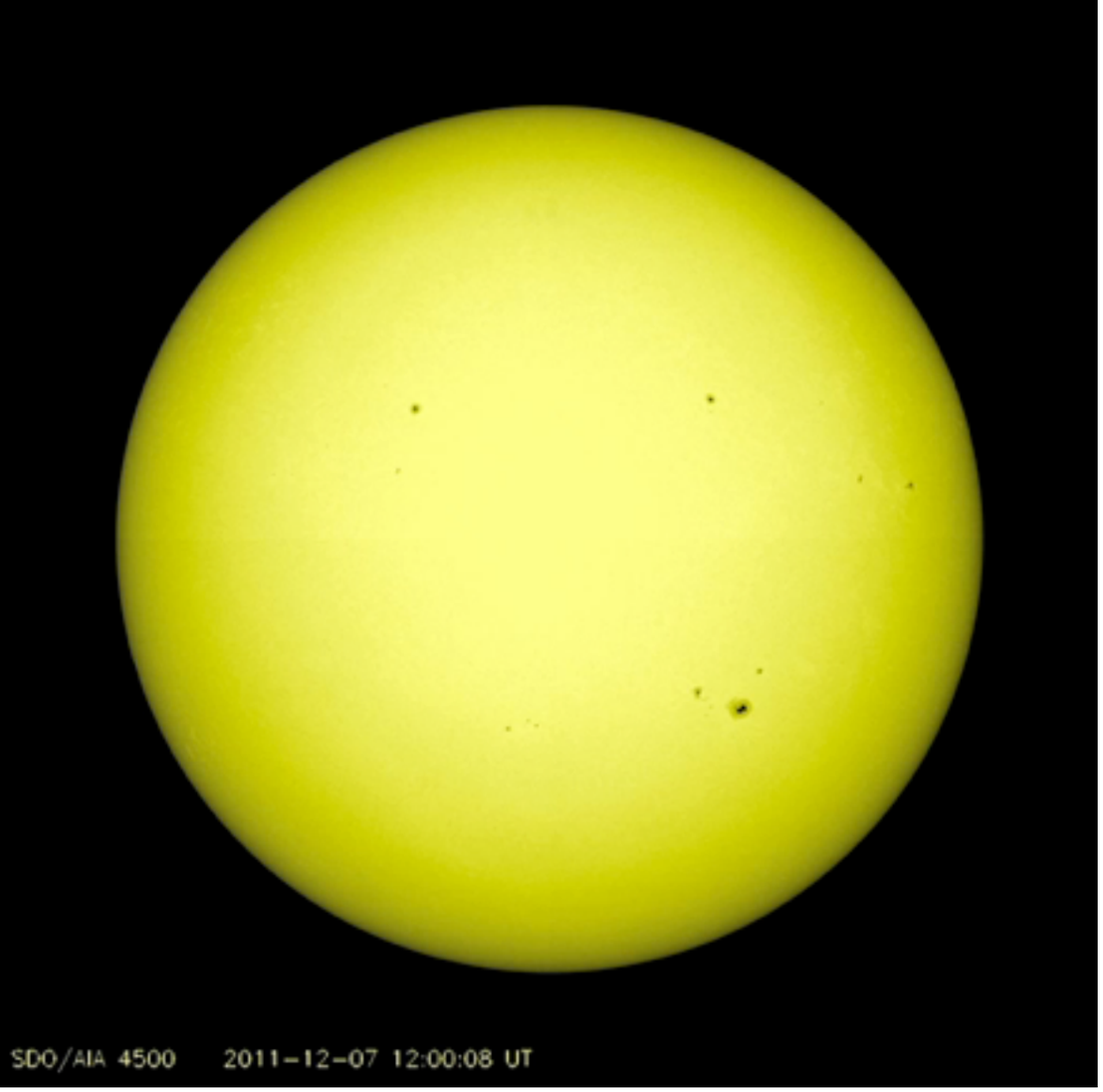


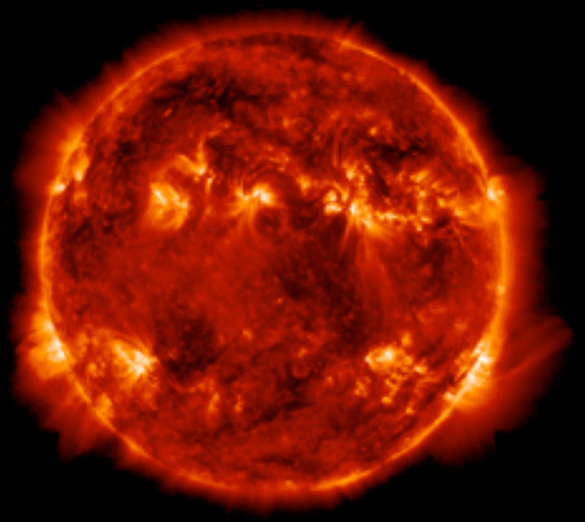
Solar Flares

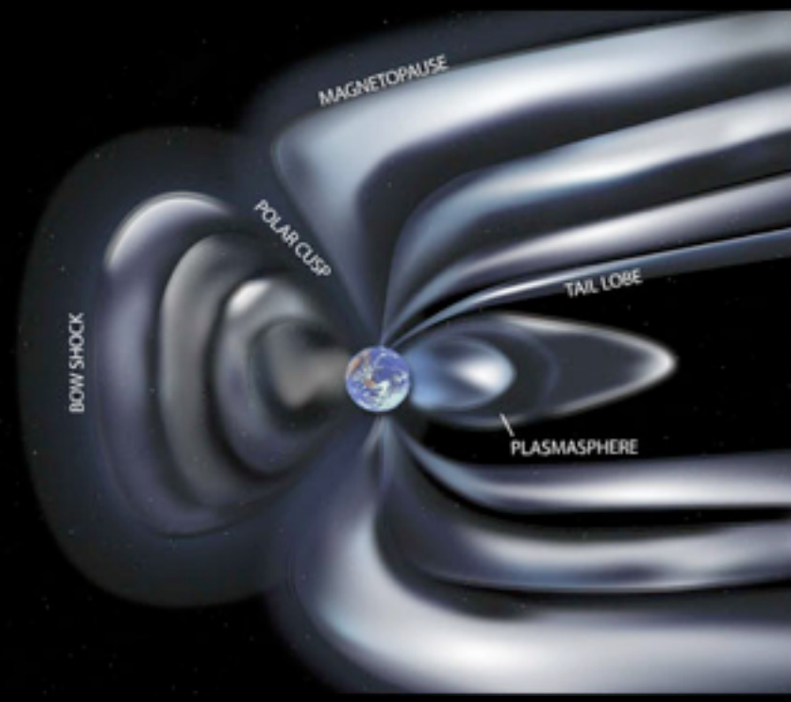
Sabrina Savage (NASA/MSFC)

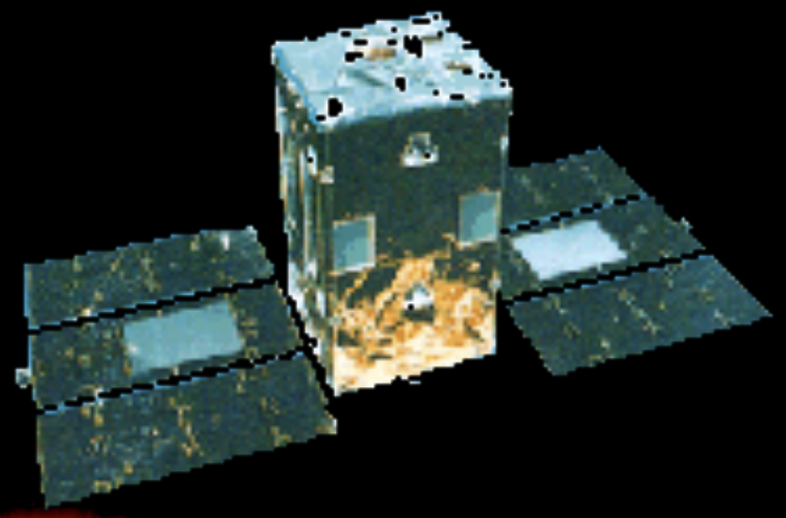
Heliophysics System Observatory (HSO)

- 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/

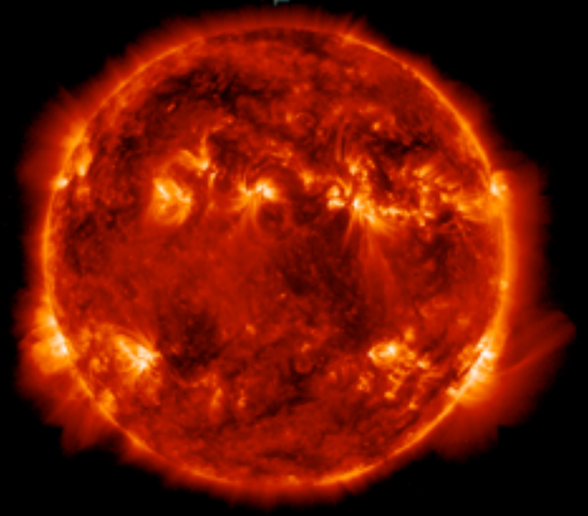


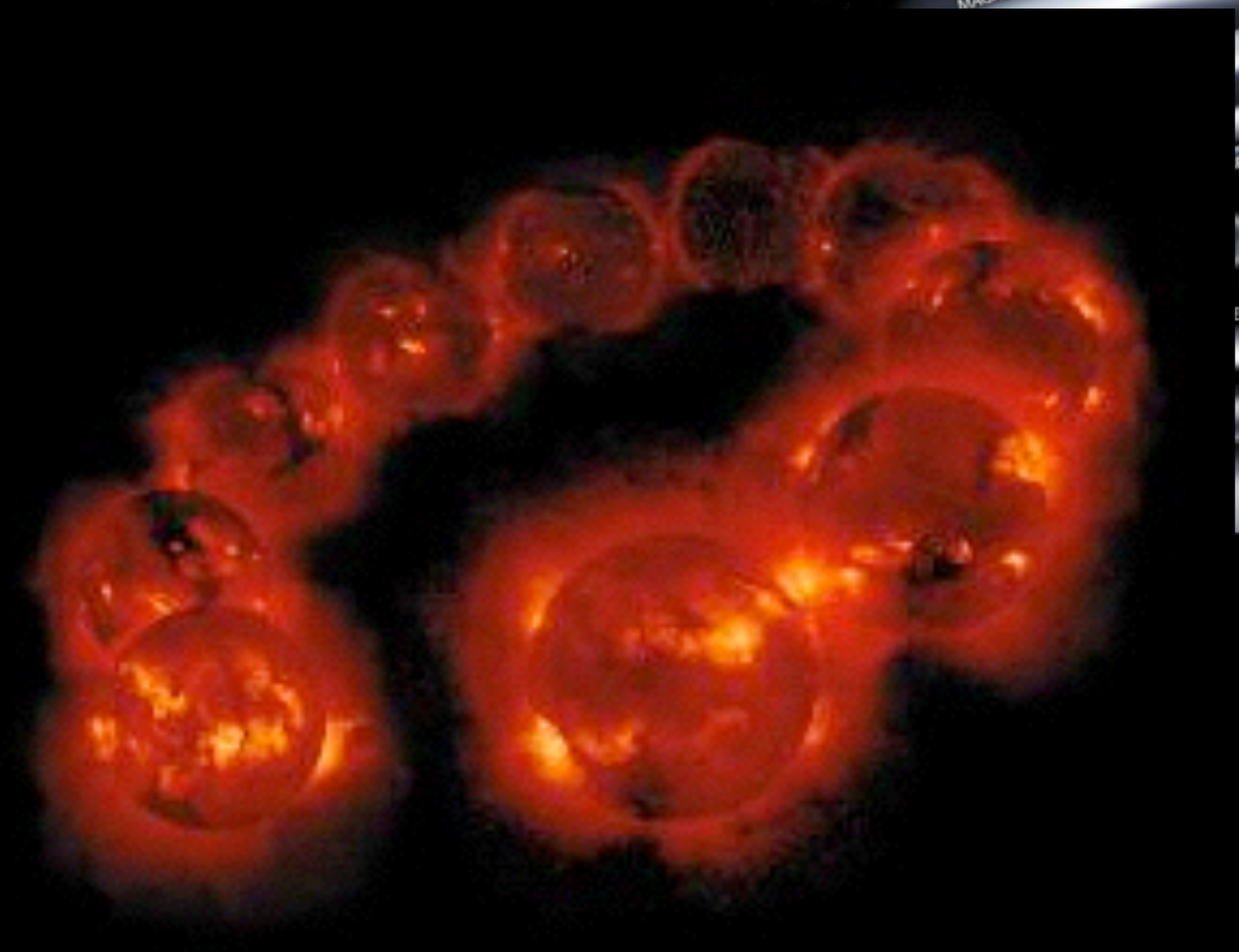

MAGNETOPAUSE
POLAR CUSP
BOW SHOCK
TAIL LOBE
PLASMASPHERE



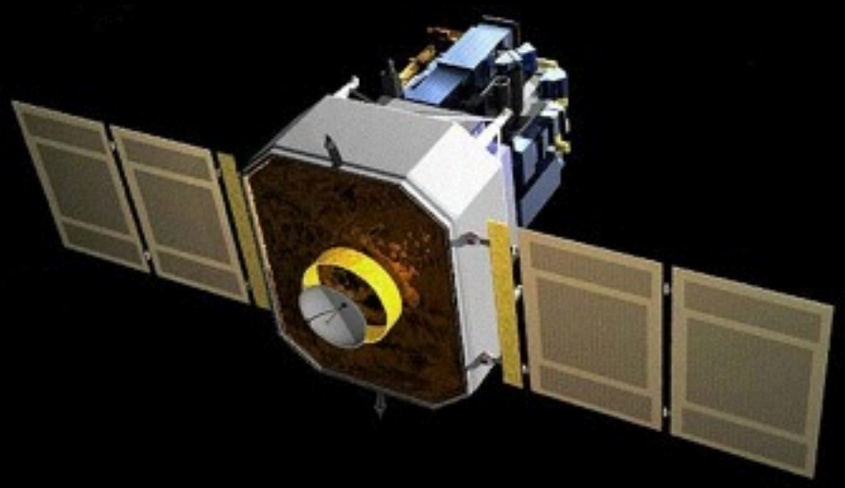
Yohkoh
[SXT/HXT]

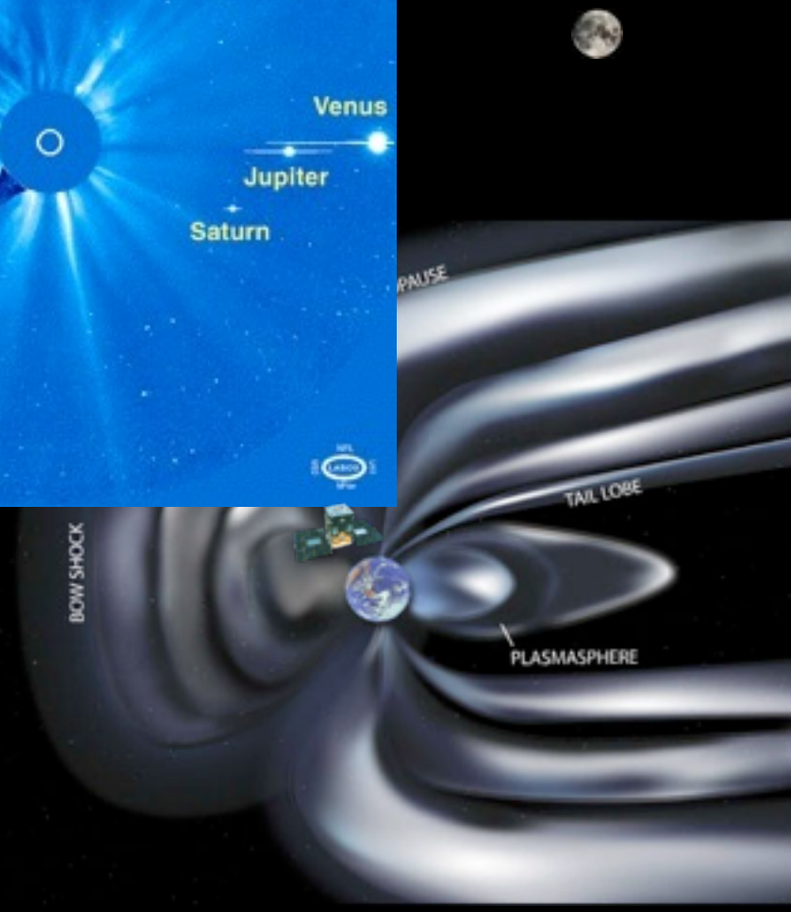
1991 - 2001





Yohkoh: http://www.lmsal.com/SXT/homepage.html — partnership with Japanese/UK/European space agencies

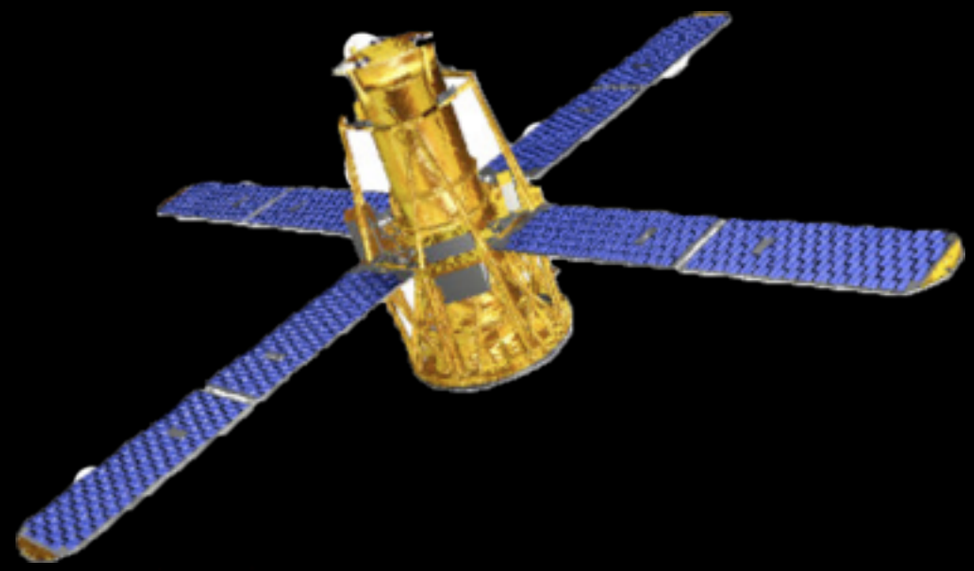




SOHO
[LASCO/EIT/SUMER/MDI]

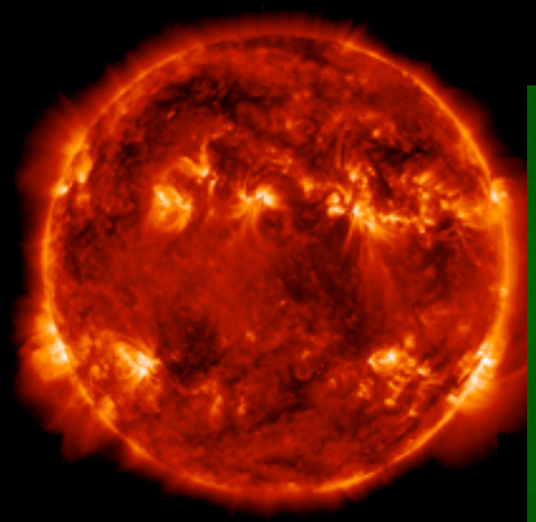
1995 -

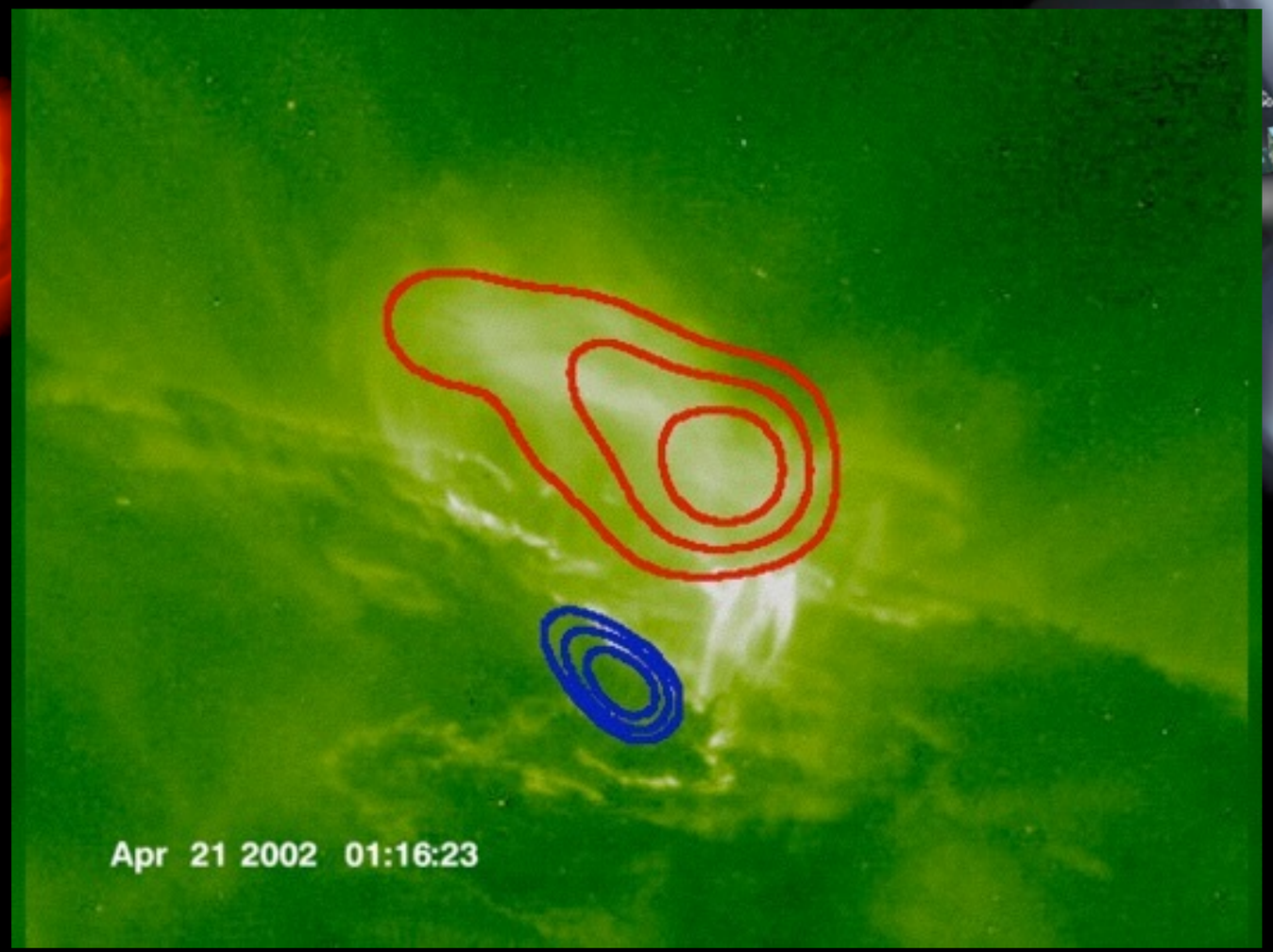
Solar and Heliospheric Observatory (SOHO): http://sohowww.nascom.nasa.gov/

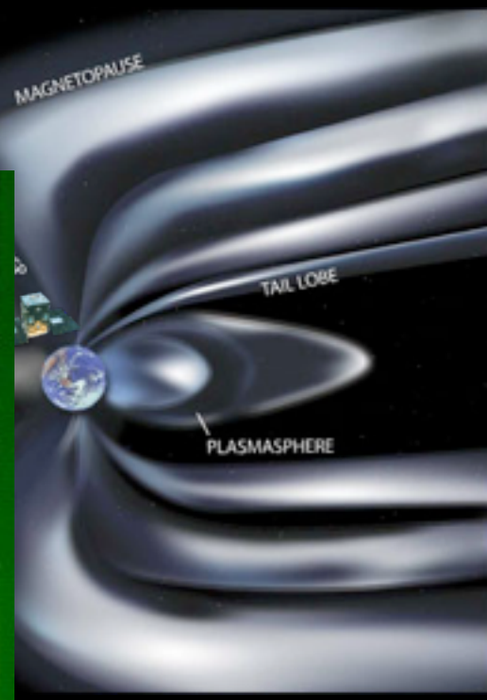


RHESSI

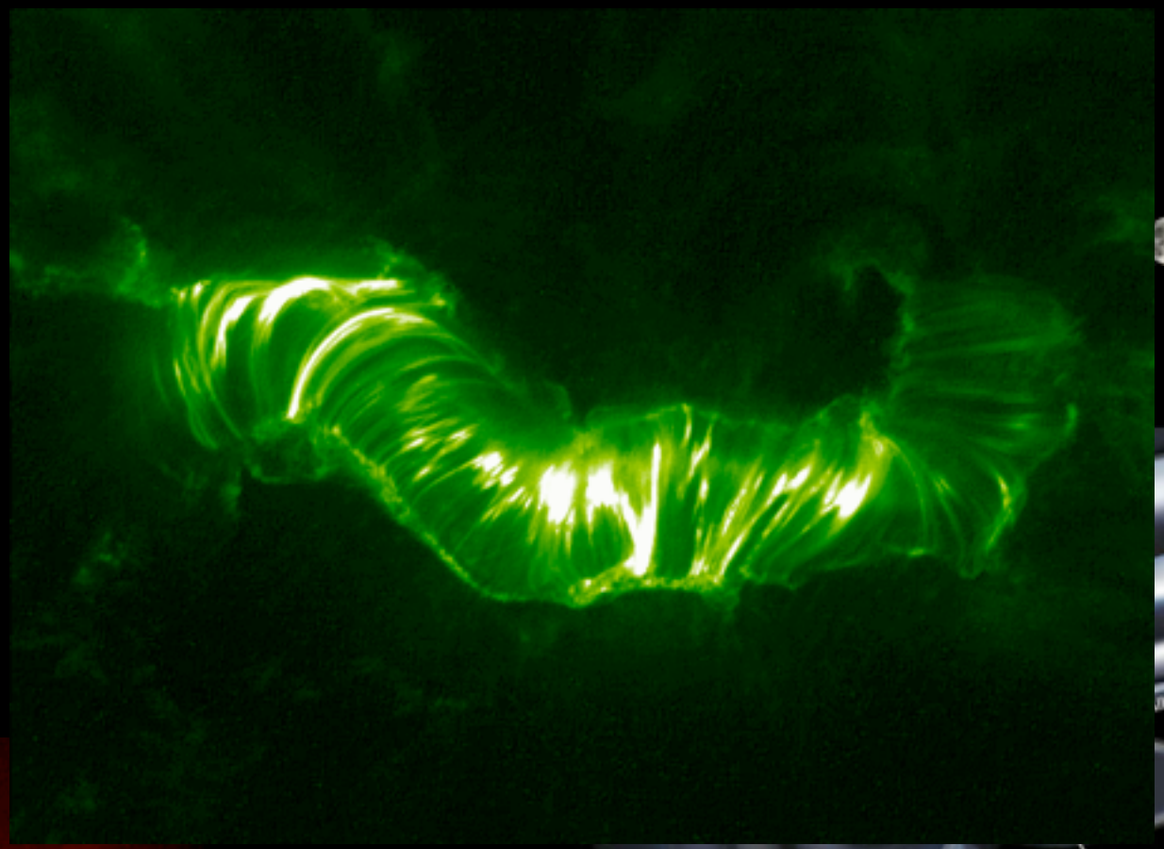
2002 -

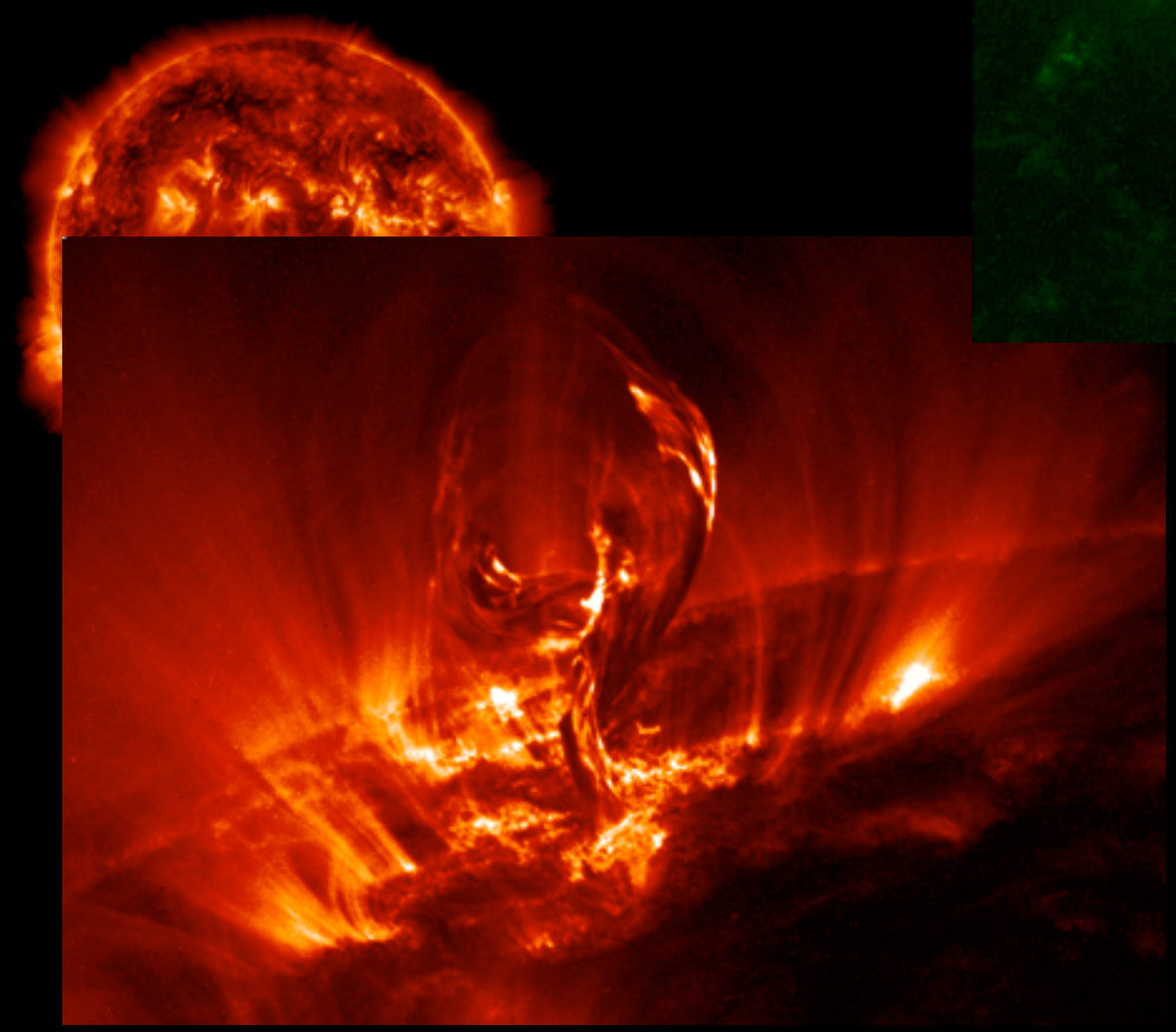






Reuven Ramaty High Energy Solar Spectroscopic Imager (RHESSI): http://hesperia.gsfc.nasa.gov/rhessi2/

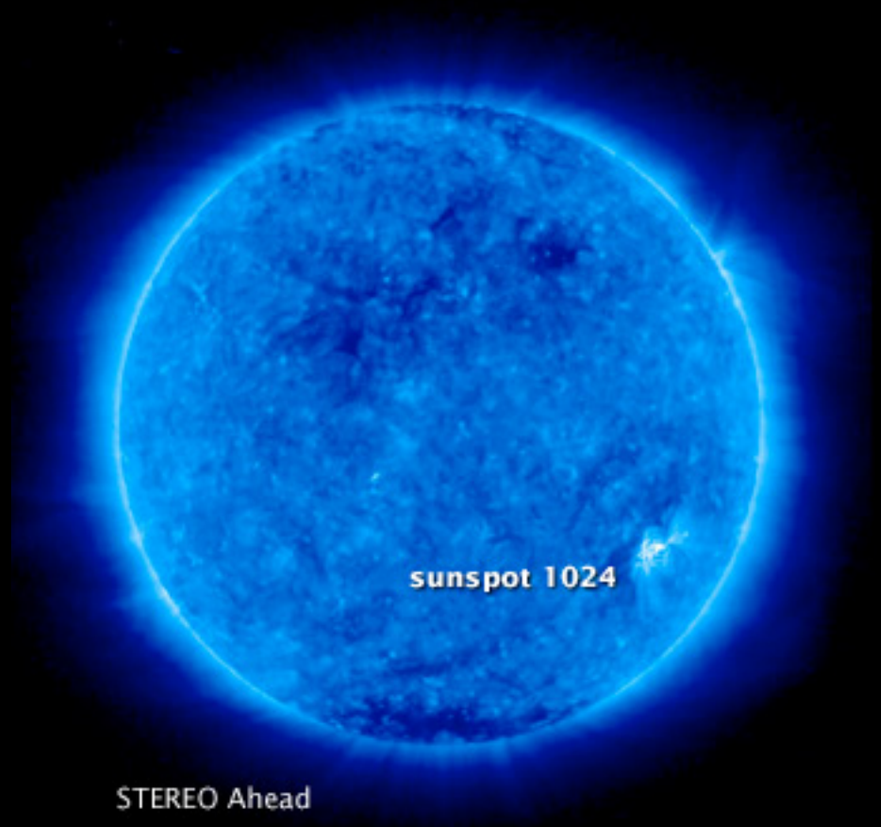




TRACE

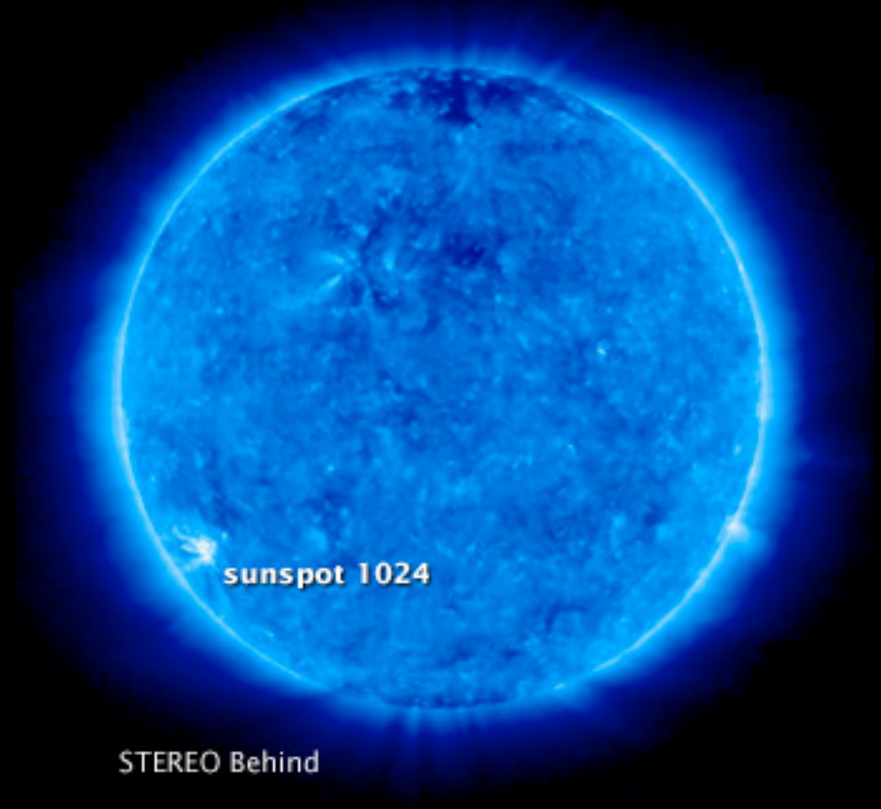
1998 - 2010

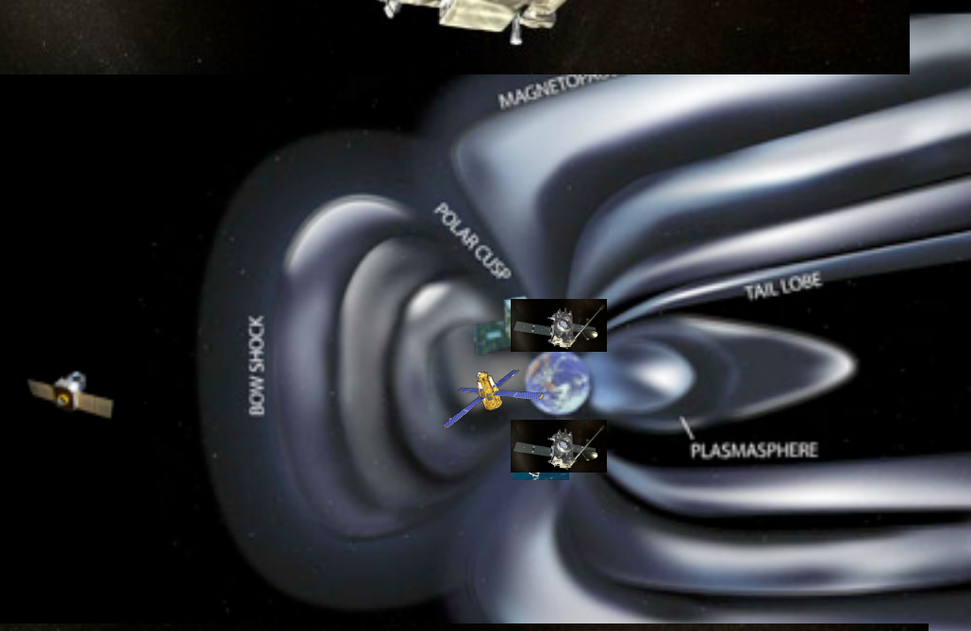
Transition Region and Coronal Explorer (TRACE): http://trace.lmsal.com/



STEREO
[SECCHI]

2006 -

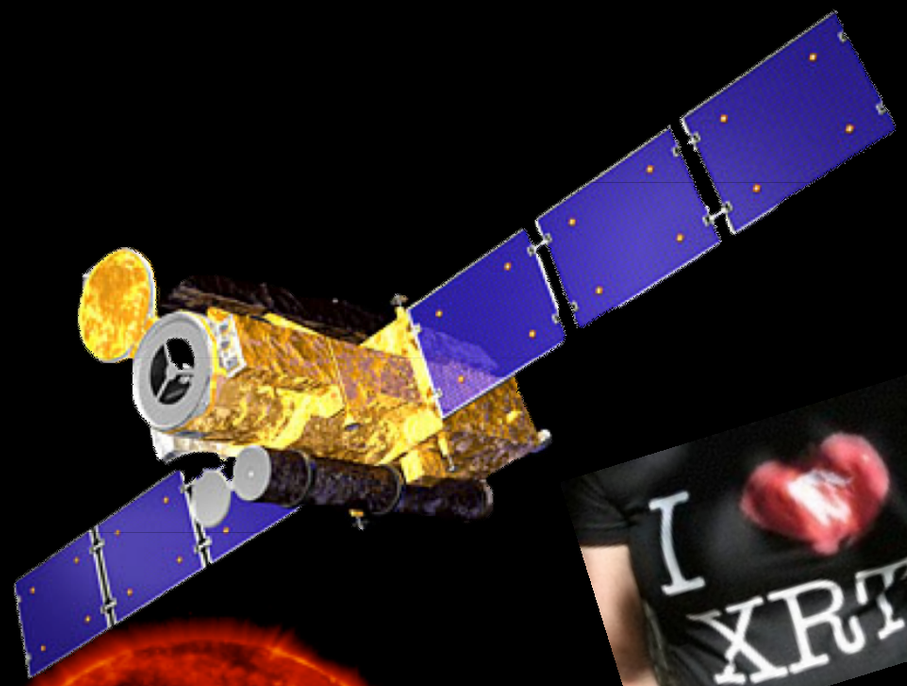


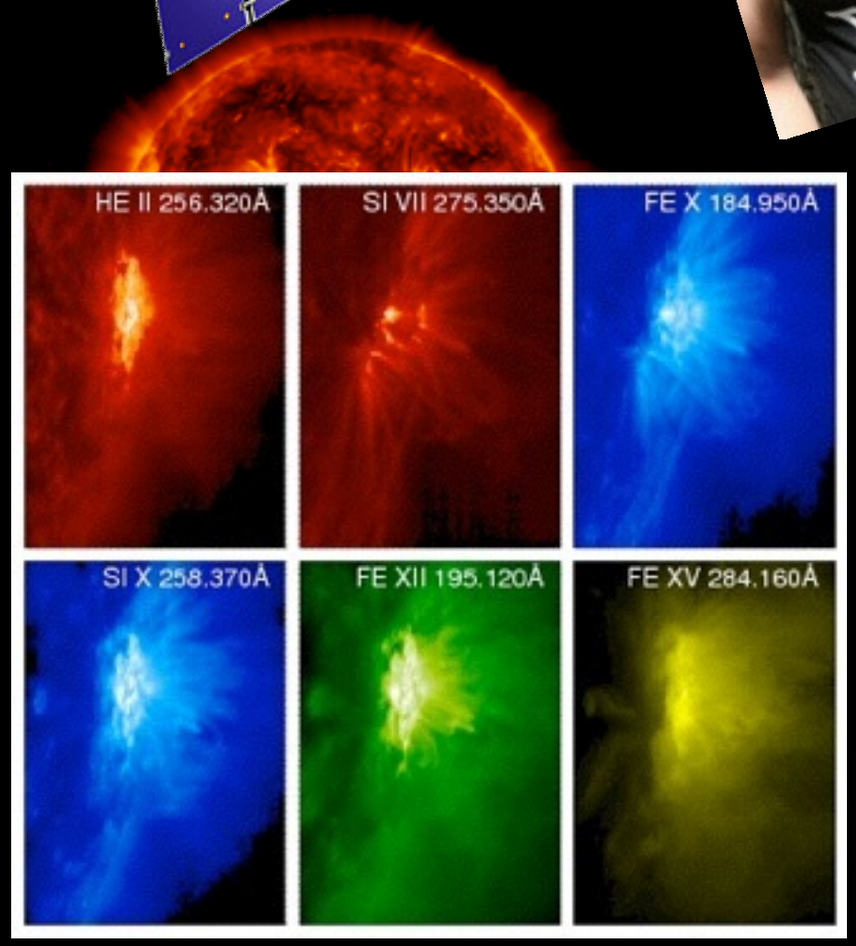


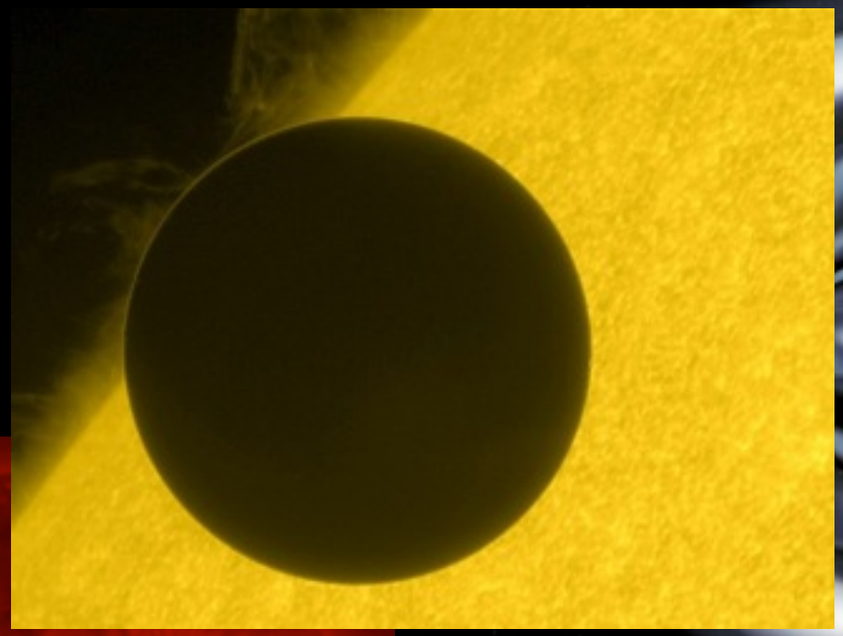
Solar Terrestrial Relations Observatory (STEREO): http://stereo.gsfc.nasa.gov/

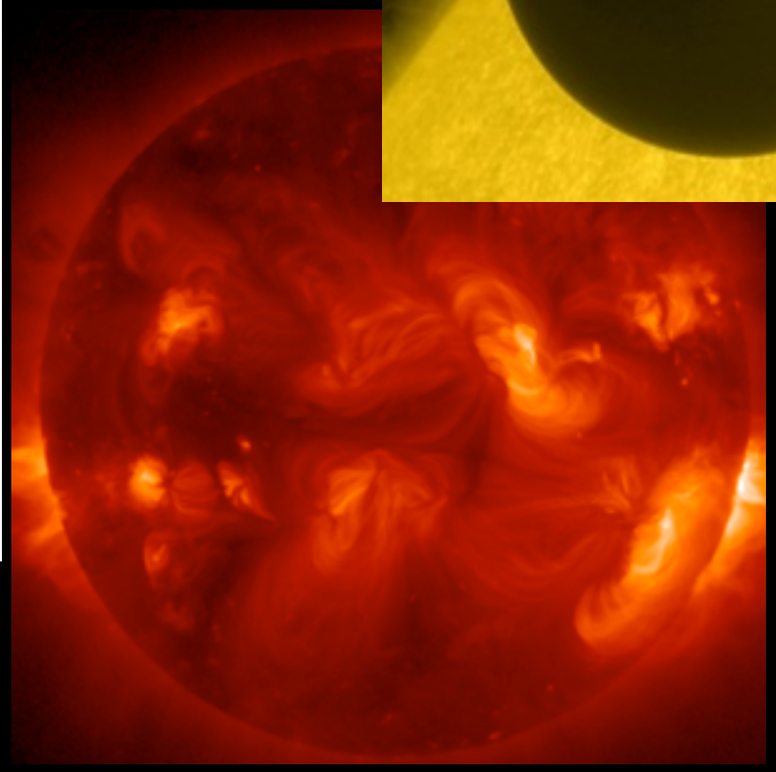
Hinode
[SOT/EIS/XRT]

2006 -





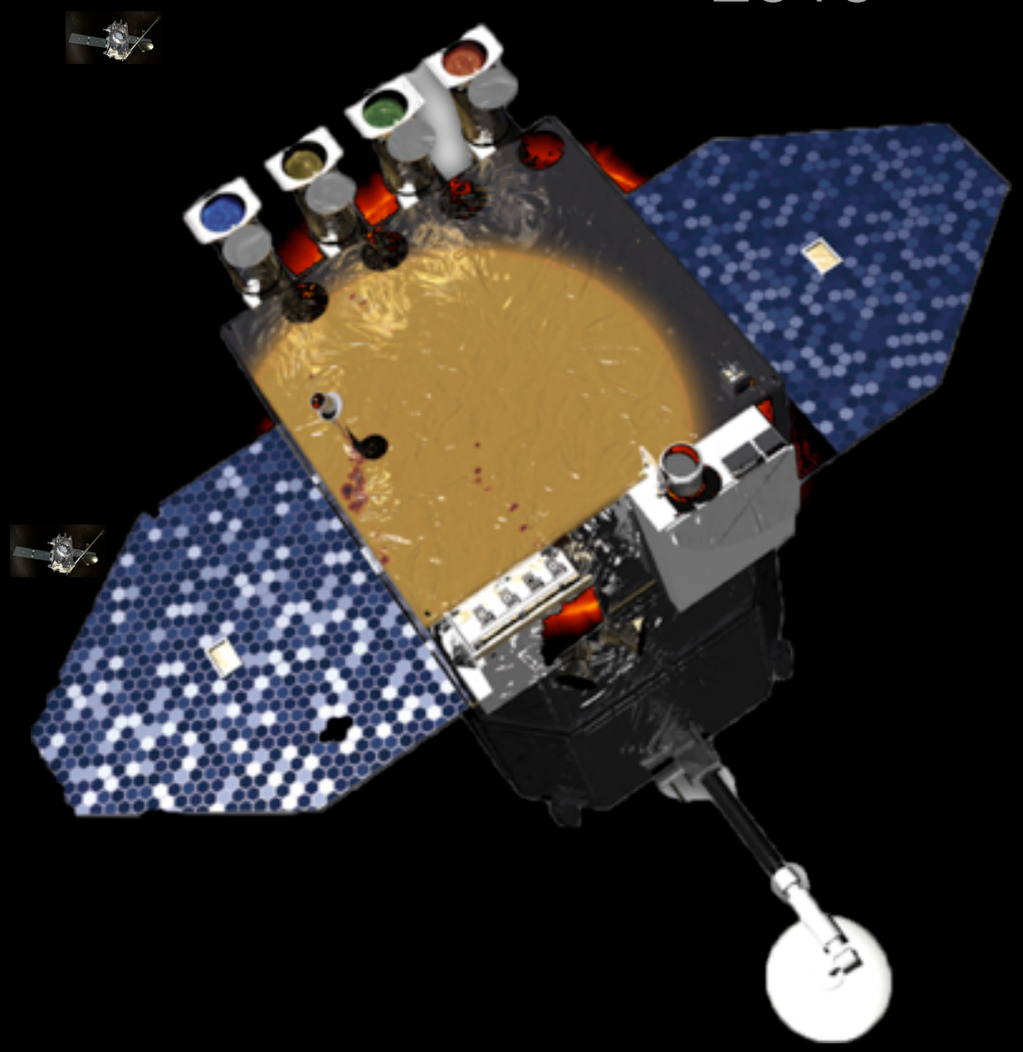


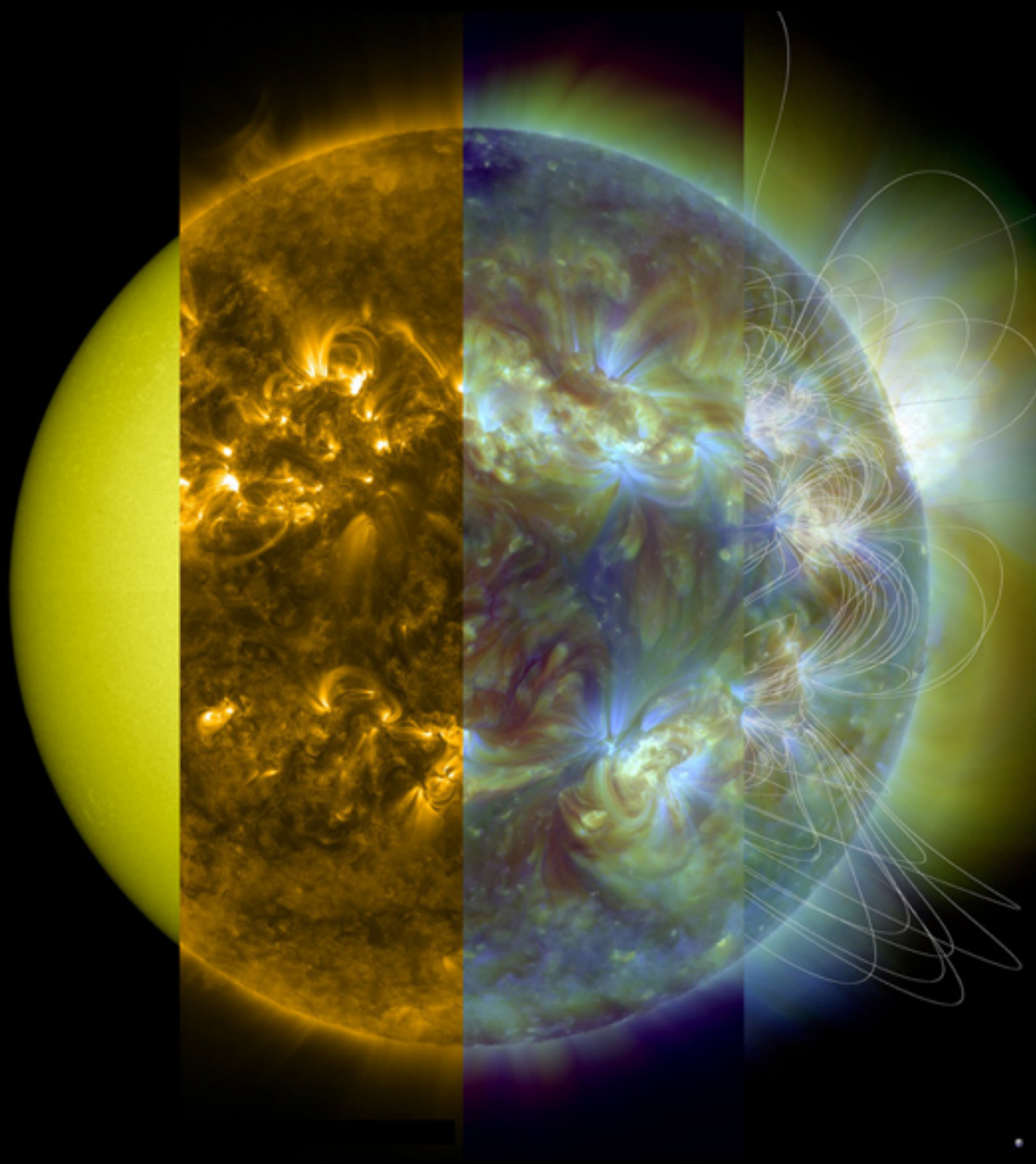


Hinode: http://hinode.msfc.nasa.gov/ — partnership with Japanese/UK/European space agencies

SDO:
[AIA/HMI]

2010 -

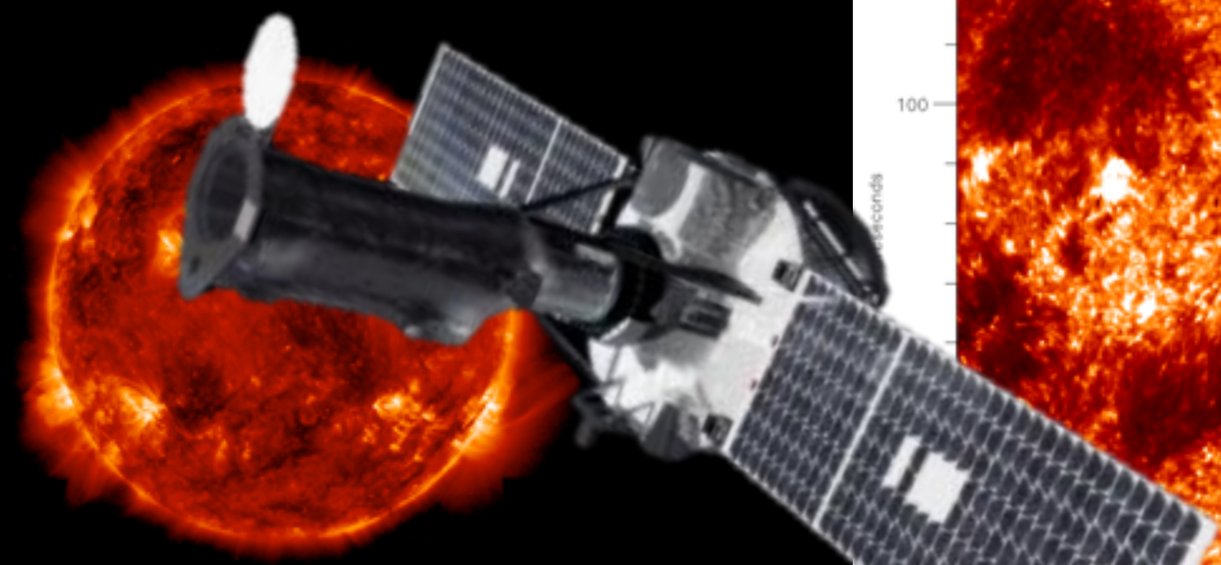


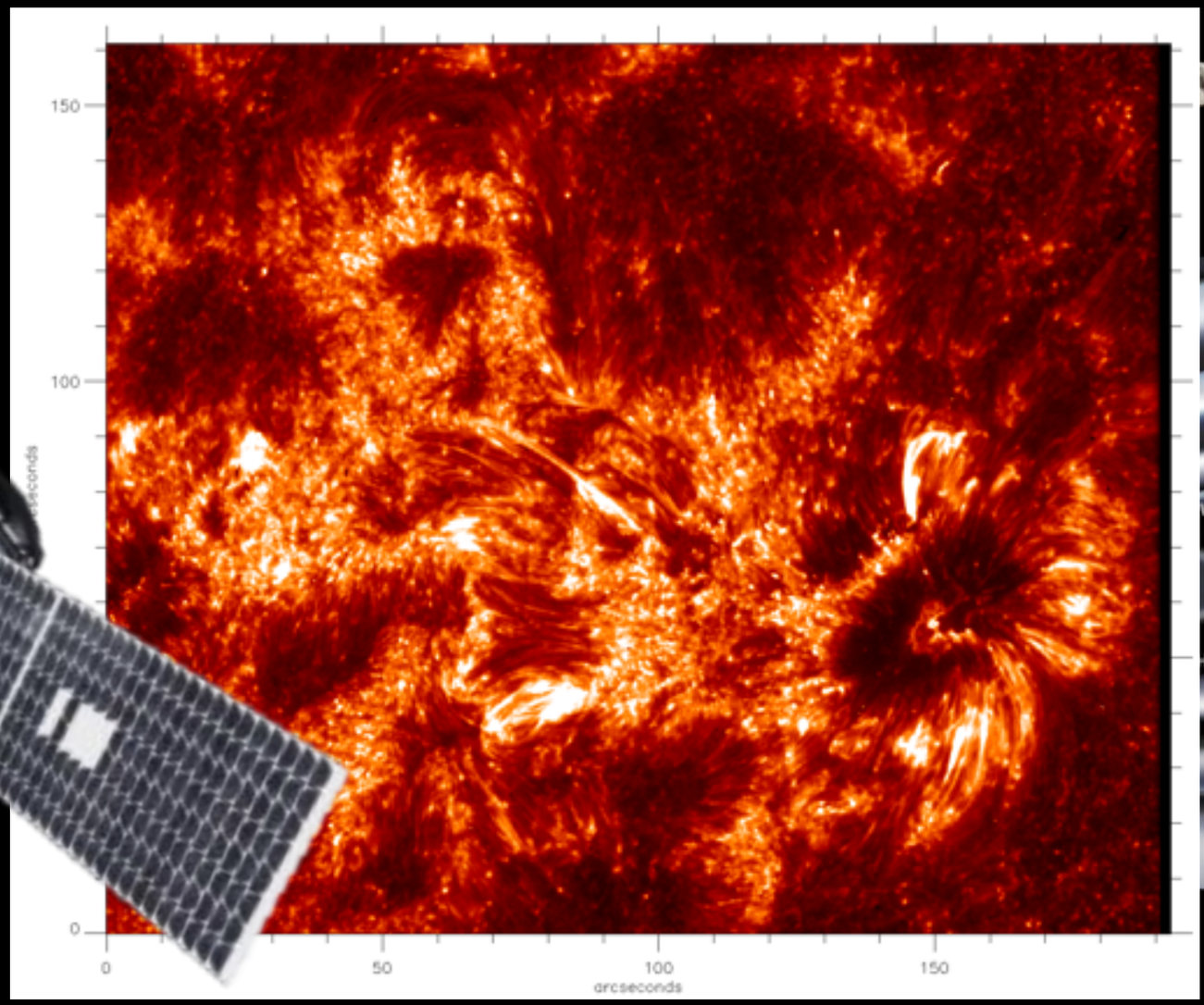


Solar Dynamics Observatory (SDO): http://sdo.gsfc.nasa.gov/

IRIS

2013 -

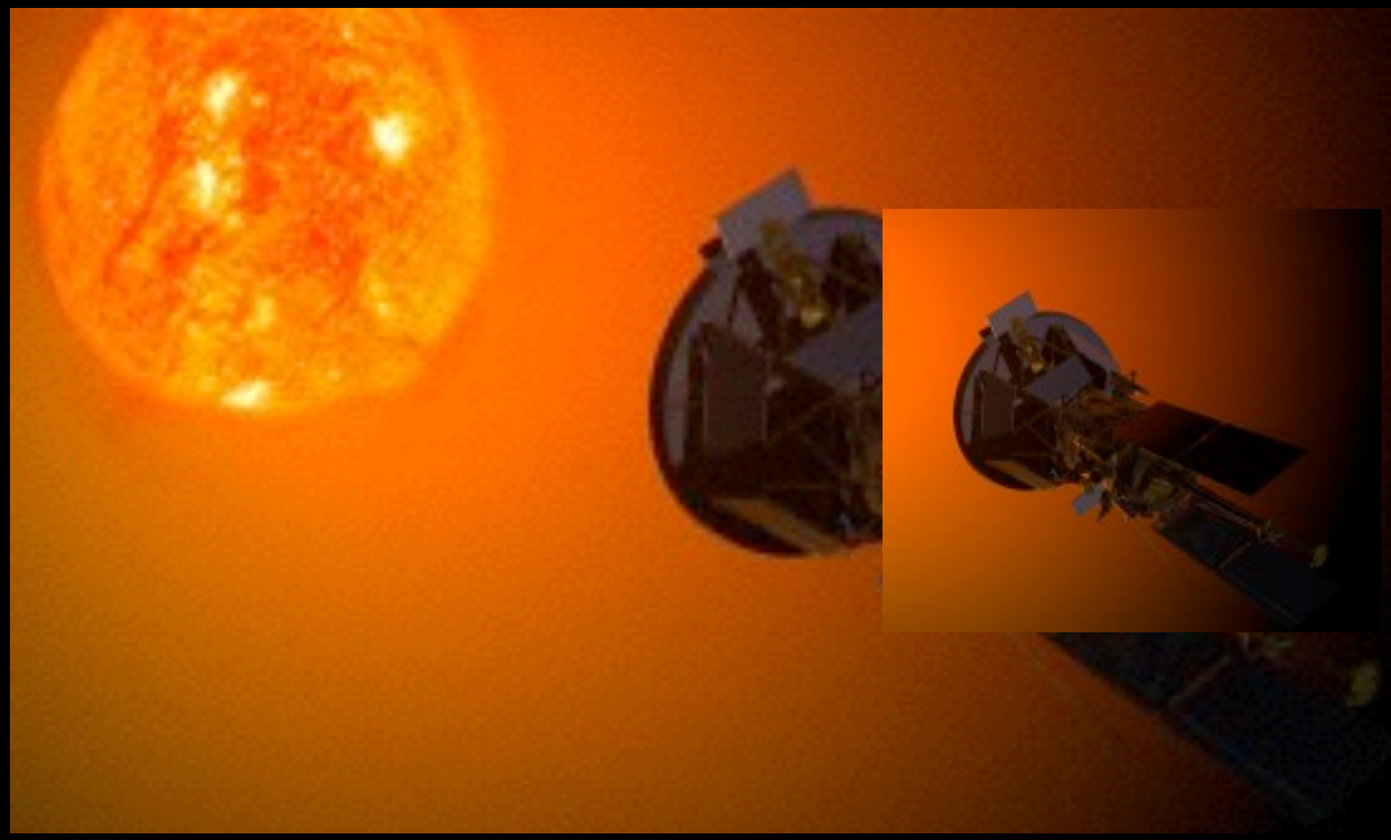


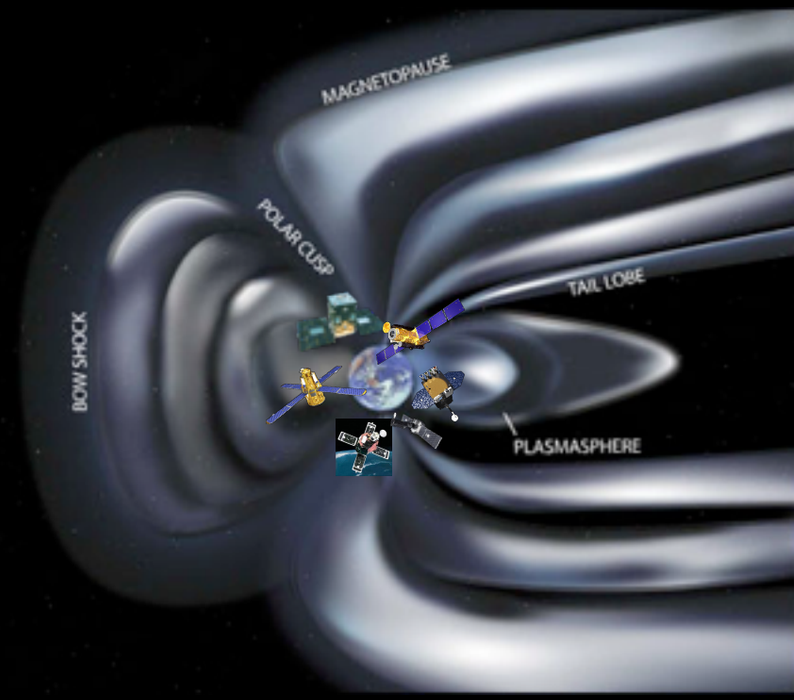


Interface Region Imaging Spectrograph (IRIS): http://iris.gsfc.nasa.gov/ & http://iris.lmsal.com/index.html

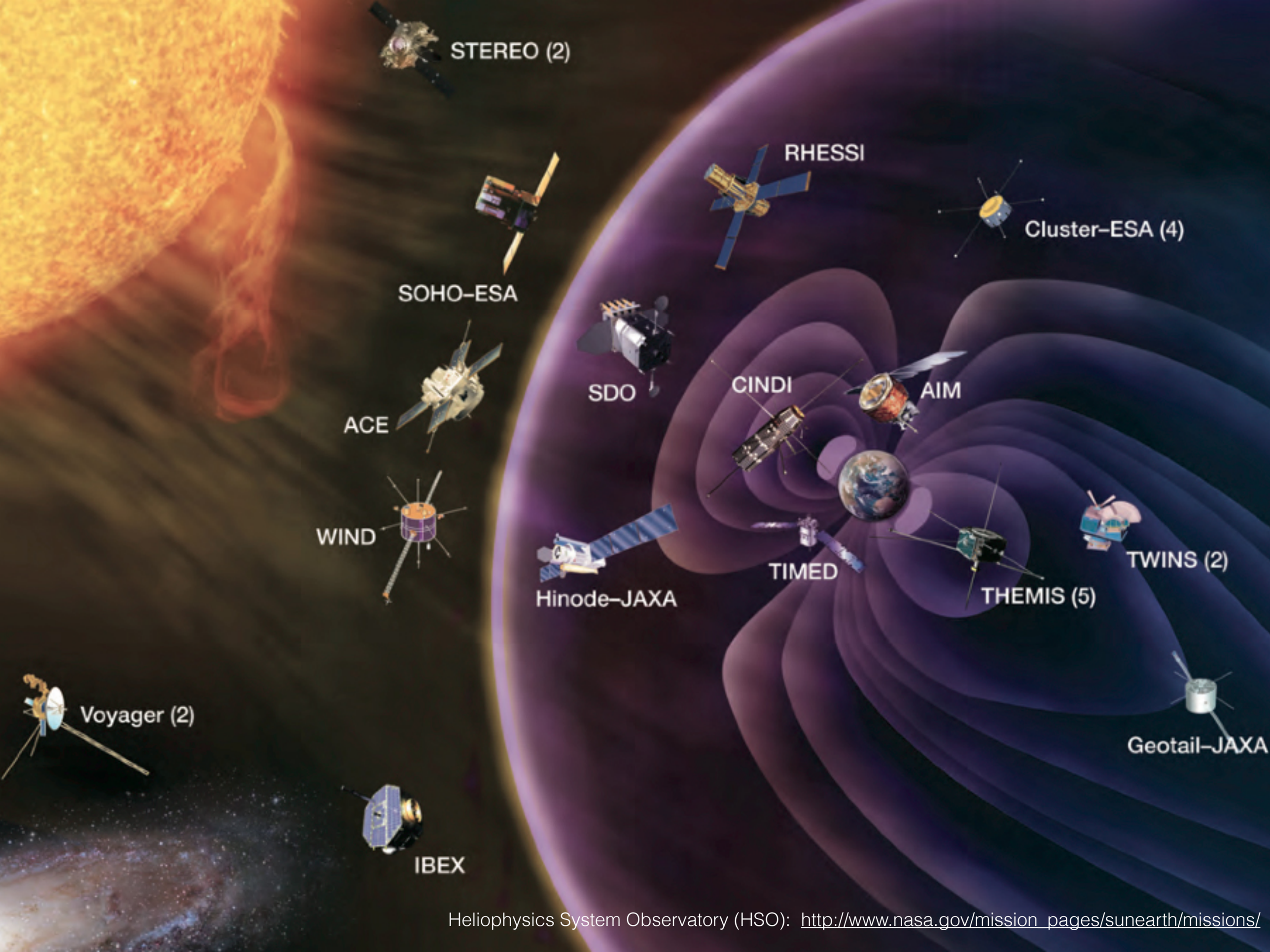
Solar Probe+

2018? -



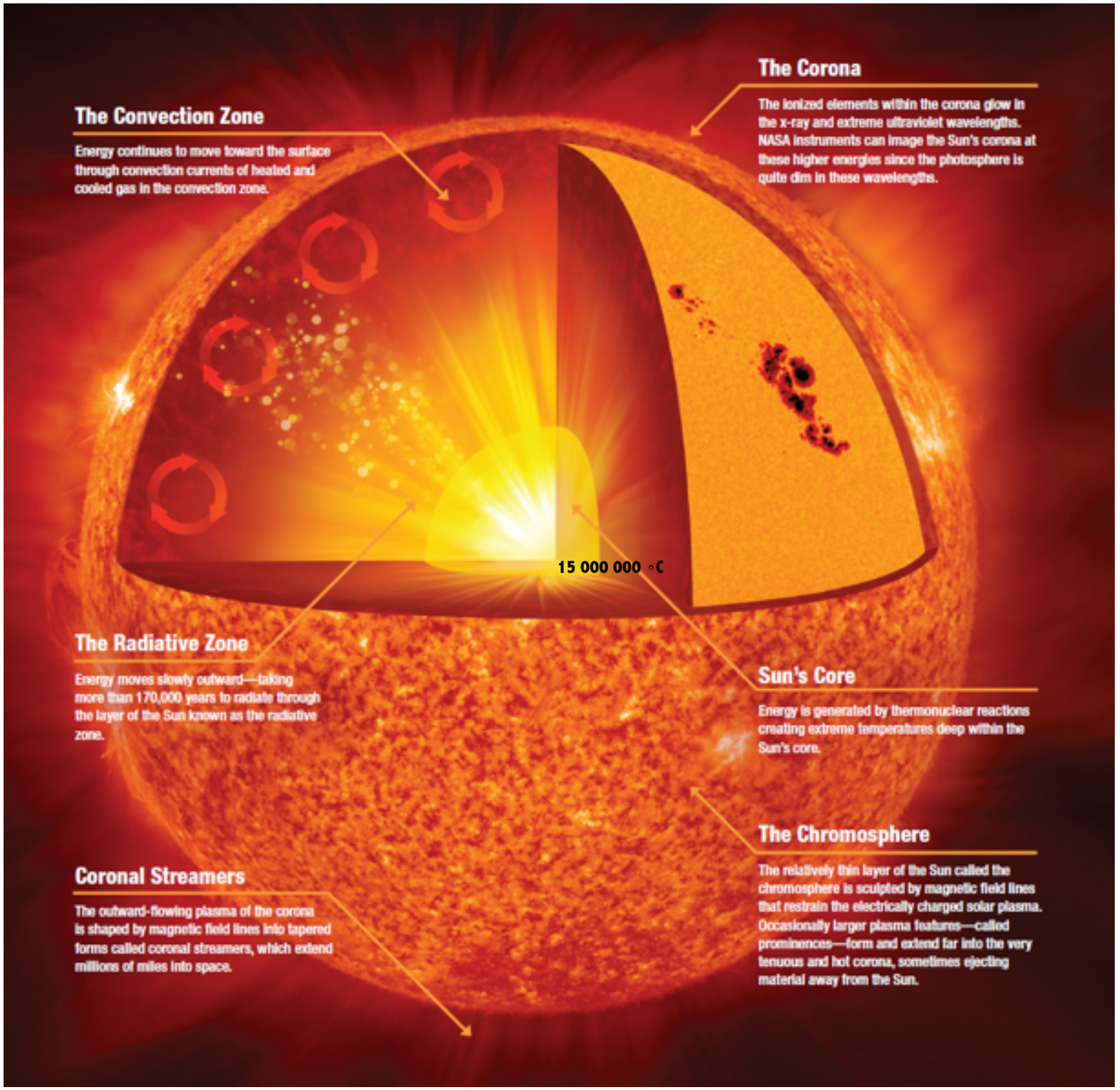


Solar Probe Plus: http://solarprobe.gsfc.nasa.gov/

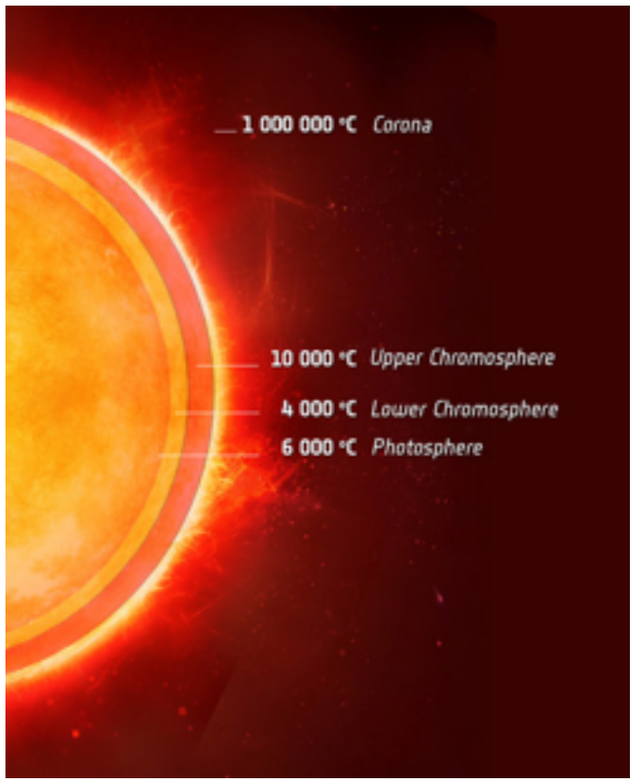


Heliophysics System Observatory (HSO): http://www.nasa.gov/mission_pages/sunearth/missions/

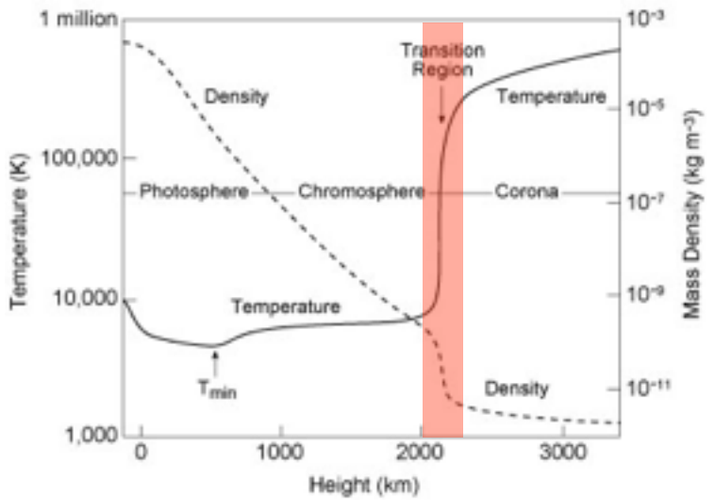
The Sun in Layers



"Mysteries of the Sun": NASA / Jenny Mottar



European Space Agency (ESA)

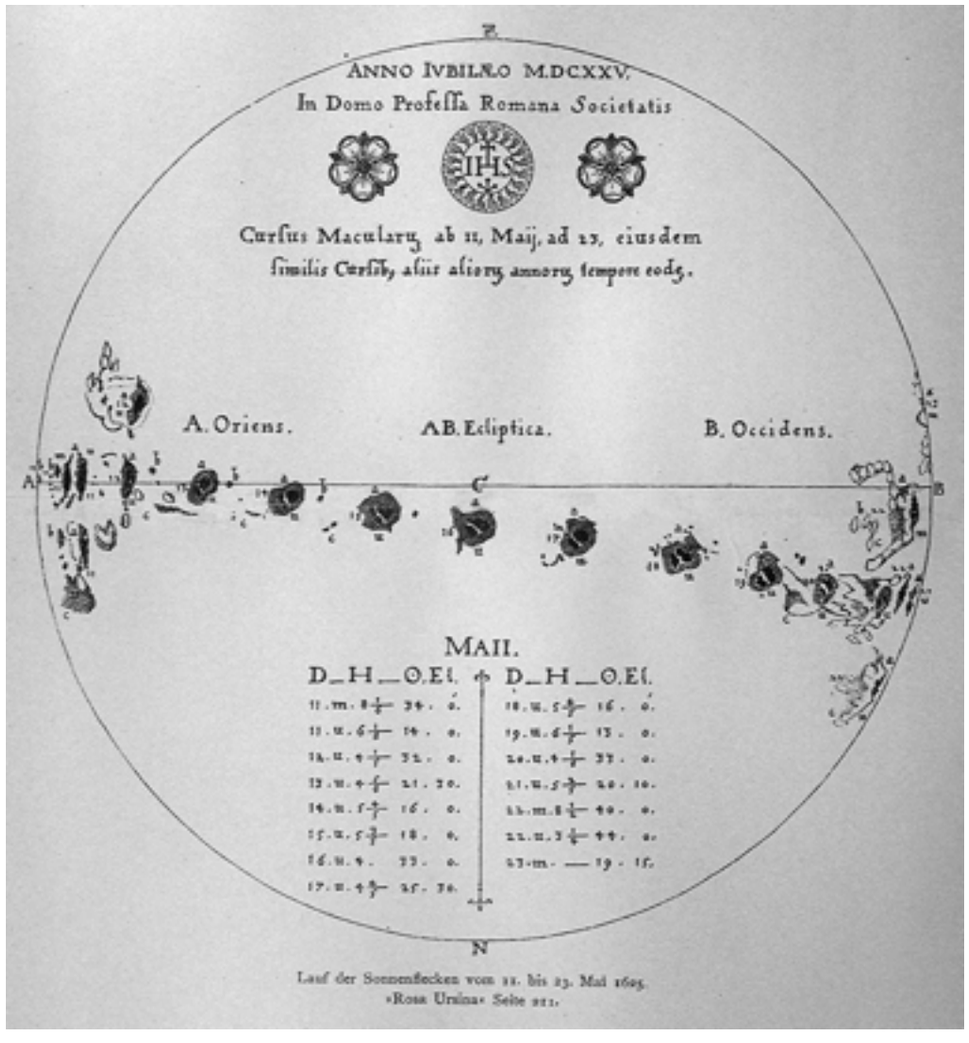


Smithsonian Astrophysical Observatory (SAO)

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

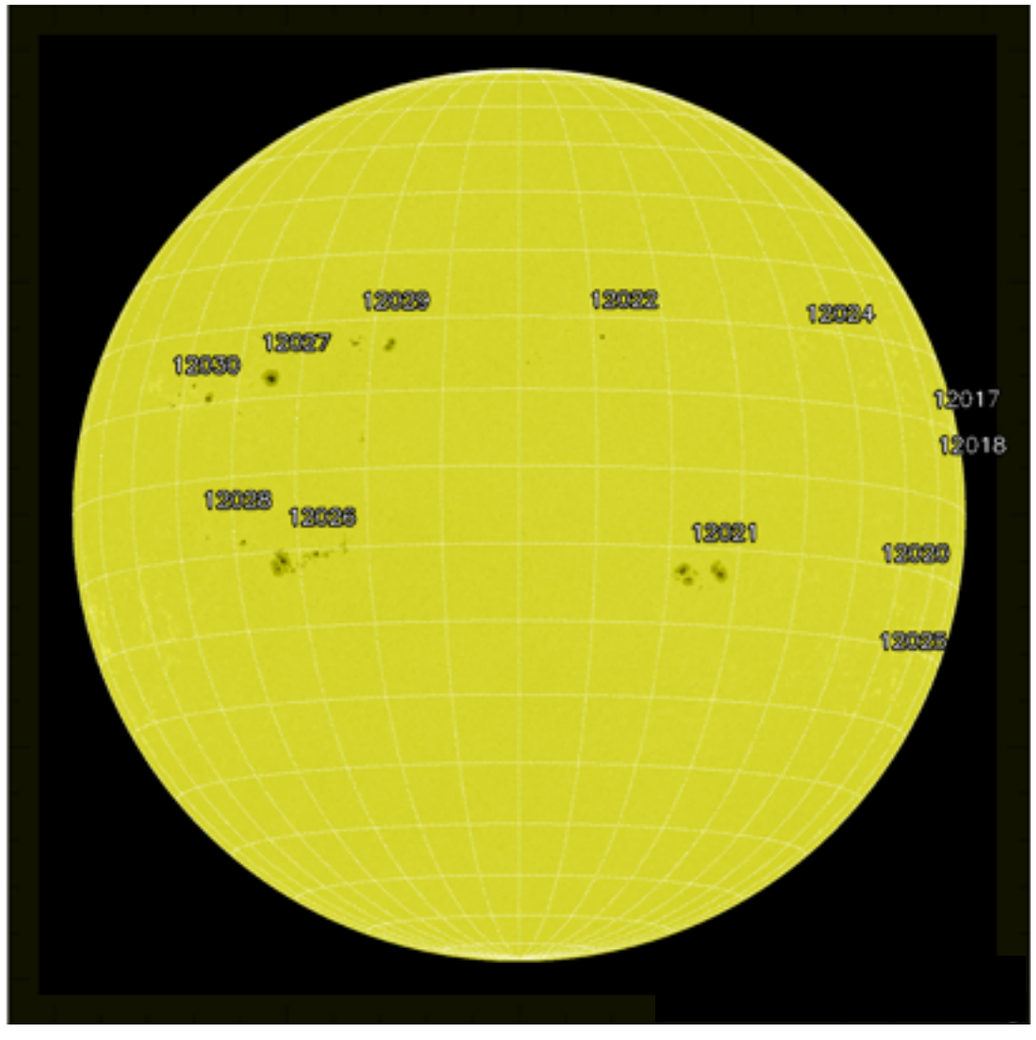
Sunspots & Active Regions

1625 May: Christoph Scheiner



Lauf der Sonnenflecken vom 11. bis 23. Mai 1625.
«Rosa Ursina» Seite 221.

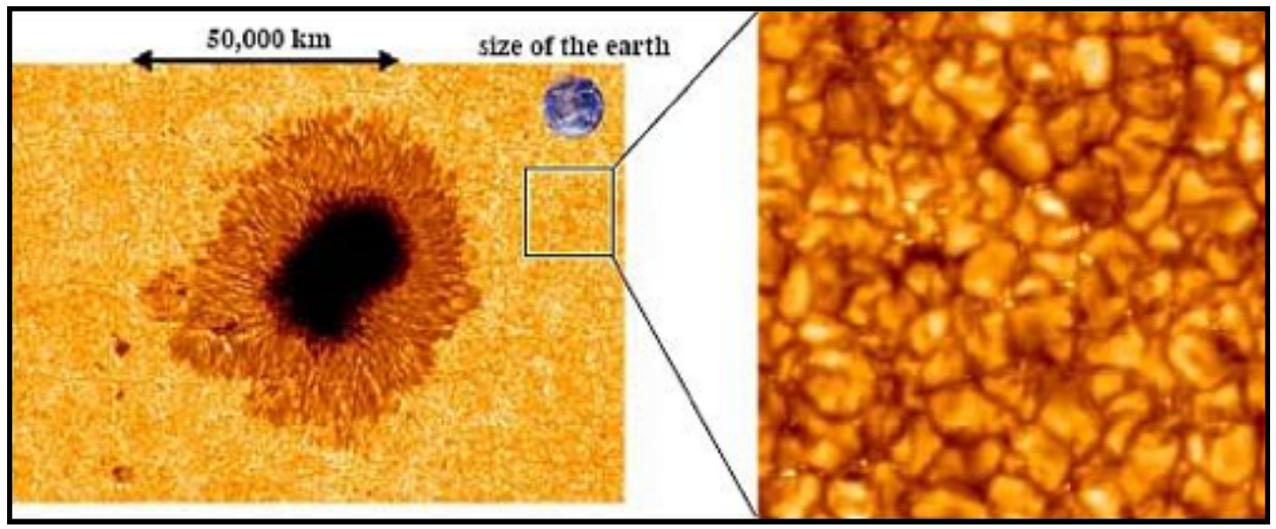
2014 April 3: SDO HMI 6173 A



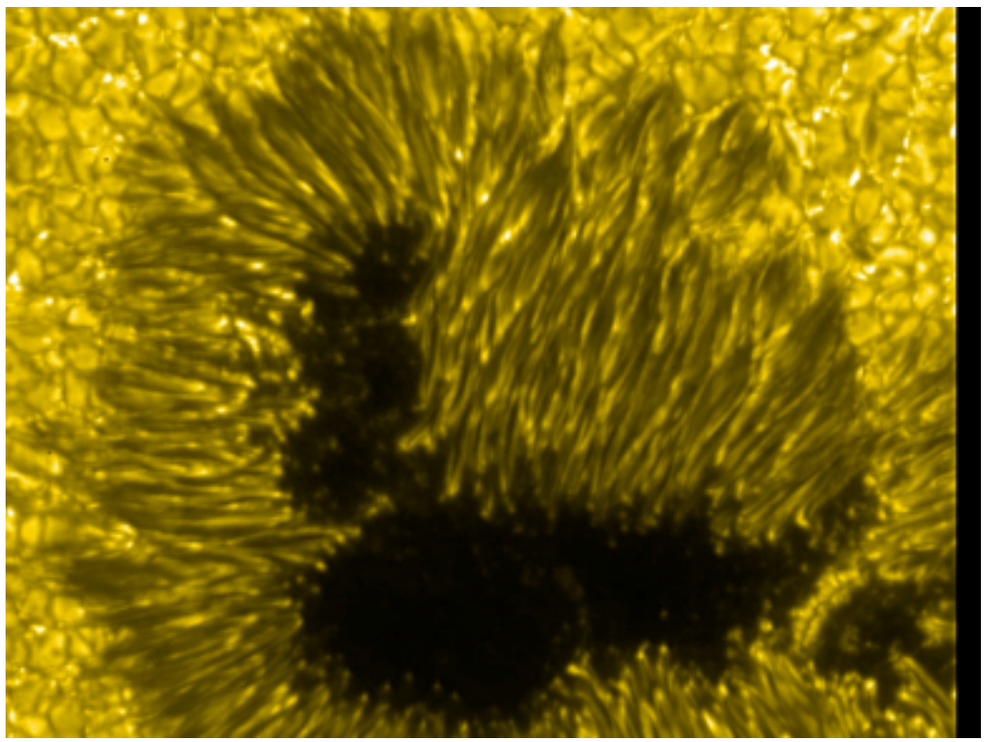
Rice Univ. Galileo Project: http://galileo.rice.edu/sci/observations/sunspots.html

NOAA Active Regions: SolarMonitor.org

Sunspots & Active Regions

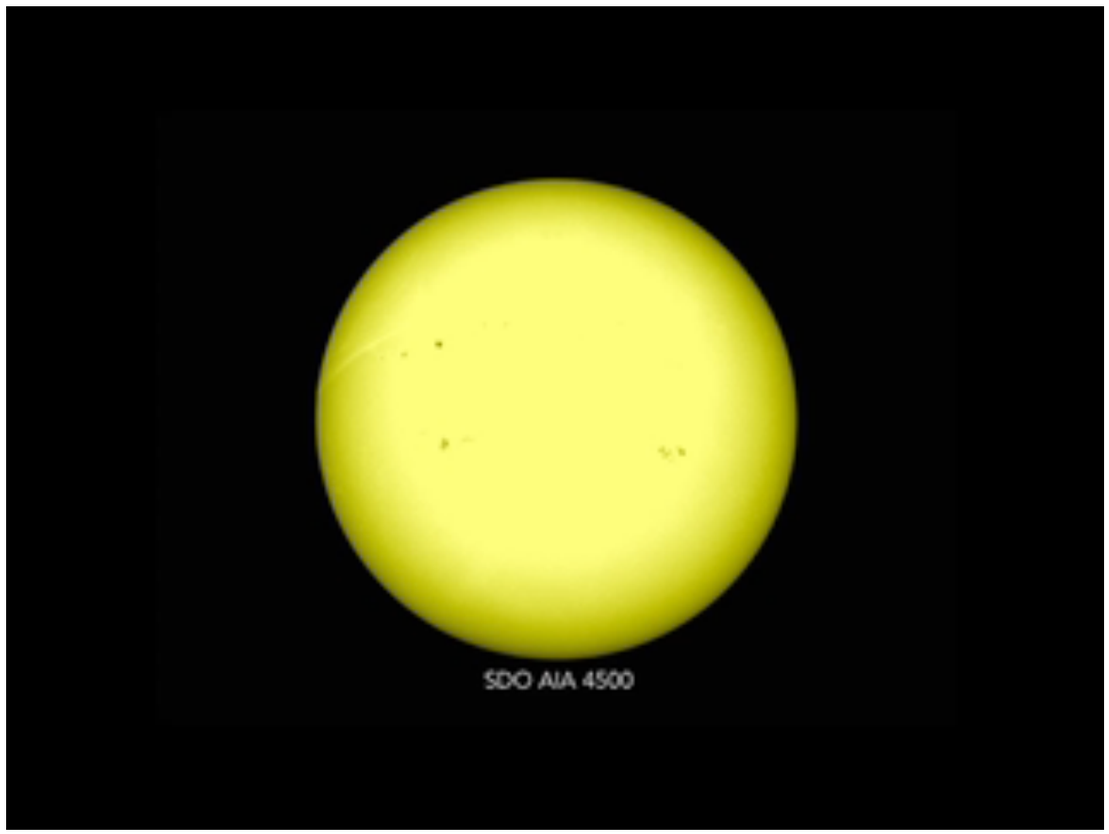


Hinode SOT: NASA / JAXA / NAOJ



SOT (CN line 3883 A); 2007 May 2

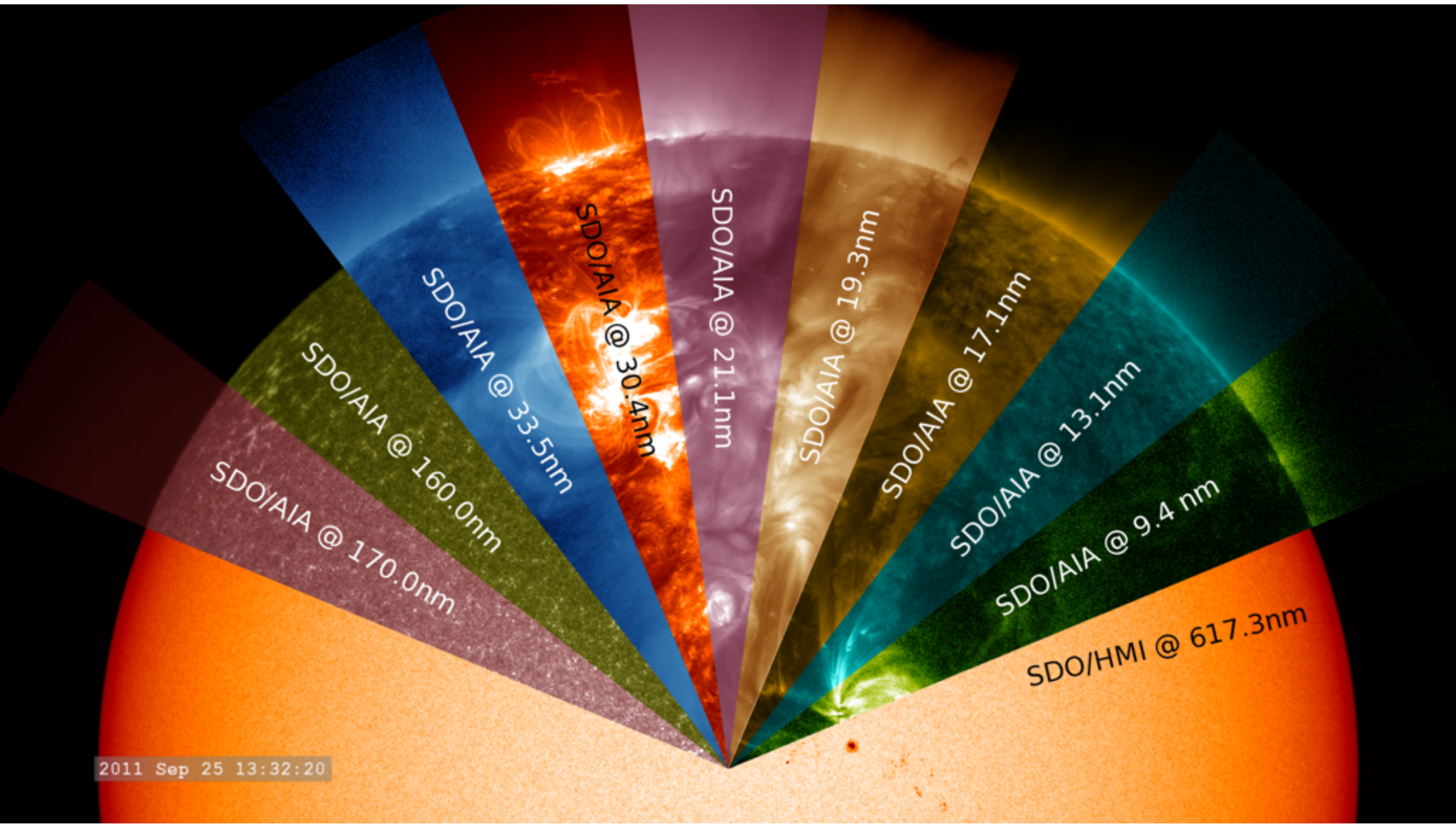
JHelioviewer 2014 Apr 04



SOHO animation gallery

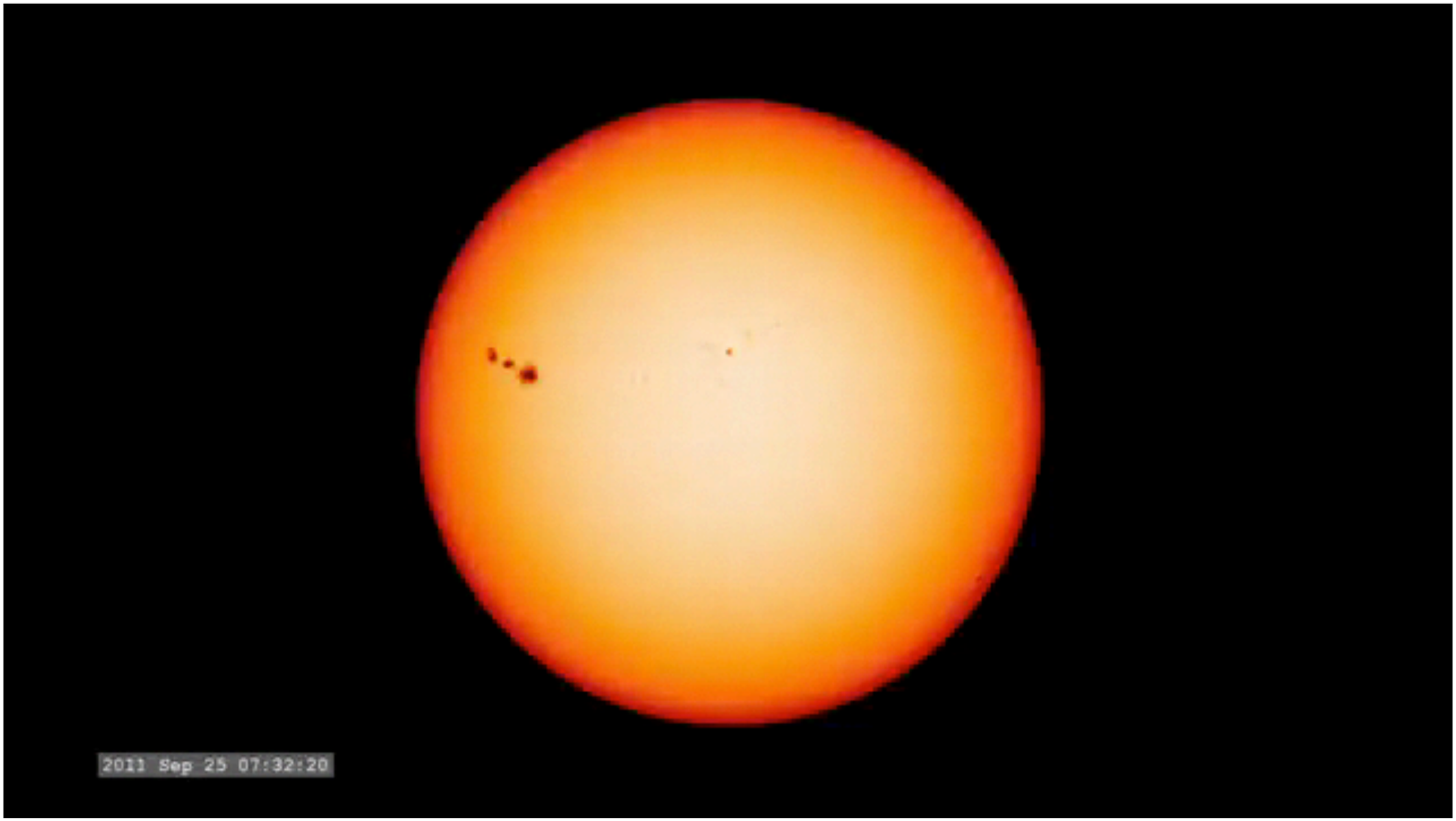
SOT Picture of the Day (POD): http://sot.lmsal.com/pod?cmd=view-gallery

Sunspots & Active Regions



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

Sunspots & Active Regions

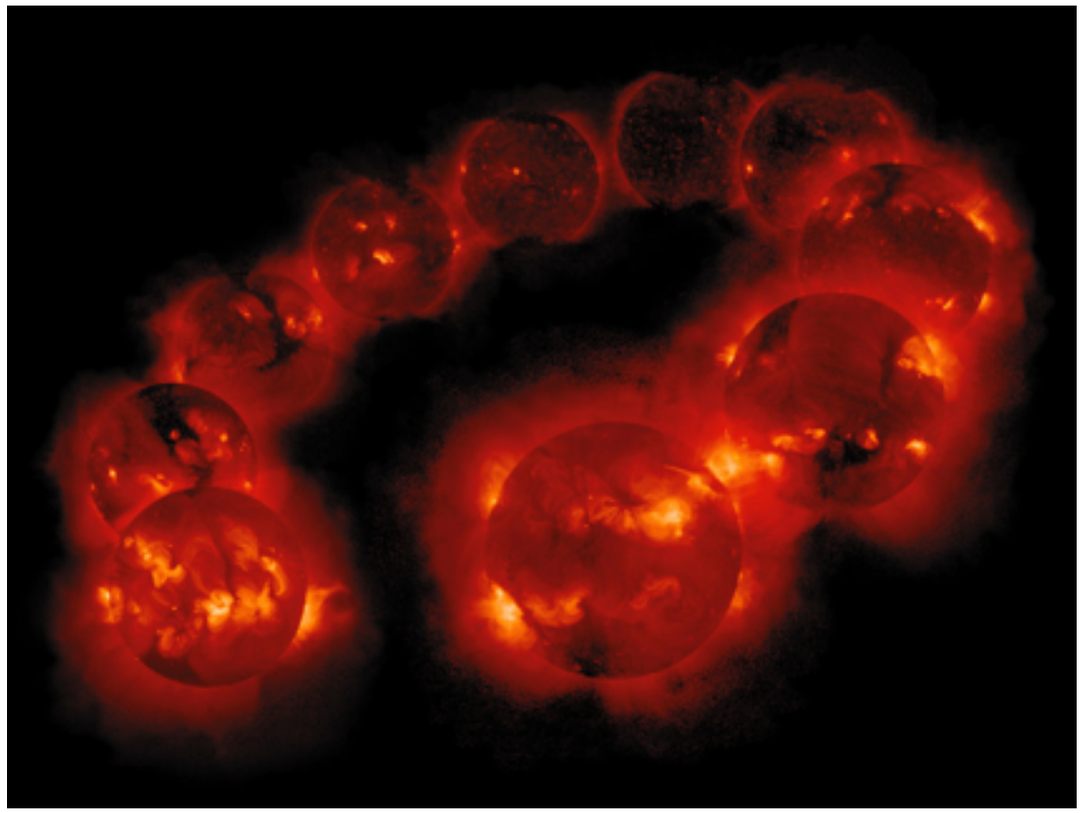


“SDO Jewel Box”

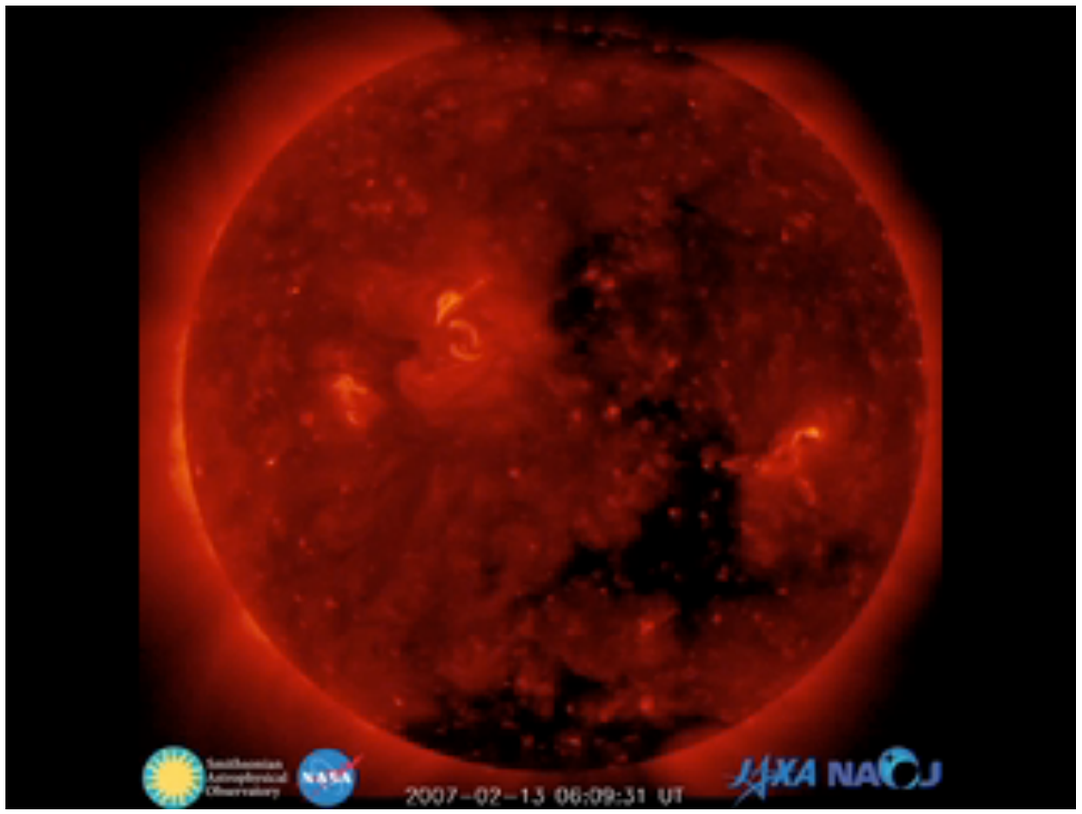
Solar features as seen with 10 different filters (i.e., plasma at different temperatures).

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

Solar Cycle



Yohkoh Soft X-ray Telescope (SXT):
1991 - 1999

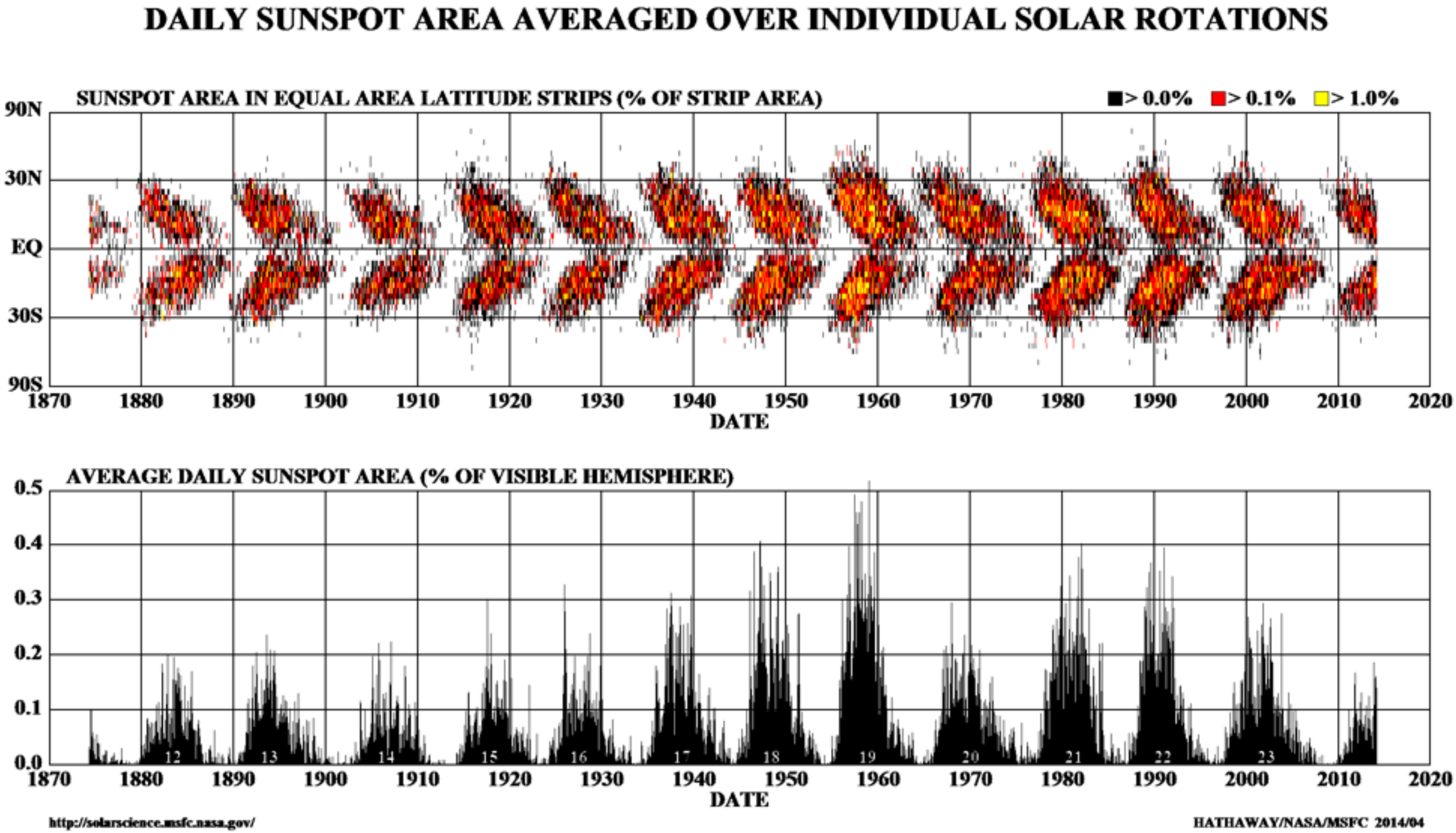


Hinode X-Ray Telescope (XRT):
2007 - 2012

SXT: http://solar.physics.montana.edu/sxt/

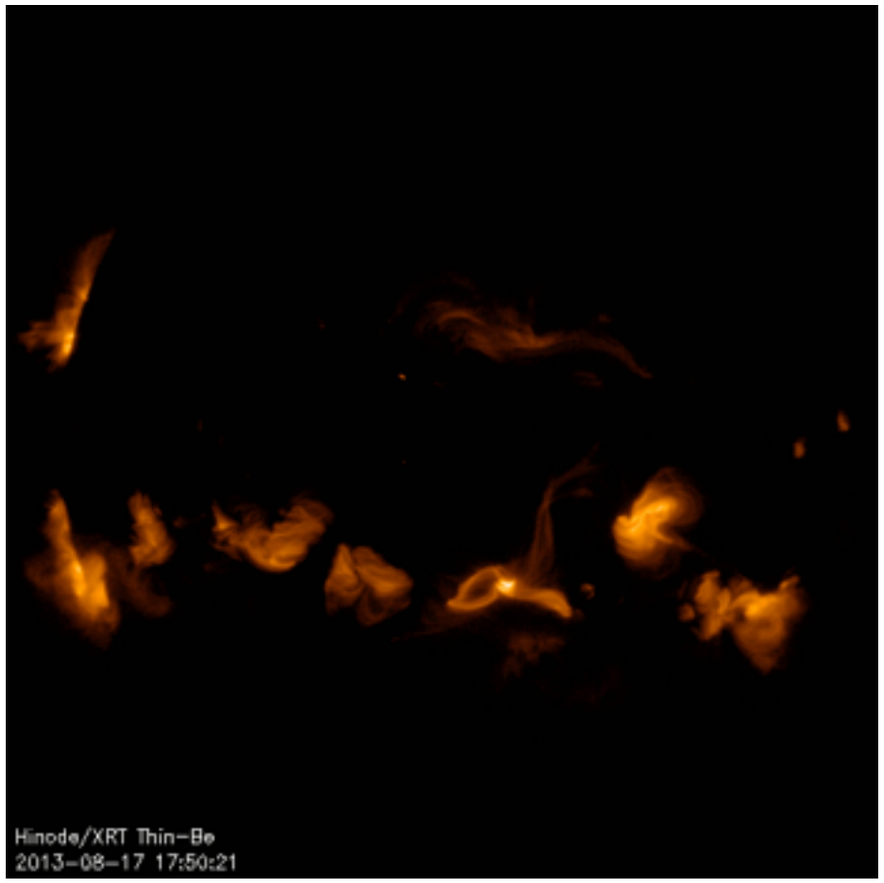
XRT: http://xrt.cfa.harvard.edu/

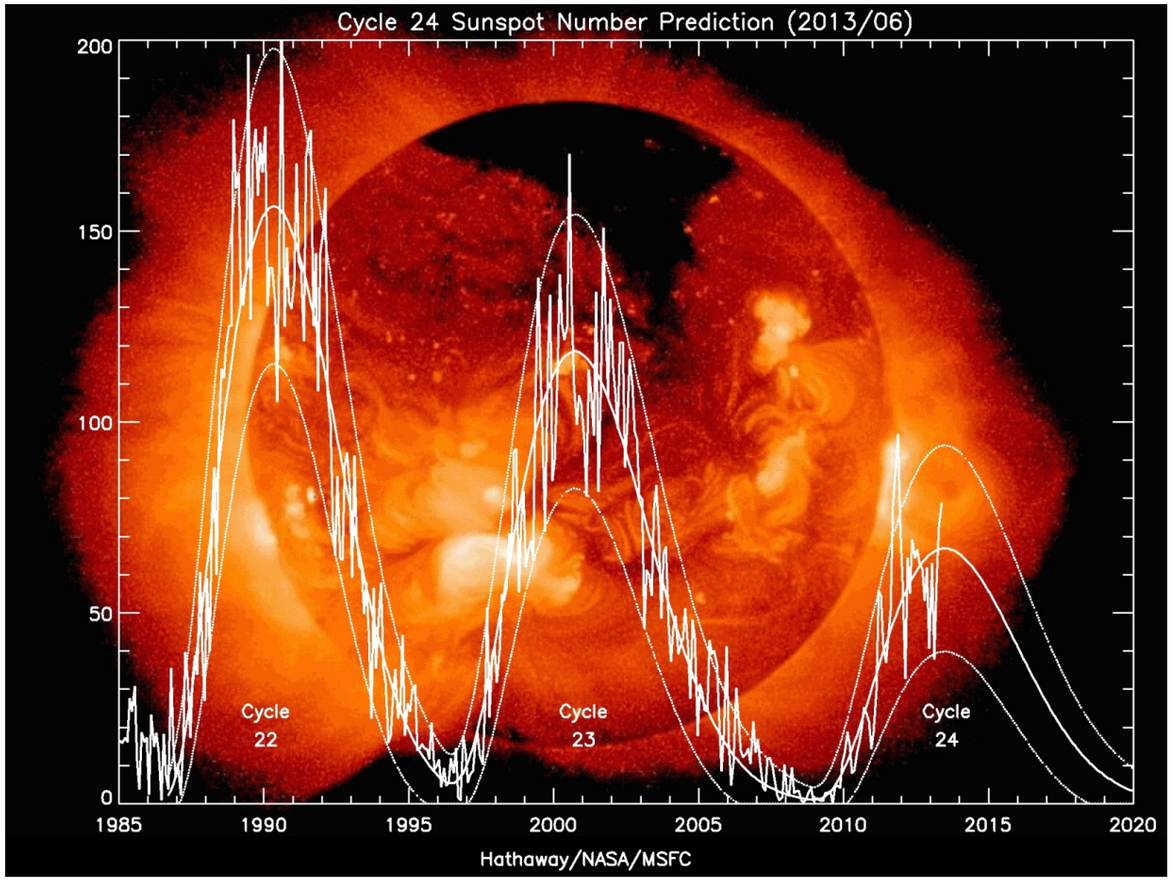
Solar Cycle



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

Current Cycle

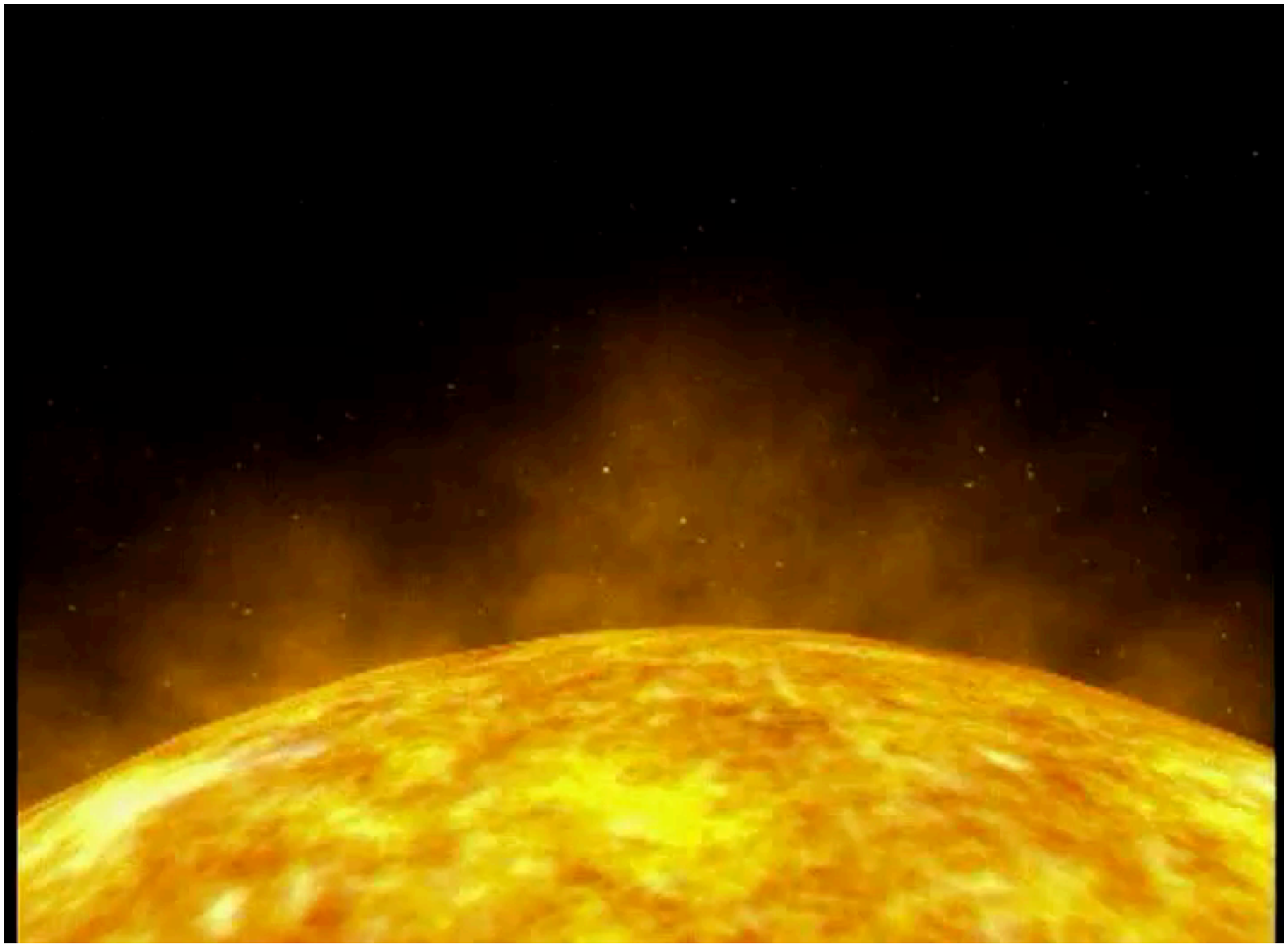




#24 — Smallest cycle in ~100 years
http://solarscience.msfc.nasa.gov/SunspotCycle.shtml

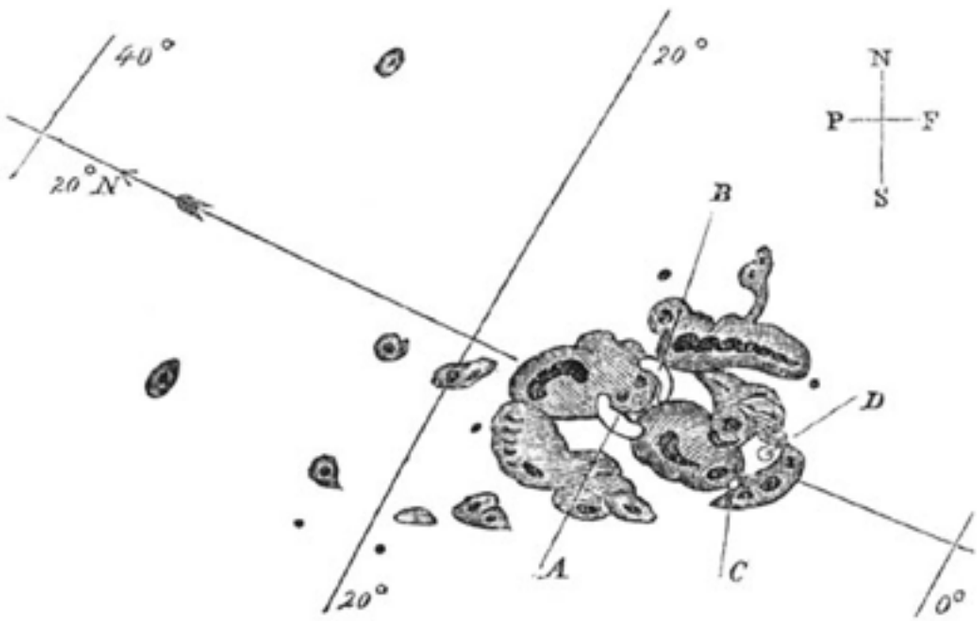
Hinode XRT Picture of the Week: http://xrt.cfa.harvard.edu/

Sun-Earth Interaction



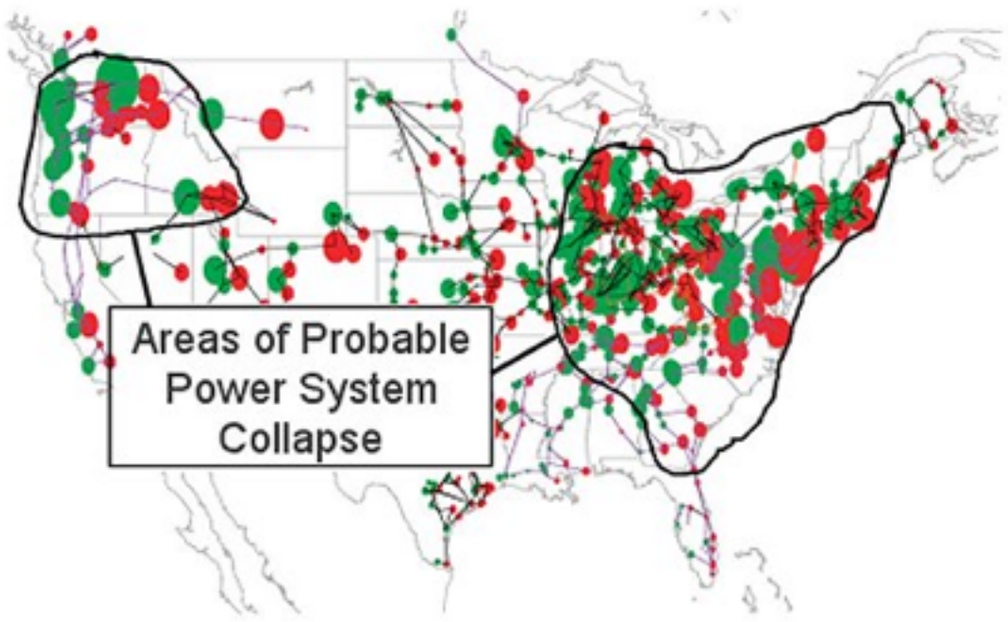
SOHO animation gallery: http://soho.nascom.nasa.gov/bestofsoho/Movies/animations.html

Impacts of Space Weather



1959 Carrington Event
Largest Geomagnetic storm recorded

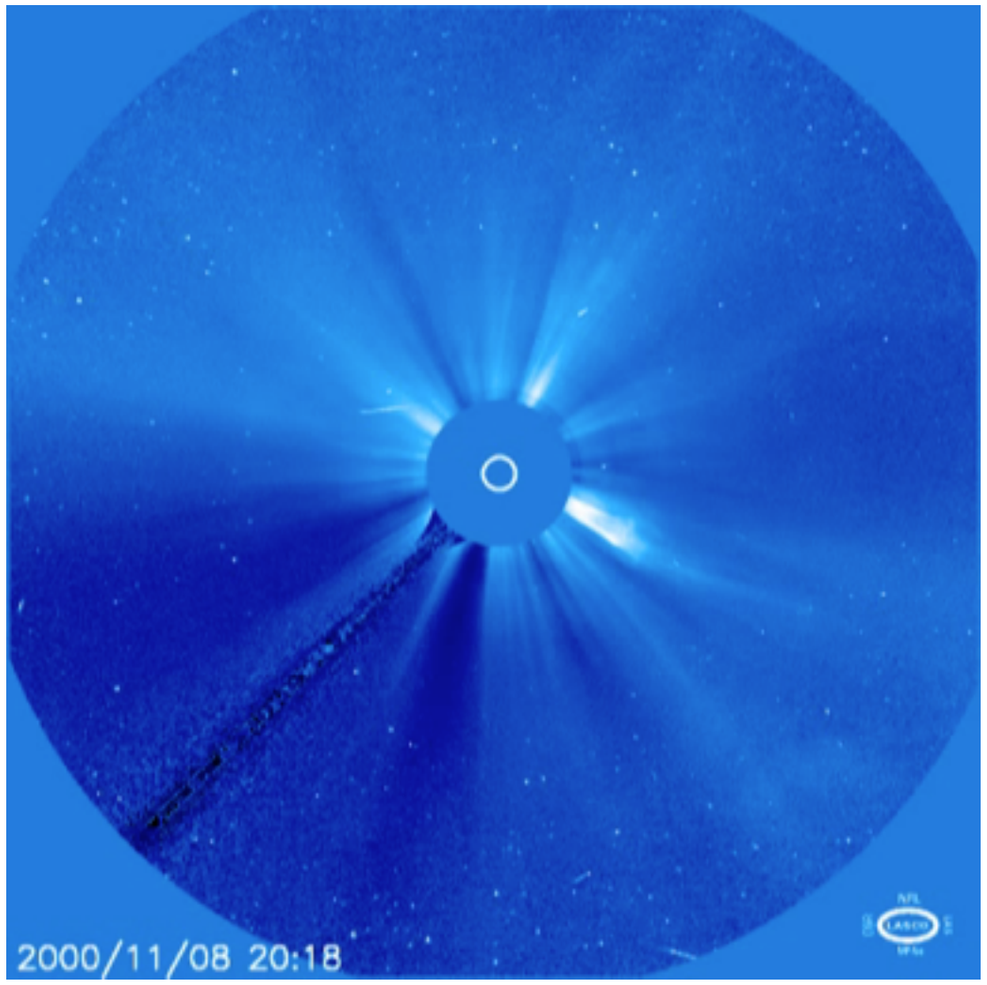
M. A. Shea, Geophysics Directorate, Phillips Laboratory
1989 Superstorm Blackout



J. Kappenman
2008

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

Impacts of Space Weather



SOHO Large Angle and Spectrometric Coronagraph Experiment (LASCO)

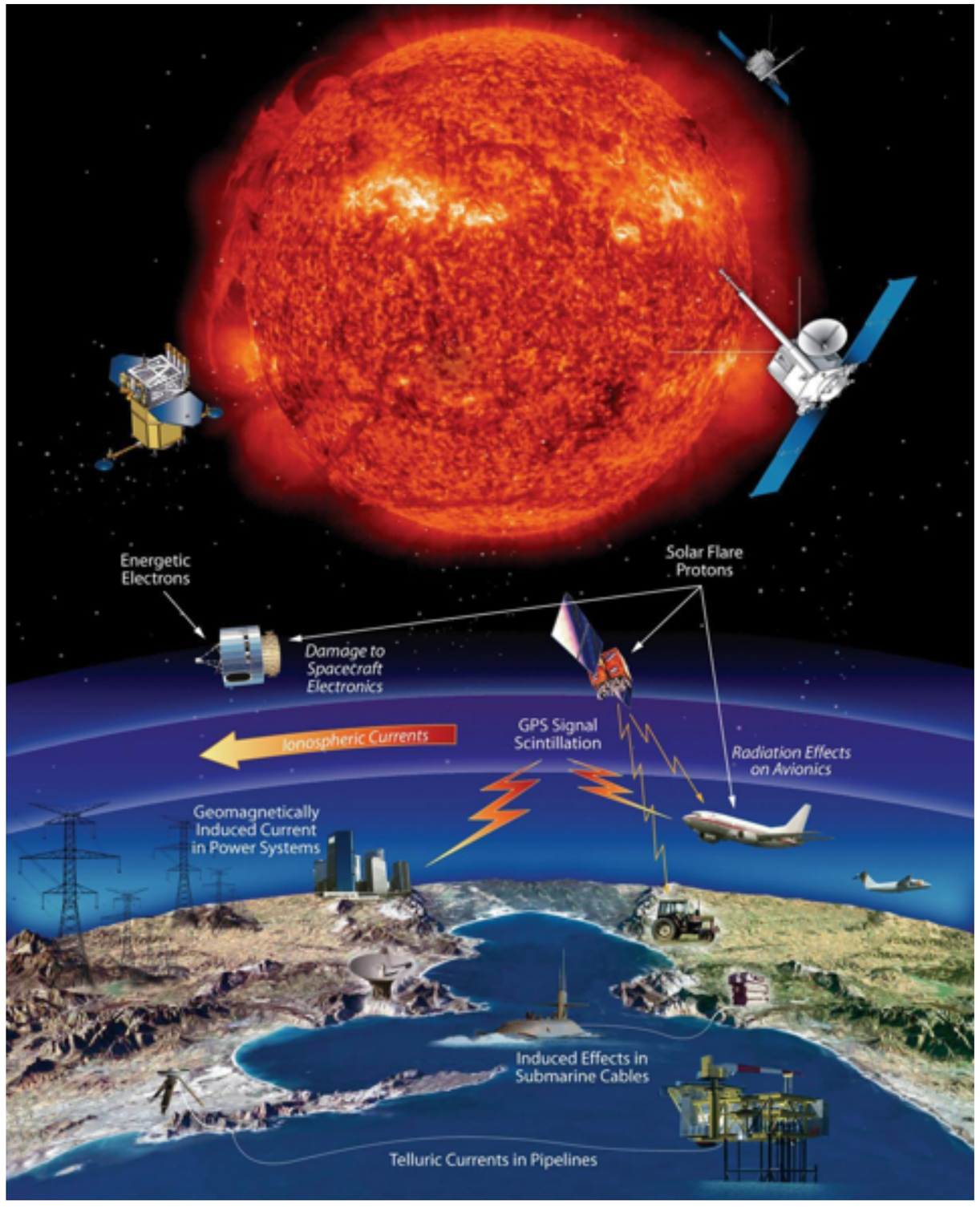
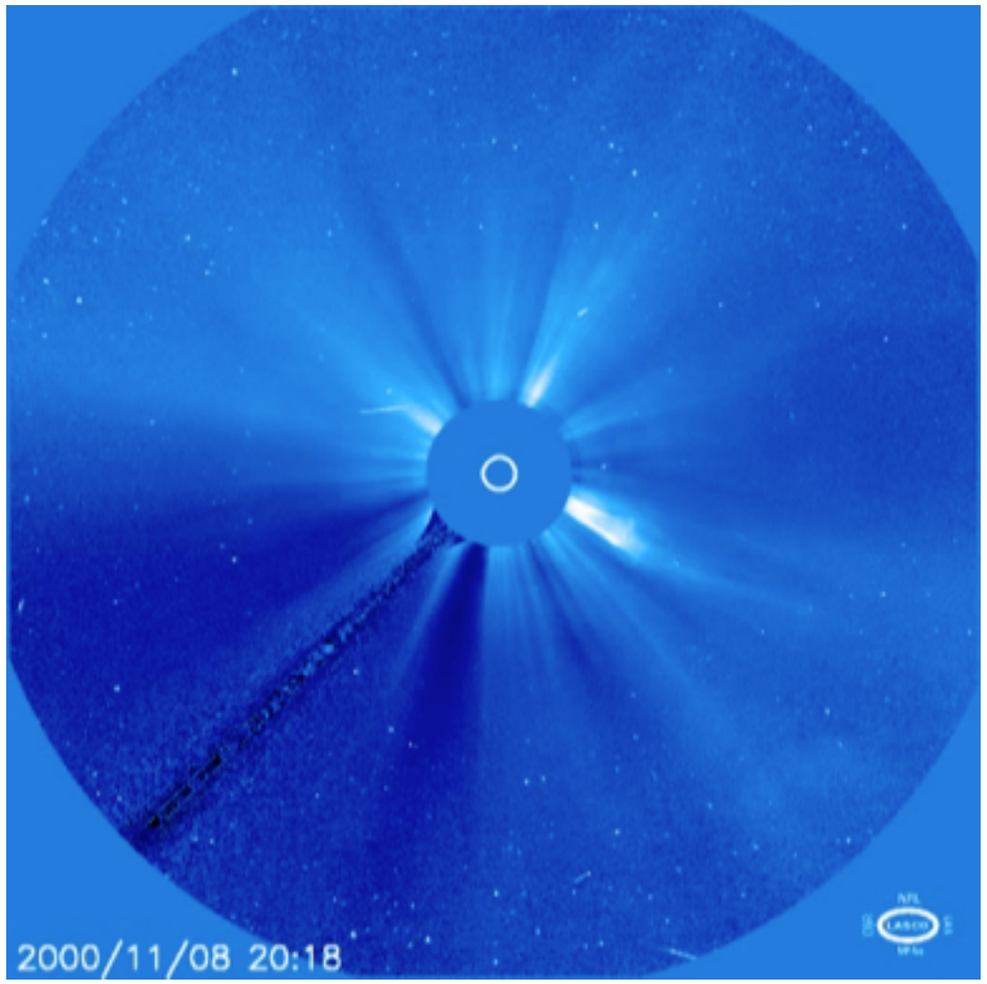


Image credit: NASA & L. Lanzerotti (NJIT)

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

Impacts of Space Weather



SOHO Large Angle and Spectrometric Coronagraph Experiment (LASCO)

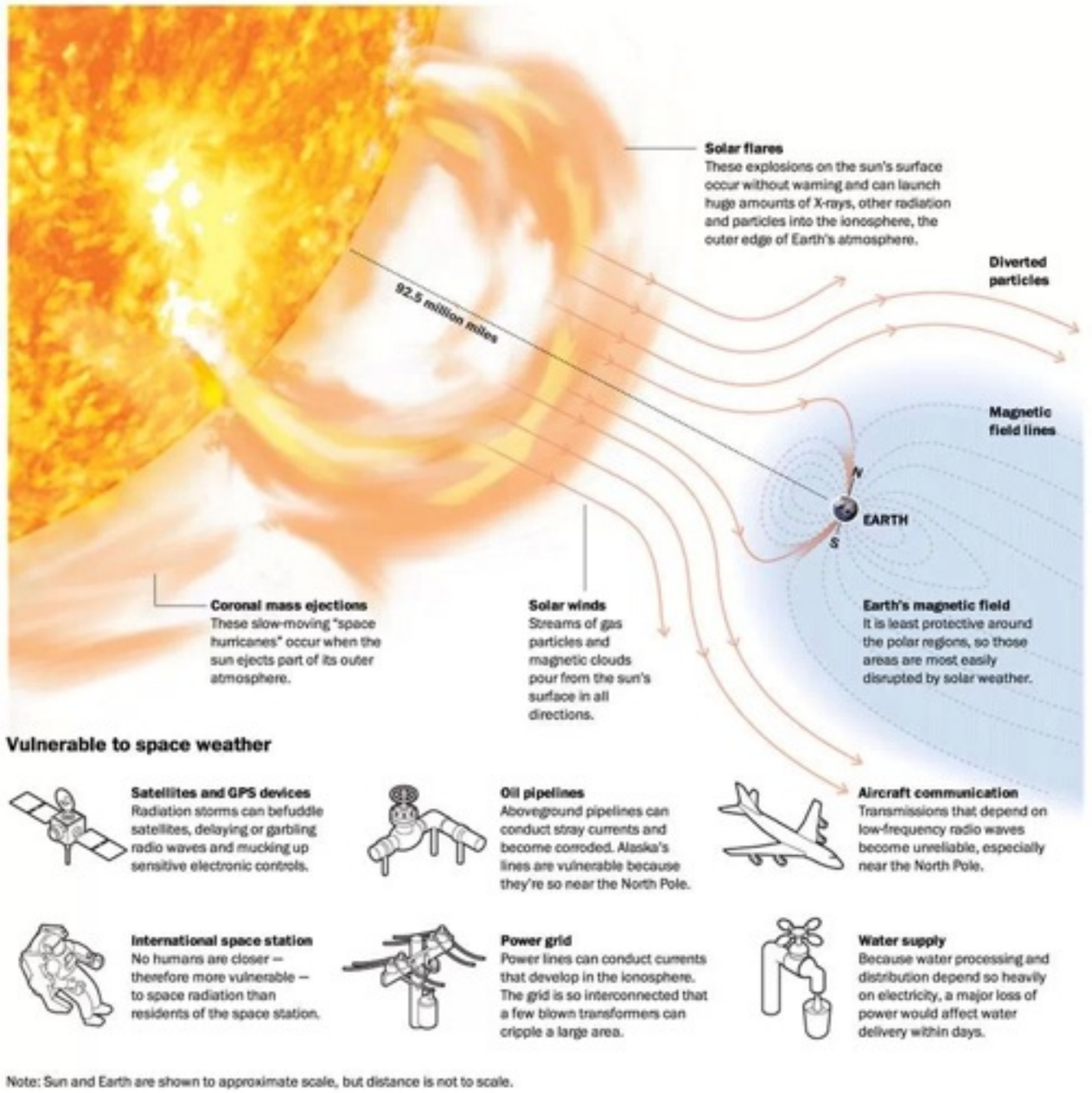
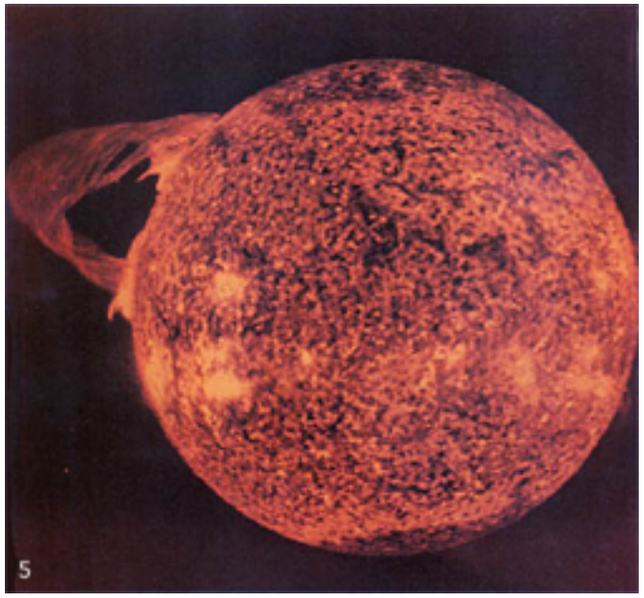


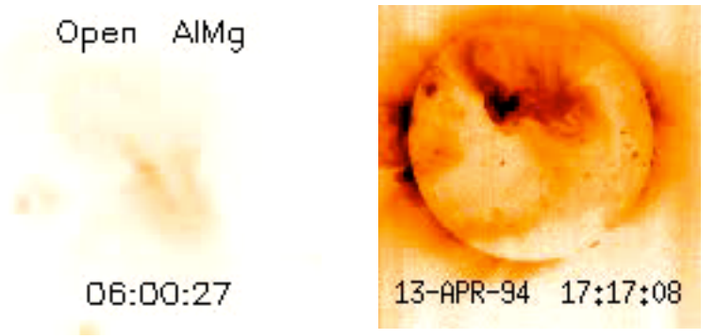
Image credit: NASA & Washington Post

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

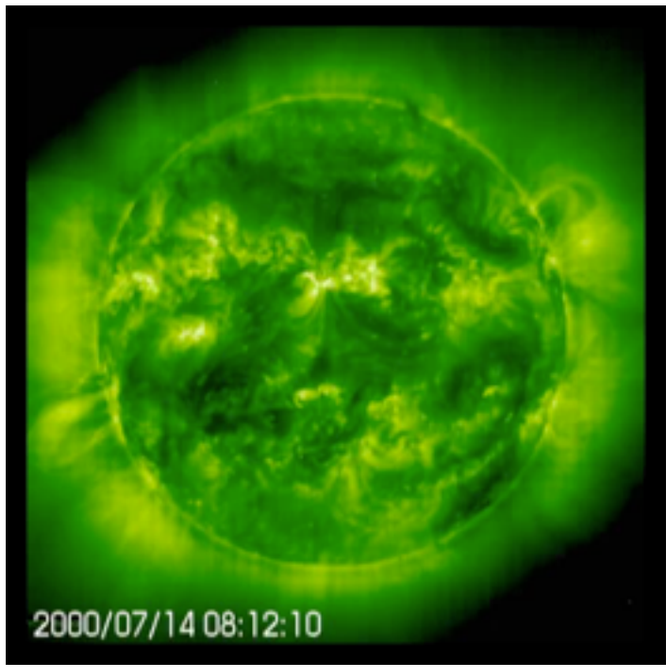
Solar Flares (A Space-Based Tour)



Skylab

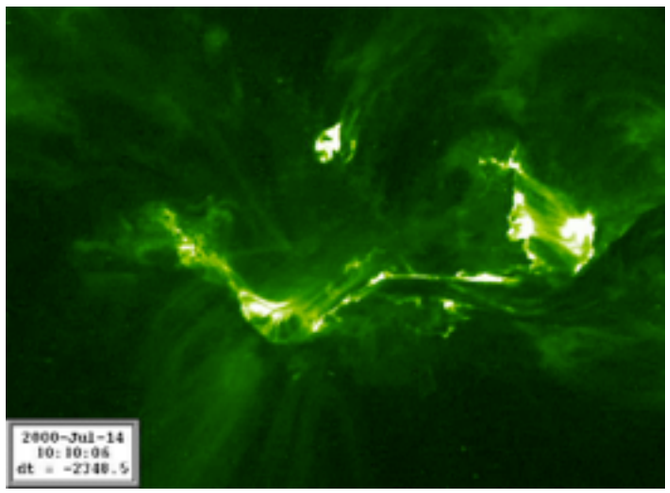


Yohkoh / SXT

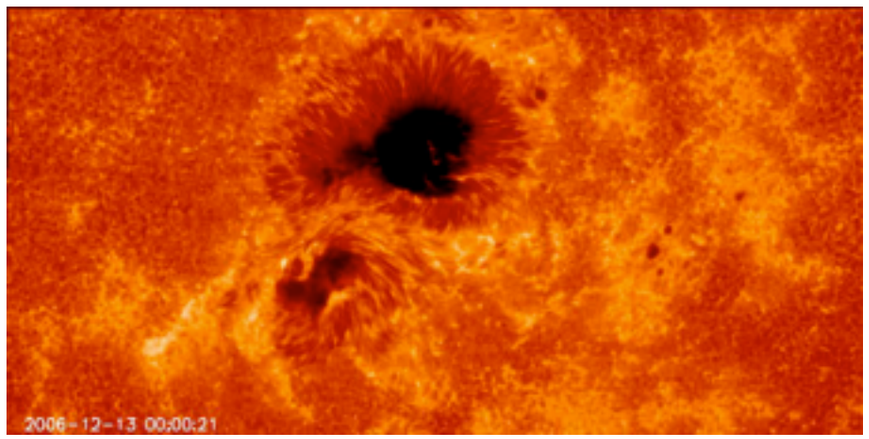


SOHO / EIT+LASCO

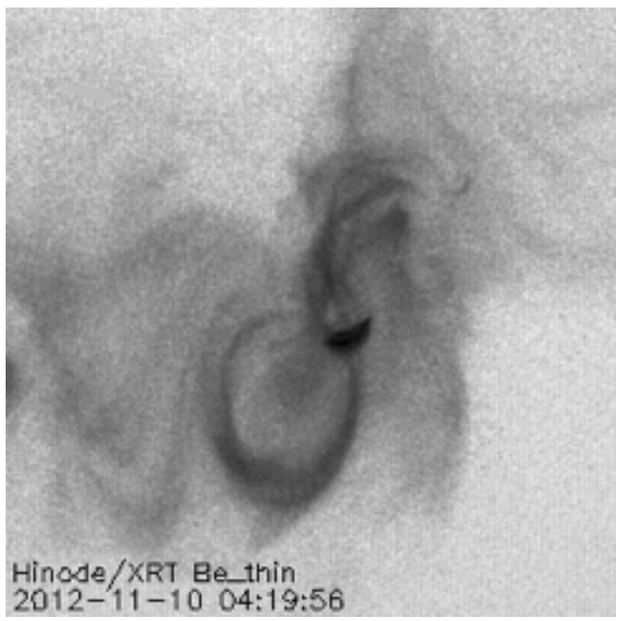
TRACE



HINODE / SOT

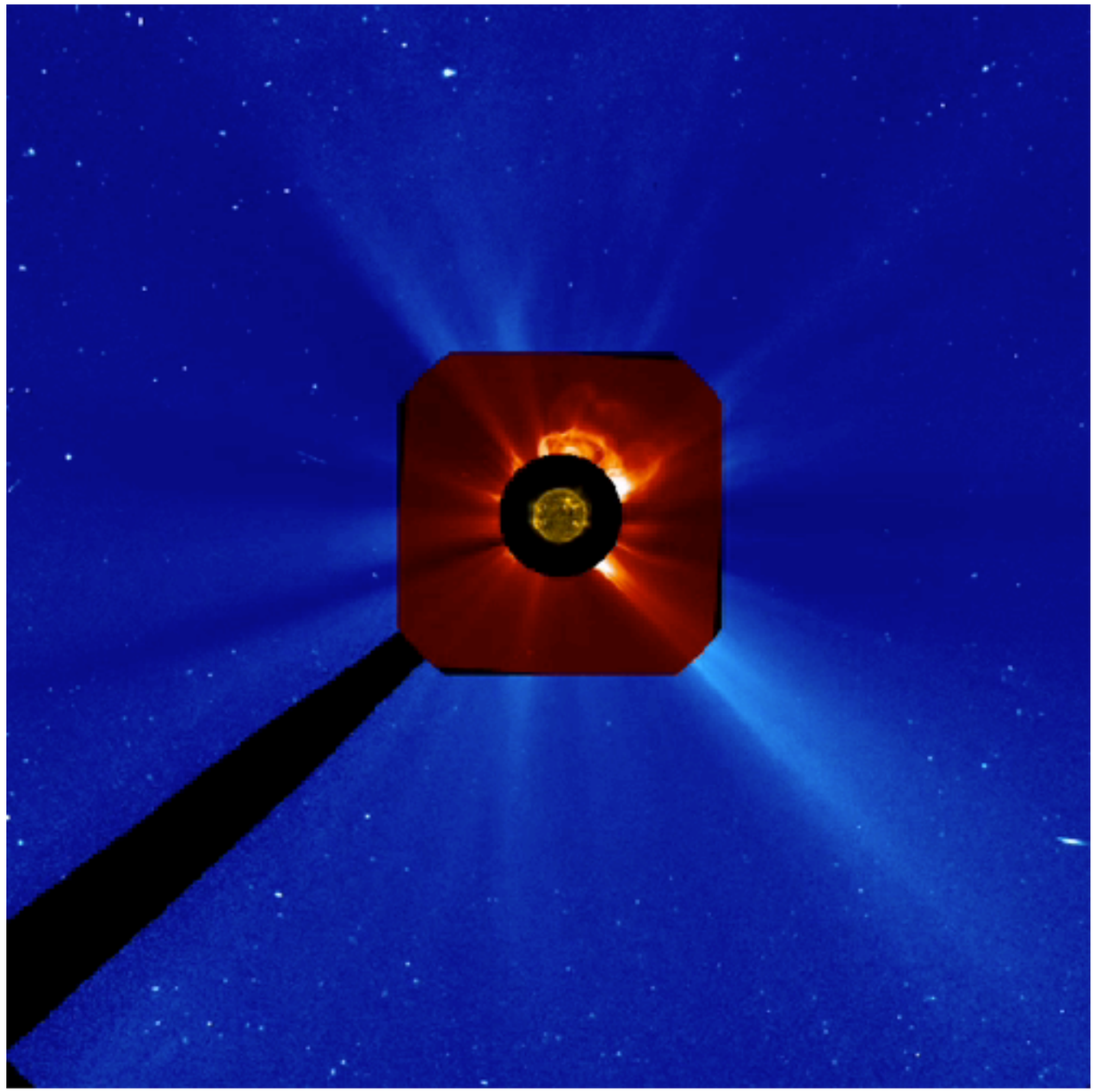


HINODE / XRT



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

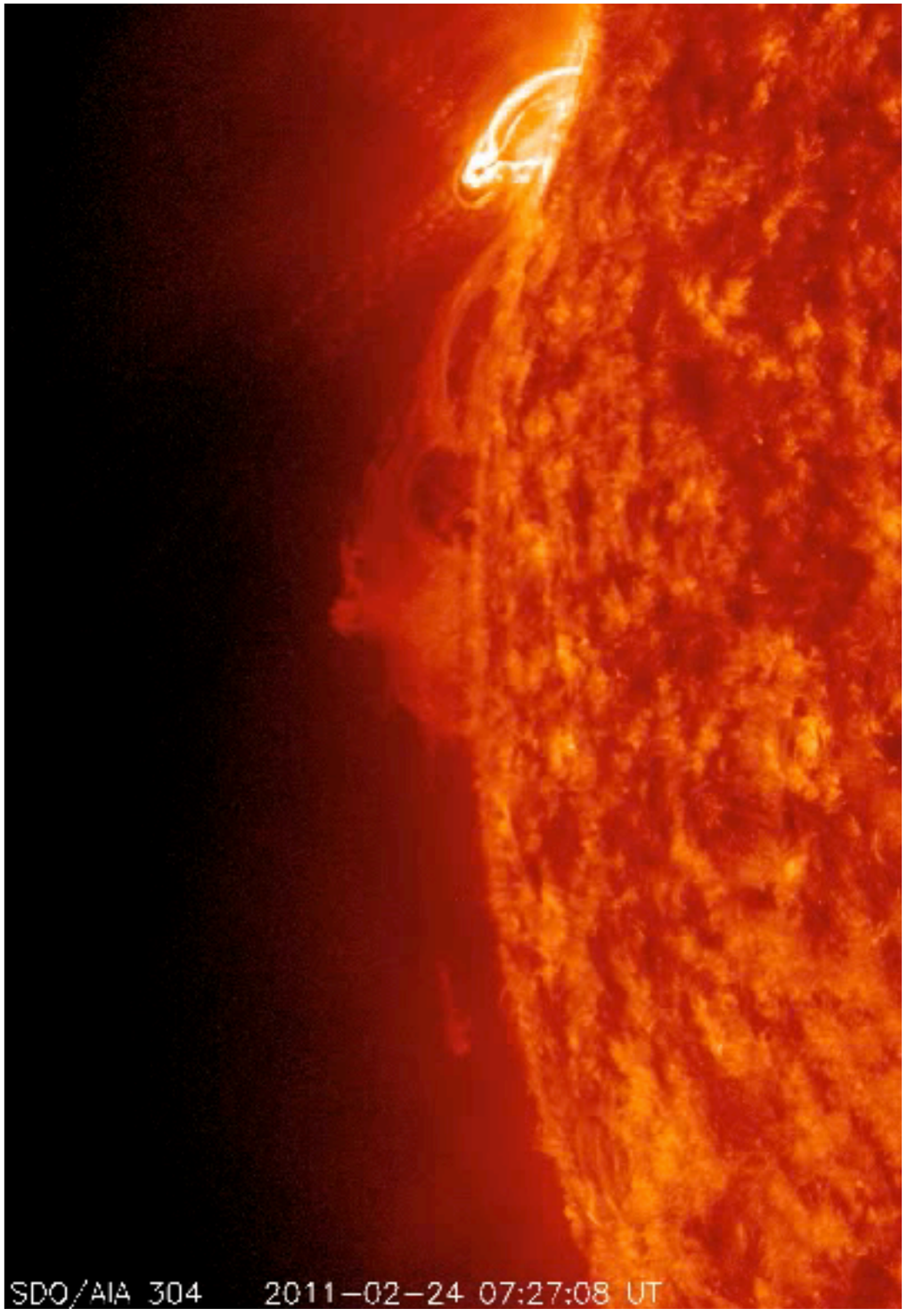
Solar Flares (A Space-Based Tour)

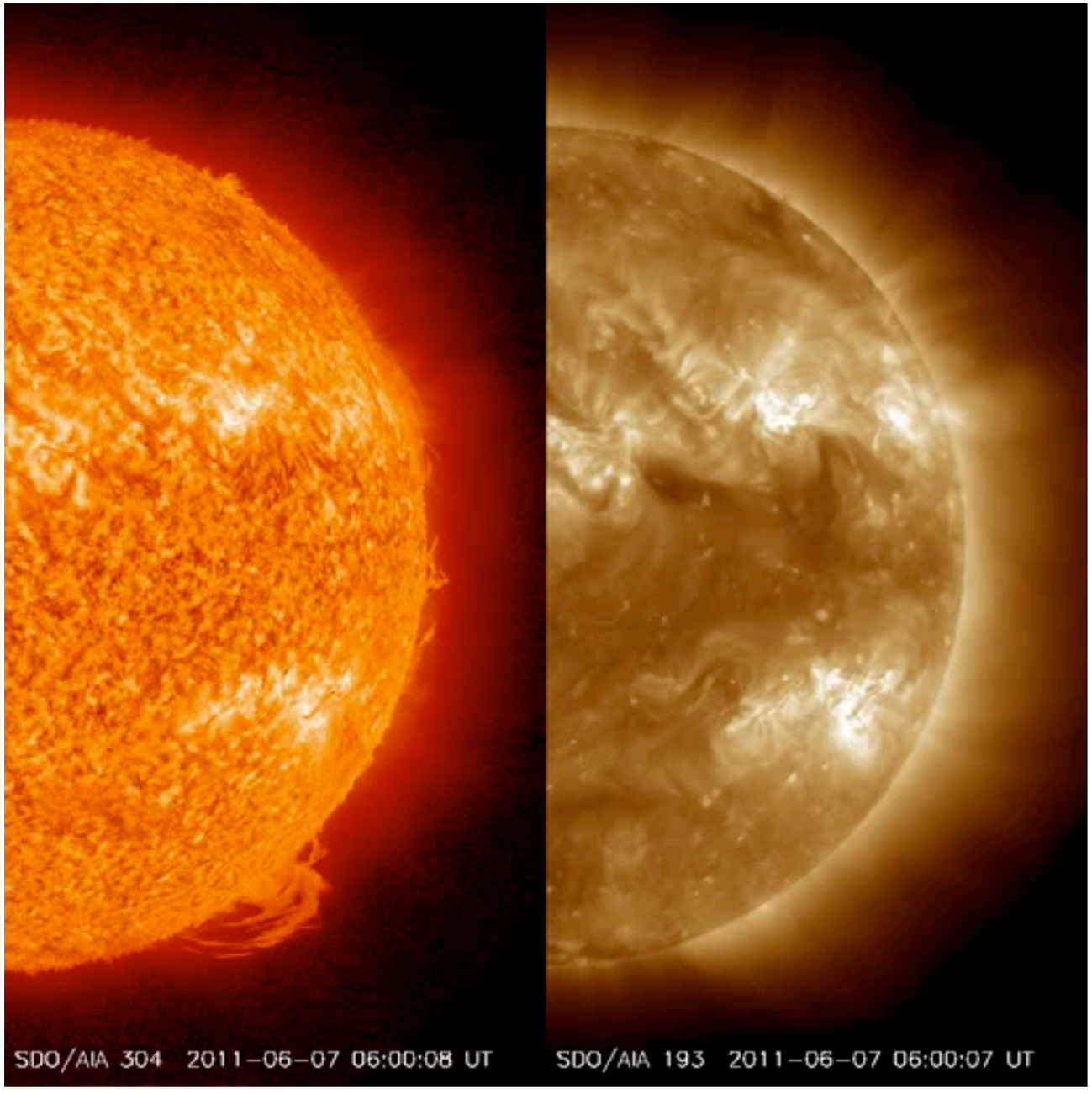


SDO / AIA + *SOHO* / LASCO

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

Solar Flares (A Space-Based Tour)

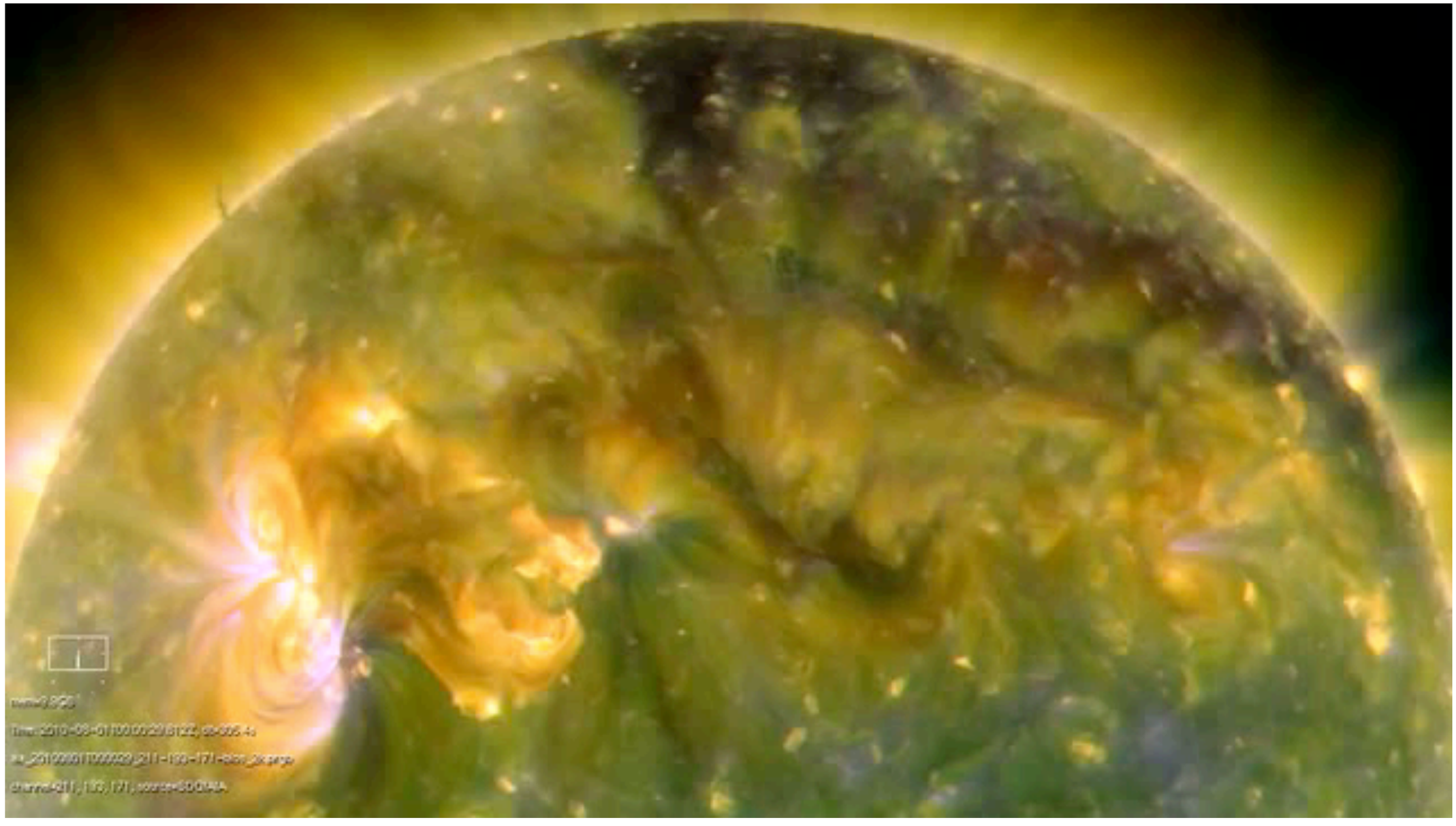




SDO / AIA

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

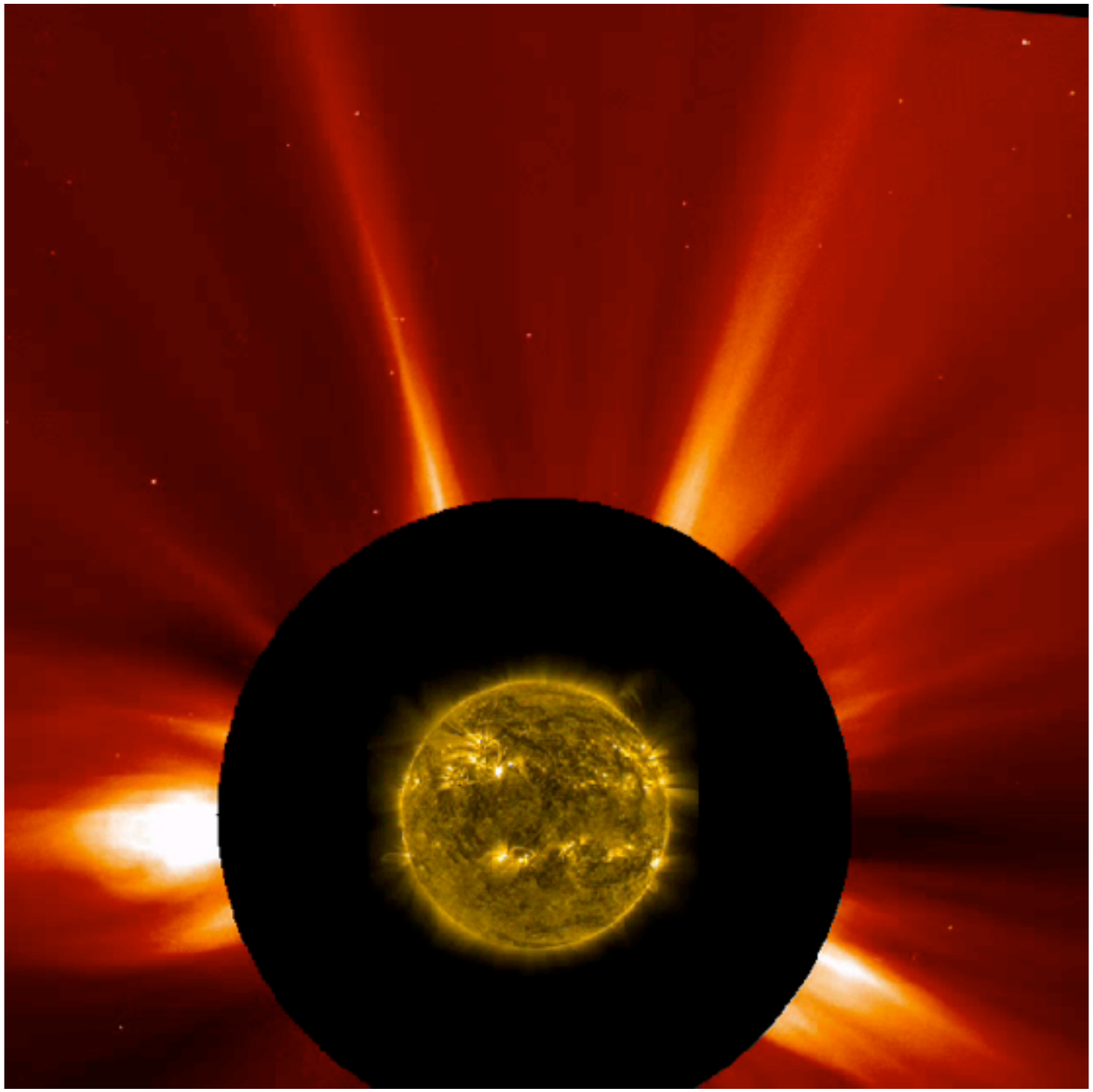
Solar Flares (A Space-Based Tour)



SDO / AIA

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

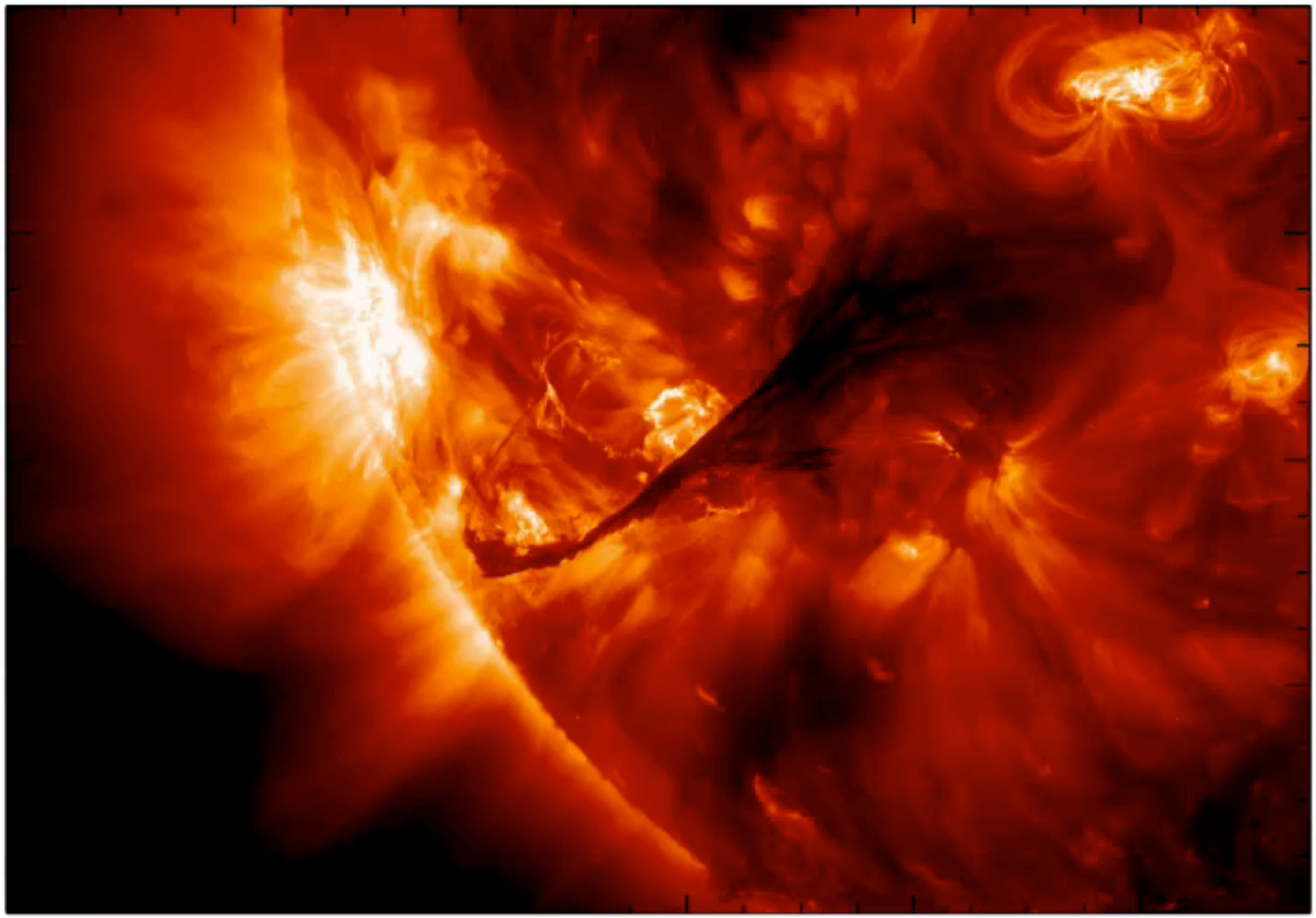
Solar Flares (A Space-Based Tour)



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)

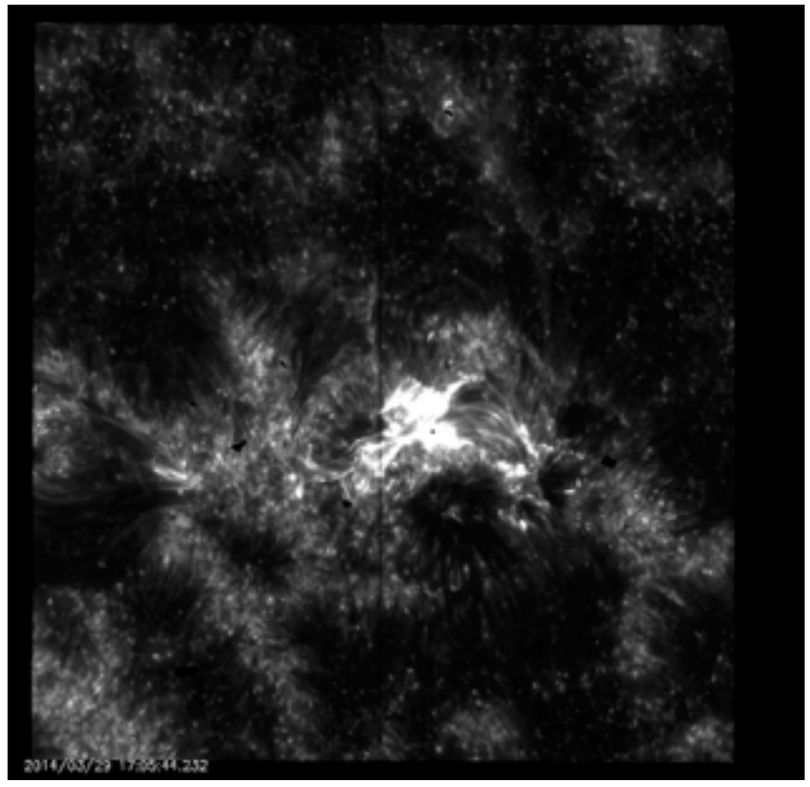


SDO / AIA + *Hinode* / EIS

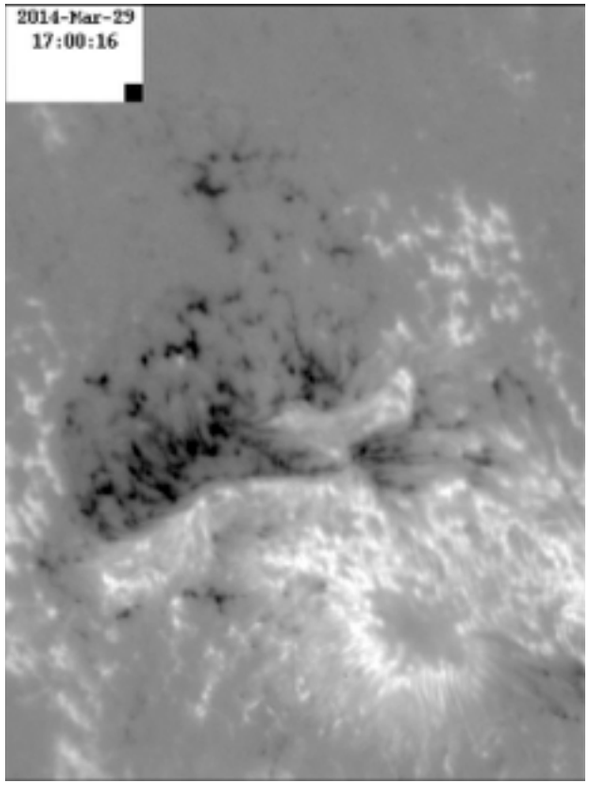
Solar Dynamics Observatory (SDO): http://sdo.gsfc.nasa.gov/ ; EIS: http://solarb.mssl.ucl.ac.uk/SolarB/Solar-B.jsp

Solar Flares (A Space-Based Tour)

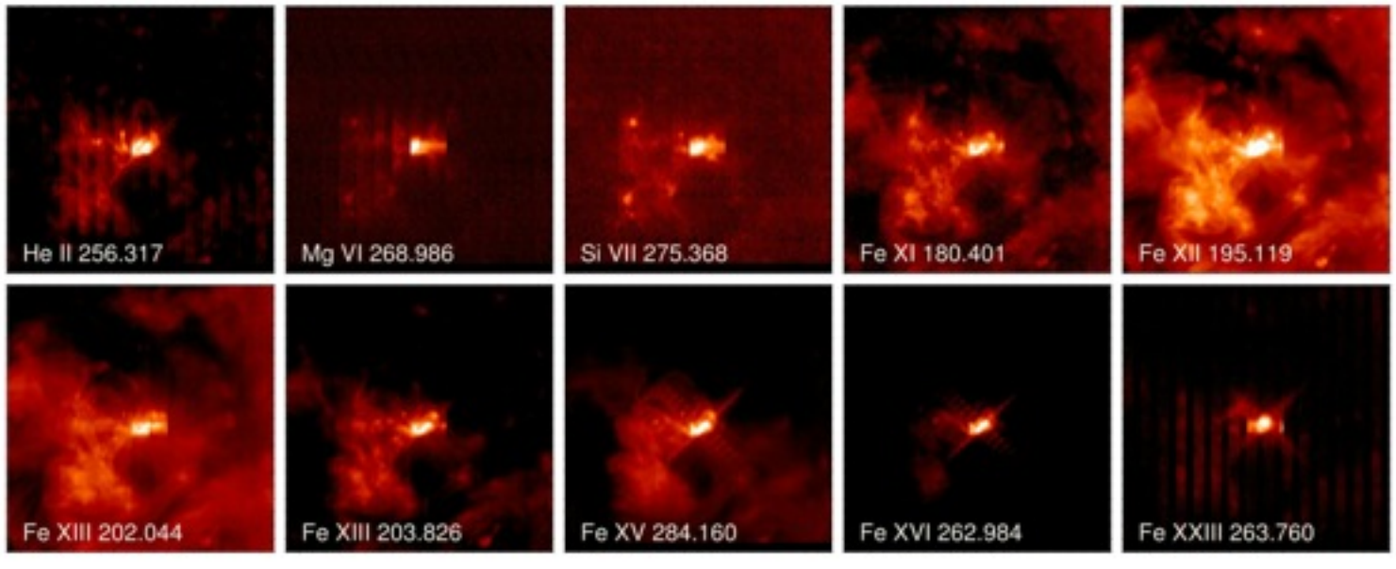
IRIS



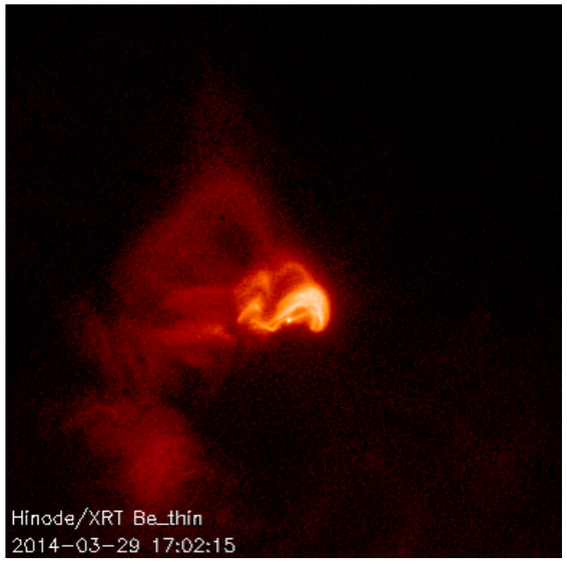
Hinode / SOT [Magnetogram]



Hinode / EIS



Hinode / XRT

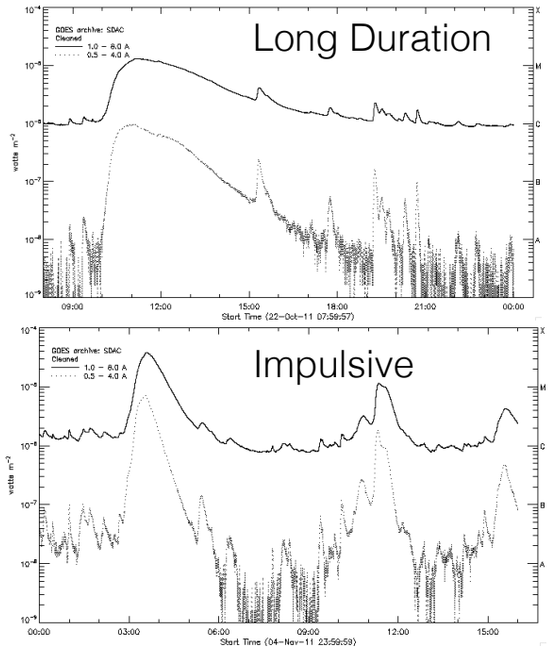


Interface Region Imaging Spectrograph (IRIS): http://iris.gsfc.nasa.gov/ ; Hinode: http://hinode.msfc.nasa.gov/

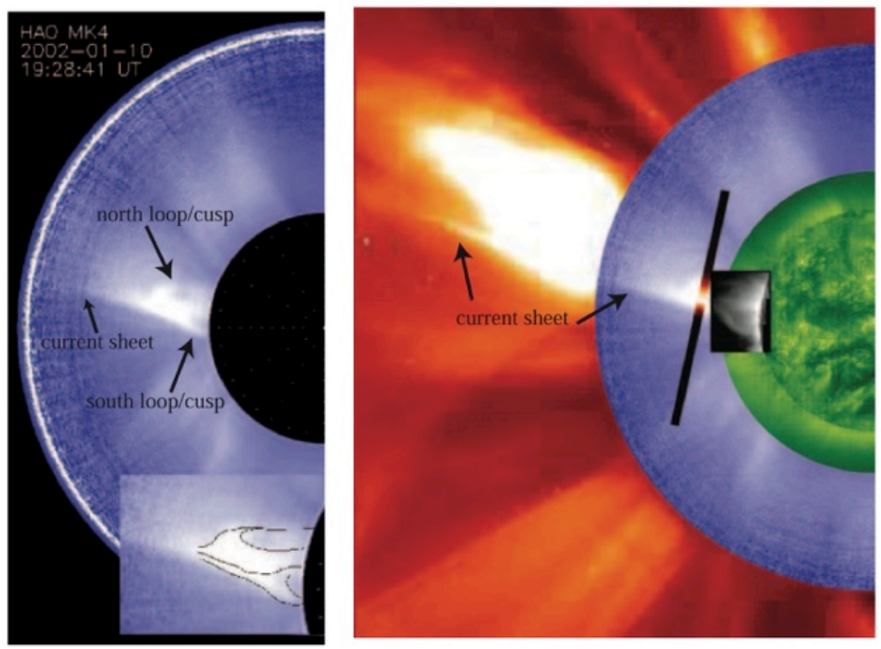
Investigating Energy Release

Focus on Long Duration Events

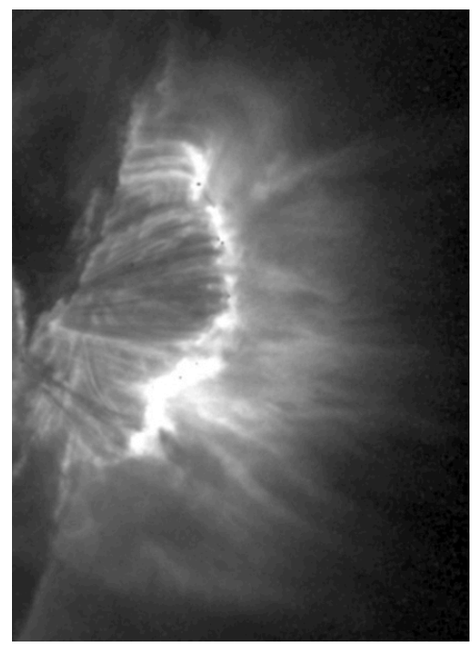
- Energy released for many hours
- Associated with Coronal Mass Ejections (CMEs)
- Development of current sheets and supra-arcade fans



Example GOES lightcurves



Ko et al. 2003

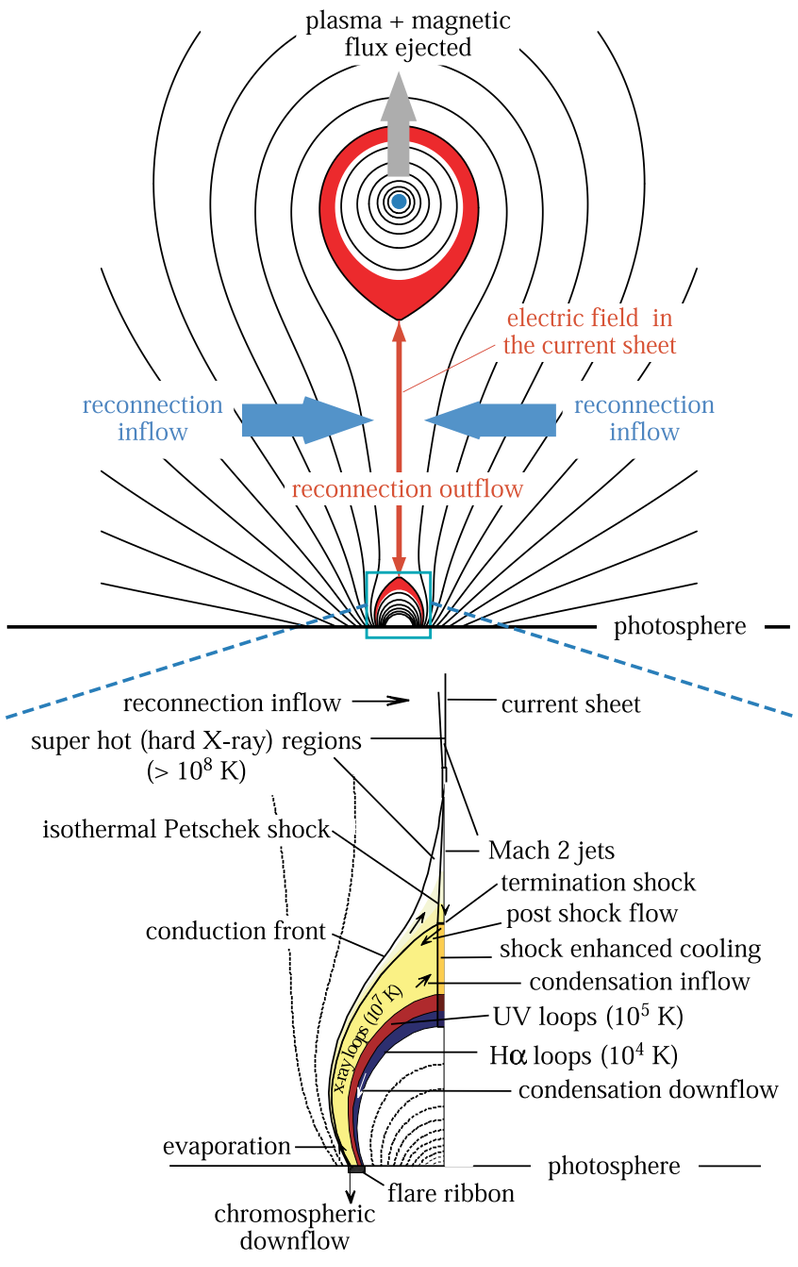


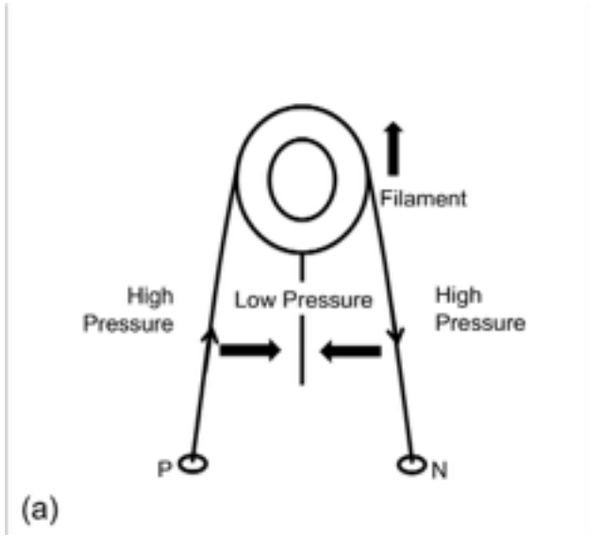
Savage & McKenzie 2011

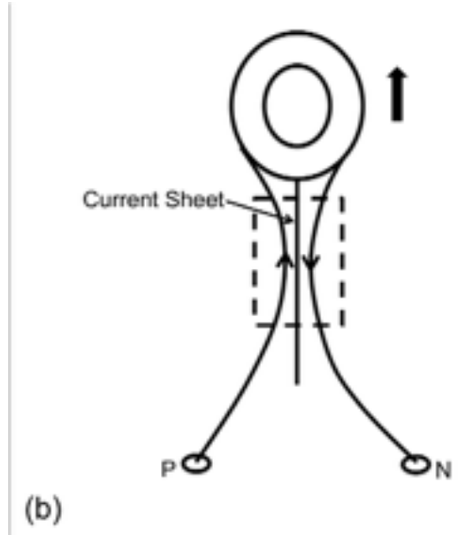
Geostationary Satellite Server (GOES) X-ray lightcurves: http://solarmonitor.org/goes_pop.php?date=20140410&type=xray

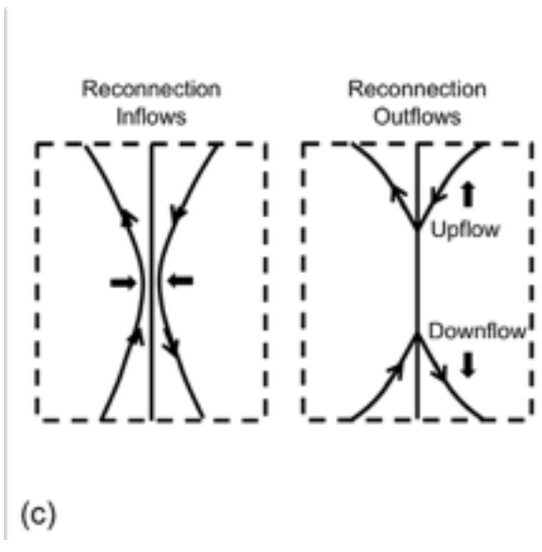
Investigating Energy Release

Standard **2-D** Flare Model









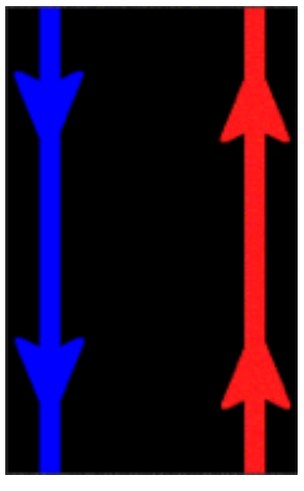
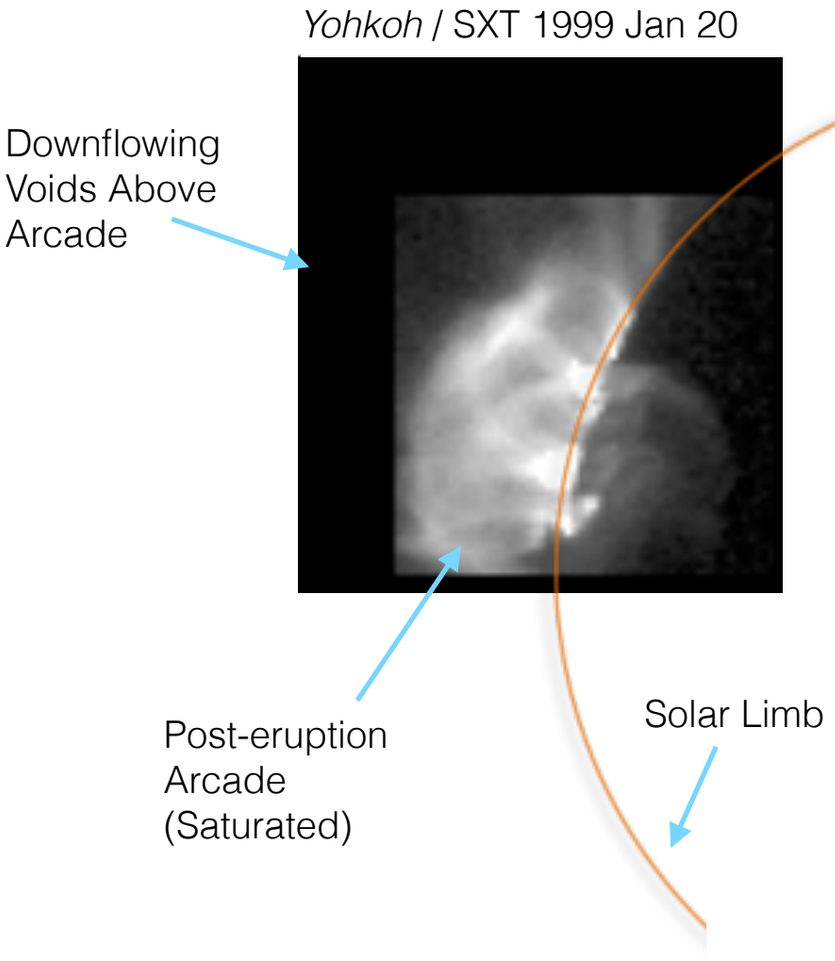


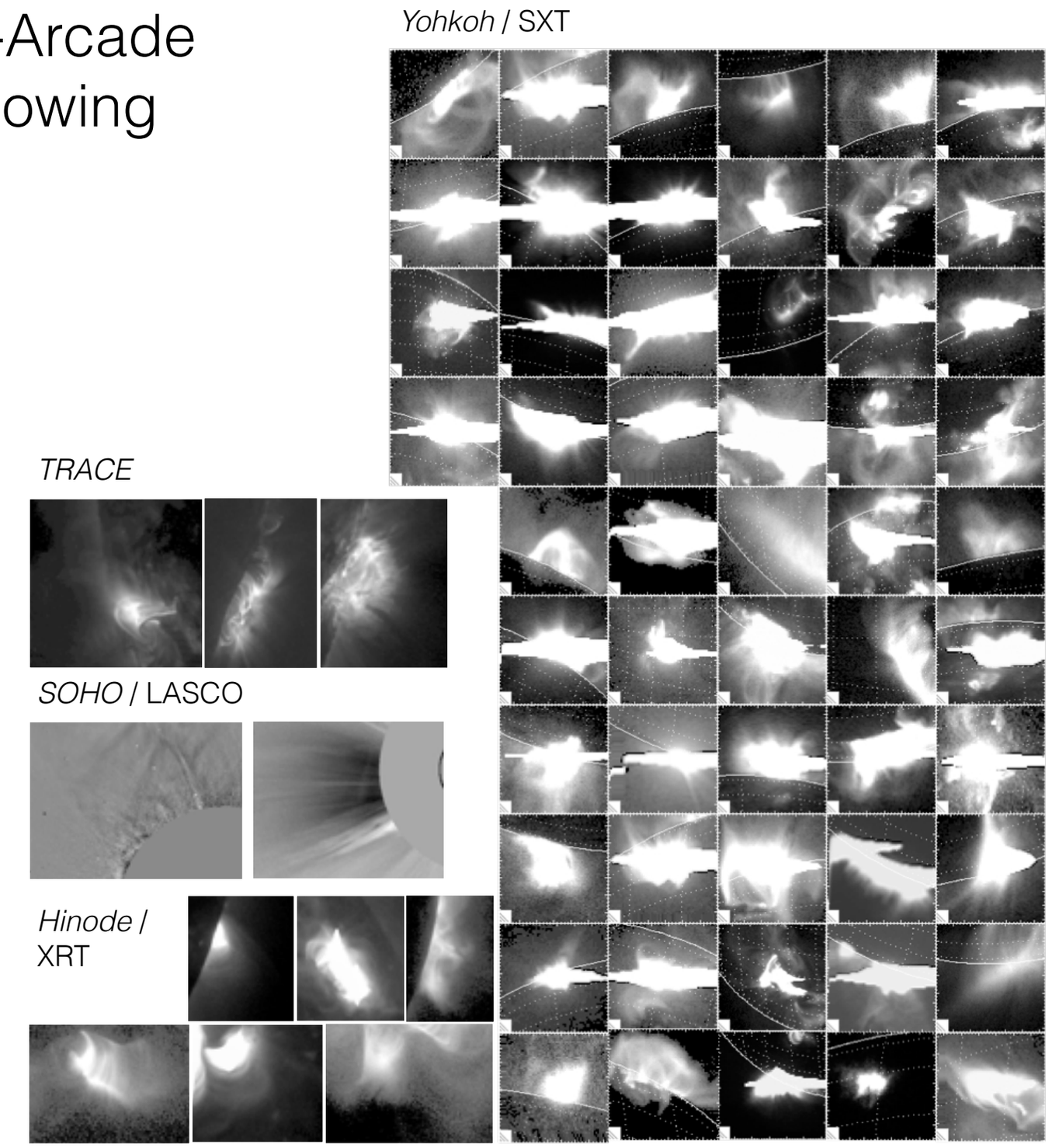
Image Credit: ESA

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)

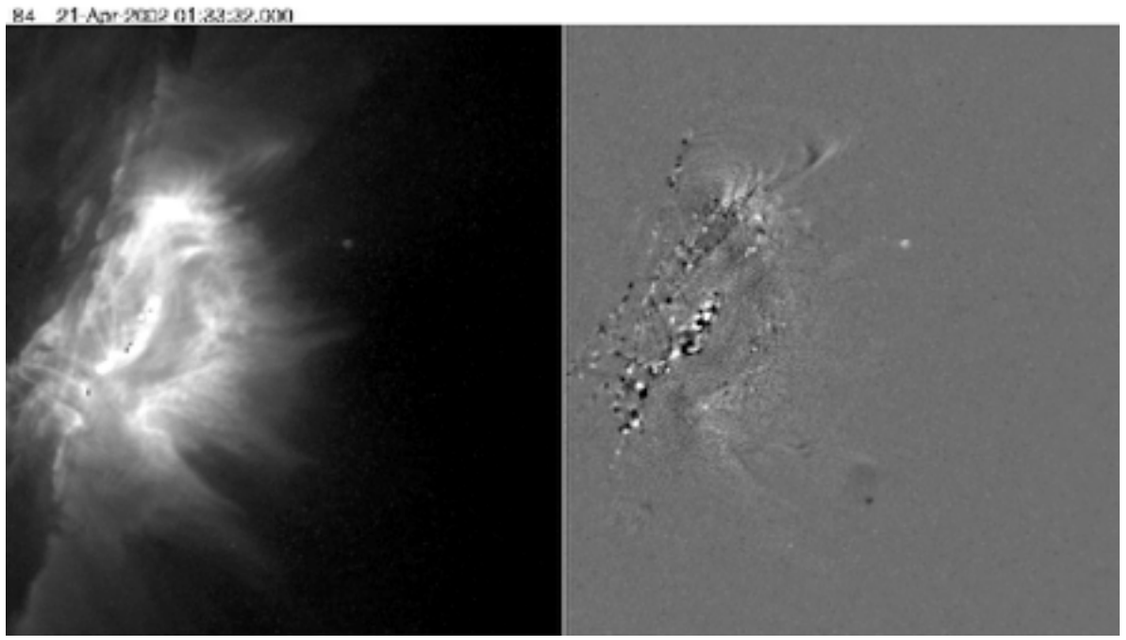


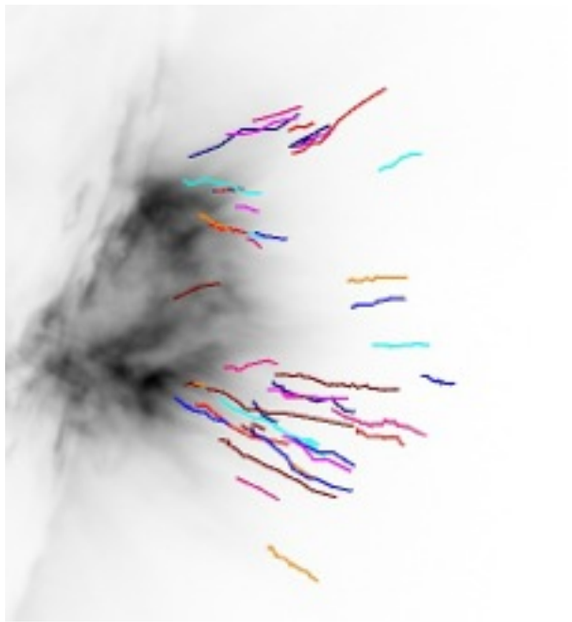


McKenzie & Hudson 1999; Khan et al. 2007; Savage & McKenzie 2011

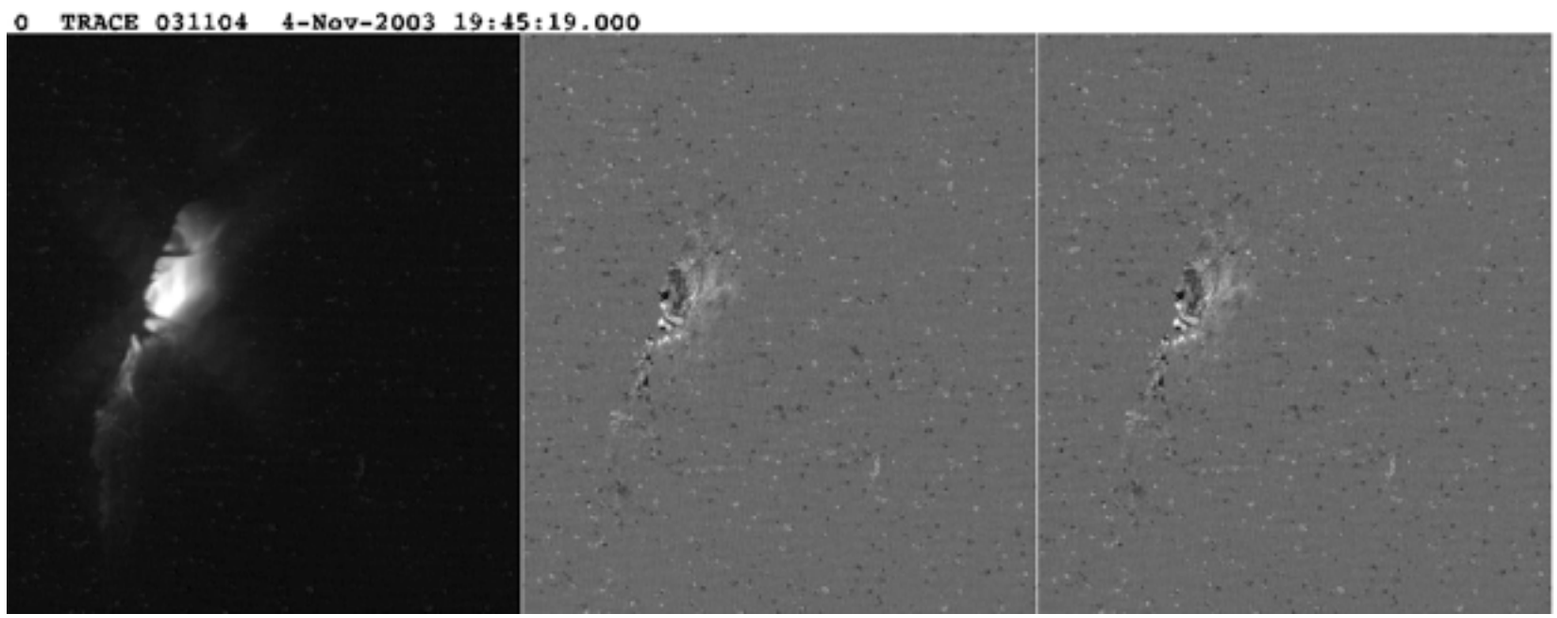
Investigating Energy Release

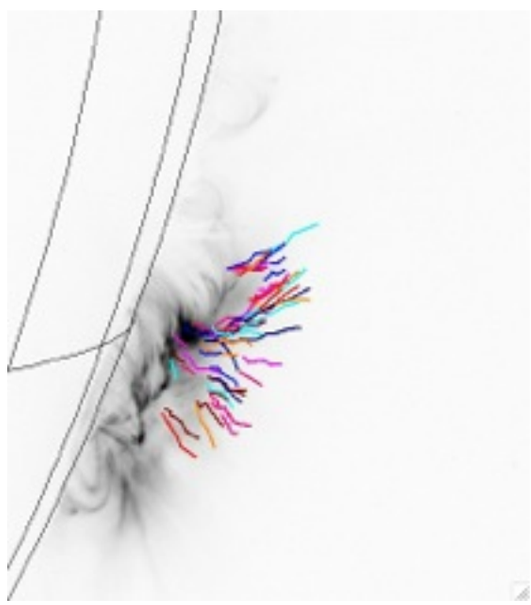
TRACE 193 A, X-flare, 2002 Apr 21





TRACE 193 A, X-flare, 2003 Nov 4

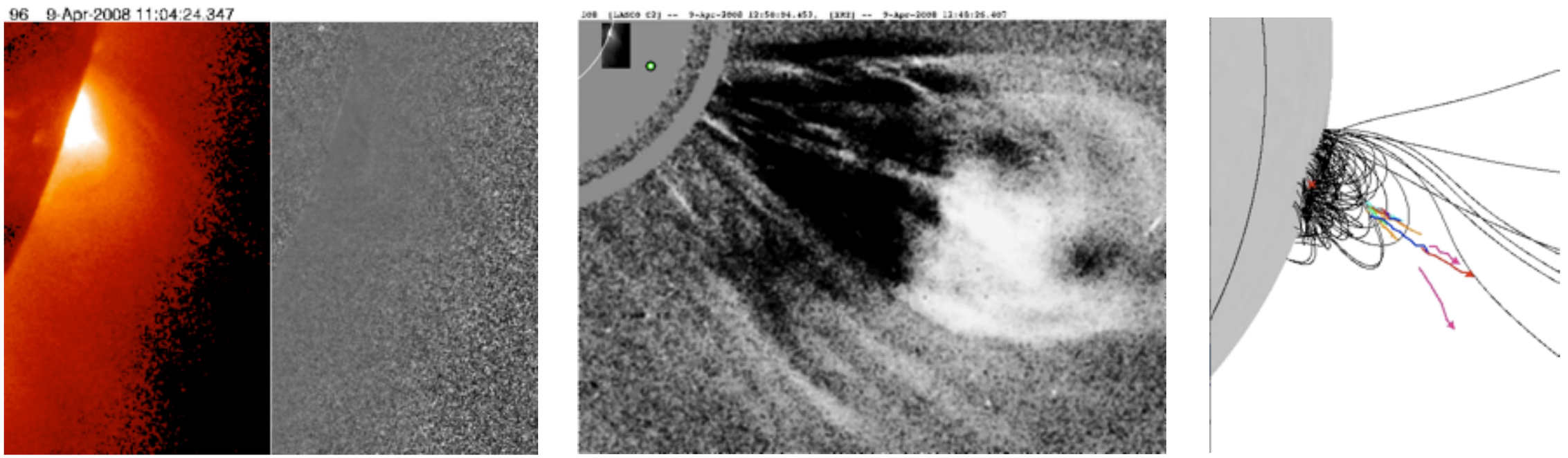




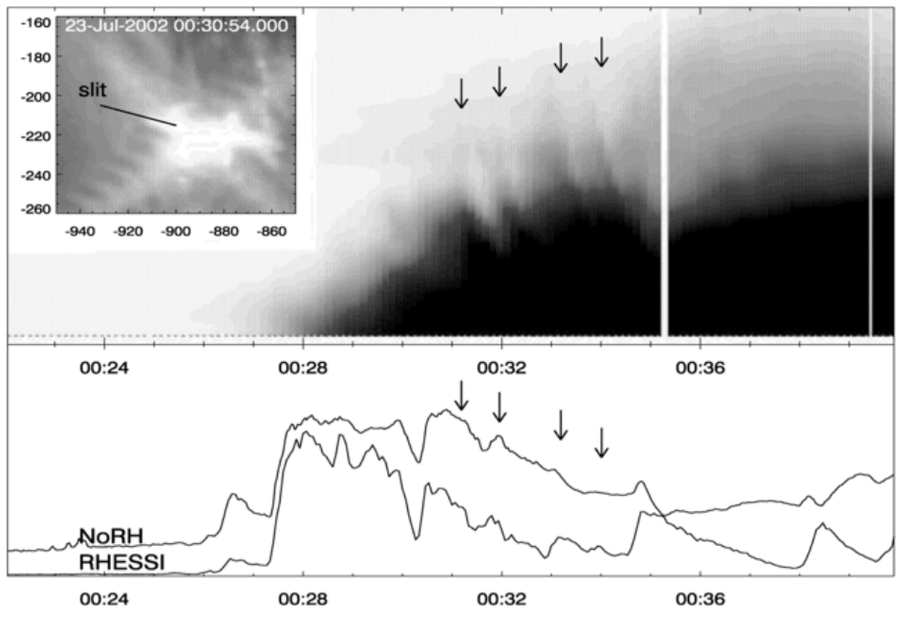
McKenzie & Savage 2009

Investigating Energy Release

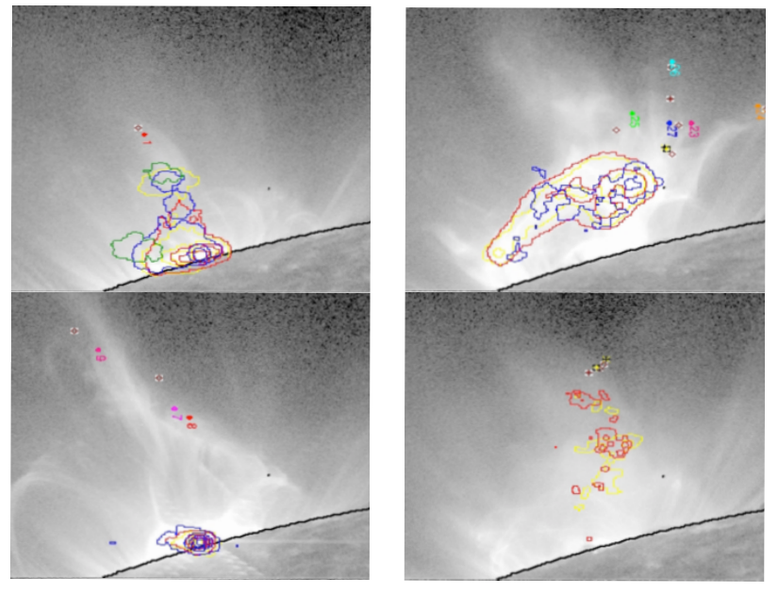
Hinode / XRT, 2008 Apr 9



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



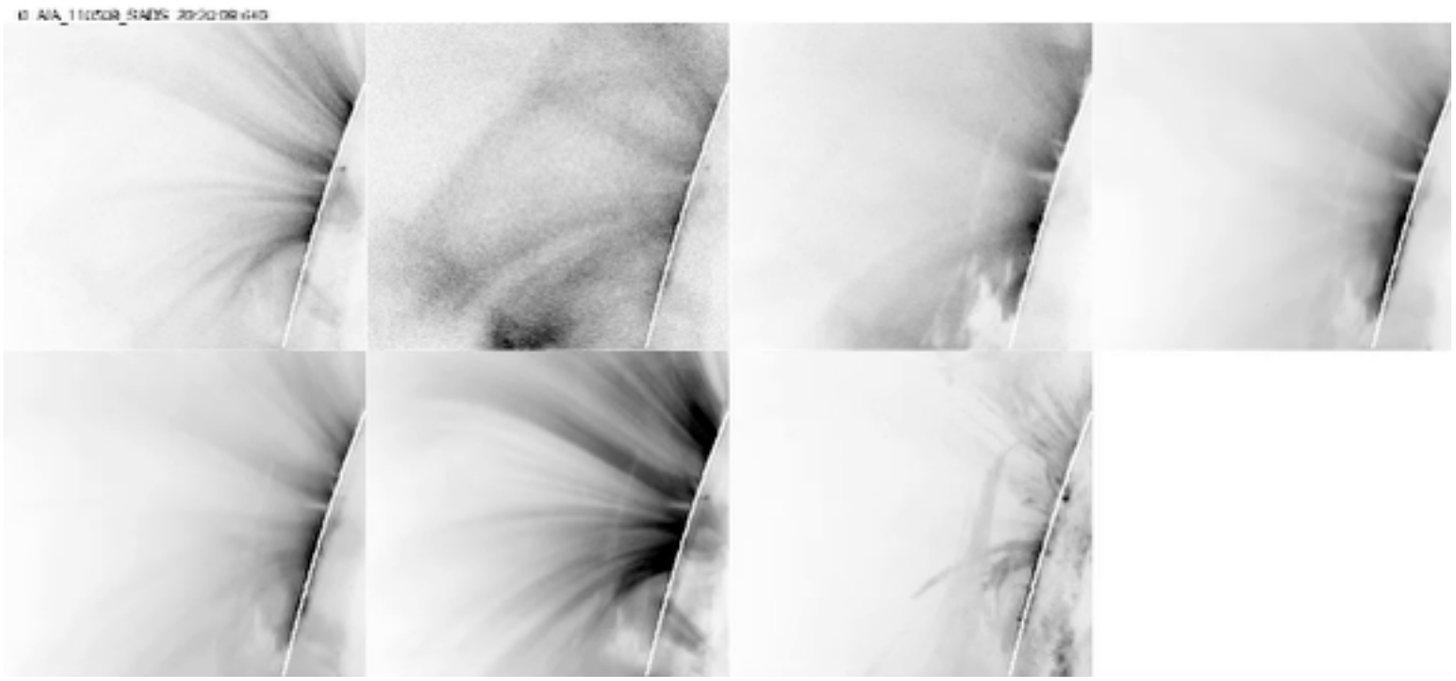
SDO / AIA + *RHESSI* (contours), 2010 Nov 3



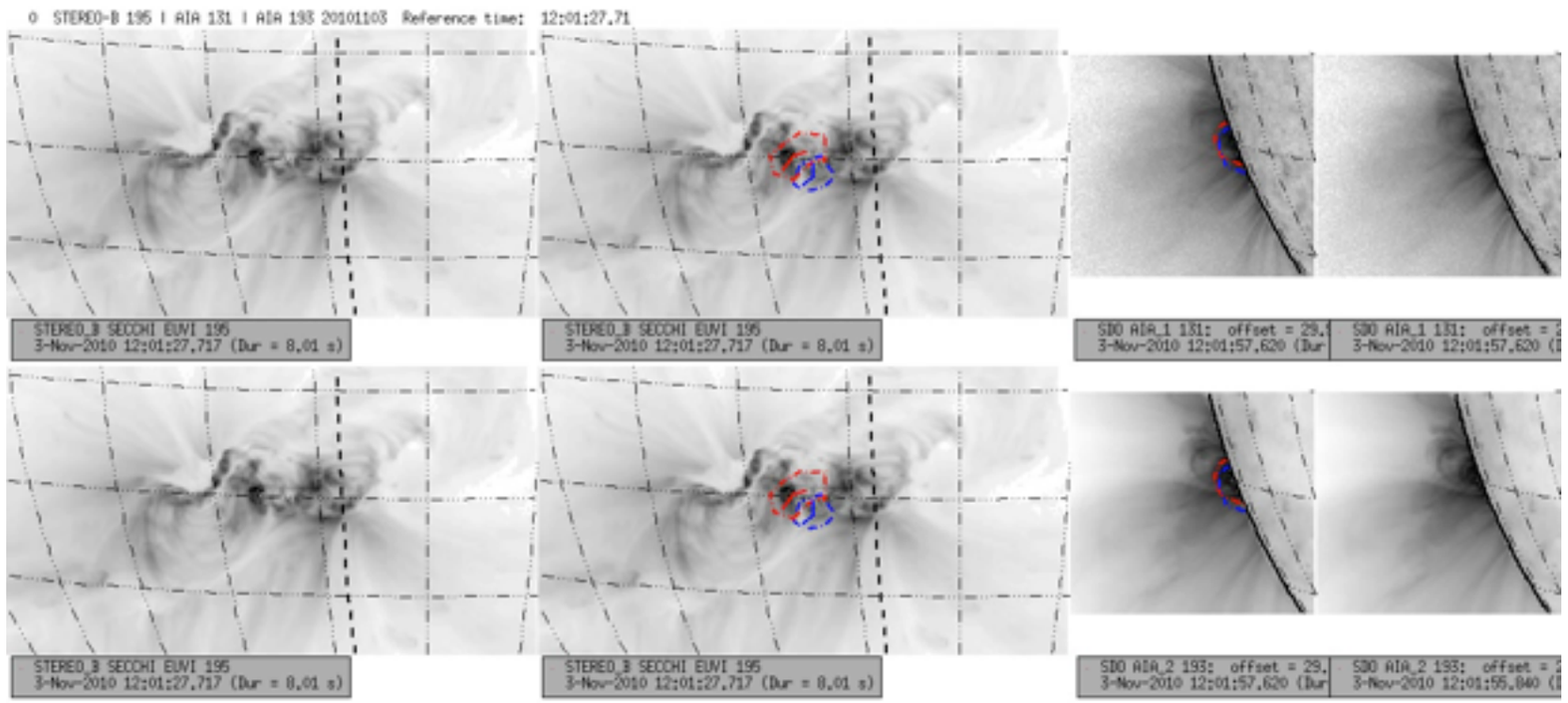
Savage et al. 2012; Savage et al. 2010; Asai et al. 2004; Yokoyama & Shibata 1999

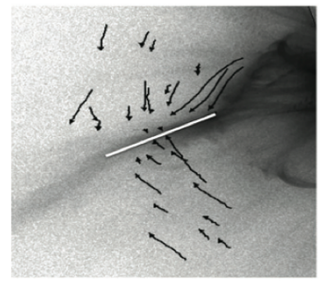
Investigating Energy Release

SDO / AIA, 2011 May 9

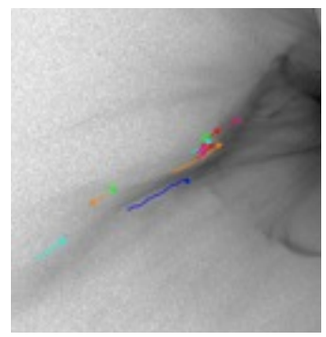


SDO / AIA + *STEREO* / SECCHI, 2010 Nov 3





Inflows
Composite



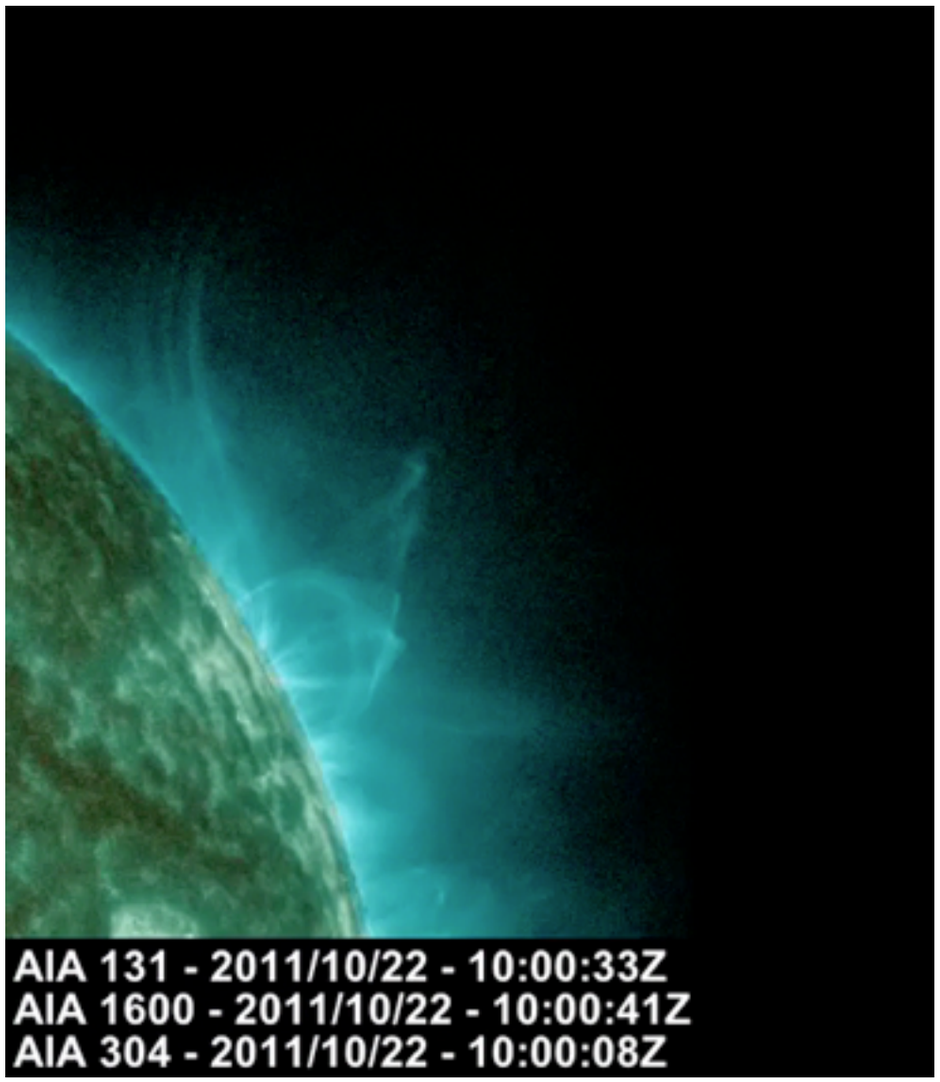
Outflows
131 A

Savage et al. 2012

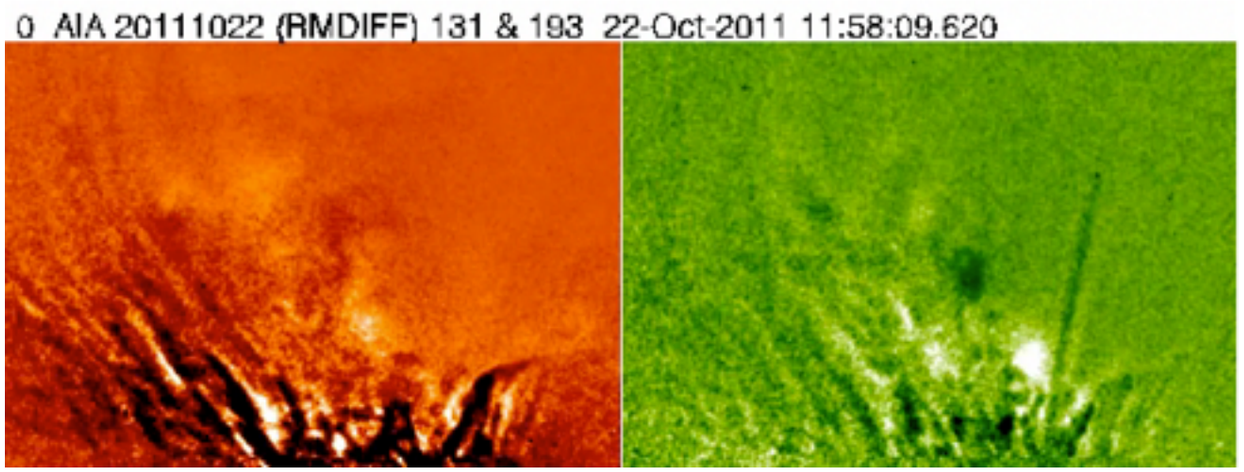
Investigating Energy Release

Explanation for SADs & SADLs converging …

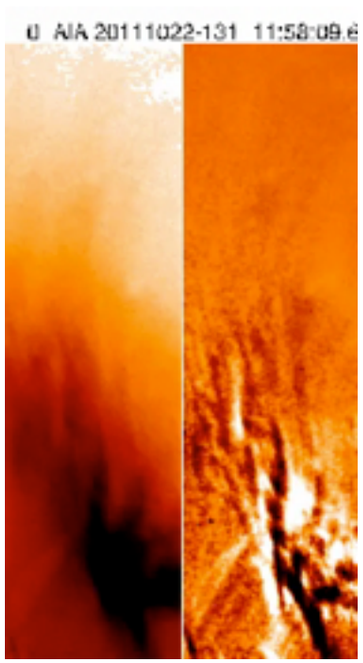
SDO / AIA, 2011 Oct 22

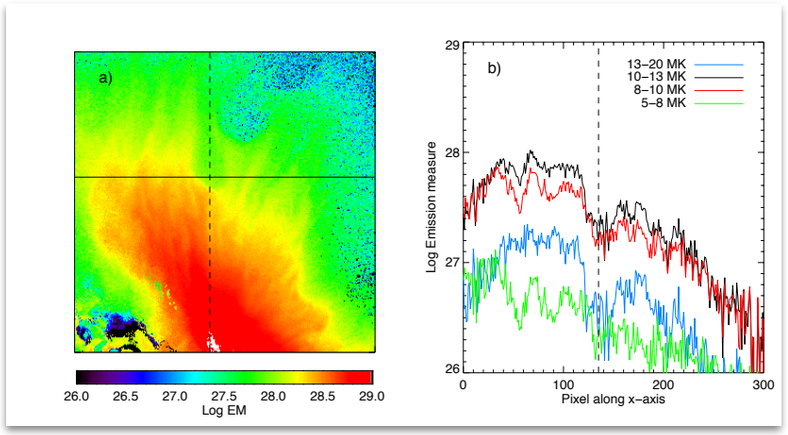


Movie Credit: D. E. McKenzie, Mont. State Univ



Bright thin loops retracting below voids.





SADs cooler than fan (and much less dense)

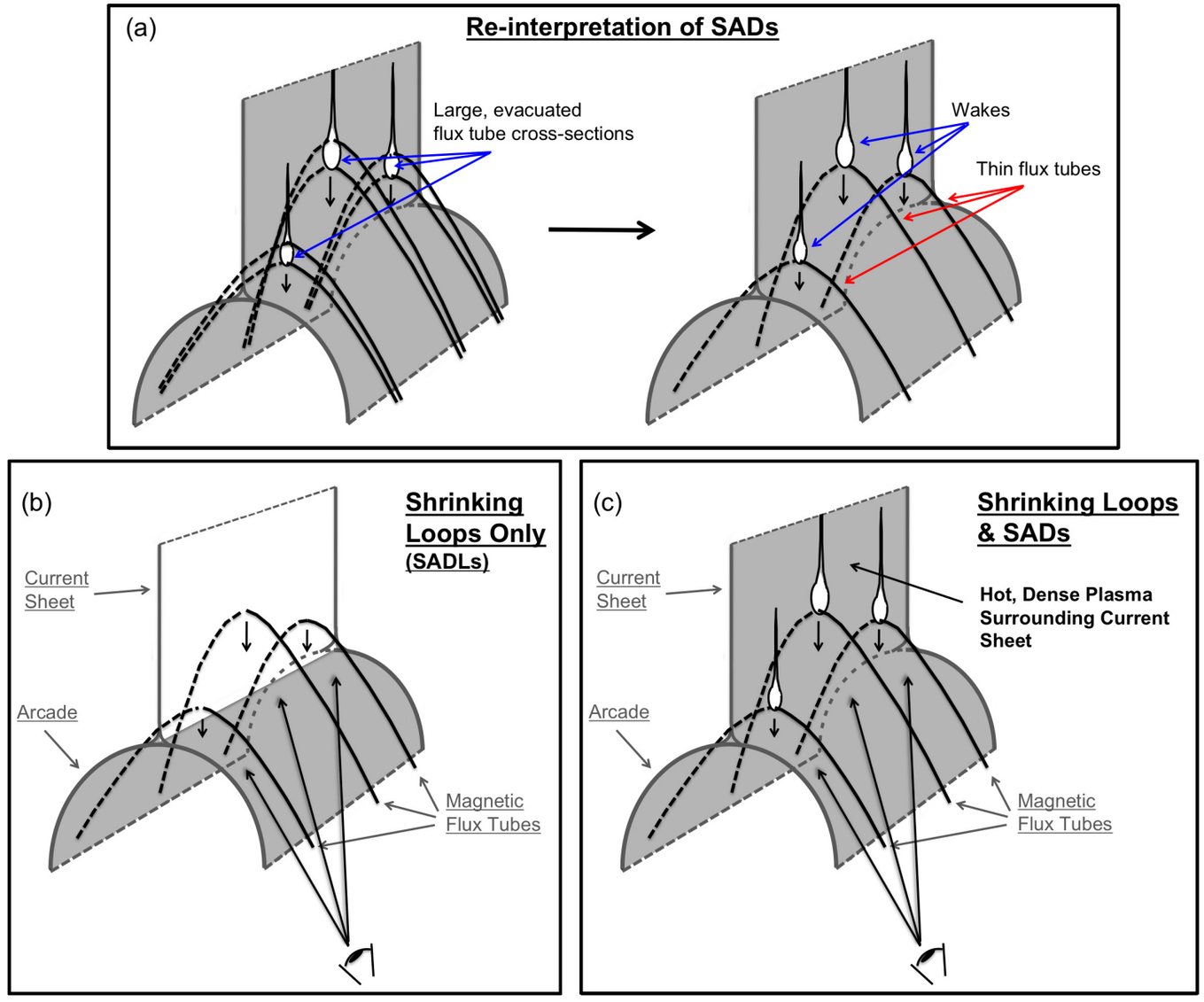
Savage, McKenzie, Reeves 2012

Investigating Energy Release

Explanation for SADs & SADLs converging …

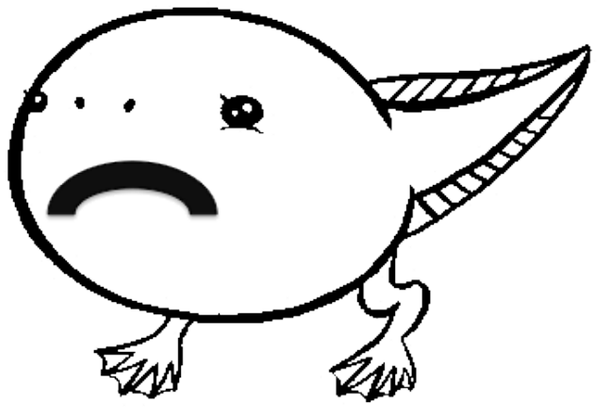
—> Loops outflows of patchy, bursty magnetic reconnection?!

—> Voids rarefaction regions behind retracting loops?



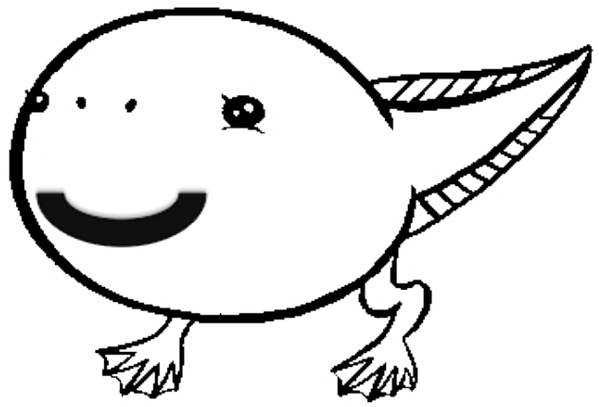
Savage, McKenzie, Reeves 2012 ; RHESSI nugget #168: http://sprg.ssl.berkeley.edu/~tohban/wiki/index.php/Supra-Arcade_Downflows

Sadpoles



?

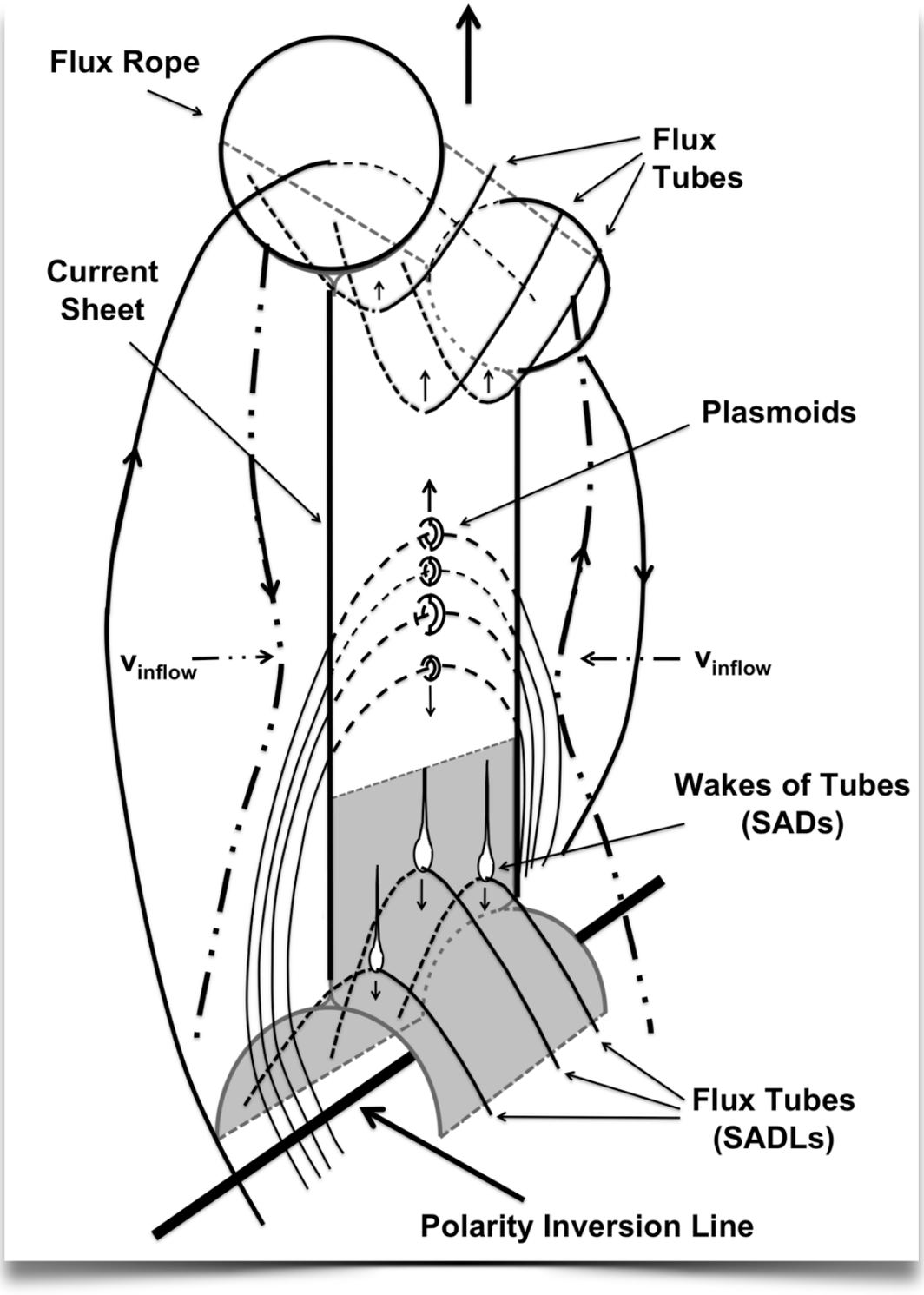
Happis



HAPPIs: High-Altitude Propagating Pressure Imbalances?

None …. yet…

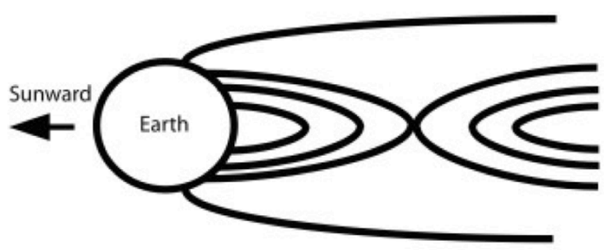
A Simplified **3-D** Solar Flare Model



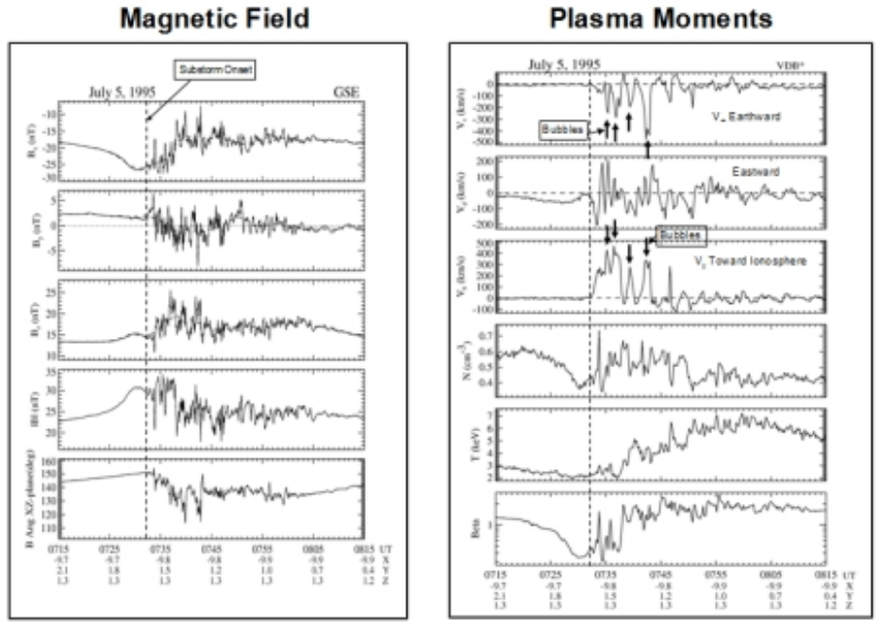
Savage et al. 2012

Observing Magnetic Reconnection

Solar flares comparable to Magnetotail substorms

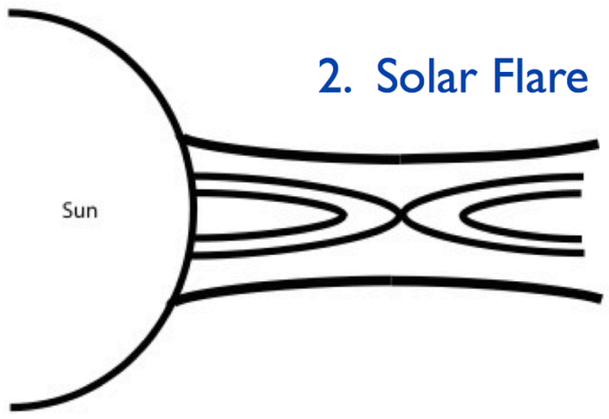


1. Magnetotail Substorm

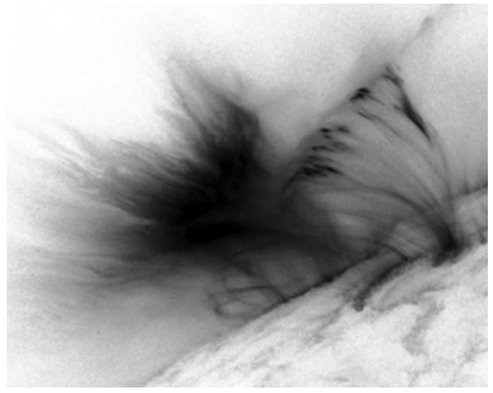


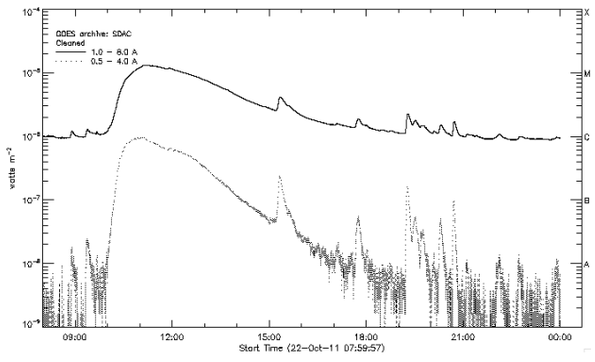
Magnetotail:

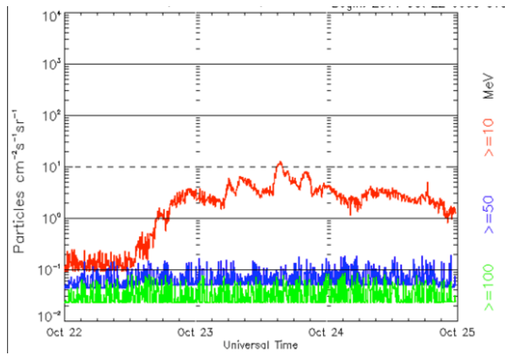
In Situ Measurements



Note: Very different scales and plasma regimes.







Solar:

Global Context

SDO 2nd Year Highlights

Goddard Multimedia: http://svs.gsfc.nasa.gov/vis/a010000/a010900/a010966/index.html

Thanks!

National Aeronautics and Space Administration (NASA): http://www.nasa.gov/