

OpenStax Astronomy, Ch.17: WS Solutions (Apr-2021)

Solutions

1. What two factors determine how bright a star appears to be in the sky?

The luminosity and distance of a star determine its apparent brightness in the sky.

2. Explain why color is a measure of a star's temperature.

The light emitted by a star approximates a blackbody. The hotter a star's temperature, the shorter the peak wavelength of its spectral curve. Therefore, cool stars exhibit reddish colors, whereas hot stars exhibit bluish colors.

3. What is the main reason that the spectra of all stars are not identical? Explain.

The primary reason that stellar spectra look different is that the stars have different temperatures. Each element (and ion) has a characteristic temperature at which the spectral lines it produces are strongest. Stars of different temperatures, therefore, exhibit different spectral lines.

4. What elements are stars mostly made of? How do we know this?

Stars are mostly made of hydrogen and helium. We know this by analyzing the relative strengths of absorption lines in their spectra.

5. What did Annie Cannon contribute to the understanding of stellar spectra?

Annie Cannon created the spectral classification system based on surface temperature that astronomers use today. She also classified the spectra of around 500,000 stars in her career.

6. Name five characteristics of a star that can be determined by measuring its spectrum. Explain how you would use a spectrum to determine these characteristics.

Temperature: Measure the relative strengths of spectral lines to determine a star's spectral class, for example, OBAFGKM. Spectral class corresponds to temperature.

Composition: Use computer models and temperature to determine elemental abundances from relative strengths of absorption lines in a star's spectrum. Classify a star as a dwarf or giant: Measure the width of spectral lines. If the lines are narrow, the star's diameter is large. If the lines are wider, the star's diameter is smaller.

Radial velocity: Measure the wavelengths of the lines in the star's spectrum. Compare the observed wavelengths to the known "rest wavelengths" of the lines to determine the Doppler shift. The Doppler shift of the star is determined by its radial velocity—its motion toward or away from Earth. Rotation: Measure the width of the star's spectral lines. The star's rotation creates a broadening of the spectral lines, which can be used to determine the star's rotation.

7. Do stars that look brighter in the sky have larger or smaller magnitudes than fainter stars?

Brighter stars have smaller magnitudes than fainter stars.

8. The star Antares has an apparent magnitude of 1.0, whereas the star Procyon has an apparent magnitude of 0.4. Which star appears brighter in the sky?

Procyon appears brighter in the sky.

9. Based on their colors, which of the following stars is hottest? Which is coolest? Archenar (blue), Betelgeuse (red), Capella (yellow).



Archenar is hottest. Betelgeuse is coolest.



10. Order the seven basic spectral types from hottest to coldest.

OBAFGKM.

11. What is the defining difference between a brown dwarf and a true star?

Stars have internal temperatures capable of sustaining hydrogen fusion. Brown dwarfs do not.

12. How would two stars of equal luminosity—one blue and the other red—appear in an image taken through a filter that passes mainly blue light? How would their appearance change in an image taken through a filter that transmits mainly red light?

The two stars have equal total luminosity, but the blue star emits most of its energy at shorter wavelengths, whereas the red star emits most of its energy at longer wavelengths. Since a blue filter transmits only blue (shorter wavelength) light, the blue star will look brighter through the blue filter while the red star will look brighter through the red filter.

13. Star X has lines of ionized helium in its spectrum, and star Y has bands of titanium oxide. Which is hotter? Why? The spectrum of star Z shows lines of ionized helium and also molecular bands of titanium oxide. What is strange about this spectrum? Can you suggest an explanation?

Star X is hotter. Looking at the Figure 17.5 Absorption Lines in Stars of Different Temperatures, we can see that ionized helium lines are strongest at high temperatures ($> 30,000$ K), whereas titanium oxide lines are strongest at lower temperatures (~ 3000 K). Therefore, Star X must be hotter than Star Y. Star Z's spectrum is strange because the presence of ionized helium and titanium oxide lines indicate both high and low temperatures at the same time. One explanation for this strange spectrum would be that Star Z is a hot star, like Star X, which creates the ionized helium lines, and that there is a cooler cloud of intervening material along the line of sight that creates the observed TiO lines. Another explanation might be that what appears to be a single star is actually two stars so close together we cannot separate them visually—a hot star with a cool companion.

14. The spectrum of the Sun has hundreds of strong lines of nonionized iron but only a few, very weak lines of helium. A star of spectral type B has very strong lines of helium but very weak iron lines. Do these differences mean that the Sun contains more iron and less helium than the B star? Explain.

No. The primary reason that stellar spectra look different is the stars have different temperatures. Most stars have compositions very similar to that of the Sun.

15. Suppose hominids one million years ago had left behind maps of the night sky. Would these maps represent accurately the sky that we see today? Why or why not?

No. The proper motions of the stars would have significantly changed their locations on the celestial sphere relative to each other over one million years.

16. Why can only a lower limit to the rate of stellar rotation be determined from line broadening rather than the actual rotation rate? (Refer to the Figure 17.14 Using a Spectrum to Determine Stellar Rotation.)

The Doppler shift can only detect radial motion, that is, motion toward or away from the observer. If the axis of rotation is perpendicular to the line of sight, then the full rotational motion is radial. However, if the axis of rotation is parallel to the line of sight, then none of the rotational motion is radial. In most cases, the inclination of the rotational axis will be somewhere between these extremes, so part of the rotational



motion will be radial, but not the full rotational motion. This means that the rotational motion detected by line broadening will usually not be the full rotational motion.



17. Why do you think astronomers have suggested three different spectral types (L, T, and Y) for the brown dwarfs instead of M? Why was one not enough?

The surface temperatures of brown dwarfs range from under 700 K to around 2400 K. Brown dwarfs of different surface temperatures show distinct characteristic spectral lines. Class L dwarfs show lines for metal hydrides and alkali metals, T dwarfs show methane lines, and Y dwarfs show ammonia lines.

18. Two stars have proper motions of one arcsecond per year. Star A is 20 light-years from Earth, and Star B is 10 light-years away from Earth. Which one has the faster velocity in space?

Since Star A is farther from Earth, its velocity in space must be greater than Star B's to produce the same proper motion (change of angle) as seen from Earth.

19. Suppose there are three stars in space, each moving at 100 km/s. Star A is moving across (i.e., perpendicular to) our line of sight, Star B is moving directly away from Earth, and Star C is moving away from Earth, but at a 30° angle to the line of sight. From which star will you observe the greatest Doppler shift? From which star will you observe the smallest Doppler shift?

Since Star B's motion is directly away from Earth, it will show the greatest Doppler shift. Star A, with its motion neither toward nor away from Earth, will show the least Doppler shift—no shift at all.

20. What would you say to a friend who made this statement, "The visible-light spectrum of the Sun shows weak hydrogen lines and strong calcium lines. The Sun must therefore contain more calcium than hydrogen."?

The temperature of a star's photosphere determines the pattern of spectral lines that we see. At the Sun's temperature, hydrogen lines are weaker in the visible-light part of the spectrum. Most stars have compositions very similar to the Sun and are made mostly of hydrogen and helium.

21. Star A and Star B have different apparent brightnesses but identical luminosities. If Star A is 20 light-years away from Earth and Star B is 40 light-years away from Earth, which star appears brighter and by what factor?

Because Star A and Star B have identical luminosities, the difference in their apparent brightness is due solely to distance. Star B is twice as far from Earth as Star A. Star A is therefore $2^2 = 4$ times brighter than Star B.