

Our Place in the Universe (Chapter 1): The Structure and Size of the Universe

Earth is a planet orbiting the Sun. The Sun is one of 100 billion stars in the Milky Way Galaxy. The Universe contains at least 100 billion galaxies.

Earth rotates around its axis once per day. Earth orbits the Sun once per year. Earth's axis is tilted by 23.5 degrees from the perpendicular to Earth's orbital plane. Earth's axis keeps pointing to the same spot in the sky as Earth orbits the Sun, which causes Earth's north pole to tilt towards the Sun for part of the year and away from the Sun for part of the year. Someone standing on Earth's equator is travelling around and around at 1670 km per hour. The Earth is orbiting the Sun at 100,000 km per hour.

The Sun is much heavier than everything else in the Solar System. It is made of hydrogen and helium, and generates energy by nuclear fusion in its core. It is a typical star, one of 100 billion in our galaxy. The Sun orbits the centre of the galaxy every 230 million years.

Nothing can travel faster than light. The speed of light is 3×10^8 m/s. The nearest star to the Sun is so far away (4×10^{13} km) that its light takes 4 years to reach us. It is 4 light-years away. The nearest galaxy to the Milky Way is 250 million light years away. When you look at that galaxy through a telescope, you see it as it was 250 million years ago. Distance and age, or space and time, cannot be considered separately beyond the Milky Way Galaxy.

All galaxies are moving apart from each other, so the Universe is expanding. More distant galaxies are moving away from us faster than those nearby. By comparing their speeds and distances from the Milky Way, it can be shown that all galaxies started expanding from the same tiny region 14 billion years ago. This event is called the Big Bang and it marks the beginning of the Universe. We cannot see any objects more distant than 14 billion light-years away because their light has not had time to reach us. The observable Universe (14 billion light-years in radius) may only be part of something larger, but we have no way of seeing beyond it. The Universe has no edges and no centre. The Big Bang formed mostly hydrogen and helium. Almost all other elements were produced by nuclear fusion inside stars. These elements were then released from the star at the star's death.

The observable Universe is 14 billion light-years in radius. A typical galaxy is 10^5 light-years across. There is lots of space between stars in galaxies. The distance from the Sun to Pluto is 0.006 light years or 6×10^9 km or roughly 100 AU. The Earth is 1 AU from the Sun. There is lots of space between planets in the solar system.

Powers of ten: $10^A \times 10^B = 10^{(A+B)}$ and $10^1 = 10$

Astronomers need to describe very small and very large distances (and times and other things) simultaneously. Powers of ten give a good notation for writing such numbers.