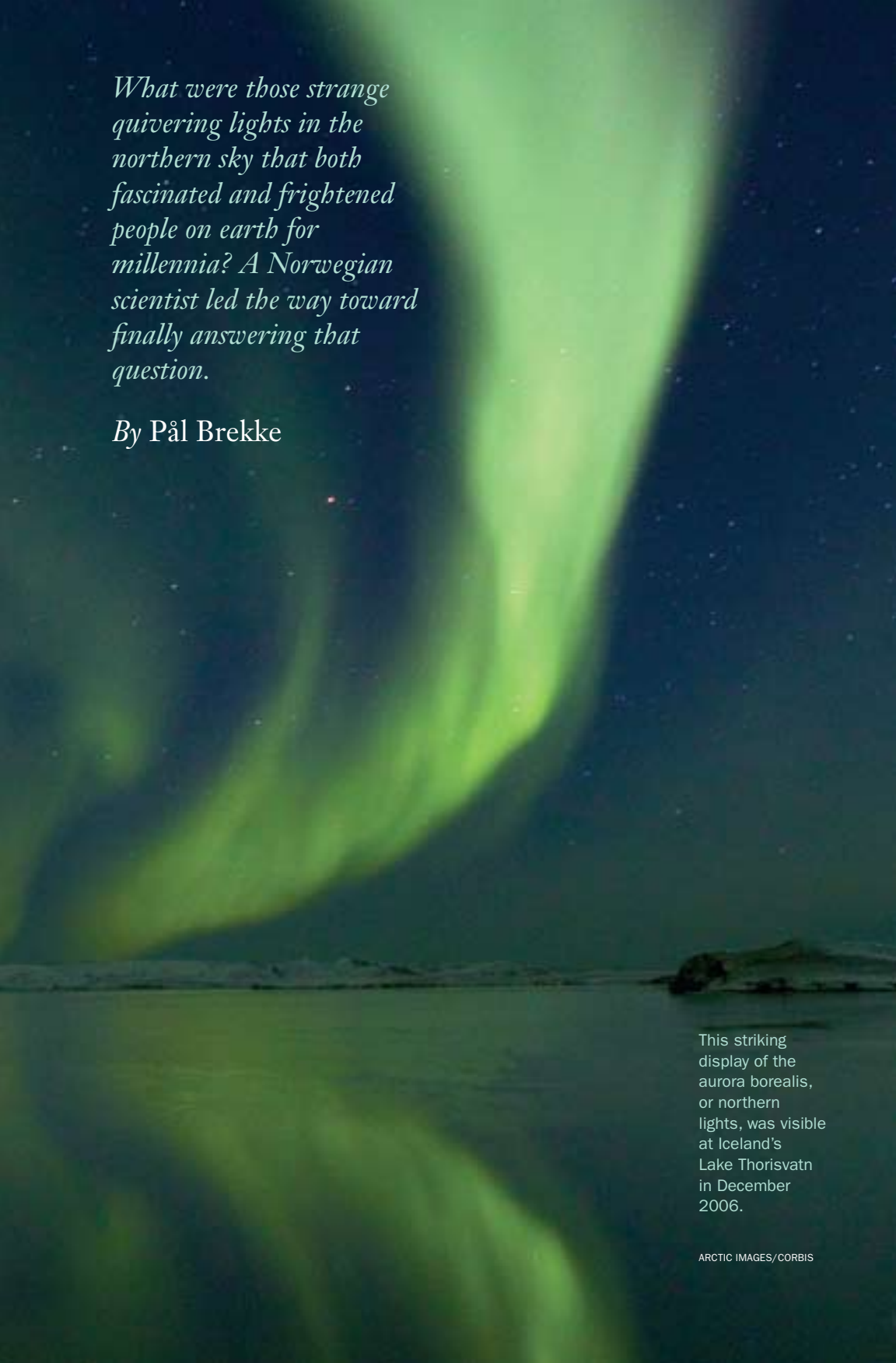
The Aurora Borealis

What were those strange quivering lights in the northern sky that both fascinated and frightened people on earth for millennia? A Norwegian scientist led the way toward finally answering that question.

By Pål Brekke



This striking display of the aurora borealis, or northern lights, was visible at Iceland's Lake Thorisvatn in December 2006.

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FOR THOUSANDS OF YEARS PEOPLE IN THE NORTHERN PART of the world have marveled at the spectacular and fearful displays that occasionally light up the night sky. There have been hundreds of stories and theories to explain what we now know as the aurora borealis or northern lights. But no one suspected until about a century ago a connection with the sun.

To be lucky enough to see the aurora is indeed a beautiful experience. As the well-known Austrian explorer Julius von Payer (1841-1915) once put it: "No pencil can draw it, no colors can paint it, and no words can describe it in all its magnificence."

Every northern culture has oral legends about the aurora, passed down for generations. During the Viking period, northern lights were referred to as reflections from dead maidens. The phenomenon was often referred to as a vengeful force. In ancient times, most people were afraid of the lights. Some people would not let their children outside to play while there were auroras, fearful they could get killed. Others thought it was all right as long as the children wore hats so that the aurora would not burn their hair off. In both Scandinavia and North America some people believed you could call the aurora by whistling, but to do so could be dangerous.

A drawing of northern lights made during a French expedition to Alta, Norway, in 1838-39. The artist was participating as an illustrator on the expedition.

Many cultures also believed that the aurora was a place for the dead—in particular for people who had died a violent or too early death, people who had been murdered, taken their own lives, been killed in war or had died in childbirth. Other cultures believed it was a message from the creator. An old tale from the Nordic countries said that, "God is angry when the aurora flames." In other cultures it was an omen of impending war, disasters or plagues.

The Sami (Lapp) people called it *guovssahas*, the light you can hear. The Eskimos in the northernmost parts of Canada believed that the northern lights were created by spirits, which, dressed in the mystical light, were having fun because the sun is away, that they were playing soccer with a walrus skull. The rapidly moving auroras were called the dance of death.

The Mandan Indians of North Dakota explained the northern lights as fires over which the great medicine men and warriors of northern nations

The aurora as depicted by the famous Norwegian explorer and statesman Fridtjof Nansen.

simmered their dead enemies in enormous pots.

The Finnish name for the northern lights, *revontulet*, is associated with the arctic fox. According to a folk tale, an arctic fox is running far in the north and touching the mountains with its fur, so that sparks fly off into the sky as the northern lights. One romantic conception found in Danish folklore is that these lights were due to a throng of swans flying so far to the north that

HINRICH BÅSEMANN, POLARFOTO

The northern lights seen over the EISCAT antenna in Tromsø. The antenna is part of an international

radar system that is observing the earth's atmosphere and aurora.

The first realistic description of auroras is found in the Norwegian chronicle The King's Mirror *from about A.D. 1230.*

they were caught in the ice. Each time they flapped their wings, they created reflections, which created the northern lights.

In Norway children were often told that waving with white clothing increased the motion of the aurora!

Auroras have been a source of inspiration for many painters, writers and composers. Many different painters have made very beautiful and realistic paintings and lithographs of auroras. A well-known Norwegian author, Theodor Caspari, finished a poem in 1882 with the following line: ". . . you are to me, Aurora, a symbol of life."

Every February there is a week-long Northern Light Festival in Tromsø, Norway, with everything from popular science lectures to jazz concerts and art displays.

The northern lights have had a number of names throughout history. The scientific name for the phenomena is aurora borealis, which is Latin for "northern dawn." Its counterpart is the aurora australis, or southern lights. It was the Italian scientist Galileo Galilei (1564-1642) who first used the expression "red dawn of the north." When the aurora borealis is extremely active it moves farther south, as will be explained later. On the latitude where Galileo was living, northern lights are mainly red in color.

The first realistic description of auroras is found in the Norwegian chronicle *The King's Mirror* from about A.D. 1230. It was originally written as a textbook, probably for the young King Magnus Lagabøte, by his father. At that time people thought the earth was flat and surrounded by oceans. One explanation was that the oceans were surrounded by fire and that auroras were the light from those fires reflected in the sky. Another possibility was that reflected sunlight from below the horizon illuminated the sky. A third explanation was fires in Greenland.

In more modern times the Swedish scientist Suno Arnelius (1681-1740) submitted his thesis in 1708 suggesting that solar rays were reflected off ice particles in the atmosphere. René Descartes also proposed a similar idea. The strong aurora on March 6, 1716, could be observed in large parts of Europe and gave birth to more modern science. Sir Edmund Halley published the first detailed description of the aurora in that year. He lamented that at the age of 60 years he had given up on experiencing this amazing phenomenon. He suggested that "auroral rays are due to the particles, which are affected by the magnetic field; the rays are parallel to Earth's magnetic field."

Joachim F. Ramus was the first Norwegian to write a scientific paper on the aurora, in 1745. The Swede Anders Celsius (1701-1744)—best known for

his temperature scale—and his co-worker Olof P. Hiorter found a correlation between intensity of the northern lights and variations of the compass needle. He concluded that the aurora was a global phenomenon. In 1868 Anders Jonas Ångström, also from Sweden, used a prism to show that auroral light differs from sunlight. That meant that the auroras could not be due to reflections from other light sources.

Christopher Hansteen (1784-1873) established several observing stations and arranged with sea captains to observe and record the magnetic field all over the world. Thus, he became the first to point out that the aurora occurs as a continuous ring around the geomagnetic pole. Sophus Tromholt (1851-1896) organized a network of northern lights observation stations. He pointed out that northern lights seemed to form a luminous ring around the North Pole. He made the first illustration of what was later to be known as the auroral oval. He also showed that auroral occurrences correlate well with the 11-year sunspot cycle.

A MAJOR BREAKTHROUGH WAS MADE BY AN ECCENTRIC Norwegian scientist—Kristian Birkeland, 1867-1917—who had a theory that charged particles from the sun could ignite auroras. To prove his theory, which is still valid today, he built his own world in a glass box, electrified his model earth with its own magnetic field and showed how particles from the sun could ignite auroras. The particles were captured by the earth's magnetic field and channeled down towards the polar regions. He also showed that they would be identical and simultaneous at both poles. Birkeland, arguably Norway's greatest scientist, also established the first permanent aurora observatory. He indicated the existence of the solar wind and the earth's magnetosphere and studied the properties of comet tails. Many of these ideas were not confirmed until after the space age some 60 years later. The electrical currents he described in the upper atmosphere are still called Birkeland currents.

Two other noteworthy Norwegians in this area were Lars Vegard, the first scientist to map the colors of the aurora, and Carl Størmer, who continued where Birkeland left off and calculated that there is a belt-like area around the earth in which particles are reflected to and from between the poles. Verification of this area came years later on the basis of satellite measurements made by the American James Van Allen. Størmer also calculated the height of the northern lights to be 80-130 kilometers.

So the source of the aurora is the sun. The sun provides energy to all life on earth, drives the climate system and is vital to our very existence. It powers photosynthesis in plants and is the ultimate source of all food and fossil fuel. Looking at the sky with the naked eye, the sun seems static, placid and constant. From the ground the only noticeable variation in the sun is its location—where will it rise and set today? But the sun gives us more than just a steady stream of warmth and light.

Every 11 years the sun undergoes a period of activity called the "solar maximum." Five years later there is a "solar minimum."

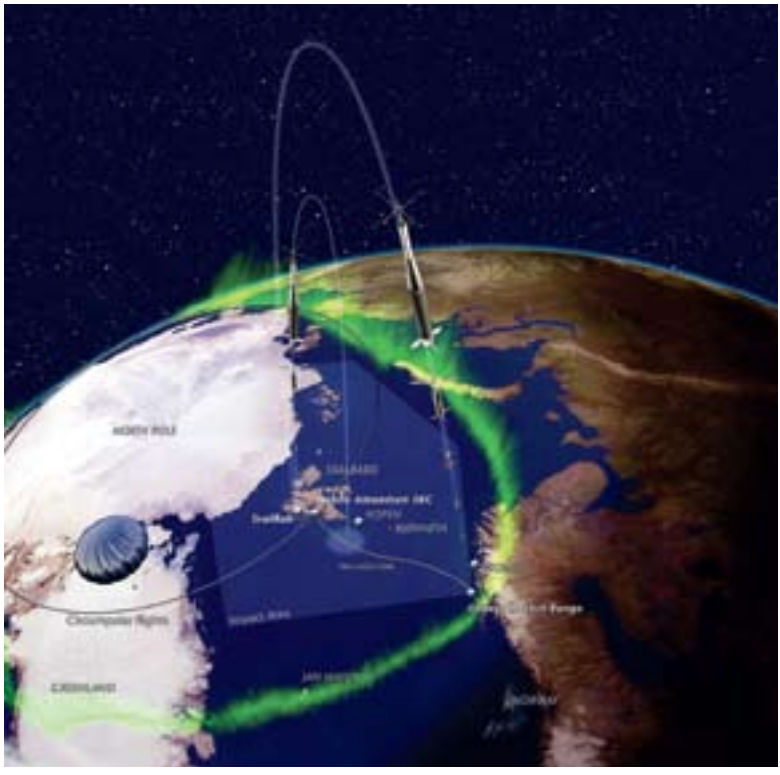
Situated 150 million kilometers away from us, the sun is a huge thermonuclear reactor, fusing hydrogen atoms into helium and producing million-degree temperatures and intense magnetic fields. Near the surface, the sun is like a pot of boiling water, with bubbles of hot electrified gas. The steady stream of particles blowing away from the sun is known as the solar wind. Blustering at 1.5 million kilometers per hour, the solar wind carries a million tons of matter into space every second; that's the mass of Utah's Great Salt Lake.

Every 11 years the sun undergoes a period of activity called the "solar maximum," followed about five years later by a period of quiet called the "solar minimum." During solar maximum there are many sunspots, and during solar minimum there are few. Thus, one way of tracking solar activity is by observing the number of sunspots. Sunspots are dark patches like freckles on the solar surface formed when magnetic field lines just below the sun's surface are twisted and poke through the solar surface. Sunspots can last from a few hours to several months, and a large sunspot can grow to several times the size of the earth. Though the Chinese recorded some observations as early as 28 B.C., scientists have been observing and recording sunspots since about 1610 when Galileo Galilei pointed his telescope towards the sun.

Why do scientists care about sunspots? Because they are visible signs of the turmoil inside the sun that lead to space weather effects on earth. Coronal mass ejections (CMEs) and solar flares are often associated with sunspot groups. The twisted magnetic field above sunspots are sites where solar flares are frequently observed to occur. Solar flares are short, intense explosions that accelerate particles and intense X-ray radiation into space. Energy equal to a billion megatons of TNT is released. CMEs, caused by temporary breaks in the magnetic controlling field lines, are much larger storms that thrust billions of tons of particles (a mass equal to that of 100,000 battleships) at speeds up to 8 million kilometers per hour!

During solar maximum, CMEs and flares can occur several times per day with some of them aimed in the earth's direction. Fortunately, our planet is protected from the harmful effects of the radiation and the hot plasma by our atmosphere and by an invisible magnetic shell known as the magnetosphere. Produced as a result of the earth's own internal magnetic field, the magnetosphere shields us from most of the sun's particles by deflecting them around the earth.

Auroras are caused by CMEs or gusts of solar wind that will push on our magnetosphere so that particles inside the magnetosphere are injected into the earth's upper atmosphere where they collide with oxygen and nitrogen.



ANDØYA ROCKET RANGE

The aurora is studied by using rockets and radars. Andøya rocket range is situated right below the nighttime aurora oval. Together with large radars, a mobile rocket launcher and a balloon launch facility at Svalbard, it makes up a powerful tool to understand the aurora.

These collisions, which usually take place between 60-300 kilometers above ground, cause the oxygen and nitrogen to become electrically excited and to emit light (fluorescent lights and televisions works in much the same way). The result is a dazzling dance of green, blue, white and red light in the sky.

The auroras never hurt a sailor or a farmer. It is only with our modern electrical, electronic and space technologies that the storms from the sun become damaging, and even personally hazardous for astronauts. The more we do in space and the more we depend on modern electronics, the more serious and potentially costly the problems will become. Storms on the sun can interfere with systems on earth that our society depends upon.

Norway, as we have seen, has a long tradition of studying the sun and auroras, due to the fact that the sun interacts with the earth system. This field of science is often called the sun-earth connection. Today, after the start of the space age, scientists are utilizing space-borne instruments and cameras to study the aurora. A sounding rocket range was established on the north Norwegian island of Andøya. It is the northernmost permanent rocket launch facility in the world and the first rocket launch there took place in 1962. More than 700 rockets have been launched, many of them NASA rockets.

Northern lights viewed from Sjonfjellet near Rana in north Norway.

Instrumented rockets have contributed to our understanding of the aurora. The rockets used in the auroral experiments are normally 10 to 20 meters long and typically carry an instrument load of 150 to 200 kilograms to a height of 300 to 500 kilometers. The altitude record so far, from the Andøya Rocket Range, is nearly 1,500 kilometers. With rockets, auroras can be studied from the inside. Scientists are also using satellites to study the aurora from above and on a global scale. Several satellites have been launched to study the aurora. In addition to providing scientists with detailed information of the physics and dynamics of the aurora, satellites can also be a very useful tool to check if there are auroras visible at your location.

The best place to see the auroras is, of course, far north at high latitudes. Also, one should travel in the winter when the nights are dark. In the summer the midnight sun will make it impossible to see it. Also, one should avoid city

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lights and find a dark place away from the city on a summit or open country with a clear view of the northern horizon. One should also avoid the full moon, which makes the sky less dark.

In parts of northern Norway you can see the northern lights almost every dark and clear night—in Fairbanks, Alaska, five to ten times a month, along the U.S.-Canadian border, two to four times a year and in Mexico, once or twice a decade. By using the Internet one can check if the aurora is visible near you or if there will be auroral displays there in the coming days.

Pål Brekke, a solar scientist, is Senior Adviser for Space Science Coordination at the Norwegian Space Center and a Norwegian delegate to the European Space Agency Program Board of Human Spaceflight, Microgravity and Exploration. He is the former Deputy Project Scientist for SOHO at NASA Goddard Space Flight Center.