

Piazzi 200

Palermo, 30 September – 2 October 2026

From Tycho Brahe to Giuseppe Piazzi: Two Centuries that Revolutionized Stellar Observation

Giorgio Strano
Museo Galileo, Florence

Piazzi's Instruments for Measuring Star Coordinates



Jesse Ramsden, *Azimuthal circle*
London, 1787-1789



Cumming & Grant, *Pendulum clock*, London, 1790



Mudge & Dutton, *Pendulum clock*, London, 1791

PRÆCIPUARUM
STELLARUM INERRANTIUM

POSITIONES MEDIÆ

INEUNTE SECCULO XIX

EX OBSERVATIONIBUS HABITIS

IN SPECULA PANORMITANA

ab anno 1792 ad annum 1802.

Omnia rerum principia parva, sed suis progressionibus
usa augentur.

Cic. v. De Finibus,



PANORMI M. DCCC. III.

TYPE REGIIS.

XV



Extracta Specula,* optimisque munita instrumentis,
multiplici observationum genere inventa ipsius Poli
altitudine, per plurimas inspectas occultationes stella-

PRÆCIPUARUM
STELLARUM INERRANTIUM

POSITIONES MEDIÆ

INEUNTE SEculo XIX

EX OBSERVATIONIBUS HABITIS

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Cic. v. De Finibus.



PANORMI M. DCCC. III.

TYPE REGIIS.

§. XXIII.

De Transitus Instrumento.

Tubus meridianus, sive Transitus Instrumentum, similiter Ramsdenii opus. Duabus insistit solidissimis marmoreis columnis; fulcra, primum ex metallo, jam

quatuor ab hinc annis ex achate affabre perpolito fieri curavi. Reticulum per axem illuminatur ut in circulari telescopio. Focus lentis objectivæ, quæ acromatica est, quinque pedum. Lens ocularis coclea ad quinque reticuli fila successive transfertur; vis amplificativa octogies. Cætera ut in omnibus hujus generis instrumentis: axis horizontalis positio libella ex spiritu examinatur & corrigitur; signo ad unius milliarii distantiam versus Boream, in meridiano restituitur.

§. XXIV.

De Horologiis.

Duo sunt horologia, utraque pendulis ex cupreis chalibeisque virgis instructa. Unum Præstantissimorum Artificum Dutton & Mudge, alterum Coming, & Grant. Hoc Circulo, illud tubo meridiano destinatum. Utriusque motus maxime regulares, Mudgiani præcipue.

§. XXV.

Giuseppe Piazzi, *Praecipuarum stellarum inerrantium positiones mediae ineunte seculo XIX*, Palermo, 1803, pp. XXXVIII-XXXIX

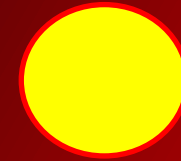
The Old Way

Claudius Ptolemy (2nd Century A.D.)

Μαθηματικὴ Σύνταξις (Mathēmatikḗ Sýntaxis) – The Almagest, in 13 books

Book 1: is (mostly) about spherical geometry

Books 1 (part) - 3: are about the Solar theory

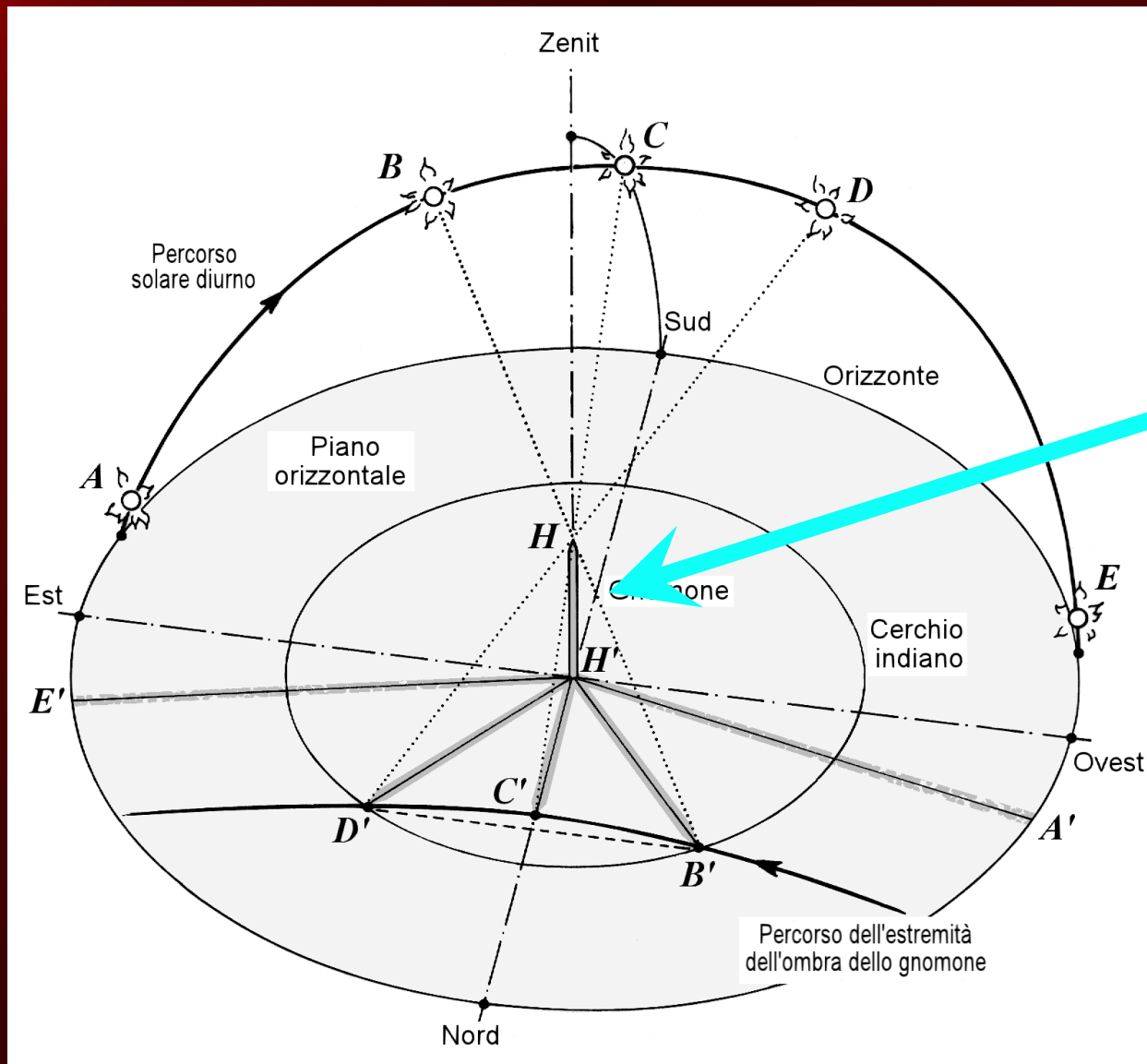


Books 4 - 6: are about the Lunar theory



Books 7 - 13: are about the stars and the planets



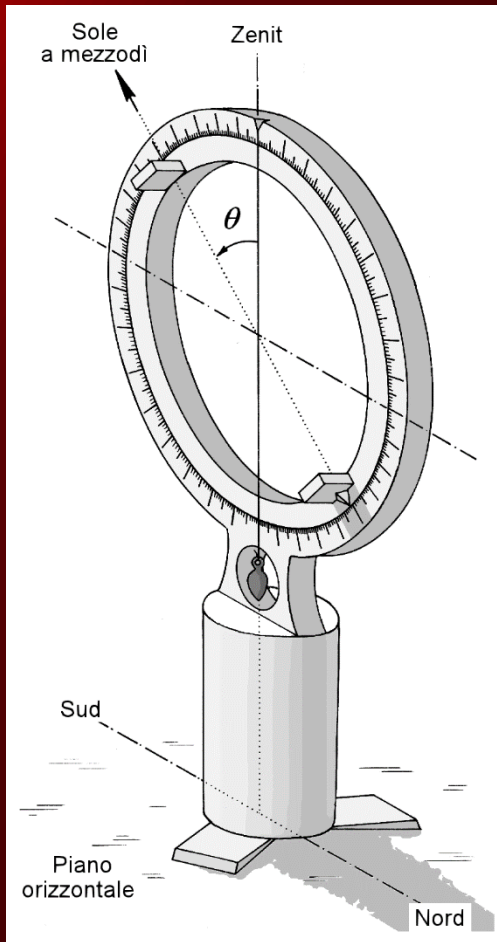


The Almagest

Books 2-3

The gnomon (a vertical stick) for determining the four cardinal points, *i.e.* the meridian line.

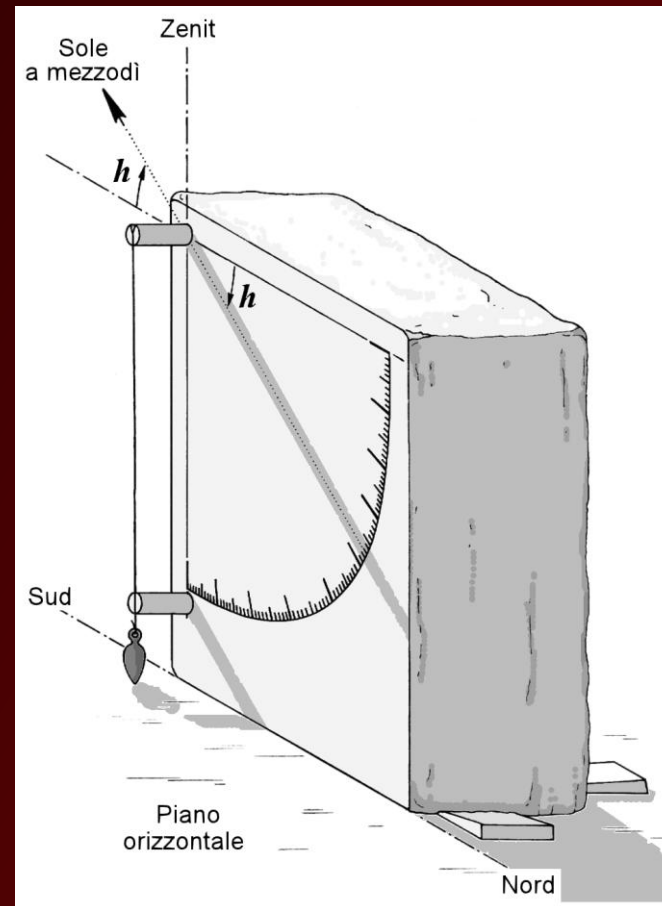


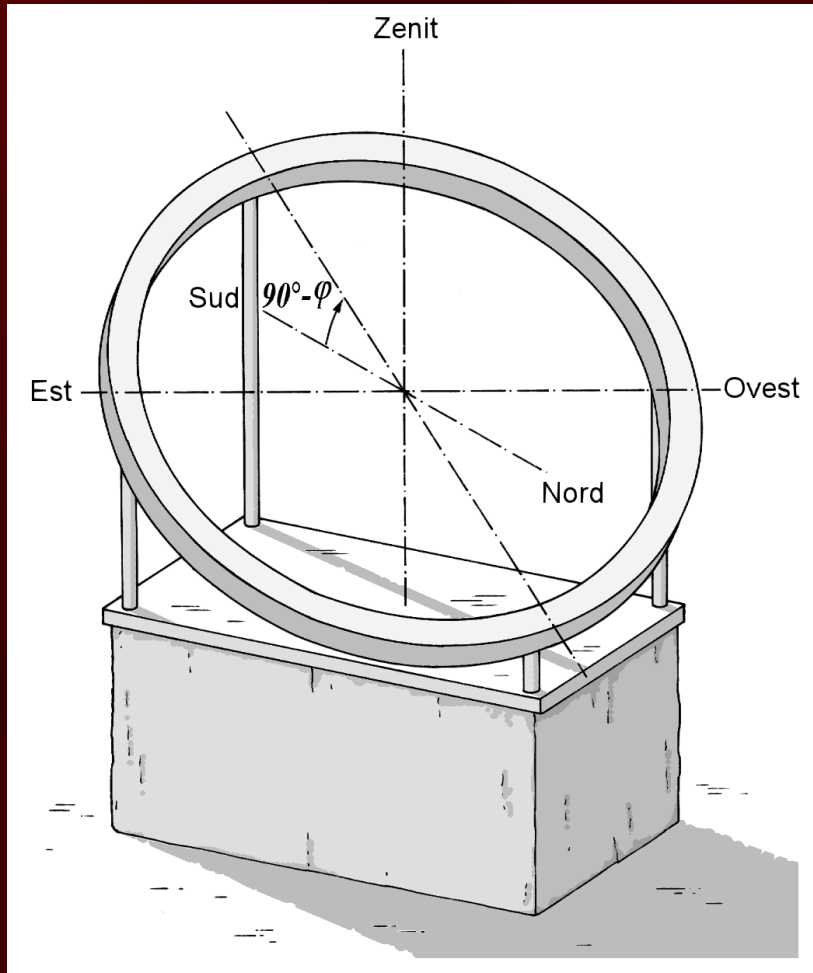


The Almagest

Books 2-3

The meridian armillary / the plinth
(vertically placed in the meridian) for
determining the obliquity of the ecliptic.



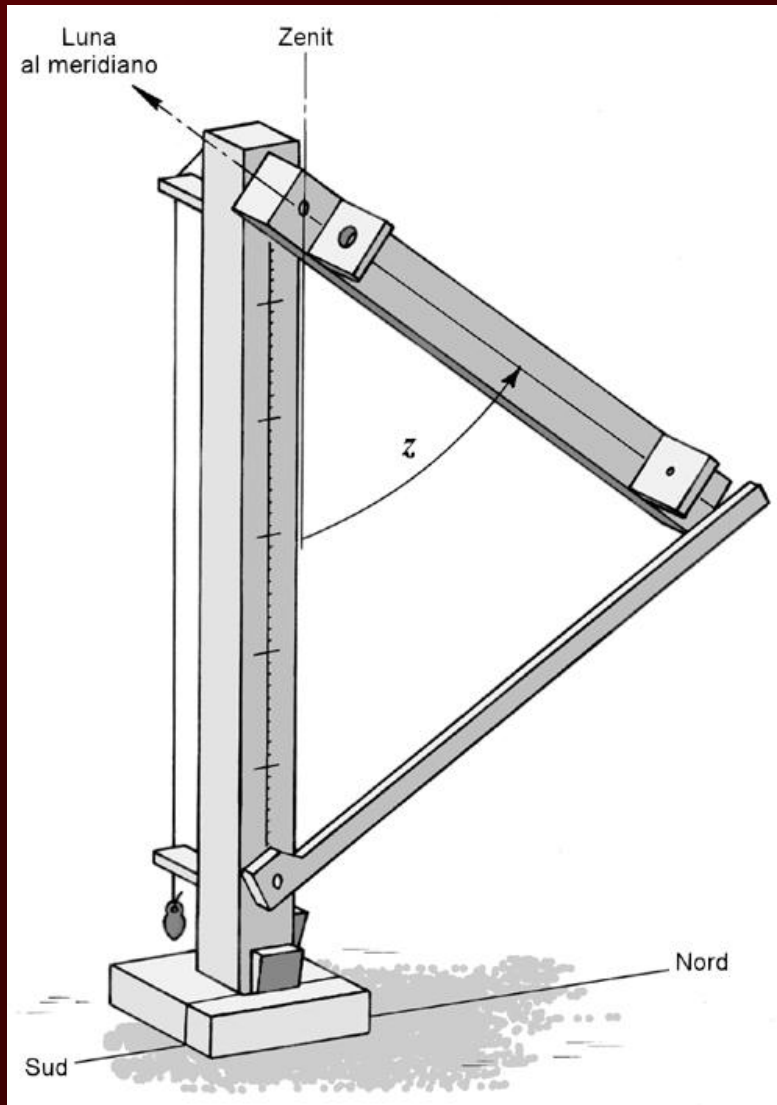


The Almagest

Books 2-3

The equatorial armillary (placed in the plane of the celestial equator) for determining the “instants” of the equinoxes.



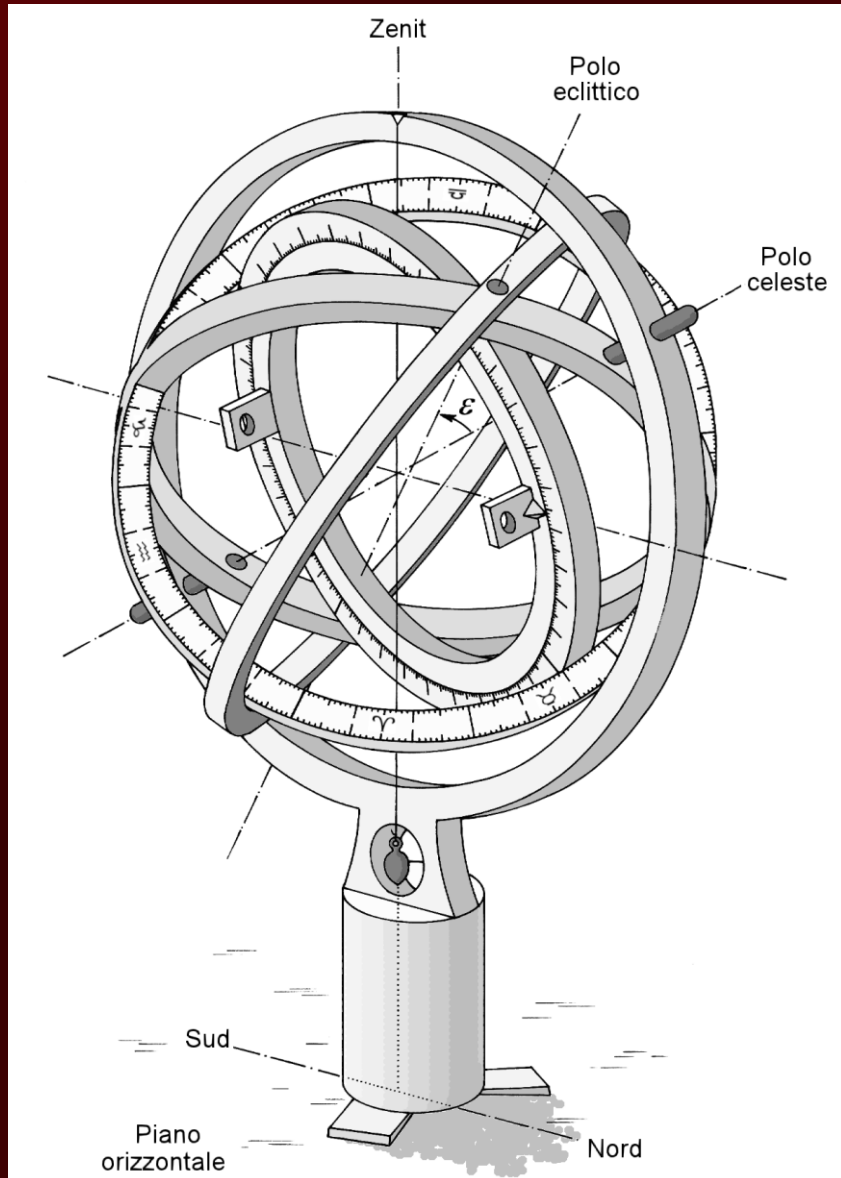


The Almagest

Books 4-6

The parallactic instrument (vertically placed in the meridian) for determining the diurnal parallax of the Moon.

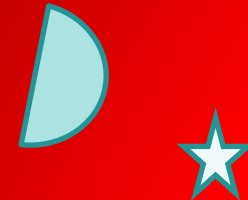




The Almagest

Books 4-6

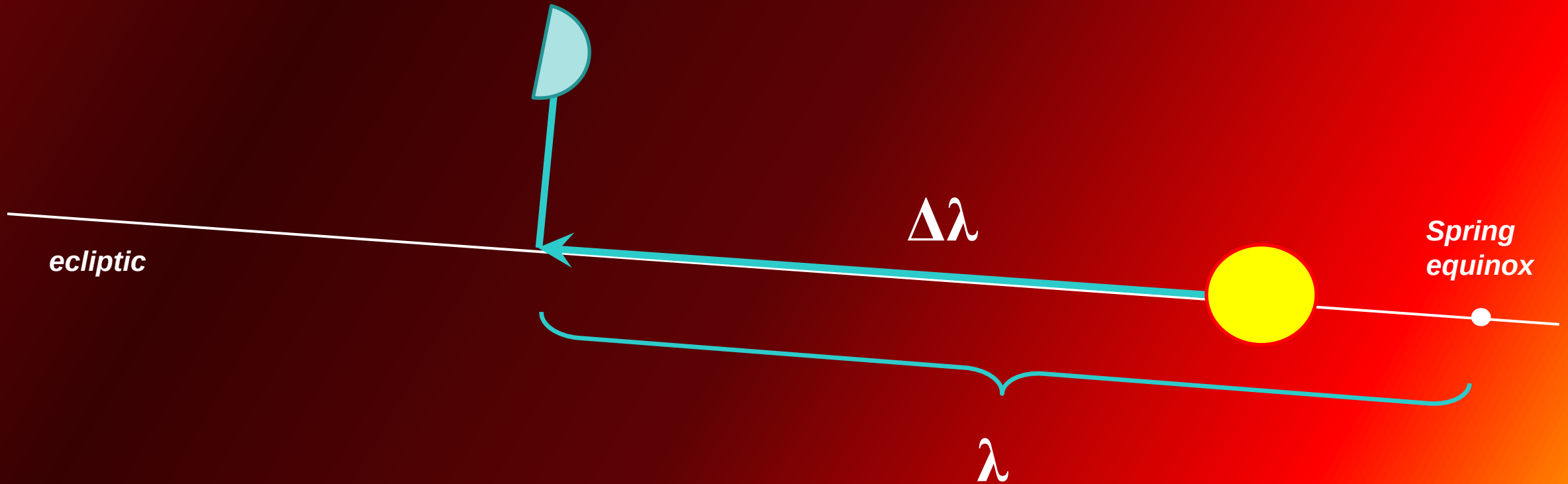
The astrolabic instrument (vertically placed in the meridian) for determining the ecliptic longitude and latitude of any other celestial body.



The observational praxis

BY DAY

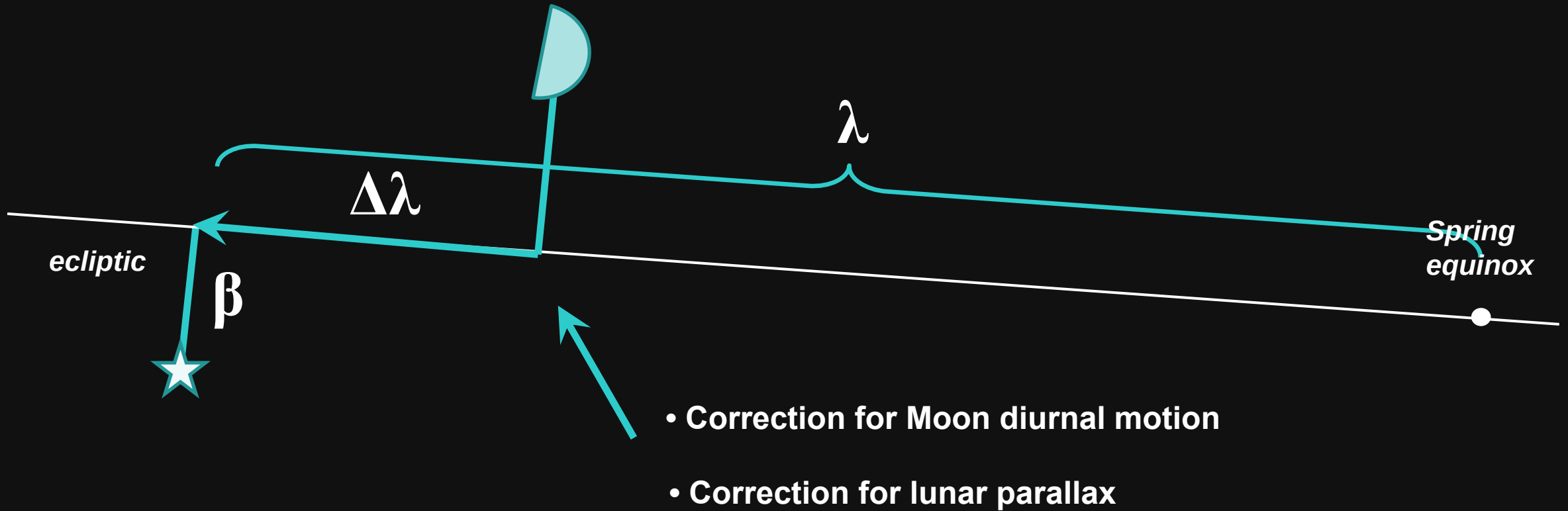
when both the Sun and the
Moon are visible



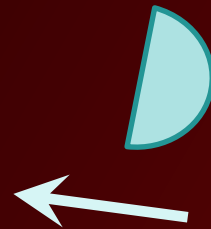
The observational praxis

BY NIGHT

when both the Moon and the
star are visible



The observational praxis
Hourly movements
(Neglecting diurnal motion)



- Hourly motion
c. $0.6^\circ / \text{h}$
- Diurnal parallax
(max $\pm$ c. 1°)

Ptolemy's theory of the Moon was very complicated, but vital for determining star ecliptical coordinates (λ , β).



- Hourly motion
c. $0,025^\circ / \text{h}$

Anonimo, *Tycho Brahe* (1546-1601), 17th Century
(Uffizi Gallery, Florence)



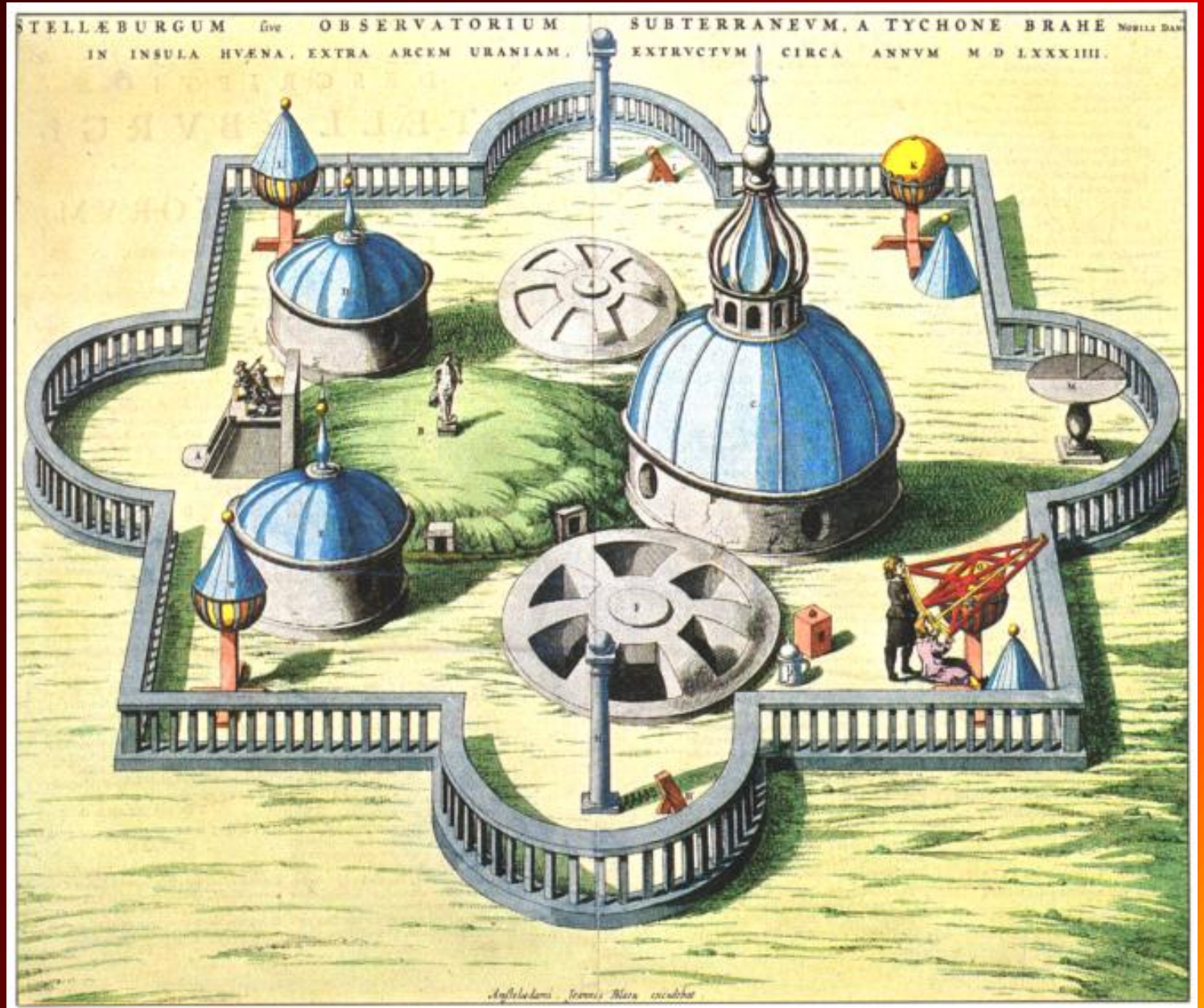


Uraniburgum 1576-1597

Willem Janszoon Blaeu, *Atlas Maior, sive Cosmographia Blaviana*, Amsterdam, 1662-1672

Stellaeburgum 1584-1597

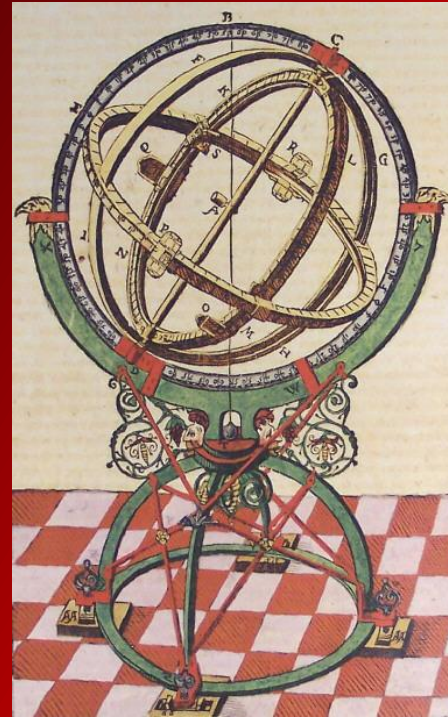
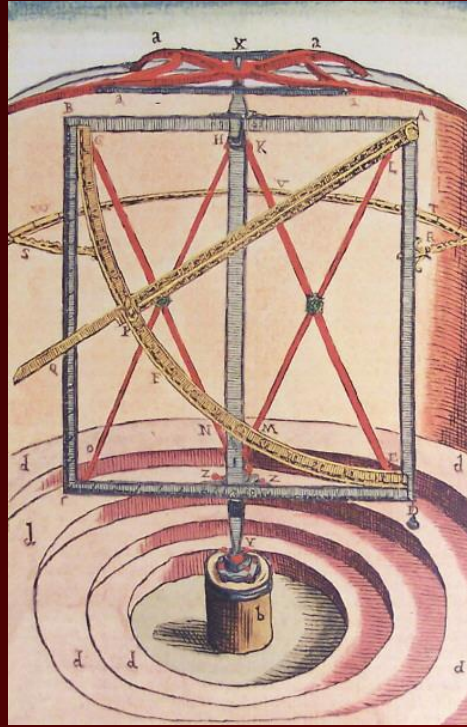
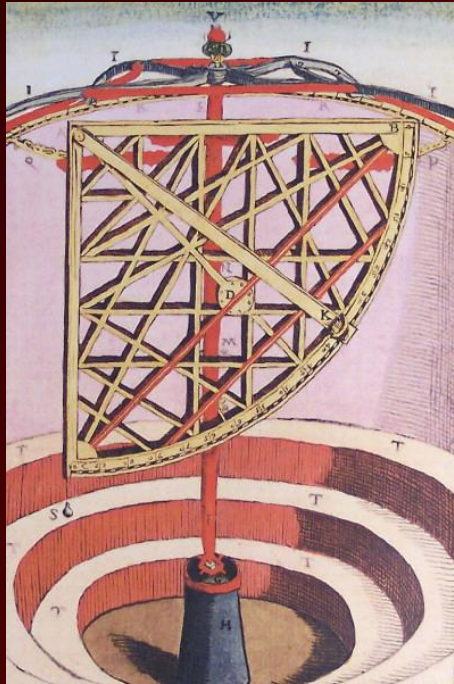
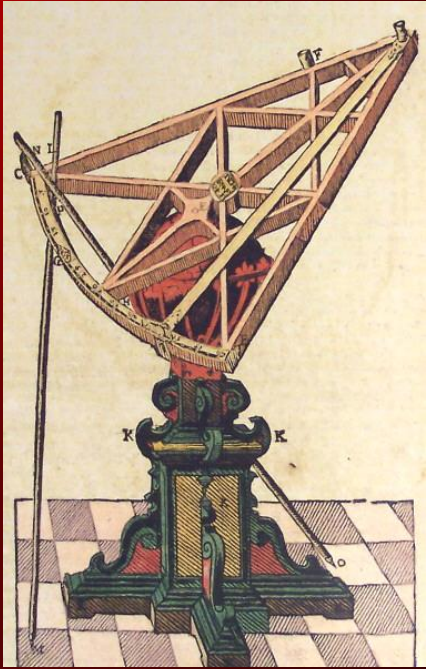
Willem Janszoon Blaeu, *Atlas Maior*,
sive Cosmographia Blaviana,
Amsterdam, 1662-1672



Tycho Brahe's mural quadrant

Tycho Brahe, *Astronomiae Instauratae Mechanica*,
Wandsbeck, 1598

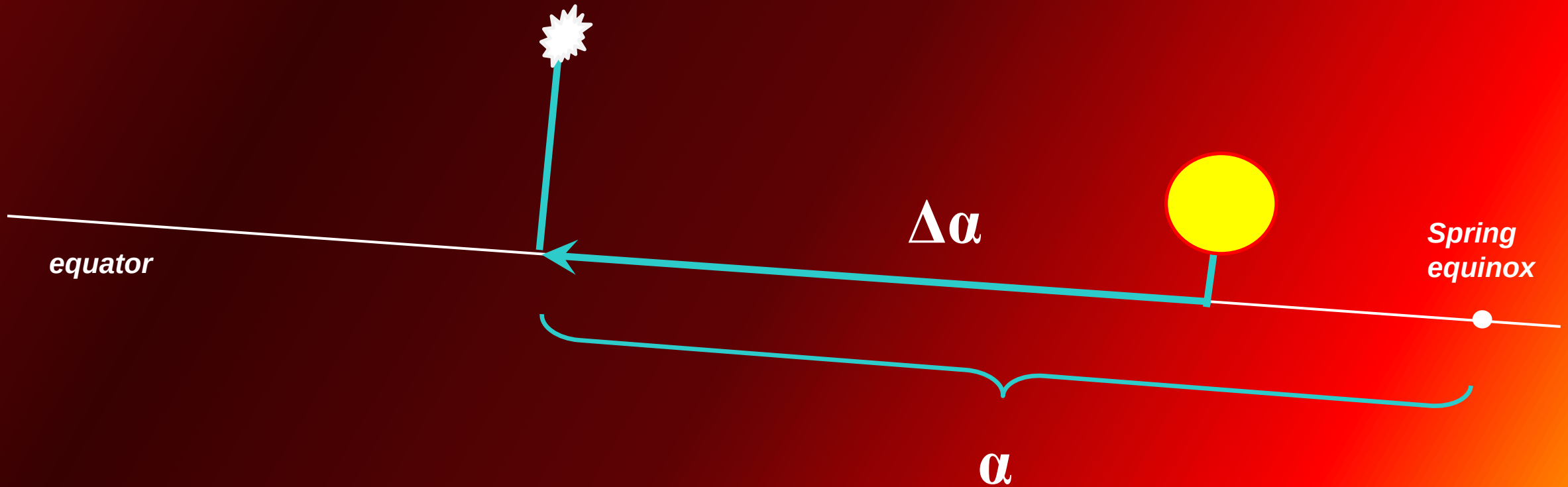




The observational praxis

BY DAY

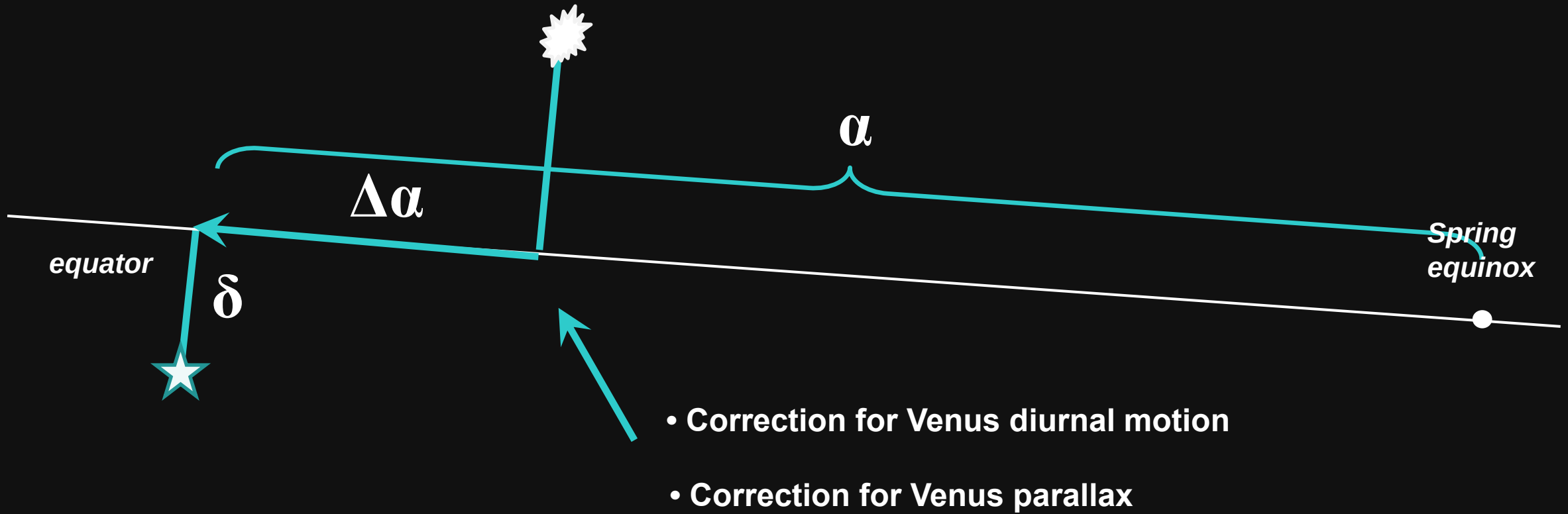
when both the Sun and the
Venus are visible



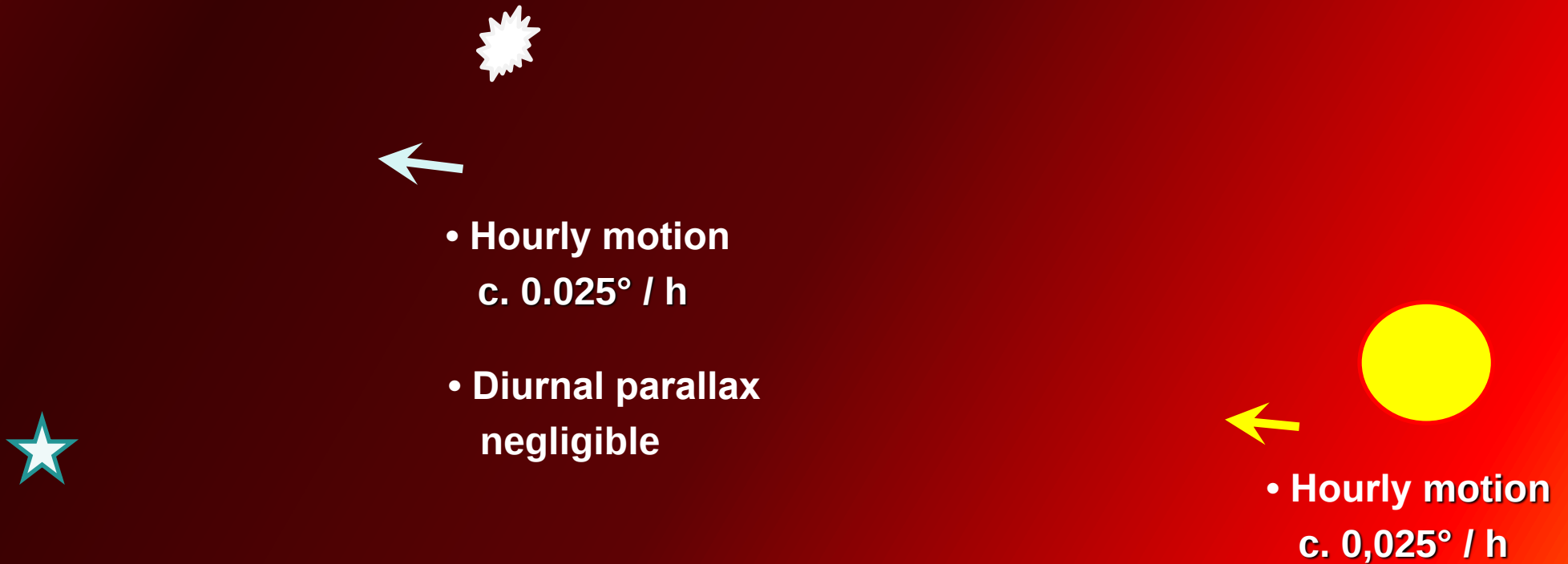
The observational praxis

BY NIGHT

when both the Venus and the
star are visible



The observational praxis
Hourly movements
(Neglecting diurnal motion)



**A theory of the motion of Venus is not relevant
for determining star coordinates (α , δ).**

Mechanical Clocks



Some of Tycho Brahe's clocks

Daily gains and losses up to 25 minutes!

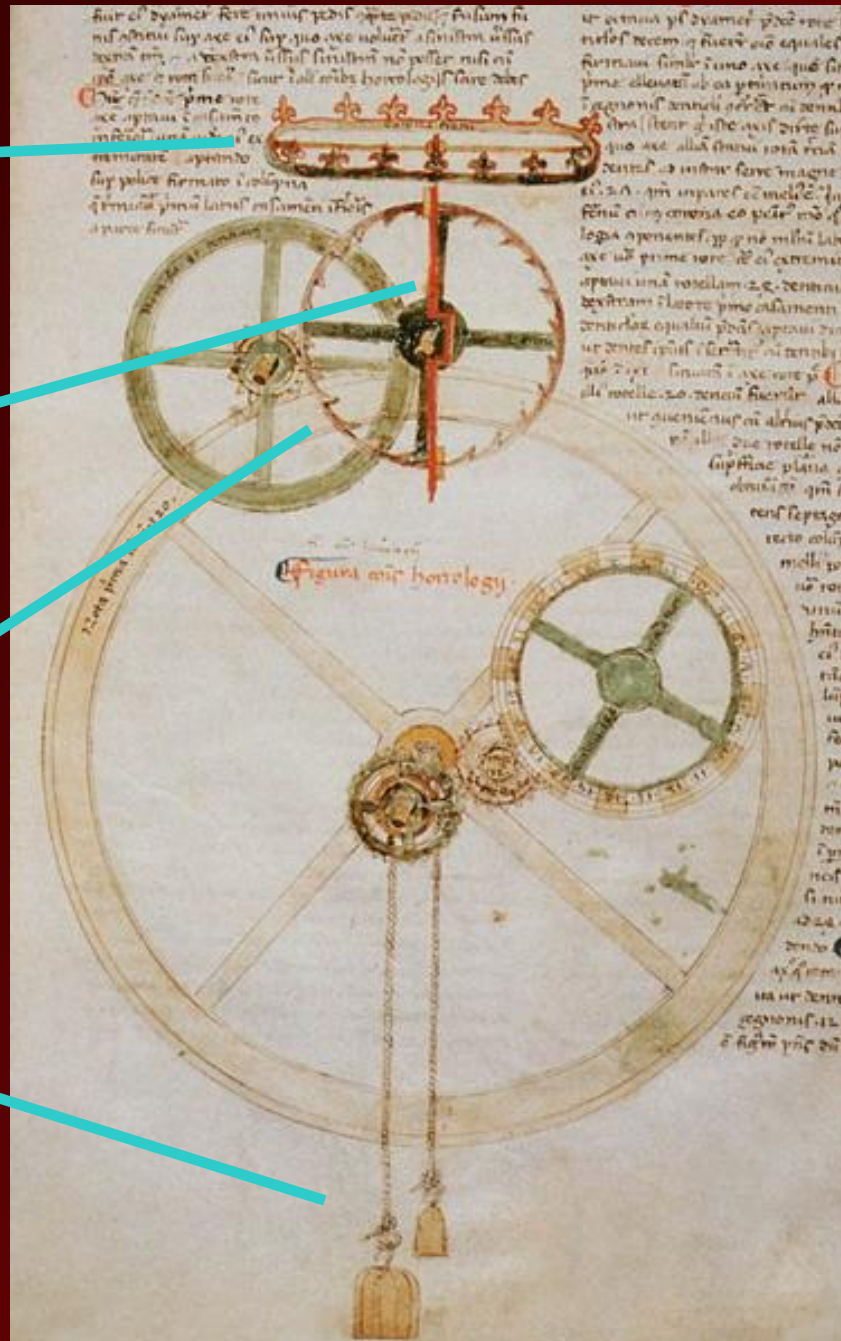
Tycho Brahe, *Astronomiae Instauratae Mechanica*,
Wandsbeck, 1598

- Balance crown-wheel
(regulates the motion)

- Verge escapement
(modulates the driving force)

- Gear train
(reduces the motion speed)

- Weights
(produce the driving force)



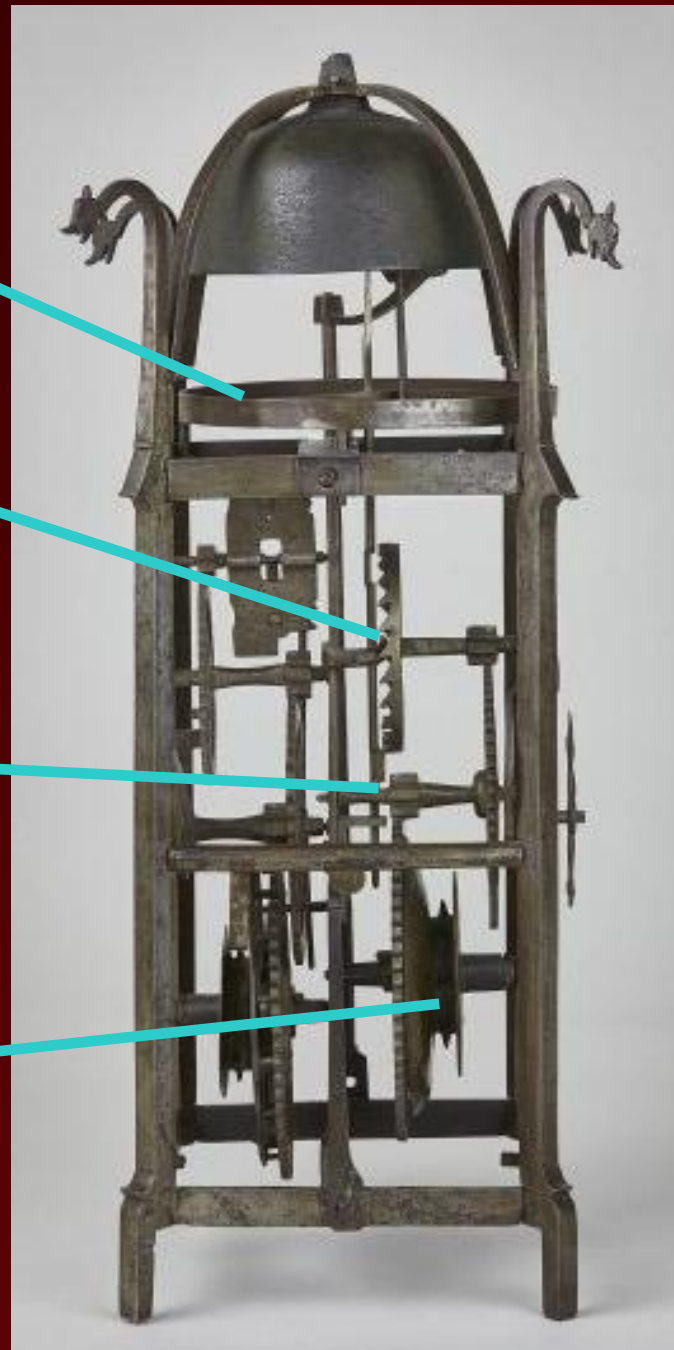
Giovanni Dondi,
Trasctatus astrarii,
c. 1375, Padua, Biblioteca
Capitolare, MS. D39

- **Balance crown-wheel**
(regulates the motion)

- **Verge escapement**
(modulates the driving force)

- **Gear train**
(reduces the motion speed)

- **Weights**
(produce the driving force)



Italian, *Mechanical clock*,
15th-16th Century
(Museo Galileo, inv. 3935)



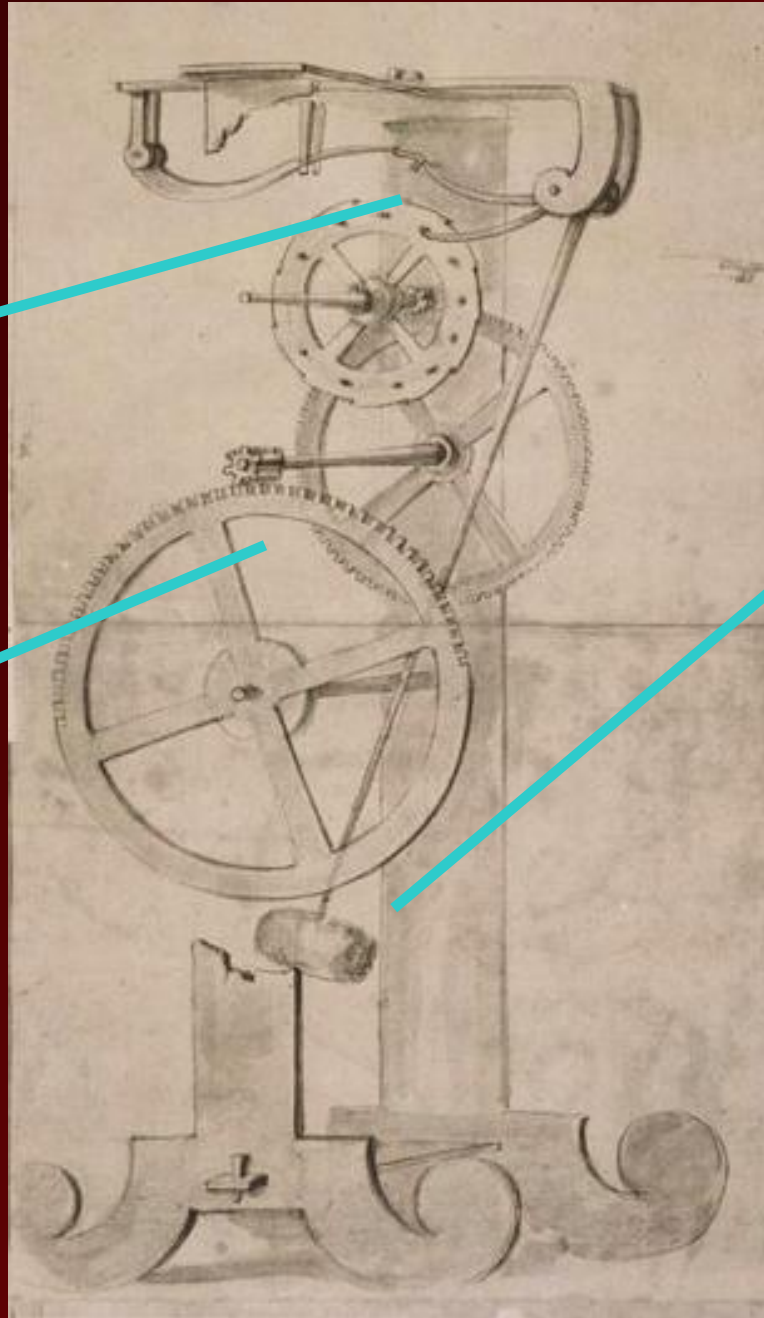
Galileo Galilei
(1564-1642)

Justus Sustermans
Galileo Galilei, Florence, 1635
(Uffizi Gallery, Florence)

- Galileo's escapement
(modulates the driving force)

- Gear train
(reduces the motion speed)

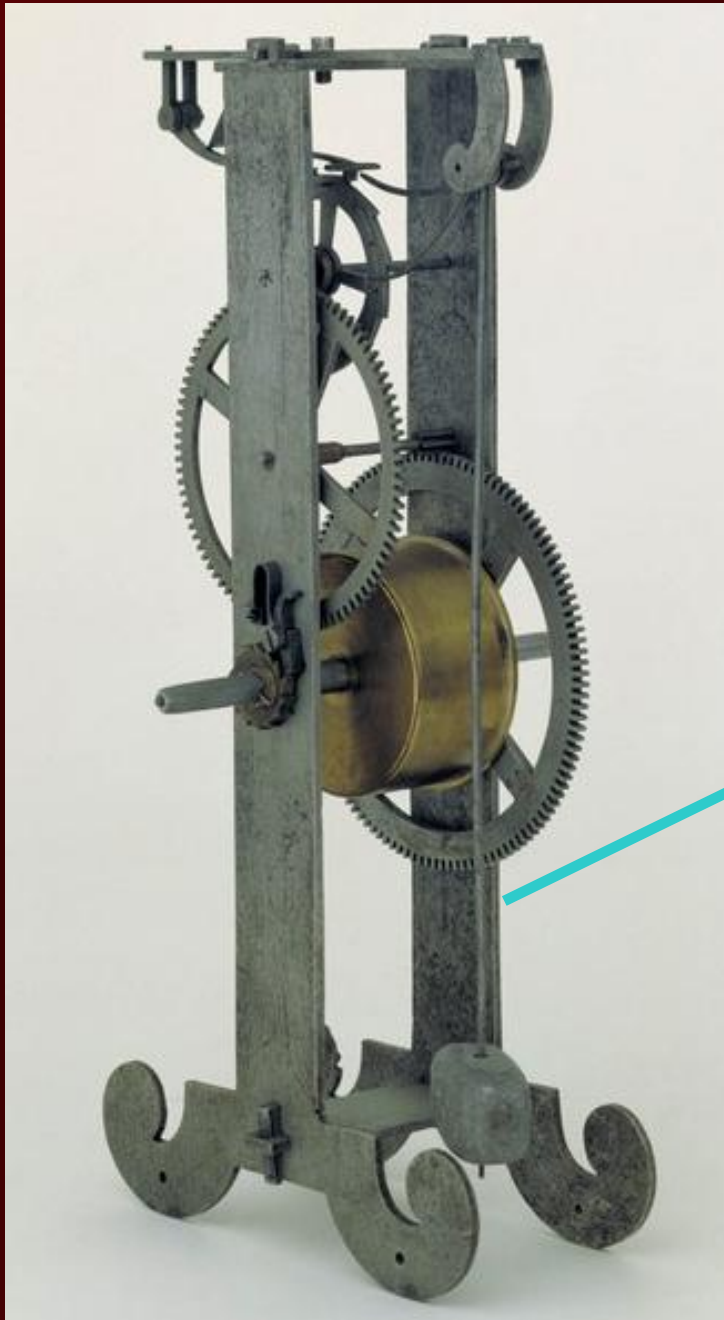
- Weights? Spring?
(produce the driving force)



- Simple pendulum
(regulates the motion)

Vincenzo Viviani, Galileo's
pendulum clock, c. 1640

(Florence, Biblioteca
Nazionale Centrale, MS.
Gal 85, c. 50)



Eustachio Porcellotti, *Reconstruction of Galileo's pendulum clock*, Florence, 1860

(Museo Galileo, Florence, inv. 3450)

- The rhythm of the simple pendulum is a constant for small oscillations only!
- If the width of the oscillations changes, the rhythm of the beats varies!



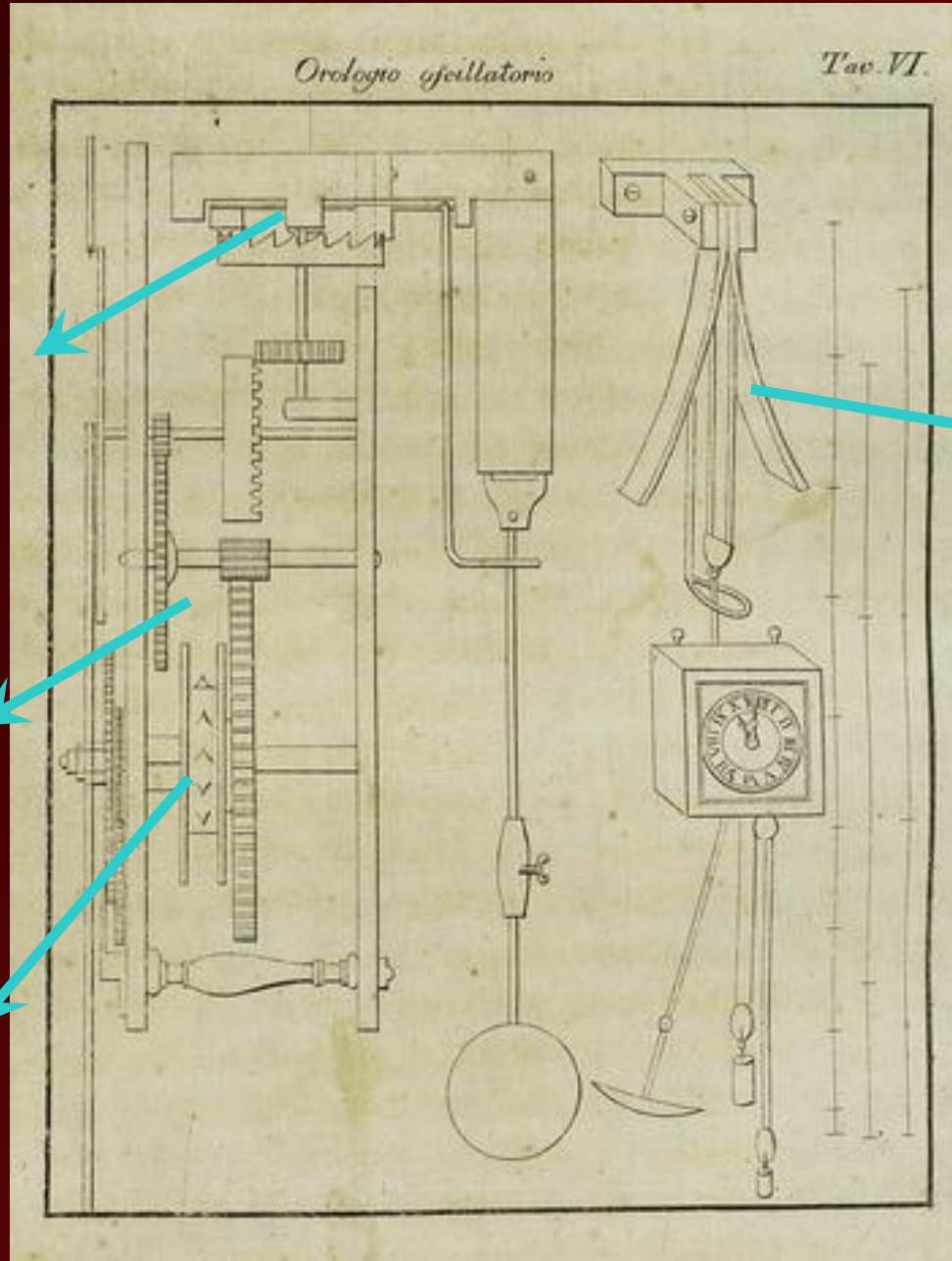
**Christiaan Huygens
(1629-1695)**

Caspar Netscher
Christiaan Huygens, The Hague, 1671
(The Hague, Haags Historisch Museum)

• **Verge escapement**
(modulates the driving force)

• **Gear train**
(reduces the motion speed)

• **Weights (not shown)**
(produce the driving force)



• **Cycloidal pendulum**
(regulates the motion)

Christiaan Huygens
Horologium oscillatorium,
Paris, 1673



Johann Philipp Treffler, *Pendulum clock drive*, Augsburg, c. 1659

(Museo Galileo, Florence, inv. 3557)

- **Cycloidal pendulum guide(s)**
(the other one was broken; the pendulum is also missing)
- **The rhythm of the cycloidal pendulum is independent from the width of its oscillations!**



**George Graham
(1673-1751)**

**Thomas Hudson, George Graham,
London, c. 1745
(London, Science Museum)**



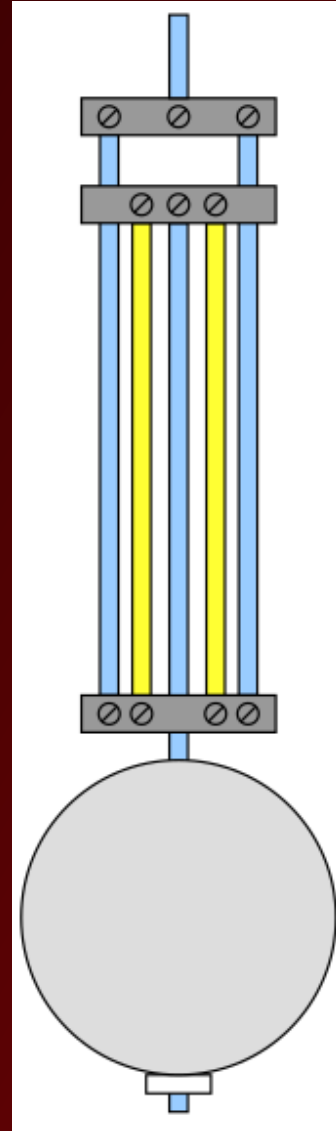
Mercury Pendulum 1721

Robert Pennington, *Astronomical
regulator*, London, c. 1810
(London, Royal Museum Greenwich)

**John Harrison
(1693-1776)**



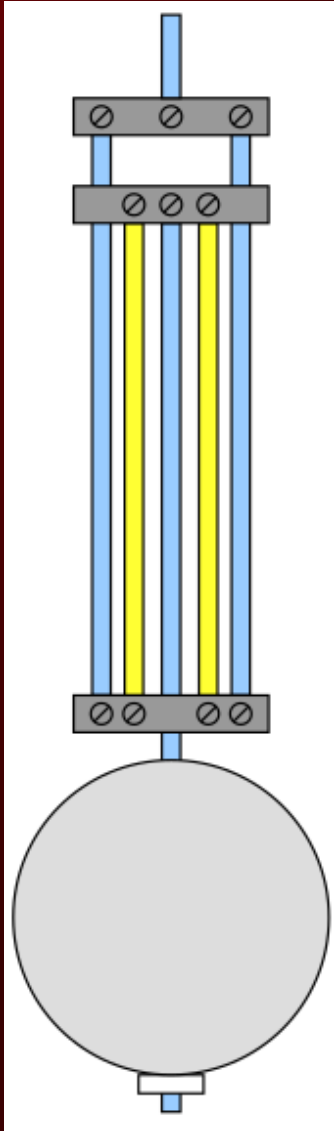
Thomas King, *John Harrison*,
London, 1767
(London, Science Museum)



Gridiron pendulum

c. 1726

Carlo Grindel, *Astronomical regulator*,
Milan, c. 1830
(INAF – Osservatorio Astronomico di
Brera, Milan)



Cumming & Grant, *Pendulum clock*, London, 1790



Mudge & Dutton, *Pendulum clock*, London, 1791

Iron and brass bars

Graduated Scales

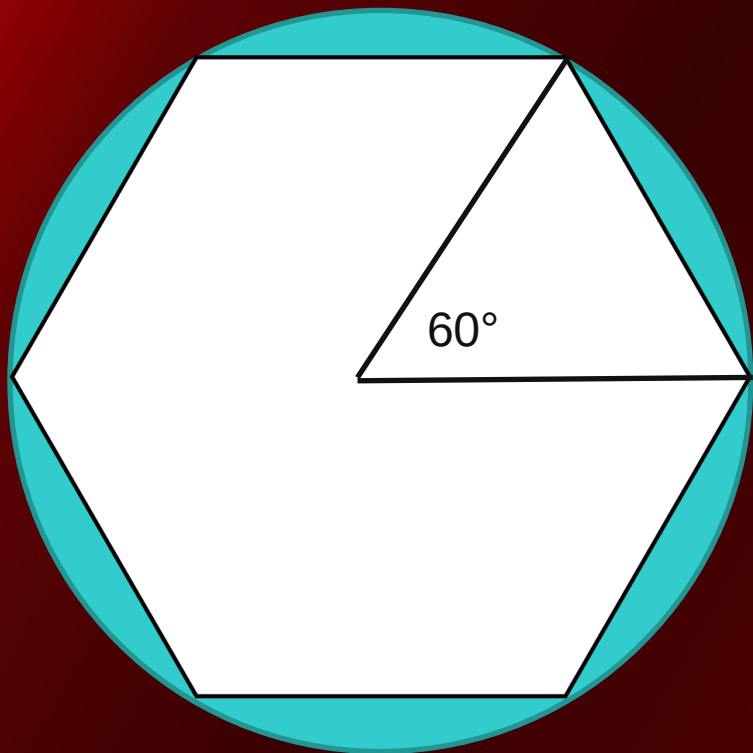
Claudius Ptolemy (2nd Century A.D.)

Μαθηματικὴ Σύνταξις (Mathēmatikḗ Sýntaxis) – The Almagest, in 13 books

Book 1: is (mostly) about spherical geometry

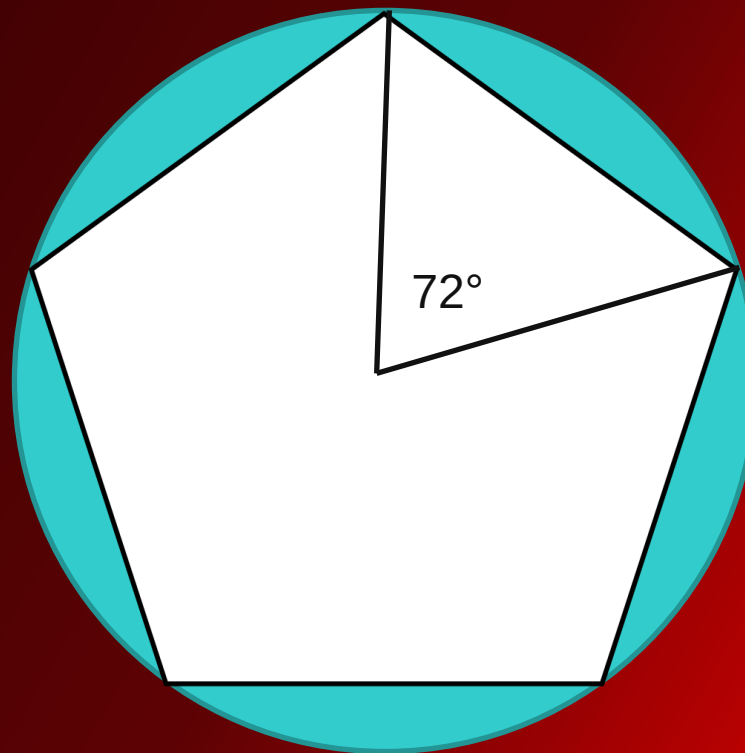
It also contains:

- **How to draw a regular pentagon with rule and compass**
- **A table of chords for each degree**



$$60^\circ : 2 = 30^\circ$$

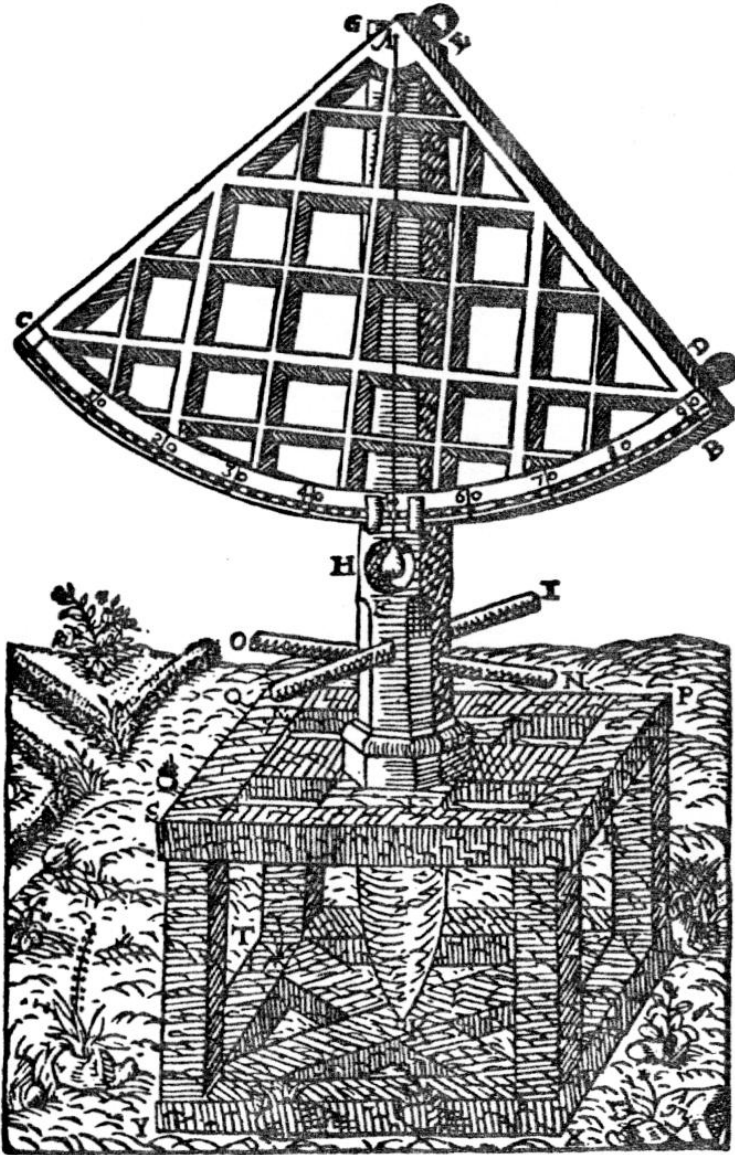
$$30^\circ : 2 = 15^\circ$$



$$72^\circ : 2 = 36^\circ$$

$$36^\circ : 2 = 18^\circ$$

$$18^\circ - 15^\circ = 3^\circ$$



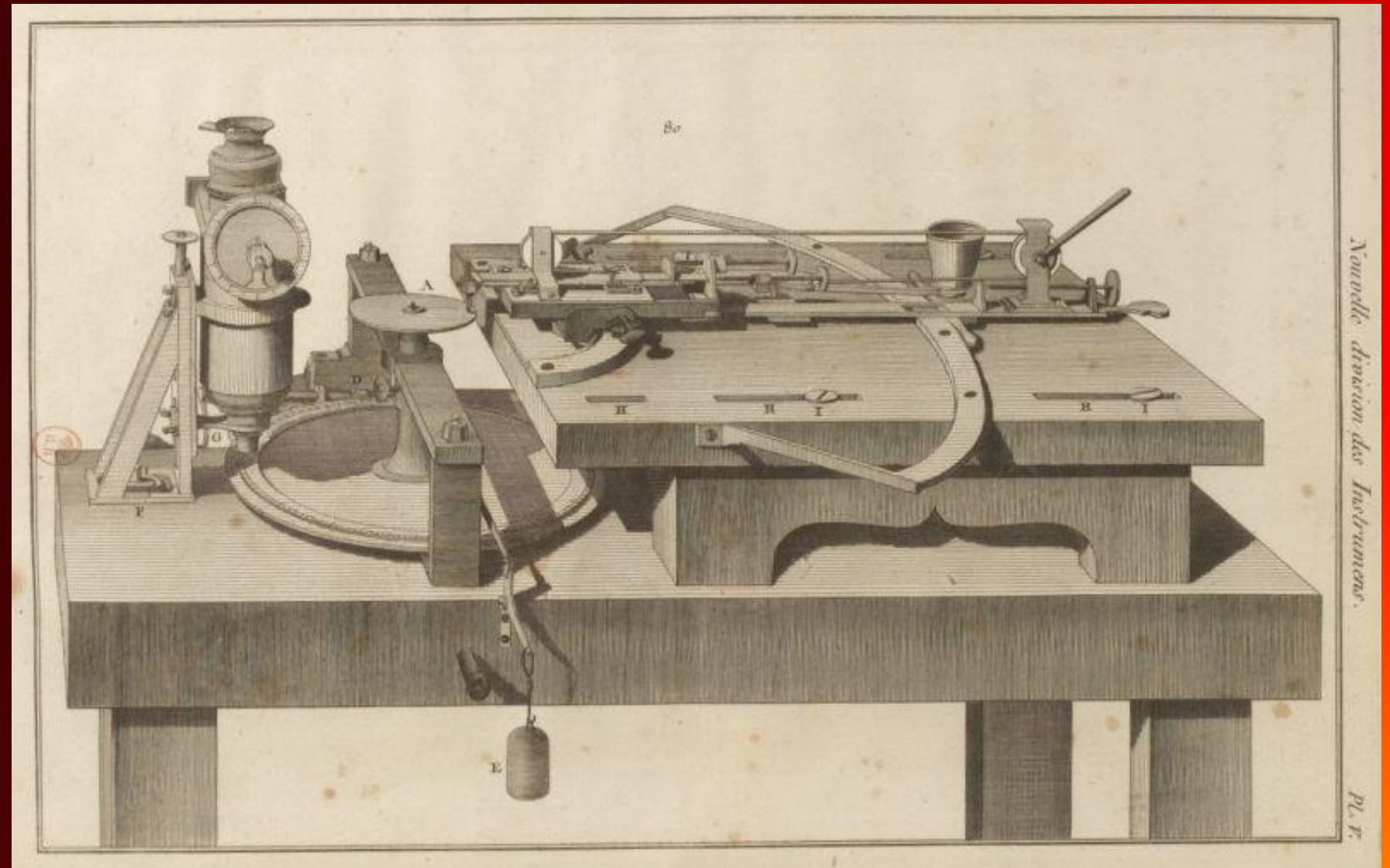
Tycho Brahe; *Astronomiae
Instauratae Mechanica*,
Wandsbeck, 1598

Carlo Rinaldini, *Astronomical
quadrant*, Florence, 1667
(Museo Galileo, Florence,
inv. 2544, 3187)

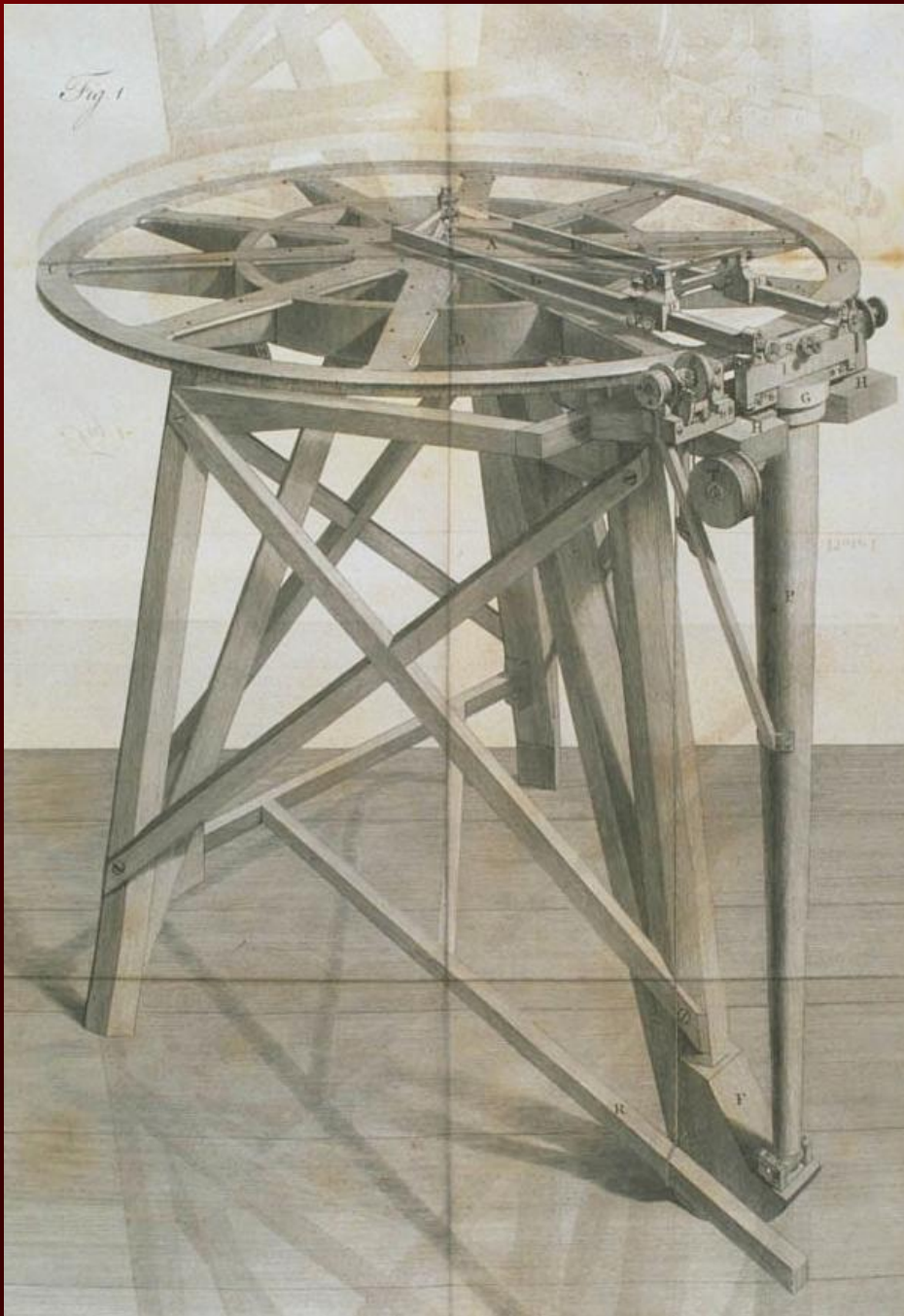




Anonymous, *Circle dividing engine*, Florence, 1762
(Museo Galileo, Florence, inv. 586, 3244)



Michel-Ferdinand d'Albert d'Ailly (Duc de Chaulnes), *Nouvelle méthode pour diviser les instruments de mathématique et d'astronomie*, Paris, 1768



Jesse Ramsden, *Description on an engine
for dividing mathematical instruments*,
London, 1777

Fractions of a Degree

Claudius Ptolemy (2nd Century A.D.)

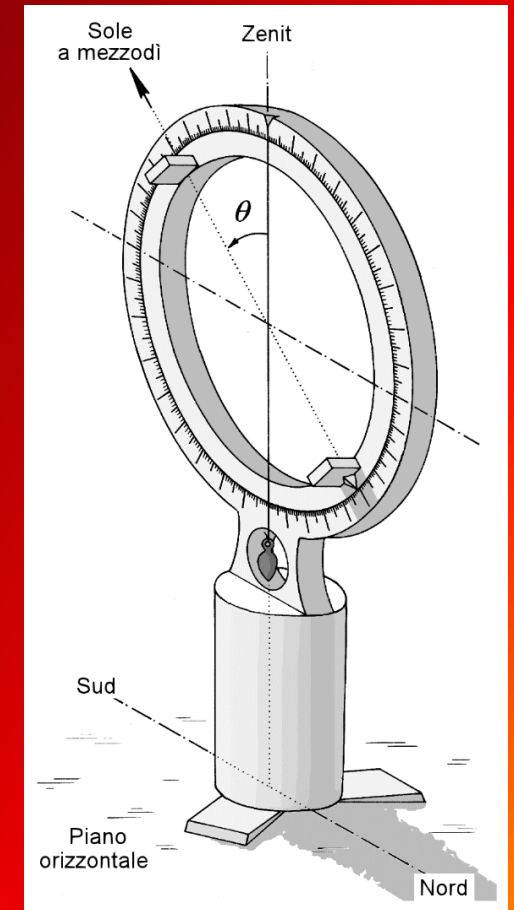
Μαθηματικὴ Σύνταξις (Mathēmatikḗ Sýntaxis) – The Almagest, in 13 books

Books 1 (part)-3: are about the Solar theory

“We use this as a meridian circle, by dividing it into the normal 360 parts of a great circle, and subdividing each degree into as many parts as [the size of the instrument] allows.” [Book 1, 12]

Books 7 - 8: Ptolemy's star catalogue

The minimal degree fraction in the data is $1/6^\circ$, *i.e.* 10'



Linear divisions



Gualterus Arsenius, *Planispheric astrolabe* (detail of its back), Leuven, 1572
(Museo Galileo, inv. 1103)

Linear divisions

The larger, the better...

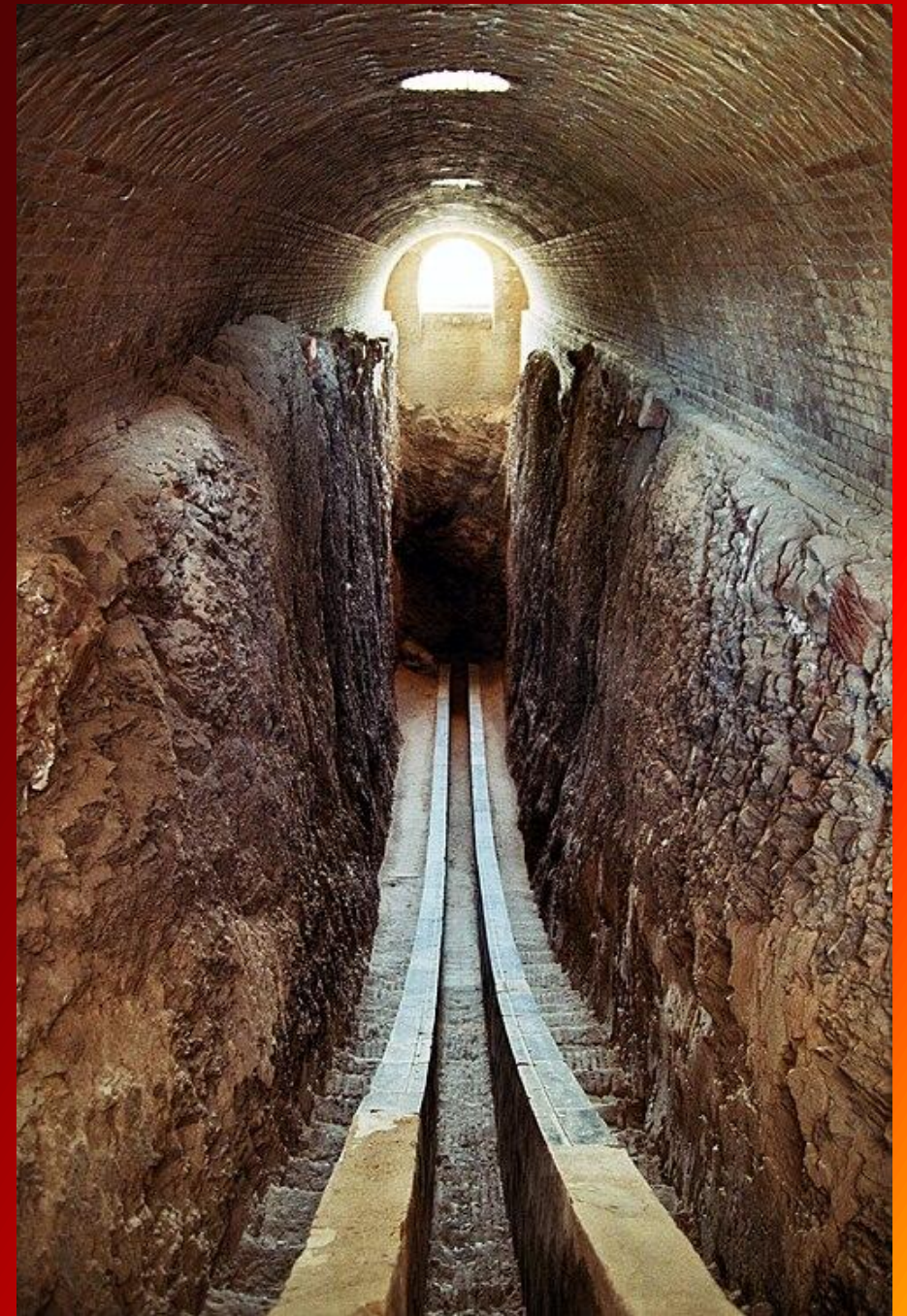
Ulugh Beg, *Meridian Quadrant or Sextant*,
Samarkand, 1420s

Radius c. 40 m

$1^\circ = \text{c. } 70 \text{ cm}$

$1' = \text{c. } 12 \text{ mm}$

$5'' = \text{c. } 1 \text{ mm}$

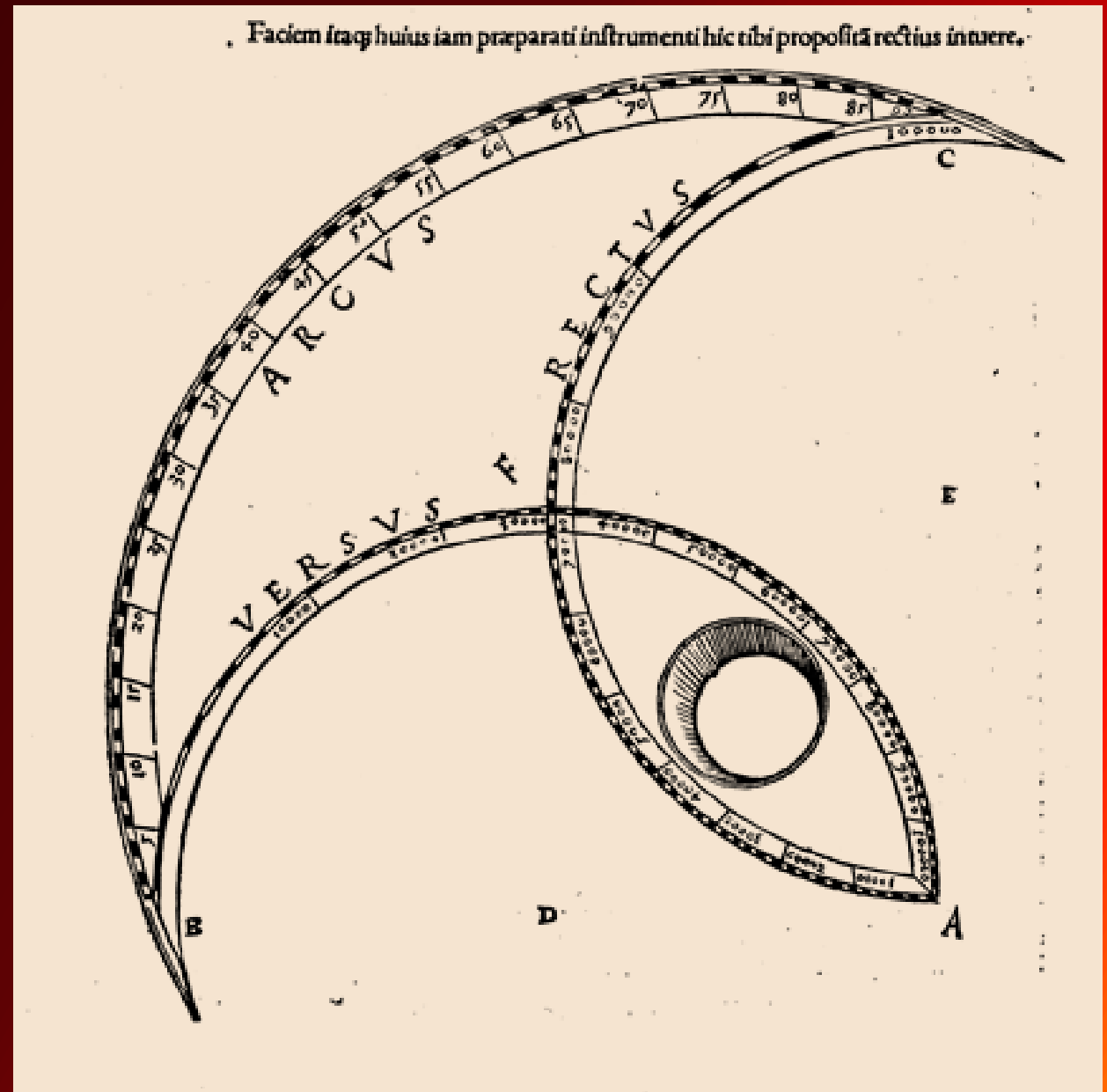


Stratagems



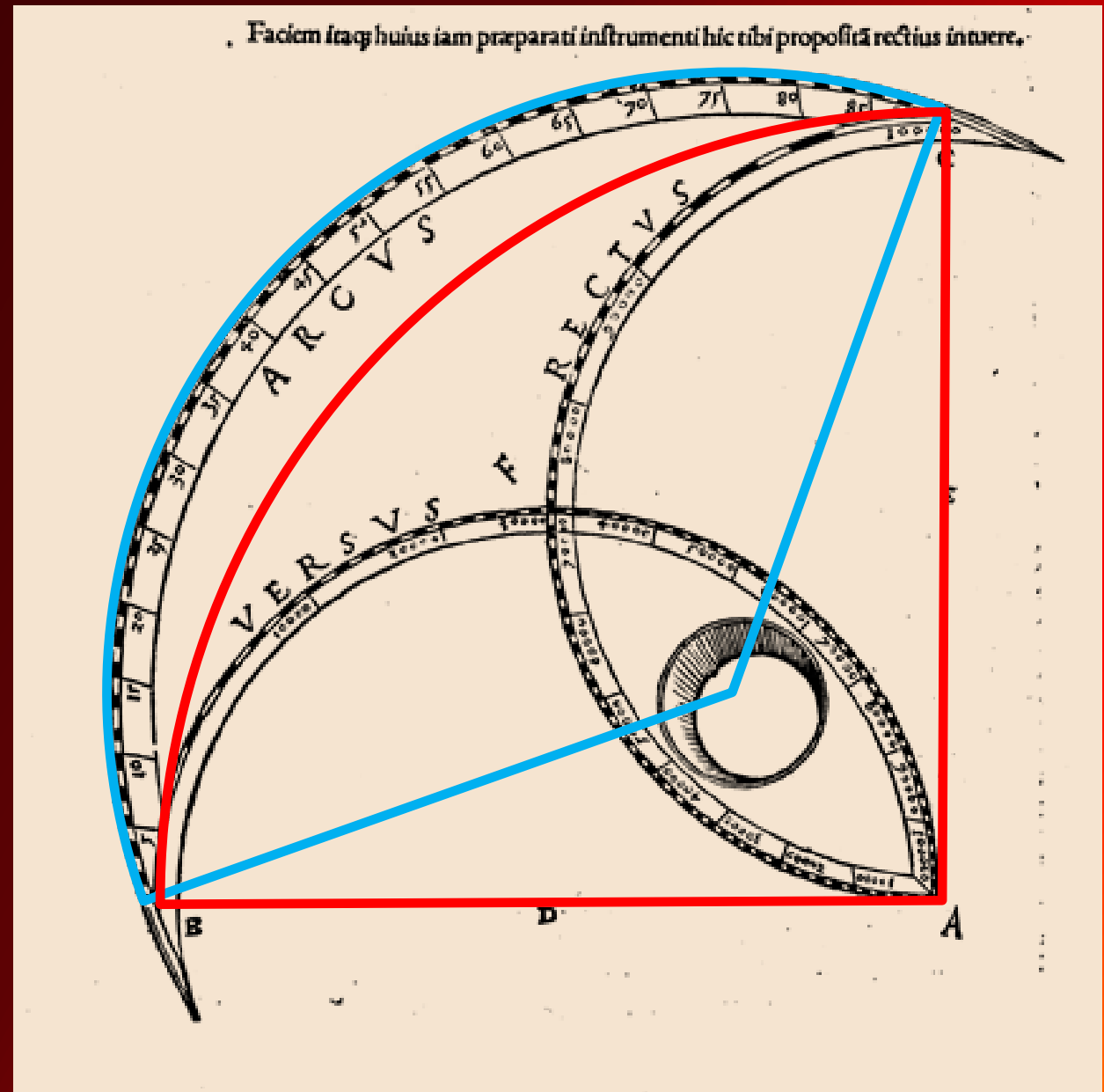
Petrus Apianus

Instrumentum primi mobilis
Nuremberg, 1534, Fol. b 1 v



Stratagems

The 90° scale is spread over a 120° arc.



Stratagems



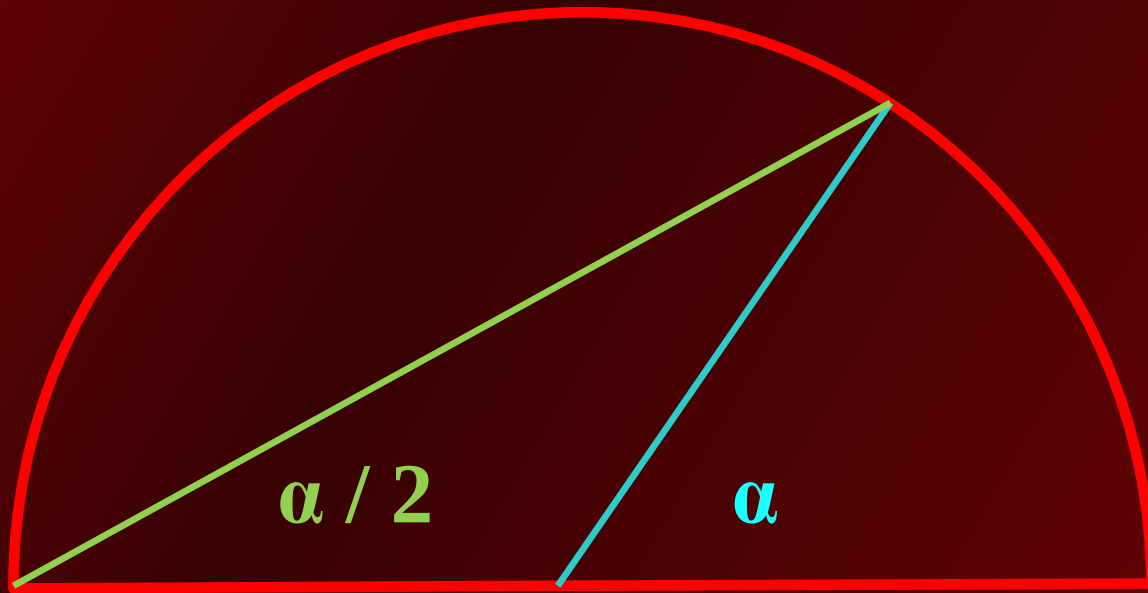
Egnazio Danti

Instrumentum primi mobilis

Florence, 1578

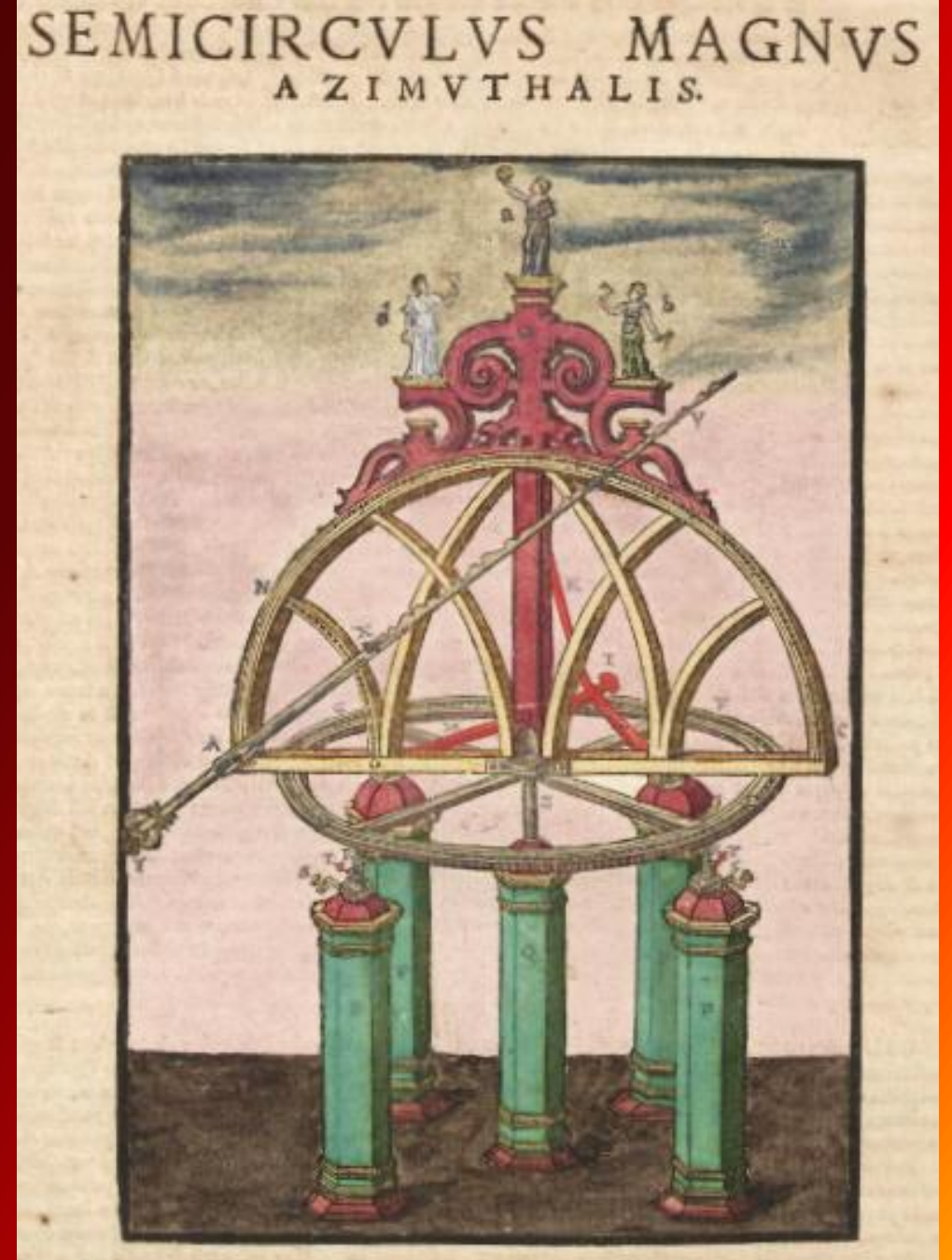
(Museo Galileo, Florence, inv. 2643)

Stratagems



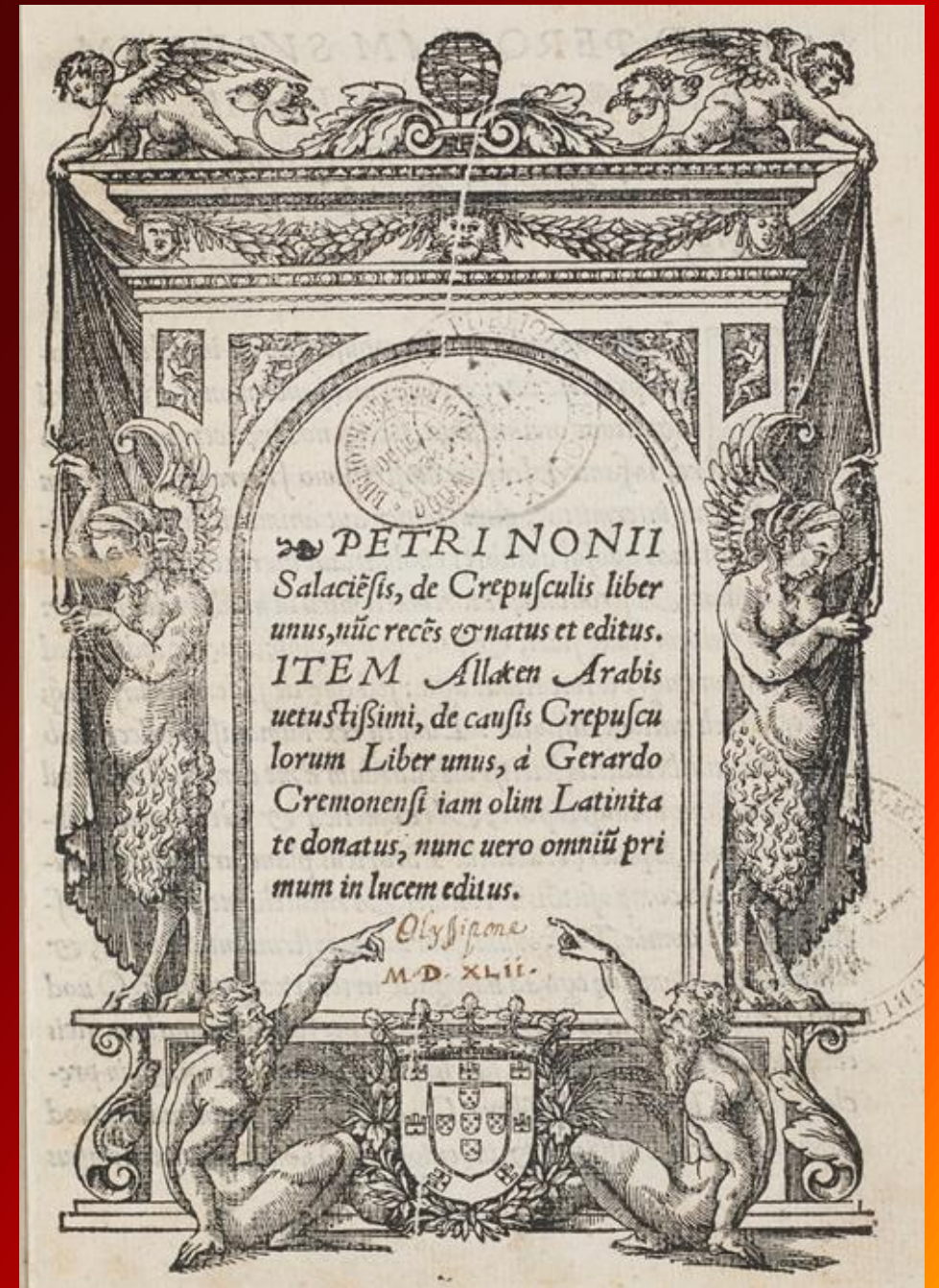
The 90° scale is spread over a 180° arc.

Tycho Brahe, *Astronomiae Instauratae Mechanica*,
Wandsbeck, 1598



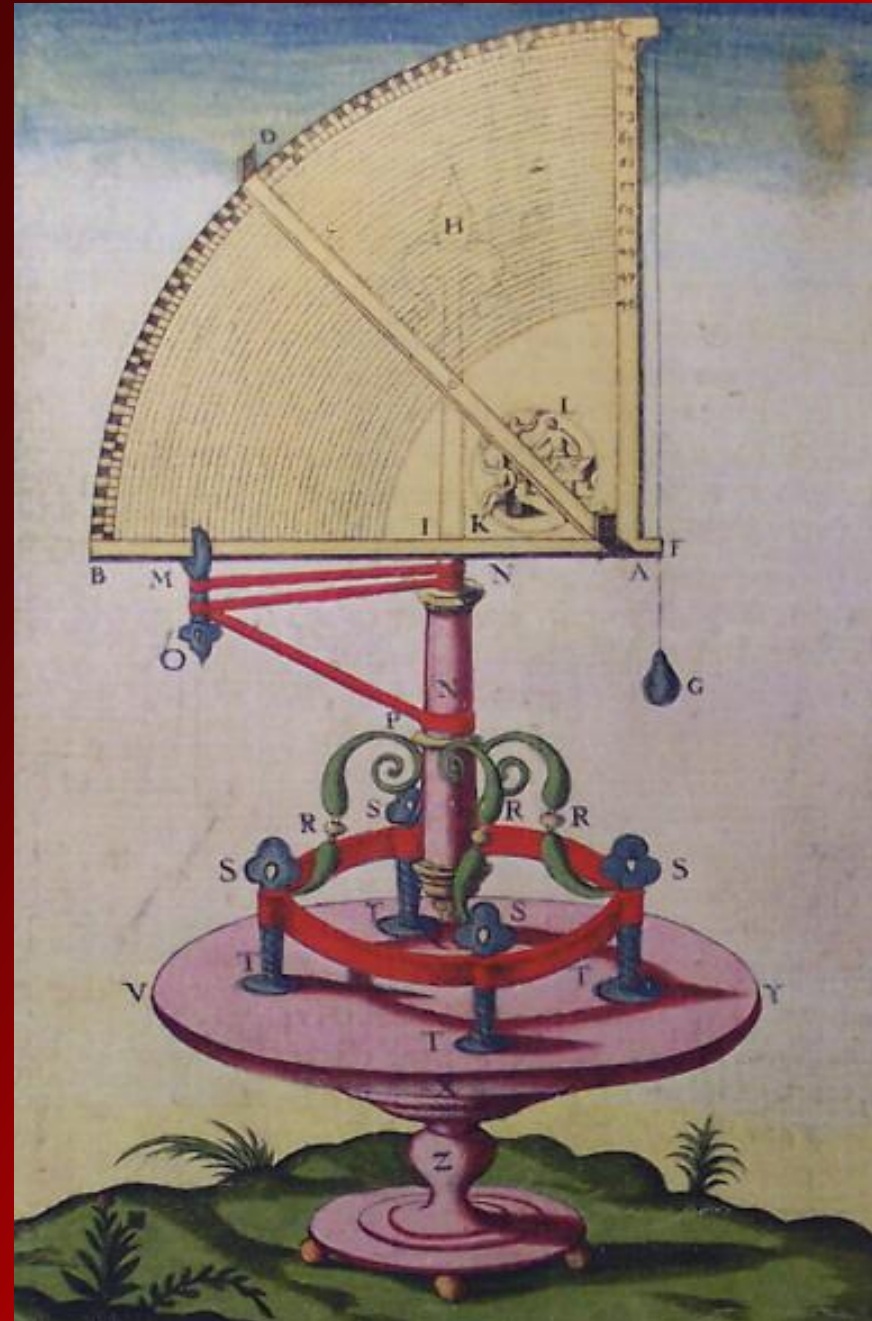
The “nonius”

Pedro Nuñez, *De crepusculis, liber unus*, Lisbon, 1542



The “nonius”

Tycho Brahe, *Astronomiae Instauratae Mechanica*,
Wandsbeck, 1598



The “nonius”

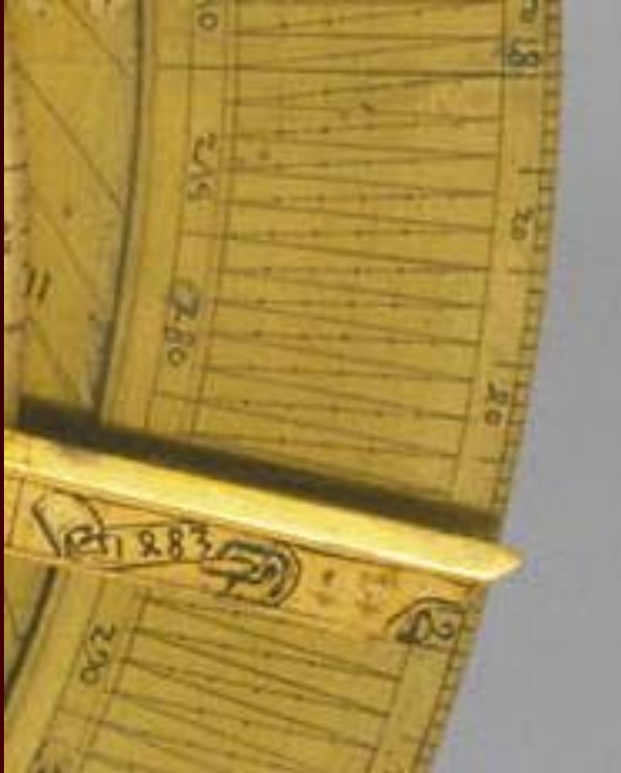
James Kynvyn [attr.], *Quadrant with “nonius”*,
London, 1595?
(Museo Galileo, Florence, inv. 242, 3362)



Transversal divisions

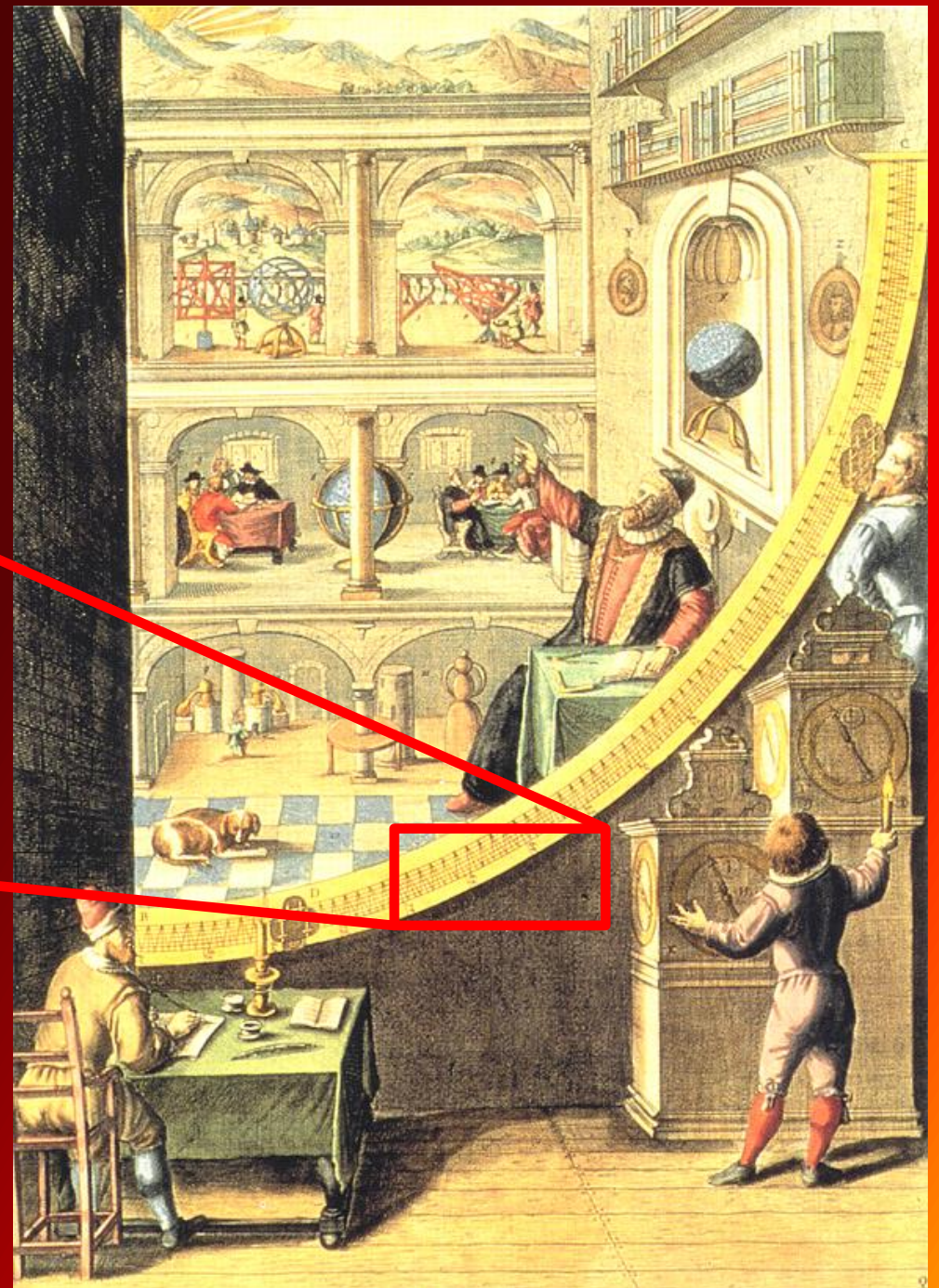
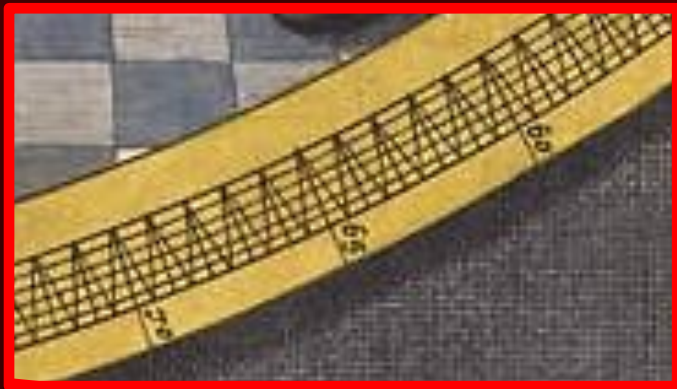


Hand Dorn [attr.], *Planispheric astrolabe*,
Hungary, 1483
(Museo Galileo, inv. 1096)

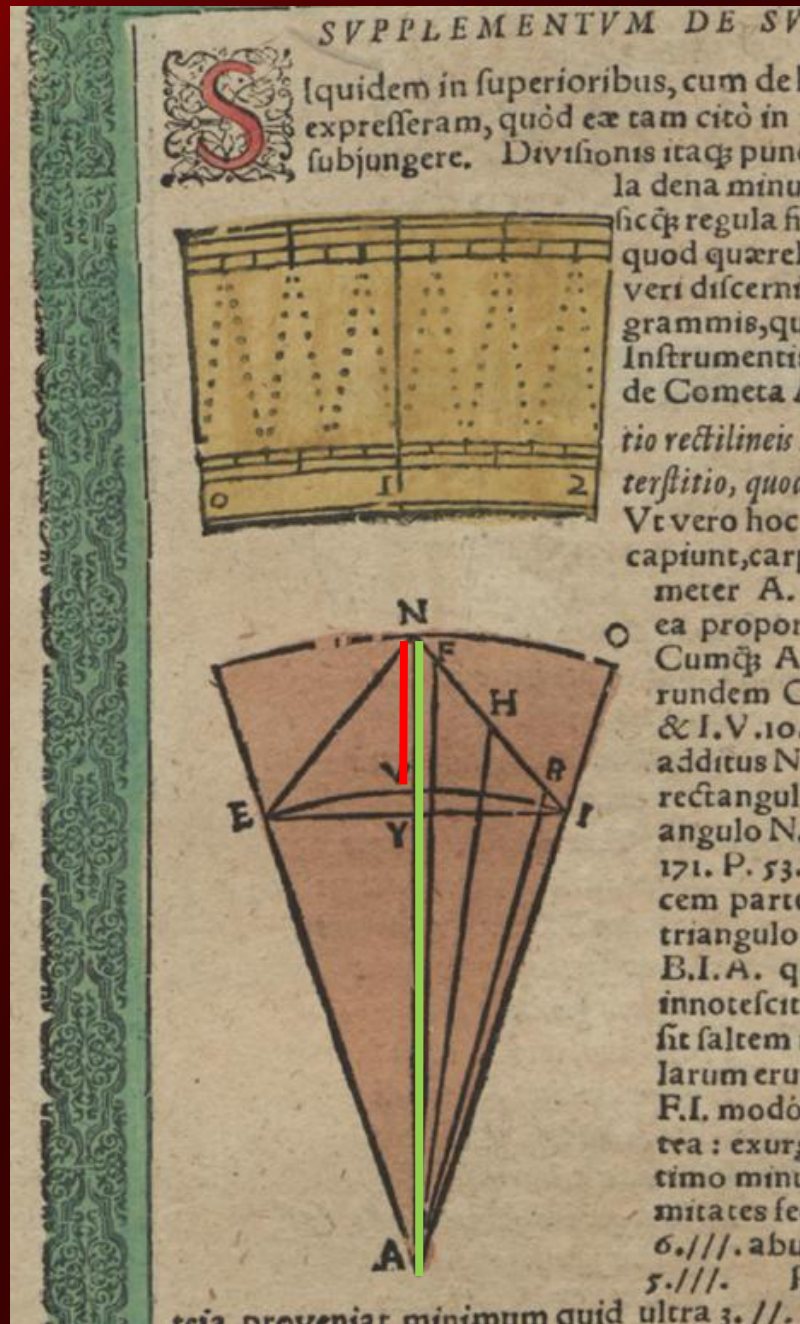


Egnatio Danti [attr.], *Planispheric astrolabe*, Florence, c. 1570
(Museo Galileo, inv. 3361)





Tycho Brahe: *Astronomiae Instauratae Mechanica*,
Wandsbeck, 1598



Ratio

$$NV / NA = 1 / 48$$

Tycho Brahe

Astronomiæ Instauratæ Mechanica

Wandsbeck, 1598



Carlo Rinaldini, *Astronomical quadrant*,
Florence, 1667
(Museo Galileo, inv. 2544, 3187)

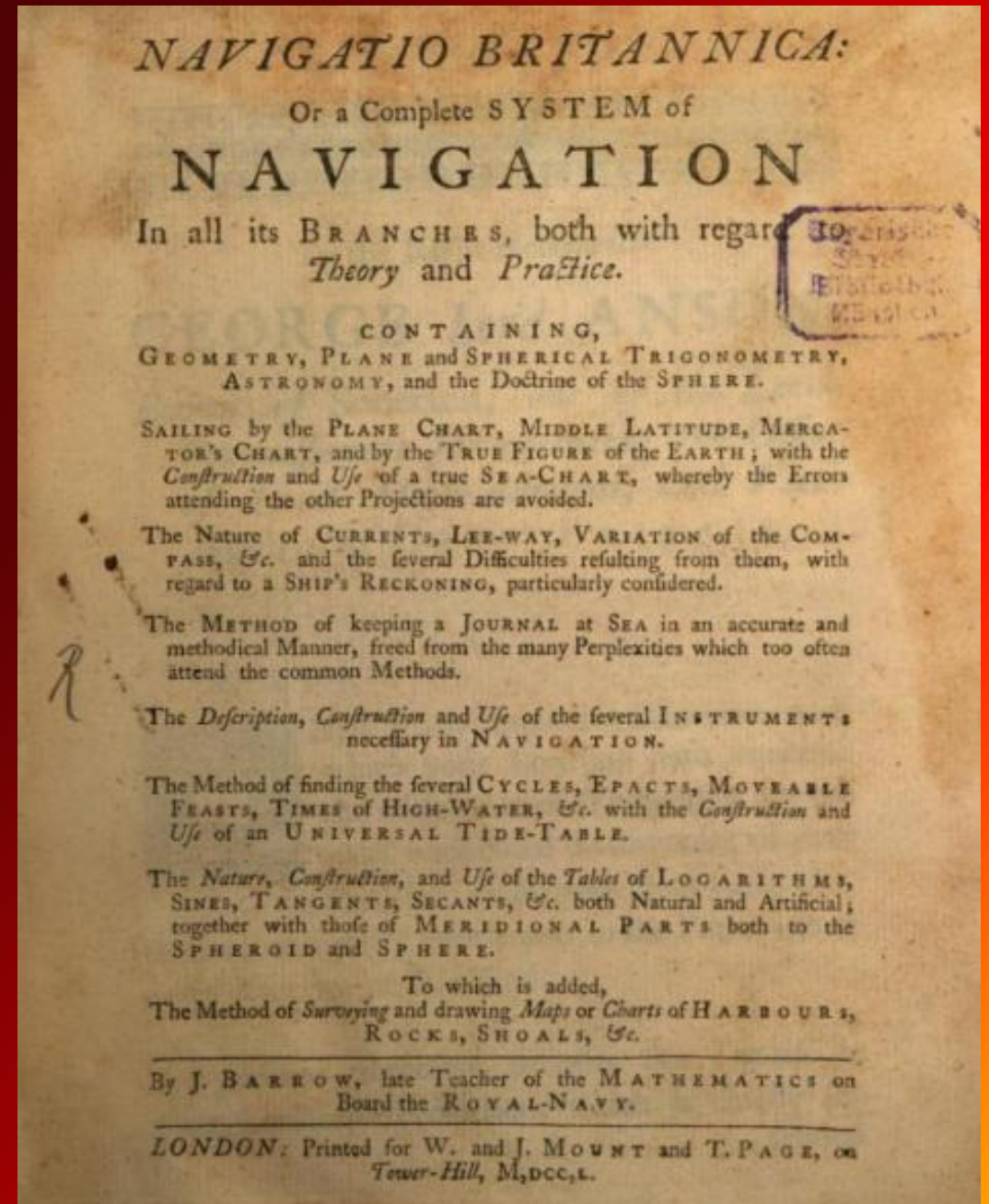


Vernier's scale

Invented by Pierre Vernier (1580-1637)

Described by John Barrow (fl. 1735-1774)

John Barrow, *Navigatio Britannica*, or a
Complete System of Navigation ...,
London, 1750

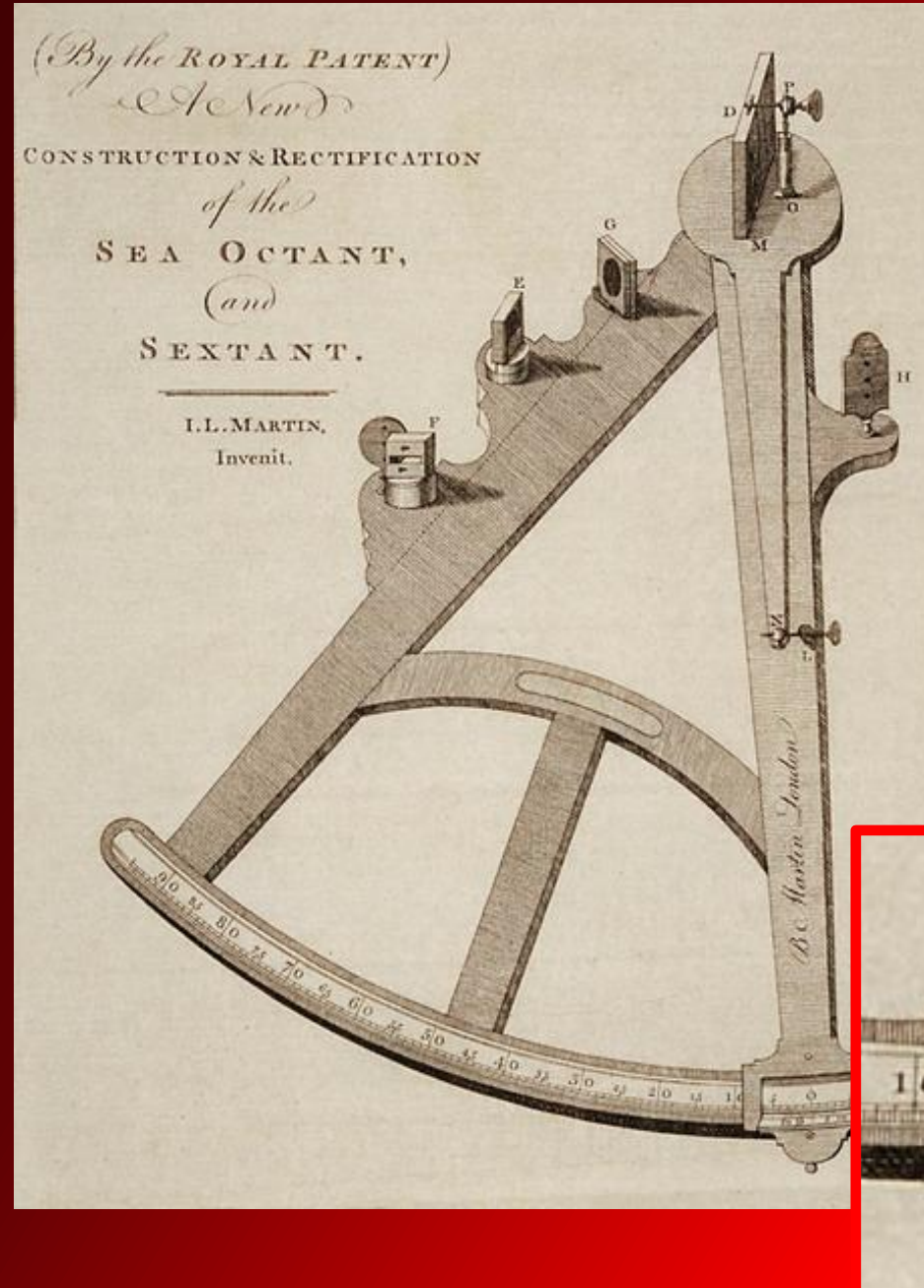


Vernier's scale

Invented by Pierre Vernier (1580-1637)

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Martin Benjamin, *An account of the new construction & rectification of Hadley's quadrant by the king's patent...*, London, 1767-1777



Vernier's scale

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Described by John Barrow (fl. 1735-1774)



Firm "Hughs - London", *Nautical octant*,
4th quarter 18th Century
(Museo Galileo, Florence, inv. 3729)

Vernier's scale

Invented by Pierre Vernier (1580-1637)

Described by John Barrow (fl. 1735-1774)

Made popular in astronomy by Jérôme Lalande
(1732–1807),

in his *Traité d'astronomie*, Paris, 1764, 2 vols.,
and its further 2 enlarged editions

Title page of tome 2, 1771 ed.

ASTRONOMIE,

PAR M. DE LA LANDE,

*Leçleur Royal en Mathématiques ; de l'Académie
Royale des Sciences de Paris ; de celles de Londres ,
de Pétersbourg , de Berlin , de Stockholm , de
Bologne , &c. Censeur Royal.*

SECONDE ÉDITION REVUE ET AUGMENTÉE.

TOME SECONDE.



A PARIS,

Chez la Veuve DESAINT, rue du Foin
Saint Jacques.

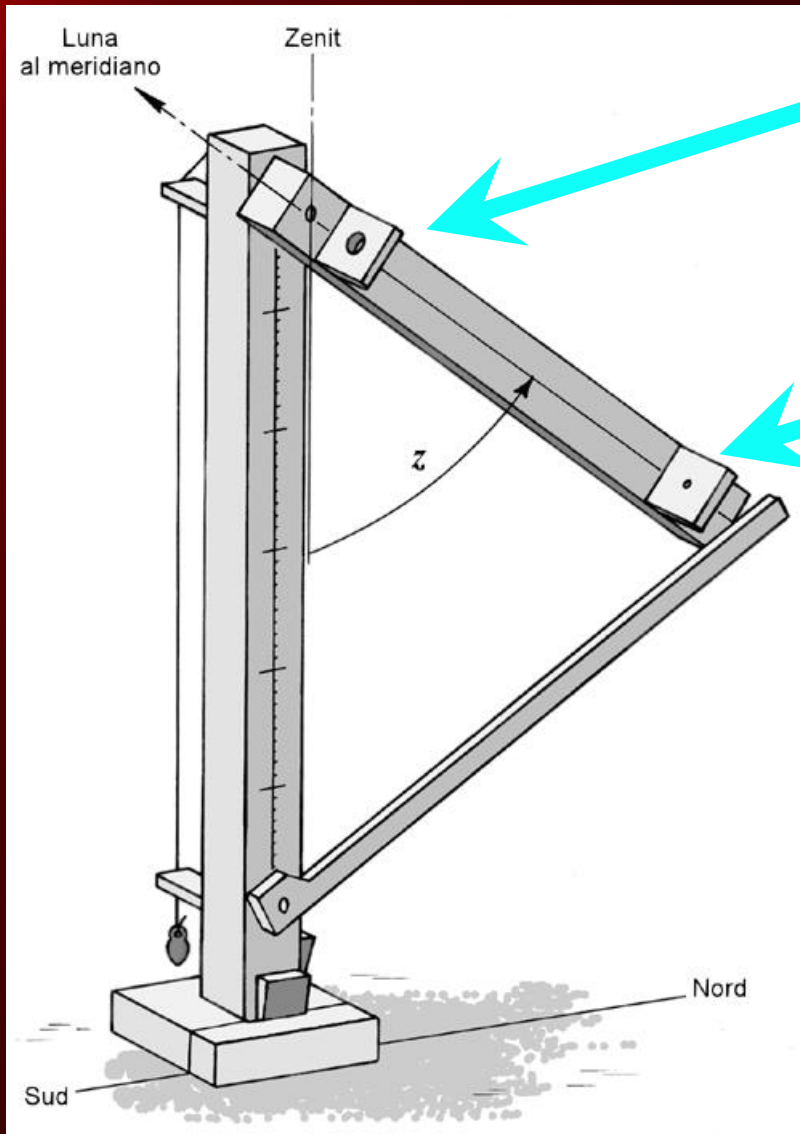
M. DCC. LXXI.

AVEC PRIVILEGE DU ROI.



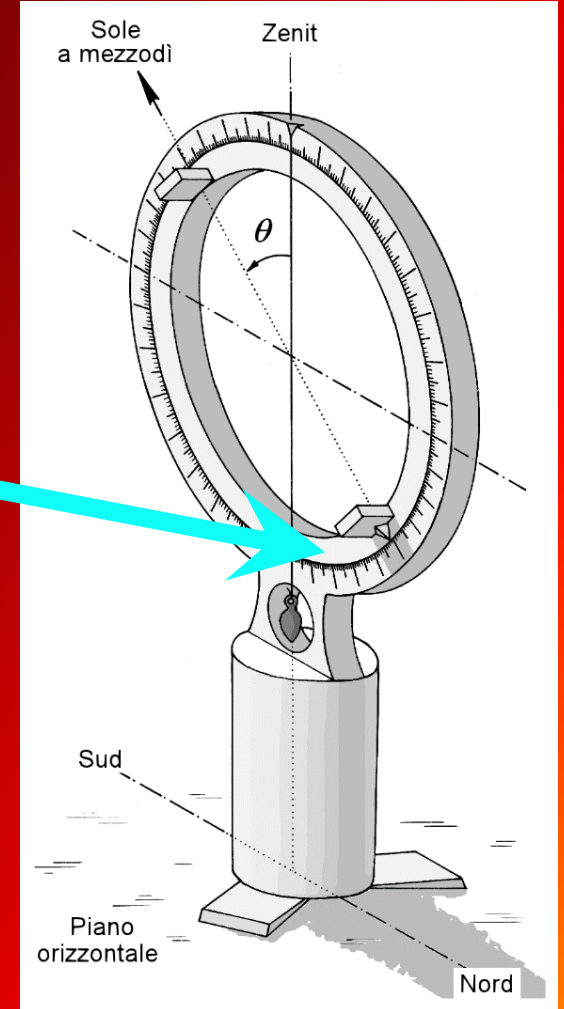
Georg Friedrich von Reichenbach, *Azimuthal circle*,
Munich, Early 19th Century
(Museo Galileo, Florence, inv. 576)

Sights



Holes

Shadow



Front



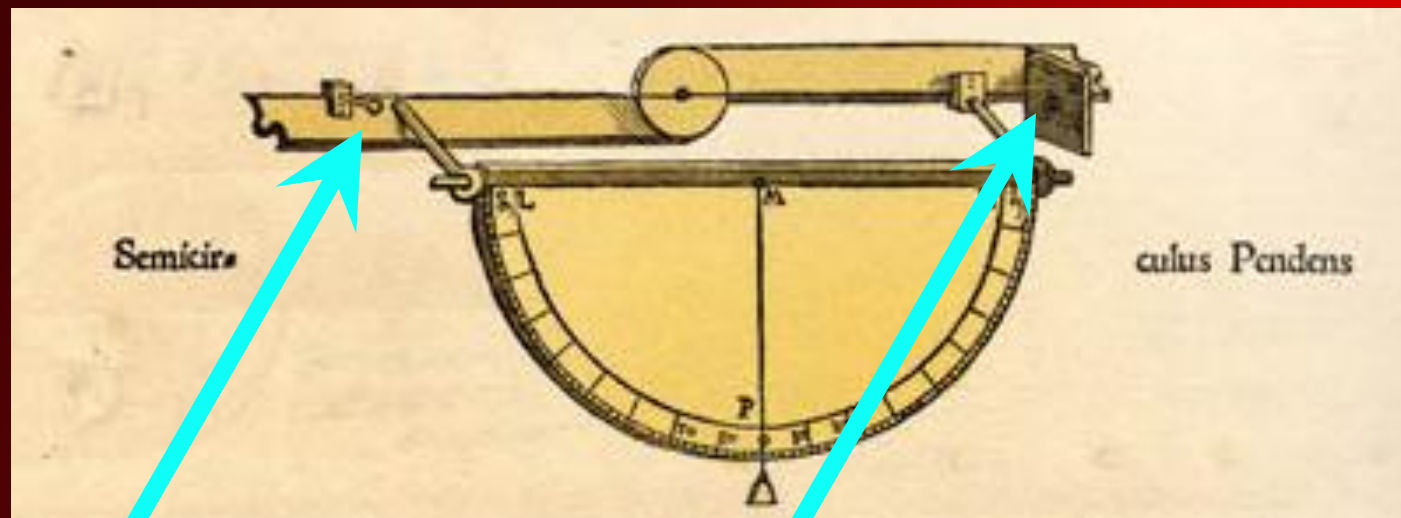
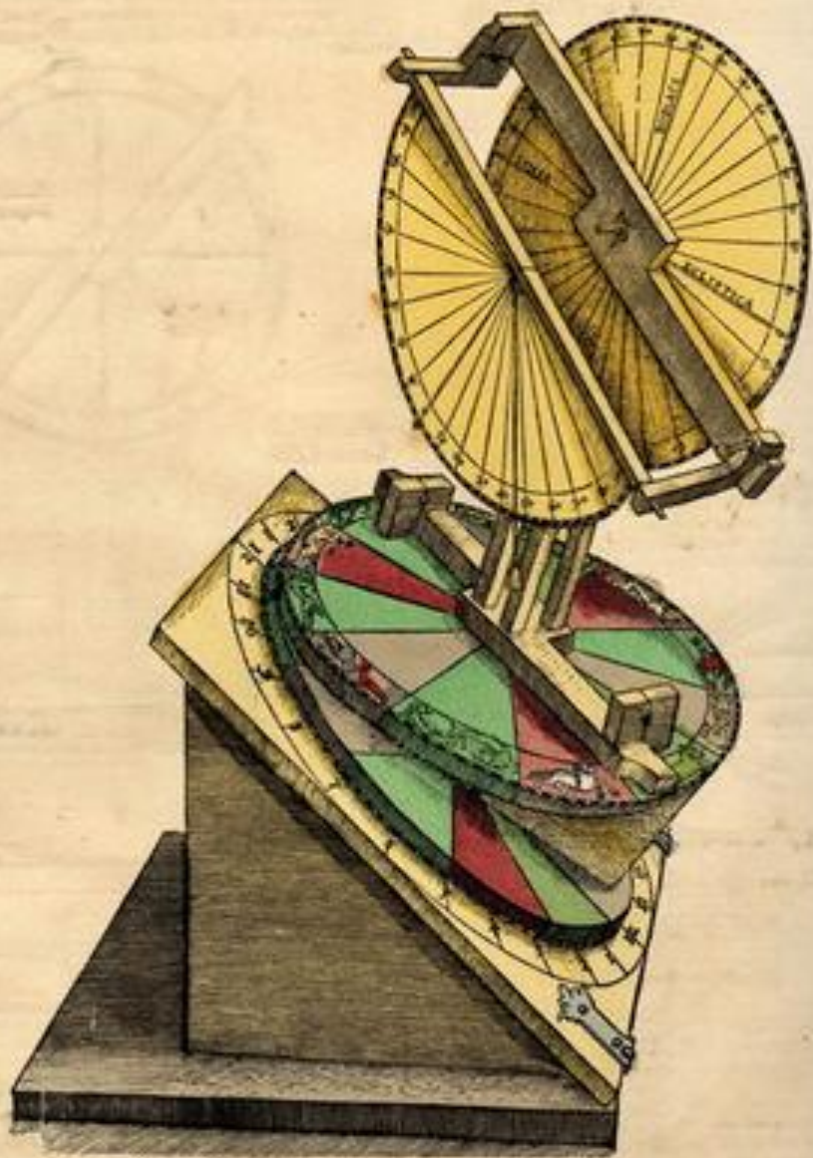
Back



Sight

Christoph Schissler, *Planispheric Astrolabe*, Augsburg, 1560
(Museo Galileo, Florence, inv. no. 1114)

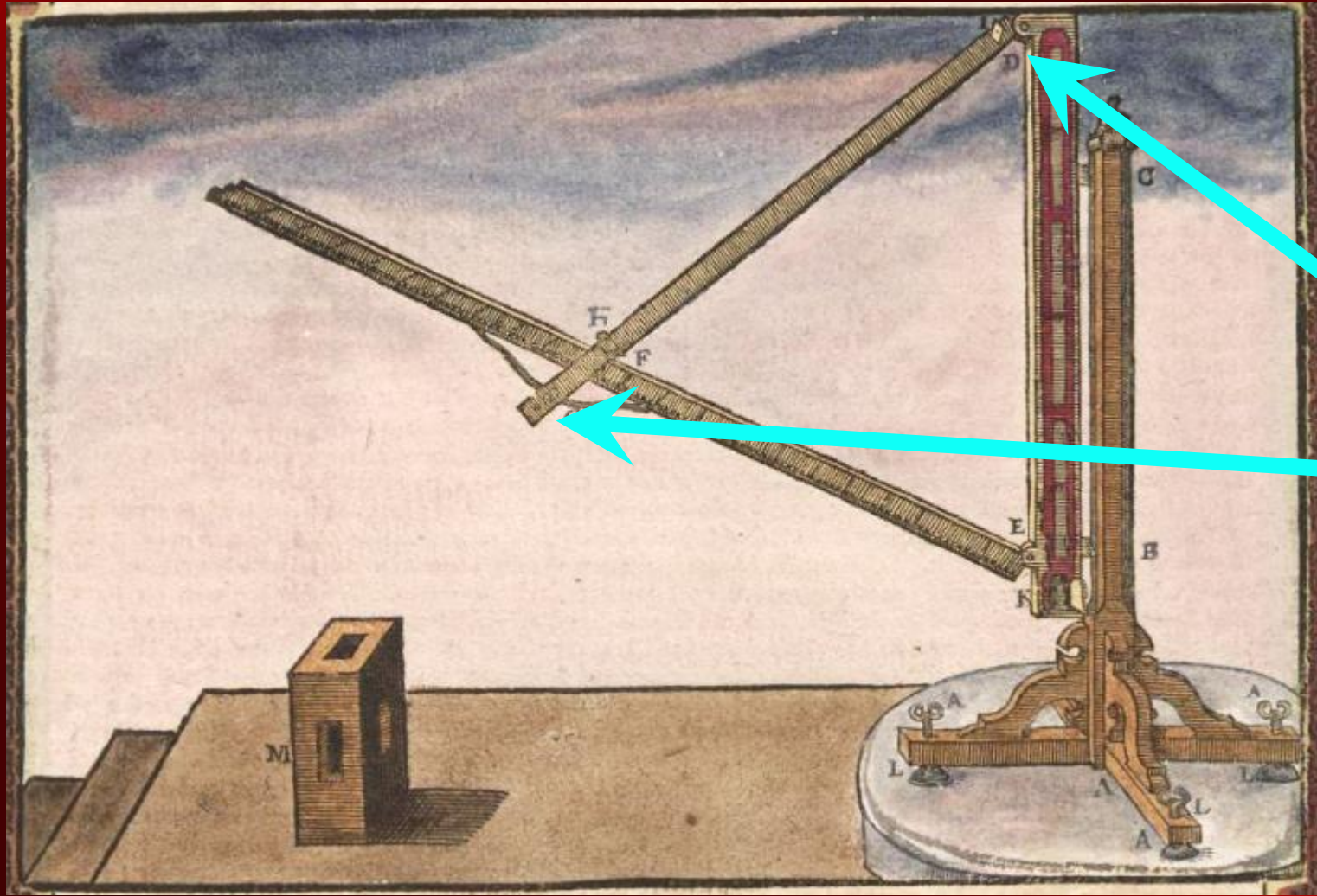
HAEC EST FORMA VIVAQUE TOR:
QVETI MAGO SVIS, ET NVMERIS, ET CIRCV-
lo, & lineamentis, & proportionibus vni perfectissimè exhibita.



Pin

Hole

Petrus Apianus, *Astronomicum Caesareum*, Ingolstadt,
1540



Nicholaus Copernicus's
"triquetrum"

Holes

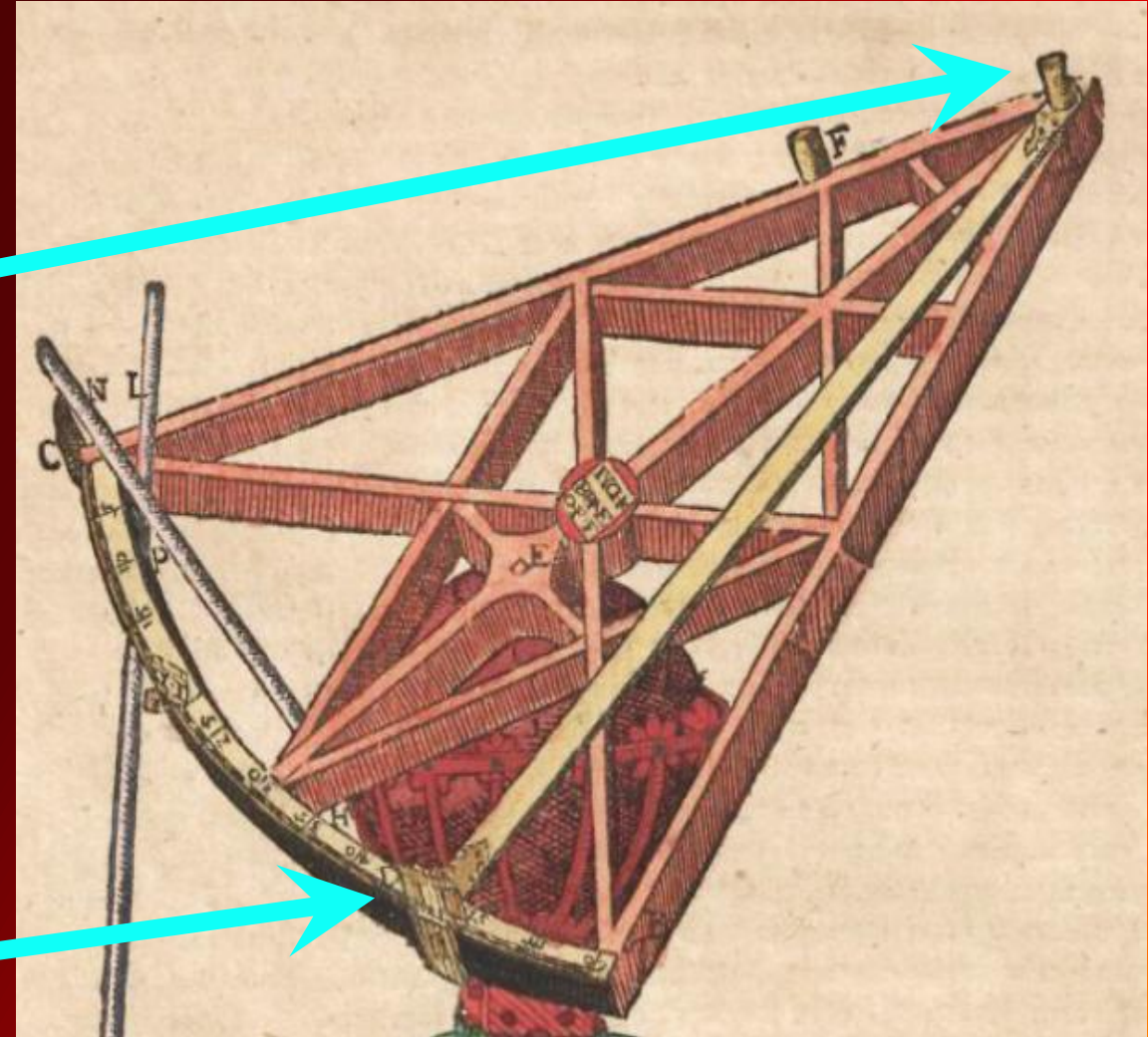
Tycho Brahe, *Astronomiae Instauratae Mechanica*, Wandsbeck, 1598



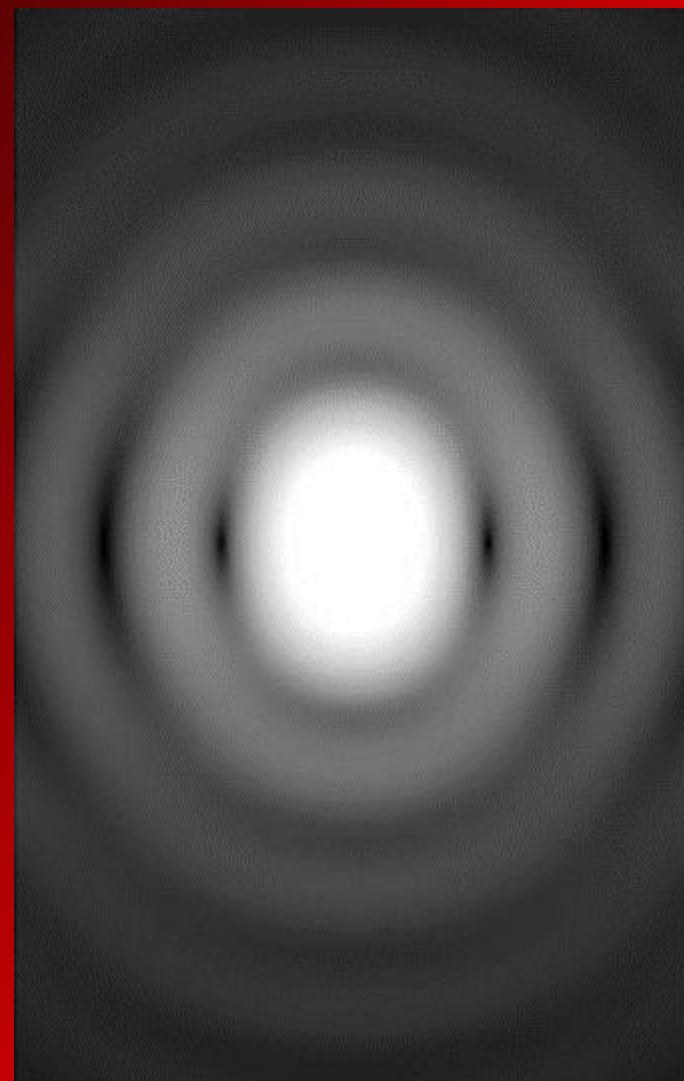
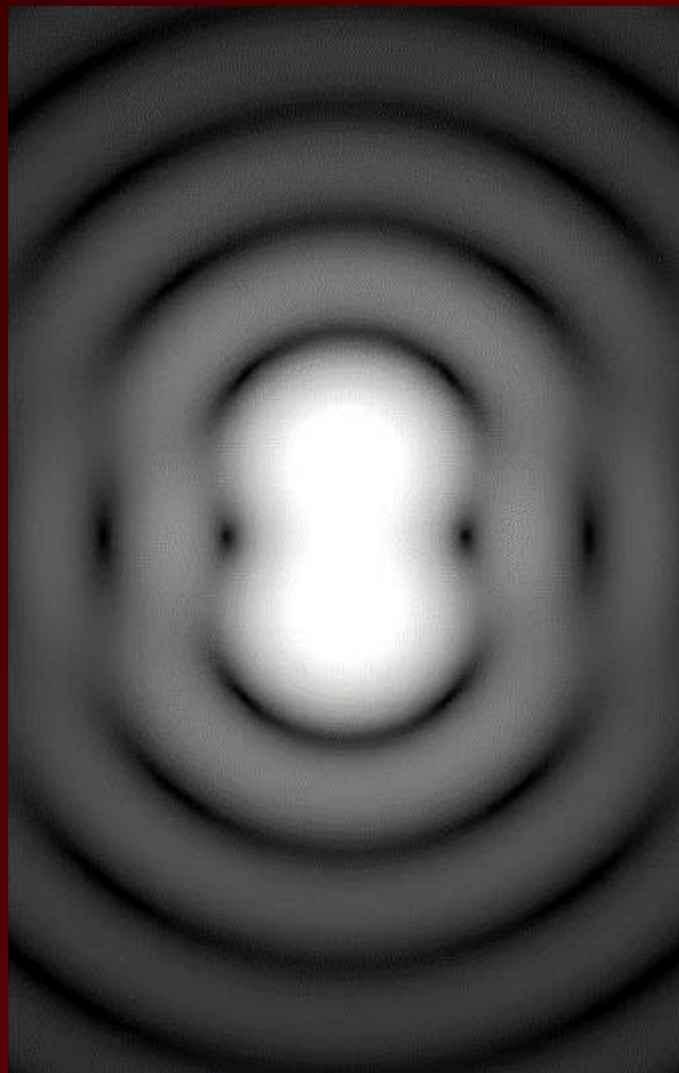
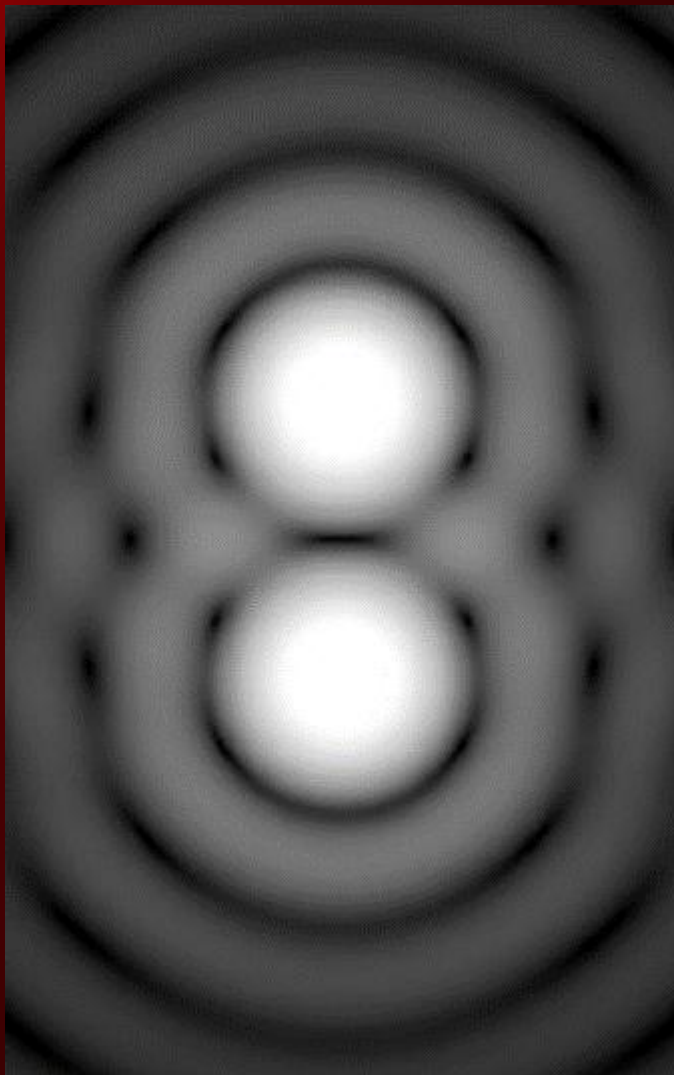
Square pinnule

Cylinder

Square pinnule
with adjustable slits



Tycho Brahe, *Astronomiae Instauratae Mechanica*, Wandsbeck, 1598

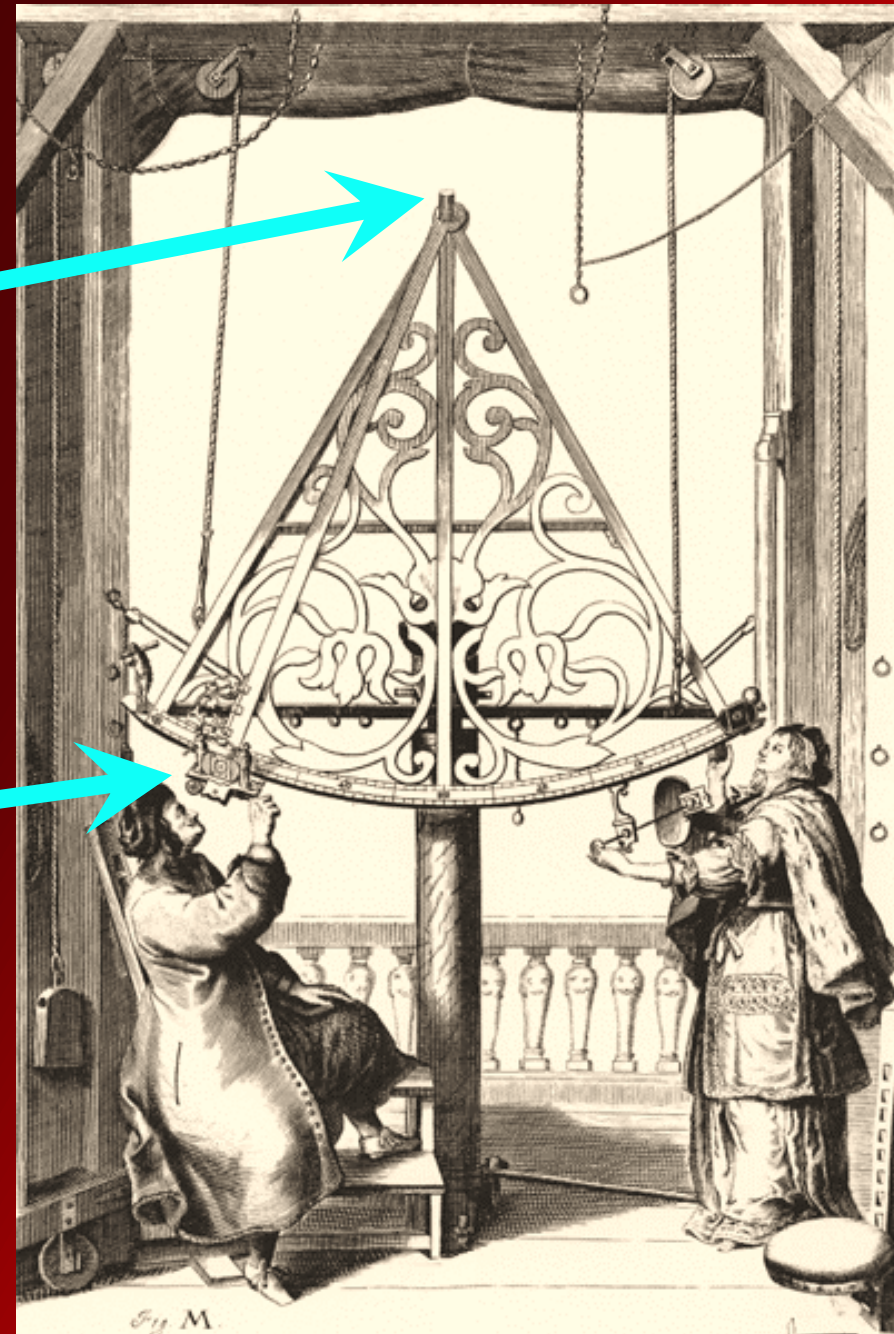


Naked eye resolution limit, c. 1'

Cylinder

Square pinnule
with adjustable slits

Johann Hoewel,
Machina Coelestis, Gdańsk, 1673



Johann Hoewel
Selenographia, Gdańsk, 1647





(One of the telescope sights was lost)

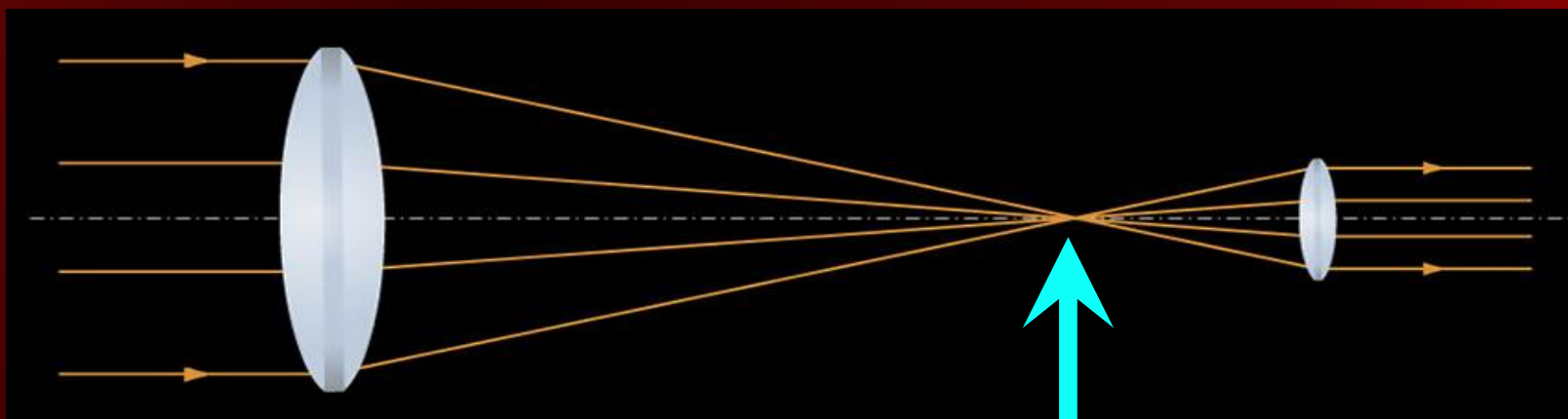
Sante Menini, *Quadrant with two telescope sights*, 1710
(Specola Museum, Bologna, inv. MdS-118)



Pierre Méignié, *Quadrant with telescope*,
mid 18th Century
(Specola Museum, Bologna, inv. MdS-4)



Galilean telescope
(since 1608)

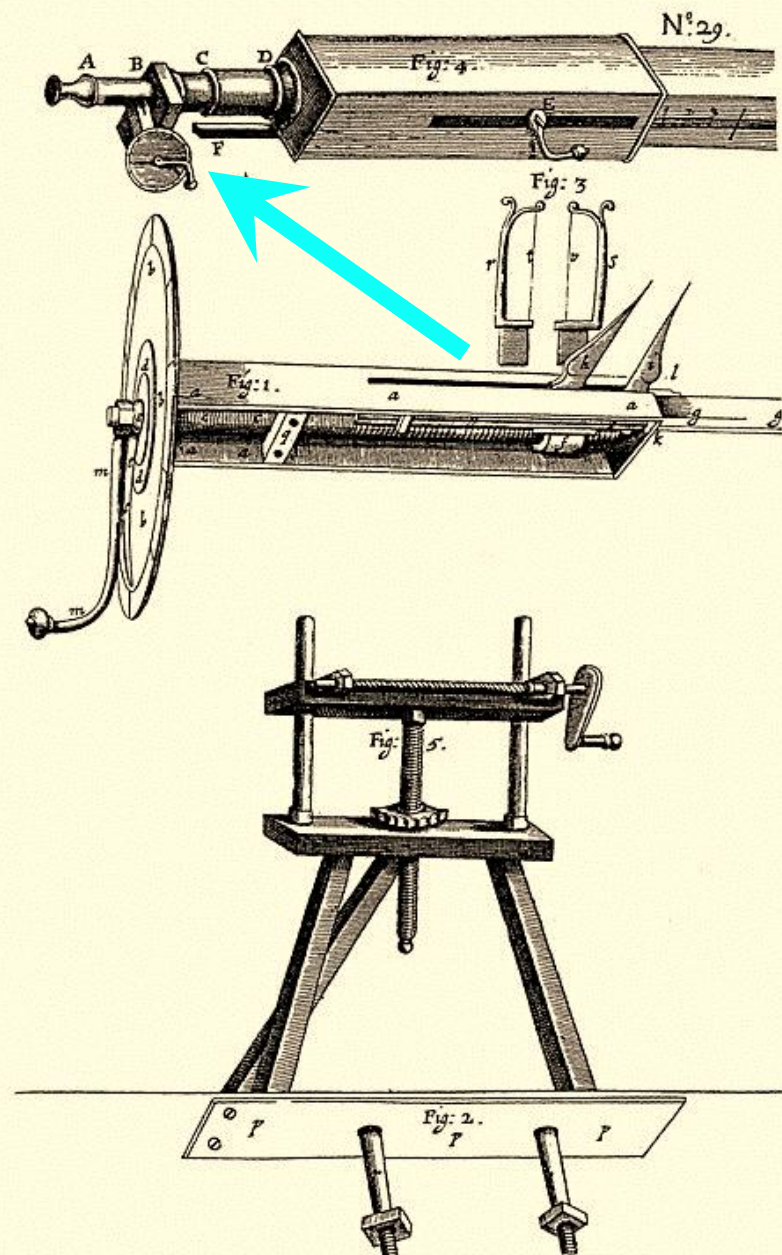


Keplerian telescope
(since 1611)



Galileo's micrometer,
c. 1612
(reconstruction)

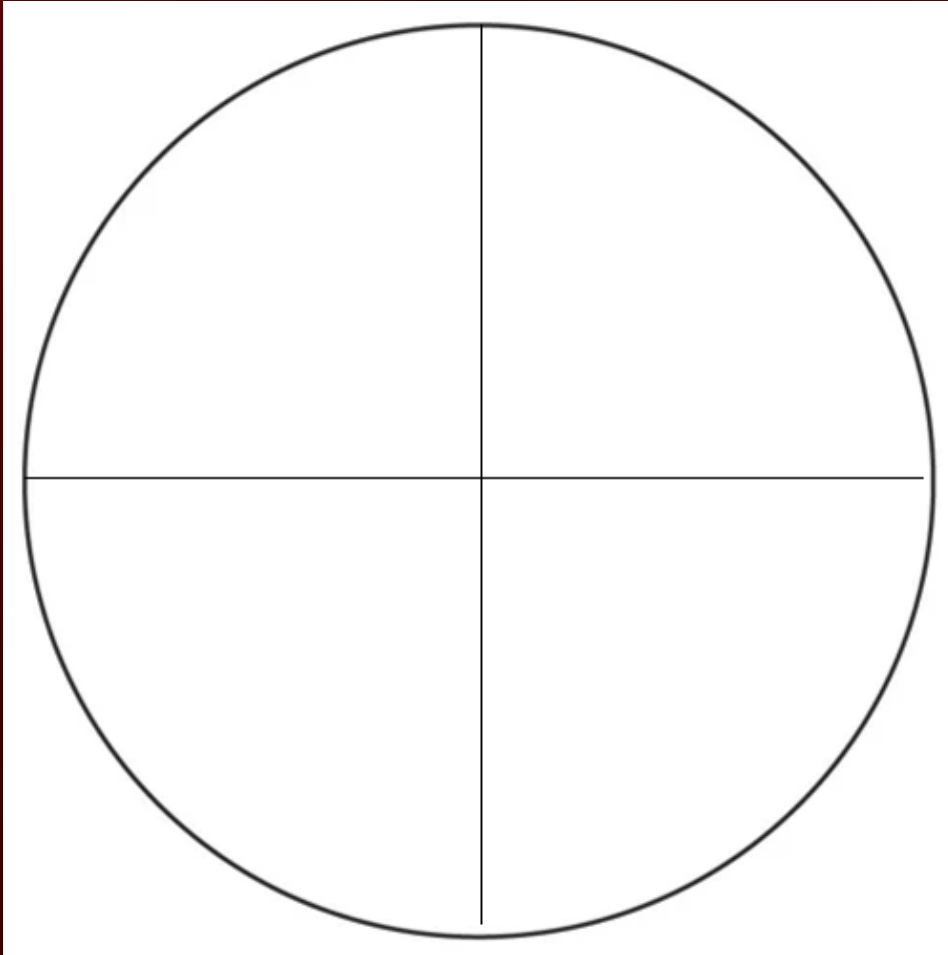




Ocular micrometer

Devised by the astronomer William Gascoigne, c. 1640

Robert Hooke, *"A Description of an Instrument for Dividing a Foot into Many Thousand Parts, and Thereby Measuring the Diameters of Planets to a Great Exactness ..."*, *Philosophical Transactions* 2, 29 (1667)

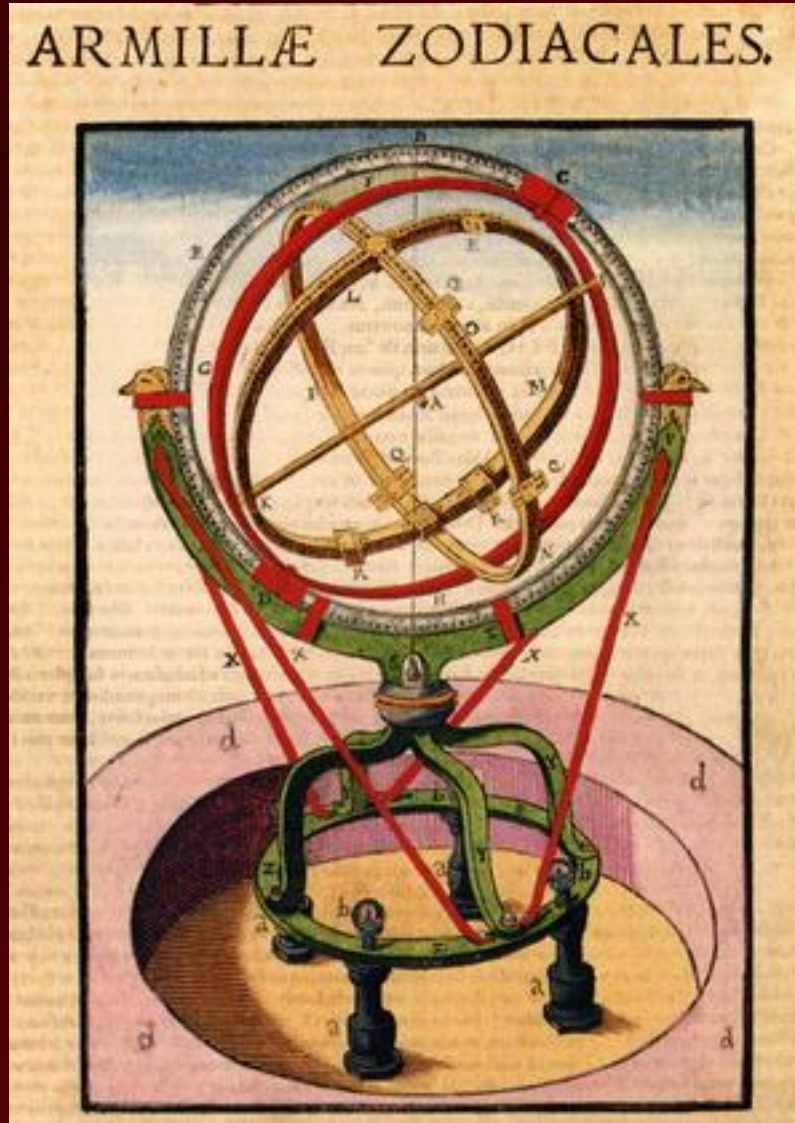
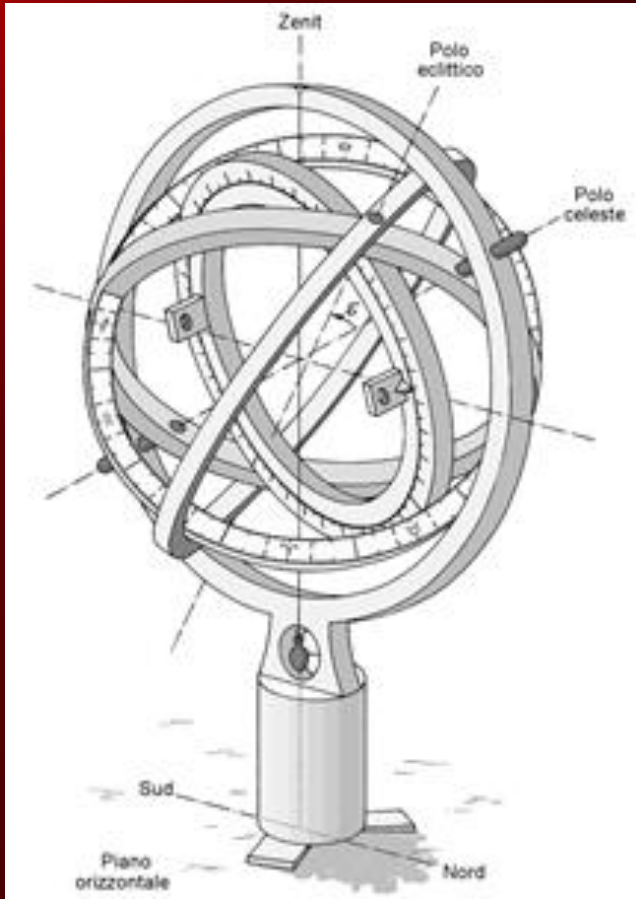


Filar micrometer



Araneus diadematus Clerck, 1757
aka "Garden" or "Cross spider"

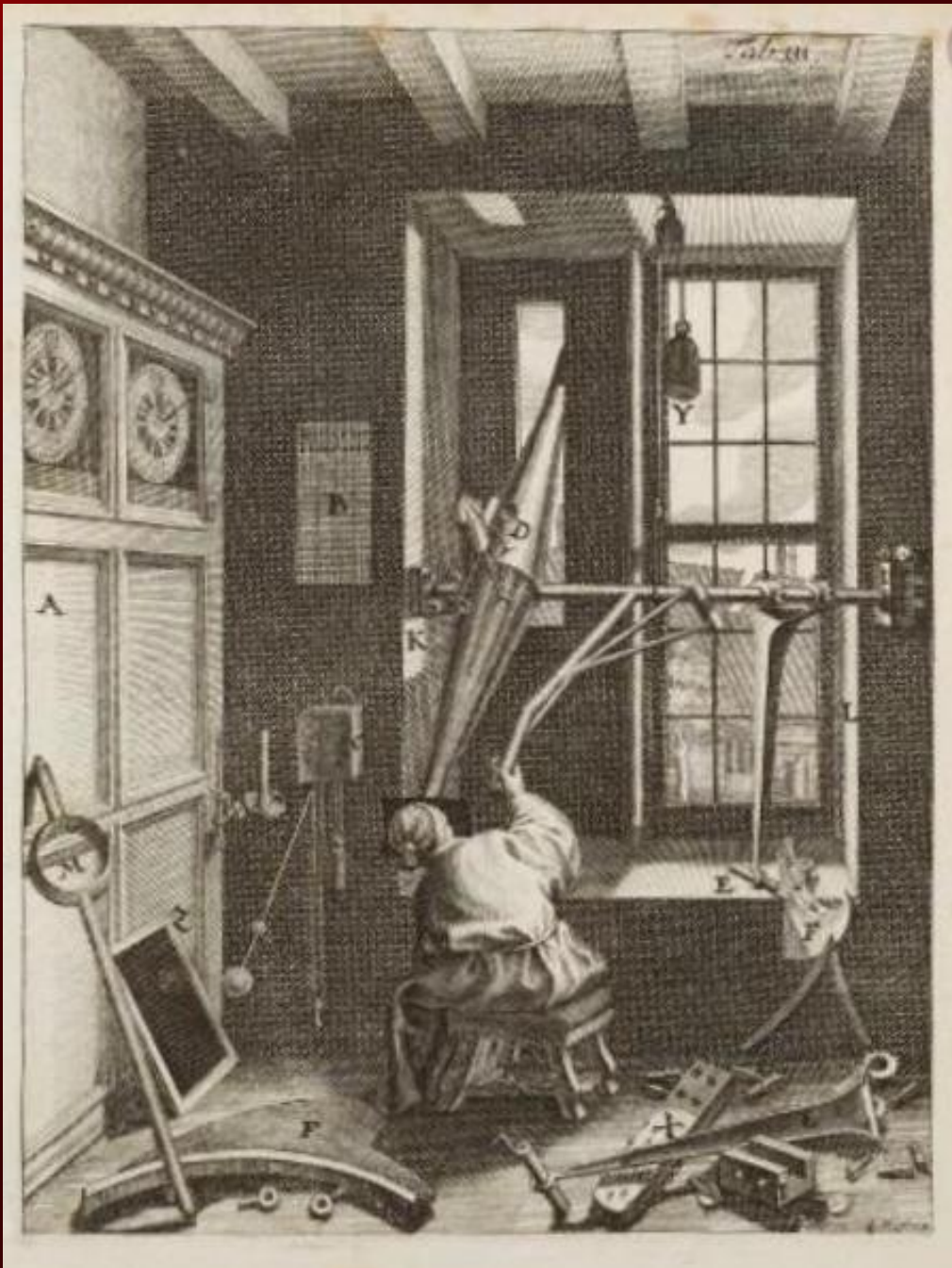
Reversible Instruments ?



Tycho Brahe, *Astronomiæ Instauratæ Mechanica*,
Wandsbeck, 1598



Ole Rømer's equatorial instrument in Copenhagen
(Peder Horrebow, *Basis Astronomiae*, Copenhagen,
1735, pl. I)



Ole Rømer (1644-1710) and his transit instrument in
Copenhagen

(Peder Horrebow, *Basis Astronomiae*, Copenhagen,
1735, pl. III)

Anonymous, *Reversible transit instrument*, c. 1850
(Royal Maritime Museum, Greenwich)



Thank you for the attention!