AURORAS

Written and compiled by Aurora G. Miller,
Chief Science Officer USS Odyssey

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Introduction

"The Valkyrior are warlike virgins, mounted upon horses and armed with helmets and spears. When they ride forth on their errand, their armour sheds a strange flickering light, which flashes up over the northern skies."

This quotation from a book by Thomas Bulfinch, published in 1855, is the claim that the Northern light or its scientific name *Aurora Borealis* has played a part in the formation of the ancient Norse Mythology.

While a striking notion, there is not a vast body of evidence in the Old Norse literature supporting this assertion. Although auroral activity is common over Scandinavia and Iceland today, it is possible that the Magnetic North Pole was considerably further away from this region during the centuries before the documentation of Norse mythology.

The first Old Norse account of *norðrljós* is found in the Norwegian chronicle *Konungs Skuggsjá* from AD 1230. The chronicler has heard about this phenomenon from compatriots returning from Greenland, and he gives three possible explanations: that the ocean was surrounded by vast fires, that the sun flares could reach around the world to its night side, or that glaciers could store energy so that they eventually became fluorescent.

In ancient Roman mythology, Aurora is the goddess of the dawn, renewing herself every morning to fly across the sky, announcing the arrival of the sun. The persona of Aurora the goddess has been incorporated in the writings of Shakespeare, Lord Tennyson and Thoreau.

But where does this light come from? And why is only visible when close enough to either the North or South Pole?

Terminology

Auroras, sometimes called the northern and southern (polar) lights or aurorae (*singular:* aurora), are natural light displays in the sky, usually observed at night, particularly in the Polar regions. They typically occur in the ionosphere. They are also referred to as polar auroras.

In northern latitudes, the effect is known as the aurora borealis, named after the Roman goddess of dawn, Aurora, and the Greek name for north wind, Boreas, by Pierre Gassendi in 1621. The *Aurora Borealis* is also called the northern polar lights, as it is only visible in the sky from the Northern Hemisphere, with the chance of visibility increasing with proximity to the North Magnetic Pole. (Earth's is currently in the arctic islands of northern Canada.) Auroras seen near the magnetic pole may be high overhead, but from further away, they illuminate the northern horizon as a greenish glow or sometimes a faint red, as if the sun were rising from an unusual direction. The Aurora Borealis most often occurs near the equinoxes. The northern lights have had a number of names throughout history. The Cree people call this phenomenon the "Dance of the Spirits." In the middle ages the auroras have been called a sign from God (see Wilfried Schröder, Das Phänomen des Polarlichts, Darmstadt 1984).

Its southern counterpart, the *Aurora Australis* or the southern polar lights, has similar properties, but is only visible from high southern latitudes in Antarctica, South America, or Australasia. *Australis* is the Latin word for "of the South."

Auroras can be spotted throughout the world and on other planets. It is most visible closer to the poles due to the longer periods of darkness and the magnetic field.

<u>The Auroral Mechanism</u>

Auroras are the result of the emissions of photons in the Earth's upper atmosphere, above 80 km (50 miles), from ionized nitrogen atoms regaining an electron, and oxygen and nitrogen atoms returning from an excited state to ground state. They are ionized or excited by the collision of solar wind particles being funnelled down and accelerated along the Earth's magnetic field lines; excitation energy is lost by the emission of a photon of light, or by collision with another atom or molecule:

Oxygen emissions
: Green or brownish-red, depending on the amount of energy absorbed.

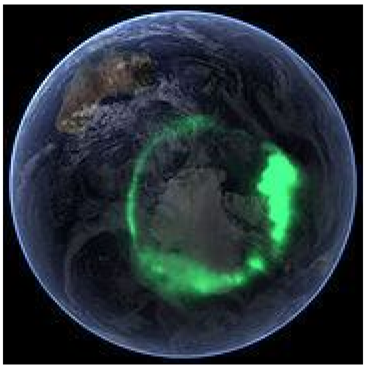
Nitrogen emissions
: Which is either blue if the atom regains an electron after it has been ionized or red if returning to ground state from an excited state.

Oxygen is unusual in terms of its return to ground state, it can take three quarters of a second to emit green light, and up to two minutes to emit red. Collisions with other atoms or molecules will absorb the excitation energy and prevent emission. The very top of the atmosphere is both a higher percentage of oxygen, and so thin that such collisions are rare enough to allow time for oxygen to emit red. Collisions become more frequent progressing down into the atmosphere, so that red emissions do not have time to happen, and eventually even green light emissions are prevented.

This is why there is a colour differential with altitude; at high altitude oxygen red dominates, then oxygen green and nitrogen blue/red, then finally nitrogen blue/red when collisions prevent oxygen from emitting anything.

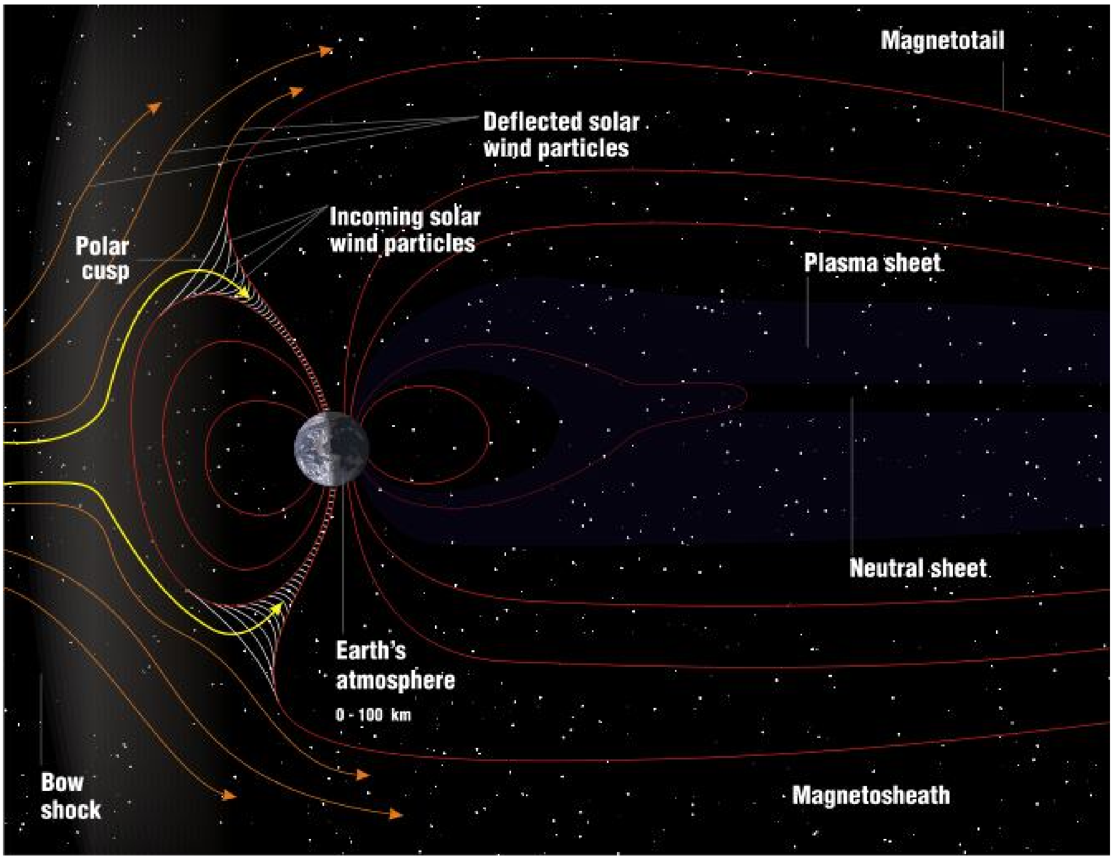
Auroras are associated with the solar wind, a flow of ions continuously flowing outward from the sun. The Earth's magnetic field traps these particles, many of which travel toward the poles where they are accelerated toward earth. Collisions between these ions and atmospheric atoms and molecules cause energy releases in the form of auroras appearing in large circles around the poles. Auroras are more frequent and brighter during the intense phase of the solar cycle when coronal mass ejections increase the intensity of the solar wind. Seen from space, these fiery curtains form a thin ring in the shape of a monk’s tonsure.

Origin



The ultimate energy source of the aurora is the solar wind flowing past the Earth. The magnetosphere and solar wind consist of plasma (ionized gas), which conducts electricity. It is well known (since Michael Faraday's [1791 - 1867] work around 1830) that when an electrical conductor is placed within a magnetic field while relative motion occurs in a direction that the conductor cuts *across* (or is cut *by*), rather than *along*, the lines of the magnetic field, an electrical current is said to be induced into that conductor and electrons will flow within it. The amount of current flow is dependent upon the rate of relative motion and the strength of the magnetic field, the number of conductors ganged together and the distance between the conductor and the magnetic field, while the *direction* of flow is dependent upon the direction of relative motion. Dynamos make use of this basic process ("the dynamo effect"), any and all conductors, solid or otherwise are so affected including plasmas or other fluids.

In particular the solar wind and the magnetosphere are two electrically conducting fluids with such relative motion and should be able (in principle) to generate electric currents by "dynamo action", in the process also extracting energy from the flow of the solar wind. The process is hampered by the fact that plasmas conduct easily along magnetic field lines, but not so easily perpendicular to them. So it is important that a temporary magnetic connection be established between the field lines of the solar wind and those of the magnetosphere, by a process known as magnetic reconnection.



It happens most easily with a southward slant of interplanetary field lines, because then field lines north of Earth approximately match the direction of field lines near the north magnetic pole (namely, *into* Earth), and similarly near the south magnetic pole. Indeed, active auroras (and related "substorms") are much more likely at such times. Electric currents originating in such way apparently give auroral electrons their energy. The magnetospheric plasma has an abundance of electrons: some are magnetically trapped, some reside in the magnetotail, and some exist in the upward extension of the ionosphere, which may extend (with diminishing density), some 25,000 km around Earth.

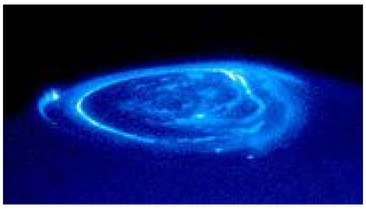
<u>Frequency of Occurance</u>

Auroras are common near the Poles. They are occasionally seen in temperate latitudes, when a magnetic storm temporarily expands the auroral oval. Large magnetic storms are most common during the peak of the eleven-year sunspot cycle or during the three years after that peak. However, within the auroral zone the likelihood of an aurora occurring depends mostly on the slant of IMF lines (the slant is known as B_z), being greater with southward slants.

Geomagnetic storms that ignite auroras actually happen more often during the months around the equinoxes. It is not well understood why geomagnetic storms are tied to Earth's seasons while polar activity is not. But it is known that during spring and autumn, the interplanetary magnetic field and that of Earth link up. At the magnetopause, Earth's magnetic field points north. When B_z becomes large and negative (i.e., the IMF tilts south), it can partially cancel Earth's magnetic field at the point of contact. South-pointing B_z's open a door through which energy from the solar wind can reach Earth's inner magnetosphere.

The peaking of B_z during this time is a result of geometry. The interplanetary magnetic field (IMF) comes from the Sun and is carried outward with the solar wind. Because the Sun rotates the IMF has a spiral shape. Earth's magnetic dipole axis is most closely aligned with the Parker spiral in April and October. As a result, southward (and northward) excursions of B_z are greatest then.

Aurora’s on other planets



Both Jupiter and Saturn have magnetic fields much stronger than Earth's (Jupiter’s equatorial field strength is 4.3 gauss, compared to 0.3 gauss for Earth), and both have large radiation belts. Aurora has been observed on both, most clearly with the Hubble Space Telescope. Uranus and Neptune have also been observed to have auroras.

The auroras on the gas giants seem, like Earth's, to be powered by the solar wind. In addition, however, Jupiter's moons, especially Io, are powerful sources of auroras on Jupiter. These arise from electric currents along field lines ("field aligned currents"), generated by a dynamo mechanism due to the relative motion between the rotating planet and the moving moon. Io, which has active volcanism and an ionosphere, is a particularly strong source, and its currents also generate radio emissions, studied since 1955. Auroras have also been observed on Io, Europa, and Ganymede themselves, e.g., using the Hubble Space Telescope. These are generated when Jupiter's magnetospheric plasma impact their very thin atmospheres. The bright spot, in the picture above, at far left is the end of field line to Io; spots at bottom right lead to Ganymede and Europa.

Auroras have also been observed on Venus and Mars. Because Venus has no intrinsic (planetary) magnetic field, Venusian auroras appear as bright and diffuse patches of varying shape and intensity, sometimes distributed across the full planetary disc. Venusian auroras are produced by the impact of electrons originating from the solar wind and precipitating in the night-side atmosphere. An aurora was also detected on Mars, on August 14, 2004, by the SPICAM instrument aboard Mars Express. The aurora was located at Terra Cimmeria, in the region of 177° East, 52° South. The total size of the emission region was about 30 km across, and possibly about 8 km high. By analyzing a map of crustal magnetic anomalies compiled with data from Mars Global Surveyor, scientists observed that the region of the emissions corresponded to an area where the strongest magnetic field is localized. This correlation indicates that the origin of the light emission actually was a flux of electrons moving along the crust magnetic lines and exciting the upper atmosphere of Mars.