about Plasmas
from the Coalition for Plasma Science

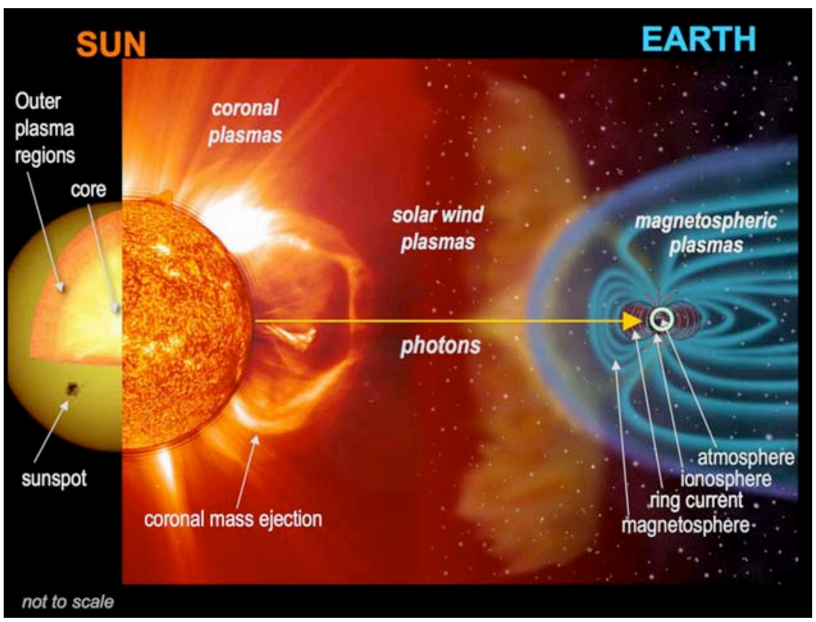
Space Weather

Does your GPS sometimes lead you astray? Does your computer power surge protector activate unexpectedly? Did your flight to China get re-routed the same time that you witnessed eerie glowing curtains of light shimmering in the polar skies? Each of these occurrences could be a scenario for a science fiction film about aliens from outer space, but they are not; it's something else from outer space – space weather playing havoc with human technology.

Space is not empty. Between the planets, moons, asteroids and comets of our solar system is an "atmosphere" so tenuous that it may appear to be just empty space. We are learning, however, that events in this space environment can determine whether our cell phones will operate as we expect, whether airplanes can fly over the poles safely, or whether it will be safe for astronauts to perform a spacewalk.

A ghostly thin breeze from the Sun, the solar wind, blows persistently through space. This electrically-conducting mix of charged particles – mostly positively charged protons and lighter, negatively charged electrons – interacts with magnetic and electric fields in ways that are quite different from how solids, liquids and neutral gases behave. This fourth state of matter is known as plasma. The solar wind, like other space plasmas, is capable of impressive effects across enormous distances, despite being very tenuous.

Plasma interactions with Earth and its space environment drive what is called "space weather." Like weather in Earth's atmosphere, space weather can dramatically affect our lives, primarily through its impact on technology. Scientists are working hard to forecast when solar storms will occur and what their effects will be. Because these storms can disrupt spacecraft and airline operations, communications, and power grids, accurate space weather forecasts are important to all of us.



The Sun is the source of most plasma that fills the space between the planets. The solar wind pushes against the Earth's magnetosphere, compressing it on the side nearest the Sun.

Solar Wind Meets Magnetosphere. Despite vast differences in density between the very low-density interplanetary plasma and our high-density atmosphere, these two regions do share some traits. The streaming solar wind plasma, like the wind on Earth, can be a gentle breeze or a furious tempest. Unlike the wind on Earth, however, such space plasmas are diverted by planetary magnetic fields. Strong or gentle, this solar wind is ever-present, buffeting our planet and its magnetosphere – that region of space within which plasmas are affected by Earth's magnetic field. As a result, Earth's magnetosphere is distorted by the solar wind into a comet-like shape, with the blunt end directed towards the Sun and a long tail stretching away from the Sun. The tail extends beyond 50 times the diameter of the Earth.

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Solar Storms and Their Effects on Earth. The Sun can unleash vast amounts of energy when tightly coiled magnetic fields release energetic plasmas, especially near sunspots. On occasion, the Earth experiences the fury of such solar storms. Some space weather effects, such as X-rays and radio interference, are fast and direct. Within one to four days, slower moving clouds of plasma from the Sun compress Earth's magnetosphere on the day side while the side opposite the Sun is stretched farther out into space. Like a rubber band, our magnetosphere tries to snap back and re-establish its original shape, accelerating plasma in the tail and causing it to rush inward towards Earth. Some plasmas get diverted around the Earth, and contribute to a ring current. Other plasmas follow the magnetic field towards Earth's northern and southern polar regions where they collide with the upper atmosphere to create glowing aurora.

Space Weather Close to Home. The X-rays from solar storms, along with energetic particles that follow soon after, pose a radiation hazard for humans and electrical devices at high altitudes. Most energetic particles are stopped before they reach the ground, but some can reach aircraft on polar routes, disrupting radio communication between those aircraft and ground control, harming electronics, and posing a health hazard to passengers and crew. Even GPS signals received from satellites can be distorted, causing position errors of several tens of meters. Furthermore, fluctuations of Earth's magnetic field as it weathers these storms cause electrical surges that can produce power blackouts. This fluctuating field also causes electrical currents to form in the Earth and in metal pipelines (e.g., oil or gas pipelines). Long pipelines at high latitudes are especially vulnerable. For underground pipelines, chemical reactions associated with the transfer of charges between the metal and the surrounding soil can increase corrosion and weaken the pipes.

Space weather influences many of the technologies that we depend on for communication, navigation and transportation.

Space weather can have important effects in space as well. For example, space weather can greatly reduce the useful lifetime of satellites that provide communications and timely weather observations. Satellites can be damaged when charges build up within electronic components or on surfaces. Solar cells on satellites also become less effective as they are peppered with energetic particles. And humans venturing into space are vulnerable; they need accurate space weather forecasts to protect both themselves and their spacecraft systems. Thus space weather can have important personal as well as economic consequences.

Current Research on Space Weather. Scientists studying space weather, like meteorologists who study weather patterns in Earth's atmosphere, seek to better predict when and where powerful storms will occur. Such predictions depend on basic research into the complex nature of the Sun, its plasma environment, and the response of the Earth's magnetosphere. With more satellites providing accurate real-time data and with better computer models, improved forecasts will help us mitigate the effects of solar storms on communications and other technologies that we increasingly depend upon today.

Suggested reading:
John Freeman, *Storms in Space*, Cambridge University Press, 2001.
Volker Bothmer and Ioannis Daglis, *Space Weather: Physics and Effects*, Berlin: Springer-Verlag, 2007.
"Space Weather Now" NWS Space Weather Prediction Center (http://www.swpc.noaa.gov/Education/index.html)
"Space Weather Center" Space Science Institute (http://www.spaceweathercenter.org/)
"Impacts of Space Weather" Sten Odenwald (http://www.solarstorms.org/)
"Space Plasmas" from the Coalition's *About Plasmas* series

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