Lecture 1

Celestial sphere

Part 1

- Celestial motions
  - Project: Conduct an astronomical observation
- Geocentric model
  - Equant & eccentric
    - Precursor of Kepler’s laws of planetary motion
- Heliocentric model
  - Inferior & superior planets

Night sky is constantly changing

- The night sky is constantly changing.
- Stellarium Web Online Star Map

Stars

- The stars move steadily from east to west during the course of a night.

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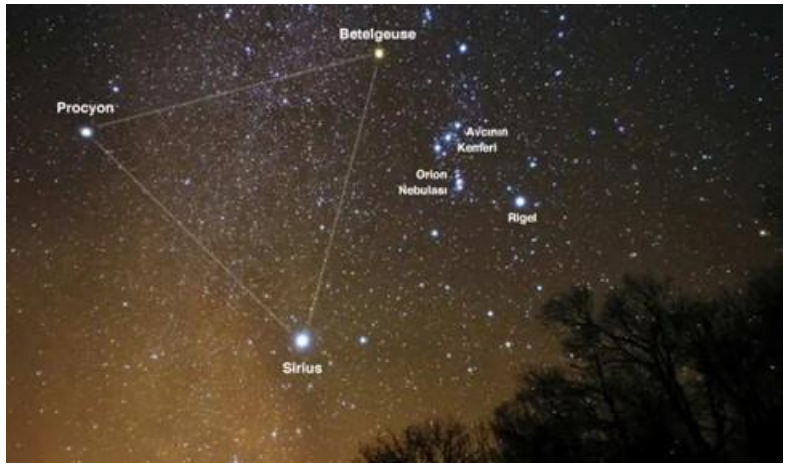
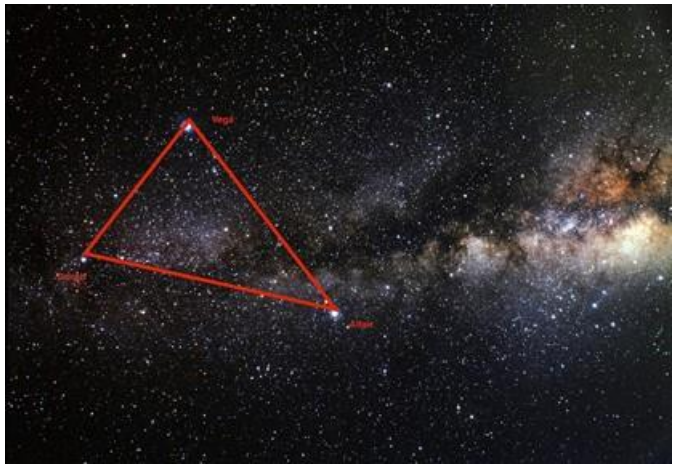
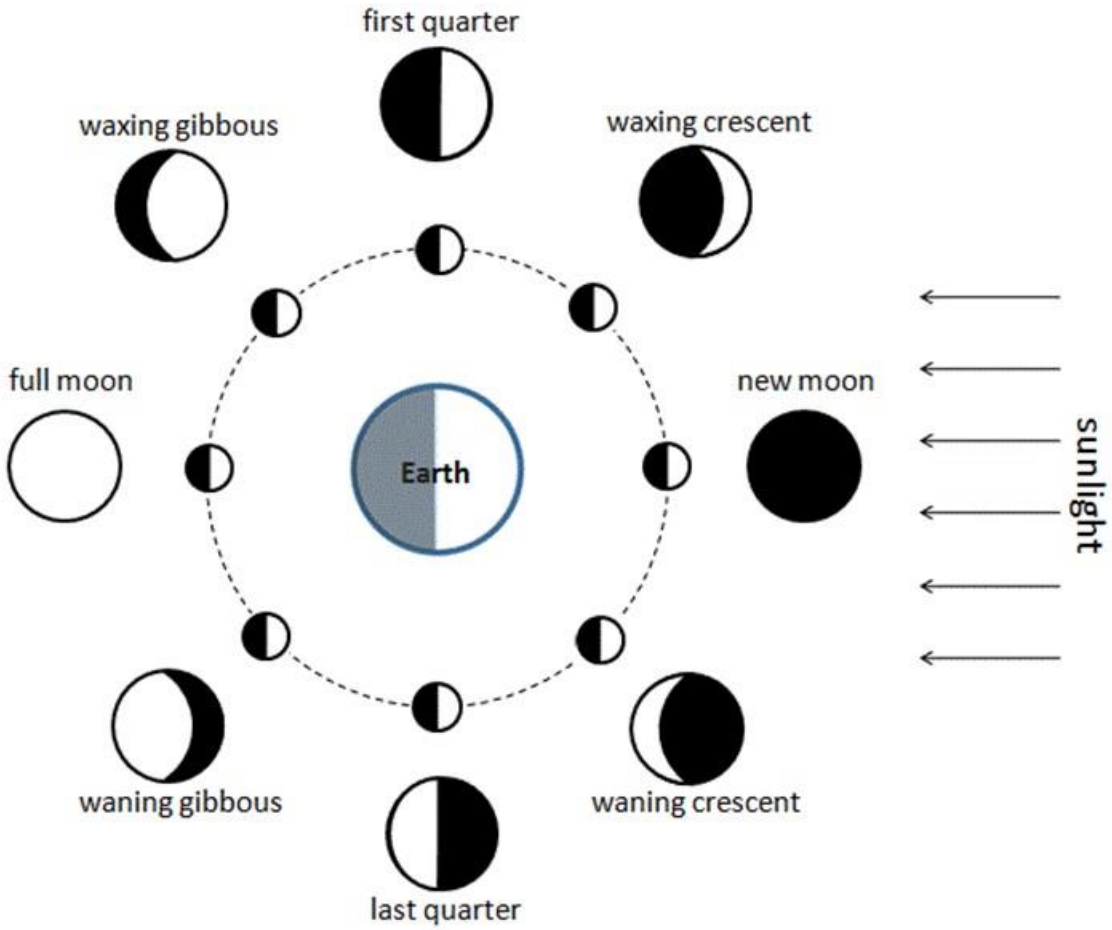
- Different stars are visible in the evening sky, depending upon the season.
  - The Winter Triangle is visible in the northern sky's winter and comprises Betelgeuse, Sirius and Procyon.
  - The Summer Triangle of Deneb, Altair, and Vega is prominent in the northern hemisphere summer skies.





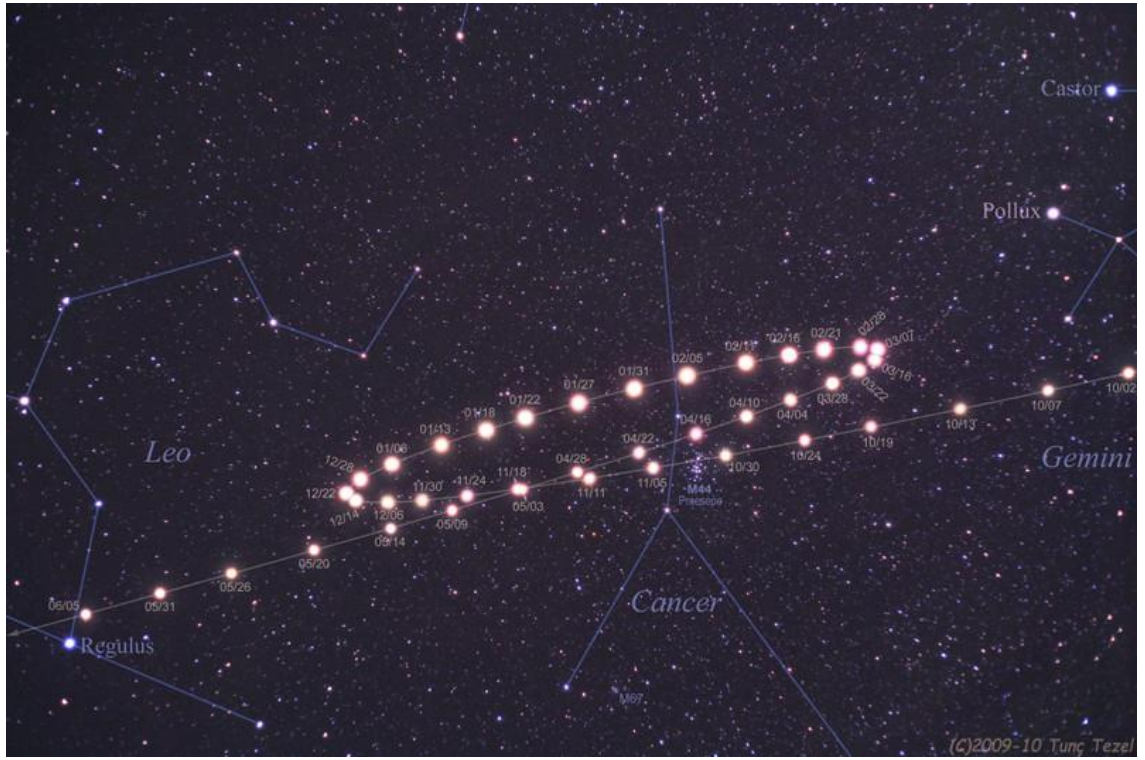
Moon

- The Moon also changes, both in its position in the sky and in its phase.



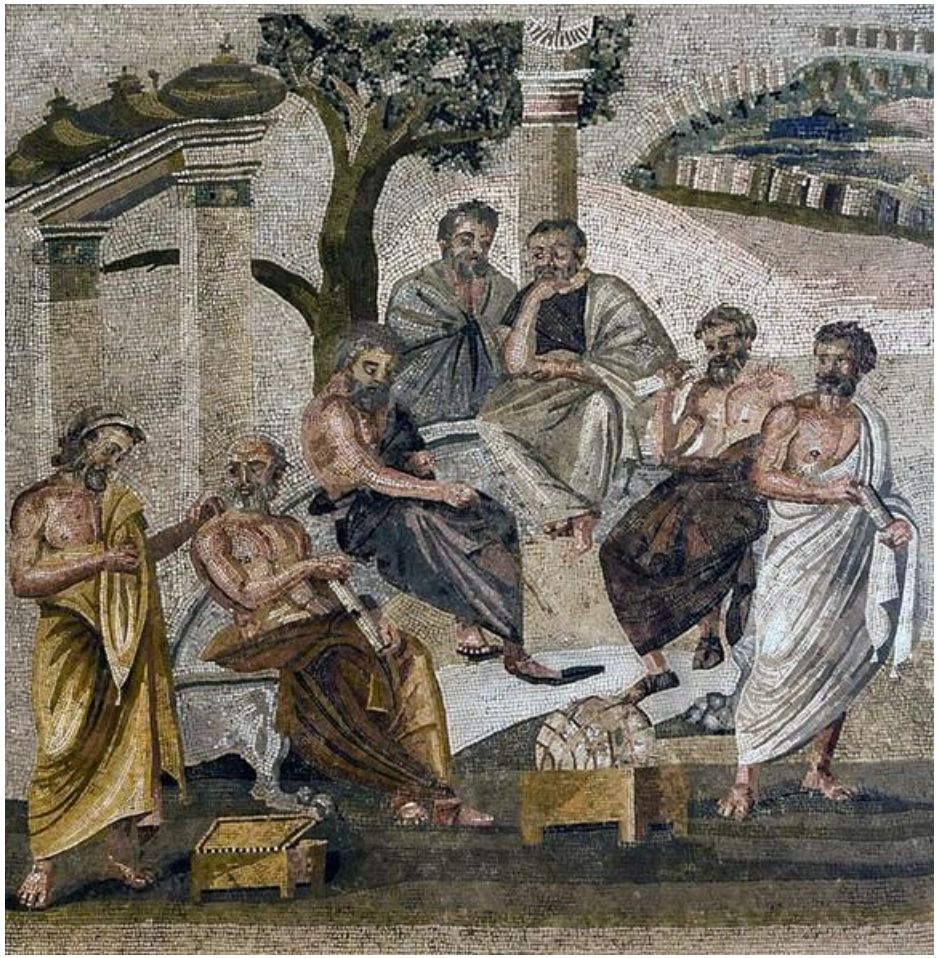
Planets

- The movements of the planets, or “wondering stars”, are more subtle and more complex.



Ancient Greek philosophy

- Our modern scientific view of the universe traces its beginnings to the ancient Greek tradition of natural philosophy.



Geocentric universe

- Plato (ca. 350 B.C.) proposed that the stars of the night sky revolved about a fixed Earth.

Uniform & circular motion

- Plato also proposed that the heavens ought to obey the purest possible form of motion.
- Celestial bodies should move about Earth with a uniform (or constant) speed and follow a circular motion with Earth at the center of that motion.

Relationship of the stars appears unchanging

- The relationship of the stars to one another in fixed constellations appears unchanging.

Celestial sphere

- If the stars were simply attached to a celestial sphere that rotated about an axis passing through the North and South poles of Earth and intersecting the celestial sphere at the north and south celestial poles, respectively, all of the stars' known motions could be described.

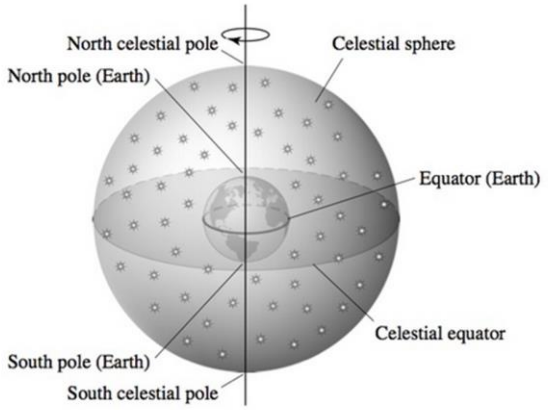
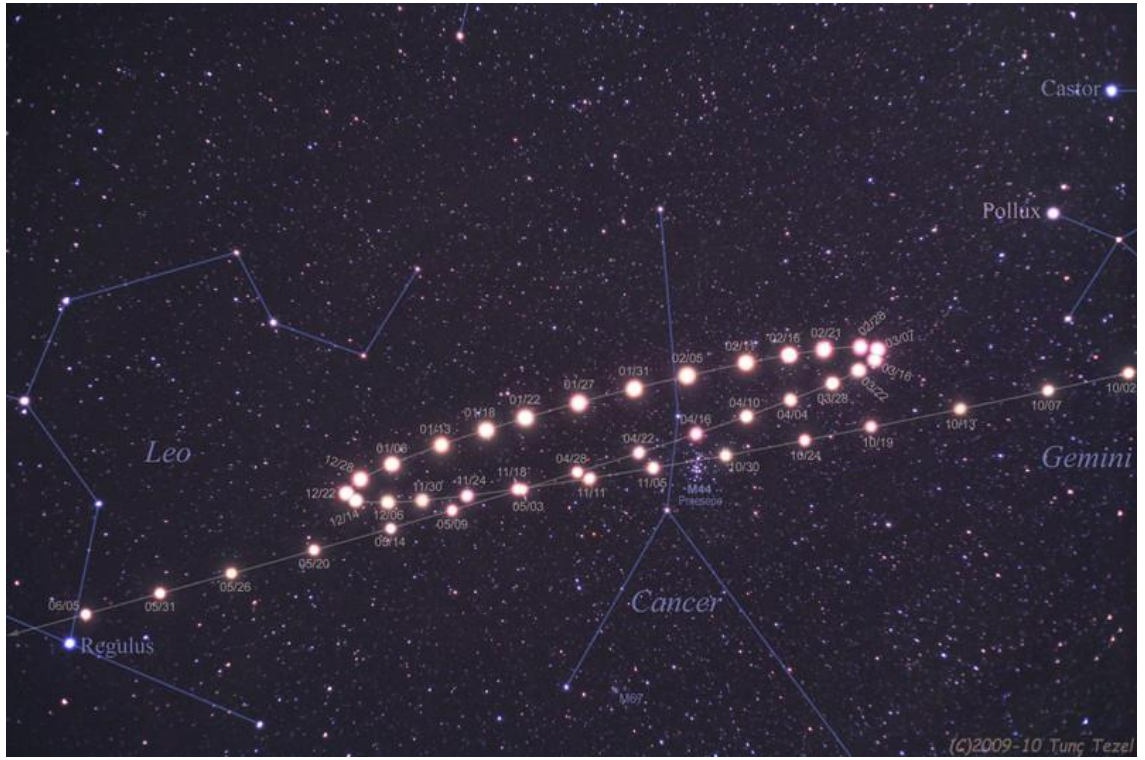


FIGURE 1 The celestial sphere. Earth is depicted in the center of the celestial sphere.

https://www.youtube.com/watch?v=aFIR7hbqed4

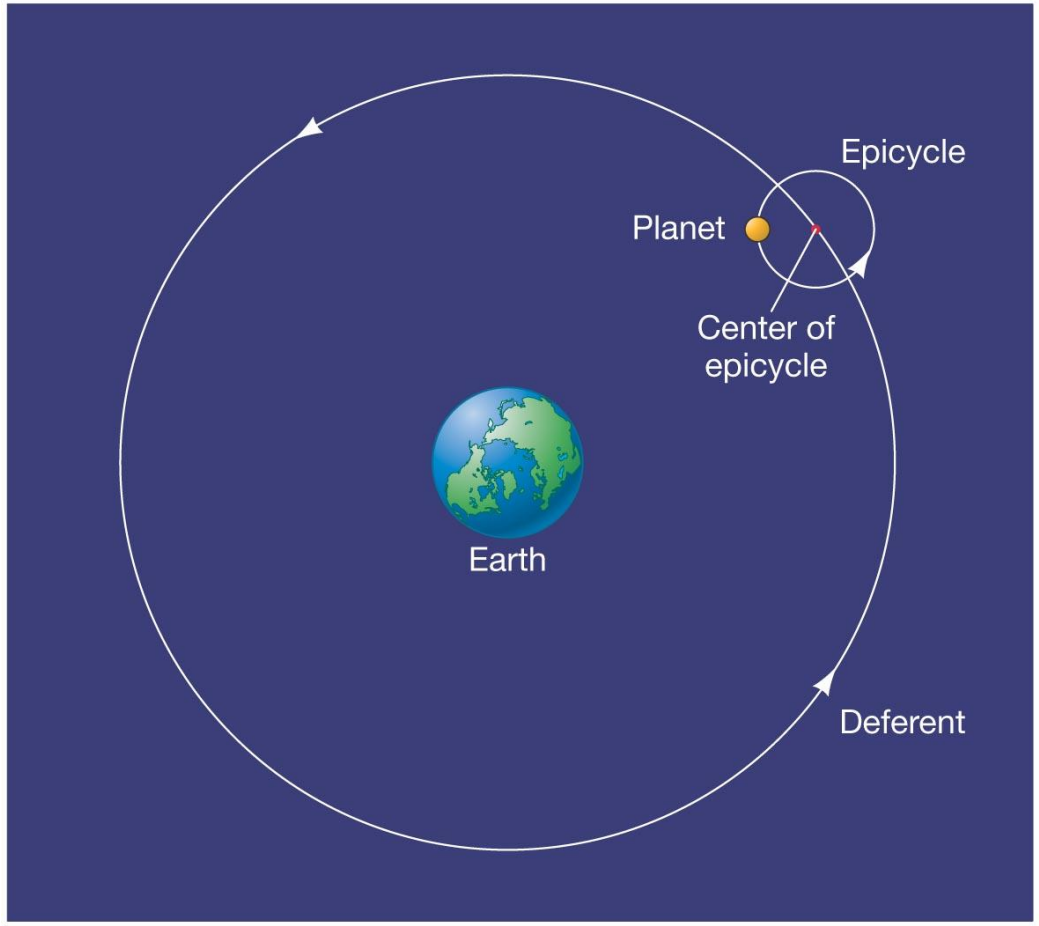
Retrograde motion

- The wandering stars posed a somewhat more difficult problem.
- A planet such as Mars moves slowly from west to east against the fixed background stars and then mysteriously reverses direction for a period of time before resuming its previous path.



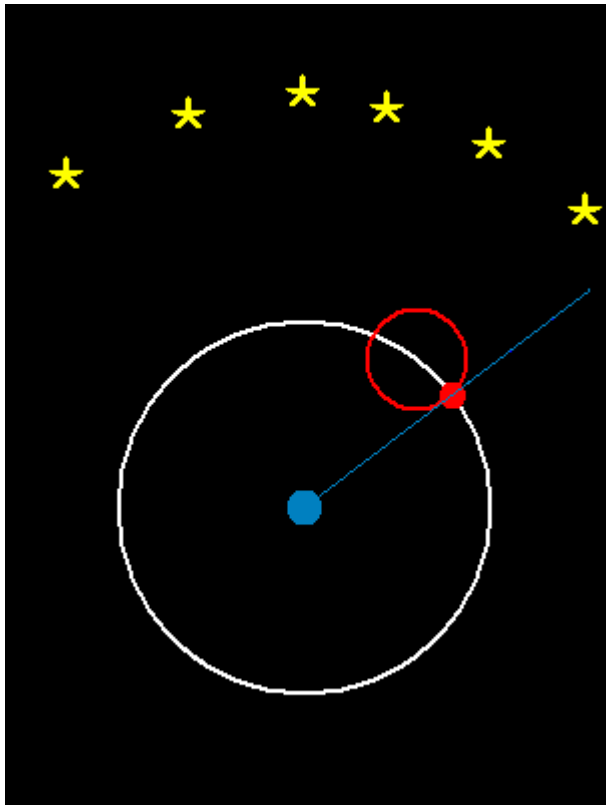
System of circles

- Hipparchus (ca. 150 b.c.) is perhaps the most notable of the Greek astronomers.
  - He created the first catalog of the stars and developed a magnitude system for describing the brightness of stars that is still in use today.
- He proposed a system of circles to explain retrograde motion.



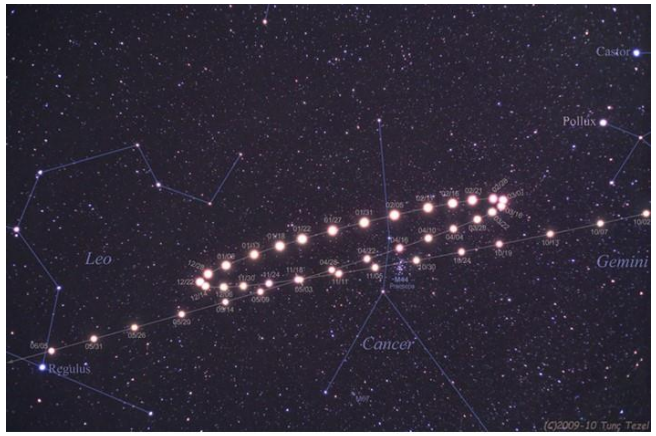
Epicycle & deferent

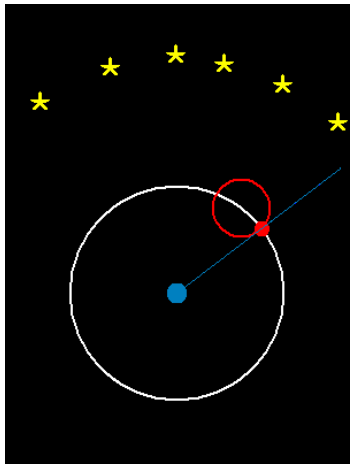
- By placing a planet on a small, rotating epicycle that in turn moved on a larger deferent, he was able to reproduce the behavior of the wandering stars.



Increased brightness during retrograde phases

- Furthermore, this system was able to explain the increased brightness of the planets during their retrograde phases as resulting from changes in their distances from Earth.





Refinements

- During the next two hundred years, the model of planetary motion put forth by Hipparchus proved increasing unsatisfactory in explaining many of the details of the observations.
- Claudius Ptolemy (ca. A.D. 100) introduced refinements to the epicycle/deferent system.

Equant & Eccentric

- Ptolemy added equants, resulting in a constant *angular* speed of the epicycle about the deferent (dθ/dt was assumed to be constant).
- He also moved Earth away from the deferent center.

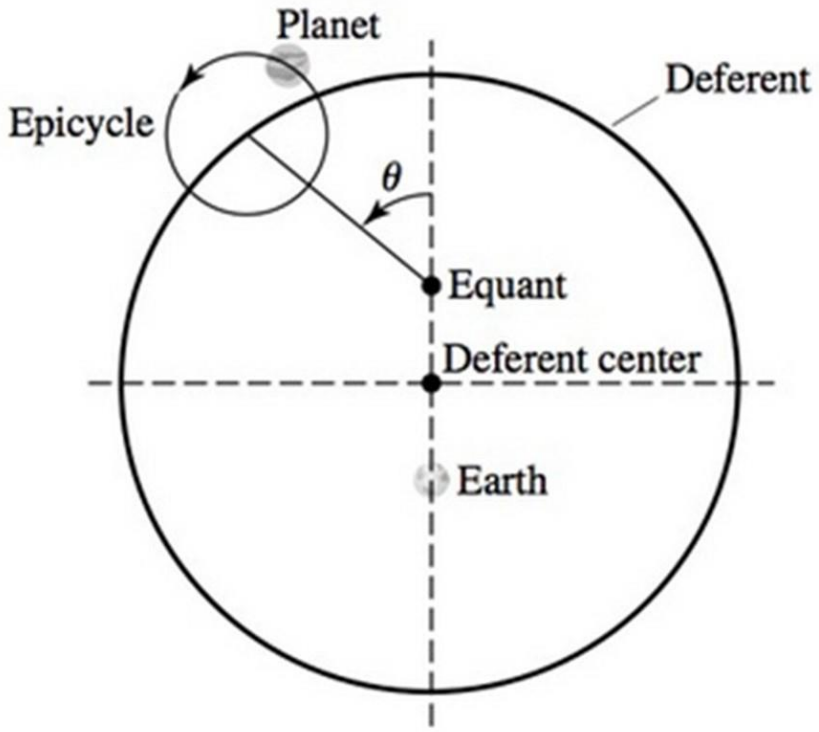
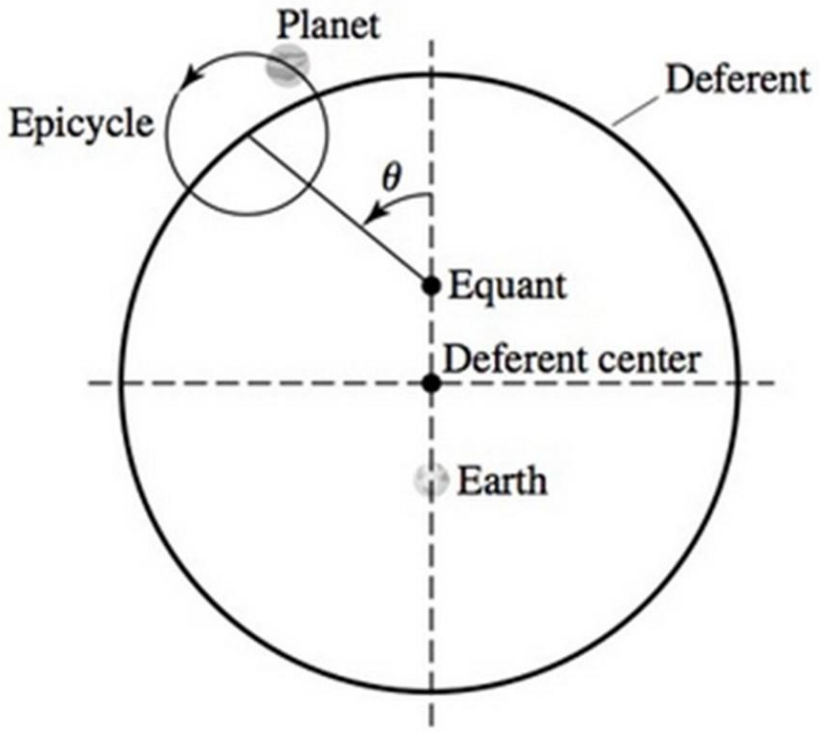


FIGURE 3 The Ptolemaic model of planetary motion.

Philosophical tenets were compromised

- Predictions of the Ptolemaic model did agree more closely with observations than any previously devised scheme, but the original philosophical tenets of Plato (uniform and circular motion) were significantly compromised.



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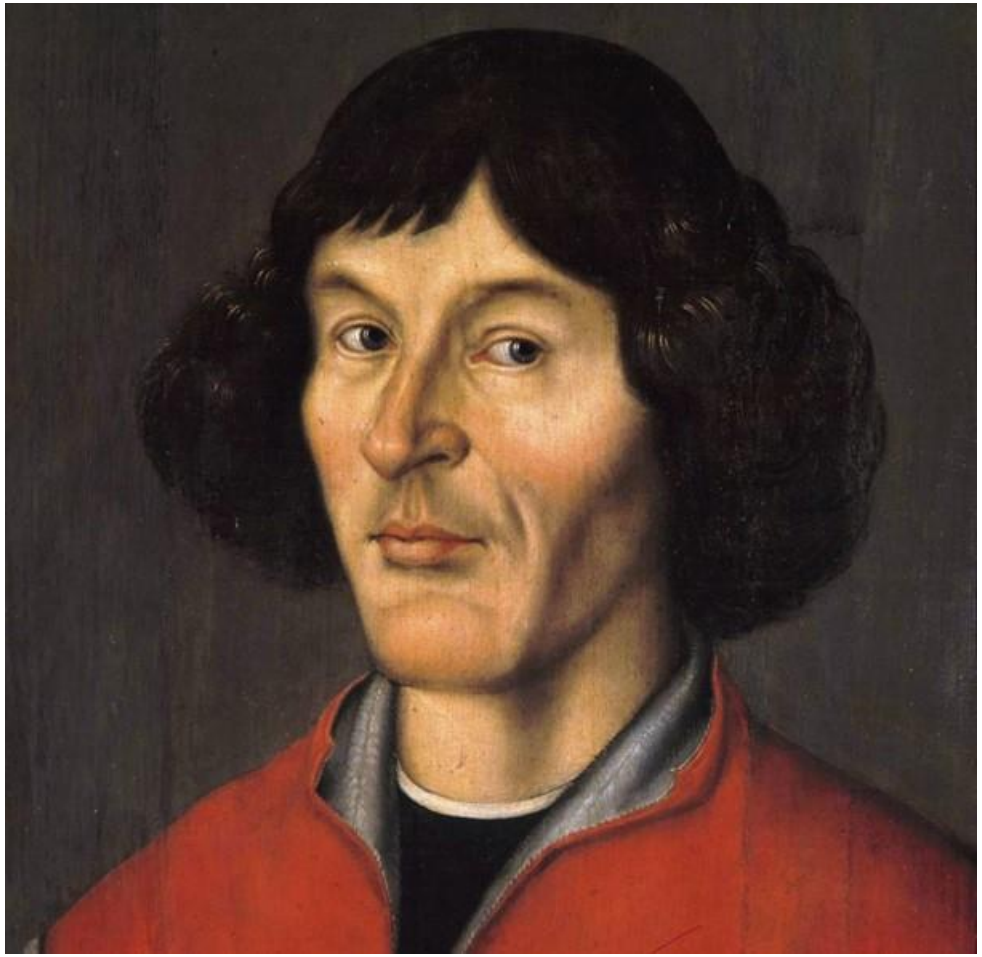
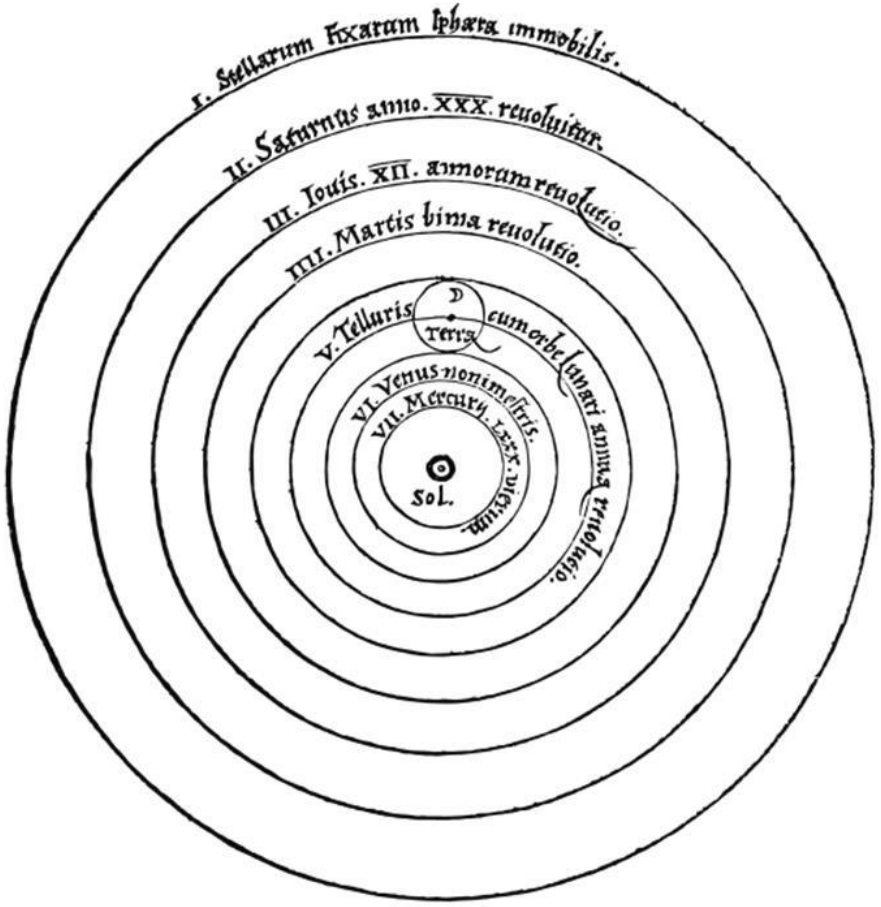
Copernican revolution

- In the 16th century, Nicolaus Copernicus suggested a heliocentric (Sun-centered) model of planetary motion.



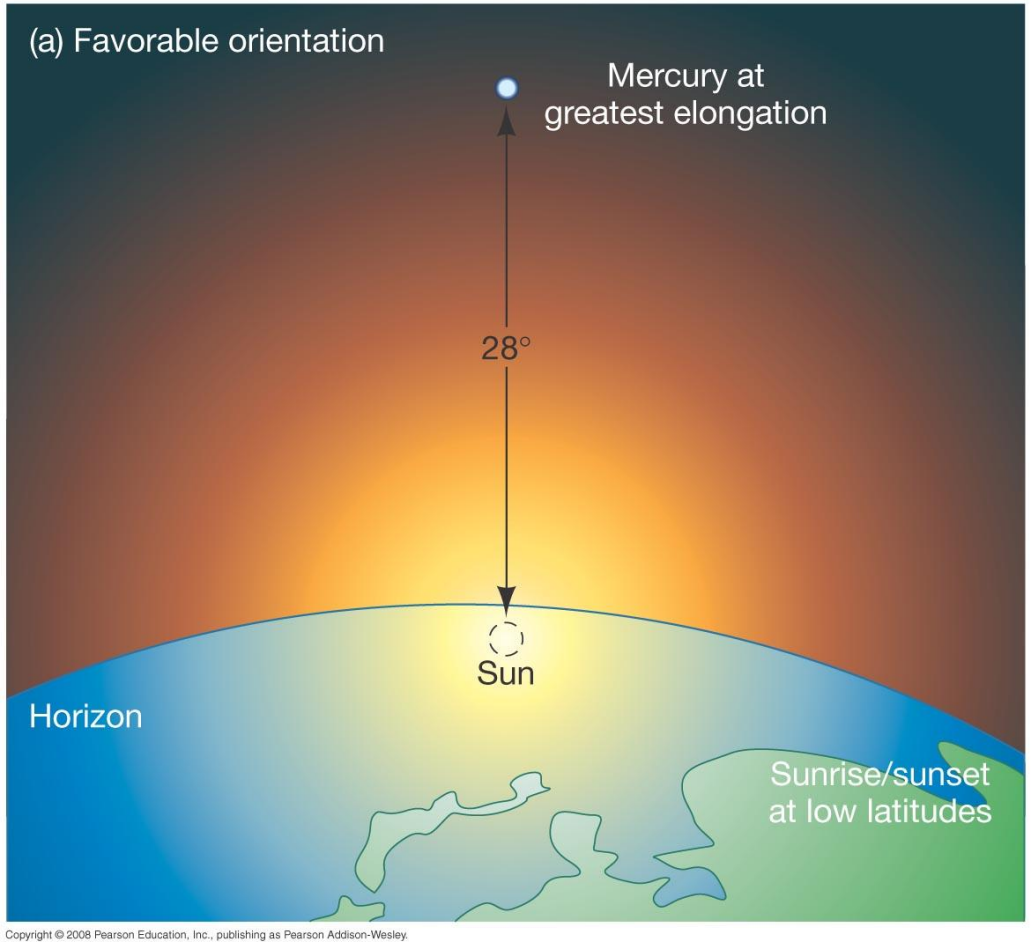
Heliocentric model

- The Copernican model had the ability to establish the order of all planets from the Sun, along with their relative distances and orbital periods.



Inferior planets

- Mercury and Venus are never seen more than 28° and 47°, respectively, east or west of the Sun.
- This establishes that their orbits are located inside the orbit of Earth.
- These planets are referred to as inferior planets.



Greatest eastern/western elongation

- Their maximum angular separations east/west of the Sun are known as greatest eastern/western elongation.

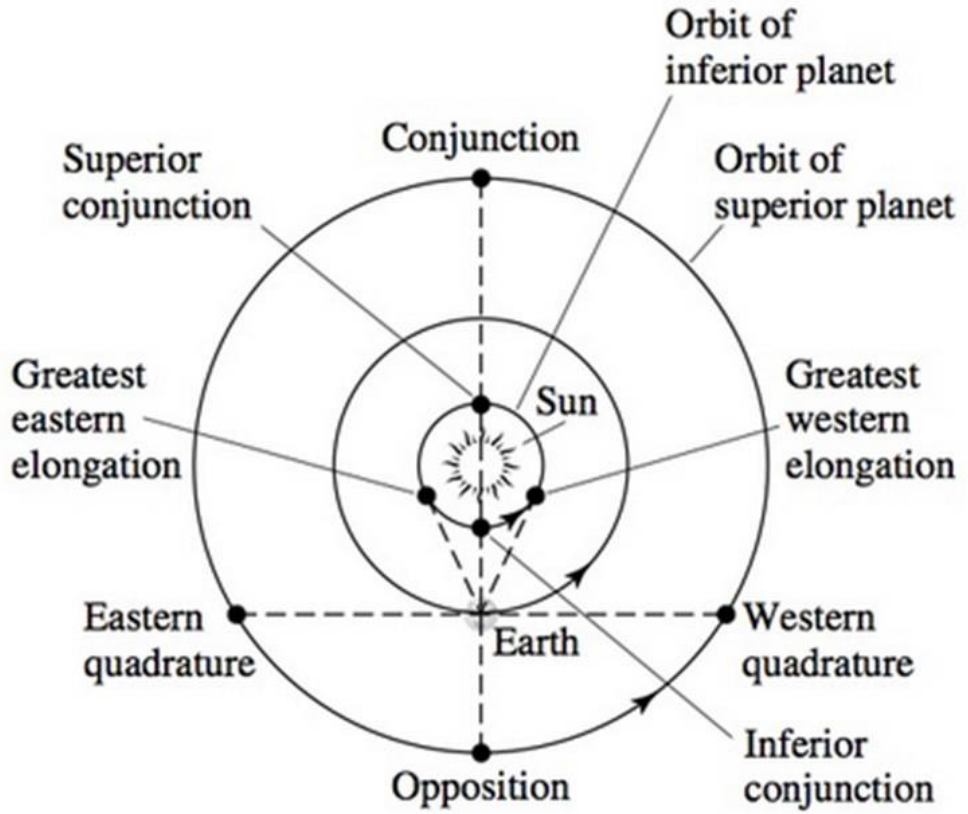
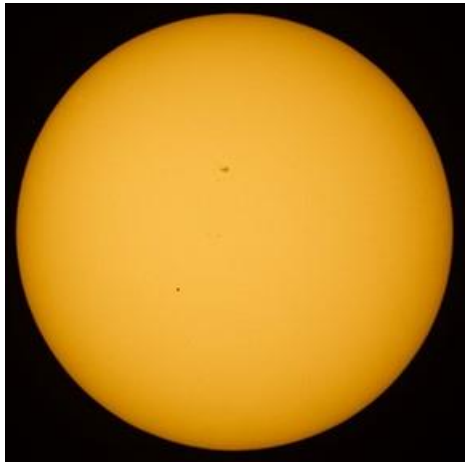
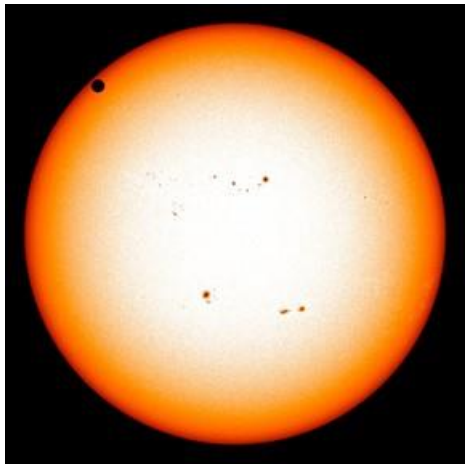


FIGURE 5 Orbital configurations of the planets.

Inferior conjunction

- The Copernican model also predicts that only inferior planets can pass in front of the solar disk, as observed.
  - The first observation of a Mercury transit was made in 1631.
  - The first recorded observation of a transit of Venus was made in 1639.





Superior planets

- Mars, Jupiter, and Saturn (the most distance planes known to Copernicus) can be seen as much as 180° from the Sun, an alignment known as opposition.
- This could only occur if these superior planets have orbits outside Earth's orbit.

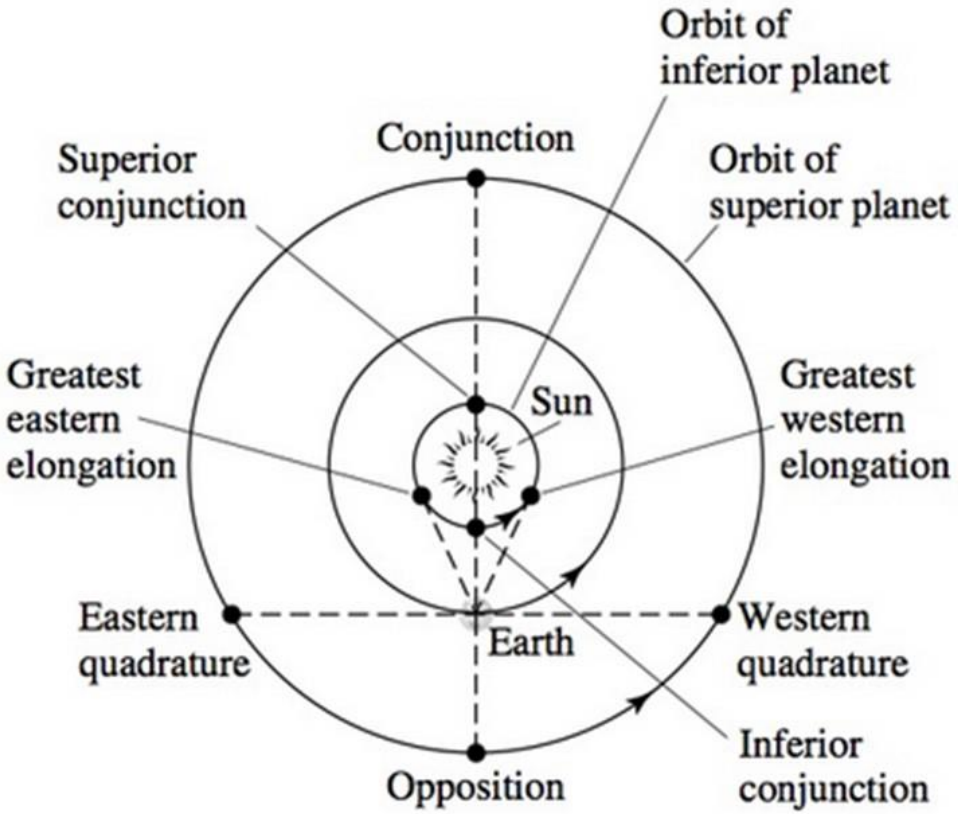


FIGURE 5 Orbital configurations of the planets.

Retrograde motion was easily explained

- Retrograde motion was also easily explained through the Copernican model.

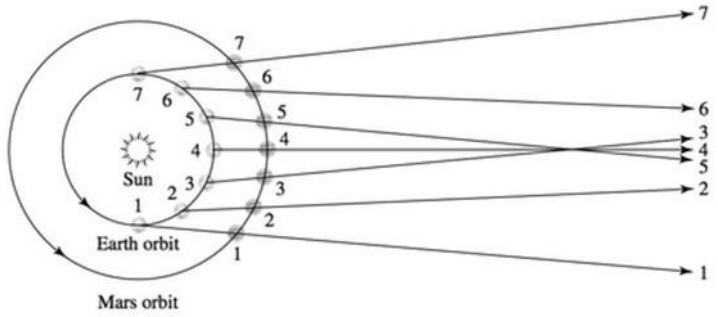
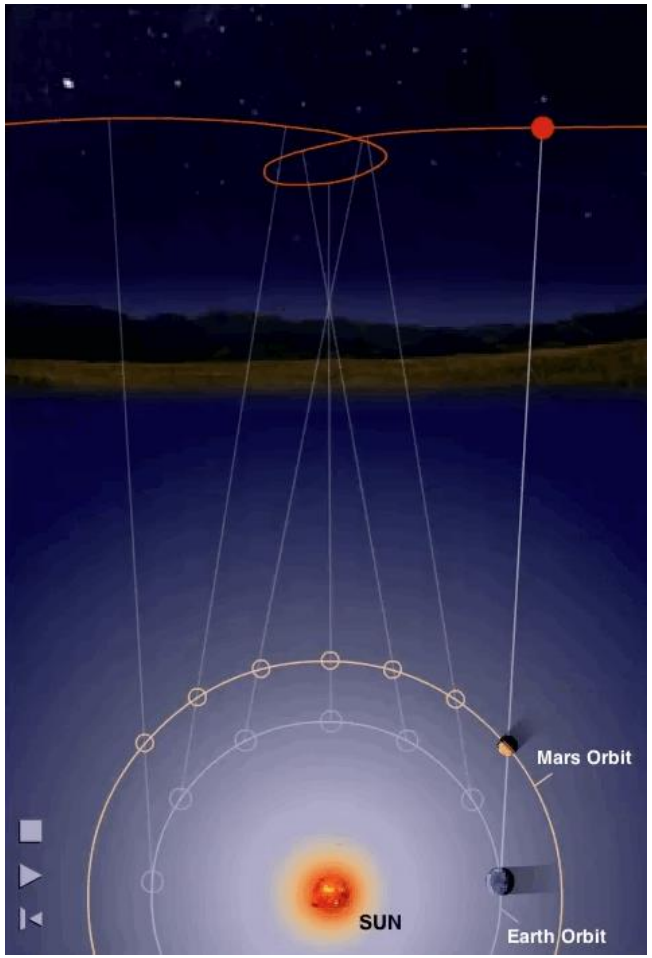


FIGURE 6 The retrograde motion of Mars as described by the Copernican model. Note that the lines of sight from Earth to Mars cross for positions 3, 4, and 5. This effect, combined with the slightly differing planes of the two orbits result in retrograde paths near opposition. Recall the retrograde (or westward) motion of Mars between October 1, 2005, and December 10, 2005, as illustrated in Fig. 2.



Summary

- Celestial motions
  - Project: Conduct an astronomical observation
- Geocentric model
  - Equant & eccentric
    - Precursor of Kepler's laws of planetary motion

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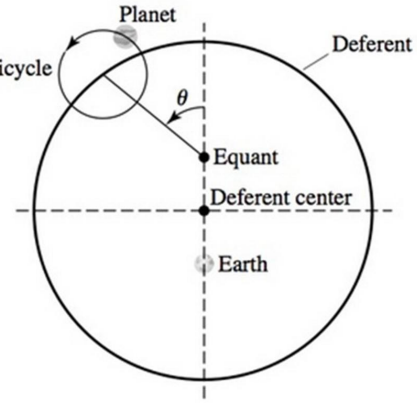
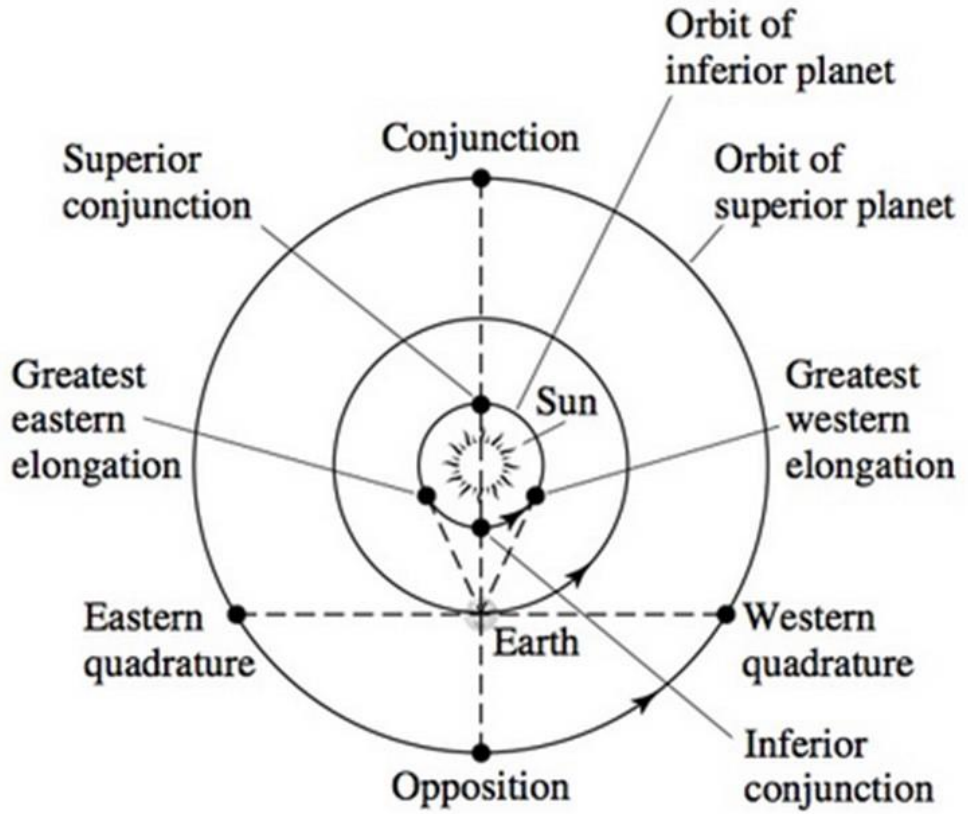


FIGURE 3 The Ptolemaic model of planetary motion.

- Heliocentric model
  - Inferior planets
    - Order of the planets from the Sun
    - Relative distances
  - Superior planets



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