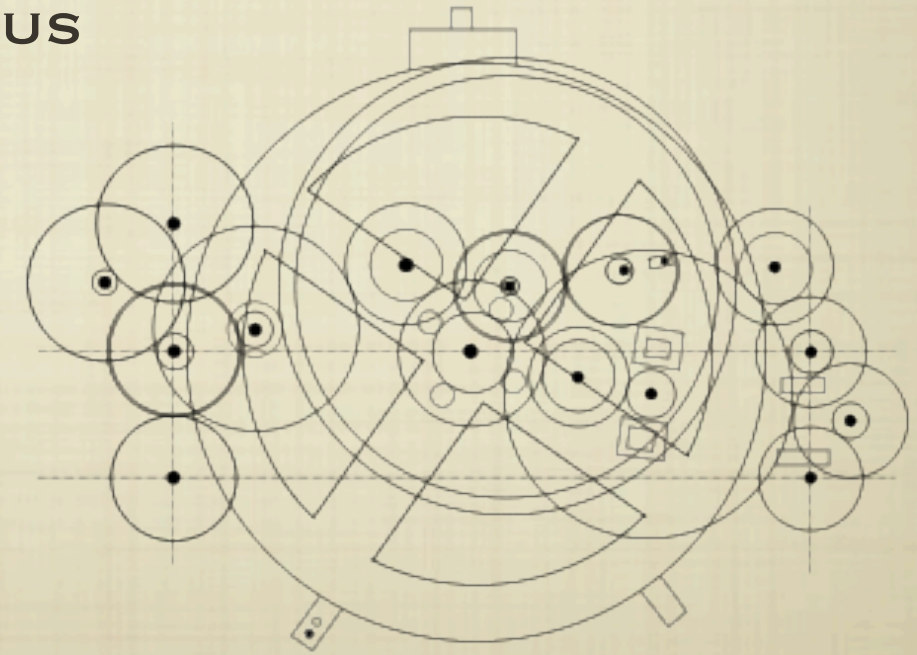
Today

first homework due

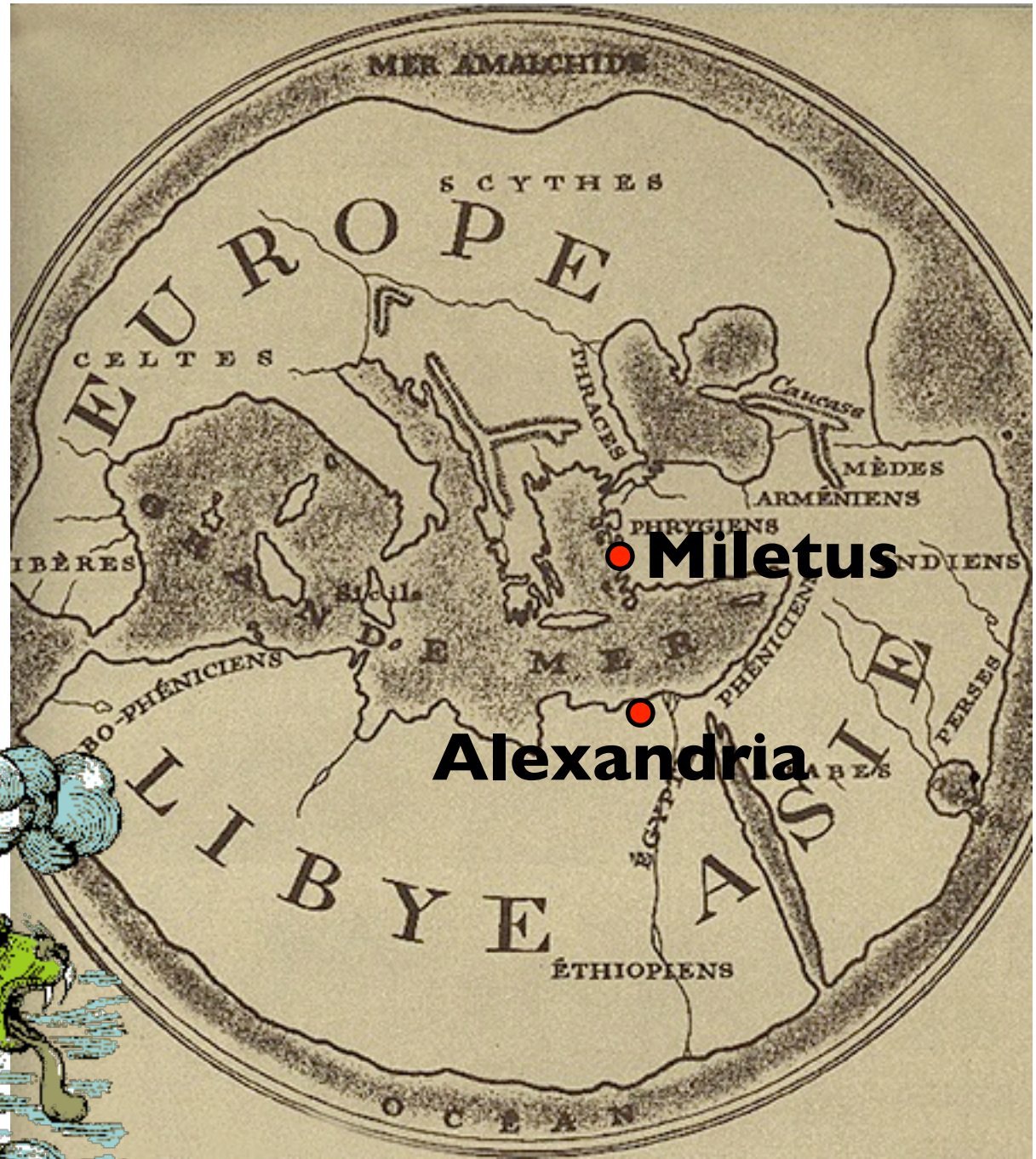
- Competing Cosmologies
  - Geocentric vs. Heliocentric
  - Ptolemy vs. copernicus
    - Retrograde Motion
    - Phases of Venus
  - Galileo



Antikythera mechanism

Ancient Cosmology: A Flat Earth

Here there be dragons!

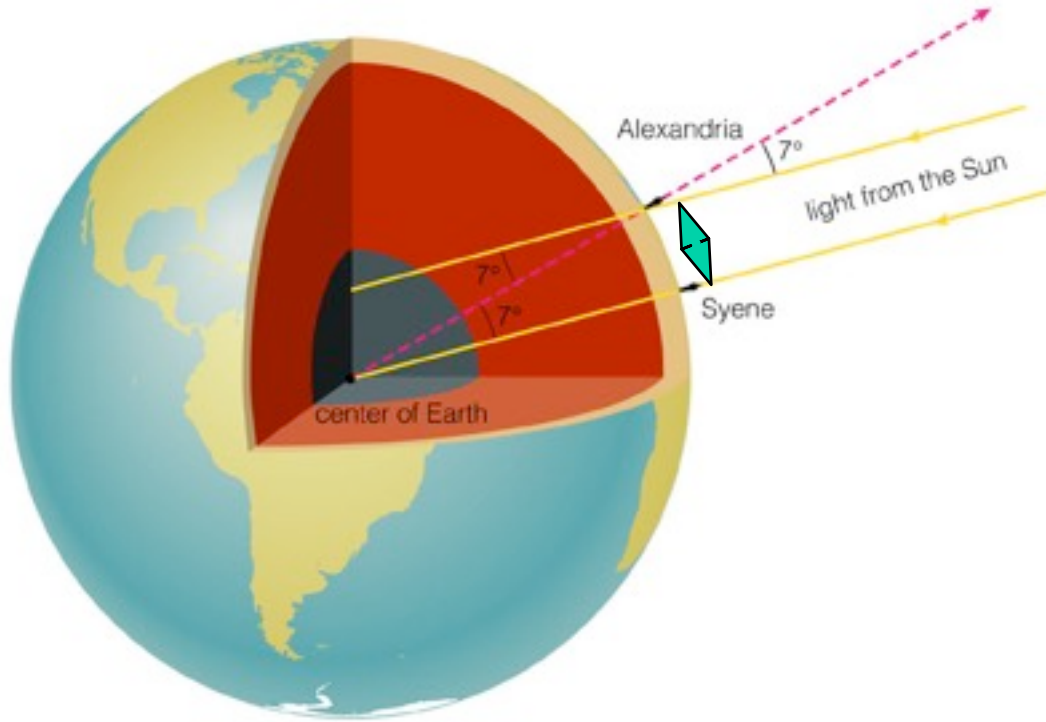


d Map of Hecataeus of Miletus (c. 500 BC)

Artist's reconstruction of the Library of Alexandria

Eratosthenes became the third librarian at Alexandria under Ptolemy III in the Hellenistic period following the conquests of Alexander the Great. Ptolemy I had been one of Alexander's generals, and had taken Egypt as his own after Alexander's untimely death.

Eratosthenes measures the Earth (c. 240 B.C.)



Measurements:

Syene to Alexandria

- distance ≈ 5,000 stadia
- angle = 7°
- i.e, 7/360 of the circumference

Calculate circumference of Earth:

(7/360) × (circum. Earth) = 5,000 stadia

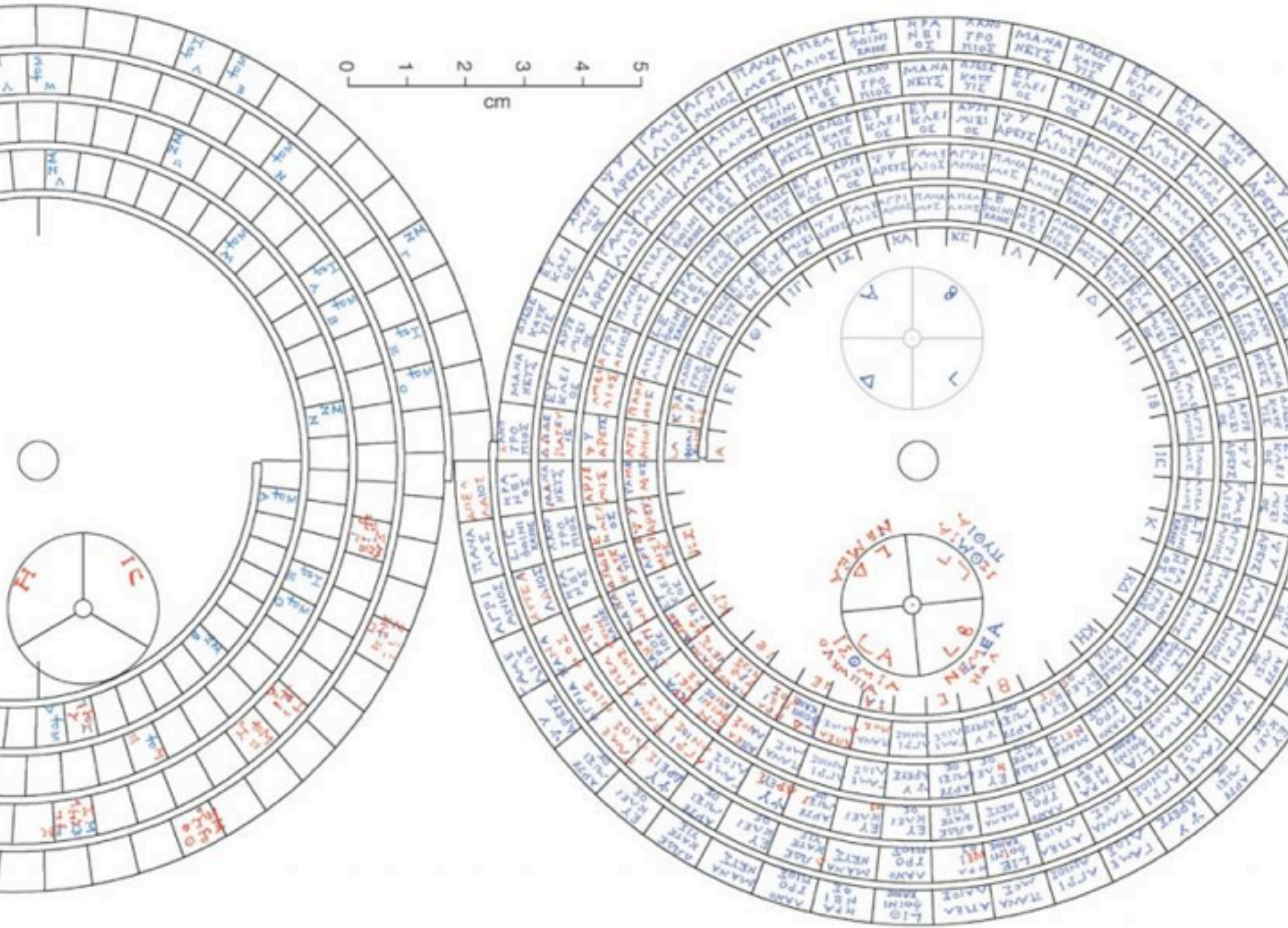
⇒ circum. Earth = 5,000 × 360/7 stadia ≈ 250,000 stadia

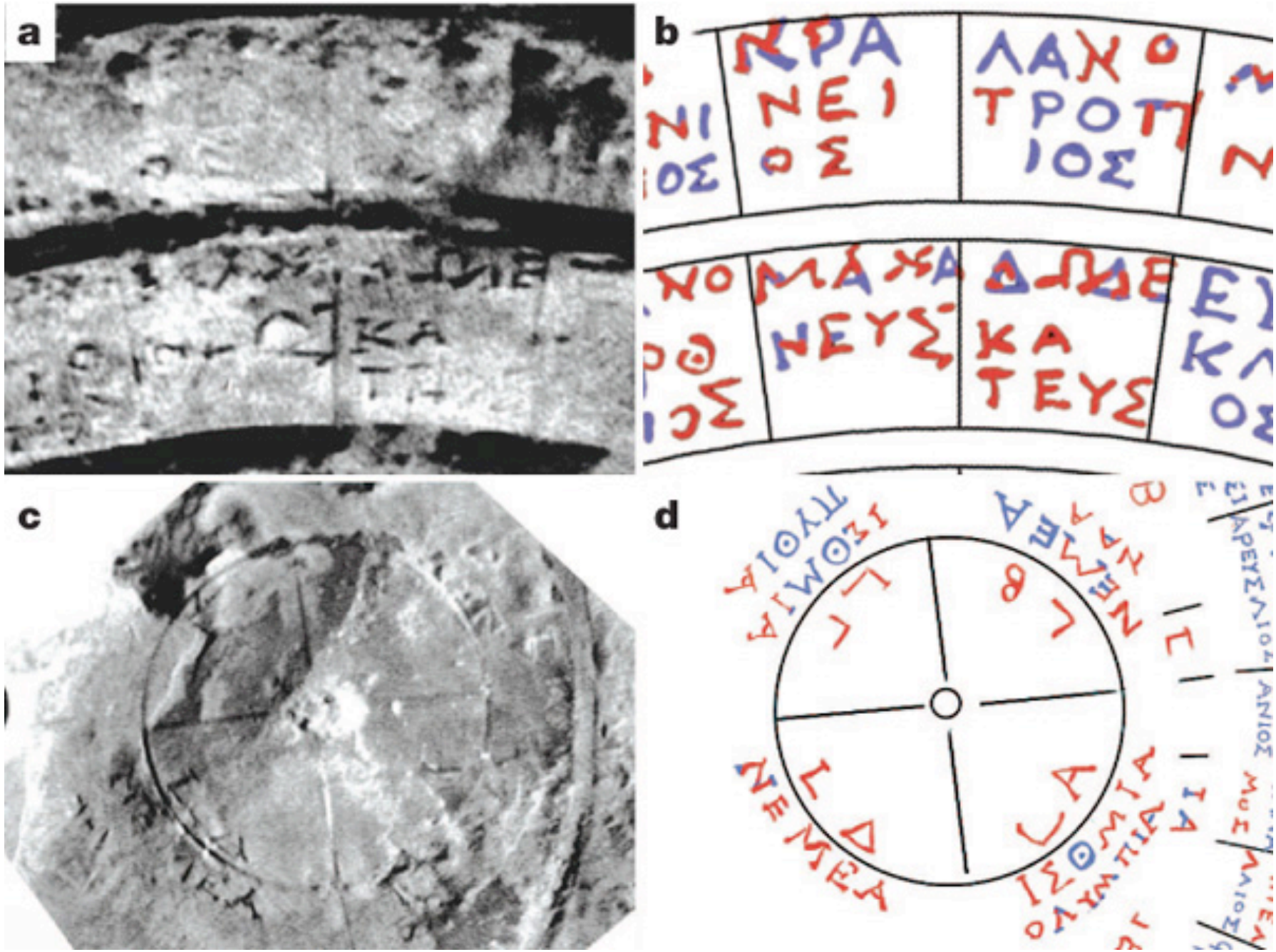
Compare to modern value (≈ 40,100 km):

Greek stadium ≈ 1/6 km ⇒ 250,000 stadia ≈ 42,000 km

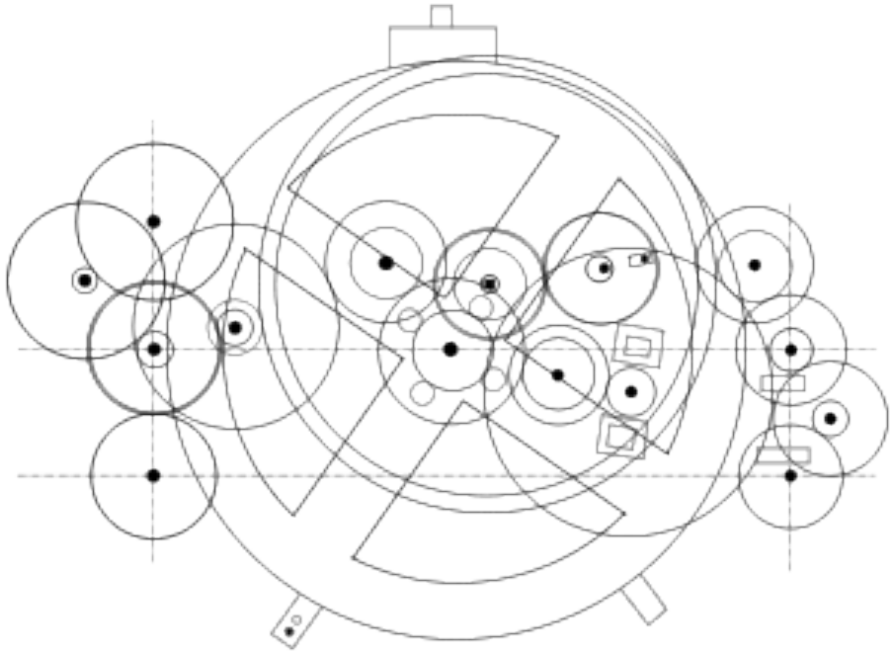
It was known long before Columbus that the Earth is not flat!

Antikythera mechanism (c. 90 BC)

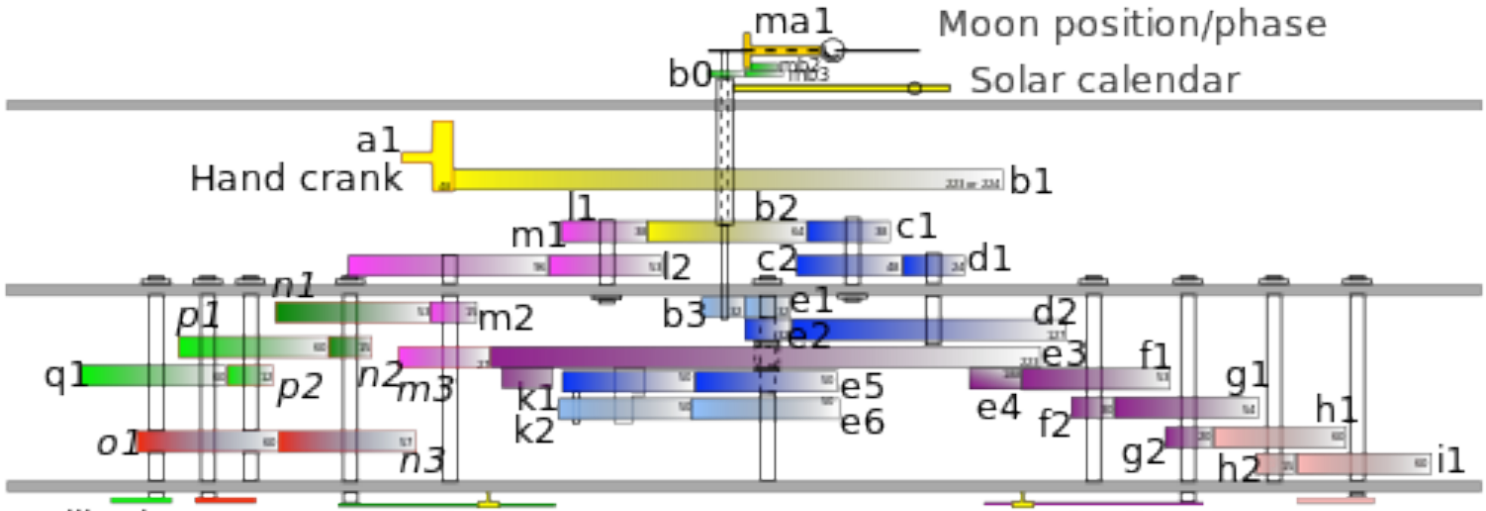

0 1 2 3 4 5
cm


a
b
c
d

Antikythera mechanism (c. 90 BC)

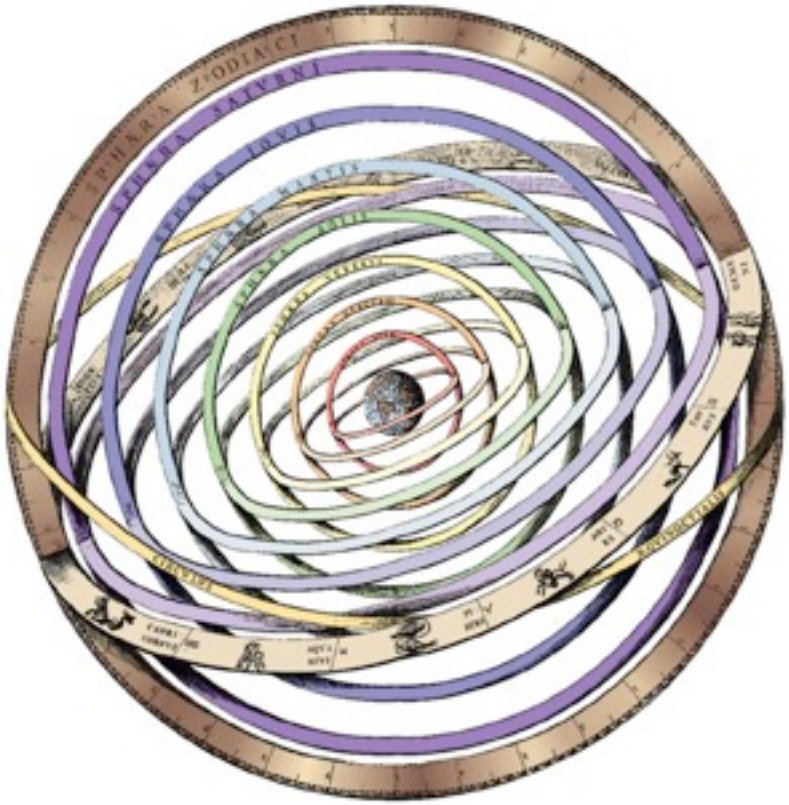


The Ancients had developed a sophisticated and detailed empirical knowledge of the motions of the sky

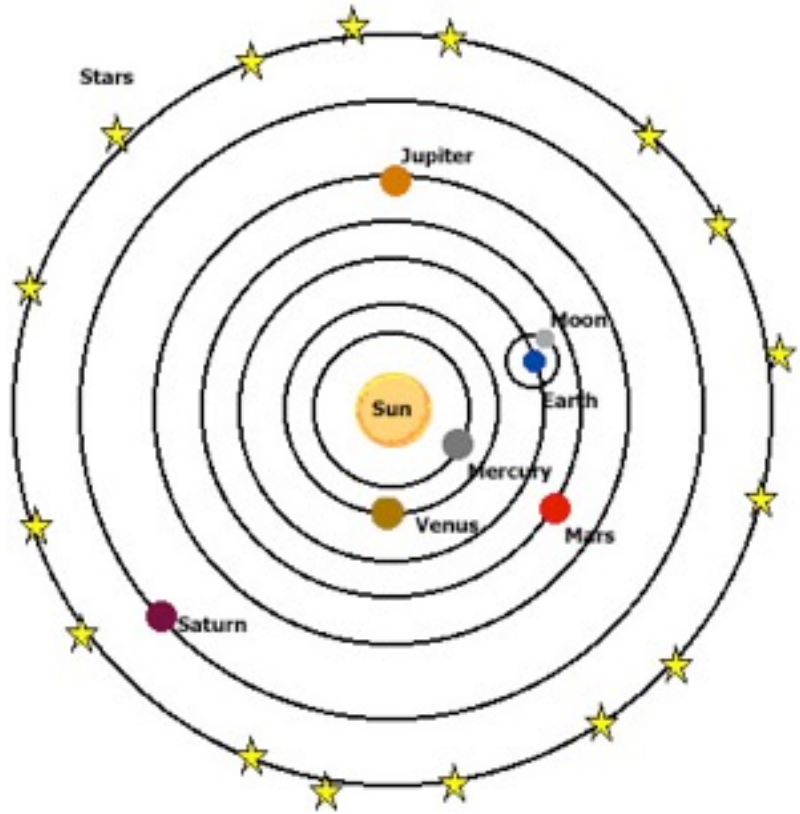


Competing Cosmologies

Geocentric
Ptolemaic
Earth at center



Heliocentric
Copernican
Sun at center



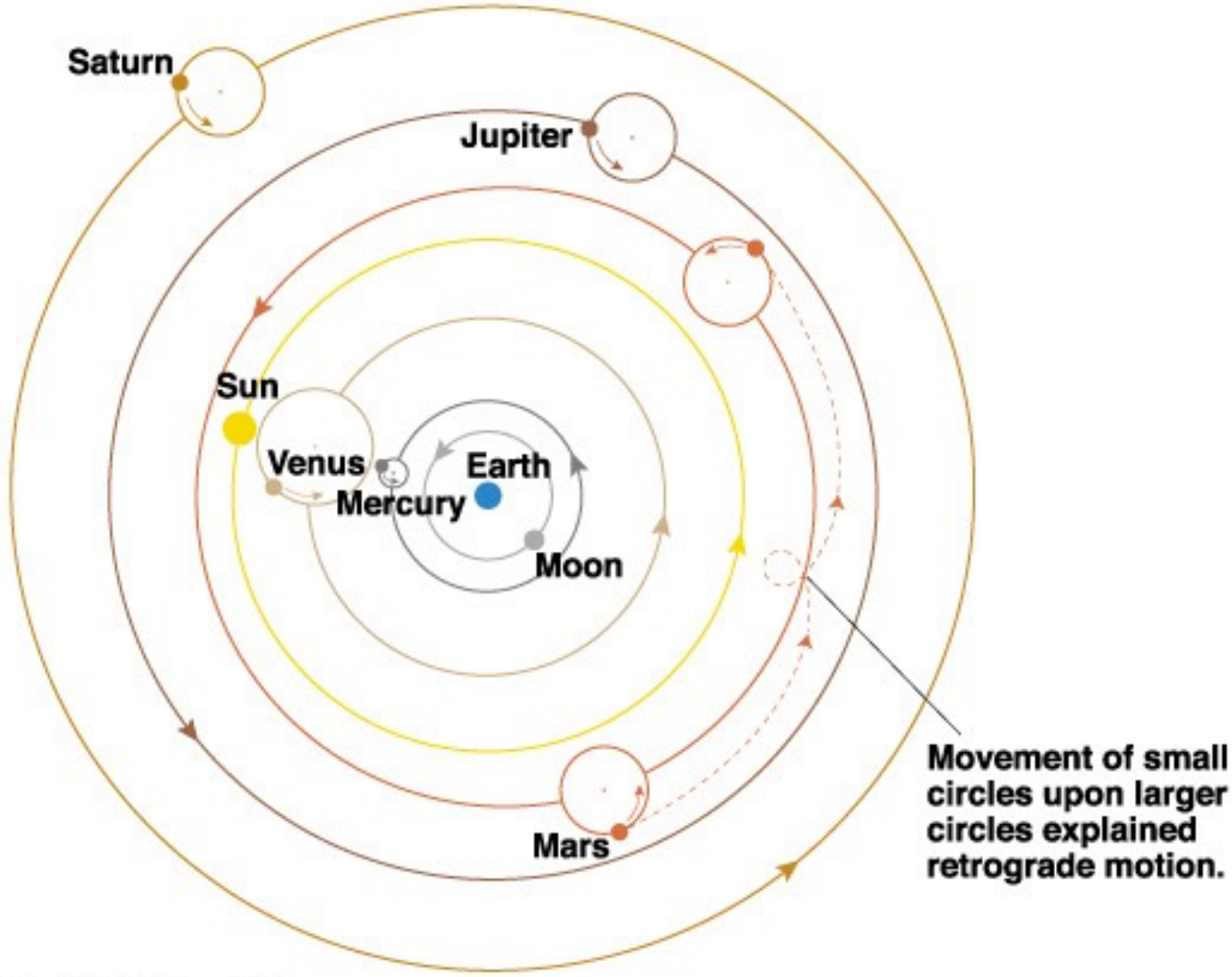
Geocentric

Ptolemy

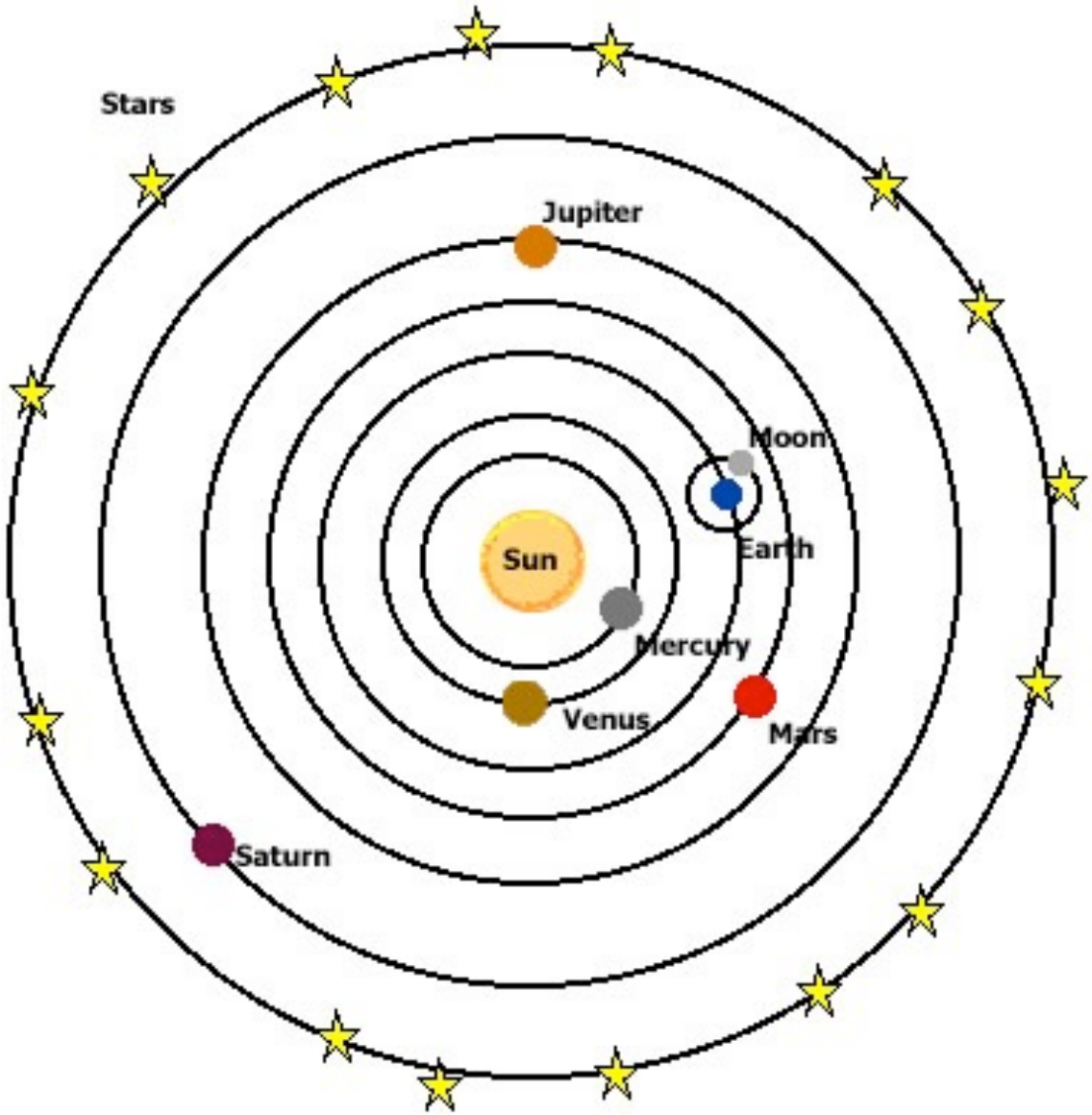
The most sophisticated geocentric model was that of Ptolemy (A.D. 100–170) — the **Ptolemaic model:**

- Sufficiently accurate to remain in use for 1,500 years
  - i.e., predicted correct positions of planets for many centuries
- Arabic translation of Ptolemy's work named *Almagest* ("the greatest compilation")

Geocentric Cosmology



Heliocentric Cosmology



Heliocentric

Copernicus (1473–1543):

- He proposed the Sun-centered model (published 1543).
- He used the model to determine the layout of the solar system (planetary distances in AU).

But . . .

- The model was no more accurate than Ptolemaic model in predicting planetary positions, because it still used perfect circles.

Heliocentric model first proposed by Aristarchus of Samos c. 280 BC. None of the original work of Aristarchus survives; it is only known through the many criticisms made of it by others.

Competing Cosmologies

Geocentric	**Heliocentric**
Ptolemaic	Copernican
Earth at center	Sun at center

The sun is the source of light in both models

Explains	**Explains**
• **Motion of Sun** • **Motion of Moon** • **Solar and Lunar Eclipses** • **Phases of Moon**	• **Motion of Sun** • **Motion of Moon** • **Solar and Lunar Eclipses** • **Phases of Moon**

Hard to tell the difference!

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Ptolemaic
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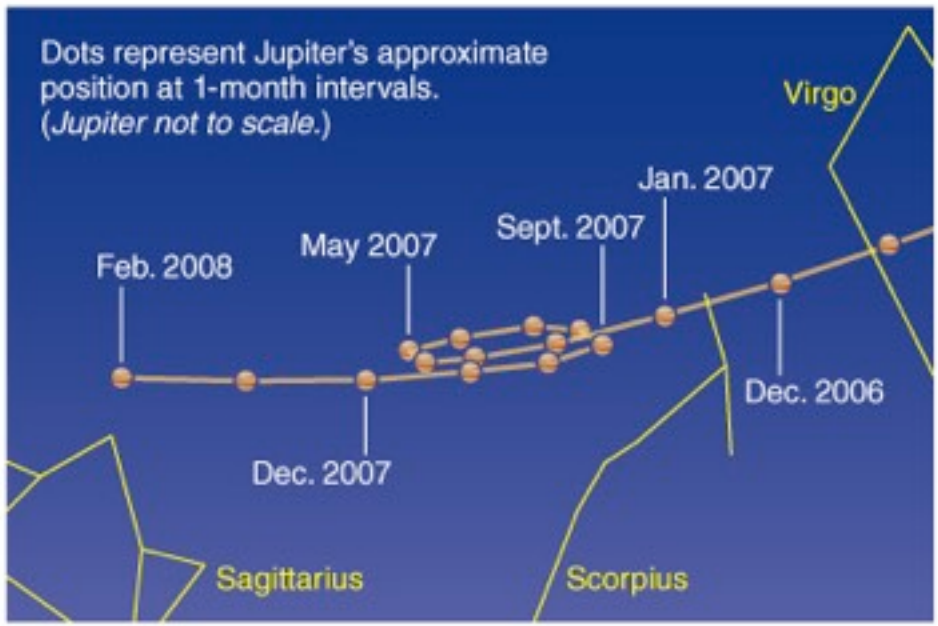
Retrograde Motion

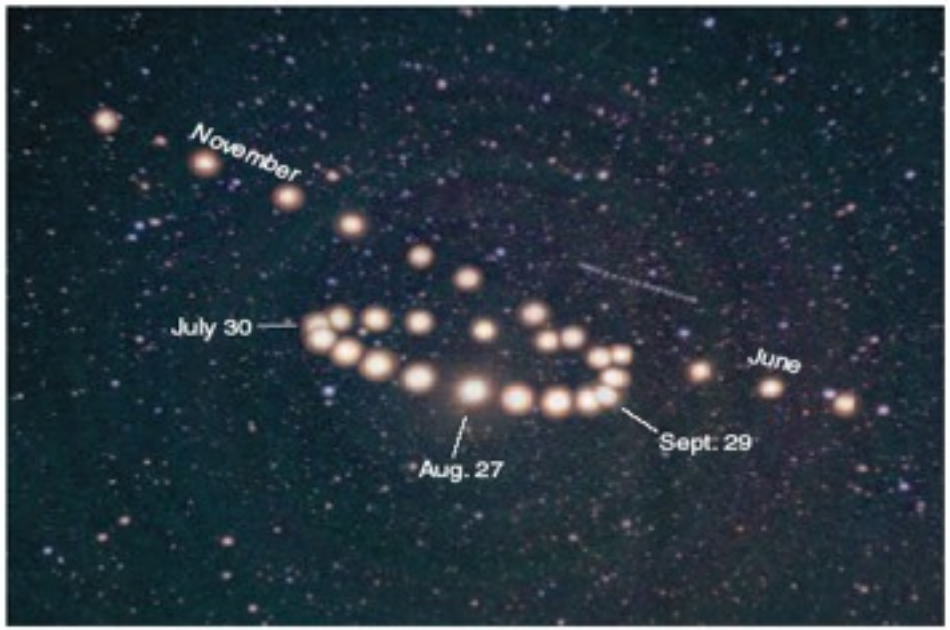
Needs epicycles

Consequence of Lapping

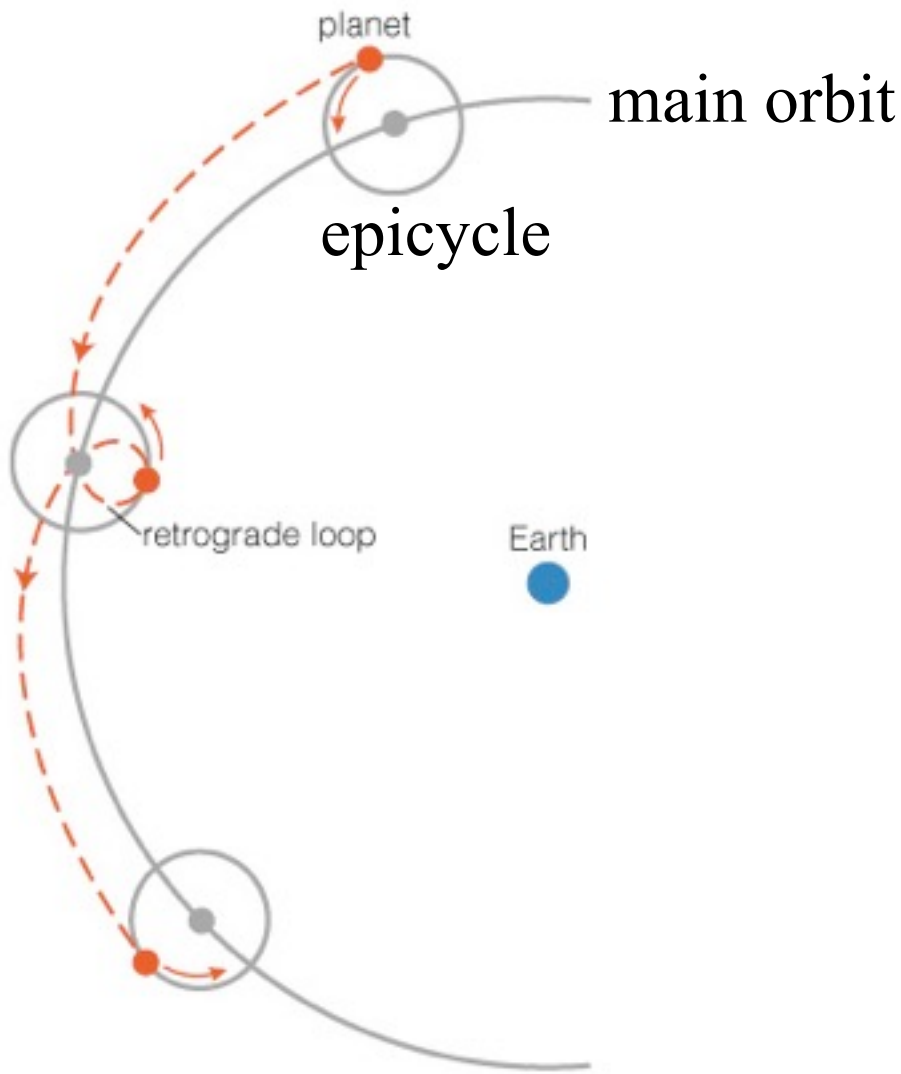
Retrograde motion

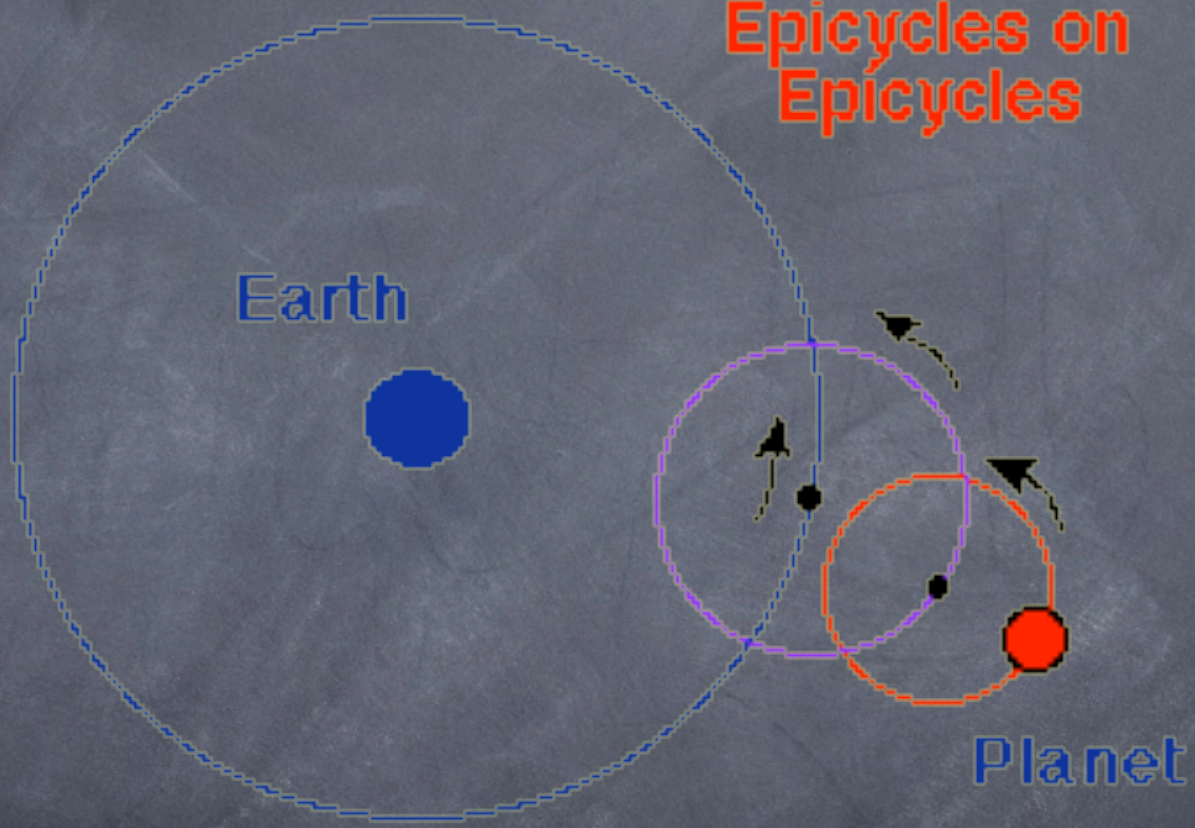
- Planets usually move slightly *eastward* from night to night relative to the stars.
- But, sometimes they go *westward* relative to the stars for a few weeks: **apparent retrograde motion.**





In the **Ptolemaic** model, planets *really do* go backwards.

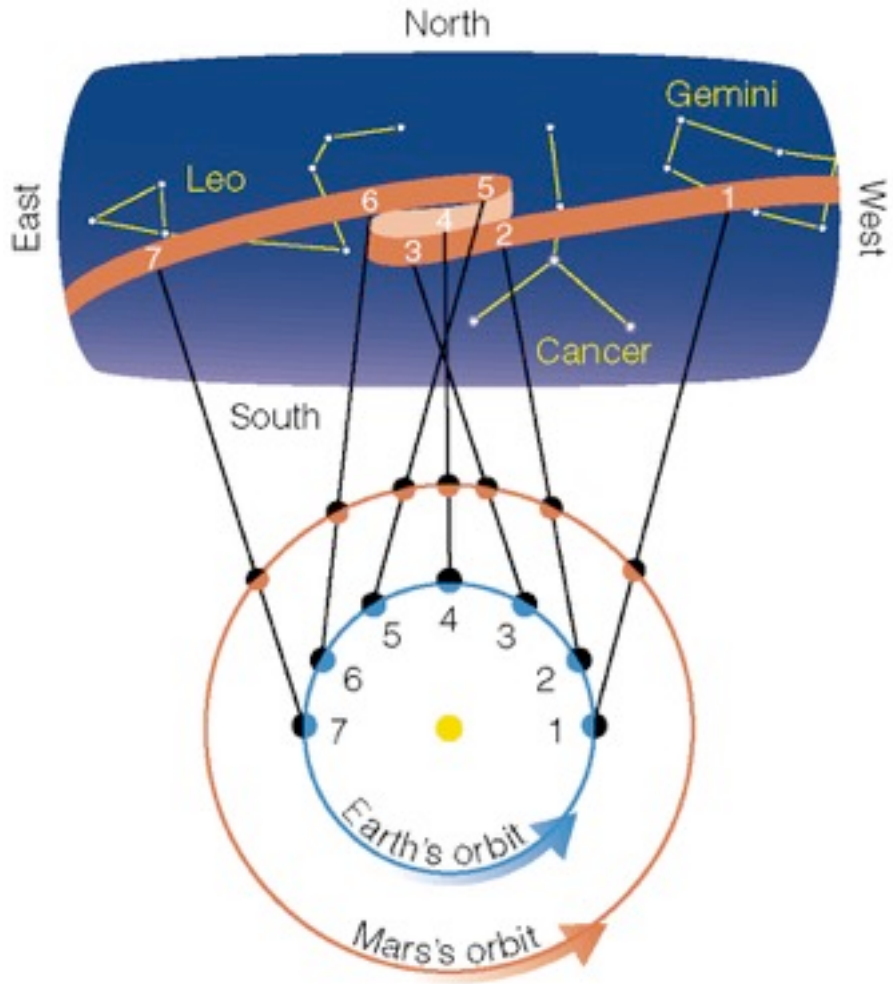




H.S. in epicycles

https://www.youtube.com/watch?v=QVuU2YCwHjw

In the **Copernican** model, retrograde motion is a consequence of one planet (Earth) "lapping" another in its orbit.



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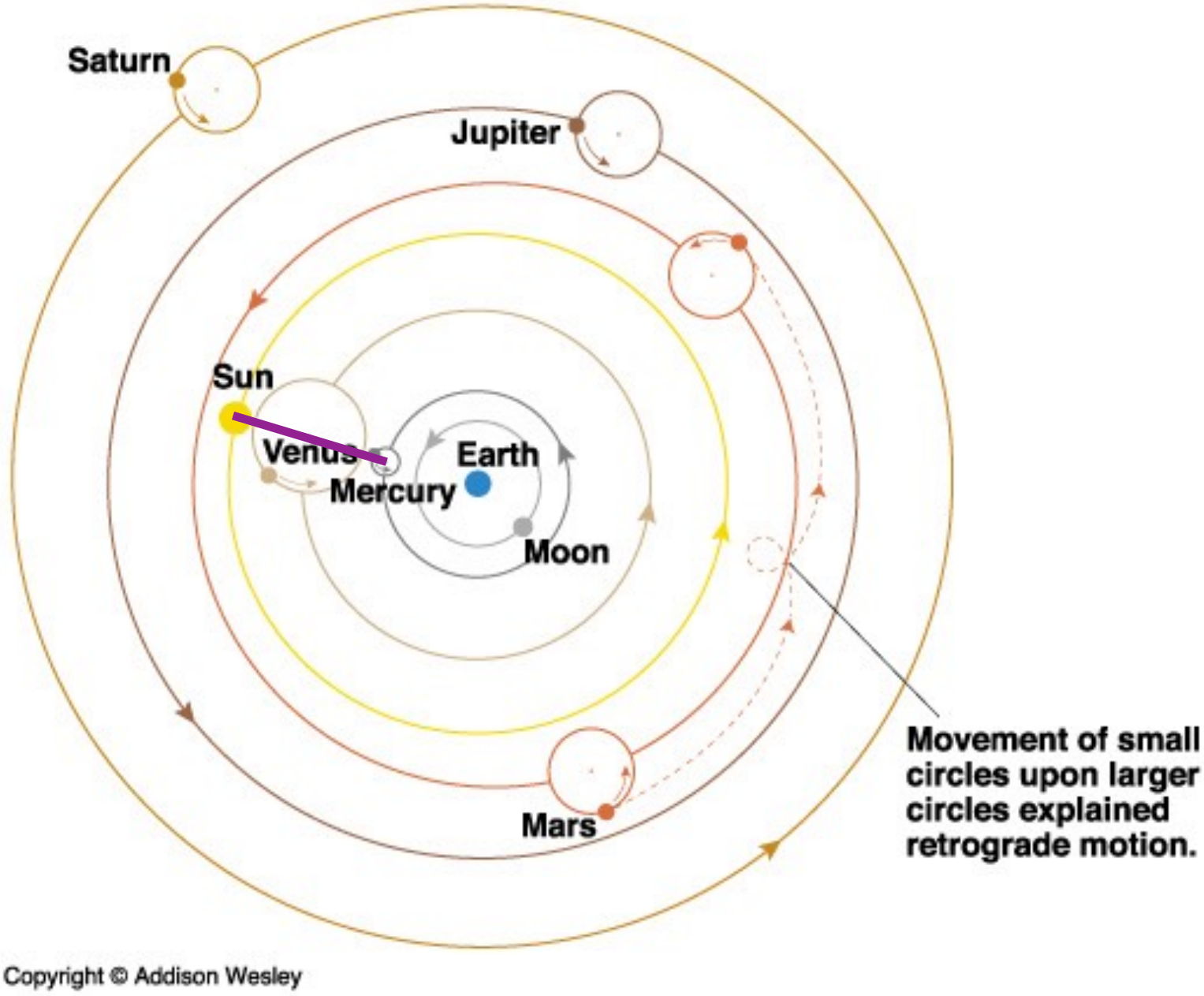
Retrograde Motion

Needs epicycles	Consequence of Lapping

Inferiority of Mercury & Venus

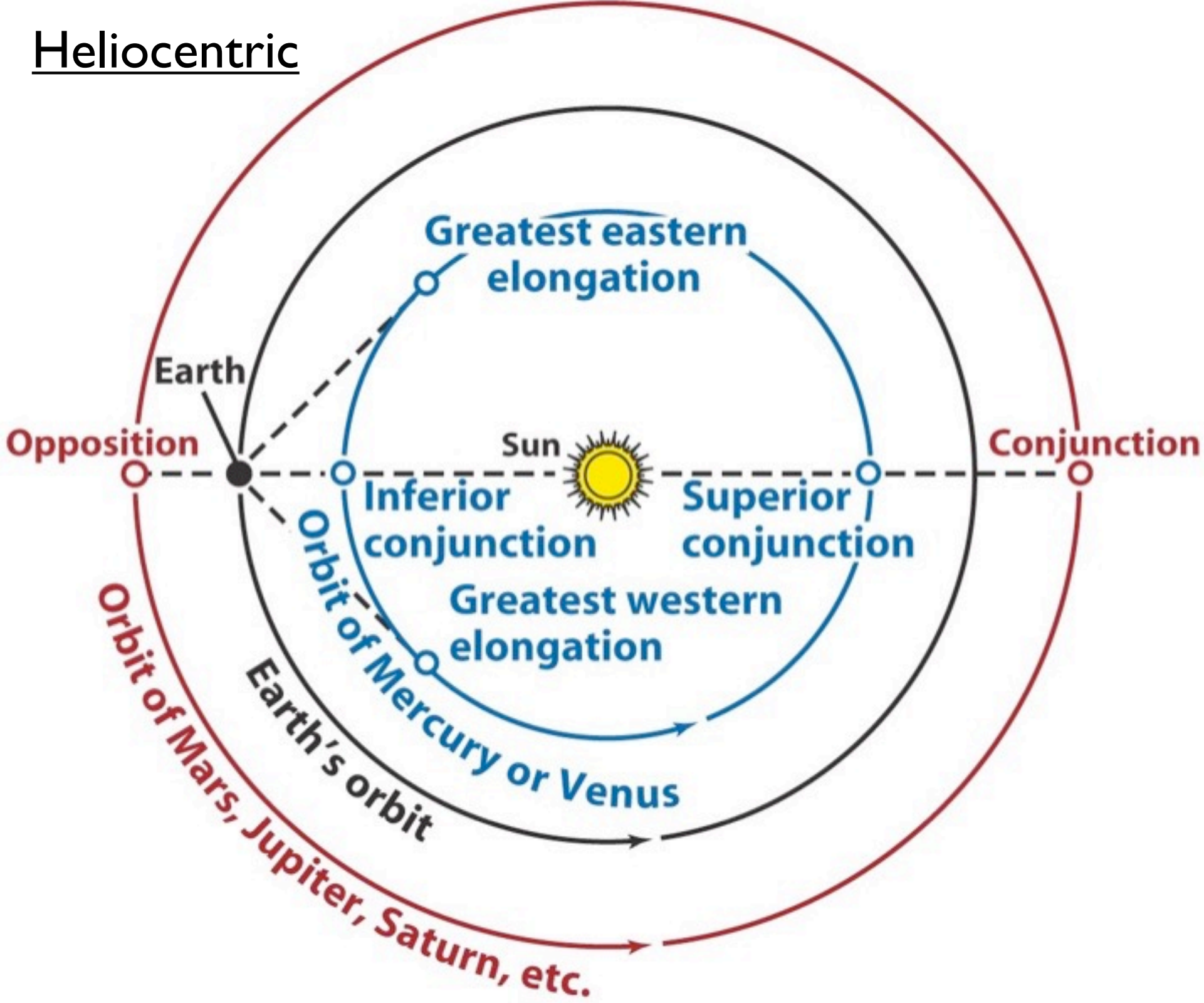
Must tie to sun	Interior to Earth's Orbit

Geocentric Cosmology



Mercury & Venus always close to sun on the sky

Heliocentric



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Retrograde Motion

Needs epicycles | Consequence of Lapping

Inferiority of Mercury & Venus — more natural

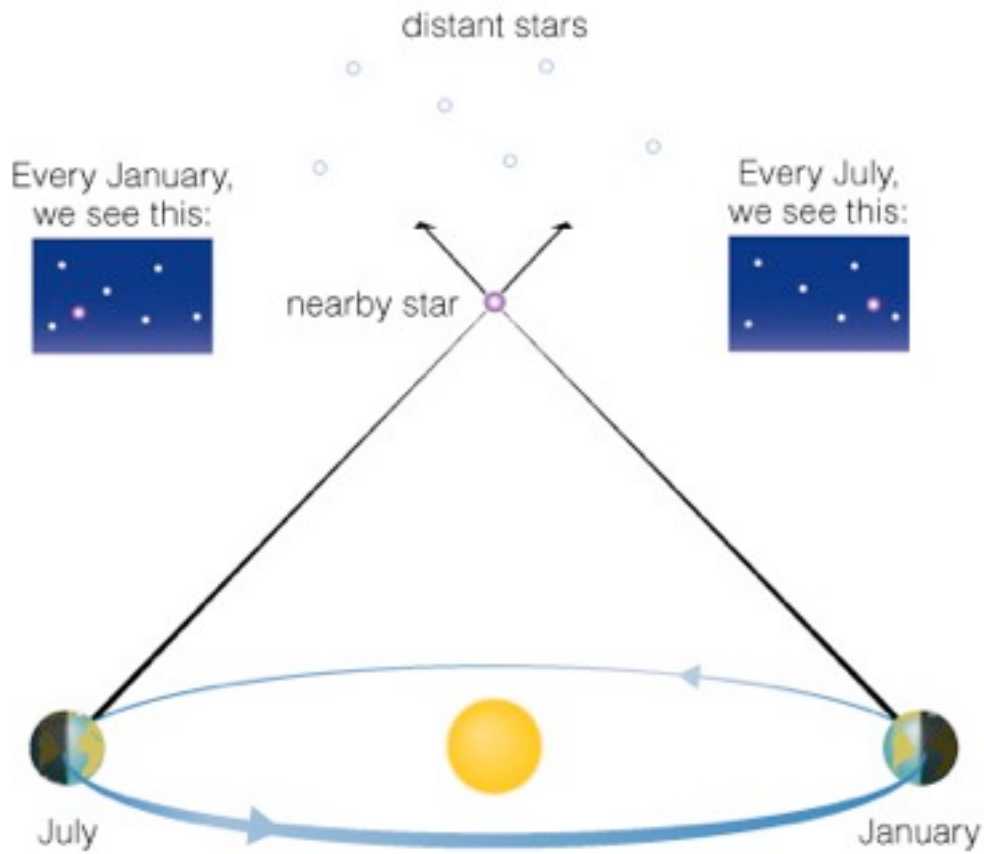
Must tie to sun | Interior to Earth's Orbit

Predicts

- No parallax	- Parallax
- Venus: crescent phase only	- Venus: all phases

Parallax

If the Earth moves around the sun, the positions of stars should shift in reflex to that motion.



- The ancients could not detect **stellar parallax**.

Competing Cosmologies

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- **Motion of Sun**
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- **Phases of Moon**

Retrograde Motion

Needs epicycles | Consequence of Lapping **nicer**

Inferiority of Mercury & Venus

Must tie to sun | Interior to Earth's Orbit **nicer**

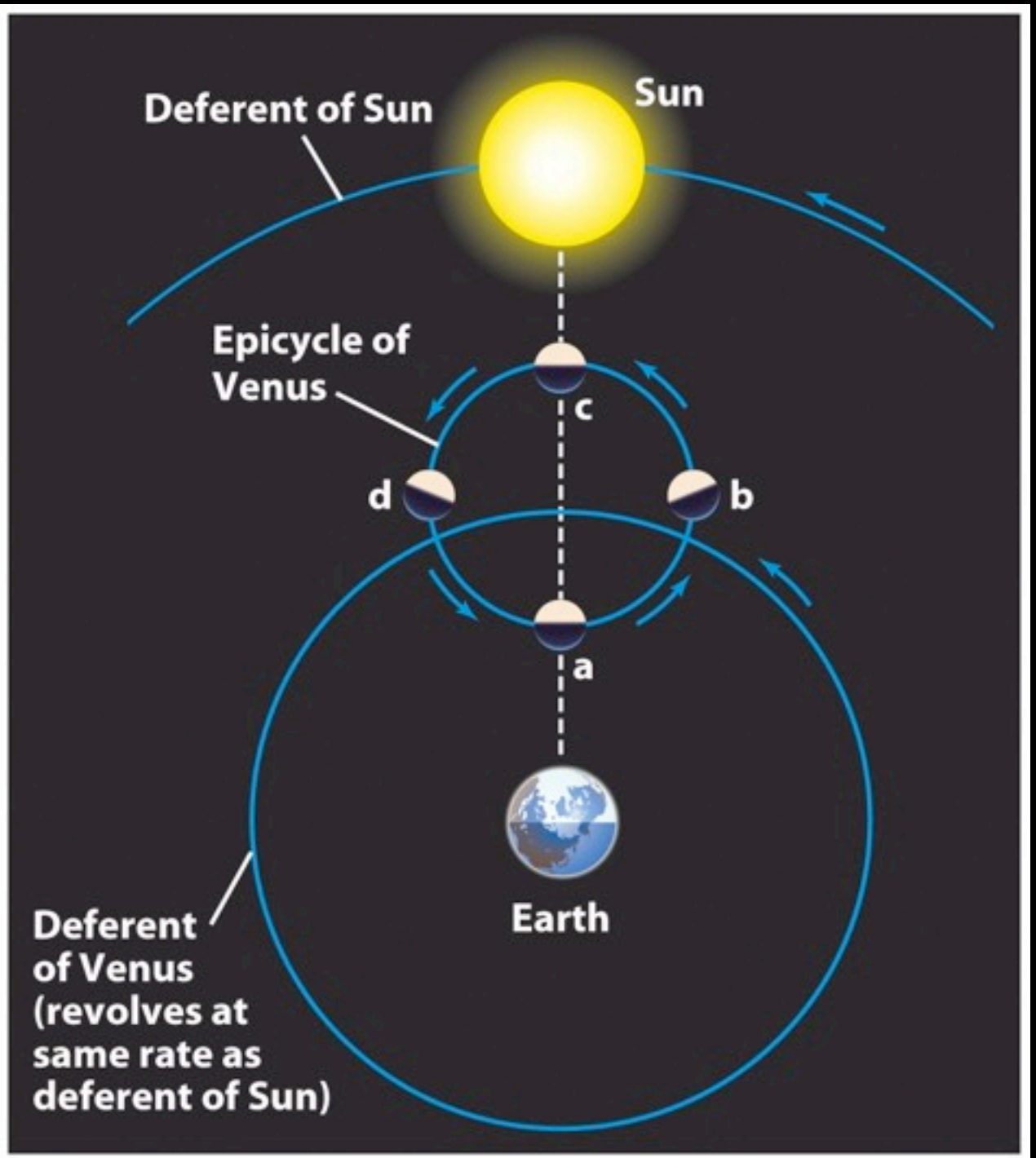
Predicts

- No parallax ✓
- Venus: crescent phase only

- Parallax **X**
- Venus: all phases

unkown to ancients

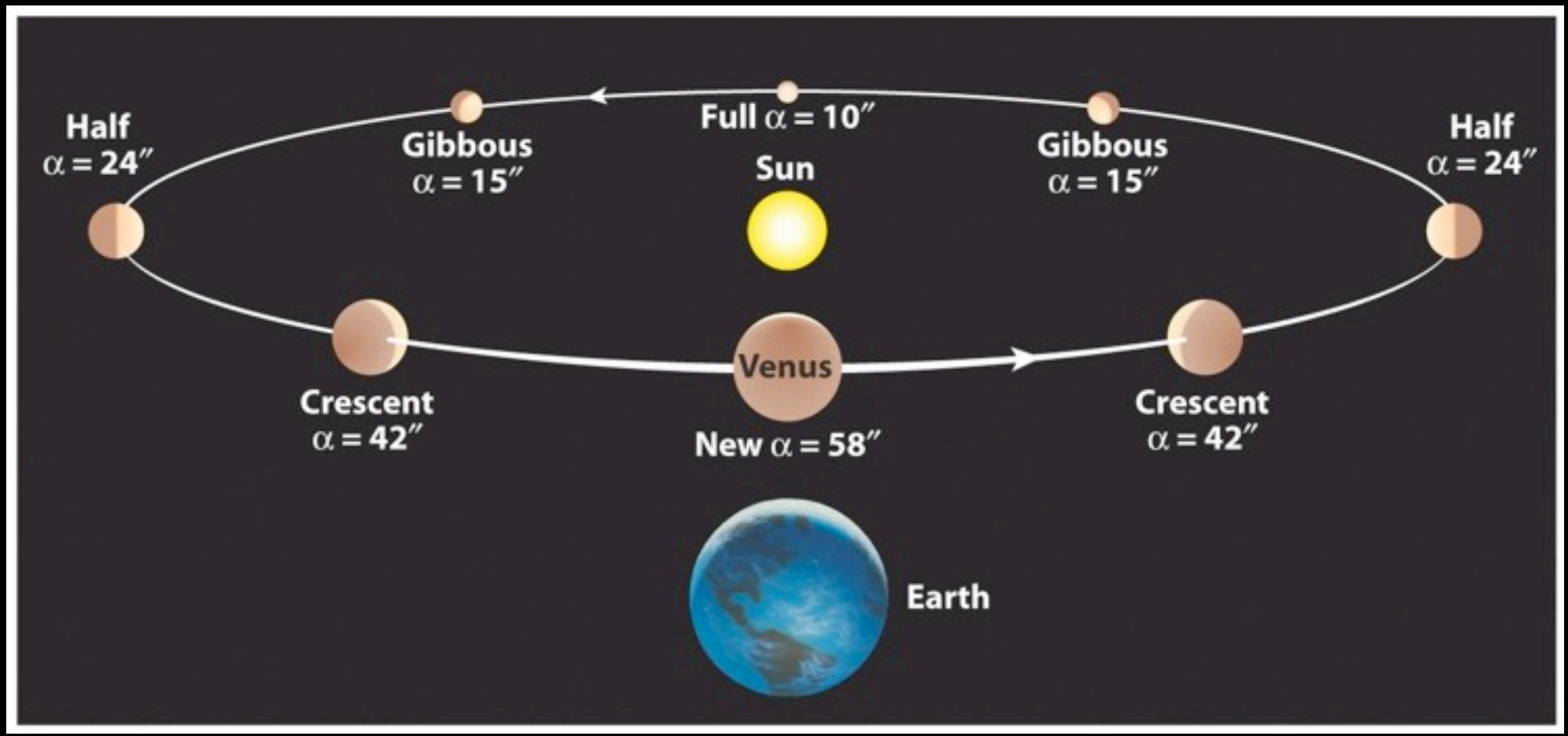
Geocentric



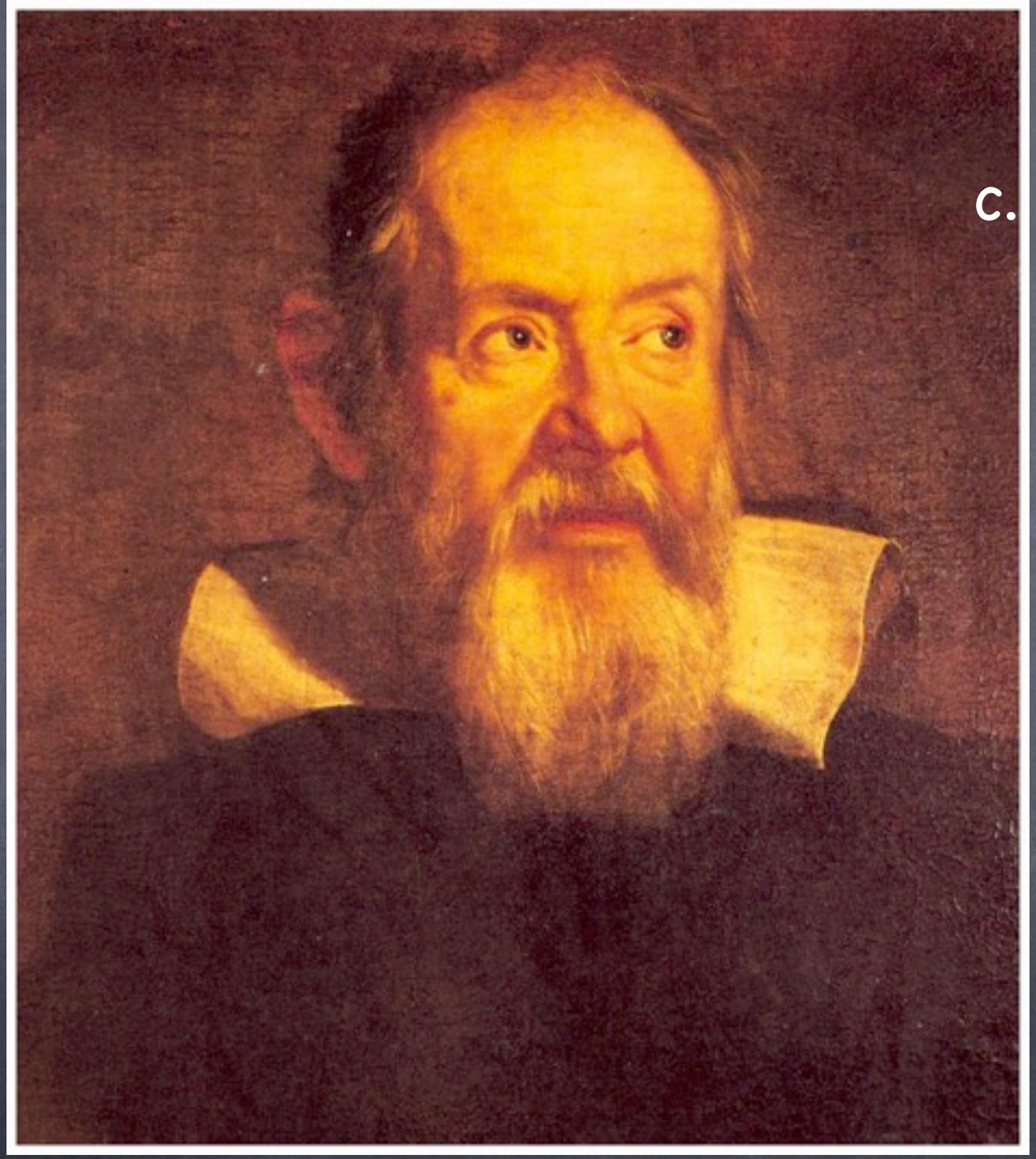
Only crescent phase can be observed - never full or even gibbous

Heliocentric

The full range of phase can be observed - from crescent to full



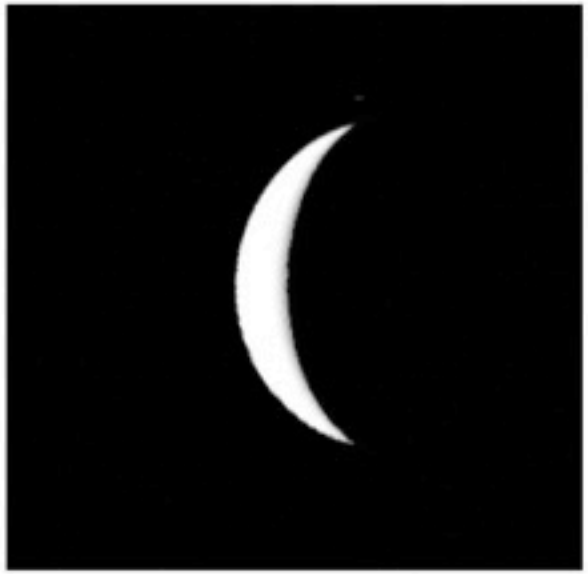
Galileo



c. 1564-1640

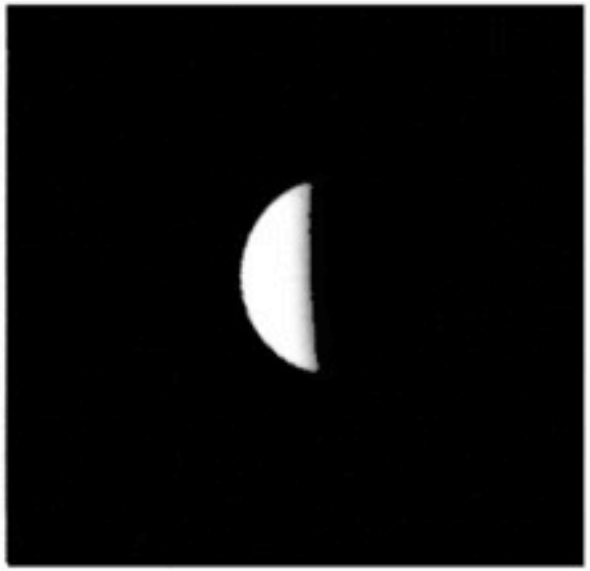
First telescopic astronomical observations

$\alpha = 58°$

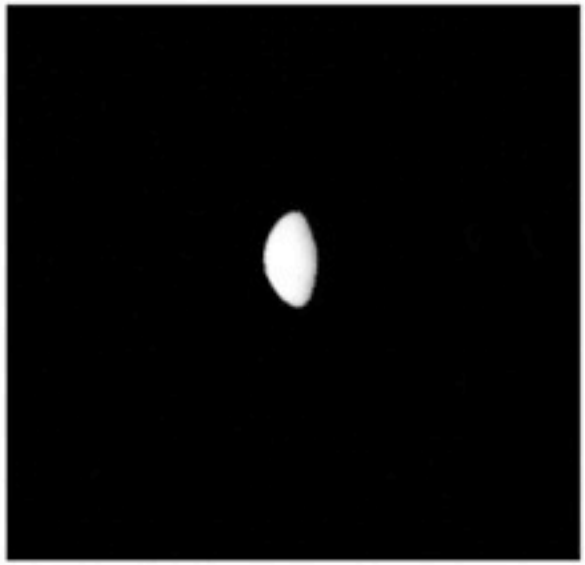


$\alpha = 42°$

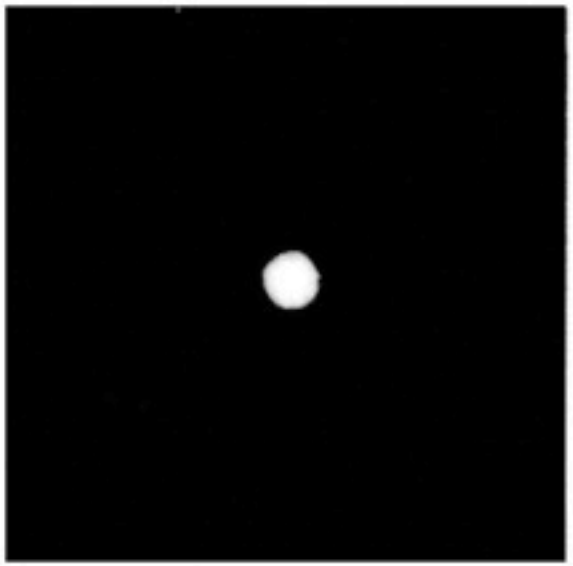
Phase and angular size of Venus depend on elongation



$\alpha = 24°$



$\alpha = 15°$



$\alpha = 10°$

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Retrograde Motion

Needs epicycles | Consequence of Lapping **nicer**

Inferiority of Mercury & Venus

Must tie to sun | Interior to Earth's Orbit **nicer**

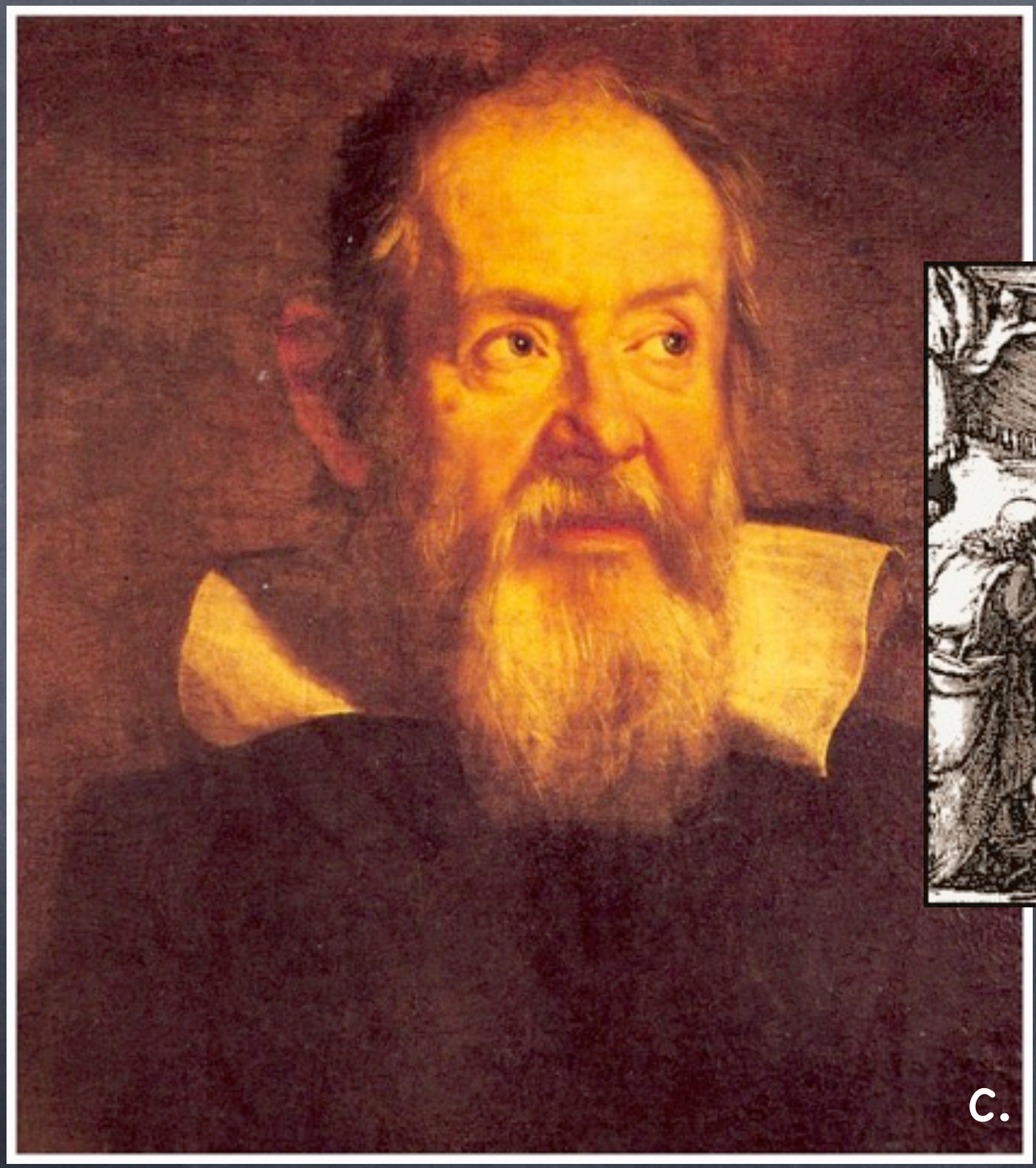
Predicts

- No parallax ✓	- Parallax X
- Venus: crescent phase only X	- Venus: all phases ✓

Heliocentric Cosmology

- Provides better explanation for
  - Retrograde motion
  - proximity of Mercury and Venus to the Sun
- Provides only explanation for
  - Phases of Venus
  - Angular size variation of Venus
- What about parallax?
  - Undetectable if stars VERY distant
    - Finally detected in 1839

Galileo



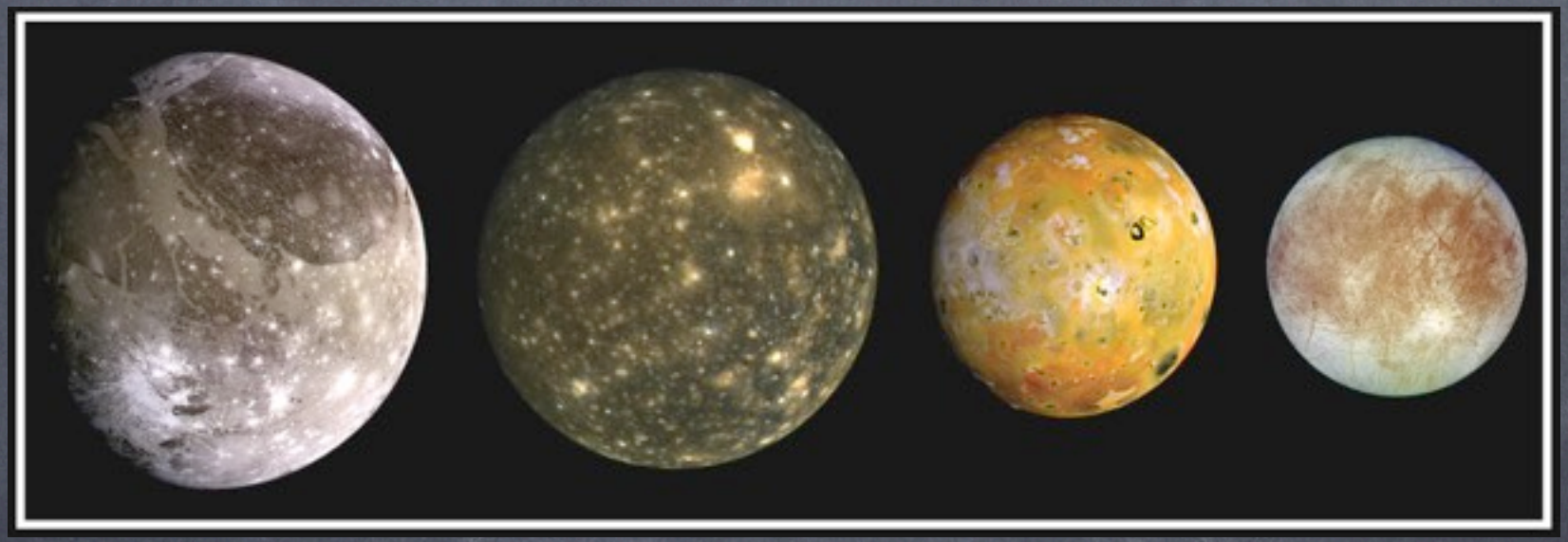
c. 1564–1640

Galileo's telescopic discoveries

- Stars in the Milky Way
- Mountains on the Moon
- Sun spots (celestial spheres NOT perfect)
- Rings of Saturn (barely resolved)
- Moons of Jupiter ("Medicean stars")
  - Earth NOT center of all revolution
- Phases of Venus
  - Good test of geocentric hypothesis

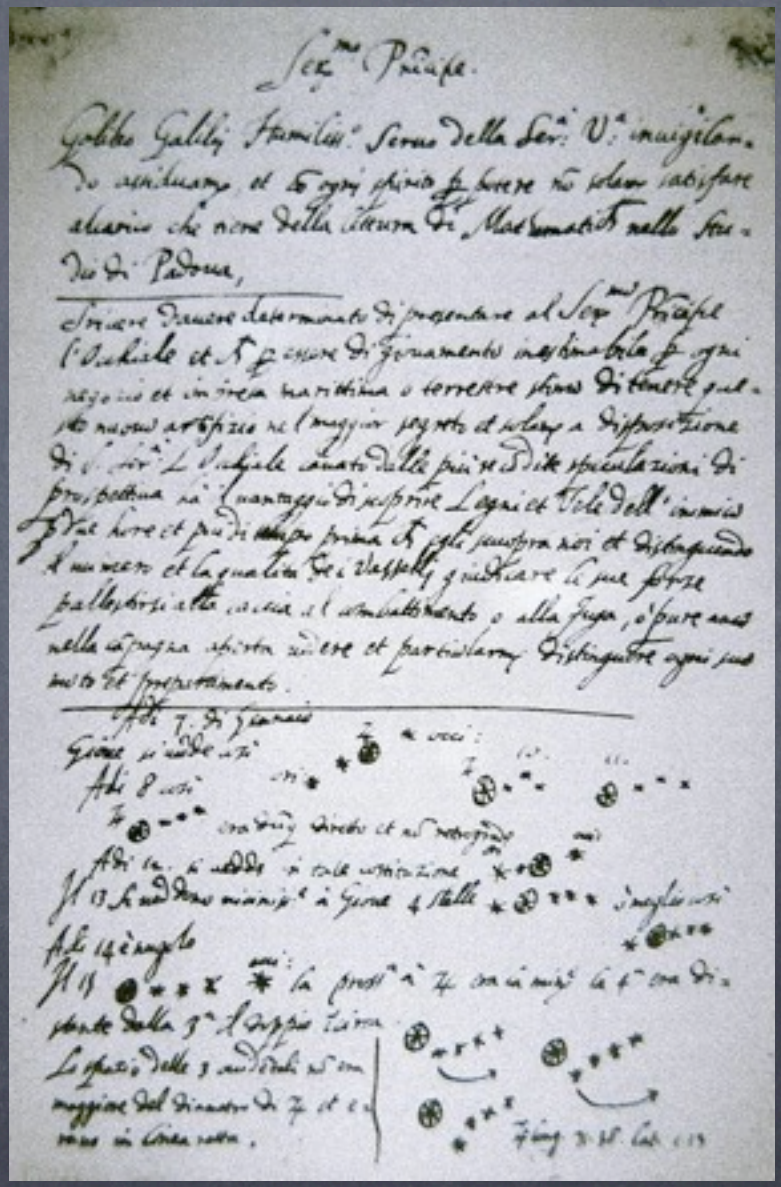
Jupiter and moons

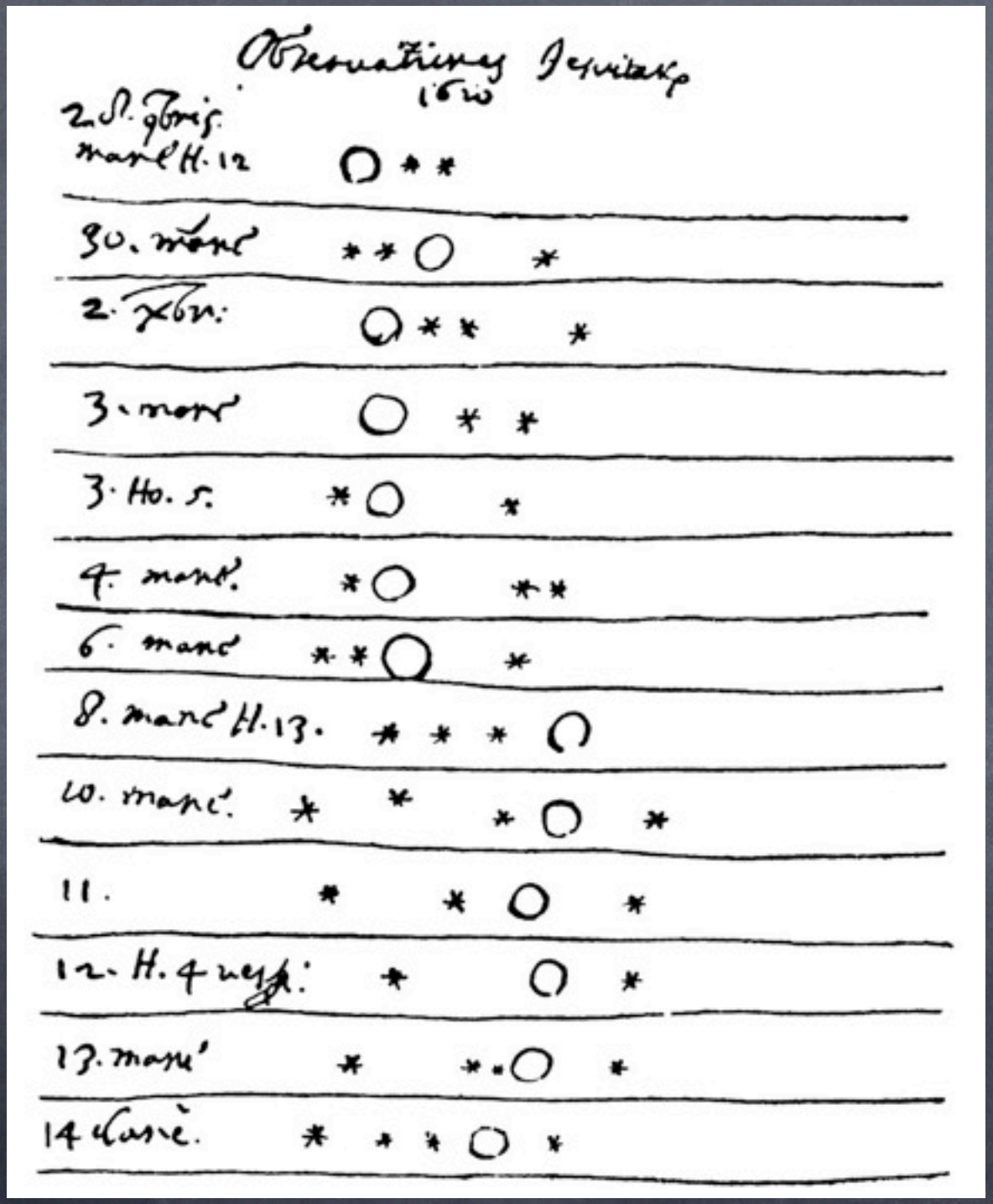
Galilean moons (from Galileo spacecraft!)



NASA

Letter from Galileo to Prince of Venice reporting the discovery of Jupiter's moons…





"Medician stars"