

13.20: The Milky Way Galaxy (Exercises)

For Further Exploration

Articles

Blitz, L. "The Dark Side of the Milky Way." *Scientific American* (October 2011): 36–43. How we find dark matter and what it tells us about our Galaxy, its warped disk, and its satellite galaxies.

Dvorak, J. "Journey to the Heart of the Milky Way." *Astronomy* (February 2008): 28. Measuring nearby stars to determine the properties of the black hole at the center.

Gallagher, J., Wyse, R., & Benjamin, R. "The New Milky Way." *Astronomy* (September 2011): 26. Highlights all aspects of the Milky Way based on recent observations.

Goldstein, A. "Finding our Place in the Milky Way." *Astronomy* (August 2015): 50. On the history of observations that pinpointed the Sun's location in the Galaxy.

Haggard, D., & Bower, G. "In the Heart of the Milky Way." *Sky & Telescope* (February 2016): 16. On observations of the Galaxy's nucleus and the supermassive black hole and magnetar there.

Ibata, R., & Gibson, B. "The Ghosts of Galaxies Past." *Scientific American* (April 2007): 40. About star streams in the Galaxy that are evidence of past mergers and collisions.

Irion, R. "A Crushing End for Our Galaxy." *Science* (January 7, 2000): 62. On the role of mergers in the evolution of the Milky Way.

Irion, R. "Homing in on Black Holes." *Smithsonian* (April 2008). On how astronomers probe the large black hole at the center of the Milky Way Galaxy.

Kruesi, L. "How We Mapped the Milky Way." *Astronomy* (October 2009): 28.

Kruesi, L. "What Lurks in the Monstrous Heart of the Milky Way?" *Astronomy* (October 2015): 30. On the center of the Galaxy and the black hole there.

Laughlin, G., & Adams, F. "Celebrating the Galactic Millennium." *Astronomy* (November 2001): 39. The long-term future of the Milky Way in the next 90 billion years.

Loeb, A., & Cox, T.J. "Our Galaxy's Date with Destruction." *Astronomy* (June 2008): 28. Describes the upcoming merger of Milky Way and Andromeda.

Szpir, M. "Passing the Bar Exam." *Astronomy* (March 1999): 46. On evidence that our Galaxy is a barred spiral.

Tanner, A. "A Trip to the Galactic Center." *Sky & Telescope* (April 2003): 44. Nice introduction, with observations pointing to the presence of a black hole.

Trimble, V., & Parker, S. "Meet the Milky Way." *Sky & Telescope* (January 1995): 26. Overview of our Galaxy.

Wakker, B., & Richter, P. "Our Growing, Breathing Galaxy." *Scientific American* (January 2004): 38. Evidence that our Galaxy is still being built up by the addition of gas and smaller neighbors.

Waller, W. "Redesigning the Milky Way." *Sky & Telescope* (September 2004): 50. On recent multi-wavelength surveys of the Galaxy.

Whitt, K. "The Milky Way from the Inside." *Astronomy* (November 2001): 58. Fantastic panorama image of the Galaxy, with finder charts and explanations.

Websites

International Dark Sky Sanctuaries: <http://darksky.org/idsp/sanctuaries/>. A listing of dark-sky sanctuaries, parks, and reserves.

Multiwavelength Milky Way: http://mwmw.gsfc.nasa.gov/mmw_sci.html. This NASA site shows the plane of our Galaxy in a variety of wavelength bands, and includes background material and other resources.

Shapley-Curtis Debate in 1920: apod.nasa.gov/diamond_jubilee/debate_1920.html. In 1920, astronomers Harlow Shapley and Heber Curtis engaged in a historic debate about how large our Galaxy was and whether other galaxies existed. Here you can find

historical and educational material about the debate.

UCLA Galactic Center Group: <http://www.galacticcenter.astro.ucla.edu/>. Learn more about the work of Andrea Ghez and colleagues on the central region of the Milky Way Galaxy.

Videos

Crash of the Titans: <http://www.spacetelescope.org/videos/hubblecast55a/>. This Hubblecast from 2012 features Jay Anderson and Roeland van der Marel explaining how Andromeda will collide with the Milky Way in the distant future (5:07).

Diner at the Center of the Galaxy: <https://www.youtube.com/watch?v=UP7ig8Gxftw>. A short discussion from NASA ScienceCast of NuSTAR observations of flares from our Galaxy's central black hole (3:23).

Hunt for a Supermassive Black Hole: https://www.ted.com/talks/andrea_ghez...ive_black_hole. 2009 TED talk by Andrea Ghez on searching for supermassive black holes, particularly the one at the center of the Milky Way (16:19).

Journey to the Galactic Center: <https://www.youtube.com/watch?v=36xZsgZ0oSo>. A brief silent trip into the cluster of stars near the galactic center showing their motions around the center (3:00).

Review Questions

1. Explain why we see the Milky Way as a faint band of light stretching across the sky.
2. Explain where in a spiral galaxy you would expect to find globular clusters, molecular clouds, and atomic hydrogen.
3. Briefly describe the main parts of our Galaxy.
4. Describe the evidence indicating that a black hole may be at the center of our Galaxy.
5. Explain why the abundances of heavy elements in stars correlate with their positions in the Galaxy.
6. What will be the long-term future of our Galaxy?

Thought Questions

1. Suppose the Milky Way was a band of light extending only halfway around the sky (that is, in a semicircle). What, then, would you conclude about the Sun's location in the Galaxy? Give your reasoning.
2. Suppose somebody proposed that rather than invoking dark matter to explain the increased orbital velocities of stars beyond the Sun's orbit, the problem could be solved by assuming that the Milky Way's central black hole was much more massive. Does simply increasing the assumed mass of the Milky Way's central supermassive black hole correctly resolve the issue of unexpectedly high orbital velocities in the Galaxy? Why or why not?
3. The globular clusters revolve around the Galaxy in highly elliptical orbits. Where would you expect the clusters to spend most of their time? (Think of Kepler's laws.) At any given time, would you expect most globular clusters to be moving at high or low speeds with respect to the center of the Galaxy? Why?
4. Shapley used the positions of globular clusters to determine the location of the galactic center. Could he have used open clusters? Why or why not?
5. Consider the following five kinds of objects: open cluster, giant molecular cloud, globular cluster, group of O and B stars, and planetary nebulae.
 1. Which occur only in spiral arms?
 2. Which occur only in the parts of the Galaxy other than the spiral arms?
 3. Which are thought to be very young?
 4. Which are thought to be very old?
 5. Which have the hottest stars?
6. The dwarf galaxy in Sagittarius is the one closest to the Milky Way, yet it was discovered only in 1994. Can you think of a reason it was not discovered earlier?
7. Suppose three stars lie in the disk of the Galaxy at distances of 20,000 light-years, 25,000 light-years, and 30,000 light-years from the galactic center, and suppose that right now all three are lined up in such a way that it is possible to draw a straight line through them and on to the center of the Galaxy. How will the relative positions of these three stars change with time? Assume that their orbits are all circular and lie in the plane of the disk.
8. Why does star formation occur primarily in the disk of the Galaxy?
9. Where in the Galaxy would you expect to find Type II supernovae, which are the explosions of massive stars that go through their lives very quickly? Where would you expect to find Type I supernovae, which involve the explosions of white dwarfs?

10. Suppose that stars evolved without losing mass—that once matter was incorporated into a star, it remained there forever. How would the appearance of the Galaxy be different from what it is now?

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