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

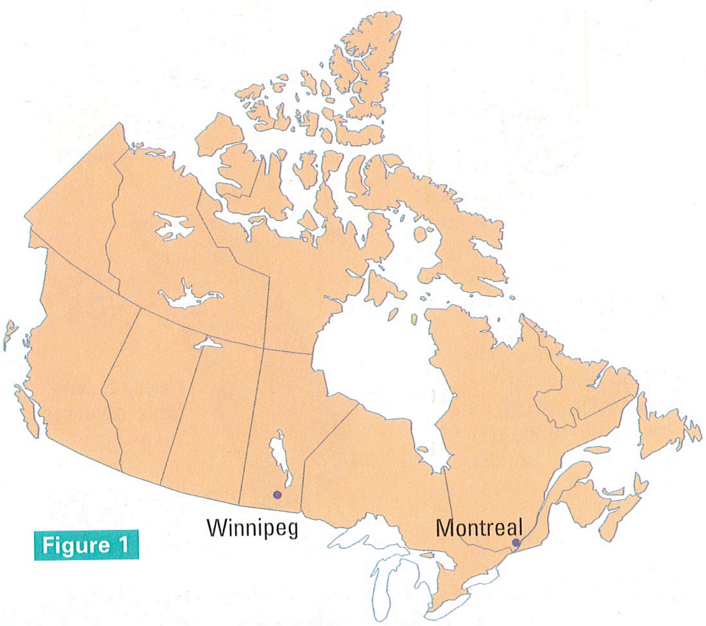


Figure 1

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

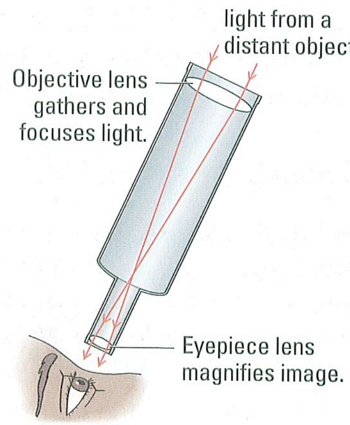
We can learn about space beyond Earth by looking at images of planets, stars, and other objects in the universe. If you were to compare the images in this textbook with the images in astronomy books published even a few years ago, you would discover that we can now see objects it was not possible to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

Using Telescopes

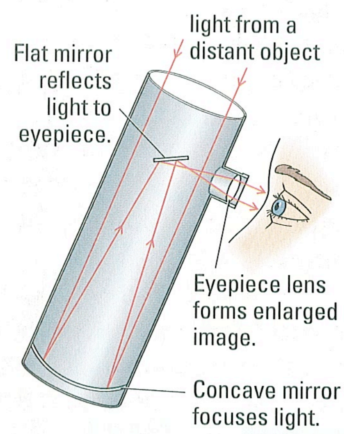
Telescopes may cost from a few hundred dollars to hundreds of millions of dollars. From Galileo's first astronomical telescope to the most sophisticated instruments now orbiting Earth, the main purpose of a telescope is to gather light. The light forms an image that can be seen or recorded using cameras 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?

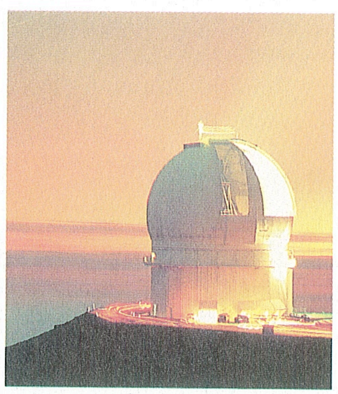
Figure 1

(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.

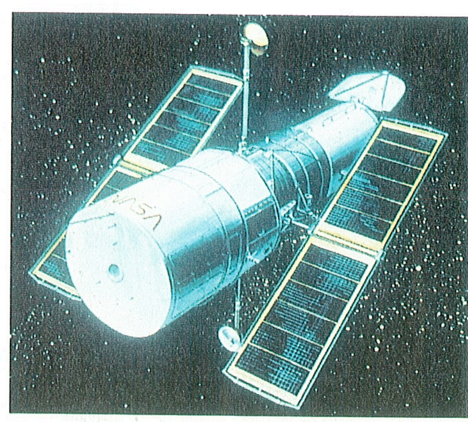


(b) A **reflecting telescope**, first constructed by Isaac Newton in 1668, uses a concave mirror to gather light. Such a mirror can be supported from underneath, so it can be built much larger than the objective lens in a refracting telescope. Large reflecting telescopes were used in the early 1800s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

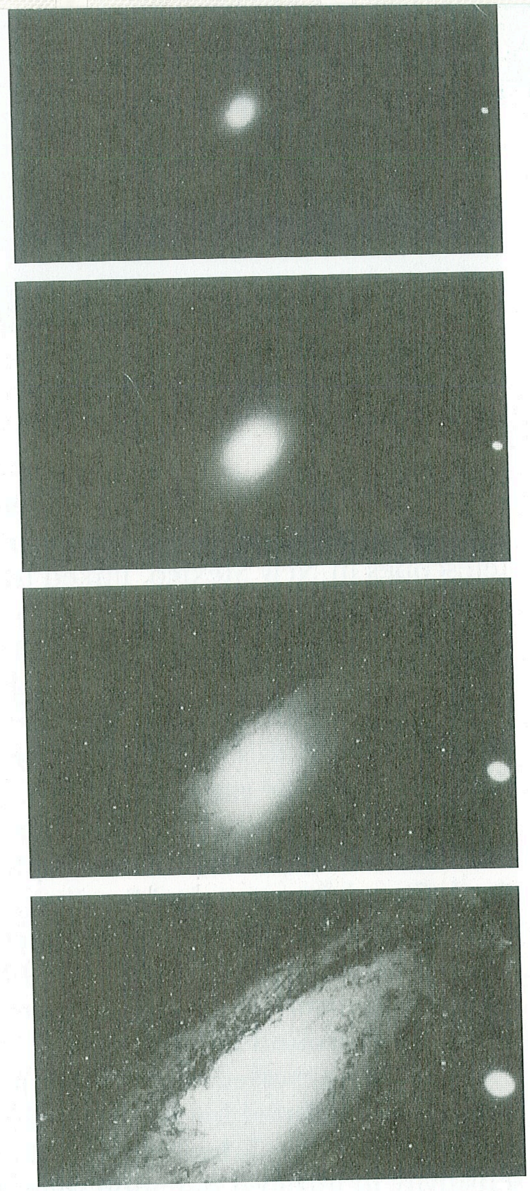


Figure 2
These views of the same object show how the amount of detail increases as the time that the camera gathers light increases. In order from top to bottom, these images show light-gathering times of 1, 5, 30, and 45 min.

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.

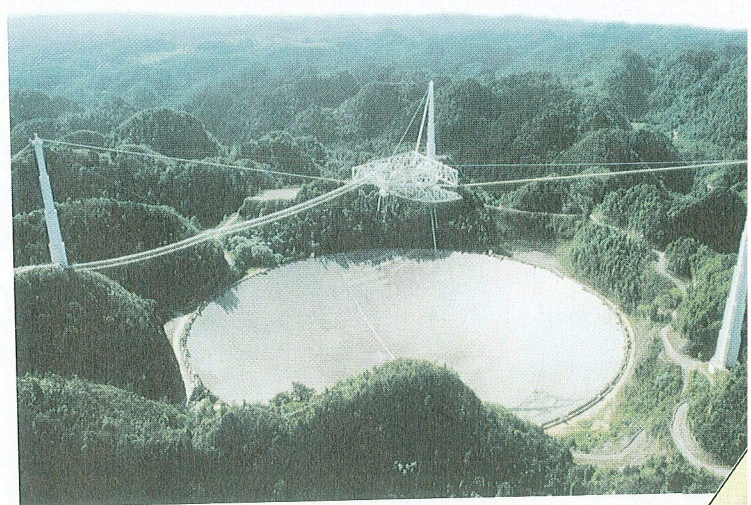


Figure 3
The Arecibo radio telescope is built into the mountains of Puerto Rico. What is the triangular structure just above the "dish"?

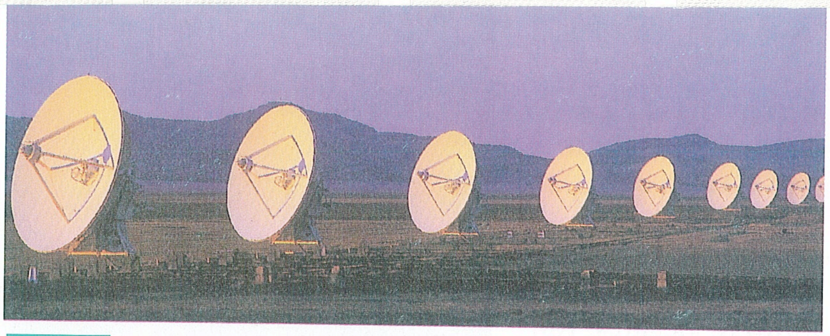


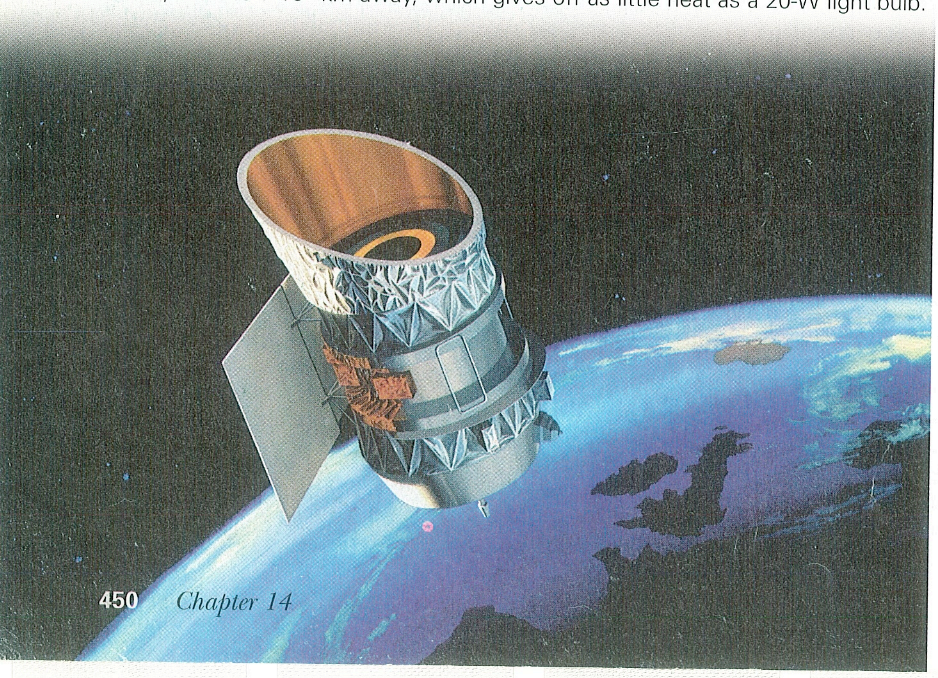
Figure 4
An array of radio telescopes produces the same results as a much larger single radio telescope.

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."

> "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."

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.

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

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.

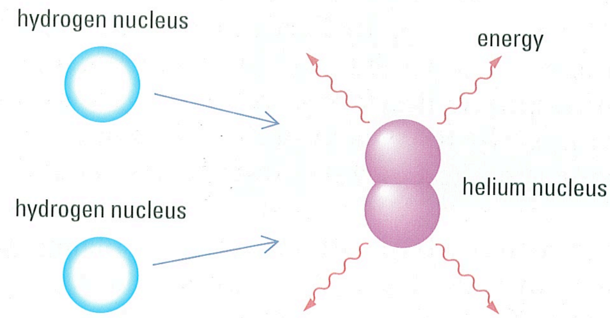


Figure 1

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.

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.

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**).

Figure 2

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

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.

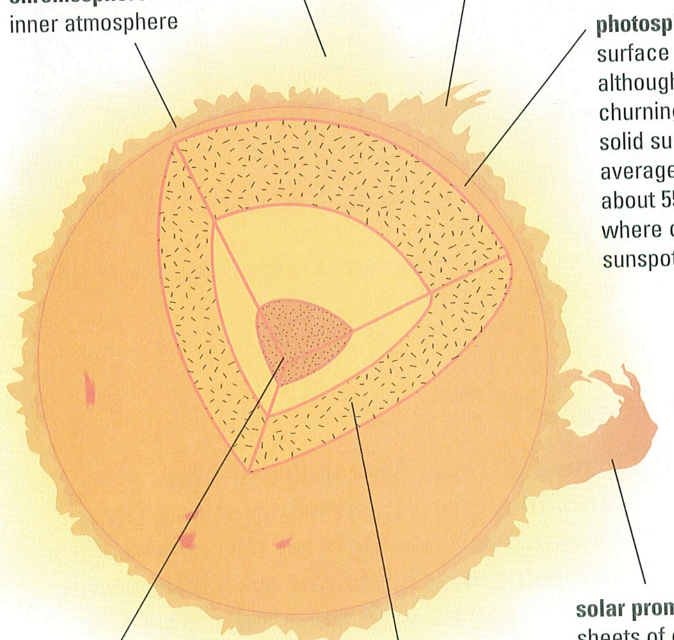


Figure 3
The structure of the Sun

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?

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.

Question

Does the Sun rotate?

Hypothesis

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

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.

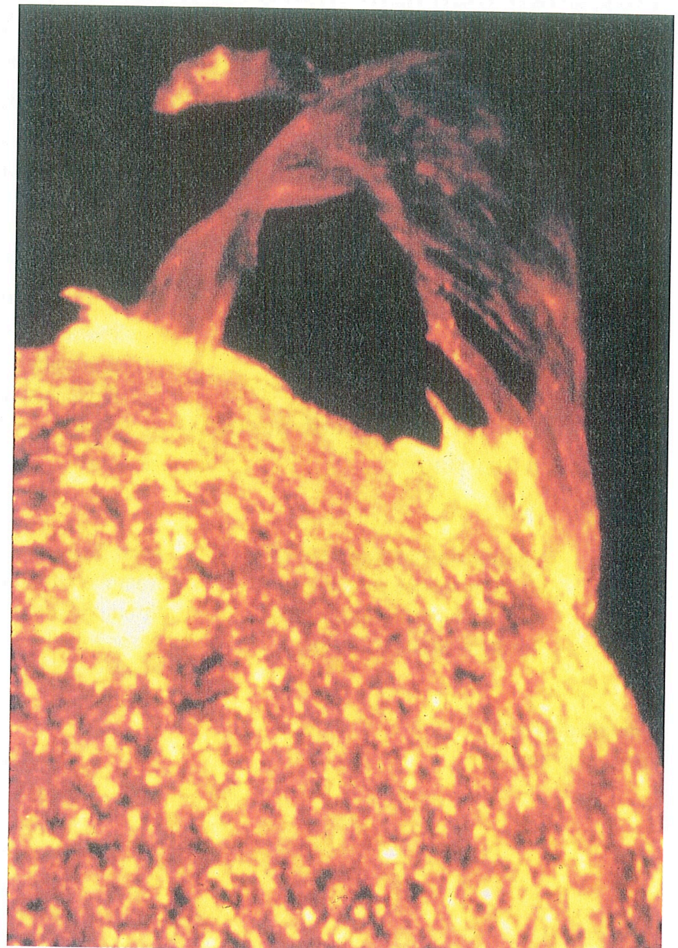


Figure 1
The numerous small, dark regions in this photograph of the Sun are called sunspots.

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.

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.

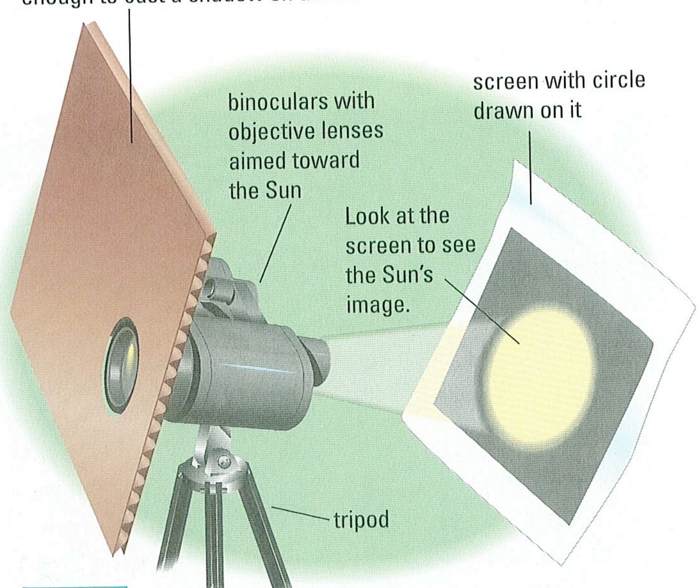


Figure 2
A safe way to view an image of the Sun

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?

14.9 Investigation

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