How do we use the big bang theory to explain what we know about the universe?

Use with textbook pages 352–369.

The Big Bang Theory and Its Evidence

The **big bang theory** explains how the universe began 13.8 billion years ago from an incredibly small and dense point. Since then, the universe has been rapidly expanding in all directions, to an incredibly huge size. It continues to expand today.

Why do scientists hold this view about our distant past? Edwin Hubble's discoveries helped with one important type of evidence. While studying galaxies and their spectra, Hubble noticed that spectral lines of most galaxies were not in the usual locations. Instead, he observed that they had moved sideways, nearer the red end of the visible spectrum. As shown on textbook page 355, Figure 4.40, distant galaxy spectra had been **redshifted** toward the longer red wavelengths. The Doppler effect explains changes in waves produced by moving objects. Just as sound waves from an object moving away are longer and have a lower pitch, wavelengths of light become longer and closer to red colours. Hubble realized that redshifted spectral lines from distant galaxies meant that they are moving away from us. Hubble also found that galaxies farther away are moving faster. This suggests that the whole universe is expanding, at a rate known as Hubble's constant.

If the universe is expanding and huge, then it must have begun as something incredibly small. Another important type of evidence for the big bang theory was the discovery of **cosmic microwave background (CMB) radiation**. This radiation comes from all directions in space and is all that remains of the huge amount of energy released by and after the big bang. Images from two NASA satellites show very small differences in temperature in the whole universe, soon after the big bang. The timeline on textbook pages 360–361 highlights key events in the evolution of the universe. Early stars and galaxies only start forming close to 1 billion years after the big bang.

Dark Matter

There is much that is known today about the universe, but also much that we still do not fully understand. For example, the Andromeda galaxy is rotating faster than it should, based only on the mass of stars we can see in it. To help explain the faster movement, scientists hypothesize that there is mass that we cannot see. This missing mass is known as *dark matter*. We infer the existence of dark matter from the way it affects other objects, such as galaxies. Most of the matter in the universe is thought to be dark matter.

Dark Energy

Scientists used to think that gravity is slowing down the expansion of the universe. However, newer information has shown that its expansion is speeding up instead. Something is opposing the effects of gravity. This "something" is named *dark energy*. Dark energy is thought to be a stabilizing force in the universe. At this time, we think that visible matter makes up only 4% of the universe. Dark matter makes up about 23%, while dark energy, at 73%, makes up the rest. There is so much more still to be discovered about the universe.

I Wonder Why?

Use with textbook pages 357-358.

Use the following reading passage to answer question 1.

In science, being curious is essential. Asking questions might even lead to answers that were really not expected. Such was the case for Arno Penzias and Robert Wilson. These American scientists were mapping radio signals of the Milky Way in the 1960s. Little did they know that their results would be crucial to our understanding of the earliest days of the universe. Penzias and Wilson were surprised to notice a background "hum," like static, everywhere they looked. It was a uniform, faint microwave signal from all directions. They thought something must be wrong with their telescope. But rather than ignoring the unwanted "noise," they looked for ways to explain it. They asked the most important question: Why was it happening?

To rule out urban signals, they pointed the telescope at New York City. This wasn't the source. The signal wasn't coming from just the Milky Way galaxy or the solar system, as they checked microwave signals from other directions over four seasons. They even removed pigeons nesting in the telescope—and swept out their droppings too. What could be causing the noise? Other scientists had predicted that if the universe began with the big bang, there should be leftover, low-level background radiation throughout the universe. In fact, this was exactly what Penzias and Wilson had found—and they weren't even looking for it! In 1978, the pair received a Nobel Prize in physics for their important discovery of cosmic microwave background (CMB) radiation.

1. Asking Questions

While reading the two paragraphs above, stop to ask these *who*, *what*, *when*, *where*, *why*, and *how* questions. See if the questions are answered in the passage. If they are not, reread the paragraphs to see if you missed something, if you can infer something, or if the information is not there in the passage that you are reading. If the information is not there, or if it is not detailed enough, skilled readers will investigate other resources to find or supplement what they are reading.

a) Who were Penzias and Wilson? ____________________

____

b) What unusual results did they notice? ____________________

____

c) Where in the universe did the "noise" signals come from? ____________________

____

d) When was the background radiation produced? ____________________

____

e) Why did they decide the noise was not from other sources?

____

____

f) How is CMB radiation important to the big bang theory?

____

____

2. Identifying the Main Idea and Details

To identify the main ideas, skim the text on pages 357 and 358 to get a sense of the content. Facts and examples provide details to help reinforce the main idea. Who were the many people who helped develop ideas about an expanding universe and cosmic microwave background radiation? Do research and make a timeline showing dates, important physicists or astronomers, and their main contribution to our knowledge, starting from Friedmann and continuing right up to Penzias and Wilson. The first one is shown as an example. Then compare your timeline with a partner's and discuss why you chose to include certain details.

Date:	1922
Scientist:	Friedmann
Details:	• expanding universe

3. What other questions do you have about CMB radiation and the big bang theory?

____

____

____

____

Name ______________________ Date ______________________

Evaluating

Topic 4.4

What's In a Name?

Use with textbook pages 358-361.

Acronyms are abbreviations used to help simplify large names. Often the first letter of each key word is used, like a code. Over time, an acronym such as NASA may become so commonplace to us that we do not remember it really stands for **N**ational **A**eronautics and **S**pace **A**dministration.

Many acronyms are found in Topic 4.4. They all relate to the universe and cosmology in some way. Using textbook pages 358–361, record the full name for each acronym and its significance to our understanding of the big bang theory and the universe. The first row is shown as an example.

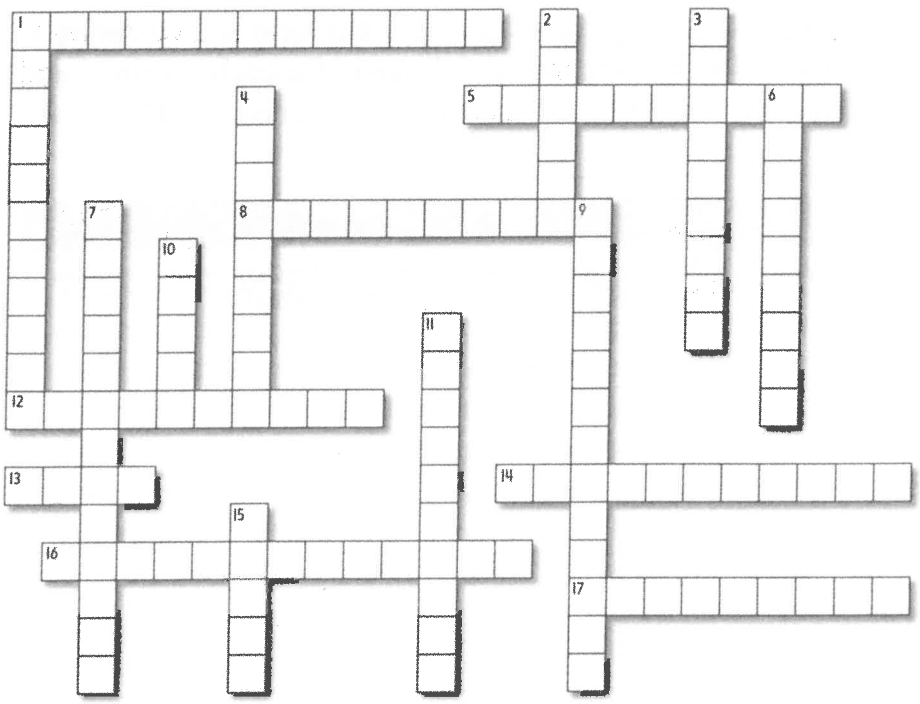
Acronym	Full Name	Significance in Our Understanding of the Universe
NASA	National Aeronautics and Space Administration	American agency responsible for space exploration and research, Apollo missions to Moon, Space Shuttle, partner in ISS
COBE		
WMAP		
CMB		
HST		
JWST		
CERN		
LHC		

The Big Bang Theory and the Universe

Use with textbook pages 354–365.

Complete the following crossword puzzle by using the clues and vocabulary list provided. Ignore spaces between words and any apostrophes.

Big Bang Theory



Vocabulary
Andromeda
big bang theory
blueshifted
cosmology
dark energy
dark matter
Doppler effect
expanding
halo
Hoyle
Hubble
Hubble's law
microwave
redshifted
slope
spectral lines
steady state
visible matter

Across	Down
1. Idea that the universe began 13.8 billion years ago from an incredibly small, dense point 5. Speed of a galaxy is proportional to the galaxy's distance from Earth 8. Objects moving away have their wavelengths lengthened, toward red in visible spectrum 12. Most of mass and energy in universe is this; causes expansion to accelerate; a stabilizing force 13. Dark matter forms huge spherical shape of this type around galaxies 14. Hoyle's idea that the universe did not begin, will not end, and does not change 16. Matter we can see, including stars, planets, and galaxies; emits light 17. Term for the way space is changing in between galaxies, and the universe as a whole	1. Objects moving toward an observer have their wavelengths shortened, toward blue end of the spectrum 2. Astronomer who found relationship between a galaxy's redshift and its distance from Earth 3. Study of the universe and its changes over time 4. Wavelength of cosmic background radiation "noise"; left over from big bang 6. Nearest galaxy to ours; stars rotating faster than predicted, suggested dark matter 7. Patterns of colours and lines produced by a spectroscope, unique to each element 9. Describes changes in wavelengths of moving objects relative to stationary observer 10. Astronomer who first used "big bang" term, originally as an insult 11. Mass that cannot be seen, does not emit light; most abundant form of matter in universe 15. Rate of expansion of universe is this feature of the line, on velocity of galaxy vs. distance from Earth graph

The Rest of the Universe: Dark Energy and Dark Matter

Use with textbook pages 362–365.

With our eyes and telescopes, we can see vast numbers of objects in the universe, including stars and galaxies. They are too numerous to count accurately. But all of these visible, celestial objects make up only about 4% of the matter and energy in the universe. The remaining 96% is mysterious and unseen. What does this really mean? Dark energy and dark matter may both be invisible or "dark," as well as complex to understand, but are very different in nature. In some ways, dark matter holds parts of the universe together while dark energy forces it apart. Using textbook pages 362–365, organize the information about dark matter and dark energy using the charts below.

Dark Matter

Things We Know About It

It Can't...

What Led to Its Discovery

Its Location

Dark Energy

Things We Know About It

What We Don't Know

What Led to Its Discovery

When Discovered

4.4 Assessment

Match each term on the left with the best descriptor on the right. Each descriptor may be used only once.

Term	Descriptor
1.____ expanding	A. wavelengths longer for objects moving away
2.____ dark energy	B. changes in sound or light wavelengths for moving object
3.____ blueshifted	C. idea of universe initially very small and dense 13.8 billion years ago, then rapidly getting bigger
4.____ CMB radiation	D. study of beginning and changes in universe
5.____ visible matter	E. lines produced by stars in a spectroscope
6.____ cosmology	F. refers to the increasing size of the universe
7.____ Doppler effect	G. missing mass in universe, doesn't emit light
8.____ big bang theory	H. wavelengths shortened for objects getting closer
9.____ redshifted	I. unseen energy overcoming effects of gravity
10.____ dark matter	J. all objects we can see are made of this
11.____ spectral lines	K. leftover radiation from early time in universe

Circle the letter of the best answer for questions 12 to 25.

12. About 7 billion years ago, the expansion of the universe began to

A. slow down.

B. speed up.

C. stay the same.

D. collapse.

13. When was the CMB radiation produced, as shown in the COBE and WMAP images?

A. at the very beginning of the universe, time = 0

B. at the birth of the Sun, 9 billion years after the beginning

C. when photons could travel, 380 000 years after the beginning

D. at many different time points in the history of the universe

14. The Andromeda galaxy is blueshifted, which means it is moving
    - A. toward the Milky Way.
    - B. away from the Milky Way.
    - C. in the same direction as the Milky Way.
    - D. parallel to the Milky Way.

15. How is the universe described at the very beginning, according to the big bang theory?

I	incredibly dense
II	incredibly small
III	incredibly cold

    - A. I and II only
    - B. I and III only
    - C. II and III only
    - D. I, II, and III

16. Hubble found that spectral lines from most galaxies were shifted toward
    - A. shorter wavelengths.
    - B. longer wavelengths.
    - C. the same wavelengths.
    - D. different wavelengths.

17. How do the speeds of galaxies compare, when they are closer to or farther away from us?
    - A. Distant galaxies move slower than closer ones.
    - B. The speeds of all galaxies are about the same.
    - C. Distant galaxies move faster than closer ones.
    - D. The speeds of galaxies are all variable, with no pattern.

18. Which of the following acronyms stands for a machine that performs particle experiments at incredibly high energies?

A. HST

B. COBE

C. JSWT

D. LHC

19. Which characteristics apply to both dark energy and dark matter?

I	cannot be seen
II	cannot be detected
III	forms bigger part of universe than visible matter

A. I and II only

B. I and III only

C. II and III only

D. I, II, and III

20. What did Penzias and Wilson discover?

A. cosmic microwave background radiation

B. large changes in temperatures in the universe

C. "noise" from one direction of the sky

D. galaxies moving toward Earth

21. The Hubble constant is

A. the speed of galaxy movement.

B. the rate of universe expansion.

C. the time since the big bang.

D. the distance to the edge of the universe.

22. Current estimates of all the mass and energy in the universe suggest almost three-quarters is

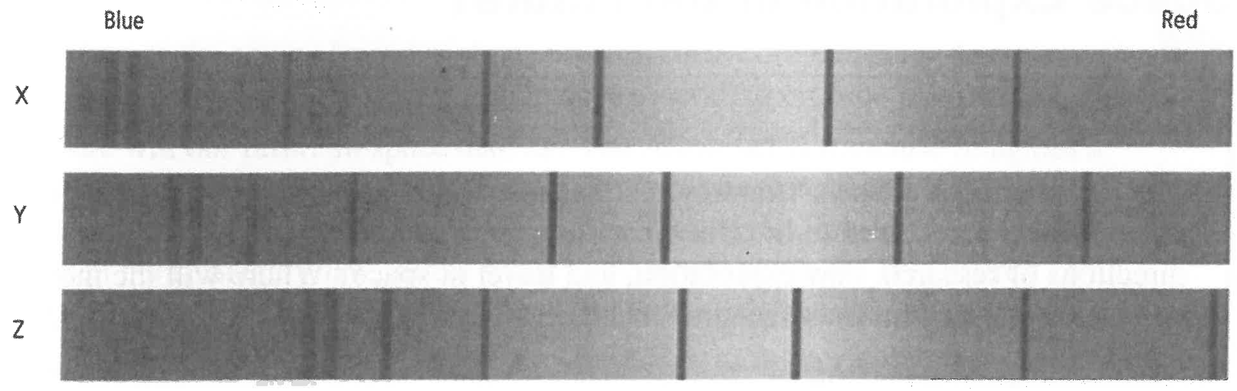
A. visible matter.

B. dark matter.

C. dark energy.

D. visible energy.

23. In the diagram below, X shows spectral lines from the Sun, while Y and Z are from different galaxies.



What do the spectra indicate about the distances of galaxies X, Y, and Z from Earth?

A. Galaxy Y is farther away than galaxy Z.

B. Galaxy Z is farther away than galaxy Y.

C. Galaxy Y and Z are the same distance from Earth.

D. Spectral lines do not indicate distance from Earth, only their speeds.

24. The big bang theory is based on which main sets of evidence?

I	dark matter
II	cosmic background radiation
III	redshift

A. I and II only

B. I and III only

C. II and III only

D. I, II, and III

25. In general, the space between galaxies is

A. expanding.

B. shrinking.

C. staying the same.

D. not predictable.

Name Date

Unit 4 AT Issue

Who Will Pay For and Control Space Exploration in the Future?

What's the Issue?

Much of the focus of the astronomy unit has been looking backwards, at how the universe began and used to be. But what about the future? What will be the directions of research, new exploration, and travel in space? Where will the money come from? Who will make the important decisions?

Thus far, government agencies such as NASA, ESA in Europe, and FKA in Russia have funded and controlled new advances in space exploration. They use tax dollars to pay for long-term projects, such as NASA's Apollo missions to the Moon in the 1960s and 1970s. When space missions cost hundreds of billions of dollars over many years, only governments could afford them. Often, the immediate benefits of space research are not obvious, and don't necessarily generate money. Huge projects such as the Voyager probes, Hubble Space Telescope, and Mars rovers take decades to design, construct, and operate. As the excitement of being first to the Moon has passed, NASA gets a much smaller percentage of the U.S. budget: from 4.4% in the 1960s to less than 0.5% in 2018. Countries have constant political pressure to reduce deficits and to spend their tax dollars on urgent needs of people here on Earth.

Enter the billionaire entrepreneurs. These people see their corporate futures linked to space. Elon Musk's private company SpaceX is working to reduce space transportation costs and eventually establish a colony on Mars. Blue Origin, founded by Jeff Bezos of Amazon fame, wants to decrease the cost and increase the safety of human space flight. Space tourism is the goal of Virgin Galactic and Richard Branson. Each of these companies has a similar strategy: to reuse launch rockets and spacecraft to cut costs. Some have government contracts, too. But unlike the government agencies, private companies must listen to their shareholders, who expect profits in the short term. As companies compete and rush to privatize space, the "final frontier" may become more about profit than pure scientific research and peaceful exploration. Will corporate directors who push for profit make decisions about space that benefit everyone, or just their shareholders?

What laws apply in space? In 1967 the UN Outer Space Treaty, signed by over 100 countries, set a framework for international space law. The goal was to make sure that exploring space was peaceful and fair. Nations are responsible for their activities in space, and they can't decide they own moons or planets, according to the treaty. Its rules about private space companies are less clear. And it doesn't set up any "space police department" to enforce laws beyond Earth.

Where will our future in space take us? The *Aliens* sci-fi franchise imagines a universe in which a greedy corporation controls entire planets and treats human lives as expendable in the quest for profit. The *Star Trek* series, however, envisions a future in which interplanetary laws direct space explorers to act in the best interest of all living things. Do you think the future will look like either of these possibilities?

Dig Deeper

Collaborate with your classmates to explore one or more of these questions—or generate your own questions to explore.

1. Find out about areas suggested by NASA as commercial partnership options. List some of the applications of "public/private partnerships" that are being developed.
2. Research laws passed by the UN, as well as the United States and other countries, that apply to space exploration. How are they expected to be enforced?
3. Research some of the companies involved in space technology. What are their aims or goals? Who chooses them? What concerns may arise from a focus linked to generating profits?
4. Investigate the weaponization of space. What countries are thought to be developing defensive or destructive weapons in space? How could this use of space be controlled?
5. Consider both positive and negative outcomes of commercializing space. Prepare your arguments on both sides for use in a debate.
6. What concerns do you have about the protection of human health and lives by space companies in the future? List some of the possible safety concerns you could have as either a space tourist or worker in space. Would you take a private company's rocket into space? How would you know you could trust the safety of the rocket?
7. Find out some of the ways in which scientific discoveries from space research have benefited humanity. Were these benefits planned or unexpected? Should potential economic gain determine which experiments are run?
8. Research science fiction coverage of the future in space. Include both idealistic, peaceful universes and dystopian futures.