The Aurora

How it works, Cultural Significances, and Mythology

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Magnetic Field and Magnetosphere

Earth has magnetic poles, much like a bar magnet, creating a magnetic field with lines of force that emerge from one pole, loop around, and re-enter at the opposite pole. This magnetic field is generated by the movement of conductive material within Earth's liquid metallic outer core, which is primarily made of iron and nickel. The circulation of this molten metal, driven by heat from the planet's interior (a process called convection) is what creates the magnetic field. (NASA, N.D.)

The location of Earth's magnetic poles is around the top and bottom of the earth's rotational axis but not directly the same and they wander over time due to changes in the flow of molten material in the core. Occasionally, the poles even reverse, swapping north and south in a phenomenon called a geomagnetic reversal, which occurs roughly every few hundred thousand years.

Earth's magnetic field extends far into space, forming the magnetosphere which is a teardrop-shaped region dominated by the planet's magnetic field. The magnetosphere acts as a protective bubble that deflects charged particles from the Sun (solar wind) and cosmic rays. When a charged particle encounters this field, it spirals along the magnetic field lines, becoming trapped in regions such as the Van Allen radiation belts–zones of high-energy particles surrounding Earth. While the magnetosphere can trap electrons and atomic particles, its capacity is limited, and only specific particles with suitable energy levels become confined. (Fraknoi et al., 2022)

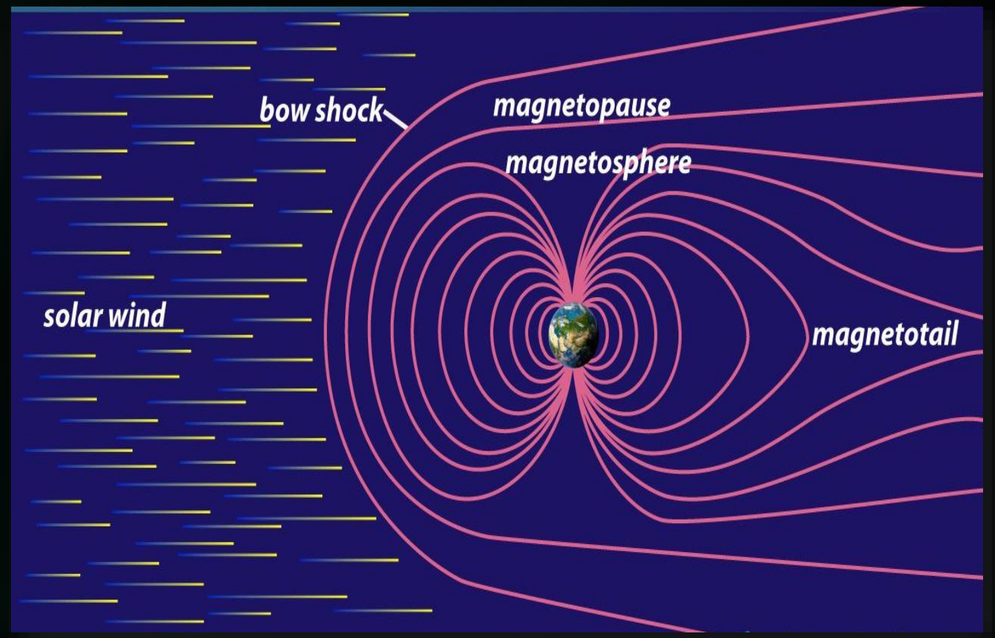


Figure 1: Illustration of the Magnetosphere. Retrieved from https://study.com/academy/lesson/magnetosphere-definition-facts.html

Solar Activity

The Sun is constantly emitting streams of charged particles in the form of the solar wind, which flows outward from its outermost layer, the corona. In the corona, temperatures soar to millions of degrees Celsius, causing the plasma (a hot, electrically charged gas) to expand to the point that it overcomes the Sun's gravity and escapes into space. The solar wind carries with it the Sun's magnetic field and travels at speeds of 300-800 km/s. While relatively steady, the solar wind interacts with planetary magnetic fields. (NASA, 2004).

Beyond the steady flow of the solar wind, the Sun also releases bursts of energy and particles during high-energy events such as solar flares and coronal mass ejections (CMEs).

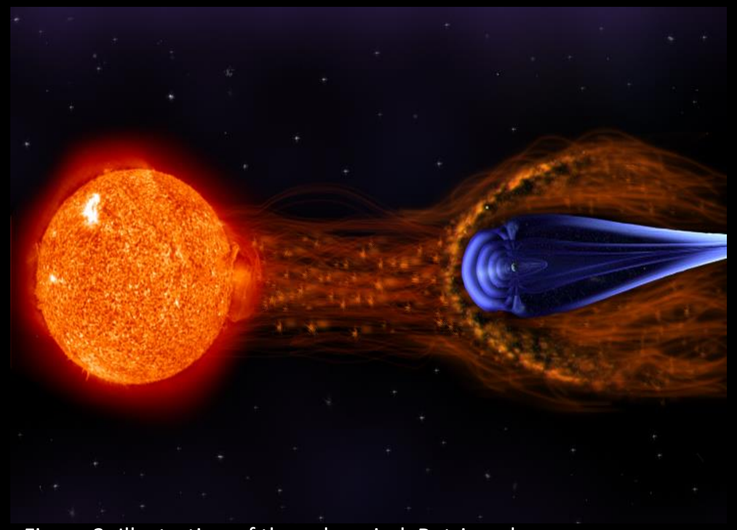


Figure 2: Illustration of the solar wind. Retrieved fromhttps://www.aeronomie.be/en/encyclopedia/solar-wind-stream-charged-particles-escaping-sun

Figure 3: Short GIF of a coronal mass ejection. Retrieved from https://www.esa.int/ESA_Multimedia/Images/2020/10/New_view_of_2012_solar_activity_gif

Solar flares are sudden, intense releases of energy caused by the twisting or reconnection of magnetic field lines near sunspots. These flares emit radiation across the electromagnetic spectrum and are associated with the rapid acceleration of particles.

Coronal mass ejections involve the ejection of massive amounts of plasma carry a magnetic field from the corona into space. CMEs are far denser and faster-moving than the solar wind, with particles traveling at speeds up to 3,000 km/s. (NOAA, n.d.-a)

There is a loose correlation between these high-energy events and sunspots, dark patches on the Sun's surface that indicate regions of intense magnetic activity. While not all sunspots lead to flares or CMEs, periods of increased sunspot activity–such as during the solar maximum of the Sun's 11-year activity cycle–are associated with more frequent solar storms. As a result, northern and southern lights are more likely and more vibrant during solar maximum periods.

Cause of the Aurora

Earth’s magnetic field and magnetosphere act as a shield against solar emissions, such as the solar wind and coronal mass ejections. However, this shield is not impenetrable. As it is constantly battling the solar wind the magnetosphere works to deflect most of the incoming charged particles away from Earth. But because Earth’s magnetic field lines converge at the poles, some particles manage to travel along the magnetic field and enter the atmosphere in these regions. (Cain, 2015)

During intense solar activity, such as a solar flare or coronal mass ejection, the influx of highly charged, fast-moving particles can compress the magnetosphere significantly. When the magnetic field embedded in the solar wind/ interacts with Earth’s magnetic field, their opposing orientations can trigger magnetic reconnection. This is a process where magnetic field lines from opposite directions are forced together, break, and reconnect.

On the day side (facing the Sun), magnetic reconnection can cause part of Earth’s magnetic field to extend into space while the rest is stretched and drawn into the magnetotail—the long, stretched-out portion of the magnetosphere on the night side. In the magnetotail, another reconnection event occurs, causing magnetic field lines to "snap" back toward Earth. This snapping releases stored magnetic energy and accelerates trapped charged particles (electrons and protons), propelling them along Earth’s magnetic field lines toward the polar regions. (Connected, 2021)

Magnetic Reconnection

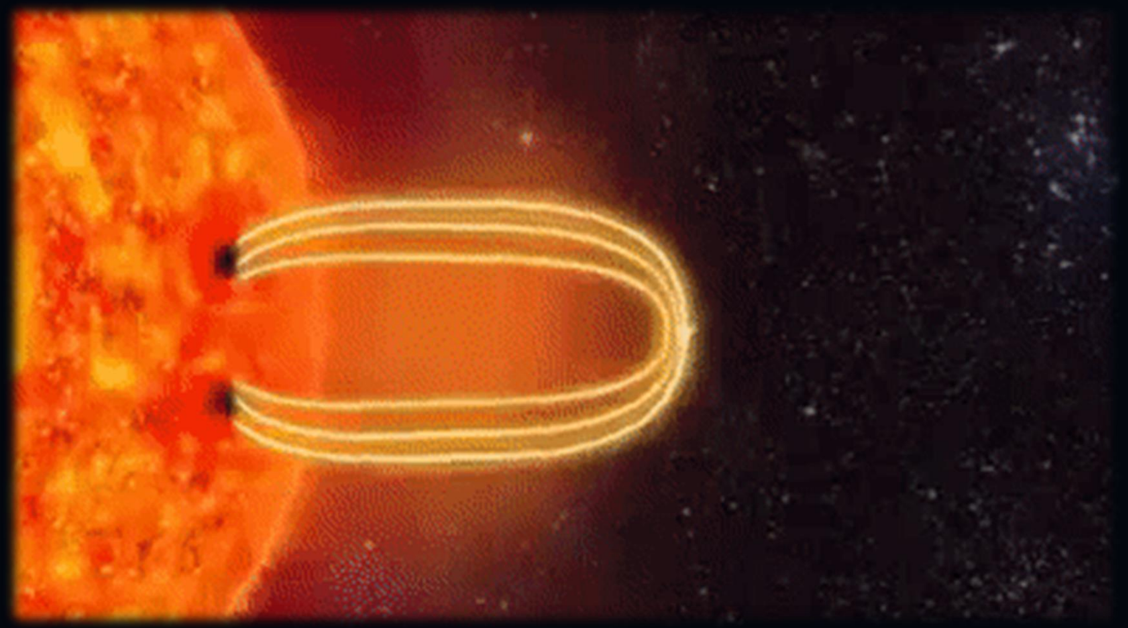


Figure 4: Recreation of a solar flare and magnetic reconnection. Retrieved fromhttps://giphy.com/gifs/xThuW8N6Ms2pgpqFGM

Colours of the Aurora

The colors of the aurora are determined by the type of atmospheric molecule the charged particles interact with, as well as the altitude at which the collisions occur. When accelerated particles from the Sun hit Earth's atmosphere, they collide with oxygen and nitrogen atoms and molecules, transferring energy and exciting these particles. As the excited particles return to their lower energy states, they emit light at specific wavelengths, producing the vibrant colors we see in auroras. (Lummerzheim, 2021)

- Red: A bit higher in the atmosphere, altitudes of ~300 to 400 km, collisions with oxygen atoms produce red auroras.
- Green: Most common colour, produced when charged particles collide with oxygen molecules at altitudes of ~100 to 300 km.
- Blue and purple: Interaction with nitrogen molecules. Typically, below 100 kilometers.
- Pink/Dark Red: Produced by nitrogen molecules at altitudes of around 100 km. (Canadian Space Agency, 2022)

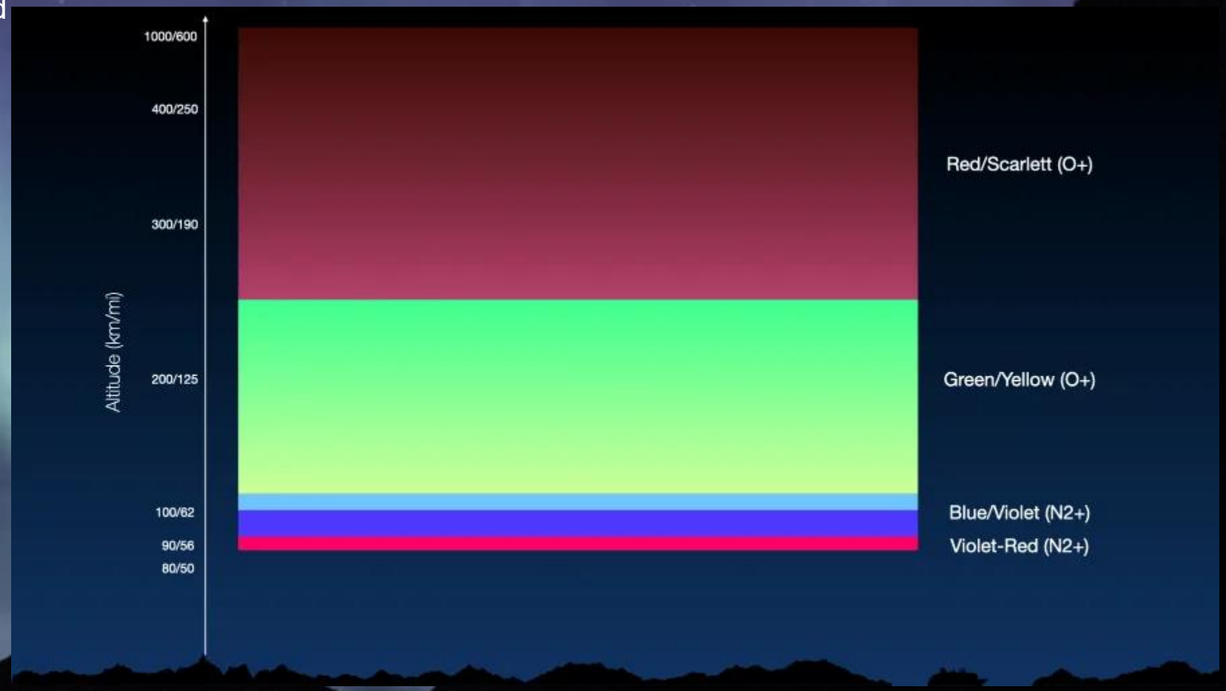
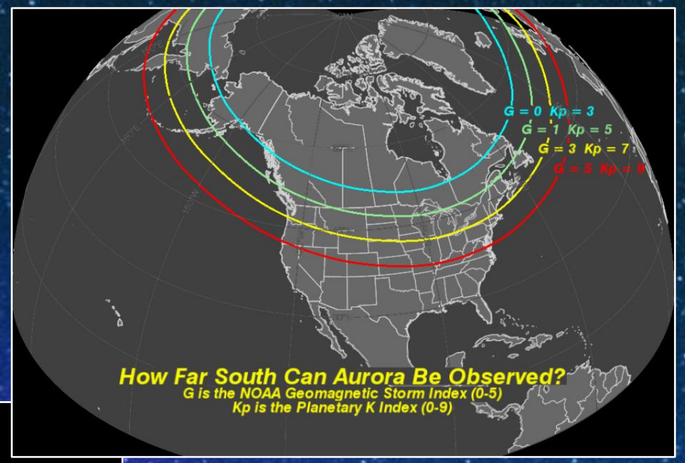


Figure 5: Illustration of the molecule and altitude that cause aurora colours. Retrieved fromhttps://images.ctfassets.net/7mmwp5vb96tc/122733/df22fb75020a2aabd9b55a7de3493b02/aurora-colour-altitudes.png?q=75&w=3840&fm=webp

Where is the Aurora

Figure 6: Graph illustration of K index. Retrieved from https://www.swpc.noaa.gov/content/tips-viewing-aurora.



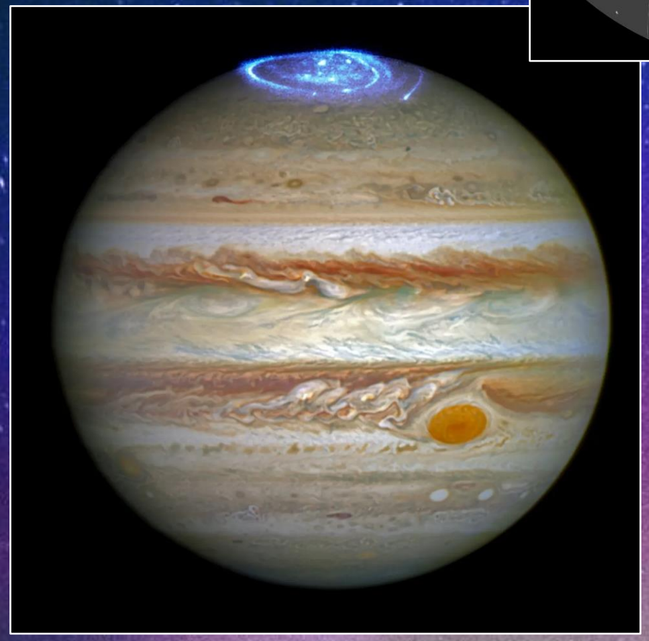


Figure 7: Combined image of Jupiter and it's aurora activity. Retrieved from https://science.nasa.gov/missions/hubble/hubble-captures-vivid-auroras-in-jupiters-atmosphere/

On Earth, the aurora is typically observed near the magnetic poles, where charged solar particles are funneled into the atmosphere along Earth's magnetic field lines. In the northern hemisphere, this phenomenon is called the aurora borealis (northern lights), while in the southern hemisphere, it is known as the aurora australis (southern lights). The visibility of the aurora depends on the intensity of geomagnetic activity, which is measured using a magnetometer. Magnetometers detect disturbances in Earth's geomagnetic field caused by solar particles. This data is converted into a K-index, a scale that predicts how far from the poles the aurora might be visible. Higher K-index values indicate stronger geomagnetic activity, allowing auroras to be seen at lower latitudes. (NOAA, n.d.-b)

Auroras are not unique to Earth. Any planet with a magnetic field and an atmosphere can experience auroras, as they result from the interaction between a planet's magnetic field and charged particles. For example, Jupiter has some of the most intense auroras in the solar system.

Unlike Earth, where auroras are primarily driven by solar storms and other high-emission solar events, Jupiter's auroras are perpetual. This is due to the planet's extremely strong magnetic field, which is about 20,000 times more powerful than Earth's. Jupiter captures charged particles not only from the solar wind but also from its surroundings, including its volcanic moon, Io. Io emits vast amounts of ionized material, which becomes trapped in Jupiter's magnetic field and contributes to its auroras.

Jupiter's auroras are hundreds of times more energetic than those on Earth, emitting light across a broader spectrum, including ultraviolet and X-rays. These continuous auroras are among the most spectacular and scientifically intriguing phenomena in the solar system. (NASA Hubble Mission Team, 2016)

How The Aurora Was Named

- The term ‘aurora borealis’ was first used by Galileo in 1619. (Gill, 2019).
- It got its name from ancient Greek and Roman mythologies. (Gill, 2019).
- Aurora Borealis combines the names Aurora (the Roman goddess of the dawn), with Boreas (the Greek name for North wind). (Gill, 2019).

- Aurora Australis (the Southern Lights) got its name from a combination of Aurora- the same Roman goddess and australis meaning ‘southern’ in Latin. (Mental Bomb, n.d.). '

Cultural Beliefs Of The Aurora

Finland

- Finnish word for aurora borealis is ‘revontulet’, which translates to “fire foxes”. (Berg, 2024).
- In folklore, the mythical fox would strike the surface of the snow with its tail or rub against the mountainside, creating sparks that would be seen in the sky. (Berg, 2024).
- The Sami (an indigenous population that spans Finland, Norway, Russia, and Sweden) used to believe that when the lights appeared, they needed to be respected. (Berg, 2024).
- Traditional Sami beliefs consider auroras to be living beings that talk and understand speech- this is why people are supposed to be quiet when auroras occur. (Berg, 2024).
- Was believed that disrespecting the lights would bring misfortune- for that reason people weren’t allowed to play or laugh when the aurora was out. (Berg, 2024).
- Was also important to not point at the lights as it would give the spirits something to grab onto to drag you off into the night sky. (Berg, 2024).

Greenland

- ‘Arsarnerit’ or the aurora is the ‘highway of the dead’. (Berg, 2024).
- The departed dance and run across the skies on it, on their way to the afterlife. (Berg, 2024).
- Along the way they kick a walrus skull around (Arsarnerit translates to ‘ball games’). (Berg, 2024).

Iceland

- The lights held many meaning for Icelanders throughout the ages. (Berg, 2024).
- Some believed the Northern Lights used to reduce the pain of childbirth; however, you could not look directly at them, or your child would be born cross-eyed. (Berg, 2024).
- Others believed it confirmed that there was a battle happening somewhere. (Berg, 2024).
- Another belief is that the weather could be predicted depending on how the aurora danced across the sky (if it was fluid, it meant a storm was coming). (Berg, 2024).

Norway

- Norse mythology associated the lights with the Bifrost, a burning rainbow bridge that connects Earth to Asgard, the realm of the Gods. (Berg, 2024).
- The lights, the Vikings believed, were the reflection of armour and shields of fallen warriors on their way to their final resting place. (Berg, 2024).
- Other sources claim female spirits called Valkyries chose who lived and died in battle. They escorted the most heroic warriors who fell to Valhalla (which is a hall of the slain in Nordic culture). The Vikings believed the lights were the reflection of the Valkyries' armour and shields as they led the dead to their final resting place. (Rose, 2019).

China

- "Auroral sightings in China would have been very rare caused by a significant solar event. Hence ancient Chinese were in awe of the lights that sporadically illuminated their night sky. It is said that many of the early Chinese legends associated dragons with the Northern Lights. The belief is that the lights were viewed as a celestial battle between good and evil dragons who breathed fire across the sky" (Rose, 2019).

Indigenous Peoples in Canada

Communities/ Stories

“For Indigenous peoples in Canada, celestial displays are not just a beautiful phenomenon; they are steeped in rich cultural significance and lore. Each Indigenous community has its own unique stories and legends that explain the Northern Lights, weaving them into the fabric of their cultural identity and spiritual beliefs” (Chloe, 2024).

Inuit

Have long believed the lights are spirits of their deceased loved ones, dancing in the sky. This belief fosters a sense of connection between the living and the dead- reminding them that their ancestors are always watching over them. (Chloe, 2024).

The lights serve as a comforting reminder that life continues beyond death, creating a bridge between the past and present. (Chloe, 2024).

Cree

The Cree people often view them as the reflections of the spirit of animals, particularly those that have been hunted. (Chloe, 2024).

According to Cree tradition, when a hunter successfully captures an animal, the spirit of that animal ascends to the sky, where it becomes part of the Northern Lights….this belief not only honours the animals that provide sustenance, but also emphasizes the importance of respect and gratitude towards nature. (Chloe, 2024).

The lights become a symbol of the interconnectedness of all living beings, reminding hunters of their responsibility to maintain balance in the ecosystem. (Chloe, 2024).

Indigenous Peoples in Canada

Moral Lessons

"It's fascinating to note how they often serve as moral lessons or cautionary tales. For example, some Indigenous stories warn against disrespecting nature or taking more than what is needed" (Chloe, 2024).

"When the lights flicker or change colours, it is interpreted as a sign that one should reflect on their behaviour and make amends." (Chloe, 2024).

"This connection between the natural world and human conduct highlights the deep respect Indigenous cultures have for their environment." (Chloe, 2024).

Self- Reflection

"These legends are not just stories passed down through generations; they are integral to community gatherings and cultural practices. During long winter nights, families would gather around fires to share tales of the Northern Lights, fostering a sense of unity and belonging. These storytelling sessions not only entertain but also educate younger generations about their heritage and the values that shape their identity. In this way, the Northern Lights become a canvas for cultural expression, illustrating the beliefs and traditions that define Indigenous life." (Chloe, 2024).

Environment

"This connection between the natural world and human conduct highlights the deep respect Indigenous cultures have for their environment." (Chloe, 2024).

Figure 8: YouTube video on the cultural and spiritual significances of the northern lights. Retrieved from https://youtu.be/wuCeGzA14vA?si=AmeXr6nZ8RtPK69u


THANK YOU!

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Image References

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