ASTRONOMY LABORATORY

THE INCREDIBLE EXPANDING RUBBER BAND[1]

I. Objectives

To investigate the expanding universe and understand how Hubble's Law describes not only the expansion of the universe, but also how it can be understood by applying it to a more "down to earth" situation.

II. Procedure

- Work in groups of two[2]
- Group member #1 will act as the "stretcher"
- Group member #2 will act as the "measurer and recorder"

III. Equipment for each group

- 1 rubber band with several black marks on it (the marks will be referred to as *mark 1*, *mark 2*, ... — from one end of the rubber band to the other).
- 1 ruler
- 1 piece of graph paper for each group member

IV. Experimental steps

1. One group member holds the *unstretched* rubber band flat, while the other records the distances between *mark 1* and all of the other marks on the rubber band (i.e. the distance from *mark 1* to *mark 2*, *mark 1* to *mark 3*, etc.).
2. Slowly the "stretcher" stretches the rubber band until the distance between *mark 1* and *mark 2* doubles (i.e. if it was 1cm then stretch until it becomes 2cm).
3. While the rubber band is stretched, carefully remeasure the distances between *mark 1* and all the other marks as in step 1.
4. Calculate the change in the distance for each point (this will be the total distance the point traveled while the rubber band was stretched)

$$\text{Change in Distance} = (\text{Stretched Distance}) - (\text{Original Distance})$$

5. Calculate the speed each of the points traveled at to get to their new (stretched) positions assuming that it took the "stretcher" 2 seconds to stretch the rubber band and the distance the point traveled is equal to the change in distance just calculated in step 4.

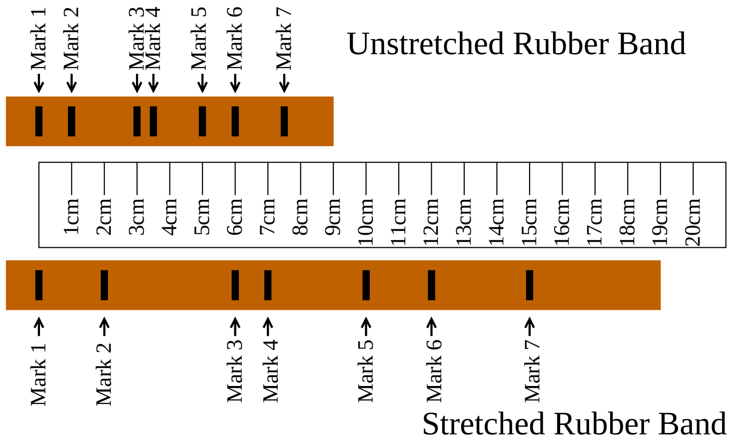
$$\text{Speed} \quad = \quad \frac{\text{Distance traveled}}{\text{Time it took}}$$

[1] Written by M. Stark, modified Feb 2005 by M. Stark.

[2] Modification for individual use: Instead of doing this activity in groups of two, it can be done individually by stretching the rubber band around a hard, flat object such as a book.

6. Example

- Given the following setup:



- These are the values recorded and calculated:

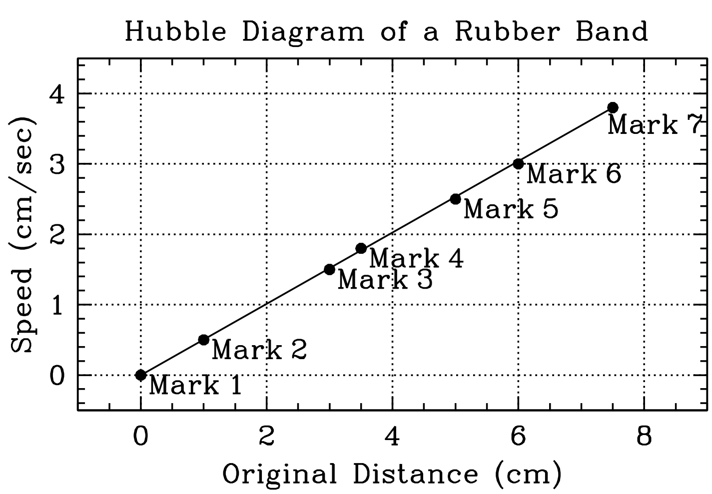
Point Number	Original Distance	Stretched Distance	Change in Distance	Speed
1	0.0 cm	0.0 cm	0.0 cm	0.0 cm/sec
2	1.0 cm	2.0 cm	1.0 cm	0.5 cm/sec
3	3.0 cm	6.0 cm	3.0 cm	1.5 cm/sec
4	3.5 cm	7.0 cm	3.5 cm	1.8 cm/sec
5	5.0 cm	10.0 cm	5.0 cm	2.5 cm/sec
6	6.0 cm	12.0 cm	6.0 cm	3.0 cm/sec
7	7.5 cm	15.0 cm	7.5 cm	3.8 cm/sec

V. Creating a “Hubble Diagram” and finding “Hubble’s Constant” for the rubber band

1. Create a plot of Speed (cm/sec) vs. Original Distance (cm), with “Speed” on the y-axis and “Original Distance” on the x-axis. Label all your points.

2. Draw a single straight line through all of the points in your Hubble Diagram that best fits the points (NOTE: it just has to go past all of the points as close as possible to them, but it does not have to touch all of them).

3. For the example given above, the Hubble Diagram would look like the following:



4. "Hubble's Constant" for the rubber band is equal to the slope of the line you just drew through the points. To find the slope of a line:

   (a) Choose two points widely separated on the line

   (b) Find the x- and y-coordinates of each of these points — point 1 (x_1, y_1), and point 2 (x_2, y_2)

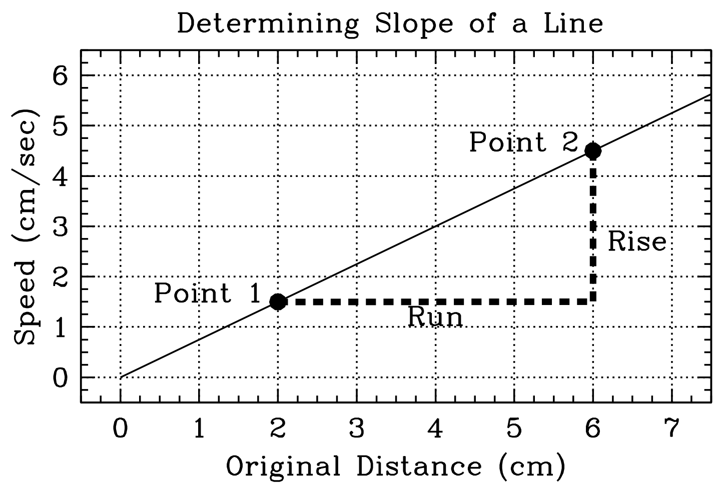
   (c) Find the "Rise" and "Run":

$$\text{Rise} = y_2 - y_1$$
$$\text{Run} = x_2 - x_1$$

   (d) Find the slope of the line:

$$\text{Slope} = \frac{\text{Rise}}{\text{Run}}$$

   (e) For example:



In this example the two points marked are:
point 1 = (2.0 cm, 1.5 cm/sec)
point 2 = (6.0 cm, 4.5 cm/sec)
Then. . .
Rise = 4.5 cm/sec – 1.5 cm/sec = 3.0 cm/sec
Run = 6.0 cm – 2.0 cm = 4.0 cm
So the slope of the line would be:
Slope = (3.0 cm/sec) ÷ (4.0 cm) = 3/4 cm/sec/cm or 0.75 cm/sec/cm
(NOTE: the slope has units!!! cm in the units actually cancel out leaving 1/sec or "per sec", I've left cm in for a reason that should become obvious when you do the lab).
For this example the value of "Hubble's Constant" (H) would be: H = 0.75 cm/sec/cm — this number describes how the rubber band expanded, much like the real Hubble's Constant describes how the universe is expanding.

VI. Questions

1. How did the distances of all the points from *mark 1* change when you doubled the distance between *mark 1* and *mark 2*?

2. Which points "moved" the fastest relative to *mark 1*? (which had the largest speed?)

3. What would have happened to this experiment if we had chosen a different mark on the rubber band to be *mark 1*? Would the results be the same or different? Why?