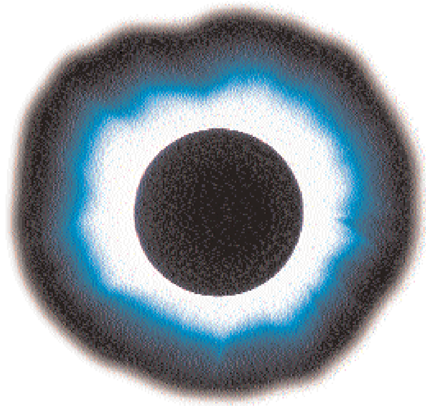
CHAPTER

14

The Nature of the Universe

Getting Started



1 Darkness in the middle of the day is an eerie sensation. Before people understood solar eclipses, this phenomenon was associated with bad luck, a message from the gods, or even a warning of the end of the world. Although we now know that a solar eclipse is caused by the Moon passing between Earth and the Sun, it is still an exciting and fascinating event. Observing a solar eclipse also helps astronomers learn about properties of the Sun, and stars in general. What do you notice when you look at this image of a solar eclipse? Do all the stars, including our Sun, have the same properties?

2 Every 10 or 11 years Earth's communication systems may be disrupted. This happens just after violent storms occur on the surface of the Sun. We know that the Sun gives us light and heat, but how else does it affect Earth? We can learn a lot about the Sun, and other stars, by observing effects of the Sun on Earth's atmosphere. Is there a change in the environmental impact of the Sun on Earth? What can you judge by looking at the photo shown here?

3 You have learned about the solar system, and stars and constellations. Are there other objects in space? What do you think the image here shows? How far away is it? How was it taken? What can you predict about the motion of what is shown in the image?

Reflecting

Think about the questions in 1, 2, 3. What ideas do you already have? What other questions do you have about the nature of the universe? Think about your answers and questions as you read the chapter.

Try This: Using Angles to Estimate Distances

An important concept you will explore in this chapter is how vast the distances are in the universe. You will discover how astronomers measure those distances by comparing the apparent position of an object viewed from two different places. In this activity you can model how they measure large distances.

- Choose a partner and obtain a metre stick. Stand as far as you can from one of the walls in your classroom. Cover one eye with one hand, then stretch out the other arm and hold your index finger up so it hides an object on a distant wall (**Figure 1**). Use the metre stick to carefully measure the distance from your finger to your eye.
- Holding your finger still, cover your other eye. Notice what object your finger now hides. Determine the angle between the first and second objects hidden. (Use the hand method from Activity 13.5.)
- How does the angle between the two objects depend on the distance between your finger and your eye? Plan steps to answer the question. Will you need to make any other measurements? Then carry out the steps, record your observations, and communicate your discoveries using a diagram, table, graph, and/or spreadsheet.

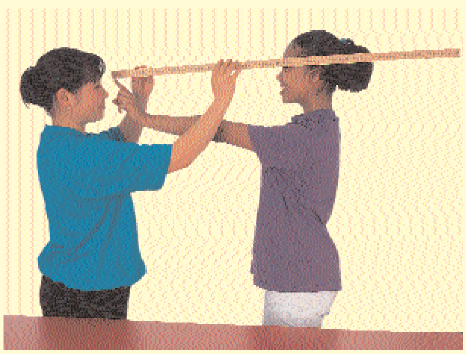


Figure 1
When your hand covers one eye and then the other, the position of the index finger shifts against the background.

Changing Ideas About the Universe

Movies about aliens from space or wars in far-away galaxies are more popular than ever. It seems that many people like to fantasize about what exists in the rest of the universe. Hollywood movies are an expression of our fascination with what is "out there."

People in ancient times didn't make science fiction movies, but they were still fascinated by the universe. Their beliefs and religious ceremonies reflected their ideas of what they thought the universe was like. These people left behind traditions, structures, and writings that give us clues about how they perceived the night sky.

In this section, you will learn how and why ideas about the universe have changed.

Ancient Ideas

Imagine that you are on a spinning merry-go-round. Your friends standing on the ground look as if they are moving in the opposite direction. Now imagine slowing the rate of spinning so that one rotation takes 24 h. At that speed, it would be difficult for you to judge whether it was the ride or the ground moving. Earth certainly seems to be stationary so, in ancient times, people thought everything else moved around it.

Everything in the sky appeared to be in motion. The Sun, Moon, stars, and planets all seemed to rise in the east and set in the west. One early idea about the stars was that they were attached to a large ball that revolved around Earth once every day. People thought that the stars were only slightly farther away than the Sun, Moon, and the planets they could see. In **Figure 1**, you can see one possible arrangement of the universe. This idea is called the **Earth-centred universe**.

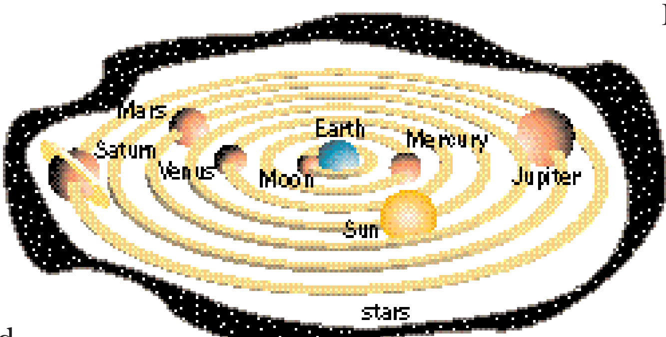


Figure 1
Many people in ancient times thought that Earth was the centre of the universe and that all the other objects revolved around it.

Improvements in Making Observations

The Earth-centred idea of the universe was popular for thousands of years. Then, around 500 years ago, some scientists began to question this idea. Scientific ideas were starting to change for two major reasons: the invention of the telescope and the fact that scientists began experimenting to learn more about nature, Earth, and the universe.

The telescope was invented in Europe in the early 1600s. The great Italian scientist Galileo Galilei improved upon the invention and was the first person to use it to view the night sky. His first telescopes made distant objects look seven to thirty times larger than normal. He saw that the planets were not merely points of light: they were circular, like the Moon. The stars, however, still appeared as points of light. From these observations, Galileo inferred that the stars must be much farther from Earth than the planets. The universe was clearly much bigger than was previously thought.

Before Galileo had discovered how different the sky looked through a telescope, other scientists had begun to question the Earth-centred view of the universe. For example, in the mid-1500s, Copernicus had presented mathematical evidence that the planets all orbit the Sun. Galileo's discoveries, especially his observation that Venus has phases like the Moon, supported the new theories. Galileo became convinced that Earth and other planets travel around the Sun. Persuading other people to accept his theory was difficult and sometimes dangerous work. The predominant view in Europe at the time was that Earth, made by God, was the centre of the universe. Anyone who challenged this idea was considered "heretical" (against the Christian Church) and was even threatened with torture. These threats forced Galileo to deny his findings that Earth travels around the Sun. Eventually, however, despite religious persecution, the idea of the **Sun-centred solar system** replaced the Earth-centred view (**Figure 2**).

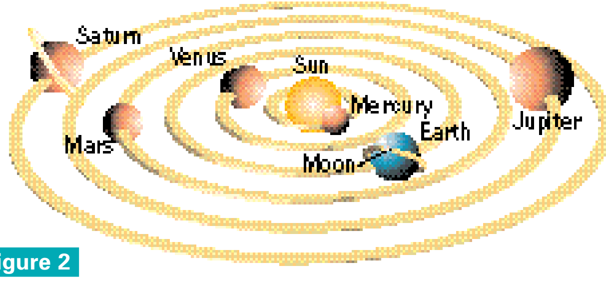


Figure 2

This is the Sun-centred view of the solar system of about 400 years ago. Compare this model with Figure 1. Which planets are not shown? Why not?

Today's Ideas

Nearly 400 years have passed since the invention of the telescope. In that time other inventions have led to many new discoveries about the universe. We now know that the planets orbit the Sun and that the Sun is just one of countless stars. Astronomers have observed that the Sun and other stars are also moving. Stars are gathered in large groups, surrounded by gas and dust. The group of stars that our Sun belongs to is called the Milky Way Galaxy. A **galaxy** is a huge collection of gas, dust, and hundreds of billions of stars and planets.

Modern telescopes show us that there is a vast region beyond the Milky Way Galaxy that appears to be almost empty. Far off in the distance there are countless more galaxies and other fascinating objects (**Figure 3**).

Our knowledge of the universe is always increasing as scientists develop new tools that let astronomers see farther into the distance. For instance, by detecting radiation that may have taken millions of years to reach Earth, they are able to learn about the early history of the universe.

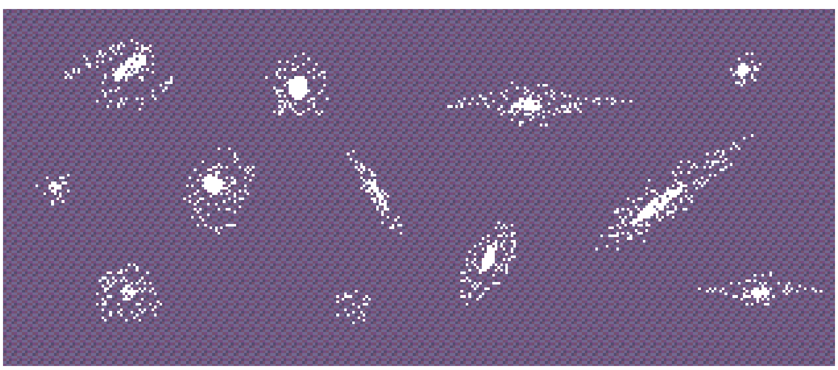


Figure 3

The universe contains huge groups of stars, called galaxies, separated by vast distances. The galaxies and everything in them are constantly in motion.

Understanding Concepts

1. **(a)** What does the expression "Earth-centred universe" mean?
   (b) What evidence helped scientists change their ideas about an Earth-centred universe?
2. How and why has our estimate of the size of the universe changed in the past few centuries?
3. **(a)** What is a galaxy?
   (b) What is our galaxy called?

Making Connections

4. Describe how "new" technology in Galileo's time helped to change an established idea. What societal effects were related to the change?

Exploring

5. 3A Research how one of the following scientists contributed to the development of ideas about the universe: Nicholas Copernicus; Tycho Brahe; Johannes Kepler; Isaac Newton. Create a written report or an audio-visual presentation.

Reflecting

6. The Earth-centred view was replaced by the Sun-centred view of the solar system. How does this illustrate the process of science?

14.2 Explore an Issue

Who Owns the Solar System?

The human race has a long history of exploration, colonization, and exploitation. From Stone Age migrations across the Bering Strait to 20th-century forays into the jungles of South America, we have set out to see what we can find and what we can make use of. Most of Earth's surface has now been explored, charted, and investigated with a view to extracting valuable resources. More recently, humans have visited Earth's Moon and sent space probes to explore outer space objects such as comets, asteroids, and other planets and their moons. These explorations have shown scientists that there may be many valuable resources on several of these objects. Mars is rich in iron oxide, which could yield both iron and oxygen, and Jupiter's moon Ganymede appears to contain hydrogen peroxide. Other outer space objects are quite likely to contain other useful substances. An additional advantage of mining a low-gravity object is that it would be easier to lift extracted resources up, into outer space, than it would be from Earth. This has potential implications for the construction of future space stations.

Some people suggest that colonies and mines could indeed be built on such bodies as Mars, our Moon, or a few other moons or large asteroids. But who owns outer space objects? Should ownership rights be awarded on a "first-come, first-served" basis? If colonies are set up, who should live in them? Who would benefit from the existence of the colonies? Who owns any resources that are mined on other bodies? Would it be a case of the rich countries getting richer, and the poorer countries having no chance of participating? What about the environmental aspect? In many instances we have not shown that we can responsibly manage Earth's resources. Do we have any right to export our mismanagement? It has been suggested that this is a way to ease the pressure of a rapidly increasing population here on Earth. Is this a valid reason? If we were to find any form of extraterrestrial life, would our decisions be altered? These questions should be discussed before such expensive projects begin.

Issue A Moratorium on Extraterrestrial Mining 8B

"We should learn to manage Earth's resources better, before exploiting extraterrestrial resources."

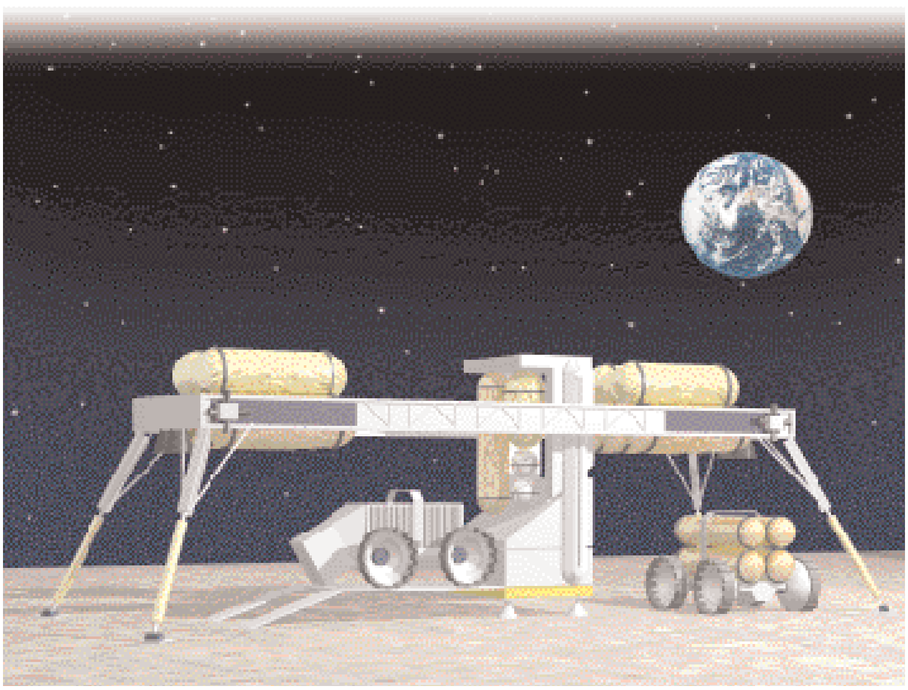
Imagine that you have been asked to participate in a panel discussion, either supporting or opposing the statement above. You might be a mining engineer, an investor, an unemployed miner, an astronomer, a lawyer, an environmentalist, a social worker, a space engineer, or anyone else who might have an opinion in the discussion. Choose your position and support it by developing a three- to five-minute presentation. Refer to the ideas below and add some more of your own. 8C

Point

- There are many untapped resources here on Earth. If we were to use and recycle them more efficiently, we would have no need of space mining.
- The cost of the technology to exploit space resources is far too high. The money would be better spent improving efficiencies on Earth.
- We have no right to take resources from outer space objects. They do not belong to us.

Counterpoint

- Using resources from outer space objects would reduce our dependence on Earth resources.
- By having resource extraction facilities set up in space, we would have bases for refuelling and manufacturing, which would make further space exploration much more economical.



Challenge

What issues presented in the panel discussion do you need to consider when participating in any endeavour involving space exploration?

Using Triangles to Measure Distances

We know that the Moon is closer to us than the Sun, and that the planets are closer than the stars. How do we know this? Because of their movements relative to each other: the stars form an almost unchanging backdrop for the wandering planets. But just how far away are these objects? How can we measure such vast distances? Try using only one eye to judge how far away something is. It is not as easy as using two eyes to judge distances. The reason is that the lines of sight from your eyes form an angle where they meet an object, and the size of the angle helps you judge distances. You may have noticed this when you did the Getting Started activity on page 437.

In this activity you will measure distances using an indirect method. You will measure angles between a baseline and the object, and draw a scale diagram to calculate the distance to the object. This indirect method of measuring the distance to an object using geometry is called **triangulation**. The more carefully you draw the triangles, the more accurate your answers will be.

Materials

- astrolabe designed in Activity 13.5 (with the string attached but the rubber stopper removed)
- metre stick
- paper
- small protractor
- centimetre ruler

Procedure

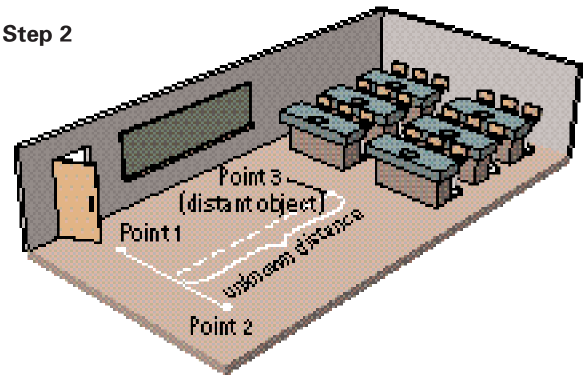
1 Your teacher will suggest an unknown distance that you will measure in the classroom. (For example, the distance could be from one wall to a door hinge on the opposite wall.) Use your eyes (and experience) to estimate the distance.

(a) Record your estimate.

2 6B Mark off two points, Point 1 and Point 2, that are at least 5 m apart, and use the metre stick to measure the distance. This distance is called the triangle baseline.

(a) Record the length of the baseline.

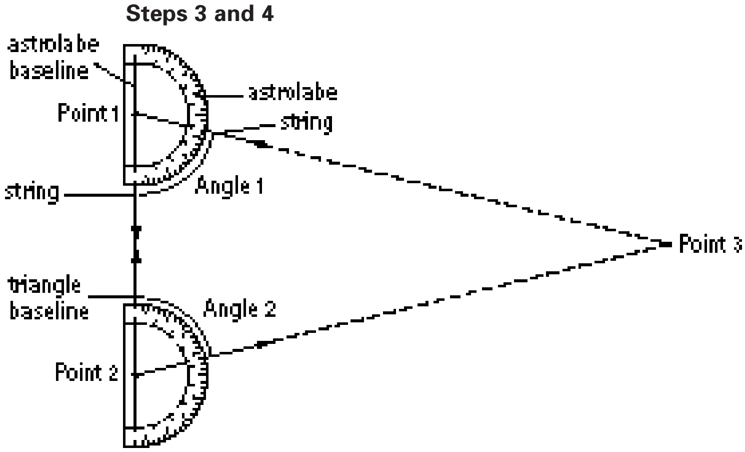
Step 2



3 Have one student stand at Point 1 holding the astrolabe horizontally, so that its baseline lines up with the triangle baseline. Another student should use the string to be sure this is as straight as possible. While one student holds the astrolabe still, another student should move the string around until it lines up with the distant object, Point 3. Measure the angle formed, Angle 1.

(a) Record the value of Angle 1.

Steps 3 and 4



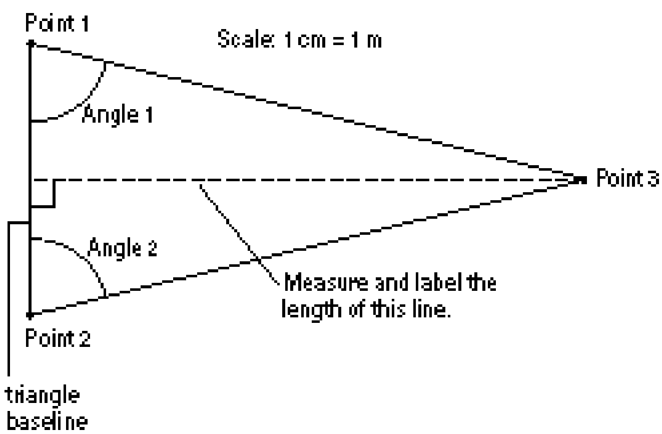
4 Repeat step 3 from Point 2.

(a) Record the value of Angle 2.

5 On a piece of paper, use the centimetre ruler to draw a diagram of your experiment. Choose an appropriate scale so that the triangle baseline will be at least 5 cm long. Label Points 1 and 2. Use a small protractor to draw Angles 1 and 2.

6 From Points 1 and 2, draw straight lines that meet at Point 3. Finally, draw a straight line from Point 3 back to the triangle baseline. (Try to make this line meet the baseline at a 90° angle.) Measure the distance from the baseline to Point 3. Label all the points and distances on your diagram.

Steps 5 and 6



7 (2A) Design your own investigation to measure large distances indirectly, either outdoors or in an appropriate area inside the school. After your teacher approves your design, carry out the investigation.

Understanding Concepts

1. Why is the method of finding distances in this investigation called an indirect method?

2. Do you think that measurements in this investigation would be more accurate with large baselines or smaller ones? Why?

3. Draw two diagrams to show the lines of sight from your eyes to an object that is near, then to one that is farther away. (Your two eyes form a baseline.) How do the angles in your diagrams relate to your ability to judge distances?

4 How could triangulation be used to find out the distance from Earth to a neighbouring star?

Exploring

5. The widely spaced eyes of hawks, eagles, and other birds of prey enable them to judge distances very well. Explain, with the aid of a diagram, why this is so.

6. Astronomers call their way of using triangulation to measure distances "parallax." Look up parallax in an astronomy reference book or other source and describe how it relates to the method you learned in this activity.

7. Use direct measurements to find out the true value of your group's measurements. Use the following equation to determine the percent error of each of your indirect measurements.

$$\%\text{ error} = \frac{\left|\text{indirect measurement} - \text{direct measurement}\right|}{\text{direct measurement}} \times 100\%$$

Reflecting

8. In Chapter 13 you learned how to use fists and fingers to measure angles. Could fists and fingers be used to measure distances indirectly as you did in this activity? Explain your answer.

9. How does the method of triangulation relate to what you discovered in the Getting Started activity on page 437?

14.4

Distances in Space

Using Scientific Notation

Distances in space are very large, so measurements written out in kilometres can become long. Scientific notation is a mathematical abbreviation for writing very large or small numbers. Using this notation, a number is written with a digit between 1 and 9 before the decimal, followed by a power of 10. That is why Canada's population of 32 million could be written as 3.2×10^7 instead of 32 000 000. The exponent, in this case 7, indicates the number of places you have to move the decimal point.

Using Long Baseline Measurements

A surveyor trying to measure the distance across a raging river can use the indirect method of triangulation. Astronomers can apply the same method to measure distances to objects in the solar system and beyond. To measure large distances with as much accuracy as possible, they use the largest baselines available.

How can scientists obtain long baselines to measure the huge distances to stars? One way to obtain a large baseline is to use diameter of Earth, about 1.3×10^4 (**Figure 1**). This method could be used to determine the distance to the Moon or a nearby planet.

What is the largest possible baseline available to observers on Earth? It is the diameter of Earth's orbit, a distance of about 3.0×10^8 km (**Figure 2**). This baseline has been used to calculate the distances to some of the stars nearest to our solar system.

Distances to the Stars

The distance from our Sun to the next nearest star that you can see without using a telescope or binoculars is about 4.1×10^{13} km. This star is called Alpha Centauri. Most other distances in space are much greater than this. To avoid using such huge numbers, scientists have developed units of distance other than kilometres or metres.

One common unit used to measure large distances is the light-year. One **light-year** is the distance that light travels in one year. Light

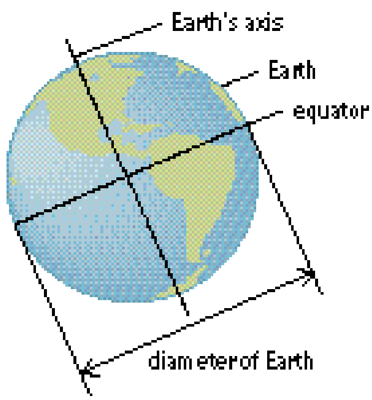


Figure 1
One example of a long baseline is the diameter of Earth at the equator. Because Earth rotates on its axis, it takes 12 h for an observer to move from one side of Earth to the other.

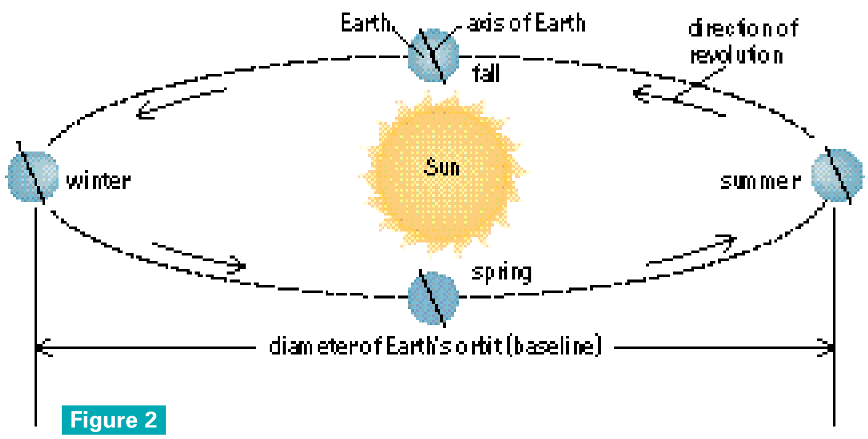


Figure 2
The largest baseline available to observers on Earth is the diameter of Earth's orbit. As it takes a year for one complete orbit, angles to the stars are measured six months apart.

travels at an enormous speed in space, about 300 000 km/s. So in one year it can travel about 9.46×10^{12} km*. Thus, the distance to Alpha Centauri, given above, is equal to 4.3 light-years. (You can prove this by dividing the distance to Alpha Centauri by the distance light travels per year.) **Table 1** lists examples of distances measured in light-years. Notice that all the stars named are different distances from Earth. This is true even for stars in the same constellation. For example, Betelgeuse and Rigel are both in the constellation Orion, but their distances from Earth are quite different.

One interesting fact about light-years is that they tell us how far back we are looking in time: the light from Alpha Centauri that we might see tonight actually left Alpha Centauri 4.3 years ago. Whatever we view on Alpha Centauri *now* has already happened! By looking at stars thousands or even billions of light-years away, astronomers can look back in time and see what the universe was like when it was much younger. Measurements in light-years tell us not only how far away an object is, but also how much time has passed since the light we see left that object.

Table 1 Some Distances of Objects from Earth

Star or object	Approximate distance (light-years)
Alpha Centauri	4.3
Sirius (brightest star in the sky)	8.8
Vega	26
Arcturus	36
Betelgeuse	700
Rigel	900
Deneb	1400
Most-distant known galaxy in the universe	15 000 000 000

*distance = speed × time
= (300 000 km/s) (1 year × 365 d/year × 24 h/d × 3600 s/h)
= 9 460 000 000 000 km or 9.46×10^{12} km

Understanding Concepts

1. Why is the length of the baseline important when you use triangulation to measure distances?
2. A surveyor (**Figure 3**) measures off a baseline of 120 m along the shore of a river. He then measures the angle from each end of the baseline to a rock on the opposite shore. The two angles that he measures from the baseline to the rock are 65° and 50°. Draw a scale diagram to determine the width of the river.

Figure 3
A surveyor measures angles with an instrument called a transit theodolite. Why do surveyors need to measure exact angles and distances?

3. **(a)** Describe the longest baseline possible on Earth.
   (b) How much time passes between the measurement of angles using the baseline you suggested in (a)?
4. What is the difference between a year and a light-year?
5. Determine the distances listed in **Table 1** in kilometres and write the final answers using scientific notation. 7C

Exploring

6. Design a way to use a triangle method to measure the height of a wall or tree indirectly. Try your method and draw a scale diagram to show your calculations.

Scaling the Universe

About how much time do you think it would take to
- drive a car across Canada?
- fly around the world in an airplane?
- travel from Earth to the Moon in a spacecraft?
- travel from Earth to the Andromeda Galaxy in a spacecraft?

Although many people may think of travelling far away in space, they first must find out how long the distances are. This activity will give you an idea of how tiny our Earth is compared with the entire universe.

The distances between different objects in the universe are given different names. Distances between planets in the solar system are called interplanetary distances (*inter* is the Latin word meaning "between"). Distances between the stars are called interstellar distances (*stellar* refers to stars). And distances that separate the galaxies are intergalactic distances (*galactic* refers to galaxies).

As you have learned, large distances in space are often measured in light-years. (Recall that a light-year is the distance light travels in one year, at a speed of 300 000 km/s. Thus, a light-year is a distance of about 9.46×10^{12} km.) In this activity, you will use a model of the light-year to help you understand the vastness of the universe. To make your calculations easier, always round off your answers to easy numbers, such as 10, 100, 1000, and so on.

Materials

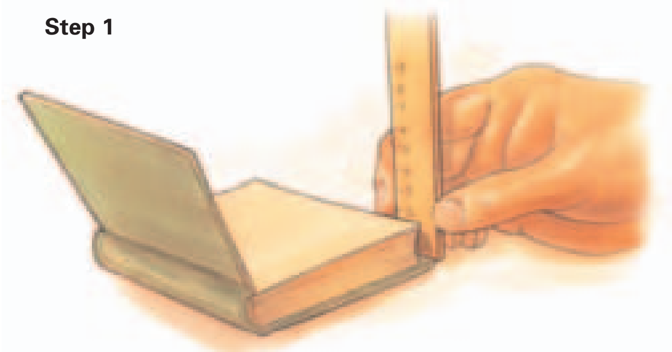
- this textbook
- ruler or metre stick with millimetre and centimetre divisions
- calculator

Did You Know ?

If the space shuttle could travel in a straight line for a year at its average cruising speed, it would travel 2.5×10^8 km. Light travels 9.46×10^{12} km in a year: more than 30 000 times farther!

Procedure

1 Count out 50 sheets of paper in your textbook. Measure the thickness of those 50 sheets together in millimetres. Use your measurement to calculate the approximate number of sheets of paper per millimetre (sheets/mm). You will need this number in the next two steps, so before going on, check with your teacher to be sure that your calculation is reasonable.



(a) Record your measurement and calculation.

2 Repeat this two more times.

(a) Record your measurements.

(b) Calculate a mean value of your results. Remember to include the units.

3 Assuming that the thickness of one sheet of paper represents a distance of one light-year, determine the number of light-years in: 1 mm; 1 cm; 1 m; 1 km; 1000 km; 2000 km (the approximate distance from Montreal to Winnipeg as shown in **Figure 1**).

(a) Record your answers.

4 Copy the first three columns of **Table 1** into your notebook and complete the required information.

(a) Write the actual distance in kilometres using scientific notation. 7C

SKILLS HANDBOOK: 7C Using Math in Science

Table 1 **Sample Distances**

Model distance	Number of sheets thick (or actual distance in light-years)	Actual distance (km)	Example of distance in the universe
0.1 mm	?	?	maximum distance of some comets from the Sun
0.4 mm	?	?	approximate distance from the Sun to the nearest star (Alpha Centauri)
thickness of two pennies (almost 3 mm)	?	?	approximate distance to the star Vega
approximate length of an adult's thumb (7 cm)	?	?	distance to the star Betelgeuse
height of a wall in a home (2.5 m)	?	?	distance from Earth to the centre of the Milky Way Galaxy
length of a science classroom (10 m)	?	?	diameter of the Milky Way Galaxy
length of two football fields (200 m)	?	?	distance to the Andromeda Galaxy
30 km	?	?	distance to the Coma cluster of galaxies
Montreal to Winnipeg (about 2000 km)	?	?	estimated size of the entire universe

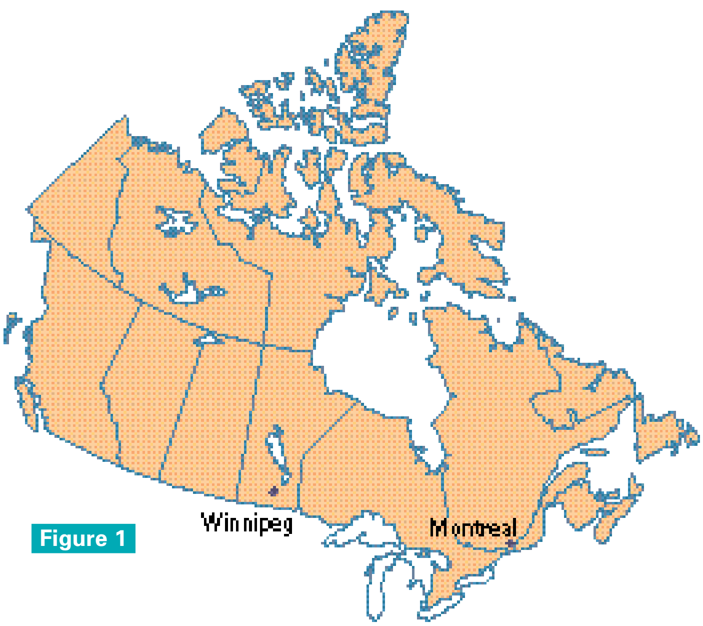


Figure 1

Understanding Concepts

1. Do you think the size of Earth's orbit around the Sun could be shown in a model of the universe, using the scale in this activity? Explain your answer.

2. Using **Table 1**, state an example of (a) an intergalactic distance and (b) an interstellar distance.

3. Why are interplanetary distances usually not stated in light-years?

Making Connections

4. Based on what you have learned in this activity, do you think it would be possible for humans to ever travel to (a) Mars, (b) the moons of Jupiter, (c) Alpha Centauri, or (d) the Andromeda Galaxy? Give reasons for your answers.

Reflecting

5. In studying distances and sizes in astronomy, it is important to develop skills in designing models. How do you think the model of distances suggested in this activity could be improved?

Challenge

How would you help audiences at the planetarium understand the different distances related to the universe? How would you alter the explanation for a young audience?

14.6

Telescopes

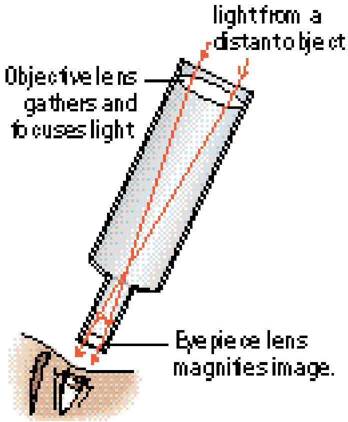
We can learn about space beyond Earth by looking at images of planets, stars, and other objects in the universe. If you were to compare the images in this textbook with the images in astronomy books published even a few years ago, you would discover that we can now see objects it was not possible to see then. We can now see better and farther than ever before.

Using Telescopes

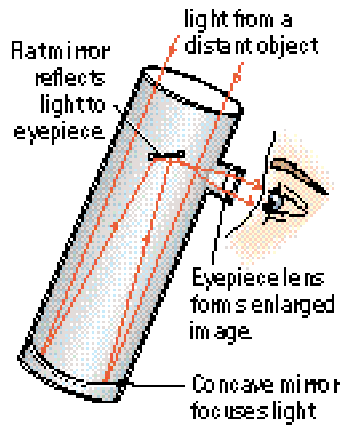
Telescopes may cost from a few hundred dollars to hundreds of millions of dollars. From Galileo's first astronomical telescope to the most sophisticated instruments now orbiting Earth, the main purpose of a telescope is to gather light. The light forms an image that can be seen or recorded using cameras or other devices. The design of optical telescopes has changed little over the years, but they are being constructed larger and more powerful than ever before. **Figure 1** shows different types and locations of telescopes. What might be their advantages and disadvantages?

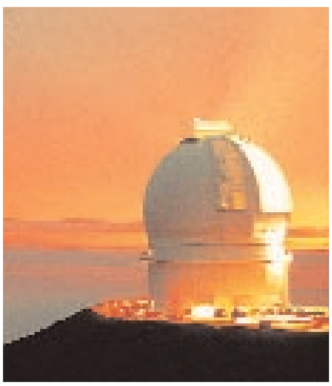
Figure 1

a In a **refracting telescope**, light rays refract (bend) as they pass through a light-gathering lens, called the objective lens. Unfortunately, there is a limit to how big objective lenses can be built. When the lenses reach about 1 m in diameter, the glass becomes too heavy, sags under its own weight, and distorts the image. Galileo developed the first refracting telescope in the early 1600s. Through it he could see that the planets are spheres, not just points of light.

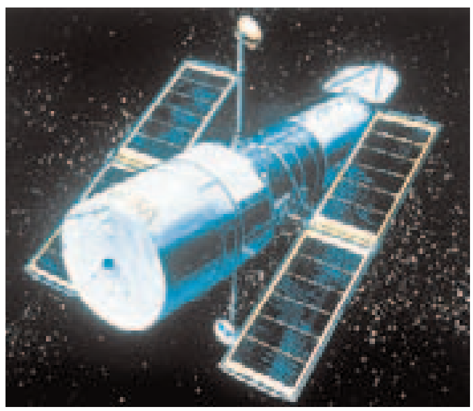


b A **reflecting telescope**, first constructed by Isaac Newton in 1668, uses a concave mirror to gather light. Such a mirror can be supported from underneath, so it can be built much larger than the objective lens in a refracting telescope. Large reflecting telescopes were used in the early 1800s to investigate nebulas.





c The biggest reflecting telescopes are located in **observatories**, which are large buildings with opening domes. Many observatories, such as the Canada-France-Hawaii observatory in Hawaii, shown here, are built on the tops of mountains. There are no city lights and the atmosphere is thin and steady. The thin atmosphere is helpful because it absorbs and scatters less light than the denser atmosphere at lower altitudes. Clearer views led astronomers to the discovery that there are other galaxies, besides our own.



d An expensive but successful way of overcoming the problem of Earth's atmosphere is to place the telescope into orbit around Earth. The Hubble Space Telescope, shown here, was put into Earth orbit in 1990. Its reflecting telescope can obtain a much more detailed view of distant objects and see much farther away than ground-based telescopes. The Hubble Space Telescope is shown in Figure 2 on page 483, and one of its famous images is featured on page 480.

Looking through a telescope at objects in the sky can be rewarding and informative. However, astronomers use another way to obtain detailed permanent images of objects in the sky. They attach an instrument, such as a digital camera, to the telescope. As the telescope follows the object across the sky, gathering light for minutes or hours or even days, more details are captured. Because the camera gathers more light from the object over time, the resulting images show stars and galaxies too faint to be seen with our eyes alone (**Figure 2**).

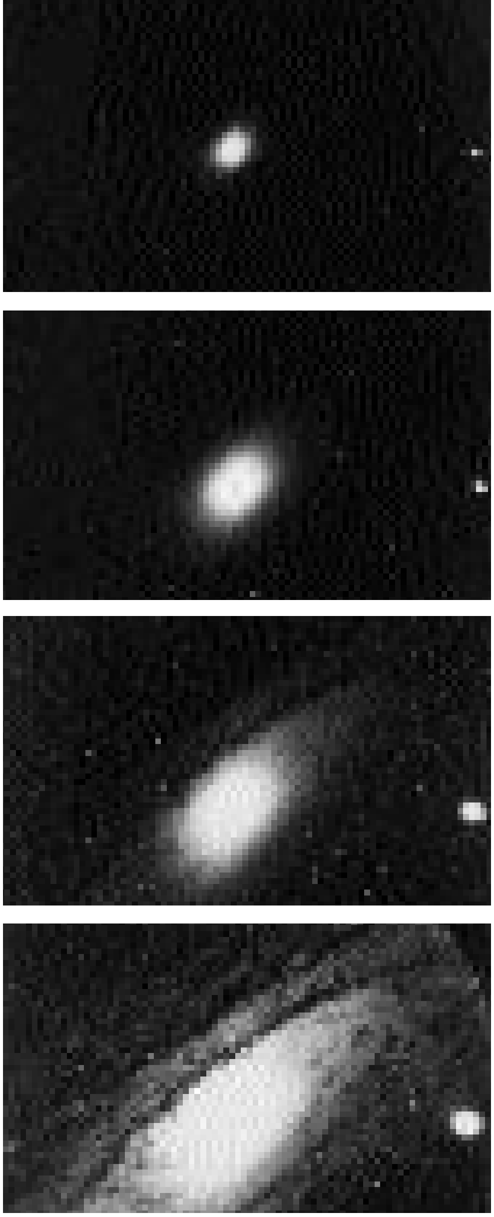


Figure 2
These views of the same object show how the amount of detail increases as the time that the camera gathers light increases. In order from top to bottom, these images show light-gathering times of 1, 5, 30, and 45 min.

Using Invisible Energies

What do you do when you want to receive radio signals sent out by a radio station? You simply tune your radio to receive them. What do astronomers do when they want to receive the radio waves sent out by some star or other object in the sky? They aim a radio receiver toward the object and try tuning the receiver until it receives waves from space.

Radio waves belong to a broad band of energies called the **electromagnetic spectrum**. This spectrum consists of radio waves, microwaves, infrared rays (heat), visible light, ultraviolet rays, X rays, and gamma rays. These types of energy are emitted (given off) by stars, galaxies, and other objects in the universe. These waves all travel at the speed of light in a vacuum, and they have energies that become greater as their wavelengths become smaller. Studying these types of energy helps astronomers understand more about the universe.

A device that receives radio waves from space is called a **radio telescope**. It is able to detect radio waves that are emitted by stars and galaxies. A radio telescope can work even on cloudy days because radio waves can pass through Earth's atmosphere, including clouds, very easily.

Radio telescopes often look like giant satellite dishes. The dish part, which may be made of wire mesh, reflects the radio waves to a collector held just in front of the dish. The radio telescope shown in **Figure 3** is the largest single radio telescope in the world, measuring more than 300 m in diameter. It was made by placing a concave wire mesh in a valley in the mountains. This radio telescope receives radio signals from many different parts of the universe, day and night, as Earth rotates.

Figure 3
The Arecibo radio telescope is built into the mountains of Puerto Rico. What is the triangular structure just above the "dish"?

Figure 4

An array of radio telescopes produces the same results as a much larger single radio telescope.

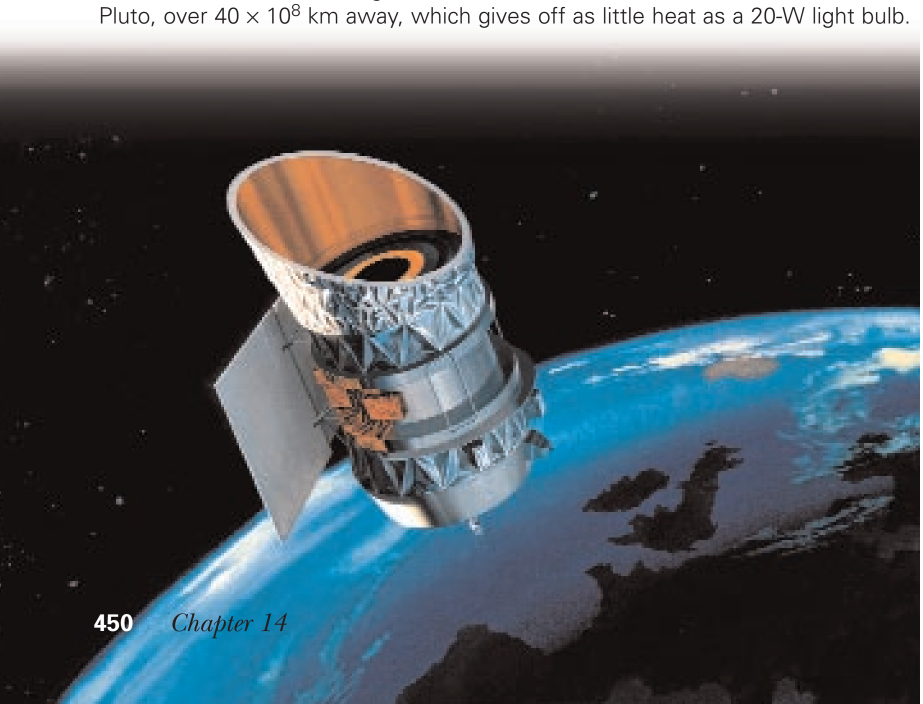
Radio telescopes can also be made to work together in sets called arrays. **Figure 4** shows an array of radio telescopes in New Mexico, linked together to produce the same results as a much larger radio telescope. Radio signals collected over a period of time are combined, using a computer, into a map of objects in the sky.

Some parts of the electromagnetic spectrum are absorbed by Earth's atmosphere, so they cannot be detected from the surface of Earth. To overcome this problem, scientists use satellites that are put into orbit above the atmosphere. One example of such a satellite is the Infrared Astronomical Satellite (IRAS), which can detect objects in space that emit very tiny amounts of heat (**Figure 5**). Launched in 1983, the IRAS made some exciting discoveries, including evidence that planets may be forming around nearby stars.

Canada is involved in the planning for a new orbiting telescope scheduled for launch in 2007: the Next Generation Space Telescope. It will have much greater sensitivity to infrared radiation than existing telescopes, allowing astronomers to look even farther back in time.

Figure 5

The IRAS is sensitive enough to detect infrared (heat) radiation from a source on Pluto, over 40×10^8 km away, which gives off as little heat as a 20-W light bulb.



Understanding Concepts

1. What is the purpose of a telescope?
2. Describe the similarities and differences between refracting and reflecting telescopes. Include a diagram.
3. **(a)** Why is Earth's atmosphere a problem for astronomers? Include a diagram.
   (b) Where would you build an observatory to overcome this problem?
4. Large astronomical telescopes are usually used together with digital cameras or other electronic instruments, and astronomers seldom look through such telescopes directly. Suggest reasons for this.

Making Connections

5. Write a brief description of how improvements in technology have altered our view of the universe.
6. Predict how future technological developments might bring new discoveries.

Challenge

Research Canada's role in the development of the Next Generation Space Telescope. Include the results in your information package.

Career Profile

Space-Age Communicator

How do you get from Amherstburg, a small Ontario town, to the Jet Propulsion Laboratory in Pasadena, California? Science journalist Ivan Semeniuk knows; he's made the journey.

At the age of eight, he visited a planetarium and was hooked on astronomy. He eventually joined the Royal Astronomical Society of Canada and, as a camp counsellor in Haliburton, Ontario, enjoyed exploring the night sky far from the city lights, and also teaching others about his favourite pastime. "It is not surprising I loved communicating," says Semeniuk. "I like writing and I did well in English at school. In high school, my English teacher was probably disappointed when I decided to pursue science."

In 1986, he got his first break: the job of running the planetarium at the Ontario Science Centre. "It was a natural fit for me because the Centre is involved in the public communication of science," he says. "I got to do it all, from writing scripts to tracking down the latest astronomical images."

By 1994, the Internet was allowing Semeniuk to make his planetarium as current as the evening news. "You can download images and communicate with experts easily. When Comet Shoemaker-Levy slammed into the planet Jupiter, the Internet allowed me to have images of the first impact in the show before the last piece of the comet had even hit the planet," he recalls.

Semeniuk writes for *Sky News*, a Canadian astronomy magazine and reports on astronomy for Discovery Channel.

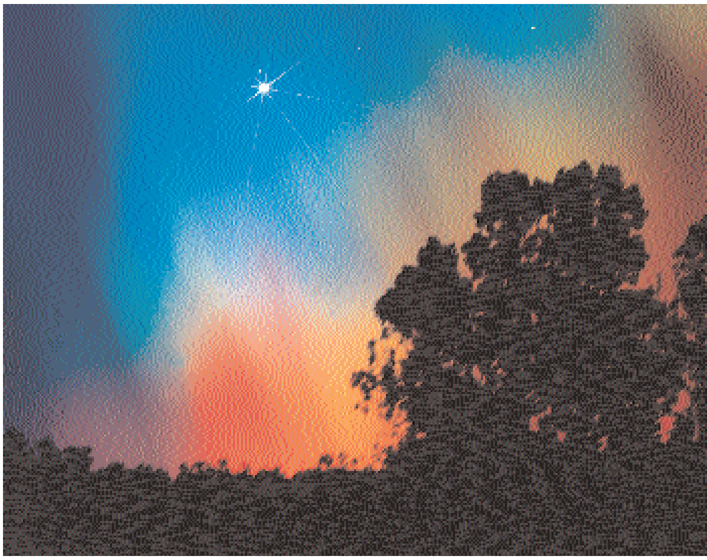
To develop his abilities further, Semeniuk decided to return to school to train as a science journalist. He learned to access and synthesize large amounts of information into stories that would interest readers and viewers.

Ivan Semeniuk continues to reach people through his writing and broadcasting, and through his work at the Ontario Science Centre.

> "Science is like a rolling landscape: the scientist works a lifetime in a small area, just uncovering a bit of it. What I get to do is wander all over the whole terrain designing voyages for people to see the boundaries and the mysteries."

Exploring

1. What service does the Royal Astronomical Society of Canada provide for its members?
2. Speculate about the kinds of traits that one would require as a science journalist.
3. Comment on the contributions that a mission, such as *Pathfinder*, makes to the understanding of the world around us.



14.7

The Sun: An Important Star

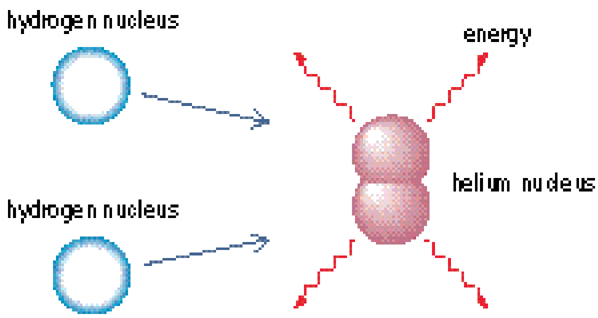


Figure 1
During nuclear fusion, substances fuse to form a new substance, releasing large amounts of energy. This is how the Sun produces energy, and it may someday become an important energy source on Earth.

By far the most important star to us is the one at the centre of the solar system: our Sun. It provides the energy needed by all the plants and animals on Earth, and its gravitational pull keeps us in our steady orbit. Learning about the Sun helps us understand about the nature of other stars. As you read about the features of the Sun, remember that we are continually learning more: about its origin, its chemistry, its radiation, perhaps even its future.

Because the Sun is the closest star to Earth, it is also the brightest object in the sky. In fact, it emits so much light energy that you cannot see the other stars until the Sun has set.

Where does the Sun's energy come from? Like all stars, the Sun produces energy through a process called **nuclear fusion**. Inside the Sun, the temperature and pressure are so high that substances fuse (join together) to form new substances. For example, hydrogen nuclei fuse to form helium nuclei. This process produces large amounts of heat, light, and other forms of energy (**Figure 1**) that travel out from the Sun through space. Every second, the Sun makes more energy than humans have used throughout our entire history (**Figure 2**).

Scientists have calculated that the Sun has been producing energy for about 5 billion years and is still 75% hydrogen. (The remaining 25% is helium, with small amounts of other gases.) Scientists estimate that it will continue producing energy for about another 5 billion years before it runs out of fuel.

Figure 2
Individuals are taking advantage of the Sun as a source of energy. Why isn't this being done on a larger scale?

A Close Look at the Sun

From Earth, astronomers can study the parts of the Sun near the equator, but not the areas near the Sun's poles. To overcome this problem, the space probe *Ulysses* was launched in 1990 to study the poles of the Sun. Another important probe, *SOHO*, has 12 instruments on board for observing the Sun. These probes, and others, have sent back data and photographs to help scientists study both the atmosphere and interior of the Sun.

Based on the observations made by these probes, and calculations made by astronomers, we can draw a model showing the various layers of the Sun (**Figure 3**).

The Sun's Effects on Earth

While astronomers can see solar flares as they happen, other effects only become apparent a few days afterwards. Solar flares emit charged particles, which travel much more slowly than light. When these particles reach Earth, they are focused, by Earth's magnetic field, at the north and south poles. The resulting electrical effects in the atmosphere interfere with the transmission of radio waves. This is why many communities in the far north of Canada sometimes lose radio communication for days at a time. The same charged particles produce the beautiful auroras seen over the North Pole (known as the Northern Lights or Aurora Borealis) and the South Pole (the Southern Lights or Aurora Australis). Photographs of auroras are shown on pages 394 and 436.

Did You Know?

Sunspots are huge cooler areas in the Sun's photosphere. Even the smallest sunspots observed are larger than Earth.

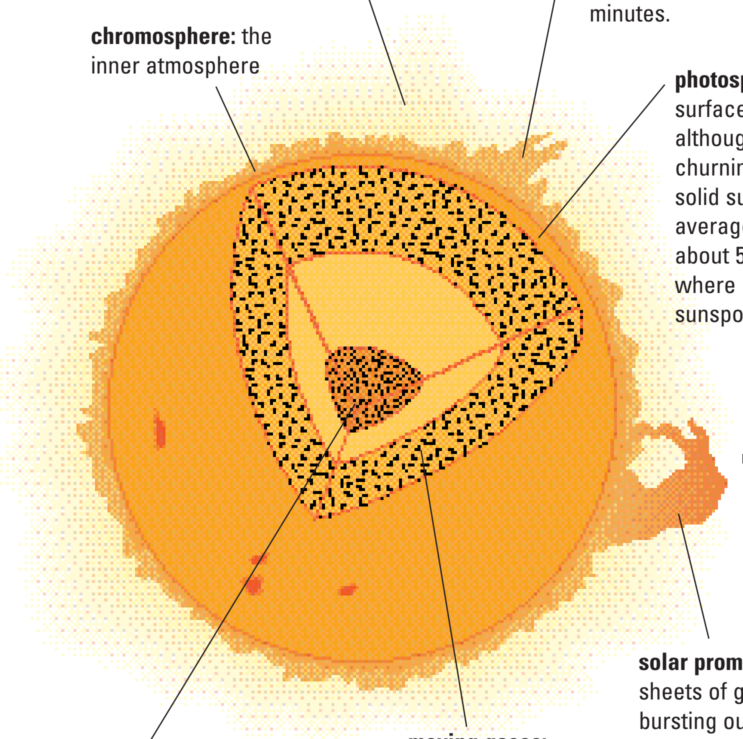


Figure 3
The structure of the Sun

Understanding Concepts

1. Describe the differences between a solar flare and a solar prominence. Which affects us and how?

2. Describe the process that occurs in the Sun's core to produce so much energy.

Making Connections

3. You have read that the Sun can continue producing energy for about 5 billion more years. Is the possible "death" of the Sun at that time a problem we should worry about? Why or why not? Discuss this with your class.

Exploring

4. The Sun's diameter is about 110 times as big as Earth's diameter, yet the Sun could hold about 1.3 million Earths. To find out why there is such a difference, use your calculator to cube the number 110. Then relate what you discover to the difference between diameter (a length) and capacity (a volume or length cubed).

5. In 1990, the space probe *Ulysses* was launched from Earth. It was a joint European-American probe and was the first probe intended to look closely at the poles of the Sun. Research *Ulysses* and describe what you find out.

6. The Sun is an almost inexhaustible source of energy. Research the technologies that are being developed to store and use that energy.

Reflecting

7. Why do we consider the Sun to be the most important star?

14.8 Investigation

SKILLS MENU
- ○ Questioning
- ● Hypothesizing
- ○ Planning
- ● Conducting
- ● Recording
- ● Analyzing
- ● Communicating

Observing Our Closest Star

You know that Earth rotates on its axis once each day. Do other bodies in the universe, such as the Sun, also rotate? In this investigation you will discover a way of observing whether the Sun, our closest star, rotates.

Approximately every 11 years, scientists observe problems that occur with our telephone and other communication systems, as well as problems with our distribution of electricity. They found that these problems occur just after they observe violent storms on the Sun's surface. These storms appear to occur when there are many dark regions on the Sun, called **sunspots**, as **Figure 1** shows. As you observe the image of the Sun in this investigation, look for evidence of sunspots.

Never look directly at the Sun and never look through binoculars or any other instrument at the Sun. The energy in sunlight is strong enough to permanently damage your eyes.

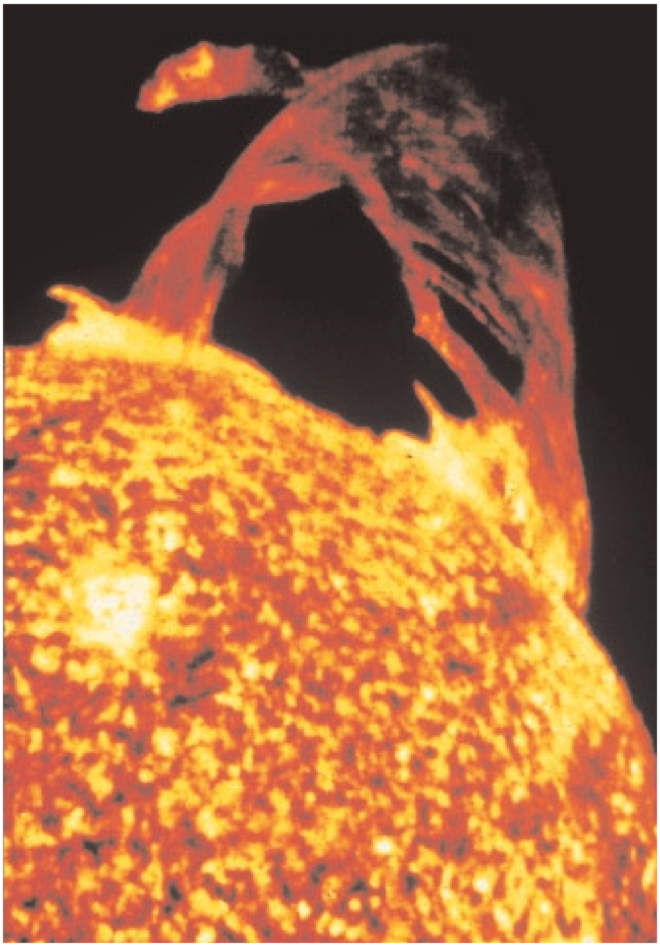


Figure 1
The numerous small, dark regions in this photograph of the Sun are called sunspots.

Question

Does the Sun rotate?

Hypothesis

1 Write a hypothesis about whether the Sun rotates and, if it does, predict how you might detect this rotation. (4A)

Materials

- binoculars (focused for distant viewing)*
- tripod
- mounting bracket (or masking tape)
- piece of cardboard
- scissors
- screen (e.g., a regular sheet of smooth white paper attached to cardboard)
- clock or watch
- log book
- a sunny day!
- digital or regular camera (optional)

*Note: This investigation can be done using a telescope instead of binoculars. If you use an astronomical telescope, however, be aware that the image you obtain may be inverted.

Procedure

2 **Figure 2** shows how to set up the binoculars for safe viewing of the Sun. Mount the binoculars on the tripod. (If a mounting bracket is not available, secure the binoculars with masking tape.) Use scissors to cut a hole in the cardboard the same size as the lens to allow light to pass through one lens. Cover the second lens with cardboard. Draw a circle about 12 cm in diameter on the screen.

SKILLS HANDBOOK: 4A Asking Questions and Hypothesizing

3 Without looking at the Sun, aim the binoculars at the Sun. **Do not look through the binoculars.** Place the screen below the eyepiece of the binoculars. Move the screen until a clear image of the Sun fills the circle on the screen. Determine east, west, north, and south.

(a) Record the starting time in your log book.

(b) Draw a diagram of the image you observe on the screen. Show parts that are lighter or darker. Indicate which way the Sun's image moves. Label the directions east, west, north, and south on your diagram. Include any other features you observe. Alternatively, photograph the image and make notes.

(c) Record the stop time.

4 Repeat your observations a few more times, on other sunny days. It is a good idea to always draw the image of the Sun the same size.

(a) Record what you see.

(b) Describe any changes you observe.

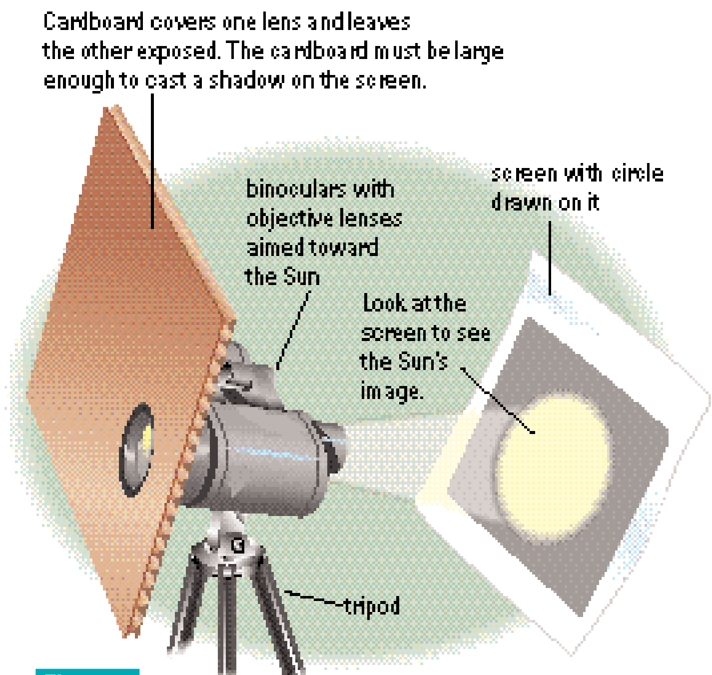


Figure 2

A safe way to view an image of the Sun

Analysis and Communication

5 Analyze your observations by answering the following questions:

(a) Describe how you figured out which edge of the Sun was north, and which was west.

(b) What is the advantage of using a tripod in this investigation?

(c) Describe the process you used in getting the Sun's image to be clear.

(d) How could the binoculars' shadow be used to aim them at the Sun?

(e) Describe the features of the Sun that you observed.

(f) What evidence would you need to answer the initial question?

6 Present your discoveries as a poster or, if you used a digital camera, as an audio-visual presentation.

Exploring

1. The predicted years of maximum sunspot activity are late 2001, 2012, and 2023, and the years of minimum activity are 2007 and 2018. Predict how what you saw would compare with what may be observed during the years of maximum and minimum sunspot activity.

Reflecting

2. Do you think that studying the Sun is important to a technological society such as ours? Why or why not?

Challenge

What considerations do you need to incorporate in your design for a space colony to prepare for potential sunspot activity?

SKILLS MENU
- ○ Questioning
- ● Hypothesizing
- ○ Planning
- ● Conducting
- ● Recording
- ● Analyzing
- ● Communicating

The Brightness of Stars

What are some of the factors that affect the brightness of ordinary light bulbs? Does the brightness change as your distance from the bulb increases? Does the power of the bulb affect its brightness? Are there other factors? If you think about these questions, you may get clues about how the brightness of stars depends on certain factors.

Part 1: The Stars in Cassiopeia

Question

What affects the apparent brightness of a light source?

Hypothesis

1 Write a hypothesis predicting which of Cassiopeia's stars are brightest. (You could refer to star maps for information.) 4A

Materials

- observation sheet
- flashlight covered with red cellophane
- pencil
- binoculars (optional)

Procedure

Do not go out alone to a dark area without permission from your parent or guardian. Make sure to dress warmly for night observations.

2 On a clear night, position yourself in an area well away from lights, with a clear view of the sky. After about 10 min, your eyes will be adapted to the dark. Make sure your flashlight, observation sheet, and pencil are ready.

3 Locate the constellation Cassiopeia.

(a) Sketch the stars that you can see in the constellation. Name as many of the stars as possible. Add any other relevant observations.

4 Rank the stars you see in Cassiopeia in order of their brightness to your eyes. Use 1 for the brightest, 2 for the second brightest, and so on.

Analysis and Communication

5 Compare your rankings of star brightness with those of your classmates. Discuss as a class what problems you think there may be with your method of ranking star brightness. Explain how you think your method could be improved. 9C

6 Your teacher will provide you with a list of the brightness of the stars in Cassiopeia.

(a) How do your rankings compare with the rankings on the list?

7 Compare any two stars that you observed.

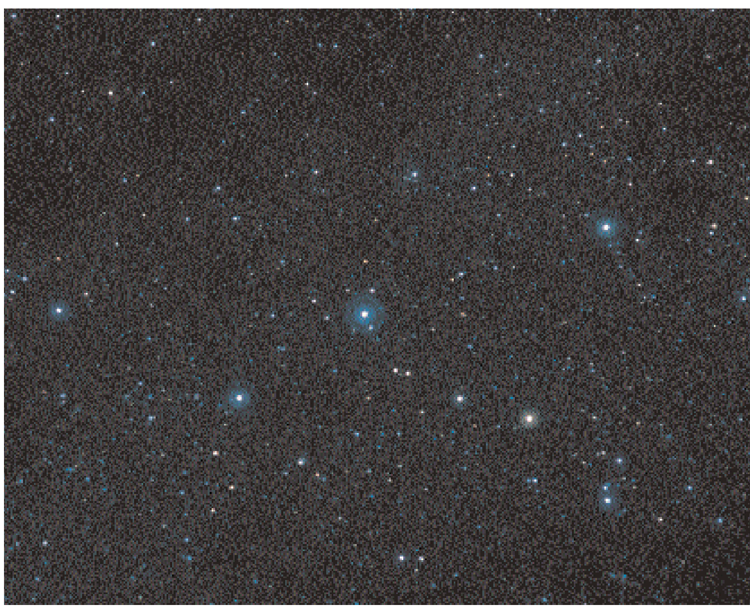
Part 2: The Brightness of Light Sources

Question

What affects the apparent brightness of a light source?

Hypothesis

8 Write a hypothesis about the factors that might affect the apparent brightness of a light source. If the light source were a star, would those factors be the same? Explain your answer.



SKILLS HANDBOOK: 4A Asking Questions and Hypothesizing 9C Working Together

Materials

- solar cell
- galvanometer
- dolly or cart with wheels
- ray box
- metre stick or tape measure
- graph paper

Procedure

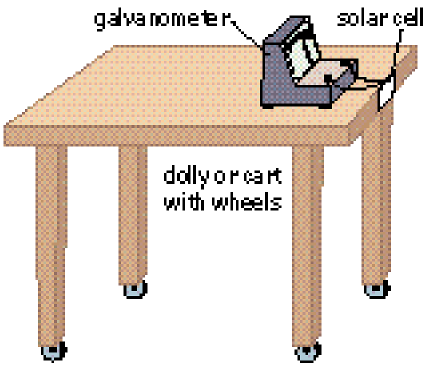
9 Copy **Table 1** into your notebook.

Table 1

Bulb number	Distance from bulb (m)	Reading on galvanometer
1	?	?
?	?	?

10 Set up the equipment as shown. Place the ray box at one end of the room. Cover all the windows to prevent stray light from affecting the results.

Step 11



11 Place the galvanometer apparatus 1 m from the ray box bulb or at some other distance suggested by your teacher.

(a) Record the electric current, with the units indicated by the galvanometer needle.

12 Repeat step 11 at distances of 2 m, 3 m, and 4 m from the ray box. (Your teacher may suggest different distances.)

(a) Record your readings.

13 Repeat steps 10, 11, and 12 using a second bulb of different power.

(a) Record your readings.

14 7B Create a graph that has the electric current on the vertical axis and the distance from the ray box on the horizontal axis.

(a) Plot the data for each bulb from your table of observations. Label the two lines on the graph.

Analysis and Communication

15 Examine the graph you made in Part 2.

(a) Describe the relationship you see between the galvanometer reading and the distance from the light source.

(b) Describe the relationship between the observed brightness of a light source and the power (or size) of the source.

16 Suppose that two stars, A and B, give off the same amount of light. From Earth, star A appears to be 100 times brighter than star B.

(a) What would you conclude about the distances of these two stars from Earth?

17 Use what you have learned about the brightness of light sources to explain the apparent brightness of the stars in Cassiopeia.

Exploring

1. Use your graph to predict what the reading would be if the galvanometer was moved to distances other than those you have already used. Extend the investigation to check your answer.

Reflecting

2. Is it possible to predict the relative distances to any two stars in the sky, using only what you have learned in this investigation? Explain.

7B Constructing Graphs

Characteristics of Stars

We know that the Sun has planets orbiting it, and life exists on at least one of those planets. There are billions of other stars in the universe and there is indirect evidence that some of these are also orbited by planets. It would be exciting to discover that life exists on these planets. To estimate the chances of finding life elsewhere, astronomers begin by studying the characteristics of stars. These characteristics include colour, temperature, size, and brightness.

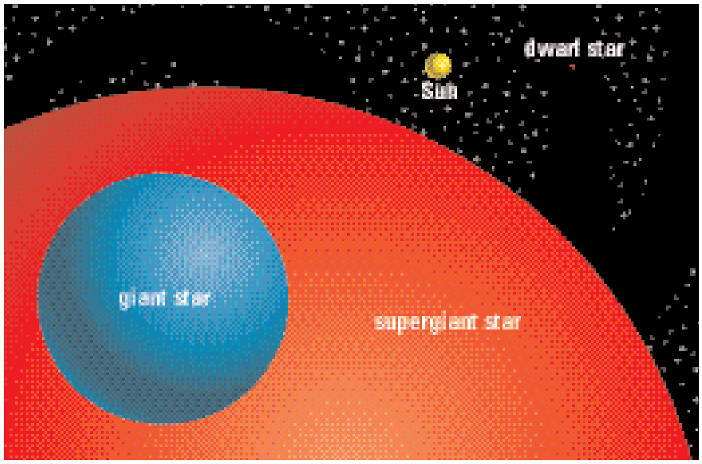


Figure 1

Star colours vary from blue (the hottest) to red (the coolest). Star sizes vary from supergiants to dwarfs. The Sun is bigger than about 95% of the stars.

The Colour, Temperature, and Size of Stars

You can tell that the element of your electric stove is hot because it glows. As it gets hotter it changes colour: red, then orange. Kitchen stoves rarely get hot enough to display other colours of the spectrum, but you have probably heard about metals being heated until they are white-hot, to make them soft enough to be bent and moulded.

The colour of a metal gives us some information about the amount of energy it has: it indicates the temperature of the metal. In the same way, scientists have discovered that the colours of stars tell us something about their temperature. A relatively cool star glows red; a very hot one glows bluish-white or even blue. **Table 1** lists the approximate temperature ranges of different colours of stars and gives examples of stars we can see in the sky. **Figure 1** shows the relative sizes of various stars.

Table 1

Colour	Temperature Range (°C)	Example(s)
blue	25 000–50 000	Zeta Orionis
bluish-white	11 000–25 000	Rigel, Spica
white	7500–11 000	Vega, Sirius
yellowish-white	6000–7500	Polaris, Procyon
yellow	5000–6000	Sun, Alpha Centauri
orange	3500–5000	Arcturus, Aldebaran
red	2000–3500	Betelgeuse, Antares

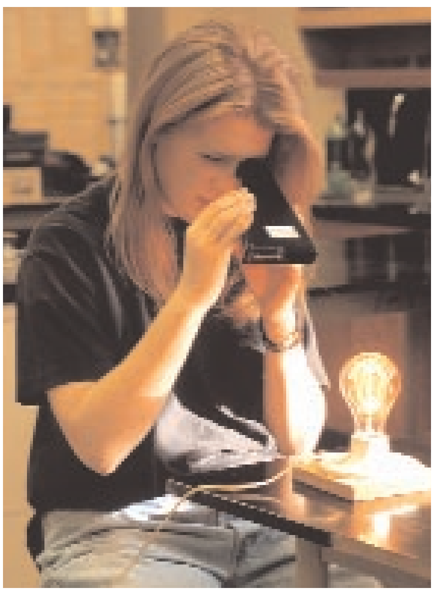


Figure 2

A spectroscope splits light energy into a spectrum of colours.

Spectroscopes and the Electromagnetic Spectrum

Scientists use special devices to look closely at the light given off by the Sun and other stars. One of the most useful instruments that astronomers use is the **spectroscope** (**Figure 2**), a device that splits light into a pattern of colours so we can see them as separate lines of colour.

This pattern of colours is called the **visible spectrum**. You may have seen one as a rainbow or when looking through a prism. The visible spectrum is a small part of the electromagnetic spectrum.

Scientists have found that when a chemical element is heated or energized, it gives off energy that shows a unique spectrum when viewed through a spectroscope. Each element tested has its own spectrum (**Figure 3**).

Scientists have also used the spectroscope, attached to a telescope, to look at stars. Much of what we know about stars today has resulted from using the spectroscope. The spectrum of a star can tell us which chemical elements make up the star, how much of each element the star contains, the temperature of the star, and in which direction the star is moving relative to Earth.

Figure 3

Each element that is heated or energized produces its own spectrum that can be seen when you look through a spectroscope.

a light from the Sun

b sodium light

c hydrogen light

The Brightness of Stars

You have learned how stars can be classified according to their colour, temperature, and size. Stars can also be classified by their age, distance from Earth, or brightness.

Almost 2200 years ago, the Greek astronomer Hipparchus developed the idea of classifying stars by their brightness. He divided stars into six categories. The brightest stars were called first-magnitude stars, and the faintest stars were called sixth-magnitude stars. Astronomers still use this classification system. Since more advanced sky-watching tools have improved our ability to see fainter stars, the magnitude scale set up by Hipparchus has been revised. Astronomers now use the word "magnitude" in two ways.

Apparent magnitude refers to the brightness of a star as it appears to us. This is the magnitude recorded by Hipparchus, or by you, if you are looking at the sky at night. In fact, two stars that have the same apparent magnitude can actually be giving off very different amounts of light. One star may simply be much closer to Earth than the other star. The term **absolute magnitude** refers to the *actual* amount of light given off by a star at a standard distance. Astronomers calculate the absolute magnitude of stars by determining how bright stars would appear if they were all the same distance from Earth.

Did You Know?

Astronomers have discovered some very unusual stars and star systems. Binary stars are pairs of stars that revolve around each other.

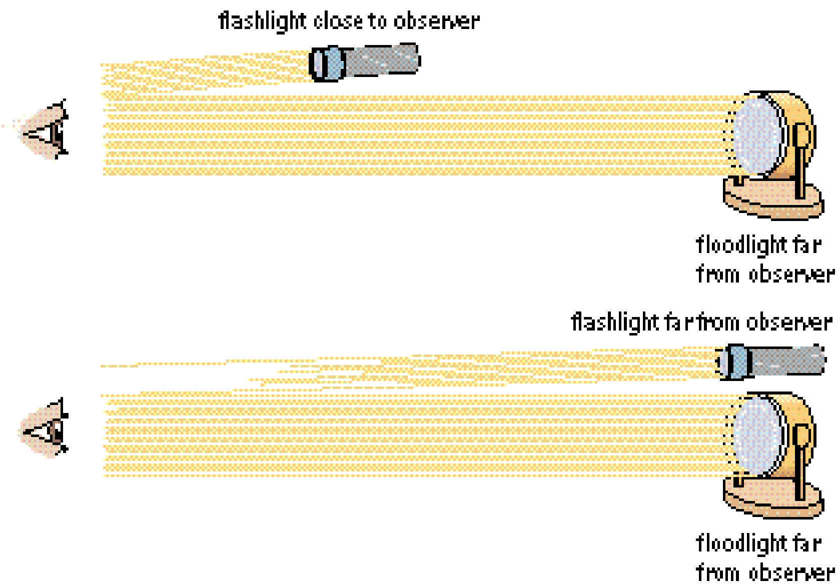
A simple example will demonstrate how astronomers compare magnitudes. Imagine that you are looking at two lights, one a flashlight located close to you, the other a bright floodlight that is far away (**Figure 4a**). Both lights appear to have the same brightness; this means that they have the same apparent magnitude. What can you do to compare their absolute magnitudes? Simply move both light sources so they are the same distance away from you (**Figure 4b**). Then you observe that the floodlight has a much brighter absolute magnitude than the flashlight.

Since we cannot move the stars around to test their absolute magnitude, astronomers have had to develop an indirect method of measuring their magnitude. They measure a star's apparent magnitude and its distance from Earth and calculate the absolute magnitude.

The Sun has the brightest apparent magnitude of any star because it is the closest star to Earth. But the Sun's absolute magnitude is only the absolute magnitude of an average star. Some stars, if they were as close to Earth as our Sun, would be nearly one million times brighter than the Sun. Others would be only one-millionth as bright as the Sun.

Figure 4

To the observer in a, the flashlight and the bright floodlight have the same apparent magnitude. In b, when the two light sources are the same distance from the observer, the floodlight is brighter. It has a much brighter absolute magnitude.



Understanding Concepts

1. How is the colour of a star related to its temperature?

2. Explain why a cooler star could actually appear brighter than a hotter star.

3. Astronomers use two systems of magnitude to measure the brightness of a star. Which system of magnitude would be more useful in comparing how two stars appear in the sky? Explain why.

4. One night, you observe two stars that have the same apparent magnitude. Could these two stars be giving off different amounts of light? Explain.

5. What effect would pollution in the atmosphere have on a star's
   (a) apparent magnitude?
   (b) absolute magnitude?

6. **(a)** What instrument does an astronomer use to determine the spectrum of a star?
   (b) Why is using this instrument better than using only a telescope to view the spectrum?

Exploring

7. (3A) Who were Hertzsprung and Russell? What is the Hertzsprung-Russell diagram? Research how they developed their diagram, and how it helps astronomers determine the absolute magnitude of stars.

Challenge

Which characteristics of stars can you incorporate in your planetarium display?

SKILLS HANDBOOK: (3A) Research Skills

Galaxies and Star Clusters

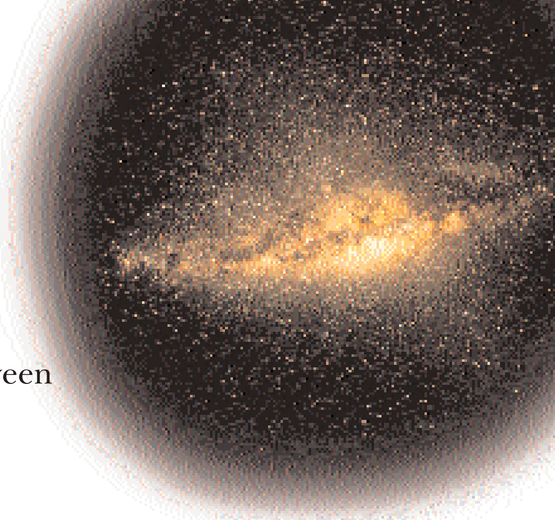


Figure 1
The bright band of stars across the centre of this image is the central bulge of the Milky Way.

If you look at a map of your province, you see cities, towns, and villages. These are places where people live close together. Between these places are large rural (country) regions where people are scattered quite far apart. Similarly, if you look at a model of the universe, you see different-sized groups of stars with different characteristics.

Galaxies

In Section 14.1, you learned that a galaxy is a huge collection of gas, dust, and hundreds of billions of stars. These stars are attracted to each other by the force of gravity, and they are constantly in motion. Astronomers can see galaxies as far away as the power of their telescopes will permit.

We are part of the Milky Way Galaxy. You might be able to see the Milky Way, in the summer or the winter, looking like a trail of milk spilled across the night sky (**Figure 1**). Astronomers estimate that there are at least 400 billion stars in the Milky Way Galaxy. The Milky Way is roughly disk-shaped, with our Sun located near the outer part of the disk (**Figure 2**). The thicker inner region of the disk is called the central bulge of the galaxy, where the stars are so numerous that they appear very close together even though they are separated by large distances. Most of the stars outside the bulge are arranged in long ribbons, called arms, which curve around the bulge. The entire Milky Way Galaxy is rotating around the bulge.

The Milky Way Galaxy is called a spiral galaxy because of its circular, spiral shape. **Figure 3** shows photographs, taken from the edge-on rather than face-on, of three other spiral galaxies.

Did You Know

Gravity is a force exerted by all objects but is only really noticeable if at least one of them is very large. A dropped cup falls to Earth because it is within Earth's gravitational field and is pulled "down." Meteors crash into the Moon because the Moon's gravity attracts them. The planets orbit the Sun because it has a huge gravitational field. Any large objects close to each other in space will attract each other because of the force of gravity.

Figure 2
The spiral arms of our galaxy contain great concentrations of stars. Our Sun is one of the many stars in the less concentrated regions between the spiral arms. If our Sun were in the central bulge of the galaxy, what do you think our night sky would look like?

a This giant spiral galaxy resembles the Milky Way Galaxy.

b This spiral galaxy is coloured to show young giant stars (blue), which are hotter than older stars.

c An example of a barred-spiral galaxy, coloured to show the central bar. The spiral arms come out from the ends of the bar-shaped area that contains the galaxy's central bulge.

Figure 3

There are other shapes of galaxies besides the spiral shape and barred-spiral shape. Some are elliptical galaxies and others that have no distinct shape are called irregular galaxies (**Figure 4**).

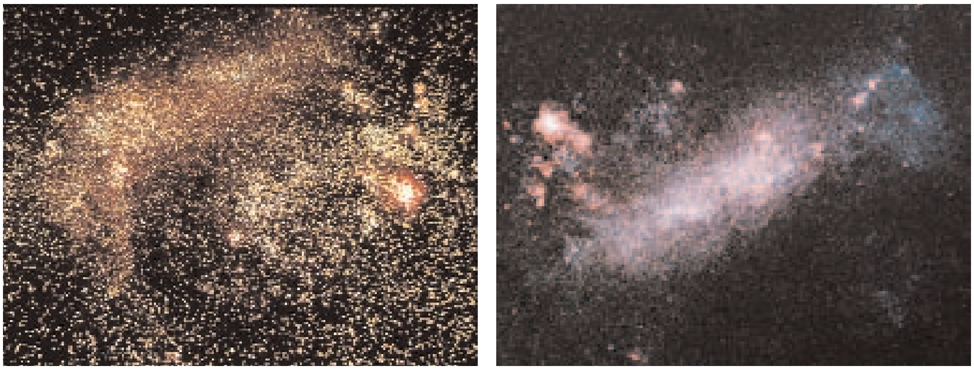


Figure 4
Two views of the Large Magellanic Cloud: an irregular galaxy about 160 000 light-years away

Unusual Galaxies

As astronomers see farther into the distance, they find answers to questions about the universe, but what they discover makes them ask more questions. Below are some observations that astronomers continue to research.

- Some galaxies appear to be in the process of colliding and recombining, tearing stars away from each other. Sometimes small galaxies are swallowed by larger ones.
- Some violent galaxies emit far more energy than average galaxies.
- Strangest of all are **quasars**, objects that look like faint stars but emit up to 100 times more energy than our entire galaxy (**Figure 5**). The word "quasar" was taken from the expression "quasi-stellar radio source," which means a starlike object that emits radio waves.

Did You Know

There are billions of galaxies in the universe. Some galaxies that gather together in groups are called galaxy clusters or superclusters. Our Milky Way Galaxy belongs to a group called the Local Group and to the supercluster called the Virgo Cluster.

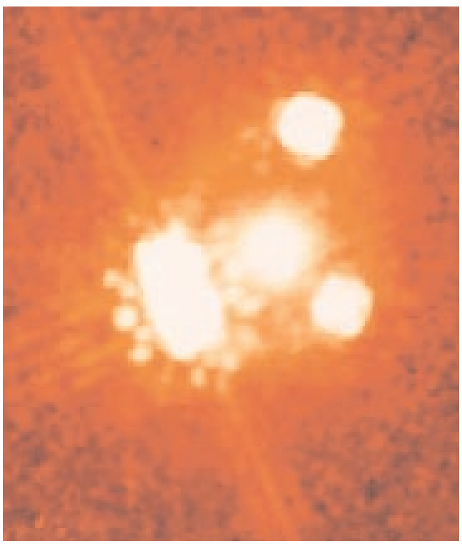


Figure 5
Quasars produce huge amounts of energy, yet appear only as faint points of light.

Try This Model a Spiral Galaxy

If you look at a photograph of people swimming under water, you can tell which way they are swimming by how their hair streams out behind them. In a similar way, astronomers can look at images of a galaxy and draw conclusions about its movement from the shape and position of its arms. You can make your own model of a spiral galaxy.

1. Plan a method for modelling a spiral galaxy, using a clear beaker or glass container, water, a stir stick, and a drop of food colouring.
2. Write your own hypothesis for what you predict you will observe.
3. Show your plan to your teacher. After getting approval, carry it out. Be sure to record your observations carefully. Include a diagram.
4. Explain your observations and how they apply to a spiral galaxy. 8A

SKILLS HANDBOOK: 8A Reporting Your Work

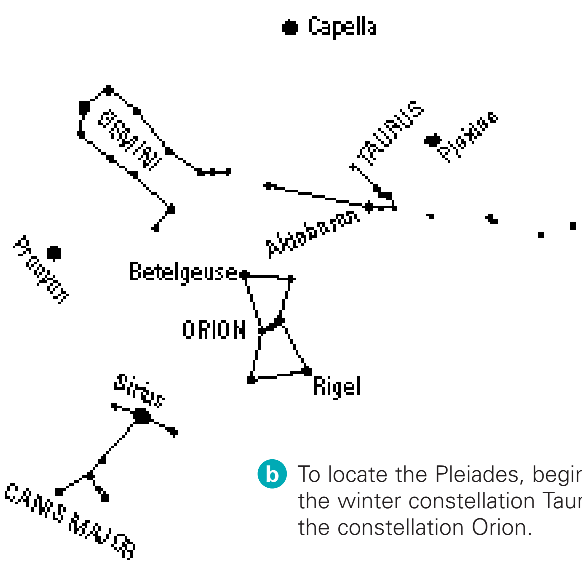
Star Clusters

Groups of stars that are fairly close and travel together are called **star clusters**. These clusters may have as few as 10 stars or as many as a million: too few to be called a galaxy. Smaller star clusters are found in the main parts of the Milky Way Galaxy. Larger star clusters are found just outside the main parts of the galaxy. If galaxies are like cities and towns, then the small star clusters are like neighbourhoods and the large star clusters are like suburbs.

One of the more interesting sights to observe in the sky is the star cluster called the Pleiades, in the constellation Taurus (**Figure 6**). With the unaided eye you can see up to six or seven stars, and many more with binoculars or a telescope.

Figure 6

(a) The Pleiades is a star cluster.



(b) To locate the Pleiades, begin by finding the winter constellation Taurus. It is near the constellation Orion.

Understanding Concepts

1. How are galaxies classified? Draw and label an example of each.
2. Arrange the following in order of size, starting with the largest: star cluster; galaxy; universe; star; planet.
3. A certain star is located 60 light-years away from us. Which galaxy do you think this star is in?

Exploring

4. Calculate the speed at which the Sun is travelling around the central bulge of the Milky Way Galaxy. Use the equation: speed = distance/time. Assume that the Sun travels in a circular path of radius 1.38×10^{17} km, taking 225 million years for each trip around the central bulge. (If you change the units of time to hours, your answer will be in km/h.)
5. Make a model of the Milky Way Galaxy. You could use a sheet of polystyrene, toothpicks, and modelling clay, or any other materials approved by your teacher. Draw diagrams of the top and side views.

Challenge

Much of the pioneering work in investigating globular star clusters was done by a Canadian astronomer, Helen Sawyer Hogg. Research about her life and contributions.

Chapter 14 Review

Key Expectations

Throughout the chapter, you have had opportunities to do the following things:

- Compare modern scientific views of the universe with the beliefs of various cultures. (14.1)
- Recognize, describe, and compare the major components of the universe. (14.1, 14.7, 14.9, 14.10, 14.11)
- Describe the Sun and its effects on Earth. (14.7, 14.8, 14.10)
- Investigate distances and properties of celestial objects, and organize, record, analyze, and communicate results. (14.3, 14.5, 14.8, 14.9)
- Formulate and research questions related to the nature of the universe, and communicate results. (all sections)
- Determine how astronomers compare distances and sizes in the universe. (14.3, 14.4, 14.5, 14.9, 14.10)
- Describe and explain how data provided by ground-based and satellite-based astronomy contribute to our knowledge of the Sun and other objects. (14.1, 14.4, 14.6, 14.8, 14.10)
- Describe and evaluate the possible impact of future human exploration and exploitation of planets. (14.2)
- Explore careers related to the exploration of space. (Career Profile)
- Organize and record information in an appropriate manner. (all sections)
- Communicate using appropriate language and formats. (all sections)

KEY TERMS

absolute magnitude
apparent magnitude
chromosphere
corona
Earth-centred universe
electromagnetic spectrum
galaxy
light-year
nuclear fusion
observatory
photosphere
quasar
radio telescope
reflecting telescope
refracting telescope
solar flare
solar prominence
spectroscope
star cluster
Sun-centred solar system
sunspot
triangulation
visible spectrum

Reflecting

- "The universe is always changing. The objects in it are in continual motion." Reflect on this idea. How does it connect with what you've done in this chapter? (To review, check the sections indicated above.)
- Revise your answers to the questions raised in Getting Started. How has your thinking changed?
- What new questions do you have? How will you answer them?

Understanding Concepts

1. Make a concept map to summarize the material that you have studied in this chapter. Start with the word "universe."

2. Explain why the distances to planets are given in kilometres, whereas the distances to stars are given in light-years.

3. (a) What is the process that produces energy inside the Sun?
(b) How fast does light from the Sun travel through space?

4. (a) Which theory do we accept today: the Sun-centred theory of the solar system or the Earth-centred theory of the universe?
(b) How do these two theories differ?

5. Copy these distances into your notebook. Beside each number, indicate whether the distance would be described as intergalactic, interstellar, interplanetary, or interstudent.
(a) 0.001 km
(b) 10 billion billion km
(c) 100 million km
(d) 100 million million km

6. Name and use illustrations to describe three types of telescope.

7. How do the wavelengths of radio waves compare with the wavelengths of visible light? Use your answer to explain some of the characteristics of radio telescopes.

8. Explain the difference between the absolute and apparent magnitudes of stars, using our Sun as an example.

9. The Milky Way is a strip of stars that we can see most easily during winter and summer. Describe how our view of the Milky Way would change if our solar system were located in the bulge of the Milky Way Galaxy.

10. Compare galaxies and star clusters.

11. Using examples, explain why humans could not travel to the stars at the speeds reached by today's spacecraft.

12. Make a list of characteristics used to describe stars. Beside each characteristic, indicate how the Sun compares with other stars.

13. What features of quasars make them unique?

14. Describe effects that particles from solar flares have on Earth.

15. (a) List models that have been used in this chapter to help you understand concepts.
    (b) Describe other models that you think might help explain other concepts.

16. Between 400 and 500 years ago, ideas about the universe began to change. What main factors caused that change?

17. A store has several telescopes on display.
    (a) How can you judge which telescopes are reflecting and which are refracting?
    (b) If you were buying a telescope, which type would you prefer? Why?

18. Some cultures in ancient times were able to catalogue stars even better than most people today, although they did not know about most of the stars in the universe. Explain why.

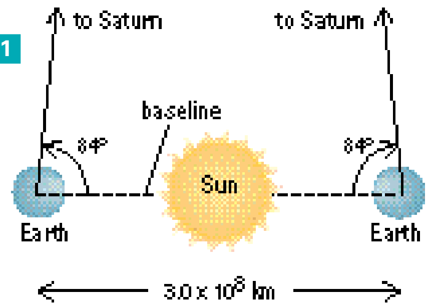
19. Write at least five questions about the universe that you would like to have answered.

20. Why is it difficult for scientists to measure interstellar and intergalactic distances? How do they solve these problems?

Applying Skills

21. An astronomer uses the diameter of Earth's orbit as a baseline to estimate the radius of Saturn's orbit. As shown in **Figure 1**, the angles to Saturn, taken six months apart, are both 84°. Use a scale diagram to find the distance from Saturn to the Sun. (When astronomers use triangulation to measure such large distances, they take into consideration the movement of the distant object.)

Figure 1



22. What advice would you give to someone who is just starting to learn how to draw scale diagrams?

23. What advice would you give to someone who wants to use binoculars to obtain an image of the Sun on a screen?

24. What safety precautions must you take when observing the Sun? Why are these precautions so important?

25. The Milky Way Galaxy is approximately 90 000 light-years across. Using correct scientific notation, express this distance in both astronomical units and kilometres. (1 light-year = 9.46×10^{12} km; 1 a.u. = 1.5×10^{8} km)

26. When using triangulation to determine distances indirectly, what can you do to improve the accuracy of the measurements?

Making Connections

27. Look back at Table 1 in Section 14.10. Describe how you think conditions on Earth would differ from conditions today if the Sun were (a) as hot as a blue star, and (b) as cool as a red star.

28. The thin atmosphere at the tops of mountains may be a great advantage for telescopes, but it is a great disadvantage for people who work there. People often become light-headed or even ill when they first arrive at a high elevation. Research altitude sickness, and write a brief report describing the causes and effects of this problem.