Activity 14 - The Sun-Earth Connection

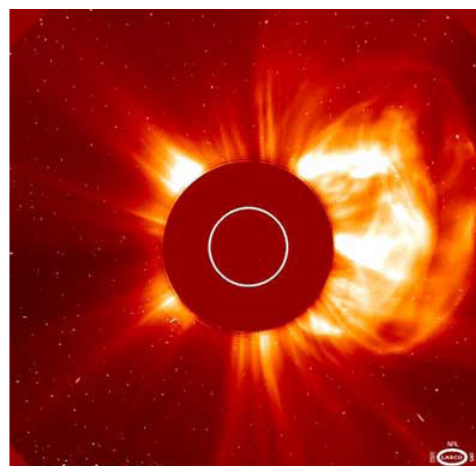
TEACHER'S GUIDE

This activity is a presentation for students about the Sun and its effects on Earth's magnetosphere and NASA's satellite mission to understand auroral substorms, THEMIS (Time History of Events and Macroscale Interactions during Substorms). This presentation and a script for the presentation is available as 1) a black and white Acrobat Reader PDF document in order to make overhead transparencies, 2) an Acrobat Reader PDF presentation, and 3) a Microsoft PowerPoint presentation. The script is available in the PowerPoint presentation in the notes section or you can download a PDF of the script. These are all found on the web at:

http://cse.ssl.berkeley.edu/exploringmagnetism/space_weather/presentation.html

GOALS

1. Students will know that the Sun is a dynamic and magnetic star.
2. Students will know that coronal mass ejections (CMEs) are large structures of magnetized plasma that are ejected at high speeds from the Sun's corona.
3. Students will know that the solar wind comes from the Sun and travels out past the planets in the solar system.
4. Students will know that Earth has a magnetic shield called the "magnetosphere."
5. Students will know that auroras are connected with Earth's magnetosphere.
6. Students will know that CMEs interact with Earth's magnetosphere and auroras are enhanced accordingly.
7. Students will know that the high-energy particles from CMEs can be dangerous to astronauts and can damage satellites.



CME photo. Courtesy SOHO satellite

MATERIALS

Either

- PDF or PowerPoint presentation from Website above
- PDF of script for the presentation
- Computer
- LCD projector

Or

- Overhead transparencies from the black and white PDF from website above
- PDF of script for the presentation
- Overhead projector

PROCEDURE

1. Give the presentation using the desired slide formats.
2. Follow the script if you would like.
3. Hand out the "IMPACT" story, and for homework have the students write about one aspect of the Sun-Earth Connection they learned from the talk and the story.

Notes: Click once on the movies to make them play in the PowerPoint presentation. Click twice on the movies to make them play in the PDF presentation.

The Sun-Earth Connection

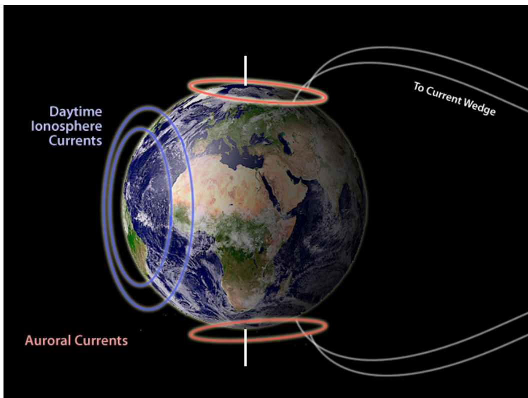
The Sun is a fiery ball of gas that reaches such extreme temperatures that gas flies out from it at very high speeds. In fact, many of the electrons in the Sun's atoms have enough energy to actually leave the atoms. The abandoned charged atoms are called *ions*. These ions and electrons (which are also charged) flow outward from the Sun, and together they are known as the *solar wind*. The ions spiral in one direction and the electrons spiral in the other—doing a kind of mirrored spiral dance around the "maypole" of the Sun's magnetic field. Scientists have discovered that the solar wind and its magnetic field flow together out past the orbits of Mercury, Earth, Pluto, and beyond. Because the magnetic field spreads throughout the solar system, we call it the *interplanetary magnetic field*—that is, the magnetic field found between (inter) the planets (planetary).

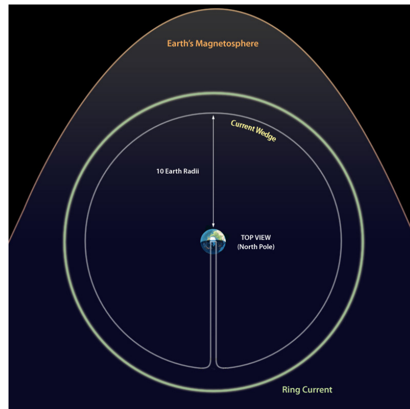
When the solar wind travels with the interplanetary magnetic field, or IMF for short, the charged particles and magnetic fields interact with Earth's magnetic field. Earth's magnetic field, as it stretches out in space, is known as its *magnetosphere*. The solar wind pushes on the side of the magnetosphere facing the Sun, and pulls it out on the side facing away from the Sun. The pulling forms a long tail moving away from the Sun, and thus the magnetosphere resembles a wind-sock blowing in the wind. Electrical currents flow in the magnetosphere, and generate the lights in the sky known as the Northern and Southern Lights. Together these lights are known as *aurora*.

Returning to our fiery Sun, scientists have noticed that the Sun goes through some markedly different cycles—rather like when people are calm and quiet some days, but on other days explode with energy and brilliance. But rather than biological rhythms driving the changes, physical principles—such as magnetic and electric forces—power the Sun's cycles. During the Sun's active cycle, parts of it will explode, sending out even more solar wind and magnetic fields than usual.

What happens to the solar wind and magnetic fields forced out into space by the explosions? Sometimes the explosive solar wind will rush by Earth, making us all potentially vulnerable. Luckily Earth has a magnetic field and a thick layer of atmosphere protecting all living creatures from the particles and radiation that can come from such solar explosions. But when astronauts are out in space, sometimes the magnetic field isn't strong enough to protect them. If they are outside their space vehicles, such as the space station, when conditions become possibly hazardous they need to hurriedly float back to the station's protection.

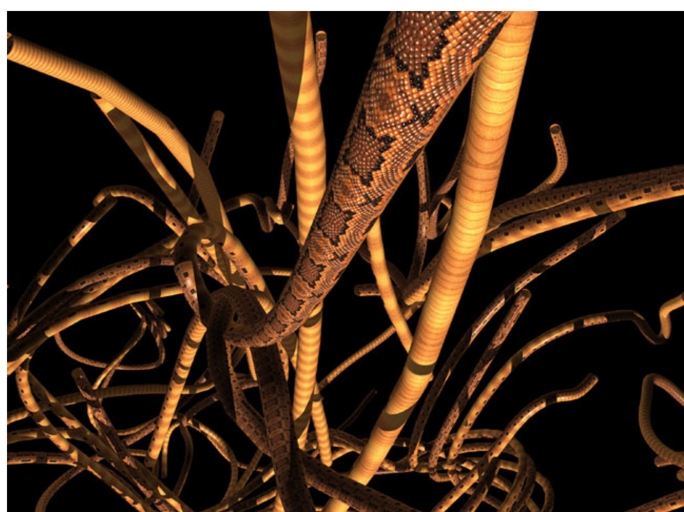
Scientists have named these solar explosions *coronal mass ejections*, or CMEs for short. When a CME interacts with Earth's magnetosphere, the electrical currents in the magnetosphere grow stronger and the aurora glows brighter. Because currents create magnetic fields, the changes in these electrical currents cause variations in magnetic data on Earth's surface. There are a number of important currents that cause magnetic changes observed on the ground as variations in Earth's magnetic field. Three specific currents are: 1) Electrical currents flow in the day-lit side of the ionosphere. The *ionosphere,* at 100 km (60 miles) above Earth's surface, is the closest signifcantly charged layer in the upper atmosphere (barring thunderstorms). In this region the Sun's light breaks apart a small portion of the gas into ions and electrons. These charged particles continually break apart and recombine throughout the day. The electrons and ions flow in different directions, creating a current above Earth's daytime surface. At night, without the Sun's influence, the electrons and ions "rest" in their recombined atomic state. Auroras also cause an enhanced ionosphere at night in an oval around Earth's magnetic poles. Enhanced currents are also found in these regions of aurora above Earth's surface during the night. 2) There is also electrical current flowing in a large belt-like region around Earth's equator, but far from Earth's surface—around 30,000 km above it. This current is called the ring current, because it makes a ring around Earth. 3) And there are also electrical currents at midnight above Earth's surface that hang out near the equator but even farther from Earth than the ring current at over 60,000 km altitude. These currents are called the *substorm current wedge*.





Two perspectives of a few of the electrical currents flowing around Earth. The figure on the left is a simplified diagram of the daytime currents, the auroral currents, and the field line currents coming from the magnetosphere. The figure on the right shows the ring current as viewed from above the North Pole.

The CMEs interacting with Earth's magnetosphere can influence all these currents. Because electrical currents create magnetic fields, the currents can be observed on the ground using devices that measure magnetic fields, called magnetometers. When a CME interacts with Earth's magnetic field, there are rapid changes in these current systems. Currents that change rapidly, within seconds, are usually carried by a wave known by the name of the man who discovered them through equations. These magnetic waves are called Alfvén waves. The picture below is a computer simulation of these waves—made to resemble snakes for fun.



A snapshot of Alfvén Waves on magnetic field lines rendered as 'snakes' at the Basic Plasma Science Facility at UCLA (http://128.97.43.7/bapsf/pages/gallery.html) which uses computer modeling to investigate laboratory plasmas in controlled fusion research. Who says scientists don't have a sense of humor?