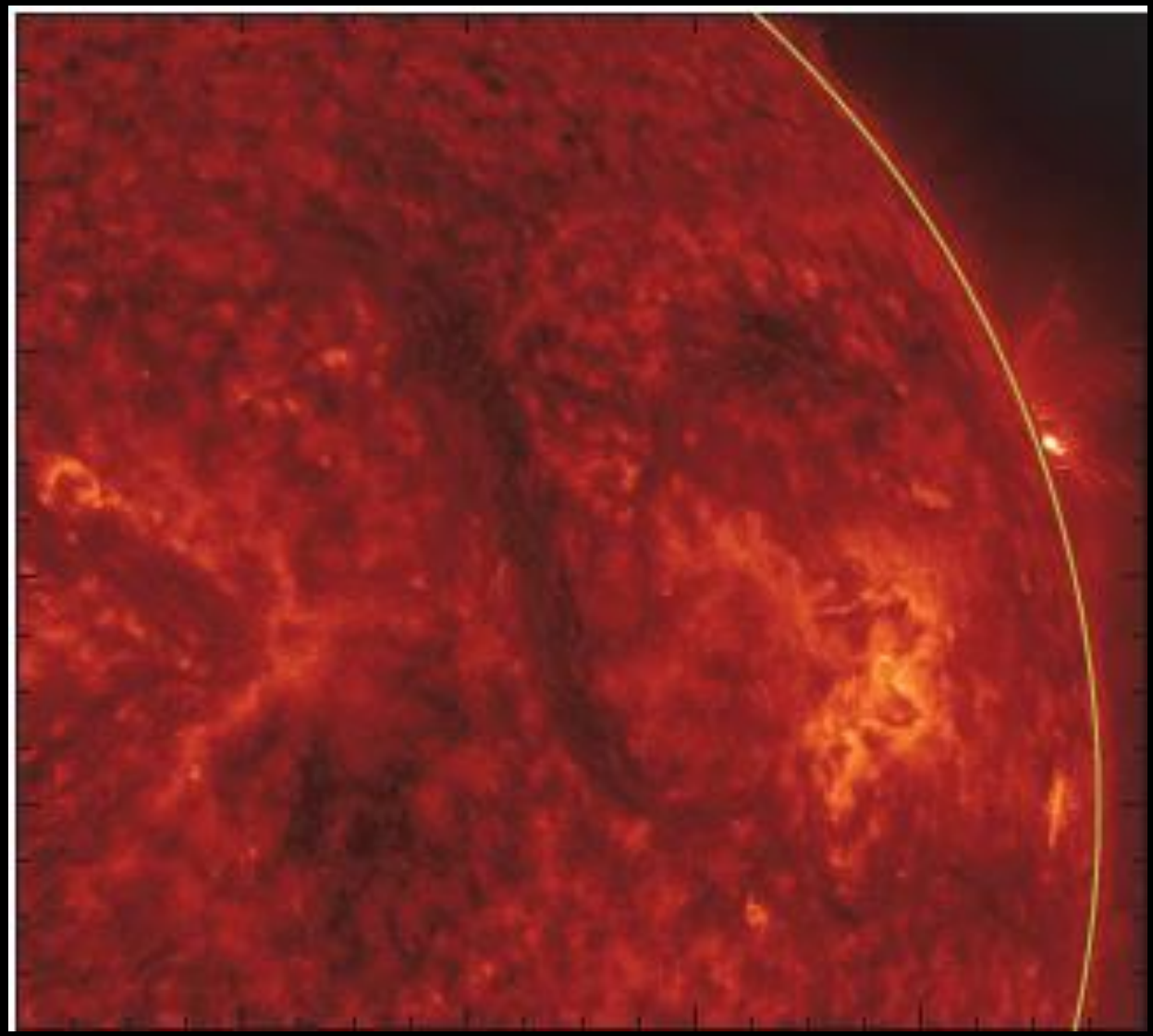
Why X-ray Observations Outside Active Regions Will Advance Our Understanding of Solar Eruptive Events

Gordon Holman

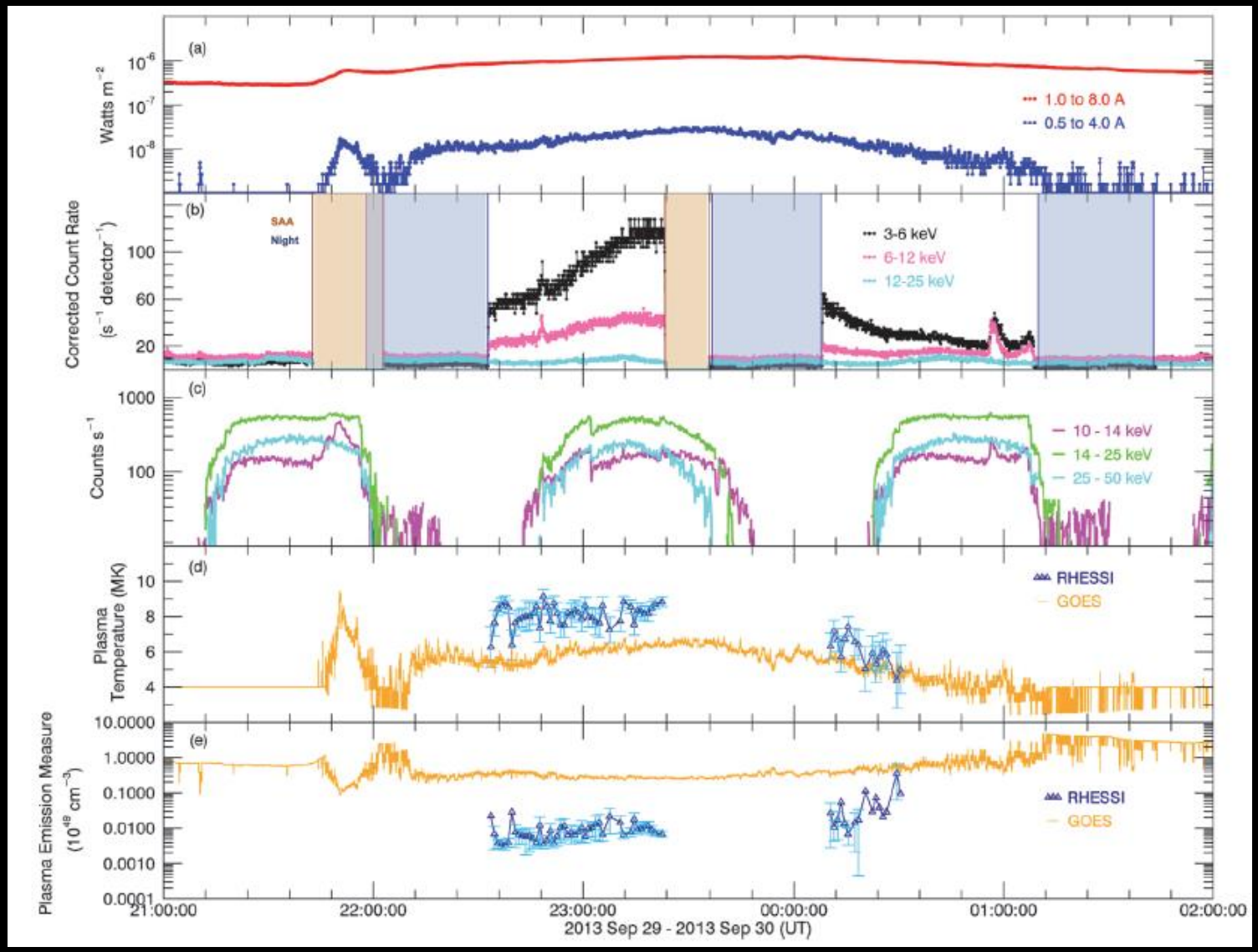
NASA Goddard Space Flight Center
Solar Physics Laboratory
Code 671

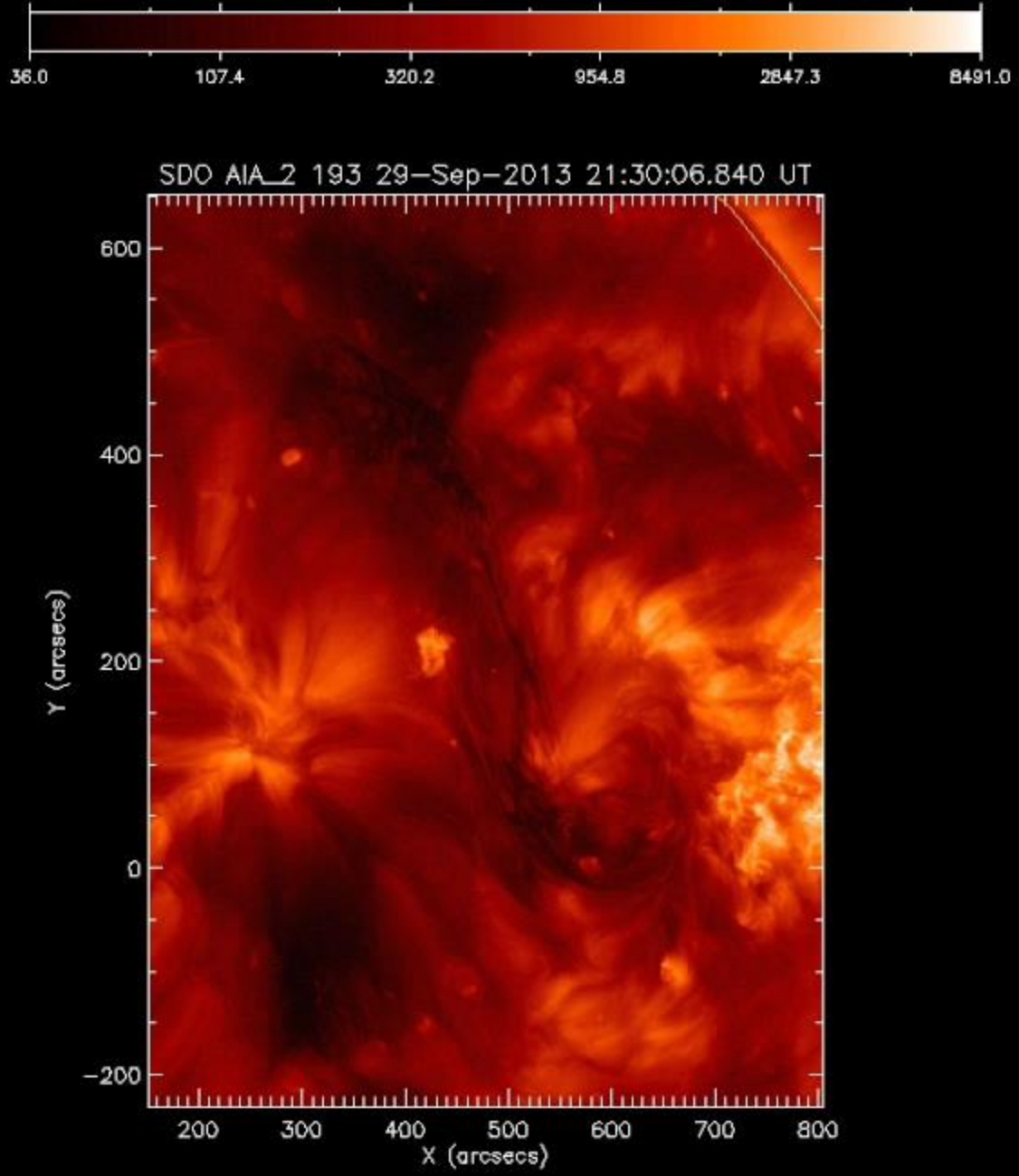
2013 September 29 Eruption of a Quiescent Filament

- AIA 304 Å band
- 21:00 UT
- Beginning of the filament eruption
- 40 min before beginning of GOES flare



GOES, RHESSI, & Fermi Lightcurves & Temperatures

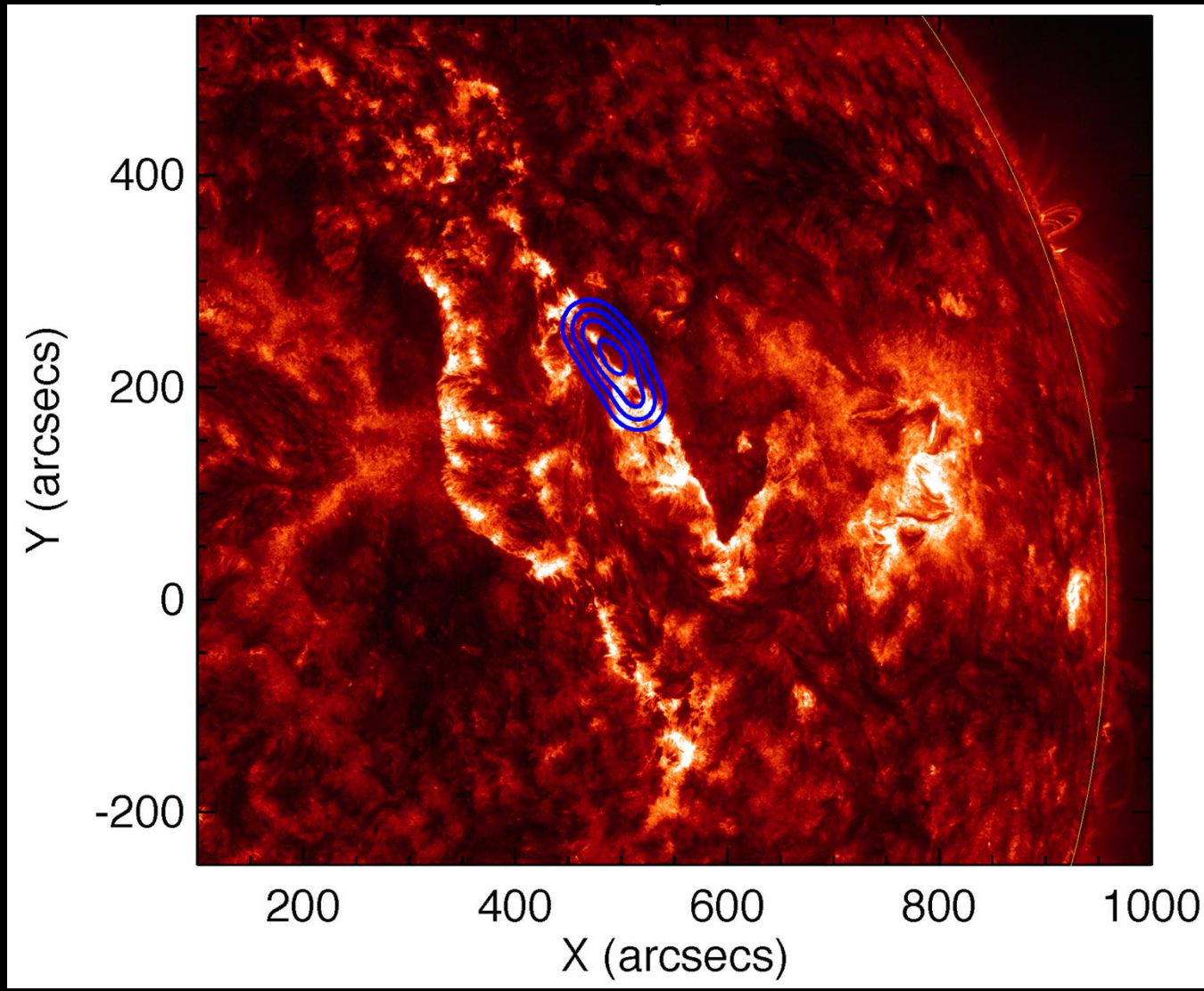



36.0
107.4
320.2
954.8
2847.3
8491.0
SDO AIA_2 193 29-Sep-2013 21:30:06.840 UT
600
400
200
0
-200
Y (arcsecs)
200
300
400
500
600
700
800
X (arcsecs)

SDO/AIA 304 Å image

RHESSI 3 – 9 keV contours

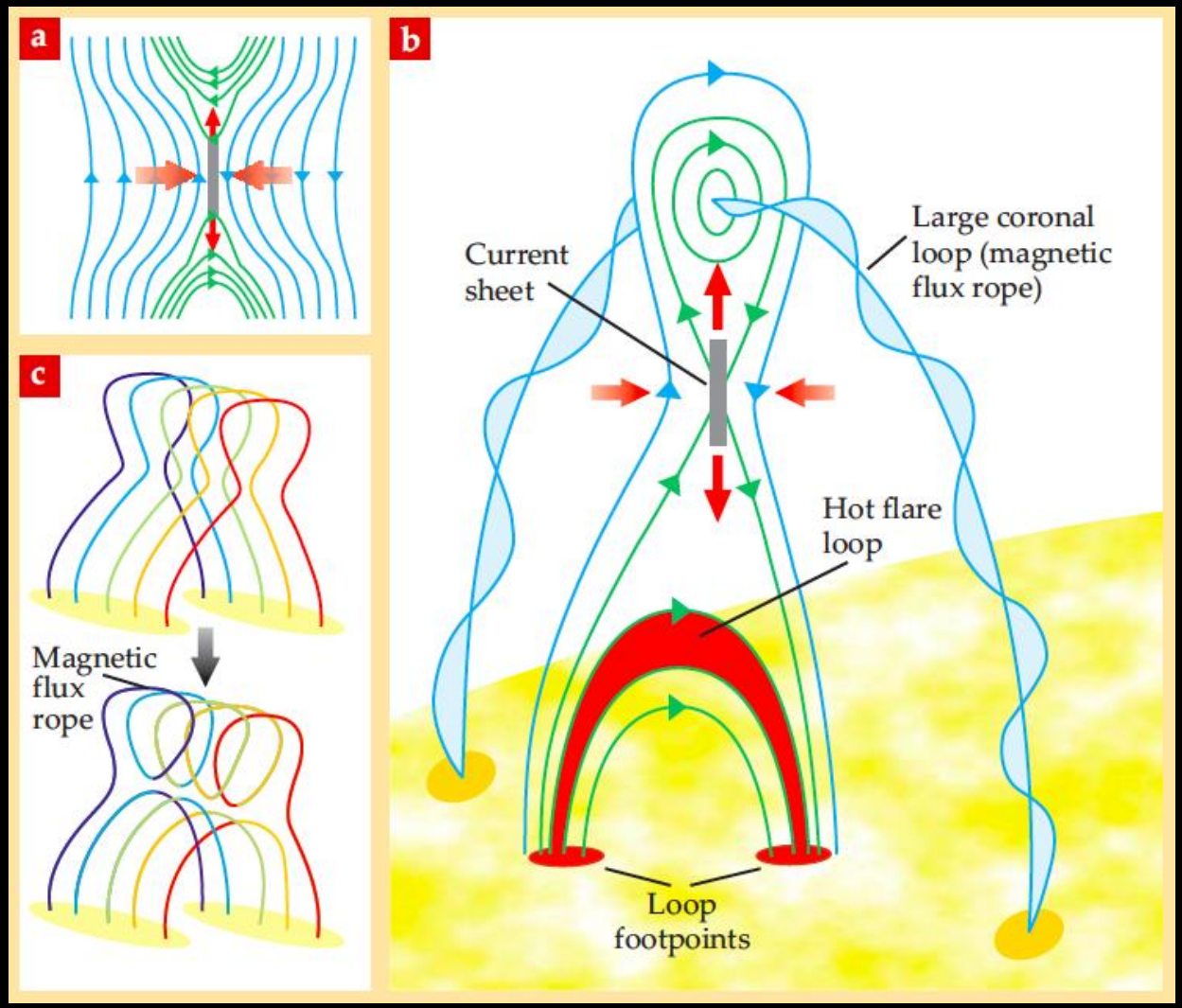
Why is the RHESSI emission limited to a short section of the western ribbon?



Holman, G. D. & Foord, A., 2015, Ap. J. 804, 108

The Standard Model for the Magnetic Evolution of Solar Eruptive Events

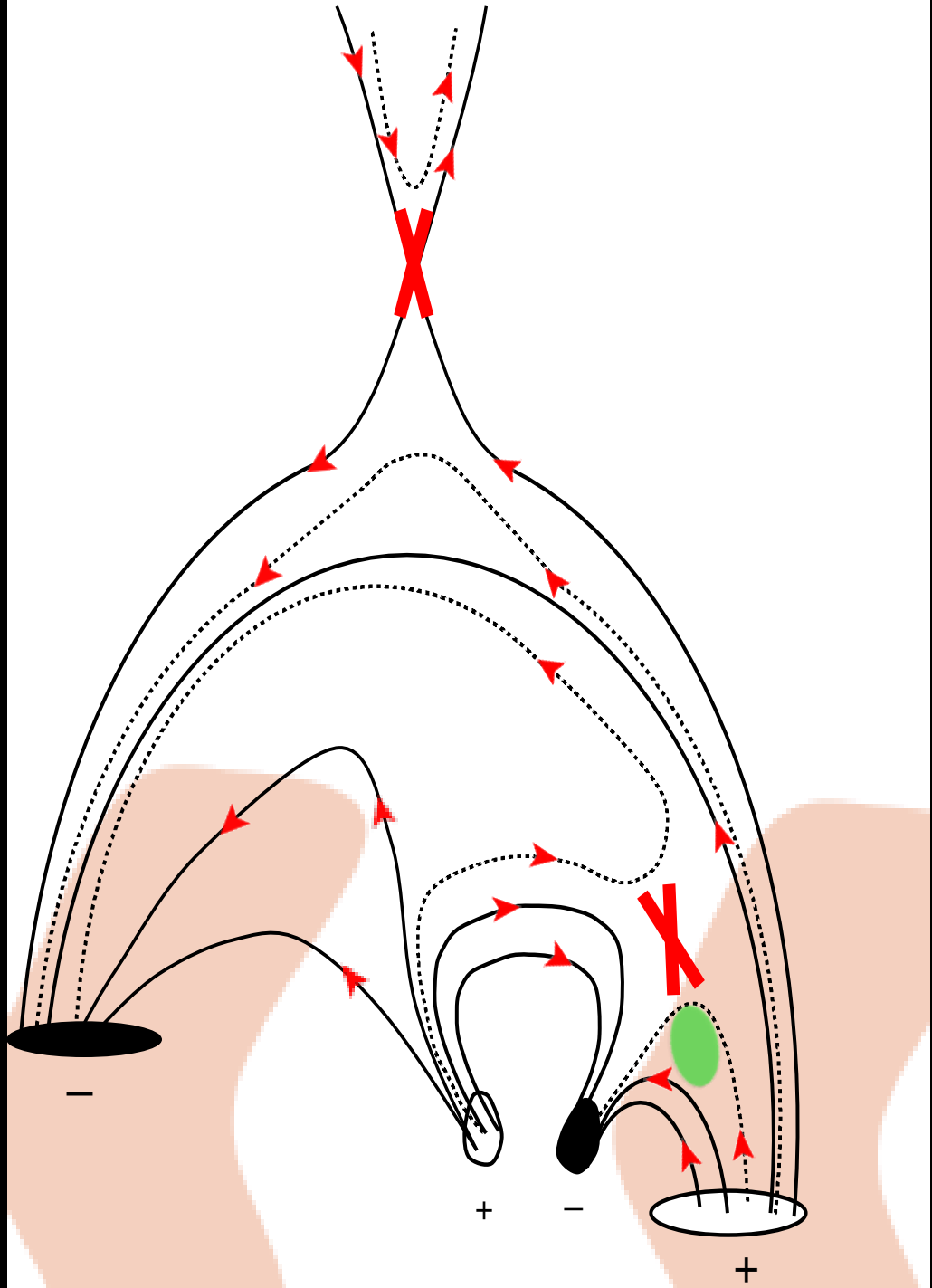
- Loops collapse inward and reconnect
- Flux rope becomes a coronal mass ejection and filament eruption
- Foot points (ribbons) separate
- Hot loops expand upward



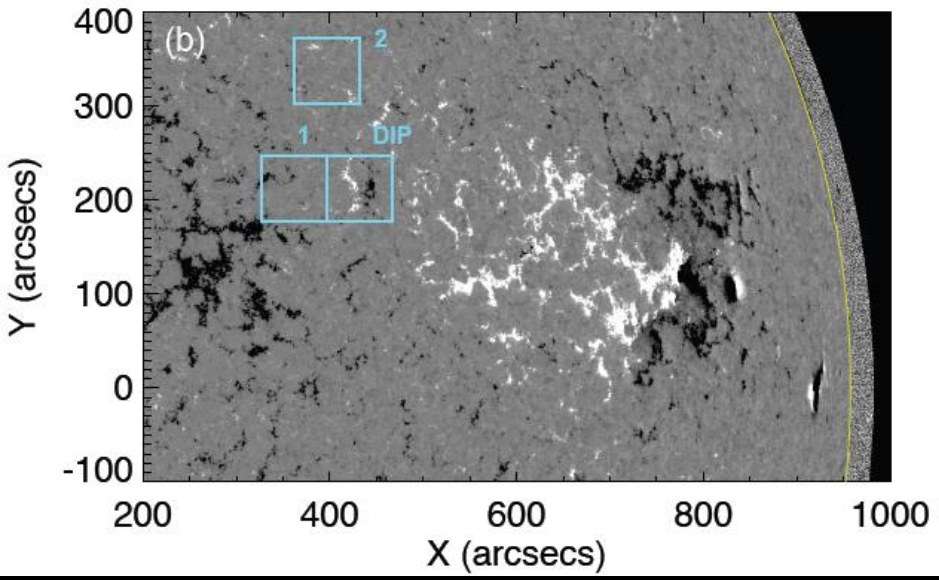
Holman, G. D. 2012, *Physics Today*, April issue

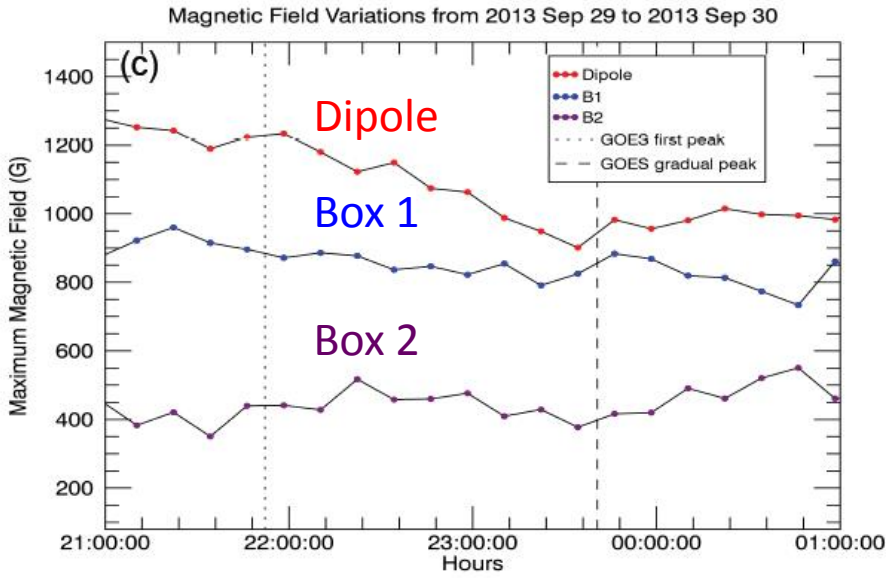
Magnetic Reconnection Explanation for X-ray Source Location

- Standard reconnection above the arcade loops
- Secondary reconnection with the strong magnetic dipole field
- X-ray source below the site of secondary reconnection



Strong Magnetic Dipole Near Location of the RHESSI Source

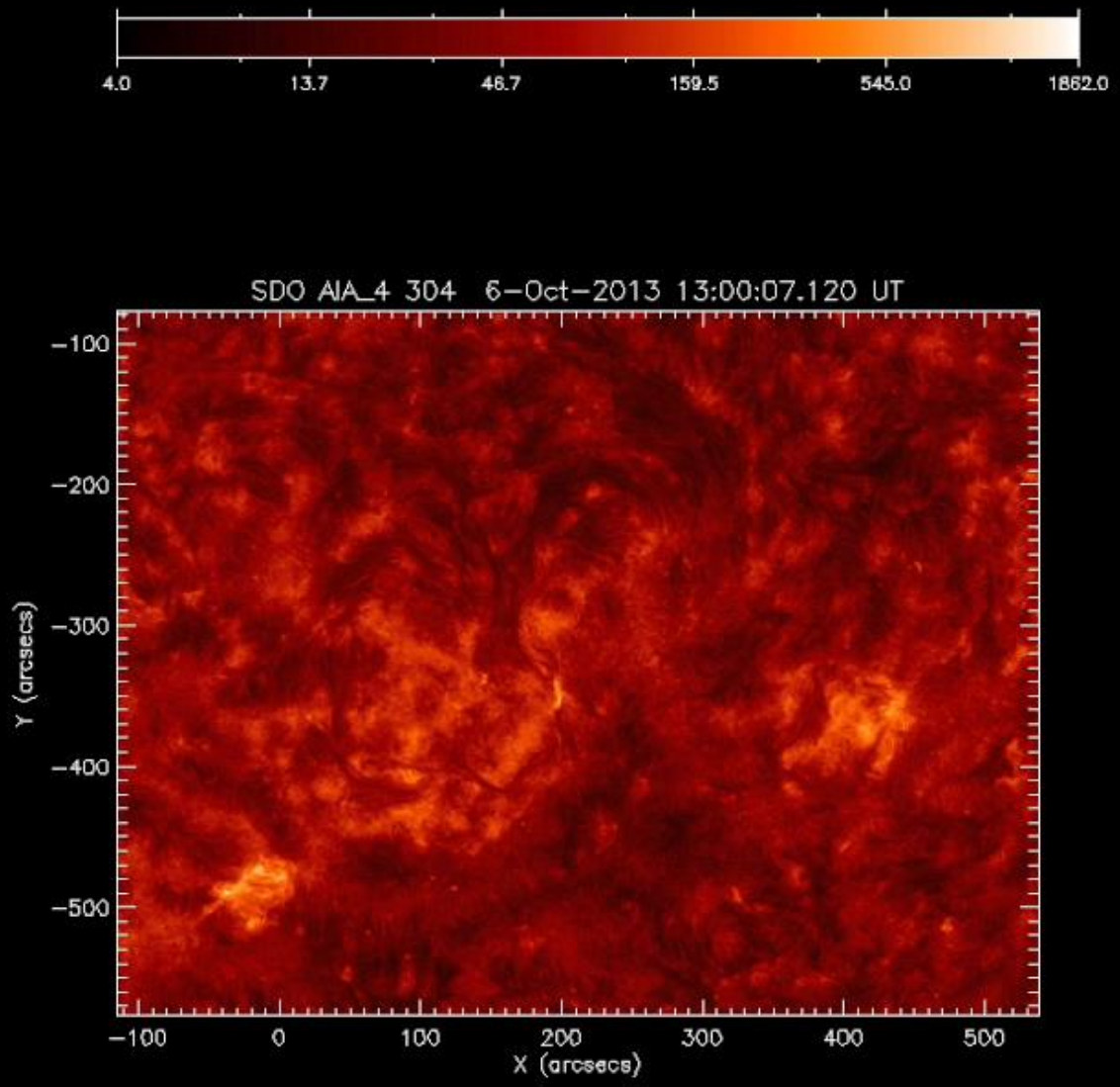




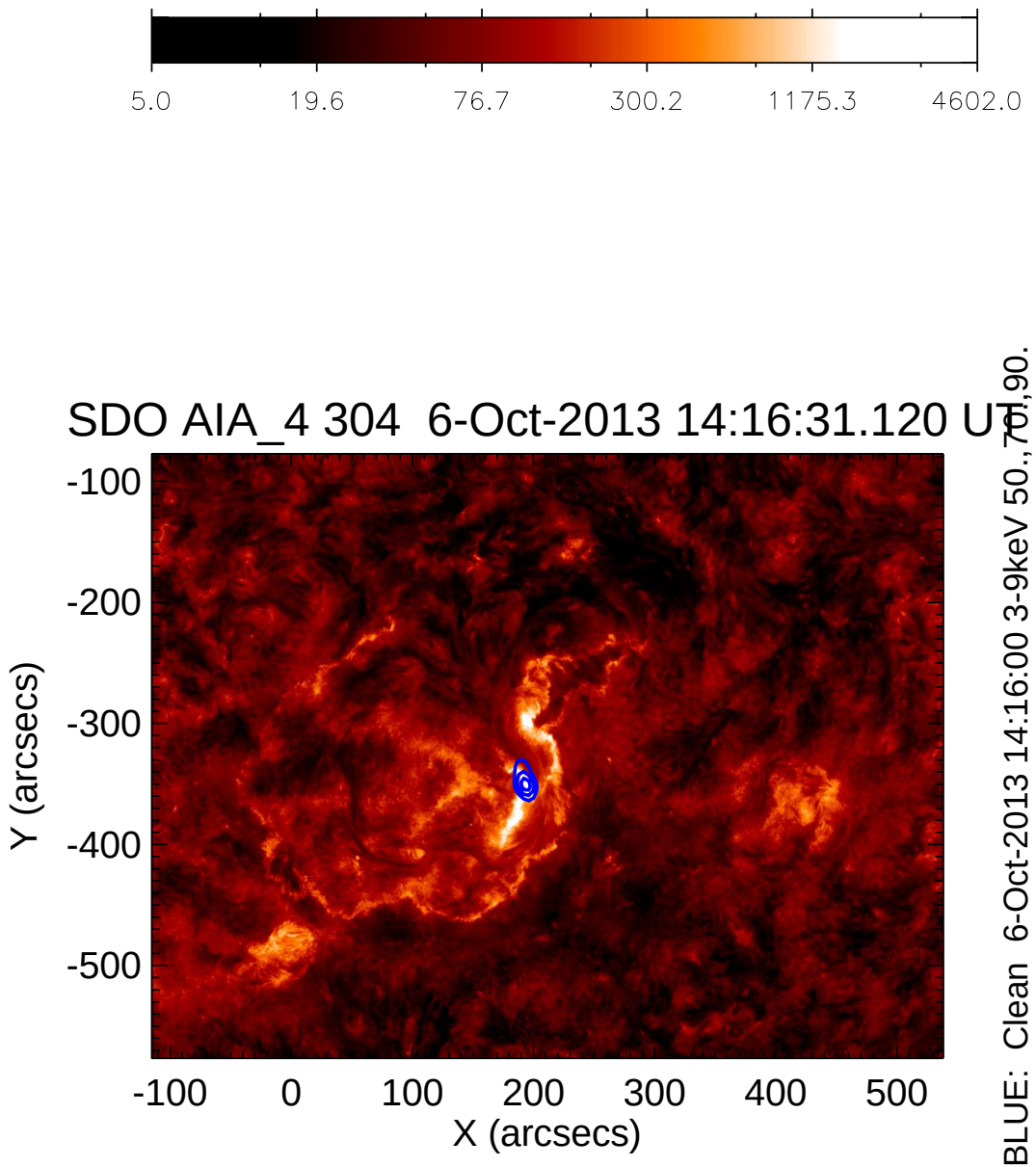
Strong dipole magnetic field strength decreases from 1200 G to 900 G from beginning to peak of flare X-ray emission

Working Hypothesis: X-ray emission is observed when and where the magnetic field strength (and flux) is strong enough (>1000 G in photosphere?) and reconnection can occur.

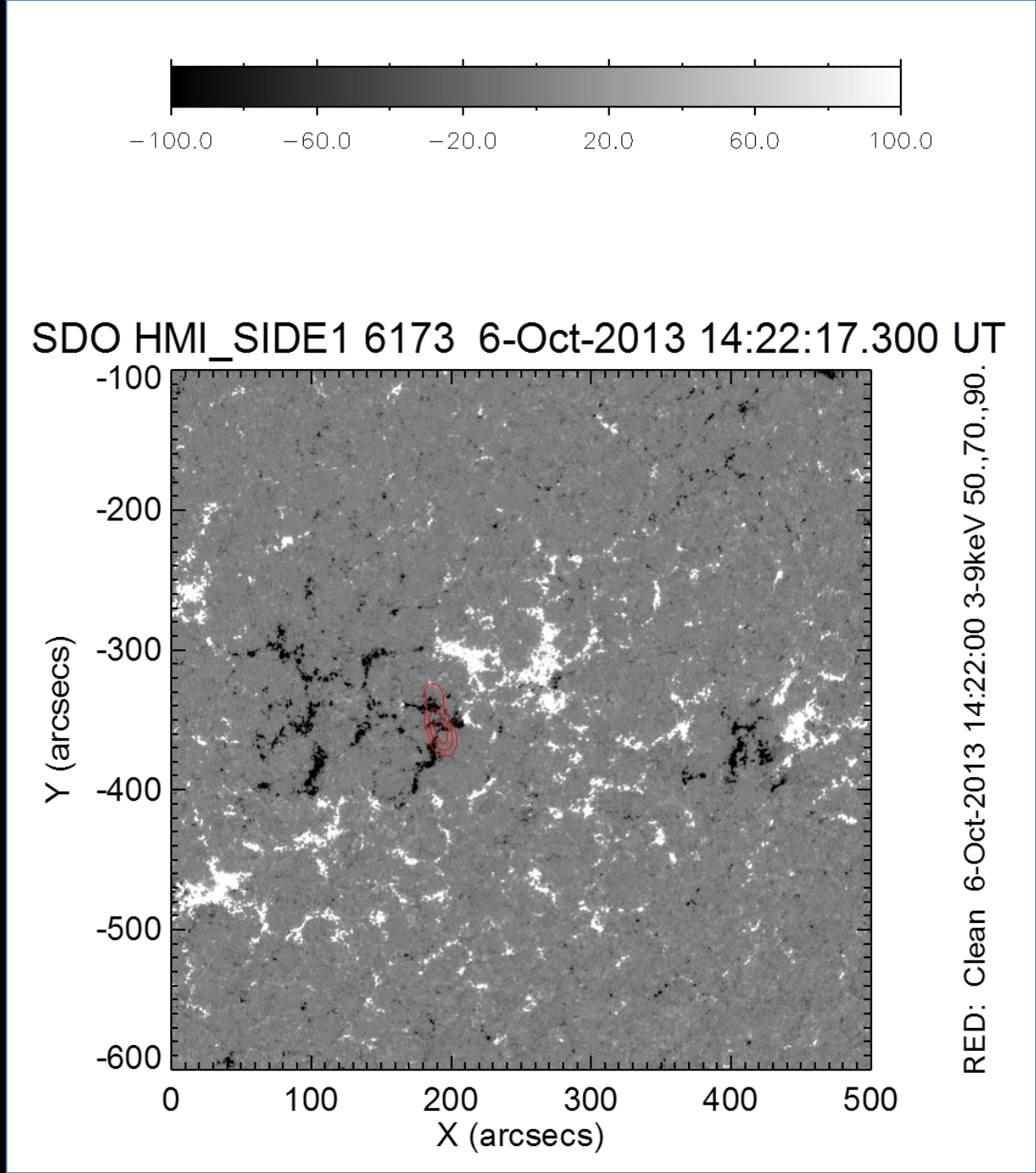
Did the strengthening magnetic dipole also trigger the filament eruption?


4.0
13.7
46.7
159.5
545.0
1862.0
SDO AIA_4 304 6-Oct-2013 13:00:07.120 UT
-100
-200
-300
-400
-500
Y (arcsecs)
-100
0
100
200
300
400
500
X (arcsecs)

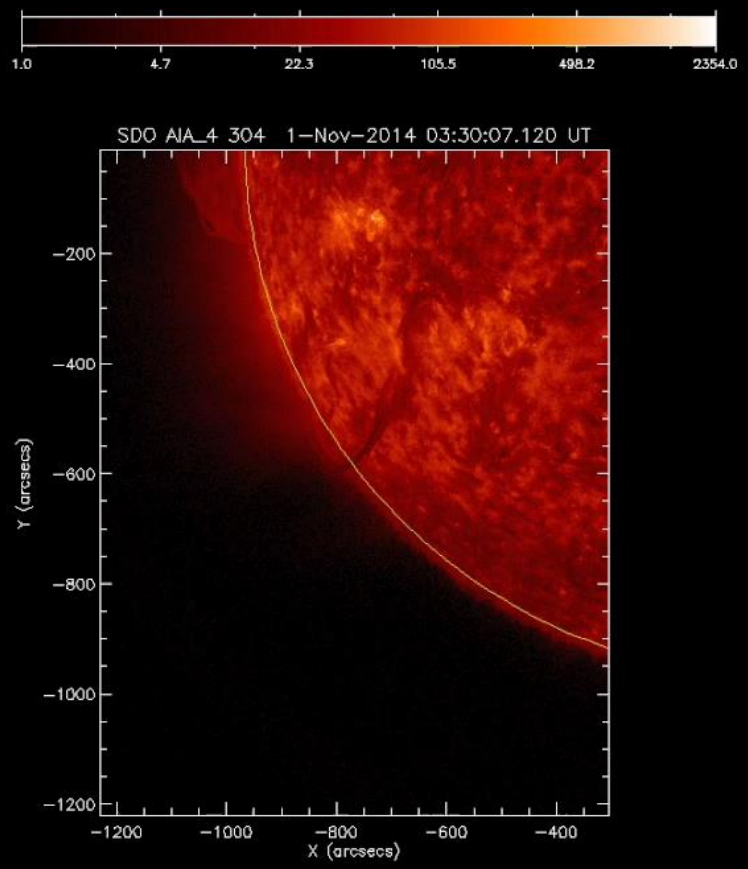
SDO AIA 304 Å Band with RHESSI 3 – 9 keV Contours



HMI Magnetogram with RHESSI 3 – 9 keV Contours



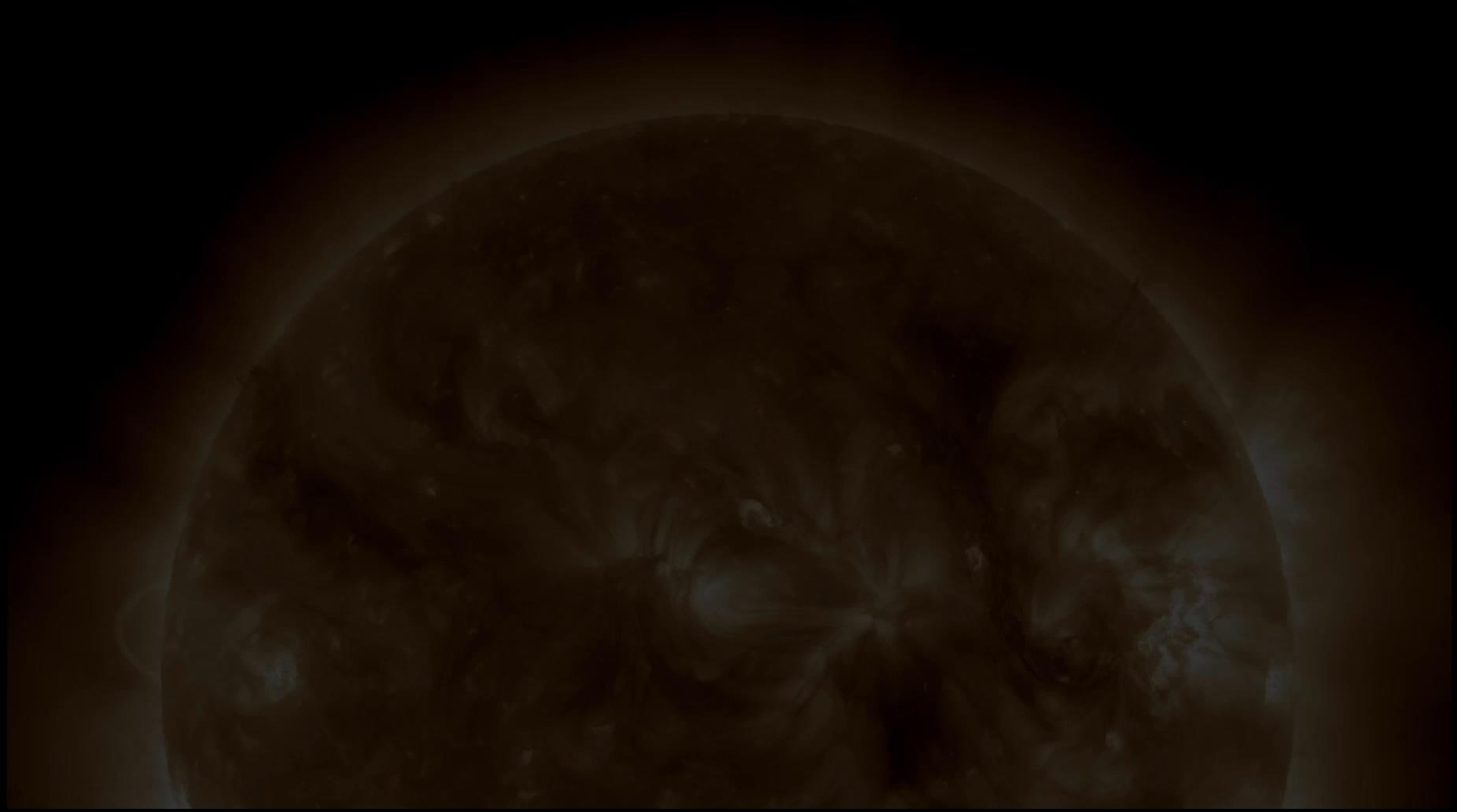
We have identified 40 quiescent filament eruptions with associated X-ray emission.



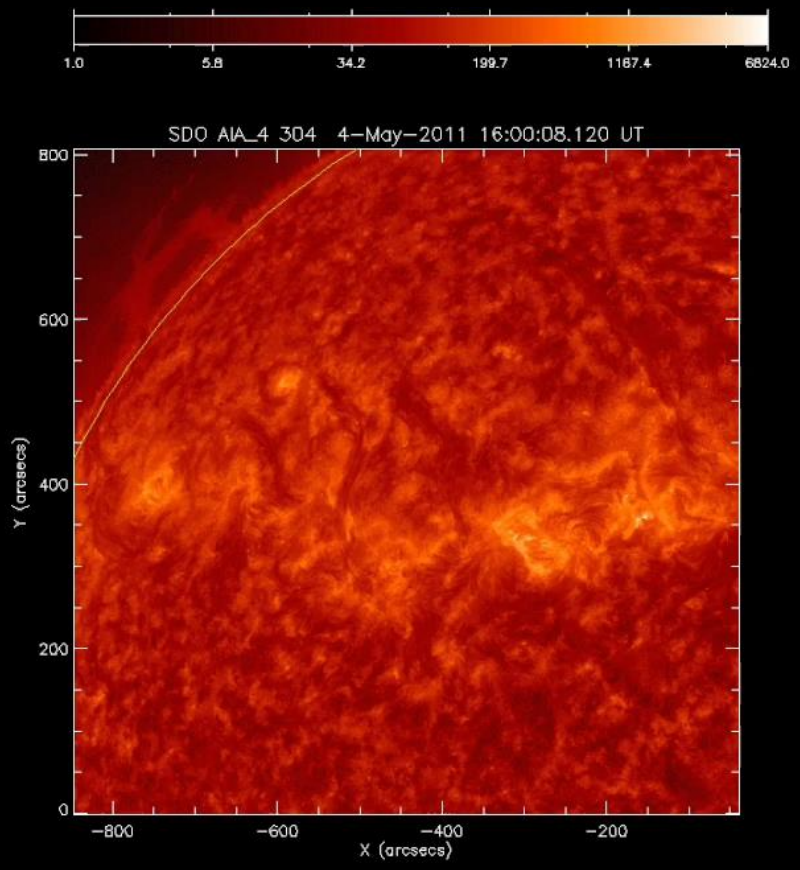
Example 2: 2014 Nov 1

Conclusions

- Eruptions of quiescent filaments (QFEs) are solar eruptive events (SEEs) from outside active regions.
- QFEs are often spatially larger but evolve more slowly than those from active regions. The average magnetic field strength is substantially lower.
- RHESSI X-ray images now provide a new window for understanding QFEs
- The Focusing Optics X-ray Solar Imager (FOXSI) will have greater sensitivity to this thermal emission, as well as any emission from non-thermal electrons.



We have identified 40 quiescent filament eruptions with associated X-ray emission.



Example 1: 2011 May 4