The solar wind is the effusion (continuous flow) of charged particles known as plasma, released from the sun's corona at a speed of about 900 km/s (one million miles per hour). It's the wind that pushes comet tails away from comet bodies as they pass through the solar system, and it's visible in the halo surrounding the sun during eclipses and occasionally when particles reach the Earth's atmosphere resulting in the aurora borealis. The solar wind has different speeds, densities, and temperatures, which can be seen when it exits from a coronal hole or as CMEs.

Corona holes are large bright regions in the sun's corona. The sun's corona is the solar atmosphere's outermost layer, expanding into space, and it's very active. Its flares are the halo you see around the sun during eclipses. While the sun's surface is blisteringly hot at 6,000 °F, the corona is over a thousand times hotter – up to 2 million °F (1.1 million °C). The sun emits two solar winds; a fast wind and a slow wind with about half the speed of the fast one. The two winds originate at different regions of the sun and reach their maximum speed at different distances from it.

Formation of the solar wind

The plasma in the sun's corona is constantly heated till gravity can no longer hold it down. As a result, particles are propelled into space, traveling along the magnetic field line that goes radially outward from the sun. The solar wind is created as the sun spins (once every 27 days), burns, and burps, creating complex swirls and eddies of particles with high and low speeds and densities.

As they pass Earth, these particles, predominantly protons, and electrons move a million miles per hour. The solar wind reaches the entire solar system at such a high speed, carrying the solar magnetic field embedded in the plasma and producing an interplanetary magnetic field (IMF) that surrounds all of our solar system's planets. However, the interaction of the solar wind with planets and, eventually, the interstellar medium is strongly affected by the extension of the sun's magnetic field into space.

Properties (Speed, Temperature, and Density)

Although the solar wind is constant, its parameters are not. Different regions of the sun produce solar wind with varying speeds, densities, and temperatures. As the sun's activity changes over its 11-year cycle, radiation levels, sunspot numbers, and ejected material also change over time, affecting the solar wind's properties, including its magnetic field. The wind also varies depending on how swiftly a region rotates. When high-speed solar collides with low-speed wind, the result is a phenomenon known as corotating interaction regions (CIRs), which, when they interact with the Earth's atmosphere, can cause geomagnetic storms.

Over coronal holes, the solar wind has a higher velocity, reaching rates of up to 800 km (500 miles) per second. The magnetic field is feeble, and the temperature and density around coronal holes are low. Thus the field lines are open to space. These holes can be found near the poles and at low latitudes, and they are at their largest when the sun's activity is at its lowest. On the other hand, temperatures in strong winds can reach 1 million °F (800,000 °C). The solar wind flows more slowly in the coronal streamer belt near the equator, at roughly 300 km (200 miles) per second. However, temperatures in the slow wind can reach 2.9 million °F (1.6 million °C).

When the solar wind travels away from the sun, it becomes too weak to withstand the inward force of the interstellar medium (the part of our galaxy that lies between the stars). It goes through a shock wave known as the "termination shock" at this point and slows down as it approaches the heliosheath, which stretches to the heliopause. At this point, the heliosphere meets the interstellar medium. According to DeForest, a solar physicist at the Southwest Research Institute (SwRI) in Boulder, Colorado, as you move away from the sun, the strength of the magnetic field drops faster than the pressure of the material streaming out from the sun. "Eventually, the material starts to act more like a gas, and less like a magnetically structured plasma." Said DeForest.

Effect of the Solar Wind on Earth

The solar wind is both good and bad. It protects our Earth and also threatens it. How?

The solar wind's magnetic field protects our planet from cosmic rays and other high-energy particles from space. But the consequences of storms or corona mass ejections (CMEs) on the sun's surface, on the other hand, pose a threat to our satellite and communications networks. Astronauts traveling through space are also at risk from the wind.

The speed of the solar wind is so great that when it is forced to flow around the planets in the solar system, it generates "bow shocks," and if such a solar wind hits the Earth, the shockwave might wreak chaos and severe damage to our communication systems. Thankfully, Earth's magnetic field shields us from the solar wind by deflecting it, causing solar wind particles to flow around the Earth and beyond it.

Sometimes the sun burps, throwing large bursts of plasma containing a billion tons of material into space, flying at several thousand kilometres per second — an event known as coronal mass ejections (CMEs). CMEs have a stronger effect than the standard solar wind, and if it happens to hit the Earth, It can cause the Earth's magnetic field to ring like a struck bell. Such a scenario would generate various disturbances, from aircrafts losing radio communication to GPS being thrown off-chart by miles. Not to mention, this also includes banking, communications, and electronic systems could also be knocked out.

When CMEs and other powerful bursts of radiation carried by the solar wind reach the Earth's magnetic field, it stretches out the magnetic field so that it is smooshed inward on the sun-side and stretched out on the night side — a process known as magnetic reconnection. Charged particles then stream back toward the planet's magnetic poles, causing beautiful displays, aurora borealis, in the upper atmosphere.

In 1859, a massive solar explosion known as the Carrington Event disrupted telegraph and electrical systems for several days. The aurora borealis was so bright that many claimed to be able to read a newspaper by its light, even at 1 a.m. According to a 2013 analysis by Lloyd's of London, if a similar storm impacted the Earth today, it might bring up to $2.6 trillion in damages to the United States alone, as well as widespread blackouts and damage to electrical grids.

Some solar wind particles are extremely energetic and can pierce tiny holes through critical spacecraft equipment, let alone human beings, posing a threat to space travel. However, NASA is conducting extensive research to understand better the components, features, and frequencies of such particles and anticipate space weather in advance for safe flights.

Not every planet in the solar system has a magnetic field protecting it from the sun's radiation. For example, because Earth's moon is unprotected, it bears the brunt of the damage. Mercury, the closest planet, has a magnetic field that protects it from the normal wind, but it absorbs the full impact of more intense outbursts like CMEs.

Scientific Facts

• At a relatively quiet period, the solar wind contains approximately 1 to 10 protons per cm^3. It moves outward from the sun at speeds of 400 to 700 km (about 220 to 440 miles) per second. This creates a positive ion flux of 108 to 109 ions per cm^2 per second, with each ion having an energy equal to at least 15 electron volts.

• Termination shock, where the solar wind slows as it hits the interstellar medium, is around 94 and 84 AU, according to the Voyager 1 and Voyager 2 spacecraft.

• Earth’s magnetic shield comprises magnetic field lines, a magnetosheath, and a magnetopause.

• The heliosphere is an enormous “bubble” formed by the solar wind around the sun. This bubble stretches well beyond the orbits of most of our solar system’s planets.

• Geomagnetic storms are caused by high-speed winds, whereas low-speed winds cause calm space weather. Corotating interaction regions can also cause geomagnetic disturbances.

• Solar ejections are the most potent drivers of the Sun-Earth interaction, according to NASA.

A lot of research has been done by scientists to study solar wind. This includes NASA’s STEREO mission that was launched in October 2006, which helped scientists study the sun’s edge to see how the solar wind is born. However, scientists are still yet to fully understand the sun and its solar wind. Hopefully, NASA’s Parker Solar Probe, launched in the summer of 2018, will help solve the largest mysteries and questions about the sun and its wind, including why the sun’s corona is so much hotter than its surface.

According to NASA, the Parker Solar Probe will “touch the sun” and use a combination of imaging and measurements. This helps to increase understanding of the solar wind’s origin and evolution, and answer questions about solar physics that have puzzled humanity for over six decades.