**Hubble’s Law**

**Purpose:** To make a plot of velocity vs. distance of galaxies and determine the value of Hubble’s constant.

**Items:** ruler with mm scale, magnifying lenses

**Procedure:** This lab uses photograph in the “Sky and Telescope” reprint “Hubble’s Law” to determine the velocity and distance. Please estimate the measurements smaller than 1 mm to a tenth of a millimeter.

**Part I: Determine Recession velocity**

1. Determine the scale of the spectra. The spectral line **a** and **g** will serve to determine the scale of the photograph.
2. Measure and Record the distance in the spectrum, in mm between lines labeled **a** and **g**.
3. Spectral line **a** represents the wavelength of 388.87 nm and spectral line **g** represents the wavelength of 501.57 nm, determine the wavelength difference between two lines by subtracting the wavelengths given above
4. Calculate the **scale factor** on the photo by diving wavelength difference get in b) by the separation in mm get in a)

**scale factor** =\_\_\_\_\_\_\_\_nm/mm

1. The Doppler shift of K and H lines of calcium are indicated by the white arrow in the graph. Measure the **length** of white arrows in mm for five galaxies and record the data in the table.
2. Convert the length of the arrow to **Redshift** by multiplyinglength and scale factor you get in 1) c) for each galaxy and record the results in the table.
3. Calculate the recessional velocity using the following equation and record the results in the table

Velocity = (Redshift / Rest average wavelength) x speed of light

The average rest wavelength of K and H lines of calcium is 395.11 nm; speed of light in vacuum is 300,000 km/s.

|  |  |  |  |
| --- | --- | --- | --- |
| **Galaxy** | **Length (mm)** | **Redshift (nm)** | **Recessional velocity (km/s)** |
| Virgo |  |  |  |
| Ursa Major |  |  |  |
| Corona Borealis |  |  |  |
| Bootes |  |  |  |
| Hydra |  |  |  |

**Part II: Determine Galaxy Distances**

1. Determine the scale of galaxy sizes. The line at bottom of image with label 150" will serve to determine the scale factor.
2. Measure and Record the length of 150" line in mm.
3. Calculate the **scale factor** on the photo by diving 150" by the length in mm get in a)

**scale factor** =\_\_\_\_\_\_\_\_"/mm

1. Measure the **diameter** of image of each galaxy to at least to mm. Note: Because the diameter of image of Hydra is smaller than 1 mm, make sure to estimate the size to tenths of mm, you can use magnifying lenses to help with the estimation.
2. Convert the diameter to **Angular size** by multiplyingdiameter and scale factor get in 5) b) for each galaxy and record the results in the table.
3. We will assume that the galaxies in each cluster as illustrated here are about the same average size; That is about 0.03 Mpc or about 100,000 light years. If we know their actual diameter, which we just assumed, their distance can readily be determined. Calculate the distances using the following equation and record the results in the table

Distance = (0.03)x( 206,265)/Angular Size

0.03 Mpc is the average size of galaxies; 206,265 is the number of arc seconds in a radian.

|  |  |  |  |
| --- | --- | --- | --- |
| **Galaxy** | **Diameter (mm)** | **Angular size (**") | **Distance (Mpc)** |
| Virgo |  |  |  |
| Ursa Major |  |  |  |
| Corona Borealis |  |  |  |
| Bootes |  |  |  |
| Hydra |  |  |  |

**Part III: Plotting and Determining Hubble’s constant**

1. Copy column of **distance** in table of part II and column of **recessional velocity** in table of part I to Excel. Select the data, click insert, select scatter chart to plot recessional velocity on the y-axis and distance on the x-axis. Click on data points on the graph, right click to add a linear trendline and choose to display equation on chart. Label both x and y axis. Copy your graph here with the equation for the trendline.
2. Determine the Hubble’s constant from the equation on the graph. Note: the slope of the equation is Hubble’s constant.

Hubble’s constant =\_\_\_\_\_\_\_\_km/s/Mpc

1. Because the Hubble constant represents the present-day rate of the universe’s expansion, we can determine the approximate age of the universe by taking the reciprocal of Hubble’s constant H you get in 10), calculate and record the age of universe. Where 1012 converts the time units from second to year.

Age of Universe = 1/H x 1012  =\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_years

1. A very simple approximation of the universe’s radius can be obtained from the following relationship, calculate and record the radius of universe. Where 300,000 km/s is speed of light, H is Hubble’s constant you get in 10).

Radius of Universe = 300,000 / H =\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_Mpc