

Space

A Comprehensive Reference Guide

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Overview

Outer space, commonly referred to simply as space, is the expanse that exists beyond Earth and its atmosphere and between celestial bodies. Outer space is not completely empty; it is a near-perfect vacuum containing a low density of particles, predominantly a plasma of hydrogen and helium, as well as electromagnetic radiation, magnetic fields, neutrinos, dust, and cosmic rays.

The Universe and Its Structure

The observable universe has a diameter of approximately 93 billion light-years and contains an estimated 2 trillion galaxies. The universe began with the Big Bang approximately 13.8 billion years ago, expanding from an incredibly hot, dense state. The universe is composed of approximately 68% dark energy, 27% dark matter, and only about 5% ordinary (baryonic) matter. The large-scale structure of the universe consists of galaxy filaments, walls, and voids, forming a cosmic web. Galaxies are grouped into clusters and superclusters, with the Milky Way belonging to the Local Group, which is part of the Virgo Supercluster and the even larger Laniakea Supercluster. The cosmic microwave background radiation, discovered in 1965, provides a snapshot of the universe approximately 380,000 years after the Big Bang and serves as strong evidence for the Big Bang theory. The expansion of the universe is accelerating, driven by dark energy, a discovery that earned the 2011 Nobel Prize in Physics.

The Solar System

Our solar system formed approximately 4.6 billion years ago from a giant molecular cloud. It consists of the Sun, eight planets, five recognized dwarf planets, hundreds of moons, and countless asteroids, comets, and meteoroids. The four inner planets—Mercury, Venus, Earth, and Mars—are rocky terrestrial planets. The four outer planets—Jupiter, Saturn, Uranus, and Neptune—are gas and ice giants. Jupiter, the largest planet, has a mass more than twice that of all other planets combined and features the Great Red Spot, a storm larger than Earth that has persisted for hundreds of years. Saturn is renowned for its spectacular ring system composed of ice and rock particles. The asteroid belt between Mars and Jupiter contains millions of rocky bodies, while the Kuiper Belt beyond Neptune is home to Pluto and other icy objects. The Oort Cloud, a theoretical shell of icy objects at the outermost edge of the solar system, may extend up to 100,000 AU from the Sun and is thought to be the source of long-period comets.

Space Exploration History

The Space Age began on October 4, 1957, when the Soviet Union launched Sputnik 1, the first artificial satellite to orbit Earth. This was followed by the launch of Sputnik 2 carrying Laika, the first animal in orbit. On April 12, 1961, Soviet cosmonaut Yuri Gagarin became the first human to travel to space aboard Vostok 1. The United States responded with Project Mercury and President Kennedy's 1961 pledge to land a man on the Moon before the end of the decade. The Apollo program achieved this goal on July 20, 1969, when Neil Armstrong and Buzz Aldrin became the first humans to walk on the Moon during Apollo 11. The Space Shuttle program (1981-2011) made space travel more routine, launching satellites, conducting scientific research, and building the International Space Station (ISS). The ISS, a joint project of NASA, Roscosmos, ESA, JAXA, and CSA, has been continuously inhabited since November 2000 and serves as a laboratory for scientific research in microgravity. Robotic missions have explored every planet in our solar system, with notable missions including the Voyager probes (launched 1977, now in interstellar space), the Mars rovers (Spirit, Opportunity, Curiosity, and Perseverance), and the Cassini-Huygens mission to Saturn.

Modern Space Programs

The 21st century has seen a renaissance in space exploration driven by both government agencies and private companies. SpaceX, founded by Elon Musk in 2002, has revolutionized the industry with reusable rockets, dramatically reducing launch costs. The Falcon 9 rocket has become the workhorse of commercial space launches, and the Crew Dragon spacecraft now regularly transports astronauts to the ISS. Blue Origin, founded by Jeff Bezos, is developing the New Shepard suborbital vehicle and the New Glenn orbital rocket. NASA's Artemis program aims to return humans to the Moon and eventually send astronauts to Mars. China's space program has made remarkable progress, including landing rovers on the Moon's far side and Mars, and building the Tiangong space station. India's ISRO has achieved notable successes, including the Chandrayaan missions to the Moon and the Mars Orbiter Mission. The James Webb Space Telescope, launched in December 2021, is providing unprecedented views of the early universe, exoplanet atmospheres, and stellar nurseries.

Astrobiology and the Search for Life

Astrobiology is the interdisciplinary scientific field concerned with the origins, early evolution, distribution, and future of life in the universe. The search for extraterrestrial life has focused on several promising locations within our solar system. Mars has been a primary target, with evidence of ancient riverbeds and seasonal methane emissions suggesting it may have once harbored microbial life. Europa, Jupiter's moon, has a subsurface ocean beneath its icy crust that may contain more water than all of Earth's oceans combined. Enceladus, a moon of Saturn, has geysers that eject water vapor and organic molecules from its subsurface ocean. Titan, Saturn's largest moon, has a thick atmosphere and liquid methane lakes, making it a unique candidate for alternative biochemistry. Beyond our solar system, the discovery of thousands of exoplanets—including many in the habitable zones of their host stars—has increased optimism about finding life elsewhere. The Drake Equation, formulated by Frank Drake in 1961, provides a framework for estimating the number of communicative civilizations in the Milky Way. SETI (Search for Extraterrestrial Intelligence) programs continue to scan the skies for signals from other civilizations.

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