



Be a Scientist!

Make a model that helps demonstrate how the universe is expanding. Follow these steps:

- 1 Use markers to make dots on the outside of an uninflated balloon to represent galaxies full of stars.
- 2 Measure the distance between at least three pairs of dots on the uninflated balloon. Record your measurements.
- 3 Inflate the balloon and measure between the same three pairs of dots again. Compare this data to your original measurements. What has happened?

What does the balloon tell you about the expansion of the universe? How is this model like the universe? How is it different?



Beyond the Book

Use the Internet to find photographs of galaxies taken by the Hubble Space Telescope.

FOCUS Book

GALAXIES FAR, FAR AWAY



: Science A-Z 

GALAXIES FAR, FAR AWAY



FOCUS Question

What can galaxies tell us about the universe?

Scale, Proportion, and Quantity

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What Is a Galaxy?

If you look at a dark sky on a clear night, you will see thousands of stars. These stars make up a very small part of the billions of stars in our home galaxy, the Milky Way.

Galaxies are enormous groups of stars, planets, dust, and gas held together by gravity. Astronomers estimate that there are *at least* 100 billion galaxies in the universe. Some “tiny” galaxies contain only a few hundred or a few thousand stars. Giant galaxies have trillions of stars.

Some galaxies are forming right now, but others are more than 13 billion years old. The light that reaches us from the most distant galaxies has traveled through space for billions of years.

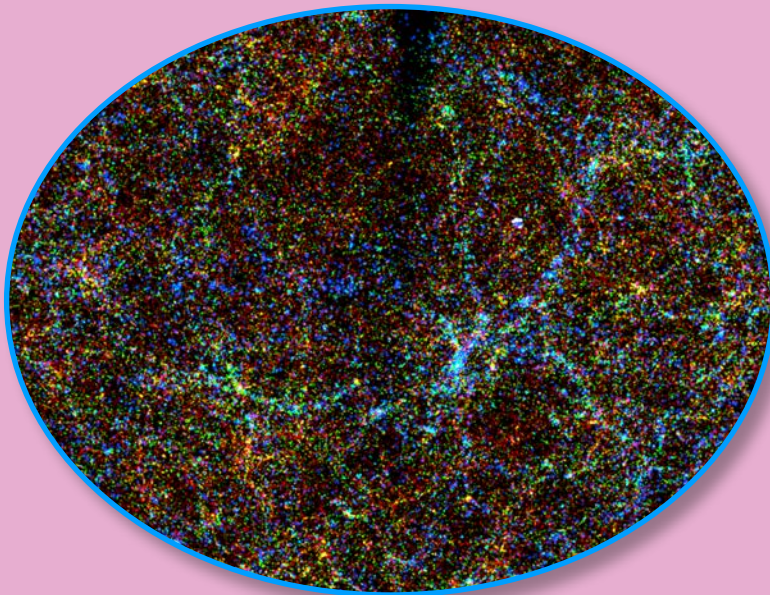
Milky Way galaxy



Exploring Galaxies

In 1923, astronomer Edwin Hubble observed the Andromeda Nebula using the Hooker Telescope in California. He discovered that the Andromeda Nebula was not a nebula, but rather a galaxy made up of billions of stars.

Before this discovery, our own Milky Way was the only known galaxy. Today, astronomers use even more powerful telescopes on land and in space to study galaxies.



This map shows more than 1.5 million galaxies as seen by telescopes on Earth. Notice that the galaxies are clustered together. These clusters are held together by gravity.

Looking Back in Time

Astronomers describe distances in space in terms of *light-years*. One light-year is the distance light travels in one year. For example, the Andromeda galaxy is about 2.5 million light-years from Earth. It takes the light from Andromeda about 2.5 million years to travel to Earth! Light travels 300,000 kilometers every second, so a light-year is a very long distance.

This means that when we look far into space, we are also looking back in time. When we look at Andromeda, we see what it looked like 2.5 million years ago. We won't know what it looks like today for another 2.5 million years!

Think About It

The Perseus galaxy cluster is 300 million light-years from Earth. Imagine that a creature living in the Perseus cluster is looking at Earth with a telescope. How might Earth look different compared to how it looks now?



This image shows about 5,500 galaxies. Some of these galaxies are more than 10 billion light-years from Earth. We are seeing what they looked like 10 billion years ago.

Astronomers are not just interested in what galaxies look like now. They also want to learn how galaxies form and how they *evolve*, or change over time. One tool that looks out into space—and back in time—is the Hubble Space Telescope (HST). The HST orbits about 569 kilometers (354 mi.) above Earth’s surface, and looks out into deep space. Astronomers use the HST to see objects that are more than 13 billion light-years away. The HST and other space telescopes can show how parts of the universe looked 13 billion years ago, shortly after it formed.



Hubble Space Telescope in orbit

Do You Know?

Astronomers think that four billion years from now, gravity will cause the Milky Way galaxy and the Andromeda galaxy to merge into a single super galaxy.

Types of Galaxies

Each galaxy is unique. Galaxies vary in size, shape, age, location, and how they move. One way astronomers classify galaxies is by their shape. There are three types of galaxies: spiral, elliptical, and irregular.

Spiral galaxies have a bright center with arms of stars, dust, and gas spinning around the center. Spiral galaxies rotate through space around a central bulge of stars.

Our home galaxy, the Milky Way, is a spiral galaxy. It contains roughly 400 billion stars.



Spiral galaxy M 101

Artists' conception, based on recent observations from NASA's Spitzer Telescope, of our home—the spiral Milky Way galaxy.



The Milky Way



**Elliptical galaxy
NGC 1132**



**Irregular galaxy
NGC 1427A**

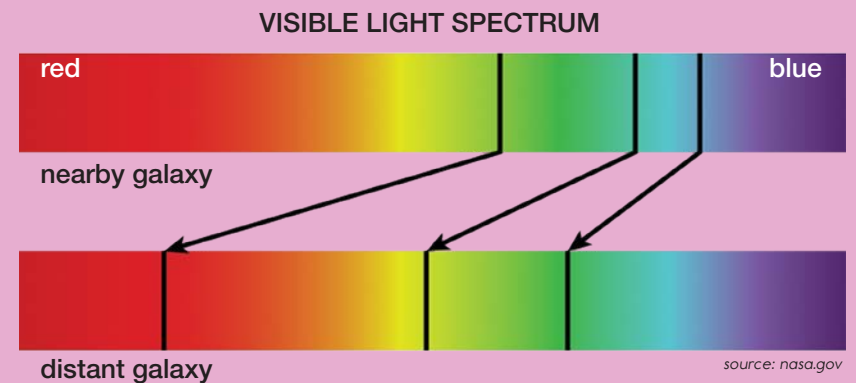
Elliptical galaxies are egg-shaped. The elliptical galaxy on the left, known as NGC 1132, has so much mass that astronomers think it may have formed by the collision of many smaller galaxies. This giant is surrounded by thousands of small dwarf galaxies in orbit around it. The largest known galaxy, IC 1101, is also an elliptical galaxy. Scientists think IC 1101 contains more than 100 trillion stars, about 1,000 times the number of stars in our galaxy.

Irregular galaxies do not have a distinct shape. Irregular galaxy NGC 1427A is located 62 million light-years from Earth. Part of the reason it has such a strange shape may be that it is close to a cluster of hundreds of other galaxies called the Fornax cluster. The strong gravitational force of the Fornax cluster pulls strongly on NGC 1427A, warping its shape.

Hubble and the Expanding Universe

The Hubble Space Telescope was named after Edwin Hubble. He changed the way we look at the universe. In the 1920s, Hubble noticed that the light coming from many galaxies was slightly redder than he expected. He also noticed that the farther away a galaxy is, the more its light is shifted toward the red end of the visible light spectrum (the part of the electromagnetic spectrum that is visible to the human eye).

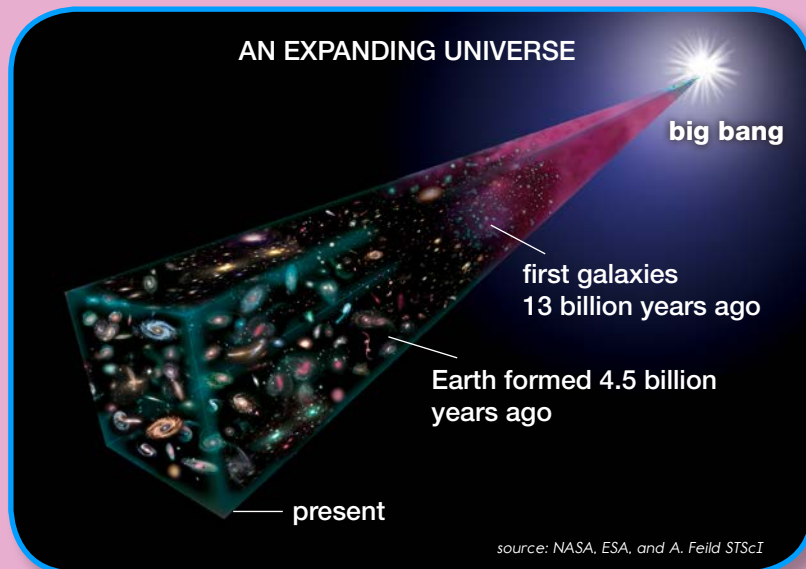
Hubble thought about what this could mean. He knew that when a light source is moving away from an observer very fast, it looks redder to the observer than when the light is still. He also knew that the faster the source is moving away, the redder it looks.



The black lines on the spectrum occur when light is absorbed by dust between stars. The top spectrum shows where the lines appear in a nearby galaxy. The bottom spectrum, from a distant galaxy, shows that the lines are shifted toward the red end of the spectrum.

Hubble inferred that galaxies whose light was shifted toward red are moving away from Earth. Light from galaxies farther away is shifted more than galaxies that are closer. Distant galaxies are moving away faster.

Hubble concluded that the clusters of galaxies in the universe are generally moving away from each other. The universe must be expanding, getting bigger every day. This observation led to the development of the *big bang theory*. This theory states that the universe formed in an instant, with a giant explosion. It has been expanding outward ever since. Astronomers think that the explosion occurred more than 13 billion years ago. Since then, galaxies have formed, changed, and moved away from each other. The universe is expanding. Will it ever stop?



Read-Think-Write

Write your answers on separate paper. Use details from the text as evidence.

- 1 Describe two ways that all galaxies are similar, and two ways that they can be different.
- 2 What is a light-year?
- 3 Compare and contrast galaxy NGC 1427A, on page 7, to the Milky Way galaxy.
- 4 Edwin Hubble observed a shift toward the red end of the visible light spectrum. Which word has about the same meaning as *spectrum*?
 - A gravity
 - B rainbow
 - C space
- 5 What does the shift of light toward the red end of the spectrum tell astronomers about the universe?

FOCUS Question

What can galaxies tell us about the universe? Think about observations that astronomers have made about galaxies. Based on these observations, how would you predict that the universe will change in the next 13 billion years?

Explain your answer.

