Session 9 – Galaxies

General Description

Students learn what a galaxy is and also learn that we live in a galaxy called the Milky Way Galaxy. They work individually or in pairs to make a model of our Milky Way Galaxy and see how our Sun and the Earth fit into it. They learn that our galaxy is only one of billions of galaxies, and that galaxies have different shapes.

Objectives

- To ensure understanding that we live in a galaxy.
- To understand that galaxies are made of stars like our Sun.
- To show that there are a very large number of galaxies in the Universe.

Concepts Addressed

- A galaxy is a very large collection of stars, gas, and dust
- Hierarchy of structure in the Universe
- Basic shapes of galaxies
- The effect of galaxy orientation on appearance

Materials

- Index cards, 1 per student
- Sturdy paper plates, about 10″–12″ diameter (alternatively you can use any other round flat board, such as cardboard, foam board, etc) — 1 per student or pair
- Diagram of Milky Way Galaxy arms (included in Appendix F) — 1 per student or pair
- Colored pencils or crayons or markers — 3 different colors per student or pair
- Yellow or red markers (or water color paints) — 1 per student or pair
- Small stickers of stars and circles/ovals — 1 packet per student or pair
- Styrofoam ball (1.5″ diameter) — 1 per student or pair
- Blunt cutter to cut Styrofoam ball in half — 1 per student or pair
- Toothpicks — 2 per student or pair
- Ruler — 1 per student or pair
- Hubble Ultra Deep Field image (included in Appendix F)
- Image of types of galaxies (included in Appendix F)
- Image of different orientations of spiral galaxies (included in Appendix F)
- Blackboard/whiteboard or flip chart
- Chalk or markers

Background

A galaxy is a large group of stars, gas, and dust bound together by gravity. Our Sun (a star) and all the planets around it are part of a galaxy known as the Milky Way Galaxy. It is called the Milky Way since it appears as a milky band of light in the sky when you see it in a really dark area. All the stars we see in the night sky are in our own Milky Way Galaxy.

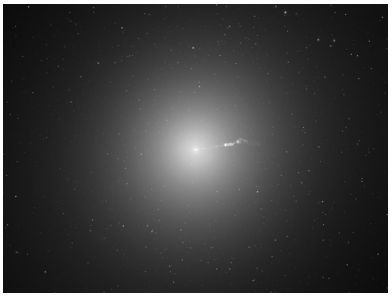
The Milky Way is made up of approximately 100 billion stars that have formed a large disk whose diameter is 100,000 light years — this means that light takes 100,000 years to go from one side of our galaxy to the other side. Our Solar System is about 25,000 light years away from the center of our galaxy — we live in the suburbs of our galaxy. Just as the Earth goes around the Sun, the Sun goes around the center of our galaxy. It takes 250 million years for our Sun and the solar system to go all the way around the center of the Milky Way. Remember that **light years are a measure of distance, not time**. A light year is the distance light travels in one year through space — about 10 trillion kilometers, or 6 trillion miles.

There are billions of other galaxies in the Universe. Only three galaxies outside our own Milky Way Galaxy can be seen without a telescope, and appear as fuzzy patches in the sky with the naked eye. The closest galaxies that we can see without a telescope are the Large and Small Magellanic Clouds. These satellite galaxies of the Milky Way can be seen from the southern hemisphere. Even they are about 160,000 light years from us, i.e., it takes light 160,000 years to get to us from those galaxies. The Andromeda Galaxy is a larger galaxy that can be seen from the northern hemisphere (with good eyesight and a very dark sky). It is about 2.5 million light years away from us, i.e., it takes light 2.5 *million* years to reach us from one of our "nearby" galaxies. The other galaxies are even further away from us and can only be seen through telescopes.

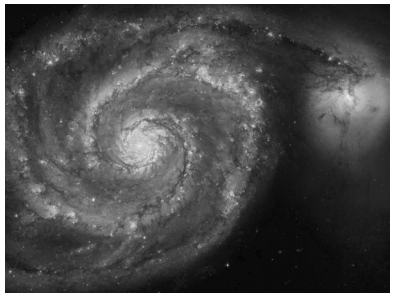
The smallest galaxies may contain only a few hundred thousand stars and be several thousand light years across, while the largest galaxies have trillions of stars and may be hundreds of thousands of light years across. Also, it is very rare to find stars in the space in between galaxies.

The color of a galaxy is determined partially by the color of the stars in it. Older stars are usually redder and younger stars are usually bluer. The presence of dust can also make a galaxy appear more red in color.

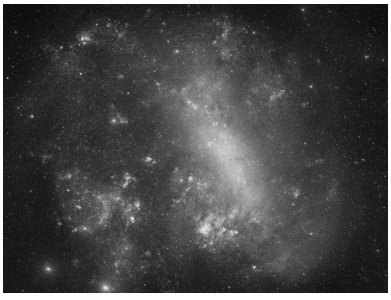
Galaxies are classified by shape. There are three general types: elliptical, spiral, and irregular. As their name suggests, elliptical galaxies are round or oval, with stars distributed fairly uniformly throughout. Spiral galaxies have disks that contain spiral arms, and a central "bulge." This bulge has a large concentration of stars, usually older stars. Our Milky Way Galaxy is a spiral galaxy. Irregular galaxies



Elliptical Galaxy



Spiral Galaxy



Irregular Galaxy

have no identifiable shape or structure to them. The different shapes and orientation of galaxies are a result of their history, which may have included interactions with other galaxies.

Galaxies sometimes collide with each other, with interesting results. These collisions can trigger bursts of star-formation in addition to changing the shapes of the galaxies that collide. However, when galaxy collisions occur, individual stars *do not* collide, due to the vast distances between them.

There are no pictures of the Milky Way Galaxy. The reason for this is that we are inside of it, and there is no way for us to go outside of it to take a picture. We sometimes compare other spiral galaxies to our galaxy, and people will sometimes get confused, but these are **not** images of our galaxy.

Session Overview

Students start by writing down their home address — or the address of the afterschool program location. They learn what a galaxy is and make a model of our Milky Way Galaxy. This model helps them visually understand how our Sun and the Earth fit into our galaxy. Then they write their full "Universal Address." The model also helps them understand that how things look depends on how they are oriented to our line of sight — galaxies we see "head-on" look different from galaxies we see from the side. Students learn that our galaxy is only one of billions of galaxies and that galaxies have different shapes.

Preparation

- Cut each styrofoam ball in half with a blunt cutting instrument, such as a sturdy metal ruler. You can smooth the halves by rubbing the cut edges together.
- If using cardboard or foam board, cut out the circles for the galaxy models.

Activity

(*Adapted from the activity "Make Your Own Milky Way Model" developed by Dr. Kumiko Usuda at the Subaru Telescope facility.*)

I. Introduction (10 minutes)

1. Give the students index cards, and ask them to write down and identify parts of their home address. Alternately, you can write out the address of your program location on the blackboard/whiteboard/flip chart. Emphasize that typical parts include house number (or an apartment number), street, city, state. Now ask what we would need to add if we had to send things to other countries? (We would have to add the name of the country.) If we had to send something to other planets, what would we add? (Name of the planet.) Now tell them that we will study our full address in the Universe.

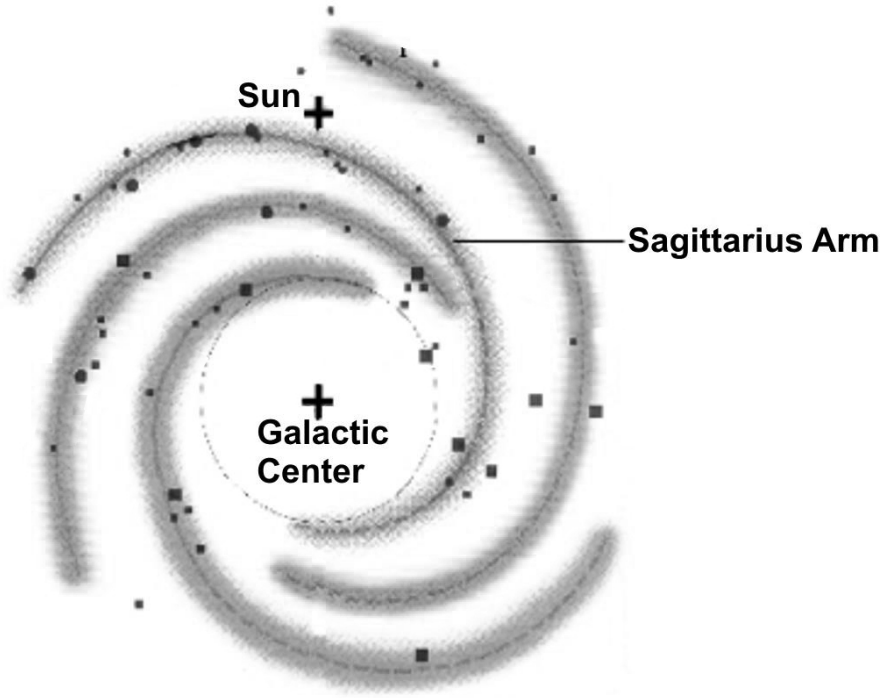
2. Ask students if they know what a galaxy is. Have they heard of the Milky Way? Do they know what it is? Lead a discussion about galaxies and our Milky Way Galaxy. Tell them

that we will now make a model of our Milky Way Galaxy. For this activity, students can work individually or in pairs.

II. Make Your Own Galaxies Activity (25 minutes)

1. Distribute one paper plate (or other circular board), the diagram of the arms of the Milky Way (to use as a model), stickers, color pencils/markers, styrofoam ball halves, toothpick, glue, and a ruler to each student or pair of students.

   It is worth noting that this diagram of the arms of the Milky Way is highly simplified. The point is to understand that our solar system is a small part of something much larger, which has a definite structure, not to understand all of the details of the structure of the Milky Way. If you want to know more, there are a number of more detailed diagrams on the internet.



The Milky Way Galaxy with its arms, showing the location of the Sun.

2. The 12″ circular board represents the full width of our Milky Way Galaxy.

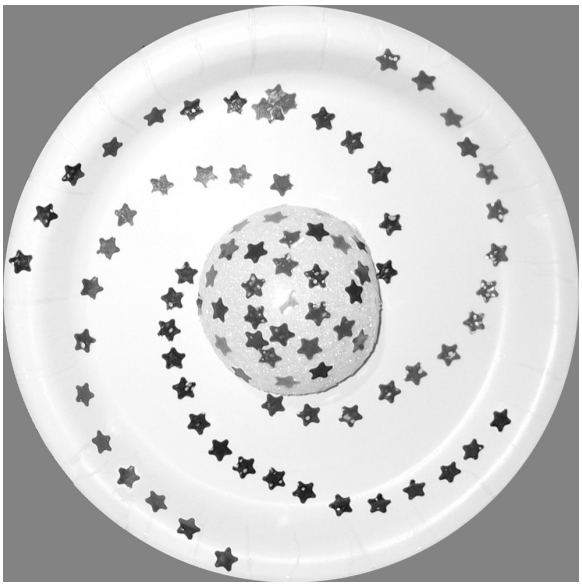
3. Paint your Styrofoam ball yellow or red (to look like the actual bulge of the galaxy).

4. Poke 1–2 toothpicks through the very center of the circular board. Now place one half of the ball on the board on each side of the center so that the toothpicks hold them in place. This is the central bulge of our galaxy.

5. The stars, dust and gases in the galaxy are not distributed evenly, but are in spiral bands or "arms." Using the image as a model, draw each of the four bands using colored pencils or markers, making sure that they show well on the board.

6. Now place the star and gas cloud stickers along the arms as close as possible to where dots are seen on the drawing.

7. Notice where the Sun is in the diagram — it is in the arm labeled "Sagittarius Arm" and is marked with a "+" sign. This is the location of our Sun and of our Solar System (it corresponds to 25,000 light years from the center of our galaxy). Place a sticker here to mark the location of the Sun. This can be a different color to show where our Sun is in our galaxy.



A sample Milky Way Galaxy model.

NOTE: If you look on the internet at other diagrams of our Milky Way Galaxy, you will frequently see our solar system listed as being on the Local or Orion Spur, which is a smaller spur or arm coming off of the Sagittarius Arm. We have chosen not to go into this level of detail here, but we do want to note it in case you or your students do extra reading and become confused.

8. This is your model of our Milky Way Galaxy!

III. Discussion (15-20 minutes)

1. While looking at this model, lead a discussion of where the Sun is in the Milky Way. Explain that galaxies are similar to "cities of stars." The Washington, DC metropolitan area (or pick the city that your students might be most familiar with) has more than 5 million (change this number as appropriate for the city you are using as an example) people living in it. Some are organized in groups of 2, 3, or more (families — much like groups of stars). Some are single individuals. Similarly, galaxies are made of huge numbers of stars. Cities have very busy places, and other places where fewer people live that are relatively quiet. Similarly, galaxies have "busy" and crowded places, usually (but not always) at their centers. You can describe our neighborhood of the Milky Way as relatively quiet. Our Sun and the solar system are in the suburbs of our Milky Way Galaxy!

2. Lead a (brief) discussion to get across some sense of distances in the galaxy. Space is so big that we discuss distances in terms of how many years it takes light to reach from one point to another. The speed of light is extremely fast! It is 300,000 km/sec (186,000 miles/sec). It can travel 7 times around the Earth in 1 second. The distance it can travel in a year, which is about 9.6 *trillion* kilometers (6 *trillion* miles), is known as a light year. Remember that a light year is defined as the *distance* light travels in one year. Sometimes the term light year sounds more like a measure of time. If you would like to draw an analogy for your students, you can have one kid walk for a second and measure that distance. The distance he or she covers in a second can be called a "kid-second." You can draw any other parallel analogy that makes sense.

   Even though light travels very fast, it takes light a fixed amount of time to reach us from its source because space is so vast. Remind students that you discussed this concept in Session 3. Here are some examples of light travel time:

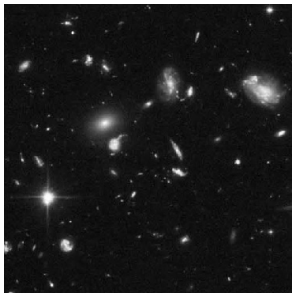
   - Moon to Earth: 1.3 seconds
   - Sun to Earth: 8 minutes
   - Mars to Earth: 12 minutes
   - Pluto to Earth: 5.5 hours
   - Nearest star to the Sun: 4.3 years

   As we go farther away from our Solar System, the distances in space become even larger. The distances within our galaxy are large and the distances between galaxies are even larger!

   - Center of the Milky Way from our Sun and the Solar System: 25,000 years
   - From one end of our galaxy to the opposite end: 100,000 years
   - Our galaxy to the "Magellanic Clouds" (our "satellite" galaxies):
     - Large Magellanic Cloud — 160,000 years
     - Small Magellanic Cloud — 200,000 years
   - Milky Way Galaxy to the Andromeda Galaxy, the nearest large galaxy from us: 2.5 million years

   Also, remind students of the Session 2 activity with the cards when they categorized objects by their distance to us. What was the closest? Farthest?

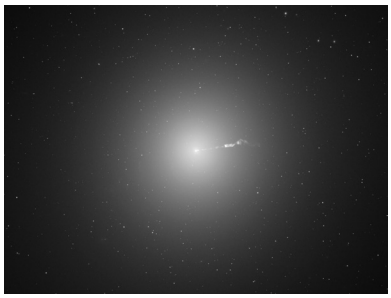
3. Show the Hubble Ultra Deep Field image. Explain that this is only a tiny portion of the sky (less than 1/100 of the area of the full moon). How many galaxies do they think there are in the Universe? There are **hundreds of billions of galaxies** in the Universe. Remind students that because galaxies are so far away, any images of galaxies they see represent the galaxies as they were a very long time ago — "looking out is looking back" (from Session 3).



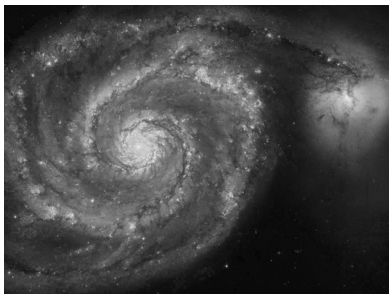
Small portion of the Hubble Ultra Deep Field image.

4. Show the images of the different types of galaxies (the picture titled "Types of Galaxies"). Ask students to examine the images and convince themselves that some have arms, some are round and some have no consistent shape at all.

There are sub-divisions within these categories, but all galaxies fall into these three types. By far most galaxies are either elliptical or spiral. Many studies say that 60–70% of all galaxies are elliptical, with the majority of the remaining ones being spiral.



Round or oval galaxies are called ***elliptical galaxies****.*

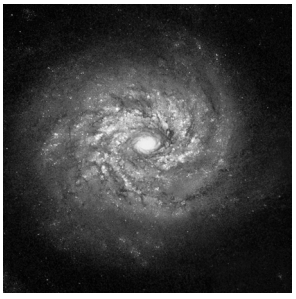


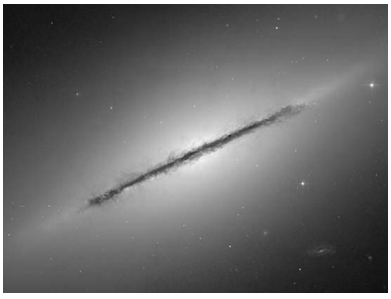
Those showing a pinwheel structure are ***spiral galaxies****. They have two or more arms winding out from a central disk*

An ***irregular galaxy*** *is one with no definite structure*

5. Ask students to hold their Milky Way model and figure out what type of galaxy it is. (Our Milky Way is a spiral galaxy.) Now have them hold their model at different angles and see if it looks the same. (It won't — the angle matters a great deal.)

6. Use the picture of the 5 different spiral galaxies to show the individual variation that can exist. Ask students why the images appear so different. Help students see that differences are mainly due to the angle or perspective from which we see these galaxies.





Three different spiral galaxies each with a different angles of viewing.

7. Ask students what they would add to their mailing address to represent their "address in the Universe". At this point, they should add the planet ("Planet Earth"), star system ("Solar System"), location in our galaxy ("Sagittarius Arm"), galaxy ("Milky Way Galaxy") and finally, "Universe"! If you would like to make this another postcard activity, that is also possible. The United States Postal Service will correctly deliver items with this lengthy address!

Suggestions for Running this Session

- If you want to, you can put a stamp on the postcards addressed with the full galactic address and put them in the mail. We've sent out a number of these postcards, and the postal service seems to be able to deal with all of the extra address elements (though they probably think we're a little weird)! It gives students a kick to receive a card at their "real" address.

Misconceptions

- In some students' minds, there is no significant difference between a solar system, a galaxy, and the universe. We hope that the sessions prior to this one will have discouraged this belief, but it can be a lasting one! We've designed this session to specifically address the hierarchy of these objects - that a solar system contains planets going around a star, a galaxy contains many stars (and therefore many solar systems), and the universe contains many galaxies.

- When we look at astronomical images, we often see a mixture of stars and galaxies in the same image. This can be confusing - where are the stars, and where are the galaxies? In these images, the individual stars we're seeing are all within our own galaxy, the Milky Way. You can think of this as being like the foreground of a painting - the flowers in the field aren't in the forest in the background. Stars exist almost entirely within galaxies, and when you see a galaxy you're seeing a collection of billions of stars so dense and so distant that you can't resolve the individual stars within.

- We live in one galaxy, the Milky Way, and all of the other galaxies exist outside of our galaxy. They are like different cities of stars.

- Most students have seen images that purportedly depict the Milky Way Galaxy, such as the "you are here" posters and shirts. As we are unable to travel outside of the galaxy, there are no photographs of our galaxy from an outside perspective. The images depicting the Milky Way are either artist's renditions or an image of another spiral galaxy that looks similar to what we think the Milky Way should look like. The only images of the Milky Way that are real are ones taken from within our solar system, and therefore only seeing a piece of the galaxy (either the disc or the bulge).

- Space is so big that we discuss distances in terms of how many years it takes light to reach from one point to another. The speed of light is extremely fast! It is 300,000 km/sec (186,000 miles/sec). It can travel 7 times around the Earth in 1 second. The distance it can travel in a year, which is about 9.6 trillion kilometers (6 trillion miles), is known as a light year. Remember that the light year is is a measure of distance. Sometimes the term light year sounds more like a measure of time. If you would like to draw an analogy for your students, you can have one kid walk for a second and measure that distance. The distance s/he covers in a second can be called a "kid-second." You can draw any other parallel analogy that makes sense.

Useful websites for background or activity extension

- **"Amazing Space" from the Space Telescope Science Institute**
  Online games, pictures to download, and explanations about galaxy shapes — from the Hubble Space Telescope
  http://amazing-space.stsci.edu/capture/galaxies/

- **HubbleSite**
  Spectacular images of galaxies taken by the Hubble Space Telescope
  http://hubblesite.org/gallery/album/galaxy/

- **Visualizing large numbers**
  Make sense of the huge numbers used in astronomy with examples from everyday life
  http://kokogiak.com/megapenny/

- **Cosmic Distance Scale**
  Gives a feeling for how immense our Universe is, starting with an image of the Earth and then zooming out to the furthest visible reaches of our Universe — as in the "powers of 10" films.
  http://heasarc.gsfc.nasa.gov/docs/cosmic/

- **Galaxy collisions and mergers**

  – Images of colliding galaxies (the "Antennae Galaxies" and "The Mice")
    http://hubblesite.org/gallery/album/entire/pr1997034d/
    http://hubblesite.org/gallery/album/entire/pr2002011h/

  – Animation of colliding galaxies
    http://chandra.harvard.edu/photo/2004/antennae/animations.html

- **Galaxy Zoo**
  Help astronomers catalog new galaxies
  http://www.galaxyzoo.org/

- **Make Your Own Milky Way Galaxy Model**
  http://www.naoj.org/staff/kumiko/MilkyWay/milkyway.html