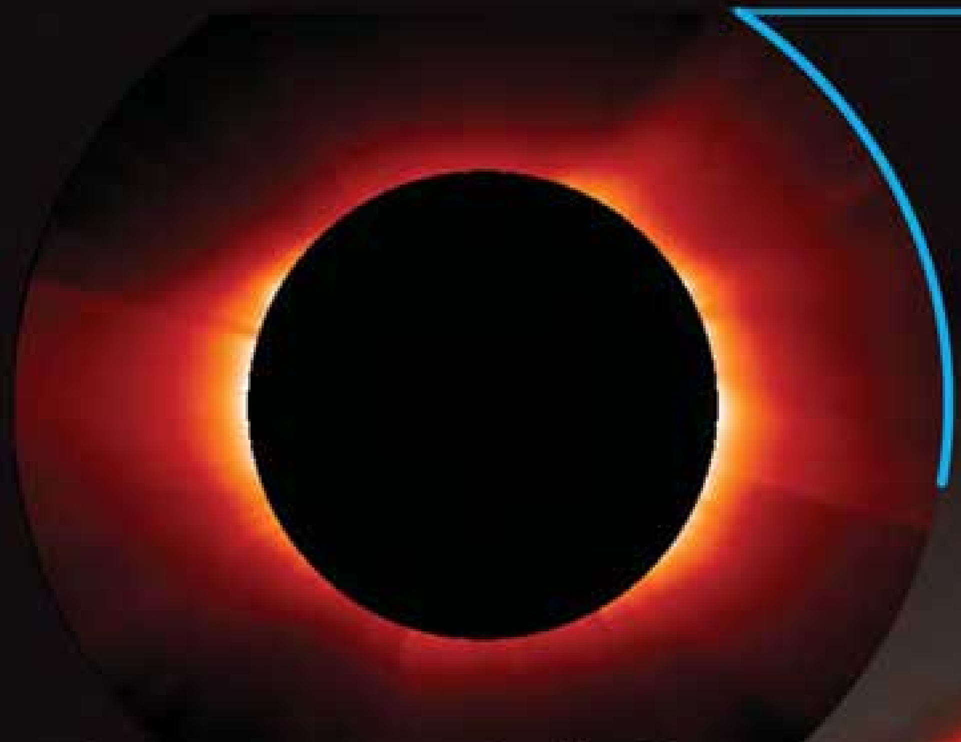
THE SUN

The Sun is our nearest star. It provides the Earth, which orbits at a distance of 150 million kilometres, the right amount of light and heat to support life.

ANATOMY OF THE SUN



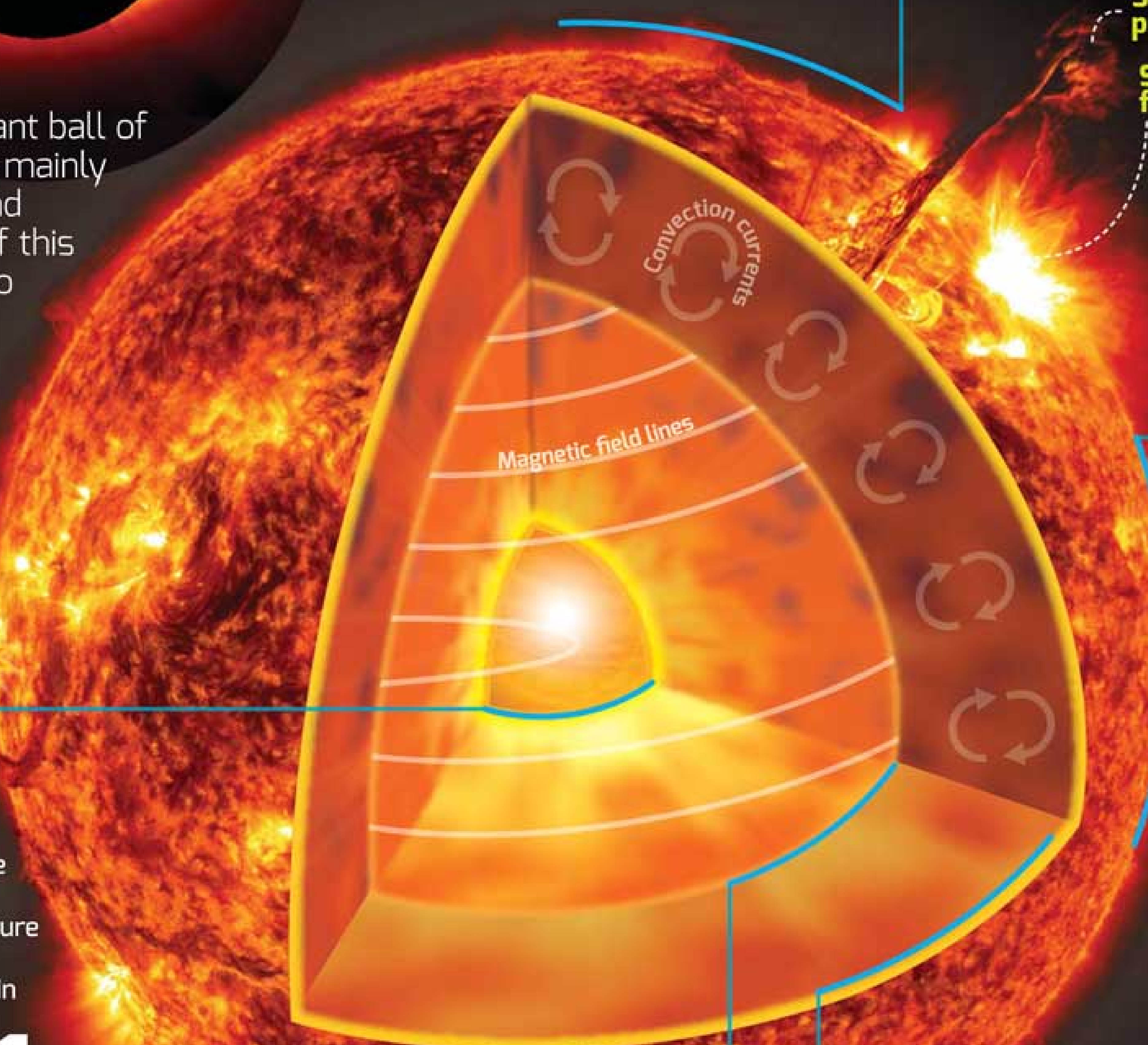
Corona

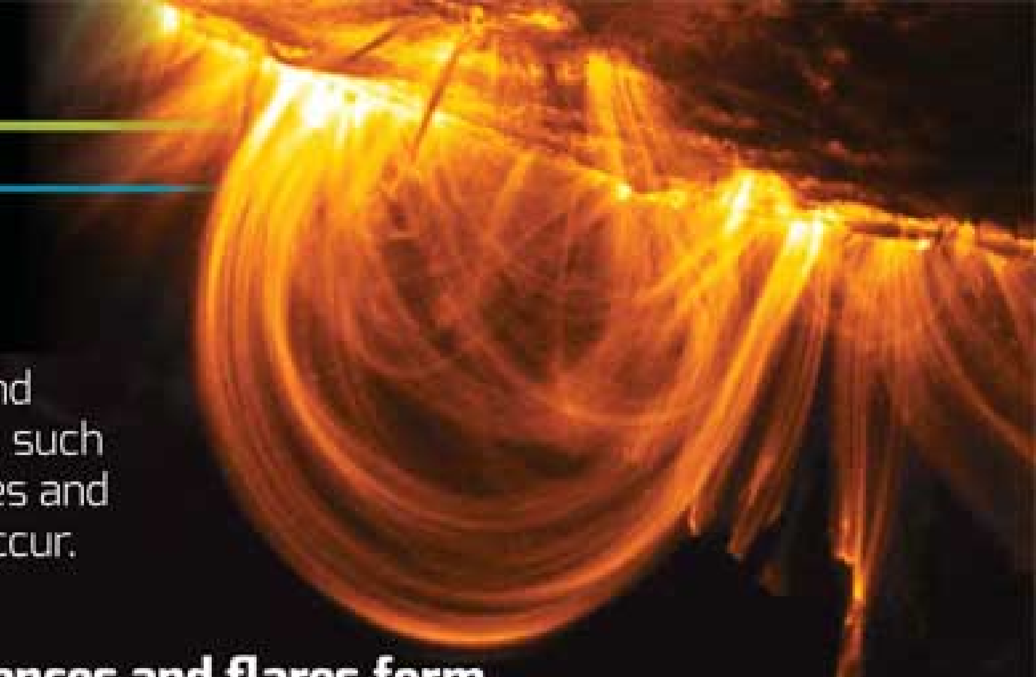
More than 1 million°C

The Corona is the Sun's extended atmosphere – larger in volume than the entire Sun.

Why the corona is so much hotter than the Sun's surface is one of science's biggest mysteries.

The Sun is a giant ball of gas, consisting mainly of hydrogen and helium. Most of this gas is heated to form an electrically-charged plasma that circulates, generating the Sun's magnetic field.





Chromosphere

6,000°C to 20,000°C

In the chromosphere, hydrogen atoms absorb energy from the photosphere and re-emit it as reddish light (chromo means colour).

It is here that spectacular and violent events, such as prominences and solar flares occur.

How prominences and flares form

1. The Sun rotates faster at its equator than it does near its poles. This difference causes the magnetic field to become distorted.

2. It becomes twisted into loops that break through the surface. In some regions, the loops merge into complex **'active regions'**, which can generate explosive **solar flares** or expel plasma into space as **coronal mass ejections**.

In some cases the loops evolve into **solar prominences** where matter is trapped in loop structures in the solar atmosphere.

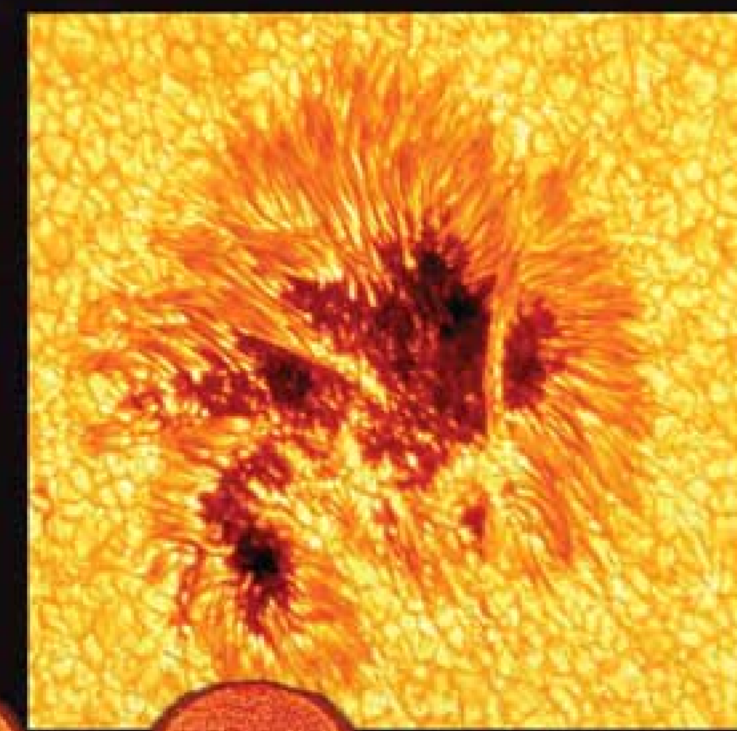
Photosphere

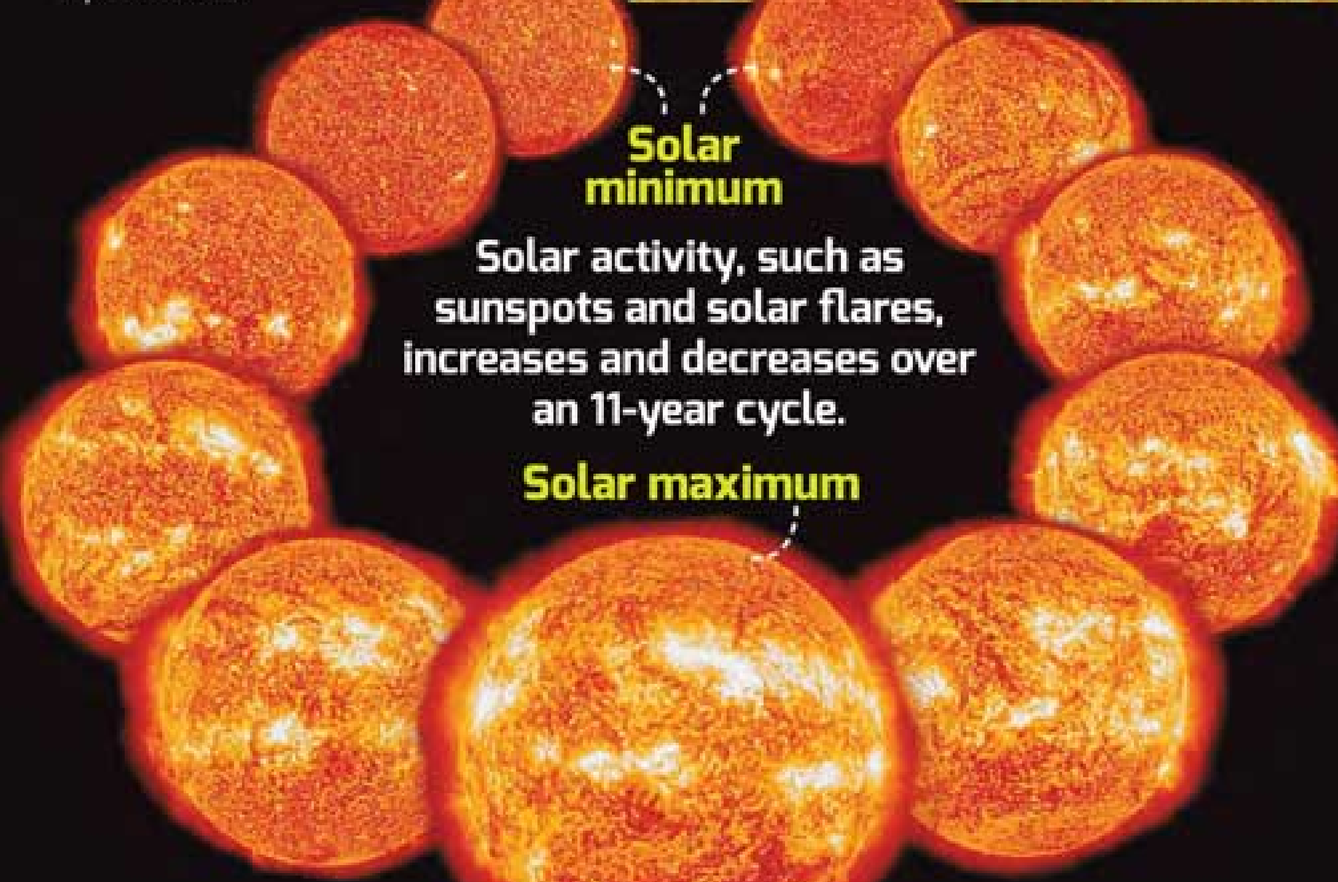
5,700°C

The photosphere is the visible surface of the Sun.

It is just 100 kilometres thick and has a granulated appearance caused by the upwelling hot material, which is brighter, surrounded by sinking cool material, which appears darker.

Sunspots are dark, planet-sized regions on the photosphere. They are dark because they are cooler than their surroundings. Sunspots are caused by strong magnetic disturbances. They evolve over several days and may last for months. They are active regions and are associated with solar flares and Coronal Mass Ejections.



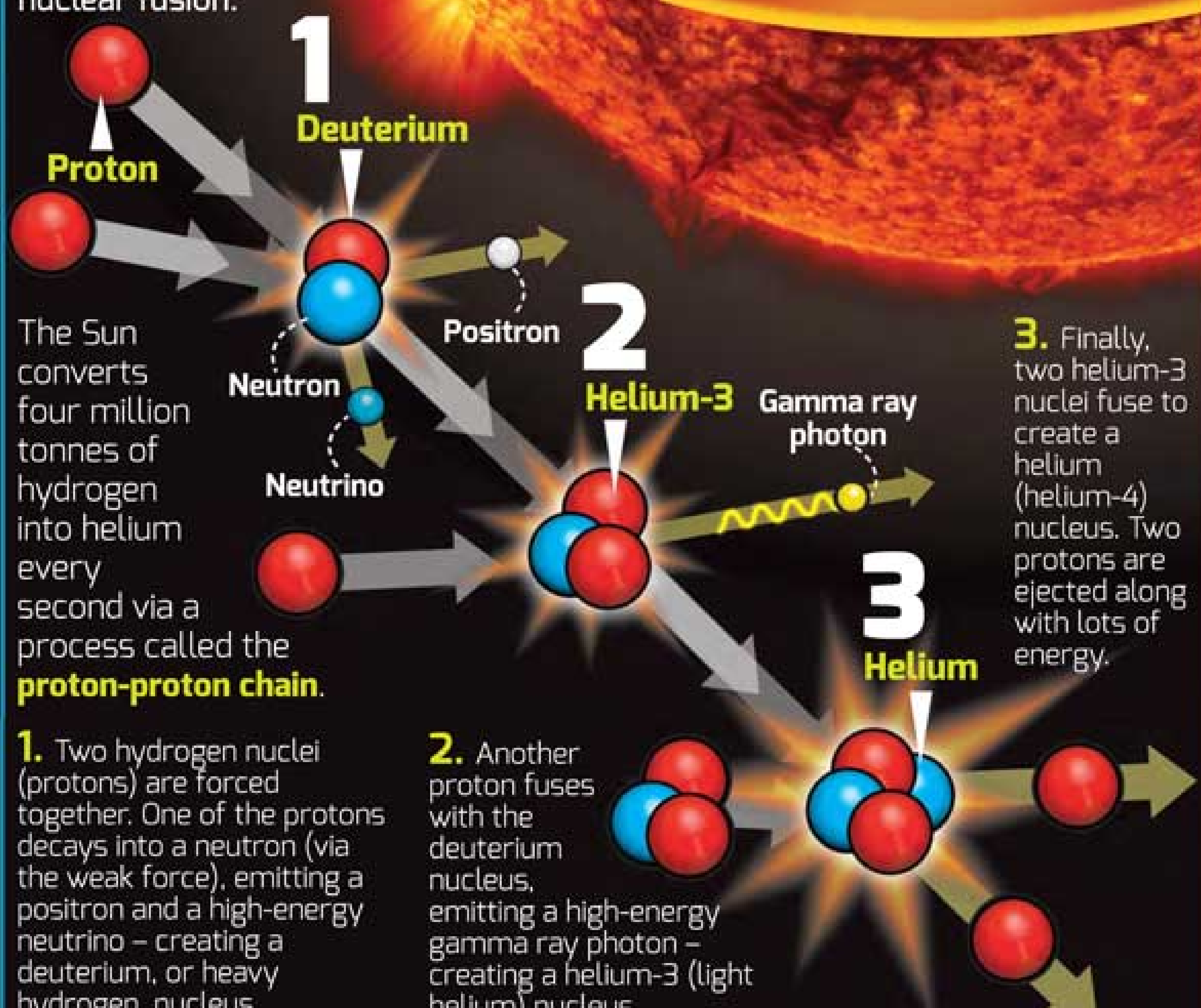


Core

15million°C

The core is the engine room of the Sun. Here, the extreme temperature and pressure is sufficient to sustain nuclear fusion.

The Sun converts four million tonnes of hydrogen into helium every second via a process called the **proton-proton chain**.



1. Two hydrogen nuclei (protons) are forced together. One of the protons decays into a neutron (via the weak force), emitting a positron and a high-energy neutrino – creating a deuterium, or heavy hydrogen, nucleus.

2. Another proton fuses with the deuterium nucleus, emitting a high-energy gamma ray photon – creating a helium-3 (light helium) nucleus.

3. Finally, two helium-3 nuclei fuse to create a helium (helium-4) nucleus. Two protons are ejected along with lots of energy.

Convection zone

2 million°C

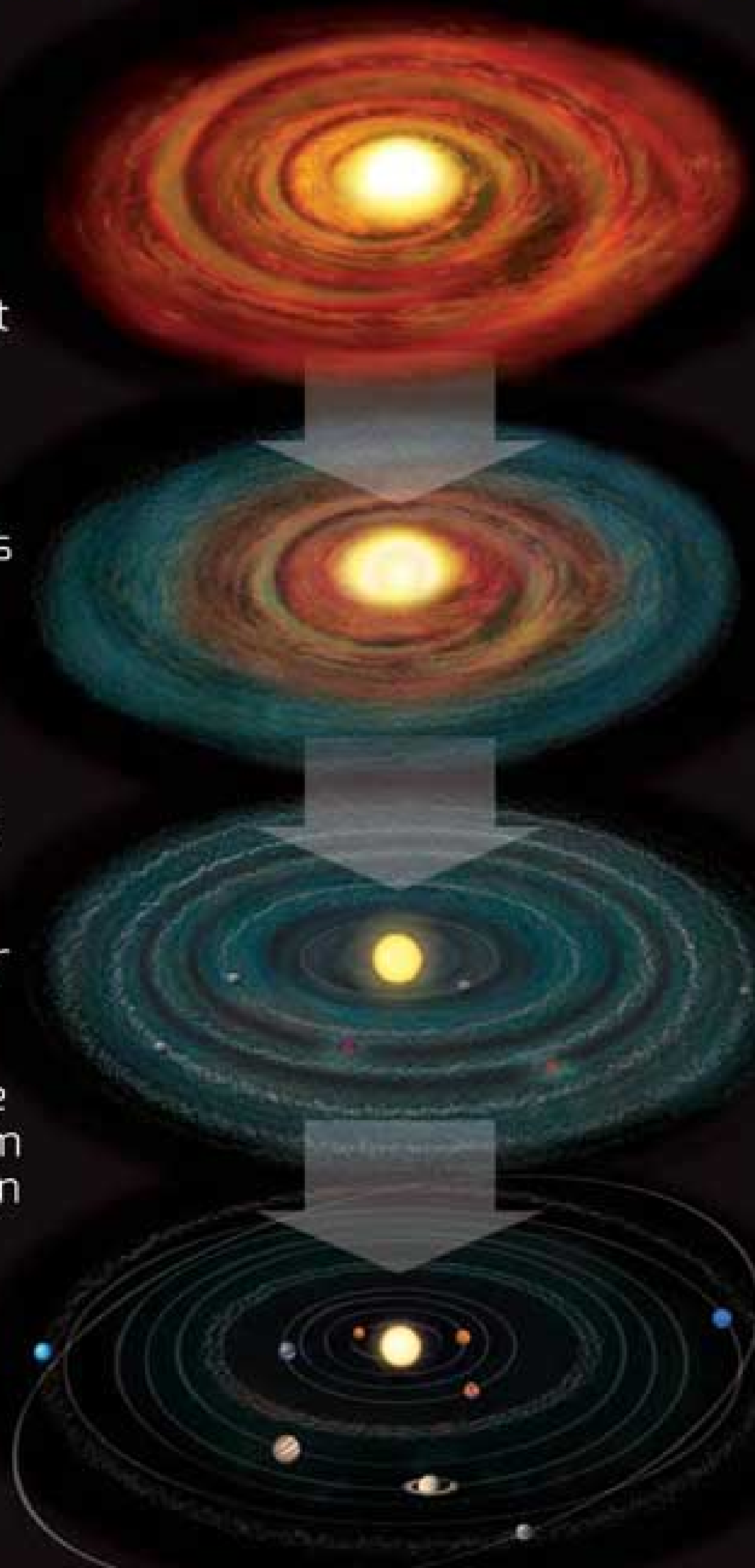
This turbulent region carries energy to the Sun's surface in thermal columns. The material cools at the surface and plunges back to the bottom of the convection zone. It is reheated by the radiation zone where it travels back to the surface once more.

Radiation zone

2 million°C to 7 million°C

Energy from the core travels through the radiation zone in the form of electromagnetic radiation (photons). The region is so dense that photons are continually absorbed and re-emitted by atoms – it takes an average 170,000 years for energy to leave it.

HOW THE SUN WAS BORN



The cloud of dust and gas that would become our solar system started to collapse about 4.6 billion years ago.

It took about 100,000 years for the protostar to become hot and dense enough for nuclear fusion to begin.

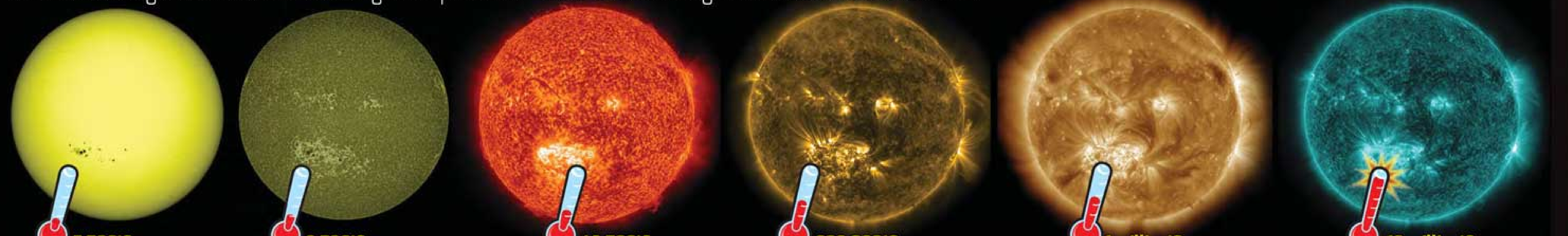
It took another 10 million years for the gas giants, like Jupiter, to form and 100 million years for the inner rocky planets to form.

STUDYING THE SUN

The Sun emits light across the electromagnetic spectrum. Different wavelengths reveals different features.

These images, taken by NASA's Solar Dynamics Observatory range from the visible spectrum to the extreme ultraviolet.

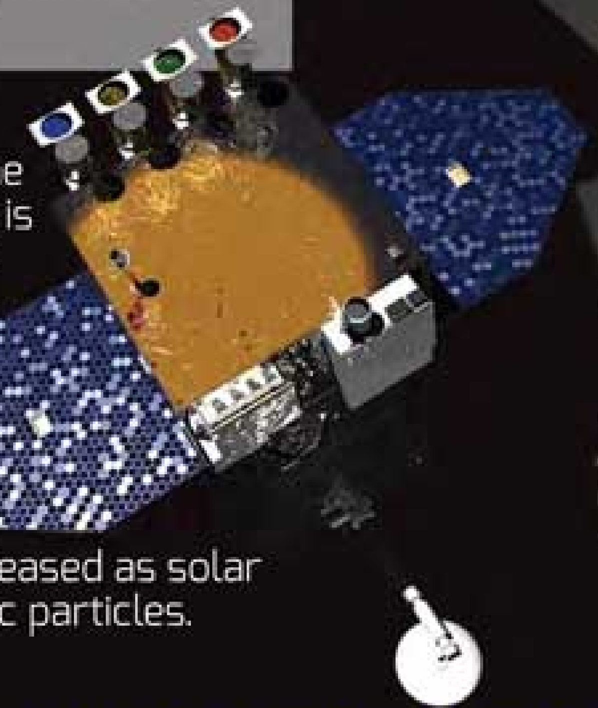
Each wavelength shows features of the Sun's surface and atmosphere shining at different temperatures.



- **5,700˚C** The photosphere (revealing sunspots)
- **9,700˚C** The upper photosphere – emitted by carbon-4
- **49,700˚C** The lower chromosphere – emitted by helium-2
- **600,000˚C** The corona (revealing solar prominences) – emitted by iron-9
- **1 million˚C** Hotter region of the corona and solar flares – emitted by iron-12
- **10 million˚C** The hottest material in a solar flare – emitted by iron-20

SOLAR MISSIONS

SDO (Solar Dynamics Observatory)



NASA's SDO has been observing the Sun since 2010. It is studying how the Sun's magnetic field is generated and how stored magnetic energy is converted and released as solar wind and energetic particles.

STEREO (Solar TErrestrial RElations Observatory)

STEREO consists of two nearly identical spacecraft. They were launched by NASA in 2006 into slowly separating orbits around the Sun. This gives them a stereoscopic view of the Sun and of events like solar flares and coronal mass ejections.

HINODE (Sunrise)

HINODE launched in 2006 to explore the Sun's magnetic fields. This joint Japanese/ US/UK mission uses optical, extreme ultraviolet (EUV), and x-ray instruments to investigate the interaction between the Sun's magnetic field and corona.

We are always planning new ways of studying the Sun, and we are working on an exciting mission with ESA called **Solar Orbiter** – you can find out about it at: *http://sci.esa.int/solar-orbiter/*

SOHO (SOlar and Heliospheric Observatory)

This joint ESA/NASA mission has revolutionised our understanding of solar physics. Launched in 1995, its twelve instruments monitor the Sun's internal structure, its outer atmosphere and the solar wind.

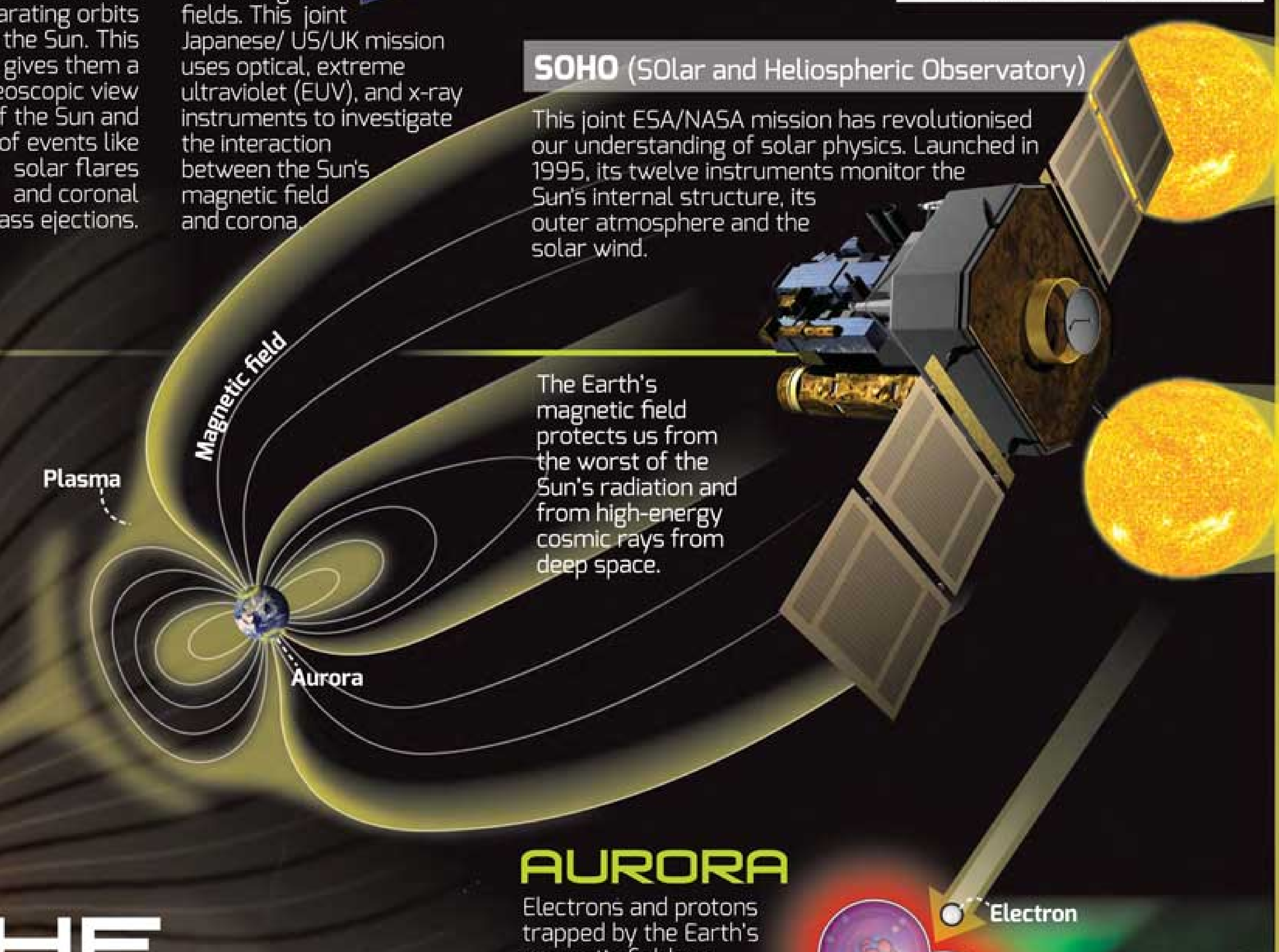
SPACE WEATHER

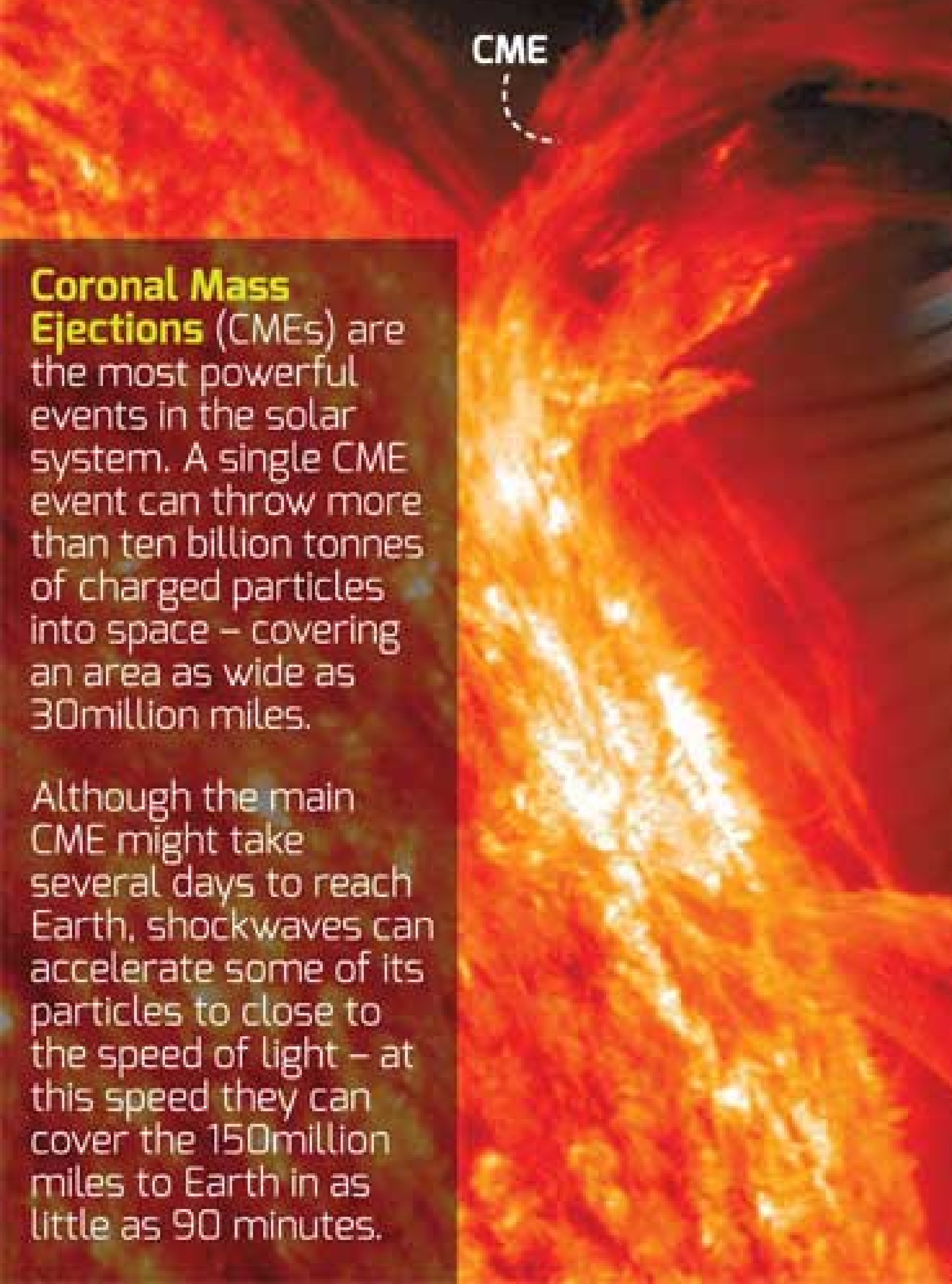
High-energy solar events, such as Solar Flares and Coronal Mass Ejections (CMEs) can produce magnetic storms on Earth that may damage satellites, disrupt communications and sometimes produce electric power blackouts.

The **solar wind** is a stream of plasma – electrons, protons and alpha particles (helium nuclei) – released from the upper atmosphere of the Sun.

The solar wind interacts with the Earth's magnetic field. The pressure it exerts deforms the field – compressing the Sun-facing part.

The Earth's magnetic field protects us from the worst of the Sun's radiation and from high-energy cosmic rays from deep space.





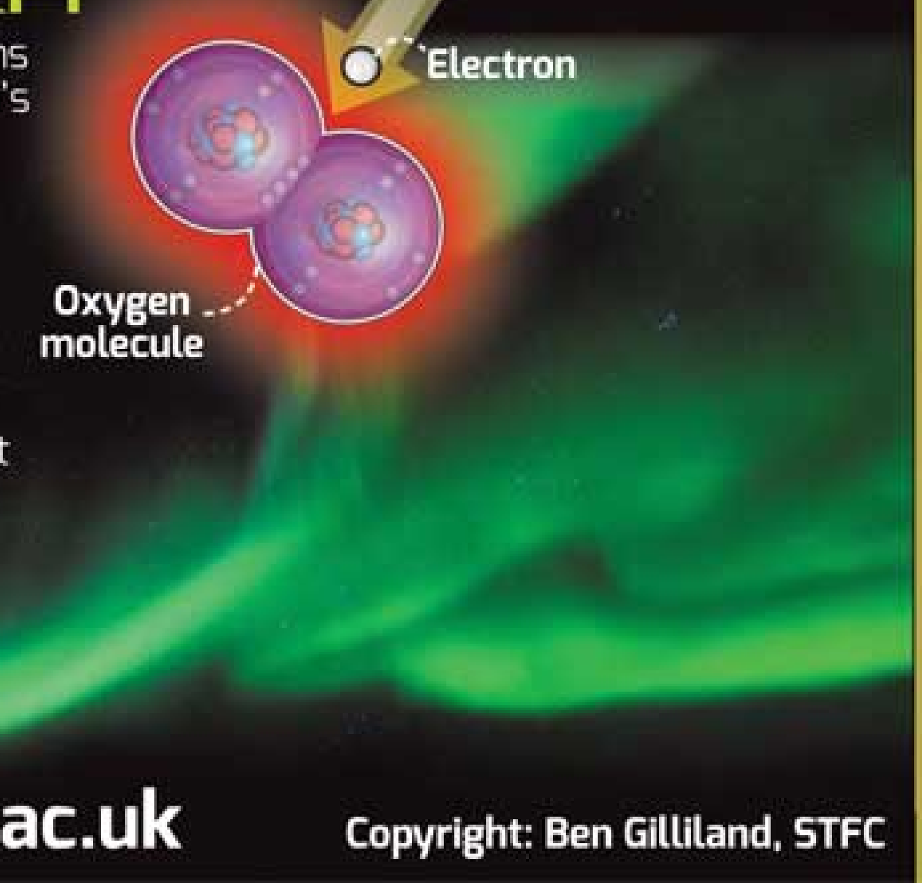
Coronal Mass Ejections (CMEs) are the most powerful events in the solar system. A single CME event can throw more than ten billion tonnes of charged particles into space – covering an area as wide as 30million miles.

Although the main CME might take several days to reach Earth, shockwaves can accelerate some of its particles to close to the speed of light – at this speed they can cover the 150million miles to Earth in as little as 90 minutes.

THE SUN

AURORA

Electrons and protons trapped by the Earth's magnetic field are accelerated and channelled into the polar atmosphere where they interact with the molecules and atoms in the air causing them to emit light, rather like in a fluorescent tube.



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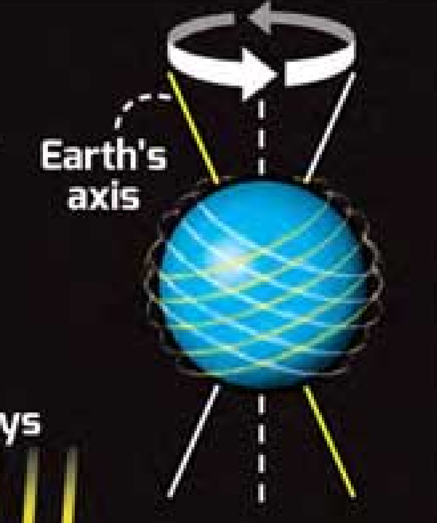
THE SEASONS

The Earth's axis is tilted at an angle of 23.45˚ so, as it orbits the Sun through the year, it wobbles from side to side.



Summer

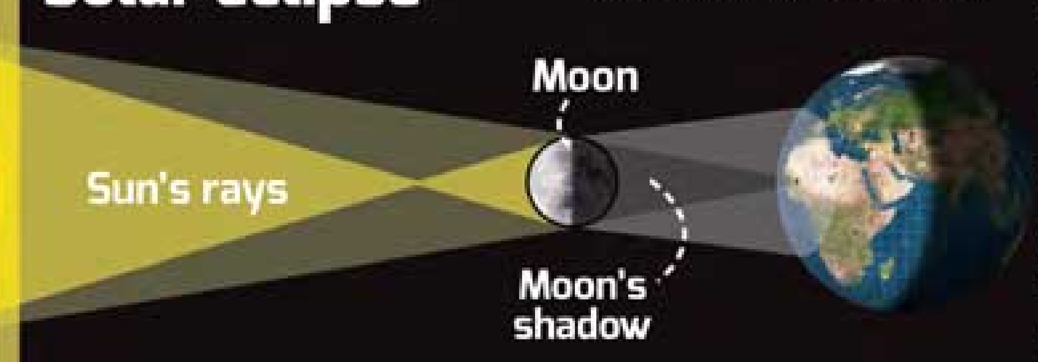
Winter

In the summer, the northern hemisphere tilts towards the Sun. The Sun's rays hit the Earth at a more direct angle – meaning more sunlight can fall on a smaller area than it does during winter.

ECLIPSES

Solar eclipse

A solar eclipse occurs when the Moon passes directly between the Sun and the Earth.



The Sun is 400 times wider than the Moon but, by a cosmic coincidence, the Moon is 400 times closer to the Earth.

This means the Moon and the Sun appear to be the same size in sky – making total eclipses possible.

Lunar eclipse

A lunar eclipse occurs when the Moon passes directly behind the Earth into its shadow.

This can only occur when the Sun, Earth, and Moon are aligned.

PHASES OF THE MOON

Only one half of the Moon is always illuminated by the Sun. During its orbit, different areas of illumination are visible from Earth.

During a full Moon, we see all of the illuminated side but, during a new Moon, the bright side is pointing away from Earth.