25th Anniversary Edition

ASTRONOMY

SCIENCE WITHOUT LIMITS

A resource book of ideas for teachers

Australian Science Teachers Association

national science week
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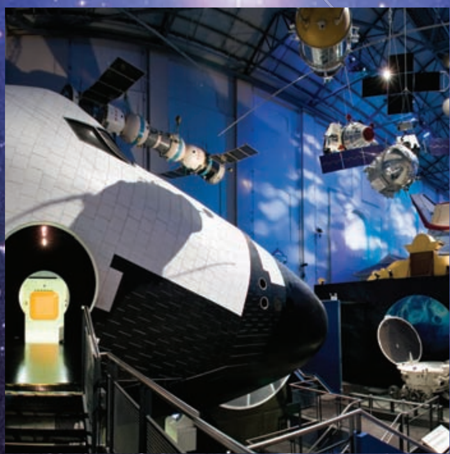


LEFT TO RIGHT: TELESCOPE VIEWING AT SYDNEY OBSERVATORY, POWERHOUSE MUSEUM'S *SPACE* EXHIBITION AND ZERO GRAVITY SPACE LAB
BACKGROUND IMAGE: PLEIADES, ANGLO / AUSTRALIAN OBSERVATORY, DAVID MALIN

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Minister's Foreword

The Australian Science Teachers Association has produced another outstanding resource for schools to coincide with National Science Week.

Astronomy: Science Without Limits will engage students in science activities ideally suited to the International Year of Astronomy. It is an excellent companion to *Out of this World: Investigating Space*, published in 2004.

Back then Pluto was still classified as a planet. Now it is considered a dwarf planet, in company with Ceres, Haumea, Makemake and Eris. These last two were only discovered in 2005, even though Eris is larger than Pluto. This is a reminder of how much we have to learn and how rapidly our knowledge is growing – even of our own solar system.

We owe much of this new knowledge to Australian astronomers – like Dr Naomi McClure-Griffiths, who discovered a new spiral arm of our Milky Way galaxy while working with CSIRO at the Parkes Observatory in 2004. Several Australian astronomers are profiled in this publication, and I hope students will be inspired by their example.

This year marks the twenty-fifth anniversary of the Association's resource book program, and the twelfth anniversary of National Science Week – which is expected to involve over half a million people in more than 800 events.

Congratulations and thanks to the Australian Science Teachers Association for this wonderful publication and its ongoing work of inspiring the scientists of tomorrow.

Senator Kim Carr

Minister for Innovation, Industry, Science and Research

CONTENTS & ACKNOWLEDGEMENTS

PRESIDENT'S MESSAGE

In bringing you the 2009 National Science Week teacher resource book, *Astronomy: Science Without Limits*, ASTA is proud to announce it as a Jubilee Edition. It is the twenty-fifth in the series of National Science Week resource books published annually by ASTA since 1984. Indeed ASTA has a very proud history of involvement in National Science Week since it initiated its precursor, Australian Science in Schools Week, in 1981.

This resource is distributed to all Australian schools, and is designed to support teachers and their students in activities before and during National Science Week and beyond. It is designed to be practical and useful, and to cater for a broad range of student ages and abilities.

ASTA acknowledges funding support for this project by the Australian Government through the Department of Innovation, Industry, Science and Research (DIISR). We also thank the many people who have contributed to the production of the resource with their research, writing, review, design or other skills. Your special focus has been on producing a book that is relevant, user friendly and classroom ready, a book by educators for educators. Thank you all.

We also thank the eight ASTA member Science Teachers Associations and their National Science Week Representatives who support school National Science Week activities at the local level. Their efforts are very much appreciated.

I hope that you will take the opportunity to participate in the unique national celebration that is National Science Week. Furthermore, I trust that you will find this resource most valuable in promoting Science within your school communities, and in engaging your students in the excitement of Science.

Peter Turnbull
President, Australian Science Teachers Association

AUSTRALIAN SCIENCE TEACHERS ASSOCIATION

Australian Government
Department of Innovation Industry, Science and Research

national science week

ASTA and the authors would like to acknowledge the following people for their valuable advice during the development of this book:

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Watts, M.M. and Muir, M.A.
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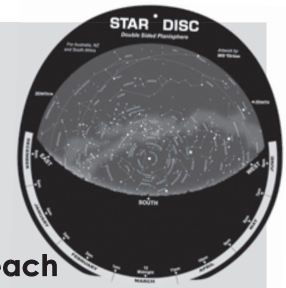

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1. Overall response to the book	1	2	3	4	5	
A valuable resource						Of little value
Well presented						Poorly presented
Information sections were helpful						Not helpful
Supports an inquiry approach to student learning						Does not support an inquiry approach
Applicable beyond National Science Week 2009						Not applicable
2. Resource Book Content	**1**	**2**	**3**	**4**	**5**	
Good balance of activities – primary to secondary						Too targeted
Includes activities relevant to the class level I teach						Irrelevant to my students
Created student interest						Little interest created
Provided a springboard to other ideas and activities						No scope for creativity
Additional resource links were useful						Not useful
Appropriate methodology						Inappropriate methodology

3. What did you find most valuable about the book? ______________________

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4. What did you find least valuable about the book? ______________________

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Introduction

The resource book ***Astronomy: Science Without Limits*** has been designed to provide teachers with ideas and activities to enhance knowledge and understanding of the science of Astronomy.

Astronomy has been a traditional inclusion in the primary and secondary school curricula, with an emphasis on the Solar System and visible features of the celestial sphere such as constellations, 'shooting stars' and some planets. Many resources are available to support the teaching of these concepts so the emphasis in this book is on the many other interesting aspects of Astronomy, which is indeed a science without limits.

The Astronomy community is truly international and cooperative – Australia has had, and will continue to play, a significant role in this community. National Science Week 2009 provides an opportunity to celebrate Australian Astronomy and astronomers. Astronomers currently working in Australia are a multicultural, multinational blend of people, with talents in a wide range of science-related fields. A few Australian astronomers are profiled in the book, but many more deserve mention – encourage your students to become familiar with our astronomers at work, both here and overseas!

Astronomy is arguably the world's oldest science and all peoples and cultures across the world have engaged in astronomical observations since humans realised that signs from the changing sky could predict weather patterns and affect food production. Observations of the night sky were also interwoven into the rules, morality tales and spiritual beliefs of various peoples. The study of Astronomy can, therefore, also become a study of the changing history of ideas about the Universe over time. Consider creating a timeline of the development of ideas, using the names in the 'Galaxy of Stars' in the centrefold of this book as signposts along the continuum. Ask your students to find and add more stars of Astronomy.

One of the great challenges for astronomers of the 21st century is to uncover the mysteries of dark energy and dark matter.

As one teacher said, "It's quite cool to think that astronomers are still searching for something that makes up nearly 96% of the Universe. They know what it does but they don't know what it is. I can compare that to when biologists knew something was causing disease but couldn't see the microbes!"

While the science may be complex, these challenges for astronomers have been incorporated in the text in a way that is accessible to all teachers and students.

Many activities are hands-on investigations but the very nature of Astronomy leads to a need for secondary information. In the choice of selected activities, every effort has been made to provide opportunities to expand student experiences in extracting, processing and presenting information via oral, written and electronic media. There are many and varied interactive sites and software now available to 'spice up' the study of Astronomy in schools. Your writers have worked hard to include the best of them in this book.

How this Book is Structured

Because the study of Astronomy pre-dates written human history, the book has been structured to provide opportunities for students to develop an understanding of the history of ideas about the celestial sphere and follow the changing nature of the science of Astronomy and its related technology.

The book has been divided into chapters broadly based on:

1. Astronomy through the Ages – this section provides insights into Astronomy in the past and some of the observations made by ancient peoples.
2. The electromagnetic spectrum and the ever-increasing range of technologies that astronomers can use to search the Universe.
3. An overview of the phenomena of the Universe.
4. Astronomy now and in the future.

It is recognised that not all schools will have access to a wide range of Astronomy resources and may not have the opportunity to have viewing nights with telescopes. For some students, just switching off the television, going outside, and lying on their backs on a blanket to look at the night sky will be a novelty. Others may be able visit planetariums. For those students who cannot access these opportunities, the activities included in the book are varied to include presentations as well as traditional hands-on investigations. This range is included to ensure that students in schools with limited resources can still engage in activities relating to the theme of National Science Week. Whilst some activities are conceptually simple and easily achieved by most students, others will challenge them to develop higher order critical thinking skills such as analysis and evaluation.

The websites identified in each section were functioning at the time of writing and a list of other useful web links has been developed that highlight some of the other outstanding sites on the World Wide Web. See Further Resources p.48.

Organisation of Chapters

Each chapter includes the following features:

* an introductory page which provides background information on the subject of the chapter,
* a series of double-page spreads, each of which can be used independently of other pages,

Each double-page spread consists of:

1. a single page of information about the header topic. This single page contains the relevant background science knowledge and understandings.
2. a page of teaching activities across four groups:
   - lower primary
   - primary
   - middle school
   - senior secondary

Not all groups are catered for in every set of teaching activities. Teachers are encouraged to read across all the activities for ideas that might be appropriate for their students' specific talents, interests and levels of conceptual development.

Curriculum Guidelines

Astronomy is part of the school curriculum across Australia and elements of Astronomy are taught in both primary and secondary schools to varying degrees. In primary schools, content tends to focus on day and night, shadows, and basic awareness of stars and planets. These topics have been briefly covered in the resource for teachers in need of ideas to teach these common concepts. However, the range of topics that can be introduced into the primary curriculum has been increased for teachers using Astronomy as a context for introducing the concepts of light and/or energy.

In secondary schools, the scope of Astronomy that is taught in the Science curriculum varies from State to State but it does form part of the junior school curriculum in all States. Whilst the traditional junior secondary Astronomy topics of planets, solar systems, galaxies, and natural phenomena such as eclipses have been included, this resource has expanded the potential scope of Astronomy in high school, with ideas on how Astronomy could be used as a context to teach the fundamentals of wave motion, the electromagnetic spectrum and properties of light in the examination of traditional Earth-based telescopes and the new technologies associated with Space-based telescopes.

Safety Awareness

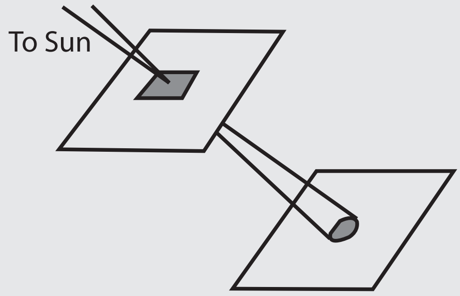
All student experiments included in *Astronomy: Science Without Limits* have been designed and selected to minimise any possible hazards. However, there is no guarantee that a procedure will not cause injury. Teachers should test all activities before using them in class and consider the OH&S requirements of their own State or Territory. All necessary safety precautions should be outlined clearly to students prior to any activity.

WARNING: It is particularly important during any daytime Astronomy activities that students are cautioned not to look at the Sun, either directly or through any device such as a magnifying glass, camera, binoculars or telescope. There is a real risk of permanent and serious damage and possible permanent blindness if the Sun's light hits the eye directly. Both the eye and artificial optical devices concentrate the extremely strong light of the Sun onto the retina. This can burn the retina and permanently destroy its ability to detect light.

Pinhole projector

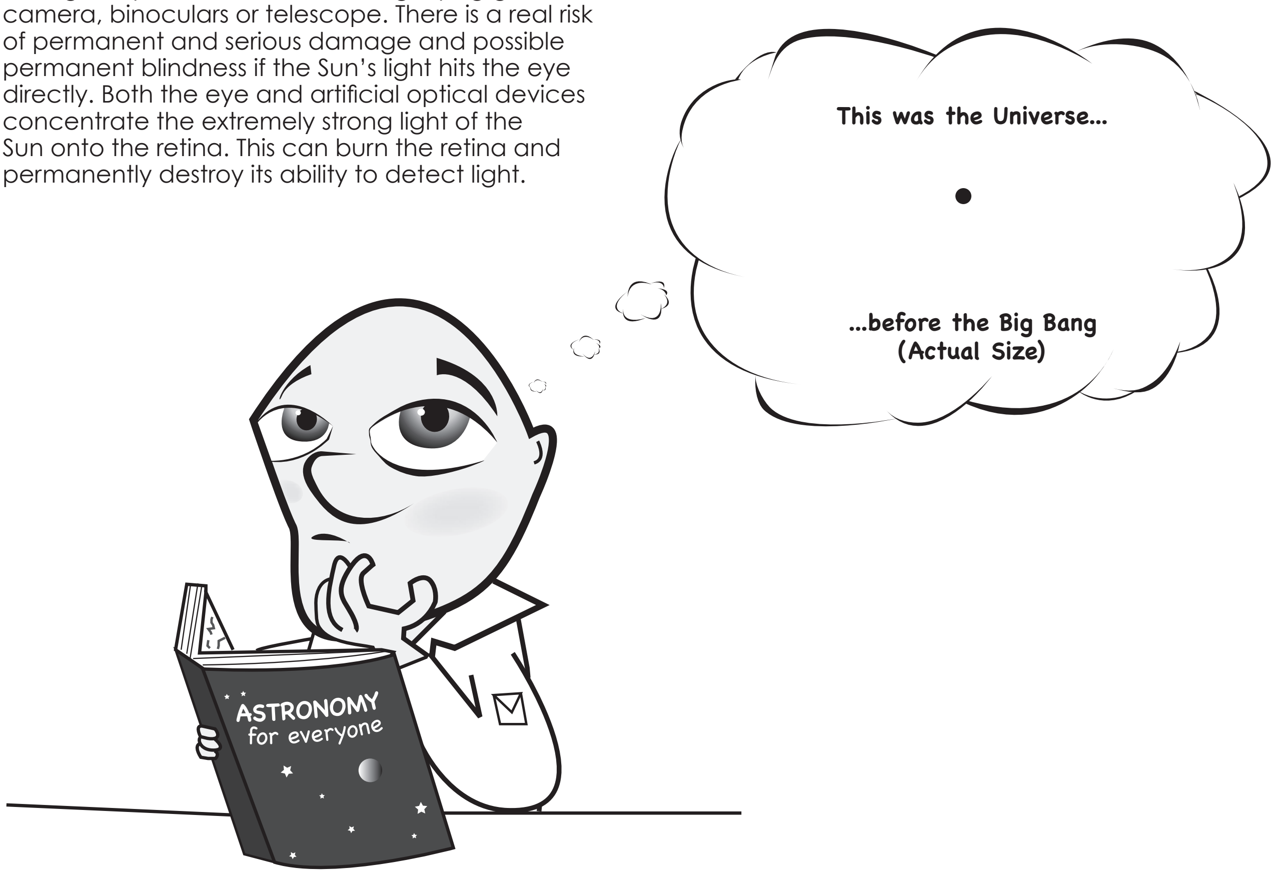
To safely observe the sun, you must use an indirect method such as a pinhole projector.

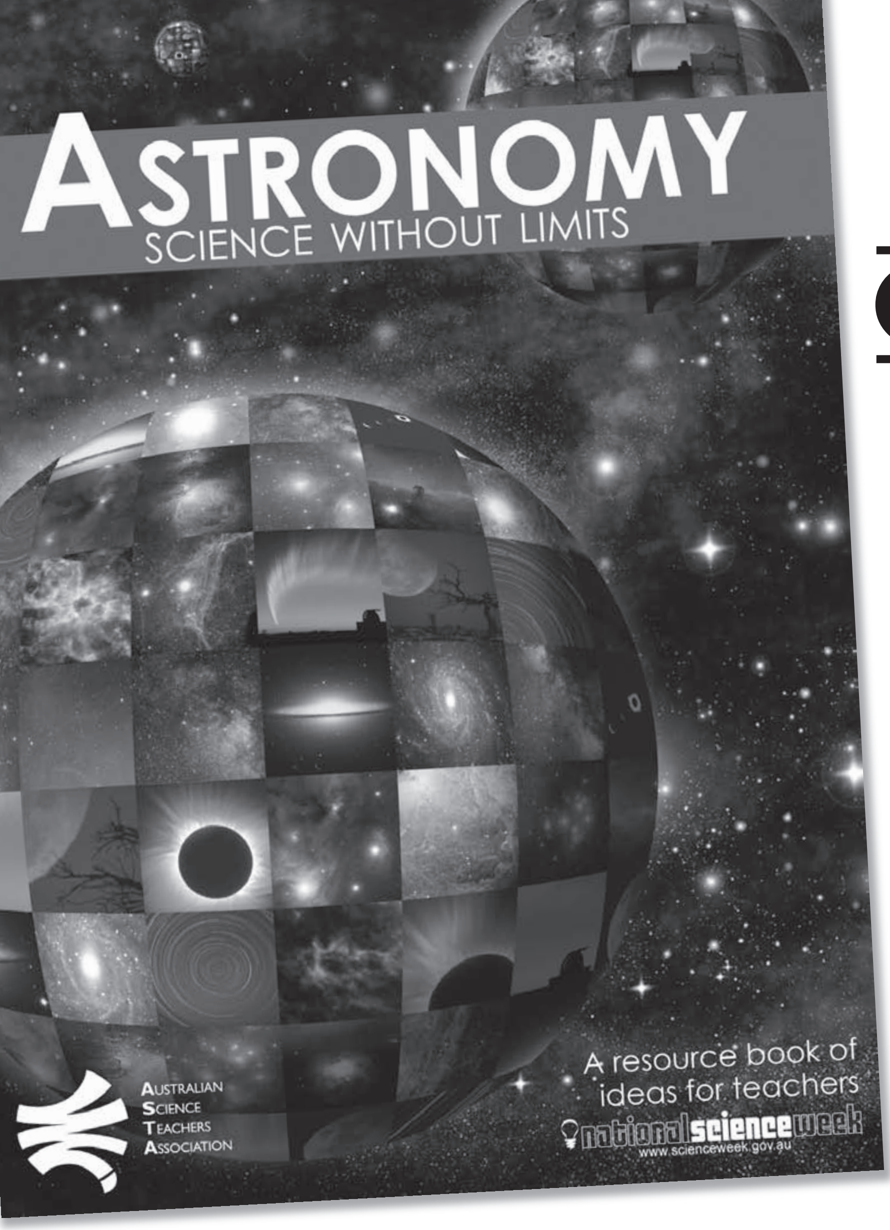
The simplest version of the pinhole sun projector requires only two pieces of cardboard, a small piece of aluminium foil, and a needle. One of the pieces of cardboard needs to be white in order to be used as a projection screen. A small square is cut in the centre of the other piece of cardboard, and a piece of aluminium foil is taped over it. A pinhole is then carefully made in the foil.



Hold the cardboard with the pinhole pointing towards the Sun. Adjust it until you can see a good round image on the screen. The further you hold the pinhole from the screen, the larger (and fainter) the image. Ideally, the pinhole should be approximately 1m from the screen. To create the best image, the screen should be propped up so that it is at a 90˚ angle to the sun, and the pinhole should be at the same 90˚ angle. This will produce the least amount of distortion of the image.

Have a Stellar Time!





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CHAPTER ONE

Astronomy – A science from the mists of antiquity

Stonehenge (3000 BC onwards) may have connections to ancient astronomy.
Image: Sophie Muir and Chris Hunt

Astronomy dates back to antiquity and has its origins in the religious, mythological, and astrological practices of civilisations before recorded history. Early Astronomy involved observing the regular patterns of the motions of visible objects in the sky, especially the Sun, Moon, stars and those planets that can be seen with the naked eye.

Astronomy is the scientific study of objects away from the Earth, such as stars and planets, and of phenomena that originate outside the Earth's atmosphere, such as radiation from the cosmos.

Astronomy began as a science of observation, mathematical computations and predictions of the motions of objects visible to the naked eye. Astronomers of early civilisations performed and charted methodical observations of the night sky and tried to interpret and explain the phenomena they saw. For example, ancient astronomers were able to differentiate between stars and planets, as stars remained relatively fixed in their positions, while planets moved an appreciable distance over a comparatively short time. They also studied the changing position of the Sun along the horizon and the changing appearances of stars with the seasons. Such observations were used in many cultures to develop calendars for agriculture and rituals.

Artefacts depicting these observations and predicting future astronomical events have been found in many ancient civilisations and cultures around the world.

Modern astronomy has access to extraordinary technology, both on Earth and in Space, that allows the gathering of extensive evidence to describe a much broader range of phenomena than the astronomers of antiquity could ever have imagined. This observational Astronomy collects data emitted as energy waves from many sources. Some forms of energy waves can be detected at the Earth's surface, while others are only detectable from high altitudes or in Space.
(See Chapter 2 for more on this)

With regard to objects away from the Earth, astronomy now investigates their:

- Evolution – How they form; how they change.
- Physics – Forces that act on them; forces exerted by them; their motion.
- Chemistry – Their composition – elements and compounds; chemical changes that take place over time.

In addition, Astronomy in the 21st century has become increasingly theoretical and is orientated towards the development of models to describe astronomical events and phenomena. In Astronomy, scientists from many scientific disciplines collaborate to understand and explain the formation and development of the Universe. Australian astronomers are at the cutting edge of scientific research and are providing significant input into building a greater body of knowledge and understanding about the cosmos.

Amateur astronomers also contribute to many important astronomical discoveries, especially in the discovery and observation of transient phenomena such as previously unknown comets entering our Solar System.

DID YOU KNOW?

Astronomy is one of the oldest natural sciences. Whilst many cultures have words to describe the the study of celestial objects, the word astronomy used in Western science comes from the Greek words *astron* meaning a star and *nomos* meaning law.

Astronomy and ***astrology*** should not be confused, although they share a common origin and use some of the same observations. Astrology is a belief system that holds that human affairs and fortunes are related to the arrangement or position of celestial objects.

Indigenous Australian Astronomy

There are at least 400 Indigenous groups across Australia, each with its own distinct mythology, ceremonies and art forms. These groups share a strong interest in the night sky, and a strong tradition of oral history, much of which has unfortunately been lost. However, in some parts of Australia, such as Arnhem Land, culture and a rich oral tradition of Aboriginal Astronomy survive. Elsewhere, evidence remains in rock paintings, carvings and similar artefacts.

THE SCIENCE

Indigenous Australians' complex systems of knowledge and beliefs about celestial bodies have evolved as part of their culture for over 50,000 years. This increasing store of knowledge, ideas and beliefs has been passed through countless generations and survived virtually unchanged until European settlement.

Indigenous astronomers differentiated between the nightly movement of stars from east to west and the more gradual annual shift of the constellations. By making accurate observations of both the fainter and brighter stars, Aboriginal cultures in various parts of Australia developed complex seasonal calendars based on the constellations of the Southern Hemisphere.

Indigenous Australians were able to predict natural events such as changing weather patterns or the availability of certain foods by identifying relationships between patterns in the sky and other phenomena. For example, for the Pitjantjatjara tribe in the Western Desert region, the appearance of the constellation called Pleiades in Greek mythology in the dawn sky in autumn indicated the beginning of the annual dingo breeding season. Fertility ceremonies were performed for the dingos and then some weeks later, the dens were raided and the young pups killed and feasted upon by the tribe. Clearly, these rituals ensured better nutrition and the continuing survival of the tribe.

The Pleiades are a prominent sight in winter in the Northern Hemisphere and in summer in the Southern Hemisphere, and have been known since antiquity to Australian Aborigines and many other cultures all around the world.

Image: http://en.wikipedia.org/wiki/Image:Pleiades_Lanoue.png

THE YOLNGU

This material contains extracts from Ray Norris' writings and research on Aboriginal astronomy. For further information and references go to: http://www.atnf.csiro.au/research/AboriginalAstronomy/index.html

The Yolngu (Yol-ngu) people of Arnhem Land in the Northern Territory continue to conduct initiation ceremonies, at which their traditional lore is passed from generation to generation. This includes knowledge and interpretation of celestial phenomena.

The Yolngu people call the Moon Ngalindi, and he travels across the sky as does the Sun. Ngalindi was a fat lazy man (corresponding to the full Moon) and his wives punished him by chopping bits off him with their axes, thus producing the waning Moon (Wells, 1964, Hulley, 1996). He managed to escape by climbing a tall tree to follow the Sun, but was mortally wounded, and died (the new Moon). After remaining dead for three days, he rose again, growing round and fat (the waxing Moon), until, after two weeks his wives attacked him again. This cycle is repeated every month.

The Arnhem Land stories go much further, such as explaining why the Moon is associated with the tides. When the tides are high, water fills the Moon as it rises. As the water runs out of the Moon, the tides fall, and the Moon is left empty for three days. Then the tide rises once more, refilling the Moon. So, the Yolngu people obviously had an excellent understanding of the motions of the Moon, and its relationship to the tides.

When Yolngu people die, they are taken by a mystical canoe, Larrpan, to the spirit-land (Baralku) in the sky, where you can see their campfires burning along the edge of the great river of the Milky Way. The canoe is sent back to Earth as a shooting star, letting their family on Earth know that they have arrived safely in the spirit-land. At a beautiful and important ceremony, the Yolngu people gather after sunset to await the rising of Barnumbirr, or Morning Star (the planet Venus). As she approaches, in the early hours before dawn, she draws behind her a rope of light attached to Earth, and along this rope, with the aid of a richly-decorated 'Morning Star Pole', the people are able to communicate with their dead loved ones, showing that they still love and remember them.

Wells, A (1964) *Skies of Arnhem Land* Angus and Robertson: Sydney, NSW

Huxley, C. E. (1996) *Dreamtime Moon* Read Books: Chatswood, NSW

Teaching ACTIVITIES

All years

Indigenous Australians were arguably the world's first astronomers. Their complex knowledge and belief systems relating to celestial phenomena have been handed down through rituals, song and dance for well over 50,000 years. Not only is the knowledge ancient but also its interpretation is diverse throughout the several hundred Indigenous tribes across Australia. Usually, the elders of the local people hold this knowledge.

If possible, talk to your local Indigenous people. Is there an elder prepared to tell the stories that his/her people know about the changing night sky and its relationship with events on Earth? It would be an excellent way to begin National Science Week to listen to the astronomical observations and inferences that have been built on from antiquity in your local area.

An excellent map that attempts to represent the language, tribal or nation groups of Australia's Indigenous peoples is located at *http://www.aiatsis.gov.au/aboriginal_studies_press/aboriginal_wall_map_*

Lower Primary – Primary

Name Your Own Constellation

Read the Aboriginal story about *Tchingal – the emu in the sky*.

Book - *There's an Emu in the Sky*, Clifford Keith Malcolm, Curriculum Corporation (Australia), Science Curriculum and Teaching Program (Australia) ISBN 186 366 2634

1) Have students draw a picture of themselves looking up at the night sky and observing a constellation, which they 'join' and name.

2) Make a 'constellation viewer/diorama' by painting the inside of a shoe box with black paint, poking holes through the cardboard and then joining the 'stars' with white chalk lines to create a constellation, which is then named.

Middle School – Upper Secondary

Testing Astrology

Astrology is not a science. There are many types of astrological systems, traditions, and beliefs. They share a common use of knowledge of the relative positions of celestial bodies and related details to understand, interpret, predict and organise information about personality, human affairs, and terrestrial events. The following critical thinking activity will demonstrate the inaccuracy of astrology.

Obtain a previous week's set of weekly horoscopes that apply to both males and females in the target age group. Remove the 'star sign' badge on each prediction and re-type them, ensuring that there are no 'clues' to the actual star sign. Number the predictions from 1-12 and cut the paper so that each prediction is on a separate strip. Create a master sheet that matches each 'star sign' to a numbered paper strip. Ask students to read the 12 predictions for the previous week and select the one that most closely matches what happened to them during the week. Students then look at the master sheet and see which 'star sign' they have selected. The chances of being correct have been shown to be less than random!

Indigenous Australian Astronomy

Science is the systematic study of the structure and behaviour of the physical world, especially by observing, predicting, measuring and investigating, and the development of hypotheses to describe the results of these activities. Astronomy is a branch of science.

Focus question for the Internet research task:
If Indigenous Australian people are described as the world's first astronomers, can we find evidence of observing, predicting, measuring and investigating, as well as the development of hypotheses about phenomena in the night sky?

Suggested strategy:

Divide the class into groups to research evidence of astronomical knowledge in Indigenous Australian people.

Students may start at this site: *http://www.virtualmuseum.ca/Exhibitions/Cosmos/english/html/skystories.html* to select an example to research further as they navigate away from the site.

or

Allocate each group one of the following topics to research with the outcome that the group prepares and delivers a short presentation on evidence of astronomical investigation in the Indigenous people studied.

- The Astronomy of the Boorong people. The appearance of the Malleefowl constellation in March tells the Boorong people in Victoria that the Malleefowl are about to build their nests. What does the disappearance of the constellation in October signify? Why is this important to the Boorong people?

- *http://bdas.fastmail.fm/astronomers/JohnMorieson/documents/World_Archaeological_Congress.pdf* is a 13-page document suitable for more able readers to use and is a good starting point.

- The star cluster Pleiades is readily visible in the night sky across Australia. The cluster figures in the Dreaming stories of many Indigenous peoples. Select one such story to demonstrate the astronomical knowledge and understanding behind the story.

- The morning star ceremony of the Yolngu people: *http://www.atnf.csiro.au/research/AboriginalAstronomy/Examples/banumbirr.htm*

THE BIRTH OF THE SCIENCE OF ASTRONOMY

People in all parts of the world were fascinated by, and made records of, their observations of the night sky. Apart from Indigenous Australians' oral history and traditions, the oldest records of astronomical observations are 30,000-year-old cave paintings in Europe. Ancient sky-watchers used their celestial observations to inform a variety of cultural and societal practices and travellers shared their knowledge, so the history of astronomy provides a great example of scientific knowledge growing through collaboration.

THE SCIENCE

ASTRONOMICAL OBSERVATIONS AND CALCULATIONS

There is evidence from around the world that people recorded their observations of the changing night sky and used these records to predict future events. Inevitably, these predictions became important in the life of the societies involved and increasing significance was placed on their accuracy. In many societies, astronomical observations became interwoven with religious rituals.

Chinese astronomy has a very long history. Detailed records of Astronomical observations were kept from about the 6th century BC. Many maps of stars were drawn over the centuries. The most famous is perhaps the Dunhuang map found in Dunhuang, Gansu, dating back to the Tang Dynasty (618–907AD). The map was drawn on paper and represents the entire sky, with more than 1,350 stars. Though ancient Babylonians and Greeks also observed the sky and catalogued stars, no comparable records have been found. The Dunhuang map remains the oldest known chart of the skies.

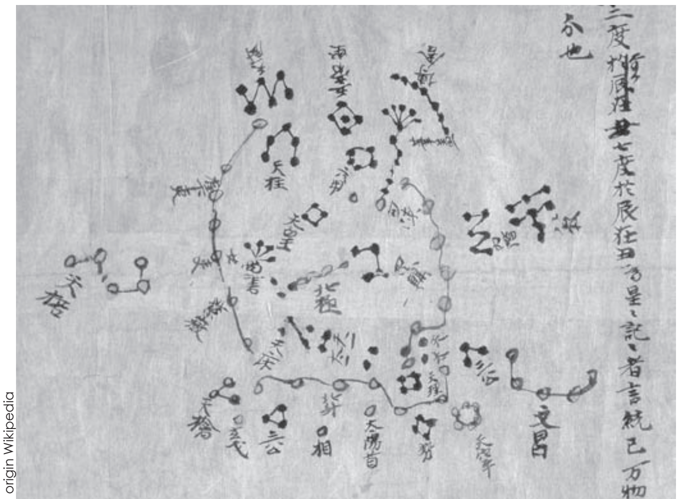


Image: origin Wikipedia

Dunhuang star map

As early as the 4th century BC, Chinese astronomers understood eclipses. The ancient Chinese astronomer Shi Shen gave instructions in his writings on how to predict eclipses by using the relative positions of the Moon and Sun. The later Song Dynasty scientist Shen Kuo (1031–1095 BC) used earlier models of lunar and solar eclipses to prove that the celestial bodies were round, not flat.

The first references to Indian astronomy are to be found in the Rig Veda, which is dated around 2000 BC. The Rig Veda is the oldest Hindu sacred text that outlines ancient writings about the Universe in verse form. One of India's most famous early astronomers is the 5th century mathematician and astronomer Aryabhatta, who used his astronomical observations with mathematical calculations to:

- describe a geocentric model of the Solar System, in which the Sun and Moon are each carried by epicycles which in turn revolve around the Earth.
- calculate the length of eclipses.
- calculate the circumference of the Earth.
- calculate the length of one rotation of the Earth on its axis.

CALENDARS

Ancient civilisations relied upon the apparent motion of celestial bodies – the Sun, Moon, planets, and stars – through the sky to determine seasons, months, and years. For example, the knowledge of changing seasons would have been crucial for survival as people decided when to travel, when to plant crops and when to hunt.

In every culture, people measured and recorded the passage of time. Ice Age hunters in Europe over 20,000 years ago scratched lines and gouged holes in sticks and bones, possibly counting the days between phases of the Moon. Most civilisations created calendars from changes they observed in the Moon's orbit. Since the first calendars, there have always been seven days in a week, to match the quarter cycles of the Moon, and always twelve months in a year, to match the twelve complete cycles of the Moon per year.

Five thousand years ago, Sumerians in the Tigris-Euphrates Valley (now Iraq) had a calendar that divided the year into 30-day months, the day into 12 periods, and these periods into 30 parts. Stonehenge's alignments show that its purposes apparently included the determination of seasonal or celestial events, such as solstices.

The Egyptians were one of the first civilisations to create an accurate calendar. Unlike most cultures, their calendar was based upon the Sun and stars rather than the Moon. With a calendar, they were able to make accurate estimates of when to plant crops, and when the Nile's annual flooding would occur, bringing soil that became the farmland for the next agricultural season.

Ancient Native Americans lined up circles of stones with the Sun and stars to chart the rising Sun and the beginning of summer. In southern Mexico, the Mayans built special buildings to watch the Moon and the planet Venus. By 800 AD they had a calendar that was more accurate than the calendar being used in Europe at the same time.

NAVIGATION

Beginning more than 2000 years ago, ancient Polynesians navigated their canoes across the vast Pacific Ocean using the stars and other signs from the ocean and sky. They used the passage of the Sun during the day, but kept very careful records of stars in order to guide them during the night. By memorising their positions, brightness, colours, and the time of year when stars were visible, sailors could navigate at any time during the year.

Similarly, people travelling across large land tracts with few landmarks, such as the deserts of Northern Africa and the Middle East, relied on their knowledge of changing star patterns to navigate as they travelled during the cooler hours.

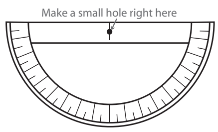
Teaching ACTIVITIES

ALL YEARS

ASTRONOMY – A MULTICULTURAL SCIENCE

Divide your class into groups and ask each group to research the astronomical observations and calculations of a specific culture selected from a list that includes Indigenous North, Central and South Americans, Chinese, Indian, Arabic, Greek, Persian, British and other Europeans. Each group should focus on the evidence of Astronomy in its chosen culture, the methods the ancient people used for their observations and calculations, important astronomical discoveries, and the influence of Astronomy on their beliefs and daily lives. Each group could present its findings as a poster or PowerPoint presentation.

BUILDING A SEXTANT



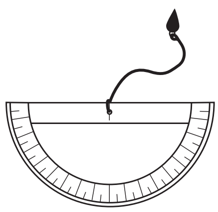


Figure A - The right way to tie the fishing line

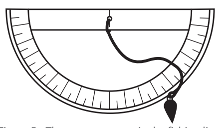


Figure B - The wrong way to tie the fishing line

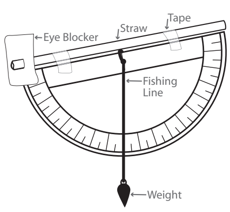


Figure C - Attaching the straw

1. **MAKE A SMALL HOLE IN THE CENTRE** of the straight edge of the protractor
2. **ATTACH THE WEIGHT** to the fishing line and then tie the fishing line to the protractor as in Figure A not as in Figure B.
3. **MAKE A HOLE IN THE CENTRE** of the cardboard so that the straw fits tightly.
4. **TAPE THE STRAW TO THE PROTRACTOR** (Figure C).
5. **PICK AN OBJECT** high on the ceiling or outdoors above ground level.
6. **SIGHT THIS OBJECT** through the straw.
7. **PRESS THE LINE AGAINST THE PROTRACTOR** when it stops swinging and read the scale (between 0 and 90 degrees) on the protractor. This is the angle of the object above ground.
8. **TAKE TWO MORE READINGS** of this object and average the results, making sure each student is at the same location. Have your students practise this procedure before taking the instrument home.
9. **BY NOTING CHANGES** in altitude over time, this sextant can be used to observe the apparent motion of the Moon, stars, and planets with respect to the Earth's rotation.

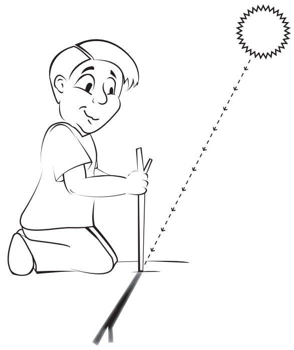
PRIMARY - MIDDLE SCHOOL

BUILDING A SEXTANT.

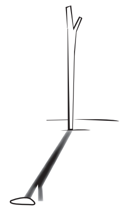
A sextant is an instrument generally used to measure the altitude of a celestial object above the horizon. To make a simple sextant, students will need a plastic protractor, a short length of lightweight fishing line or beading thread, a weight (such as a sinker), straw, small piece of cardboard and masking tape.

As a long-term project, students could map the position in the night sky of the Moon or a constellation, such as the Southern Cross, over a given period of time.

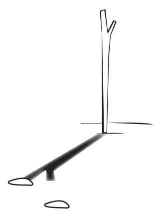
FINDING NORTH USING THE SUN



1. **PLACE A STICK UPRIGHT IN THE GROUND** so that you can see its shadow. Alternatively, you can use the shadow of a fixed object. Nearly any object will work, but the taller the object is, the easier it will be to see the movement of its shadow, and the narrower the tip of the object is, the more accurate the reading will be. Make sure the shadow is cast on a level, brush-free spot.



2. **MARK THE TIP OF THE SHADOW** with a small object, such as a pebble, or a distinct scratch in the ground. Try to make the mark as small as possible so as to pinpoint the shadow's tip, but make sure you can identify the mark later.



3. **WAIT 10-15 MINUTES.** The shadow tip will move mostly from west to east in a curved line.
4. **MARK THE NEW POSITION OF THE SHADOW'S TIP** with another small object or scratch. It will likely move only a short distance.

5. **DRAW A STRAIGHT LINE** in the ground between the two marks. This is an approximate east-west line.
6. **STAND** with the first mark (west) on your left, and the other (east) on your right. **YOU ARE NOW FACING MOSTLY TOWARD TRUE NORTH,** regardless of where you are in the world.

UPPER SECONDARY

MODELING ANCIENT ASTRONOMY

Ask your students to duplicate some of the work of the ancient astronomers. This would require them to carry out research and then construct appropriate models. Some questions could be:

- How did they predict eclipses?
- How did they determine the length of the year?
- How did they use shadows to determine the circumference of the Earth?

IMAGINING TIME AND MEASURING DISTANCE

Astronomy is all about looking up to the skies and time travelling to the past, since it takes time for electromagnetic radiation such as light and radio waves to reach the Earth or telescopes orbiting the Earth. As our telescopes improve and detect weaker and weaker signals from radiation sources, astronomers are looking further and further into the past. The radiation detected from any celestial object tells astronomers about conditions that existed when the radiation was emitted. Consequently, very distant objects are giving information about conditions that existed long before our galaxy was formed.

THE SCIENCE

TIME

From the dawn of civilisation to the twentieth century, people have measured time based on the same unchanging principle: the interval of passing time is referred to as some form of motion. Over the ages all that has changed is the kind of motion that is used to measure time.

Astronomy used the movement of the Earth about its axis (the day) and the motion about the Sun (the year) to mark time. Whilst earlier methods, such as using seasonal time intervals measured by plant and animal reproductive cycles, varied in accuracy, time keeping became more sophisticated and accurate with the invention of mechanical clocks.

By the mid-twentieth century, time was being kept using atomic clocks with the movement of electrons between the nucleus of an atom and the surrounding electron orbits as their timekeeping element. They do not use radioactivity but rather the precise microwave signal that electrons in atoms emit when they resonate between energy levels. Atomic clocks are the most accurate time and frequency standards known.

In addition, millisecond pulsars have been described as 'nature's most stable clocks' because they emit highly stable and regular pulses of energy. Pulsar timing measurements made at the Parkes, NSW radio telescope are linked to atomic time scales, and test our understanding not only of these exotic objects but also of fundamental physics, including general relativity and gravity.

DISTANCE

The Universe is so vast that measures of distance used here on Earth, such as centimetres, metres and kilometres, become irrelevant. The most commonly used measure of distance in Space is the *light-year*. A light-year is the distance that light travels in a vacuum (a theoretical volume of space that is empty of matter) in 365.25 days (one year), which is equal to exactly 9,460,730,472,580.8 km. The speed at which light travels to cover this distance is 2.99792458×10^8 metres per second (m/s).

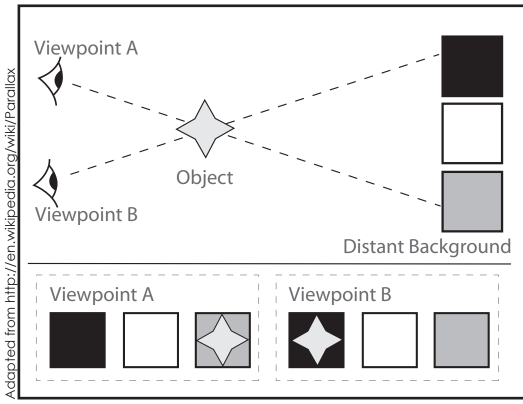
The light-year is useful for describing very large distances in Space. For example, it is easier to say it is 4.4 light-years to our nearest star, Alpha Centauri than 41,626,904,000,000 km. We can also say that:

- The Crab Nebula supernova remnant is about 4,000 light-years from Earth.
- The Milky Way Galaxy is about 150,000 light-years across.
- The Andromeda Galaxy is 2.3 million light-years from Earth.

The next most commonly used measure of distance is the *astronomical unit* (AU), which is the mean distance between the Earth and the Sun, and is equal to 149,597,870,000 km. It is useful for measuring and comparing distances between planets. Mercury can be said to be about 1/3 of an AU from the Sun, and Pluto (a dwarf planet) averages about 40 AU from the Sun. The AU, however, is not sufficiently large a unit to describe distances to objects outside our Solar System.

For distances to other parts of the Milky Way Galaxy (or even further), astronomers use units of the light-year or the *parsec*. The parsec is equal to 3.3 light-years.

One effective method for determining distances for objects close to us (i.e. within the Solar System and a few close stars) is trigonometric *parallax*. Parallax is the apparent movement of a star with respect to a background of more distant stars when it is viewed from two different locations (e.g. when the Earth is at opposite ends of its orbit). To understand this idea, hold your pen out in front of you, close one eye, and line it up with a background object. Without moving the pen, change your viewing eye. You will notice that the pen appears to change its location. The parallax (apparent movement) of an object is related to its distance from the Earth, so using trigonometric principles we can work out how far away it is.



When viewed from Viewpoint A, the object appears to be in front of the grey square. When the viewpoint is changed to 'Viewpoint B, the object appears to have moved to be in front of the black square.

For stars too far away to use the parallax method, *Cepheid* variables, stars that have a regular change in their brightness, can be used. How quickly they pulse is directly related to their luminosity, which is directly related to their distance from Earth. We have been able to accurately determine the distance of Cepheids, which allows us to use them as distance indicators. Cepheid variables can measure distances as far away as 20 million light-years. Beyond this there are a variety of other celestial objects that act as distance indicators including planetary nebula, most luminous supergiants, most luminous globular clusters, most luminous hydrogen regions and supernovae, as well as red shifts. (see page 42).

TIME AND DISTANCE

Since the light from a celestial object can take millions of years to reach Earth, we are observing the object as it was back in time. When we are describing distance in light-years, we are also describing the time, in Earth years, that it has taken for radiation from the object to reach Earth. Studying stars of varying distances from Earth essentially allows us to travel back in time and study the history of the Universe because the further away the radiation source is, the older the radiation that we see and the further back in history we go.

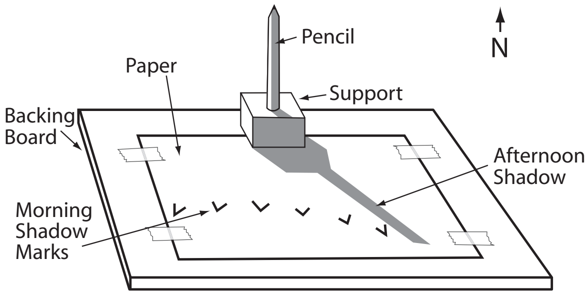
Teaching ACTIVITIES

LOWER PRIMARY

MAKE A GNOMON

The gnomon was one of the first astronomical instruments. The Egyptians built decorated obelisks of gnomons to keep time. These were upright shafts of stone surrounded by the hours of the day written on horizontal surfaces. The hours were read like reading a sundial, noting the position of the shadow like the hour hand of a watch across a face marked in hourly increments.

For each group, you will need: a backing board, paper, tape, piece of Blu Tack and pencil. Assemble the apparatus as shown in the diagram below.



For a simpler set-up: use a paper plate with a pencil stuck through its centre into grass.

Align the top edge of the backing board to sit East/West at right angles to North/South. This will require using a compass. Draw N, S, E and W on the board and be careful to ensure that the board is not moved during the measurement period. Leave the apparatus set up outside on a sunny day, preferably starting in the morning. Ask students to outline the tip of the pencil's shadow at regular intervals throughout the day. Students may need help to understand that the shadow moves because the sun's position in the sky is changing. **NB** Make sure that students are told that they must on no account look directly at the sun.

PRIMARY

MAKE A GNOMON. (SEE ACTIVITY FOR LOWER PRIMARY)

Unfortunately, the gnomon system of timekeeping was complicated by the fact that the same marks could not be used to measure the same hours of the day throughout the year. By setting up the investigation over a longer period of time, students can be led into a discussion about why this might be and also discuss weather issues impacting on using sundials.

Perhaps show the video at *http://videos.howstuffworks.com/hsw/8225-investigating-astronomy-measuring-time-video.htm* to expand students' knowledge of the history of time measurement.

MEASURING TIME – A WATER CLOCK

http://www.planet-science.com/sciteach/index.html?page=/experiment/ has a 34-page pdf file for download called *New Experiments – Part 2*. Pages 34-35 of the file have a detailed description of the materials and steps needed to make a water clock. The double-page spread also includes some historical information about water clocks.

LIGHT AND SHADOWS

Astronomy is a good context in which to teach the properties of light. *http://www.standards.dfes.gov.uk/schemes2/science/sci3f/sci3fq1?view=get* has a detailed set of lesson plans set at Year 3 level that will take about 12 hours to teach. Worth a visit if you are interested in integrating this science into a full suite of lessons.

http://www.eyeonthesky.org/lessonplans/04sun_shadows.html also has a well-designed lesson plan on using shadows to show changes in the position of the Sun over time. This lesson sequence could be used to illustrate the importance of these observations for ancient people who needed to know when to expect changes in the seasons.

LOOKING BACK IN TIME – THE TELESCOPE AS A TIME MACHINE

http://school.discoveryeducation.com/schooladventures/universe/itsawesome/lightyears/index.html is an interactive site that introduces the concept of light-years and provides images of celestial objects and their distances from Earth in light-years.

http://school.discoveryeducation.com/schooladventures/universe/itsawesome/mindgame/index.html The opening page states: "Imagine that you could hop aboard a spaceship that travelled at the speed of light. Well, you'll have to imagine it, because it's impossible – but that's what imagination is for! So all aboard the Seeker 2000, bound for the outer edges of the Universe. You can help by figuring out how far you'll go and how long it will take to reach different places. Like all astronomers, you'll need sharp maths skills to determine distances in space, so grab a calculator and let's go."

MIDDLE SCHOOL

MEASURING THE UNIVERSE

http://www.youtube.com/watch?v=wg1fs6vp9Ok *Measuring the Universe Part 1* is a nine-minute video about introducing the Universe and the measurements that would need to be made to determine its size. Whilst it goes beyond simply the contents of this section, it would be a useful resource to stimulate discussion about what astronomers currently do and do not know and how they draw conclusions from their observations.

DISTANCE TO THE MOON

http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Distance_Moon.html has links to a six-page downloadable pdf with an easy activity for students with a calculator. Students are required to select suitable scale models of the Earth and Moon and use these to calculate the distance apart that these models would need to be to represent the distance between the Earth and the Moon. The activity is well described, with background information and guide questions to assist students.

UPPER SECONDARY

USING PARALLAX TO MEASURE THE DISTANCE TO A STAR

http://www.sciencebuddies.org/science-fair-projects/project_ideas/Astro_p019.shtml If your school has a telescope, perhaps you could arrange two viewing nights, some nights apart, to collect measurements for the activity on this page. The goal of the project is to measure the distance to some distant small objects using motion parallax. In the list of resources required is a football field!

Getting Started in Astronomy

It is very easy to get caught up in the wonders of modern Astronomy and miss the fundamental questions that students will still ask about the world they can see. A good place to start in Astronomy is to consider how the relationships between the Sun and the Earth affect daylight hours. Why do we experience day and night? Where does the Moon go? Why does its shape seem to change? Where do the stars go in daytime? These concepts require fundamental understandings about light sources, light reflectors and the way in which materials block light to create shadows.

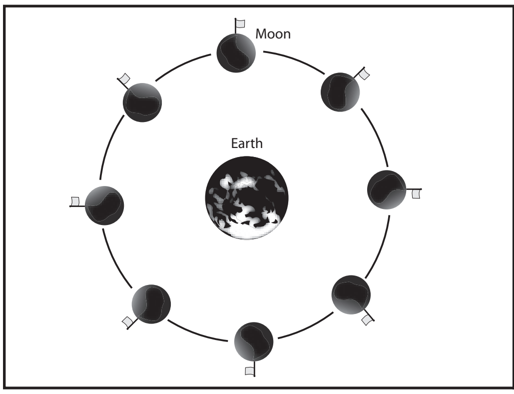
THE SCIENCE

The Earth Spins on Its Axis

The Earth spins counter-clockwise as seen from above with North being up. The word 'day' is used to describe the time (24 hours) in which Earth completes one full rotation. The part of the Earth that is facing the Sun is in daylight whilst it is the Earth's own shadow that makes the night side of the Earth dark. Spinning about an axis is known as rotation.

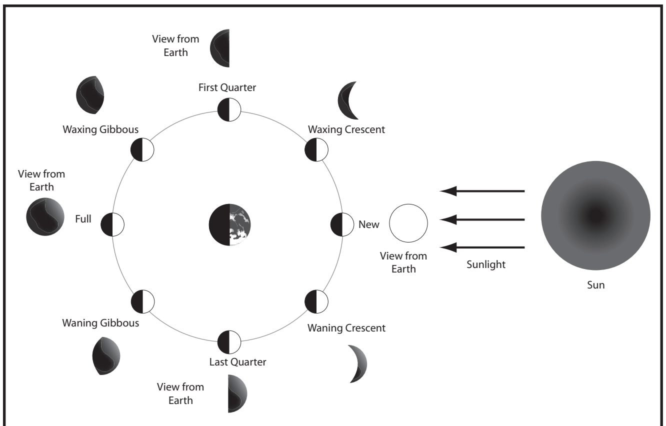
The Moon Orbits the Earth

The Moon orbits the Earth and also spins on its axis. The rate of each of these motions is the same, so the same surface of the Moon faces Earth all the time. Orbiting is known as revolution, so the Moon is revolving AND rotating.



The flag on the Moon images shows how one full rotation occurs as the Moon revolves around the Earth.

The Moon can be seen from Earth because sunlight hits the surface of the Moon and is reflected back into Space, including to Earth. The position of the Moon with respect to the Sun and the Earth changes during the Moon's orbit of the Earth. As a result, the amount of the Moon's surface in shadow changes, giving rise to the phases of the Moon as seen from Earth.

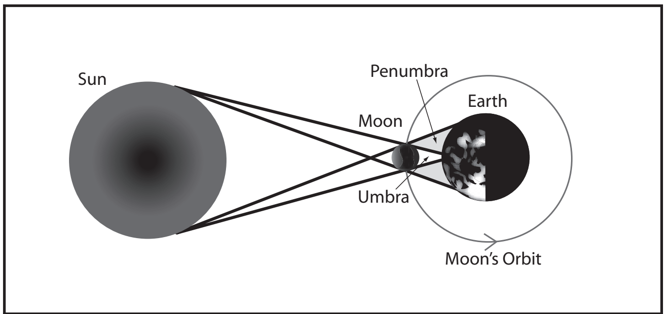


The same amount of the Moon is illuminated by the Sun at all times – see inner circle. The phases of the Moon depend on how much of the Moon's illuminated surface can be seen from Earth during the Moon's orbit – see outer images.

Eclipses

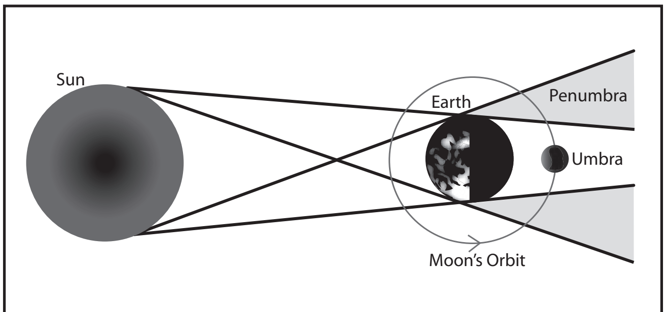
Eclipses are shadows caused by the relative positions of the Sun, Earth and Moon during their orbits.

An eclipse of the Sun (solar eclipse) can only occur when the Moon passes between the Earth and the Sun. The Moon's shadow usually misses Earth as it passes above or below our planet but at least twice a year, the Sun, Moon and Earth line up so that some part of the Moon's shadow falls on the Earth's surface. If the Moon's shadow does happen to fall upon Earth's surface, a portion of the Sun's disc appears covered or 'eclipsed' by the Moon. When this happens, an eclipse of the Sun is seen from that region.



A solar eclipse happens when the position of the Moon causes a shadow on Earth. Note that this drawing is not to scale.

An eclipse of the Moon (lunar eclipse) only occurs if the Moon passes through some portion of the Earth's shadow. The outer or penumbral shadow occurs where the Earth blocks some of the Sun's rays from reaching the Moon. In contrast, the inner or umbral shadow is a region where the Earth blocks all sunlight from reaching the Moon.



A lunar eclipse happens when the Moon moves into the Earth's shadow. Note that this drawing is not to scale.

Where are the stars?

During a total eclipse of the Sun, the sky goes black and stars can be seen. We cannot see them during normal daylight, as the light from the Sun is too bright and our eyes cannot detect the fainter light of the stars. Similarly, in areas of high light pollution, our eyes do not detect the light from distant and fainter stars. In dark areas, away from city lights, the number of stars visible at night increases dramatically.

Teaching
ACTIVITIES

LOWER PRIMARY - MIDDLE SCHOOL

http://hea-www.harvard.edu/ECT/ has developed a series of inquiry-based investigations in an Astronomy context. The topics include examination of astronomical features such as the Sun's path in the sky, Sun's height in the sky, Sun-Earth motions, length of day, degrees, the nature of light, and time zones in relation to the Sun's motion. Each activity is graded for K-2, 2-4, 4-6 and contains outlines of the activities and the pedagogy behind them. The whole resource is available as large downloadable pdf files.

LOWER PRIMARY

PLAYING WITH SHADOWS

http://www.planet-science.com/outthere/index.html?page=/outthere/primary/night_day.html has a very simple exercise to demonstrate the shadow effect using a torch. Then use the first sunny day to get your students out into the playground to try the following activities:

1. Escape their shadow by separating it from their body.
2. Cover their shadow.
3. Make their shadow disappear.
4. Ask each student to stand in one spot and have a friend use chalk to outline his or her shadow, including the feet. Make sure each shadow is labelled. About an hour later, go out and ask each student to have his or her shadow redrawn while standing in the same footprints. It will have moved! Some hours later, the shadow will be pointing in a completely different direction. Why?
5. Use these observations to help your students identify the relationship between the Sun, object and shadow. If the shadow has moved, what does this tell them about the position of the Sun in the sky?
6. You can extend this activity by drawing an outline of the horizon and plotting the position of the Sun over a day. **WARNING**. Do not let your students look directly at the Sun.

BRING THE NIGHT SKY INDOORS.

Read nursery rhymes, poems, and other stories that talk about the stars and the Moon. By the way, why did the cow jump over the Moon?

http://www.planet-science.com/under11s/index.html Nursery rhymes with a science twist pdf files to download. This is a 12-page coloured booklet with some interesting science versions of the old favourites.

http://www.virtualmuseum.ca/Exhibitions/Cosmos/english/html/skystories.html has many stories from Indigenous Australia about the Moon and constellations in the night sky.

SUNLIGHT IS STRONGER THAN STARLIGHT

To demonstrate the effect of the Sun's light on other stars in the sky, invest in a packet of 'glow in the dark' stars. Before your students enter the room, put the stars on the ceiling (or a backing board). With the lights switched on, they won't notice the stars. At some time during proceedings, with shades pulled, switch the lights off and ask them to take note of what they see. Do the stars stop glowing when the lights are switched back on?

PHASES OF THE MOON #1

You will need enough paper plates to give one to each of your students. Set up a large chart that has 28 boxes (4 rows of 7 days (Monday – Sunday)).

Each afternoon, give one of your students a plate and ask him/her to look at the Moon and draw its shape that night. Each day, put a drawing of the agreed shape of the Moon on the previous night into the appropriate box. Over the course of the month, your class will map the phases of the Moon. Use this exercise as part of a unit dealing with light and dark.

PRIMARY

EXPLAINING DAY AND NIGHT

For older children, this is an opportunity to introduce language terms such as transparent, translucent and opaque and how they relate to light energy. http://www.eyeonthesky.org/lessonplans/05sun_daynight.html has a detailed lesson for two 30-minute lessons over two days that will demonstrate to students how and why day and night occur.

PHASES OF THE MOON #2
Modelling the Phases of the Moon

http://www.newtonsapple.tv/TeacherGuide.php?id=1671 has a great hands-on exercise for students to model the phases of the Moon. Have students watch the animations first at *Views from the Southern Hemisphere*, an excellent site from New Zealand that uses Shockwave visualisations to show the motion of the Moon and Sun and lunar phases. The site can also be downloaded and run offline. http://www.tki.org.nz/r/science/day_night/index_e.php

Follow up the video with a practical whole class experience. The class, sitting on the floor in a tight(ish) group, represents the Earth. One student carrying a soccer ball and moving around the perimeter of the group represents the Moon. The Sun is simulated by a large light source over the heads of the sitting students. As the Moon orbits the Earth, the earthlings will observe a representation of the lunar phases, and see clearly that they are not caused by the Earth's shadow.

MIDDLE SCHOOL

A STUDY OF THE MOON

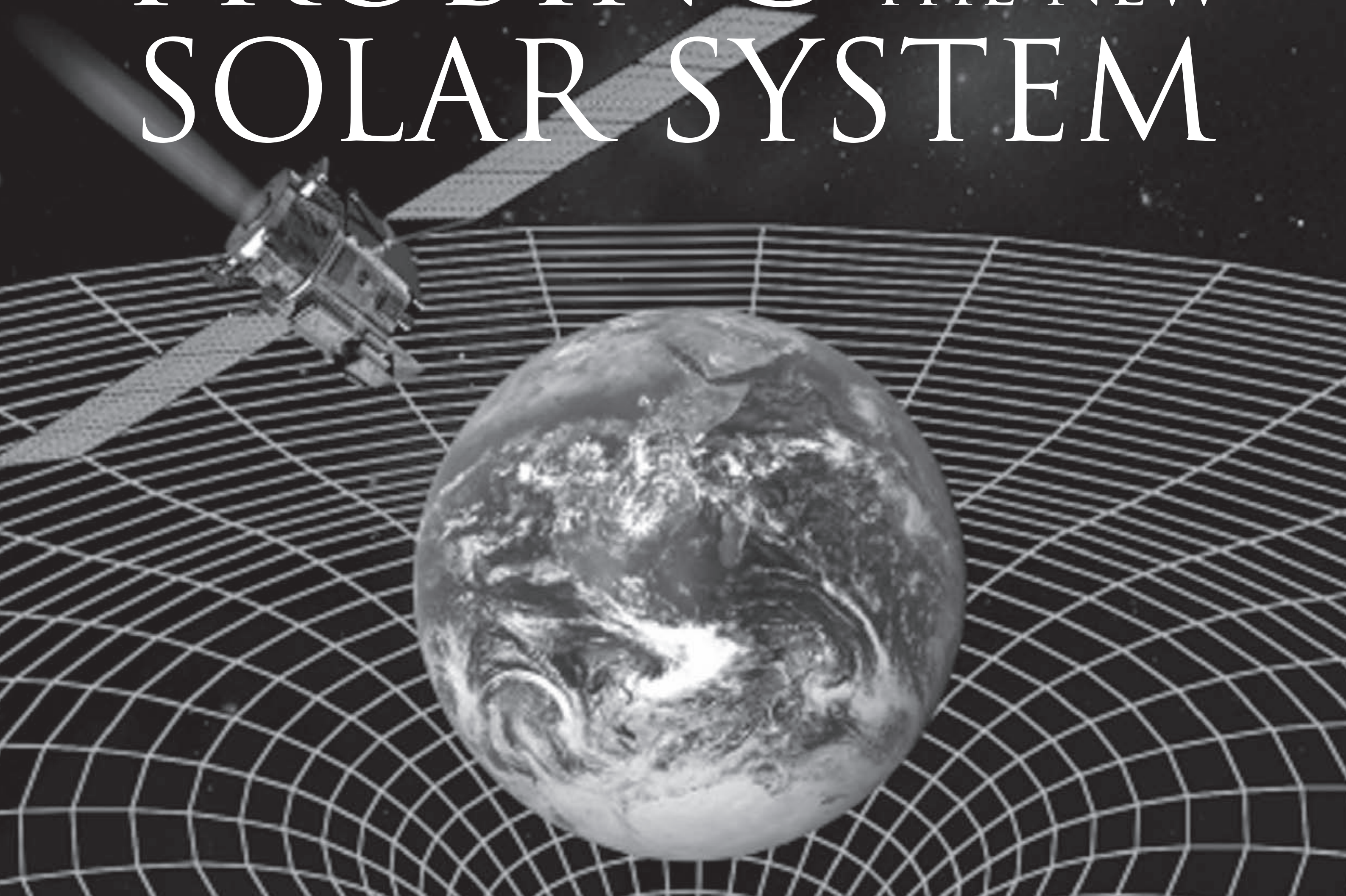
If your students have access to digital cameras and tripods, perhaps they could be given the task of photographing the Moon with a view to identifying its visible features. If this is not realistic, http://www.spacegrant.hawaii.edu/class_acts/LunarLandformsTe.html has an exercise with downloadable Moon images. This activity includes identification of impact craters and can lead to a discussion about the origins of these craters, and the reasons why they are still intact.

MODELLING A SOLAR ECLIPSE

http://www.newtonsapple.tv/video.php?id=920 has a short video clip that models the combination of events that cause a solar eclipse. Follow this clip with http://solar-center.stanford.edu/eclipse/model.html It has some simple activities that can be used to model solar and lunar eclipses in the classroom. Equipment needed includes a standard lamp, Styrofoam balls and hula-hoops.

INTRODUCTORY STARGAZING

http://www.astronomyinyourhands.com/activities/activities.html *Starry Starry Night* is a detailed work program that has been developed to help teachers with no scientific background to teach a course in introductory stargazing during the day, even though no stars are visible. A 'Stars as Compass' kit is needed – subscriber only, but you can obtain a star kit for your specific area at a very reasonable cost (US$10 for a school of less than 500 students).



CHAPTER TWO
The Astronomers' Toolkit

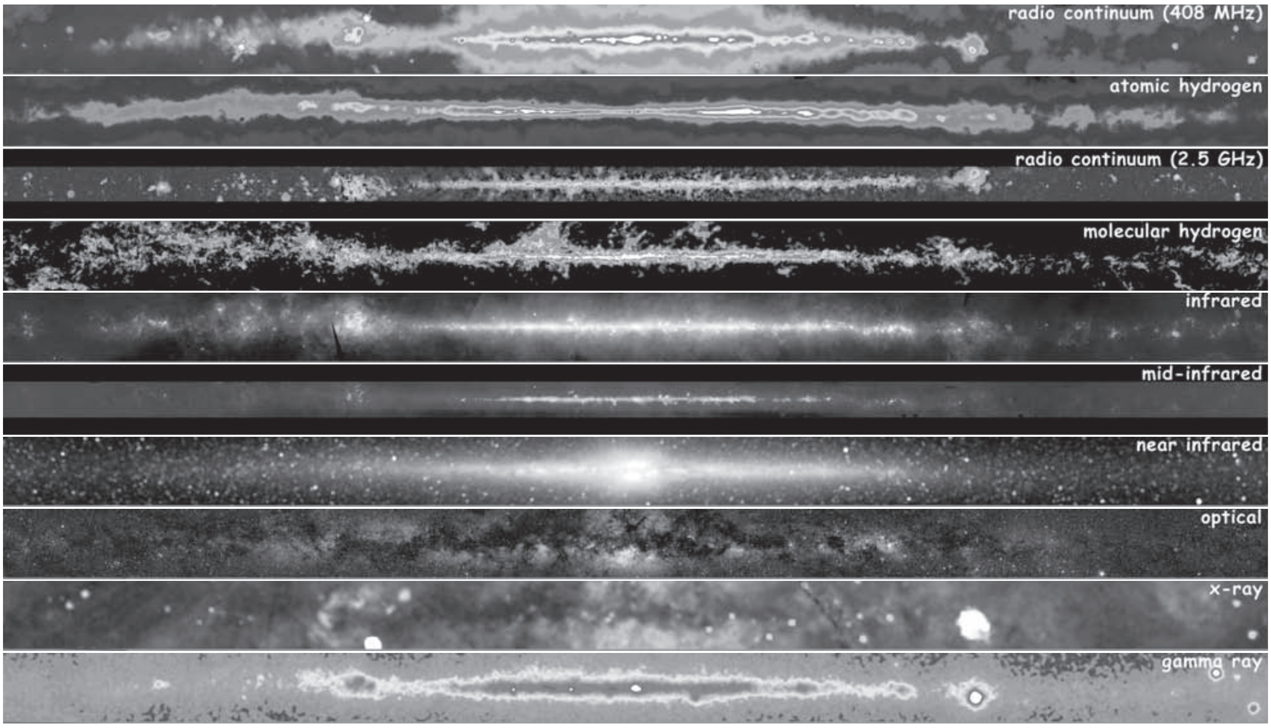
Horsehead Nebula
Image: Anglo-Australian Observatory/David Malin Images

Our knowledge about the Universe is a 'shared legacy' of humankind that has been gathering since humans first walked the Earth. This legacy of knowledge about the Universe has expanded as technology has increased in sophistication – sharing the technology has facilitated the growth of knowledge but has also multiplied the number of unanswered questions about the Universe.

In 1609, Galileo improved the newly invented telescope, turned it toward the heavens, and revolutionized our view of the Universe. However, the 20th and 21st centuries saw the introduction of new technologies that opened the skies further for astronomers. Until the 1950s, the only image that existed of the Milky Way was the one labelled 'optical' in the chart below.

As astronomers discovered how many other radiations were reaching Earth and its atmosphere, they worked with engineers, computer technicians and software developers to produce technologies capable of capturing and analysing this information.

Nowadays, the astronomer peering through a telescope throughout the dark hours of the night is now likely to be an amateur as it is very rare for a modern professional astronomer to use an eyepiece on a larger telescope. The telescope is more likely to controlled by, and sending information to, a computer. The modern astronomers' palette is still the electromagnetic spectrum and their tools are still telescopes, with additional technologies such as cameras and computers that can produce images of the patterns produced by radiation as it is captured.



Multiwavelength Milky Way. See this wonderful set of images in colour at http://mwmw.gsfc.nasa.gov/mwpics/mwmw_8x10.jpg

Electromagnetic Radiation - The Astronomers' Palette

Astronomers are scientists who collect and analyse energy from the Universe. The invention of photography enabled records to be kept of light energy from Space. In the 20th and 21st centuries, computers have been able to produce similar images of all types of energy emissions. The name 'electromagnetic spectrum' is used to describe the range of energy emissions captured by modern technology and analysed by astronomers as they search for the secrets of the Universe.

THE SCIENCE

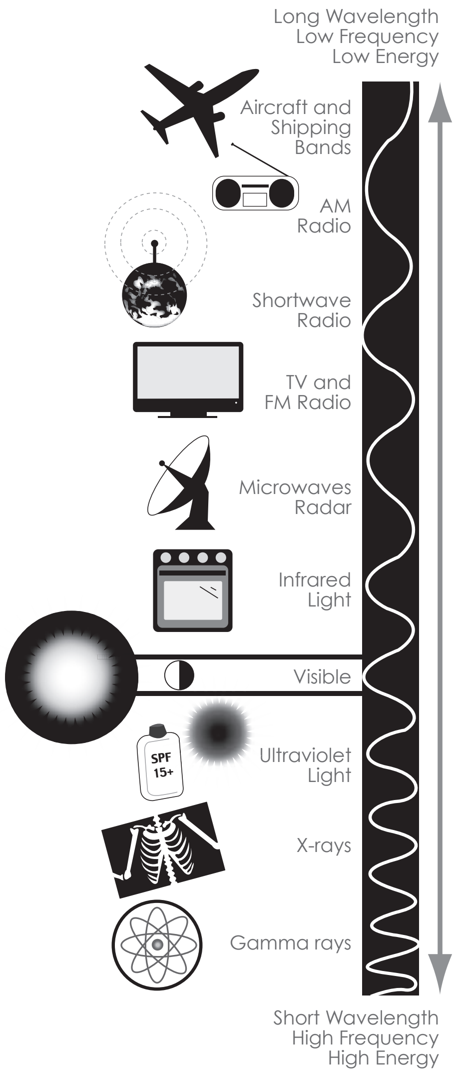


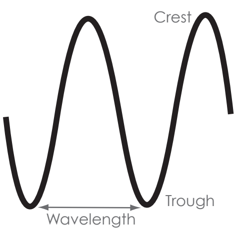
Diagram adapted from http://imagine.gsfc.nasa.gov/docs/teachers/lessons/roygbiv/spectrum.html

Electromagnetic Radiation (EMR) - photons and waves

EMR travels as waves. These waves have **wavelength** (λ) and a **frequency** (*f or v*)
The energy of EMR is carried by **photons**.

Wave length
- Distance crest to crest
- Or trough to trough
- Expressed in **distance** (e.g nm)

Frequency
- No. of waves that pass a point in a unit of time (e.g 1 sec.)



Many objects in Space emit energy in the form of electromagnetic radiation (EMR). Scientists who study Space can detect this energy using different sensors. An example is an optical telescope that detects visible light, which is a form of EMR. Scientists have found that the energy carried by EMR exists in tiny bundles called *photons*. The different forms of EMR, e.g. microwaves, infrared, and light, have photons of different energy depending on how they were produced.

Hotter, more energetic objects and events release higher energy radiation than cool objects. Only extremely hot objects or particles moving at very high speeds can create high-energy radiation such as X-rays and gamma rays.

The *electromagnetic spectrum* is the name given to types of radiant energy which all travel at the same speed but have different frequencies. As the diagram to the left shows, we can generate and use all forms of EMR on Earth.

EMR also travels through Space. Stars, galaxies and gas clouds in Space emit visible light as well as radio waves, gamma rays, X-rays, and infrared radiation so the Earth is constantly bombarded with EMR from the Sun and other distant objects.

Astronomers have always collected the light from celestial objects. The technology of telescopes has allowed them to collect photons and study the light emitted. During the 20th century, when astronomers detected other forms of radiation coming to Earth from outer Space, they worked with engineers to develop technology to capture and study these as well. They also worked to collect more photons. The development of more sophisticated computers and software has also allowed modern astronomers to analyse immense amounts of data in very short periods of time.

The Problem of the Atmosphere

EMR can be absorbed when it strikes matter, or matter can reflect it. As EMR passes from one medium (such as Space) into another medium (such as air), it may also be refracted (slowed down and bent). The Earth's atmosphere acts as a filter to remove radiation such as gamma rays, X-rays, UV rays, and large portions of the electromagnetic spectrum through the processes of reflection, absorption and scattering by gases, water vapour, and particulate matter (such as dust).

Scattering: This occurs when particles or large gas molecules present in the atmosphere interact with and cause the EMR to be deflected from its original path.

Reflection: Some radio waves are reflected from the ionosphere (70 – 400km above the Earth's surface) and light is reflected off clouds lower in the atmosphere.

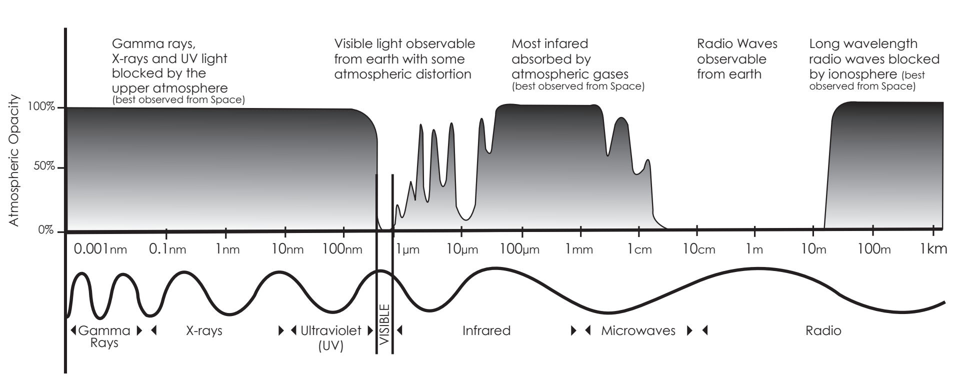
Absorption: Much infrared radiation does not reach ground level because of absorption in the upper atmosphere by water and some carbon dioxide and oxygen molecules that lie between the ground and an altitude of about 15km (the troposphere). Ozone and oxygen in the stratosphere (10 – 50km above the Earth's surface) absorb much of the ultraviolet radiation.

Astronomers are thus only left with 'windows' of EMR that they can collect and observe from Earth. This has led to the development of Space-based telescopes that can capture a complete picture of the EMR spectrum emitted by objects in Space.

Definitions

A **wave** is a disturbance that moves through space and time, usually transferring energy as it moves.

A **photon** is a 'packet' of electromagnetic energy that acts like a particle.



Atmospheric opacity is the measure of impenetrability of electromagnetic radiation through the atmosphere. One hundred per cent opacity means that none of that particular wavelength can get through the atmosphere to Earth. The white spaces indicate those wavelengths of EMR that are observable from Earth. Telescopes on Earth can also pick up wavelengths where there is less than 100% atmospheric opacity but Space-based telescopes will collect more data.

Teaching ACTIVITIES

Lower Primary

Temperature – Is it hot or cold?

http://www.eduref.org/cgi-bin/printlessons.cgi/Virtual/Lessons/Science/Process_Skills/SPS0034.html has an interesting exercise to carry out over a few days to demonstrate the difference between hot and cold air temperatures. The background to this exercise is that the air surrounding the Earth is warmed by the Sun. That is why the air is usually warmer during the day—when the Sun is shining—than at night. This exercise can be extended to measure seasonal differences in temperature.

Black vs Shiny – Which heats up best?

Infrared radiation is more readily absorbed by black objects. Take two empty metal cans of the same size and construction (e.g. cat food tins) and remove any paper labelling. Paint the outside of one tin with black paint and leave the other shiny. Lay them both on their sides in the sun and place a thermometer in each can. The thermometer in the black can will show greater increases in temperature. Use this demonstration to discuss suitable colours for clothing, cars and houses in hot climates.

Primary

Catching Solar Energy – demonstration

http://solarcooking.wikia.com/wiki/How_solar_cookers_work has photos of solar cookers used where electricity and gas are not generally available. Use the concave surface of a new wok, or that of an old wok covered with new aluminium foil, as a solar collector. You'll need to find the best point where most heat is being focused by using a thermometer. Is the heat at that point sufficient to heat a small glass of water or cook an egg?

Catching Solar Energy

http://files.asme.org/asmeorg/Education/PreCollege/2855.pdf has a differentiated challenge about using solar energy in which older primary students could engage. The challenge is described in sufficient detail to make it reasonably simple for students. Further information to assist teachers is also available in the four-page document.

Middle School

Why Is The Sky Blue?

You will need clear glass or plastic bottles, water, powdered milk and a torch.

1. Fill a clear bottle with water and shine a torch through the bottle.
2. Add the powdered milk a pinch at a time until you can clearly see the beam of light inside the bottle.
3. Look at the beam of light passing out of the bottle. You should notice that the beam is made up of mostly yellow and orange light.
4. Now view the light beam from the side (perpendicular to the light beam). You should see a blue/white colour in the bottle. What is happening? When the visible light spectrum passes through a medium such as air, glass or water, each colour is bent, separated and scattered by different amounts. Blue and violet light are scattered the most, while red and orange light are scattered the least. The Earth's atmosphere contains particles of water vapour, dust and various gases. The blue and purple light is scattered within the atmosphere, causing the sky to appear blue. At sunrise and sunset, sunlight passes through more of the atmosphere. The blue and purple light is scattered so much that it bends away from you. The yellow and red light now scatters within the atmosphere and the sky appears orange.

The Herschel Infrared Experiment

In the year 1800, Sir William Herschel discovered the existence of infrared radiation by passing sunlight through a prism, which divided the light into a spectrum. Herschel was interested in measuring the amount of heat in each colour. In doing so, he found a 'colour' beyond the visible spectrum. His experiment is easily reproduced. For full details, go to http://coolcosmos.ipac.caltech.edu/cosmic_classroom/classroom_activities/ If you can obtain some blueprint paper, you could also reproduce the similar Ritter experiment that discovered ultraviolet radiation in 1801.

Middle School – Upper Secondary

Solar Cookers

Ask your students to design and build a solar energy cooker as a Science Week project with materials such as aluminium foil and cardboard boxes. If you have thermometers available, the students may be able to judge their cooker in terms of the increases in temperature achieved. Some basic information about solar cookers is available at http://solarcookers.org/basics/how.html Alternatively, instruction sheets are available at http://www.solarschools.net/resources/pdf/Solar%20Cooker.pdf

Lessons on Infrared

http://coolcosmos.ipac.caltech.edu/sitemap.html#cosmicclassroom has a number of lessons on the infrared region of the electromagnetic spectrum.

Atmosphere Model

http://mjksciteachingideas.com/pdf/AtmosphereFoldable.pdf has a three-page pdf with instructions on producing a model of the atmosphere and its layers. This may assist students in visualising the upper layers and relating these to the effects on incoming EMR.

Optical Telescopes

An optical telescope is used to observe light in the visible part of the electromagnetic spectrum at a magnified level. Optical astronomy is useful for studying any object that emits visible light, such as a star or a galaxy.

THE SCIENCE

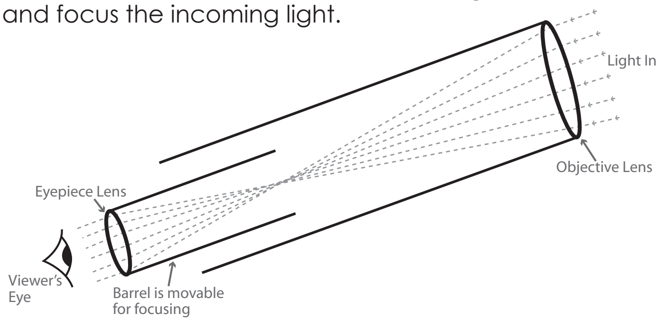
Structure

Components of an optical telescope include; the telescope (to gather the light), detectors (to record information from the light), and computers (to control telescopes and detectors).

Types of Optical Telescopes

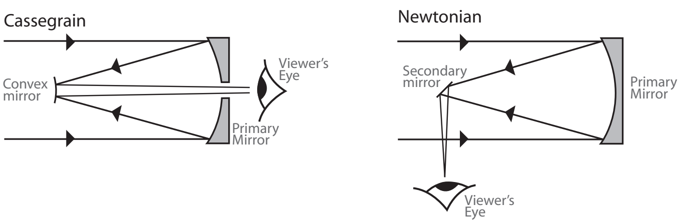
There are two main types of optical telescope: refracting and reflecting. The main difference between the two is the way in which they gather light.

The **refracting telescope** was invented in 1608 in the Netherlands by Lippershey and Janssen, spectacle-makers in Middelburg, and Metius of Alkmaar. These telescopes use lenses to gather and focus the incoming light.



The path of light through a refracting telescope. Modern refracting telescopes include technologies that improve on this fundamental design

Isaac Newton is generally credited with constructing the first practical **reflecting telescope**, the Newtonian telescope, in 1669. Reflecting telescopes use one or more curved mirrors to gather the incoming light and focus it back along a path called the focal plane.



The path of light through a reflecting telescope. These diagrams represent two of the many designs of reflecting telescopes.

http://www.stargazing.net/naa/scope2.htm#newt is an interactive site on which students can both see the components of, and trace the path of light through, refracting and reflecting telescopes.

The limits of Ground-Based Optical Telescopes

Because of the effects of air turbulence, looking through the Earth's atmosphere is like looking through a layer of water with ripples on its surface. Atmospheric gases also absorb specific wavelengths of light so that any light gathered may not represent all the wavelengths of the light spectrum emitted from an object. For example, the Sun appears white in space, not yellow as it appears on Earth.

All modern optical telescopes are reflecting telescopes for four reasons:

1. The size and resolution (image detail) of refracting telescopes is limited by the size, weight and quality of the lenses that can be manufactured. Because light is reflecting off the objective mirror, rather than passing through it, only one side of the reflector telescope's objective mirror needs to be perfect.
2. Since mirrors can be supported by a back surface, the primary mirror in a reflecting telescope can be very much larger, and thus collect more incoming light from distant objects and produce a higher resolution image.
3. The objective lens of a refracting telescope absorbs some light, so any study of the light spectrum of a distant object has to be adjusted for the effect of the glass lens.
4. The images from refracting telescopes may be distorted due to the fact that lenses bend light of different colours by different amounts. Reflector telescopes do not suffer from this chromatic aberration because all wavelengths of light reflect off the mirror in the same way.

Optical Astronomy In Australia

Australia's major optical telescope facility is the Siding Spring Observatory in NSW, which houses several telescopes. These include the 3.9m Anglo-Australian Telescope (AAT), which is very useful due to new instruments such as AAOmega, a multi-fibre spectrograph that allows it to obtain hundreds of spectra simultaneously from a two-degree field. Built in 1974, it has been used to study objects not easily visible from the northern hemisphere, such as the centre of the Milky Way and the neighbouring Magellanic Clouds.

The AAT is frequently used to produce spectrographs, which split the light from distant objects into its constituent colours. Spectrographs can provide information about temperature, chemical composition, velocity and distance of an object, which standard photographs cannot. The AAT is also able to detect light energy from the infrared spectrum, which allows objects too cool to emit visible light to be observed (e.g. dust clouds during early star formation).

Australia is also a partner in two major future telescope projects:

- The Giant Magellan Telescope is due for completion in 2018. It is being built at the existing Las Campanas Observatory near La Serena in Chile (South America) and has seven 8.4m mirrors arranged in a hexagonal pattern which combine to give the equivalent of a 24.5m mirror. It will have four times the light-gathering ability of existing telescopes and produce images up to 10 times sharper than the Hubble Space Telescope.
- The PILOT (Pathfinder for an International Large Optical Telescope) is a 2.4m optical/infrared telescope proposed to be built in Antarctica. The PILOT is still in its preliminary design phase.

Teaching ACTIVITIES

Lower Primary

Bubble Trouble

You will need:

- Liquid detergent,
- Small trays (such as flat takeaway food containers or ice cream containers) – one per group
- Drinking straws – at least one per student,
- Pipe cleaners or small lengths of wire to form loops with a handle,
- A warm, sunny day and an outdoor area to use.

1. Gently mix the detergent and water in each tray.
2. Ask the students to blow large bubbles.
3. Observe the bubbles in sunlight and discuss the colours that appear on their surface.
4. Have children record the colours observed in pictures.
5. Ask them to use the loops to gently blow and hold big bubbles; ask them to describe what they see if they look through the bubbles. (Even a small bubble in the loop will act as a magnifier.)

If you have access to a hose, in afternoon or early morning, when the sun is lower in the sky, have children use it with a sprinkler to create a rainbow. Use these activities to introduce the concepts of the different colours that make up sunlight.

Spectra without Water

The shiny side of a CD or CD-ROM scatters light, so you can use it to see spectra! Find a CD you no longer need and shine a torch light on to its surface. If you tilt the CD, you will see the full spectrum of colours.

Mirror Magic

You will need:

- 1 large flat mirror,
- some shiny soup spoons or dessert spoons, (one per student if possible). The back of the spoon forms a convex mirror; the front or bowl of the spoon forms a concave mirror. Light reflected off these surfaces will not form the same images as a flat (plane) mirror.

Ask your students to look at themselves in the back and front of the spoon and then compare how they look in a normal mirror.

Primary

Demonstrating Refraction

Light rays, which normally travel in a straight line, are bent (refracted) as they pass from one medium such as air into another medium such as water. You can demonstrate this effect in the following experiments, all of which, with further variations and explanations, are described at http://www.opticsforkids.org/ in the section for 'Future Scientists'. Well worth a visit.

Make Money Appear

You need an opaque bowl, Blu Tack, a coin and some water.

Use the Blu Tack to stick the coin to one side of the bottom of the bowl. Standing so that you cannot see the coin, gently pour the water into the bowl. The coin will appear. The light rays are bent differently in water than in air, so your eyes are now able to register them.

Bend a Pencil Without Breaking It

You need a transparent drinking glass/tumbler, water and a pencil. Fill the glass with water and place the pencil in the glass so it leans against the side of the glass. View from the side. Why does the pencil appear bent?

Upside-Down Images

You need a magnifying lens, a piece of white cardboard or paper for a screen, and a light source such as a classroom window. Set the white 'screen' up facing the window. Hold the magnifying lens between the screen and the window, moving it until an image appears on the screen. Ask your students to compare the image with the original light source. The image of the window on the screen should be inverted (upside down) and students can investigate the focusing of the image by gently moving the magnifying glass closer to and further away from the screen.

Optics for kids

http://www.opticsforkids.org/teachersparents/classroomactivities/ has several activities that demonstrate the effects of reflection and refraction. For example, a two-page downloadable pdf called 'Pinholes and Lenses' provides detailed instructions on how to use readily-available materials to simulate the effect of a lens by using a pinhole.

Middle School

Optics for kids

http://www.opticsforkids.org/teachersparents/classroomactivities/ has some excellent ideas for optics experiments without the need for a ray box and a set of glass lenses. For example, 'Optics Fun With Gelatin' is a two-page pdf with background information and instructions for a set of experiments using nothing more than gelatin and a light source to illustrate some basic optical principles.

Make a telescope

http://www.opticsforkids.org/futurescientists/intermediate/maketelescope.html has instructions for making a telescope from two lenses, a cardboard tube and sticky tape. If students are directed to this address, they may need some assistance with terms (such as 'focal length') used in the instructions.

Upper Secondary

Celebrate a 400th Anniversary

In 1609, Galileo Galilei first used a telescope to look at the night sky and made astounding discoveries that changed humans' understanding of our position in the Universe.

Ask your students to research the following:

1. What features of the night sky did Galileo discover?
2. How did Galileo's discoveries help overthrow the Ptolemaic (Geocentric) model of the universe and replace it with Copernicus' model?
3. Older students could find evidence to support the following statement made by Steven Hawking, "Galileo probably bears more of the responsibility for the birth of modern science than anybody else."
4. Students could replicate Galileo's telescope and see for themselves the difficulties that he would have encountered when using it.

http://outreach.atnf.csiro.au/education/senior/astrophysics/galileo.html and https://www.galileoscope.org/gs/content/galileos-classroom are good sites for students to commence an Internet search.

Radio Telescopes

Radio frequency (RF) radiation was first discovered on Earth in 1888, but it was not until more than 40 years later that scientists realised it came from astronomical objects deep in Space. Observing objects by means of their emitted RF allows a broader understanding of their structure, composition and motion.

THE SCIENCE

Radio frequency radiation

Radio waves have the most varied wavelengths in the electromagnetic spectrum, ranging from as little as a few millimetres to as long as hundreds of kilometres. However, the Earth's atmosphere acts as a barrier to most radio waves. Radio waves with a wavelength greater than 10m are absorbed as they enter the atmosphere; however, radio wavelengths between 1mm and 10m that are emitted by astronomical objects can be detected by radio telescopes here on Earth.

Radio telescopes

The first radio telescope to detect RF radiation was built in 1931 by Karl Jansky, an American radio engineer. The first dish-shaped telescope, built in 1937 by Grote Reber, became the prototype for modern telescopes.

All radio telescopes have two basic components; an *antenna* and *receiver*. The antenna is made out of a conducting metal that reflects radio waves to the central receiver. Most antennas are dish-shaped and movable so that they may be pointed at any point in the sky. Larger antennae are needed to detect the longer wavelengths. Telescopes operating at mm wavelengths are usually only a few tens of metres in diameter, while those operating at cm wavelengths can be more than 100m in diameter. The largest steerable dish is 101m whilst the largest radio telescope at Arecibo, Puerto Rico, is 300m wide and fixed in the ground.

If antennae have larger collecting areas, fainter signals can be detected. Furthermore, better *resolution* can be achieved, as the search for detail is the ultimate goal of radio astronomers. One way to increase the collecting area is to combine the signals being received simultaneously by two or more telescopes. This is known as *arraying* and relies on a process called *radio interferometry*.

The sources of signals detected by the collecting antennae can be numerous. However, when the direction of the radiation can be determined, it is said to originate from a discrete source.

Discrete sources are referred to as localised if they come from a single object (e.g. a star), and extended if they come from a relatively large part of the sky (e.g. a galaxy such as the Milky Way).

Radio astronomers must also deal with natural and artificial sources of radio frequency interference (RFI), which can include things such as the Sun, atmosphere, lightning, airborne radar, analogue and digital TV signals, mobile phones, mains electricity and computers. Radio observatories need to be located in *radio-quiet areas*. For this reason they are usually located away from major cities.

The receiver amplifies all signals so that they can be measured and recorded. Radio astronomers then rely on carefully programmed computers to sort the signals gathered by the antennae and separate out those signals originating from distant objects in outer Space.

Radio Emitters

Since the discovery of extra-terrestrial sources of radio waves, astronomers have identified other galaxies and thousands of stars (including our own Sun) that are emitting RF radiation. Strong emitters of RF radiation include pulsars (see page 39) and quasars (see page 36). Indeed, radio astronomy was used to confirm that quasars are the highly energetic centres of distant galaxies, rather than being nearby stars as previously believed.

As optical telescopes continue to improve in resolution, astronomers do not observe many 'normal' stars with radio telescopes. Whilst they can see objects billions of light years away with optical telescopes, astronomers cannot view the centre of our galaxy with them due to the absorption of light by dust and gas. Fortunately, RF radiation is detectable from such areas, and radio telescopes are excellent tools for exploring regions that are inaccessible with optical telescopes.

Radio astronomy is also used for observing any emissions from the gases in Space, including atomic hydrogen. As such it is able to map the distribution of gas in galaxies, which cannot be detected by any other means. *Cosmic Microwave Background Radiation* is also detectable through radio telescopes.

Definitions

Antenna is a metallic electrical device that receives radio signals.

Arraying is achieved by a set of telescopes, usually dentical, arranged in a pattern on the ground. This pattern allows high-resolution observations using a cost-effective cluster of comparatively small telescopes rather than a single very expensive and very large telescope.

Cosmic Microwave Background Radiation is a form of electromagnetic radiation that fills the Universe. Radio telescopes detect a faint background glow of radiation that is almost exactly the same in all directions and is not associated with any star, galaxy, or other object. Cosmologists believe that this radiation is left over from the Big Bang that formed the Universe.

Radio interferometry is the technique of using the pattern of interference created by the *superposition* of two or more waves to diagnose the properties of the waves.

Radio-quiet areas are locations far away from RF radiation-emitting devices such as radio, TV, and radar stations, as well as telephone transmitting towers.

Receiver is a device that converts radio waves into electrical signals for further analysis.

Resolution is the degree to which fine details on an image can be distinguished.

Superposition occurs whenever two (or more) waves travel through the same medium at the same time. The waves pass through each other without being disturbed, and the resultant wave is the combined effect of each wave on the medium. http://www.kettering.edu/~drussell/Demos/superposition/superposition.html has an animation that will assist in explaining this phenomenon.

Teaching ACTIVITIES

Middle School – Upper Secondary

Make a radio wave transmitter

Adapted from
http://electronics.howstuffworks.com/radio1.htm

Part (i) Students, working in small groups, will need:

- new 9-volt battery,
- metal coin,
- AM radio receiver.

Instructions to students

1. Tune the AM radio until you hear static. The radio is going to act as a receiver of radio waves.
2. Now hold the battery near the radio and quickly tap the two terminals of the battery with the coin so that you connect the terminals for an instant.
3. Describe what you hear.

Students should hear a crackle in the radio. Radio waves caused by a surge of electricity in the coin will be picked up by the radio.

This demonstration can be expanded to find out:

- how far the radio waves can travel, and
- what materials can be used to prevent the radio waves reaching the receiver. Try aluminium foil, paper, wood etc.

Additional investigation adapted from http://electronics.howstuffworks.com/radio2.htm

Part (ii) For this activity, students will need:

- new 9-volt battery,
- metal file such as a nail file (if it has a plastic handle make sure that the students connect the copper wire to the metal and not the plastic!),
- two short lengths of insulated copper wire, with insulation stripped off the ends,
- AM radio receiver.

Instructions to students

1. Connect the metal handle of the file to one terminal of the 9-volt battery using one piece of copper wire.
2. Connect the other piece of wire to the other terminal.
3. Tune the AM radio until you hear static. The radio is going to act as a receiver of radio waves.
4. Move the battery close to the radio.
5. Tap the free end of the wire up and down the file.

Students should hear much more static as the wire is moved up and down the file. If the room is darkened, they will be able to see very small 9-volt sparks running along the file as the end of the wire connects and disconnects with the file's ridges. This demonstration can also be expanded as in Part (i).

Images from radio astronomy

A radio telescope scans across an object and receives radio waves from each little spot in space around that object. The telescope sends the information to a very sensitive receiver, which amplifies the waves and converts them into a signal that can be stored in a computer. Astronomers use computers to turn this information into grid 'pictures' that they can investigate.

Each grid square stores information about the radio waves coming from a point in space. Some points may have stronger radio waves coming from them than others and the computer converts this information into numbers. For example, if radio waves are weak at a particular position, a small number will be recorded in the grid square. If no radio waves are coming from that spot, the computer would put a zero in that square, and so on.

http://www.nrao.edu/index.php/learn/radioastronomy/makeradioimage explains the above process further and has two data sheets for download. By assigning a colour to each number, students can make their own 'radio telescope picture'. If students have access to the Internet, they will be able to view examples of images from radio telescopes on the same site.

http://coolcosmos.ipac.caltech.edu/cosmic_classroom/multiwavelength_astronomy/multiwavelength_astronomy/gallery3.html is an excellent site to demonstrate the difference in information obtained when the Milky Way is 'photographed' for the different wavelengths of EMR emitted from this galaxy. (see image page 17)

Radio Telescopes in Australia

The table below summarises current and immediate-future radio telescopes in Australia but is incomplete. Copy this table for your students. If this is to be a short classroom project, the tasks could be divided and completed as a jigsaw activity. (If you are not sure how to organise a jigsaw activity, go to http://www.jigsaw.org/steps.htm)

Ask your students to:

1. Research and complete the information on each of the radio telescope systems listed in the table.
2. On a map of Australia, identify the location (or proposed location) of each telescope. Research the environment of each location and suggest reasons why each telescope was constructed there.
3. Consider the following scenario: A new radio telescope with a 100m dish antenna is proposed for Australia. What advice would you give to the Australian government on where to build this telescope? Justify your reasoning.

Telescope	Location	Operated Since	Operated By	Number & Size of Telescopes	Used For
Parkes Observatory	Parkes, NSW		CSIRO		Pulsar, galaxy and gravitational wave detection, Mapping of hydrogen gas in galaxies, space probe data transmission
Australia Telescope Compact Array				☐x 22m radio telescopes	Observation of star formation, remnants of supernovae, magnetic fields, black holes and hydrogen mapping
	Warrumbungle Mountains, NSW		ATNF	1 x 22m radio telescope	
Tidbinbilla Observatory		1965			
Australian Long Baseline Array	Parkes, Narrabri, Mopra, Tidbinbilla, Ceduna, Perth & Hobart		CSIRO	A network of various-sized radio telescopes	
Australian Square Kilometre Array Pathfinder		Due to be operational by ☐		36 x 12m radio telescopes	Detailed, large scale sky survey

The Astronomy GALAXY

HENRY CAVENDISH
(1731-1810)
In 1797 Cavendish, an English chemist and physicist first produced an accurate value for the gravitational constant (Newton's Law of Universal Gravitation) allowing him to determine the mass of the Earth (six billion trillion metric tonnes).

ISAAC NEWTON
(1643-1727)
Newton defined the three laws of motion and also developed calculus, using it to develop a Universal Law of Gravitation. These laws allowed him to predict precisely the motions of planets around the sun. He also used his discoveries in optics to develop an alternate design for a reflecting telescope in 1668.

GEORGE ELLERY HALE
(1868-1938)
An American astronomer, he invented the spectroheliograph, with which he made discoveries of solar vortices and magnetic fields of sunspots.

HENRIETTA LEAVITT
(1868-1921)
An American astronomer, she discovered more than 2400 variable stars and the cepheid variable period-luminosity relationship. She also developed a photographic method for ordering stars based on their magnitude of brightness.

EDMUND HALLEY
(1656-1742)
He researched comets of 1456, 1531, 1607, and 1682 and hypothesized that it was a single object on an orbit that bought it close to the sun every 76 years. He predicted that it would return again in 1758, which it did, and it has since been named Halley's Comet in his honour.

TYCHO BRAHE
(1546-1601)
A Danish astronomer and alchemist credited with the most accurate astronomical observations of the pre-telescopic era his time. His long-term accurate observations of the planets allowed Kepler to develop his Laws of Planetary Motion.

NICOLAS COPERNICUS
(1473-1543)
Born in Poland and considered the founder of modern Astronomy, he was the first to propose that the Sun was the centre of the Solar System rather than the earth.

JAMES GREGORY
(1638-1675)
A Scottish mathematician, he invented one of the first types of reflecting telescopes in 1663.

JOHANNES KEPLER
(1571-1630)
A German mathematician, astronomer, astrologer and assistant to Tycho Brahe. He developed Laws of Planetary Motion to describe the motion of planets in the Solar System.

ARISTARCHUS OF SAMOS
(310-ca.230 BC)
A Greek astronomer and mathematician, he was the first to present an argument for a heliocentric model of the Solar System. He also put some of the planets in the correct order from the sun.

CLAUDIUS PTOLEMAEUS
(2nd Century AD)
A Greek mathematician, astronomer, geographer and astrologer, he compiled a catalogue of the stars and explained celestial motions by assuming that the Earth was the centre of the universe and that the moon, sun and planets revolved around it.

GALILEO GALILEI
(1564-1642)
He was the first to use the newly invented refracting telescope to discover the phases of Venus, the craters and mountains on the Moon, the four largest satellites of Jupiter (named the Galilean moons in his honour), and observe and analyse sunspots.

PYTHAGORAS
(569-475 BC)
A Greek philosopher, mathematician, and astronomer, he correctly realised that the morning star and the evening star were the same object, the planet Venus.

CALLIPUS
(370-300 BC)
A Greek who accurately measured the length of the seasons, Callipus improved the Greek calendar by reconciling the lunar month with the solar year.

HIPPARCHUS
(190-120 BC)
A Greek astronomer, he compiled the first-known catalogue of stars and first map of the skies. He listed 850-1000 stars, organised by constellation and noting their brightness.

EDWIN HUBBLE
(1889-1953)

Hubble proved the existence of galaxies other than our own (the Milky Way), and through studying the speed at which galaxies move away from each other, discovered that the universe expands uniformly.

STEVEN HAWKING
(1942-)

A British theoretical physicist, he showed that Einstein's General Theory of Relativity implied space and time would have a beginning in the Big Bang and an end in black holes. He was instrumental in unifying General Relativity with Quantum Theory.

SUSAN JOCELYN BELL BURNELL
(1943-)

Susan Bell is an astronomer who discovered the existence of pulsars in 1967, while she was a graduate student at Cambridge University.

HARLOW SHAPLEY
(1885-1972)

An American astronomer, he was the first person to accurately estimate the size of the Milky Way Galaxy and our position in it.

CLYDE TOMBAUGH
(1906-1997)

An American astronomer, he discovered Pluto in 1930.

ARNZO PENZIAS
(1933-)
& ROBERT WILSON
(1936-)

In 1963, Penzias and Wilson accidentally discovered what is now called Cosmic Microwave Background radiation left over from the Big Bang. The discovery provided proof that the Universe was born at a definite moment, thought to be some 13.7 billion years ago.

OF STARS

CAROLINE HERSCHEL
(1750-1848)

An English astronomer, she discovered a number of astronomical objects between 1783-87 including the second companion galaxy to the Andromeda Galaxy and 8 comets. She also revised the Catalogue of the Stars that was published by the Royal Society in 1798.

GERARD KUIPER
(1906-1973)

A Dutch-American astronomer, he predicted the existence of the Kuiper Belt in 1951. The first Kuiper Belt object was identified in 1992 and thousands more have been discovered since.

KARL G. JANSKY
(1905-1949)

An American radio engineer, he pioneered and developed radio astronomy. In 1932, he detected the first radio waves from a cosmic source – in the central region of the Milky Way Galaxy.

ALBERT EINSTEIN
(1879-1955)

A German theoretical physicist, he made many important contributions to physics for which he is probably best known for his theory of relativity and mass-energy equivalence (E=mc2). His work had important implications for astronomy and cosmology.

JAN HENDRIK OORT
(1900-1992)

A Dutch astronomer, he made significant contributions to our understanding of the Milky Way galaxy. He is best known for his suggestion that the Solar System is surrounded by a vast cloud of perhaps 100 000 million comets. The as-yet unconfirmed cloud is usually known as the 'Oort Cloud'.

SIR WILLIAM HERSCHEL
(1738-1822)

A British astronomer and organist, he built an improved reflecting telescope and used it to discover the planet Uranus, and the moons of Uranus and of Saturn. Herschel catalogued over 2500 discoveries, mostly deep sky objects.

SIR WILLIAM HUGGINS
(1824-1910)

An amateur English astronomer, he was the first person to use spectroscopy to determine the compositions of astronomical objects (in 1861). He determined that the Sun and the stars are composed mostly of the element hydrogen.

A Science Week Activity: Expand on this Galaxy of Stars to include modern Australian Astronomers

Space-Based Telescopes

Astronomical observations from the Earth's surface are limited by the filtering and distorting effect of the atmosphere on incoming radiation. Astronomers have bypassed this problem by launching telescopes into Space. Space-based astronomy allows us to detect frequency ranges outside the *optical and radio windows* including the full range of infrared radiation as well as gamma-ray, X-ray, and ultraviolet radiations, which are almost impossible to detect from Earth.

THE SCIENCE

Putting a telescope in Space is costly, time consuming, and high maintenance, and the telescope itself has a limited lifespan. Space telescopes were proposed as early as 1923, but it was not until years later that the first Space-based antenna and transmitter were launched. The information gathered by these telescopes is not only adding to our knowledge of the Universe but is posing a multitude of questions. Astronomy truly is a science without limits!

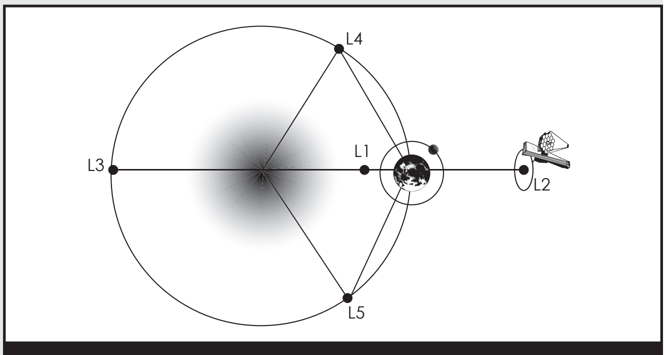
Date	Telescope	Orbit	Description
1990 - 2013?	Hubble Space Telescope (HST)	The HST orbits Earth every 96 minutes, 575 km above its surface.	One of the largest and most versatile telescopes in operation. Able to detect visible, ultraviolet and near-infrared light. It has produced the most detailed visible-light images ever made of some of the most distant objects in our Universe, and led to breakthroughs in astrophysics. http://hubblesite.org/
1999 - ?	Chandra X-ray Observatory (CXO)	The CXO takes over 64 hours to complete one elliptical orbit, and is more than 16000 km from Earth.	The CXO, one of the most sophisticated X-ray telescopes ever built, has observed highly energetic objects such as quasars, supernova remnants, black holes and high temperature gases. It is expected that the Chandra will improve our understanding of the origin, evolution and destiny of the Universe. www.nasa.gov/mission_pages/chandra/main/index.html
2001 - ?	Wilkinson Microwave Anisotrophy Probe (WMAP)	The WMAP follows an *L2 orbit* 1.5 million km from Earth	The WMAP measures temperature differences in Cosmic Microwave Background (CMB) Radiation. It has produced a detailed full sky map showing the faint variations in the temperature of CMB radiation. The data collected by the WMAP has allowed a calculation of the age of the Universe (13.73 ± 0.12 byo), as well as identifying the Universe as being composed of 4.6% baryonic matter, 23% dark matter, 72% dark energy, and less than 1% neutrinos. http://map.gsfc.nasa.gov/news/index.html
2003 - ?	Spitzer Space Telescope (SST)	The SST orbits the sun, taking one year to complete a rotation.	The SST detects infrared light, which is useful for observations of cooler objects in the Universe. The SST will improve our knowledge of smaller stars that are too dim to be detected by their visible light, *exoplanets*, and giant molecular clouds. www.spitzer.caltech.edu/spitzer/index.shtml
2006 -	Hinode	Hinode has been placed on a 96-minute orbit around the Earth at an altitude of 600km	This X-ray telescope's sun-synchronous polar orbit allows it to make continuous observations of the Sun for more than nine months of the year. The Hinode is making observations of the Sun's magnetic field, with the hope of gaining a better understanding of the mechanisms that power the solar atmosphere and trigger solar eruptions. http://solarb.msfc.nasa.gov/
2008 -	Fermi Gamma-ray Space Telescope	The Fermi orbits at an altitude of 550km	Gamma rays are the highest-energy form of light. Fermi's data will provide answers to questions across a broad range of topics, including super massive black hole systems, pulsars, the origin of cosmic rays, and searches for signals of new physics. The gamma-ray burst in the constellation Carina recorded in September 2008 by the telescope has been confirmed to have 'the greatest total energy, the fastest motions, and the highest-energy initial emissions' ever seen. http://fermi.gsfc.nasa.gov

Definitions

Optical and radio windows: The Earth's atmosphere absorbs some wavelengths of the visible light spectrum and the longer wavelengths of the radio wave spectrum. The 'windows' are the wavelengths that do reach the Earth's surface. (See Diagram, page 19)

Exoplanets: Extrasolar planets, or planets beyond our Solar System. They are orbiting a star other than the Sun. As of February 2009, 342 exoplanets had been found.

L2 orbit: The L2 orbit is an elliptical orbit about the semi-stable second Lagrange point. It is one of the five solutions to the three-body problem found by the mathematician Joseph-Louis Lagrange in the 18th century. Lagrange was searching for a stable configuration in which three bodies could orbit each other yet stay in the same position relative to each other. He found five such solutions, which are called the five Lagrange points in honour of their discoverer.



The five Lagrange points

Teaching ACTIVITIES

ALL YEARS

MAKE A MODEL SPACE TELESCOPE

If you would like to turn your classroom into a repository for Space junk, hang some model Space telescopes around the room!

The Hubble Telescope
_http://hubblesite.org/the_telescope/hand-held_hubble/_ has instructions for easy, through to quite complicated, model telescopes that students of all ages will enjoy making. One section of the site has measurements and other information on the Hubble Telescope so that students can add details to their own models. They could also use this information to construct accurate scale models of the telescope.

The Spitzer Telescope
http://www.spitzer.caltech.edu/features/downloads/files/Spitzer-Paper-Model.pdf
has a 15-page pdf file for download.
This resource includes colour cut-outs of the various parts of the telescope, with instructions on how to assemble them.

MIDDLE SCHOOL

THE HUBBLE TELESCOPE

http://sm3a.gsfc.nasa.gov/classrm.html is a site written for middle-school students about the Hubble Telescope. Use this site with students who are interested in expanding their understanding of how the telescope works, how it is maintained and what observations are being made. This site would work well to assist students in understanding the model they built in the activity above.

THE ASTRONOMERS' PALETTE – ARE ALL WAVELENGTHS COVERED?

Help your students to list and then research the important ground-based and space-based telescopes used by astronomers in Australia and internationally. Ask your students to draw a large image of the electromagnetic spectrum. On this image, ask your students to:

1. identify the range of wavelengths that can be detected by each ground-based telescope that they have researched,
2. identify the range of wavelengths that can be detected by each space-based telescope,
3. outline the type of objects or observations suitable to be researched at each range of wavelengths (eg infrared is useful for star formation and planet searches),
4. research the following proposed telescopes and place their range on the same drawing
   a. James Webb Space Telescope
   b. Herschel Space Observatory
   c. World Space Observatory,
5. identify any gaps in the wavelengths that will be able to be detected. Do any new telescopes need to be designed?
6. describe the main purpose or goal of the following telescopes/space missions?
   a. Kepler, b. LISA, c. GAIA.

UPPER SECONDARY

THE LIMITS OF VISION

_http://nightsky.jpl.nasa.gov/download-view.cfm?Doc_ID=300_ is a 23-page downloadable pdf with some interesting exercises that can be done in daylight hours. It provides background information and activities to answer the following questions:

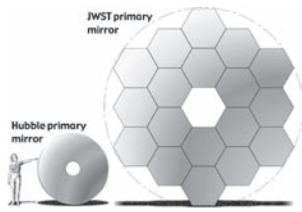
1. Why don't I see any colour?
2. What is averted vision?
3. How much of the sky are we seeing through a telescope?

THE L2 ORBIT

The James Webb Space Telescope (JWST) is a large infrared telescope being developed by NASA. It is intended to replace the Hubble Space Telescope (HST) and is due for launch in 2013. It will find the first galaxies and planetary systems that formed after the Big Bang, helping us to better understand our own solar system and galaxy. Information about the JWST is available at _http://www.jwst.nasa.gov/about.html._

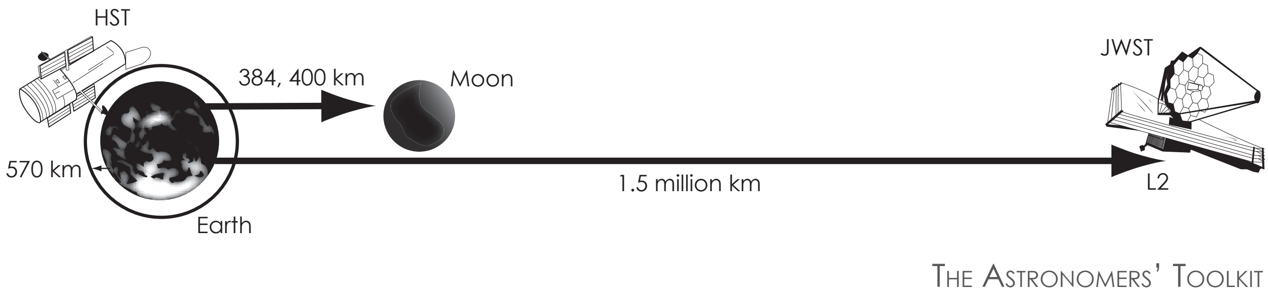
The image at the bottom of the page compares the orbit of the Hubble Telescope with that proposed for the James Webb telescope. The image is available at low resolution at: _http://www.ngst.nasa.gov/comparison.html#orbit_

_http://www.jwst.nasa.gov/images_mirror.html_ also has the scale model image below to compare the sizes of the HST and JWST mirrors. Students could use this image to estimate the size of the JWST's primary mirror.



Older students can consider the following questions:

1. Why is the JWST being placed so far out in Space?
2. What new technologies are necessary for this telescope to function perfectly?
3. Use the JWST project to demonstrate the multidisciplinary nature of Astronomy. Supply students with the profile of Greg Forbes, (page 47) who is working on this telescope's development from Sydney, NSW. Ask students to identify the skills of other scientists who would be needed on this project.
4. For the foreseeable future, scientists will not have opportunities to carry out maintenance on this telescope, as they have with the Hubble Telescope. How does this problem impact on the planning for this telescope?
5. Is the telescope worth the expense? Ask your students to justify their answer. This question could lead to a class debate on the topic.



CHAPTER THREE

The Phenomena of the Universe

Star trails, South Celestial Pole
Image: Anglo-Australian Observatory/David Malin Images

The Universe is a huge wide-open space that holds everything from the smallest particle to the largest galaxy. About 13.7 billion years ago, the Big Bang occurred, forming the Universe. The history, size, and components of the Universe are difficult to imagine since they do not compare to anything we understand on Earth.

Gravity and the Universe

Gravity is the name given to the force that pulls any two masses together. Any substance with mass (no matter how small) will exert its own attraction on other matter. The greater the mass, the greater the force it exerts on other masses. The question of why masses attract one another is still not understood and remains one of the great mysteries of science.

Gravity is one of the four basic forces of nature and influences the evolution of the large scale structure of the Universe. Without gravity there would be no stars or planets, only a cold thin mist of particle soup left over from the Big Bang. Small variations in that particle soup caused slight fluctuations in particle motion. As a consequence, gravity began to concentrate tiny amounts of matter into larger amounts of matter. The end result of the pull of gravity was galaxies, stars and planets.

In Space, almost every object is in an orbit around a more massive object. Each maintains an orbit because of its motion and the forces of gravity between the objects involved. Planets orbit stars, stars orbit galactic centres, galaxies orbit a centre of mass in clusters, and clusters orbit in superclusters.

The force of gravity can also distort the surface of planets. For example, Earth's Moon, a natural satellite, causes tides on Earth. Even the volcanic eruptions that have been detected on Io, Jupiter's closest-orbiting moon, are believed to be caused by that planet's force of gravity.

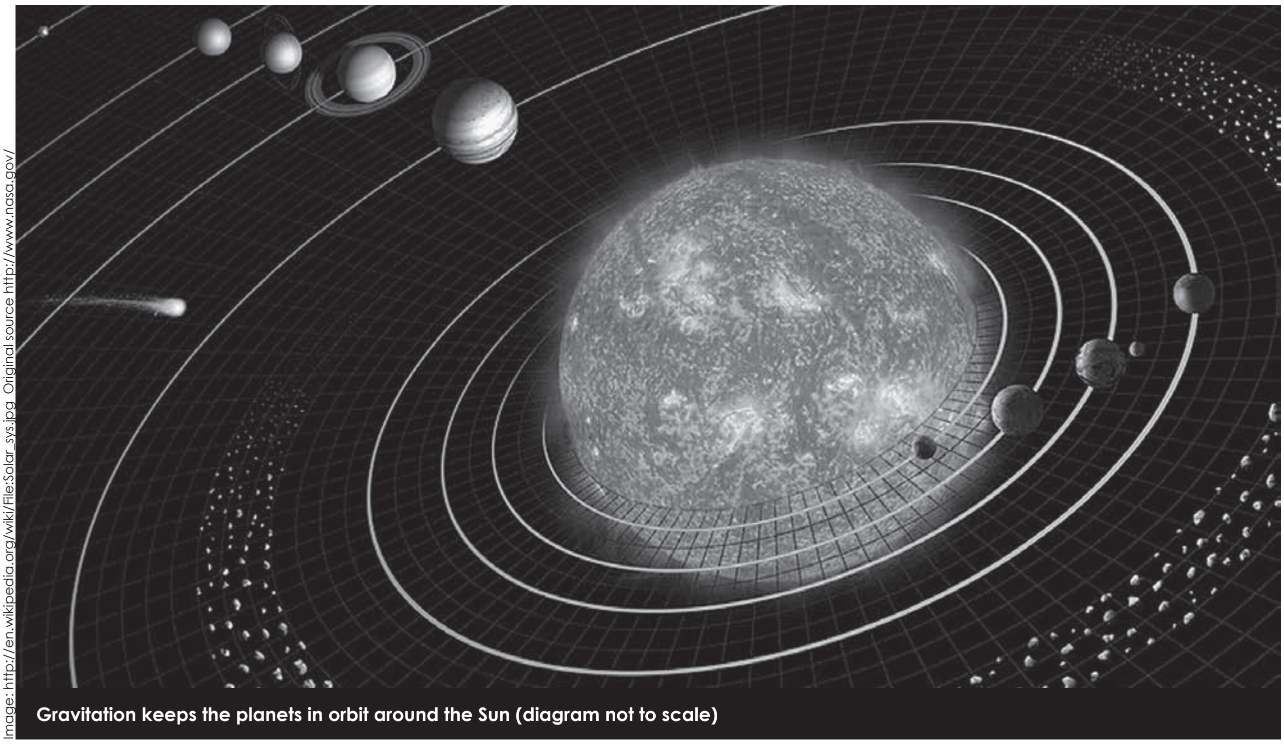


Image: http://en.wikipedia.org/wiki/File:Solar_sys.jpg Original source http://www.nasa.gov/

Gravitation keeps the planets in orbit around the Sun (diagram not to scale)

Inside the Solar System

All the planets orbit the Sun because it has by far the greatest mass of the group of celestial bodies that make up our Solar System. Technology continues to provide answers to astronomers' questions about the Solar System but there are still more questions to be answered.

THE SCIENCE

We know that it is gravity that continues to hold our Solar System together. Our Solar System consists of the Sun (a star), 8 planets, 166 known moons, 5 dwarf planets that have been discovered so far, and billions of 'small bodies'.

The **planets**, in order of distance from the Sun, are Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus and Neptune.

Five **dwarf planets** (Ceres, Pluto, Haumea, Makemake, and Eris) are currently recognised, but it is thought that there may be as many as 2000!

Small body is the name given to any object orbiting the Sun that is not a planet or dwarf planet; namely asteroids, comets and meteors. The Kuiper Belt consists of as many as 70, 000 small bodies, which orbit in a region beyond Neptune. They are thought to be remnants of an early *accretion disc*, which still remain because planet building in the region stopped before any large objects were formed.

Satellites are objects that orbit planets and can be natural or man made. Natural satellites of planets are also known as moons. All the planets (except Mercury and Venus) and the dwarf planets, Pluto, Haumea and Eris, have one or more moons. Moons are not classified as small bodies because they orbit planets rather than the Sun.

We believe that our Solar System arose from a rotating cloud of gas and fine dust that formed after the Big Bang (see page 36). Under the pull of gravity, matter began to accumulate in the centre of this cloud, and as it compressed under its own weight, it became hot and dense, forming the nucleus of our Sun. The cloud of dust and gas surrounding the Sun flattened into a disc, and grew hotter in the inner region, where most matter accumulated. Gravitational attraction caused dust and other materials to collide and clump together. All the matter revolving in any particular orbit accumulated to form a planet, which is why no two planets share the same orbit.

The age of the Solar System has been estimated at about 4.5 billion years. Scientists worked this out by measuring the ages of the oldest rocks on Earth, rocks from the Moon and meteorites, using radioactive dating methods. Since the oldest rocks on Earth have been destroyed by tectonic processes, this method relies mostly on rocks from the Moon and meteorites. It assumes that these objects were created at the same time that the Solar System was evolving, so their age should reflect that of the Solar System.

The study of the Solar System has been transformed by the development of more powerful telescopes and camera-carrying spacecraft. Many space missions to various parts of the Solar System have been completed, mostly targeting the Moon and the nearby planets, Mars and Venus.

One of the most significant missions has been NASA's *Voyager* program. The unmanned probes *Voyager 1* and *Voyager 2* were launched in 1977 with the aim of exploring Jupiter and Saturn over a period of five years. The spacecrafts' nuclear power sources are still providing electrical energy, allowing them to continue along their trajectory and transmit scientific data on their surroundings.

The spacecraft have now exited the Solar System and are approaching the *heliopause*, the boundary where the Sun's dominance ends and *interstellar space* begins. The two probes are travelling in roughly opposite directions away from the Sun. On 1st February 2009 *Voyager 1* was about 16,247,000,000 kilometres from the Sun (about three times as far from the Sun as Pluto) and *Voyager 2* about 13,149,000,000 kilometers. It is expected that they will have enough power to continue on their mission until at least 2020.

Astronomers have yet to find out if there is, or has been, any life on any of the planets, moons or small bodies apart from life on Earth. We do not know exactly how comets form. Many comets are found in the Kuiper Belt but we do not know why. We are not even sure how many small bodies there are in the Kuiper Belt.

There are also still plenty of questions to be answered about the Sun, such as: Why is the *solar corona* so hot? What would happen if there was a prolonged period of inactivity on the Sun? Can we find a way to predict when the next powerful solar flare or coronal mass ejection will occur, because they interfere with navigation and communication systems on Earth?

Definition

Accretion disc: Accretion discs are formed when material around a massive object is flattened into a disc shape. They form around many types of astronomical objects, such as stars, in their early stages of development.

Interstellar space: The space between stars that is outside any system of planets and other matter that orbits the stars.

Solar corona: The solar corona is a type of plasma 'atmosphere' of the Sun, extending millions of kilometres into space. It is most easily seen during a total solar eclipse.

Teaching
ACTIVITIES

Lower Primary

Construct a Solar System mobile

Take out the paint pots and make a wonderful mess! *http://www.astronomy-for-kids-online.com/solarsystemforkids.html* has information about, and images of, each of the planets. Use the images as 'models' for the students to produce a disc representing each of the planets.

You will need piece of card (at least 860mm x 700mm), coloured pencils/markers or paints, string and a frame for the mobile, and a compass to draw circles. Use the table below to produce circles to scale for each planet. If you want to include the Sun, the circle needs to be four metres in diameter! Hang each planet from the frame using string or fishing line, then arrange them in a line on your ceiling in order from the Sun.

Planet	Colours	Scale Diameter (cm)	True Diameter (km)
Mercury	Brown-gray	1	4,880
Venus	Blue and white	4	12,100
Earth	Blue and white	4	12,760
Mars	Orange and red	2	6,790
Jupiter	Brown and yellow	48	143,000
Saturn	Yellow	38	120,500
Uranus	Blue-green	20	51,100
Neptune	Blue	20	49,500

Primary

Experience the Force of Gravity while Orbiting

1) Firstly demonstrate to the class – a teacher and a smallish child stretch their crossed arms straight out in front of them.
2) Hold hands and lean back – still with arms outstretched.
3) Twizzle (spin in a circle around a point on the floor).
4) The spinners will feel the pull of the other person as they 'orbit' each other.

In the same way, large and small objects can orbit each other without being pulled inwards e.g. the Moon is MUCH smaller than the Earth but remains in orbit around it.

Researching the Solar System

http://www.cosmos4kids.com/files/solsyst_intro.html Facts on the Solar System explained simply. *http://www.cosmos4kids.com/activities.html* has some simple interactive quizzes that students can use to test their knowledge.

Model Solar System

http://school.discoveryeducation.com/lessonplans/programs/classroomplanetarium/ has a well-thought-out lesson plan to model the Solar System, with follow-up ideas to stimulate discussion. NOTE: this lesson was uploaded before Pluto was demoted from planet status.

Facts about the Solar System

http://starchild.gsfc.nasa.gov/docs/StarChild/StarChild.html has two levels of interactive games about features of the Solar System that students could use to learn and test their knowledge. Level 1 is suitable for 8-10 year olds with reasonable reading skills.

http://starchild.gsfc.nasa.gov/docs/StarChild/teachers/teachers.html has the corresponding lesson plans, activity sheets and work sheets for use with the interactive games.

Celebrity Heads of the Solar System

Write out the names of celestial bodies (e.g. Sun, Pluto, Earth, comet, Moon, meteorite) on pieces of cardboard. Have three students sit on chairs at the front of the room facing the rest of the class. Stick a piece of cardboard onto a party hat and place the hat on the student without letting them see the word. Do this for each student – they may see each other's word, but not their own. They then take it in turns to ask the rest of the class yes/no questions until they have worked out what they are. The activity will require students to recall facts they have learnt about stars, planets, dwarf planets, moons and small bodies.

Middle School – Upper Secondary

http://videos.howstuffworks.com/ has a series of short videos about gravity and why it is so important to astronomers. Type 'Gravity' into the search facility.

Middle School

Weighing up the Solar System

The sun constitutes 99.85% of the mass in our Solar System, the planets 0.135%, comets 0.01%, satellites 0.00005%, dwarf planets 0.0000002%, meteoroids 0.0000001% and interplanetary medium 0.0000001%. If you want to test your students' skills in developing scales, ask them to represent these values in a suitable graphic.

Make an Accurate Scale Model of the Solar System

http://www.exploratorium.edu/ronh/solar_system/ has an interactive calculator that provides students with sizes and distances in metric and imperial units. More able students may not need this facility and the exercise could be given as a problem-solving activity.

Information about the Solar System

http://starchild.gsfc.nasa.gov/docs/StarChild/StarChild.html has two levels of interactive games about features of the Solar System that students could use to learn and test their knowledge. Level 2 is suitable for 11-13 year olds with reasonable reading skills. The teachers' section has the corresponding lesson plans, activity sheets and work sheets for use with the interactive games.

Upper Secondary

The Day the Sun Brought Darkness

On Friday March 10, 1989 astronomers witnessed a powerful explosion on the Sun. Within minutes, tangled magnetic forces on the Sun had released a billion-ton cloud of gas. The impact on Earth of this explosion was extraordinary. Older students with some knowledge of the interaction between electrical energy and magnetic fields will be interested in researching the impact of that solar storm and will thus acquire a better appreciation of why scientists would like to be able to predict such events.

http://www.sciencedaily.com/releases/2009/03/090316144521.htm has a full description of this event and provides hyperlinks to further information about the science surrounding it.

STAR GAZING

A star is a huge, shining ball in Space that releases a tremendous amount of light and other forms of radiation. The Sun and most other stars are made of gas and a hot, gas-like substance known as plasma. Some stars, called white dwarfs and neutron stars, consist of tightly-packed atoms or subatomic particles and are much more dense than anything on Earth.

THE SCIENCE

WE KNOW THAT stars change throughout their life. The typical stages of a star are summarised, in order, below.

1. **Nebula:** Particles within a nebula become attracted to one another by gravitational force. The molecular cloud at this stage is very cold (about 100*K* or –173˚C). As the particles concentrate, they speed up and the temperature of the cloud increases.

2. **Proto-star:** The continuing compression of the cloud creates heat, which gives off light. It is no longer a dark interstellar cloud, but a glowing proto-star. No thermonuclear reactions are occurring yet.

3. **Young star or brown dwarf:** If the temperature within a proto-star reaches around 15,000,000K, thermonuclear fusion begins to occur at its core, and the proto-star officially becomes a *star*. Only large proto-stars have a mass sufficient to generate enough heat to trigger fusion. Smaller proto-stars end their lives as brown dwarfs, with no fusion occurring.

4. **Main sequence star:** These stars are changing hydrogen gas into helium gas in their core. The effective outer temperature of such stars ranges between 30,000K and 3000K. Hotter stars appear white to bluish, while cooler stars appear yellowish or reddish. Our Sun is a main sequence, medium-sized star that is relatively cool.

5. **Red giant:** Helium accumulates in the core of the star until the core is so large that fusion stops. The star cools and becomes reddish in appearance, hence the name red giant. With no energy being produced to push atoms apart, the effect of gravity is not counteracted and the star collapses. This heats the core up, triggering fusion reactions once more and burning up the remaining hydrogen around the core. The outer layers of the star then begin to expand again. Examples are Antares and Aldebaran.

Image: Anglo-Australian Observatory/David Malin Images

Antares (bright star at bottom left) is a red supergiant star in the Milky Way Galaxy. It has a diameter approximately 700 times that of the Sun.

6. **White dwarf or supernova:**
   a. When a star about the same mass as our Sun runs out of fuel, it cools down, and the outer layer expands to form a planetary nebula (e.g. the Hour-glass Nebula). A white dwarf is the remaining core, which glows white as it dissipates the stored heat from the nuclear reactions (e.g. Sirius B).
   b. For stars with higher masses, the cessation of nuclear reactions causes the star to contract, triggering fusion once again. This time carbon is being consumed, so the temperature and pressure are higher and the result is a massive supernova explosion, which flings about 90% of the star's matter out into Space.

7. **Black dwarfs, pulsars, neutron stars and black holes:** These are the end stages of the life cycle of stars. For example, a white dwarf cools slowly over time to become a cold, dark black dwarf but this takes tens of billions of years, so the Universe is not yet old enough for this to have occurred. Read more on page 40 about about black holes and other mysterious phenomena in the Universe.

The study of stars includes a study of the wavelengths of the electromagnetic spectrum that they emit. Most individual stars do not emit with the same strength in all bands of the spectrum. For example, they may emit most strongly in the infrared visible or ultra-violet band. Each star has its own radiation signature.

We believe that stars begin in dense regions of the interstellar medium. Star formation probably peaked about 0.5-1 billion years after the Big Bang, but new generations of stars continue to form all the time. Since the light from a star can take many millions of light years to reach Earth, there may be stars we are seeing now that are actually non-existent. Conversely, there are likely to be newly-formed stars whose light has not yet reached us.

We still do not know when and how the first stars formed. Cosmologists have used sophisticated computer simulation techniques to model how the clumps of matter left over from the Big Bang could have evolved into the first stars. These models suggest that the first stars were most likely quite massive and luminous and that they would have produced and dispersed the first heavy elements, paving the way for the eventual formation of solar systems such as our own.

DEFINITION

Kelvin (K) is the temperature scale where 0° K represents absolute zero, i.e. the point at which all molecular motion ceases; the freezing point of water is 273° K (O°C), and the boiling point of water is 373° K (100°C)

Teaching ACTIVITIES

All years

Star Party

As a celebration of National Science Week, try to organise a night sky viewing with telescopes. Even with the naked eye, and especially if the sky is dark, students will be able to find stars of different colours, pick out constellations, and if they are lucky, see some 'shooting stars'. Can they spot the orbiting space station? _http://www.astrosociety.org/education/astro/astropubs/htm_events.html_ has step-by-step instructions on the issues to consider in arranging an astronomy night. Use it as a checklist!

Stargazing in the Classroom – free software

Free software is available at _www.stellarium.org_ to create your own planetarium on a computer in your classroom. The program has a broad range of applications limited only by your imagination. Fortunately, there is help! _http://www.stellarium.org/wiki/index.php/Main_Page_ is set up to support the program, with instructions on how to use it, and the Education section has K-12 lesson ideas. Highly recommended.

Another program for download is available at _http://www.shatters.net/celestia/_ This is an extract from its home page: "The free Space simulation that lets you explore our Universe in three dimensions. Celestia comes with a large catalogue of stars, galaxies, planets, moons, asteroids, comets, and spacecraft."

Online lessons for download

http://www.digitaliseducation.com/curricula.html has a series of lesson plans for K-12 that are readily adaptable for use in other contexts, such as during a 'Star Party' or with one of the software programs above.

Lower Primary and Primary

http://www.deakin.edu.au/arts-ed/education/sci-enviro-ed/early-years/light.php and the downloadable pdf at _http://www.deakin.edu.au/arts-ed/education/sci-enviro-ed/early-years/pdfs/light.pdf_ are well worth checking out, as it has some useful activities and also some information about the misconceptions that young children may develop about light, luminosity and the properties of light.

Lower Primary

The following activity is adapted from: _http://science.preschoolrock.com/index.php/Preschool_Astronomy/preschool_space_activity_building_a_planetarium_with_your_preschooler_

You will need:

- A medium-sized plastic funnel,
- Black construction paper,
- A push pin,
- A pencil or pen,
- Tape,
- A small flashlight,
- Two desks pushed together,
- One or two old blankets.

Tape the piece of black construction paper over the top of the funnel, and use the push pin and a pencil to poke holes in the paper. Set up the 'planetarium' under the desks, with a blanket covering the sides. The idea is to make the area under the desks as dark as possible. Pull down blinds and turn off lights in the classroom if you can. Shine the torch through the tube of the funnel and your students will have their own planetarium. Tell your students that the small holes are stars while the bigger holes are the planets.

Primary

http://www.enchantedlearning.com/subjects/astronomy/ has some simply-written text with animations to illustrate it. These pages would be useful for a research assignment on stars, their origins, types and life spans. The activities section has quizzes, printable worksheets, and cloze passages.

Middle School

Light and Stars

http://amazing-space.stsci.edu/resources/explorations/ opens on to a page with a broad range of interactive activities across all the areas of Astronomy. Select the 'Star Light, Star Bright' option for some interactive activities that will assist students in developing knowledge and understanding about the electromagnetic spectrum, heat and light in Astronomy, and stars.

http://amazing-space.stsci.edu/eds/tools/ has teaching tools for use with students of various ages. This page provides indexes to tools by topic and tools by activity. The activities include classroom tasks, graphic organisers, pictures and facts, questions and answers, myths vs realities, resources with educator guides, science content reading materials and online explorations.

The closest star to the Earth is the Sun. Where did it come from, and what will happen to it and the Solar System in the future? This 3-D movie tells the life story of the Sun and other stars, from birth to their sometimes violent death. Go to _http://deimos3.apple.com/WebObjects/Core.woa/Browse/swin.edu.au.1547787534_ Open "Our Sun - What a Star"

Upper Secondary

Stellar Evolution

http://amazing-space.stsci.edu/capture/stars/ has eleven downloadable pdf lithographs with a stunning full-page image taken by the Hubble Space Telescope in colour on the front page of each of the four-page documents. There is information for teachers and a set of directions for students. Each activity is 'inquiry-based' and requires the student to examine the photograph carefully and research further information from hard copy and electronic sources.

Evidence from the Stars

Astronomers are able to describe the chemistry of many stars by examining their electromagnetic emissions. They can also determine the size, rate of spin and surface temperature of the star, as well as its motion relative to us. Subtle shifts in spectral lines can also indicate the presence of one or more planets orbiting the star and allow their masses to be determined.

More able students would enjoy the challenge of researching and preparing a presentation that describes how stellar spectra can be used to deduce information about one topic from the paragraph above.

Galaxies

Humans have always been entranced by that hazy band of white light—our Milky Way Galaxy—arching across the entire night sky. To comprehend its size, consider that, if the Solar System was the size of a cell in the human body, our galaxy would still measure nearly two kilometres across. Want to feel even more insignificant? Astronomers today think there are more than one billion galaxies in the known Universe. If galaxies were frozen peas, there would be enough peas to fill a large auditorium like the main hall of the Sydney Opera House.

THE SCIENCE

We know that a galaxy is a massive collection of stars and their planets, interstellar medium (mostly hydrogen and some helium, with traces of carbon, nitrogen, oxygen, calcium and dust), and dark matter, held together by gravity and revolving around a central point. The number of stars in a galaxy can vary from as few as 10 million up to many billions of stars.

Galaxies tend to be found in clusters of different sizes with multiple star systems and interstellar clouds. However, each galaxy is moving through Space and astronomers have found many examples of galaxies colliding and merging to form new galaxies. In our local neighbourhood in Space, the Andromeda Galaxy (2.5 million light years away) is heading towards the Milky Way for a possible future collision – many billions of years from now!

Many types of galaxies have been found, with the four classical types being:

1. **Spiral galaxies** are disc shaped with a bulge in the centre and arms that spiral outwards. They contain more middle-aged stars, are rich in gas and dust and have stars still forming in their arms.

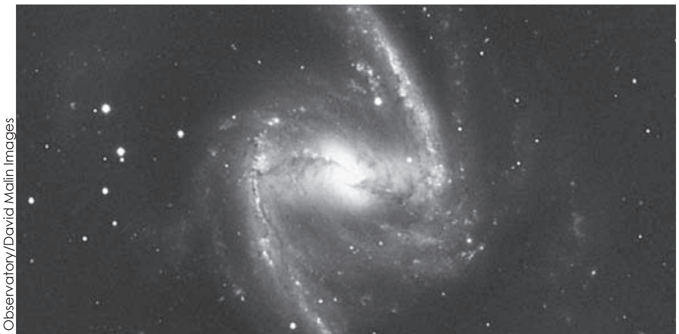


Image: Anglo-Australian Observatory/David Malin Images

This beautiful galaxy is about 60 million light years away and is about as massive as the Milky Way. The obvious 'bar' has the nucleus of the galaxy at its hub and is surrounded by masses of yellow, cooler stars. The bar itself is also yellowish, and has distinct dust lanes, but it terminates abruptly in slender, curved arms that are lit by hotter blue stars and the pink star-forming regions from which they originate.

2. **Elliptical galaxies** vary in shape and contain older stars and very little gas and dust.

Image: Anglo-Australian Observatory/David Malin Images

Centaurus A is a most unusual galaxy about 14 million light years away. The circular bright portion contains several thousand million stars, most of them old and yellowish. The galaxy is surrounded by dense dust, with younger, blue stars at the edges of the dust cloud. This galaxy is a powerful radio source and also emits X-rays and gamma rays, as well as visible and infrared radiation.

3. **Lenticular galaxies** are so called because they appear to be shaped like lenses. A lenticular galaxy has a spherically-shaped component like an elliptical galaxy, and a disc. It is generally gas poor and contains few if any young stars.

Image: Anglo-Australian Observatory/David Malin Images

This lenticular galaxy is traversed by a distinct dusty band visible against the bright background of the galaxy itself. The dust lane is warped and broadened, probably by interaction with the faint companion galaxy that is distorted into an 'S' shape and can be seen below the large galaxy. Astronomers have found many such galaxies that are merging to form a single galaxy. It is likely that the dust lane of the larger galaxy is the remnant of a dusty galaxy that fell into it long ago. These galaxies are about 80 million light years away from us.

4. **Irregular galaxies** such as our neighbours the Magellanic Clouds and the Sagittarius Dwarf Elliptical Galaxy, have an undefined shape and large quantities of young stars, dust and gas.

Image: Anglo-Australian Observatory/David Malin Images

In visible light, this galaxy (about 15 million light years away) seems dominated by scattered patches of star formation giving a rather ragged appearance. The clouds of bluish stars seem to have burst into existence at random, without the normal trigger gravitational interaction or even a distinct spiral to prompt them. However, radio telescopes reveal that the galaxy is rich in hydrogen, the raw material of stars, and the gas circulates around the centre of the galaxy in a well-ordered way.

Astronomers have yet to find out the details of how galaxies are formed and what gives them their shapes. They do not know how the chemical elements are distributed through the galaxies, and are still searching for answers to what happens when small and large galaxies collide or join.

Current and future earth-bound and Space-based telescopes may find some clues, as they will allow astronomers to compare more ancient galaxies with those that are closer to us. For example, the Space-based X-ray observatory XMM-Newton has discovered the most massive cluster of galaxies seen in the distant Universe until now. The galaxy cluster is calculated to be 7.7 thousand million light years away and is estimated to contain as much mass as a thousand large galaxies. Much of it is in the form of 100-million-degree hot gas.

Teaching ACTIVITIES

Lower Primary

http://www.enchantedlearning.com/subjects/astronomy/

Zoom Astronomy is a comprehensive online site about Space and Astronomy. It is designed for people of all ages and levels of comprehension. The opening page has a wealth of hyperlinks to information and activities on the topic of Astronomy. There are classroom activities as well as fun things to do.

For younger students, this is a great time to bring out the glitter, stick-on stars and glue! Click on the link 'Astronomy Crafts' to find simple instructions on how to make a Solar System mobile or glitter galaxy, both of which students should be able to do with a minimum of assistance.

Primary

Tour of Galaxies

http://school.discoveryeducation.com/schooladventures/universe/galaxytour/toknow.html

This is an interactive site that students can move through at their own pace for a guided online research project about galaxies near and far. At each step along the way, there are audio files with Q&As from an astronomer. Students will need RealPlayer 7 to listen to the audio files – the program is available for free download.

All about Galaxies

http://amazing-space.stsci.edu/resources/explorations/galaxies-galore/ has some excellent interactive activities that students can engage in with minimal assistance (on a computer with Adobe Shockwave Player installed). *Galaxies Galore*, *Games and More* consists of three modules. The first two modules should be completed before the *Galaxy Games.*

- In Build Our *Milky Way* students construct the galaxy we call home.
- In *Galaxies Galore* students learn to identify spiral, elliptical and irregular galaxies. In *Galaxy Games* students apply their observational skills and knowledge in three different games.
- Each page of the activities has two extensions: *Galaxy Gossip* and *Galaxy Gallery*. *Galaxy Gossip* has extra information, and in *Galaxy Gallery* there are additional images to extend the concept.

http://www.kidsastronomy.com/ is another great site for students with basic reading skills. Use this during Science Week to find out about various parts of the Universe. It also has a Teacher's Corner with simple worksheets.

Middle School

Coffee Cup Galaxy

If you want to demonstrate the concept of a revolving spiral maintaining its shape, use the following analogy:

Gently place a teaspoon of cream into a strong cup of black coffee and stir it slowly in one direction. Once you have a spiral pattern on top of the coffee stop stirring. Notice how the spiral shape is maintained even as the fluid spins around, just as the arms in a spiral galaxy are. Note: try not to drink your coffee before you have made your galactic observations!

See: *http://school.discoveryeducation.com/schooladventures/universe/galaxytour/toknow.html*

Middle and Upper Secondary

'Real' Astronomical Research

http://www.noao.edu/education/arbse/arpd

Stellar evolution occurs in galaxies where there are raw materials for star formation. This website has Astronomy research projects and data for middle and upper secondary students. Each activity is supported by a range of downloadable files, which direct the students towards examining real astronomical data about stellar evolution. The site is well worth a visit if you have able students who would enjoy working with real data.

For example, the activity at *http://www.noao.edu/education/jewels/home.html Jewels of the Night* has this information on the front page "Jewels of the Night is a hands-on, teacher-tested activity for middle school and older students. Students measure the colour and brightness of stars in the Jewelbox Cluster from a colour image. They determine the age of the cluster by plotting their measurements in a colour-brightness diagram. The activity develops classification and graphing skills and fosters observation, communication, and cooperative learning. Students are exposed to ideas about the nature of stars, temperature and colour, stellar evolution, the time scales of astronomical phenomena, and how astronomers can determine the ages of objects in the Universe.

The activity is designed to be printed for use in the classroom. The student instructions, answer sheet, and graph worksheet can be printed directly from these web pages in black and white, and reproduced for classroom use. The Jewelbox Image and StarGauge must be printed with a good-quality colour printer. Several image formats and resolutions are provided for convenience."

Classifying Galaxies – Citizens Participating in Astronomy

https://www.galaxyzoo.org/

To give students some idea of how astronomers work, direct them to this website, where they can help real astronomers to classify galaxies. The original Galaxy Zoo was launched in July 2007, with a data set made up of a million galaxies imaged with the robotic telescope of the Sloan Digital Sky Survey. Within 24 hours of being launched, the site was receiving 70,000 classifications an hour, and more than 50 million classifications were received by the project during its first year, from almost 150,000 people. The site 'trains' observers, so your students will learn much about galaxies by participating in the project. An excellent resource.

Universe

The Universe is defined as everything that physically exists, the entirety of space and time, all forms of matter and energy, and the physical laws and constants that govern them. At this point in time, the known Universe is 100 billion light years across and is thought to contain more than 100 billion galaxies. We say ‘at this point in time’ because our knowledge of the Universe increases as technology improves and our telescopes become more powerful.

THE SCIENCE

The Universe: Early models described a steady-state Universe. However, in 1929, astronomer Edwin Hubble showed that other galaxies appeared to be moving away from the Milky Way (our galaxy) – the Universe was actually expanding! Hubble’s discovery led to the development of the Big Bang model to explain the origin of the Universe.

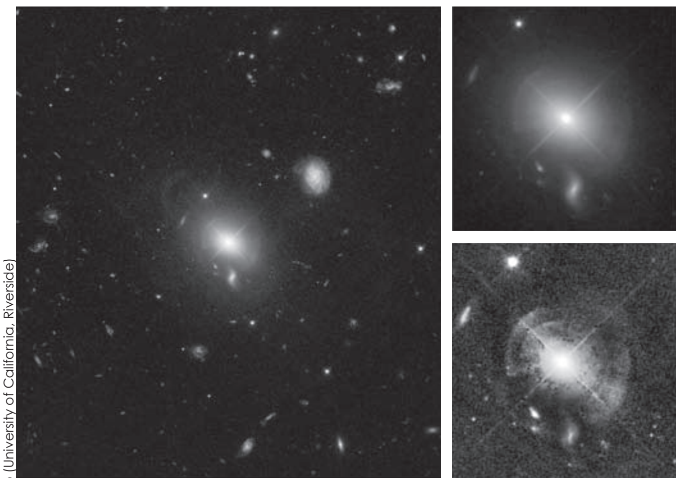
Evidence for the Big Bang was discovered by accident by Arno Penzias and Robert Wilson at the Bell Laboratories in 1963. They came across radio noise that was interfering with communication satellites. What they had actually discovered is what we now call Cosmic Microwave Background Radiation (see page 22), which is radiation thought to be left over from the Big Bang.

The age of the Universe has now been accurately determined as 13.7 billion years, and the birth of stars has been pinpointed to just 200 million years after the Big Bang.

Composition of the Universe: Astronomers used to think that the Universe was composed almost entirely of ordinary atoms. However, in the past few decades, there has been ever more evidence accumulating that suggests there is something in the Universe that we cannot see, perhaps some new form of matter.

Scientists now believe that the Universe is made up of:

- 4% = the physical Universe as we know it.
- 96% = an unknown substance and energy known as ‘dark matter and dark energy’. (Read more about these on page 42)



NASA, ESA, and G. Canalizo (University of California, Riverside)

These images taken with NASA’s Hubble Space Telescope reveal at least five shells of stars surrounding a brilliant quasar at the heart of a giant elliptical galaxy. The image at left shows the quasar, known as MC2 1635+119, and its host galaxy [centre] against a backdrop of distant galaxies. In the image at top right, the shells can barely be seen because of the bright light from the central quasar. The image at the bottom right was enhanced to reveal details of the faint shells.

These recent conclusions, arrived at from evidence provided by Space telescopes, are consistent with the Big Bang and Inflation theories which state that the Universe materialised in a Big Bang from a single, inconceivably-dense point and immediately began expanding (i.e. inflating) and cooling.

A Dynamic Universe: Since the Big Bang, the Universe has been expanding and evolving. For example, while some galaxies are older and darker, and have far fewer stars than our own galaxy, others are more energetic, ejecting jets of high-speed material from their centres and distorting the shape of the galaxy.

The most active type of galaxy is one that has a *quasar* at its core. A quasar is a disc of gas and stars surrounding and powered by a *supermassive* black hole, which has a mass over a billion times greater than that of our Sun and emits intense heat and light. (Read more about black holes on page 40). Quasars are typically 100 times brighter than the galaxy that hosts them. More than 100,000 quasars are now known, most of which are billions of light years away from Earth. Astronomers think they represent an earlier, more violent phase in the evolution of galaxies and the Universe.

However, further investigation raises still more questions about the evolution of the Universe. For example, an international team of astrophysicists using both ground- and Space-based telescopes recently found unexpected changes in radiation emitted by a distant active galaxy. The information gathered from these first-ever simultaneous observations with optical, X-ray and new-generation gamma ray telescopes is much more complex than scientists expected and challenges current theories of how the energy is generated.

The Fate of the Universe: Different models predict different fates for the Universe. In some, gravity continues to slow the expansion rate and the Universe becomes static. In other models, the force of gravity is strong enough to overcome the expansion. After reaching its maximum size the Universe would contract and end in a Big Crunch. Still other models predict that the expansion rate will accelerate and the Universe will continue to grow in size forever.

In 1997, advances in telescope technology enabled astronomers to look further back into the Universe’s history than previously possible. Their stunning results turned cosmology on its head. While most theoretical models predicted that the expansion of the Universe would continue to slow, the expansion rate is actually accelerating. There is no explanation from classical physics to explain this observation. The acceleration indicates that gravity (which slows down the expansion) is counterbalanced by a mysterious repelling force. Physicists call this mysterious force dark energy.
(Read more on page 42)

Teaching ACTIVITIES

Primary

The Language of Astronomy

Whilst not exactly science lessons, it is interesting to investigate how words associated with Astronomy are used in everyday life.

1. In groups, ask your students to brainstorm a list of as many words or phrases as possible from everyday life that involve Space in some way e.g. Mars Bar, over the moon etc. Perhaps you could have a mystery prize for the group that comes up with the longest list?
2. In groups, ask your students to type an astronomy word such as 'comet' into Google search. What results do they get? Part of this exercise could include two discussions:
   a. How do you make sure that you get astronomical results for 'comet'?
   b. Why would an astronomy word be used in another context? For example, why would a type of aircraft be called 'Comet'? What impression are the manufacturers trying to convey by using that name?

Mind mapping the Universe

Working in groups of four, ask your students to produce a mindmap on a overhead transparency showing the relationships between the following components of the Universe: Milky Way Galaxy, Universe, comet, asteroid, star, nebula, Moon, Sun, Solar System, Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus and Neptune. For experts: Write a word on each linking line to explain the relationship.

Address an envelope for your place in space.

John Smith, 12 Travellers Way, My Town, Australia > Planet > Solar System > Galaxy > Local Group > Cluster > Super Cluster > Universe. Ask your students to find the specific names for each step along the way to the edge of the Universe (e.g. Australia is on the planet Earth.)

Middle School

Cosmic Calendar

Your students can develop a visual aid to help them comprehend the vast time scales of the Universe.

http://www.astrosociety.org/education/astro/act2/cosmic.html has excellent step-by-step instructions on how to build a cosmic calendar that begins with the Big Bang and continues until the present day. The activity is also available in a print-friendly version that can be handed out to students.

Associated with this activity at: *http://www.astrosociety.org/education/astro/act2/cosmic3.html#spinner* is a 'Cosmic Spinner' that can be constructed to help find information to enter on the calendar. There is also a printable 'Cosmic Calendar Math', which assist students with the calculations needed to make their scaled time-line.

Imagine the Universe – Gamma Ray Bursts

http://imagine.gsfc.nasa.gov/docs/teachers/gammaraybursts/gammaraybursts.html has downloadable posters for use in the classroom.

http://imagine.gsfc.nasa.gov/docs/teachers/gammaraybursts/starchild/starchild_full.pdf is a 40-page booklet with information about the electromagnetic spectrum in general, and gamma rays in particular, followed by a series of simple activities which will appeal to more able junior students and lower secondary students.

Middle School – Upper Secondary

The Universe Adventure

http://universeadventure.org/ is an excellent website to use for Astronomy and Cosmology lessons. It has a guided sequence of reading, with animations and questions to test knowledge acquired at each step throughout the website. The concepts are simple to begin with and become increasingly complex as the participant moves through the material. Expect your students to 'peel off' as the concepts become too difficult for them. However, if you are looking for a differentiated sequence of lessons on Astronomy, this site is well worth a look. The *Universe Adventure* also provides a variety of supplementary resources to bring Cosmology into the classroom. Click on *http://universeadventure.org/index/teachers.htm* to find activities, worksheets, and quizzes in doc, pdf or rtf formats.

Upper Secondary

The Hidden Lives of Galaxies

http://imagine.gsfc.nasa.gov/docs/teachers/galaxies/galaxies.html has posters and student activities accessible directly from the Internet. *http://imagine.gsfc.nasa.gov/docs/teachers/galaxies/imagine/imagine_book_2009.pdf* is a downloadable 60-page booklet with information about galaxies and their contents as well as a series of student activities. These are designed for Year 9 upwards and should be suitable for most upper secondary students.

Imagine the Universe – Gamma Ray Bursts

http://imagine.gsfc.nasa.gov/docs/teachers/gammaraybursts/gammaraybursts.html has downloadable posters for use in the classroom.

http://imagine.gsfc.nasa.gov/docs/teachers/gammaraybursts/imagine/imagine_full.pdf is an excellent 43-page booklet that provides information about gamma ray bursts and includes a series of hands-on activities for the classroom. The activities are suitable for more able Year 9 and10 students, as well as senior secondary students.

The Composition of the Universe

If your students are still asking for more information, refer them to this site!

http://www.metafilter.com/79066/Composition-of-the-Universe is a one-hour YouTube video. Topics covered include ordinary matter, the standard model, dark matter, dark energy, string theory, supersymmetry, and the expanding Universe.

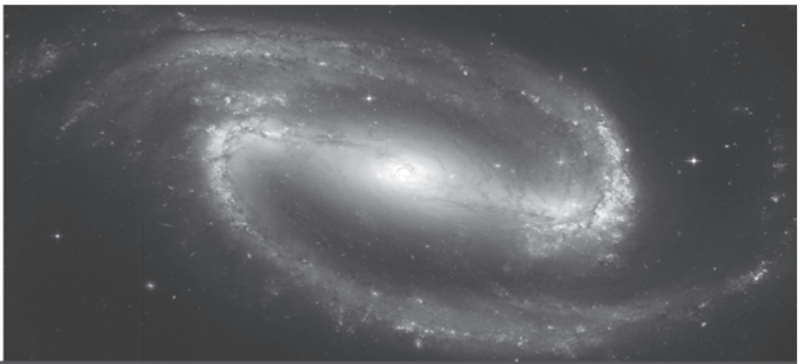
Alternatively, *http://map.gsfc.nasa.gov/Universe/* has a booklet on the *Cosmology of the Universe* that can be downloaded as a 37-page document. Recommended for more able students and teachers only.

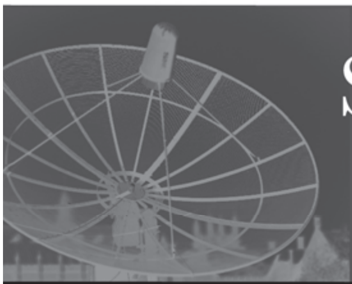
More Animations

http://podcasts.swinburne.edu.au/itunesu/ has a link to some short but useful podcasts. To launch any one of these, first open your iTunes program. Need the program? There is a link to use for a download. Alternatively, use the link below to go directly to the index:

http://deimos3.apple.com/WebObjects/Core.woa/Browse/swin.edu.au.1547787534 has several short movie animations that can be viewed via iTunes U.

The University of Sydney





Study the Universe at SIfA

the Sydney Institute for Astronomy

School of Physics

TALENTED STUDENT PROGRAM (TSP)

The TSP offers students challenging extra material and research projects right from first year. Jie-Lei Zhang (far left) studied high-velocity hydrogen clouds in her first-year TSP project.

"Measuring the thickness of the galaxy using high-velocity hydrogen clouds was mind-blowing!"

WORLD-CLASS RESEARCHERS

Bryan Gaensler was in the first intake of TSP students in 1992. Now he is a world-famous professor of astrophysics supervising his own TSP students.

He studies extreme astrophysics; the most distant, faint, bright or magnetic things in the universe.

SIfA operates two observatories, SUSI in Narrabri and MOST near Canberra and is a key part of a strong community of astronomers in Sydney.

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CHAPTER FOUR

21ST CENTURY ASTRONOMY

The Crab Nebula is one of the strongest radio-wave radiation sources in the sky. At the heart of the nebula is a rapidly spinning neutron star or pulsar.
Image: Caltech/Passachof/Malin

While Astronomy may be an ancient science, astronomers in the 21st century are using technologies and applying theories and laws that were undreamt of only 100 years ago. Albert Einstein's Theory of General Relativity (1916) expanded understanding of gravity and gave a better understanding of the Universe.

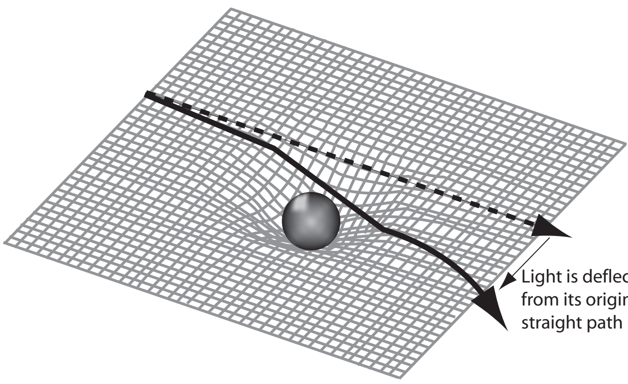
Enter Einstein with more about gravity

Spacetime is the combination of the 3-dimensional space we live in plus time. According to the Theory of General Relativity, spacetime can be visualised as a rubber sheet that is deformed by any object which has mass or energy. This deformation is called curvature of spacetime. All the stars, planets and particles in the Universe cause spacetime to curve. The amount of curvature caused by any one object is proportional to its mass and energy.

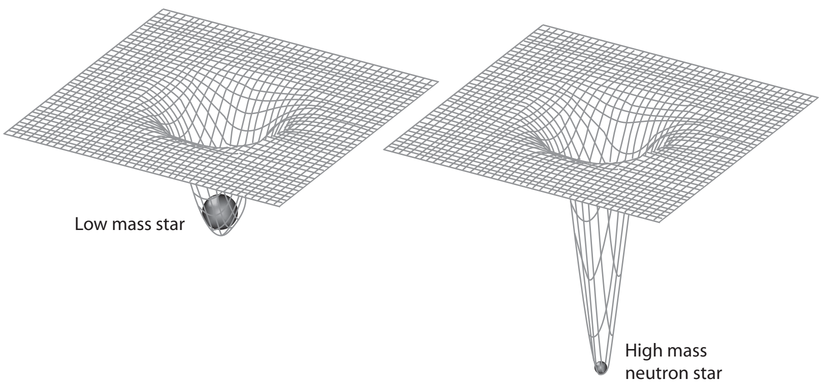
Einstein's theory also predicts that objects such as spinning, superdense neutron stars, collapsing and exploding stars, and black holes, emit gravity waves, which move unseen through the Universe, subtly distorting the world around us in terms of both space and time.

Although these waves have so far gone undetected, astronomers have seen their effects. A *pulsar* is a rotating neutron star that emits radio-wave radiation in regular bursts. When a pulsar is paired up with another star, the pulsar gradually tracks an ever-smaller orbit. The orbital energy it loses matches the energy that the Theory of Relativity predicts the pulsar will emit as gravity waves.

Just as light carries information about a star's surface to Earth, gravitational ripples in spacetime will bring astronomers invaluable clues about the interiors of stars and the nature of gravity itself.



Light travels along the curved space taking the shortest path between two points. Therefore, light is deflected toward a massive object! The stronger the local gravity is, the more the light path is bent



Graphic from http://www.astronomynotes.com/relativity/s3.htm

General Relativity: Einstein described gravity as a warping of space time around a massive object. The stronger the gravity, the more spacetime is warped

Black Holes - The Physics of the Extreme

A black hole is a super-dense region of Space that has a gravitational field so strong that matter and radiation are unable to escape. The only way to detect a black hole is to observe its effect on the surrounding environment.

THE SCIENCE

The existence of black holes was first proposed in the 18th century, based on the known laws of gravity at the time. Einstein's Theory of General Relativity (1916) refined our knowledge of gravity, and predicted that if enough mass is concentrated in a small enough region of spacetime, the spacetime curvature can become infinite. In this situation, the pull of gravity will become so strong that nothing, not even light, can escape this region. This prediction ultimately led to a greater understanding of what black holes would be like and how they would behave.

Three types of black holes have since been discovered:

- ***Stellar black holes*** have a mass of about 5-100 suns, and form when an extremely massive star, at least 10-15 times larger than the Sun, dies. As a star runs out of fuel, it cools and collapses in on itself, forming a deep gravitational warp.
- ***Supermassive black holes*** are found at the centres of large galaxies and have a mass of more than one million suns. Their origin is uncertain – it is thought they may have formed from the collapse of the dust cloud that formed the galaxy, the growth of a stellar black hole, the merging of several black holes, or by some other mechanism.
- ***Mid-mass black holes*** are smaller than supermassive black holes, but larger than stellar ones. They are found away from galactic centres, disproving the belief that black holes only form at the centres of galaxies. It is thought that mid-mass black holes may form from the merging of several stellar black holes, or the collapse of a superstar. It has been estimated that at least a fifth of the galaxies near Earth have at least one mid-mass black hole.

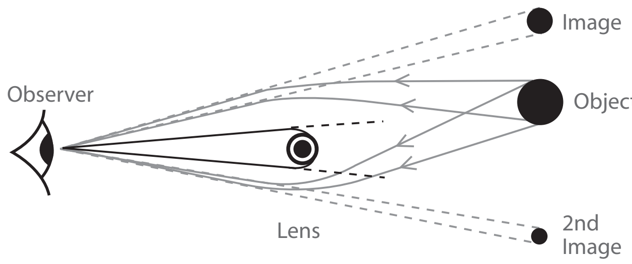
The boundary between a black hole and the interstellar medium is known as the event horizon. Anything that passes beyond the event horizon does not make it out again! A black hole increases in size proportionally to the amount of matter that is drawn into it. They are relatively small – usually only a few tens of kilometres across.

A black hole cannot be viewed directly because light cannot escape it. Effects on the matter that surrounds a black hole infer its presence and size since matter swirling around a black hole heats up and emits radiation that can be detected. Around a stellar black hole this matter is composed of gas and dust. Around a supermassive black hole in the centre of a galaxy the swirling disc is composed of stars as well as gas.

The Space Telescope Imaging Spectrograph aboard the Hubble Space Telescope has provided information that tells scientists how fast the stars and gas are swirling at locations near black holes. With that information, the central mass that the stars are orbiting can be calculated. The faster the stars, the more massive the central object must be. For example, the spectra near one black hole showed a rotation velocity of 400 km/s, equivalent to 1.4 million km every hour! The Earth orbits our Sun at 30 km/s. If Earth moved at 400 km/s our year would be only 27 days long!

Recently an analysis of over 200 separate active galactic nuclei-cores of galaxies powered by discs of hot material feeding a supermassive black hole has shown that they all have a consistent, ordered physical structure that seems to be independent of the black hole's size. The shape of material around black holes has been seen for the very first time – they could be thought of as doughnut holes.

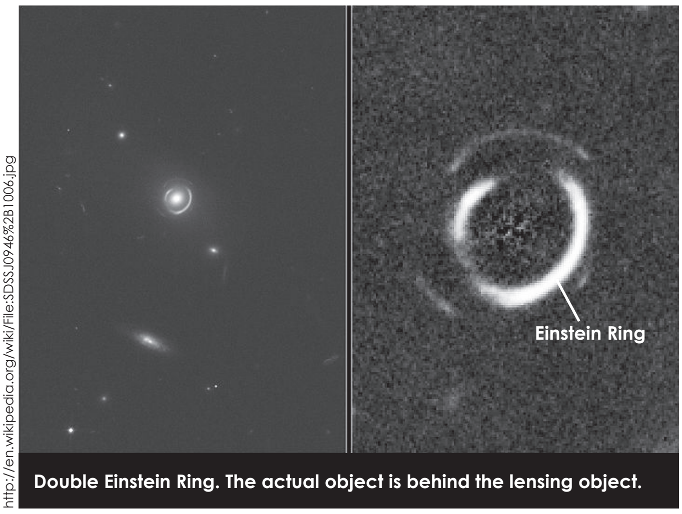
Black holes may also cause gravitational lensing. This happens when the light from a very distant, bright source is 'bent' around a massive object (such as a black hole) between the light source and the observer. This process is one of the predictions of the General Theory of Relativity.



Gravitational lensing. Solid lines indicate the actual path of light from the object.

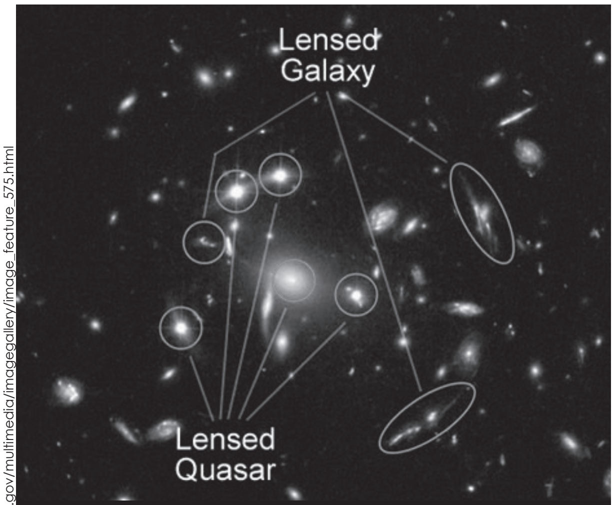
A source image behind the lens may appear as multiple images to the observer. In cases where the source, massive lensing object, and the observer lie in a straight line, the source will appear as a ring behind the massive object. This ring is called an Einstein Ring.

http://en.wikipedia.org/wiki/File:SDSSJ0946%2B1006.jpg



Double Einstein Ring. The actual object is behind the lensing object.

Gravitational lensing can be caused by objects other than black holes, because any very strong gravitational field will bend light rays. Some of these multiple-image effects are probably produced by distant galaxies.



NASA's Hubble Space Telescope captured the above image of a group of five star-like images of a single distant quasar. The gravitational field of a massive cluster of galaxies bends and amplifies light from a quasar that is further behind it.

http://www.nasa.gov/multimedia/imagegallery/image_feature_575.html

Teaching
ACTIVITIES

PRIMARY – MIDDLE SCHOOL

http://imagine.gsfc.nasa.gov/docs/teachers/blackholes/blackholes.html has a downloadable pdf 32-page activity book, which is suitable for more able students in the primary and upper primary years. The booklet is designed to be used with the *StarChild* website developed by NASA for younger children.

George's Secret Key to the Universe, written by Lucy Hawking and Stephen Hawking, is an adventure story where all the adventures are based on real science. It is a journey across Space to learn more about the Universe in which we live and a journey through the laws that govern the Universe to understand more about it. _http://www.georgessecretkey.com/_ is the website associated with the book and has some attractive interactive sections for younger students. A second book *George's Cosmic Treasure Hunt*, also based on real science, was released in April 2009.

MIDDLE SCHOOL – UPPER SECONDARY

_http://hubblesite.org/explore_astronomy/black_holes/_ *Black Holes – Gravity's Relentless Pull* is an excellent interactive resource, which can be used at several different levels. The website explains in great detail the properties of black holes and the various proofs of their existence. It also has many animations, including one that simulates travel towards and even into a black hole. There are Q&A sections and simulated experiments, with alternate paths for students to select. This website is well worth a visit – it has won prizes for excellence in multi-media education.

http://jilawww.colorado.edu/~ajsh/insidebh/schw.html is a movie on what happens as a body moves towards and enters a simple black hole. _http://www.newtonsapple.tv/TeacherGuide.php?id=1156_ has an activity simulating the effect of a black hole. The video at _http://www.newtonsapple.tv/video.php?id=1156_ is well worth watching.

BLACK HOLES AND SCIENCE FICTION

Scientists are yet to find evidence to prove the existence of 'worm holes', which are theoretical openings in spacetime at which two black holes are connected by a passageway. Apologies to the sci-fi die-hards! Perhaps your students could be inspired by the following extract to write a science fiction story with some real science, create models of black holes and 'worm holes', or produce a play or film relating to travel though a black hole? _http://www.astrosociety.org/education/publications/tnl/24/blackhole2.html_

"Black holes and science fiction: A concept as bizarre as a black hole naturally attracts the interest and creativity of science fiction writers. A favourite theme is the use of a black hole as a path to elsewhere in the Universe. Mathematically, a pair of black holes could form a 'bridge'' between two locations in the Universe, but it is not clear how such a bridge could form or survive. A black hole, such as one formed as a stellar corpse, would be rather inconvenient for space travel, because the matter falling into it would be crushed and incinerated by gravitational tidal forces as it entered the black hole. A supermassive black hole would have less extreme tidal forces, but the nearest one is thought to be at the centre of our galaxy – and therefore inconveniently distant! A rotating black hole has more interesting possibilities, because there exists a region called the ergosphere, just outside the event horizon, which has the following property – objects can enter and exit from it (if they could withstand the tidal forces). A spaceship full of rubbish could enter the ergosphere, dump its load into the black hole, and come out with more energy than it entered with – simultaneously solving our energy crisis and pollution problems (at least in theory!)"

UPPER SECONDARY

http://imagine.gsfc.nasa.gov/docs/teachers/blackholes/blackholes.html has a downloadable pdf 43-page booklet *The Anatomy of Black Holes*, with information and activities for Years 9-12. Some of the problems involve the use of mathematical concepts with extension activities for students using graphical calculators. These activities will challenge more able students. _http://imagine.gsfc.nasa.gov/docs/teachers/teachers_corner.html_ has extra videos that can be downloaded, such as *Beyond Einstein* (5.5 MB)

This presentation uses the following videos:

- Gravitational Waves from Orbiting Black Holes,
- Effects of a Black Hole on X-ray Emission,
- Measuring the Temperature of an X-ray.

http://www.phys.unsw.edu.au/einsteinlight/ is an excellent website on relativity. Einstein's Theory of Special Relativity includes electricity and magnetism in a simple, logical extension of the relativity of Galileo and Newton. Its conclusions, including time dilation, length contraction, and E=mc2 have profoundly changed our ideas of time, space, matter and energy. The site offers multimedia modules that give a brief overview of relativity. There are also links to more complete explanations, with or without mathematics.

Dark Energy, Dark Matter

One of the great accomplishments of modern Astronomy has been to establish a complete inventory of the matter and energy content of the Universe. Celestial objects that emit any type of radiation make up only a tiny fraction of the Universe. At the moment, it can be said that almost the entire Universe is made of two components that nobody really understands! The search continues for ways of detecting and understanding this unseen matter and energy.

THE SCIENCE

Dark Matter

The realisation that astronomers could not see most of the Universe began to be accepted in 1967 when Vera Rubin, an American astronomer, observed stars in the Andromeda Galaxy with unexpectedly high orbital speeds. There was insufficient visible mass in the galaxy to account for the high orbital speeds, so it was concluded that the additional mass must be coming from invisible matter.

The rest of the Universe is made of unseen material that does not emit, reflect, or absorb any type of electromagnetic radiation. This 'dark matter' dominates galaxies, making up about 90% of the mass of every galaxy in the Universe. Without it, galaxies (including our own) would be inherently unstable and would rapidly fall apart.

Thus, we can infer dark matter by observing its gravitational effect on visible matter. There are several lines of evidence for dark matter, all which suggest that there is a great deal more mass in the Universe than is visible:

1. **Rotational speed of spiral galaxies:** The mass of a galaxy can be determined by measuring the orbital speed of its constituent matter. For many spiral galaxies the mass of visible matter alone is insufficient to account for orbital speeds.
2. **Hot gas in elliptical galaxies and galaxy clusters:** The pressure of hot gas in a galaxy is balanced by the gravitational pull of its constituent matter. For many elliptical galaxies and galaxy clusters, there is insufficient visible mass to provide the necessary gravity.
3. **Gravitational lensing of background objects:** This is the distortion of light as it passes through a galaxy cluster due to the presence of strong gravitational fields. The level of distortion depends on the gravity, and therefore the mass, of the cluster. The visible mass of the cluster is often insufficient to produce the observed level of distortion.
4. **Fluctuations in Cosmic Microwave Background:** Radiation Astronomers expected that cosmic background radiation would be spread uniformly across the Universe. What they have found, however, are uneven temperature distributions that appear to be caused by interactions with undetectable sources.

What is dark matter? Scientists are still uncertain as to exactly what it is made of, but it is believed to have *baryonic* and *non-baryonic* components. The baryonic component is possibly just normal matter that does not give off much light. There are several theories as to what the non-baryonic material is, but most physicists believe that it is some type of as-yet-undetected subatomic particle.

Dark Energy

Dark energy is a hypothetical form of energy that comprises about 72% of the Universe, and has a type of anti-gravity effect that accelerates the Universe's rate of expansion. Ever since Cosmic Microwave Background Radiation (see page 22) was discovered in 1963, it has been accepted that the Universe is expanding.

However, in 1998, astronomers discovered, through measuring the *red shift* of supernovae, that the rate of expansion is actually increasing. This came as a shock because it seemed logical that the rate of expansion would decrease over time.

Dark energy is also needed to add mass to the Universe. Astronomers have calculated the critical mass required for the Universe to maintain its geometry (flat), but found that the combined mass of baryonic and dark matter is only about 30% of this figure. It is believed that dark energy must account for the remaining 70% of the mass of the Universe.

Astronomers currently have no method for detecting dark energy, either directly or indirectly. They presume it exists because its presence is needed to account for the acceleration of Universe expansion, and discrepancies in the mass of the Universe.

However, when using NASA's Chandra X-ray Observatory, astronomers have clearly seen the effects of 'dark energy' on the hot gases in dozens of galaxy clusters, which are the largest collapsed objects in the Universe. The results show that the increase in mass of the galaxy clusters over time correlates with a Universe dominated by dark energy. These new X-ray results provide a crucial independent test of dark energy, which depends on how gravity competes with an accelerated expansion in the growth of cosmic structures.

Scientists think dark energy is a form of repulsive gravity that now dominates the Universe, although they have no clear picture of what it actually is. Understanding the nature of dark energy is one of the biggest challenges in science today. Perhaps there is a student in a class somewhere in Australia who is being 'switched on' by this Astronomy and will one day find the answer?

Definitions

Baryonic particle: Any of the elementary particles having a mass equal to or greater than that of a proton and that participate in strong interactions; neutrons and protons are examples of baryonic particles.

Red shift: a shift in the spectra of very distant galaxies toward the red end of the spectrum, generally interpreted as evidence that the Universe is expanding.

Teaching ACTIVITIES

PRIMARY

MODELLING AN EXPANDING UNIVERSE

This activity is adapted from:

http://www.pas.rochester.edu/%7Eafrank/A105/LectureXVI/LectureXVI.html The expanding Universe can be demonstrated by the following:

You will need:

Spherical balloon, tape or Blu Tack, five small coins or coloured plastic counters.

Partially inflate the balloon. One person holds the balloon while another person sticks the five coins at equal distances from each other on one side of the balloon. Then inflate the balloon further. What happens?

Point out to your students that extra energy was needed to push the air into the balloon to inflate it further. Energy is also needed in the Universe for galaxies to move apart. The coins will move away from each other as the balloon inflates. As they move the distance between any two of them increases. The rate of this increase is proportional to the distance between the two coins. This is what happens to galaxies in the Universe.

MIDDLE SCHOOL – UPPER SECONDARY

> ***" This is what Science is all about: getting thrown a curveball by Nature and plunging in to find out what's going on."***
>
> ***~ Andreas Albrecht***

The last few decades have brought dramatic changes in the direction of scientific investigation in Astronomy. The emergence of the concepts of dark matter and dark energy have completely revolutionised scientific thinking about the Universe, its structure and its function.

Ask your students to consider the quotation and statement above in terms of:

1. describing how the science of Astronomy has changed from the 20th to the 21st century.
2. the role that improved technology has played in understanding Astronomy.
3. researching and developing short presentations on other 'curveballs' thrown by Nature that have caused scientists to change their thinking, such as:
   a. theories of inheritance
   b. causes of disease
   c. discovery of the atom
   d. evidence for continental drift.

UPPER SECONDARY

THE HIDDEN LIVES OF GALAXIES – DARK MATTER

http://imagine.gsfc.nasa.gov/docs/teachers/galaxies/imagine/act_dark_matter.html has an elegant activity relating to researching dark matter. In it, students investigate one specific topic related to dark matter, using available resources. They are required to organise their findings and present this information in a creative and engaging fashion. There is a student worksheet for download as a pdf which suggests topics to research and provides suggestions for reference sites and ways in which their findings can be presented.

DARK MATTER: PROBING WHAT YOU CAN'T SEE

http://universe.sonoma.edu/activities/dark_matter.html The introductory paragraphs of this complex task state: "Astronomers have known for many years that most of the matter in the Universe is invisible. Identifying this 'dark matter' is a crucial step in understanding the Universe. Dark matter is transparent and emits no light. Theories for its composition predict the scales on which it can clump gravitationally. The gravitational attraction of the dark matter drives the development of structure in the Universe. But if we can't see it, how will we ever learn anything about it? How can we answer such questions as:

- What is dark matter?
- Is there more than one type of dark matter?
- What roles did dark matter play in the formation of structure in the Universe?
- Are there other relics from the early Universe awaiting our discovery?
- Does the dark matter content change as we look back in time?

Astronomers are coming up with all sorts of inventive ways to approach the unveiling of dark matter. We will learn more about this research in later sections, as this lesson looks into how we learn about things we cannot see by using standards-based means such as gravity, rotation, torque, equilibrium of forces, and more."

This task uses a modelling exercise to demonstrate strategies that can be used to work out an unseen problem. There is a hyperlink to a printable lab sheet with detailed instructions For more able students, there is also further information on the mathematics behind the task. If your students would enjoy a hands-on activity that encourages lateral thinking, consider this one.

THE MYSTERY OF DARK MATTER (PERIMETER INSTITUTE FOR THEORETICAL PHYSICS)

www.perimeterinstitute.ca/Perimeter_Explorations/The_Mystery_of_Dark_Matter/The_Mystery_of_Dark_Matter/ Opening the *Teachers Guide* (available as a downloadable pdf) is, in itself, testament to the international nature of Astronomy. The Perimeter Institute for Theoretical Physics in Canada has Dr Damian Pope, a physicist from the University of Queensland as Senior Manager for its Outreach Program. The 56-page booklet is full of simple demonstrations and activities relating to dark matter, with supplementary information on mathematical solutions to some of the physics problems discussed. This booklet can be used in conjunction with a downloadable streaming video. This package is suitable for extension work with Years 9 and 10 as well as with senior physics students.

Astronomer Profile - Chief Scientist for Australia

Professor Penny Sackett

Science is an international human endeavour pushing forward collective human knowledge in all fields including astronomy. Very often scientists also follow their line of research around the world. Australia's Chief Scientist, Professor Penny Sackett, is an astronomer whose career mirrors this process. After gaining a PhD in theoretical physics from the University of Pittsburgh, Professor Sackett has held positions in the USA and the Netherlands before coming to Australia.

So how did a little girl from Omaha USA become Chief Scientist for Australia? Professor Sackett spoke of her early years, "I'd always been interested and curious as a child in understanding the world around me. Originally I thought I would pick a biological field, perhaps medicine. But I had a wonderful teacher in physics in Year 11 who made me realise that physics was much more than pulleys and levers as I'd been previously told, and I think that was a turning point for me. I was lucky to have an inspirational teacher who nurtured my passion for science."

A physicist by training and an astronomer by profession, Professor Sackett's research interests include extrasolar planets where she was an innovative user of gravitational microlensing, a phenomenon predicted by Albert Einstein, to search for planets orbiting distant stars in our galaxy. She has also worked on researching dark matter and galactic structure. In 2006, Professor Sackett was one of a team of 73 astronomers from 31 institutions in 12 countries that discovered a small, cool planet orbiting a star in the inner Milky Way, one of the smallest planets known.

And what brought Professor Sackett to Australia? She was appointed Director of the ANU Research School of Astronomy and Astrophysics at Mount Stromlo and Siding Spring Observatories in 2002, serving a five-year term. Professor Sackett soon experienced the Australian climate at its most destructive when disaster struck Mt Stromlo. The Canberra bush fire of 18 January 2003 destroyed, beyond repair, all five telescopes. The grand 1924 heritage building and extensive Stromlo technical workshop were gutted. Under Professor Sackett's direction, the reconstruction process began. Both the heritage building and a modern high-tech instrumentation centre are now back on Stromlo, and a new telescope called SkyMapper will be commissioned under the dark skies of Siding Spring Observatory soon.

Before taking up her current post as Chief Scientist, Professor Sackett was asked about her most recent interests in Astronomy. She replied, "I've been working on a very big project, the Giant Magellan Telescope which will allow us to see so much more of the Universe. It will help scientists to discover a great deal more about planets orbiting other suns than we currently know. It's really been in about the last 10 or 15 years that we have been certain that there are planets orbiting other stars and we've been very surprised about the diversity of planets that we've found so far. We need a very large telescope in order to be able to observe them directly and to study their composition. The Giant Magellan Telescope would enable us to do this."

"What about the Square Kilometre Array Telescope?" she was asked. Professor Sackett replied, "The largest scientific benefit may be learning more about the Universe when it was young, in particular what's called the Epoch of Re-ionisation. This is the time when the hydrogen, which is the most common element in the Universe, was being ionised: that is the electrons separated from the protons as the first stars lit up in the Universe. This is a remarkable period in the history of our cosmos and the Square Kilometre Array (SKA) would allow us to peer into that early period of our Universe's history and map it out both spatially and in time."

She went on to point out, "That's what this remarkable telescope would do scientifically. Technically, the project will lead to better techniques for massive data transfer. Whilst this technology may be developed for the SKA, the flow-on effort will benefit other aspects of data management recognised by society ."

Since her appointment as Chief Scientist for Australia, Professor Sackett has resigned from her research position at Australian National University, but will continue working with the research students she is currently supervising. "I'm excited and honoured to take up the Chief Scientist role," Professor Sackett said. She said the biggest scientific challenges facing Australia are climate change, water and sustainable energy. "Climate change is clearly an issue that affects both the health and the wealth of the nation going forward. We have to call on all sectors of society for their advice."

When asked about the importance of Science in our society, Professor Sackett replied, "I am a strong advocate for increasing the number of young people contributing to the future of Australia through Science, engineering, technology and innovation. I believe we need to draw on all the human resources skills and resources we can across Australia to encourage both boys and girls to pursue science. Science is about helping people fulfil their aspirations."

Finally, Professor Sackett, "What advice do you have for any student considering a career in Science?" Her reply echoed that of many career scientists. "Science isn't just a subject at school or a job – it's a way of asking questions about the world around us, and learning how to translate the answers when the world speaks back. What could be more wonderful than having a conversation with nature, the world or the whole universe? Keep up your interest in science and one day you might be researching the stars, finding solutions to climate change, or inventing amazing new technologies."

Astronomer Profile

Professor Bryan Gaensler

Professor Bryan Gaensler is an astronomer, former Young Australian of the Year in 1999 and, since 2006, has been an Australian Research Council Federation Fellow in the School of Physics at the University of Sydney, NSW. Born in 1973, his career and exceptional talent has already taken him around the world.

Q. How did you get into Science and particularly into Astronomy?

A. As soon as I began to read as a young child, I became fascinated by books on dinosaurs, Space, geology, and the human body. I was also quite good at mathematics at school, and so the calculations and measurements associated with science came pretty naturally to me. I loved the idea of having a job in which I would often not know how things would turn out, or what I would be working on next.

One of my biggest fears as a child was being bored and running out of things to do. I found Astronomy especially comforting and attractive, because I realised that Astronomy would never be boring or that astronomers would run out of things to discover.

Q. What excites you most about Astronomy?

A. Astronomers ask some of the most important questions that we can ask: Where do we come from? How does the Universe work? Are we alone? This is what excites me! We tackle questions that humans have no right to even ask, let alone answer! Astronomy makes clear how privileged we are, that we tiny dust mites in an unimportant part of Universe can understand so much of how the Cosmos works and our place in it.

Q. Tell us about your work as an astronomer.

A. Most of my work is in the area of radio astronomy. After a lot of computer processing of the signals collected, we can use powerful mathematical techniques to reconstruct pictures from these data of what the sky would look like if you could look at it with “radio goggles”. So the main skills needed to do my experiments are a fair bit of computing and programming.

Once I have my pictures, I then have to think about what these images are actually telling us. This requires knowledge of physics (especially things like electromagnetism, circular motion, atomic physics and ideal gas laws), mathematics (usually for me this involves trigonometry and some basic calculus) and sometimes a bit of chemistry or geology also.

Q. What are you working on now?

A. A remarkable discovery made by 20th century astronomers was that the Universe is magnetic. At the moment, my main goal is to use powerful radio telescopes to measure an effect called “Faraday rotation”, in which background light is changed when it passes through a magnetised gas cloud. By measuring the Faraday rotation of thousands of distant galaxies, I aim to detect magnetic fields throughout the Cosmos, to reveal what these magnets look like, and to determine what role they have played in the evolving Universe.

Q. What advice would you give to a young person thinking about entering this field of science?

A. If you want to try and answer the hardest questions possible, and if you have a burning desire to truly understand how the world works, then you will find Astronomy a very rewarding career. You will also be given unique opportunities to use some of the most sophisticated technology and equipment ever built, and you will get to travel to observatories all over the world.

I don’t think you need to be especially smart or brilliant to succeed as an astronomer, but you need to be prepared to work hard over many years of university studies. Nobody makes discoveries or thinks up new ideas in an intellectual vacuum so it’s also vital to keep up with the steady stream of discoveries that astronomers all over the world are making.

Q. You are obviously passionate about your work in Astronomy. Do you have any interests outside of Astronomy?

A. I love sport! I enjoy reading history, science-fiction, politics and law and I can’t survive without my iPod! I regard the evening meal as one of the great pleasures of life, and especially crave Indian or Turkish food most nights. I used to have lots of other interests too, but raising a family doesn’t leave a lot of free time!

Q. Do you have a website that you are happy for students to access?

A. My personal WWW page, at *http://www.physics.usyd.edu.au/~bmg* provides many links to popular articles I have written and to news reports about my discoveries.

Astronomer Profile

Minnie Yuan Mao

Minnie Yuan Mao is a 1st Year PhD Student at the University of Tasmania, who is currently based at the Radio Telescope Facility in Narrabri. Her work and studies include frequent trips to Sydney.

Minnie's PhD project involves a region of sky that can be seen at radio, optical, infrared and X-ray wavelengths. By studying galaxies at different distances from Earth, astronomers are also studying galaxies as they were at different times in the Universe! Using this information, Minnie hopes to find out how galaxies were formed.

Minnie actually started off in a Science/Law degree. She said, "Thankfully, I saw the light (literally) and decided that while law was not the career for me, astronomy most definitely was!" She followed up her science degree, when she majored in Astronomy, with a year of honours and now she is doing her PhD.

Minnie was asked what led her to study Astronomy. Her answer echoes that of people from all eras in the history of humans. "I've always loved the night sky – there is something grand and mysterious about it all." Minnie continued, "When I got to university I discovered that astronomy was a comfortable intersection between maths and physics with plenty of scope for imagination!"

Minnie went on to describe the excitement of astronomy and the vastness of the Universe. She said, "The Universe is so big, it takes light billions of years to travel across it. This means that every time we look at the sky we are seeing into the past – it's a real-life time machine! Astronomy is quite literally the study of life, the Universe and everything!"

Minnie was asked, "As a mentor, what advice would you give to a young person thinking about entering this field of science?" She replied, "People are always telling me how difficult it is to get a job in astronomy. But hey! Challenges are what make life fun! I have only just started on the journey to becoming a full-grown astronomer but so far the adventure has been awesome. My only advice here is that if you are passionate about astronomy and you want to be an astronomer then you should go for it!"

So what sort of person becomes an astronomer? Does Minnie have other interests? She answered, "I love lots of things such as Latin dancing, bushwalking and chocolate ice-cream. One of the perks of astronomy is that you get to travel. I can't wait to wander around the globe seeing amazing sights, meeting fascinating people and eating tasty foods!"

Find out more about Minnie Yuan Mao at *http://www-ra.phys.utas.edu.au/~mymao/*

Associate Professor Stuart Wyithe

Associate Professor Stuart Wyithe is a Queen Elizabeth Research Fellow, at the School of Physics, University of Melbourne. His academic journey to become an astronomer included a BSc with Honours, majoring in Physics. At this level, he began his studies in gravitational lensing. After beginning his PhD at Melbourne, with extended study at Princeton University, Associate Professor Wyithe continued his work in gravitational lensing, but also studied eclipsing binary stars.

As with many other successful scientists, Associate Professor Wyithe credits a teacher with raising his interest in Science. He said, "I became interested in astronomy at school, especially the astronomy club run by Robert Hollow." (see acknowledgements on inside front cover).

Professional scientists invariably have a passion for their work and Associate Professor Wyithe is no exception. He says, "Astronomy is exciting because studying astronomical objects at great distances equates with looking back in time due to the finite speed of light. Fields of astronomy, particularly cosmology, therefore have a historical flavour. We would like to understand how the Universe came to look the way it does."

When asked to describe his work, Associate Professor Wyithe answered, "My primary research interests lie in the field of quasar formation and re-ionisation in the early Universe. In particular, I am interested in the evolution of the earliest galaxies and how this evolution may be studied with the next generation of radio telescopes. I also work in the field of gravitational lensing. Specifically, I study problems in quasar microlensing, and the statistical properties of gravitational lensing by galaxies and clusters of galaxies."

Associate Professor Wyithe goes on to explain, "Over the past decade astronomers have obtained a detailed understanding of the gravitational evolution of structure in the Universe. Sometime during the first billion years of the Universe's history, galaxies formed within this structure. Unfortunately we don't yet understand when these galaxies formed or what they looked like. My primary interests in the first generation of galaxies are part of the field trying to address these questions."

Associate Professor Wyithe was asked, "What advice would you give to a young person thinking about entering this field of science?" He replied, "Astronomy is a very exciting field which tries to answer fundamental questions about our Universe. By studying Astronomy students also learn very practical skills, particularly in technical and computing areas. There are many examples of these skills being transferred into areas like bioinformatics and climate modelling."

For relaxation, Associate ProfessorWyithe leaves the office, computers and telescopes for equally challenging pursuits. "I like to go rock climbing and snowboarding," he said. For more information about his work as an astronomer, go to

http://astro.ph.unimelb.edu.au/~swyithe/Site/Welcome.html

ASTRONOMER PROFILE

GREG FORBES

Greg Forbes is a Senior Scientist for QED Technologies Inc. Although this company is based in Rochester, NY, USA, Greg works from a home office in Sydney.

Greg was asked to describe his work. "My basic research relates to theories and models for the propagation of light. Some of the more interesting parts of this relate to reconciling the very different models associated with ray and wave theories. Ray models are simple and familiar, but it is oftentimes a challenge to understand how they can describe wavelike phenomena so accurately. My work is aimed at getting a better understanding of these connections, and then using that to advantage in various applications."

Greg's expertise is in understanding the propagation of light and in applying mathematical methods to real problems. He was asked if there were any practical applications of this work.

He replied, "Oh, Yes! Like any human endeavour, science involves a community. My colleagues and friends whom I've met along the way have created opportunities for me to work in areas that I wouldn't have thought possible!"

Greg's work helps in the technological side of astronomy. For example, the systems that he has worked with others to develop are used to polish and measure the large optical surfaces that are essential for astronomy.

"My applied research involves the development of processes and algorithms that are then implemented in software for computer-controlled machines to polish and measure optical surfaces. So, while I don't work directly in astronomy, it is hard to imagine not being excited about further knowledge of our place in the Universe and any new astronomical clues about the nature of this place that we find ourselves in."

Greg was asked to explain how mathematics was involved in polishing optical surfaces. He explained, "The polishing work is largely a blend of applied and numerical mathematics where the goal is to determine motions of a polishing tool so that it will correct the shape error on an optical surface."

Greg went on to explain, "The overall time should be minimized while respecting speed and acceleration limits on the six motors (that move and rotate the tool) and finishing up with an acceptable residual error including tool marks.

The conceptual difference between this and, say sanding a table surface to be flat, is that you get no continuous feedback: the measurements happen only before you start and after you're done. It's like working blindfolded, so you must know your tool well and it must be worthy of your trust in order to set it loose on what may literally be a million-dollar surface!"

Challenging work indeed!

As Greg said, "Things get even more interesting when, say for segments of astronomical primary mirrors, the surface must be good more or less all the way out to the edge.

My work on measuring the shapes of optical surfaces is for the development of systems that are accurate to small fractions of a wavelength of light, and even down at the nanometre level for next-generation optics in systems that print computer chips. This involves accurate modelling of light propagation in the associated optical measurement systems."

What about very large mirrors? Like so many current technologies, all these activities rely on high-performance computers to let scientists create unprecedented capabilities.

Greg explained. "I worked to develop systems that measure a surface by measuring overlapping patches all over its face, and then fusing this information together to determine the overall shape. Another area of my work is to develop methods to support optical designers so that they can ensure that the systems they propose can be manufactured and tested cost effectively by using our current technology."

Greg's experience has led to his role serving on the NASA's Product Integrity Team overseeing the integration and testing of the replacement for the Hubble Space Telescope. The new system, called the James Webb Space Telescope, is an enormous collaborative multi-billion-dollar effort over many years to put a telescope in the cold of space to see aspects of the Universe that cannot be observed from the ground.

Finally, Greg was asked for advice on pursuing a career in science. His reply was similar to many received from career scientists. "Discovery can be a pure thrill. Regardless of how well known an idea is in the broader community, when you find something out for yourself, even as simple as a different way of understanding something, or an application of some idea in a new context, it can be a real delight. The joy of such discovery can be carried through school and university, and throughout life. I have been lucky enough to carry it into a career path," he said.

Greg went on, "In my experience, science gets much more interesting and satisfying the further you take it. If you have delighted in the taste of discovery and are attracted to any sort of science, I'd strongly encourage you to pursue it: it just gets better."

Further resources

The World Wide Web has some excellent Astronomy resources available for use with groups from preschool to post compulsory secondary school. Many resources have been identified throughout the body of this resource as suitable for specific purposes. The four resources below will enrich any studies of Astronomy.

Stellarium – download and use without the need for Internet access.

Stellarium is available from www.stellarium.org and offers the opportunity to bring a planetarium into your classroom. There really is no substitute for the real thing but unfortunately organising a class to view the night sky can be fraught with problems, especially if the weather is inclement. Enter *Stellarium* that shows a realistic 3D simulation of the night sky on your computer screen!

Stellarium is a free GPL software (40Mb) that renders realistic skies in real time with openGL. It is available for Linux/Unix, Windows and MacOSX. With *Stellarium*, you see the night sky just like you were outside looking up with your eyes, binoculars or a small telescope. The program can show the sky based on your current geographical location or any other place on Earth – all the major cities across Australia are included but the option also exists to add your own co-ordinates into the software.

Stellarium includes a default catalogue with more than 600,000 stars, images of nebulae and the Milky Way, as well as planets and their satellites. You can click on each object to view the name, distance and other details and also zoom in for a closer look. Other features include very realistic atmosphere, sunrise and sunset simulations, star twinkling effects and shooting stars, skinnable landscapes, constellations for eleven different cultures, night vision mode and more. You can even change the ground view from the default field to a few other options – including the view from a Mars rover. Load this onto the laptops and the night sky can enter the classroom.

Navigation is simple with a series of horizontal and vertical toolbars to guide users. You can move about the sky at will, zooming in on objects of interest at any point in time. The program also allows you to simulate movements by going back and forth in time at different speeds. For example, you could watch the transit of Venus when Captain Cook sailed the Pacific!

Suitability: all ages with guidance

Day and Night: views from the Southern Hemisphere – download and use without the need for Internet access.

http://www.tki.org.nz/r/science/day_night/index_e.php

As the front page of this site states: "This interactive resource is designed to clarify students' understanding of why the Sun and the Moon both seem to 'move across the sky' and why the Moon seems to gradually change shape. It has a southern hemisphere perspective, with images, times, cycles, and phases of a theoretical (average) month. However, seasonal variation is not allowed for."

The resource has animations to answer the following:

1. In what direction do we see the Sun moving?
2. What causes the patterns of day and night?
3. How does the Moon's appearance change over a month?
4. What do we see as the Moon orbits the Earth?
5. What is the pattern of the lunar cycle?
6. A challenge: can you complete the lunar cycle?

The activities require the free Macromedia Shockwave Player and there is a direct link on the front page to this free software. Whilst the resource can be used directly from the Internet, this interactive resource can be viewed off-line by downloading and unzipping the 455Kb zip file to your hard-drive. Once the file has been unzipped, open the "index.html" file into your web browser.

Suitability: This resource will be useful to clarify misconceptions in older students but will be of most benefit to younger students.

The World Wide Telescope – Broadband Internet access required

http://www.worldwidetelescope.org/Home.aspx A service free of charge from Microsoft lets students and lifelong learners tour the night sky using high-resolution images from the world's best land- and Space-based telescopes. This program works in the same way as many online mapping tools. It allows users to zoom around on an interactive canvas combining images and data drawn from the world's leading astronomical research organisations. It provides an extraordinary opportunity for anyone to explore the planets, Sun, Solar System and beyond.

Choose from a growing number of guided tours of the sky by astronomers and educators from some of the most famous observatories and planetariums in the country. Feel free at any time to pause the tour, explore on your own (with multiple information sources for objects at your fingertips), and rejoin the tour where you left off.

You do have to have a good speed of connection to really capitalise on the program's benefits but reasonable downloads do allow most of it to work. The World Wide Telescope comes as a 20MB download and requires a fairly recent computer with at least 1Gb of RAM. It only works on the Windows operating system so Mac users will need to instal a version of Windows to use the program. The content requires the Adobe Flash Player and a browser with JavaScript enabled.

The service goes well beyond the simple browsing of images. Users can choose which telescope they want to look through, including the Hubble Space Telescope, the Chandra X-Ray Observatory Centre, the Spitzer Space Telescope or others. They can view the locations of planets in the night sky – in the past, present or future. They can view the Universe through different wavelengths of light to reveal hidden structures in other parts of the galaxy. Taken as a whole, the application provides a top-to-bottom view of the science of Astronomy.

Suitability: all ages with guidance but middle school and upper secondary students will derive most benefit.

Astronomy Images – Internet access required

http://www.davidmalin.com/index.html is the place to start if you simply wish to show your students the beauty of astronomical images. There are many sets of images to observe but it is worth directing your students to those from the Anglo-Australian Observatory as each image has text to describe the image. Students can be learning more about the complexity of the Universe as they tour the site.

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