Name _____ Class _____ Date _____

CHAPTER 20 The Universe

SECTION 3

Origin of the Universe

KEY IDEAS

As you read this section, keep these questions in mind:

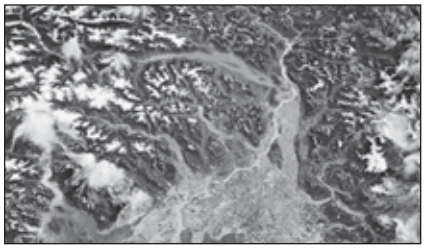
- What is the universe?
- How do scientists think the universe began?
- How can scientists predict the future of the universe?

What Is the Universe?

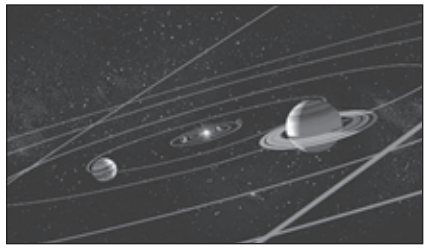
The **universe** is everything physical in space and time. It includes all space, matter, and energy that has existed, now exists, and will exist in the future. Objects in the universe range in size from subatomic particles to superclusters of galaxies. The further away you look, the more of the universe you can see. This is shown in the figure below.

From 10 m above home plate, you could see some of the players on a baseball team.

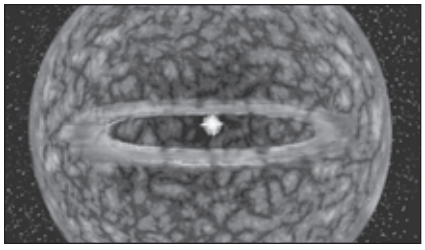
From 1 km away, you could see the whole baseball stadium.



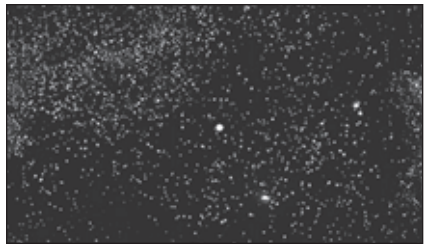
From 100 km away, you could see the whole city in which the baseball stadium is located.



From about 5 light-hours away, you could see the planets orbiting our sun.



From about 150 light-days away, you could see the solar system surrounded by a cloud of icy comets.



From about 10 light-years away, our sun would look like any other star in the sky.

READING TOOLBOX

Compare After you read this section, make a chart comparing three possible futures for the universe. In the chart, explain what conditions could lead to each possible future.

Talk About It

Brainstorm How do you think scientists know what our solar system would look like from far away? How do you think scientists look for planets orbiting other stars? In a small group, brainstorm some different possible answers to these questions.

LOOKING CLOSER

1. Infer What is a light-day? (Hint: What is a light-year?)

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How Do We Study the Universe's History?

Light takes time to travel through space. The farther an object is from us, the older the light is that reaches us from that object. For example, our sun is eight light-minutes away from Earth. That means that we always see the sun as it was eight minutes ago. We never see it as it is in the present. This is also true for planets, stars, and galaxies. The chart below shows how far away other objects are.

Math Skills

2. Compare About how many times longer does it take light from Polaris than light from Proxima Centauri to reach Earth?

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Object	Distance from Earth (light-years)
Proxima Centauri	4.3
Sirius	8.7
Polaris (the North Star)	430
Andromeda galaxy	2.2 million

Because light takes time to travel through space, looking at distant objects is like looking back in time. The farther away an object is, the older the light from it is. Therefore, by studying distant stars and galaxies, scientists can learn what the universe was like long ago. ☑

READING CHECK

3. Explain How do scientists study what the universe was like long ago?

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Astronomers interested in the early history of the universe use powerful telescopes to study the most distant objects. Those objects, such as quasars, emitted light and other radiation billions of years ago. Studies of such old radiation have helped scientists develop theories about how the universe began.

In 1929, American astronomer Edwin Hubble announced that the universe was expanding. He based his conclusion on studies of spectra from other galaxies. The light in the spectra from these galaxies appeared redder than it should have been. Hubble proposed that this "red shift" is caused by the Doppler effect. The **Doppler effect** is a change in the measured frequency of radiation from an object moving toward or away from us. ☑

READING CHECK

4. Identify What was Hubble's evidence that the universe is expanding?

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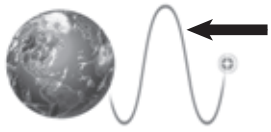
You can hear the Doppler effect when a car drives past you. When the car is moving toward you, its engine has a higher pitch. This is because the sound waves from the car's engine are compressed when the car is moving toward you. The compression causes the sound to have a higher frequency or pitch. The figure at the top of the next page shows how the Doppler effect applies to light.

The star and Earth are not moving relative to each other. The light we see from the star looks the same color as the light the star gives off.

If the star and Earth are moving toward each other, the star's light appears bluer. It is "blue-shifted."



If the star and Earth are moving away from each other, the star's light appears redder. It is "red-shifted."

LOOKING CLOSER

5. Identify A star is moving toward Earth. Will its light be red-shifted, blue-shifted, or not shifted at all?

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WHAT EXPANSION MEANS

Based on Hubble's observation of red shift, astronomers think that most galaxies in the universe are moving away from us. This suggests that the universe is expanding in all directions. However, it does not mean that our galaxy is at the center of the universe. ☑

READING CHECK

6. Describe What does Hubble's observation that galaxies are moving away from Earth suggest about the universe?

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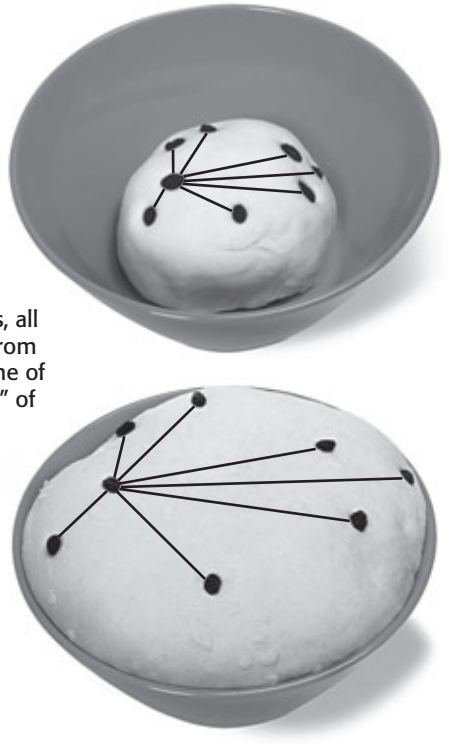
A lump of raisin bread dough like the one in the figure below shows how this can be. As the dough rises and expands, all the raisins move away from each other. If you stood on any one raisin, nearly all the other raisins would seem to be moving away from you.



As raisin bread dough rises, all of the raisins move away from one another. However, none of the raisins is at the "center" of the dough.

LOOKING CLOSER

7. Apply Concepts If the universe were the bread dough, and the raisins were galaxies, which of the raisins could be the Milky Way galaxy?

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Critical Thinking

8. Predict Consequences Suppose Hubble's observations had shown that light from distant galaxies was blue-shifted. Would this observation provide clear evidence for the big bang theory? Explain your answer.

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THE BIG BANG THEORY

Scientists have suggested several theories to explain why the universe is expanding. The most complete and widely accepted is the **big bang theory**. According to this theory, all of the matter and energy in the universe were once compressed into a single point. This point was infinitely dense and infinitely small. Then, about 13.7 billion years ago, the point began to expand extremely rapidly in a "big bang."

According to the big bang theory, nothing existed before the big bang. There was no time and no space. Although this may seem hard to understand, the big bang theory can explain all available observations about the universe. Therefore, most astronomers think that the big bang theory is the most likely explanation for how the universe began.

The expansion of the universe is one piece of evidence supporting the big bang theory. Another observation that supports the theory is cosmic background radiation. *Cosmic background radiation* is a field of microwave radiation that comes from everywhere in the sky.

Cosmic background radiation was discovered in 1965 by astronomers Arno Penzias and Robert Wilson. They were using radio telescopes to examine the sky. They noticed a steady, dim signal of microwave radiation that seemed to be everywhere in the sky.

Today, scientists think that these microwaves are dim remnants of radiation produced during the big bang. Further observations have allowed scientists to create maps of cosmic background radiation, such as the one below. The maps indicate that the universe has an overall temperature of about 2.7 K.

LOOKING CLOSER

9. Describe What do scientists think cosmic background radiation is?

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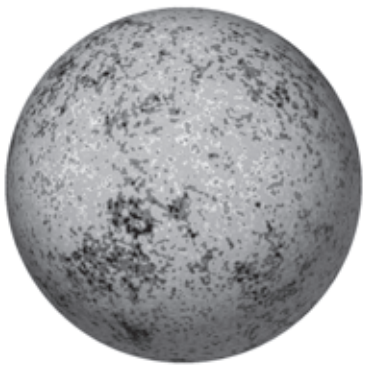
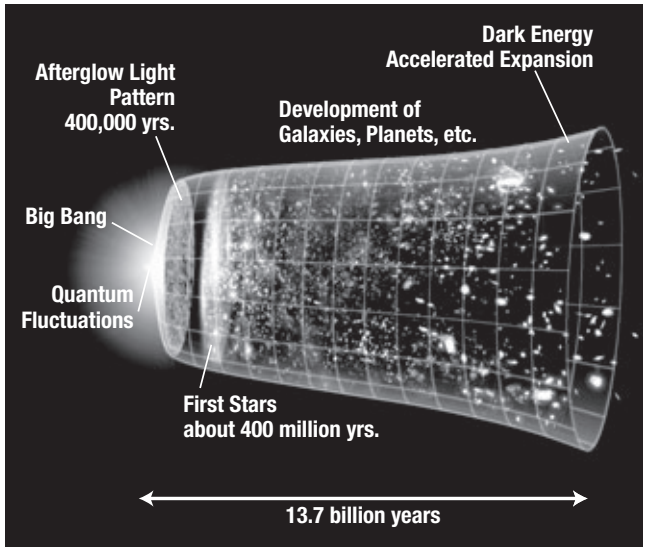


This is an image of cosmic background radiation that was produced by a computer. The different shades represent tiny differences in temperature from 2.7 K.

How Has the Universe Evolved?

According to the big bang theory, the universe consisted of pure energy immediately after the big bang. It was extremely hot. As the universe expanded, it cooled. The lower temperature allowed sub-atomic particles, such as protons, electrons, and neutrons, to form. ☑

Protons began to appear about one second after the big bang. Atomic nuclei began to form soon after that. It took about 380,000 years for electrons to combine with atomic nuclei to form atoms. The first stars appeared about 400 million years after the big bang. The figure below shows how scientists think the universe has changed with time.



Scientists have used information from instruments in space to construct a model of how the universe has evolved. Based on this information, scientists think the universe expanded very quickly just after the big bang. Over time, the universe's expansion has slowed.

READING CHECK

10. Identify What had to happen to the early universe before matter could form?

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LOOKING CLOSER

11. Describe When did the first stars in the universe form?

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Will the Universe Keep Expanding?

The universe is still expanding, but it may not do so forever. Forces from the big bang expansion are pushing matter in the universe apart. At the same time, gravity is pulling matter in the universe together. Depending on the relative strengths of these forces, there are three possible futures for the universe: ☑

- The universe could keep expanding forever.
- The expansion could gradually slow down, and the universe could approach a limit in its size.
- The universe could stop expanding and start to collapse back on itself.

READING CHECK

12. Identify What force could prevent the universe from expanding forever?

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Critical Thinking

13. Apply Concepts Why does the amount of matter in the universe affect what its future will be? (Hint: What affects gravity?)

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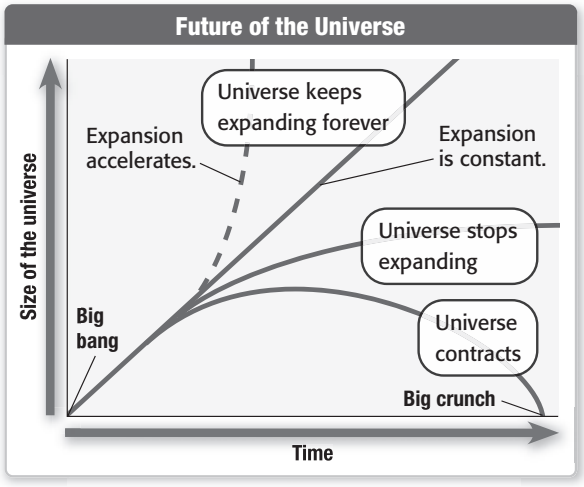
MATTER AND THE FUTURE OF THE UNIVERSE

What will actually happen to the universe in the future depends on the amount of matter it contains. If it does not have enough mass, gravity will be too weak to stop the expansion. The universe will expand forever. With just the right amount of mass, the expansion will keep slowing down but will never stop completely.

Too much mass will mean that gravity will eventually overcome the expansion. The universe will then start to contract. It could condense back into a single point. Then, the universe may end. Alternatively, another big bang could start the cycle again. The figure below shows these three possible futures for the universe.



This figure shows some of the possible futures of the universe. Which path the universe will actually follow depends on the amount of matter in the universe.

Scientists do not know exactly how much matter is in the universe. They are still trying to figure that out. Therefore, scientists don't know which future for the universe is most likely. ☑

READING CHECK

14. Explain Why can't scientists predict exactly what will happen in the future of the universe?

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TECHNOLOGY FOR TESTING THEORIES

In order to determine the amount of matter in the universe, scientists continually develop new tools and technology. These tools and technology allow scientists to study the universe in greater detail.

The Chandra X-ray Observatory is an example of new technology. Launched into orbit in 1999, it can take photographs in the X-ray part of the electromagnetic spectrum. X rays typically come from matter with temperatures of more than one million K.

What Is Dark Matter?

Astronomers estimate the mass of the universe by measuring stars, galaxies, and all the matter between them. However, the gravitational forces between galaxies are too great to be produced by the observed amount of matter in the universe. This suggests that more matter exists than astronomers can see. Astronomers think that this "missing" matter may be invisible. They call it *dark matter*. ☑

Dark matter may consist of planets, black holes, and small stars that emit no light. It could also be strange atomic particles that present-day instruments cannot detect. Whatever dark matter consists of, astronomers think that the universe contains more of it than of visible matter. In mid-2006, the Chandra Observatory found direct evidence of dark matter in a collision between two clusters of galaxies.

READING CHECK

15. Explain Why do scientists think there is a great deal of invisible matter in the universe?

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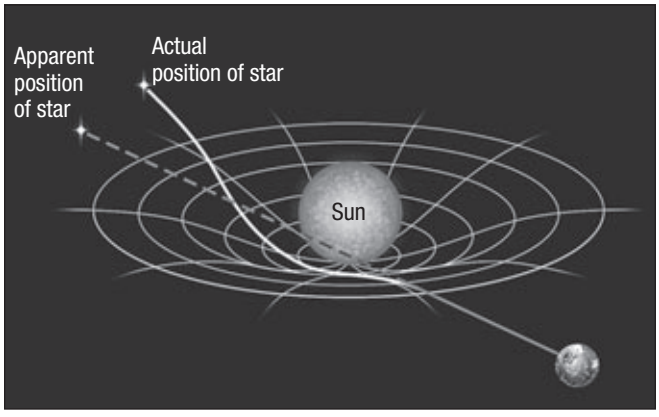
MATHEMATICS AND MODELS

Many of the theories astronomers use to explain their observations rely on mathematics. For example, in 1916, Albert Einstein developed the general theory of relativity. This theory describes the effects of gravity with mathematical equations.

Einstein's theory states that mass curves space. It does so in much the same way that your body curves a cushion you sit on. In 1919, observations of a total solar eclipse showed that Einstein was right. Astronomers looked at stars in the direction of the sun that they could see only during the eclipse. The mass of the sun curved space. That made the starlight appear to come from a direction slightly different than the star's actual location.



According to Einstein's theory of relativity, the sun's mass curves space near the sun. This causes light from stars to bend as it moves past the sun.

LOOKING CLOSER

16. Describe What causes light to bend as it moves past the sun?

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Name _____ Class _____ Date _____

Section 3 Review

SECTION VOCABULARY

big bang theory the theory that all matter and energy in the universe was compressed into an extremely small volume that 13 billion to 15 billion years ago exploded and began expanding in all directions	**Doppler effect** an observed change in the frequency of a wave when the source or observer is moving **universe** the sum of all space, matter, and energy that exist, that have existed in the past, and that will exist in the future

1. **Identify Relationships** Explain how Edwin Hubble's observations of distant galaxies support the big bang theory. Use the term "Doppler effect" in your answer.

2. **Explain** Why can't we observe distant stars and galaxies as they are right now?

3. **Describe** How does the amount of matter in the universe affect the possible futures of the universe?

4. **Infer** Imagine that you are able to travel back through time. Describe what would happen to the universe's size and temperature as you traveled farther and farther back.