

## How do Auroras Occur?

### Overview

Before the 20<sup>th</sup> century, mysterious curtains of lights appearing in the night sky have always intrigued and charmed observers. Folklores were fabricated to animate people's fascination but lack of understanding on the subject. In Inuit folklore, the phenomenon was expressed as spirits playing football with a walrus skull over the sky. Early Chinese record described it as "a red cloud spreading over the entire sky." (Reddy, 2005)

With the invention of space satellites comes the solving of this mystery that has baffled our ancestors. After reading the description process, astronomy enthusiasts (who already have high school background in physics) will continue to marvel at the natural wonder but equipped with a better understanding on how they occur. The process also includes technical terms which are defined in the glossary. This article describes the mechanisms of auroras, their characteristics, prime viewing locations, and potential problems they may cause. Some developments in this area of space science are discussed briefly.

### Magnificent Lights in the Night Sky

Aurora, Latin for "dawn," is an event defined by colorful displays of light in the night sky, particularly in the northern and southern hemispheres where they are in proximity to the Polar Regions. Other names include aurora borealis, literally "northern dawn", if it appears in the northern latitudes, and aurora australis, literally "southern dawn", if in the southern latitudes. Figure 1 and 2 depicts each type of auroras respectively.



**Figure 1.** Aurora Borealis  
Photo by Craig M. Groshek



**Figure 2.** Aurora Australis  
Photo by Craig M. Groshek

No physical differences exist between both types of auroras except the location of their occurrences. Happening at irregular intervals, the atmospheric phenomenon is caused by the interaction of charged particles from the solar wind and Earth's magnetic field (Reddy, 2005). They appear in different colors, depending on the concentration of atmospheric gases present in the air. While oxygen atoms emit yellow and green light, which are the most common colors observed, nitrogen produces blue and violet light. At lower altitudes, these gas atoms glow a reddish hue. On rare occasions, a faint blue color is spotted

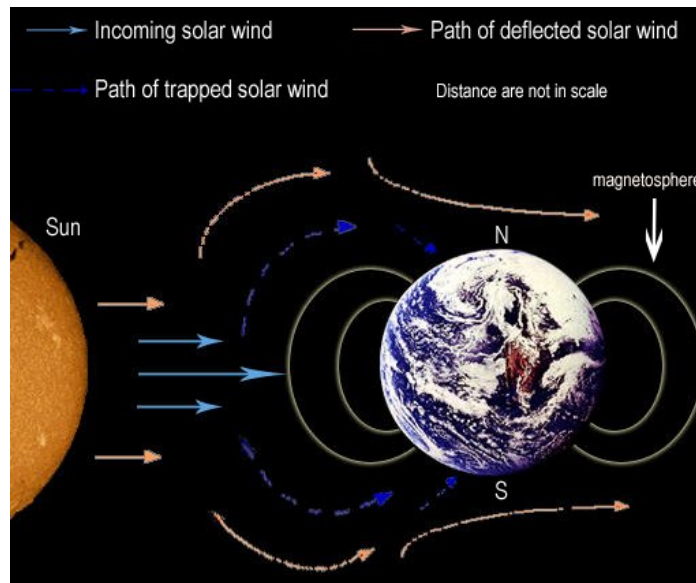
when sunlight hits the top part of the aurora. A greenish hue is perhaps the most common aurora spotted. More will be discussed later about the auroras' color mechanism.

Auroras have several unique characteristics: (1) the brighter rays fade while the dimmer ones brighten; (2) the direction of the rays is slanted with relation to the magnetism of the Earth (Stern, 2002). They resemble flames in a fireplace, and also just as mesmerizing. If auroras are observed carefully, parallel rays running across an aurora's width are distinguishable. Furthermore, auroral features vary in shapes and sizes. Tall arcs and rays originate at 100 kilometers above Earth's surface and extend upwards for hundreds of kilometers. These arcs are approximately 100 meters in thickness, extending across the horizon. Do not let the magnificent works of Nature deceive you. In reality, the brilliant displays of lights offer an uncomplicated and fundamental explanation.

### How an Aurora occurs

The mechanism of an aurora can be compared to that of a neon sign, except that in the aurora, the conducting gas is in the ionosphere instead of a glass tube, and the current travels along magnetic field lines instead of copper wires.

Before understanding how an aurora is formed, one needs to be aware of the elements constituting the celestial event. The solar wind, Earth's magnetic field, magnetosphere, magnetotail, and ionosphere are the building blocks for an aurora. Figure 3 illustrates the path of the solar wind, which is the foundation of all auroras.



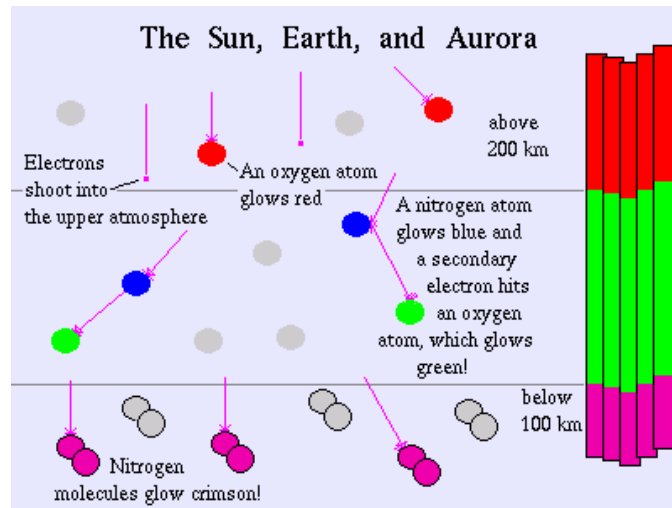
**Figure 3.** Path of Solar Wind

Source: Author's own image

The path of the solar wind originates from the sun. It streams out from the Sun at 250 miles (400 kilometers) per second, flowing past Earth's magnetic field. As observed in Figure 3, this magnetic field carried by the solar wind must also be aligned opposite of Earth's magnetic field, which follows a course from south to north. Such a condition is necessary for the charged particles to break into magnetic covering that usually deflects them. Once they have entered, the particles stream along the outermost field lines of the

magnetosphere (see Figure 3), which is a compressed field around the sunward side, while stretching its night side beyond the Moon's orbit, hence forming the magnetotail (Seeing the light, 2000, para. 16).

Energy from the solar wind is constantly building up in the magnetosphere, and this energy is what increases the aurora's power. The build-up of pressure from the solar wind also creates an electric potential between the magnetotail and the Earth's polars, a condition which in turns accelerates trapped electrons from the magnetotail and strikes the Earth's ionosphere. Figure 4 describes how electrons interact with the atmospheric gases in the ionosphere and the respective colors emitted.



**Figure 4.** Forming Colors in Auroras

Source: University of Alaska Geophysical Institute

### How Auroras produce Colors

Auroral colors are determined on a particular atmospheric gas, its electrical state, and the energy of the electron hitting the gas. The displays of light are caused by the interaction of high energy electrons with the Earth's ionosphere. These speeding electrons collide violently with gas atoms in the ionosphere, and in the process excite the atmospheric gas atoms. After this chemical reaction, the electrons return to their initial, lower energy state, and release photons, which are light particles that compose the colors of the aurora. (Auroras: What makes them happen? , 2002, para. 13)

At higher altitudes approximately 200 kilometers or 120 miles above Earth's surface, oxygen atoms are responsible for emitting red auroras, a situation that is less frequently observed. At about 100 to 200 kilometers (or about 60 miles), a green-yellow color is observed, the most common situation observed. Nitrogen in an ionized state produces blue light, while neutral nitrogen molecules emit purplish-red colors.

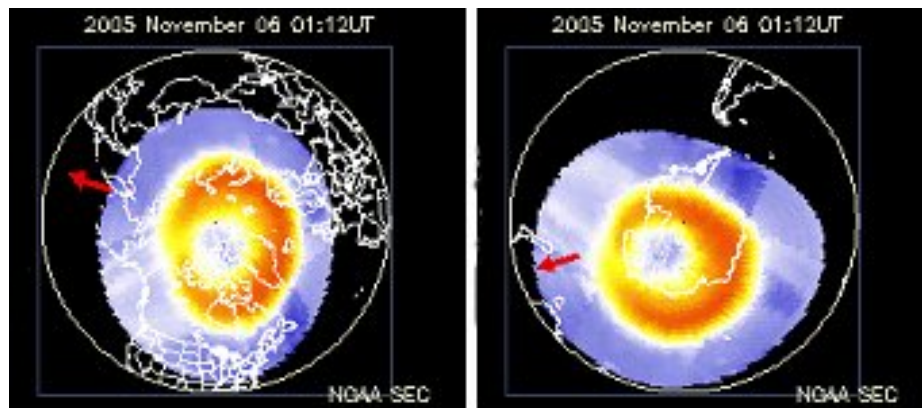
### Dancing lights

Whereas the atmospheric gases rule color emission, they are not responsible for the irregular brightening and fading of auroras. A delay of 0.5 to 1 second exists between collision and emission of light, a reason why the rays of auroras brighten and fade intermittently. The beam of electrons that reacts with the atmospheric gases may only last a

small fraction of a second, but the afterglow persists 0.5 to 1 seconds or more. These gases conduct flowing electric currents into and out of the polar region (Stern, 2002) .

## Aurora Sightings

Because auroras follow the Earth's magnetic field, they are observed near the Earth's poles. They form in an oval band centered at each magnetic pole (Figure 5), having a width ranging from 10 to 1,000 kilometers. Auroral activities are visible near this region and optimal viewing of auroras requires clear skies and minimal city lights. Locations about 2,000 kilometers (1,500 miles) from the magnetic pole are where auroras are seen most frequently; further away or nearer to the magnetic pole, they become rarer.



**Figure 5.** Auroral regions: Oval bands over Northern and Southern Hemisphere  
Source: Space Environment Center (SEC) of National Oceanic & Atmospheric Administration

The plots show the extent and position of the auroral oval at each pole on the stated date, extrapolated from measurements taken during the most recent polar pass of the National Oceanic & Atmospheric Administration's (NOAA) Polar-orbiting Operational Environmental Satellite (POES). The blue and orange shaded regions cover optimal viewing locations for auroras: Greenland, Canada, Siberia, North America, North Europe and Alaska. Enthusiasts should take note that the North Pole has sunlight throughout the whole day from April to September, making aurora viewing almost impossible during this period.

The optical phenomenon is not restricted only to Earth's boundaries. NASA spacecrafts have shown that the giant planets—Jupiter, Saturn, Uranus, and Neptune—all possess much stronger magnetic fields than Earth and therefore also experience auroras. Inner planets such as Mars and Venus have auroras occurrences as well.

## Potential Problems related to Auroras

As beautiful as these auroral sightings may be, they are the source for potential earth and space-based telecommunication problems. As solar activities heighten, solar wind increases both its speed and density, causing a profound effect on our atmosphere. When it increases energy flow into the magnetosphere, auroral substorms may result (NOAA, 2002, para. 14). The magnetic fluctuations of these substorms cause surges in electric power lines and possibly equipment failures in the power grid, resulting in power outages.

In more severe cases, auroral substorms may affect the performance of radio communications and satellite navigation systems. Such storms can last several hours or even

days, producing electrical energy that is equivalent to the amount consumed in the United States over 10 hours. A classic scenario occurred in March 1989, when Quebec, Canada, experienced a power outage for more than 9 hours because of increased solar activities that also triggered exceptionally intense auroras over the region.

## Developments

Many other questions still persist. Essentially, the aurora is a picture of space activities. Scientists need to find out why auroras erupt abruptly and not continue at a low level, instead of fading and brightening. In March 2003, NASA funded an auroral satellite mission with the aim to understand the physics and evolution of substorms that is also critical to explaining why auroras erupt.

## Conclusion

An auroral display can last anywhere from a few minutes to several hours, with prime viewing near the northern and southern hemispheres. Reaction of the particles in solar wind and particles in Earth's ionosphere triggers the formation of auroras, while colors depend on atmospheric gases colliding with the energetic particles. Auroral activities correlate with solar activity, which changes according to an 11-year solar cycle. Therefore, auroral displays peak around the time when solar activity is high. During this period, auroras can also occur further south away from the North Pole. Even though we now have a substantial explanation to auroras, scientists are still researching for more solutions to unanswered questions.

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## Glossary

### Auroral Substorms

Auroras caused when particles in the magnetotail becomes energized at a fast rate and flows towards Earth.

### Charged Particles

Particle with an electric charge.

### Electrons

Tiny particles with negative electric charge.

### Electric Potential

The difference in electrical charge between two points.

### Ionosphere

Layers of the Earth's atmosphere located above the stratosphere from about 70 to 400 kilometers (40 to 250 miles) above the earth's surface, and composed of gases that have been ionized

### Magnetic field

Region of magnetic force that surrounds Earth, flowing from south to north.

### Magnetotail

A long structure on the anti-sunward side of Earth's magnetic field, pushed in the direction of the solar wind.

### Magnetosphere

A zone of charged particles trapped by a planet's magnetic field, lying above the atmosphere.

### Polar Regions

Areas of the globe surrounding the poles, north of the Arctic Circle, or south of the Antarctic Circle. They are characterized by extremely cold temperatures, and extreme variations in daylight hours, with 24 hour daylight in summer (the midnight sun), and permanent darkness at mid-winter.

### Solar Activity

Solar variations are fluctuations in the amount of energy emitted by the Sun.

### Solar Wind

A stream of charged subatomic particles (mainly protons and electrons) flowing into space from the sun.

### Substorms

Injections of charged particles from the magnetotail into the ionosphere.