# Hubble's Law Lab

In 1929 Edwin Hubble showed that galaxies seem to be receding with velocities that were proportional to their distances from us.

**v = H x D**, where H is called the Hubble constant.

In this lab you will calculate the Hubble constant, and thus, the size and age of the universe!

On the next page are photos and spectra of five galaxies. (They are named by the constellations in front of them.) You can calculate their velocities from the red shift of their spectra and the Doppler equation. From the apparent size in photos and the estimated actual size of the galaxies you can calculate distances to the galaxies.

**Velocities:**

1. The horizontal white arrows in each spectrum picture show how far the Doppler effect has shifted the H and K dark lines of calcium. For each galaxy measure to the nearest 0.1 mm the length of the arrow.

2. The scale factor for these spectra is 2.15 nm (nanometer = $10^{-9}$ m) of wavelength per mm (millimeter) in the pictures. Multiply by this scale factor to find the actual wavelength shift ($\Delta\lambda$ in nm) for each galaxy. a. $1.0\,mm \cdot \frac{2.15\,nm}{mm} = 2.15\,nm$

3. Use the Doppler equation to find the velocities at which the galaxies are receding from us.

   $v_r = c \bullet \Delta\lambda/\lambda$, where $\lambda$ is the laboratory wavelength, or 395.11 nm for the average of the two calcium lines, and c is the speed of light in km/sec. a. $v = 3\times10^5 \frac{km}{s} \cdot \frac{2.15\,nm}{395.11\,nm} = 1.63\times10^3 \frac{km}{s}$

| | Galaxy | 1. $\Delta\lambda$ in photos (mm) | 2. $\Delta\lambda$ actual (nm) | 3. Velocity (km/s) | 4. Size in photo (mm) | 5. Actual angular size (radians) | 6. Distance (Mpc) |
|---|---|---|---|---|---|---|---|
| a. | Virgo | 1.0 | 2.15 | $1.63\times10^3$ | $\frac{14+11}{2} = 12.5$ | $5.21\times10^{-4}$ | |
| b. | Ursa Major | 8.7 | 18.705 | $1.42\times10^4$ | $\frac{3.3+2.8}{2} = 3.05$ | $1.27\times10^{-4}$ | |
| c. | Corona Borealis | 13.8 | 29.67 | $2.25\times10^4$ | 1.8 | $7.5\times10^{-5}$ | |
| d. | Bootes | 22.0 | 47.3 | $3.59\times10^4$ | 1.0 | $4.16\times10^{-5}$ | |
| e. | Hydra | 34.0 | 73.1 | $5.55\times10^4$ | 0.8?? | $3.33\times10^{-5}$? | |

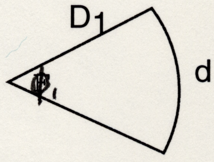
↑ yours may be slightly different

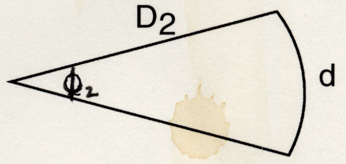
**Distances:**

4. Measure the diameters of the galaxies in the photos. If they are not circular, average the long and short diameters of each.

5. These photos are all to the same scale: 150" (angular arc in seconds) = 17.4 mm, so change to arcsec. Then change from arc seconds to radians.
   That is, multiply the average diameter in mm by (150"/17.4 mm) x ($2\pi$ radians/360°) x (1°/60') x (1'/60").
   a. $12.5\,mm \times \frac{150''}{17.4\,mm} \times \frac{2\pi}{360^\circ} \times \frac{1^\circ}{60'} \times \frac{1'}{60''} = 5.21\times10^{-4}$ radians

6. These galaxies are believed to be of type where they are all of the same actual size, 0.03 Mega parsec.
   A Mega parsec, Mpc, is a million parsecs. A parsec is the distance for which the parallax is one second, about 3.26 light years. A light year is about 6 trillion miles. So a Mega parsec is a distance of about 2 x $10^{19}$ miles.




From geometry, $\Phi$ = 1 radian when D = d.