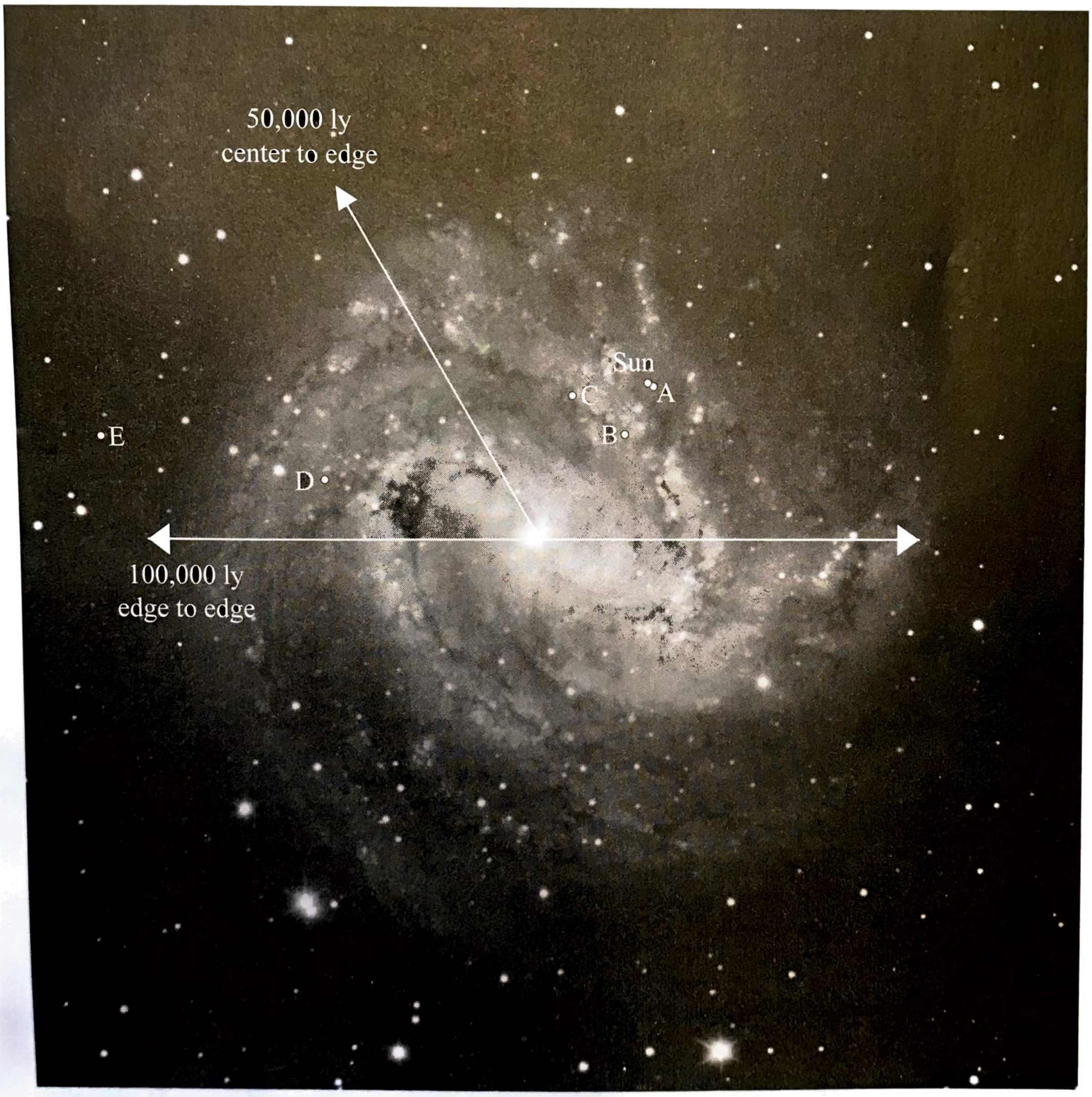
This tutorial will give you a better understanding of the size of the Milky Way Galaxy by investigating the distances and sizes of objects within the Milky Way Galaxy and outside the Milky Way Galaxy elsewhere in the universe. Because we are located within the Milky Way, we are unable to take a picture of our entire galaxy from the outside. Below is a picture of a spiral galaxy similar to the Milky Way. Let's assume that this picture represents our Milky Way Galaxy and has the dimensions labeled below. **Note that in this picture, 1 centimeter (cm) represents 10,000 light-years (ly); equivalently, you can use 1 millimeter (mm) to represent 1,000 light-years (ly).**



1) The Sun's position in the Milky Way is shown in the picture above. What is the approximate distance from the Sun to the center of the Milky Way? Recall that 1 cm represents 10,000 ly.

2) The table below lists five bright stars in the night sky. Write the letter of the dot (A–E) from the picture on the previous page that best represents the location of each star. You can use letters more than once. Recall that 1 mm represents 1,000 ly.

Star	Distance from Sun (in light-years)	Letter
Sirius	9	
Vega	26	
Spica	260	
Rigel	810	
Deneb	1,400	

3) We normally consider Deneb to be a bright but distant star at 1,400 ly away from the Sun. Compared to the size of our Milky Way Galaxy, is Deneb truly distant? Explain your reasoning.

4) Are the stars from Question 2 inside or outside the Milky Way Galaxy? Explain your reasoning.

5) The table below lists three Messier objects and their distances from the Sun. Write the letter of the dot (A–E) from the picture on the previous page that best represents the location of each object. You can use letters more than once.

Messier Object	Distance from Sun (in light-years)	Letter
M45 Open Cluster (Pleiades)	380	
M1 (Crab Nebula)	6,300	
M71 Globular Cluster	12,700	

6) Are these Messier objects part of the Milky Way Galaxy? Explain your reasoning.

7) The Crab Nebula has a width of about 11 light-years. If you wanted to accurately draw the Crab Nebula on your diagram, would you use a small blob or a tiny dot at the location you indicated in Question 5? Explain your reasoning. Note: The dots marking the locations on the picture are about 1 mm across.

8) The Sun is much smaller than a nebula. We used a dot to represent the Sun's location in the picture. Is this dot too small, too large, or just the right size to represent the size of the Sun in the picture? Explain your reasoning.

9) The Milky Way Galaxy is one of the largest galaxies in a group of nearby galaxies called the Local Group. The following table lists the distances to the centers of three Local Group galaxies. Draw a dot on your picture (if possible) to represent the center of each galaxy. Don't worry about the direction (left/right/up/down) for each galaxy; just place a dot an appropriate distance from the Sun.

Galaxy	**Distance from Sun** (in light-years)
Sagittarius Dwarf Elliptical Galaxy (SagDEG)—closest galaxy to Milky Way	80,000
Large Magellanic Cloud (LMC)	160,000
Andromeda Galaxy (M31)	2,500,000

Do any of these galaxies fit on the page? Which one(s)?

10) Are the objects listed in Question 9 inside or outside the Milky Way? Explain your reasoning.

11) SagDEG is approximately 11,000 ly across. Is this galaxy better represented on your diagram by a small blob or a tiny dot? Explain your reasoning, and make an appropriate sketch to represent the galaxy.

12) Within the Local Group, the two largest galaxies are the Milky Way and Andromeda Galaxies. From Question 9, we saw that the Andromeda Galaxy was about 2,500,000 ly from us. On the picture, this location would be 250 cm (about two-and-a-half meters or 8 feet) away from the dot representing the Sun.

The nearest group of galaxies to us (not counting our own Local Group) is the Virgo Cluster, about 60,000,000 ly away. How many centimeters away would this cluster be on our picture? How many meters away would this be?

When stars are viewed through a telescope, they typically appear as bright points of light without any apparent size or structure. However, there are some objects in the sky that, when viewed through a telescope, look "fuzzy" and cloudlike. Some of these objects, like those shown in the *Hubble Space Telescope* image to the right, are actually galaxies (containing billions of stars) that are much farther from us than the individual stars we see in the night sky.

Part I: Applying Hubble's Classification Scheme

1) Using the images of galaxies provided on the inside back cover of your *Lecture-Tutorial* book, sort these galaxies (using Hubble's categories) as being either an elliptical or a spiral galaxy. Use the table below to record your results. Try to find patterns in terms of shape, size, color, or any other distinct features that help in sorting the galaxies.

Hubble's Categories	**Galaxy ID Numbers**	**Defining Characteristics** (Describe the characteristics that you used to distinguish one class of galaxy from the other)
Elliptical		
Spiral		

Part II: Understanding the Types of Galaxies

In Part I you classified the galaxies into different categories according to their appearance, or *morphology*. We will now investigate what a galaxy's morphology can tell us about its physical characteristics. These physical characteristics include: (a) the ages of the stars in the galaxy; (b) the presence or absence of dust in the galaxy; and (c) the presence or absence of gas and star formation. Keep in mind that these properties are linked together in a physical way. The objective of this activity is for you to learn how these characteristics are related to galaxy classification and morphology.

The Ages of Stars:

2) Which of the galaxies appear to be mostly red? (Note: The word "red" is used to also include the colors orange and yellow.) Record the number and classification (elliptical or spiral) of each galaxy. Why do you think these galaxies appear red?

3) Which of the galaxies appear to be mostly blue? Record the number and classification (elliptical or spiral) of each galaxy. Why do you think these galaxies appear blue?

4) Which types of galaxies appear to have many young stars: elliptical, spiral, or both? Explain your reasoning.

5) Do the galaxies that you identified in Question 4 also contain old stars? Explain your reasoning.

Dust in Galaxies:
Besides stars, galaxies sometimes also contain dust. This dust produces dark bands across, or patches in, the galaxy.

6) Which of the galaxies show evidence of dust? Record the number and classification (elliptical or spiral) of each galaxy. Explain your reasoning.

Gas and Star Formation in Galaxies:
In addition to stars and dust, galaxies may also contain gas.

7) Would you say that a galaxy that is experiencing active star formation contains little or abundant gas? Explain your reasoning.

8) Which type of galaxy (elliptical or spiral) would have abundant gas available? Explain your reasoning.

9) Which type of galaxy (elliptical, spiral, both, or neither) is likely to contain both O-spectral type stars as well as M-spectral type stars? Explain your reasoning.

10) Which type of galaxy (elliptical, spiral, both, or neither) is likely to contain many M-spectral type stars but very few (if any) O-spectral type stars? Explain your reasoning.

11) Which type of galaxy (elliptical, spiral, both, or neither) is likely to contain only O-spectral type stars? Explain your reasoning.

12) Consider the discussion among three students about a galaxy that appears red.

Student 1: *Because there is mainly red light in this galaxy and no blue light, I think that only small, red stars formed in this galaxy and not any big, blue ones.*

Student 2: *I disagree. It's just that blue stars don't last very long. I think the blue stars that may have been there in the past have already evolved into red giants, so the galaxy looks red due to the light from all the red giants.*

Student 3: *Wait a minute. I think you are both wrong. I thought that both blue stars and red giants live short lives, so they should both be gone. I think that all the blue stars that formed early on have evolved into the red stars that are there now. So the galaxy appears red because it's full of a lot of old, red stars that used to be the blue stars.*

Do you agree or disagree with any or all of the students? Explain your reasoning.

13) Hubble imagined the tuning fork diagram (shown at right) as representing an evolutionary sequence for galaxies, with galaxies starting off as elliptical and developing more structure over time. Do you think Hubble's proposed evolutionary sequence is correct? Why or why not?