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FirstNews

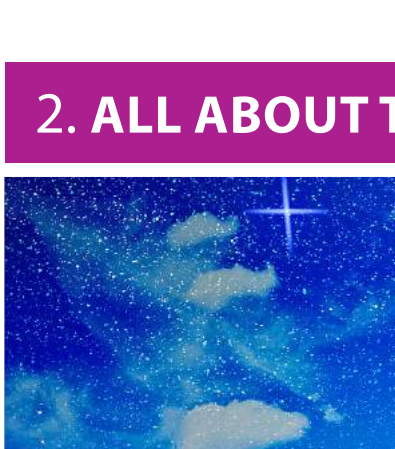
IN FOCUS

SPACE

In association with the Science Museum, part of the Science Museum Group.

SO, WHAT IS SPACE?

SINCE this whole issue is about space, that's a good question to start with. Although you might expect space to be the same everywhere, the space around Earth is very different from the space between galaxy clusters. Join us on a quick tour of the universe…



The International Space Station in orbit around Earth

The space around Earth is known as **geospace** and is where you'll find the International Space Station. The Earth's **gravity** keeps our planet's atmosphere pulled in, but the higher up you go, the weaker gravity becomes and the thinner the atmosphere is. Most scientists say that geospace starts around 100km (62 miles) above Earth. At that distance, the atmosphere pretty much disappears and the sky looks black.

We see blue skies on Earth because particles in the atmosphere scatter blue light from everywhere in the sky, but in geospace there are hardly any particles to scatter the light. In geospace, gravity becomes less powerful, so other things have more effect, like the Earth's magnetic fields and charged particles from the sun, known as the **solar wind**.

The solar wind can be very dangerous to life but, thankfully, the Earth's magnetic field deflects the wind around our planet and keeps us all safe.

Charged particles from the sun striking Earth's magnetic field cause the northern lights, which are strange shifting patterns of colour in the sky

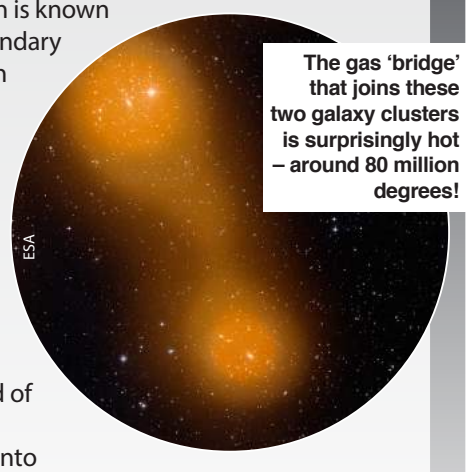
Instead of the gases present in our atmosphere, geospace contains **plasma**, which is the fourth state of matter after solid, liquid and gas. A plasma is made up of lots of charged particles and can conduct electricity much better than our atmosphere.

As you get even further away from Earth, you move into what's known as **interplanetary space**, which is the space between the planets in our solar system. This makes up most of our solar system and is dominated by the solar wind, which blasts out from the sun at speeds of 400km/s (a million miles per hour). For planets or other bodies that don't have a magnetic field (like our moon), the solar wind constantly bombards them with charged particles.

A coronal mass ejection (CME) on the sun. Although it isn't really that close, the Earth is shown nearby for scale

The solar wind only reaches a certain distance into space. The 'bubble' of space it sits in is known as the **heliosphere**. The blurry boundary at the edge of this bubble is known as the heliopause, and outside this is where you'll find **interstellar space**. This region between stars in a **galaxy** is much more tightly packed with particles, although it is generally colder. The particles in interstellar space come from things like **supernovae**, which are the huge explosions that happen when a star collapses in on itself at the end of its life (see p7).

When a star dies it creates a huge blast called a supernova



The gas 'bridge' that joins these two galaxy clusters is surprisingly hot – around 80 million degrees!

As you move outside a galaxy, you get into **intergalactic space**. There are hardly any particles at all in these vast areas – only around six protons in every cubic metre. Compare that to interstellar space, where there are around a million hydrogen atoms (made from a proton and an electron) per cubic metre. So you'd expect these huge, empty regions of space to be cold, right? Nope, not all of it – X-ray emissions from galaxy clusters show that certain parts can range in temperature from 100,000 degrees to ten million degrees!

How BIG is it?

iStock

Away from street lights, you can see the band of stars that make up our own galaxy, the Milky Way

TO quote author Douglas Adams: "Space is big. Really big. You just won't believe how vastly, hugely, mind-bogglingly big it is."

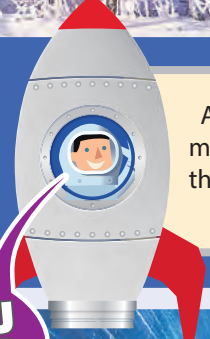
To give you an idea of the size of our **universe**, let's start with a tiny part of it – our own galaxy, the Milky Way. A galaxy contains lots and lots of stars, like our sun, and although no-one knows how many stars are in the Milky Way, estimates say that it's between 100 billion and 400 billion.

The fastest thing in the universe is light, which travels at around 300,000,000 metres per second (671,000,000mph). But, even if you travelled at the speed of light, it would still take you 100,000 years to cross from one side of the Milky Way to the other! That's just one galaxy, and there are about 100 billion galaxies that we can see in the universe.

It's impossible for us to know exactly how big the universe is because we can't see all of it. The universe is around 13.8 billion years old, so we can only see light that has been travelling for this long. Our universe is also expanding (see below) and things are moving further apart from each other, so the observable universe is around 93 billion light years across.

But what's our universe expanding into? And is it the only one?

The Big Bang and our expanding universe



A LIGHT year is a common distance measurement in astronomy. It is the distance that light travels in one year, which is around 9.5 trillion kilometres (5.9 trillion miles).

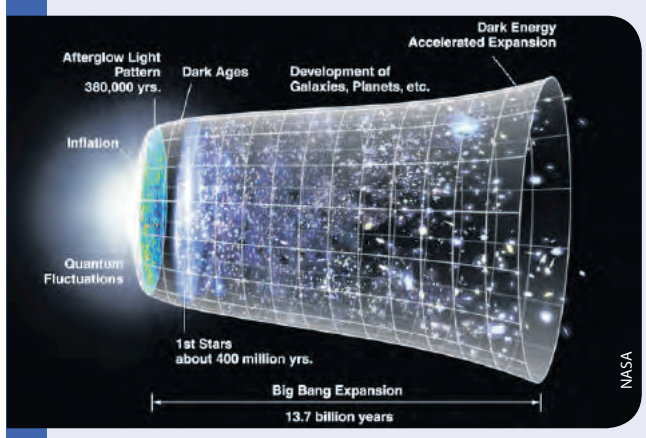
SCIENTISTS think that our universe started expanding really quickly after an event called the Big Bang.

At this point, all of the material in the universe – including our own **solar system** – was squashed into one tiny point and atoms hadn't formed yet.

After the Big Bang, everything started to accelerate away from this tiny point, with particles gradually forming atoms. The gravity of the slightly heavier clumps of atoms slowly started to form clouds of gas, which eventually formed into stars and planets (see p6).

For a long time, scientists thought that gravity would slow down the expansion of the universe, as galaxies pulled each other closer. Many even thought that the universe would collapse back in on itself in a Big Crunch, the opposite of the Big Bang.

However, evidence published at the end of the last century showed that the universe's expansion was accelerating. So something is pushing the universe apart, but what is it? Scientists have given it the name **dark energy**, but no-one really knows what it is. Results have shown that around 68% of the universe is dark energy, so this mysterious force makes up more than two thirds of everything. But is it just a property of empty space that we don't know about yet, or some kind of new energy? It's also possible that our current theories of gravity aren't quite right and that they need to be changed slightly to include the dark energy effect.



NASA

To blow your mind even further, another 27% of the universe is thought to be made up of another baffling mystery: **dark matter**. This is stuff that we can't see but is thought to have a big effect on the formation and rotation of galaxies. So, after dark energy and dark matter, the 'normal' matter that makes up stars and planets and us is only actually 5% of the universe!

The graphic to the left shows a timescale of when things formed after the Big Bang. The 'dark ages' is the time before photons (what we see as light) formed so, even if you had a time machine, it wouldn't be possible to see anything during this period!

DID YOU KNOW?

iStock

The Big Bang wouldn't have looked like a bright flash, as there was no such thing as light at that time

LOOK OUT for the words in purple throughout this newspaper. They appear in the glossary on page 30.

LITTLE ROCKS AND SPACE GIANTS

From left to right after the sun in the corner, are Mercury, Venus, Earth and Mars (the rocky planets), followed by Jupiter and Saturn (the gas giants), then Uranus and Neptune (the ice giants). It's not to scale – we're nowhere near that close to our neighbouring planets

DID YOU KNOW?

ANCIENT astronomers thought the Earth was the centre of the universe and that the sun and all other stars revolved around it. Copernicus, a 16th-century astronomer, is credited with spreading the idea that Earth and the planets orbit the sun instead.

OUR solar system is made up of the sun, the eight planets that are held in orbit around it by gravity, and all the moons, comets, asteroids and dust that orbit the sun and planets.

Mother sun

THE key part of our solar system is the sun – without it, we wouldn't exist!

It's strange to think that life on Earth is only possible because of a massive ball of hydrogen and helium 150 million kilometres away that burns at temperatures of 15 million degrees Celsius, isn't it?

Without the sun, plants couldn't use photosynthesis to make energy, so we'd have nothing to eat. Trees and plants also wouldn't be able to make oxygen, so we couldn't breathe either. Plus obviously we wouldn't be able to see where we were going, so life without the sun would kind of suck and wouldn't last very long!

Earth's movement in orbit around the sun also gives us our calendar and the seasons (see p9 to learn why), so there isn't really any part of our lives that it doesn't affect. See p8-9 to find out more about our own solar system.

Beyond our system

OUR sun is one of at least 100 billion stars in our own Milky Way galaxy, and each of those stars could have their own set of planets.

A NASA worker assembles part of the Kepler telescope

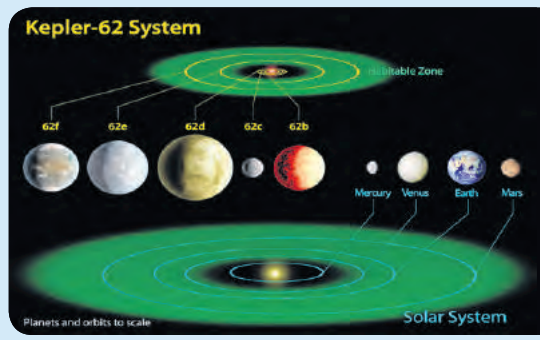
In 2012, scientists found the first likely planetary system outside of our own. It includes seven **exoplanets** orbiting a star with the small, rocky planets close to their sun and the gas giant planets further away – similar to our solar system.

The system was found thanks to the Kepler space telescope, which has since revealed more than 300 planetary systems similar to our own. We don't have many details about these planets or their features because they are so far away, but thanks to Kepler we do at least know that our solar system isn't alone.

Kepler is a NASA mission to search our part of the Milky Way galaxy to find other planets that could host some form of life.

Kepler was able to work out the size of planets and their surface temperatures, which, in turn, tells us if the planets could potentially be lived on or not.

For more about Kepler's search for life, see p31.



This NASA diagram compares the planets of our inner solar system to Kepler-62, a five-planet system about 1,200 light years from Earth. The five planets of Kepler-62 orbit a star two-thirds the size of our sun and a fifth as bright. Planets 62f and 62e could host a form of life

FIRST NEWS AND BLIPPAR

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STAR FACTORIES

A picture of the spiral galaxy NGC 441, taken by NASA's Hubble Space Telescope

Getty

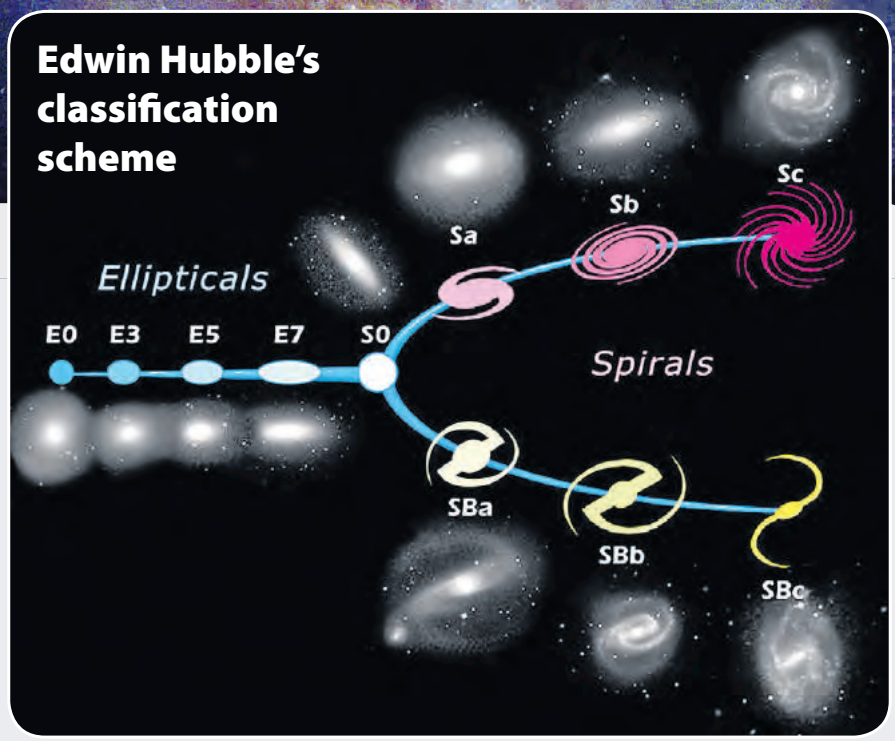
A GALAXY is an enormous family of stars held together by gravity. Earth and our solar system are in the Milky Way galaxy.

Galaxies are the building blocks of the universe and they come in various different shapes and sizes (see below). Some are so big that they contain hundreds of billions of stars, and all galaxies appear to have been formed soon after the universe began.

Normally arranged in clusters, which themselves are part of even bigger clusters, a neighbourhood of galaxies is vast: it takes hundreds of millions of **light years** to cross one of the big clusters!

In some galaxies, stars are still being formed, while in others there have been no new stars created for billions of years.

Edwin Hubble's classification scheme



TYPES OF GALAXY

IN 1926, American astronomer Edwin Hubble came up with a system to classify galaxies. Now known as the Hubble sequence, it organises galaxies in three main categories based on shape (right).

- **SPIRAL** – These are, err, spiral-shaped. They have a bright nucleus (centre), with a thin outer disc and spiral arms. There are two types of spiral galaxy: normal and barred. The normal ones have arms that spiral out from the nucleus, while the barred have a bright, straight bar that crosses the nucleus.
- **ELLIPTICAL** – These are filled with very old stars and few new ones are created, making them shine less brightly than spirals. They don't have the swirling arms of spiral galaxies, but are shaped more like a stretched circle.
- **LENTICULAR** – Containing elements of both spiral and elliptical galaxies (S0 on the diagram to the right), their formation is difficult to explain.

There are also IRREGULAR galaxies, that are neither spiral nor elliptical.

Getty

Clusters of stars inside the Large Magellanic Cloud galaxy

THE MILKY WAY

OUR galaxy is part of the Local Group, a collection of 54 galaxies and dwarf galaxies. This group is part of a larger formation known as the Virgo Supercluster.

The Milky Way is a barred spiral galaxy, containing a bulge at its centre and a spiral disc of stars, gas and dust around it.

NASA

What our galaxy, the Milky Way, is thought to look like from the outside

A thick layer of dust makes it difficult for astronomers to study certain parts of the Milky Way with optical telescopes. Instead, they have to use **radio telescopes** and **infrared telescopes** to see through the dust.

A STAR IS BORN (AND SOME PLANETS)

DISCOVERING planets and stars became the easy part for ancient astronomers. The tricky thing was working out what made them.

DID YOU KNOW?

THE comets that still roam the outer edges of our solar system haven't really changed since it formed, so scientists think that studying them can tell us more about what happened 4.6 billion years ago when our solar system was born.

ESA

The discovery of neighbouring stars has given us the opportunity to learn a lot, because scientists have been able to study the formation of other solar systems.

The Hubble Space Telescope (HST) has played a big part in helping us understand the origins of our galaxy, as it has allowed us to see beyond our solar system. Sitting in Earth's orbit since 1990, the HST is the most sophisticated observatory humans have ever created (see p24-25 for more).

Dusty clouds

Some of the HST's most important finds were young stars with discs around them. This gave scientists a vital clue to help them understand just how planets are created. They decided that a star and its planets form out of a collapsing cloud of dust and gas, which is part of a **nebula** (a much bigger cloud of dust and gas).

iStock

Something like a shockwave from a collision or explosion in space could cause a cloud to begin to collapse. When it does start to collapse, gravity takes hold and squashes it even more. It gets hotter and hotter as more dust and gas is squeezed together, until eventually it forms the core of a new star.

Planetary pizza

But not all of this material becomes a star. As the new star is squished, the material inside it is churning around, which eventually makes the star spin in one direction. This spinning makes the remaining bits of the cloud flatten out into a disk, kind of like a chef spinning a lump of dough to make a pizza base.

Some of the bigger lumps in the disk join together to form planets, whereas other chunks will collide and shoot off to become comets or asteroids.

NASA, ESA, M Robberto (STSCI/ESA) and the Hubble Space Telescope Orion Treasury Project Team

This Hubble image shows the Orion Nebula, a huge cloud of dust and gas that is the nearest star-forming region to Earth. It contains around 3,000 stars, many of which are young enough to still have a disc of gas surrounding them

Greedy sun

It's thought that when our solar system formed, 99% of the dust and gas became the sun, and the last tiny 1% made all the rest of the planets, asteroids and comets in our system. The rocky planets formed near the sun where it's warm, whereas the gas planets and icy planets formed further away where it's colder (see p8-9).

A VIOLENT DEATH

Generally speaking, the bigger the star, the shorter it lives, but an average star lives for billions of years.

A star's main fuel is hydrogen and the star produces energy by a process called nuclear fusion, which involves pushing atoms together to make heavier ones. This is the opposite of nuclear power stations on Earth. They produce energy by breaking atoms apart, which is known as nuclear fission.

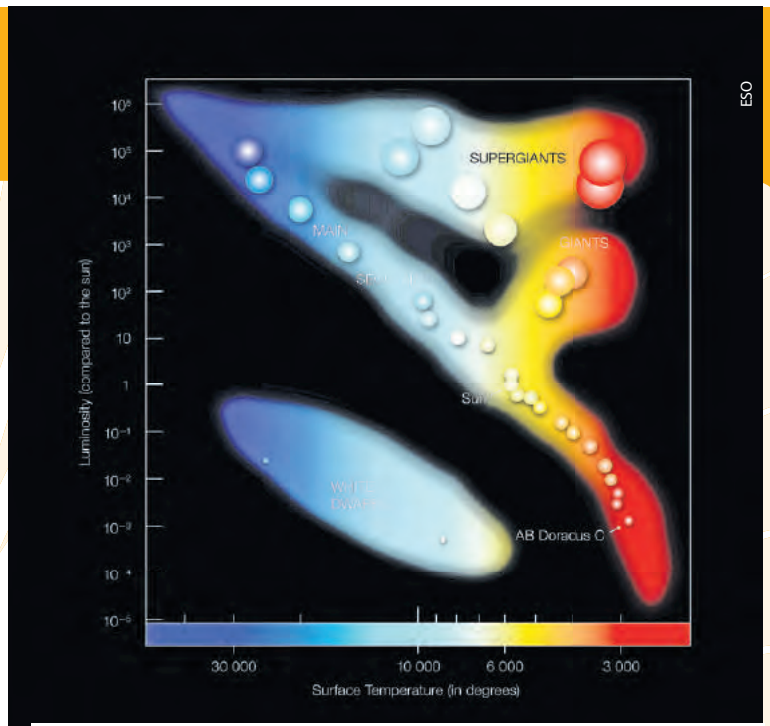
Red giants

Over time, the hydrogen in the core runs out and the fusion reactions that keep the star alive begin to fade. The star starts to collapse in and its core gets hotter, while pushing away its outer layers, which cool down. The star then turns into what's known as a red giant, which is what our sun will likely become in five billion years.

This red giant will then change into something new, but what that is depends mostly on the size of the star. Here are some of the possibilities.

From giant to dwarf

Medium and small-sized stars are likely to turn into something called a white dwarf. This is what's left after a red giant has pushed away all of its hot outer layers. Over time, they slowly cool down and simply fade away. Experts think that white dwarfs eventually fade so much that they give off no light at all and become a black dwarf, although this is thought to take so many billions of years that the universe isn't old enough for any to have been created yet.



This graph is the Hertzsprung–Russell diagram, which plots a star's brightness against its temperature. As stars get older, they will slowly move to a different position on the graph. Our sun, for instance, will move off the main sequence into the white dwarf region

Exploding stars

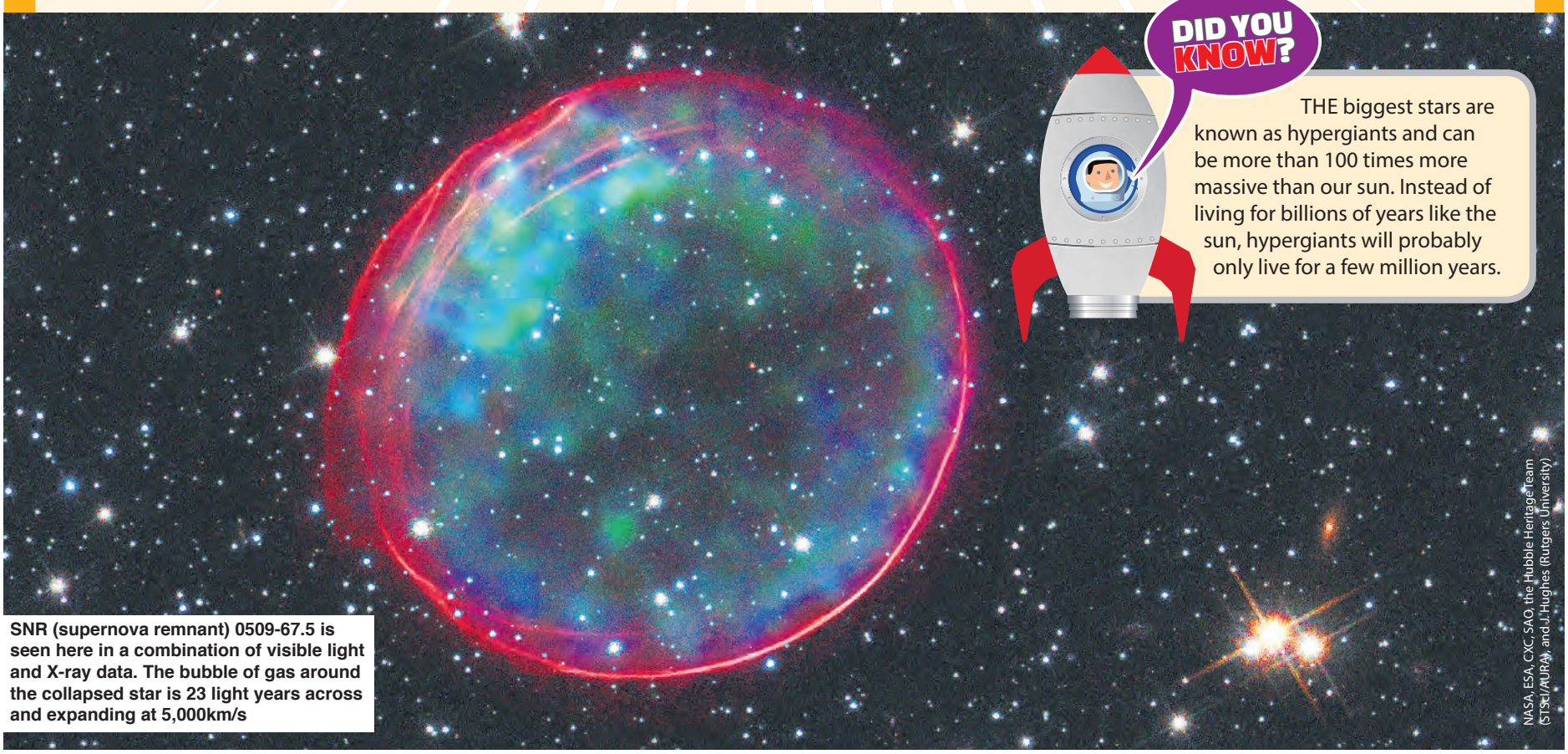
More massive stars suffer a pretty spectacular end to their life. They will use all of their fuel, eventually giving the star a core made mainly of iron.

When the nuclear reactions stop, there is no outward pressure to resist the star's own gravity, causing the star to collapse incredibly quickly, going from a few thousand kilometres across to less than a hundred in seconds. This incredible pressure can heat the star up to more than 100 billion degrees, before it explodes in a huge explosion known as a **supernova**. They can be even brighter than whole galaxies, and they spread iron and other heavy elements across the universe, which will eventually be recycled into other stars and planets.

If the collapsed star's core is heavy, it can form a black hole or a neutron star (see p22-23).

SN 2006gy, a supernova discovered in 2006 that was the brightest ever recorded at the time. On the left is the X-ray light coming from the centre of galaxy NGC 1260, while on the right is SN 2006gy – just one star that is shining as brightly as its home galaxy

An artist's impression of supernova SN 2006gy

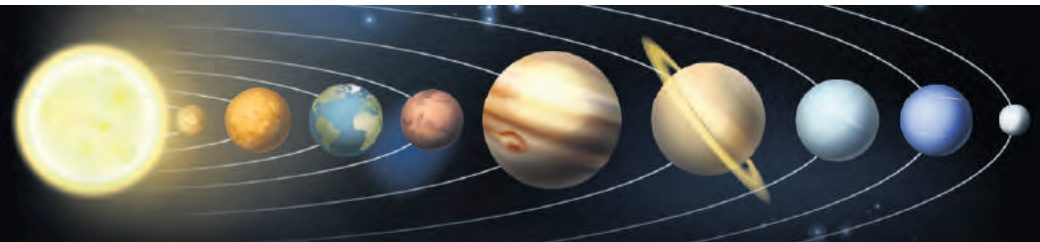


SNR (supernova remnant) 0509-67.5 is seen here in a combination of visible light and X-ray data. The bubble of gas around the collapsed star is 23 light years across and expanding at 5,000km/s

DID YOU KNOW?

THE biggest stars are known as hypergiants and can be more than 100 times more massive than our sun. Instead of living for billions of years like the sun, hypergiants will probably only live for a few million years.

INSIDE OUR SOLAR SYSTEM

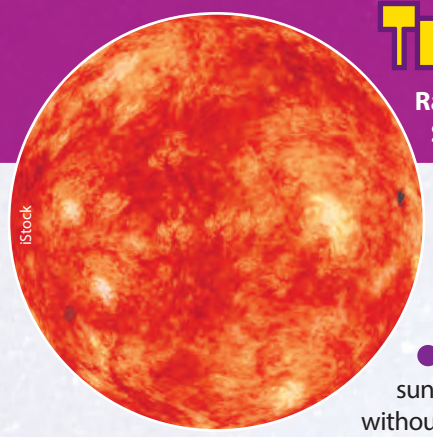


OUR solar system formed around 4.6 billion years ago and contains eight planets and their satellites (such as Earth's moon), dwarf planets like Pluto, plus lots of asteroids, comets and meteors.

The four planets closest to the sun are Mercury, Venus, Earth and Mars. These are known as rocky planets, because their surfaces are solid and contain rock and metal.

The two planets beyond Mars – Jupiter and Saturn – are known as the gas giants, while Uranus and Neptune are both gas and ice giants. These two have lots of icy material because they are really far away from the sun and never get warm.

The sun



Radius: 109 Earths
Surface temperature: 5,505°C

- The sun is the centre of our solar system. It's a giant ball of gas orbited by eight planets, at least five dwarf planets, tens of thousands of asteroids and millions of comets.
- Thanks to the incredible energy the sun gives off, there is life on Earth. In short, without the sun, none of us would be here!

Earth

Radius: 6,378.14km
Surface temperature: -88 to 58°C
Time to orbit sun: 365.24 days

- Earth's rotation is slowing down so, in 140 million years, a day will last 25 hours!
- The hottest recorded temperature is 56.7°C, but the average across the whole planet is a cool 16°C.
- Earth is the only planet in the solar system not named after a Roman or Greek deity (god or goddess).

Mercury

Radius: 0.3825 Earths
Surface temperature: -173 to 427°C
Time to orbit sun: 87.97 days

- The smallest planet in the solar system and has no moons.
- Although it's the closest planet to the sun, it's not as hot as Venus, which is further away. That's because Venus has an atmosphere, which traps heat and warms the planet even more, like the greenhouse effect that's causing climate change on Earth.

Mars

Radius: 0.5326 Earths
Surface temperature: -87 to -5°C
Time to orbit sun: 686.93 days

- Mars is nicknamed 'the red planet' because it's, well, red.
- Just like Earth, Mars has seasons, ice caps, volcanoes, canyons and weather.
- One day on Mars lasts a little over 24 hours.
- Although water used to flow on the surface of Mars, its river beds all dried up around four billion years ago. There's no life there now that we know of, but it's possible that there was a long time ago.

Venus

Radius: 0.9488 Earths
Surface temperature: 462°C
Time to orbit sun: 224.7 days

- Named after the Roman goddess of love and beauty.
- The rotation of Venus is so slow that it travels around the sun quicker than it can spin round once. This means that Venus has a longer day than it does a year! A 'day' there is 243 Earth days, compared to 224.7 Earth days for one orbit of the sun. The same happens on Mercury, where a 'day' actually lasts 176 Earth days, but it only takes 88 days for it to orbit the sun. So a day on Mercury is twice as long as a year. Try and get your head round that!

DID YOU KNOW?

THERE are a number of mnemonics (memory aids) for the order of planets. The first letter in each word matches the first letter of each planet. Here are a few:

My **V**ery **E**asy **M**ethod: **J**ust **S**leep **U**ntil **N**oon

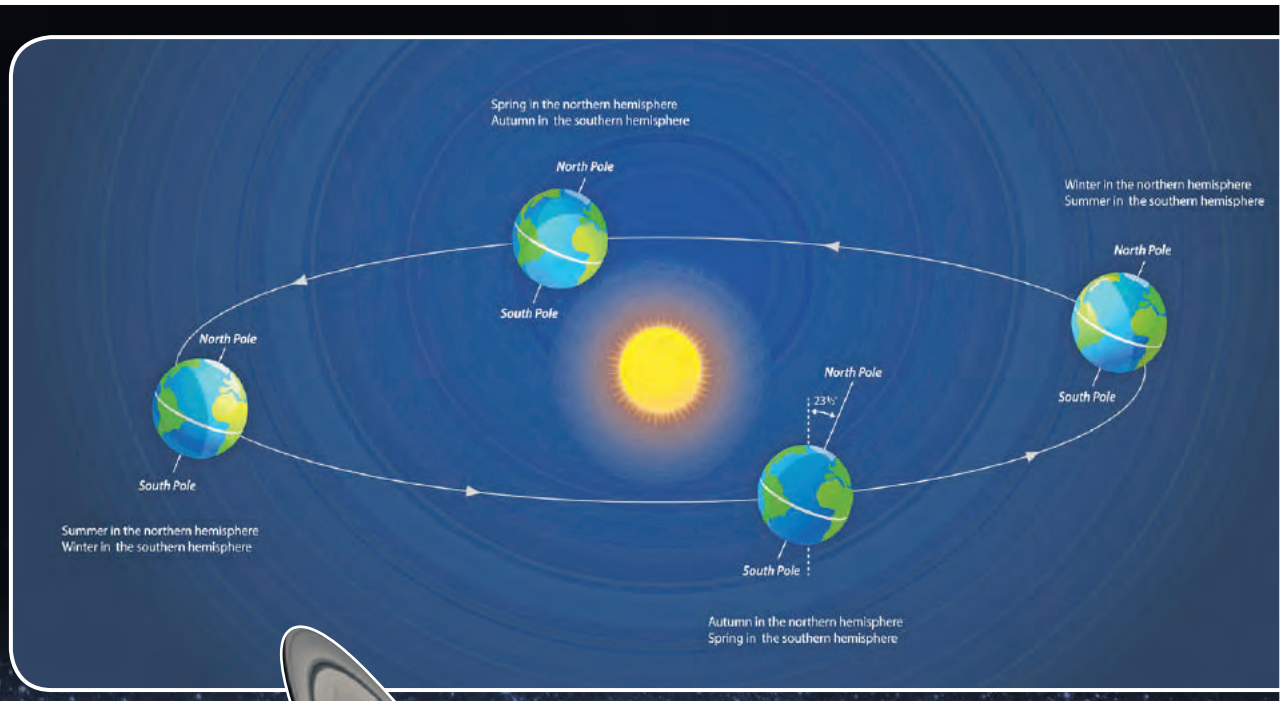
My **V**ery **E**ducated **M**other **J**ust **S**erved **U**s **N**achos

My **V**iolent **E**vil **M**onster **J**ust **S**cared **U**s **N**uts

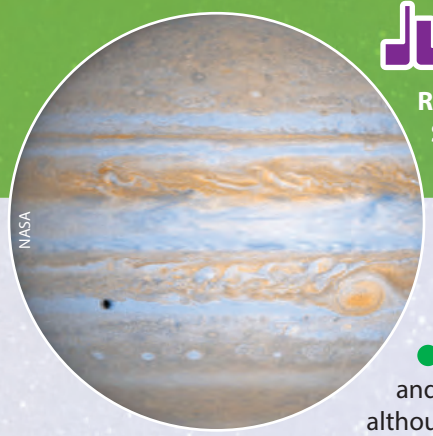
What causes the seasons?

Like other planets, Earth's rotational axis is tilted away from its orbital plane. If you imagine the Earth as an apple, put a stick right through the core and that would be its axis of rotation – the line that the planet spins round. Its orbital plane is the path it makes as it travels around the sun. Earth's axis is tilted around 23° away from the orbital plane (see right), which leads to the northern and southern parts of Earth getting more sun at different times of the year.

That's what causes the seasons, and why when it's summer in the UK, it's winter in places like Australia.



Jupiter



Radius: 11.209 Earths
Surface temperature: -148°C
Time to orbit sun: 4,330.6 days

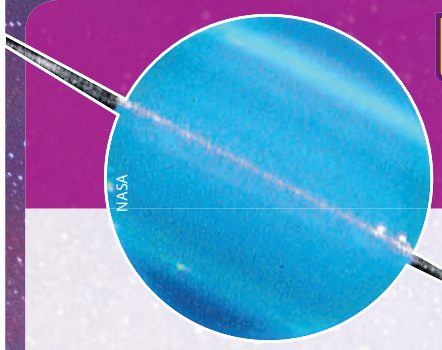
- The gas giant Jupiter is the largest planet in the solar system by far. It's big enough to fit every single other planet inside it!
- It has 67 moons that we know of and the largest ocean of any planet – although it's a strange liquid form of hydrogen rather than water.
- One day on Jupiter only lasts about ten hours.
- The winds on Jupiter are fierce and can reach 400mph (640km/h)!

Saturn

Radius: 9.449 Earths
Surface temperature: -178°C
Time to orbit sun: 10,755.7 days

- Another gas giant, and made mostly of hydrogen and helium, Saturn is the lightest planet in the solar system – so light that it could float on water!
- Surrounded by seven main rings made of bits of ice and rock.
- It has 62 moons, some of which may be able to support life – but we still don't know this for certain.
- A single day on Saturn lasts just 10.7 hours.

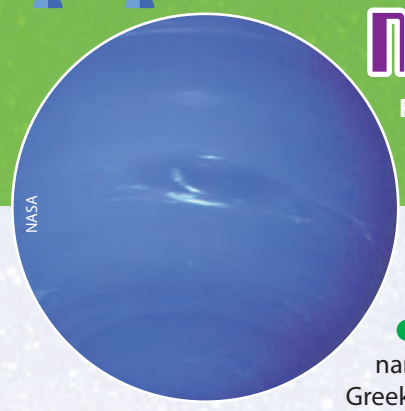
Uranus



Radius: 4.007 Earths
Surface temperature: -216°C
Time to orbit sun: 30,687.2 days

- A day on Uranus lasts 17 hours.
- The methane in Uranus's atmosphere gives it a blue colour.
- It has 27 moons, named after characters from the works of British writers William Shakespeare and Alexander Pope.

Neptune



Radius: 3.883 Earths
Surface temperature: -214°C
Time to orbit sun: 60,190 days

- Neptune is a very cold, dark and windy planet.
- A day lasts 16 hours.
- Neptune has 13 moons, which are named after sea gods and nymphs from Greek mythology.

Dwarf planets, comets and more...

Dwarf planets orbit the sun like planets, but can't clear their path. This means there are similar objects at roughly the same distance from the sun. Pluto (left) is the most famous dwarf planet. It was classed as a planet until 2006, when the official definition of a planet was changed.

Comets are made of ice, dust and rock. Their 'tails' are a mixture of ice and dust that have melted away from the main nucleus. When Earth's orbit moves through a comet's path, particles from the tail pass through our atmosphere, causing a meteor shower.

Tiny chunks of rock or metal in orbit around the sun are known as meteoroids, and often come from asteroids or comets. When they enter a planet's atmosphere and burn up, they are called meteors. If a meteor survives entry and lands on the surface, it becomes known as a meteorite.

Asteroids are rocky worlds that are too small to be called planets. Most of them lie in the asteroid belt between Mars and Jupiter.

Getty

The first known image of Halley's Comet is on the Bayeux Tapestry, which was made following the Norman conquest of England in 1066. The comet can be seen with the naked eye every 75-76 years and is next due to appear in 2061

iStock

The band of stars that makes up our own galaxy, the Milky Way, seen above an array of radio telescopes

NASA

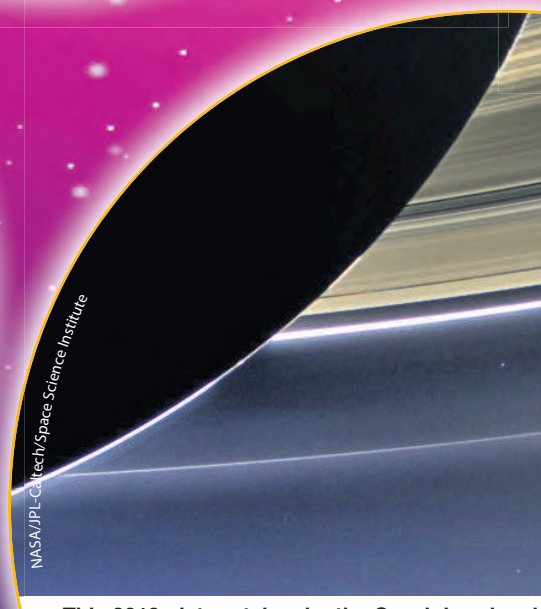
The most populated parts of Europe can be seen easily from space at night, as the glow from buildings and street lights shows up clearly

NASA

Earth rising above the horizon of the moon, as seen from Apollo 8 on Christmas Eve in 1968. The three astronauts – Frank Borman, James Lovell, and William Anders – were the first humans to see this amazing sight

NASA, ESA and E Karkoschka

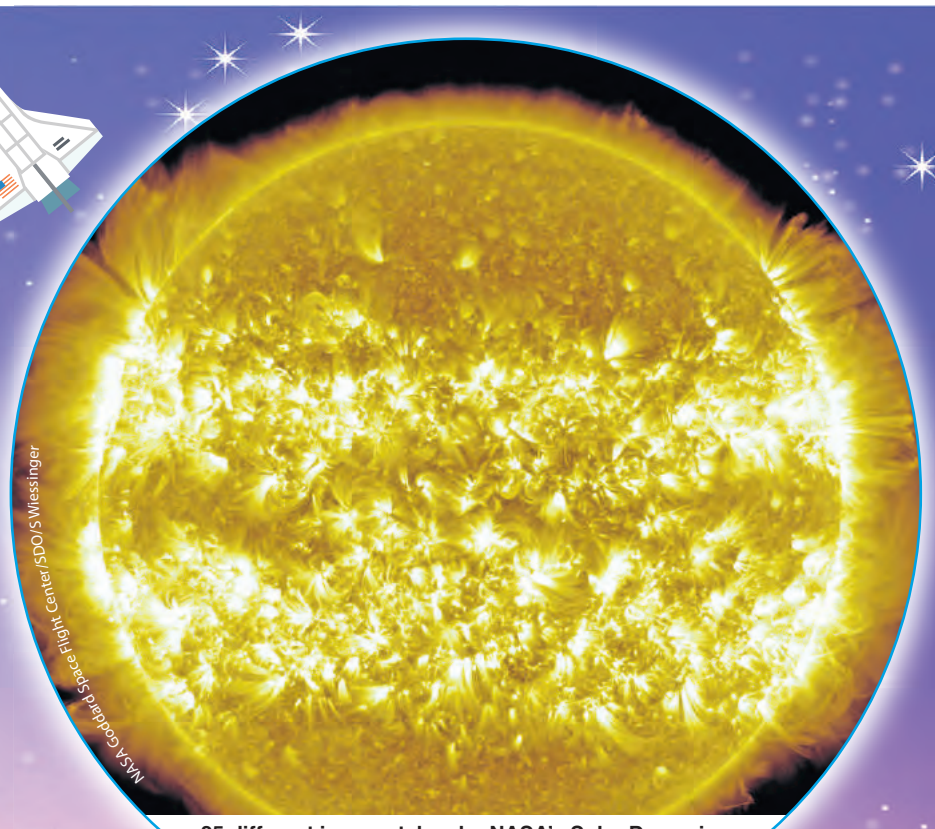
Jupiter's moon Ganymede peeks out from behind its home planet. Jupiter is the largest planet in our solar system and Ganymede is the largest moon. The Giant Red Spot (top left) on Jupiter is a storm that has been raging for more than 300 years – and it's the size of two Earths!



NASA/JPL-Caltech/Space Science Institute

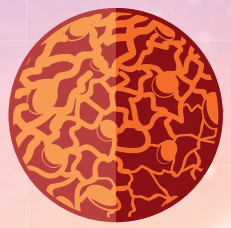
This 2013 picture taken by the Cassini probe shows Saturn and some of its many rings. The tiny blue dot at the bottom right is Earth – 1.44 billion km (898 million miles) away!

US astronaut James Irwin on the moon during the Apollo 15 mission. It was the fourth manned landing and the first where astronauts went for a drive on the moon, using the Lunar Roving Vehicle

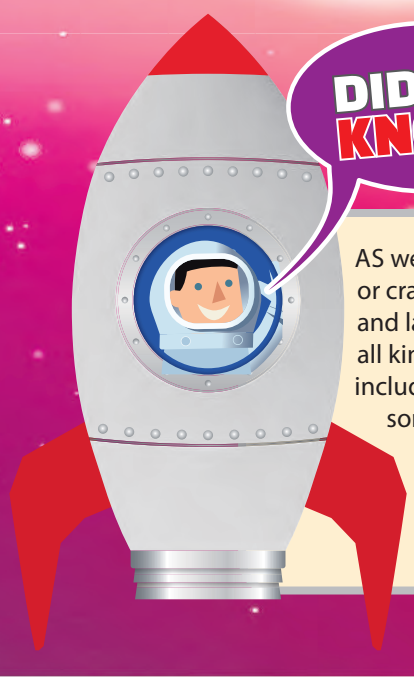


25 different images taken by NASA's Solar Dynamics Observatory (SDO) were used to make this image, which shows the most active regions of our sun

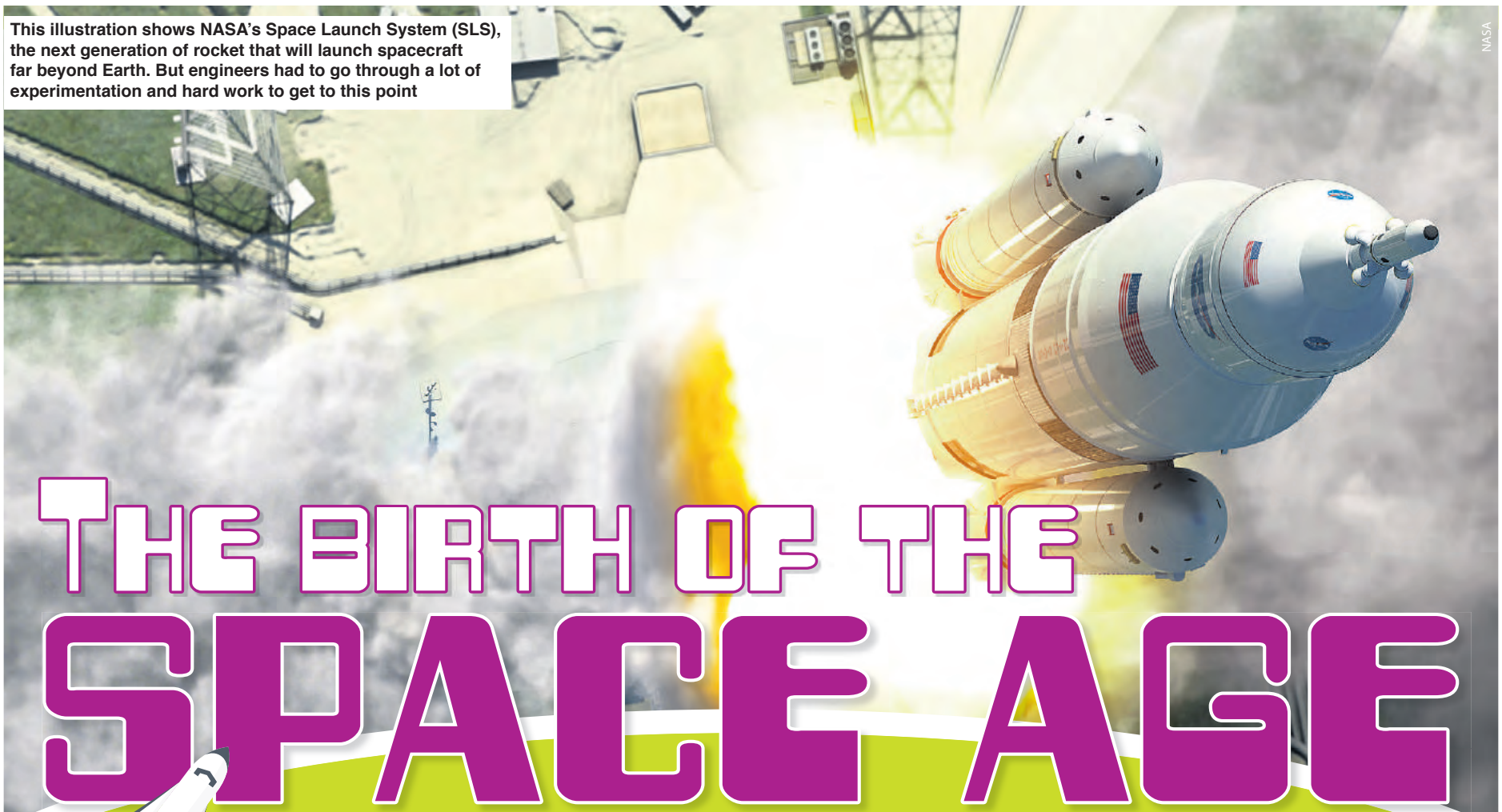
A picture taken by the Mars rover Curiosity, looking back at its own tyre tracks. This snap has been 'white balanced' to show what Mars would look like if the lighting conditions were the same as on Earth



One of the best space pictures ever, this shot from February 1984 shows astronaut Bruce McCandless using a nitrogen-fuelled jetpack to fly up to 97m (320ft) away from the Space Shuttle Challenger. The jetpack, known as the Manned Maneuvering Unit (MMU), was only used three times, as it was judged to be too risky



AS well as dozens of used or crashed space probes and landers, our moon has all kinds of junk on it now, including three buggies, some cameras and three golf balls that Alan Shepard hit with a club during Apollo 14!



This illustration shows NASA's Space Launch System (SLS), the next generation of rocket that will launch spacecraft far beyond Earth. But engineers had to go through a lot of experimentation and hard work to get to this point

NASA

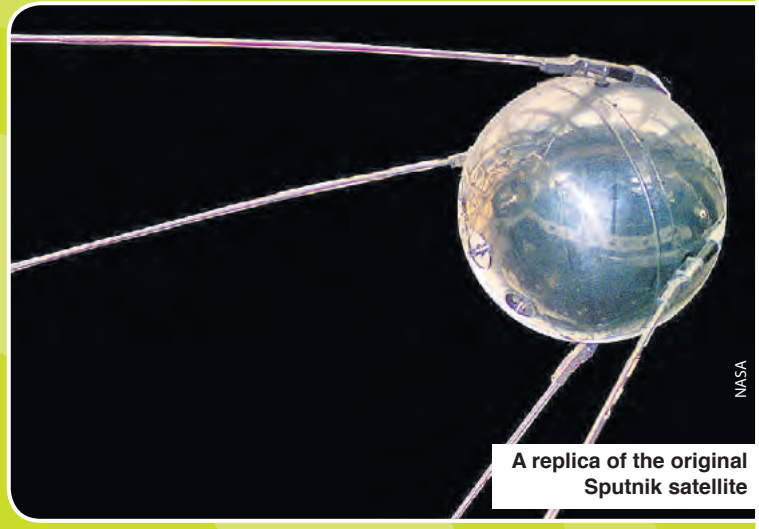
THE BIRTH OF THE SPACE AGE

STRAP yourselves in, as Doug Millard, Lead Curator of the Cosmonauts exhibition at the Science Museum, takes us on a whirlwind tour through the early days of space exploration.

FIRST ARTIFICIAL SATELLITE

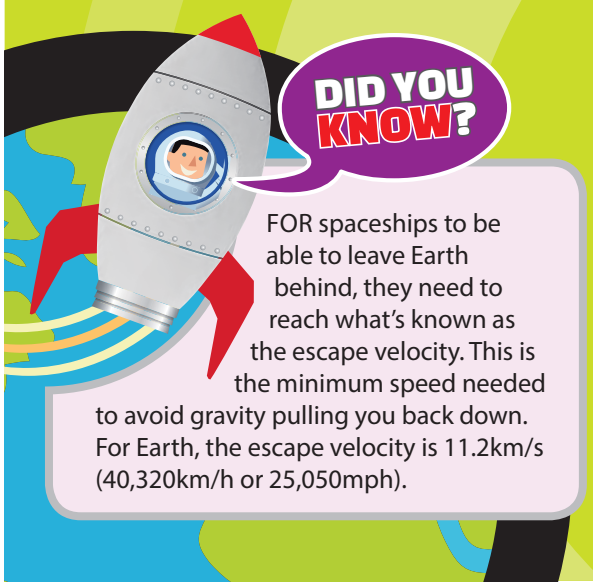
THE very first spacecraft to be launched into an orbit of the Earth was called Sputnik.

This means 'Fellow Traveller' in Russian. The moon also orbits the Earth and is called our natural satellite. Sputnik was Earth's first artificial satellite. Sputnik was a small shiny sphere just over half a metre in diameter. Two pairs of radio antennas projected out and swept back. A transmitter inside gave out a 'beep-beep-beep' signal that was heard by millions on their radio and TV sets around the world. Sputnik's launch by the Soviet Union in 1957 shocked the world, and the United States especially – many people had expected the US to launch first. Sputnik opened the space age. It showed that spaceflight was possible and that, with time, larger spacecraft should be able to carry humans into space.



NASA

A replica of the original Sputnik satellite



FOR spaceships to be able to leave Earth behind, they need to reach what's known as the escape velocity. This is the minimum speed needed to avoid gravity pulling you back down. For Earth, the escape velocity is 11.2km/s (40,320km/h or 25,050mph).

Getty

Laika was the first creature to orbit Earth

FIRST DOGS IN SPACE

THE first dogs launched into space stayed there for only a few minutes.

They were called Tsygan and Dezik and were launched by the Soviet Union in 1951 on the top of a rocket that took them high above Earth but not around it. Over the next few years the Soviet Union launched many more dogs on similar missions but then, in 1957, just a month after the launch of Sputnik, Laika was sent into orbit around the Earth. She was the first animal to do so but died in space when she overheated. In 1960 the dogs Belka and Strelka became the first animals to return safely from orbit. The success of their mission paved the way for the first human spaceflight just one year later.

FIRST MAN IN SPACE

IN 1959 the Soviet Air Force started recruiting for pilots to carry out a special, secret mission.

Later, the candidates were told that it would be to become the first cosmonaut. Eventually, a short list of just seven pilots were ready and Yuri Gagarin was chosen as the first cosmonaut. Gagarin passed all the strict tests with lightning-quick reflexes and responses, an excellent memory and keen imagination. He was also a good team worker with a mischievous sense of humour. Soon after his pioneering mission on 12 April 1961 when he became the first human to orbit the Earth, his smiling face appeared in newspapers and on television all around the world. He was the first space superstar.

Yuri Gagarin just before he made history by becoming the first man in space

Getty

FIRST CREW IN SPACE

BY 1964 the Soviet Union had launched the first artificial satellite, first animal and first human into orbit.

Soviet leader Nikita Khrushchev was anxious the successes should continue. The Chief Designer of the space programme – Sergei Korolev – set about the modification of a one-man Vostok ('East') spacecraft into a three-man Voskhod ('Ascent' or 'Dawn'). Korolev also insisted the crew of three should include other types of specialist other than air force pilots. Voskhod 1 was launched on 12 October 1964 with command pilot Vladimir Komarov (air force pilot), engineer Konstantin Feoktistov and medical doctor Boris Yegorov. Feoktistov was one of Korolev's team who had designed both Vostok and Voskhod. Their mission lasted just one day and chalked up another space first for the Soviet Union. It had, however, been by far the most dangerous flight so far. The spacecraft was so cramped that there was no room for the cosmonauts to wear spacesuits. A leak in the spacecraft would have killed the three men.

Vostok 1 is shown off to the public in Moscow

Getty

FIRST WOMAN IN SPACE

VALENTINA Tereshkova became the first woman in space on 16 June 1963, orbiting the Earth for almost three days in her Vostok 6 spacecraft (which you can see in the Science Museum's Cosmonauts exhibition).

Tereshkova was in space at the same time as cosmonaut Valery Bykovsky, who was in Vostok 5. This was the first time two spacecraft had orbited the Earth together, and they talked to each other using radio. Tereshkova never flew again but became a champion of women's rights and an active member of the Soviet parliament.

Valentina Tereshkova during training

Getty

FIRST SPACEWALK

ON 18 March 1965, cosmonaut Alexei Leonov left his Voskhod 2 spacecraft and made the world's first spacewalk.

He was astonished at the experience, feeling like part of the universe as he floated silently above Earth, hearing only his breathing and the blood flowing through his veins. Within minutes he realised that his suit was expanding in the vacuum of space and he would be unable to get back into the spacecraft. He took the dangerous decision to let air out of the suit so that it would shrink and allow him to re-enter Voskhod to join his crewmate Pavel Belyayev. The problems were not over, as the two men then had to manually steer the spacecraft back to Earth when the automatic control system failed. They landed successfully but in the wrong place, and had to survive two nights in sub-zero temperatures in Siberia until a rescue party arrived.

Alexei Leonov during the first ever spacewalk

Getty

Cosmonauts: Birth of the Space Age is on at the Science Museum until 13 March 2016. Tickets can be booked in the Museum or at sciencemuseum.org.uk/cosmonauts.

TIM'S TIME

BRITAIN has a big space industry and has helped to build loads of important satellites and telescopes, but we haven't sent many people to space (see p18-19 for a British space history).

The latest Brit to blast off into space is Tim Peake, a former major in the British Army. His epic mission to the International Space Station (ISS) is named Principia. It'll be six months long and he'll be doing lots of work with schools from up in orbit. He'll also be helping to run lots of science experiments, including more than 20 on his own body! This means that Tim will have to take lots of samples of his own blood, saliva and wee, as well as taking part in tests to see how being in space affects his eyesight, digestion and other bodily functions.

The lack of gravity in space has lots of funny effects on the body, including the blood rushing to the head and making your face go puffy! Unfortunate side-effects include feeling sick and getting really bad headaches.

Any astronaut going to the ISS has to have years of training, so Tim had already been through quite a lot before even getting close to lift-off. Things he had to go through include being spun around in a giant centrifuge (like an extreme fairground ride) at eight times the force of gravity to simulate a rocket launch; lift loads of heavy weights to build up his muscles and bones, because these gradually waste away in space; spend seven days in a cave system in Sardinia; and survive for days in the freezing Russian countryside, to prepare for a possible crash landing if something goes wrong.

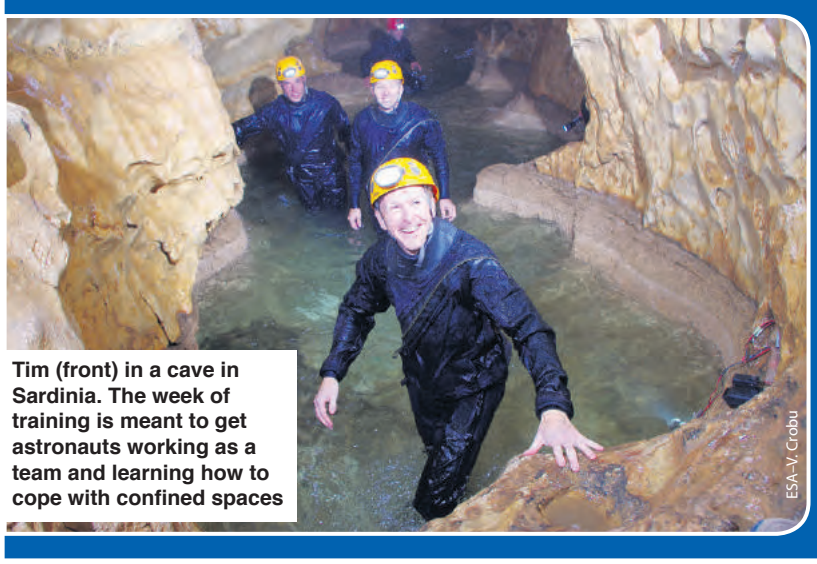
Tim says that there are plenty of ways to do something wrong on board a machine as complicated as the ISS, so he'll be repeating his version of the astronaut's prayer: "God, just please don't let me mess up!"

DID YOU KNOW?

THE Principia mission is named after Sir Isaac Newton's revolutionary three-part physics reference book, *Philosophiæ Naturalis Principia Mathematica* (Latin for *Mathematical Principles of Natural Philosophy*).

Tim (centre) during survival training in Russia

Tim (left) learning to cope with microgravity conditions on board an aeroplane. If a plane flies in a series of peaks and troughs, it gives short periods of weightlessness. Many trainees are sick, which led to the planes being nicknamed 'vomit comets'!



Tim (front) in a cave in Sardinia. The week of training is meant to get astronauts working as a team and learning how to cope with confined spaces

WHO IS TIM PEAKE?

Tim was born in Chichester and is married with two children. He spent many years as an officer in the British Army Air Corps, flying planes and helicopters, including the fearsome Apache (right). His career has involved everything from flying reconnaissance missions, to being a test pilot and training other pilots.

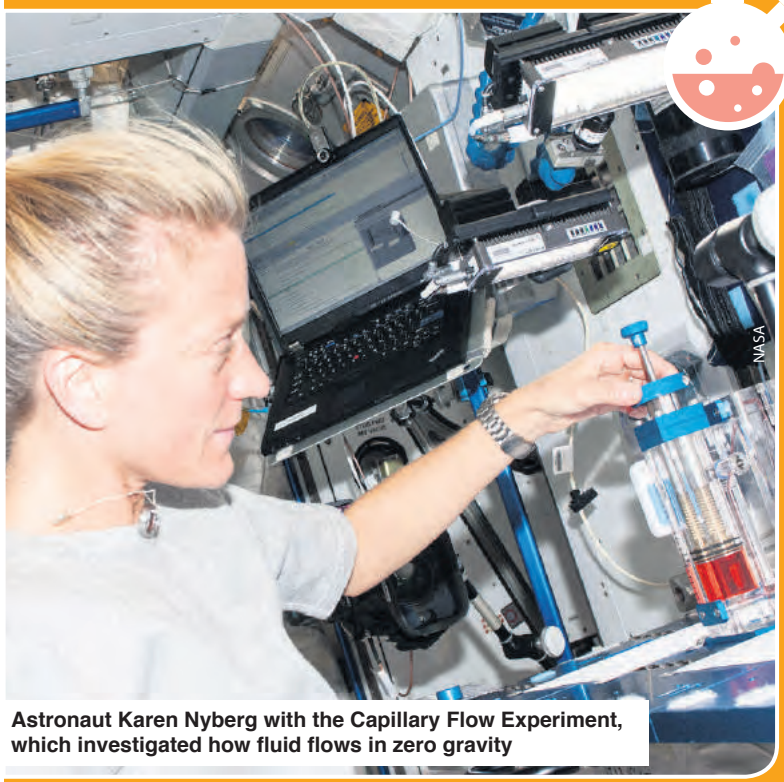
He was selected by the European Space Agency back in 2009 and has been in training ever since. For 12 days, he even lived 20m under the sea off the coast of Florida, as part of NASA research to test new technology in extreme environments.

SCIENCE IN SPACE

THERE are dozens of experiments and tests that will be going on while Tim is on the ISS. Although astronauts are trained for more than they'll be involved with, here's a selection of the science that Tim will likely be getting stuck into while he's orbiting Earth.

NASA

TJ Creamer with the APEX-Cambium experiment. It used willow tree cuttings to understand how wood cells grow in trees



NASA

Astronaut Karen Nyberg with the Capillary Flow Experiment, which investigated how fluid flows in zero gravity

- **Astro Academy: Principia** – this is a whole set of experiments and demonstrations that Tim will do to help schools give more interesting physics and chemistry lessons. Pupils will be able to do the experiments on Earth, then watch videos of Tim repeating them in space to see what effect the microgravity on the ISS has on them.
- **Airway monitoring** – this test will use ultra-sensitive gas analysers to check Tim's breath, to see if he develops any lung problems while he's in space. Although the ISS is very clean, there is still dust floating about, so scientists want to know how much inflammation of the lungs it causes, as this may be more of a problem on longer journeys to Mars or elsewhere.
- **Cartilage** – this experiment is looking at how much of an astronaut's cartilage wastes away while in space for a long time. Cartilage is a spongy tissue found in lots of places in the body, such as in the knees and elbows, and helps bones to move smoothly past each other.
- **Circadian rhythms** – this is the proper name for the body's 'biological clock', which regulates things like how alert or sleepy we are and how hungry we are at various times of the day. New experiments will see how the odd cycles of light and dark in orbit, as well as reduced gravity and other factors, change Tim's body clock.
- **Skin-B** – skin ages much more quickly in space than it does on Earth, so astronauts will be helping experts to understand why this happens and if anything can be done about it.
- **Space headaches** – most astronauts suffer from headaches in space, so new tests will hopefully help to find ways of dealing with them. It could also lead to new ways to treat patients on Earth who suffer from them.

A QUICK HISTORY OF SPACE STATIONS

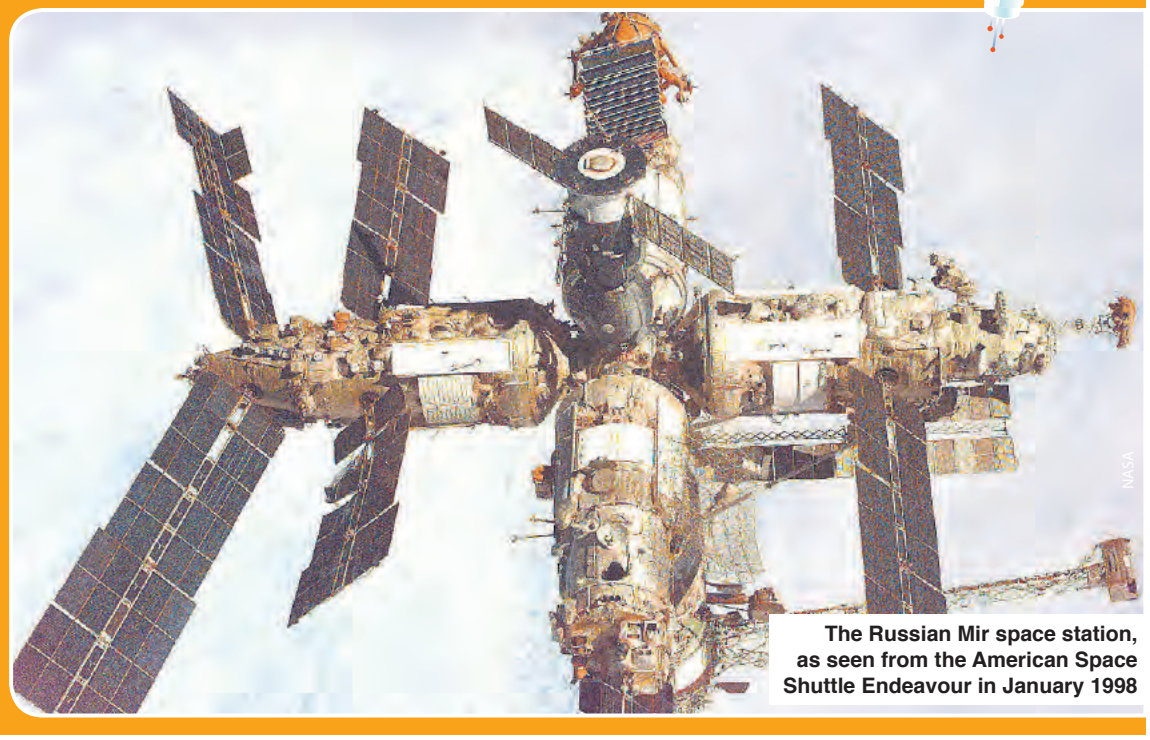
YOU can read all about the ISS over the page, but it isn't the first space station in orbit.

by the Science Museum's Doug Millard

The first was Salyut 1, launched by the Soviet Union in 1971. Over the next decade a series of larger Salyuts were launched, the final one – Salyut 7 – being the most sophisticated. It suffered a power failure and had to be brought back from the dead by the next crew, which was one of the most difficult space missions ever launched.

In 1986 the Soviets started to assemble the Mir space station and this became the largest and most ambitious to date. Its design allowed many more modules to be attached. During the 1990s it was also visited by American astronauts, as the USA worked closely with the Russians to see how humans could live in space.

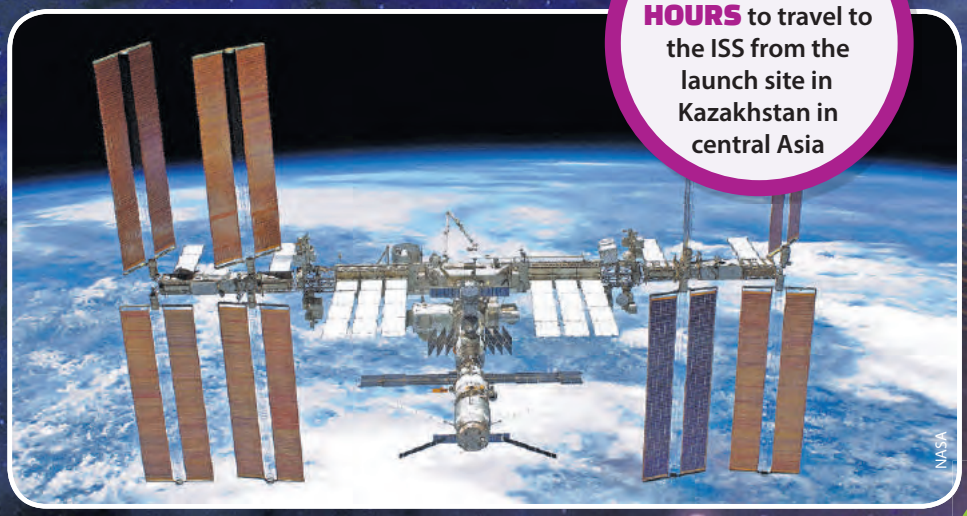
Today, both the US and the Russian federation, along with many other countries, work together on the ISS, the largest structure ever assembled in space.



NASA

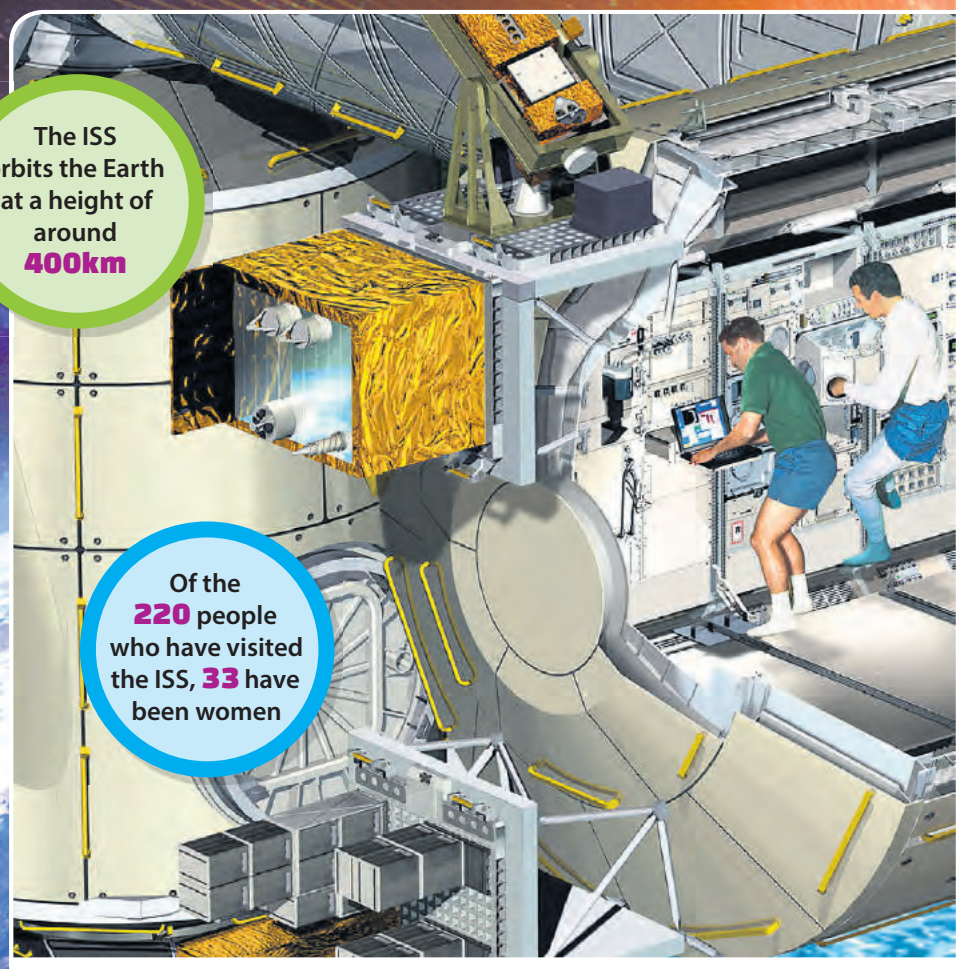
The Russian Mir space station, as seen from the American Space Shuttle Endeavour in January 1998

It takes just under **SIX HOURS** to travel to the ISS from the launch site in Kazakhstan in central Asia



Inside t

THE International Space Station (ISS) has been orbiting above us years since then, more than 200 people from 15 countries have vi



The ISS orbits the Earth at a height of around **400km**

Of the **220** people who have visited the ISS, **33** have been women

The first section of the ISS was put in place by a Russian proton rocket that launched in November 1998. It took 30 missions in total to assemble the ISS. Then, in 2000, an American and two Russians became its first crew members. It sp kil

What's the point?

Space stations give us an opportunity to learn a great deal about Earth, the universe and the potential for exploring our solar system.

Laboratories on board provide crew members with a chance to study medicine, biology, new technology and lots of other science.

The ISS is teaching us a great deal about the effects on the human body of being in space for a long period of time. Safe long-distance space travel, such as to Mars, should one day be possible thanks to these studies.

Astronauts also study how plants grow in zero gravity, which will help future explorers to produce their own food and not have to rely on deliveries from Earth.

The current crew of the ISS

End-to-end, the ISS measures **108 METRES**

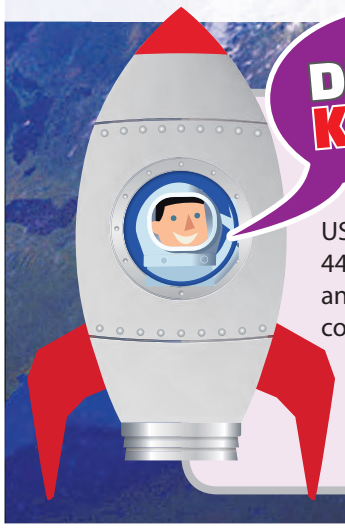
Going the distance

Two of the current crew, Scott Kelly and Mikhail Kornienko, will be on the station for a year. They will be closely monitored, to help plan for future exploration to Mars and beyond.

Scientists are keen to find out how the human body might react on a trip to Mars. The journey to and from the red planet, which is not likely to happen for at least 20 years according to NASA, will take around 30 months.

Kelly and Kornienko will be tested to see what effect their year-long stay has on their heart, brain, behaviour, eyes, metabolism, circulation, muscles, bones, co-ordination, and even the population of microbes on, and in, their bodies!

Scott Kelly (left) and Mikhail Kornienko



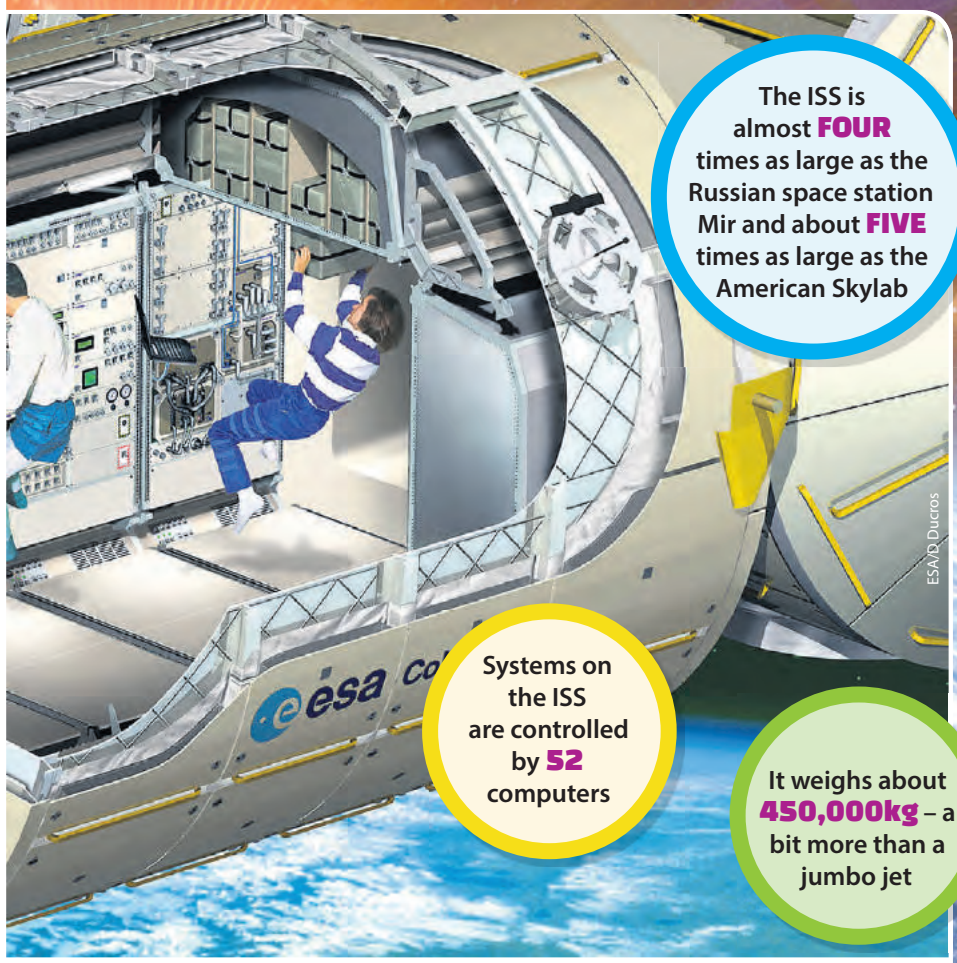
DID YOU KNOW?

MOST of the visitors to the ISS have come from the USA (a total of 141). There have been 44 Russians, seven each from Canada and Japan and five from Italy. Other countries represented include Sweden, Brazil, South Africa and Germany. The UK's first visitor, Tim Peake, will arrive in December 2015 (see p14).

There have been **188** spacewalks at the ISS

THE ISS

ove us since 1998, acting as a research laboratory in space. In the ave visited to gather scientific information about space and Earth.



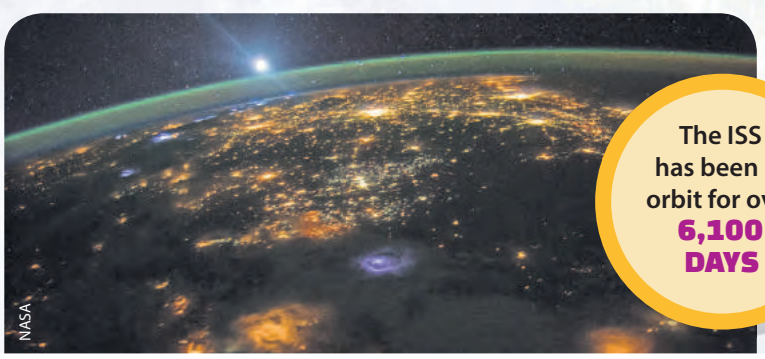
It has been inhabited ever since – the longest continuous human presence in space. It orbits the Earth once every 90 minutes, travelling at a speed of eight kilometres per second, or 18,000mph (29,000km/h).

Spotting the station

You don't need a telescope to see the ISS. It's often visible with the naked eye as it passes overhead (even from the middle of a busy city), as it's the third-brightest object in the sky. It looks a bit like a fast-moving star.

At **spotthestation.nasa.gov** you can find out when the ISS will be flying over your town.

You can also keep up-to-date with the ISS on social media. Many astronauts on board upload pictures and messages, including this snap of sunrise over the USA (below), taken by Scott Kelly.



NASA/Bill Stafford

Life on board


Getty

Packed lunch, ISS style: the food items above are all strapped down to a tray

So what's it like to eat, sleep and work on the International Space Station?

There are usually six crew members up there at one time, so it's important that everyone gets along and shares the daily tasks.

Astronauts on the ISS eat a balanced, nutritious diet that includes chicken, beef, noodles and the odd sugary treat, too! Drinks include coffee, tea, orange juice and lemonade. Food is eaten from special packaging to stop it floating away in the microgravity environment.

The ISS has an oven for heating up lunch and dinner, but no fridge. Things like ketchup, mustard and mayonnaise are there, but salt and pepper are only available in liquid form. This is because if astronauts sprinkled salt and pepper on their food it would float away, possibly clogging air vents or getting in someone's eye.

A hard day's work

In between meals comes the small matter of work! The astronauts are not only conducting experiments and research: they also have to maintain the space station and make sure it stays in good condition. This means checking support systems, updating computer networks and maintaining close contact with controllers on Earth. Cleaning the ISS is done on a rota basis and every astronaut shares the workload.


Best view ever?

Time for fun

Passing the time on the ISS isn't as tricky as you might think. Obviously options are limited – no swimming pools, tennis courts, or concerts to go to, for instance – but there are things to do during down-time. The station has several windows, and NASA says that astronauts especially enjoy peering down to Earth. Every 45 minutes they can witness a stunning sunset or sunrise – that's 16 of each every day!

Crew members can also watch films, play music, read books, play cards and talk to their families back home. In order to keep fit, there's an exercise bike, treadmill and other bits of gym equipment.

Going to the loo

Astronauts used to use an odd shower that was wrapped in a plastic sleeve to keep water in. They then used a vacuum hose to suck up all the water from their bodies. However, it wasn't very successful, so now astronauts just use wet towels to clean themselves.

When it comes to taking a wee or having a number two, things get very interesting! Astronauts have to use special toilets with leg restraints so that they don't float away while in the middle of having a poo. The toilet sucks air and waste away, and each astronaut has a funnel for their wee that attaches to a device that sucks liquid away into a wastewater tank.

When it's time to rest, the crew settle down in sleeping bags inside individual cabins and have to attach themselves to surfaces so they don't float around while they snooze!


An ISS toilet. Use *Blippar* to see how to wash your hair in space!

BRITS in SPACE

Helen Sharman in 1991

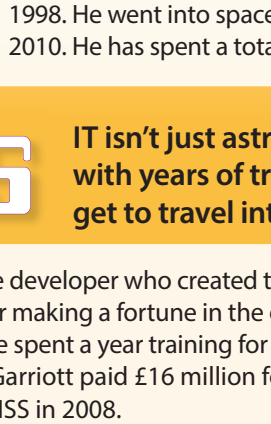
MOST of the astronauts who've launched into space have been from America or Russia. It wasn't until 1991 that the first British astronaut went into orbit.

Helen Sharman's story is quite unusual, and not just because she's one of the small number of female astronauts (out of more than 500 people who've been into space, only 59 so far have been women). As well as being the first Briton in space, she was also the first woman to visit the Mir space station, which was the Russian station that orbited Earth before the bigger International Space Station (ISS) was built.

Sharman, aged 27, was working for the sweet company Mars, researching the physical properties of chocolate, when she heard an advert on the radio asking for volunteers to go into space. Since the ad said there was "no experience necessary", she thought that she had nothing to lose and signed up. Although 13,000 people applied, she was the one astronaut selected and spent eight days on board Mir carrying out various science experiments.

At the time, the UK didn't have an organisation that could send astronauts into space. The Project Juno mission was mostly funded by the Soviet Union (Russia), but the UK's share of the money came from businesses, a lottery and television rights for ITV.

THREE other Brits travelled to space as NASA astronauts. NASA only allows American citizens to fly into space, so they all had dual nationality, which means they were citizens of both Britain and the USA.



Michael Foale

Piers Sellers

Nicholas Patrick

Michael Foale applied to become a NASA astronaut twice but was rejected. At the third attempt in 1987, he was selected and flew on his first mission in 1992, when he spent almost nine days in space on the shuttle Atlantis. He went on to complete six missions. Foale was the first British citizen to do a spacewalk and holds the record for the most time spent in space by a Briton – a total of 375 days.

Piers Sellers was born in Sussex and moved to the US in the early 1980s. He worked as a **meteorologist** at NASA and became an American citizen in 1991. Five years later, he was selected as an astronaut. He completed three space flights – two on Atlantis and one on Discovery – and spent a total of almost 35 days in space.

Nicholas Patrick learned to fly with the Royal Air Force at Cambridge University before working as an aircraft engineer in the USA. After becoming an American citizen in 1994, he was selected to be an astronaut by NASA in 1998. He went into space twice: aboard Discovery in 2006 and Endeavour in 2010. He has spent a total of 26 days in space.

SPACE TOURISTS

IT isn't just astronauts with years of training who get to travel into space.

A handful of very wealthy individuals have paid for the privilege of having a little holiday on the ISS.

Businessman **Mark Shuttleworth**, who holds British and South African citizenship, spent eight days on the ISS in 2002, paying £13.5 million for the experience. While there, he conducted a number of experiments under the guidance of South African scientists.

The only other British space tourist (so far) is **Richard Garriott**, a videogame developer who created the *Ultima* series. After making a fortune in the games industry, he spent a year training for spaceflight in Russia. Garriott paid £16 million for an 11-day trip to the ISS in 2008.

Both tourists (officially known as 'spaceflight participants') travelled on a Russian Soyuz spacecraft. There have been a total of seven tourists, the last of whom travelled in 2009.

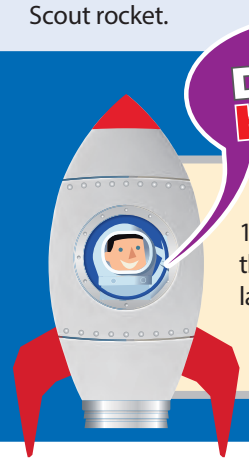
Mark Shuttleworth on board the Russian shuttle

Richard Garriott, hours before he went into space

BRITISH BLAST-OFF

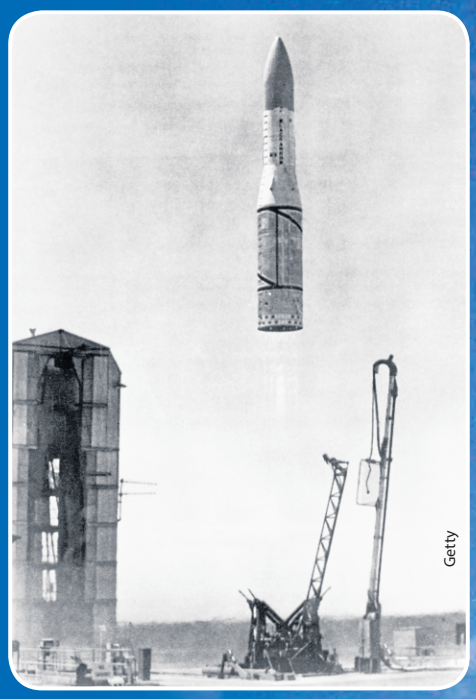
BRITAIN has made many artificial satellites over the years but only one, Prospero, was launched by a British rocket.

Prospero was a research satellite, designed to test new materials in space, and was launched in 1971 by Britain's Black Arrow rocket. Black Arrow was built and tested on the Isle of Wight, and the rocket was launched from the Woomera range in South Australia. But the demand for launches was too small and so Black Arrow was cancelled and the successor to Prospero (Miranda) was launched by an American Scout rocket.



DID YOU KNOW?

THE Black Arrow rocket was 13m (43ft) tall and weighed more than 18 tonnes! It was only ever launched four times – two of those were successful but the other two failed.



Getty

A replica of Black Arrow on display in Woomera, Australia

atq55/Flickr

So you want to be an astronaut?

BEING an astronaut has got to be just about the coolest job in the world (or rather out of this world!), but how do you get to be one?

The good news is that you don't need your own spaceship, but you will need to study hard and get some qualifications.

The bad news is that the European Space Agency doesn't select astronauts very often, maybe once every ten years. During the last round of selection between May 2008 and May 2009, thousands of people applied for the available places. Just over 8,400 qualified for selection, but that was gradually narrowed down to just six astronauts!

So, if you still want to give it a shot, you're going to need a degree in physics, biology, chemistry, maths, engineering or medicine, plus either three years of professional experience related to your degree or some experience as a pilot, especially a test pilot. Studying aeronautics (the science of flight) or astronautics (the same, but for space flight) is also a bonus.

Certain other skills are useful, such as being able to speak a bit of Russian, as most of the training currently takes place in Russia, where most European space launches happen.

iStock

It's BUSY UP THERE

iStock

RIGHT now, there are between 2-3,000 satellites orbiting Earth. But what exactly is a satellite, what does it do, and why are there so many?

What is a satellite?

Any object in space that moves around a larger object is a satellite. For instance, the Earth is a satellite of the sun, and the moon is a satellite of Earth. But usually when we say 'satellite' we mean a man-made device that orbits Earth or another planet or moon. Some are permanently in orbit, while others are only there temporarily.

What do they do?

Some popular uses include:

- Enabling telephone communication on Earth
- Sending TV signals
- Transmitting photographs of cloud patterns and measurements of other **meteorological** conditions to help forecast the weather
- Transmitting GPS (Global Positioning System) signals, allowing people to use map apps and satnavs. The GPS system has more than 30 satellites (see diagram right)
- Providing communications and images of locations on Earth for the military
- Allowing countries to spy on other nations and their armed forces

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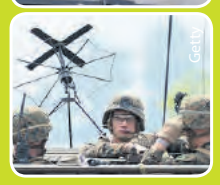
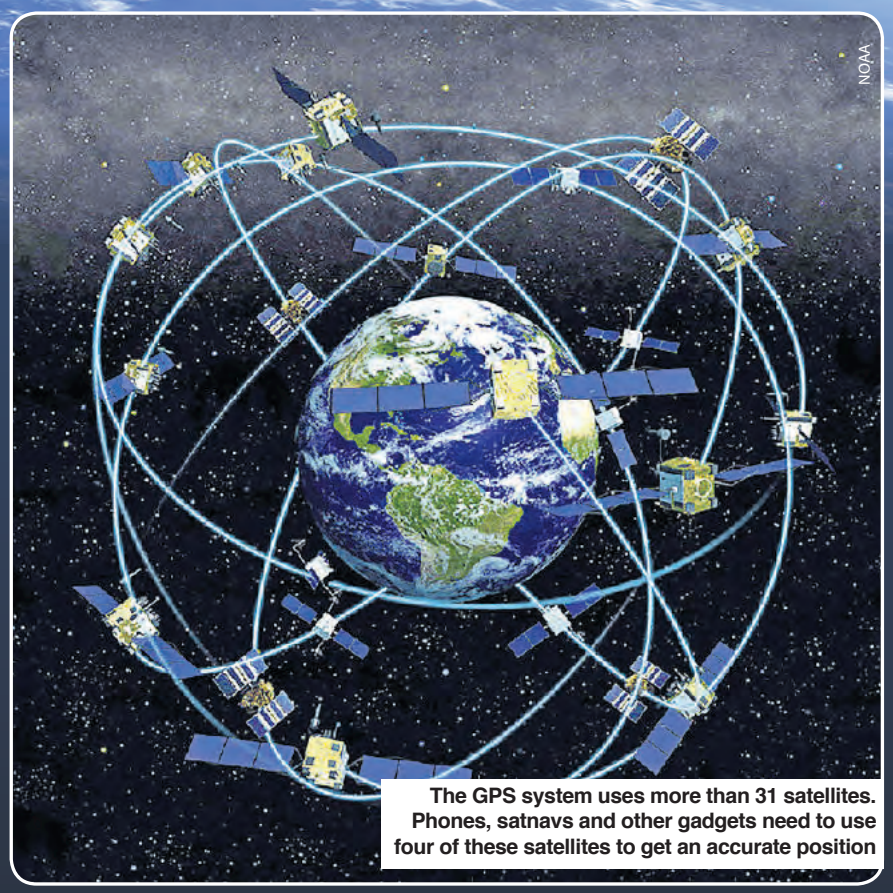


Getty

How do they stay up?

There are various different types of satellite, and they vary greatly in size. They usually have an antenna (to communicate with Earth) and a power source, such as a solar panel or battery. There are many different types of orbit, but generally a satellite's speed is balanced against the gravitational pull of Earth, so that it doesn't just fly off into space or come crashing down to Earth.



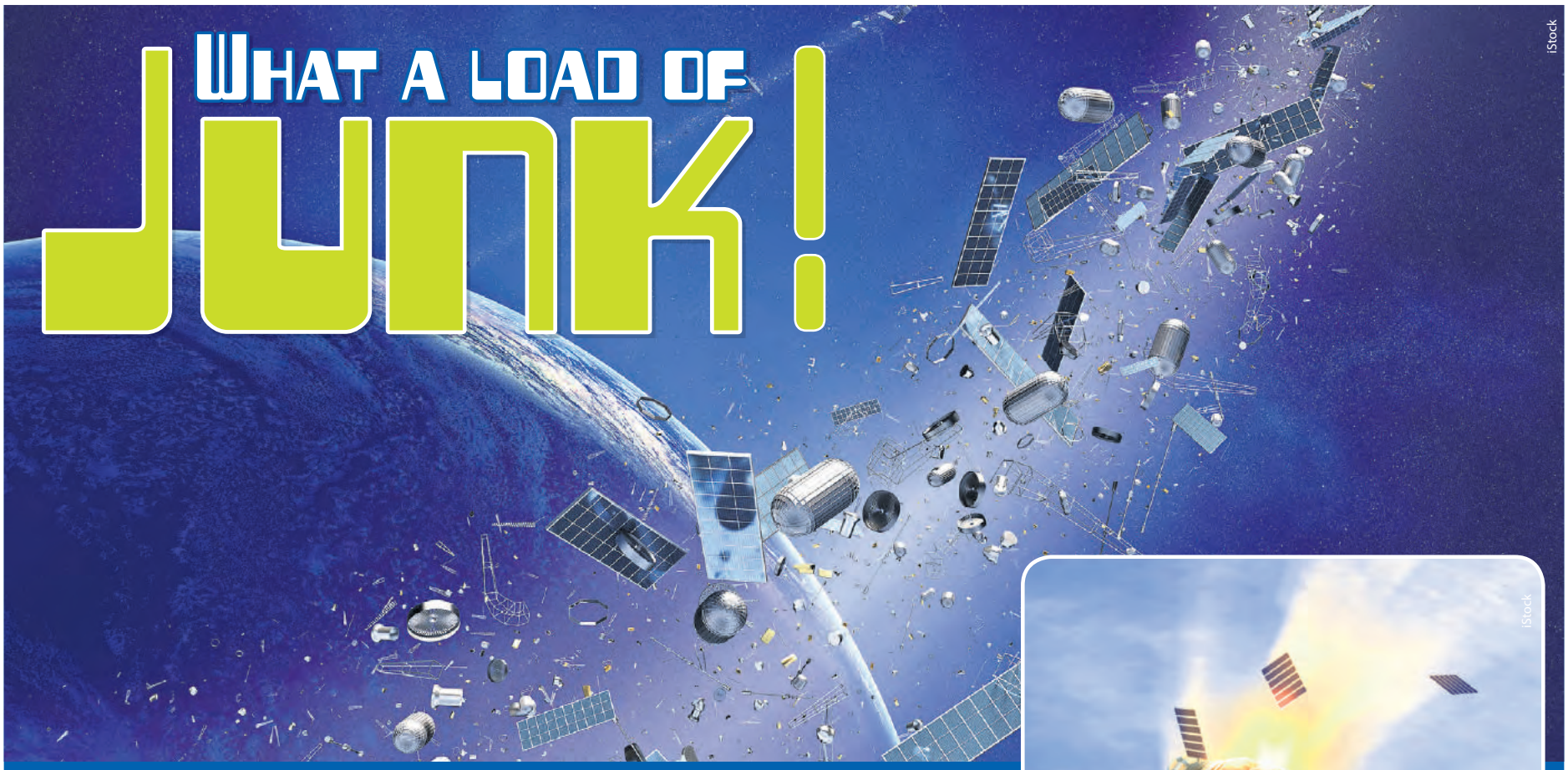
NOAA

The GPS system uses more than 31 satellites. Phones, satnavs and other gadgets need to use four of these satellites to get an accurate position

What happens when they break or wear out?

Like any piece of scientific equipment, satellites eventually break down or reach the end of their mission. If it's in a low orbit, controllers can slow it down so that it gradually falls into Earth's atmosphere and burns up. For higher orbits, it's often easier to boost them up into a 'graveyard orbit' out of the way, more than 22,000 miles (36,000km) above Earth. For bigger objects, like rockets or space stations, they can be steered so that they crash into the South Pacific Ocean, far away from any country. There's even a place there known as the 'spacecraft cemetery'!

What a load of JUNK!



What on Earth is space junk?

Also known as space debris, this is the term given to the discarded, man-made items that are still in orbit around Earth.

They include old satellites, rocket parts and items lost by astronauts, such as a glove worn by the first American to walk in space, and cameras.

What's the oldest piece of space junk?

The early American satellite, Vanguard 1. It was launched on 17 March 1958 and has been in space longer than any other man-made object.

How much junk is out there and how big is it?

NASA says there are 500,000 items between 1-10cm in orbit, each travelling up to 28,000km/h (17,500mph). At that speed, even a small object can cause significant damage to a spacecraft or satellite. There are also more than 21,000 pieces larger than 10cm and 100 million pieces smaller than a marble. These are almost impossible to monitor, but can still cause damage.

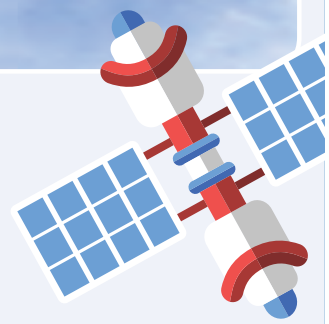
How dangerous is this?

According to NASA: "The rising population of space debris increases the potential danger to all space vehicles, but especially to the International Space Station, space shuttles and other spacecraft with humans aboard."

Incident report

There have been some serious collisions caused by space junk, but surprisingly few considering how many objects are up there.

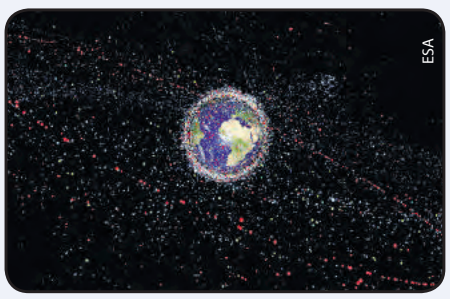
- The first known collision between two artificial objects in space took place in 1996. The French military spy satellite Cerise was struck by a piece of a European Space Agency rocket.
- In 2009, an out-of-service Russian military satellite crashed into an active US communications satellite at 42,000km/h (26,000mph). Both were destroyed. Over 2,000 bits of space junk were created in the smash.
- In 2007, China fired a missile at one of its own weather satellites, creating 3,000 bits of space junk. It was the first deliberate strike on a satellite since 1985, when the Americans tested an anti-satellite missile. China's actions were criticised by many countries, who thought China was showing off its military power.

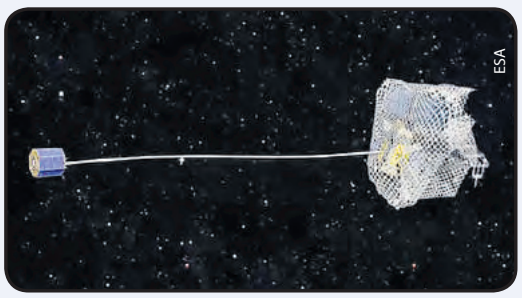


How to prevent space junk collisions

With so many important satellites orbiting Earth – including the International Space Station – and so many of our activities on Earth relying on these satellites, there is a real risk that a collision could cause big problems on our planet.

The ISS already performs "collision avoidance manoeuvres" to move out of the way of debris. If they detect the junk too late, astronauts on the ISS climb into a special safety capsule. Fortunately, the ISS is in a fairly low orbit where there is less space junk.

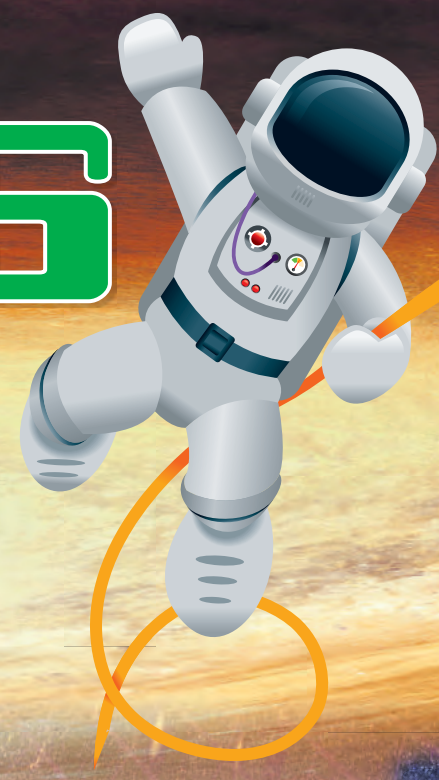




The European Space Agency (ESA) has started the Clean Space project to remove large items such as old satellites and rocket parts. These objects are also dangerous because their fuel or batteries could explode.

The ESA's e.Deorbit mission aims to capture drifting bits of space junk. Ideas being explored include using a large net, robotic arm or a harpoon.

SPACE ODDITIES



STARS and planets and galaxies are all strange enough, but space is also filled with some REALLY weird things, with exotic names like black holes, neutron stars and magnetars. Prepare to have your mind boggled…

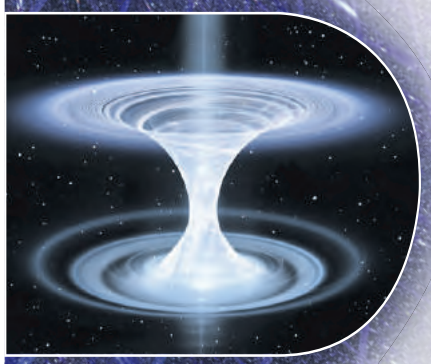
BLACK HOLES

Anyone who's ever read or seen any sci-fi has probably heard of **black holes**, but what are they and where do they come from?

It's likely that some black holes formed soon after the universe exploded into life after the Big Bang (see p3), but most black holes are the leftovers of a dying star. When a star runs out of fuel, it collapses in on itself and ends its life in a huge explosion called a supernova (see p7).

After the supernova, many stars will turn into black holes. The exact limit isn't really known, but many experts think that the original star would need to have around 25 times the **mass** of our sun to form a black hole. When the star collapses, its gravity is more powerful than any pressure inside it, so everything gets squeezed more and more. If this collapsed core has more than three times the mass of the sun, it will become a black hole.

Experts think that there could be millions, maybe even a billion, black holes in our Milky Way galaxy alone. The black hole at the centre of our Milky Way galaxy, Sagittarius A*, is thought to be about the same size as our sun, but four million times more massive! Black holes this size are rather brilliantly called supermassive black holes. Most big galaxies are thought to have a supermassive black hole at their centre.



Why are they black?

The incredibly strong gravity of something so massive is the reason why black holes are black – because even light can't escape the gravitational pull. Once something crosses a boundary known as the **event horizon**, it will get pulled into the black hole and will never be able to get out. So if a space probe went there, we'd lose sight of it and it wouldn't be able to send any signals out. It would also get ripped apart by the immense gravitational force.

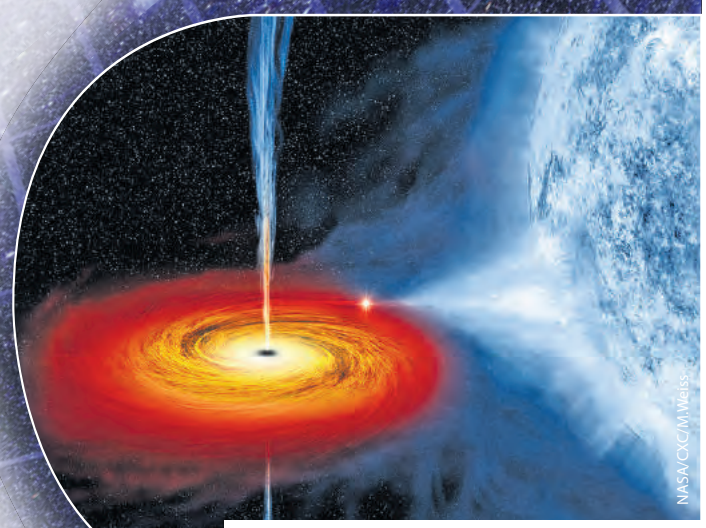
What's inside one?

We're not too sure, but it's thought that all the mass inside the black hole is squished together in one tiny point, known as a singularity. However, our current theory of gravity doesn't really work at the tiny scale of atoms, so this is still a bit of a mystery.

So if they're black, how can we see them?

Good question there at the back; well done for paying attention! If a black hole passes through a cloud of dust or gas, its gravity will start pulling material towards it. This is known as accretion, and it means the black hole builds up an accretion disk around itself. All of this stuff starts to accelerate and heat up, which produces powerful X-rays that we can see with special telescopes.

In the same way, black holes can also rip stars to pieces if they pass too close to them. When this happens, we can also see the changes that happen to the unfortunate star.



NASA/CXC/M.Weiss

What a black hole (left) might look like when it starts drawing in material from a nearby star

To give you an idea of how incredibly odd a neutron star is, here's one that's 500,000 times more massive than Earth, but smaller than the city of Boston in the US

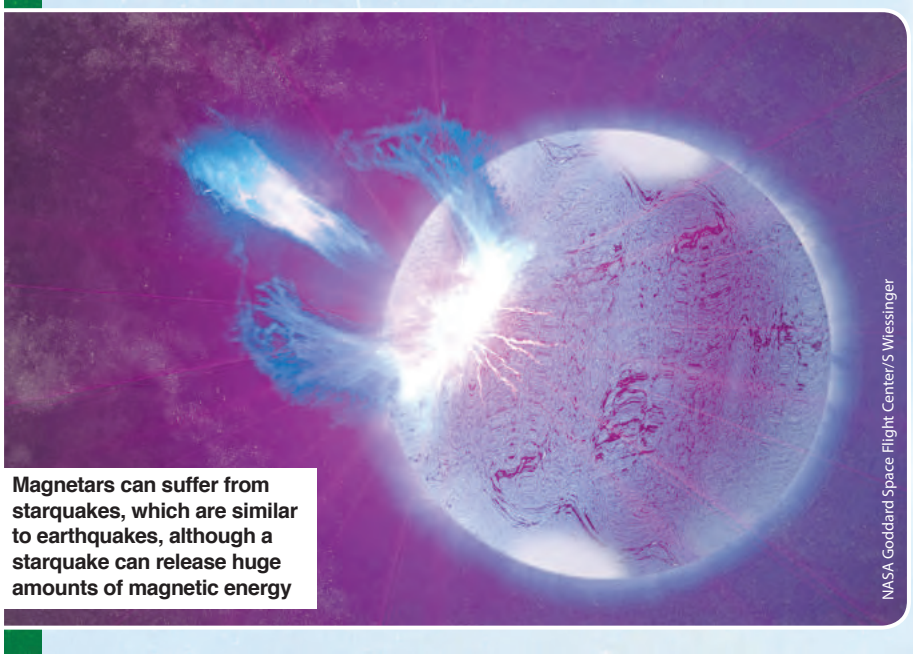
NASA Goddard Space Flight Center

NEUTRON STARS AND THEIR MANY DISGUISES

After a supernova, if the collapsed core of the star is between about 1.4 to 3 times the mass of the sun, it won't be heavy enough to become a black hole. Instead, it will become what's called a **neutron star**. Although they're not as tightly-packed as black holes, they squeeze up to three suns' worth of stuff into a ball with a radius of just 12km (7 miles). So a teaspoonful of neutron star material could weigh more than a billion tonnes!

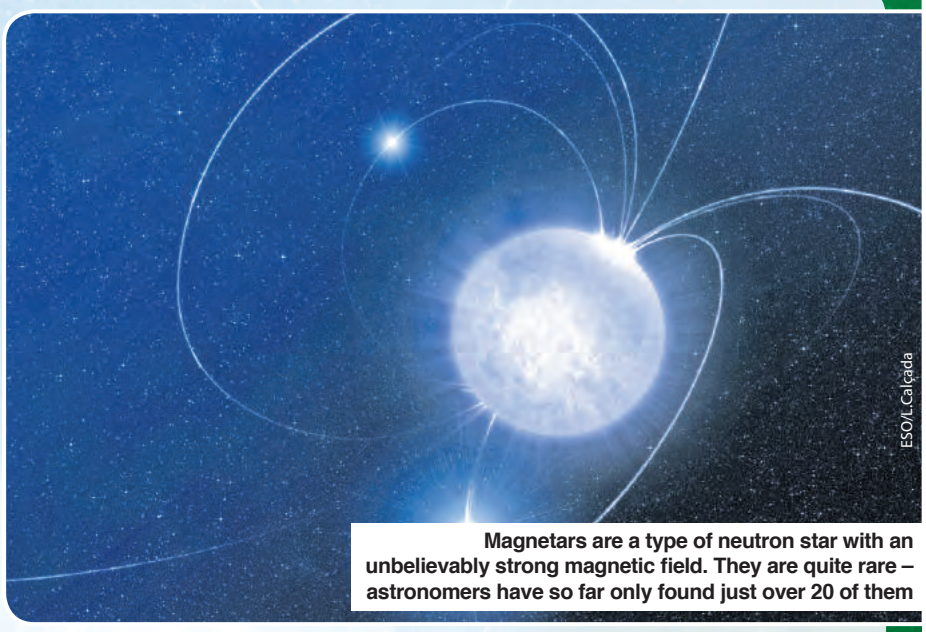
They get their name because of how squeezed they are. Everything in the star is forced so close together that the electrons and protons in the atoms combine together into neutrons.

As they collapse and get squeezed, neutron stars start to turn more rapidly, like an ice skater pulling their arms into their body so that they spin faster. Some neutron stars spin round hundreds of times per second.



Magnetars can suffer from starquakes, which are similar to earthquakes, although a starquake can release huge amounts of magnetic energy

NASA Goddard Space Flight Center/S Wiessinger



ESO/L.Calçada

Magnetars are a type of neutron star with an unbelievably strong magnetic field. They are quite rare – astronomers have so far only found just over 20 of them

Lighthouses of the universe

Some neutron stars that spin really quickly give off an incredibly powerful beam of radiation from their north and south magnetic poles. This beam sweeps across the universe as the star spins, like a lighthouse beam. If the beam crosses Earth, our telescopes can see it. Neutron stars like this are known as **pulsars**, because they pulse regularly with the star's spin.

Mega-magnets

Neutron stars already have magnetic fields many times greater than Earth's, but some known as **magnetars** are even more powerful. Their magnetic fields are 1,000 times more powerful than an ordinary neutron star's and a quadrillion (a million billion) times more powerful than Earth's. It wouldn't be possible to make such strong magnets on Earth, as they would be ripped apart by the magnetic forces. It is only the extreme gravity of a magnetar that allows the field to become this strong.

HUBBLE'S GREATEST HITS

THE Hubble Space Telescope has been in orbit around Earth since April 1990 and has proved to be one of the most important tools in the history of astronomy.

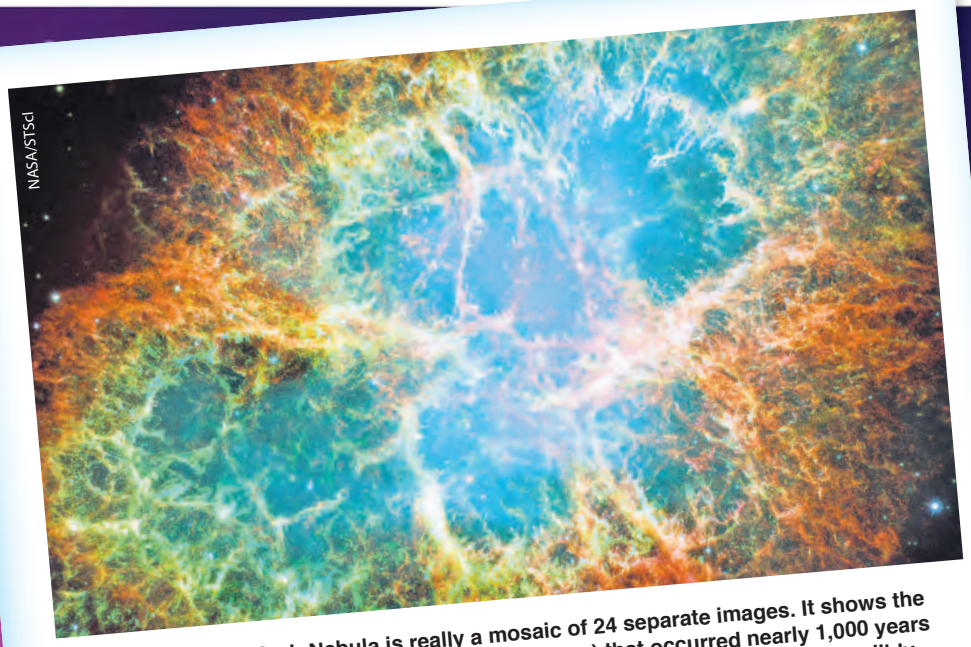
However, because the main mirror wasn't made as accurately as planned, some images were a bit fuzzy until December 1993, when astronauts made some crucial repairs to the telescope while orbiting Earth. Since then, Hubble has sent back some truly stunning images regularly, as you can see from this small selection. To see more, just go to **hubblesite.org**.

Attached to the robotic arm of the Space Shuttle Endeavour, astronaut F Story Musgrave helps to install new equipment on Hubble to correct the blurred images caused by the telescope's faulty main mirror

The Hubble Space Telescope completes one orbit around Earth every 95 minutes, moving at around 27,300km/h (17,000mph). Because Hubble orbits 550km (340 miles) above the Earth's atmosphere, the light entering the telescope isn't affected by air or pollution like telescopes on the ground, so its images are much sharper

The spiral galaxy known as Messier 74 (or just M74), which is around 32 million light years away from Earth. This Hubble picture uses several filters to highlight different areas. The blue parts are young stars, while the pink regions contain lots of hydrogen. M74 is a bit smaller than the Milky Way and is thought to contain around 100 billion stars

The Pillars Of Creation is one of Hubble's most famous images. It shows the huge hydrogen and dust-filled clouds of the Eagle Nebula, which contain lots of newborn stars. Each of the pillars is around five light years tall



This picture of the Crab Nebula is really a mosaic of 24 separate images. It shows the leftovers from the explosion (known as a supernova) that occurred nearly 1,000 years ago when a star reached the end of its life and blew apart. A supernova is incredibly bright, so there are records from Chinese and Japanese astronomers who witnessed it in the year 1054

Another example of a nebula, this one is known as the Cat's Eye, although it has also been compared to Sauron from *Lord Of The Rings*! It shows at least 11 shells of dust that expanded into space after the star at the centre exploded. It's thought that the shells are formed in a series of pulses separated by 1,500 years, although we don't understand why that happens

Hubble doesn't just use visible light. This image of the Tarantula Nebula was taken using near-infrared light, which allows us to see stars that would otherwise be hidden in thick clouds of dust. The image is around 600 light years across

The eXtreme Deep Field or XDF shows more than 5,500 galaxies in just one tiny patch of sky. It was put together using ten years' worth of Hubble images and shows the faintest and most distant galaxies we've ever seen. The faintest galaxies in this picture are one ten-billionth the brightness of what the human eye can see

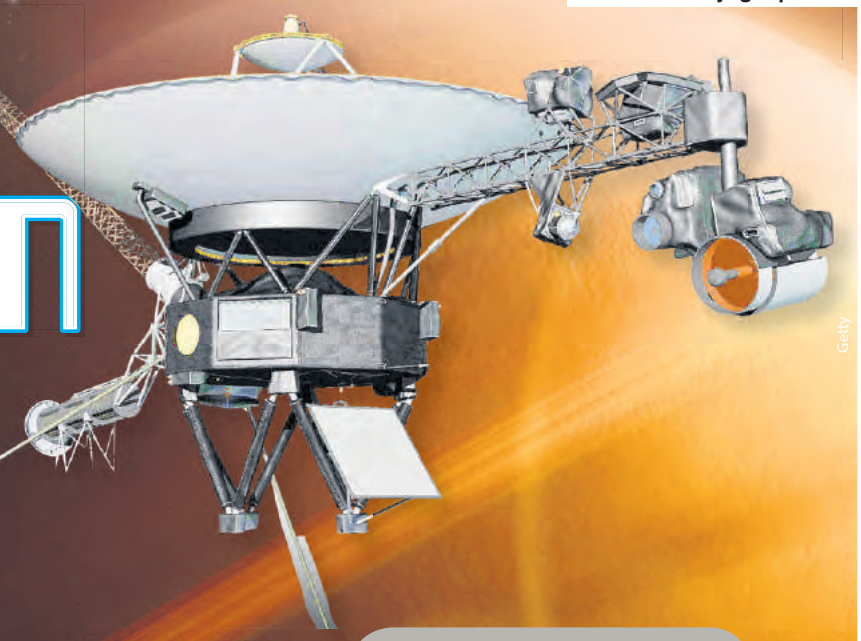
DID YOU KNOW?

THE Hubble Space Telescope is named after American astronomer Edwin Hubble. He became famous for publishing evidence that showed that our universe is expanding.

DID YOU KNOW?

ONE of the Hubble telescope's many important discoveries was that the Andromeda galaxy will eventually collide with our own Milky Way to make one huge galaxy. But don't panic – it won't happen for four billion years!

VOYAGE INTO THE UNKNOWN



One of the Voyager probes

Getty

IN the 1970s, NASA launched two identical robotic probes into space with the aim of exploring the four planets furthest from our sun. Voyager 2 launched on 20 August 1977, while Voyager 1 set off soon after on 5 September. Nearly 40 years on, both are still going strong, billions of kilometres away from the sun and exploring areas of space where nothing from Earth has gone before.

The project to send probes to far-flung parts of the solar system was hatched in 1972, led by a NASA scientist named Ed Stone. Just five years later, the two Voyager probes were ready to go.

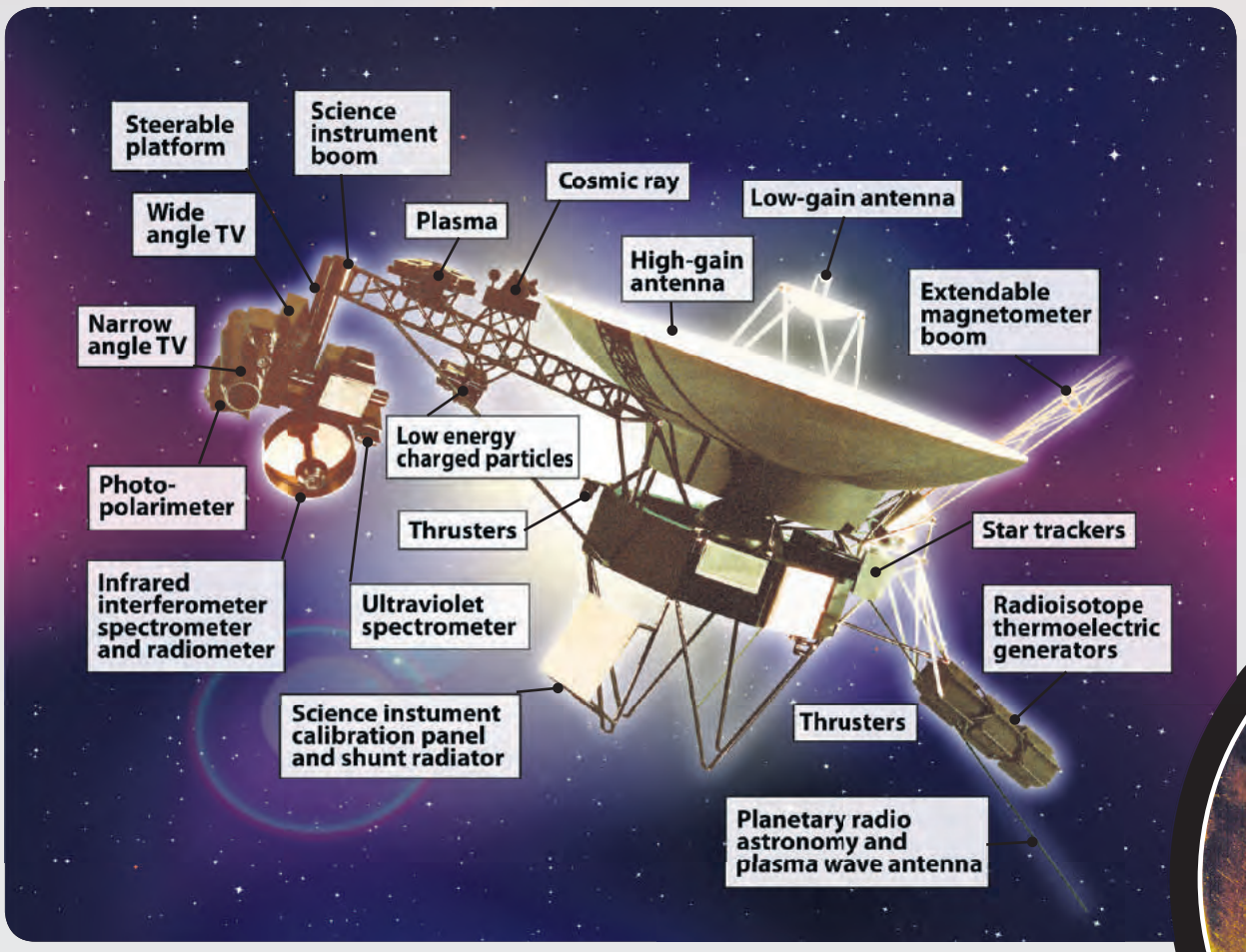
It may seem strange that Voyager 2 launched before Voyager 1 but, in fact, it was always scheduled to be that way. This is because the two probes travelled on different paths, with Voyager 1 scheduled to reach Jupiter and Saturn first.

In the beginning, the mission was to approach Uranus, Saturn, Neptune and Jupiter and beam pictures and data back to Earth. Both probes cleverly used each planet's gravity to increase their speed and fling them towards the next planet. This is known as a gravitational slingshot, and it took Voyager 1 from Jupiter to Saturn and then into the dark and mysterious **interstellar space**.

Voyager 2 travelled more slowly, flying past Jupiter, Saturn, Uranus and Neptune. It was the first and only probe to explore Uranus and Neptune.

VOYAGER 1 FACT FILE

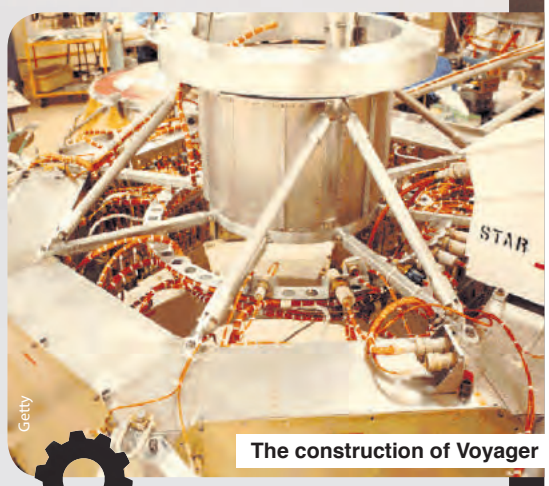
LAUNCH DATE: 5/9/1977
WEIGHT: 722 kg
REACHED JUPITER: 5/3/1979
REACHED SATURN: 12/11/1980
LEFT SOLAR SYSTEM: August 2012
CURRENT DISTANCE FROM EARTH: 19.9 billion kilometres
FACT: It is the furthest man-made object from Earth



This diagram (above) shows the setup of both Voyager probes.

It's pretty amazing that the Voyagers are still active considering how old they are, and the fact that their primary mission was 'just' the exploration of Jupiter and Saturn. Both have gone much, much further and are still sending scientific information back to Earth through the **Deep Space Network** (DSN).

The probes also carry a gold-plated copper disc containing sounds and images of Earth, including 55 different languages. If aliens exist, they might find the Voyagers and enjoy some Earth music!



Getty

The construction of Voyager

NASA

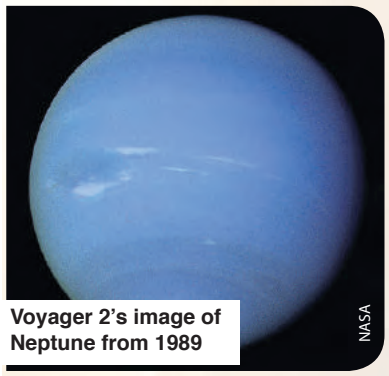
The golden record that both Voyagers carry on board

PLANET DISCOVERIES

Back in 1977, we knew very little about Jupiter and Saturn. Voyagers 1 and 2 had a simple mission: explore both worlds and teach us more.

Data and photos collected by the Voyager cameras, **magnetometers** and other scientific instruments ended up teaching us a great deal more about the planets and their moons. Close-up images showed Jupiter's clouds, winds and storm systems, as well as capturing volcanoes on its moon, Io. This was the first time active volcanoes had been seen on another body in the solar system.

Voyager 1's Jupiter encounter began in January 1979 and ended that April. In those three months, it took almost 19,000 pictures and lots of scientific measurements. Voyager 2 did the same from April-August 1979.



Voyager 2's image of Neptune from 1989

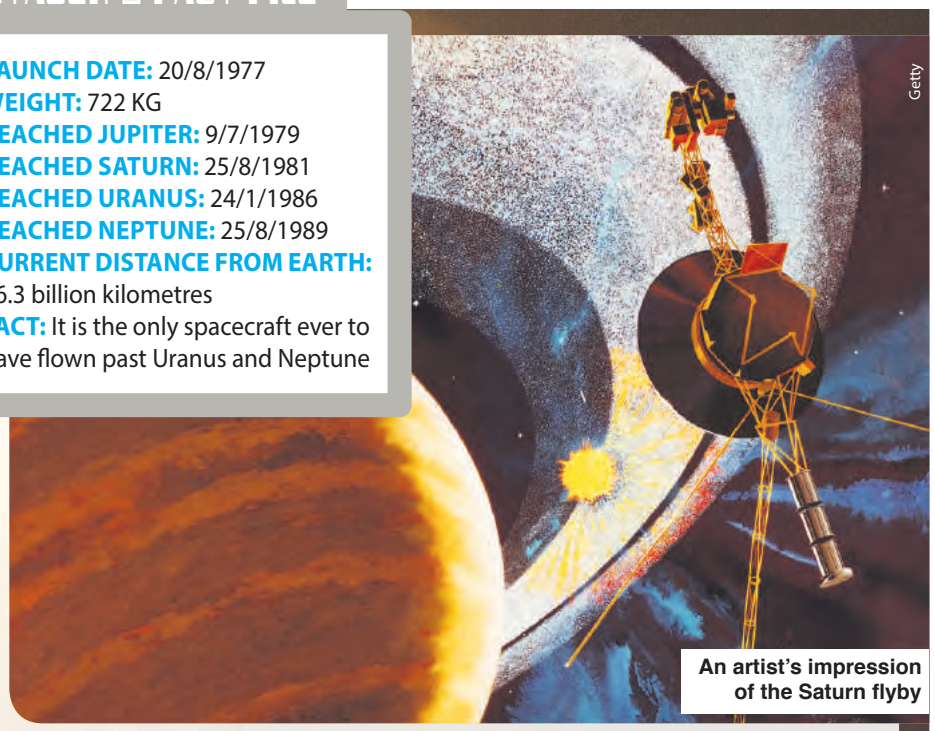
The Voyagers' findings also revealed details of Saturn's rings, while Voyager 2's mission to Uranus in January 1986 showed us ten moons we didn't know existed until that point. It also measured a major magnetic field around the planet.

Voyager 2 also visited Neptune in August 1989, passing 4,950km from the planet's atmosphere. It discovered rings around Neptune, as well as six moons, a magnetic field and **auroras**.

The plan after all these planetary flybys was to retire the Voyagers, but the probes kept on flying, so NASA kept the mission alive. The goals changed: from discovering more about our neighbouring planets, it became a mission to see how far a man-made object could go in space.

VOYAGER 2 FACT FILE

LAUNCH DATE: 20/8/1977
WEIGHT: 722 KG
REACHED JUPITER: 9/7/1979
REACHED SATURN: 25/8/1981
REACHED URANUS: 24/1/1986
REACHED NEPTUNE: 25/8/1989
CURRENT DISTANCE FROM EARTH: 16.3 billion kilometres
FACT: It is the only spacecraft ever to have flown past Uranus and Neptune

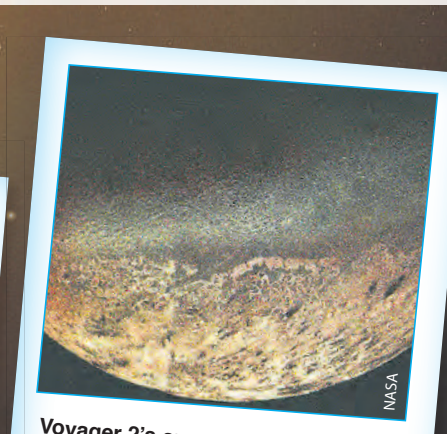


An artist's impression of the Saturn flyby

VOYAGER GALLERY

Larissa, a moon of Neptune first seen by Voyager 2

The Great Red Spot on Jupiter, as seen by Voyager 1



Voyager 2's snap of Triton, one of Neptune's 14 moons

A 1979 picture of Jupiter, taken by Voyager 1

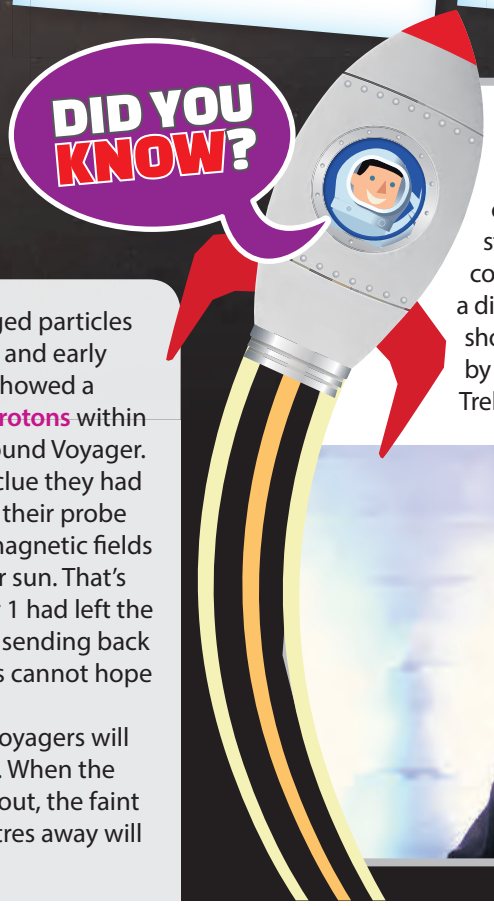
AGAINST THE ODDS

The Voyagers have already gone way beyond what was originally expected of them. To understand how amazing they are, think about this:

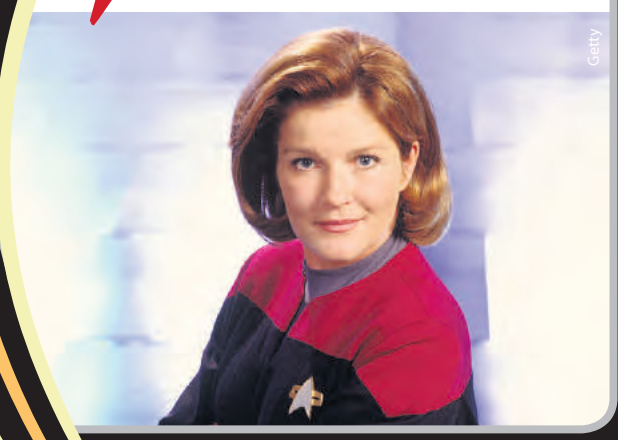
- They each have just 69KB of memory. A 64GB iPhone 6 has about a million times more memory!
- It takes 18.5 hours for a signal from Earth to reach Voyager 1, and 15 hours to reach Voyager 2
- The probes send data to Earth with a 23-watt transmitter, which is about the same power as a fridge lightbulb!

So how do we know for sure that Voyager 1 has left the solar system and is now hurtling through interstellar space? Its Plasma Wave Science (PWS) instrument measures the number of charged particles around the probe. In late 2012 and early 2013, readings from the PWS showed a huge spike in the number of **protons** within every cubic metre of space around Voyager. This gave NASA scientists the clue they had been looking for to prove that their probe was no longer influenced by magnetic fields and charged particles from our sun. That's when it was clear that Voyager 1 had left the **heliosphere**. Now Voyager 1 is sending back data from an area that humans cannot hope to explore any time soon.

NASA scientists think both Voyagers will have power until around 2020. When the plutonium power sources run out, the faint signals from billions of kilometres away will finally stop.



IN 1995, the popular TV franchise *Star Trek* launched a new series called *Star Trek: Voyager*. The starship Voyager explored far-flung corners of space after getting lost in a distant part of the Milky Way. The show ran for seven series, and was led by the first (and so far only) female Trek captain.



THE FUTURE OF SPACE EXPLORATION

SO far, humans have visited Earth's orbit and the surface of the moon, but there's still the rest of our solar system, galaxy and universe to explore. But where should we go?

A full-scale model of the JWST in Austin, Texas

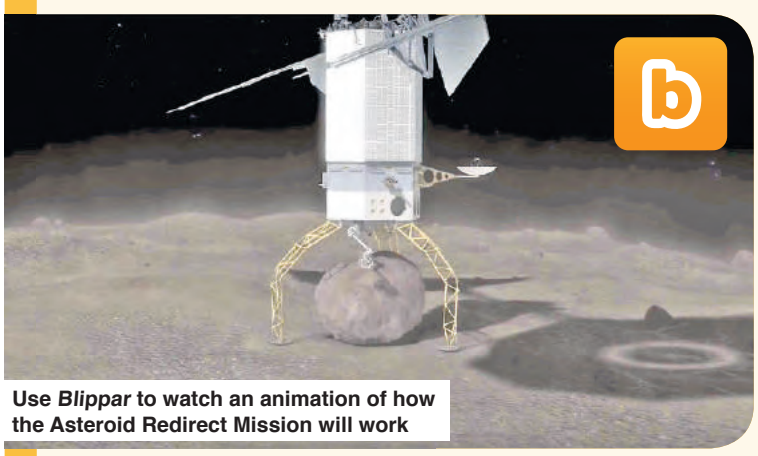
Before we get too carried away with visiting other galaxies, there's still plenty of cool stuff for us to explore closer to home. Here's our rundown of the most exciting space missions that you can expect to see over the coming years.

Although it won't be landing on any other worlds, the **James Webb Space Telescope** (JWST) is due to launch in October 2018 and will reveal more about how our universe began and how galaxies and solar systems like ours formed.

Even though there have been six manned moon landings, the last one was in 1972 and there's still a lot we can learn from our nearest neighbour.

At the moment, no country has announced firm plans to land people on the moon, but it seems likely that China will be the next to try, as NASA seems to be concentrating on landing people on Mars.

There are lots of orbiter and rover missions to the moon planned for the coming years, but China's Chang'e 5 is one of the most interesting. This rover is set to take a drilling rig so that it can collect around 2kg of rock samples from up to 2m below the moon's surface, then put them in a capsule and blast it back to Earth. The Chang'e rovers are testing technology that could allow China to send astronauts to the moon so, if Chang'e 5 is a success, we could see astronauts on the moon for the first time since the early '70s.



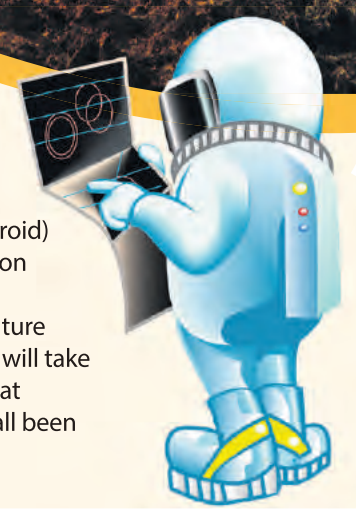
Use *Blippar* to watch an animation of how the Asteroid Redirect Mission will work

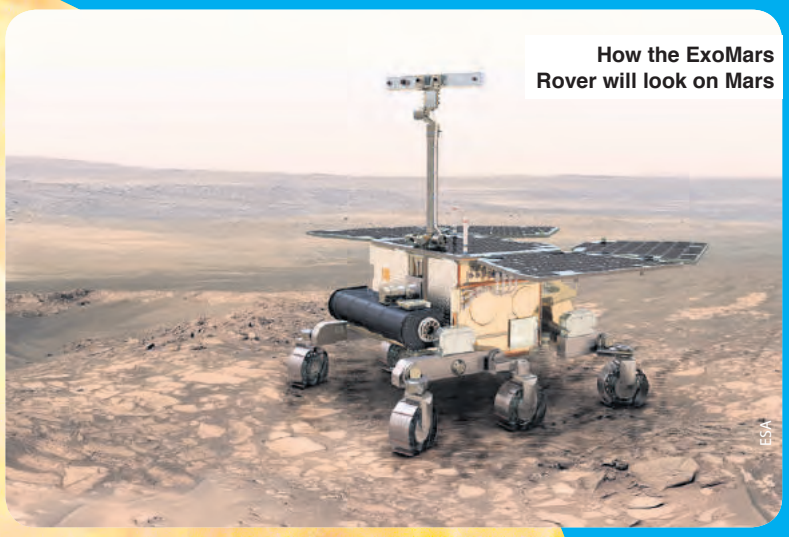
One of the craziest-sounding missions in the near future will be NASA's Asteroid Redirect Mission. The US space agency plans to collect a small asteroid (or a boulder from a larger asteroid) weighing several tonnes, then drag it into orbit around the moon to study it.

The mission will test the equipment needed to deflect any future asteroids that could strike Earth, as well as the technology that will take astronauts to Mars one day. The asteroid will also be the first that astronauts can study up close, as other asteroid samples have all been taken by unmanned probes.

DID YOU KNOW?

NASA'S Near-Earth Object Program monitors any asteroids that could hit Earth, but you can sleep soundly – all known asteroids have a less than 0.01% chance of hitting Earth in the next 100 years.





How the ExoMars Rover will look on Mars

ESA

There's still more to Mars

Robots and orbiters have explored the surface of Mars, but there's still a lot that we don't know about it. The European Space Agency's ExoMars programme could help, even revealing whether life exists or has existed there. One of the programme's main purposes is to test technology for a sample return mission in the 2020s, when a lander will send back rocks from Mars.

The first ExoMars mission is set for 2016. An orbiter will look for tiny amounts of gases in Mars' atmosphere, such as methane, which is often (but not always) a sign of life. A lander will test technology for the sample return mission and use sensors to study the landing site.

The second part of the programme will put a rover (left) on the surface in 2018. It will be capable of drilling up to two metres below the planet's surface. The rover will have an onboard laboratory where samples can be heated and studied to learn more about the chemistry of the rock and soil.

The sample return mission will be one of the most complicated space journeys ever. Experts say that the ESA and NASA will have to work together, probably with the help of other countries, such as Russia and China.

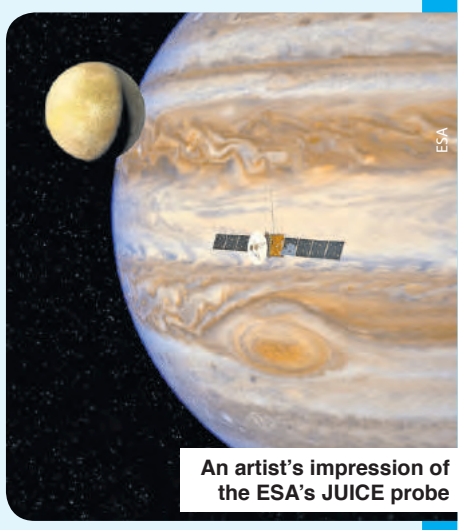
Where should we look for life?

Apart from Earth, the two places in our solar system that have been studied most are our moon and Mars. So far we haven't found any evidence for life there, although many scientists think that life could have existed on Mars in the past. It's also possible that bacteria or other microbes could live underneath the surface of Mars now.

One of the most likely places for us to find life will be on Europa, one of the moons of Jupiter, or Enceladus, one of Saturn's moons. Flybys of Europa have shown that there is likely to be a salty ocean beneath its icy surface.

In 2022, the ESA will launch JUICE (JUpiter ICy moons Explorer), which will reach Jupiter in 2030. It will study the largest planet in our solar system, as well as three of its largest moons: Ganymede, Callisto and Europa. It will investigate the water and ice on each of the moons as well as the chemistry on Europa and could reveal if life exists there. JUICE will also tell us more about how 'gas giant' planets like Jupiter interact with their moons and what sort of habitats can exist there. Gas giant planets are very different from rocky planets like Earth or Mars.

Enceladus is known to have water because it often spouts liquid from large cracks (nicknamed 'tiger stripes') in its icy coating. Even though the ice at Enceladus' south pole is around 30-40km (19-25 miles) thick, there is probably a 10km (six mile) deep ocean underneath the ice. The Cassini probe will be sending back more data from its trips around Enceladus throughout the end of 2015 and early 2016, which might give us more of an insight into this strange icy world.



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An artist's impression of the ESA's JUICE probe

Leaving our solar system

With current technology, there's no way that we can explore any planets outside our own solar system. After our sun, the nearest star to us is Proxima Centauri, which is 4.24 light years away. To give you an idea of how far that is, our sun is 150 million kilometres (93 million miles) away from Earth, but it only takes eight minutes for the light from the sun to reach us, never mind 4.24 years! If you travelled to Proxima Centauri in a jumbo jet at 970km/h (600mph), it'd take you five million years to get there!

The movies are full of spaceships that travel at light speed or have crew that can be kept in suspended animation for decades, but nothing like that is possible in real life now. But who knows what technology we'll have in the future? As the famous rocket engineer Robert Goddard once said: "It is difficult to say what is impossible, for the dream of yesterday is the hope of today and reality of tomorrow."

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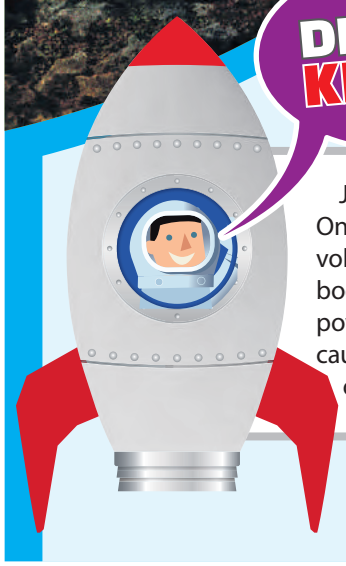
Could spaceships of the future take us to other solar systems?



JUPITER has 67 known moons. One of them, Io, has more volcanic activity than any other body in our solar system. The powerful gravity of Jupiter also causes 'tides' on the solid surface of Io that reach 100m high!

THE SEARCH FOR LIFE

THE big question about space that everyone wants to know is whether there's life somewhere other than our planet.

You should already have seen on p28-29 where we're planning to look for life in our solar system, although we're unlikely to find anything bigger than bacteria or other microorganisms on our neighbouring planets.

We don't really have the technology to send people outside our solar system yet, but we can build space telescopes that help us to study other galaxies and solar systems to find planets that could host life. The most important piece of kit in this search so far has been the Kepler space telescope. It has spent years studying the light coming from distant stars, to see if any of them have Earth-like planets orbiting them.

The most Earth-like so far is known as Kepler-452b (below right). It's around one-and-a-half times the diameter of Earth and orbits a star very like our own sun.

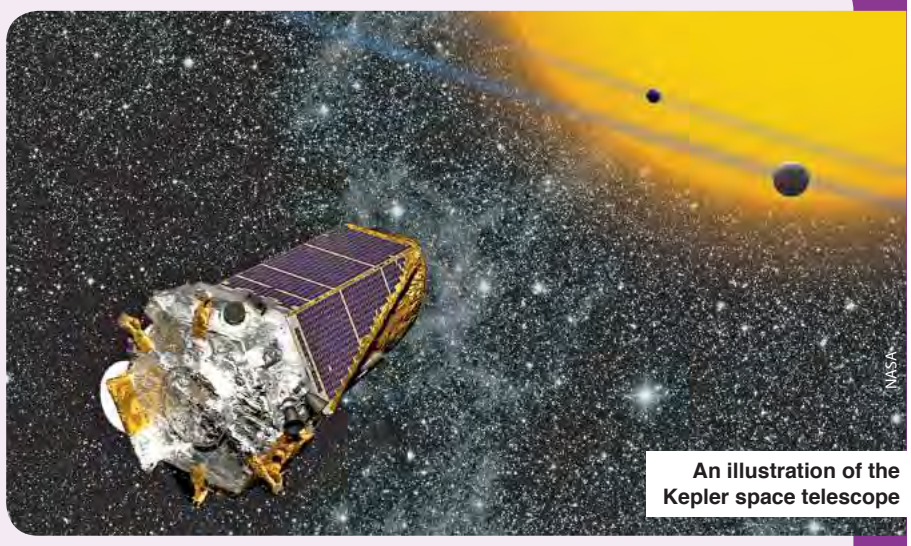
Data from Kepler has shown that planets orbiting in the **habitable zone** around a star are very common. The habitable zone is the distance from a star where it would be possible for liquid water to exist on the surface of a planet. A planet's suitability for life depends on lots of things, such as an atmosphere and magnetic field, but liquid water is the one thing that scientists think is essential for life. Or at least life as we know it – it's possible that life on other planets may be so different from Earth that it uses totally different substances.

It's quite exciting to think that there could be billions of Earths out there, but the big problem is that they're so far away that it's unlikely we'll ever get to any of them unless someone invents time travel or a spaceship that can travel faster than the speed of light. Unfortunately, both of those are thought to be impossible to achieve!

But even though current technology means that we can't get out to other worlds to explore them, isn't it possible that aliens somewhere have spaceships that are far beyond what human engineers can build? Maybe there are some super-clever aliens who've learned how to bend the rules of physics and can travel wherever they want in the universe.

So have little green men ever visited us? The RAF used to gather letters, emails and phone calls from the UK public about suspected UFO sightings, although they closed that department down in 2009, saying that it was a waste of time and money. In a report for Defence Minister Bob Ainsworth, Carl Mantell of the RAF's Air Command wrote that "no UFO sighting reported to us has ever revealed anything to suggest an extra-terrestrial presence or military threat to the UK".

However, since scientists think that there are something like 100 billion galaxies in our universe, the chances are that there's life out there somewhere…



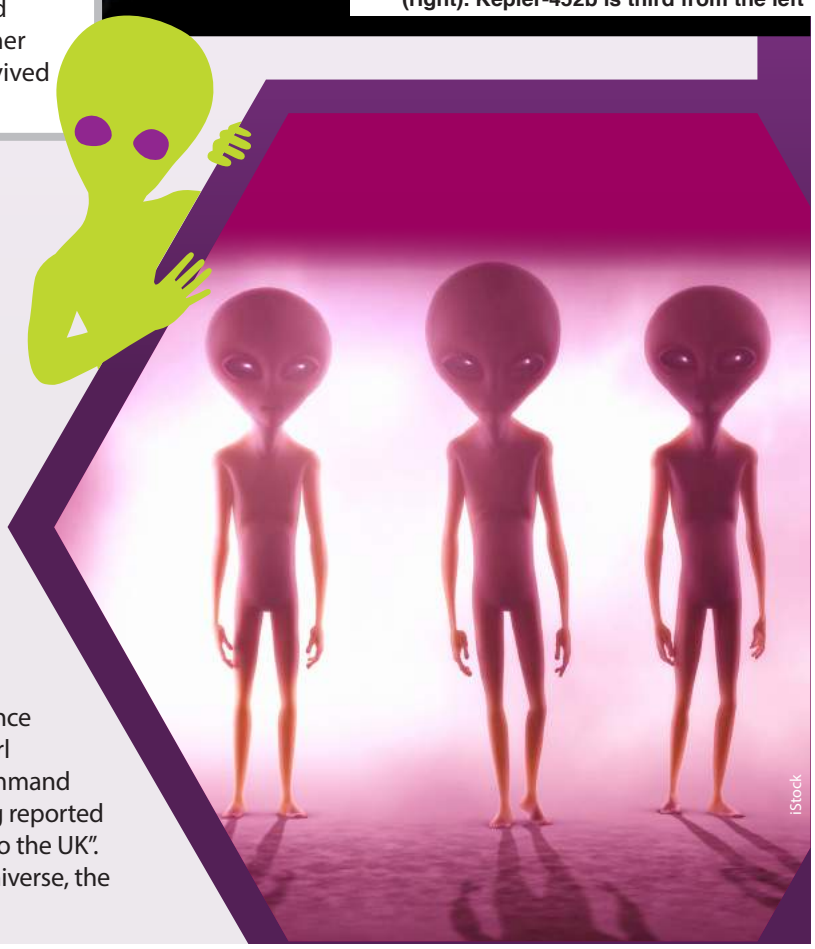
An illustration of the Kepler space telescope

Artist's impressions of some of the planets discovered by Kepler, compared to Earth (right). Kepler-452b is third from the left

DID YOU KNOW?

SOME scientists think that life could have been passed on to planets by comets or asteroids. Water, other chemicals and even tough bacteria or other organisms could have survived a trip through space.

If there are aliens, will they look like us? Robots? Or something totally different? And will they be friendly?



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