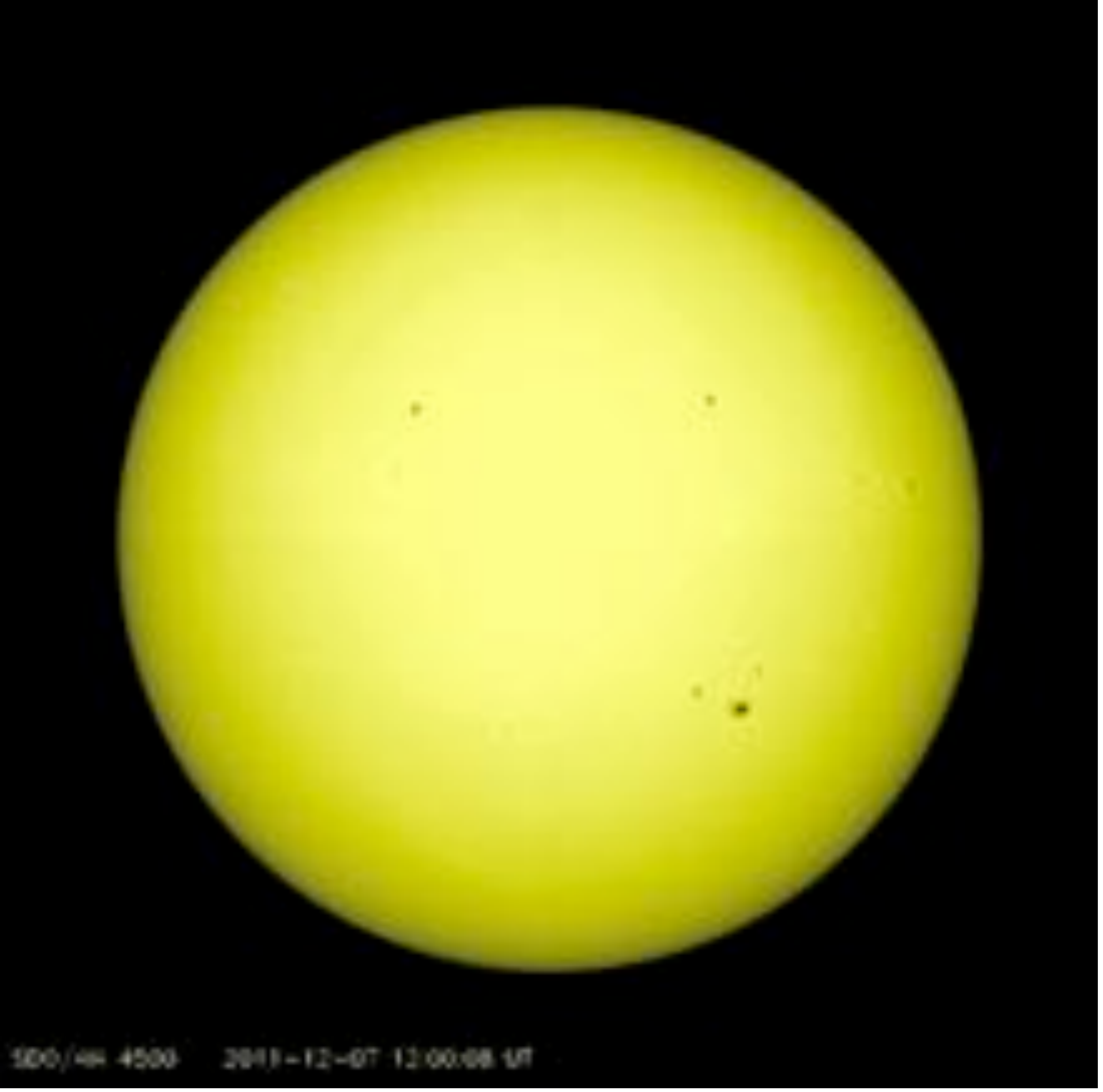


Solar Flares

The Great American Solar Eclipse

August 21, 2017

National Aeronautics and
Space Administration

What is a Solar Eclipse?

A **solar eclipse** happens when the Moon, as it orbits Earth, fully or partially blocks the light of the Sun, thus casting its shadow on Earth.

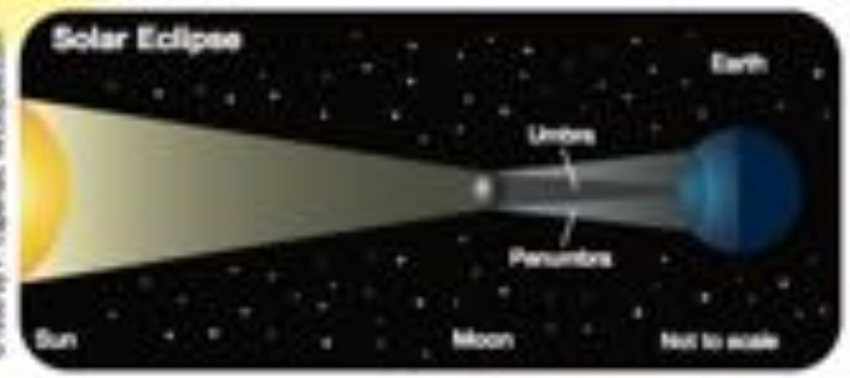
Observers within the path of totality can expect to see something like the image below. bservers outside the path of totality will see the Sun partially eclipsed as a crescent Sun (with safe filters).

Greatest Eclipse

Time	Location
10:17 a.m. PDT	Lincoln Beach, OR Depoe Bay, OR
11:26 a.m. MDT	Lime, ID
1:19 p.m. CDT	Valley View, MO Bloomsdale, MO
1:28 p.m. CDT	Calistia, TN
2:47 p.m. EDT	Bethera, SC

After the 2017 solar eclipse, the next **total solar eclipse** visible over the continental United States will be on **April 8, 2024.**

If the Sun is scaled to about 10 cm (3.9 in), Earth would be about 10 meters away (33 feet).



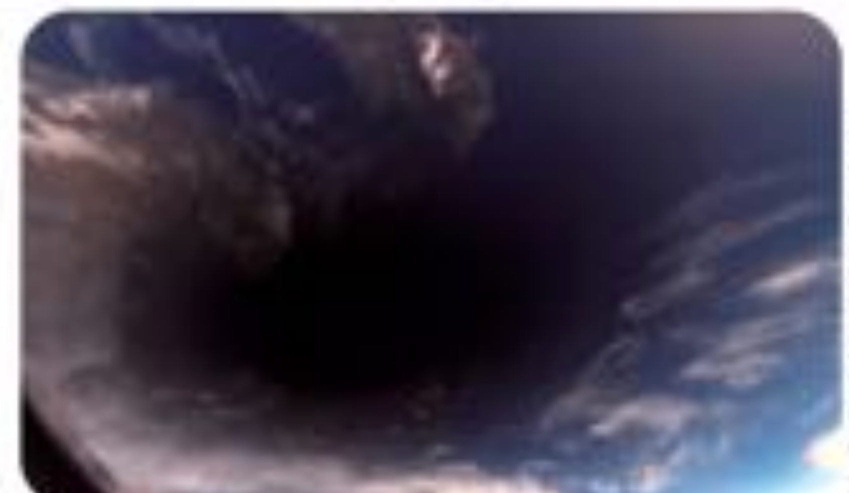
The predicted path of the August 21, 2017 solar eclipse

Duration of Greatest Eclipse:
2 min 40 sec
(18:25 UT=13:25 CDT or 1:25 p.m. CDT)

Location Greatest Eclipse:
36 deg 58 min N; 87 deg 40 min W
(between Princeton and Hopkinsville, KY)

Path Width: **approximately 115 km**

Eclipse Predictions by Fred Espenak, GSFC, NASA-emeritus



The NASA image above shows the Moon's umbral shadow as seen from the International Space Station during the total solar eclipse on 29 March 2006.

Never look directly at the Sun unless you have filters that you know are safe.

For more information: http://eclipse/gsfc.nasa.gov/SEhelp/safety.html

For more information about solar eclipses: http://eclipse.gsfc.nasa.gov/solar.html
http://eclipsewise.com/solar
http://eclipse2017.org/

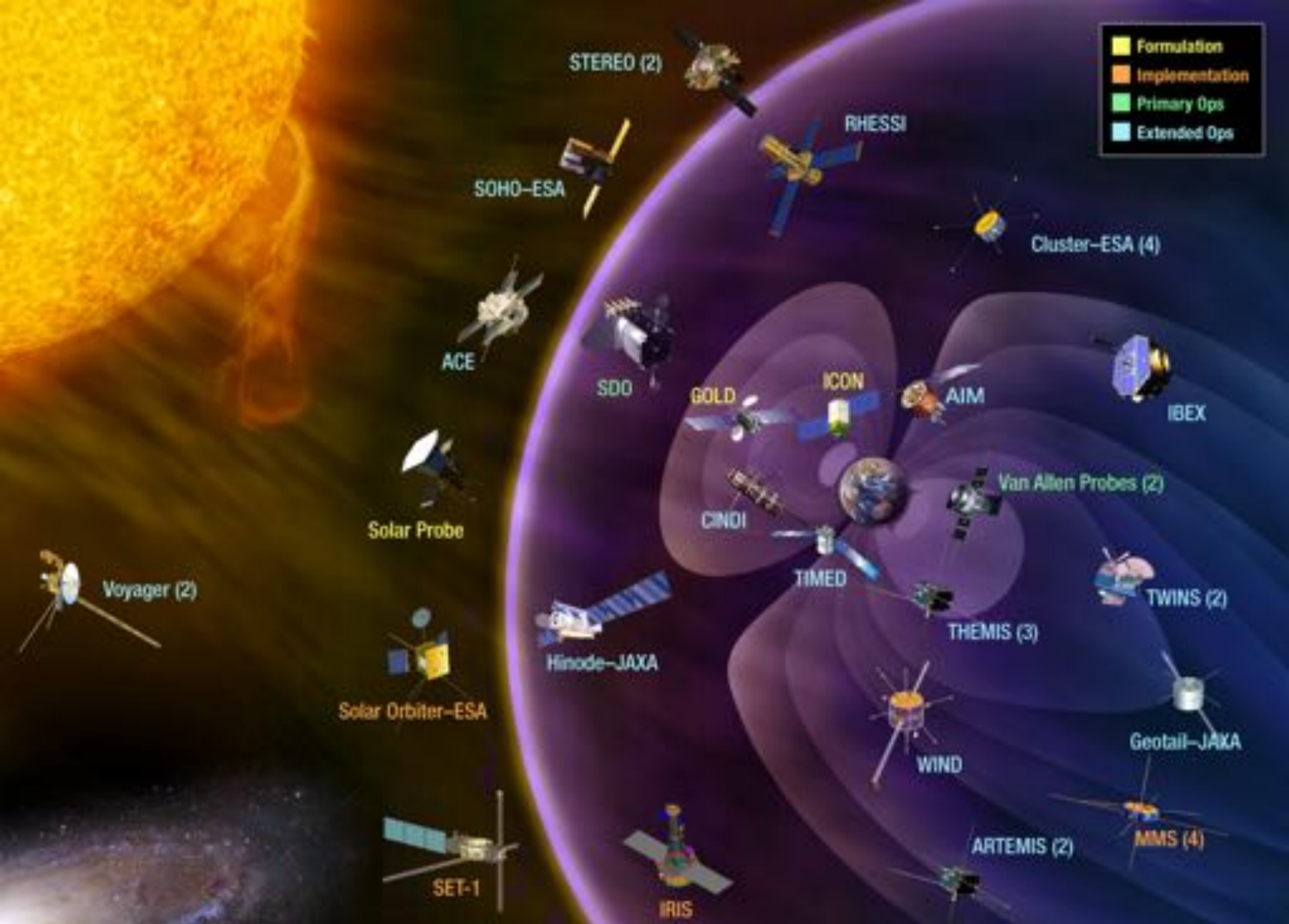
www.nasa.gov

Mitzi Adams • *mitzi.adams@nasa.gov* • **256–961–7626**

Heliophysics System Observatory (HSO)

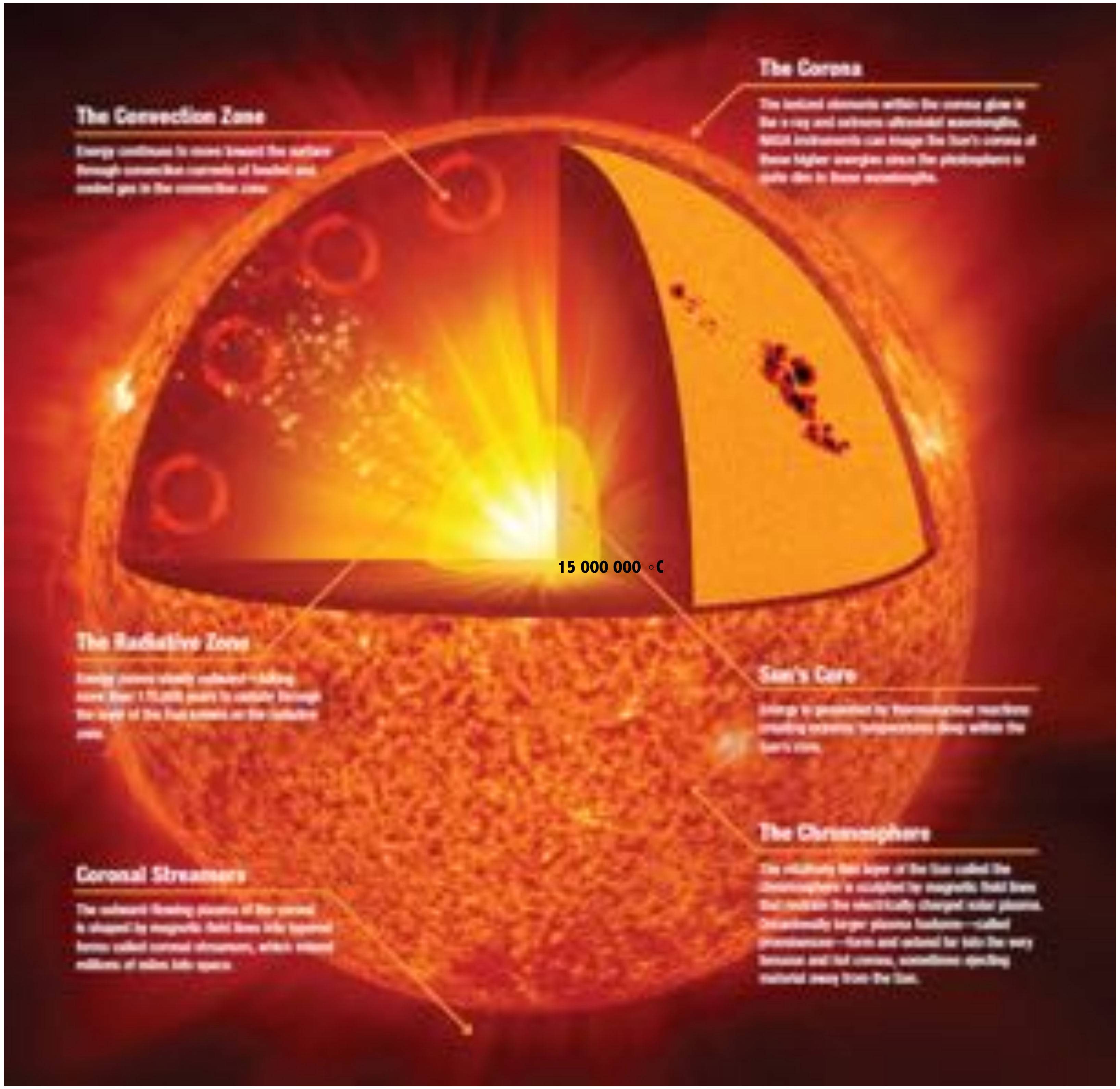
- Fleet of solar, heliospheric, geospace, and planetary satellites designed to work independently while enabling large-scale collaborative investigations.

http://www.nasa.gov/mission_pages/sunearth/missions/



Heliophysics System Observatory (HSO): http://www.nasa.gov/mission_pages/sunearth/missions/

The Sun in Layers



"Mysteries of the Sun": NASA / Jenny Mottar

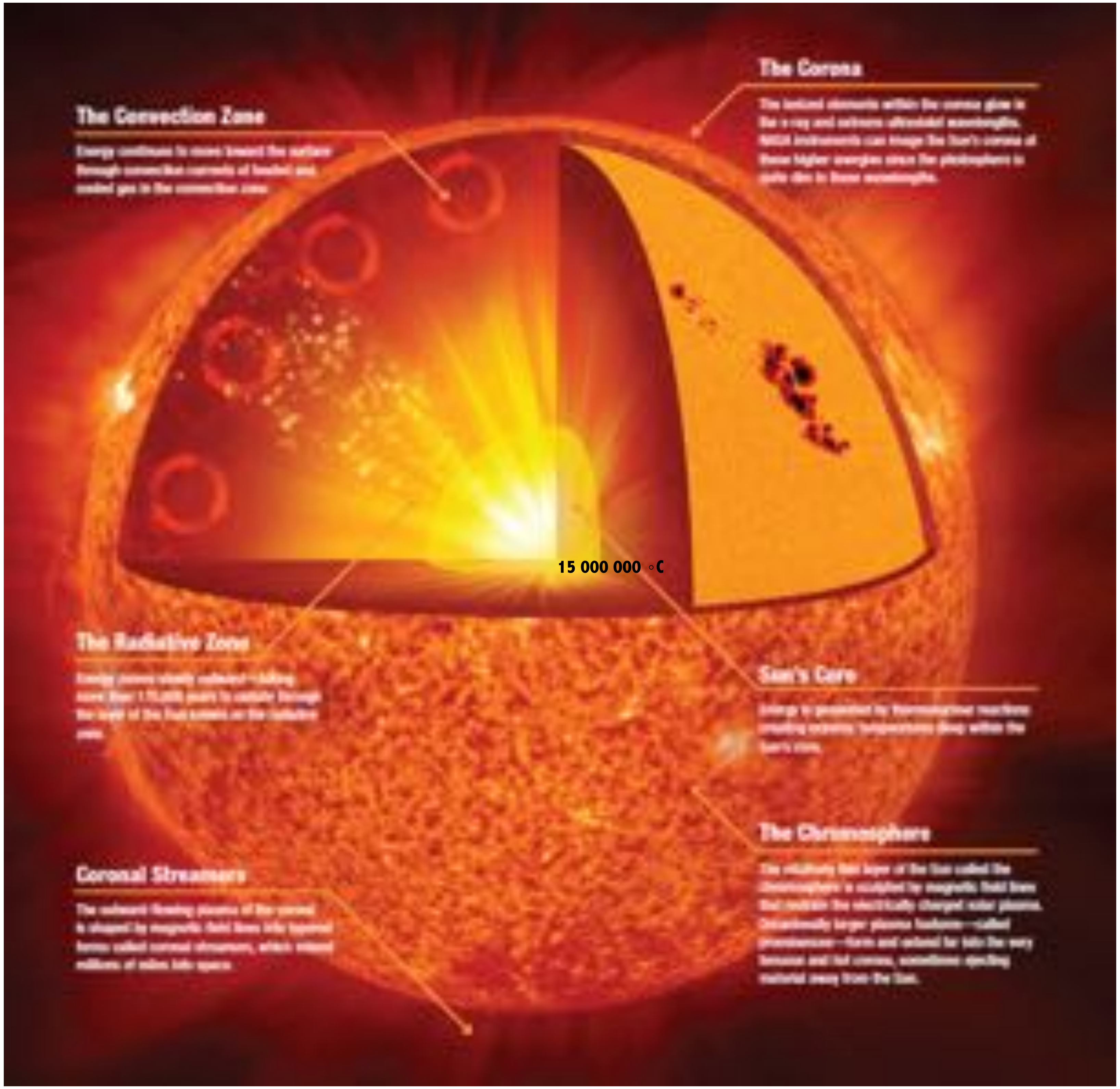
Converts 4 million tons of matter into energy every second.

Core is as dense as lead.

Interplay between magnetic pressure and gas (plasma) pressure.

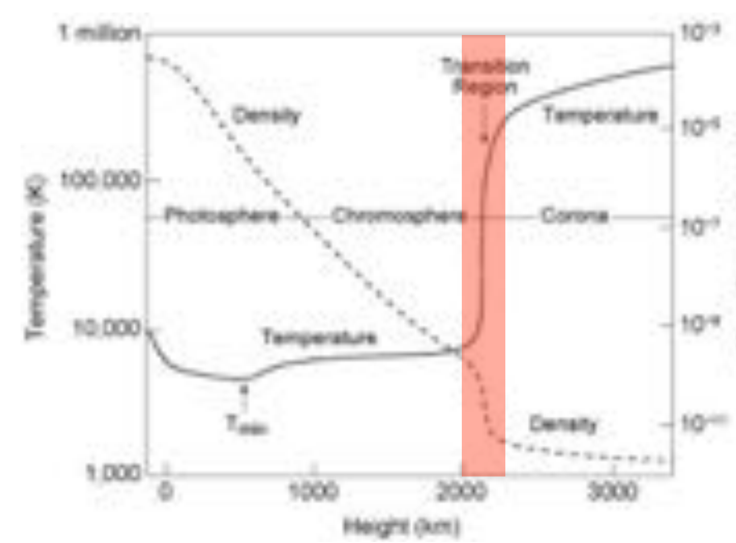
Sun Facts: http://solarscience.msfc.nasa.gov/

The Sun in Layers



"Mysteries of the Sun": NASA / Jenny Mottar

European Space Agency (ESA)

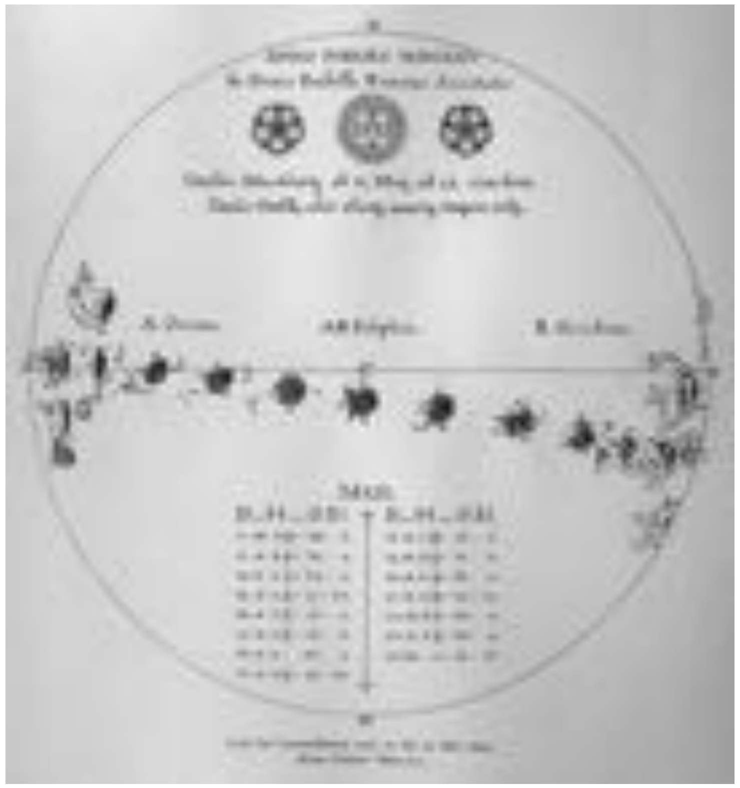


Smithsonian Astrophysical Observatory (SAO)

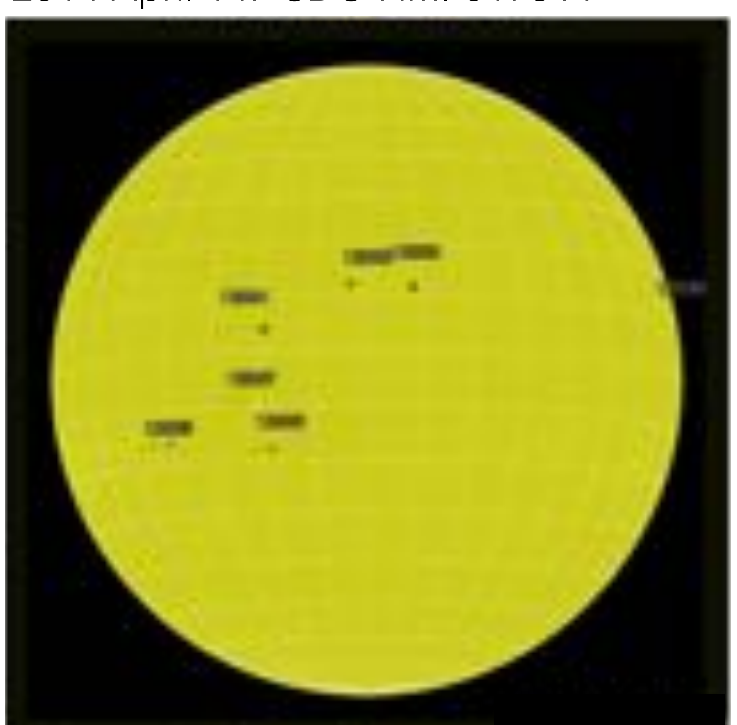
Sun Facts: http://solarscience.msfc.nasa.gov/

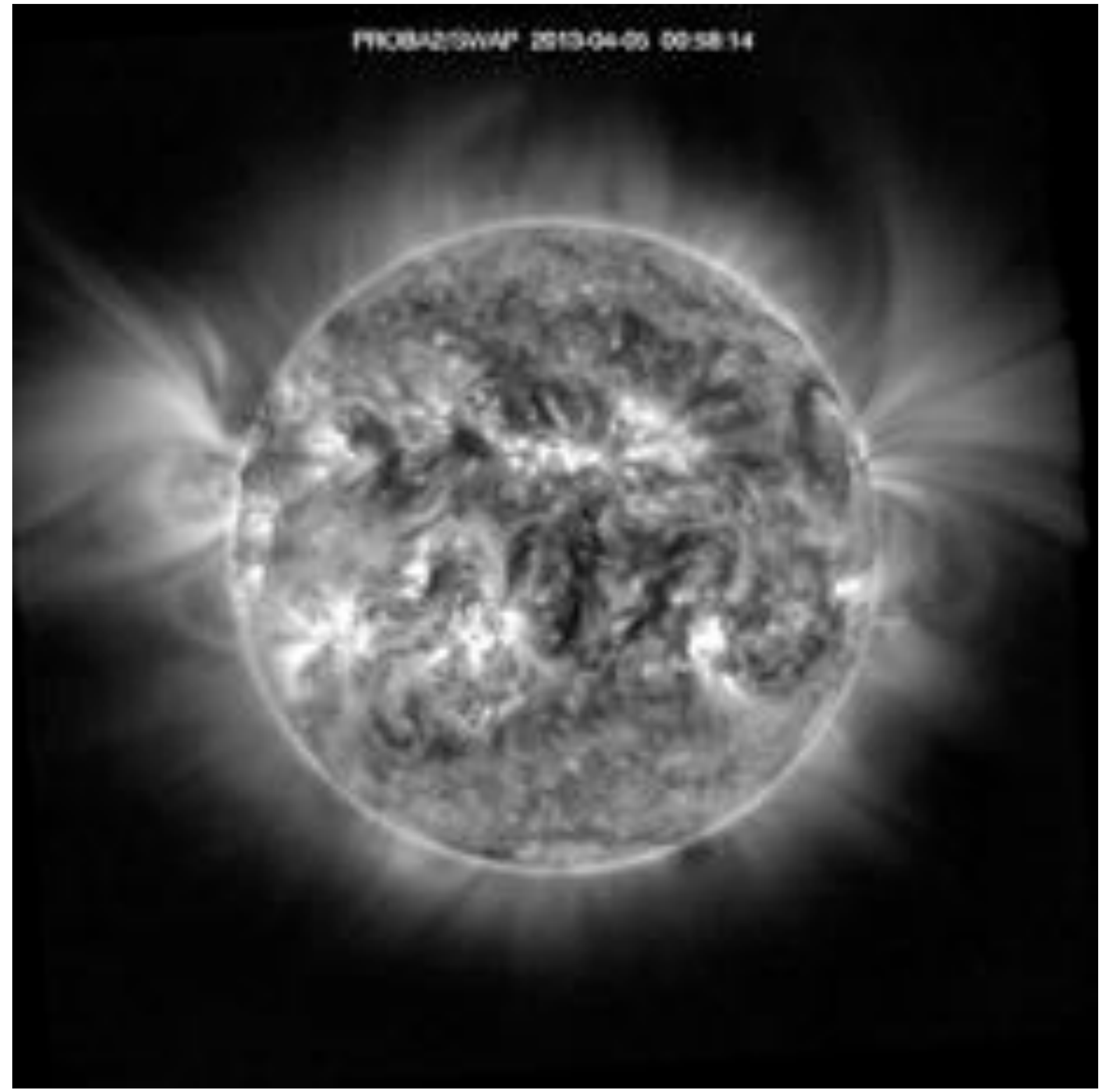
Sunspots & Active Regions

1625 May: Christoph Scheiner



2014 April 14: SDO HMI 6173 A





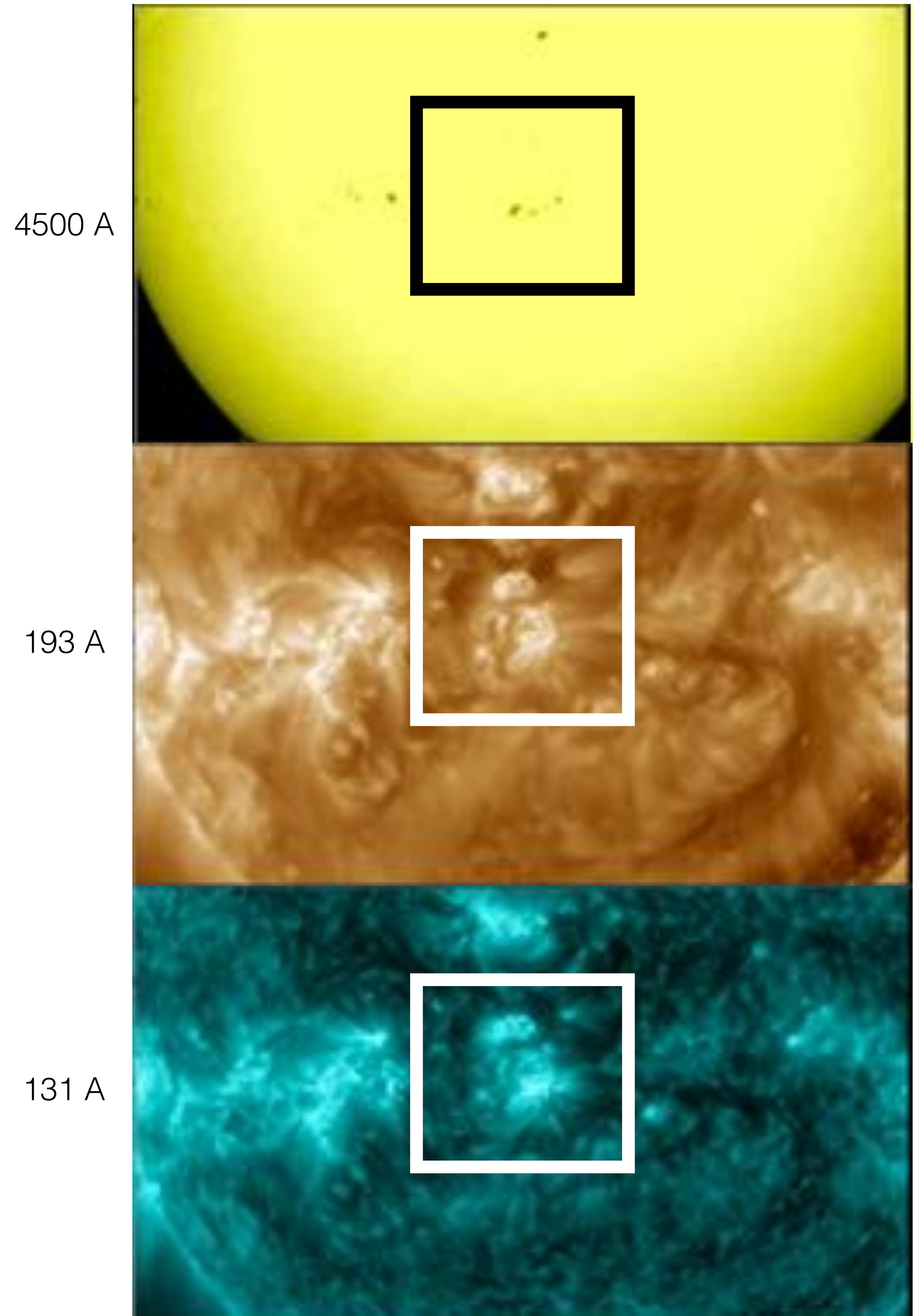
European Space Agency (ESA) / Royal Observatory Belgium (ROB)

NOAA Active Regions: SolarMonitor.org

PROBA2 Science Center (ROB): http://proba2.sidc.be/

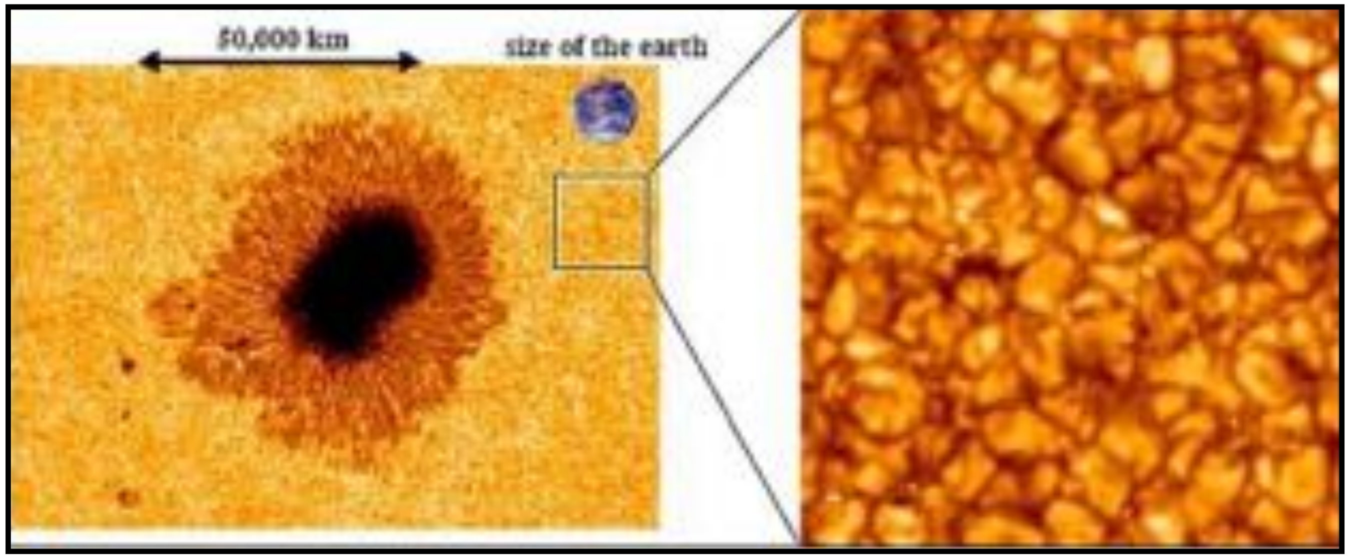
Sunspots & Active Regions

Formation

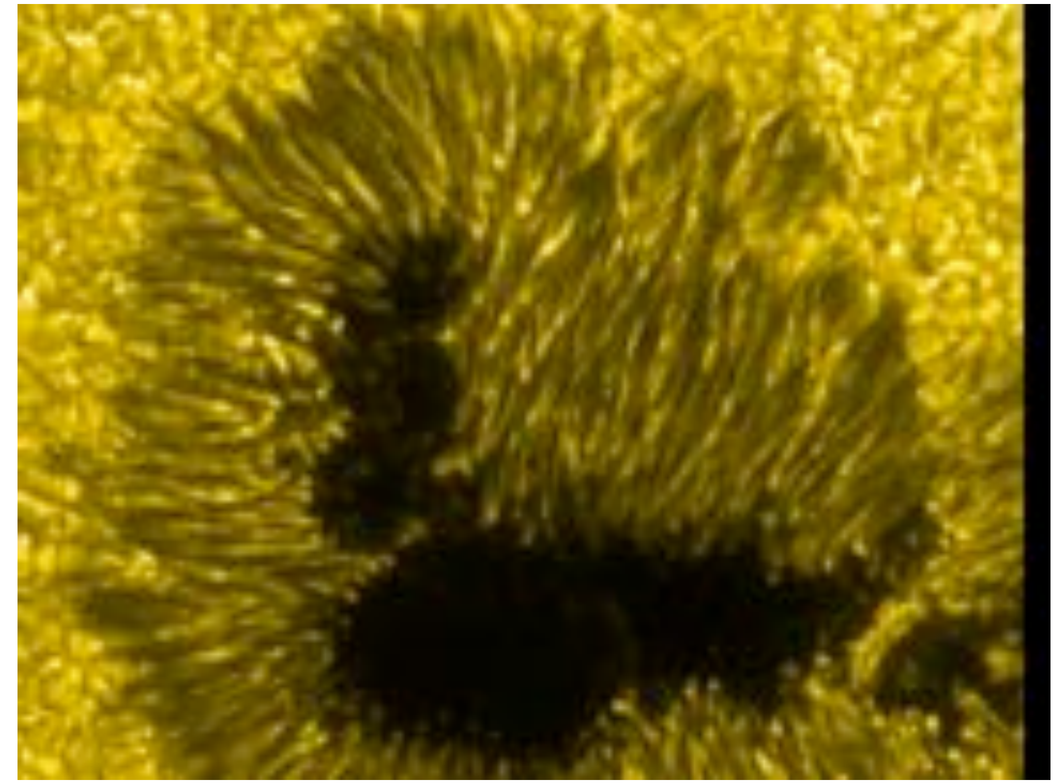


SDO / AIA
2014 Apr 13 - 15

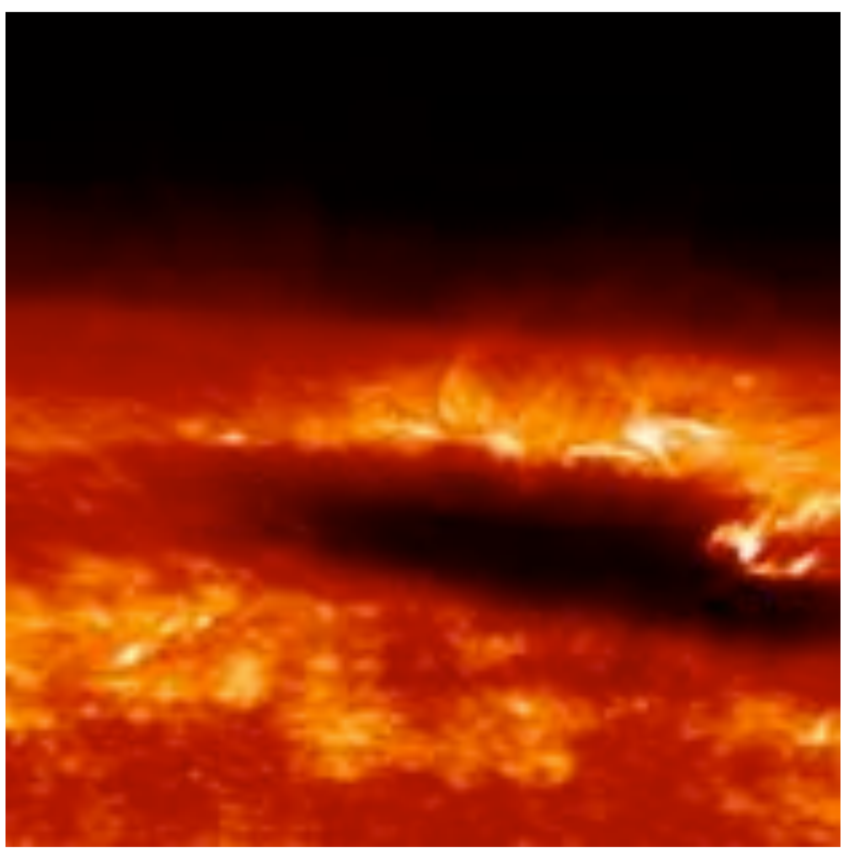
Sunspots & Active Regions



Hinode SOT: NASA / JAXA / NAOJ
Magnetic fields ~ 6000 times stronger than Earth's field.
Magnetic pressure dominates gas pressure in spot, thus inhibiting convective flow of heat.

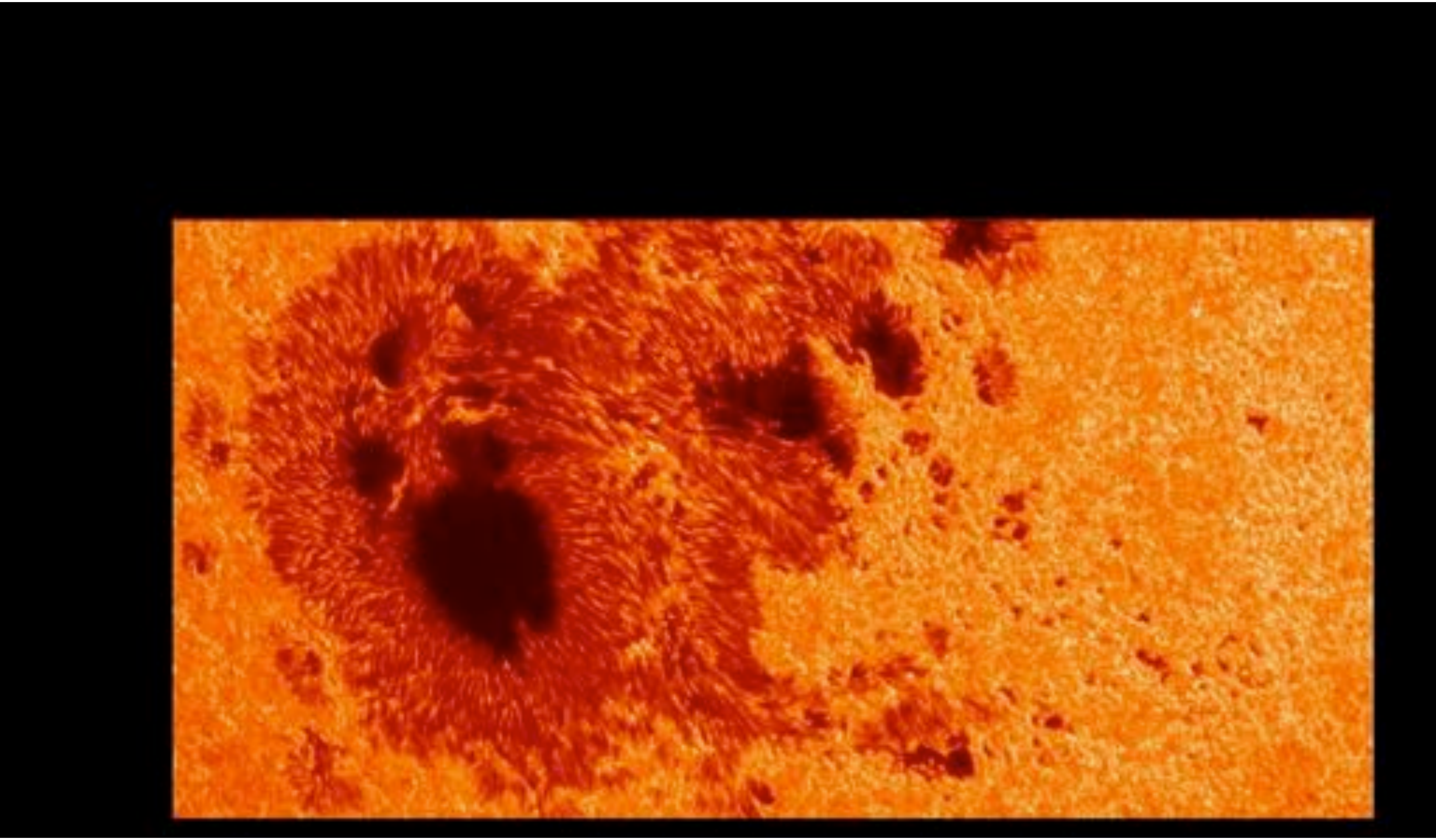


SOT (CN line 3883 A); 2007 May 2



SOT (Ca H-line); 2006 Nov 20

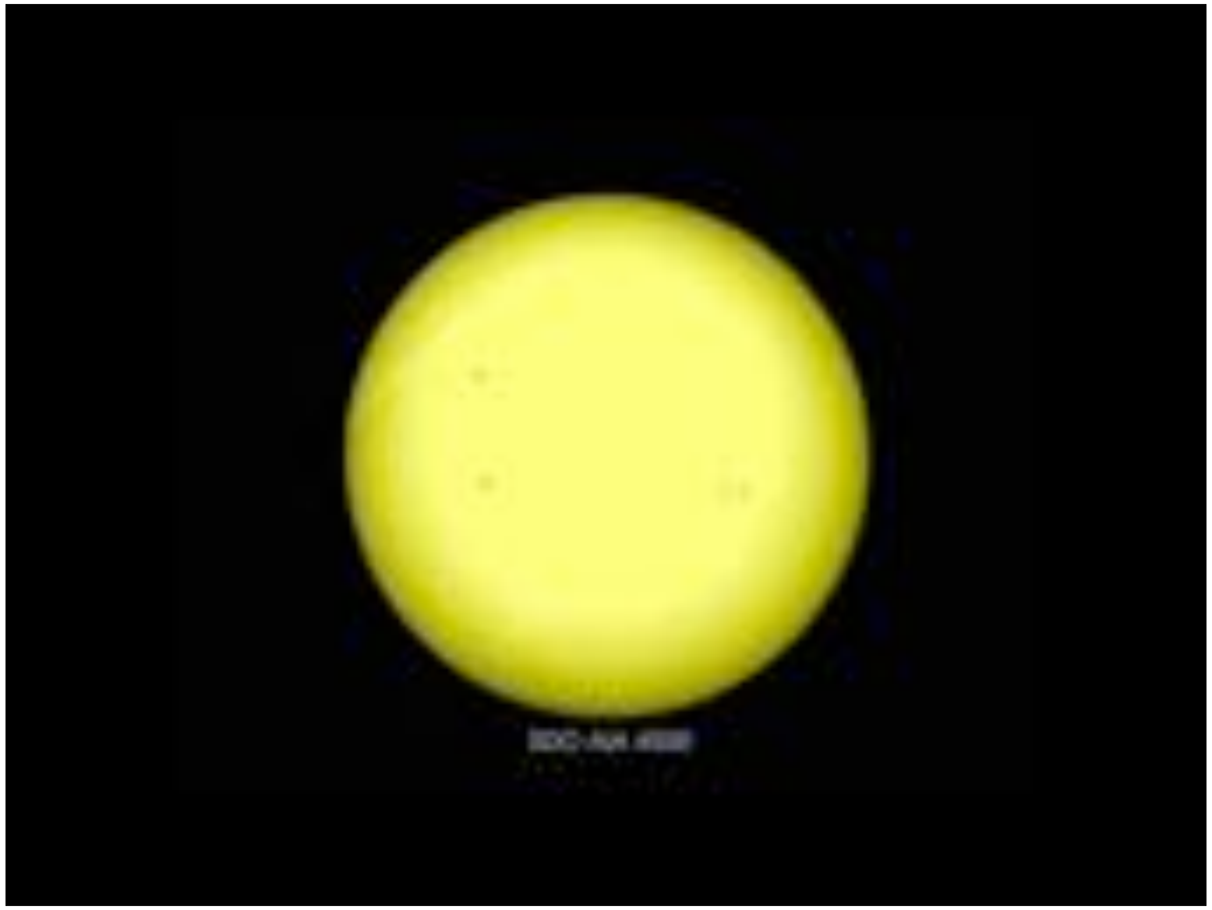
Sunspots & Active Regions



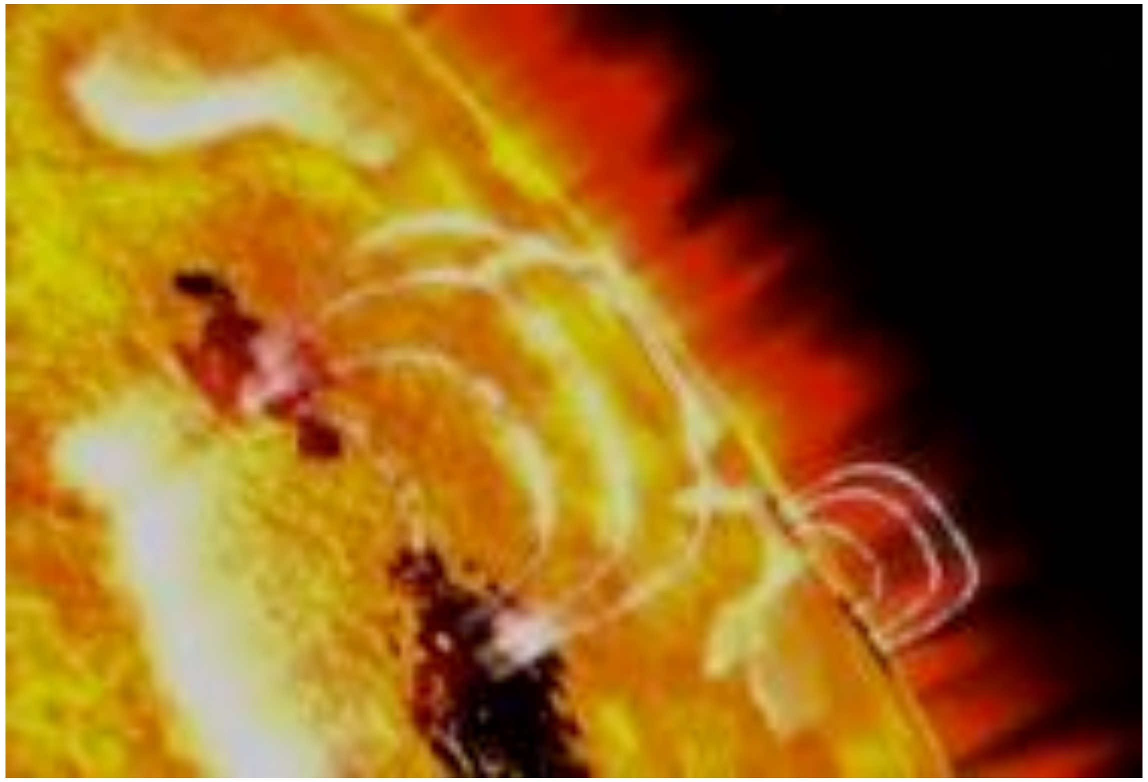
Hinode / SOT: Disk crossing of AR 12192, the largest sunspot group to appear on the Sun in 25 years.

Sunspots & Active Regions

JHelioviewer *SDO* / AIA 2014 Apr 04

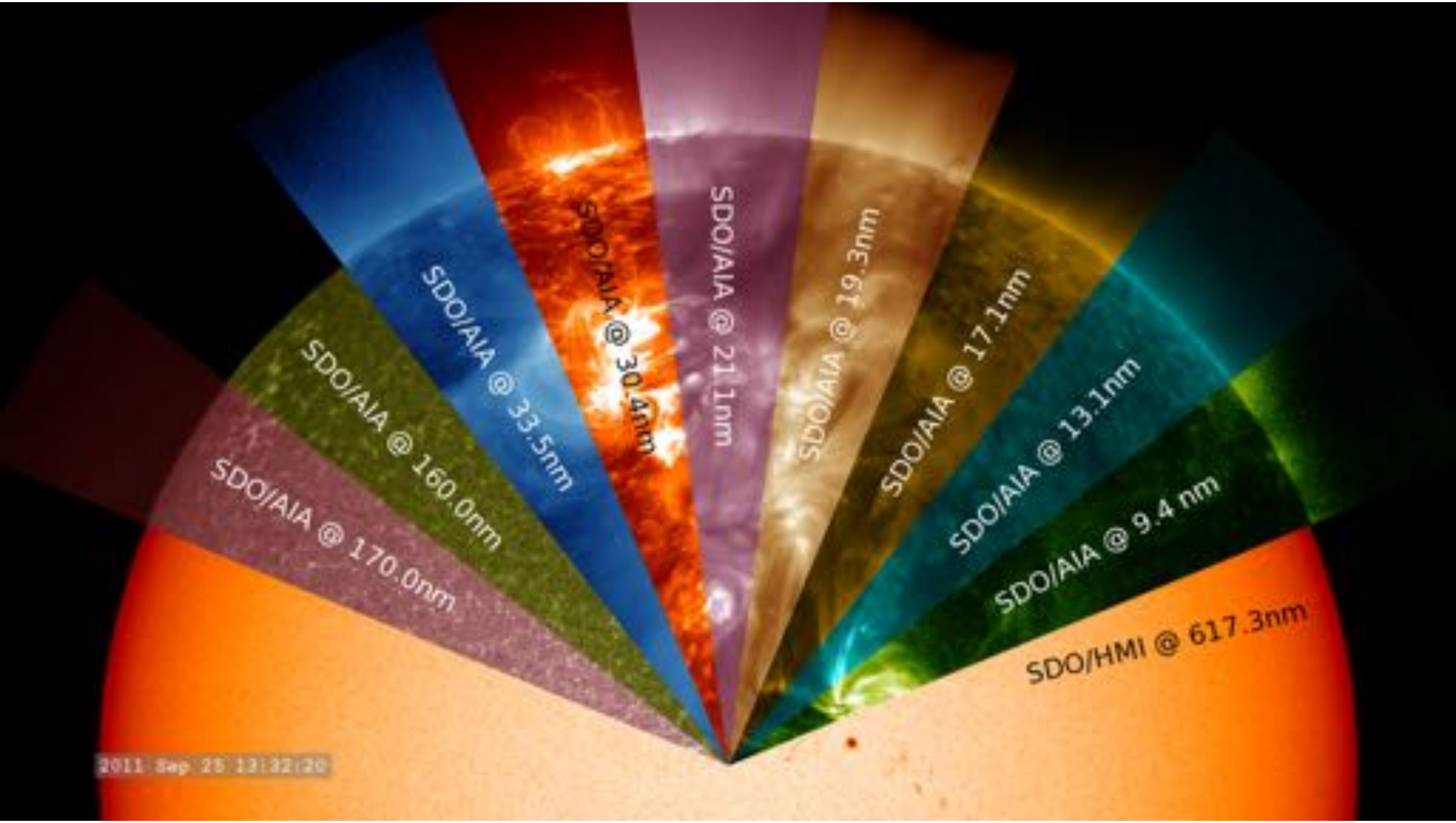


SOHO animation gallery



http://www.jhelioviewer.org/, https://sohowww.nascom.nasa.gov/bestofsoho/Movies/animations.html

Sunspots & Active Regions



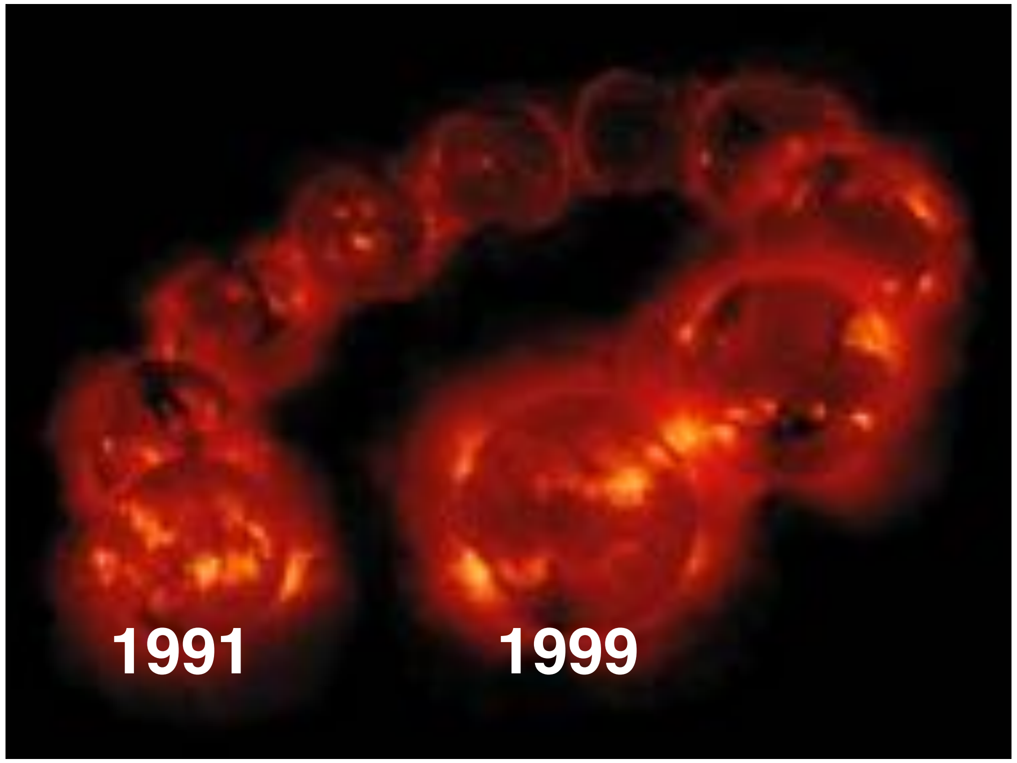
Solar Dynamics Observatory (GSFC) Jewel Box: http://svs.gsfc.nasa.gov/vis/a000000/a004100/a004117/

Sunspots & Active Regions

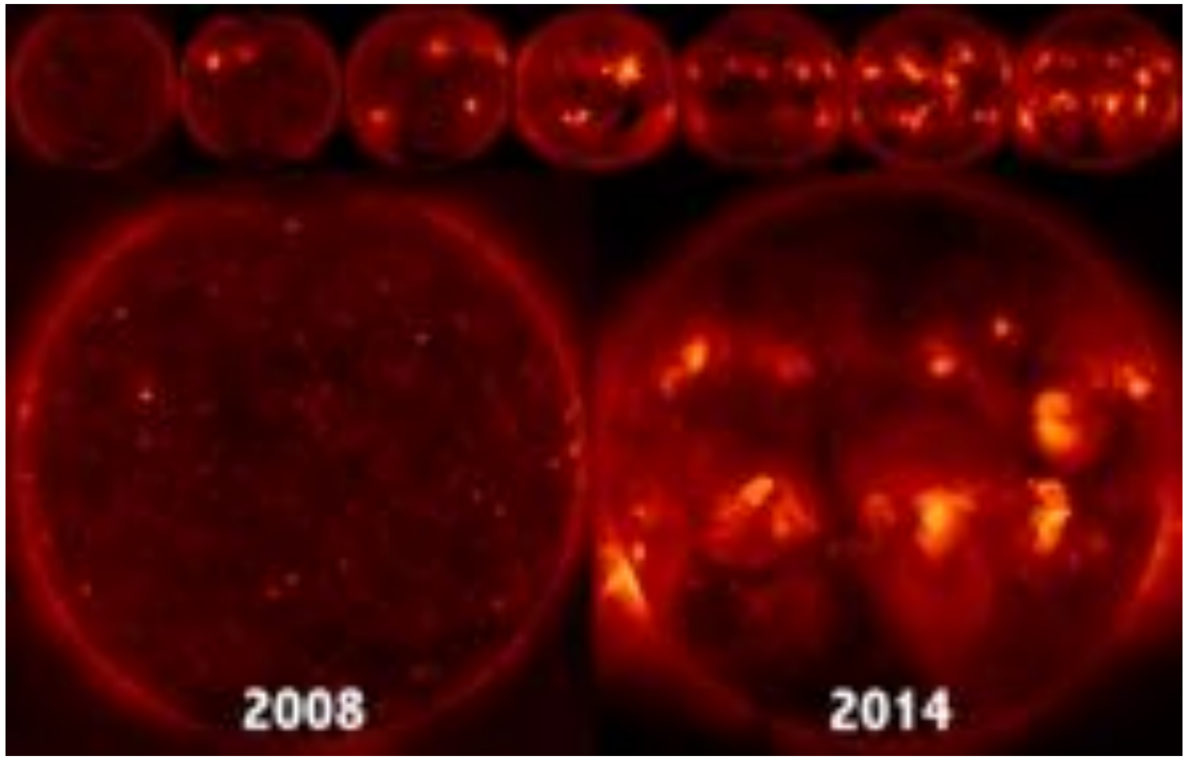
“SDO Jewel Box”

Solar features as seen with 10 different filters (i.e., plasma at different temperatures).

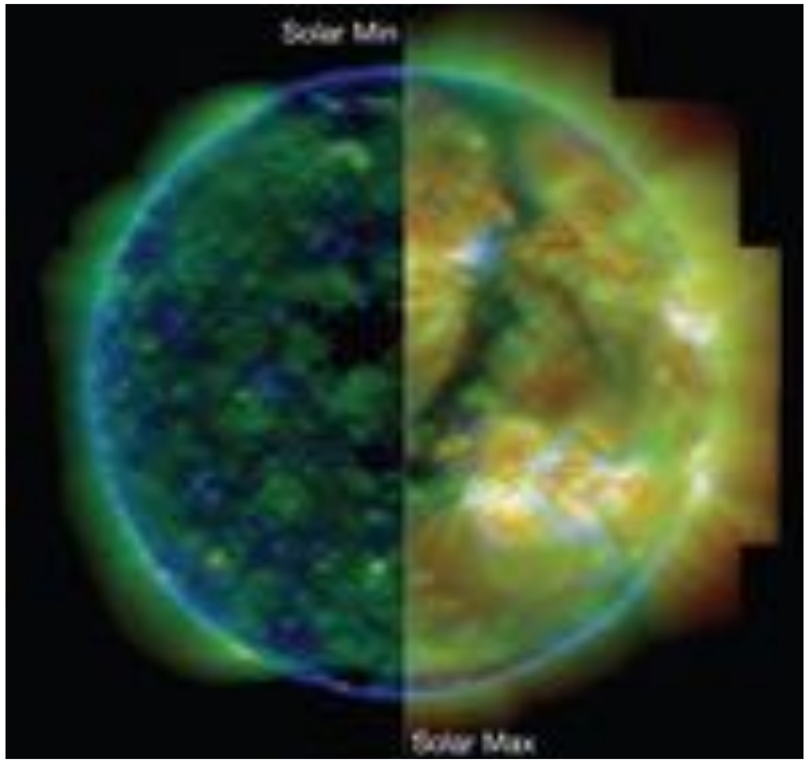
Solar Cycle (9-14 years)



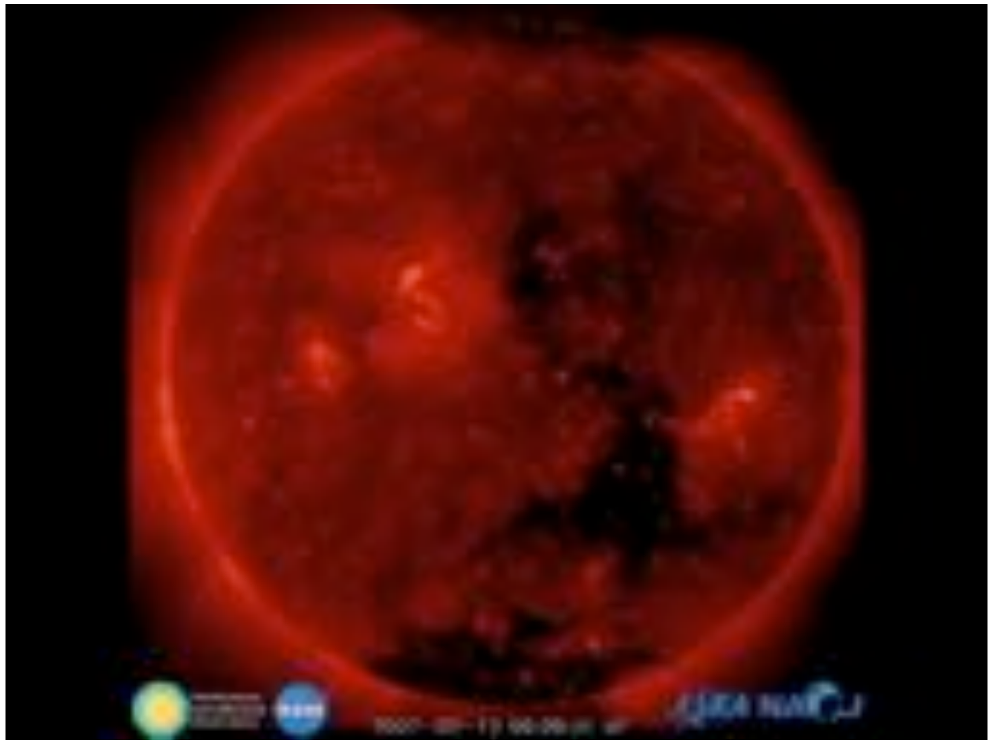
Yohkoh / SXT, ~ Full cycle



Hinode / XRT, ~ *Half cycle*



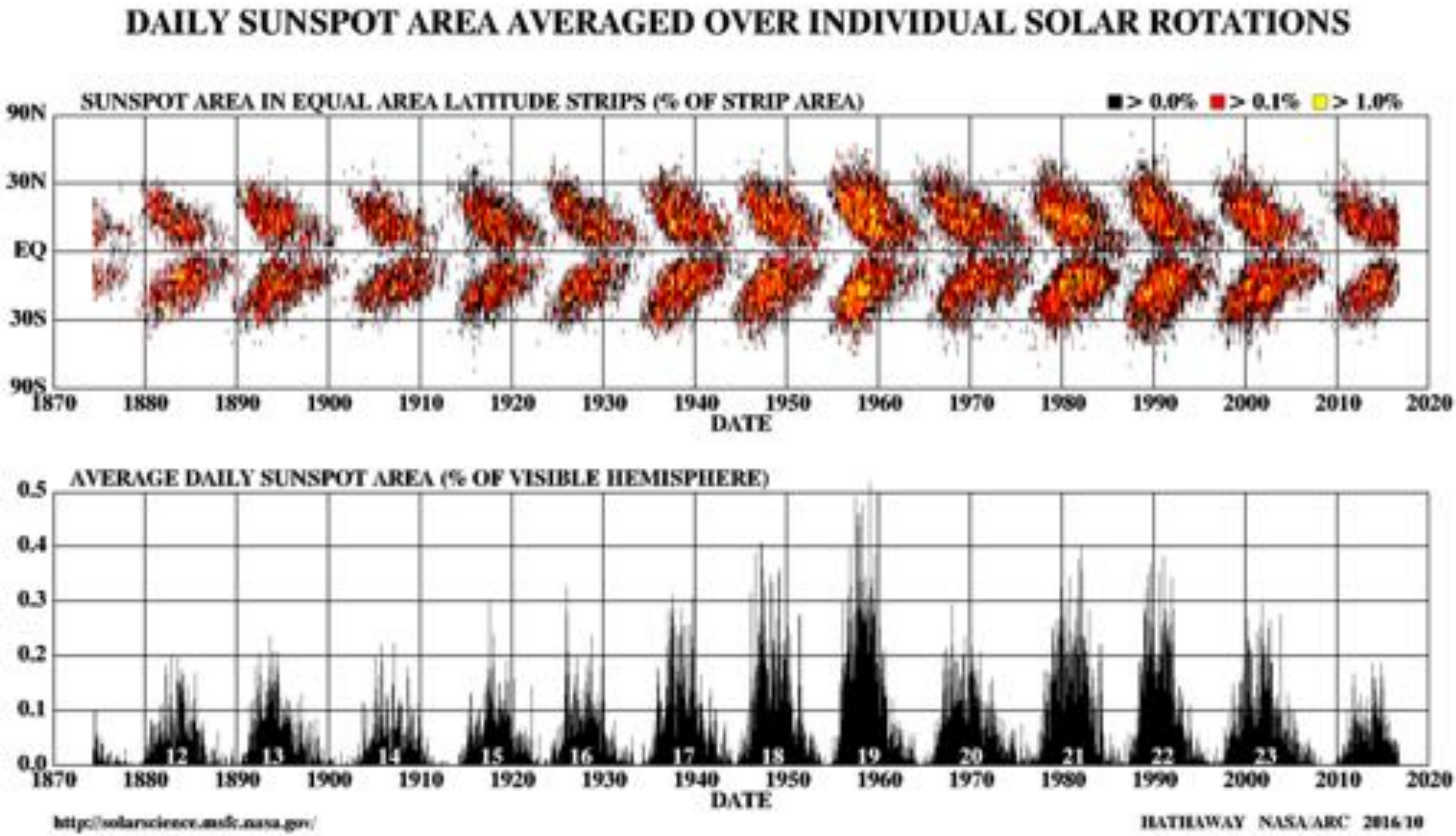
Hinode / EIS, ~ *Half cycle*



Hinode / XRT 2007 - 2012

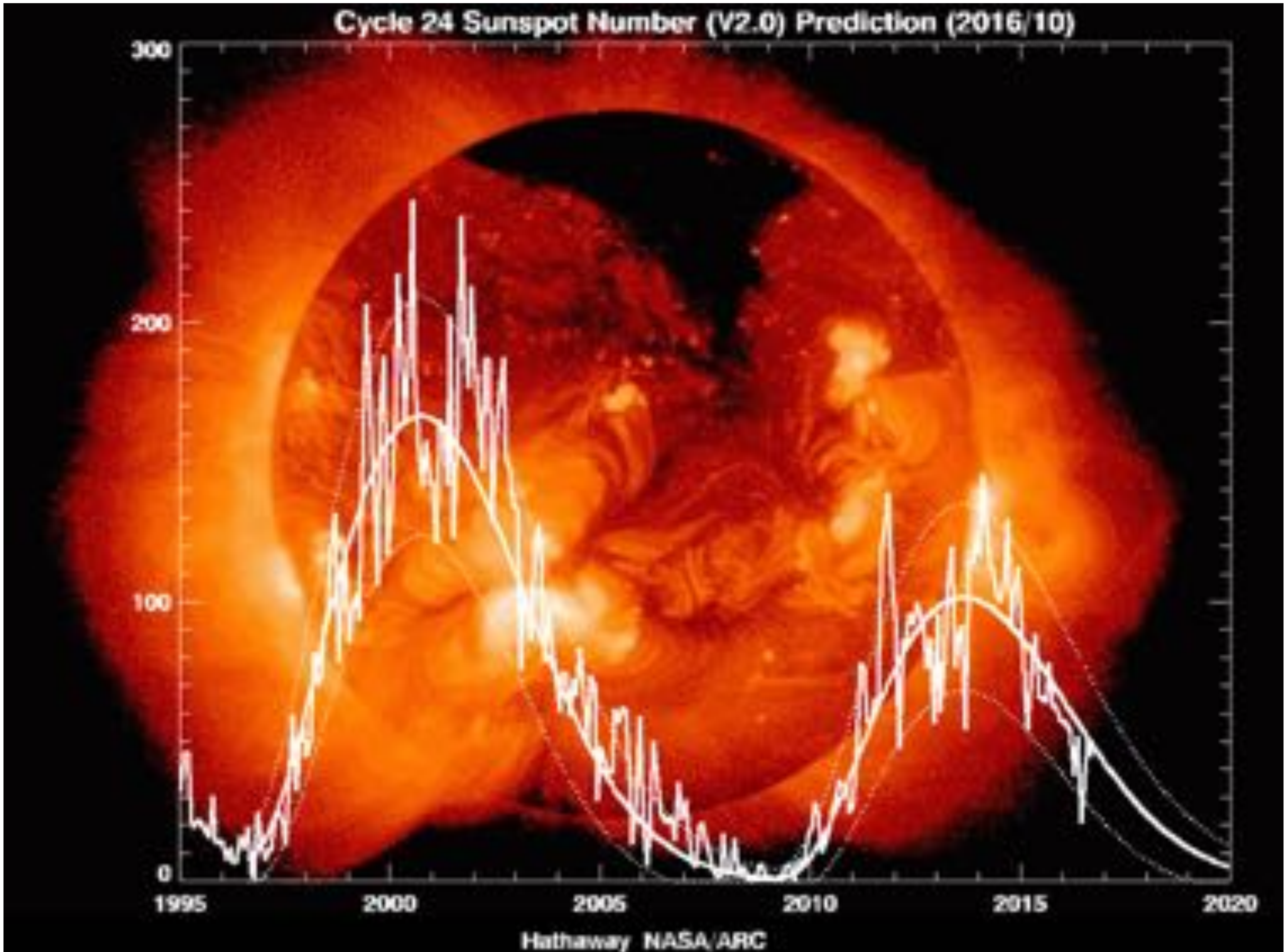
SXT: http://solar.physics.montana.edu/sxt/   XRT: http://xrt.cfa.harvard.edu/   SDO: http://sdo.gsfc.nasa.gov/

Solar Cycle



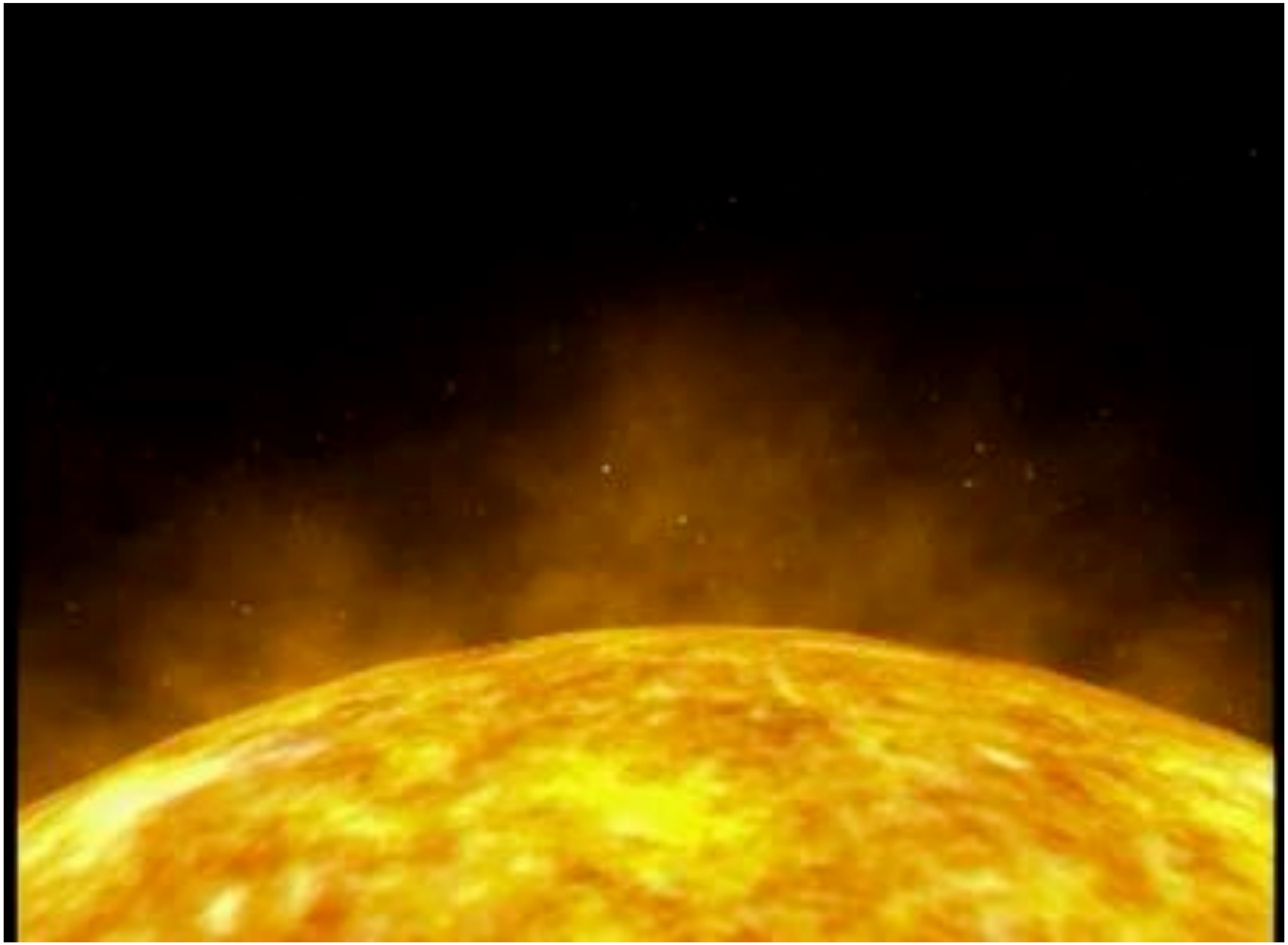
Data from the Royal Greenwich Observatory since 1874: http://solarscience.msfc.nasa.gov/SunspotCycle.shtml

Solar Cycle



#24 — Smallest cycle in ~100 years: http://solarscience.msfc.nasa.gov/SunspotCycle.shtml

Sun-Earth Interaction



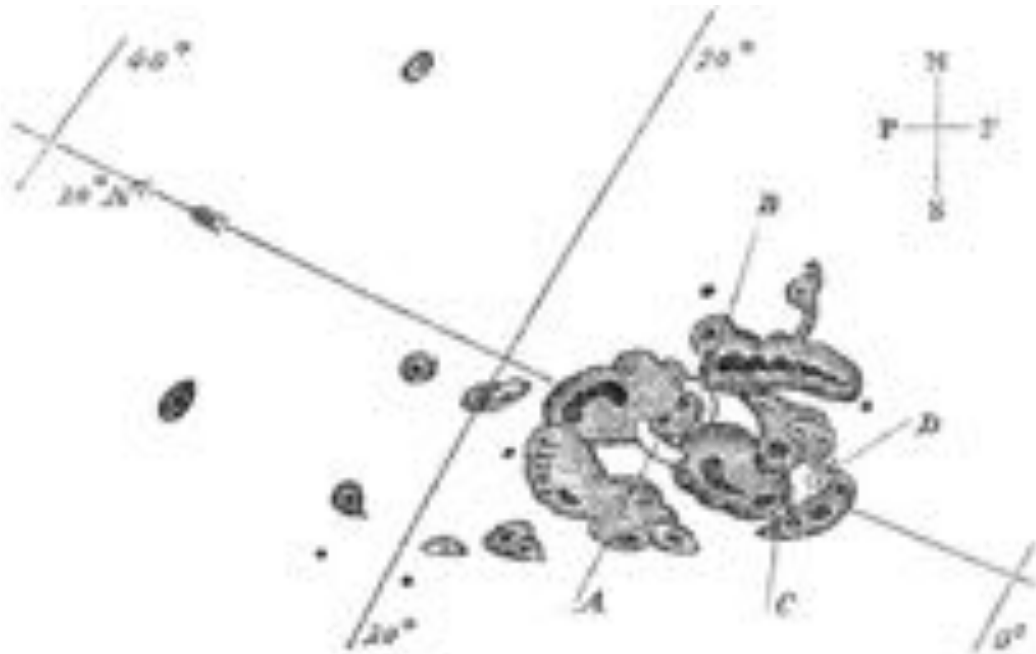
Solar storms cause the *Earth* to lose up to 100 tons of atmosphere into space.

Aurora mostly caused by ionospheric particles disrupted by currents induced from the coronal mass ejection — not the solar wind directly.

Aurora can generate up to 100 trillion watts of power.

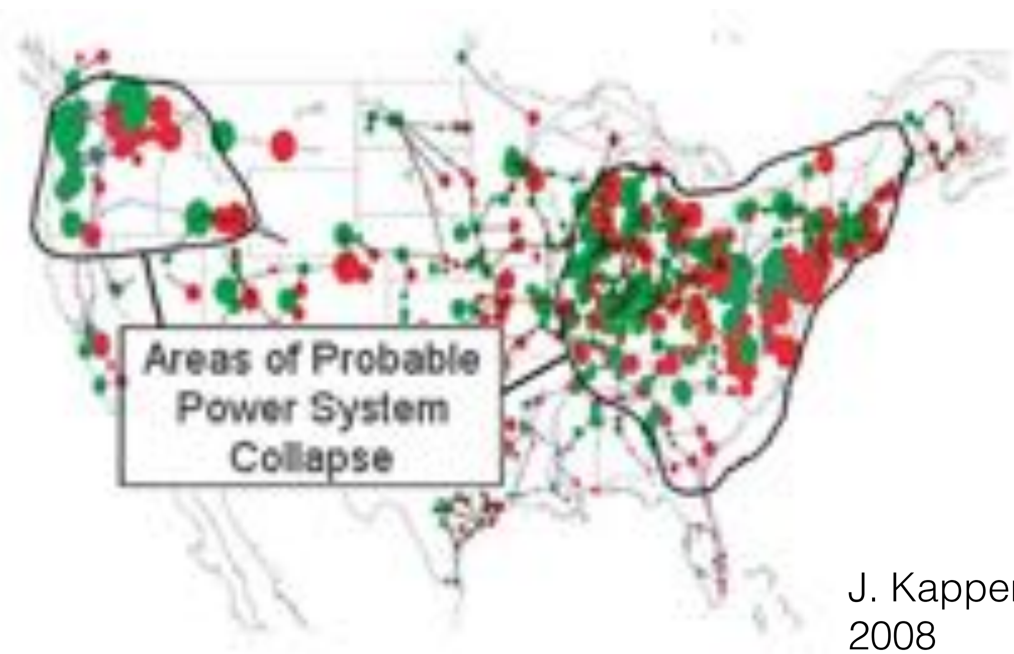
SOHO animation gallery: http://soho.nascom.nasa.gov/bestofsoho/Movies/animations.html

Impacts of Space Weather

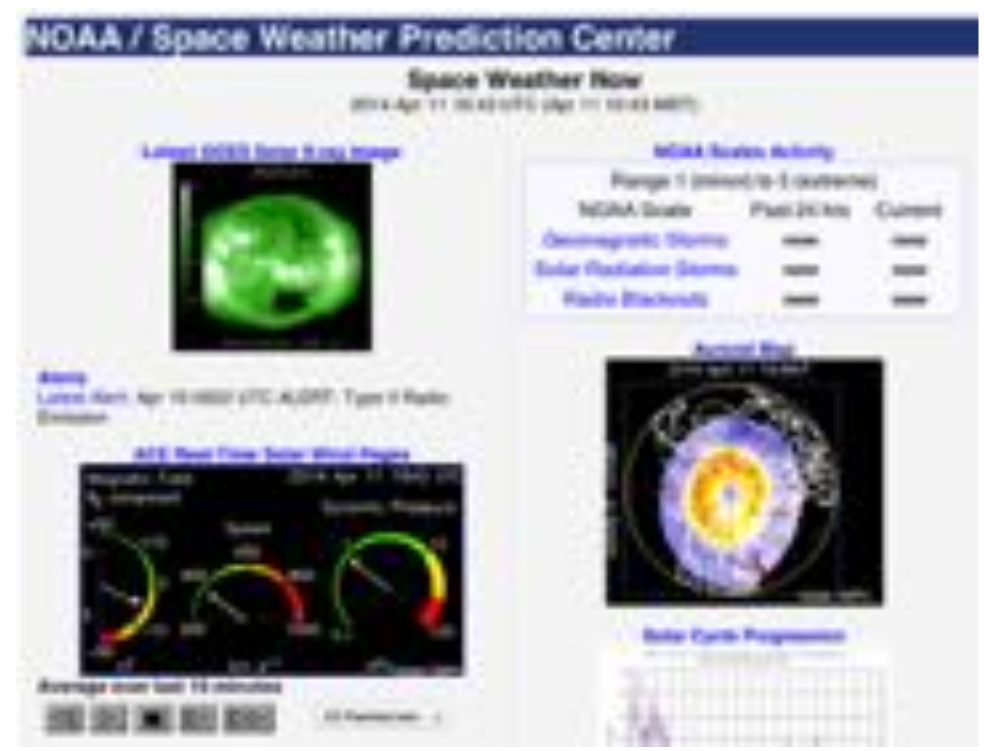


1959 Carrington Event
Largest Geomagnetic storm recorded

M. A. Shea, Geophysics Directorate, Phillips Laboratory
1989 Superstorm Blackout, $6 Billion loss to economy



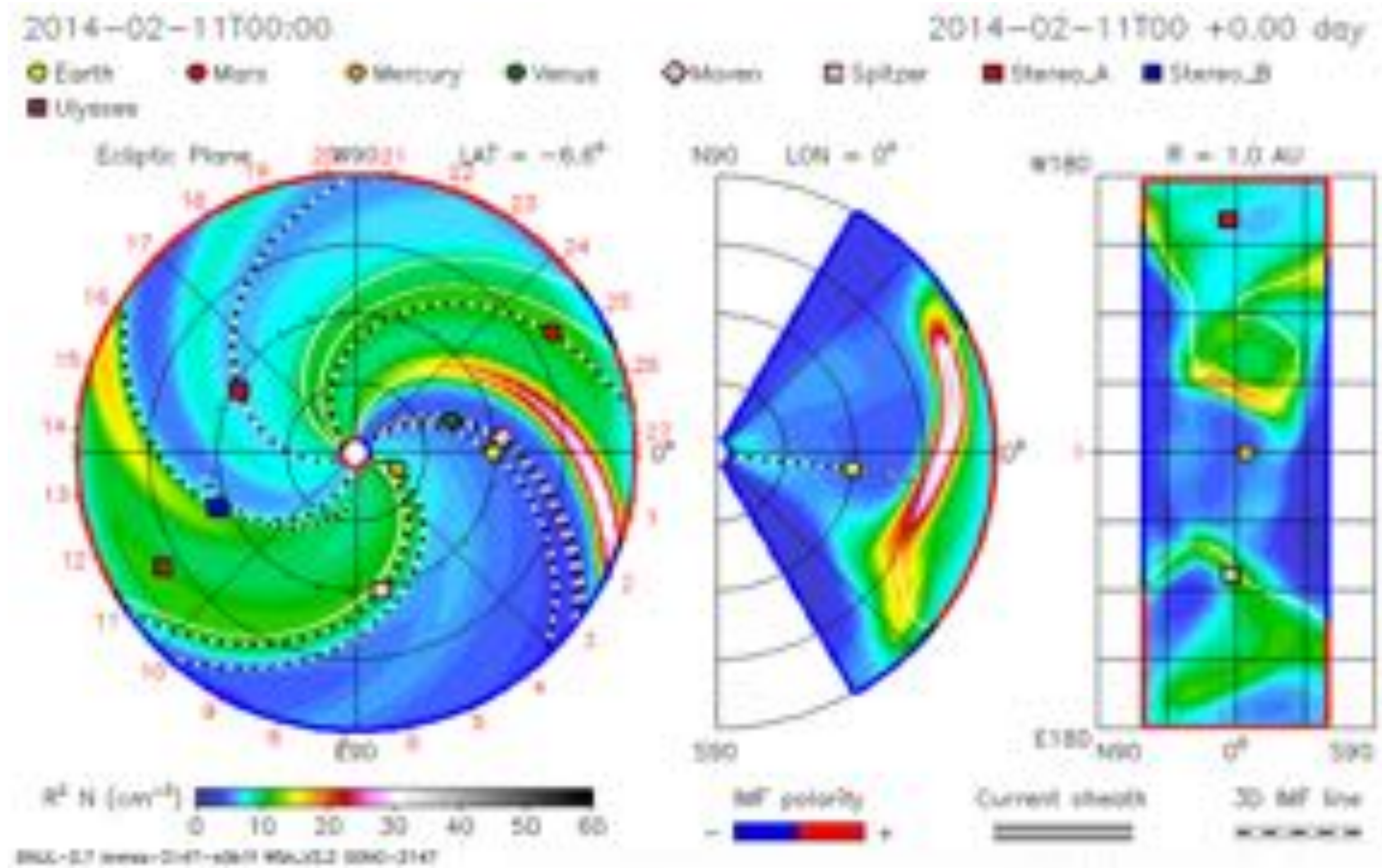
J. Kappenman
2008

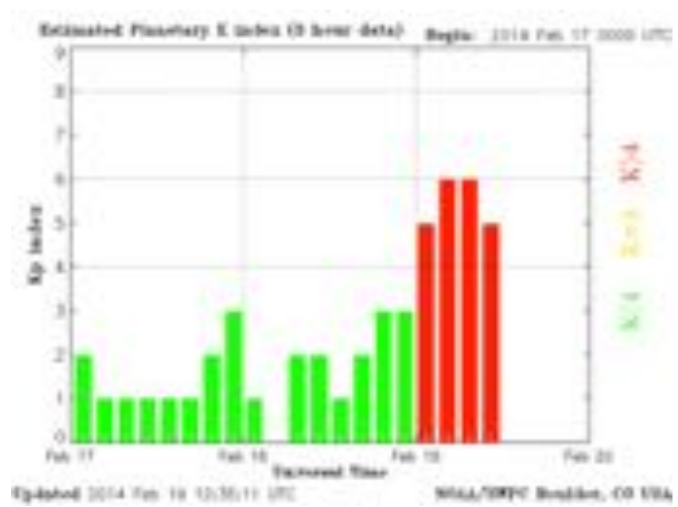


http://www.swpc.noaa.gov/SWN/

National Academy of Sciences Report Summary: http://event.arc.nasa.gov/swsw/pdf/Kappenman_AMES_Oct16.pdf

Impacts of Space Weather



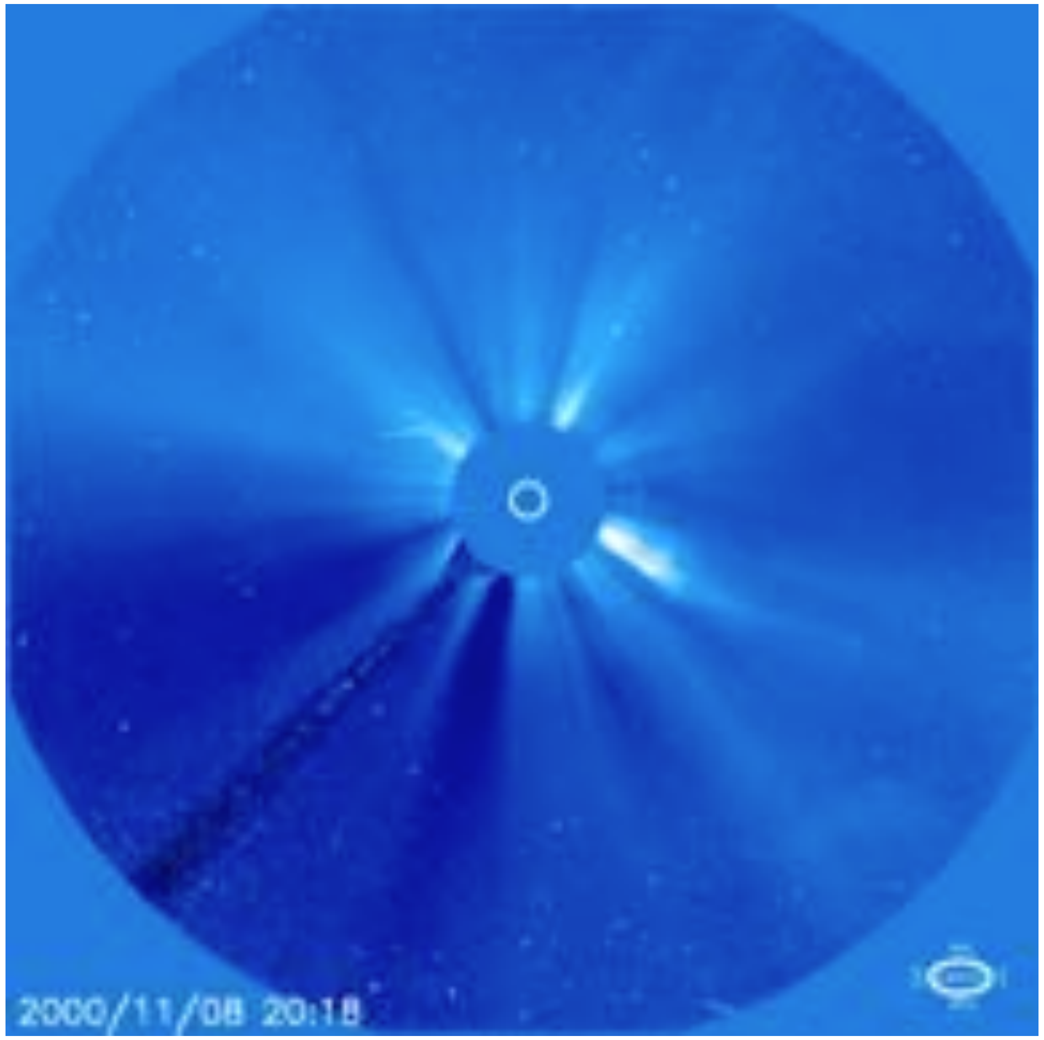


NOAA / SWPC

http://www.spaceweather.com

NASA SWRC: http://swrc.gsfc.nasa.gov/main/cmemodels , The Sun Today: http://www.thesuntoday.org/space-weather/

Impacts of Space Weather



SOHO Large Angle and Spectrometric Coronagraph Experiment (LASCO)

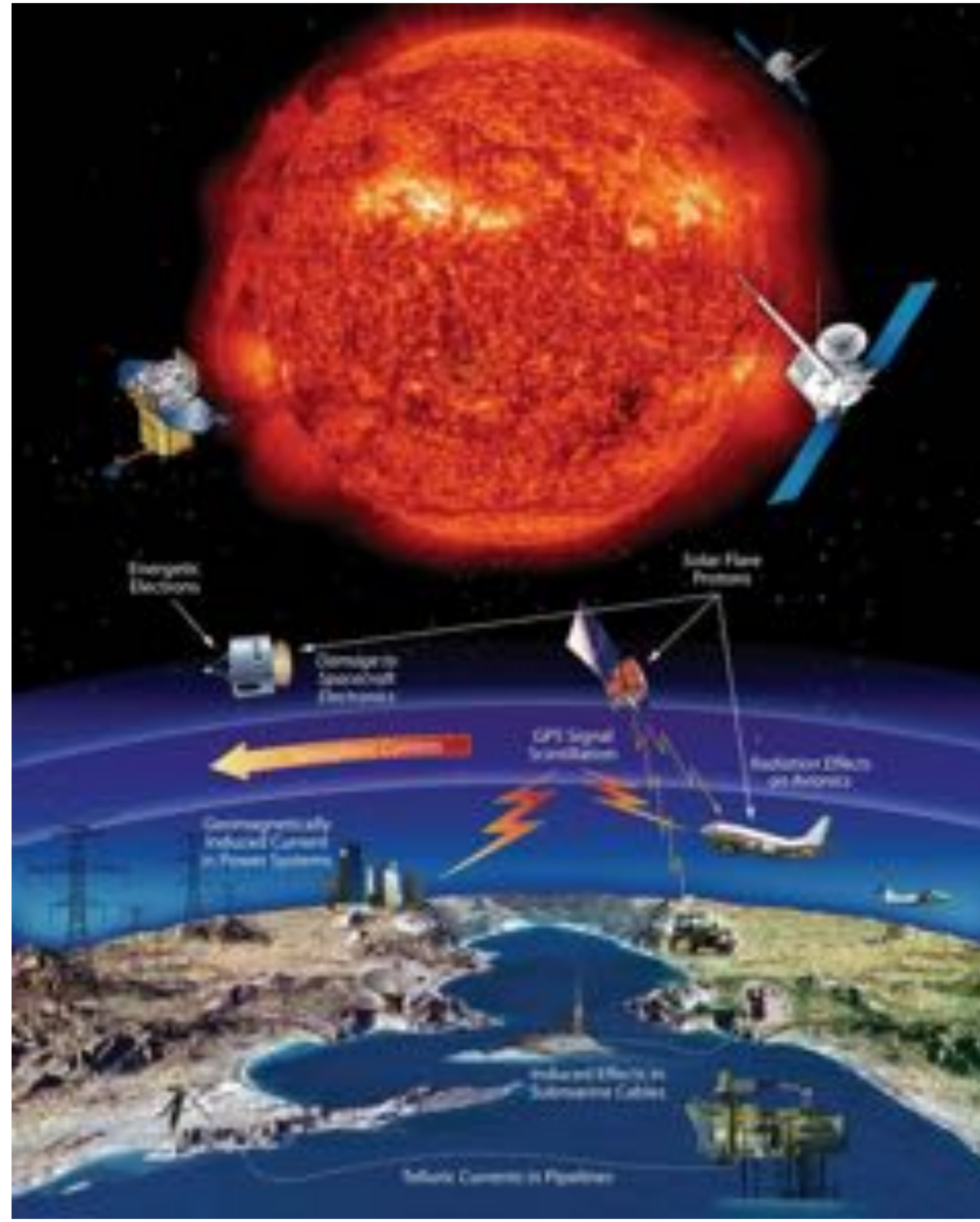
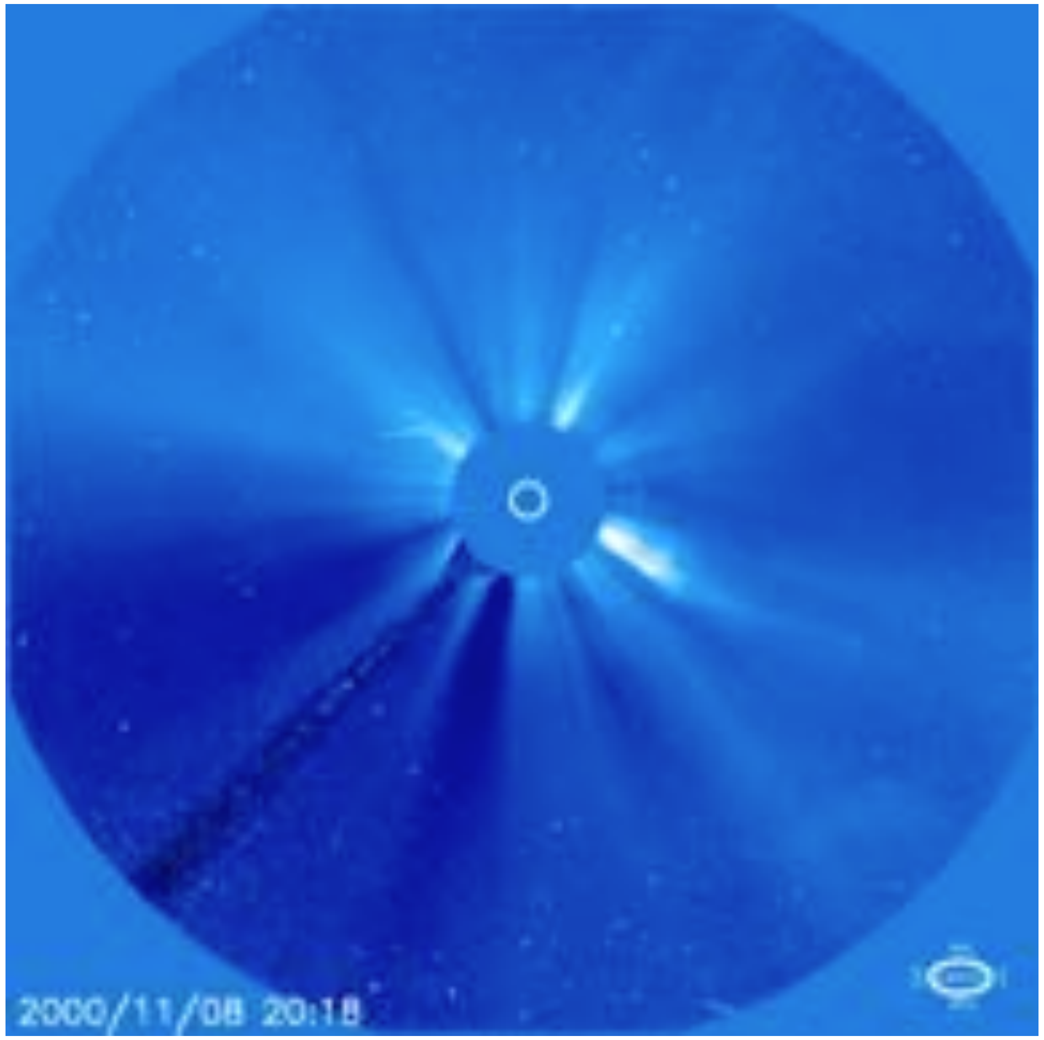


Image credit: NASA & L. Lanzerotti (NJIT)

LASCO: http://lasco-www.nrl.navy.mil/

Impacts of Space Weather



SOHO Large Angle and Spectrometric Coronagraph Experiment (LASCO)

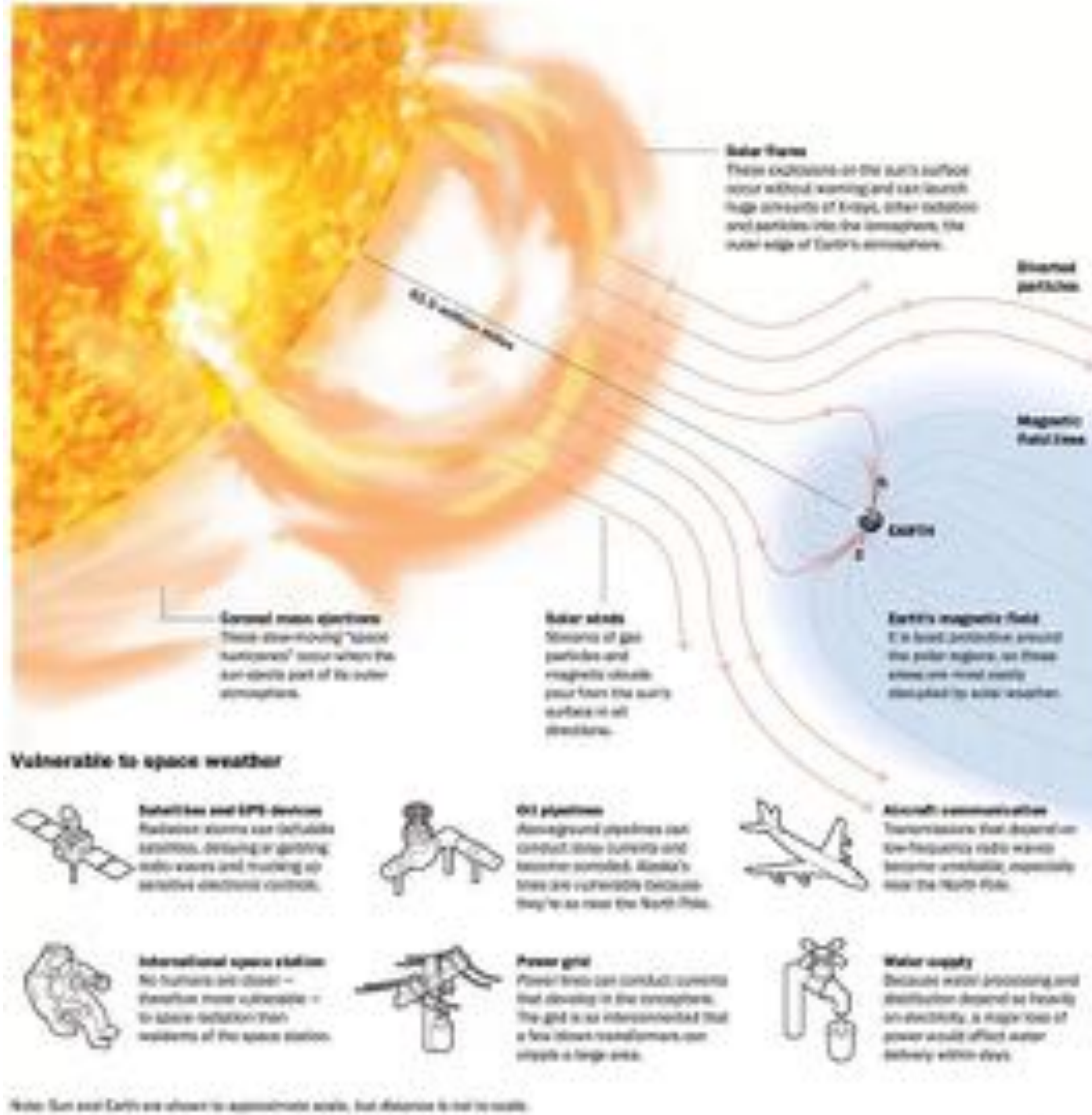
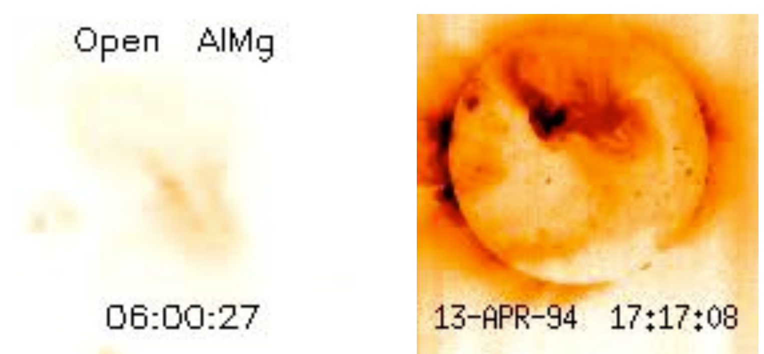


Image credit: NASA

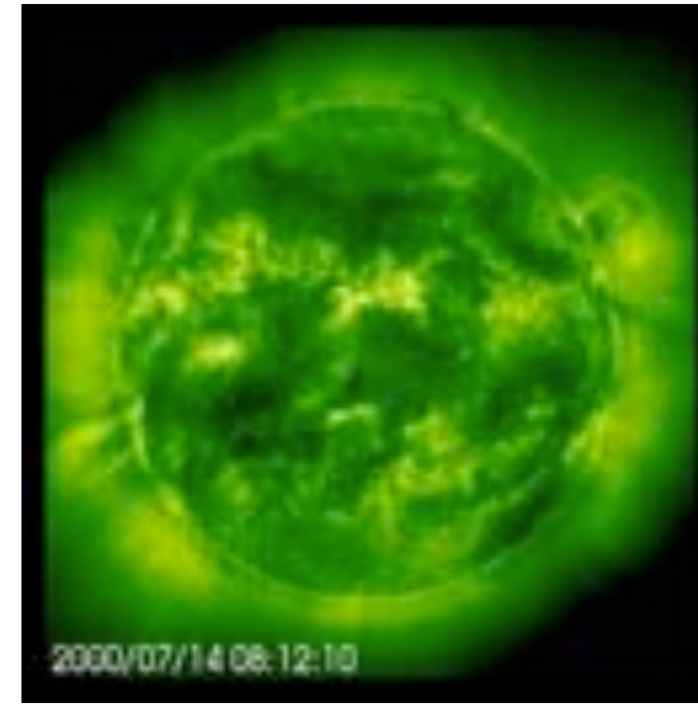
LASCO: http://lasco-www.nrl.navy.mil/

Solar Flares (A Space-Based Tour)

Skylab

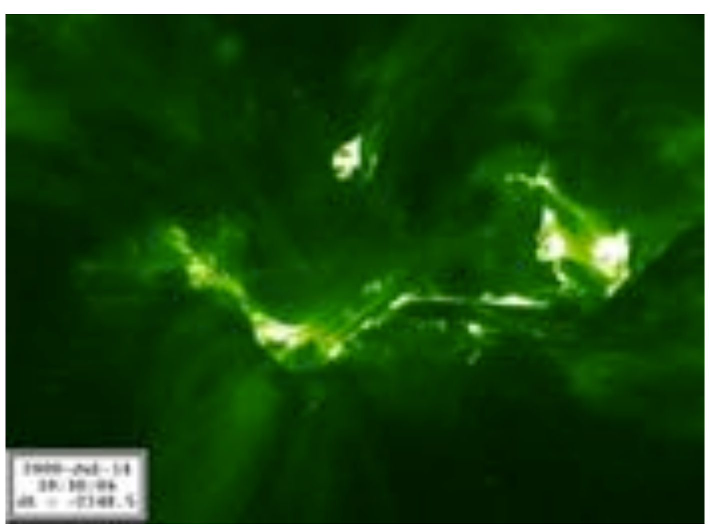


Yohkoh / SXT

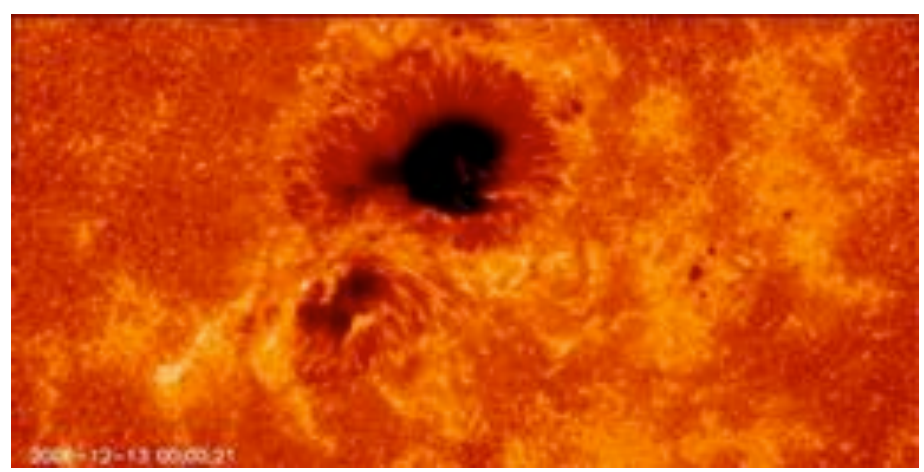


SOHO / EIT+LASCO

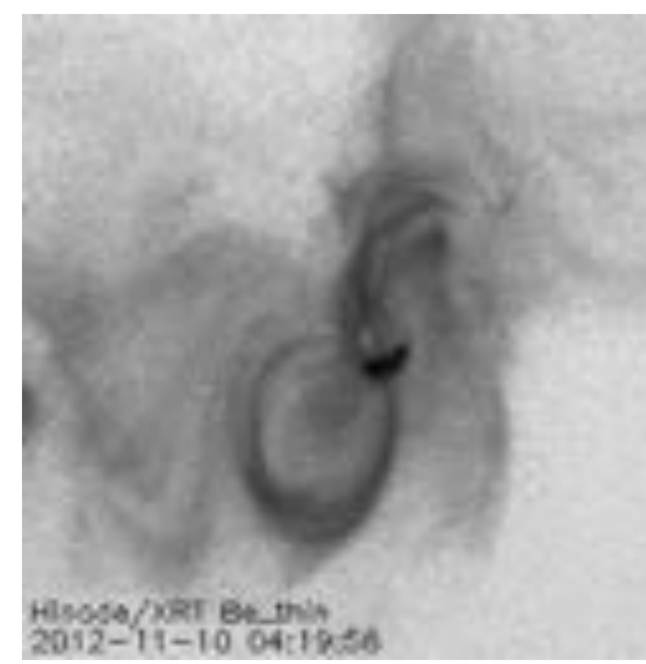
TRACE



HINODE / SOT

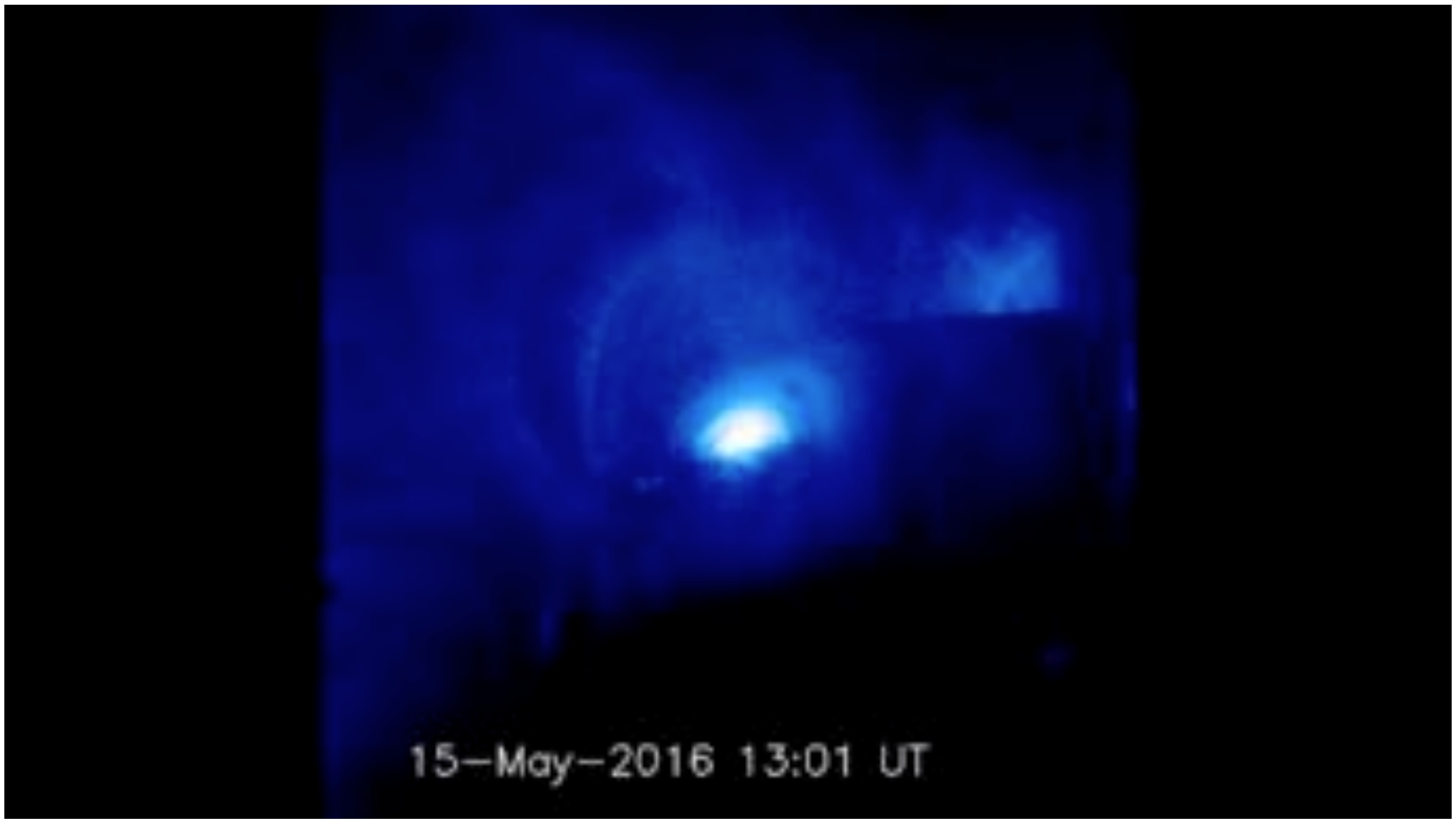


HINODE / XRT



Skylab SP-402 The Active Sun: http://history.nasa.gov/SP-402/ch7.htm

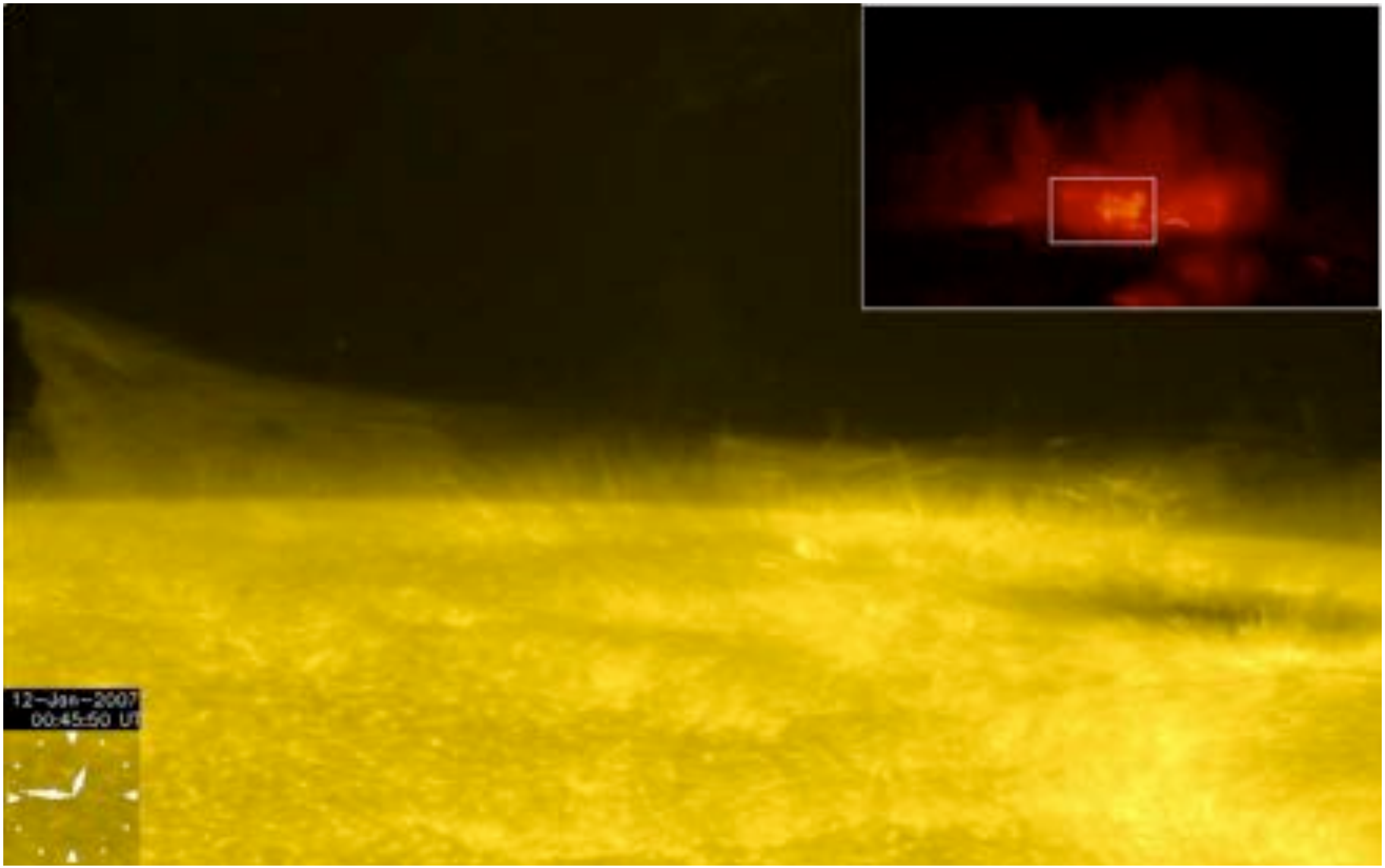
Solar Flares (A Space-Based Tour)



Hinode / XRT

Hinode / XRT: http://xrt.cfa.harvard.edu

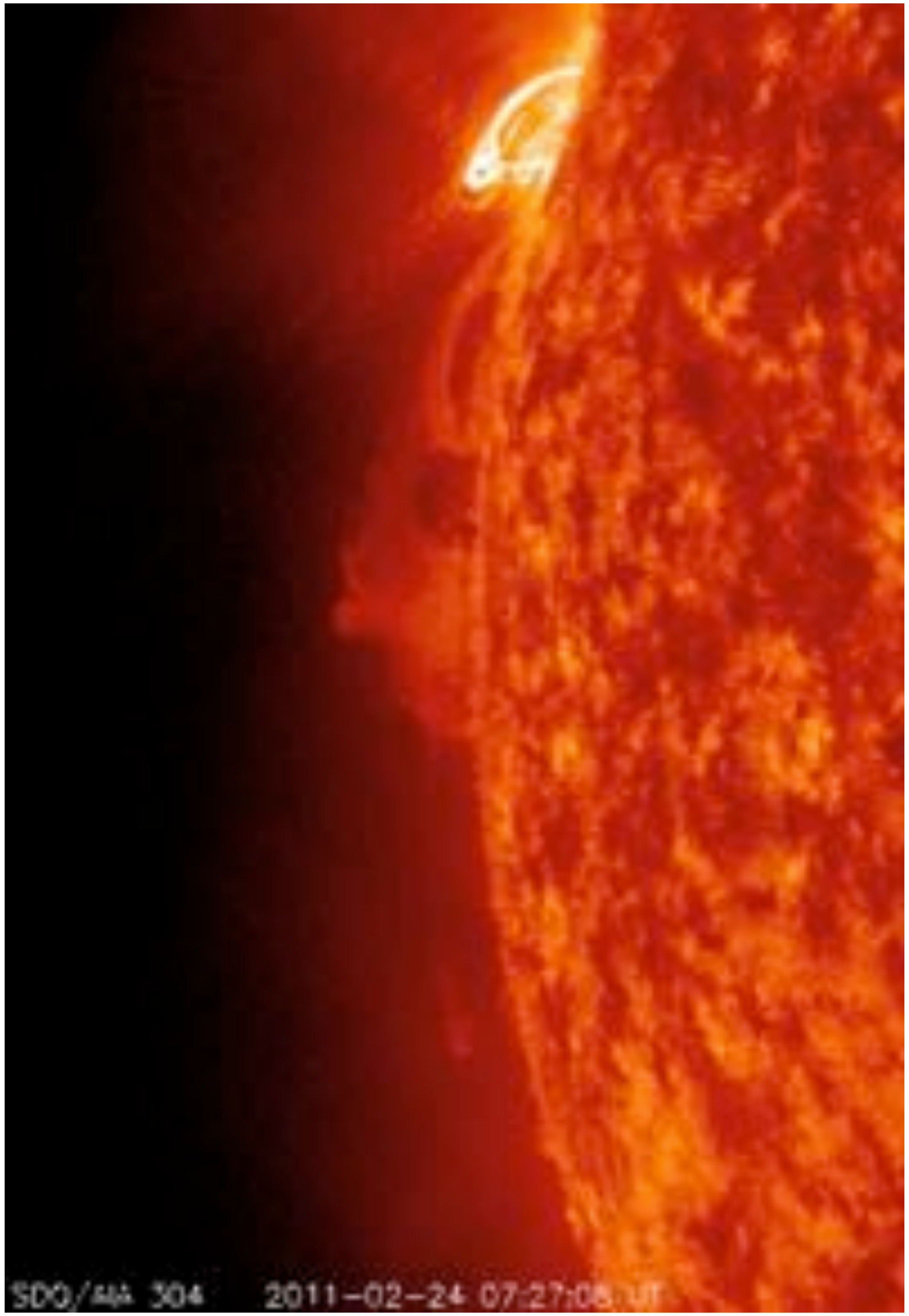
Solar Flares (A Space-Based Tour)

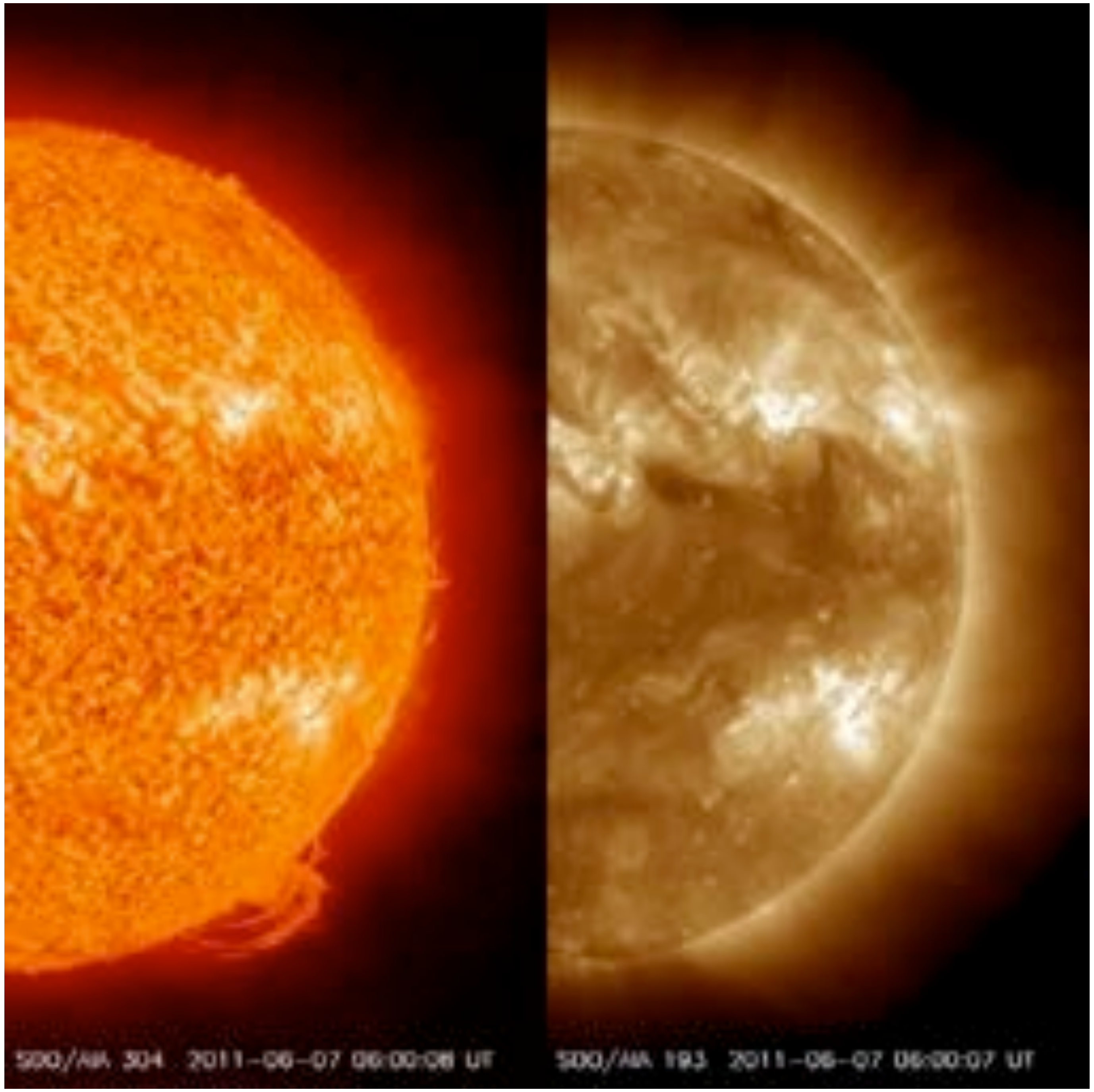


Hinode / SOT

Hinode / XRT: http://xrt.cfa.harvard.edu; SOT: http://sot.lmsal.com/

Solar Flares (A Space-Based Tour)

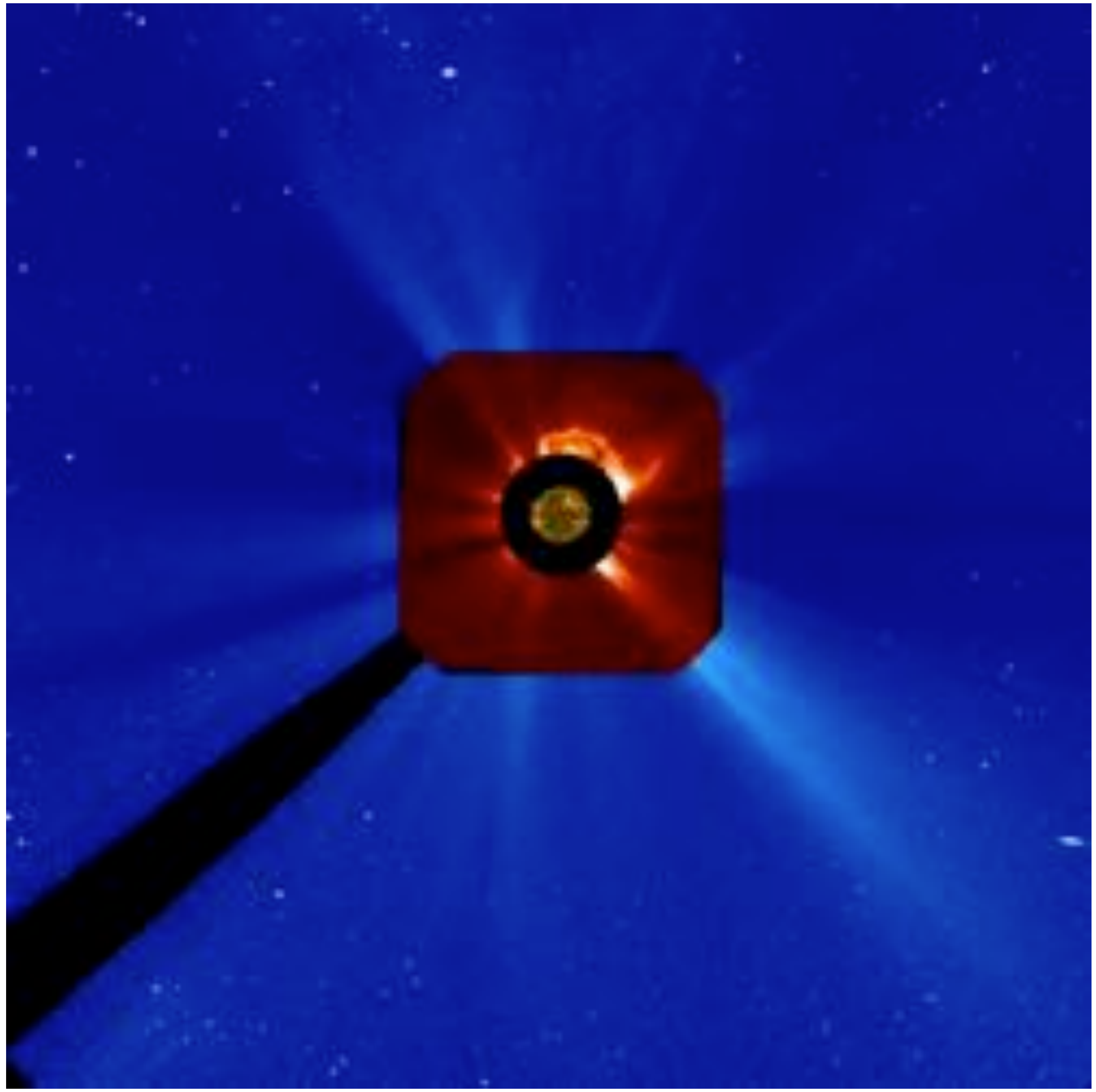




SDO / AIA

Solar Dynamics Observatory (SDO): http://sdo.gsfc.nasa.gov/

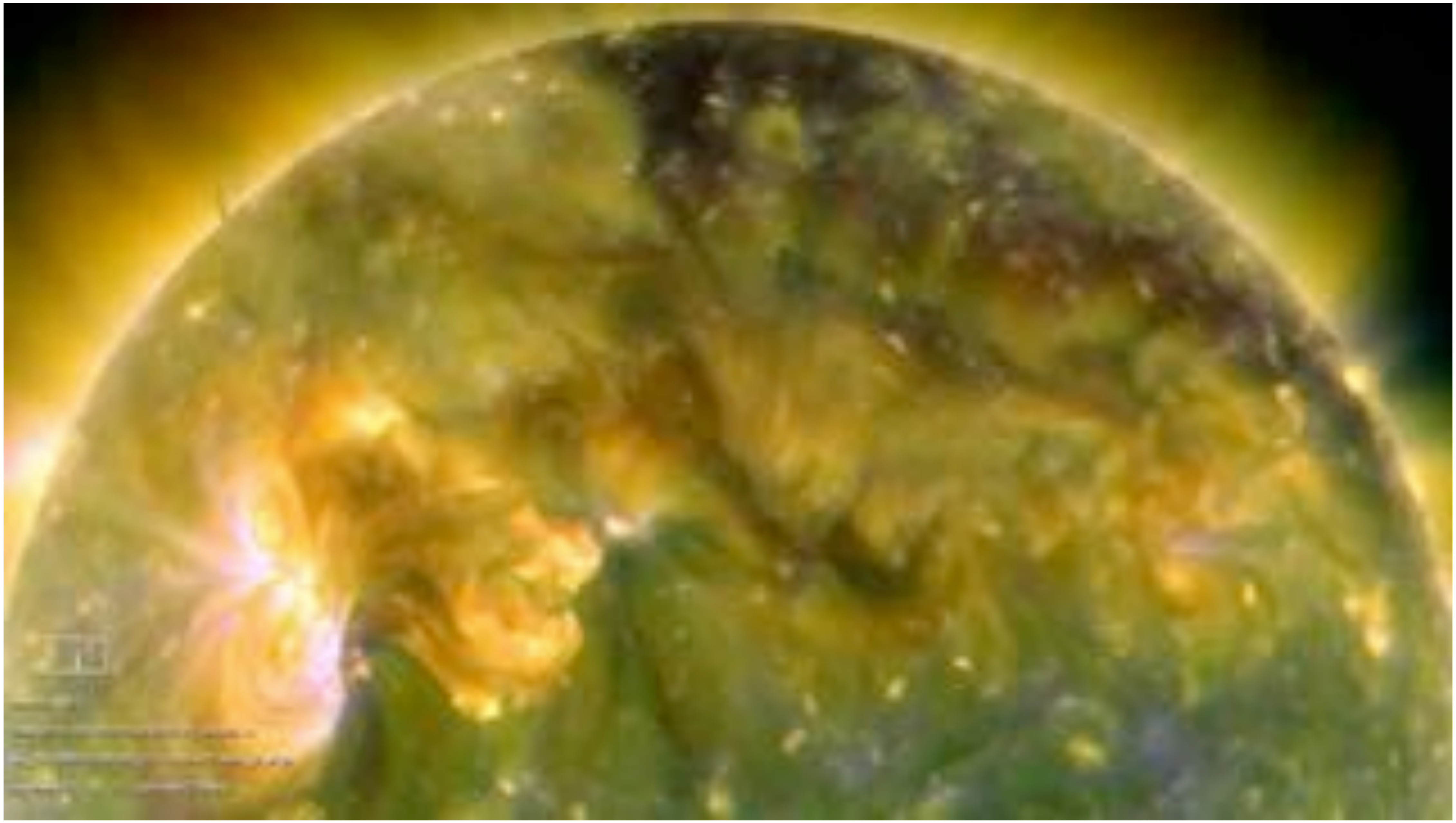
Solar Flares (A Space-Based Tour)



SDO / AIA + *SOHO* / LASCO

Solar Dynamics Observatory (SDO): http://sdo.gsfc.nasa.gov/ ; LASCO: http://lasco-www.nrl.navy.mil/

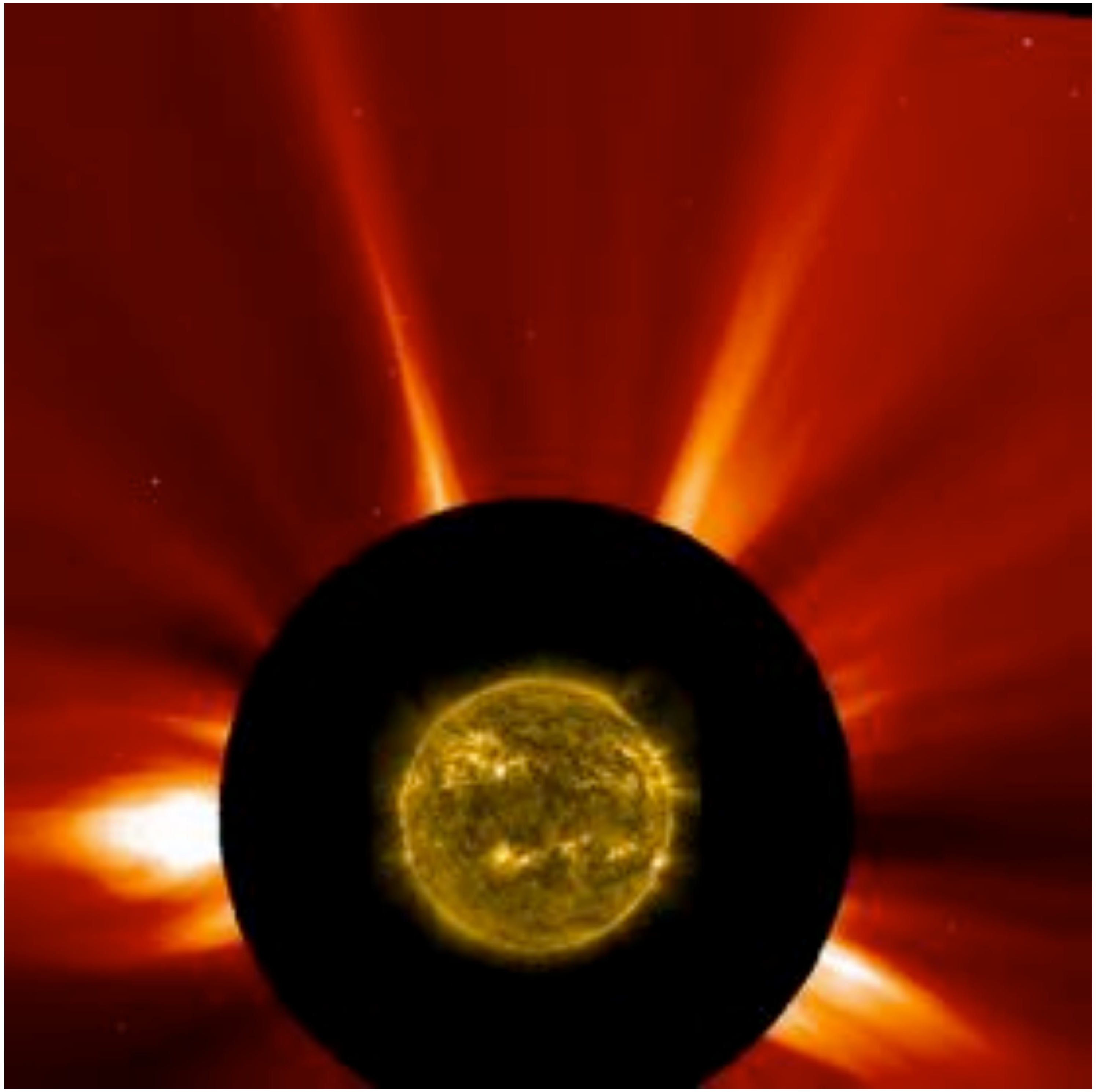
Solar Flares (A Space-Based Tour)



SDO / AIA

Solar Dynamics Observatory (SDO): http://sdo.gsfc.nasa.gov/

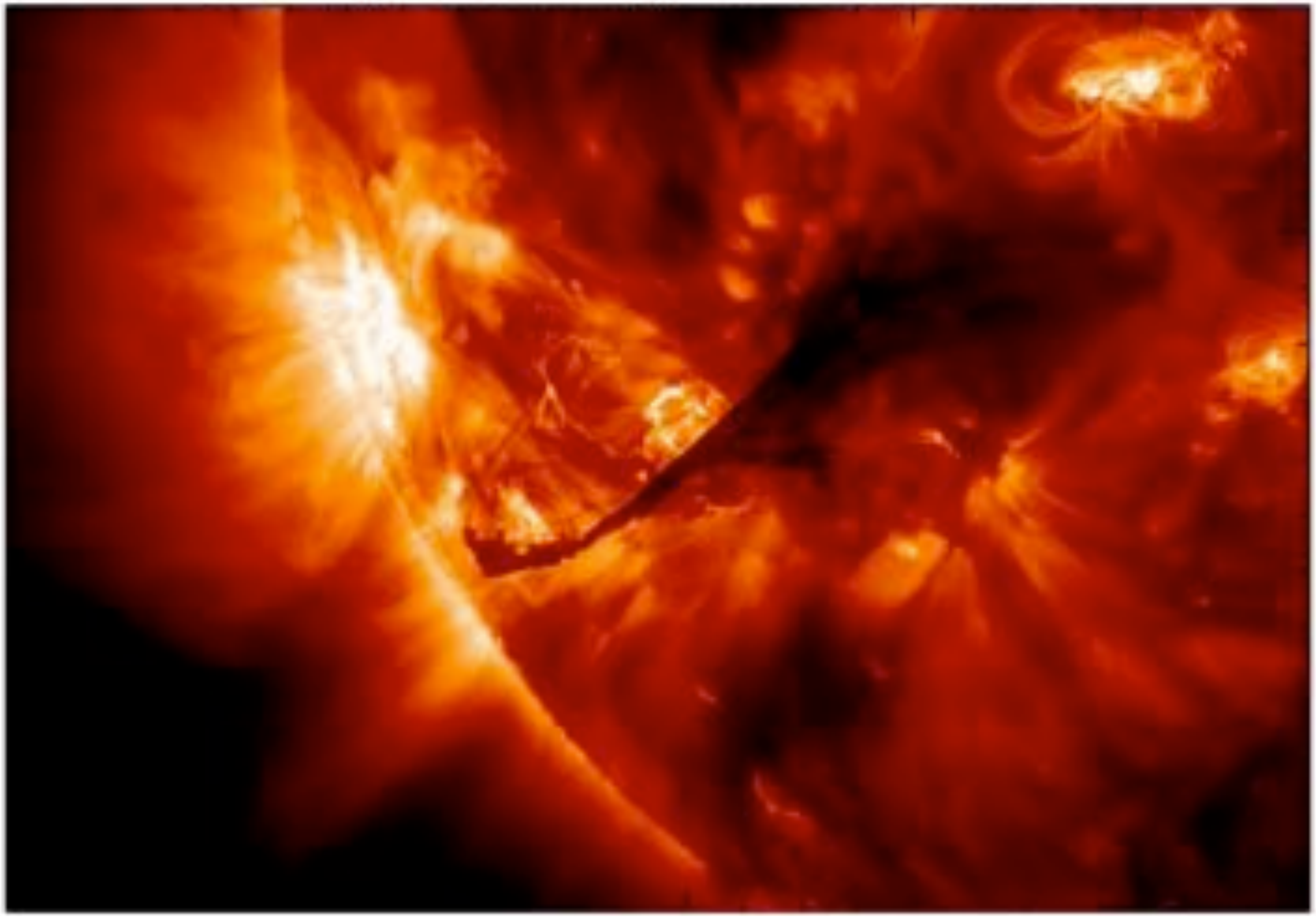
Solar Flares (A Space-Based Tour)



SDO / AIA + *SOHO* / LASCO

Solar Dynamics Observatory (SDO): http://sdo.gsfc.nasa.gov/ ; LASCO: http://lasco-www.nrl.navy.mil/

Solar Flares (A Space-Based Tour)

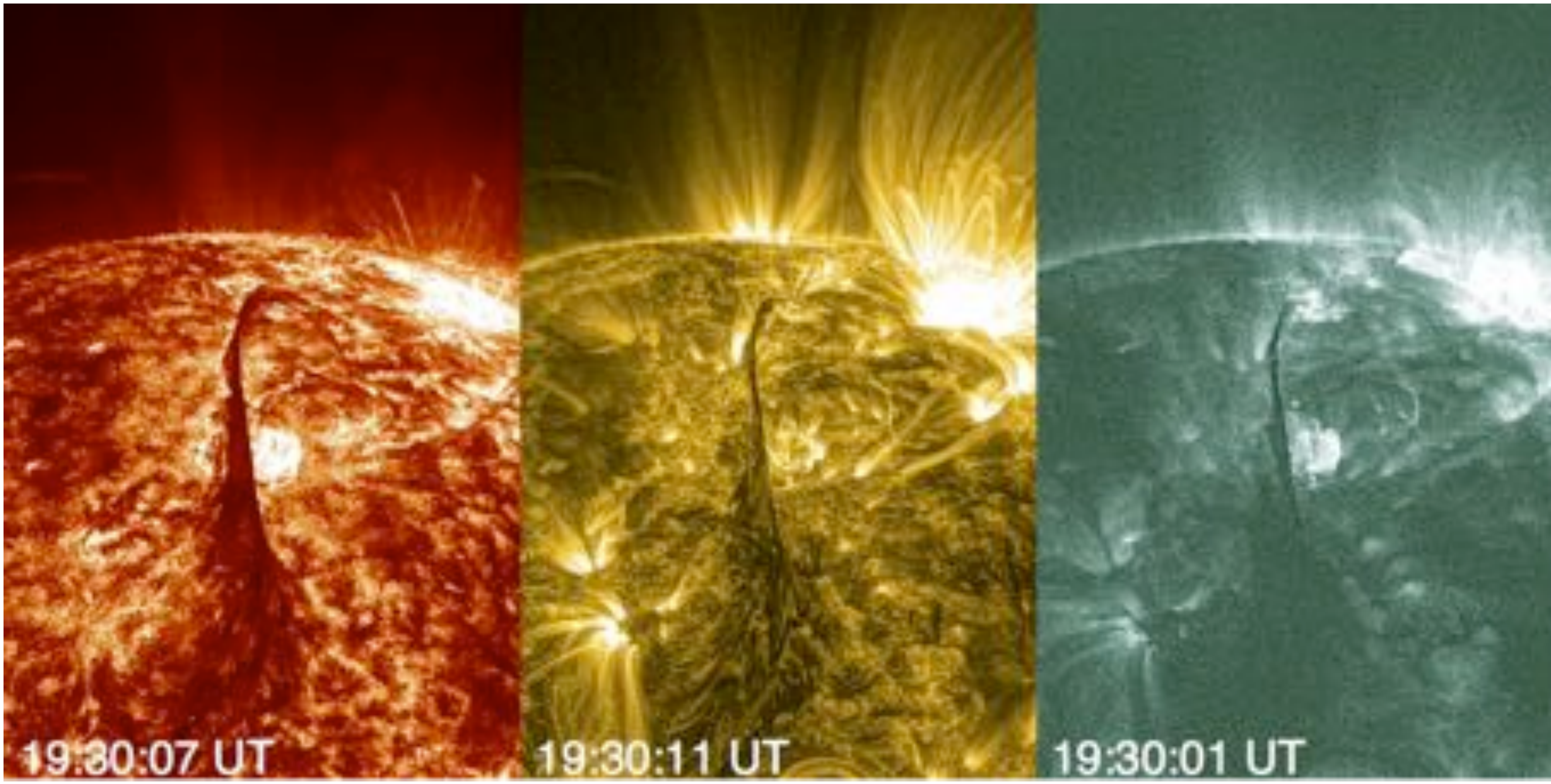


SDO / AIA + *Hinode* / EIS

Solar Dynamics Observatory (SDO): http://sdo.gsfc.nasa.gov/ ; EIS: http://solarb.mssl.ucl.ac.uk/SolarB/Solar-B.jsp

Solar Flares (A Space-Based Tour)

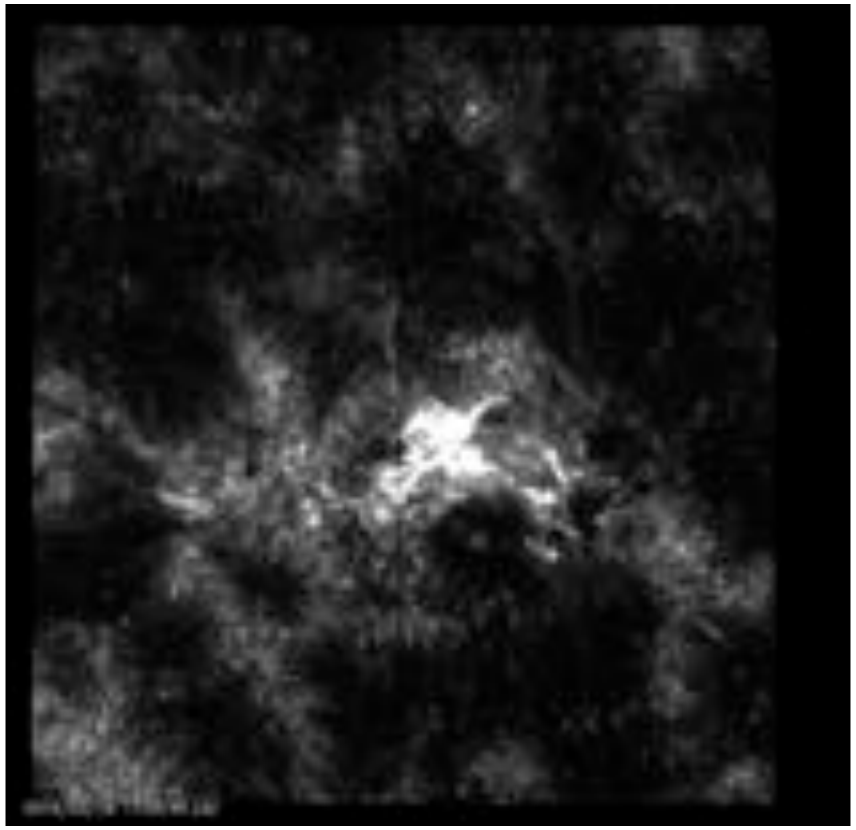
Same flare as previous slide but in 3 different AIA channels and enhanced for contrast.



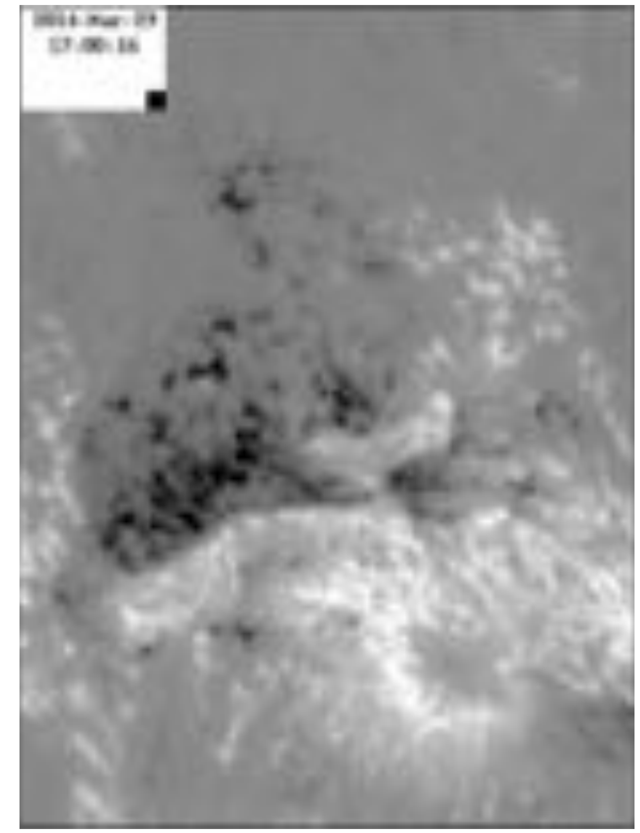
SDO / AIA

Solar Flares (A Space-Based Tour)

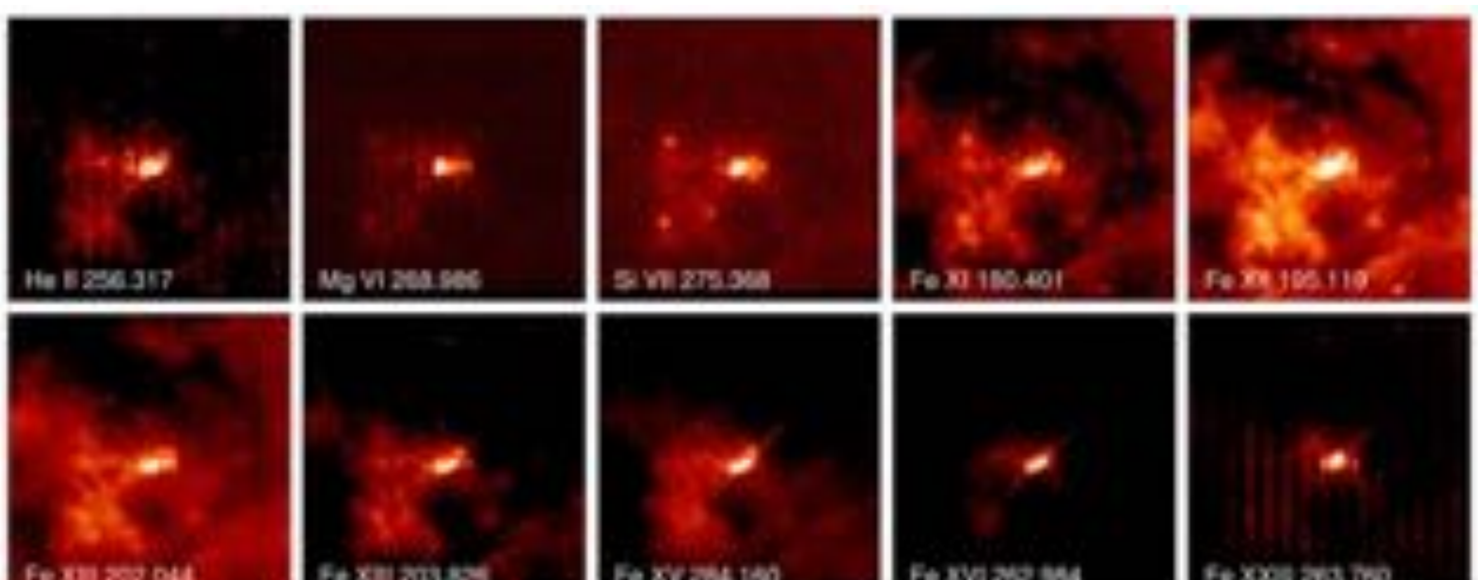
IRIS



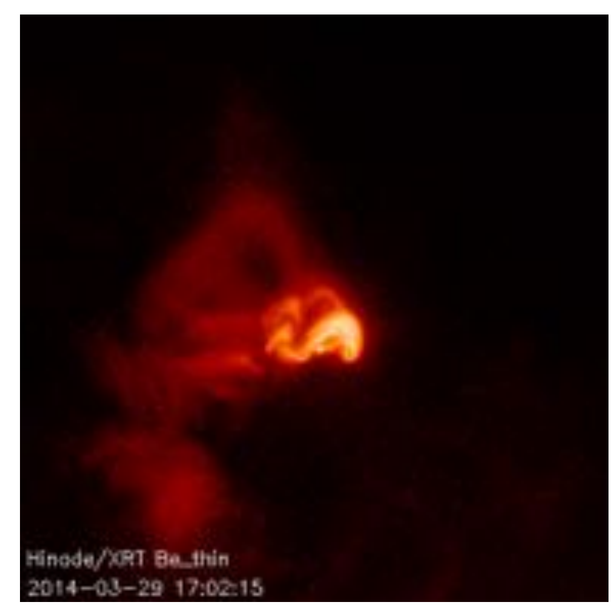
Hinode / SOT [Magnetogram]



Hinode / EIS



Hinode / XRT



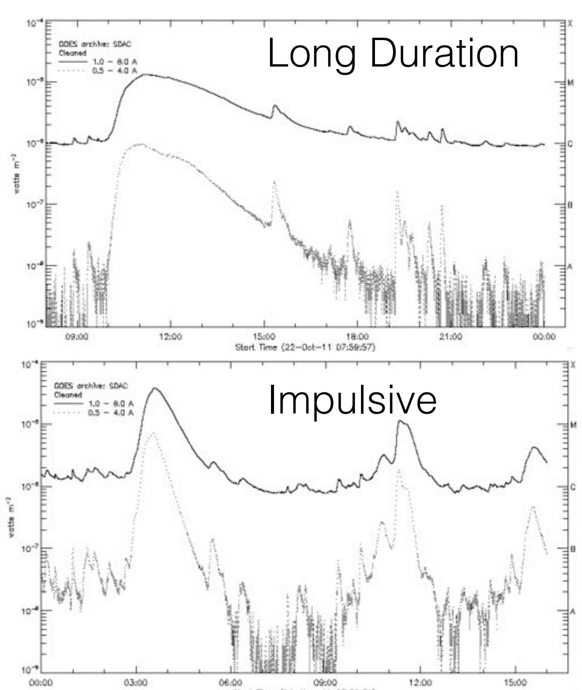
Interface Region Imaging Spectrograph (IRIS): http://iris.gsfc.nasa.gov/ ; Hinode: http://hinode.msfc.nasa.gov/

Investigating Energy Release

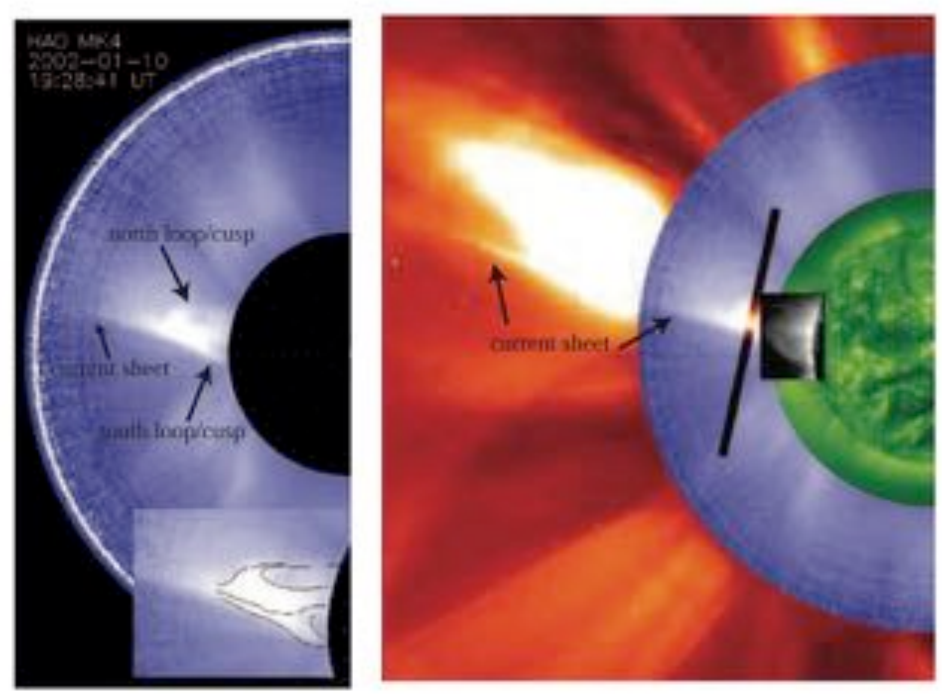
Investigating Energy Release

Focus on Long Duration Events

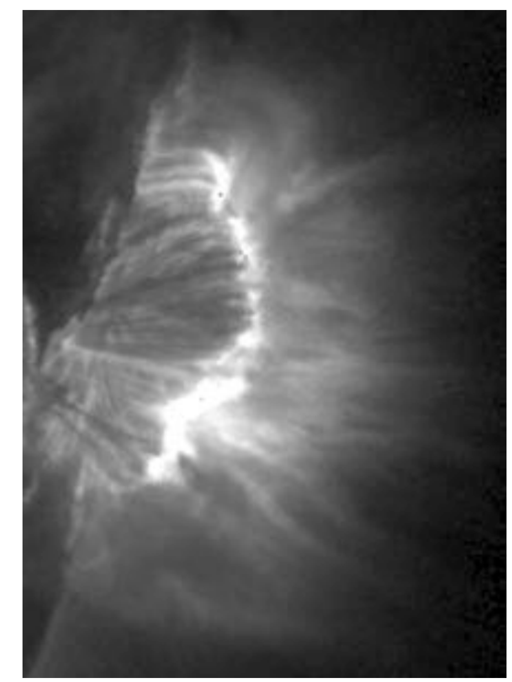
- Energy released for many hours
- Associated with Coronal Mass Ejections (CMEs)
- Development of current sheets and supra-arcade fans



Example GOES lightcurves



Ko et al. 2003

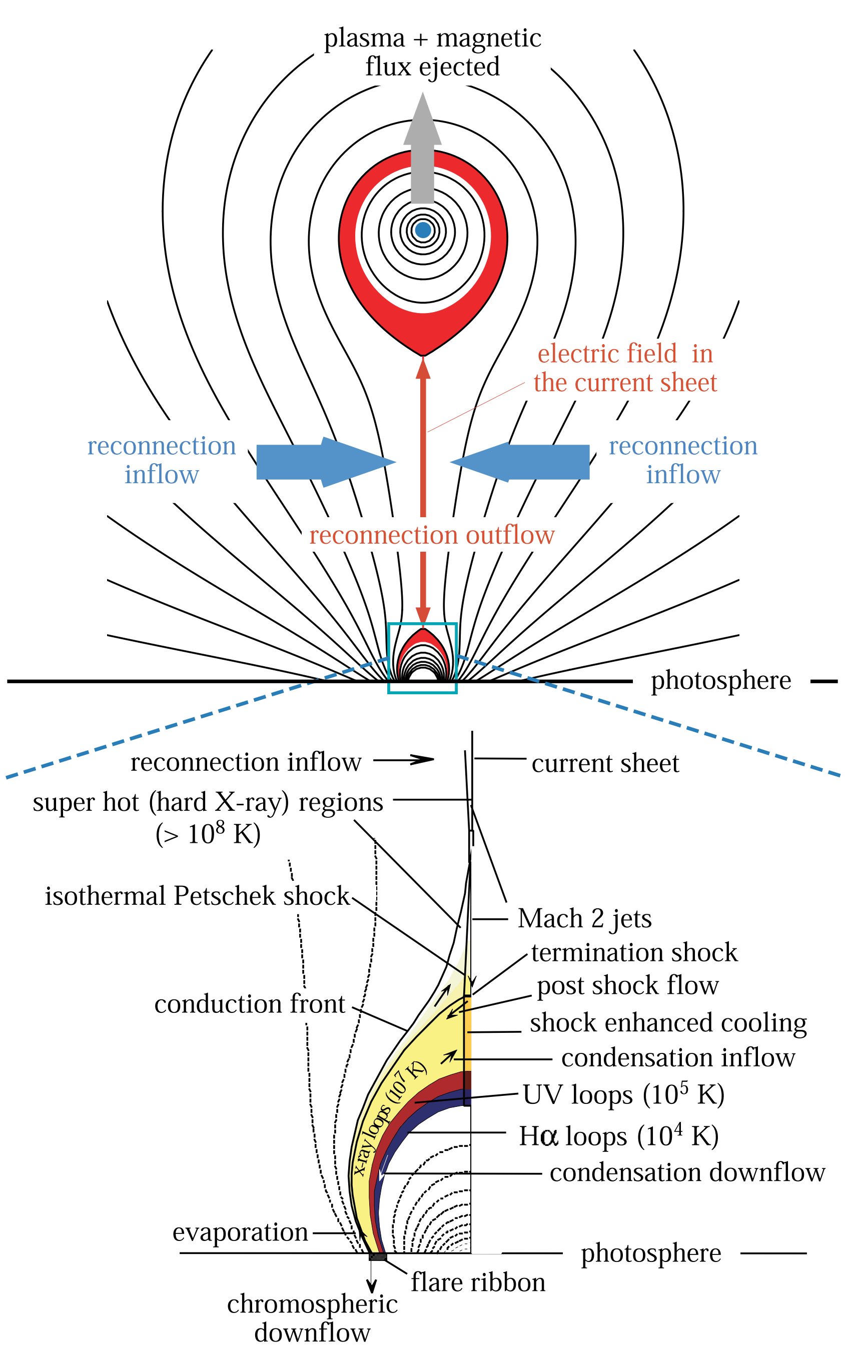


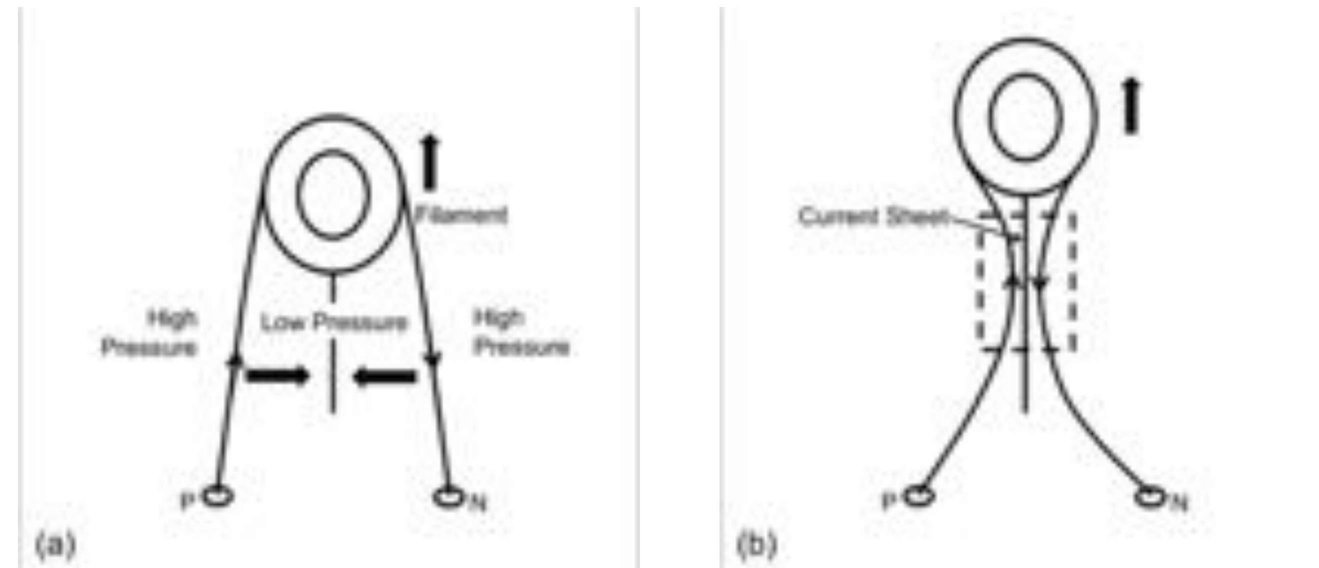
Savage & McKenzie 2011

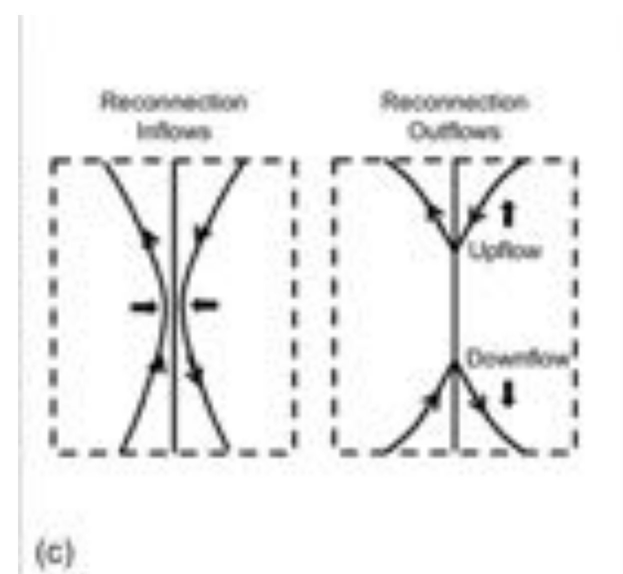
Geostationary Satellite Server (GOES) X-ray lightcurves: http://solarmonitor.org/goes_pop.php?date=20140410&type=xray

Investigating Energy Release

Standard **2-D** Flare Model







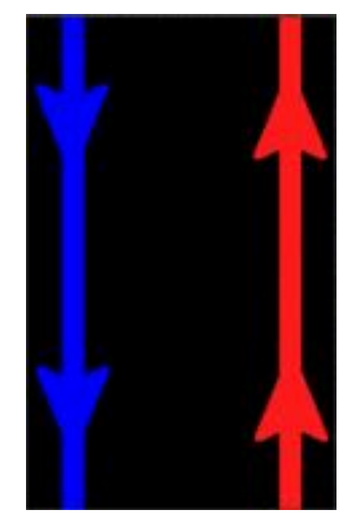


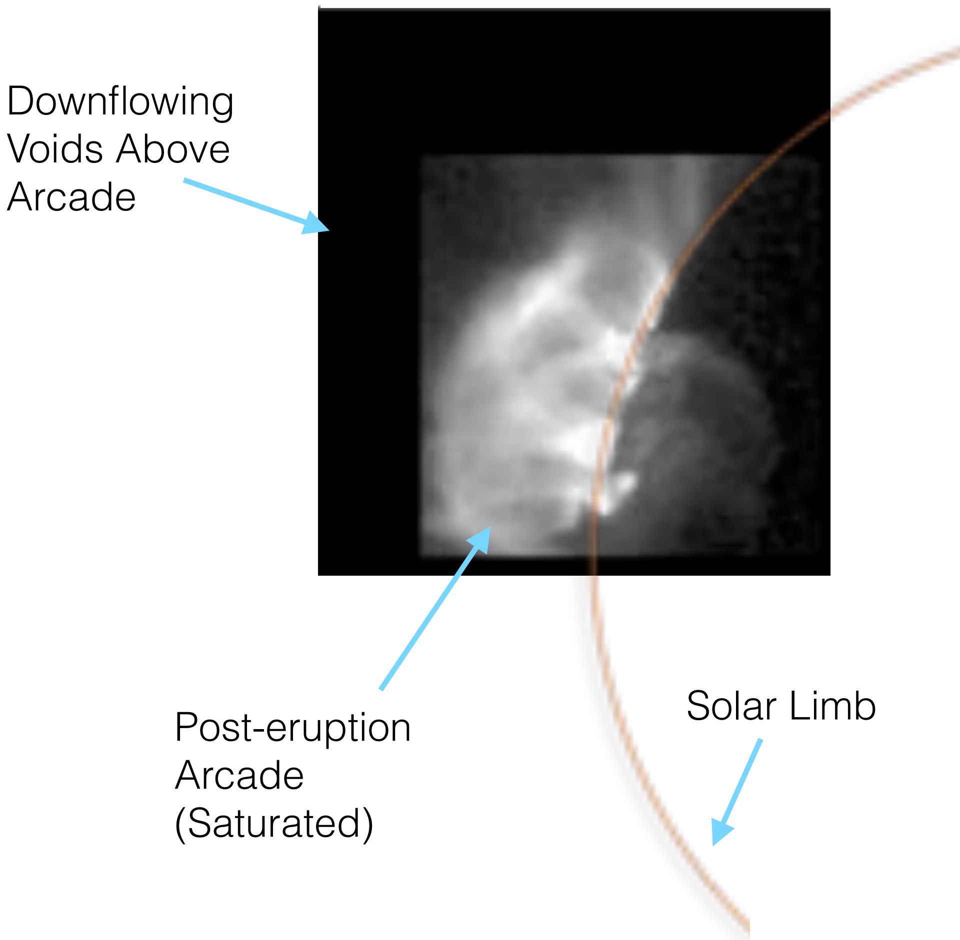
Image Credit: ESA

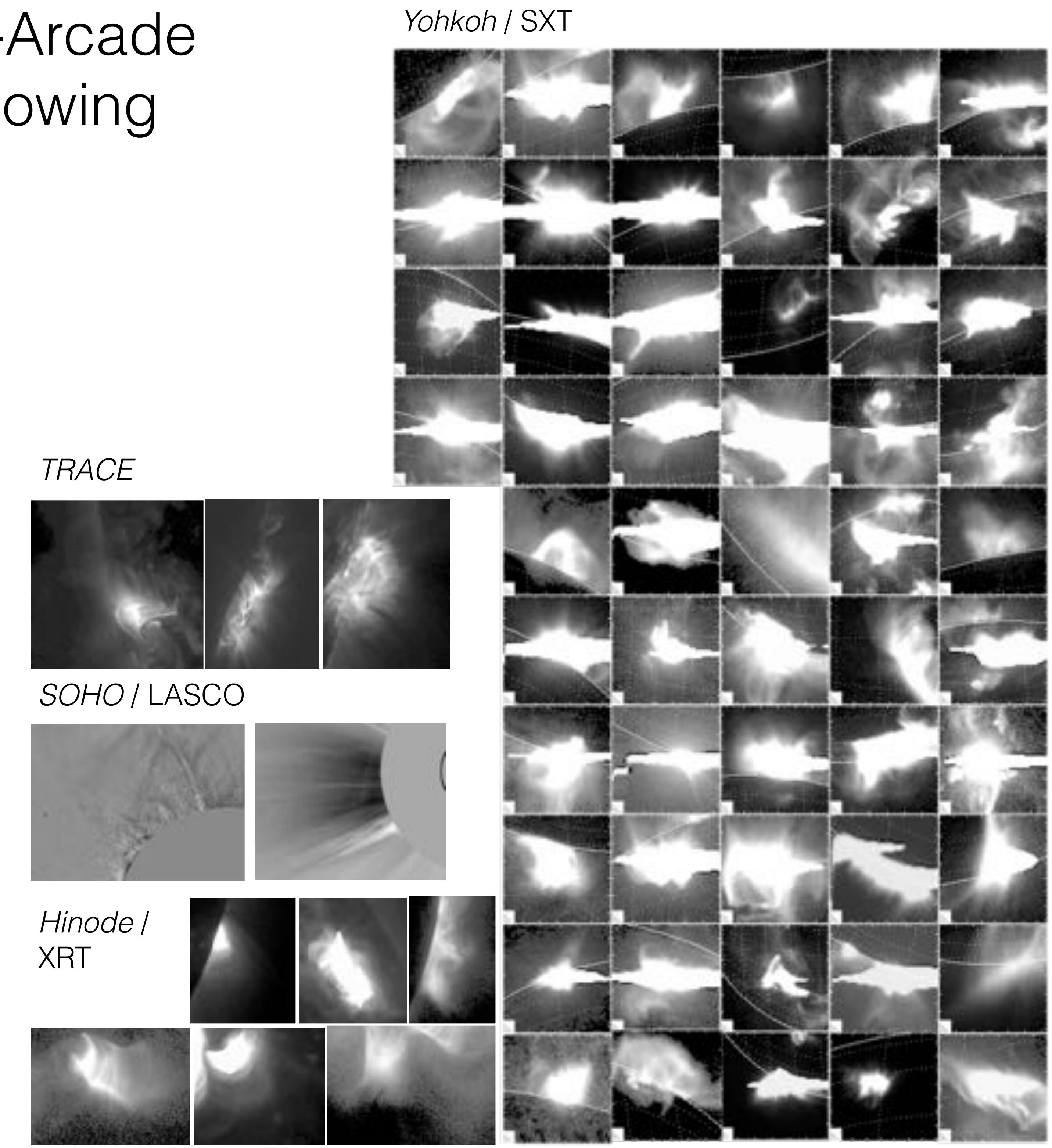
Updated CSHKP model: Forbes & Acton 1996; Lin & Forbes 2000; Ko et al. 2003

Investigating Energy Release

Early observations of Supra-Arcade Downflows (SADs) & Downflowing Loops (SADLs)

Yohkoh / SXT 1999 Jan 20

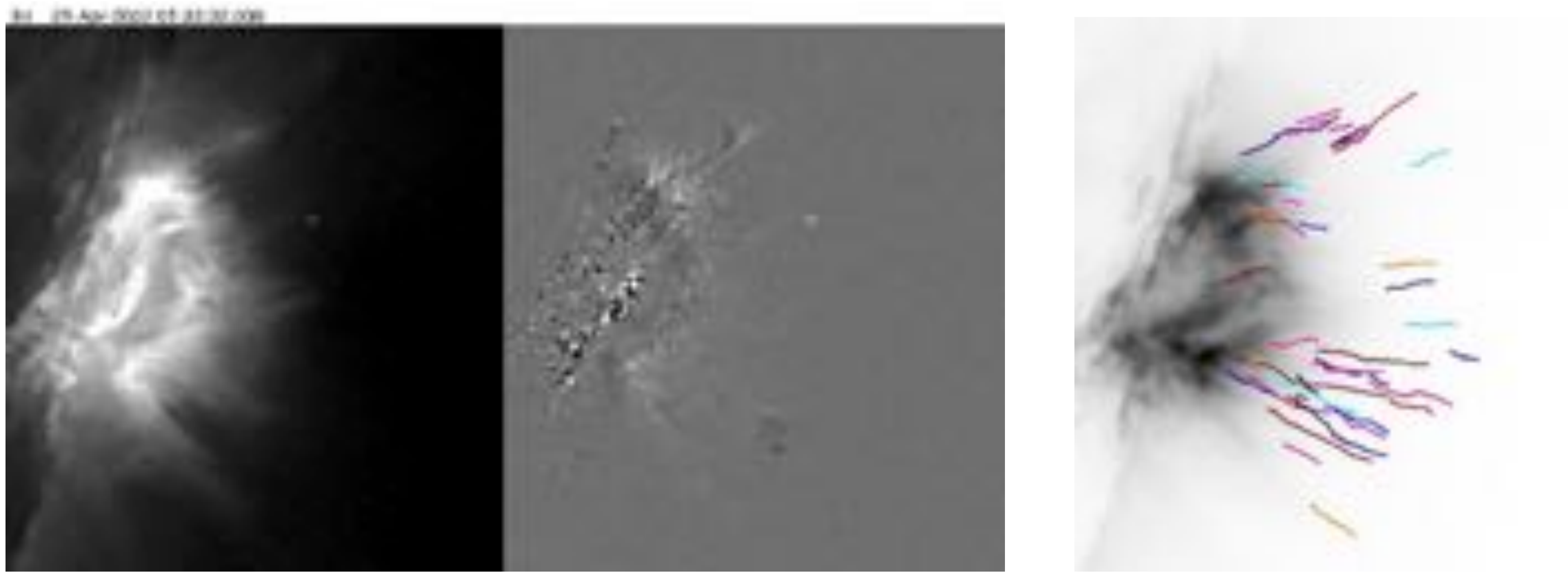




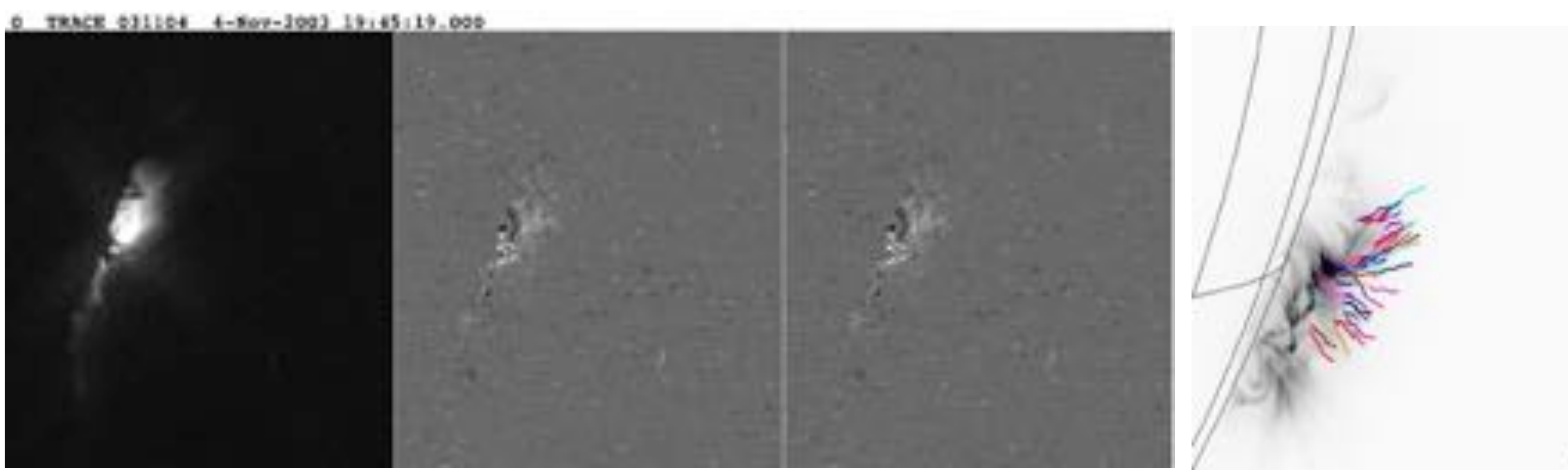
McKenzie & Hudson 1999; Khan et al. 2007; Savage & McKenzie 2011

Investigating Energy Release

TRACE 193 A, X-flare, 2002 Apr 21



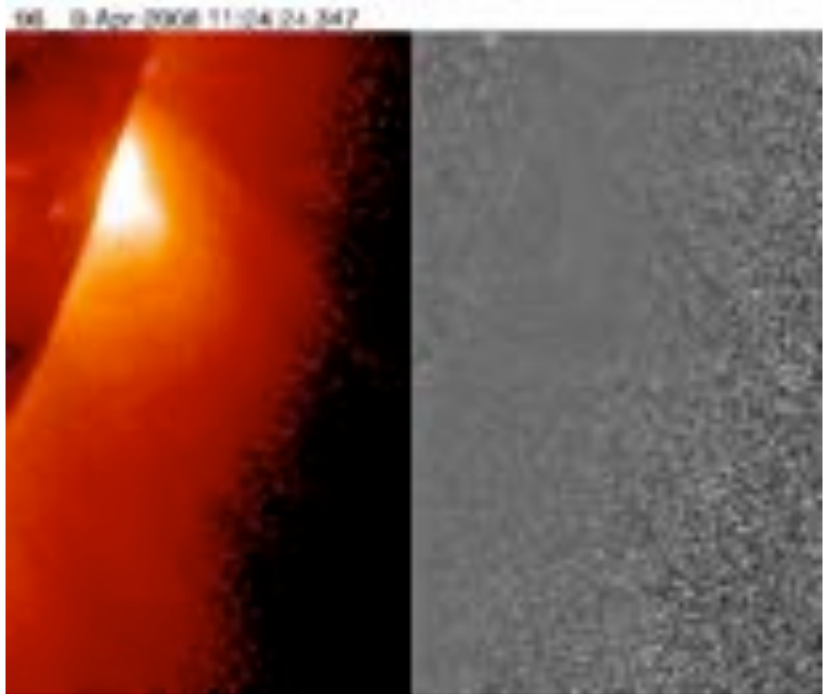
TRACE 193 A, X-flare, 2003 Nov 4

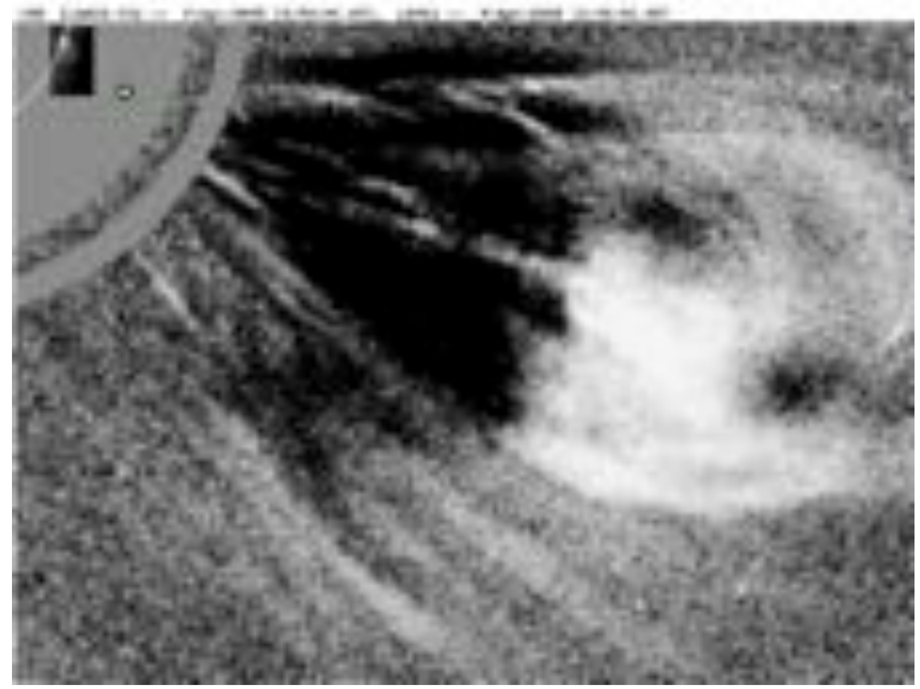


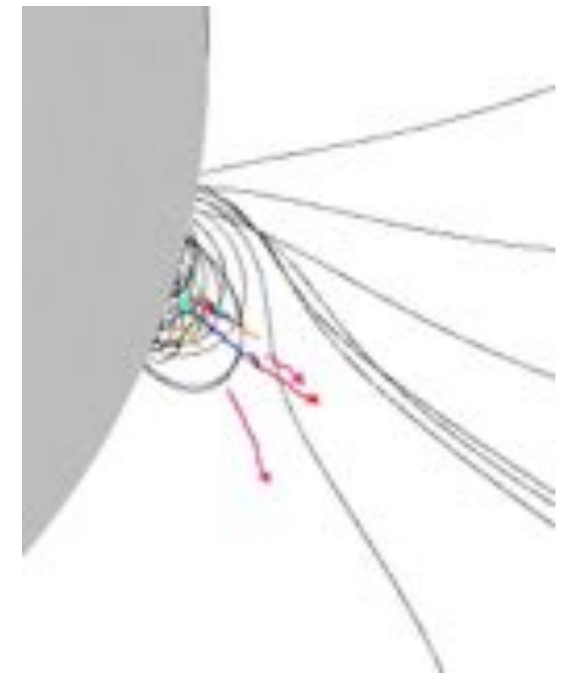
McKenzie & Savage 2009

Investigating Energy Release

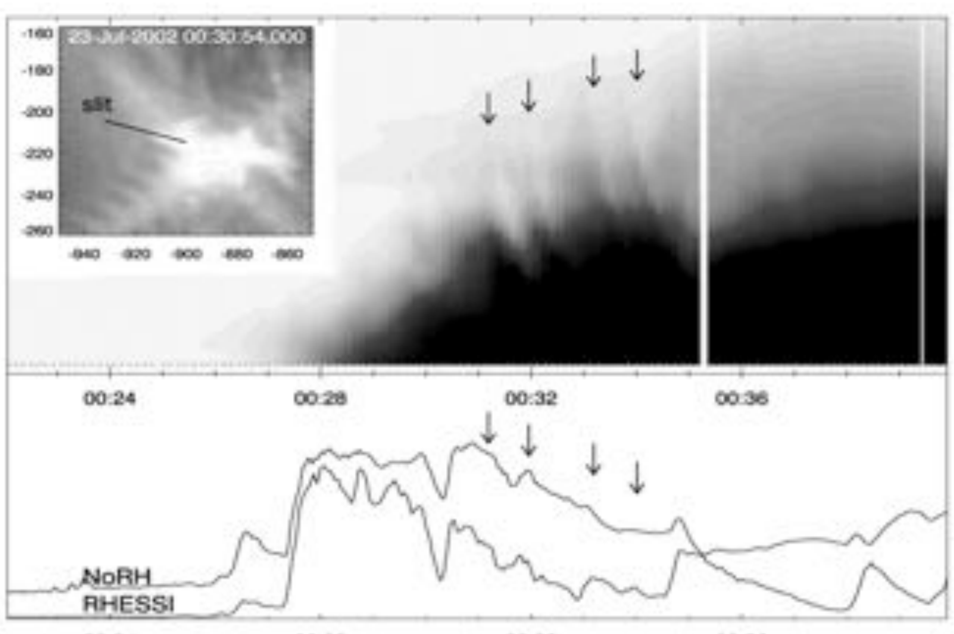
Hinode / XRT, 2008 Apr 9



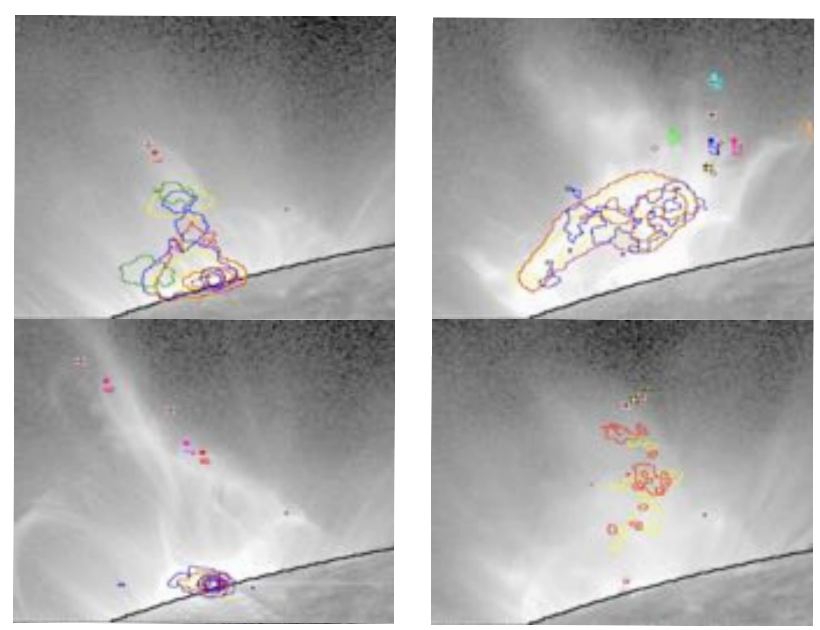




TRACE + *RHESSI* + NoRH radio (lightcurve), 2002 Jul 23



SDO / AIA + *RHESSI* (contours), 2010 Nov 3

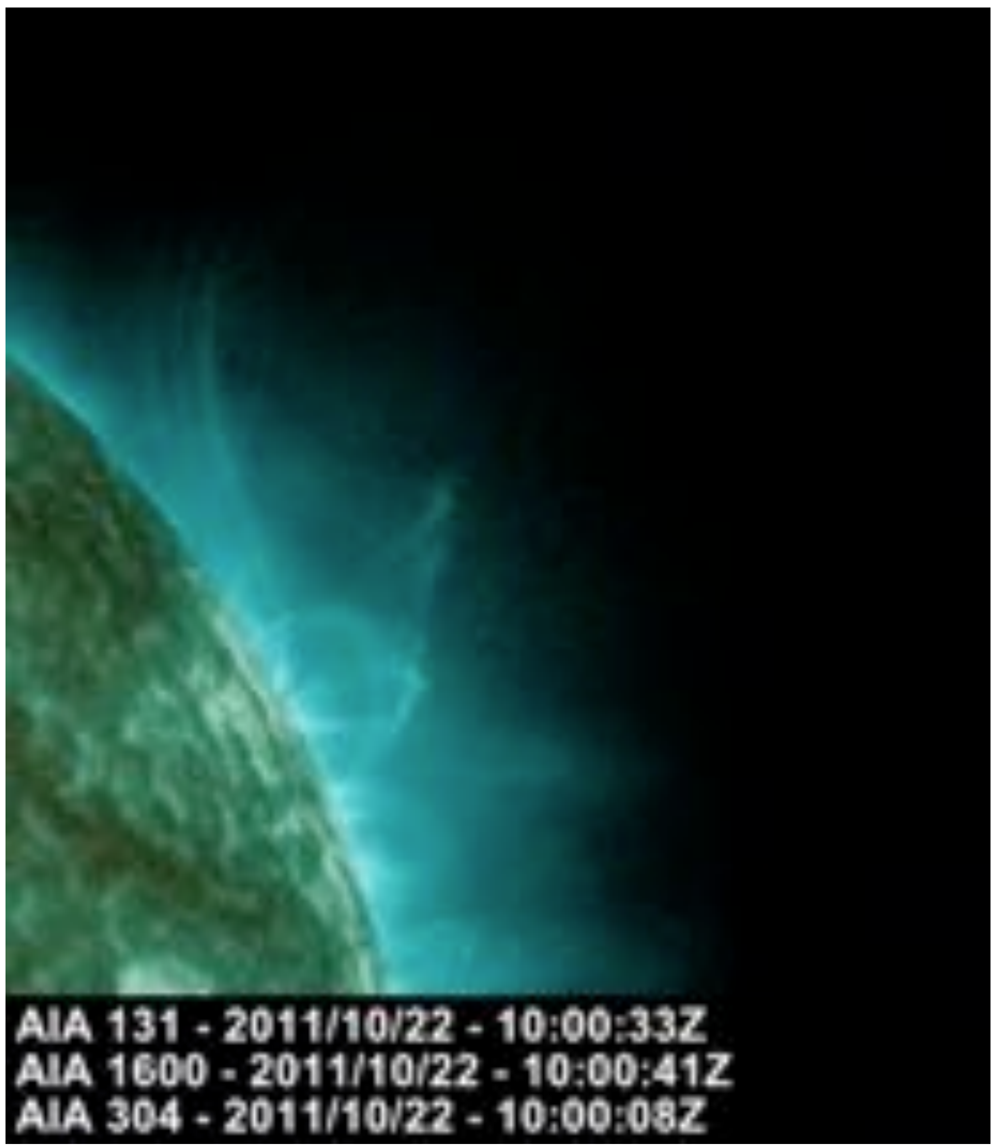


Savage et al. 2012; Savage et al. 2010; Asai et al. 2004; Yokoyama & Shibata 1999

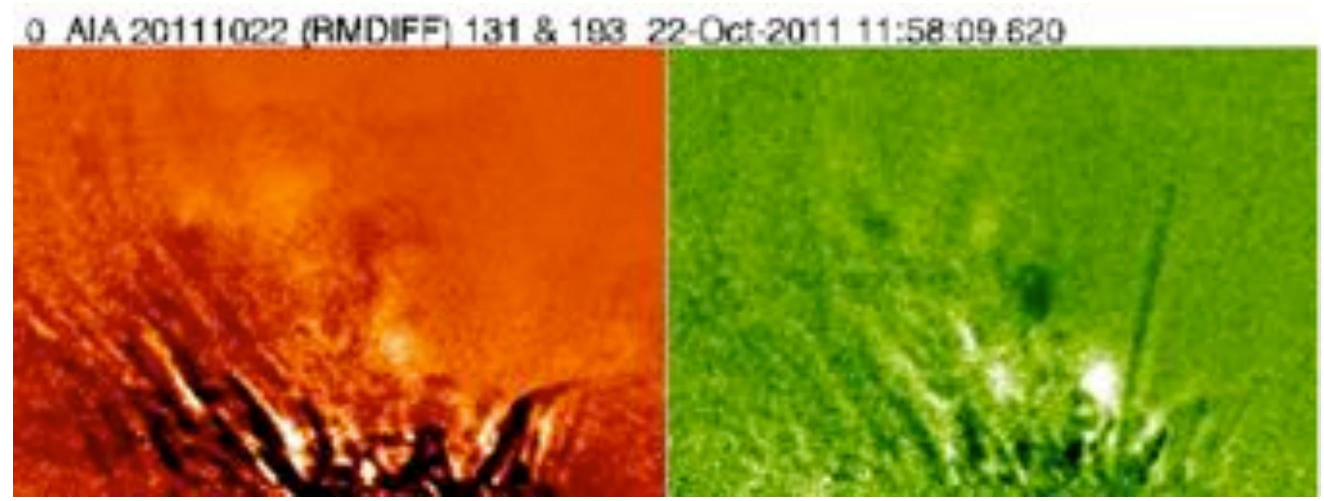
Investigating Energy Release

Explanation for SADs & SADLs converging …

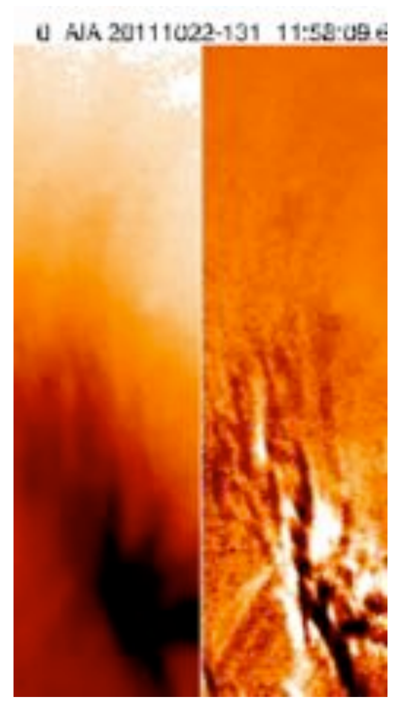
SDO / AIA, 2011 Oct 22

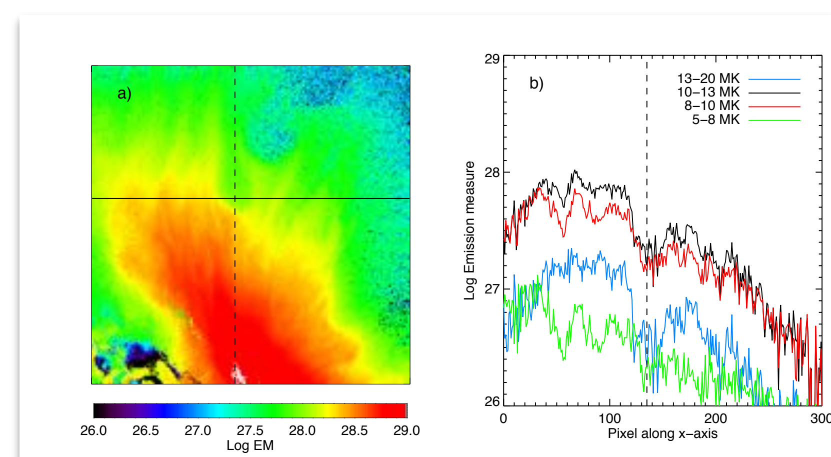


Movie Credit: D. E. McKenzie, Mont. State Univ



Bright thin loops retracting below voids.





SADs cooler than fan (and much less dense)

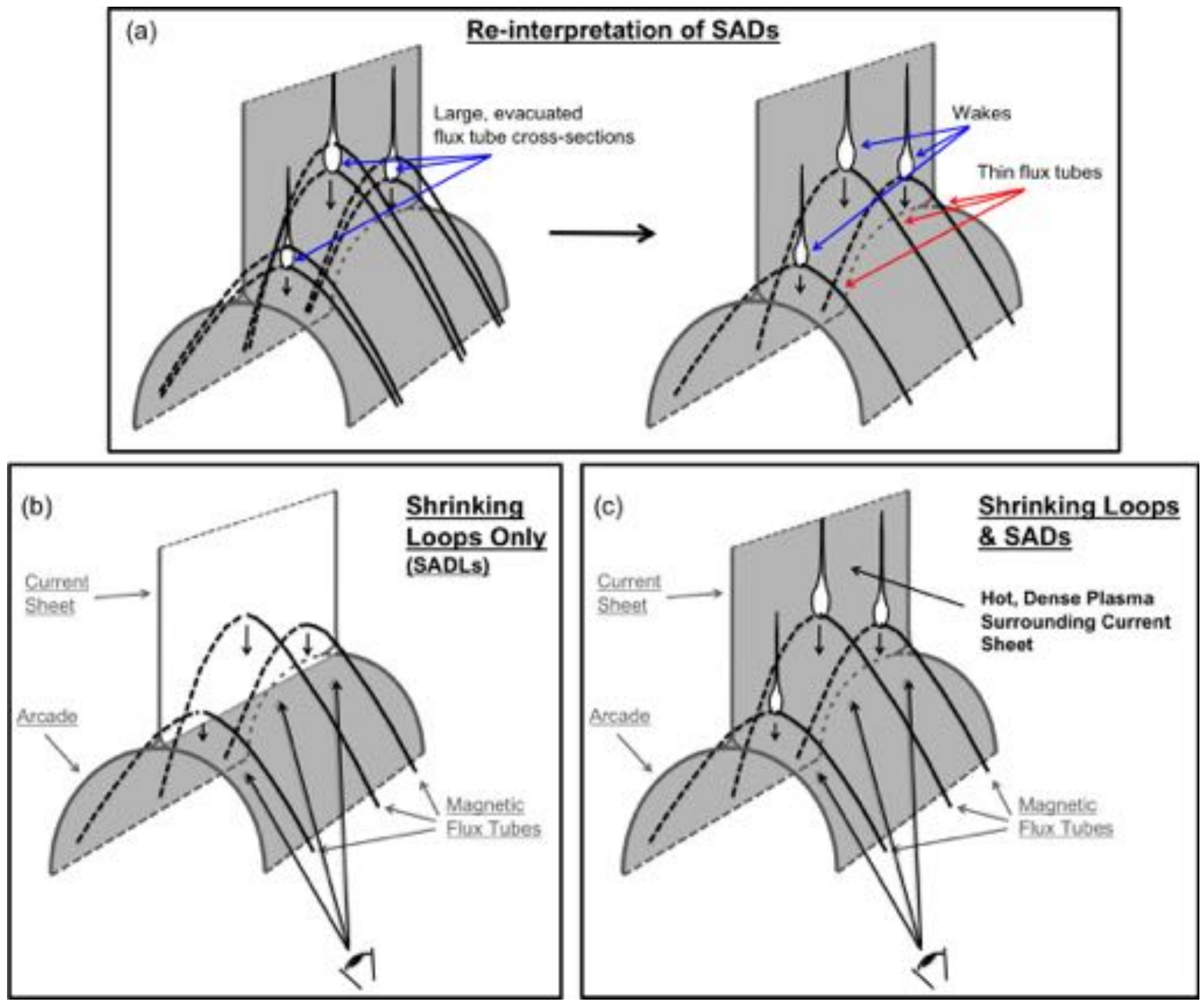
Savage, McKenzie, Reeves 2012

Investigating Energy Release

Explanation for SADs & SADLs converging …

—> Loops outflows of patchy, bursty magnetic reconnection?!

—> Voids rarefaction regions behind retracting loops?



Savage, McKenzie, Reeves 2012 ; RHESSI nugget #168: http://sprg.ssl.berkeley.edu/~tohban/wiki/index.php/Supra-Arcade_Downflows

Sadpoles

?

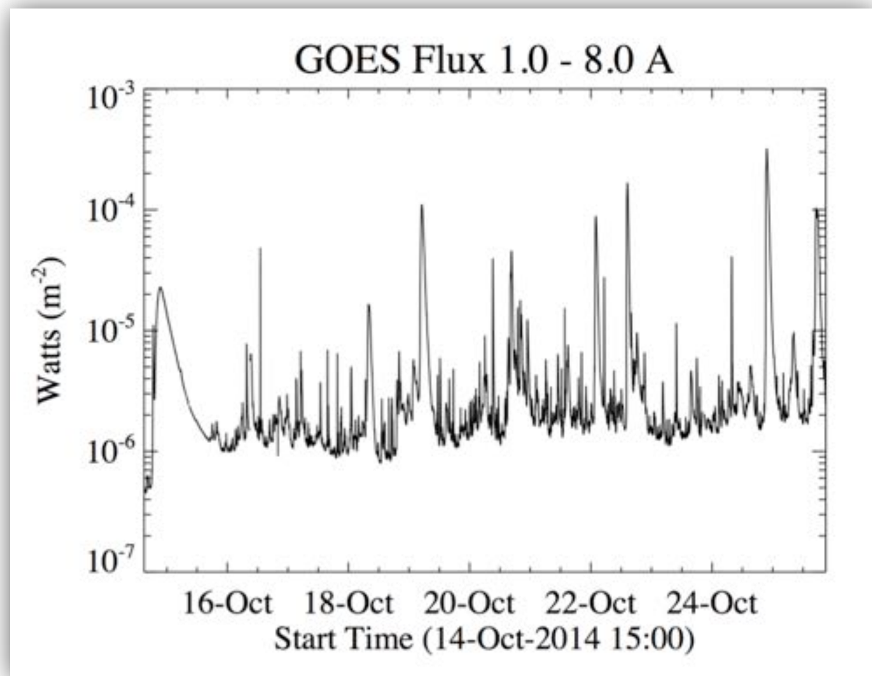
Happis

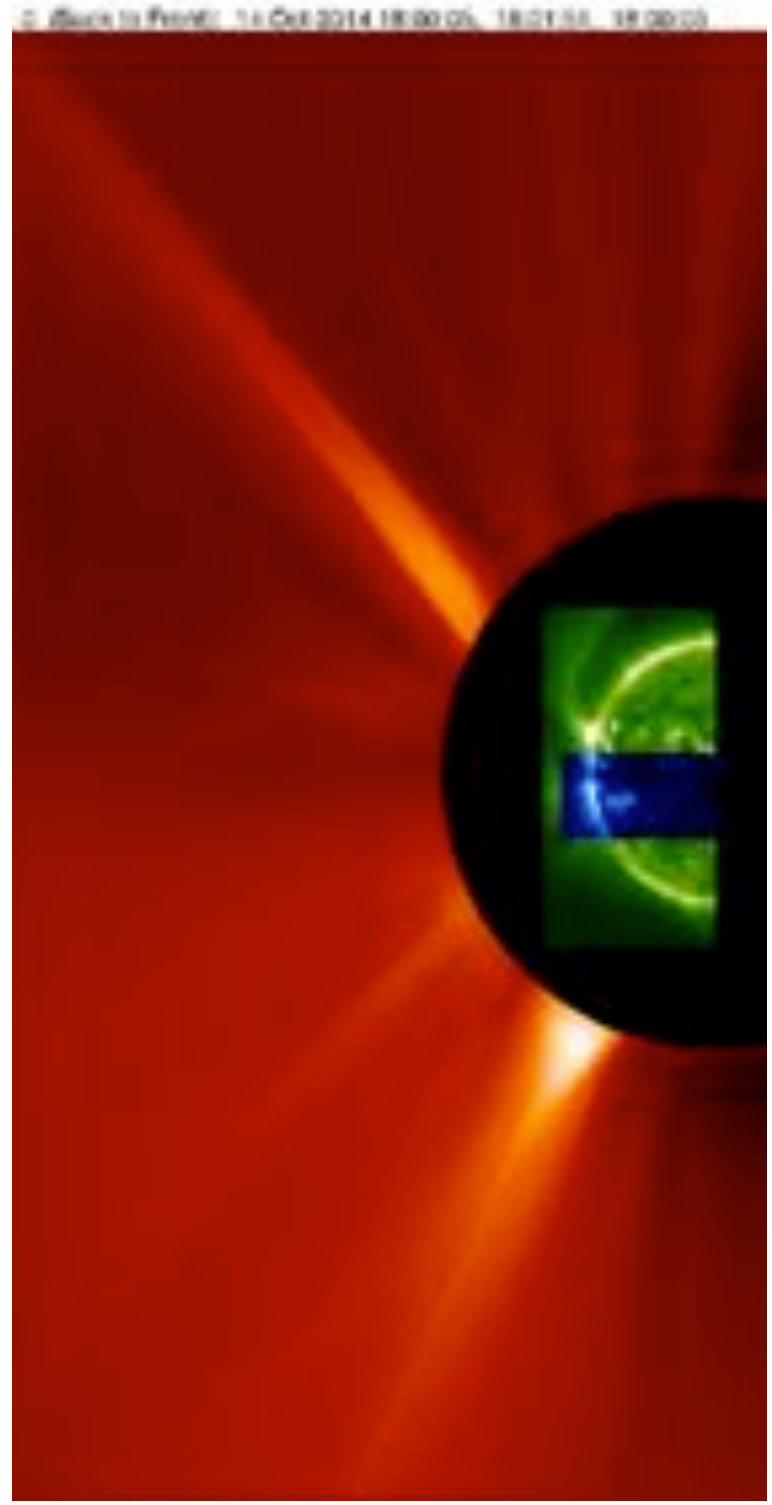
What’s the [X-]point?

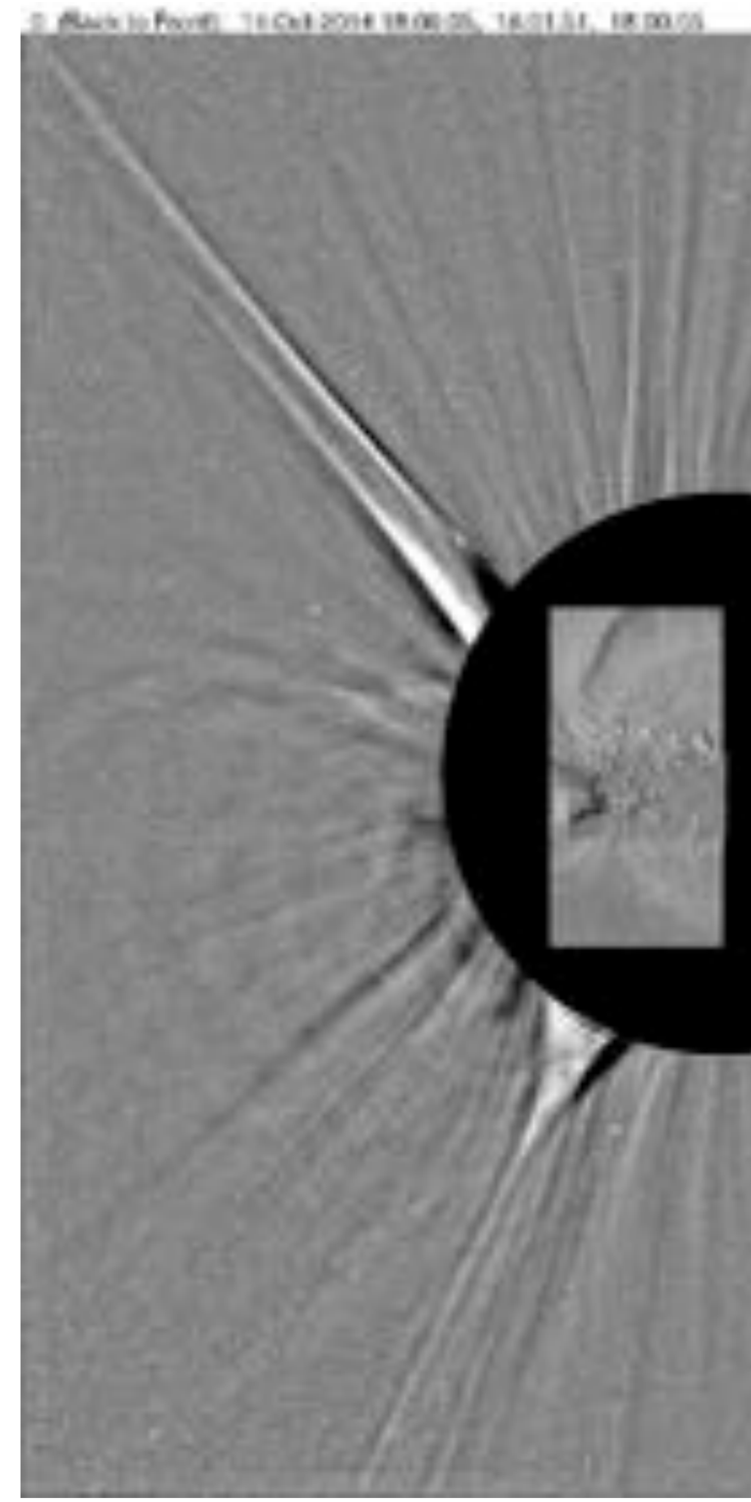
-> High-Altitude Propagating Pressure Imbalances?

Investigating Energy Release

Long-lived, highly extended phenomena







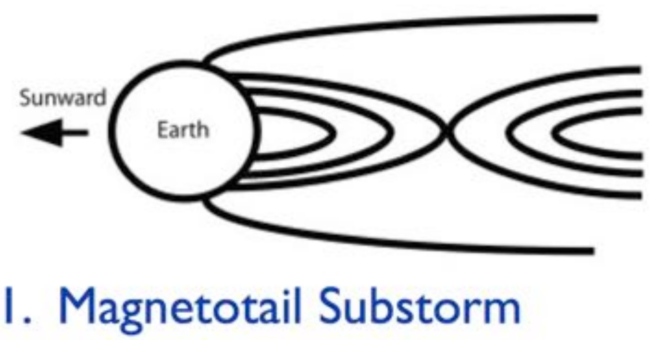
SADs in the lower corona are typically observed well after reconnection has occurred.

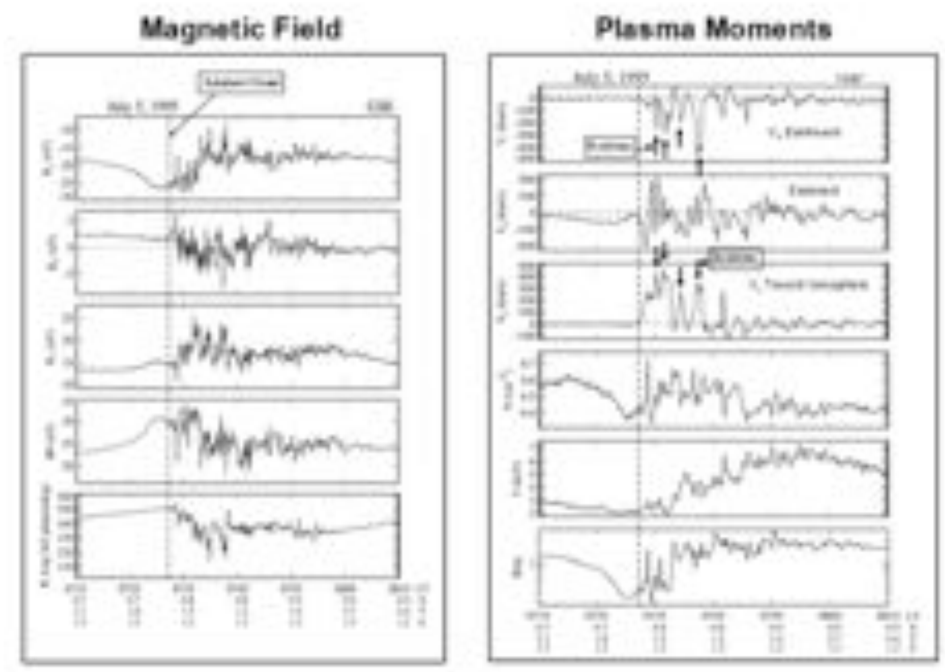
In the extended corona, we are better able to observe the migrating reconnection sites.

Savage, Seaton, West, in prep.

Observing Magnetic Reconnection

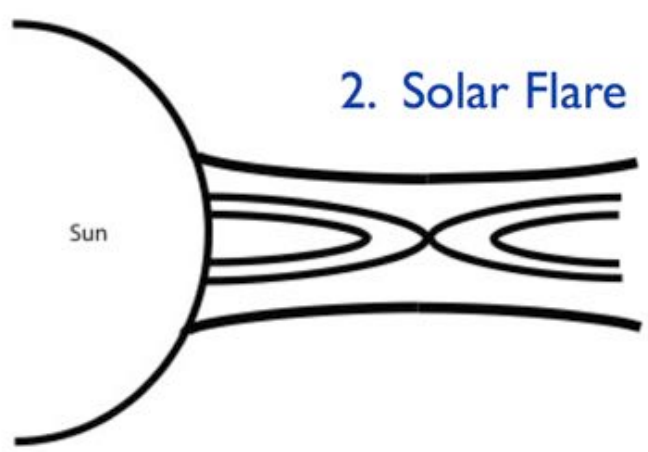
Solar flares comparable to Magnetotail substorms

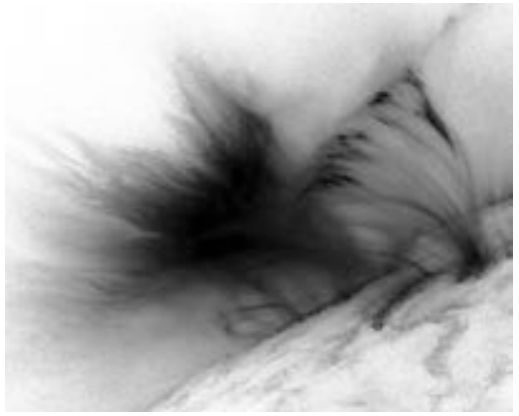




Magnetotail:

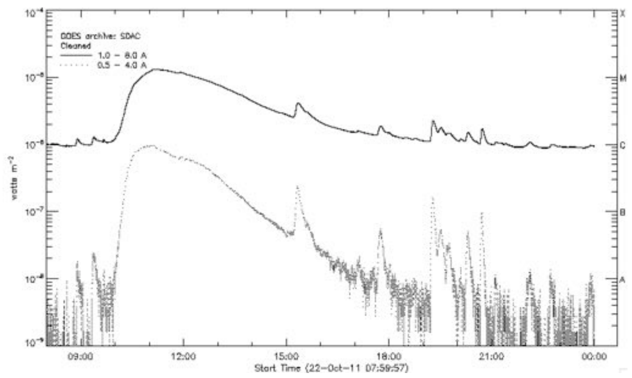
In Situ Measurements

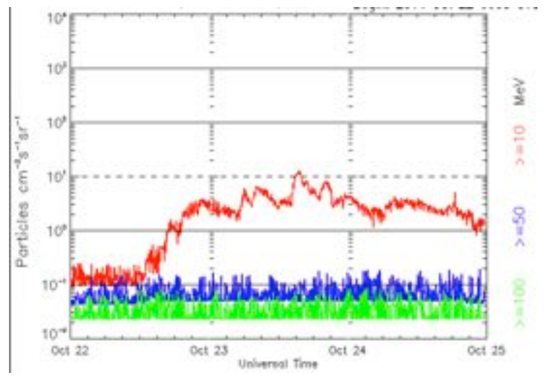




Solar:

Global Context

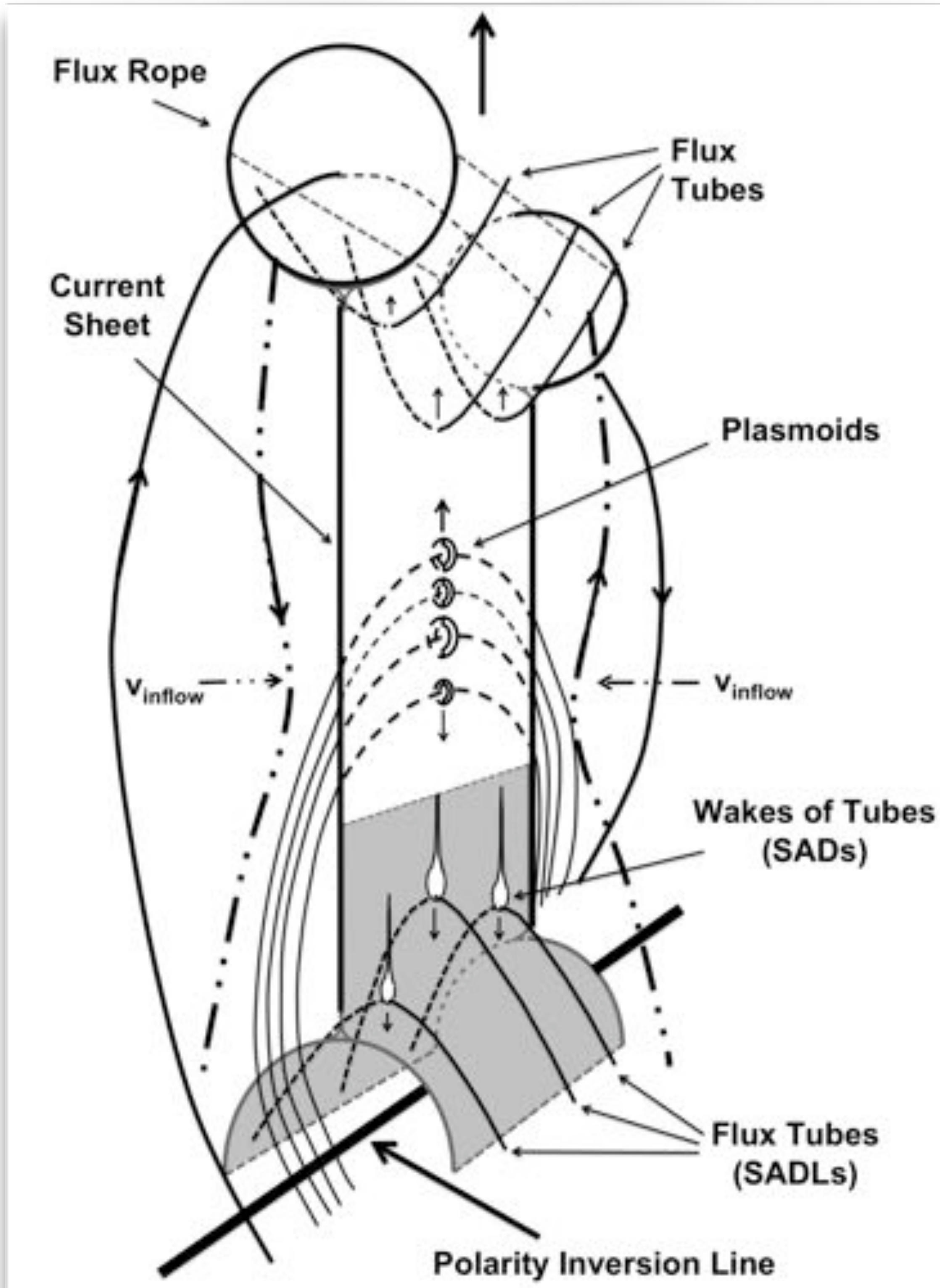




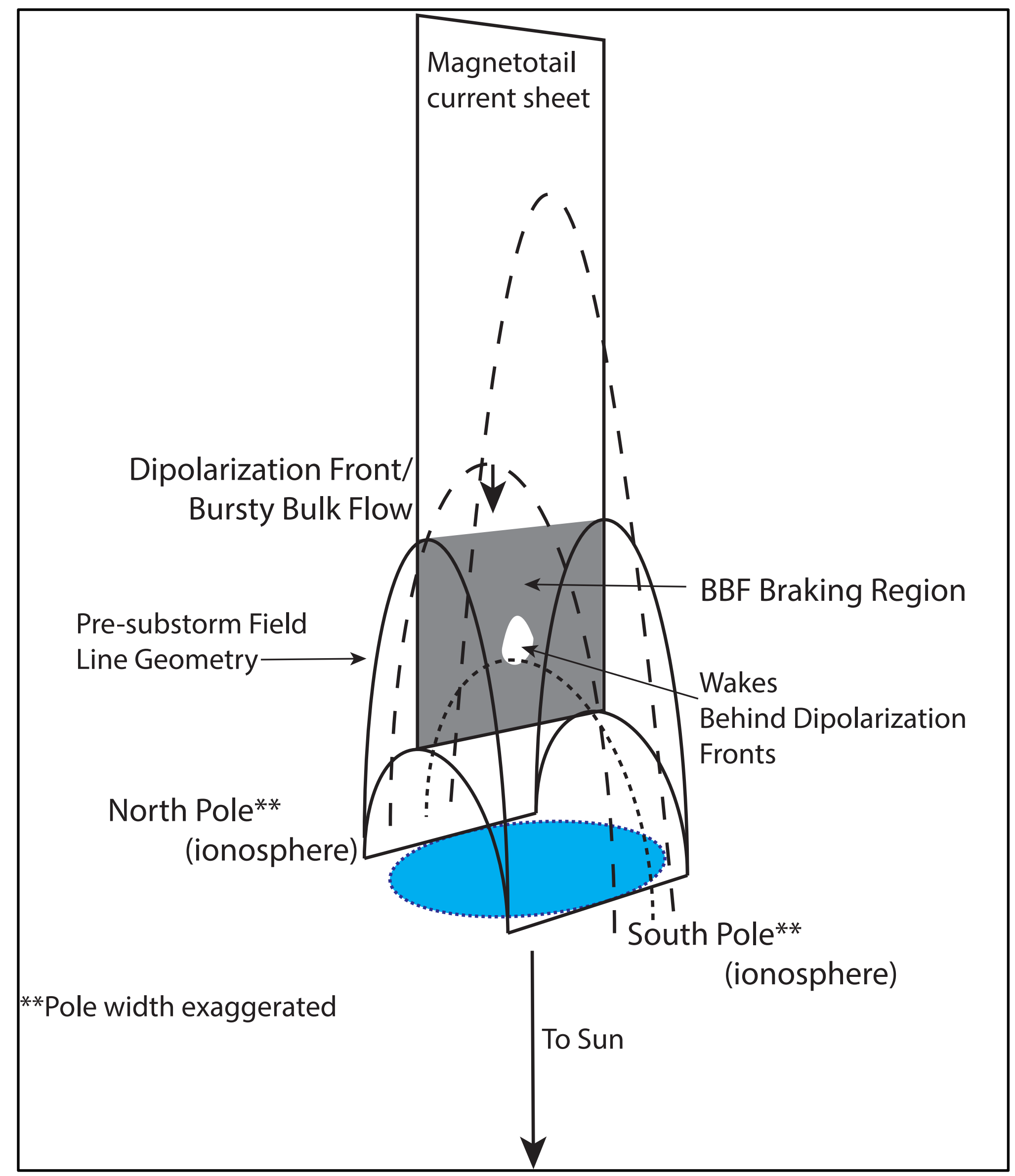
Note: Very different scales and plasma regimes.

Reeves et al. 2008

A Simplified **3-D** Solar Flare Model

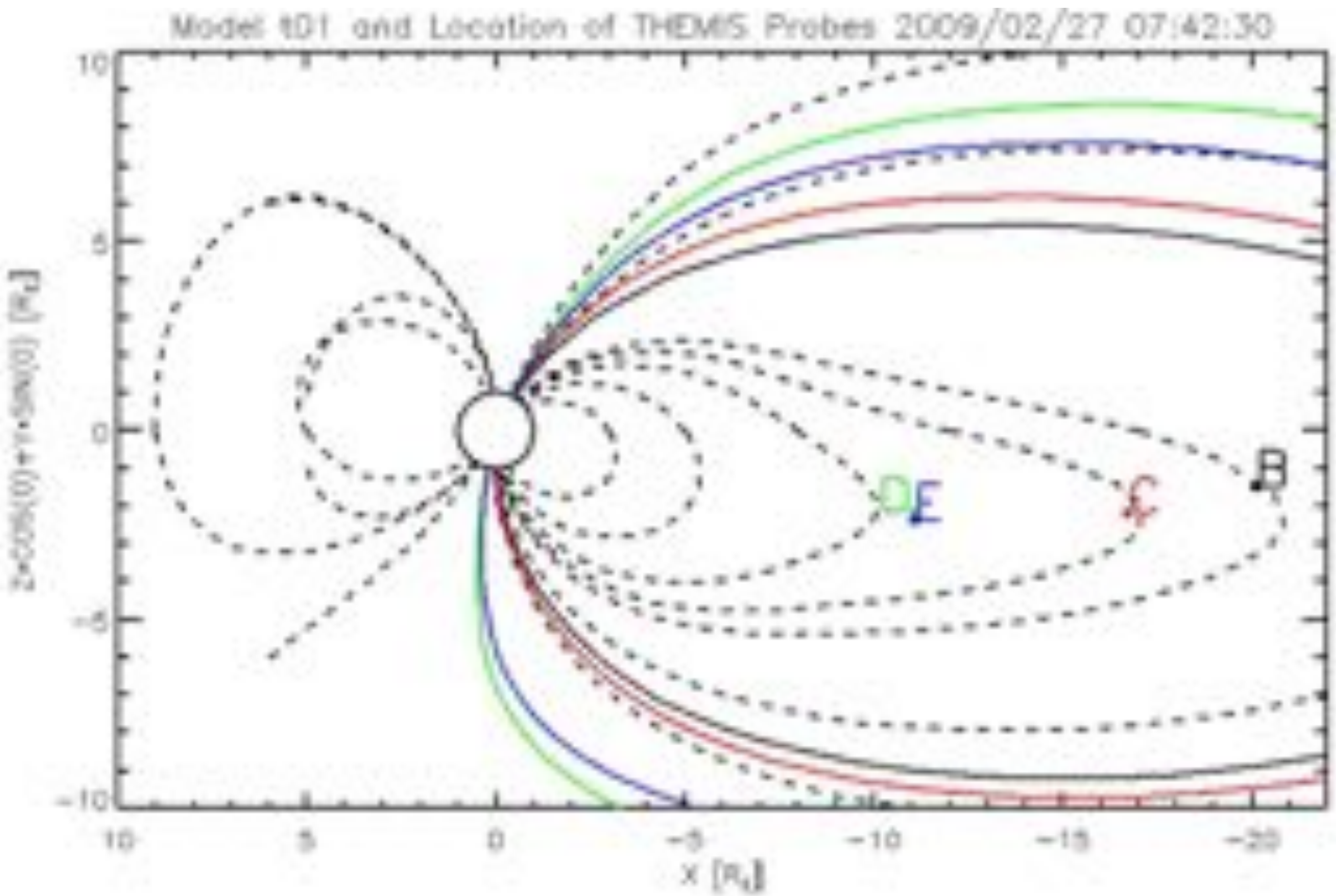


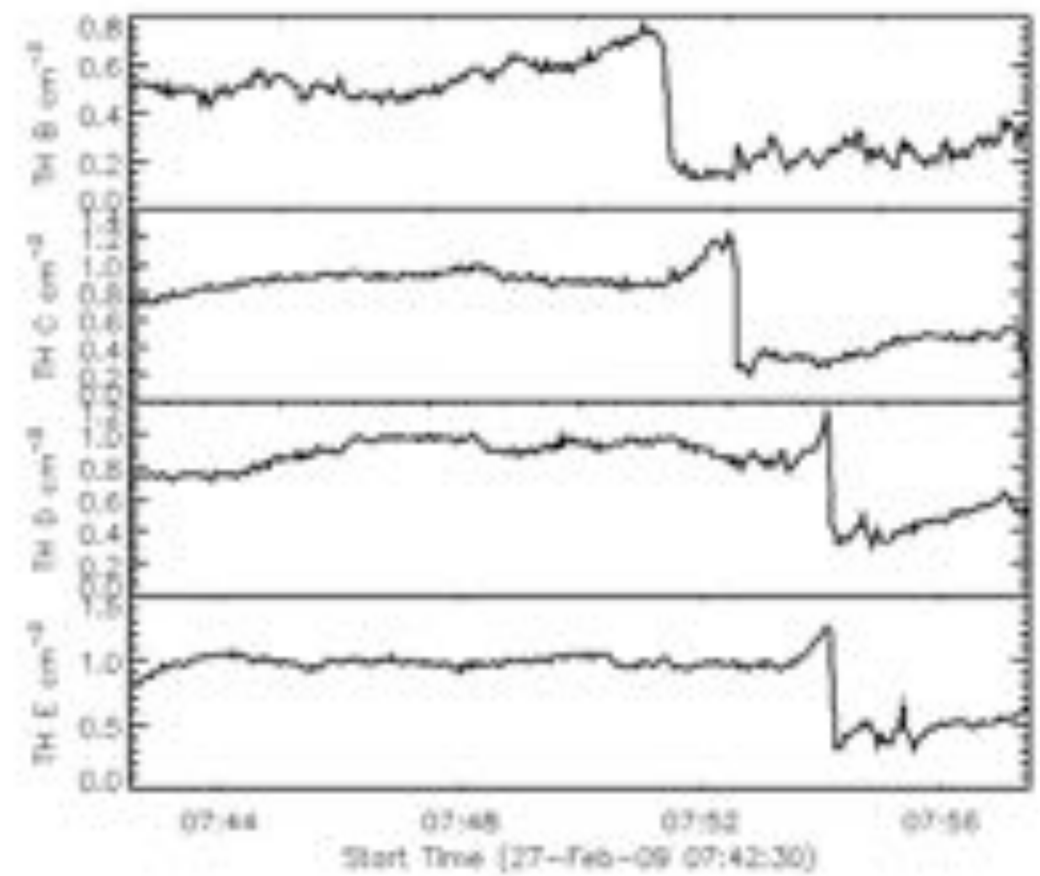
Strong potential analogy with magnetotail substorms



Savage et al. 2012

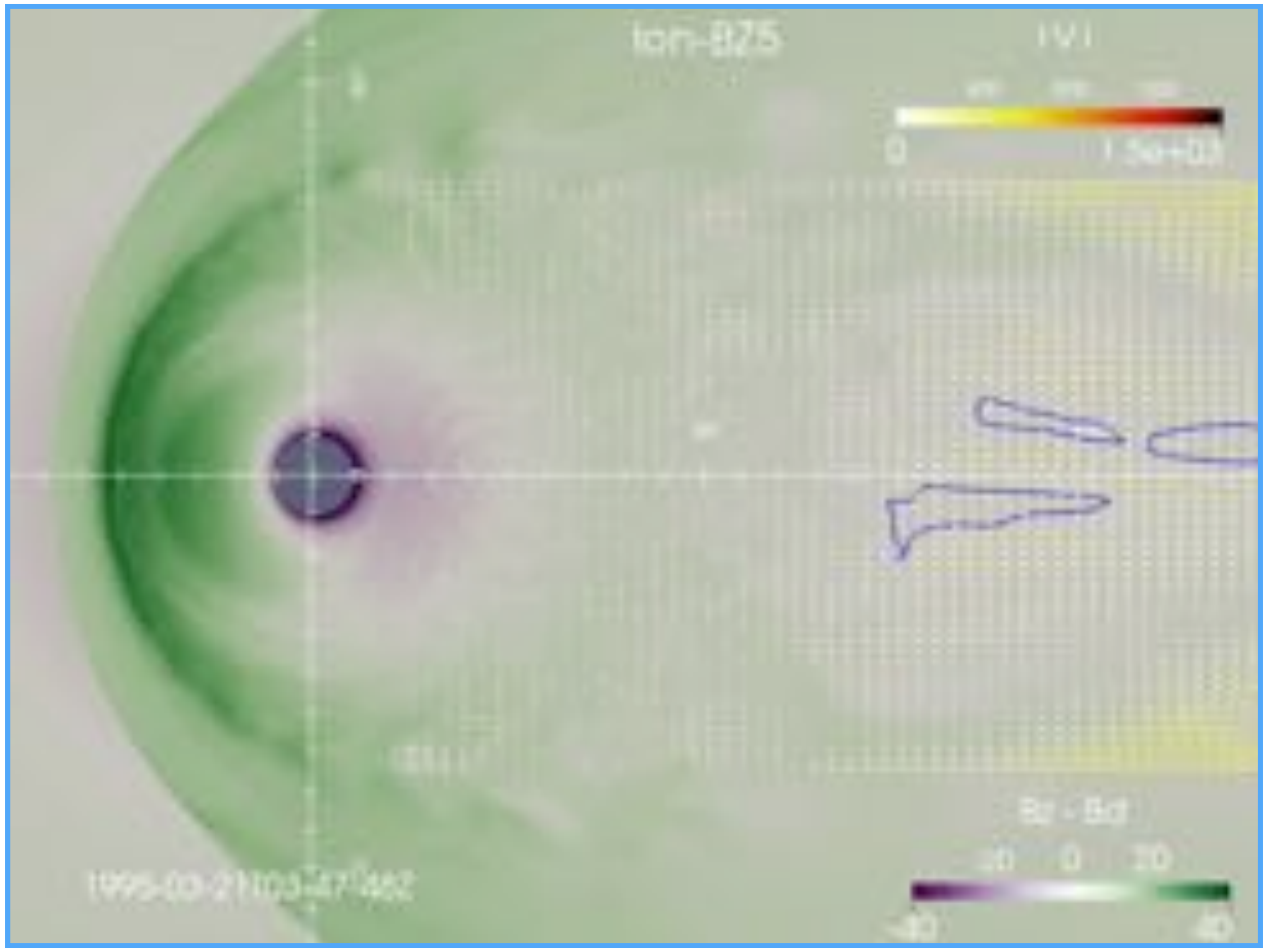
Observing Magnetic Reconnection

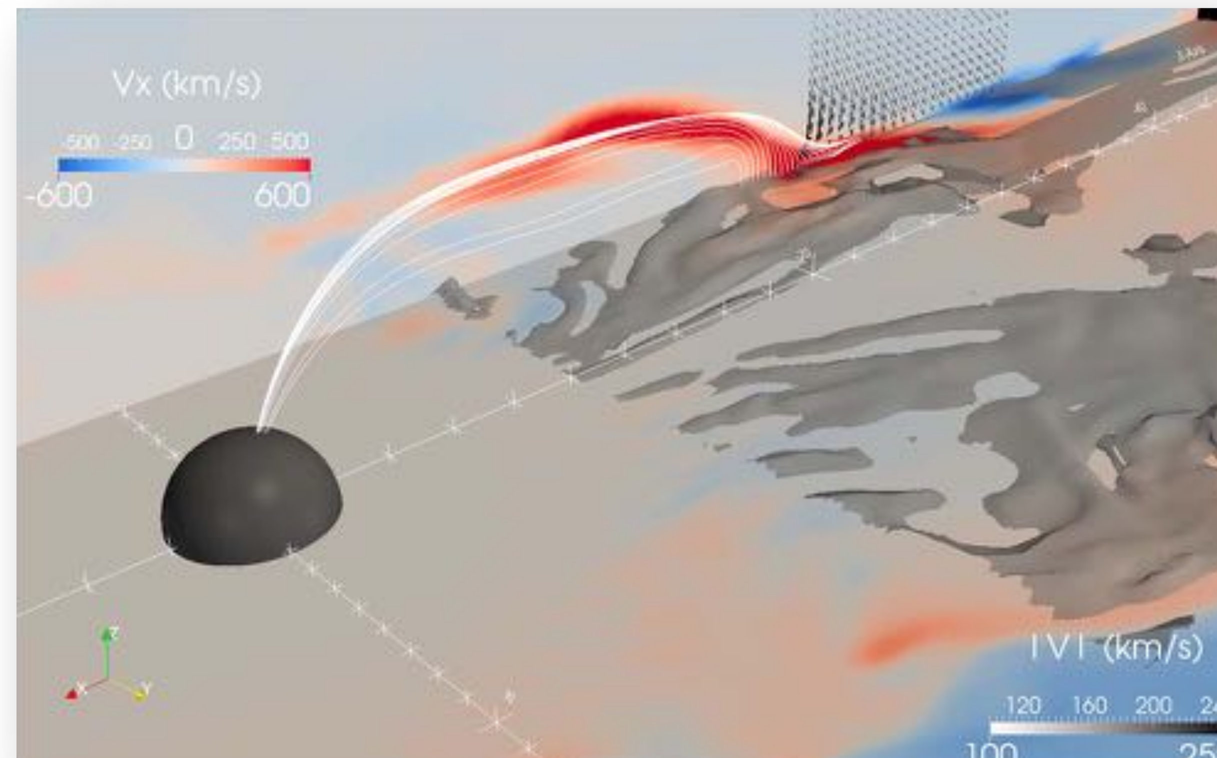




Substantial density drop following the dipolarization event!

Observing Magnetic Reconnection

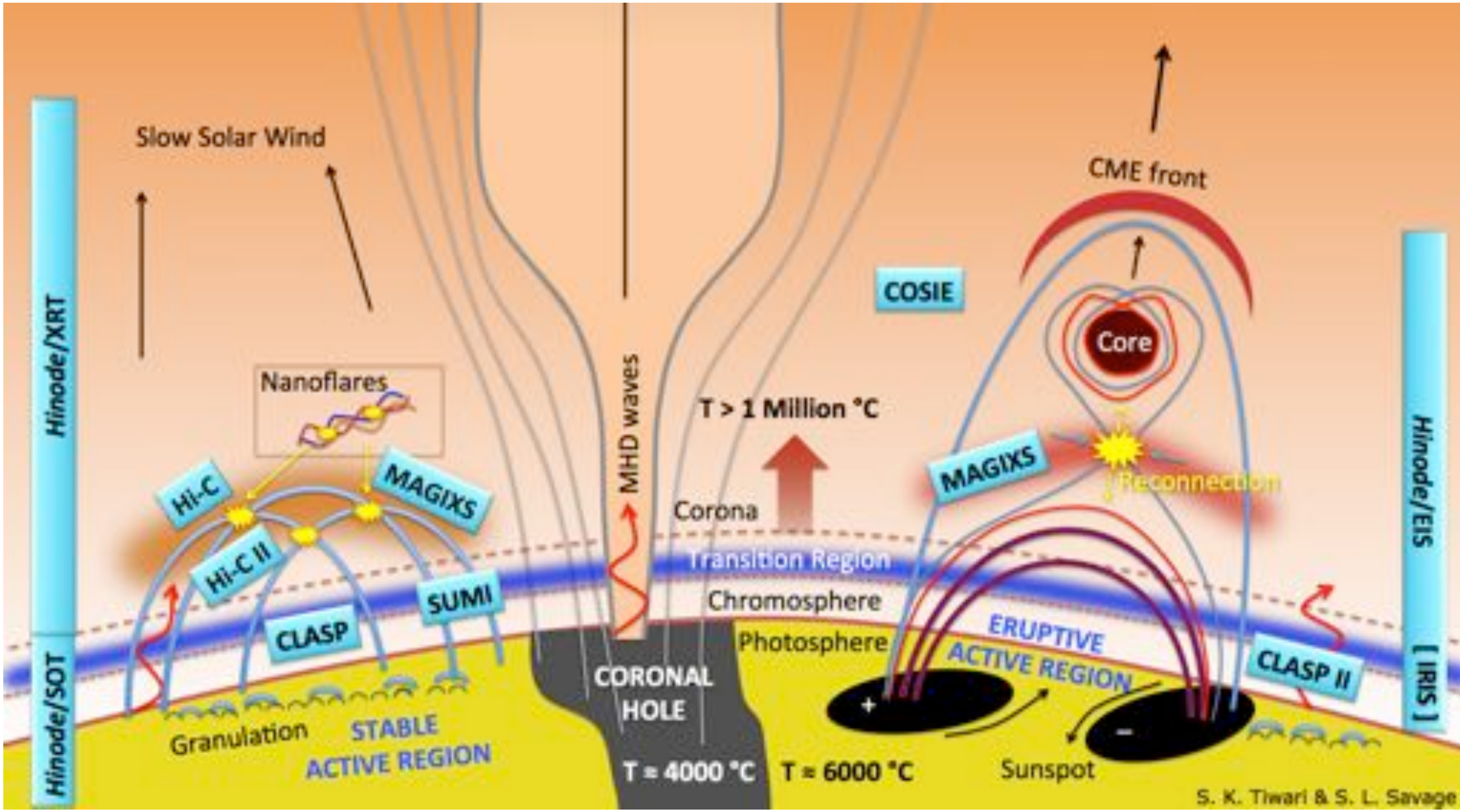




Wiltberger et al. 2015

Role of Marshall Space Flight Center

Role of Marshall Space Flight Center



We build and operate instruments and experiments in space!

Role of Marshall Space Flight Center

Hi-C

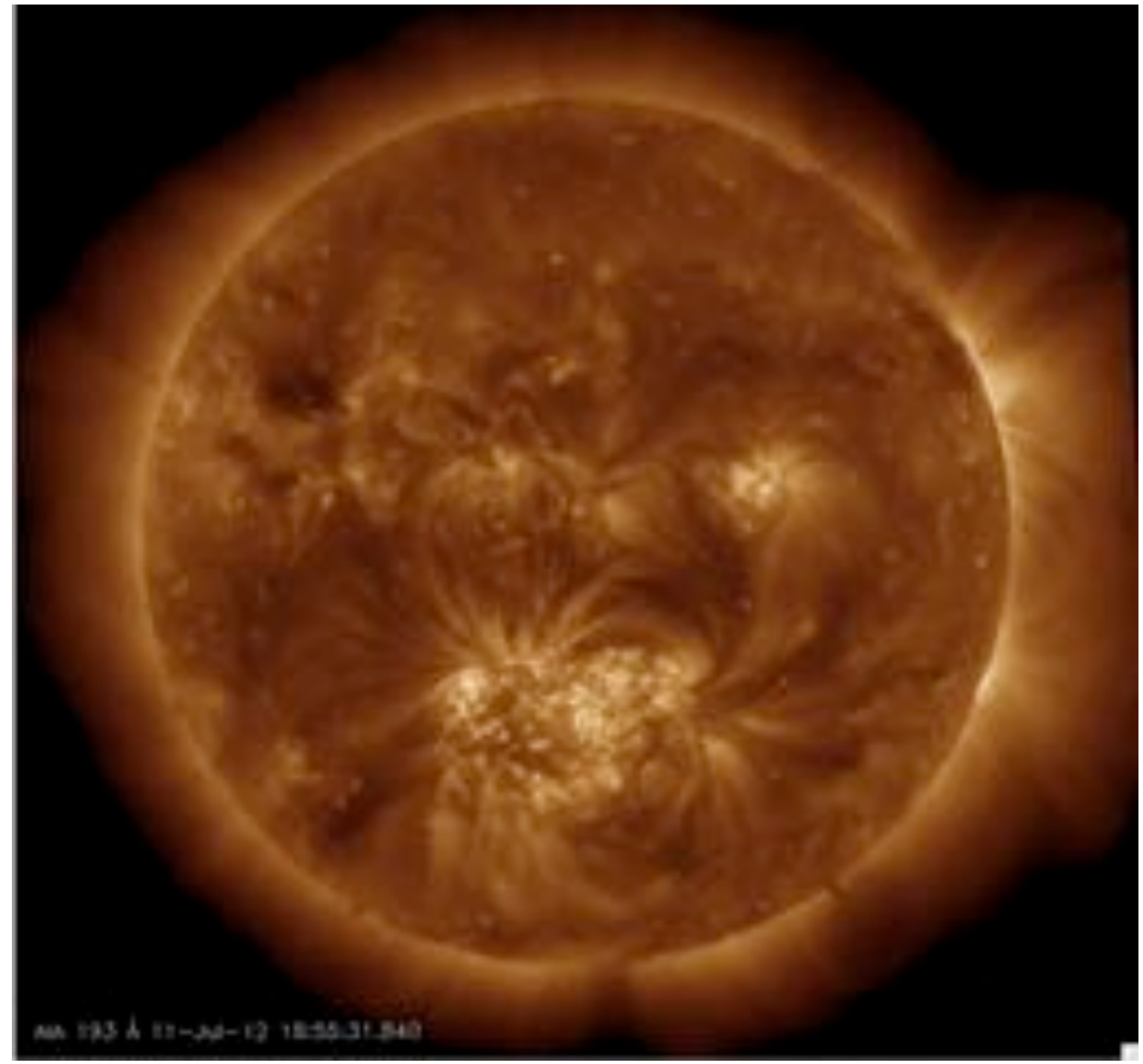
Active Region 11520
July 11, 2012

22 publications for 5 minutes of data!

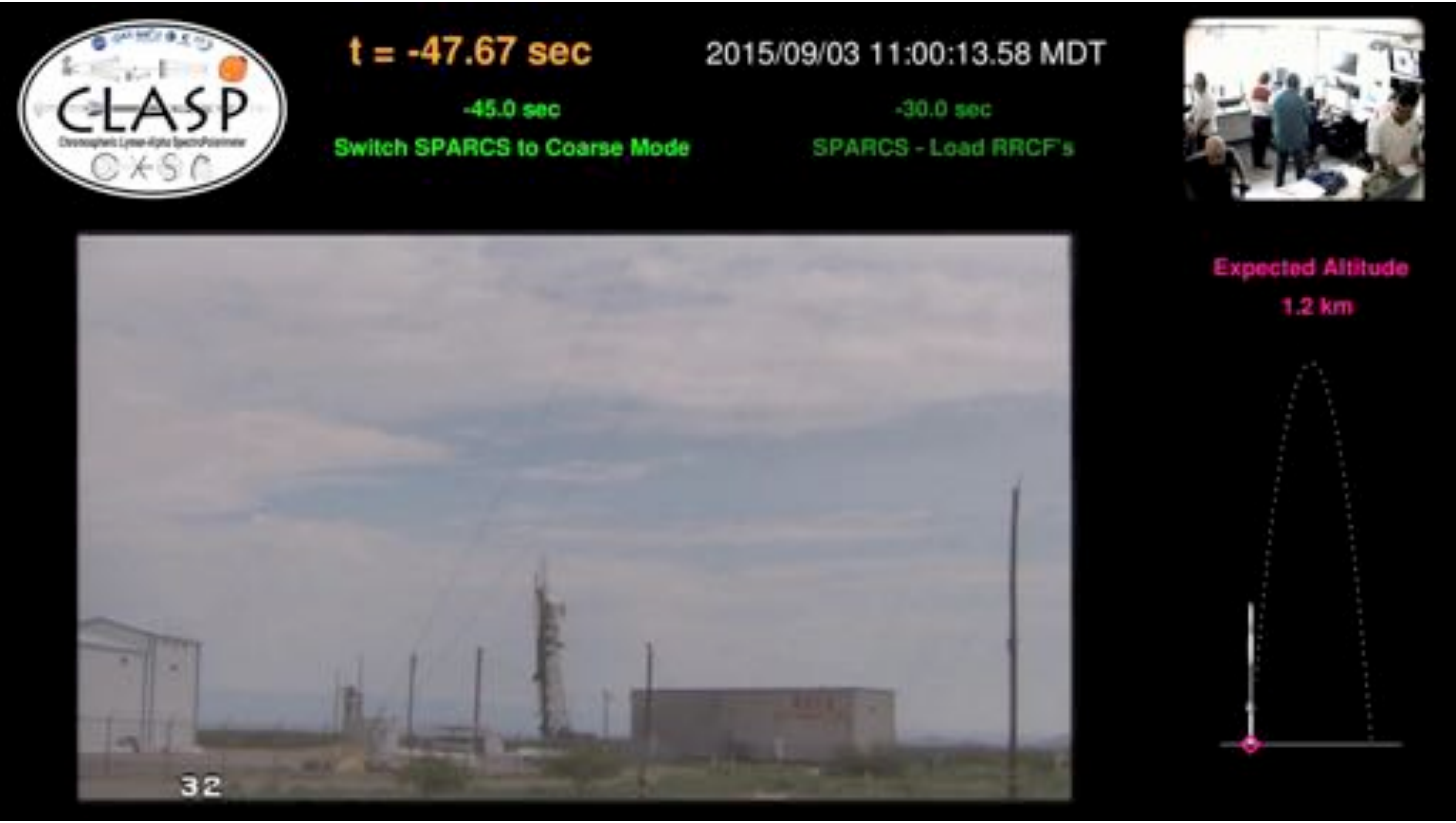
Science highlights:

Braided loops triggering energy release through magnetic reconnection (*Cirtain et al. 2013, Nature*)

Subflare triggers
Nanoflare heating
Loop sub-structure
Moss dynamics
Penumbral jets
Flows along filament threads
MHD waves



Sounding Rockets for Technology Development



CLASP sounding rocket launch

Role of Marshall Space Flight Center

Hi-C II rocket launch at White Sands Missile Range, New Mexico.

The Great American Solar Eclipse

August 21, 2017

National Aeronautics and Space Administration

What is a Solar Eclipse?

A **solar eclipse** happens when the Moon, as it orbits Earth, fully or partially blocks the light of the Sun, thus casting its shadow on Earth.

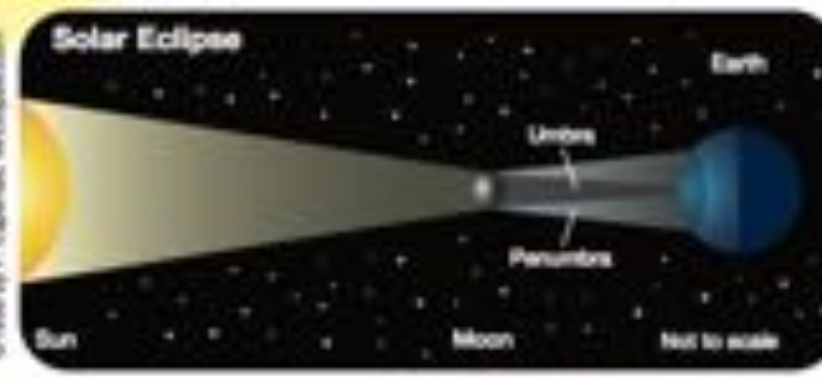
Observers within the path of totality can expect to see something like the image below. bservers outside the path of totality will see the Sun partially eclipsed as a crescent Sun (with safe filters).

Greatest Eclipse

Time	Location
10:17 a.m. PDT	Lincoln Beach, OR Depoe Bay, OR
11:26 a.m. MDT	Lime, ID
1:19 p.m. CDT	Valley View, MO Bloomsdale, MO
1:28 p.m. CDT	Calistia, TN
2:47 p.m. EDT	Bethera, SC

After the 2017 solar eclipse, the next **total solar eclipse** visible over the continental United States will be on **April 8, 2024.**

If the Sun is scaled to about 10 cm (3.9 in), Earth would be about 10 meters away (33 feet).



The predicted path of the August 21, 2017 solar eclipse

Duration of Greatest Eclipse:
2 min 40 sec
(18:25 UT=13:25 CDT or 1:25 p.m. CDT)

Location Greatest Eclipse:
36 deg 58 min N; 87 deg 40 min W
(between Princeton and Hopkinsville, KY)

Path Width: **approximately 115 km**

Eclipse Predictions by Fred Espenak, GSFC, NASA-emeritus

The NASA image above shows the Moon's umbral shadow as seen from the International Space Station during the total solar eclipse on 29 March 2006.

Never look directly at the Sun unless you have filters that you know are safe.

For more information: http://eclipse/gsfc.nasa.gov/SEhelp/safety.html

For more information about solar eclipses: http://eclipse.gsfc.nasa.gov/solar.html
http://eclipsewise.com/solar
http://eclipse2017.org/

www.nasa.gov

Mitzi Adams • *mitzi.adams@nasa.gov* • **256-961-7626**

Thanks!