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Abstract: The article presents information on celestial phenemenon of light called aurora borealis. While the lights do happen in our atmosphere, for their ultimate cause we need to look all the way back to the sun. The sun's complex magnetic fields can twist together which then trap the superheated coronal gas. The fields store up energy until it can't be twisted and stretched anymore, the fields break. Earth's molten interior generates a magnetic field that surrounds our planet and extends far into space. When solar particles fall from space they follow the magnetic field lines down to Earth, trying to converge on the tip of the bar magnet deep inside the planet. INSETS: Cycles of the Sun;Circles in the Sky;AURORAL MISCONCEPTIONS.

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When the Heavens Dance

How does nature stage a breathtaking light show called the aurora borealis?

The night starts out like any other clear evening for stargazing...until an unusual green “cloud” appears across the northern sky. The cloud brightens and begins to take shape, forming rippling curtains. They grow in size and climb the sky, and then patches of red appear, as if the heavens are catching fire. It's like nothing you've ever seen before.

Then the sky explodes. The curtains shoot up and cover the sky, meeting straight above you, like searchlights or lasers playing across the heavens. But this display is much more complex and unpredictable. It's as if you're looking down a tunnel of shimmering light. All around you the colorful curtains ripple and dance, like luminous veils being blown in a wind high above your head. Bright greens mix with deep reds and pinks. You might even catch sight of subtle blue and purple tints as you stand beneath the climax of nature's most spectacular light show. After a few minutes, the display dims and fades into random patches of light, switching off and on across the sky for the rest of the night.

What you have just witnessed is a grand display of northern lights, also known as the aurora borealis, the Latin words for “northern dawn.” Most people in North America might be lucky to see such an awe-inspiring spectacle once or twice a decade. Perhaps only once

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in a lifetime! People living in the northern United States (especially Alaska) and in Canada are more fortunate. They can see outstanding displays of northern lights every few months, with lesser displays shining in northern skies almost every week. By checking aurora-watch Web sites (see "Will I See Lights Tonight?", p. 13), you increase your chances of being outside and looking up when a great display begins to dance across your sky.

Solar Explosions

Though displays of auroras have been recorded by cultures around the world for thousands of years, only in the last few decades have we begun to understand what causes the light shows. While the lights do happen in our atmosphere, for their ultimate cause we need to look all the way back to the sun.

Massive explosions near the surface of the sun called flares release more energy in seconds than humans have generated in all of history. What triggers these flares is still unclear. The sun's bright surface is a tangled carpet of magnetic fields, twisting and coiling. The magnetic fields reach up into the atmosphere of the sun, called the corona, a region of thin but superhot gas glowing at temperatures of millions of degrees. (Technically, matter so hot isn't called a gas, but a plasma — a state of matter made of atoms ripped apart into bare nuclei and free-flying electrons.)

The sun's complex magnetic fields can twist together like rubber bands, which then trap the superheated coronal gas. The fields store up energy until, like a rubber band that can't be twisted and stretched anymore, the fields snap. They suddenly release torrents of intensely hot gas and searing radiation such as X-rays and ultraviolet light.

Space Weather

The expanding gas and radiation can blow a bubble in the sun's tenuous atmosphere. The bubble bursts, blowing a cloud of atomic particles away from the sun and into space. This event is called a coronal mass ejection. In time-lapse movies from satellites such as SOHO, the mass ejections make the sun look as if it is blowing off puffs of smoke.

One of the earliest discoveries in the space age was that the space between the planets always is filled with atomic particles blowing from the sun, in what we call the solar wind. Like the wind you feel outside on a pleasant day, the wind from the sun usually blows in a gentle "breeze."

But those powerful solar flares can stir up storms in the solar wind. The bursting bubbles of the sun's atmosphere can shoot dense streams of particles at high speed across the solar system, creating the space version of a squall or windstorm on Earth. Sometimes, Earth lies directly in the path of one of these solar storms. About two or three days after it leaves the sun, the storm front reaches Earth and hits us with a gale-force blast of energized particles — electrons and protons — that were generated 149 million kilometers away on the sun.

Magnetic Attraction

Fortunately, Earth has a "deflector shield" that usually protects us from the full blast of the solar storm cloud. The shield is our planet's magnetic field. Earth's molten interior generates a magnetic field that surrounds our planet and extends far into space. When solar wind particles reach Earth, they usually flow around our magnetic "force field," like water flowing around an island in a stream. But thousands of miles downstream, on the night side of Earth in our magnetic "tail," some of those streaming particles tunnel their way into our magnetic shield, in a sneaky rear-guard action.

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What happens then is still poorly understood, although orbiting satellites are beginning to provide a better picture. During an intense solar storm, our magnetic shield fills to the brim with energized particles that entered through the back door. These particles build up in number and intensity, like a battery being charged up. Then — zap! In a process perhaps similar to the twisting magnetic lines on the sun that created the storm in the first place, the magnetic field lines downstream from our planet twist and pinch off. They squeeze the energetic particles and squirt them toward Earth at the breakneck speed of 1,500 kilometers per second. The high-speed electrons and protons rain down onto our upper atmosphere from the region of space far above the night side of our planet.

All Charged Up

The particles act like a beam of electricity (in fact, that's what they are) shooting through a neon lamp. The lamp is almost a vacuum inside, with just a small amount of neon gas. When charged up by a jolt of electric current, the atoms first absorb the shot of energy, and then release it again in the form of light. The gas begins to glow.

In a similar process, the incoming beams of electrons and protons charge up atoms and molecules in our atmosphere such as oxygen and nitrogen. Zapped by the current of particles from space, these gases glow in shades of green, red, blue, and pink. Our atmosphere acts like a giant neon lamp, being hit with a billion kilowatts of energy in just a few minutes.

All that energy pulses far above us. The curtains of northern lights start about 500 kilometers up, so high that the space shuttle and space station sometimes fly through the tops of aurora displays. Very intense displays can penetrate down to an altitude of 80 kilometers. But usually the brightest auroral light we see comes from heights of 100-120 kilometers. That's still ten times higher than most jet airliners fly, and well within the layer of our atmosphere called the ionosphere, where the air is so thin that it remains a near-vacuum. You couldn't breathe up where the aurora dances, but electricity can work its magic to create a colorful light show.

So, if you are lucky enough to see a display of northern lights, think about where the action started, 149 million kilometers away at the sun. You are seeing the power of electricity, magnetism, chemistry, and atomic physics working together to make the heavens dance.

PHOTO (COLOR): A brilliant aurora captured on film by the author on November 11, 2002

PHOTO (COLOR): INSET: A powerful solar flare associated with an Earth-directed coronal mass ejection caught by a SOHO (Solar and Heliospheric Observatory) instrument on July 15, 2002

PHOTO (COLOR): INSET: This illustration shows a coronal mass ejection (CME) blasting off the sun's surface in the direction of Earth. Two to four days later, the CME cloud is shown striking and beginning mostly to be deflected around the Earth's magnetosphere. The green paths flowing out from the Earth's poles represent some of its magnetic field lines. The magnetic cloud of plasma can extend to 48 million kilometers wide by the time it reaches Earth.

PHOTO (COLOR): A veil of red and green photographed by the author

PHOTO (COLOR): The SOHO (Solar and Heliospheric Observatory) satellite is stationed 1.5 million kilometers out, on the sunward side of the Earth. The spacecraft is a big box crammed with instruments pointing continuously at the sun. Experts around the world use SOHO images and data to help them predict bad space weather affecting our own planet.

PHOTO (COLOR): A magnificent arc of auroral light!

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By Alan Dyer

Alan Dyer is an astronomer and program producer at the Calgary Science Centre, in Calgary, Alberta, Canada, a city that enjoys dozens of auroral displays every year.

Cycles of the Sun

The sun has its ups and downs. Every eleven years the sun peaks in activity, and erupts with more flares and coronal mass ejections. Dark regions of cool gas called sunspots break out over the surface. More auroras dance in our sky. This period of stormy solar behavior is called solar maximum and lasts one or two years.

Then, over several more years, the sun quiets down. Only the occasional flare explodes, and the sun's face can go unblemished by sunspots for days at a time. Few auroras appear, especially at southern locations.

The last solar maximum peaked in 2000, but some giant solar storms blew our way in 2001 and 2002, creating lifetime-best displays of northern lights in the spring and autumn of both years. The sun is now heading toward solar minimum, likely bottoming out in 2005 or 2006, before it climbs back to the next “solar max” in 2011 or 2012. However, large flares can still erupt without warning, giving us nights of dancing auroras at any time in 2003.

A.D.

PHOTO (COLOR): Approx. size of Earth

Circles in the Sky

When electrons and protons beam down from the magnetic fields around our planet, they form a unique pattern in the sky. Seen from space, our atmosphere lights up in two glowing rings, each about 4,000 kilometers wide. One ring is centered on the north magnetic pole in the Canadian Arctic, while the other is centered on the south magnetic pole in Antarctica. These rings are called “auroral ovals” — a bit misleading, as the rings are usually round.

They form because Earth behaves as if it has a giant bar magnet inside the planet. The “force-field” lines from Earth's magnetic interior extend out from the tips of the core magnet like a widening cone. When solar particles rain from space they follow the magnetic field lines down to Earth, trying to converge on the tip of the bar magnet deep inside the planet. The particles hit the atmosphere first, creating twin glowing rings of

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light. At the bottom of the world, the southern oval creates aurora australis, the southern lights, a mirror image of the more familiar northern lights.

In North America, the northern auroral oval usually shimmers over Alaska and Canada's northern territories, where people see northern lights almost every night. During a powerful solar storm, the auroral oval expands and heads south, bringing glowing lights to the skies of the southern United States and, on rare occasions, even Mexico.

A.D.

PHOTO (COLOR): Auroral oval as Imaged on December 9, 2002. The color bar indicates intensity of electrical activity, with red indicating areas of aurora visibility.

AURORAL MISCONCEPTIONS

Despite decades of scientific research, misconceptions and disproven theories about the northern lights persist in people's minds.

• “The lights are just sunlight reflecting off Arctic ice.”

You still hear people “explain” the aurora with this old idea. Somehow sunlight bounces off Arctic ice and lights up the atmosphere. OK, then how can we see auroras in winter when the polar regions are in constant darkness? This old idea never did work — satellite measurements and images now firmly have proven that the source of the northern lights is atomic particles hitting our atmosphere as they shoot down from space.

• “You can see the lights only in winter.”

Because the northern lights are associated with Arctic locations, people assume the lights can only appear when it is cold. Actually, the best displays often come in Spring and autumn, when Earth's magnetic field tends to connect more directly to the storm clouds coming from the sun. Even summer nights can be filled with auroral displays (except for Arctic regions when, during summer, the sky never gets dark at night).

• “The lights come down and touch the ground.”

Photographs and measurements from the ground and from rockets have proven that the curtains of auroral light descend to no lower than about 80 kilometers above the Earth. In fact, it is physically impossible for auroras to happen in the dense, bottom layers of our atmosphere such as the stratosphere (where jets fly) or troposphere (where weather clouds form). For auroras to “light up,” the air must be thin, just as a neon lamp must have a near-vacuum inside to work. Let in the dense outside air, and the lamp won't light.

A.D.

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