

Key Figures in the Early Modern History of Western Astronomy (a brief summary by S. Kannappan)

**Nicolaus Copernicus** (1473-1543, Polish/Prussian) – proponent of the **heliocentric** model to replace the **geocentric** model of the Earth, Sun, and planets. A heliocentric model was first proposed by the Greek philosopher Aristarchus in the 3<sup>rd</sup> century B.C. but was not favored at the time due to unanswered concerns (for example, why can't we feel the Earth moving?). Copernicus revived the heliocentric model in the 16<sup>th</sup> century as a better explanation for **retrograde motion** than the then-popular geocentric model of the Greek philosopher Ptolemy, dating to the 2<sup>nd</sup> century A.D. Ironically, although Copernicus removed the **epicycles** Ptolemy used to explain retrograde motion, he added other epicycles to predict the planetary motions more accurately, and his model still predicted those motions no better than Ptolemy's had. Nonetheless, Copernicus clearly showed that the heliocentric model was simpler and revealed regularities absent in the geocentric picture (e.g., planets with larger orbital radii relative to the Sun have longer orbital **periods**).

**Tycho Brahe** (1546-1601, Danish) – director of two observatories at which he and his assistants collected vast quantities of highly accurate data on star and planet positions, taking multiple measurements to reduce errors. His goal was to test heliocentrism by looking for **parallax** (slight shifts in the apparent location of nearby stars relative to background stars), which would be predicted if the Earth moves around the Sun. He failed to detect parallax and concluded that the Copernican system was wrong – apparently logical, except that we now know parallax *does* exist, requiring a telescope to detect. He died too soon to see the first telescopes, invented by Dutch opticians in the early 17<sup>th</sup> century.

**Johannes Kepler** (1571-1630, German) – discoverer of **Kepler's Laws** describing mathematical regularities in the orbits of the planets in a heliocentric system (elliptical orbits, equal area in equal times, and  $P^2 \propto a^3$ ). He inherited Tycho Brahe's data on the planets and used it to develop his own heliocentric model without epicycles, some 50 times more accurate than any other model. Owen Gingerich has called Kepler "the first scientist to demand physical explanations for celestial phenomena" because Kepler thought the Sun was not merely located at the center, but provided a cause for the planets' motion. Kepler was deeply spiritual in his own way and sought God's harmony in "the music of the spheres" as well as the sizes of the six planetary orbits, which he at one time believed circumscribed the five regular convex polyhedra of geometry. He also advanced the study of optics and mathematics.

**Galileo Galilei** (1564-1642, Italian) – first astronomer to use a telescope, famously employed to detect the **phases of Venus** and the **moons of Jupiter**. Both were inexplicable under the old Ptolemaic system, so Galileo is often credited with "proving" the heliocentric system correct. The Catholic Church, which at the time held that Earth must be at the center of the Universe, disputed Galileo's logic, tried him for heresy, and sentenced him to house arrest. The case was not as clear then as it might look now: Galileo chose to advocate for the Copernican model (rather than that of Kepler, which was genuinely superior to Ptolemy's model in predictive power), and he chose to frame his discoveries in terms of proof rather than disproof, which theologians saw as a logical overstep.

**Isaac Newton** (1642-1727, English) – first scientist to quantify and test a theory in which the same physical mechanisms acting on Earth also govern the motions of the heavens. He showed that the physical principles embodied in **Newton's Laws** (inertia,  $F=ma$ , equal and opposite reaction, and universal gravitation) can be used to predict Kepler's Laws. Newton was also one of the inventors of calculus and a key figure in the history of optics and mechanics. He was deeply religious, though unorthodox, and wrote more extensively on theology than on science.