Light Years

Reflect

Distances between objects in space are too great to measure using Earth units.

Which units do you use to measure lengths or distances? The answer depends on what you want to measure. You might measure the length of an ant in millimeters. You might use meters to measure the length of a soccer field and kilometers to measure the distance between your home and school. You could even use kilometers—lots of them!—to measure the distance from Earth to the Moon.

Beyond the Moon, however, distances between objects are tremendously large. About 150 million kilometers (km) separate Earth from the Sun. The farthest planet from the Sun is Neptune—about 4.5 billion km away. And the distances to objects beyond our solar system are even greater. Why would it be difficult to measure these distances in units such as kilometers? How can scientists measure distances in space more easily?

The Light-Year: A Unit of Distance

Scientists use the astronomical unit (AU) to measure distances within our solar system. One AU is the mean distance between Earth and the Sun: 150 million km. Beyond our solar system, even AUs are not convenient units for measuring distance. Instead, scientists use a unit called the light-year (LY).

A unit that contains the word *year* may seem to be measuring a quantity of time. However, a light-year is actually a unit of distance. One *light-year* equals the distance light travels in one year. Light travels at about 300,000 kilometers/second (km/s). This is the *speed of light*. To appreciate why light-years are convenient for measuring distances in space, let's convert a light-year into kilometers.

$$\frac{300{,}000\text{ km}}{1\ \cancel{\text{s}}} \times \frac{60\ \cancel{\text{s}}}{1\ \cancel{\text{min}}} \times \frac{\cancel{60\text{ min}}}{\cancel{1\text{ hr}}} \times \frac{\cancel{24\text{ hr}}}{\cancel{1\text{ day}}} \times \frac{\cancel{365\text{ days}}}{1\text{ year}} = \frac{9{,}460{,}800{,}000{,}000\text{ km}}{1\text{ year}}$$

Light travels 9,460,800,000,000 kilometers per year. That means 1 LY equals nearly 9.5 trillion km, or approximately 63,000 AU. Even relatively close stars may be separated by dozens of light-years. Imagine trying to measure these distances in kilometers or astronomical units! This table lists approximate distances from Earth's Sun to several stars in the universe.

From the Sun to …	Distance in LY	Distance in AU	Distance in km
Sirius	8.6	541,800	81,362,880,000,000
Betelgeuse	489	30,807,000	4,626,331,200,000,000
Deneb	1402	88,326,000	13,264,041,600,000,000

What Do You Think?

The distance between the Sun and Proxima Centauri, the nearest star to our solar system, is about 39,900,000,000,000 km. The distance across our galaxy, the Milky Way, is about 1,000,000,000,000,000,000 km. What are these distances in LY? What are these distances in AU? You can check your answers on the next page.

Look Out!

If light from space takes hundreds or even millions of years to reach Earth, are we looking into the past when we observe distant stars? The answer is yes. When you observe Proxima Centauri through a telescope, you see the star as it appeared about 4.2 years ago.

The most distant galaxy yet discovered in the universe is about 13.3 billion light-years away. Light from the galaxy has been moving through space for over 13 billion years! Therefore, the universe must be at least 13 billion years old. (In fact, scientists have calculated the universe's age to be closer to 14 billion years.)

Clues from the Electromagnetic Spectrum

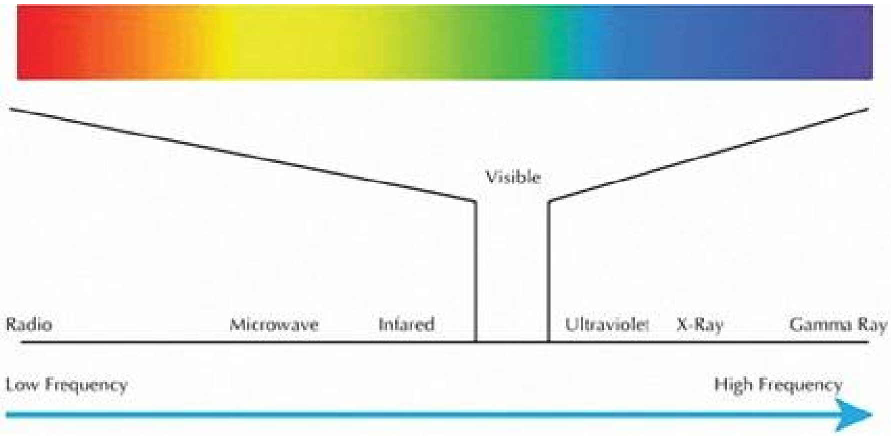
The light we can see, known as visible light, is a form of **electromagnetic radiation**. However, stars emit other types of electromagnetic radiation. In fact, all the objects in the universe emit and absorb at least some *electromagnetic radiation*. The electromagnetic spectrum, shown on the next page, arranges the different types of electromagnetic radiation from lowest to highest energy.

By studying the electromagnetic radiation emitted or absorbed by an object, scientists can learn about the object's properties. These properties include temperature, brightness, and chemical composition, as well as how far the object is from Earth and how quickly it is moving. Remember that energy from space does not tell us about objects as they exist *now*. Rather, scientists learn what objects were like in the past, when they emitted the energy we now detect from Earth. Electromagnetic radiation from a star located 30 LY from Earth reveals the star's properties as they were 30 years ago.

Sunlight takes about 8.3 minutes to reach Earth. The distance between Earth and the Sun can be expressed as 8.3 light minutes.

electromagnetic radiation: energy that travels through space in wavelike patterns at approximately 300,000 km/s

Look Out!



There are seven main types of electromagnetic radiation: radio waves, microwaves, infrared waves, visible light, ultraviolet radiation, X-Rays, and gamma rays. Waves with low frequencies (left) have less energy than waves with high frequencies (right). People can see different colors of visible light. Red light waves have less energy than violet light waves.

What Do You Think?

Let's check your answers:

- The distance from the Sun to Proxima Centauri is approximately 4.2 LY or 266,000 AU.
- The distance across the Milky Way galaxy is approximately 105,000 LY or 6.67 billion AU.

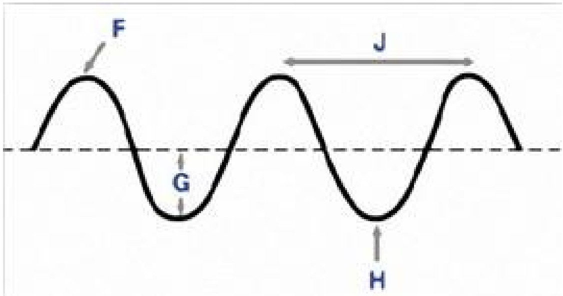
As these examples show, using kilometers to measure distances in space makes for some difficult calculations. Light-years are much easier units to understand and work with.

The Milky Way galaxy is over 100,000 LY across (from left to right).

What Do You Think?

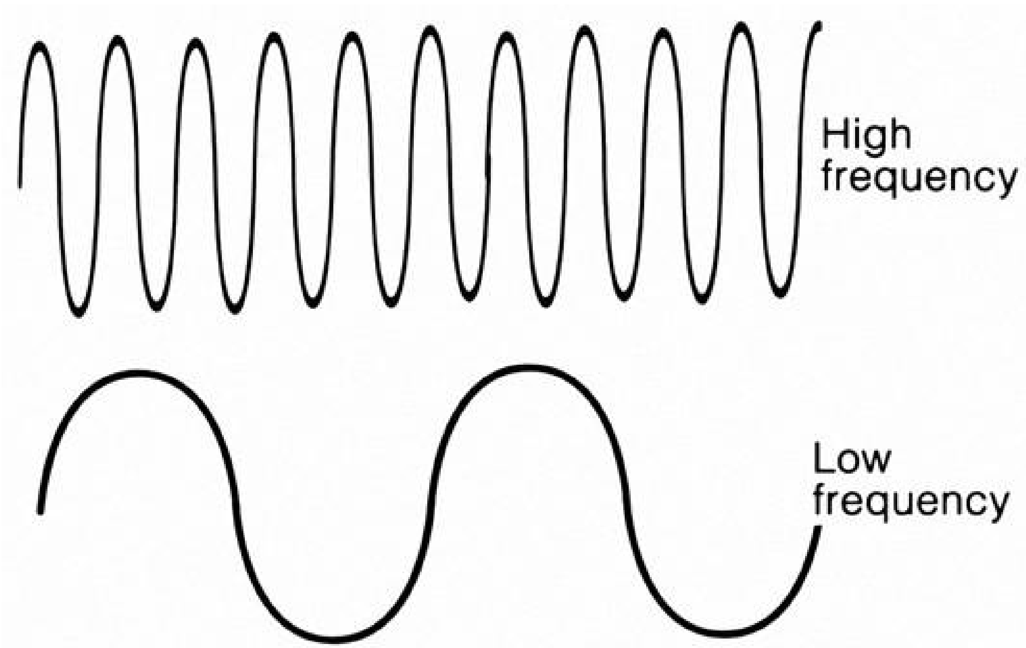
Discover Science:
What are the main properties of electromagnetic waves?

Electromagnetic radiation travels in waves. All waves have certain basic properties. The following diagram shows some of these properties.



F. Crest: The crest of a wave is its highest point.
G. Amplitude: The amplitude of a wave is half the vertical distance between its crest and trough.
H. Trough: The trough of a wave is its lowest point.
J. Wavelength: The wavelength of a wave is the horizontal distance between two successive crests (or two successive troughs)

Another important property of waves is frequency. *Frequency* refers to the number of waves that pass a given point in a given period of time (usually one second). Waves with longer wavelengths have lower frequencies and less energy: fewer waves pass a given point each second. Waves with shorter wavelengths have higher frequencies and more energy: more waves pass a given point each second.



A high-frequency wave (top) has a shorter wavelength than a low-frequency wave (bottom). However, a high-frequency wave has more energy. Each dashed, vertical line in this diagram represents 1 second (s) of time. In 1 s, the low-frequency wave completes 1 cycle, while the high-frequency wave completes 4 cycles.

What Do You Think?

Review the diagram of the electromagnetic spectrum from earlier in this companion.
Which type of electromagnetic radiation has the longest wavelengths? Which type of electromagnetic radiation has the shortest wavelengths? How does this relate to the energy of each type of radiation?

Try Now

What do you know?

Listed below are some distances from Earth to other objects in the Milky Way galaxy. Convert each distance to light-years. (Each of these distances is less than one light-year. For an added challenge, convert each distance to light minutes or light seconds.)

1. The distance from Earth to the Moon is about 384,400 km. How many light-years is this?

2. The distance from Earth to Mars is about 784,000,000 km. How many light-years is this?

3. The distance from Earth to Pluto is about 5,750,000,000 km. How many light-years is this?

Connecting With Your Child

An "Everyday" Scale for Light-Years
Even using relatively convenient units such as light-years, it can be difficult to imagine the vast distances between objects in space. One way to make this process easier is to compare distances measured in light- years to distances measured in smaller units such as meters.

With your child, determine an "everyday" scale: for example, one light-year might be equivalent to one centimeter or one inch. (You can also use everyday objects to do this: for example, one light-year might be equivalent to the length of a pencil or a textbook.) Then, research the distance in light-years between Earth and other objects in our solar system or galaxy, or between our galaxy and other galaxies in the universe. You can find this kind of information in many places online; to ensure the reliability of your data, stick to websites managed by the National Aeronautics and Space Administration (NASA).

After your child has gathered 5–10 distances, convert the data from light-years to your chosen "everyday" unit. (For example, if your scale is one light- year equals one centimeter, then Proxima Centauri is 4.22 centimeters from the Sun.) Try to create a map of the solar system, galaxy, or even universe based on your scale. This can help your child visualize the distances between objects in a more concrete, manageable way.

Here are some questions to ask your child:

- Why are light-years more convenient than our "everyday" unit, such as kilometers, for measuring distances in space?
- How large is our solar system when using our "everyday" scale? How large is our galaxy?
- Why are we "looking into the past" when we look at stars? Explain in your own words.