Space Environment TOPICS

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SE-12

Aurora

The beautiful and often eerie curtains of light in the night-time sky known as aurora have been enjoyed by people for millennia. Called the *aurora borealis* or "northern lights" (fig. 1), aurora also occur in the Southern Hemisphere and are called the *aurora australis*.

Many legends, myths and superstitions have revolved around the aurora throughout the history of mankind. The early dragon legends of China and Europe are said to have originated from the aurora. Some cultures have regarded the sighting of the aurora as a sign of royal birth; to others it suggests ghosts of the dead or

Figure 1.—Aurora borealis *taken in the Copper River Delta, Alaska; ©1990 by Dave Parkhurst, Alaska Naturally.*

the precursor for war. The Eskimos of North America believed that if you whistled at the aurora it would sweep down and take you from the earth; by clapping your hands you could force it to retreat.

Magnets Are the Key

The origin of the aurora is 93 million miles (149 million km) from Earth at the Sun. Energetic particles from the Sun are carried out into space along with the ever-present hot solar wind. This wind sweeps supersonically toward Earth through interplanetary space at speeds ranging from 300 to over 1000 km per second, carrying with it the solar magnetic field. The solar wind distorts the Earth's magnetic field to create the comet-shaped magnetosphere (fig. 2).

The terrestrial magnetic shield acts as a barrier, protecting the Earth from energetic particles and radiation in the hot solar wind. Most of these energetic particles are deflected around the Earth by the magnetosphere, but some get trapped. Electrons trapped in the Earth's magnetic field are accelerated along the magnetic field toward the polar regions and then strike the atmosphere to form the aurora.

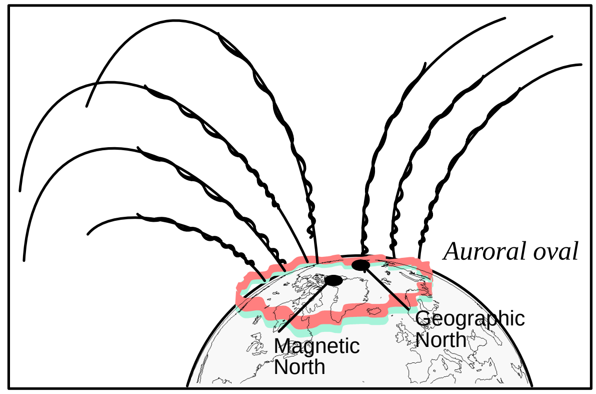

Figure 3. Energetic electrons spiral down the geomagnetic field lines towards the polar regions, striking the upper atmosphere, resulting in the display of auroral lights.

The particles, which stream down the magnetic field of the Earth, reach the neutral atmosphere in a rough circle called the auroral oval. This circle, or annulus, is centered over the magnetic pole and is around 3000 km in diameter during quiet times. The annulus grows larger when the magnetosphere is disturbed. The location of the auroral oval is generally found between 60 and 70 degrees north and south latitude (fig. 3).

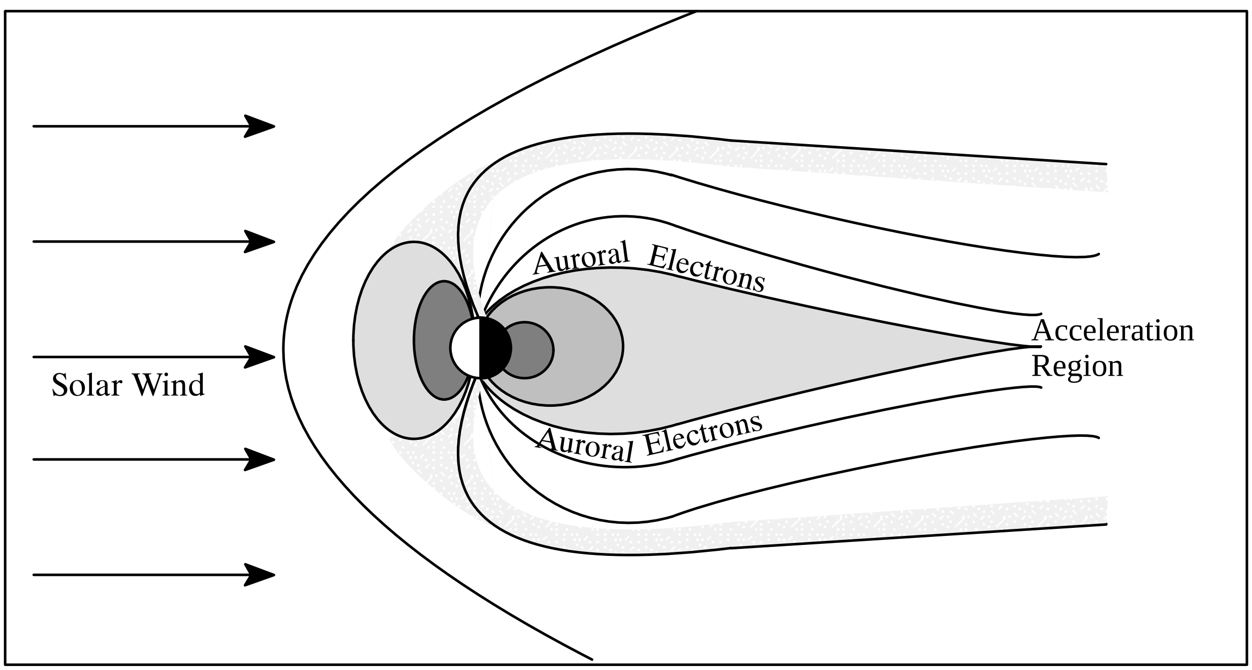

Figure 2.—A "side view" of the Earth and magnetosphere showing some of the important regions.

Auroral features come in many shapes and sizes. Tall arcs and rays start brightly 100 km above the Earth's surface and extend upward along its magnetic field for hundreds of km. These arcs or curtains can be as thin as 100 meters while extending from horizon to horizon. Auroral arcs can nearly stand still and then, as though a hand has been run along a tall curtain, the aurora will begin to dance and turn. After midnight, the aurora can take on a patchy appearance and the patches often blink on and off once every 10 seconds or so until dawn.

Most of the auroral features are greenish yellow but sometimes the tall rays will turn red at their tops and along their lower edge. On rare occasions, sunlight will hit the top part of the auroral rays creating a faint blue color. On very rare occasions (once every 10 years or so) the aurora can be a deep blood red color from top to bottom. In addition to producing light, the energetic auroral particles deposit heat. The heat is dissipated by infrared radiation or transported away by strong winds in the upper atmosphere.

The Chemistry of the Aurora

The aurora is caused by the interaction of high-energy particles (usually electrons) with neutral atoms in the Earth's upper atmosphere. These high-energy particles can "excite" (by collisions) valence electrons that are bound to the neutral atom. The excited electrons can then return to their initial, lower energy state, and in the process release photons (light particles). This process is similar to the discharge in a neon lamp (fig. 4).

Any particular color of the aurora depends on a specific atmospheric gas and its electrical state, and on the energy of the particle that hits the atmospheric gas. Atomic oxygen is responsible for the two main colors of green (wavelength of 557.7 nm) and red (630.0 nm).

Variations on the Sun

The Sun is a highly variable star that changes on time scales of hours to hundreds of years. The interplanetary magnetic field direction and solar wind speed and density are driven by the activity on the Sun. They can change drastically and influence the geomagnetic activity. As geomagnetic activity increases, the southern edge of the *aurora borealis* usually moves to lower latitudes. Similarly, solar mass ejections coin-

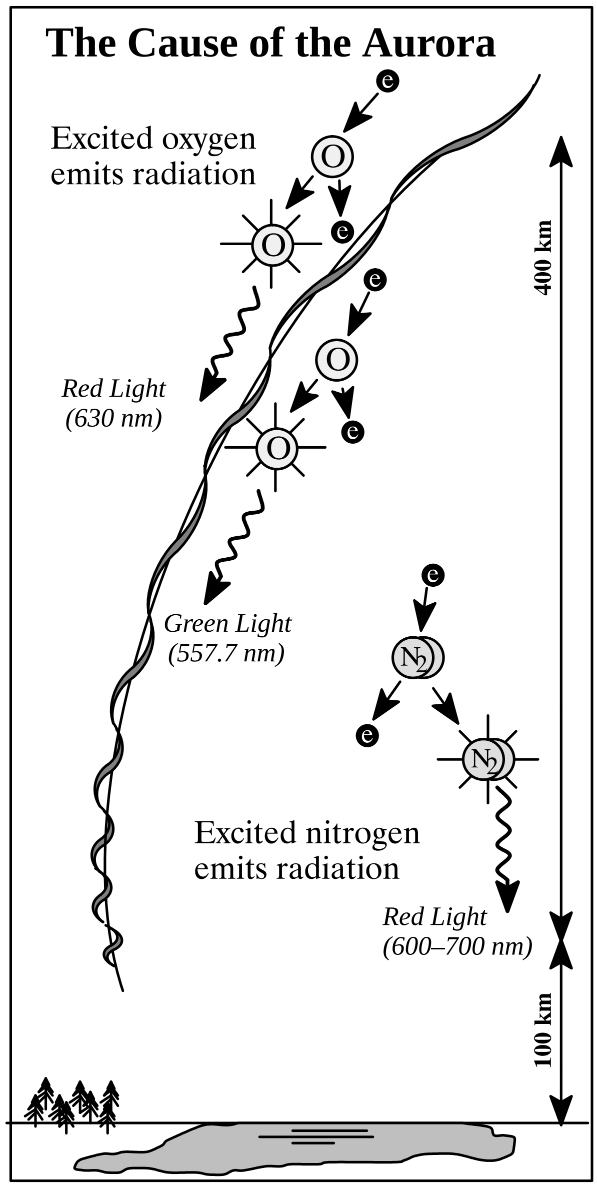

Figure 4.—Fast electrons from space travel along the magnetic field and strike oxygen atoms or nitrogen molecules in the atmosphere. Energy from an atom or molecule excited by fast electrons is released as different colors of light.

cide with larger auroral ovals. If the interplanetary magnetic field is in the opposite direction of the Earth's magnetic field, there can be increased energy flow into the magnetosphere and thus, increased energy flow into the polar regions of the Earth. This will result in an intensification of the auroral displays.

Disturbances in the Earth's magnetosphere are called geomagnetic storms. These, in turn, can produce sudden changes in the brightness and motion of the aurora called auroral substorms. The magnetic fluctuations of these storms and substorms may cause surges in electric power lines and occasional equipment failures in the power grid, resulting in wide-spread power outages. They can also impact the performance of satellite-to-ground communications and navigation systems. Magnetospheric storms can last several hours or even days, and auroral substorms can occur several times a day. Each substorm can deliver several hundred terajoules of energy—as much as the electrical energy consumed in the entire United States over 10 hours.

Measuring the Geomagnetic Field

The geomagnetic field can be measured with instruments called magnetometers. Data from many magnetometers allow observers to track the current state of the geomagnetic conditions. The magnetometer data are often given in the form of 3-hourly indices that give a quantitative measure of the level of geomagnetic activity. One such index is called the K-index.

The K-index value ranges from 0 to 9 and is directly related to the amount of fluctuation (relative to a quiet day) in the geomagnetic field over a 3-hour interval. The higher the K-index value, the more likely it is that an aurora will occur. The K-index is also, necessarily, tied to a specific observatory location. For locations where there are no observatories, one can only estimate what the local K-index would be by looking at data from the nearest observatory. A global average of auroral activity is converted to the Kp index. This index is available on a daily basis over the World Wide Web.

Resources

There are many sources for beautiful pictures of the aurora. A few are suggested here, and a longer list can be obtained from Space Environment Center.

Gift Shop, Geophysical Institute
University of Alaska
Fairbanks, AK 99775–0800

Astronomical Society of the Pacific
390 Ashton Ave.
San Francisco, CA 94112

National Geophysical Data Center
NOAA, E/GC2 Dept. 945
325 Broadway, CO 80303–3328
info@ngdc.noaa.gov

Remember also that many resources exist on the World Wide Web. Space Environment Center Web page is a good starting point for some of these resources:

http://www.sec.noaa.gov

References

Many beautiful pictures have been published in articles and books. Here are two:

Majestic Lights, Robert H. Eather, American Geophysical Union, Washington, D.C., 1980

Aurora Borealis, S.-I. Akasofu, Alaska Geographic Society, vol. 6, no. 2, Anchorage, AK, 1979.

Do-It-Yourself Resources

You can take your own photos of the aurora if you are in a location that permits good viewing of the event. This is an excellent article that will help you to do that:

"How to Photograph the Northern Lights," Floyd Damron, *Alaska* magazine, November, 1973.

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