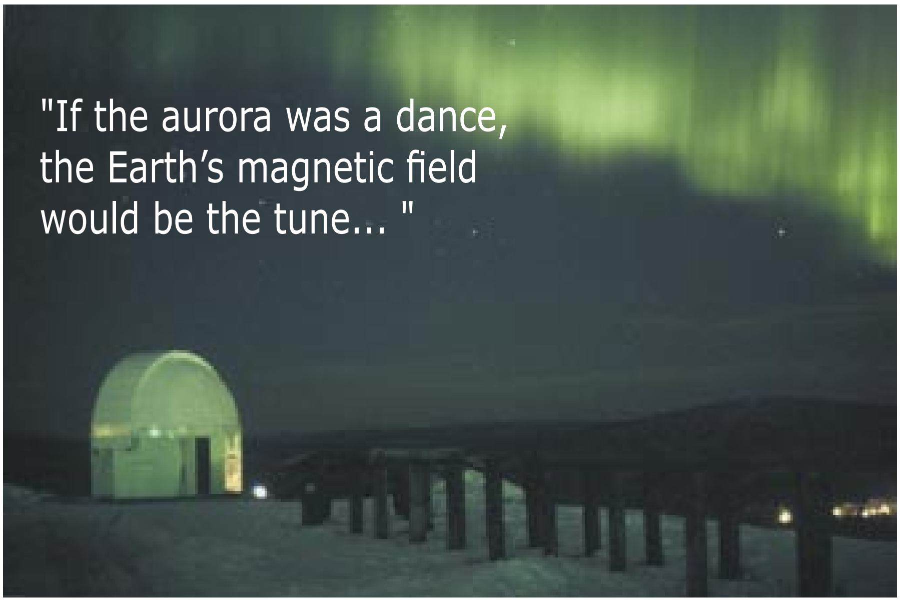
Aurora - Light Dancing in the Earth’s Magnetic Field



“Aurora above the Bengt Hultqvist Observatory in Kiruna (http://bho.spelaroll.se/). Photo: Martin Bohm, Department of Space Science, Luleå University of Technology.”

The Earth is a giant magnet. This simple fact, established at the end of the 16th century, is essential to an understanding of the processes that give rise to the aurora or Northern (and Southern) Lights.

The magnetosphere is the area around the Earth which is controlled by the latter’s magnetic field; it contains a mass of electrically-charged particles, known as plasma. The magnetosphere in its turn is shaped and defined by the solar wind, a stream of charged particles which flow from the sun at speeds of up to 1,000 kilometers per second. The solar wind compresses the Earth’s magnetosphere on the sunward side, forming a bow shock (much as the bow of a boat does in moving through water) at about ten Earth radii or 65,000 kilometers from the Earth. (The bow shock varies depending on the strength of the solar wind, from about five to 20 Earth radii.) On the side that faces away from the sun, the solar wind stretches the magnetosphere out in a long tail far into space.

The magnetosphere forms an almost unbreachable wall against the solar wind and thus protects the Earth’s atmosphere from direct contact with it, a contact which would strip away the atmosphere at a much faster rate than is the case at present. Some of the charged particles in the solar wind manage nonetheless to find their way into the Earth’s magnetosphere, either where the magnetic field divides itself over the poles in the so-called polar cusp, or on the downstream side of the Earth, in the magnetotail.

These particles, together with those already present in the magnetosphere, are accelerated to high speeds. The magnetic field leads them down towards the Earth in ring-shaped zones round the North and South Poles where they collide with atoms

Rick McGregor, Swedish Institute of Space Physics

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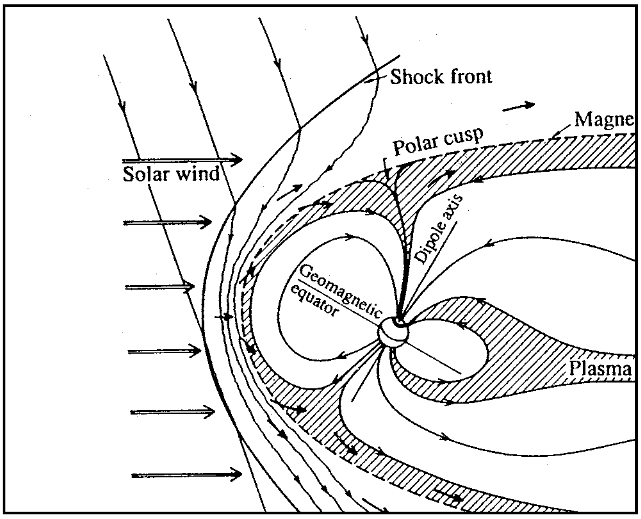
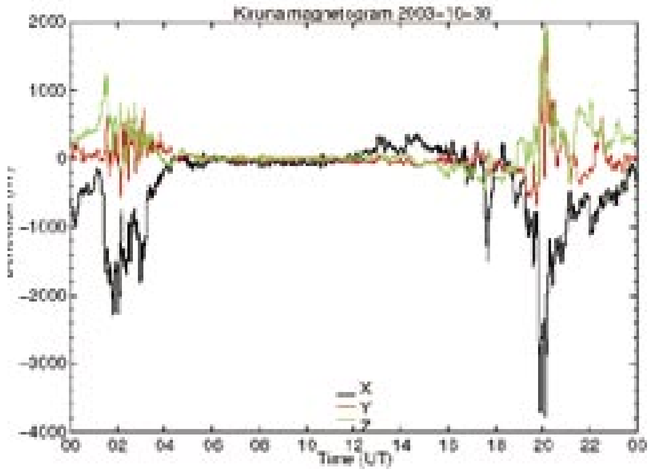
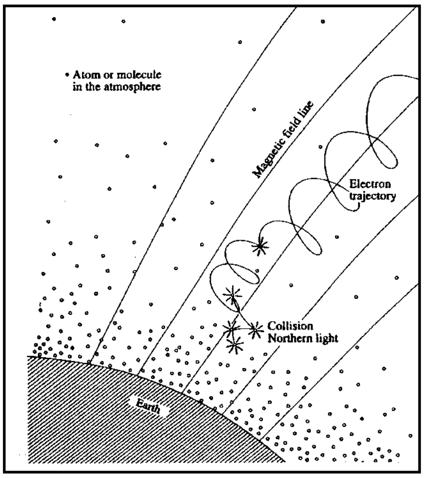




This magnetogram from 30 October 2003 shows the highest measured disturbance in the magnetosphere since IRF's measurements began over 40 years ago. Picture credit: IRF.



and molecules in the upper atmosphere. From space one can see that the aurora forms almost unbroken rings over the Arctic and over Antarctica, but with the naked eye it can only be seen at night. In general the auroral oval in the north is over northern Scandinavia when it is night-time in Europe and over Spitsbergen when it is day-time.

The auroral ovals are roughly centred on the Earth's magnetic poles, but pushed slightly towards the nightside (the side away from the sun) by the solar wind. One should note, however, that the North Magnetic Pole has wandered around considerably over the centuries. Studies of the magnetic field information preserved in solidified lava and in lake-bottom sediments have enabled scientists to reconstruct the position of this, the dipole pole. At present it is on northern Ellesmere Island off the north-western coast of Greenland, but 2000 years ago it was much closer to the geographic North Pole. A thousand years ago it was between Siberia and the pole.

Most of the visible aurora is caused by electrons with a typical velocity of about a tenth the speed of light. When they collide with atoms and molecules in the atmosphere some of this energy is tranferred from the electron to the atom. The excess energy is emitted in the form of a flash of light. Aurora consists of a myriad of such flashes. A considerable number of charged particles are involved and during a relatively active aurora each cubic millimetre of the atmosphere is struck by hundreds of millions of electrons every second. Each high-velocity electron from space can excite many atoms before it is slowed down completely. These collisions begin out at 300 kilometres altitude or more and continue down to about 90 kilometres, the lower limit of the aurora.

The true source of the aurora is the sun. It radiates energy in all directions, most of it in the form of electromagnetic radiation such as visible light. The sun also radiates plasma (charged particles, primarily electrons and protons) and this is important for an understanding of the processes giving rise to the aurora. This stream of particles, the solar wind, moves through the solar system at an average speed of 400 km/sec. Solar wind plasma comes from such features on the solar surface as corona holes and the long tail-like formations called streamers.

Plasma and the magnetic field are so strongly linked that the solar wind plasma can carry the solar magnetic field with it out into space, where it is known as the Interplanetary Magnetic Field (IMF). The IMF points in two different directions, and at the boundaries between them, the solar wind is unusually fast. Where this occurs, aurora is more active, though not as active as that caused periodically by the giant bubbles of solar plasma called Coronal Mass Ejections (CMEs). When these plasma bubbles reach the Earth, violent magnetic storms occur and Aurora Borealis (in the north) and Aurora Australis (in the south) extend over large parts of the globe.

Charged particles, electrons and ions, are steered along the magnetic field lines in spirals. The rays of light in the aurora are thus oriented in the same direction as the magnetic field. To determine the reason for a particular type of aurora we should therefore follow the magnetic field line out from the outer, ionized part of the atmosphere (the ionosphere) into the magnetosphere.

Aurora can take many forms, from green arcs early in the evening with undefined edges, arcs which can transform into curtains and even spirals as the shape of the magnetic field is changed by electric currents. If one is directly under an aurora the rays can appear to come from a single point in the sky and radiate out in all directions as a corona. The most impressive auroras occur during so-called substorms, and the whole sky can be covered by the most fantastic shapes in green, red, blue and violet which change shape continually. Later these active auroras can give way to fainter, pulsating aurora. The atoms and molecules which are excited by the electrons give off light of different wavelengths and thus different colours: green and red (up high) from oxygen, blue and red (down low) from nitrogen.

The Swedish Institute of Space Physics, with headquarters in Kiruna, monitors the aurora in northern Scandinavia with the aid of such observatory instruments as magnetometers (which measure absolute and short-term variations in the magnetic field) and an all-sky camera (which takes photographs of the whole sky once a minute during winter nights). The institute also studies the underlying processes behind the aurora with the aid of ground-based systems such as ALIS (a system of light sensitive digital imagers) and EISCAT (the European Incoherent Scatter radar facilility) and with instruments on board satellites in orbit in the Earth's magnetosphere.

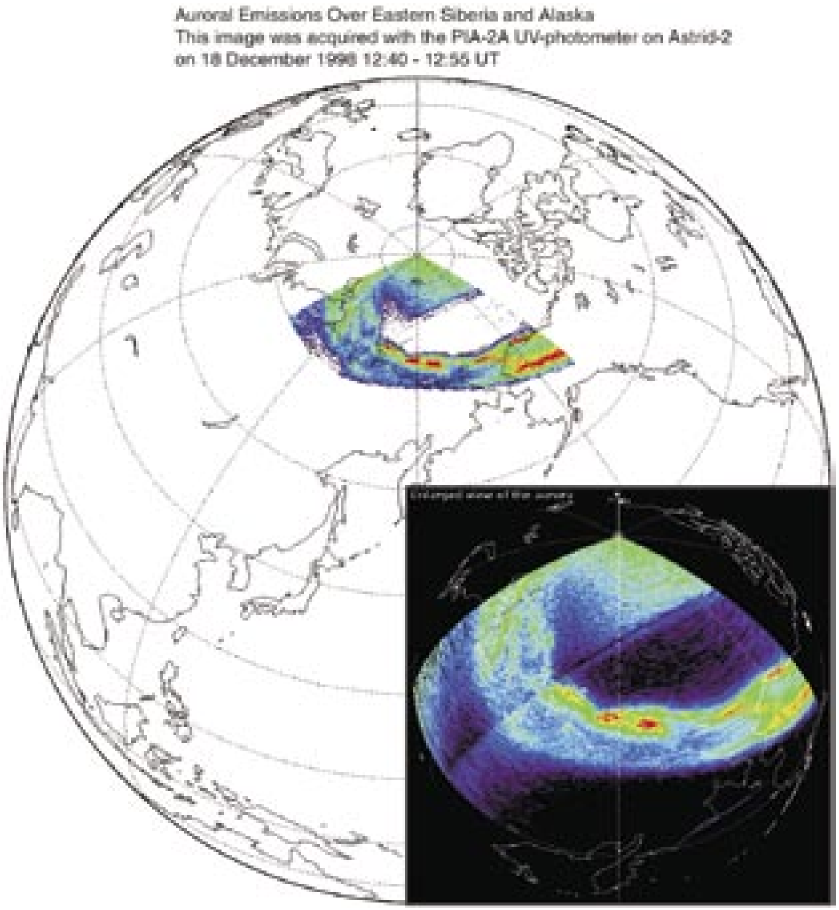
Web pages:

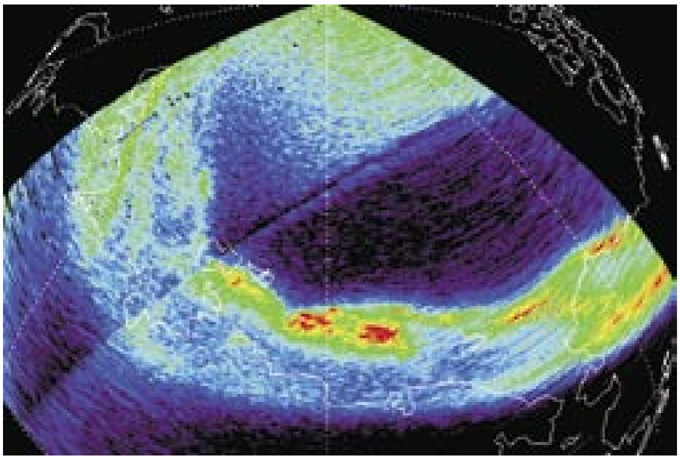
Swedish Institute of Space Physics (IRF): http://www.irf.se

IRF's observatory page: http://www.irf.se/Observatory (magnetometer and all-sky camera)

Auroral Large Imaging System (ALIS): http://www.alis.irf.se/ALIS/

EISCAT Scientific Association: http://www.eiscat.se/





"The instrument PIA on board the Swedish satellite

Astrid-2 was able to make this image of aurora as seen from space. PIA was designed and built at the Swedish Institute of Space Physics (IRF) in Kiruna. Picture credit: IRF."