

OpenStax Astronomy, Ch.19: WS Solutions (Apr-2021)

Solutions

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?

The parallax of a star is its shift in position during the course of half a year as measured against stationary background objects (distant stars or quasars). As a star gets more distant, the shift decreases, making more distant stars more difficult to measure.

2. Suppose you have discovered a new cepheid variable star. What steps would you take to determine its distance?

First, measure the period of pulsation of the star. Then, use a period-luminosity relation to calculate the mean luminosity. Finally, compare the luminosity to the mean apparent brightness and calculate a distance.

3. Explain how you would use the spectrum of a star to estimate its distance.

Begin by examining the detailed spectrum to estimate the star's spectral type and luminosity class. Use this to find the place where the star belongs on the H-R diagram, and then read off the star's luminosity from the diagram. Finally, measure the distance by comparing the apparent brightness to the luminosity.

4. Which method would you use to obtain the distance to each of the following?

- A. An asteroid crossing Earth's orbit
- B. A star astronomers believe to be no more than 50 light-years from the Sun
- C. A tight group of stars in the Milky Way Galaxy that includes a significant number of variable stars
- D. A star that is not variable but for which you can obtain a clearly defined spectrum

A. Radar would be the best tool for measuring distances to objects in the solar system. B. A parallax measurement would be best for this nearby star. C. Cepheids or RR Lyraes would be useful for determining the distance to this cluster. D. The method using the H-R diagram and getting a spectrum to determine the luminosity class of the star.

5. Most distances in the Galaxy are measured in light-years instead of meters. Why do you think this is the case?

The stars are very far away, and the meter is a small unit at the scale of humans. Even if we used AU instead of meters to measure the distances to stars, the closest star is almost 900,000 AU away. It is easier to use light-years to measure the distances between stars. That makes Proxima Centauri just over 4 light-years from Earth.

6. 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?

Earth has an elliptical orbit, which means that its distance from the Sun changes throughout the year. Its average distance, however, is a constant.

7. What would be the advantage of making parallax measurements from Pluto rather than from Earth? Would there be a disadvantage?



Since Pluto takes about 249 Earth years to orbit the Sun, the baseline would be much larger, but it would take a very long time to get two observations of the same star from the two sides of the orbit.

8. Parallaxes of stars are sometimes measured relative to the positions of galaxies or distant objects called quasars. Why is this a good technique?

The advantage of measuring the parallaxes of stars relative to galaxies or quasars is that we know the reference objects are very much more distant than the stars and therefore will show no parallax of their own. Quasars make better reference markers than ordinary galaxies because they are smaller (they look like stars and so appear to be mere points of light); thus, their positions can be measured more precisely.

9. 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.

The radial velocity, temperature, and apparent magnitude can all be estimated without knowing the distance to the star. The radial velocity and temperature can be estimated by a spectrum (you can get a rough measure of the temperature from the star's color.) The apparent brightness can be directly observed. In order to estimate a star's luminosity, however, we must know its distance.

10. 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?

According to Figure 19.15 Luminosity Classes, a G star with a luminosity of $100 L_{\text{Sun}}$ is a giant. Since it has the same temperature as the Sun but emits 100 times more energy, its surface area must be 100 times larger. Since the area of a sphere is given by $A = 4\pi R^2$, the radius of the giant G star must be the square root of 100 or 10 times larger than the radius of the Sun.

11. A star has a temperature of 10,000 K and a luminosity of $10^{-2} L_{\text{Sun}}$. What kind of star is it?

According to Fig 19.15, this star is a white dwarf. These stars are small, dim, and very hot.

12. What is the disadvantage of the parallax method, especially for studying distant parts of the Galaxy?

The main disadvantage to using parallaxes for distances is that it does not reach far into the Galaxy, although the Gaia mission should help with this.

13. 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?

Because these brown dwarfs are incredibly dim in visible light, they did not get detected by the surveys of the past. Specifically, since astronomers are now using infrared-sensitive detectors, they can see many more cool brown dwarfs which are more easily seen in infrared than visible light.

14. Most stars close to the Sun are red dwarfs. What does this tell us about the average star formation event in our Galaxy?

We don't think that Earth and Sun are in a special place in the Galaxy. This means that the mix of stars around us is likely to be representative of most of the Galaxy. Since there are mostly red dwarfs near the Sun, then we expect these stars to be quite common throughout the Milky Way, even at distances that are beyond our reach right now.

15. 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?

Leavitt knew that all of the cepheids in the Large Magellanic Cloud were at the same distance. Thus, she could relate their changes in apparent brightness to changes in actual luminosity. If she had used stars spread all over the Galaxy, she wouldn't know the distance to each star, and could not calculate the luminosity of one star compared to another.

16. In 1974, the Arecibo Radio telescope in Puerto Rico was used to transmit a signal to M13, a star cluster about 25,000 light-years away. How long will it take the message to reach M13, and how far has the message travelled so far (in light-years)?

Radio waves travel at the speed of light, which is a distance of 1 light-year every year. The cluster is about 25,000 light-years away, and the message has been traveling for 42 years as of 2016, so it only has 24,958 years to go. The message has travelled 42 light-years.

17. The New Horizons probe that passed by Pluto during July 2015 is one of the fastest spacecraft ever assembled. It was moving at about 14 km/s when it went by Pluto. If it maintained this speed, how long would it take New Horizons to reach the nearest star, Proxima Centauri, which is about 4.3 light-years away? (Note: It isn't headed in that direction, but you can pretend that it is.)

Proxima Cen is about 4.3 light-years away, which corresponds to 4×10^{16} m. To determine the time it would take, we use:

$$t = \frac{d}{v} = \frac{4 \times 10^{16} \text{ m}}{14,000 \text{ m/s}} = 2.86 \times 10^{12} \text{ s} = 90,600 \text{ years.}$$

It's going to be a while before we can travel interstellar distances.

18. What physical properties are different for an M giant with a luminosity of $1000 L_{\text{Sun}}$ and an M dwarf with a luminosity of $0.5 L_{\text{Sun}}$? What physical properties are the same?

The main difference between the dwarf and the giant star is that the giant is much larger. The temperature of the two stars is the same, but the giant will be more luminous due to its size.