Illustration Credit: NASA/JPL-Caltech/R. Hurt SSC)

In This Exploration:

- *Find out about our galaxy, the Milky Way, and our neighboring galaxies*
- *Create and use a galaxy-sized scale factor to explore distances between galaxies*
- *Classify galaxies and look back in time on a Hubble image*

A Gaggle of Galaxies Teacher Guide

In this exercise, students will model the size of our galaxy, the Milky Way, and the distances between our galaxy and several others in the Local Group of Galaxies. Students will then examine the Hubble Ultra Deep Field, which shows a view of the earliest galaxies in the Universe, and create a classification scheme based on galaxy characteristics. In a discussion of the numerous red galaxies in the Hubble Ultra Deep Field, students will be introduced to the idea of redshift and the Big Bang theory of the origin of the Universe. An expanding balloon or stretchable exercise band will be used to model redshift.

Recommend Prerequisites: Scale Model Solar System, Sizes of Stars

Grade Level: 6-8

Curriculum Standards: A Gaggle of Galaxies is matched to:

- National Science and Math Education Content Standards for grades 5-8.
- National Math Standards 5-8
- Texas Essential Knowledge and Skills (grades 6 and 8)
- Content Standards for California Public Schools (grade 8)

Time Frame: The activity should take approximately 45 minutes to 1 hour to complete, including a short introduction and follow-up.

Purpose: To aid students in understanding the scale of our galaxy and its relationship to other galaxies, how galaxies are classified, and evidence for the Big Bang theory of the origin of the Universe.

Key Concepts:

- Our galaxy, the Milky Way, is a barred spiral containing 200 to 500 billion stars.
- Our own galaxy is one of hundreds of billions of galaxies in the known universe.
- Galaxies are closer together in comparison with their size than are stars.
- Galaxies can take many different forms.
- Galaxies are classified by their morphology.
- The red shift of galaxies in the Hubble Ultra Deep Field is evidence for the Big Bang.

Required Supplies:

- A student sheet for each student
- One color printout of the Hubble Ultra Deep Field for each small group of students
- A light colored balloon or stretchable exercise band for the teacher to use in a demonstration
- A marker (if the balloon is not already marked with a sine wave)

Note: The use of *italics* indicates information or instructions from the student version

Scale Modeling Activities are presented as instructions in the sidebars. The author recommends that students both discuss the information presented in the reading and work through the scale modeling activities in small groups.

Introduction: Before giving students the student reading, ask them what they know about our own galaxy. Some possible questions include:

- What is our galaxy called?
- Why it is called the Milky Way?
- What shape it is the Milky Way?
- How many stars are in the Milky Way?
- How big do they think our galaxy is?
- How many other galaxies are there in the universe?

Our own galaxy, the Milky Way, has between about 200 billion and 500 billion stars. There are so many stars that all but the closest blur together into a milky haze. The Milky Way is a big galaxy, (although not the biggest) at 100,000 light years across (that's 1,000,000,000,000,000,000 km or 1,000,000 trillion km). Our small sun is a star a bit more than halfway out from the center of the galaxy. The Milky Way is a barred spiral galaxy. It has a flat shape with a 3000 light-year-thick bar-like bulge in the middle, and spiral arms. *We live on the edge of the spiral arm called the Orion arm. Almost all of the individual stars you can see when you look up at the night sky are in the same arm of the Milky Way that we are.*

The Galaxies in our Neighborhood

Our galaxy is one of approximately 50 galaxies in a small cluster of galaxies known as the Local Group. Most of the galaxies in the Local Group are small. M 33 (also known as the "Triangulum Galaxy") and M 31 (also known as the "Andromeda Galaxy") are the only other large galaxies in the Local Group, and both are also spiral galaxies. Andromeda is the biggest, at about twice the width of the Milky Way, and M 33 is only 50,000 light years across. Many of the smaller galaxies in the Local Group are satellites of the bigger ones. The Milky Way has several satellite galaxies, including the Large and Small Magellanic Clouds. Distances between star systems are almost unimaginably big compared with the sizes (distances between) of stars, but galaxies can be close together compared with their size.

A Scale Factor Big Enough to Fit Galaxies

Thinking about the size of the Milky Way

How much space would you need to make a scale model of the Milky Way using a scale factor of 1:10 billion? **Answer**: 100 million km. That's 2/3 of the distance between the Earth and the Sun on our scale model!

If you could build such a model, would it fit on the REAL Earth? **Answer:** No.

Would your model galaxy fit in our REAL solar system? **Answer:** Yes

Let's imagine we could shrink the Milky Way down to a diameter of 1 m (about the size of a desk) and shrink the rest of the local group by the same amount. We then have a new scale factor, where 1 m on our new scale model equals 100,000 light years in the real local group. The actual Large Magellanic Cloud is 160,000 light years from the center of the Milky Way.

Using Our Galaxy Scale Factor: 1 m = 100,000 ly

If the center of your desk or table is the center of the scale model Milky Way, how far away from the your desk would the scale model Large Magellanic Cloud be? **Answer:** 1.6 m from the center

Andromeda and M33 are the farthest objects in the Local Group. Both are about 3 million light years away from the Milky Way. How far away would the model Andromeda or model M33 be from your desk? **Answer:** 30 m from the center of the desk/table

Would the model Andromeda and M33 fit in your school? Would they fit in your classroom? **Answers:** Probably, No

(Note: on this scale, the distance between the Sun and the Alpha Centauri system would be 0.04 mm, which is too small to see!)

There are about as many galaxies in the known universe as there are stars in the Milky Way. These galaxies come in many different shapes and sizes. With our best telescopes, we can see galaxies more than 13 billion light years away. That means it has taken more than 13 billion years for their light to get to us. The light we see with our telescopes started its journey from the most distant galaxies more than 13 billion years ago. Looking at objects so far away really is looking back in time!

Andromeda Galaxy and M33 Galaxy

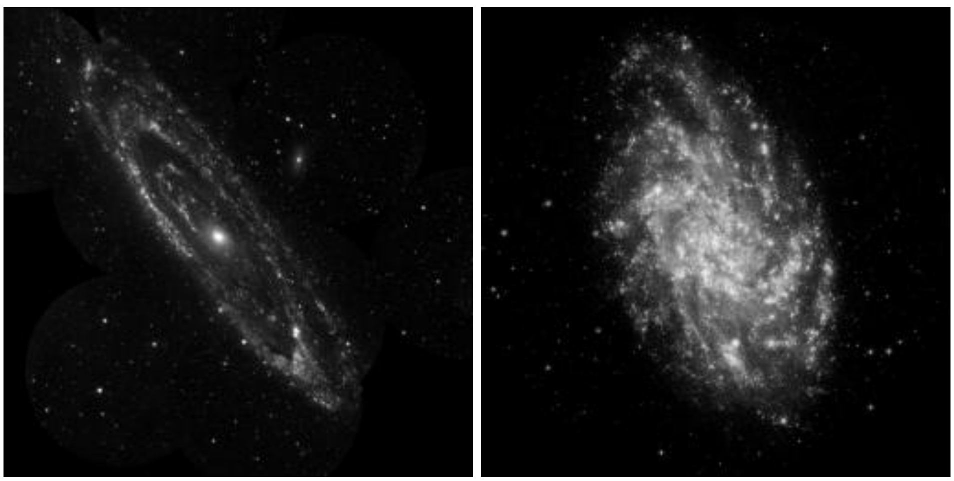


Image Credits NASA/JPL/California Institute of Technology, Galaxy Evolution Explorer (GALEX)

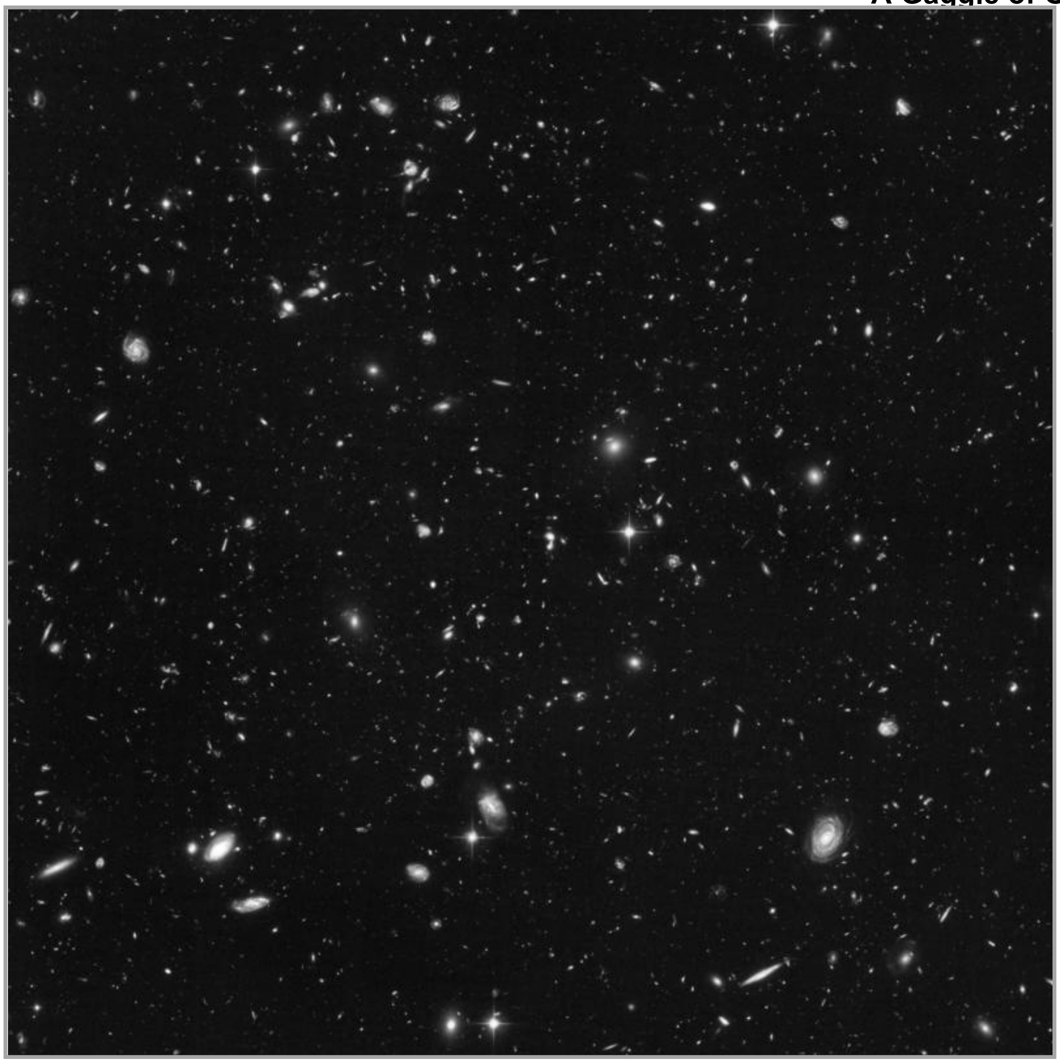


Image Credit: NASA, ESA, S. Beckwith (STScI) and the Hubble Ultra Deep Field Team

Using the Hubble Ultra Deep Field: Break your students into groups of two - three students and give each group a color copy of the Hubble Ultra Deep Field. Have them read the information sheet individually in groups, or as a class.

This Hubble Ultra Deep Field image is a picture of 10,000 extremely distant galaxies in a very tiny area of the sky. (This image is of an area of the sky the tenth of the size of the full moon as seen from Earth.) The Hubble Space Telescope took this composite image in 2004 using two different cameras. One camera used infrared light to see the small, most distant, and reddest galaxies in the image. Some of the galaxies that look the biggest and the brightest are a bit closer, but still about 13 billion light years away. One thing you should be able to see in the picture is that galaxies come in many different shapes. (A few stars in our own galaxy are also in this image, but you can tell those by the four points of light that they seem to have because they are so bright compared to the distant galaxies.)

Galaxy Activity

Look carefully at the Hubble Ultra Deep Field.

- *Can you find galaxies that look similar to one another?*

Now come up with a classification scheme of your own.

- *Pick a name for a type of galaxy, and list three characteristics of that galaxy.*
- *Do this for three different types of galaxies.*

Name of Galaxy Type	***Characteristics***
Example: Spiral	*Flat, pancake shaped, spiral arms.*

How Astronomers Classify Galaxies.

Astronomers classify galaxies by their shapes into three major categories: elliptical, spiral (normal and barred), and irregular. Your students may come up with some much more creative names and descriptions! What is important is that they use their observations to categorize galaxies. Be sure they understand the task is not to name individual galaxies.

Redshift and the electromagnetic spectrum:

Before discussing the concept of redshift, your students may need an introduction or review of the electromagnetic spectrum, including wavelength and color.

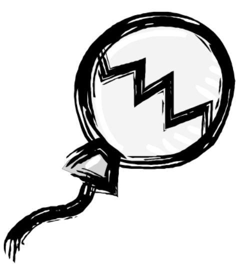
Red Galaxies, Expansion of the Universe, and the Big Bang

The small red galaxies in the Hubble Deep Field are the farthest away from us. The fact that they are so red is also evidence for the Big Bang!

Not so long ago, astronomers thought that the Milky Way was the entire universe, and that the universe remained static (unchanging) with time. Astronomers didn't even realize that there were other galaxies until the 1920s. Edwin Hubble *realized that many “nebula” which astronomers had found were distant galaxies. He also discovered something else very strange – the farther away the galaxies were, the more red their light had become. This* ***red shift*** *showed that most galaxies were moving away from each other, which led to the idea of the* ***Big Bang****. If galaxies are moving apart, at some point in the past, they must have been close together.*

The universe had a beginning, which we now call the Big Bang. The idea that the universe began billions of years ago and has been expanding ever since was very strange to scientists when it was first suggested. Even Albert Einstein had accepted the idea of a static universe before Hubble’s observations. The reddest galaxies in the Hubble Ultra Deep Field look so red that a special infrared camera had to be used to see them. The universe is about 14 billion years old, and the light we see was emitted only 800 million years after the universe was born.

Space Expansion Demo: Take a light colored balloon or stretchable and draw a wave on it with several equally spaced peaks and valleys. Ask the students to watch carefully as you inflate the balloon, or stretch the exercise band.



Imagine a balloon that has a picture of a wave drawn on it.

This wave represents a wave of light.

Now inflate the balloon. What happens?

The peaks and valleys of the wave stretch out and become farther apart. The ***wavelength*** *has increased. If the wave was visible light, the light would be more red because red light has the longest wavelength of all visible light. The balloon represents the expansion of space that has continued since the Big Bang. Early in the Universe, the galaxies were much closer together. The light emitted by far away galaxies has been expanding with the Universe since the moment it was emitted.*

Note: When using a balloon for this demonstration, the students may think that the amplitude (height) of the wave increases too. It doesn’t. That is a limitation of using a balloon for this demonstration. A material that stretches in only one dimension will not have problem.

Do the galaxies, stars, planets, and people expand with the Universe? No. We are held together by gravity or by the materials we are made of. Galaxies that aren't kept together by gravity are pulled apart from one another, but their stars and planets travel with them. Each galaxy is like a little island universe in space. Think of galaxies as raisins in a loaf of bread dough rising in the oven. As the bread expands, the raisins get further apart.

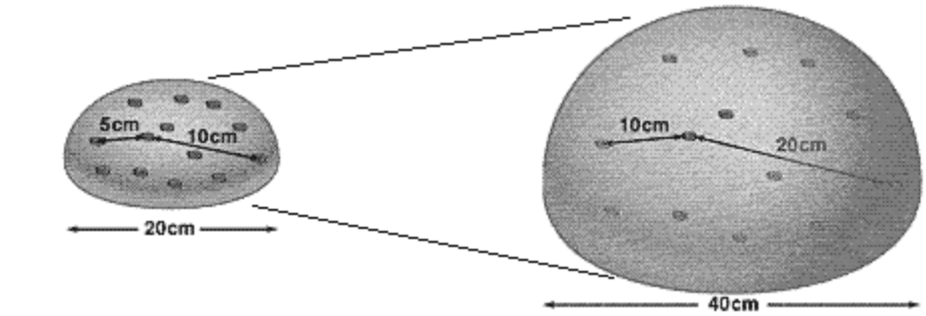


Image adapted from http://map.gsfc.nasa.gov/m_uni/uni_101bbtest1.html

Using glitter or other non-expanding objects on the surface of the balloon or stretchable band will help illustrate this concept for the students.

Internet Extension:

Have students compare and contrast galaxies and clusters of galaxies as seen by the Hubble Space Telescope, Spitzer Space Telescope, and from ground-based telescopes as seen in the SEDS Messier Database or the Astronomy Picture of the Day. Many of the galaxies have strange names such as M 33 or NGC 1300, which are really just astronomical catalog designations. What similarities and differences can your students find in galaxies in these images?

From Hubble Space Telescope (hubblesite.org)

- Coma Galaxy Cluster: http://hubblesite.org/newscenter/newsdesk/archive/releases/1995/07/
- Hickson Compact Group 87 http://hubblesite.org/newscenter/newsdesk/archive/releases/1999/31/
- Barred Spiral http://hubblesite.org/newscenter/newsdesk/archive/releases/2005/01/
- Spiral http://hubblesite.org/newscenter/newsdesk/archive/releases/2004/25/
- Ring Galaxy (once an ordinary spiral) http://hubblesite.org/newscenter/newsdesk/archive/releases/2004/15/
- Spiral with aging (bright red) star http://hubblesite.org/newscenter/newsdesk/archive/releases/2004/43/

- Sombrero Galaxy
  http://hubblesite.org/newscenter/newsdesk/archive/releases/2003/28/
- Colliding Spirals
  http://hubblesite.org/newscenter/newsdesk/archive/releases/1999/41/
- Small Elliptical Galaxy
  http://hubblesite.org/newscenter/newsdesk/archive/releases/1999/40/

From SEDS Messier Database (http://www.seds.org/messier/)

- Andromeda Galaxy (M 31) in the Local Group
  http://www.seds.org/messier/xtra/ngc/lmc.html
- Trianglulum Galaxy (M 33) in the Local Group
  http://www.seds.org/messier/m/m033.html
- Large Magellanic Cloud (satellite galaxy of the Milky Way)
  http://www.seds.org/messier/xtra/ngc/lmc.html
- Small Magellanic Cloud (satellite galaxy of the Milky Way)
  http://www.seds.org/messier/xtra/ngc/smc.html
- Giant Elliptical M87 at the heart of the Virgo Cluster
  http://www.seds.org/messier/m/m087.html