12 Exploring the universe

Planning page

Getting started

Activity page 269
Investigate 27 Locating stars
Activity page 271

12.1 The universe from Earth page 267

Activity page 278

12.2 Stars page 274

Assessment task 12 Space exploration

Activity page 285
Activity page 287

12.3 Star life cycles page 281

Main ideas

Chapter 12 crossword

Review

Chapter 12 test

Essential Learnings for Chapter 12

Essential Learnings	References		
	Student book (page number)	Workbook (page number)	Teacher Edition CD (Assessment task)
Knowledge and understanding ***Earth and beyond*** Scientific ideas and theories offer explanations about the earth that extend to the origins of the universe	p. 276 pp. 286–287	Exercise 8 p. 99	
Ways of working Evaluate data, information and evidence to identify connections, construct arguments and link results to theory	pp. 281–288		
Communicate scientific ideas, explanations, conclusions, decisions and data, using scientific argument and terminology, in appropriate formats		p. 100	Assessment task 12 Space exploration
Research and analyse data, information and evidence			Assessment task 12 Space exploration

QSA Science Essential Learnings by the end of Year 9

Vocabulary

alpha
astrology
astronomer
azimuth
beta
binary
chromosphere
constellation
corona
cosmology
ecliptic
galaxies
gravitational
helium
nebula
photosphere
plasma
prominence
pulsar
supernova
universe
zenith
zodiac

Focus for learning

Apply their knowledge of space to discuss whether aliens exist (page 266).

Equipment and chemicals (per group)

Activity page 269	star chart
Investigate 27 pages 270–271	sheet of graph paper, piece of firm cardboard larger than the sheet of graph paper, magnetic compass, torch
Activity page 271	newspaper, magazine and books (for horoscopes)
Activity page 278	12 V bulb and socket (eg from ray box), stand and clamp, power pack and connecting wires
Activity page 287	round balloon, marking pen

12 Exploring the universe

Getting Started

Do aliens exist? If so, where do they come from? To answer these questions you need to know something about the structure of the universe. Form a group of three or four people to discuss the questions below.

1 If aliens exist, is it likely that they come from our solar system or somewhere else? Give your reasons.
2 The nearest star is 4.2 light-years away. What does this mean?
3 How could you estimate the number of stars in the night sky? Is this the total number of stars in the universe? Explain.
  Could we get to any of these stars using our present methods of space travel? Suggest other ways of travelling to stars.
4 What is the Milky Way? Is it the whole universe?
5 How does the Sun produce its energy? Will it go on shining forever?

Starting point

1 Consider organising an excursion to the Planetarium. They will often organise a program to suit the year level and subject contents. The CosmoDome and Starlab are portable planetariums and it is well worth organising them to come out to the school. They come with experienced presenters and there are many programs to choose from, including tailor-made ones.
2 You could organise a star-gazing night for the class or whole school. It requires a lot of forward planning. More details can be found in the Learning experience on page 270.
3 There are many interactive applications on the internet which can be used throughout this topic. Try compiling a list of web addresses which could be handed out to the students so they can explore them in their own time.
4 You may like to get your students to link up and join an online student astronomy club. They inform students of upcoming astronomical events, track comets and have blog pages where students can write their own comments and observations. Encourage them to find a club specifically for the southern hemisphere.
5 There are many commercial DVDs on astronomy which can be used throughout this chapter. Make sure to preview any before the class to determine if they are appropriate, and prepare worksheets for the students to fill in.
6 Ask the students to skim through the chapter and jot down about 10 questions about stars they would like to know the answers to. Allow them to use the section headings as pointers to help generate their questions. At the completion of this chapter, get the students to check their set of questions to see how many they can answer.
7 Gold-anodised aluminium plaques were placed on board the *Pioneer 10* and *Pioneer 11* spacecrafts. They feature pictorial messages from humanity in case either of the spacecraft is intercepted by extraterrestrial beings. See if the students can find pictures of the plaques and explain what the symbols represent.
8 The students could investigate what SETI does. SETI stands for Search for Extraterrestrial Intelligence and the institute is based in the Silicon Valley in California, USA.
9 The closest star to Earth is our sun, called Sol. The next closest star is Proxima Centauri which is about 4.2 light-years away. This means light from this star takes 4.2 years to reach the Earth, so we see Proxima Centauri as it existed 4.2 years ago. However, it is classified as a red dwarf and contains only a fraction of the mass of our Sun. It is too faint to see with the naked eye. (Astronomers usually measure star distances from the Sun, rather than from the Earth.)
10 The universe is so immense that there are too many stars for scientists to actually count one by one. It is suggested that the number of galaxies in the observable universe is around 100 billion (10^{11}) and that each galaxy contains about 100 billion stars. This means that the estimated number of stars in the universe is in the order of magnitude of 10^{22}, or 10 thousand billion billion stars.

12.1 The universe from Earth

On a clear night you can see about 3000 stars in the sky. To the ancient astronomers these stars, plus the Moon and Sun, made up the universe. And all the objects in the universe revolved around the Earth.

We now know that the Earth is not the centre of the universe, and that the Sun is only one of millions and millions of stars. There are so many stars that if each of them was a grain of sand they would fill up the Sydney Opera House!

Star patterns

Many of the stars visible to the naked eye form recognisable patterns. These groups of stars are called **constellations.** A constellation keeps the same shape, although with the Earth's revolution around the Sun, you see some constellations on summer nights and others in winter.

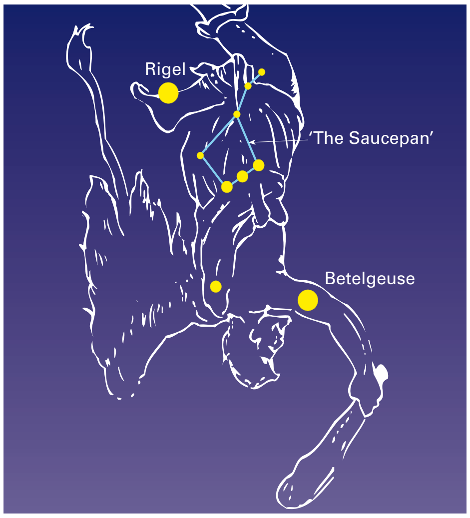


Fig 2 Ancient Greek astronomers named this constellation Orion after the mythological person who was a mighty hunter of great strength and beauty. The three bright stars that form Orion's belt are in a group of stars which we sometimes call The Saucepan.

People of all cultures have given names to the constellations. However, most astronomers accept the naming of constellations based on the ancient Greek classification. For example, most of the constellations have been named after animals or other objects such as the sails of a ship or a clock. Altogether there are 88 recognised constellations.

Astronomers use Latin names for the constellations. (Latin was the language of Ancient Rome.) The Southern Cross is called Crux (the Latin word for cross), and the lion is called Leo. More recently named constellations are also given Latin names. For example, the constellation shaped like a telescope is called Telescopium, even though there were no telescopes in Roman days.

Star distances

The closest star, our Sun, is 150 000 000 km away. (It would take over 6 months to reach the Sun if you travelled in the Space Shuttle.) The next closest star is 41 000 000 000 000 km away, or 270 000 times the distance of the Sun. You can see from these figures that the distances to the stars are enormous, with vast spaces between them.

The distances to the stars are far too large to measure in kilometres. Instead an astronomical unit of distance called the **light-year** is used. This is the distance light travels in one year. Light travels at about 300 000 000 metres per second (3×10^8 m/s), so in one year light travels about 9 500 000 000 000 km (9.5×10^{12} km).

The stars in a constellation are not all the same distance from Earth. For example, the four bright stars in the Southern Cross are very far apart. The closest star is 220 light-years away, while the furthest one is 570 light-years away. See Fig 3 on the next page.

When you look at stars you are looking back in time. The light from the closest star in the Southern Cross left that star 220 years ago. In other words, you are seeing the star as it used to be in the 1790s!

Hints and tips

Students often think that a light-year measures time rather than distance. Reinforce that it is an astronomical unit of distance. Confusion can arise when explaining how long it takes for light to travel from a celestial body to Earth. If a star is 220 light-years away this means its distance from Earth is $220 \times 9.5 \times 10^{12}$ km (2 090 000 000 000 000 km)—a very, very large distance!

Homework

Ask students to list the nearest 25 stars to Earth and put their names in a table. Add the column headings 'Distance from Earth', 'Type of star', 'Brightness' (if possible) and 'Other interesting information', eg which constellation it is in. Explain to students that the list is continually being updated as astronomers use more sensitive detectors to discover nearby stars in a variety of spectral ranges, especially the infrared, where numerous small stars emit their energy.

Learning experience

Give the students a pre-test on astronomy to determine what they already know. Make sure you include some fundamental questions such as:

- What is the difference between the Earth's rotation and its revolution?
- Why do we have day and night?
- Why do we have seasons?
- List the order of the planets in our solar system from the Sun.
- What is the difference between an asteroid and a meteorite?

If the students do poorly on the pre-test, allow them to take it home and complete it correctly as a homework activity.

Learning experience

To help the students comprehend how fast light travels, measure out a distance of about 15 metres outside and ask them to see if they can run the length in one second. Now ask them to imagine running the length of a sports field in one second, and then across Australia in one second, and so on. Very soon they will realise just how fast light travels! Consider this: if the circumference of the Earth is about 40 075 km and light travels 300 000 km per second, then in about one second light can effectively travel 7.5 times around the Earth.

Hints and tips

- Fig 3 is an excellent diagram showing the relative patterns of stars. Make sure the class understands why the appearance of the star patterns would change if they were viewed from somewhere else in the universe.
- Explain what is meant by 'hemisphere' and that we live in the Southern Hemisphere. (A hemisphere is half of a sphere.)
- Alpha Centauri lies 4.35 light-years from the Sun and is a triple star system. The two brightest stars, Alpha Centauri A and B, form a binary, and Proxima Centauri (Alpha Centauri C) is a red dwarf which is not visible to the naked eye. This system of stars is closest to the Sun, hence the Earth, so it is often said that Alpha Centauri is closest to the Earth.

Research

Ask the students to research and form a table of the 88 recognised constellations with their official Latin name and English meaning. They should order them into three groups: 'Southern Hemisphere', 'Northern Hemisphere' and 'Both Southern and Northern hemispheres'. How many constellations can be seen in both hemispheres? Why can they be seen in both? Is it only at certain times of the year that each can be seen in a different hemisphere, or can they be seen in both hemispheres at the same time? Asking questions like this leads into the Activity on the next page.

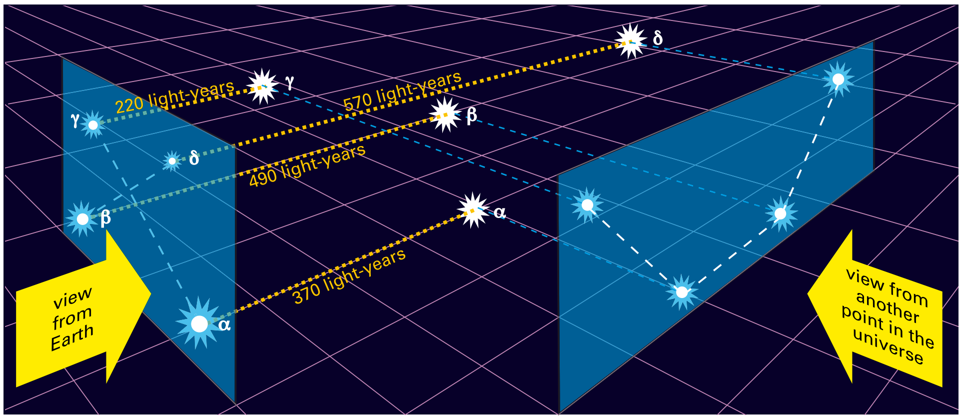


Fig 3 The four main stars in the Southern Cross appear to be in the same plane when viewed from Earth. However, you would not see the cross pattern if you looked at these stars from somewhere else in the universe.

Naming stars

Many of the bright stars in the sky have been given names. For example, the brightest star in the sky is called Sirius, and the two stars that make up the constellation Gemini are called Pollux and Castor. However, naming every individual star in the sky would be a huge task, even if you could remember their names.

In 1603 a German astronomer, Johann Bayer, thought up a system of naming stars in a constellation according to their brightness. The brightest star is called the alpha star (α-star), the second brightest the beta star (β-star), then gamma (γ), delta (δ), and so on.

If the sky is clear tonight look for the Southern Cross. You will find the brightest star at the base of the cross. This is called α-Crucis (CREW-sis). Near the Southern Cross are the two bright stars in the constellation Centaurus (sen-TOR-us). These stars we usually call the Pointers. The brighter of the two stars in the Pointers is called α-Centauri and is the closest star to the Earth (apart from the Sun).

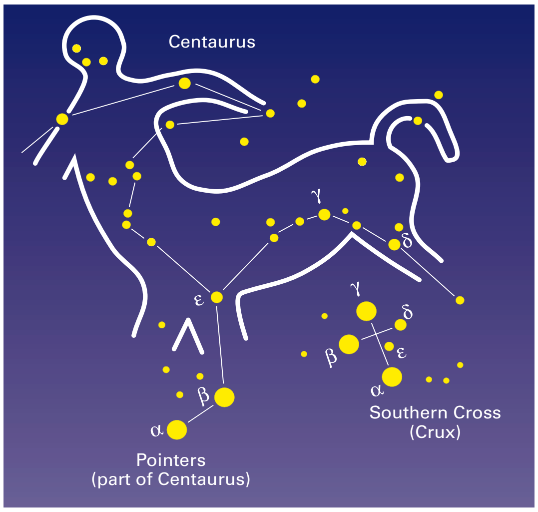


Fig 4 Stars in the constellations Crux and Centaurus

α-Centauri and β-Centauri form the front legs of the mythical half-human half-horse creature called the Centaur. This constellation was named by the Greek astronomer Ptolemy (TOL-em-ee) in about AD 150.

Research

Ask the students to research and write a brief history of Ptolemy and his naming of 48 of the 88 recognised constellations. The students' reports should include:

- when and where Ptolemy lived
- his main contributions to astronomy
- why he became well-known
- information about his study of constellations.

On the constellation table constructed in the previous Research activity, students should show which ones were named by Ptolemy. Which hemisphere are most of them located in, or are they evenly distributed across both hemispheres? Ask the students to come up with possible reasons for this. Alternatively, students could complete a similar task on the German astronomer Johann Bayer.

Learning experience

Often students find it difficult to comprehend the vast distances of space. The expanse of the universe can be illustrated by using this analogy. If one student represents the Earth, then the classroom is the solar system, the whole school is our galaxy, other schools are different galaxies and the whole of Australia is the universe. Ask the students to come up with their own analogies for the vastness of the universe and share them with the class.

Activity

This is a night-time activity. Try to find a dark place without bright street lights. You will need a star chart like the one in the photo and a torch.

1 Read the instructions on the star chart. You will notice that one side of the star chart is used when looking in a southerly direction and the other side is used when looking north.

2 Rotate the star chart wheel until you come to the current month. Hold the South side of the star chart over your head and try to identify some of the constellations that are visible.

   Look at the Crux. Identify the α, β, γ, δ and ε stars in this constellation.

   Identify α-Centauri and β-Centauri.

3 Hold the North side of the star chart over your head and identify some of the constellations in the northern sky.

The movement of stars

The movement of the stars across the sky is caused by the west-to-east rotation of the Earth. If you point a camera in a southerly direction and leave the shutter open for a few hours, your photo will have dozens of concentric lines produced by the time-exposure of each of the stars as the Earth rotates. The centre of these concentric lines is an imaginary point in the sky called the *South Celestial Pole*.

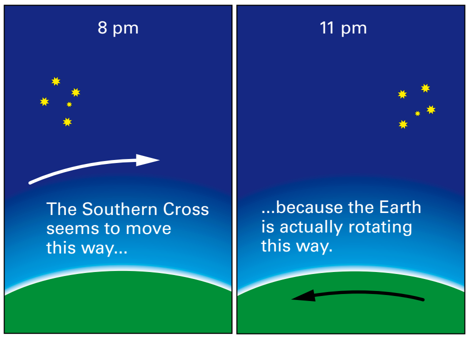
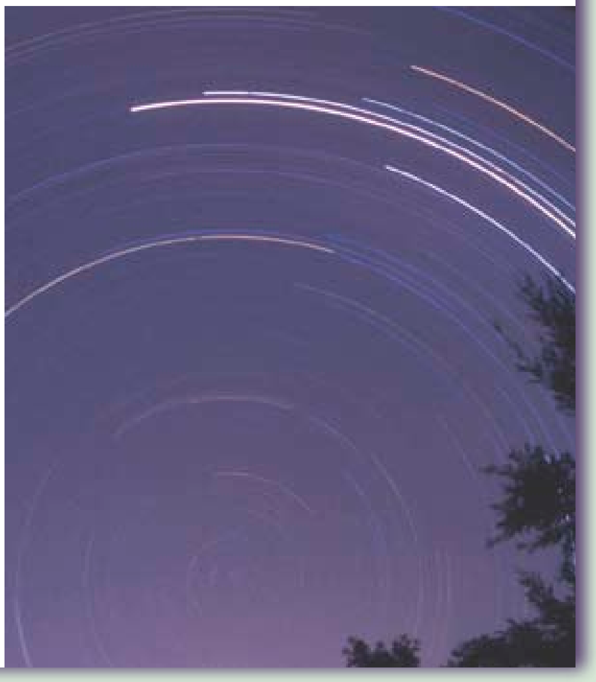


Fig 7 A time-exposure of the stars looking directly south. The bright arcs on the right were formed by the stars in the Southern Cross.



Activity notes

- The students can make their own star chart; this way you don't have the worry of having to get them back. Templates can be downloaded from the internet or you could make your own by photocopying an original chart. Use squares of cardboard for the base and split pins to hold the sheets together. If the students make their own chart, stress the importance of accuracy, especially when they cut the centre section out.
- Alternatively, if the department has a class set and the star charts are carefully stored and properly used, they will last for many years. If students take them home, make sure they are kept in plastic sleeves.

Hints and tips

If it is at all possible, set up a video camera on time lapse to video part of the night sky so the students can observe the apparent motion of the stars. Enthusiastic students might like to attempt to do this themselves or take their own digital photos. They will need to make sure they use a correct time exposure for this. (Remember that it is because of the Earth's rotation that the stars appear to move across the sky.)

Homework

Students will need a relatively cloud-free night to do this. Ask them to use their star charts to locate the positions of the Southern Cross (Crux) at 7 pm, 8 pm, 9 pm and 10 pm one night during the week. Then ask them to answer the following questions.

1 Write down the direction the constellation *appears* to be moving across the night sky.

2 Is this the direction it is really moving? Explain your answer.

Lab notes

You need a clear night sky, preferably away from city lights, to do this investigation. Encourage the students to do it as a group task with their parents. (It is very important to remind students of safety issues concerning their wellbeing.)

Investigate 27 LOCATING STARS

Aim

To locate and record the positions of various stars in the sky.

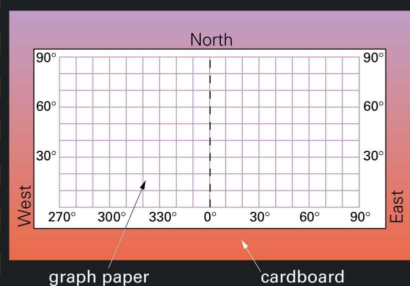
Materials

- sheet of graph paper
- piece of firm cardboard larger than the sheet of graph paper
- compass
- torch

Planning and Safety Check

This experiment has to be done at night. But before you begin your night-time observations you have to prepare a sky grid.

Draw up your graph paper as shown in the diagram below, then paste it onto a piece of firm cardboard.



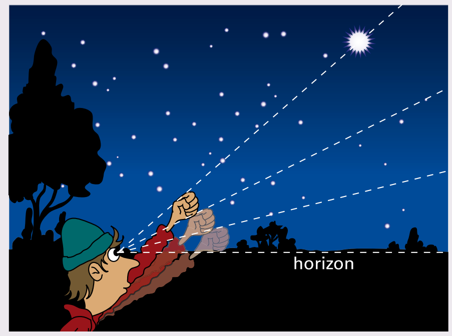
This is your sky grid for locating stars in the northern sky. If you hold the grid vertically at eye level, the bottom horizontal axis represents the horizon. The top horizontal line is directly overhead or 90° from the horizon and is called the *zenith*.

The vertical dotted line in the middle of the grid (0°) is the north–south line.

If you have time you can prepare a sky grid for locating the stars in the southern sky.

Method

1. Go outside on a clear night and use the compass to find north. Then lay your grid on the ground so that the compass needle and the north–south line (0°) line up.
2. Select a bright star in the sky. You now have to find its vertical angle or *elevation* from the horizon.
3. Use the 'fist method' to find the star's elevation. To do this clench your fist and hold it straight out from your body. Position the bottom of your fist on the horizon, ie the 0° mark. The top of your fist is about 10° above the horizon. So if the star is 3 'fists' above the horizon, its elevation is 30°.

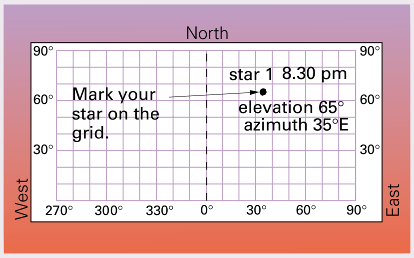


4. Measure how many 'fists' there are from the horizon (0°) to the star. Convert this to degrees. This is the star's elevation.
   Record this angle.
5. The horizontal angle is called the *azimuth*. This is the angle measured from the 0° line, in an easterly direction through 360°. Now measure how many 'fists' from the 0° line the star is, and convert this to degrees. (If the star is to the west of the 0°, you subtract the angle from 360°.) This is the star's azimuth.
   Record this angle.
6. Use the two angles to mark the position of the star on the grid. Also record the time next to the star.

Learning experiences

It is worth arranging an Astronomy Night with your class(es). The following checklist may be helpful.

- Clear the event with your head of department and the school administration.
- Choose a suitable, safe venue away from too many lights. Try the school oval or a local park.
- Pick a night around the time of the new moon, not the full moon, and try for a relatively cloudless night.
- Organise notes and permission slips to go home to parents.
- Arrange transport.
- Students should bring torches but tape red cellophane over the light.
- Try to get the use of a good telescope. You might be able to borrow one from a local astronomy group or a keen parent.
- Ask a local astronomer, other staff or parents to assist you on the night, preferably those who have a knowledge of astronomy.
- Consider having a simple worksheet and/or showing a video or DVD on astronomy so the whole class isn't trying to observe the night sky at once.



7 Select another star and plot its position.

Discussion

1 Why did you record the time next to each of the stars on your grid?

2 What things might affect the accuracy of your star location measurements?

3 Suppose you found the location of a star and then repeated the measurement at the same time one week later. Would the star be in the same position? Explain your answer.

try this

The 'fist' method of locating stars is only very approximate. Work in a group of two or three people and design a method to find the position of stars accurately. Write up your design and discuss it with your teacher.

The zodiac

You may have noticed that the Sun and Moon follow much the same path across the sky. The planets also follow this path, which is called the **ecliptic** (ek-CLIP-tick). For people in Australia the ecliptic is in the northern part of the sky, and it is higher in the sky when viewed from Brisbane and lower when viewed from Hobart.

The ecliptic also passes through the twelve constellations which we call the **zodiac**. The symbol of each constellation is the shape each is supposed to make in the sky. Astrologers (not astronomers) use the zodiac and the positions of the Sun, Moon and planets to make predictions about your health and other life matters.

Making predictions from the positions of objects in the sky has been done for thousands of years. Many cultures have believed that everyday events such as the planting of crops and business dealings are influenced by the stars.

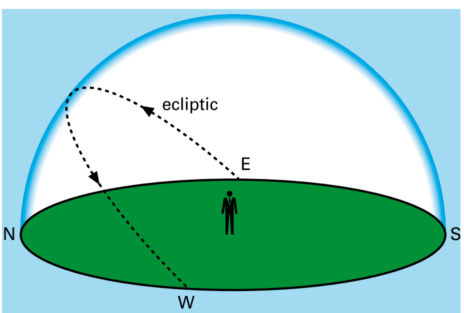


Fig 11 The ecliptic is the path followed by the Sun, Moon, planets and the twelve constellations in the zodiac.

Activity

1 Use newspapers or magazines to find out the names, symbols and birth dates for the 12 constellations in the zodiac.

2 Find out from horoscope books the personal characteristics of 3 or 4 star signs, including your own. Then group the members of your class into these star signs.

Would you say that the members of each group have similar characteristics? List these.

What other astronomical objects, other than the constellations, do astrologers believe influence these characteristics?

Hints and tips

- If you have a celestial globe, bring it into class and show the students how it works. If you are considering purchasing one, an acrylic transparent globe is a cheaper alternative.
- There is a free astronomy program for PCs called SkyGlobe which provides a view of the sky from anywhere at any time. It includes a fast forward option to show the motion of the planets and stars over any time period. There is a version you can download which opens up with the view from Melbourne. Go to <www.vicphysics.org>, click on *Teachers*, then *VCE*, then *Unit 1 Resources: Astronomy*, then *IT Applications: Sky Globe* for a file to download.

Activity notes

Make sure students understand the distinction between astronomy, which is a science, and astrology, which is not!

Learning experience

Most days in the media there is some sort of report describing an astronomical event: satellites docking, comets close to the Earth and so on. Ask the students to collect astronomy-related articles and bring them into class to discuss. They could compile a journal of articles for this chapter as an ongoing homework exercise. They should write the date of each article, a summary outlining the main points and an explanation of how it relates to astronomy. This task promotes science awareness, literacy and critical thinking.

Learning experience

Get the students to make a word list for this chapter. This is particularly useful for ESL students as they can write the words in their native language. Ask students to write sentences next to each word which use it in the correct context. Where appropriate, ask the students to draw labelled diagrams to help with their explanations.

Hints and tips

Australia has over 20 known impact craters as a result of meteorites striking the ground (the list is frequently being updated). Australia's most famous crater is Wolfe Creek Crater, located south of Halls Creek in Western Australia. It is the second most perfect crater on Earth. Other craters in Australia include the Henbury Craters south of Alice Springs, a collection of 14 craters scattered over a 1 km^2 area. The craters range from 10 m to about 73 m in diameter. The Aboriginal name for these craters is *chindu chinna waru chingi yabu* which translates to 'sun walk fire devil rock'. They are quite young and are estimated to be about 15 000 years old.

science bits

Cosmic catastrophes

Astronomers know that meteorites or comets have crashed into the Earth in the past. Two massive impacts 250 million years ago and 65 million years ago may have caused the extinction of many land and marine organisms. Nearly 70% of all known species of land animals and plants became extinct over a relatively short time.

Did an enormous meteorite cause the mass extinction of the dinosaurs and many other species about 65 million years ago? Many scientists believe the meteorite impact theory is the most likely cause of the massive loss of species around the world at that time.

Evidence for a meteorite impact

Iridium is a metal that is extremely rare on Earth but common in meteorites. In 1978 scientists found iridium in rocks about 65 million years old in Italy. Since then iridium has been found in rocks of the same age in many places throughout the world, for example Denmark, Spain and New Zealand.

Fig 12 The Barringer crater formed 30 000 years ago when a meteorite estimated to be 100 m in diameter and weighing 2 million tonnes slammed into the Arizona desert.

What could have happened 65 million years ago? The meteorite, perhaps about 13 km in diameter, is thought to have crashed into the ocean near Mexico. The impact would have thrown ash and dust into the atmosphere causing global darkness over a long time. Fragments of the red-hot meteorite would have been thrown into the atmosphere, landing in forests across the world and causing widespread firestorms. The resulting smoke from the fires, as well as the ash and dust, would have reduced the amount of sunlight reaching the surface, causing a drop in global temperatures and almost stopping photosynthesis.

The impact would have caused enormous waves and tides—like when somebody jumps into a swimming pool. This movement of water would have killed many land organisms.

Questions and research

1 Suggest why a huge meteorite impact would result in loss of many plant and algae species.
2 Explain what you think the term *global firestorm* means.
3 Make a list of the changes a massive meteorite impact would cause if it occurred today.
4 Use the links below to find out why some scientists do not agree that a meteorite impact caused mass extinctions.

WEBwatch

Go to www.scienceworld.net.au and follow the links to the websites below, or search under *meteorite impacts* or *meteorite mass extinctions*.

All about meteorites
Lots of information about the formation and history of meteorites as well as frequently asked questions.

Crater links

Mass extinctions
Refutes the theory that meteorites caused mass extinction of life.

Dinosaur extinction page
Theories about the extinction of the dinosaurs.

Learning experience

Ask the students to investigate other known craters on the Earth's surface and write a list with the crater's name, location, size and other interesting facts. There are Earth impact databases which the students can access on the internet showing maps of crater strikes and aerial photos. The Earth Impact Database is worth investigating at <www.unb.ca/passc/ImpactDatabase>.

Learning experience

You might like to show the movie *Deep Impact* or another relevant science fiction film if there is time. The students could write their own creative story about a cosmic catastrophe. You could give them the start of a story and they could finish it. Remind them about the importance of being scientifically accurate as well as creative. Alternatively, you could ask the students to write a song or poem describing a cosmic catastrophe.

Check! solutions

1 A light-year is the distance travelled by light in a year. Astronomers use this as a unit of distance rather than using billions and billions of kilometres.

2 Altogether there are 88 recognised constellations. The zodiac refers to the 12 constellations, which lie near the imaginary line in the sky called the ecliptic. Their apparent path across the sky is similar to that followed by the Sun and Moon.

3 a The South Celestial Pole is the point in the sky towards which the South Pole points. It is the central point, in a photograph, around which the star paths are seen as circles.
b The elevation increases because you are nearer to the South Pole in Hobart.
c Yes, you would see the South Celestial Pole directly overhead if you were at the South Pole. The reason is that the Earth's South Pole is the nearest point on our planet to the South Celestial Pole.

4 The ecliptic is the path across the sky through which the Sun, Moon, planets and constellations of the zodiac apparently pass. In the northern hemisphere the ecliptic is in the southern part of the sky.

Check!

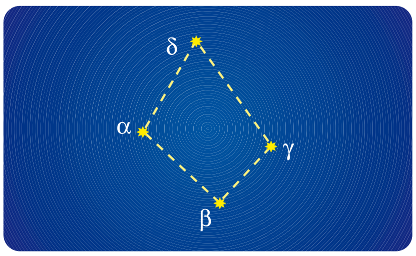
1 What is a light-year? Why do astronomers use this unit to measure distances?

2 How many constellations are recognised? Why are the constellations in the zodiac different from the others?

3 a What is the South Celestial Pole?
b Why does the elevation of the South Celestial Pole decrease as you travel from Melbourne to Brisbane?
c Would you ever see the South Celestial Pole directly overhead? Explain.

4 What is the ecliptic? Where would it be in the northern hemisphere?

5 The drawing below shows the four stars in the constellation Libra. What do the letters next to each of the stars mean?



6 In Australia the constellation Leo can be seen during the months of December through to June. Why can't it be seen in the other months?

7 The bright star Canopus, which can be seen due south during March, is 98 light-years away.
a How far away is Canopus in kilometres?
b During which year did the light you see today from Canopus leave the star?

8 What is the difference between astronomy and astrology?

9 The group of stars we call the Saucepan is part of the constellation Orion. How would you explain to a group of younger children that these stars in the Saucepan may not be anywhere near each other in space?

10 The Sun is 1.5×10^8 km from Earth. How long does light from the Sun take to reach the Earth?

11 You have met a number of new words so far in this chapter—zodiac, ecliptic, zenith, azimuth and elevation. Without looking in your textbook, write your own definitions for these words. Then check them on pages 270 and 271 or in the glossary.

challenge

1 Two of the stars in the constellation Centaurus are α-Centauri and β-Centauri. Can you tell from this information:
a which star is closer to Earth?
b which star is the larger?
c which star is the brighter?
Give reasons for your answers.

2 Pluto is a dwarf planet in our solar system—about 5.8×10^9 km from Earth. Why would it be inappropriate to use light-years to measure the distance to Pluto?

3 Lim told Yolanda that the bright blue-white star in the constellation Orion is called Rigel. It is 900 light-years away. Yolanda then wondered whether Rigel still exists. What answer could Lim give Yolanda?

4 Fig 7 on page 269 shows the movement of the stars when looking due south. What type of pattern would you get if you pointed the camera due east?

5 Look at Fig 3 on page 268.
a How far away from the Earth are each of the four brightest stars in the Southern Cross?
b Is there a relationship between the distance of the star from Earth and how bright it appears from Earth? Explain your answer.

6 Find out from the internet or library why astrologers associate a particular constellation with a particular time in the year.

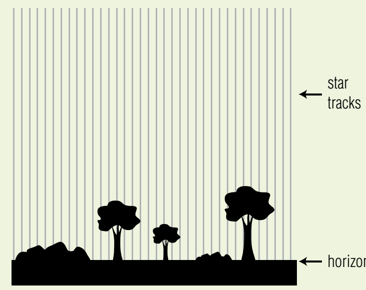
Challenge solutions

1 a No, α-Centauri is the brighter, but it may not be the closer of the two.
b No, α-Centauri is the brighter, but this could be because it is closer.
c α-Centauri is brighter.

2 Light takes only approximately 29 000 seconds or approximately 5 hours to travel to Pluto and this is only a very small fraction of a year.

3 Lim could say that it is very likely that Rigel is actually still there, unless it has exploded and disappeared in the past 900 years.

4 If the camera is pointed due east the pattern would look something like this:



5 a The α star is 370 light-years from Earth. The β star is 490 light-years from Earth. The γ star is 220 light-years from Earth. The δ star is 570 light-years from Earth.
b Generally, you can say that the closer a star is, the brighter it will be because as you move towards a light its brightness increases. However, this is not always the case with stars. For example, the closest star in the Southern Cross (γ-Crucis) is only the third-brightest.

6 At certain times of the year the Sun eclipses particular constellations (hence the term 'ecliptic'). Astrologers associate that time of the year with the constellation that is being eclipsed.

5 These Greek letters indicate the relative brightness of the four stars. In decreasing order of brightness they are α, β, γ and δ.

6 During the other months this constellation is not visible because it is below the horizon and visible from the other hemisphere of the Earth.

7 a Each light-year is 9.5×10^{12} km. Canopus is therefore $98 \times 9.5 \times 10^{12}$ km = 931×10^{12} km
b The light we see today (2008) left Canopus in the year 1910 AD.

8 Astronomy is a branch of science involved in the study of the universe beyond the Earth's atmosphere. Astrology is the fanciful use of some astronomical information to predict the future.

9 There are many ways of explaining this. Here is one way: You are looking out to sea at night and you see several lights that appear to be together. You cannot be sure of this, but they may be at different distances. It is just that they are all a long way away from you and in the same direction. It is like this with the stars in the 'Saucepan'.

10 Light travels at 3×10^8 m/s or 3×10^5 km/s.

You can use the formula $t = \frac{d}{v}$

$$= \frac{1.5 \times 10^8 \text{ km}}{3 \times 10^5 \text{ km/s}}$$
$$= 500 \text{ seconds}$$
$$= 8 \text{ min } 20 \text{ s}$$

11 See the correct definitions in the glossary or on pages 270–271.

Hints and tips

- Before starting new material, have the students document and prepare the key points from the last few lessons. How much they can recall will determine how much time you need to spend on review before moving on to new concepts. Alternatively, you could conduct a short quiz or mini-test on the chapter so far.
- Remind the students of the structure of an atom and its subatomic particles, particularly those contained within the nucleus. Reinforce the difference between chemical energy in the context of bonding and nuclear energy in the context of fusion. Make sure the students do not confuse nuclear *fusion* with nuclear *fission*.
- Reinforce that the unit of energy is the *joule*. It is also worth revising types of energy.
- In the previous section a light-year was described as the distance light travels in one year. This means the light from a star 1000 light years away will take 1000 years to reach us. The light from that star has travelled at the speed of light and so the light is from 1000 years ago. The star we are seeing is really how the star looked 1000 years ago, not how it looks today. Likewise, the light from our sun takes about eight minutes to reach Earth, and when we view it we are really seeing what it looked like eight minutes ago. If the Sun were to suddenly explode, we wouldn't know about it for eight minutes because that is how long it would take for the light of the explosion to reach Earth.

Learning experience

'If our Sun is a star, then all stars are suns.' Use this statement as a discussion starter with the students. Get them to generate a list of questions about stars that they wish to have answered by the end of this section.

12.2 Stars

What are stars made of?

Stars are gaseous objects in space that give off light and heat. They are made mainly of hydrogen and helium, with traces of heavier elements such as boron, carbon and nitrogen. For example, our sun contains about 80% hydrogen and 19% helium, while the remaining 1% is made up of the heavier elements. Compared with the size of the Earth, the sizes of stars are enormous. The Sun is over one million times the size of the Earth, while one of the largest stars, Canopus, is 80 000 times the size of our Sun.

The enormous size of a star creates huge gravitational forces which squeeze the atoms of the gases together and create immense pressure and heat. At this temperature electrons are stripped away from the atoms, leaving positively charged nuclei which are in constant rapid motion. The hot gases are in the state of matter called **plasma** which has different properties from the other three states of matter. Plasma conducts electricity and also generates a magnetic field.

In the core of the sun, hydrogen nuclei join together (fuse) and release energy. This type of reaction is called *nuclear fusion*. Fusion reactions can occur only in extreme temperatures and pressures like those which exist in stars.

The reaction that occurs in stars involves the fusion of hydrogen nuclei to produce helium. Albert Einstein reasoned that under certain conditions mass could be converted to energy. He proposed his famous equation $E = mc^2$ to explain this. (E stands for energy, m for mass and c for the speed of light.) In the fusion reactions that occur in the Sun, about 655 million tonnes of hydrogen are converted to 650 million tonnes of helium every second. The 5 million tonnes of hydrogen used up release about 4.5×10^{26} joules of energy every second. This is about the same amount of energy that all the power stations in Australia could produce in 7 billion years!

If you would like to know more about Albert Einstein's famous equation, go to page 276.

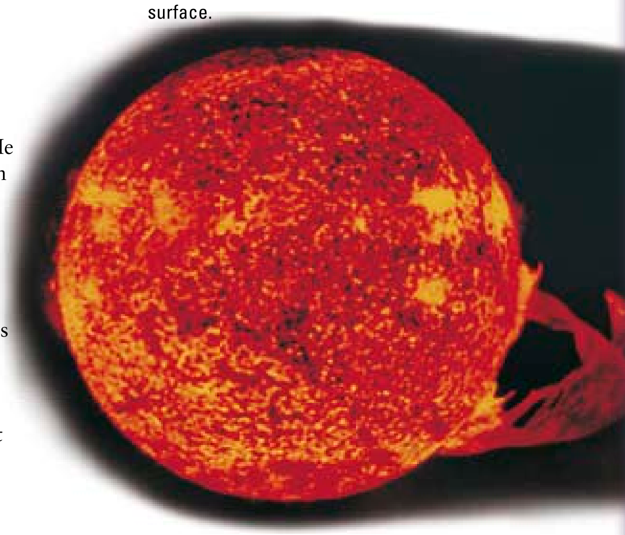
Structure of the Sun

The energy produced in the core of the Sun radiates outwards through thousands of kilometres of very dense gases. During this journey the radiation is absorbed and then re-radiated. This process takes a very long time, perhaps a million years for the radiation to get to the surface. This is why the Sun's energy is released at a constant rate and not all at one time as in a nuclear bomb.

As the energy moves outwards from the core, the gases begin to transfer their energy by convection rather than by radiation. This process creates huge convection currents which boil up to the surface. (See Fig 15 on the next page.)

The **photosphere** is the visible part of the Sun, the bright disk we actually see. It is the coolest part of the Sun, with a temperature of about 6000°C. Over half the radiation released by the photosphere is visible light, with the remainder being infra-red, ultraviolet, radio and X-rays. The photo of the Sun below shows its surface speckled with what astronomers call *granules*. These are caused by columns of hot gases bubbling up in the convection currents beneath the Sun's surface.

Fig 14 This photo of the Sun was taken with special filters and shows the granules on the surface.



Learning experience

- Ask the students to find out some specific facts about stars and prepare a fact sheet to share with the class. You could pin the sheets around the room for the students to read.
- Conduct a quiz based on the information on the sheets to see what students can remember. One way to do this is to use a true/false format. Ask all members of the class to stand up. Ask a question. If the students think it is true they put their hands on their heads; if they think it is false, they put their hands on their hips. Only the students who answer the question correctly are to remain standing. Continue this process until you have a winner. You might like to reward the winner with a treat, like glow-in-the-dark stickers of planets and stars.

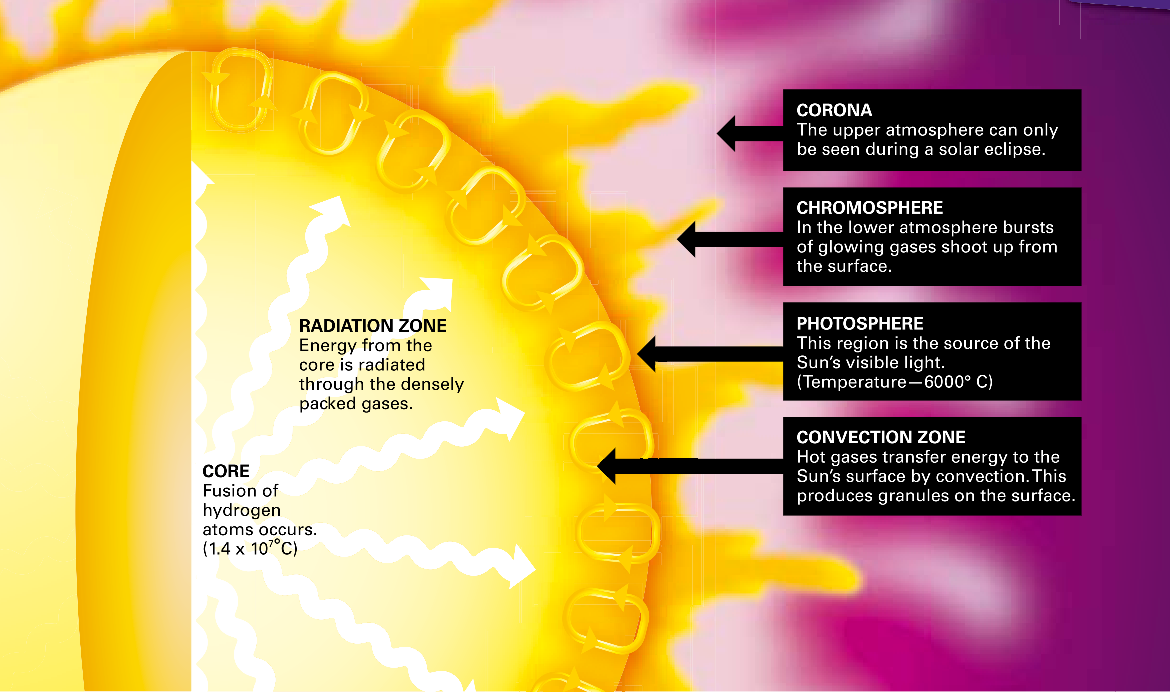


Fig 15 A cross-section of the Sun

Small bursts of hot glowing gas constantly shoot out from the photosphere into the lower atmosphere or **chromosphere**. (Chromosphere means 'coloured ball' and it gets its name from the red colour of the glowing hydrogen atoms.) But sometimes massive bursts of hot erupting gases shoot out into space. (See Fig 14 on the previous page.) These are called *solar prominences*, and can extend out into space for up to half a million kilometres (about 50 Earth diameters).

The upper atmosphere of the Sun is called the **corona**. Corona means crown, and it can be seen during solar eclipses as a halo of white light extending out into the blackness of space. The odd thing about the corona is that its temperature is about 1 000 000°C—hotter than the chromosphere and photosphere. Astronomers think that the heat comes from the ions and electrons that are being accelerated out into space from the corona.

Fig 16 The brightly glowing gases in the corona of the Sun can be seen only during a total solar eclipse.

Hints and tips

- Students often mix up the different regions of the Sun. Design an activity to reinforce what each region is. You might like to draw a flow chart showing the energy/light sequence or the processes involved. Start with what happens in the core of the Sun, eg:
  Energy produced in the core radiates outwards through thousands of kilometres of dense gas ⟶ *Energy is absorbed and then re-radiated (this process takes a very, very long time)* ⟶ and so on.
- Sunspots are regions on the solar surface that appear dark because they are cooler than the surrounding photosphere. They have been observed since the time of Galileo. The number of sunspots noted in a given year varies dramatically but in a highly predictable way. The activity level of sunspots follows an 11-year cycle where a maximum corresponds to a period of high solar activity, which can include increased solar wind and phenomena such as auroras and magnetic storms.

Learning experience

Ask the students to draw an informative poster about the Sun explaining its structure, energy conversion process and interesting information. Alternatively, they could present their information as a PowerPoint or multimedia display.

Learning experience

Get the class to investigate what sunspots are, and explain their 11-year cycle. Is the Earth's climate affected by high sunspot activity?

Extension

Obtain some data of sunspot cycles and turn it into a graphing exercise. Ask the students to explain what the data is about and interpret the graph.

Hints and tips

- Do not assume the students understand scientific notation (powers of 10). It is worth going over this with the class. Give them some examples on the board and reinforce it with a follow-up exercise. If calculators are used, make sure students know how to use them correctly.
- You may need to go over the questions in class, particularly question 3, to make sure students understand.

Research

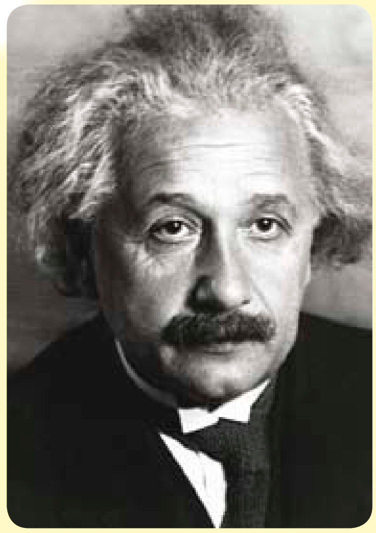
Keen students could research Einstein's Special Theory of Relativity in more detail. Ask them to present their information as a series of dot points and then use these dot points to write a paragraph explaining how the theory relates to the study of stars.

Homework

The Sun has enough energy to shine for about 15 000 billion years. Ask students to show the necessary calculations needed to arrive at this figure. (They may need to round their figure up.)

Science in action

$E = mc^2$



The Sun's energy source

If the Sun gives off about 4.5×10^{26} joules of energy each second, what is its source of energy? Will this energy source run out? When?

Fossil algae have been found on Earth that are more than 1000 million years old. These organisms could not have grown if the temperature of the Earth varied by more than 20°C from what it is now. Therefore the Sun could not have changed its size or brightness over this time.

Geologists estimate using data from the radioactive decay of rocks, that the Earth is about 4.6 billion years old. Assuming that the Sun is about 5 billion years old, then 7×10^{43} joules of energy must have been given off during this time.

Early theories

Many ancient cultures believed that the Sun was a fiery mass whose fuel was wood. Scientists in the 1700s realised that chemical energy alone could not have supplied the Sun's energy over millions of years. In fact it would have run out of fuel after about 300 000 years.

In the 1800s a popular theory among astronomers was that the Sun's energy source was gravitational potential energy. How does this work?

The Sun has gravitational potential energy because of its large mass and volume. The laws of physics tell us that if the mass of the Sun's gases contract inwards towards the centre, its volume will reduce and it will give off energy. Astronomers at the time believed that this was an acceptable theory. In the late 1800s, physicists calculated that if the Sun used gravitational potential energy as its energy source it would be 20 million years old. However, geologists objected to this theory because their evidence suggested that even the Earth was older than this.

Science was in a quandary. A new idea was needed.

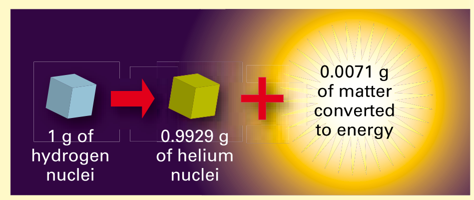
Special Theory of Relativity

Ever since the days of Newton, scientists thought that matter and energy were separate. They used the law of conservation of mass which said that the total mass of the reactants equals the total mass of the products.

In 1905, Albert Einstein published his Special Theory of Relativity. In this he reasoned that minuscule amounts of matter are actually lost in reactions, particularly the reactions in stars. This matter could be converted to energy according to his famous formula $E = mc^2$. This incredibly simple formula showed that large amounts of energy could be produced for very small amounts of matter. This is because the velocity of light, c, is such a large number (3×10^8 m/s).

Einstein showed that the Sun could shine for billions of years if it used some of its mass to supply its energy. For example, if the mass of the Sun is 2×10^{30} kg, then using $E = mc^2$, the Sun could give off 2×10^{47} joules, or enough energy to shine for 15 000 billion years!

In the fusion reactions in the Sun in which hydrogen nuclei are converted to helium nuclei, each gram of hydrogen loses 0.0071 g which is converted to energy.



Questions

1. What were the problems with the early theories about the Sun's source of energy?
2. In what main way is Einstein's theory different from the early theories?
3. How much energy would 1 kg of hydrogen give off in a fusion reaction?

Light from stars

You may have noticed when looking at the stars that some stars are much brighter than others and that they are not all the same colour. Some look red, while others look yellow, or white or even blue. The brightness and the colour of a star are very important factors in determining its size and its life expectancy.

Brightness

The brightness of a star when viewed from Earth is measured on a scale and is called *apparent magnitude*. The brightest star in the sky, excluding the sun, is Sirius with a magnitude of –1.4. The stars just visible with the naked eye have magnitudes of about 6. The apparent magnitude becomes more positive as the brightness of the star decreases.

The apparent magnitude is a useful scale for identifying stars from Earth, but it is not a measure of a star's *actual* brightness. This is because a star that is actually very bright may be a long way from Earth and appear quite dim. To measure the actual brightness of a star another scale, called absolute brightness or *absolute magnitude*, is used. The absolute magnitude scale compares the amount of light given off by a star if it was a set distance from Earth. Like the apparent magnitude scale, very bright stars have negative numbers. As the brightness decreases the numbers become more positive.

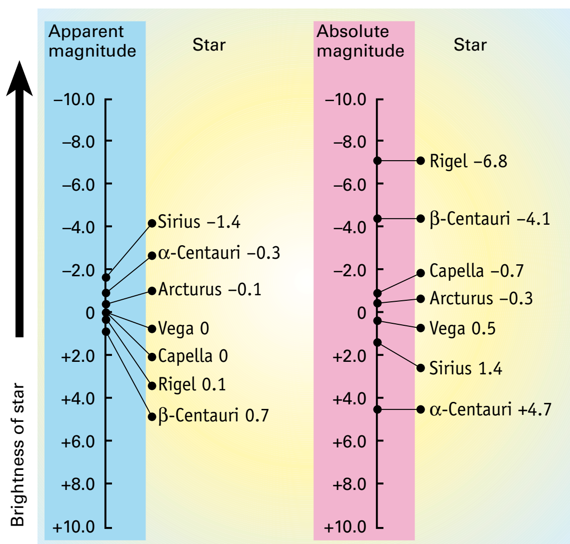
The amount of light a star gives off is determined usually by its size or the amount of matter in it. The rate of energy radiated by massive stars like Canopus (80 000 Sun masses) is much greater than from smaller stars like our sun.

Colour

The colours of stars vary from blue to red. The hottest stars give off a white to blue light, while the coolest stars give off red light. Very hot stars like Rigel give off large amounts of ultraviolet light, but because our eyes cannot detect this light we see Rigel's colour as blue.

Astronomers are able to calculate the surface temperature of stars by measuring the wavelength of the light given off. A simple equation proposed by the German physicist Wilhelm Wien (pronounced VEEN) in 1907 and later called Wien's Law is used to do this.

How then are brightness and colour related? Firstly, if two stars are the same colour they must have the same surface temperature. But if the absolute brightness of one of the stars is greater than the other, then it must be larger, since the size of the star determines its brightness. Secondly, if a red star and a blue star have the same size they will have the same brightness, but the blue star will radiate more energy per second because it is hotter.



Hints and tips

- It is important that students grasp what is meant by the magnitude of something. *Apparent magnitude is* how we perceive the brightness of the star from Earth. Make sure the students understand the difference between *apparent* and *absolute* magnitudes of stars.
- If there is time, you might like to explain about red and blue shift in relation to moving stars. Stars moving away from Earth are red shifted, while stars moving towards Earth are blue shifted. This is to do with the Doppler effect. Use the analogy of sound waves from an approaching police car with its siren on to explain this concept.

Research

If some stars are at the red end of the spectrum in colour and others are at the blue end, what colour is the universe? If all the light from the stars was combined, what colour would it make? These questions puzzled astronomers for some time, and in 2002 it was reported the universe is beige in colour. Ask the students to investigate how astronomers arrived at this conclusion. They could write a newspaper report, perhaps in the form of an interview with the astronomer who made this claim.

Learning experience

Get the students to make a list of reasons why stars are different colours. If we were able to travel to Alpha Centauri, what would our Sun look like from there? Turn this into a Think/Pair/Share activity.

Learning experience

If the students completed the Homework activity on page 267 listing the nearest 25 stars to Earth, they could add another column to the list for 'Colour of star' and fill it in. It may be tricky to find this information, so they could pool their results and complete the table as a class.

Learning experience

The students could use a spectroscope to study the spectrum of light from a light bulb, or the sunlight from a window. They should, however, *never* use the spectroscope to view the sun directly. Ask them to draw what they see. They could put coloured filters over the spectroscope window and again draw what they see. Ask them to explain how this exercise relates to the colours of stars.

Activity notes

- Remind the class that light travels in waves. Explain what is meant by a wave's *wavelength*. The most appropriate unit for measuring the wavelength of electromagnetic radiation (which includes visible light) is the *nanometre* (nm).
- You could try other types of light bulbs, eg microscope lamps.
- It's better to do the Activity in a darkened room, with the usual caution about student behaviour.

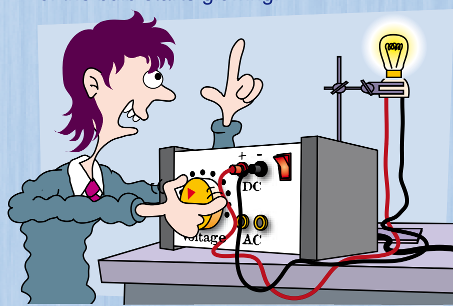
Activity

A: Colour of a filament

For this part of the activity you will need a 12 volt bulb and socket (eg from a ray box), a clamp and stand to hold it, and a power pack.

1 Connect the bulb and socket to the power pack.

2 Set the power pack on the lowest voltage, then increase the voltage until the filament of the bulb starts glowing.



3 Slowly increase the voltage up to 12 V.
Record the change in the colour of the light emitted from the filament as the voltage increases.
At what voltage does the filament give off most light energy? Explain.
Infer which would be the hotter filament—the yellow one at a low voltage or the white one at a higher voltage.
Give another example where the colour changes when an object's temperature changes.

B: Calculating the temperature of stars

All stars give off light. The wavelength of this light can be accurately recorded by electronic equipment, especially in satellites above the Earth's atmosphere.

Wien's Law shown below can then be used to calculate the temperature of the star:

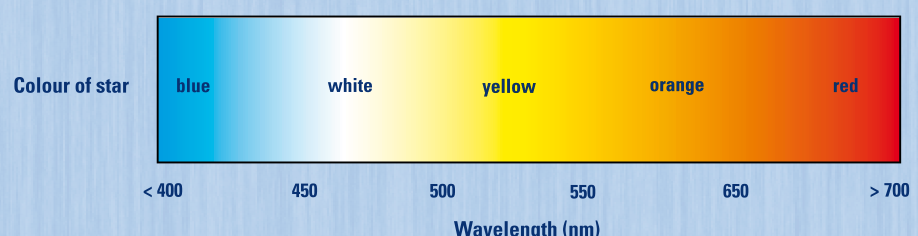
$$\text{temperature} = \frac{3 \times 10^6}{\text{wavelength}}$$

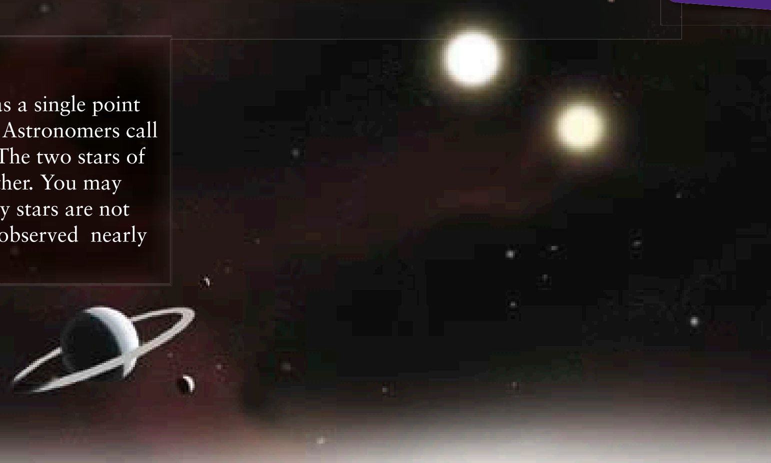
where the wavelength is measured in nanometres (nm) or 10^{-9} m, and the temperature is measured in Kelvin. (The Kelvin scale is the same as the Celsius scale except that zero degrees on the Kelvin scale is –273°C. This means you add 273 to the Celsius reading to get the temperature in Kelvin.)

1 Use the information in the table below and the formula above to calculate the temperature of each of the stars.

Star	Wavelength emitted (nm)
Capella	545
Canopus	440
Arcturus	667
Sun	510
Betelgeuse	700

2 Use the information below to prepare a data table listing each of the five stars, its temperature and its colour.





Binary stars

Many of the stars that you see as a single point of light are in fact double stars. Astronomers call these star couples **binary stars**. The two stars of a binary revolve around each other. You may be surprised to know that binary stars are not uncommon. Astronomers have observed nearly 700 000 binaries.

Usually the stars revolve around each other over a very long time—the revolution time is measured in centuries. For this reason the revolution time for only about 100 binaries has been accurately measured.

Sometimes one star in a binary will pass in front of the other during their revolution. This happens because we see the orbits of the binaries edge-on. The best example of this is a binary in the constellation Perseus near Orion. The beta star (Algol) is sometimes called the Demon Star because its brightness keeps changing. Astronomers now know that the two stars are very close together and revolve around each other in a very short time—2.8 days.

When the dimmer star (apparent magnitude 3.4) passes in front of the brighter star (apparent magnitude 2.0), the binary becomes three times fainter when viewed from Earth. Two other famous binaries in the southern hemisphere are α-Centauri and α-Crucis.

Some binary stars can be seen with binoculars. However, if you have access to a telescope you will see the binaries in the list below very clearly. Use your star chart to find and observe the following binary stars:

- α-Centauri—magnitudes 0 and 1.7 (the brighter star of the Pointers)
- α-Crucis—magnitudes 1.4 and 1.9 (the star at the foot of the Cross)

Fig 23 Star 1 is the brighter star in this binary. In the position shown, the binary appears bright from Earth.

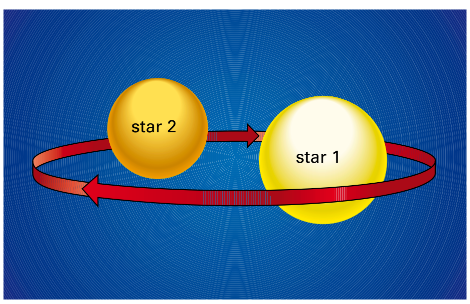
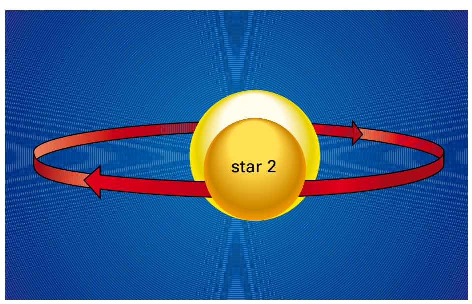


Fig 24 When star 2 passes in front of star 1, the brightness of the binary as seen from Earth decreases.



Hints and tips

One way to explain why you usually see binary stars as a single point of light is to use car headlights as an analogy. At night time, if a car is driving towards you from a great distance away, you will see the pair of headlights as a single light. As the car comes closer, the single light separates into two points. This is also the case with binary stars. Because they are such great distances away from the Earth, they are seen as a single point of light. Powerful telescopes are used to magnify binary stars so that each star can be observed individually.

Assessment task

This would be a good place to set *Assessment task 12: Space exploration*, found on the CD.

Learning experience

Get the students to make a fact sheet on different types of stars. They could also make informative posters with colourful pictures on them.

Learning experience

Ask the students to produce their own astronomy picture gallery of different types of stars, constellations, galaxies and nebulae from the internet. They could make a slide show in PowerPoint to display their pictures. Make sure the students reference their pictures—what the image is, its name and its location in the universe.

Check!

1 Some of the following statements are incorrect. Choose the incorrect ones and rewrite them to make them correct.
 a The photosphere is the visible part of the Sun.
 b The only energy the photosphere releases is visible light.
 c In the outer regions of the Sun the energy is transferred by conduction rather than radiation.
 d The chromosphere of the Sun can only be seen during a total solar eclipse.

2 a Explain how energy is produced in a star like our Sun.
 b Why doesn't the fuel in the Sun explode all at once in one gigantic nuclear explosion?

3 a What is the difference between a star's apparent brightness and its absolute brightness?
 b Design an activity using a 25 watt bulb and a 100 watt bulb that would demonstrate the difference.

4 a What do the E, m and c stand for in Einstein's formula $E = mc^2$?
 b How does this formula explain how energy is released in the nuclear reactions in the Sun?

5 How do astronomers think the granules that can be seen on the Sun's surface are formed?

6 What is a binary star? Suppose our Sun was a binary, describe what a 'day' would be like. How would it affect life on Earth?

7 What do the words chromosphere and corona mean? Suggest what the word photosphere means. Why was this part of the Sun given this name?

challenge

1 Star A gives off light of wavelength 430 nm while that of star B is 670 nm. What colours are the stars?

2 Suggest why plasma (like that found in the Sun) conducts electricity. How is it different from the way a salt solution conducts electricity?

3 Use the information in the diagram on page 277 to answer the following questions.
 a Which star is the brightest from Earth?
 b Which star is giving off most light?
 c What does the diagram say about Vega and Capella?
 d What can you infer about the two stars in the Pointers?

4 a The ratio of hydrogen to helium in the Sun is decreasing with time. Suggest why.
 b The ratio of hydrogen to helium is not constant throughout the Sun. Suggest why the ratio is different in the core from what it is in the chromosphere.

5 Two stars of equal size have temperatures of 4500 K and 7600 K.
 a What does the K after the numbers mean?
 b Which star gives off more energy per second? Explain your answer.
 c Use Wien's Law and the information on page 278 to find the colour of each star.

6 Two stars called Uno and Duo form a binary star. They revolve around each other in 15 days. Uno has a magnitude of –1.1 and Duo has a magnitude of 1.3.
 a Would the magnitudes given be apparent magnitudes or absolute magnitudes? Justify your answer.
 b The light from most of the binary stars viewed from Earth does not change. Why is this?

7 Sunspots are dark areas that can be seen on the Sun's surface.
 a Galileo calculated that the Sun's period of rotation is about 25 days by observing sunspots. Suggest how he did this.
 b Astronomers have found that the Sun's equator rotates in 25 days while a point at latitude 45° rotates in 31 days. How could this be possible?
 c How could the brightness of a star be affected by sunspots?

8 Write a narrative about life in a solar system that has a binary star as its sun.

Check! solutions

1 a Correct.
 b Incorrect. The photosphere releases invisible radiation such as infra-red and ultraviolet as well as visible light.
 c Incorrect. In the outer regions of the Sun the energy is transferred by convection rather than radiation.
 d Incorrect. The corona of the Sun can only be seen during a total solar eclipse.

2 a Energy is produced by nuclear fusion. This process involves two hydrogen nuclei combining to form a helium nucleus and releasing energy.
 b The Sun does not explode because the reactions that produce the energy occur in the densely packed core, and the energy is very slowly radiated out towards the surface. The materials in the Sun are also held together by the force of gravity, which is very strong.

3 a A star's *apparent* brightness is a measure of how bright it is when observed from Earth. Its *absolute* brightness is how bright it is compared with other stars.
 b It is possible to get a light meter which will accurately measure the intensity of light emitted by a light globe. If you place a 25 W bulb and a 100 W bulb at the same distance away from you, the 100 W bulb is much brighter. This means that it has a greater *absolute* brightness than the 25 W bulb. However, if you move the 100 W bulb further away, at some distance the two bulbs will glow with the same brightness. This means that their *apparent* brightness is now the same.

4 a In this formula 'E' represents the energy, 'm' the loss of mass and 'c' the speed of light.
 b It means that under certain conditions, mass can be converted to energy. If, during a nuclear reaction, there is a loss of mass, then there is a huge amount of energy produced.

5 Astronomers think that these granules are caused by columns of hot gases bubbling up from the interior of the Sun. They are similar to the bubbles that you see on the surface of boiling water.

6 a These are apparent magnitudes because they must be close together and can be easily viewed and measured from Earth.
 b The light will only change when one of the stars passes in front of the other, which will only occur rarely.

7 The chromosphere means 'coloured ball'. It is the lower atmosphere of the Sun and is so named because of the red colour caused by the glowing hydrogen atoms. The corona means 'crown'. It is the upper atmosphere of the Sun and is so named because during eclipses it can be seen as a 'halo' or 'crown' extending out into space. The photosphere is the bright disc we actually see as it emits light and other radiation. It was given this name because the word 'photo' means visible light.

Challenge solutions

1 Star A is blue and Star B is red.

2 Stars have enormous masses, which cause great forces of gravity. These forces cause the atoms to be tightly packed together and the electrons to be stripped away from the nucleus. The resulting plasma is able to conduct electricity and generate magnetic fields. This is different from a salt solution, which conducts electricity because the charged ions are able to move through the solution.

3 Using the information on page 277:
 a From Earth the brightest star is Sirius.

12.3 Star life cycles

Fig 25 The Great Nebula of Orion is a huge expanding cloud of gas that resulted from a supernova.

If you look at the sword in the constellation Orion (the handle of the Saucepan) with powerful binoculars you will see a fuzzy bright object. This is a massive cloud of gas and dust called a **nebula** (NEB-you-la) and was caused by a **supernova**: a spectacular explosion which ended the life of a star. See the photo above.

Astronomers believe that stars are born in clouds of gas (mainly hydrogen) and dust that occur throughout the universe. Occasionally one of these clouds collapses on itself, becoming hotter and denser as the gravitational force increases. This is the embryonic stage in the life of a star and it is known as a *protostar*. Eventually the gas becomes hot enough to start nuclear fusion reactions and the star begins to glow.

Birth and death of stars

The life cycle of a star depends entirely on its mass. A protostar with a mass less than 0.1 of the mass of the Sun will continue to shrink but will never get hot enough for nuclear reactions to begin. It will fade to form a small red star before turning cold and dead.

When a star about the size of our Sun forms, it initially glows very brightly. After this initial period, the star settles down to a long stable middle-life period of about 10 billion years. Our sun is now at about midlife and has another 5 billion years to go before it runs out of fuel.

As the star ages and much of the hydrogen is used up, its surface temperature decreases. Finally, when little hydrogen remains, the star's core shrinks, the outer layers expand and cool, and the star forms a *red giant*. After this, the gases in the outer regions drift into space and the remaining gases collapse into a small, very dense object known as a *white dwarf*. These stars are

---

b The star giving off most light is Rigel.

c Even though these two stars appear to have the same brightness (apparent magnitude), Capella is actually brighter than Vega (absolute magnitude).

d You can infer that although β-Centauri appears to be brighter than α-Centauri when viewed from the Earth, it is, in fact, the other way around.

4 a The ratio is decreasing because each second approximately 655 million tonnes of hydrogen are converted to about 650 million tonnes of helium.

b In the core of the Sun, hydrogen atoms react with each other to produce helium atoms. Hence, you would expect the ratio of helium to hydrogen atoms to be greater than in the chromosphere.

5 a K is the symbol for absolute temperature and is measured in Kelvin (not degrees K).

b The star with the greater surface temperature (7600 K) will give off more energy because, generally, more energy is radiated from objects at higher temperatures.

c Using Wien's law:

$$\text{wavelength} = \frac{3 \times 10^6}{\text{temperature}}$$

The wavelength of the cooler star is $\frac{3 \times 10^6}{4500\ \text{K}}$ = 667 nm. This means that it is a red star.

The wavelength of the hotter star is $\frac{3 \times 10^6}{7600\ \text{K}}$ = 395 nm. This means that it is a blue star.

6 a These are probably apparent magnitudes because they are being viewed and measured from Earth.

b The light from the binary stars does not change much because they revolve around each other over very long periods of time (ie hundreds of years).

7 a Galileo was able to observe patterns of sunspots with his telescope and noted that they reappeared in the same position on the Sun's surface after approximately 25 days. From this, he inferred that the Sun was rotating approximately every 25 days.

b The Sun is not solid but a plasma, which has liquid–gas properties. Because of this, the regions around the equator rotate faster than regions around the poles.

c Because sunspots are darker areas on a star's surface, they will give the impression that a star is less bright and therefore cooler than it really is.

8 In your narrative you might mention the following points:

- whether the stars are close together or far apart
- whether the planet(s) orbit around one or both of the stars
- that there will be great variations in light and heat depending on whether neither, one or both of the stars are visible
- that it is unlikely that there will be regular and gradual seasons such as we have on Earth
- that day length(s) may vary greatly
- that there will often be two shadows cast by the same object (like shadows under lights at sporting events).

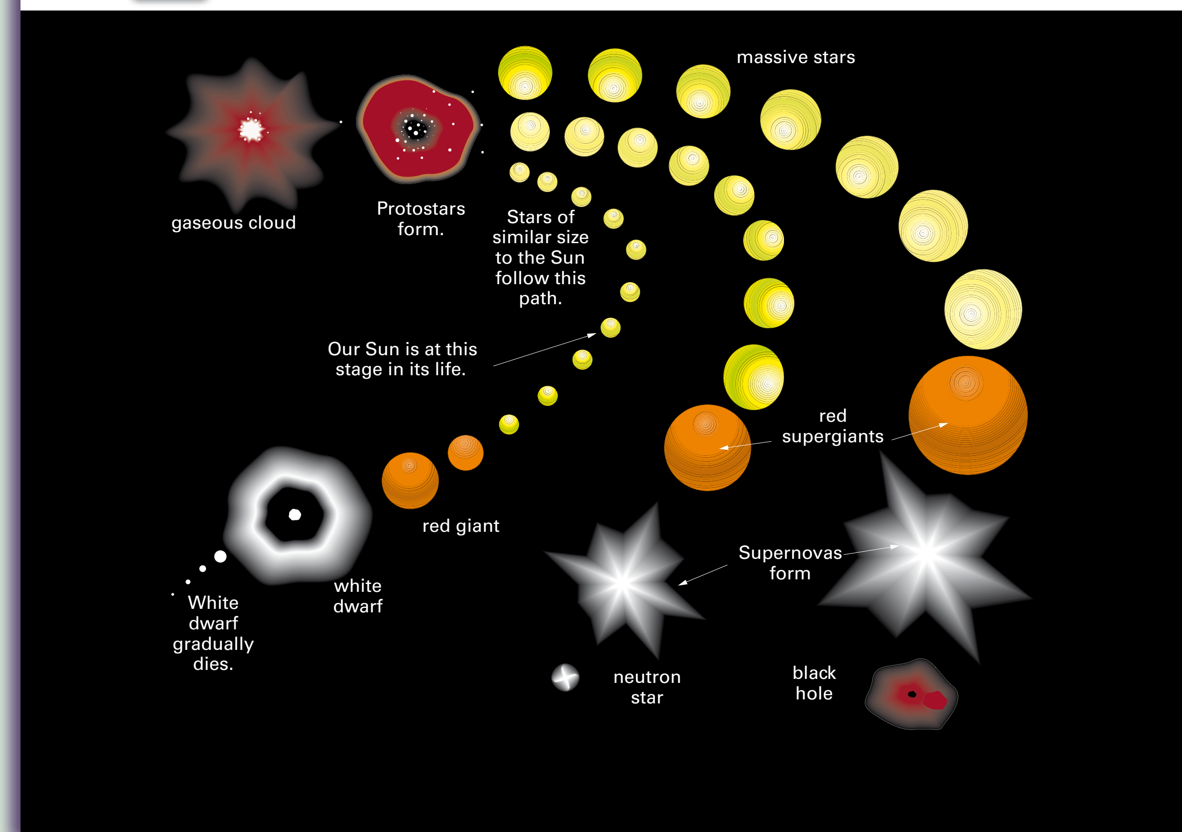
Such a possibility has been mentioned in the science fiction movie *Star Wars*. More information can be found at <www.badastronomy.com/bad/movies/starwars2.html>

very small and can be seen only with a powerful telescope. Eventually the white dwarf cools down and fades away. Betelgeuse, the red star in the constellation Orion, is a red giant and was probably once similar in size to the Sun.

Stars two to six times the size of the Sun have a much shorter but spectacular life. These stars live for only about one million years. The mass in large stars creates enormous gravitational forces in the core of the star. The nuclear reactions use fuel very rapidly, creating very hot bright stars which glow blue in the night sky. When the fuel runs out there is a tremendous outburst of energy which we see as a supernova. Much of the star's matter is blown into space, leaving a nebula. When such an explosion takes place the brightness of the star increases a billion times.

Fig 27 The Ring Nebula in Aquarius is expanding into space at 25 km/s. It has a central star which is probably forming into a white dwarf.

Fig 26 The evolution of stars. Our Sun at present is in the middle of a stable period of its life.



Hints and tips

- Make sure the students can properly distinguish between a nebula and a supernova. Also reinforce that the life cycle of a star depends entirely on its mass.
- Students might have heard about imploding stars. If so, discuss them.

Learning experience

If possible, get the students to interview an astronomer, preferably an Australian. Perhaps they could meet the astronomer and record the interview to show the class. They should ask the astronomer about their work, how they became interested in astronomy, any discoveries they have made, and what they see as the future in astronomy. Contact a local astronomy group or universities, or check out the internet for possible astronomers.

Learning experience

The students could construct a concept map about stars to link words and terms from Chapter 4. Alternatively, they could construct a sunshine wheel, a concept map with 'spokes' coming out from a central term. The word 'Stars' goes in the middle, while the spokes radiating outwards are used to write connecting sentences. This activity doesn't have to be limited to theoretical concepts. Emotions and thoughts about the topic could also be explored.

Hints and tips

You might like to talk to the students about the Hubble Space Telescope. Many images we see today from space are from this telescope. The telescope is named after Edwin Hubble (1889–1953) who showed that the universe has many galaxies, not just the Milky Way as was once thought.

Learning experience

The students could make a flip book of the theorised cycle of stars. Get them to choose which path the star will take (white dwarf, neutron star or black hole). Alternatively, they could design a flow chart of the life cycle of stars. It should contain three branches.

Learning experience

Get the students to make star mobiles showing each possible star cycle. Hang them around the room. They could make 3D models using different-sized painted polystyrene balls. Let them be creative with materials for other stages of the cycle.

Homework

Ask students to have a look at the night sky and see if they can observe any red or blue stars. With their star chart (see Activity notes page 269), they could try to identify the stars.

Nebulas and neutron stars

When a massive star ends its life in a supernova explosion, much of its mass is blown out into space. Supernovas do not happen very often since most of the stars in the visible universe are of medium size. Astronomers estimate that a supernova occurs about once every 75 years in our galaxy.

Some nebulas emit their own light and glow like stars. They can glow pink, blue, yellow or green depending on the type of gases in the cloud. The rich pink colour of the Great Nebula of Orion indicates the presence of hydrogen gas. Other nebulas do not glow and block out the light from the stars behind them. The Horsehead Nebula (see the photo on page 288) is a dark nebula which can be seen against the glow of stars in the background.

During a supernova explosion, astronomers believe that the remainder of the star's core is pulled inwards by immense gravitational forces to form an incredibly dense star less than 20 km in diameter. The original protons and electrons in the core are squeezed so much that they fuse to form neutrons—atomic particles with zero charge. Thus this type of star is called a **neutron star** and its density is estimated to be a thousand billion billion times that of water. Because they are so small, neutron stars do not glow very brightly, but they do send out pulsating radio signals. For this reason they are often called *pulsars*. Astronomers do not understand pulsars very well but they think that the pulsating radiation they emit is due to the star spinning on its axis.

Black holes

It seems hard to imagine anything odder than a neutron star. But the greatest oddity of the universe is reserved for **black holes** which form when the massive stars, about ten times the size of our Sun, explode.

After the supernova explosion, the core collapses on itself, and unlike a smaller star, these massive stars keep on collapsing. Nothing can halt this collapse, and the gravitational force that is created is so strong it will not even allow light to escape. What remains of the massive star is a dark 'hole' in space which astronomers call a black hole. Astronomers have detected strong X-rays coming from invisible objects in space which they believe are black holes.

WEBwatch

Go to www.scienceworld.net.au and follow the links to the websites below.

Is a black hole really a hole?
Informative site with great graphics.

Black holes and beyond

Black holes
This site has an animation of a journey into a black hole.

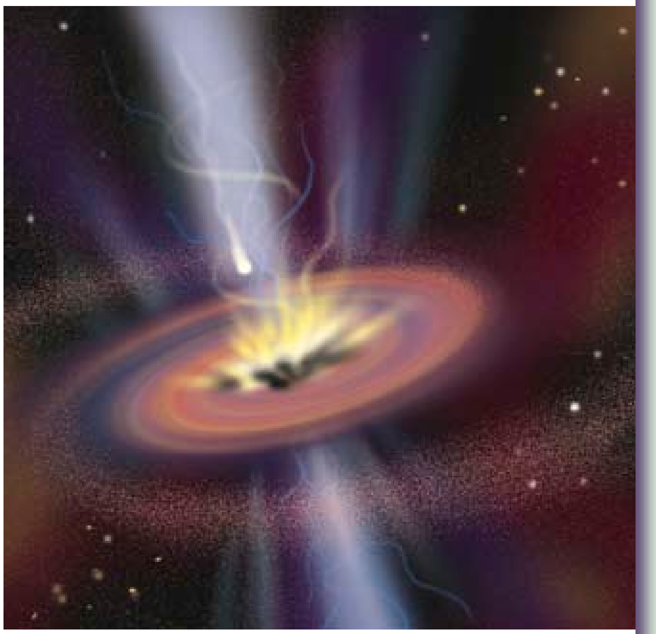


Fig 28 An artist's impression of a black hole. Gas and dust from a nearby star is being drawn towards the black hole where it circulates, heats up and gives out streams of X-rays.

Hints and tips

Is it possible to photograph a black hole? Why or why not? Why do we know they exist? Get the students to generate a series of 'Why' questions around this page and use them as discussion points.

Homework

Ask students to write a creative story about being sucked into a black hole. They will need to do some more research on black holes and can use the Webwatch links for this.

Learning experience

Place some detailed information sheets about stars and cosmology around the room. Get the students to design one card for each sheet using dot points, or ask them to do a 10-point summary about each sheet. Then ask each student to read out one of their points to the class, making sure each point is different. This is a good way to revise the chapter so far.

Learning experience

Get the students to imagine they have just discovered a new star, and ask them to answer the following questions:

- What would they call it?
- Where is it located?
- What type of star is it?
- How was it discovered?
- How did they feel when they realised they were the first person to discover it?

Ask them to give as much information as they can about this new star. They can then present their work as a media article in the form of an interview. The students might also like to act out the interview as a role play.

Hints and tips

- Remind students again what scientific notation is.
- Go through the questions relating to 'The death of a star' on the board with the class, particularly questions 1 and 2.
- Ensure that students are clear on the definitions of *astronomy*, *cosmology* and *astrophysics* and understand the differences between them.

Science in action

Bryan Gaenslar: astronomer

In 1999 Bryan Gaenslar won the Young Australian of the Year award for outstanding achievement in the field of astrophysics. During his PhD studies at Sydney University, he discovered that a supernova acts as a 'cosmic compass' because it lines up with the magnetic field of the galaxy it is in. In the same year he won an international fellowship to study at the prestigious Centre for Space Research at the Massachusetts Institute of Technology in the USA. He is only the second Australian to have won this award.

Bryan is Professor of Physics in the Institute of Astronomy at Sydney University. He is currently studying neutron stars and the 'dark matter' in space. He is using the data sent back to Earth from the Chandra X-ray Observatory which was sent into an Earth orbit in 1999.

One of the first images sent back to Earth was the nebula called Cassiopeia A (see the photo below). Astronomers for years had been unable to detect any neutron star at its centre, even though they had predicted it had to be there. But in Chandra's images, Bryan found a bright central point which could be the missing neutron star.

<WEBwatch>

If you would like to find out more about Bryan Gaenslar's work, go to www.scienceworld.net.au and follow the links to **Bryan Gaenslar**. There you will find links to many interesting articles written for science magazines and newspapers.

The death of a star

Cassiopeia A, or CAS A, was a giant star ten times larger than our Sun and 12 x 10^{13} km away. The star had existed for more than 10 million years but was now running out of hydrogen fuel.

Stars exist because the radiation forces generated by the fusion reactions pushing outwards are balanced by the inwards pull of gravity due to the star's enormous mass. Then 10 320 years ago, with the nuclear fuel gone, the massive inward pull of gravity made the star collapse. What followed was a massive explosion and the total destruction of the star.

Cassiopeia's first pictures

In July 1999, after two attempts, the telescope Chandra was launched on board the Space Shuttle *Columbia*. Then on 19 August 1999 Chandra pointed its mirrors towards the supernova and took its first detailed picture of CAS A.

Questions

1 Use a diagram to show the forces acting in a star like our Sun.
2 What date on Earth was it when CAS A exploded?
3 Use the internet or books to describe the conditions on Earth at the time of CAS A's birth and death.
4 In mythology, Cassiopeia was banished to the sky to hang head downwards for half the year. Find out about Cassiopeia and why she was punished.

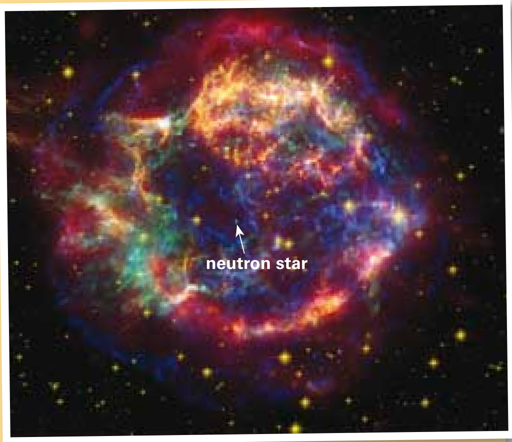


Fig 29 The nebula Cassiopeia A showing a probable neutron star in the centre

Learning experience

Use some relevant questions as the basis of a Round Table activity (see Learning experience page 196), or ask the students to brainstorm and research the answers in small groups.

- What are *dark matter* and *dark energy*?
- How have astrophysicists defined each?
- What hypothesis have they made about dark energy?

Learning experience

Do the Webwatch if you have access to computers in class, or give it as a homework exercise.

Cosmic explosion lights up the galaxy

On 27 December 2004, a collegue of Bryan Gaenslar sent him an email saying that he had detected a massive flash of light across the Milky Way galaxy. It was so bright that it bounced off the Moon and lit up the Earth's atmosphere. The flash was the brightest explosion in the history of astronomy—brighter than any other explosion ever detected from outside our solar system.

What caused the flash?

Byran Gaenslar and his team of astronomers now know that the small neutron star called a *magnetar* exploded, releasing an enormous pulse of gamma-ray radiation. The magnetar, named SGR 1806-20, was only about 20 km in diameter, but it gave off more energy in the 0.2 second flash than our Sun gives off in 200 000 years.

Gamma-ray radiation is very high energy radiation and can damage cells and tissues. It can also promote changes in chromosomes, leading to mutations.

Three other magnetar explosions have been recorded but this one was by far the biggest. Could a magnetar explosion closer to our solar system have been responsible for the mass extinction of organisms on Earth in the past?

Fig 30 An artist's impression of the gamma-ray flare expanding outwards towards the Earth from the exploding magnetar SGR 1806-20

Activity

In your previous studies in science, you have learnt how to write a feature article. Here is a reminder.

1 Structure

There are three parts, the introduction, body and conclusion. The introduction entices the reader to want to read more. The body needs to elaborate the issue raised in the introduction. The conclusion reminds the reader of the issue and finishes with a strong punchline.

2 Writing style

- The article must be a human interest story.
- Write in the active voice.
- Avoid lengthy, complex sentences. Use two to three sentences per paragraph.
- Make sure your information is accurate. Don't make it up!

Your task

Write a feature article about the life and death of stars, nebulas, black holes, space telescopes, or a day in the life of an astronomer like Bryan Gaenslar.

Write about 700 to 1000 words. Your teacher may check your first draft of the feature article.

To read an example of a feature article, go to Bryan Gaenslar's website and select the article 'A star is burst'.

Hints and tips

This chapter has a lot of written material in it, so make sure you are monitoring students who experience language difficulties. Students with a language or learning difficulty could be encouraged to draw concept diagrams to display information rather than write notes.

Activity notes

If students are using a computer to write their article, remind them to use the spellcheck feature. If they are not using computers, encourage them to use dictionaries for spelling. You may need to give ESL students and students with language difficulties extra time to complete this task.

Learning experiences

If you asked students to skim through this chapter and jot down about 10 questions about stars (see Starting point page 266), ask them to review their questions now and see how many they can answer. Any question they cannot answer can be discussed with the student next to them. If they still cannot answer the question, open it up to the whole class.

Homework

Have students do some reflective thinking about this chapter so far. Write the following questions out as a worksheet for the students to take home:

- What do you think is the most important point that you have learnt?
- How has your thinking about this topic changed from the start of the chapter?
- What is the most exciting thing you have learnt?
- What do you feel most confident/least confident about in relation to this chapter?
- How well do you think you have worked with other people?
- What is one thing you can do to improve your learning?

It is not necessary to grade the work as it is mainly students' reflections, but encourage them to take the task seriously.

Hints and tips

Remind the students that a theory is not proof that something has happened or will happen. The models of the origins of the universe are simply 'best guesses' based upon data collected about the cosmos. Scientists use their theories to make predictions that they or other scientists can test.

Origin of the universe

Astronomers who study the universe are called *cosmologists*. **Cosmology** is the study of the origin and structure of the universe. Over the years a number of models for the origin of the universe have been put forward by astronomers. Two of these models are described on this page.

The Steady State model

This model proposes that the universe has always existed. That is, we see the universe now as it was in the past and will be in the future. This means that the universe would be infinitely old, it would have no birth date and would never end.

The model suggests that new matter is created everywhere in the universe, and this matter forms galaxies which slowly move away from each other. This means that some galaxies in a particular region of space should be younger than others. However, evidence gathered over a number of years suggests that neighbouring galaxies are roughly the same age.

The Steady State model has some attractive features. Firstly it says that the universe is endless in time and space. Secondly it accounts for the fact that stars and galaxies die and re-form. And it avoids the difficult question of how the universe was created. However, today the Steady State model has few supporters because recent astronomical evidence does not fit it at all.

The red shift

A spectrometer is an instrument that measures the wavelength of light. Astronomers have found that the wavelength of the light coming from most stars has shifted towards the red end of the spectrum. This is called the red shift.

Astronomers know that a red shift occurs when stars are moving rapidly away from Earth. This is considered evidence that the universe is expanding.

The Big Bang model

The Milky Way galaxy is one of about thirty neighbouring galaxies in a cluster called the Local Group. Astronomers studying the galaxies in the Local Group noticed that many were moving away from us. And other galaxies deeper in space were moving away from us at even greater speed. It seemed that the universe was expanding in all directions.

Evidence that the universe is expanding has led astronomers to propose that all the matter in the universe must have come from a single source. At the beginning of time this source exploded, sending matter in all directions. This model for the origin of the universe is called the **Big Bang model**.

The Big Bang model suggests that about 10 billion years ago all the matter in the universe was contained in a hot, dense ball of radiation and subatomic particles. The temperature of this ball of matter was incredibly high—billions and billions of degrees. The model makes no attempt to explain the origin of this dense ball of matter.

An explosion took place and the matter expanded. As it expanded it cooled and electrons, protons and neutrons formed. On further expansion and further cooling small gaseous atoms like hydrogen and helium formed, then larger ones.

The matter thrown out by the Big Bang was denser in some places than others. In these denser places, gravitational forces squeezed particles of matter together and formed galaxies containing stars. However, astronomers predicted that small amounts of matter and also radiation would have been trapped in the spaces between galaxies as a result of the Big Bang explosion. Until recently these intergalactic spaces seemed totally empty. In 1989 the Cosmic Background Explorer satellite (COBE), and more recently the Hubble Space Telescope, have detected small amounts of matter and radiation in the intergalactic spaces.

Learning experience

Conduct a 'What am I?' quiz using questions about different features of the universe. Either use pre-prepared notes or flip through the chapter to help prompt your questions.

Learning experience

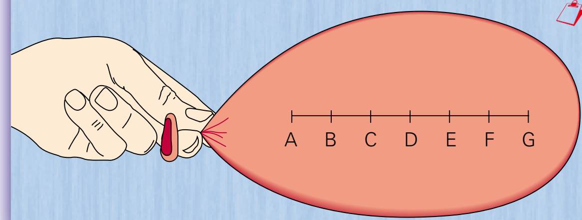
Ask the students to spend five minutes writing down as many points as they can about what they learnt from this chapter, or the previous lesson. Also ask them to write down one question relating to the chapter that they would like to know the answer to. Let the students share their points with the person next to them and discuss the questions. If they cannot answer a question even after discussing it, open it up to the class. If no one can answer it then it might be a good idea to set it as a homework activity or research it at the end of the lesson if there is time.

Activity

You can make a balloon model of the expanding universe.

1 Inflate a round balloon until it is just tight and hold the end.

2 Use a marking pen to draw a line on the surface. Mark seven points (A to G) at 1 cm intervals along this line. These points represent galaxies.



3 Inflate the balloon further. Measure and record the distances between the points.
 Did the points move apart by the same amount? How can you explain this?
 Suppose you live in galaxy D. In which direction would the other galaxies move? Would they move at the same speed? Try to explain your answers.
 How does this model demonstrate the expanding universe theory? What are the model's shortcomings?
 Design a model that more accurately demonstrates the expanding universe.

Activity notes

A slight variation of this activity is to draw different-shaped galaxies on an uninflated balloon. Circle or label the Milky Way as this is our galaxy. Slowly blow the balloon up, noting the movement of the galaxies. You can use the same questions in the Activity for this method.

The future of the universe

What will happen to the expanding universe in the future? There seem to be two answers to this question.

Firstly, some astronomers believe that the universe will go on expanding forever. This theory is based on the inference that the universe does not have enough mass to create the gravitational forces needed to pull it back together. The universe will eventually die as the stars and galaxies are reduced to clouds of gas and dust.

The second, less popular view, is that the universe will expand to a certain point and then collapse back on itself in a reversal of the Big Bang called the 'Big Crunch'. This will once again form a hot, dense ball of matter. This will start a second Big Bang and a new universe will be born containing all the matter that was in the previous universe.

The websites on the right contain information about cosmology, the origins of the universe, and dark matter. You could find other websites by searching under *Big Bang*, *Big Crunch* or *cosmology*.

WEBwatch

Go to www.scienceworld.net.au and follow the links to the websites below.

The Big Bang Time Machine
This site has an animated timeline of the events that occurred during the Big Bang. There are also links to information pages.

History of the Universe
A more detailed animation of the events in the Big Bang.

The Big Bang
Detailed information on the Big Bang.

Astronomy and the universe
This is a very easy-to-read site with information on the history and origin of the universe.

The future of the universe
Will the universe expand forever or will it finish?

The Big Crunch
A theoretical animation of what might happen when energy flips and pulls the universe together.

Hints and tips

Explain to students how the Open Universe, Closed Universe and Flat Universe theories suggest that gravitational attraction should slow or even stop the universe expanding. However, recent research by cosmologists indicates the expansion of the universe may be accelerating, due to some mysterious force called 'dark energy'. This cosmological force somehow appears to be overriding gravitational attraction.

Learning experience

The students could do a Venn diagram of the future theories of the universe. Venn diagrams help make comparisons and identify similarities. The overlapping area shows similarities and the differences are shown in the areas that do not overlap. You might also like to give them some information on the Closed, Open and Flat Universe theories. Gifted and talented students could do some further research on all three models.

Learning experience

Allow the students some time to surf through the Webwatch sites. You might need to prepare some instruction sheets, and question and answer sheets, for the students. They could explore the websites in pairs and write down five points they have learnt from each site.

Check! solutions

1 Astronomers expect the Sun to follow the same pattern that they have observed with other stars of a similar size. In approximately another 5 billion years all of the Sun's hydrogen will be used up and the outer layers will expand and cool to form a red giant.

2 Such a massive star will end its life in a supernova explosion and much of the mass of the star will be blown out into space, forming a nebula. This nebula can glow with different colours depending on the gases present. After the explosion, the remainder of the star's core will be pulled inwards by gravity so strong that not even light can escape. This is called a 'black hole'.

3 Protostars, which do not have sufficient mass, will never get hot enough for nuclear reactions to begin and will never become mature stars. Instead, they fade to form small red stars before turning cold and dead.

4 After a supernova explosion much of the mass of the star is blown into space and may form a nebula. The remainder of the star's core is pulled inwards and forms a very dense star with a diameter of less than 20 km. These stars are extremely dense and they largely consist of neutrons that are packed closely together. They are called 'neutron stars'.

5 The only factor that determines the length of a star's life is its size.

6 Here is one possible explanation. A supernova occurs when a star explodes. It is a bit like a fireworks display. All that is left is a glowing cloud of gas that can be seen in the sky for many years afterwards. The cloud of gas gets smaller and the gravity gets stronger and stronger. Eventually, the gravity is so strong that nothing can escape, not even light. This is why it is called a 'black hole'.

7 The nebula consists of particles of matter that act like a curtain and block out the light from the stars behind.

8 Neutron stars do not glow very brightly but they do emit pulsating radio signals. These pulsating signals are caused by the star spinning on its axis. This is the reason why they are sometimes called 'pulsars'.

9 A white dwarf is formed from a red giant when the star runs out of fuel and dies. Although very dense, white dwarf stars are very small and difficult to see. They eventually cool down and fade away, leaving a mass of gases in space. Neutron stars are formed after a supernova, when the remainder of the star's core is pulled inwards to form a very dense star with a diameter of approximately 20 km. This star is extremely dense and largely consists of neutrons that are packed closely together, hence the name 'neutron star'.

10 Telescopes on Earth have to receive light that has passed through the atmosphere and, as a result, lose some detail. A telescope that is mounted in a satellite, however, can receive signals directly from deep space and will show much more detail. These signals are then relayed back to Earth by way of radio waves, which are not distorted. This explains why the Hubble Telescope has been so successful in detecting new objects in space.

11 One theory about the origin of the universe is the Steady State model, in which matter was thought to be continuously created to fill space as it expanded. The Big Bang model suggests that all matter began with a major explosion, which created electrons, protons and neutrons from which all matter is made. It is currently the most acceptable theory simply because it can explain most observations and has also been used to make accurate predictions.

Check!

1 Why do astronomers expect that our Sun will end its life as a red giant?

2 A star has a mass 10 times greater than our Sun. Describe the inferred life of this star.

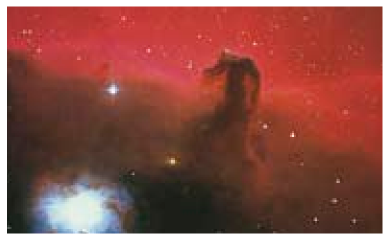
3 Why do protostars, which have a very small mass, not form mature stars?

4 How does a neutron star form? Why is it given this name?

5 Stars have a definite lifetime. What is the characteristic of a star that will determine the length of its life?

6 Suppose you were explaining the evolution of stars to some 9-year-old children. How would you describe a supernova and a black hole to them?

7 The photo below is the Horsehead Nebula in the constellation Orion. Suggest why the light of the stars behind it cannot be seen.



8 Why are neutron stars sometimes called pulsars?

9 How does a white dwarf differ from a neutron star?

10 The Hubble Space Telescope (see the photo below) is in an Earth orbit. Suggest why this telescope has detected objects in space that were previously unknown.
To find out more and to look at the photos and movies on Hubble, go to www.scienceworld.net.au, and follow the links to **Hubble**.

11 Compare and contrast the Steady State and Big Bang theories on the origin of the universe.

Fig 33 The Hubble Space Telescope in orbit around the Earth, with the Space Shuttle nearby

challenge

1 The Crab Nebula is 6300 light-years from Earth (see photo on page 266). If the supernova was seen in AD1064, work out when the actual supernova took place.

2 Astronomers have calculated that stars moving rapidly away from Earth cause a shift towards the red in the wavelength of light coming from them. Suggest what might happen if a star was moving rapidly towards the Earth.

3 A star has a surface temperature of 6200 K.
  a Use Wien's Law on page 278 to determine the wavelength of light actually coming from the star.
  b If the observed light coming from the star is yellow, is the star moving away from Earth or coming towards it? Explain your answer.

4 The fastest moving galaxies in the universe are the ones furthest away, whereas the slowest ones are located near the centre of the universe. How do these facts support the Big Bang theory of the formation of the universe?

5 Quasars are mysterious star-like objects that astronomers think may have the mass and energy of a galaxy concentrated into the size of our solar system. If you would like more information about quasars go to www.scienceworld.net.au, and follow the links to **Frequently Asked Questions about quasars**.

MAIN IDEAS

Copy and complete these statements to make a summary of this chapter. The missing words are on the right.

1 The stars that we can see in the sky form patterns called ______.

2 Because of the Earth's ______, an observer in the southern hemisphere sees the stars rotate from ______ around the South Celestial Pole.

3 Stars are made mainly of ______ and smaller amounts of helium. The energy in stars is released when hydrogen nuclei fuse to form helium nuclei. In the process ______ is converted to energy.

4 The Sun's energy is generated in its ______. It then travels by radiation and ______ towards the surface (photosphere) where it is released in the form of ______.

5 The ______ or magnitude of a star depends on the amount of energy it radiates into space and is determined by its size.

6 Stars form in ______ of condensing gases. Some stars like the sun glow for a long time, whereas massive stars have a shorter life and end in a ______ explosion.

7 There are two main theories on the origin of the universe. The ______ model is most favoured and suggests that the universe is rapidly ______.

Big Bang
brightness
clouds
constellations
convection
core
east to west
expanding
hydrogen
mass
supernova
rotation
visible light

Try doing the Chapter 12 crossword on the CD. Working with technology

Main ideas solutions

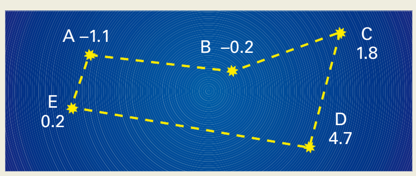
1 constellations
2 rotation, east to west
3 hydrogen, mass
4 core, convection, visible light
5 brightness
6 clouds, supernova
7 Big Bang, expanding

REVIEW

1 The visible part of the Sun is called the:
A corona
B photosphere
C chromosphere
D core

2 A light-year is:
A the distance light travels in one year
B the distance from the Sun to the nearest star in our galaxy
C the distance the Earth travels in one year
D the distance from the Milky Way galaxy to the nearest galaxy

3 The diagram below shows a constellation and the apparent magnitude of five of its stars.
a List the stars in order from brightest to dimmest.
b Which star is the alpha star?



Review solutions

1 **B**

2 **A**

3 **a** A –1.1 brightest
B –0.2
E 0.2
C 1.8
D 4.7 dimmest

b Star A is the alpha star because it is the brightest.

Challenge solutions

1 The Cassiopeia was observed 320 years ago. Because the light actually took approximately 10 000 years to travel to Earth, the actual explosion took place 10 320 years ago.

2 If light or radio waves are being emitted by an object that is moving away, then the wavelength of the radiation will appear to the receiver to be longer. As this has the effect of increasing the wavelength towards the red end of the spectrum, it is called the red shift. (It is very similar to the change in the pitch of sound as a train goes past you. This is called the 'Doppler effect'.)
If the opposite occurred you would expect the wavelength to decrease, resulting in a 'blue shift'.

3 a Wien's law states that:

$$\text{temperature} = \frac{3 \times 10^6}{\text{wavelength}}$$

$$\text{wavelength} = \frac{3 \times 10^6}{\text{temperature}}$$

$$= \frac{3 \times 10^6}{6200\ \text{K}} = 484\ \text{nm}$$

b Using the information on page 278, the colour of this star will be yellow–white. If the star looks yellow (wavelength 520 nm), then there has been an increase in the wavelength. This is the 'red shift' explained in Challenge 2, and occurs because the star is moving away from Earth.

4 During an explosion the material on the outside moves faster than the material near the centre of the explosion. Hence, the Big Bang theory seems to fit observations of the speeds at which galaxies move.

5 As well as other interesting information, you will find that a quasar is thought to be the nucleus of a galaxy in which there is violent activity. They are approximately 10^{10} light-years away and emit powerful radio waves.

REVIEW

4 A neutron star forms when:
A a white dwarf forms from a red giant
B a star like our Sun explodes
C a massive star explodes
D a protostar condenses

5 Explain in simple language what Einstein's equation, $E = mc^2$, means.

6 Suppose you found the position of a bright star using your star grid. It had a 75° elevation and a 310° azimuth. In which part of the sky would you look to find the star?
A high in the sky in a north-east direction
B low in the sky in a south-east direction
C low in the sky in a north-west direction
D high in the sky in a north-west direction

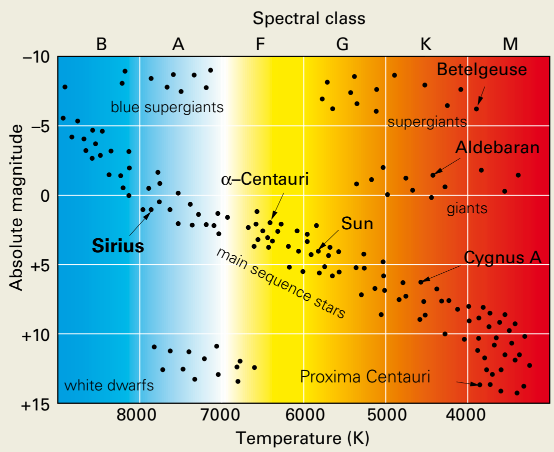
7 Star A has an apparent magnitude of –1.3 while that of star B is +3.5. On the other hand, the absolute magnitude of star A is +4.5 while that of star B is –5.2. Explain what this means.

8 Explain why nuclear fusion reactions in the Sun occur only in the core and not throughout the Sun.

9 What do the words ecliptic and zodiac mean? Why is the ecliptic higher in the sky in Cairns than in Melbourne?

10 The two stars in a binary have magnitudes of 3.6 and 5.8. However, the magnitude of the binary varies from a maximum of 2.3 to a minimum of 4.6 over a period of 30 days.
a Which of the stars in the binary is the brighter?
b Suggest why the magnitude of the binary changes over time.

11 The absolute magnitude (brightness) of the known stars in the universe can be plotted against their temperatures on a graph. The spectral class indicates a star's colour.
Use the graph at the bottom of the page to answer the following questions.
a Which one of the statements is *incorrect*?
A Sirius is a main sequence star.
B Sirius has a greater surface temperature than the Sun.
C Blue supergiants are hotter than giants.
D Spectral class G includes white stars.
b What is the approximate absolute magnitude of Sirius and Cygnus A? What does this indicate about the relative sizes of these two stars?
c Which of the stars α-Centauri, Sirius and our Sun would probably be the oldest? Explain your answer.
d Compare and contrast the stars Proxima Centauri and Betelgeuse.
e Write a generalisation linking the absolute magnitude of the main sequence stars to their temperature and colour.



Check your answers on pages 324–325.

4 C—see page 283

5 Einstein's equation, $E = mc^2$, means that matter, under conditions of extreme heat and pressure such as in a star's core, can be converted to energy.

6 D

7 If star A has an apparent magnitude of –1.3 it is much brighter when viewed from Earth than star B with an apparent magnitude of +3.5. However, star A must be very close to Earth because its absolute magnitude is only +4.5. The absolute magnitude of star B is –5.2 which means that it is a very bright star. However, it must be a very long way away because it looks dim when viewed from Earth.

8 Fusion reactions occur only in conditions of extreme temperature and pressure. These conditions occur only in the core of the Sun where the gravity is the strongest.

9 The ecliptic is the path across the sky followed by the planets, Sun and Moon. The ecliptic is also the path followed by the 12 constellations which make up the zodiac.
Because of the curvature of the Earth, the ecliptic becomes lower in the sky as you move southwards in Australia.

10 **a** The star of magnitude 3.6 is brighter.
b The binary varies in magnitude when seen from Earth because the stars eclipse one another during their revolution. When the dimmer star passes in front of the other star the brightness of the binary will decrease to a minimum. When they are side-by-side the brightness increases to a maximum.

11 **a** D—Stars in spectral class G are mainly yellow-orange.
b Sirius is about 1 and Cygnus A about 6. Bright stars like Sirius have a greater mass than dimmer stars like Cygnus A.
c As main sequence stars age, their surface temperature decreases. Therefore, our Sun is older than α-Centauri and Sirius.
d Proxima Centauri and Betelgeuse have the same surface temperature and hence the same colour. However, Betelgeuse is much brighter than Proxima Centauri and hence must be much larger.
e As the surface temperature of main sequence stars decreases, their colour changes from blue through to red and their absolute magnitude decreases.