EARTH AND SPACE

Teacher Support for Science in the National Curriculum for Secondary Schools

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Earth and Space

One small step for man, one giant leap for mankind.

Neil Armstrong - 20th July 1969

Earth and Moon photographs by kind permission of NASA

To the Teacher

Astronomy is the oldest science in the world. In ancient Greek, Chinese, Babylonian and Arabic records we find that people have observed the sky and described sightings of comets ('hairy stars'), planets ('wandering stars'), novae ('new' stars) and eclipses. In recent decades our understanding of the Universe has developed enormously through manned and unmanned space-probes and through new observations made at radio, infrared, ultra-violet and X-ray wavelengths.

Space and space travel fire the imagination of most of us. With children this can bring an interest in science. At the heart of some of the activities in this book are the basic scientific skills of careful observation and accurate recording of measurements. These make a vital contribution to the formation of concepts and ideas about the Earth and Solar System which can then be explored and reinforced using 3-D models. Transition from an "Earth-based" view of the sky to a more general perspective of the planets (as if in space themselves) is not at all easy. This change of perspective may develop slowly but it is essential for the correct understanding of the phenomena we observe.

This book does not follow a teaching scheme. However, the first sections unfold a series of ideas about day and night and the seasons which make more sense if presented in order. Each topic has notes for the teacher and for the pupils.

It would keep interest levels high if the material were to be augmented by some of the spectacular videos, DVDs and posters now available.

Finally astronomy need not be confined to science. Many cross-curricular themes present themselves, linking with geography (time-zones, continents and poles), with maths (distances and scales), with art and with drama. Much imaginative art-work and drama can be inspired by considering the conditions on distant planets, inhabited or otherwise.

The material in this book was devised in answer to a need expressed by many teachers for support in the teaching of astronomy. The aim of the Association for Astronomy Education is to promote the teaching of astronomy at all levels and to provide such support. A second book by members of the AAE's Education Group is entitled "Earth and Beyond". It is for use in primary and middle schools and completes the package of support for 5 to 16 year olds.

The first edition of "Earth and Space" was written by Anne Cohen, Bob Kibble, Martin Suggett and Dave Mannion of the AAE. The text was prepared for publication by Julian Ravest and Suzanne Tyler. Jackie Chadwick created the illustrations.

The second edition has been completely re-typeset by Alan Pickwick, who is a member of the Council of the AAE. The content of the second edition has been revised by AAE member Anne Cohen (now Anne Urquhart-Potts). We are grateful to Jane Hanrott at ASE Headquarters for her help in the publication of this edition. XXXXXXX created illustrations for this edition.

We would be pleased to receive your comments or suggestions.

First Edition (Earth and Space) September 1992.

Fully Revised Second Edition (Earth and Space) 4th February 2006.

PREFACE TO THE FIRST EDITION BY THE ASTRONOMER ROYAL

It gives me great pleasure to write this brief preface for “Earth and Space”, a book that I recommend very warmly.

Astronomy is essentially the oldest of the sciences and a subject that has a fascination for all – young and old alike. As time goes on, Mankind’s interest in the cosmos has changed from one of superstitious fear to one of increased understanding and appreciation, but our sense of awe remains.

This book represents a milestone along the path of understanding whereby the young are presented with contemporary ideas not only about the heavens but also about the Earth and Mankind's place within the cosmos. No educated person worthy of the name can fail to have a grasp of the basics described in this book, nor to have a thirst for more knowledge from the continually expanding research in this area.

For those with a more professional interest in science, the subject represents a magnificent laboratory in which whole areas of science and mathematics come together. As a vehicle for interesting young people in science, astronomy has no equal. As time goes on and the need for a scientifically aware populace increases, this book will become more and more important.

Good luck to it and to those who teach and learn from it.

Professor A W Wolfendale F.R.S.
The Astronomer Royal and Patron of the Association for Astronomy Education.

1. Day and Night

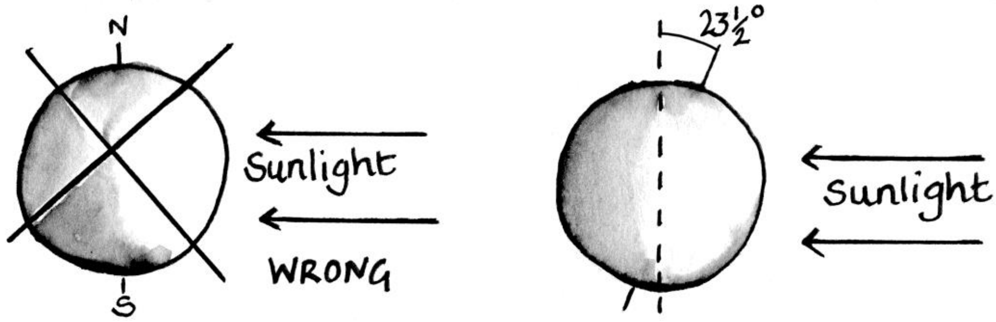
Teacher Notes

Main Ideas:

* The Earth spins about an axis.
* The Earth spins once in 24 hours.
* The Sun shines on only one side of the Earth – we call this daytime.
* The other side of the Earth is in its own shadow – we call this night.

Common misconceptions:

Three-dimensional models and demonstrations are of paramount importance in helping students to visualise the effects of Earth's spin. Representations in textbooks and worksheets which are drawn in 2-dimensions may be misinterpreted by students until the 3-D model is fully understood. One common problem is caused by thinking that the Earth's spin axis is upright with respect to the rays from the Sun. It is actually tilted at 23.5° to the "vertical".

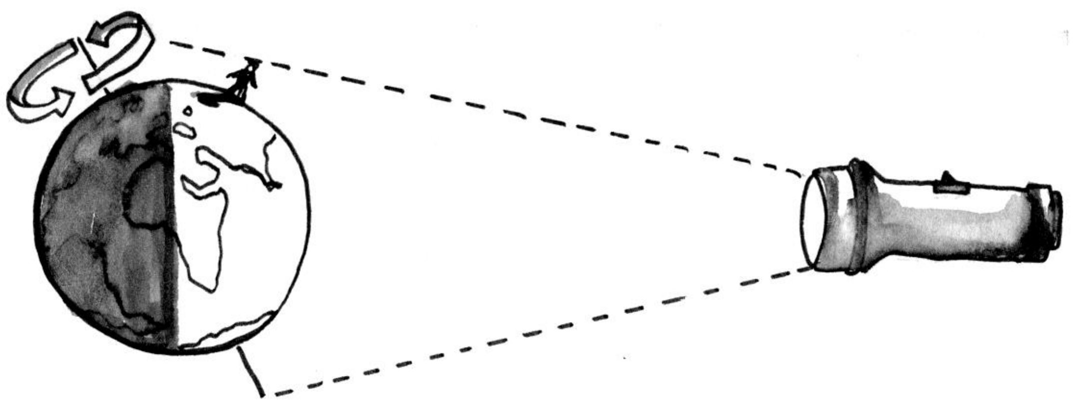


Other problems may arise from confusing the effects of day and night with seasons. Beware statements from students such as "The Sun shines on one side of the Earth where it is summer. It is winter on the other side" – this is WRONG!

Classroom Activity:

You need a globe (not the "lamp in the middle" variety) and a strong source of directed light such as an overhead projector, strong torch or a slide projector). The room must be partially darkened to view the effects satisfactorily.

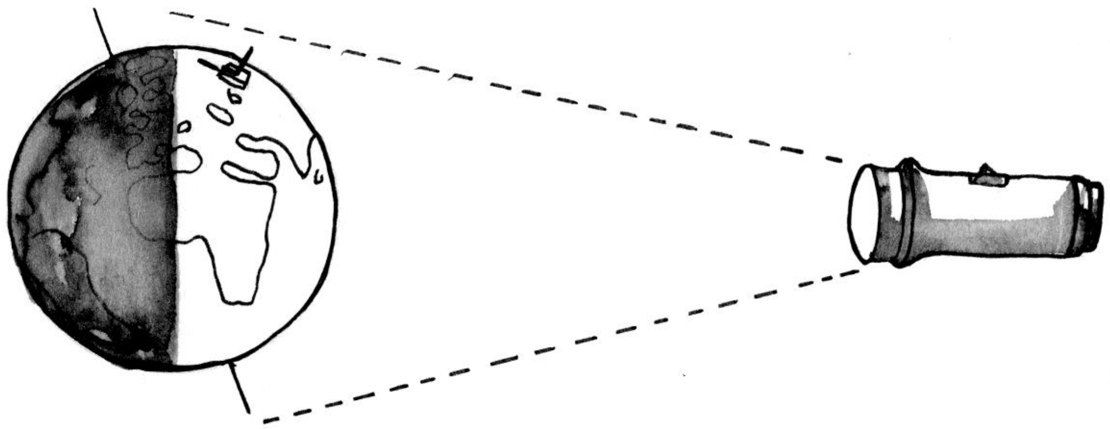
Scale: Remember to point out that the scale is all wrong. If your globe is about 30 cm in diameter, the Sun should be 32m wide at a distance of about 3.5 km!

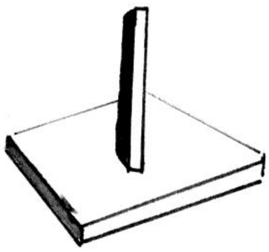


Turn the globe very slowly (anticlockwise when viewed from above the North Pole). Each country passes from daylight into darkness and back again. A model figure such as a Lego person experiences time passing – you can talk about the time of day for him/her and what the figure might be able to see in the sky. Try to help the students make the link between what they can see from their position which is from above Earth, in space, and what a person standing on the globe would see. This transfer of view is not easy and may need some emphasis.

Main Idea: For a person on Earth the SUN seems to move, rising in the East and setting in the West. From the model it should be clear that it is *not the Sun which is moving* but the Earth which is *spinning*. The Sun (and everything else in the Universe) only *seems* to go round the Earth.

Shadows: A bonus with this model is that the shadow of the figurine moves round just like a sundial shadow. It gets short at midday and longer in the evening. If you place your person near the equator, the shadow may even disappear at midday and this is when the Sun is "overhead". To extend this idea, a little sundial, made of half a matchstick and square of card, can be stuck to the globe. As you turn the globe the stick's shadow will move. Try different places on the globe.

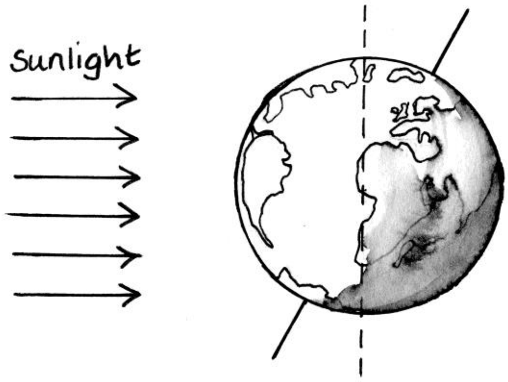




For Class Discussion:

* What would happen if the Earth did not turn?
* Would you like to have endless day? What would happen to plants and animals?
* What might happen to the weather and temperature?
* How would we measure time and date?

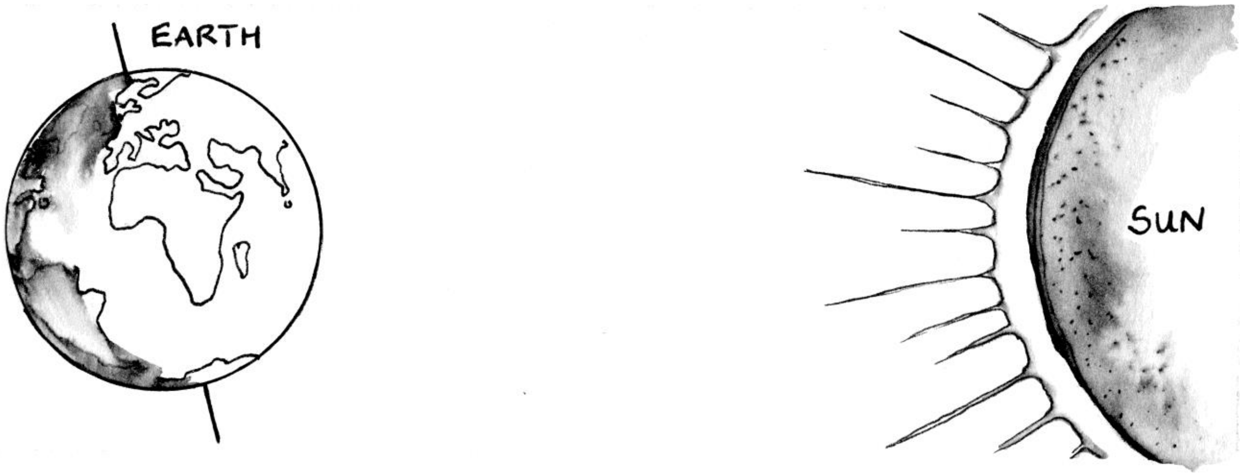
Day and Night



1) On the diagram:

   a) Shade the side of the Earth which is in night-time
   b) Label the side of the Earth which is having day-time

2) On the diagram below:
   a) Shade in pencil the dark side of the Earth.
   b) Draw a curved arrow above the diagram to show which way the Earth turns.



   c) Draw a cross on a country or continent which is having daylight. Name it.

      ……………...……………...

   d) Write “D” on the diagram on a country or continent where it is dark. Name it.

      ……………...……………...

   e) Name a place where the Sun is just rising.

      ……………...……………...

   f) Is it day or night at the North Pole? ……………...……………...
   g) Explain what will happen at the North Pole as the Earth turns.

      ……..…………………………………………………………………

      ……..…………………………………………………………………

3) a) Suppose you are in the park (in Britain) on a fine sunny Spring day. You note the position of the Sun in the sky at various times. Draw on the diagram below five circles to show where the Sun was at dawn, mid-morning, mid-day, mid-afternoon and sunset. Label each one.

b) Why does the Sun appear to move across the sky every day?

……..…………………………………………………………………………

4) On a clear night a camera was pointed towards North and the shutter was kept open for about 6 hours. The photograph showed a number of star trails.

a) Why do the stars move in this way?

……………………..………………………

b) The bright star in the middle is called the Pole Star. Why doesn't it move?

……..…………………………………………………………………………

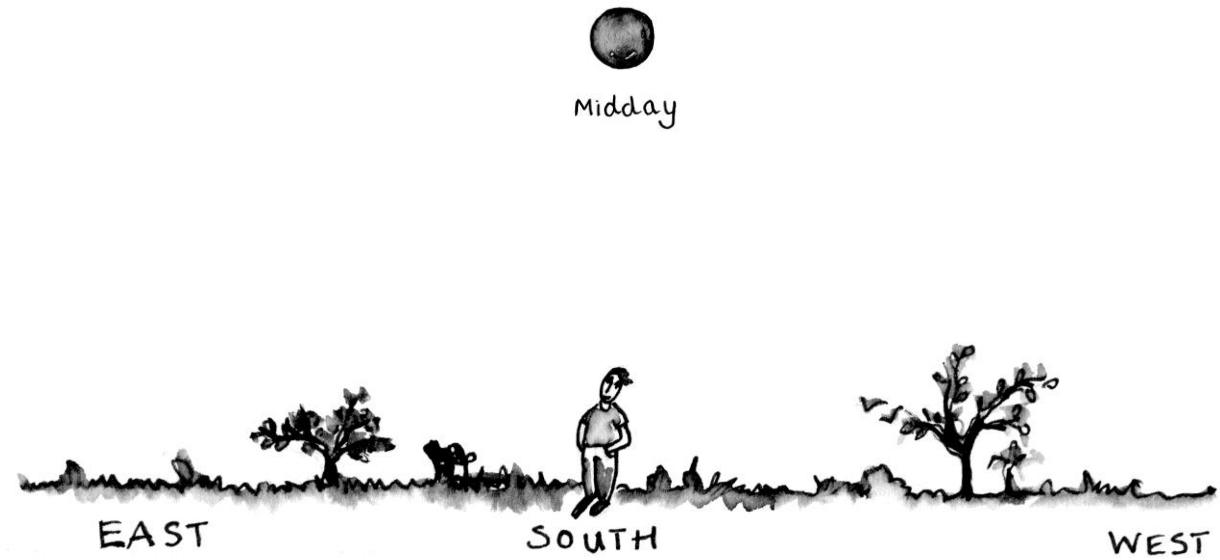
HOMEWORK – Day and Night

1) Why do we have day and night? Use the words *Earth, axis, spin, 24 hours, sunlight,* in your answer.

   ……………………………………………………………………………………….

   ……………………………………………………………………………………….

2) The Sun appears to move across the sky during the day. The drawing shows the position of the Sun at midday. Mark with a dotted line the path the Sun appears to take during the day. Label sunrise and sunset.



3) Mel lives in Britain. She sees the sunrise:

   a) Where does the Sun rise in the morning? Tick the correct box.

In the North	☐	In the South	☐
In the East	☐	In the West	☐

   b) In which direction will Mel see the Sun at midday?

   ……………………………………………………………………………………….

4) Mel saw a bright star at night. It appeared to move across the sky slowly from hour to hour.

a) Why do stars seem to move across the sky?

………………………………………..

………………………………………..

b) Choose form the words below to complete the sentence:

North *East* *West* *South*

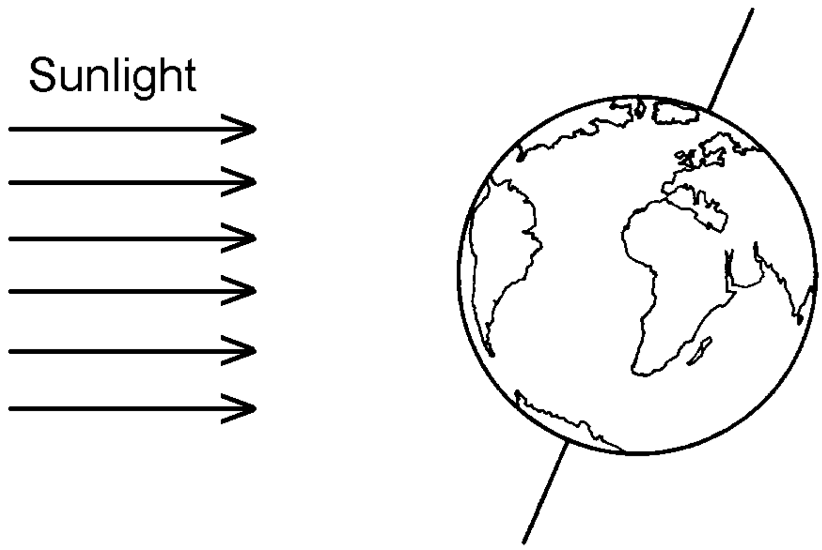
The star seems to rise in the ………….. and set in the …………...

5) Look at the diagram of the Earth below.

a) What time of day is it in Britain? ……………………

b) Mark an arrow to show the direction that the Earth is turning.

c) Name one continent or country that is in darkness. …………………



2. The Year and Seasons

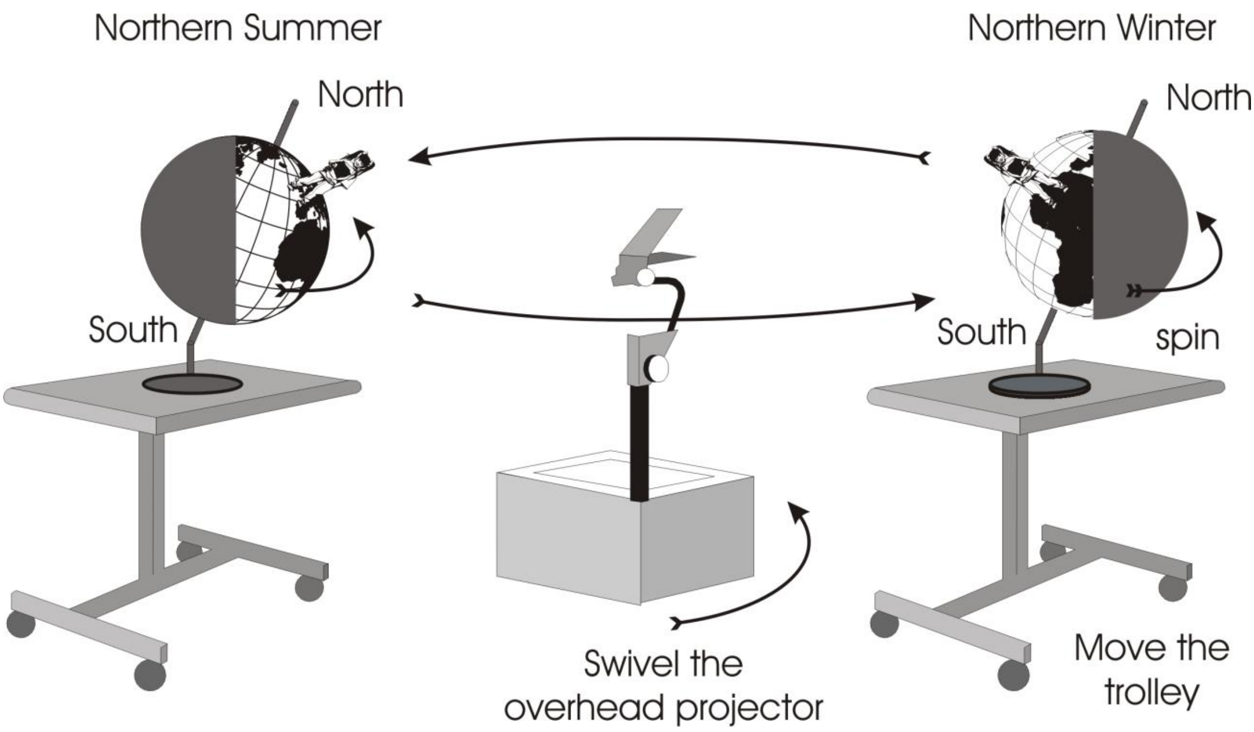
Teacher Notes

Main Ideas:

* The Earth orbits the Sun in a near circular path taking 365¼ days to complete one orbit.
* The time for one orbit is called a year.
* The tilt of the Earth's axis remains constant and causes the seasonal changes in the length of daylight and in the intensity of the sunlight.

Classroom demonstration:

Again you will need a globe and a light source for sunlight. This three-dimensional visualisation is essential for understanding how the changing angle of sunlight comes about.



Make sure that the globe can be moved freely around the light source – it could be on a small trolley. If you are using an overhead projector as the light, it will need to be turned around as the Earth orbits.

This demonstration has obvious limitations which you may feel should be stated. The model is not to scale but only represents the Sun and Earth as seen from space.

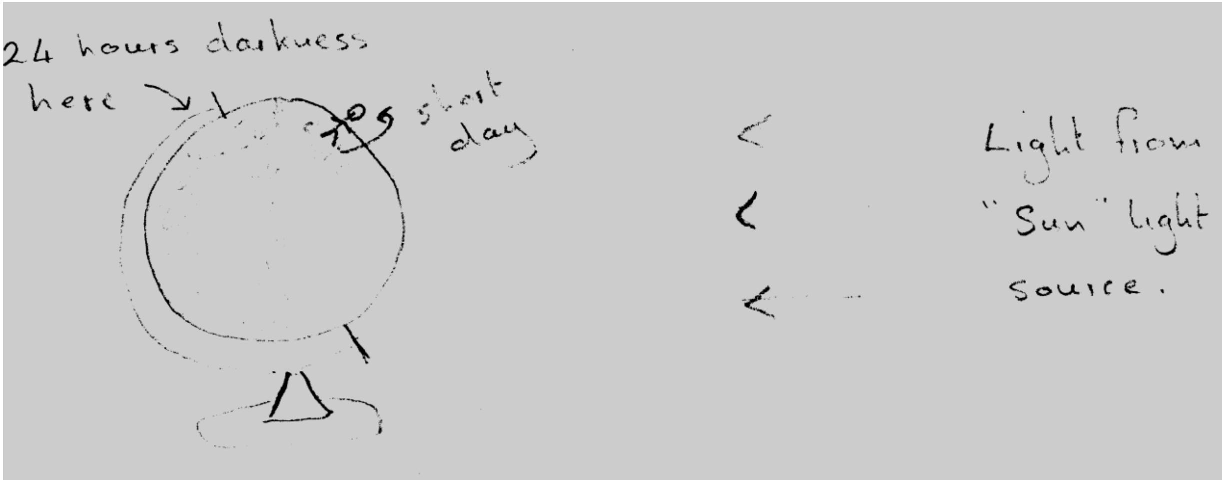
Simulate one day – turn the Earth globe once and in this time move the globe a tiny fraction of the circle around the Sun. Repeat for another day, and so on. Explain that after 365 such turns the Earth would be back where you started. The class may already know that it actually takes 365¼ days for a year but that we forget the quarter days for four years and then add them all together to get the extra day in a "Leap Year".

* The axis of the globe should remain pointing in the same direction all the way round the orbit.

* The Earth's orbit is not quite circular (slightly elliptical) and so the Earth is very slightly closer to the Sun in January than it is in July.

Explaining the Seasons:

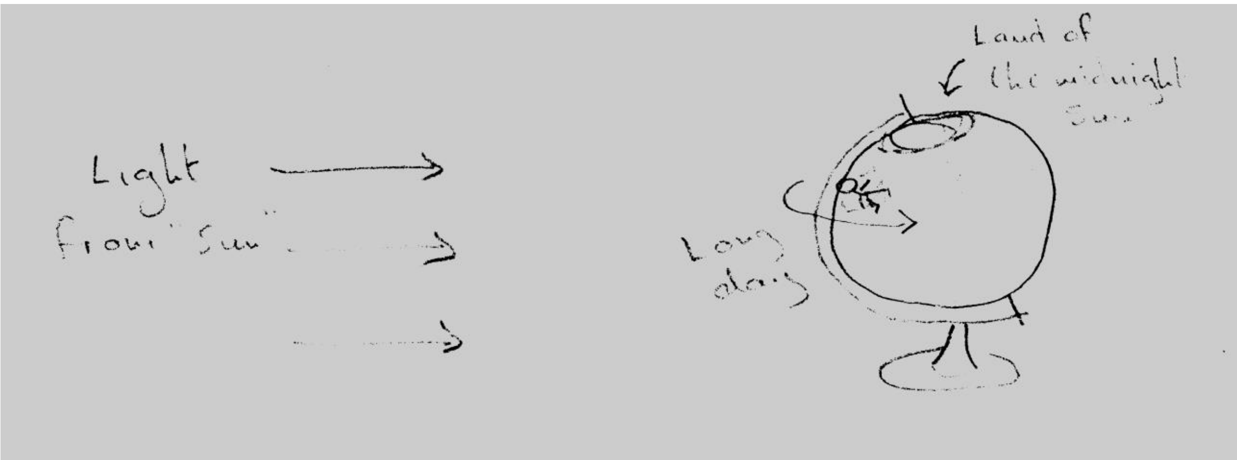
1) Winter: When the light falling on the globe is like this we have Northern winter. It helps to have a small figure stuck to Britain and to imagine his/her day.



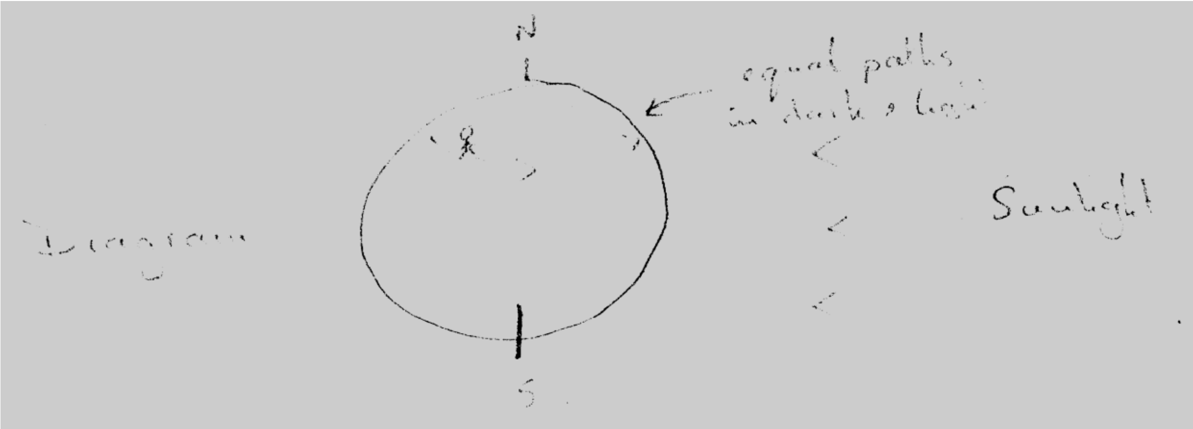
Try turning the globe slowly. The little person has only a short time in the light and a long time in the dark part – in other words a short day and a long night. Furthermore a person living within the Arctic Circle never gets into the daylight however much you spin the globe (This only works well if you have a rather small figure. Tall ones tend to get their head in the light!). Here there are 24 hours of darkness.

2) Summer: Half way around your circle, if you have managed to keep the axis pointing in the same direction, the light should be falling on your globe as in the following diagram. It is summer in the Northern hemisphere.

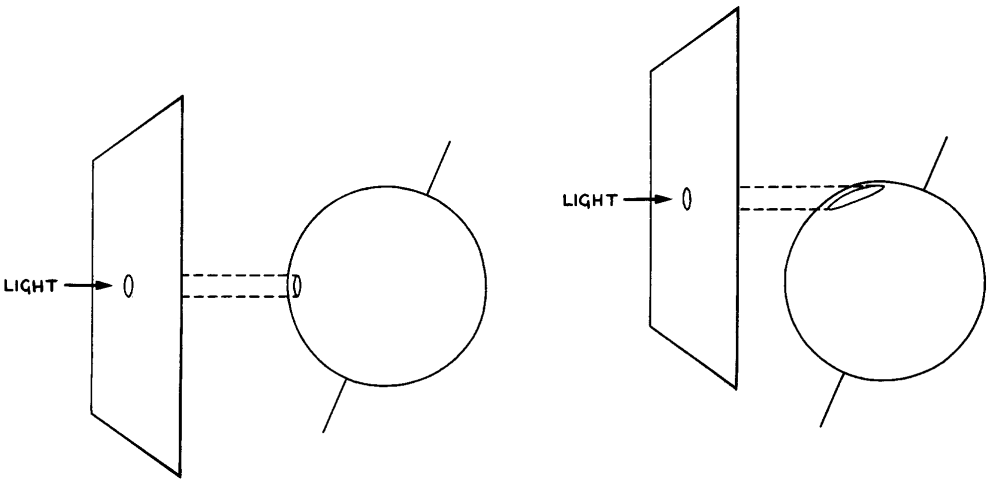
Turn the globe slowly and the little person should experience a long day and a very short night. The north polar regions should be in daylight all the time.



3) In between these two extremes you will find that you arrive at a place in your circular path where the dividing line between night and dark goes right through both poles. This happens twice in the year, at the Spring Equinox and the Autumn Equinox. All countries, including those near the poles, receive 12 hours of daylight and 12 hours of darkness.



4) The reason for the seasonal changes in temperature (rather than the number of hours of daylight) is the changing angle of sunlight caused by the change in the maximum height of the Sun in the sky. In winter in Britain the Sun appears low in the sky and the rays of light reach us at a slanting angle. This can be demonstrated with a piece of card with a circular hole cut into it:



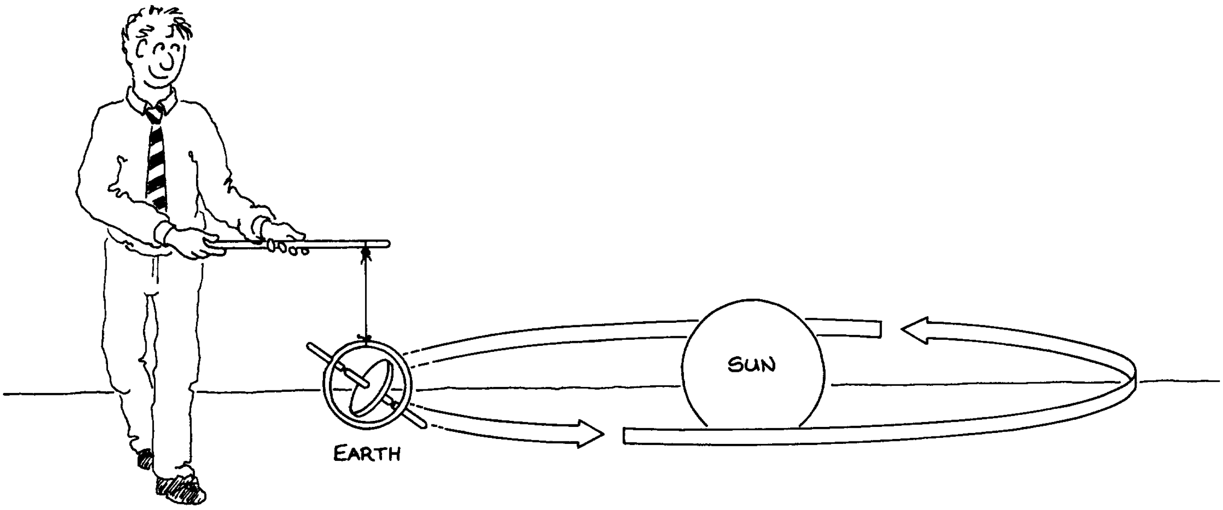
In northern winter it can be seen that the light beam is more spread out because the surface of the Earth in the Northern Hemisphere slants away. Conversely in northern summer the same area light beam falls on the Earth's surface more directly and the light (and heat) is therefore concentrated onto a smaller area. This makes the light and heat feel more intense (and you are far more likely to get sunburned than in winter). Shadows can also show this effect – the figure has a long shadow in winter, but quite a short one in summer, showing that the Sun must be higher in the sky.

5) If you repeat the circuit and explore the whole year again but this time looking at what is happening in the southern hemisphere, you will find the opposite seasons to the northern hemisphere. They have longer days when we are having short days and so on.

Why does the Earth's axis point in the same direction in its orbit?

Try this experiment out for yourself first! Some gyroscopes work better than others!

Hang a small spinning gyroscope on a long thread and take it slowly around your "Sun", just as you did for the globe. It should keep its axis pointing in the same direction as you walk round. The Earth spins a lot slower but the principle is the same (conservation of angular momentum).



Misconceptions

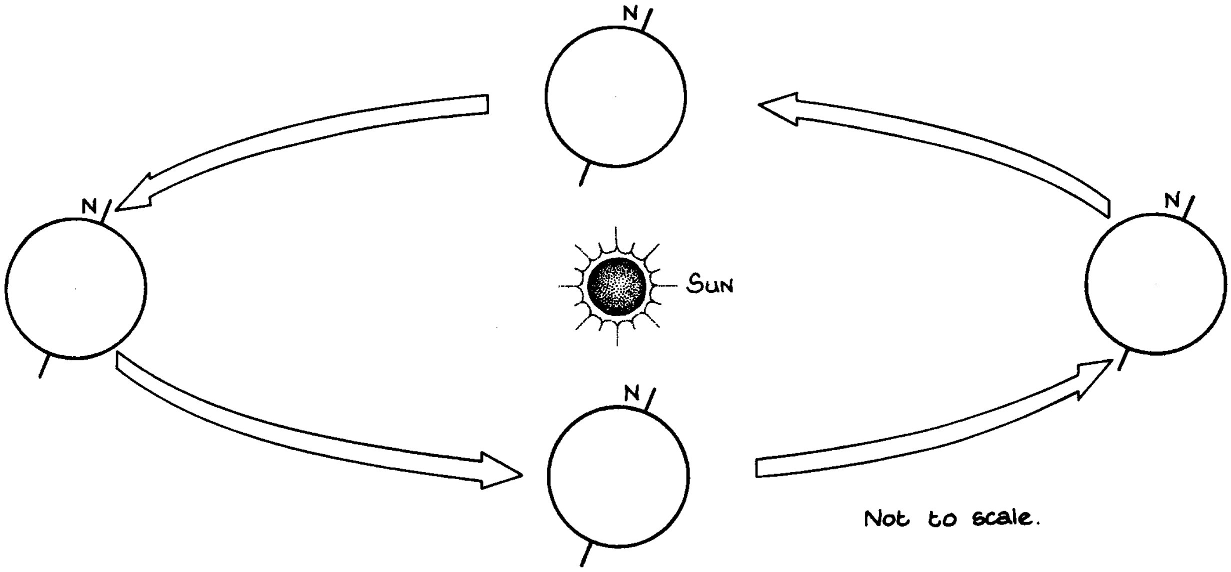
1) That it is hotter in the summer because Earth is nearer the Sun in its orbit. WRONG, because although the Earth's orbit is slightly non-circular it is at its closest to the Sun in January (not in northern summer) and furthest away in July.
2) That it is hotter in northern summer because the northern hemisphere is tilted towards the Sun and so is slightly closer to the Sun. WRONG because although we are indeed tilted towards the Sun this does not make us very much nearer and does not compensate for the Earth actually being further away in its orbit in July (a much bigger distance than the tilt).
3) The Sun goes around the Earth once a year. It is winter in Britain because the Sun has "gone round the other side of the Earth". WRONG – this describes day and night, not the seasons, and also the Earth goes around the Sun, not vice-versa.

Extension Activity: Measuring the Height of the Sun

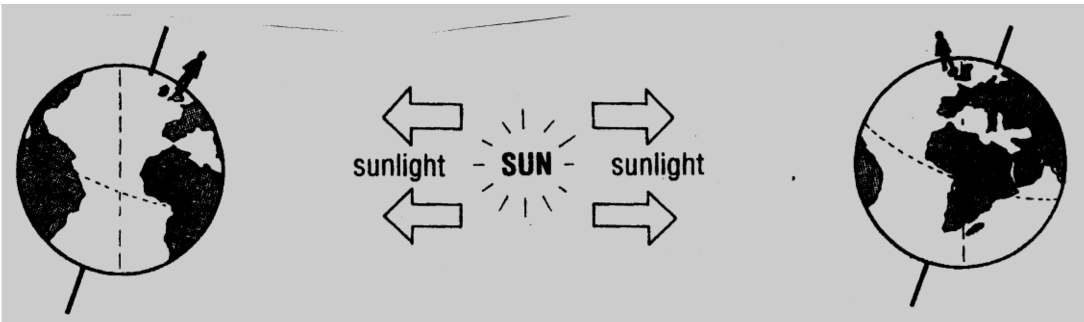
At the end of this chapter is an optional "make-and-do" activity suitable for homework, activity days, holiday work or clubs. It is important to stress to pupils that you should never look directly at the Sun. See Worksheet on Page ????????????????????.

THE SEASONS

1) This diagram shows the Earth orbiting the Sun, taking one year to complete its orbit. The Earth is drawn at four different times during the year. Beside each Earth write the season that the northern hemisphere is having at that time.



2) On the diagram below shade the parts of the Earth that are in darkness. Then fill in the missing words.



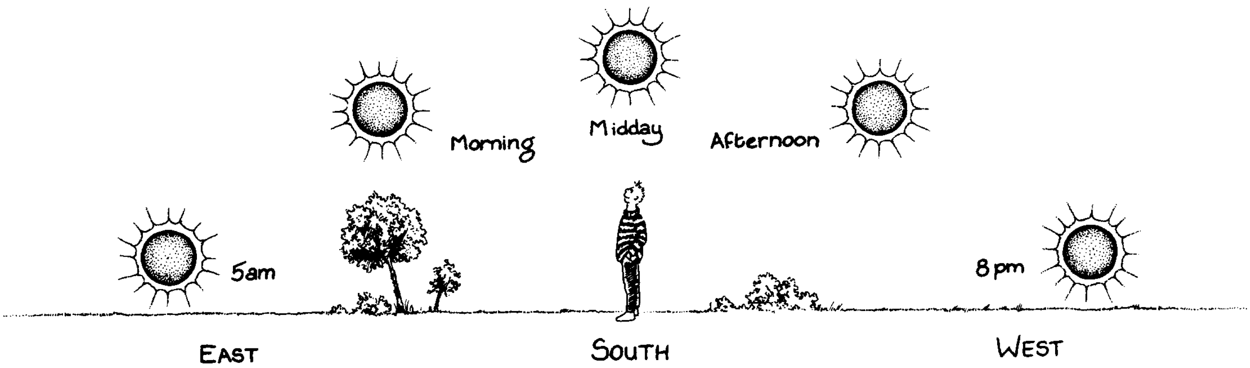
This is ………….. in the Northern hemisphere.

We have ………….. days and ………….. nights.

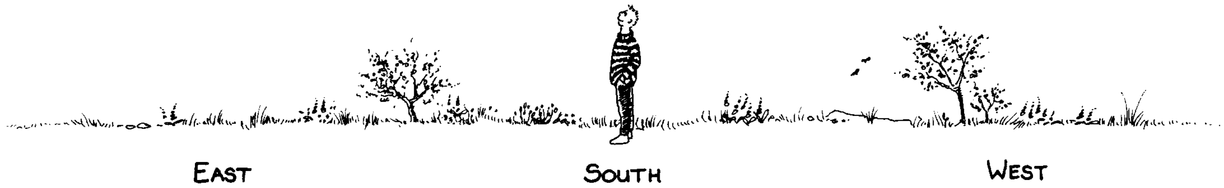
This is ………….. in the Northern hemisphere.

We have ………….. days and ………….. nights.

3) John notices the position of the Sun during one summer day.



Here is the same view but in mid-winter. Where would the Sun be at the same times? Draw circles for the Sun onto the picture and label them "*morning", "midday" or "afternoon"*.



Why is it impossible to draw on a Sun at 5 a.m.?

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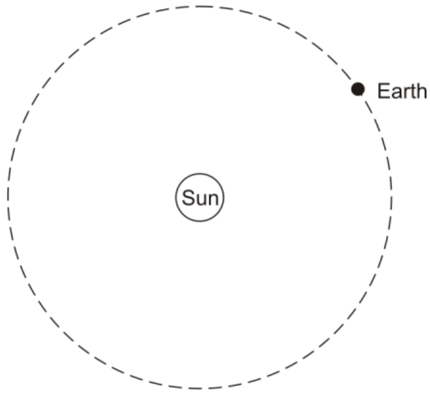
HOMEWORK – The Seasons

1) The dotted line shows the Earth's orbit around the Sun.



a) Draw arrows on the dotted line showing which way the Earth travels in its orbit.

b) The Earth is shown in its position when it is summer in the northern hemisphere. Draw another circle to show where the Earth will be in nine months' time. What season will it be in Britain then? …………..

2) Fill in the missing words:

The Earth orbits the Sun once in ………….. days. We call this one ………….. .

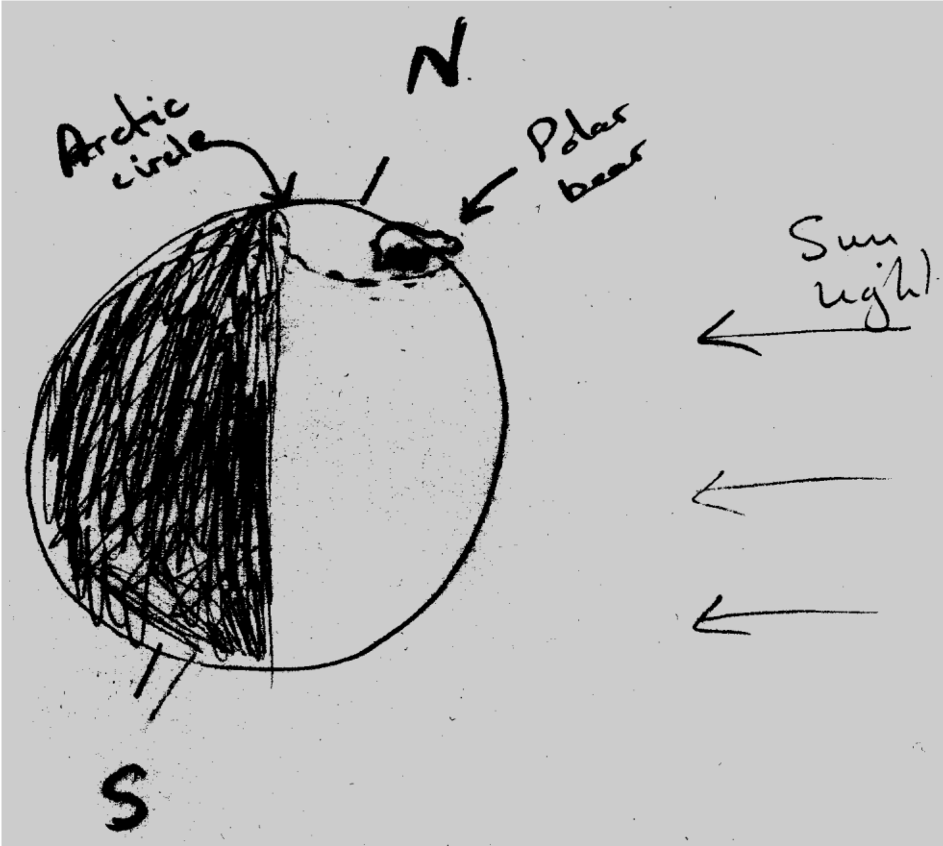
The Earth spins on its axis once in ………….. .

The Earth's axis is tilted. This gives us four ………….. .

When the Northern hemisphere is tilted towards the Sun, the season in Britain is ………….. . We have ………….. days and ………….. nights. The Sun seems to rise ………….. in the sky at midday making the Sun's ………….. and ………….. more intense.

When the Northern hemisphere is tilted ………….. ………….. the Sun we have winter in Britain. We have ………….. days and ………….. nights. The Sun does not rise so ………….. in the sky, even at midday. The Sun's ………….. and ………….. arrive at the Earth's surface at a slanting angle making the average temperature in Britain much ……….. .

3)



a) Look at the diagram. What season is it in the northern hemisphere?

……………………

b) What season is it in the southern hemisphere? ……………………

c) The polar bear lives within the Arctic Circle (shown dotted on the diagram). Describe the pattern of day and night for him in the summer.

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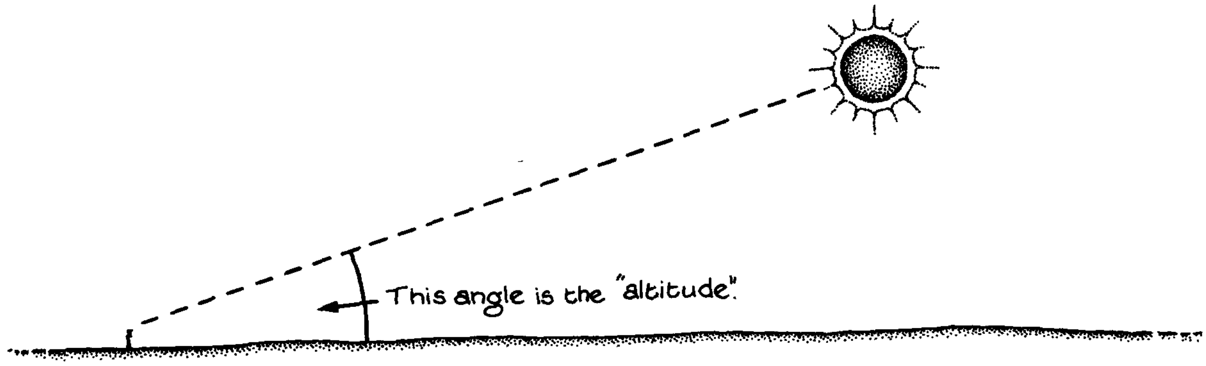
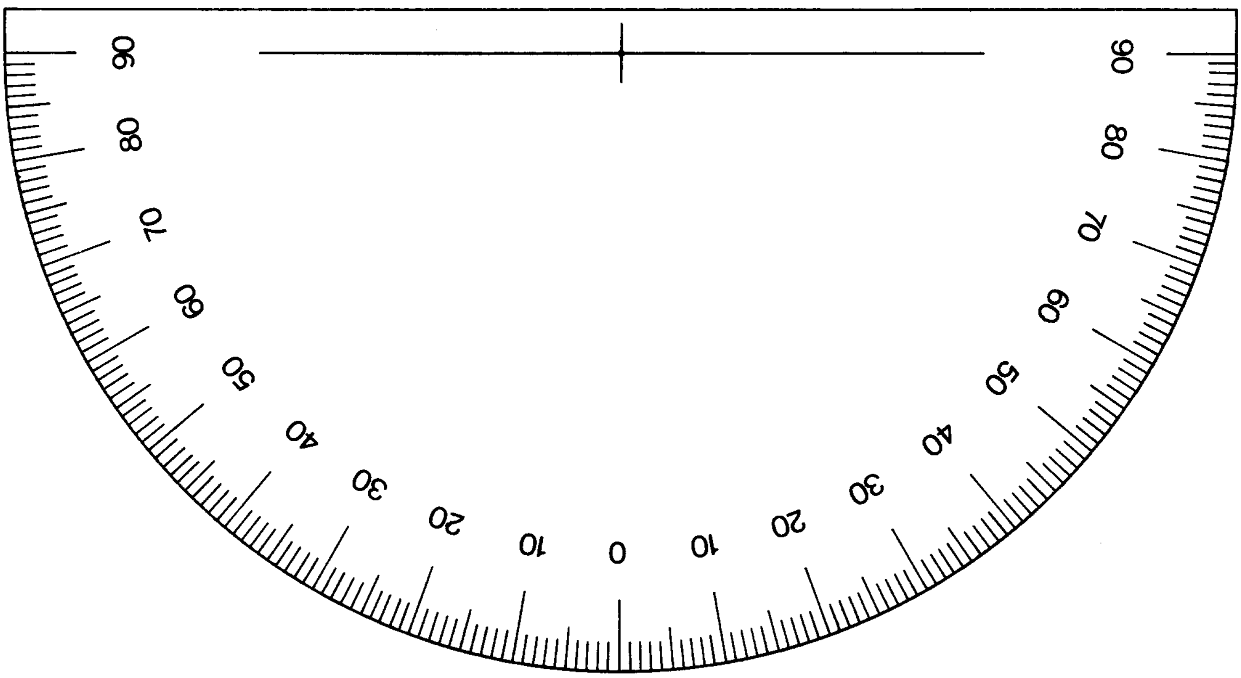
Extension Activity: The Height of the Sun

The height of the Sun above the horizon cannot of course be measured in centimetres or miles! But we can measure its “altitude” as an angle in degrees.

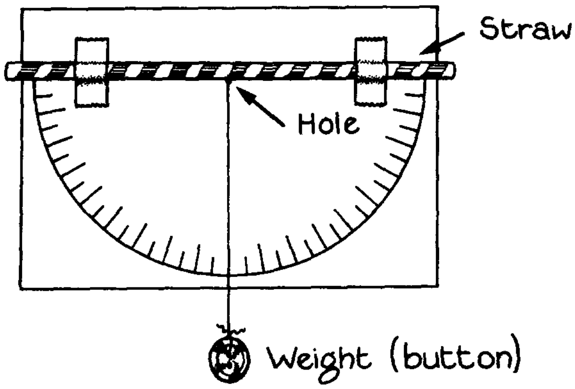


To make your own altitude measuring device

1) Cut out this diagram of a protractor and stick it onto thin card.



2) Make a small hole through the card as shown, and thread a 15 cm length of cotton into the hole. Sellotape the top end of the thread onto the back of the card.
3) Using two small bits of Sellotape, fix a drinking straw along the top of the semicircle. Make sure that one end of the straw sticks out over the edge of the card a little.
4) Tie a small weight to the long end of the thread so that it hangs just below the bottom edge of the card.

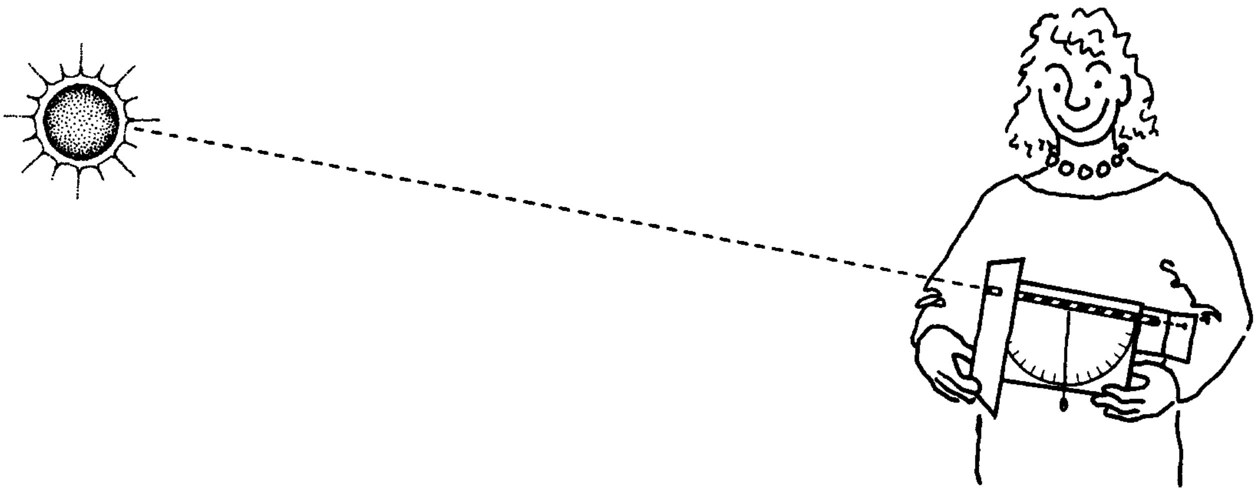


Making your observations.

The straw is the sighting tube **BUT NEVER LOOK AT THE SUN THROUGH THE STRAW!**

The Sun's light is so strong it could damage your eye.

Instead cut another square of thin card and make a small round hole in the centre of it. Poke the end of the straw through the hole as shown in the diagram. Stick a piece of card onto the other end of the altimeter and bend through a right angle to make a screen.



Now line up the straw so that sunlight falls directly down it onto the screen. When a bright spot can be seen, ask a friend to read the angle marked by the thread. Make sure the weight hangs freely when the reading is taken.

Project 1: Measure the altitude of the Sun at intervals during one day. How high does it get in the middle of the day? Present your results as a graph.

Project 2: Find out about the seasonal change in the midday height of the Sun by repeating measurements three or four months later.

3. The Moon

Teacher Notes

Main Ideas:

* The Moon orbits the Earth about once a month.
* We see the Moon because sunlight falls on its surface and reflects off it towards Earth.
* Only half of the Moon can be lit by sunlight, the other half being in darkness – this causes the changing shape of the bright part of the Moon called "phases".

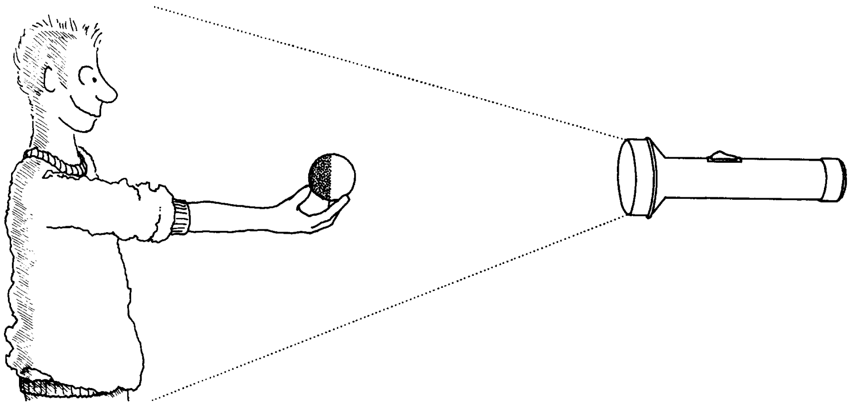
The Moon is our nearest neighbour in space. Its pull of gravity causes tides and we use the regularity of the phases as a basis for our calendar. The timing of many religious festivals is also based on the phases of the Moon: Christian Easter and Muslim Ramadan for example. It is, to date, the only other world to be visited by humans, back in 1969.

The Moon takes about 29.5 days to go from one full Moon to the next. Our calendar uses this period very loosely for its months, the name deriving from "moonths". However there are not an exact number of lunar orbits in a year (there is no reason why there should be) and so we cannot have an exact number of equal months in a year. For historical reasons our calendar is a mixture of months with 28, 29, 30 or 31 days.

Classroom Demonstration

Demonstrate this yourself first. Then let pupils try it out so that they can see the "Earth-based" view of the Moon themselves.

To get good phases you will need a darkened room. A light coloured ball such as a tennis ball represents the Moon. A strong source of light such as a torch or overhead projector supplies "sunlight". The important thing to note is that your head represents the Earth so that your eyes can see the view of the Moon as if seen from Earth. Only in this way will you see the correct sequence of phases. The rest of the class have a view as if seen from space which is not the same as the Earth-based view.

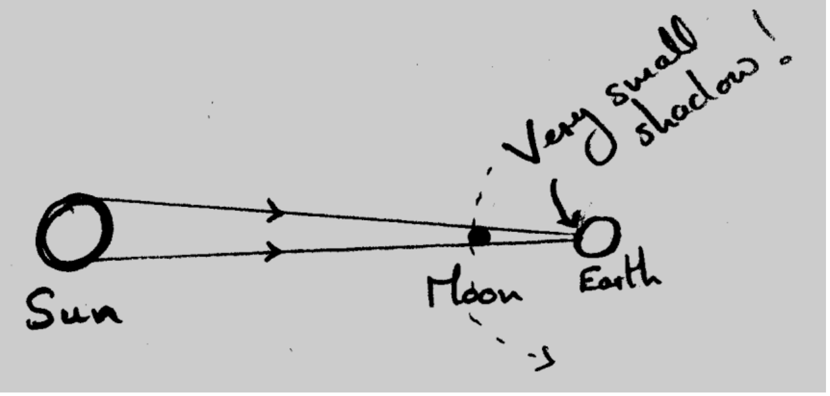


Move the ball around you anti-clockwise (i.e. to your left). Keep the ball in the beam of light and hold it quite high to try to avoid getting it in the shadow of your head. You should see different parts of the ball lit up, starting with none of it (when it is between you and the "Sun"), then a slender crescent increasing to a half circle when you are a quarter of the way round. The next quarter turn brings you to a "full" Moon when you can see all of the lit side of the ball.

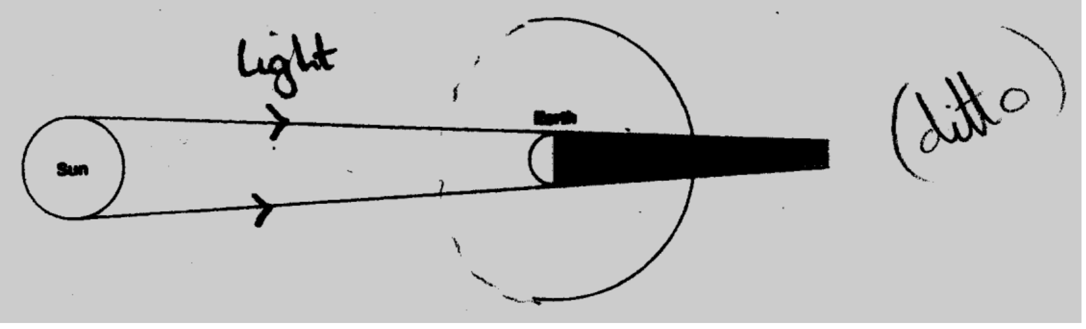
Get pupils to take your place and describe what they can see. Familiarity with this three-dimensional explanation is the key to understanding two-dimensional drawings of it.

Eclipses

Two types of eclipses may actually occur during your demonstration. When the ball is between the Sun and the "Earth" (your head), a shadow of the ball may fall on your face and you may even see the sunlight blocked out. This occurs at "New Moon" which is when you can only see the dark side of the Moon. If the shadow falls on the Earth's surface, people living in the countries under that shadow see the sunlight blocked out for a few minutes – a **Total Solar Eclipse**.



The other sort of eclipse occurs at full moon when the Moon disappears into the shadow of the Earth. The Full Moon goes dark for a few hours because the Earth is stopping the sunlight reaching it. This is called a **Lunar Eclipse**.



Homework exercise: This is ambitious and will take more than a month to get enough observations to see the pattern.

The pupils will be expected to infer the pattern from their table of observations. The exercise runs as follows:

Check in a newspaper or a diary for Moon data:

* Note the rising and setting and setting times of the Moon will be so that you can brief the students – the Moon is sometimes seen in the morning sky and sometimes in the early evening.

* Find out the dates of the New Moons and Full Moons that happen during your observations. You can make a note of them here:

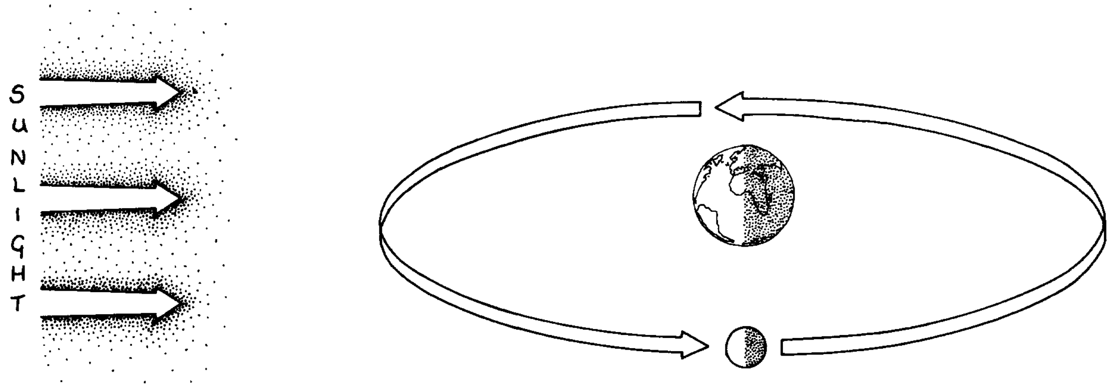
	New Moon	**Full Moon**	**New Moon**	**Full Moon**	**New Moon**	**Full Moon**
Date						

Teachers may look up this data in a newspaper or from the Web.

HOMEWORK – The Moon

We can see the Moon because sunlight shines onto its rocky surface and is reflected back to us on Earth. The Moon does not shine with any light of its own.

1) As the Moon orbits the Earth we see different amounts of its sunlit side. These give the different "phases" of the Moon.



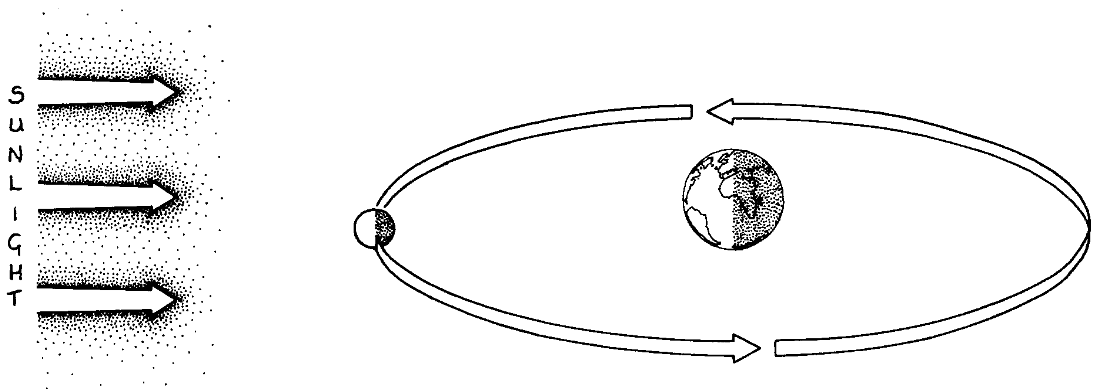
   a) Label the Earth and the Moon in the diagram above.

   b) Imagine you are on the Earth, on the side facing the Moon. How much of the Moon's bright side can you see? ……………………

   c) Draw a sketch of what you would see in the box.

2) How much of the Moon's bright side can be seen from Earth now?

   …………………..

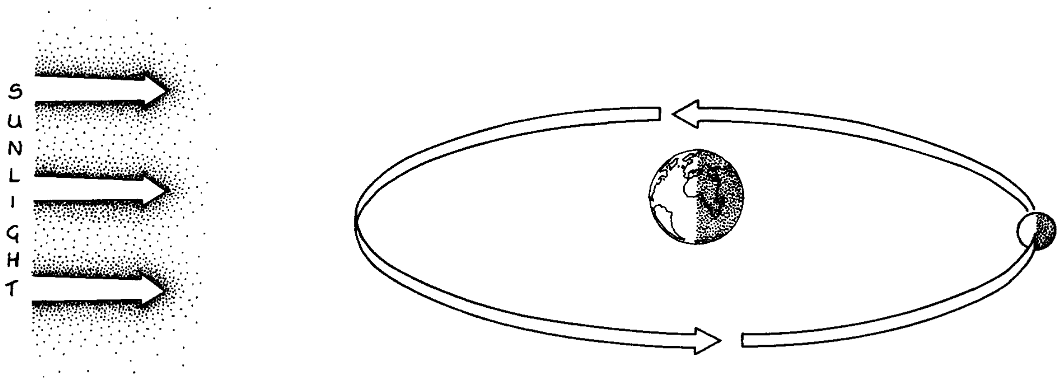


   What do we call this "phase" of the Moon? ……………………

3) Phases of the Moon

a) How much of the Moon's bright side can be seen from Earth?

……………………



b) What is the name of the “phase” now? ……………………

c) Draw a sketch of what you would see in the box.

4) What do you think the surface of the Moon is like? We can get a clue from the way light is reflected back from the Moon. Do you think the Moon is:

a) As smooth as a mirror – perhaps covered in water?

b) Not very smooth. Perhaps rough like a tennis ball?

Give a reason for your answer.

………………………………………………………………………………

………………………………………………………………………………

………………………………………………………………………………

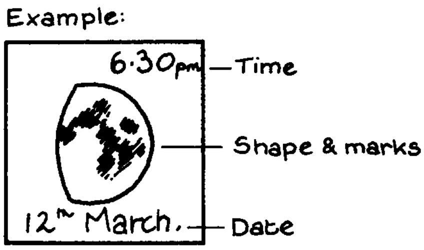
5) We see the Moon because sunlight is reflected off it. How is it possible then for us to see the Moon at night when the Sun is below our horizon?

………………………………………………………………………………

………………………………………………………………………………

HOMEWORK – Observing the Moon

If it is clear, draw a sketch of how the Moon looks in the sky. Try and show the shape ("phase"), any markings seen and write in the date and time of the observation. If it is cloudy, look in a newspaper or on a web site for the information.



Name:
Date you started your observations:

Sunday	Monday	Tuesday	Wednes-day	Thursday	Friday	Saturday

From your observations record the dates of the New and Full Moons in the table:

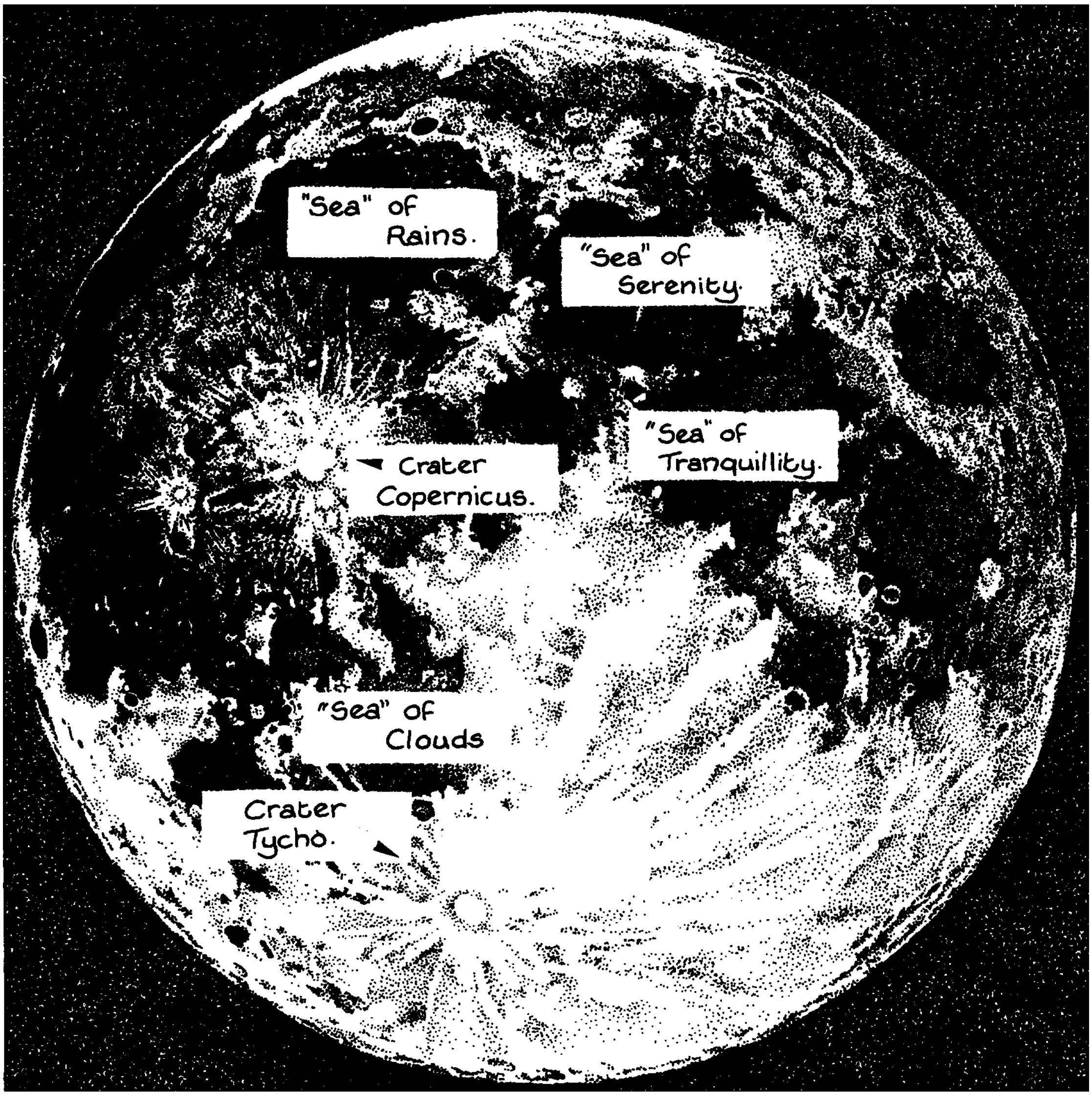
	New Moon	Full Moon	New Moon	Full Moon	New Moon	Full Moon
Date						

From these data, answer these questions:

a) How many days between two Full Moons? ………… days.

b) How many days from one New Moon to the next? ………… days.

THE "FULL" MOON



In this drawing of the Moon, there are light and dark areas. The light areas are mountain regions and the darker areas are the insides of huge old craters that filled up with lava and solidified shortly after the Moon formed.

Before anyone knew what the surface of the Moon was really like, people thought the darker patches were seas with water, as on the Earth. These names are still used and some of the "seas" are shown in the drawing above.

You can discover for yourself that the Moon is not flat if you can get hold of a pair of good binoculars. The best time is when the Moon is not "Full". Look at where the sunlit and dark part of the Moon meet, (where it is "evening" on the Moon and the shadows are long), and you may be able to see small craters or mountains. A small telescope will show even more detail but the view is usually upside down.

4. The Solar System and Gravity

Teacher Notes

Main Ideas:

* The Solar System consists of the Sun, nine major planets, their moons, asteroids and comets.
* The planets orbit the Sun in slightly elliptical paths
* Gravity is a force which acts between all masses and which holds the planets and moons in their orbits.

Historical Background

Before the invention of the telescope, only five planets were known apart from Earth. They look just like bright stars in the sky but early astronomers realised they were different from the stars because, week by week, they moved slowly against the background of these "fixed" stars. The word "planet" comes from the Greek word for "wanderer".

Three other planets. were discovered with telescopes:

Uranus, 1781	William Herschel (Bath, England)
Neptune, 1846	Leverrier (France) and Galle (Germany)
Pluto, 1930	Clyde Tombaugh (U.S.A.)

On 8th January 2005, a new planet with the temporary name 2003 UB313 was discovered. It orbits about three times further away from the Sun than Pluto. This great distance together with its small size (less than twice Pluto's diameter) makes it extremely faint. It is currently classed as a Minor Planet, although its is a contender for the title of Tenth Planet.

Spaceprobes have probably added more to our knowledge of the Solar System in the past 30 years than was discovered in all of history before!

Solar System Models

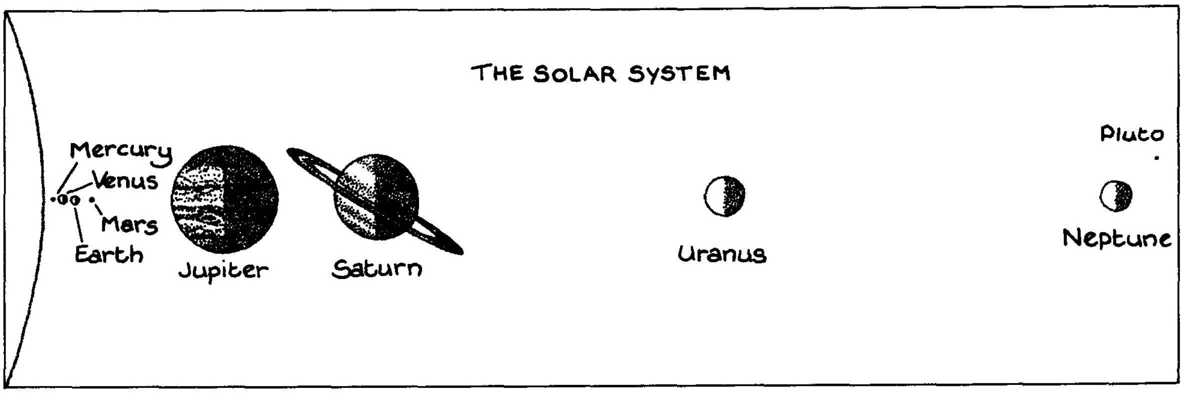
Making a model of the Solar System allows explorations of its scale and structure. As a pupil-orientated activity it can demand research, measurement, calculation and creativity.

Scale: In the following we suggest two scales; one for the sizes of the planets and another for the distances between.

In the diagram on the next page, the scale is .1 cm = 100 000 km for the diameters of the planets. If we were to use the same scale for distances between the planets, then Neptune would be 450 metres away from the Sun.

Incidentally, tiny Pluto has an eccentric orbit and, between 1979 and 1999 it was actually closer to the Sun than Neptune.

Shape: Most models, (like the diagram below), put the planets in a long line for practical reasons. In reality of course they are distributed around the Sun as they move in their orbits.



The planets are roughly spherical, not flat discs. Planet models made of beads, polystyrene spheres or even fruit in roughly the correct proportions add reality.

Motion: Working models are available through educational suppliers. Videos and computer programs are useful. Try the "Places To Visit" section at the end of this book for possible help. Getting the pupils to be a planet and run round the Sun in the playing field at the correct relative speed is another solution. In practice this is quite a challenge! An example of how this can be laid out successfully can be seen in the grounds of Armagh Observatory.

Choosing the Dimensions

You can devise your own scale using the "Average Distance" and "Size" columns in the Solar System Data Sheet on page ??????????????????.

The table on the next page has a few examples for larger scale constructions. They can be scaled up or down and adjusted for individual circumstances as necessary. Try and make the model as large as possible – along a corridor on a roll of wallpaper for instance. Only then can you hope to show the emptiness even within the Solar System.

The radii of the models (see distances to Pluto), are 3, 30 and 100 metres. Choose whichever is appropriate. The first three columns show the distances of each planet from the "Sun" for that particular model.

The fourth column gives the diameter of each planet to the same scale as the "100 metre" model. Note the small size of the planets compared to their distances from the Sun.

Use the Solar System Data Sheet on page ????????????? if you want the pupils to calculate their own scales.

Table of Alternative Scales				Diameter of body to same scale as in largest model in millimetres
	Distance from Sun in metres			
Sun				23.40
Mercury	0.029	0.29	0.98	0.08
Venus	0.055	0.55	1.83	0.2
Earth	0.076	0.76	2.54	0.22
Mars	0.116	1.16	3.86	0.11
Jupiter	0.397	3.97	13.22	2.41
Saturn	0.726	7.26	24.18	2.03
Uranus	1.46	14.60	48.64	0.87
Neptune	2.29	22.90	76.27	0.84
Pluto (average)	3.00	30.00	100.00	0.04
Nearest Star Proxima Centauri	20 km	200 km	675 km	

Note the impossibly small size of the planets, even on the largest scale given here.

SOLAR SYSTEM DATA SHEET

Information is given in "Earth" years, days, hours and minutes where appropriate

PLANET	AVERAGE DISTANCE FROM SUN	ORBITAL PERIOD	ROTATION PERIOD	SIZE	MASS	AVERAGE DENSITY	SURFACE TEMPERATURE	SURFACE GRAVITY AT EQUATOR	NO. OF MOONS KNOWN
	(millions of km)	(planet's "year")	(planet's "day")	(diameter in km)	(Earth=1)	(Water=1)	(degrees Celsius)	(Earth=1)	
MERCURY	58	88 days	59 days	4 878	0.055	5.42	430° max (day) - 170° min (night)	0.39	0
VENUS	108.2	224.7 days	243 days (retrograde rotation)	12 100	0.815	5.25	480° max	0.88	0
EARTH	149.6	365.25 days	23 hours 56 minutes	12 756	1	5.52	14° average	1	1
MARS	227.9	687 days	24 hours 47 minutes	6 794	0.108	3.94	-55° average	0.38	2
JUPITER	778.3	11.86 years	9 hours 50 minutes	142 984	317.9	1.31	-150° (at cloud tops)	2.64	63
SATURN	1 429	29.46 years	10 hours 36 minutes	120 536	95.1	0.69	-180° (at cloud tops)	0.92	34
URANUS	2 870.6	83.7 years	17 hours	51 118	14.5	1.19	-210° (at cloud tops)	0.79	27
NEPTUNE	4 504	163.8 years	16.3 hours	49 528	17.2	1.71	-220° (at cloud tops)	1.12	13
PLUTO	5 900	247.7 years	6 days 9 hours	2 274 (approx.)	0.0021	1.2	-230°	0.44	1

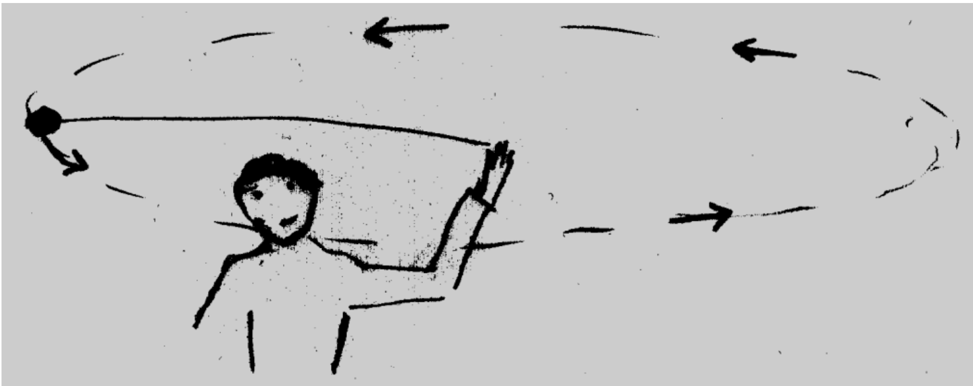
This data table may be photocopied for use in the classroom.

Gravity and Orbits

Gravity is an attractive force acting between all masses, e.g. two books, two people. However you would not notice the force between everyday objects because it is so small. It only becomes appreciable when very large masses are considered, such as the Sun, Moon or planets.

A smaller object will stay in orbit around a larger object such as the Sun because of the combination of the inwards pull of gravity, towards the centre of the Sun, and the high orbital speed.

To demonstrate an orbit, whirl a cotton reel or ball around your head by attaching it to a string. In this model your head represents the Sun and the cotton reel the planet.



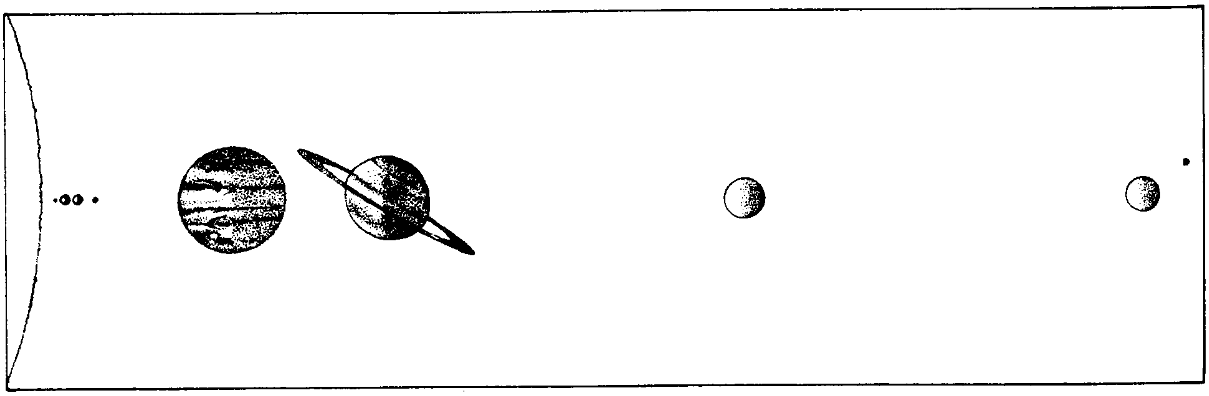
Explain that your hand must pull on the string to keep the cotton reel going round and that this represents the inwards pull of gravity. If the string were to be cut suddenly then the cotton reel would move off in a straight line – in the direction it happened to be going at that moment. The inwards pull prevents this and makes it go in a curve instead.

Try demonstrating a planet in a closer orbit. The circle is smaller, you have to pull harder and the cotton reel orbits faster. Then try a large orbit – the pull is gentle and the cotton reel goes much slower. This also happens in the Solar System where the closer the planet is to the Sun, the greater the pull of gravity and therefore the faster its sideways speed must be for it to remain in orbit.

NB! There is an equal and opposite attractive gravitational force on BOTH objects. The Sun pulls the Earth and the Earth also pulls the Sun with an equal force. However the Sun is much more massive and so does not get noticeably moved by the force! It does however wobble a very tiny amount and this is the method by which most of the extra-solar planets have been discovered so far – by the star’s very small regular wobbles, caused by the gravitational tugs of their planets.

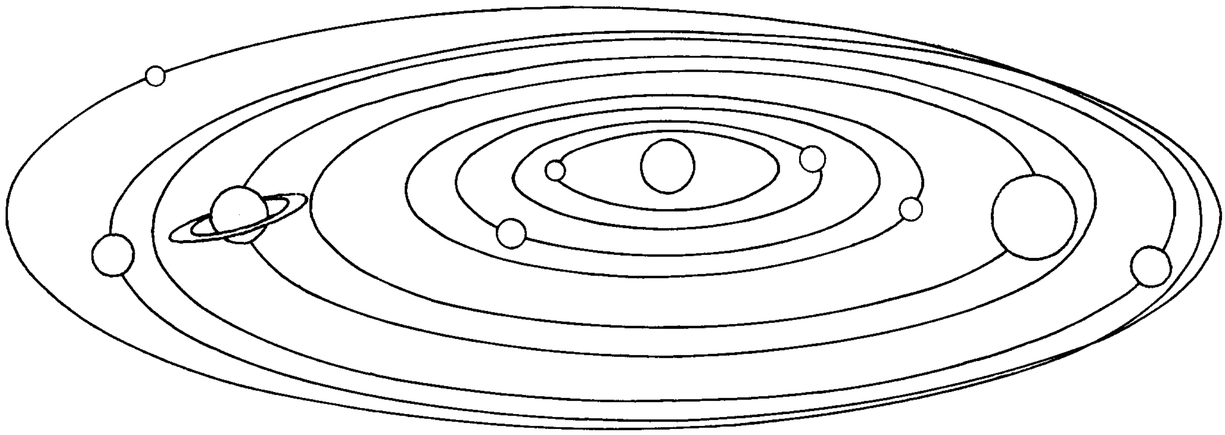
How the Planets are arranged in the Solar System

1) In the diagram below, we have drawn all the planets in a straight line with part of the Sun at the left. The sizes of the planets and Sun are to scale. Of course they very rarely ever line up like this! Label the planets in the diagram.



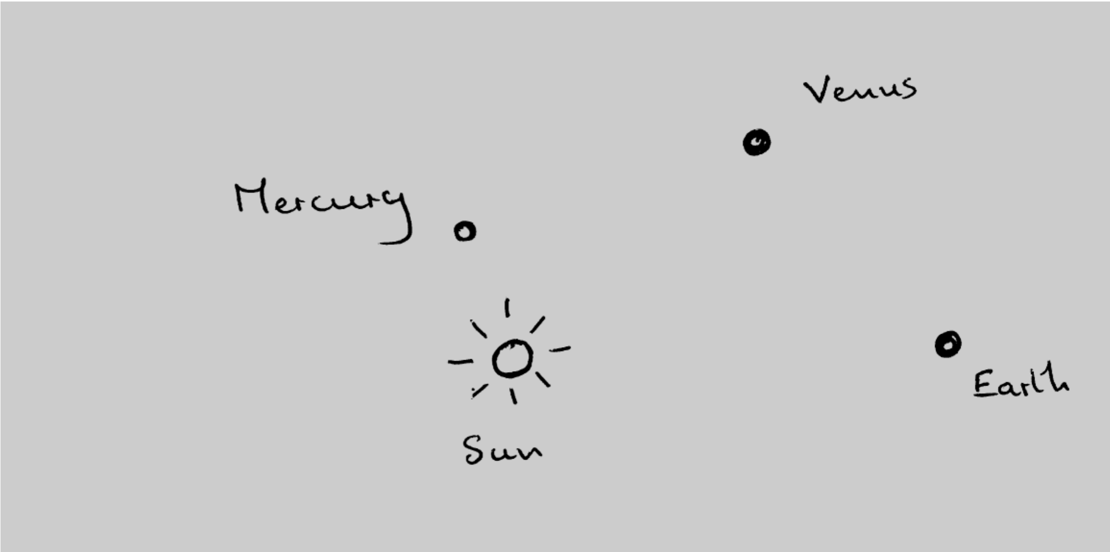
2) The diagram below shows the Solar System as seen from outside it. The lines show the orbits of the planets round the Sun.

   Notice how all the planets except Pluto are laid out in a flat disc. (The planets are not drawn to scale.)



Mark in the names of the planets in the drawing.

3) Gravity is an attractive force between all masses. Draw arrows on this diagram to show the forces acting on the Sun and these planets:



4) The table gives information about five planets in the Solar System.

Planet	Distance	Time for one orbit	Average orbital speed
	(millions of km)	(Earth years)	(km/s)
Mars	230	1.88	24
Jupiter	800	12	13
Uranus	2870	84	6.8
Neptune	4500	165	5.2

a) Draw a graph of each planet's orbital speed (on the y axis) against its distance from the Sun (on the x axis). Remember to label your axes.

b) Describe the relationship shown by your graph line:

……………………………………………………………………………………

c) Saturn orbits at an average distance of 1430 million km from the Sun. Use the graph to estimate its orbital speed. ……………………

HOMEWORK – The Solar System

Note: You need a copy of the data sheet.

Our planet is one of nine major planets orbiting the Sun. There are also many smaller "minor" planets. These include the asteroids, the majority of which have orbits between those of Mars and Jupiter, and some newly discovered "Trans-Neptunian" objects which orbit far beyond Neptune and Pluto. The latest of these to be discovered is called Sedna.

This exercise is only about the nine major planets listed in the data sheet.

1) Which are the largest and the smallest planets?

   Largest …………………… Smallest ……………………

2) Which planet is the coldest? Why do you think this is?

   ………………………………………………………………………

   ………………………………………………………………………

3) Here is a drawing of the planet Venus showing the clouds in its atmosphere.

How long does it take Venus to orbit the Sun?

……………………

Life has not been found on Venus. Why would visitors find it impossible to survive for long on the planet?

…………………………………………

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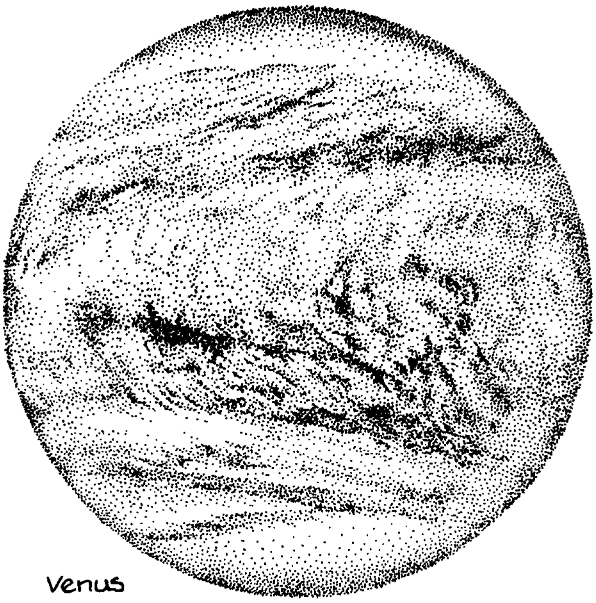
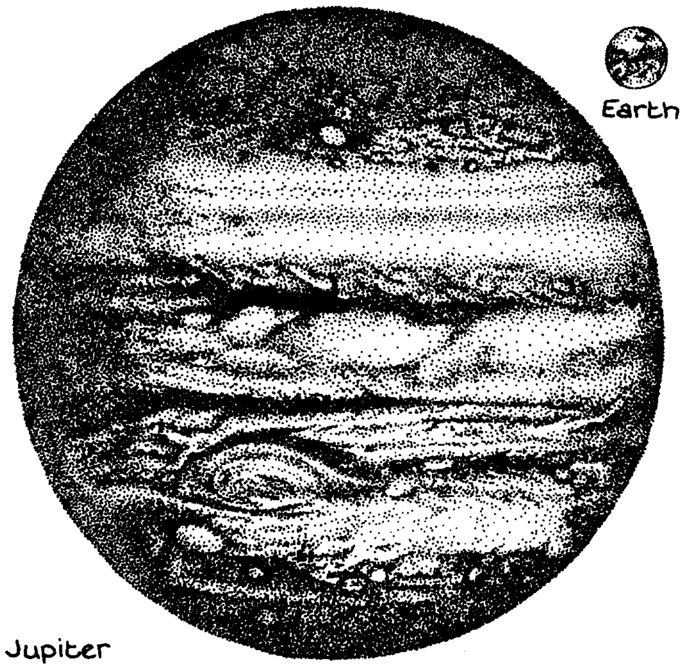


Venus

4) This drawing of Jupiter shows swirls of clouds going around the planet.



The Earth is also shown here to the same scale.

Jupiter and the large planets beyond it do not have a solid surface for spacecraft to land on. The planets are made of gas and spacecraft would just sink in.

How many Earths would it take to fit across Jupiter? Measure the planets in the drawings and then check your answer by using the information table.

…………………… times.

5) Which planet orbits the Sun in (a) the shortest time and (b) the longest?

(a) …………………… (b) ……………………

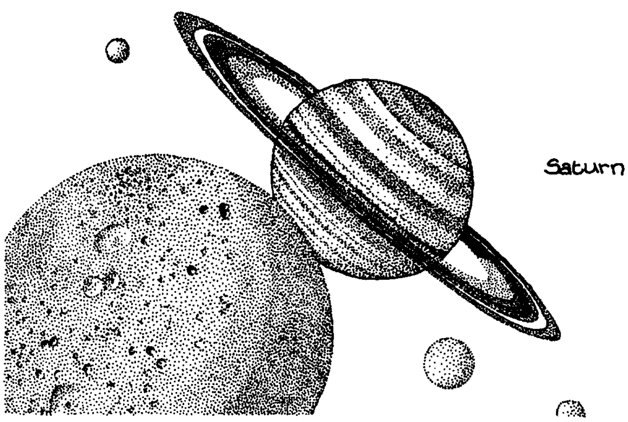
About how many times does (a) orbit the Sun while the Earth orbits the Sun once?

……………………

If you lived on (a), how old would you be in this planet's "years"?

……………………

6) This is a drawing of Saturn as seen from near one of its moons. Planets with many moons have been called "Solar Systems in miniature"; can you say why?



……………………………………

……………………………………

……………………………………

……………………………………

……………………………………

7) Uranus, Neptune and Pluto were discovered after the other planets. Why was this and why do you think they were discovered in that order?

………………………………………………………………………………

………………………………………………………………………………

………………………………………………………………………………

8) If a spacecraft takes about 3 years to reach Saturn, about how long would it take to reach Pluto from Earth? Use the planets' distances from the Sun in your calculation as a rough approximation.

………………………………………………………………………………

………………………………………………………………………………

………………………………………………………………………………

9) What is the force that keeps the planets in orbit around the Sun?

……………………

10) Give two reasons why Saturn takes about 30 years to orbit the Sun but Mars takes less than 2 years.

Reason 1 ……………………………………………………………………

Reason 2 ……………………………………………………………………

11) As the planets orbit the Sun, so the distances between the planets vary. Work out roughly the shortest distance between Venus and the Earth. What is the longest distance? (Assume the planets orbit the Sun in circles).

………………………………………………………………………………

………………………………………………………………………………

5. Observing a Planet

Teacher Notes

Main Ideas:

* Planets can be seen in the night sky because they reflect sunlight.
* Planets move across the sky relative to the background of the star patterns.

The practical observing is included here for those who feel confidant in locating planets in the night sky and therefore feel able to explain to classes where to look. The students could observe on their own at home or you could organise an after-school session in the winter.

At the beginning or end of each month many daily newspapers give information on the night sky, mentioning any planets that are currently visible.

Planets are moving objects

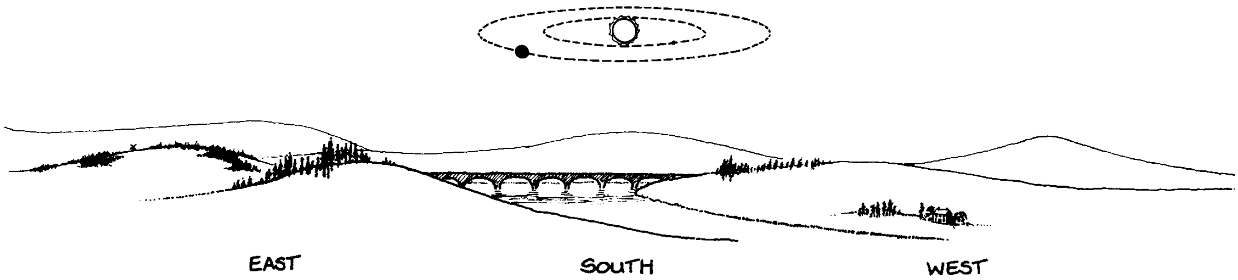
Everything in space is moving but the stars are such a long way away that, even over hundreds of years, they change their relative positions in the sky very little.

The planets are much closer and we can plot them moving against the background stars often from week to week. As they orbit the Sun so their positions can be predicted very precisely.

The Inner Planets

The planets Mercury and Venus are never far from the Sun in the sky. However they are too faint to be seen in daylight and so they are only visible just after sunset or before sunrise depending on their position in their orbits. Of course we cannot see them when they are behind the Sun.

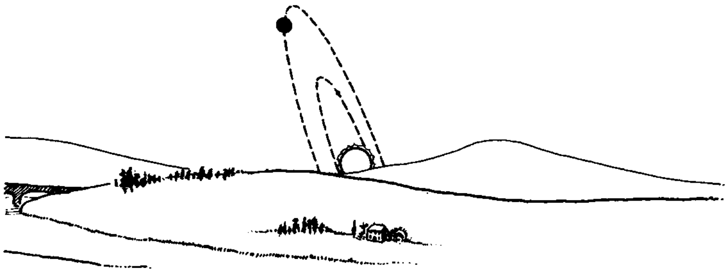
This is a diagram of the inner Solar System as it might be positioned in the middle of the day in our sky.



It shows how Mercury and Venus do not move very far away from the Sun wherever they are in their orbits. As they move around the Sun so we see them only alternately in the evening and morning.

Mercury is always fairly close to the Sun. It is a small planet and moves quickly around the Sun. Consequently it is not an easy planet to observe unless you know exactly when to look out for it. It is visible just after dark three or four times a year for a period of about a fortnight only and for perhaps an hour each evening. It is a difficult object for the novice without precise information.

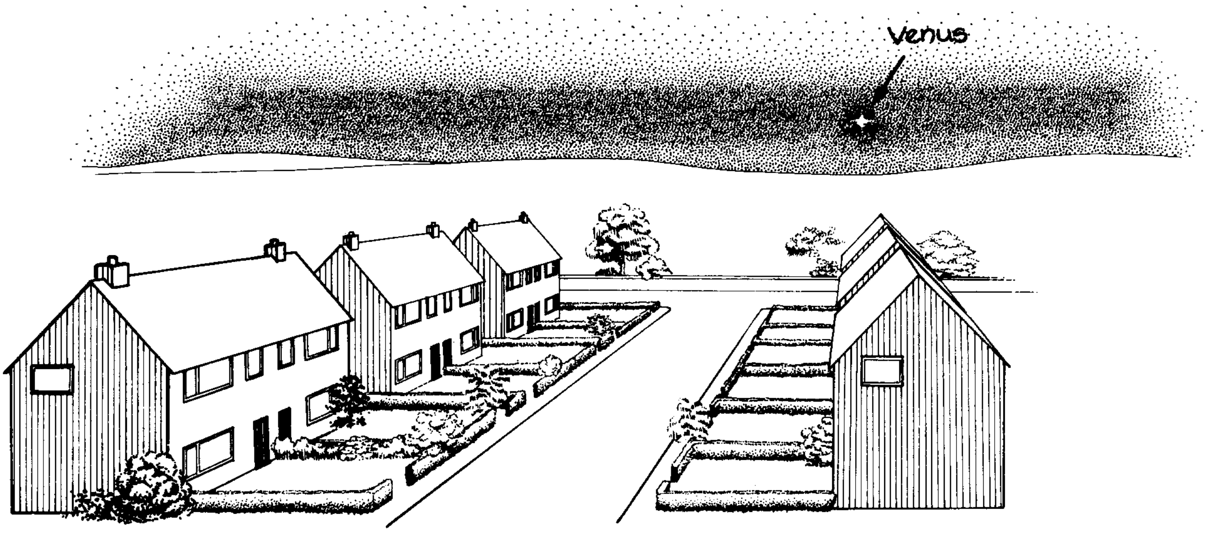
Venus always stays within 44° of the Sun itself. Because of the tilt of the Earth and our position on it, we see the Sun and inner Solar System in the evening rather like this.



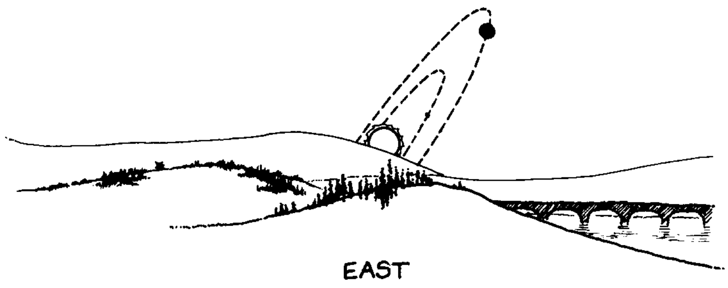
Venus as an Evening Object

When Venus (or Mercury) are in the "left-hand" part of their orbits, they set after the Sun and we see them in the west just after sunset.

Wait until it is reasonably dark and look towards where the Sun has set. Venus is much brighter than the stars and is fairly easy to spot if you look in the right part of the sky. As the Sun slips further below the horizon so Venus will drop lower. It generally sets within 3 hours of sunset.



When Venus is on the "right-hand" side of its orbit then it sets before the Sun. However, the following morning it will be visible before sunrise. But this is for early risers even in winter!



Venus as a Morning Object

The Outer Planets

The planets with orbits “outside” that of the Earth, are not restricted to positions near the Sun in our sky and can be seen all round the night sky. But, again, we do have to know where and when to see them in the sky.

* Mars is a small planet and does not get as bright as Venus or Jupiter in the sky. It looks an orange colour which no doubt gave it its name as the “God of War” or conflict. A telescope with good optics is needed to see any details on the surface of Mars.
* Jupiter often rivals Venus for brightness in the sky. With a good pair of binoculars held still, the four largest moons of Jupiter can be seen changing position from night to night as they orbit the planet.

JUPITER MOON STRIP 1 TO BE ADDED HERE ??????????????????????????????

View of Jupiter and its Four Largest Moons

JUPITER MOON STRIP 2 TO BE ADDED HERE ??????????????????????????????

A few nights later the Moons have moved in their orbits around Jupiter

* Saturn orbits the Sun every 29 years, moving very slowly against the background of stars. A telescope is needed to see the rings of Saturn – binoculars do not usually magnify enough.
* Uranus, Neptune and Pluto are too far away and therefore too faint to be seen with the naked eye and were discovered only after the invention of the telescope. Definitely for the enthusiasts!

SEEING PLANETS

1) Planets look bright in the night sky because they reflect sunlight. They do not make their own light.

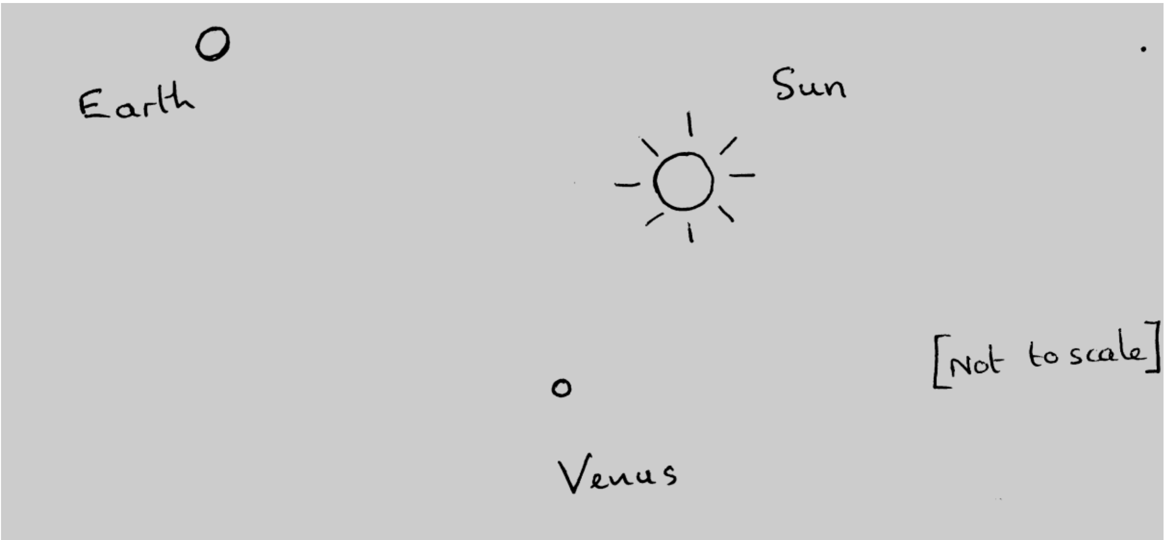
   Here are some astronomical objects.

   Sun ***Moon*** ***Stars*** ***Planets*** ***Satellites***

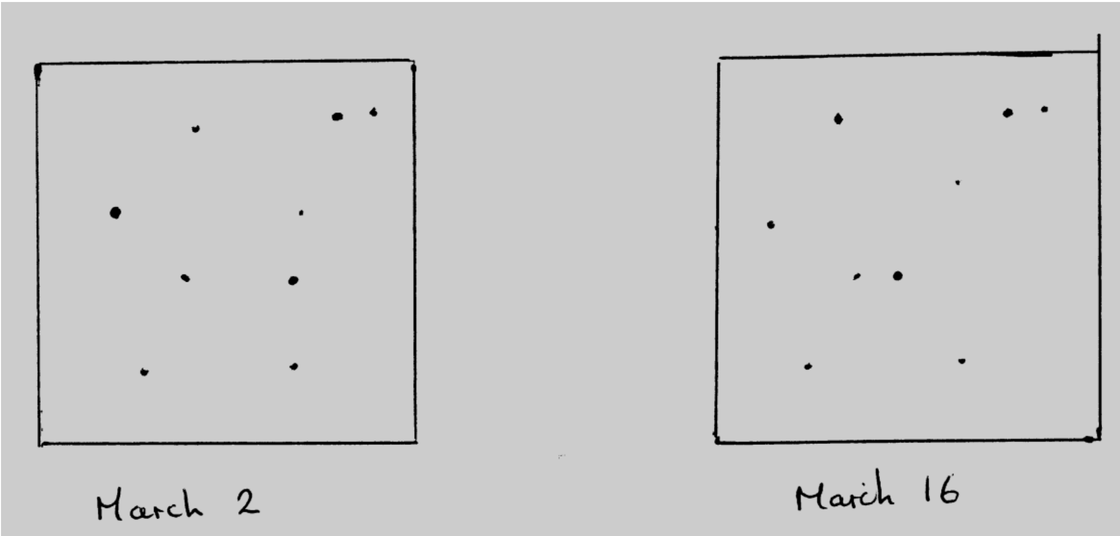
   List these objects under the headings below:

Objects which make their own light (luminous)	Objects seen by reflected light (non-luminous)

2) Venus is a planet that can be seen easily in the early morning or evening sky. It looks just like a bright star. On the diagram below draw arrows to show the path of the sunlight as it goes from the Sun to Venus and then to Earth so that we see it.



3) a) These two pictures of the stars in the night sky were taken fourteen days apart. Circle the dot which is a planet.



b) Explain how you knew this one was a planet:

……………………………………………………………………………

……………………………………………………………………………

……………………………………………………………………………

4) Some people call Venus the "Evening Star" Look at the diagram showing how Venus can be seen in the evening sky.

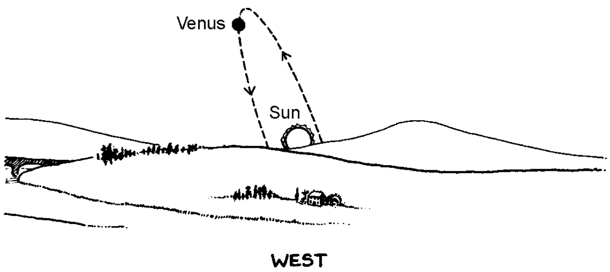
a) Why is Venus sometimes wrongly called the "Evening Star"?

…………………………………

…………………………………

b) Why is this name wrong?

…………………………………



6. Artificial Satellites

Teacher Notes

Main Ideas:

* There are many artificial satellites placed in orbit about the Earth.
* Gravity is the force which keeps these satellites in orbit.
* The satellite's orbital speed must be exactly right to keep it in orbit and prevent it falling back to Earth.
* Low orbit satellites can be used to monitor land use and the environment, collect high resolution data on weather patterns and for military purposes (spying).
* Geostationary satellites orbit once in 24 hours, at the same rate as the Earth spins. They therefore appear to remain stationary above the same spot on the Earth's surface. They are used for telecommunications or for monitoring global weather patterns.
* Astronomical telescopes can be placed in orbit on a satellite. These have a much clearer view of the Universe because they are above the Earth's atmosphere.

Misconceptions

Satellites orbit because of gravity. They have not "escaped" the Earth's gravity. However there is **only one** force acting on a satellite in orbit – the inwards pull of the Earth's gravity. Mistaken ideas about circular motion are common, including the idea that there is an outwards force.

Orbiting astronauts seem "weightless" because they are freely falling towards the centre of the Earth under the influence of gravity. The spacecraft in which they are travelling is also falling at the same velocity for the same reason. A common misunderstanding is that they float around because they have escaped gravity. Geostationary satellites ARE moving as they orbit once in 24 hours. They only ***appear*** to be stationary above one spot on the Earth's surface.

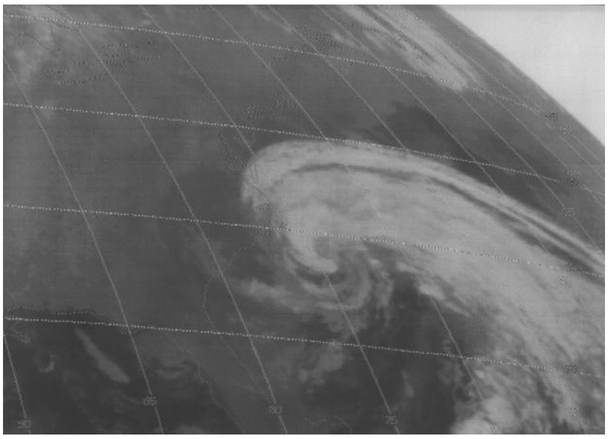
Observing Satellites

Some satellites in low polar orbits may be seen from the ground without any optical aid at all – on a clear night of course! They look like faint stars but shine by reflected sunlight. Satellites take several minutes to cross the sky. Make sure it is not flashing – that would be an aircraft.

Some daily newspapers give details of the satellites visible that evening and websites also give more detailed information:

http://www.satobs.org/satintro.html – gives predictions for the next few nights.
http://spaceflight.nasa.gov/station – for the International Space Station.

SATELLITES OLD AND NEW

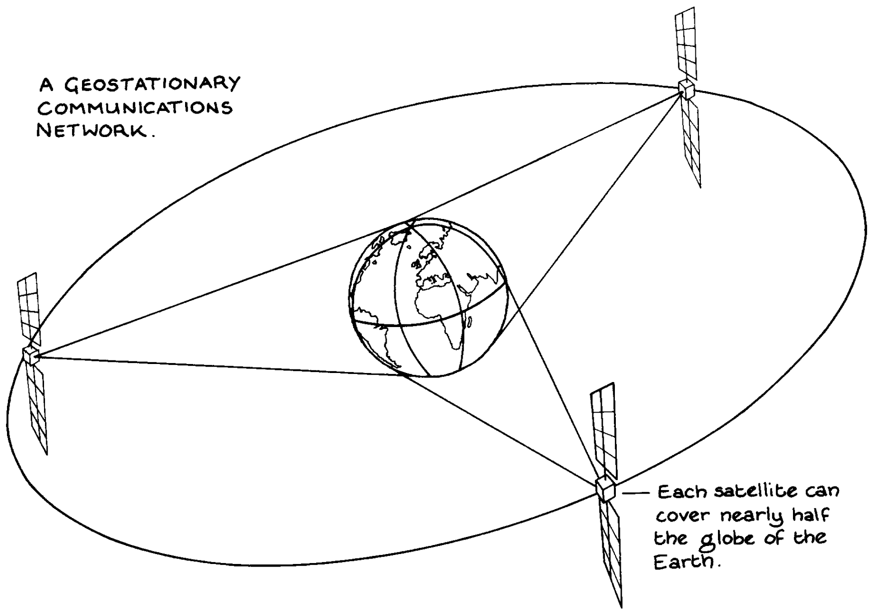


As you read this sentence you are being watched from cameras far above the Earth. The cameras are carried by satellites circling the Earth. Over 2000 artificial satellites have been launched into space. Some are old and are now redundant. Others are being used to bounce communications signals between continents. Some are sending weather photographs to Earth. Others are just watching.

The Moon is the Earth's only natural satellite. It orbits the Earth a little more than once a month. There are about 29 days between one Full Moon and the next.

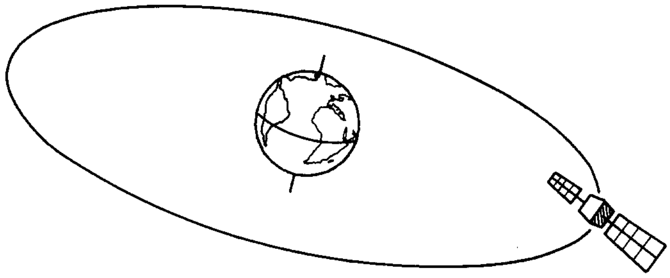
Isaac Newton calculated how the force of gravity between the Earth and the Moon kept the Moon in its orbit.

The idea that satellites could be used to send information round the Earth is not new. In 1945, the science fiction writer Arthur C Clarke first suggested the possibility of an artificial satellite which, placed at 36 000 kilometres above the Earth, would remain in a 24 hour orbit and so stay above the same place all the time. This is called a "geostationary" orbit. Three such satellites could cover the entire globe in a communications network.

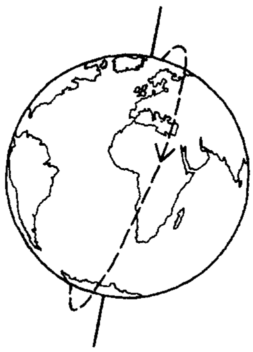


The first artificial satellite, Sputnik 1, was successfully launched in October 1957. This Russian satellite followed a fast, low orbit, circling the Earth in under two hours. The Americans followed with Explorer 1 in January 1958. The first real communications satellite, the American Telstar, was launched in 1962. All these early fast satellites passed overhead quickly and could be tracked only for a few minutes.

However Arthur C Clarke's idea was realised in 1964 when Syncom 1 was launched by the Americans into a geostationary orbit at a height of 36 000 km.



Geostationary Orbit



Polar Orbit

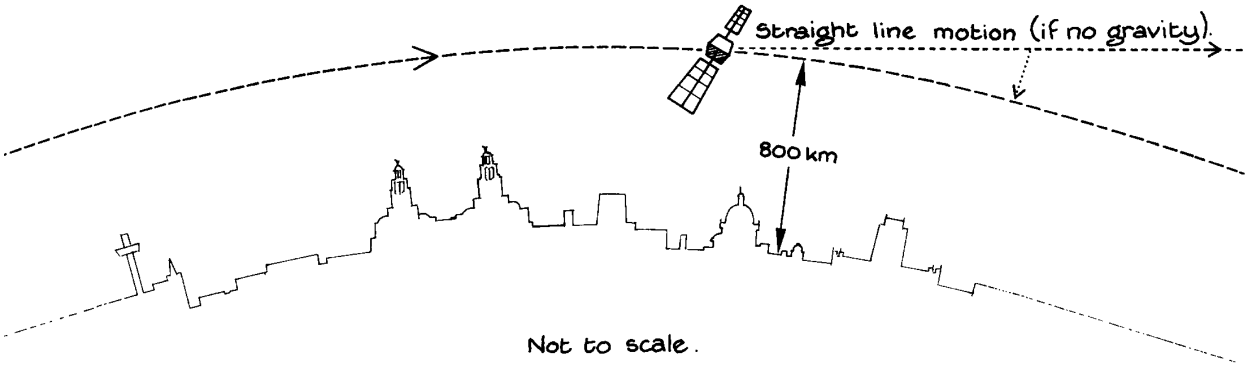
Many of today's weather photographs are taken by cameras in space. Some of these weather satellites are geostationary, while others have low, fast polar orbits, perhaps 1000 km above the surface. A satellite in a polar orbit will pass over a narrow band of the Earth's surface but as the Earth turns so the satellite passes over different bands in successive orbits. In this way photographs of all the Earth's surface can be taken every day.

Launching a Satellite

Launching a satellite means forcing it upwards against gravity. All early satellites were carried up by rockets which could only be used once. More recently, re-usable launchers like the American Space Shuttle have been designed not only to launch satellites but also to retrieve and repair low-orbit satellites if necessary.	

A satellite in Earth orbit is continually falling to Earth under the attractive force of gravity. So why doesn't it crash down to Earth? As well as being pulled by gravity, satellites are given a sideways ("orbital") speed. Because the Earth is round and not flat, the Earth's surface drops away beneath the satellite as the satellite free-falls towards it under the pull of gravity. The path of the falling satellite becomes an ellipse or a circle.

Once a satellite is moving in an orbit, its orbit may be adjusted by firing small booster rockets in appropriate directions.

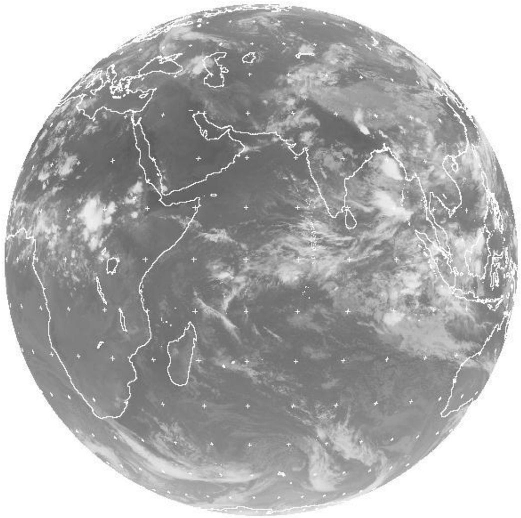


ARTIFICIAL SATELLITES:

Where are they and what do they see?

Meteosat

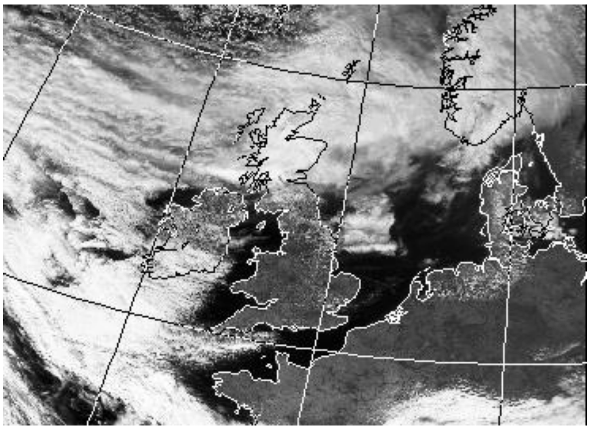
There are five geostationary meteorological satellites. These observe the clouds, measure the temperature of the atmosphere by detecting infrared radiation and study differences in water vapour absorption. Europe's METEOSAT orbits 36 000 km above 0° longitude and covers Europe, Africa and the South Atlantic Ocean. Another METEOSAT is positioned over the Indian Ocean to cover India, China and Indonesia.



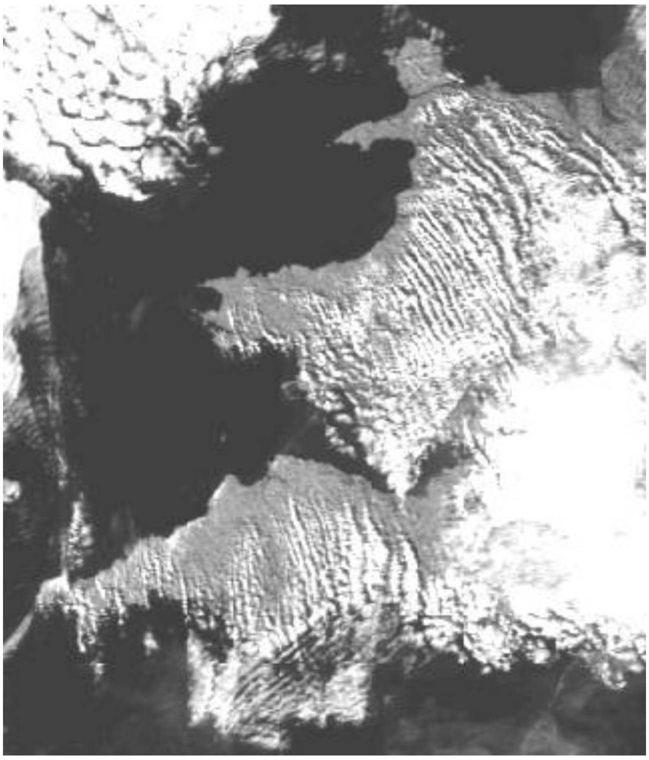
An image taken by Meteosat-5, now re-positioned at (63° East)
for Indian Ocean data coverage

NOAA

The NOAA series of satellites are polar orbiting and monitor the weather in much more detail. They scan from south to north, over the poles, and on each successive orbit they scan a strip further to the west. These strips can then be put together to produce a larger picture.



To give a better idea of scale, here is an example showing Wales and south-west England during February.



Global Positioning Satellites (GPS)

These orbit at an “intermediate” height of 17 500 km and have an orbit time of about 12 hours. They are regarded as “high” orbit but are not geostationary. They provide a very accurate navigation system which in the future will allow a plane to land in zero visibility. Other uses are accurate surveying, assisting medical rescue helicopters and measuring the height of Mount Everest!

Intelsat Communications Satellites

There are dozens of geostationary satellites providing service to the television and communications industries, relaying telephone calls and TV programmes around the world.

The Hubble Space Telescope

This satellite is in a low orbit, but well above the atmosphere. It carries a telescope which can view the Universe without the atmosphere distorting the picture. It is used to study detail on planets, faint stars and very distant galaxies.

INTERNET INFORMATION ON SATELLITES

Try these web sites:

www.eumetsat.de This leads you to the METEOSAT satellite images. Click on “Meteosat images” and explore the latest pictures of Earth’s weather, updated every half hour. Try the colour images, the “Special Images” (there is one of the 1999 eclipse as seen from space).

wwwghcc.msfc.nasa.gov/GOES/satlinks.html This gives a long list of favourite weather picture sites. Choose the “Dundee Weather satellite receiving station” and enjoy “Some Satellite Images”. Then roll to the bottom of this page and click on “More Interesting Images” to see views of snow, flooding, Mount Etna eruptions and many more. Then go back to the main page and use their link to “Related Web Sites”. Choose the Earth Observatory to see some “Natural Hazards”. Among these will be the most recent disasters such as the bush fires in Australia and the dust storms in the Canary Islands.

www.satobs.org/satintro.html You can see low orbit satellites in the night sky as they pass overhead. They look like very slowly moving stars. This site gives predictions for most satellites for the next few nights, so that you can work out which one you have spotted!

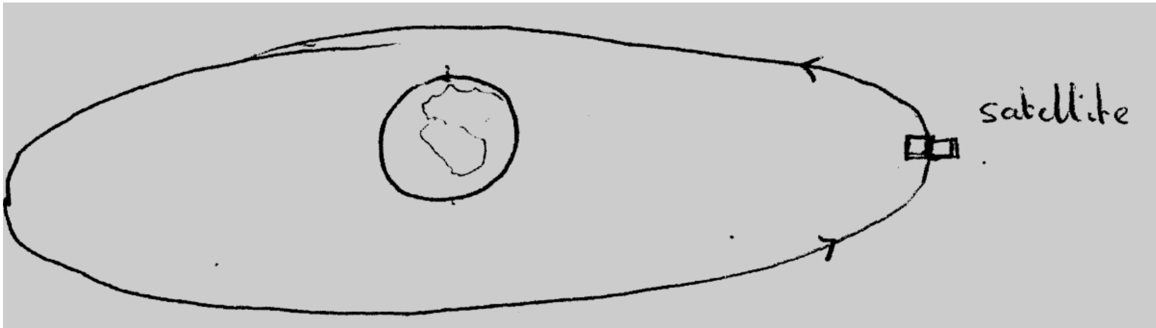
www.esa.int European Space Agency. A wide range of high-quality resources.

The First Meteosat Image

Artificial Satellites

Geostationary Orbits

The diagram below shows one type of orbit for a satellite – a geostationary or synchronous orbit.



1) Mark on the diagram with an arrow the force acting on the satellite.
2) What causes this force?

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3) How long does it take this satellite to orbit the Earth?

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4) Why is this kind of satellite called geostationary? Explain:

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5) Give two important uses of this type of satellite:

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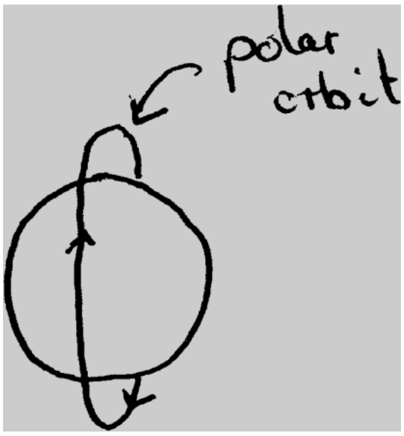
Polar Orbits

The diagram below shows a satellite in a low orbit which takes it above the poles of the Earth.



1) How does the ***time*** for one orbit compare with the time for a geostationary orbit?

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   Explain why:

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2) Suggest, with reasons, three uses of satellites in polar orbits:

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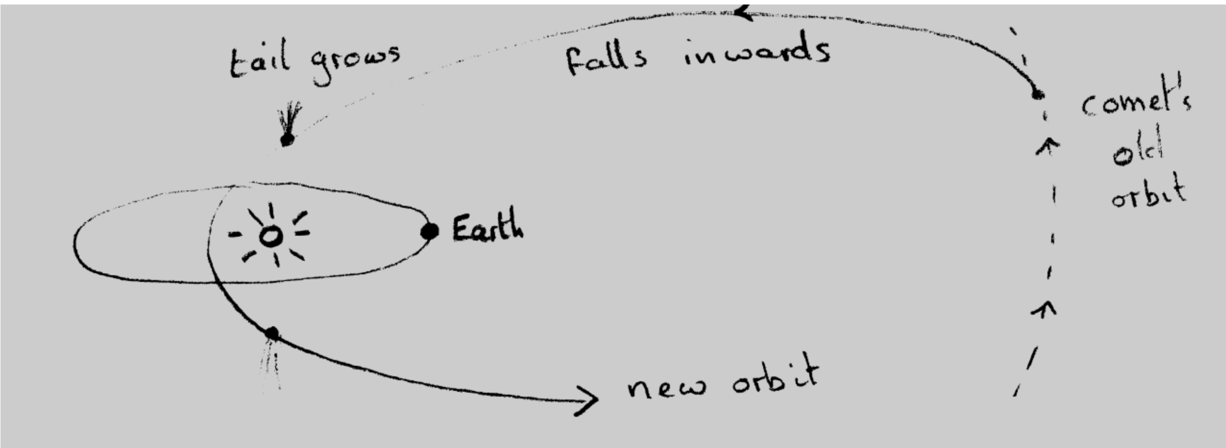
7. Comets

Teacher Notes

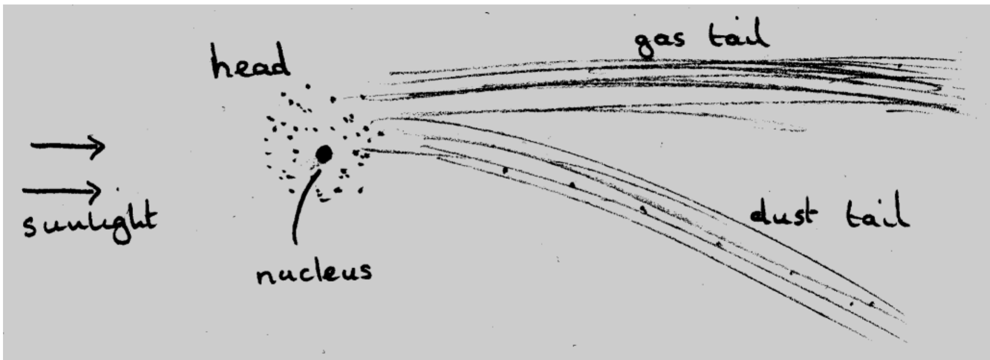
Main Ideas:

* Comets orbit the Sun, often in very elliptical paths.
* Comet nuclei are made up of rock, dust and ices and are only a few kilometres in size.
* Comets only develop their tails when they are near the Sun.

Comets are quite tricky to observe and it is likely that most pupils in your class will never have seen one. They are thought to originate from a belt of small rocky, icy objects which orbit the Sun far beyond Neptune. Occasionally one of these may be disturbed from its far orbit, perhaps by the gravitational tug from another object, and then it begins to fall towards the Sun.



It may go round the Sun and be slung out of the Solar System for ever or it may go into a very elliptical path such as that of Halley's comet which orbits once every 76 years. The bright head and tail of a comet only develop when the tiny nucleus begins to approach the Sun. The solar radiation warms and sublimes the ices in the comet and this also releases dust particles trapped in the ices. The gases and dust are pushed away from the nucleus by the solar radiation and create the gas and dust tails. These are seen from Earth by reflected sunlight.



Variation in Speed

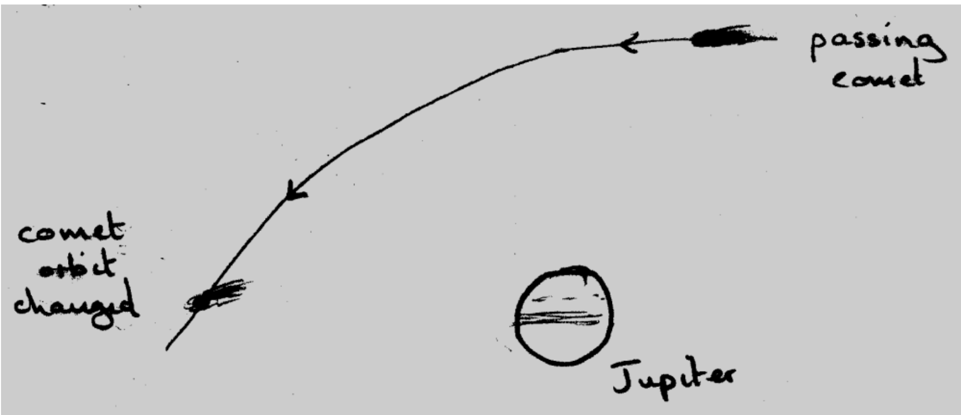
Comets orbit under the influence of the Sun's gravity. They therefore speed up as they fall towards the Sun, going at the greatest speed when closest to the Sun and decelerating again as they move (tail first) back out to the furthest reaches of the Solar System. This means that they spend most of their time at very great distances from us and very little time in the inner Solar System where we could see them. Therefore they are quite difficult to spot.

Observing a Comet

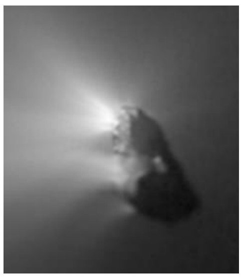
Predictions of cometary orbits are tricky. The British Astronomical Association has information on regular comets and magazines such as Astronomy Now will give viewing hints and maps. (See Appendix ??????????). Comets do NOT streak across the sky but move very slowly across the constellations form night to night, making it possible to see the same comet several nights or even weeks running. Most are quite faint and need at least a pair of binoculars to spot them.

Comets and Jupiter

Any comet approaching Jupiter, the largest planet, will have its orbit altered. In July 1994 Comet Shoemaker-Levy 9 was pulled right into Jupiter after several orbits of the planet itself. The gravitational forces on it broke it up and the pieces plunged into Jupiter's atmosphere. Pictures of this impact can be viewed on the Jet Propulsion Laboratory website at www.jpl.nasa.gov



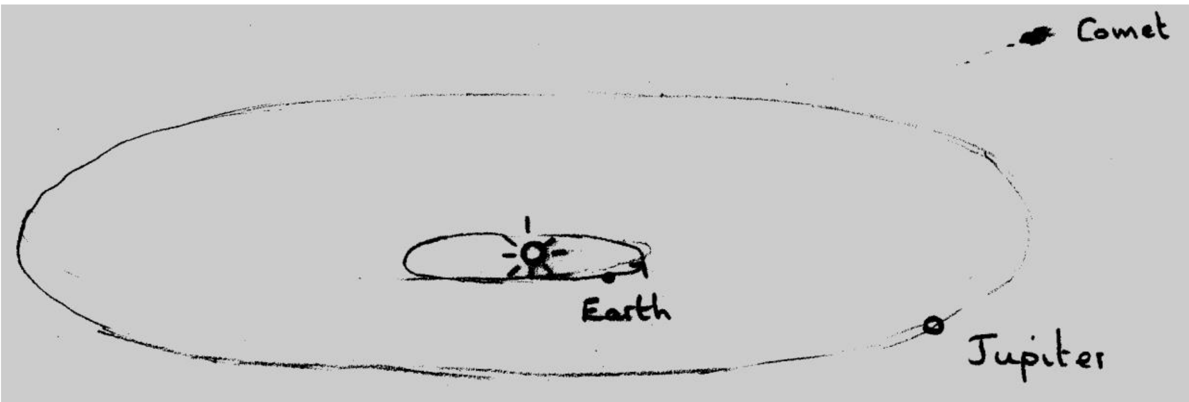
Many other comets must have suffered similar fates, disappearing into Jupiter, the Sun or even crashing down to Earth. One of the theories about the sudden death of the dinosaurs involves a comet or asteroid colliding with the Earth.

Comets Comet A Comet B ?????????? ESA Giotto ??????

COMETS

1) The diagram shows the orbits of Earth and Jupiter. A comet is approaching from the outer Solar System.



a) Draw an orbit for the comet. Add an arrow on the path to show which way it is travelling.

b) How does the path of a comet differ from the orbits of the planets?

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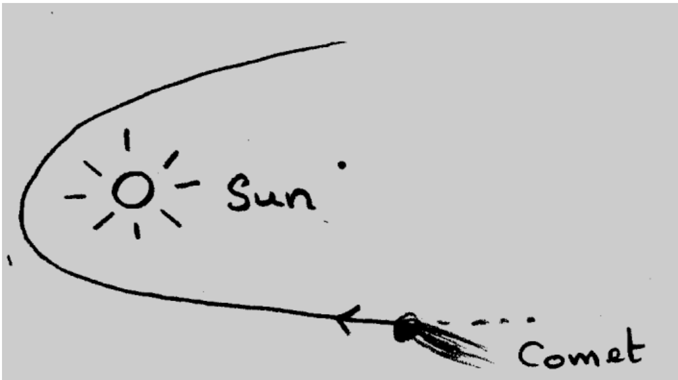
2) This comet is approaching the Sun.



a) Explain how the force on the comet changes as it moves along its path:

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b) How does the speed of the comet change as it orbits?

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3)

a) Draw a possible path for this comet as it passes Jupiter.

b) Explain why the comet follows this path:

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4) Comets are not often seen in the night sky. Explain in as much detail as you can why this is so. You may wish to draw a diagram to help you.

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8. Stars and Galaxies

Teacher Notes

Main Ideas:

* A star is a huge sphere of very hot glowing gas.
* Our Sun is an ordinary star, just one of many thousands of millions in the Milky Way Galaxy.
* There are more than a billion galaxies in the Universe.

The stars we see in the night sky are similar to the Sun but at much greater distances. Many are larger and more luminous. Students may find this idea difficult to accept since the Sun looks so much bigger and brighter. The activities in this chapter are intended to help visualise stellar distances. Orion is an easy constellation for the students to identify as it is high in the evening winter skies. Here one can find examples of very young and very old stars and a blue supergiant, Rigel.

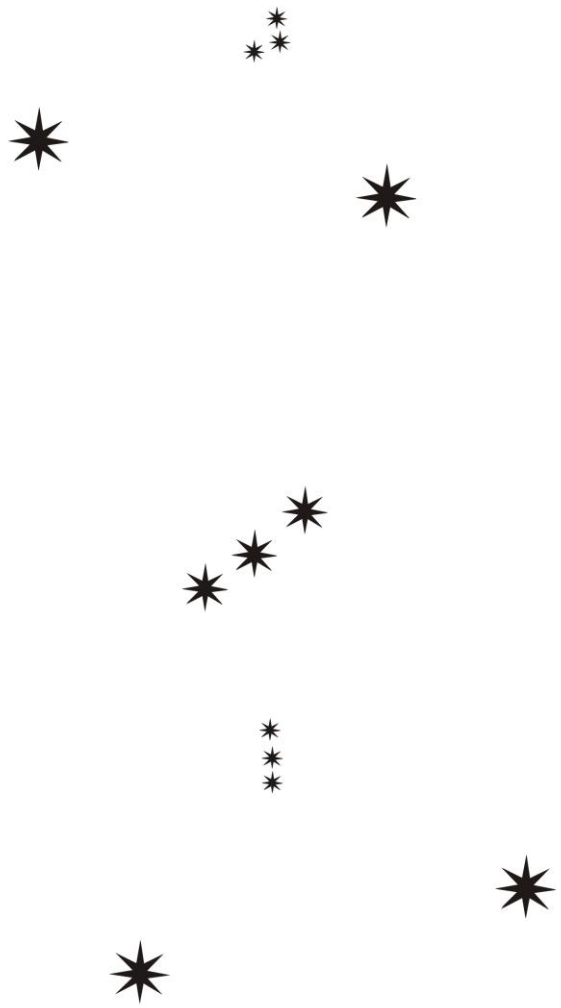
Our Galaxy, the Milky Way is a giant spiral galaxy containing about 100 thousand million stars together with some interstellar gas and dust. The spiral structure is now well studied although the Solar System is, of course, embedded within a spiral arm and our view of our own Galaxy is “from within”. On a very clear dark summer evening the Milky Way can be seen arching overhead as a band of very faint stars which totally encircles us.

One other galaxy can be seen with the unaided eye, the great spiral galaxy in Andromeda, M31. Even this, our nearest neighbour giant spiral galaxy, is only a faint fuzzy patch in the sky. The activity to find it is for enthusiasts!

Any light pollution from street lights etc. will reduce the chances of seeing the Milky Way or the Andromeda galaxy to almost nil. If your school's neighbourhood suffers from heavy light pollution, your students might wish to write a letter to the local council about their street-lighting policy. Help with campaigns like this can be obtained from the Campaign for Dark Skies (CfDS) at www.dark-skies.org

SEEING STARS

With your naked eye you can see only about 1500 stars, depending on the darkness at your observing location. Orion is an easy pattern to spot on a winter's evening. Look South. These stars are all in our Galaxy.



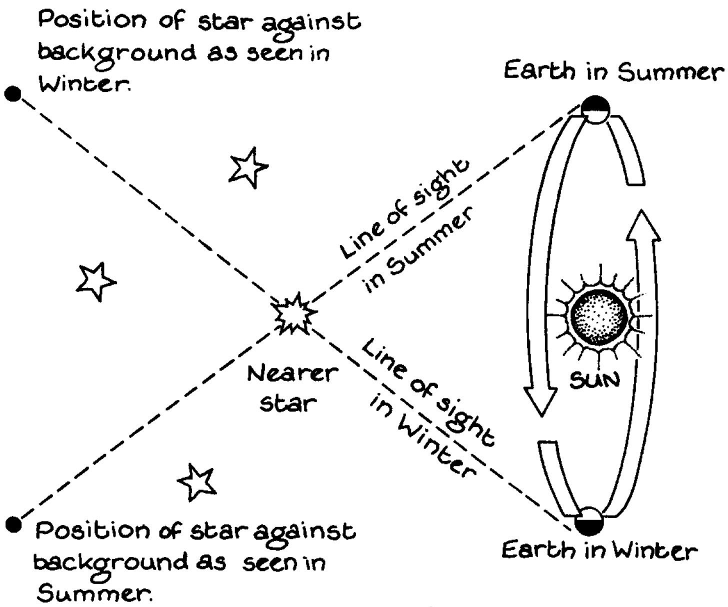
Orion – The Hunter

These stars are not all at the same distance from us so that the pattern we see is a trick of perspective. Orion would not look the same from another viewpoint in our Galaxy.

It is impossible to tell which stars in the night sky are further away than the others just by looking. The distances to the nearby stars was first measured in 1837 or 1838 ??????????? by seeing how a "nearby" star seemed to move very slightly against the background of the more distant stars when measured at the two opposite sides of the Earth's orbit around the Sun.

DISTANCES TO THE STARS

One method of measuring star distances uses this effect, called parallax. This method has given astronomers a good idea of the distances to most of the nearby stars:



PARALLAX

You can see this effect if you hold up a finger in front of your eyes and look at it. Open and close each eye in turn. Notice how the finger seems to move or jump when seen against its background. The closer your finger is to your face, the more it moves. Your brain uses the slightly different views of a nearby object as seen by each eye to judge distances.

LIGHT YEARS

Distances across the Galaxy are often measured in “light years”. This is because huge numbers of kilometres are difficult to deal with. For instance Pluto is about 6 000 million km away from the Sun. The nearest star is almost 7000 times further away, about 40 000 000 000 000 km. Light travels through empty space at 300 000 km/s. In a year it travels about 9.5 million million km. This distance is called a “light year”.

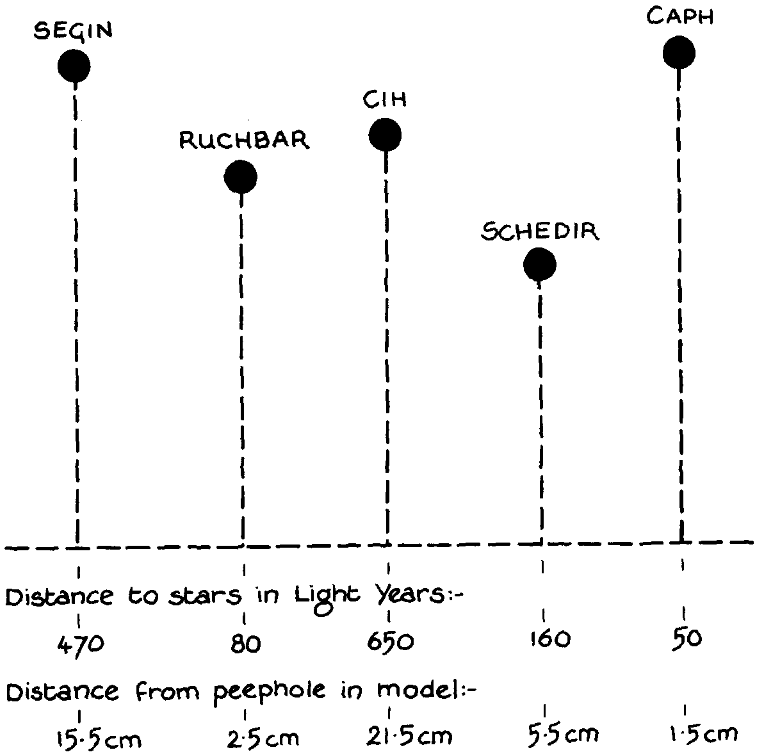
A MODEL TO MAKE YOURSELF

Cassiopeia – a "W" in the sky

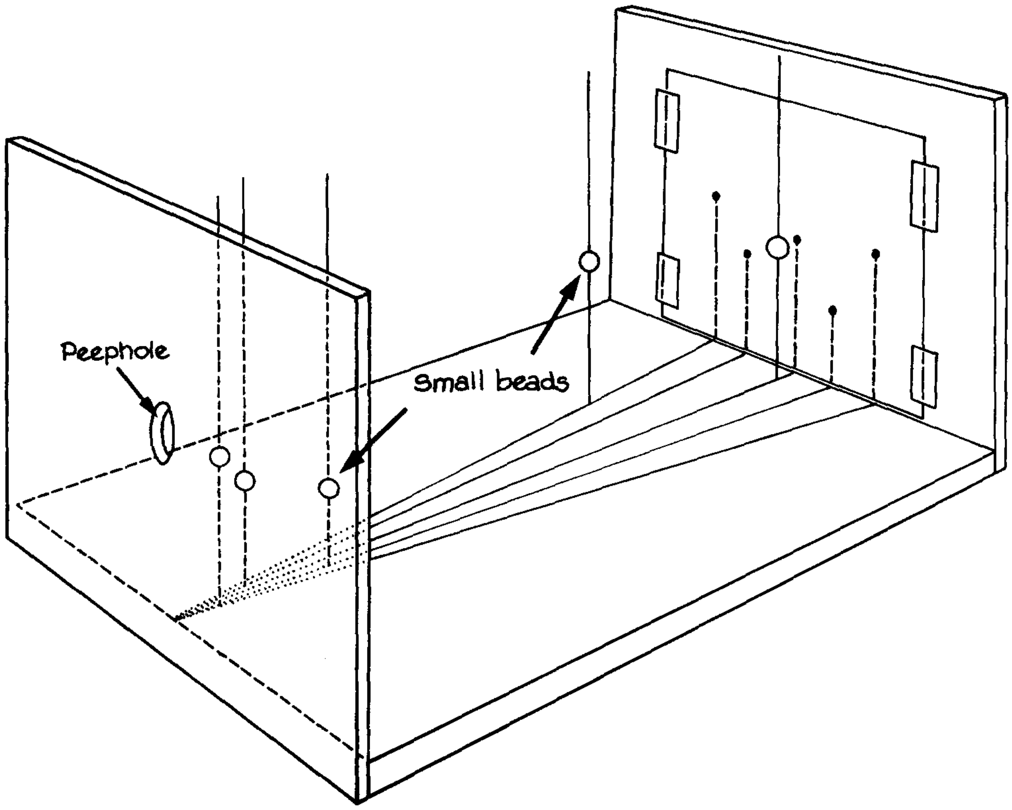
Some stars are nearer to us than others. By using "parallax" we do know the rough distances to some of the nearest stars.

This is a model of a "constellation", (or star pattern), called Cassiopeia, visible in the clear night sky if you look North.

The large black dots (below) show how the star pattern looks in the sky. The Earth turns so the pattern may appear on its side or upside down at different times.



How to make the model



* Use an old shoe-box or make an open box of cardboard, polystyrene or wood. it must be at least 25 cm long. 1f you want to make a larger mode! increase the distances given to fit your box.
* Fasten a copy of the diagram on the previous page, including the “horizon”, to the back.
* Draw radiating fines from the points underneath each star to the “peephole” at the front.
* Stick a cocktail stick at the correct “distance” of each star from the peephole.
* Look through the peephole and trim the sticks so that the top of each one covers the picture of the star on the back.
* Place a very small bead, or ball of clay, etc. on the tops of each stick.
* Paint the box black and the beads with fluorescent paint.

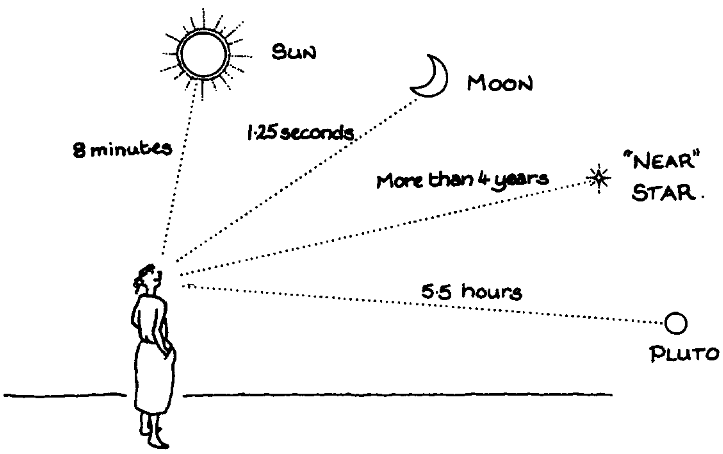
You will see that the "W" pattern can only be seen from one position, through the peephole. This is where the Earth is. From planets around other stars, or from the spacecraft of future star-travellers, Cassiopeia would look completely different.

The same box can be used for other star patterns if you can find out the distances to the stars.

Apart from the Sun, the nearest star to us (Proxima Centauri) is 4.24 light years away. If it seems strange to measure distances in units of time, remember how we do the same for even small distances. We often say "It's only 10 minutes walk away" or "It's half an hour by bus".

Because light takes time to travel to us from the stars, we see them not as they are now but as they were when the light left them. So as we look out into space we look back in time. We see the Sun as it was 8.3 minutes ago and the next nearest star as it was four years ago.

This also makes it difficult to communicate with spacecraft visiting other planets because the radio messages, travelling at the same speed as light, take such a long time to get there and back.



OUR GALAXY – THE MILKY WAY

What is a galaxy?

A galaxy is a huge group of stars in space and there is even more matter between the stars in the form of gas and dust. It is all held together by gravity.

The Sun and all the other stars we see in the sky are stars in our own Galaxy called the Milky Way.

A Spiral Galaxy

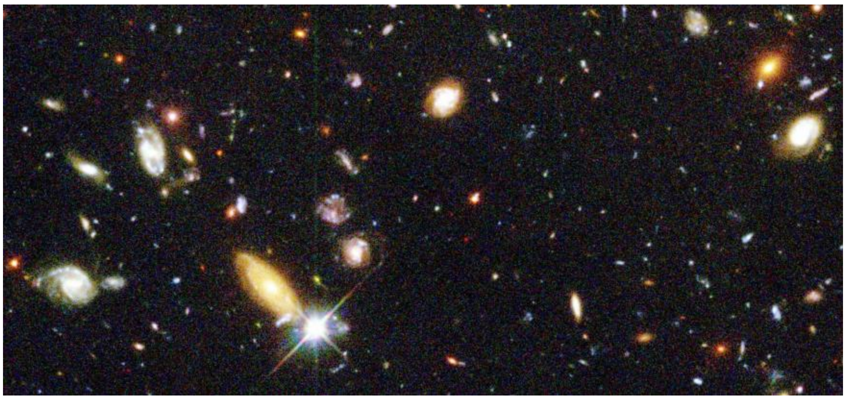
NGC 628 (M 74) is a typical spiral galaxy and is similar to our Milky Way.

It is about 100 000 light years in diameter and rotates about once every 250 million years. It is about 55 million light years distant.

Our Solar system would be about two-thirds of the way out from the centre; in one of the spiral arms.

This image was taken using the 8.1 metre Gemini North Telescope on Mauna Kea, Hawaii. The UK has a 25% share in this state-of-the-art instrument and in its sister Gemini South in Chile.

Other galaxies are different shapes and sizes although many are spiral like our own. Some are irregular in shape and some are spherical or elliptical. It is thought that the Universe has about one hundred thousand million galaxies in it.



This is the famous NASA Hubble Space Telescope “Deep Field” image.

HOMEWORK QUESTIONS

Bigger and Bigger – The Size of the Universe

Space is bigger than you can imagine. In fact it is also very nearly empty – that is why it is called space.

Each diagram on the next page shows a "snapshot" of what we would see if we took a photograph one metre away from a person, then moved 1000 times further away (one kilometre), took another photo, moved 1000 times further away again, and so on. The sides of each picture are one thousand times bigger than the sides of the picture before it.

Each diagram on the next page

The distances along each side are marked. Sometimes alternatives are given. See how the units change as we go to bigger and bigger distances. Why don't we use the same units all the time?

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Each diagram is around a thousand times bigger than the picture before it, (and represents a thousand million times increase in volume!).

1) Write down what you think are the main objects in each picture.

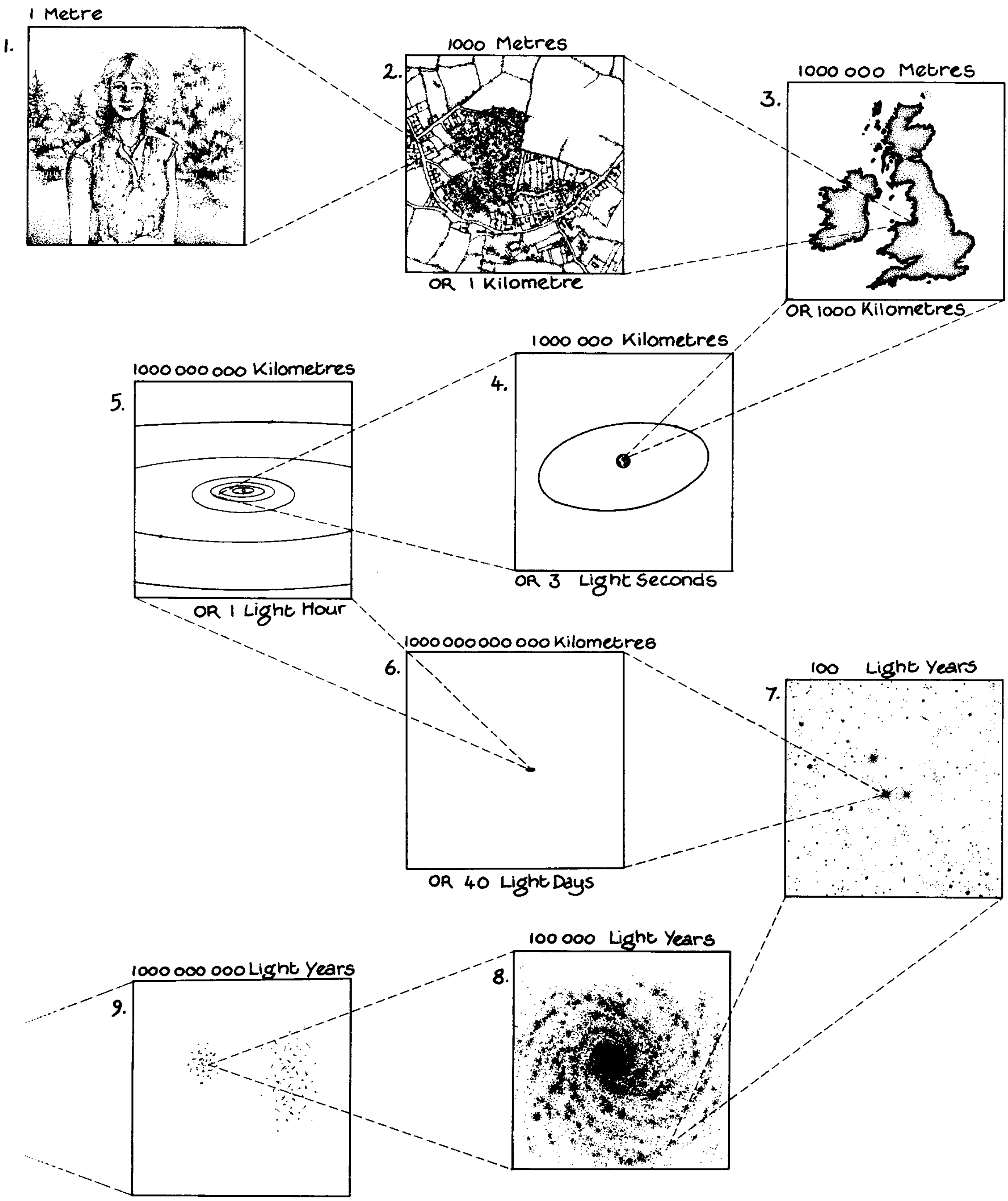
Picture: 1) ………………………… 2) …………………………

3) ………………………… 4) …………………………

5) ………………………… 6) …………………………

7) ………………………… 8) …………………………

9) …………………………



OUT INTO SPACE

* The sides of each square are a thousand times longer than those of the square before.

2) What would be your full school (or home) address if you wanted to send a letter to an alien in another galaxy?

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EXTENSION ACTIVITIES

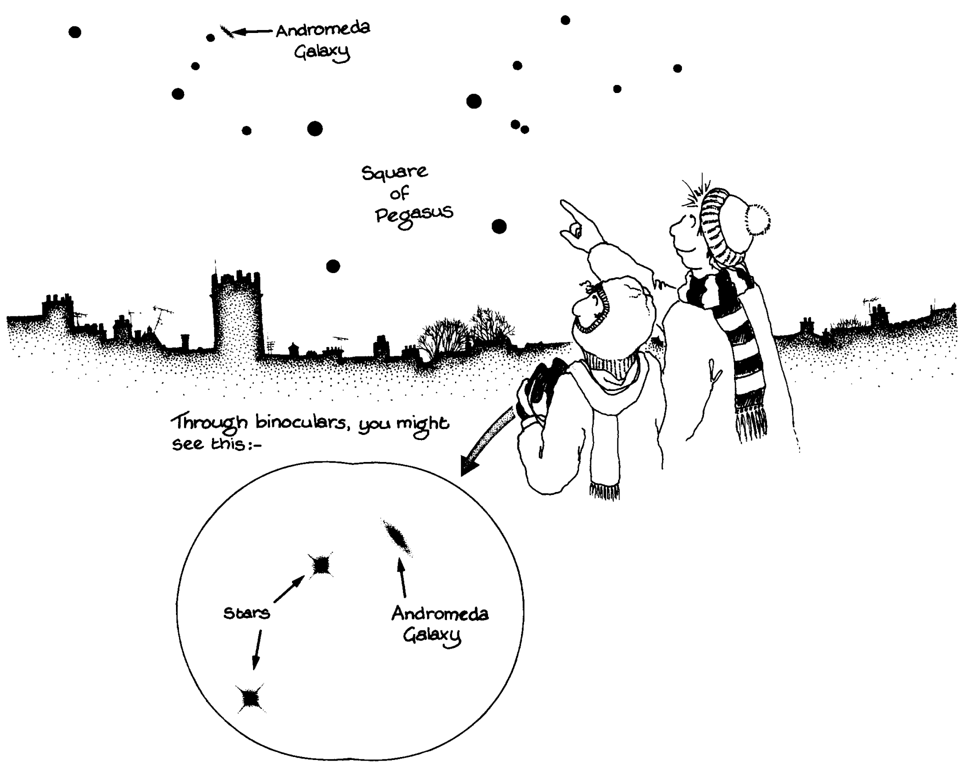
Observing Another Galaxy – the Andromeda Galaxy

An observation exercise for autumn or winter. This can be difficult but may be worth trying, especially in dark skies away from cities.

All the stars we see in the night sky are in our own Galaxy, the Milky Way. However it is just possible to see outside our Galaxy to a neighbouring galaxy, the Andromeda Galaxy. Although astronomers call it a “local” galaxy compared with others, it is still 2.2 million light years away. Like the Milky Way it is also a swirling mass of thousands of millions of stars.

In autumn or winter first find the four stars of the square of Pegasus in the night sky then “star-hop” to the Andromeda Galaxy. If you live in the country you will have more chance of seeing this faint smudge of light. Use the sketch as a map to find it. It may be best to use the technique of averted vision – don’t look directly at the galaxy but just to one side. If you have a pair of binoculars you can see it as an oval-shaped faint patch of light. The galaxy is in fact shaped like a flat disc but we are seeing it sideways on.

As you look at this distant monster of a galaxy, ask yourself, “Is there anybody out there watching the Milky Way, asking themselves if there is life here?”



1) The Circumference of the Earth. Eratosthenes' Method. If the height of the Sun at Alexandria in Egypt is about 7° lower in the sky than at Syene, (where it is directly overhead), what is the circumference of the Earth? The distance between the two towns is 800 kilometres. Can you find out how accurate this is?
2) Distances to the Planets. Radio waves are beamed from the Earth towards Venus when it is near the Earth in its orbit. The waves take exactly 4 minutes 40 seconds to return to Earth. If radio waves travel at the speed of light, (300 000 kilometres a second), how far away is Venus? Would this make telephone conversations with space travellers around Venus very easy?
3) Time for Space Travel. How long would it take to travel:
   a) by car at 120 km per hour (75 mph) (if that was possible!)
   b) by spacecraft at 30 000 km per hour (19 000 mph)
   c) to one or more of the following objects:
      i. The Moon – distance 400 000 kilometres.
      ii. Pluto – (average) distance 6 000 000 000 kilometres.
      iii. The nearest star – distance 40 000 000 000 000 kilometres!

Have a guess first and then try and work it out.

4) Distances to the Stars. Why does it get more and more difficult to measure the distances to very distant stars by the "parallax" method? Try the "finger" experiment with the finger at different distances from your face.

9. The Birth, Life and Death of Stars

Teacher Notes

Main Ideas:

* Stars are formed from the interstellar gas and dust. Gravity pulls a cloud of gas and dust together into denser clumps and each clump begins to collapse to form a star.
* The heat released by the collapse and the growing density eventually reach the point where fusion reactions can begin in the core. Hydrogen nuclei are fused to produce helium. The energy released by these reactions causes the star to shine. It also ends the collapse as the hot gas pressure balances the inwards force of gravity.
* Old stars have used most of the hydrogen in their core and begin to fuse the helium to produce other elements. The outer layers swell up to form a huge star called a “red giant”.
* The red giant phase is comparatively short. The outer layers are puffed off as an expanding gas cloud called a planetary nebula. This exposes the white hot core of the star – called a “white dwarf”.
* Much more massive stars are denser and hotter in the centre and so can fuse nuclei to form elements up to iron in the periodic table. They end their lives with a spectacular explosion called a “supernova”. The remnant of the core, if any is left, is so dense that atoms cannot exist. Electrons and protons are forced together and it becomes a super-dense star of neutrons. Even more massive remnants may collapse in on themselves to form a black hole.

Second-hand star

Our Sun and Solar System formed from gas that had been inside a previous massive star. How do we know? The elements that make up Earth and other planets in the Solar System include those heavier than iron. The only way that these can be formed is inside the centre of a supernova explosion. It is the only place dense and hot enough for the required fusion reactions to take place. After the explosion the expanding gas cloud was enriched with the heavier elements and these drifted off to join the nebula from which our Solar System condensed.

So our Sun is made form second-hand material, and you and all your pupils are made from atoms that were synthesised inside a star. We are all made from star-dust!

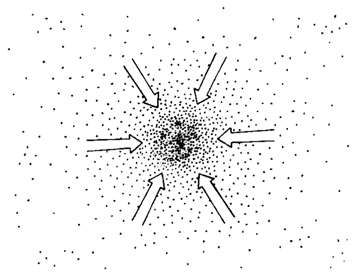
The Life of a Star

A star is just a huge ball of extremely hot glowing gas. Our Sun is an average star and is near the middle of its life cycle but eventually it will die and grow cold.

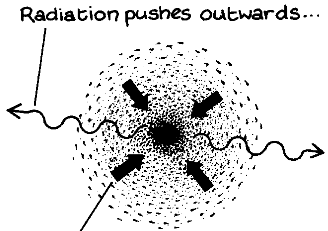
The night sky reveals stars in a variety of stages of development. Some are young stars, just recently formed, and others are in their final stages.

A Star is Born

Drifting in the apparently empty spaces between the stars are molecules of gas, mostly hydrogen and helium. However, over the vastness of space, this adds up to a lot of gas. Over millions of years this gas slowly comes together, attracted by its own gravity into a denser mass. As the gas forms into a ball, the temperature rises and the fledgling star begins to give out heat as infrared radiation.



When the temperature and the pressure in the centre rise very high, a very powerful form of energy production begins. The hydrogen nuclei in the centre of the star begin to fuse together to form helium nuclei. In the process some of the mass of the hydrogen is converted to energy, releasing immense amounts of heat. Our Sun converts 5 million tons of matter into energy every second. This is not a chemical reaction but a nuclear reaction where one element is converted into another.



Albert Einstein’s famous equation $E = mc^2$ allows us to calculate how much energy (E) is made out of mass (m) in these nuclear reactions. Since “c” is the speed of light, (a very large number), a small amount of matter can be converted to a huge amount of energy in the Sun. This is why the Sun and other stars can burn for thousands of millions of years before they run short of hydrogen.

The radiation given off in these nuclear reactions in the star pushes outwards against gravity and prevents further collapse.

This whole birth process can take a million years or so.

Image courtesy of the
European Southern Observatory.

The Orion Nebula

The Orion Nebula is easily visible in the winter night sky.

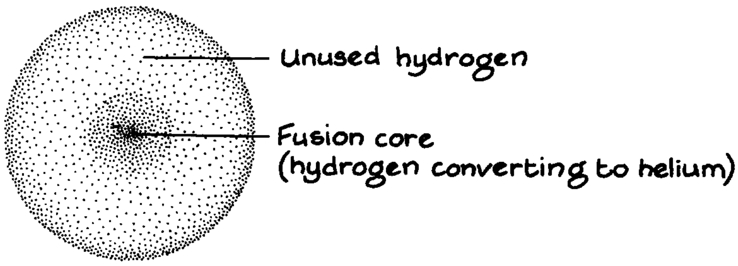
To the naked eye it is a small fuzzy patch of light below the three stars of Orion's Belt.

Through binoculars or a telescope you can see the blues and reds of the gas and dust cloud.

It is almost certainly a place where dust clouds are collapsing to form new stars and planets.

The Main Sequence

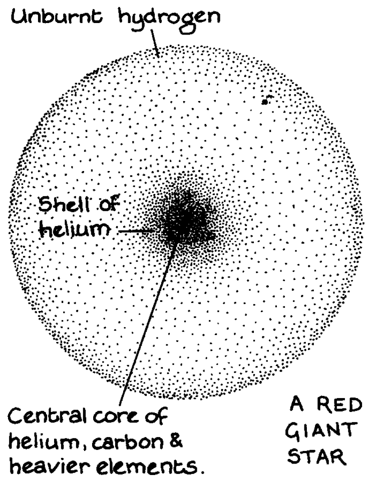
Once formed, a star will continue to fuse hydrogen into helium until most of the hydrogen fuel in its centre is used up.

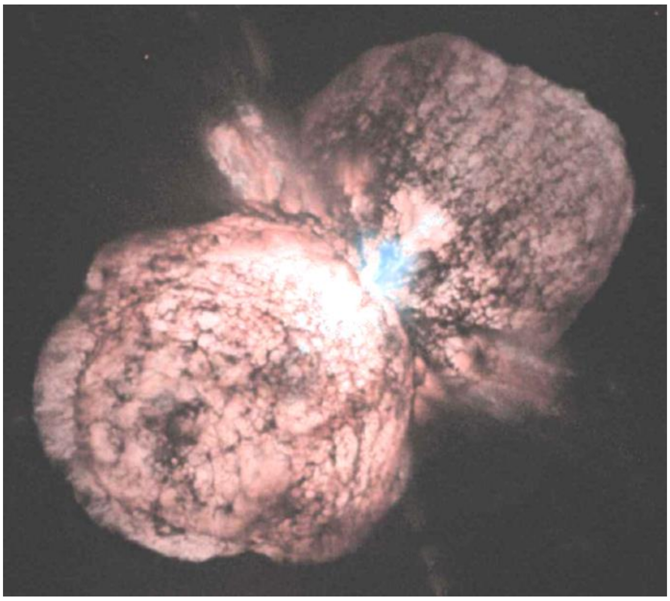


Throughout this time there will be a balance between the radiation and gas pressures pushing outwards and the gravity pulling inwards. The star will remain stable as long as it still has fuel to maintain this balance. In the case of the Sun this could be about 10 thousand million years. It is about half-way through this time.

Nearing the End

When most of the hydrogen in the centre of a star is used up, the star becomes a large cooler red giant star with a core of helium. Heavier elements like carbon begin to be formed by new fusion processes in the core of the red giant as the helium itself becomes the fuel for these further reactions.





The Doomed Star Eta Carinae

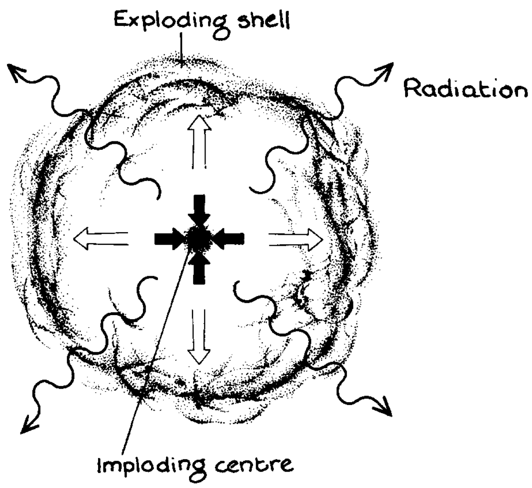
Eta Carinae is about 100 times more massive than our Sun and is probably one of the most massive stars in our Galaxy. It radiates about five million times more power than our Sun.

A huge, billowing pair of gas and dust clouds are captured in this stunning NASA Hubble Space Telescope image. The supermassive star is 8 000 light years away. Dust lanes, tiny condensations and strange radial streaks all appear with unprecedented clarity.

Eta Carinae made a giant outburst about 150 years ago, when it became one of the brightest stars in the Southern sky. Though the star released as much visible light as a supernova explosion, it survived the outburst. Somehow, the explosion produced gas and dust clouds above its poles and a thin disk around its equator, all moving outwards at about 670 km/s. This star remains one of the great mysteries of astronomy.

The Death of a Star

Most stars die peacefully. After their red giant phase, they puff off their outer layers and then collapse into a hot, very dense object. This is called a White Dwarf which over millions of years gradually cools down. If a star has a large mass it may end violently as a "supernova".



A SUPERNOVA

In a supernova explosion, the central core collapses inwards and a rebounding shockwave makes the outer layers explode. A sudden outburst of energy will accompany a supernova stage. The core will collapse under its own gravity until it becomes a "neutron star", perhaps only about 20 km across. The density of the core is now about 10^{16} kg/m^3. A single cubic centimetre of a neutron star will have a mass of a thousand million kg!

The radio signals emitted by rotating neutron stars can often be detected by radio telescopes as pulses. These stars are called "Pulsars".

At the supernova stage a very massive star can continue to collapse under its own gravity. This collapse could continue until all the mass is attracted to a single point. This would be a "Black Hole".

The gravitational pull near a Black Hole would be so strong that even light would be unable to escape from it.

Questions

1) What force causes a gas cloud in the Galaxy to collapse?
2) Explain why the Sun does not continue to collapse.

   ……………………………………………………………………………

   ……………………………………………………………………………

   ……………………………………………………………………………
3) What elements would you find in the core of:
   i. a young star. ………………………………………………………
   ii. an old star. ………………………………………………………
4) What changes take place in a star when it forms a White Dwarf?

   ……………………………………………………………………………

   ……………………………………………………………………………

   ……………………………………………………………………………
5) What changes take place in a massive star to form a Black Hole?

   ……………………………………………………………………………

   ……………………………………………………………………………

   ……………………………………………………………………………
6) Why is a Black Hole called a Black Hole?

   ……………………………………………………………………………

   ……………………………………………………………………………

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10. Redshift and the Expansion of the Universe

Teacher Notes

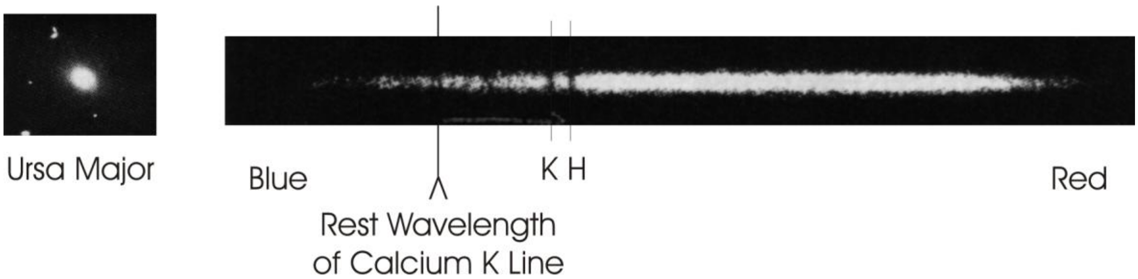
Main Ideas:

* The spectrum of the combined starlight from a galaxy shows an effect called the "redshift". The spectral lines, together with the whole spectrum of light, are shifted towards the red.
* This is caused by the Doppler Effect, so it implies all the galaxies are receding from us at high speeds.
* The further away a galaxy, the greater its redshift. Therefore the more distant galaxies are receding faster.
* This is generally interpreted as the expansion of the entire Universe.
* The Universe was therefore much smaller and denser a long time ago and at a particular time in the past, billions of years ago, it was all concentrated in infinite density and vanishingly small volume. This is called the "Big Bang".

Galaxy Spectra

The idea of the expansion of the Universe grew from experimental data gathered by Edwin Hubble in the late 1920's. He observed the spectra of distant galaxies using the 100 inch diameter reflecting telescope at Mount Wilson and he found that their spectral lines were always shifted towards the red. The wavelengths of these dark absorption lines in the spectrum of stars are all very well known and it was therefore a great surprise to find them shifted so much in this way. It was soon interpreted as being due to the Doppler Effect, which led astronomers to the extraordinary conclusion that the galaxies must be all speeding away from us at enormous speeds.

Pupils will probably need some help with interpreting the spectra presented in the worksheet. The image of the galaxy in the left hand column is named for the constellation in that part of the sky.

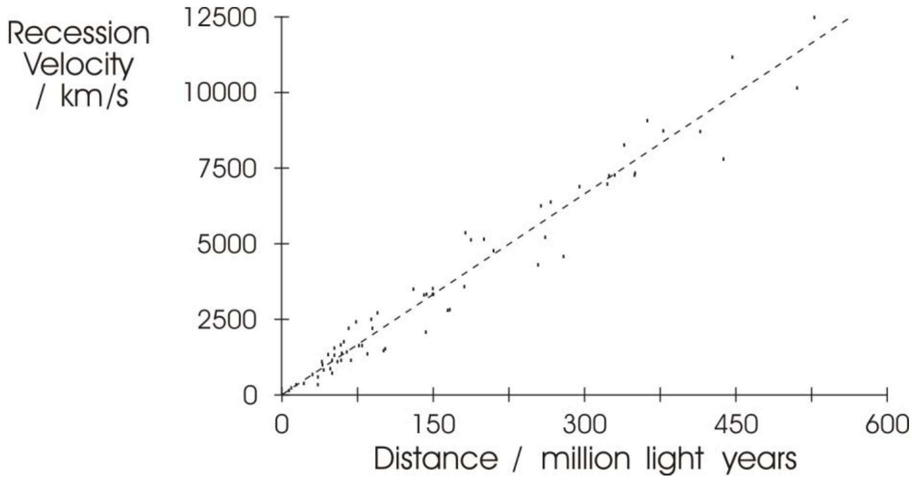


You are of course looking far beyond the stars of that constellation, way out of our Galaxy and across much empty space. The block to the right of each galaxy is a black and white photograph of its spectrum, with violet to the left end and red to the right. The white lines along the top and bottom are known spectral lines from a laboratory source for comparison. The white streak down the middle is the faint light from the galaxy spread into a spectrum. Two dark absorption lines may be seen; these are due to calcium atoms in the atmospheres of the stars in the galaxy. These lines do not appear where they should be if the galaxy was at rest relative to us. It is possible to measure the amount of shift horizontally along the diagram and then calculate the speed of the galaxy.

We are more familiar with examples of the Doppler shift in the sound of a car or train approaching a bridge or platform (higher pitch) and then speeding away (lower pitch).

The Hubble Law

Even without measurement it is clear from the data on pXXX????????? that the more distant galaxies have greater redshifts. Therefore they seem to be receding from us faster. However if you plot velocity against distance, this relationship turns out to be more precise. The velocity is proportional to distance.



Hubble Expansion

This led to the now widely accepted conclusion that all space is expanding, carrying the galaxies along with it and making every galaxy appear to move away from every other galaxy. It is NOT that the galaxies are rushing about in space. The grid activity is optional but it does illustrate how a general increase in scale can cause more distant points to recede faster.

This can be modelled very simply by a balloon with small galaxies drawn on it. When you blow up the balloon all the galaxies get further from each other. A slightly more elegant version of this can be arranged (in one dimension only) by placing paper clips onto a long rubber band. When you stretch the rubber band the distances between all the galaxies (paper clips) increase so they move away from each other.

However beware of limitations of these models. The balloon should strictly have galaxies dotted about inside it as well, not just on the surface. The rubber band has ends which are meaningless in the real Universe which is infinite.

The Fate of the Universe

The pupil sheet explores several possible alternative futures for our Universe. However at the time of going to press, recent measurements of supernova explosions in distant galaxies have indicated that the expansion is ***accelerating***. This should not happen if the only large scale force in the Universe is the gravitational attraction of all the matter on itself. This should be ***slowing*** the expansion. Astronomers have been forced to suggest the existence of “Dark Energy” to power this acceleration.

Galaxy Spectra and Redshift

Absorption Spectra

The light from a galaxy contains light from all its thousands of millions of stars combined. When the light is spread into a “spectrum” we see a wide range of colours but also dark lines where particular wavelengths are missing due to light being absorbed by atoms in the gas in stars. Two lines due to calcium are very common in star spectra.

Spectrum showing Absorption Lines

In the diagram overleaf there are five galaxy spectra adapted from Hale Observatory originals. One of the spectral lines of calcium is marked on each one. If the galaxy is stationary with respect to us then this line is at its “rest” wavelength. If the galaxy is moving the line is shifted down the spectrum. You will see that all these galaxies are moving, and their lines are shifted towards the red end of the spectrum. This is known as the “redshift” and is caused by the Doppler Effect due to a moving source.

Stationary star: * Earth

Waves travelling towards us

???

Star moving towards us: * *

Earth

Waves have less space so
are shorter (bluer) wavelength

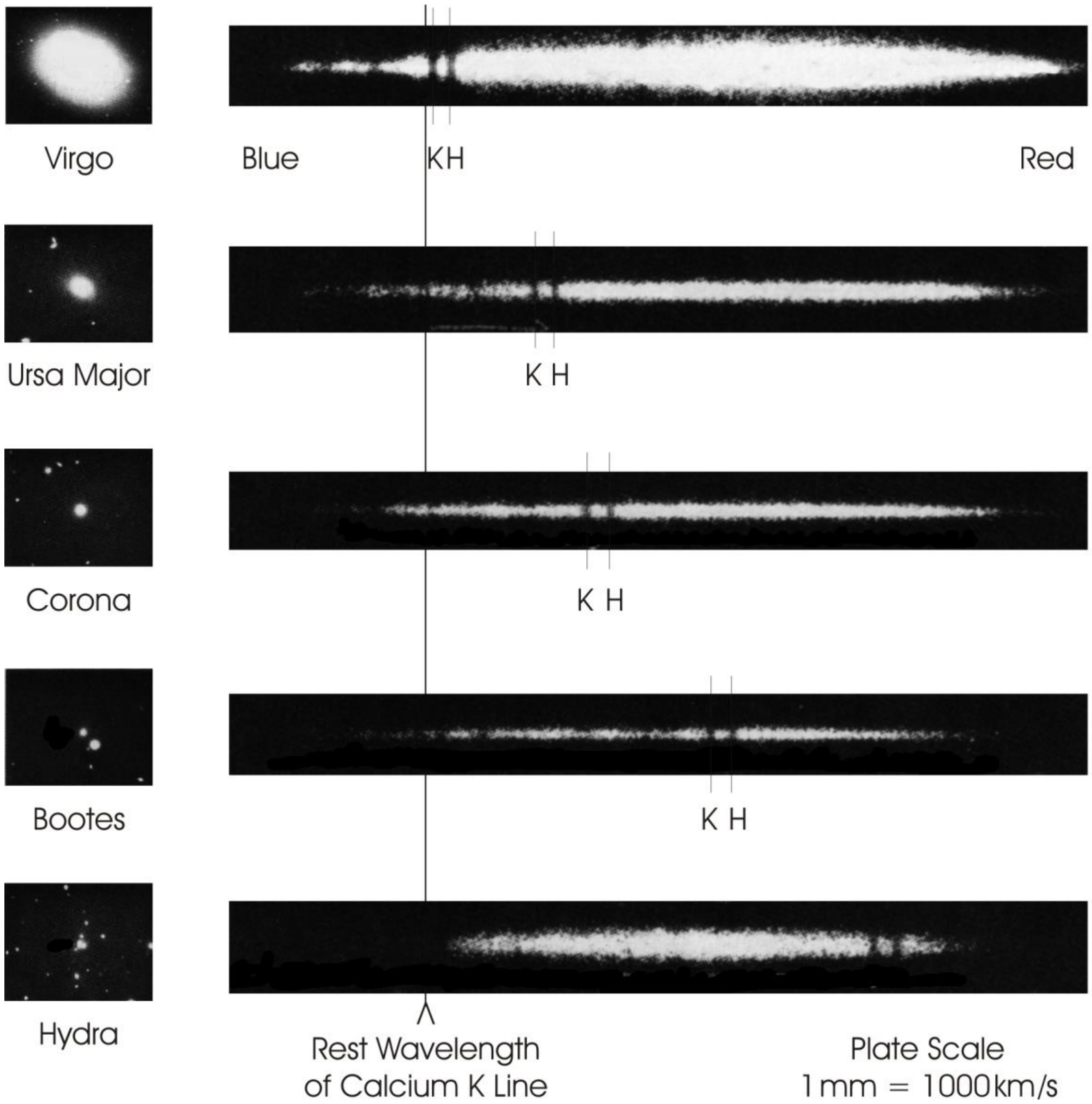
Star moving away from us: * *

Earth

Waves have more space and so
Are longer (redder) wavelength

We experience a similar effect with sound waves when a car or train speeds past us. The sound is higher in pitch (shorter wavelength) as it approaches, and drops noticeably as it passes us and speeds away.

Diagram: Galaxy Spectra



You will see that all the galaxies have a shift towards the red and therefore all the galaxies are ***moving away from us***.

Now do the activity on the next page

Questions

1) In the table, four of the galaxies have their distances given in units of light years. You will need to measure the amount of redshift for each of these four in mm and convert to a speed using the scale factor given.

Galaxy	Velocity / km/s	Distance / Millions of light years
Virgo		52 000 000
Ursa Major		652 000 000
Corona		955 000 000
Boötes		1 695 000 000
Hydra		

a) Fill in the table for the first four galaxies.

b) Plot a graph of recession velocity against distance. Draw the best fit straight line. This is the graph Hubble used to draw his conclusions.

c) Use the graph to find the distance to the galaxy in Hydra.

d) What is the relationship between the two variables in these results:

…………………………………………………………………………………

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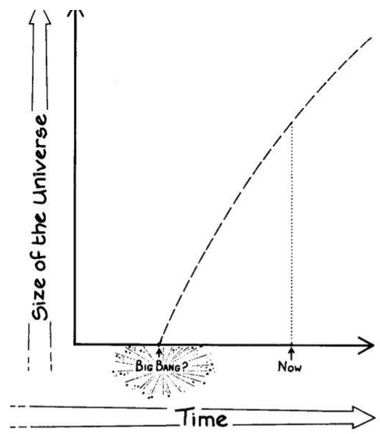
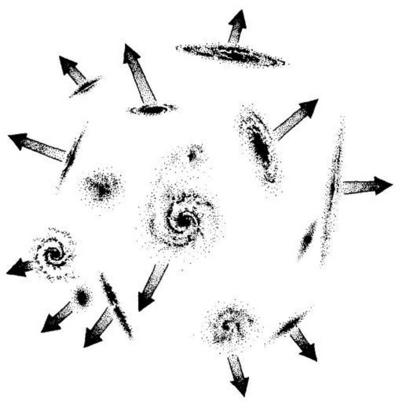
This relationship is generally interpreted as showing that the Universe is ***expanding***. If you look back in time the galaxies must have been closer together and if you look back far enough (about 13 billion years) the galaxies would have all been on top of each other in a very dense, very hot, vanishingly small Universe which has been spreading out ever since. This early hot phase is known as the ***"Big Bang"*** and is thought to have been the beginning of our Universe when all matter and energy was created.

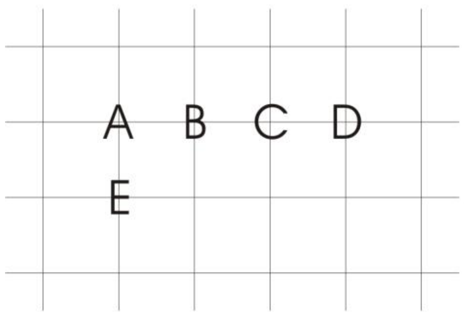


2) Expanding Universe Exercise

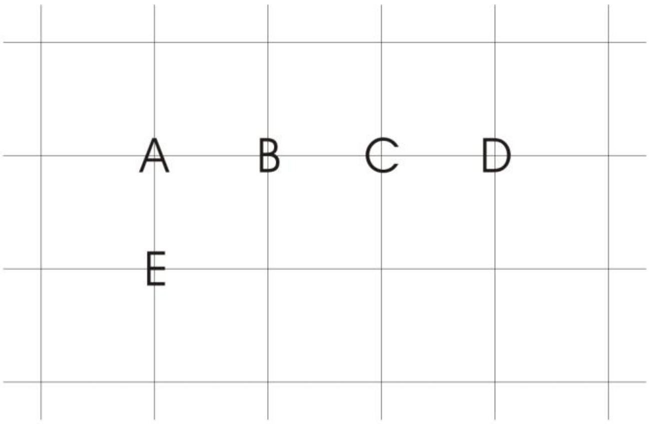


The distant galaxies are moving away from each other.

The left hand diagram shows five galaxies at some particular time. The right hand diagram shows them some time later. The expansion of the Universe is evident.



Each square is
100 Mly by 100 Mly



Each square is
150 Mly by 150 Mly

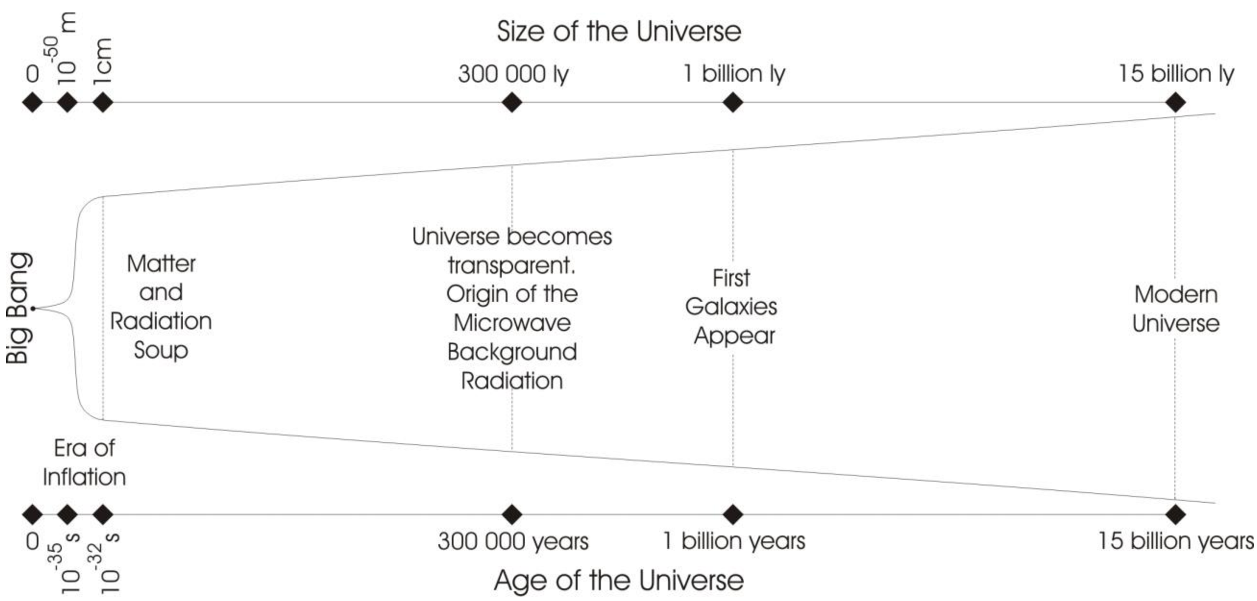
Measure the distances from the grid and complete the table.

Galaxy Pair	Original Separation / Mly	Later Separation / Mly	Change in Separation / Mly
A-B	100	150	50
A-C			
A-D			
E-D			

From the table it is apparent that the farther apart the galaxies are to start with, the greater the change in their separation. As all the calculations refer to the same length of time, the more distant pairs are moving apart more quickly. This is called the "Hubble Flow".

The Evolution of the Universe

The Universe grew very rapidly at first and then settled down to steady expansion. One of the great unanswered questions of astronomy is that of the fate of the Universe. As yet we do not have enough data to tell if it will expand forever or eventually collapse in a "Big Crunch"!



Further Evidence for the Big Bang

The Microwave background radiation: The Big Bang theory says that the Universe was once very dense and hot. The radiation would have been light in the visible range – a "glow". But as the Universe expanded the temperature dropped and the radiation became longer wavelength until today it is in the microwave region of the electromagnetic spectrum. This microwave radiation from all over the sky was first detected in 1965 and provided good evidence that there was a hot early phase in the life of the Universe.

The Elements formed in the Big Bang: The Big Bang theory can predict the proportions of chemical elements that would have bee formed in the first three minutes after the Big Bang. We should see 93% hydrogen, 7% helium and a very tiny trace of lithium. In the neighbourhood of our Solar System this ratio has changed because stars have fused hydrogen together to build up other elements but measurements of the very distant

Universe (which we see as it was a long time ago) show that it does indeed have the correct ratios of these three elements.

The Future of the Universe

1) The Big Bang Theory

This theory is a direct result of thinking back in time. If the Universe is expanding then, thinking of time running backwards, like a film in reverse, the Universe must have been more dense and smaller in the past. In fact, calculations show that about 15 000 million years ago the whole of the Universe must have been concentrated at a single point. The Universe must have started with an enormous explosion sending the Universe expanding outwards. This is known as the “Big Bang”.

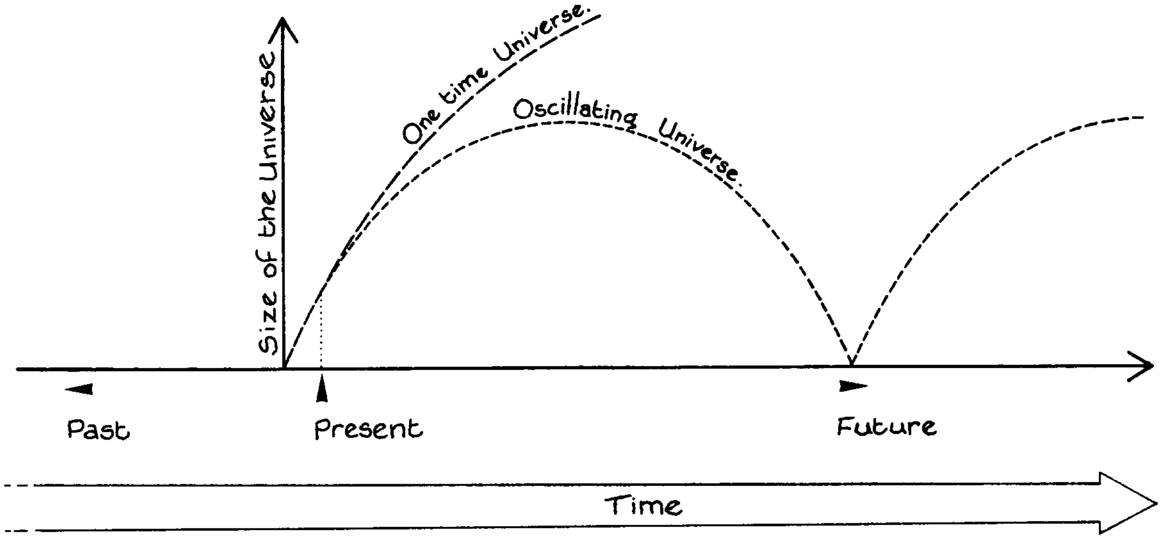
2) The Steady State Model

When the Big Bang was proposed, not everyone accepted the idea. Some wondered, “How did all the matter in the Universe get made all at once?” and “Is a violent start to the Universe necessary?”. In 1948, a small group of astronomers suggested the matter we see today could be continuously created as the Universe expands. All that is needed is for one hydrogen atom to be created every year for every hundred cubic kilometres of space. This would keep the Universe at a constant density – the “Steady State” theory.

In 1964 the discovery of low energy radio waves, the “cosmic microwave background radiation”, coming from all directions in space, has come to be seen as proof of the violent start to the Universe. It is thought to be the remains of the glow from the very hot early Universe. The Steady State theory is not now generally accepted.

A forever expanding Universe?

Does gravity play any part in an expanding Universe? The attraction of all bodies to all other bodies should be slowing down the expansion of the Universe. But is there enough matter in the Universe eventually to stop the expansion completely? If so, then the Universe would start contracting again under gravity. The Universe would then fall back together into a massive collapsed super-dense single lump. Perhaps this would explode in another Big Bang and the whole process would start again. This would be an “oscillating” Universe.



Astronomers have been “adding up” how much matter they can detect in the Universe. At the moment they have not found enough for the combined gravitational pull of all the matter in the Universe to slow and eventually stop the expansion. But astronomers suspect there may be a lot more undetected matter in the Universe. This matter may be made up of “Black Holes”, small “Brown Dwarf” stars, or lots of other strange things. If enough missing mass is found this could change the picture completely.

At the time of going to press, recent measurements of supernova explosions in distant galaxies have indicated that the expansion is *accelerating*. This should not happen if the only large scale force in the Universe is the gravitational attraction of all the matter on itself. This should be *slowing* the expansion. Astronomers have been forced to suggest the existence of “Dark Energy” to power this acceleration.

The study of ideas about the Universe, its history and its future is called cosmology.

Questions

1) White light is really a mixture of light of different colours. Find out what colours can be found in white light.
2) What is meant by the “spectrum” of light from a galaxy?
3) What evidence has been found to support the Big Bang idea?
4) Explain why the search for missing matter is important to cosmologists.

11. Is There Life Elsewhere?

Teacher Notes

Main Ideas:

* Biological activity as we know it needs certain conditions including liquid water and an energy source such as sunlight, chemicals or "food".
* These conditions may exist on other planets or moons in our Solar System e.g. on Mars or Europa.
* There may be other Earth-like planets orbiting other stars in the Milky Way Galaxy and in more distant galaxies.
* If life has given rise to intelligent species elsewhere, we may be able to detect signals from them.

This is a topic evolving so fast that anything we say here will shortly be out of date. The presupposition that life needs liquid water will possibly be overthrown if microbes are found on Mars or in very dry conditions in space such as on interstellar grains of dust.

Discoveries of planets orbiting other nearby stars are reported frequently: 136 are known to date and this number is likely to rise as new telescopes are designed which are larger and have more sensitive detection techniques.

The Drake Equation

The "Numbers Argument" worksheet introduces a simple version of the Drake equation. Except for f1 and f2, most of the fractions in this calculation were not even roughly known to Frank Drake himself, but we will soon have good estimates of f3 and f4. In the future it is possible that new measurements will give indications of the "order of magnitude" size of f5 and f6. It seems likely that the answer given by the equation for the number of planets in the Universe that look suitable for life will be very high.

But what of that last fraction – that of the number of those planets where life has appeared? The first living cells appeared on Earth very early on, indicating perhaps that if the conditions ARE right then simple life starts quickly. It has however taken until very recently in the history of the Earth for intelligent species to evolve. By "intelligent" we mean beings who would be capable of interstellar communication.

Answers to numerical problems:

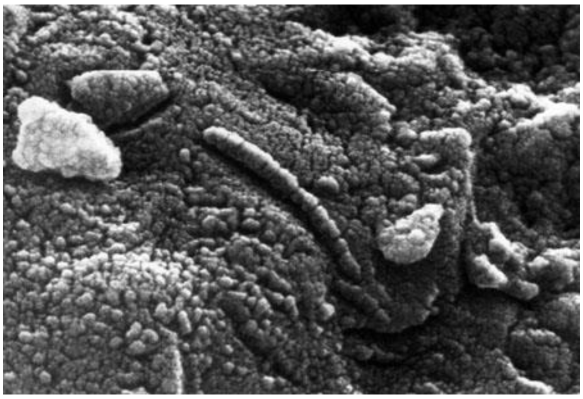
1) a) 700 seconds b) 1400 seconds (23.3 minutes)
2) 10.5 years
3) 7566666667 seconds = 240 years

This last figure shows how difficult communication will be even to relatively nearby stars in our own Galaxy. This kind of wait does not make conversation flow easily!

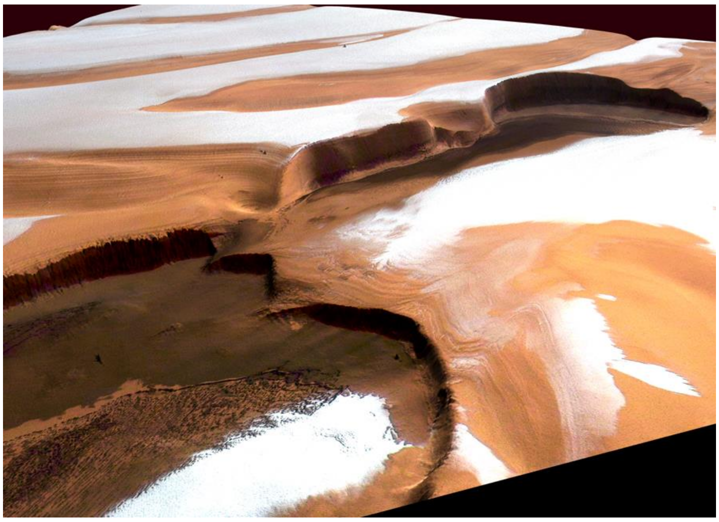
Are We Alone in the Solar System?

* Could there be life on a different planet in our Solar System?
* How might we search for it, and where should we look?

Mars could be a possible home for extraterrestrial life. Recent studies show that large amounts of water once flowed there. A meteorite that landed on Earth but once was part of Mars was thought to have fossilized bacteria in it. Scientist are still undecided on this issue.



Meteorite (ALH 84001) was found in the Allan Hills of Antarctica.
The electron microscope image on the right might
possibly show the fossil of a Martian microbe. (NASA)



Ice and dust at Martian north pole

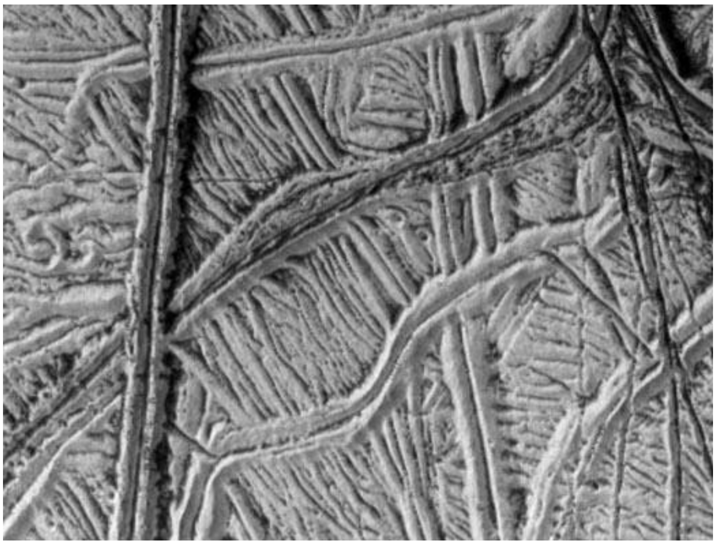
This image of the Martian north polar ice cap shows layers of water ice and dust for the first time in perspective view. Here we see cliffs which are almost 2 kilometres high, and the dark material in the caldera-like structures and dune fields could be volcanic ash.
(ESA/DLR/FU Berlin)

How would scientists detect the signs of life?

1) Plant life on Earth has produced all the oxygen in our atmosphere. This would not be there if there was no life on Earth. Perhaps we can detect similar changes in the atmospheres of other planets. Water is essential to life so we need to find plenty of liquid water on another planet if life is to be possible there. Space missions to other parts of the Solar System monitor conditions on planets and moons to look for oxygen and water.
2) The rocks of other planets may contain the remains of past life, as either fossilized organisms or chemicals that show there was once life. To detect this, a spacecraft must land on the planet's surface to sample the rocks. Then the sample can be analysed on site or brought back to Earth for study.

Europa, a moon of Jupiter, is roughly the same size as our own Moon. It has a very smooth icy surface and possibly a liquid ocean underneath its ice crust. Where there is liquid water, there may also be life, but here it would be cut off from sunlight and would need a different energy source.

However bacteria on Earth can survive under similarly extreme conditions, for example hundreds of metres below the sea near fissures in the Earth's crust. Here water soluble chemicals provide the source of energy.



Europa's cracked icy surface. (NASA)

Comets may also contain the chemicals that are the basis of life. They are made from a loose dust and ice ball with many chemicals frozen into the ices. One theory says that comets could have fallen to Earth millions of years ago bringing life with them!

Activity

Look up data on the planets and moons. Collect the information in a table like this:

Planet name	Oxygen in the Atmosphere?	Liquid Water?	Temp (^oC)	Life possible?
Earth	Yes	Yes	-50 to +40	Yes
Moon	No	No	-100 to +100	No

Life in the Universe?

Planets in other Solar Systems

To date, well over a hundred planets have been discovered orbiting other stars in our Galaxy. They are currently extremely hard to detect directly as they are do not shine and so they are lost in the glare of their nearby star. The main method of detection is to watch for a regular wiggle in the motion of the star. Then you know something is orbiting it and pulling it with the force of gravity. This method favours the detection of massive planets like Jupiter because they have a greater pull of gravity and so affect their stars' motion more. It also favours the detection of planets in very close orbits for the same reason – the pull of gravity on the star is more. Therefore most of the planets known so far are like very hot Jupiters and therefore they are unlikely to harbour life. Techniques are rapidly improving and it is only a matter of time before many small planets in wider orbits are found.

1) The Numbers Argument

There are over one hundred thousand million stars in our galaxy, the Milky Way. In the Universe there may be as many as one hundred thousand million galaxies. This means there is an unbelievable number of stars in the Universe, many of which could have a planetary system around them. Surely at least one planet must be like Earth!

One way of trying to estimate the chance of intelligent life elsewhere is the "Drake Equation". This starts with the total number of stars in the Universe, N, and multiplying by a series of fractions. For example:

Number of realistic candidates = N x f1 x f2 x f3 x f4 x f5 x f6 x f7
where, for instance, the fractions might be:

f1 the fraction of stars roughly as old as the Sun.

f2 the fraction of these stars that are not double star systems.

f3 the fraction of these that might have planets round them.

f4 the fraction of these planets that are the right distance from the star, (not too hot or cold).

f5 the fraction of these planets that are spinning at a safe rate.

f6 the fraction of these which might have the right chemical elements needed for life to start.

f7 the fraction of these planets which might have intelligent life evolving.

There are probably several more factors, like the size of the planet or even whether it has a moon, that could affect the chances of life. Everybody's choice of numbers for the fractions (f1 etc.) will be different and some are little more than guesses. However, even when all these things are considered, most calculations suggest there should be a large number of candidates for life-supporting planets in the Universe! Surely then we are not alone.

2) Speculations from Observations

Many people enjoy science fiction. Some stories involve life from space and visitors from other worlds. There are many stories about UFOs (Unidentified Flying Objects) but no hard scientific evidence that they do or do not exist.

But there is scientific evidence of some of the very simplest building blocks of life in space – simple molecules. The radiation we receive from stars gets changed a little as it passes through gas clouds in space. These changes can be detected by radio and other telescopes on Earth. They tell us what chemicals can be found in the gas clouds.

Questions

1) Why is there no life on the planet Mercury?
2) Why is it unlikely that there will be life on Pluto, the most distant known planet from the Sun?
3) Some stars are "binaries". This means that two stars rotate about each other. What effect do you think this would have on the motion and temperature of a planet near these stars?
4) How do you think molecules like methane could find their way from a gas cloud in a galaxy onto the surface of a planet?
5) The Earth is about 4 500 million years old but only recently has the technology been available to try and contact possible civilisations on other planets. If this has been true for these other civilisations also, how does this affect our chances of finding life elsewhere?
6) Do you think there is anyone "out there" watching us? In your own words explain why you think there is or is not any life elsewhere in space.

How Would We Communicate?

Suppose we did find intelligent life out there. What messages would we send? What messages might we pick up? This section is about communicating across the vastness of our Galaxy.

Messages through Space

A telephone message travels as electric signals along wires or even as light impulses along a fibre optic cable in modern systems. Light, radio waves and all other electromagnetic radiation all travel at the same speed, 300 000 000 m/s in a vacuum. The speed changes a little in other substances.

Albert Einstein suggested that the speed of light was special. He proposed that no information could travel faster than light. This means that if we wanted to communicate with other solar systems or even travel to distant galaxies then the fastest speed possible would be the speed of light. Today, even the fastest space rockets only travel at one ten thousandth of the speed of light!

The Voyager spaceprobes, travelling at about 10 000 m/s, took two years to reach the planet Jupiter. However, if they were travelling in the direction of the nearest stars they would take 100 000 years or so to reach them!

The only realistic way to communicate across the vastness of space is by the use of light or radio waves.

Time Taken for Messages

Here is a chance for you to calculate the time taken for a radio signal to reach some destinations around the Galaxy. You will need a scientific calculator and the usual equation for speed.

Take the speed of radio waves to be 300 000 000 m/s

1) You send a message to Mars which at this time is 210,000 million metres away. (You may need to enter this into your calculator as 2.10×10^{11}m).

   a) How long before your friend on Mars receives it?

      ………………………………………………………………………………

      ………………………………………………………………………………

   b) Your friend replies immediately. How long do you have to wait for the reply?

      ………………………………………………………………………………

2) You send a series of instructions to a spacecraft visiting a nearby solar system 10.5 light years away.

   How soon does the spacecraft respond? ………………………………..

   (HINT: You do not need to do any calculations!)

3) The star Spica is 2.27×10^{18} m away from Earth. Find the travel time for a radio message from a fictitious civilization on a planet orbiting Spica. Remember your answer will be in seconds!

   ………………………………………………………………………………

   ………………………………………………………………………………

   ………………………………………………………………………………

The Search for Extraterrestrial Intelligence (SETI)

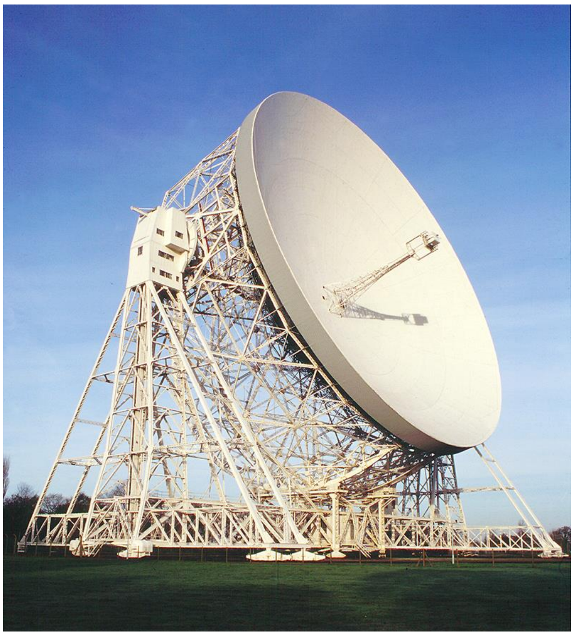
There is one way in which the painstaking search for extrasolar planets, and for life on them, could be bypassed. This is through contact with an extraterrestrial intelligence. This would show at once that life does indeed exist elsewhere and that it has given rise to intelligent species.

There is no evidence at all that the Earth has ever been visited. Therefore the search for extraterrestrial intelligence (SETI) involves searching for signals. For several decades radio astronomers on Earth have had the technology to send and receive signals. Extraterrestrials with our sort of technological intelligence could have had this capability for millions of years.

Since 1959 astronomers have conducted over 100 searches for radio signals that could not be natural. In recent years they have been joined by astronomers searching for optical pulses. So far no “intelligent” signals have been detected, but there is a lot more searching to be done.

If in a few decade’s time there is still silence then we would have to conclude that even if life is common in our Galaxy, intelligent life that attempts interstellar communication with radio waves or light is probably rare.

If you have a computer you can help SETI by allowing your machine to be used to analyse signals received by radio telescopes. For more details see http://setiathome.ssl.berkeley.edu/



The Lovell radio telescope at Jodrell Bank in Cheshire. It is 76.2 metres in diameter and has been used to search for signals from extraterrestrial intelligence.
(Ian Morison)

12. GLOSSARY OF TERMS

ASTEROID	Rocky objects that orbit our Sun, mostly between Mars and Jupiter. Also called "Minor Planets", they are nearly all less than 1000 km in diameter, and most are less than 100 km.
ATMOSPHERE	A layer of gases around the solid surface of some of the larger planets and moons. The Earth's atmosphere mostly consists of nitrogen and oxygen.
BIG BANG	A model for the history of the Universe. Between 10 and 20 billion years ago all the material and energy in the Universe exploded from a single point. The fragments expanded and cooled down to form the galaxies which are still racing way from each other today.
BLACK HOLE	The region of space near a collapsed star from which even light cannot escape. When a massive star runs out of nuclear fuel it cannot withstand the pull of its own gravity and so it collapses to a point. Within a few kilometres of that point the force of gravity is so strong that neither particles nor light can escape.
COMET	Lumps of frozen ices and dust that normally orbit the Sun far beyond the orbits of the planets. They are large dirty snowballs up to a few kilometres in diameter. If any comets come close to the Sun, some of the outermost ice vaporises, releasing some of the dust as well. This shows up as long thin 'tails' stretching millions of kilometres into space.
CONSTELLATIONS	Patterns of stars in the sky, often having names of imaginary figures given to them by ancient civilisations.
CRATERS	Pits found on nearly all the solid planets and moons in the Solar System, caused by impacts of rocks or comets from space.
ECLIPTIC	As the Earth moves round the Sun over the course of a year, it makes the Sun appear to move through the constellations. This path is called the Ecliptic. The orbits of all the major planets lie close to the plane of the Ecliptic.
GALAXY	A huge collection of between ten million and a million million stars travelling together through space. Our Milky Way is spiral-shaped and is a galaxy of about 100 thousand million stars. The Sun is just one of these stars. All the stars we can see in the night sky belong to the Milky Way.
GRAVITY	A force which pulls together all matter. It keeps us on the Earth, keeps the Moon going around the Earth, and holds galaxies of stars together.
LIGHT YEAR	A measure of large distances. It is the distance travelled by light in a year, or 9.4 million million kilometres. The nearest star is over 4 light years from the Sun.

MASS	A measure of how much material an object contains. The mass of an object stays the same wherever it is. It is a measure of how hard it would be to push the object along in empty space. It is **not** the same as weight. On the Moon your weight would be about one sixth of that on Earth but your mass would be unchanged (See also GRAVITY).
MOON	An object going around a planet. The Earth has one, called the Moon (note capital "M"), although there are now many "artificial moons" or satellites. (See SATELLITE).
ORBIT	The path taken by an object which moves around another, like the planets round the Sun and the Moon round the Earth.
PHASE	One of the recurring shapes of the portion of the Moon illuminated by the Sun. Mercury and Venus also show phases.
PLANET	A large object going round a star but not giving out any visible light of its own. There are nine major planets going around the Sun and most have moons going around them. (See also ORBIT, ASTEROID, COMET and MOON).
SATELLITE	Another word for an object going around a planet, (see MOON), though nowadays used also used for artificial (manufactured) objects launched round the Earth and the planets.
SOLAR SYSTEM	The collection of planets, moons, comets etc. and the star or stars that they orbit. Usually refers to our Sun and its "family".
STAR	Huge balls of glowing gas, like our Sun. We can see hundreds of other stars in a clear night sky, at immense distances away from us. They are powered by nuclear reactions taking place deep inside them.
TELESCOPE	An arrangement of lenses or mirrors which has the effect of magnifying the image of a distant object. This makes it appear closer.
UNIVERSE	Contains everything that there is. As far as we know, there is only one Universe and there is nothing that is not part of it.

13. ASTRONOMY AND SPACE BOOKS

This list includes a few of the many books available. At the time of writing all titles listed below were available and have been included on their merit.

Pupils 11 to 14 years:

Pupils 11 to 18 years:

Dictionary of Space and Astronomy **Robin Kerrod**
Collins 0001911244

Guide to the Night Sky (Guided tour of the naked eye stars)
Patrick Moore
Philip's £4.99 0540063150
Moon Map
Philip's £4.99 0540012084
Planisphere (10 inch circular star map - shows the sky at any time of the year - excellent for beginners)
Philip's £5.99 0540012343

CD-ROMs and Computer Programs:

Space Andromeda Interactive Tel: 01235 529595
£30
Welcome to the Planets CD-ROM
Best value ever! Has all the best images of the planets in easily accessible form as well as teacher guides. Windows or Mac on same disk.
National Space Science Data Centre,
NASA/Goddard Space Flight Centre, Code 633,
Greenbelt, MD 20771, USA. Fax: 001 301 286 1635
$15 inc.
Fax your credit card details.
Encyclopaedia of Space and the Universe
Dorling Kindersley £30 0751315370

Redshift 6
Maris Multimedia. Phone 01903 266165
?????????????????????????? £40

SkyGlobe - DOS/Windows
Public Domain & Shareware

Middle School Teachers:

Secondary School Teachers:

A Concise Dictionary of Astronomy	**Jacqueline Mitton**
OUP	£12.95 0198539673

14. PLACES TO VISIT

This list contains places to visit for all who are interested in astronomy and space sciences. Bear in mind that some institutions only allow group visits. Centres are often attached to observatories, planetaria or museums. Some can help with project work when you visit with your class. Some have shops where you can buy items for school work and some run teachers' courses. We advise that all visits should be arranged in advance by telephone, email or letter. Always check availability, facilities, prices, opening times and if necessary, access for disabled members of your party.

Liverpool Museum
William Brown Street, Liverpool, L3 8EN, 0151 207 0001 x.4235
66 seater planetarium. The Museum's Space and Time Galleries, include displays on meteorites, moon rock, historical and modern astronomy and spaceflight. Group educational visits, teachers' courses and evening classes, also catered for. The Liverpool Astronomical Society holds regular meetings at the Museum. Ring the above number for details.

Aberdeen Technical College Planetarium
Gallowgate, Aberdeen, AB9 1DN, 01224 640366
30 seater planetarium.

The Planet : Earth Centre
Clough Bank, Bacup Road, Todmorden, Lancashire, OL14 7HW, 01706 816964
25 seater planetarium. Camera obscura. Teacher support. All visits must be arranged in advance. Ring for details of special events.

Armagh Planetarium and Observatory
College Hill, Armagh, Northern Ireland, BT61 9DB, 01861 523689
Interactive planetarium. Exhibitions. Stock a wide range of goods, for mail order. Portable planetarium for hire.

Aylesbury Astronomical Society
20, Woodcote Green, Downley, High Wycombe, 01494 438090
School and other educational groups welcome for observatory visits, and talks (free of charge).

Bristol Exploratory Hands-On Science Centre
The Old Station, Temple Meads, Bristol, BS1 6QU, 0117 907 5000
Hands on exhibitions and stardome.

Cambridge University
Institute of Astronomy, Madingley Road, Cambridge, CB3 0HA, 01223 337548
Venue for party visits, max. size 20. Visitors can see: 36" reflector, 24" Schmidt, 12" Northumberland refractor.

Canterbury High School
Knight Avenue, Canterbury, Kent, CT2 8QA, 01227 463971
Science dept has an observatory (350 mm Schmidt-Cassegrain) that can be visited by schools. Teaching materials may be loaned for short periods.

Central Museum and Planetarium
Victoria Avenue, Southend-on-Sea, Essex, SS2 6EW, 01702 330214
25 Seater planetarium.

Cleveland and Darlington Astronomical Society
5, Fountains Crescent, Eston, Middlesborough, Cleveland, TS6 9DF, 01642 454064
Public Observatory also available for schools visits.

Coats Observatory, Paisley
49, Oakenshaw Street West, Paisley, Strathclyde, PA1 2DR, 0141 889 2013
Observatory with 128 mm and 256 mm refractors, meteorological, station, seismic station. Visits for public, schools and other, pre-arranged groups.

Cotswold Astronomical Society
8, Merestones Drive, The Park, Cheltenham, GL50 2SS
Mr. John Fletcher, a member of the society, allows school visits to his observatory.

Croydon Astronomical Society
5, Dagmar Road, South Norwood, London, SE25 6HZ, 0181 771 0477
Visits to Kenley Observatory (250 & 450 mm reflectors) by arrangement. Practical help for teachers and students on National Curriculum.

Dyfed Spacewatch
Dyfed Educational Resource Centre, Ysgol Gryffyd-Jones, St. Clears, Dyfed, SA33 4BT, 01994 231223
Portable Starlab planetarium plus associated activities for schools. In Dyfed area only.

Fort Victoria Planetarium and Astronomy Resource Centre
Westhill Lane, Yarmouth, Isle of Wight, PO41 0RR, 01983 761555
33 Seater Planetarium.

Glasgow College of Nautical Studies
21, Thistle Street, Glasgow, G5 9XR, 0141 429 3201
40 seater planetarium. Available for school groups and other, parties Tuesday-Thursday afternoons, and for public visits on Tuesday and Thursday evenings. All visits by prior arrangement.

Glasgow University Planetarium
Acre Road, Maryhill, Glasgow, G20 0PL, 0141 946 5213
30 seater planetarium. Support for schools.

Goonhilly Satellite Earth Station
Goonhilly Downs, Heston, Cornwall, TR12 6LQ, 01872 325400
British Telecom's largest gateway Earth station for international, satellite communications. Open to school parties from Easter to the end of October, 10-6 pm.

Greater Manchester Museum of Science and Industry
Liverpool Road, Manchester, 0161 832 2244
"Out of this World" space exhibition, "Xperiment" interactive, centre on light and energy.

Hampshire Astronomical Society
1, Conifer Close, Cowplain, Waterlooville, Portsmouth, Hants, PO8 8AF, 01705 254032
Local schools and colleges are actively encouraged to visit Clanfield observatory (130 mm refractor, 500 mm reflector).

Herschel House and Museum
19, New King Street, Bath, BA1 2BL, 01225 311342
House belonging to Sir William Herschel, famous astronomer and discoverer of the planet Uranus in 1781. Open Daily from March-October 2-5 pm daily. Weekends only at other times. School visits by prior arrangement.

Huddersfield Astronomical and Philosophical Society
4A, Railway Street, Huddersfield.
It has a 16" Newtonian reflector in the observatory at Crosland Hill, which is open at times to the public. Group visits can be arranged at any time at a small charge.

Jewell and Esk Valley Nautical College
24, Milton Road East, Edinburgh, EH15 2PP, 0131 669 8461
25 seater planetarium.

Jodrell Bank Science Centre and Arboretum
Macclesfield, Cheshire, SK11 9DL, 014775 71339
Opening Times: For Schools - All year by arrangement. Public - Mid-March to end October : Daily 10:30 am-5:30 pm, November-Mid March: Weekends only, 12:00 pm-4:30 pm.

London Planetarium
Marylebone Road, London, NW1 5LR, 0171 487 0229
400 seater Planetarium, shows for all levels and special needs, groups. Exhibition. Teachers' packs available. Group bookings by prior arrangement.

Mills Observatory
Balgay Park, Glamis Road, Dundee, DD2 2UB, 01382 667138
Planetarium, observatory, workshops and courses available. Group visits must be booked in advance.

National Maritime Museum, Old Royal Observatory and Planetarium
National Maritime Museum, Greenwich, London, SE10 9NF, 0181 858 1167
Planetarium, teachers' packs, supporting material, Greenwich, Meridian and historical astronomy displays.

National Museum of Science and Industry
Exhibition Road, London, SW7 2DD, 0171 589 3456
Large exhibition on Space Technology and Launch Pad interactive, science centre. 'George III' collection includes early astronomical instruments.

Natural History Museum
Cromwell Road, South Kensington, London, SW7 5BD, 0171 938 9123
Mineral Gallery; the most representative collection of meteorites in the world. Earth Galleries with various astronomy-related exhibitions including 'Story of the Earth'. Finest Moon rock outside, the USA. Open Monday-Saturday 10-6 pm, Sunday 11-6 pm. Closed 23-26 December inc. and 1 January. Admission £4.50, £2.20 Children, Senior Citizens, UB40's etc. Special rates for groups, all of which must be pre-booked.

Natural Sciences Centre
Newchapel Observatory, Newchapel, Stoke-on-Trent, ST7 4PT
Educational and recreational visitor centre. Themes include, astronomy and space sciences, geosciences, alternative energy and, conservation. Planetarium. Caters especially for schools in, connection with science and geography curriculum.

Norman Lockyer Observatory
Salcombe Hill Road, Sidmouth, EX10 0NY, 01395 68591
The observatory is open to the public on Bank holidays and Sunday, afternoons during the Summer and on some evenings during the Autumn and winter when visitors may look through telescopes if the sky is clear. Demonstrations and talks are given by prior arrangement to parties of schoolchildren and adults.

North Yorkshire Education Department
Yorkshire Museum, 150, Haxby Rd., York, YO3 7JN
Since 1989, the Yorkshire Museum with the North Yorkshire Education Department have organised a space event for primary school pupils. Lasts 2-3 weeks and is supported by displays, mobile planetarium and observatory.

Royal Observatory Edinburgh Visitor Centre
Blackford Hill, Edinburgh, EH9 3HJ, Tel: 0131 668 8405
Open October-March 13.00-17.00 daily (21.00 on Fridays), April-September 12.00-17.30 daily. Admission charges (1995): £2.00 (£1.25), (closed December 25 and Jan 1 only). The Visitor Centre contains several exhibition areas. Current exhibitions include images of the stars, planets and galaxies taken by the Hubble Space Telescope. There are computers equipped with interactive CD-ROMs about space, astronomy and science in general. The two large telescopes are now part of the Visitor Centre. There is also a well-stocked shop. During the winter months public observing sessions are held on most clear week nights and there is a lecture series on Friday evenings. Group visits are welcome at any time but should be pre-booked.

Somerset Schools Observatory
Somerset Education Authority, County Hall, Somerset, 01823 333451
At Charterhouse-on-Mendip, Somerset LEA maintain a 460 mm Newtonian, Reflector for use by schools. The site also possesses full, residential facilities for up to 16 people.

South Tyneside College Planetarium
St. George's Avenue, Tyne and Wear NE34 6ET, 0191 427 3589
75 seater planetarium, in-service courses, observatory. Visits, by prior arrangement.

Techniquest
Stuart Street, Cardiff, CF1 6BW, 01222 475475
An interactive science centre with Starlab portable planetarium for hire.

University of Central Lancashire, Alston Hall Observatory
School of Physics and Astronomy, Moor Park, Preston, PR1 6AD, 01772 57181
Multi aperture telescope (largest optical telescope in Britain), high dispersion spectrometer and CCD camera, twin 15" refractors, numerous 8" Celestrons, visiting speakers. Weather station, lectures and courses for up to 25 visitors, aged 7-15 years old. Observatory open certain evenings. LEA schools participation scheme.

University of London Observatory
Mill Hill Park, London, NW7 2QS, 0181 959 0421
24", 18" refractors, 24" Cassegrain Coudé reflector and several smaller instruments. Open to the public by appointment on 1st and 3rd Friday of the month, October to March. Group visits by special arrangement up to a maximum of 15. Cost £50 per party. Parties from the London Borough of Barnet are free.

University of Plymouth, William Day Planetarium
Drake Circus, Plymouth, PL4 8AA, 01752 232462
63 seater planetarium. Group visits available if booked in advance. Sessions on Monday and Wednesday mornings and certain evenings.

West Yorkshire Astronomical Society
Rosse Observatory, The Grange, Carleton Road, Pontefract, West Yorkshire, WF8 4BU
Visits for schools and scout groups etc. to observatory, equipped, with a 450 mm Newtonian Reflector.

Widegates Observatory
Channel View, Widegates, Looe, PL13 1QJ, 015034 218
A working observatory with various facilities available to the public. Local school groups are encouraged to visit the observatory, which has a small classroom and exhibition area.

Yorkshire Museum
Museum Gardens, York, YO1 2DR, 01904 629 745
North Yorkshire geology collection includes Middlesborough, meteorite, which fell in 1881. The Observatory, housed in the, Museum grounds, was built in 1832 by the Yorkshire Philosophical Society. It now contains a 4.5" Cooke refractor and display areas. The Observatory is open every Thursday evening between 6 pm-8 pm, during November-February. Other times, visits must be arranged by appointment.

15. OTHER RESOURCES

The only way to keep abreast of the rapid advances in Astronomy and Space Flight and the rapidly changing scene in resources such as videos, CD-ROMs, slides and posters is to receive a regular magazine. These are the main ones:

Astronomy Now - popular and well produced UK monthly newsstand magazine with features such as A to Z of Astronomy, Sky Diary and current review articles. Subscriptions £23 (1996) information from AIM, PRE Complex, Pallion Industrial Estate, Sunderland, SR4 6SN. Suitable for all schools.

Popular Astronomy - covers Astronomy and Spaceflight produced quarterly for members, who are often beginners in the subject. Articles cover observing, current space-flight events and other topical issues. Subscription £12 per year (1996). Details available from The Society for Popular Astronomy, 36 Fairway, Keyworth, Nottingham, NG12 5DU. Please enclose a self-addressed stamped envelope. Suitable for all schools.

Federation of Astronomical Societies - produce a handbook listing many places of interest to write to and visit. Lists local astronomical societies and resources. Obtainable from FAS, c/o Mr Malcolm Jones, Tabor House, Norwich Road, Mulbarton, Norwich, Norfolk, NR14 8JT. Price £4.50 (1996).

POSTERS, DVDs and BOOKS - major suppliers

Armagh Planetarium, College Hill, Armagh, Northern Ireland, BT61 9DB, 01861 524725. Produces a catalogue of large colour posters and many slide sets on the solar system, planets, comets, space shuttle, stars and galaxies. Good range of books and videos. Mail order and shop facilities. Write, phone or email for a free catalogue.

Earth & Sky, ??????????????????????????????????????74 Sutton Spring Wood, Calow, Chesterfield, S44 5XF, 01246 850665. Extensive range of astronomy books by mail order.

Most Planetaria have items on sale locally and would be able to help with suggestions of other suppliers.

OTHER WORKPACKS

Earth and Beyond (Primary), AAE. ISBN 0863572715. A book with teacher notes and photocopiable pupil worksheets for 5-13 year olds. Available from the ASE Bookshop.

Project Star teaching models and ideas. The Project Star Spectroscope (PS-14/Plastic) is available at $18 + p&p from: Learning Technologies Inc., 40 Cameron Avenue, Somerville, MA, 02140, USA. Phone: 001-617-628-1459. Fax: 001-617-628-8606.

Royal Greenwich Observatory Information Leaflets. Copyright-free information sheets on numerous topics. Free/Nominal Charge. Phone: 01223 374000. Internet: http://www.ast.cam.ac.uk/pubinfo/

??????????????????????????? Hands On Universe, Royal Greenwich Observatory. Copyright-free school worksheets with activities for 7 to 11 year olds. Available from Educational Project Resources Limited, 126-128 Cromwell Road, London, SW7 4ET. Free/Nominal Charge.

?????????????? The Universe at your Fingertips ed. A Fraknoi. A massive compilation of teaching material suitable for teachers to dip into. Middle school and above. Available from The Astronomy Society of the Pacific, 390 Ashton Avenue, San Francisco, California, 94112, USA. $25 (1996). Direct order.

16. ADDRESSES FOR FURTHER INFORMATION

ALL WEB SITES

AAE

European Space Agency, Publications Division, ESTEC, 2200 AG Noordwijk, The Netherlands. Information on European Space Agency projects including Ariane rockets, communications and Earth observation satellites.

British National Space Centre, 151 Buckingham Palace Road, London, SW1W 9SS. Brochure on the many activities of the BNSC and information on the Lunar Sample package available to educational institutions.

FAS

PPARC

Royal Astronomical Society, Burlington House, Piccadilly, London W1V 0NL. Information on astronomical research in Britain.

NASA

(Please note that 'Multiple requests from the same address for photographs and/or literature are not honoured'.)

Astronomical Society of the Pacific, 390 Ashton Avenue, San Francisco, California, 94112, USA.

Sky Publishing Corporation, 49 Bay State Road, Cambridge, MA 02138, USA.
(Publishers of Sky and Telescope magazine).

ASTRONOMY ON THE INTERNET

Association for Astronomy Education
http://www.star.ucl.ac.uk/~aae/homepage.htm

Astronomy Now Magazine http://www.demon.co.uk/astronow/

Cambridge Astronomy	http://www.ast.cam.ac.uk
European Association for Astronomy Education	???????????????
Hands On Universe Project	http://hou.lbl.gov/
Hubble Space Telescope	http://www.stsci.edu/top.html
NASA	http://www.nasa.gov/
Shuttle Flights	http://www.ksc.nasa.gov/shuttle/
Space Calendar	http://newproducts.jpl.nasa.gov/calendar/

Welcome to the Planets
http://stardust.jpl.nasa.gov/planets/welcome/cdrom.htm

MAIL ORDER BOOKS

Astro Art, 99 Southam Road, Hall Green, Birmingham, B28 0AB. 0121-777 2792.

Beacon Hill Books, 112 Mill road, Cleethorpes, South Humberside, DN35 8JD. 01472 692959.

Earth and Sky, 74 Sutton Springwood, Calow, Chesterfield, Derbyshire, S44 5XF. 01246 850665.

Highfield Books, 62 Fairview Road, Headley Down, Hampshire, GU35 8HQ.

Midland Counties Publications, Unit 3, Maizefield, Hinckley, Leicestershire, LE10 1YF. 01455 233747.

Society for Popular Astronomy, 36 Fairway, Keyworth, Nottingham, NG12 5DU.

The Planetarium Armagh, College Hill, Armagh, Northern Ireland, BT61 9DB. 01861 528187.

UK ASTRONOMICAL AND SPACE ORGANISATIONS

Association for Astronomy Education, Burlington House, Piccadilly, London, W1J 0BQ.

www.aae.org.uk

British Astronomical Association, Burlington House, Piccadilly, London, W1V 0NL.

Federation of Astronomical Societies, 'Whitehaven', Maytree Road, Lower Moor, Pershore, Worcs., WR10 2NY. 01386 860202.

Society for Popular Astronomy, 36 Fairway, Keyworth, Nottingham, NG12 5DU.

UKSEDS (Students for the Exploration and Development of Space), Royal Aeronautical Society, 4 Hamilton Place, London W1V 0BQ. 01795 521784.

17. ADVERTISEMENTS

In the next few pages you will find adverts for astronomy resources. If you make contact with any of our advertisers, please mention that you saw their advert in ‘Earth and Beyond’. Here is an alphabetical list:

Armagh Planetarium, Northern Ireland

Astronomy Resource Centre, Hawkwell, Essex

Astronomy Roadshow, Gillingham

Guide to the 1999 Total Eclipse of the Sun, RGO, Cambridge

Jodrell Bank Science Centre, Cheshire

Kent Astrodome, Gillingham

Liverpool Museum Planetarium, Liverpool

London Planetarium

Mizar Planetarium, Dorset

Planet : Earth Centre, Todmorden

Royal Greenwich Observatory, Cambridge

Royal Observatory, Edinburgh

Sherwoods, Birmingham

Skylab Mobile Planetarium, Crowborough

Society for Popular Astronomy

South Tyneside College Planetarium, Tyne and Wear

Starlab UK

Star Trail Planetarium, Didcott

Stargazer Planetarium, Hartlepool