

## The Science of Astronomy (Chapter 3): The Orbits of the Planets

The Sun, Moon, stars, and planets all appear in the sky. Planets move across the sky in unusual ways, sometimes moving backwards (retrograde motion) to everything else. Their speeds and brightnesses also vary.

The Ancient Greeks concluded that the Sun, Moon, and planets all orbited around Earth, while Earth remained fixed at the centre of the Universe. Ptolemy described the motions of the Sun, Moon, and planets around Earth by a series of circles-upon-circles, or epicycles. Ptolemy rejected the idea that the Earth orbited another body, because that should cause nearby stars to shift in position compared to far-away stars (parallax). Although such changes do occur, they were too small for Ptolemy to detect.

Ancient cultures also thought that things in the heavens were perfect and unchanging, unlike things here on Earth. That would mean that the laws of physics are very different on the Earth and in the heavens.

Nicholas Copernicus (1473-1543) argued that Earth and the planets all orbit around the Sun. He used his model to determine the distances of other planets from the Sun in terms of the Earth-Sun distance.

Tycho Brahe (1546-1601) made naked-eye observations of the positions of planets that supporters of both Ptolemy's and Copernicus's models used to test those models. Tycho used observations of a supernova and a comet to show that the heavens were not unchanging.

Johannes Kepler (1571-1630) proposed three laws of planetary motion that were consistent with Tycho's observations. Planets orbit the Sun in ellipses with the Sun at one focus. Planets sweep out equal areas in equal times. The square of the orbital period in years equals the cube of the average planet-Sun distance in AU. Perihelion distance =  $a(1-e)$ . Aphelion distance =  $a(1+e)$ . Average distance from Sun =  $a$

Galileo (1564-1642) saw sunspots blemishing the surface of the Sun and mountains and craters blemishing the surface of the Moon. This showed that the Sun and Moon were not "perfect" objects. Galileo discovered four moons orbiting Jupiter and the phases of Venus, which both supported Copernicus's Sun-centred model.