26.E: Galaxies (Exercises)

For Further Exploration

Articles

Andrews, B. “What Are Galaxies Trying to Tell Us?” *Astronomy* (February 2011): 24. Introduction to our understanding of the shapes and evolution of different types of galaxies.

Bothun, G. “Beyond the Hubble Sequence.” *Sky & Telescope* (May 2000): 36. History and updating of Hubble’s classification scheme.

Christianson, G. “Mastering the Universe.” *Astronomy* (February 1999): 60. Brief introduction to Hubble’s life and work.

Dalcanton, J. “The Overlooked Galaxies.” *Sky & Telescope* (April 1998): 28. On low-brightness galaxies, which have been easy to miss.

Freedman, W. “The Expansion Rate and Size of the Universe.” *Scientific American* (November 1992): 76.

Hodge, P. “The Extragalactic Distance Scale: Agreement at Last?” *Sky & Telescope* (October 1993): 16.

Jones, B. “The Legacy of Edwin Hubble.” *Astronomy* (December 1989): 38.

Kaufmann, G. and van den Bosch, F. “The Life Cycle of Galaxies.” *Scientific American* (June 2002): 46. On galaxy evolution and how it leads to the different types of galaxies.

Martin, P. and Friedli, D. “At the Hearts of Barred Galaxies.” *Sky & Telescope* (March 1999): 32. On barred spirals.

Osterbrock, D. “Edwin Hubble and the Expanding Universe.” *Scientific American* (July 1993): 84.

Russell, D. “Island Universes from Wright to Hubble.” *Sky & Telescope* (January 1999) 56. A history of our discovery of galaxies.

Smith, R. “The Great Debate Revisited.” *Sky & Telescope* (January 1983): 28. On the Shapley-Curtis debate concerning the extent of the Milky Way and the existence of other galaxies.

Websites

ABC’s of Distance: http://www.astro.ucla.edu/~wright/distance.htm. A concise summary by astronomer Ned Wright of all the different methods we use to get distances in astronomy.

Cosmic Times 1929: http://cosmictimes.gsfc.nasa.gov/onl...mic/index.html. NASA project explaining Hubble’s work and surrounding discoveries as if you were reading newspaper articles.

Edwin Hubble: The Man Behind the Name: https://www.spacetelescope.org/about...hind_the_name/. Concise biography from the people at the Hubble Space Telescope.

Edwin Hubble: http://apod.nasa.gov/diamond_jubilee...ge_hubble.html. An article on the life and work of Hubble by his student and successor, Allan Sandage. A bit technical in places, but giving a real picture of the man and the science.

NASA Science: Introduction to Galaxies: http://science.nasa.gov/astrophysics...-are-galaxies/. A brief overview with links to other pages, and recent Hubble Space Telescope discoveries.

National Optical Astronomy Observatories Gallery of Galaxies: www.noao.edu/image_gallery/galaxies.html. A collection of images and information about galaxies and galaxy groups of different types. Another impressive archive can be found at the European Southern Observatory site: https://www.eso.org/public/images/ar...gory/galaxies/.

Sloan Digital Sky Survey: Introduction to Galaxies: http://skyserver.sdss.org/dr1/en/ast...s/galaxies.asp. Another brief overview.

Universe Expansion: http://hubblesite.org/newscenter/arc...leases/1999/19. The background material here provides a nice chronology of how we discovered and measured the expansion of the universe.

Videos

Edwin Hubble (Hubblecast Episode 89): http://www.spacetelescope.org/videos/hubblecast89a/. (5:59).

Galaxies: An Introduction: https://www.youtube.com/watch?v=HYYgangrkZg. A compilation of several short European videos that first describe galaxies in general and then focus on galaxies in Hubble telescope images (12:48).

Hubble's Views of the Deep Universe: https://www.youtube.com/watch?v=argR2U15w-M. A 2015 public talk by Brandon Lawton of the Space Telescope Science Institute about galaxies and beyond (1:26:20).

Collaborative Group Activities

1. Throughout much of the last century, the 100-inch telescope on Mt. Wilson (completed in 1917) and the 200-inch telescope on Palomar Mountain (completed in 1948) were the only ones large enough to obtain spectra of faint galaxies. Only a handful of astronomers (all male—since, until the 1960s, women were not given time on these two telescopes) were allowed to use these facilities, and in general the observers did not compete with each other but worked on different problems. Now there are many other telescopes, and several different groups do often work on the same problem. For example, two different groups have independently developed the techniques for using supernovae to determine the distances to galaxies at high redshifts. Which approach do you think is better for the field of astronomy? Which is more cost effective? Why?
2. A distant relative, whom you invite to dinner so you can share all the exciting things you have learned in your astronomy class, says he does not believe that other galaxies are made up of stars. You come back to your group and ask them to help you respond. What kinds of measurements would you make to show that other galaxies are composed of stars?
3. Look at the chapter thumbnail with your group. What does the difference in color between the spiral arms and the bulge of Andromeda tell you about the difference in the types of stars that populate these two regions of the galaxy? Which side of the galaxy is closer to us? Why?
4. What is your reaction to reading about the discovery of the expanding universe? Discuss how the members of the group feel about a universe "in motion." Einstein was not comfortable with the notion of a universe that had some overall movement to it, instead of being at rest. He put a kind of "fudge factor" into his equations of general relativity for the universe as a whole to keep it from moving (although later, hearing about Hubble and Humason's work, he called it "the greatest blunder" he ever made). Do you share Einstein's original sense that this is not the kind of universe you feel comfortable with? What do you think could have caused space to be expanding?
5. In science fiction, characters sometimes talk about visiting other galaxies. Discuss with your group how realistic this idea is. Even if we had fast spaceships (traveling close to the speed of light, the speed limit of the universe) how likely are we to be able to reach another galaxy? Why?
6. Despite his son's fascination with astronomy in college, Edwin Hubble's father did not want him to go into astronomy as a profession. He really wanted his son to be a lawyer and pushed him hard to learn the law when he won a fellowship to study abroad. Hubble eventually defied his father and went into astronomy, becoming, as you learned in this chapter, one of the most important astronomers of all time. His dad didn't live to see his son's remarkable achievements. Do you think he would have reconciled himself to his son's career choice if he had? Do you or does anyone in your group or among your friends have to face a choice between the passion in your heart and what others want you to do? Discuss how people in college today are dealing with such choices.

Review Questions

1. Describe the main distinguishing features of spiral, elliptical, and irregular galaxies.
2. Why did it take so long for the existence of other galaxies to be established?
3. Explain what the mass-to-light ratio is and why it is smaller in spiral galaxies with regions of star formation than in elliptical galaxies.
4. If we now realize dwarf ellipticals are the most common type of galaxy, why did they escape our notice for so long?
5. What are the two best ways to measure the distance to a nearby spiral galaxy, and how would it be measured?
6. What are the two best ways to measure the distance to a distant, isolated spiral galaxy, and how would it be measured?
7. Why is Hubble's law considered one of the most important discoveries in the history of astronomy?
8. What does it mean to say that the universe is expanding? What is expanding? For example, is your astronomy classroom expanding? Is the solar system? Why or why not?
9. Was Hubble's original estimate of the distance to the Andromeda galaxy correct? Explain.
10. Does an elliptical galaxy rotate like a spiral galaxy? Explain.
11. Why does the disk of a spiral galaxy appear dark when viewed edge on?
12. What causes the largest mass-to-light ratio: gas and dust, dark matter, or stars that have burnt out?
13. What is the most useful standard bulb method for determining distances to galaxies?
14. When comparing two isolated spiral galaxies that have the same apparent brightness, but rotate at different rates, what can you say about their relative luminosity?

15. If all distant galaxies are expanding away from us, does this mean we're at the center of the universe?
16. Is the Hubble constant actually constant?

Thought Questions

1. Where might the gas and dust (if any) in an elliptical galaxy come from?
2. Why can we not determine distances to galaxies by the same method used to measure the parallaxes of stars?
3. Which is redder—a spiral galaxy or an elliptical galaxy?
4. Suppose the stars in an elliptical galaxy all formed within a few million years shortly after the universe began. Suppose these stars have a range of masses, just as the stars in our own galaxy do. How would the color of the elliptical change over the next several billion years? How would its luminosity change? Why?
5. Starting with the determination of the size of Earth, outline a sequence of steps necessary to obtain the distance to a remote cluster of galaxies. (Hint: Review the chapter on Celestial Distances.)
6. Suppose the Milky Way Galaxy were truly isolated and that no other galaxies existed within 100 million light-years. Suppose that galaxies were observed in larger numbers at distances greater than 100 million light-years. Why would it be more difficult to determine accurate distances to those galaxies than if there were also galaxies relatively close by?
7. Suppose you were Hubble and Humason, working on the distances and Doppler shifts of the galaxies. What sorts of things would you have to do to convince yourself (and others) that the relationship you were seeing between the two quantities was a real feature of the behavior of the universe? (For example, would data from two galaxies be enough to demonstrate Hubble's law? Would data from just the nearest galaxies—in what astronomers call "the Local Group"—suffice?)
8. What does it mean if one elliptical galaxy has broader spectrum lines than another elliptical galaxy?
9. Based on your analysis of galaxies in Table $26.3.1$ in Section 26.3, is there a correlation between the population of stars and the quantity of gas or dust? Explain why this might be.
10. Can a higher mass-to-light ratio mean that there is gas and dust present in the system that is being analyzed?

Figuring for Yourself

1. According to Hubble's law, what is the recessional velocity of a galaxy that is 10^8 light-years away from us? (Assume a Hubble constant of 22 km/s per million light-years.)
2. A cluster of galaxies is observed to have a recessional velocity of 60,000 km/s. Find the distance to the cluster. (Assume a Hubble constant of 22 km/s per million light-years.)
3. Suppose we could measure the distance to a galaxy using one of the distance techniques listed in Table $26.4.1$ in Section 26.4 and it turns out to be 200 million light-years. The galaxy's redshift tells us its recessional velocity is 5000 km/s. What is the Hubble constant?
4. Calculate the mass-to-light ratio for a globular cluster with a luminosity of 106 L_{Sun} and 10^5 stars. (Assume that the average mass of a star in such a cluster is 1 M_{Sun}.)
5. Calculate the mass-to-light ratio for a luminous star of 100 M_{Sun} having the luminosity of 10^6 L_{Sun}.