Hubba Hubba Hubble- HONORS

Atomic spectra can tell us many things about celestial objects, including temperature, composition and distance. In 1929, Edwin Hubble applied the Doppler Effect to compare known atomic emission spectra to those same spectra found in galaxies to determine galaxies were in motion. Since it was light waves that were shifted toward longer wavelengths he called the change in emission lines red-shift and used the percentage of shift to determine both the velocity of galaxies and the distance of those galaxies from earth. He plotted those distances against their velocities and the slope of that line is the rate at which the universe is expanding. A rate called the Hubble Constant.

Purpose- How does the amount of red-shift determine both the distance and velocity of a galaxy? (Will farther galaxies have more or less red-shift? Will they be traveling faster or slower?)

Procedure Overview: Measure the amount of red-shift that exists in the Hydrogen emission spectra for three galaxies and use that amount to determine the distance and velocity for each galaxy. Organize in a data table.

1. Using the reference table in the Atomic Spectra Lab, determine the color of each line in Hydrogen's atomic emission spectra-then color them appropriately using colored pencils. These are the EXPECTED wavelengths based on observing Hydrogen on Earth. Repeat your coloring for Hydrogen's emission spectra as found in each of the galaxies. Note; these are all Hydrogen, how are they different?

2. All stars are made of Hydrogen. *Discuss: What is an atomic emission spectra and how is it made?* Determine the ACTUAL wavelength for shortest emission spectra line (labeled line A) in the Hydrogen spectra for each galaxy. Using a scale of 5mm = 100A measure the actual wavelength for that line and record in a data table.

3. The spectral lines for Hydrogen are not where they were expected due to motion of the stars. The Doppler effect has red-shifted them to new locations. *Discuss: are these wavelengths longer or shorter than expected? Does that mean the galaxies are traveling toward us or away from us?* Calculate the amount of wavelength shift for each line as follows:

   Wavelength shift = (actual λ – expected rest λ)

4. Red shift is exaggerated further by velocity (the greater the velocity the more the shift). Find the percentage of red-shift for line A by dividing the wavelength shift by the expected position of the line. Record as the % of red-shift.

   % Red-shift = Wavelength shift / expected position X 100

5. How fast the star is going can be determined by the percentage shift. Determine the velocity (in km/sec) of each galaxy based on their average % red-shift multiplied by the speed of light, c= 300,000 km/sec. Record for line A in km/sec

   V = (c) x (% red-shift)

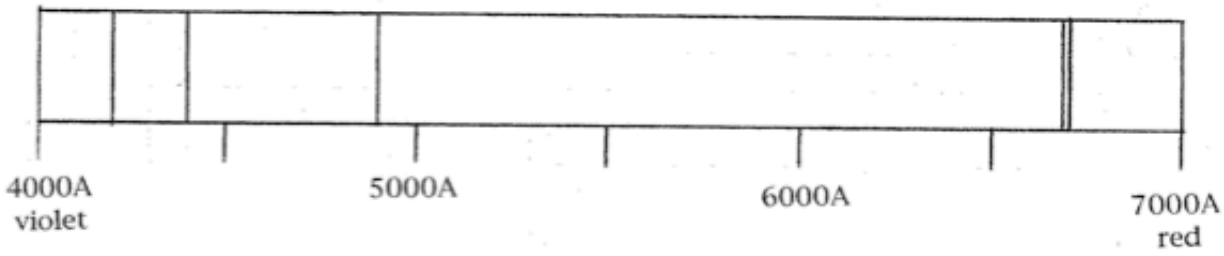
6. Farther galaxies have been found to be have greater velocities the amount of which is a measure of the rate of expansion of the universe called Hubble constant (H_0). Use the value of Hubble Constant (70Km/sec / Mpc) to determine the distance of each galaxy. Mpc= Megaparsec or 10^6 parsecs, 1 parsec is equal to 3.26 light years.

   $$\text{Distance} = \frac{V}{H_0}$$

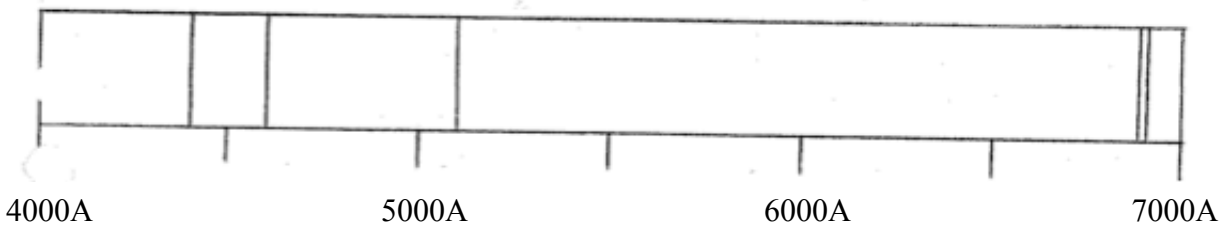
7. Graph red-shift (x axis) against velocity (y-axis). Using the same graph plot red-shift against distance creating a second y axis on the far right (a U shaped graph). Calculate the slope of the line- this should be H_0 = Hubble's Constant.

Scale 5mm = 100A

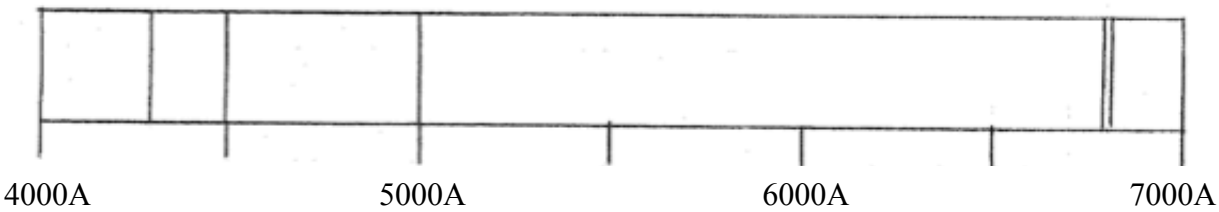
Hydrogen (on Earth)



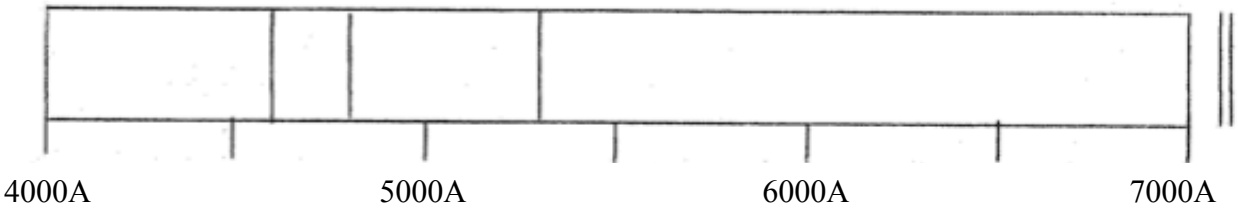
Andromeda Galaxy



Triangulum Galaxy



Hydra Galaxy



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Follow-up Q

1. What is happening to both the wavelength and frequencies of the light coming from these distant galaxies as they recede away from us? How does the Doppler effect explain the apparent change to wavelength and frequency?

2. How does velocity affect the amount of red-shift? Why? All but a couple of galaxies have a red-shift. What does this tell us about the universe? What is this idea called?

3. Red-shift doesn't only apply to the spectra in the visible portion of the EMR spectrum. The most distant, farthest and thus most red-shifted light would be in what form? Why?

4. Remember that light takes time to get here! The light from a star that is one light year away took one year to get here! How **old** is the light from Andromeda and Triangulum Galaxies? Convert Mpc to light years. 1 Mpc = 3.26×10^6 l.y Show your work.

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