Activity 11: Measuring your latitude using hand spans

Background information
Latitude is the angular distance of a location north or south of the equator. The latitude of Melbourne is about 38 degrees south. The latitude of a location can be determined using the stars, by measuring the height of one of the celestial poles above the horizon. In the Southern Hemisphere, we use the South Celestial Pole. If you are unfamiliar with using the Southern Cross to find the South Celestial Pole, refer to the relevant activity in this education kit.

In the Northern Hemisphere, the North Celestial Pole is used to measure latitude. The North Celestial Pole is marked by the star Polaris. The angle measured between the horizon and Polaris in degrees at a location in the Northern Hemisphere is equal to the latitude of that location.

You can make approximate angular measurements using your fingers and hands at arm's length. This helps you to measure your latitude, and to find the positions of particular stars and constellations.

Measuring large angles
Outstretch one arm so that it is parallel with the horizon. This are will act as your baseline. Hold your other arm straight up beside your head. Both arms are now at right angles. A 45 degree angle can be made by moving your upright arm to half the 90 degree angle. With practice you can even divide the 90 degree angle into thirds and measure a 30 degree angle.

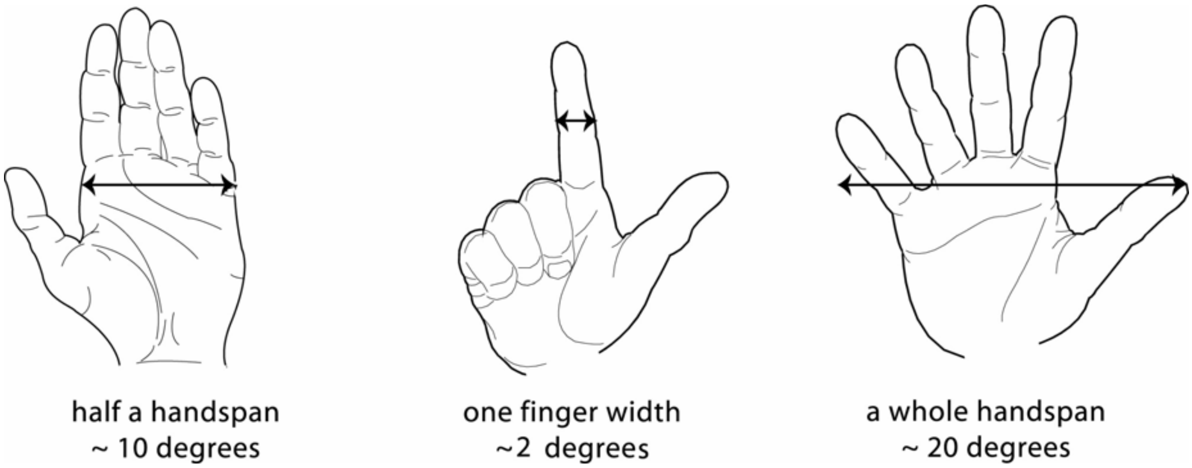
Measuring smaller angles
One finger width at arms length covers about two degrees of sky and can be used to measure small distances between stars.

Half a hand-span (at arms length) is the distance across the knuckles of one hand. It covers about 10 degrees across the sky.

A whole hand-span is an outstretched open hand. It measures 20 degrees across the sky.

Australian latitudes

Melbourne	~ 38 degrees
Sydney	~ 34 degrees
Brisbane	~ 27 degrees
Adelaide	~ 35 degrees
Perth	~ 32 degrees
Hobart	~ 43 degrees
Darwin	~ 12 degrees
Canberra	~ 35 degrees



What you need

1. Star maps or planisphere
   A star map for the current month for observers in the Southern Hemisphere at 7pm or 8pm is available at http://www.skymaps.com/downloads.html or at http://museumvictoria.com.au/Planetarium/DiscoveryCentre/Sky-Maps/

What to do

Ask your student to:

1. On a clear night, find the Southern Cross and use it to find the approximate position of the South Celestial Pole. (An activity in this kit shows you how to do this).
2. Measure your latitude by measuring the distance between the horizon and the South Celestial Pole using hand-spans and finger width measurements as accurately as you can.
3. Discuss how accurate the measurements are. Compare measurements with other students. Who had the closest value to the tabulated value? Find out why.

Optional

4. Use a star map to help you find particular stars and constellations in the current night sky.
5. Research the azimuth and altitude of particular stars or constellations.
   See 'The Local Coordinate System' activity in this kit, and then use your hand or finger measurements to find stars and constellations in the real night sky.

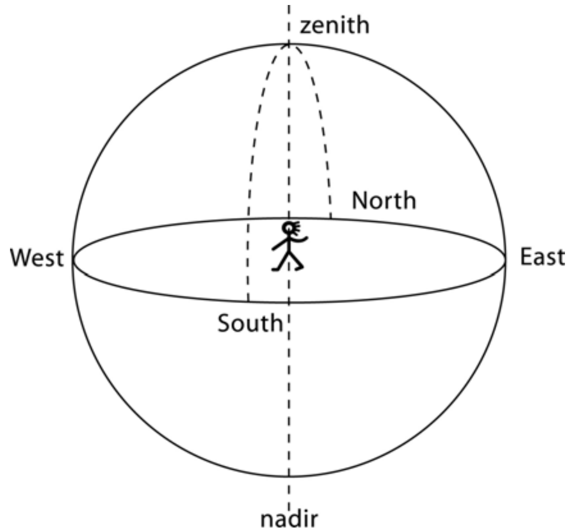
Question

What would your latitude be if you were standing at:

- the South Pole
- the North Pole
- the Equator?

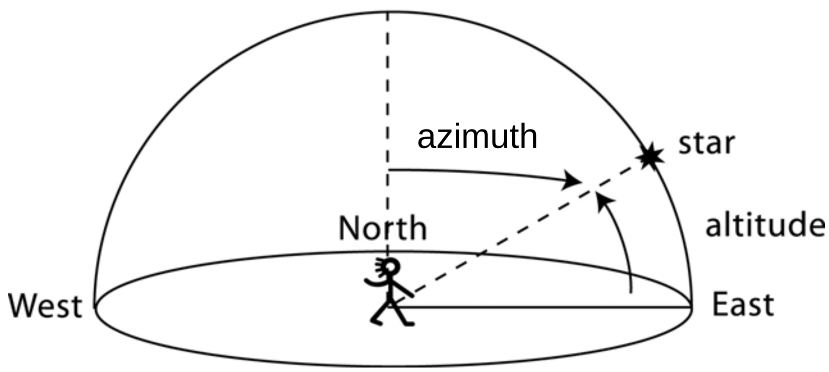
Activity 12: The Local Coordinate System

Introduction



Celestial coordinates are used to find the locations of celestial bodies such as the Sun, Moon, planets and stars just like the terrestrial coordinates locate specific places on Earth. One commonly used coordinate system that astronomers use is the Local Coordinate System. In this system, an object in the sky can be located relative to an individual observer standing on the surface of the Earth. The observer is thought of as being in the centre of (i) a disc with the horizon marking the edges, and (ii) an imaginary sphere with stars and celestial bodies surrounding the observer. Half the sky is above the horizon and half is below the horizon. The point directly overhead is called the zenith. The point directly below the observer is called the nadir.

The position of an object in the sky is defined by two coordinates: azimuth and altitude. Azimuth is measured clockwise around the horizon from North in degrees. Altitude is measured from the horizon up to the object in degrees. Local coordinates are different for each individual observer. As the Earth rotates on its axis and makes its way around the Sun, the objects change position in the sky relative to the observer. The altitude and azimuth of an object in the sky therefore varies with the location of the observer on Earth, the time of day and the time of year.



What you need

2. Star map for the current month for observers in the Southern Hemisphere at 7pm or 8pm: http://www.skymaps.com/downloads.html or http://museumvictoria.com.au/Planetarium/DiscoveryCentre/Sky-Maps/

What to do

Use the star map and the notes above to estimate the altitude and azimuth of the bright stars that are currently in the evening sky. Five stars have been suggested below as a start.

You might like to work in pairs, and then compare your answers with other students.

Star	***Altitude***	***Azimuth***
Canopus		
Alpha Crux (in Southern Cross)		
Alpha Centauri		
Beta Cantauri		
Achernar		

Activity 13: Changing constellations

Background information
Due to the Earth's orbit around the Sun, the constellations seen in the night sky change throughout the year. The constellations Orion and Scorpius are located at opposite sides of the Celestial Sphere (the imaginary sphere of stars that surrounds our Solar System). So as Orion sets in the west, Scorpius rises in the east, and vice versa.

During the Southern Hemisphere summer, when the South Pole of the Earth is pointed towards the Sun, the Earth is positioned between the constellation of Orion and the Sun. This is why Orion can be seen in our night sky during summer evenings. As the Earth continues to move around the Sun throughout the year, Orion is observed low in the eastern sky during the evening from December, sits overhead throughout February, and sinks low in the western sky come April.

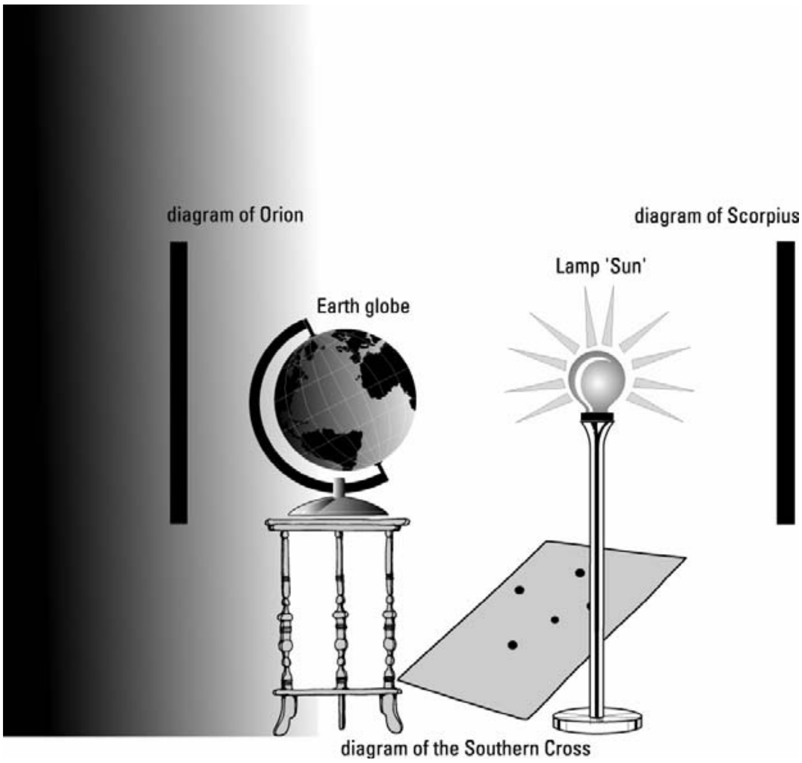
During the Southern Hemisphere winter, when the South Pole of the Earth is pointed away from the Sun, the Earth is positioned between the constellation of Scorpius and the Sun. This is why Scorpius can be seen in our night sky during winter evenings. Scorpius is observed low in the eastern sky during the evening from May, appears overhead during August, and sinks low in the western sky come November.

The Southern Cross is positioned close to the South Celestial Pole, so from Melbourne it can be seen all year round.

The following activity demonstrates how the position of the Earth relative to the Sun causes the various constellations to be visible at different times during the year.

What you need
- Diagrams of the Southern Cross, Orion and Scorpius
- Earth globe (tilted at 23.5 degrees to represent the Earth)
- Blu-Tack
- Lamp with no shade (to represent the Sun)

What to do
1. Blu-Tack the diagrams of Orion and Scorpius on opposite sides of the room. Ensure that both these constellations are lying on their sides.
2. Place the diagram of the Southern Cross about half way between these constellations (on the floor).
3. Place a lamp representing the Sun on a chair or table half way between and about the same height as the two constellations (Orion and Scorpius).
4. Switch the lamp on and darken the rest of the room.
5. Position yourself with the Earth globe so that it is between the Sun and the constellation of Orion. The South Pole should be pointing towards the Sun. Explain to your students that this position represents summer in the Southern Hemisphere (approximately December 22).
6. Allow students to use the globe to identify Australia in the Southern Hemisphere, and some of the countries in the Northern Hemisphere.

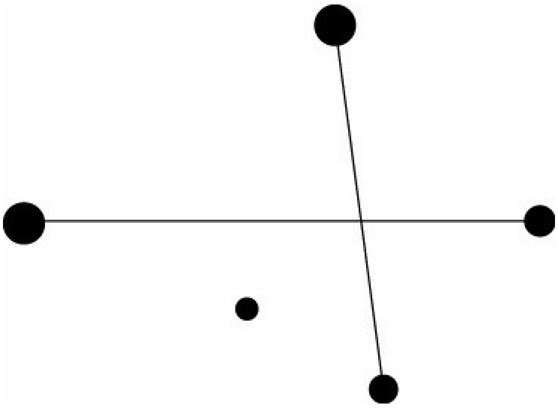


7. As you turn the Earth globe, you should be able to see that Orion is visible in the night sky and that Scorpius appears during the day but is drowned out by the Sun.
8. Ask the students whether the Southern Cross can be seen during summer in Australia. (The Southern Cross never drops below the horizon in Melbourne.)
9. Position the Earth between the Sun and the constellation of Scorpius. The South Pole and all of Antarctica should now be pointing away from the Sun and in 'darkness'. Explain to the students that this represents winter in the Southern Hemisphere (approximately June 22).
10. As you turn the globe, you should be able to demonstrate that during winter Scorpius can be easily seen in the night sky. However, the stars in Orion can't be seen during the day as these stars are drowned out by the light of the Sun.
11. Ask the students whether the Southern Cross can be seen during winter in southern Australia. (It can be seen, as the Cross never sets below the horizon at the latitude of Melbourne).

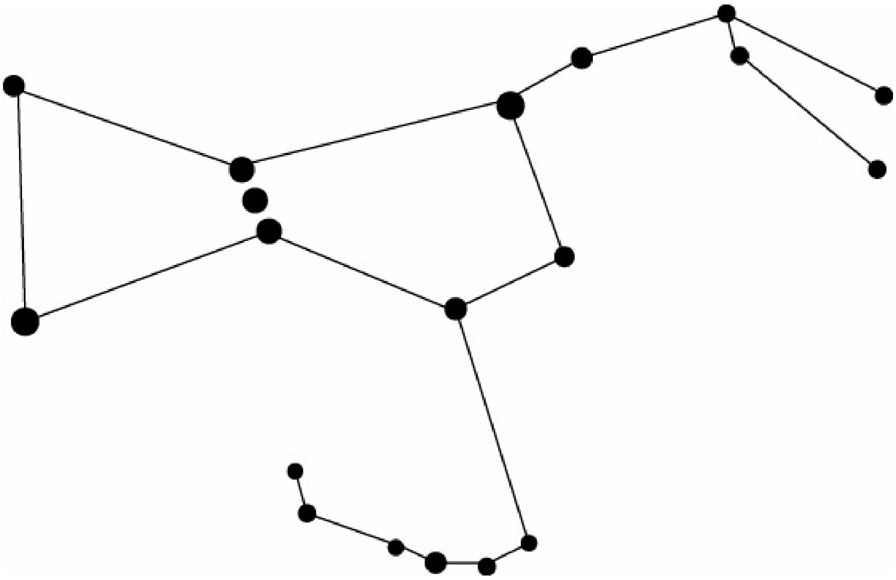
Optional
Ask your students to:
- Investigate whether Orion and Scorpius can be seen during autumn and spring using the same model.
- Research other constellations that are visible during winter or summer in the Southern Hemisphere.
- Look up the word *circumpolar* and name some circumpolar constellations in the Southern Hemisphere. (The use of a planisphere will be useful here.)

Changing constellations

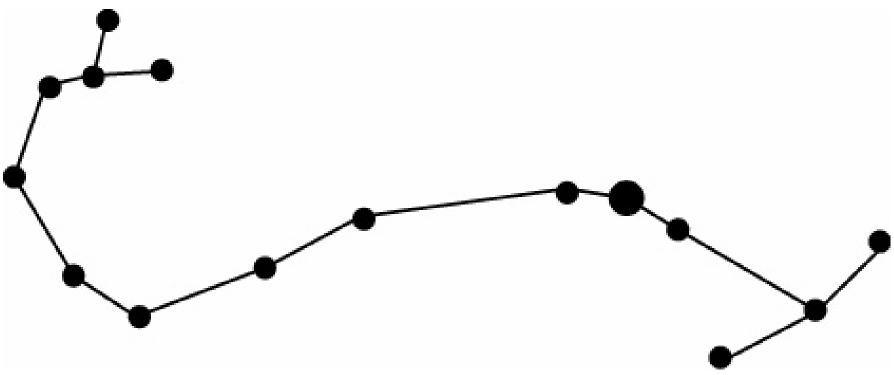
The Southern Cross



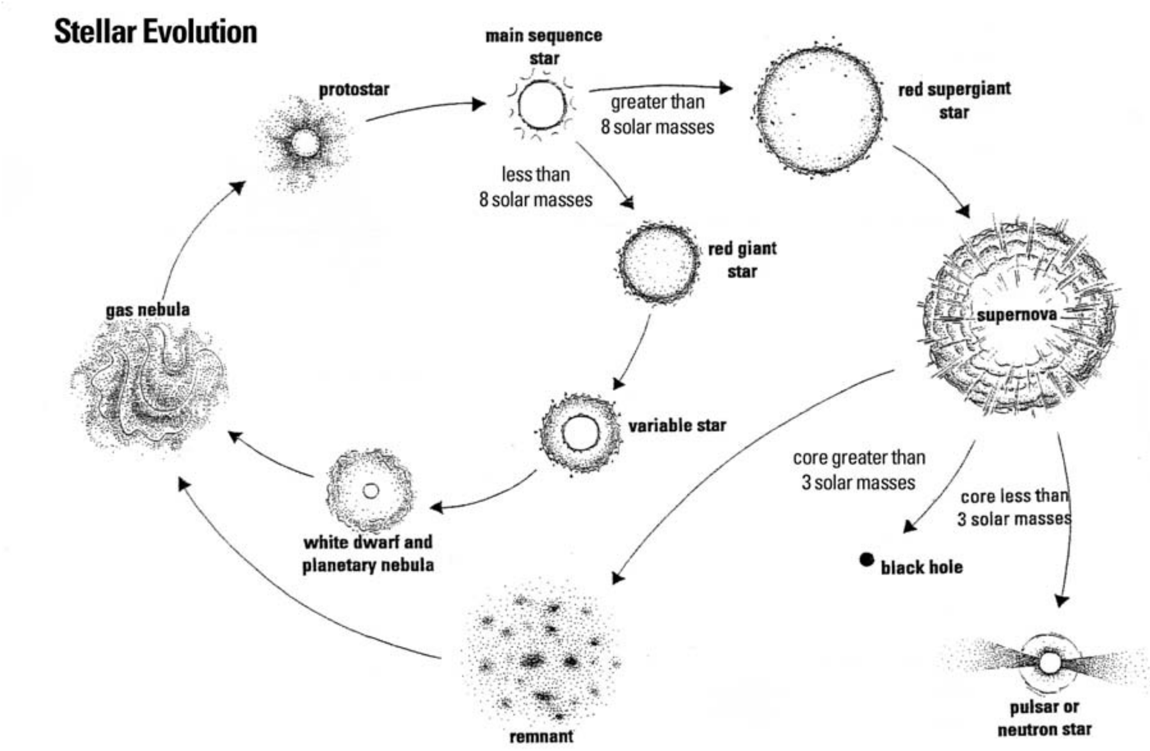
Orion



Scorpius



Activity 14: The life cycle of stars



Introduction
The following information outlines the life cycle of stars with varying masses.
The cycle begins with a gas nebula.

Gas Nebula

Cloud of gas and dust.

Protostar

This is the earliest phase in the life cycle of a star and is dominated by gravity. High density clumps of gas form in the nebula. As more matter is attracted to the clump, its gravity increases and the clump begins to contract. This contraction causes the pressure and temperature at the core to increase greatly. When the temperature reaches about 100 million degrees C, nuclear fusion reactions begin. The protostar stops contracting because the force of gravity pulling inwards is balanced by the force produced by the nuclear reactions pushing outwards. A star is born.

Main Sequence Star

This is the longest and most stable part of a star's life. In the core of the star, nuclear fusion reactions convert hydrogen into helium, producing energy to make the star shine. The pressure produced by the nuclear reactions counteracts the force of gravity. The star is in 'hydrostatic equilibrium'. The gravitational force is balanced by the high pressure gas. To maintain this high pressure, the gas must be kept at a high temperature. The nuclear reactions at the centre of the star ensure that this high temperature is maintained.

Low mass stars (less than 8 solar masses)

Red Giant Star

After the star's core has been completely converted from hydrogen to helium, nuclear fusion ends. The star begins to contract gravitationally, causing the pressure and temperature inside the star's core to rise. Heat generated by the collapsing core spreads to the inner layers of the star. Hydrogen in the inner layers then becomes hot enough to fuse into helium and nuclear fusion reactions begin. These reactions add heat to the star, causing the outer layers to expand, while the core continues to contract. This expansion cools the star, causing it to glow red in colour. Helium in the contracting core begins to fuse to form carbon and oxygen. This new cycle of nuclear reactions halts the collapse of the core.

Variable Star

Some stars then become variable stars. The brightness of these stars varies by up to 10% over a few days to months. The brightness changes because the star is expanding and contracting periodically. Astronomers can use the period of the star (or the time it takes to vary) and its luminosity to measure the distance to the star. The nuclear fusion reactions continue until all the helium in the core has been converted to carbon and oxygen. The nuclear reactions end and the core contracts under the force of gravity. How the star continues to evolve depends on the mass of the star's core.

White Dwarf and Planetary Nebula

For stars with a core that is less than eight times the mass of the Sun, the temperature of the core never becomes high enough to start the next round of nuclear fusion reactions. The core continues to contract until the electrons in the core can't be squeezed any closer together. The star is now considered to be a white dwarf. It has the mass of the Sun but is only about the size (diameter) of the Earth. As the core of the star shrinks to become a white dwarf, the star's outer layers lift off forming a ring of gas around the collapsing core known as a planetary nebula.

Black Dwarf

With no nuclear reactions sustaining the star's energy, the white dwarf will eventually cool down, radiate its last bit of energy into space and fade out. At this stage it is known as a black dwarf. Although the size of this star approximates the size of the Earth, the density is so great that the gravitational pull is 350 000 times the force of gravity on the surface of the Earth. On a Black Dwarf, you would weigh 350 000 times more than you do on Earth.

The Helix Nebula
http://www.nasa.gov/multimedia/imagegallery

High mass stars (greater than 8 solar masses)

Red Supergiant Star

For stars with a mass greater than eight solar masses the contracting core is able to reach a higher temperature, allowing further nuclear reactions to take place. The star begins to resemble an onion with layers of nuclear reactions. In the outermost layers hydrogen is being converted to helium; as we move towards the centre of the star helium is being converted to carbon and oxygen, then carbon and oxygen to sulphur and silicon, and finally sulphur and silicon to iron. Once iron has formed at the core, the run of nuclear reactions is complete. The star cannot use iron as a fuel, so the force of gravity causes the atoms to be squeezed inside the star's core. The atoms break up and neutrons are formed by the fusion of protons and electrons, causing a catastrophic collapse of the core.

Supernova

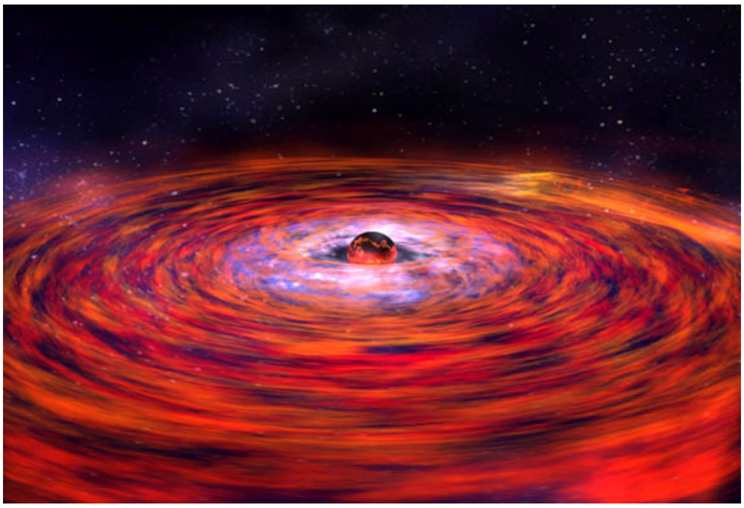
When the core of a supergiant star has been transformed to neutrons, the collapse stops abruptly. This sends out a shock wave that blows off the outer layers of the star in a violent explosion. The energy released is greater than all the energy produced by the star over its entire life-time. After the explosion, new elements are scattered into space, available for the formation of new stars. This explosion is known as a supernova.

Pulsar or Neutron Star

After the supernova explosion, all that remains is the core of the star, completely made up of neutrons. A neutron star is as massive as our Sun but only about 20 km in diameter. A special type of neutron star is the pulsar. Pulsars give off radio beams at their magnetic poles. The pulsar spins like a light house, and the radio beams pass by the Earth producing pulses of radio 'noise'.

Black Hole

If a stellar core is greater than three times the mass of the Sun, the catastrophic collapse which produced the neutron star continues until the core becomes extremely dense and incredibly small. The gravitational pull becomes so great that not even light can escape it. A black hole is formed.



Artist's depiction: hot gas whipping around a neutron star
http://www.nasa.gov/centers/goddard/

What to do

1. Use the information provided on the life cycle of stars to do one of the following:
    - create a role play
    - develop a comic strip
    - write a creative story or play
    - design, then play an educational game
    - make a multimedia or physical model that illustrates or describes the different stages in a star's life.
2. Present your choice to the rest of the class on your own or as a group.

Extension

- Find and print out images of the different stages in the life cycle of stars by searching the Internet. Use these images to display the life cycle of stars as a concept map. Use the diagram of the life cycle provided above as a guide.

  Some useful websites to visit to help you make a start are listed on the Melbourne Planetarium website and on the Hubble Space Telescope sites:
  http://museumvictoria.com.au/Planetarium/
  http://hubble.nasa.gov/index.php
  http://hubblesite.org/

Research

- What will happen when all the hydrogen in the Sun's core is fused into helium? What type of star will the Sun become?
- Is the Sun likely to become a black hole? Explain your answer.
- In groups, find out the different stages the Sun will move through during its life cycle. Present your findings in an appropriate format. Allow other students (the audience) to judge the accuracy of the researched content.
- Use poster paper to illustrate the different stages the Sun will go through during its life cycle, symbolising as much of the process as possible. Try to use very few words in your poster.

Activity 15: A closer look at the Sun

Background information
Our Sun is a medium sized yellow star. Its diameter is 109 times that of Earth and its mass is 795 times as large as the total mass of all the planets in the Solar System. The Sun is the closest star to Earth; it is about 150 million kilometres away. It's so close that it is dangerous to look directly at it with the naked eye or any optical instrument. A safe way to view the Sun is by projecting its image from a telescope onto a screen or white sheet of paper.

The Sun rotates on its axis from west to east (like Earth), taking about 25 days for one rotation. Due to the Sun being gaseous, all of the Sun does not rotate in the same amount of time. The gas at the equator takes about 24 days to rotate once, while rotation at the poles takes about 30 days. The time it takes for the Sun to orbit around the whole galaxy is 225 million years.

Most of what we know about the Sun comes from the energy it radiates. Sophisticated equipment available today allows us to peer into the Sun, revealing its structure, history and even its future.

The structure of the Sun

The Sun is made up of about 95% hydrogen and 1% helium. The other 4% consists of elements like carbon, nitrogen, oxygen, aluminium, sodium, potassium, copper and iron. For the Sun to contain these types of elements suggests that it is made up of gas recycled from a supernova explosion.

Matter at the centre of the Sun is so hot it exists in a special state called plasma. (Plasma is a form of matter that consists of charged particles. The more familiar types of matter are solid, liquid and gas, which are made up of neutral atoms).

The Sun can be divided into three main layers: the interior, the surface layer and the atmosphere. The layers don't have defined boundaries, but merge into one another.

The interior

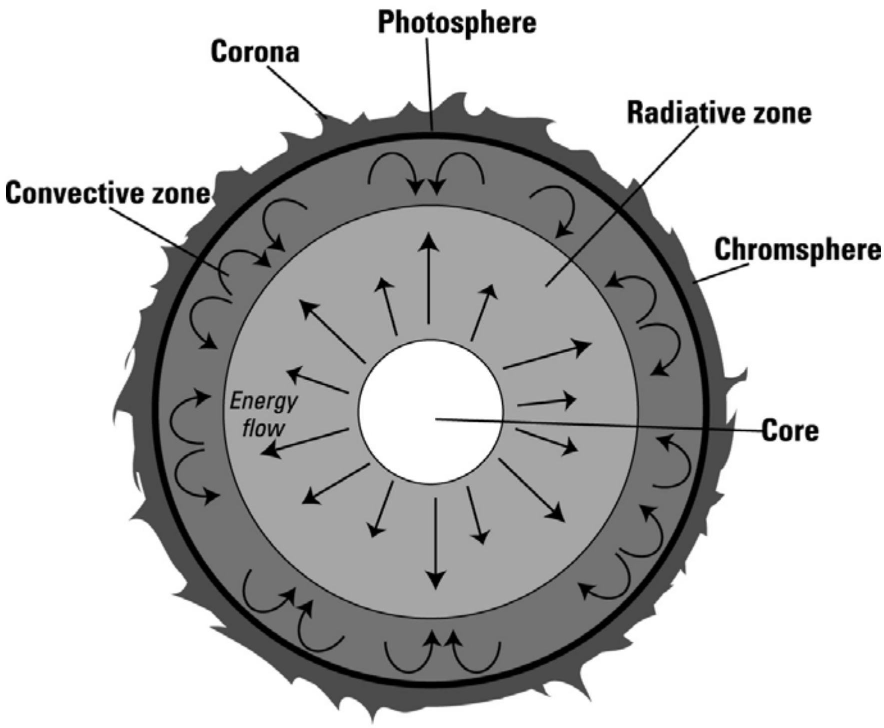
The interior is split into three parts: the core, radiative zone and convective zone. The core is very dense (about 160 times the density of water on Earth) and has a temperature of about 15 million degrees C. The core transfers heat through to the radiative zone via a heat transfer process called radiation. The radiative zone is not as hot or as dense as the core. It is one or two million degrees C cooler than the core and has about the same density as water (on Earth). The next layer, the convective zone, is even cooler and less dense than the radiative zone. In the outer areas of this zone, the temperature is about two million degrees C.

The surface layer

The surface layer is called the photosphere. This is the layer of the Sun that we see from Earth. Sunspots, which are the dark, cooler regions visible on the Sun, appear on this layer. It is thinner than the others layers, and ranges in temperature from about 6 000 degrees C to about 4 500 degrees C on the outer surface.

The solar atmosphere

The Sun's atmosphere consists of the chromosphere and the corona.
The density of the chromosphere is less than the photosphere but the temperature rises to about 100 000 degrees C or more at the top. Scientists can not yet explain what heats the chromosphere to this very high temperature. The corona is even hotter than the chromosphere and varies from about one million degrees C to about five million degrees C. The corona extends millions of kilometres out into space. The corona can be seen during total solar eclipses.



What to do

Ask your students to:

1. Research information about each layer of the Sun. Present a PowerPoint or multimedia report on your findings.

2. Use a five cent piece to represent the diameter of the Earth.
   Calculate the diameter of the Sun on the same scale. Cut a piece of string to represent the radius of the Sun.

   Go outside into the school yard. Tie one end of the string onto a piece of chalk. Ask two students to hold the ends of the string and draw a circle on the ground (like a large compass). You now have a scaled diagram of the relative size of the Sun and the Earth.

   The five cent piece (representing the diameter of the Earth) would need to be placed about 234 metres away from the chalk circle (representing the diameter of the Sun) to represent the distance between the Sun and the Earth using this scale.

Activity 16: What's so special about Eta Carinae?

Introduction
Lying between the Southern Cross and the False Cross is the most luminous and massive star in our Milky Way Galaxy – Eta Carinae. It radiates five million times more brightly than the Sun and is about 120 times more massive. It sheds about two Earth masses each day in its stellar wind. If the Sun gave off this much mass it would be gone in a mere 300 years.

The star lies within a hot cloud of glowing pink hydrogen gas called the Eta Carina Nebula. (Visit the web site http://allthesky.com/constellations/crux/main.html for a photograph of the Eta Carina Nebula, labelled NGC 3372, close to the Southern Cross). Eta Carinae is 7 500 light years away and at present can only be seen by using binoculars. However, back in 1843 it was almost as bright as the star Sirius, the brightest star in our night sky. The reason for Eta Carinae's rapid brightening was a 20 year eruption which threw off enough material to create three Suns.

Using the Hubble Space Telescope, which sits above the Earth's atmosphere, astronomers have been able to obtain images of the star. They have found two bubbles of expanding gas that were thrown out from the star's poles during the 1843 eruption. This material is travelling at 2.4 million km/hr (fast enough for a spaceship to travel to the Moon and back in 20 minutes). You can see the Hubble image of this eruption by visiting the web site: http://apod.nasa.gov/apod/ap060326.html

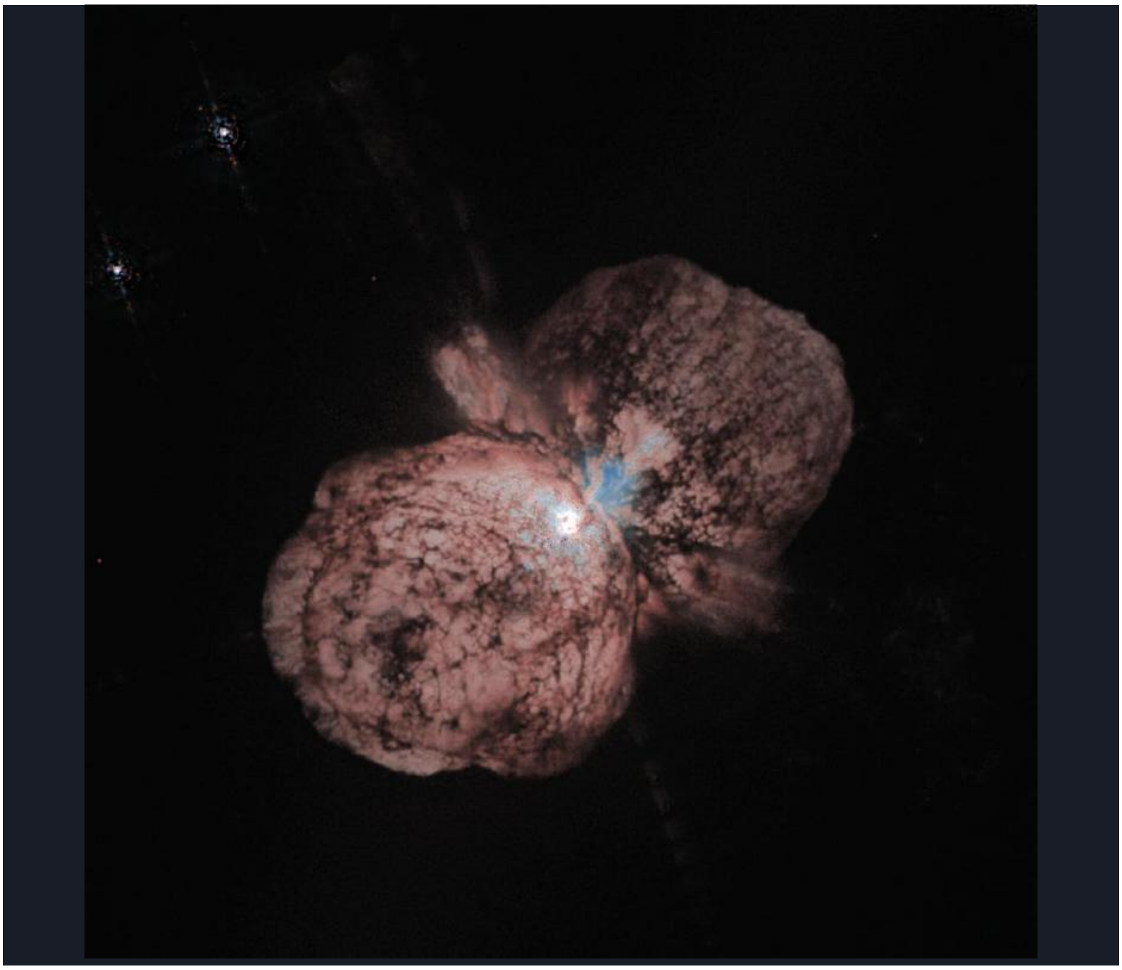
Eta Carinae is a good candidate for the next supernova in our galaxy. On average, a supernova goes off in a galaxy every 50 years. The last supernova in our own Milky Way Galaxy occurred in 1604, just six years before the telescope was invented. That supernova explosion would have given off more energy than the entire Milky Way Galaxy, and the star would have been visible during the daytime. We are long overdue for a supernova and now have a large number of telescopes searching the sky to record images of these violent deaths of massive stars.

Some comparisons with the Sun

Features	**The Sun**	**Eta Carinae**
Mass	2×10^{30} kg	120 times bigger
Luminosity	4×10^{26} W	5 million times brighter
Star type	yellow medium	blue variable
Distance	150 million km	473 million times further
Main gas composition	hydrogen	hydrogen

What to do
Read the information about Eta Carinae (above), and use the Internet to find additional information.

Create a poster or PowerPoint presentation that illustrates the differences between Eta Carinae and the Sun. You should not have to include many words or sentences. Use basic facts and illustrations to emphasise and communicate the major differences between these two stars.



The doomed star Eta Carinae
Photo Credit: Jon Morse (University of Colorado), and NASA
http://hubblesite.org/gallery/album/entire_collection/pr1996023a/

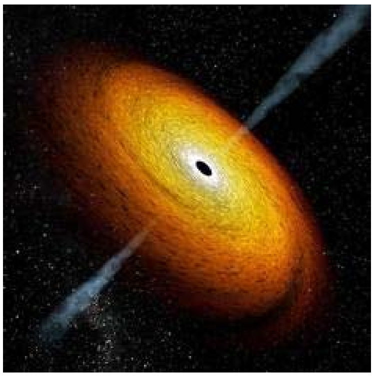
Activity 17: Stellar black holes

Introduction
A black hole is a region of space where gravity is so strong that nothing, not even light can escape. Black holes are formed by the complete gravitational collapse of very massive stars (more than eight times the mass of our Sun). The large mass of these objects is squeezed into a very small space making the gravitational strength of black holes enormous.

The boundary of a black hole is called the event horizon. The event horizon is not visible but once across it, objects are pulled in towards the black hole with no means of escape. It acts like a very strong magnetic field around a magnet. Once a metallic object is in the vicinity of the magnetic field, it is quickly sucked towards the magnet. The radius of the event horizon (in kilometres) is equal to three times the mass of the black hole (in solar masses).

Towards the centre of a black hole, the gravitational pull gradually increases, which produces a gravitational gradient. If an object were to fall into a black hole, it would be stretched by the gravitational gradient. Say you were to cross the event horizon feet first. Your feet, being closer to the centre, would feel stronger gravity than your head. Furthermore, the left half of your body would be pulled towards the right and vice versa. As a result, you would be stretched length-ways and squeezed sideways to form a long thin string of spaghetti. You would be spaghettified before being ripped completely apart.

For a long time, astronomers thought that black holes could never become smaller but could become bigger as they sucked more objects in. The work of Stephen Hawking (physicist) and others has shown that black holes can radiate energy and lose mass. The rate at which these black holes are thought to evaporate is extremely slow – longer than the lifetime of the Universe.



In the following activity you will be able to test your knowledge about black holes by completing the quiz provided.

What you need
- copy of the quiz for each student
- research facilities (Internet or library)

What to do
1. Each student takes a copy of the Stellar black holes quiz.
2. Allow about 10 minutes to answer the quiz.
3. Students form groups of three or four to discuss their answers.
4. Each group is to fill in the quiz again, this time collaborating and discussing their answers. A different coloured pen can be used to mark these answers.
5. The group then separates the statements into two columns – those that the group agrees are correct and those that they believe need further research.
6. Students then undertake the further research that they agree is needed.
7. All groups should then come together and share their answers and research, using the solutions to the quiz provided below.
8. If time allows, students can produce a report summarising the information they have obtained on black holes.

Stellar black holes quiz

Circle true (T) or false (F) for the following statements.

1. A black hole is black because we can't see it. **T / F**
2. Black holes roam around the universe devouring everything in their path. **T / F**
3. The gravity of a black hole is so strong that not even light can escape it. **T / F**
4. Our Earth will become a black hole victim in the next 10 billion years. **T / F**
5. Black holes are formed by the complete gravitational collapse of massive stars about the size of our Sun. **T / F**
6. Red supergiants can progress to become black holes according to the life cycle of massive stars. **T / F**
7. An object can survive a weak black hole beyond the event horizon (the area surrounding the black hole), but nothing can survive all the way to the centre. **T/F**
8. If you were able to compress an object the size of the Earth into the size of a marble, you could (theoretically) produce a black hole. **T / F**
9. Black holes can't suck in other black holes because of their mass. **T / F**
10. Our Sun will become a black hole in the next 10 billion years. **T / F**
11. Black holes evaporate. **T / F**
12. Like stars, black holes rotate about themselves. **T / F**
13. If it were possible for you to get close to a black hole, you would be stretched length-ways and squeezed sideways to form a long thin string of spaghetti, before being ripped completely apart. **T / F**
14. The planet Jupiter has the right ingredients to form a star and is massive enough to eventually form a black hole. **T / F**
15. The star Sirius will eventually become a black hole. **T / F**
16. Black holes can be detected with x-ray telescopes. **T / F**
17. If we could somehow survive the journey through a black hole, we would reach a place where time and space would go backwards. **T / F**
18. The reason why black holes have such strong gravity is because so much mass is squeezed into such a small amount of space. **T / F**
19. Eta Carinae is a massive star in the southern sky that will eventually become a black hole. **T / F**
20. There are two types of black holes: stellar black holes, which form from the death of stars, and super massive black holes, which are found in the centre of galaxies. **T / F**

Solutions to the quiz:

1 TRUE — A black hole is black because it absorbs all wavelengths of light, which makes a black hole virtually invisible. We can't see black holes, but we can detect them by the effect they have on objects around them. For instance, black holes can be detected by X-ray telescopes. The X-ray emission is caused by material from a visible star close to the black hole being pulled towards the black hole and forming an accretion disk. Material closer to the black hole is spinning faster than the material at the edge of the accretion disk. This generates friction, heating the disk to temperatures over 100 million degrees C. Matter this hot emits X-ray radiation. Black holes can also be found if a star is discovered to be orbiting an invisible object that is greater than three solar masses. The invisible object is a likely candidate for a black hole.

2 FALSE — Black holes are like stars in that they are in fixed orbits. They don't 'roam around'.

3 TRUE — The speed of light is 300 000 km/s, which is the speed limit of the Universe. Even at this speed, light is not fast enough to escape the enormous force of gravity of black holes.

4 FALSE — This is extremely unlikely.

5 FALSE — Black holes are formed by the complete gravitational collapse of massive stars with core masses of at least eight times the mass of the Sun.

6 TRUE — Check the diagram showing the life cycle of stars included in this kit. Red supergiants have enough mass to eventually become black holes.

7 TRUE — Yes it is possible for an object to cross the event horizon and survive, if the black hole is weak. If the black hole is weak, its gravitational gradient is weak and it is this gradient that pulls objects apart after they cross the event horizon. However, nothing can survive all the way to the centre (the 'singularity'). It would inevitably be destroyed and become part of the mass of the black hole.

8 TRUE — However, the Earth is not a star and therefore will not collapse as a star can. Theoretically though, if you could squeeze the mass of the Earth into the volume of a marble, you could produce an object with an enormous amount of gravity that you could call a black hole.

9 FALSE — There would be no reason why two black holes could not collide. This is a major area of research involving very complicated computations. The research aims to define what sort of gravitational wave output two colliding black holes would create, so that this could be searched for and detected.

10 FALSE — Our Sun is not massive enough to become a black hole. A star needs to be at least eight times the mass of the Sun to form a black hole.

11 TRUE For a long time astronomers thought that black holes could only grow, as they swallow up matter in their path. The work of Stephen Hawking and others has shown, however, that black holes can radiate energy and lose mass (by quantum processes). It would, however, take longer than the lifetime of the universe for a stellar black hole to evaporate.

12 TRUE There is no direct evidence that black holes rotate. However, the stars from which they form rotate and there is no reason to believe that they don't (due to the conservation of angular momentum).

13 TRUE If you were to fall into a black hole feet first, you would be stretched by the strong gravitational gradient. Your feet, being closer to the centre of the black hole, would feel stronger gravity than your head, while the left part of your body would be pulled towards the right and vice versa. The result is that you would be stretched lengthways and squeezed sideways to form a long thin string of spaghetti before your very atoms were ripped completely apart.

14 FALSE The planet Jupiter does have the right ingredients to form a star but is not heavy enough or massive enough to induce the necessary reactions for a star to form. If the gaseous planet Jupiter had been about 60 times more massive than it actually is, it would have become a small star. Since it is not massive enough to form a star, it certainly isn't massive enough to eventually form a black hole.

15 FALSE Sirius is not massive enough to form a black hole.

16 FALSE The existence of black holes is inferred by the effect on their environment. The accretion disk circling the event horizon can be detected at all wavelengths. See the solution to question one (above).

17 FALSE It is highly unlikely. The equations of Einstein's Theory of General Relativity indicate that it is virtually impossible, but who knows?

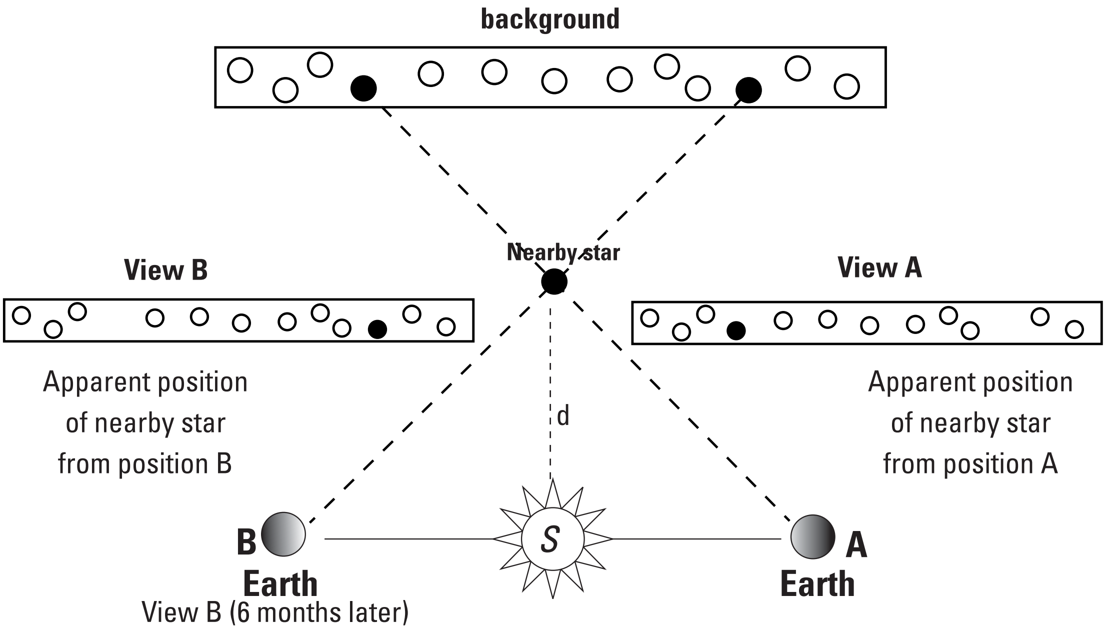
18 TRUE The strength of an object's gravity depends on its mass and radius. The larger its mass and the smaller its radius, the stronger its gravity.

19 TRUE Eta Carinae is the most luminous star in our galaxy, radiating 5 million times more brightly than our Sun. It is probably the most massive star in our galaxy, being 120 solar masses. Eta Carinae may become the next supernova (explosion in the life cycle of very massive stars) in our galaxy. It is definitely massive enough to eventually be a black hole.

20 TRUE There is increasing evidence to suggest that super massive black holes are found in the centres of galaxies (even our own Milky Way Galaxy). Unlike stellar black holes, these black holes have masses around 100 million solar masses. Their origins are still unknown.

Activity 18: Trigonometric parallax

Introduction
Astronomers use a principle called 'trigonometric parallax' to measure the distance of stars.



Nearby stars can be seen to shift against background stars that are much further away. If we look at a nearby star when the Earth is on one side of the Sun and again six months later when the Earth is on the opposite side of its orbit, the nearby star appears to shift against the more distant background stars.

What to do
To demonstrate this effect hold a finger out close to you and close your left eye, then open it and close your right eye. The image of your finger seems to move against the background. Now move your finger further away from you. You should notice that your finger does not move by as much as when it is close to you.

Closing and opening each eye is like having the Earth move in its orbit around the Sun. When comparing the trigonometric parallax of two stars, the one that seems to move the most will be closest to Earth. Astronomers can calculate the distance (d) a star is from Earth (and the Sun) by using simple trigonometric rules.

Activity 19: Apparent and absolute magnitude

Introduction

Apparent magnitude

Apparent magnitude is a measure of an object's brightness as seen from Earth. Hipparchus, a Greek astronomer and mathematician, classifed observable stars so that he would have some indication of their relative brightness. He decided to divide the observable stars he catalogued into 6 groups or magnitudes. The brightest stars were classified as apparent magnitude 1 and the faintest or those at the limit of visibility were classified as apparent magnitude 6. This is why a smaller numerical value of apparent magnitude corresponds to a brighter looking star or object.

Later, when the brightness of stars was measured with a photometer, it was found that the first magnitude was roughly 100 times the sixth magnitude. Mathematically, the difference in brightness between each step is the fifth root of 100 = 2.512. The apparent magnitude is calibrated logarithmically because our eyes identify differences in brightness in a logarithmic way.

Using this scale for other celestial objects, negative numbers were required to describe brighter objects like the Sun. The Sun has an apparent magnitude of -26, a full Moon has an apparent magnitude of -13 and the planet Venus -4. The brightest star in the night sky (Sirius) has an apparent magnitude of -1.5.

Absolute magnitude

Absolute magnitude gives a measure of the true brightness of a star by giving an indication of brightness if the stars were at a fixed distance of 10 parsecs or about 33 light years. Keeping the distance of the star fixed, the brightness or luminosity of stars can be compared. (Most stars are much further away than 10 parsecs).

Example

The Sun appears to us with apparent magnitude of -26 (150 million km away). Alpha Centauri appears with apparent magnitude of 0.02 (4 light years away). If we were to put them both at the fixed distance of 33 light years away, both Alpha Centauri and the Sun would have an absolute magnitude of 4.5 (the same brightness).

What you need
Access to the Internet

What to do

1. Explain the difference between apparent magnitude and absolute magnitude.
2. Compare the apparent and absolute magnitude of stars like Sirius, Alpha Centauri, the Sun, Antares, Rigel.
3. Go to the website: http://antwrp.gsfc.nasa.gov/apod/ap060501.html
   This is a photograph of the Open Cluster NGC 290 or the Stellar Jewel Box.
   a) What might make some of these stars appear brighter than others?
   b) Why are some of these stars different colours?
   c) Now go to: http://antwrp.gsfc.nasa.gov/apod/ap060419.html
   Mars appears much bigger and brighter than the stars. Why?
4. With the use of a number of torches with different brightness and a darkened room, design an experiment for young children aged 10-12 years old to explain the difference between apparent magnitude and absolute magnitude of stars. Include two or three questions that they would need to answer to reinforce their learning.

Activity 20: The Hertzsprung-Russell diagram

Introduction

In about 1910, Ejnar Hertzsprung and Henry Norris Russell independently developed a diagram that was able to summarise the differences between stars by comparing their luminosity, colour and surface temperature. The diagram is called the Hertzsprung-Russell diagram or the H-R diagram. After plotting luminosity and surface temperature of known stars on this diagram, the two astronomers noticed that stars fell into certain groups. White dwarfs formed a group on the bottom left hand side of the diagram. The red supergiants formed a group on the top right hand side of the graph and the red giants covered a region underneath them. Most of the stars were spread along a rough diagonal line from the top left corner to the bottom right corner. These stars were given the name 'main sequence' because of their position on the graph. The Sun is a member of the main sequence group and lies close to the middle of the sequence.

The H-R diagram showed a clear life cycle for stars. The relatively small number of blue and red supergiants and white dwarfs reflects the relatively short time that stars remain in these phases compared to the main sequence phase.

Note that the colour of a star indicates its surface temperature. When an object (black body) is heated, the colour of the light it emits changes from red to orange to yellow to white. (You can observe this using a dimmer switch and incandescent globe).

The following activity will help you become familiar with the H-R diagram. It demonstrates how the diagram can be used to provide information about the life cycle of stars and the characteristics of particular stars.

What you need

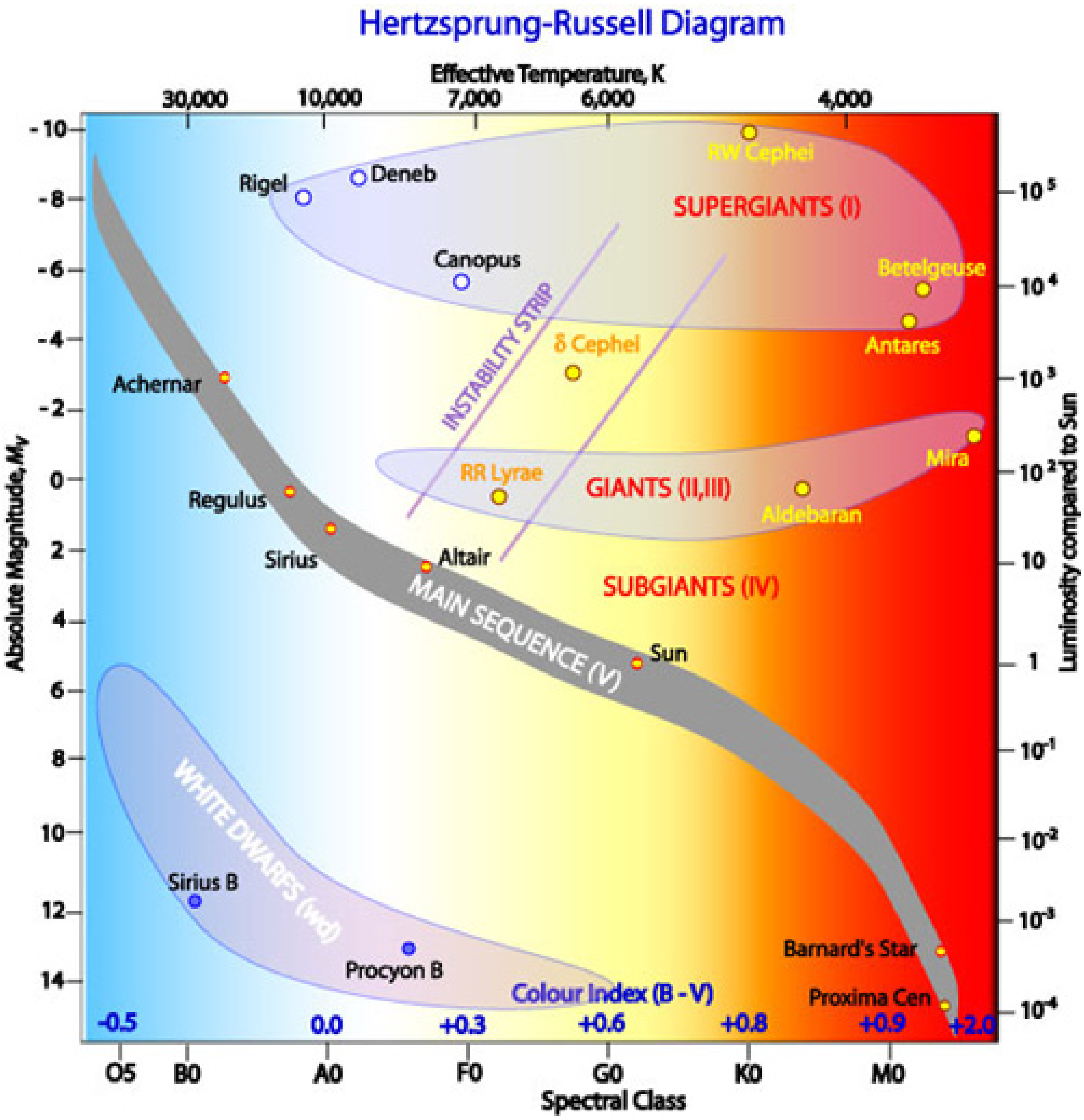
- Copy of H-R diagram worksheet
- Glue
- Coloured pencils
- Scissors
- Pen

What to do

1. Study the notes and Hertzsprung-Russell diagram overleaf.
2. Colour-code the different groups of stars shown on your H-R diagram worksheet.
3. Draw a colour-code key at the bottom of the worksheet to indicate the type of stars that each colour represents.
4. What types of stars are Antares, Betelgeuse, Capella, Sirius, Proxima Centauri, Rigel, the Sun, Formalhaut and Spica?
   On your worksheet, indicate the location of these stars (with their names) in the correct groups.
5. Cut out the diagram and the colour-code key and glue them into your books.
6. Copy and answer the following questions in your book.

Questions

1. What does the H-R diagram tell you about the differences between:
   a) supergiants (like the stars Deneb and Betelgeuse) and white dwarfs (like the star Sirius B)?
   b) red giants (like Betelgeuse and Antares) and our Sun?
   c) blue supergiants (like Rigel and Deneb) and red giants (like Aldebaran and Mira)?
   d) red dwarfs (like Proxima Cen) and white dwarfs (like Sirius B)?
2. Why did astronomers conclude that the H-R diagram showed a relationship between the brightness and surface temperature of stars?
3. Why do 90 percent of stars fall into the main sequence group?
4. On your H-R diagram, draw arrows to show the path the Sun would take in its life cycle from where it is now to the end of its life. You may need to do some research to answer this question.



The Hertzsprung-Russell diagram worksheet