10.15: Celestial Distances (Exercises)

For Further Exploration

Articles

Adams, A. “The Triumph of Hipparcos.” *Astronomy* (December 1997): 60. Brief introduction.

Dambeck, T. “Gaia’s Mission to the Milky Way.” *Sky & Telescope* (March 2008): 36–39. An introduction to the mission to measure distances and positions of stars with unprecedented accuracy.

Hirshfeld, A. “The Absolute Magnitude of Stars.” *Sky & Telescope* (September 1994): 35. Good review of how we measure luminosity, with charts.

Hirshfeld, A. “The Race to Measure the Cosmos.” *Sky & Telescope* (November 2001): 38. On parallax.

Trefil, J. Puzzling Out Parallax.” *Astronomy* (September 1998): 46. On the concept and history of parallax.

Turon, C. “Measuring the Universe.” *Sky & Telescope* (July 1997): 28. On the Hipparcos mission and its results.

Zimmerman, R. “Polaris: The Code-Blue Star.” *Astronomy* (March 1995): 45. On the famous cepheid variable and how it is changing.

Websites

ABCs of Distance: http://www.astro.ucla.edu/~wright/distance.htm. Astronomer Ned Wright (UCLA) gives a concise primer on many different methods of obtaining distances. This site is at a higher level than our textbook, but is an excellent review for those with some background in astronomy.

American Association of Variable Star Observers (AAVSO): https://www.aavso.org/. This organization of amateur astronomers helps to keep track of variable stars; its site has some background material, observing instructions, and links.

Friedrich Wilhelm Bessel: http://messier.seds.org/xtra/Bios/bessel.html. A brief site about the first person to detect stellar parallax, with references and links.

Gaia: http://sci.esa.int/gaia/. News from the Gaia mission, including images and a blog of the latest findings.

Hipparchos: http://sci.esa.int/hipparcos/. Background, results, catalogs of data, and educational resources from the Hipparchos mission to observe parallaxes from space. Some sections are technical, but others are accessible to students.

John Goodricke: The Deaf Astronomer: http://www.bbc.com/news/magazine-20725639. A biographical article from the BBC.

Women in Astronomy: http://bit.ly/astronomywomen. More about Henrietta Leavitt’s and other women’s contributions to astronomy and the obstacles they faced.

Videos

Gaia’s Mission: Solving the Celestial Puzzle: https://www.youtube.com/watch?v=oGri4YNggoc. Describes the Gaia mission and what scientists hope to learn, from Cambridge University (19:58).

How Big Is the Universe: https://www.youtube.com/watch?v=K_xZuopg4Sk. Astronomer Pete Edwards from the British Institute of Physics discusses the size of the universe and gives a step-by-step introduction to the concepts of distances (6:22)

Women in Astronomy: http://www.youtube.com/watch?v=5vMR7su4fi8. Emily Rice (CUNY) gives a talk on the contributions of women to astronomy, with many historical and contemporary examples, and an analysis of modern trends (52:54).

Review Questions

1. Explain how parallax measurements can be used to determine distances to stars. Why can we not make accurate measurements of parallax beyond a certain distance?
2. Suppose you have discovered a new cepheid variable star. What steps would you take to determine its distance?
3. Explain how you would use the spectrum of a star to estimate its distance.
4. Which method would you use to obtain the distance to each of the following?
   1. An asteroid crossing Earth’s orbit
   2. A star astronomers believe to be no more than 50 light-years from the Sun

3. A tight group of stars in the Milky Way Galaxy that includes a significant number of variable stars
4. A star that is not variable but for which you can obtain a clearly defined spectrum

5. What are the luminosity class and spectral type of a star with an effective temperature of 5000 K and a luminosity of 100 L_{Sun}?

Thought Questions

1. The meter was redefined as a reference to Earth, then to krypton, and finally to the speed of light. Why do you think the reference point for a meter continued to change?
2. While a meter is the fundamental unit of length, most distances traveled by humans are measured in miles or kilometers. Why do you think this is?
3. Most distances in the Galaxy are measured in light-years instead of meters. Why do you think this is the case?
4. The AU is defined as the *average* distance between Earth and the Sun, not the distance between Earth and the Sun. Why does this need to be the case?
5. What would be the advantage of making parallax measurements from Pluto rather than from Earth? Would there be a disadvantage?
6. Parallaxes are measured in fractions of an arcsecond. One arcsecond equals 1/60 arcmin; an arcminute is, in turn, 1/60th of a degree (°). To get some idea of how big 1° is, go outside at night and find the Big Dipper. The two pointer stars at the ends of the bowl are 5.5° apart. The two stars across the top of the bowl are 10° apart. (Ten degrees is also about the width of your fist when held at arm's length and projected against the sky.) Mizar, the second star from the end of the Big Dipper's handle, appears double. The fainter star, Alcor, is about 12 arcmin from Mizar. For comparison, the diameter of the full moon is about 30 arcmin. The belt of Orion is about 3° long. Keeping all this in mind, why did it take until 1838 to make parallax measurements for even the nearest stars?
7. For centuries, astronomers wondered whether comets were true celestial objects, like the planets and stars, or a phenomenon that occurred in the atmosphere of Earth. Describe an experiment to determine which of these two possibilities is correct.
8. The Sun is much closer to Earth than are the nearest stars, yet it is not possible to measure accurately the diurnal parallax of the Sun relative to the stars by measuring its position relative to background objects in the sky directly. Explain why.
9. Parallaxes of stars are sometimes measured relative to the positions of galaxies or distant objects called quasars. Why is this a good technique?
10. Estimating the luminosity class of an M star is much more important than measuring it for an O star if you are determining the distance to that star. Why is that the case?
11. Figure 19.3.1 in Section 19.3 is the light curve for the prototype cepheid variable Delta Cephei. How does the luminosity of this star compare with that of the Sun?
12. Which of the following can you determine about a star without knowing its distance, and which can you not determine: radial velocity, temperature, apparent brightness, or luminosity? Explain.
13. A G2 star has a luminosity 100 times that of the Sun. What kind of star is it? How does its radius compare with that of the Sun?
14. A star has a temperature of 10,000 K and a luminosity of 10^–2 L_{Sun}. What kind of star is it?
15. What is the advantage of measuring a parallax distance to a star as compared to our other distance measuring methods?
16. What is the disadvantage of the parallax method, especially for studying distant parts of the Galaxy?
17. Luhman 16 and WISE 0720 are brown dwarfs, also known as failed stars, and are some of the new closest neighbors to Earth, but were only discovered in the last decade. Why do you think they took so long to be discovered?
18. Most stars close to the Sun are red dwarfs. What does this tell us about the average star formation event in our Galaxy?
19. Why would it be easier to measure the characteristics of intrinsically less luminous cepheids than more luminous ones?
20. When Henrietta Leavitt discovered the period-luminosity relationship, she used cepheid stars that were all located in the Large Magellanic Cloud. Why did she need to use stars in another galaxy and not cepheids located in the Milky Way?