

Presentation for  
Student Scientists  
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# How is Science Done?

## The Scientific Method, Basic Problem Solving

- Make an Observation:
- An astronomer notices that the number of sunspots changes in a cyclical way (over about 11 years, duration between minima or maxima).
  - A marine ecologist notices bleaching of coral reefs.
  - A ham radio operator notices that she can communicate over longer distances at night.
- Form a hypothesis:
- The Sun's magnetic field creates these changes.
  - Seawater is becoming more acidic.
  - Recombination of ions in the atmosphere allow radio waves to go higher before being reflected back to Earth.
- Make a Prediction:
- With a mathematical model, the Sun's magnetic field can be "turned off". If this happens, sunspots will go away.
  - Coral in a more alkaline or neutral pH will not bleach.
  - Radio waves will travel farther at midnight than at dusk or dawn.

Test!  
Iterate!

# What Does a Scientist Do?

## Research

- Pick a topic
- Review the literature
- Collect data
- Analyze the data
- Form a hypothesis
- Write papers describing the research
- Submit papers for peer review
- Revise papers for publication
- Publish

# What Does a Scientist Do?

## Proposals

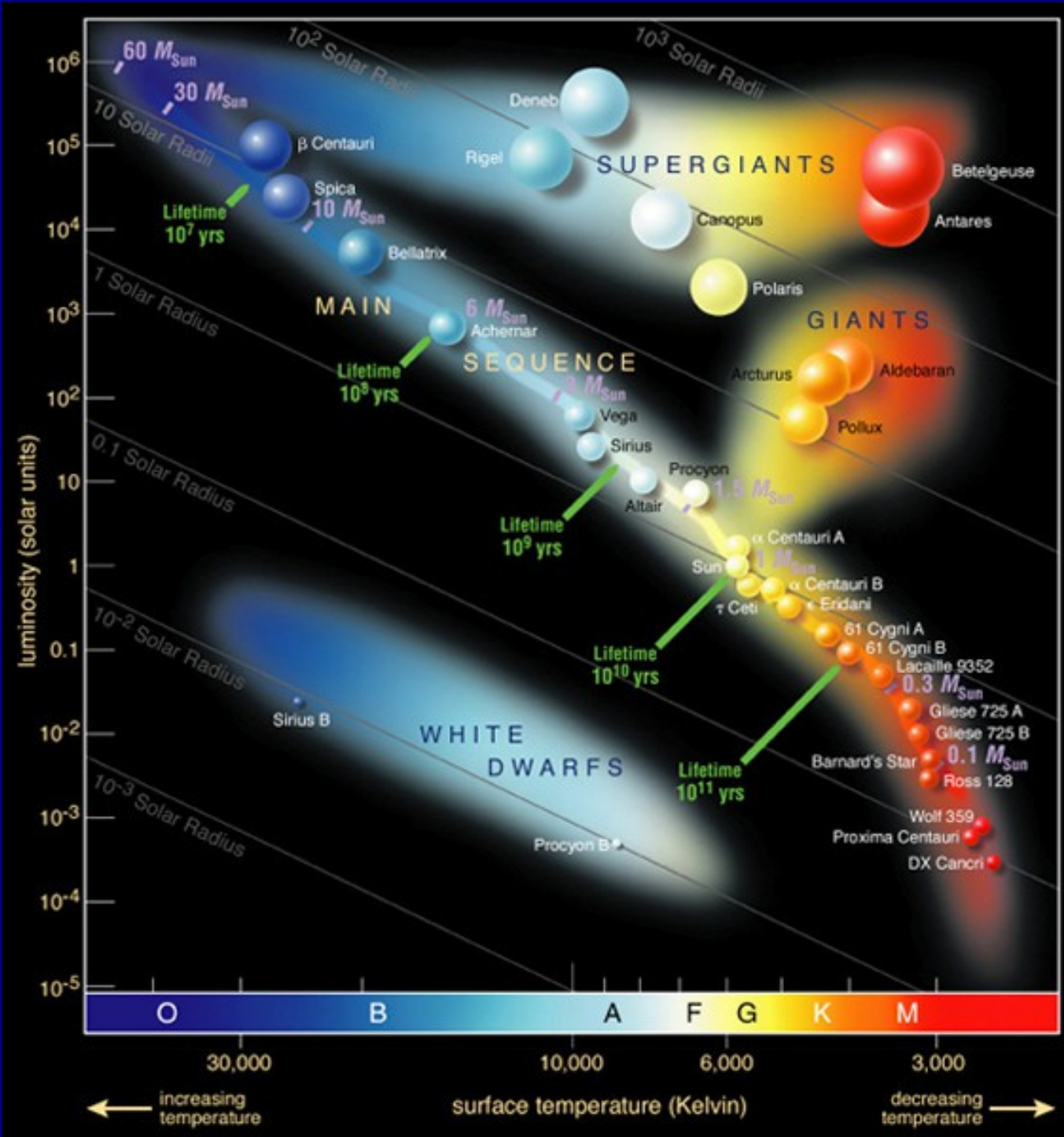
- From previous research, propose new research
- Review the literature
- Collect data
- Analyze the data
- Form a hypothesis
- Write a proposal describing the new research
- Consider how the research will advance the field
- Submit proposal
- Wait for panel review
- Deal with the rejection, but learn from comments of panel

# The Sun and an Eclipse Overview



Image Courtesy of Dr. Alphonse Sterling, NASA/MSFC  
August 1, 2008 Gansu Province, China

# What IS the Sun?



The Sun is a Star  
Stars are Mostly Hydrogen Gas

$\alpha$ -Cen-A is G2,  
 $\alpha$ -Cen-B is K1,  
Proxima ( $\alpha$ -Cen-C) is M6,

the Sun is G2  
8.5 light minutes away

Betelgeuse is M2  
643 ly

Bellatrix is B2    Rigel is B8  
250 ly            860 ly



# Layers of the Sun

## The Convection Zone

Energy continues to move toward the surface through convection currents of heated and cooled gas in the convection zone.

## The Corona

The ionized elements within the corona glow in the x-ray and extreme ultraviolet wavelengths. NASA instruments can image the Sun's corona at these higher energies since the photosphere is quite dim in these wavelengths.

## The Radiative Zone

Energy moves slowly outward—taking more than 170,000 years to radiate through the layer of the Sun known as the radiative zone.

## Sun's Core

Energy is generated by thermonuclear reactions creating extreme temperatures deep within the Sun's core.

## Coronal Streamers

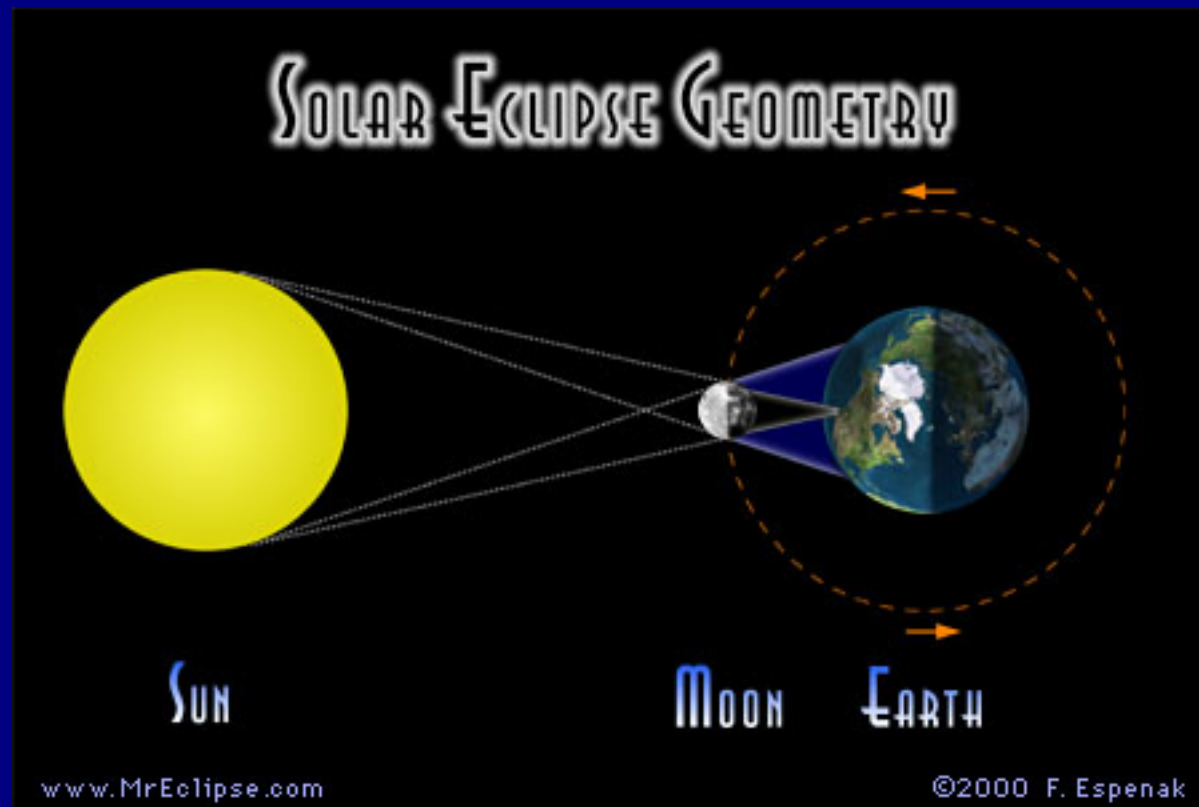
The outward-flowing plasma of the corona is shaped by magnetic field lines into tapered forms called coronal streamers, which extend millions of miles into space.

## The Chromosphere

The relatively thin layer of the Sun called the chromosphere is sculpted by magnetic field lines that restrain the electrically charged solar plasma. Occasionally larger plasma features—called prominences—form and extend far into the very tenuous and hot corona, sometimes ejecting material away from the Sun.



# Solar Eclipses



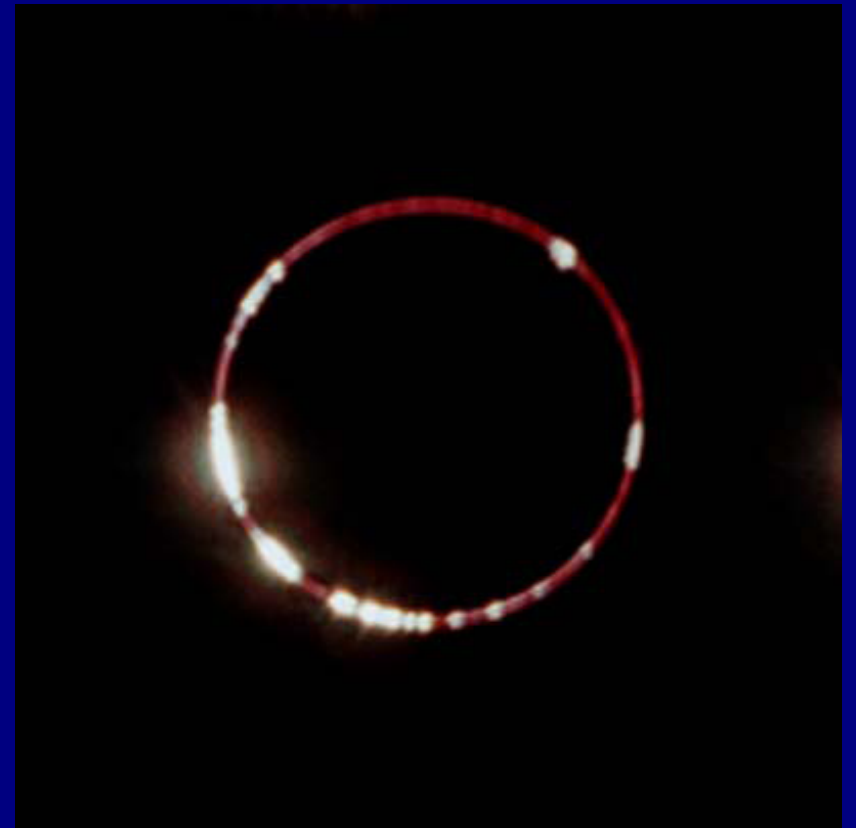
Images Used With Permission



# Use a Kitchen Colander or Trees For Partial Phases



# Total Eclipse: Diamond Ring and Bailey's Beads



# What You Can See: Total Eclipse



Zophia Edwards wide-angle view, from Jay Pasachoff's Eclipse 2013 page

Image Used With Permission

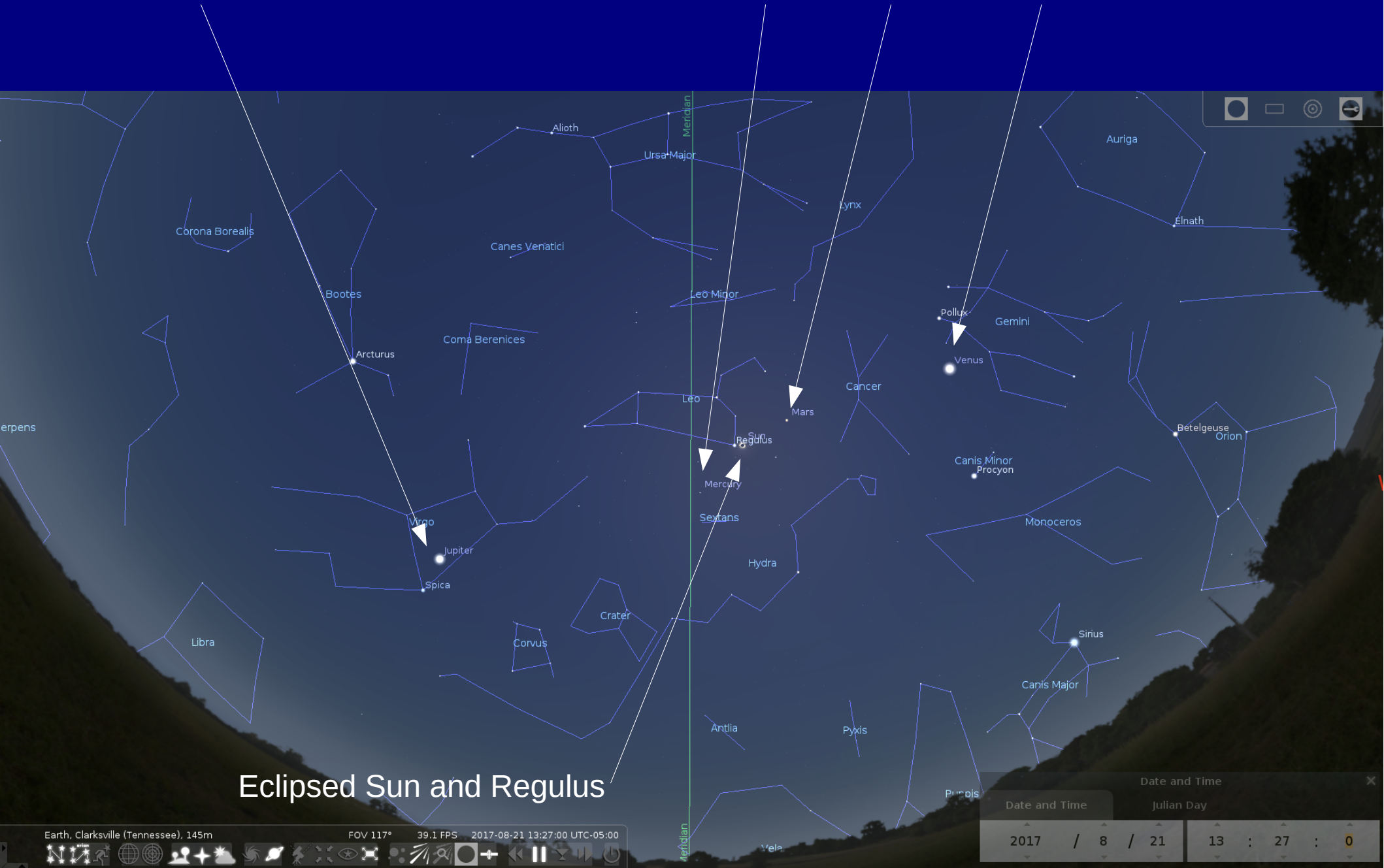
# The Corona and Prominences



Rob Lucas, with Jay Pasachoff's 2013 Eclipse Expedition  
Image Used With Permission

# The Sky During Totality

Jupiter is to the east of the Meridian (left), Mercury, Mars, and Venus to the west.



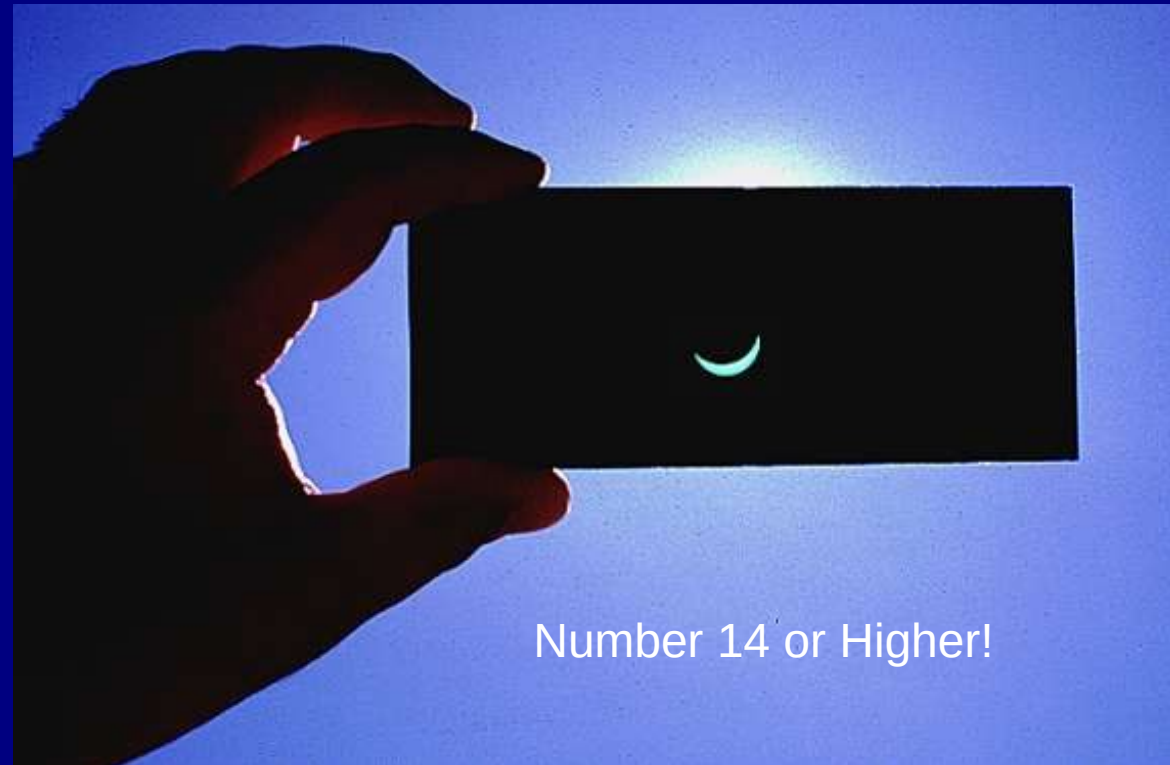
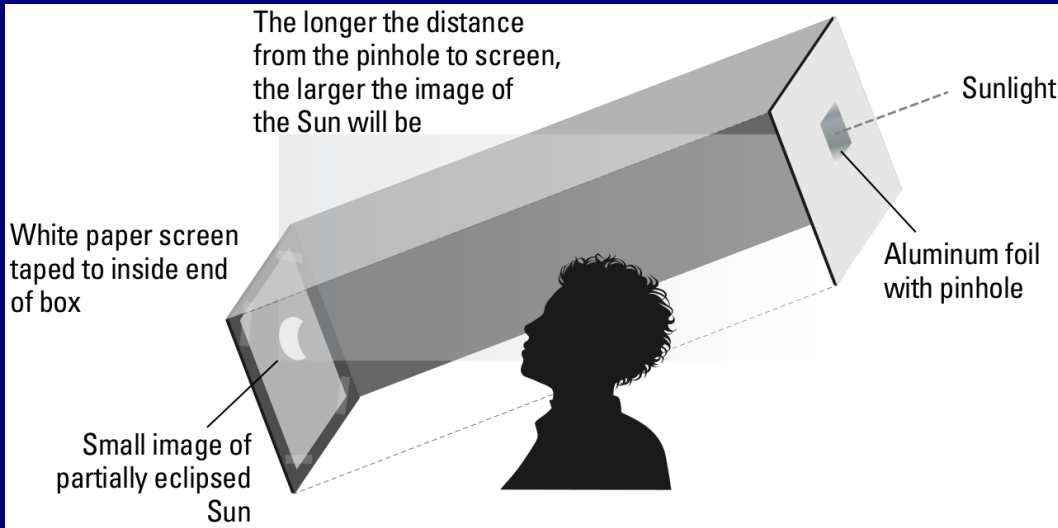
Eclipsed Sun and Regulus

Earth, Clarksville (Tennessee), 145m FOV 117° 39.1 FPS 2017-08-21 13:27:00 UTC-05:00

2017 / 8 / 21 13 : 27 : 0

# Safely Viewing an Eclipse

# Projection, Special Telescope Filters, Eclipse Glasses, Number 14 Welder's Glass



# More Information

[http://www.astrosociety.org/tov/Build\\_a\\_Sun\\_Funnel2.pdf](http://www.astrosociety.org/tov/Build_a_Sun_Funnel2.pdf)



<http://www.nasa.gov/offices/education/about/index.html>

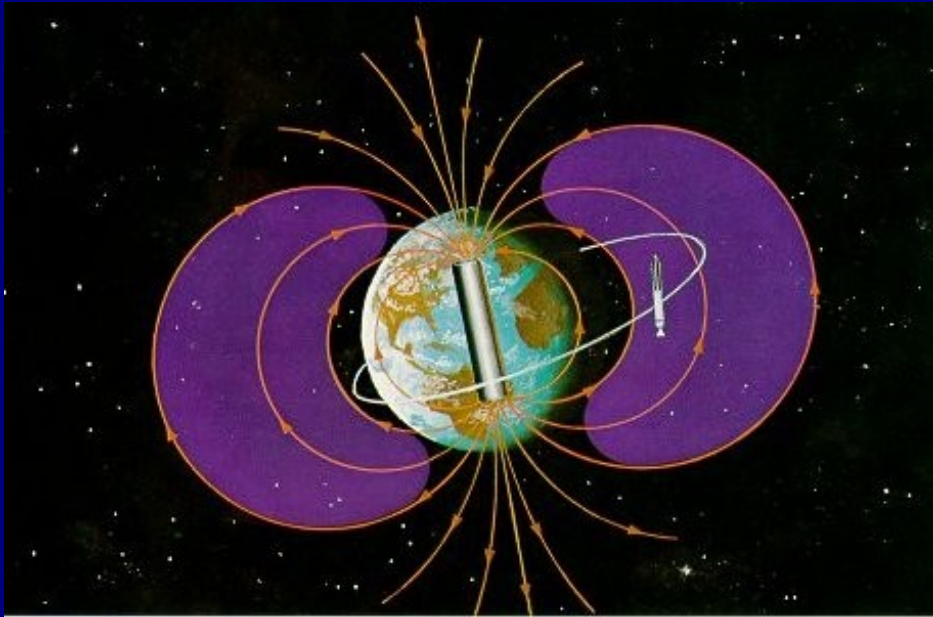
<http://www.greatamericaneclipse.com/>

<http://eclipse.gsfc.nasa.gov/SEgoogle/SEgoogle2001/SE2017Aug21Tgoogle.html>



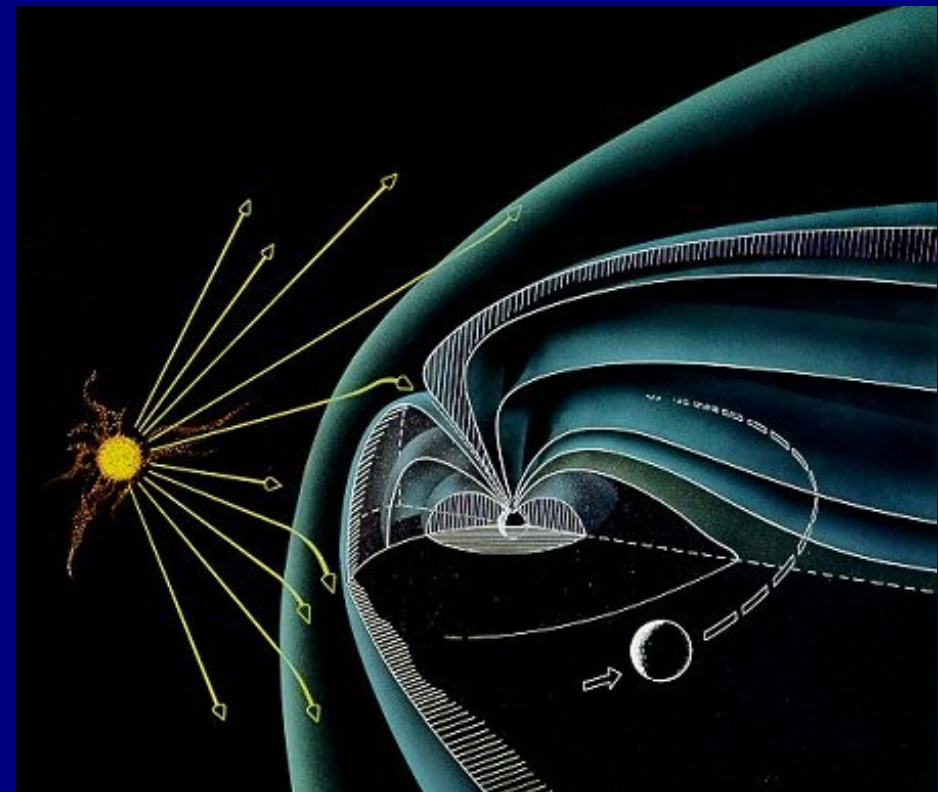
# The Magnetosphere

From NASA's History Office  
(<https://history.nasa.gov/EP-177/ch3-4.html>)

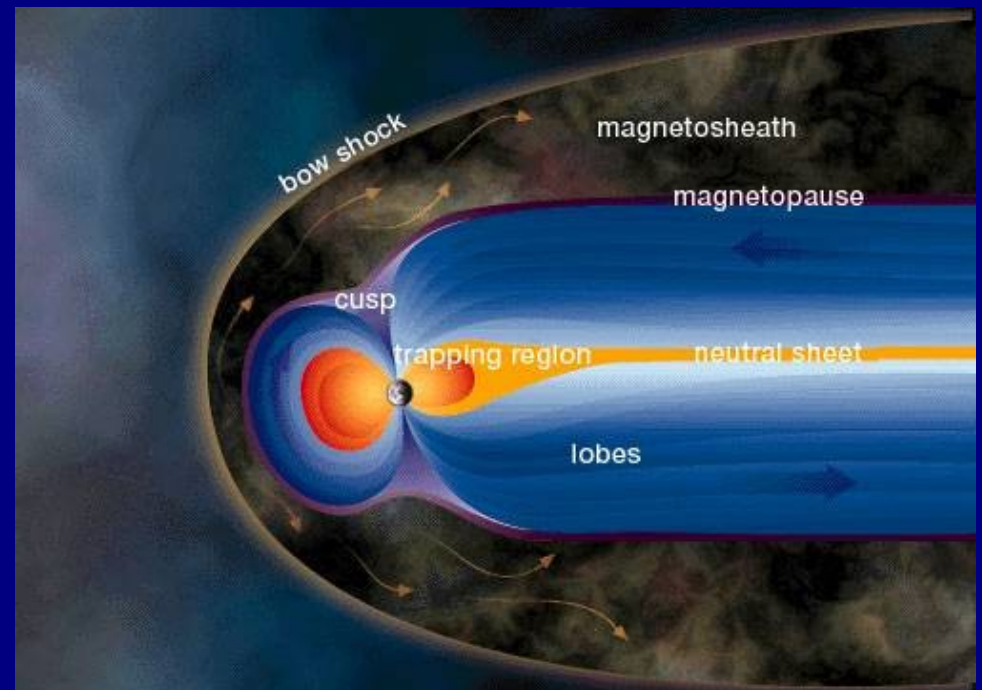
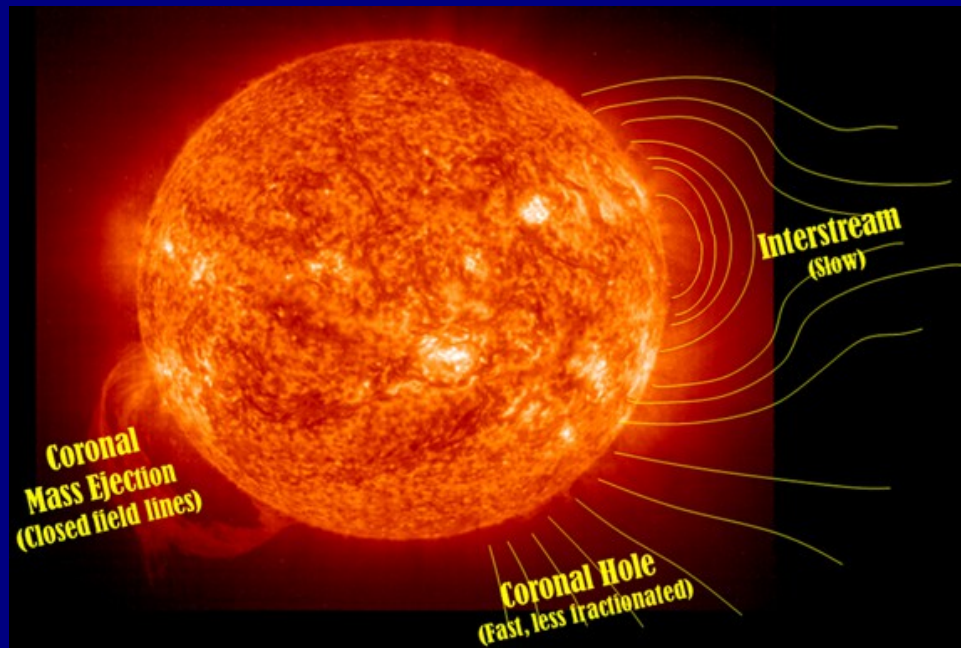


Explorer I (1958) discovered radiation belts,  
named for James Van Allen

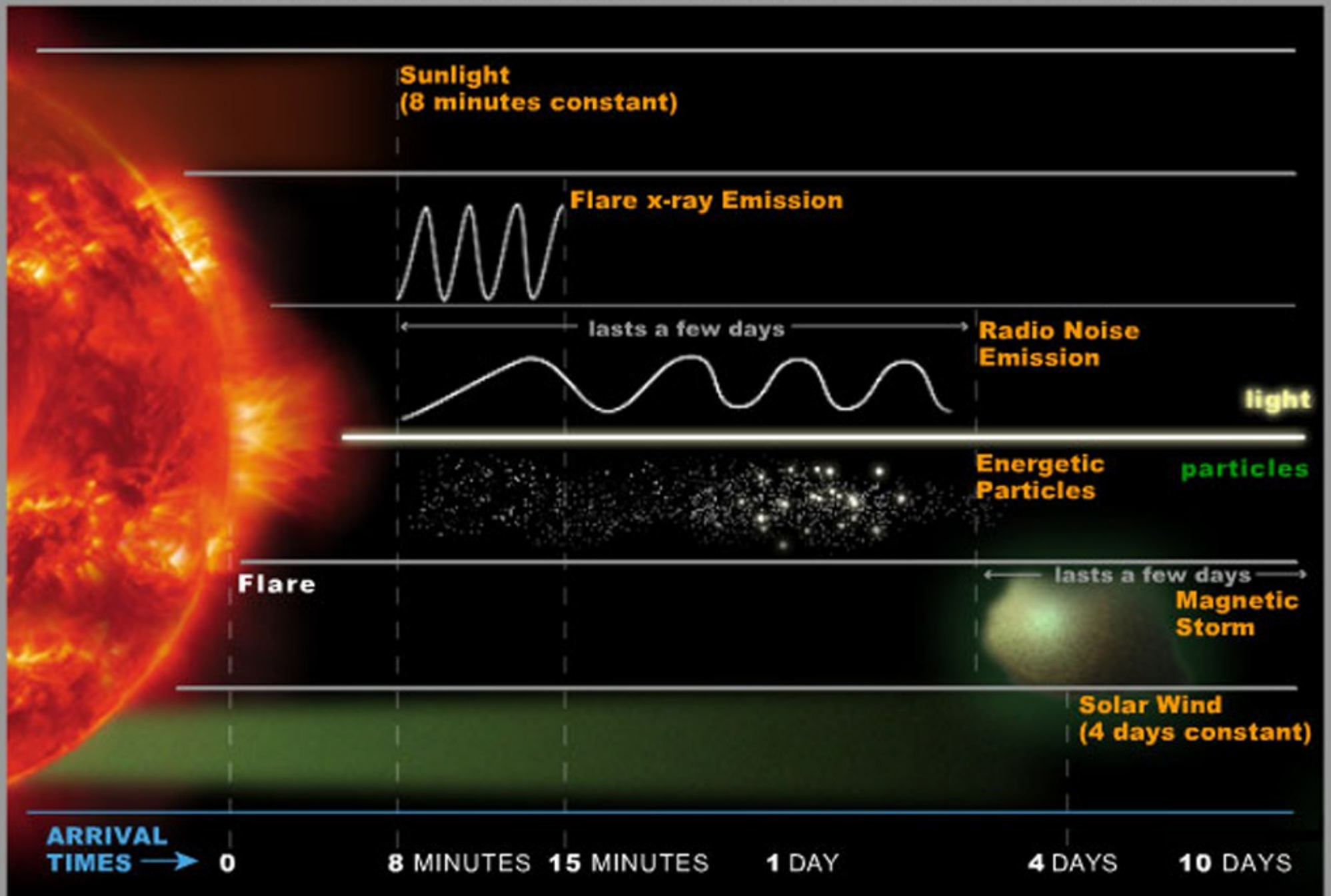
Magnetosphere and Magnetotail

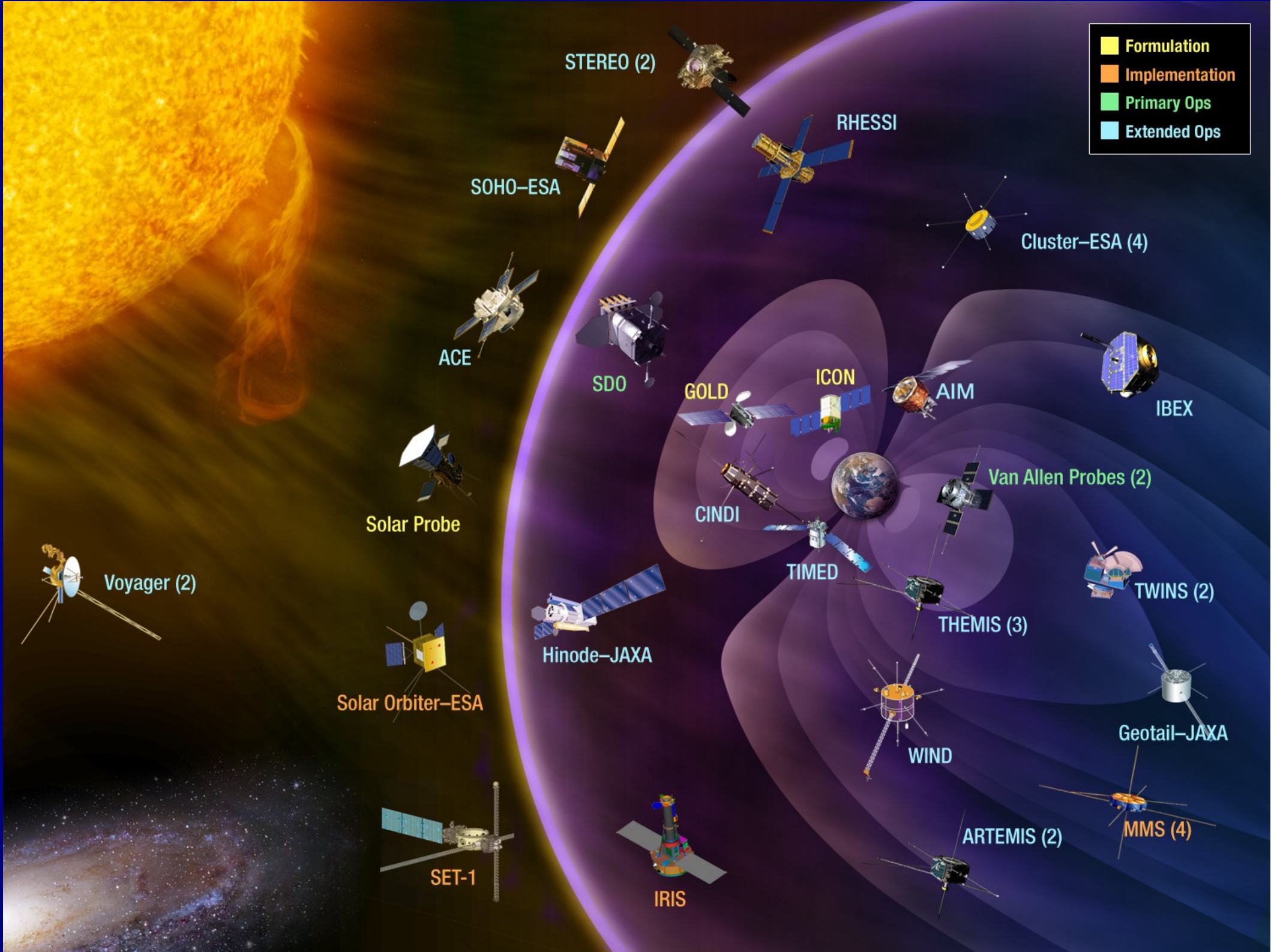


# The Solar Wind Interacts with Earth's Magnetosphere



# DYNAMIC AND CONSTANT SOLAR EFFECTS ON EARTH



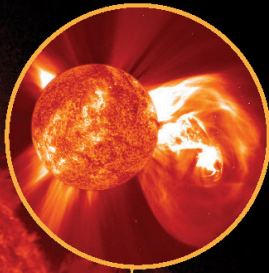
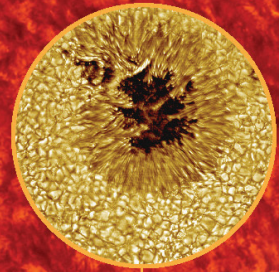


# Space Weather

Space weather refers to the variable conditions on the Sun and in the space environment that can influence the performance and reliability of space-based and ground-based technological systems, as well as endanger life or health. Just like weather on Earth, space weather has its seasons, with solar activity rising and falling over an approximate 11 year cycle.

## Sunspots

Sunspots are comparatively cool areas at up to 7,700° F and show the location of strong magnetic fields protruding through what we would see as the Sun's surface. Large, complex sunspot groups are generally the source of significant space weather.

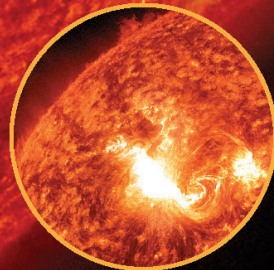


## Coronal Mass Ejections (CMEs)

Large portions of the corona, or outer atmosphere of the Sun, can be explosively blown into space, sending billions of tons of plasma, or superheated gas, Earth's direction. These CMEs have their own magnetic field and can slam into and interact with Earth's magnetic field, resulting in geomagnetic storms. The fastest of these CMEs can reach Earth in under a day, with the slowest taking 4 or 5 days to reach Earth.

## Solar Wind

The solar wind is a constant outflow of electrons and protons from the Sun, always present and buffeting Earth's magnetic field. The background solar wind flows at approximately one million miles per hour!



## Solar Flares

Reconnection of the magnetic fields on the surface of the Sun drive the biggest explosions in our solar system. These solar flares release immense amounts of energy and result in electromagnetic emissions spanning the spectrum from gamma rays to radio waves. Traveling at the speed of light, these emissions make the 93 million mile trip to Earth in just 8 minutes.

## Earth's Magnetic Field

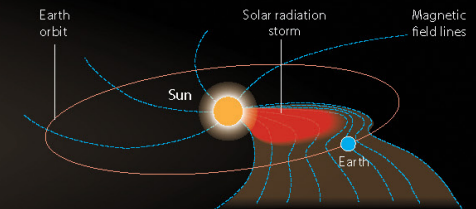
Earth's magnetic field, largely like that of a bar magnet, gives the Earth some protection from the effects of the Sun. Earth's magnetic field is constantly compressed on the day side and stretched on the night side by the ever-present solar wind. During geomagnetic storms, the disturbances to Earth's magnetic field can become extreme. In addition to some buffering by the atmosphere, this field also offers some shielding from the charged particles of a radiation storm.

## Sun's Magnetic Field

Strong and ever-changing magnetic fields drive the life of the Sun and underlie sunspots. These strong magnetic fields are the energy source for space weather and their twisting, shearing, and reconnection lead to solar flares.

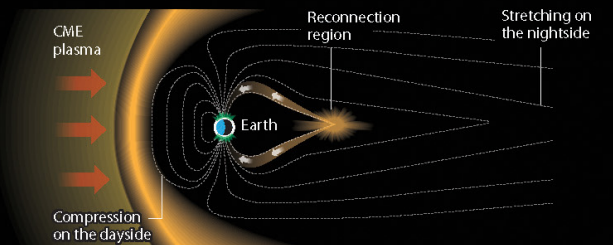
## Solar Radiation Storms

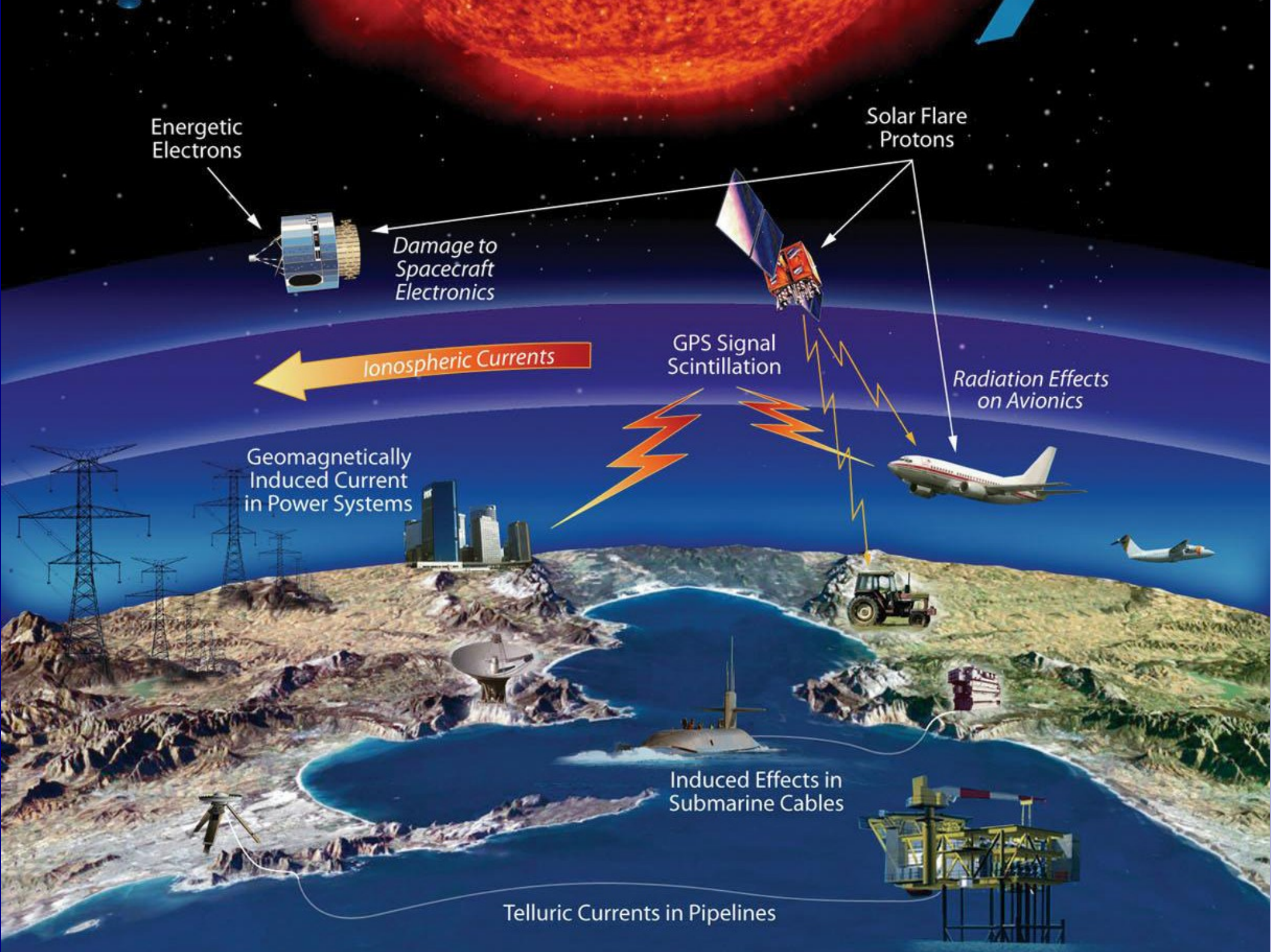
Charged particles, including electrons and protons, can be accelerated by coronal mass ejections and solar flares. These particles bounce and gyrate their way through space, roughly following the magnetic field lines and ultimately bombarding Earth from every direction. The fastest of these particles can affect Earth tens of minutes after a solar flare.



## Geomagnetic Storms

A geomagnetic storm is a temporary disturbance of Earth's magnetic field typically associated with enhancements in the solar wind. These storms are created when the solar wind and its magnetic field interacts with Earth's magnetic field. The primary source of geomagnetic storms is CMEs which stretch the magnetosphere on the nightside causing it to release energy through magnetic reconnection. Disturbances in the ionosphere (a region of Earth's upper atmosphere) are usually associated with geomagnetic storms.





Energetic Electrons

Solar Flare Protons

Damage to Spacecraft Electronics

Ionospheric Currents

GPS Signal Scintillation

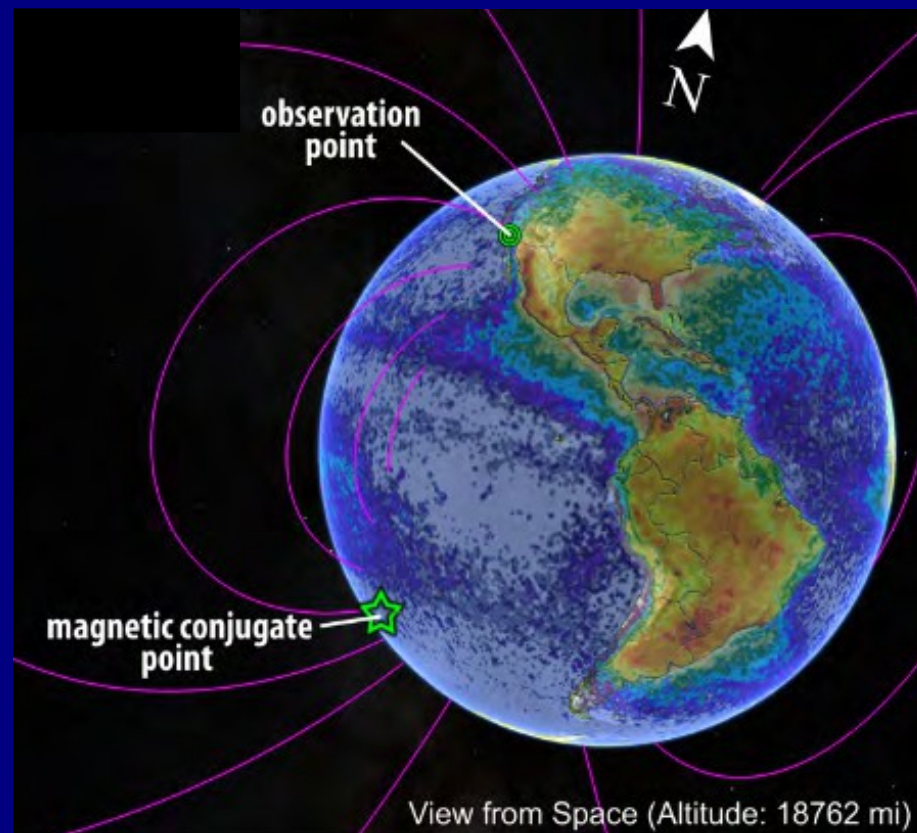
Radiation Effects on Avionics

Geomagnetically Induced Current in Power Systems

Induced Effects in Submarine Cables

Telluric Currents in Pipelines

The INSPIRE Project provides creative hands-on opportunities for students of all ages to observe Very Low Frequency waves (i.e. lightning and other atmospheric sounds) by using the INSPIRE VLF-3 Natural Radio Sound Receiver.

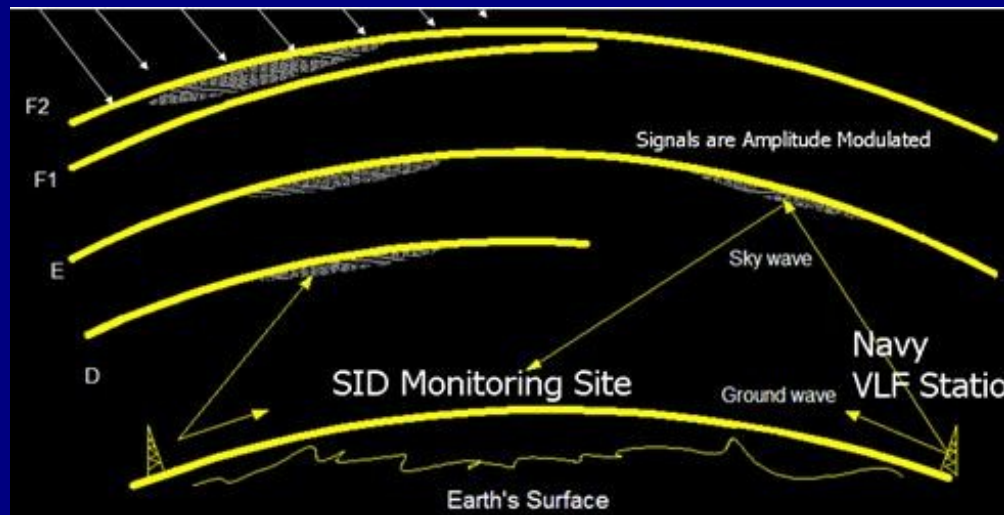
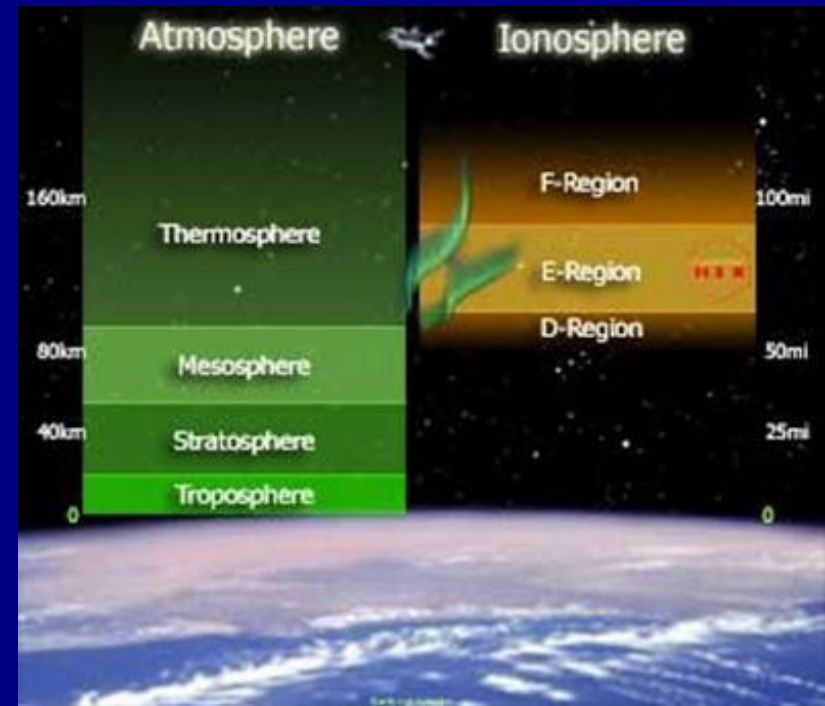
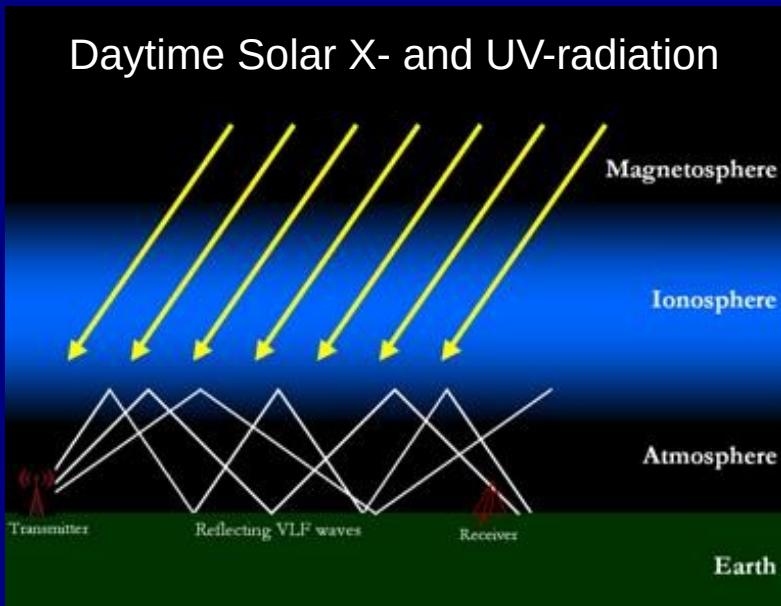


WAV File!



# The Ionosphere

## Daytime Solar X- and UV-radiation



At night (on right), ions recombine, ionosphere has only F and E layers, transmitted radio signals travel higher before bouncing, so can be received at larger distances.

