# Lab 12
# Hubble's Law

**Exercise 1:** *(10 points)*

**(a)** Is the spectrum of the star redshifted or blueshifted?

**(b)** Calculate $\Delta\lambda$ :

$\Delta\lambda =$ _____ Å

**(c)** What is the radial velocity?

$v =$ _____ km/s

**Exercise 2:** *(15 points)*

| A<br>Galaxy Cluster | B<br>Measured shift (mm) | C<br>Redshift (Å) | D<br>Velocity (km/s) | E<br>Distance (Mpc) | F<br>Value of H (km/s/Mpc) |
|---|---|---|---|---|---|
| Virgo | 0.9 | 17.7 | 1352 | 20 | 67.6 |
| Ursa Major | | | | 110 | |
| Corona Borealis | | | | 180 | |
| Bootes | | | | 300 | |
| Hydra | | | | 490 | |

**Exercise 3:** *(15 points)*

**(a)** Find the average value of the Hubble constant.

$H =$ _____ $\frac{km}{sMpc}$

**(b)** Convert your value of $H$ into units if 1/s:

$H =$ _____ $\frac{1}{s}$

**(c)** Convert this into seconds by inverting it:

Age of the Universe = _____ s

**(d)** How many years is this?

Age of the Universe = _____ yrs

**Exercise 4:**

**(a)** If the apparent brightness (or intensity) of an object is proportional to $1/R^2$, how much brighter is an object in the Virgo cluster, compared to a similar object in Hydra? [Hint: how many times further is Hydra than Virgo?] *(2 points)*

**(b)** Using the fact that brightness decreases as $1/R^2$, how far away (in Mpc) could the Keck telescope see a supernova like the one that blew up in the Andromeda galaxy? [Hint: here we reverse the equation. You are given the brightness ratio, 6 million, and must solve for the distance ratio, remembering that Andromeda has a distance of 1 Mpc] *(2 points)*

**(c)** Could the Keck telescope see a supernova in Hydra? *(1 point)*

**Exercise 5: Questions**

1. Explain how the Doppler shift works. *(5 point)*

2. In the waterbug analogy, we know what happens to waves in front of and behind the bug, but what happens to the waves directly on his left and right (Hint: is the bug's motion compressing these waves, streching them out, or not affecting them at all)? With this in mind, what can the Doppler shift tell us about the motion of a star which is moving only at a right angle to our line of sight? *(5 points)*

3. Why did we use an average value for the Hubble constant, determined from the five seperate galaxies, in our age of the Universe calculation? What other important factor in our determination of the age of the Universe did we overlook? (Hint: It was mentioned in the lab) *(5 points)*

4. Does the age of the Universe seem reasonable? Check your textbook or the World Wide Web for the ages estimated for globular clusters, some of the oldest known objects in the Universe. How does our result compare? Can any object in the Universe be older than the Universe itself? *(5 points)*