SDO Project Suite Module 2

2B Magnetic Solar System

student-directed introduction to understanding solar magnetic fields

Adapted resource courtesy of
Deborah Scherrer, Stanford Solar Center

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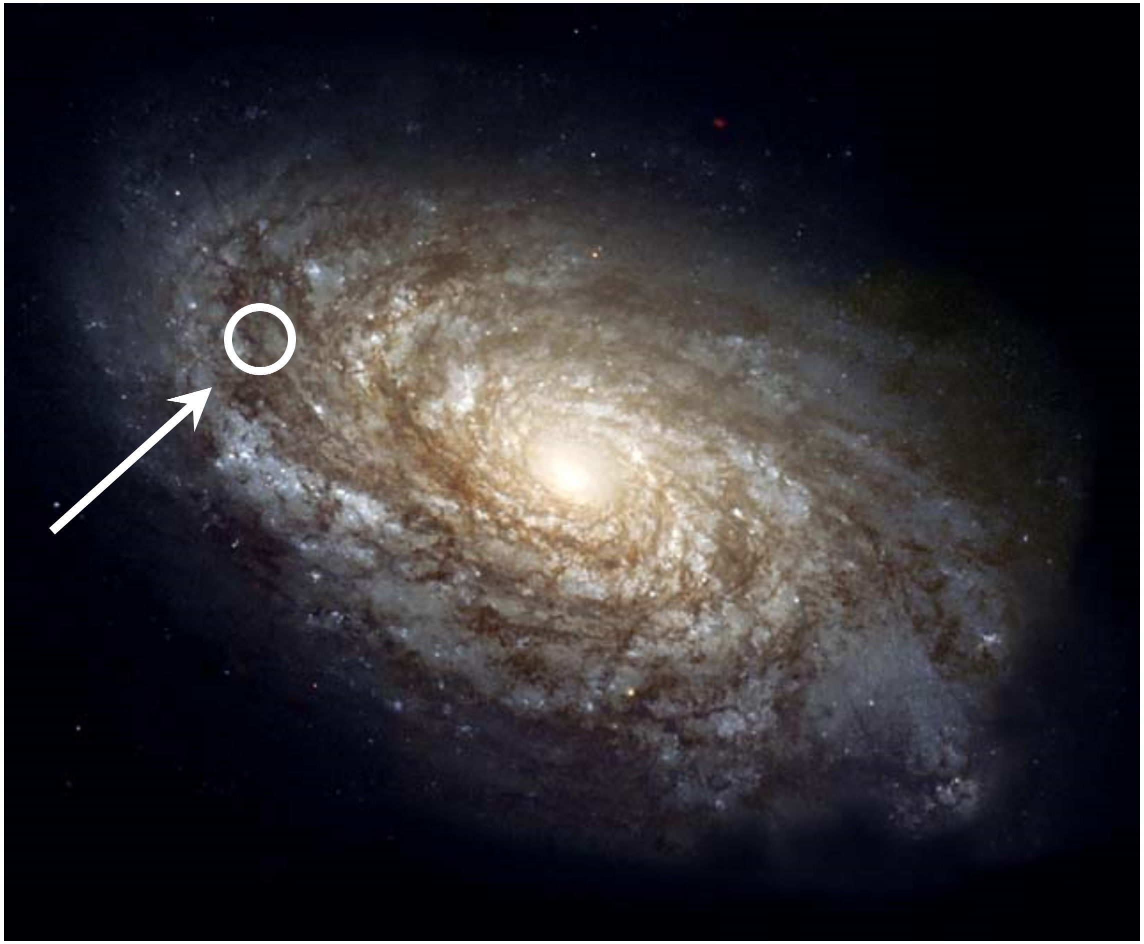
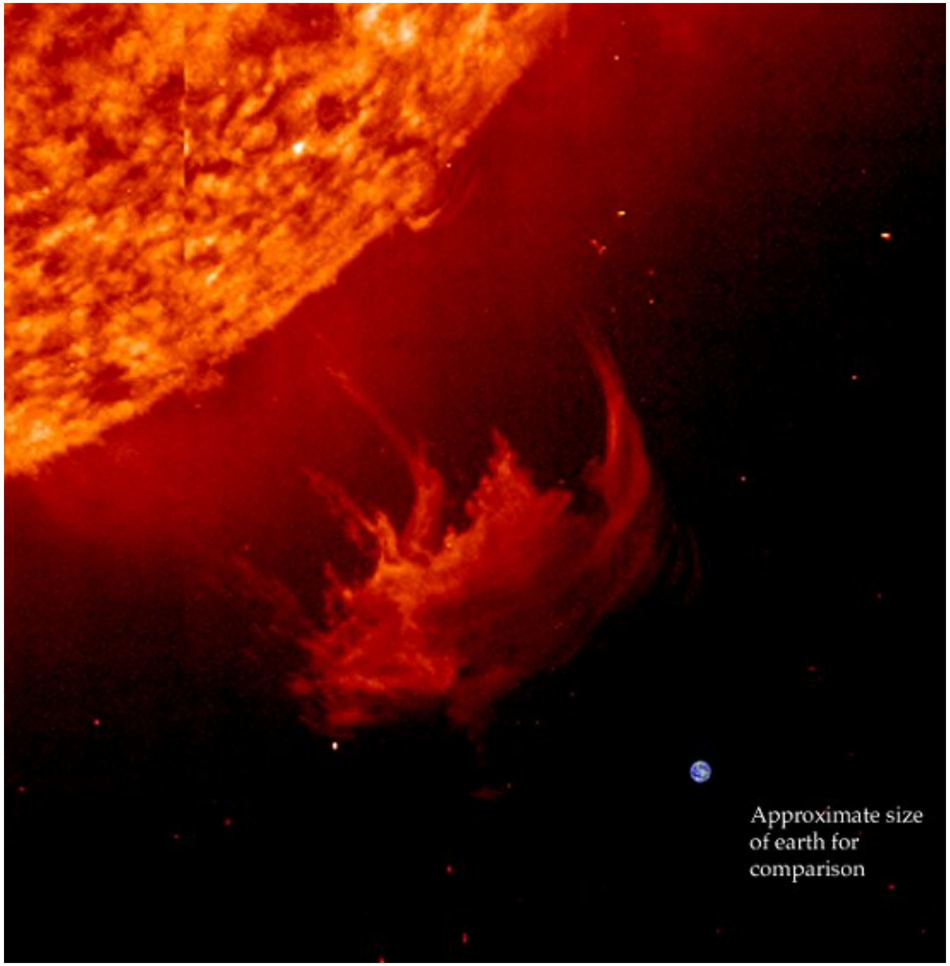
The Sun's Place in our Galaxy



The Sun is one of about 200 billion stars in our Milky Way galaxy. The Sun is on the "edge", about 28,000 light years from the galaxy's center.

Size & Distance to the Sun

- The Sun is 109 times the diameter of Earth
- Over 1,000,000 Earths could fit inside the Sun
- The Sun is 150 million kilometers away from Earth - 390 times farther away than the Moon
- You would need to line up 11,700 Earths side by side to cover the distance between Earth and Sun
- It takes 8 minutes for sunlight to travel 93 million miles to the Earth



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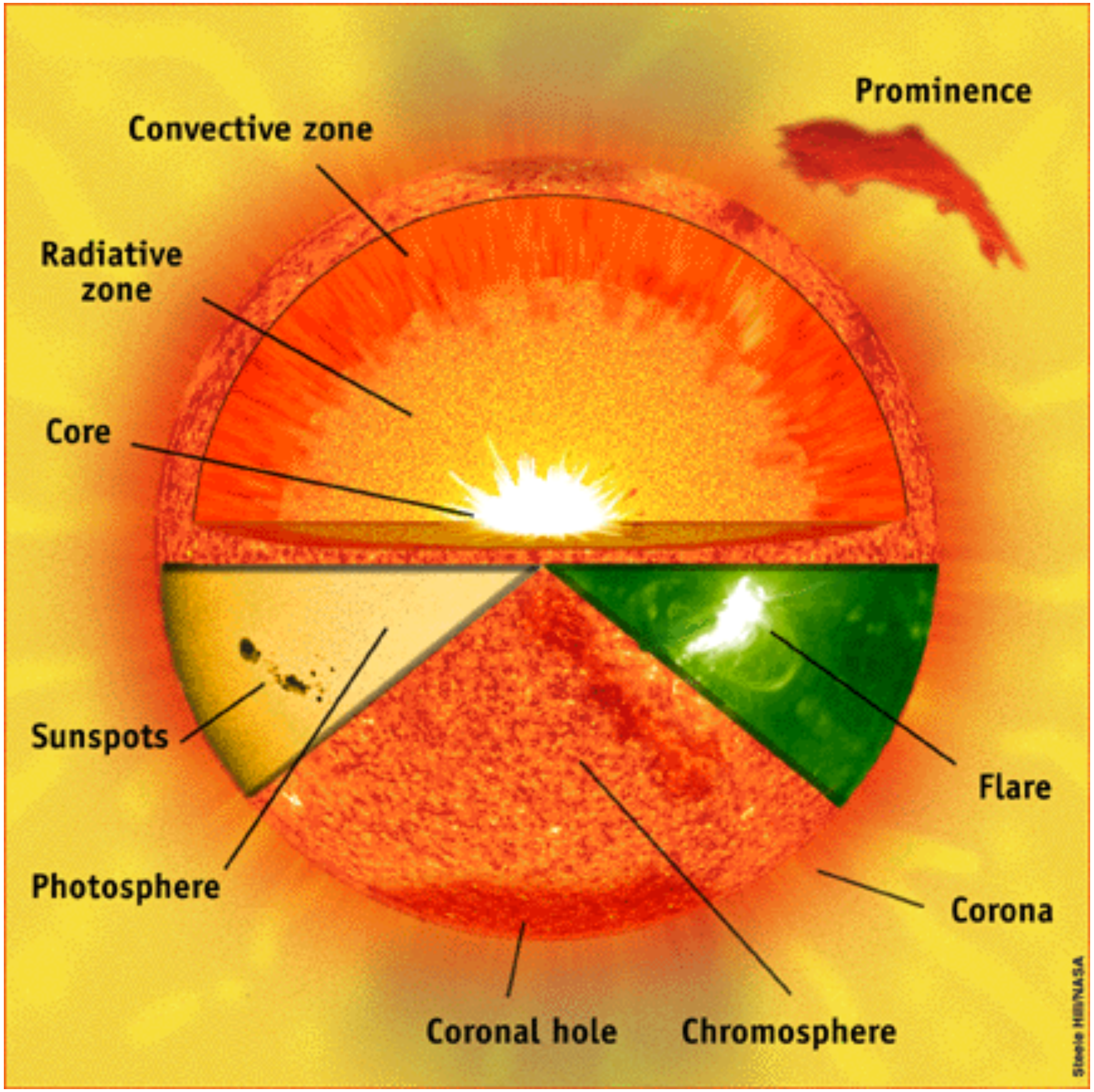
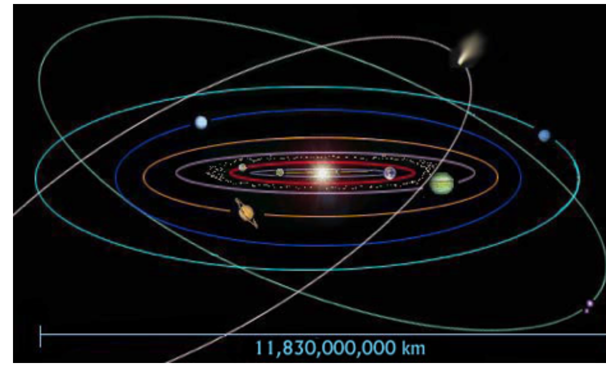
The Sun from the Inside Out



Our Sun is a turbulent, active star…

Video (click image to start & stop)



that can have dramatic effects on the Earth and other planets.

All solar activity is caused by changes in the Sun’s magnetic fields!

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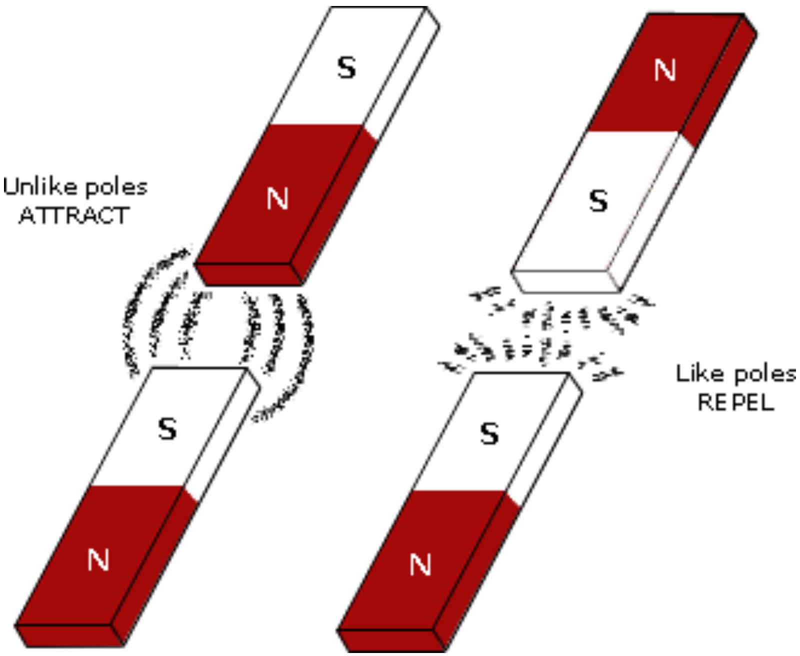
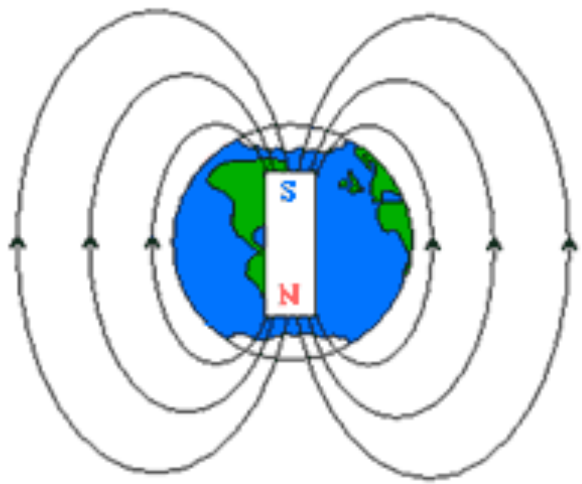
Magnetic Poles: Opposites Attract



Magnets have at least 2 poles (a dipole).

- Opposite poles attract:
  -North & South poles attract
- Like poles repel:
  -North & North and South & South poles repel

Magnetic dipoles are labeled as +/-, North/ South, red/blue, etc. Earth's north magnetic pole is negative (- polarity) and attracts the positive (+ polarity) compass needle.



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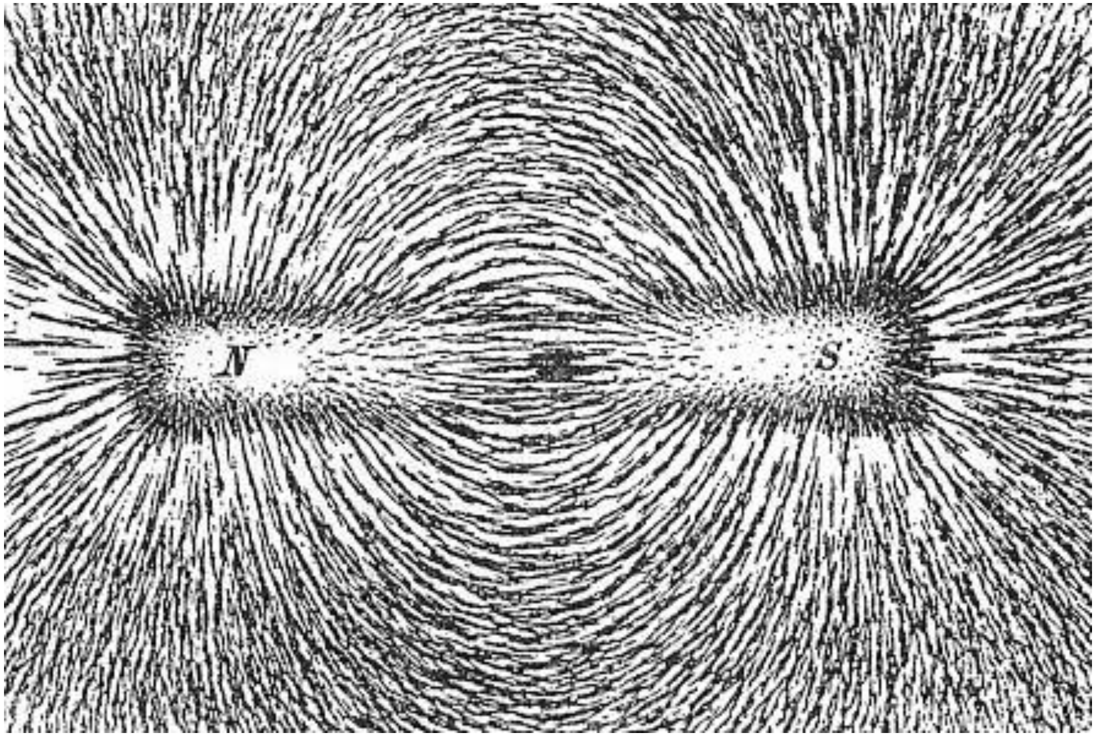
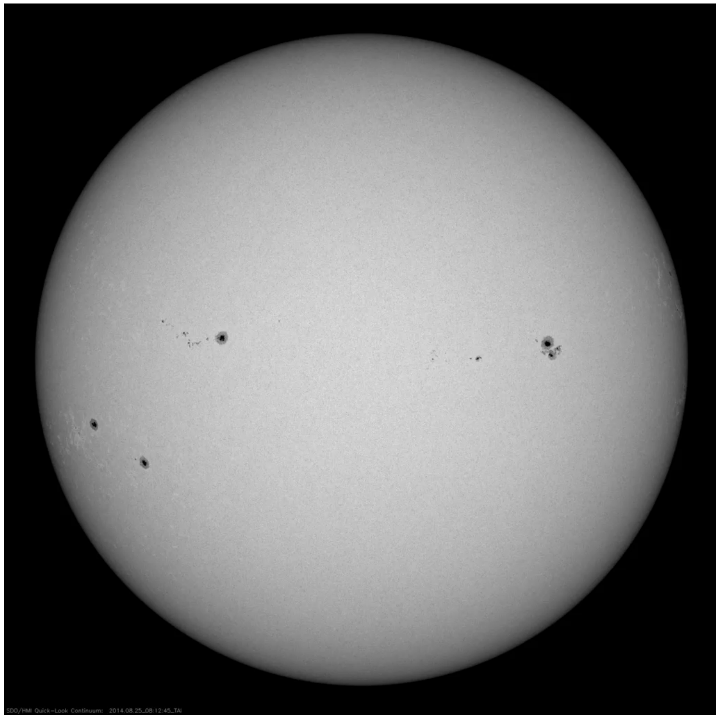
Magnetic Field Lines

Magnetic field lines represent where the magnetic fields are located.



Magnetic fields cannot be seen but their effects can be detected and measured.

Sunspots & Solar Rotation



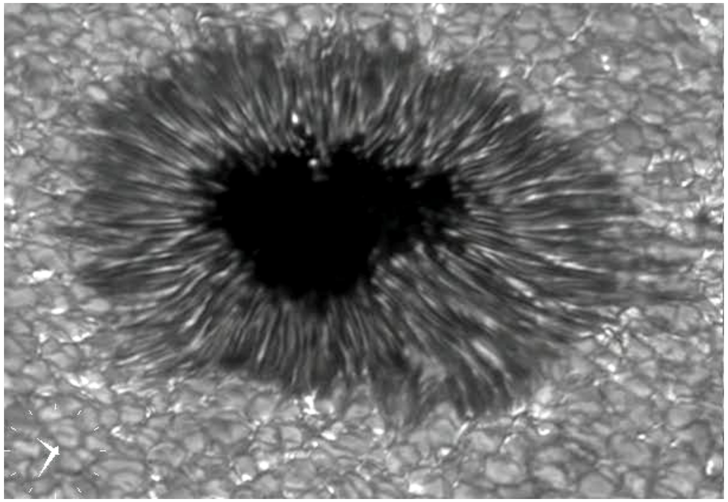
Video (click image to start & stop)

Sunspots are moving, temporary dark splotches on the surface of the Sun. Sunspots are about 2,000 Kelvin cooler than the average temperature of the surrounding photosphere (~6000 K). Sunspots appear dark because they are cooler but **not** cool!

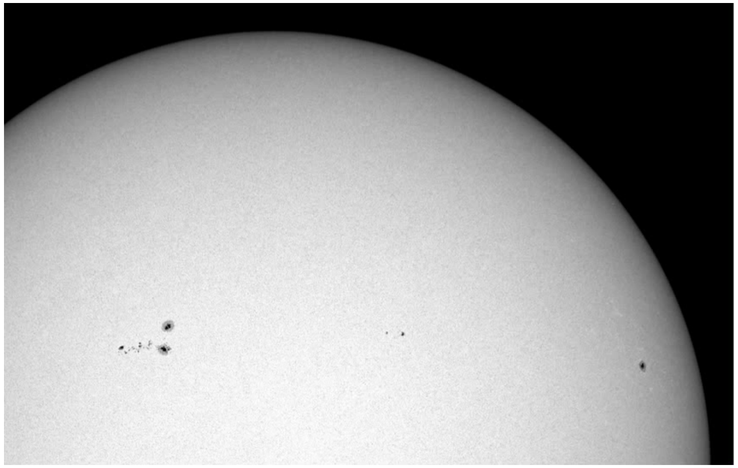
Differential Rotation

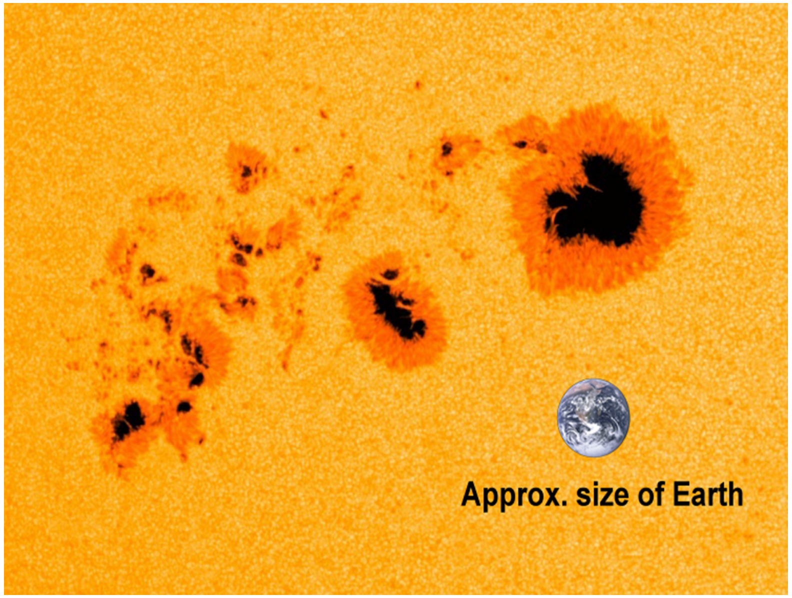
Tracking long-lived sunspots through time allows scientists to determine the rotation rate of the Sun. It turns out that the Sun spins faster at the equator than at its poles.

Sunspots



Videos (click images to start & stop)



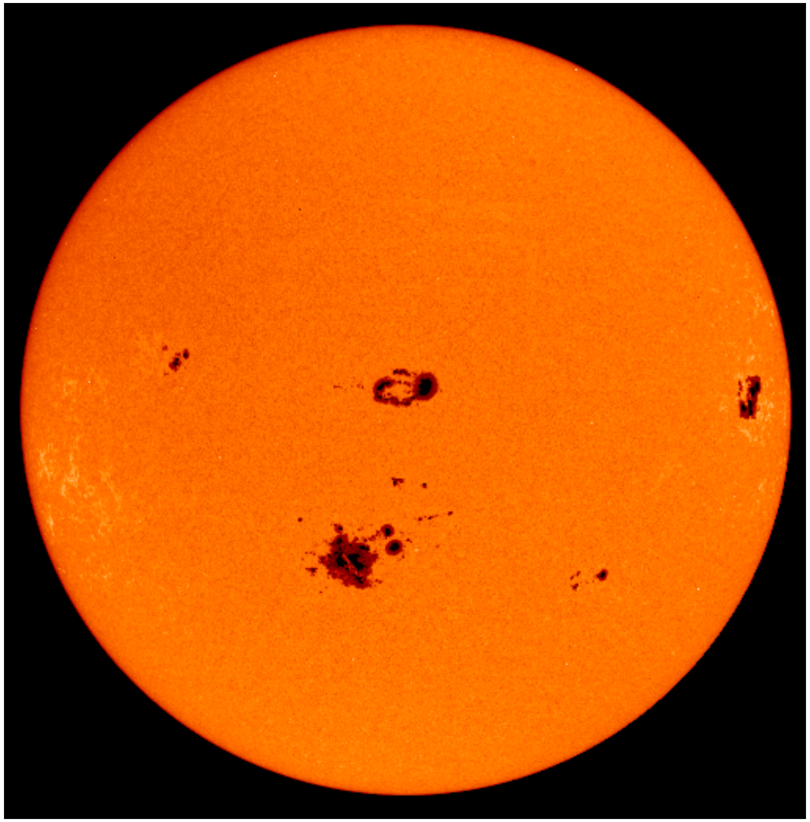


Sunspots are caused by and signs of magnetically active regions on the Sun.

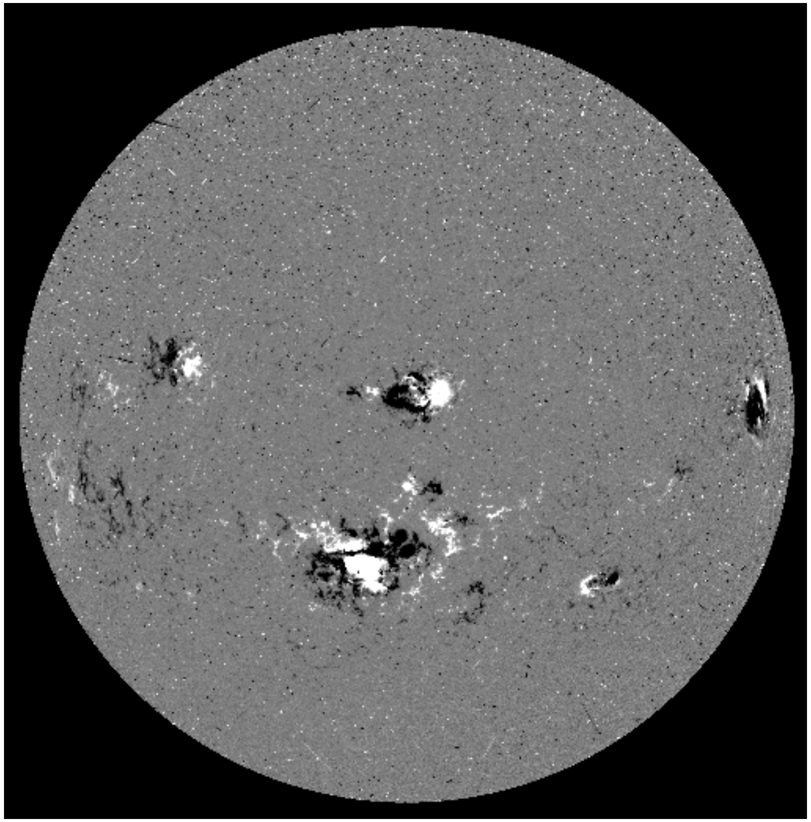
Sunspots are usually dipoles (2 poles), positive and negative pairs, like a magnet.

Sunspots and Magnetic Fields

Visible light image of the Sun showing sunspots



Magnetic image of the Sun



Note the black and white polarity of the magnetic fields of the Sun's image on the right that match the sunspot locations of the Sun's image on the left. Sunspots in the northern hemisphere have the opposite polarity of sunspots in the southern hemisphere.

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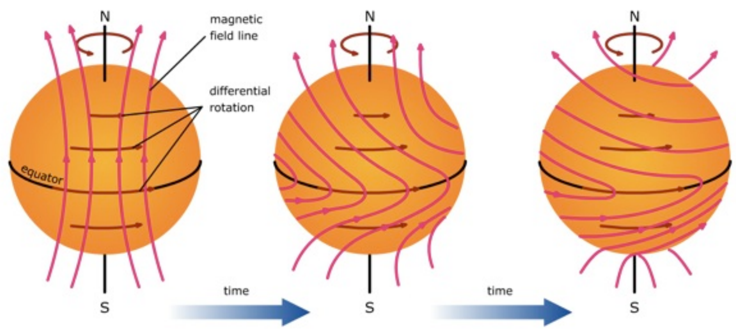
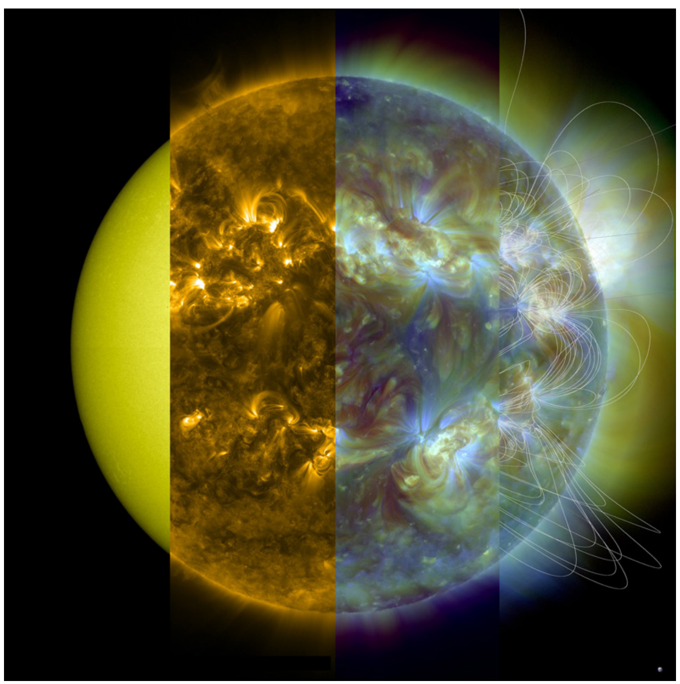
What causes the Sun's magnetic fields?





- The *solar dynamo* is the physical process that generates the Sun's magnetic fields.
- An electric current is produced in the Sun's Convection Zone by shear forces (stretching & churning of plasma) caused by the Sun's differential rotation.
- As the Sun's magnetic fields twist, they can "pop out" through the solar surface.

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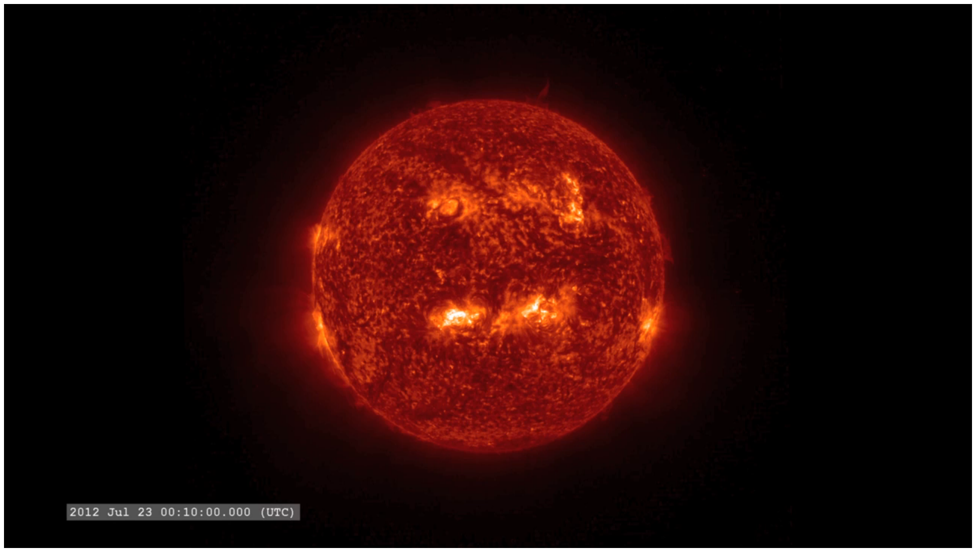
How do magnetic fields cause solar activity?

Animation (click image to start & stop)

Most sunspots on the Sun are caused by the tangles and eruptions of complex magnetic fields twisted and distorted by the Sun's uneven rate of rotation.

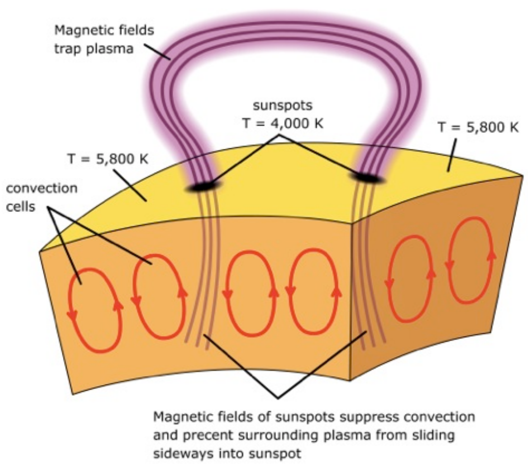
Seeing Magnetic Field Lines



Video (click image to start & stop)

Plasma traces out the magnetic fields into the atmosphere of the Sun's corona.

The magnetic fields originate from sunspot regions of opposite polarity (+/-).



Magnetism = Solar Flares & Coronal Mass Ejections

Animation (click image to start & stop)

Magnetic field lines poking through the solar surface produce sunspots, solar flares, and coronal mass ejections.

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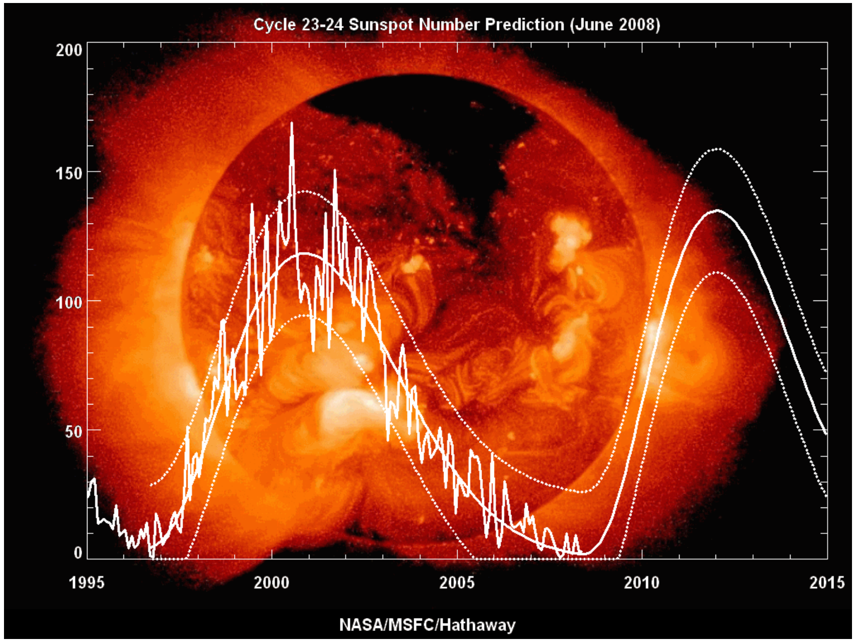
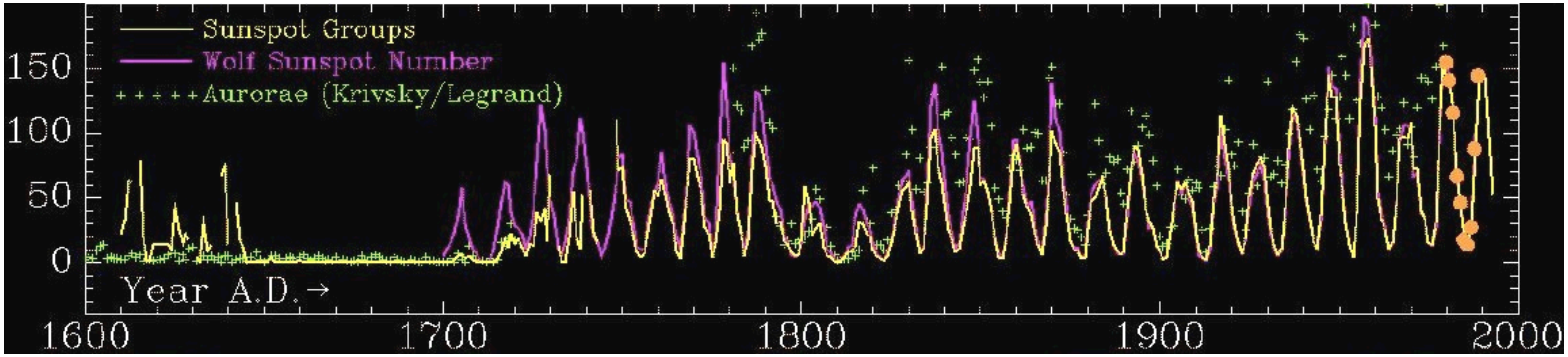
The Solar Cycle



The amount of magnetic activity on the Sun varies in approximately an 11-year cycle, which is known as the sunspot cycle. About half way through a sunspot cycle there is a solar maximum (high level of magnetic solar activity) that is linked to an increase in the number of sunspots. The second half of the sunspot cycle is noted by a decrease in sunspot numbers, which is the solar minimum (low level of magnetic solar activity).



The solar cycle over the past 300 years shows a repeating pattern of sunspot solar maximum and solar minimum.

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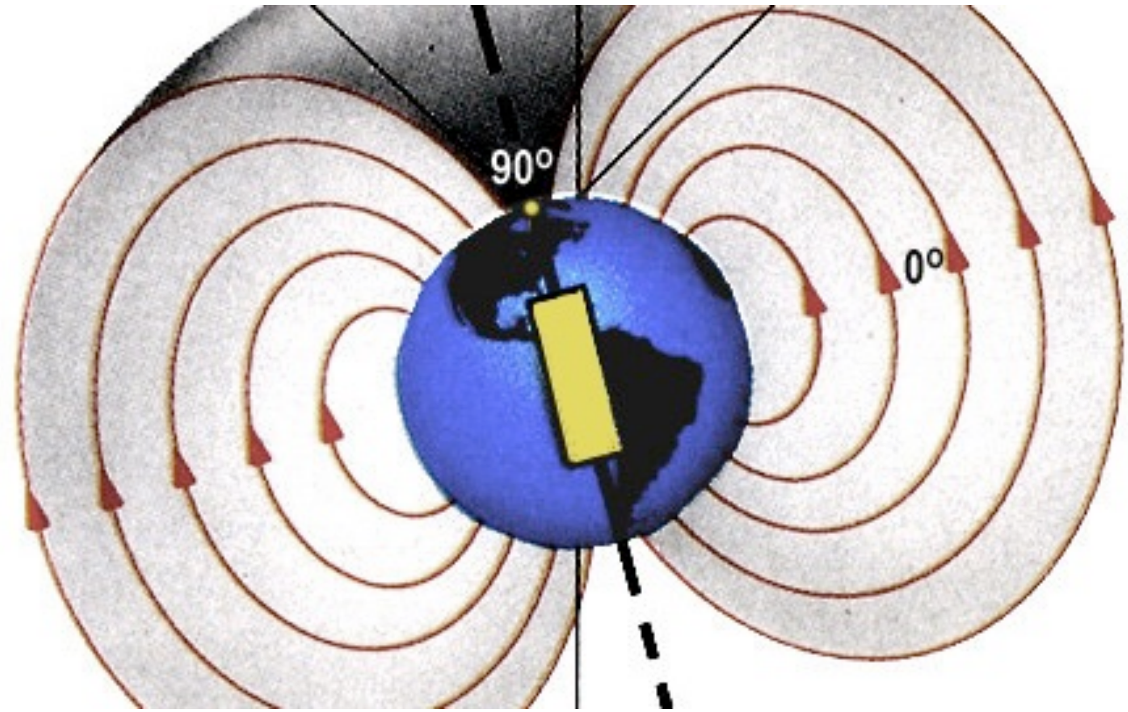
Earth's Magnetosphere (magnetic field)



The Earth has a 3-D magnetic field generated by electrical currents in its molten core.

Magnetic poles move as much as 15 km per year. The poles have flipped polarity many times. This occurs at an average of 300,000 years and takes 10,000 or so years to accomplish. There is no evidence that this flipping of magnetic poles affects life on Earth.

The Sun is the Source of Space Weather

Video

Animation (click image to start & stop)

Solar flares and coronal mass ejections (CMEs) on the Sun burst huge amounts of charged particles as solar storms and solar wind, called space weather, that impact and affect Earth and beyond.

Earth's protective magnetosphere keeps us safe from dangerous solar radiation from space weather.

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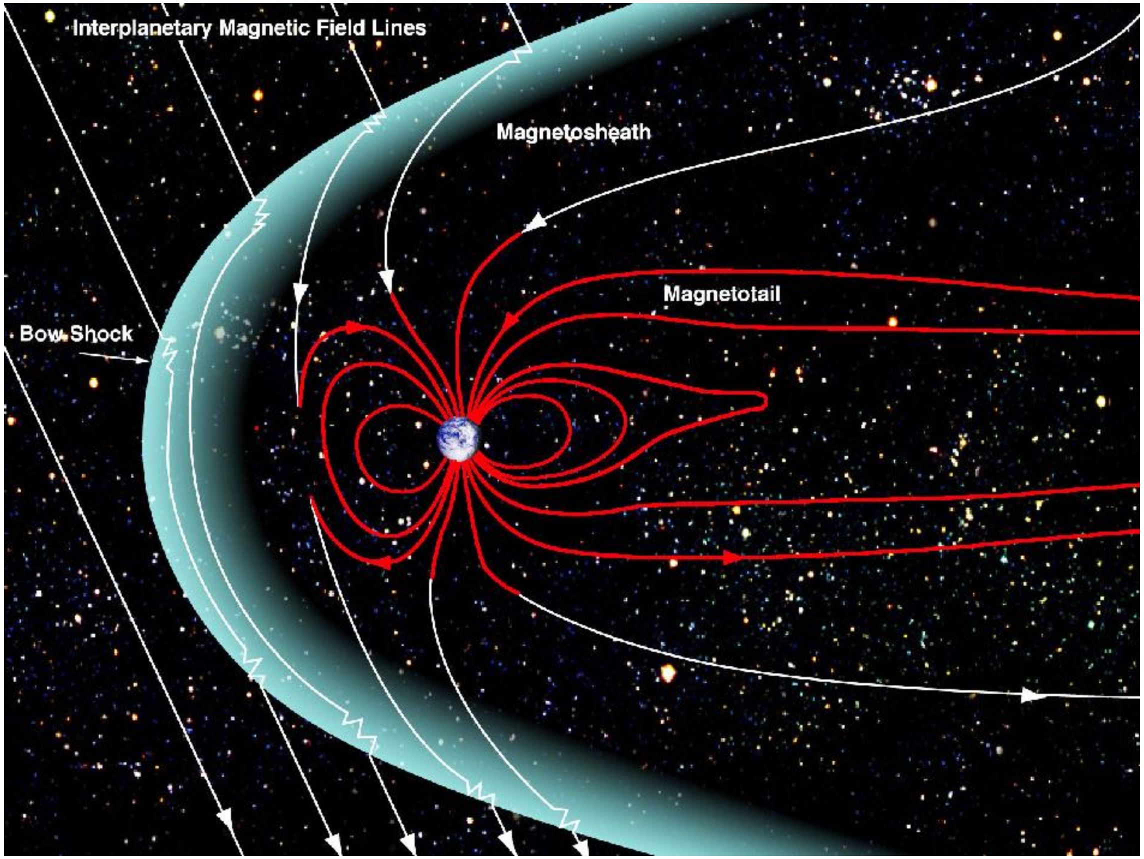
Magnetic Storms from the Sun



The strength of a geomagnetic storm (a solar storm impacting Earth) is determined by the strength and direction of its magnetic field and the pressure of the solar wind.

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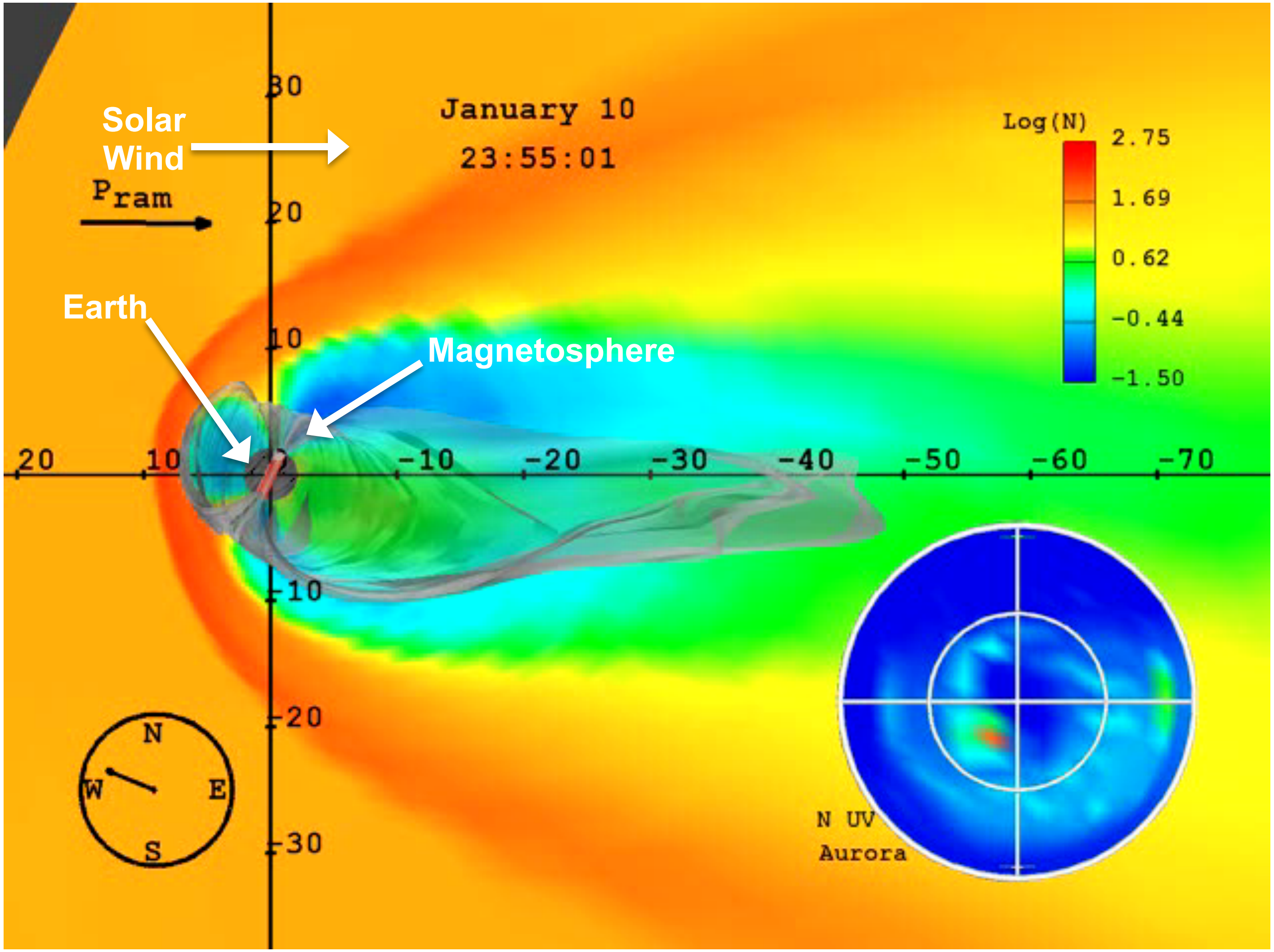
Earth's Magnetosphere & Solar Storm



Computer Simulation (click image to start & stop)

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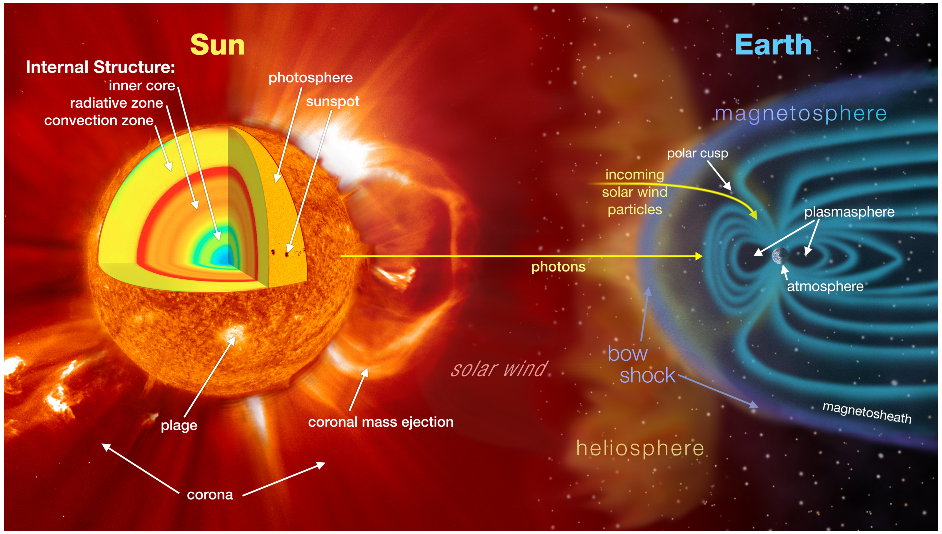
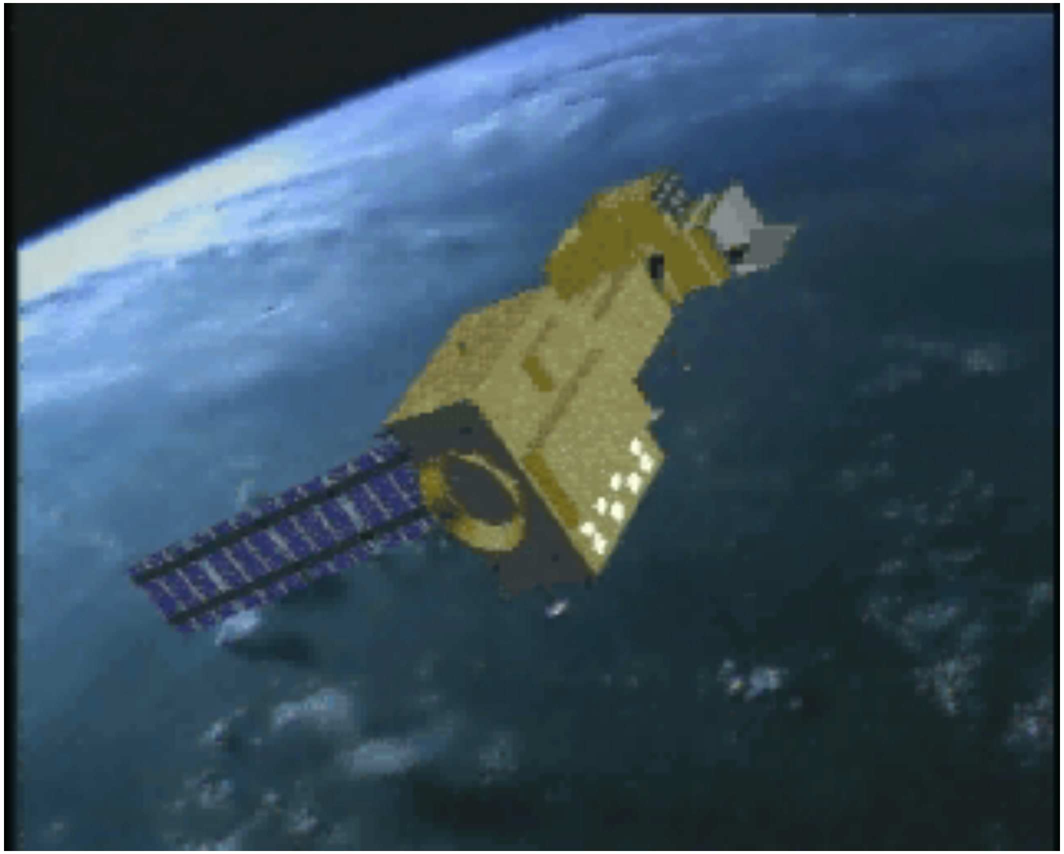
Why is the magnetosphere important to life on Earth?

- Earth's magnetosphere protects the ozone layer from the solar wind. The ozone layer protects the Earth (and life on it) from dangerous ultraviolet (UV) radiation from the Sun.
- The magnetosphere also protects us from other dangerous radiation caused by high-energy charged particles coming from the Sun.
- The magnetosphere is essential to protecting life on Earth from Space Weather.



The Effects of Space Weather



Animation (click image to start & stop)

Solar activity can have a dramatic impact on power grids, communication systems, satellites, astronauts, and animals.

Solar Storms Threaten Technology

- In 1989, a solar storm caused 6 million people in Quebec to lose power for 9 hours.
- A solar flare in 1997 destroyed the Telstar 401 satellite (which transmitted “Star Trek”).

- An October 2003 solar storm knocked out the Mars Odyssey probe and destroyed transformers in South Africa, which took 4 months to repair.

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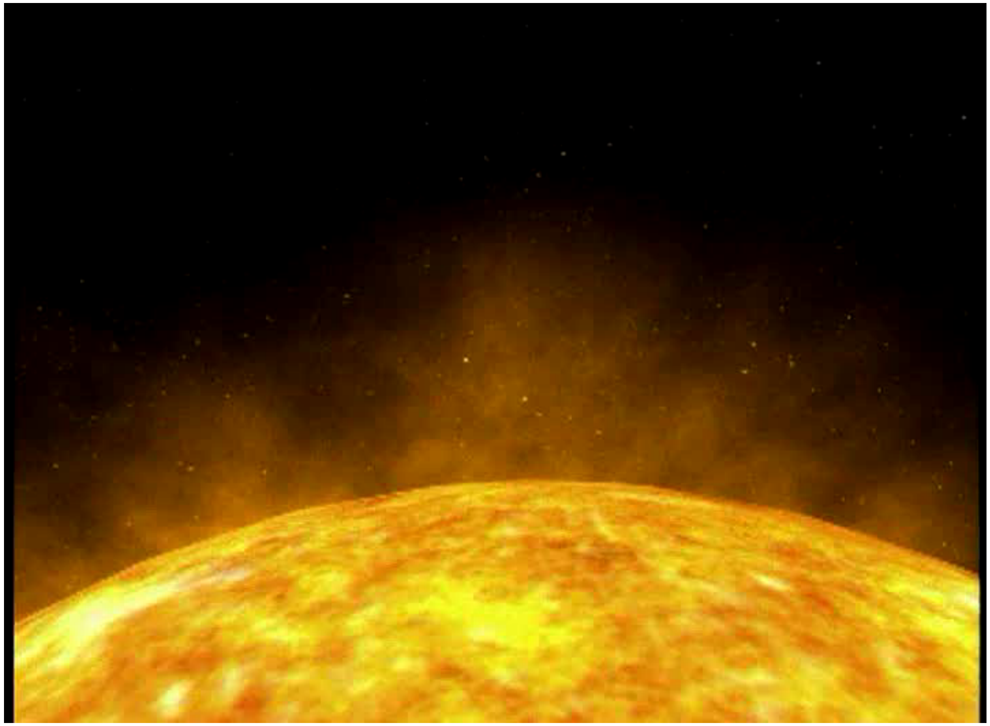
Auroras: Natural Effects of Space Weather

Evidence of space weather activity is seen at Earth's poles as colorful Aurora Borealis (northern lights) and Aurora Australis (southern lights). Auroras are caused by collisions between fast-moving electrons from space with the oxygen and nitrogen in Earth's upper atmosphere making the atoms and molecules "excited". When the gases return to their normal state, they give off small bursts of energy in the form of light.



Animation (click image to start & stop)

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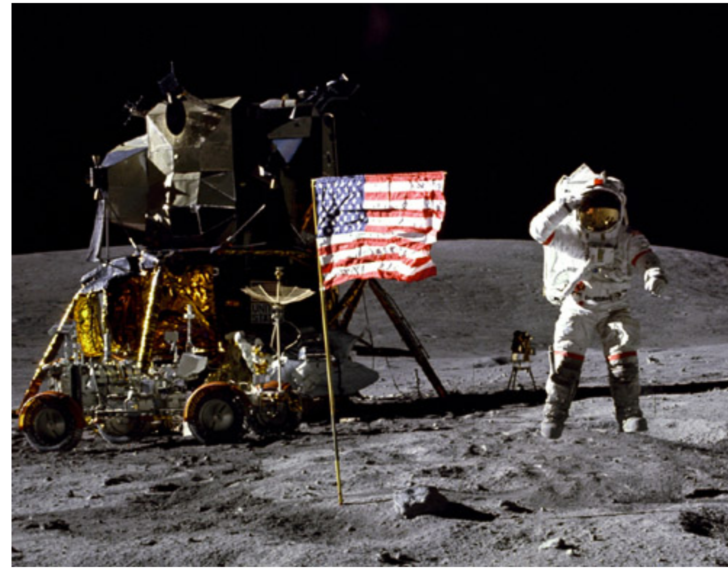
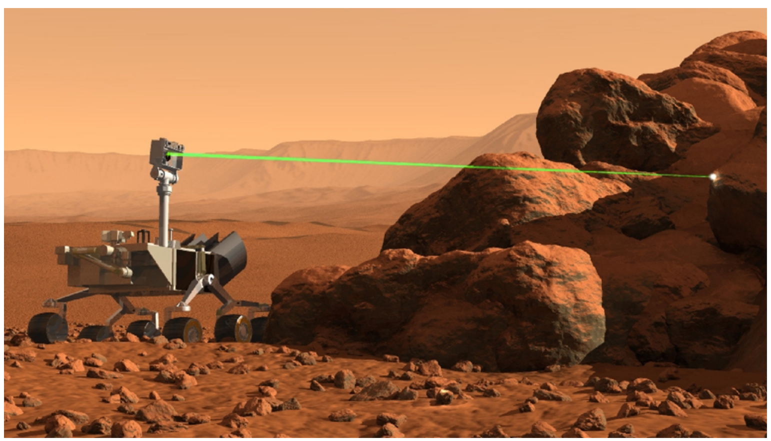
Space Weather in the Solar System

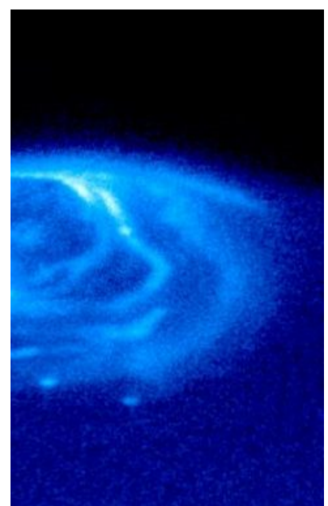
Space Weather affects the entire heliosphere (the Sun's atmosphere), which reaches from the Sun to the edge of our Solar System. Space Weather not only affects Earth but also the Moon and other planets in our Solar System, too.



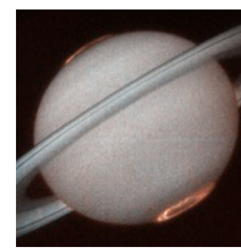
Lunar Landing



Mars



Aurorae on Neptune, Saturn, and Jupiter



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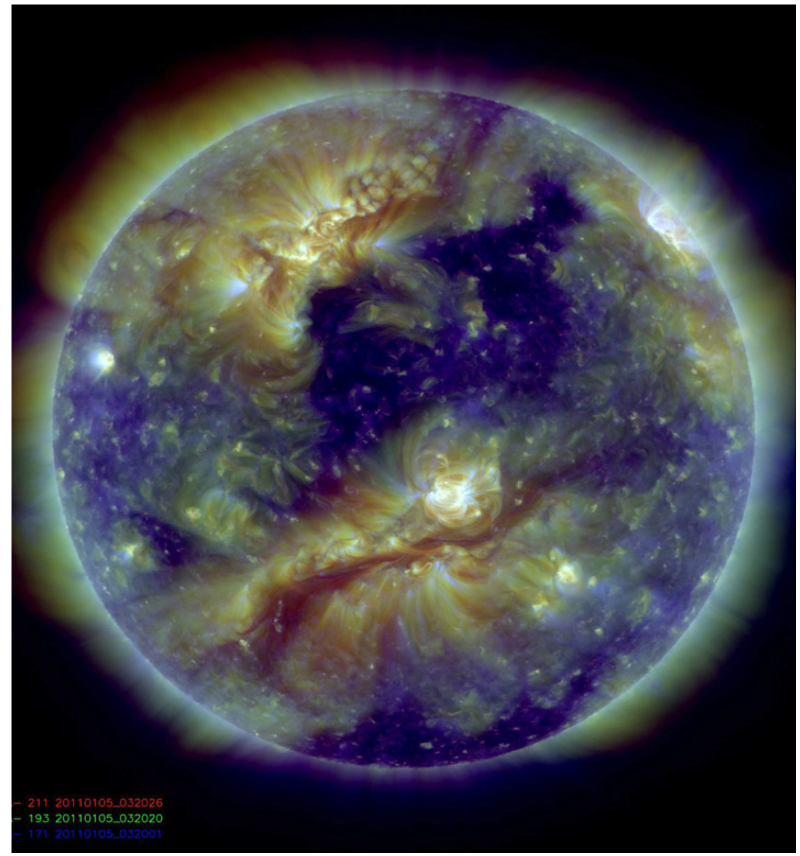
Remember…

The Sun's solar activity is caused by changes in its magnetic fields, which create Space Weather in our Solar System.

The Sun will continue to impact the Earth for another 5 billion years!



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