Astronomy studies the Universe using scientific method:
1. Scientific method begins with many observations over a period of time.
2. From the observations, scientists develop a model of the particular phenomenon we want to understand. New models or ideas are sometimes called hypotheses. If there is no possible way to testing a hypothesis, it does not belong in the realm of science.
3. Hypothesis must stand up to being tested via appropriate experiments and observations.

Scientific Notation
Astronomy is a subject of extremes. An astonishing range of conditions is found in the Universe: from the incredibly hot, dense centers of stars to the cold near-vacuum of interstellar space. To describe such divergent conditions accurately, we have to use both large and small numbers. Astronomers avoid such terms as “a million billion billion” by using a standard shorthand system: all the cumbersome zeros that accompany a large numbers are consolidated into one term consisting of ten followed by an exponent, which is written as a superscript and called the power of ten.

This shorthand system can be applied to numbers that are less than one by using a minus sign in front of the exponent. A negative exponent tells you to divide by the appropriate number of tens. The location of the decimal point is as follows:

- $10^0 = 1$
- $10^1 = 10$
- $10^2 = 100$
- $10^3 = 1,000$
- $10^4 = 10,000$

and so forth. The exponent tells you how many tens must be multiplied together to give the desired number. The distance between the Earth and the Sun, for example, can be written as $1.5 \times 10^8$ km, which, once you get used to it, is more convenient than writing “150,000,000 kilometers”.

Astronomical Distances
When discussing distances across the solar system, astronomers use a unit of length called the astronomical unit (abbreviated AU).

**Astronomical unit** (abbreviated AU) is the average distance between the Earth and the Sun:

$$1 \text{AU} = 1.496 \times 10^8 \text{ km} = 93 \text{ million milles}$$

When discussing distances to the stars, astronomers use two different units of length, light year or parsec.

**The light year** (abbreviated ly) is the distance the light travels in one year:

$$1 \text{ly} = 9.46 \times 10^{12} \text{ km}$$

$$1 \text{ly} = 63,240 \text{AU}$$

This distance is roughly equal to 6 trillion miles. Proxima Centauri, the nearest star other than the Sun, is 4.3 light-years from Earth, for example.

The **parsec** (abbreviated pc) is related to the method of measuring distances to the stars. Imaging taking a journey far into space, beyond the orbits of the outer planets. As you look back toward the Sun, the Earth’s orbit subtends a smaller angle in the sky the farther you are from the Sun.

The distance at which 1 AU subtends an angle of 1 arcsec is defined as one parsec.
Thus, the distance to the nearest star can be stated as 1.3 pc as well as 4.3 ly. Whether you choose to use parsecs or light-years is a matter of personal taste.

For even greater distances, astronomers commonly use kiloparsecs or megaparsecs (abbreviated kpc and Mpc), in which the prefixes simple mean “thousand” and “million”, respectively:

\[
\begin{align*}
1 \text{ kpc} &= 10^3 \text{ pc} \\
1 \text{ Mpc} &= 10^6 \text{ pc}
\end{align*}
\]

For example, the distance from Earth to the center of our Milky Way Galaxy is about 8 kpc, and the rich cluster of galaxies in the direction of constellation of Virgo is 20 Mpc away.

Units of length, time, and mass

In SI units, length is measured in meters (m), time is measured in seconds (s), and mass is measured in kilograms (kg). How are these basic units related to other measures?

\[
\begin{align*}
1 \text{ inch} &= 2.54 \text{ cm} \\
1 \text{ foot} &= 0.3048 \text{ m} \\
1 \text{ mile} &= 1.609 \text{ km}
\end{align*}
\]

A Tour of the Universe

We begin with our planet, the Earth. The Earth is a nearly spherical planet about 13,000 km in diameter. Liquid water covers about two-thirds of its surface. Our planet has continents, lots of water, and an atmosphere. The planet is volcanically active. It also has a magnetic field. The Earth revolves around our star, the Sun. The average distance from the Earth to the Sun (about 150 million km) is called an astronomical unit (AU). It takes for the Earth one year (3 \times 10^7 s) to go around the Sun. The Earth moves around the Sun at speed of 110,000 km/h (66,000 mi/h).

The Earth has one natural satellite – the Moon. Distance from the Moon to the Earth is about 384,000 km (thirty times the Earth’s diameter). The Moon’s diameter is one fourth of the Earth’s diameter. It takes a month for the Moon to revolve around the Earth.

Planet is a cosmic object of significant size that orbits a star and does not produce its own light. We can see the nearby planets because they reflect the light of the Sun. The Earth is one of nine planets that revolve around the Sun. These planets, along with their satellites and other small bodies, make up the Solar System. Mercury, Venus and Mars show some similarities to the Earth. Therefore they are called terrestrial planets. Jupiter is the largest planet of the Solar System. It is a huge gas ball about 143,000 km in diameter. Distance from Jupiter to the Sun is about 5 AU.

The Sun is our local star. It is an enormous ball of glowing gas that generate vast amounts of energy by nuclear reactions deep within. The diameter of the Sun is about 1.5 million kilometers. The Sun produces energy at the rate of 10 billion nuclear bombs going off every second. However the Sun is a fairly ordinary star. There are stars that generate a million times more energy than the Sun.

Our Sun is roughly half-way through its lifetime, and has about another 5 billion years of existence in more or less its present state. It take 240 million years for the Sun to complete one revolution around the center of the Galaxy. The Sun already has completed 20 trips around the center of the Milky Way Galaxy. When the Sun has exhausted its hydrogen fuel, it will go through catastrophic changes resulting in destroying the Earth and other planets.

When we look up at the night sky on a clear night, all the stars visible to the unaided eye turn out to be part of a single collection of stars we call the Milky Way Galaxy. The Sun is one of hundreds of billions stars that compose the Galaxy.

The whole Milky Way Galaxy has visible diameter 100,000 light years. It is a spiral galaxy, a vast rotating disk-shaped gathering of stars, gas, and dust 100,000 light years across and about 1,000 light-years thick. At its heart is a dense ball of old stars known as the central budge. Around the budge spins the disk of younger stars, concentrated into spiral arms. Our Sun is in one of the spiral arms, some two-thirds of the way out from the central budge.

Our own Galaxy belongs to a small cluster, the Local Group, which is nearly 7 million light-years across. There are over 30 galaxies in the Local Group besides the Milky Way Galaxy. In the same way that planets move around the Sun and stars move around the Galaxy, the galaxies in the Local Group slowly move around one another due to their mutual gravitational attraction.

Billions of the galaxies are thought to exist, but the Universe does not go on forever. It has finite boundaries in both space and time – about 15 billion years – before which there was something we have no idea about.