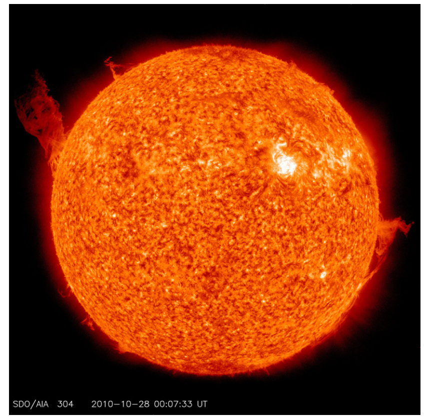
Teacher Background:

The Dancing Lights Program

Margaux Krahe

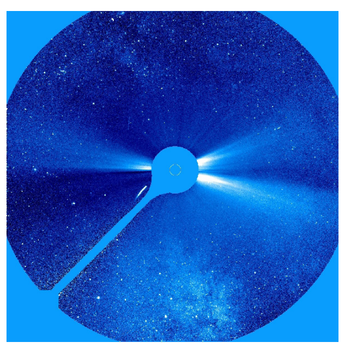
The Sun

Many people think the Sun is just a fiery yellow ball. The Sun is not actually burning because fire requires oxygen. Really, the Sun is a giant ball of plasma—one of the four states of matter—which is similar to a gas but is produced at much higher temperatures. Instead of being on fire, you can think of the Sun as being at such a high temperature that it glows. The surface of the Sun is always convecting—it boils and roils like a pot full of soup. The Sun also rotates on average every 27 days, but since the Sun is not a solid body it rotates different speeds at different latitudes—something we can call differential rotation—and it moves fastest at the equator.



Looking at the Sun in different wavelengths of light affords us a glimpse of plasma in motion not normally visible to the naked eye. This false color image (above) of the Sun in extreme ultraviolet (EUV) was taken by an instrument onboard the Solar Dynamics Observatory (SDO) spacecraft.

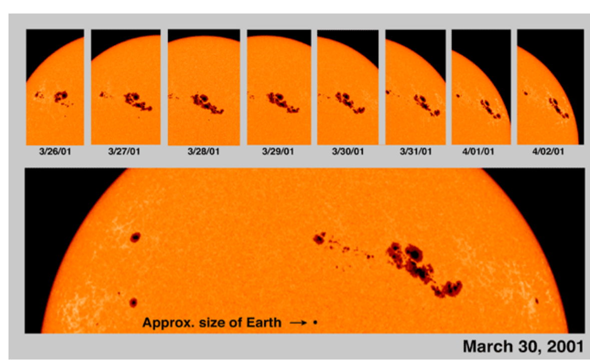
The Sun not only radiates light, it also radiates plasma, which moves into the solar system continuously. We call this the "solar wind." Normally, the solar wind flows out at about 400 kilometers per second (250 miles per second).



This image (left), shows the solar wind emanating from the surface of the Sun. This image was created by a coronagraph onboard the SOHO spacecraft, and a disk blocks the light from the Sun in the center so the solar wind can be seen. Courtesy of SOHO.

The Sun goes through an 11-year cycle of activity. The solar minimum is when the Sun has the fewest number of sunspots, which are cooler regions of the solar surface. During solar maximum the Sun has more sunspots. Sunspots are areas of intense magnetic field.

This false color composite image (right) shows sunspots over time on the photosphere. The photosphere is the surface of the Sun. Image courtesy of SOHO.



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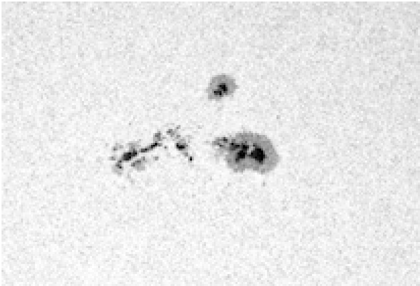
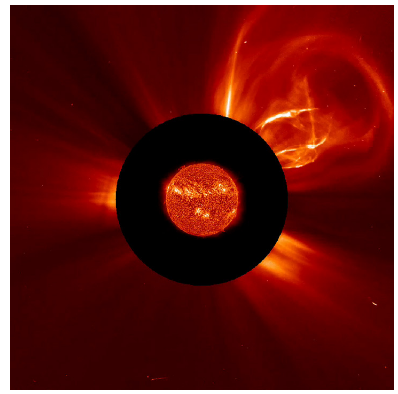


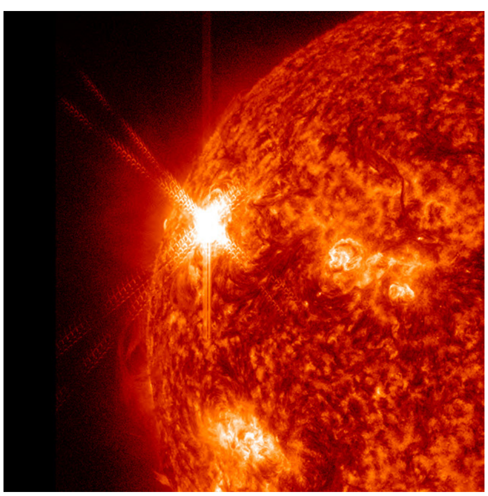
A close up of sunspots on the solar surface (above) taken from the Helioseismic and Magnetic Imager (HMI). Image courtesy of SDO.

Solar storms are often associated with sunspots. Imagine a U-magnet directly under the surface of the Sun creating sunspots. Solar material moves along the magnetic field from one magnetic pole to the other. In extreme cases, interactions between the convecting movement of the Sun and the motion of the Sun's magnetic field cause the material to erupt into the solar system. This type of solar storm called a Coronal Mass Ejection (CME). A CME travels at tremendously fast speeds through the solar system and carries with it billions of particles. CME speeds often exceed the speed of the solar wind, and may be nearly five times faster in rare cases.



This SOHO coronagraph image shows the tremendous size of a CME as it leaves the Sun (above). The false color Sun superimposed over the black disk is a SDO image showing the Sun's actual size. Courtesy of SDO.

A solar flare is another type of solar storm. Flares send light, including X-ray radiation, into the solar system. Often, a flare and CME will occur together, so that X-rays and solar material are traveling through the solar system.



False color image of a solar flare (above). Image courtesy of SDO.

Both solar flares and CMEs occur when the energy of the Sun builds up causing radiation and material to shoot off of its surface; however, X-rays travel at the speed of light, but solar material travels more slowly. If a flare and CME simultaneously headed in the direction of Earth, X-rays would reach us in about eight minutes but the material from a CME could take up to a few days.

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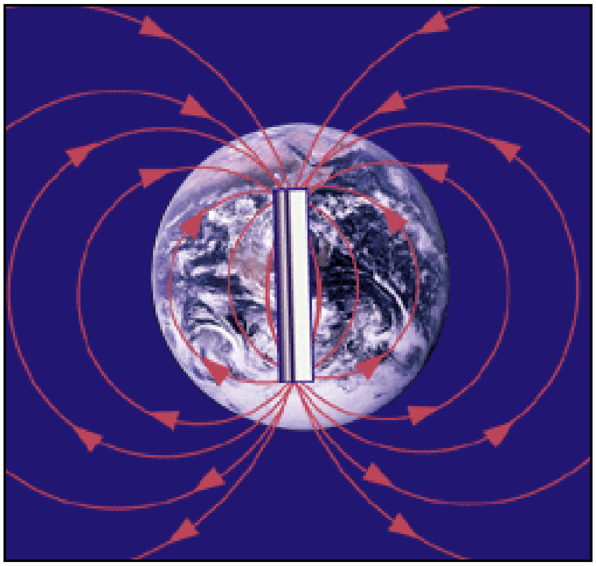
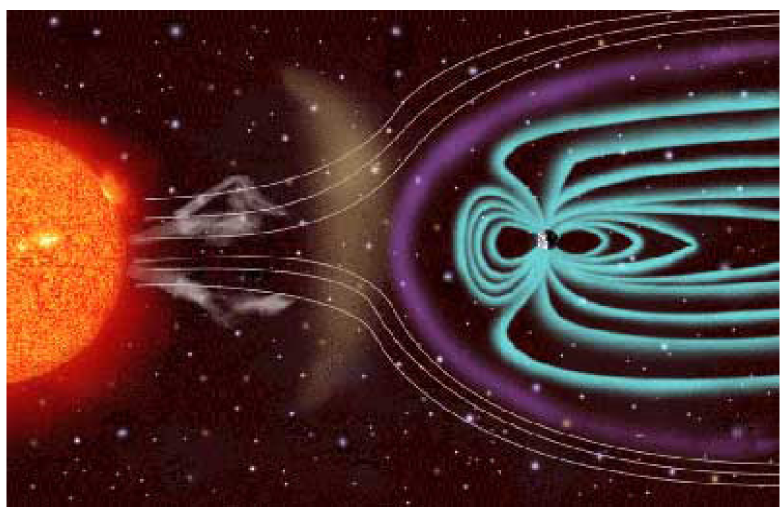
The Earth



A representation of the Earth's magnetic field (above). The field lines travel out of the south pole and into the north pole. Image courtesy of NASA.

The Earth is similar to a big bar magnet. Earth's molten iron outer core convects. This convection coupled with the rotation of the Earth creates a magnetic field. If you have ever poured iron filings over a bar magnet, you will see circular field lines traveling from the south pole to the north pole. The Earth is similar, having a north and south pole, but the field lines on the side on the Earth furthest from the Sun are stretched out due to the solar wind.

Our magnetic field is very important because it protects us from fast-moving charged particles in the solar wind that are traveling toward the Earth from the Sun. Charged particles are either deflected by the magnetic field or become trapped in it.

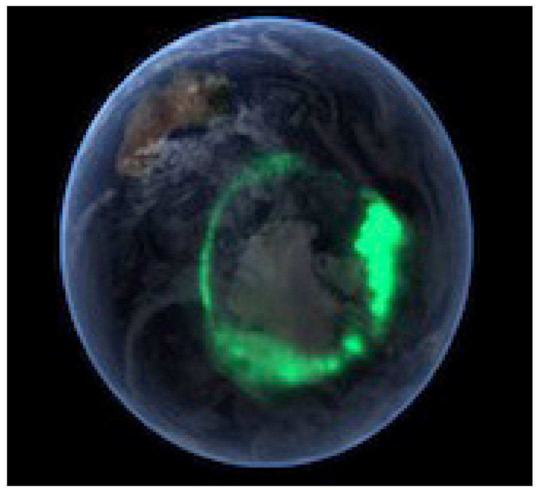


This artist's representation shows the solar wind interacting with the Earth's magnetic field (above). Image courtesy of NASA.

Sun-Earth Connection

When a CME is moving toward the Earth, it will typically arrive within two to three days. At Earth, CMEs sometimes just glance past us while others strongly interact with Earth's magnetic field. If the CME interacts with our magnetic field, it can cause a geomagnetic storm in which charged particles gain energy and follow the magnetic field toward the poles and into our atmosphere. The charged particles collide with atoms in our atmosphere causing them to excite and produce light, otherwise known as an aurora. This colorful glow appears as an oval shaped ring around the each of the poles.

The mixture of the different atoms in the atmosphere creates the different colors of the aurora. Oxygen gives off a green glow, the most common color, and is seen at an altitude of about 100—240 kilometers (60-150 miles). Oxygen can also give off a reddish glow above 150 kilometers, but that is more rarely seen from the ground. The red or blue violet glow, seen at an altitude of about 100 kilometers (60 miles), is from nitrogen atoms.



A view of the Aurora Australis (above) taken by IMAGE. Courtesy of NASA.

Picture of an aurora taken from the International Space Station. Courtesy of NASA.

The way an aurora looks gives us a hint about what is going on in space. The diffuse aurora, from a constant drizzle of particles into our atmosphere, occurs every day and is not an indication of a geomagnetic storm. The bright aurora, where vibrant light and structures such as arcs, curtains and rays can be seen, is called the discrete aurora. During geomagnetic storms the discrete aurora dances across the sky.

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Aurora (above) seen in the skies of Finland in 2003. Photo Courtesy of Tom Eklund.

Auroras are called “Aurora Borealis” at the Northern Hemisphere and “Aurora Australis” at the Southern Hemisphere. Discrete auroras occur more frequently when the Sun is more active, such as during solar maximum.

In the Northern Hemisphere, the Aurora Borealis is most commonly seen in central Canada, Alaska, Greenland, northern Russia, and northern Scandinavia because they are located close to the magnetic pole. The Aurora Australis is most commonly

Aurora can only be seen when it is dark outside, so a good time to see these glowing skies is during the winter months, when the amount of daylight is limited. The best months to see an aurora are around the equinox.

“Northern Lights” (above) taken in November 2003. Photo courtesy of Tom Eklund.

An example of a rippling curtain aurora (above) taken in 2005. Photo courtesy of Tom Eklund.

This photo (left) is of the Aurora Borealis, taken about 390 kilometers (240 miles) over the northern Atlantic. The lights are from the cities in Ireland and the United Kingdom. This photo was taken from the International Space Station. Courtesy of NASA.

In the United States, Alaska is known to be one of the best places to see an aurora. Alaska's nickname is the "land of the midnight Sun". The North Pole receives 24 hours of daylight all summer. Latitudes within the Arctic Circle, above 66.5 degrees north, can receive up to 24 hours of daylight in the summer depending on the exact date and latitude, with the most daylight hours recorded on the summer solstice, June 21st.

During the winter, however, the opposite is true. At latitudes above the Arctic Circle, the Sun does not rise on the winter solstice, December 21st, and receives few daylight hours during the winter months, again depending on the exact date and latitude. The North Pole remains dark through the winter until the spring equinox. This makes winter in Alaska an ideal place to view the aurora because it is near the geomagnetic pole and has dark skies.

Photo courtesy of Tom Eklund.

While summer is not a good time for aurora spotting in Alaska, the reverse is true for latitudes within the Antarctic Circle. Since Northern Hemisphere summer is Southern Hemisphere winter, areas within the Antarctic Circle experience few daylight hours. You would have a great chance of seeing an aurora if you traveled to Antarctica in June!

Web Collection

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