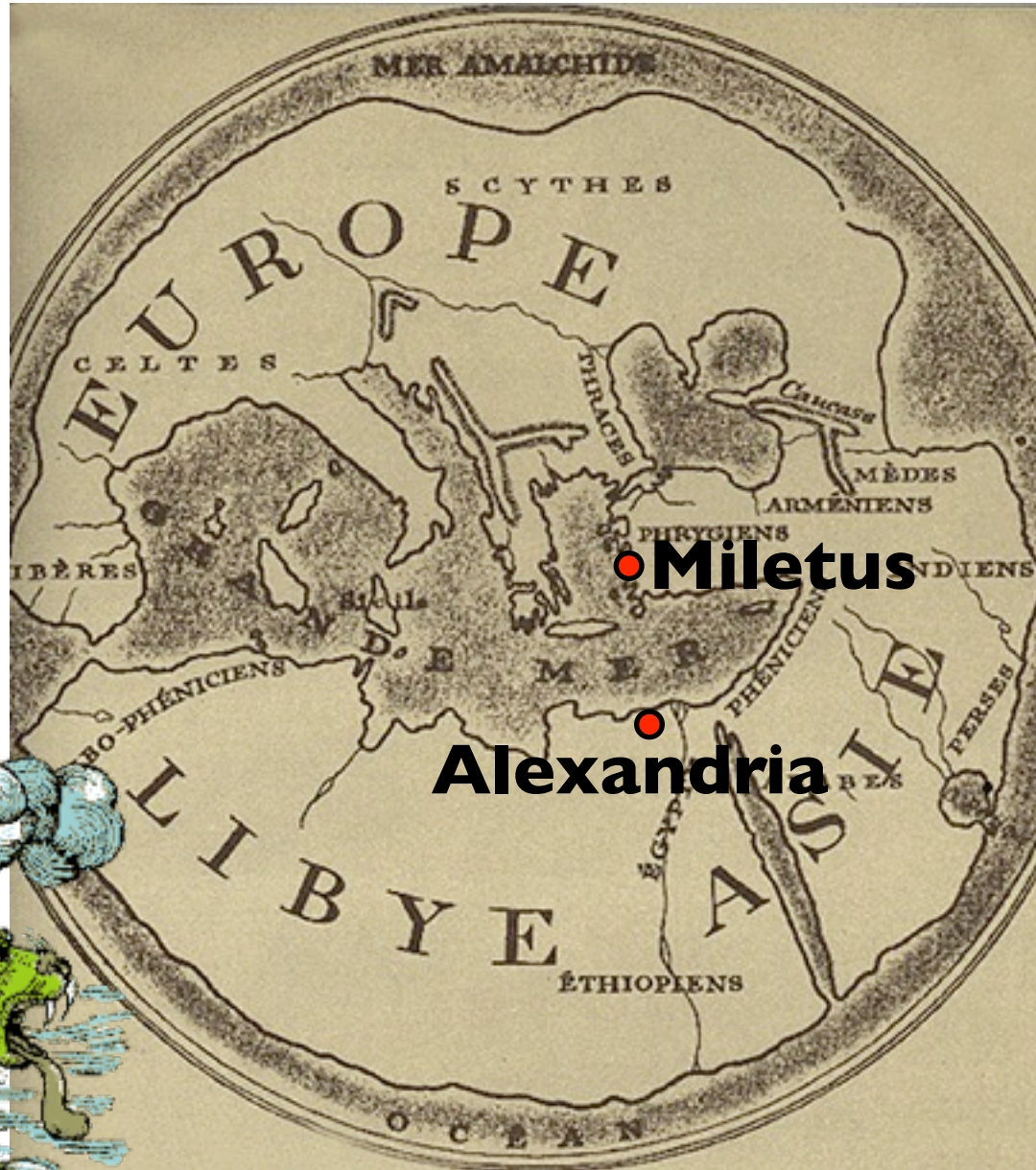


# TODAY

## FIRST HOMEWORK DUE

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

# Ancient Cosmology: A Flat Earth



Here there  
be  
dragons!



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





## Artist's reconstruction of the Library of Alexandria

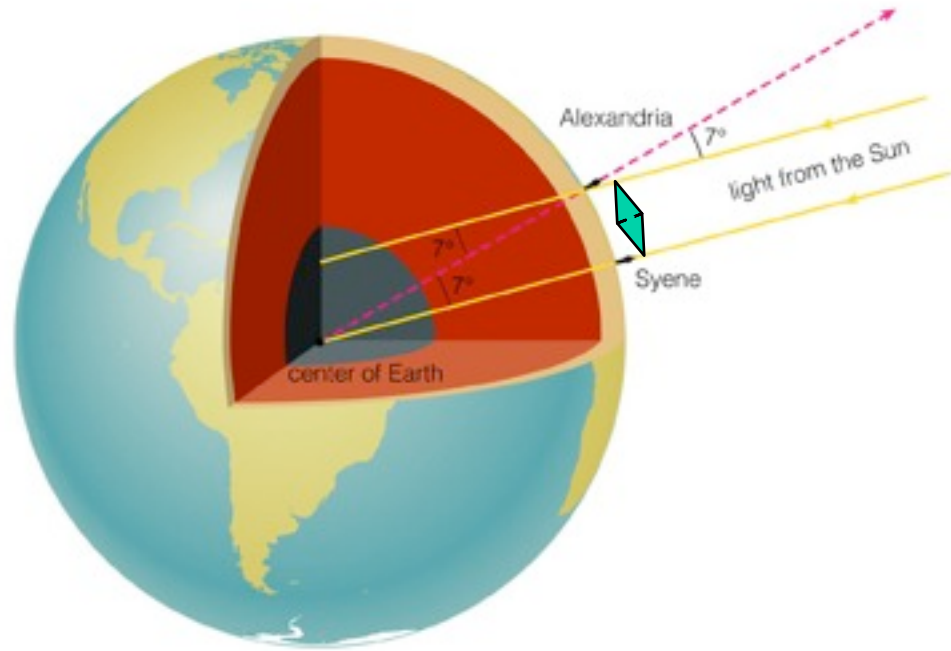
**Eratosthenes** became the third librarian at Alexandria under Ptolemy III in the Hellenistic period following the conquests of Alexander the Great. Ptolemy I had been one of Alexander's generals, and had taken Egypt as his own after Alexander's untimely death.

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

## Measurements:

### Syene to Alexandria

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



## Calculate circumference of Earth:

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

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

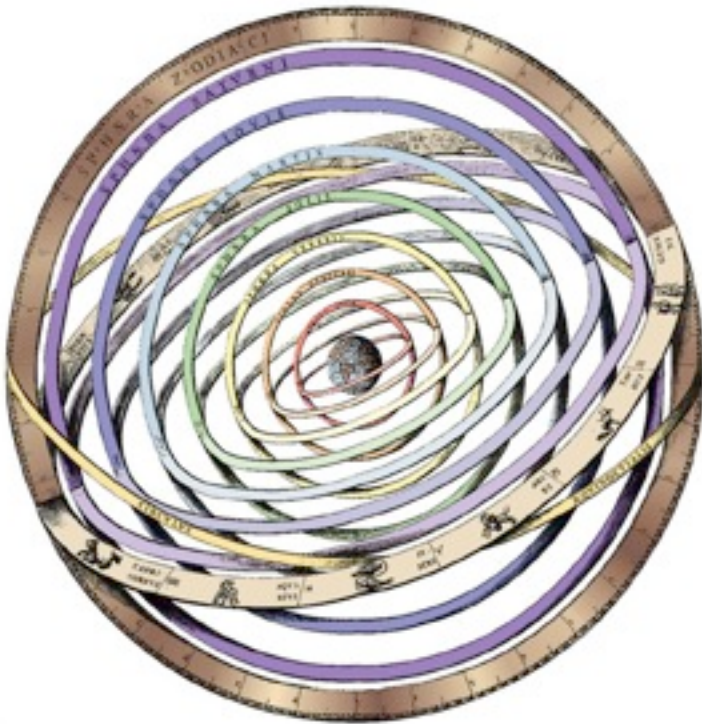
## Compare to modern value ( $\approx 40,100$ km):

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

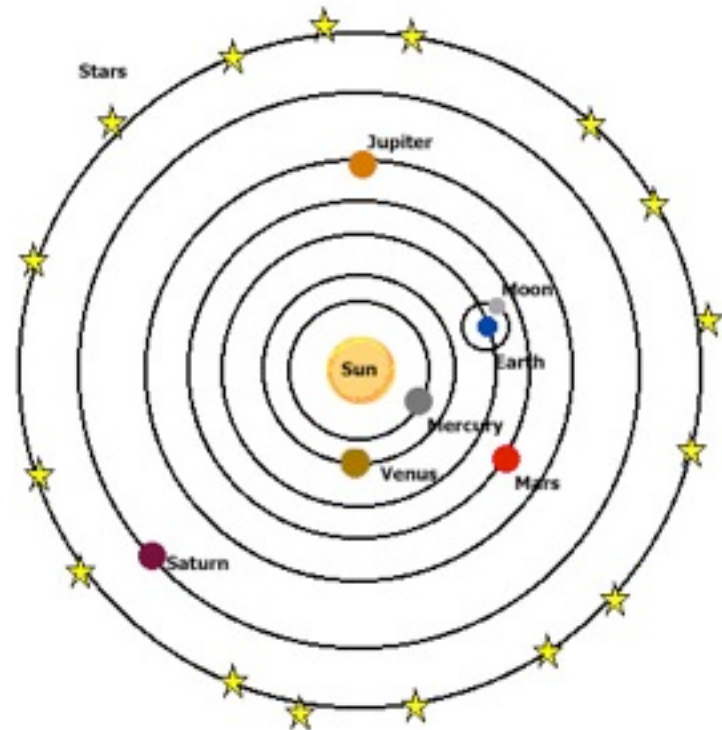
**It was known long before Columbus that the Earth is not flat!**

# Competing Cosmologies

**Geocentric**  
Ptolemaic  
Earth at center



**Heliocentric**  
Copernican  
Sun at center





# Geocentric

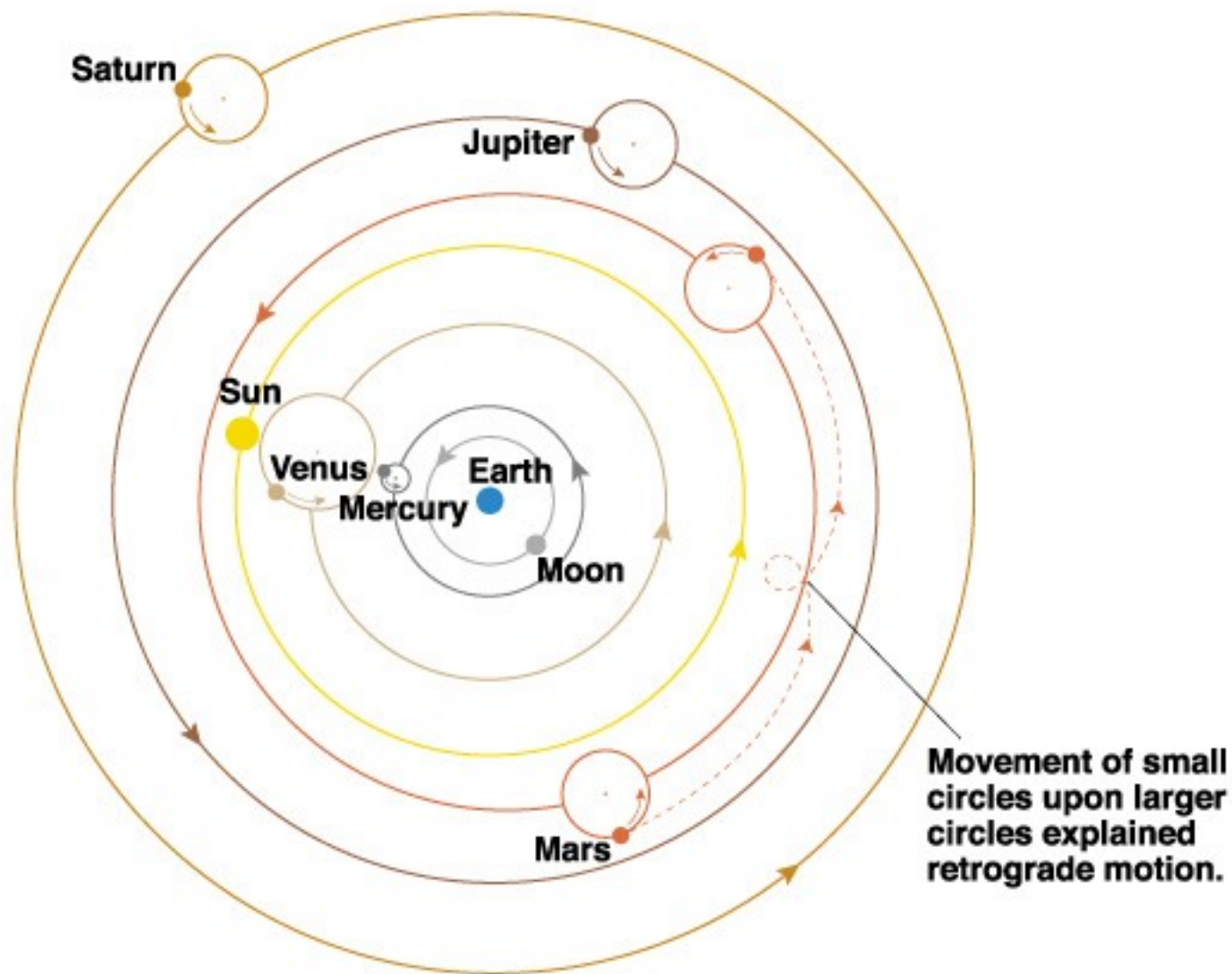


Ptolemy

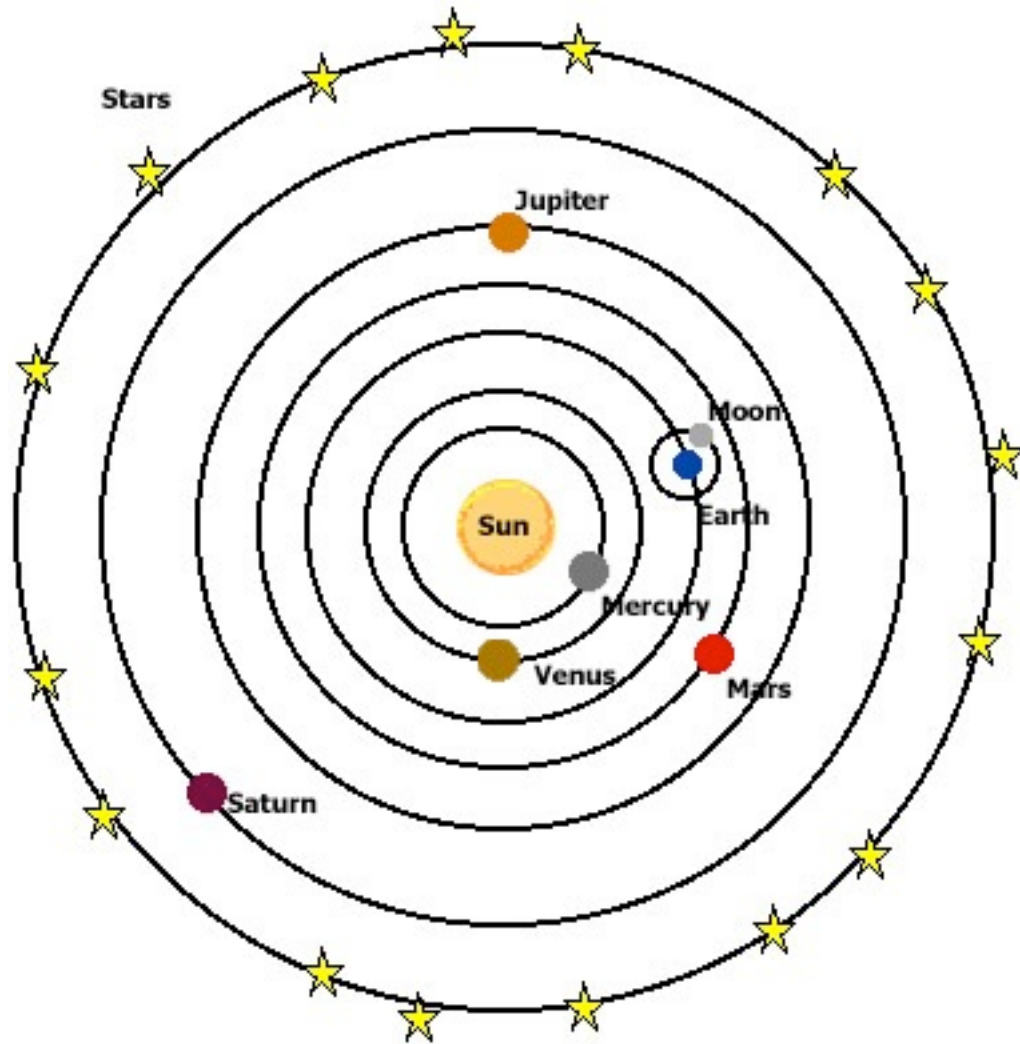
The most sophisticated geocentric model was that of Ptolemy (A.D. 100–170) — the **Ptolemaic model**:

- 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**

### **Explains**

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

Hard to tell the difference!

# Competing Cosmologies

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Retrograde Motion

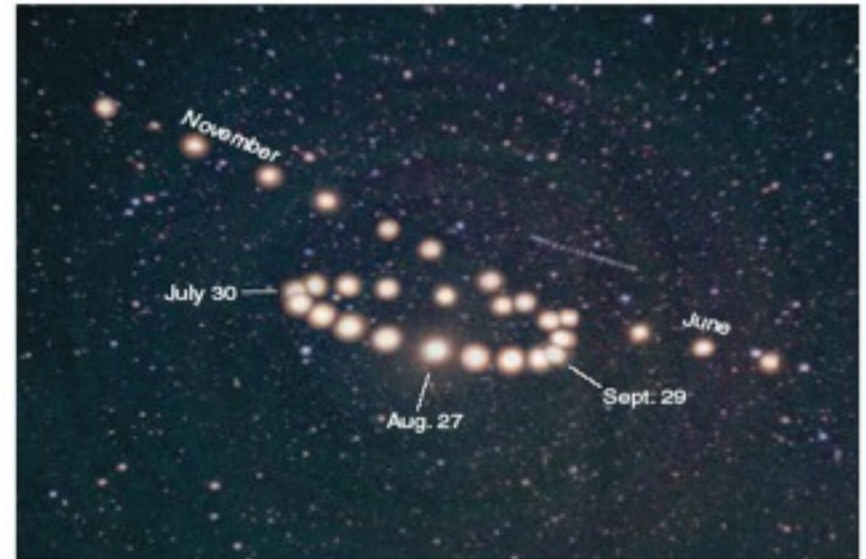
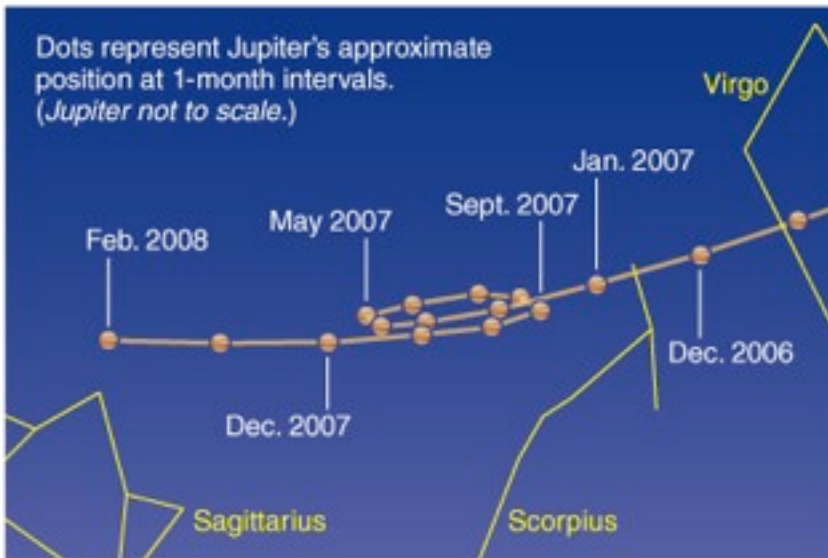
Needs epicycles

Consequence of Lapping

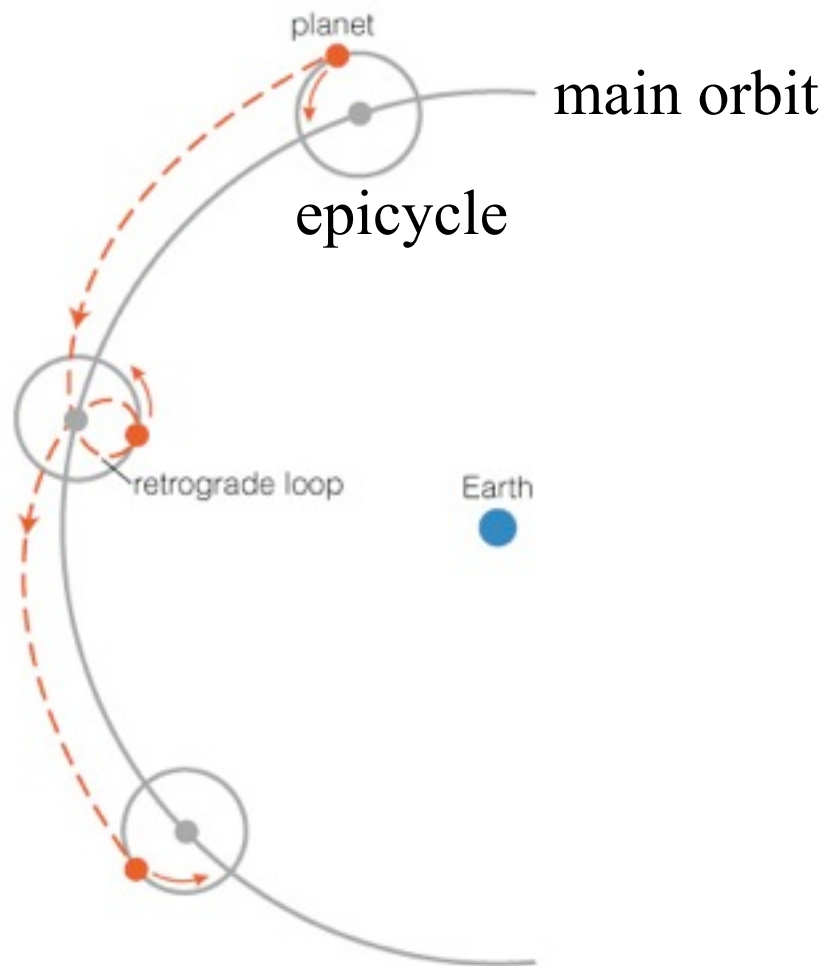


# Retrograde motion

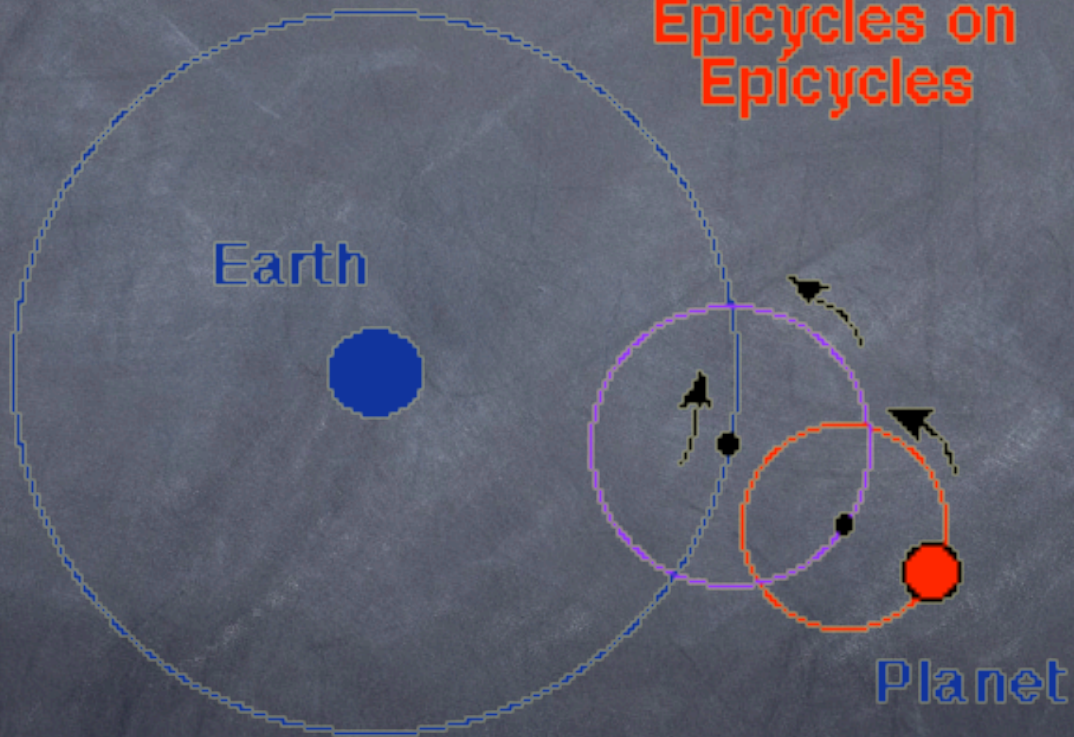
- Planets usually move slightly *eastward* from night to night relative to the stars.
- But, sometimes they go *westward* relative to the stars for a few weeks: **apparent retrograde motion.**



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

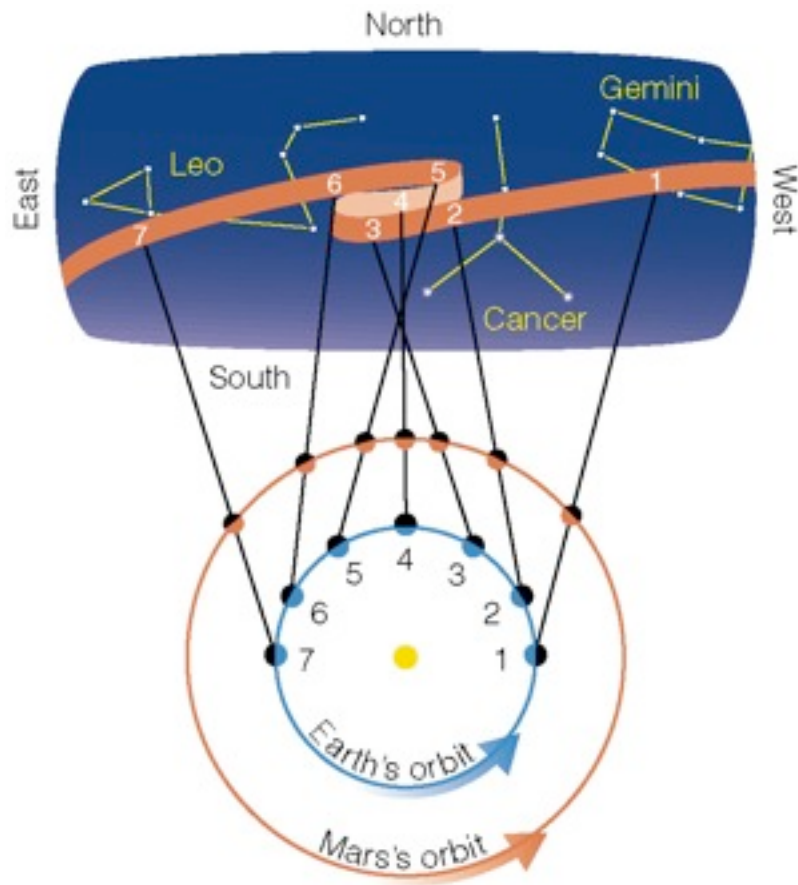


# Epicycles on Epicycles





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



# Competing Cosmologies

## **Geocentric**

Ptolemaic

Earth at center

## **Heliocentric**

Copernican

Sun at center

The sun is the source of light in both models

### **Explains**

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### **Explains**

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## Retrograde Motion

Needs epicycles

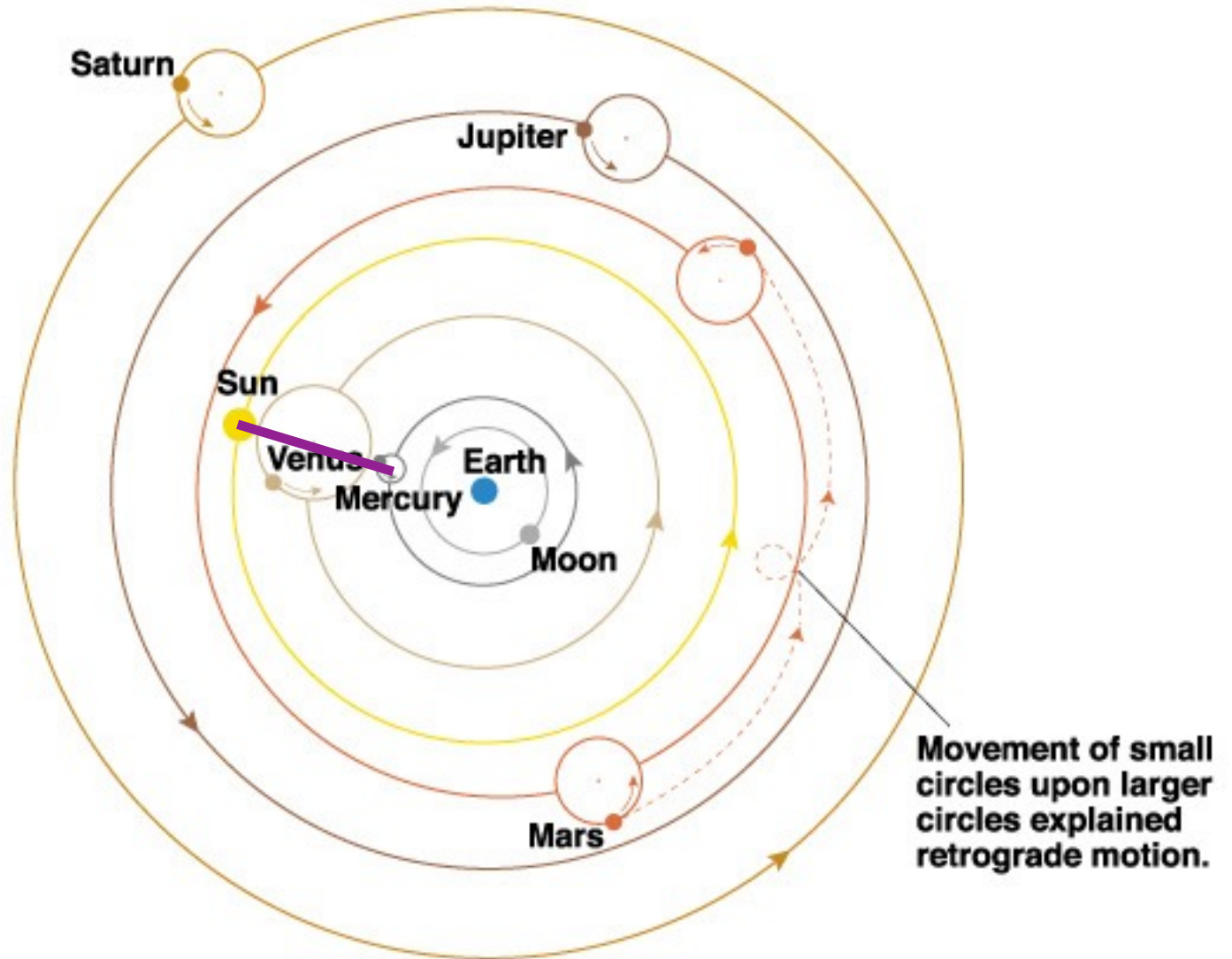
Consequence of Lapping

Inferiority of Mercury & Venus

Must tie to sun

Interior to Earth's Orbit

# Geocentric Cosmology

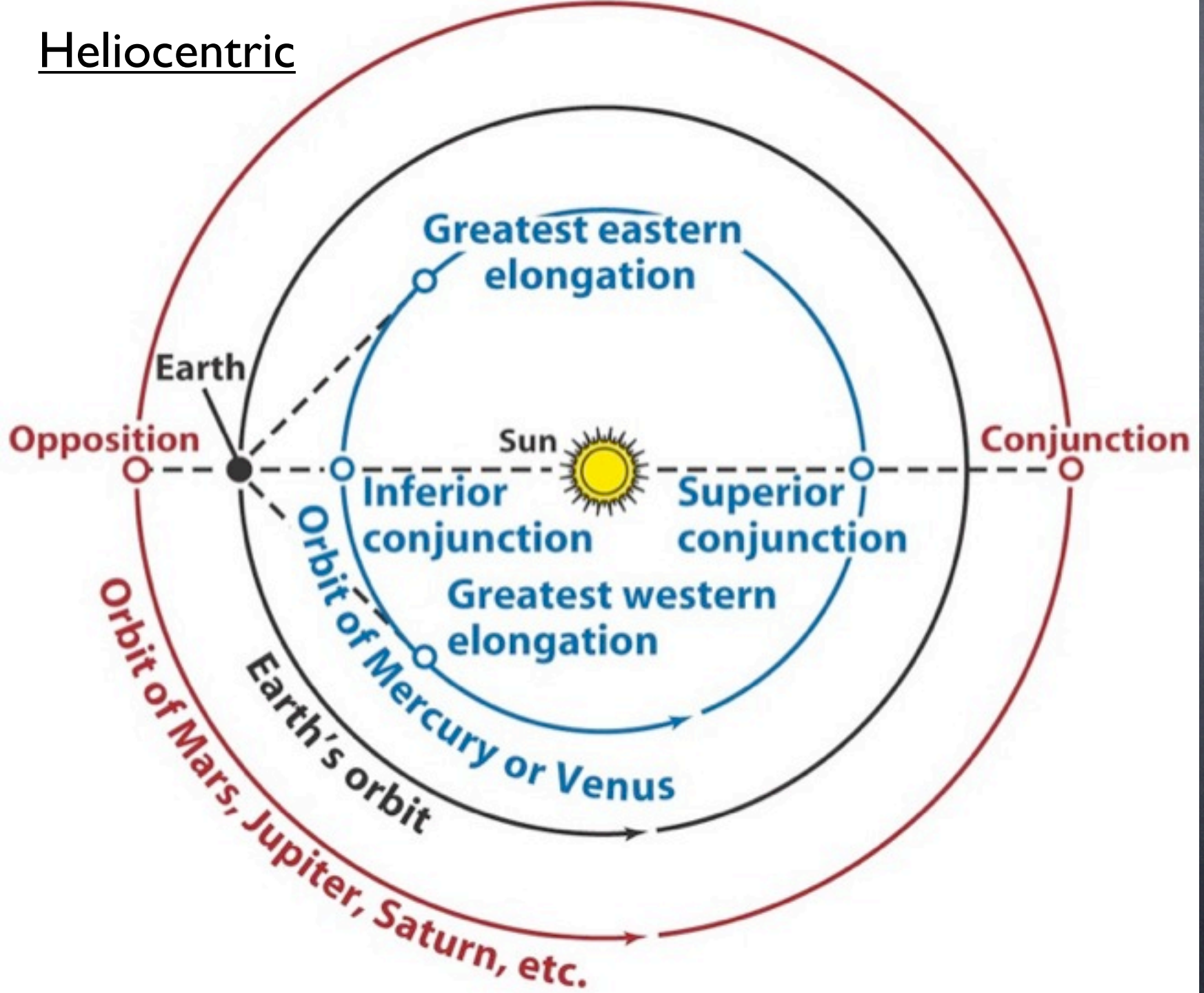


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Mercury & Venus always close to sun on the sky



# Heliocentric



# 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**

### **Explains**

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

## Retrograde Motion

Needs epicycles

Consequence of Lapping

Inferiority of Mercury & Venus

**more natural**

Must tie to sun

Interior to Earth's Orbit

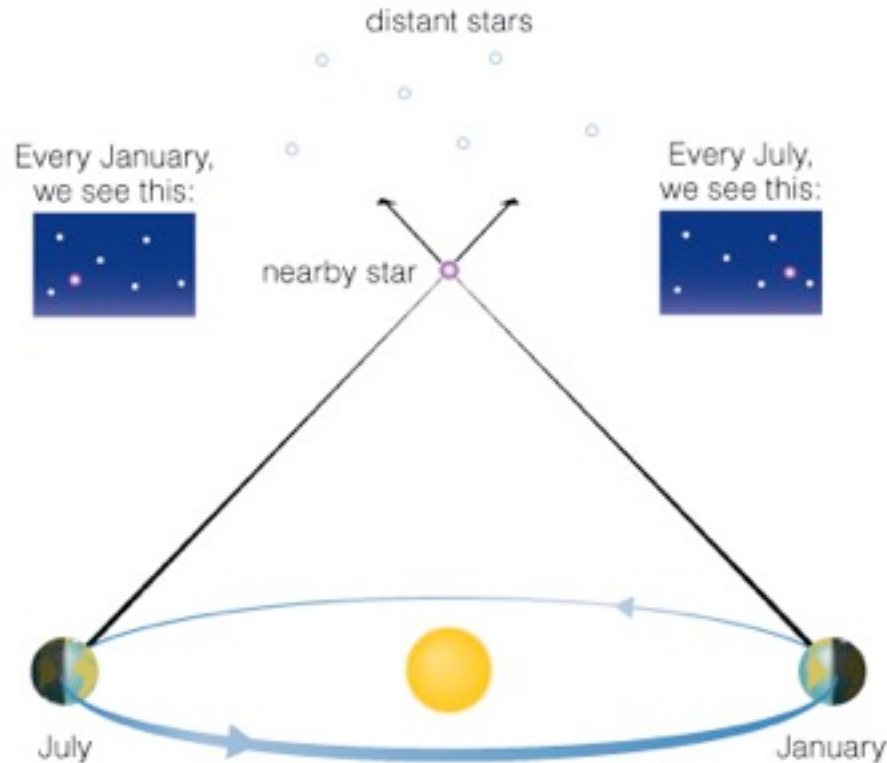
### **Predicts**

- 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**.

# Competing Cosmologies

## **Geocentric**

Ptolemaic

Earth 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**

## **Heliocentric**

Copernican

Sun at center

### **Explains**

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

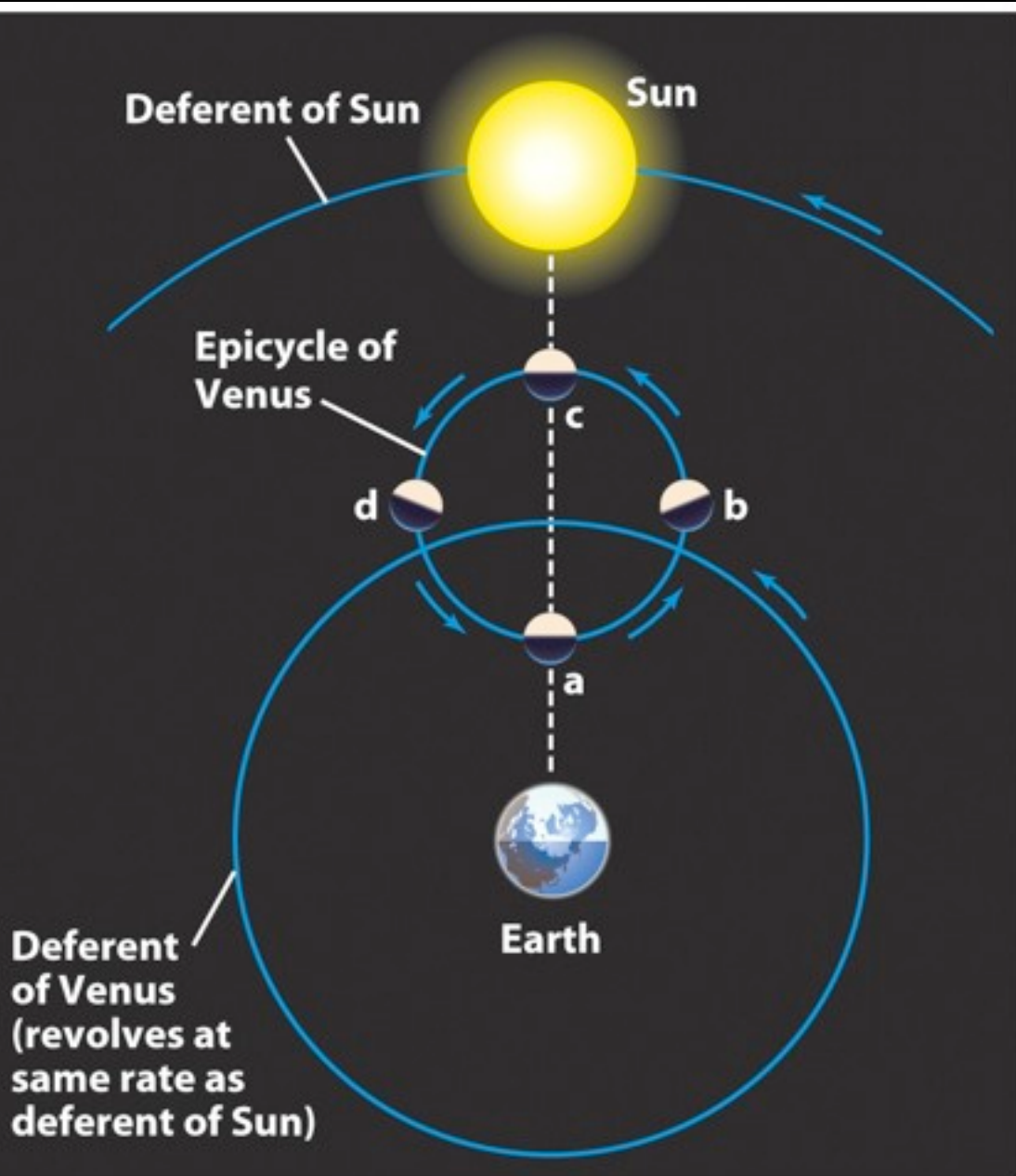
## **Predicts**

- No parallax ✓
- Venus: crescent phase only

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



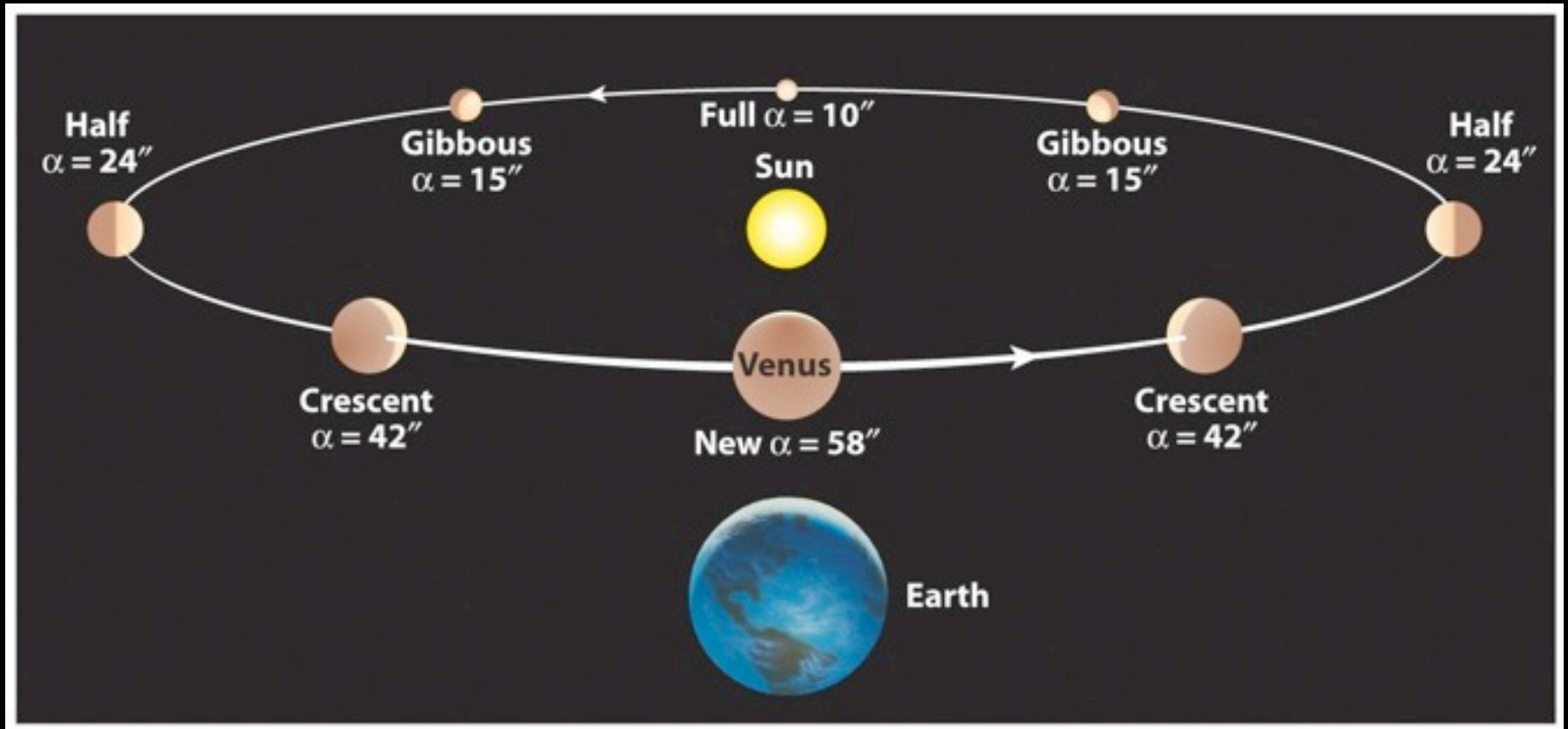
# Geocentric



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

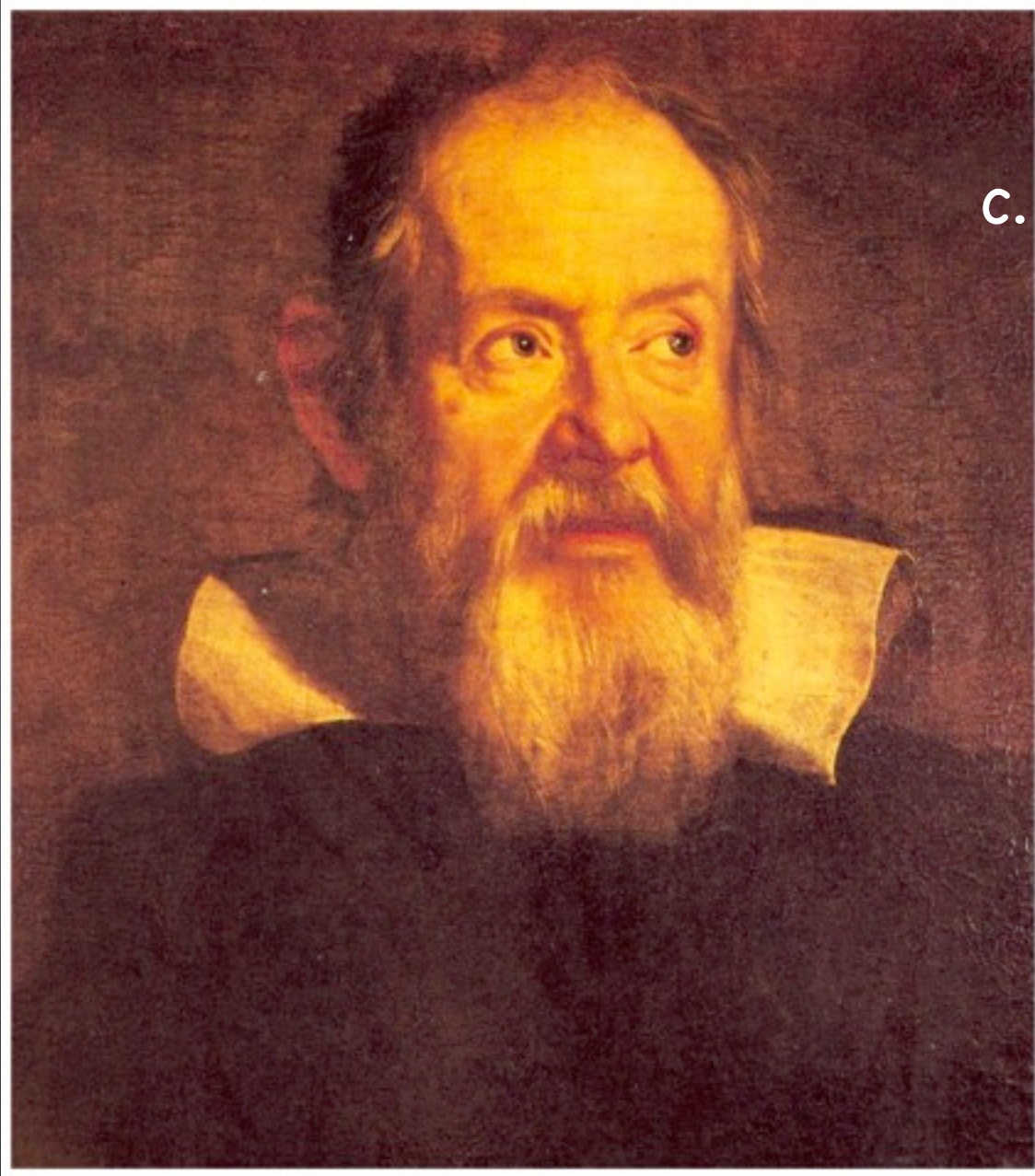
# Heliocentric

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



Galileo

c. 1564-1640

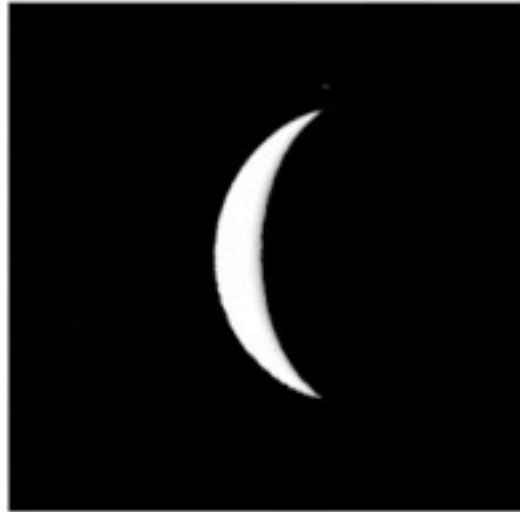


First telescopic astronomical observations

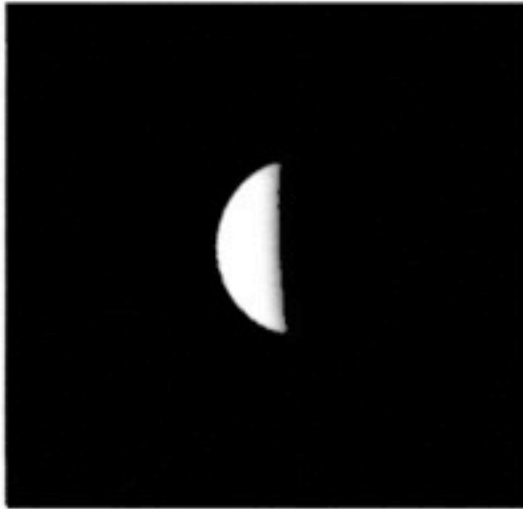




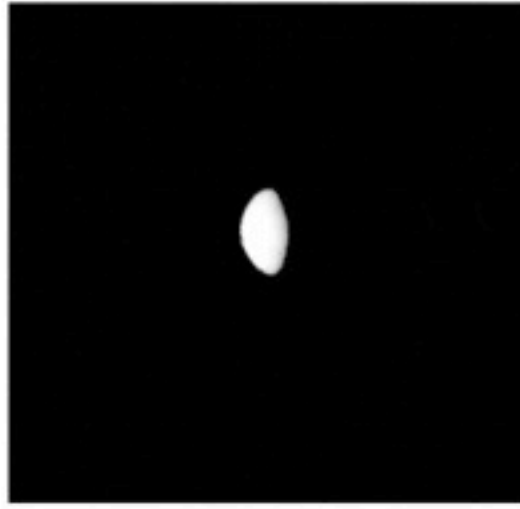
$\alpha = 58^\circ$



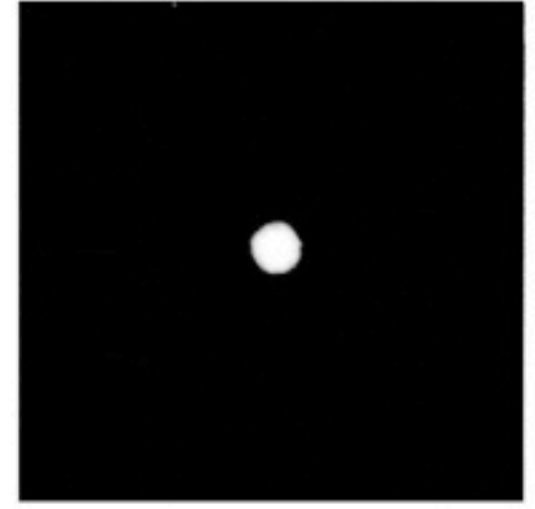
$\alpha = 42^\circ$



$\alpha = 24^\circ$



$\alpha = 15^\circ$



$\alpha = 10^\circ$

Phase and angular size of Venus depend on elongation