To Touch The Sun: The Parker Solar Probe

a presentation for the
Von Braun Astronomical Society
March 24, 2018

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Background Image: Joe Matus, NASA/MSFC, August 21, 2017

Outline

- A bit of history
- The Sun vs. a couple of stars
  - What is a Star?
  - What is the Sun like?
- The Parker Solar Probe

First Contact, August 21, 2017 Solar Eclipse

Image Credit: Mitzi Adams, NASA/MSFC, August 21, 2017
from Clarksville, Tennessee

History

"Simpson's Committee" of the Space Science Board (National Academy of Sciences, 24 October 1958) Interim Report, Long Range Plans:

-- a lunar satellite and a station on the Moon for the study of particles and fields;

-- ***a solar probe to pass inside the orbit of Mercury to study the particles and fields in the vicinity of the Sun;***

-- probes to the planets to study their magnetospheres;

-- two kinds of Earth satellites, one in a highly eccentric orbit, the other in a geostationary orbit. Both satellites would be used to study the particles and fields in the Earth's magnetosphere and in interplanetary space outside the magnetosphere.

Professor Eugene Parker, S. Chandrasekhar Distinguished Service Professor Emeritus, Department of Astronomy and Astrophysics, University of Chicago

Image from: https://blogs.nasa.gov/drthomasz/2017/06/05/parker-solar-probe/

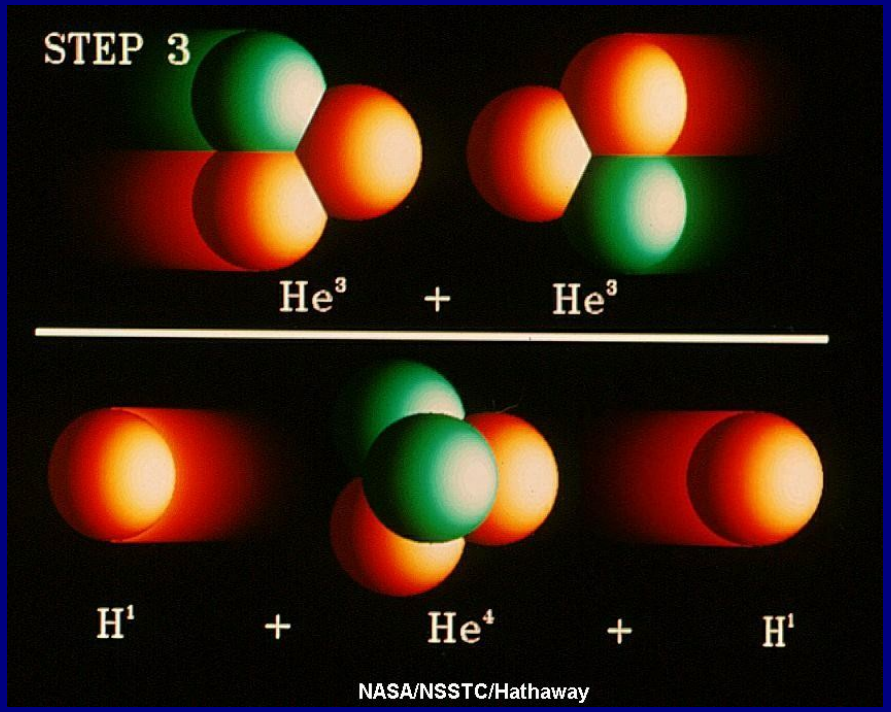
What is a Star?

What is a Star? -- Energy Production

A star is an astrophysical body that produces its own light by thermonuclear reactions in its core.

For solar-type stars, this is the proton-proton chain

1. Two protons collide, form deuterium, a positron, and a neutrino.



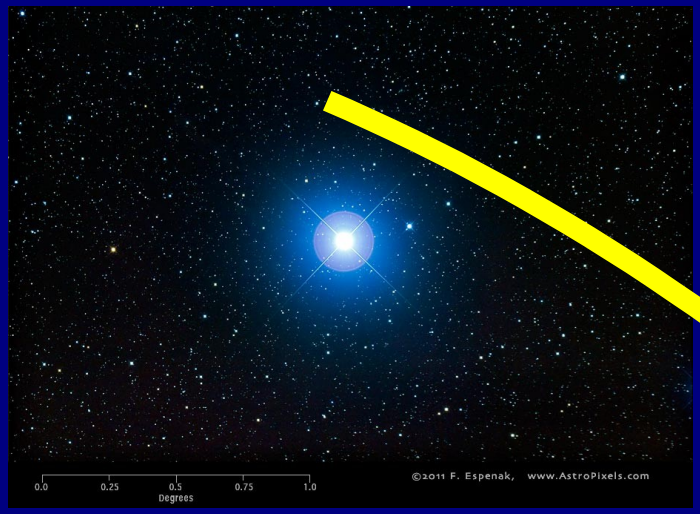
2. A proton collides with the deuterium, forming helium-3 and a gamma ray

3. Two He-3s collide to form He-4 plus two protons.

Basically, Hydrogen converts to Helium

(High-mass stars, greater than about 2 solar masses use a different procedure, the CNO cycle.)

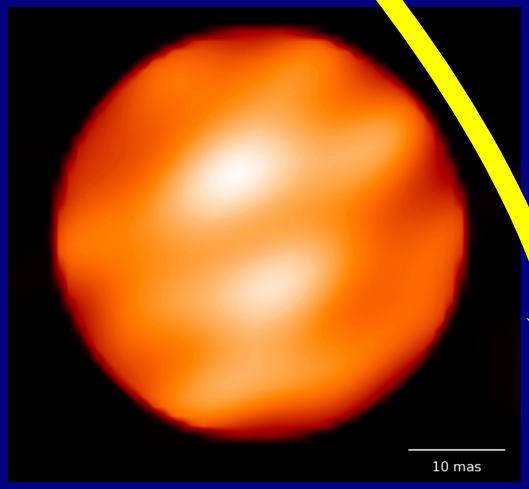
What is a Star? -- Differences



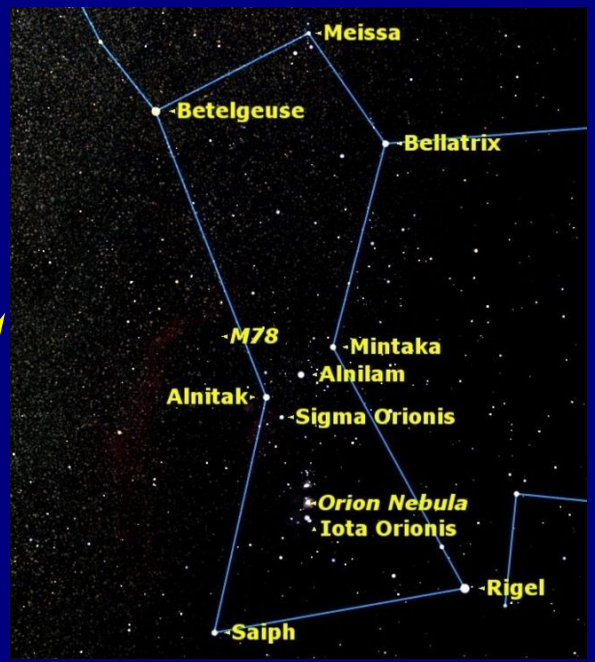
Rigel: A blue-white star, about 8600 ly away, 12,000 K, 80 $R_{\odot}$, 23 $M_{\odot}$, 8 million years old.

Aging

Our Sun: A yellow star, ~8 lm away, 6,000 K, ~700,000 km (432,000 mi), 2 x 10^{30} kg, 4.5 billion years old, ~ 5M yr left.



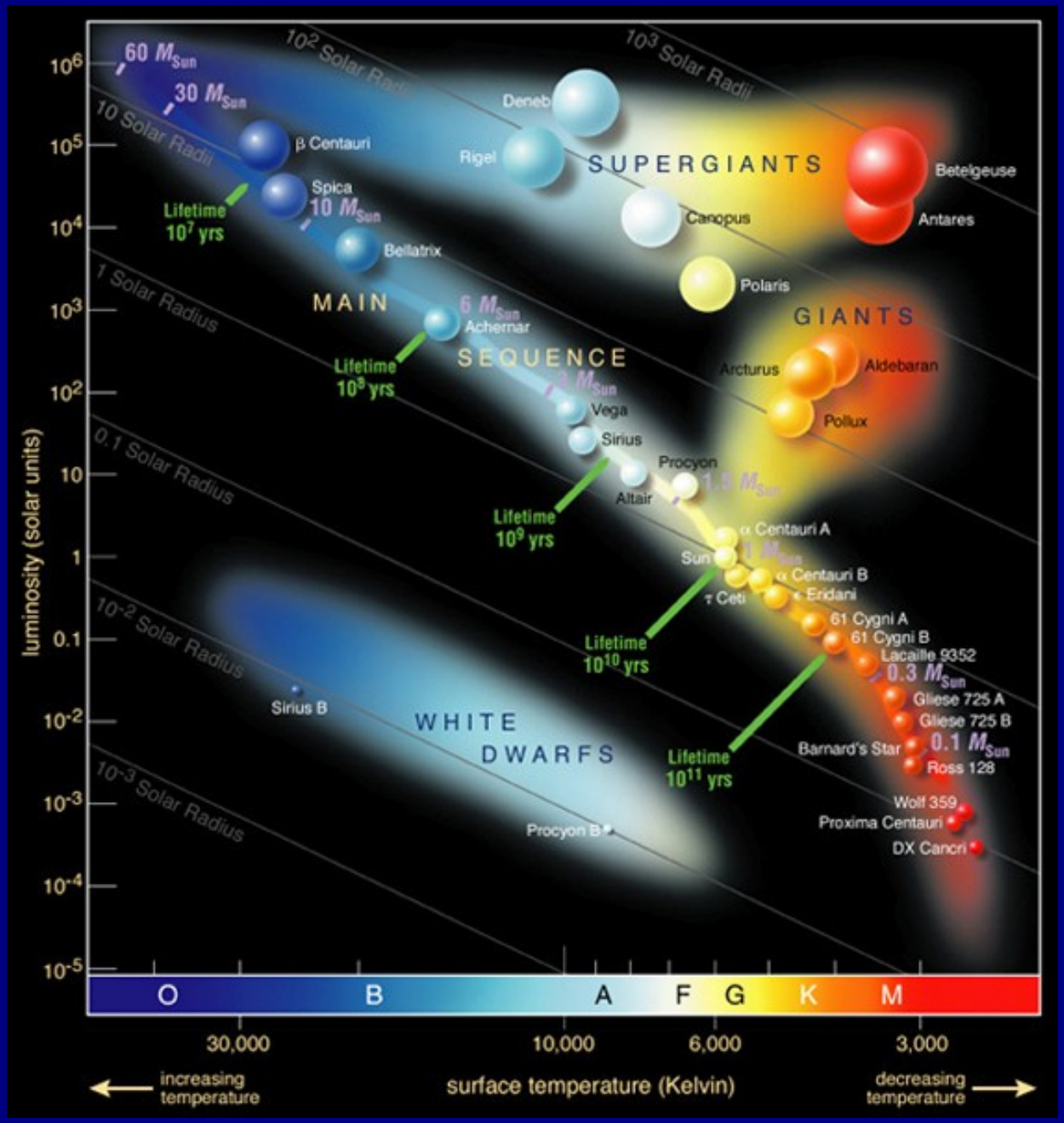
Betelgeuse: A red-giant star, about 650 ly away, 3500 K, 862 $R_{\odot}$, 20 $M_{\odot}$, 8.5 million years old, ~100,000 years left .



Brightness

Color

Hertzsprung-Russell Diagram



α-Cen-A is G2,
α-Cen-B is K1,
Proxima (α-Cen-C) is M6, 4.2 ly

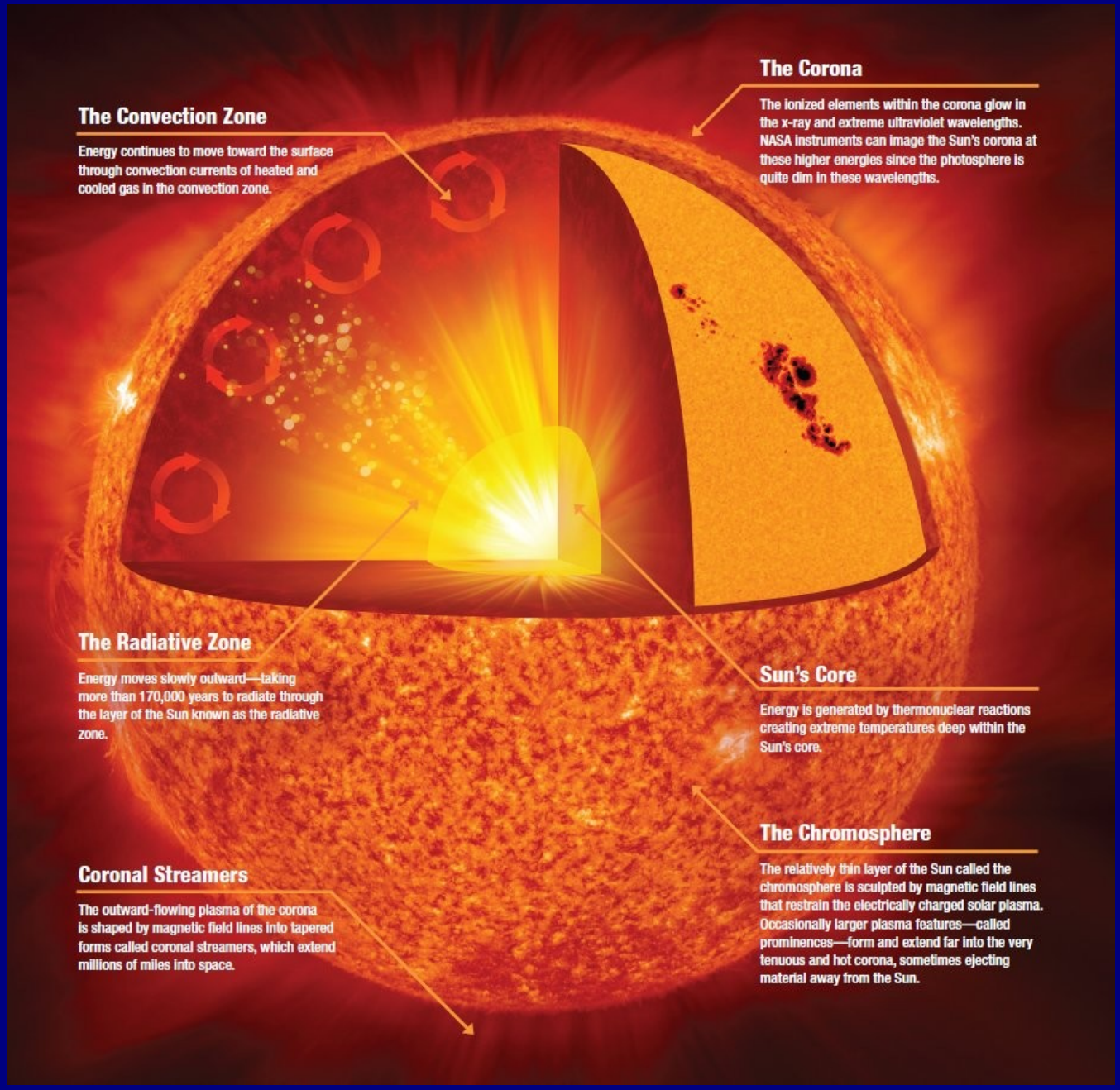
Sun is G2
8.5 light minutes away

Betelgeuse is M2
643 ly

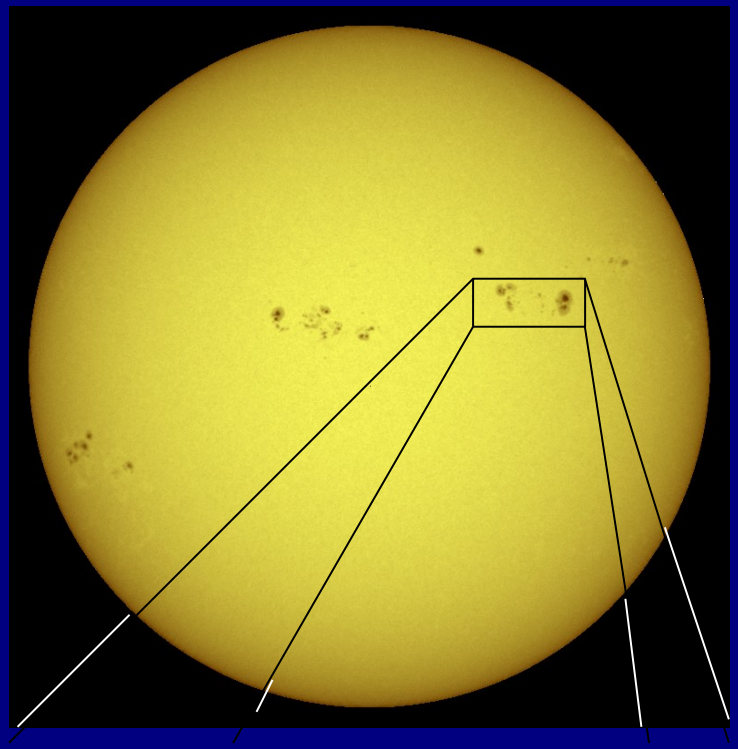
Rigel is B8
860 ly

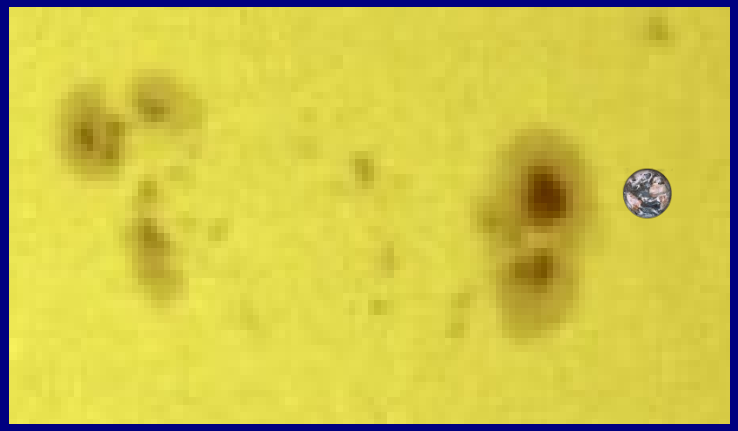
What is the Sun like?

The Sun: Structure



The Sun: Surface Features - Sunspots



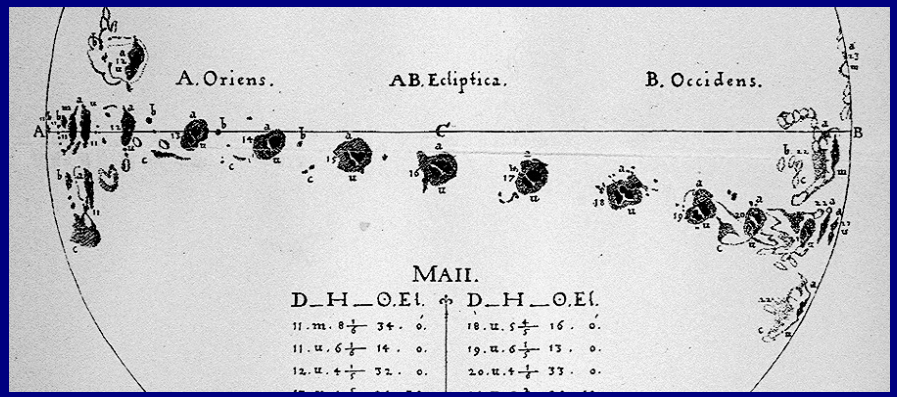


Sunspots are regions that are cooler than their surroundings, produced by strong magnetic fields.

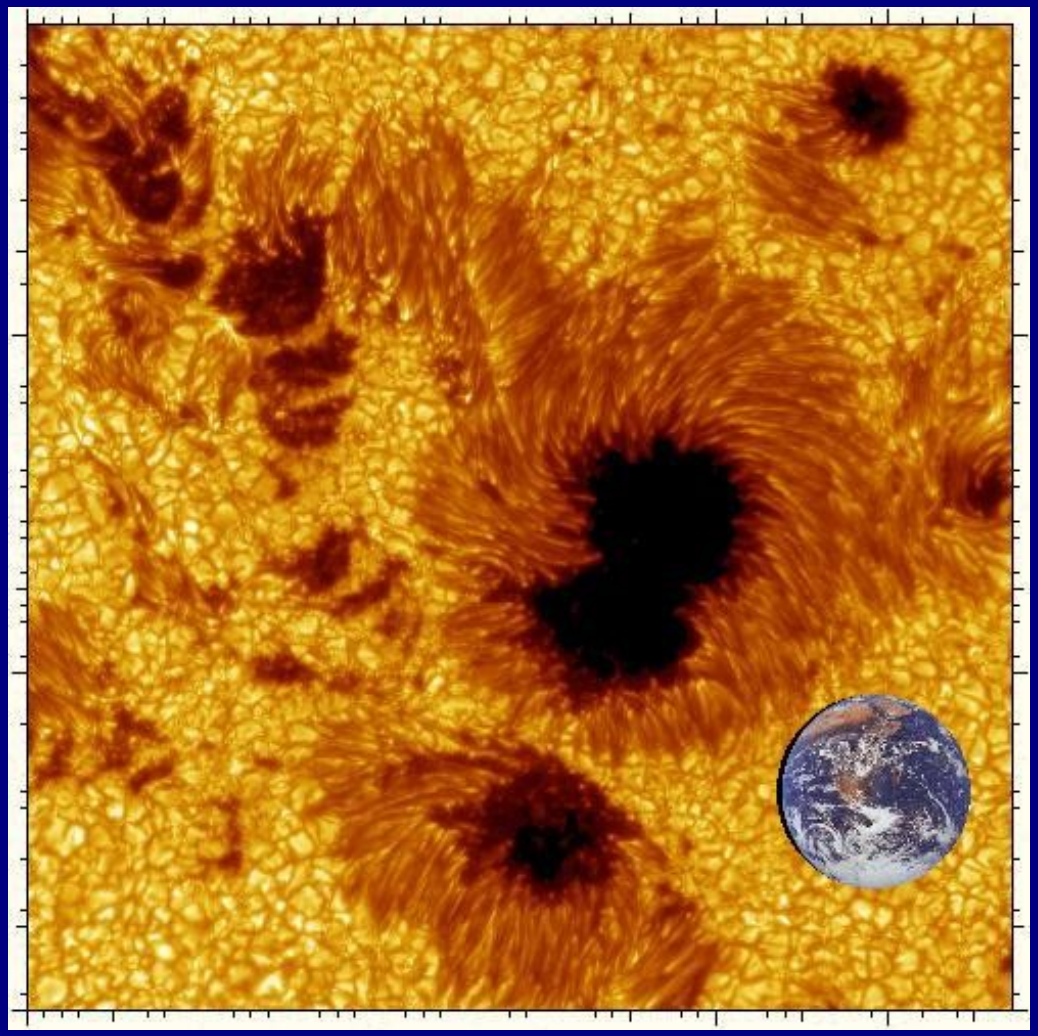
Sunspots have an Umbra surrounded by the lighter Penumbra.

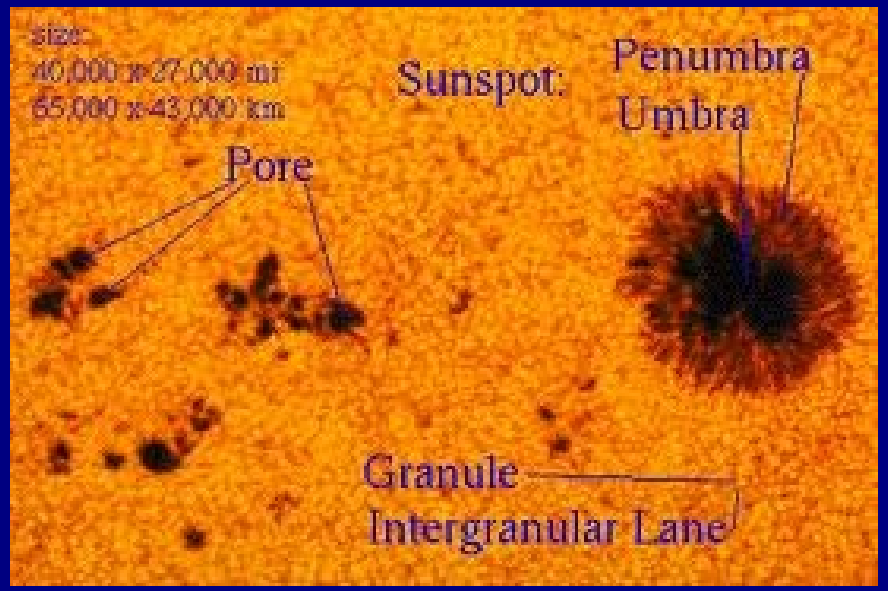
Sunspots usually appear in groups, with lifetimes of days or weeks.

The earliest sunspot observations (c. 1609) indicated that the Sun rotates once in about 27 days.

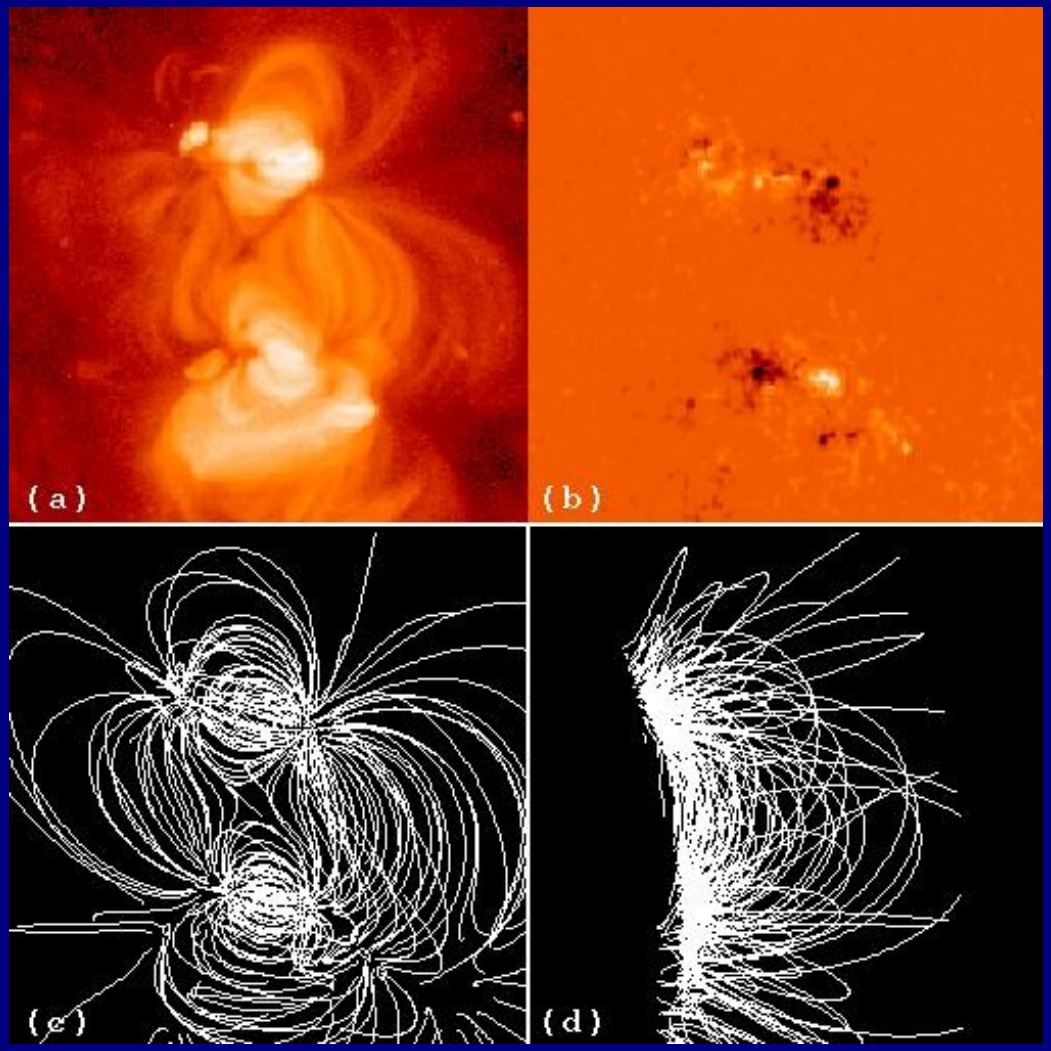


The Sun: Sunspot Examples





The Sun: Sunspot - Magnetic Fields



(a) Yohkoh Soft X-ray Telescope, Corona
4 Jan, 1994 7:35 UT

(b) Line-of-Sight magnetic field from Kitt Peak National Observatory at 16:31 UT

(c), (d) Extrapolated Magnetic Field

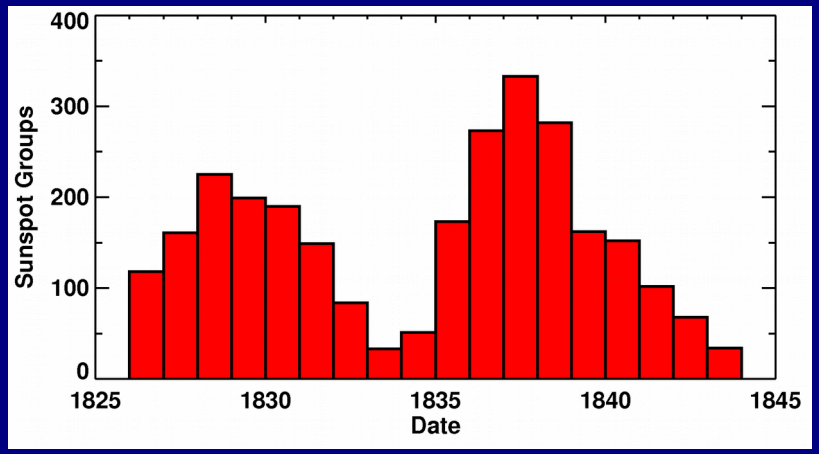
The Sun: The Solar Cycle

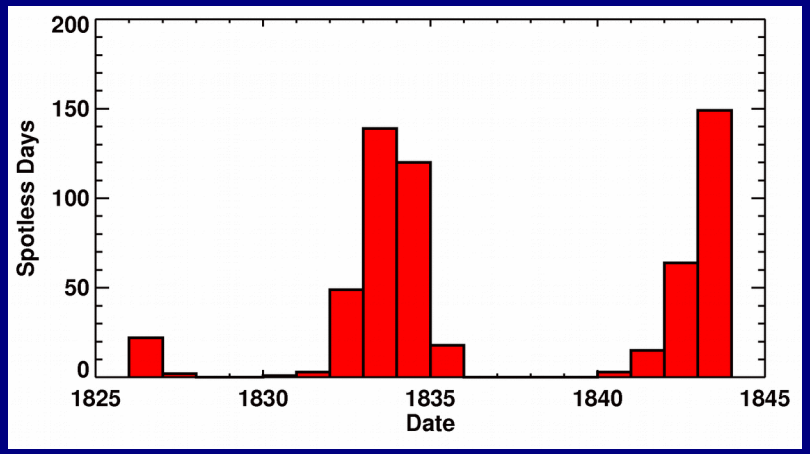
The Sun: Sunspot Cycle Discovery

Sunspots observed > 230 years
1844 Heinrich Schwabe, amateur astronomer, Dessau, Germany

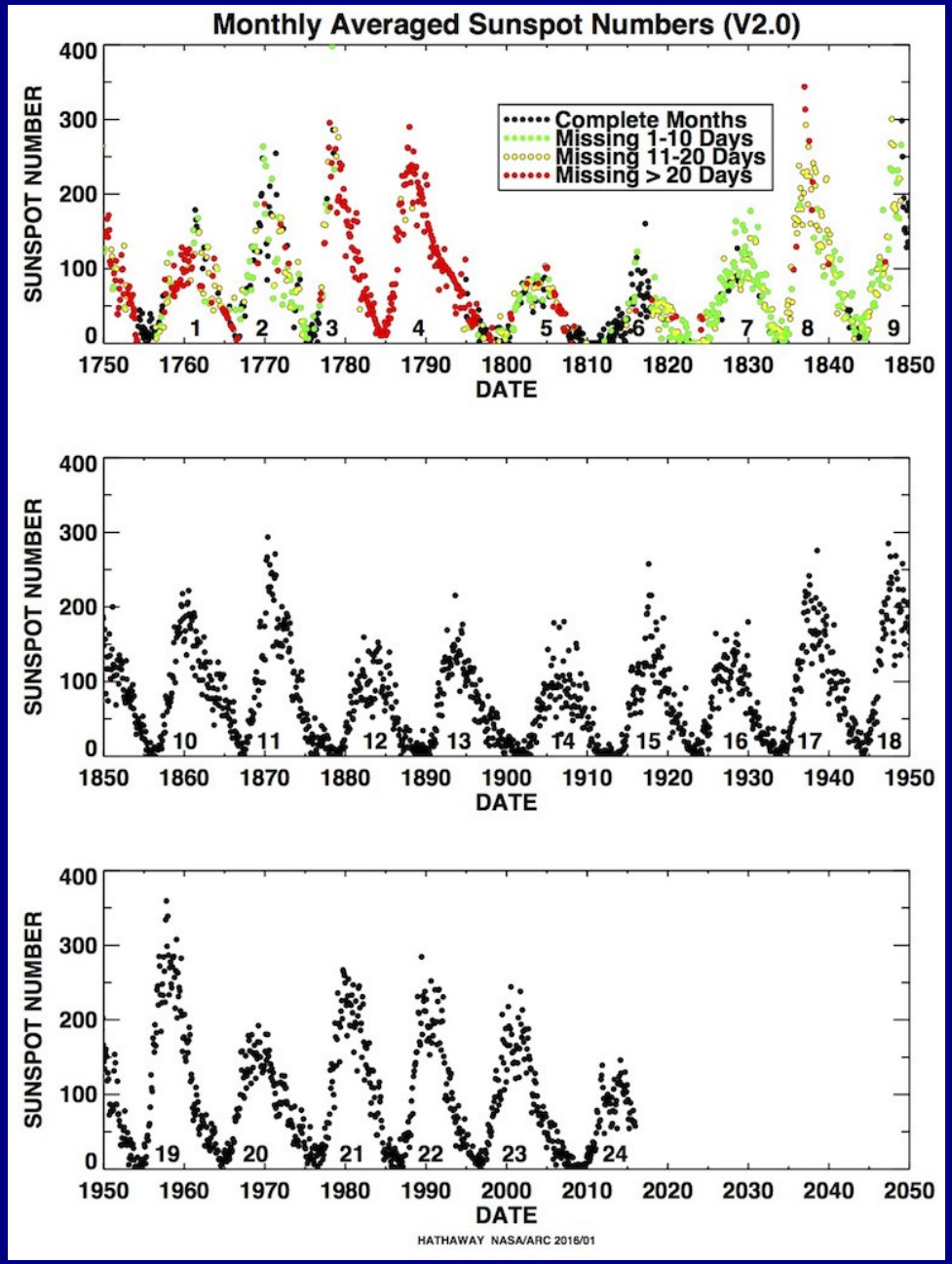
Cycle: increase and decrease over ~10-years
- number of sunspot groups and the
- number of days without sunspots

Schwabe's data for 1826 to 1843





The Sun: 23 Full Cycles Observed

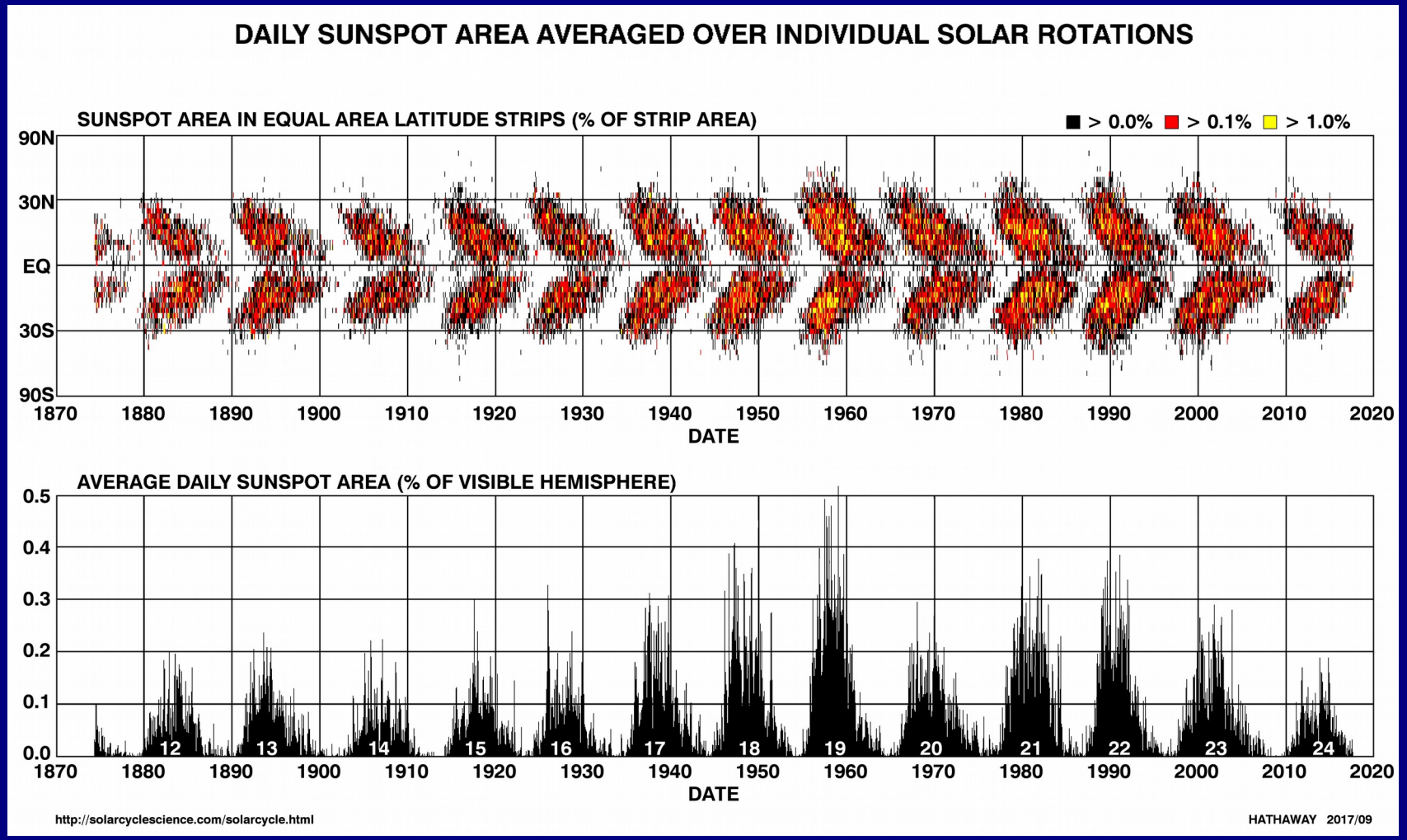


Rudolf Wolf 1849 -- "Relative" Sunspot Number = 10 times number sunspot groups + total distinct spots

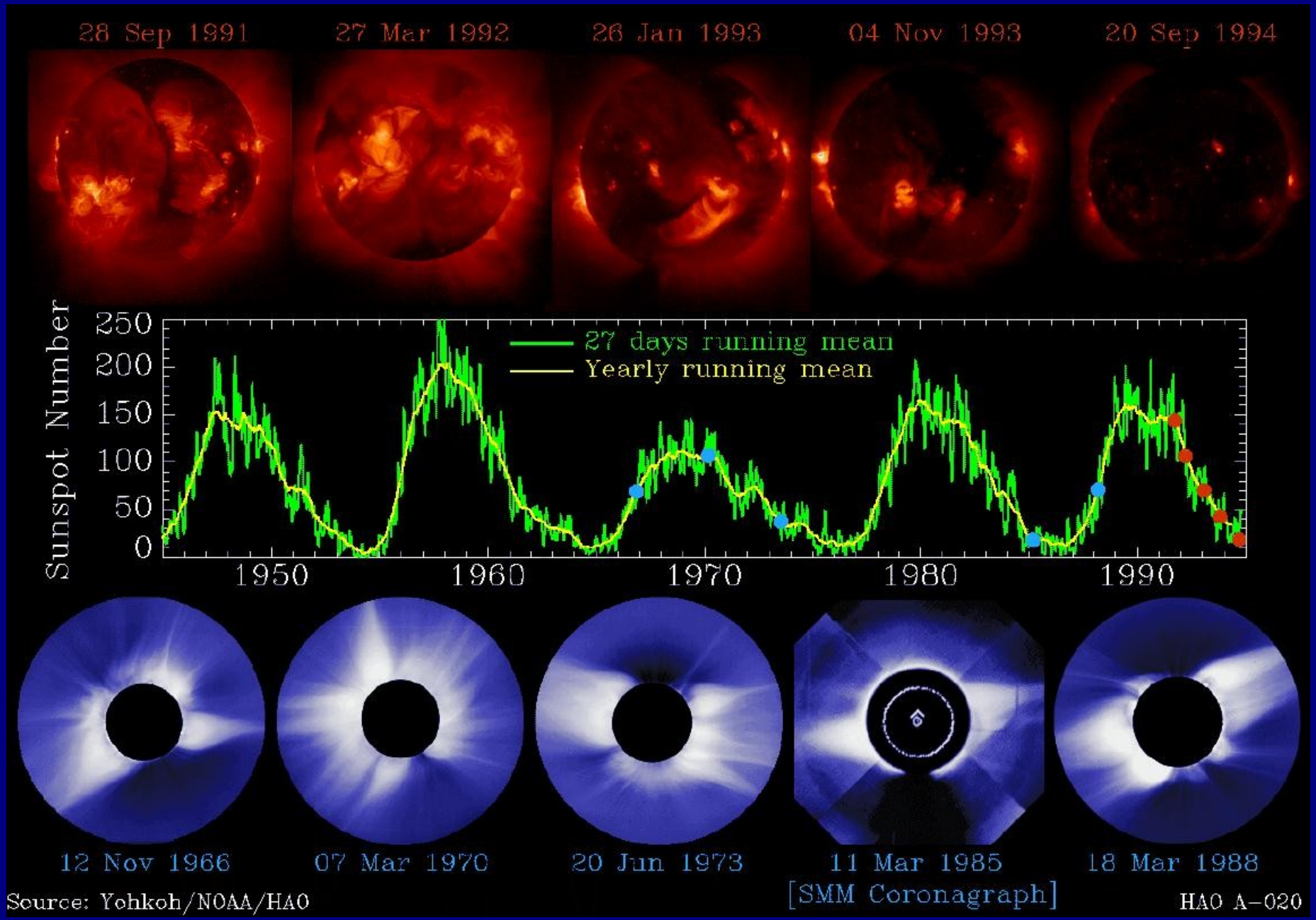
Average cycle: ~11 years, -2, +3

Average amplitude: ~100, with range from 50 to 200

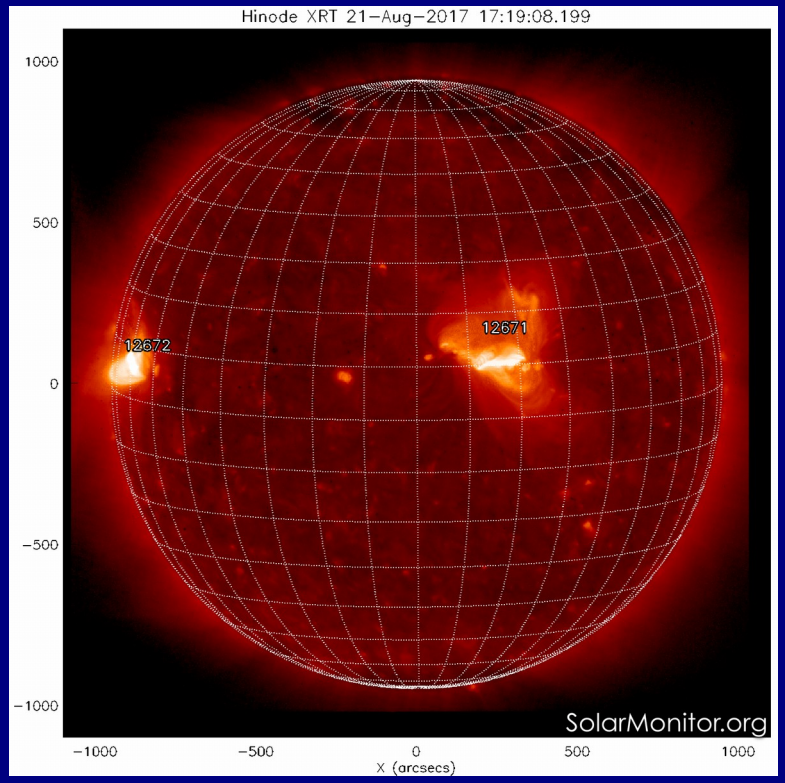
The Sun: Sunspot Latitudes



The Corona and the Solar Cycle



The Corona, August 21, 2017



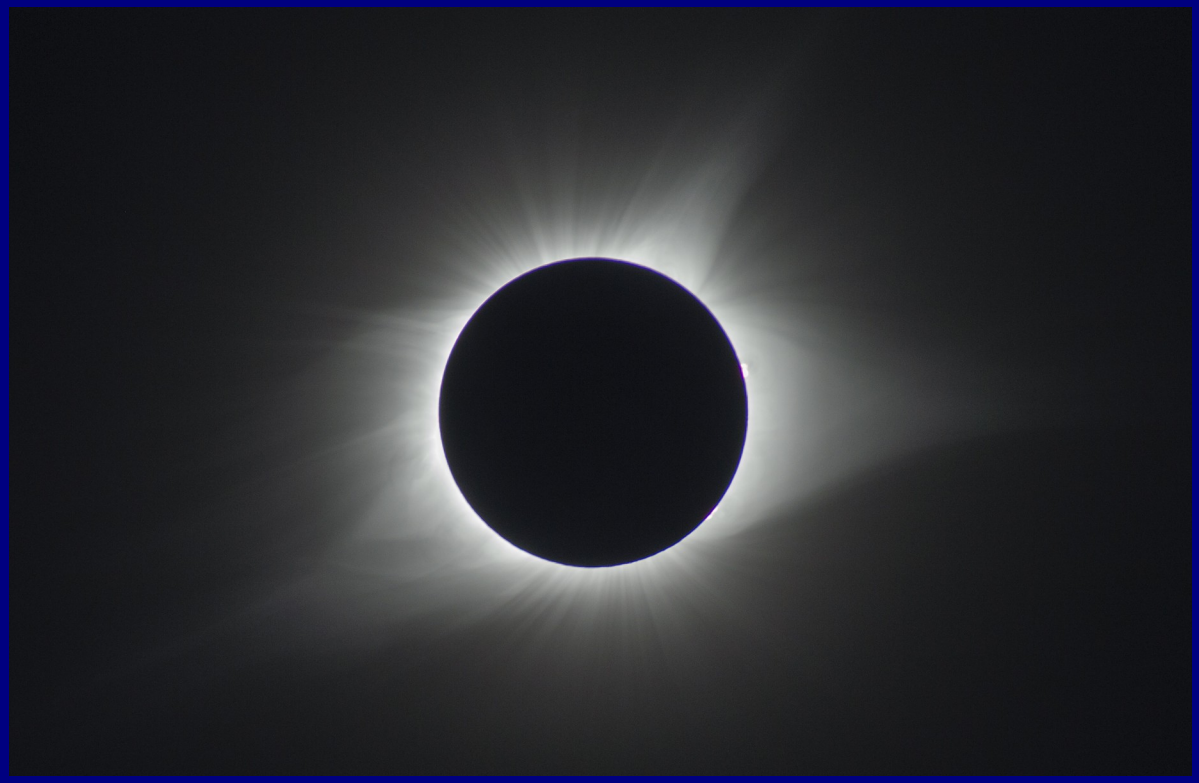
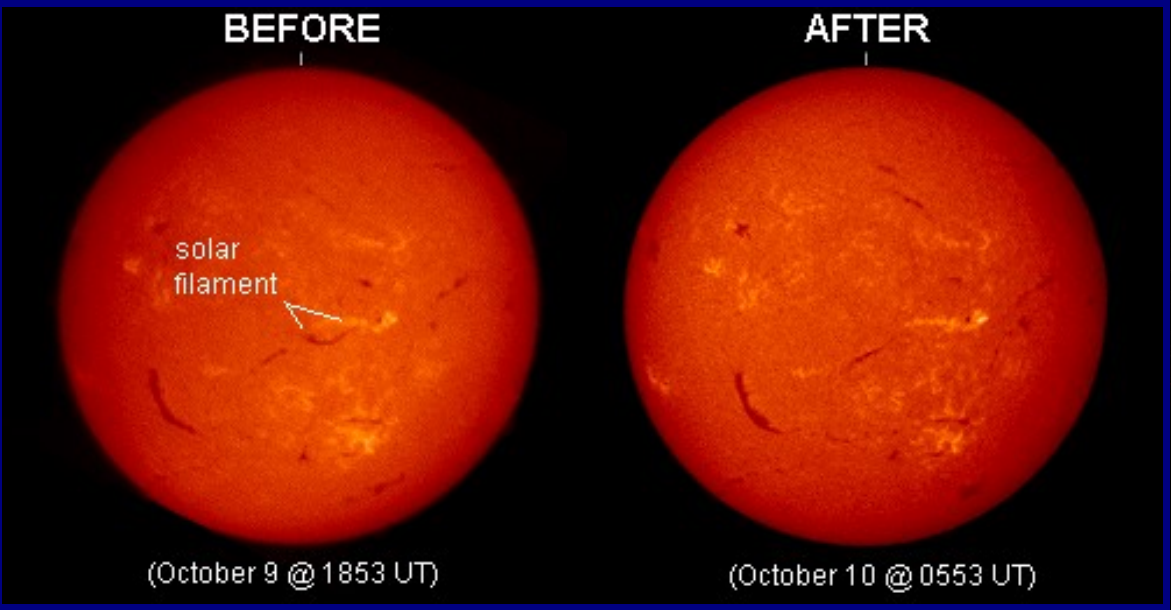


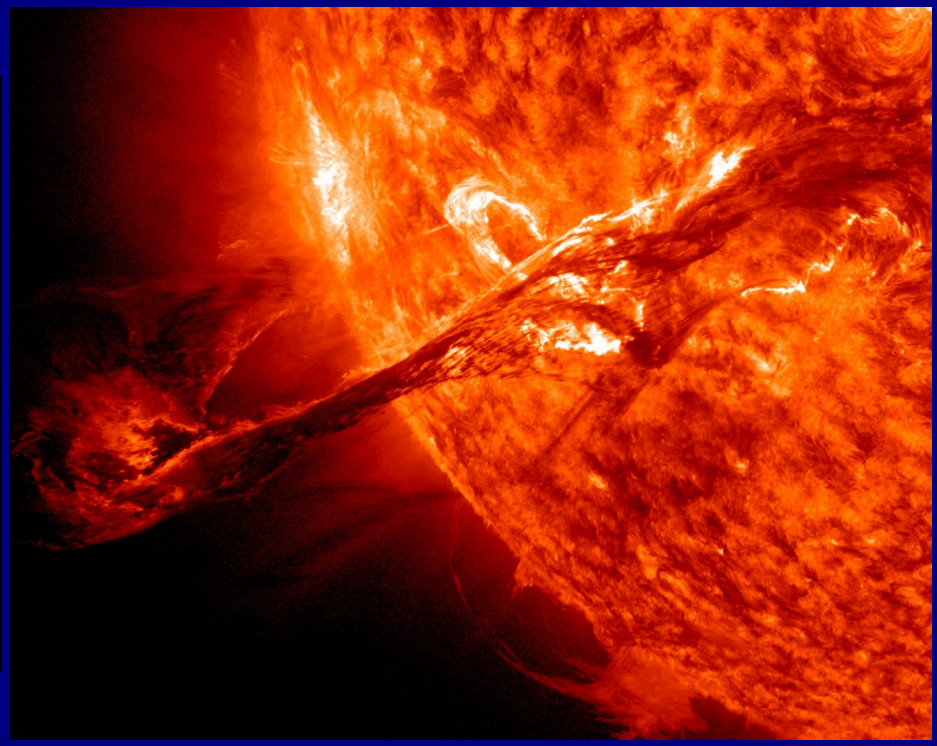
Image by Joe Matus, NASA/MSFC from Hopkinsville, KY

Solar Eruptions

Filament Eruptions

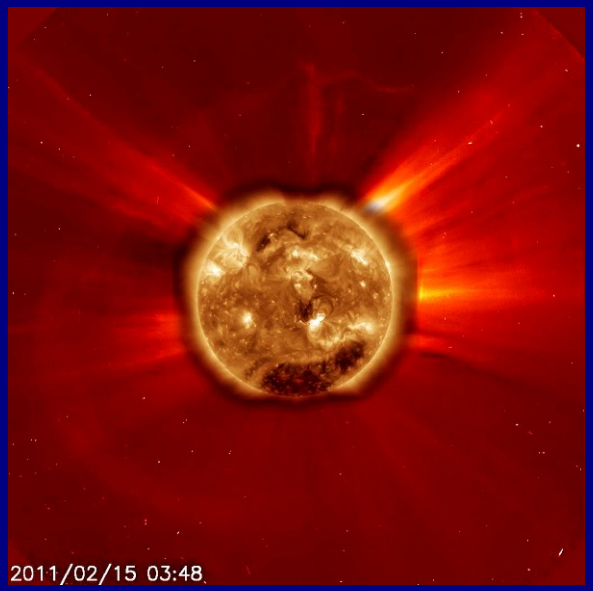


October 2000
Filament around AR 9182
C-7 flare triggered
Halo coronal-mass ejection (CME)
Image Credit: NOAA/SEC

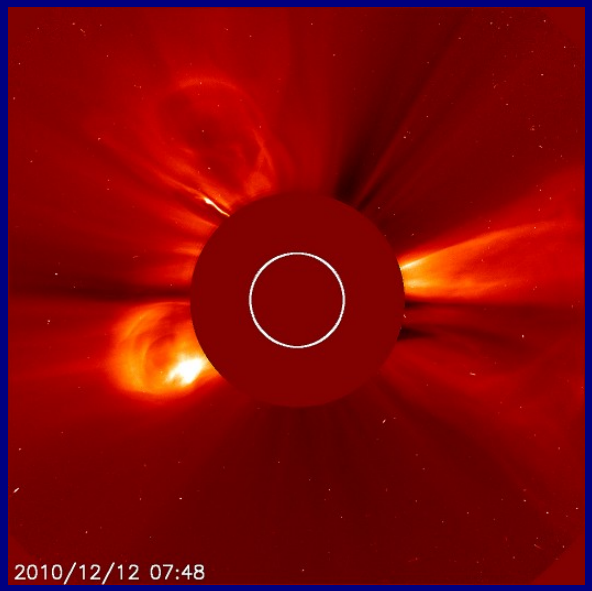


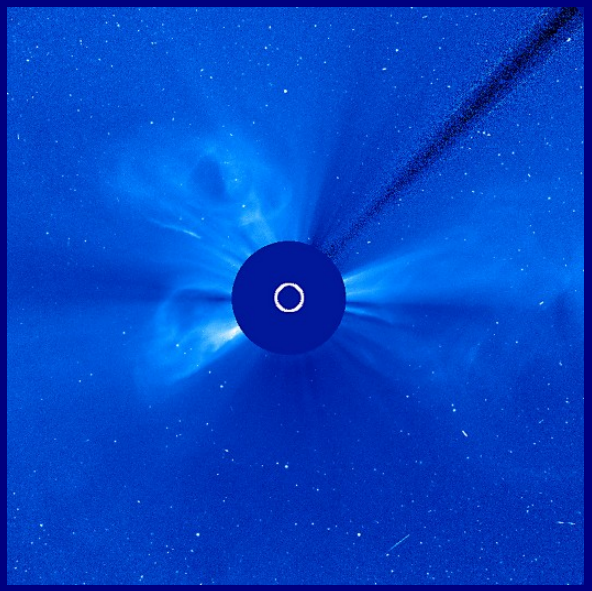
August 31, 2012
Filament eruption, CME
Plasma Speeds: > 900 mi/s
Normal Solar Wind Speed: ~250 mi/s
Image Credit: SDO/AIA in 304 Å.

More Solar Eruptions



SDO plus Soho C2
X2-flare and halo CME

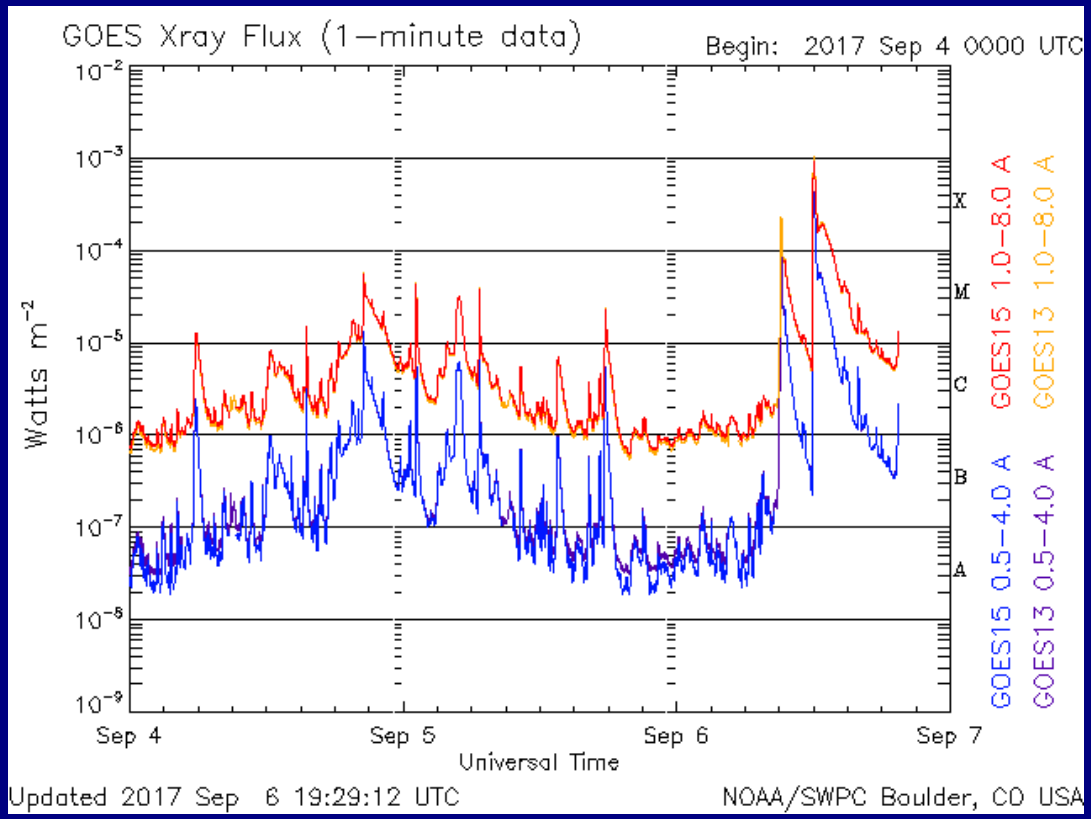


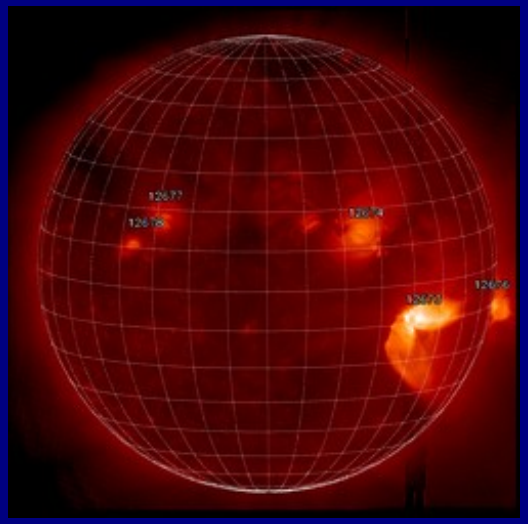


Three distinct CMEs
1. To right in both images, from a filament eruption,
2. From North Pole,
3. From far side of Sun.
All three eruptions happened within hours of each other.

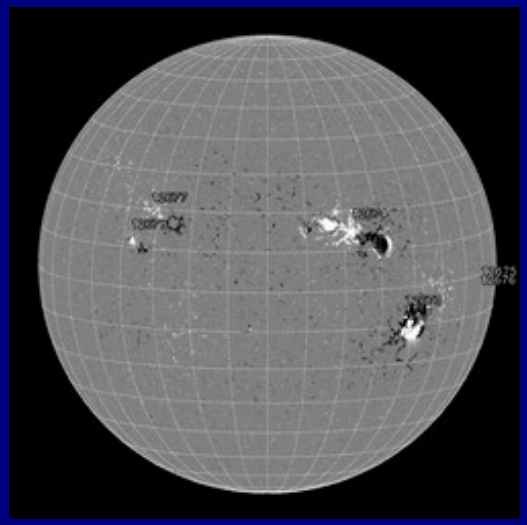
Image Credit:
SDO and
SOHO/LASCO

Solar Flare Classification





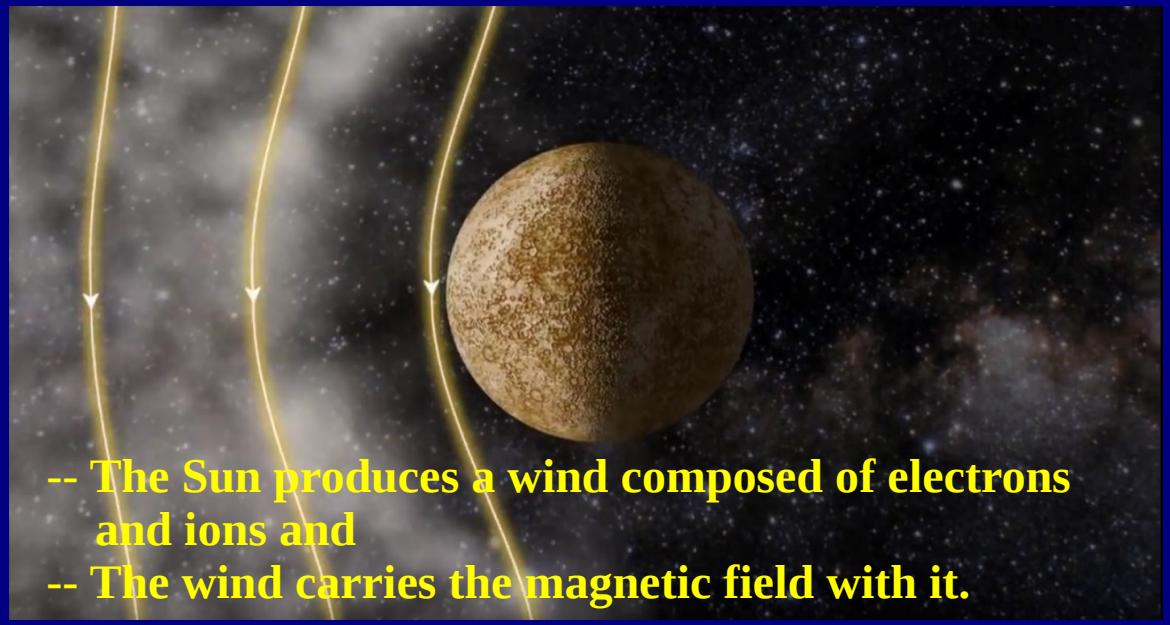
Sept. 6, 17:59UT
Hinode XRT
X9 flare



Sept. 6, 18:46 UT
SDO/HMI

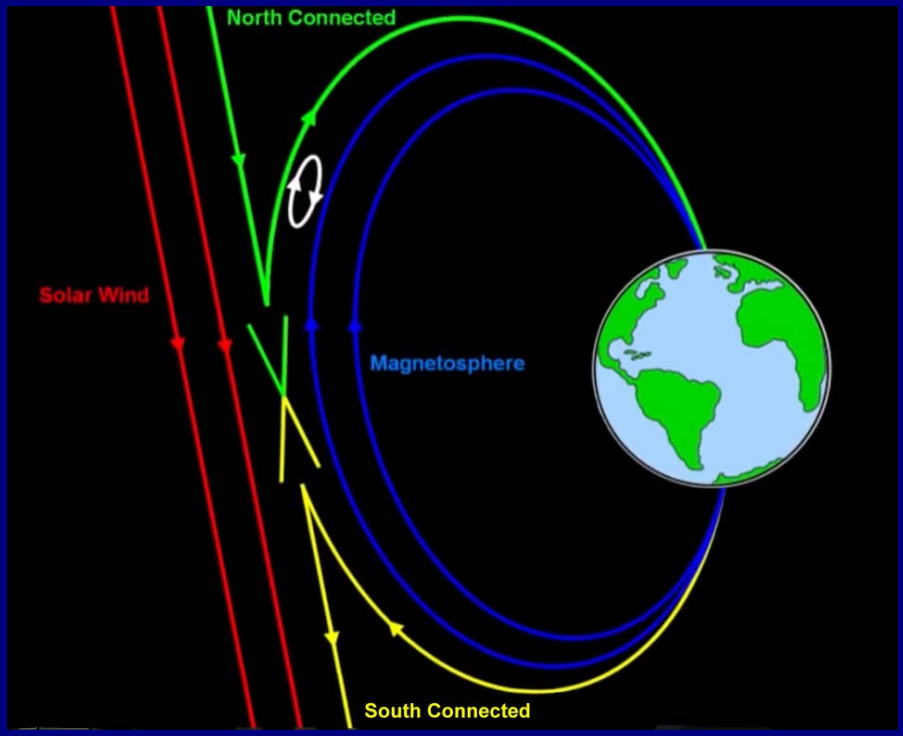
Parker Solar Probe (PSP)

PSP: What Do We Know and Why Do We Care?



-- Anti-parallel magnetic field reconnects
-- Plasma is redirected backwards to the magnetotail...more active when Bz is southward

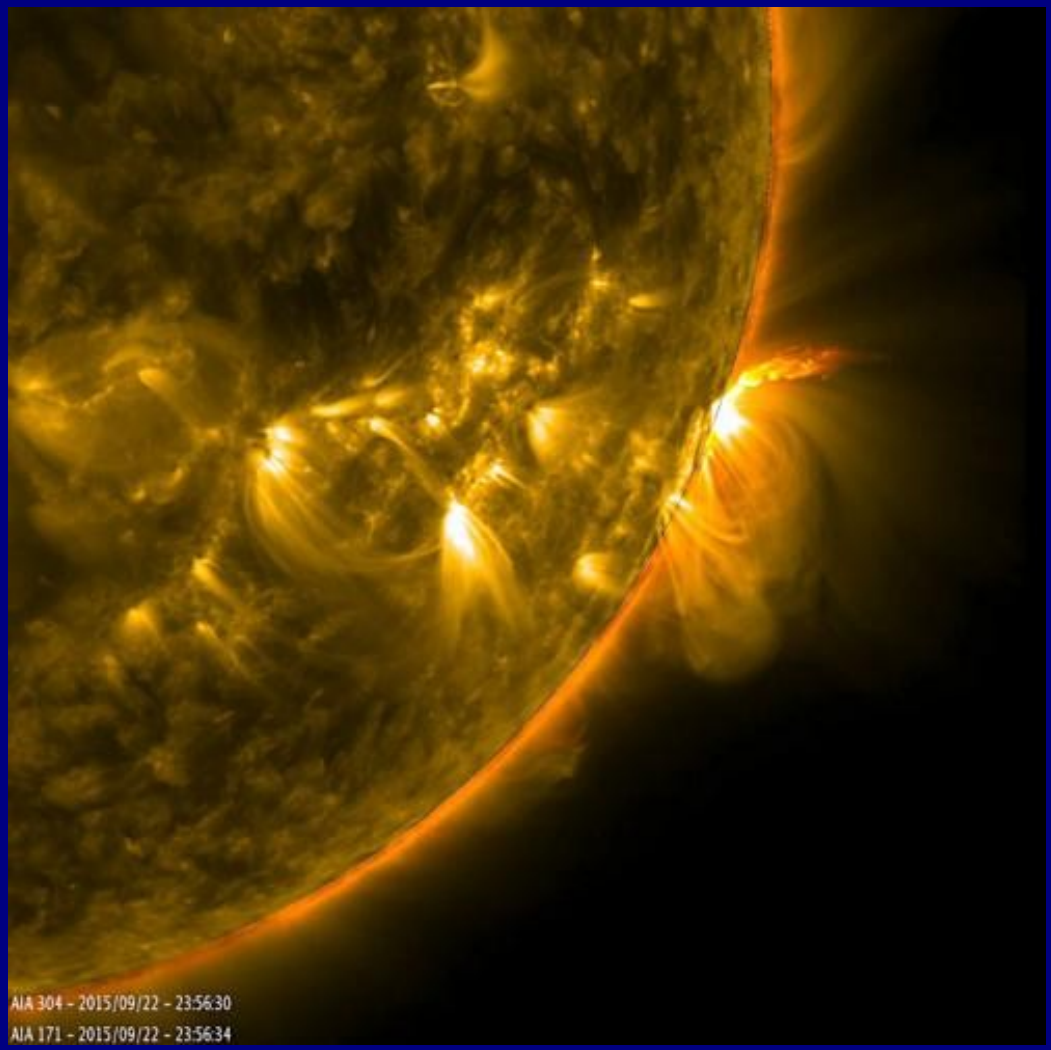
Events: Coronal Mass Ejections and Corotating Interaction Regions



Images From: https://www.nasa.gov/mission_pages/themis/images/index.html

PSP: Why Do We Care?

PSP: What Do We Not Know?



1. Why is the corona so hot?
2. What accelerates the solar wind?
3. What are conditions like in the corona at 9 solar radii?
4. How are energetic particles accelerated and what is their origin?
5. How is the magnetic field there structured and how does it change?

Images From: https://sdo.gsfc.nasa.gov/gallery/main

Parker Solar Probe: Science Objectives

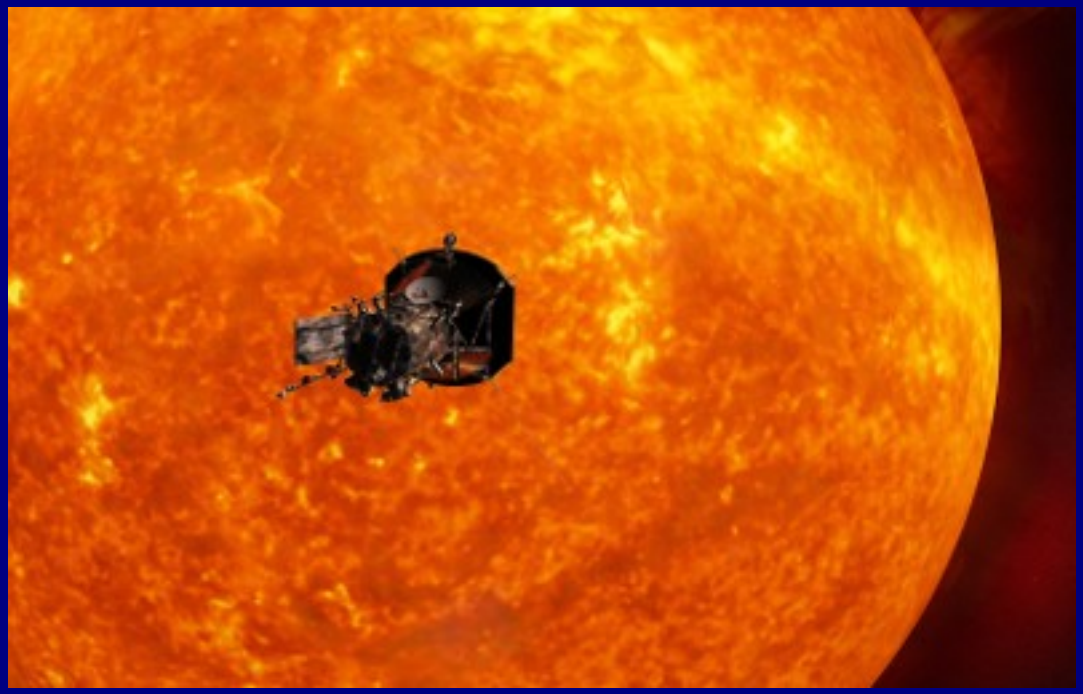


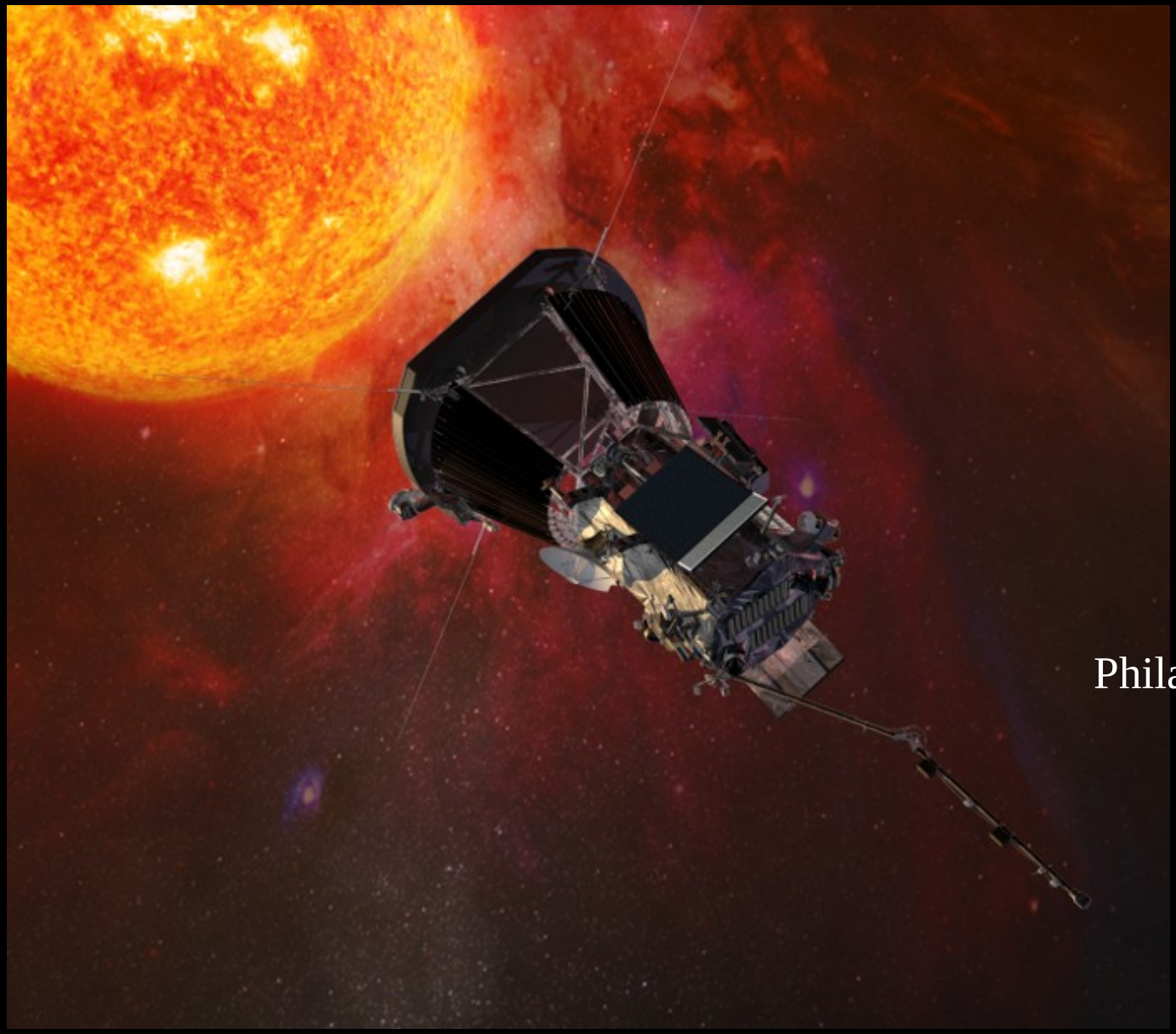
Image Credit: Johns Hopkins University Applied Physics Laboratory, Artist's Concept

- Trace flow of energy that heats and accelerates the corona and solar wind

- Determine structure and dynamics of plasma and magnetic fields at solar wind sources

- Explore mechanisms that accelerate and transport energetic particles

Parker Solar Probe: Approaching the Sun



Closest Approach:
3.83 million miles

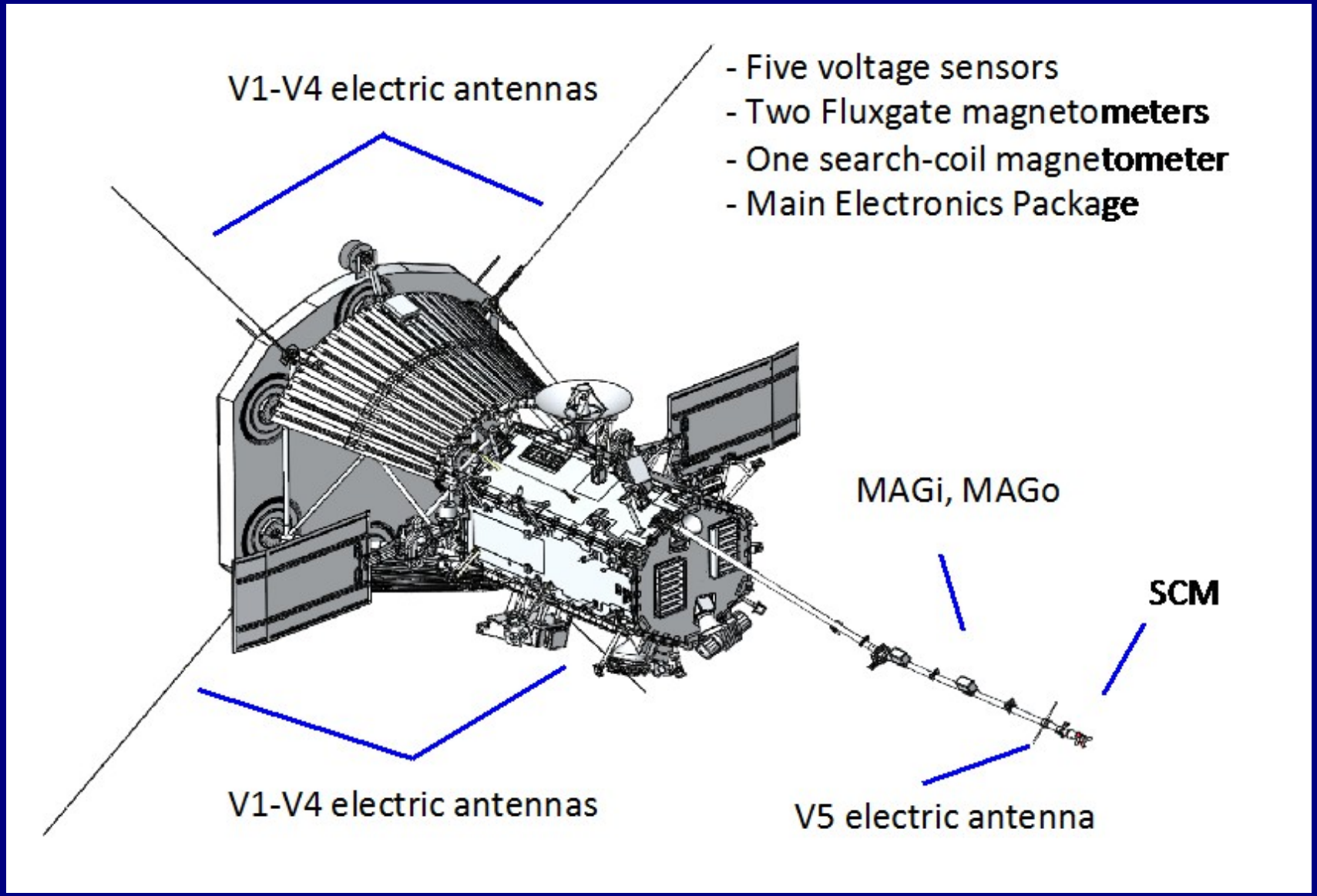
Fastest Speed:
450,000 mph
Philadelphia to D.C. in one second

Image Credit: Johns Hopkins University Applied Physics Laboratory, Artist's Concept

Parker Solar Probe: Investigations

Fields Experiment

Measurements of: electric and magnetic fields and waves, Poynting flux, absolute plasma density and electron temperature, spacecraft floating potential and density flucuations, and radio emissions.

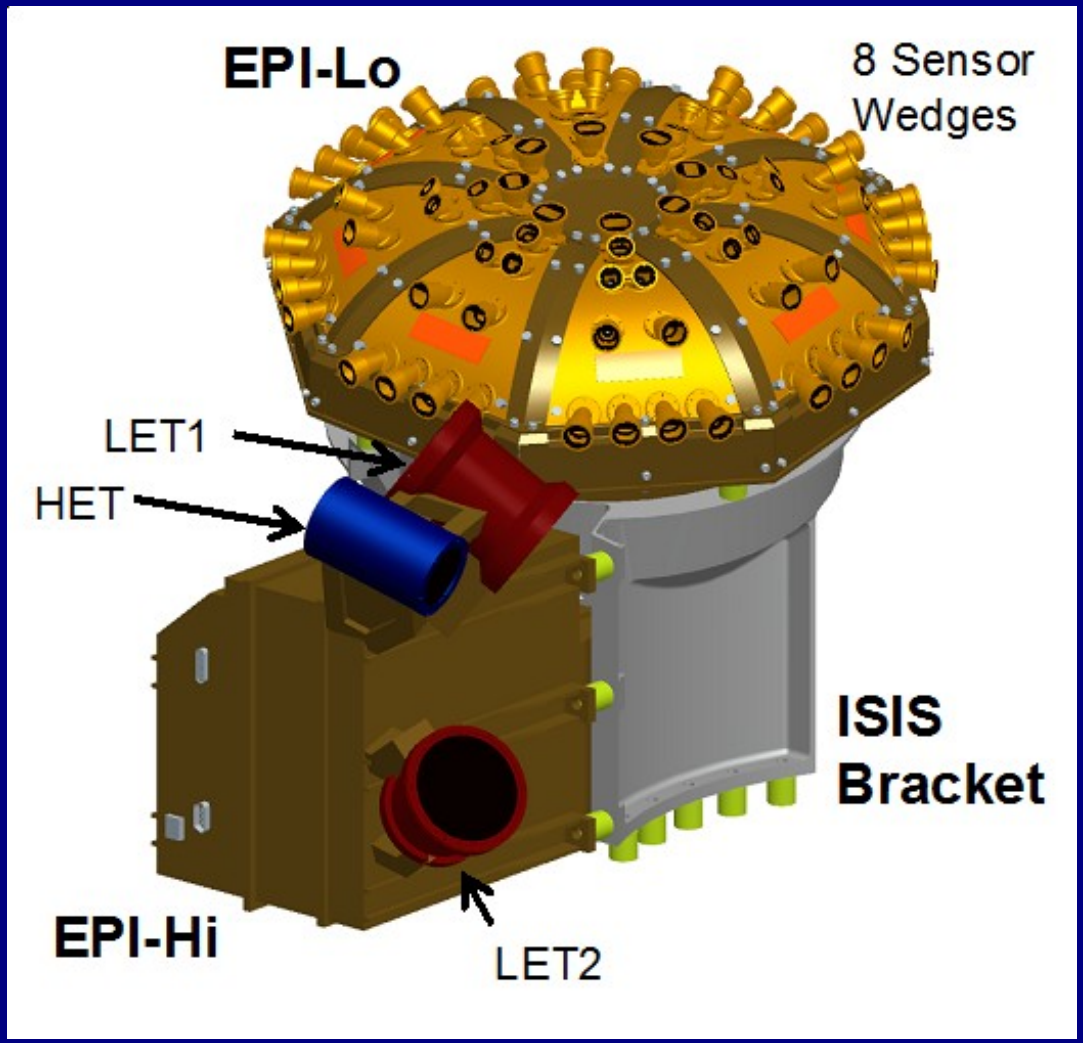


Parker Solar Probe: Investigations

Integrated Science Investigation of the Sun (ISIS)

Observations of: energetic electrons, protons, and heavy ions (10s of keV to 100 Mev)

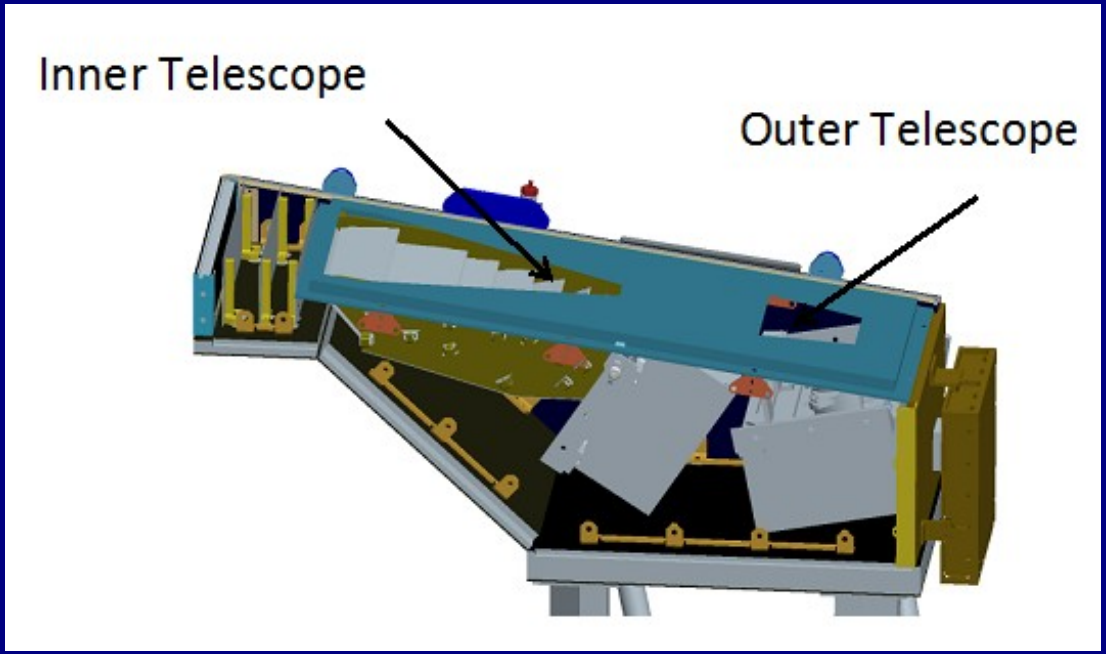
Correlates with : solar wind and coronal structures



Parker Solar Probe: Investigations

Wide-field Imager for Solar PRobe (WISPR)

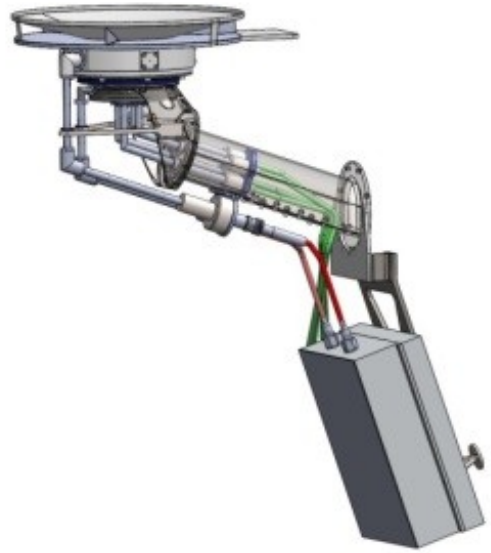
Images of: solar corona, inner heliosphere, solar wind, and shocks



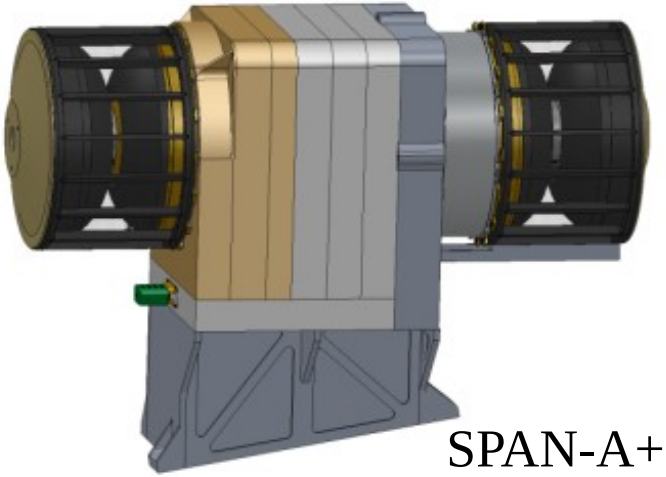
Parker Solar Probe: Investigations

Solar Wind Electrons Alphas and Protons (SWEAP)

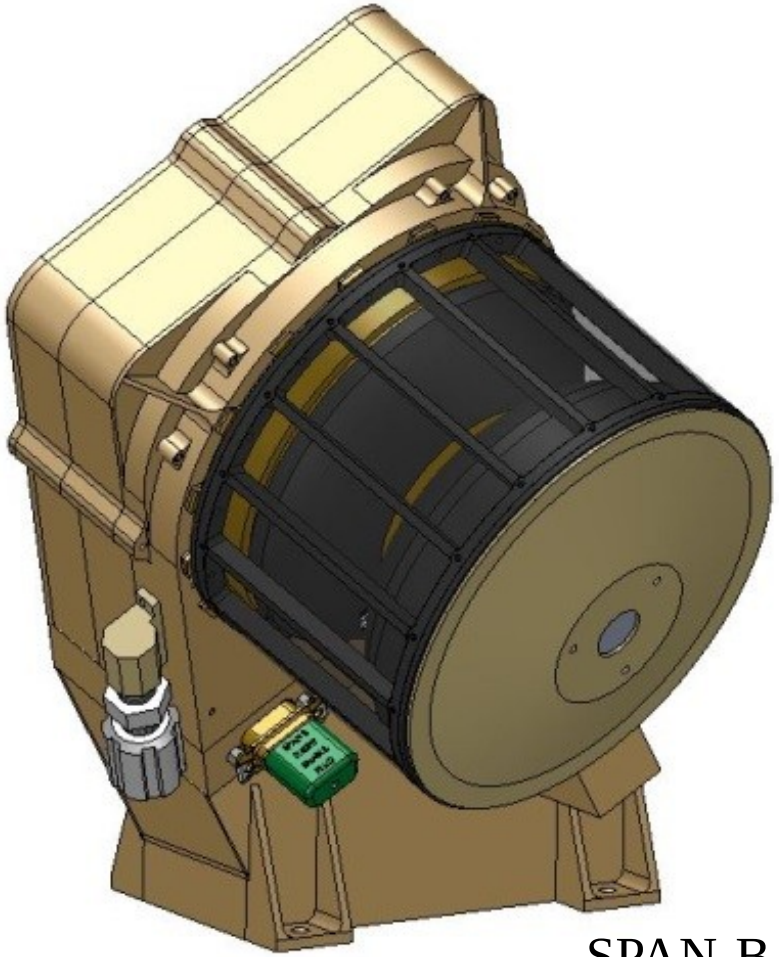
Counts: electrons, protons, helium ions
Measures: velocity, density, and temperature



SPC

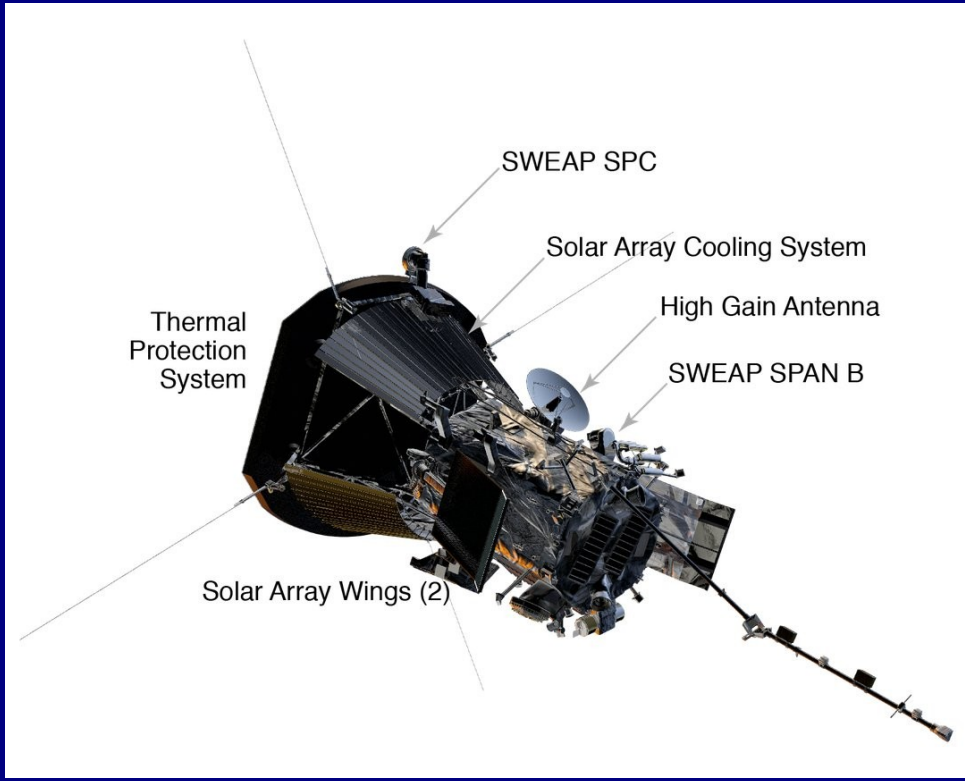


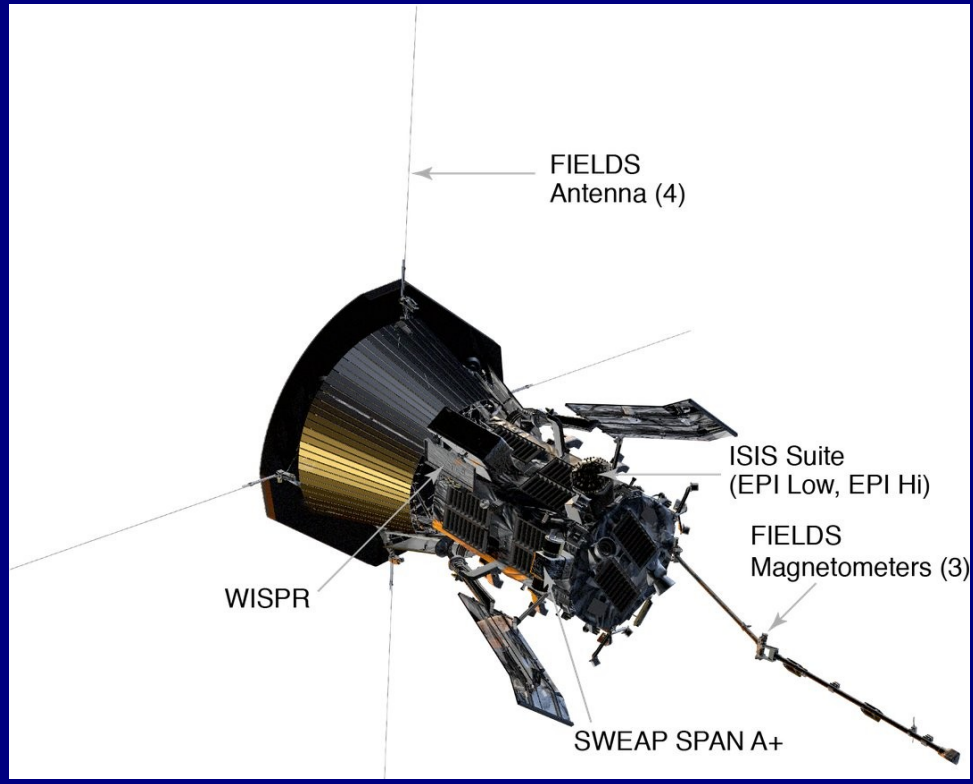
SPAN-A+



SPAN-B

Parker Solar Probe: Spacecraft





Mass: 685 kg

S/C height: 3 m

TPS max diameter: 2.3 m

S/C bus diameter: 1 m

Actively cooled solar arrays

388 W at encounter

Solar array area: 1.55 m^2

Radiator area under TPS: 4 m^2

Wheels for attitude control

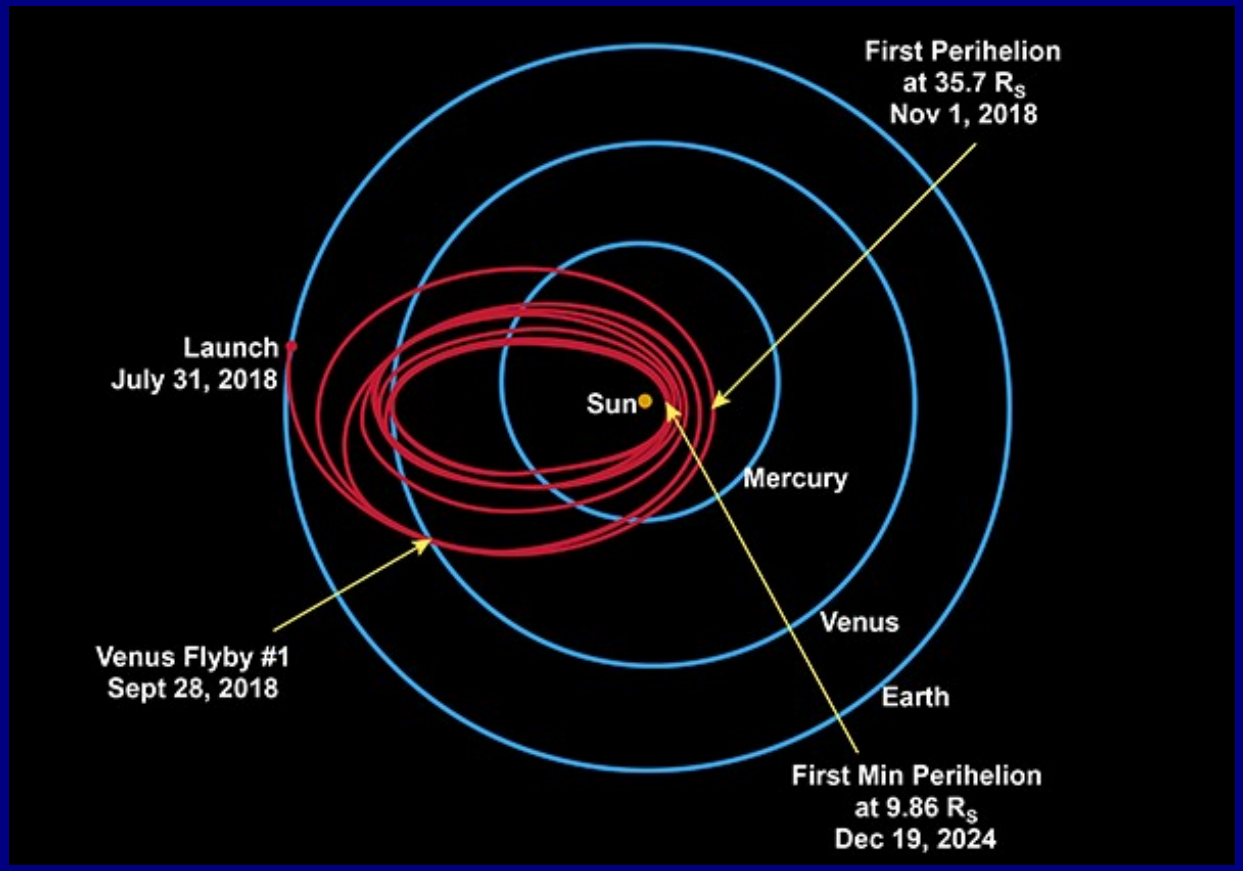
Science downlink rate: 167 kb/s at 1AU

Parker Solar Probe: Launch

Launch Window: July 31 - August 19, 2018

Delta IV-Heavy with Upper Stage
Image Credit: ULA

Parker Solar Probe: Trajectory



24 Orbits

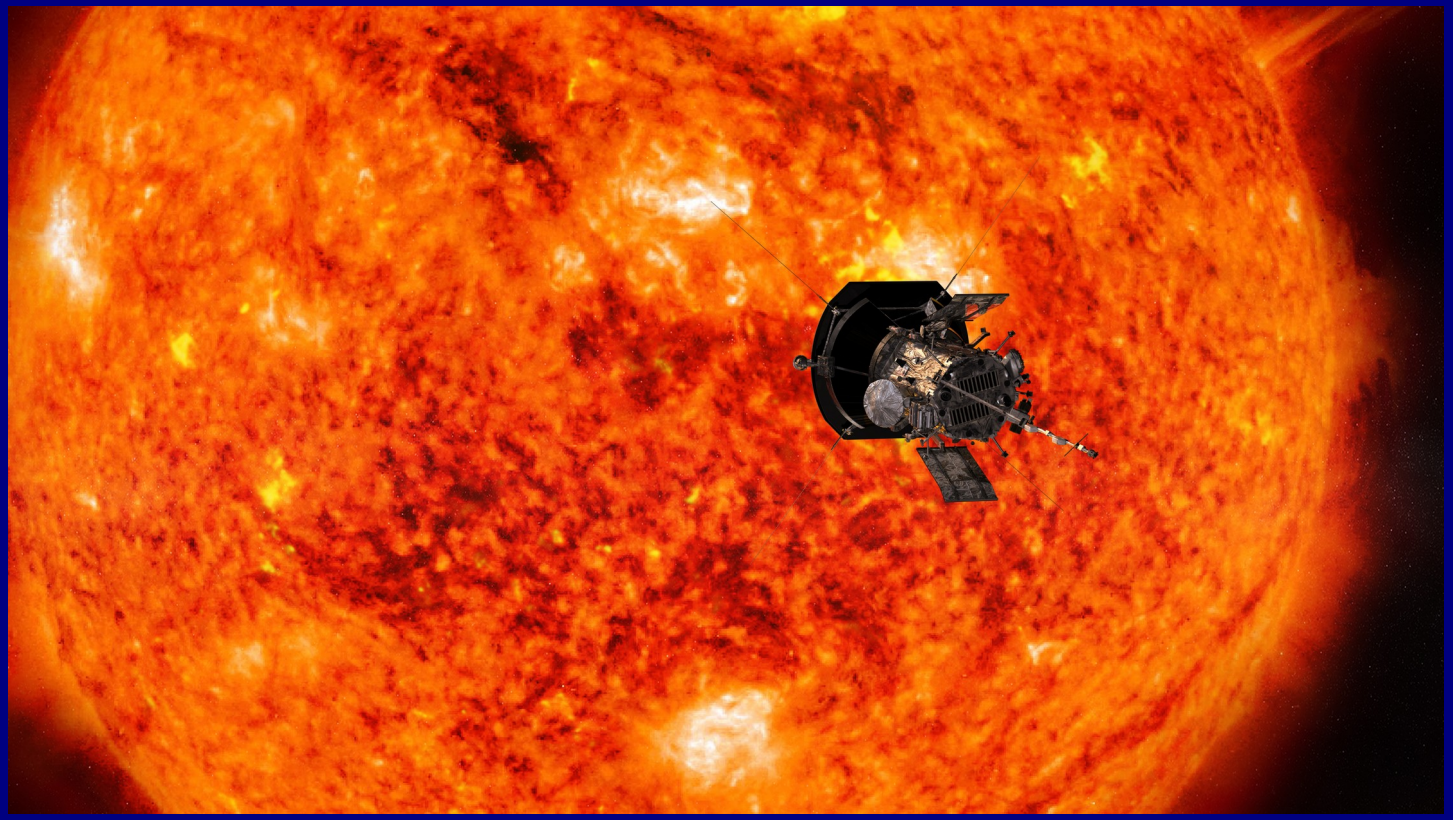
7 Venus Gravity Assists

Temps at Closest Approach:
1400° C at shield
~25° C behind shield

First Close Approach
December 19, 2024

Last Close Approach
June 14, 2025

Send Your Name to the Sun



Submissions Accepted until April 27, 2018
Go Here: http://go.nasa.gov/HotTicket

Image from: http://parkersolarprobe.jhuapl.edu/News-Center/Show-Article.php?articleID=70