Galaxies

Teacher's Notes

Introduction

A galaxy is a collection of stars, the remains of stars, gas and dust, and the mysterious dark matter. There are many different types and sizes of galaxies, ranging from 'dwarf galaxies' containing as few as 10 million stars, to giant galaxies containing one trillion stars. Our Galaxy, The Milky Way, is a fairly average galaxy, thought to contain several hundred billion stars. Astronomers estimate that our Universe – or at least, the observable Universe – consists of over 170 billion galaxies.

Democritus, one of the early Greek philosophers, proposed that the bright band we refer to as the Milky Way, might consist of distant stars. However, it wasn't until 1610 and Galileo's observations with a telescope that this was proven.

The earliest recorded observation of another galaxy dates back to the 10th century, when a Persian astronomer known in the West as Azophi, recorded his observation of the Andromeda galaxy, describing it as a "small cloud". It wasn't until the 18th century that astronomers began to correctly speculate that some of the objects observed in the night sky, might be out with the Milky Way and it was only in the 1920's that this was finally demonstrated.

Different Types of Galaxy

Shape

Galaxies can be categorised in terms of their apparent shape. The 2 main types are spiral and elliptical. Those which do not fit easily in either of these shape categories are referred to as 'irregular' galaxies. Often, these 'irregular' shapes are the result of disruption by the gravitational pull of nearby galaxies or collisions between galaxies.

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Teacher's Notes

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Spiral galaxies are disk-shaped and have dusty arms. Our galaxy is thought to be a spiral galaxy.

Elliptical galaxies have a more featureless brightness profile, and look smoother.

Spiral Galaxy

Elliptical Galaxy

Colour

Galaxies tend to look mostly blue or red in colour, and this can give us a clue to their age. The colour is primarily due to the stars from which the galaxy is made up. Stars come in a range of sizes, from objects about 1/10 the size of the sun, up to massive stars, perhaps 150 times as big as our sun. Not surprisingly, the more massive a star, the hotter it will be and this means it will generally be bluer in colour.

Classroom demo:
Use your Bunsen burner to back up the idea that blue stars are hotter than red stars.

What might be surprising though is that the massive stars burn up their fuel more quickly and die sooner than smaller stars. Consequently, as a population of stars ages, it will become redder in colour because all the blue massive stars die out and we are left with just the red stars. Because of this, we know that the stars in the red ellipticals must be older than the blue spirals. In fact, astronomers often call big red ellipticals "red and dead galaxies".

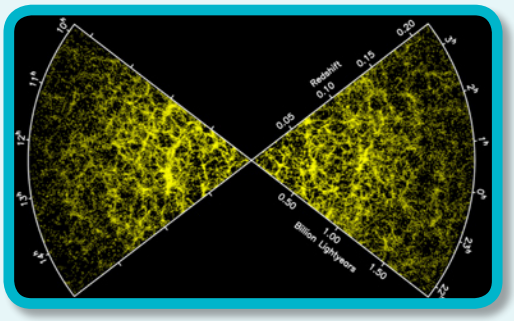
Classroom demo:
To demonstrate why more massive stars die out quicker than lower mass stars, ask 2 students to come to the front of the class. Give one student some heavy books to hold at arms length, while the other student has one thin book held at arms length. The class will see that holding up the larger mass burns up energy more quickly.

Galaxies

Teacher's Notes

The Large Scale Structure of the Universe

Astronomers have found that the large scale structure of the Universe is not completely random, and that galaxies tend to be found in groups or clusters, containing from ten to thousands of galaxies. Our own Milky Way belongs to the 'Local Group' which contains around 40 galaxies, including the Andromeda galaxy just 2.5 million light years from us.



Recent studies show the structure of the Universe as a collection of 'voids', with no or very few galaxies, separated by sheets or 'filaments' of galaxies.

Observational Methods

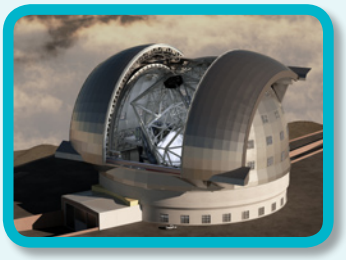
Galaxy clusters have been detected in many astronomical surveys. A survey generally involves 'mapping' a particular region of the sky, and can be carried out in different wavelengths.

One such survey is The Sloan Digital Sky Survey (SDSS), which from 2000 – 2008, mapped around 35% of the sky. This particular survey transformed the study of galaxies and provided great insight into the physical processes that govern galaxy formation, through the high quality images and other information it produced. The images and positional information the students are given in this class exercise have come from SDSS data.

Future Technology

There are various ground and space-based telescopes currently being planned, designed and built which will aid the research of galaxies and the evolution of galaxies.

One such telescope is the European Extremely Large Telescope (E-ELT). This telescope is currently in its planning stages, and when built will have a mirror with a diameter of around 40m – larger than all the current ground-based telescope mirrors put together. With a mirror of this size, the E-ELT will be able to help astronomers see the Universe in greater detail than even the Hubble Space Telescope. Scientists and engineers at the Royal Observatory Edinburgh are involved in designing and planning this new telescope. One of the science goals of the E-ELT is to study the earliest galaxies, and follow their evolution through cosmic time.



European Extremely Large Telescope (E-ELT)

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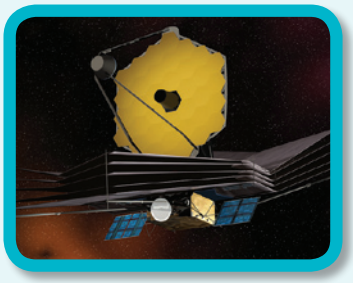
One of the most well-known telescopes is the Hubble Space Telescope (HST). It has been in space now since 1990 and has made many amazing discoveries and given us many beautiful images. The HST will soon be at the end of its life and will be replaced by the James Webb Space Telescope (JWST). This telescope is due to be launched around 2018 and the development of one of the instruments on board has been led by scientists and engineers here at the Royal Observatory Edinburgh. Studying the formation and evolution of galaxies is one of the main science objectives of the JWST.



James Webb Space Telescope (JWST)

Classroom Activities:

In groups of 4-5, pupils are given an information pack which contains:

- Galaxies Fact Sheet
- Task Skeet
- Galaxies data sheet (4 different data sheets available, each making up one quarter of the Virgo Cluster)

Pupils are given images of around 18 galaxies from the Virgo Cluster, along with co-ordinates. They are asked to plot their galaxies on a model. For this, each group will require:

- Polystyrene board cut to approximately 55cm x 55cm (large polystyrene sheets available from most major DIY stores)
- Black sugar paper to cover the board
- Toothpicks
- Galaxy flags
- Ruler
- Pen/Pencil

The pupils are asked to think about the galaxy images they have (what type and colour are they, anything different about the image). They are then asked to think about whether the different types of galaxies are evenly distributed in their model.

To finish off the activity, all 4 models should be put together to make up the Virgo Cluster model. Pupils should be encouraged to see if they can spot any patterns in the distribution of the types of galaxies, and asked if they can suggest what might be happening in the cluster.

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Extensions:

There are many ways in which this topic can be extended within the science class, and many opportunities for cross-curricular links. Below are some suggestions:

Science

- You could ask the pupils to research the Virgo Cluster further. There is lots of information available through sites such as wikipedia. They could find out information such as how far away the cluster is, how many galaxies it contains, when they were discovered, and by whom.
- Stargazing – why not organise an evening of stargazing to look for the constellation of Virgo, the Andromeda galaxy and try to see our own Milky Way

Geography

- As the galaxies are a certain number of light years away from the Earth, pupils could look at what the Earth would have been like at the time the light left the galaxy (e.g. the Virgo cluster is 59 million light years away, the Andromeda galaxy is 2.5 million light years away)

English

- Pupils could write a travel brochure for visiting another galaxy

Maths

- Calculate the distance the galaxies are away from Earth in kilometres or miles

Art

- Pupils could create 3D models of galaxies or create artwork inspired by images of galaxies
- Pupils could create animations relating to travelling through space to another galaxy