BRITISH COUNCIL

Science in schools: **The Expanding Universe**

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This unit provides opportunities for your students to learn about the way the universe expands, and how this leads to more distant galaxies moving away from us faster.

As part of the activities, students can:

- Create a simple hands-on model of the universe.
- Take measurements leading to calculations of the speeds of galaxies.
- Graph their measurements, and/or real galaxy data.
- Use their graph(s) to calculate the age of the universe.

Preparation needed

You will need:

- Rubber bands of different lengths.
- Metal washers of different sizes, pins and board or thick card.
- Small coloured stickers to identify the galaxies.
- Rulers, pencils, and tape measures.
- Graph paper.
- Access to the internet.

You will need to:

- Photocopy the table – at least one per group.

Main Vocabulary

- Galaxy, distance, speed, universe, expand, size, washer, rubber band, million, billion

Age range: 14-18

Curriculum Links: Science – Physics, Cosmology, Maths, Art and Design

Objectives:

- To understand how the expansion of the universe leads to increasing galaxy speed at greater distance, and the illusion of Earth being at the centre of the universe.
- Practise simple measurement and scale conversions.
- Practise speed calculations.
- Learn some technical terms in space science and develop transferable skills.
- Draw graphs of galactic speeds versus distance.
- Use their graphs to calculate the age of the universe.

Learning Focus: The expanding universe.

Language Functions: Describing, naming, asking and answering questions.

Background Information

In 1929, Edwin Hubble surveyed many galaxies and discovered graphically that the speed they move away from us is proportional to their distance from us. This revolutionised our view of the development and age of the universe, and led to the concept of the Big Bang.

The Hubble telescope © Shutterstock

Activity 1: Make a rubber band universe

Divide your class into pairs or small groups. Give each group a selection of elastic bands and washers. Ask them to work collaboratively together to build their own 'universe' in which a number of 'galaxies' (washers) of different sizes are connected together with different distances (rubber bands) between them. Rubber bands should be held taut but not stretched as can be seen in the photograph.

Rubber band universe © British Council

Invite each group to choose one of the metal washers to be our galaxy – The Milky Way and mark it with a pen or sticker so they remember which one it is. Mark all the other galaxies with names, or numbers and record them in a column on a grid as shown on the next page.

Ask each group to lay their rubber universe out in a line, fix it in position, and measure the distance from The Milky Way to each other 'galaxy'. Depending on the age and attainment of your students, you might ask them to use an appropriate scale such as 1 cm = 1 km, or 1 cm = 100 million km. The older students could use 1 cm = 10^{20} km. Record this in column 2 of their grid.

Galaxy name	Start distance from Milky Way km	Final distance from Milky Way km	Change in distance km	Speed km/s

Tarantula Nebula ©NASA and the Hubble Heritage Team

Activity 2: Measuring the expansion of the universe

If you pull at each end of your string of 'galaxies', space time will stretch, and you can see how the universe expands – with every galaxy getting further away from every other galaxy. It does not matter which galaxy we live in, they all move further away from us.

Ask your students to stretch their rubber universe to twice its original size and fix it into a new position. Depending on the age of the students you could say the expansion took ten seconds, 30,000,000 seconds (approximately one year), or one billion years (and they must convert into seconds). The timescale used will impact on the difficulty of the speed calculations for the galaxies.

Invite each group to then re-measure the distances from the Milky Way to the other galaxies and note the new distances. Then they subtract to find the change in distance and record these on their grid in columns 3 and 4.

Challenge them to then calculate the speed at which each galaxy is moving away from us using the formula.

$$\text{Speed} = \frac{\text{Change in distance}}{\text{Time}}$$

Write these speed answers in the final column in the table.

Astronomers have used this method, with real galaxies, to find out that our universe is 13.8 billion years old.

Hubble's Law Graph

Edwin Hubble, an American astronomer first plotted a graph in 1929, to show that the universe is expanding. This tells us that the universe started from a single point and expanded outwards to the size we see today. The graph allows us to calculate how old the universe is.

He developed Hubble's Law:
speed = Hubble constant x distance
$v = H_0D$

Here is some data for six galaxies.

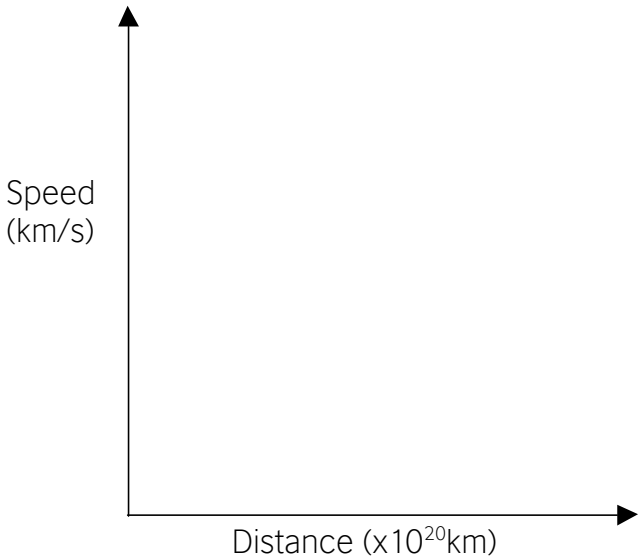
Galaxy	Distance ($\times 10^{20}$ km)	Speed (km/s)
NGC 3627	3.1	750
NGC 1357	7.7	2100
NGC 4775	8.2	1900
NGC 3147	13.6	2550
NGC 6745	19.7	4250
NGC 554	22.1	5200

Data from the Perimeter Institute for Theoretical Physics

Plotting the expansion of the universe

Ask your students to plot a graph to show this datawith distance on the horizontal axis and speed on the vertical axis.

Hubble's Law Graph of the rubber universe



Draw a line of best fit through the points and repeat the activity for your rubber galaxies.

Hubble's Law Graph – activity sheet

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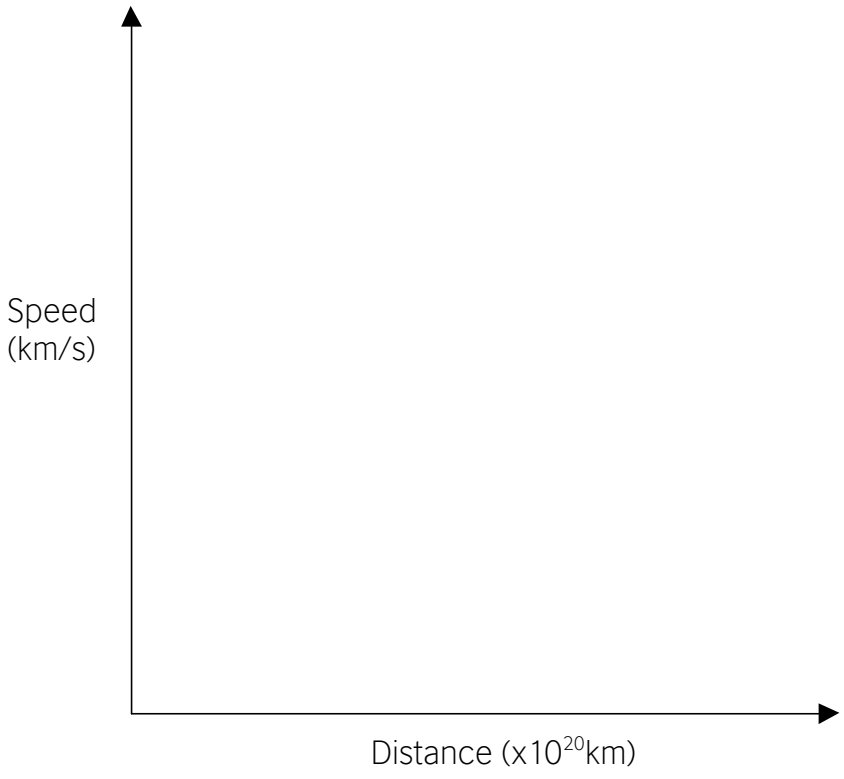


Draw a line of best fit through the points and repeat the activity for your rubber galaxies.

Additional activities

Measuring the age of the universe

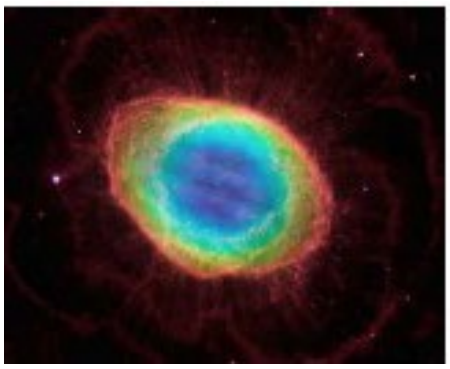
As an additional activity you could encourage your students to measure and write down the values you will need to calculate the gradient; then calculate it.

The gradient is equal to Hubble's constant, H_0.

- Find the reciprocal, $1/H_0$, which is equal to the age of the universe in seconds.
- Age of Universe = $\frac{1}{H_0} = \frac{1}{\text{gradient}}$
- Use the answer to calculate the age in years (1 year= 31,536,000 seconds).

The Hubble Space Telescope was launched in 1990 and orbits the Earth. Its position above the atmosphere gives it an amazing view of the universe from where it sends back spectacular pictures of stars, galaxies and nebulas. Encourage your students to look at some of the images taken in the Hubble Gallery at http://hubblesite.org/gallery

Ask them to choose one, make notes about what is portrayed and then recreate or interpret the image in a media of their choice.



Ring Nebula

Horsehead Nebula

Interacting galaxies

Large Magellanic Cloud

Sombrero Galaxy

Star-forming region

Partner School Activities

If you are working with a partner school you could:

- Exchange photographs of your rubber universe creations and Hubble Telescope inspired artwork.
- Carry out further research and write a paragraph about The Expanding Universe and swap with students at your partner school. It could start with the following... The universe is expanding. We see that every galaxy looks like it is moving away from us, and it does not matter which galaxy we choose. The speed that they move away from us ...

Further information can be found at:

- Canada's Perimeter Institute pages for teachers and students at: https://www.perimeterinstitute.ca/outreach
- Explanation of ideas by the BBC: www.bbc.co.uk/science/space/universe/questions_and_ideas/hubbles_law
- Explanations of ideas by the American Institute of Physics: https://www.aip.org/history/cosmology/ideas/expanding.htm
- Ideas for teachers from the Institute of Physics: http://tap.iop.org/astronomy/index.html
- http://hubblesite.org
- https://principia.org.uk – This link brings you all the news about Tim Peake's mission to the International Space station and information on how schools can follow the progress of the mission and get involved.

Credits
This education pack was curated on behalf of the British Council by Miles Hudson and Alison Willmott. With thanks to the scientists, researchers and engineers from the institutions that provided the original resources: Bradford University, Durham University, University of Hertfordshire, Newcastle University, The Royal Institution and the Airbus Group.