

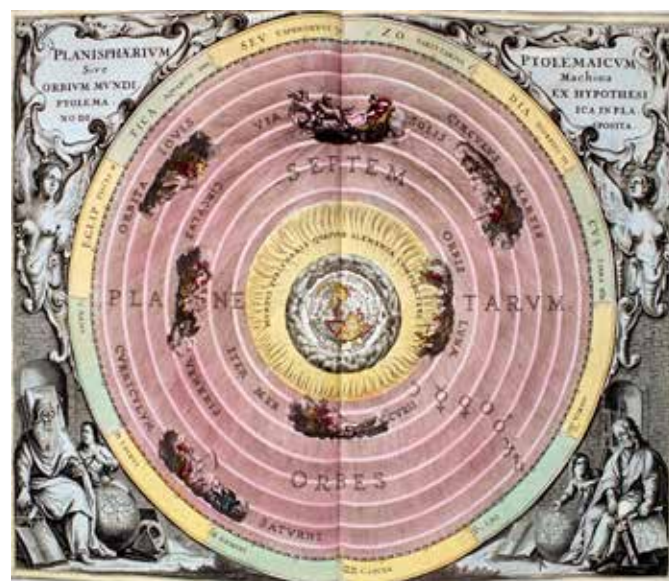
The fundamentals of astronomy for beginners



# EXPLAINER

## Ptolemy

The ancient astronomer shaped our view of the cosmos for centuries



▲ Ptolemy's system placed the heavenly bodies in circular orbits around a stationary Earth. His geocentric model of the Universe held sway for around 1,400 years

for astronomical functions and movements of heavenly bodies.

In the *Almagest*, he introduced the geocentric system, arguing that Earth was stationary at the centre of a large crystalline celestial sphere – the Universe – around which the stars and planets orbited in a broadening nested circle of spheres. However, as we now know today, all the planets – including Earth – orbit the Sun. This means our celestial neighbours appear to move back and forth across the night sky. To explain these strange motions, Ptolemy employed an ingenious system of epicycles, originally devised by Apollonius of Perga (circa 240–190 BC). This asserted that there was a large circle centred on Earth, known as the deferent. Each heavenly body moved along its own smaller epicycle, which moved around the circumference of the deferent. This became known as the Ptolemaic system – attributable not so much to the *Almagest* but to a later two-book treatise *Hypotheseis tōn planōmenōn* (Planetary Hypotheses).

Other volumes in the *Almagest* described the daily

▲ Astronomer, mathematician and geographer Ptolemy flourished in the 2nd century AD

**C**laudius Ptolemaeus (circa AD 100–170), better known as Ptolemy, was a Greco-Roman astronomer, mathematician, geographer and cartographer. He was a citizen of Alexandria, Egypt, in the 2nd century AD. Although his writings influenced astronomy for over a millennium – not always correctly – very little is known about his life. Ptolemy devoted most of his time and effort to astronomy. His first major work was the 13-volume *Almagest*, meaning 'the greatest' and known to him as the *Mathematike Syntaxis* (The Mathematical Collection). It was a synthesis of all the results obtained by Greek astronomy up to then, especially the earlier findings of Hipparchus, providing a model



The final volume he dedicated to what he called motion in latitude, tracking the apparent path of the Sun against the stars.

In conclusion, Ptolemy proposed that the planets were closer to Earth than the fixed stars, but their sphere was not the outer limits of the Universe; there were other spheres and the Universe was eternal.

The geocentric model spread throughout the classical world, eventually making it to the hands of Arabic astronomers who gave it the name *Almagest*. It formed the basis of our knowledge of the Universe for centuries, until Copernicus put forward the

heliocentric model in the 16th century.

Despite its mistaken model of the Universe, the *Almagest* still contained a collection of astronomical tables that allowed astronomers to calculate the motions of the heavens. Ptolemy later rearranged these into a set of 'Handy Tables' for more convenient, practical use.

He later wrote the four-volume *Tetrabiblos*, the *Almagest*'s astrological counterpart. The work once again gathered material from earlier sources, providing a comprehensive thesis on how the heavens were thought to affect Earthly matters, and was regarded at the time as being as authoritative as the Bible.

He also wrote on other areas of science, including a major work on geography, a thorough discussion on maps and the geographical knowledge of the Greco-Roman world, as well as lesser works on harmonics (musical theory) and optics. Ptolemy was clearly indefatigable and his astronomical theories, whether right or wrong, stood for over a thousand years.

▲ Its astronomical tables ensured the popularity of Ptolemy's great compendium, the *Almagest*, for generations



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rise and setting of heavenly bodies, the motion of the Sun through the zodiac and the motion of the Moon. Capitalising on Hipparchus's earlier work, Ptolemy calculated the sizes and distances of the Sun and Moon. He was able to determine that the Sun was considerably larger than Earth, though he still deemed our planet to be the centre of the Universe.

### Counting the stars

Later volumes were dedicated to solar and lunar eclipses, the motion of the stars and the precession of the equinoxes. Also included was his famous star catalogue. The list was based on one created by Hipparchus centuries earlier, but increased the number of stars from 850 to 1,022. They were separated into 48 different constellations that form the basis of those we recognise today.

In the remaining volumes of the *Almagest*, Ptolemy modelled the motions of the planets more precisely.

## Hipparchus

Ptolemy's *Almagest* built on work by a much earlier astronomer

Three centuries before Ptolemy, Hipparchus (circa 190–120 BC), born in Nicaea, Bithynia (now Iznik, Turkey), was one of antiquity's greatest astronomers and mathematicians. Based on the island of Rhodes, Greece, from 147 BC he used a surveying instrument known as a dioptra to systematically observe the heavens and record the positions of over 850 stars for his pioneering catalogue.

Credited as the father of trigonometry, he was the first to employ geometric models to explain astronomical motions, as well as applying trigonometric calculations to determine the distance between Earth and the Moon, and study solar and lunar eclipses.

Significantly, he also discovered the precessions of the equinoxes, realising that the solstice points moved slowly from east to west against the fixed background stars, and calculated the length of the year to within 6.5 minutes. Both of these achievements were remarkable for the time.

Hipparchus was also the first to divide stars into classes according to their brightness; the 20 brightest stars he called 'first magnitude', decreasing in brightness to sixth magnitude – those stars on the limit of naked-eye visibility. A revised version of this system is still in use today.

Unfortunately, his original work is lost to history, and we only know of it through later writers such as Ptolemy. Instead, he has lunar and Martian craters and



Greek astronomer Hipparchus had a profound influence on Ptolemy

the asteroid 4000 Hipparchus named in his honour, as well as the European Space Agency's astrometry satellite Hipparcos, launched in August 1989.