Section 3 Origin of the Universe and the Solar System

What Do You See?

Learning Outcomes

In this section, you will

- **Describe** the Doppler effect.
- **Explain** the big bang theory of how the universe was formed and the evidence supporting it.
- **Explain** the nebular theory of the formation of the solar system.
- **Examine** planetary systems outside of our solar system.

Think About It

When you think you are standing still on Earth, you are actually moving rapidly through space. Earth rotates once about its axis every 24 hours and revolves around the Sun once every 365 days. You are gaining a lot of mileage without taking a step. When you look up at the stars in the sky, they also seem to be still, although they are moving through space at incredible speeds.

- **How do astronomers measure how stars and galaxies move?**
- **What do these movements tell astronomers about how the universe formed?**
- **How did the solar system form?**
- **What is the probability that there are planetary systems beyond our own? How do you know?**

Record your ideas about these questions in your *Geo* log. Be prepared to discuss your responses with your small group and the class.

Investigate

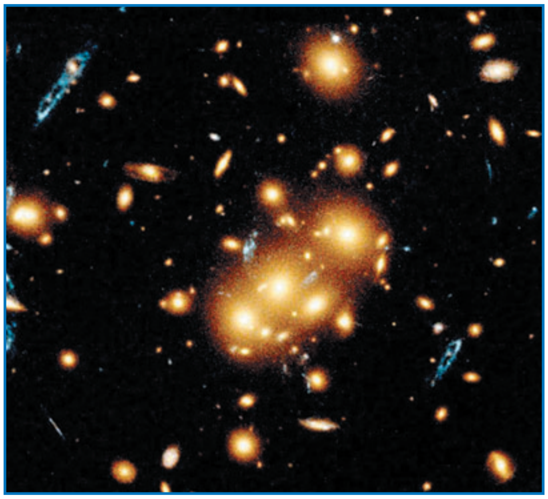
In this *Investigate*, you will explore how the universe formed and continues to expand. You will then run a model that examines how scientists measure the motion of stars and galaxies. Finally, you will observe a model that demonstrates how the solar system formed.

Part A: Evidence of Motion

1. Scientists have found that the motion of a star or galaxy relative to Earth can be determined by a shift in the *wavelength* of the light it emits. You will model this effect using sound. One person from your group will swing an alarm clock, buzzer, or constant-pitch noisemaker around on a string. The other members of your group will stand outside the reach of the swinging noisemaker.
   a) How will the circular swinging of the noisemaker affect the sound it produces? Record your prediction.
2. Turn on the noisemaker and observe the sound it makes when stationary.
3. Attach a string securely to the noisemaker. Have one person from your group swing the noisemaker around on the string while the other members of your group stand outside its reach.
   a) How does swinging the noisemaker affect the pitch of the sound that is heard?
   b) Explain your observations.
   c) What other changes in pitch have you observed from an object in motion?
   d) How do you think the change in pitch that you observed compares to a change in light produced by a moving star or galaxy?

Part B: Model of an Expanding Universe

1. Many astronomers theorize that our universe is expanding. They support their ideas by observations of distant galaxies that appear to be moving away from our galaxy at enormous speeds. You will use a large balloon, marker, and tape measure to model the movement of galaxies away from each other as the universe continues to increase in size. Mark 10 dots on the surface of the deflated balloon. Distribute the dots all over the balloon. Label the dots with letters. The dots represent galaxies. Galaxy A is the Milky Way Galaxy.
   a) Predict what will happen to the distances between the galaxies as the balloon is inflated.



2. Have one person from your group inflate the balloon until its diameter is about 20 cm. Pinch the opening of the balloon to keep air from leaking out.
3. Have another person use a tape measure to measure the distance from the Milky Way to each of the other galaxies.
   a) Record your measurements in a data table in a row labeled "Expansion Time 1."

4. Inflate the balloon until its diameter is about 28 cm. Pinch the opening of the balloon to keep air from leaking out.

   a) Record the new distance from the Milky Way to each of the other galaxies. Record your measurements in the data table in a second row labeled "Expansion Time 2."

5. Calculate the increase in distance between expansion times. Do this by subtracting the distance for each galaxy at "Expansion Time 1" from the distance for each galaxy at "Expansion Time 2."

   a) Record the increase in distances in the data table in a third row.

6. Assume that the time between expansions was a period of 8 years. Calculate the speed that each galaxy moved away from the Milky Way using the equation:

$$\text{speed} = \frac{\text{distance}}{\text{time}}$$

   a) Add a fourth row to your data table to record the rate of expansion.

7. Use the rates to calculate how far each galaxy will be from the Milky Way after 24 years and after 32 years.

   a) Record these distances in the table.

8. Use your results to help you answer the following questions:

   a) How do the distances from the Milky Way Galaxy to the other galaxies change over time?

   b) What happens to the size of each galaxy over time?

   c) If the universe is expanding, do galaxies that are close together move apart faster or slower than galaxies that are far apart?

Part C: Formation of the Solar System

1. Scientists believe that the Sun and planets formed at the same time from a large cloud of gas and dust. You will observe a model of the formation of the solar system using a cup of hot chocolate and powdered coffee creamer. The hot chocolate represents space and the coffee creamer represents gas and dust.

   a) Predict what will happen when you swirl the creamer on the surface of the hot chocolate.

2. Prepare a cup of hot chocolate using lukewarm water. Now, sprinkle some creamer onto the surface of the hot chocolate.

3. Use a spoon to stir the liquid inside the cup in a gentle, circular motion.

4. Observe how the creamer moves in the cup.

5. Use your observations to help you answer the following questions:

   a) What is the effect of swirling on the creamer?

   b) How does this model demonstrate how the Sun and planets formed from a cloud of gas and dust?

Learning Through Technology

To use online resources to find out the latest information on *extrasolar planets*, go to the *EarthComm* Web site at http://www.agiweb.org/education/earthcomm2/. There you will be able to visit NASA's Jet Propulsion Laboratory Web site to access current data on extrasolar planets.

Digging Deeper

FORMATION OF THE UNIVERSE, SOLAR SYSTEM, AND PLANETS

The Big Bang Theory

You just modeled how the universe formed and is expanding. You also investigated how scientists track the motion of objects in the universe. The Milky Way Galaxy formed about 10 billion years ago and is one of billions of galaxies in the universe. According to a popular theory, the universe itself formed somewhere between 12 and 14 billion years ago in an event called the big bang. This is known as the **big bang theory**. Big bang makes it sound like the universe began in an explosion. However, it did not. Scientists call the beginning of the universe "time zero." At time zero, the universe consisted almost entirely of energy. The energy was concentrated into a volume smaller than a grain of sand. The temperatures were unimaginably high. Then the universe expanded extremely rapidly. As it expanded, the temperature dropped. As the temperature dropped, matter was formed from some of the original energy.

Cosmologists are scientists who study the origin and dynamics of the universe. Cosmologists think that most of the **matter** in the universe was formed within minutes of time zero. Initially, this matter was too hot to form into atoms. After a few hundred thousand years, the temperature of the universe dropped to the point where atoms could exist. The atoms were mostly hydrogen and helium. Eventually, under the force of gravity, these atoms began to clump together. They clumped into clouds of gas, which in time formed the first stars. As more stars formed, they grouped together to form the earliest galaxies. The expansion and cooling that started with the big bang continues to this day.

Geo Words

big bang theory: a theory to try to explain the origin of the universe, which proposes that the universe has expanded from a condition that existed at "time zero."

cosmologist: a scientist who studies the origin and dynamics of the universe.

matter: a solid, liquid, or gas that possesses inertia and is capable of occupying space.

wavelength: the horizontal distance between two successive crests of a wave.

Doppler effect: the apparent change of wavelength occurring when an object is moving toward or away from an observer.

Doppler Effect: Evidence of the Big Bang

Scientists point to shifts in the **wavelength** of light produced by distant galaxies as evidence that the universe is expanding. This phenomenon is known as the **Doppler effect**. You experienced the Doppler effect in the *Investigate* when you were swinging the noisemaker. You probably noticed that the pitch of the noisemaker grew higher as it approached you and

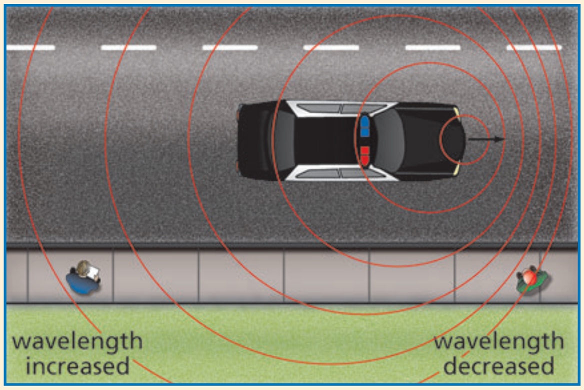


Figure 1 When a police car is coming toward you, the pitch of the siren is increased. When it is moving away from you, the pitch is decreased.

then dropped suddenly as it passed by you. You may have had a similar experience with the changing pitch in the tone of the siren of a passing emergency vehicle. (See *Figure 1*.)

Sound occurs in waves. When a moving object producing a sound approaches you, the sound waves are compressed, causing wavelengths to decrease (the distance between wave crests becomes shorter). This causes the pitch of the sound to become higher. The pitch of a sound is related to its wavelength. The higher the pitch, the shorter the wavelength. As the object moves away, the wavelengths of the sound waves increase and the pitch drops. The longer the wavelength, the lower the pitch.

Light also occurs in waves. As a result, the Doppler effect can be used to determine whether a star or galaxy is moving toward Earth or away from it. Light from a star or galaxy can be detected as a *spectrum* of colors. You will learn more about the spectrum of light in a later section. Shorter wavelengths of light are blue or violet in color. Longer wavelengths of light are red. If a star or galaxy is approaching Earth, the wavelengths of light it emits become shorter. If a star or galaxy is moving away from Earth, the wavelengths of light are longer.

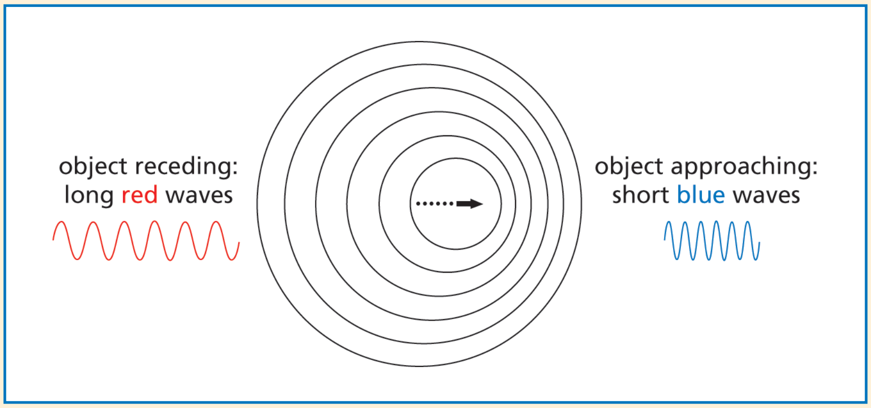


Figure 2 The wavelengths of light from a receding star or galaxy are stretched toward the red end of the light spectrum, while wavelengths of light from an approaching star or galaxy are shortened toward the blue end of the light spectrum.

Scientists have observed that the wavelengths of light emitted by all galaxies, except our close neighbors, are being shifted toward the red end of the spectrum. The wavelengths at this end of the spectrum are longer. They have concluded that these galaxies must be moving away from Earth. Therefore, the entire universe must be expanding. Remember your model of an expanding universe from the *Investigate*? The dots (galaxies) on the balloon moved apart as the model universe expanded. In a similar way, distant galaxies, beyond our own and those close by, are moving away from Earth.

Geo Words

radiation: emission of energy in the form of rays or waves.

cosmic background radiation: a form of electromagnetic radiation that fills the universe.

steady-state theory: a theory that proposes that matter in the universe is continuously being created at a rate that allows the density of the universe to remain constant as it expands.

The galaxies and stars are the visible evidence of the big bang. However, there is other, unseen evidence in the form of **radiation**. This evidence is called the **cosmic background radiation**. This is radiation that is left over from the initial moments of the big bang. Using special instruments, astronomers have detected this radiation coming in from all directions of the universe. The existence of the cosmic background radiation is generally considered to be solid evidence of the big bang.

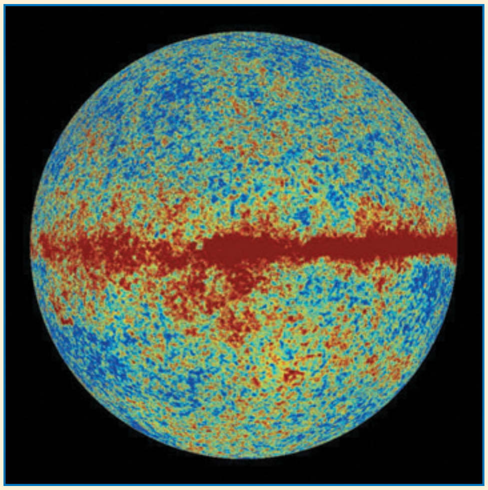


Figure 3 This image of the universe shows remnant heat left over from the big bang. Temperature fluctuations displayed are 13.7 billion years old, from the time when the big bang was thought to have occurred. Red is hot and blue is cold.

There is strong evidence for the big bang theory. However, it continues to be tested and examined. Another explanation is the **steady-state theory**. It is also known as the infinite-universe theory. This theory suggests the universe has always existed. It did not have a moment of creation, or a time zero. The theory suggests that new matter is continuously created out of empty space. The matter created out of empty space is mostly hydrogen. The rate at which new matter appears is in balance with the expansion of the universe. Therefore, the average density of the universe remains constant.

There are arguments against the steady-state theory. They include the discovery of the cosmic background radiation. As you read earlier, this radiation indicates that the universe did have a beginning. Just after the big bang, all that existed in the universe was energy. As the universe expanded, it cooled. About 300,000 years after the big bang, the temperature of the universe had cooled enough to allow atoms to form. Leftover energy from this moment can be observed today. This radiation comes from all directions in the universe.

The steady-state theory has also been challenged by the discovery that galaxies were more crowded together in the past. This is evidence that the density of the universe has changed over time.

It is impossible to know for certain how the universe began. Today, the evidence is in favor of the big bang theory. However, one day scientists might make a discovery that cannot be explained by this theory. Scientists would then have to start looking for a new model of the origin and evolution of the universe.

The Fate of the Universe

What will ultimately happen to the universe? Historically, cosmologists have considered three possible outcomes: it will expand forever; it will expand to a certain size and stop; it will stop expanding and begin to collapse. All three cases are based on the idea that the rate of expansion of the universe has slowed down since its beginning.

Recall from the previous sections that galaxies are millions and even billions of light-years away. It takes light a long time to reach Earth from far away galaxies. When astronomers observe the most distant galaxies, they are observing the galaxies as they existed far back in time. These observations can provide an idea of what the universe was like when it was much younger.

Scientists measure the extent to which light from these galaxies is shifted toward the red end of the spectrum. This helps them to determine the expansion rate of the universe in the past. They can then compare that rate to today's rate.

Scientists are surprised by recent observations of the change in the rate of expansion of the universe. Data suggest that the rate of expansion slowed for a while. Now it is speeding up. The current explanation for this change is that the universe is filled with an unidentified form of energy. That energy is causing the expansion of the universe to speed up. Scientists are calling this energy dark energy. If these observations are correct, scientists think that the universe will continue to expand forever.

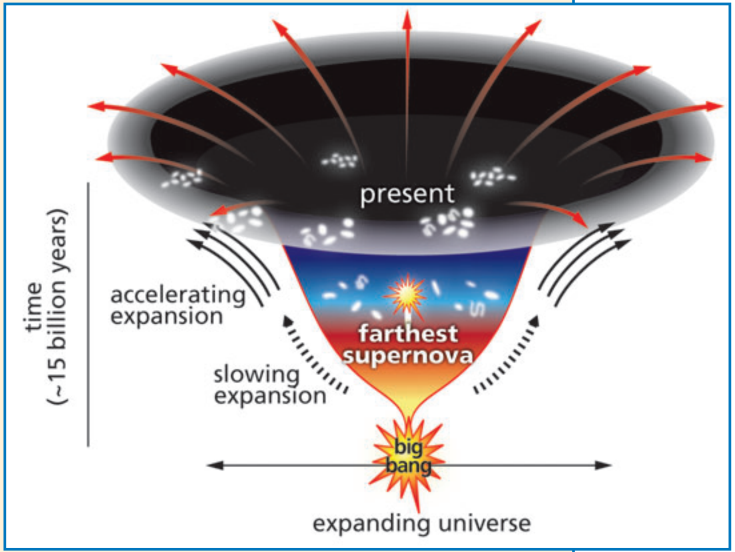


Figure 4 How the rate of expansion of the universe has changed over time.

The Nebular Theory

If there was a big bang, how did the solar system form? When you made a scale model of the solar system in *Section 1*, you probably noticed how large the Sun is in comparison to most of the planets. In fact, the Sun contains over 99 percent of all of the **mass** of the solar system. Where did all this mass come from? According to current thinking, the birthplace of our solar system was a **nebula**. A nebula is a cloud of gas and dust. This particular nebula that gave rise to our solar system was probably cast off from other stars that existed in this region of our galaxy. More than 4.6 billion years ago, this nebula started the long process that led to the formation of a star and planets. The idea that the solar system evolved from such a swirling cloud of dust is called the **nebular theory**.

Geo Words

mass: the amount of matter an object contains.

nebula: general term used for any "fuzzy" patch in the sky, either light or dark; a cloud of interstellar gas and dust.

nebular theory: scientific idea that our solar system formed from a giant, rotating cloud of gas and dust.

You can see one such nebula in the constellation Orion, just below the three stars that make up the belt of Orion. (See *Figure 5*.) Through a pair of binoculars or a small telescope, the Orion Nebula looks like a faint green, hazy patch of light. If you were able to view this star-birth region through a much higher-powered telescope, you would be able to see amazing details in the gas and dust clouds. The Orion Nebula is very much like the one that formed Earth's star, the Sun. There are many star nurseries like this one scattered around our galaxy. On a dark night, with binoculars or a small telescope, you can see many gas clouds that are forming stars.

Figure 5 Orion is a prominent constellation in the night sky.

In the nebula that gave birth to our solar system, gravity caused the gases and dust to be drawn together into a denser cloud. At the same time, the rate of rotation (swirling) of the entire nebula gradually increased. The effect is the same as when a rotating ice skater draws his or her arms in, causing their rate of rotation to speed up. As the nebular cloud began to collapse and spin faster, it flattened out to resemble a disk. Most of the mass collapsed into the center. You saw something similar when you sprinkled the creamer onto the hot chocolate. Initially, the creamer spread out over the surface of the liquid. But, when you stirred the chocolate in a circular motion, the creamer clumped together in the center. Matter in the rest of the disk of the nebula clumped together into small masses called **planetesimals**. The planetesimals gradually collided together to form larger bodies called **protoplanetary bodies**.

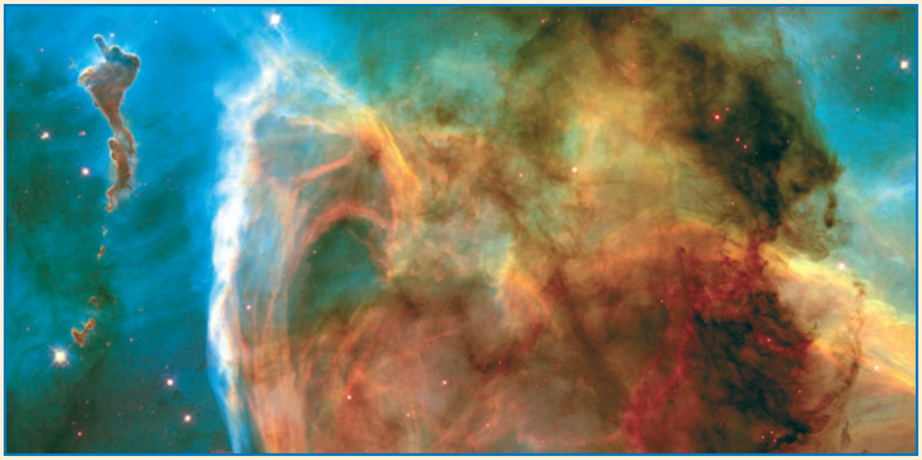


Figure 6 The Keyhole Nebula. (Imaged by the Hubble Space Telescope.)

Geo Words

planetesimal: one of the small bodies (usually micrometers to kilometers in diameter) that formed from the solar nebula and eventually grew into protoplanets.

protoplanetary body: a relatively large clump of material, formed in the early stages of solar-system formation, which was the seed of the planets you see today.

At the center of the developing solar system, material kept collapsing under gravitational force. As the moving gases became more concentrated, the temperature and pressure of the center of the cloud started to rise. The same kind of thing happens when you inflate a bicycle tire with a tire pump. As the air is compressed it gets warmer and heats the pump. When you let the air out of the tire, the opposite occurs. The air gets colder as it expands rapidly. When the temperature in the center of the gas cloud reached about 15 million degrees Celsius, hydrogen atoms in the gas combined or fused to form helium atoms. This process, called **nuclear fusion**, is the source of the energy from the Sun. A star—the Sun—was born.

Fusion reactions inside the Sun create very high pressure. This pressure threatens to blow the Sun apart. The Sun does not explode under all this outward pressure, however. The Sun is in a state of equilibrium. The gravity of the Sun is pulling on each part of it and keeps the Sun together. It radiates energy out in all directions, providing solar energy to the Earth community.

The Birth of the Planets

The rest of the solar system formed in the swirling disk of material surrounding the newborn Sun. Eight planets, more than 100 moons, and a large number of comets and asteroids formed. Moons are also called satellites. New moons are still being discovered today.

Four of these planets, shown at the top of *Figure 7*—Mercury, Venus, Earth, and Mars—are called the **terrestrial** ("Earth-like") **planets**. They formed in the inner part of our solar system, where temperatures in the original nebula were high. They are relatively small, rocky bodies. Some have molten centers, with a layer of rock called a mantle outside their centers, and a surface called a crust. Earth's crust is its outer layer. Even the deepest oil wells do not penetrate the crust.

The larger planets, shown at the bottom of *Figure 7*—Jupiter, Saturn, Uranus, and Neptune—consist mostly of dense fluids like liquid hydrogen. These **gas-giant planets** formed in the colder, outer parts of the early solar nebula. They have solid, rocky cores about the size of Earth. The solid cores are covered with layers of hydrogen in both gas and liquid form. These planets lie far from the Sun and their surfaces are extremely cold.

Figure 7 Composite image of the planets in the solar system.

Geo Words

nuclear fusion: a nuclear process that releases energy when lightweight nuclei combine to form heavier nuclei.

terrestrial planet: any of the planets Mercury, Venus, Earth, or Mars, or a planet similar in size, composition, and density to Earth. A planet that consists mainly of rocky material.

gas-giant planets: the outer solar system planets: Jupiter, Saturn, Uranus, and Neptune, composed mostly of hydrogen, helium, and methane.

Geo Words

comet: a chunk of frozen gases, ice, and rocky debris that orbits the Sun.

asteroid: a small planetary body in orbit around the Sun, larger than a meteoroid but smaller than a planet.

extrasolar planet: a planet beyond our solar system, orbiting a star other than our Sun.

There are trillions of **comets** and **asteroids** scattered throughout the solar system. Earth and other solar-system bodies were scarred by impact craters. These craters were formed when comets and asteroids collided with them. On Earth, erosion has removed obvious signs of many of these craters. Astronomers see these comets and asteroids as the leftovers from the formation of the solar system.

Asteroids are dark, rocky bodies that orbit the Sun at different distances. Many are found between the orbits of Mars and Jupiter, making up what is called the asteroid belt. Many others have orbits outside of the asteroid belt.

Comets are mixtures of ice and dust grains. They exist mainly in the outer solar system. However, when their looping orbits bring them close to the Sun, their ices begin to melt. That is when you can see trails streaming out from them in the direction away from the Sun. Some comets come unexpectedly into the inner solar system. Others have orbits that bring them close to the Sun at regular intervals. For example, the orbit of Halley's comet brings it into the inner solar system every 76 years.

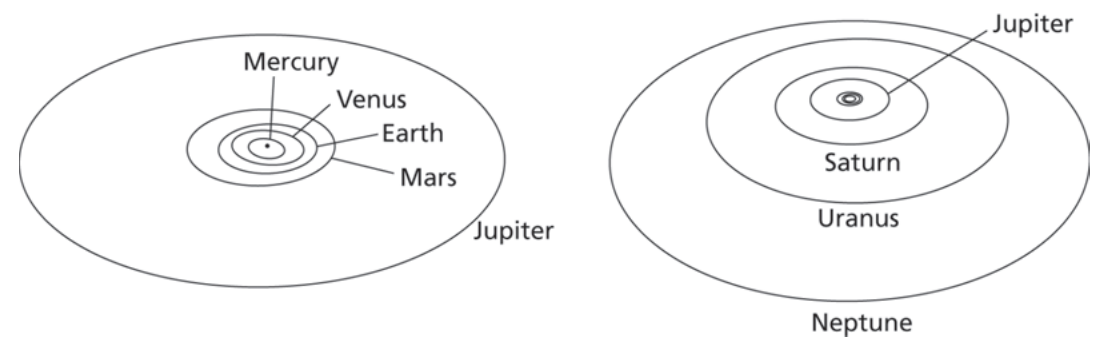


Figure 8 Two diagrams are required to show the orbits of the planets to scale.

Extrasolar Planets

Have you ever looked up at the sky and wondered whether there are planets outside of our solar system? Planets orbiting stars other than the Sun are known as **extrasolar planets**. To date, astronomers have found hundreds of such planets, and new discoveries are made every month. All of the extrasolar planets discovered so far are in our galaxy. (See *Figure 9*.)

Finding extrasolar planets is difficult. Distant planets are often masked by the light of the star that they revolve around. A star can be millions or even billions of times brighter than its orbiting planets. For this reason, it is almost impossible to observe these planets directly. Instead, astronomers gather indirect evidence of their existence.

The most common technique is to analyze a star's light. As a planet orbits a star, the planet's gravity tugs on the star. This causes the star to move away from and toward Earth slightly as the planet orbits the star. Due to the Doppler effect, this small movement affects the light emitted by the star. When the star moves away from Earth, the wavelength of the light becomes longer. When the star moves toward Earth, the wavelength becomes shorter. This change in wavelength results in a change in the color of the light. The change in color indicates that a planet is pulling the star. This provides indirect evidence of the existence of a planet.

The hundreds of extrasolar planets discovered so far are extremely varied in terms of their physical properties and orbits. Most are gas giants, but a few terrestrial planets have been identified. Many are extremely hot because of a close orbit to a star. Some have an orbit that is very distant from the star and are icy-cold. Some orbit massive stars, many times bigger and more brilliant than our Sun. Others circle dim stars that are much smaller than the Sun.

Most extrasolar planets that have been identified are Jupiter-like gas giants. The largest extrasolar planet found to date is HD 43848 b. This planet is about 120 light-years away. It has a mass equal to 25 Jupiters. It has an orbital period of about 2371 days. The smallest extrasolar planet to date is Gliese 581 e. It has a mass equal to 1.9 Earths and an orbital period of 66.8 days. This planet is over 20 light-years away. Some astronomers believe that eventually, the discovery of small planets will outnumber giant planets. Some of these small planets will probably resemble Earth.

Scientists have discovered stars that do not have any planets, but are solar systems in the process of forming. Vega, the brightest star in the constellation Lyra, is one example. Beta Pictoris, a star in the southern constellation Pictor, is another. Both have disk-shaped clouds around them. (See *Figure 10* on the next page.) Scientists believe these disks are massive, rotating clouds of dust and gas. These clouds of dust and gas could eventually form planets. This is much like how our own solar system formed.

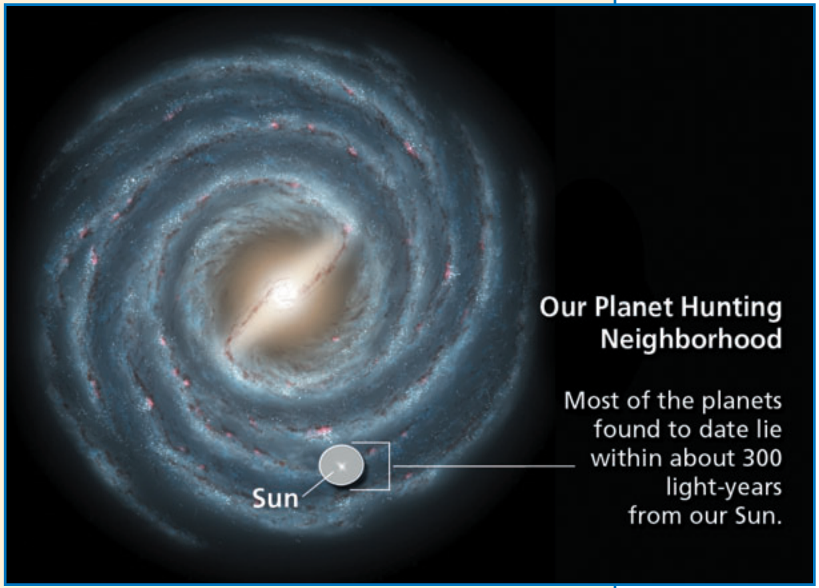


Figure 9 All of the known extrasolar planets are within the Milky Way Galaxy.

Checking Up

1. What is the Doppler effect?
2. Which way are most galaxies moving relative to each other?
3. What is the origin of the cosmic background radiation?
4. How do the big bang and steady-state theories differ in their explanations of how the universe was created?
5. What is a nebula?
6. Explain why the material surrounding a young star forms a disk.
7. Which elements are primarily involved in the Sun's fusion reaction?
8. The planets formed from a collapsing nebular cloud that flattened into a disk. From which part of the disk did terrestrial planets form?
9. Where are asteroids hypothesized to have originated?
10. Have planets been discovered outside of our solar system? Where?

Not all the newly discovered solar systems fit this pattern. A recently identified young solar system shows a different pattern. The inner part is orbiting in one direction. The outer part is orbiting in the opposite direction. No planets have formed yet. However, eventually this system could have planets orbiting in different directions. This pattern of the orbiting planets would be different from our own solar system.

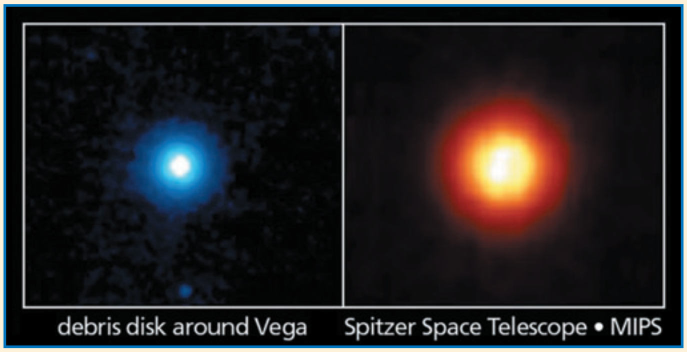


Figure 10 Disk-shaped clouds around Vega.

What is the Difference Between a Law and a Theory?

Sometimes the meaning of a word in science is different from its everyday meaning. For example, you may say that you have a theory about something when you mean you have a hunch or a guess. You also may say that you obey the law, referring to laws that are written and passed by a government. However, in science, the words theory and law have very different, but very precise meanings.

In their observations over long periods of time, scientists often notice certain patterns that occur over and over again. From these observations, they develop a scientific law to describe the patterns they have observed. For example, over time, scientists observed that each object in the universe attracts every other object with a force that is related to the mass of the objects and the distance between them. Newton stated this as the *law of universal gravitation*. This law does not explain why all objects experience this force of attraction, but provides a way of describing what has been observed.

A scientific theory provides an explanation for those observations and can be used to predict new phenomenon that have not been observed. For example, the big bang theory explains the development of the universe. This theory is not a hunch or a guess. It is the result of years of experiments, observations, measurements, and mathematical applications. The work of many people over many years culminates in a theory and the subsequent work of many people and many years is required for acceptance of that theory in the science community. Though related, laws do not become theories and theories do not become laws.

Think About It Again

At the beginning of this section, you were asked the following:

- **How do astronomers measure how stars and galaxies move?**
- **What do these movements tell astronomers about how the universe formed?**
- **How did the solar system form?**
- **What is the probability that there are planetary systems beyond our own? How do you know?**

Record your ideas about these questions now. Be sure that you describe the evidence that scientists have gathered to support their ideas about the formation of the universe and the solar system, and the existence of extrasolar planets.

Reflecting on the Section and the Challenge

You observed the change in pitch that occurs with the motion of an object emitting sound. A similar effect occurs with the shift in the wavelength of light emitted by a star or galaxy when it moves relative to Earth. You then ran a model of the universe that demonstrated the movement of galaxies away from each other as the universe expands. Next, you observed a model of the formation of the solar system from a cloud of gas and dust. This will help you to describe the formation and evolution of the solar system as part of the *Chapter Challenge*.

Understanding and Applying

1. Briefly describe the origin of the universe according to the big bang theory.
2. How does the Doppler effect allow astronomers to detect the motion of a star or galaxy?
3. What can astronomers infer from the fact that other galaxies are moving away from ours?
4. Why was the cosmic background radiation an important discovery?
5. Explain how the Sun produces energy. What keeps the Sun from blowing apart?
6. Explain the basic process of planet formation.
7. Compare the inner planets and the outer planets.
8. Would it be possible for a gas giant to form close to the Sun? Explain your answer.
9. What are the differences between asteroids and comets?
10. Why are there no comets in an orbit that is always close to the Sun?
11. ***Preparing for the Chapter Challenge***

    Continue developing your radio or podcast script for the *Chapter Challenge*. Describe how the universe and our solar system formed and evolved. Explain what comets and asteroids are and how they formed within our solar system. Be sure to include information about planetary systems outside of our own solar system.

Inquiring Further

1. **Nuclear fusion**

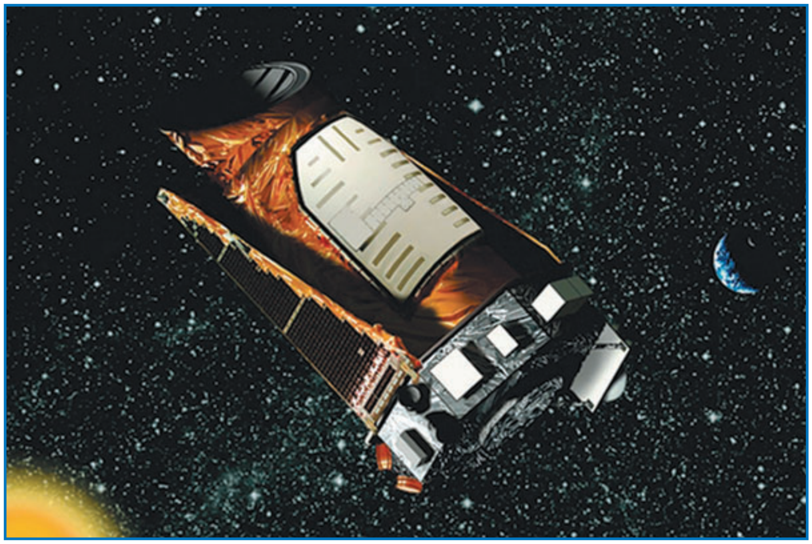
   Find out more about the process of nuclear fusion. Explain how and why energy is released in the process by which hydrogen atoms are converted into helium atoms within the Sun. Be sure to include Albert Einstein's famous equation, $E = mc^2$, in your explanation, and explain what it means.

2. **Star formation**

   Write a newspaper story about star formation. Visit the *EarthComm* Web site at http://www.agiweb.org/education/earthcomm2/ to find information available on the Web sites of the Hubble Space Telescope and the European Southern Observatory. You will find examples of star-forming nebulae in the galaxy. How are they similar? How are they different? What instruments do astronomers use to study these nebulae?

3. **Extrasolar planet research**

   NASA's Kepler Mission will survey our region of the Milky Way Galaxy to detect and characterize hundreds of Earth-sized and smaller planets. It will tell scientists whether planets like Earth are common or rare in our galaxy. Describe the various missions NASA has planned for extrasolar planet research. When will these missions be launched? How will they support efforts already in place to detect planets outside of our solar system?



An artist's drawing of the Kepler Mission telescope.