

19.1 Tools of Astronomers

Frequently in the news we hear about discoveries that involve space. Since the 1970s, space probes have been sent to all of the planets in the solar system and we have seen them “up close” for the very first time. An *astronomer* is a scientist who studies objects in space. In this section, you will learn about some of the tools of astronomers.

Writing very large numbers

Scientific notation

When you look up at the night sky, do you ever think about how far away the stars are? The closest star to the Sun, Alpha Centauri, is 41,000,000,000,000 kilometers away. As you can see, trying to write out such huge distance as 41 trillion requires a lot of zeros.

Scientific notation is a mathematical abbreviation for writing very large (or very small) numbers. Numbers are written as a value between 1 and 10, multiplied times a power of 10. For example, the distance in the example above can be written as 4.1×10^{13} km.

How to use scientific notation

Earth is approximately 150,000,000 kilometers from the Sun. How do you write this value using scientific notation (Figure 19.1)? 1. Move the decimal until you get a value that is between 1 and 10. Count the number of times you move the decimal. 2. Write down the new number without all of the zeros. 3. Write $\times 10$ after the number. 4. Write the number of times you moved the decimal as the power of 10 (the *exponent*). If you moved the decimal to the left, the exponent will be positive. If you moved the decimal to the right, the exponent will be negative. The answer is 1.5×10^8 km.

Units of distance in space

What is a light year?

Astronomers have developed units other than kilometers or meters to measure the vast distances in space. You may have heard of *light years* (ly), an astronomical term. Even though the name may sound like it, this unit does not measure time. One **light year** is equal to the *distance* that light travels through space in one year.

Calculating a light year

In space, light travels at the amazing speed of about 300,000 km/s. How far will light travel in one year? We can calculate the distance light travels in one year by multiplying the speed of light (300,000 km/s) by time (1 year). To get the correct answer, we must convert years into seconds since the value for the speed of light contains seconds. There are 31,536,000 seconds in one year! Here’s how to find the distance of one light year, in kilometers:

$$\begin{aligned} 1 \text{ light year} &= \text{speed of light} \times \text{time} \\ &= 300,000 \text{ km/s} \times 31,536,000 \text{ s} \\ &= 9,460,000,000,000 \text{ km} \\ &= 9.46 \times 10^{12} \text{ km} \end{aligned}$$

Unit conversion How many light years away is Alpha Centauri, the closest star to the Sun? We already know that it is 4.1×10^{13} km away. We also know that one light year is equal to 9.46×10^{12} km. Using unit conversion, we get:

$$\frac{4.1 \times 10^{13} \text{ km}}{9.46 \times 10^{12} \text{ km}} \times \frac{1.0 \text{ ly}}{1.0 \text{ ly}} = 4.3 \text{ ly}$$

Can you see why astronomers like to use light years instead of kilometers when measuring distances to stars? Figure 19.2 shows the distances, in light years, from Earth of some objects outside of our solar system.

Studying the universe

What is the universe?

When you look up at the sky, you can see the Moon and many stars. If you watch the sky each night over a few months, you will notice that some of those “stars” change position over time and appear to wander in the sky. These are the planets of our solar system—our own small corner of the universe. The **universe** is defined as everything that exists, including all matter and energy.

Galaxies

A **galaxy** is a huge collection of gas, dust, and billions of stars. These stars are attracted to each other by gravitational force and are constantly in motion. If you look at the sky on a clear night, you can see a milky-white trail across the stars. You are looking at part of the Milky Way—the galaxy to which we belong. Our galaxy contains billions of stars! The location of the Sun in the Milky Way galaxy is shown in Figure 19.3.

Light years and time

Since most objects in space are many light years away, the light we see is as old as the number of light years the object is from Earth. The light we see from 4.3 years ago. When astronomers use a powerful telescope to view the Andromeda galaxy, they are looking back in time 2.5 million years! The farther away the object they are viewing, the further back in time they are looking. This fact has become an important tool that astronomers use to piece together how the universe began, and how it has changed over time.

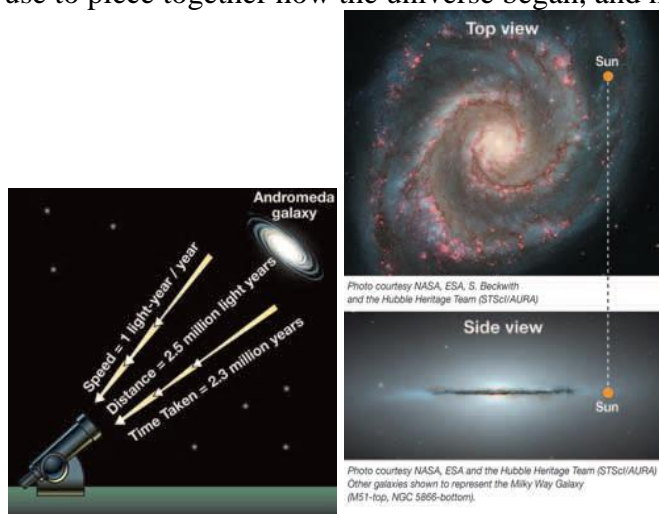


Figure 19.3: The location of the Sun in the Milky Way Galaxy

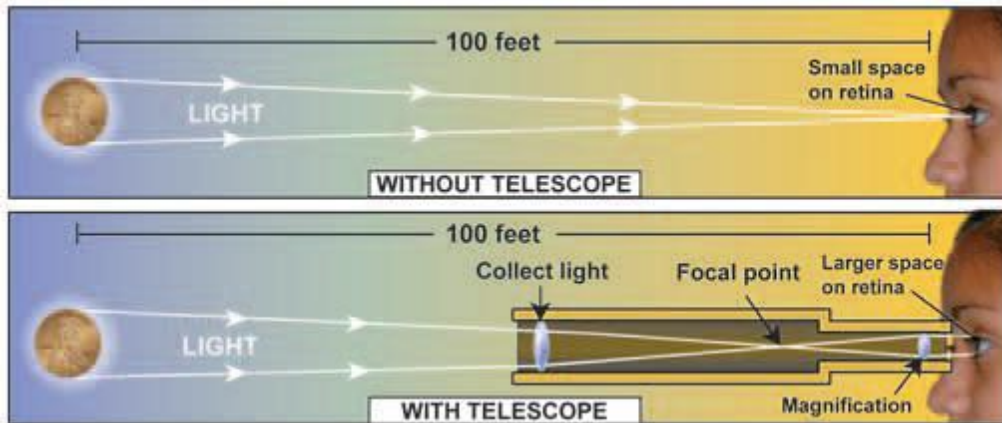
Telescopes

History of the telescope

A **telescope** is a device that makes objects that are far away appear closer. In the 1600s, Galileo was the first to use a telescope for astronomical observations. He observed craters on the Moon, tiny moons around Jupiter, and the rings of Saturn. Since then, astronomers have developed powerful telescopes that continue to add to our knowledge of the universe.

How does a telescope work?

Have you ever tried to read the writing on a penny from 100 feet away? The reason you cannot read it with your naked eye is that the image of a penny from 100 feet away does not take up much space on your retina (the screen of your eye). Telescopes work by collecting the light from a distant object with a lens or mirror and bringing that light into a concentrated point, called the *focal point*. The bright light from the focal point is then magnified by another lens so that it takes up more space on your retina. This makes the object appear much larger and closer.



Telescope milestones

3500 BC

Phoenicians discover glass while cooking on sand.

AD 1350 Craftsmen in Venice begin making lenses for spectacles.

1608 Hans Lippershey applies for a patent for the refracting telescope.

1609 Galileo is the first to use a telescope to view craters on the Moon.

1704 Newton invents the reflecting telescope.

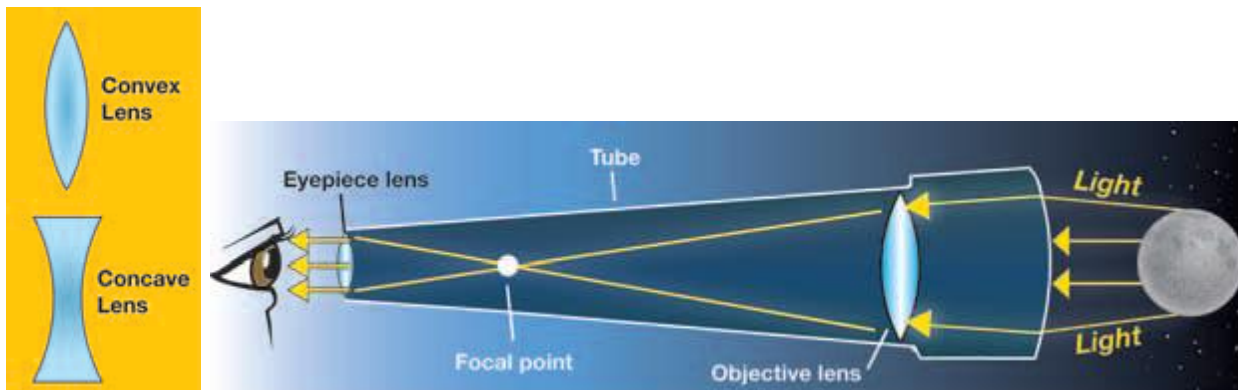
1897 World's largest refracting telescope built and housed in Yerkes Observatory, Wisconsin.

1990 The Hubble Space Telescope is launched from the space shuttle *Discovery*.

Refracting and reflecting telescopes

Refracting telescopes

A *refracting telescope* uses lenses to bend, or refract, light, making objects look bigger. Refracting telescopes are made from a long *tube*, a glass *objective lens* that you point toward the sky, and an *eyepiece lens*—another glass lens that magnifies the object. The tube holds the two lenses the correct distance from one another. The objective lens gathers light from an object, and bends it to a focal point near the back of the tube. The objective lens is *convex*, that is, wider in the middle than at the edges. The eyepiece lens magnifies the image. The eyepiece lens can be either convex or *concave* (thinner in the middle and wider at the edges). The picture below shows how light travels through a refracting telescope to your eye.



Reflecting telescopes

A *reflecting telescope* uses mirrors instead of lenses to gather and focus light. A concave mirror (called the *primary mirror*) is placed at the back of a tube. Light enters the tube and is reflected off the primary mirror to a focal point. Another small, flat mirror (called the *secondary mirror*) is placed in the path of the focal point at an angle that deflects the light to an eyepiece lens, located at the side of the tube. The eyepiece magnifies the image, just like in a refracting telescope (Figure 19.4).

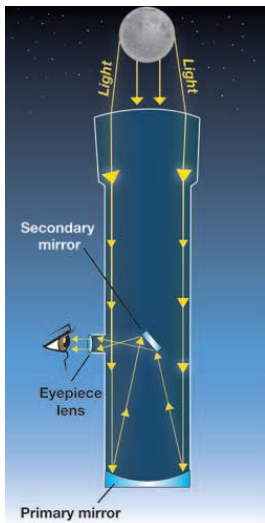


Figure 19.4: How a reflecting telescope works.

Other types of telescopes

Electromagnetic waves

Visible light is a type of *electromagnetic wave*. Objects in the universe give off many other types of electromagnetic waves that we cannot detect with our eyes. These include radio waves, infrared waves, and X-rays. Astronomers use different types of telescopes to view the different types of waves emitted by objects in space.

Radio telescopes

A *radio telescope* works like an extremely powerful receiver that picks up radio waves from space. The radio waves are analyzed by a computer, which draws an image of the source of waves. Astronomers use radio telescopes to produce images of stars and galaxies, analyze the chemical composition of objects, and map the surfaces of planets. Figure 19.5 shows an image of the Crab Nebula (the remnants of an exploded star) taken by a radio telescope.

Infrared telescopes

Another type of telescope looks at infrared waves. Since this type of wave is mostly absorbed by Earth's atmosphere, *infrared telescopes* are often placed on satellites that orbit Earth. In 1983, the Infrared Astronomical Satellite (IRAS) was launched to map the entire sky at infrared wavelengths. It discovered a new comet, found evidence of another solar system, and discovered a new type of galaxy. Figure 19.6 shows an image of the Crab Nebula captured by IRAS.

X-ray telescopes *X-ray telescopes* are designed to detect high-energy radiation (X-rays) from space. Since these waves cannot penetrate our atmosphere, X-ray telescopes are always placed on satellites. One of the most powerful, NASA's Chandra X-ray Observatory, was launched on the space shuttle *Columbia* in 1999. Its mission is to observe X-rays that are emitted by high-energy objects in the universe such as stars that have exploded. Figure 19.7 shows an image of the Crab Nebula captured by Chandra.

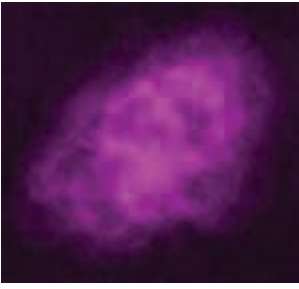


Figure 19.5: *An image of the Crab Nebula taken by a radio telescope (Photo courtesy Very Large Array/National Radio Astronomy Observatory).*

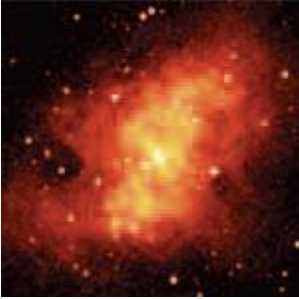


Figure 19.6: *An image of the Crab Nebula taken by an infrared telescope (Photo courtesy NASA/IRAS).*

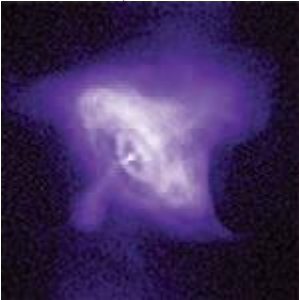


Figure 19.7: *An image of the Crab Nebula captured by an X-ray telescope (Photo courtesy NASA/Chandra).*

19.1 Section Review

1. Convert the following values to scientific notation.

- The distance around Earth's equator is 40,076 km.
- The Moon is 384,400 km from Earth.
- Earth is 4,600,000,000 years old.

2. Why do scientists use scientific notation?

3. Convert the following values into regular numbers.

- 1.5×10^{13} km
- 4.8×10^4 km
- 9.46×10^{12} kilometers in a light year

4. What is a light year? Why do astronomers use light years instead of kilometers to describe distances outside of the solar system?

5. List the following terms in order from smallest to largest: galaxy, solar system, universe.

6. What is the universe?

7. What is a telescope? How does a telescope work?

8. Explain the major difference between a refracting telescope and a reflecting telescope.

9. Regulus, the brightest star in the constellation Leo, is approximately 77 light years from Earth. Which year did Regulus give off the light you see when you look at the star today?

10. Name three types of electromagnetic waves.

11. List three types of telescopes that do not view objects using visible light.