Techniques for observing solar phenomena

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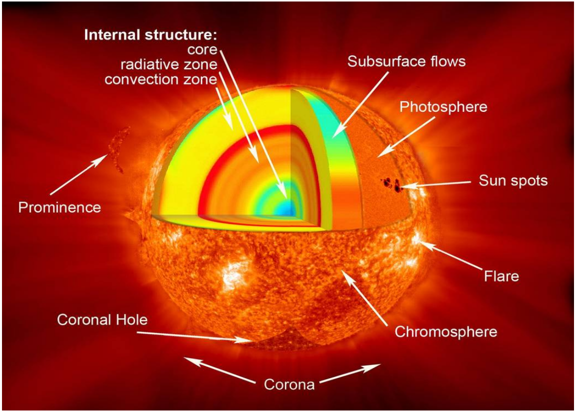
Presentation Outline

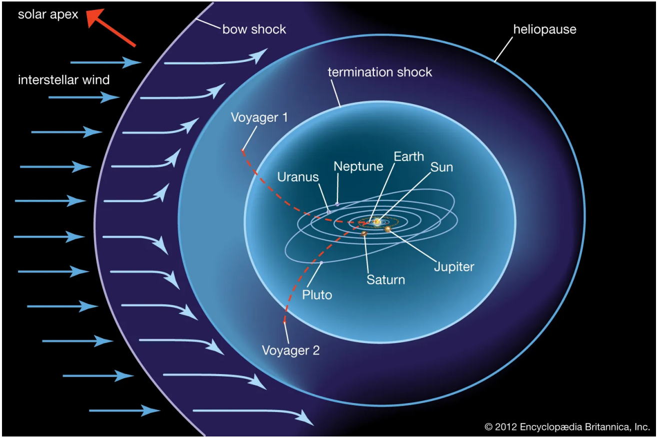
- The Sun
- Solar phenomena
- Techniques to look at the Sun
- Space missions observing the Sun
- Conclusions

The Sun

- The Sun is the star at the center of the Solar System. It is a massive (864,000 miles (1,392,000 km) in diameter, which makes it 109 times wider than Earth), hot ball of plasma, inflated and heated by nuclear fusion reactions at its core.



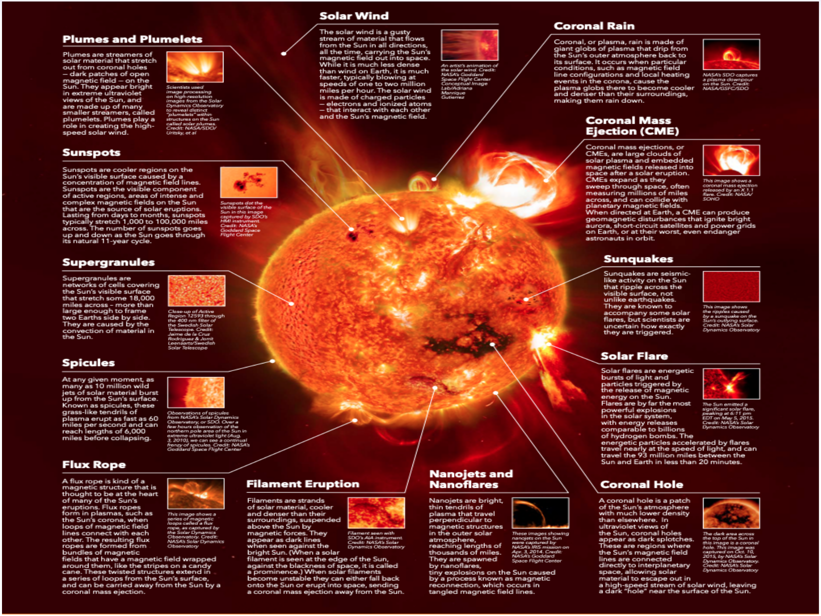
- The sun sends out a constant flow of charged particles called the solar wind, which ultimately travels past all the planets to some three times the distance to Pluto before being impeded by the interstellar medium. This forms a giant bubble around the sun and its planets, known as the heliosphere.



Solar phenomena

- Solar phenomena are natural phenomena which occur within the atmosphere of the Sun.

- These phenomena take many forms, including solar wind, solar flares, coronal mass ejections (CME), and sunspots.


Plumes and Plumelets
Plumes are streamers of solar material that stretch out from coronal holes – dark patches of open magnetic field – on the Sun. They appear bright in extreme ultraviolet views of the Sun, and are made up of many smaller streamers, called plumelets. Plumes play a role in creating the high-speed solar wind.
Scientists used image processing on high-resolution images from the Solar Dynamics Observatory to reveal distinct "plumelets" within structures on the Sun called solar plumes. Credit: NASA/SDO/Uritsky, et al
Solar Wind
The solar wind is a gusty stream of material that flows from the Sun in all directions, all the time, carrying the Sun's magnetic field out into space. While it is much less dense than wind on Earth, it is much faster, typically blowing at speeds of one to two million miles per hour. The solar wind is made of charged particles – electrons and ionized atoms – that interact with each other and the Sun's magnetic field.
An artist's animation of the solar wind. Credit: NASA's Goddard Space Flight Center Conceptual Image Lab/Adriana Manrique Gutierrez
Coronal Rain
Coronal, or plasma, rain is made of giant globs of plasma that drip from the Sun's outer atmosphere back to its surface. It occurs when particular conditions, such as magnetic field line configurations and local heating events in the corona, cause the plasma globs there to become cooler and denser than their surroundings, making them rain down.
NASA's SDO captures a plasma downpour on the Sun. Credit: NASA/GSFC/SDO
Sunspots
Sunspots are cooler regions on the Sun's visible surface caused by a concentration of magnetic field lines. Sunspots are the visible component of active regions, areas of intense and complex magnetic fields on the Sun that are the source of solar eruptions. Lasting from days to months, sunspots typically stretch 1,000 to 100,000 miles across. The number of sunspots goes up and down as the Sun goes through its natural 11-year cycle.
Sunspots dot the visible surface of the Sun in this image captured by SDO's HMI instrument. Credit: NASA's Goddard Space Flight Center
Coronal Mass Ejection (CME)
Coronal mass ejections, or CMEs, are large clouds of solar plasma and embedded magnetic fields released into space after a solar eruption. CMEs expand as they sweep through space, often measuring millions of miles across, and can collide with planetary magnetic fields. When directed at Earth, a CME can produce geomagnetic disturbances that ignite bright aurora, short-circuit satellites and power grids on Earth, or at their worst, even endanger astronauts in orbit.
This image shows a coronal mass ejection released by an X.1.1 flare. Credit: NASA/SOHO
Supergranules
Supergranules are networks of cells covering the Sun's visible surface that stretch some 18,000 miles across – more than large enough to frame two Earths side by side. They are caused by the convection of material in the Sun.
Close-up of Active Region 12593 through the 400 nm filter of the Swedish Solar Telescope. Credit: Jaime de la Cruz Rodriguez & Jorrit Leenaarts/Swedish Solar Telescope
Sunquakes
Sunquakes are seismic-like activity on the Sun that ripple across the visible surface, not unlike earthquakes. They are known to accompany some solar flares, but scientists are uncertain how exactly they are triggered.
This image shows the ripples caused by a sunquake on the Sun's outlying surface. Credit: NASA's Solar Dynamics Observatory
Spicules
At any given moment, as many as 10 million wild jets of solar material burst up from the Sun's surface. Known as spicules, these grass-like tendrils of plasma erupt as fast as 60 miles per second and can reach lengths of 6,000 miles before collapsing.
Observations of spicules from NASA's Solar Dynamics Observatory, or SDO. Over a few hours observation of the northern pole area of the Sun in extreme ultraviolet light (Aug. 3, 2010), we can see a continual frenzy of spicules. Credit: NASA's Goddard Space Flight Center
Solar Flare
Solar flares are energetic bursts of light and particles triggered by the release of magnetic energy on the Sun. Flares are by far the most powerful explosions in the solar system, with energy releases comparable to billions of hydrogen bombs. The energetic particles accelerated by flares travel nearly at the speed of light, and can travel the 93 million miles between the Sun and Earth in less than 20 minutes.
The Sun emitted a significant solar flare, peaking at 6:11 pm EDT on May 5, 2015. Credit: NASA's Solar Dynamics Observatory
Flux Rope
A flux rope is kind of a magnetic structure that is thought to be at the heart of many of the Sun's eruptions. Flux ropes form in plasmas, such as the Sun's corona, when loops of magnetic field lines connect with each other. The resulting flux ropes are formed from bundles of magnetic fields that have a magnetic field wrapped around them, like the stripes on a candy cane. These twisted structures extend in a series of loops from the Sun's surface, and can be carried away from the Sun by a coronal mass ejection.
This image shows a series of magnetic loops called a flux rope, as captured by the Solar Dynamics Observatory. Credit: NASA's Solar Dynamics Observatory
Filament Eruption
Filaments are strands of solar material, cooler and denser than their surroundings, suspended above the Sun by magnetic forces. They appear as dark lines when seen against the bright Sun. (When a solar filament is seen at the edge of the Sun, against the blackness of space, it is called a prominence.) When solar filaments become unstable they can either fall back onto the Sun or erupt into space, sending a coronal mass ejection away from the Sun.
Filament seen with SDO's AIA instrument. Credit: NASA's Solar Dynamics Observatory
Nanojets and Nanoflares
Nanojets are bright, thin tendrils of plasma that travel perpendicular to magnetic structures in the outer solar atmosphere, reaching lengths of thousands of miles. They are spawned by nanoflares, tiny explosions on the Sun caused by a process known as magnetic reconnection, which occurs in tangled magnetic field lines.
These images showing nanojets on the Sun were captured by NASA's IRIS mission on Apr. 3, 2014. Credit: NASA's Goddard Space Flight Center
Coronal Hole
A coronal hole is a patch of the Sun's atmosphere with much lower density than elsewhere. In ultraviolet views of the Sun, coronal holes appear as dark splotches. These are regions where the Sun's magnetic field lines are connected directly to interplanetary space, allowing solar material to escape out in a high-speed stream of solar wind, leaving a dark "hole" near the surface of the Sun.
The dark area across the top of the Sun in this image is a coronal hole. This image was captured on Oct. 10, 2015, by NASA's Solar Dynamics Observatory. Credit: NASA's Solar Dynamics Observatory

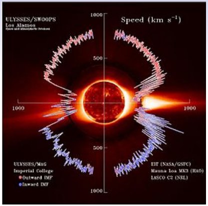


Fig. 1: The solar wind is a stream of charged particles released from the atmosphere of the Sun, called the corona.

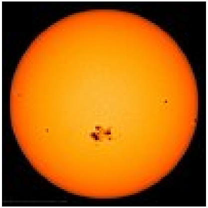


Fig. 2: Sunspots are phenomena on the Sun's photosphere that appear as temporary spots that are darker than the surrounding areas.

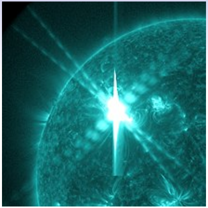


Fig. 3: A solar flare is an intense localized eruption of electromagnetic radiation in the Sun's atmosphere.

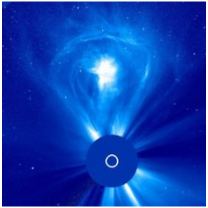


Fig. 4: A coronal mass ejection (CME) is a significant ejection of magnetic field and accompanying plasma mass from the Sun's corona into the heliosphere.

Techniques to look at the Sun

- There are two techniques to look at the Sun safely: by direct viewing, with a proper filter over the front of the telescope, or by projecting the Sun's image onto a piece of paper.

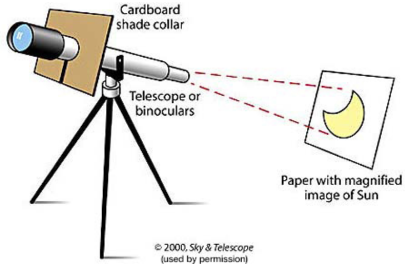
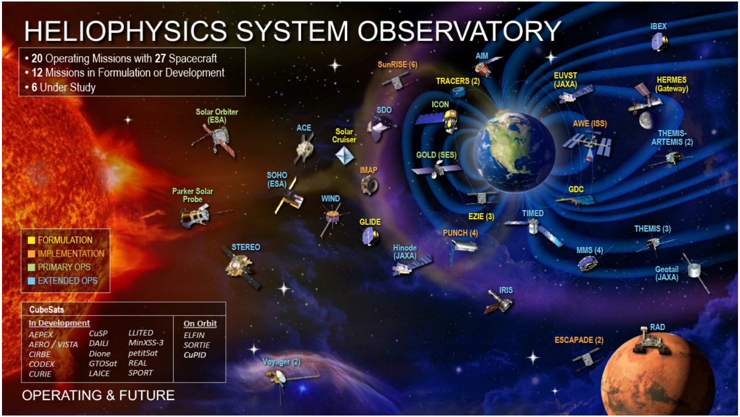


Fig. 5: You can use a telescope or binoculars to project images of the partially eclipsed Sun onto a surface for convenient viewing. This is called optical projection

Fig. 6: The only safe way to look directly at the sun is through specifically designed solar filters, using solar eclipse glasses for direct viewing

Space missions observing the Sun

- Over the past five decades, many spacecraft have journeyed into interplanetary space, investigating the particles and fields environment of the solar system or the Sun itself. Now the Sun is continuously observed from space.

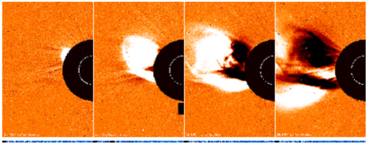


- Sunspots are observed with land-based and Earth-orbiting solar telescopes. These telescopes use filtration and projection techniques for direct observation, in addition to various types of filtered cameras.
  - Specialized tools such as spectroscopes and spectrohelioscopes are used to examine sunspots and sunspot areas.
  - Artificial eclipses allow viewing of the circumference of the Sun as sunspots rotate through the horizon.

Solar Influences Data Analysis Center (SIDC):World Data Center for the production, preservation and dissemination of the international sunspot number :
https://www.sidc.be/SILSO/datafiles

- The Large Angle Spectrometric Coronagraph (LASCO) routinely observe solar phenomena launched along the Sun-Earth line as halo-like brightenings.
    - The LASCO instrument is one of 11 instruments included on the joint NASA/ESA SOHO (Solar and Heliospheric Observatory) spacecraft.

- A coronagraph is a telescope that is designed to block light coming from the solar disk, in order to see the extremely faint emission from the region around the sun, called the corona.



https://cdaw.gsfc.nasa.gov/CME_list/index.html

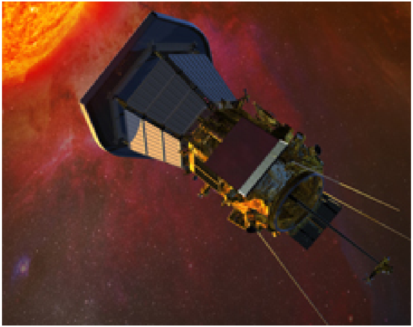
Task: Visit the cdaw website and navigate through the CME list. Look out for the partial halo CME on 01 November, 2021

- The Advanced Composition Explorer (ACE), a NASA mission with 9 instruments, continuously surveys the isotopic and elemental composition of particles from the solar corona, the interplanetary medium, and the interstellar space. In 1998, the ACE data system began providing public, real-time observations that can give warning of solar events that cause geomagnetic storms.

- TRACE A small Explorer satellite launched in 1998, TRACE provides nearly continuous solar coronal observations with high spatial and temporal resolution, complementing the data from SOHO.

https://cdaweb.gsfc.nasa.gov/
Task: Navigate through cdaweb website and view the missions and datasets available

- NASA's Parker Solar Probe is the first-ever mission to "touch" the Sun. The spacecraft, about the size of a small car, travels directly through the Sun's atmosphere –ultimately to a distance of about 4 million miles from the surface. Parker Solar Probe launched aboard a Delta IV-Heavy rocket from Cape Canaveral, Aug. 12, 2018 at 3:31 a.m. EDT.



Conclusions

- The most significant solar phenomenon for space weather is a CME. Heading Earthward in one to three days, CMEs evolve as they interact with the ambient solar wind flow.

- The space age has provided the means to dispatch robotic instrumentation into the environment around Earth and at great distances from Earth in order to measure and study the near Earth and interplanetary regions.

- The advances made by the use of spacecraft in understanding the solar-terrestrial environment have been enormous. However, even as the basic morphology and some physical processes of this environment have become better known, it has also become clear that there are many physical processes occurring in it—from the sun through the interplanetary medium, and at the Earth—that yet defy complete understanding.

- News and information about the Sun-Earth environment: https://spaceweather.com/

  Task: Visit the space weather website and navigate through its different features.

End of Part One

Thank you for listening