

Greek Cosmology (600 B.C~200 A.D): Earth-centered Universe

- Pythagoras (560-480 B.C.)
 - The first to teach that Earth is a sphere
 - Heavenly bodies are perfect spheres moving in perfect circles
- Eudoxas (400-347 B.C.)
 - Many-sphere model that includes motion of planets
 - Moon, Mercury, Venus, Sun, Mars, Jupiter, Saturn, then stars
 - Failed to explain the **retrograde motion** of planets
- Apollonius (240-190 B.C.)
 - *Epicycles* could explain the retrograde motion
- Ptolemy (100-170 A.D.)
 - *Almagest*
 - Good agreement with observations
 - A **standard model of the universe for 1,400 years**

Emergence of Sun-centered Universe

- Aristarchus (310-230 B.C.)
 - c.f. Aristotle (384-322 B.C.); Apollonius (240-190 B.C.)
 - The first person to suggest that the Earth rotates around the Sun
 - Not widely accepted until ~1,800 years later...
- Copernicus (1473-1543 A.D.)
 - Aware of Aristarchus's work
 - Much simpler to explain the retrograde motion
 - But, no more accurate than Ptolemy's model...
- Tycho Brahe (1546-1601)
 - Very precise measurements of motion of stars and planets
 - Convinced that planets must orbit the Sun
 - But still supported the geocentric model? **Parallax** problem
 - Invented a compromised model
- Galileo Galilei (1564-1642)
 - Introduced the telescope to astronomical observations: No parallax problem!
 - Observations of phases of Venus finally gave convincing evidence for the heliocentric model.

Kepler Finally Removed Epicycles

- Kepler (1571-1630 A.D.)
 - Hired by Tycho Brahe to assist his research
 - Ptolemy's model could not be made to fit Tycho's data better than 8 arc-minutes.
 - Breakthrough: **elliptical orbits**
 - People have always assumed that heavenly bodies orbit in perfect circles, for nearly 2000 years!
 - Elliptical orbits completely removed the need for epicycles
 - Three empirical laws of planetary motion derived from Tycho's data, known as **Kepler's Laws**:
 - Elliptical orbits
 - Equal-area orbits
 - Period-distance relation
- Newton (1642-1726 A.D.)
 - Gave theoretical explanations to Kepler's Laws by his universal laws of gravity