

Anne
Chadwick

What causes the Aurora?

These giant curtains of light in the night sky are the aurora borealis.

Key words

aurora
magnetic field
spacecraft
solar wind

Aurora is the Latin word for dawn. The plural in English is either **auroras** or **aurorae**.

At night, around the Arctic and Antarctic circles, a spectacular light show fills the sky. These constantly moving curtains of light are the aurora borealis (in the northern hemisphere) and the aurora australis (in the southern hemisphere). Through the centuries, many cultures and civilisations have observed and recorded the aurora, one of the most beautiful natural phenomena on planet Earth.

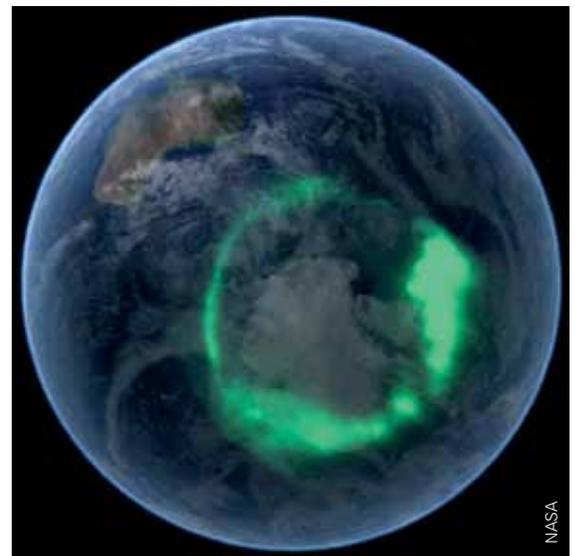
Anne Chadwick describes how the aurora is created and how scientists are using spacecraft to unravel some of its remaining mysteries.

What do we know about the Aurora?

The most common colour of the aurora is green. However, the aurora can appear as a variety of colours. Views from space confirm that the auroras reach round the Earth at high latitudes in regions known as auroral ovals, centred on the Earth's magnetic poles.

If there are low levels of solar activity, then the size of the auroral oval is fairly constant, and it is usually visible from the ground in Canada, Scandinavia and northern Russia for example.

The aurora moves to lower latitudes (towards the Equator) when the Earth's magnetic field is engulfed by a storm of particles and energy from the Sun. During a large geomagnetic storm, it may be possible to see the aurora in the United Kingdom.



The auroral oval of the aurora australis



Other planets with magnetic fields also have auroras, for example Saturn (pictured) and Jupiter.

Earth's magnetic field

The Earth has a strong magnetic field due to electric currents flowing in its hot interior. The electric currents exist in the molten metal outer core which has a temperature of more than 5000°C.

The Earth's magnetic field can be detected with a simple magnetic compass. In the UK, the compass points north, and also downwards into the ground at an angle. This is because the Earth's magnetic field is similar to that of a bar magnet, a simple dipole. The north magnetic pole is not in exactly the same place as the north geographic pole, and is slowly moving from northern Canada towards Russia.

The Earth's magnetic field is stable on timescales of hundreds of thousands of years, but the north and south poles have swapped places many times in its history.

The solar wind and Earth's magnetic field

The Sun's atmosphere – the corona – is so hot that its constituent particles 'boil off' into space, in a continuous stream known as the **solar wind**. This supersonic gale of ions and electrons blows away from the Sun typically at 450 km/s (1 million miles per hour!), but it can gust up to even higher speeds, perhaps 1000 km/s. Under normal circumstances, it takes 3-4 days for the solar wind to travel from the Sun to the Earth.

About 50 000 tons of solar wind flows past the Earth every day, carrying as much energy as humans

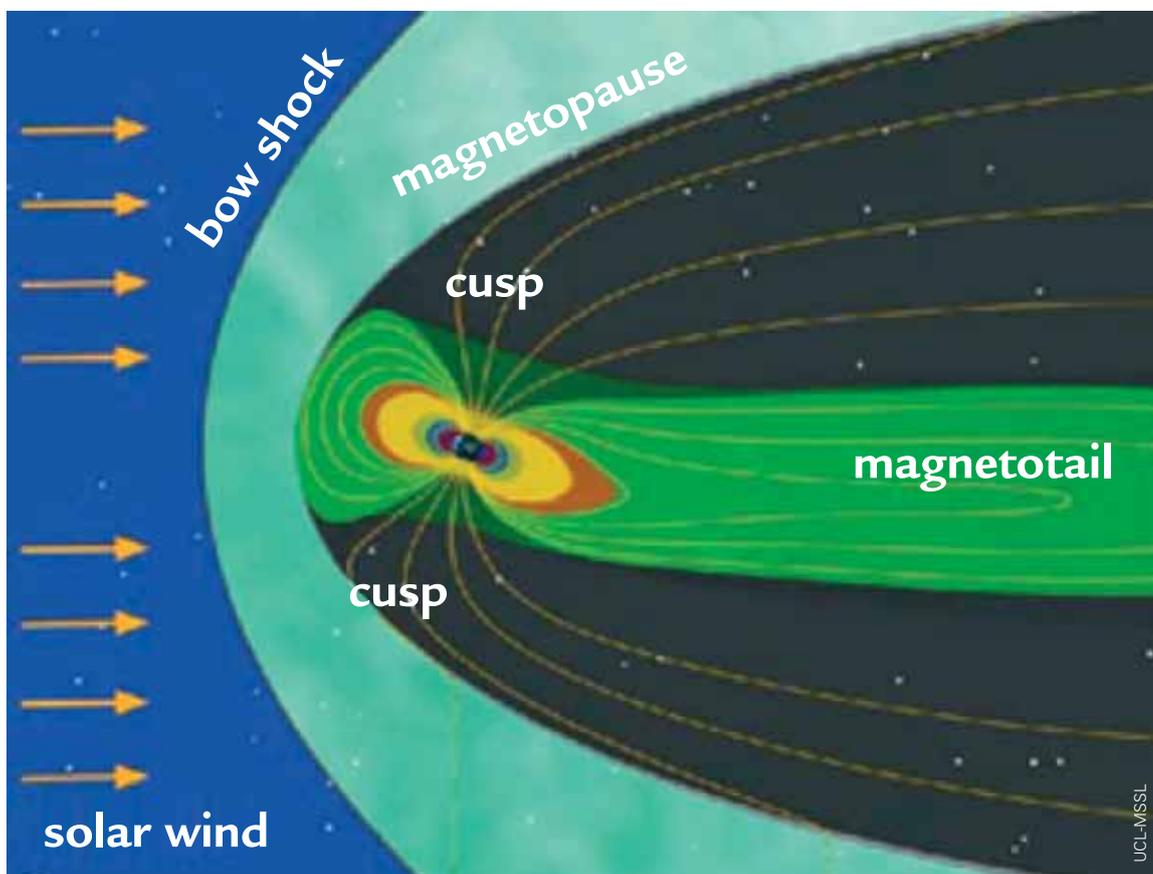
use worldwide on Earth. The flow rate of the solar wind past the Earth is one hundred million billion times greater than the Amazon river!

The Earth's magnetic field extends into space and forms a protective bubble called the magnetosphere. Acting like a shield, it deflects the solar wind so that it passes around the Earth. The magnetosphere is largely invisible, and so it must be measured locally by satellites.

The solar wind pressure changes the shape of the Earth's magnetosphere, squashing it on the Sun side and making a tail on the other side, like a wind sock. At its closest point, on the side that faces the Sun, the edge of the magnetosphere is approximately 70 000 km away from you. On the side of Earth facing away from the Sun, it has been measured at least 25 times further away. In fact, no-one really knows how long this magnetotail is! The Moon's orbit passes through the magnetotail.

Most of the time, the solar wind cannot penetrate the Earth's magnetic field. The bubble of the magnetosphere usually does a good job of protecting us from dangerous solar particles, but violent events on the Sun can break down the magnetosphere's protection. Coronal mass ejections, solar flares and solar energetic particles can cause severe space weather in the Earth's magnetosphere.

The Sun's activity follows an 11-year cycle. In the last few years, the Sun has been very quiet. However, the Sun's activity is increasing, with the next maximum due in 2013. We can expect more severe space weather as the Sun becomes more active.



The Earth's magnetosphere protects us from the solar wind

How the auroras are made

The auroral light emission occurs at roughly 100 km altitude, within the Earth's upper atmosphere, called the ionosphere. Energetic electrons crash down into the very thin air in the ionosphere and hit air particles (molecules and atoms), which become excited before releasing the energy they have gained.

Green and red auroras are both due to energy released as light from excited (energised) atomic oxygen ions. Blue light comes from singly charged nitrogen molecules.

Excited oxygen ions release energy as red light relatively slowly. If an excited ion collides with another atom or molecule, its excess energy will be shared and so no red light will be released. In the rarefied air between 100-200 km altitude molecules are far apart, collisions are rare and so this red light is more likely to be emitted. Green light is released much faster by oxygen, and at altitudes below 100 km where air is denser, there is sufficient time for this to be released before collisions happen. Hence red is often seen above green in the sky in an aurora.

The energy of the electrons that hit the air particles is also important. Less energetic electrons do not reach so deeply into the atmosphere and make high altitude red aurora. The most common energies produce green aurora. Occasionally, very energetic electrons produce a red aurora below the green aurora, down to 80 km.

The Cluster Mission

What causes the strange shapes and motion of the aurora? The answer to this may become clearer once the process that accelerates the electrons in the first place is better understood. Observations made by the European Space Agency's 'Cluster' Mission can help to provide answers.

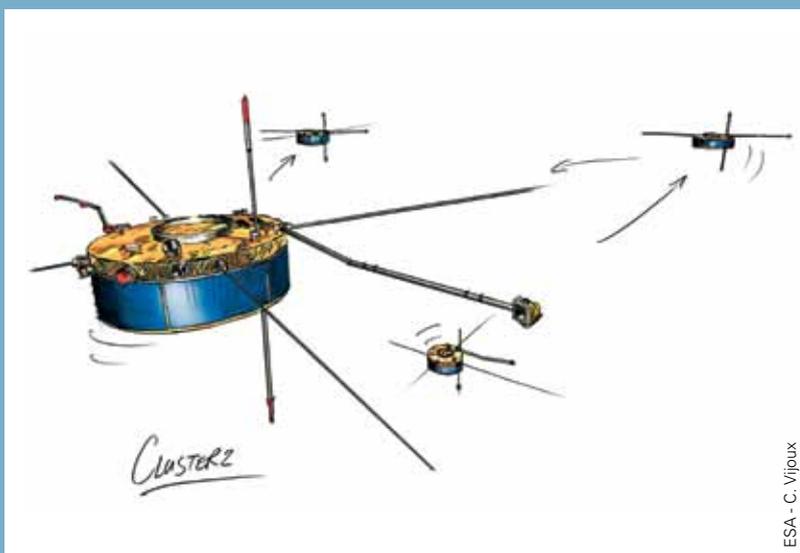
Cluster is a European Space Agency mission that investigates the Earth's magnetic environment and its interaction with the solar wind. Cluster consists of four satellites flying in formation through the Earth's magnetosphere and into the solar wind. Why four spacecraft? The four Cluster spacecraft fly in formation. Together, they can discover things that one spacecraft cannot.

One satellite can tell you about the magnetosphere at a single point. However, we need a three dimensional view to answer the big questions, like how the particles that create the aurora are accelerated. To get a 3D view, you need more satellites. The simplest 3D object is a tetrahedron (a triangular pyramid), so the Cluster mission has four satellites positioned so that they form a tetrahedral, three-dimensional observatory.

We cannot see the magnetosphere, so Cluster uses 11 scientific instruments on each spacecraft to 'touch', 'taste' and 'hear'. Cluster measures magnetic and electric fields, the solar wind and the ions and electrons in the magnetosphere.

Introducing the four spacecraft

The Cluster satellites were launched in the year 2000. More than 10 years after launch they are still making new and exciting scientific discoveries, travelling to different parts of the magnetosphere such as the auroral regions. In the next few years Cluster will complete a full set of observations over a whole cycle of solar activity.



This artist's impression of the Cluster satellites shows the long wire booms carrying instruments which make measurements of magnetic and electric fields in space.

Each Cluster spacecraft is 3m across and 1.3m high, with mass of 530 kg excluding fuel.

650 kg of fuel was originally carried, mainly for reaching the proper orbit. The remainder is needed to adjust the distance between the spacecraft at times through the mission.

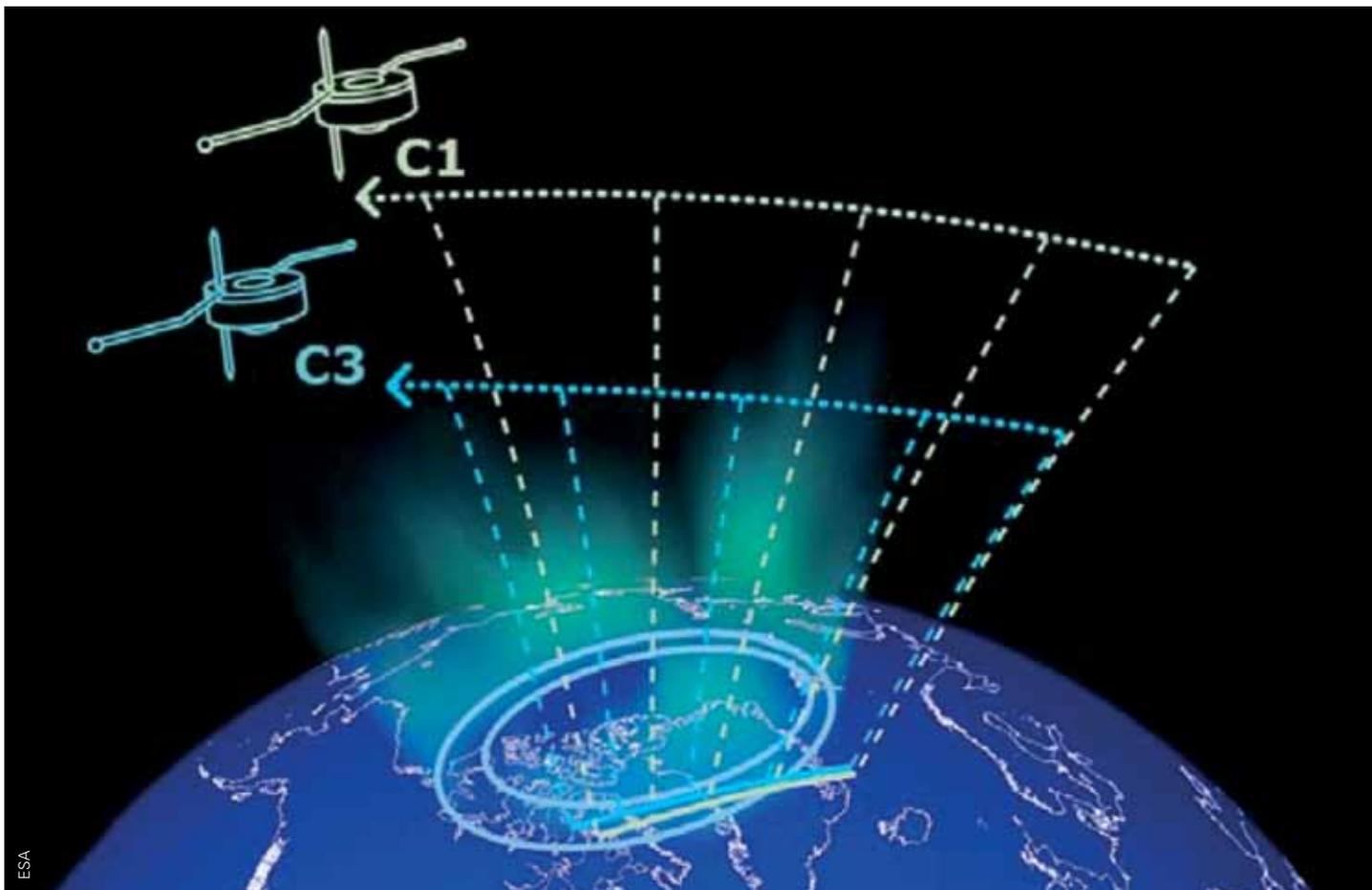
Power is provided by solar arrays, with batteries to provide power during eclipses.

The spacecraft spin once every 4 seconds (15 revolutions per minute).

Two pairs of wire booms, each pair 88m long tip to tip, measure electric fields & plasma waves.

The design life of the spacecraft was 5 years; all the spacecraft still work after more than 10!

The UK plays a leading role in Cluster. Parts of the satellites were built in the UK, while scientists and engineers in the UK built several of the science instruments that are now flying in space. UK scientists and engineers are also responsible for helping to provide the satellites' science operations, and for ensuring that the data they collect is returned safely to Earth and properly stored. UK scientists have led many of Cluster's scientific discoveries.



These pictures show two of the Cluster satellites, C1 and C3 (red dots), flying above the aurora at different heights on a single magnetic field line (yellow). By comparing measurements taken by the two spacecraft, Cluster scientists can understand better the conditions which cause electrons to be accelerated.

What can we discover with Cluster?

Scientists have developed a diverse set of theoretical ideas about what accelerates auroral electrons and thus produces the aurora. Cluster's unique observations will allow the first tests of these ideas.

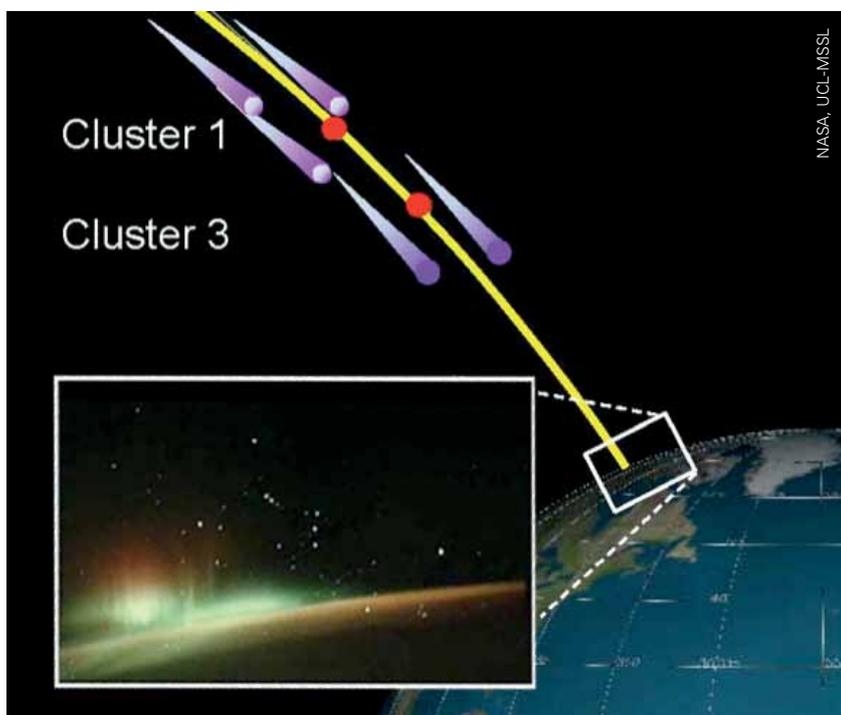
To test theories about the aurora, it is best to fly satellites above the aurora where they can measure the properties of the electrons that end up creating the aurora.

Cluster will discover where these electrons are accelerated so that they have enough energy to make the aurora. We need at least two spacecraft at different heights on the same magnetic field line to tackle this problem.

When the acceleration region or regions are identified, Cluster can help to tell us what sort of process causes the acceleration there.

To do this, in 2006 the shape of Cluster's orbit was allowed to slowly change, so that the lowest point of the orbit moved closer and closer to Earth. The four Cluster spacecraft are now in exactly the right place to measure electrons just above the aurora.

Cluster scientists are using this new data to explore the aurora, and learn how electrons are accelerated into the atmosphere.



Look here!

Is there going to be an aurora near you? To find out, visit: <http://aurorawatch.lancs.ac.uk>

More about the Cluster mission at: sci.esa.int/cluster

Ms Anne Chadwick is a space scientist at the Rutherford Appleton laboratory, and has worked on the coordination of science operations on the Cluster mission for 10 years.