

Amazing space!

Workshop introduction

This is a workshop about the nature of the Universe and how scientists today are extending Einstein's work to investigate the birth, life and possible end of the Universe.

The workshop consists of three main parts. There are also three extension activities that can be used to lengthen or change the content of the workshop. The extension activities can be found at the back of these notes.

Time requirements

Main workshop:

- introduction: 5 minutes
- activity 1: 10 minutes
- activity 2: 15 – 20 minutes
- discussion: 10 minutes
- activity 3: 10 -15 minutes
- summary: 5 minutes

Extension activities:

- extension 1: 10 minutes
- extension 2: 5-10 minutes
- extension 3: 5 minute demonstration

Materials

The following materials are provided in the kit box:

- 18 galaxy pictures today on a transparency
- 18 galaxy pictures 2.5 billion years ago on paper
- 70 balloons
- 18 marker pen
- 16 tape measures

For extension activity 2 there are plastic rulers and for extension activity 3 there are two clamp stands, clamps, wooden bars and a variety of weights.

Preparation

- 1 Photocopy galaxy picture today onto transparencies if more are needed.
- 2 Photocopy galaxy picture 2.5 billion years ago onto paper if more are needed.
- 3 Get balloons and permanent marker pens ready (one per pair of students).
- 4 Get the material tape measures or flexible rulers ready.
- 5 Print out student worksheet for balloon activity (one per pair of students).
- 6 Print out graphs (one set of 4 per pair of students).
- 7 Print out table of exo-planet data (one per pair of students)
- 8 Print out diagram of wobbling stars! (one per pair of students).

Introduction

This year marks the 100th anniversary of the work of a very special scientist. Ask the students to name some scientists and lead them towards Albert Einstein.

Briefly introduce the idea that Einstein worked on a theory which describes gravity and the Universe.

This workshop teaches the students how scientists study the Universe and the techniques that they use.

Activity 1

Ask the students what is out there in the Universe. Lead them through stars, gas, dust, planets to the idea that there are thousands of millions of galaxies. (A galaxy is a collection of thousands of millions of stars held together under gravity.)

Show the students the picture of the galaxies as they were 2.5 billion years ago and the picture today. Split the students into pairs and hand out an image and a transparency to each pair and ask them to overlay them and consider the following questions. Give them 5 minutes.

- How are the galaxies moving with respect to each other?
- Have they all moved the same distance?
- Is there a centre?

The answers are:

- The galaxies are all moving away from each other.
- If you pick a centre, the galaxies further away have moved more.
- There is no real centre to the expansion. If you move the overlay around you can choose your centre!

Main points:

Astronomers have seen that the Universe is expanding and that galaxies further away from our own galaxy, the Milky Way, have moved more, but they do not think about there being a centre to the expansion.

Activity 2

The fact that galaxies further away from a given point move more than those closer is just a consequence of the expansion of space, and this activity will demonstrate this phenomenon with a balloon.

Give each pair of students a balloon, tape measure or flexible ruler and one 'Expanding space' worksheet to record their results.

Get the students to take a balloon and inflate it to about the size of their fist. Then get them to mark on 4 dots in a cluster or a line near the middle of the balloon. Mark the dots 1-4 in order.

With the tape measure calculate the distances from dot 1 to the other 3 dots and record the distances under the column 'Partially expanded balloon' on the worksheet.

After this inflate the balloon (but don't pop it!) and make the same measurements again and record them in the column 'Inflated balloon'. In the final column calculate the distance that each dot has moved away from dot 1.

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Sample data

Distance between dots	Partially expanded balloon (cm)	Inflated balloon (cm)	Distance moved (cm)
Dot 1 and dot 2	2	3	1
Dot 1 and dot 3	2	4	2
Dot 1 and dot 4	2	6	4

Main points

This activity shows that the dots on the balloon further away from dot 1 move more. This is just a consequence of the expansion of space. It happens with the balloon and in the Universe! Imagine if the tape measure was to expand and each 1 cm became 1.5 cm. A dot 1 cm away would move by 0.5 cm away. But a dot 5 cm away would move by 5 times 0.5 cm.

Einstein predicted that the Universe is expanding but thought that it couldn't possibly be true. So he added an extra factor into his equations to make the Universe static!

Extension activities

Extension 1 – How old is the Universe?

Extension 2 – Size of the galaxies

Discussion

What we have learnt so far is that the Universe is expanding. A natural question to ask now is whether the Universe will continue to expand forever? To be able to answer this we need to know how much 'stuff' there is in the Universe.

Ask the students what is holding the galaxies together? Lead them towards gravity. Gravity is the glue that holds things together on the large scale. The more mass there is, the stronger the pull of gravity is. The more gravity there is in the Universe pulling on the galaxies, the more likely it is that in the future the expansion of the Universe may slow down or even stop.

In this discussion lead the students into realising that scientists have discovered that we can only see 4% of the Universe! That is stars, galaxies and anything that shines. The other 96% is made of matter that does not shine and we cannot see. This kind of material is called Dark Matter. The amount of Dark Matter (and so pull of gravity) out there will dictate what will happen to the Universe.

Lead the students into a question and answer session where you talk about the Solar System and what would be considered Dark Matter and what wouldn't. The only light source is our Sun and everything else is seen by reflected light. The planets could be considered to be Dark Matter.

Other forms of Dark Matter include objects from massive black holes to tiny particles that we still don't fully understand.

Activity 3

In this activity students will use real data to learn how astronomers detect planets that they cannot see.

A planet orbiting around another star is very hard to detect against the glare of the star. It is a bit like trying to see a grain of sand in a car headlight from 100,000 miles away!

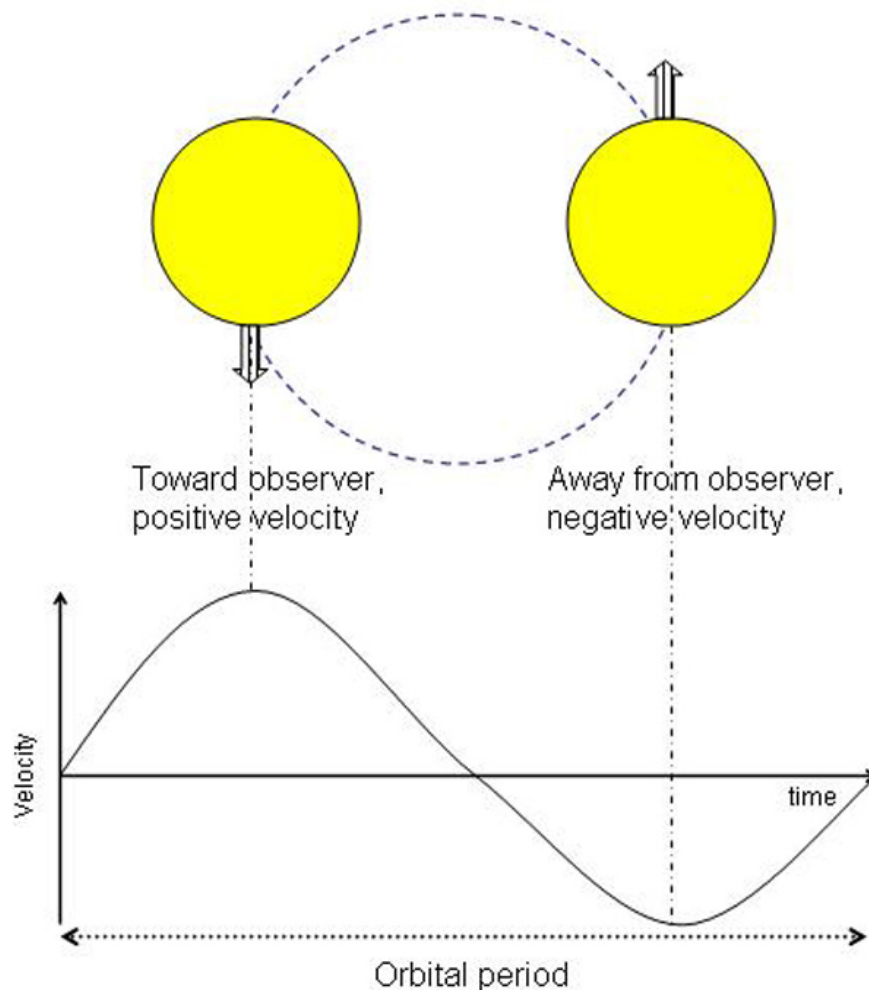
Workshop notes

Because we cannot see them directly we have to do some detective work. The star pulls on the planet orbiting it because of gravity. But the planet also pulls on the star; the larger the planet, the larger the pull. In fact, the planet pulling on the star makes the star do its own little circle in space too. So, if a star is wobbling in space it means that a planet is going round it.

The data provided in this activity is real data supplied by Prof. Geoff Marcy from California. In this activity they are doing exactly what the scientists do to find planets.

Give each pair of students one set of 4 graphs (and an exo-planet data sheet if desired). You will need to draw the picture below or give as a handout to explain to the students that as the planet goes round its circle, the plot of the velocity forms a sine curve. NOTE: in the diagram we are looking at the star from above. In reality this star is doing a circle toward and away from us.

The students need to work out the orbital period. This is the time the star takes to complete a circle, and is also the time it takes the planet to go around the star once.



The graphs already have the data points plotted on them and the students must fit a curve between the points. To make a good curve they need to think about the order that they put the graphs in. They will need to fold the sides of the graphs in. They can then count the number of days of the orbital period.

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The answers are:

- The correct order is data set 1, data set 4, data set 2 then data set 3. The students will need to fold the sides of the graphs in to join up the curve.
- The time the planet takes to go around the Sun is 18 days. (Remember that the Earth takes 365 days to go around the Sun!)

More information

If you want to go into more detail you could start to discuss spectroscopy. As the star wobbles the light we receive from the star contains clues about its motion. When the star is moving toward us the light is squashed, or blue-shifted, and when the star is moving away from us the light is lengthened or red-shifted. From this effect we can tell how fast the star is moving and whether it is moving toward or away from us. The motion toward or away from us is called the radial velocity. This effect is the same as the one that causes the pitch of an ambulance to increase as it travels toward us and decrease as it travels away.

The 'Move over Einstein: the next generation is here!' exhibition gives information on the Higgs particle. This particle is currently being looked for, and if found may help us understand how material gets its mass. This could also be discussed here.

National curriculum links

Simple harmonic motion, centre of mass, gravity, spectroscopy, scientific investigation

Extension activities

Extension 3 – Stars on a see-saw

Show this as a demonstration.

Summary

In this workshop the students have learnt about the Universe by looking at observations in much the same way as scientists do. They have demonstrated that:

- the Universe is expanding by studying the motion of galaxies
- we cannot find a centre to the expansion
- planets can be detected by watching stars wobble.

They have also:

- learnt that we currently only know about 4% of the Universe
- understood what makes up the other 96% will help us understand what the fate of the Universe will be.

Extension activity 1 (How old is the Universe?)

Materials required

- plastic rulers
- How old is the Universe? worksheets

The galaxies are currently moving away from each other, but if we could go back in time, like watching a film on rewind, the reverse would happen and they would start to move closer together. If time were rewound enough, we would be able to go back to a period when all the galaxies merged. This is known as the Big Bang and is thought to be the point at which the Universe was born.

In this activity the students will calculate how long ago the Big Bang happened.

In Activity 1 they looked at how the galaxies had moved during the 2.5 billion years between the 'pictures' and saw that the Universe is expanding. In this activity they will measure how far the galaxies have moved in 2.5 billion years to work out how long ago the Big Bang happened and so when the Universe was formed.

Ask the students to pick a galaxy near the centre of the picture and match it up with the galaxy on the transparency to produce a random 'centre'. Call this galaxy A and pick 4 galaxies around A at differing distances. Label them 1 to 4. Get the students to record the following on the worksheet:

- measure the distance galaxies 1 to 4 have moved in 2.5 billion years
- calculate the velocity (in cm per billion years)
- measure the distance of galaxies 1 to 4 from galaxy A **today**
- calculate the time taken to move from galaxy A to the position today. This is the age of the Universe!

They will need to remember the equation:

$$\text{velocity} = \frac{\text{distance (cm)}}{\text{time (billions of years)}}$$

and be able to re-arrange to

$$\text{time} = \frac{\text{distance (cm)}}{\text{velocity (cm/billion years)}}$$

Sample data

Galaxy	Distance moved during 2.5 billion years (cm)	Velocity (cm/billion years)	Distance from A today (cm)	Age of the Universe (billion years)
1	1.0	0.4	6	15
2	0.7	0.3	5	17
3	1.0	0.4	6.5	16
4	1.5	0.6	9.7	16

Average value for age of the Universe = 16 billion years

Current accepted value for the age of the Universe = 13.7 billion years

Extension activity 2 (Size of the galaxies)

The students have learnt that space between the galaxies is expanding and pushing the galaxies apart. Now test their observations skills and ask them whether the galaxies themselves are expanding.

Q. Do the galaxies in the 'pictures' change in size?

Answer:

The galaxies do not appear to be getting bigger or smaller with time. So, the galaxies are not expanding, just the space between the galaxies is expanding.

Lead the students into a discussion about why this is the case.

Main points:

The space between the galaxies is thought to be expanding, but not the galaxies themselves. Galaxies contain thousands of millions of stars (you could also mention Dark Matter here). This means a fairly strong gravitational pull is acting on all the objects in the galaxy to keep them together.

Extension activity 3 (Stars on a see-saw)

Materials required

- Clamp stand with clamp attached
- Wooden bar with string attached
- Variety of weights

Summary

This demonstration shows why a star wobbles when a planet is in orbit around it. The correct way to think of this situation is that both the star and the planet orbit a common point called the **centre of mass**. Imagine a star on one end of a see-saw and a planet on the other, the centre of mass is the point at which you could place a pivot and the see-saw would be balanced.

Hang the piece of wood using the string on the clamp stand. Then place equal masses on each end and see where you need to hang it for the wooden bar to look horizontal.

Answer:

The wooden bar is balanced when hung from the centre of the length of string. That is, the centre of mass is in the middle.

Then change the masses so that you have the 50 g mass on one end and the 200 g mass on the other. Is the piece of wood still balanced? How do you get it balanced again?

Answers:

No. The piece of wood becomes unbalanced when unequal weights are hung on each end. In order to make the wood horizontal you need to move the point at which it is hanging off the clamp stand closer to the heavier mass. Therefore, the centre of mass is now closer to the heavier object.

For a planet and a star, the centre of mass will lie much closer to the star. This means that the star does a small circle in space and the planet a much bigger circle.

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