Module 5: To the Galaxies and Beyond!

Lesson 1: The Hubble Classification of Galaxies

Overview

We give an overview of the many different shapes and sizes that galaxies have, starting with the broad categories of spiral, barred spiral, elliptical, and irregular, and relating each kind to terrestrial objects. Given prototypical shapes of these categories, students will then categorize shapes of real galaxies.

Learning Outcomes

• Explain what the Hubble Tuning Fork for classifying galaxies is and how astronomers classify galaxies.
• Briefly describe the main characteristics of the 3 main types of galaxies as well as irregular galaxies.
• List the types of stars found in each type of galaxy, whether star formation is happening, and if there is abundant gas and dust present.
• Classify shapes of galaxies and identify the difficulties in classifying strictly by how galaxies look.

Materials

Pieces of stiff paper or light card board cut into the shapes of various different types of galaxies. Keep the shapes basic; the goal is for students to categorize the galaxies by the basic groups of elliptical spiral, barred spiral, and irregular without consideration of sub-types.

Figure 5.1.1 Examples http://spaceplace.nasa.gov/galactic-mobile/). Make a Galactic Mobile available at this website includes galaxy patterns covering all classifications and ideas for making a galaxy mobile.
Pre-assessment Questions and Discussion

Q. What type of galaxy is the Milky Way?  
A. The Milky way is a barred spiral galaxy

Q. Do all Galaxies look the same? If not what can they look like?  
A. No, there are spiral galaxies, elliptical galaxies and lenticular galaxies. The look like our galaxy, footballs and basket balls.

Q. How do you think astronomers might classify different galaxies?  
A. By their different shapes; location; number of stars; colors; ages.

Text

Galaxies come in many different shapes and sizes, not just barred spirals like our Milky Way galaxy. Astronomers find it useful to divide galaxies into groups based on how they look in visible light, much like one would see if looking through a telescope. The Hubble sequence is a way of classifying galaxies that was invented by Edwin Hubble in 1936. It is often referred to as the "Hubble tuning-fork" because the different galaxies are laid out in a shape much like a tuning-fork. The galaxies are classified based on their shapes. We are going to consider elliptical galaxies, spiral galaxies, barred spiral galaxies, and irregular galaxies in this lesson. As you might guess, an irregular galaxy is one that doesn’t fit anywhere else in the classification.

Elliptical galaxies have shapes that resemble basketballs or footballs. Unlike spiral galaxies that we learned about during our Milky Way lesson, ellipticals do not have spiral arms. They are basically made up of one gigantic bulge. They are represented by the letter E and a number representing how round or flattened they look. For example, an elliptical galaxy that was perfectly round like a basketball would be called E0, while the one that looked like a football that had been badly squished would be called E7. Elliptical galaxies tend to made up of only very old stars and have far less dust and gas than spirals. There are exceptions to these rules, as it appears some ellipticals are the result of the mergers of one or more spiral galaxies.

Spiral galaxies have a flattened disk with two or more arms spiralling out from it, and a bulge in the center. Spiral galaxies are broken up into two types, those having a bar-like structure as part of their bulge and those that do not. The ones with the bar-like structure are referred to as barred spirals and are given the capital letters SB. The ones without a bar get just the letter S. Both of the classifications are divided into even more groups, depending on how tightly the spiral arms are wrapped up and how large the central bulge is. Of the three types of galaxies, spirals have the most dust and gas, and also are still forming new stars. Our Milky Way is a barred spiral galaxy and is classified as an SB galaxy.

Irregular galaxies come in all shapes and sizes, and usually look distorted and basically like something crazy has happened or is happening to them. Usually these galaxies are undergoing active star formation and can contain lots of dust. Astronomers observe irregular galaxies that have long wispy tails, look like 2 big eyes, have rings of stars around them, have a "path" of gas going to a nearby galaxy, just about anything imaginable. Observations have led astronomers to guess that these irregular galaxies have had close encounters with other galaxies.

The Hubble tuning-fork is represented with the elliptical galaxies, on the left and the barred and unbarred spirals forming the two parallel prongs of the fork. Irregular galaxies do not get included under this classification, as they just do not seem to fit anywhere in it.

Follow-Up Questions on the Reading

1. How do astronomers divide up the different types of galaxies?
2. Briefly describe each type of galaxy.
3. Which types of galaxies have the youngest stars, as well as abundant gas and dust?
4. Which type of galaxy has mainly very old stars, no new star formation, and little if any gas and dust?
Reinforcing Activity

Students are given containers with small cardboard cut-outs of different 2-D representations of galaxies and label them by using the Hubble tuning-fork classifications. During the activity, one will be able to point out how hard it is to classify a galaxy if you do not have a good face-on image of it.

Students discuss which galaxies they had the hardest time classifying and why. Discuss what is learned by classifying objects, and why humans seem to do this for lots of things.

Summary and Post-Assessment

Discuss with students what they learned.

Have them list at least 3 things they didn't know before doing this study.

Ask, “If you could choose to be a galaxy, what kind of a galaxy would you be and why?”

Do you think that these classifications would work for galaxies extremely far away, such as in the Hubble Deep Field.

Relevant Information and Links


Lesson 2: Universal Scales and Hubble Ultra-Deep Field

Overview
Students get a feel for size and distance of things in the universe, starting from Earth to the Solar system, galaxy, local group, super cluster to the edge of the observable universe. Students also explore the “Hubble Ultra Deep Field” simulated by covered square foam boards of integer ratios, and estimate the number of “galaxies” in the largest board by counting and scaling.

Learning Outcomes
• Define light year and the astronomical unit.
• Relate distances to galaxies to the time it would take to get there.
• Translate the amount of time needed to get to a place to the number of steps it would take at a set speed.
• Rank celestial objects by distances away from us.
• Estimate the number of observable galaxies in the Universe by scaling from smaller sections.

Materials
• foam boards sized to ratios 12:4:1
• and wrapped with beaded cloth (fabric stores)
• star shaped tacks (found at arts and crafts stores)

Figure 5.2.1. These cloth-covered boards represent sections of the celestial sphere imaged by the Hubble Space Telescope for the Deep Field image. The raised beads that are part of the cloth represent galaxies. Students can count the number of beads in each square, round-off or average based upon what other students count, and then extrapolate that count to larger and larger areas.

Pre-Assessment Questions and Discussion
Q. If you had a space ship that could travel at the speed of light, how long do you thing it would take you to leave the solar system? How about the Galaxy? A. Leaving the solar system would take about 1 light year; leaving the Galaxy via the shortest route would take about 1000 light years.

Q. How far away do you think the nearest galaxy is from the Milky Way? A. The nearest galaxy to the Milky Way is the dwarf galaxy Canis Major. It is located about 25,000 light-years away.

Q. If there were an alien race in the Andromeda galaxy that built a space ship that somehow managed to travel twice the speed of light, but only had enough fuel to last for a million years of travel, would they be able to visit us? A. Leave the question unanswered until end of exercise, this is more about seeing their idea of distances between galaxies.
Trying to understand the scale of distances and sizes in the universe is really hard. Things are just so big and far away that we really need new words to describe them. However, we are going to try to get a feel for things by using our imagination to take a little trip out to the edge of the Observable Universe.

We have learned earlier that the average distance from the Sun to the Earth is given by astronomers as 1 AU (astronomical unit). This is roughly 93,000,000 miles (150,000,000 km), which is equal to traveling around the Earth about 25,000 times. The distance from the Earth to the edge of our Solar System is about 50,000 AU, or about 1 light year (10 trillion km). Even traveling at the speed of light, it would take us a whole year to get to the edge.

Our solar system and sun are part of the immediate galactic neighborhood known as the Local Interstellar Cloud or Local Fluff. You can picture it as your house being the solar system and the Local Fluff being your neighborhood. So far it has taken you a year just to cross through the front door. The Local Fluff is 300 light years across. Imagine you could break the laws of physics and travel a light year in 1 day. It would still take almost an entire year just to leave your neighborhood. In case you are wondering, the closest star, actually a triple star system, is about 4.5 light years away.

If you were going to head to the center of the Milky Way galaxy is would take between 25,000 and 28,000 years; the exact distance to the very center of the Galaxy is not accurately known. If you were going to shrink the Milky Way to 10 meters in diameter (about 33 feet), the Solar System would be no more than 0.1 mm (0.004 inches) in width, or about half the width of one of the hairs on your head. Lucky for us the solar system is close to the edge of the galaxy so it will only take us about 25,000 years to reach our nearest neighbor, the Canis Major Dwarf galaxy. Since we do not have all day to consider this, we might as well speed up our spaceship so we are traveling at a speed of one light year per second. In this way, it will take us about 7 hours reach the dwarf galaxy, and we could be there in time for a late dinner. The nearest spiral galaxy is the Andromeda galaxy, which is about 2,500,000 light years away, or traveling at our current speed about 9.5 months away.

Follow-Up Questions on the Reading
1. What is meant by a light year?
2. Which object would take the longest to get to: the Andromeda galaxy or the Canis Major Dwarf galaxy?
3. If you took 1 step every second, and each second was equivalent to 1 light year, how many steps would it take, on land obviously, to reach the object representing the nearest star? How about the center of the Milky Way?
4. Why is the distance known as the astronomical unit important?
5. Of the objects mentioned here – dwarf galaxy, nearest star, edge of the solar system, Andromeda galaxy – rank them from nearest in distance away to farthest.

Answer to the question about the aliens from the Andromeda galaxy: Since the Andromeda galaxy is about 2.5 million light years away and the aliens have only enough energy for a million years, they wouldn’t quite make it to Earth. They would have to travel 2.5 times the speed of light, but then they would be out of fuel, and would crash onto the Earth’s surface.

Reinforcing Activity - The Hubble Ultra-Deep Field
The goal of this activity is to give students more of an understanding of the scale of the the Hubble ultra-deep field and how many galaxies are found within it, and thereby the number of galaxies in the sky that we have the ability to detect with our most powerful telescopes.

Read aloud: The Hubble Deep Field is an image taken by the Hubble telescope in 1995 of a small region of sky in the constellation of Ursa Major. In this image it mapped 3,000 galaxies. More recently,
over a period from September 24, 2003 through to January 16, 2004, the Hubble telescope took an even
deep image of the sky, this time a small region of space in the southern constellation of Fornax, which
is just below the constellation Orion. The image they took covered an area about the size of the head of a
pin held at arm's length. Because this time the Hubble space telescope observed galaxies farther away
than it observed in the deep field, astronomers call it the “ultra-deep field,” meaning “extra” far away.
The galaxies that are the farthest in this image are believed to be around 12 billion light years away.

For this activity you are going to first estimate the number of galaxies on a small square. This square
represents just a small portion of the Hubble ultra-deep field. The galaxies are represented by the small
beads on the material. Though the image was taken in a part of the sky that had very few stars, you will
also be able to feel what astronomers call “foreground” stars, meaning those stars that are located in our
galaxy. These are represented by star shaped tacks and are larger than the beads representing the galaxies
because they look brighter.

How many galaxies do you count in the smallest square? Please make an estimate on the number of
galaxies. What would your number round off to? How many galaxies did your fellow classmates count?
Approximately 20 galaxies per square?

When you are given a middle-sized section of the ultra-deep field, use your small square to help you
estimate how many galaxies you could find on the new board. Do this by estimating how many of the
smaller squares fit onto the larger square. Based on your answer, how many galaxies do you estimate
there are on the larger or middle-sized board?

Please estimate and then round off your number. Did you get about 240 galaxies? Did you figure out that
the larger board is cut so that 3 by 4 of the smaller squares, or 12, will fit inside it? Remember, this
represents but a small part of the Hubble ultra-deep field.

When you are given the biggest board, please use the middle-sized board and your estimate for the
number of galaxies there (240) to estimate the number of galaxies on the biggest board. To do this, you
need to estimate how many of the middle-sized board fits into the larger board. What is your answer for
this? What is your estimate for the total number of galaxies on the largest board?

Did you find that the middle-sized board should fit 4 times in the largest board, for an overall estimate of
around 1,000 galaxies?

**Read aloud:** One thousand galaxies seems like a lot of galaxies; however, if we represented the Hubble
ultra-deep field by yet another board, this fourth board would be ten times bigger than the largest board
we worked with. How many galaxies are in the Hubble Ultra-deep field?

Answer: around 10,000.

Recall that the Hubble Ultra-deep field looks at only a very tiny portion of the sky. It would take a very
long time to take similar deep images over the entire sky.

Anyone want to guess how many galaxies are in the whole sky? To do this, we’d have to figure out how
many of the largest boards it would take to represent that!

**Summary and Post-Assessment**

Does anyone now want to count the number of galaxies represented on the largest board that we used?
Of what use, then, is our estimating the number of galaxies over larger and larger areas if we don't get
exactly the correct number?

Have students discuss what they now think of how big known the Universe is compared to how they
pictured it before. What would it be like to travel faster than the speed of light if it were possible? What
do astronomers mean when they talk about taking a "deep image"?
Relevant Resources and Links

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