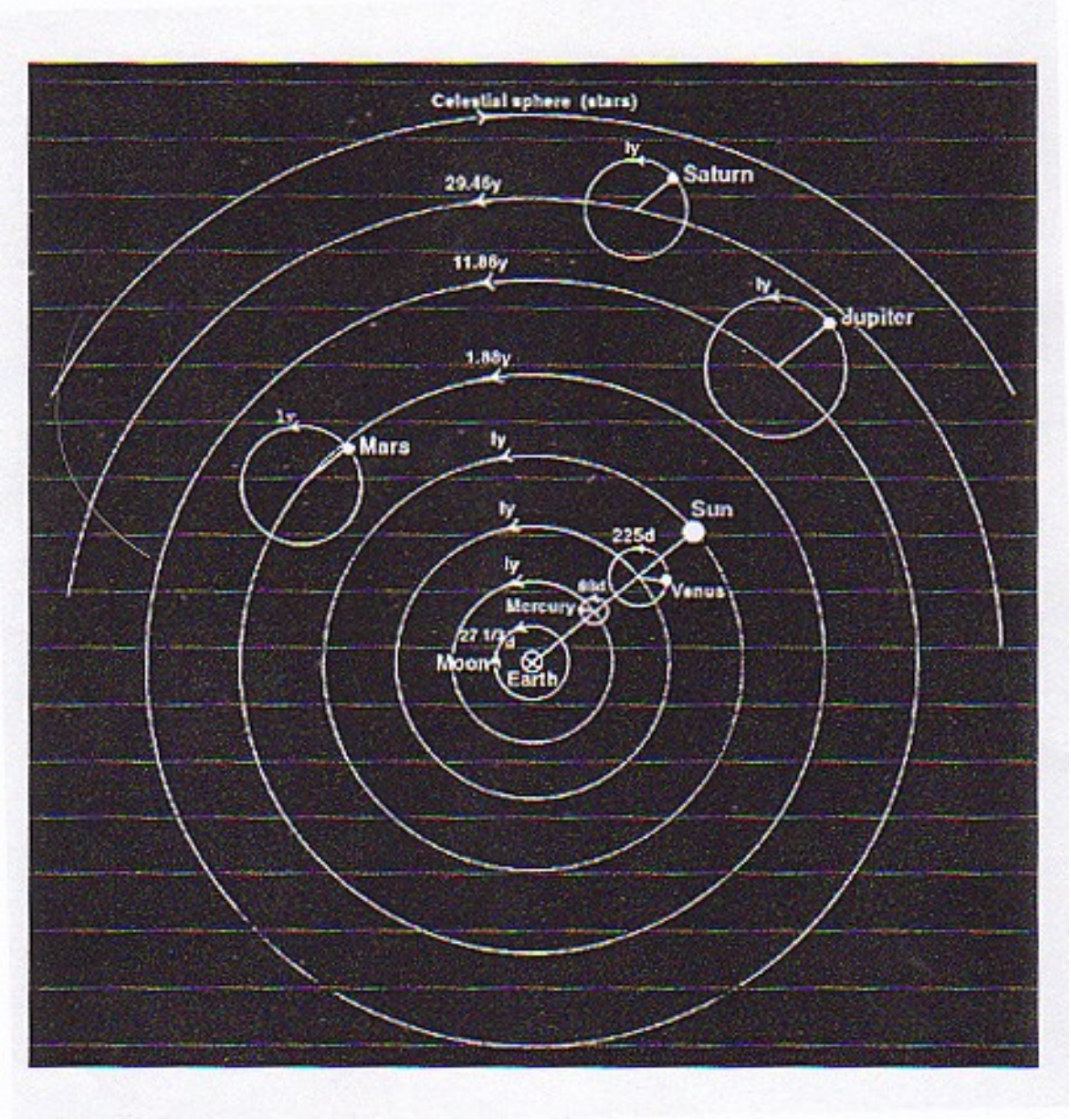
Ptolemy

Claudius Ptolemaeus (c. 85 – c. 165), known as **Ptolemy,** was the most renowned astronomer and geographer of the ancient world. His expertise also extended to the fields of optics, astrology, physics, mathematics, and music. His book, which came to be called the *Almagest* (from the Arabic for the "Greatest"), was the most important astronomical compendium until the 16th century. He originally named it *Mathematical Syntaxis*, which means "the mathematical collection." Developed around 150 A.D., his system, based on an Earth-centered universe (the *Ptolemaic system*), prevailed for 1400 years until Copernicus, Kepler and Galileo showed that the sun and not the earth must be regarded as the center of the solar system. Ptolemy also compiled a *Geographia*, a catalogue of places on the Earth together with their longitude and latitude. His depiction of Asia extending much too far east and his too small estimate for the circumference of the Earth encouraged Christopher Columbus in his westward expedition across the Atlantic Ocean seeking a quicker route to India.

The Ptolemaic dynasty established two great institutions in Alexandria, the Library and the Museum. It was not a museum, as we know it, but rather the prototype of a research university. While he clearly made extensive use of the Library, Ptolemy (no relation to the dynasty) most likely "worked" in the great Museum. Ptolemy's name came from his birthplace. Much of the contents of the *Almagest* may be ascribed to the lost works of Hipparchus, who should also be credited with the method of determining latitude and longitude used in the *Geographia*. Ptolemy acknowledged his debt to earlier investigators, urging those who would understand the difficulties of the questions considered to read the books of the

ancients, especially those of Hipparchus, whom he praised as “a lover of labor and a lover of truth.” Ptolemy used geometric models to predict the positions of the sun, moon, and planets, using combinations of some 80 circular motions known as *epicycles*. He taught that the five then known planets and Sun orbited the Earth in the order Mercury, Venus, Sun, Mars, Jupiter, and Saturn [Figure 11.6a]. Although based on naked-eye observations, his system predicted the positions of the planets fairly accurately. The *Almagest* contained tables needed for astronomical calculations, as well as a star catalogue of 1028 stars in 48 constellations, whose names are still used today.

Ptolemy introduced very few new mathematical techniques, but modified existing ones to suit his needs. In his system a planet moves on perfect circles, but not at uniform speed. He introduced a geometric device that he called an *equant point* around which the planet moves at a steady angular speed. Given any ellipse, we can draw its eccentric circle by constructing the circle that has the same center as the ellipse and has a radius equal to the semi-major axis of the ellipse [Figure 11.6b]. That is, the eccentric circle circumscribes the given ellipse. The equant point (**Q**) is located on the line connecting the earth (**E)** with the center of the planet’s eccentric circle (**C**), such that **QC = CE** [Figure 11.6]. From the equant point there is the illusion that the motion of the orbiting planet is at a steady speed.



11.6

Ptolemy did not intend to develop a new theory of cosmology. Instead, he did what he could to re-establish Aristotle's claims for a geocentric universe. Ptolemy argued that since all bodies fall to the center of the universe, the Earth must be fixed at the center; otherwise falling objects wouldn't be seen to drop toward the center of the Earth. He believed that the Earth is stationary; otherwise, a body

thrown vertically upward would not fall back to the same place, as in fact it does. This constituted his proof of the Earth as the center of the universe. He introduced the notion of *deferents*, large orbits about the Earth that the planets followed while circulating in their own epicycles located on the deferent orbit. Ptolemy wrote that: "the first order of business is to grasp the relationship of the earth taken as a whole to the heavens taken as a whole." He reported that the heaven is spherical in shape and moves spherically. Likewise, when taken as a whole, the Earth is sensibly spherical in shape and is the middle of the heavens. The Earth has the ratio of a point relative to the size of the heavens and it has no motion from place to place. He added that there are two different primary motions in the heavens: the first is the daily motion, which "carries everything from east to west"; the second is the motion of the sun, moon and five planets along the ecliptic from west to east. His configuration was surprisingly adequate mathematically, despite being based on an erroneous model of the universe.

Ptolemy can't be held accountable for the results of his theories being accorded almost divine authority when they re-entered Christian Europe in the 12th and 13th century in Latin translations of Arabic works. They were so revered that to challenge their erroneous pronouncements about the universe and the geocentric theory of the cosmos was to find oneself subject to censure, excommunication and worse. Ptolemy's geocentric system represented the best science of his day, but St. Thomas Aquinas did such a remarkable job of incorporating it into Christian theology, that lesser thinkers concluded that Christian doctrine required that Ptolemy's models be taken as the definitive explanation of the workings of the universe. It required considerable daring to propose other explanations. Even with the invention of the telescope, which made the errors of the Ptolemaic system apparent to those who would look through it to the heavens; it was defended vigorously as if it was gospel. Nevertheless it would be an injustice not to honor Ptolemy for his accomplishments. Although his scientific explanations of the universe have been superseded by others this doesn't detract from his brilliance as a scholar and scientist.

Ptolemy is celebrated as a geographer as well as an astronomer. In *Geographia*, he attempted to map the known world by assigning coordinates to major places in terms of longitude and latitude. He discussed the known continents at that time, Africa, Asia and Europe, but the work did not extend below the equator. His 26 color regional maps and single world map were often inaccurate due to the vague reports from traveling merchants and Roman officials. Ptolemy's estimates of the size of the known world were roughly 4,580 miles from north to south and 8,250 miles from west to east. While his map of Greece and the Aegean was rich in detail and elegantly executed, he underestimated the size of the oceans and overestimated the landmass from Spain to China. Despite their errors his maps were far superior to those drawn in the Dark Ages of Europe. It was from Ptolemy's rediscovered works that Renaissance mapmakers learned their craft, without which the navigations of the fifteenth and subsequent centuries could not have taken place.

Quotation of the Day: "Ptolemy … fully realized that his theory [of planetary motion] was just a convenient mathematical description which fit the observations and was not necessarily the true design of nature. For some planets he had a choice of alternate schemes and he chose the mathematically simpler one. Ptolemy says in Book XIII of his *Almagest* that in astronomy one ought to seek as simple a mathematical model as possible. But Ptolemy's mathematical model was received as the truth by the Christian world." – Morris Kline