

## 13.21: 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: [http://apod.nasa.gov/diamond\\_jubilee...ge\\_hubble.html](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](http://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.

#### Videos

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

### 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. 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?
6. 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?)

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