The Universe

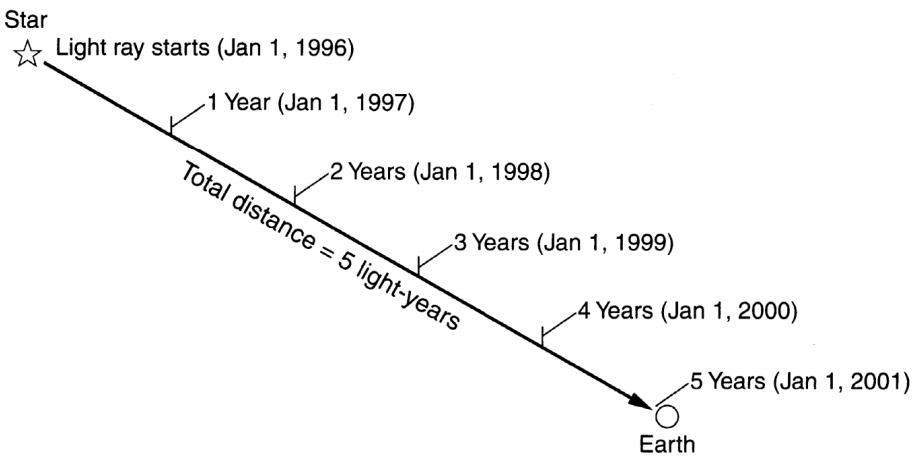
The *universe* consists of space and all matter and energy scattered throughout space. There are far more stars in the universe than there are grains of sand on all the beaches on Earth. Nevertheless, the distances between stars are so vast that most of the universe is empty space.

Stars are not evenly distributed in space, but are clustered together in large groups called *galaxies*. The universe contains billions of galaxies, and each galaxy contains billions of stars. Galaxies are separated by great distances in space. Our sun is a star in the galaxy called the *Milky Way*. From Earth on a clear night, we can see only a few thousand nearby stars in our own galaxy. Astronomers must use telescopes to see stars in other galaxies.

Distances in Space

Distances in space are so great that they are difficult to fully understand. For example, the distance from Earth to our nearest neighbor star (besides the sun) is about 41,000,000,000,000 (41 trillion) kilometers! Because such numbers are so large, astronomers use a unit called a light-year to express distances to the stars. A ***light-year*** is the distance light travels in one year, about 9.5 trillion kilometers (see Figure 8-21). Using light-years allows us to describe distance to stars with more convenient size numbers. Our sun, the closest star to Earth, is a little more than 8 light-minutes from Earth. Our nearest neighbor star is 4.3 light-years away. Many other stars are billions of light-years away. This means we are just seeing the light that left these stars more than a billion years ago.

Figure 8-21. *A beam of light travels about 9.5 trillion kilometers per year. The light from a star that is 47.5 trillion kilometers from Earth takes 5 years to reach us.*



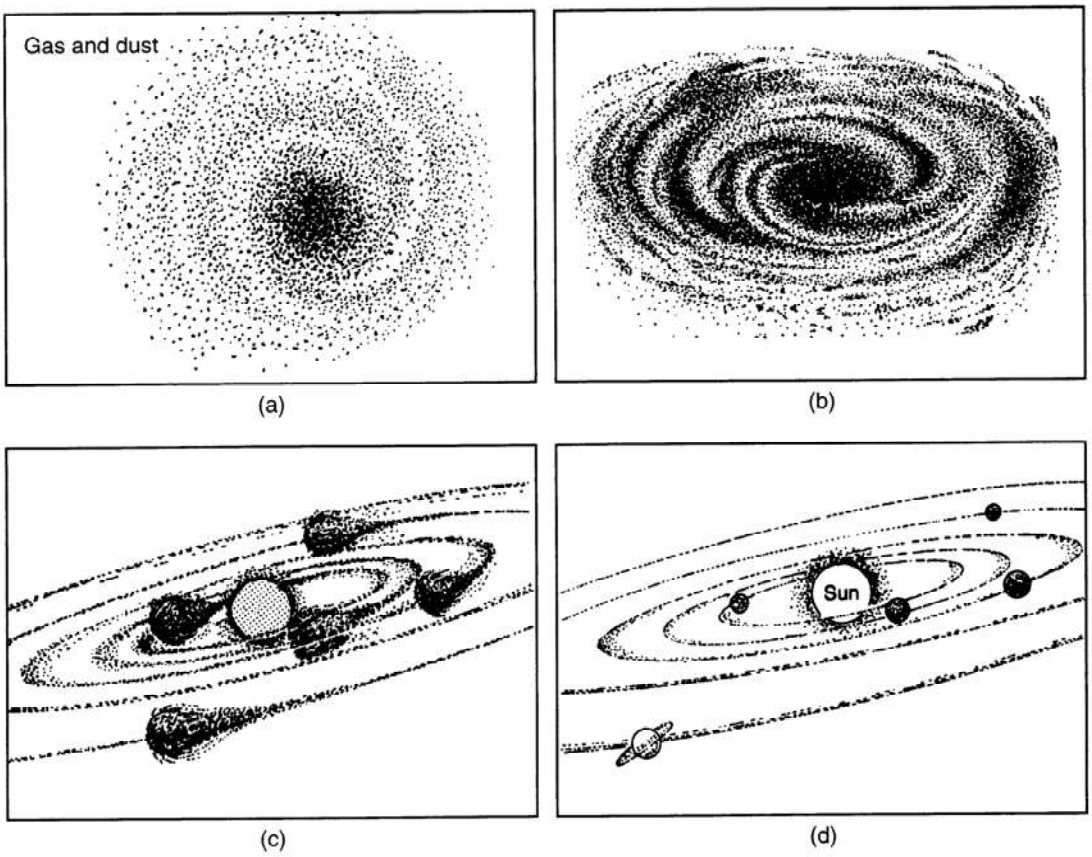
Many stars are as large or larger than our sun. However, because they are so far away, they appear as points of light in the night sky.

Formation of the Solar System

Although astronomers have some evidence to support their theory of the origin of the universe and our solar system, many of the details are still missing. Scientists think that between 15 and 20 billion years ago, a violent explosion created the universe, producing all the material from which the stars, planets, satellites, and other objects formed. This idea is called the *big bang theory*. If such an explosion did occur, one would expect to find all the galaxies moving outward and away from one another; this is exactly what astronomers have found.

Scientists further think that the expanding gases and dust particles condensed into local systems to form galaxies filled with stars. About 5 billion years ago, a dense area in the center of our local cloud of rotating gases and dust became our star, the sun (see Figure 8-22). The sun contains about 99 percent of the original cloud material. Soon afterward, the remaining material condensed into the planets, satellites, comets, meteoroids, and asteroids. The age of the oldest rocks from Earth, the moon, and meteorites is 4.5 billion years for all of them. This is evidence of a similar time of origin.

Figure 8-22. *(a) Cloud of gas and dust in space, (b) Condensation of cloud, (c) Early sun and planet formation, (d) Present-day solar system.*



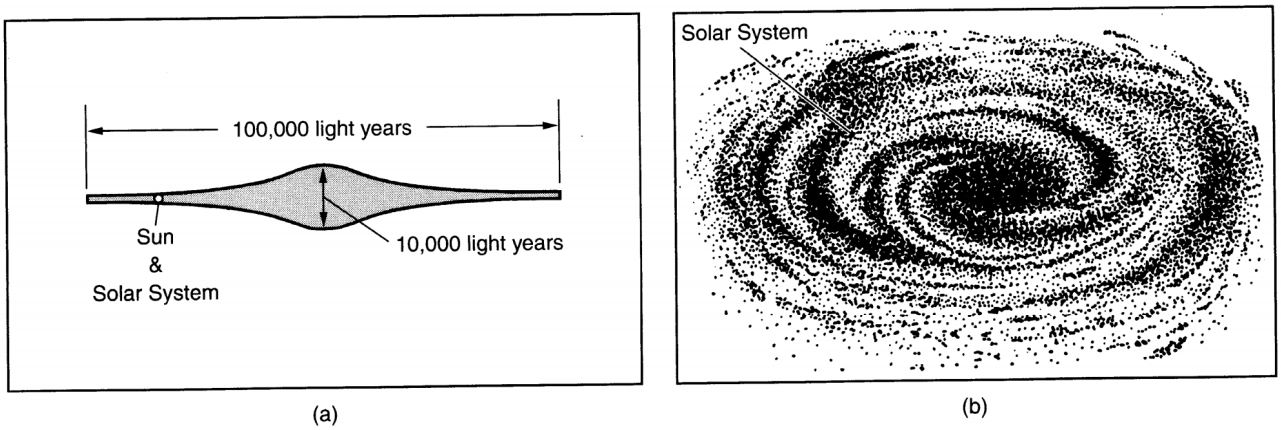


Figure 8-23. *The Milky Way galaxy and the location of the solar system.*

Earth's Position in the Universe

Our sun is one of 800 billion stars located in a star cluster called the Milky Way Galaxy. The Milky Way Galaxy is a large, disk-shaped group of stars that somewhat resembles a pinwheel. It is 100,000 light-years across and about 10,000 light-years thick in the center. As shown in Figure 8-23, our sun, along with Earth, all the other planets, satellites, asteroids, and comets, is located about two-thirds out in one of the spiral arms of the galaxy.

On a clear night we can see a few thousand neighbor stars all within our galaxy. If we observe carefully, we can see a band of closely packed stars that appear as a haze, or cloud across the night sky. This milky-like patch across the sky contains many stars also in the Milky Way Galaxy. Despite the fact that stars appear near each other, the distances between them are vast. Other galaxies and their stars are so distant that a telescope is necessary to see them. When you look at the night sky, you are seeing stars in a very small portion of the universe that is near us.

Stars

Table 8-5 lists the general characteristics of stars. Astronomers think that stars begin as clouds of gas and dust in space. Gravity causes the ma-

Table 8-5. *General Star Characteristics*

Distance:	Sun	150,000,000 km
	Neighbor star	4.3 light-years
	Distant star	Millions of light-years
Composition		Hydrogen and helium
Size		100 km–several billion km
Temperature (surface)		3000°-30,000°C

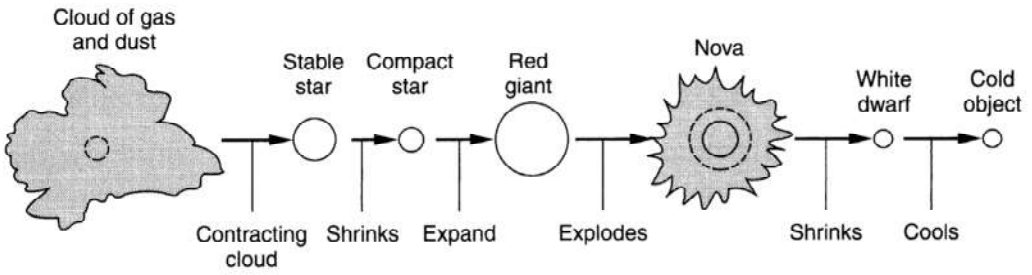


Figure 8-24. *Life cycle of a typical star.*

terial to contract and form the nucleus of a new star that begins radiating energy. Over millions of years, the new star becomes hot enough to glow. Stars, like planets, are nearly spherical.

In this early developmental stage, stars appear reddish because they are relatively cool. Depending on the amount of material present, the star will continue to grow in size and temperature. As it becomes hotter, its surface color changes from red, to orange, to yellow, and possibly to white. If the star is massive enough, it will become bright blue-white. Eventually, the cloud of gas and dust is used up and the star stabilizes. Our sun is an average-size, yellow star in this stable stage of development (see Figure 8-24).

The thermonuclear reaction that changes hydrogen into helium continues to release energy in the form of light and heat. When the star's hydrogen is exhausted, the star collapses. Collapsing compresses the star and causes it to heat and rapidly expand into a cooler red giant or supergiant.

The giant star eventually explodes, losing its outer layer with a burst of energy. This bright flare-up of a star is called a *nova*. Finally, the star will shrink into a white dwarf and evolve into a cold object.

The amount of time it takes for a star to go through its life cycle depends on the original amount of material in the cloud and the size of the star. Our sun's life span is estimated to be about 10 billion years. Our sun appears to have another 5 billion years of life left.

Review Questions

Multiple Choice

31. Evidence for the big bang theory includes the fact that

(1) the universe is shrinking

(2) all galaxies are moving away from Earth

(3) stars and galaxies are moving toward Earth

(4) stars are exploding

32. Analyses of meteorites, Earth rocks, and moon rocks indicate a maximum age of 4.5 billion years. This is evidence that all three bodies probably formed

(1) independently

(2) as a single body in the solar system

(3) less then 4.5 billion years ago

(4) at the same time

33. The Milky Way appears as a hazy band of light that stretches across the night sky. Actually, it is our view outward of our galaxy. The hazy band of light is produced by

(1) sunlight

(2) reflected moonlight

(3) stars in our galaxy

(4) distant city lights

34. The sun and our solar system are located

(1) in the center of the Milky Way Galaxy

(2) within the spiral arms of the Milky Way Galaxy

(3) outside of the Milky Way Galaxy

(4) on the outer edge of the Milky Way Galaxy

35. Stars appear to have life spans of billions of years. During that time they

(1) never change

(2) constantly get larger

(3) constantly get smaller

(4) change in size and temperature

36. Our sun is a stable, yellow star. It is considered to be a(an)

(1) young star

(2) middle-aged star

(3) old star

(4) nova star

Review Star Data Table and answer questions 37 and 38.

Star Data Table

Star	***Absolute Magnitude (Brightness)***	***Apparent Magnitude (Brightness)***	***Distance***
Sirius	1.4	−1.5	8.8
Vega	0.5	0.04	26.4
Capella	−0.6	0.05	45.6
Antares	−4.7	1.0	423.8

37. What units of measurement do the numbers in the Distance column most likely represent?

(1) miles (2) kilometers (3) light-years (4) years

38. Apparent magnitude is how bright a star appears when viewed from Earth. The lower the magnitude number the brighter the star. Which star appears the brightest when viewed from Earth?

(1) Sirius (2) Vega (3) Capella (4) Antares

39. Billions of stars clustered together in large groups are called

(1) solar systems (2) galaxies (3) asteroid belts (4) constellations

40. Which of the following objects is the largest?

(1) sun (2) galaxy (3) solar system (4) Earth

Thinking and Analyzing

Review the *Distances of Some Objects from Earth* table and answer questions 41 and 42.

Distances of Some Objects from Earth

Object	***Average Distance***
Sun	149,600,000 km
Moon	384,000 km
Pluto's Orbit	5,750,000,000 km
Neighbor Star	4.3 light-years
Neighbor Galaxy	2,200,000 light-years
Distant Galaxy	65,000,000 light-years

41. How do the distances between the planets in our solar system compare with the distance between stars?

42. Why do astronomers use light-years to measure distance to stars and galaxies?

Review the *Star Classification* table and answer question 43.

Star Classification

Class	***Color***	***Surface Temperature***	***Example***
O	blue	30,000°C–60,000°C	No common star
B	blue-white	10,000°C–30,000°C	Rigel
A	white	7500°C–10,000°C	Sirius
F	white-yellow	6000°C–7500°C	Polaris
G	yellow	5000°C–6000°C	Sun
K	orange	3500°C–5000°C	Arcturus
M	red	2400°C–3500°C	Betelgeuse

43. To what is the color of a star most closely related?