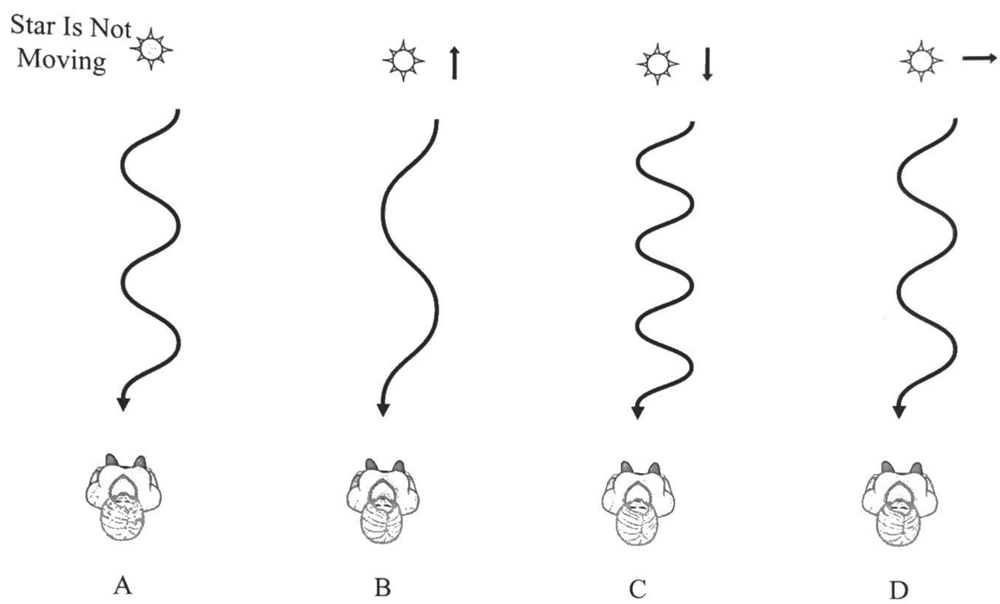
Because of the Doppler effect, light emitted by an object can appear to change wavelength due to its motion toward or away from an observer. When the observer and the source of light are moving toward each other, the light is shifted to shorter wavelengths (blueshifted). When the observer and the source of light are moving away from each other, the light is shifted to longer wavelengths (redshifted).

Part I: Motion of Source



1) Consider the situations shown (A–D).

   a) In which situation will the observer receive light that is shifted to shorter wavelengths?

   b) Will this light be blueshifted or redshifted for this case?

   c) What direction is the star moving relative to the observer for this case?

2) Consider the situations shown (A–D).

   a) In which situation will the observer receive light that is shifted to longer wavelengths?

   b) Will this light be blueshifted or redshifted for this case?

   c) What direction is the star moving relative to the observer for this case?

3) In which of the situations shown (A–D) will the observer receive light that is not Doppler shifted at all? Explain your reasoning.

4) Imagine our solar system is moving in the Milky Way toward a group of three stars. Star A is a blue star that is slightly closer to us than the other two. Star B is a red star that is farthest away from us. Star C is a yellow star that is halfway between Stars A and B.

   a) Which of these three stars, if any, will give off light that appears to be blueshifted? Explain your reasoning.

   b) Which of these three stars, if any, will give off light that appears to be redshifted? Explain your reasoning.

   c) Which of these three stars, if any, will give off light that appears to have no shift? Explain your reasoning.

5) You overhear two students discussing the topic of Doppler shift.

Student 1: *Since Betelgeuse is a red star, it must be going away from us, and since Rigel is a blue star it must be coming toward us.*

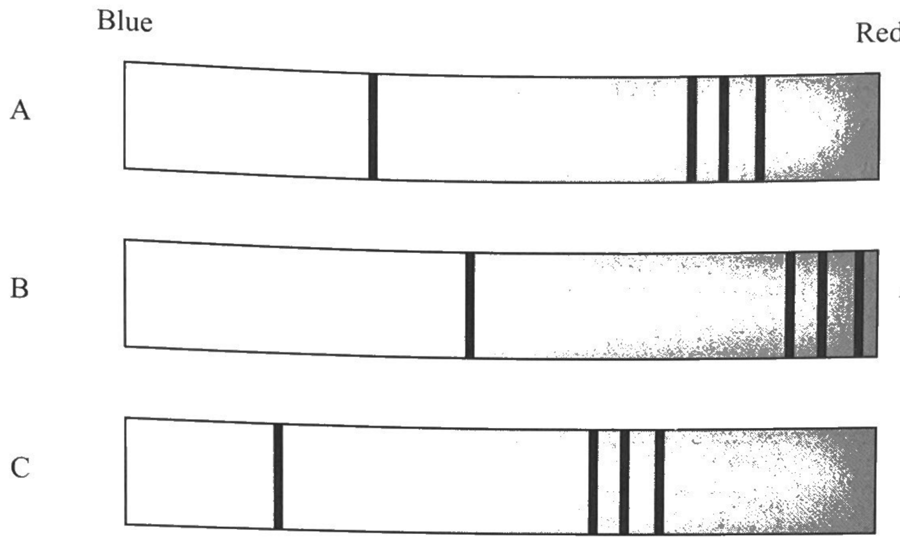
Student 2: *I disagree, the color of the star does not tell you if it is moving. You have to look at the shift in wavelength of the lines in the star's absorption spectrum to determine whether it's moving toward or away from you.*

Do you agree or disagree with either or both of the students? Explain your reasoning.

Part II: Shift in Absorption Spectra

When we study an astronomical object like a star or galaxy, we examine the spectrum of light it gives off. Since the lines of a spectrum occur at specific wavelengths, we can determine that an object is moving when we see that the lines have been shifted to either longer or shorter wavelengths. For the absorption line spectra shown on the next page, short-wavelength light (the blue end of the spectrum) is shown on the left-hand side, and long-wavelength light (the red end of the spectrum) is shown on the right-hand side.

For the three absorption line spectra shown below (A, B, and C), one of the spectra corresponds to a star that is not moving relative to you, one of the spectra is from a star that is moving toward you, and one of the spectra is from a star that is moving away from you.



REST

6) Which of the three spectra above corresponds with the star moving toward you? Explain your reasoning.

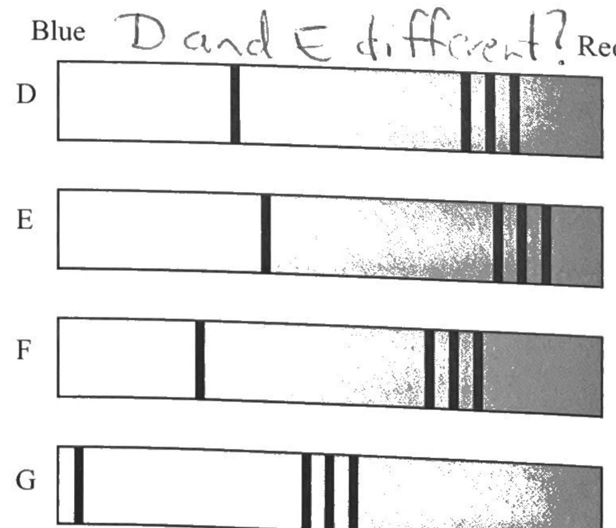
7) Which of the three spectra corresponds with the star moving away from you? Explain your reasoning.

REPEAT (6) AND (7) FOR D, E, and G below. HOW ARE D and E different?

Part III: Size of Shift and Speed

If two sources of light are moving relative to an observer, the light from the star that is moving faster will appear to undergo a greater Doppler shift.

Consider the four spectra at the right. The spectrum labeled F is an absorption line spectrum from a star that is at rest. Again, note that short-wavelength (blue) light is shown on the left-hand side of each spectrum, and long-wavelength (red) light is shown on the right-hand side of each spectrum.



REST

Part I: Expansion, Distance, and Velocity

Consider the small section of the universe containing four galaxies (A–D), shown in Figure 1 below. The distances between each galaxy are also shown.

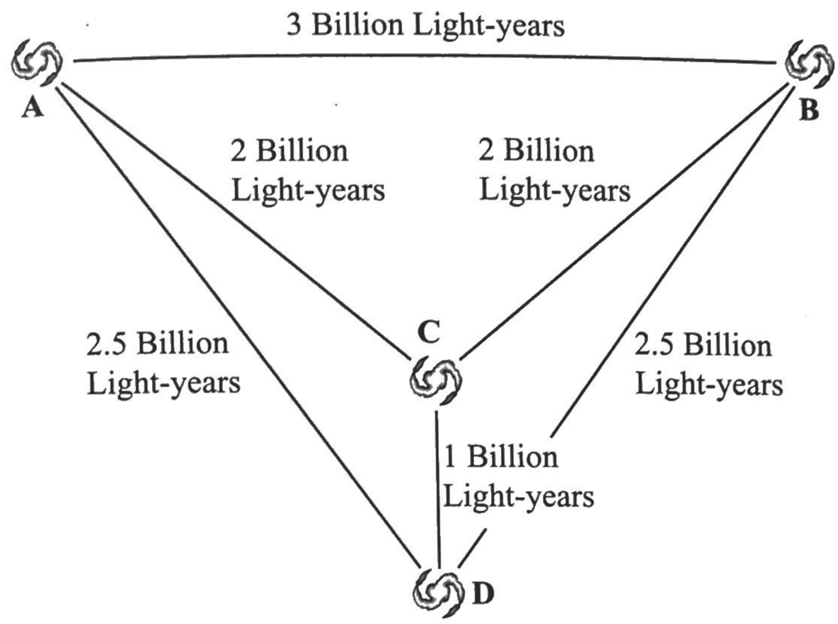


Figure 1

1) Imagine that this section of the universe doubles in size over time due to the expansion of the universe. Draw what the above section of the universe would look like after it doubles in size. Be sure to identify the new distances between the galaxies.