Expansion of the Universe: Name

**Summary**

In this exercise, you will use a two-dimensional, the surface of a balloon, to explore the expansion of the Universe.

**Equipment Needed**

1. Light colored balloon,

2. Ink pen or marker,

3. String, ruler, or fabric tape measure

**Background and Theory**

The origin of the universe remains one of the greatest questions in science. The "big bang" theory places the origin between 12 and 14 billion years ago, when the universe began in a hot dense state; according to this theory, the universe has been expanding ever since.

The universe has 4 dimensions: height, width, depth, and time. They are bound together as space-time.  As the universe expands, the view from any one place in the universe remains the same.  It is homogeneous and appears linear in its progression. The Hubble Law states that the recessional velocity of a galaxy is proportional to its distance from us.  The velocity of the moving body is measured using the Doppler Effect or spectral line shift.  The distance is more difficult to measure.  It is measured by its apparent angular size or brightness of objects.

Using observable evidence Hubble Law tells us that our Universe is expanding. We observe galaxies, find their distances and their velocities, and find that they are all moving away from us. The more distant the galaxy, the faster it is moving away. The observed relationship between galaxy recession velocity and distance is linear: *v* = *H d,* where v is the velocity a galaxy appears to move away from us, d is its distance measured in *megaparsecs*; 1 Mpc = 1 million parsecs, and H is the Hubble constant. From this information, we can estimate the age of our Universe. If we assume that the Universe has always been expanding at the same rate, then we know how long distant galaxies have been traveling in order to get where they are today.

**Procedure**:

1. Draw nine galaxies (dots) on the balloon (away from the valve on the inflatable part of the balloon). Mark one of these galaxies as the “home” galaxy, number the remaining galaxies 1 through 8. The “home” galaxy will be the galaxy that *you* live in and are making your measurements from.

2. Blow up the balloon until the diameter is 40 cm. DO NOT TIE IT SHUT! Pinch and fold over the stem use a paper clip to keep the air from escaping. The diameter represents time of expansion for our experiment.

3. Measure the distance between the “home” galaxy and each of the numbered galaxies use millimeters as your unit of measure. The easiest way to do this is to use a piece of string. Stretch it between the two points on the balloon, then measure the string. Record these data, including units, in the row “Distance (mm) at time = 40 years”.

4. Blow up the balloon, until the diameter is 60 cm. Re-clip the balloon to prevent the air from escaping. Measure the new distance in millimeters from between the “home” galaxy and each of the numbered galaxies. Write the results in the data table in the row “Distance (mm) at time = 60 years”

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Points on the Balloon** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Distance (mm) at time = 40 years |  |  |  |  |  |  |  |  |
| Distance (mm) at time = 60 years  x-axis |  |  |  |  |  |  |  |  |
| Distance increase (mm) |  |  |  |  |  |  |  |  |
| Rate of distance increased (mm/yr)  y-axis |  |  |  |  |  |  |  |  |
| Predicted distance at time = 70 years |  |  |  |  |  |  |  |  |
| Measured distance at time = 70 years |  |  |  |  |  |  |  |  |

5. Subtract the distances at time = 40 years from the distance at time = 60 years. Record the results in the row “Distance increase (mm).”

6. Assume that the distance measurements were actually taken 20 years apart. Compute the average speed that each point is moving away from the “home” galaxy. Record your answer

in the row “Rate of distance increased (mm/yr)”. Hint: the average speed = total distance ÷ total time.

7. Make a scatter plot of the data from your calculations. Label the x-axis with “Distance at time = 60 years”. Label the y-axis with the “Rate of distance increased (mm/yr)”. Draw a best fit line from the points on the scatter plot. Use a ruler to draw a straight line through the center of the band of points on the graph, so that approximately as many points lie above the line as lie below it. Make sure your line starts at the origin.



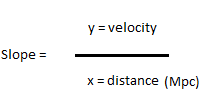
8. Using the results you found in “Rates of distance increase” predict how for each point on the balloon may be from the “home” galaxy at 70 years. Assume the balloon will expand at the same rate as it did between 40 and 60 years. Record your predictions in the row “Predicted distance at time = 70 years”.

9. Unclip your balloon and inflate to the diameter of 70 cm. Re-clip your balloon to keep the air from escaping.

10. Use your string to measure the new distances between the “home” galaxy and the other points on the balloon. Record the data in the row “Measured distance at time = 70 years”.

**Analysis and Conclusions**

1. Calculate the slope of the best fit line in your scatter plot. What are the units for the slope of the best fit line? Measure the slope by choosing two points on the line and dividing the speed at that point by the distance. (This value is **H** or what is referred to as the Hubble Constant)

To find the slope, you use the following formula:

1. What value did you obtain for your Hubble Constant?

Include units on your answer. \_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. If the dots represent galaxies, do they get larger as the balloon expands?  Why do you think this is or is not so?
2. What relationship exists between the speed of the galaxies moving apart and their initial distance from one another?
3. If you had picked another galaxy to be your "home galaxy" would your results be different?
4. If the balloon itself represents space, what's really moving? The galaxies or space?