# Additional Background for the Teacher. Galileo: Revealing the Universe

### *Geocentric versus Heliocentric Worldviews*

Ancient astronomers from both Eastern and Western cultures constructed explanations of the motions of the celestial bodies based on mathematics, philosophy, and careful observations of the skies as visible to the human eye. They observed that the stars, sun, and planets appear to revolve around the Earth each day, and that the stars circle around the pole with those stars nearer the equator rising and setting each day and circling back to their rising point. That the Earth was the center of all of this spherical motion was reinforced by its solid nature and by the fact that, to its inhabitants at least, it was stationary. This model was also part of a cosmology named after the early Greek philosopher and naturalist Aristotle that understood the Earthly realm as corrupt and mutable and the heavenly realm, including the stars as fixed, perfect, and unchangeable. In the 2nd century BCE, the Roman astronomer Ptolemy (90–168 CE) further refined the geocentric view by stating that all planets moved in perfect circles, attached to perfect spheres, all of which rotated around the Earth, a theory that predicted the paths of the planets fairly well.

This view remained predominate for 1,400 years. Its limitations were exposed by Polish astronomer Nicholas Copernicus (1473–1543), who formulated a new heliocentric theory in *De Revolutionibus Orbium Coelestium* (*On the Revolutions of the Celestial Orbs*) that better explained the motions of the planets by expanding the size of the universe and displacing the Earth as its center. Copernicus's treatise was admired for its mathematical elegance, but his tables were adapted by others to accord with the prevailing geocentric system, which had deep roots in scientific thought and also in the powerful, religious world-view that had set the standard for the organization of Western society for more than a millennium.

*De Revolutionibus*, published in 1543 and dedicated to Pope Paul III (Copernicus was a member of the Roman Catholic clergy), caused no consternation until 1616, when it was placed on the list of banned books. By that time, however, Galileo Galilei's publications and pronouncements about his own astronomical findings made with the new telescope were being widely circulated and a serious questioning of the old geocentric system was underway.

### *Galileo and the* Sidereus Nuncius

In 1610, Italian astronomer Galileo Galilei (1564–1642) published his treatise *Sidereus Nuncius* (*Starry Messenger*), in which he took up and expanded Copernicus's heliocentric theory. Unlike Copernicus or Galileo's older contemporary Tycho Brahe (1546–1601), who could not shed his attraction to geocentricism, the Italian astronomer based his work on direct observation through powerful lenses that he developed shortly after the telescope's invention in 1608. The improvements he made to the telescope's magnification (from 3X to 20X, by1609) allowed him to deal a crippling blow to geocentric theory when he proved that the planet Jupiter had four

moons and that these bodies revolved around it. He published this finding in *Starry* Messenger and the discovery made him famous.

The reading selection for this lesson is the portion of *Starry Messenger* that deals with Galileo's observations of the stars, which helped to further overturn the old Aristotelian cosmology. Galileo began by explaining that the stars, when viewed through his telescope, did not increase in brightness or size in the same proportion as did the moon and planets. He also pointed out that the telescope revealed a distinction between planets and fixed stars:

*"The planets present entirely smooth and exactly circular globes, that appear as little moons, entirely covered with light, while the fixed stars are not seen bounded by circular outlines, but rather as pulsating all around with certain bright rays."*

In Aristotelian cosmology, all heavenly bodies, including the Moon, were thought to be made up of the same material, and the fixed stars were all thought to be just beyond Saturn. To Galileo, the difference in appearance indicated that the planets were much closer than the stars.

Galileo also reported that he saw at least ten times as many stars through the telescope as with the naked eye, and he published star charts of the belt of Orion and the Pleiades showing some of the newly observed stars. He also pointed his telescope at regions of the sky that the astronomer Ptolemy has referred to as nebulous or cloudlike. When Galileo observed some of the "nebulous" stars in the Ptolemaic star catalog, he deduced that rather than being cloudy, they were made of many small stars. From this, he further deduced that the nebulae, and the Milky Way itself, were collections of stars too small and far away to be resolved into individual stars by the naked eye.

In fact, the development of more powerful telescopes eventually proved that Galileo was both right and wrong. Some of the deep sky objects that had been thought to be nebulous by earlier astronomers were in fact clusters of stars, while others were indeed nebulous clouds of dust, hydrogen, helium, and other gases.

**Further EDSITEment-reviewed Resource Websites**

The Scientific Revolution: Science & Society from the Renaissance to the Early Enlightenment, at the Teaching Institute @ Ohio University: (Historical Resources) http://hti.osu.edu/scientificrevolution/historical_resources)

The Galileo Project, at Rice University: http://galileo.rice.edu/index.html