Materials

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

Procedure

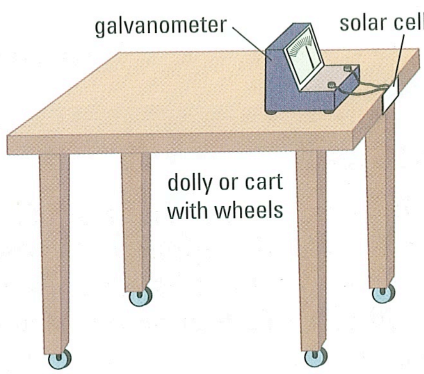
9 Copy **Table 1** into your notebook.

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.

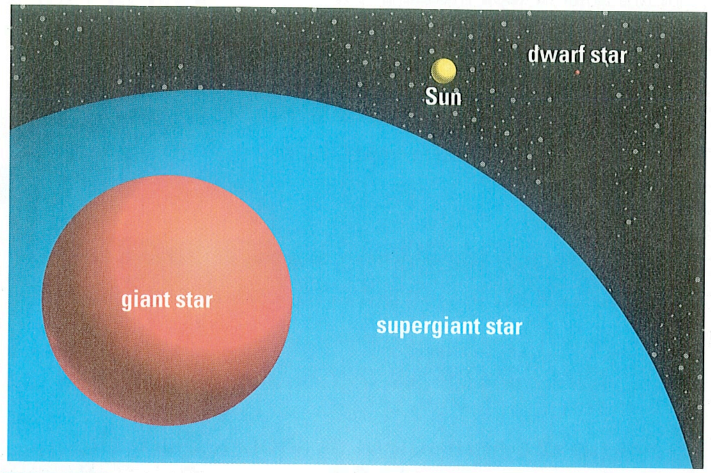


Figure 1

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

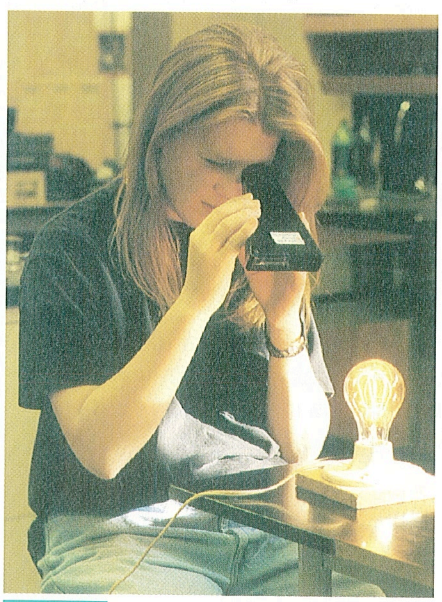


Figure 2

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.

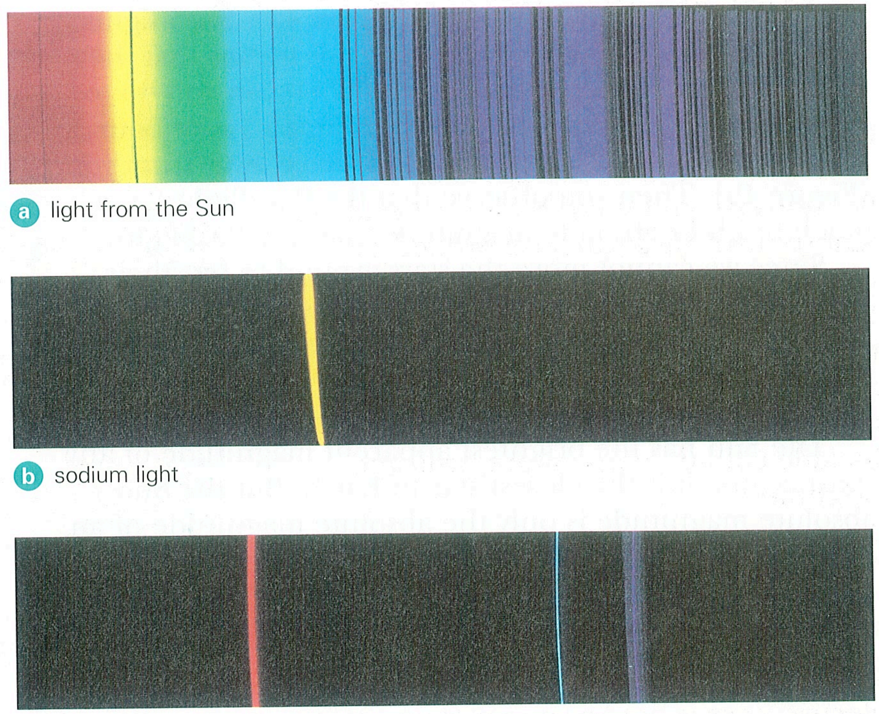
This pattern of colours is called the **visible spectrum**. You may have seen one as a rainbow or when looking through a prism. The visible spectrum is a small part of the electromagnetic spectrum.

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.

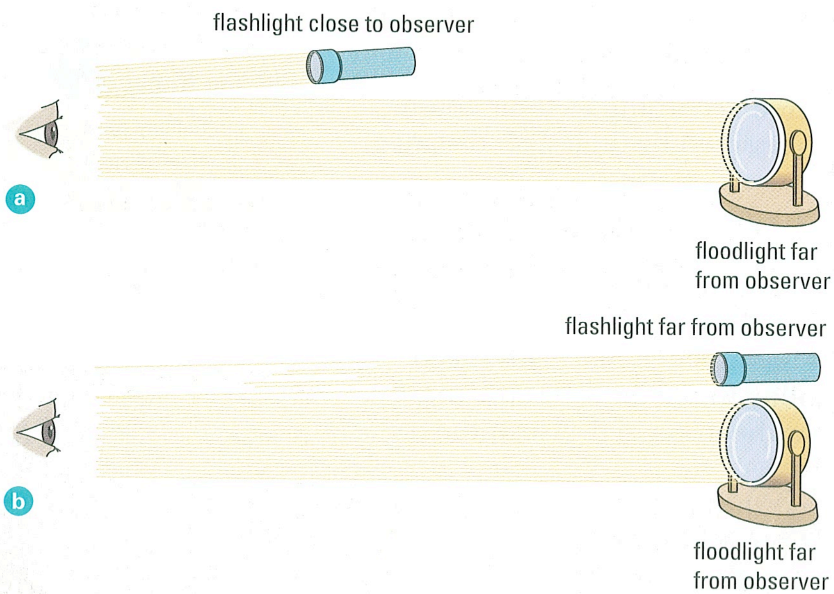
A simple example will demonstrate how astronomers compare magnitudes. Imagine that you are looking at two lights, one a flashlight located close to you, the other a bright floodlight that is far away (**Figure 4a**). Both lights appear to have the same brightness; this means that they have the same apparent 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

14.11

Galaxies and Star Clusters

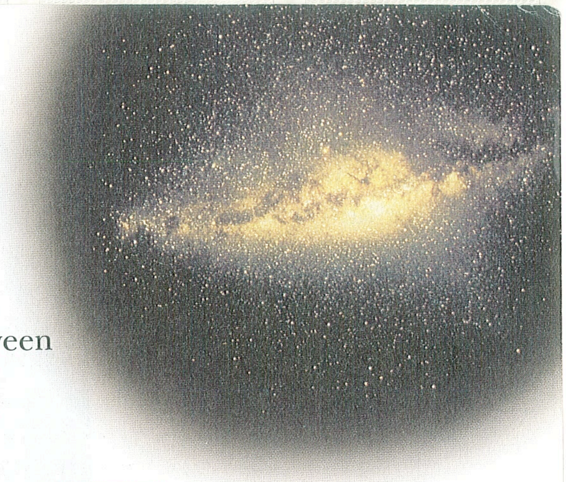


Figure 1
The bright band of stars across the centre of this image is the central bulge of the Milky Way.

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.

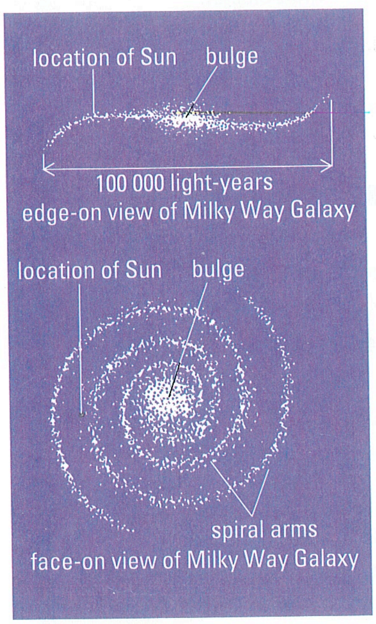
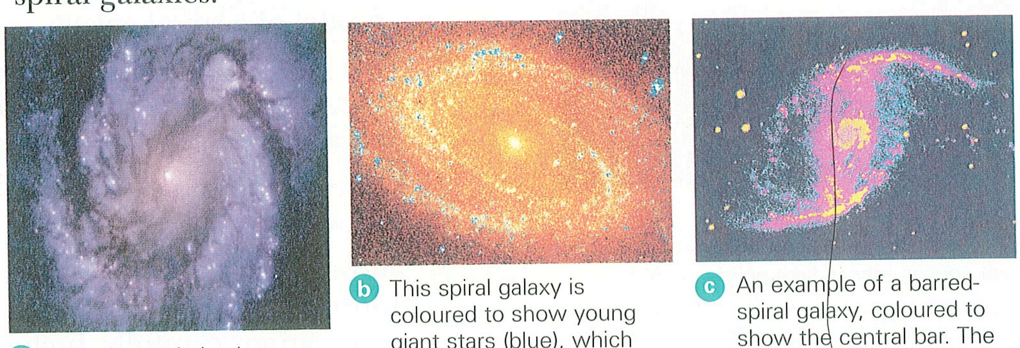


Figure 2
The spiral arms of our galaxy contain great concentrations of stars. Our Sun is one of the many stars in the less concentrated regions between the spiral arms. If our Sun were in the central bulge of the galaxy, what do you think our night sky would look like?



(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.

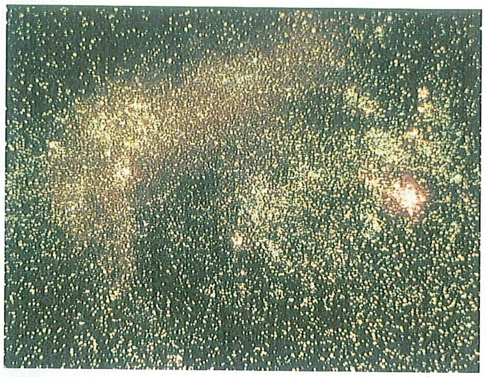
(c) An example of a barred-spiral galaxy, coloured to show the central bar. The spiral arms come out from the ends of the bar-shaped area that contains the galaxy's central bulge.

Figure 3

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.

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**).



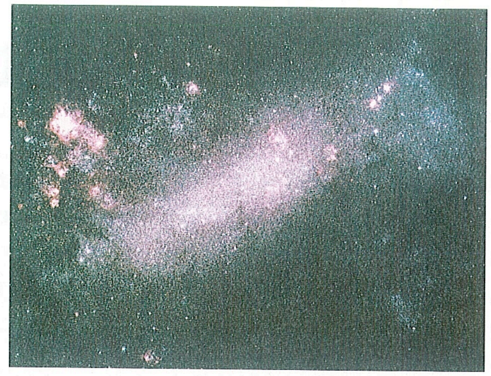


Figure 4

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.

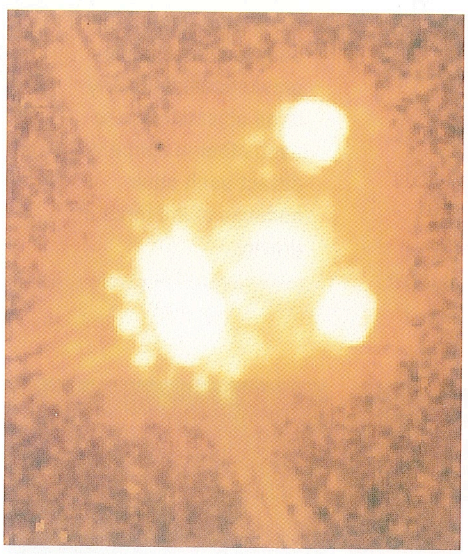


Figure 5

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

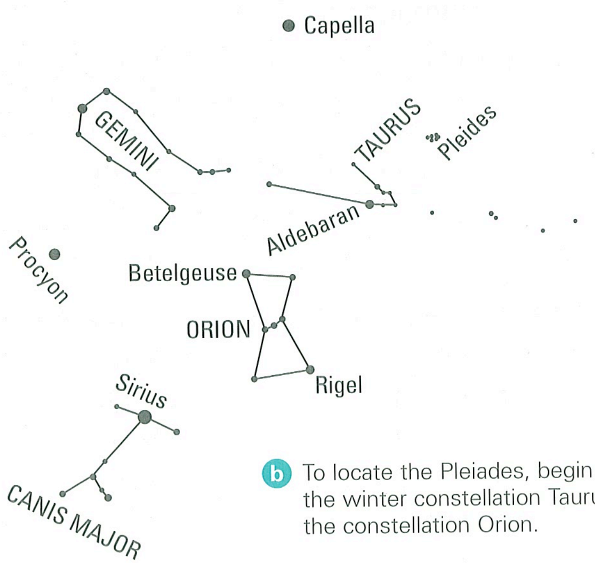
Star Clusters

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.

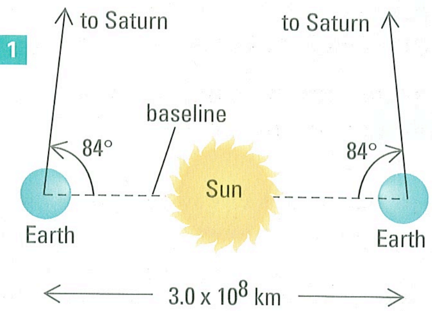
19. Write at least five questions about the universe that you would like to have answered.

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

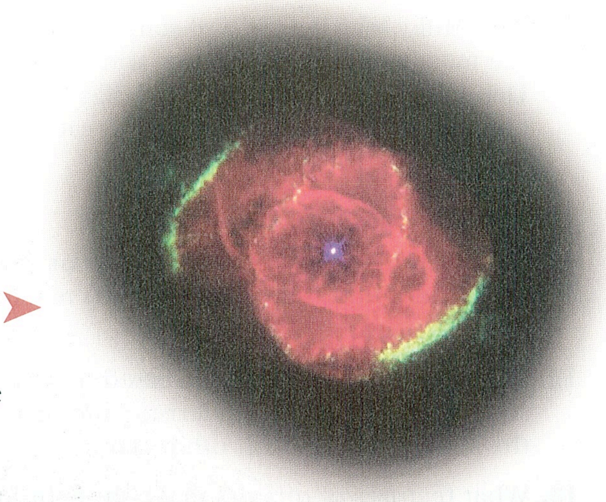
27. Look back at Table 1 in Section 14.10. Describe how you think conditions on Earth would differ from conditions today if the Sun were (a) as hot as a blue star, and (b) as cool as a red star.

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.

CHAPTER

15 The History of the Universe

Getting Started



1 This is the Cat's Eyes Nebula. Using technology that allows them to see events that happened billions of years ago, scientists have collected evidence that nebulas are one of the stages in the lives of stars. What is this amazing technology? Are the stars we see at different stages of their existence? What do we know about the "birth" of stars? Are stars still being formed? Do stars die?

2 The nebula shown here, called the Lagoon Nebula, is a nursery for new stars. Scientists have proposed that planets sometimes form at the same time as stars, so our solar system is probably not the only planetary system in the universe. What is their evidence? Why is it so difficult to prove that there are planets travelling around other stars? How old is the solar system? How did the planets form? Will they last forever?