CLOSE ENCOUNTERS

Solar Orbiter and Parker Solar Probe are the spacecraft tasked with plunging into the Sun's scorching atmosphere to discover its secrets.

An artist's impression of Solar Orbiter approaching the Sun.

Unless you're slapping on sunscreen or snapping a selfie at sunset, you probably don't spend too much time thinking about the Sun. Stop for a second and think about it now. Even on the gloomiest, most overcast day in winter, you rely on this glowing disc in the sky for light, warmth and food. The Sun provides the energy that sustains life on this planet. Most ancient civilisations understood this and told fantastic stories about our nearest star.

Mission to touch the Sun

Thankfully, today we know there is no danger of the Sun being eaten by a hungry wolf, dragon or squirrel, as some old myths warned. Astronomers and solar scientists have discovered what it is made of and the source of its fierce glow, but you may be surprised to learn how much there is still to explain about this star.

Enter NASA's Parker Solar Probe and ESA's Solar Orbiter, the robotic space probes on a mission to unravel the Sun's riddles. Packed with $3 billion of cutting-edge technology, they promise to let us "touch the Sun", looking more

GIANT REACTOR

Each second, the Sun converts four million tonnes of matter into pure energy.

closely at it than ever before, sniffing the corona and listening in to the solar wind.

Sizzling science

It's tricky to study an object that is dangerous to look at. The Sun is so bright you should never look at it directly. In the 17th century, the famous scientist Isaac Newton joined the long list of curious sunchasers who (temporarily) damaged their sight trying to study the Sun. Modern instruments help people to look at our star safely, but even the world's most powerful solar telescope – the newly opened Daniel K. Inouye Solar Telescope in Hawaii – only squints at the Sun from 93 million miles away. Space scientists say this is like trying to examine a waterfall by standing at the bottom drenched in spray. To get a better view, there's no option but to get closer.

What is the Sun?

The Sun is a medium-sized star called a yellow dwarf star. It is actually pretty ordinary – just one of billions of stars in the Milky Way galaxy. The star fired up about five billion years ago, and today lies at the centre of a solar system of trillions of orbiting space rocks, including Earth. Even the biggest planets are minuscule compared with the Sun, which contains 99.8% of the mass of the solar system. All the planets, dwarf planets, moons, asteroids, comets and living things together make up just 0.2% of the total mass.

A giant nuclear reactor

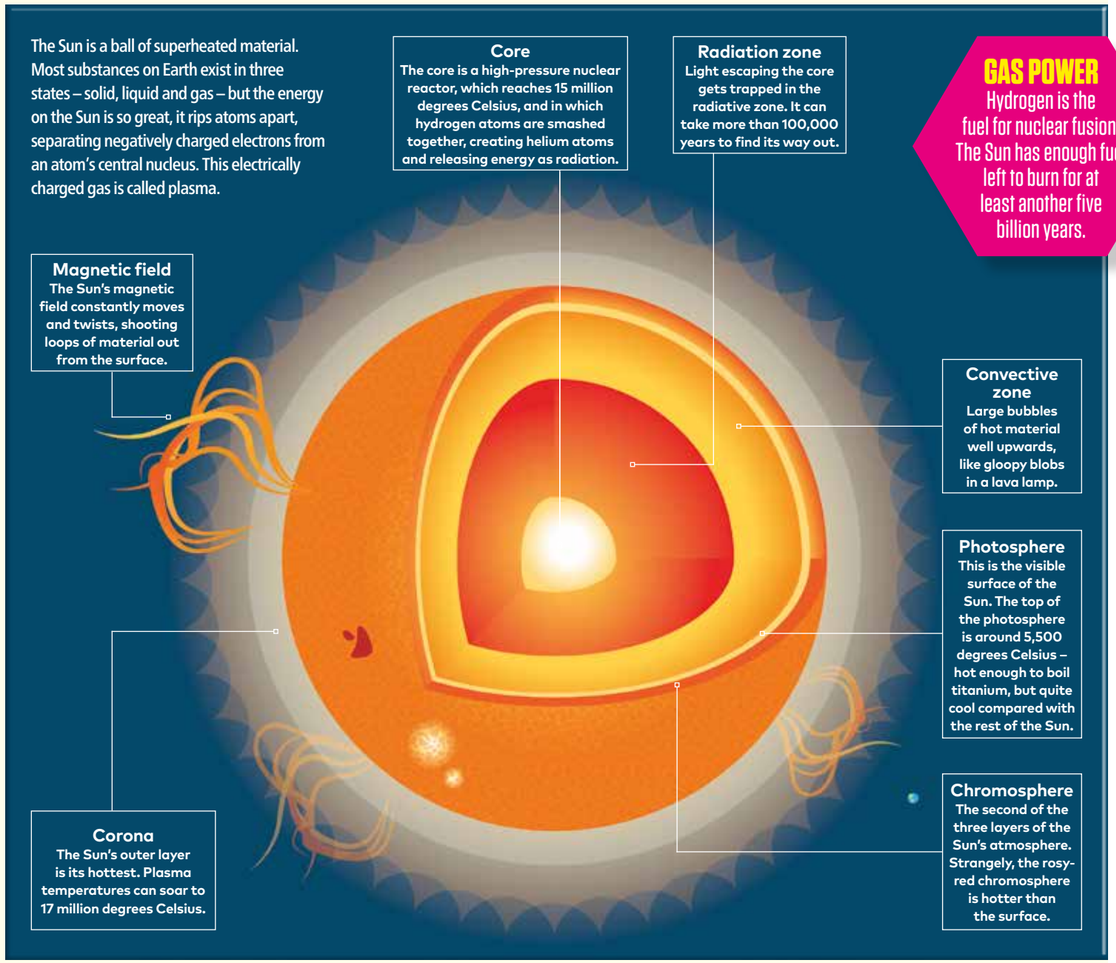
People often describe the Sun as a giant fireball, but it's not the sort of fire you sit round to toast marshmallows. Campfires are an example of combustion, a chemical reaction in which atoms (the basic building blocks of a substance) in matter shuffle themselves about and make different substances such as ash and smoke, giving off a little energy in the process. At the centre of the Sun, however, atoms aren't simply recombining, they are being crushed together so violently that they change into completely different types of atoms. This is a nuclear reaction, called nuclear fusion. It releases vast amounts of energy – enough to burn our skin and melt ice creams hundreds of millions of miles away.

Space weather

As well as heat and light, the Sun gives off a constant stream of material. Called the solar wind, the stream is made of high-energy, electrically charged particles driven out from the corona (the Sun's outer layer). This wind streaks across the solar system at almost

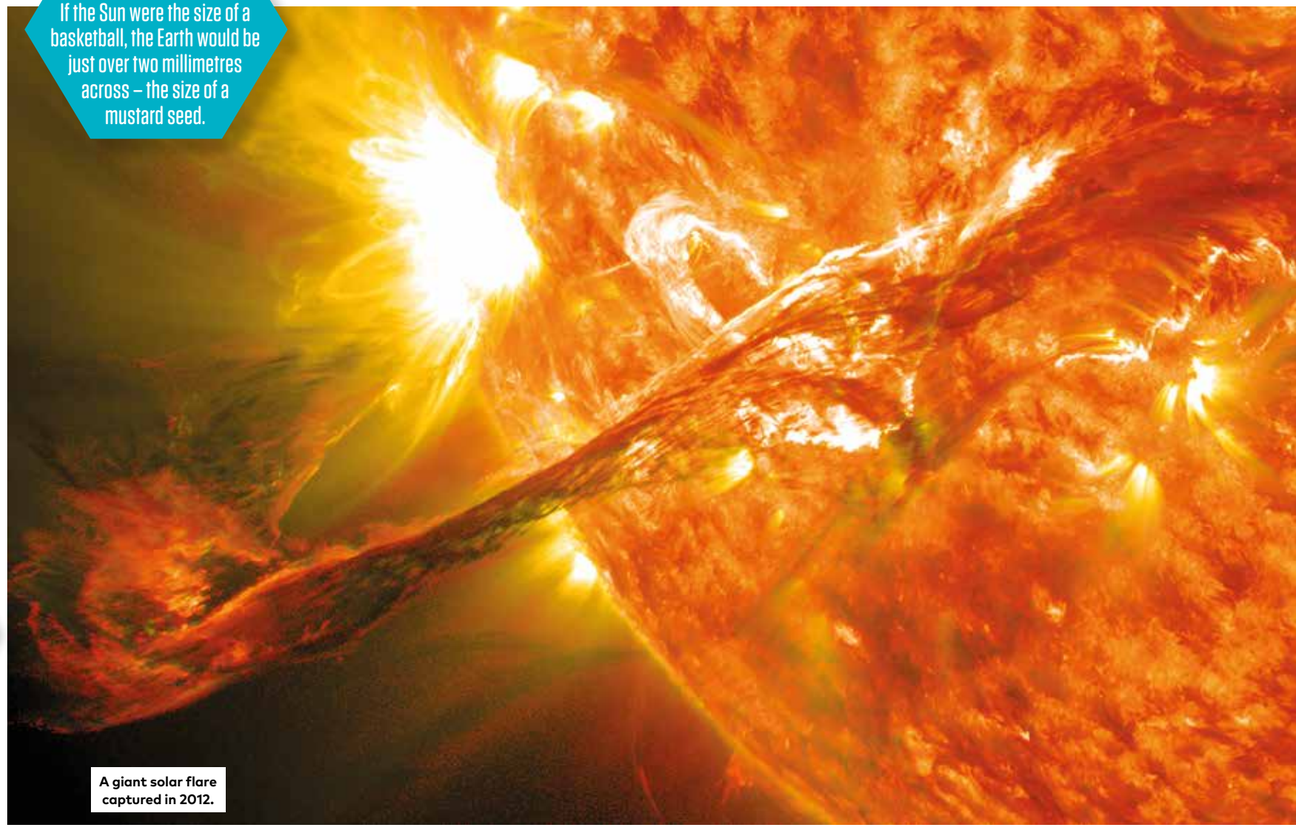
A trip to the heart of the Sun

The Sun is a ball of superheated material. Most substances on Earth exist in three states – solid, liquid and gas – but the energy on the Sun is so great, it rips atoms apart, separating negatively charged electrons from an atom's central nucleus. This electrically charged gas is called plasma.



GAS POWER
Hydrogen is the fuel for nuclear fusion. The Sun has enough fuel left to burn for at least another five billion years.

GOLDEN BALL
If the Sun were the size of a basketball, the Earth would be just over two millimetres across – the size of a mustard seed.


A giant solar flare captured in 2012.

500 miles per second. Even though they are smaller than atoms, at this speed the particles slam hard into every object in their path. Earth lies deep inside the danger zone, so we take the full force of the solar wind. Luckily, our planet is protected by its magnetic field, which deflects most of the wind. Even so, some of these charged particles make it into our atmosphere. As they interact with the gas high up in the atmosphere, they cause the colourful northern and southern lights (aurorae) that dance across polar skies.

Earth's atmosphere is thin and cold, and doesn't blow off into space because our planet's gravity keeps the gases clustered around it. However, the Sun's atmosphere is incredibly hot and its plasma gases (as shown in the box, left) have much more energy. Because of this, they push out much further from the Sun, and have enough energy to escape its (much greater) gravity and shoot off into space. The Sun loses about a million tons of plasma every second.

Although this sounds like a very large number, the Sun is so massive that in five billion years it has only shrunk by a mere 1/20,000 of its total mass.


Northern lights over Canada.

Solar flares

Gigantic explosions on the Sun's surface, called solar flares, also blast vast quantities of material into space. If one of these tidal waves heads towards Earth, it spells trouble. The solar storm that hits our planet brings brighter, more colourful aurorae, but can also disrupt radio signals, fry electricity grids and even trigger bombs to explode. The electrical surges they generate could short-circuit GPS and communication

SCIENCE FACT OR SCIENCE FICTION?

The Sun is yellow

Sadly, for everyone who draws a yellow circle for the Sun, this is pure science fiction. Sunlight is white – a mixture of every colour in a rainbow. This is how astronauts in space see it. On Earth, we see sunlight after it has passed through the atmosphere. This big blanket of air scatters blue, violet and indigo light more than other colours. This makes the sky look blue, and means slightly more red, orange and yellow light reaches our eyes, giving the Sun its yellow glow.


An astronaut in space pretends to hold the Sun.

Meet a scientist

DR MIHO JANVIER

SPACE SCIENTIST AND SOLAR STORM CHASER, INSTITUT D'ASTROPHYSIQUE SPATIALE, FRANCE.

Dr Janvier helps develop operations for the scientific equipment on board Solar Orbiter. She will be analysing the data collected by different instruments on the mission.

How do you chase solar storms?
I study how solar storms are born at the Sun, and how they propagate (spread around) in space. I use different types of observations: telescopes, to see our star from afar and instruments that measure what happens around the probe – what we call "in situ" instruments.

How will Solar Orbiter help you understand solar weather better?
Solar Orbiter carries both types of instruments, gets close to the Sun, and will also take the first images of the Sun's poles. All these observations are incredibly important for my research, because they are missing pieces of the puzzle of how solar storms start moving away from the Sun.

What does it feel like to watch Solar Orbiter being launched?
It is an exciting time! I never imagined that I would work on a space mission, although space science was always a dream for me. So for this to be happening, and to actually see the launch where so many historical missions – including the space shuttles and the Apollo missions were launched – is going to be magical.

Then there is of course the excitement of the first data, the new science we will get to do, and the first images of the poles. The mission has many milestones to look forward to in the coming years, and I feel extremely lucky to be part of this. It's a great reward for the many years put working towards this outcome.

Parker Solar Probe.

SUN-GRAZER
Parker Solar Probe is already the fastest human-made object. By the end of its mission, it will be travelling at 430,000mph – fast enough to get from London to Cardiff in one second!

satellites, and may even mess with the navigation systems of migrating animals, such as pods of whales. Scientists monitor solar activity closely, keeping an eye out for flares, so that people get advance warning of incoming bad space weather. The solar wind typically takes two to four days to reach Earth.

Burning questions

Our closest star still holds many secrets. Among many unanswered mysteries is why the Sun's atmosphere is 300 times hotter than its surface, how the solar wind speeds up after leaving the Sun, and whether it will ever be possible to predict solar flares.

Ferrying a whole laboratory of high-tech gadgets and gizmos deep into the Sun's scorching atmosphere, Parker Solar Probe and Solar Orbiter promise to shed new light on the most puzzling questions about this fiery ball. Parker was launched in August 2018, and in January of this year it swooped just 11.6 million miles above the Sun's surface – the closest a human-made craft has ever been to a star. This February, it was joined by Solar Orbiter.

Parker Solar Probe

Parker's seven-year voyage will take it just four million miles from the Sun's surface. This sounds like a safe distance, but imagine cool Earth and the scorching Sun at opposite ends of a metre stick. The probe will end up just 10 centimetres from the hot end. To get this close, it has a special carbon heat shield, which ensures that the instruments behind the shield don't get any warmer than 30˚C.

However, heat isn't the only challenge. Parker is constantly being sandpapered by dust from pulverised asteroids. Each speck of cosmic dust is tiny, but smashes into the spacecraft at about 250,000mph. Parker's instruments pick up the sound of these microscopic impacts as a constant hiss.

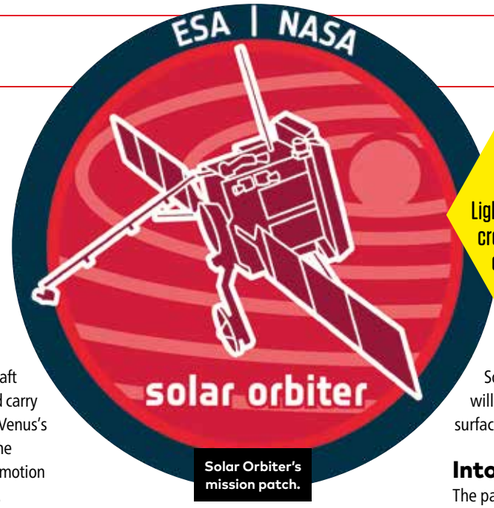
Why is it hard to get to the Sun?

Despite the Sun's enormous gravity, it's surprisingly difficult for a spacecraft to move towards it. Parker Solar Probe and Solar Orbiter began their missions on Earth, which is travelling sideways to the Sun at about 67,000mph. Changing direction is like trying to edge towards the centre of a spinning roundabout – if that roundabout were moving more than 100 times the cruising speed of a passenger jet. To fall towards the Sun, a spacecraft must gradually reduce its speed. No probe could carry enough rocket fuel to do this, so Parker is using Venus's gravity to help it put the brakes on. Every time the probe goes round the Sun and passes Venus its motion slows and it gets pulled a little closer to the Sun.

First discoveries

The Parker Solar Probe has already beamed back twice as much data as expected. In December, space scientists revealed that they had been able to listen in to the solar wind itself – Parker detects disturbances in the wind, which move through the Sun's corona like ripples in a pond. Back on Earth, these are converted to sound waves, which solar scientists have described as "a scene from *Star Wars*". Listen for yourself here, at tinyurl.com/SN-SunSound

These mysterious ripples in the magnetic field and plasma of the corona reveal that the solar wind is more chaotic than we had imagined. Parker has also spotted signs of a dust-free zone around the Sun, suggesting that cosmic dust is vaporised if it gets anywhere within 3.5 million miles. These early discoveries are a taste of the wonders to come as this amazing space probe circles ever closer to the Sun.



Solar Orbiter's mission patch.

LIGHT SPEED
Light takes eight minutes to cross the 93 million miles of space from the Sun to Earth.

So long, Solar Orbiter

Like Parker, the Solar Orbiter is a supersonic lab, packed with high-tech instruments to measure conditions in the heliosphere. Solar Orbiter is the photographer to Parker's roving reporter, snapping pictures from a distance, including the first ever images of the Sun's poles. When Parker measures something unusual in the corona, Solar Orbiter's photos of the solar surface will help scientists work out the cause. Although Solar Orbiter won't fly into the corona itself, it will get as close as 26 million miles from the surface – closer than Mercury.

Into the light

The pair of probes will help us become better at forecasting space weather. Advance warning of solar storms could protect technology and astronauts on future crewed missions to the Moon and Mars. Once astronauts venture beyond the shield of Earth's giant magnetic field, they are exposed to deadly radiation from the Sun. Having plenty of warning of solar flares will allow mission planners to schedule safer flights. Better predictions will also help defend the satellites orbiting Earth so that we can navigate, watch TV and play on our smartphones. Perhaps most importantly, however, the Parker Solar Probe and Solar Orbiter will give us a much better understanding of the inner workings of our star.

Young people observe a 2019 solar eclipse using special eclipse glasses.

WARNING!
Never, ever look at the Sun directly, in a mirror or through any kind of lens – not even through sunglasses.