

FANTASTIC LIGHTS

Aurorae: Their appearance, causes and observation

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Aurorae, popularly known as the northern lights, are an entrancing phenomenon of the Earth's upper atmosphere. They're caused by atomic particles from the Sun, primarily electrons, bombarding the atmosphere in a ring around the Earth's poles and making it glow like a fluorescent lamp. The purpose of these notes is to explain why aurorae occur and what you can expect to see.

Why aurora?

[Aurora](#) was the Roman goddess of the dawn. According to the mythologists, every morning she threw open the gates of dawn so her brother the Sun god could drive his chariot across the sky. And that's what we see her doing in this painting by the English artist Herbert James Draper who's illustrating the quote shown here from the Roman poet Ovid.

AURORA

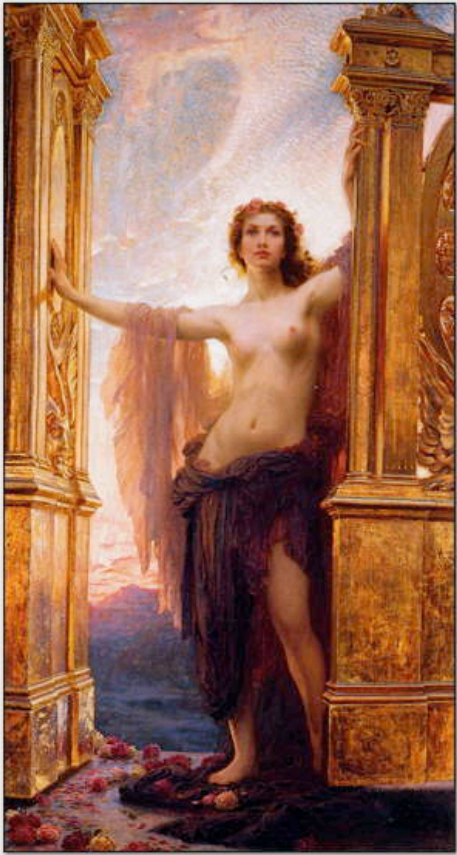
Roman goddess of the dawn

Her Greek equivalent was Eos

**"Far in the crimsoning east
wakeful Dawn threw wide the
shining doors of her rosefilled
chambers"**

Ovid, Metamorphoses

**Right: *The Gates of Dawn*
Herbert James Draper
(1864–1920)**



The first person to apply the name aurora is said to have been the Italian astronomer Galileo Galilei around 400 years ago. The additional distinction between "borealis" meaning north and

“australis” meaning south only came later when explorers such as Captain Cook first ventured far into the southern hemisphere in the 1770s and it was realized that there were southern aurorae as well as northern ones. However, few people live in the auroral zone in the southern hemisphere, which mostly covers Antarctica.

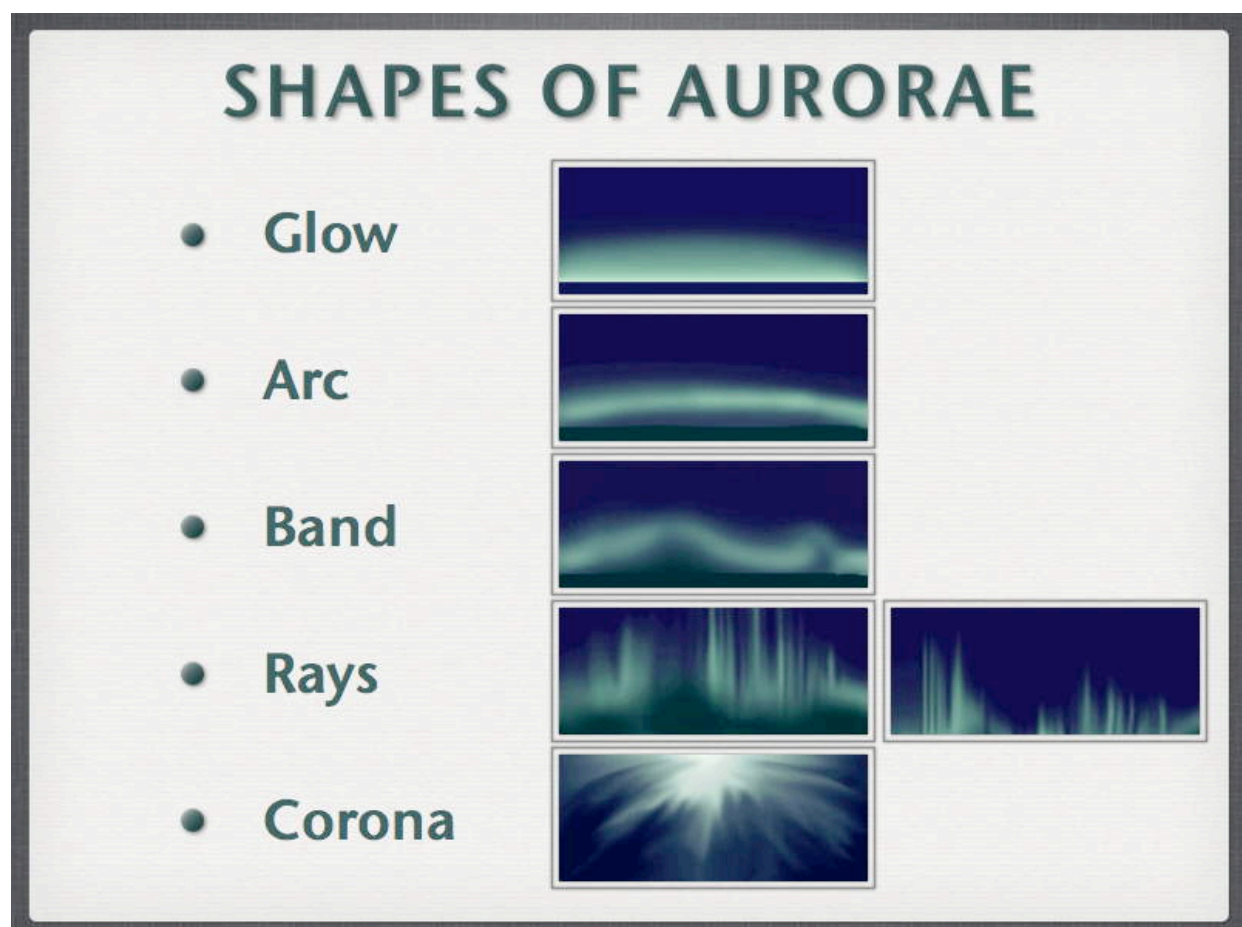
So the term aurora borealis actually means *northern dawn*, and that’s a good description of it as seen from latitudes like southern England, where we see only the top of the activity, low on the northern horizon like a false dawn.

Auroral forms

Aurorae are very fluid and mobile, changing in appearance all the time, and that’s one of their great delights. But you can distinguish a few basic shapes and structures.

⌘ The simplest is a **glow** on the horizon. For those in southern England this is all you’ll usually see. Nowadays, a glow like this will be completely swamped by the glare from street lights unless you happen to live out in the country.

⌘ As the activity rises higher in the sky you see what’s called an **arc**. If this starts to fold it will turn into a **band**, which is what most people think of when they think of an aurora – long rippling bands that move like drapery gently blowing in a breeze. You’ll often see these referred to as curtains, but I like to think of them as the billowing sails of Nordic longships.



⌘ In addition to these basic shapes are **rays**, vertical streaks that extend upwards like searchlight beams. These are a sign of a really active display. If the aurora is far to the north of you, you might only see the tops of them peeking above the northern horizon.

⌘ If the display is right above you, you might see what's called a **corona**. This is a perspective effect when the bands and rays seem to converge on a point overhead.

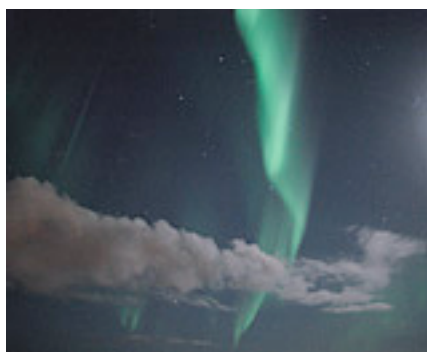
All these formations can move, brighten and fade over a matter of seconds to minutes.

Aurorae in action

Virtually all videos you will see of the aurora in action, such as [this one](#), are made from a sequence of stills stitched together, and the result is considerably speeded up. However, a company in Iceland called Aurora Experience has succeeded in producing real-time movies of high quality which are [available on a DVD](#). Here are some brief clips from it, as posted on their website:



[This sequence](#) shows how the auroral curtains move and ripple like drapery blowing in the wind. Note that aurorae are translucent – you can see stars through them.



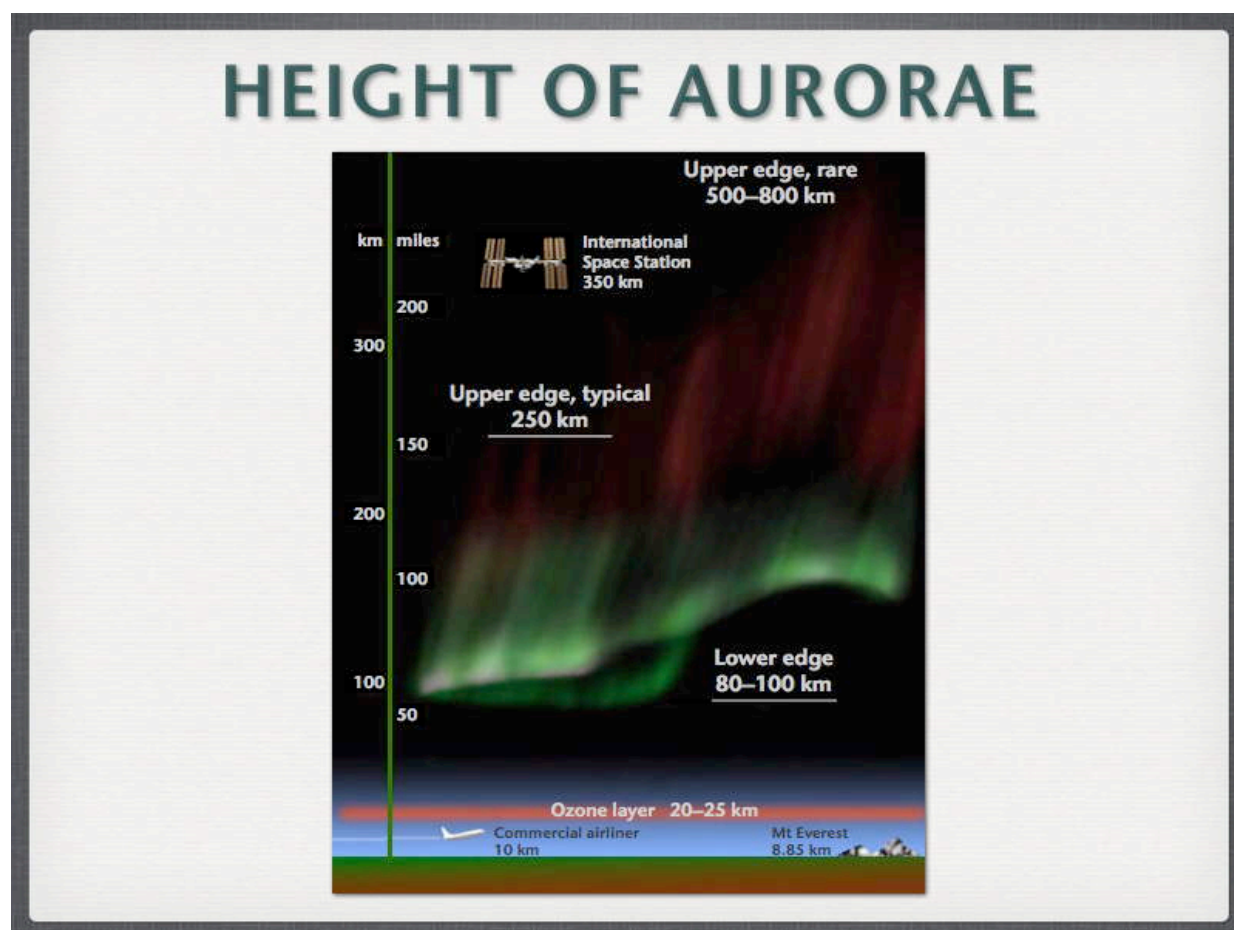
[Here](#) is an aurora with clouds drifting in front of it. If an aurora is bright enough you can even see it behind the clouds, turning them green.



This is quite a rare [red aurora](#) – if you didn't know what it was you could easily mistake it for a fire, and indeed it's said that in AD 37 the Roman Emperor Tiberius sent his fire-brigades to the port of Ostia because he thought it was burning down. But he had been fooled by an aurora.

Height of aurorae

Aurorae occur typically at altitudes between about 100 km (60 miles) at their lower edge up to 250 kilometres (150 miles) or even higher. This is in the ionosphere and extends to heights at which satellites orbit.



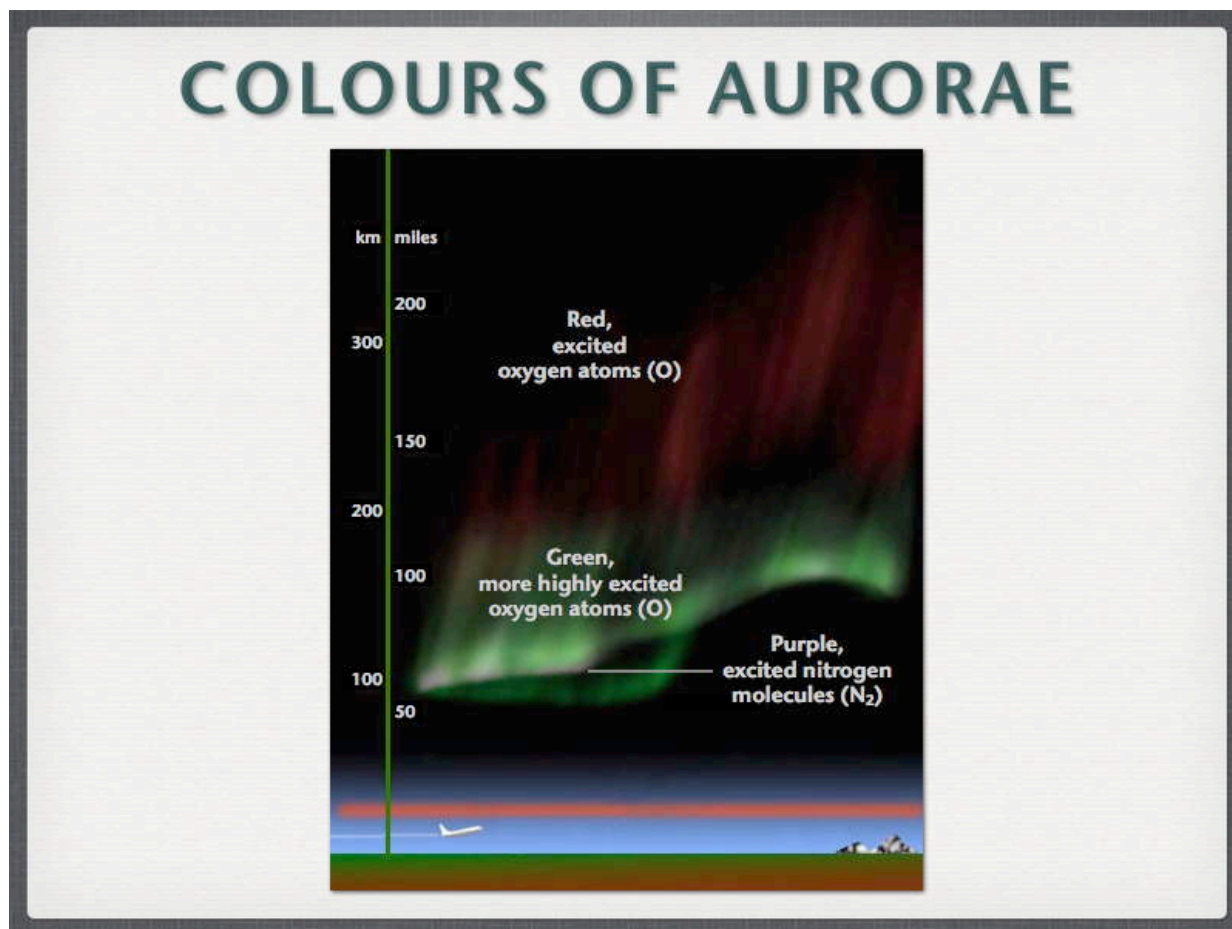
Colours of aurorae

Aurorae are usually green and red, sometimes with traces of purply-blue as well. These colours are caused by oxygen and nitrogen gas in the atmosphere glowing as it's hit by electrons. Nitrogen and oxygen are the main gases in our atmosphere so it's no surprise that they should be involved. In practice, most of the colours in a typical aurora come from oxygen rather than nitrogen.

The top of the aurora is red (*see diagram on next page*), although the reddishness isn't very prominent visually if the aurora is faint. The red is caused by excited atoms of oxygen at high altitude.

Mostly what we see is the green part, lower down. Our eyes are most sensitive to greenish wavelengths so this part of the aurora usually looks brightest.

The most energetic electrons of all can penetrate lower still to excite molecules of nitrogen, which produces a fringe of purple at the bottom of the aurora, although you'll only see this in the most energetic storms.

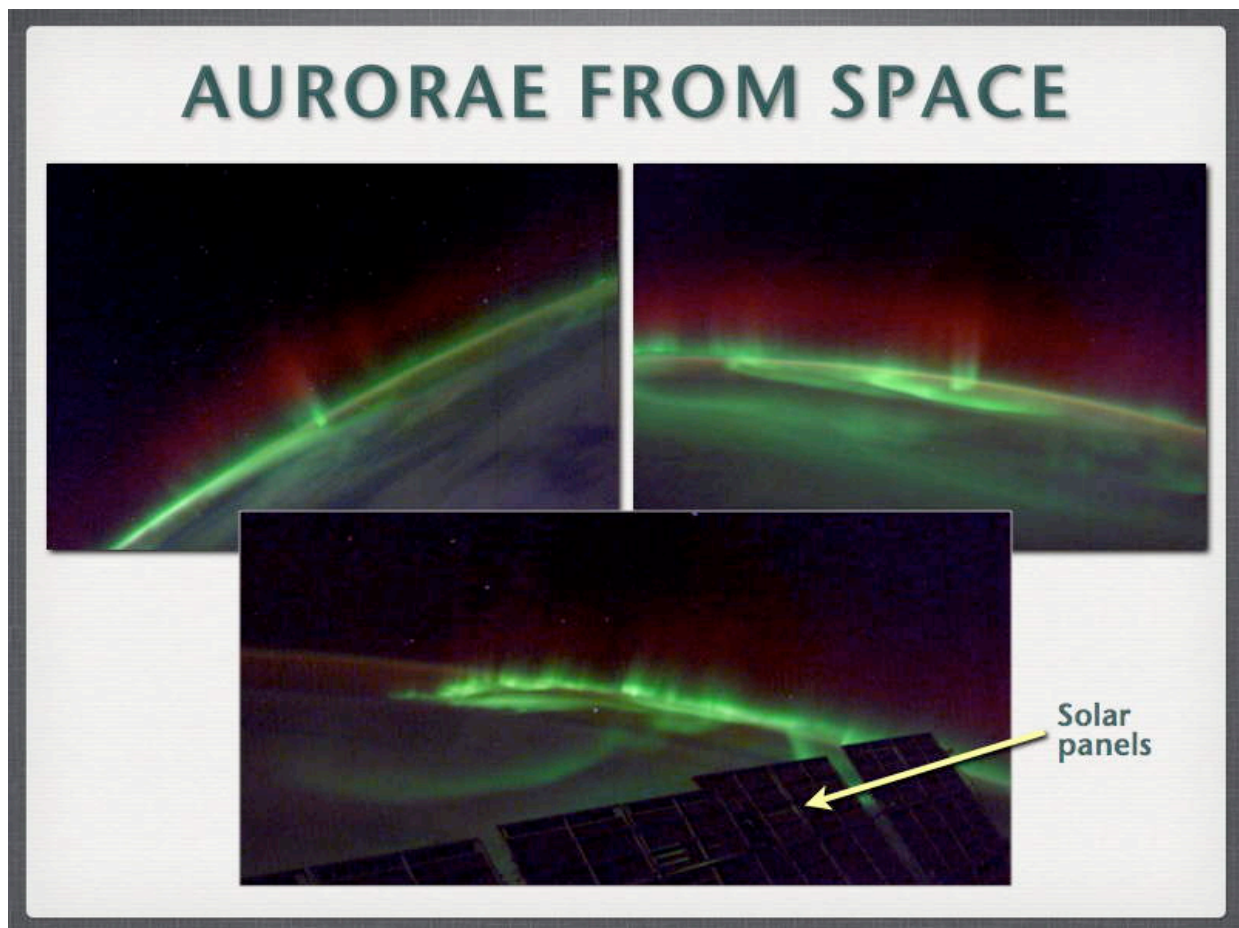


You've probably seen pictures [like these](#) that show the aurora bright green. But to the eye, most aurorae look more greyish. The colours show up much better on photographs than they do to the eye, as you'll realize if you take some pictures of your own. The reason is that the human eye is not very sensitive to faint light. Think for example of a garden at twilight – all the colours become washed out and turn to shades of grey.

Because of this, you might easily mistake a faint aurora for thin cloud. The way to tell the difference is to take a picture. If it comes out green, it's an aurora. If it's grey or orange, it's cloud.

Aurorae from space

From the ground we don't really appreciate how high up aurorae can go, but you can get a better idea from space. On the next page are some pictures of aurorae taken by astronauts in orbit aboard the International Space Station (parts of the station's solar panels intrude into the lower picture). The aurorae in these pictures are clearly layered, with red at the top and green at the bottom. See [here](#) for some astounding video sequences of the aurora taken from the International Space Station in 2011.



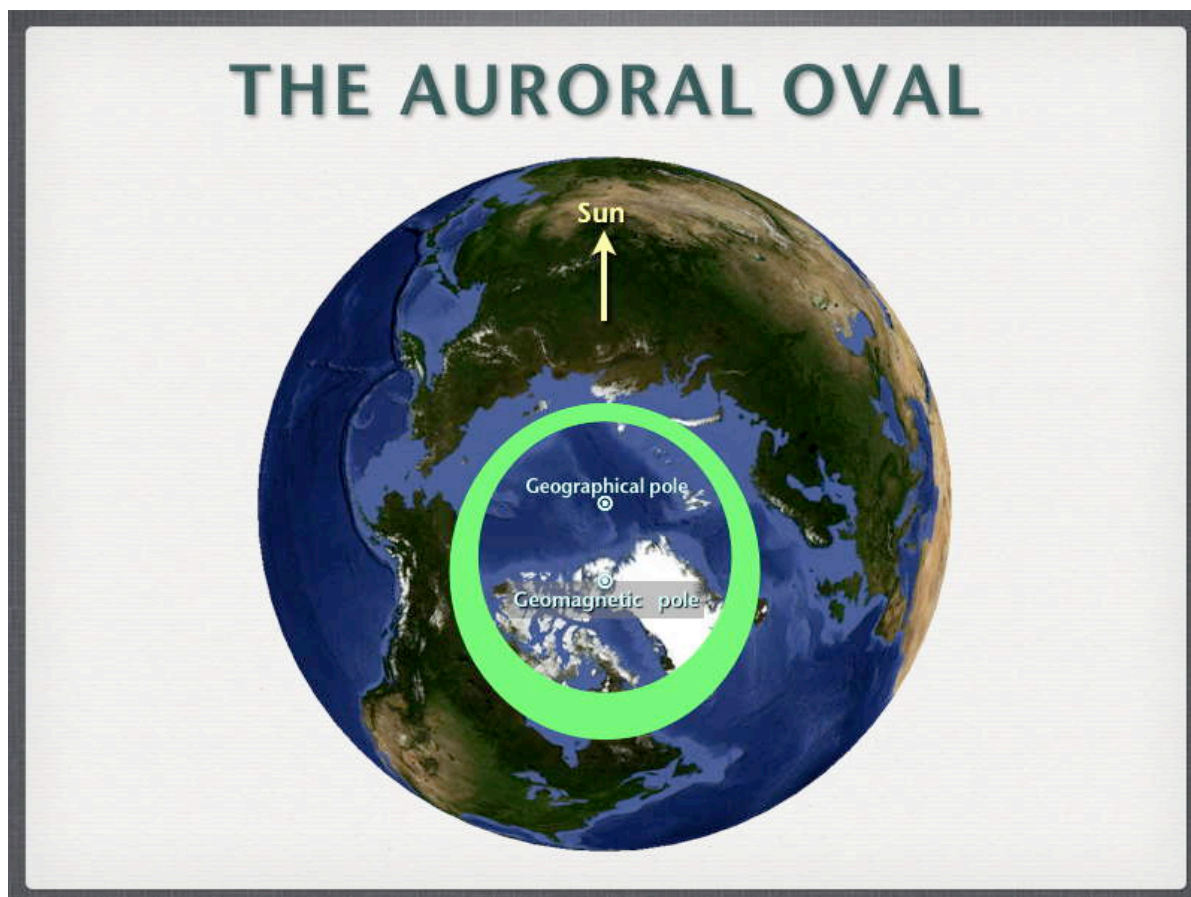
The Sun – the cause of aurorae

Although aurorae are a phenomenon of the Earth's upper atmosphere, their cause actually lies 93 million miles away – the Sun. There's a continual flow of gas streaming away from the Sun called the solar wind, and it's the particles in the solar wind that cause aurorae. When the solar wind reaches the Earth it doesn't just slam straight into us. The Earth's magnetic field deflects the atomic particles of the solar wind and funnels them down onto the atmosphere in a ring around the Earth's poles called the *auroral oval*. This is a band of virtually permanent aurorae about 10 degrees wide in latitude, where the atomic particles from the Sun are being accelerated down the lines of magnetic force onto the upper atmosphere.

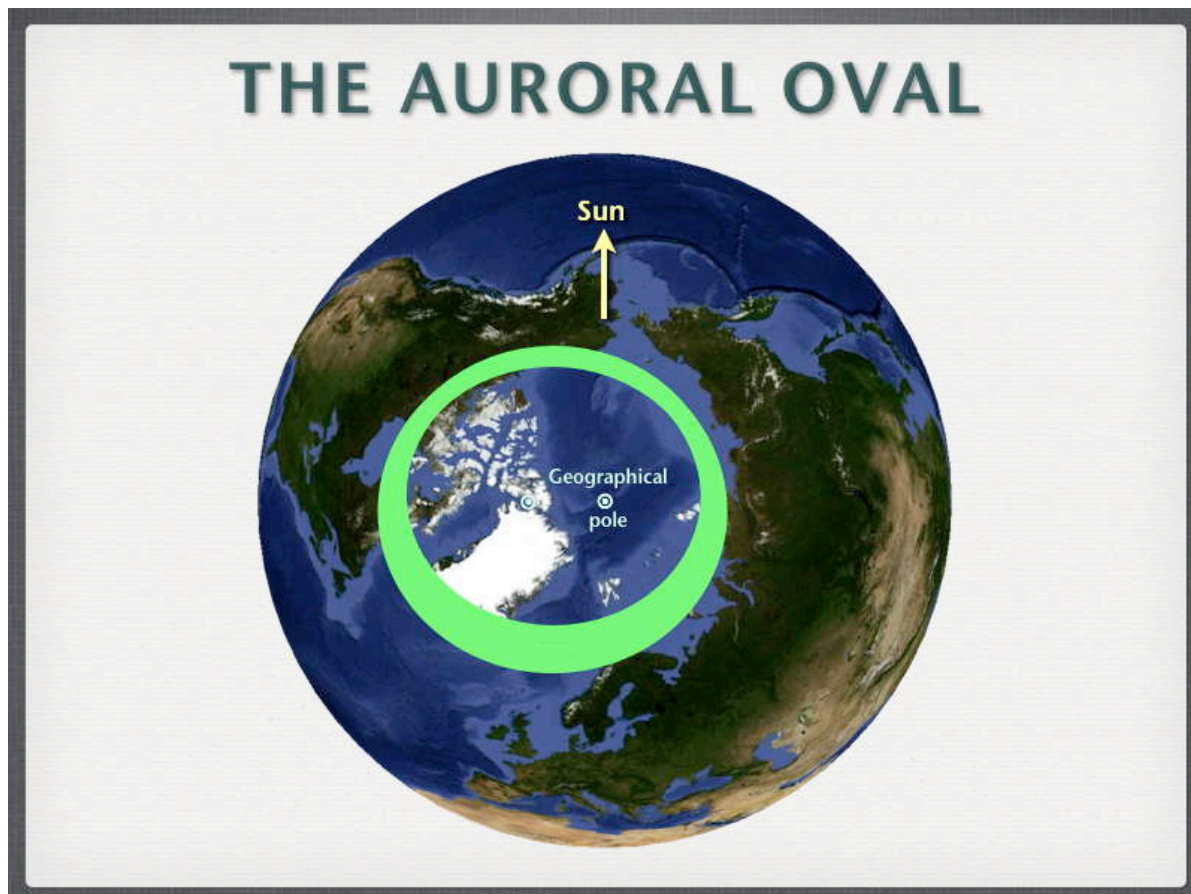
The auroral oval

The auroral oval is centred not on the geographical (true) pole, but the *geomagnetic* pole. The difference arises because the Earth's magnetic field is tilted relative to the Earth's axis of rotation. The tilt is about 10 degrees, so that the north pole of the magnetic field is about 700 miles from the geographical pole, just to the northwest of Greenland.

The auroral oval is broader on the night side of the Earth because the solar wind stretches out the Earth's magnetic field on the night side. Being shaped by the solar wind, the auroral oval is more or less fixed in space while the Earth rotates underneath it, as the diagrams on the next page illustrate.



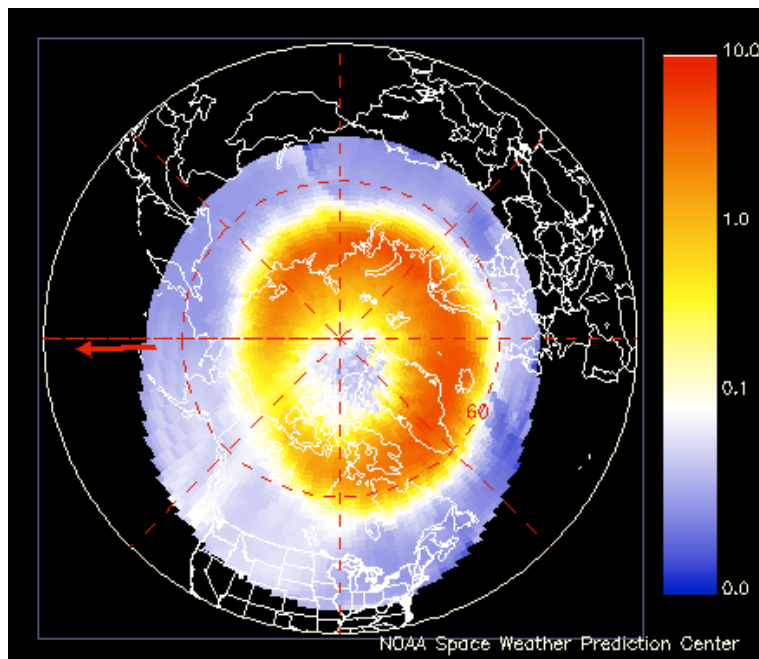
Above: Auroral oval during night time in North America. The broadest side of the oval (the side away from the Sun) is over North America.



Above: Auroral oval during night time in Europe. The oval is now broadest on the side over Europe and extends over northern Norway.

There's an oval around the south magnetic pole as well, but you'll need to go to Antarctica to see it.

The ovals in the diagrams above are highly idealized – the real ones are a lot more irregular. But what's important to realize is that there's a basic level of auroral activity almost all the time in this ring around the poles. For people who live under the auroral oval, such as northern Norway, Iceland or Alaska, the northern lights are a regular feature of the night sky. That's why it's necessary to go north to see the aurorae.



At left is a moderately active auroral oval, coloured orange and yellow, from observations made by one of the series of Polar-orbiting Operational Environmental Satellites (POES) operated by the US National Oceanic and Atmospheric Administration (NOAA). The red arrow at left indicates the direction of the Sun, which in this case shows the time to be near midnight in Europe. Note that the oval is broadest and strongest on the side away from the Sun.

It should also be apparent from the preceding diagrams that you can actually go too far north in search of aurorae. If you go beyond the auroral oval you're no better off in terms of seeing aurorae than if you'd stayed south of it. You might have thought that aurorae would be visible all the time at the north pole but in fact they aren't.

Coronal mass ejections

Back home in Britain some auroral activity is occasionally visible from Scotland but in England, particularly southern England, the aurorae are usually too far north to see.

Usually – but not always. Every so often there's an eruption on the Sun that causes a major disturbance of the Earth's magnetic field. And when this happens the auroral oval gets much bigger. It expands and moves further south, and that's when aurorae become visible not just in England but right down to the Mediterranean.

These eruptions on the Sun are called *coronal mass ejections*, or CMEs. These weren't even known about until the 1970s when astronomers first put telescopes in space. Previously it was thought that solar flares were the cause of major auroral displays, but we now know that's not the case. Flares sometimes occur at the same time as CMEs, but it's the CME that causes the aurora rather than the flare.

The picture below shows a CME seen through a special telescope on a Sun-watching satellite called SOHO. There's a disk in the centre that blocks light from the Sun, but emerging from behind it at top left is a coronal mass ejection. It's a huge bubble of gas consisting of atomic particles thrown off by a magnetic storm on the Sun, and although the CME has only just left the surface you can see it's already larger than the Sun (shown yellow at centre).



Typically the atomic particles from CMEs take around three days to reach the Earth, travelling at speeds of a million miles per hour or more. The one shown in the picture above is going off to the side, so it's not heading for the Earth – it's the ones that come straight at us that cause all the effects.

Click [here](#) for a movie of a series of CMEs that occurred in October 2003, culminating in a major outburst on October 28 known as the Hallowe'en storm. This storm hit Earth directly, saturating the detectors aboard SOHO (the 'snowstorm' effect) and causing aurorae visible as far south as Texas and Florida in the USA and the Mediterranean in Europe.

The Sun goes through a cycle of activity lasting 11 years or so, during which the number of such storms on its surface rises and falls, and the number of aurorae follows the same cycle. Currently solar activity is picking up towards the next maximum [expected early in 2013](#) and with it the number of bright aurorae is increasing. Activity should remain high throughout 2014 and into 2015.

Measuring activity levels

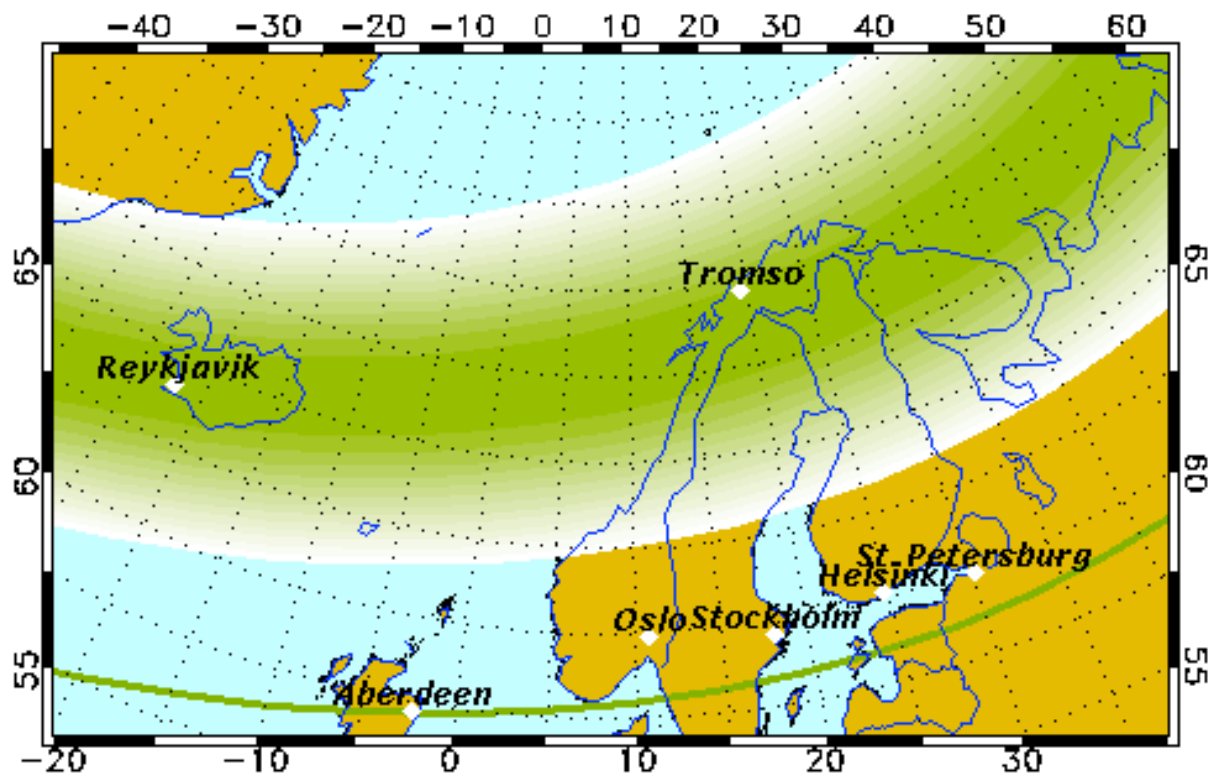
Geophysicists measure the disturbance of the Earth’s magnetic field with a figure called the Kp index. The K is short for Kennziffer, which is a German word meaning simply index number, and the p suffix means it’s the average for the whole planet based on readings from stations around the world. The higher the Kp index, the greater the level of auroral activity.

A value of 1 or 2 means that nothing much is happening, 3 or 4 indicates moderate activity and 5 or above is a real storm, up to a maximum of 9.

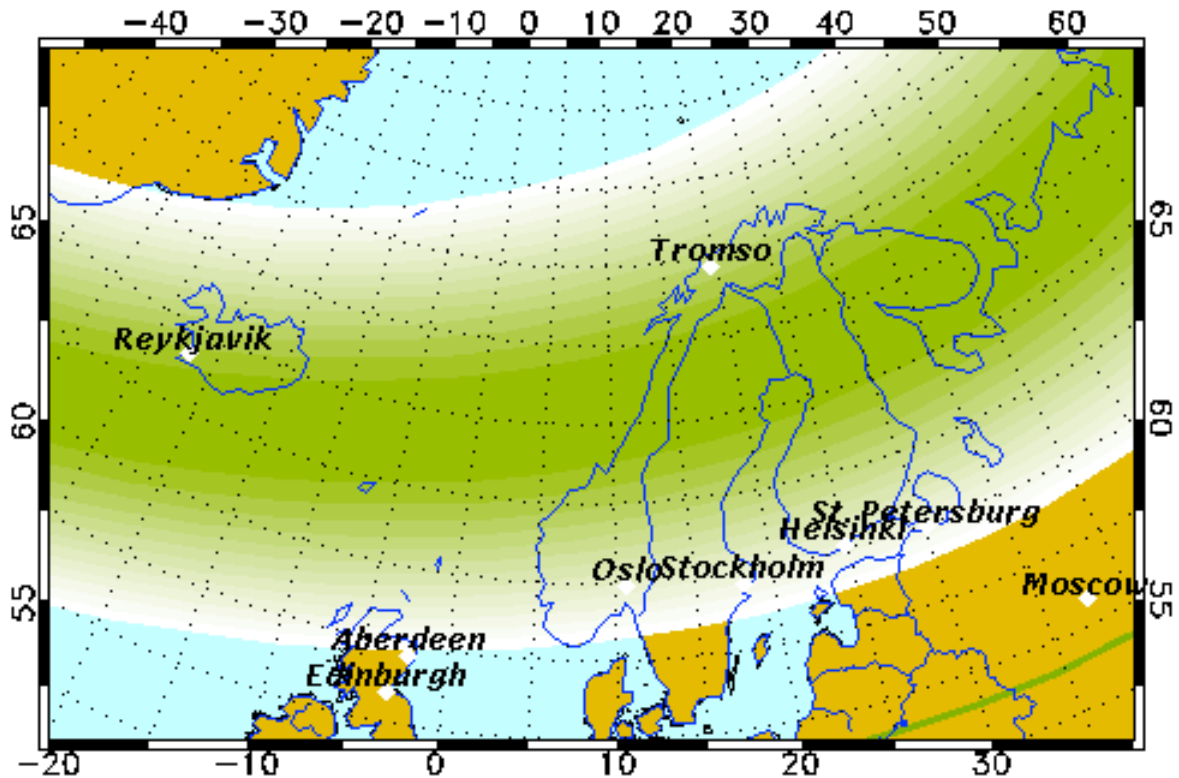
How do these figures translate into what you can actually see?

The amazing expanding oval

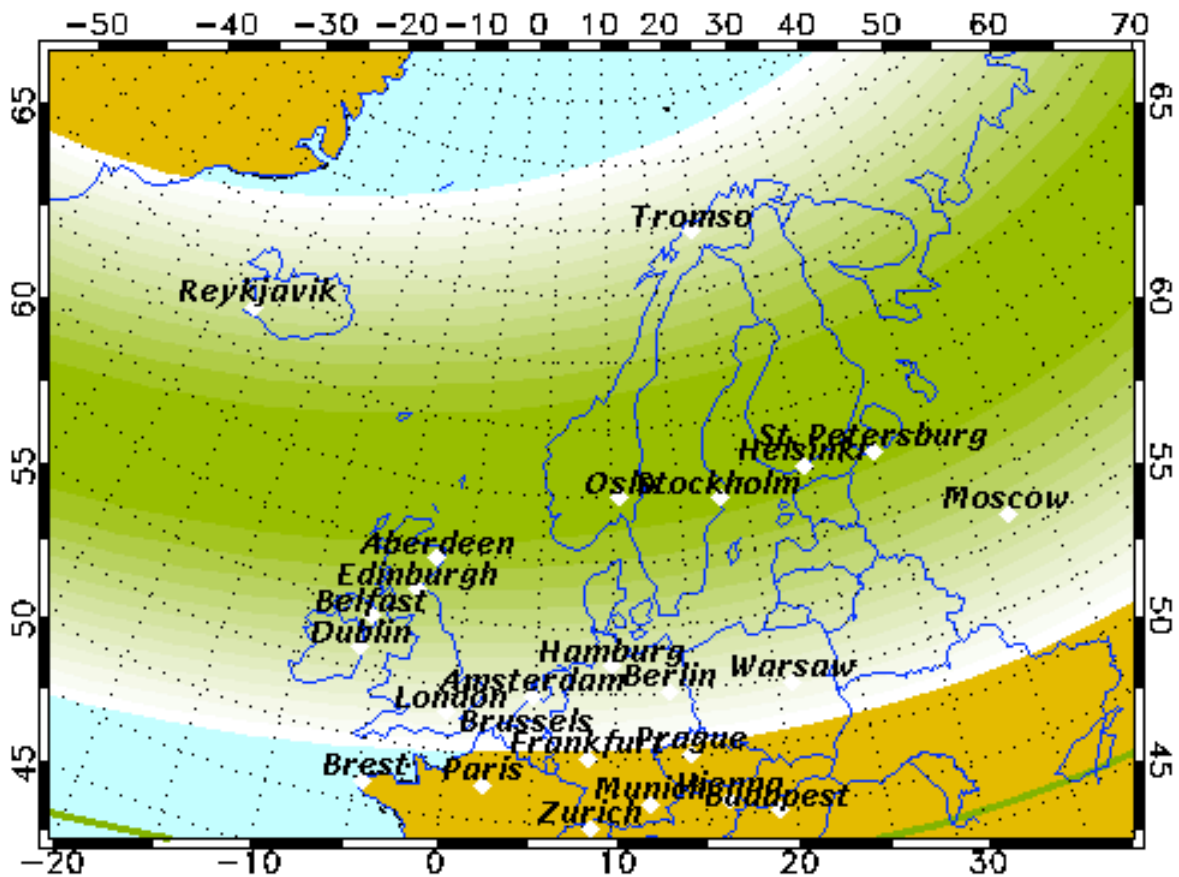
The following diagrams from the [Geophysical Institute at the University of Alaska](#) give some idea of how far south the auroral extends for various Kp levels. The light green band is the auroral oval, and the green curve to the south of it is the southernmost latitude at which you’d expect to see the top of the aurora peeking up above the horizon.



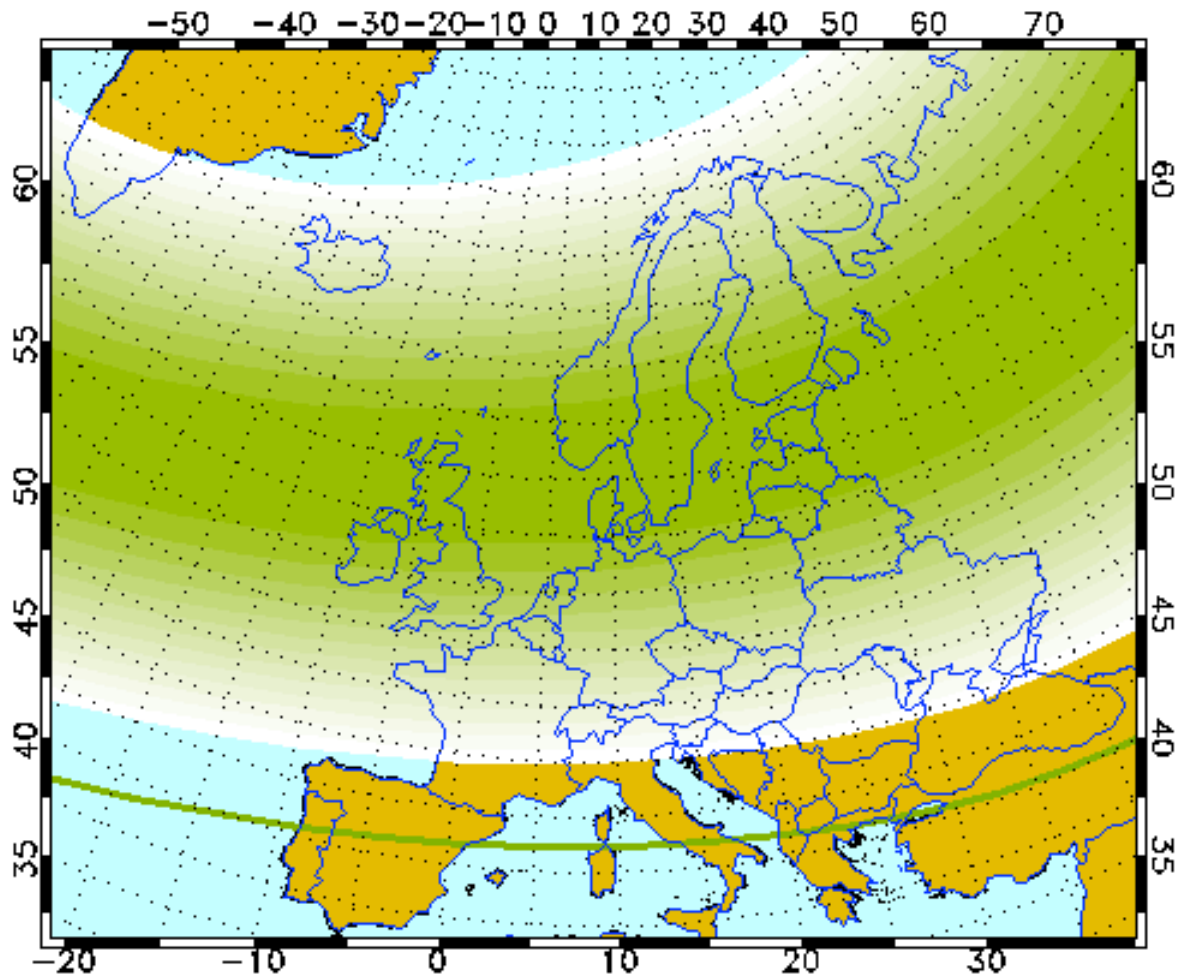
For a Kp index of 4 (above) the auroral oval itself is still clear of the north of Scotland, but the curved green line goes through Aberdeen so you’d expect to see some activity down to about there, and also in the southernmost parts of Norway.



When the Kp reaches 6 (*above*) the auroral oval extends down to Aberdeen. The green curve showing the southern limit of visibility is off the bottom here but it actually goes through central England. So when the Kp reaches 6 even people in the south of England should start looking out because the level of activity might become strong enough to be visible.



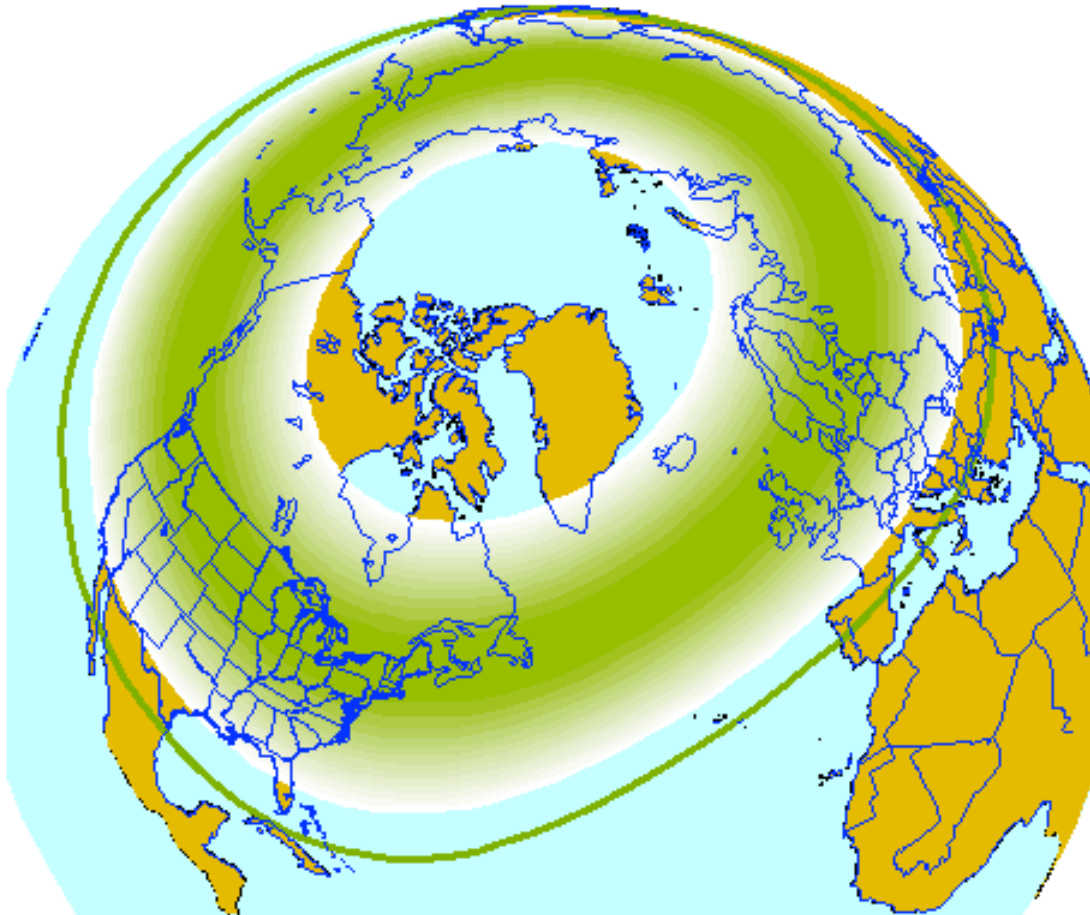
At a Kp of 8 (*previous page*) the auroral oval covers all the British Isles and into northern France, so this is a really major storm. Although of course it's still not guaranteed that we'll see anything – the aurora could happen while we're on the day side or when it's cloudy so there's still an element of luck involved.



If the Kp reaches its maximum level of 9, as shown above, the auroral oval spreads down as far as southern France, and aurorae are visible into central Spain and Italy. It's storms of this intensity that would have been seen by Galileo in Italy and which led him to coin the term aurora.

Zooming out for a wider view (*next page*) we see that at a Kp level of 9 the auroral oval reaches even farther south in the USA, down to the southern states, which goes back to the fact that the geomagnetic pole is tilted 10 degrees in that direction.

Notice by the way that the northern boundary of the oval remains pretty much unchanged in all this – it's only the southern edge that expands.



Stylized view of the complete northern auroral oval for a Kp index of 9.

Observations and forecasts

Images of the current auroral oval from observations by the National Oceanographic and Atmospheric Administration's Polar-orbiting Operational Environmental Satellites (POES) can be found at <http://www.swpc.noaa.gov/pmap/index.html>.

The website www.spaceweather.com has regular news on solar and auroral activity, along with stunning photographs, and issues alerts by phone to subscribers.

Measurements of the Kp index at 3-hourly intervals are published online by the German Research Centre for Geosciences (GFZ):

http://www-app3.gfz-potsdam.de/kp_index/quicklook.html.

Local observations for three stations in Norway (including Tromsø) and one in Denmark are at <http://flux.phys.uit.no/Kindice/>.

Short-term forecasts are issued by the Geophysical Institute of the University of Alaska: <http://www.gi.alaska.edu/AuroraForecast/ShortTerm.asp>.

Aurorae on stamps: for a selection of postage stamps depicting aurorae, see [here](#).

Photographing aurorae

It's possible to take decent photographs of the aurorae with modern digital cameras, provided you follow a few golden rules.

- ▶ **TAKE MANUAL CONTROL** (the M setting). Don't use the special Scene position settings supposedly for night photography. They won't do the job. Use the M setting so you can control exactly what the camera's doing.
- ▶ **APERTURE** Open up the lens aperture (also known as the f-number or f-stop) to its widest to let as much light in as possible. Many cameras these days have apertures as wide as f/2.8 which is good.
- ▶ **ISO** Crank up the ISO setting to 800 or higher. ISO is what used to be known as film speed, and the bigger the number the more sensitive it is. A lot of cameras have ISO settings that go up to 1600 or even 3200, so if you've got it, use it. The downside is that the faster the setting the more grainy the pictures will be but if that's the difference between getting a shot and not getting one then it's a price worth paying.
- ▶ **TURN OFF AUTO FOCUS** The camera hasn't got anything to focus on when it's dark so it won't work. Use the manual focus and set it to infinity, which is the symbol that looks like a figure 8 on its side (∞).
- ▶ **TURN OFF THE FLASH** All you'll do is waste the battery and annoy everyone around you. If you can't turn it off, try taping over it.
- ▶ **EXPOSURES** Try a range of exposures between about 5 and 15 seconds, depending on the aperture and ISO speed you've got. The shorter ones will be better to cut down any movement of the camera and aurora but you'll only get away with those if you've got a very wide aperture and very high ISO speeds. There's really no hard and fast rule – just try a range. If you haven't got a tripod you'll need to rest the camera securely somewhere.
- ▶ **DON'T USE THE ZOOM** Aurorae cover a large area of sky, so zoom out to the widest angle possible.
- ▶ **KEEP THE CAMERA WARM** You'll find that the batteries drain quickly when it's very cold.
- ▶ **SHOULD I USE THE RAW SETTING?** This depends whether you are familiar with image processing. Raw files contain the unprocessed data from the chip which can then be manipulated on your computer with an image processing program. This can result in better-quality images. The downside is that the chip defaults to its maximum file size (such as 12 Megapixels) when shooting Raw so you will use up your memory card more quickly and each image will take longer to save.

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