

Astronomy activities for the classroom

Useful astronomy software

Stellarium

Stellarium is a planetarium computer program that is an extremely useful aid to teaching astronomy. The program is freely available from www.stellarium.org and versions are available to run on Windows, Mac and Linux computers. Please see the attached article for a more detailed introduction to Stellarium that also contains some suggestions for using Stellarium in the classroom.

Celestia

Another very useful astronomy teaching resource is Celestia which is a 3D simulation of the local universe. Celestia is also available for different computer platforms and is easy to use. You can download Celestia from <http://www.shatters.net/celestia/>.

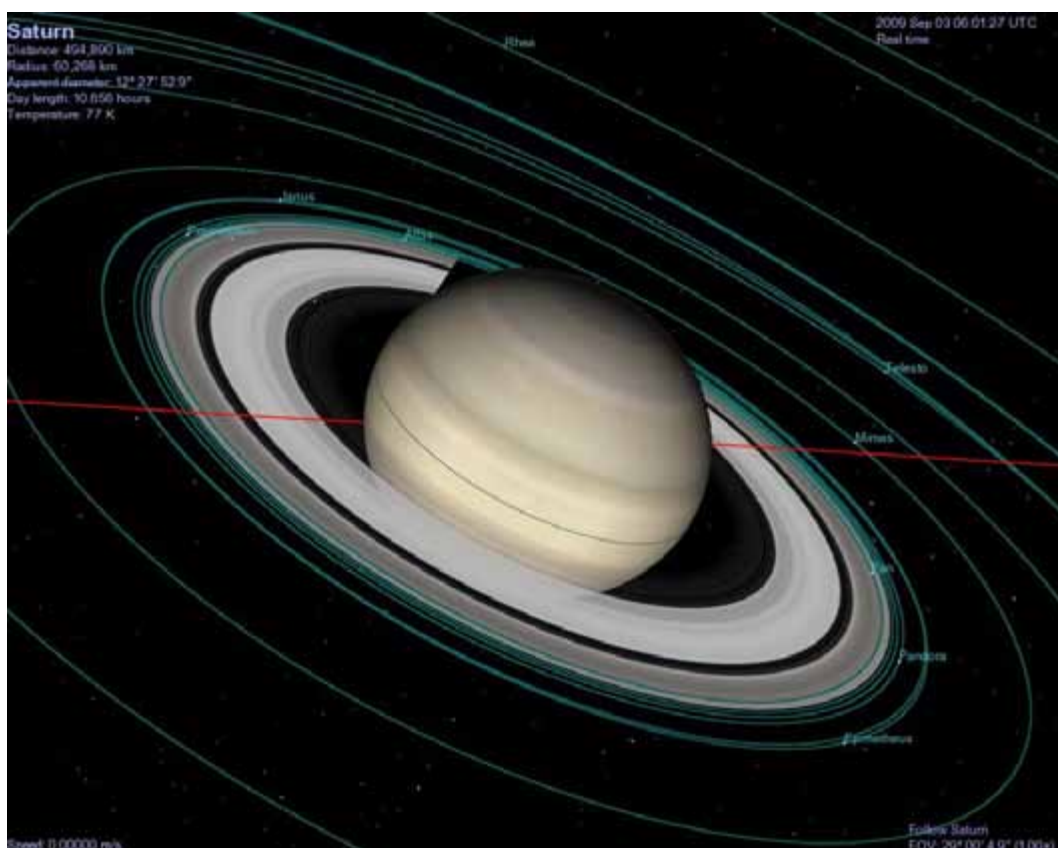


Figure 1. Saturn and Moons as seen on Celestia.

When Celestia is run you can travel to any of the planets in the solar system by typing in the number order of the planet from the sun (Mercury is “1”, Venus “2”etc) followed by “g”. So to fly to Mars type “4g”. Use the right click to view the planet from different directions. Switch orbits on and off using “o”. Switch moons on and off using “m”. Control orbit speed using “l” – faster and “k” slower.

Classroom demonstrations

Tide machine

Most people know that the Moon is connected in some way to the tides on the Earth. People who live on the coast may have noticed that high tide occurs when the Moon is close to overhead. This can be readily understood as being due to the Moon pulling on the oceans. However, there are two high tides 12 hours apart. How can the Moon that pulls up the sea on the side of the Earth closest to the Moon push the sea on the other side of the Earth out? The reason for the ‘second bulge’ can be demonstrated using a ‘Lazy Susan’, as shown in the diagram.

A glass of water is first placed in the centre of the Lazy Susan and the table spun. The water level will remain level. When the glass of water is placed away from the centre of rotation and the table spun, the water level will bank up on one side. This side will always be on a line joining the centre of the glass to the axis of rotation and will be on the side of the glass furthest away from the axis of rotation. A ball can be placed on a straight line passing through the axis of rotation of the Lazy Susan and the centre of the glass. Note that the ‘Moon’ and the bulge stay on this line. (N.B. As the glass rotates the liquid will tend to stay where it is. This is still a mystery but is thought to be due to the entire universe acting as a frame of reference for the liquid.).

The Earth and Moon both orbit around the common centre of mass (known as the *barycentre*) between the Earth and Moon, the rotation period being 27.4 days, i.e. a sidereal month. The oceans on the opposite side of the barycentre are being ‘flung’ out and so rise up. At the same

time the Earth is rotating on its axis once every 24 hours and so rotates 'under' the bulge.

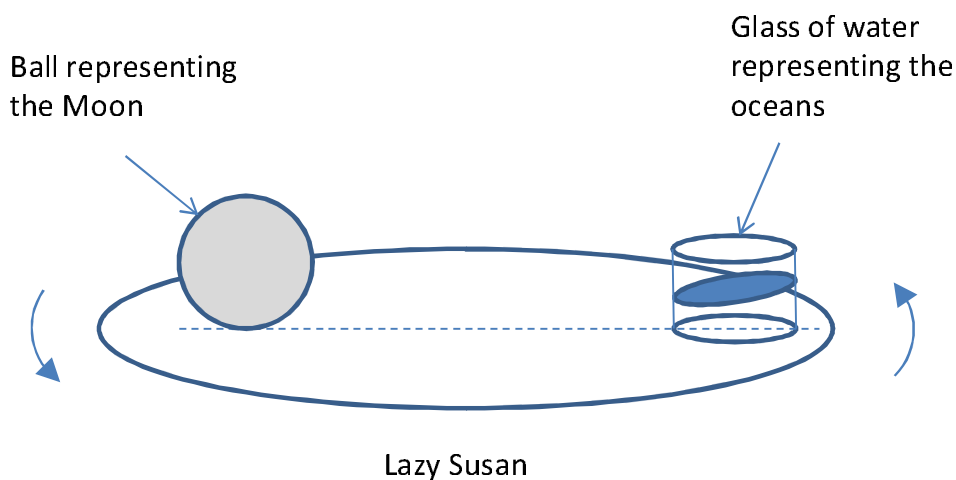


Figure 2. Schematic diagram of using a Lazy Susan to demonstrate the ocean bulge on the opposite side of the Earth from the Moon. The effect could be made more dramatic by using blue lemonade.

Friction between the water in the oceans and the moving Earth cause the bulge to be slightly ahead of the Moon. The Earth rotates in the same direction as the orbit of the Moon around the Earth and so the bulge gets pulled ahead. High tide actually occurs about 40 minutes *after* the Moon reaches its highest point in the sky, as shown in figure 3.

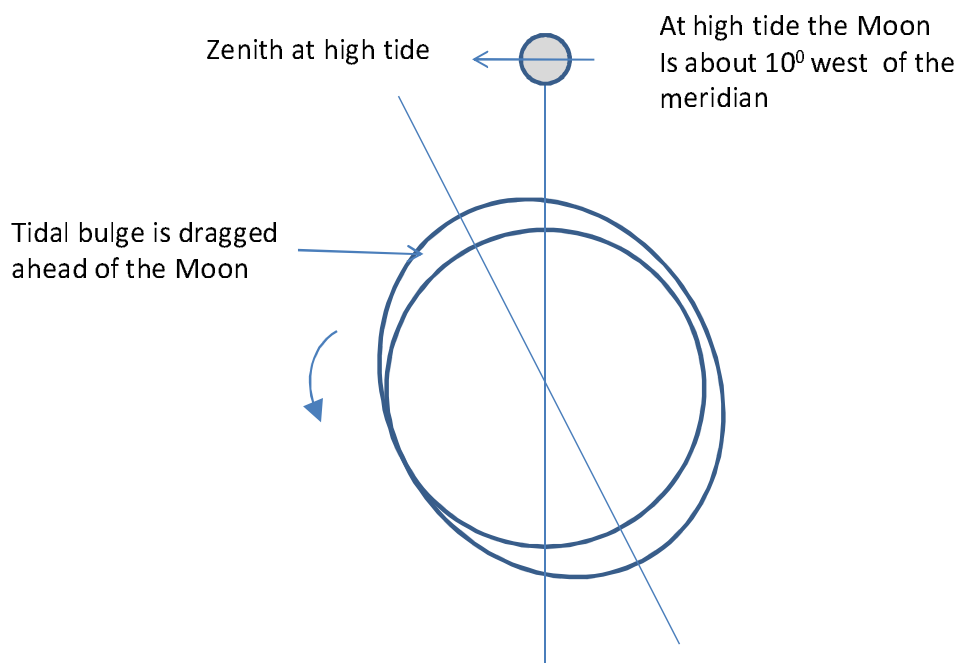


Figure 3. Schematic diagram of the equatorial tidal bulge looking down on the North Pole.

Sunset simulator

The questions why is the sky blue and why are sunsets red are related. As light from the sun passes through the atmosphere the shorter wavelengths, i.e. blue light are scattered by air

molecules and small dust particles. The effect is more noticeable when the rays of the Sun pass through more atmosphere –i.e. at sunrise and sunset. The blue light is scattered in all directions and so the sky appears blue in all directions. Blue light is also scattered in water producing blue oceans.

Red sunsets can be simulated by adding a small drop of milk to a glass of water. If a torch is shone through the water the emerging light will become redder. This demonstration could be done in front of a class with torch beam being shone through the glass towards the class. With a sufficient volume of water it may be possible to see blue light at right angles to the beam of light.

Inflatable celestial sphere

An inflatable celestial sphere could be useful for teaching students about the constellations. An interesting point to note is that the southern constellations relate to the building of the New World – especially relevant to Australia, one of the countries of the New World. Also some of the constellations relate to instruments of science which were being developed as the New World was being discovered – e.g. the telescope and microscope.



Figure 4. Inflatable celestial sphere useful for teaching students about the constellations.

Phases of the Moon

Understanding the phases of the Moon is quite difficult. The exercise describe here is a minimalist approach to try and get the concept across. A ball is used to represent the Moon – one half of the Moon in painted black or covered in black material. The demonstration could be enhanced if a light, e.g. a small LED torch can be placed in the ball.

The ball is passed around the edge of the classroom so that all the students in the classroom are ‘on’ the Earth. The main rule of the exercise is that the light side of the Moon must always face the front of the class which represents the Sun. A picture of the Sun should be drawn on the whiteboard at the front of the class or another ball placed at the front of the class representing the Sun.

The ‘Moon’ begins its journey at the front of the classroom. In this position the light side of the ball appears as a thin crescent. As the ball arrives at the side of the classroom it appears half lit. When it arrives at the rear of the classroom the light side is seen in its entirety representing the full Moon.

A schematic diagram of the arrangement is shown in figure 5. The activity could be enhanced by getting students to pass the ball around the edge of the room. The activity could also be used to teaching about solar and lunar eclipses. A circle the same diameter as the ball representing the Moon is drawn on the white board, or a ball the same diameter as the ball representing the Moon is placed at the front of the classroom. This will represent the Sun.

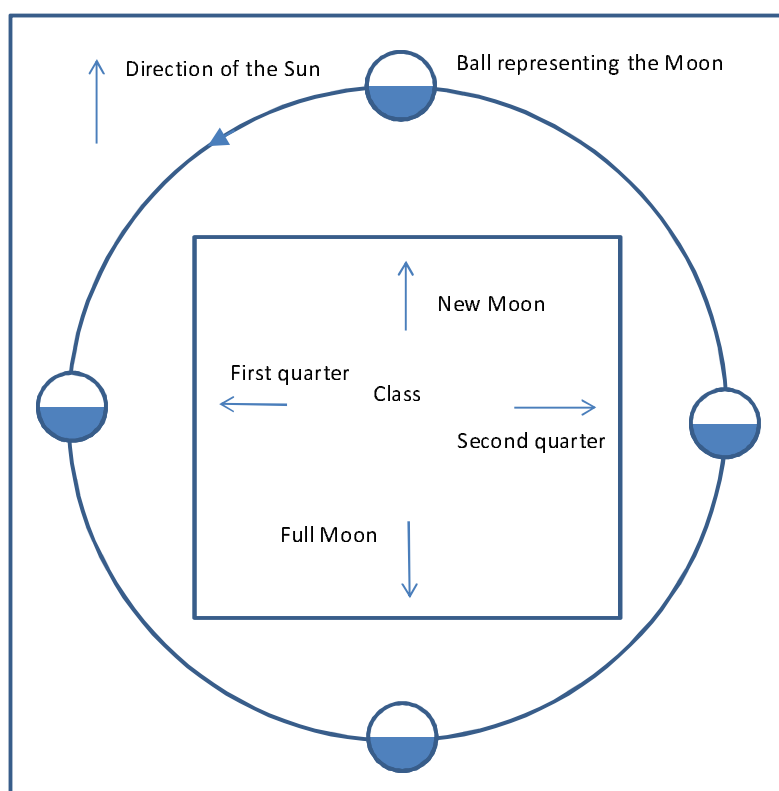


Figure 5. Teaching the phases of the Moon using a ball blacked out on one side. The ball is moved around the perimeter of the classroom with the light side always facing the front of the classroom which represents the Sun.

The arrows indicate the direction that the students look to see how the Moon looks at different times of the month.

A total solar eclipse can be simulated by passing the 'Moon ball' in front of the 'Sun disc/ball'. A partial solar eclipse can be simulated by passing the Moon ball slightly above or below the centre of the Sun disc/ball. Most the time the Moon passes above or below the Sun as it crosses from one side of the Sun to the other at the time of new Moon. This is why a total solar eclipse does not occur each month.

Bicycle pump and thermometer

Stars form in cold, dark, denser regions of nebulae called Bok globules in a nebula called 'The running chicken' nebula. These particular Bok globules are also called Thackeray's globules after the South African astronomer who discovered them in 1950. Bok globules shrink under the influence of gravity and eventually become hot enough to form stars. In this experiment, an electronic thermometer is used to measure the temperature of the end of a bicycle pump before and after pumping air into a tyre or football. A temperature increase of several degrees should be noted, clearly demonstrating that compressed gas gets hot.

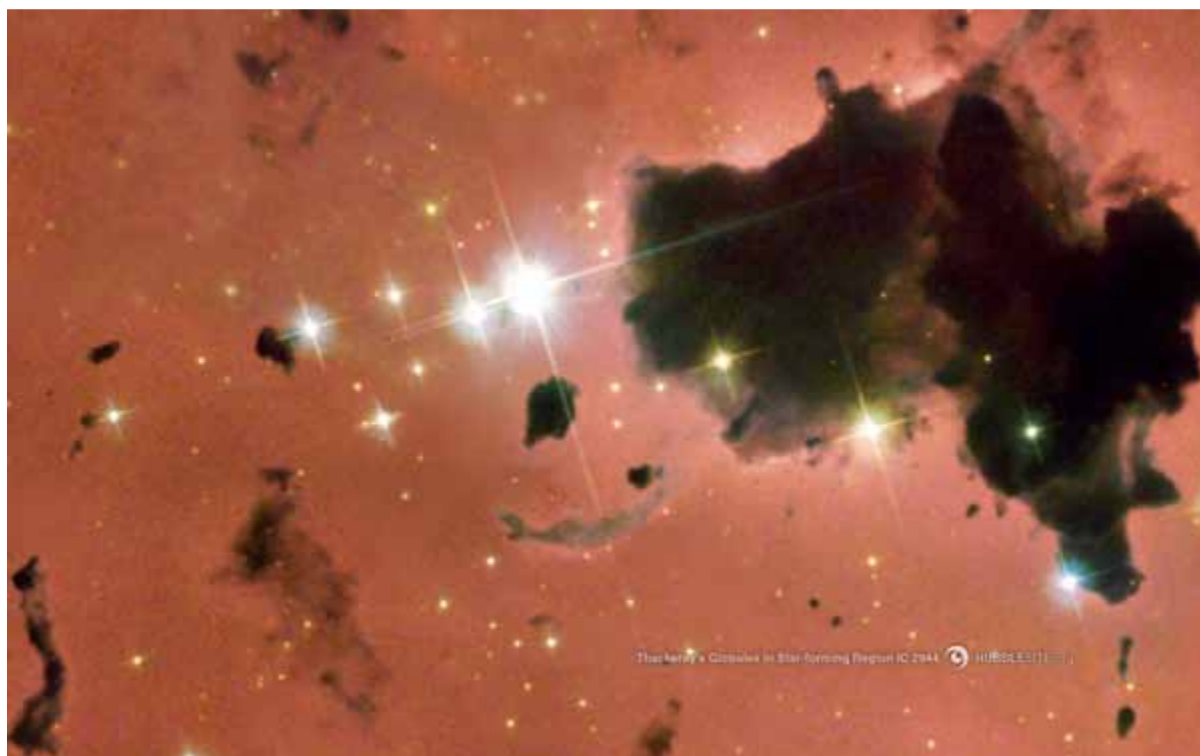


Figure 6. Dense, dark, cold regions in a nebular and newly formed stars. The dark regions are known as Thackerays globules. They eventually collapse under the influence of gravity and become stars.

Plasma ball

Plasma balls can be obtained for about \$50. The one shown in figure 7 was obtained from the Australian Geographic shop (www.australiangeographic.com.au). The central ball that glows pink is covered in electric charge and is surrounded by low pressure hydrogen gas. The electric field produced by the charges on the ball in the middle rips electrons off the hydrogen atoms, a process known as *ionization*. Ionised gas is known as *plasma*.



Figure 7. Plasma ball – excited hydrogen gas glows with the same pink glow seen in nebulae.

The ions in the gas surrounding the central ball provide a path for electric charge to flow from the inner ball to the outer ball. If you place your hand onto the surface of the ball, the electric charge flows through the plasma to the surface and then through your hand to ground.

The pink glow produced by the hydrogen gas is exactly the same colour as produced by clouds of hydrogen in space, as seen for example in figure 6. When a fluoro tube is brought close to the plasma ball, the electric field produced by the plasma ball is enough to ionise the gas inside the fluoro tube causing it to light up. Since the fluoro tube lights up, energy must be transferred through space from the plasma ball to the tube.

This illustrates what happens when a rapidly spinning neutron star is able to transfer energy out to a surrounding nebular as seen for example in the Crab nebula shown in figure 7.

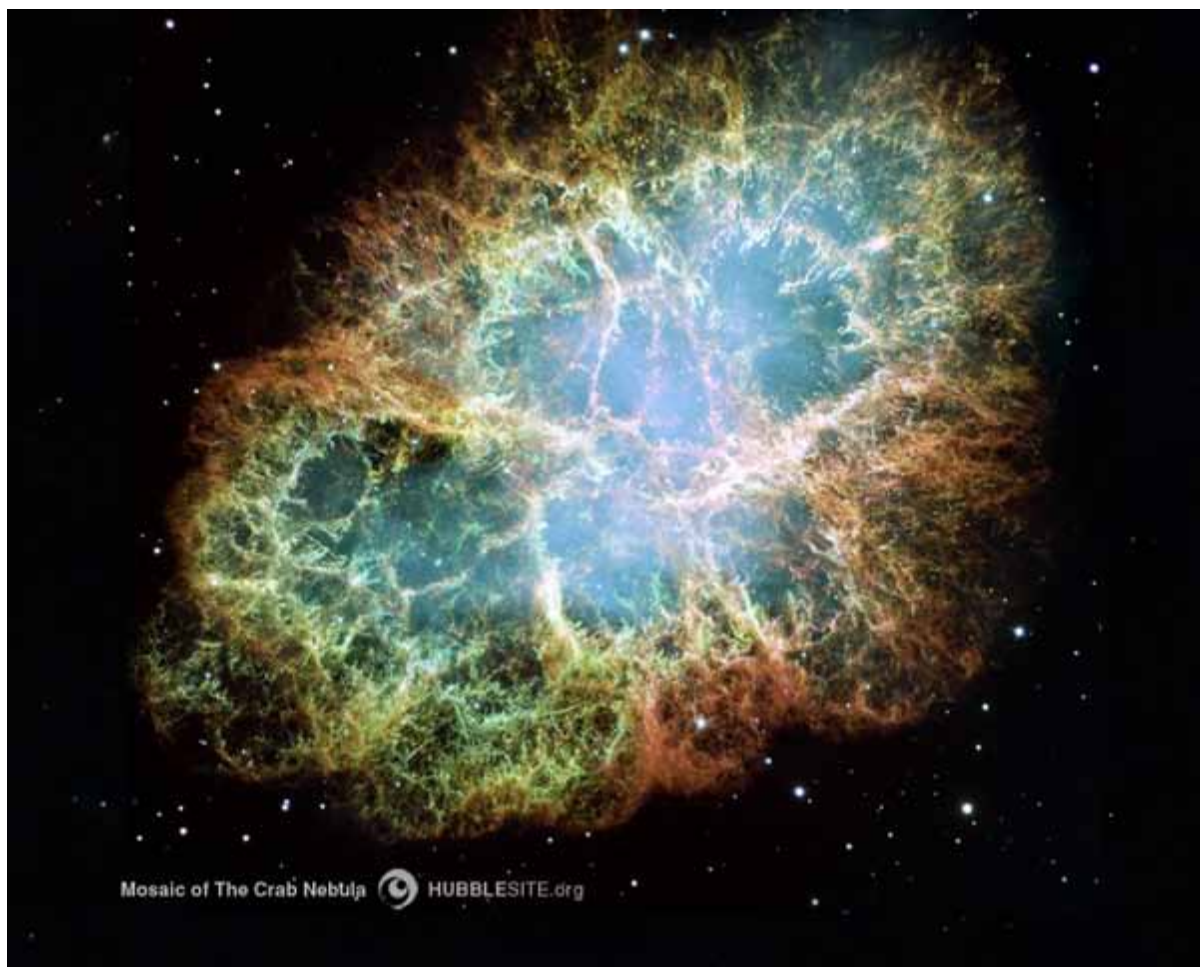


Figure 7. Mosaic image of the Crab Nebula taken by the Hubble Space Telescope. The neutron star (pulsar) in the middle of the nebula is radiating energy into the surrounding material causing it to light up like a fluoro tube near a plasma ball.

Gold leaf electroscope

In the centre of any main sequence star (i.e. a star that is burning hydrogen in its core) protons are moving very fast. Most of the time the protons cannot get close to each other as they bounce off each other due to electrostatic repulsion. However, sometimes two protons are able to get close enough to fuse into helium nuclei through a process known as *quantum tunnelling*.

Electrostatic repulsion can be demonstrated using a gold leaf electroscope which is a metal rod in a glass jar with a piece of gold foil attached. A metal disc is attached to the metal rod where it protrudes through the plastic bottle top. When a charged object such as a comb that has just been combed through some hair is brought close to the metal disc on top of the jar, charge goes onto the plate and flows onto the metal strip and gold foil. Since the same charge exists on the strip and foil the foil is forced away from the strip as like charges repel.

When a comb is moved up and down above the metal disc the foil moves up and down as well. If the charge on the disc is suddenly removed by touching for example, the foil drops onto the strip simulating quantum tunnelling.

Supernova cola experiment

When a star 8 times or greater more massive than our sun or greater runs out of fuel, the core suddenly collapses from a radius of about 1000 km to just 10 km. The collapsed core rebounds and slams into the surrounding material of the star raining down onto the core. An enormous shock wave travels through the star that rips the star to pieces, as seen in figure 7. The resulting explosion is known as a type II supernova explosion. Material from the explosion speeds through interstellar space and eventually becomes the raw material for subsequent generations of stars.

Some of the physics of a type II supernova explosion can be simulated using a plastic bottle filled to the brim with water. When the bottle is banged down onto the bench, as shown in figure 8, water is ejected from the neck of the bottle. In this case when a plastic bottle is slammed down onto a bench, the base of the bottle is suddenly compressed. This compression travels up through the water to the top of the bottle. At the top of the bottle water explodes into air, which is much less dense than the water below. (N.B. This experiment is called the *supernova cola* experiment just for rhyming purposes - using Coca Cola instead of water probably isn't a good idea!).



Figure 8. The supernova cola experiment being performed. A plastic bottle is filled with water and slammed down onto a bench – water is ejected from the top of the bottle illustrating the physics that destroys a star in a type II supernova explosion.

Lava lamp

Lava lamps (figure 9) are useful for illustrating how energy is transferred from the depths of the Sun to the surface. In a lava lamp wax is heated by a lamp in the base causing the wax to decrease in density and rise in the surrounding water. At the top of the lamp the wax cools which results in the wax increasing in density and sinking back down to the bottom where the process is repeated.

In the Sun there is a convection layer which transports energy from the depths of the Sun out to the shining surface (the photosphere). Hot plasma rises up to the surface of the Sun, cools and then falls back down into the depths to be re-heated which repeats the cycle. Hot plasma rises in the centre of convection cells and falls back down the sides. Convection cells are seen in figure 10. between the radiation zone which transports energy from the



Figure 9. Lava lamp, wax changes density and rises and falls

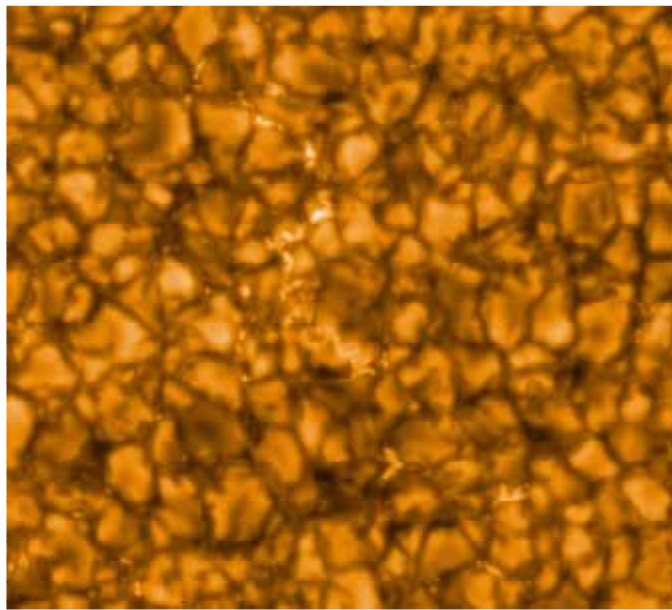


Figure 10. Convection cells on the Sun. The bright areas are where hot plasma is rising from the depths and the dark edges are where cooled plasma is flowing back down into the depths. (Image courtesy of NASA).

Rotating chair

When the core of a star collapses in a type II supernova explosion, the core starts to spin very fast. This is due to something known as the *conservation of angular momentum*. This can be simulated using a rotating chair. Get someone to sit on a rotating chair, e.g. a rotating office chair. Get someone to sit on the rotating chair and stretch out their arms and legs. Rotate the chair and get the person sitting on the chair to bring in their arms and legs. They will begin to spin much faster. It is a good idea to have someone ready to catch the person should they fall off the chair.

Advanced exercises

The experiments described in this section would be suitable for more advanced students and would be particularly suitable as home work assignments. These exercises involve the use of a digital camera, a tripod and free image analysis software. If a digital camera is available then these activities cost nothing.

Spectroscope

A spectrometer splits light into its constituent components. Astronomers use spectroscopes to analyse the light coming from the universe. For example the colour of a star indicates its temperature and how much energy is coming out of each square meter of the star. Spectrometry is also used to search for planets around distant stars. Simple hand-held spectroscopes can be obtained for a few dollars.

Get students to look at different lights, e.g. fluoro and incandescent lights. Fluoro tubes produce spectra with emission lines whereas incandescent lights have a continuous spectrum. A hand held spectrometer can also be used to look at sunlight reflected off a white surface, e.g. a white sheet of paper – the spectrum will appear similar to that of an incandescent light. A digital camera can be used to obtain a photo of a spectrum by placing the camera lens up against the eyepiece of a hand-held spectroscope, as shown in figure 11.

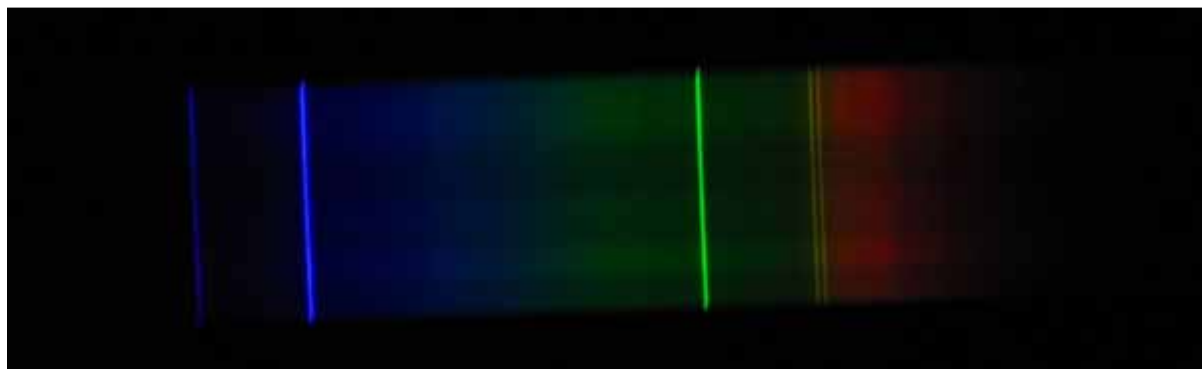


Figure 11. Photo of daylight fluorescent tube taken with a digital camera placed at the eyepiece of a spectrometer.

Incandescent light bulbs can be used as a simple model of a star. Stars vary enormously in size and colour. The colour of a star is indicative of surface temperature. A red giant star, such as Antares in Scorpio have a surface temperature of about 3,500 K. A yellow star like our Sun has a surface temperature of about 5,800 K. The hotter the surface temperature of a star the bluer the colour. A computer program such as ImageJ, can be used to produce a spectrum.

A model of a star can be made very simply using an incandescent torch bulb, a 9 V battery and potentiometer (variable resistor). As the potential across the bulb is varied the bulb brightness and colour also varies. When the bulb is viewed through a spectrometer you can see the colour balance change. For example when the potential across a bulb is decreased, the spectrum becomes brighter in the red part of the spectrum.

Measuring the colour and brightness of stars using a digital camera

A digital camera is in effect a miniature version of a telescope with electronic camera attached. Figure 12 shows a photo of the Orion constellation taken by the author with an Olympus FE-220 7 megapixel digital camera on a tripod set to night mode with the flash switched off.



Figure 12. The Orion constellation taken at Siding Spring Observatory with a digital camera on night setting.

The picture shows the Orion constellation above the astronomer's lodge at the Siding Spring Observatory, Coonabarabran (NSW). Two prominent stars in Orion are Betelgeuse and Bellatrix, which are next to each other at the base of Orion (in the southern hemisphere). Betelgeuse is a red giant star and Bellatrix is a blue star. The colour and relative brightness of the stars can be measured as follows.

A free image analysis program called ImageJ (<http://rsbweb.nih.gov/ij/>) can be used to analyse star images taken by a digital camera. The photo is then loaded on a computer and a program called *ImageJ* used to analyse the images.

Figure 13 shows an example of what can be done with ImageJ. The photo in figure 12 was loaded into ImageJ and a circle placed around Betelgeuse. The option Plugins/3D/Interactive 3D surface plot was chosen to produce a 3D mesh of the pixels. ImageJ can also be used to

separate out the red, green and blue components of a colour image, enabling the brightness of a star in the red, green and blue colour bands to be measured.

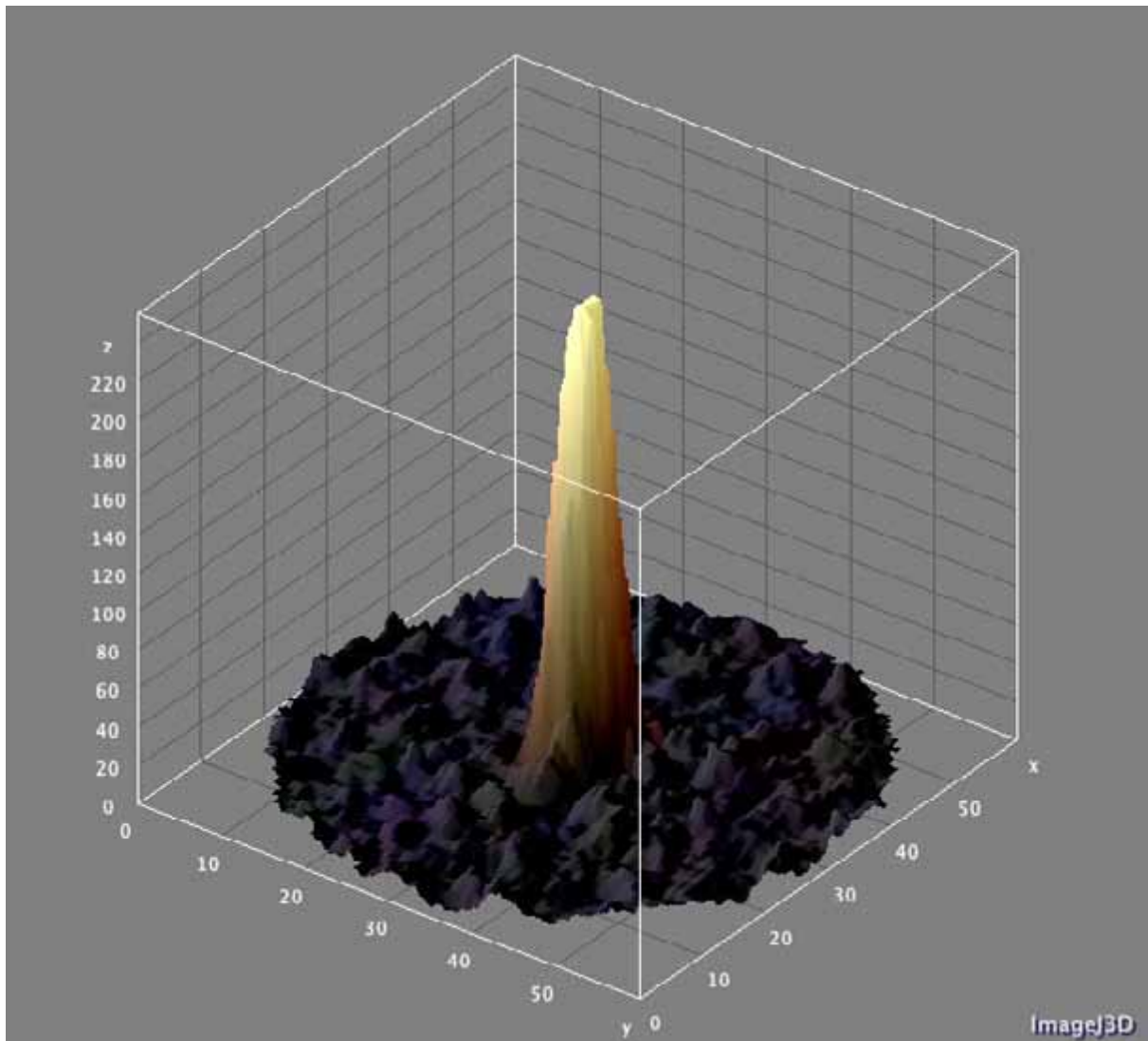


Figure 13. 3D surface plot of the star Betelgeuse in the constellation Orion. The surface has a distinctive red colour.