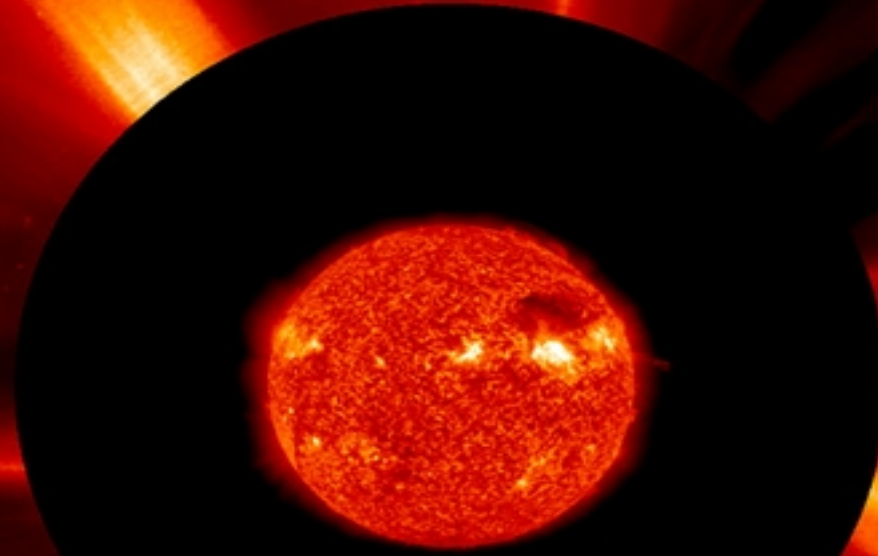
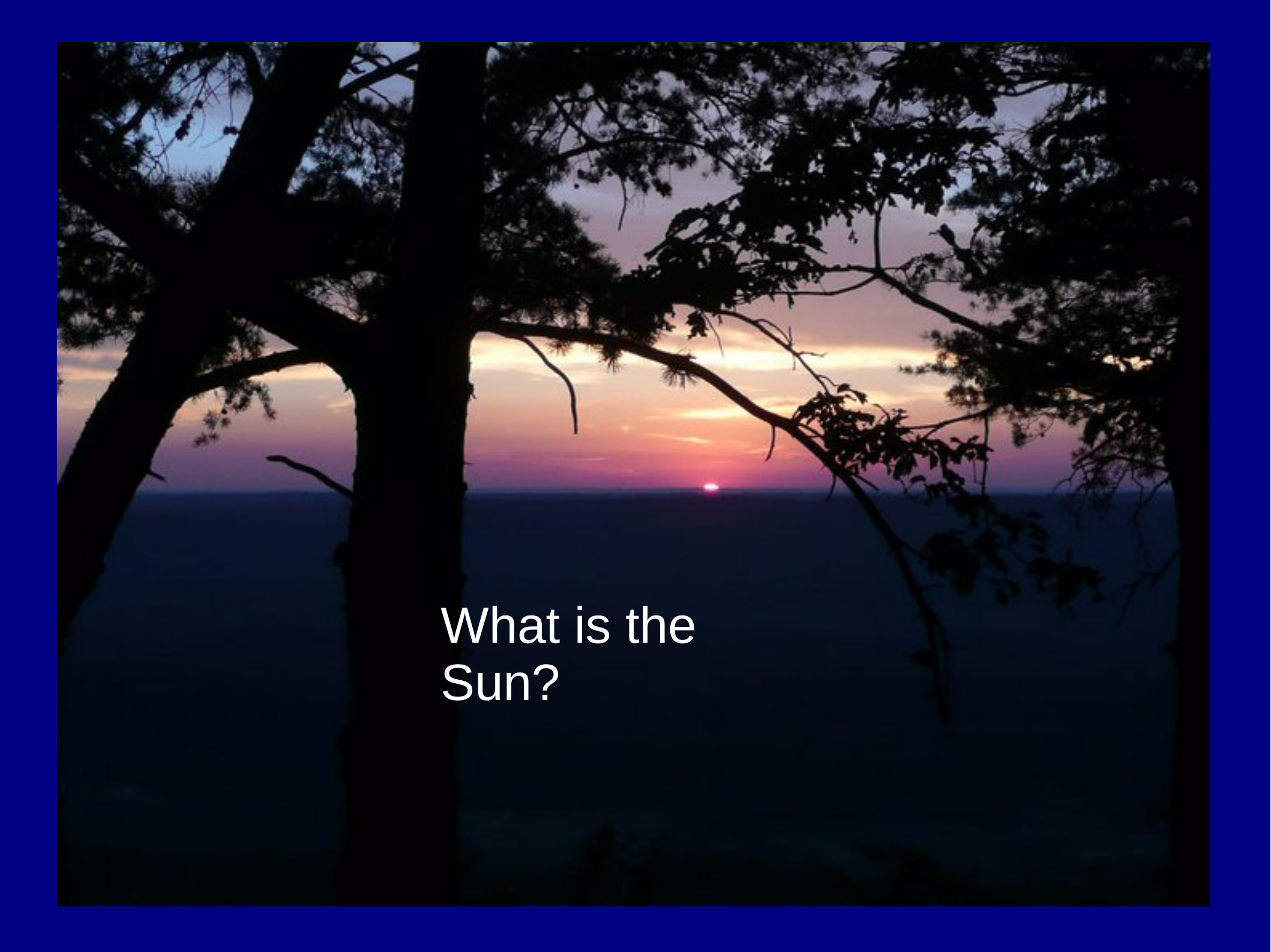


*The Sun
and
Space Weather*



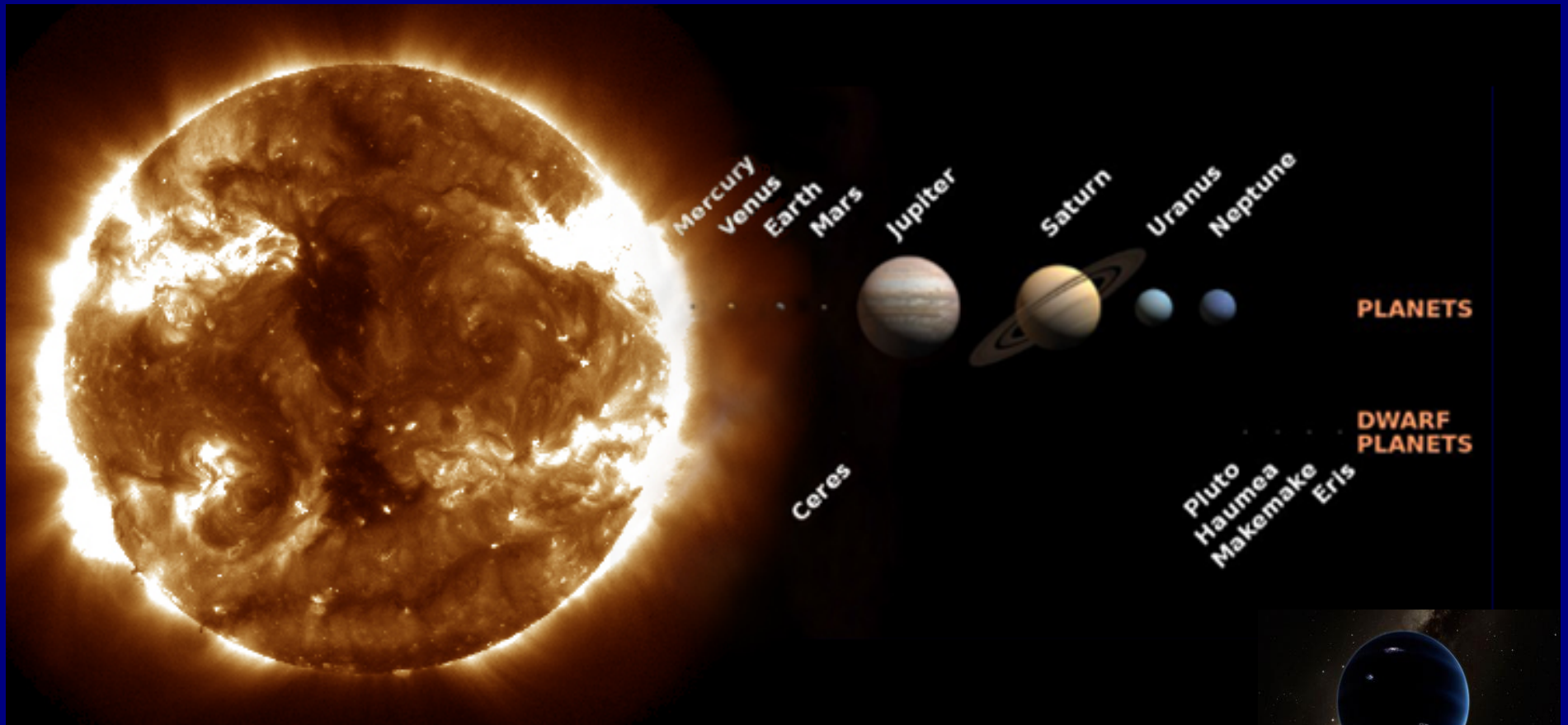
Mitzi Adams, M.S.
Solar Scientist
NASA/MSFC
ST 13

for Fernbank Science Center
January 11, 2020

A photograph of a sunset over a body of water, framed by the dark silhouettes of trees in the foreground. The sun is a small, bright orange-red dot on the horizon, with a gradient of colors from purple to yellow in the sky above it. The water is a deep blue-grey color.

What is the
Sun?

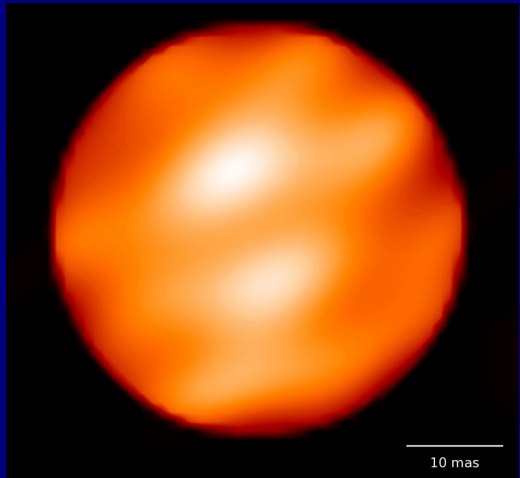
The Sun: A Star at the Center of our Solar System



Planet
Nine?

What is a Star?

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



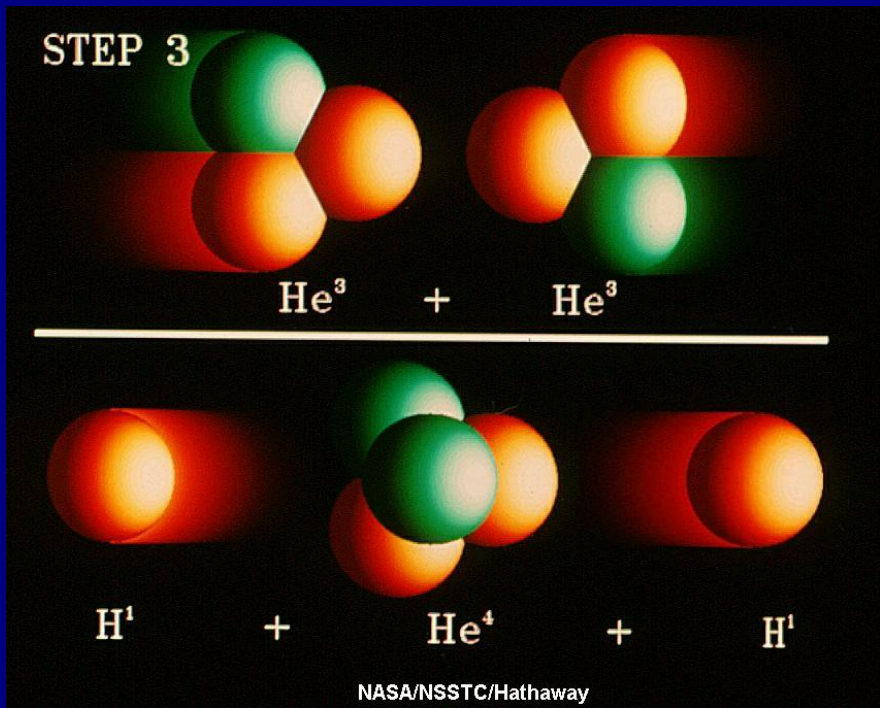
Betelgeuse: A red giant star, about 600 ly away, 3500 K, 1,180 R_{\odot} , 7.7 M_{\odot} .



Rigel: A blue-white star, about 770 ly away, 11,000 K, 80 R_{\odot} , 20 M_{\odot} .

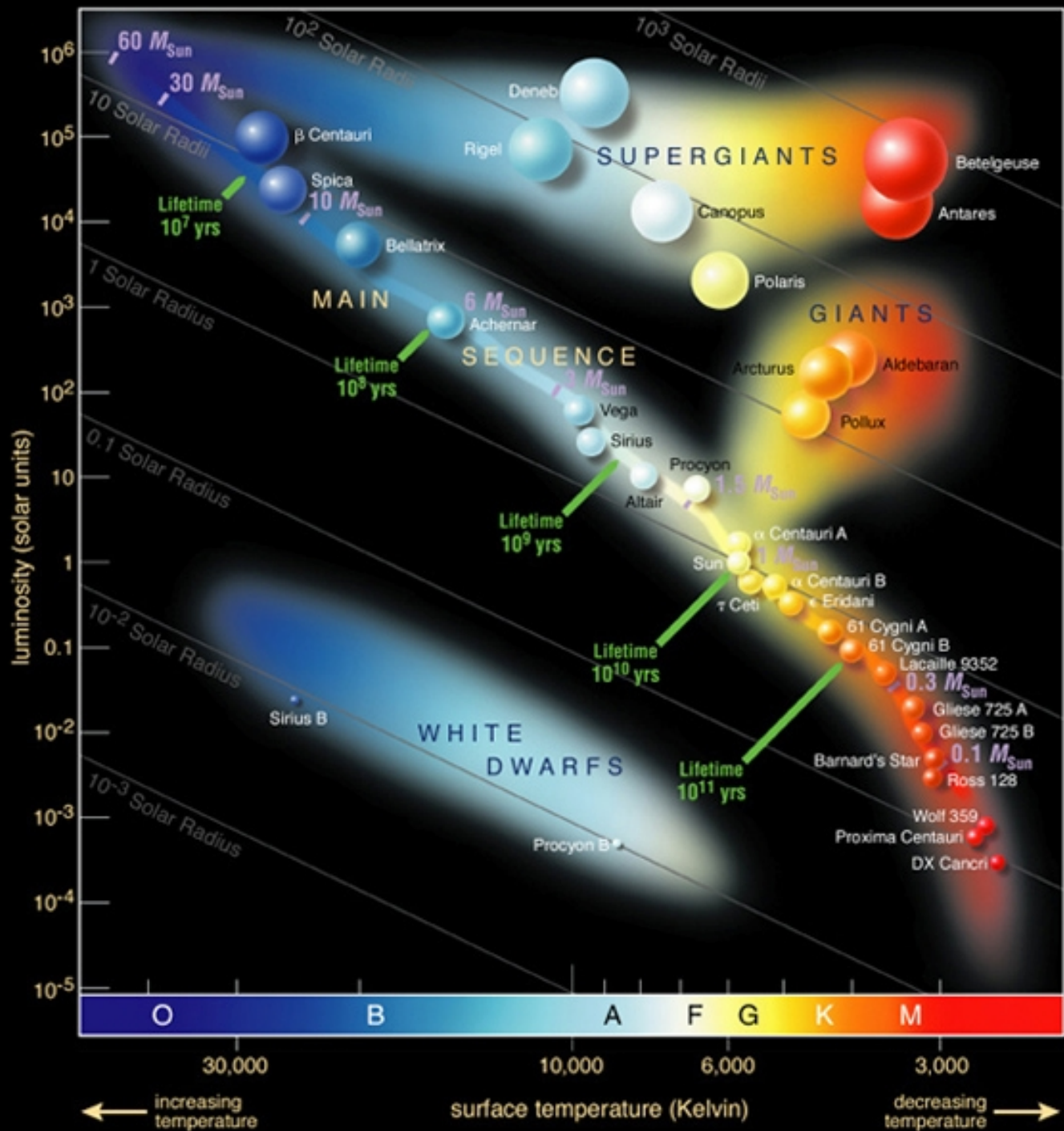
Basically, hydrogen converts to Helium

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



- For sun-type stars, there are three steps in the proton-proton chain:
1. Two protons collide, form deuterium, a positron, and 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.

Stellar Differences



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

the Sun is G2
 8.5 light minutes away

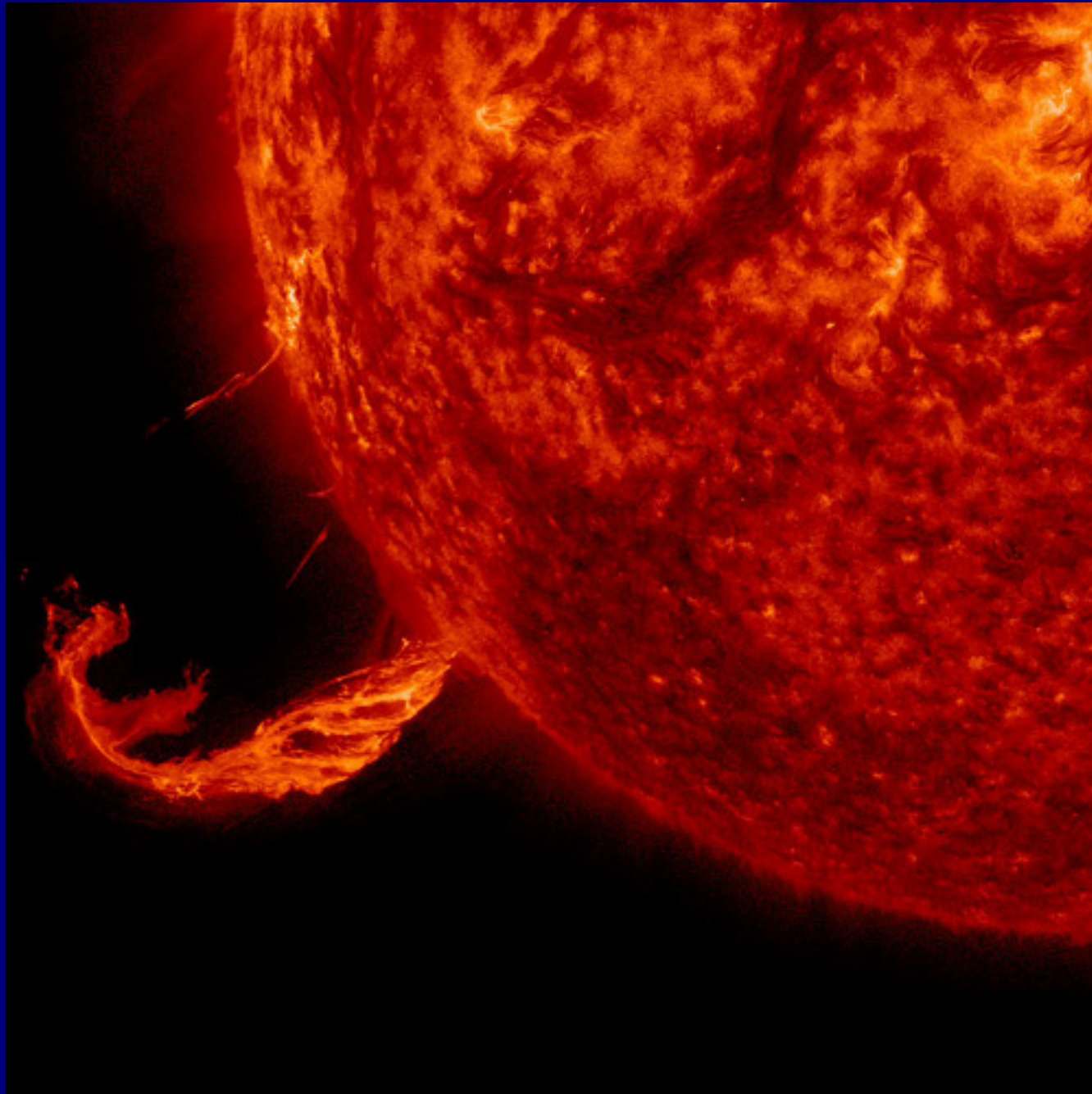
Betelgeuse is M2
 643 ly

Bellatrix is B2
 250 ly

Rigel is B8
 860 ly

Saiph is B0
 650 ly

The Sun -- How Big ? How Powerful ??



1.3 million Earths can fit
inside the Sun

The Sun contains more than
99.8% of the total mass of
the Solar System.

Pressure in the core is
approximately
250 billion billion atmospheres

Energy conversion rate:
4.26 million metric tons/second,
this produces approximately
38,460 septillion Watts/second

(Outburst304_big.mp4)

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

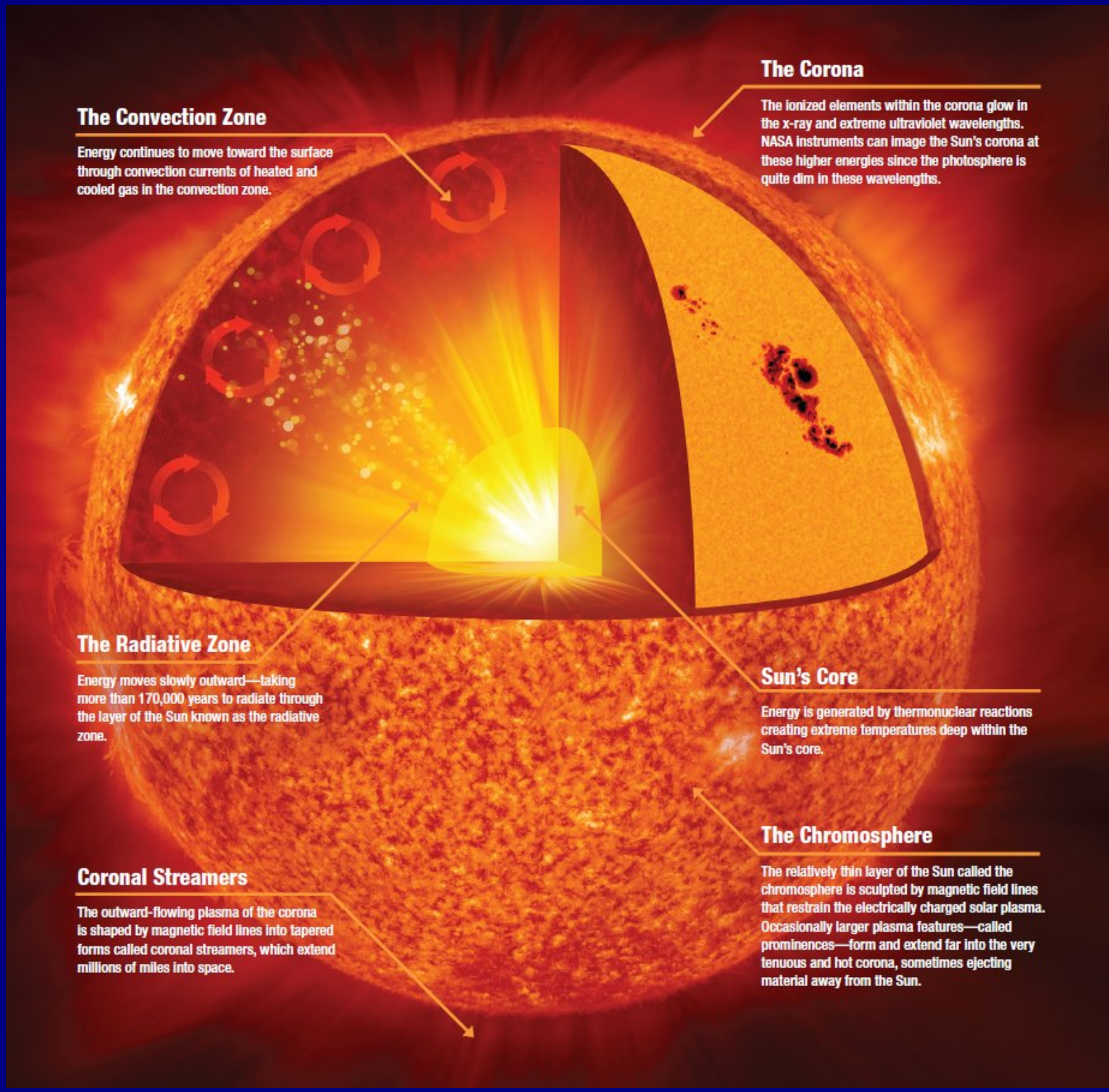
Energy is generated by thermonuclear reactions creating extreme temperatures deep within the Sun's core.

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.

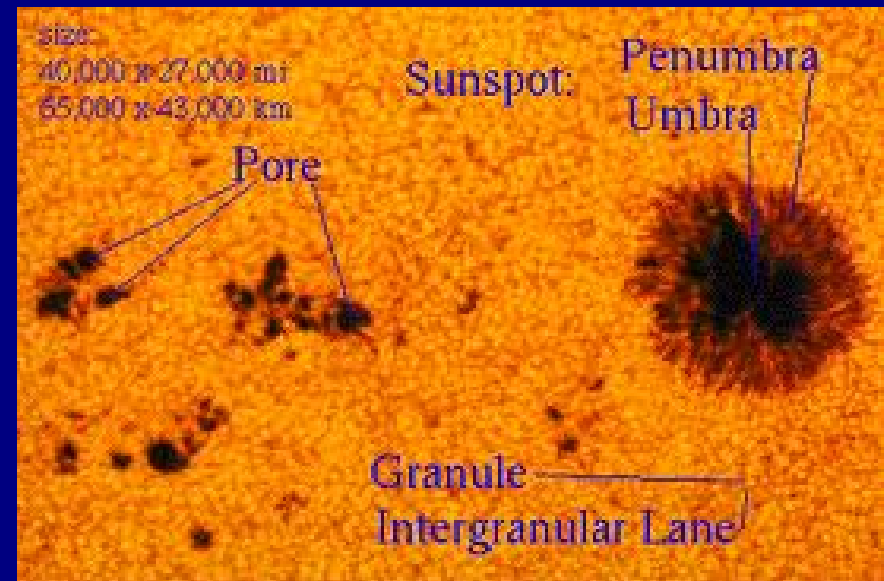
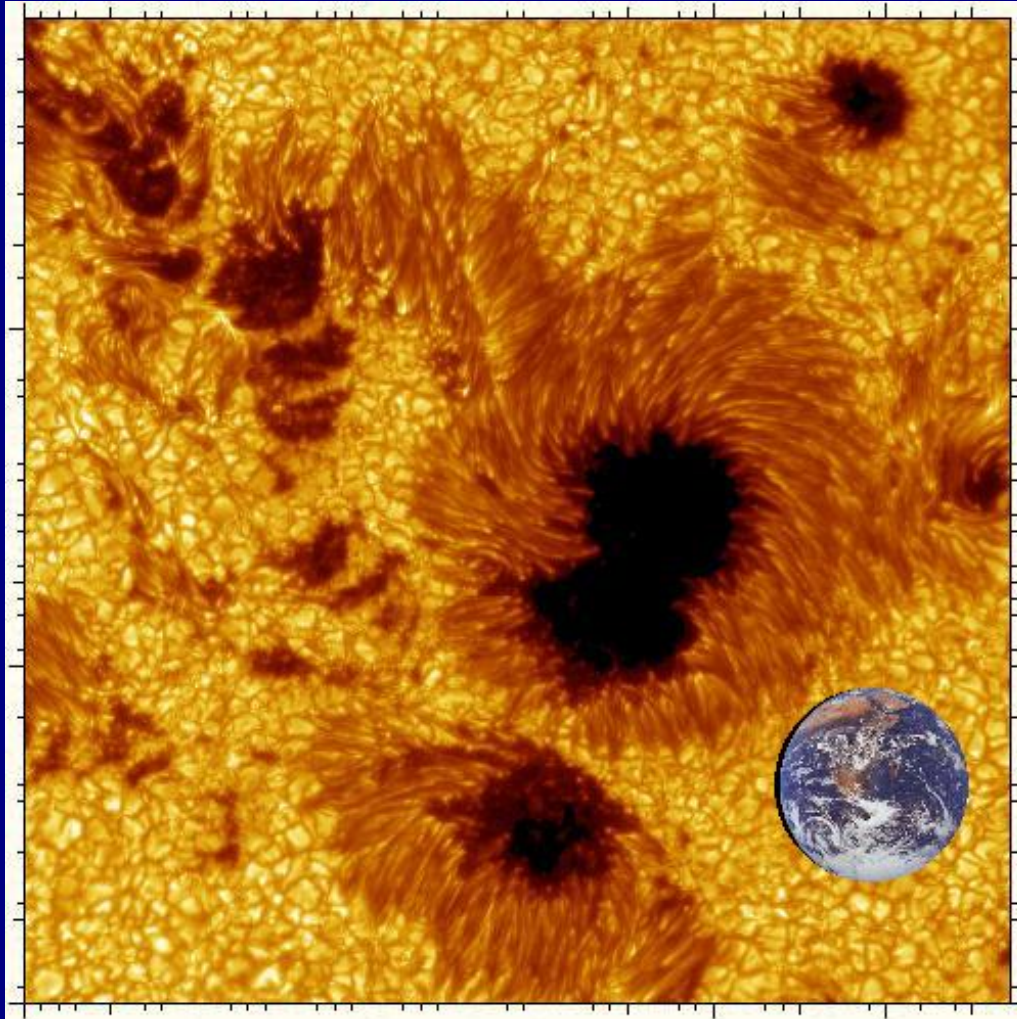
The Chromosphere

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.



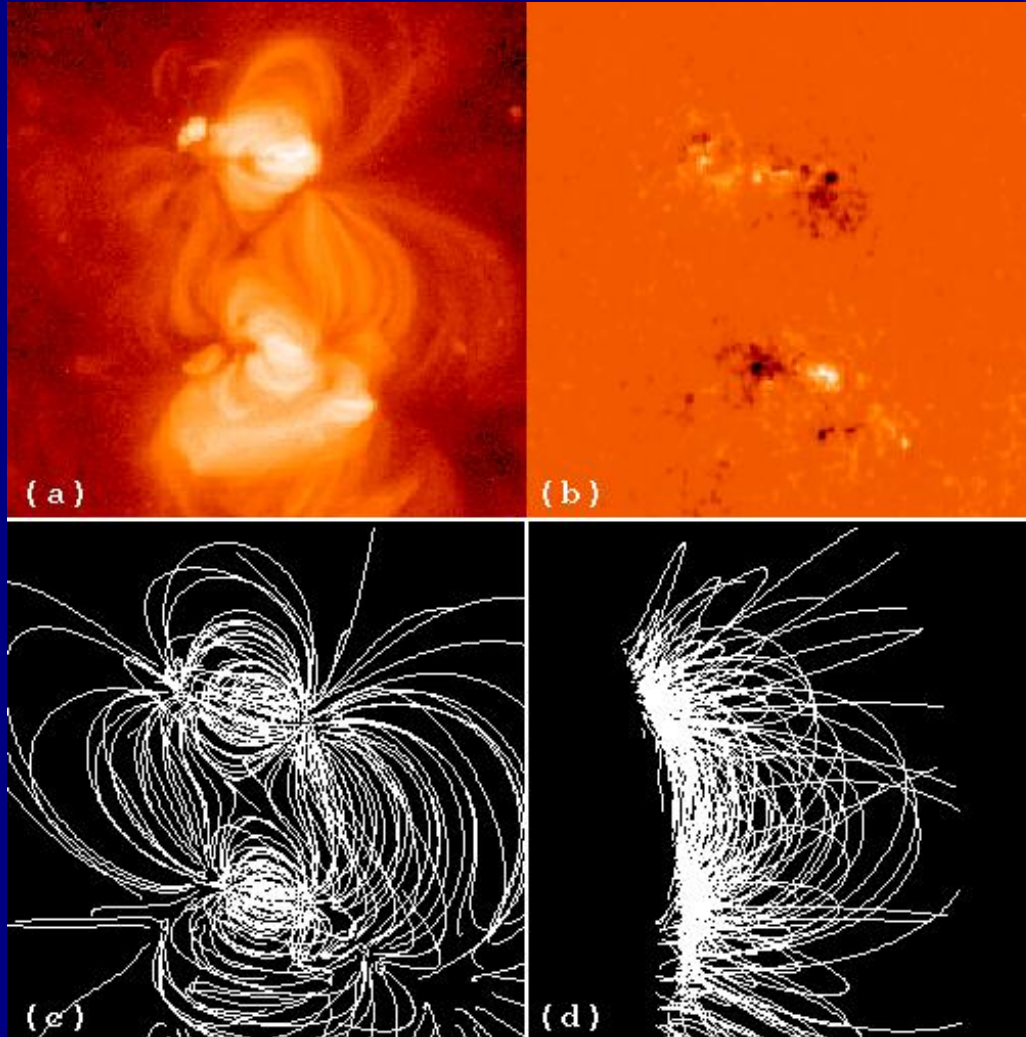
Sunspots

Examples



Magnetic Fields ABOVE the "Surface"

Yohkoh, 4 Jan, 1994



L-O-S magnetic field

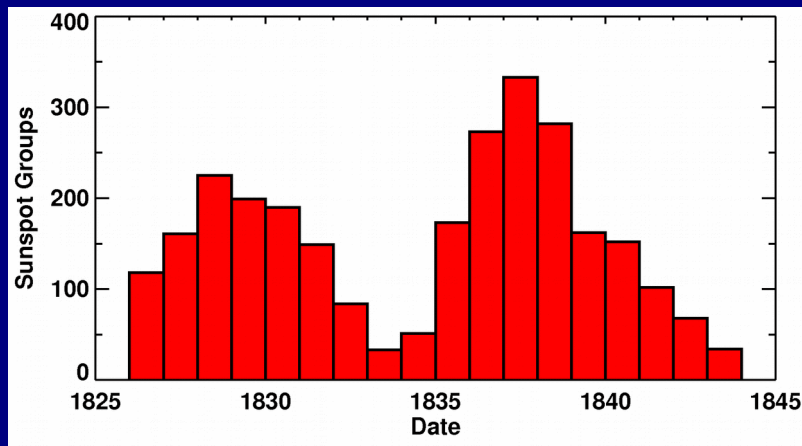
Extrapolated Magnetic Field

The Solar Cycle

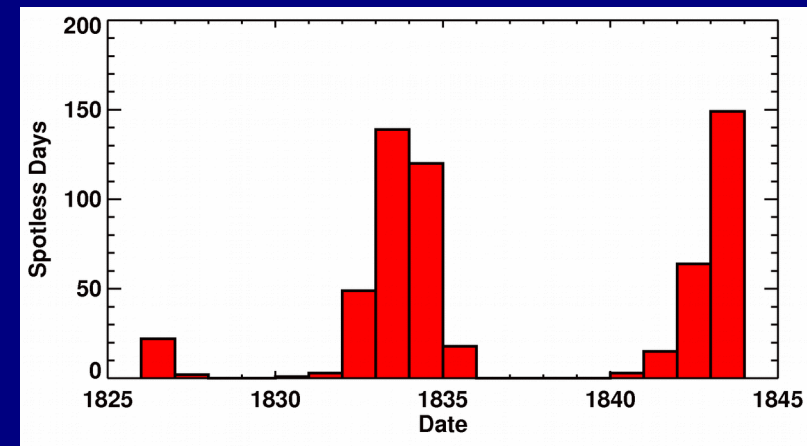
Sunspot Cycle Discovery

Astronomers had been observing sunspots for over 230 years before Heinrich Schwabe, an amateur astronomer in Dessau, Germany, discovered in 1844 that the number of sunspot groups and the number of days without sunspots increased and decreased in cycles of about 10-years.

Schwabe's data for 1826 to 1843

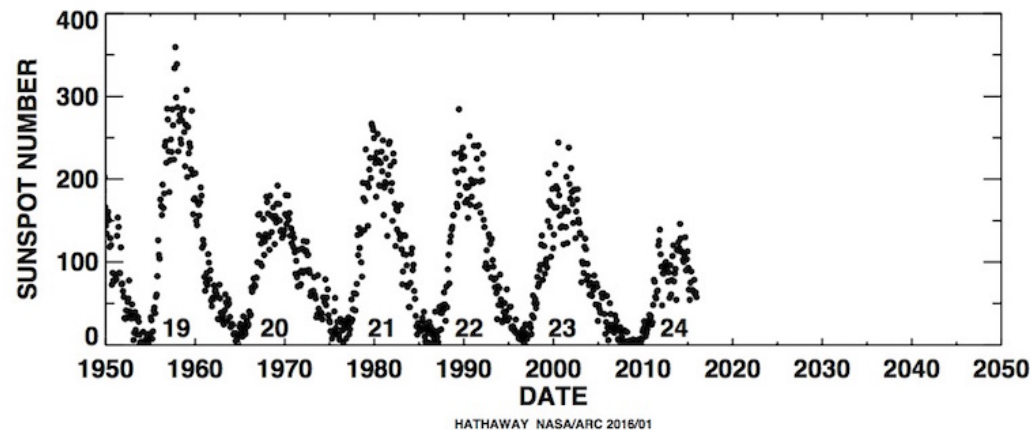
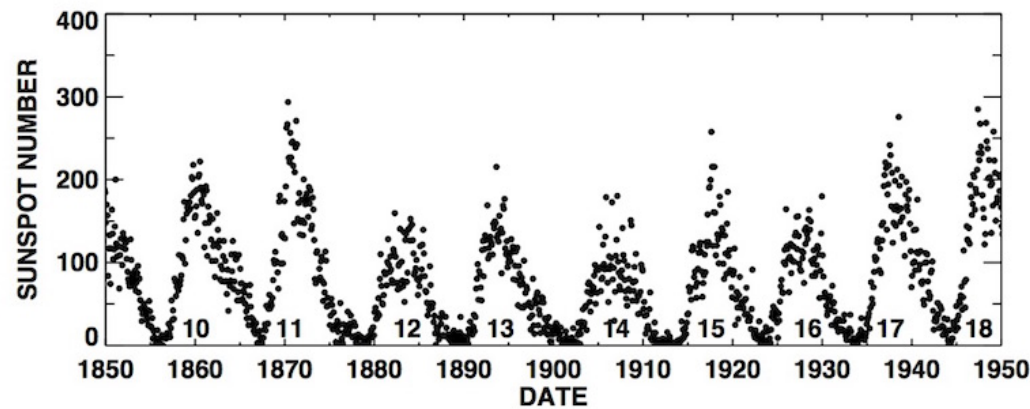
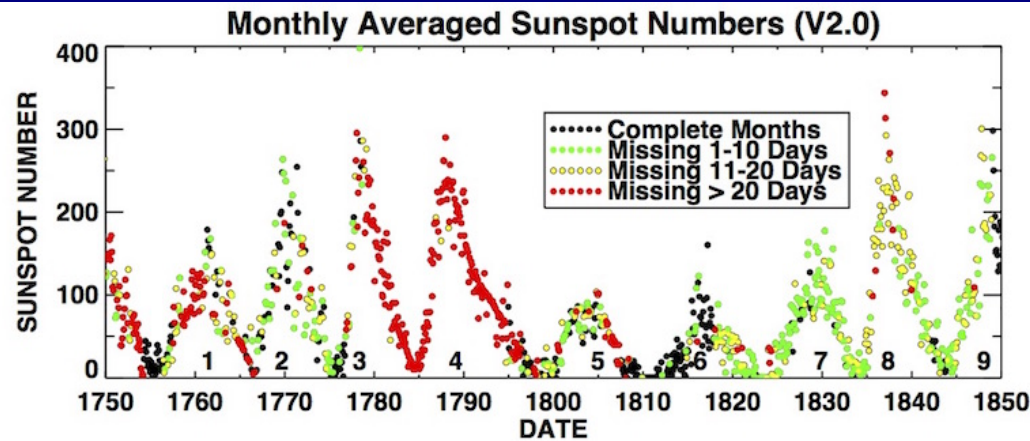


Number of Sunspot Groups per Year



Number of Spotless Days

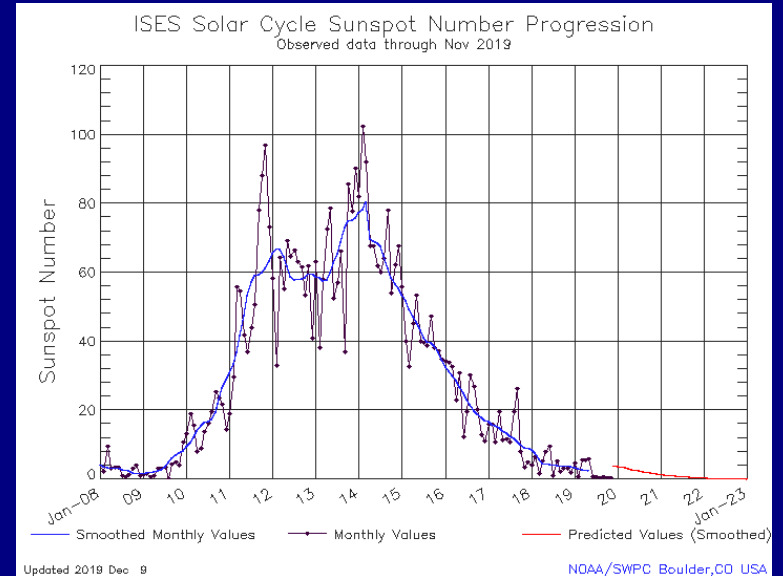
23 Full Cycles



Shortly after Schawbe's discovery Rudolf Wolf proposed using a "Relative" Sunspot Number count. Prior to 1849, sunspots were not counted every day. We continue to use Wolf's Relative Sunspot Number and his cycle numbering.

Average cycle: 11 years, with a range from 9 to 14.

Average amplitude: 100, with a range from 50 to 200.



Solar Eruptions

Flares

May 5, 2015, X2.7 flare

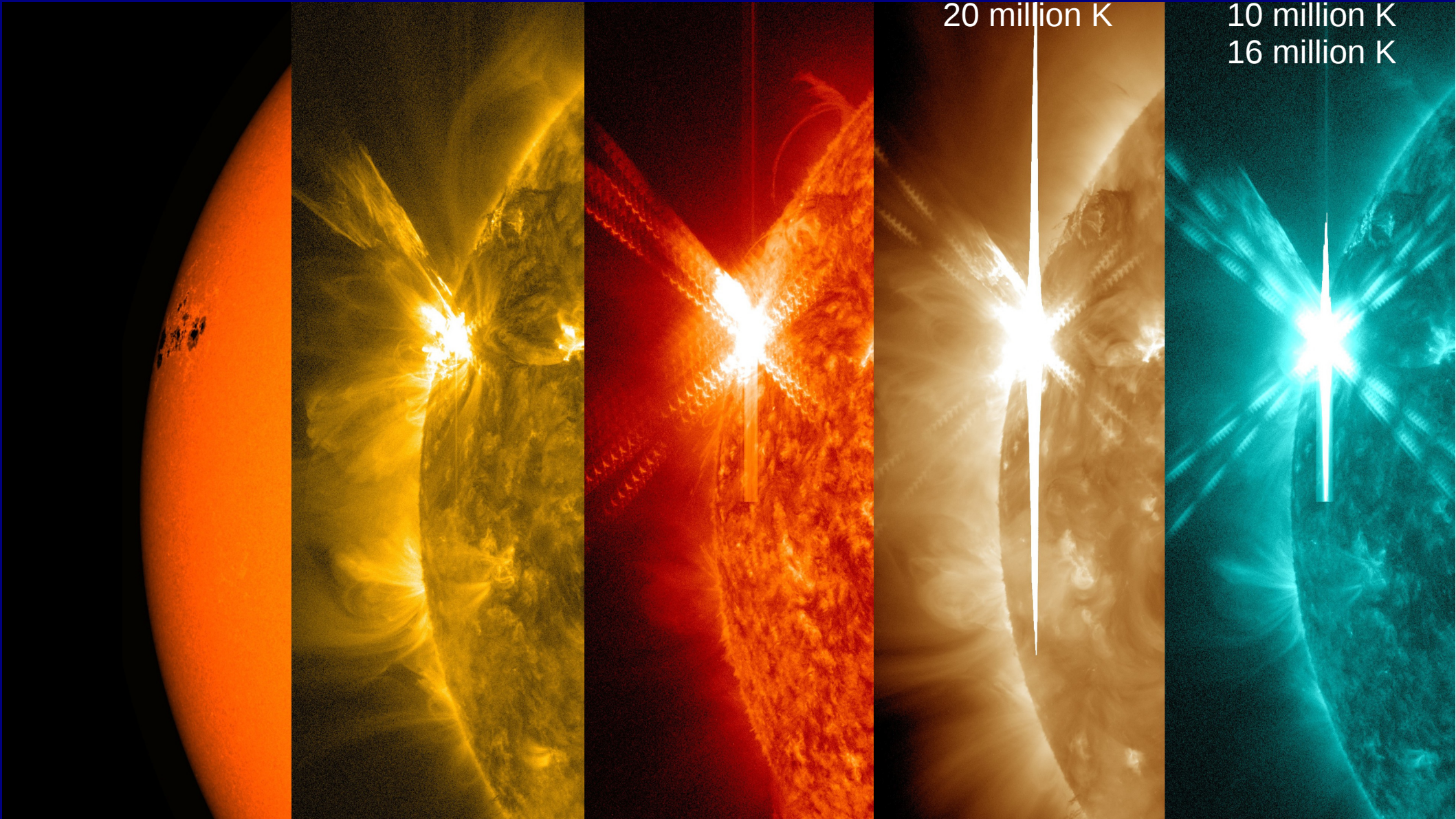
White Light
~5000 K
(10,000 F)

171 Å
Fe IX
63,000 K

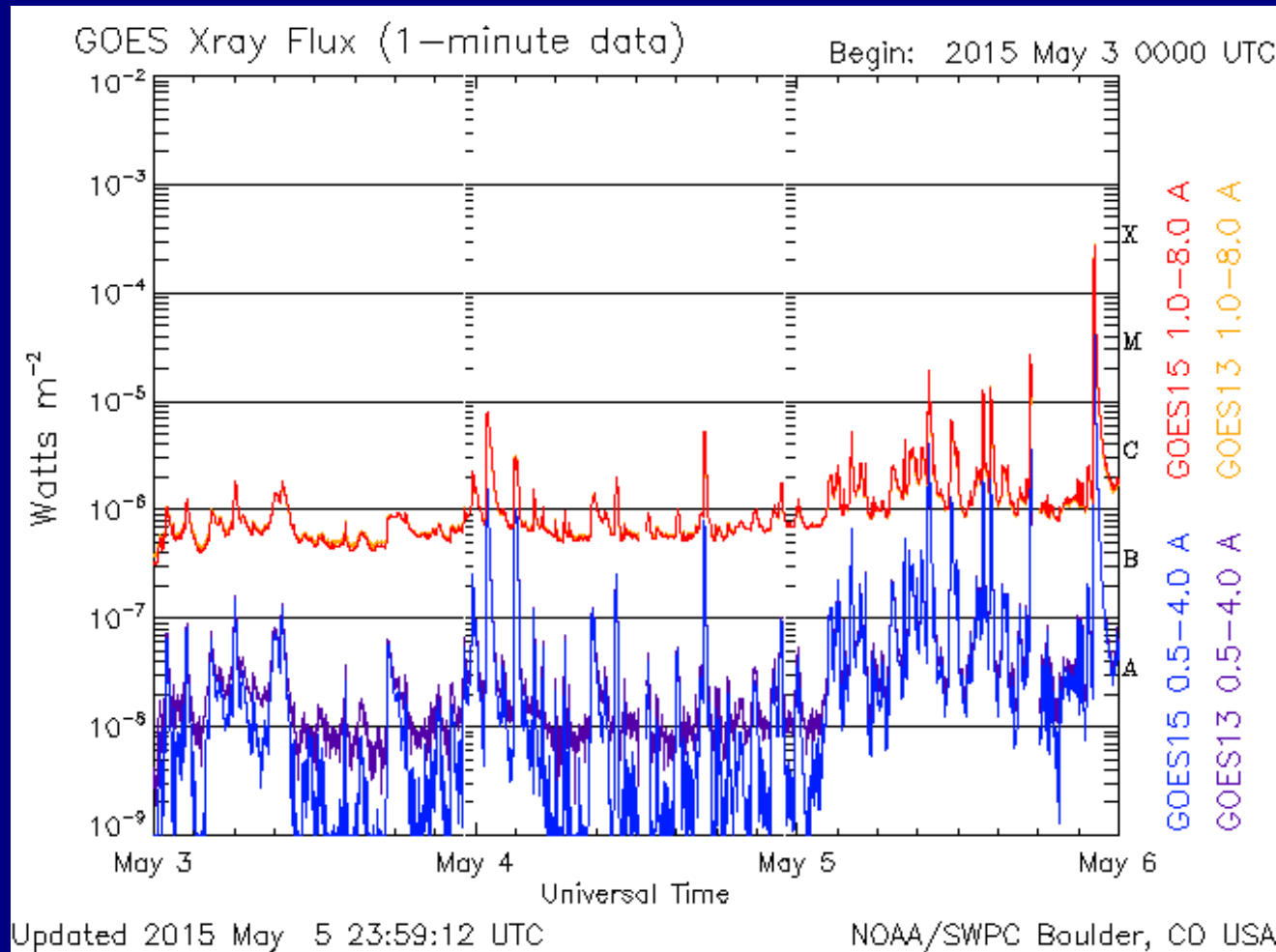
304 Å
He II
50,000 K

193 Å
Fe XII, XXIV
1.2 million K,
20 million K

131 Å
Fe VIII, XX, XXIII
40,000 K,
10 million K
16 million K

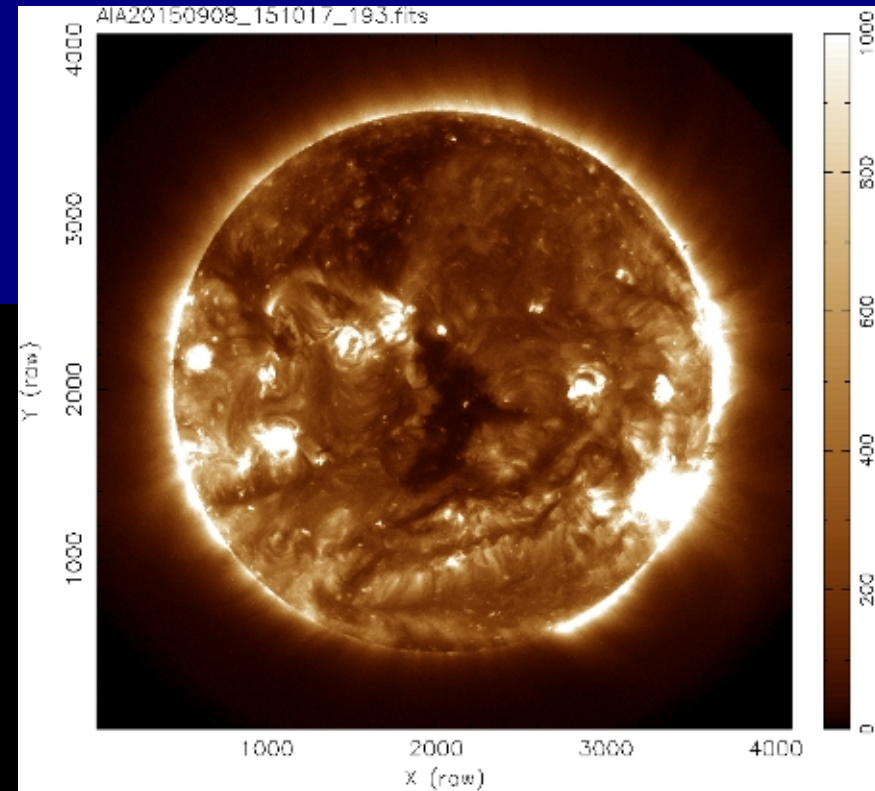
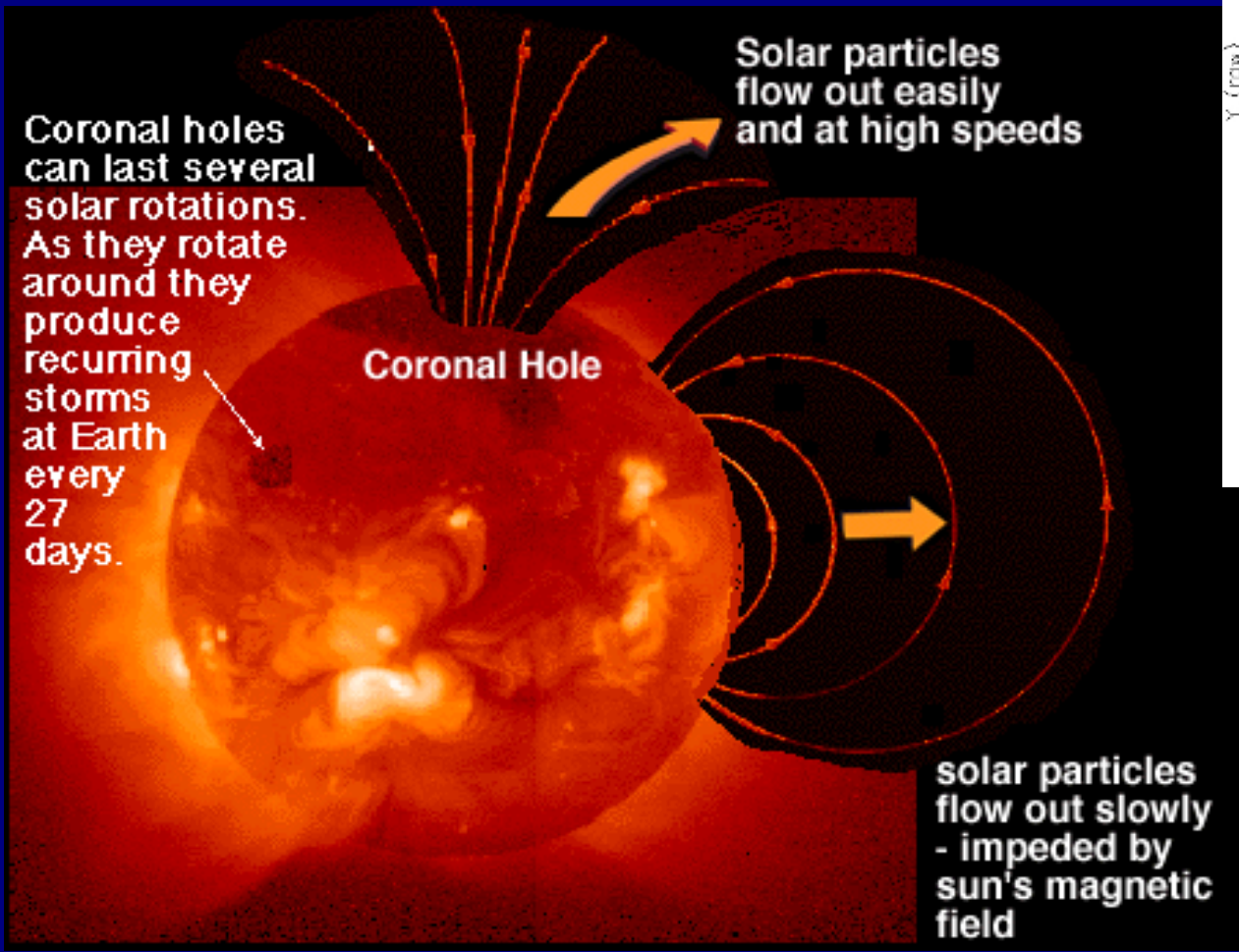


How to Classify a Solar Flare



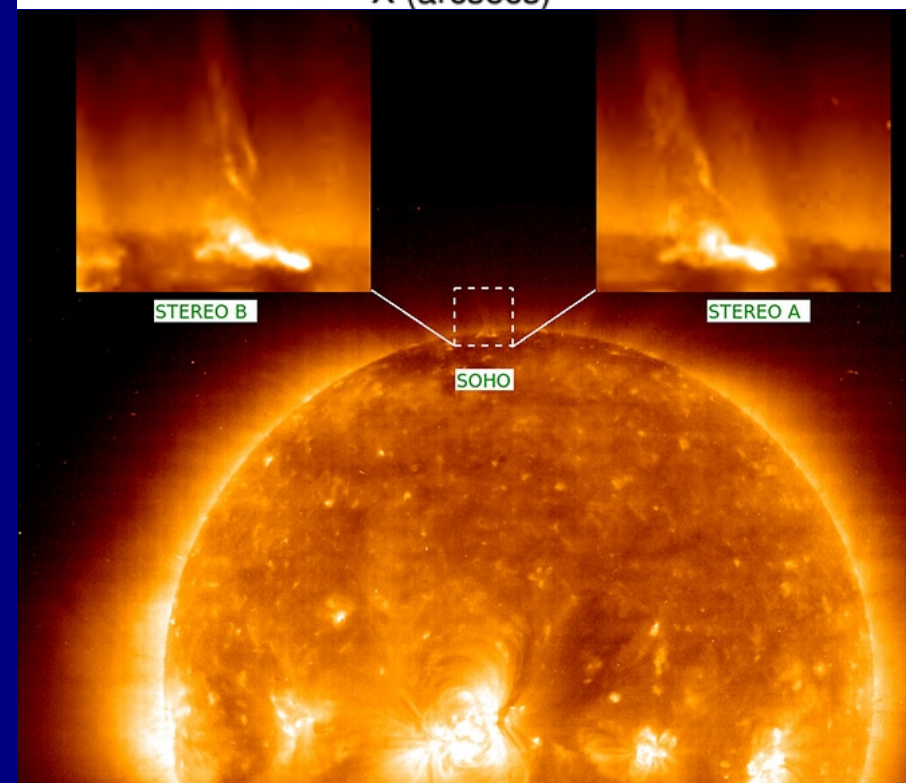
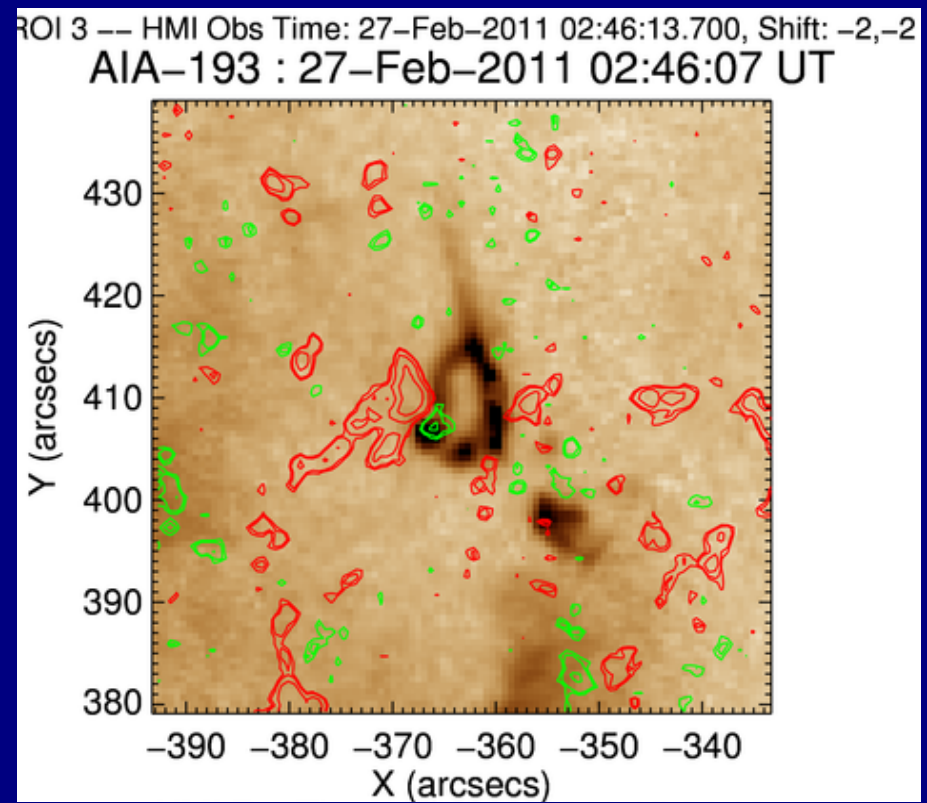
Hiroshima Bomb ~ 15 kiloton TNT
A flare ~ 1 billion megaton tNT

Coronal Holes as Seen in X rays and EUV

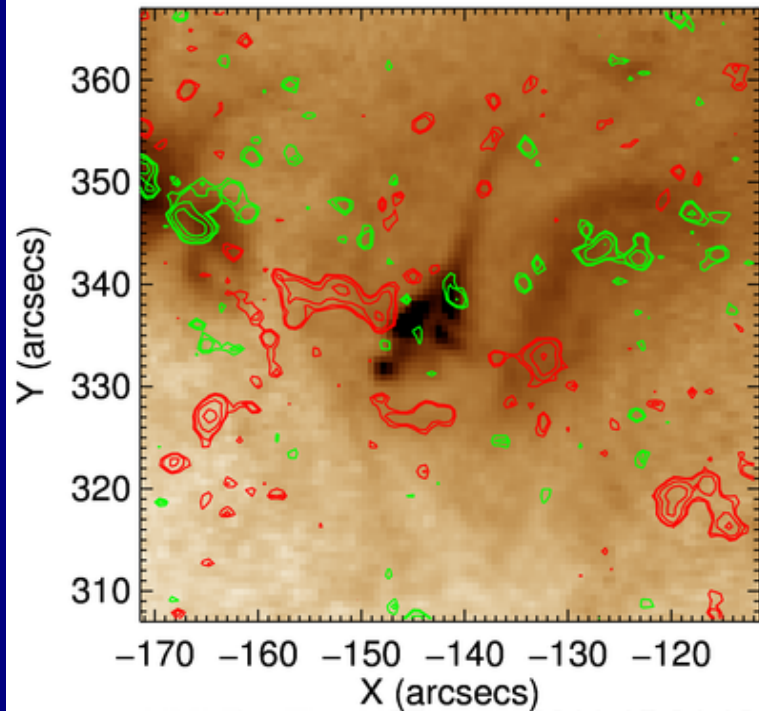


Jets in Coronal Holes

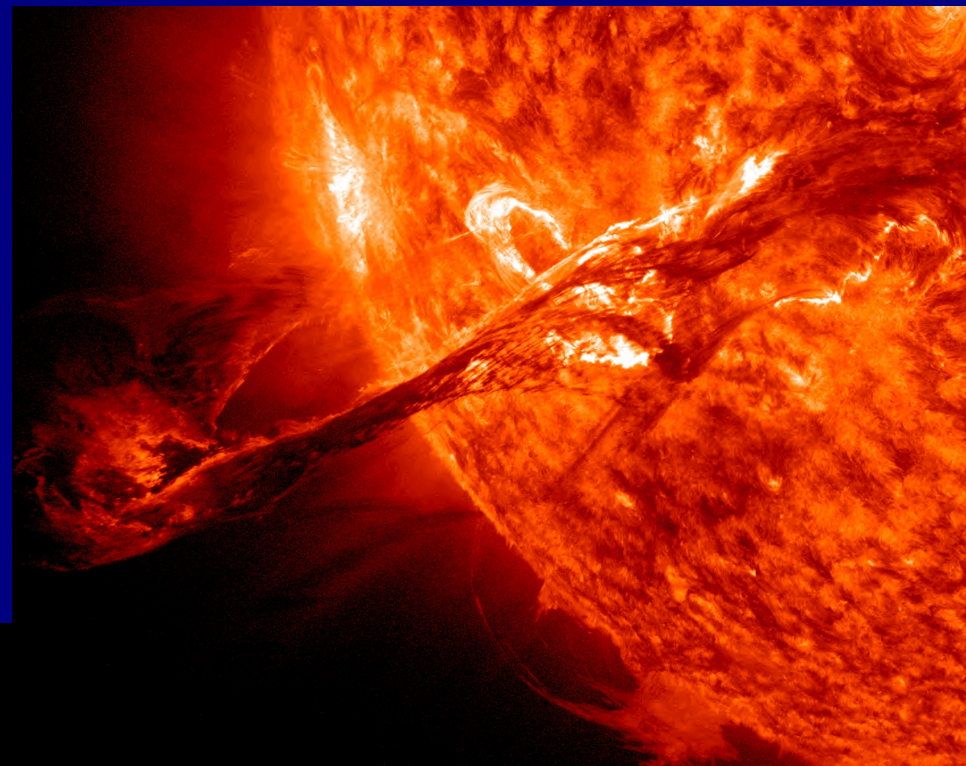
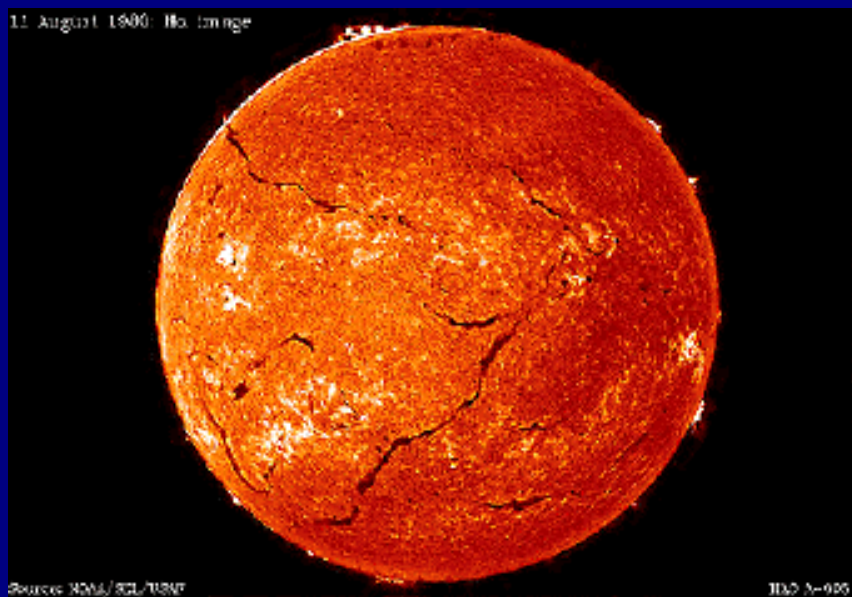
South Polar Jet: Hinode/P. Grigis



ROI 4 -- HMI Obs Time: 27-Feb-2011 03:41:43.700, Shift: -2,-2
AIA-193 : 27-Feb-2011 03:41:43 UT

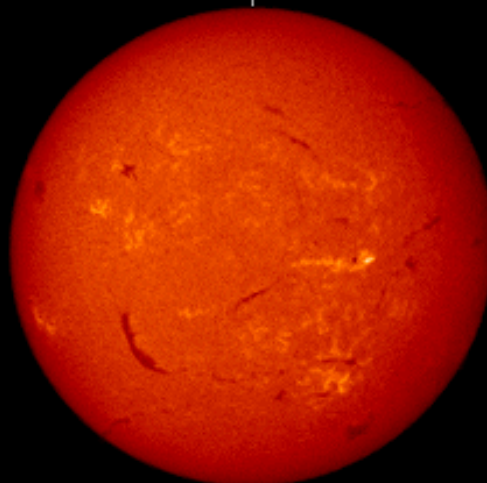
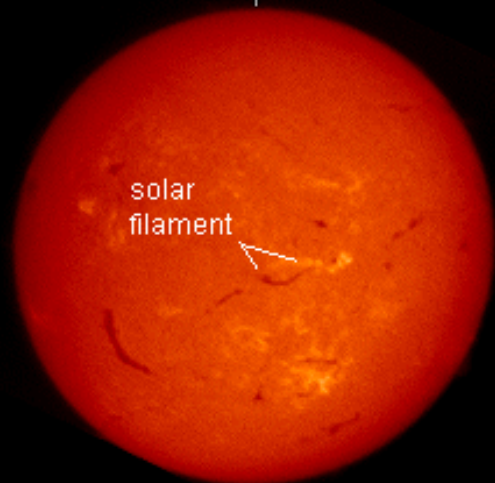


Filament eruptions



BEFORE

AFTER



(October 9 @ 1853 UT)

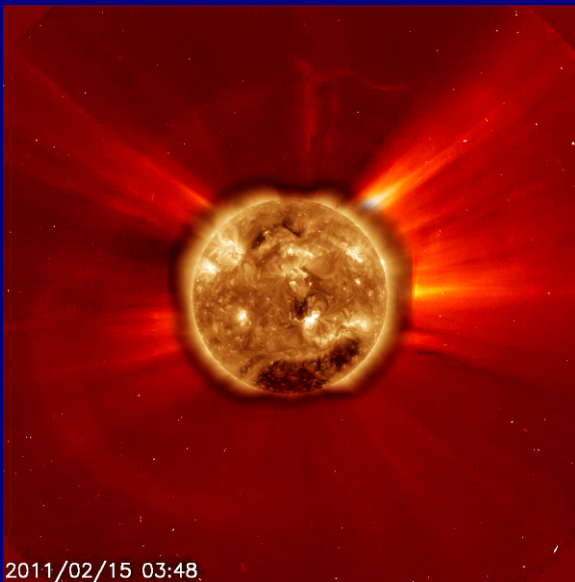
(October 10 @ 0553 UT)

August 31, 2012, a filament erupted, triggering a CME. The plasma had speeds > 900 mi/s. This image is from SDO in 304 \AA .

A filament around AR 9182 in October 2000. A C-7 flare was triggered, as well as a halo coronal-mass ejection (CME). Images from NOAA/SEC.

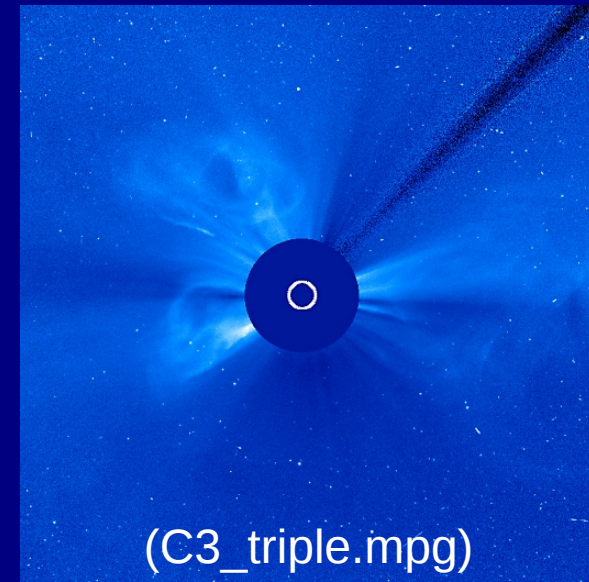
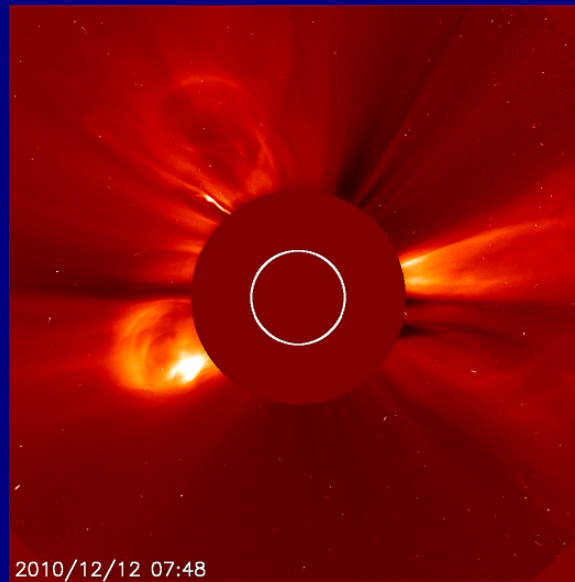
Other Types of Solar Eruptions

Solar Flares and Coronal Mass Ejections (CMEs)



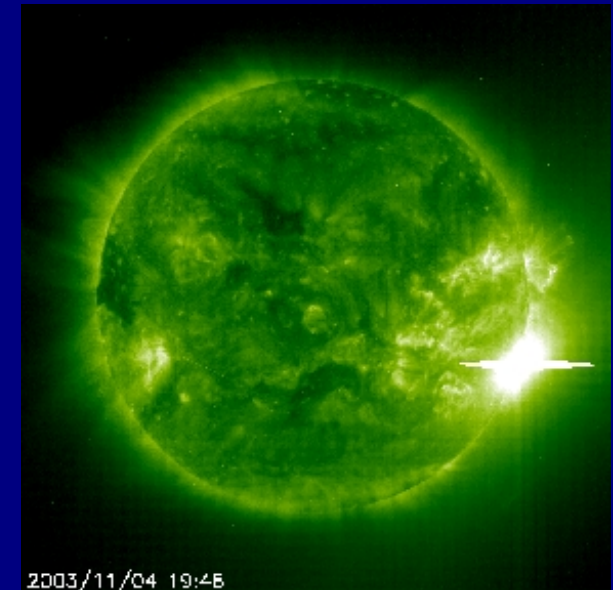
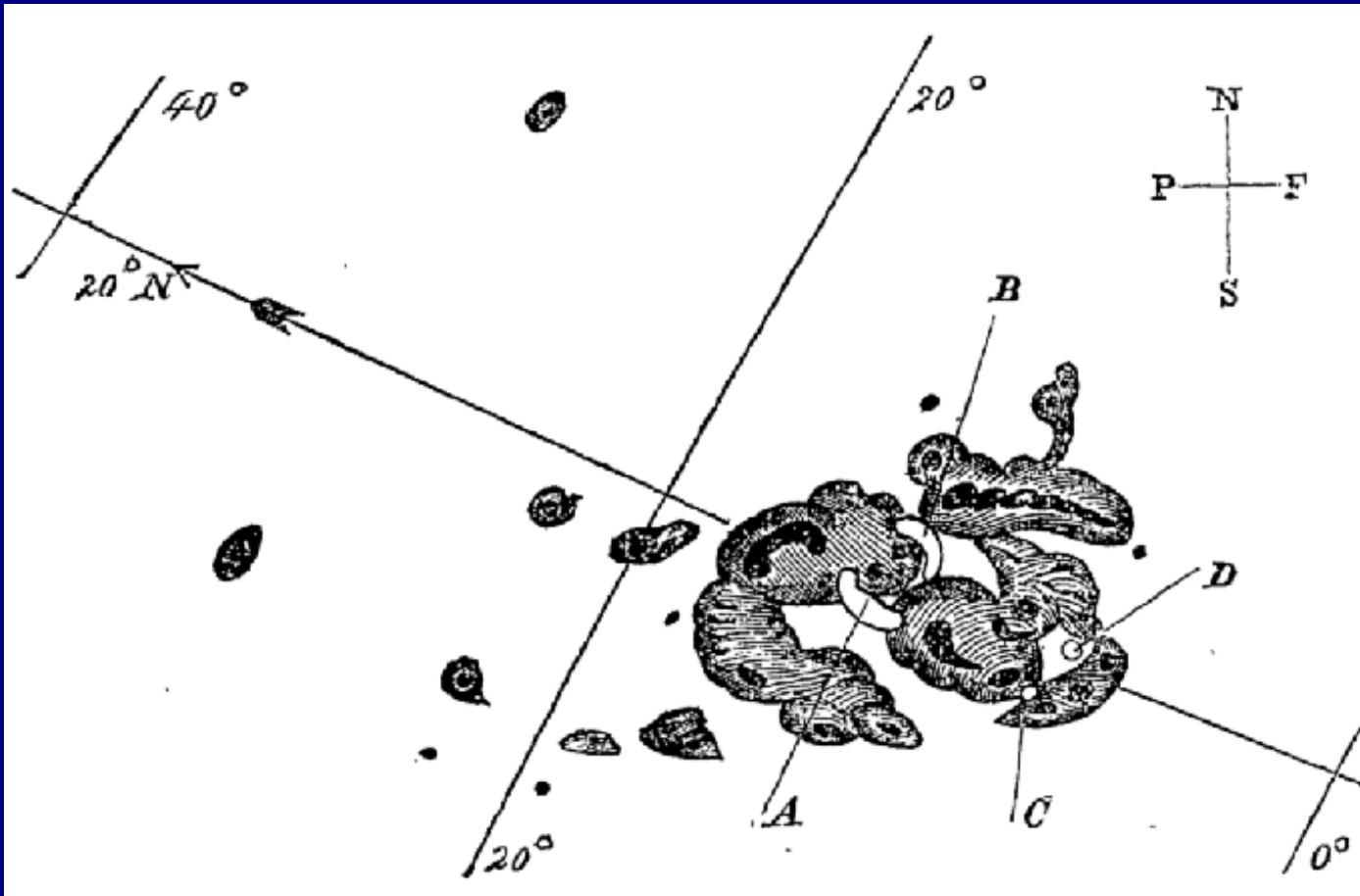
This combo of SDO and
Soho C2 shows X2-flare
and CME

(X2_C2_combo_best.mpg)



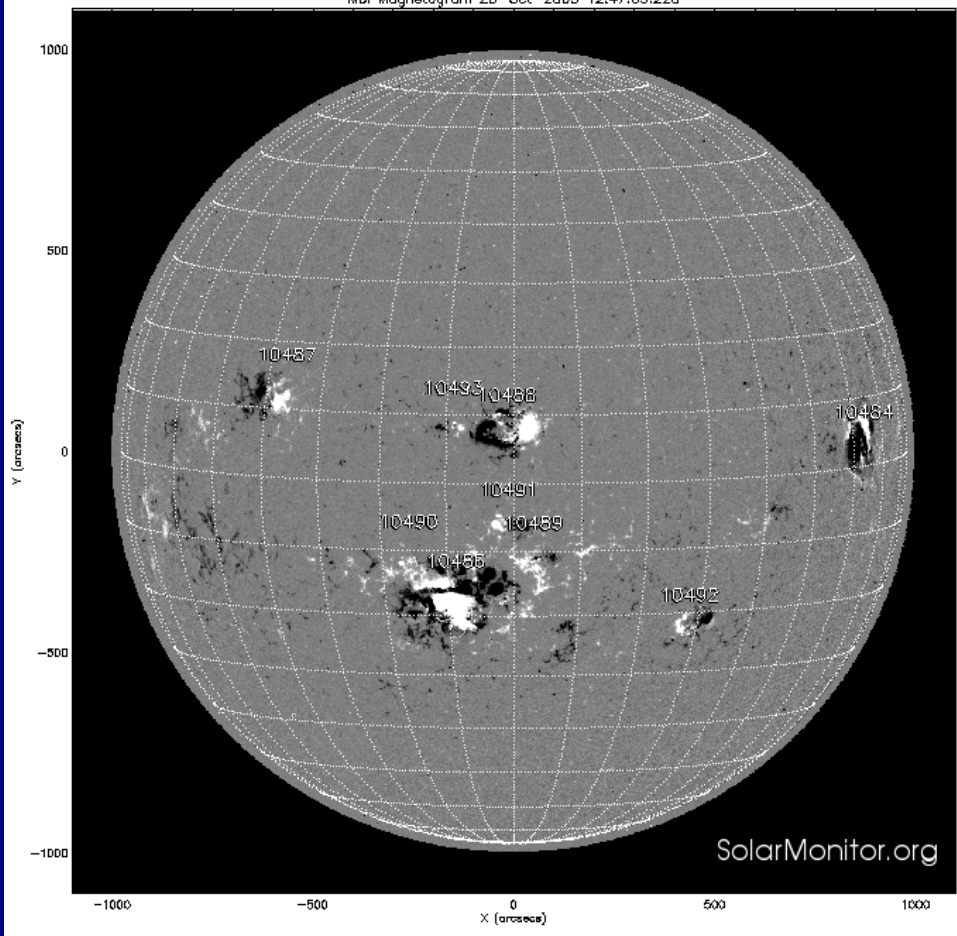
Three distinct CMEs: First (to right) was from a filament eruption, second from north pole, third from far side of Sun. All three eruptions happened within hours of each other.

August 28 - September 2, 1859 The Carrington Event (and Richard Hodgson)



2003/11/04 19:46

A brilliant display of Northern lights was witnessed from 8 o'clock to half-past 9 last night. The glare in the northern sky, previous to defining itself into the well-known features of the Aurora Borealis was sufficiently vivid to call out some of the fire companies. [The Evening Star (Washington DC)]



...Large print could no doubt have been easily read, for we can testify that the time on the face of a watch was easily legible...[Washington Daily National Intelligencer, September 3, 1859].

...The northern sky, for an extent of some forty five degrees, was luminous with a mass of red light, from whence shot up towards the zenith the usual streaks, at times vivid and beautiful...[New Orleans Daily Picayune, September 3, 1859].

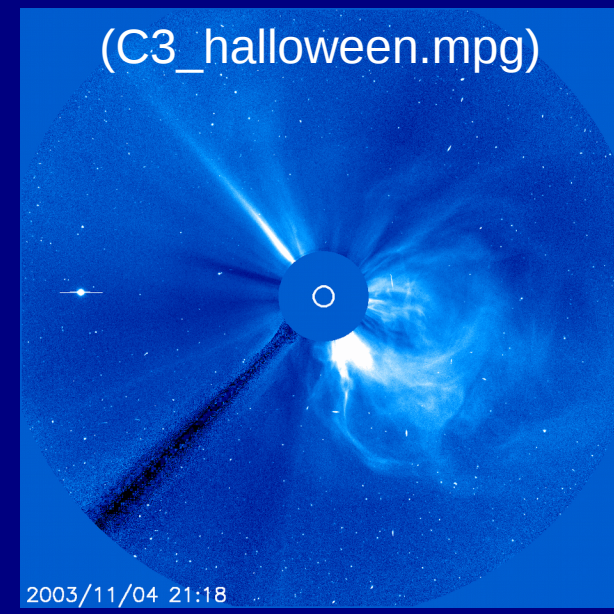
...There were strong currents of electricity observed on the wires, to which no batteries were attached, and some extraordinary electrical phenomena, difficulty of explanation, noticed... [New Orleans Daily Picayune, Saturday, September 3, 1859].

...The wire was then worked for about two hours without the usual batteries on the auroral current, working better than with the batteries connected. This is the first instance on record of more than a word or two having been transmitted with the auroral current...[Washington Daily National Intelligencer, Tuesday, September 6, 1859].

...The French telegraph communications at Paris were greatly affected, and on interrupting the circuit of the conducting wire strong sparks were observed. The same thing occurred at the same time at all the telegraphic station in France...

[The Illustrated London News, September 24, 1859].

(C3_halloween.mpg)



Executive Order: Coordinating Efforts to Prepare the Nation for Space Weather Events

October 13, 2016

Issued in the final days of President Barack Obama's Presidency, the Executive Order called for (in brief):

1. Collaboration among agencies: Homeland Security, NASA, NSF
2. Cooperation between Secretaries of Defense, Interior, Commerce, Transportation, and Energy
3. The National Science and Technology Council (NSTC) shall establish a Space Weather Operations, Research, and Mitigation Subcommittee

Has become Space Weather Strategy and Action Plan, released March, 2019

Space Weather Research and Forecasting Act
Passed Senate May 2, 2017
Out of Committee January 3, 2019

Excerpts:

An interagency working group shall leverage capabilities across participating Federal agencies, including -- National Oceanic and Atmospheric Administration (NOAA), NASA, NSF, DOD, Dept. of Interior, Dept. of Homeland Security, Department of Energy, Department of Transportation, including FAA and the Department of State

The Act includes Space Weather Metrics, a section describing the Protection of Critical Infrastructure, Protection of National Security Assets, and Ensuring the Safety of Civil Aviation.

See: <https://www.govtrack.us/congress/bills/115/s141/text>

