Student activities

The Big Bang Theory

Background information
The Big Bang theory was developed in the early 1900s. It states that about 15 billion years ago an explosion caused the expansion of matter and radiation into space. The explosion was the beginning of space and time as we know it. Seconds after the explosion, energy was converted into particles and anti-particles (i.e. electrons and positrons). Within minutes, traces of hydrogen and helium nuclei were created. Millions of years later, stars and galaxies began to form. The chemical reactions in stars created all the other elements found in the Universe today.

Technology now exists to look at the sky by focussing on forms of radiation other than light. As a result we have gained a different perspective and have increased our knowledge of the Universe. Since the sky was first viewed using microwaves in 1965, it has been found that the Universe is filled with microwave radiation. This is now known to be traces of radiation coming from the remnants of the Big Bang. The energy of the Big Bang has been red shifted into microwaves because the Universe is expanding. This light is seen today as the Cosmic Microwave Background Radiation (CMBR) - the ‘afterglow’ of the Big Bang.

The Big Bang theory is based on the General Theory of Relativity, the theory of gravity developed by Albert Einstein. The major observations that support the Big Bang theory are the expansion of the Universe (first seen by Edwin Hubble in the 1920s), the abundance of the different chemical elements seen in the Universe and the detection of the CMBR.

The name ‘Big Bang’ is a little misleading as it suggests that there was a huge explosion in space. Instead, it is better to think of the Big Bang as an expansion. The name ‘Big Bang’ was invented by astronomer Fred Hoyle who was trying to ridicule the theory, but it was so catchy that it stuck.

Albert Einstein, Edwin Hubble, and Walter Adams (l-r) in 1931 at the Mount Wilson Observatory 100" telescope, in the San Gabriel Mountains of southern California. It was here in 1929 that Hubble discovered the cosmic expansion of the universe. *Courtesy of the Archives, California Institute of Technology* http://www.interactions.org/quantumuniverse

Doppler, Hubble, the Universe and Everything

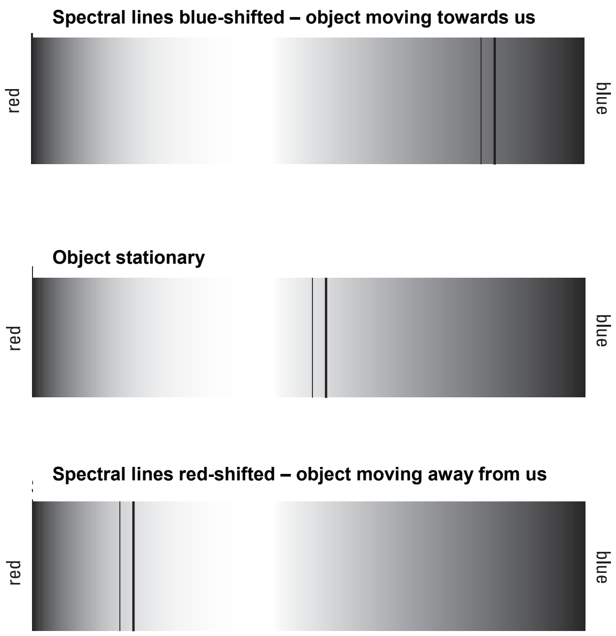
Background information

The Big Bang Theory suggests that the universe is continually expanding. Measurements of the Doppler Effect support this theory. The Doppler Effect is the change in frequency (and wavelength) of a source when it is moving relative to an observer. If the source is moving towards an observer, the wavelength squashes up and the frequency increases. When the object is moving away from the observer, the wavelength spreads out and the frequency decreases. This can be witnessed in everyday life when you hear the siren of an ambulance or police car moving towards you then away from you. The siren sounds higher in pitch (higher frequency) when the vehicle comes towards you and then seems lower in pitch (lower frequency) when it moves away from you.

The same effect can be observed with light. Light can be split up into its spectrum of colours using a prism or thin glass plate etched with hundreds of parallel lines called a diffraction grating. Spectroscopy splits the light coming from stars or galaxies into wavelengths; at each wavelength a peak (emission line) or trough (absorption line) can be detected. Every chemical element has a characteristic spectrum, that is, a particular pattern of peaks and troughs found at specific wavelengths. An instrument that produces a spectrum is called a spectroscope.

Edwin Hubble used the Doppler Effect to determine that the Universe is expanding. Hubble found that the light from distant galaxies was shifted towards lower frequencies, or the red end of the spectrum. This is known as a Red Doppler Shift, or a Red-shift. If the galaxies were moving towards Hubble, the light would have been blue-shifted.

By analysing the spectra of distant galaxies, it has been discovered that, on average, galaxies are rushing away from our Milky Way Galaxy at thousands of kilometres per second. We know this because the spectra of these galaxies are red-shifted and the further out they are, the faster they are found to be moving. This at first seems to indicate that we may be at the centre of the Universe. However, it is thought that no matter where you are in the Universe, galaxies race away from you. Galaxies are not moving through space but space is thought to be expanding. On a smaller scale though, some galaxies are colliding with others due to the large force of gravity between them. The Large and Small Magellanic Clouds are two dwarf galaxies gravitationally attracted to our own Milky Way Galaxy. (The spectra of these two galaxies are blue-shifted.) It is hypothesised that they will eventually collide with our galaxy, although this is billions of years away!



Activity 1: Expanding Universe demonstration

Introduction

A common analogy used to model the Universe is the balloon model. Stickers stuck on the surface of a balloon represent galaxies in our Universe and the balloon itself represents space. When the balloon is blown up, it simulates how space between the galaxies is thought to be expanding. (Note that the galaxies are not all on the outside of the Universe as the balloon analogy suggests.)

What you need

- Black or white balloon
- White or coloured circular stickers
- Black felt pen
- String
- Ruler

What to do

- Draw and label galaxies of different shapes and sizes on separate stickers.
- Blow up the balloon to a diameter of about 22cm, and stick the galaxy stickers all over the balloon.
- Shrink the balloon to about 10cm.
- Use the string and ruler to measure the distances between the labelled galaxies.
- Blow the balloon up fully to demonstrate how space is thought to be expanding. Measure the new distances between the galaxies. Tabulate your results for easy comparison.

Activity 2: Simulating the Big Bang using ICT

Introduction

The previous activity used a very simplistic model to illustrate the Big Bang theory. Today's technology allows us to use far more sophisticated models simply by accessing the Internet.

What you need

- Access to the Internet

What to do

Use a suitable search engine to find a Big Bang simulation. Keep in mind that a simulation should make the concept easier for you to understand. Share your results with the class and decide which of the simulations is most appropriate for your level of understanding.

Some sites to get you started:

http://users.telenet.be/nicvroom/progrm18.htm
http://faculty.washington.edu/jcramer/BBSound.html
http://www.meta-library.net/media/bbang-body.html
http://news.bbc.co.uk/1/hi/sci/tech/4600981.stm
http://www.allaboutscience.org/big-bang-theory-video.htm
http://hubblesite.org/education_and_museums/

Spiral galaxy NGC 3949
http://www.nasa.gov
NASA/ESA/Hubble Heritage Team

Activity 3: Big Bang or ...?

Introduction

The following activity allows students to investigate and compare different theories about the beginning of the Universe.

What you need

- Research facilities and resources (Internet of library)
- Recording materials

What to do

1. Form groups of four or five students.
2. Each group chooses and researches information about one of the theories that describe the beginning of the Universe. Each group should have a different theory.
3. As a group, research the evidence that supports your theory.
4. Present the case for the validity of your theory to the class. This could be done in character to reflect your theory.
5. The class should then vote on which theory was best supported and best presented. You might like to agree on the assessment criteria you could use to judge each group.

Some theories to examine:

- Steady State
- Big Bang
- Quasi-Steady State
- Cosmic Inflation
- Religious Cosmology
- Metaphysical Cosmology

Whirlpool Galaxy M51
http://www.cbc.ca
(NASA, ESA, Hubble Heritage team)

Some websites to get you started (search 'Cosmology'):

- American Institute of Physics: http://www.aip.org/
- British Institute of Physics: http://www.iop.org/
- AllAboutScience.org: http://www.big-bang-theory.com/
- CALResCo: http://www.calresco.org/cosmic.htm

Activity 4: The Universe in a year

Background information
Represent the 15 billion year history of the Universe as dates on a calendar:

The Calendar of Time

January	**1**	**Big Bang**
	5	First stars are born
	20	First galaxies form
March		**The Milky Way Galaxy forms**
September		The Solar System forms – The Sun, planets, asteroids, moons
October		**First single celled organisms**
November		**First multi-celled organisms**
December	**19**	**First animals with shells and hard parts**
	20	**First vertebrates**
	21	Life still confined to the sea, seaweed is the only plant
	22	**First signs of land plants and animals**
	23	First insects and spiders
	24	**Amphibians dominant**
	26	**Mammal-like reptiles appear**
	27	Dinosaurs abundant, first birds appear
	20	Dinosaurs extinct, increase in diversity of mammals of all kinds
	31	**11:50pm – Anatomically modern humans appear**

What you need
- A3 cardboard or paper
- Current calendar for reference

What to do
Ask the students to:
1. Draw or use a calendar to show days and months, or for a blank calendar go to the following website:
   http://www.eduplace.com/rdg/gen_act/nature/graphics/cal.html
2. Add the bold information from the table above to the calendar.
3. Add drawings or pictures to the calendar to make it more attractive.
   If 15 billion years = one year on this calendar,
   - calculate when the first stars and galaxies formed – add this to the calendar,
   - calculate when our Solar System formed and add this to the calendar,
   - add other significant events in the history of the Universe.

   Hint: Work out what a month, day, hour and minute represent on your Calendar of Time.
4. Find out what class mates have added to their calendars. If they have added the same events, check calculated dates are the same/correct.
5. Now draw and illustrate a timeline showing the main events in the history of the Universe. Calibrate your timeline in millions and billions of years from the present.

Activity 5: Telescopes from the ground up – A computer based activity

Introduction

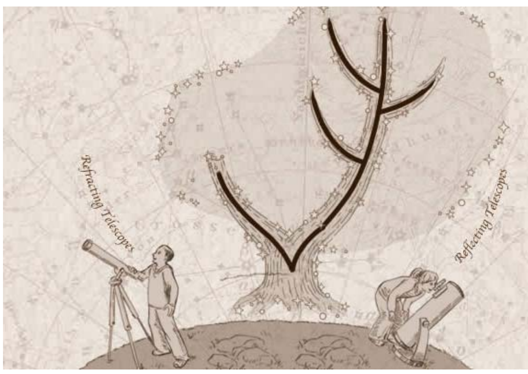
The knowledge of celestial bodies that we have today is based on thousands of years of observation and calculation. Observations were made a great deal easier with the invention of the telescope. The website below traces the history of telescope development and highlights the interplay between technological and scientific advances. Milestones in telescope development are highlighted in the 10 sections called ‘eras’, with specific examples included in the associated ‘telescope pages’. The biography pages provide a glimpse of the inventors and astronomers behind the telescopes. The science of light and telescopes is presented in the section ‘Get to the root of it’.

What you need

- Internet access. Go to the ‘Telescopes from the Ground Up’ web site: http://amazing-space.stsci.edu/resources/explorations/groundup/
- Poster paper
- Printer
- Writing materials

What to do

- Work through ‘Telescopes from the Ground Up’ independently or in pairs. Note the different topics relating to telescopes and the science and history behind their development.
- In pairs, decide on a topic about telescopes for a poster that you will design for students in your group.
- Think about how much text you will include and the number of diagrams that will support your text. Note: You can only use information and diagrams from this website. Any information used must be summarised in your own words.
- Design the poster so that it provides a good summary of a topic from the website and looks interesting when pinned on the wall.



Activity 6: Scientists and the Universe

Introduction

The following activity is designed to help students recall astronomers who helped shape our view of the Universe.

What you need

- Coloured cardboard and glue
- Two copies of the cards, one with name cards and discovery cards cut out separately.

What to do

1. Photocopy the next four pages and provide copies as solution sheets for each player.
2. Photocopy all the cards again but this time, cut out each astronomer's name and their contribution (separately) and stick them on coloured cardboard. The astronomers' names should be stuck onto cardboard that is a different colour from that used for the cards that describe their discoveries/contributions.
3. Separate the cards into two piles – one of cards showing astronomers' names and the other of cards describing their discoveries/contributions.
4. Put all the cards face down so that the astronomers' names are separate from the descriptions of their discoveries/contributions.

   You are now ready to play the memory game.
5. Each player, one at a time, turns over two cards – one of each type.

   If the two cards are a match (use the solution sheet as a reference), that player keeps the pair and has another go.

   If the two cards are not a match, the player puts the cards back face down and the next player has a turn.
6. The winner is the person who has the most correct pairs.
7. Play the game two or three times. Then try to play the game without the solution sheets. Really test your memory!

Extension

Research when the discoveries on the cards were made and then put them in chronological order.

Nicolaus Copernicus,
who proposed a heliocentric Solar System,
Jan Matejko painting, Copernicus Museum Frombork
http://www.spacetoday.org/Europe/EuroAstronomy.html

Edwin Hubble (1889-1953)	Developed a system to classify galaxies by their structure that is still used today.

Edwin Hubble (1889-1953)	Recognised galaxies outside the Milky Way Galaxy and showed that the Universe is expanding.

Edwin Hubble (1889-1953)	Discovered that distant galaxies are moving away from each other. The greater the distance between the two galaxies, the faster they are moving away.

Georges Lemaitre (1894-1966)	Showed that the expanding Universe observed by Hubble was a natural consequence of Relativity.

Arno Penzias (1933-) and Robert Wilson (1936-)	Detected microwave radiation in all parts of the sky with their sensitive equipment and concluded that this was a remnant of the 'Big Bang'.

Arno Penzias (1933-) and Robert Wilson (1936-)	Won the Nobel Prize for physics in 1978 for the discovery that convinced most astronomers that the Big Bang theory was correct.

Nicolaus Copernicus (1473-1543)	Postulated that the Earth spins on its axis, which is why the sky seems to revolve around the Earth.

Nicolaus Copernicus (1473-1543)	Argued that the Earth was not the centre of the Universe, but was one of the planets that revolved around the Sun.

Georges Lemaitre (1894-1966)	In 1931, proposed that at some point in the distant past, the Universe was compressed into a tiny object he called the 'cosmic egg'. This theory later became the Big Bang theory.

Nicolaus Copernicus (1473-1543)	Explained retrograde motion of the planets.

Johannes Kepler (1571-1630)	Showed that planets move in elliptical orbits around the Sun and not in perfect circles.

Albert Einstein (1879-1955)	Showed that acceleration due to gravity and the gravitational field strength are equivalent.

Johannes Kepler (1571-1630)	Hypothesized that the time it takes for planets to orbit the Sun increases with the size of their orbits.

Albert Einstein (1879-1955)	Developed the Theory of Relativity which was later used to interpret Hubble's discovery of the expanding Universe.

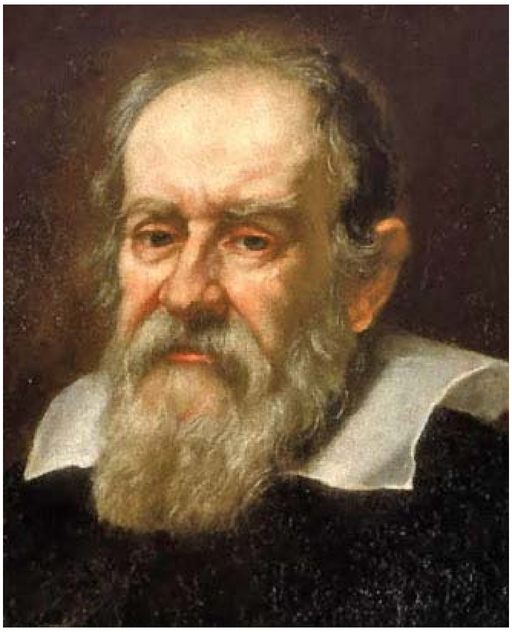
Johannes Kepler (1571-1630)	Showed that planets travel faster in their orbits if they are closer to the Sun and slower if they are further away from the Sun.

Isaac Newton (1642-1727)	His study of light led him to invent the reflecting telescope, which is still the basis of those used today.

Albert Einstein (1879-1955)	Founded the theory that light moves at a constant speed, measured by all observers, whatever their state of motion.
Isaac Newton (1642-1727)	Discovered the universal law of gravitation. He found that the force that pulls an apple to the ground is the same force that keeps the Moon in orbit.
Albert Einstein (1879-1955)	Theorized that energy can be converted into mass and vice versa.
Isaac Newton (1642-1727)	Demonstrated that white light is a mixture of the rainbow spectrum of colours.
Tycho Brahe (1546-1601)	Invented and improved the measuring instrument called the quadrant and used it to accurately plot planets and stars.
Galileo Galilei (1564-1642)	With his telescope, was the first to see mountains and valleys on the Moon.
Tycho Brahe (1546-1601)	Discredited the idea that heavens are static and unchanging.
Galileo Galilei (1564-1642)	Supported the Copernican Theory of the Solar System with his telescopic observations of the phases of Venus and Jupiter's four largest moons.

Tycho Brahe (1546-1601)	In 1572, made a careful observation of a 'new star' (actually a supernova) that appeared in the constellation of Cassiopeia.

Galileo Galilei (1564-1642)	Was the first astronomer to turn the telescope to the sky.



Portrait of Galileo Galilei by Giusto Sustermans
http://en.wikipedia.org/wiki/Galileo_Galilei

Activity 7: Our changing view of the SolarSystem

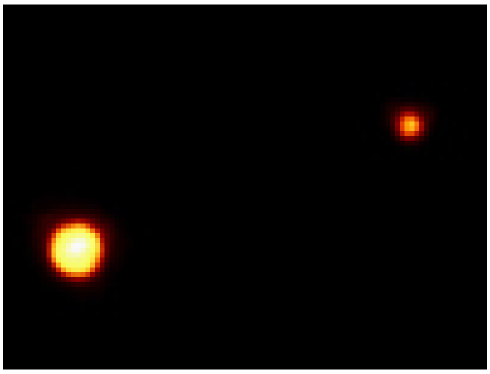
Background information
People have observed the movement of the Sun, Moon, stars and planets for thousands of years. These observations have led to the development of models to explain the movement of these bodies.

What you need
- Research facilities and resources (Internet or library)
- Recording materials

What to do
Ask the students to
1. Research and describe the ways in which our our view of the Solar System has changed. Be sure to include the following:
   - Early geocentric models of the Universe and the epicycle orbits of planets
   - Ptolemy
   - Copernicus and his heliocentric model of the Solar System
   - Galileo's telescopic observations and their relationship to the heliocentric model
   - Modern amendments to the heliocentric model, including the orbits of planets and the definition of planets.
2. Choose an appropriate way to present your research. The following are some suggestions:
   - Poster
   - PowerPoint presentation
   - Website
   - Actual models with written labels
   - Written report.

Extension
Our view of the Solar System changed recently with the formal definition of the word 'planet'. Pluto has been reclassified as a 'dwarf planet'.

Research and explain the reasons for this change.



Hubble image of Pluto and Charon.
www.nasa.gov

Activity 8: Travelling beyond Earth

Background information
The aim of this activity is to discover how to calculate distances in space.

What you need

- Research facilities and resources (Internet or library)
- Recording materials

What to do
Ask the students to:

1. Find out how long it takes to walk from Melbourne Museum to the Bourke Street Mall (without actually walking the distance).
   - List the things that you need to know in order to answer accurately.
   - What resources do you need?

   HINTS: What is the distance from Melbourne Museum to the Mall?
   What is the average walking speed of a student?

2. Find out how long it would take to travel from Earth to our nearest star if we were travelling on the Voyager II space probe.
   - What is the approximate distance to the nearest star?
     How fast does the Voyager II probe travel? (Watch your units!)
   - How long would it take to make the journey?

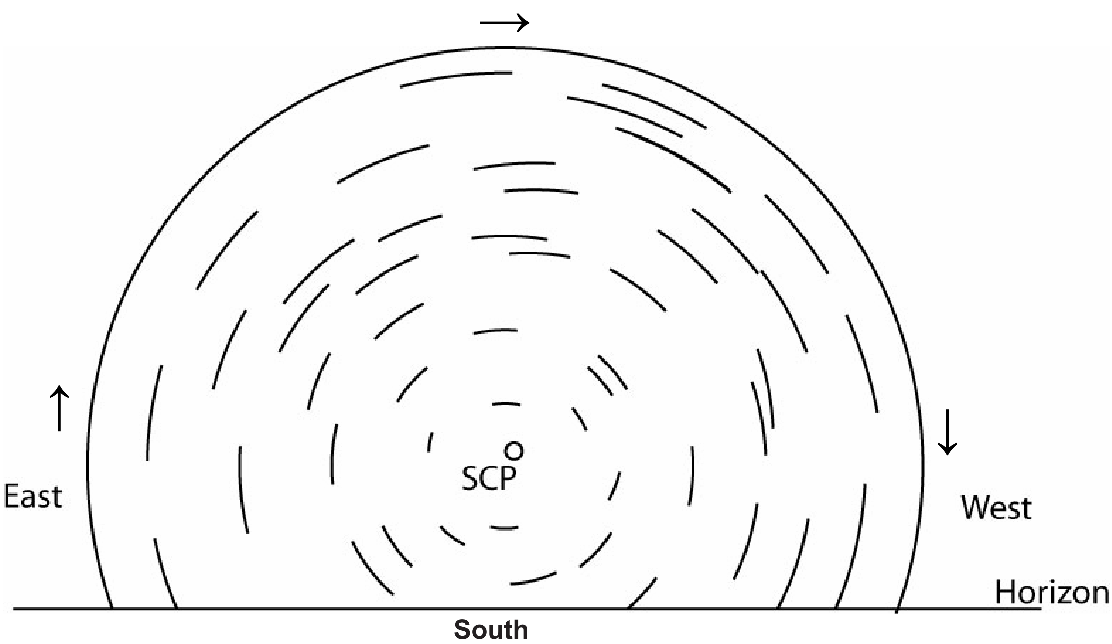
3. Find out how long it takes for light to travel from the Sun to the Earth. The speed of light is 300,000 km/sec.

   HINT: What is an astronomical unit (AU)?
   One AU = 149,597,870.691 kilometres

Artist's concept of Voyager probe. NASA/JPL
http://www.nasaimages.org/

Activity 9: Using the Southern Cross (Crux) to find south

Background Information
One of the things that make finding stars and constellations difficult is that the stars seem to move slowly across the sky during the night, rising in the east and setting in the west, just like the Sun during the day. From southern Australia, if you watch the stars for a few hours, they move like this, if you are facing south:



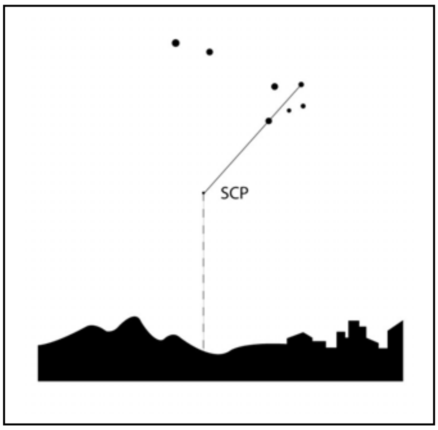
Some stars travel in a large arc across the sky, then disappear below the horizon. Other stars never 'set' below the horizon but trace a circle in the sky. At the centre of these circles is a point called the South Celestial Pole. This part of the sky is directly above the South Pole of the Earth. That is, if you stood at the South Pole, the South Celestial Pole would be directly overhead.

In the Northern Hemisphere, a star called Polaris or the Pole Star marks the North Celestial Pole. There is no star near the South Celestial Pole, so instead, southerners must use the Southern Cross to find South.

Once you are familiar with finding the Southern Cross, it can be used to work out the direction of south at any time of night and at any time in the year. This is because the Southern Cross never sets when viewed from the southern part of Australia.

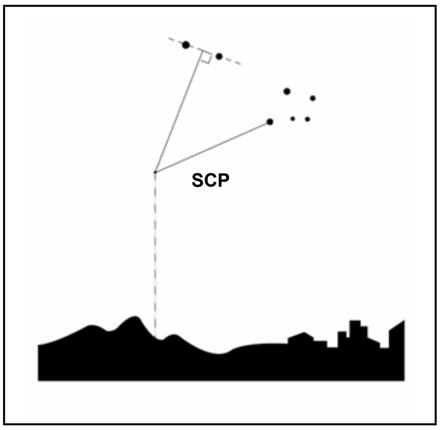
What to do

To find south:
1. Find the Southern Cross.
2. Draw an imaginary line through the long axis of the Southern Cross beginning with the star that marks the top of the cross. (Note: during summer, the Southern Cross is low in the sky and therefore upside-down).
3. Extend the line four and a half times the length of the cross.
4. This will bring you to the point in the sky called the South Celestial Pole.
5. From this point, drop a line vertically down to the horizon. This gives you the direction of true south. Compasses find magnetic north/south, not true north/south – a compass needle will show magnetic south to be 11° west of true south when measured from Victoria.



Alternative method of finding south:
This method involves using the two bright Pointer stars (Alpha Centauri and Beta Centauri) that lie near the Southern Cross in the constellation of Centaurus.

- After step 2 above, draw a perpendicular bisector between the two Pointers, that is, a line starting at the mid-point between the two Pointers and coming out at right angles. This line should cross the line you drew in step 2.
- The intersection of these two lines is close to the South Celestial Pole.



Activity 10: The Southern Cross finder

Introduction
The position of the stars in the sky slowly changes as the Earth rotates on its axis and revolves around the Sun. The position of the Southern Cross therefore varies according to the time of day/night and the time of year.

The following activity explains how to make a Southern Cross finder. The position of the split pin in the diagrams below represents the South Celestial Pole. This an imaginary point that is an extension of the South Pole into the sky. The South Celestial Pole is the point around which all the stars seem to rotate as the Earth turns on its axis and revolves around the Sun. In southern Australia, the Southern Cross never sets below the horizon so can always be seen at night.

What you need

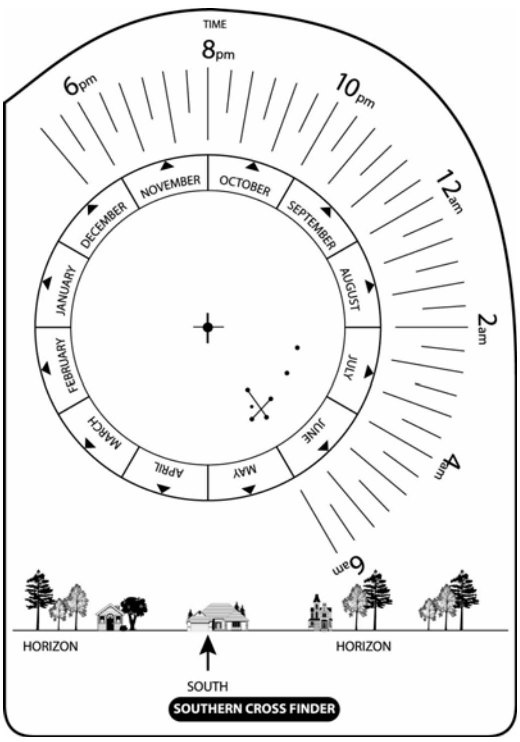
- Scissors
- Southern Cross finder worksheet
- Cardboard
- Split pin

What to do

1. Paste the worksheet onto thin cardboard.
2. Cut out around the dark outline of the two shapes on the worksheet.
3. Use a split pin to join them through the points marked +.

You can now use the Southern Cross finder to show you the approximate position of the Southern Cross at any time of year and at any time of night as viewed from Melbourne.

4. First choose a month and time.
   Example: End of October at 8pm.
5. Line up the line dividing October and November with 8pm as shown in the diagram. The Southern Cross will be in the position shown relative to the horizon.



You can also use the Southern Cross finder in reverse to give you an approximate time.

6. On a clear night, face south to locate the Southern Cross in the night sky.
7. Hold the Southern Cross finder up in front of you so that the horizon on the finder matches the real horizon.
8. Rotate the dial so that the Southern Cross and the Pointers on the finder approximate their position in the real night sky.
9. Locate the approximate time of the month on the dial and read the corresponding time.

The Southern Cross finder worksheet