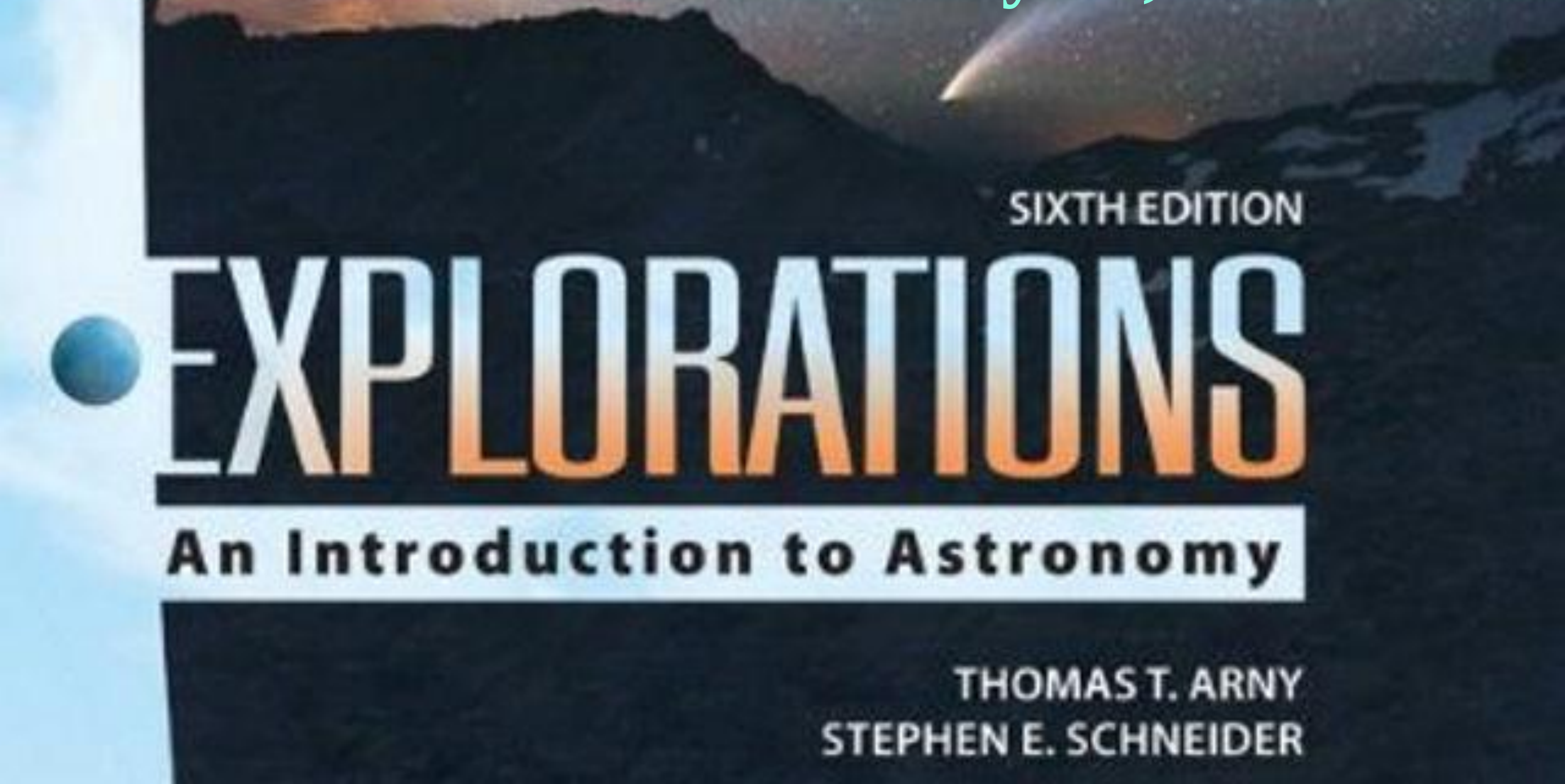
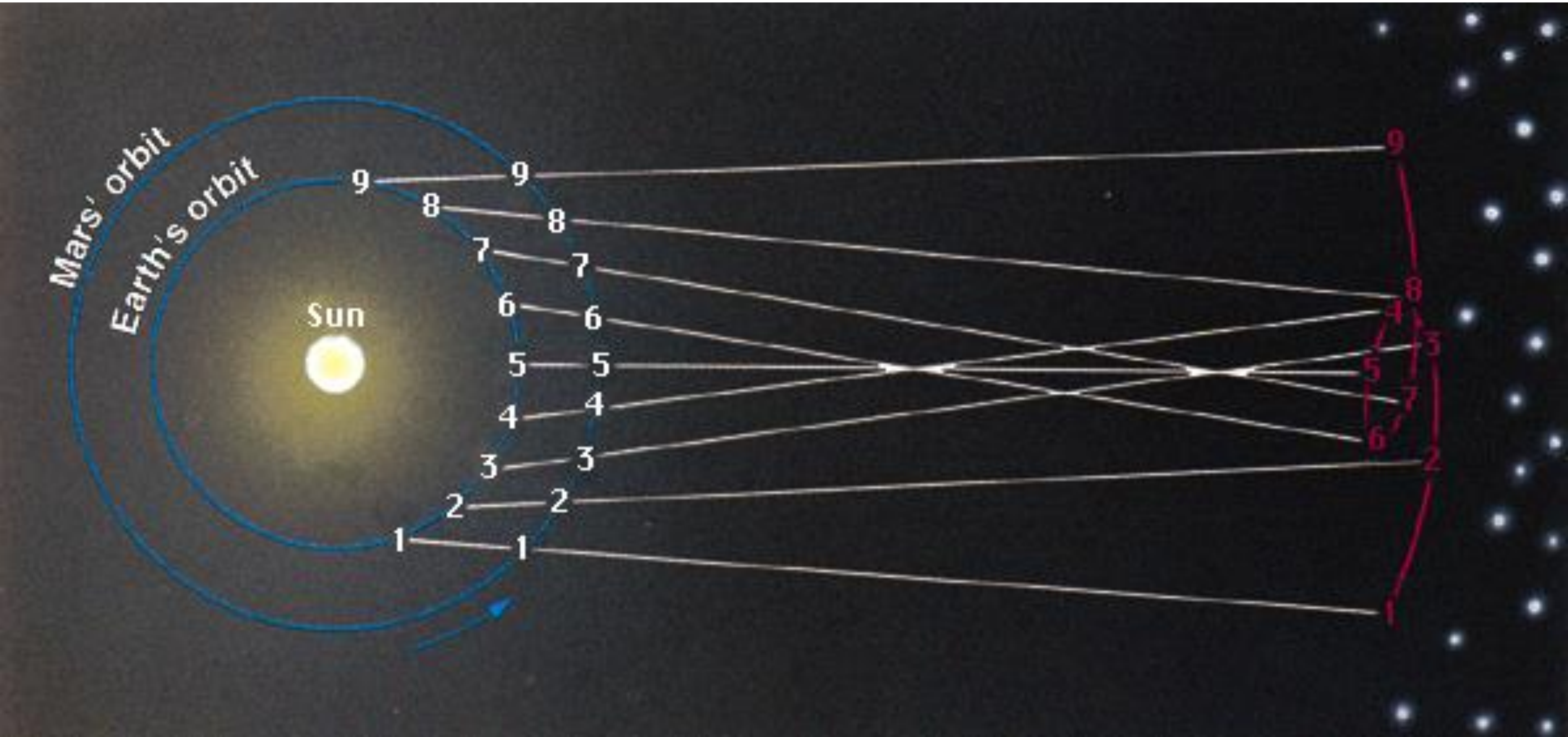
Lecture 5
The Heliocentric Model of the Universe

January 3b, 2014



Aristarchus (310-230 BC)

- Proposed Earth orbited the Sun.
- More easily explained retrograde motion.
- Animation

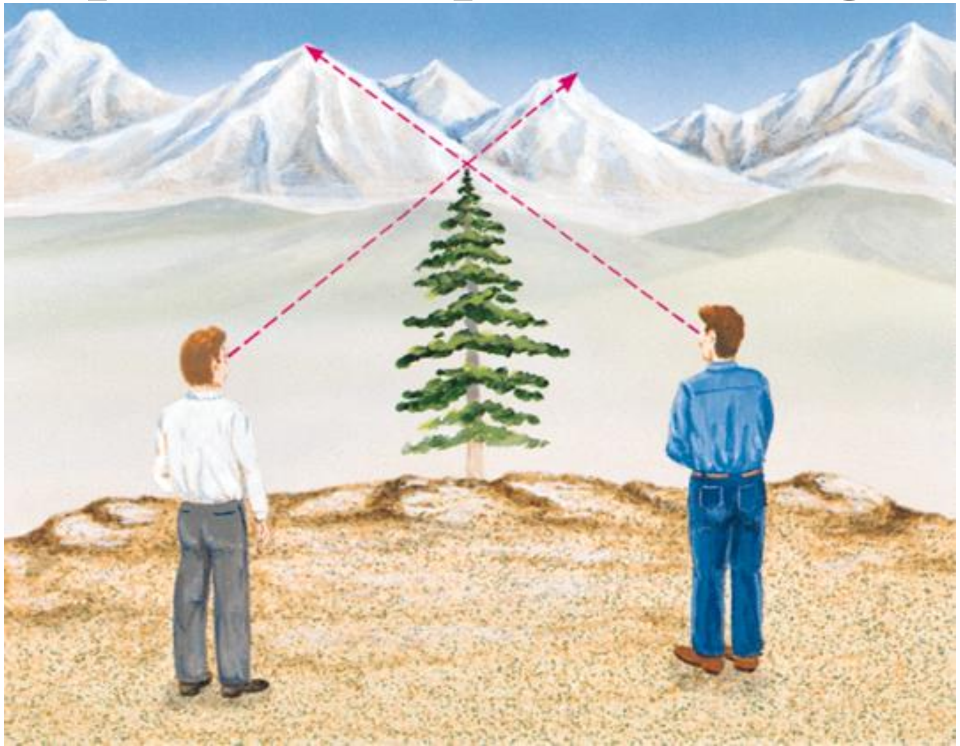


Aristarchus (310-230 BC)

- His hypothesis was rejected
  - Earth does not feel like it is moving.
  - No parallax of stars was observed.

Parallax

- If you look at an object from two different places (but at same distance) it will appear to move with respect to the background.
- Change in position = parallax angle



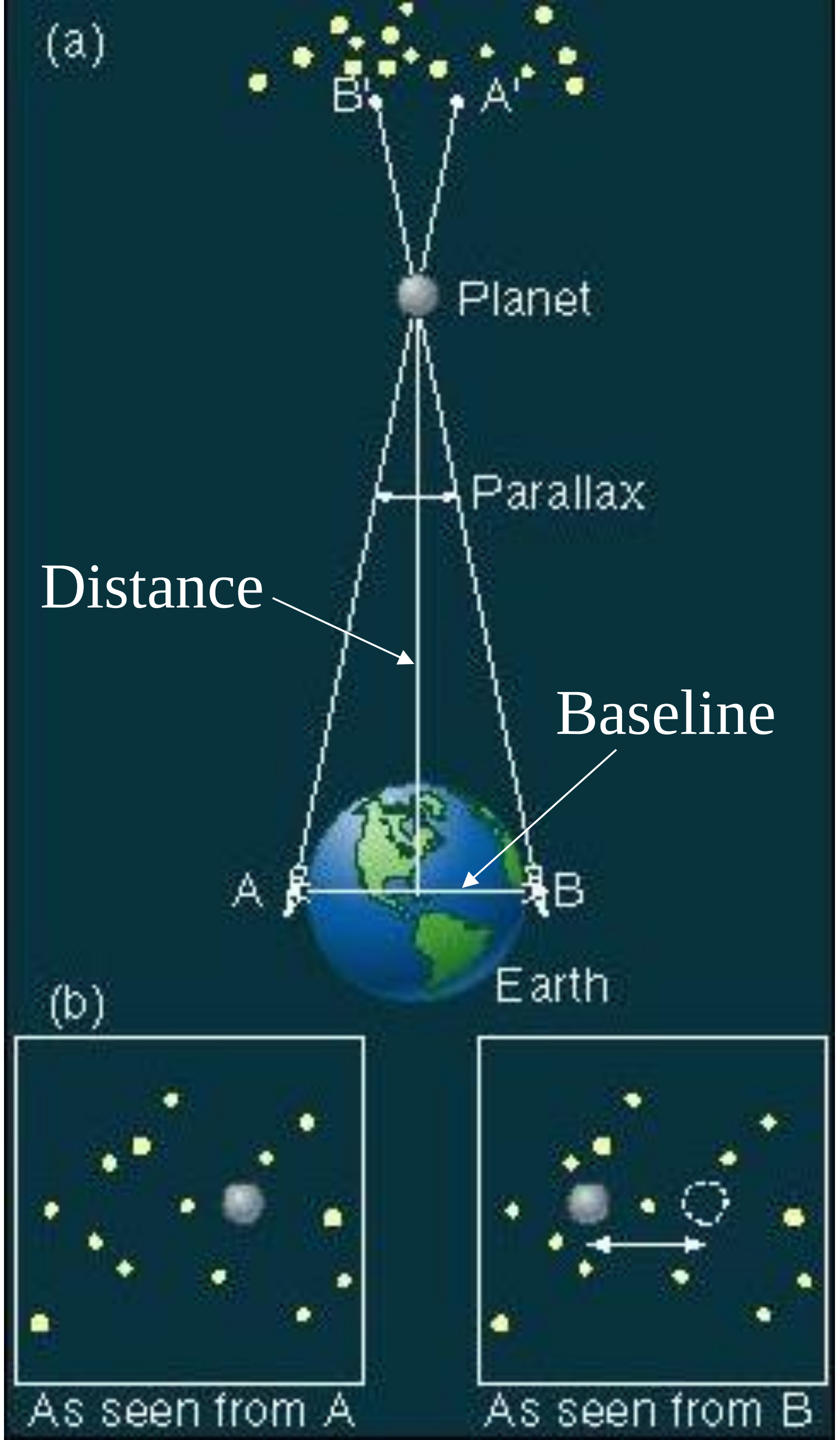
Parallax

- The greater the distance, the smaller the parallax angle
- The greater the baseline (distance from A to B), the greater the parallax angle.

$$\text{parallax angle } (^\circ) = 57.3 \times \frac{\text{baseline (km)}}{\text{distance (km)}}$$

or

$$\text{distance (km)} = 57.3 \times \frac{\text{baseline (km)}}{\text{parallax angle } (^\circ)}$$



Distance and the Parallax-Second

- A parsec is the distance that corresponds to one arc second of parallax when the baseline is 1 astronomical unit
- 1.00 AU = 1.50×10^{8} km

$$1.00\text{ pc} = 57.3\times\frac{\text{baseline (km)}}{\text{parallax angle }(°)}$$

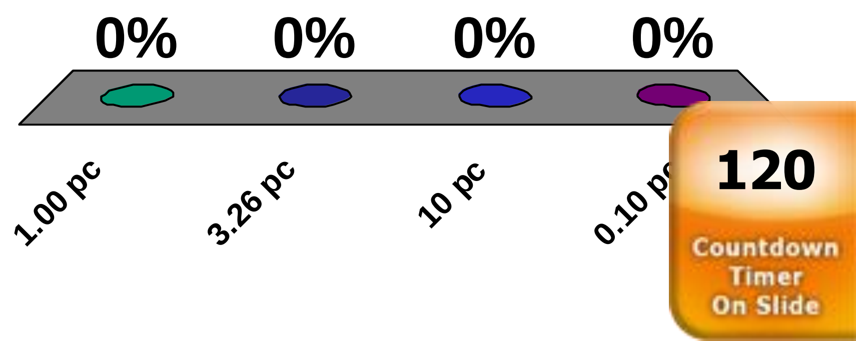
$$= 57.3\times\frac{1.50\times10^{8}\text{ km}}{\left(1/3600\right)°}$$

$$= 3.09\times10^{13}\text{ km}\times\frac{1\text{ ly}}{9.46\times10^{12}\text{ km}}$$

$$1.00\text{ pc} = \boxed{3.26\text{ ly}}$$

A star shows a parallax angle of 0.10 arcsec when the Earth moves one AU. What is the distance to the star?

A. 1.00 pc
B. 3.26 pc
C. 10 pc
D. 0.10 pc



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A star shows a parallax angle of 0.10 arcsec when the Earth moves one AU. What is the distance to the star?

A. 1.00 pc
B. 3.26 pc
C. 10 pc
D. 0.10 pc

(see p. 349 of the text)

$$\text{distance (pc)} = \frac{1}{p} = \frac{1}{0.10\ \text{arcsec}}$$

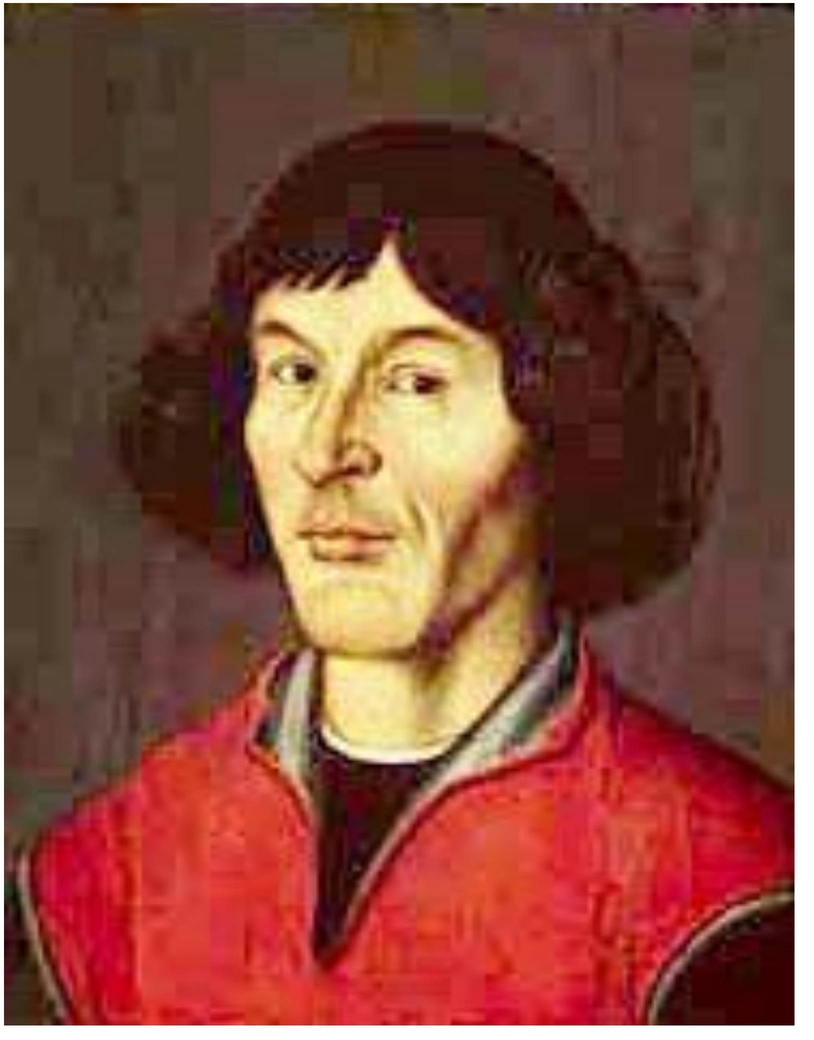
$$= \boxed{10\ \text{pc}} = 32.6\ \text{ly}$$

After a Few Centuries…

- Geocentric model became more complicated.
  - Ptolemy used inaccurate data
  - Predictions not accurate on large time scales

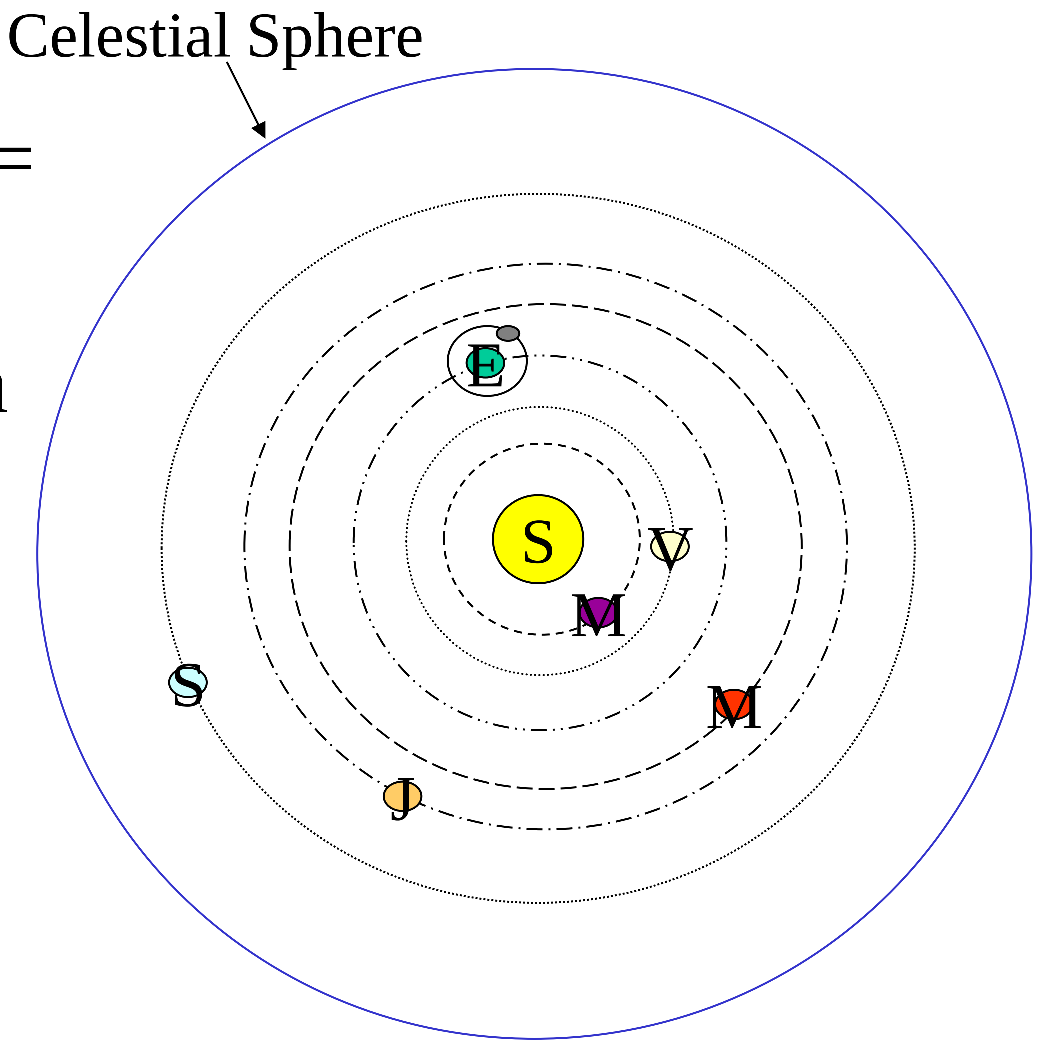
Nicholas Copernicus (1473-1543)

- Heliocentric (sun centered) model of the Solar System.
- De Revolutionibus Orbium Coelestium (1543)
- Knew about work of Aristarchus



Basic Heliocentric View

- Heliocentric Model = Sun at center
- Planets orbit the Sun
- Moon orbits the Earth.
- Circular orbits



Accuracy

- NOTE: The heliocentric model did NOT predict positions better than the geocentric model
  - But it was simple.

- Occam's Razor: If choosing between competing theories that are all similarly accurate, choose the simplest one.

Results of Heliocentric Model

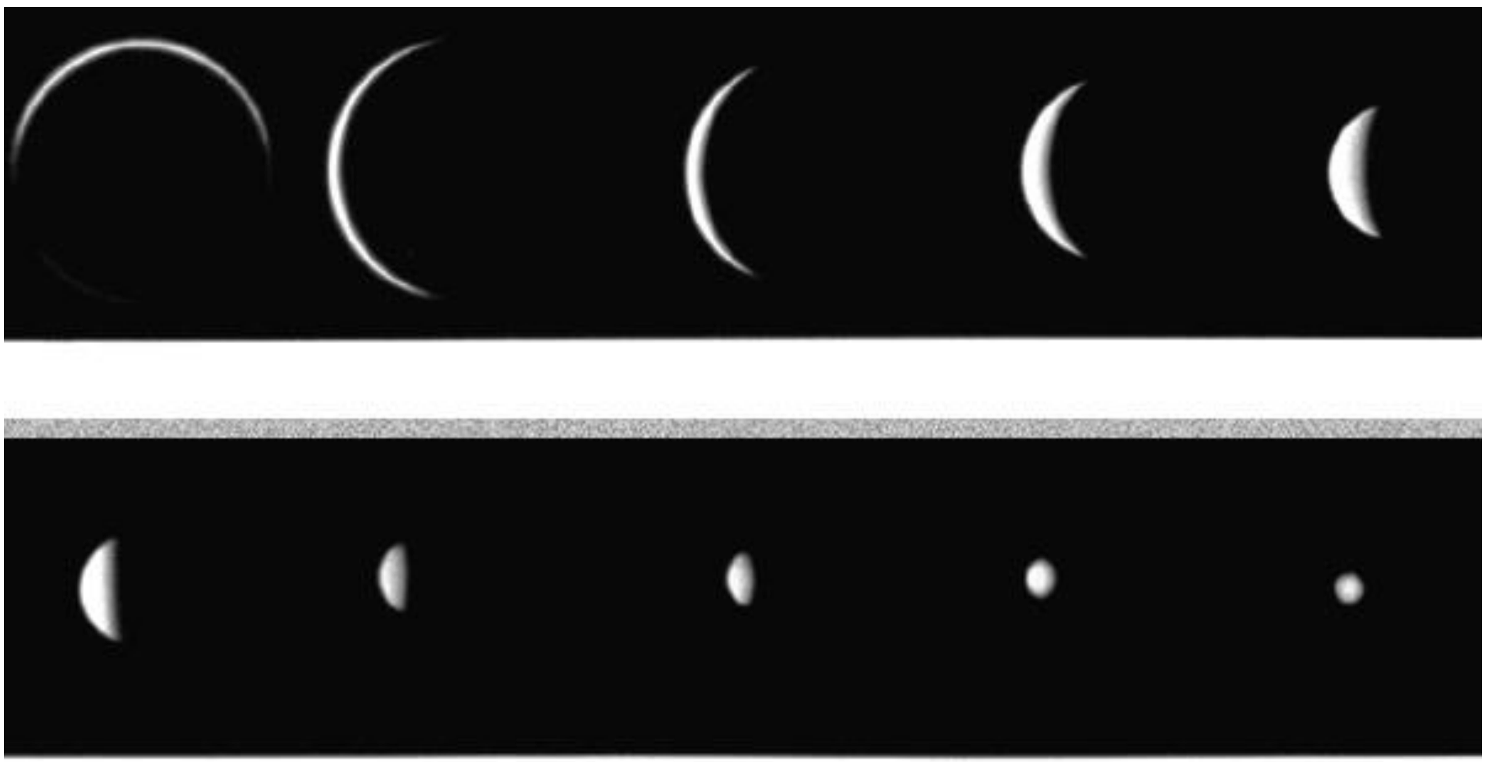
- Could predict positions of planets
  - BUT only as well as Ptolemy's model
- Could calculate distances to planets in units of distance between the Earth and the Sun
  - BUT the results could not be checked.

Galileo Galilei (1564-1642)

- Supported Copernican model.
- Used telescope to observe sky (1610).
  - Mountains on the moon
  - Rings of Saturn
  - Sunspots
  - Milky Way is made of stars

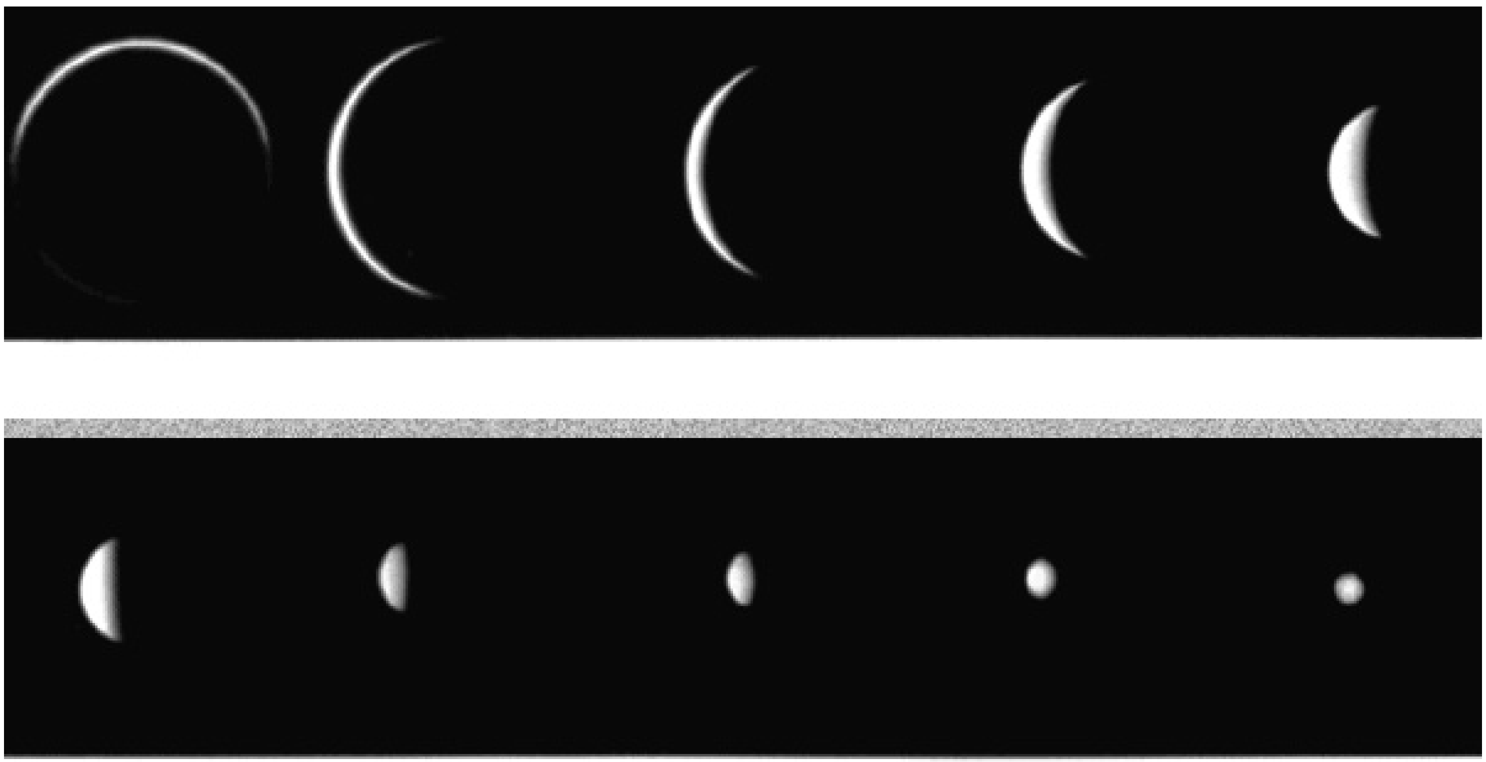
Observations of Venus

- Venus has phases similar to the moon.
- The apparent size of Venus changes with the phase.

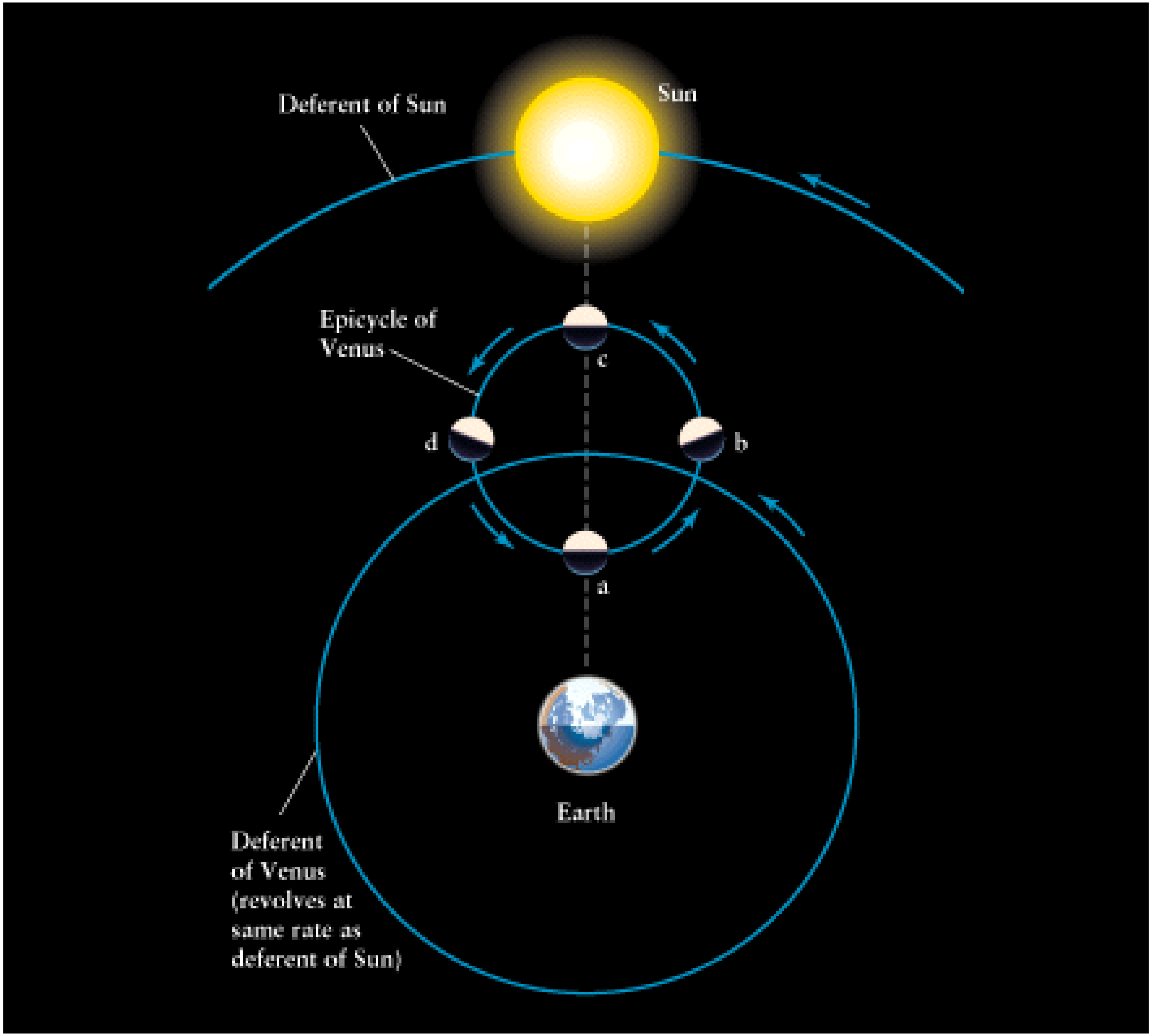


Question

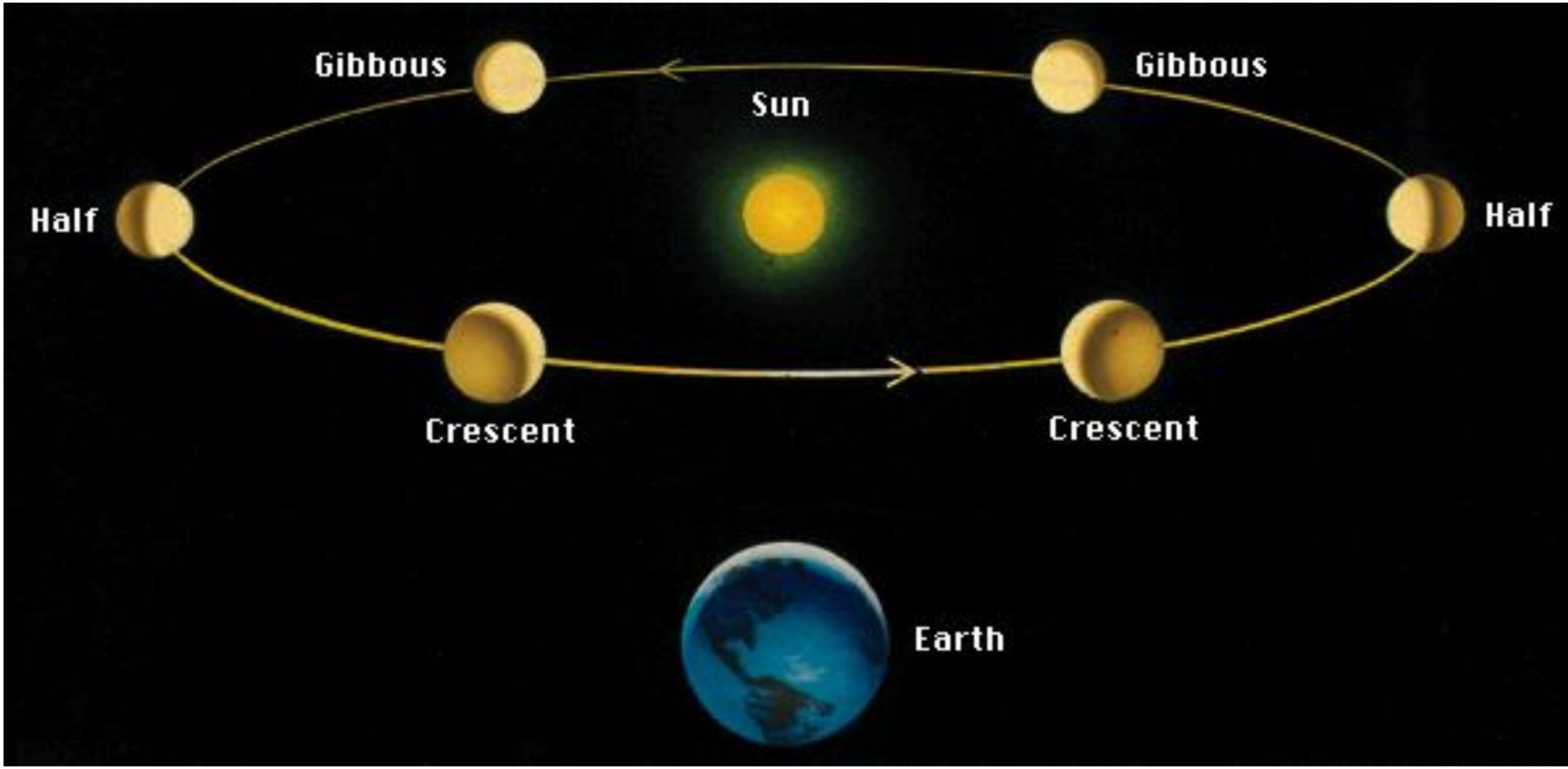
- What would you expect to see if Venus orbited the Earth?
- How does Galileo's observation support the heliocentric model?



Geocentric Model of Venus



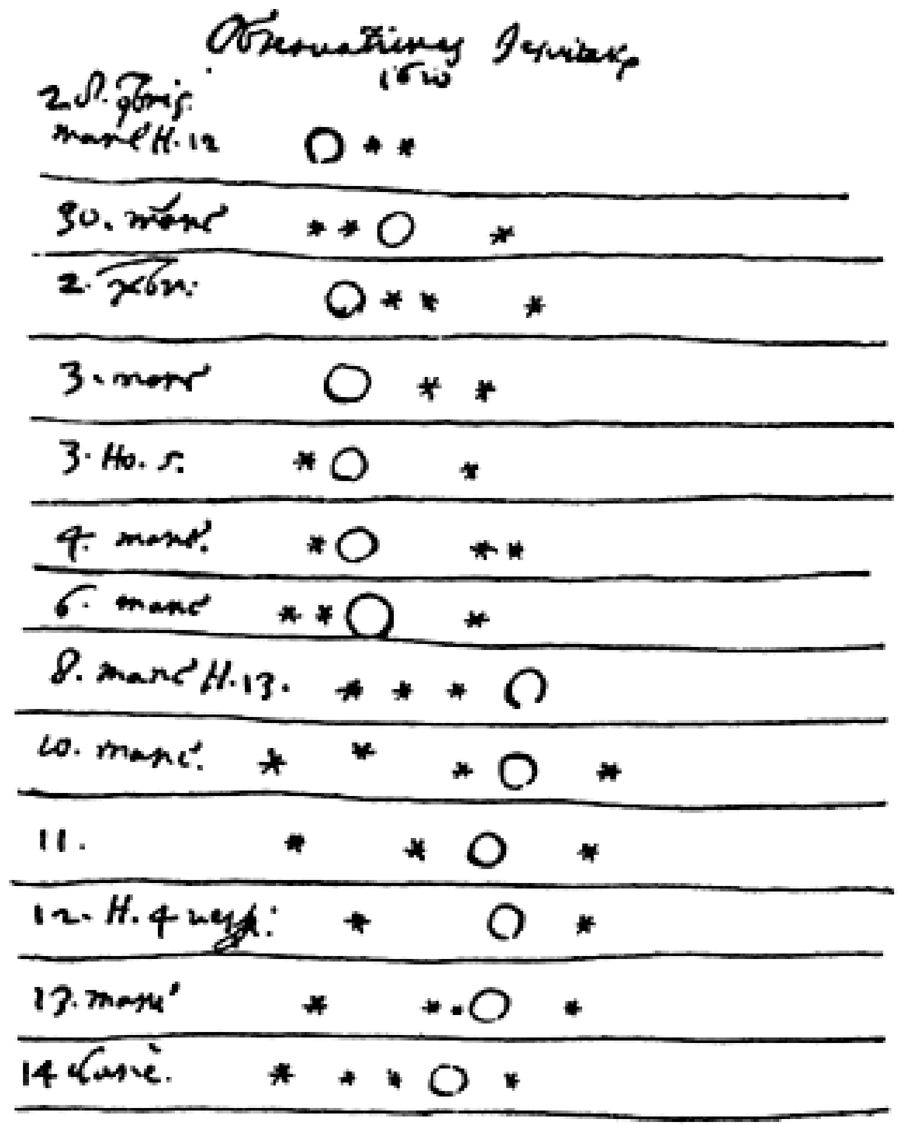
Phases of Venus



- If Venus was orbiting the Earth, its distance would not change and its size would stay the same.

Observations of Jupiter

- Observations of Jupiter
  - Observed the 4 largest moons of Jupiter (Galilean Moons).
  - The fact that bodies could orbit other planets supported heliocentric view.

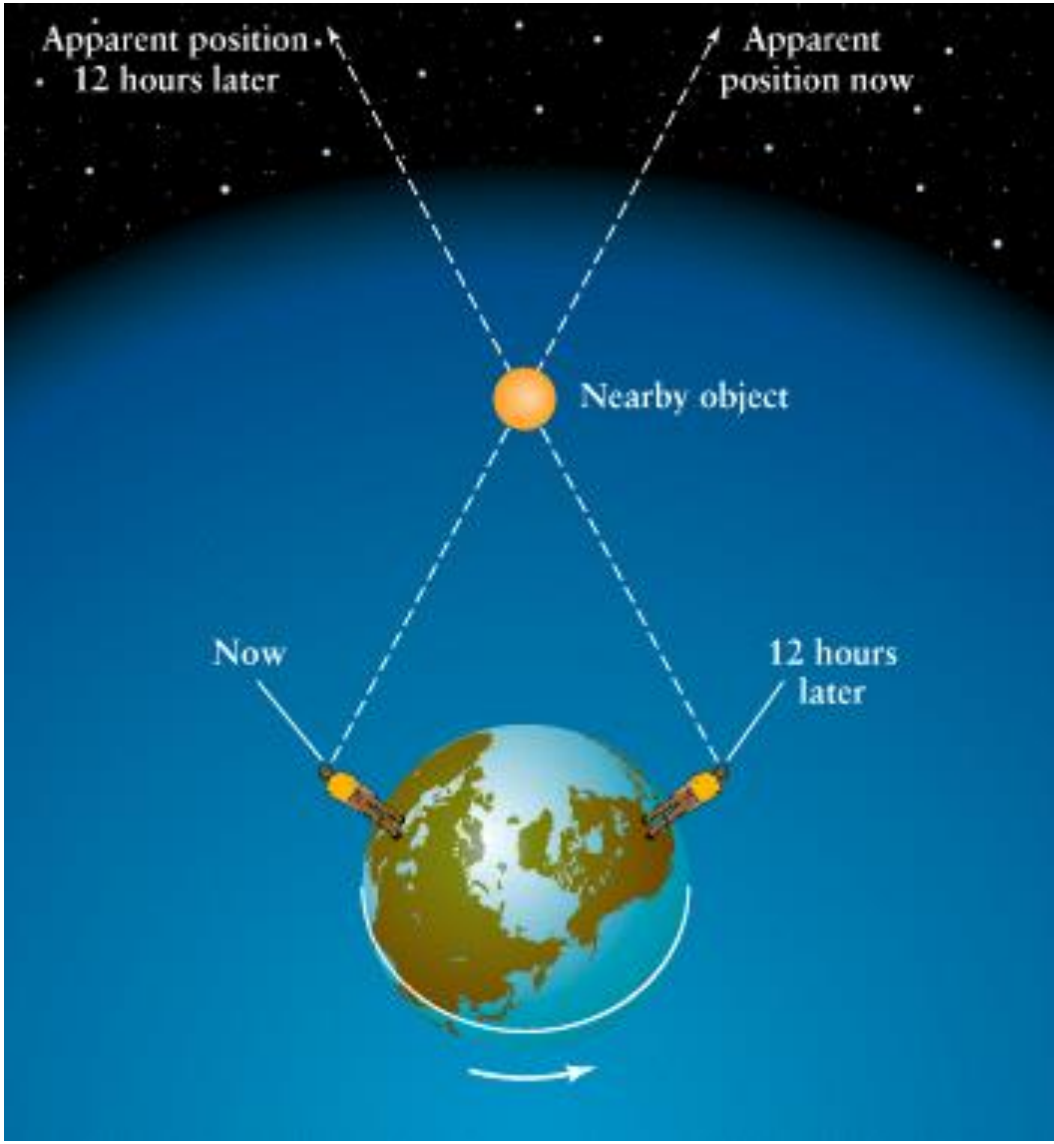


Tycho Brahe (1546-1601)

- Supported geocentric model
- Pre-dates invention of telescope
- Observed supernova (1592)
- Believed stars unchanging
  - “New” star must be near Earth

Tycho's Supernova

- Tried to measure distance to supernova using parallax.
- No parallax observed
  - Why?
  - Supernova much more distant that originally thought.
- Heavens are NOT unchanging

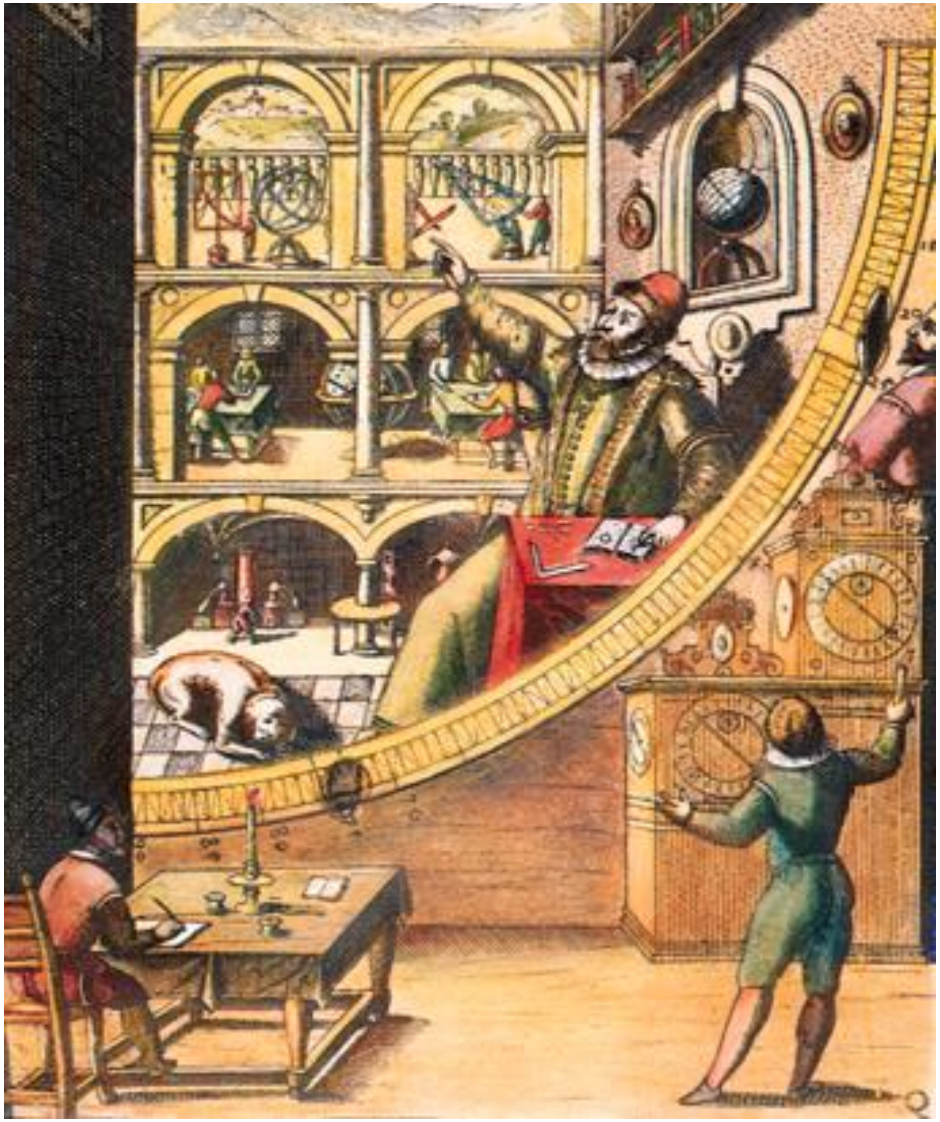


Tycho’s Observations

- He was given an island for observatory by King of Denmark
  - “Uraniborg”
- He designed state-of-the-art instruments to observe sky (all naked eye observations).
- He made detailed observations of planetary and stellar positions.
  - His positions accurate up to 1 arcminute (1/60 of a degree)

Tycho's observations

- Used many instruments to confirm results.
- Same method used by modern astronomers.
- Measurements eventually used by others to distinguish between geocentric and heliocentric theories, as well as to determine the exact shape of planetary orbits.



Planetary Configurations

- Some of the simplest planetary observations you can make are their positions relative to the Earth and the Sun – the planetary configuration
  - Inferior conjunction – between us and the Sun (a *transit* occurs when it is silhouetted against the Sun's bright disk)
  - Superior conjunction – on the other side of the Sun from us
  - Opposition – directly opposite the Sun in the sky
  - Greatest elongation – for Venus and Mercury, when they are at their greatest angular separation from the Sun. Can be either eastern or western

Planetary Configurations

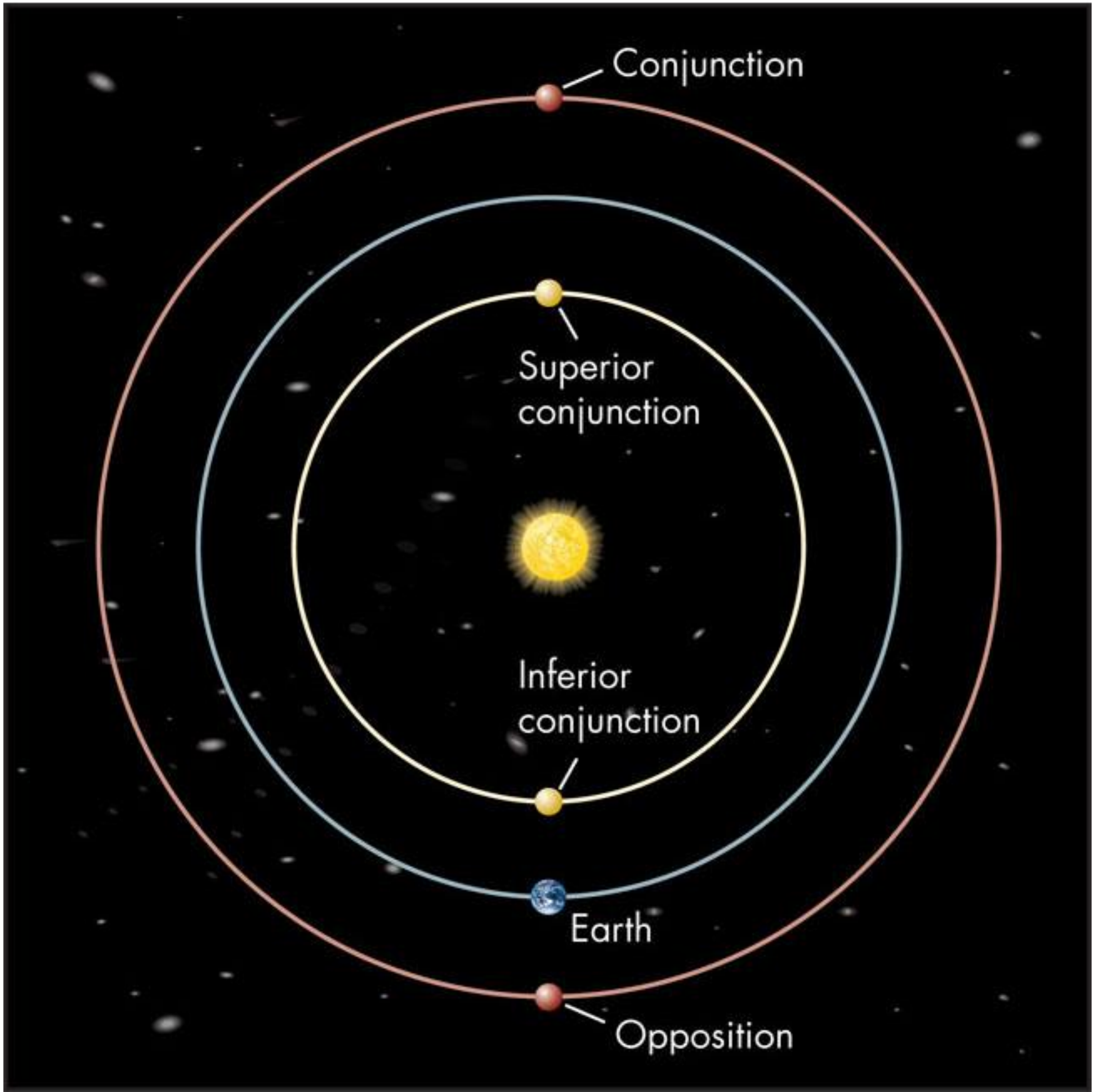
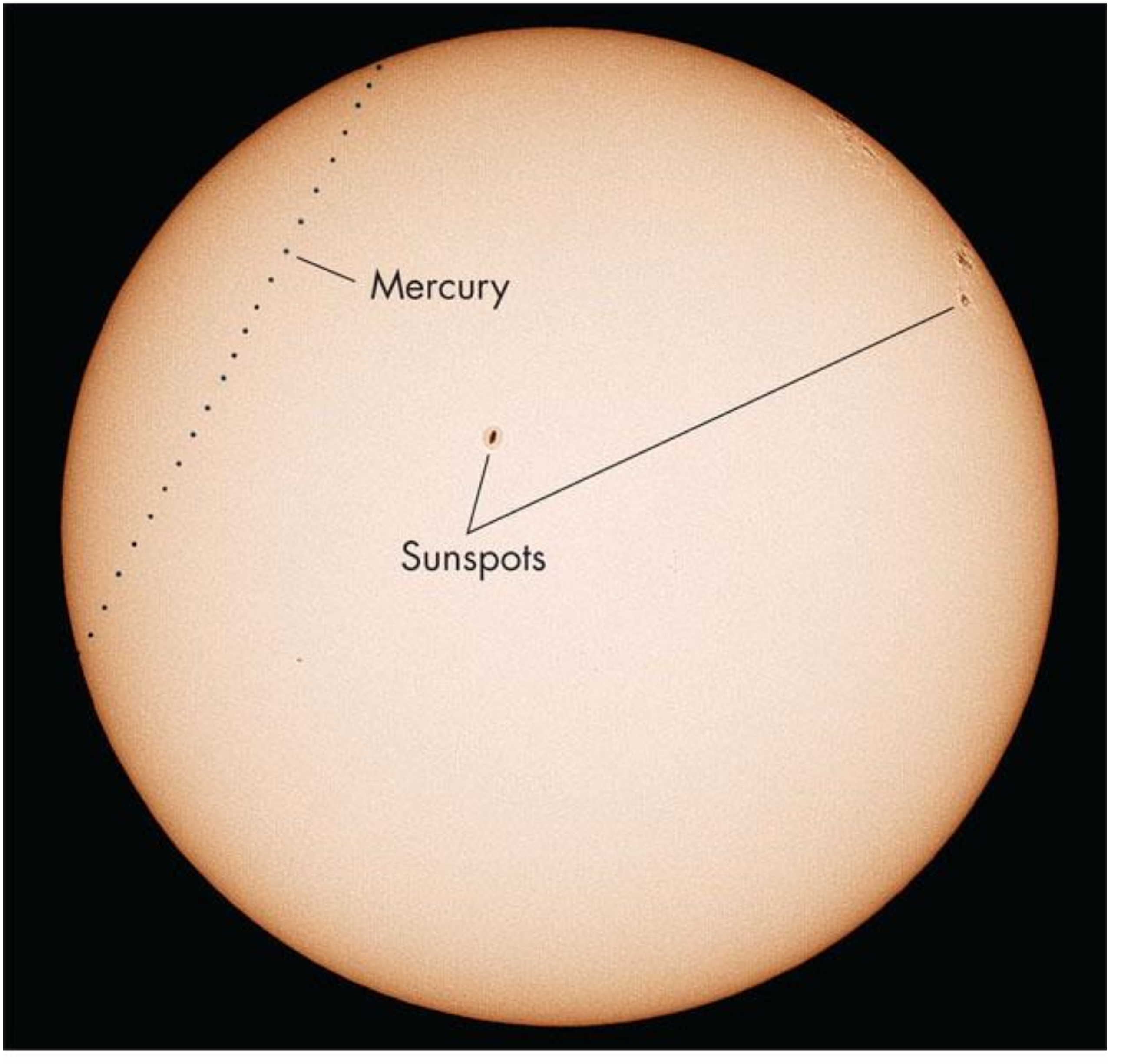


Figure E1.9

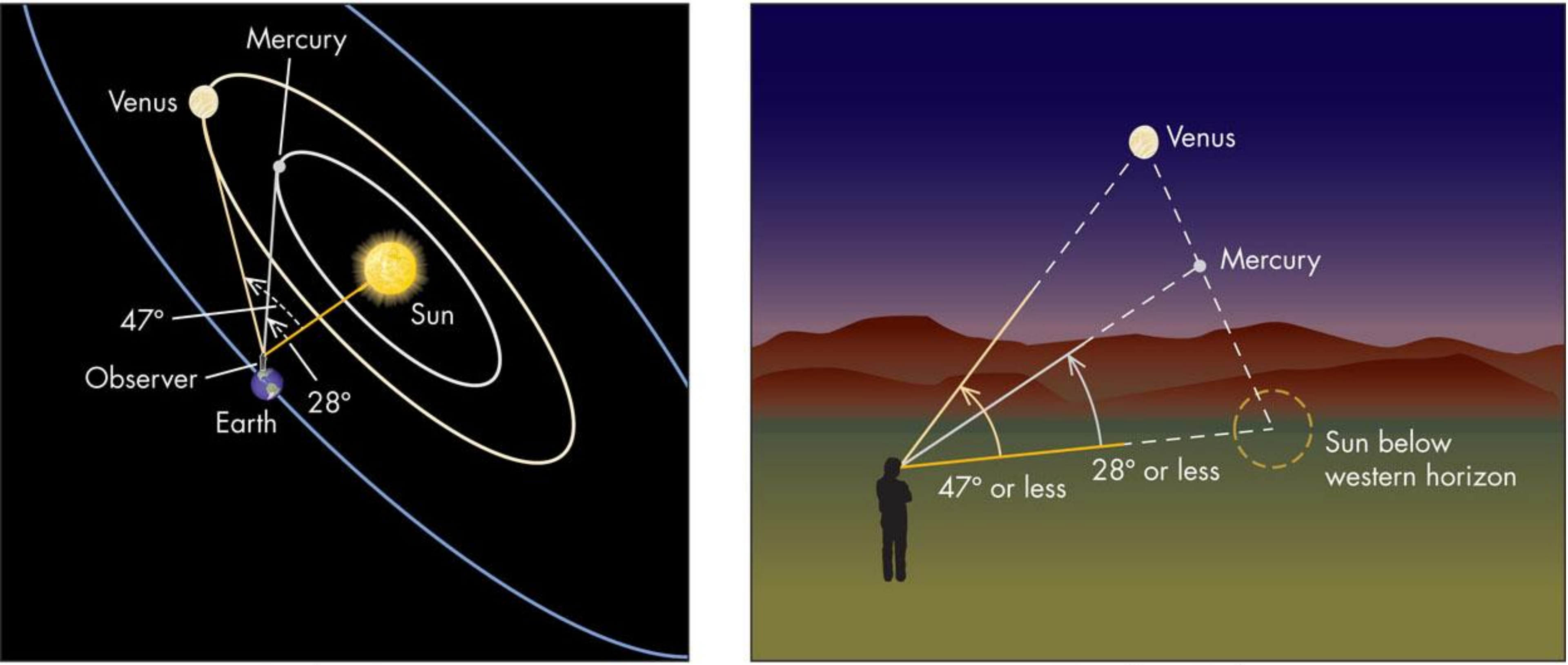
Transit of Mercury



Courtesy of Dominique Dierick

Figure E1.10

Greatest elongations of Mercury and Venus



View from Space

View from Earth

Figure E1.11

Sidereal vs. Synodic Period

- Each planet can be described by two periods
  - Sidereal Period – the time required for the planet to orbit the Sun once with respect to the fixed stars
  - Synodic Period – the time required for the planet to return to the same configuration
- The two periods differ due to the motion of the Earth in its orbit around the Sun