TOPIC 6
The mysterious universe

6.1 Overview

6.1.1 Why learn this?
On any cloudless night, a pattern of stars, galaxies and clouds of gas appears to spin above our heads. Yet against this backdrop, changes are taking place — often hard to see and sometimes spectacular, but always raising questions in our minds about the past and the future. How and when did it all begin?

6.1.2 Think about the universe
• Where are stars formed?
• Why do stars appear to show different colours?
• How old is the universe?
• How does a red giant become a white dwarf?
• What can we actually see from space?
• The universe may have started with a ‘big bang’, but what is the ‘big crunch’?

LEARNING SEQUENCE

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Numerous videos and interactivities are embedded just where you need them, at the point of learning, in your learnON title at www.jacplus.com.au. They will help you to learn the concepts covered in this topic.
6.1.3 Your quest
Awesome stars
When they gazed at the night sky, the earliest humans would have been in awe of the stars. What questions would they have asked? What are the stars made up of? Where did they come from? Are they alive? Humans were driven to find a way to explain the stars’ existence.

Think
1. Why do we know so much more about stars and the universe than the earliest humans?
2. What is a star? Write your own description of what a star is.
3. What is the name of the nearest star to the planet Earth?
4. How are stars formed?
5. Does a star ever die?
6. List all of the objects other than stars that you can see in the night sky.

6.1.4 Looking back in time
The object in photograph (a), below, is not a star. It is a quasar called PG 0052+251. It emits much more light than any star could. Quasars are found only at very large distances from the solar system. Observations of distant objects like quasars provide clues about how the universe began.

Think
7. Astronomers believe that quasars are formed when black holes at the centre of galaxies begin to pull in gas and stars from the galaxy.
   (a) What is a black hole?
   (b) What is a galaxy?
   (c) To which galaxy does the solar system belong?
8. The photograph of PG 0052+251 was taken by the Hubble Space Telescope.
   (a) Where is the Hubble Space Telescope?
   (b) Why are the photographs taken by the Hubble Space Telescope clearer than those taken by larger telescopes on the Earth’s surface?

(a) The quasar PG 0052+251 is 1.4 billion light-years away. That is, when you look at its image, you are seeing it as it was 1.4 billion years ago.

(b) The Hubble Space Telescope. Even though it is much smaller than many telescopes on the ground, it can see much further into the universe because it is above the Earth’s atmosphere.
6.1.5 Where Earth fits into the universe

Until almost 400 years ago, most astronomers believed that the Earth was at the centre of the universe. It was surrounded by a ‘celestial sphere’ on which the stars were attached. The Moon orbited the Earth. The sun and planets were also believed to orbit the Earth. Then, quite quickly, the idea that the sun was the centre of the universe became accepted. We now know that the Earth is just a tiny part of the solar system, which is a tiny speck in a galaxy known as the Milky Way. The sun is one of up to 400 billion stars in the Milky Way, and the Milky Way galaxy is one of more than 100 billion galaxies in the universe.

Think

9. Which people and events caused the change in thinking about the place of the Earth in the universe about 400 years ago?
10. How do we know so much more about the distant parts of the universe now, in the twenty-first century, than we did 400 years ago when people were arguing about whether the Earth or the sun was the centre of the universe?
11. Given that the Earth is such a tiny speck, would you expect to find other, similar planets in the universe? If so, where would you expect to find them?

6.2 Observing the night sky

6.2.1 Seeing stars

When you look up into the sky on a clear night, you will see countless specks of light stretching from horizon to horizon.

Looking again later the same night, you should clearly see many of the same recognisable patterns as before, but they will have moved to a different position in the sky. From these simple observations, it is easy to conclude that the sky is a crystal-clear sphere dotted with the tiny lights we call stars. This ‘celestial sphere’ seems to rotate above our heads, carrying with it the fixed patterns or constellations of gleaming stars.

6.2.2 Constellations

Ancient astronomers grouped stars according to the shapes they seemed to form. The shapes were usually of gods, animals or familiar objects. The most well-known constellations are the 12 groups we know as the signs of the zodiac. These constellations follow the ecliptic and their names include Taurus (the bull), Leo (the lion) and Sagittarius (the archer). You probably know the rest. If not, a discussion with your friends will help.

Today, astronomers recognise 88 constellations. When observed from Earth, the stars in each constellation appear to be very close to each other. But the stars that make up constellations can be located at very different distances from Earth. For example, the star Betelgeuse in the Orion constellation is approximately 650 light-years from Earth, whereas the star Bellatrix in the same constellation is about 240 light-years from us.
6.2.3 Constellations ‘on the move’

We know now that the celestial sphere proposed by the Greek astronomer Ptolemy in 150 CE was wrong. The apparent motion of the fixed pattern of stars at night, shown in the time-lapse photograph below, is due to the rotation of the Earth.

The apparent change in position of the constellations is due to the Earth’s orbit around the sun. Sky charts, sometimes called sky maps, star maps or star charts, show the position of constellations, stars and the planets from different locations for each month of the year.

6.2.4 A closer view

The development of the telescope in the sixteenth century allowed Earth-bound astronomers to see objects in the sky with much greater precision than ever before. Observations using telescopes showed that many different types of objects in the sky could be identified. These included single or double stars, groups of stars called galaxies, clusters of galaxies, and clouds of gas and dust called nebulae.

In 1718, English astronomer Edmond Halley, who is well-known for identifying the comet named after him, used his telescope to check three particularly bright stars: Sirius, Procyon and Arcturus. He found that the position of each one relative to surrounding stars was noticeably different from the positions recorded by ancient Greek astronomers centuries before. There were even slight differences between Halley’s observations and those of Danish astronomer Tycho Brahe about 150 years earlier. Never again could the stars be described as ‘fixed in the heavens’.

INVESTIGATION 6.1

Using a sky chart

AIM: To use a sky chart to locate some constellations, stars, planets and other celestial features

Materials:
- torch covered with red cellophane
- compass
- star chart for the current month
- highlighter pen
6.2.5 Questions about stars

Halley’s observations raised some new questions about stars. Why should only a few stars move quickly enough for their motion to be noticed? Why do they happen to be among the very brightest stars? Perhaps some stars are closer to Earth than others. Being closer, they would appear brighter than other stars and their motion would be detectable against the backdrop of more distant, and therefore dimmer, stars.
It's all relative

The apparent movement of objects at different distances is due to the actual movement of the observer. It is an effect called **parallax**. In 1837, German astronomer Friedrich Bessel became the first person to provide proof of a parallax effect when observing stars. As the Earth orbits the sun, the positions of stars change very slightly relative to each other. If all the stars were the same distance from the Earth, this would not happen.

**HOW ABOUT THAT!**

A light-year is not a measure of time! It's a measure of distance. In one year, light travels a distance of 9500 000 000 000 or 9.5 × 10¹² kilometres. This distance is called a light-year.

Observations of a stellar parallax effect indicate that some stars are relatively close to us while others are much farther away. The transparent celestial sphere idea of the past must be banished, replaced by an even more awe-inspiring image — that of star-studded space stretching before us with no known boundary or end.

**USING LARGE NUMBERS**

Very large numbers are often written using **scientific notation**. This allows us to avoid writing lots of zeros and also makes the numbers easier to read, because the reader does not have to count the zeros. For example, the distance between the Earth and the sun averages 150 million kilometres. This could be written 150 000 000 km or, in scientific notation, as 1.5 × 10⁸ km.

Some other examples are:

- 45 000 000 000 = 4.5 × 10¹⁰
- 700 000 000 000 000 000 = 7.0 × 10¹⁷.

**INVESTIGATION 6.2**

**The effect of parallax**

**AIM:** To observe the effect of parallax

**Materials:**
- a number of traffic cones (witch’s hats)
- pencil and paper

**Method and results**

- Mark a circle on the school oval to represent Earth’s orbit around the sun.
- Place a series of traffic cones at different distances from the circle to represent stars nearby and far away.
- Take a walk around Earth’s ‘orbit’ and, at several different points, sketch the appearance of the ‘stars’ relative to one another and to even more distant objects such as trees and fence posts.

**Discuss and explain**

1. Looking at your sketches, did the positions of the stars relative to one another appear to change as you moved around the orbit?
2. Can you see any difference between the relative movements of the nearby stars compared with those of the more distant stars?

**6.2 Exercises: Understanding and inquiring**

To answer questions online and to receive immediate feedback and sample responses for every question, go to your learnON title at www.jacplus.com.au. Note: Question numbers may vary slightly.

**Remember**

1. Explain why stars appear to rotate during the night.
2. Explain why stars gradually change their position in the night sky throughout the year.
3. What do the constellations of the zodiac have in common?
6.3 Stars — a life story

6.3.1 Stars come and go

Movie stars come and go. Some have brief careers while others seem to go on forever. It’s much the same with the stars in the sky. Stars come and go — they don’t last forever. However, their ‘careers’ are usually much longer than those of the movie variety.

A star is born

Dust and gas are not evenly distributed in interstellar space. There appear to be currents of denser material swirling throughout the universe. Within these currents, the density sometimes reaches the critical figure of 100 atoms per cubic centimetre. At this point, gravity takes hold and the gas and dust begin to collapse, forming a cloud. Such clouds of interstellar matter are called nebulae and are really like star nurseries.

Evaluate

8. The estimated distances from Earth to some stars and galaxies are listed below. How long would it take to reach each of them, travelling at the speed of light (about 300,000 km/s)?

<table>
<thead>
<tr>
<th>Star</th>
<th>Description</th>
<th>Distance (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sun</td>
<td>Our own star</td>
<td>1.5 x 10^8</td>
</tr>
<tr>
<td>Proxima Centauri</td>
<td>The closest star after the sun</td>
<td>4.0 x 10^13</td>
</tr>
<tr>
<td>Centre of Milky Way</td>
<td>Our own galaxy</td>
<td>2.5 x 10^17</td>
</tr>
<tr>
<td>Magellanic Clouds</td>
<td>One of the closest galaxies</td>
<td>1.5 x 10^18</td>
</tr>
<tr>
<td>Andromeda galaxy</td>
<td>One of the closest galaxies</td>
<td>1.4 x 10^19</td>
</tr>
<tr>
<td>Quasars</td>
<td>Very distant objects</td>
<td>1.4 x 10^23</td>
</tr>
</tbody>
</table>

Think

9. Explain why it is easier to observe the night sky in rural areas than in the city.
10. All of the stars in the constellation Orion appear to be the same distance from Earth. Explain how observers on Earth know that they are not.
11. Explain why the planets that are visible to the naked eye appear to change position against the fixed patterns of other stars.
12. Radio waves travel through space at the same speed as light, which is about 300,000 km/s. How long would it take a radio message from Earth to reach the solar system’s nearest neighbouring star?

Imagine

13. Is it likely that a spacecraft from Earth will ever venture out to planets orbiting the closest stars? Present some calculations to support your answer.
The Great Nebula in the constellation of Orion is a nebula large enough to be seen with the naked eye. The collapse continues under the influence of gravity, forming visible globules in the nebula cloud. As the globules collapse further, the formation of any original gas cloud is accelerated. The now dense cloud is known as a protostar. At the same time, the increasing pressure causes the temperature to rise. This effect is modelled in Investigation 6.3.

**INVESTIGATION 6.3**

**Heat produced by compressing a gas**

*AIM: To model the generation of heat during the formation of a star*

*Materials:*
  - a bicycle pump
  - a tyre with inner tube

*Method and results*
- Using an energetic pumping action, inflate a tyre with the bicycle pump. Alternatively, just pump the bicycle pump with your finger partially covering the open end so the air does not escape.
- Now feel the body of the pump.

*Discuss and explain*
1. What change has been observed?
2. How does an increase in air pressure affect the temperature of the surroundings?
   (The opposite effect can be observed when carbon dioxide gas is released from a soda bulb.)

### 6.3.2 Nuclear fusion

The temperature and pressure of the gases in a protostar eventually rise high enough for atomic nuclei to become joined together by a process called nuclear fusion. As a result of fusion, two isotopes of hydrogen, deuterium (hydrogen-2) and tritium (hydrogen-3) combine to form helium nuclei, neutrons and vast amounts of energy.

### 6.3.3 The young, the old and the dead

A quick glance around the night sky shows us that stars differ quite noticeably from one another, both in how bright they appear to us and in their colour (see Investigation 6.4). Some of them are relatively close to the Earth, while others are much further away. There are young stars, middle-aged stars like the sun, old and dying stars, and exploded stars. By collecting details of a wide range of stars, we can trace the various stages of development of typical and unusual stars.

### 6.3.4 Star light, star bright

How bright a star appears to us (its apparent magnitude) depends on its actual brightness (its absolute magnitude) and its distance from Earth. A dim star close to us may appear brighter than a really bright star a long way away. To calculate the absolute magnitude of a star, astronomers must know how far away it is. The colour of a star depends on its surface temperature: red stars are cool, and white and blue stars are hot.
A question of magnitude

How bright a star or planet appears as viewed from Earth is measured on a scale of apparent magnitude. On this scale, brighter objects have the lowest apparent magnitudes. For example, the sun has an apparent magnitude of –27. A full moon has apparent magnitudes of approximately –13. The brightest stars have apparent magnitudes between –1 and 1. The weakest objects visible with the naked eye have an apparent magnitude of approximately 6.

The absolute magnitude is a measure of how much light an object emits. The sun is much smaller than Rigel in Orion and it emits a lot less light. However, it appears brighter to us because it is much closer than Rigel. The Moon emits no light of its own.

The table below shows some typical values of apparent and absolute magnitudes.

<table>
<thead>
<tr>
<th>Star and constellation</th>
<th>Apparent magnitude</th>
<th>Absolute magnitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sun</td>
<td>–27</td>
<td>+4.7</td>
</tr>
<tr>
<td>Sirius (Canis Major)</td>
<td>–1.5</td>
<td>+8.7</td>
</tr>
<tr>
<td>Canopus (Carina)</td>
<td>–0.73</td>
<td>–4.6</td>
</tr>
<tr>
<td>Alpha Centauri (Centaurus)</td>
<td>–0.33</td>
<td>+4.7</td>
</tr>
<tr>
<td>Rigel (Orion)</td>
<td>+0.11</td>
<td>–7.5</td>
</tr>
<tr>
<td>Beta Centauri (Centaurus)</td>
<td>+0.60</td>
<td>–5.0</td>
</tr>
<tr>
<td>Betelgeuse (Orion)</td>
<td>+0.80</td>
<td>–5.0</td>
</tr>
<tr>
<td>Aldebaran (Taurus)</td>
<td>+0.85</td>
<td>–0.3</td>
</tr>
<tr>
<td>Alpha Crucis (Southern Cross)</td>
<td>+0.90</td>
<td>–3.9</td>
</tr>
</tbody>
</table>

Colour and brightness

An interesting way of displaying the data collected about stars was developed independently by two astronomers, Ejnar Hertzsprung from Denmark and Henry Norris Russell from America. This method has now been named after both of them. In the Hertzsprung–Russell diagram, the absolute brightness of a star is plotted against its surface temperature, which is deduced from its colour. When data for many stars are plotted, most of them, including our sun, fall into what is known as the main sequence. Exactly where a star is found along the main sequence is determined by its mass. Low-mass stars tend to be cooler and less bright than high-mass stars.

Other types of stars show up very clearly on the Hertzsprung–Russell diagram but in much smaller numbers than in the main sequence. The names of these stars — white dwarfs, red giants, blue giants and super giants — clearly describe their characteristics. Astronomers suggest that all stars begin their existence in the main sequence and spend the largest part of their life there. This explains why most of the stars observed at a particular time are found in the main sequence. The rarer types are stars passing relatively quickly through later stages of development on the way to extinction as their nuclear fuel runs out.
Red giants

In a stable main sequence star, hydrogen is steadily turned into helium by the process of fusion. As helium builds up in the core of the star, the region where energy is produced by the fusion of hydrogen becomes a shell around the core. The shell gradually expands and the star swells to 200 or 300 times its original size, cooling as it does so, to become a red giant. This will eventually happen to our sun, which will grow large enough to swallow up the inner planets, including Earth.

The brightness of many red giants varies greatly because they have become unstable after many millions of years of stability. The red giant Mira in the constellation Cetus (the Whale) was the first variable red giant discovered. The brightness of Mira increases and decreases over a huge range in a cycle that averages 320 days. Not surprisingly, it is known as a pulsating star. The shorter cycles of some pulsating stars are so predictable that they can be used as markers to measure vast interstellar distances in the universe.

In the core of a red giant, new fusion processes take place, turning helium into heavier elements such as beryllium, neon and oxygen. This increases the rate of energy production and raises the star’s temperature. A sun-like star might shine 100 times more brightly than it did in its stable period as part of the main sequence.
6.3.5 The death of a star

Eventually, the rapid pulsations lead to the destruction of the star. The nature of its death depends on the size of the star.

White dwarfs

For stars less than about eight times the mass of our sun, the destruction begins when the outer layers are thrown off into space and the core flares brightly, forming a ring of expanding gas called a planetary nebula. The name planetary nebula is misleading because it is not related to planets. But it does have the cloud-like nature of other nebulae. The name came about because astronomers using very early telescopes thought that the clouds resembled the planets Uranus and Neptune.

The remaining star fades to become a white dwarf, typically about the size of the Earth but with a very high density and a surface temperature of about 12,000°C. It then slowly cools, becomes a cold black dwarf and disappears from view.

Coming to a violent end

Stars that are more than about eight times the mass of our sun come to a much more violent end. They swell into much larger red giants called supergiants and blow up in a huge explosion called a supernova. The matter making up the star is hurled into space along with huge amounts of energy. A supernova can emit as much energy in a month as the sun radiates in a million years. Supernova events are very rare, being seen only every 200 to 300 years on average and fading within a few years. They are extremely
important in the universe because it is within these violent explosions that the heavy elements such as iron and lead are produced.

What remains of a supernova is extremely dense; the pull of gravity becomes so great that even the protons and electrons in atoms are forced together. They combine to form neutrons, and the resulting solid core is known as a **neutron star**. If the remaining core has a mass more than about three times that of our sun, the force of gravity is great enough to suck in everything — even light. Such a core becomes a **black hole**.

### 6.3.6 Galaxies

Stars group together in groups to form galaxies, attracted towards each other by gravitational forces. Our own sun is one of an estimated 200–400 billion stars in the **Milky Way** galaxy. We think there are more than 100 billion other galaxies of different sizes and shapes throughout the universe. Each of these galaxies is home to stars at all stages of their life cycles.

The Milky Way galaxy, shown below, is a spiral galaxy. Our solar system is found on the Orion arm of the spiral. Due to the rotation of the galaxy, our solar system orbits the centre of the galaxy at a speed of about 200 kilometres per second.

### 6.3 Exercises: Understanding and inquiring

To answer questions online and to receive immediate feedback and sample responses for every question, go to your learnON title at www.jacplus.com.au. *Note: Question numbers may vary slightly.*

#### Remember

1. Explain why most stars are found in the main sequence of the Hertzsprung–Russell diagram.
2. To which group of stars shown on the Hertzsprung–Russell diagram does the sun belong?
3. How does a red giant become a white dwarf?
4. Why is the term *planetary nebula* a misleading way to describe the ring of expanding gas thrown out by a red giant during its transformation into a white dwarf?
5. Explain how galaxies are formed.
6. In which galaxy can the Earth and the rest of our solar system be found?

#### Evaluate

7. The table at right lists information about three bright stars.
   (a) Which star has the greatest actual brightness?
   (b) Which star is the faintest as seen from Earth?

<table>
<thead>
<tr>
<th>Star</th>
<th>Apparent magnitude</th>
<th>Absolute magnitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rigel</td>
<td>0.11</td>
<td>−7.5</td>
</tr>
<tr>
<td>Aldebaran</td>
<td>0.86</td>
<td>−0.3</td>
</tr>
<tr>
<td>Canopus</td>
<td>−0.73</td>
<td>−4.6</td>
</tr>
</tbody>
</table>

#### Think

8. Why are nebulae often referred to as star nurseries?
9. Deuterium and tritium, both isotopes of hydrogen, combine in nuclear fusion reactions in stars. How are the atoms of these two isotopes different from each other?
10. Is it likely that our own star, the sun, will become a supernova? Explain your answer.
11. What would the night sky look like if you had eyes that could see like the Hubble Space Telescope?

#### Investigate

12. Find out more about the formation and destruction of a supernova. For example, when was the last supernova seen? Can we predict when the next one will be seen?
13. Find out more about fusion science by using the **Princeton Plasma Physics Laboratory** weblink in your Resources section.
6.4 The changing universe

6.4.1 Stars on the move

Will the sky you see tonight ever be the same again? Within a person’s lifetime, the patterns of stars and galaxies in the night sky do not seem to change, but each night’s sky is different. Photographic techniques show us the movements of the stars and tell us that what we see as permanent is actually a universe in a state of continuous and often violent movement and change.

The movement of stars towards or away from the Earth can be measured using the Doppler effect. Christian Johann Doppler was an Austrian physicist who noted the change in pitch that results from a source of sound approaching or moving away. We hear the same effect when a high-speed train or aeroplane passes us or when we hear the pitch of a fire-engine’s siren drop as it goes by.

Doppler suggested that the same effect we notice in sound waves might be seen in light as well. The Doppler effect would produce a change in the frequency of light waves emitted from a moving source. In 1851, the French physicist Armand Fizeau suggested that this change in frequency might be seen by comparing the spectrum of light from a moving source with that from a stationary one.

As the train approaches, the sound waves reaching you are bunched up. The frequency is higher and you hear a higher pitch.

As the train speeds away, the sound waves reaching you are more spread out. The frequency is lower and you hear a lower pitch.

The spectrum of white light from a nearby star. The black lines show which colours have been absorbed by elements in the star. The numbers indicate the wavelength of the light in nanometres.
6.4.2 The spectra of stars

When the spectrum of the light from a star is analysed, some dark lines are observed. These correspond to colours of light that have been absorbed by substances in the star. Different substances absorb different colours of light. By identifying the wavelengths of the colours missing from the spectrum, astronomers can find out which elements are present in the star.

In many cases, missing colours in the spectra of stars are shifted from their expected positions. A shift to lower or ‘redder’ frequencies is called a red shift and results from a star’s movement away from the Earth. A shift to higher or ‘bluer’ frequencies is called a blue shift and is caused by a star’s movement towards the Earth.

Nearby objects show a range of Doppler shifts. Some stars, like Sirius (the Dog star), are moving away from us and others are moving slowly towards us. Some even show alternate red and blue shifts in step with changes in brightness, suggesting that these stars have an invisible dark companion orbiting them. The brightness is reduced as the circling star passes between us and the main star, while the Doppler shift is caused by the main star moving in response to the gravitational pull of its dark companion.

6.4.3 Retreating galaxies

On a much larger scale, the study of the Doppler shifts of galaxies provides us with an amazing picture of the universe. A relatively small number of galaxies, including the nearby Andromeda galaxy, are moving towards the Earth, but the majority of galaxies are moving away from us at a considerable speed. Even more extraordinary is the relationship between the size of the red shift and the distance from Earth. This was first investigated by the astronomer Edwin Hubble and is now referred to as Hubble’s law. Hubble proposed this law in 1929 while working at what was then the largest telescope in the world in California. The law states that the further away a galaxy is, the greater its red shift and so the faster it is moving away from us.

While this finding appears to put the Earth in a very special position at the centre of a rapidly expanding universe, it is in fact an illusion. Observers anywhere in the universe will see the surrounding galaxies moving away from them at a speed that is consistent with Hubble’s law.

6.4.4 Estimating the size of the known universe

We can only say that the universe is as big as we can see, so the size of the known universe has steadily increased over the centuries as observation techniques have improved. The Hubble Space Telescope is finding more and more distant objects and so the known universe is still getting bigger. Objects have been
seen at distances estimated to be about 14 billion light-years from Earth, which suggests that the universe is at least 14 billion years old.

### 6.4 Exercises: Understanding and inquiring

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**Remember**

1. Why are there black lines in the spectra of the light emitted by stars?
2. Which colour of light has the higher frequency — red or blue?
3. What is a red shift? What does it tell us about how a star is moving relative to the Earth?
4. What is Hubble’s law?

**Think**

5. The light from a star is often analysed by its wavelength instead of its frequency. Long wavelengths correspond to low frequencies and short wavelengths correspond to high frequencies. The spectrum of colours emitted by excited atoms of hydrogen on Earth contains the wavelength 656.365 nm. This same wavelength is observed in the spectrum of light from the bright star Vega at 656.255 nm. Is Vega moving towards or away from Earth?
6. The most distant objects in the universe are estimated to be about 14 billion light-years from Earth. Explain why the age of the universe is thought to be at least 14 billion years.

**Imagine**

7. Collect and summarise a media report about a new discovery about space outside the solar system.

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### 6.5 How it all began

#### 6.5.1 How it all begin

When and how did the universe begin? Was there a beginning? Perhaps it was always there. If there was a beginning, will there be an end? The study of the answers to these questions is called **cosmology**.

Following Edwin Hubble’s discoveries about the expanding universe, two major theories about the beginning of the universe became popular — the **big bang theory** and the **steady state theory**.

#### 6.5.2 The big bang

According to the most commonly accepted theory among cosmologists, the universe began about 15 billion years ago with a ‘big bang’.

1. **The big bang** ($t = 0$)
   
   It’s hard to imagine, but at this moment there was no space and no time. All that existed was energy, which was concentrated into a single point called **singularity**.

2. **One ten million trillion trillionthms of a second later** ($t = \frac{1}{10^{43}}$)
   
   Time and space had begun. Space was expanding quickly and the temperature was about 100 million trillion trillion degrees Celsius. (The current core temperature of the sun is 15 million degrees Celsius.)
3. **One ten billion trillion trillionths of a second after the big bang** \( (t = + \frac{1}{10^{34}} \text{s}) \)

The universe had expanded to about the size of a pea. Matter in the form of tiny particles such as electrons and **positrons** (positively charged electrons) had formed. Particles collided with each other, releasing huge amounts of energy in the form of light. Until this moment there was no light.

4. **One ten thousandth of a second after the big bang** \( (t = + \frac{1}{10^4} \text{s}) \)

Protons and neutrons had formed as a result of collisions between smaller particles. The universe was very bright because light was trapped as it was continually being reflected by particles.

5. **One hundredth of a second after the big bang** \( (t = + \frac{1}{100} \text{s}) \)

The universe was still expanding and cooling rapidly. It had grown to the same size as our solar system, but there was still no such thing as an atom.

6. **One second after the big bang** \( (t = + 1 \text{ s}) \)

The universe was probably more than a trillion trillion kilometres across. It had cooled to about ten billion degrees Celsius.

7. **Five minutes after the big bang** \( (t = +5 \text{ min}) \)

The nuclei of hydrogen, helium and lithium had formed among a sea of electrons.

8. **Three hundred thousand years after the big bang** \( (t = +300000 \text{ years}) \)

The universe was about one thousandth of its current size. It had cooled to about 3000 °C. Electrons had slowed down enough to be captured by the nuclei of hydrogen, helium and lithium, forming the first atoms. There was now enough empty space in the universe to allow light to escape to the outer edges. For the first time, the universe was dark.

9. **Two hundred million years after the big bang** \( (t = +200000000 \text{ years}) \)

The first stars had appeared as gravity pulled atoms of hydrogen, helium and lithium together. **Nuclear reactions** took place inside the stars, causing the nuclei of the atoms to fuse together to form...
heavier nuclei. Around some of the newly forming stars, swirling clouds of matter cooled and formed clumps. This is how planets began to form.

10. One billion years after the big bang ($t = +1000000000$ years)

The universe was beginning to become a little ‘lumpy’. The force of gravity pulled matter towards the ‘lumpier’ regions, causing the first galaxies to form.

The Einstein connection

The big bang theory would not make any sense at all if it were not for Albert Einstein’s famous equation. How could matter be created from nothing? Well, the singularity before the big bang was not ‘nothing’. It was a huge amount of energy (with no mass) concentrated into a tiny, tiny point.

Einstein proposed that energy could be changed into matter. His equation $E = mc^2$ describes the change. $E$ represents the amount of energy in joules. $m$ represents the mass in kilograms. $c$ is the speed of light in metres per second ($300000000$ m/s).

Einstein’s equation also describes how matter can be changed into energy. That is what happens in nuclear power stations, nuclear weapons and stars.

WORKING WITH BILLIONS AND TRILLIONS

One billion is equal to one thousand million; that is, $1000000000$ or $10^9$.
One trillion is equal to one thousand billion; that is, $1000000000000$ or $10^{12}$.
So one billion trillion is $1000000000000000000$ or $10^{21}$.
When numbers get that large, there are too many zeros to count. It is much easier to use powers of ten notation, also known as scientific notation.

6.5.3 The steady state theory

According to the steady state theory, which was proposed in 1948, there was no beginning of the universe. It was always there. The galaxies are continually moving away from each other. In the extra space left between the galaxies, new stars and galaxies are created. These new stars and galaxies replace those that move away, so that the universe always looks the same.

6.5.4 The great debate

A huge debate between those who supported the steady state theory and those who supported the big bang theory raged from 1948 until 1965. During that period, the evidence supporting the big bang theory grew.

The red shift

The red shift provides evidence for an expanding universe. This evidence supports the big bang theory and causes problems for those supporting the steady state theory. A steady state universe could expand only if new stars and galaxies replaced those that moved away. There is no way to explain how these new stars and galaxies could be created from nothing. Apart from that, these young stars and galaxies have not been found by astronomers.

The elements

The amounts of hydrogen and helium in the universe support the big bang theory. According to the steady state theory, the only way that helium can be produced is by the nuclear reactions taking place in stars. About 8.7 per cent of the atoms in the universe are helium. This is far more than could be produced by the stars alone. The percentage of helium atoms can, however, be explained by their creation as a result of the big bang.
The afterglow
When George Gamow and Ralph Alpher proposed their version of the big bang theory in 1948, they calculated that the universe would now, about 15 billion years after creation, have a temperature of 2.7 °C above absolute zero. That’s −270 °C. Anything with a temperature above absolute zero emits radiation. The nature of the radiation depends on the temperature. Gamow predicted that, because of its temperature, the universe would be emitting an ‘afterglow’ of radiation. This afterglow became known as cosmic microwave background radiation.

This radiation was discovered by accident in 1965. Engineers trying to track communications satellites picked up a consistent radio noise that they couldn’t get rid of. The noise wasn’t coming from anywhere on Earth, because it was coming from all directions. It was the cosmic microwave background radiation predicted by Gamow. Its discovery put an end to the steady state theory, leaving the big bang theory as the only theory supported by evidence currently available. Even Fred Hoyle, who had ridiculed the idea of a ‘big bang’, admitted that the evidence seemed to favour the big bang theory.

6.5.5 Mapping the universe
In 1989, a satellite named COBE (COsmic Background Explorer) was put into orbit around Earth to accurately measure the background radiation and temperature of the universe. COBE could detect variations as small as 0.00003 °C. As predicted by Gamow, it detected an average temperature of −270 °C.

In 2001, a probe called WMAP (Wilkinson Microwave Anisotropy Probe) was sent into orbit around Earth at a much greater distance to gather even more accurate data, detecting temperatures within a millionth of a degree. WMAP’s first images were released by NASA in February 2003.

The computer-enhanced image of cosmic microwave background radiation shown below was produced by the WMAP mission. The background radiation detected was released only 380,000 years after the big bang — the first radiation to escape. The image shows how the temperature varied across the universe as it was 380,000 years after the big bang. The blue parts of the map are the cooler regions. These regions were cool enough for atoms, and eventually
galaxies, to form. The red parts are warmer regions. The map shows that galaxies are not evenly spread throughout the universe. They support the theory of an expanding universe that began with a big bang.

The Wilkinson Microwave Anisotropy Probe (WMAP). Its main mission was to gather evidence to help cosmologists find out how the universe began and predict what will happen in the future.

6.5.6 Will it ever end?

Will the expansion of the universe continue forever? If the universe does stop expanding, what will happen to it? There are several competing theories about the answers to these questions. One theory suggests that there is not enough mass in the universe for gravity to be able to pull it all back, so it will continue to expand forever. Other theories suggest that the universe will eventually end. According to these theories, the end will come when:

• the universe snaps back onto itself in a ‘big crunch’ (the big crunch theory). If this happens, the end result will be a single point — singularity. Some cosmologists believe that the big crunch will be followed by another big bang.

• the expansion of the universe continues and stars use up their fuel and burn out, causing planets to freeze (the big chill theory). The universe would then consist of scattered particles that never meet again.

• the universe rips itself apart violently as a result of expanding at an increasing speed (the big rip theory). According to this theory, the end of the universe will also be the end of time itself.

6.5 Exercises: Understanding and inquiring

To answer questions online and to receive immediate feedback and sample responses for every question, go to your learnON title at www.jacplus.com.au. Note: Question numbers may vary slightly.
Remember
1. What is the science of cosmology?
2. How old is the universe believed to be?
3. According to the big bang theory, what was there at the time of the universe began?
4. Why could there not have been anything before the big bang?
5. Approximately how long after the big bang did:
   (a) time and space begin to exist
   (b) matter appear
   (c) protons and neutrons form
   (d) neutral atoms first exist
   (e) galaxies begin to form?
6. How did galaxies begin to form?
7. What does Einstein’s famous equation have to do with the big bang theory?
8. Which of the two theories about the ‘beginning’ of the universe proposed that there was no beginning?
9. How did the steady state theory explain that the universe was expanding, yet remained the same?
10. What evidence put an end to the steady state theory?
11. List three major pieces of evidence that supported the big bang theory.
12. Name and describe three theories about how the universe might end.

Think
13. What would have happened to the universe if, one million years after the big bang, the matter in it was perfectly evenly distributed and not moving?
14. Explain why neutral atoms were not likely to form during the first five minutes after the big bang.
15. WMAP is able to provide a picture of the universe as it was 380,000 years after the big bang. Why is it unable to provide a map of the universe as it was before that time?
16. Why go to the expense of measuring background radiation with a satellite or space probe when it could be done from Earth?

Create
17. Draw flowcharts to describe:
   (a) the big bang theory
   (b) how the big bang and big crunch cycle might work together.
18. To find out more about the WMAP mission, including data and images obtained since the publication of this book, use the WMAP weblink in your Resources section. Use the information obtained from the website to answer the following questions.
   (a) What is the average temperature of the universe as measured by WMAP?
   (b) When were the first stars formed?
   (c) According to WMAP, how old is the universe and how accurately is its age known?
6.6 Eyes on the universe

6.6.1 Detecting radio waves
For hundreds of years, light telescopes have been used to observe what lies beyond the solar system. To find out what’s in deep space, in the most distant parts of the universe, observing visible light is not enough. We rely on other parts of the electromagnetic spectrum.

Until the accidental discovery in 1931 that stars emitted radio waves as well as light, the only way to observe distant stars and galaxies was with light telescopes. Like light and other forms of electromagnetic radiation, radio waves travel through space at a speed of 300,000 kilometres per second. Radio waves from deep in space are collected by huge dishes and reflected towards a central antenna. The waves are then analysed by a computer, which produces an image that we can see.

Radio telescopes can detect tiny amounts of energy. In fact, the total amount of energy detected in ten years by even the largest radio telescopes would light a torch globe for only a fraction of a second. They can detect signals from much further away than light telescopes.

Unlike light waves, radio waves can travel through clouds in the Earth’s atmosphere, and can be viewed in daylight as well as at night. Radio waves also pass through clouds of dust and gas in deep space.

Sharpen up!
Images produced by single radio telescopes are not very sharp. To solve this problem, signals from groups of telescopes pointed at the same object are combined to produce sharper images.

6.6.2 Learning from radio waves
As well as telling us about the size, shape and movement of every type of star (from our own sun to stars at the outer edges of the universe), radio telescopes reveal information about a star’s temperature and the substances from which it is made. Radio telescopes can work out what a star is made up of by using the fact that different elements emit different frequencies of radio waves.

Radio waves have, among other things, allowed us to:
- analyse the distribution of stars in the sky
- discover quasars, which, before 1960, were believed to be normal stars. They are like stars, but emit a lot more radiation and are travelling away from us at huge speeds. Quasars are believed to be the most distant objects in the universe.
- discover pulsars, which are huge stars that have collapsed, emitting radio waves. Because pulsars spin rapidly — a bit like a lighthouse — the radio waves reach the Earth as radio pulses.

6.6.3 Eyes in orbit
There are more than 2500 satellites currently orbiting the Earth, many of them constantly watching the Earth’s surface and atmosphere. Others provide views of the universe that could never be seen from the Earth’s surface.
Trash 'n' treasure in orbit

Some of the satellites orbiting the Earth are active and use radio signals to send streams of data down to the surface. Others have stopped working but continue to circle the globe. Some satellites in lower orbits will gradually slow down as a result of the thin atmosphere. They will spiral in towards the Earth in a fiery finish as they burn up on re-entry. The fate of others far beyond the atmosphere is an eternity of circling the Earth. They have joined the pile of 'space junk' gradually accumulating in near-Earth orbit.

All satellites orbiting the Earth are held there by the Earth’s gravitational pull directed to the planet’s centre. This means that the centre of every orbit coincides with the centre of the Earth. Some orbits skim as close as a few hundred kilometres above the surface. Others take a more distant view. The time taken for one complete revolution (the period of orbit) of a satellite depends on its height above the Earth. Greater heights result in greater periods.

Looking in, looking out

Artificial satellites can be used to look at the Earth or to look into space. An inward-looking satellite can sweep the surface of the Earth every day, using cameras and remote sensors to observe and measure events on the surface hundreds or thousands of kilometres below. An outward-looking satellite can see directly into space, its view unobstructed by the atmosphere, pollution or dust. Light pollution, an increasing problem for Earth-bound observers as our cities grow, is not an issue for an observer in space.

Inward-looking satellites are used for:
- collecting weather and climate data, providing early warning of events (such as volcanic activity and changing ocean currents) and showing long-term trends
- collecting data used for mineral exploration, crop analysis, mapping, and identifying long-term erosion or degradation
- strategic defence ('spy-in-the-sky') systems
- communications for telephones, television, radio and computer data.

Outward-looking satellites are used for:
- observing the other planets and bodies circling the sun
- observing stars, galaxies and other remote objects in space
- watching for comets and asteroids that may hit the Earth
- listening for signs of extraterrestrial life.

The International Space Station

The primary purpose of the International Space Station (ISS), completed in 2011 with the support of a number of different space agencies, was to provide laboratories in space for research into microgravity and fields such as medicine, geology and technology. The ISS also provides the opportunity to investigate the effect of a space environment on humans and prepare for the exploration of Mars and beyond by humans. Crew
members, which can include astronauts, scientists of all kinds and engineers, are generally on board for several months before returning to Earth.

However, the ISS, with the recent addition of sophisticated sensors and other new technology, is now also being used as an inward-looking satellite. It is able to provide images similar to those from other inward-looking satellites, but has the advantage of having a crew who can respond to unfolding events immediately, rather than waiting for further ‘instructions’ from the ground. This is especially helpful when natural disasters such as volcanic eruptions, earthquakes and tsunamis occur. In addition, the orbit of the ISS is different from most other satellites and is able to collect images at different and often more suitable times.

### Hubble Space Telescope

The Hubble Space Telescope is an example of an outward-looking satellite. It was carried into orbit about 600 kilometres above the Earth’s surface by the space shuttle *Discovery* in 1990. The Hubble Space Telescope collects images by collecting and analysing data in the form of visible light, ultraviolet radiation, and infra-red radiation from deep space. It produces spectacularly clear images that are relayed back to Earth by radio waves.

The Hubble Space Telescope was the first space telescope that could be serviced while in orbit, and its useful life has been dependent on transporting astronauts to and from Earth aboard space shuttles. Now that NASA’s space shuttle program has ceased, servicing is no longer possible. When the orbiting telescope stops functioning it will be ‘deorbited’ by an unmanned space mission so that it plunges harmlessly into the ocean.

The Hubble Space Telescope will eventually be replaced by the James Webb Space Telescope, which will collect infra-red radiation from the most distant parts of the universe. At the time this book was published,
the launch is scheduled for some time in 2018. The uncertainty of the launch date is not surprising, because the James Webb project is a collaboration between three space agencies: NASA, the European Space Agency (ESA) and the Canadian Space Agency (CSA). Each of these agencies is dependent on government funding, which is often uncertain.

There are several other space telescopes in orbit around the Earth. They all collect radiation from parts of the electromagnetic spectrum and send images and other data back to Earth using radio waves. They include the Chandra X-ray Observatory, carried into orbit by the space shuttle Columbia in 1999. Most X-rays from space approaching the Earth are absorbed by the atmosphere. By collecting high-energy X-rays coming from neutron stars and black holes, Chandra is able to gather data that could never be collected by X-ray telescopes on Earth’s surface.

Data overload?
The unprecedented amount of data coming from telescopes of all types on the ground and in orbit requires processing by supercomputers with capabilities well beyond those of personal computers and even large computers used in most industries. IT specialists play a crucial role in developing new and faster computer systems to ensure that exploration of the universe is not limited by data overload.

6.6.4 An accelerating expansion
In 1997, a group of astrophysicists, including Australian National University’s Professor Brian Schmidt presented evidence that the expansion of the universe was speeding up. Their research took several years to complete and required the analysis of images of the most distant supernovas that could be observed. The images were from light and infra-red telescopes in several locations, including Australia, and from the Hubble Space Telescope. The successful outcome of the research was only possible with the use of advanced digital imaging sensors and powerful state-of-the-art computers. Brian Schmidt and two other members of the team of astrophysicists were awarded the Nobel Prize for Physics in 2011 for their research.

6.6.5 Telescope of the future
The Square Kilometre Array (SKA) is a new radio telescope currently being designed with the cooperation of ten countries including Australia, New Zealand, the United Kingdom, South Africa and China. It is likely that more countries will join the project as it progresses.

The SKA will consist of thousands of dish-shaped antennas in South Africa and Australia, linked together by optical fibre. It will be about 50 times as sensitive as the best of the current generation of radio telescopes and will be able to scan the sky up to 10 000 times faster. The
SKA is scheduled to be in full operation in 2024. It will allow astronomers to investigate events that took place within the first second after the big bang and fill gaps in our knowledge of the period when the universe became dark and the first galaxies formed.

The SKA is sensitive enough to detect weak extraterrestrial signals (if they exist) and planets in other galaxies capable of supporting life. The SKA should also provide answers to questions about distant galaxies, dark energy, gravity and magnetism.

The amount of data the SKA will collect in a single day would take almost two million years to play back on an iPod. Its processing power will be the equivalent of about 100 million personal computers.

Of course, the completion of the SKA is dependent on funding from governments of the participating nations. Whether it is completed on time, or at all, depends on the continuation of current funding.

6.6 Exercises: Understanding and inquiring
To answer questions online and to receive immediate feedback and sample responses for every question, go to your learnON title at www.jacplus.com.au. Note: Question numbers may vary slightly.

Remember
1. Describe at least two advantages of Earth-based radio telescopes over light telescopes.
2. Images produced by single radio telescopes are not very sharp. Explain how this problem is solved.
3. List the information that can be revealed by images from radio telescopes.
4. Outline the advantages of telescopes in orbit over telescopes on the Earth's surface.
5. Which part or parts of the electromagnetic spectrum have been collected by the Hubble Space Telescope?
6. State two reasons why the International Space Station is useful as an inward-looking satellite.
7. Explain why fast computers are important to exploration of the universe.

Think
8. Explain why orbiting space telescopes have a limited lifetime.
9. Outline at least four reasons why there can be no certainty about the launch dates of future space missions and projects like the Square Kilometre Array.

Investigate
10. Use the Astronomy weblink in your Resources section to find out about the research conducted by the Centre for Astrophysics and Supercomputing in Melbourne. Report on:
(a) the areas of research being conducted
(b) the range of courses available for students with an interest in the universe
(c) career opportunities in astrophysics and supercomputing.
11. Australia has always played a crucial role in space missions and space exploration. Use the internet to research and report on the role of each of the following Australian facilities in space exploration and the way in which they are funded:
(a) Australia Telescope Compact Array
(b) Canberra Deep Space Communication Complex
(c) Parkes radio telescope
12. Identify one scientist, engineer or IT specialist who works at one of the facilities listed in question 11 and write a brief report about his or her role in investigating the universe.
6.7 Priority grids and matrixes

6.7.1 Priority grids and matrixes

1. Draw two continuums that cross through each other at right angles.
2. Divide each line into six equal parts.
3. Put a label such as ‘Difficult’ on the left end of the horizontal line and ‘Easy’ on the right.
4. Put a label such as ‘High reward’ at the top of the vertical lines and ‘Low reward’ at the bottom.
5. Think of an activity and assess it using these two line, placing a mark where you think it fits best. Repeat this for other activities or ideas.
6. Compare and discuss your marked positions with those of others in your class. Share your ideas, values, views and judgements, and listen to those of others.
7. After your discussions and reflections, write your final positions directly onto the grid.

Helps you make decisions and see how your views and judgements compare with others.

Which is the best option to follow and why?

Why use?

Also called

Priorities grid; decision grid

How to ...?

Similarity

Both help you to think about patterns or key points in the information.

Comparison

Difference

Matrices classify information based on the presence or absence of key features; priority grids help you to ‘scale’ various perspectives.

<table>
<thead>
<tr>
<th>Topic</th>
<th>Feature A</th>
<th>Feature B</th>
<th>Feature C</th>
<th>Feature D</th>
<th>Feature E</th>
</tr>
</thead>
<tbody>
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<td>3</td>
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<td></td>
</tr>
</tbody>
</table>
### 6.7 Exercises: Understanding and inquiring

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note: Question numbers may vary slightly.*

#### Think and create

1. Use a priority grid to evaluate each of the following current and future challenges in space exploration.
   - (a) Extending the life of the International Space Station
   - (b) Continuing funding for the Square Kilometre Array
   - (c) Researching supernovas to find out what happened after the big bang
   - (d) Building and operating a permanent base on Mars
   - (e) Sending a space probe to Proxima Centauri
   - (f) Searching for extraterrestrial life forms

2. A matrix can be used to compare the twentieth century’s two competing theories about the universe. Copy and complete the **matrix below**, using ticks to show which statements apply to one, both or neither of the theories.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Big bang theory</th>
<th>Steady state theory</th>
</tr>
</thead>
<tbody>
<tr>
<td>The universe has no beginning.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The universe began with a single point called singularity.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The universe is expanding.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The universe always looks the same.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The red shift in the spectrum of visible light coming from stars and galaxies provides evidence for the theory.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>New stars and galaxies are created to replace those that move away due to expansion of the universe.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>This theory explains the amount of helium in the universe.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>This theory is supported by the measurement of the current temperature of the universe (about −270 °C).</td>
<td></td>
<td></td>
</tr>
<tr>
<td>This theory was first supported by a Catholic priest.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The theory will never be proven incorrect.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>An end was put to this theory in 1965.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3. Use matrices to compare:
   - (a) radio telescopes and light telescopes
   - (b) inward-looking satellites to outward-looking satellites
   - (c) red giants and white dwarfs
   - (d) three theories about how the universe might end
   - (e) living in space and living on Earth.

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A permanent base on Mars is a real possibility. But how important is it? Are the benefits worthwhile? A priority grid can be helpful in answering questions like this.
6.8 Review

6.8.1 Study checklist

Stars

• describe and distinguish between planets, stars, constellations, galaxies and nebulae
• describe and explain the motion of stars and planets of the solar system as seen from Earth
• identify the sun as a star
• explain how stars are able to emit energy
• describe the lifetime of stars of different sizes and appreciate the timescale over which changes in stars take place
• interpret the Hertzsprung–Russell diagram in terms of the absolute magnitude, temperature and classification of stars
• distinguish between absolute and apparent magnitude

The changing universe

• identify evidence supporting the big bang theory, such as Edwin Hubble’s observations and the detection of background microwave radiation
• compare the big bang theory with the steady state theory
• describe how the universe has changed since the big bang and how it might continue to change in the future

Science as a human endeavour

• describe how radio telescopes and arrays of radio telescopes are used by astronomers and astrophysicists to observe distant parts of the universe
• explain how orbiting space telescopes are used to gather data from deep space and how they compare with Earth-based telescopes
• recognise the role of Australian astronomers and astrophysicists and facilities such as telescopes, arrays and observatories in the exploration and study of the universe
• recognise the importance of IT specialists and the development of fast computers in processing the data obtained by Earth-based and orbiting telescopes
• appreciate that the study of the universe and the exploration of space involves teams of specialists from different branches of science, engineering and technology
• recognise that financial backing from governments or other organisations is required for major scientific investigations and that this can determine if and when research takes place
6.8 Review 1: Looking back

To answer questions online and to receive immediate feedback and sample responses for every question, go to your learnON title at www.jacplus.com.au. Note: Question numbers may vary slightly.

1. Solve the crossword puzzle shown.

ACROSS
2. Square Kilometre Array (abbreviation)
5. The constellation the Saucepan is a part of (also known as the Hunter)
6. The name given to the range of colours of visible light
8. The distance travelled by light in a year
12. The closest star to the sun: _______
13. The galaxy of which the solar system is a part (two words)
14. Most of the interstellar matter between the stars consists of this element.

DOWN
1. An effect that shows that some stars are closer to us than others
2. The sun is an example.
3. The famous equation $E = mc^2$ is attributed to this man.
4. The violent fate of some very massive stars
7. Most stars fall into this sequence on the Hertzsprung–Russell diagram.
9. A group of stars. The solar system is a tiny speck in one such group.
10. The universe seems to be doing this.
11. A probe launched in 2001 to map cosmic microwave background radiation.

2. Why are the constellations we see now so different from the way they were many centuries ago?
3. During which process is energy emitted by stars? Describe the process.
4. Explain the difference between the apparent magnitude of a star and its absolute magnitude.
5. Use the data in the table in section 6.3 to answer the following questions.
   Which of the stars Alpha Centauri, Betelguese and Rigel:
   (a) is brightest when viewed from Earth on a clear night
   (b) has the greatest actual brightness
   (c) is faintest when viewed from the Earth on a clear night?
6. How have scientists gained their knowledge of the life and death of stars if the processes involved take millions of years to occur?
7. What is the difference between a neutron star and a black hole?
8. What makes stars group together to form galaxies?
9. The Doppler effect is most commonly associated with the changing pitch of a sound as its source moves past you. For example, the pitch of the noise made by a speeding train increases as it approaches you and decreases as it moves away from you. Explain how the Doppler effect is relevant to the study of the universe.
10. State Hubble’s Law.
11. Two different theories about the beginning of the universe emerged during the twentieth century.
   (a) Name the two theories.
   (b) Which theory proposed that there was no beginning?
   (c) Which theory lost favour in 1965? Why did it lose favour?
12. In your own words, write an account (about 200 words) of the first second after the big bang.
13. Which of the three theories about the end of the universe described in section 6.5 do you think is the most likely to be correct? Give reasons for your answer.
14. For what do each of the following abbreviations stand?
   (a) COBE
   (b) WMAP
   (c) ISS
15. What is cosmic microwave background radiation and why does it exist?
16. At what speed do radio waves travel through space?
17. Outline two major advantages of using radio telescopes instead of light telescopes to view events in deep space from the Earth’s surface.
18. Describe the original purpose of the International Space Station.
19. For what contribution to our knowledge of the expansion of the universe was Brian Schmidt awarded the Nobel Prize?