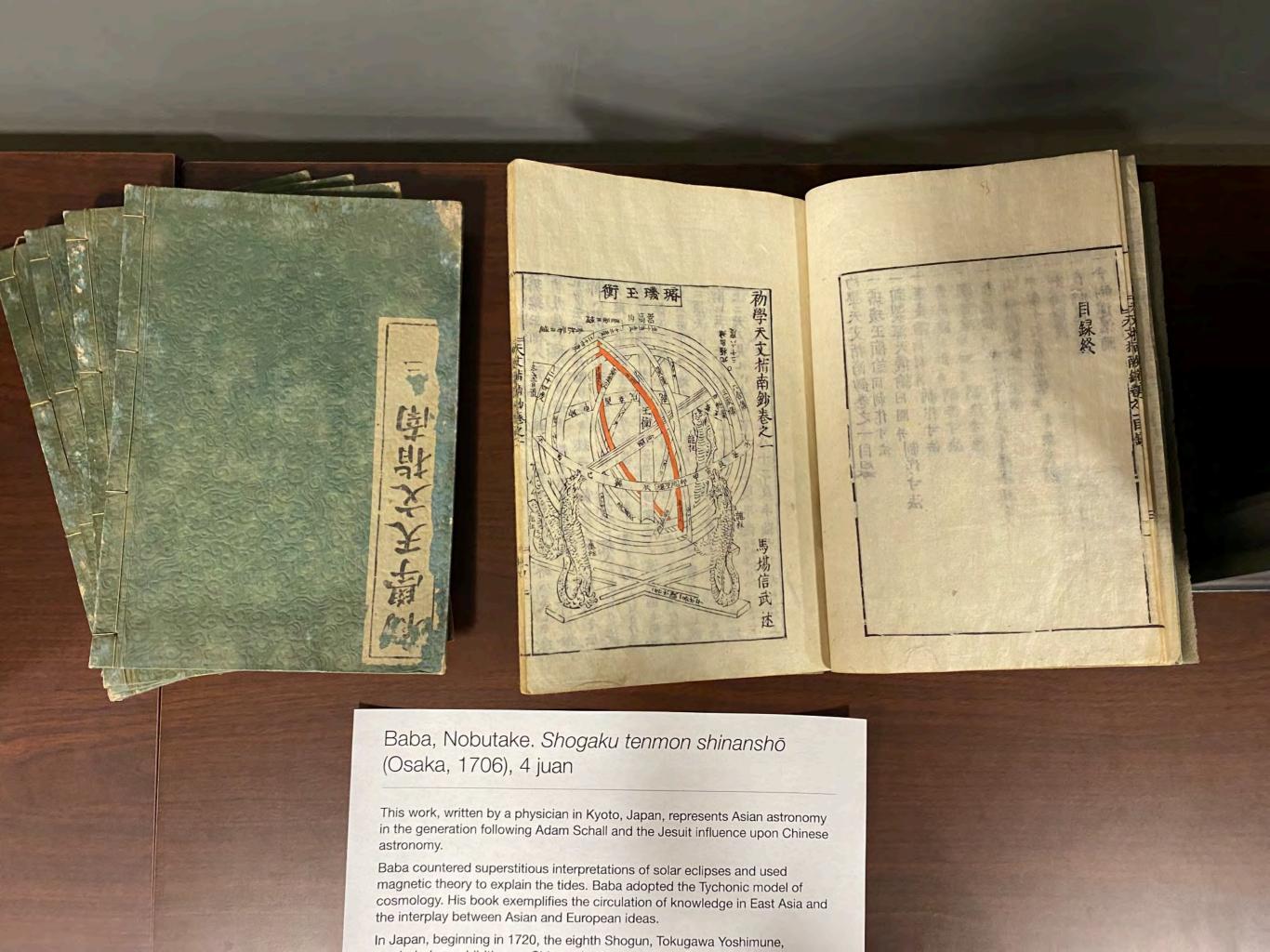
cultures

# Baba, Nobutake. *Shogaku tenmon shinanshō* (Osaka, 1706), 4 juan

This work, written by a physician in Kyoto, Japan, represents Asian astronomy in the generation following Adam Schall and the Jesuit influence upon Chinese astronomy.

Baba countered superstitious interpretations of solar eclipses and used magnetic theory to explain the tides. Baba adopted the Tychonic model of cosmology. His book exemplifies the circulation of knowledge in East Asia and the interplay between Asian and European ideas.

In Japan, beginning in 1720, the eighth Shogun, Tokugawa Yoshimune, rescinded a prohibition on Chinese books containing European science that had been in force since 1630. Thereafter, the ban pertained only to books concerning Christianity or written by Christians, including the engineering work by Schreck which was not printed until 1830.



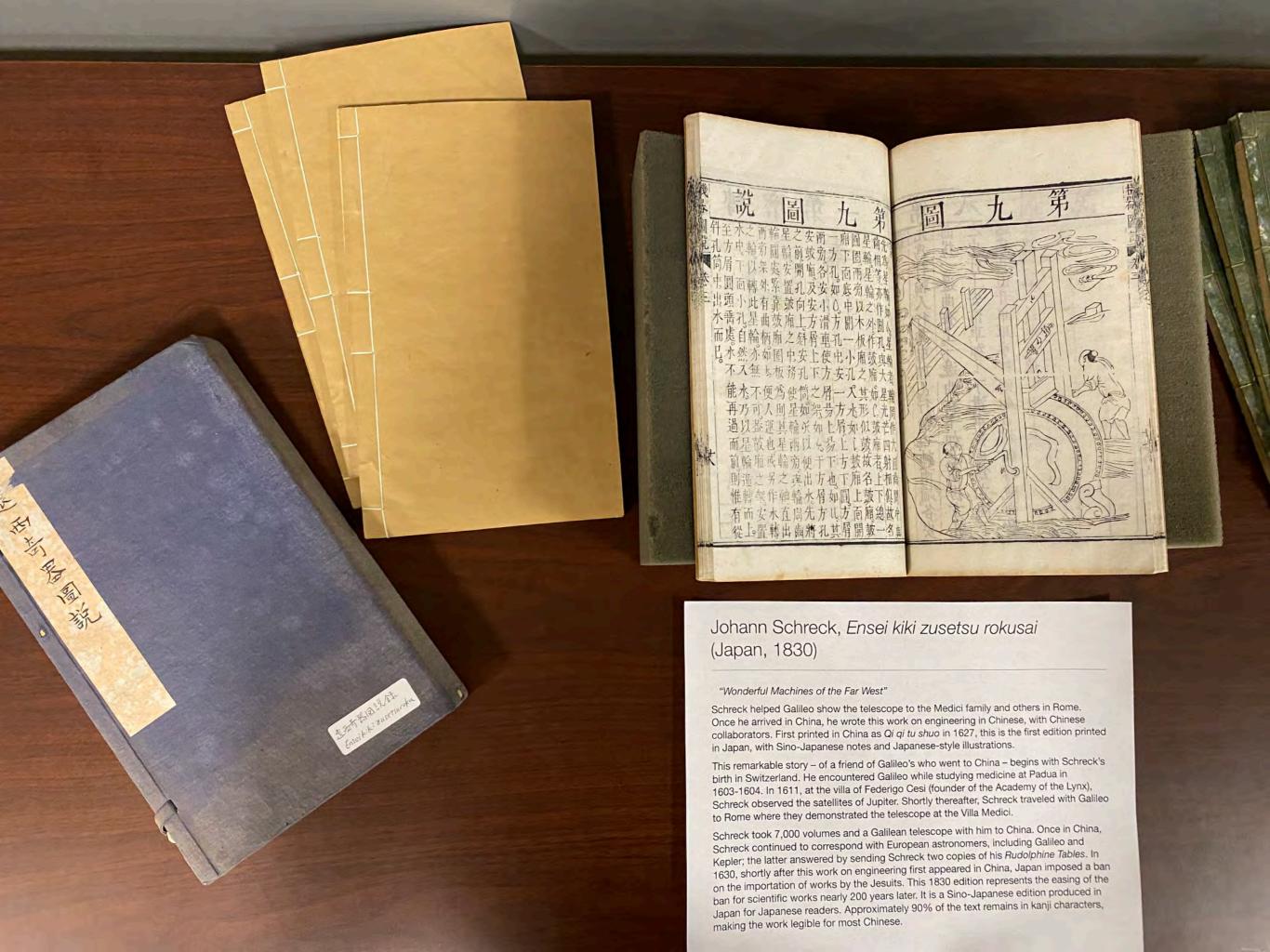
# Johann Schreck, *Ensei kiki zusetsu rokusai* (Japan, 1830)

#### "Wonderful Machines of the Far West"

Schreck helped Galileo show the telescope to the Medici family and others in Rome. Once he arrived in China, he wrote this work on engineering in Chinese, with Chinese collaborators. First printed in China as *Qi qi tu shuo* in 1627, this is the first edition printed in Japan, with Sino-Japanese notes and Japanese-style illustrations.

This remarkable story – of a friend of Galileo's who went to China – begins with Schreck's birth in Switzerland. He encountered Galileo while studying medicine at Padua in 1603-1604. In 1611, at the villa of Federigo Cesi (founder of the Academy of the Lynx), Schreck observed the satellites of Jupiter. Shortly thereafter, Schreck traveled with Galileo to Rome where they demonstrated the telescope at the Villa Medici.

Schreck took 7,000 volumes and a Galilean telescope with him to China. Once in China, Schreck continued to correspond with European astronomers, including Galileo and Kepler; the latter answered by sending Schreck two copies of his *Rudolphine Tables*. In 1630, shortly after this work on engineering first appeared in China, Japan imposed a ban on the importation of works by the Jesuits. This 1830 edition represents the easing of the ban for scientific works nearly 200 years later. It is a Sino-Japanese edition produced in Japan for Japanese readers. Approximately 90% of the text remains in kanji characters, making the work legible for most Chinese.



#### Solar Eclipse, August 19, 1887 Tokyo: Shinkichi Kobayashi, Meiji 20 [July or August 1887]

A fascinating print illustrating a solar eclipse predicted to occur on August 19, 1887. The eclipsed sun shows a narrow crescent band of rose, suggesting the eclipse would not be total. Indeed, the eclipse was annular, of about 99% totality as seen from Tokyo, where the print was published. The print was probably issued as an "extra" in city newspapers in the days or weeks preceding the event.

What are the people doing?

What are they saying to each other, or thinking to themselves?

The image illustrates amazed viewers from all social classes, including children and gentlemen dressed in Western clothes, a policeman, a jinrikisha driver, and, most curiously, a photographer, hidden beneath the cloak of his tripod-mounted camera.



## FlamSteed

#### John Flamsteed, Atlas coelestis (London, 1729)

Flamsteed (1646-1719) was England's first Astronomer Royal, charged with improving star positions accurately enough to determine longitude at sea. In 1676, he completed the building of the Greenwich Observatory.

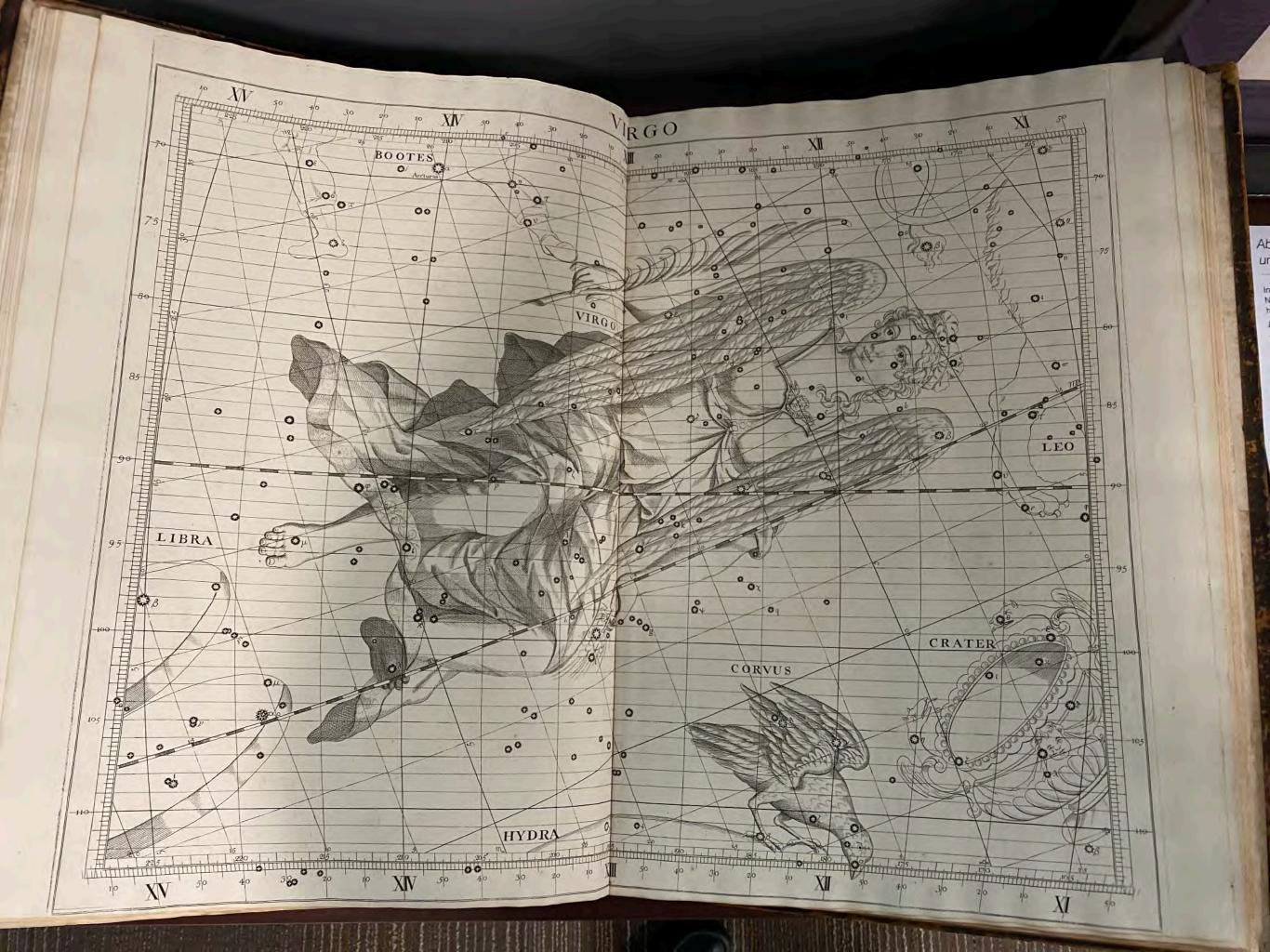
Flamsteed's star atlas, published posthumously, became the most celebrated and influential star atlas of the 18th century. At the time, it was the largest star atlas ever printed. Its 28 copperplate engravings include 25 double-page star charts and 2 double-page planisphere maps.

Constellation figures are viewed from the front, matching the traditional names of stars. Sir James Thornhill was among the artists who designed the constellation figures in a Rococo style that was soon copied in Paris and Berlin.

Flamsteed determined star positions using observing instruments equipped with telescopic sights (a first among major atlases).

Newton relied on Flamsteed's star coordinates, made available to him at an earlier date, for his theory of universal gravitation and his explanation of the motion of the Moon.

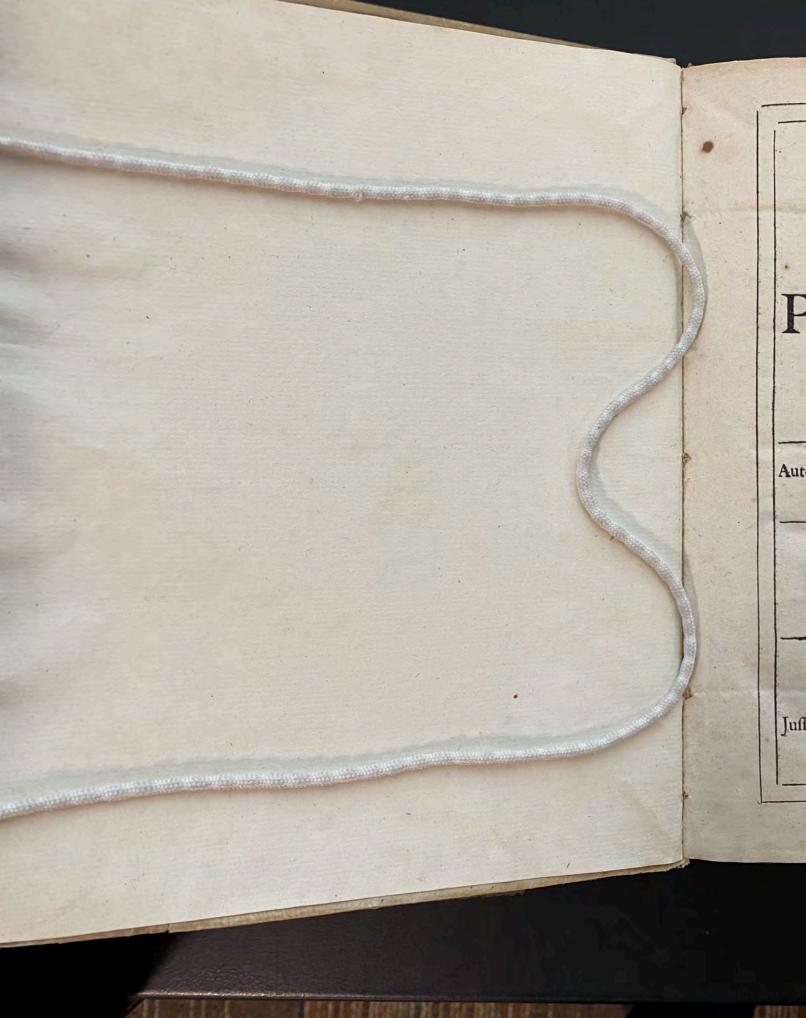
More than 3,000 stars are presented, double the number in the Hevelius atlas.



## Isaac Newton, *Philosophiae naturalis principia* mathematica (London, 1687)

The Copernican idea that the Earth moves as a planet required a thorough revision of physics. Galileo undertook this task in his *Discourse on Two New Sciences*, published 80 years after Copernicus. With a mathematical description of the law of universal gravitation, Newton in this book unified the terrestrial physics of Galileo with the celestial mechanics of Kepler's laws. The development of science from Copernicus to Newton then became recognized as a "Scientific Revolution," a complete overthrow of Aristotelian physics and cosmology.

Newton's title in the *Mathematical Principles of Natural Philosophy* (1687) is a deliberate rejection of Descartes' approach to scientific explanation in the *Principles of Philosophy* (1644). Whereas Descartes engaged all of philosophy, deducing cosmology from first principles of ontology and epistemology, Newton claimed only to address "Natural" philosophy. And whereas Descartes' "Principles" were mechanical causes, even hypothetical ones, Newton argued that "Mathematical" laws suffice for science, since they are certain, even if they are only descriptive rather than causal.



#### PHILOSOPHIÆ

NATURALIS

#### PRINCIPIA

MATHEMATICA.

Autore J.S. NEWTON, Trin. Coll. Cantab. Soc. Matheseos Professore Lucasiano, & Societatis Regalis Sodali.

#### IMPRIMATUR.

S. PEPYS, Reg. Soc. PRÆSES.
Julii 5. 1686.

LONDINI,

Justu Societatis Regia ac Typis Josephi Streater. Prostat apud plures Bibliopolas. Anno MDCLXXXVII. c Nev

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## Abbildung und Beschreibung deß wunderwürdigen unvergleichlichen Cometen (Nuremberg 1680)

In this rare broadsheet, the great comet of 1680 illumines the sky above Nuremberg. One person among the onlooking crowd observes through a handheld telescope.

Do you see a telescope in the crowd? Children? Animals?

This was the first comet to be discovered by means of a telescope. Gottfried Kirch, a German astronomer, first saw it on November 14, 1680, before it was bright enough to be seen with an unaided eye. The comet reached its peak brightness at the end of December 1680, when it was visible even in daylight. It remained visible through the middle of March, 1681, and was likely the most widely observed comet of early-modern times.

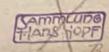
Hevelius observed this comet in Gdansk. Eusebio Kino observed this comet in Cádiz late in 1680 while waiting to sail to Mexico. Upon his arrival in Mexico City, he published his study of the comet's trajectory as Exposisión astronómica de el cometa (1681), one of the earliest astronomical works printed in America. Isaac Newton used this comet's trajectory to test Kepler's laws of planetary motion.

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deß wunderwardigen unvergleichlichen Omeken.



Der erstmals zu Anfang des Wintermonats vor Aufgang der Sonnen erschienen / pub anjegt nach derselben Untergang sich entseylich sehen lässet.



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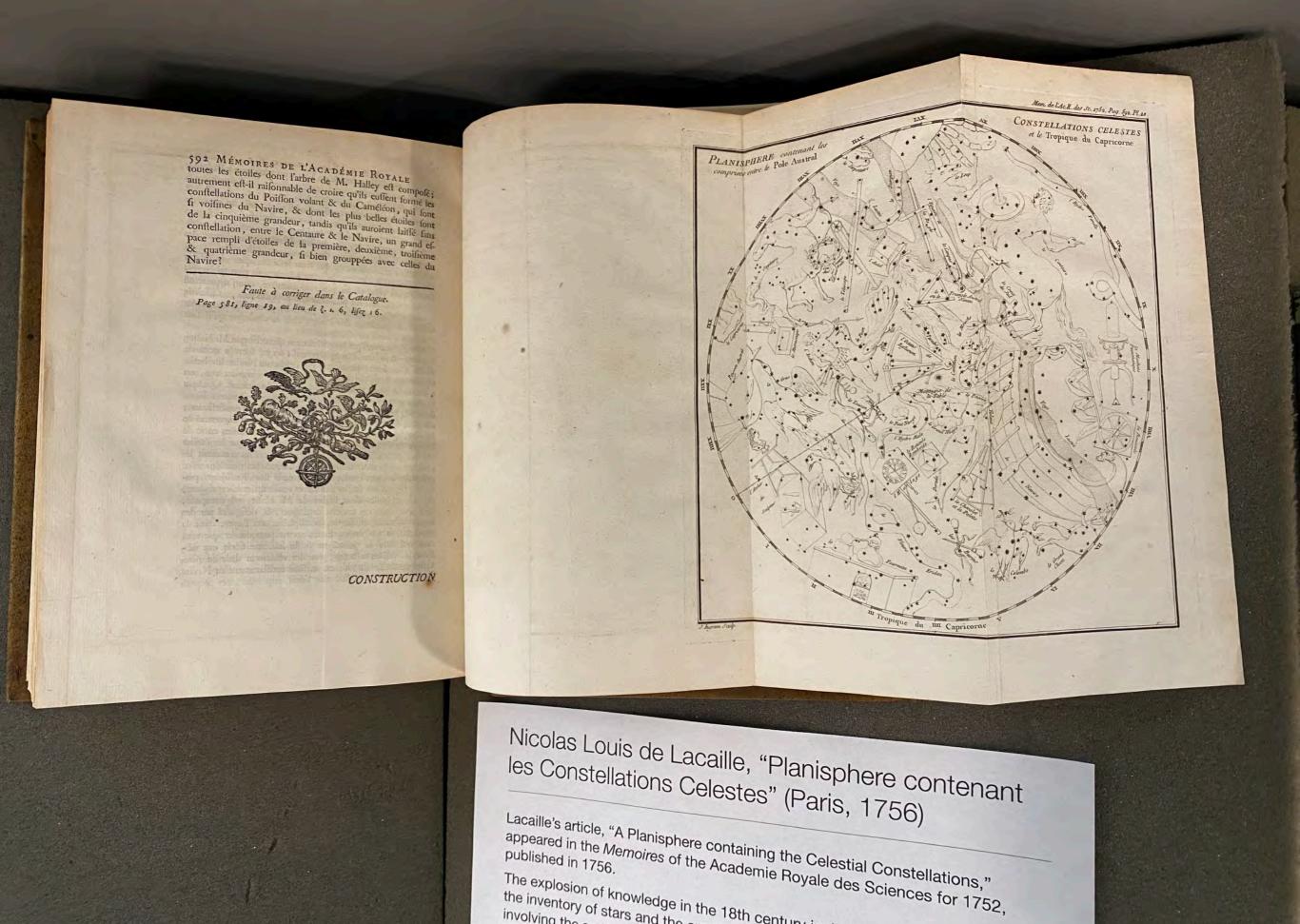


## Nicolas Louis de Lacaille, "Planisphere contenant les Constellations Celestes" (Paris, 1756)

Lacaille's article, "A Planisphere containing the Celestial Constellations," appeared in the *Memoires* of the Academie Royale des Sciences for 1752, published in 1756.

The explosion of knowledge in the 18th century included a dramatic increase in the inventory of stars and the creation of new constellations, particularly involving the southern hemisphere. From an observatory in the Cape of Good Hope, Lacaille recorded 9,000 star positions. He invented 14 constellations which first appear in this article, including the Clock, Telescope, Microscope and the Southern Cross.

One of his 14 new constellations is small Pyxis, the Compass of Argo Navis, located nearby. Lacaille dismantled Argo Navis into a set of smaller constellations: Carina the Keel, Puppis the Stern or Poop, and Vela the Sail, although these do not appear in the star map. To view Argo Navis you'll need to sail to Australia or South America; only Puppis becomes visible to observers in the US. The bright star Canopus, once alpha-Argus, now lies in Carina.



The explosion of knowledge in the 18th century included a start

## Charles Messier, "Catalogue des Nébuleuses et des Amas d'Étoiles" (Paris, 1774)

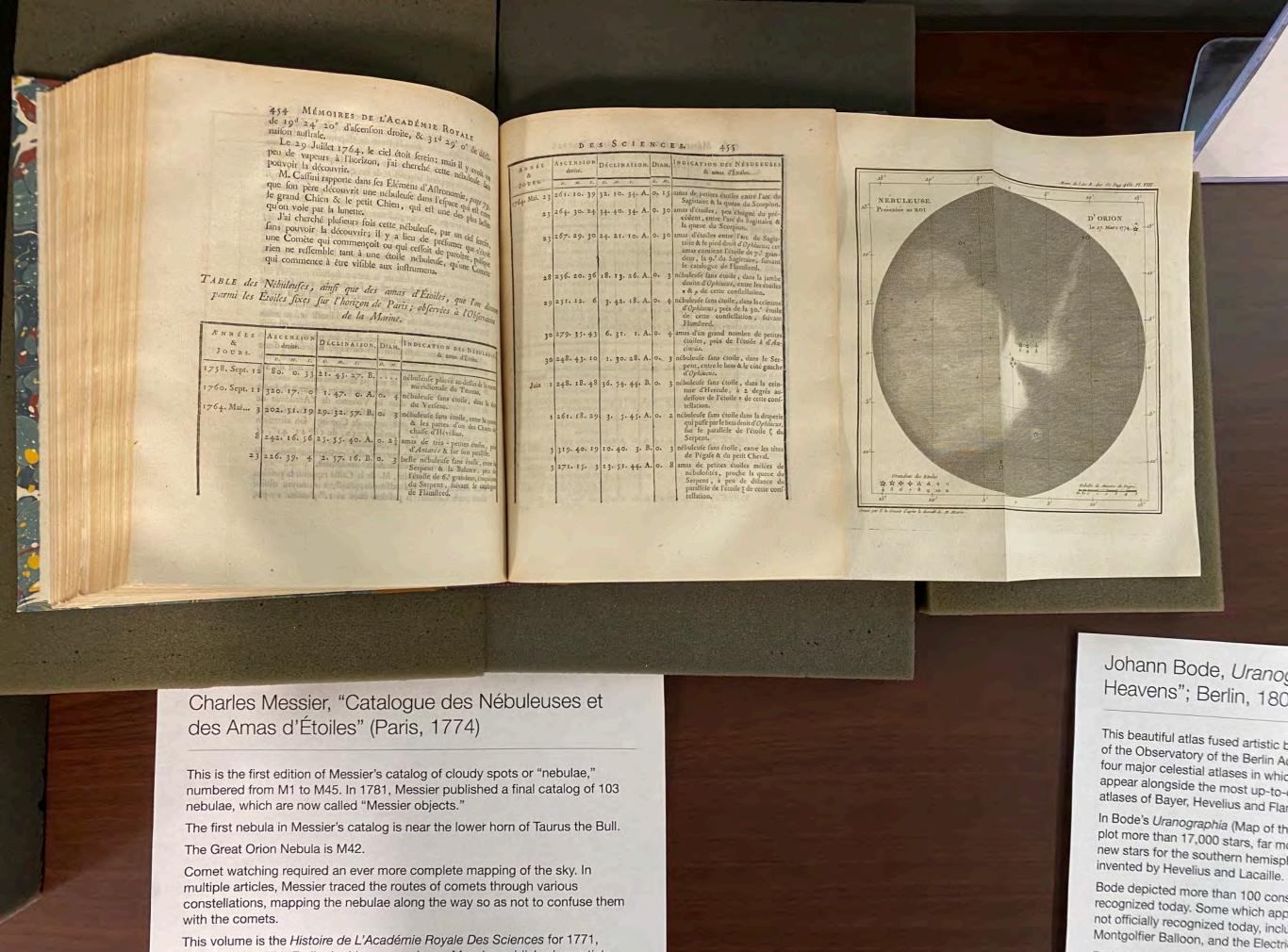
This is the first edition of Messier's catalog of cloudy spots or "nebulae," numbered from M1 to M45. In 1781, Messier published a final catalog of 103 nebulae, which are now called "Messier objects."

The first nebula in Messier's catalog is near the lower horn of Taurus the Bull.

The Great Orion Nebula is M42.

Comet watching required an ever more complete mapping of the sky. In multiple articles, Messier traced the routes of comets through various constellations, mapping the nebulae along the way so as not to confuse them with the comets.

This volume is the *Histoire de L'Académie Royale Des Sciences* for 1771, published in 1774. Earlier in this same volume, Messier published an article, with a star map, describing the second comet of 1770-1771, which passed near Orion.



Bode also included 2 500 cloudy by

This volume is the Histoire de L'Académie Royale Des Sciences for 1771, published in 1774. Earlier in this same volume, Messier published an article,

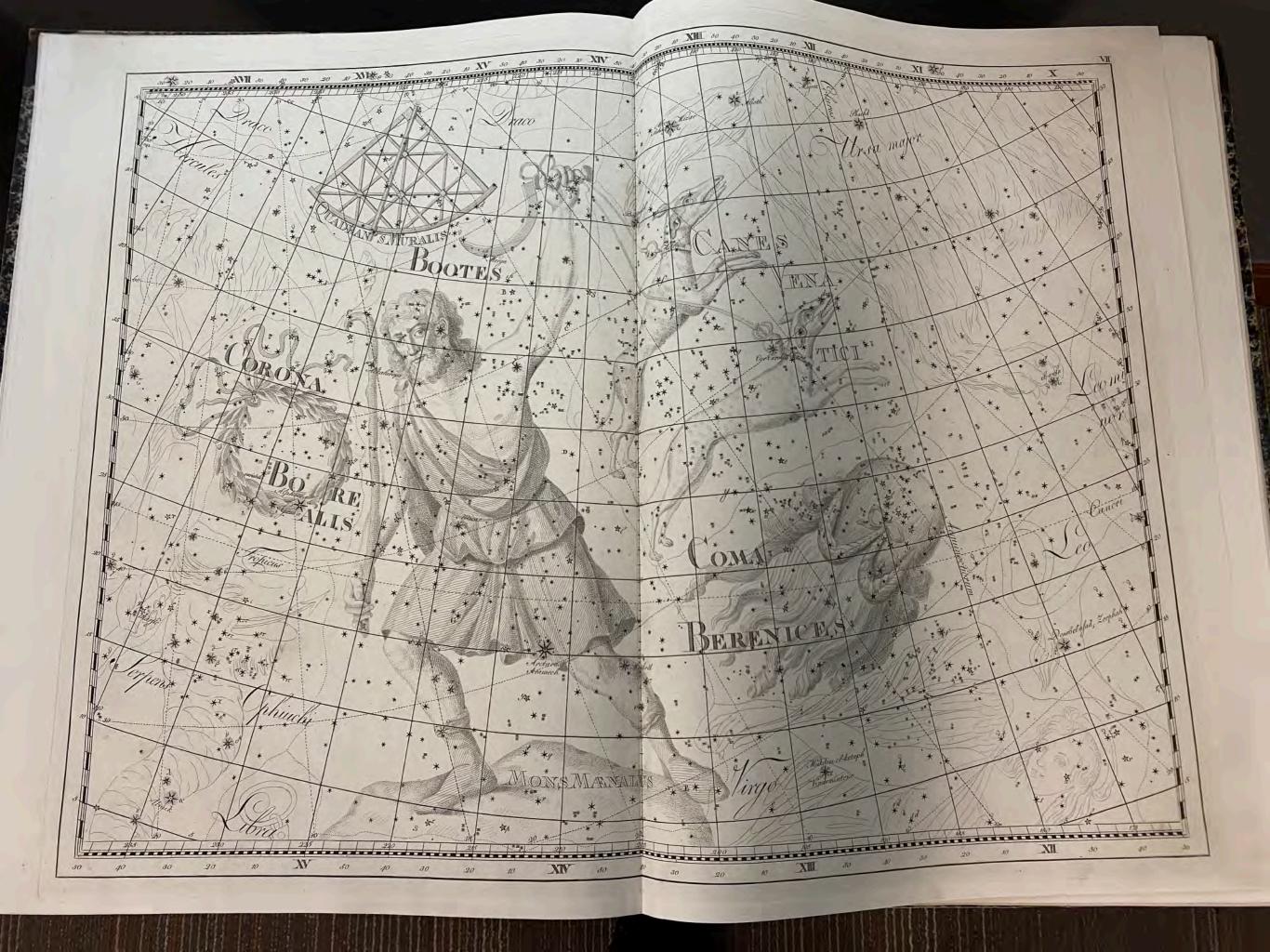
## Johann Bode, *Uranographia* ("Map of the Heavens"; Berlin, 1801)

This beautiful atlas fused artistic beauty and scientific precision. Bode, director of the Observatory of the Berlin Academy of Sciences, produced the last of the four major celestial atlases in which artful depictions of constellation figures appear alongside the most up-to-date scientific data. (The other three are the atlases of Bayer, Hevelius and Flamsteed.)

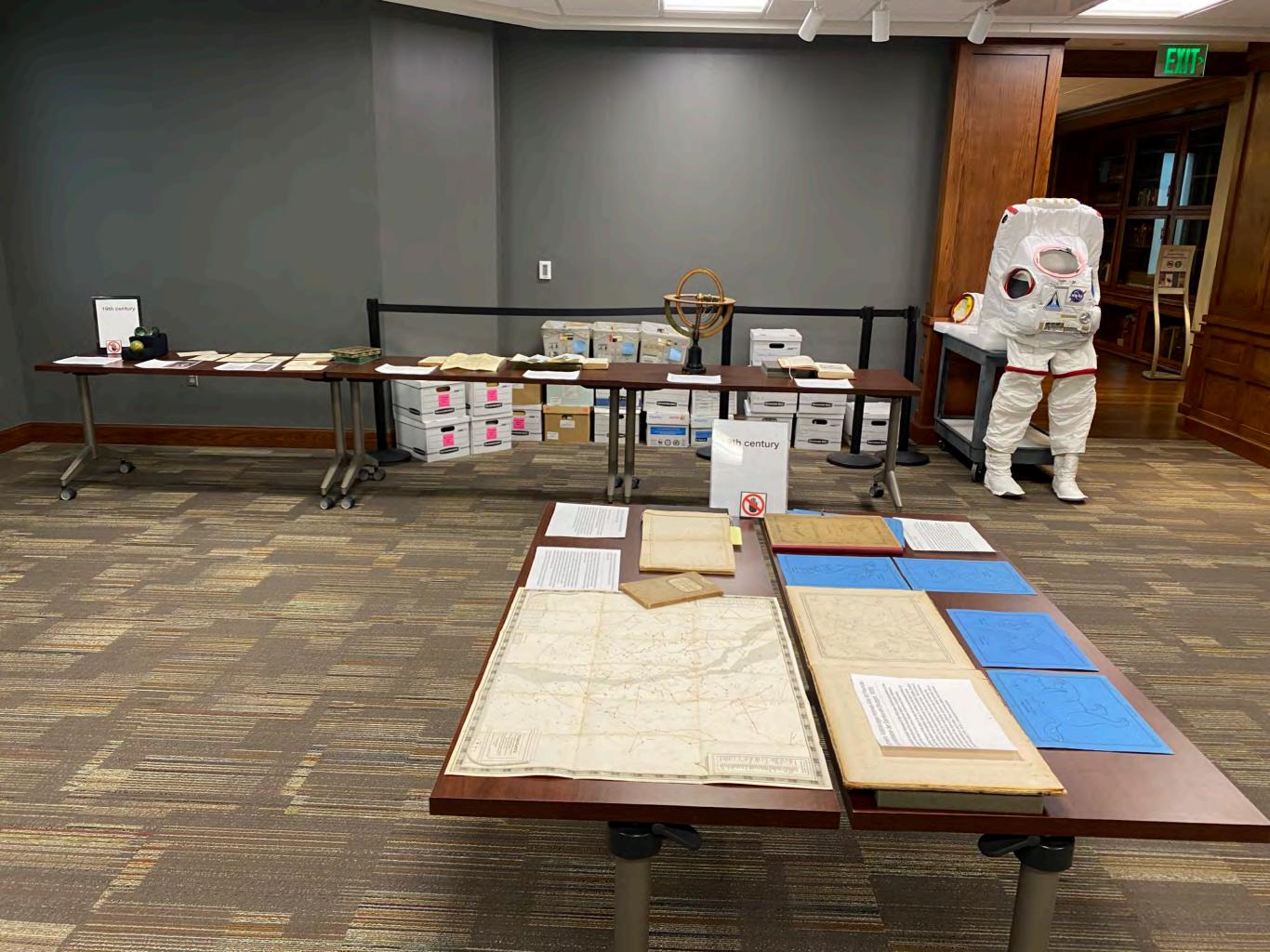
In Bode's *Uranographia* (Map of the Heavens), 20 large copperplate engravings plot more than 17,000 stars, far more than any previous atlas. Bode included new stars for the southern hemisphere, along with constellations recently invented by Hevelius and Lacaille.

Bode depicted more than 100 constellations, compared with 88 officially recognized today. Some which appeared in this atlas for the first time, but are not officially recognized today, include the Cat, the Printing Press, the Montgolfier Balloon, and the Electric Generator.

Bode also included 2,500 cloudy patches, or "nebula," cataloged by William and Caroline Herschel.



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#### Nicolas Lane, Pocket globe (London, 1809)

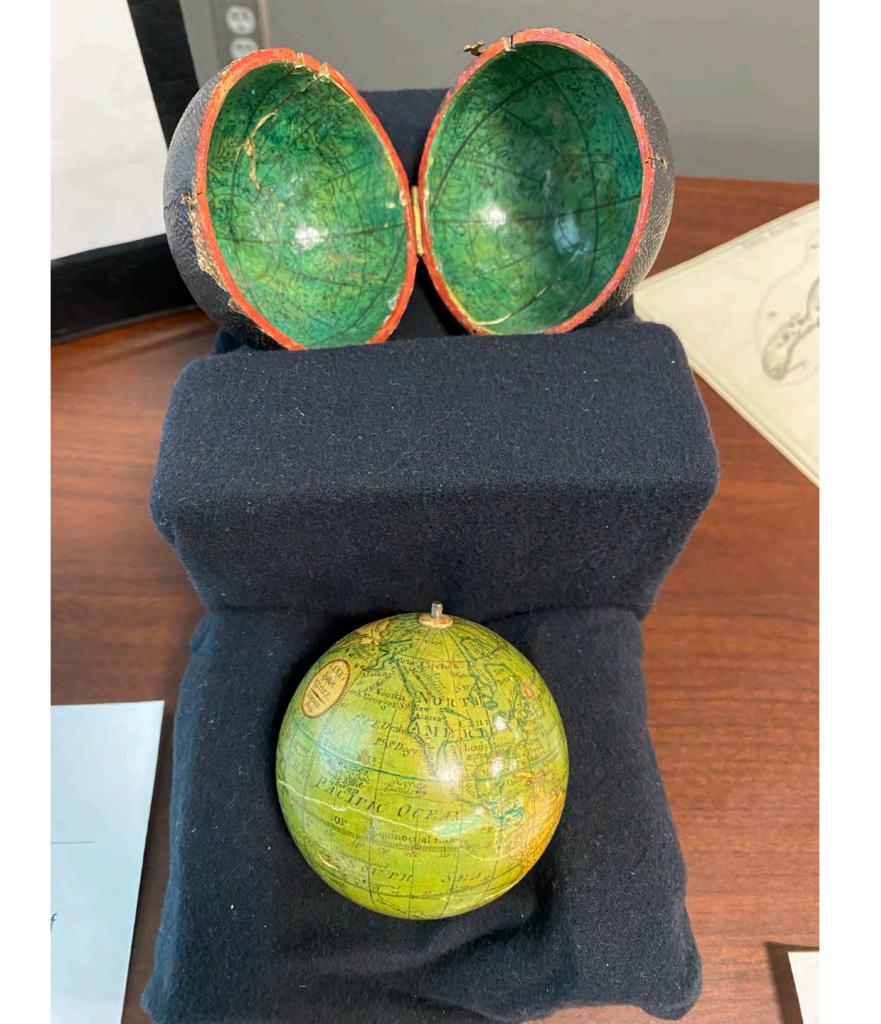
Imagine being a youth in England and holding the entire world in your hand! And not only the globe, but the heavens as well. The concave hemispheres of the black sharkskin case display vibrantly colored celestial charts.

The globe is made of paper mache covering a plaster sphere. The gores were printed using copper-plate engravings, then hand-colored.

On the globe itself, the Rocky Mountains of the American west are shown as the "Stony Mountains." The globe includes Cook's third voyage.

Lane specialized in producing such globes from 1775.

Pocket globes were costly accoutrements of young gentlemen and ladies. A pocket globe could express one's identity as a member of the globe-spanning British empire, and doubtless also reflected individual curiosity about the Earth and heavens.

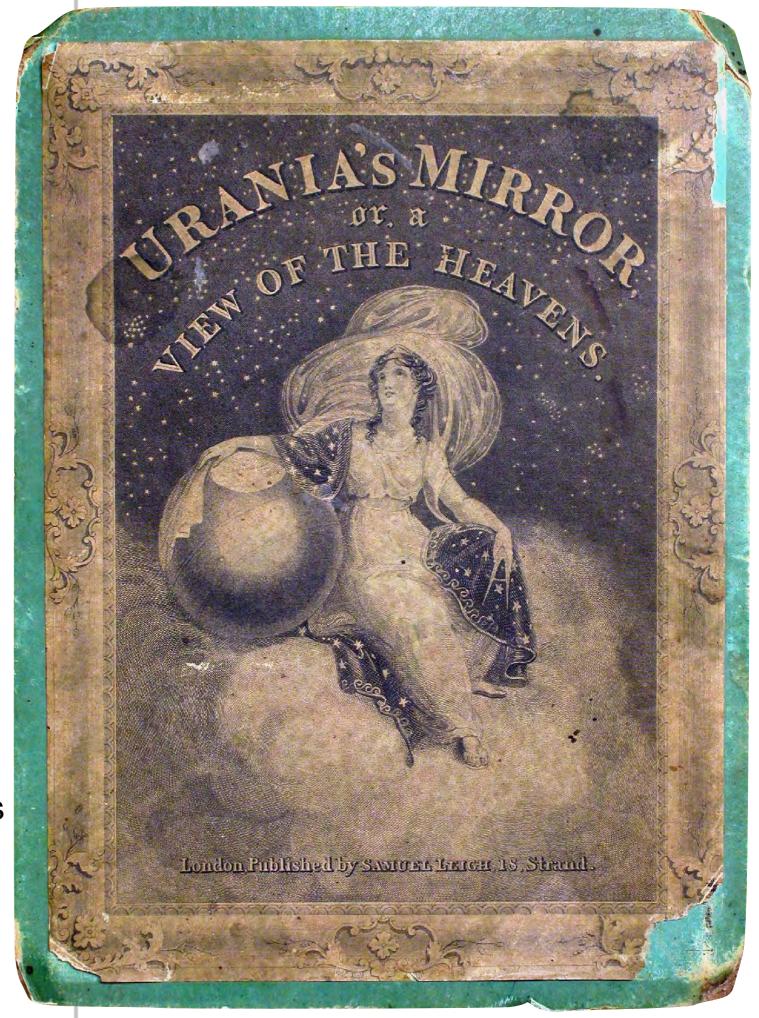


#### Urania's Mirror

London, 1825

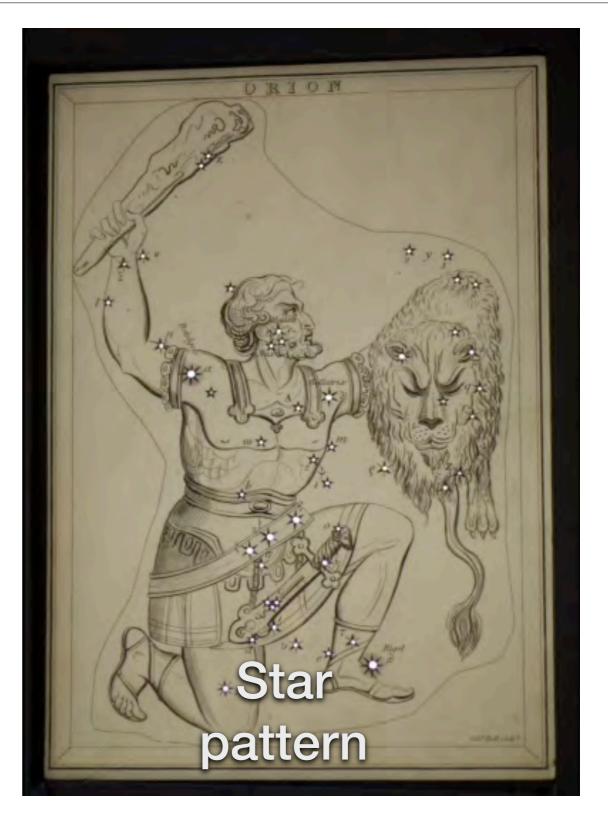
32 cards 66 constellations

This box of constellation cards (from the early 19th century) makes learning the constellations fun. Urania, the Muse of Astronomy, appears on the cover of the box.



Holes are punched in the positions of bright stars. Hold any card up to a light and compare the star pattern with the constellation figure.





#### Scorpius the Scorpion



Look for the Fish hook

#### Ursa Major the Big Bear



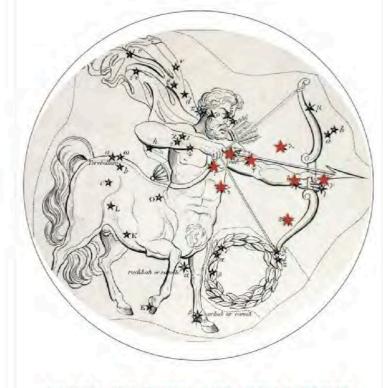
Look for the Big Dipper

Orion the Hunter



Look for the 3 stars in his belt

Sagittarius the Archer



Look for the Teapot, with spout & handle

Ursa Minor the Little Bear



Look for the Little Dipper

Leo the Lion



Look for the backwards Question Mark



## Jehoshaphat Aspin, A Familiar Treatise on Astronomy (London 1825)

While the creator of *Urania's Mirror* was a mystery, Jehoshaphat Aspin issued this book as a companion to *Urania's Mirror*, to provide a simple introduction to the night sky. Aspin asserted that the *Urania's Mirror* constellation cards "were designed by a lady."

Aspin's based his constellation figures upon the celestial atlas of Alexander Jamieson, published in 1822.

#### CHART OF THE HEAVENS.

The accompanying Chart of the Heavens exhibits at one view all the constellations that are at any time visible in the latitude of London; and affords an easy method of discovering their situation for every month in the year. The hieroglyphical figures are omitted, in order to display the heavens as they naturally appear; and the constellations are separated by dotted lines, and distinguished by colours, as are countries and states upon a terrestrial map. The Chart is also furnished with twelve portions of meridians, each bearing the name of its appropriate month.

To use this Chart, take the length of one of the meridional lines between the points of a pair of compasses, and, placing one point upon the northern end of the line, describe a circle, which will include all the constellations visible for the month named upon the line, at the time indicated in the subjoined calendar, which is taken generally about the middle of the month, between nine and ten o'clock in the evening.

But as this method would encumber the Chart with so great a number of curves as to confuse the student, the same object may be more neatly obtained by the following method. Upon a sheet of drawing-paper, or a card of sufficient dimensions, draw a line as nearly as possible across the middle. From the centre of this line, with a radius equal to one of the meridional lines, strike a circle, and cut away the interior, so as to form an artificial horizon. Produce the meridional line through the pole of the equator to a sufficient distance; and place the artificial horizon in such a position that the ends of the right line drawn upon it may coincide with the southern end of the meridional line, and with its prolongation through the

THE HEAVENS FOR THE LATITUDE OF CHART OF Magnitudes of the Stars BY JEHOSHAPHAT ASPIN, 1825 London, Published by Samuel Leigh, 18, Strand

#### iliar Treatise on

nystery, Jehoshaphat Aspin issued wastide a simple introduction to

## Catherine Whitwell, *An Astronomical Catechism* (London, 1818)

This dialogue between a mother and her daughter offers a delightful introduction to the night sky.

It contains 23 engraved plates drawn by Whitwell herself, including four hand-colored folding plates. One of the plates depicts the constellations of Corvus the Crow, Crater the Cup and Hydra the Water Snake.

Another plate conveys a dramatic impression of the Full Moon at night, shown against a striking black background.

Whitwell, who also wrote on economics and education, taught at Robert Owen's school at New Lanarck, Scotland, in the 1820's. Owen later came to America and founded New Harmony, a utopian socialist colony in Indiana.



#### ASTRONOMICAL CATECHISM;

OR

#### Dialogues

BETWEEN

HYDRA

A MOTHER AND HER DAUGHTER.

TILUSTRATED WITH NUMEROUS ENGRAVINGS.

BY

CATHERINE VALE WHITWELL.

#### LONDON

PRINTED FOR AND SOLD BY THE AUTHOR,
NO. 8, BUSSELL SQUARE;
MAY BE HAD ALSO OF GEORGE WILSON,
CORNER OF EASEX STREET, STRAND.
1818.

Price One Guinca in Boards.

Catherine Whitwell, An Astronomical Catechism (London, 1818)

This dialogue between a mother and her daughter offers a delightful

The Cuttine and the Stars from Flamsteads Atlas Celestus

CV.Whitsvell.delt

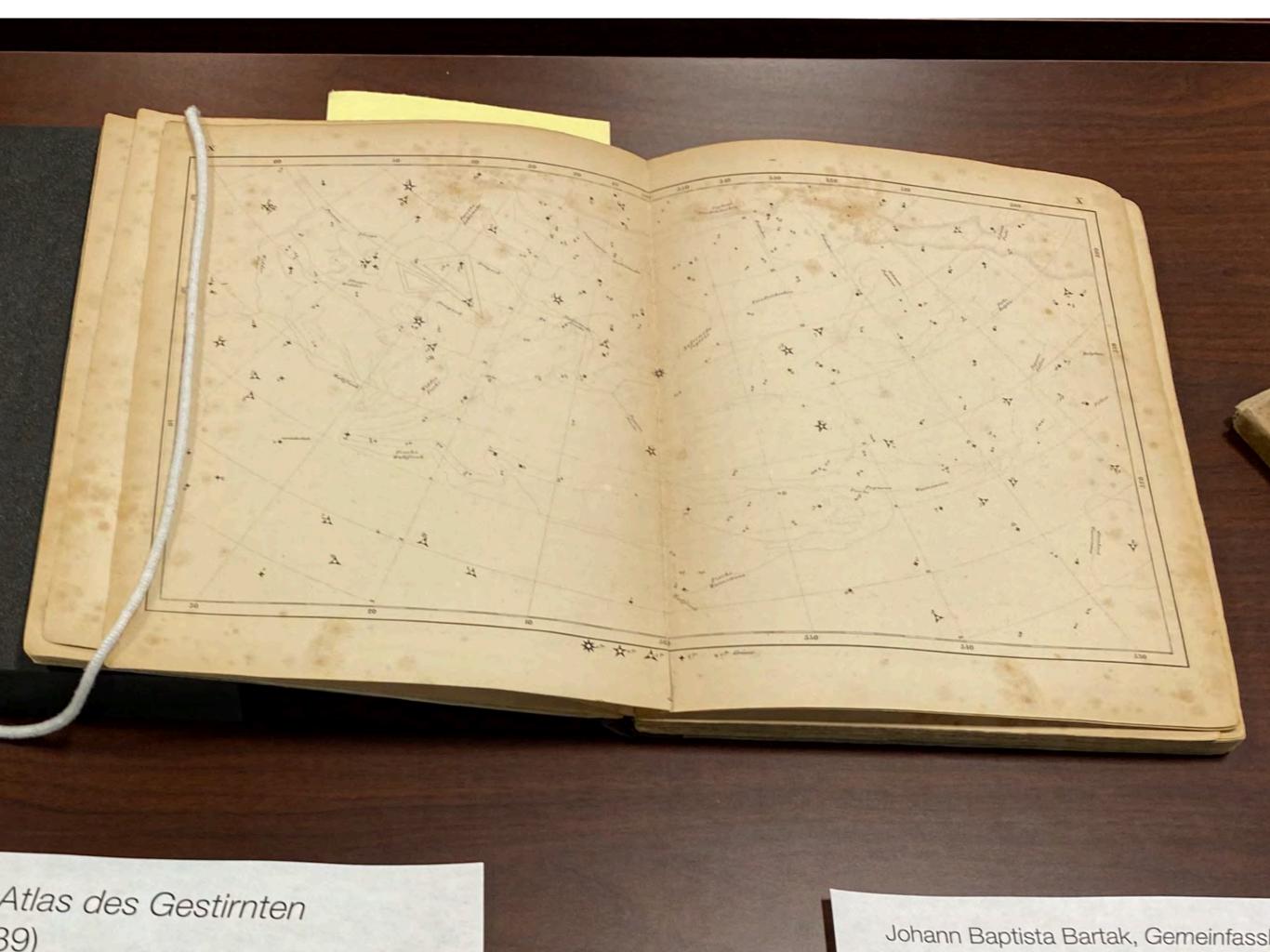


## Joseph J. von Littrow, *Atlas des Gestirnten Himmels* (Stuttgart, 1839)

"Atlas of the Starry Heavens"

Von Littrow, a Czech astronomer who was Director of the Vienna Observatory, adopted Bode's constellation figures and star positions. In von Littrow's atlas, the constellation figures appear faintly in the background.

The four great celestial atlases of Bayer, Hevelius, Flamsteed and Bode were each distinctive in their artistic style as well in their scientific importance. After Bode, this fusion of art and science in celestial atlases ceased, as scientific atlases no longer could print plates large enough to accommodate full-size, artistic depictions of constellation figures. After Bode's monumental production, scientific star atlases became more specialized in scope, or dispensed altogether with the artistic depiction of constellation figures.



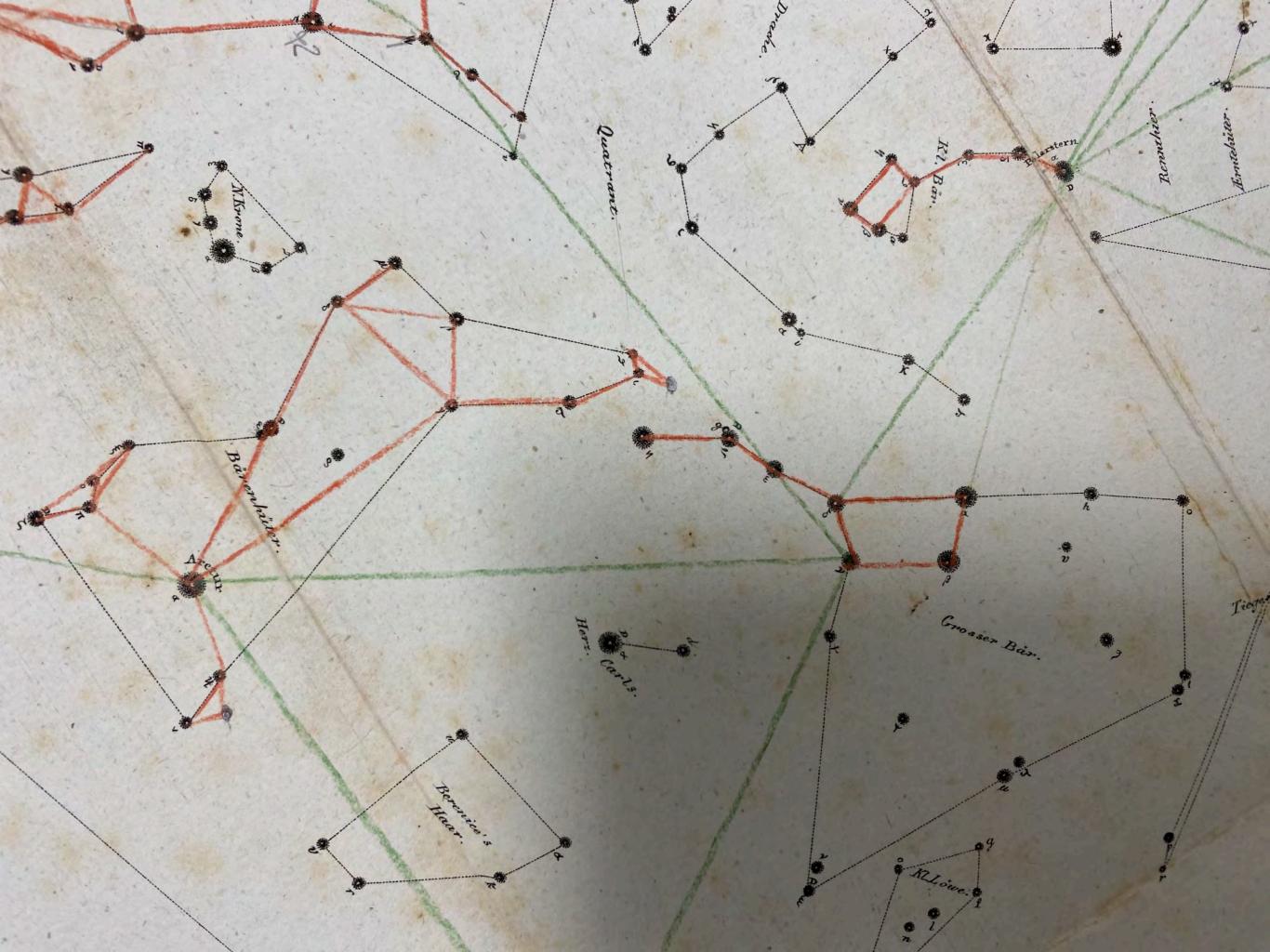
Johann Baptista Bartak, Gemeinfassliche Anleitung zur leichten Kentniss des gestirnten himmels mittelst einer beygefuegten grossen Sternkarte (Vienna, 1827)

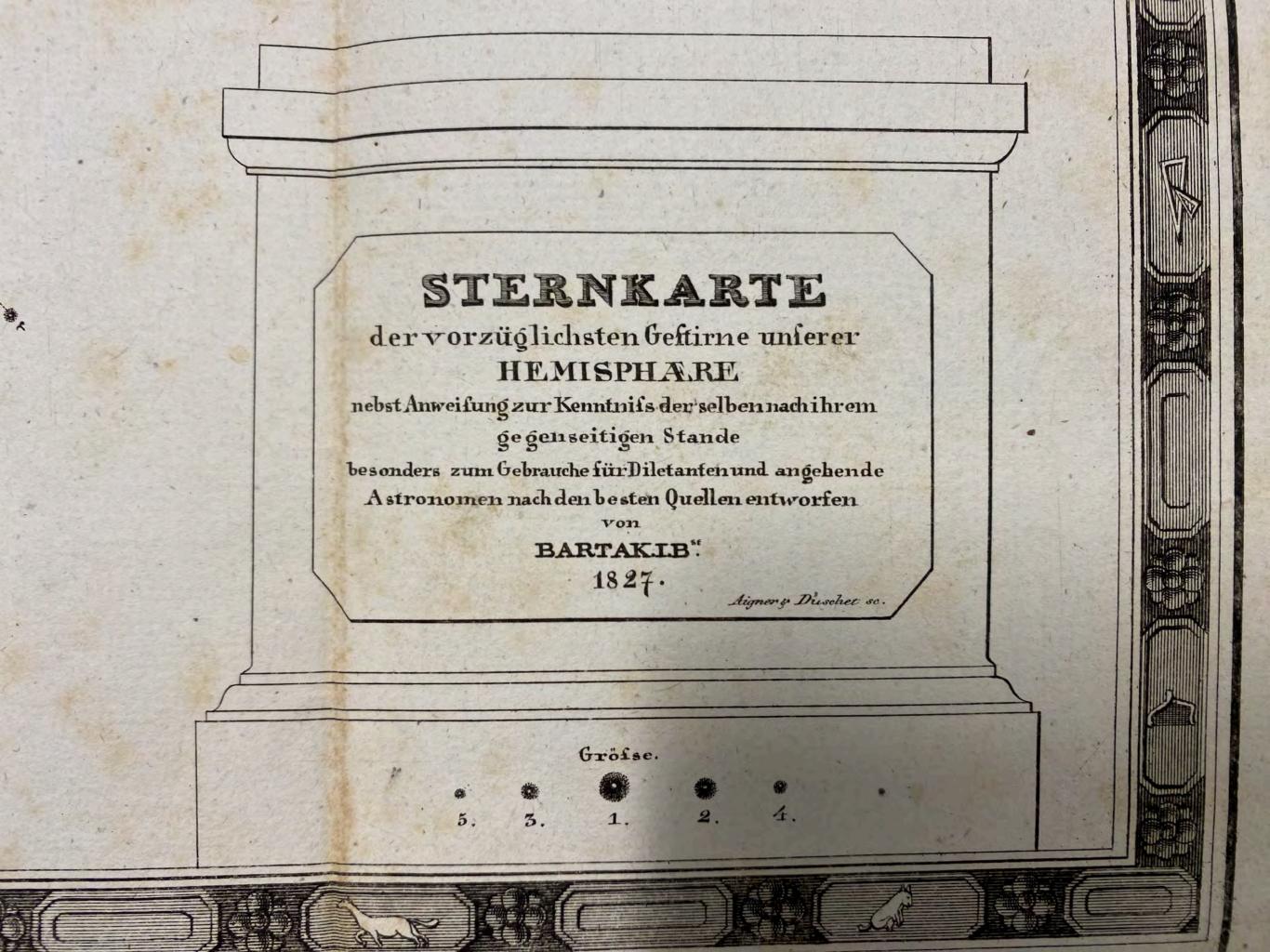
This work includes a little book of 52 pages along with a folded star atlas in a cardboard slipcase. The book is an introduction to astronomy for amateur observing. It notes the recent discoveries of Ceres and Uranus, and includes a foreword by von Littrow. Not much is known of Bartak other than that he was a student of von Littrow.

The engraved star map shows constellations of the northern hemisphere. The map shows miniature depictions of the zodiac signs and some constellation figures. Constellations are depicted as lines connecting the relevant stars; some lines were colored red or green by an early hand. Distinct star symbols stars show relative magnitude. The Milky Way is depicted as a darker amorphous region. One small chart lies in each corner: two tables for calculating declination and ascension (lower left); a list of constellation names (upper left); a list of star names (upper right); and an explanation of relative magnitude star-symbols (lower right).

A very rare and little-known book which provides an interesting view into the nature of 19th-century introductions to astronomy designed for amateurs.







### Hoffmann, Vollständiger Himmels Atlas für Freunde und Liebhaber der Sternkunde (Stuttgart, 1835)

Karl Friedrich Vollrath Hoffmann (1796-1842) was a German geographer at the University of Munich and the Geographical Institute in Stuttgart. Hoffmann dedicated this book to von Littrow, director of the Vienna Observatory.

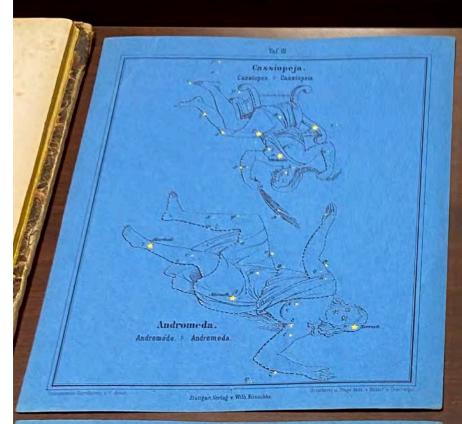
A significant feature of this atlas is the way the stars are presented relative to the beautifully drawn constellation figures. In contrast to the style of most earlier star atlases, which typically accentuate the constellation images, greater emphasis is placed on the stars themselves in the present book. This is done in two principal ways: firstly, by including many more stars than those involved in the constellations illustrated on each plate; and secondly, by showing the relative magnitudes of the stars as different, variously colored symbols, with a separate key provided on each plate. These remarkable plates were prepared by Wenzel Pobuda (1797–1847), a lithographer and engraver.

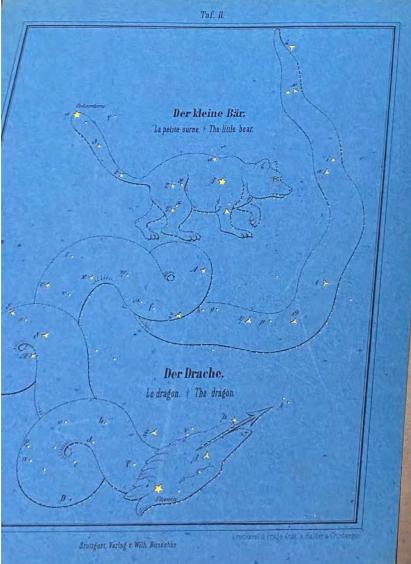


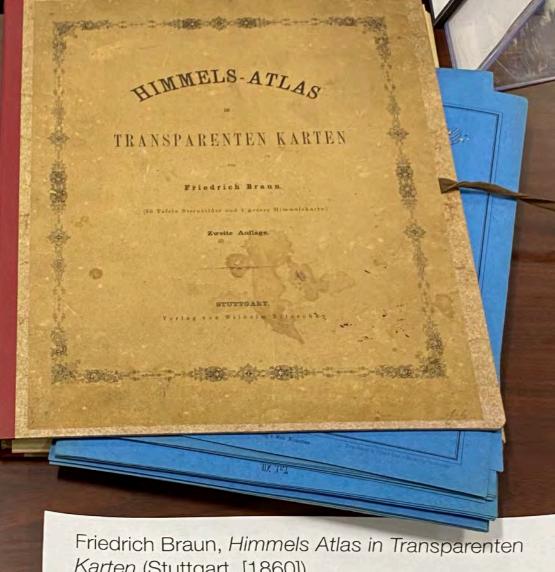
# Friedrich Braun, *Himmels Atlas in Transparenten Karten* (Stuttgart, [1860])

Constellation figures are printed on 30 numbered blue cards; an additional chromolithographic folding star map is comprised of four cards joined together.

These handsome cards were designed to show the outlines of the constellation figures, and the positions of the stars that comprise them, when held against a light source. The constellation figures are printed on blue cardboard, backed by blank transparent paper, with small perforations along the printed outline to allow the passage of light. Star positions within the constellations are represented by punched out, star-shaped holes of variable size (to approximate relative magnitude), backed with transparent, gold-colored paper. The stars are beautifully illuminated when the card is held against a light source, while the shape of the constellation is made visible by light passing through the perforated outlines. A strong light source might project the image against a wall or screen. The effect must have seemed spectacular to students and amateur astronomers of the nineteenth century.



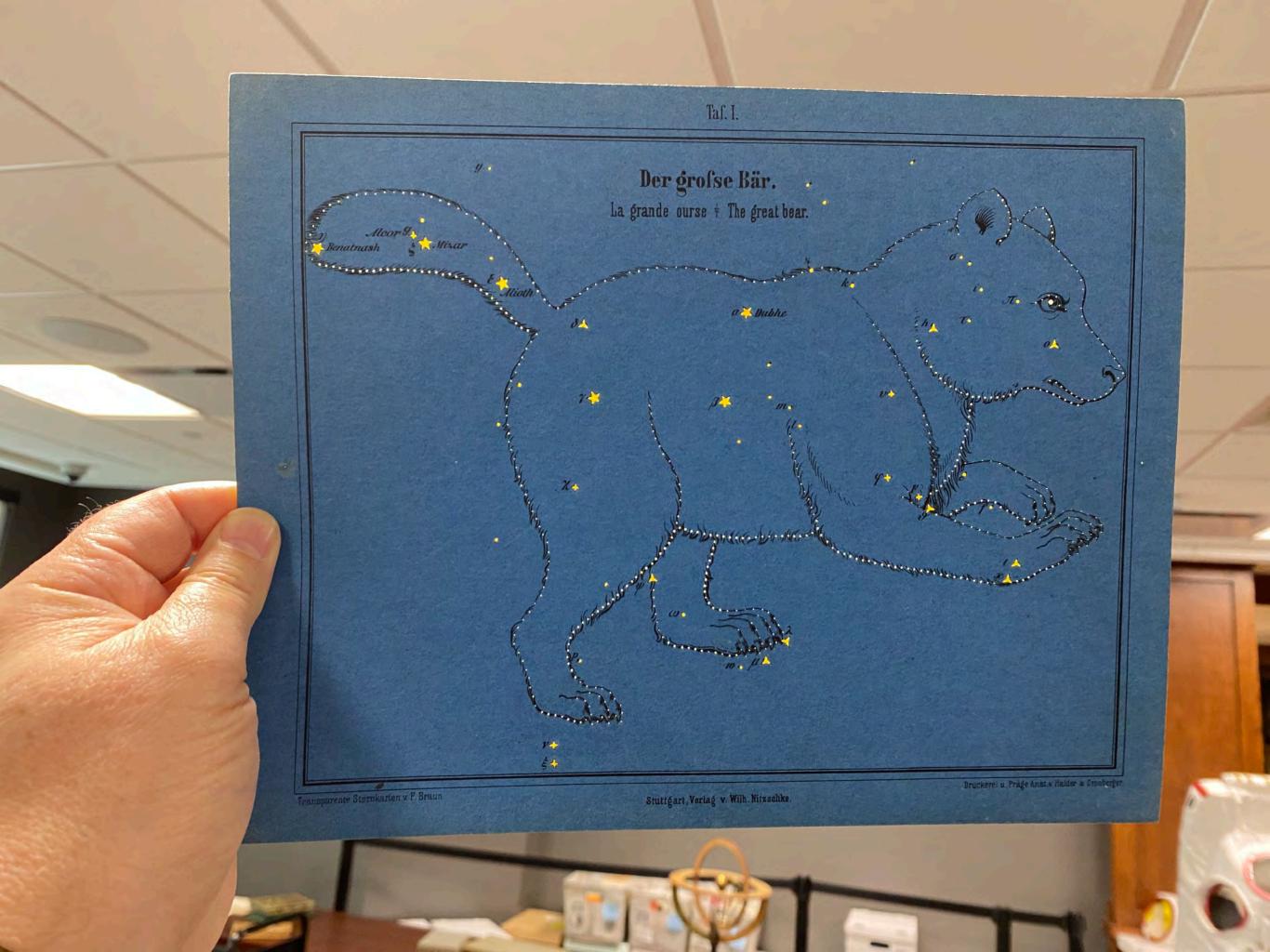




Karten (Stuttgart, [1860])

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#### Delamarche Orrery (Paris)

An orrery, also called a planetarium, shows the choreography of planets as they dance with coordinated precision around the Sun. Early models were geocentric (Earth-centered), including the ancient Antikythera device and large mechanical clocks.

This model was made in Paris by the Delamarche family of instrument makers. Charles François Delamarche (1740-1817) was one of the leading orrery makers in Paris. His son Felix Delamarche (d. 1847) continued in the craft after his father's death.

Orreries are named after Charles Boyle (1676-1731), Earl of Orrery. Heliocentric (Sun-centered) orreries with 6 planets replicate the solar system as it was known before the discovery of Uranus in 1781 by William Herschel. Neptune was discovered by J.G. Galle in Berlin in 1846, after its prediction by Urbain Le Verrier.

How many planets are present in this orrery?

Can you deduce from this information when was it made?







# Camille Flammarion, *L'Atmosphere: Météorologie Populaire* (Paris, 1888)

"The Atmosphere: Popular Meteorology"

Natural science is a quest of discovery, the challenge of boldly exploring where no one has gone before. That is the appeal and rhetorically durable theme which has made this woodcut so appealing.

People in ancient and medieval times knew the Earth was round and not flat. In this they followed the arguments of Plato, Aristotle, Ptolemy, Augustine, Dante, Sacrobosco, and countless others. There was no serious dissent. So this book shows that the myth of the flat Earth was already taking root in the late 19th century.

Many who have reprinted this illustration through the years have not recognized that it first appeared in a popular work on meteorology. Often misattributed to the Middle Ages or Renaissance, this book is its original source. Flammarion was an astronomer and popular science writer who worked at the Juvissy Observatory in Paris.

réfléchit dans le miroir des lacs, donne à la nature sa grâce et sa beauté.

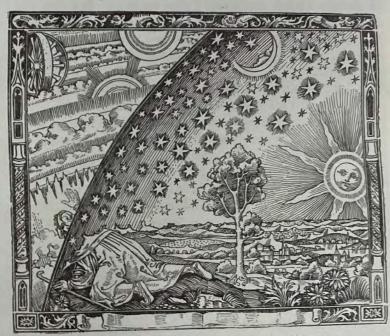
Que le ciel soit pur ou couvert, il se présente toujours à nos yeux sous l'aspect d'une voûte surbaissée. Loin d'offrir la forme d'une circonférence, il paraît étendu, aplati au-dessus de nos têtes, et semble se prolonger insensiblement en descendant peu à peu jusqu'à l'horizon. Les anciens avaient pris cette voûte bleue au sérieux. Mais, comme le dit Voltaire, c'était aussi intelligent que si un ver à soie prenait sa coque pour les limites de l'univers. Les astronomes grecs la représentaient comme formée d'une substance cristalline solide, et jusqu'à Copernic un grand nombre d'astronomes l'ont considérée comme aussi matérielle que du verre fondu et durci. Les poètes latins placèrent sur cette voûte, au-dessus des planètes et des étoiles fixes, les divinités de l'Olympe et l'élégante cour mythologique. Avant de savoir que la Terre est dans le ciel et que le ciel est partout, les théologiens avaient installé dans l'empyrée la Trinité, le corps glorifié de Jésus, celui de la vierge Marie, les hiérarchies angéliques, les saints et toute la milice céleste... Un naîf missionnaire du moyen âge raconte même que, dans un de ses voyages à la recherche du Paradis terrestre, il atteignit l'horizon où le ciel et la Terre se touchent, et qu'il trouva un certain point où ils n'étaient pas soudés, où il passa en pliant les épaules sous le couvercle des cieux.... Or cette belle voûte n'existe pas! Déjà je me suis élevé en ballon plus haut que l'Olympe grec, sans être jamais parvenu à toucher cette tente qui fuit à mesure qu'on la poursuit, comme les pommes de Tantale.

Mais quel est donc ce bleu qui certainement existe, et dont le voile nous cache les étoiles pendant le jour?

Cette voûte, que nos regards contemplent, est formée par les couches atmosphériques qui, en réfléchissant la lumière émanée du Soleil, interposent entre l'espace et nous une sorte de voile fluide qui varie d'intensité et de hauteur suivant la densité variable des zones aériennes. On a été très longtemps à s'affranchir de cette illusion et à constater que la forme et les dimensions de la voûte céleste changent avec la constitution de l'Atmosphère, avec son état de transparence, avec son degré d'illumination.

Une partie des rayons lumineux envoyés par le Soleil à notre planète est absorbée par l'air, l'autre réfléchie; l'air néanmoins n'agit pas également sur tous les rayons colorés dont se compose la lumière blanche: il se comporte comme un verre laiteux, laisse passer plutôt les rayons

de l'extrémité rouge du spectre solaire, et réfléchit au contraire les rayons bleus; mais cette différence n'est sensible que lorsque la lumière traverse de grandes masses d'air. Les montagnes lointaines se nuancent d'une teinte bleuâtre due à cette réflexion des particules de l'air et surtout de la vapeur d'eau qui s'interpose entre ces montagnes et l'observateur. Une expérience de Hassenfratz prouve aussi que le rayon bleu est réfléchi avec plus de force. En effet, plus la couche



Un missionnaire du moyen âge raconte qu'il avait trouvé le point où le ciel et la Terre se touchent...

atmosphérique qu'un rayon traverse est épaisse, plus les rayons bleus disparaissent pour laisser la place aux rouges; or, quand le soleil est près de l'horizon, le rayon parcourt une plus grande épaisseur d'air: aussi cet astre nous paraît-il rouge, pourpre ou jaune. Les rayons bleus manquent souvent aussi dans les arcs-en-ciel qui apparaissent peu de temps avant le coucher du Soleil.

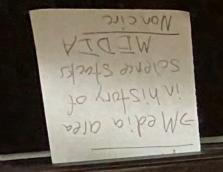
Nous verrons plus loin que c'est la vapeur d'eau répandue dans l'air qui joue le rôle principal dans cette réflexion de la lumière à laquelle est dû l'azur du ciel aussi bien que la clarté diffuse du jour.

Tout récemment, John Tyndall, le savant professeur anglais, vient









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