Modeling Hubble's Law Using a Balloooniverse

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Objective: To understand how the universe is expanding and how this affects the observed motions of galaxies.

Materials: Balloon, 6 hole punch holes, tape, magic markers, ruler.

Part A: Possible Pre-Lesson Questions

1. If we see all galaxies moving away from us, does that mean the we are in the center of the universe?

2. Would you expect a relationship between how far away a galaxy is and how fast it moves away from us?

3. If you tape pieces of paper on a balloon and blow it up, what will happen to the distances between the pieces of paper?

4. On the surface of a round planet like Earth, if you walked in one direction (assuming no obstacles like mountains and oceans), where would you eventually end up?

Part B: Setup

1. Blow the balloon up to about the size of a small watermelon, but **DO NOT TIE IT OFF.**

2. Using 6 "galaxies", number them 1-6 and tape them randomly to the balloon. Use small pieces of tape (otherwise you will warp space).

3. Assume we are in galaxy #1. Use a magic marker to draw straight lines connecting our galaxy with all the others (1-2, 1-3, 1-4, 1-5, 1-6).

Part C: Expanding the Universe

1. Deflate the balloon until it is about the size of a large grapefruit or until the tape begins to buckle.

2. Measure in centimeters the distance from galaxy #1 to each galaxy along the line you have drawn. This distance will be called **d1**. Record these in the table below.

3. Blow up the balloon back to the size of a small watermelon and tie it off. We will assume that the time to inflate the balloon for everyone was 10 seconds.

4. Measure in centimeters the new distances from galaxy #1 to the galaxies. This is called **d2**. Record these in the table below.

5. How fast the galaxies are moving is given by the distance traveled divided by the time taken. Use the equation:

$$v = (d2 - d1) \div 10$$

to calculate the velocity of each galaxy. Record these in the table below.

Galaxy #	d1 (cm)	d2 (cm)	v (cm/s)
2			
3			
4			
5			
6			

6. On the graph grid at the end of the lab, plot a graph of **d2 vs. v**, with d2 on the x-axis and v on the y-axis. Label the axes.

Part D: Possible Follow-Up Questions

1. Based on your graph, how does the distance to a galaxy relate to the speed it moves?

2. If you did the same measurements from a different galaxy and made a graph of distance vs. velocity, would you get the same relationship between distance and velocity as you did for Galaxy #1?

3. **Why** do more distant galaxies appear to move faster than nearby galaxies?

4. Is there anywhere on the ballooniverse while it was being blown up where you would see galaxies move toward you?

5. As your balloon universe expanded, did the galaxies move in position **on** the balloon?

6. As your balloon universe expanded, did the galaxies change in size?

7. What parts of your balloon universe **did** change?

8. If you walked forward in a straight line on your ballooniverse, what would happen?

9. Ignoring where you blow up the balloon, on its surface, is there any place that is at the "middle" of the surface (that is, some special place that is different from the rest)?

Graph of Distance vs. Velocity For Galaxy #1