Astro 10 **Spring 2006**

Hubble Trouble: The Expansion of the Universe[1]

The two transparencies we'll be looking at today are representations of a two dimensional universe at different times. The first transparency represents galaxies in the universe when it is young (Time I); the second transparency represents the same galaxies when the universe is somewhat older (Time II).

- We'll begin at Time I. We need to choose a galaxy in the universe to be our "home galaxy," so that we'll have a reference point. Label our home galaxy H (for Home!).

- Now that we have our "home galaxy," let's measure the distance from it in centimeters to four *other* galaxies (choose whichever galaxies you want). If you don't have a ruler, or don't have one that has centimeters, use a strip of college-ruled loose-leaf paper and measure the distances in "lines of loose-leaf paper." Label the four galaxies A, B, C, and D (where galaxy A is the closest to home and D is the furthest from home).

  Distances at Time I: A: B:

  C: D:

- Now let's do the time-warp (again) to Time II and measure the distance in centimeters (or lines of loose-leaf paper) from our home galaxy to the same four galaxies. Again label our home galaxy H and the other four galaxies A, B, C, and D. Note that these galaxies appear to have moved away from us since we last checked, so be sure that galaxy A at Time II is actually the corresponding dot to galaxy A at Time I.

  Distances at Time II: A: B:

  C: D:

- Suppose the two transparencies were snapshots of the universe taken ten years apart. Using our measured distances, calculate the recession speeds (the speed each galaxy appears to be racing away from our home galaxy) in centimeters (or lines of loose-leaf paper) per year.

  Recession speeds: A: B:

  C: D:

- Next, compare the positions of all of the galaxies at Time I with their positions at Time II. To do this, simply align the two transparencies. Note: *We* haven't moved; we're still at the same home galaxy. Thus if we want to accurately compare Time I and Time II, we need to line up galaxy H at Time I with galaxy H at Time II. Now that galaxy H is lined up on both transparencies, what do you notice about the positions of all other galaxies (relative to galaxy H) after ten years have passed?

- How does the change in distance for galaxies far from H compare to the change in distance for galaxies close to H?

[1] Thanks to Holly for much of this worksheet.

- Make a **Hubble Diagram** for our toy universe by plotting the distance to our four galaxies at Time II on the horizontal axis and the recession speed of those same galaxies on the vertical axis. Be sure to label the four points with which galaxy letter they represent and also label the actual numbers for each point on both axes (please make the scale relatively accurate).

Distance at Time II (in cm or lines of loose-leaf paper)

- Draw a straight line through the points on our diagram. What is the slope of this line? Reminder: The slope of a line is the difference in the vertical direction divided by the difference in the horizontal direction to get from a point on a line to another point on the line. Hint: The slope should be a positive number. Note: Don't cancel out common units for now.

- The slope of our line is our **Hubble constant** (H_0) which relates a galaxy's recession velocity to its distance by **Hubble's Law**: $v = H_0 * d$. What is the reciprocal of our Hubble constant (i.e. what is $1/H_0$)? Now cancel out any common units. What does $1/H_0$ represent?

- Now make a prediction: What will we see if we choose a different "home galaxy?"

- Test your prediction: Label a new home galaxy H' on both transparencies and align them on top of each other. What happens to the distances between H' and all other galaxies? What about the galaxies closest to H'? Farthest from H'?

- Keeping H' as home, what will we see if we look at an even later time (call it Time III)?