Biographical Encyclopedia of Astronomers

Ptolemy

Flourished Alexandria, (Egypt), second century

Hundreds of years of Greek geometrical astronomy were systematized, with rigorous demonstrations and proofs, by Claudius Ptolemy. His intent was to do for applied mathematics what Euclid had done for pure mathematics (geometry). Ptolemy produced handbooks containing all that was known about astronomy, optics, geography, astrology, musical theory, geometrical constructions using spherical projection, the structure and size of the Universe, and mechanics. Although his primary goal was to summarize what was already known, Ptolemy also advanced astronomical knowledge to such an extent that he earned himself a reputation as the greatest astronomer of the ancient world. He showed how, based upon observation and empirical data, geometrical models could be constructed that simulated nature. His astronomical textbook surpassed all that had gone before and dominated future astronomy for well over a millennium In replacing much of previous astronomy, however, Ptolemy helped cause the loss of a vast body of earlier data.

Of the man himself almost nothing is known. His recorded observations were purportedly made—some assert they were fabricated—between the 9th year of Hadrian's reign (125) and the 4th year of Antoninus Pius (141) "in the parallel of Alexandria." Most writers assume that Ptolemy worked in Alexandria, Egypt, but according to Olympiodorus the Younger, a philosopher teaching in Alexandria in the 6th century, Ptolemy worked for 40 years at Canopus, a town 15 miles to the east of Alexandria (and hence in the same parallel). One tradition even has it that Ptolemy in 147 erected in the temple of Seraphim at Canopus a pillar to commemorate his discoveries. Wherever he actually resided, Ptolemy is rightly associated with Alexandria, whose library provided him with the observations of his predecessors, upon which he constructed his great synthesis

Ptolemy's mathematical systematic treatise of astronomy, *The Mathematical Syntaxis*, soon attracted the appellation *megiste*, the Greek adjective for "greatest," which was transliterated into Arabic. With the addition of the definite article *al*, Ptolemy's complete exposition of mathematical astronomy became, upon passing from Arabic into Medieval Latin, the *Almagest*. Ptolemy's treatise was lost in the West soon after its completion, but was copied and studied in the Byzantine Empire. Manuscript versions in the original Greek and dating from the 9th century are extant, as are Arabic translations dating from the 11th century and later. A Latin translation from Arabic was made in 1175. This was rendered, in 1515, into the first printed version of the *Almagest.*

The *Almagest* begins with a brief introduction to the nature of astronomy and a presentation of the necessary trigonometric theory and spherical astronomy. Then come theories of the Sun and the Moon, an account of eclipses, a discussion of the fixed stars, and finally a discussion of the planets. The motivation underlying Ptolemy's study is found in an epigram:

> I know that I am mortal and a creature of a day; but when I search out the massed wheeling circles of the stars, my feet no longer touch the Earth, but, side by side with Zeus himself, I take my fill of ambrosia, the food of the gods

Ptolemy proposed to begin with reliable observations and attach to this foundation a structure of ideas using geometrical proofs. Had he completely replaced the Greek deductive geometrical science he inherited with an inductive observational procedure, the result would have been a scientific revolution. However, determining the reliability of observations other than from their agreement with the very theory that were to be used to confirm proved a major problem for Ptolemy

Ptolemy sought to explain the apparent irregularity of the Sun's motion as a combination of regular circular motions (defined as motions that cut off equal angles in equal times at the center of the circle). In the eccentric hypothesis, the circle carrying the Sun was not centered on the Earth, and thus regular motion as viewed from the center of the Sun's orbit appeared irregular when viewed from the Earth. In the epicycle hypothesis, a small circle (the epicycle) had its center fixed on a large circle (the deferent), and the combination of their regular motions was irregular. In the case of the Sun, either hypothesis could produce the observed motion. The hypotheses were interchangeable in a mathematical sense, though not in a physical sense.

Ptolemy next presented a table of the motions of the Moon and showed that the eccentric circle and the epicycle hypotheses could produce the same appearances. He reported lunar observations of greater accuracy than ever made before, using an astrolabe, which he described in detail

To reproduce the more complex movements of the planets, Ptolemy found it necessary to employ both hypotheses simultaneously. Furthermore, difficulties in matching theory to observation eventually forced Ptolemy to violate his own definition of uniform circular motion. This violation would become one of the major causes of dissatisfaction with Ptolemy's system, leading to Nicolaus Copernicus' revision and revolution 14 centuries later.

In several instances in the *Almagest*, reported observations match corresponding theory more accurately than could be expected of random observations subject to probable errors, and Ptolemy is thus suspected of having fabricated the purported observations. There exists, however, a close agreement between Ptolemy's numerical parameters and modern observational values, so Ptolemy must have had a large, if unreported, body of real observations from which he derived his accurate parameters Once a theory and its quantitative parameters were determined from a large body of real observations, Ptolemy next might have selected from among the observations a few in best quantitative agreement with the theory and then presented these examples to illustrate—not necessarily to determine, or to prove—the theory. Furthermore, Ptolemy was working within the tradition of Greek geometrical astronomy, originally concerned almost totally with geometrical procedure and very little, if at all, with specific numerical results. The objective of the Almagest could have been didactic. Ptolemy may not have intended to deceive his readers, but he was less than candid concerning the manner in which he arrived at his results and was most remiss if his conduct is judged against the ethics of modern science.

Another question involving Ptolemy and his astronomy is whether the many circular motions compounded to determine the trajectory of a planet had a physical reality. Did Ptolemy envisage actual physical structures in the heavens carrying around The planets? Or were his planetary theories merely a means of calculating the apparent places of the planets without pretending to represent the true system of the world? His lunar theory accurately predicted the Moon's positions in longitude and latitude but greatly exaggerated the monthly variation in the Moon's distance from the Earth. Hence, the argument goes, Ptolemy could not have intended the theory to be interpreted realistically. In one of his other books, however, Ptolemy showed a concern with the physical world. In the *Planetary Hypotheses*, he nested the mechanism of circles for each planet inside a spherical shell between adjoining planets. And a passage in the Almagest is susceptible to the interpretation that a construction in the heavens made not of wood, nor of metal, nor of other earthly material, but of some divine celestial material offering no obstruction to the passage of one part of the construction through another, controlled the motions of the planets.

After all is said—the charges of fraud leveled, the scientific shortcomings revealed, and the unanswerable questions exhausted—the historical influence and significance remain. Ptolemy's *Almagest* was the culmination of Greek astronomy, unrivaled in Antiquity, surpassing all that had gone before, and not itself surpassed for some 1400 years, until the time of Copernicus.

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Alternate name:

Claudius Ptolemaius

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