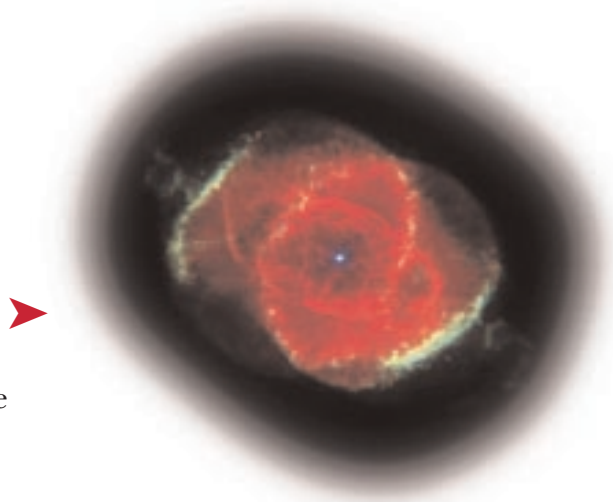


The History of the Universe

Getting Started

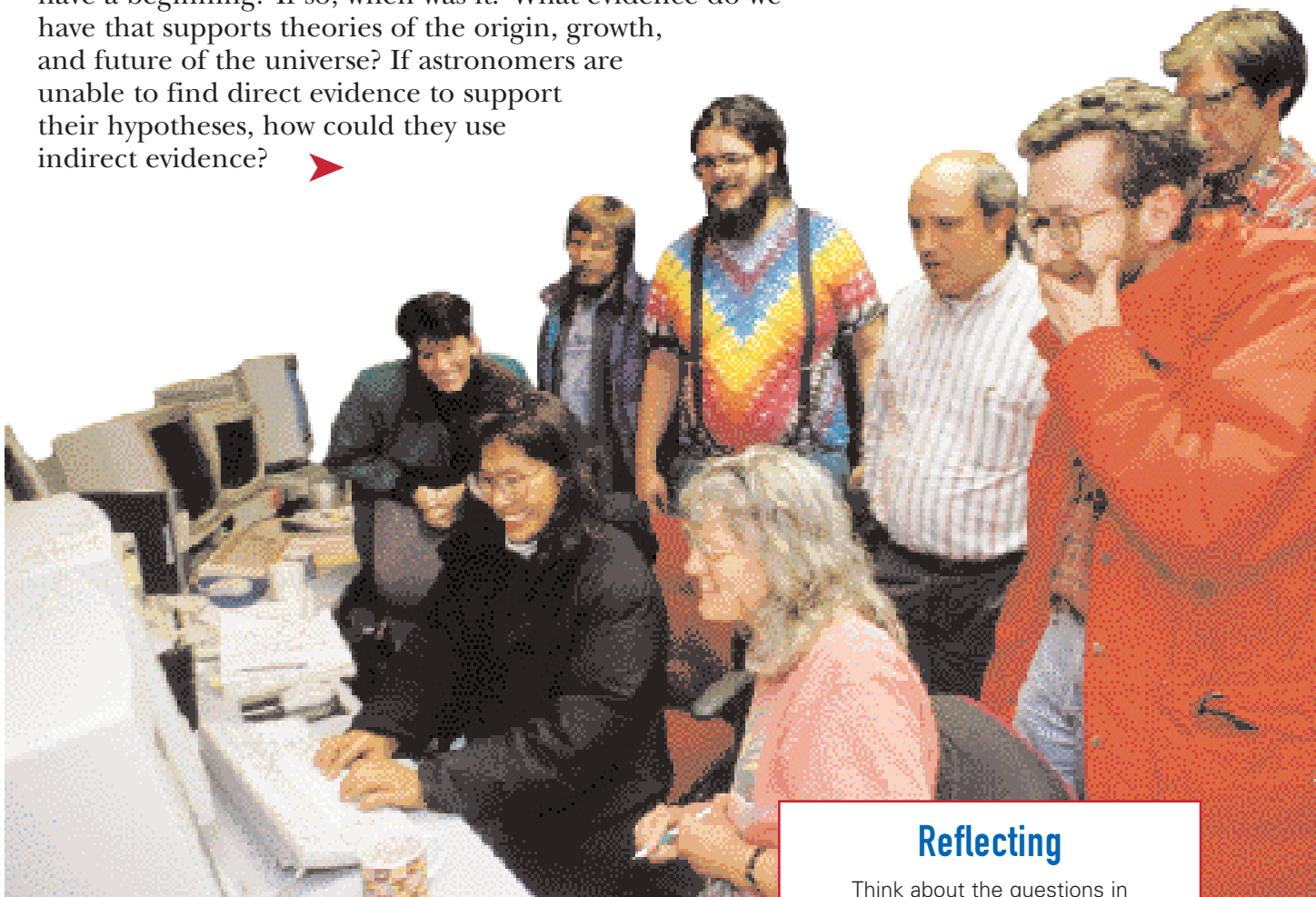
1 This is the Cat's Eyes Nebula. Using technology that allows them to see events that happened billions of years ago, scientists have collected evidence that nebulae are one of the stages in the lives of stars. What is this amazing technology? Are the stars we see at different stages of their existence? 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?



- 3** Canadian astronomers join other astronomers in the search for answers to questions about the universe. Did the universe have a beginning? If so, when was it? What evidence do we have that supports theories of the origin, growth, and future of the universe? If astronomers are unable to find direct evidence to support their hypotheses, how could they use indirect evidence? ➤



Reflecting

Think about the questions in **1**, **2**, **3**. What ideas do you already have? What other questions do you have about the history of the universe?

Think about your answers and questions as you read the chapter.

Try This Using Indirect Evidence

Many scientists, from space scientists to chemists, are sometimes unable to make direct measurements or collect direct evidence for their investigations. Instead they use many kinds of indirect evidence. You have already used an indirect method to measure distances that you could not measure directly. Now you can discover features of something you can't see by gathering indirect evidence.

1. At a station set up by your teacher, a flat, horizontal board hides something from

your direct view. Observe carefully as one student at a time rolls a small steel ball along the surface of the board.

- 2.** Continue observing until you are satisfied that you can describe what is hidden.
- 3.** Draw a diagram of what you think is hidden beneath the board.
- 4.** What is "indirect evidence"?

The Life of a Star

We say that stars have a “life” because they evolve from clouds of gas and dust and follow a predictable series of stages: they begin (are “born”), develop, and end (“die”). Each life may take billions of years or more, a length of time that is difficult for humans to imagine.

Using modern instruments and looking at stars billions of light-years away, astronomers have been able to examine millions of stars at different stages in their lives. Scientists have put together many pieces of information, like the pieces of a puzzle, to develop a theory of the life of a star.

One of the first pieces of information came in 1678 with Isaac Newton’s discovery of **gravity**. We now know that gravity is a force that pulls objects toward each other. The more mass an object has, the more gravity it exerts, so the Sun has stronger gravity than Earth. But the force gets smaller as the distance between objects increases.



Figure 1

The Trifid Nebula has two separate regions. The pink region has a high concentration of hydrogen, and the bluish-violet region is reflecting light from nearby stars. The dark patches are caused by dust clouds located between the nebula and Earth.

All stars begin their lives in **nebulas**, which are huge clouds of dust and gases, mainly hydrogen and helium (**Figure 1**). The dust and gases swirl around, breaking into clumps and contracting because of gravitational forces. As the clumps bump into each other and get bigger, their gravity gets stronger, and they are able to attract more particles and pack more tightly together. Eventually, the clumps are dense and hot enough for nuclear fusion to start. They have become new stars.

Just as no two clouds on Earth are identical, no two stars are identical. Although scientists understand the stages of stars fairly well (**Figure 2**), our knowledge of the details is far from complete. That is part of the excitement of studying astronomy. All these ideas are theories that are undergoing confirmation, development, or change based on further observations and evidence.



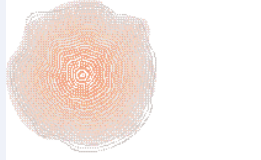
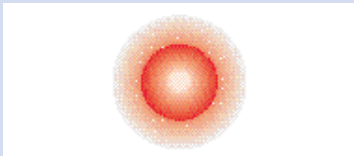
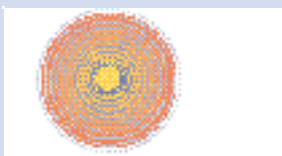
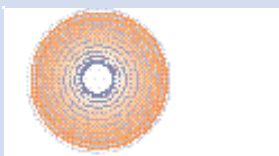



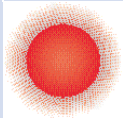
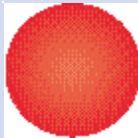
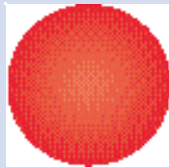

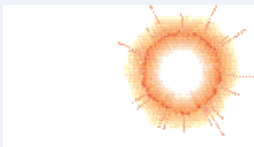
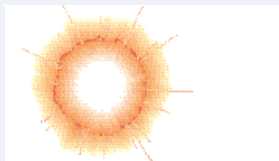



Try This

Graphing Gravity

What factors affect the force of gravity between two objects? Make a prediction. The equation for two objects interacting is $F = (Gm_1m_2)/d^2$, where F is the force in newtons (N), G is a constant ($6.67 \times 10^{-11} \text{ Nm}^2/\text{kg}^2$), m_1 is the mass of object 1, m_2 is the mass of object 2, and d is the distance between the centres of the objects.

1. Find the masses and radii of the planets in our solar system and calculate the force of gravity on a 1.0-kg rock at the surface of each one.
2. Determine the force of gravity on the rock when its distance from the centre of Earth is 2, 4, 6, and 8 Earth radii. Plot a graph to show your discoveries.
3. How accurate was your prediction?

Figure 2 The Life of Different Types of Stars

Type of Star	Small or Medium Star (mass the same as the Sun's or less; the most common type of star)	Large Star (mass about 10 times the mass of the Sun; rare)	Extremely Large Star (mass about 30 times the mass of the Sun; very rare)
Birth	 <p>Forms from a small- or medium-sized nebula.</p>	 <p>Forms from a large nebula.</p>	 <p>Forms from an extremely large nebula.</p>
Early Life	 <p>Gradually turns into a hot, dense clump that begins producing energy.</p>	 <p>In a fairly short time turns into a hot, dense clump that produces large amounts of energy.</p>	 <p>In a very short time turns into a hot, dense clump that produces very large amounts of energy.</p>
Major Part of Life	 <p>Uses nuclear fusion to produce energy for about 10 billion years if the mass is the same as the Sun's, or 100 billion years or more if the mass is less than the Sun's.</p>	 <p>Uses nuclear fusion to produce energy for only a few million years. It is perhaps 5000 times as bright as our Sun.</p>	 <p>Uses nuclear fusion to produce energy for only about one million years. It is extremely bright.</p>
Old Age	 <p>Uses up hydrogen and other fuels, and swells up into a large, cool red giant.</p>	 <p>Uses up hydrogen and other fuels, and swells to become a red supergiant.</p>	 <p>Uses up hydrogen and other fuels, and swells to become a red supergiant.</p>
Death	 <p>Outer layers of gas drift away, and the core shrinks to become a small, hot, dense white dwarf star.</p>	 <p>Core collapses inward, sending the outer layers exploding as a supernova.</p>	 <p>Core collapses, sending the outside layers exploding in a very large supernova.</p>
Remains	 <p>White dwarf star eventually cools and fades.</p>	 <p>Core material packs together as a neutron star. Gases drift off as a nebula to be recycled.</p>	 <p>Core material packs together as a black hole. Gases drift off as a nebula to be recycled.</p>

Note: These drawings are not to scale.

Giants and Dwarfs

You can see in **Figure 2** that when a star nears the end of its life it runs out of hydrogen and other fuels needed to produce energy. When this happens, the pressure holding the star together becomes reduced, so the star swells up while at the same time cooling down. Thus, in “old age” the star becomes larger and red. Stars the size of the Sun or smaller become **red giants**, while stars with masses 10 times (or more) larger than the Sun’s become **red supergiants**.

A star the size of the Sun or smaller is said to “die” when the nuclear reactions die down, the core shrinks, and the outer layers of the star drift away. The remaining material becomes a **white dwarf**, a small star with a higher temperature than red or yellow stars.

Supernovas

A **supernova** is an enormous explosion that occurs at the end of a large star’s life. By this stage, the star has used up the fuels needed to keep producing energy by the process of nuclear fusion. With reduced pressure on the core, the core collapses inward to become either a neutron star or a black hole (described below). At the same time, shock waves cause the outer layers to explode outward in a rapidly expanding nebula of dust and gases.

Supernovas are rare events. A famous one was observed in the year 1054 and was recorded in both China and India. It was so bright that people could see it even in daylight. It was visible for about 21 months. The gases spreading out from this supernova now form the Crab Nebula, which can be seen in the constellation Taurus (**Figure 3**).

Since the telescope was first invented about 400 years ago, only one supernova has ever been seen with the unaided eye. This event, now called Supernova 1987A (**Figure 4**), was discovered by a Canadian named Ian Shelton working at an observatory in Chile, South America.

Neutron Stars

When a star about 10 times the mass of the Sun dies, the resulting core is called a **neutron star**, an extremely dense star composed of neutrons. The neutrons are so tightly packed,



Figure 3

The supernova that created the Crab Nebula was observed in 1054. Other nebulas seen in the sky provide evidence that supernovas have occurred many times.

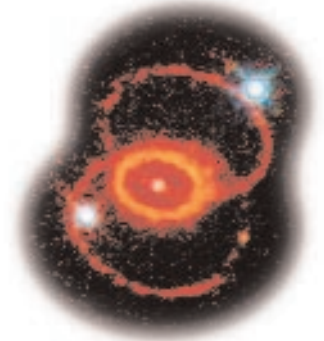


Figure 4

Supernova 1987A, photographed three years after the supernova was first seen by Ian Shelton. Astronomers are observing this supernova with great care. What they learn from their observations may help them improve their theories about the lives of stars.

Did You Know

When our Sun eventually swells into a red giant star, its outer layers will grow to be about 100 times its present size swallowing up Mercury, Venus, Earth, and maybe even Mars.

Try This

Modelling a Black Hole

In a large, open area, securely tie a one-holed rubber stopper onto a 1-m length of string. Whirl the stopper around a finger (without hitting anybody!), allowing the string to wind up on your finger until the stopper crashes into the finger.

1. In this model, what acts as the black hole? What acts as the material near it? What force represents the force of gravity?
2. What happens to the motion of the rubber stopper as it gets closer and closer to the finger? Relate this to what happens to material near a black hole.

with no space between them, that a cupful of a neutron star would have a mass of millions of kilograms. A **pulsar** is one type of neutron star. Pulsars emit pulses of very high energy radio waves. Pulsars are very small, only about 20 km in diameter, but very dense, with about the same mass as a normal star. Pulsars rotate while emitting energy in the form of light and radio waves, like the rotating light of a lighthouse—the effect is the energy reaches us as pulses. Today more than 400 pulsars have been identified.

Black Holes

When a star about 30 times the mass of the Sun dies, the resulting core is called a **black hole**, which is a small, very dense object with a force of gravity so strong that nothing can escape from it. Even light cannot be radiated away from its surface. That is why it is called a black hole (**Figure 5**).

Because light cannot escape the surface of black holes, they can exist undetected. Yet a Canadian astronomer, Tom Bolton, was able to confirm the existence of black holes. What was his evidence? He observed a star that appeared to be circling an invisible partner and noticed that this partner was emitting X rays as it drew matter toward itself from the star. These X rays confirmed Bolton's suspicions that the "invisible partner" was a black hole. The word "hole" is misleading because it sounds as though there is nothing there; it actually has a huge amount of matter packed into a sphere only a few kilometres across. It is so dense that a handful of it would have a mass of perhaps 10 billion cars! This explains its strong gravitational pull. Perhaps "dark body" would be a better name for this extremely rare type of object.

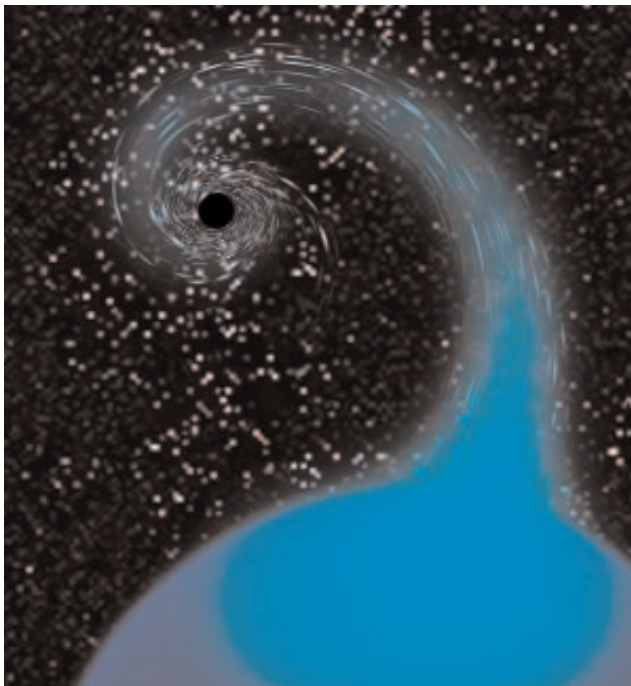


Figure 5

This is an artist's view of what happens near a black hole. As it twirls around, the hole attracts materials from a nearby star toward it. Why is this an example of indirect evidence?

Understanding Concepts

1. Describe how a star forms.
2. Describe the differences between the life of a low-mass star and that of a star 10 times the Sun's mass.
3. What is a supernova?

Exploring

4. Design and make a set of three-dimensional models to illustrate the life of one of the types of stars described in **Figure 2**.
5. Design a model of a black hole. Your model could use a circular magnet, metal washers, and thread. If your teacher approves your design, try it. In what ways is it accurate?

Reflecting

6. Describe why observing evidence of a black hole is an example of indirect evidence.
7. Think of circumstances in your life where you draw conclusions using indirect evidence. In each situation, what do you have to know already, before you believe the indirect evidence?

Challenge

How does the use of models help to communicate the information in the challenge you have chosen? What kind of models are most effective?

The Origin of the Planets

You know how difficult it is to see the planets in our own solar system. Now imagine looking for planets travelling around stars other than our own: other **planetary systems**. Planets are smaller than stars and do not emit light, so the task is not easy. Astronomers are continually using newer and better technology and making use of both direct and indirect evidence to search for other planetary systems in the universe. Learning about the formation of planets at various stages will help us better understand the development of the solar system and our own planet.

Evidence of Planetary Systems

What evidence do astronomers have of other planetary systems? Shortly after its launch into orbit in 1983, the Infrared Astronomical Satellite or IRAS made some exciting discoveries. It detected a large cloud of tiny particles in orbit around the star Vega. This was the first direct evidence that solid matter exists around a star other than our own Sun. Astronomers thought that the clouds of particles could be an early stage of the development of planets. Four months later, IRAS discovered solid material orbiting another star.

More recently, the Hubble Space Telescope has obtained images of planetary systems being formed. Astronomers also have indirect evidence of other planetary systems. The pull of gravity between a star and a nearby planet causes a slight wobble of the star's motion. This wobble can be detected by observing the star's spectrum.

Formation of the Solar System

Figure 1 shows the steps that may have occurred in the formation of the Sun, planets, and other parts of our solar system. In its early stages, our solar system was part of a nebula consisting mainly of hydrogen and helium. Minute particles of matter, such as iron, rock, and ice, made up about 1% of the nebula. This solid matter formed as a result of neighbouring supernova explosions from nearby stars.

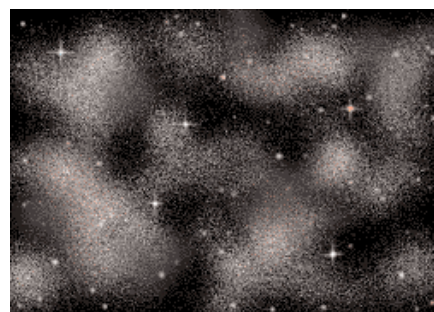
Scientists think that our Sun formed about 4.6 billion years ago. At the same time, smaller clumps of matter began to contract in the outer regions of the solar nebula. Attracted by the force of gravity, the clumps formed planets. This theory explains the formation of the gas giants

Did You Know ?

The belt of asteroids located between Mars and Jupiter likely would have formed into a planet if Jupiter's strong force of gravity hadn't prevented the particles from gathering together.

Figure 1

Astronomers think there were three main stages in the formation of the solar system.



a Gravity caused components of a rotating nebula to unite. Because of its rotation, the nebula flattened out as it contracted.



b As the process continued, a bulge formed toward the centre. This bulge later became the Sun. Some of the dusty disk of cooler material further from the centre gathered together to form smaller chunks.



c These smaller chunks away from the bulge gradually grew into larger chunks, which eventually formed into planets.

(Jupiter, Saturn, Uranus, and Neptune). The gas giants are composed mainly of hydrogen and helium gases: the same gases that make up much of the Sun. These planets probably formed in a way similar to the Sun—through the clouds of gases contracting due to gravity. But what about the terrestrial planets? What is the current theory about their formation?

The Terrestrial Planets and Minor Bodies

Mercury, Venus, Earth, and Mars are composed largely of rock and iron, with little hydrogen and helium. In the early stages of solar system formation, the gases in the inner regions of the solar system were probably too hot to condense. The young Sun produced enough solar wind (bursts of charged particles) to blast most of the hydrogen and helium out of the inner regions of the solar system. Only the chunks of heavier matter—iron and rock—were left behind (**Figure 2**).

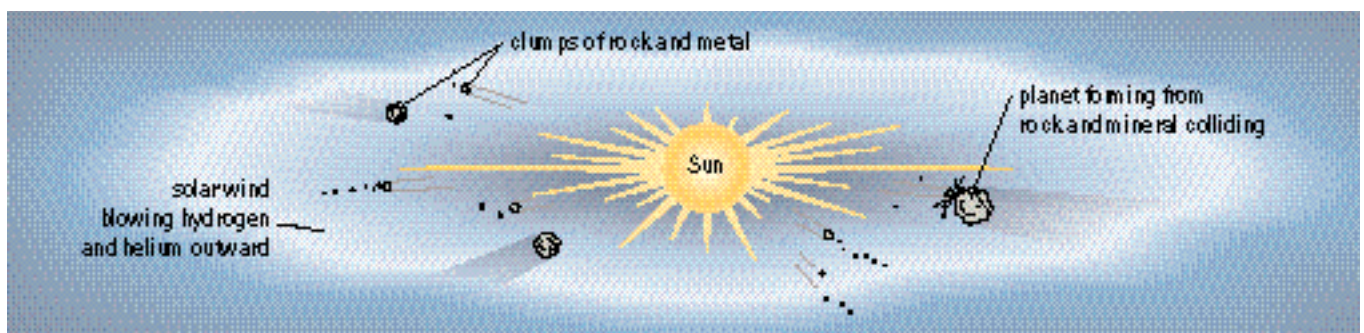
The terrestrial planets formed from those solid chunks. As chunks of solid matter circled the Sun, they eventually collided with one another and joined together. During millions of years, some of the chunks grew in size until their mass was large enough to have strong gravity. The more massive chunks pulled in all the matter in the space around them. They eventually became the planets.

Over a long time (perhaps 10 million years), most of the matter in the solar system became concentrated into the terrestrial planets and gas giants. The remaining matter makes up the asteroids, meteoroids, and comets—the minor bodies. Studying these minor bodies provides information about the early stages of our solar system, before most of the matter formed into the planets.

Pluto's origin is not certain as it has characteristics of a minor body, but is too far from the Sun to be explained by the theory of formation for the terrestrial planets. It may be more like a giant comet nucleus. The research is continuing.

Figure 2

The history of the terrestrial planets is



Understanding Concepts

1. What force is responsible for bringing together the particles found in space?
2. Describe, in order, the stages of the formation of the solar system.
3. (a) Which of the planets in the solar system are thought to have formed in a similar manner to the Sun?
(b) Why is it unlikely that the other planets formed this way?
4. (a) What are the minor bodies of the solar system?
(b) What do astronomers hope to learn from the minor bodies?
5. Assume that 10 years from now astronomers discover planets travelling around hundreds of different stars. Are the planets they discover more likely to be gas giants or terrestrial planets? Explain.

Exploring 3A

6. Research the Kuiper Belt. Why is its discovery a good example of a theory being supported by observations? Why do astronomers think Pluto and Neptune's moon Triton may have come from the Kuiper Belt?
7. Research and report on the Oort cloud. Explain why comets provide an opportunity to study what the solar system may have been like before the planets formed.
8. Use an Internet resource to research recent discoveries of planetary systems. Make a visual display of your discoveries.



Space Artist

Paul Fjeld gives a thumbs up sign as he steps out of the high performance jet in which he has just pulled 6 *g*'s. His call sign is “Fingers,” and he flies in jet fighters whenever he can as part of his research: Paul Fjeld is a

Canadian artist interested in space.

Between 1971 and 1973 the *Montreal Star* newspaper sent a young artist to cover the last three launches of *Apollo*. He convinced NASA to include him in their official Art Program; soon Fjeld got to go where even the press could not, including the *Apollo* simulator. His greatest thrill was working in Mission Control during the 1975 *Apollo/Soyuz* mission where he was made welcome and encouraged to “document what we were doing in a different way—for history.”

Fjeld’s first painting for NASA was of a crippled Skylab module with torn thermal shield and damaged solar arrays. Working with engineers from the manufacturer, he had to assess what the damage might look like and prepare a visual image for the press. The Canadian Space Agency has commissioned Fjeld to create large images of the *International Space Station*, the Canadarm, the SPDM (Figure 2, p. 499), and the various satellites. His work has appeared in *National Geographic* and on the cover of *Aviation Week*.

His favorite spacecraft is the *Apollo Lunar Module* (seen in the painting with Armstrong and Aldrin). The skin of the insect-like robot is a paper-thin wrapping of aluminum. It is a great subject to paint against the blackness of space. Actor Tom Hanks hired Fjeld to recreate that lunar moment on a huge set for the TV series *From the Earth to the Moon*.

What’s next for Paul Fjeld? Another painting? A script for a movie? Whatever it is, it will almost certainly involve his passion: space.

Explore

1. What skills and attitudes does the artist need to capture what the camera cannot capture?
2. If you were going to follow a similar career path, what would you study at secondary and post-secondary school, and why?
3. When might humans again land on the Moon? Provide a rationale for your answer.

“I want to paint a picture as if you are actually there.”



15.3 Activity

A Model of the Expanding Universe

In this activity, you will use a model to illustrate the concept of an expanding universe. As you use the model, think of ways it might be improved.

Materials

- 1 round balloon
- black, fine point, felt tip pen
- metric tape measure


Procedure

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


Table 1

	Measured distances (cm)			Calculated distances (cm)	
	A to B	B to C	C to D	A to C	B to D
"Orange" stage	?	?	?	?	?
"Basketball" stage	?	?	?	?	?


- 2 Blow up the balloon to the size of an orange. While your partner keeps the balloon at that size by pinching the opening, use the felt tip pen to mark the balloon with four dots, each separated by about 1 cm. Measure the exact distances between the dots with the metric tape. Label the dots in order, A, B, C, D.

-  (a) Record the measured distances between the dots in your data table.

- 3 Now inflate the balloon until it is about the size of a basketball. Measure the distances between the dots.

-  (a) Record the measured distances in your data table.

- 4 Calculate the distances A to C and B to D for both the first and second stages.

-  (a) Record these calculated distances in your data table.

- 5 Look at how much the distances A to B, B to C, and C to D increased when you inflated the balloon to the second stage.

- (a) Compare those increases.

- 6 Suppose you continued to blow up the balloon.

- (a) How do you think the change in the distances A to B, B to C, and C to D would compare with the change from the first stage to the second stage?

- 7 Imagine that you are standing on dot A while the balloon is expanding.

- (a) Which dot would appear to be moving away from you most quickly?
- (b) Which dot would appear to be moving away from you most slowly?
- (c) Would any dot appear to be moving toward you?

- 8 Imagine that the dots on your expanding balloon are galaxies of stars in an expanding universe.

- (a) What difference would you expect to find in how quickly nearby and distant galaxies are moving away from Earth?

- 9 Now imagine that you are on a planet in galaxy B looking at a planet in galaxy C.

- (a) Do you think the spreading of the galaxies would appear to be any different from these two locations? Explain.
- (b) If galaxy B is the Milky Way Galaxy, is it correct to say that galaxy B is the centre of an expanding universe? Explain.

Reflecting

1. Although the balloon model was useful to illustrate the concept of an expanding universe, it also had a major limitation. Identify the limitation and suggest a way to overcome it.

Evidence of an Expanding Universe

A balloon is a useful model in helping us imagine how the universe expands: as the balloon expands, closely spaced dots on the surface spread apart slowly; dots that are far apart spread apart more quickly. However, as a model, an expanding balloon has limitations. For example, galaxies are not found on a skin or membrane; instead, they are scattered throughout the universe.

How can we tell whether a galaxy is moving away from us? After all, the galaxies are very far away.

Before looking at evidence of an expanding universe, let's review the properties of light. Light is a form of energy that travels as a wave. Each colour has a wavelength, which is the length of one wave. The visible spectrum (**Figure 1**) consists of different colours, ranging from the longest wavelengths (red) to the shortest wavelengths (violet).

You already know that different stars have characteristic colours. The same is true for galaxies: each galaxy emits its own spectrum or range of colours in a pattern that astronomers recognize. As early as 1912, astronomers observed evidence that the galaxies are moving away from Earth and from one another. This evidence came from looking at the light spectra (patterns of colours) given off by nearby galaxies. The spectrum of a moving object in space is different from the spectrum of an object that is not moving. An example will help explain this.

Imagine a duck bobbing up and down on the surface of a pond (**Figure 2**). Suppose the duck represents a source of energy. The ripples that spread out from the duck represent waves of energy emitted by the source. The distance from the top of one ripple to the top of the next ripple represents one wavelength.

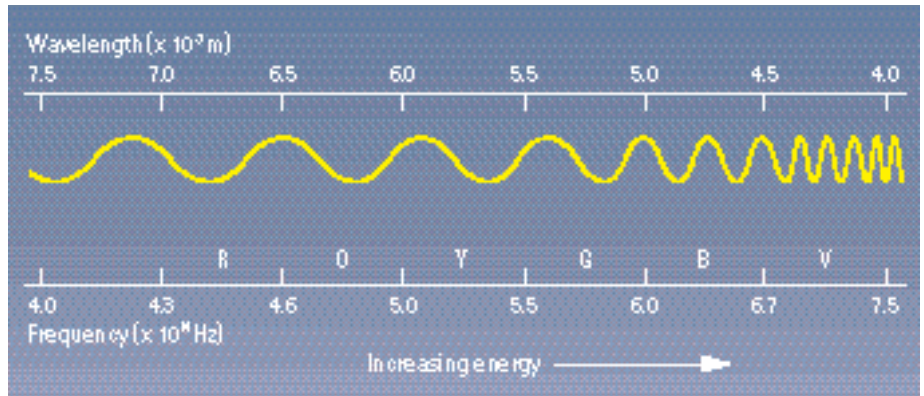


Figure 1
The visible spectrum

Figure 2



- a** This model shows an energy source (the duck) sending out waves (the water ripples) with a constant wavelength (the distance from the top of one ripple to the top of the next).



- b** Side view of the waves.

Figure 3



- a** The wavelengths become shorter in one direction and longer in the other direction.



- b** A side view of the waves created by a bobbing duck moving to the left.

Now, imagine yourself standing on the shore, watching the duck. If the duck swims toward you, the ripples in front of it are squeezed together and therefore have shorter wavelengths (**Figure 3**). Meanwhile, the waves behind the duck are spread farther apart and so have longer wavelengths. Even if you could not see the duck itself, you could observe from the changing wavelengths which way the duck was moving. Shorter wavelengths indicate that the duck is moving toward you; longer wavelengths indicate that the duck is moving away from you. Of course you have to know what the wavelengths would be if the energy source were stationary, relative to you.

When astronomers look at a distant source of light, such as a galaxy, through a spectroscope, they recognize the *pattern* of the spectrum but observe that the *colours* of its lines are not the same as they would expect. The lines are moved toward the red end of the spectrum (**Figure 4**) meaning that they have a longer wavelength. Searching for an explanation, astronomers concluded that the light has a longer wavelength than normal because the galaxy is moving away from us. This movement, or shift, into the red end of the spectrum is called **red shift**.

The light energy from all distant galaxies shows red shift. However, there are different amounts of red shift. The greatest shifts occur for galaxies that are farthest away from us. From this information, we can infer that all galaxies are moving away from us and away from each other. But what is causing this movement? Why is the universe expanding? Astronomers are investigating the answers to these questions.

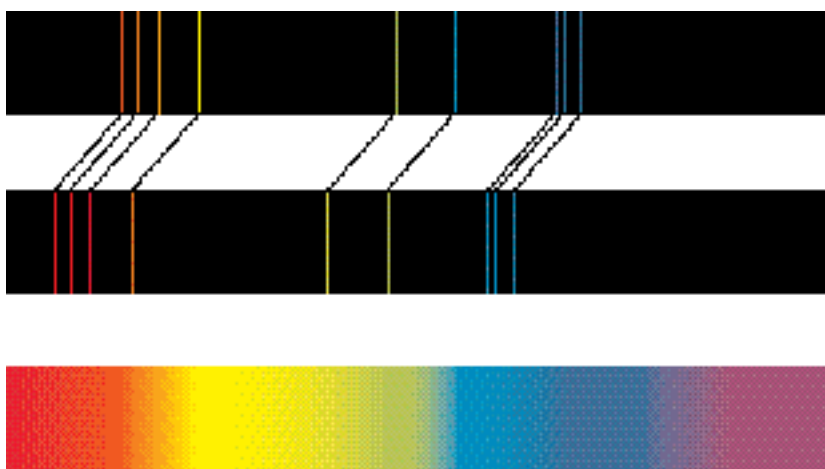


Figure 4

The top diagram represents the nine lines of a spectrum emitted by a stationary galaxy. The second diagram represents the same nine lines of the same spectrum emitted by the galaxy if it were moving away from us rapidly. The wavelengths of all the lines in the spectrum have shifted (moved) toward the red end. The bottom white light spectrum is shown for reference.

Understanding Concepts

1. Copy **Figure 5** into your notebook. It is a pattern of ripples. Label the ripples that have shorter wavelengths and those that have longer wavelengths. Indicate the direction of movement of the "object" causing the waves. Explain your answer.

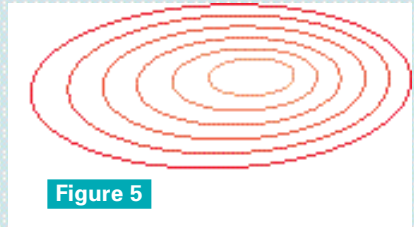


Figure 5

2. What does "red shift" mean?
3. What evidence do astronomers have that the universe is expanding?
4. If astronomers were to observe a "violet shift" for a certain star, what could they infer? Explain why.
5. If the duck in **Figure 3a** were travelling from the top of the diagram toward the bottom, what would you observe? Draw a diagram and explain why.

Exploring

6. How could you use water in a flat container and a bobbing finger to illustrate changes in wavelength as the source of the waves moves?
7. The scientific name for the cause of red shift is the "Doppler effect." Research this effect and relate it to what you have learned about red shift. (The Doppler effect relates to all types of waves, including sound waves. For now, focus on light waves.)

The Origin of the Universe

Do you enjoy solving mysteries or putting the pieces of a puzzle together? If so, perhaps a career in astronomy is ideal for you! One of the main goals of many astronomers is to solve the mystery of the origin of the universe. These astronomers search for an answer to the question, “How did the universe begin?”

If stars go through cycles, beginning and ending as nebulas, does the entire universe also go through some type of cycle? Scientists do not know the answer to this question, but they have gathered enough information to formulate a theory. This theory is based on evidence that the size of the universe is not constant but is expanding. This is the accepted theory, but it may be modified as more evidence is collected and analyzed.

The study of the origin and changes of the universe is called **cosmology**.

The Big Bang Theory

If the galaxies are moving apart, then presumably they used to be closer together. Still earlier, they must have been even closer together. Continue to move backward in time in your imagination and you will reach what we call “time zero.” Scientists estimate time zero as being between 10 and 15 billion years ago. At that time, all the matter of the entire universe was packed together into one small, extremely dense, hot mass under enormous pressure. The event that occurred when the universe emerged from this state of enormous density and temperature is known as the Big Bang (**Figure 1**). Scientists use the **Big Bang theory** to describe the beginning of the universe that we know.

Scientists have more than just the red shift of distant galaxies as evidence of the Big Bang. They have also collected data that suggest that, even today, the entire universe is “glowing” from that initial explosive event, just as a piece of firewood continues to glow even after the fire has been put out. In 1965, for example, two scientists made an

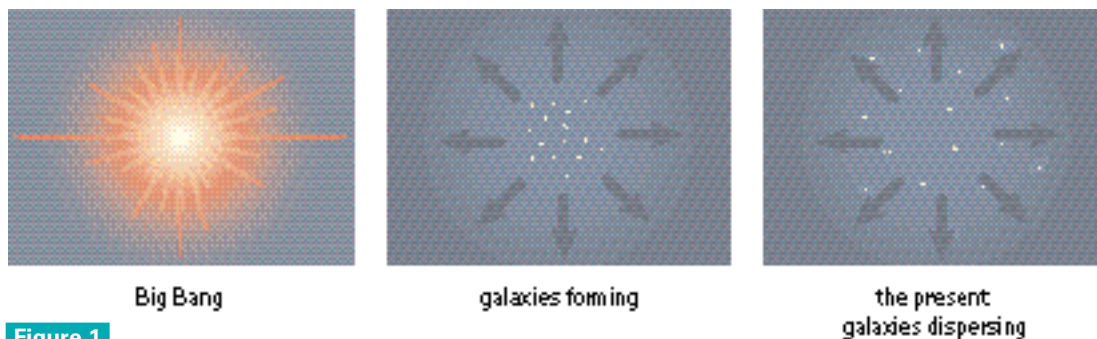


Figure 1

These diagrams illustrate the Big Bang theory of the formation of the universe. The density of the material that made up the universe shortly after the Big Bang was immense. One cubic centimetre of the material is estimated to have had a mass of one billion kilograms!

accidental discovery using a radio telescope. They detected unexpected radiation coming from all directions in space. After checking that there were no defects in their equipment, they concluded that this faint, unknown energy is all that remains of the enormous amount of energy that exploded outwards at the time of the Big Bang. The intense radiation from the tremendous explosion has faded to only a faint “whisper” after travelling for thousands of millions of years through space.

The Big Bang theory can be used to explain our observation that the universe is expanding. But we still don't know everything about how the universe began. For example, while scientists can describe what they think occurred a fraction of a second after the Big Bang, they do not know what the universe was like (or even if it existed) just before the Big Bang explosion. Changing our theories about the universe is a continuing scientific process as we try to explain the new discoveries that astronomers make year after year (**Figure 2**).

However, the Big Bang theory is not the only way that the origin of the universe has been explained. In the past, many cultures have held different beliefs of their own. These beliefs, however, are not the same as scientific theories—they cannot be tested, explored, and either supported or disproved by evidence. But each is a kind of model that helps people understand how the world works.

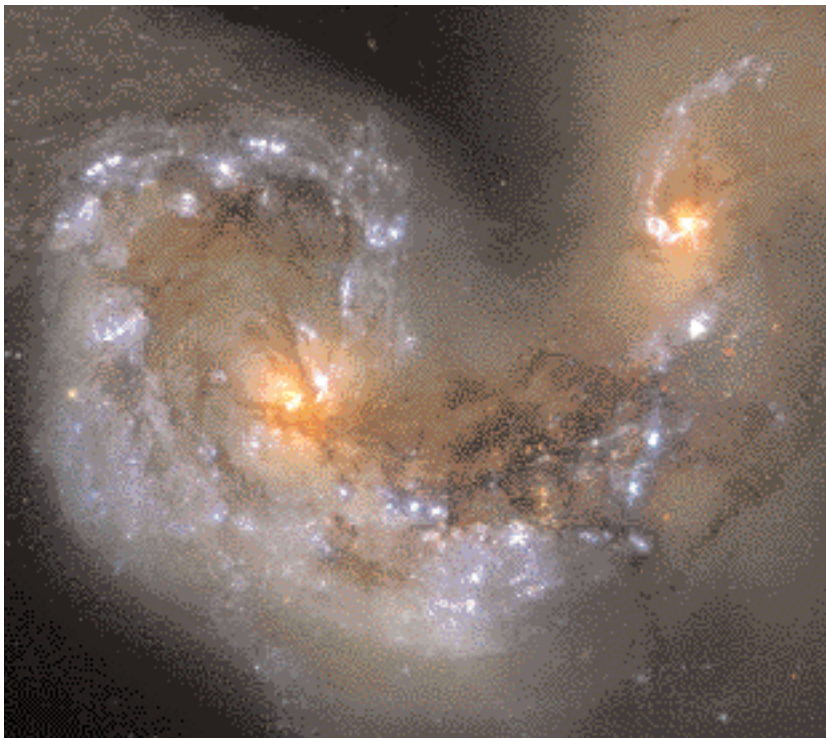


Figure 2

The Antennae galaxies are a pair of galaxies whose collision has resulted in a firestorm of star birth activity. It is proving to be an excellent “laboratory” for studying the formation of stars and star clusters.

Understanding Concepts

1. How does the Big Bang theory explain an expanding universe?
2. How does the development of the Big Bang theory illustrate the scientific process?
3. How could you use all the students in your class to act out a model of the expanding universe shortly after the Big Bang?

Exploring

4. Older theories about the universe include the oscillating theory and the steady state theory. Find out about these theories, then write an article for a science magazine describing one of them. Draw illustrations representing the theories to go with your article.
5. People in all parts of the world have had, and still do have, other ideas about the origin of the universe. Research and compare at least two contrasting cultural views. Present your findings in a creative way.

Reflecting

6. How does a scientific theory, such as the Big Bang theory, differ from a belief?

Challenge

The Big Bang theory is a difficult idea to conceptualize. What model or diagrams will you use to explain it to the general public?

The Hubble Deep Field

Figure 1 shows one of the most amazing images ever taken of outer space. It is called the *Hubble Deep Field*. When you look at it, you are peering back in time up to 8 billion years, into a part of the sky that appears no bigger than a grain of sand resting on a fingernail of your outstretched hand! Although this picture only shows you a tiny piece of the sky, it contains a lot of information. The only stars in the photograph are the objects that appear to have spikes. (This feature results from the wave nature of light.) All the other objects are galaxies.



Figure 1

This image was captured by the Hubble Space Telescope when it was aimed toward a part of the sky above the Northern Hemisphere.

(a) What can you infer about the number of galaxies in the universe? (In your answer, be sure to consider the concept of the “grain of sand” mentioned above.)

(b) Which types of galaxies can you see?

The image in Figure 1 was obtained by the Hubble Space Telescope over a period of about 100 h. It is similar to a time-lapse photo that might be taken here on Earth.

(c) Why is time-lapse imaging important when viewing faraway galaxies?

The “optical” portion of the Hubble Space Telescope includes a very large mirror, specially engineered with great precision. Unfortunately, there was an error in the manufacturing that was not detected until the telescope was launched: the curvature of the mirror was out by the thickness of a human hair, so it could not focus as well as had been hoped. Fortunately, astronauts were able to correct the problem in 1993 by adding a secondary mirror during a series of space walks. It was a delicate but successful operation. Other instruments have since been added to Hubble, improving its performance still further.

(d) Why are more instruments added to the Hubble Space Telescope, instead of being put into orbit separately? What might be the advantages of each alternative?

Advanced technology is needed to keep a telescope, travelling at almost 30 000 km/h while orbiting Earth, aimed steadily at one tiny spot for such a long time.

(e) Why wouldn't the telescope naturally stay pointed in the same direction? Make some predictions.

This image sees deeper into space than any previous image. That is why it is called the “Hubble Deep Field.” The farthest objects, which are galaxies, are up to 8 billion light-years away. Galaxies 8 billion years ago had less structured shapes than galaxies now appear to have. This feature helps support the Big Bang theory.

(f) Explain how the less structured shape of early galaxies supports the Big Bang theory.

Astronomers observe evidence of several galaxies colliding with each other shortly after the Big Bang.

(g) Propose a reason why galaxies in the past were more likely to collide than they are now.

Studying such images in more detail will help scientists better predict what might happen to the universe in the future.

(h) If you were a scientist studying images like this, what would you look for? Why?

Understanding Concepts

1. How was the universe different 8 billion years ago than it is now?
2. Explain how this image allows scientists to “peer back in time.”

Exploring

3. If you were responsible for aiming the Hubble Space Telescope to take a new Deep Field image, in which direction would you aim it? Give reasons.
4. Research the problems with Hubble's mirror and how they were corrected. Draw a labelled diagram to explain the repairs.
5. Research the costs involved with the Hubble Space Telescope. Do you think it is a good use for the money? Explain reasons for your opinion in a brief letter to a science magazine.
6. Find out what other Deep Field images have been taken. View the images on a NASA web site.

How Astronomers Use Computers

When you imagine an astronomer at work, you probably think of someone gazing up at the sky or perhaps peering through a telescope. Actually, today's astronomers spend most of their time in front of computers. The computers analyze the vast amounts of data that are collected by various instruments and reorganize the information into forms that help the astronomer pick out what is important (**Figure 1**). Without computers, most research in astronomy would be slowed down because we would not be able to analyze information as fast as we are collecting it. Computer technology has made a large contribution to the extensive knowledge and understanding we now have of Earth and its place in the universe.

For example, an astronomer can study the glowing image of an exploding star on a computer screen. The computer created the image from data gathered by a series of radio telescopes. The information is stored in the computer, which creates a radio-wave “picture” of the exploding star—what you would see if you had eyes that could see radio waves. Images like this give astronomers a new view of the universe. The astronomer may use the computer to display the image in different ways to show certain features more clearly and to take measurements and make comparisons with previous data.

Computers are also essential in the radio search for extraterrestrial life. Only by using computers can scientists listen to all parts of space, at many different radio frequencies, for long periods of time. Scientists hope to detect radio signals that unknown beings might have sent from other parts of the universe.

The Hubble Space Telescope (**Figure 2**) is constantly sending computerized images of space to Earth. Astronomers can display these images on their computer screens, explore certain features, and make calculations. They can also store the data, keeping it on hand for easy retrieval, should it be needed again.

As well as helping astronomers analyze, display, and store data, computers are used to control the operation of astronomical instruments. Imagine the problem of focusing on a galaxy when your telescope is moving along with Earth as it rotates. In the past, astronomers had to constantly turn their telescopes in the opposite direction to Earth's rotation. Now, computers do all the calculations and control the movement of the instruments.

Simulations are another important use of computers. Scientists may apply known equations to simulate conditions deep within the Sun or test models of the formation of the universe. Simulations can help

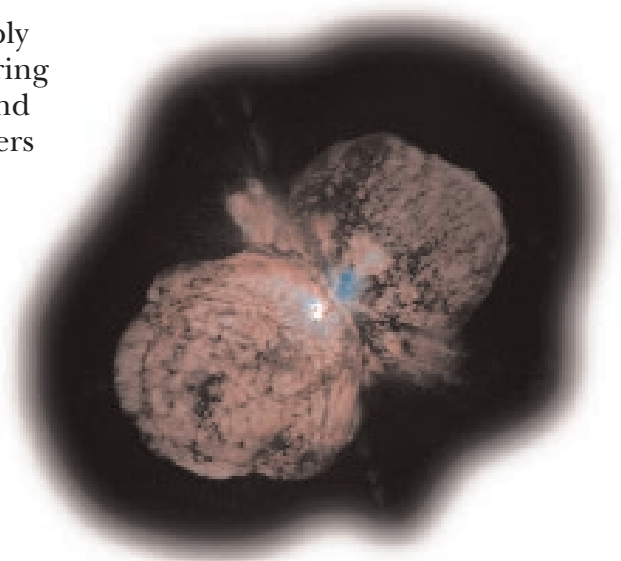


Figure 1

This is a false-colour image generated by computer using the image from a telescope. It shows Eta Carinae—a dying star.

Did You Know ?

Earth may be the only planet in our solar system with the right conditions to support life. But does life exist only on this one planet in the entire universe? Scientists look at many factors when trying to determine if a planet can support life. In one ongoing investigation, a radio telescope scans the sky 24 h a day. It is linked to computers that sift through all the incoming radio signals in a search for signs of intelligent civilizations. So far, no signals have been observed, but research continues. This kind of search is called SETI, which stands for Search for ExtraTerrestrial Intelligence.

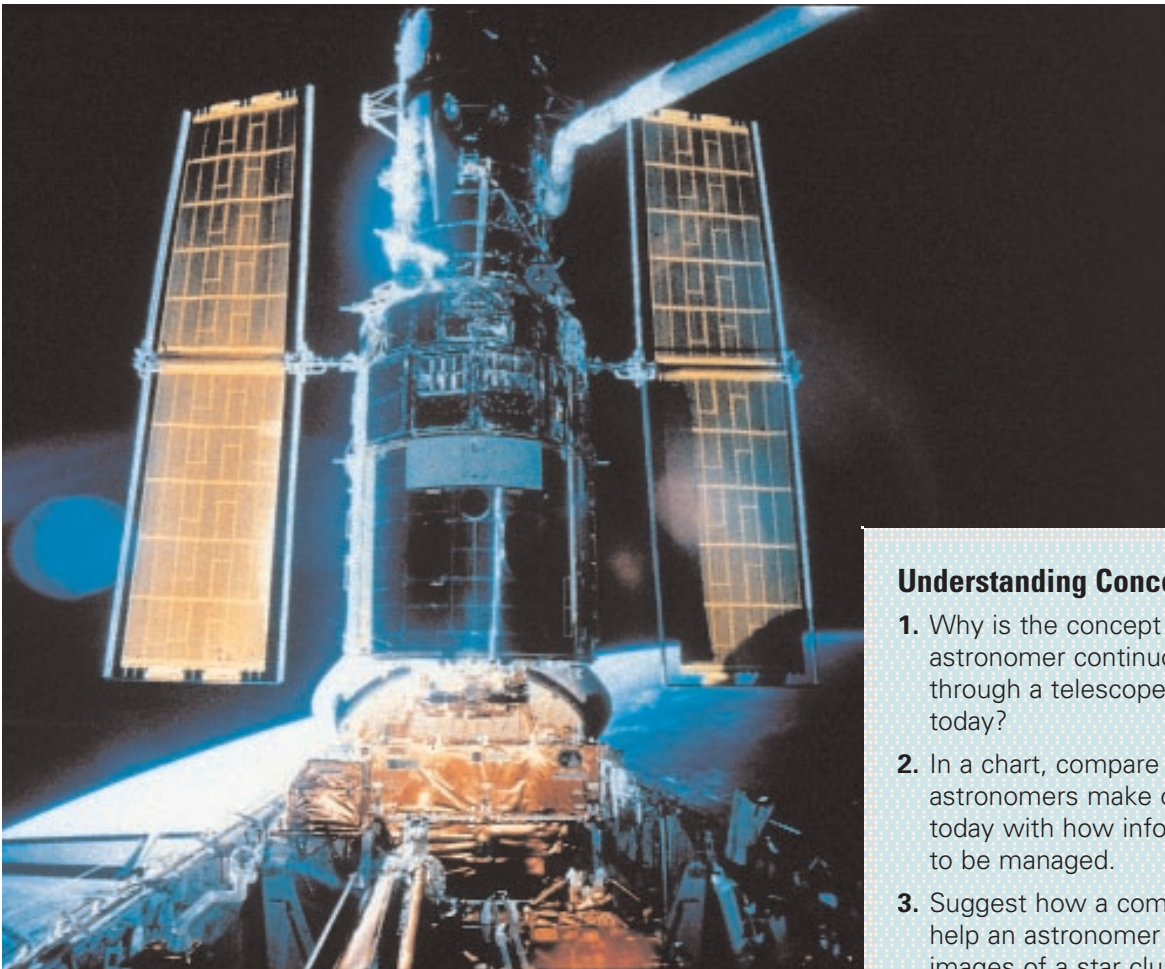


Figure 2

This view of the Hubble Space Telescope shows the solar panels that change light energy into electrical energy. Earth is seen in the background.

people learn about the universe and our own fragile and beautiful planet as it travels in one tiny corner of a galaxy that contains about 400 billion stars.

Computers record large amounts of data, analyze them, create pictures, do mathematical calculations, and operate complicated astronomical instruments. They help to bring the past into the present. But to some astronomers, the most exciting thing computers do is electronically link scientists all over the world. Through their computer networks, astronomers can share ideas, data, calculations, computer images, and the latest scientific information.

Understanding Concepts

1. Why is the concept of an astronomer continuously peering through a telescope not valid today?
2. In a chart, compare three uses astronomers make of computers today with how information used to be managed.
3. Suggest how a computer could help an astronomer analyze images of a star cluster.

Making Connections

4. How can computers help in time-lapse imaging of components of the sky? How do these images enhance our understanding of the history of the universe?

Exploring

5. List concepts in the study of astronomy that you think you could understand better if you could watch computer simulations of the concepts. If a simulation program is available, try it out and evaluate its benefits.

Challenge

How can you use your computer as a tool to help you in the challenge you have chosen?

Chapter 15 Review

Key Expectations

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

- Outline the current theory explaining the origin, evolution, and fate of the Sun and other stars. (15.1)
- Describe these components of the universe: nebulas; supernovas; neutron stars; black holes. (15.1)
- Outline the current theory explaining the formation of the solar system. (15.2)
- Describe and evaluate scientific evidence of origin and evolution of the universe. (15.1, 15.4, 15.5, 15.6)
- Plan ways to model answers to questions about the history of the universe, and communicate results. (15.3)

- Formulate and research questions related to the history of the universe, and communicate results. (all sections)
- Describe how computers are used to enhance our understanding of the universe. (15.7)
- Identify contributions of Canadian scientists to the exploration of the universe. (15.1)
- Explore careers related to the exploration of space. (Career Profile)

KEY TERMS

Big Bang theory
black hole
cosmology
gravity
nebula
neutron star
planetary system

pulsar
red giant
red shift
red supergiant
supernova
white dwarf

Reflecting

- “Scientists use models and simulations to visualize and explain the dynamic processes that form the universe.” 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 words “Big Bang.”
2. (a) Arrange the following stages of the life of a star in the order in which they occur: black hole; supernova; nebula; red supergiant.
(b) Is there more than one possible answer in (a)? Explain.
(c) Which type of star would go through these stages?
3. (a) What is a nebula?
(b) How are nebulas important to the formation of stars and planets?
4. What process causes stars to reach “old age”?
5. What force leads to the formation of planets?
6. Why are white dwarf stars much more common than black holes in the universe?
7. Describe the relationship between a red giant and a white dwarf.
8. The following is a list of stages in the lives of stars: white dwarf, supernova, red giant, neutron star, black hole.
(a) Which of these stages, if any, will the Sun pass through in the future?
(b) Explain why the Sun will not pass through the other stages.
9. (a) Since the invention of the telescope, how many supernovas have been observed with the unaided eye?
(b) How do astronomers benefit from studying supernovas?
10. Describe the Big Bang theory.

11. Why is it difficult to observe planets in orbit around distant stars?
12. Describe the current theory of the formation of the planets of our solar system. Illustrate your answer with drawings.
13. (a) What is red shift?
(b) How does red shift provide evidence for the Big Bang?
14. What evidence besides red shift supports the Big Bang theory?
15. As scientists continue to observe the spectra of stars and galaxies, what do you think they would conclude if they observed the following?
(a) Red shift continued.
(b) Red shift was no longer observed for any star or galaxy.
(c) A shift was observed toward the violet end of the spectrum.
16. State, with reasons, whether you agree with this statement: "Nebulas provide a good example of recycling in the universe."

Applying Skills

17. If you look at photographs of the Moon, Mercury, Mars, and the moons of other planets, you will see evidence of collisions.
(a) What is this evidence?
(b) How does this evidence support the theory of the formation of the solar system?
(c) What evidence of collisions on Earth supports the theory?
18. Describe examples in this chapter of indirect evidence used by astronomers.
19. Make a physical model or a computer model to illustrate one of the concepts covered in this chapter, such as the life of a star, or the expanding universe.
20. The discovery of red shift supports the theory of an expanding universe. However, it is indirect evidence, not proof, that galaxies are moving away from each other. What other interpretations could there be of red shift?
21. Write at least five questions about the universe that you would like more complete answers to.
22. Choose one of the questions from your list in 21. Describe how you would go about finding the answer(s) to that question.
23. Research the most recent ideas about black holes and prepare a presentation.
24. The light from two distant galaxies, A and B, is examined through a spectroscope. The two line spectra have a similar pattern of lines, but the lines of Galaxy A's spectrum have slightly longer wavelengths than those of Galaxy B.
(a) Draw what their two spectra might look like.
(b) What might you conclude about the motions of the two galaxies, relative to Earth?
25. The star probe *Stardust* was launched in 1999 to collect dust from the tail of comet Wild-2. Research the purpose and current status of this mission.

Making Connections

26. Design a visual image that could be attached to a space probe leaving the solar system. The image should communicate information about ourselves and our planet to intelligent aliens discovering the probe. Remember, they would not be able to read our written communications! Research plaques that have been attached to probes that have already been launched.
27. Assume you have unlimited funds to carry out investigations to test one of the theories presented in this chapter. Which theory would you test? How would you test it? Predict your results.
28. Some radio telescopes are used to try to detect intelligent life that may exist on planets revolving around other stars in the universe. What other methods could you suggest for trying to find evidence of intelligent life beyond Earth (extraterrestrial intelligence)? Explain your answer.
29. Do you expect computers will be more or less important in the study of astronomy in the future? Why?