Acting Out the Expansion of the Universe
Team Milky Way

The students standing in front of you represent some nearby galaxies that have been "creatively" named by astronomers (note that these are all actual galaxy names used by professional astronomers!). As the Universe expands, you will measure their motion over time and derive what's known as **Hubble's Law**.

The *Milky Way Galaxy* will be your reference point since it's our home galaxy. Your job will be to measure how the other galaxies appear to be moving away from your home galaxy.

1. Let's begin at Time 1, when all of our galaxies are "shoulder-to-shoulder," and mark the position of each galaxy.

2. Now let's measure the distance from the Milky Way to the other galaxies (in centimeters).

   Distances at Time 1: Large Magellanic Cloud: Andromeda:
   Cigar: Pinwheel:
   Sombrero: Tadpole:

3. Now the Universe will expand some, which has the effect of "expanding the space" between galaxies. To do this, we'll have our galaxies move to arm's length from each other. Now let's mark their new positions using a different color and again measure the distance from the Milky Way to the other galaxies.

   Distances at Time 2: Large Magellanic Cloud: Andromeda:
   Cigar: Pinwheel:
   Sombrero: Tadpole:

4. Now let's say it took 1 year to go from Time 1 to Time 2. Using your measured distances, calculate the recession speeds (or the speed each galaxy appears to be moving away from the Milky Way) in centimeters per year (cm/yr).

   Recession Speeds: Large Magellanic Cloud: Andromeda:

   Cigar: Pinwheel:

   Sombrero: Tadpole:

5. How does the recession speed of galaxies farther from the Milky Way compare to the recession speed of galaxies closer to it?

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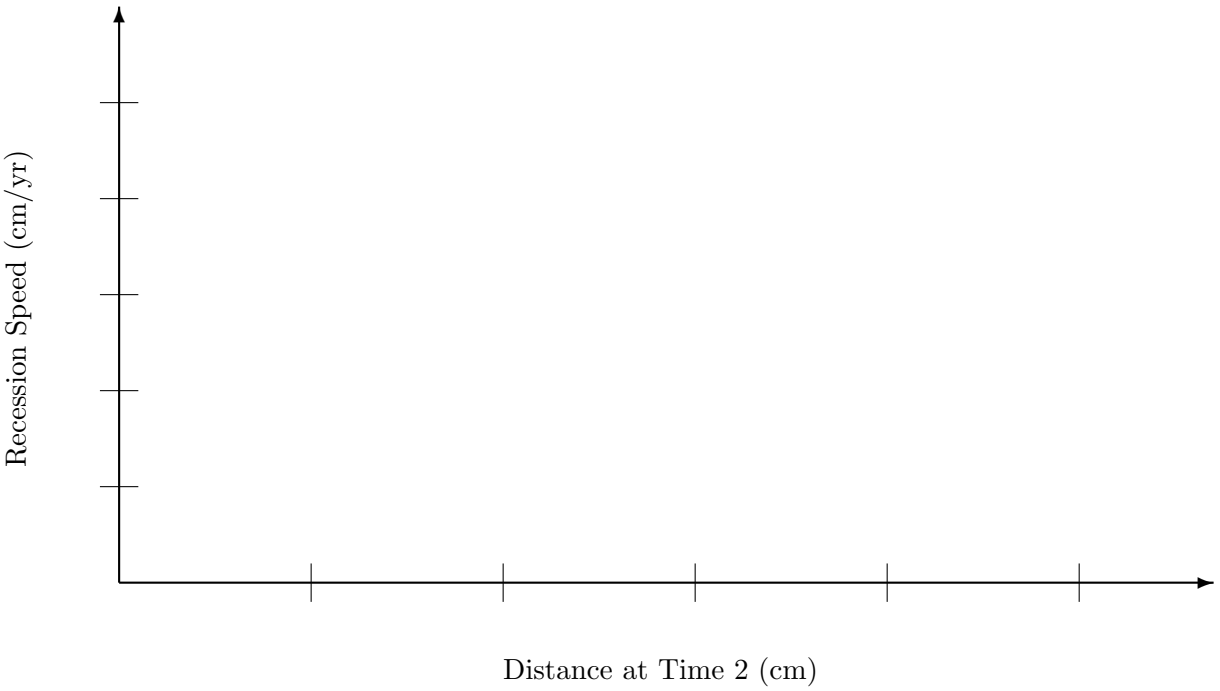
6. Now let's make a **Hubble Diagram** by plotting the distance from the Milky Way to each galaxy at Time 2 on the x-axis and the recession speed of each galaxy on the y-axis. Be sure to label actual, numerical values on both axes.



7. Now draw a straight "line of best fit" through the points on your Hubble Diagram. What is the numerical value (and units) of the slope of this line? The slope should be a positive number. Don't cancel out units for now. *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 the line to another point on the line.

8. The slope of this line is known as the **Hubble constant**, H_0. This relates a galaxy's recessional velocity (v) to its distance (d) by using **Hubble's Law**: $v = H_0 \times d$. What is the value (and units) of the reciprocal of the Hubble constant, $\frac{1}{H_0}$? Now cancel out any common units. What do you think the number $\frac{1}{H_0}$ represents?

9. Compare your observations to people who used the Tadpole as their "home galaxy". Is the Milky Way Galaxy at the center of the Universe? Is the Tadpole Galaxy at the center of the Universe? Does the observable Universe have a center?!?!