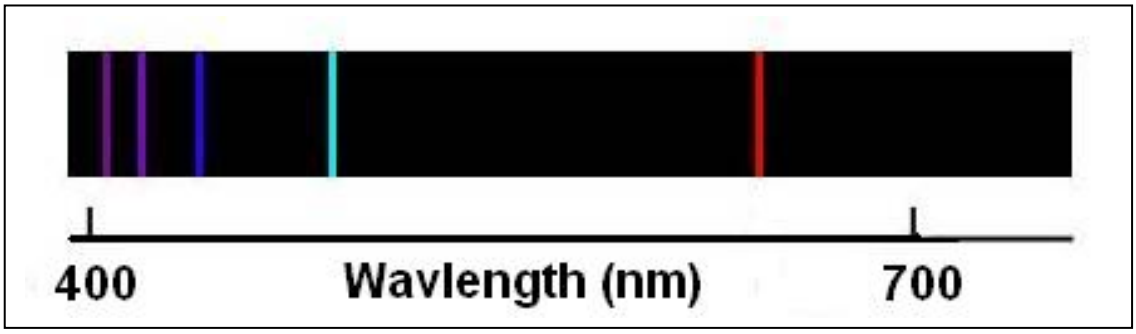
The Doppler Shift



The spectrum is of the element hydrogen seen under laboratory conditions with a spectroscope.

An astronomer measures a distant hydrogen cloud in space and sees the above spectrum. The spectral lines form an identical pattern, but they are shifted slightly in wavelength. The Doppler Effect causes the wavelength of light and sound waves to be shifted to longer wavelengths if the source is moving away from you, or shorter wavelengths if it is moving towards you.

Problem 1: Is the interstellar cloud moving towards Earth or away from Earth?

If the spectral line shifts are caused by the Doppler Effect, there is a simple formula that lets you calculate the speed, V, of the source. It looks like this:

$$V = 300{,}000 \frac{W(source) - W(Lab)}{W(Lab)}$$

If you use the same wavelength units for W(source) and W(lab), the formula gives the speed of the source in km/s.

W(source) is the wavelength (nm) of the source spectral line

W(Lab) is the wavelength (nm) of the same spectral line seen in the laboratory.

Problem 2: From the data in the two spectra and the Doppler formula, what is the speed of the gas cloud?

Problem 1 – The spectral lines in the lower spectrum are located at longer wavelengths than for the laboratory spectrum, so the source is moving away from Earth.

Problem 2 - First determine the wavelength scale for each of the two spectra. Use a millimeter ruler, and measure the distance between the 400 and 700 nm marks on the scale. For example, Top = 109 millimeters; Bottom = 107 millimeters. In both cases, the wavelength span is 700 - 400 = 300 nm, so the scales are Top: 300/109 = 2.75 nm/mm; Bottom: 300/107 = 2.80 nm/millimeters.

Now we need to find the wavelengths for one of the common lines in the two spectra. We will select the red line on the far right. It is located 20.5 mm to the left of the '700 nm' axis mark, so its wavelength is 700 nm - 20.5x2.75 = 643.6 nm. For the bottom spectrum, this line is located 12 mm to the left of the '700 nm' tick mark, so its wavelength will be 700 - 12.0 x 2.8 = 666.4 nm. Remember to use the correct wavelength scale!

From the Doppler formula

W(lab) = 643.6 nm, W(source) = 666.4 nm so

V = 300,000 x (666.4 - 643.6)/643.6
= + 10,628 km/sec.