A Great Scientific Instrument
Zaragoza Astrolabe

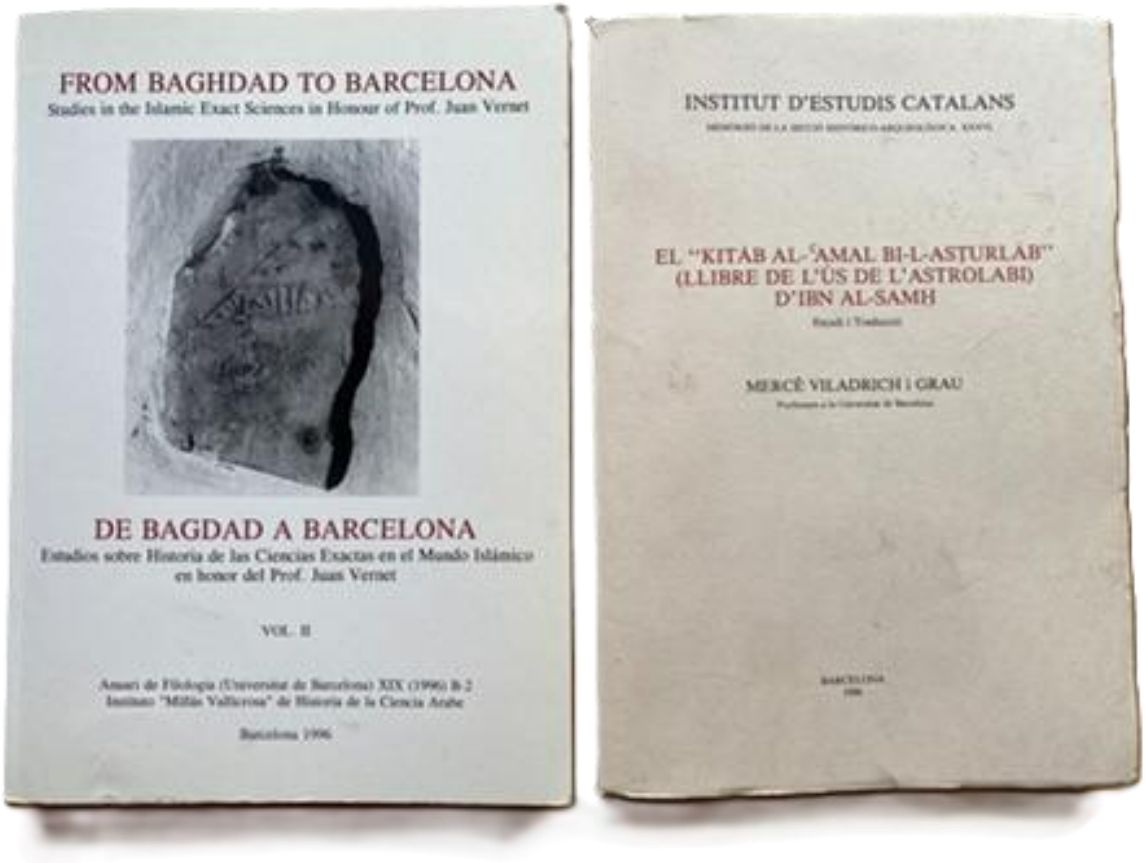


Germanisches Nationalmuseum. CCA 1099. AHP no. A10:
http://objektkatalog.gnm.de/objekt/WI353

From Bagdad to Barcelona
the education of astrologers

Henk Hietbrink

- retired math teacher in the Netherlands
- went to Utrecht University for a teaching licence



From Bagdad to Barcelona Via Franeker:
we are proud of our heritage



Eise Eisinga Planetarium in Franeker

wooden construction (1774-1781) still in use



Copyright Eise Esinga Planetarium: https://www.eisinga-planetarium.nl/

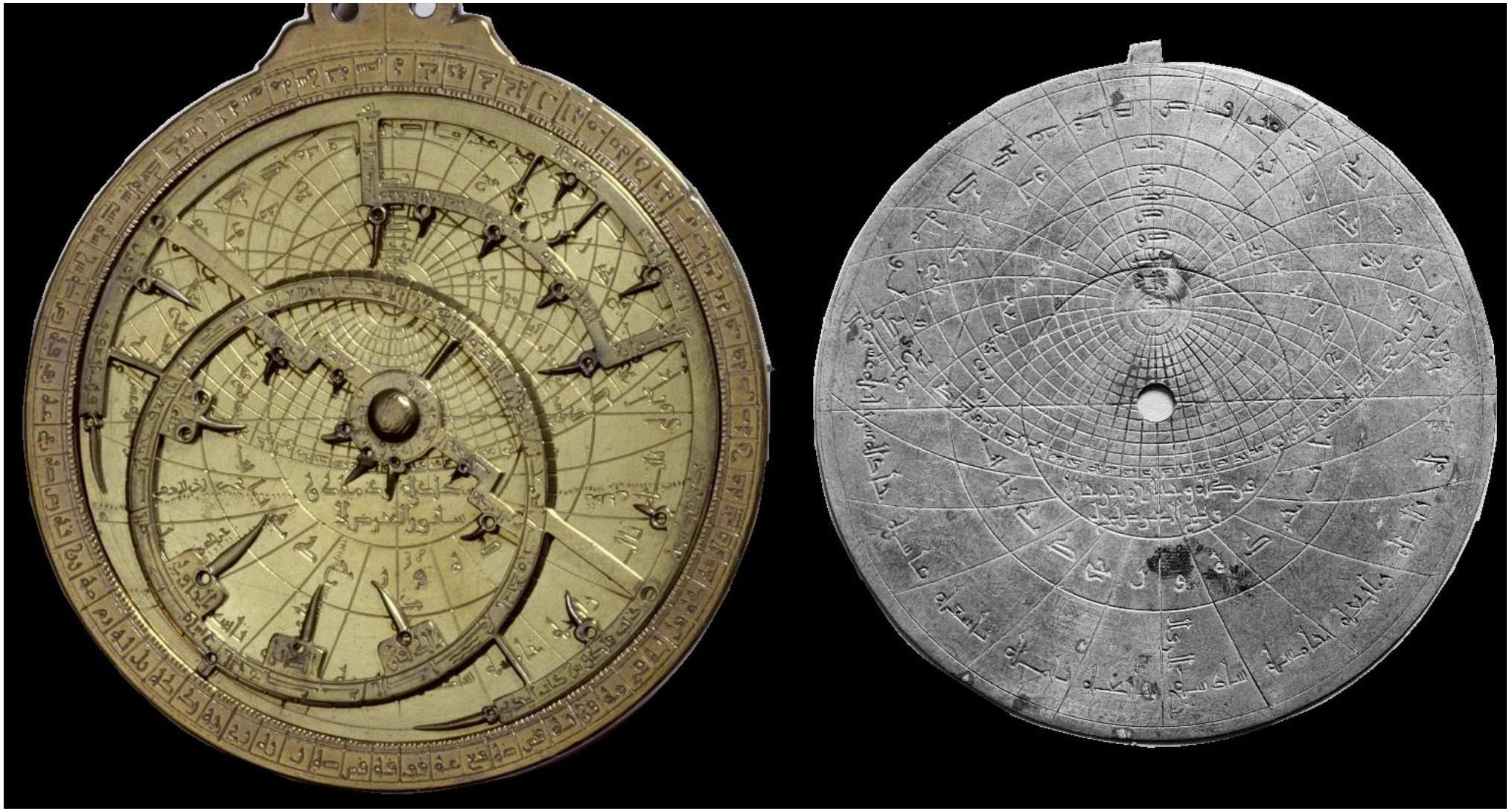
Frisian Astrolabe (1606)
made by the Frisian craftsman Pybe Wouters





Copyright Arie de Ruiter: https://ariederuiter.nl/zwk/

From Bagdad to Barcelona
➔Istanbul➔Frankfurt➔Zaragoza ➔ Nürnberg



Copyright: Germanisches Nationalmuseum - Astrolabium des Ahmad ibn Muhammad al-Naqqash 1079/1080

From Bagdad to Barcelona
➔Zaragoza ➔Frankfurt ➔Istanbul ➔Franeker



Copyright: Institut für Geschichte der Arabisch–Islamischen Wissenschaften an der Johann Wolfgang Goethe-Universität

ChatGPT
proposal for a monument in Zaragoza



The Astrolabe as a Sundial

This monumental astrolabe is a fully functional sundial, inspired by medieval Islamic instruments and the scientific heritage of Zaragoza. The gnomon casts a shadow that shows the local solar time throughout the year.

Tells the time
The shadow falls on the hour lines of the astrolabe, showing the true solar time for Zaragoza (41.65° N).

A symbol of knowledge
The design reflects the rich astronomical and mathematical tradition of Al-Andalus and its legacy in Zaragoza.

A meeting place
A striking landmark in the historic city centre, inviting citizens and visitors to look up, learn and experience the sky.

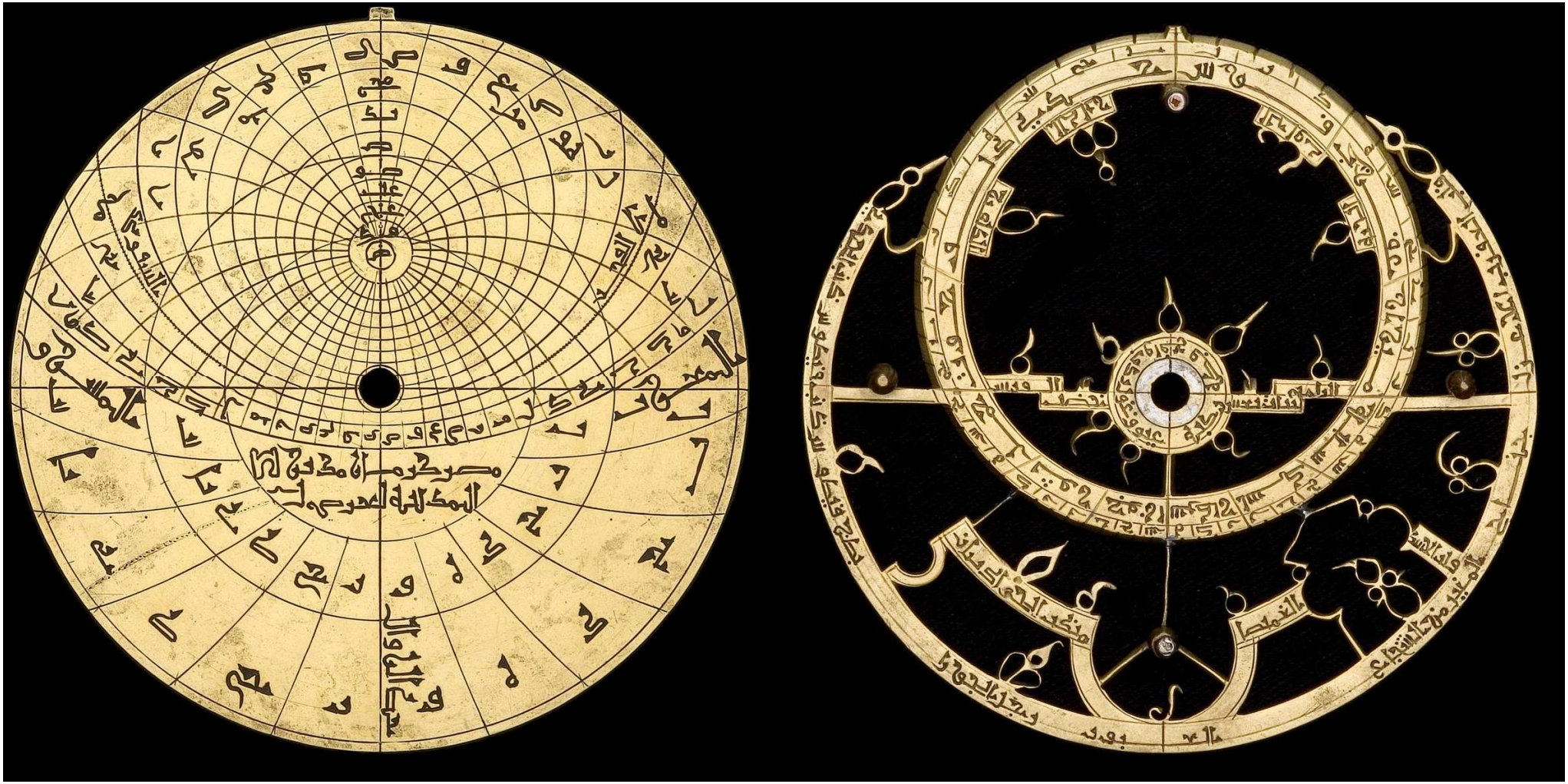
"The same sun that guided the astronomers of the past can still guide us today."

From Bagdad to Barcelona
➔Iran➔Oxford



Copyright: Oxford Museum of the History of Science Muḥammad Muqīm al-Yazdī 1647/8 (A.H. 1057)

From Bagdad to Barcelona
➔Spain➔Oxford



Copyright: Oxford Museum of the History of Science - Muḥammad ibn Sa'īd as-Ṣabbān – Guadalajara – 1081/82

Ibn al-Samh (10th – 11th century)
Educating Astrologers





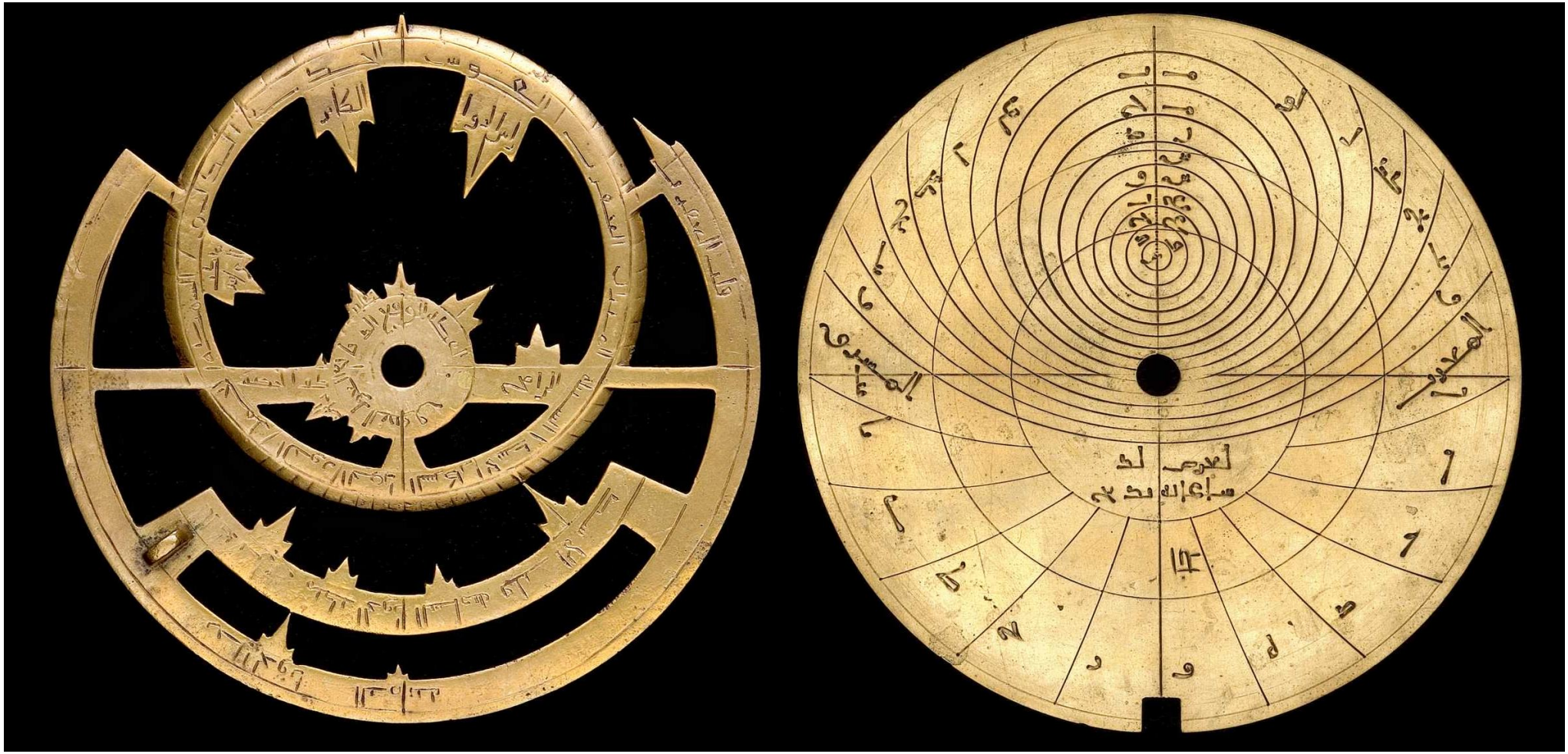


Kitāb al-ʿAmal bi-l-Asturlāb

the Book on the Use of the Astrolabe

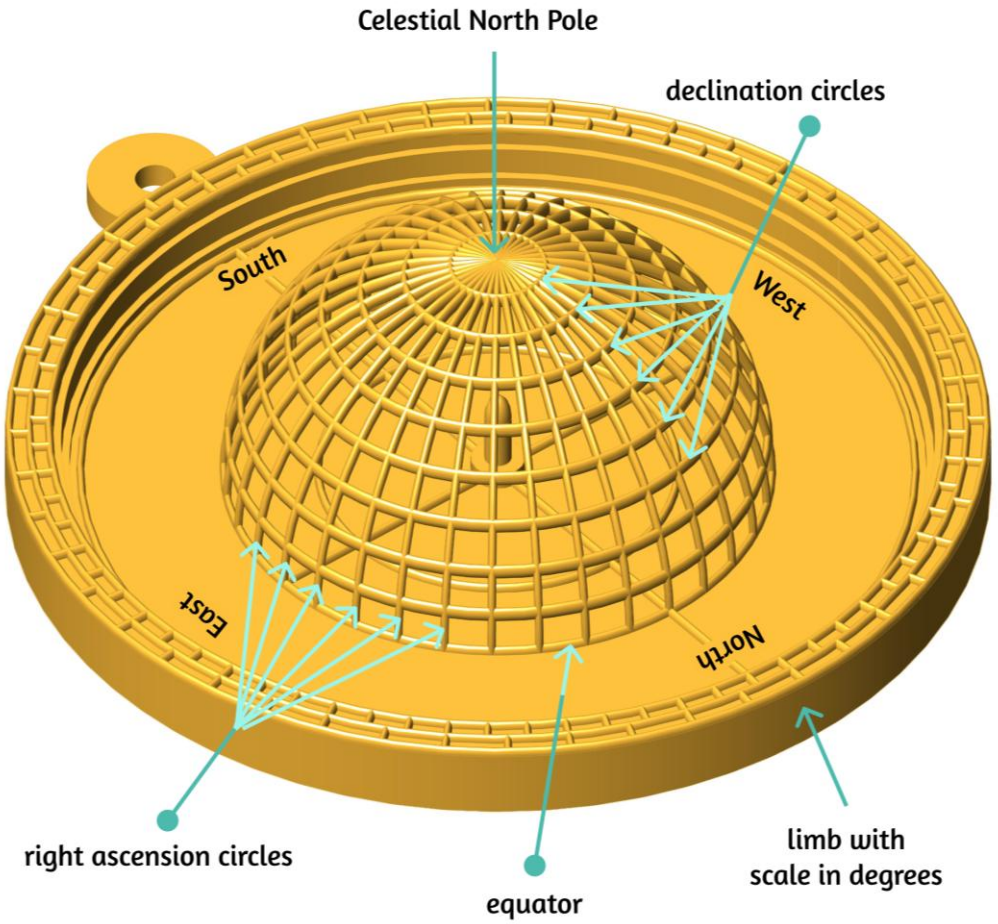
Copyright: British Library: Oriental Manuscripts, Add MS 9602, ff 25v-55v, in Qatar Digital Library

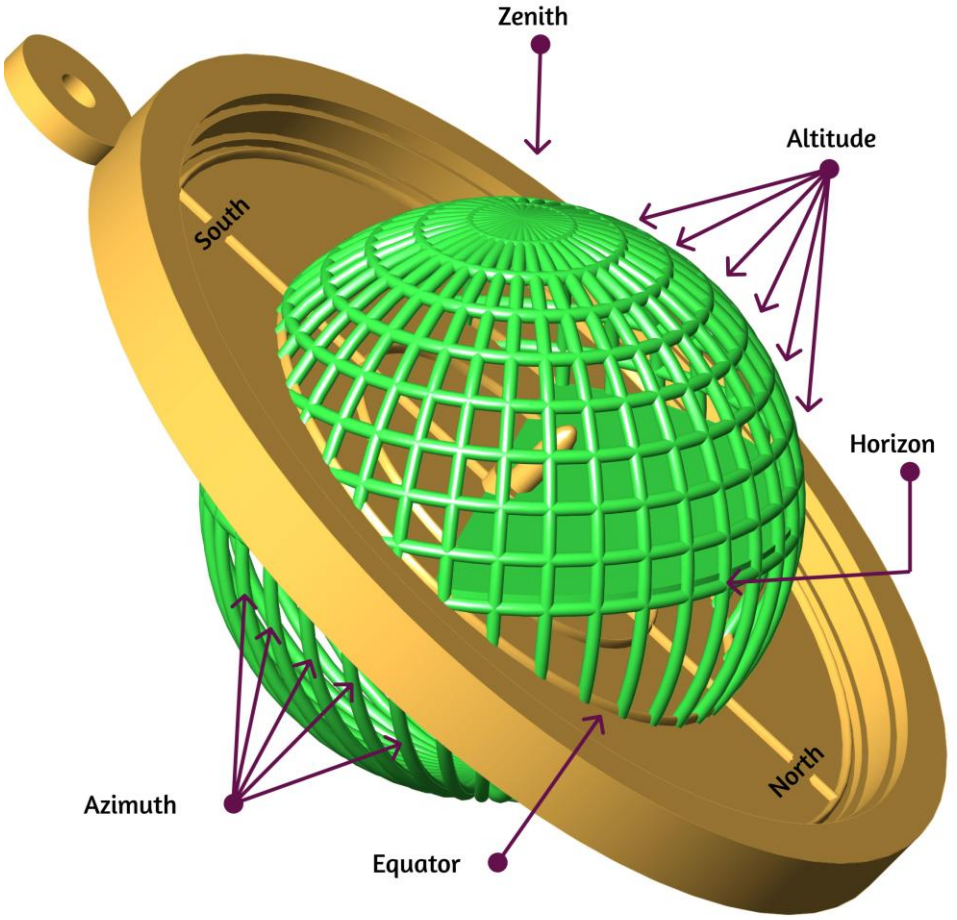
From Bagdad to Barcelona
➔Syria➔Oxford



Copyright: Oxford Museum of the History of Science - Khafīf, apprentice of ‘Alī ibn ‘Īsā late 9th century

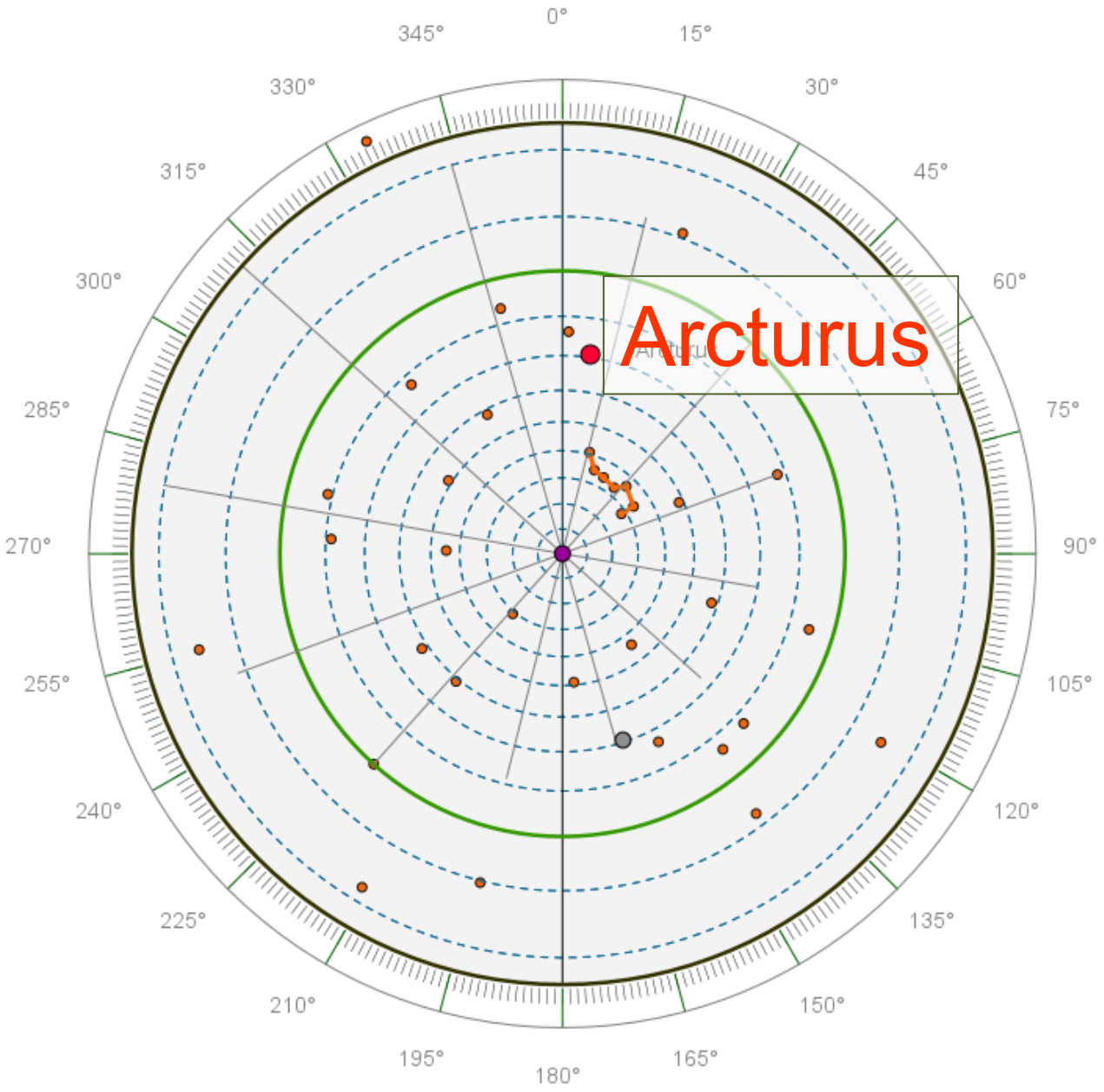
Coordinate Systems
Celestial circles: altitude and declination





Coordinates of Arcturus

Declination



Distance from the Polestar

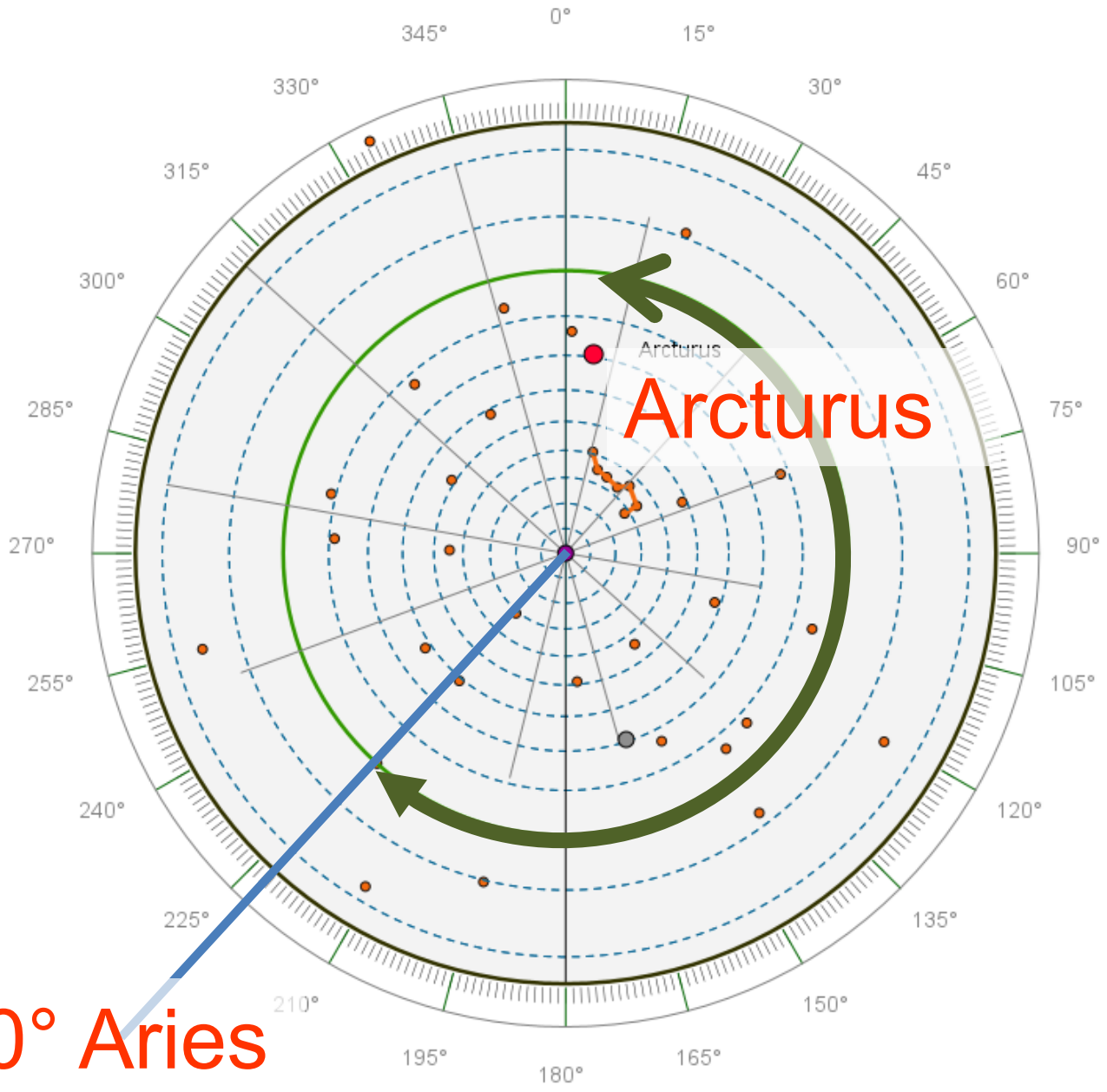
+71°

Declination

+19°

Coordinates of Arcturus

Right Ascension and Declination



Distance from the Polestar

+71°

Declination

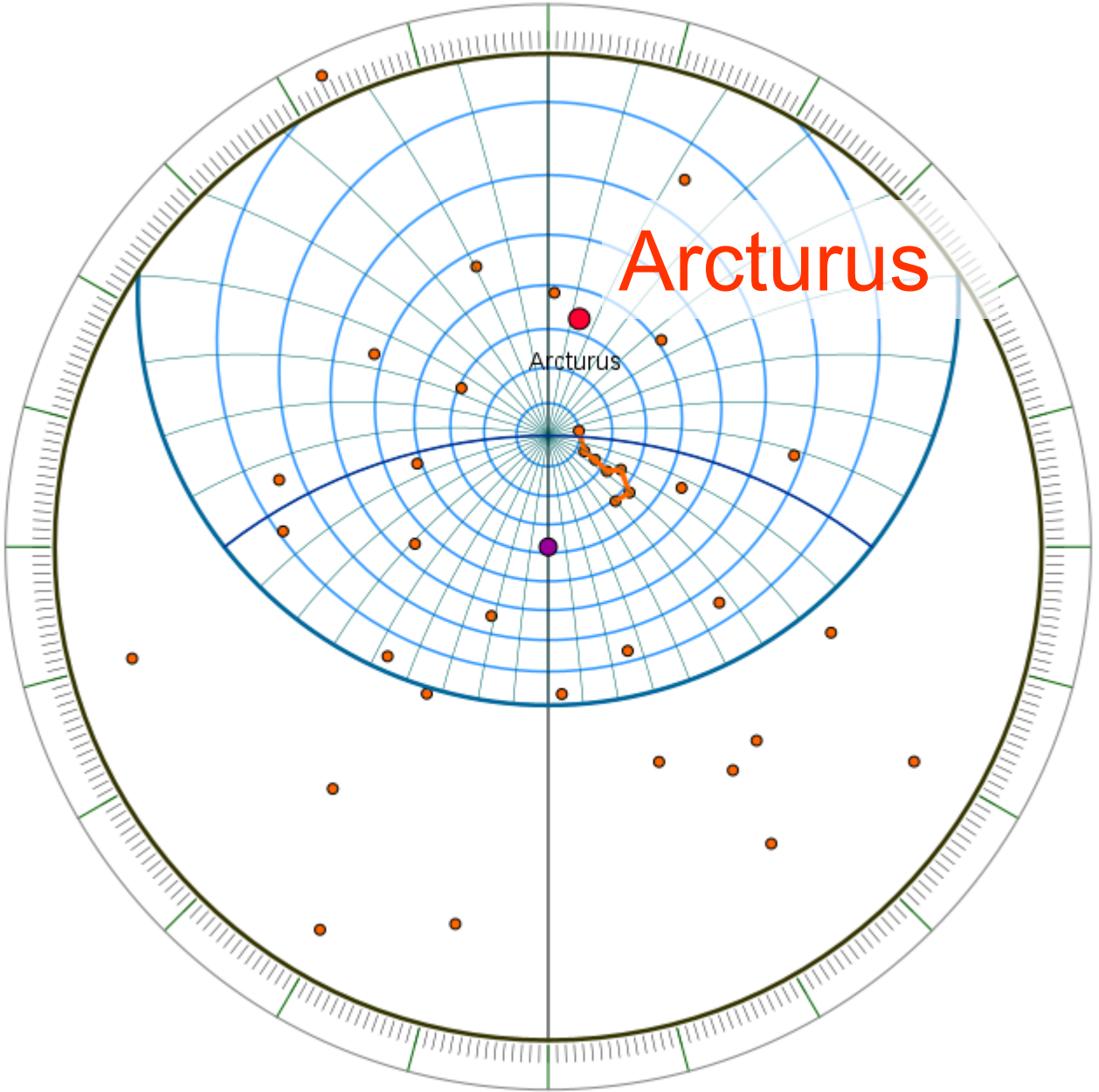
+19°

Right Ascension

214°

14h 15m

Coordinates of Arcturus
Altitude and Azimuth



Altitude

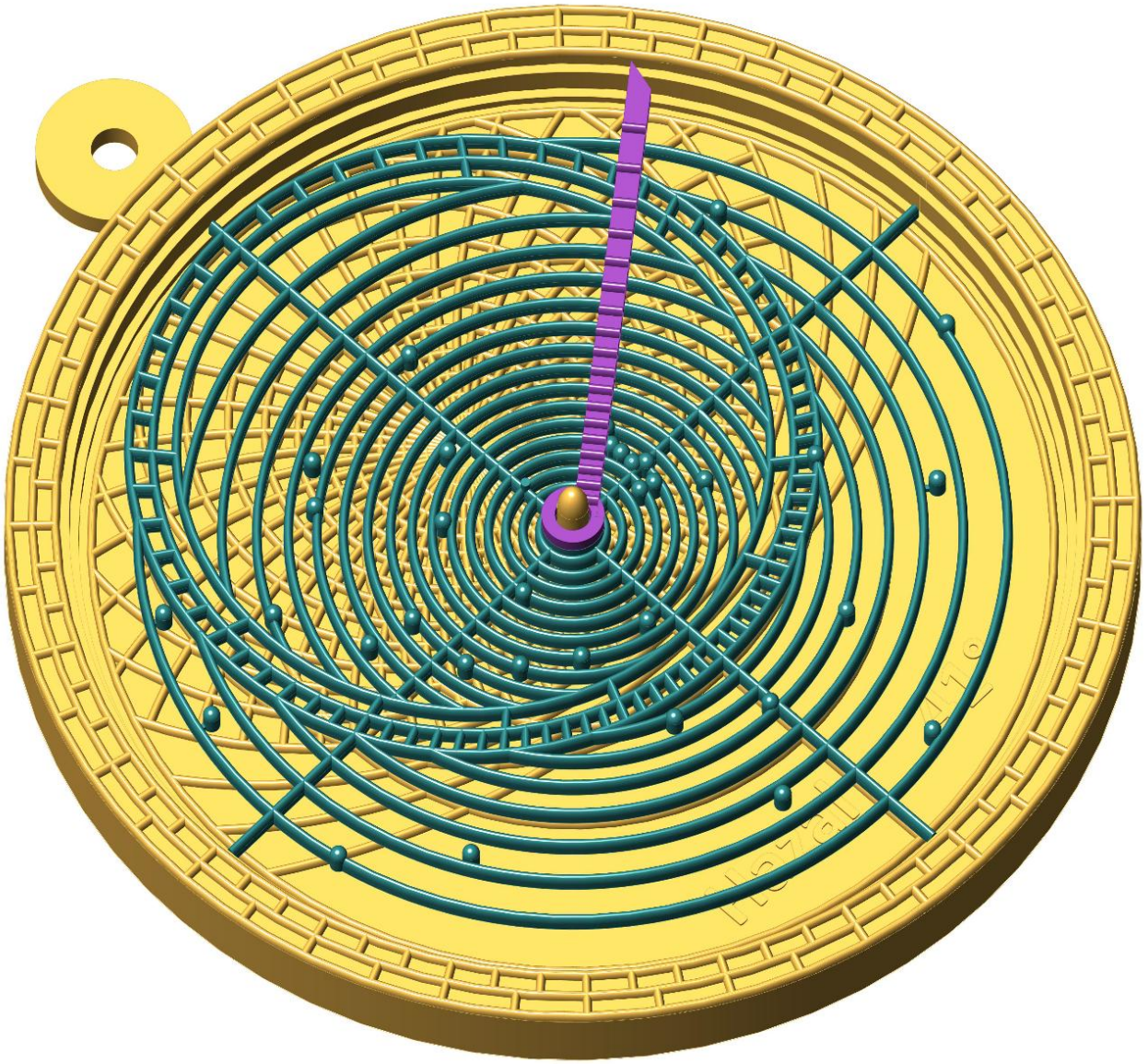
57°

Azimuth

12°
from South
to West

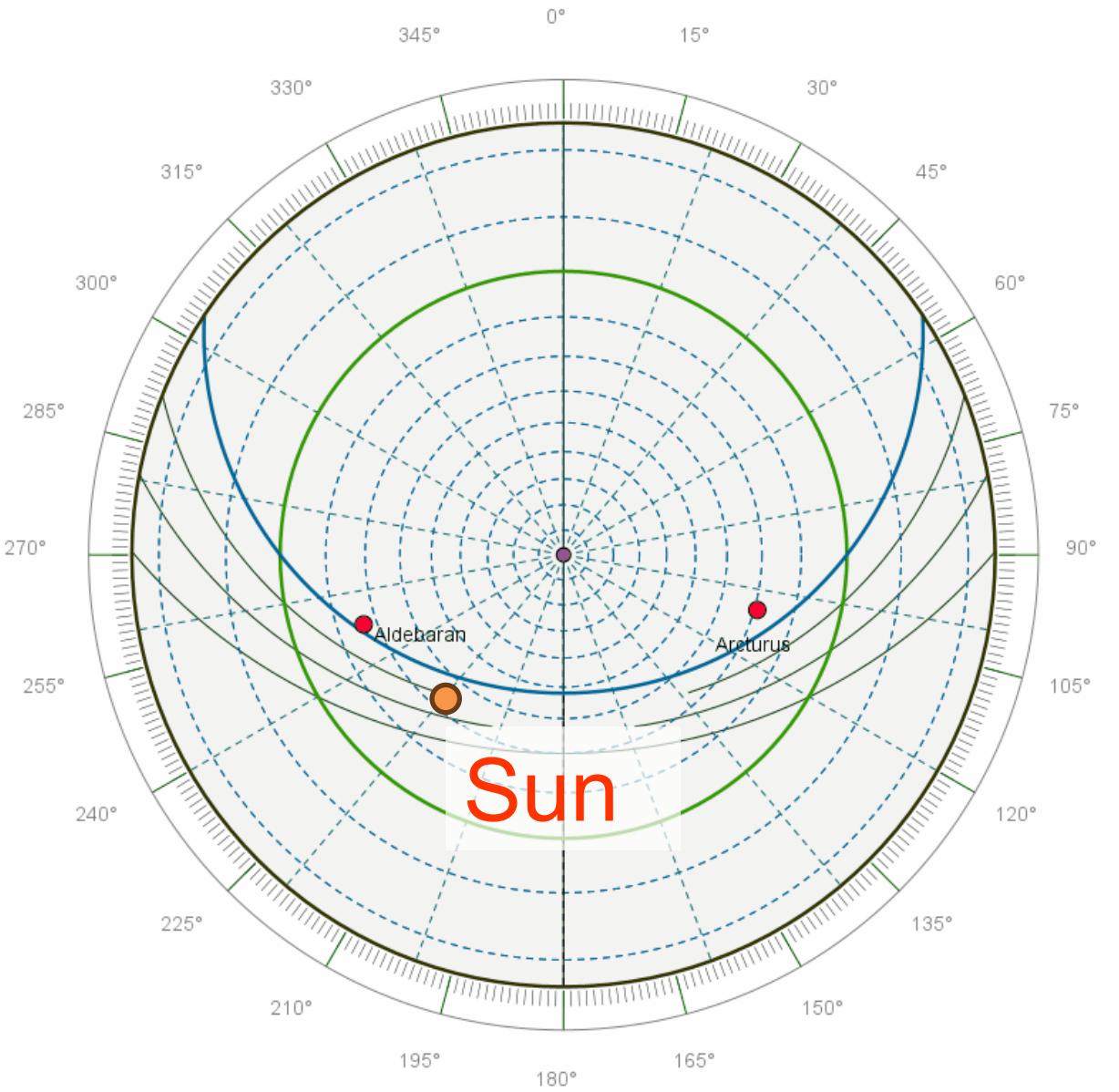
Plate and Rete

Plate shows altitude + Rete shows declination



Rete shows declination

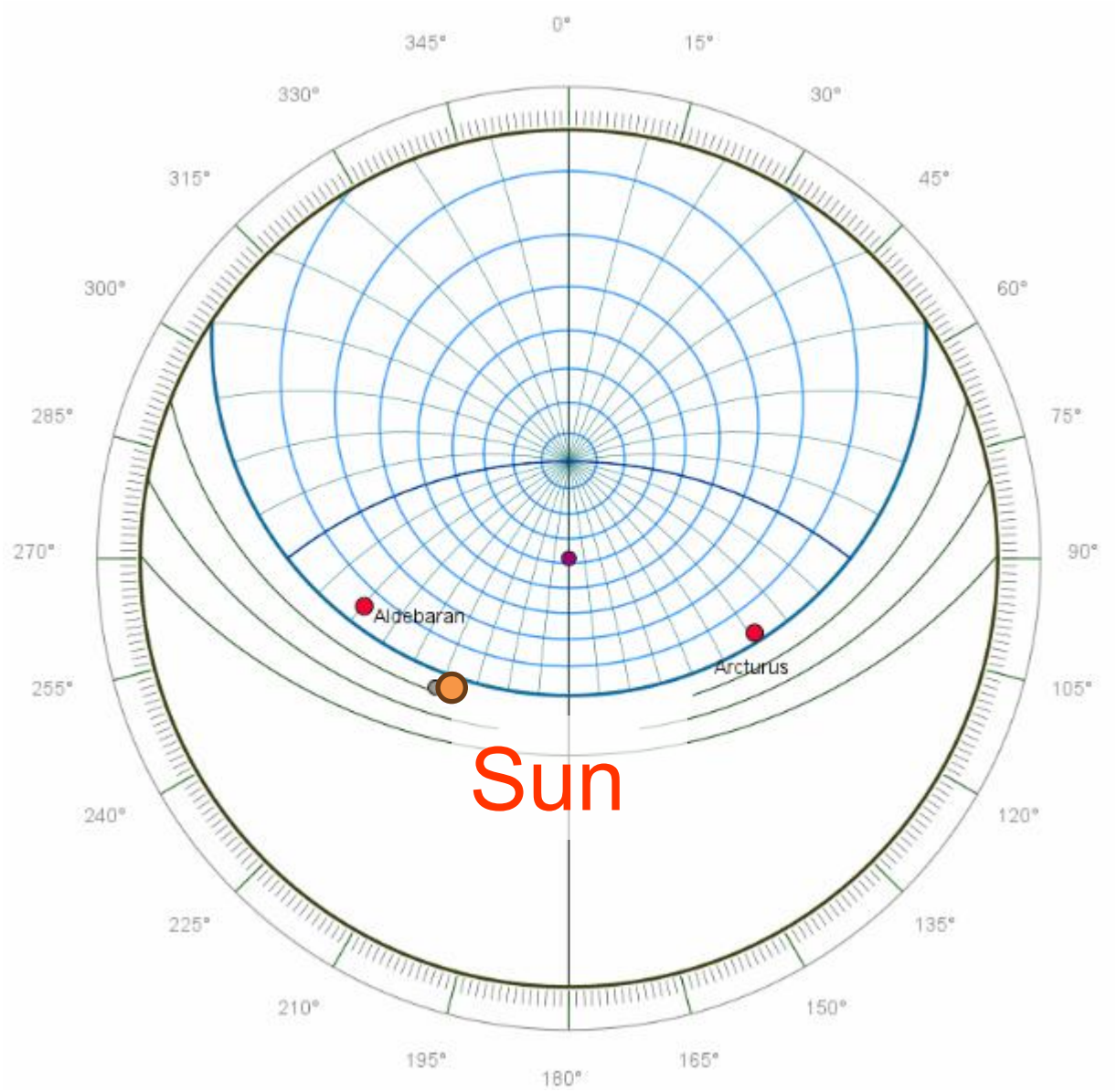
Animation Franeker 2 july: Sunrise and Sunset



https://fransvanschooten.nl/astrolabe/Astrolabe_89a06_k21_declination.gif

Plate shows Altitude

Animation Franeker 2 july: Sunrise and Sunset



https://fransvanschooten.nl/astrolabe/Astrolabe_89a06_k21_altitude.gif

What shall we teach to whom?

Ali Nesin Math Village 2023 + 2024

NESİN MATEMATİK KÖYÜ



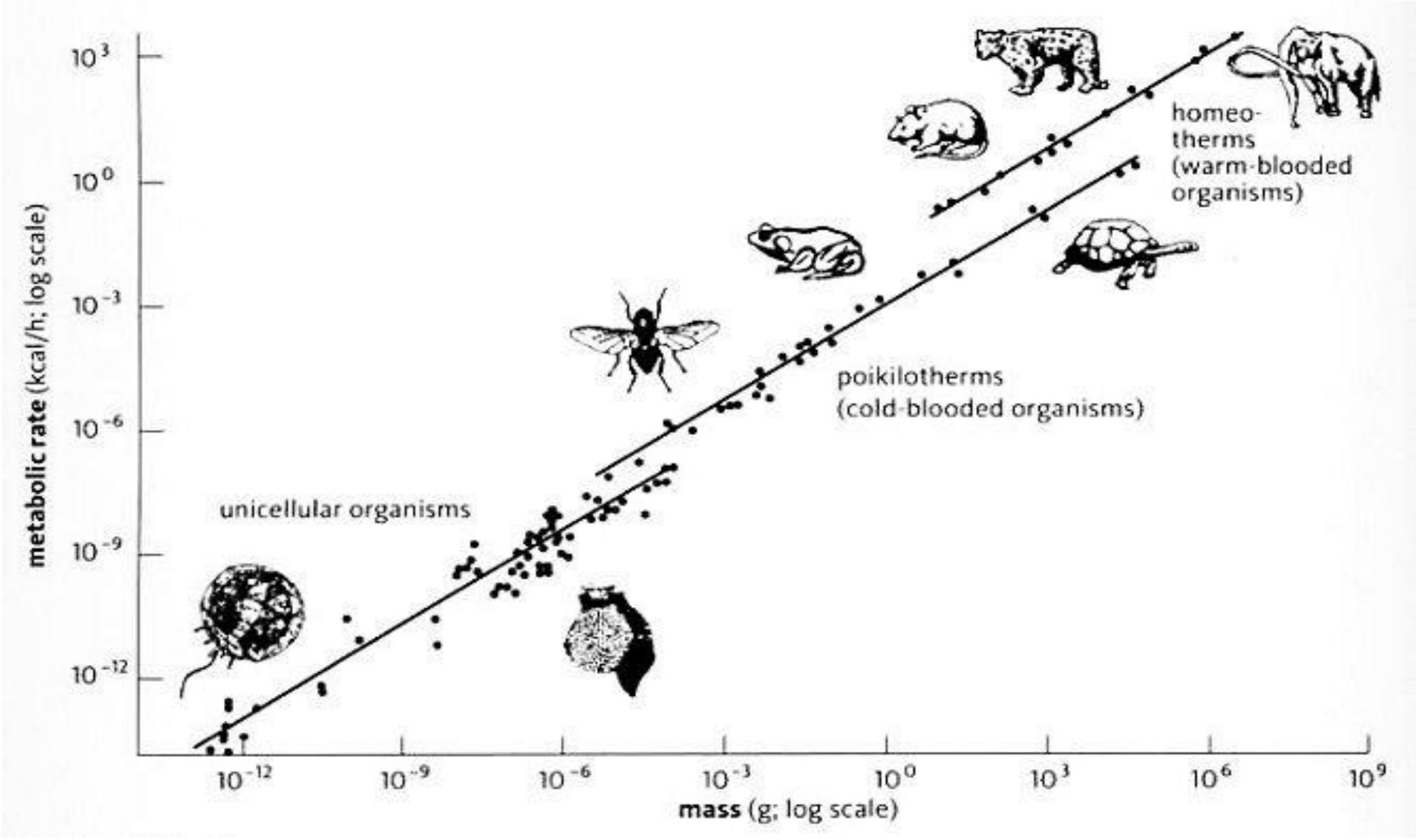
Four Levels of Math Education
Free after al-Biruni

Al-Biruni already made a distinction between different levels of mathematical education

These are my levels:

- **Professor**
- **Master‘s student**
- **High-school teacher**
- **Pupils**

Logarithms Metabolic Rate and Mass
Max Kleiber (1893–1976)



Star Trail

Long Exposure Photo at Doğu Anadolu Gözlemevi



Owners and Users
What to do with an astrolabe

In the 15th century

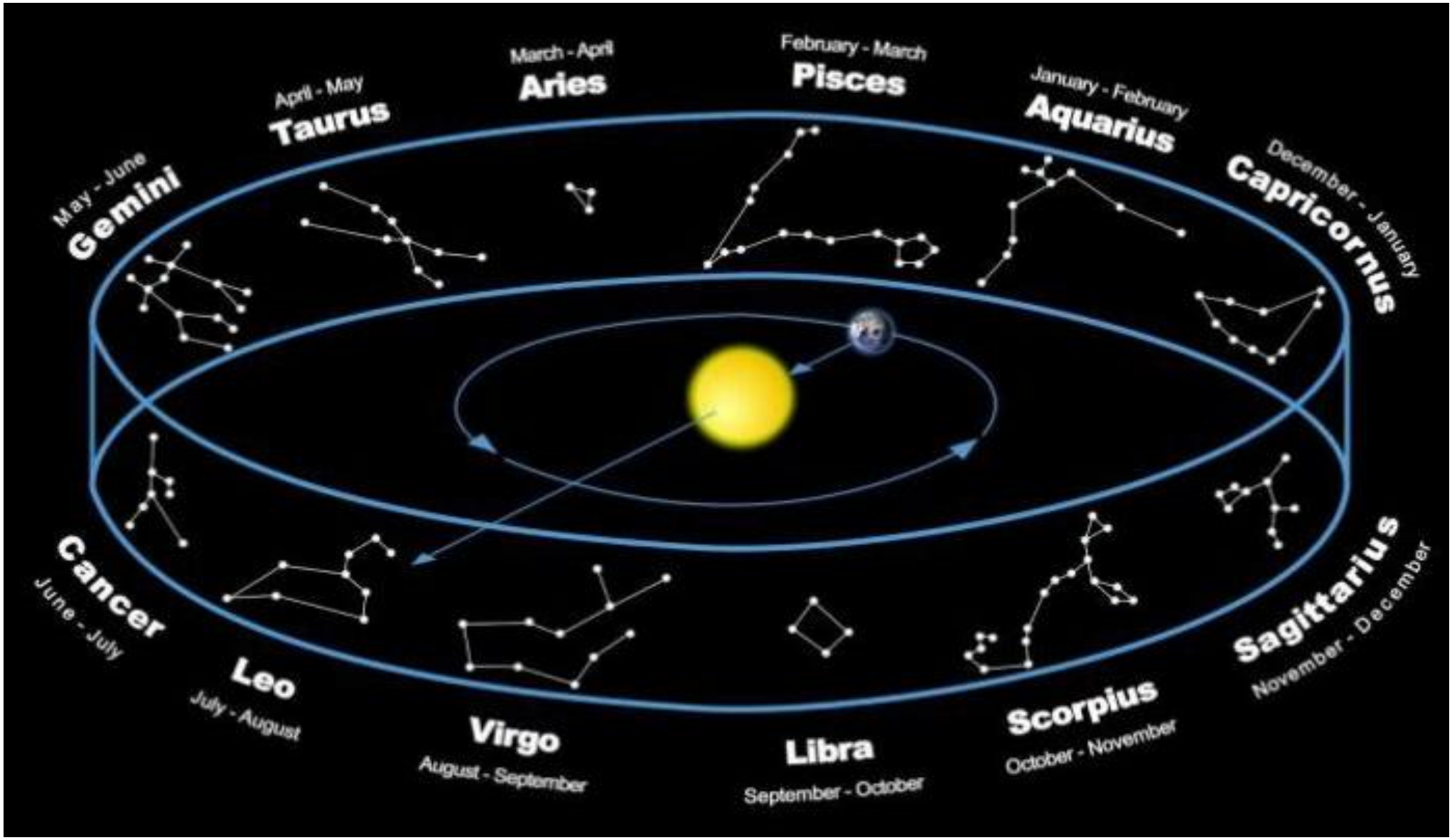
- **measure time during the night**
- **teach astronomy**
- **teach mathematics**
- **do astronomy**
- **do astrology**

Today

- **teach history of science**

The needs of an astrologer

Construct a horoscope



Concepts

How many could you explain at home?

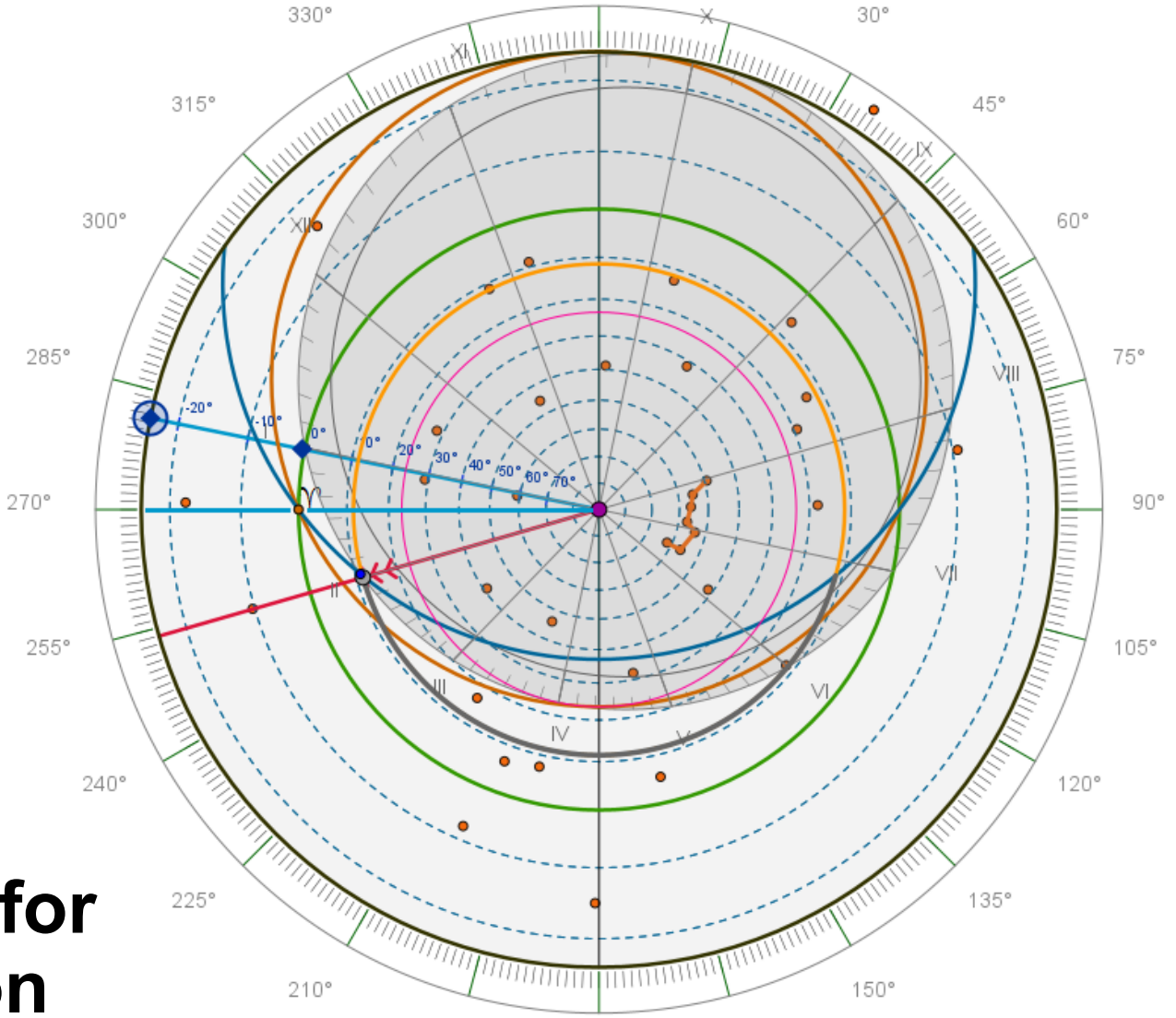
- **Equator, Tropic of Cancer , Tropic of Capricorn**
- **Declination, Right ascension**
- **Ecliptic**
- **Hour angle**
- **Vernal equinox**
- **Horizon, Latitude, Twilight**
- **Meridian, Prime vertical**
- **Temporal hours**
- **Altitude, Azimuth**
- **Oblique ascension**

Astrologers ask many questions
Right and Oblique Ascension

Your friend is an astrologer and wants to know:

- **Sign at birthday**
- **Sign at horizon at time of birth**

- **You might know right ascension**
- **Your friend asks for *oblique* ascension**



Example Ibn al-Samh: Recipe of chapter 54
Determine the oblique ascension

We are in Zaragoza, at a latitude of 40.7°**.**

We want to determine the oblique ascension of 17° Leo, corresponding approximately to 9 August**.**

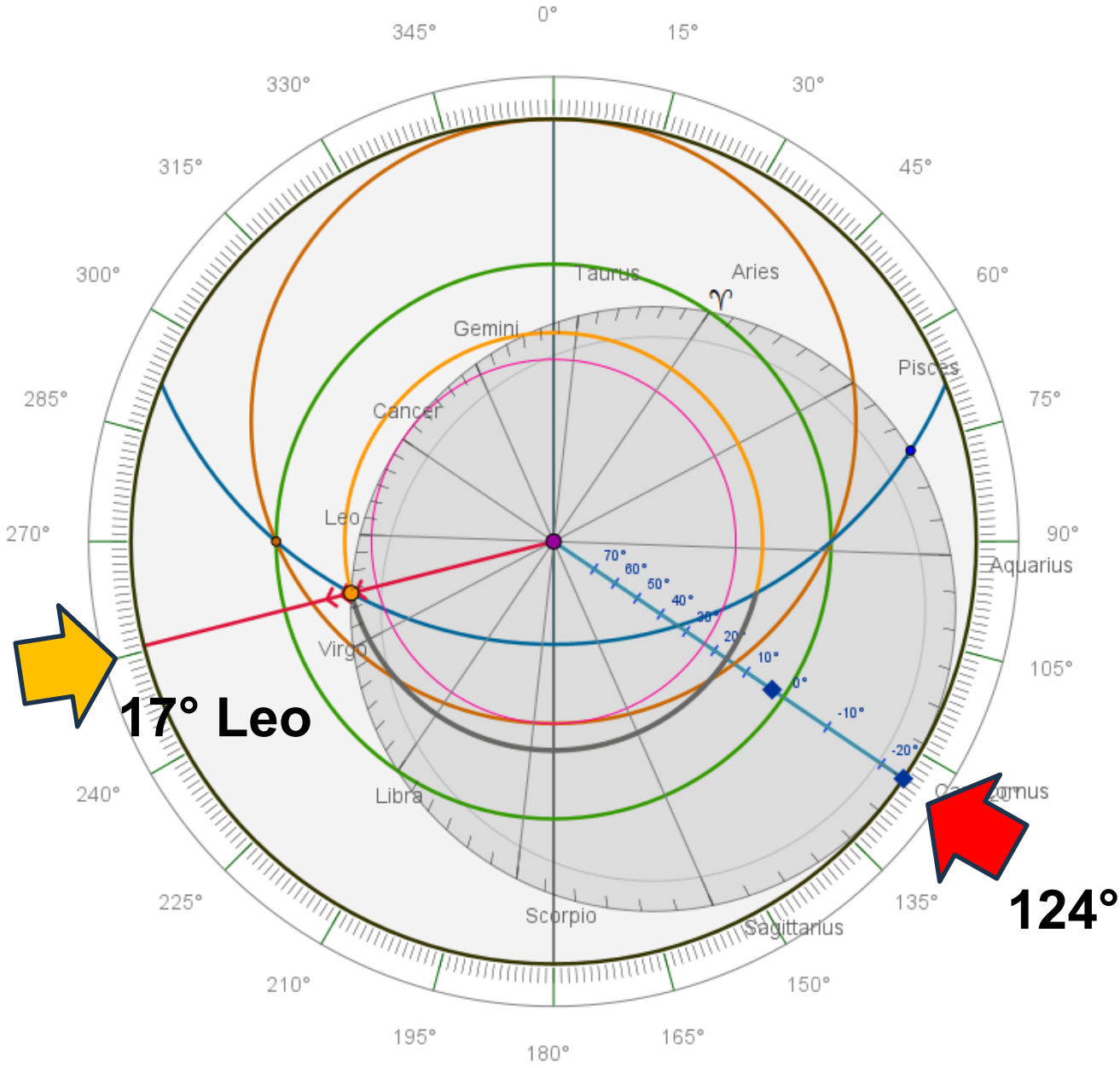
Ibn al-Samh wrote:

- **Place the degree of the zodiac that you wish to determine on the eastern horizon.**
- **Then observe on which degree of the limb the degree index falls.**
- **This gives the oblique ascension of that degree.**

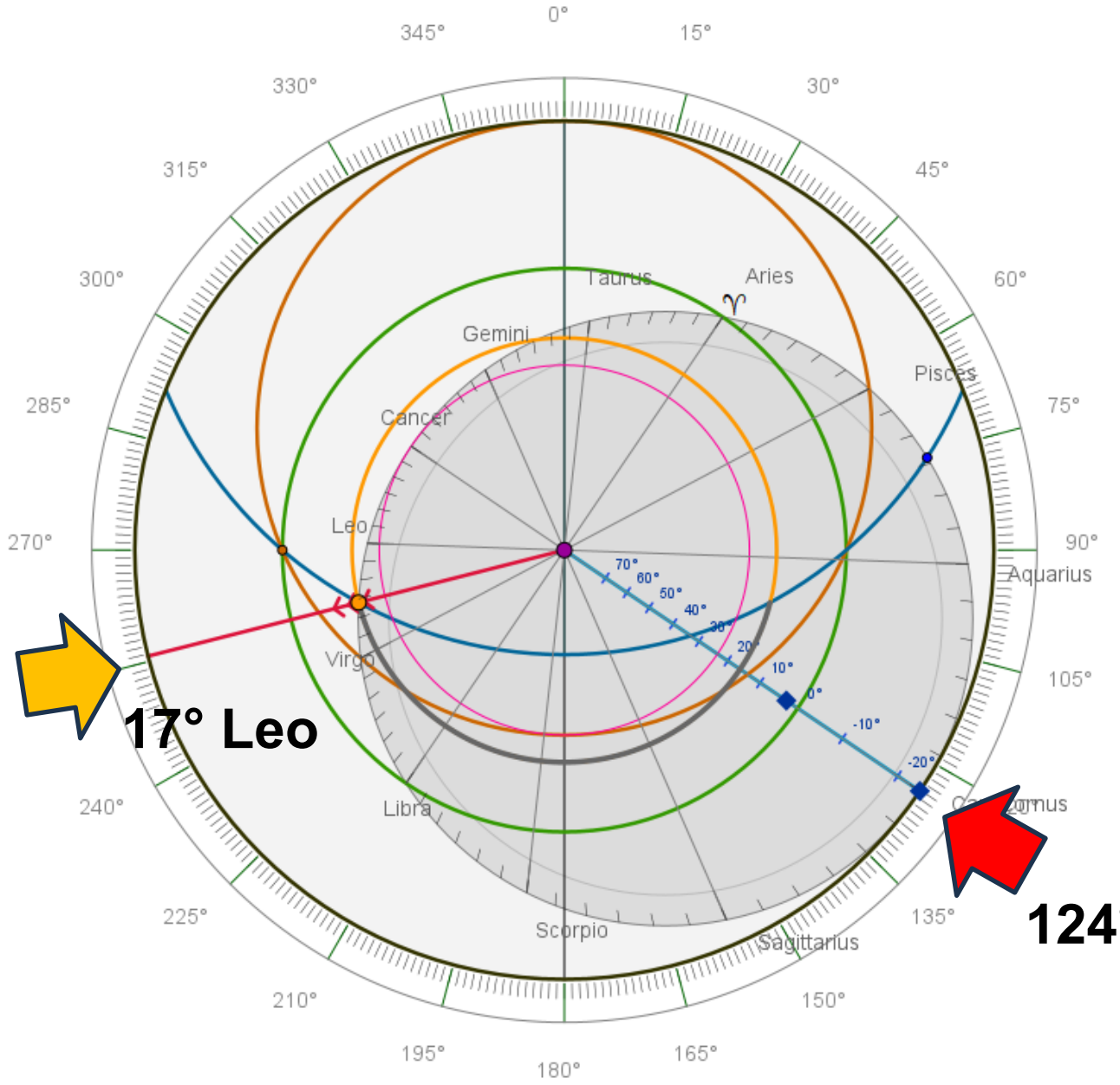
Example: Recipe of chapter 54
Determine the oblique ascension of 17 Leo

Latitude of 40.7°.

- **Place the degree of the zodiac that you wish to determine on the eastern horizon of the plate for the appropriate climate.**
- **Then observe on which degree of the limb the degree index falls.**
- **This gives the oblique ascension of that degree: 124°**



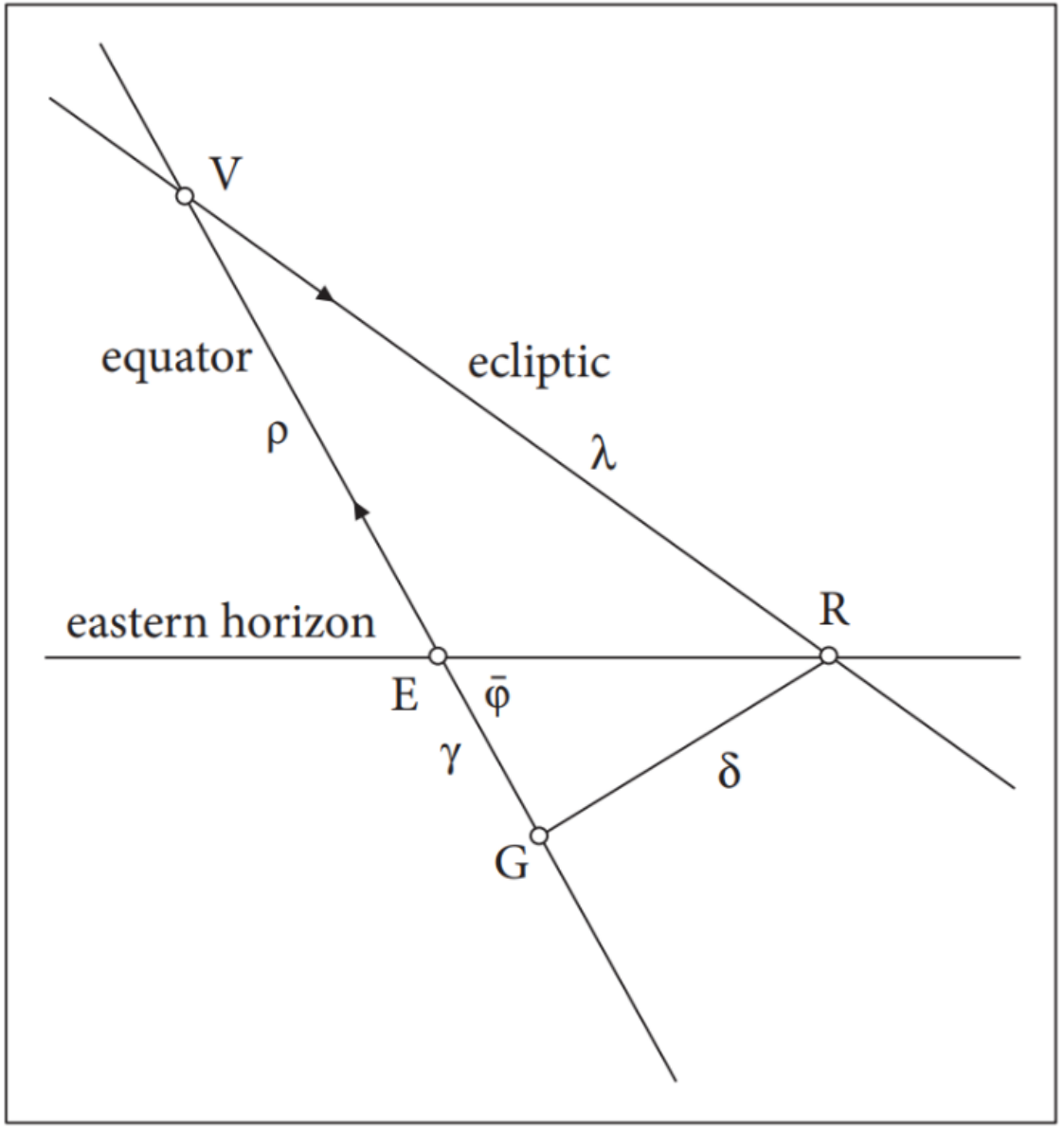
Example: Recipe of chapter 54
Homework: Prove that this recipe is correct



Ibn al-Samh
(10th – 11th century)

Right Ascension & Oblique Ascension
Theory

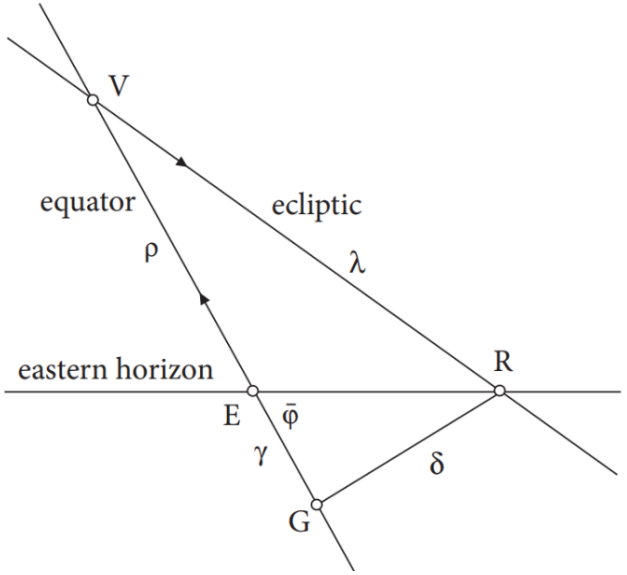
- The solar **longitude λ** is the angular distance VR along the ecliptic.
- The solar **declination δ** is the angular distance RG.
- The **right ascension α** is the angular distance VG along the equator measured eastwards from point V.
- The **oblique ascension ρ** of a point R on the ecliptic, rising on the horizon is the angular distance VE.



Right Ascension & Oblique Ascension
Explanation: Spherical Trigonometry Formulas

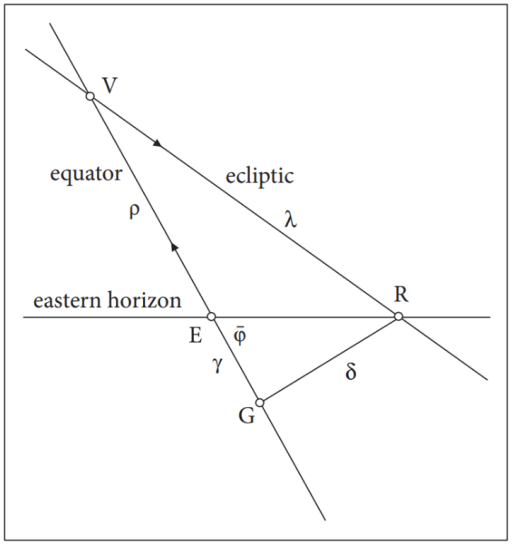
- The solar **longitude λ** is the angular distance VR along the ecliptic.
- The solar **declination δ** is the angular distance RG.
- The **right ascension α** is the angular distance VG along the equator measured eastwards from point V.
- The **oblique ascension ρ** of a point R on the ecliptic, rising on the horizon is the angular distance VE.

- Obliquity **ε** = 23,4°.
- Longitude distance between 1 Aries and 17 Leo is **λ** =137°.
- **sin δ = sin λ · sin ε**
- **tan α = cos ε · tan λ**
- Difference **γ = α – ρ**
  sin γ = tan δ · tan φ
- **ρ = α – γ**



Right Ascension & Oblique Ascension
Calculations

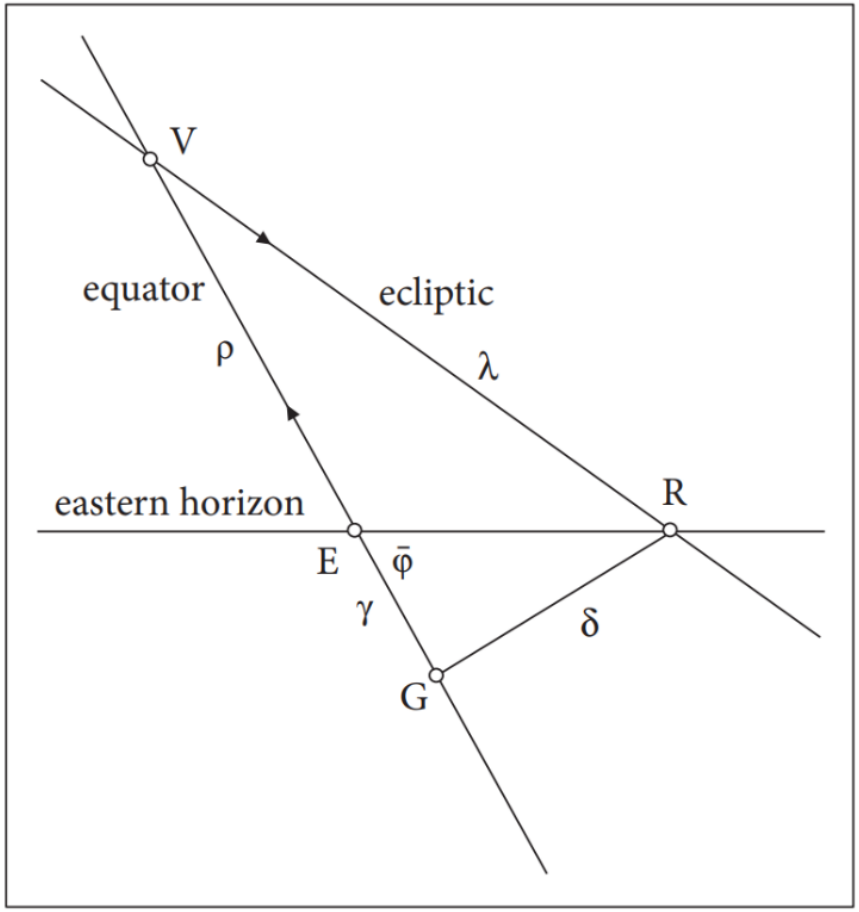
- **Say, geographical latitude φ = 40,7° for Zaragoza.**
- **Say, date is 17 Leo, that is 9 August. So, solar longitude is λ = 137°.**



declination	$\sin \delta = \sin \lambda \cdot \sin \varepsilon$	$\sin \delta = 0{,}2756$	$\delta = 16{,}00°$
right ascension	$\sin \alpha = \tan \delta / \tan \varepsilon$	$\sin \alpha = 0{,}6614$	$\alpha = 138{,}60°$
right ascension	$\tan \alpha = \cos \varepsilon \cdot \tan \lambda$	$\tan \alpha = -0{,}8817$	$\alpha = 138{,}60°$
difference	$\sin \gamma = \tan \delta \cdot \tan \phi$	$\sin \gamma = 0{,}2466$	$\gamma = 14{,}28°$
oblique ascension	$\rho = \alpha - \gamma$		$\rho = 124{,}32°$

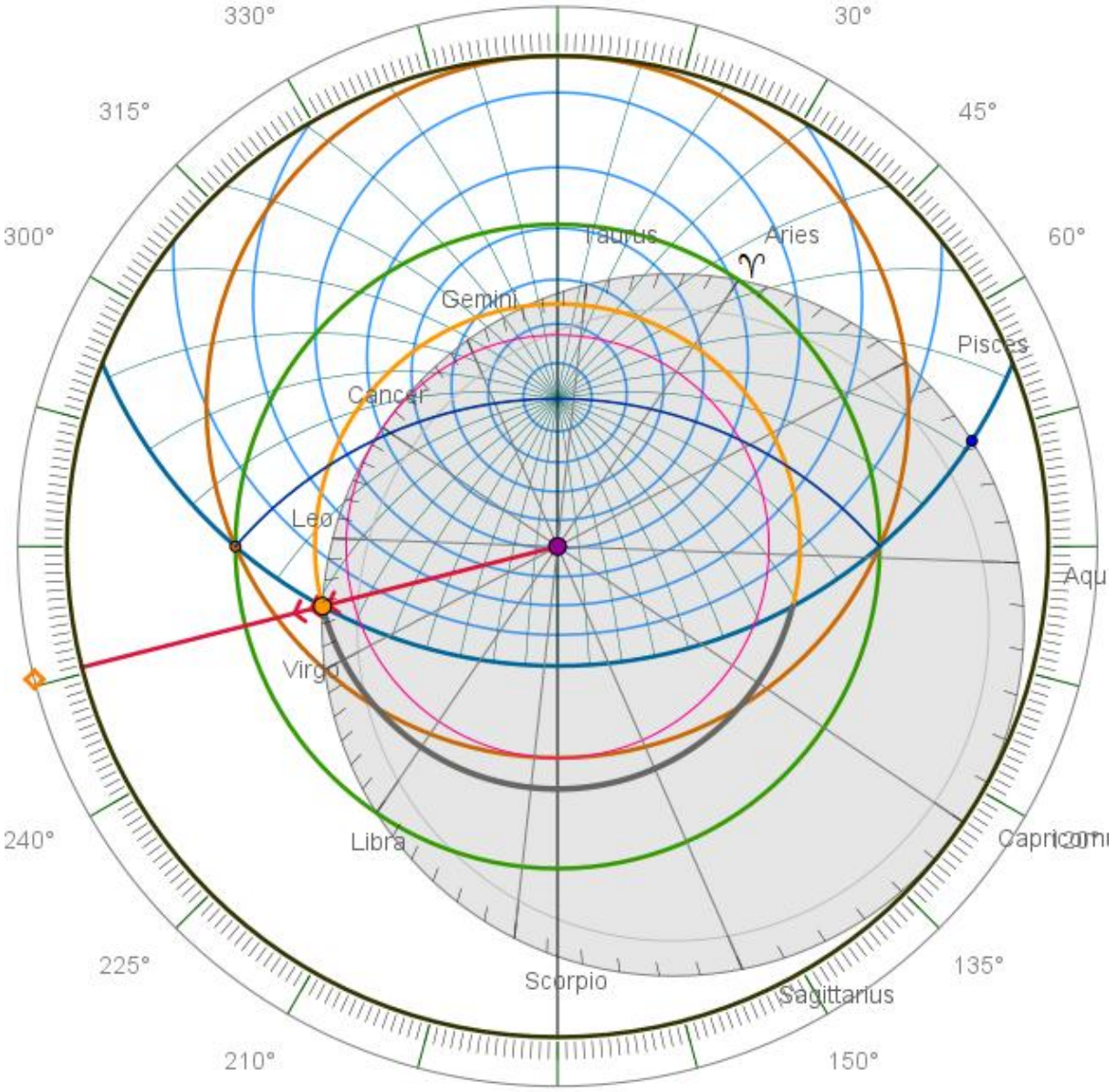
Right Ascension & Oblique Ascension
Solution of Ibn al-Samh

- Latitude **φ** = 40,7°.
- Longitude **λ** = 137°.
- Point **V** is at the intersection of the ecliptic and the equator, at 34°.
- Point **E** is East at 270°.
- Point **R** is at the intersection of the ecliptic and the horizon, that is point **G** at 256° at the equator scale.
- Now, right ascension is the arc **VG**, that is 34° - 256° = -222° = +138°.
  That is close to calculated 137°.
- Oblique ascension is the arc **VE**, that is 34° - 270° = -236 ° = +124°.
  That is close to calculated 124,32°.



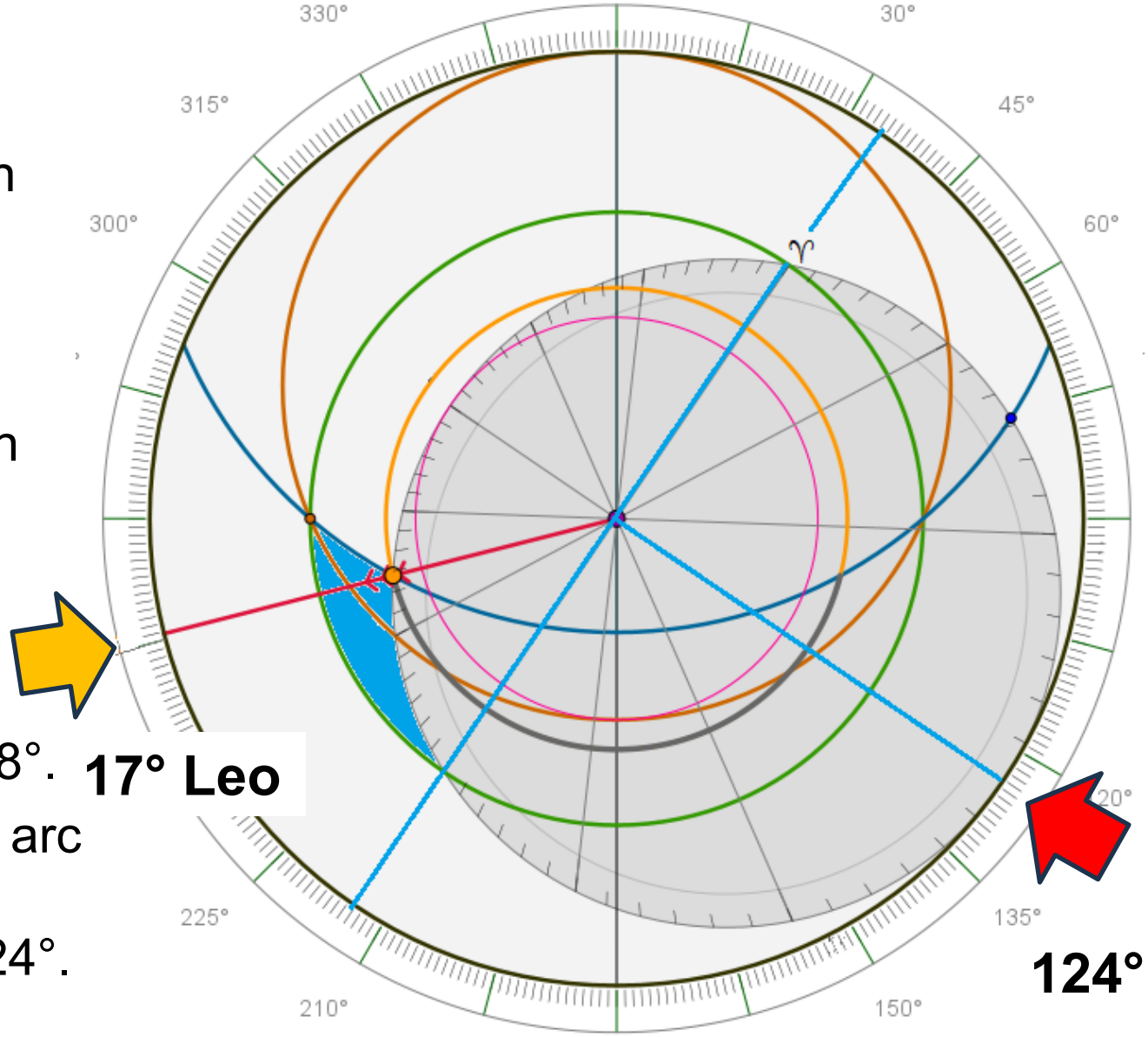
Right Ascension & Oblique Ascension
Ibn al-Samh and his astrolabe

- Latitude **φ** = 40,7°.
- Longitude **λ** = 137°.
- Point **V** is the intersection of the ecliptic and the equator, at 34°.
- Point **E** is East at 270°.
- Point **R** is the intersection of the ecliptic and the horizon, at 256°.
- Now, right ascension is the arc **VG**, that is 34° - 256° = -222° = +138°.
- Oblique ascension is the arc **VE**, that is 34° - 270° = - 236° = +124°.



Right Ascension & Oblique Ascension
Astrolabe shows Spherical Triangle

- Latitude **φ** = 40,7°.
- Longitude **λ** = 137°.
- Point **V** is the intersection of the ecliptic and the equator, at 34°.
- Point **E** is East at 270°.
- Point **R** is the intersection of the ecliptic and the horizon, at 256°.
- Now, right ascension is the arc **VG**, that is 34° - 256° = -222° = +138°.
- Oblique ascension is the arc **VE**, that is 34° - 270° = - 236° = +124°.



Work in Progress
Translate into English + Add Examples

Example for Chapter 54: Determining the Oblique Ascension

Use the degree of the sign or star to determine the oblique ascension.

- Suppose we are in London at a latitude of 51,5°.
- Given the degree, for example 25 Aries.

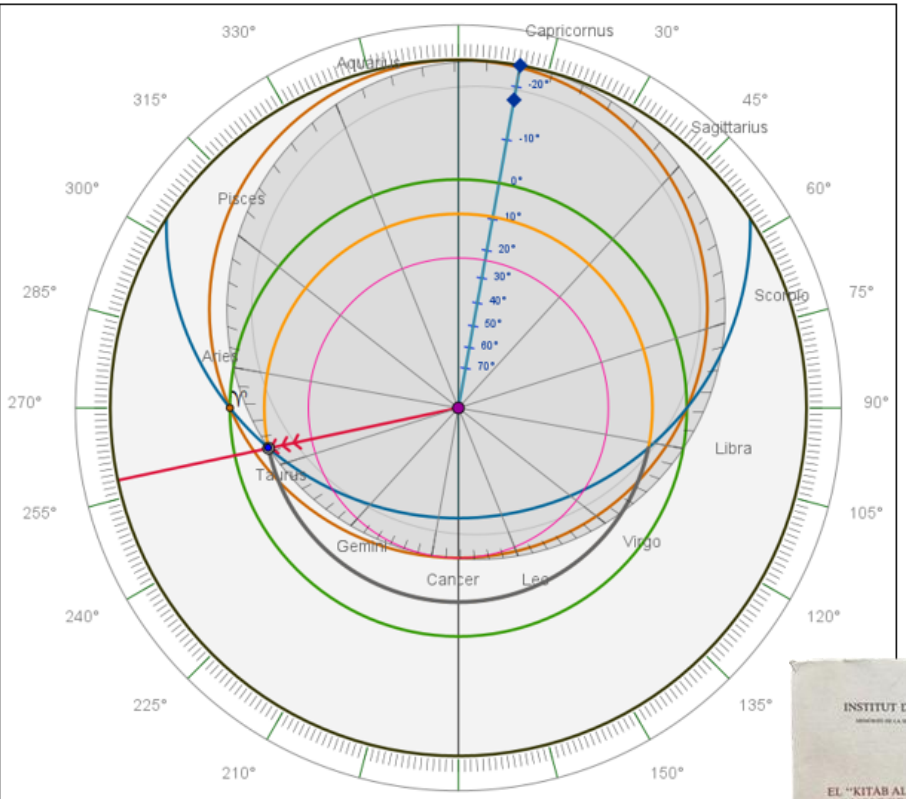
Place the degree of the zodiac that you wish to determine on the eastern horizon of the plate for the appropriate climate.

Observe on which degree of the limb the degree index falls.

This is the oblique ascension of that degree, measured from the beginning of Aries.

This chapter is called: The Conversion of Degrees of Longitude into Degrees of Oblique Ascension.

In this example, the degree index falls on 10°. This is the oblique ascension[23].





My Personal Astrolabe

18 steps guide you through the geometry

Place yourself on the world time zone map in the Northern hemisphere

your timezone = 1

your latitude = 40.7° — use the sliders for finetuning

your longitude= -0.9° — of latitude and longitude

<< < step = 0 > >> use

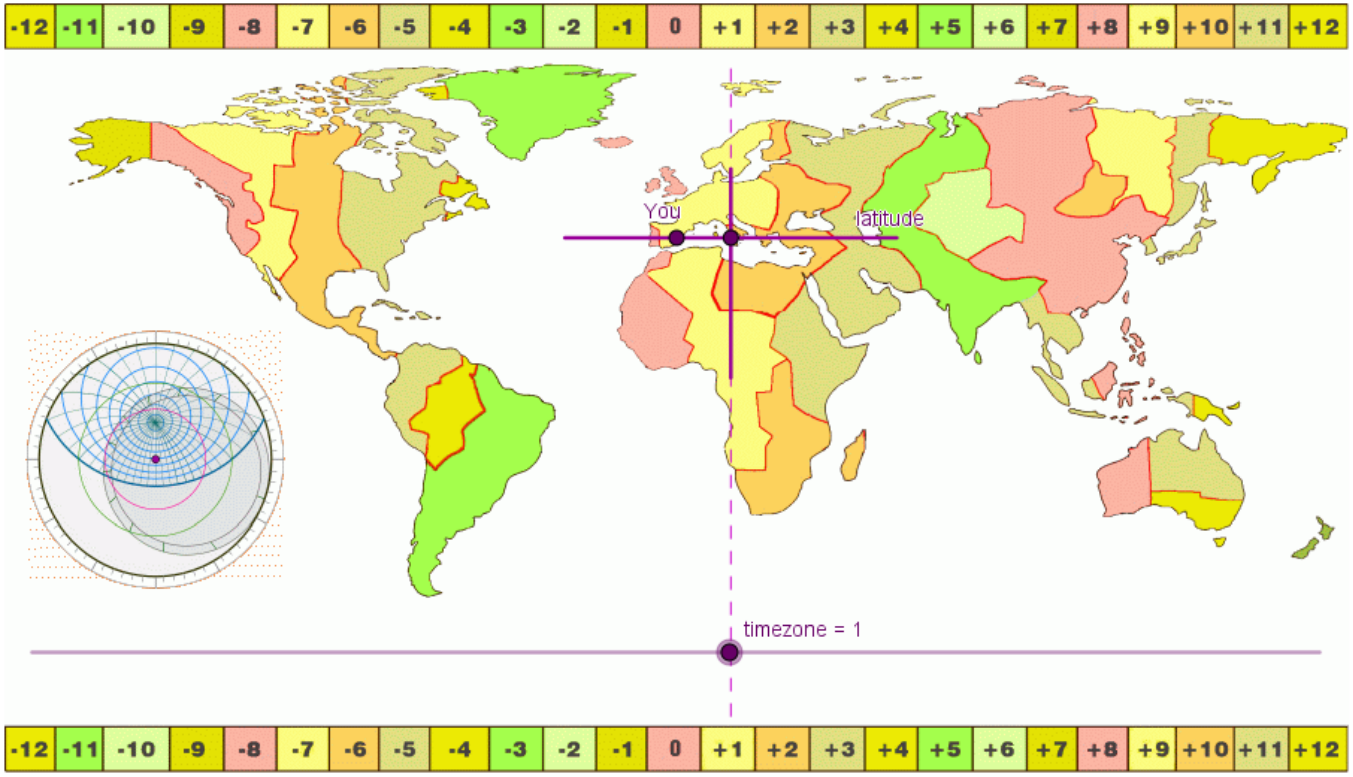
difference between local mean time and standard time = -64 min

your city Zaragoza

Info

grid latitude

grid longitude



https://www.geogebra.org/m/m43ry8wk#material/HNFqFkzf

My Personal Astrolabe

Screen 19 with a lot of tailoring option

Large Astrolabe

You are in Zaragoza at a latitude of 40.7°.

Sun longitude in the zodiac is 29 Virgo

<< < step = 19 > >>

Date is 22 September

Sun declination is +0.8°

Number of circles = 9

Local apparent solar time is 11:00 , altitude of sun is 47.8°

Civil clock time is 12:56

Temporal hour is 5:00

☑ track time

☐ animation

Sun index is at 345°

Capricorn index is at 253.2°

Hour angle is 76°



I	Aries
II	Taurus
III	Gemini
IV	Cancer
V	Leo
VI	Virgo
VII	Libra
VIII	Scorpio
IX	Sagittarius
X	Capricornus
XI	Aquarius
XII	Pisces

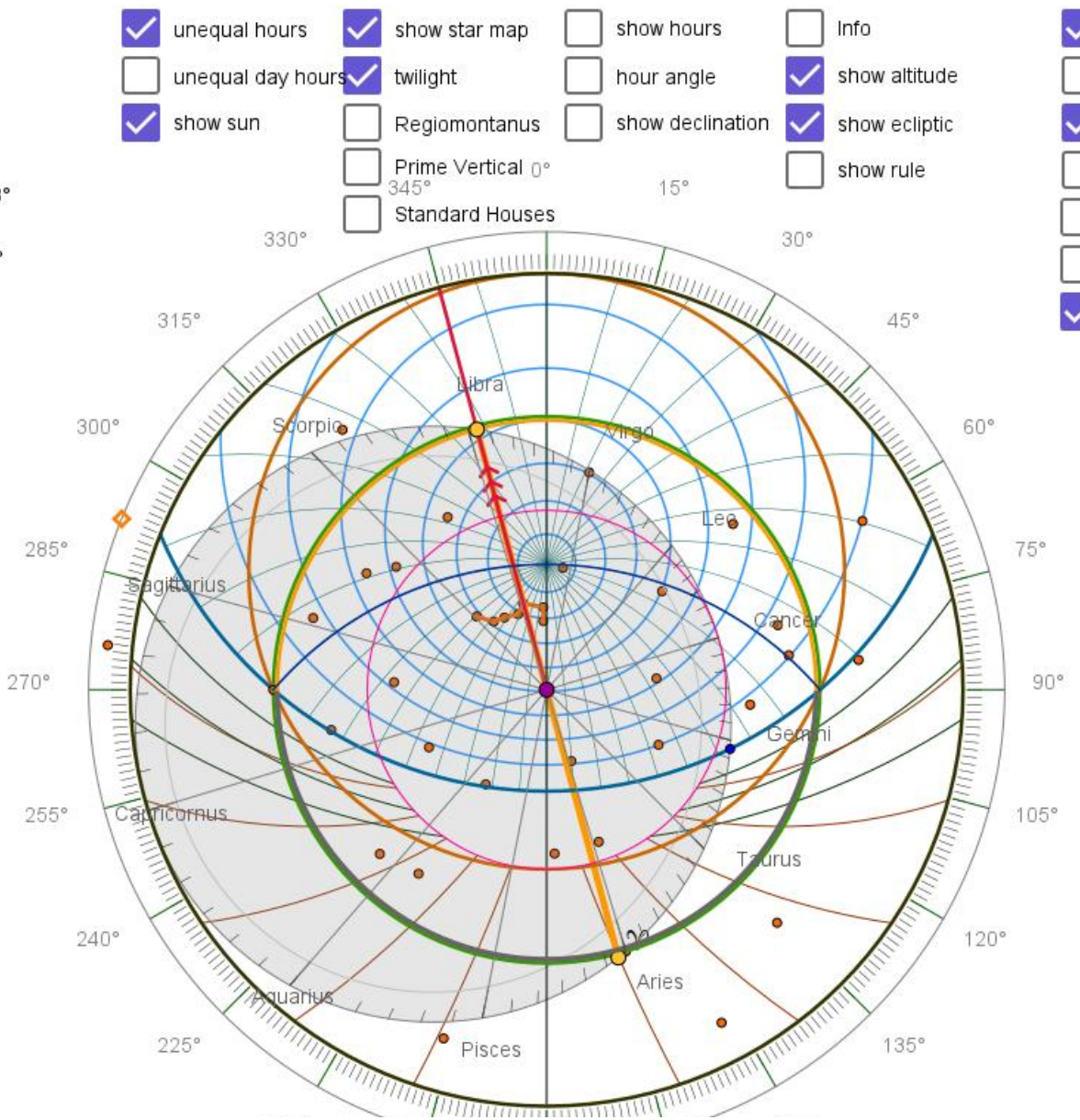
☑ unequal hours ☐ unequal day hours ☑ show sun

☑ show star map ☑ twilight ☐ Regiomontanus ☐ Prime Vertical ☐ Standard Houses

☐ show hours ☐ hour angle ☐ show declination

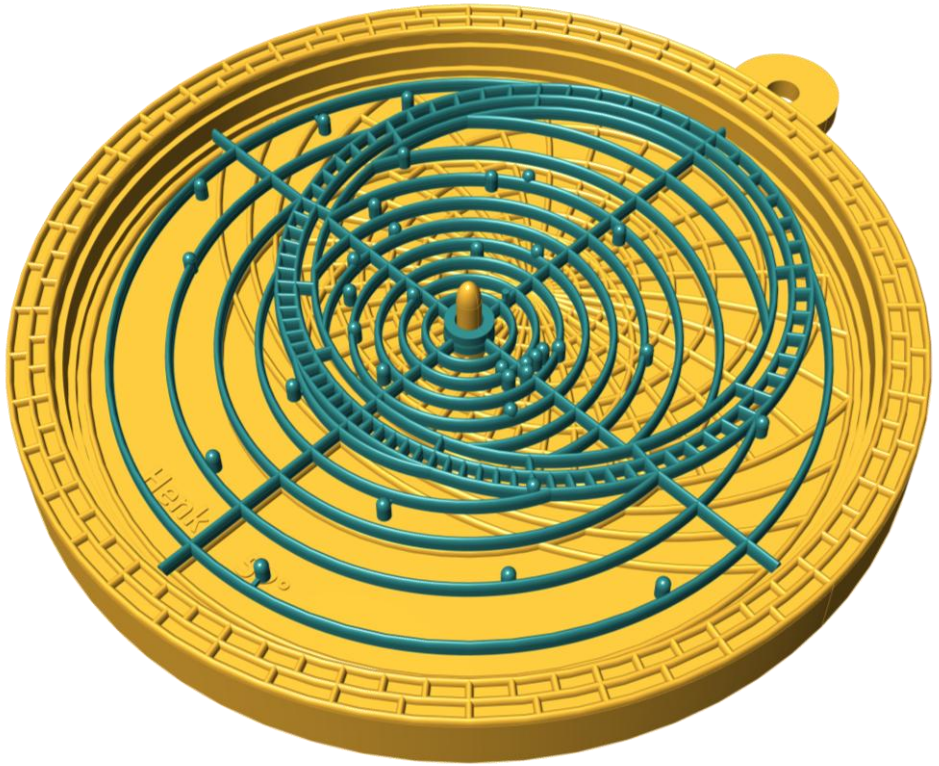
☐ Info ☑ show altitude ☑ show ecliptic ☐ show rule

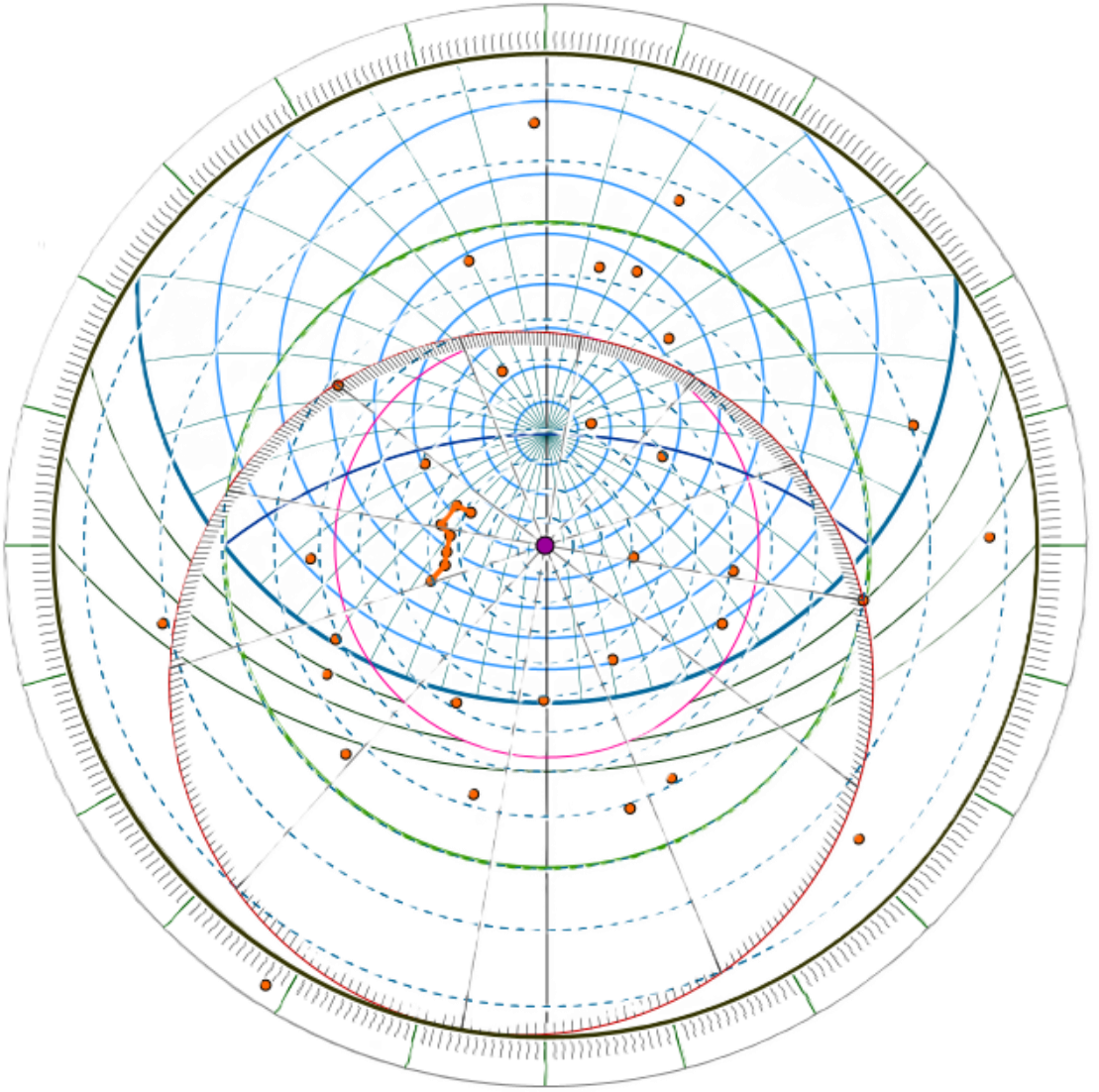
☑ show title ☐ Milky Way ☑ opposite side of sun ☐ show Arcturus ☐ show Aldebaran ☐ show star names ☑ show constellations



https://www.geogebra.org/m/m43ry8wk#material/HNEqEkzf

The Best: Laminated paper + Transparancy
A Gimmick: Affordable 3D printed astrolabe





Adriaan Metius (1571 - 1635)

Matheseos Professoris in Acad. Frisiorum



© https://www.museummartena.nl/collectie/universiteitszaal



Fundamentale onder-
wijsinghe/
Aengaende de *Fabrica*, en het veelvoudigh gebruyck
van het *Astrolabium*,
Soo *Catholicum*, als *particulier*.
Beschreven door *Adrianum Metium M. D.* ende *Professorem*
in de Mathematische consten binnen Franeker.

LEIDEN POLYTECHN. SCHOOL BIBLIOTHEEK

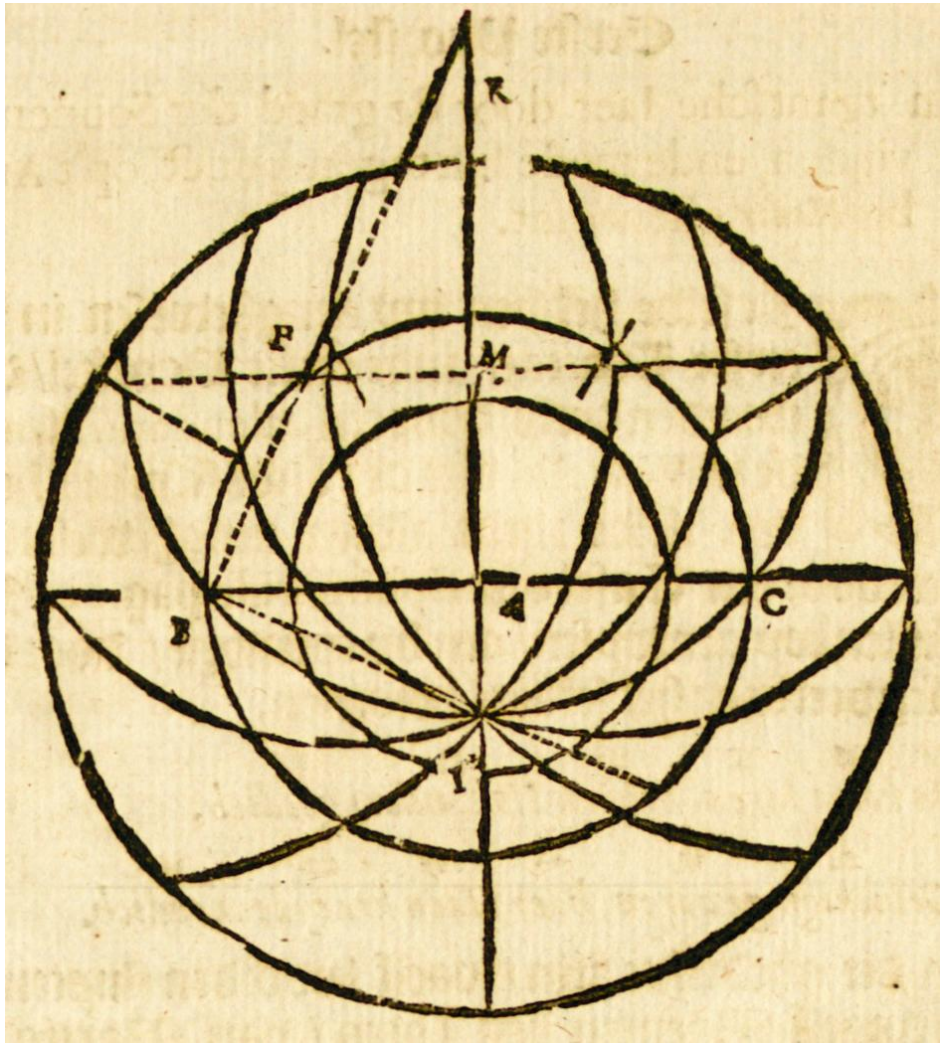
Voor Hendrick Lauwerens, Boeckvercoper tot Amsterdam.

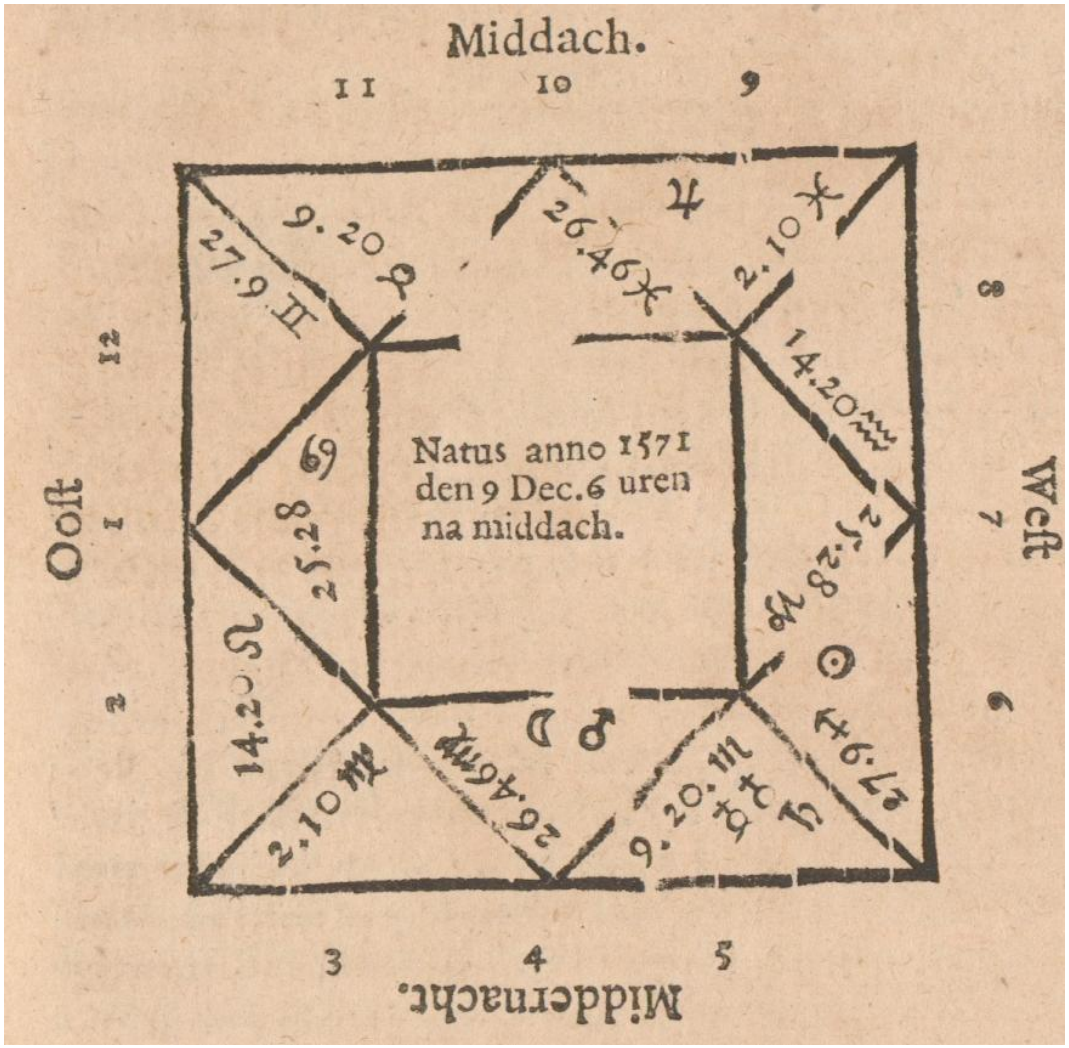
Tot Franeker,
Ghedruckt by Vlderick Balck, geordineerde Boeck-
druckter der E. H. Staten van Frieslandt. Anno 1627.

© https://www.e-rara.ch

Adriaan Metius (1571-1635)

Astrological houses for horoscopes





© https://www.e-rara.ch/ the platform for digitized rare books from Swiss institutions

Conclusion
History of Mathematics

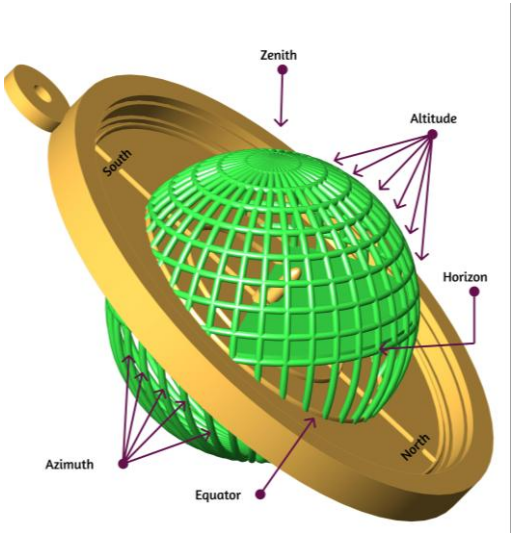
- **History is often about big discoveries**
- **Remember:** More people can work successfully with graphs with logarithmic scales than can manipulate the rules or know the history.
- **The same is true for astrolabes**
  and for many more applications
- **History of use deserves a place**
  - Ibn al-Samh's *Book on the Use of the Astrolabe*

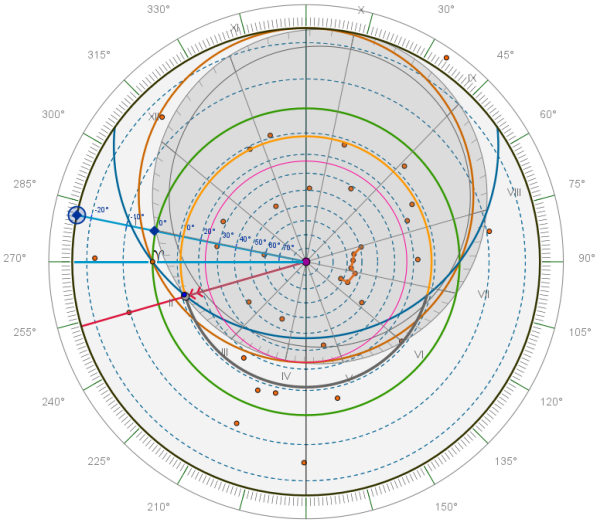
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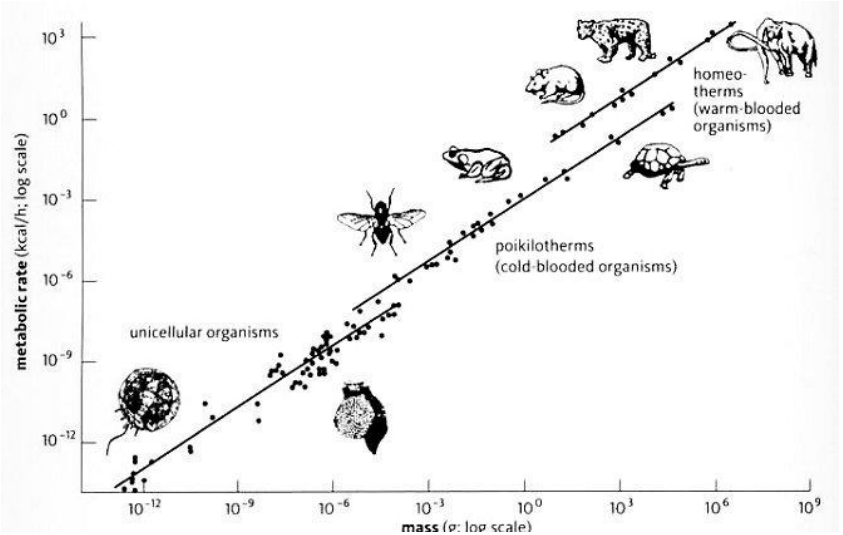












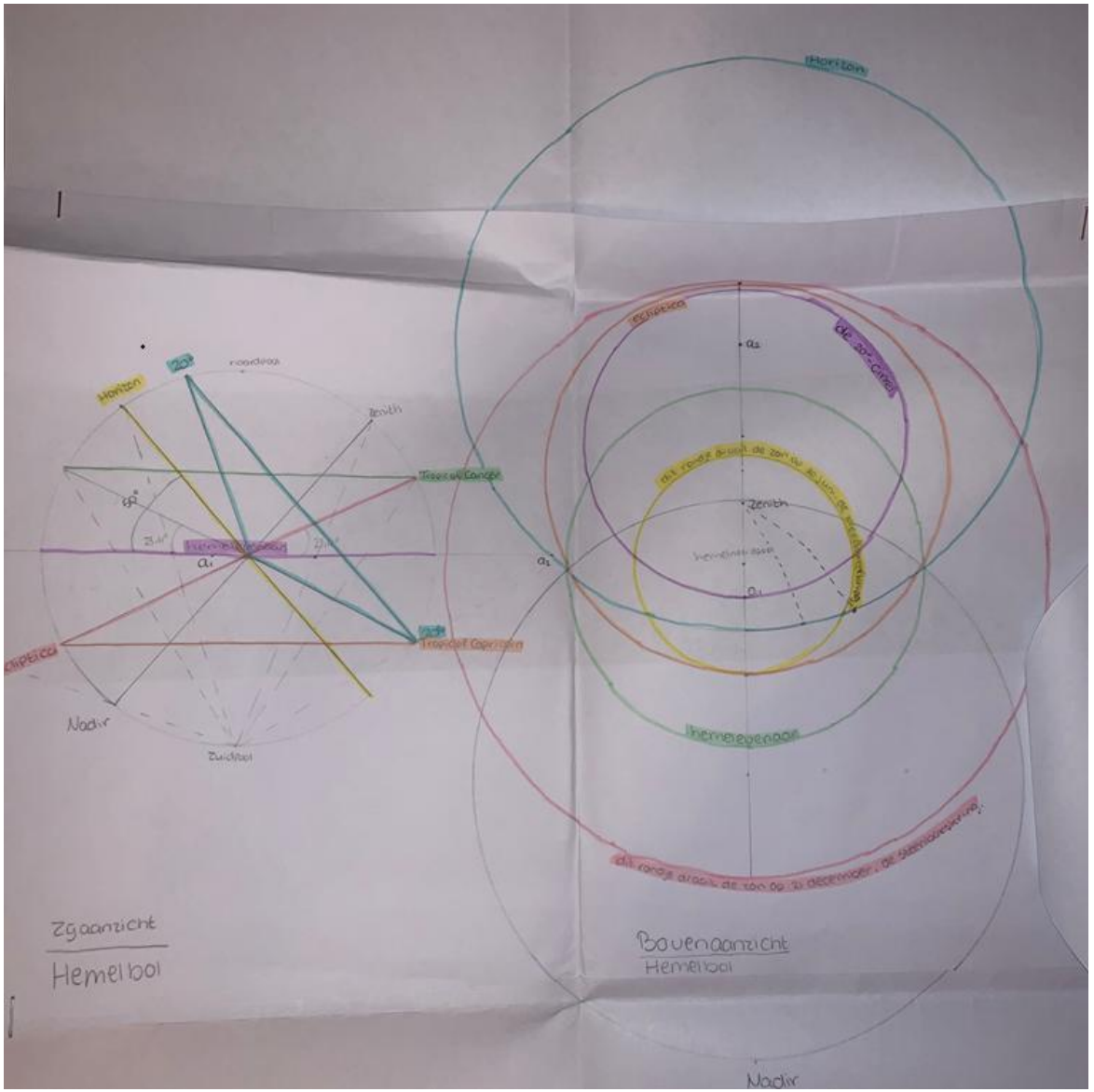


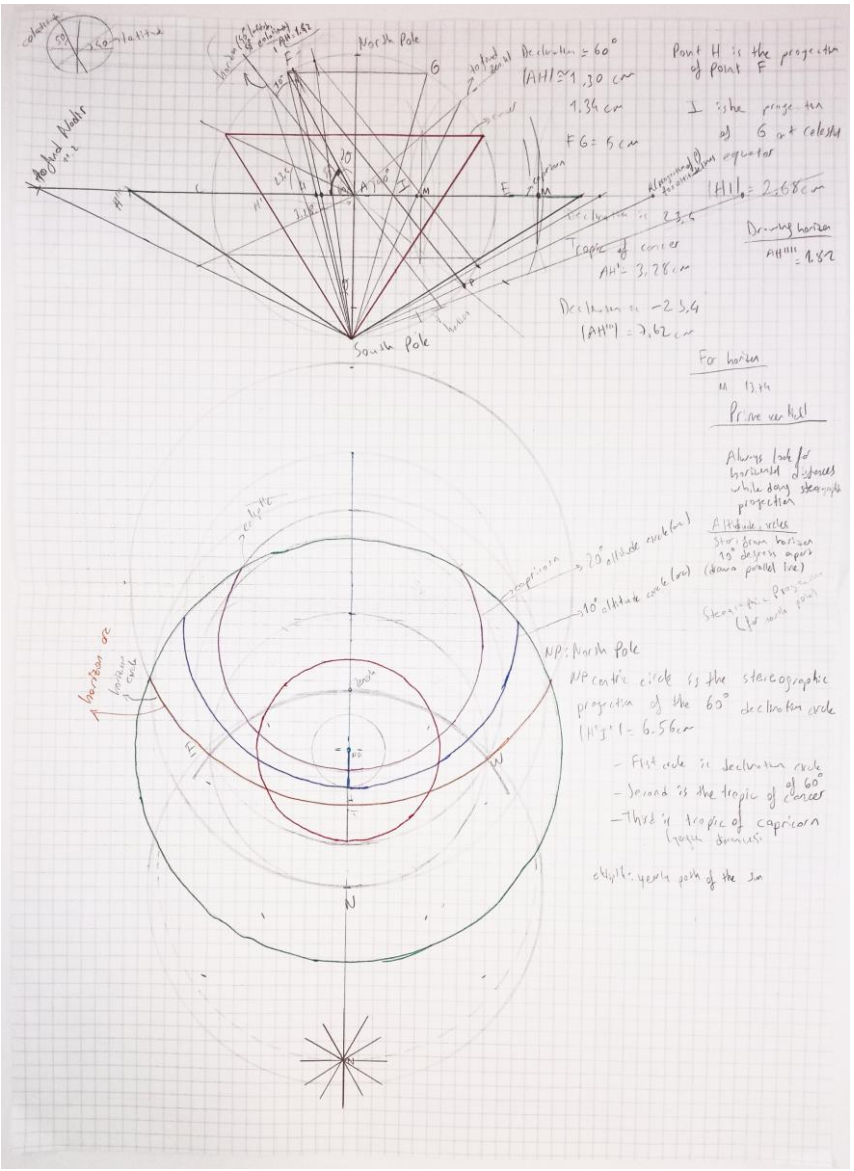
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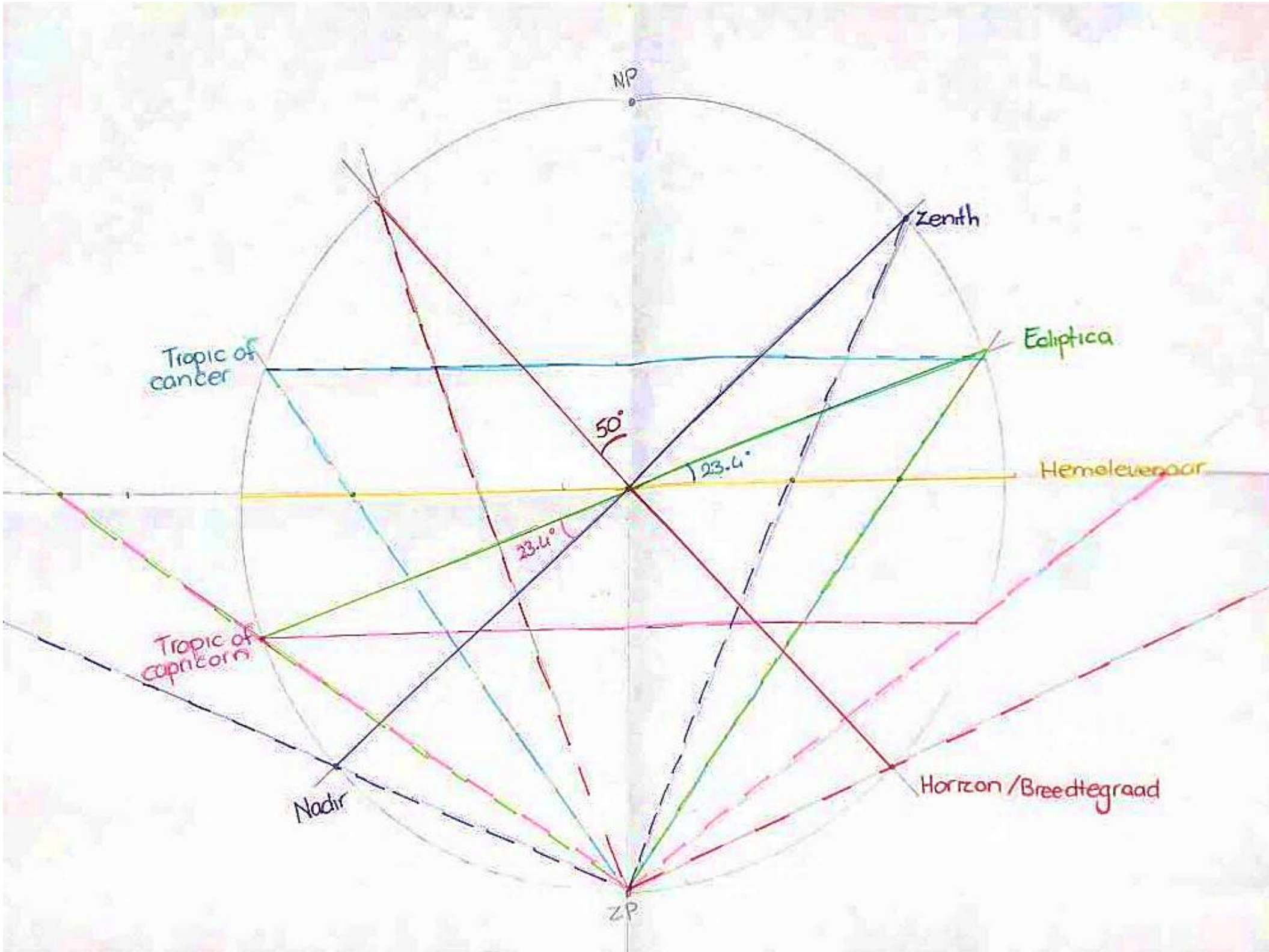


Eveyone Can Draw an Astrolabe
a 15 year old could do

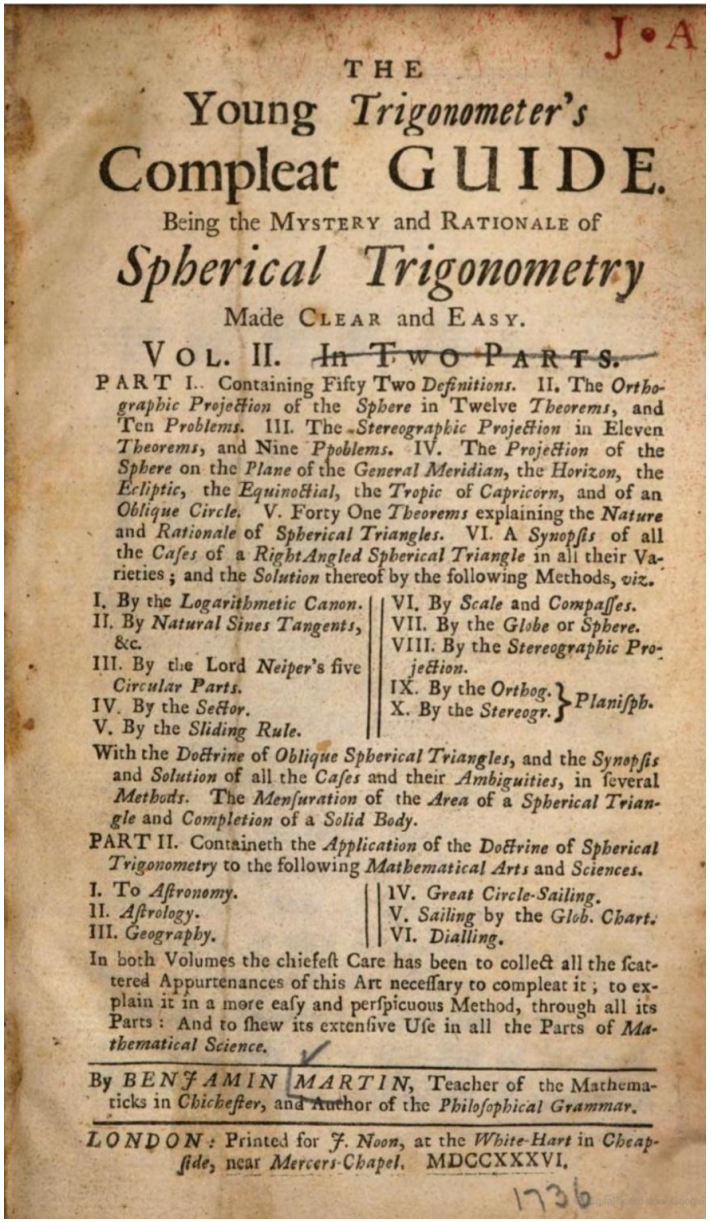




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NP
Zenith
Tropic of cancer
Ecliptica
50°
23.4°
Hemelevenaar
23.4°
Tropic of capricorn
Nadir
Horizon / Breedtegraad
ZP

Everyone can draw an astrolabe
Benjamin Martin (1705-1782)



J. A

THE

Young *Trigonometer's*

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Being the MYSTERY and RATIONALE of

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I. By the *Logarithmetic Canon*.
II. By *Natural Sines Tangents*, &c.
III. By the Lord *Neiper's* five *Circular Parts*.
IV. By the *Sector*.
V. By the *Sliding Rule*.
VI. By *Scale* and *Compasses*.
VII. By the *Globe* or *Sphere*.
VIII. By the *Stereographic Projection*.
IX. By the *Orthog.* } *Planisph.*
X. By the *Stereogr.* }

With the *Doctrine* of *Oblique Spherical Triangles*, and the *Synopsis* and *Solution* of all the *Cases* and their *Ambiguities*, in several *Methods*. The *Mensuration* of the *Area* of a *Spherical Triangle* and *Completion* of a *Solid Body*.

PART II. Containeth the *Application* of the *Doctrine* of *Spherical Trigonometry* to the following *Mathematical Arts* and *Sciences*.

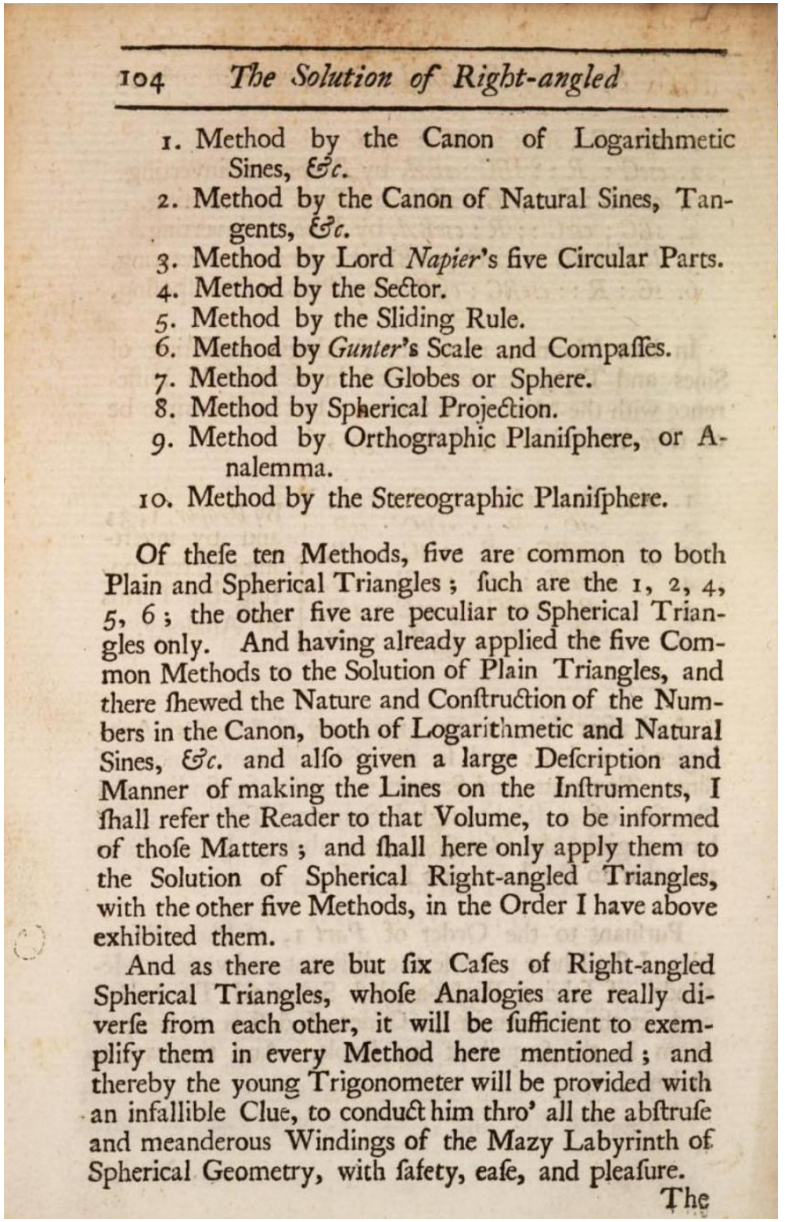
I. To *Astronomy*.
II. *Astrology*.
III. *Geography*.
IV. *Great Circle-Sailing*.
V. *Sailing* by the *Glob. Chart*.
VI. *Dialling*.

In both Volumes the chiefest Care has been to collect all the scattered Appurtenances of this Art necessary to compleat it; to explain it in a more easy and perspicuous Method, through all its Parts: And to shew its extensive Use in all the Parts of *Mathematical Science*.

By BENJAMIN MARTIN, Teacher of the Mathematicks in *Chichester*, and Author of the *Philosophical Grammar*.

LONDON: Printed for *J. Noon*, at the *White-Hart* in *Cheapside*, near *Mercers-Chapel*. MDCCXXXVI.

1736



1. Method by the Canon of Logarithmetic Sines, &c.
2. Method by the Canon of Natural Sines, Tangents, &c.
3. Method by Lord *Napier*'s five Circular Parts.
4. Method by the Sector.
5. Method by the Sliding Rule.
6. Method by *Gunter*'s Scale and Compasses.
7. Method by the Globes or Sphere.
8. Method by Spherical Projection.
9. Method by Orthographic Planisphere, or Analemma.
10. Method by the Stereographic Planisphere.

Of these ten Methods, five are common to both Plain and Spherical Triangles; such are the 1, 2, 4, 5, 6; the other five are peculiar to Spherical Triangles only. And having already applied the five Common Methods to the Solution of Plain Triangles, and there shewed the Nature and Construction of the Numbers in the Canon, both of Logarithmetic and Natural Sines, &c. and also given a large Description and Manner of making the Lines on the Instruments, I shall refer the Reader to that Volume, to be informed of those Matters; and shall here only apply them to the Solution of Spherical Right-angled Triangles, with the other five Methods, in the Order I have above exhibited them.

And as there are but six Cases of Right-angled Spherical Triangles, whose Analogies are really diverse from each other, it will be sufficient to exemplify them in every Method here mentioned; and thereby the young Trigonometer will be provided with an infallible Clue, to conduct him thro' all the abstruse and meanderous Windings of the Mazy Labyrinth of Spherical Geometry, with safety, ease, and pleasure.

The

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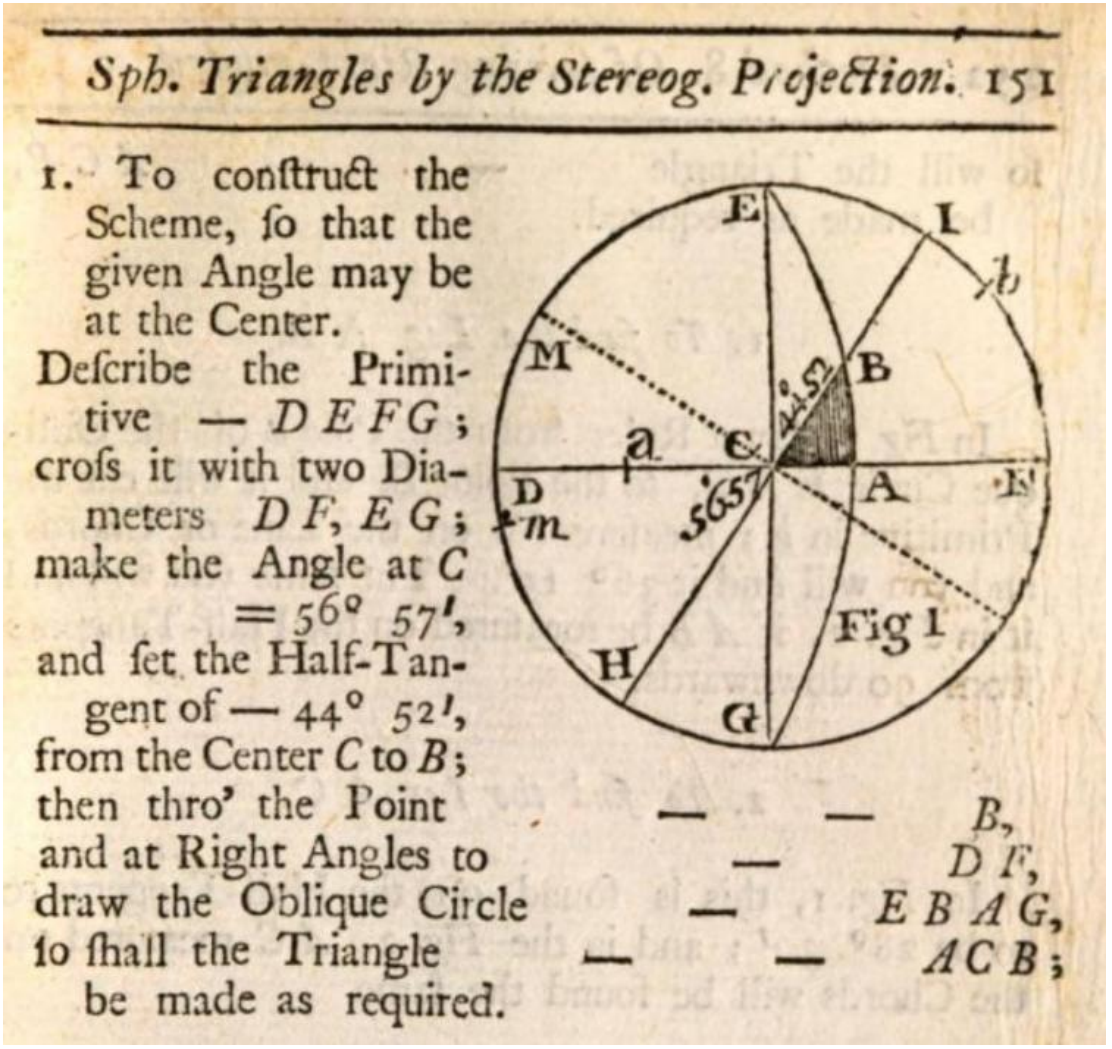
CHAP. XVI.

The eighth Method of ſolving Right-angled Spherical Triangles, *by the* Stereographic Projection.

THIS Way is (generally ſpeaking) more artful than uſeful; not but that to a Perſon well verſed in Spherics, it is of peculiar Uſe and Service; for this Method diſpels all Ambiguity, and Errors, which attend the Solution by moſt other Methods; and by a little Uſe, is very practicable and eaſy. So that if the *Ingenuity*, *Certainty*, *Eaſe*, and *Expeditiouſneſs*, of any Method, be ſufficient to recommend it, this cannot fail of Acceptance with all thoſe who have the leaſt Genius and Taſte for this Science.

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Sph. Triangles by the Stereog. Projection. 151

1. To conſtruct the Scheme, ſo that the given Angle may be at the Center.

Deſcribe the Primitive — *D E F G*; croſs it with two Diameters *D F*, *E G*; make the Angle at *C* = 56° 57′, and ſet the Half-Tangent of — 44° 52′, from the Center *C* to *B*; then thro' the Point — — *B*, and at Right Angles to — *D F*, draw the Oblique Circle — *E B A G*, ſo ſhall the Triangle — — *A C B*; be made as required.

Fig 1

