



Astronomy

The study of the Universe and the matter it contains

Astronomy is the oldest science—it began when people first looked at the sky and wondered about the objects they saw there. At first, they used the regular cycles of movement purely for measuring time, but they were also fascinated by what these objects were, and this gave rise to myths, legends, and practical theories about the Universe. Today, astronomers use huge telescopes and powerful computers to answer some of the biggest questions about the past and future of the cosmos (the Universe).

Early astronomy

Archeological sites around the world show that ancient peoples had a good understanding of the objects and cycles they saw in the sky, even before they invented writing. Monuments as far apart as Stonehenge in England and the Temple of Karnak in Egypt are aligned to sunrises and sunsets at important times of the year. The ancient Egyptians also used the annual movement of the Sun against the background stars to predict the flooding of the River Nile.

However, the real birthplace of scientific astronomy is probably Mesopotamia (part of modern Iraq). Around the 5th century B.C.E., astronomers were drawing star maps, creating constellation patterns in the sky, and predicting the paths of the Sun, Moon, and planets. Their main reason for doing this was astrology (attempting to predict the future from the movements of the stars), but their methods were scientific. In fact, astronomy and astrology were one and the same until just a few centuries ago.

HIGHLIGHTS

- Astronomy is the study of the Universe.
- Modern astronomy uses space probes, powerful telescopes, and supercomputers to understand the planets, stars, and the Universe itself.
- The most important revolution in astronomy came when people realized Earth moved around the Sun, and not the other way around.

Greek astronomers and philosophers created some of the first theories of the Universe based on observation. Most put Earth (which they knew was round) at the center, with the Sun, Moon, planets, and stars moving around it, but, around 270 B.C.E., Aristarchus of Samos discovered that the Sun was larger than Earth. He therefore realized that the Sun should be at the center. However, religious teachings and apparent common sense (if the Earth is moving, why can its movement not be felt?) meant that his ideas did not catch on.

One major problem for early astronomy was the belief, passed down from Greek philosophers, that everything in the Universe had to move in perfect circles. This caused major difficulties in understanding the movement of the planets, which occasionally slow down, speed up, or even travel backward as seen from Earth. Finally, in the 2nd century B.C.E., Greek astronomer Ptolemy came up with a theory of epicycles. These are mini-orbits fixed to the main circles that allowed the planets to behave correctly. Though Ptolemy's theory seems very elaborate, it was accepted for over a thousand years and became an important part of the Christian church's teachings, preventing the further development of astronomy.

Figuring out the Universe

In the 15th century, things finally began to change. A revival of learning, arts, and sciences called the Renaissance swept across Europe, and people began to question the accepted wisdom passed down from Greek and Roman times.

In 1543, a Polish priest, Nicolaus Copernicus (1473–1543), produced a new theory of the Universe with the Sun at the center and Earth in orbit around it. However, Copernicus's Universe was flawed because he too believed the planets had circular orbits. His theory worked no better than Ptolemy's and was easily ignored.

DISCOVERERS

Brahe and Kepler

Tycho Brahe (1546–1601) was a Danish astronomer who worked with his sister Sofie Brahe (around 1556–1643). Tycho Brahe worked before the invention of the telescope, but he still developed measuring instruments that allowed him to make the most accurate tables of the movements of planets. Although he did not believe in the Copernican idea of a Sun-centered Solar System, his measurements were later used by his student Johannes Kepler (1571–1630), who proved that the Copernican model could work. Kepler's three laws of planetary motion explained that the planets moved in ellipses rather than circles, that they moved faster closer to the Sun, and that the time they take to orbit the Sun depends on their average distance from it.

The great revolution in astronomy came in the 1600s. The principle of the telescope was discovered around 1608 by a Dutch lensmaker. Within a year, astronomers across Europe were using their own instruments to look at the sky.

The most important and controversial observations were made by Italian scientist Galileo Galilei (1564–1642). He sketched sunspots covering the supposedly perfect face of the Sun, found that the Milky Way was made up of countless faint stars, that the planet Jupiter has four moons, and that the planet Venus shows phases like our own Moon as different parts of it face the Sun. The moons of Jupiter proved that not everything in the Universe revolved around Earth, and the phases of Venus showed that it had to be orbiting the Sun closer than Earth. Galileo's announcement of these discoveries and his insistence on teaching a Sun-centered model of the Universe led him into conflict with the Church, but the new ideas spread, and astronomy started to develop rapidly.

Understanding orbits

The movement of the planets was still a problem to be solved. The solution came from the careful observations of Danish astronomer Tycho Brahe (1546–1601), his sister, astronomer and alchemist Sofie Brahe (around 1556–1643), and their student Johannes Kepler (1571–1630). Kepler proved that the movements of all the planets made sense if they orbited the Sun in stretched elliptical (oval) orbits rather than perfect circles.

Still, no one knew what kept the planets in their orbits. The ancients had thought planets were fixed to the inside of invisible spheres, but the Brahes' observations showed that comets pass through the spheres without any effect—proving the spheres were not there at all. English physicist Isaac Newton (1642–1727) finally found the answer in gravity, which he explained in his 1687 book, the *Principia Mathematica*.

Expanding Universe

Having solved the mysteries of the Solar System, astronomers now turned their attention to what lay beyond. For example, how far away are the stars? The whole question of measuring distances in the vastness of space was a difficult one. Kepler's laws could be used inside the Solar System, but beyond it astronomers had to build up a wide range of techniques.

STORY OF SCIENCE

Newton's Laws

Isaac Newton (1642–1727) realized there was some sort of force that pulled objects together. He thought the same force, gravity, was responsible for keeping the Moon in orbit around Earth or causing an apple to fall to the ground. He developed his ideas into four laws. The fourth of these—his law of gravitation—describes how the force of gravity between two objects increases if the mass of either object increases, and decreases rapidly as the distance between the objects decreases. Although his laws do not provide a good description of the behavior of the smallest particles or of objects moving near the speed of light, they describe the behavior of objects in all but the most extreme situations.

The first was measurement by parallax. This is the effect that makes nearby objects seem to move against background objects when the point of view changes slightly. This is easily demonstrated by holding out a finger at arm's length against a distant background and looking at it through one eye, and then the other. By measuring the angle by which an object shifts against the background, it is possible to calculate its distance if the separation between the two points of view is known. Astronomers used this principle by observing stars from opposite sides of Earth's orbit—six months and 190 million miles (300 million km) apart—and measuring their shifts against the background. From this, they discovered that the stars were immensely distant, so far away that today their distances are measured in light-years.

The vast distances to the stars led astronomers to realize that they were actually distant suns. Parallax measurements revealed that some must be much brighter than the Sun, but the wide range of colors they displayed were a mystery.

Some of the most important breakthroughs around this time came from British Astronomer Royal, William Herschel (1738–1822), assisted by his sister Caroline Herschel (1750–1848). In 1781 he had discovered Uranus, a new planet in the outer Solar System, but was also fascinated by some of the bigger questions. While analyzing sunlight split into a rainbow spectrum through a prism (PRIH-zuhm; a transparent body that separates the different colors in light), he discovered invisible infrared (heat) radiation, opening the way for modern astronomy, which looks at a wide range of different radiations. Herschel was also the first astronomer to suggest that the Sun, all the stars in the sky, and the Milky Way were part of a huge, disk-shaped star system, which he called the galaxy.

In the 19th century, astronomers used photography to record images of the Sun, Moon, and stars. German scientist Joseph von Fraunhofer (1787–1826) had discovered dark lines crossing the spectrum of light from the Sun. He realized they were caused by elements in the Sun's atmosphere absorbing light. These lines are termed spectra. Photography allowed astronomers to record the spectra of faint stars, and work began to classify the stars into a sequence according to their color and the elements within them. This eventually resulted in the Hertzsprung–Russell diagram, which shows how the brightness of a star depends on its color, mass, and the stage in its life cycle. With this information, astronomers could work out the distance to almost any star in the galaxy and could begin to work out how stars shine.

Cepheid variables

Another important method of finding distances in the Universe uses Cepheid (SEH-fee-id) variables—stars that change their brightness in a regular cycle. The length of this cycle depends on the star's average brightness, so if astronomers work out the length of the cycle, they can find the star's brightness and therefore its distance.

Edwin Hubble used Cepheid variables to measure the distance of some of the faint spiral nebulae in the sky, discovering that they were millions of light-years away in separate galaxies. He also discovered that the dark lines in the spectra of these galaxies were slightly shifted toward the red end of the spectrum. This red shift, caused by the Doppler effect, shows that other galaxies are moving away from us. Hubble found that the farther away the galaxy was, the bigger the red shift. This could only mean one thing: the Universe is expanding.

DISCOVERERS

Henrietta Leavitt

American astronomer Henrietta Leavitt (1868–1921) pioneered stellar photometry—photographic measurement of the brightness of stars. She discovered new celestial bodies, including 2,400 variable stars, which alter their brightness over time. Using light curves to record the way their brightness changed, she distinguished several different types of variables.

Leavitt's most influential work involved the Cepheid variables. She proved that the stars' periods were directly related to their real brightness. Other

astronomers used this rule to establish distances on the other side of the Milky Way and in other galaxies.

Astronomy today

Although astronomers argued fiercely about the meaning of Hubble's discovery, nearly all now agree that the Universe is rushing outward from a huge explosion—the big bang—which created the Universe around 12 billion years ago.

Thanks to astronomy, more is known about the Universe than ever before. Space probes have provided close-up views of all the planets. Astronomers today use giant telescopes in space and on the ground. Because of the length of time that light from distant objects takes to reach Earth, astronomers can look back in time.

The full range of the electromagnetic spectrum can also be used to look at objects much cooler or hotter than those that shine in visible light. However, there are still questions to be answered. Astronomers still do not understand exactly what happened in the big bang, how the galaxies formed, whether there is life elsewhere in the Universe, and what the Universe's ultimate fate will be. Astronomers hope to answer these questions in the near future.

See also: [DOPPLER EFFECT](#); [STAR](#); [SUN](#); [UNIVERSE](#).

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