Module 4: Milky Way Galaxy and Dark Matter

Lesson 1: The Milky Way

Overview

Since there is no corresponding extensive content in Touch the Stars book, we give here an overview of what kind of galaxy the Milky Way is, its regions, its contents, and our location in it. Students will investigate the structure of the Galaxy and then categorize objects as in the disk, bulge, or halo by putting various representative objects into their correct plate, box, or bowl.

Learning Outcomes

• Name the three main regions of the Milky Way and their locations relative to each other.
• List various objects that are located in each of these regions.
• Identify where the Earth is located in Milky Way.
• Describe the general shape of the Milky Way and state its galaxy type.

Materials

• Paper plates, small boxes, and bowls to represent the disk, bulge and halo
• A variety of objects, easily distinguishable by touch, to represent objects found in the Galaxy.
• Foam galaxy models (shaped using a hot-tip foam cutter)

Pre-assessment Questions and Discussion

Q. What is the Milky Way and what does it look like?
   A. The Milky way is the galaxy in which we live, it is a spiral galaxy.

Q. What type of things is the Milky Way made of?
   A. Stars, gas, dust, and dark matter.

Q. Where in the Milky Way is the Earth located?
   A. The earth is located close to the edge in one of the arms, within the Orion spiral arm.

Text

The Milky Way is the galaxy in which the Solar System is located. The Galaxy is around 13 billion years old, which is just a little less than the age of the Universe. The Milky Way is just one of billions of galaxies that astronomers observe. We didn't always know this. Up until the 1920's, astronomers thought that the Milky Way was the entire universe. We have learned that the Galaxy is a barred spiral galaxy, which means it looks a lot like a pinwheel with a bar at the center and several spiral arms coming out of it (a bit like bent spokes of a bike wheel). Our Sun is located about two-thirds of the way out from the center of the Galaxy on what is known as the Orion spiral arm. The Sun takes over 220 million years just to make one loop around the center of the Galaxy, and this is traveling at the incredibly fast speed of 800,000 kilometers per hour.
The Milky Way is made up of hundreds of billions of stars, along with dust, gas, dark matter, and even a really massive black hole at its center. The Milky Way, like most spiral galaxies, can be separated into different regions: the halo, bulge and disk. Each of these regions is slightly different from the other two in where it is located, the kinds of objects it contains, and its shape.

• **Halo:** The halo surrounds the galaxy. It is made up of dark matter and also very large clusters, or groups, of extremely old stars called globular clusters. There is no dust or free gas in the halo (just the gas making up the old stars). Dark matter, though found throughout the Galaxy, has the strongest influence in the halo. This is because there are far fewer stars there than in the disk or the bulge, so the dark matter makes up more of the mass. Dark matter is matter that we can't detect even with telescopes and don't really know what it is; however, we can infer that it exists by measuring its gravitational effects on things we can observe. Evidence indicates that dark matter may be shaped like a huge football completely surrounding the Milky Way.

• **Disk:** The disk is flat and thin with a bulge at its center, shaped a lot like a pancake but with a fried egg on top. It contains the spiral arms, and probably looks like a many-armed starfish. Since we are inside the Galaxy, it is hard to determine exactly how many arms the Milky Way has. Astronomers used to think the disk had just four arms, but now viewing the galaxy using infrared telescopes, astronomers think that it is made of two major arms, named Scutum-Centaurus and Perseus that wrap around a dense, bar shaped core of stars. There are also two less dense arms that are located between the two large ones; these are named Sagittarius and Norma. Recently a third less dense arm has been discovered via a radio telescope. This arm is named the "Far-3-Kiloparsec Arm" and is smaller than the two main ones.

• **Bulge:** The central or galactic bulge is located in the center of the Galaxy, picture a fried egg with its yolk in the middle, or a CD with half a golf ball in the middle. The bulge contains the bar of the Galaxy. The stars in the bulge are generally a lot older than the stars in the disk. Most of the youngest stars and most of the free gas are found in the smaller arms. Star formation occurs in the arms, and it is in these arms that we find what are known as open clusters made up of fairly young stars. Massive stars, and everything associated with their lives, are found in the disk. Our own star, the Sun, is located between the two main arms and is around 4.5 billion years old, which is about one-third the age of the Milky Way. It takes the Sun about 230 million years to go once around the galaxy’s center.

Follow-up Questions on Reading

1. What are the three main regions of the Milky Way and where are they located?
2. List some of the objects found in each of the main regions of the Galaxy: disk, bulge, halo.
3. What type of galaxy is the Milky Way and what does it look like?
4. Where is the Earth located?
5. How long does it take the Sun to travel all the way around the center of the Milky Way?
Reinforcing Hands-On Activity

Make a Milky Way galaxy using a large paper plate for the disk, a bowl for the halo, and a small box that is small enough to place in the middle of the paper plate to represent the bulge. Read off all or some of the Milky Way objects given in the table below, and have students separate the representative objects into the plate, bowl, or box. Sometimes objects are located in 2 or even all 3 regions.

Where in the Galaxy would you find:

<table>
<thead>
<tr>
<th>Representative object suggestions</th>
<th>Milky Way Object</th>
<th>Disk</th>
<th>Halo</th>
<th>Bulge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food</td>
<td>Non-food</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cotton candy</td>
<td>Cotton balls</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blackberry</td>
<td>Ping pong ball</td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Gummy worms</td>
<td>Short ropes</td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Cotton candy</td>
<td>Cotton balls</td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Stick of gum</td>
<td>Erasure</td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Extra dark chocolate</td>
<td>Silky scarf overlaid</td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>M &amp; Ms</td>
<td>Small beads</td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Macadamia nut (high energy density)</td>
<td>Heavy ball bearing</td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Donut holes</td>
<td>Large foam ball</td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Life Savers</td>
<td>Plastic bracelets</td>
<td></td>
<td>x</td>
<td>x</td>
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</tbody>
</table>

Summary and Post-Assessment Questions

1. Discuss your view of the Milky Way galaxy now that you have gone through this lesson. What did you know before, and what did you learn that impressed you the most?

2. Compare your thoughts with those of another classmate. What differences did you find? What similarities?

3. With the model of either the spiral or barred spiral galaxy, point out the bulge and the disk. Use a motion to indicate the location of the halo.

4. Think of a way to picture just how large the Milky Way galaxy is and the various objects that it contains. Share it with the group.

5. What would it be like if the Solar System were located in the bulge? How about in the halo?

Relevant Information and Links

Figure 4.1.2: Natalie and Sarah prepare the objects to be used in describing the kinds of objects found in each part of the Milky Way galaxy.

Figure 4.1.3: Abby and Nicole work with the “disk” part of the Galaxy to identify the various celestial objects that are located there.
Lesson 2: Dark Matter

Overview

The detection of something in the Universe that is totally invisible at all wavelengths of light is demonstrated through the detection of magnets hidden between two smooth foam boards. This we call dark matter. Students will explore invisible "detection" after reading a segment about dark matter and our current understanding of its nature based on objects that dark matter is affecting through its gravitational force.

Learning Outcomes

• Describe why it is called “dark matter.”
• Explain what observational evidence there is for its existence.
• List those objects we know dark matter is not.
• Summarize what WIMPs are and how we expect to someday detect these subatomic particles.

Materials

• "Dark matter detection board":
• Two foam rectangular boards, tape, several smaller magnets, and a stronger magnet.
• The smaller magnets are taped between the boards.

Figure 4.2.1. The dark matter detection board consists of two rectangles of foam board (about 12 x 14 inches) with 2 - 3 flat magnets sandwiched in between. The foam boards are then taped together. Magnets such as the one shown at the left, can then be moved over the foam board to "detect" dark matter.

Pre-assessment Questions and Discussion

Q. How would you go about finding something that appeared to be totally invisible here on Earth?
   A. See if it bumps into something. See if it leaves footprints. Similar answers.

Q. Have you heard of "dark matter" before?
   A. Encourage all answers.

Q. What do you think dark matter might be?
   A. Lots of soccer balls? Huge number of black holes? A gazillion Jupiter-like planets?

Text

You may have heard of the mysterious term "dark matter" before. Similar to black holes, dark matter does not emit light. However, unlike black holes, dark matter does not absorb light either. Instead, dark matter lets light pass right through it, so it is impossible to take pictures of it.
You might wonder how we know dark matter really exists if we can't take a picture of it. The reason we know it exists is that we can measure its influence on normal matter in space. Recall gravity is a force that exists between any two objects with mass. Because dark matter has mass it exerts a discernible gravitational force on the objects that surround it.

Dark matter was first proposed by Fritz Zwicky in 1934 to explain why galaxies seemed to move much more quickly around each other than predicted. He suggested that if there were unseen matter tugging on these galaxies, it would cause them to orbit one another at a faster pace. In the mid-1970s, astrophysicist Vera Rubin showed that objects located at the outer limits of spiral galaxies also revolve far too quickly to be explained by just the stars, gas, and dust present in the galaxy alone. In other words, if there were not something with mass that was gravitationally holding on to the galactic material, the stars, gas, dust, and other material would be flying out away from the galaxies.

Today we understand that most of the matter in the Universe must be this unseen matter; in fact, only 5% of matter in the Universe is the normal matter that we are made of and another 23% is what we refer to as dark matter. There is thought to be something else in the Universe that makes up the remaining 72%, dark energy. We will have to leave our lessons about dark energy for the future as scientists are still trying to figure out what it is.

Originally, scientists thought that dark matter was just normal matter that was hard to photograph; dark stars and dark planets were proposed as potential candidates for dark matter. However, the results of astronomical surveys like the Optical Gravitational Lensing Experiment or OGLE survey in Poland have convinced scientists that there are not enough dark stars or planets in the Universe to cause the gravitational effects they have measured.

Most scientists think that dark matter is something much more bizarre than normal matter. It is likely a special type of exotic sub-atomic particle that we refer to as a WIMP. WIMP stands for Weakly Interacting Massive Particle. While an individual WIMP likely has a lot more mass than a neutrino or an electron, it is likely to be extremely small. To have such an effect on other objects, there must be a whole lot of them together in space. Dark matter exists everywhere in our galaxy, from the central bulge to well beyond the edge of the disk.

Experimental physicists are currently trying to create and detect WIMPs in the lab. The investigation of dark matter is a very active area of research in both astronomy and physics.

Follow-up Questions on the Reading
1. Why do scientists call dark matter "dark"? (Be specific.)
2. What kind of force does dark matter have on other objects?
3. If we cannot actually see dark matter, how do we know it exists?
4. What observations have provided evidence that dark matter is present in spiral galaxies?
5. What kinds of objects have scientists eliminated as possible candidates for dark matter?
6. What are these things called WIMPs?

Reinforcing Hands-On Activity
We will now do a demonstration to show how this works. Much like holding two magnets near each other exerts an electromagnetic tug between them, dark matter tugs on stars and gas in galaxies through the force of gravity. While we can't see the dark matter, we are reasonably sure it exists because of how the stars and gas move as a result of its gravitational influence. Imagine you were being twirled around very fast in a circle, so fast that if your partner let go, you'd go flying away. But, as long as your hands are joined, you stay together no matter how fast you are going. Stars and gas at the very edge of the Milky Way we see, are moving way too fast to stay attached to it. Something we cannot see is exerting a gravitational force on them, a force so strong that the stars and gas do not fly away.
Dark detection board exploration:

• Have students place the flat foam board on their lap.
• Ask them to glide their hands along the top of the board to establish that they can see nothing unusual about the surface. Is it perfectly smooth?
• Give them a magnet and ask them to slowly glide it over the foam board surface.

Ask the following questions:

1. Is it easy to glide the magnet over the board?
2. Are there regions of the board that the magnet wants to be in more than others?
3. Why might the magnet want to be one region more than another?
4. Do you know for sure that there are magnets underneath the board?
5. Is it likely there magnets underneath the board?

Summary and Post-Assessment

• Why is it called “dark matter.”

2. Discuss how the magnet-board or "Dark-Matter Detection Board" relates to the real dark matter and how scientists detect it even though it is invisible. Is the detection board a good analogy for the observational evidence astronomers rely upon?

3. Explain everything you know about dark matter to someone who has never heard about it.

4. List those objects we know dark matter is not.

5. What do we think those WIMPs are? How we expect to someday detect them?

Relevant Information and Links

• Dark Energy, Dark Matter — [http://science.nasa.gov/astrophysics/focus-areas/what-is-dark-energy/](http://science.nasa.gov/astrophysics/focus-areas/what-is-dark-energy/)


• What is Dark Matter? A Mystery of the Universe — [https://youtu.be/XCwWxrx1SIU](https://youtu.be/XCwWxrx1SIU)
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