STUDENT WORKSHEET

THE EXPANDING UNIVERSE

Part 1

A rubber band universe

1. Make a model universe from rubber bands and washers, as shown in the photo. Each washer represents a different galaxy.
2. Choose one washer to be our galaxy, the Milky Way. Label it with a sticker.
3. Make up names for the other galaxies in your model. Label the galaxies with stickers, and write the names in column 1 of the table below.
4. Put your model on a card. Use pins to fix it in a line. Do not stretch the rubber bands.
5. Measure the distance from the Milky Way to one of the other galaxies. Write the distance in column 2 of the table.
6. Convert the distance in cm to distance in 100 million km. Write the converted distance in column 3 of the table.
7. Repeat steps 5 and 6 for all the other galaxies.
8. Take the pins out. Stretch your universe until its length doubles. Pin it back on the card.
9. Repeat steps 5 and 6 again. Write the distances in columns 4 and 5.
10. Use subtraction to calculate the change in each distance from the unstretched to the stretched universe. Write the changes in column 6.
11. Calculate the speed at which each galaxy is moving away from the Milky Way. Use the formula below, and assume that the stretching required 10 seconds. Write the speeds in column 7.

$$\text{speed} = \frac{\text{distance in km}}{\text{time in s}}$$

COLUMN 1	COLUMN 2	COLUMN 3	COLUMN 4	COLUMN 5	COLUMN 6	COLUMN 7
Galaxy name	Unstretched distance from Milky Way		Stretched distance from Milky Way		Change in distance	Speed
	in cm	in 100 million km	in cm	in 100 million km	in 100 million km	in millions of km/s
Milky Way	0	0	0	0	0	0

Part 2

Hubble's law graph

Edwin Hubble was an American astronomer. In 1929 he used newly-obtained data to plot a graph to show that the universe is expanding. This tells us that the universe started from a single point and expanded outwards to the size it is today. We can use the graph to calculate the age of the universe.

Hubble worked out Hubble's Law:

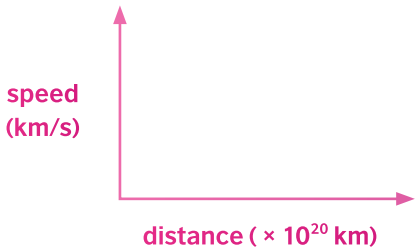
speed = Hubble constant × distance

The table shows data for six galaxies.

Galaxy	Distance ($\times 10^{20}$ km)	Speed (km/s)
NGC 3627	3.1	750
NGC 1357	7.7	2100
NGC 4775	8.2	1900
NGC 3147	13.6	2550
NGC 6745	19.7	4250
NGC 554	22.1	5200

Data from the Perimeter Institute for Theoretical Physics

- Plot a Hubble's Law graph to show the data in the table above, for the real galaxies listed. Label the axes as shown below. Draw a line of best fit through your points.
- Plot a Hubble's Law graph to show the data in your table, for the rubber universe.
- Label the x-axis unstretched distance (in 100 million km) and label the y-axis speed (in millions of km/s). Draw a line of best fit through your points.



Extra activities

1. Calculate the gradient of the graph for real galaxies.
   This is equal to Hubble's Constant, H_0.
2. Find the reciprocal of Hubble's Constant, $\frac{1}{H_0}$. This is the age of the Universe in years.

Practical or investigation

Mathematical task