

TODAY

FIRST HOMEWORK DUE

- **COMPETING COSMOLOGIES**
 - **GEOCENTRIC VS. HELIOCENTRIC**
 - **PTOLEMY VS. COPERNICUS**
 - **RETROGRADE MOTION**
 - **PHASES OF VENUS**
- **GALILEO**

Ancient Cosmology: A Flat Earth



Here there
be dragons!



Map of Hecataeus of Miletus (c. 500 BC)



Artist's reconstruction of the Library of Alexandria

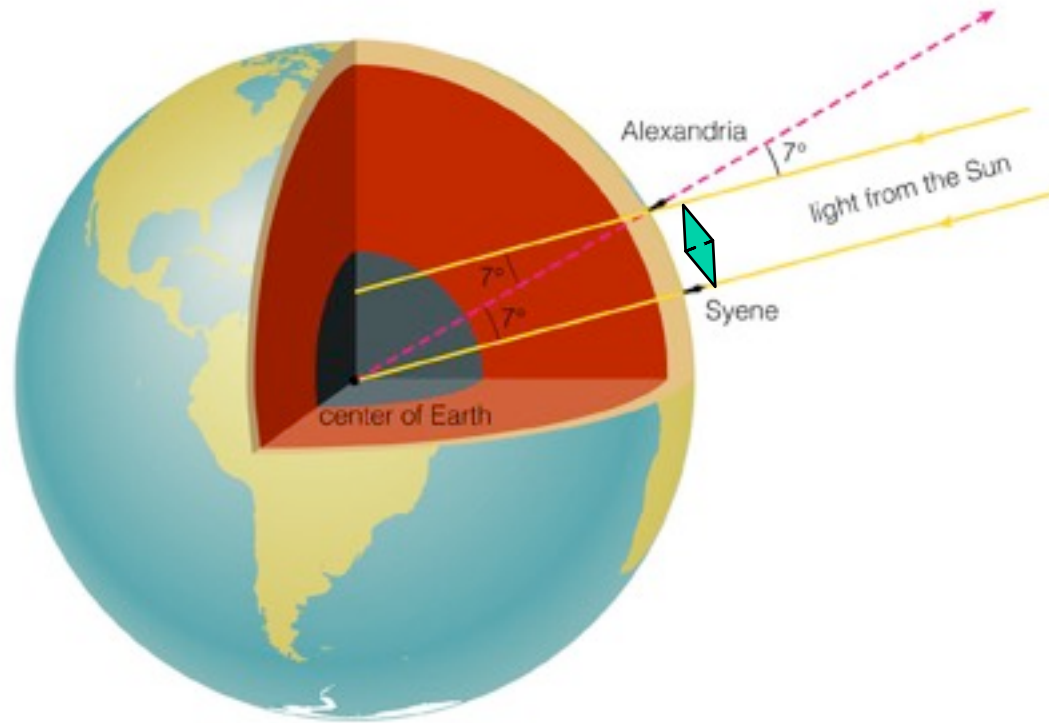
Eratosthenes became the third librarian at Alexandria under Ptolemy III in the Hellenistic period following the conquests of Alexander the Great. Ptolemy I had been one of Alexander's generals, and had taken Egypt as his own after Alexander's untimely death.

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

Measurements:

Syene to Alexandria

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



Calculate circumference of Earth:

$$(7/360) \times (\text{circum. Earth}) = 5,000 \text{ stadia}$$

$$\Rightarrow \text{circum. Earth} = 5,000 \times 360/7 \text{ stadia} \approx 250,000 \text{ stadia}$$

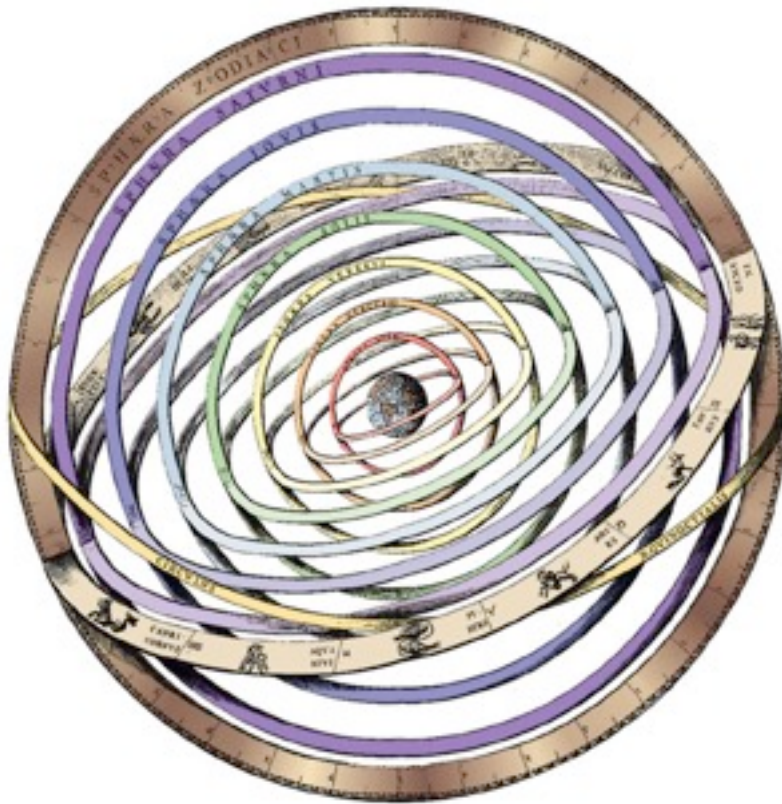
Compare to modern value ($\approx 40,100$ km):

$$\text{Greek stadium} \approx 1/6 \text{ km} \Rightarrow 250,000 \text{ stadia} \approx 42,000 \text{ km}$$

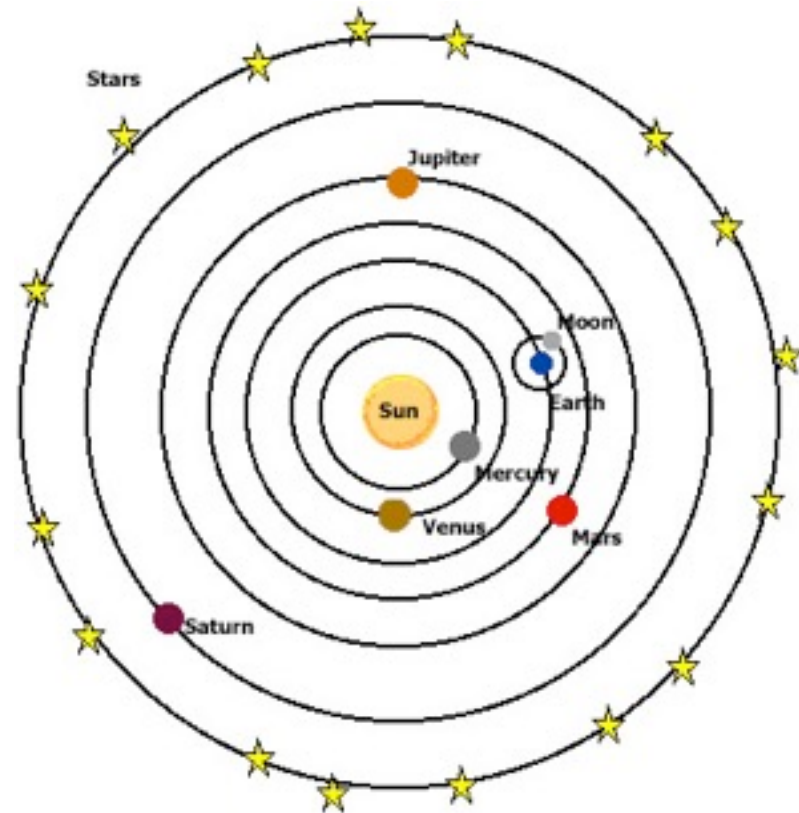
It was known long before Columbus that the Earth is not flat!

Competing Cosmologies

Geocentric
Ptolemaic
Earth at center



Heliocentric
Copernican
Sun at center



Geocentric

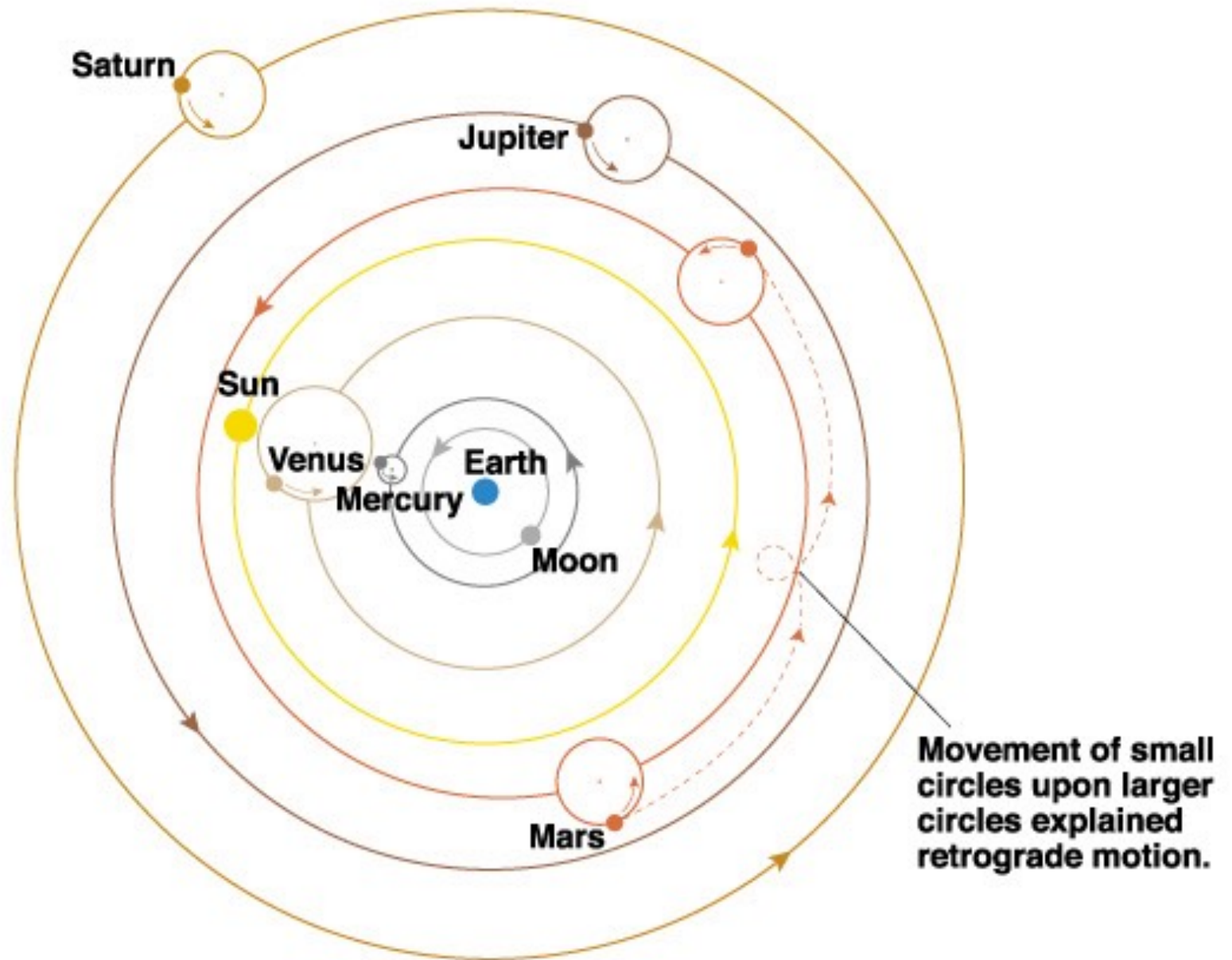


Ptolemy

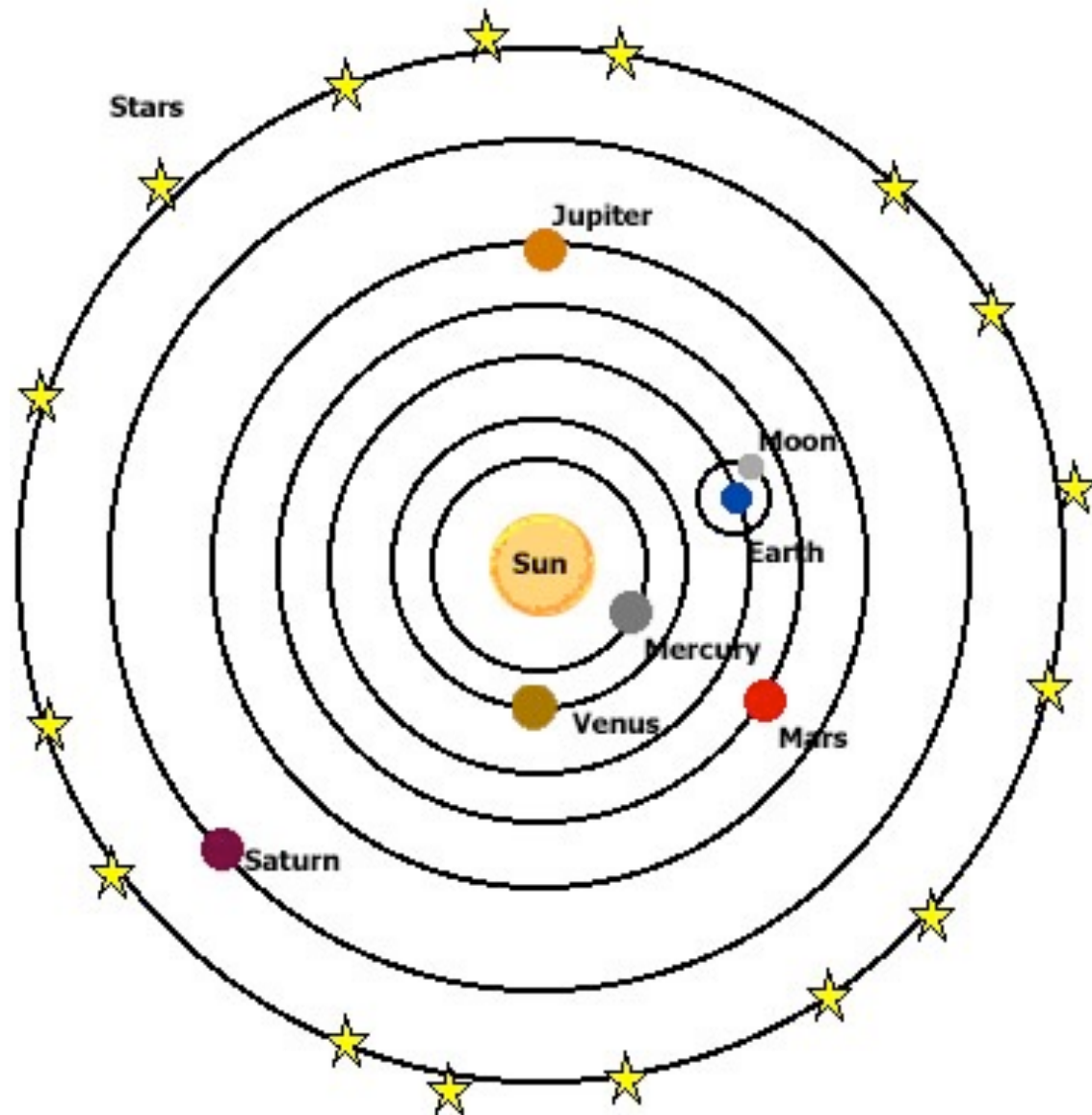
The most sophisticated geocentric model was that of Ptolemy (A.D. 100–170) — the **Ptolemaic model**:

- 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.

Competing Cosmologies

Geocentric

Ptolemaic

Earth at center

Heliocentric

Copernican

Sun at center

The sun is the source of light in both models

Explains

- **Motion of Sun**
- **Motion of Moon**
- **Solar and Lunar Eclipses**
- **Phases of Moon**

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Hard to tell the difference!

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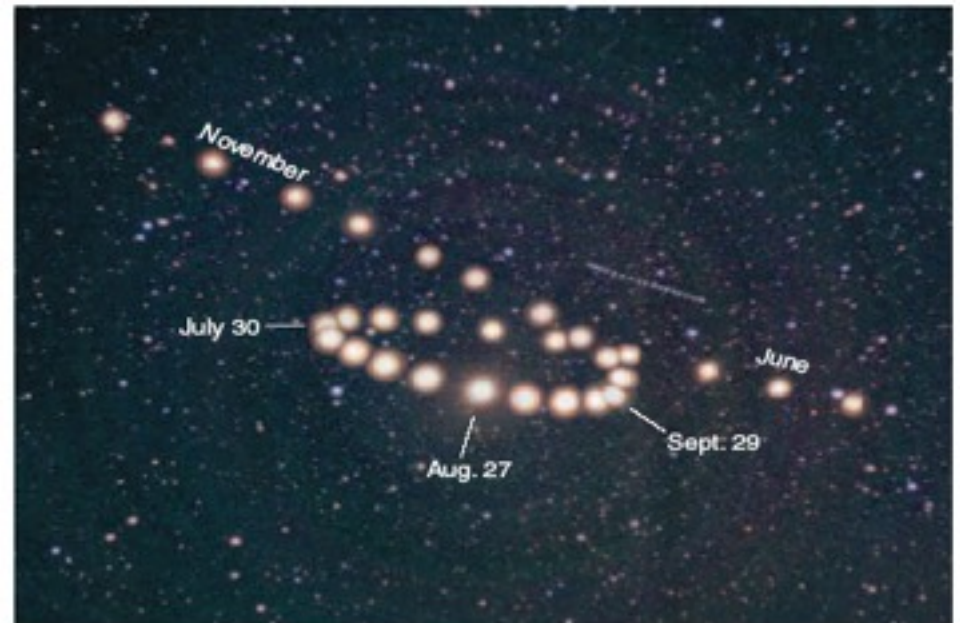
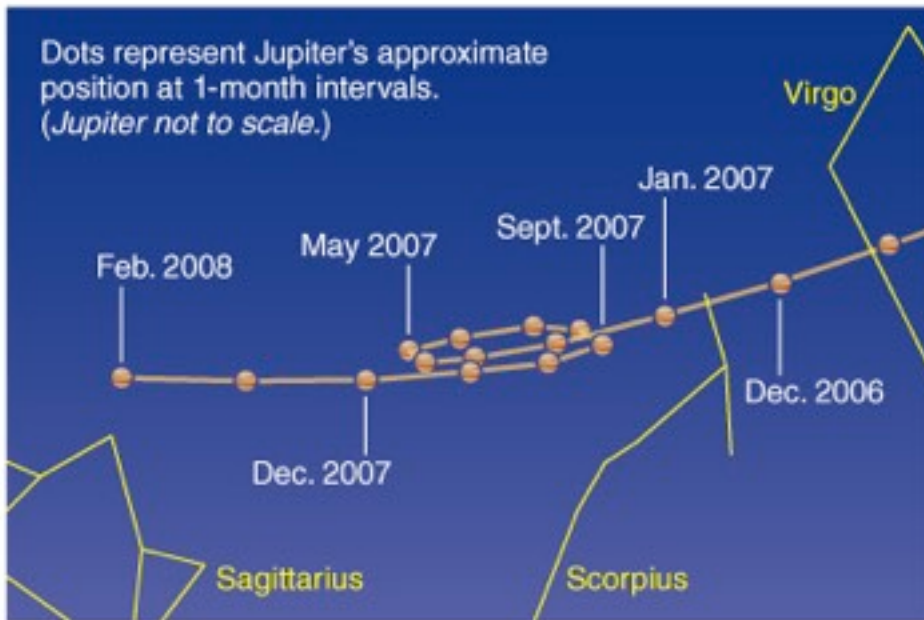
Retrograde Motion

Needs epicycles

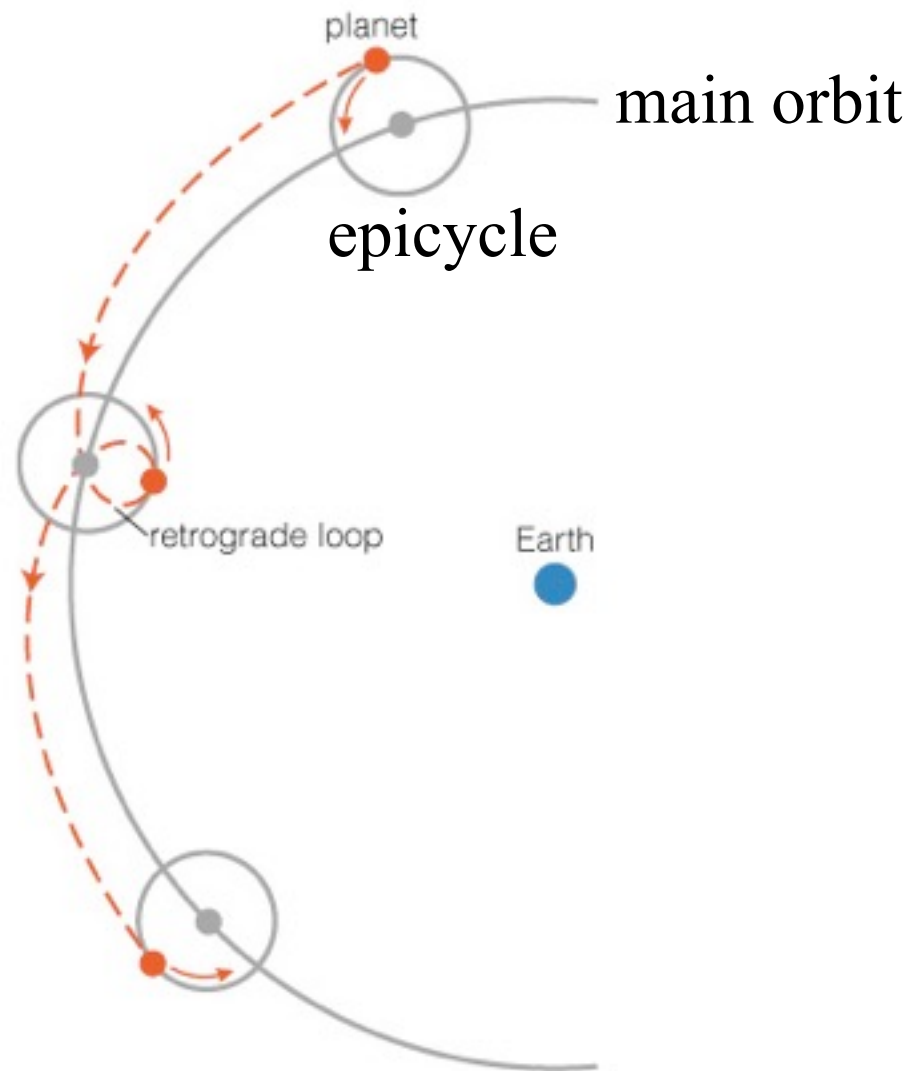
Consequence of Lapping

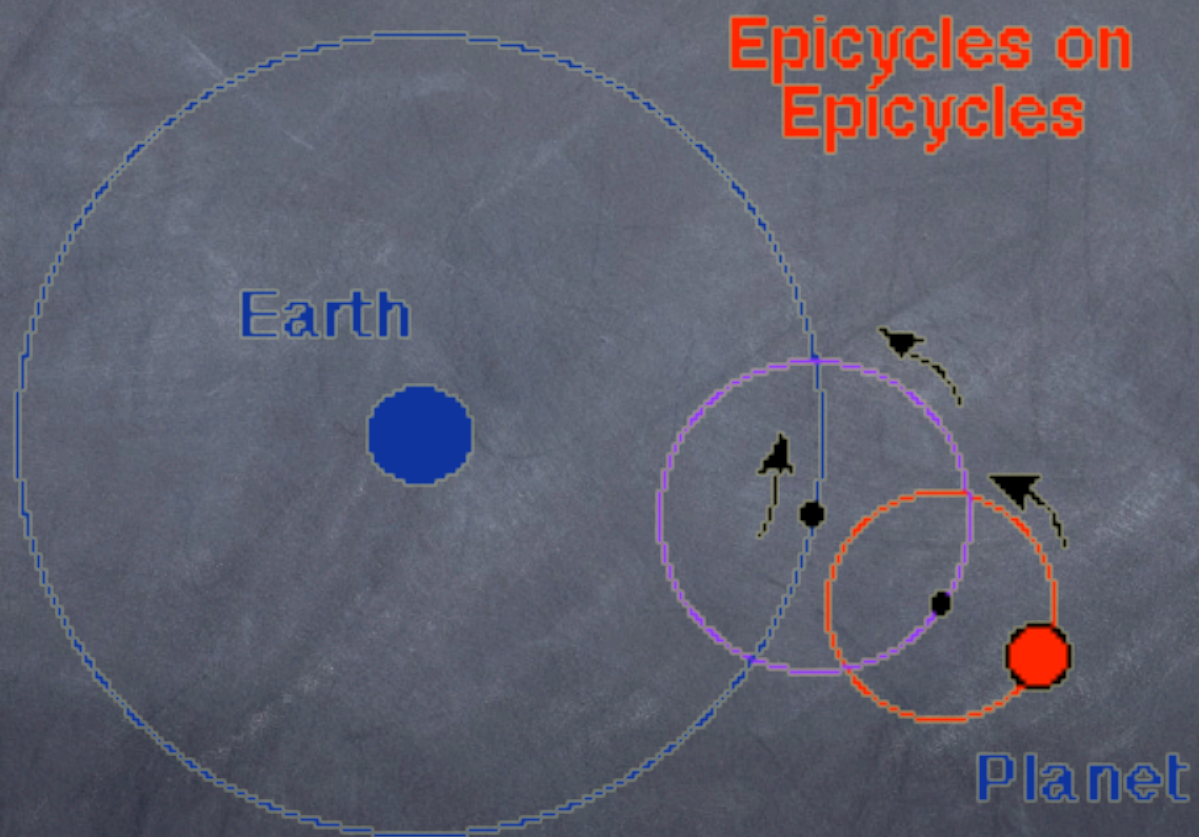
Retrograde motion

- 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.**



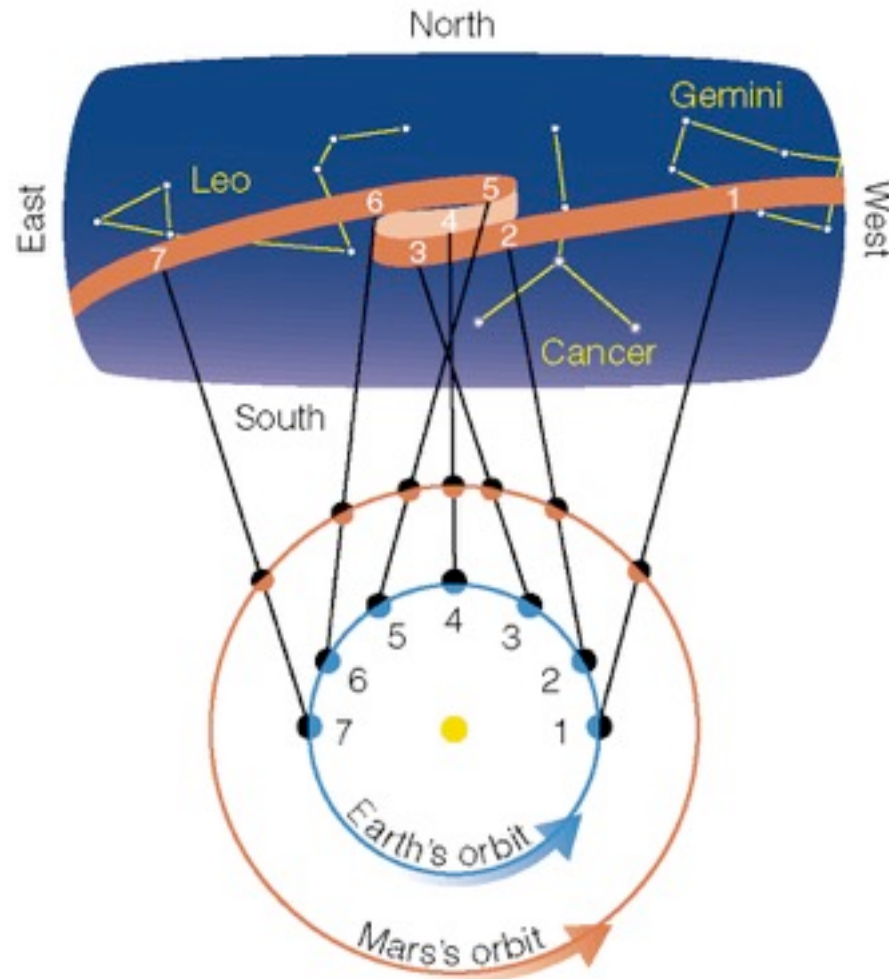
In the **Ptolemaic** model, planets *really do* go backwards.





H.S. in epicycles

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



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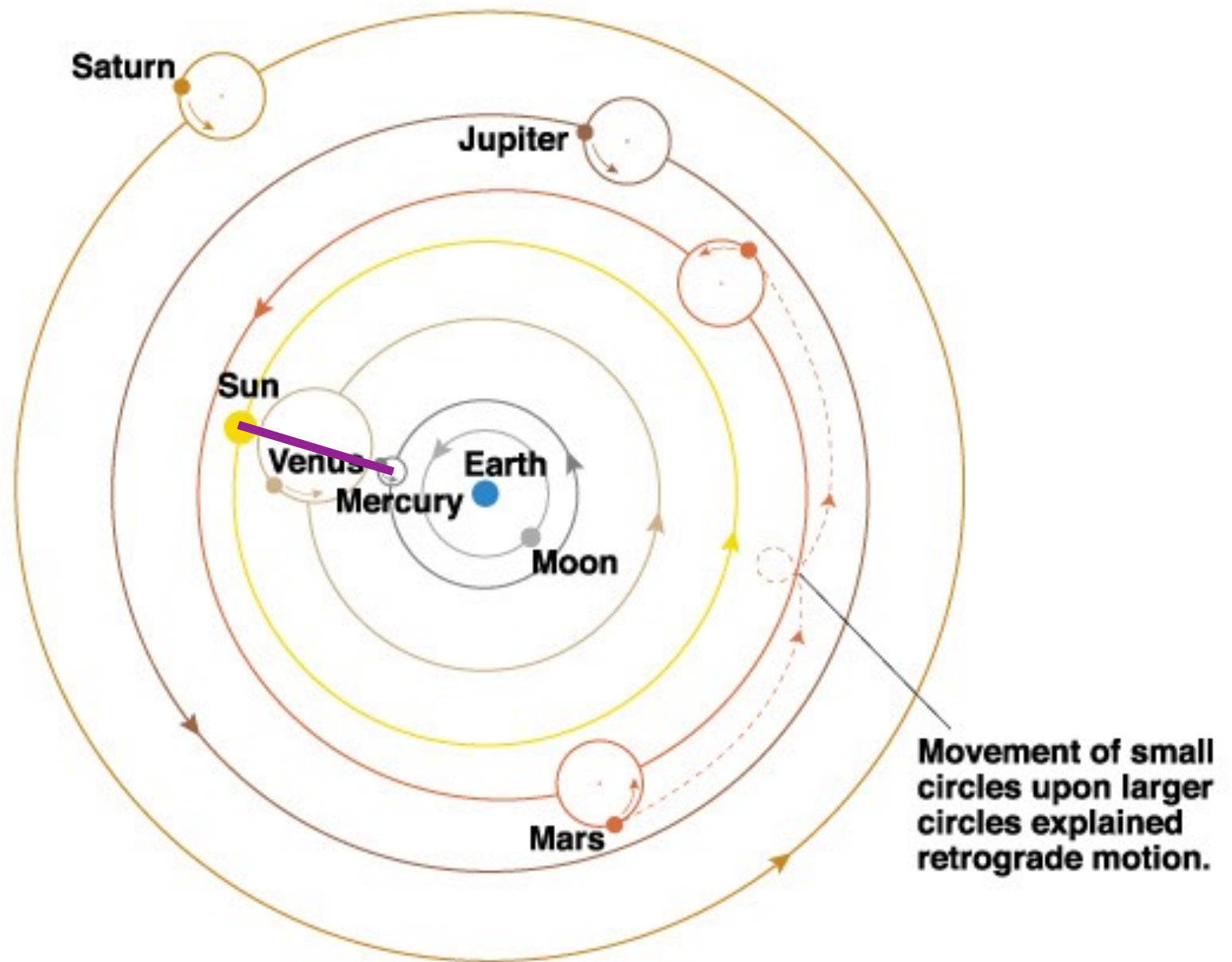
Consequence of Lapping

Inferiority of Mercury & Venus

Must tie to sun

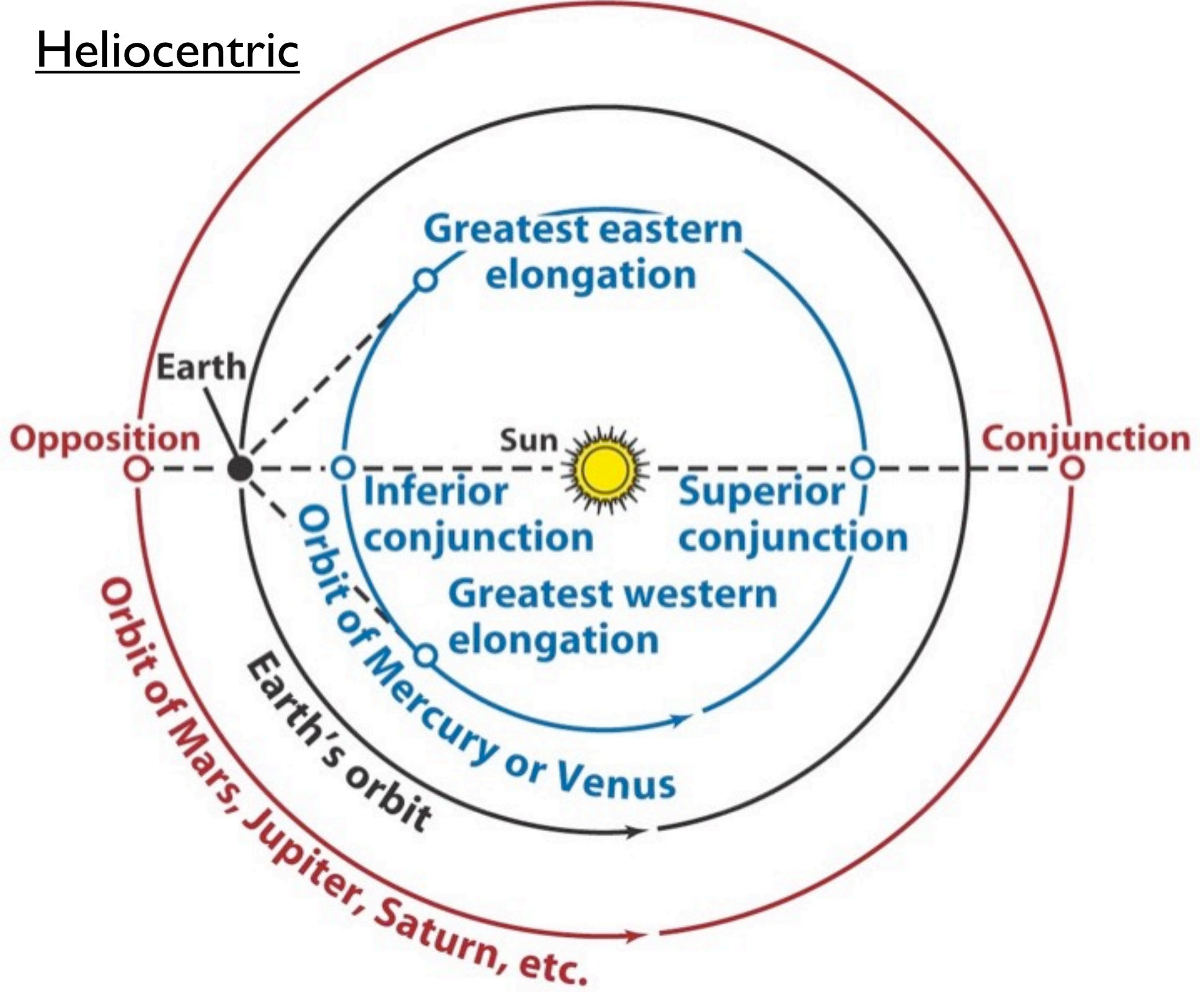
Interior to Earth's Orbit

Geocentric Cosmology



Mercury & Venus always close to sun on the sky

Heliocentric



Competing Cosmologies

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Ptolemaic

Earth at center

Heliocentric

Copernican

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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

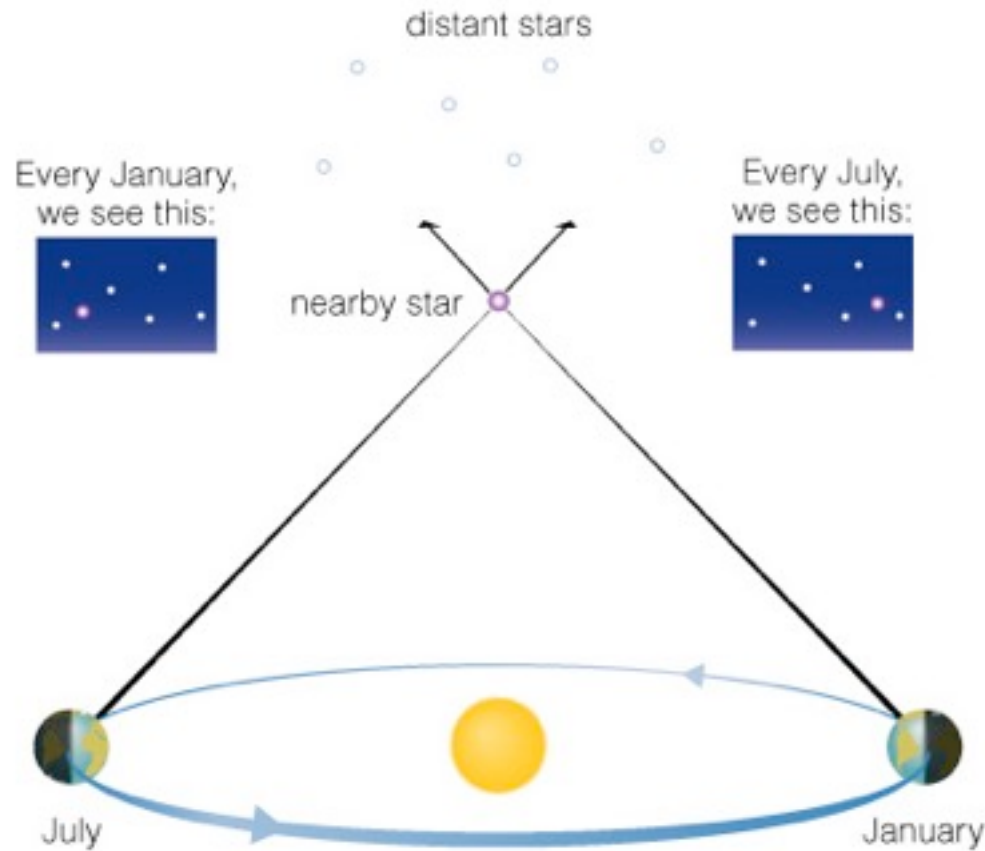
Predicts

- No parallax
- Venus: crescent phase only

- Parallax
- 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**.

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Ptolemaic

Earth at center

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Heliocentric

Copernican

Sun at center

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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

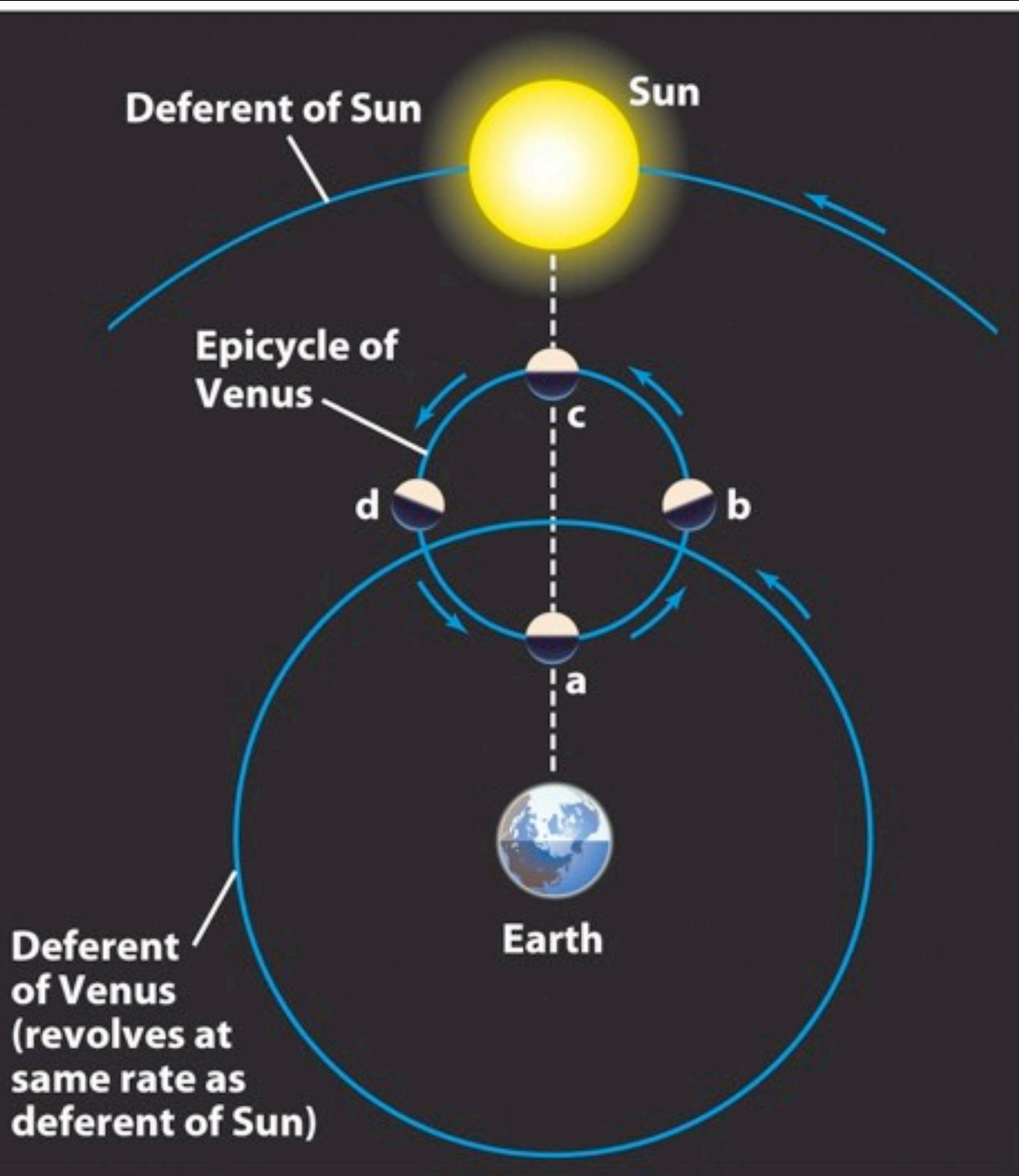
nicer

Predicts

- No parallax ✓
- Venus: crescent phase only

- Parallax **X**
- Venus: all phases
unknown to ancients

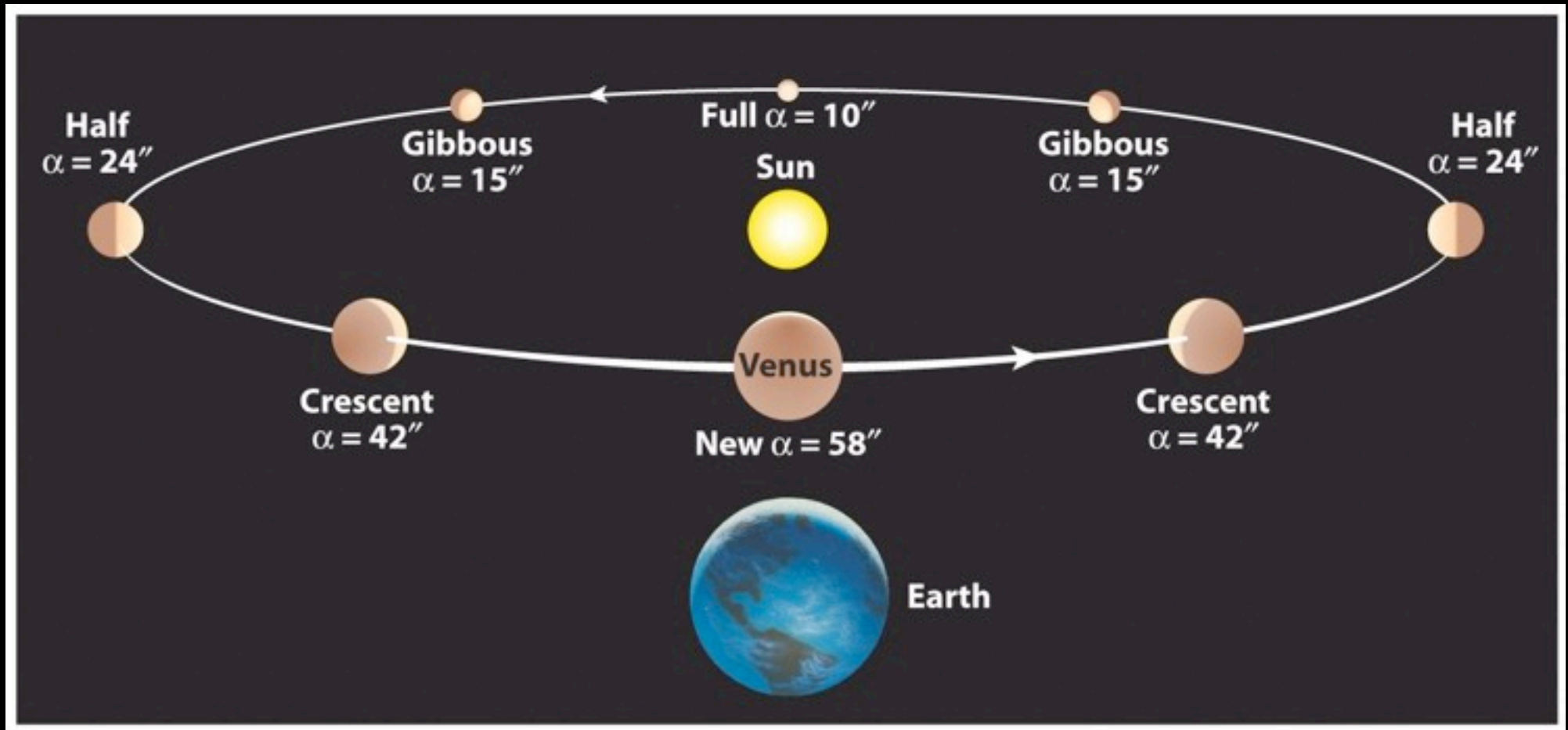
Geocentric



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

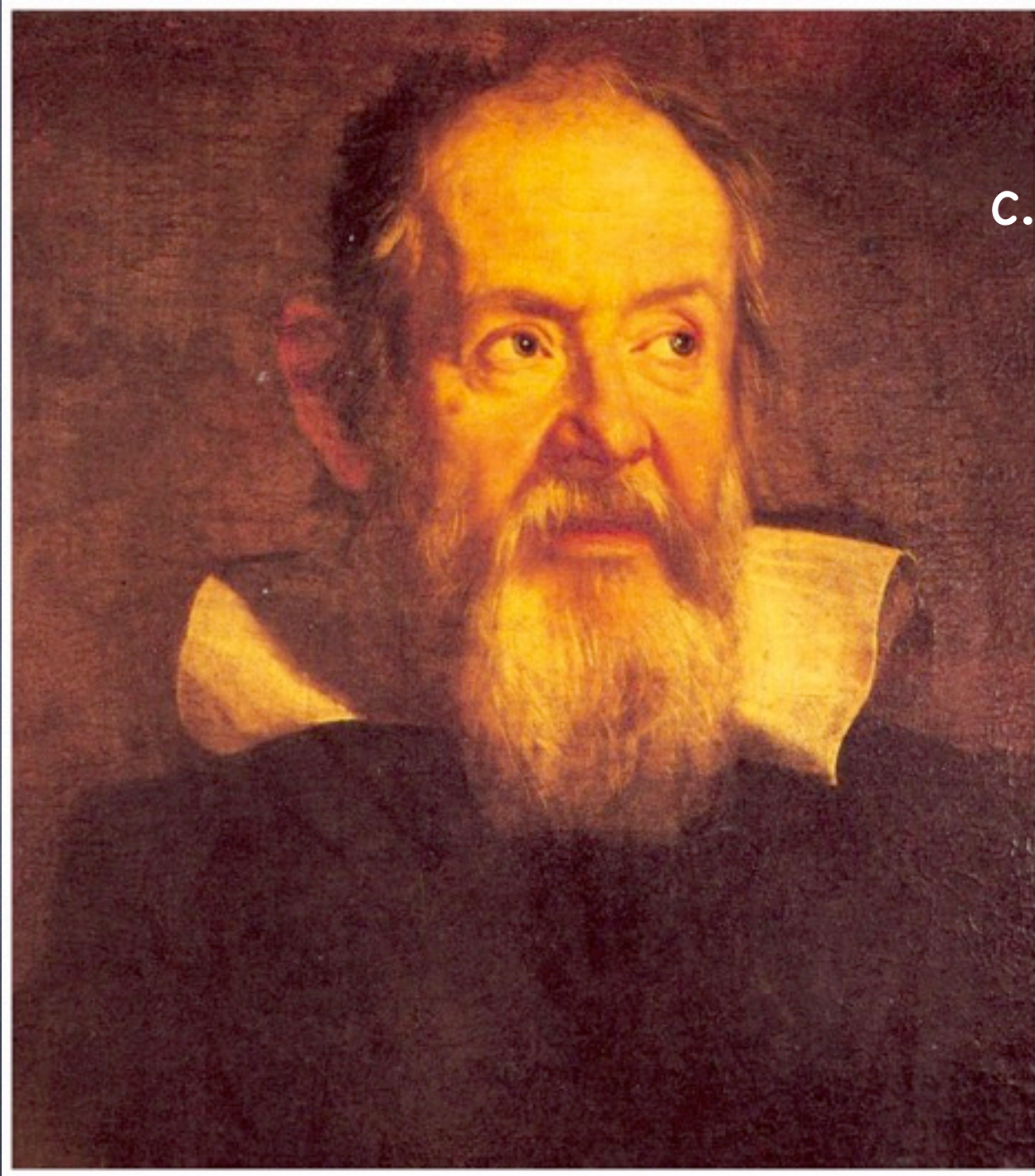
Heliocentric

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



Galileo

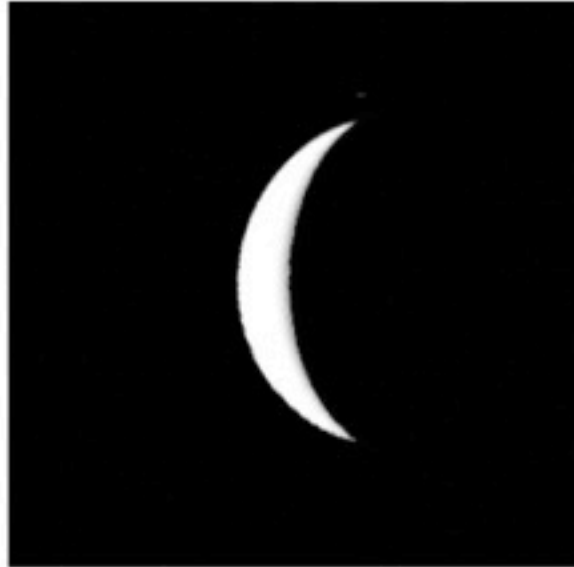
c. 1564–1640



First telescopic astronomical observations

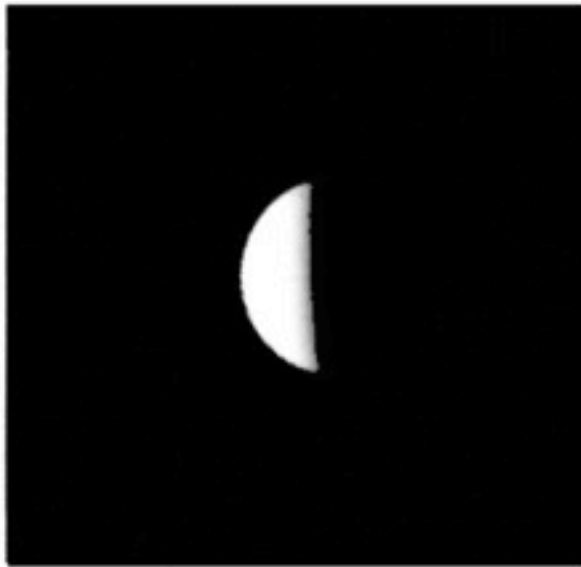


$\alpha = 58^\circ$

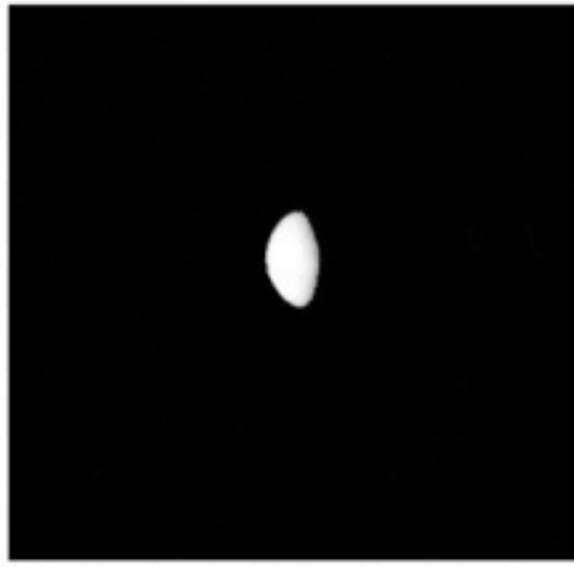


$\alpha = 42^\circ$

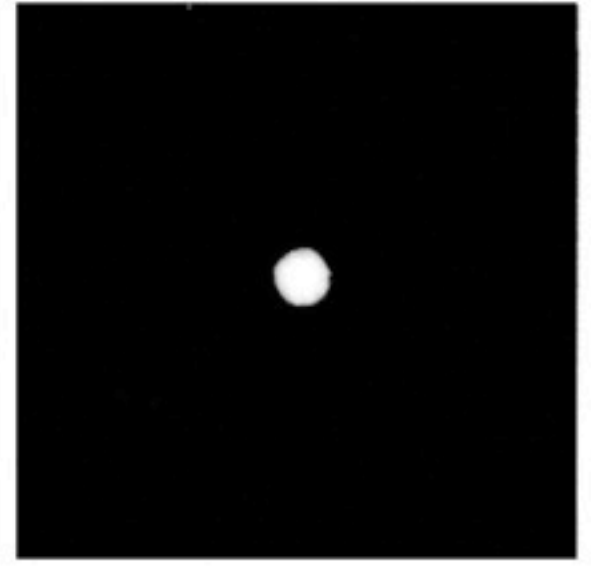
Phase and angular
size of Venus
depend on
elongation



$\alpha = 24^\circ$



$\alpha = 15^\circ$



$\alpha = 10^\circ$

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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 ✓
- Venus: crescent phase only X

- Parallax 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

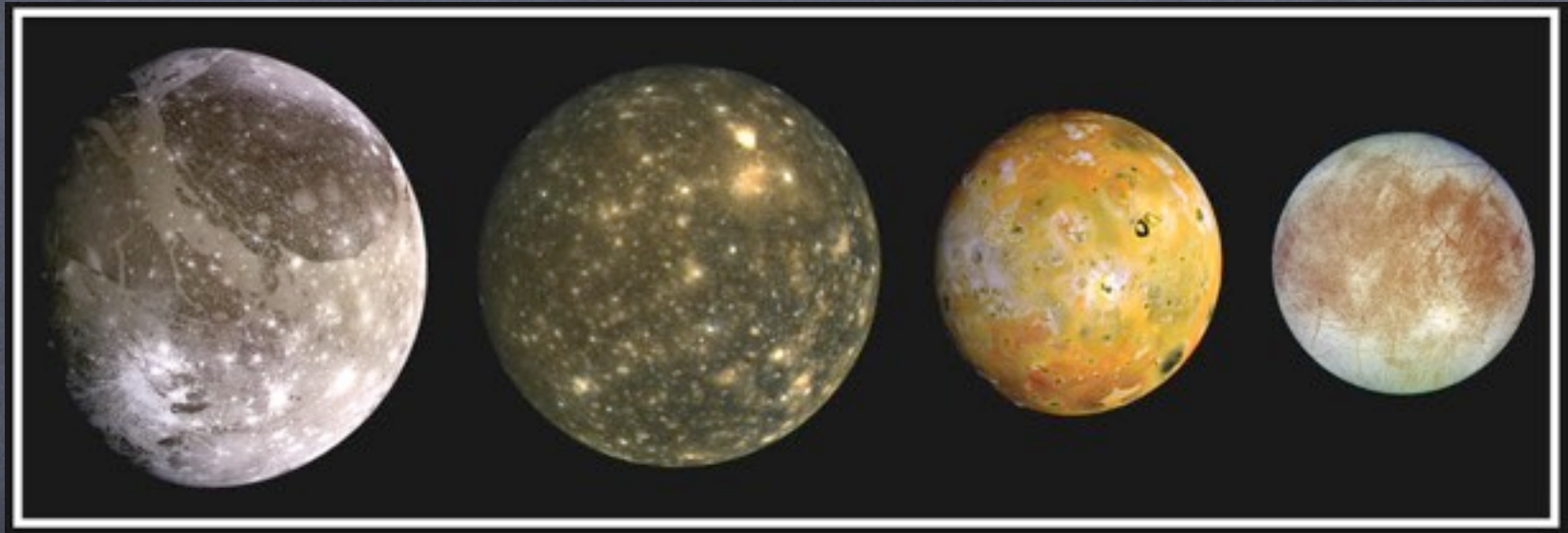
Galileo's telescopic discoveries

- 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

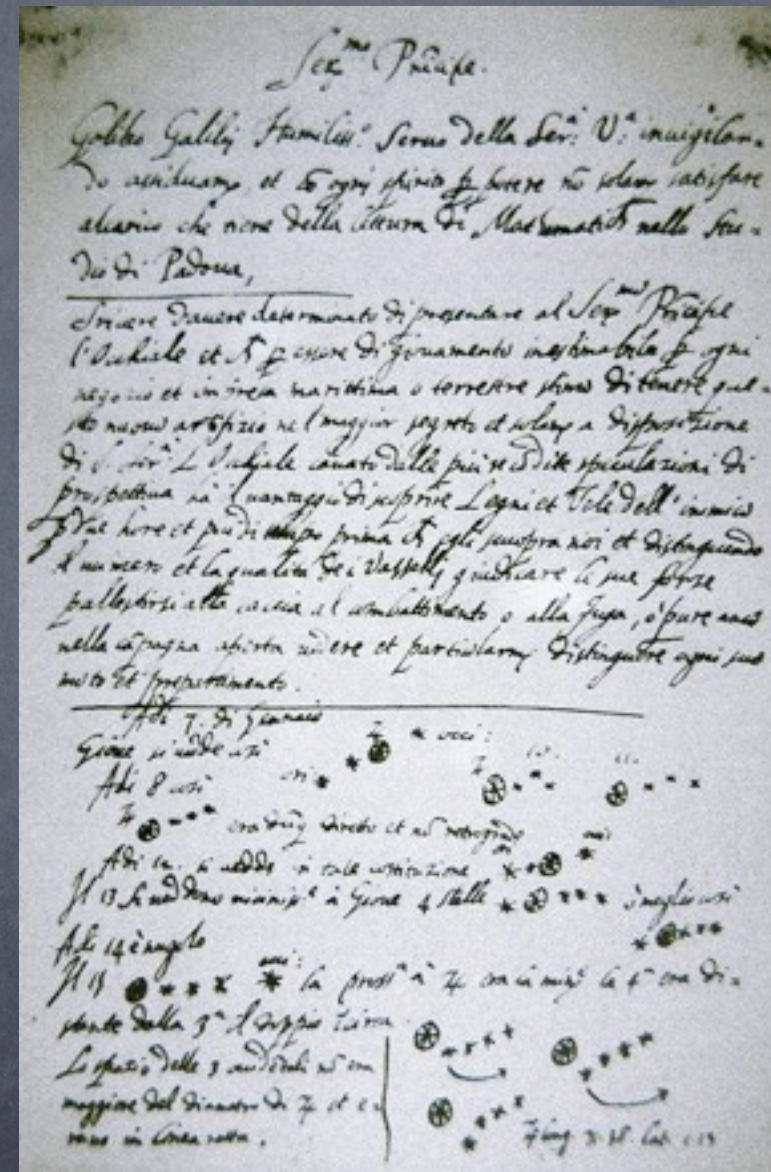


Galilean moons (from Galileo spacecraft!)



NASA

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



Observations Jevitaro 1610

2. J. Bris.
marc H. 12

○ **

30. marc

** ○ *

2. J. Bris.

○ ** *

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○ * *

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4. marc

* ○ **

6. marc

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8. marc H. 13.

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10. marc

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13. marc

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14. Casé.

* * * ○ *

"Medician
stars"

Heavenly
spheres
NOT
perfect



Even the
sun has
spots!



How did Galileo solidify the Copernican revolution?



Galileo (1564–1642) overcame major objections to the Copernican view. Three key objections rooted in the Aristotelian view were:

1. Earth could not be moving because objects in air would be left behind.
2. Noncircular orbits are not “perfect” as heavens should be.
3. If Earth were really orbiting Sun, we’d detect stellar parallax.