Modeling the Expansion of the Universe

Part of a Series of Activities in Cosmology
to Accompany the chart
The History and Fate of the Universe

Student Version

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Modeling the Expansion of the Universe

Materials needed: elastic (approx. 1" wide and 30 cm long), meter stick, pen

Procedure: Part I

1. Cut a piece of elastic to a length of approximately 30 cm. (A rubber band may be used in place of the elastic, but the initial length and distances may need to be scaled down.)
2. Without stretching the elastic, flatten the elastic next to a meter stick. Place small dots (galaxies) every 5 cm (at 5, 10, 15 and 20).
3. While keeping the line of galaxies next to the meter stick, hold *Galaxy a* at the 5 cm position. *Galaxy a* will be considered the "observer's galaxy". While holding *Galaxy a* at the 5 cm position, stretch the elastic (from the opposite end) until *Galaxy b* (nearest the "observer's galaxy") has traveled 1 cm (time 1). Note the positions of each of the galaxies on the chart below.
4. Stretch the elastic again so that *Galaxy b* has traveled 2 cm (time 2).
5. Try again for 3 cm (time 3).

Galaxy	X_0 Position at time 0 (cm)	X_1 Position at time 1 (cm)	Distance moved (X_1-X_0) (cm)	X_2 Position at time 2 (cm)	Distance moved (X_2-X_1) (cm)	X_3 Position at Time 3 (cm)	Distance moved (X_3-X_2) (cm)	Average distance moved (cm)
a	5	5	0	5	0	5	0	0
b	10	11	1	12	1	13	1	1
c	15							
d	20							
e	25							

Analysis and Discussion: Part I

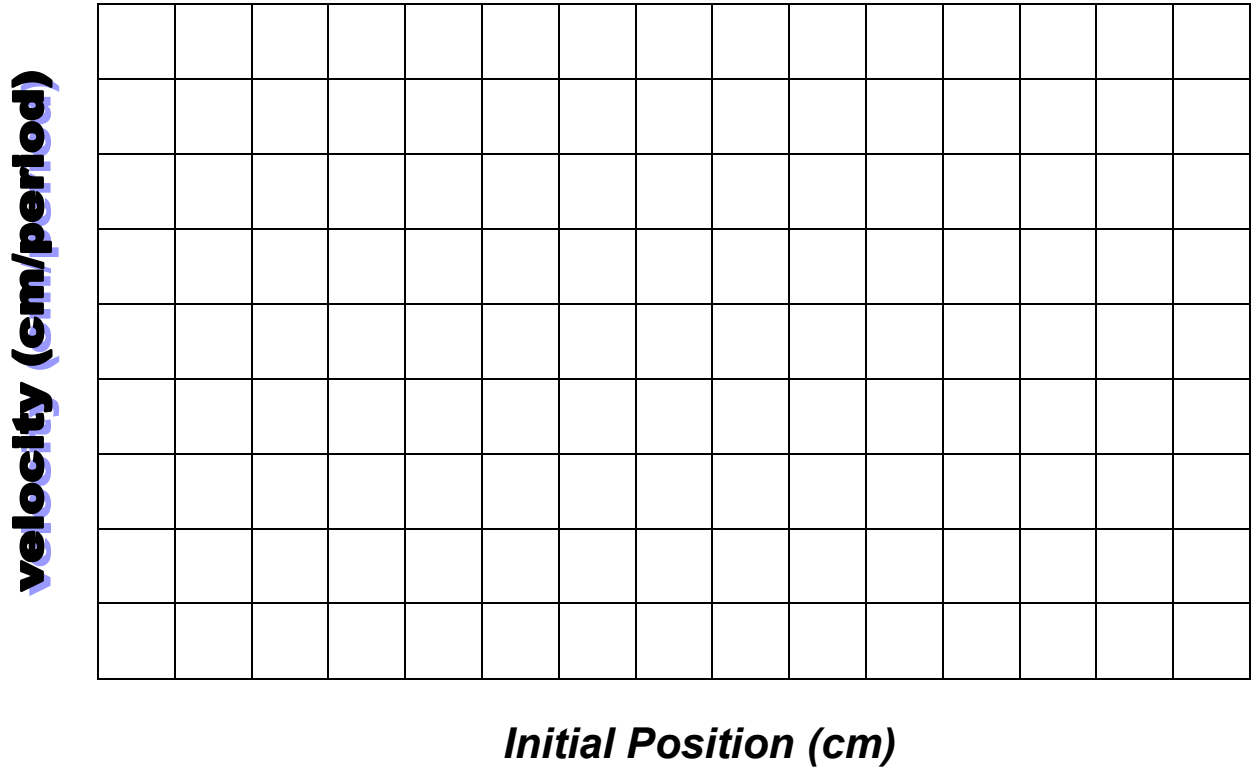
1. Is there a pattern in the distances the galaxies moved? Describe.

2. Predict the type of pattern that would be observed if another galaxy was chosen to be the observer's galaxy.

3. How do the speeds of the galaxies (distance moved per time period) relate to the position?

4. The galaxies farther away from the observer's galaxy move _____ those close to the observer's galaxy.
   a. faster than
   b. slower than
   c. the same speed as
   d. unrelated to

5. Using your data from Part I, plot the initial positions (X_0 values) on the x-axis and the average distance moved per time period (the velocity) on the y-axis.



According to Hubble's Law ($v_r = H_0 \times d_G$ where v_r is the velocity of recession, H_0 is the Hubble constant, and d_G is the distance to the galaxy) the speed at which galaxies move away from each other is proportional to their distance. v_r / d_G (or the slope of the velocity vs. distance graph) is the Hubble constant. Hubble's value of the slope was approximately 500 km/s/Mpc. The current value is approximately 72 km/s/Mpc.

6. What was the value of slope for your universe (your Hubble constant)? _____cm/period/cm

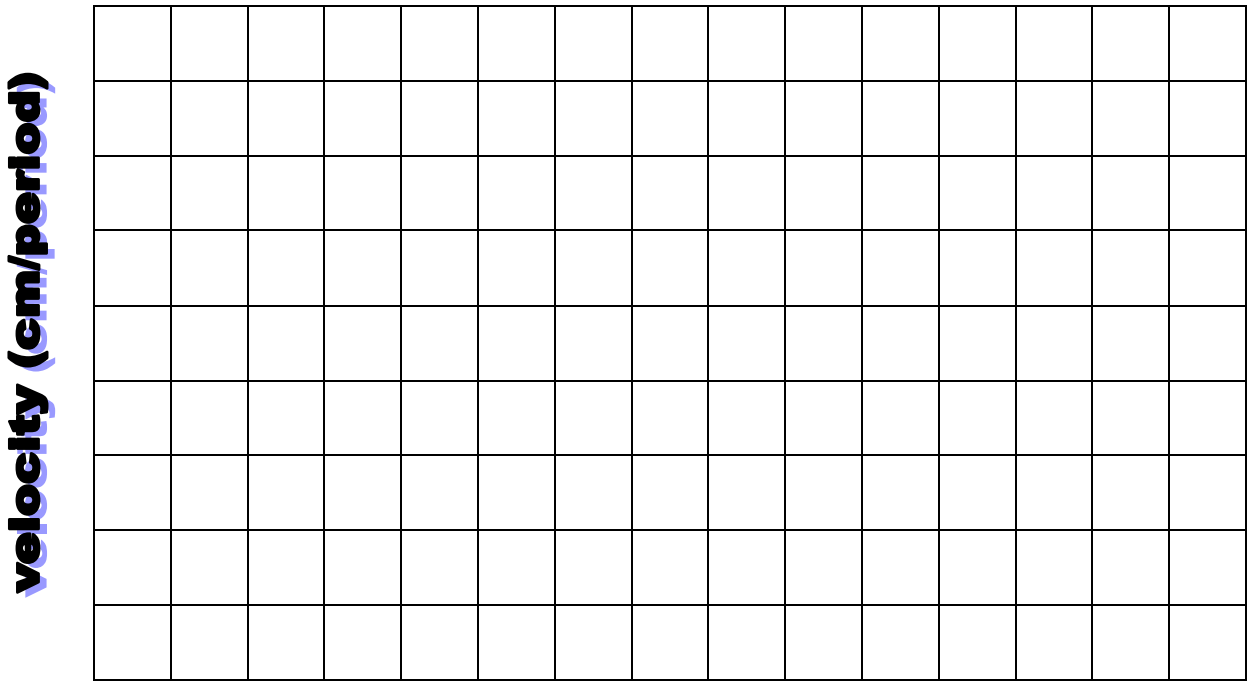
Procedure: Part II

Select *Galaxy b* to be the "observer's galaxy". Repeat steps 3, 4, and 5. You may need a partner to hold *Galaxy b* stationary while you stretch the ones on either side.

Galaxy	X_0 Position at time 0 (cm)	X_1 Position at time 1 (cm)	Distance moved (X_1-X_0) (cm)	X_2 Position at time 2 (cm)	Distance moved (X_2-X_1) (cm)	X_3 Position at Time 3 (cm)	Distance moved (X_3-X_2) (cm)	Average distance moved (cm)
a	5	4	-1	3	-1	2	-1	-1
b	10	10	0	10	0	10	0	0
c	15	16	1	17	1	18	1	1
d	20							
e	25							

Analysis and Discussion: Part II

1. Using your data from Part II, plot the initial positions (X_0 values) on the x-axis and the average distance moved per time period (the velocity) on the y-axis.



2. What was the value of slope for your universe (your Hubble constant)? _____cm/period/cm

3. Did the expansion of the universe look different when we changed our viewing location?

4. Considering your answer to the question above, is our location "special"? Are we at the center of the expanding universe?

5. Sketch four small graphs showing:

    a. no expansion.

    b. constant rate of expansion.

    c. rate of expansion is increasing.

    d. rate of expansion is decreasing.

9. Explain in terms of the graph, how the universe can have an expansion rate that is decreasing but still be expanding.