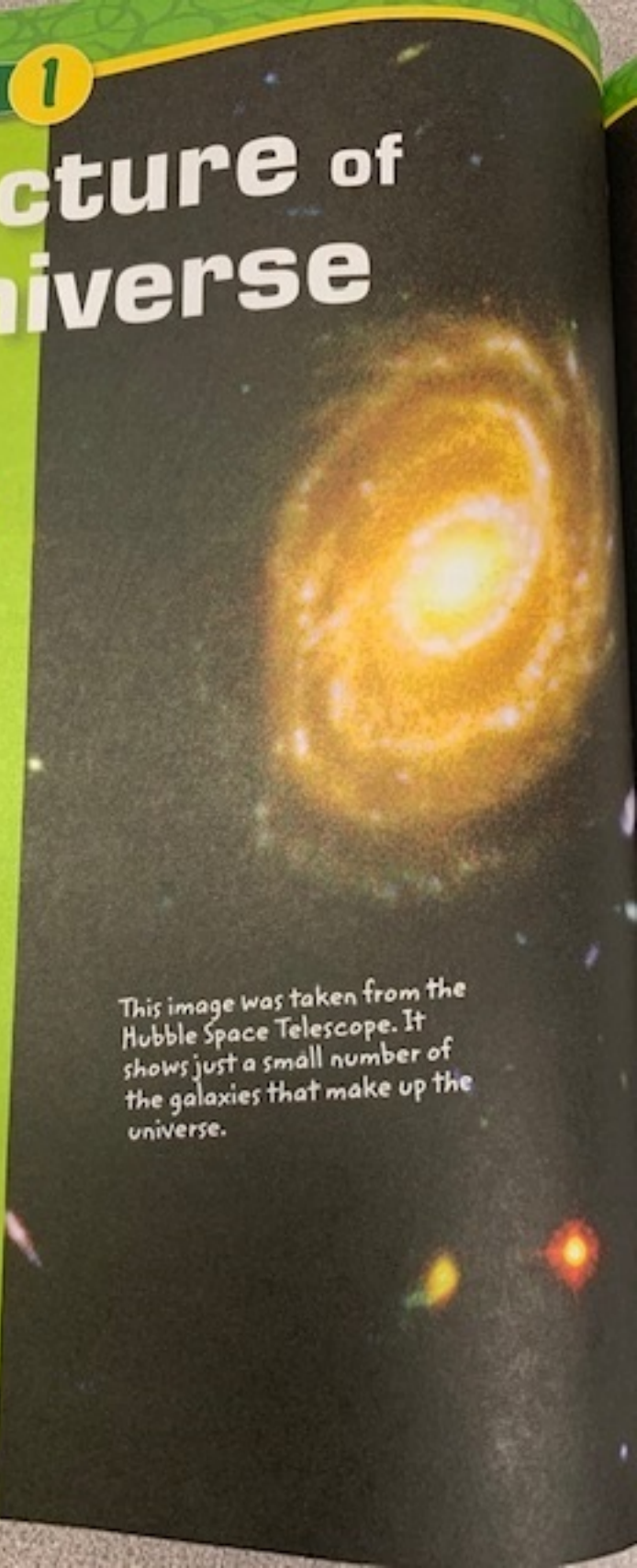
Lesson 1

Structure of the Universe

ESSENTIAL QUESTION

What makes up the universe?

By the end of this lesson, you should be able to describe the structure of the universe, including the scale of distances in the universe.



This image was taken from the Hubble Space Telescope. It shows just a small number of the galaxies that make up the universe.

TEKS 8.8A describe components of the universe, including stars, nebulae, and galaxies, and use models such as the Hertzsprung-Russell diagram for classification

TEKS 8.8B recognize that the Sun is a medium-sized star near the edge of a disc-shaped galaxy of stars and that the Sun is many thousands of times closer to Earth than any other star

TEKS 8.8D model and describe how light years are used to measure distances and sizes in the universe

Our place in space

What makes up the universe?

You live on Earth, which is one of eight planets in the solar system that orbit the sun. As you probably know, the sun is a star. A *star* is a large celestial body that is composed of gas and emits light. Stars are grouped together in structures known as galaxies. A *galaxy* is a large collection of stars, gas, and dust. Based on observations by the Hubble Space Telescope, there are an estimated 100 billion or more galaxies in the universe. **Universe** is the word that scientists use to describe space and all of the energy and matter in it.

Active Reading

5 **Identify** As you read the text, underline those characteristics of Earth that make it a suitable place for life.

Earth—Our Home Planet

Earth is a special place. Imagine Earth without liquid water. There would be no vast, deep, blue oceans or broad, muddy rivers. The water would not evaporate and condense to form clouds in Earth's atmosphere. It would not fall to the ground again as rain or snow. Without water, there would be no plants to add oxygen to the atmosphere. And without oxygen, there would be no animal life on Earth.

Earth's atmosphere contains the combination of gases that animals need to breathe. The atmosphere also contains a thin layer of ozone gas. Ozone molecules in this layer absorb radiation from the sun that can be harmful to life. In addition, there are certain gases in the atmosphere that keep temperatures on Earth warm enough for life to exist.

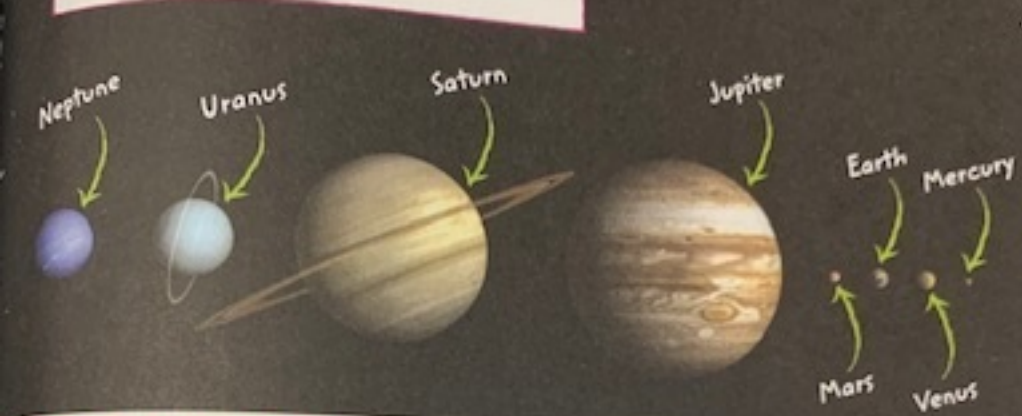
From the moon, you can see Earth's continents, dark-blue oceans, and white clouds swirling in the atmosphere.

The Sun

The sun appears to be much bigger and brighter than any of the stars you see at night. However, the sun is actually a medium-sized star. It seems bigger than other stars because it is the nearest star to Earth. The next-closest star to Earth is Proxima Centauri. It is 270,000 times farther away from Earth than the sun is.

Visualize It!

6 **Analyze** What is the relationship between the sizes of the planets and their distances from the sun?



Sizes are roughly to scale. Distances are not.

The Solar System

Active Reading 7 **Identify** As you read the text, underline the different bodies that make up the solar system.

The **solar system** is the collection of large and small bodies that orbit our central star, the sun. The contents of the solar system are numerous and stretch across a large area of space. For example, the solar system is so big that the distance from the sun to Neptune is 4.5 billion kilometers.

If you crossed the solar system beginning at the sun, you would encounter eight large bodies called *planets*. A **planet** is a spherical body that orbits the sun. Planets are generally larger than the other bodies in the solar system. The four planets that orbit nearest to the sun are the terrestrial planets. They are Mercury, Venus, Earth, and Mars. The terrestrial planets are all rocky, dense, and relatively small. The four planets that orbit farthest from the sun are the gas giant planets. They are Jupiter, Saturn, Uranus, and Neptune. These large planets have thick, gaseous atmospheres; small, rocky cores; and ring systems of ice, rock, and dust.

Orbiting most of the planets are smaller bodies called *moons*. Earth has only one moon, but Jupiter has more than 60. The rest of the solar system is made up of other small bodies. These include dwarf planets, comets, asteroids, and meteoroids. Altogether, there are up to a trillion small bodies in the solar system.

Stars

A **star** is a large celestial body that is composed of gas and emits light. Like the sun, most stars are composed almost entirely of hydrogen and helium. Small percentages of other elements are also found in stars. Energy production takes place in the center, or core, of a star. Energy is produced by the process of nuclear fusion. In this process, stars fuse lighter elements, such as hydrogen, into heavier elements, such as helium. This energy leaves the core and eventually reaches the star's surface. There, energy escapes as visible light and other forms of radiation.

Stars vary greatly in size. Small stars, such as white dwarfs, may be about the size of Earth. Giant and supergiant stars may be from 10 to 1,000 times as large as the sun is. The sun is a main-sequence, yellow dwarf star that is about 5,500 °C at its surface.

Think Outside the Book

8 **Apply** Conduct research about one of the following aspects of stars:

- composition
- layers
- energy production
- size

Present your findings to the class in the form of an oral presentation or a poster presentation.

Galaxies

Our solar system is located in the Milky Way galaxy. A **galaxy** (GAL•uhk•see) is a large collection of stars, gas, and dust that is held together by gravity. Small galaxies, called *dwarf galaxies*, may contain only a few million stars. Giant galaxies, however, may contain hundreds of billions of stars.

The Milky Way is a spiral galaxy. Spiral galaxies are shaped like pinwheels. They have a central bulge from which two or more spiral arms extend. Stars form in or near the spiral arms. The sun is located in a partial spiral arm of the Milky Way galaxy, near the edge of the galaxy. Elliptical galaxies and irregular galaxies are two other kinds of galaxies. Elliptical galaxies look like spheres or ovals, and they do not have spiral arms. Irregular galaxies appear as splotchy, irregularly shaped "blobs." Irregular galaxies are very active areas of star formation.

The Small Magellanic Cloud is an irregular dwarf galaxy that is located near the Milky Way. The blue stars are very young and are still surrounded by the gas and dust from which they formed.

Nebulae

A **nebula** (*plural*, nebulae) is a large cloud of gas and dust in space. Most stars form in nebulae. Nebulae are found in the arms of spiral galaxies and throughout irregular galaxies.

Nebulae may form from stars. Planetary nebulae form as stars like the sun age and push away their outer layer of material. Nebulae also form after supergiant stars that are much larger than the sun explode. The nebulae that form from remains of these explosions are called *supernova remnants*.

There are three other main types of nebulae. Emission nebulae glow. Stars that are forming in these nebulae give off light and often have a red glow. The Orion Nebula is an emission nebula. Reflection nebulae reflect the light from other stars. These nebulae are often blue. The third type of nebulae are dark nebulae. Dark nebulae appear as dark regions in the sky because they block the light of stars behind them.

Active Reading

9 Compare How does a planetary nebula differ from other types of nebulae?

_____

_____

_____

Visualize It!

10 Describe Write the name of the correct type of nebula (dark nebula, emission nebula, or reflection nebula) under each of the three images below. Then, write a few words to describe each type.

Visualize It!

11 Describe In the boxes below, write in your answers to each of the questions.

You live on Earth. What is Earth's place in the universe?

Earth is part of the solar system. What objects make up our solar system?

The solar system is located within a partial spiral arm of the Milky Way galaxy. What is a galaxy?

How big is big?

The Voyager 2 spacecraft was launched in 1977. It explored Jupiter, Saturn, Uranus, and Neptune and is now close to moving out of the solar system and into interstellar space.

How are distances in the universe measured?

Distances between most objects in the universe are so large that astronomers do not use kilometers to measure distance. Instead, astronomers measure distance using the speed of light. This unit of measure is known as a light-year. A **light-year** (ly) is the distance that light travels through space in one year. Light travels through space at about 300,000 km/s, or about 9.5 trillion km in one year. The closest star to the sun and Earth is Proxima Centauri. It takes light about 4.3 years to travel from Proxima Centauri to us. Therefore, the distance from Proxima Centauri to Earth is around 4.3 ly. Light from the sun travels to Earth in a little more than 8 minutes. Thus, the distance from the sun to Earth is around 8 light-minutes.

How do distances affect space travel? Our fastest interplanetary spacecraft, *Voyager 1*, travels through space at about 17 km/s. At this speed, it would take *Voyager 1* more than 70,000 years to reach Proxima Centauri.

Do the Math

12 Compute If *Voyager 1* is now moving at 17 km/s, how far will *Voyager 1* travel in one year?

Images are not to scale

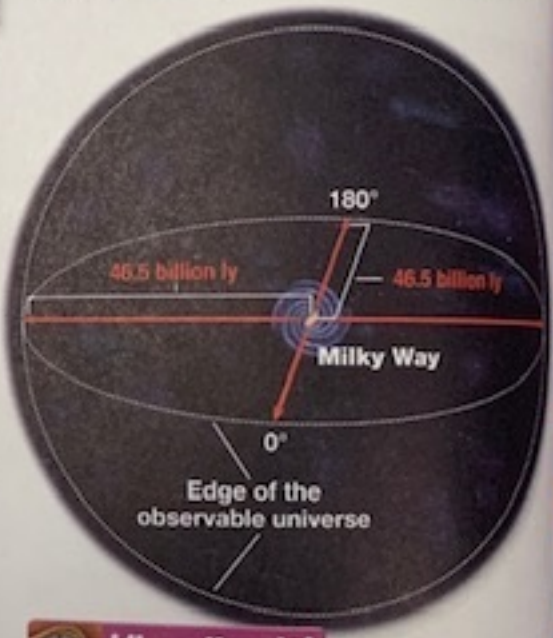
How are sizes in the universe measured?

The sizes of objects in the universe vary greatly. The units used to measure the size of an object in the universe depend on the object. The size of smaller objects, such as moons, planets, and stars, are often measured in kilometers. The size of these objects is often given as the diameter because they are close to being spherical. The diameter of Earth is about 12,742 km. The diameter of the sun is 1,391,000 km, making it about 109 times larger than Earth.

Light-years are used to measure the size of large objects in the universe, such as nebulae, galaxies, and galaxy clusters. The Milky Way galaxy has a diameter of about 100,000 ly across. Most of the other galaxies in the Local Group are smaller than the Milky Way. The Local Group is about 10,000,000 ly across. The Local Group is also part of the even bigger Virgo Supercluster. The Virgo Supercluster is about ten times wider than the Local Group, so it takes light 100,000,000 years to travel all of the way across.

What is the size of the observable universe?

Scientists still do not know the actual size of the entire universe. They only know the size of the universe that they can observe. Radiation from objects that formed early in the history of the universe has not yet reached Earth. And that takes time. Scientists have been able to take images of radiation that took around 14 billion years to reach Earth. These data tell scientists that the universe has a radius of at least 14 billion ly. However, the universe has been expanding in all directions since it formed. This means that objects are moving farther apart at an ever-increasing rate. Because the universe continues to accelerate outward, the universe is much larger than 14 billion ly in radius. Using the best current scientific techniques, it is estimated that the universe is around 93 billion ly in diameter and growing larger.



Visualize It!

13 Justify Use the model above to justify the current estimation of the diameter of the universe.

What is the structure of the universe?

The universe can be defined as space and all the matter and energy in it. However, this definition does not tell us about the structure of the universe. Astronomers now know that throughout the universe there are areas where galaxies are densely concentrated. These are areas where galaxies are found in what are called *clusters* and *superclusters*. Clusters contain as many as several thousand galaxies. Superclusters can be made up of ten or more clusters of galaxies. There are also areas throughout the universe where very little matter exists. These are huge, spherical volumes called *voids*.

Astronomers have begun to think of the universe as having a structure similar to a three-dimensional web. Clusters and superclusters of galaxies make up the web. The large, empty volumes within the web are voids. It takes light hundreds of millions of years to cross the largest voids.

Active Reading **14 Describe** What is the general structure of the universe?

This supercomputer image is part of a simulation—the Bolshoi Simulation—of the evolution of the cosmos in a cube that is one billion light-years across.

Think Outside the Book Inquiry

15 Apply Astronomers have begun to think of the universe as a system of clusters and superclusters of galaxies and voids. The clusters/superclusters of galaxies form the skeleton of the universe. Research the "cosmic web" of galaxies, and write a short essay or give a poster presentation

Lesson Review

Lesson 1

Vocabulary

Fill in the blank with the term that best completes the following sentences.

1 A _____ is a large collection of stars, gas, and dust that is held together by gravity.

2 Space and all matter and energy in it is called the _____.

3 A _____ consists of a star and all of the bodies in orbit around it.

Key Concepts

4 **Identify** What is a large celestial body that is composed of gas and emits light?

5 **Compare** How does the size of the sun and its distance from Earth compare to the sizes and distances of other stars?

6 **Compare** What is the difference between an emission nebula and a reflection nebula?

7 **Describe** What is a light-year? Explain why light-years are used to measure distances and sizes in the universe.

Critical Thinking

Use the table to answer the following question.

Object	Distance from Earth
sun (nearest star)	8.3 light-minutes
Proxima Centauri (nearest star to sun)	4.3 light-years
center of Milky Way galaxy	25,000 light-years
Andromeda galaxy (nearest large galaxy)	2.5 million light-years

8 **Apply** How far is the sun from the center of the Milky Way galaxy? Explain your reasoning.

9 **Determine** A planet in our solar system is one of the farthest planets from the sun. Describe the size and composition of this planet.

10 **Deduce** What do you think that astronomers mean when they use the term *observable universe*? (Hint: Think of the time it takes for light from very distant objects to reach Earth.)