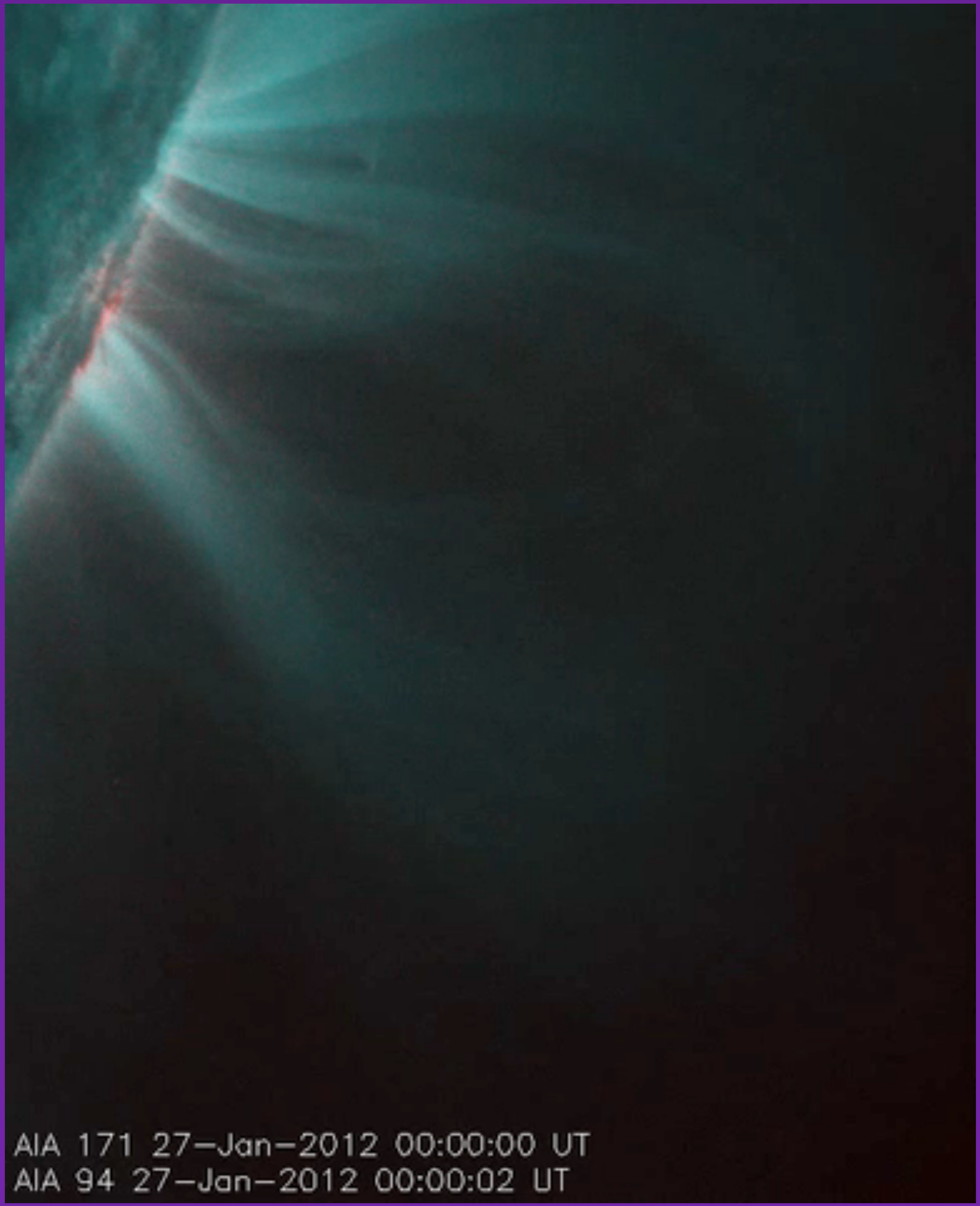
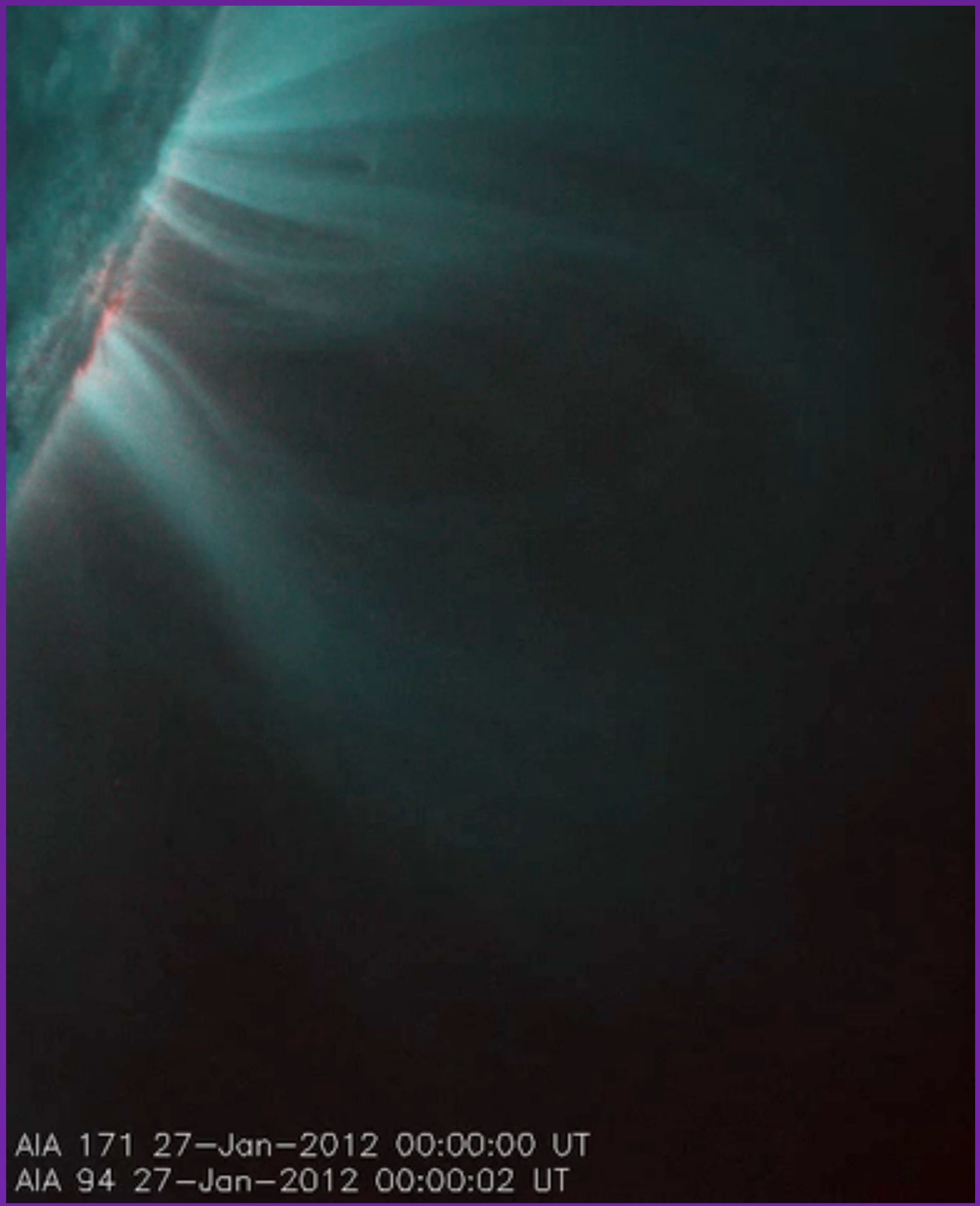
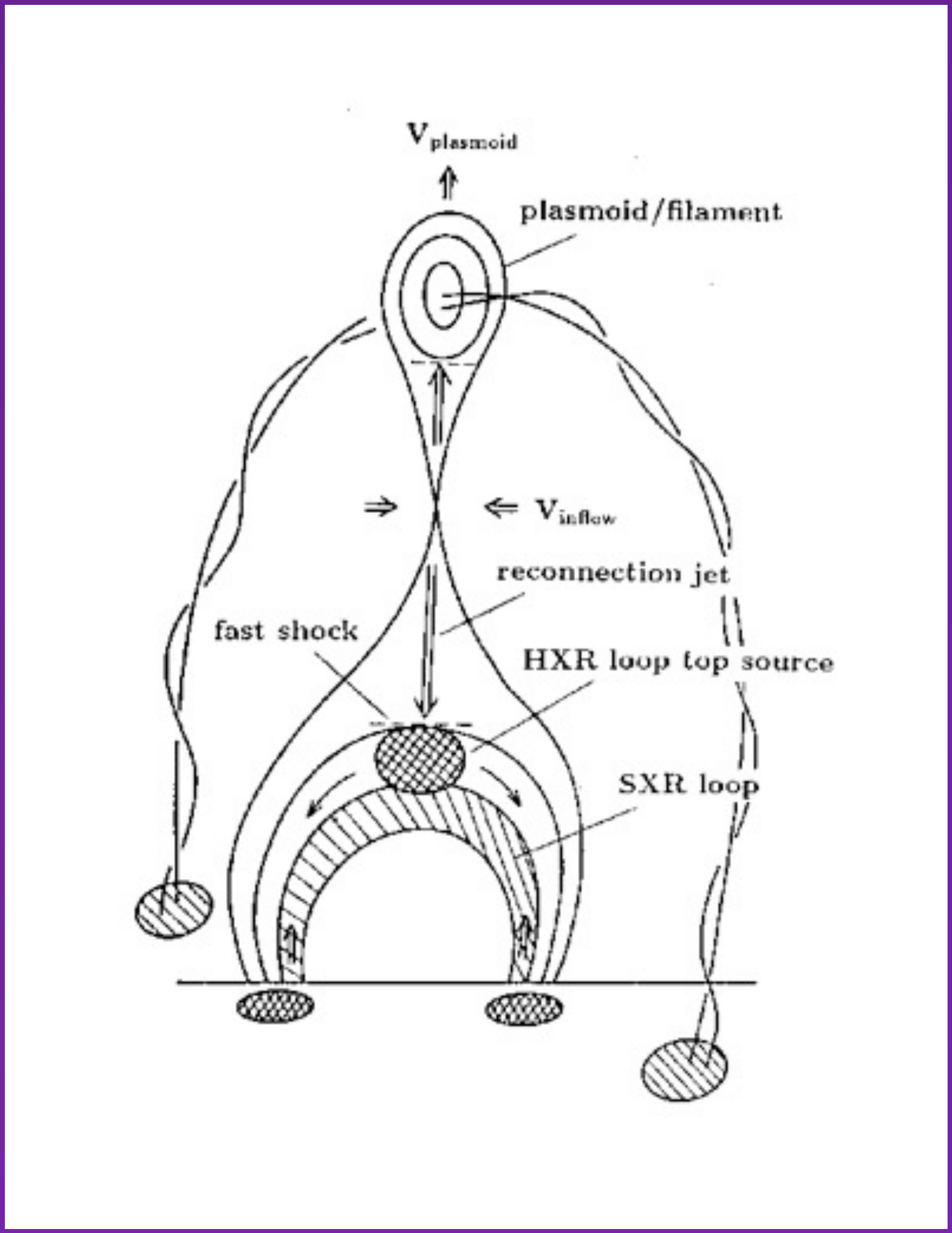
Evolution Toward Eruption and Erupiton of Filaments

Alphonse C. Sterling



A. Sterling, Sep 2015, Solar-C, Belfast





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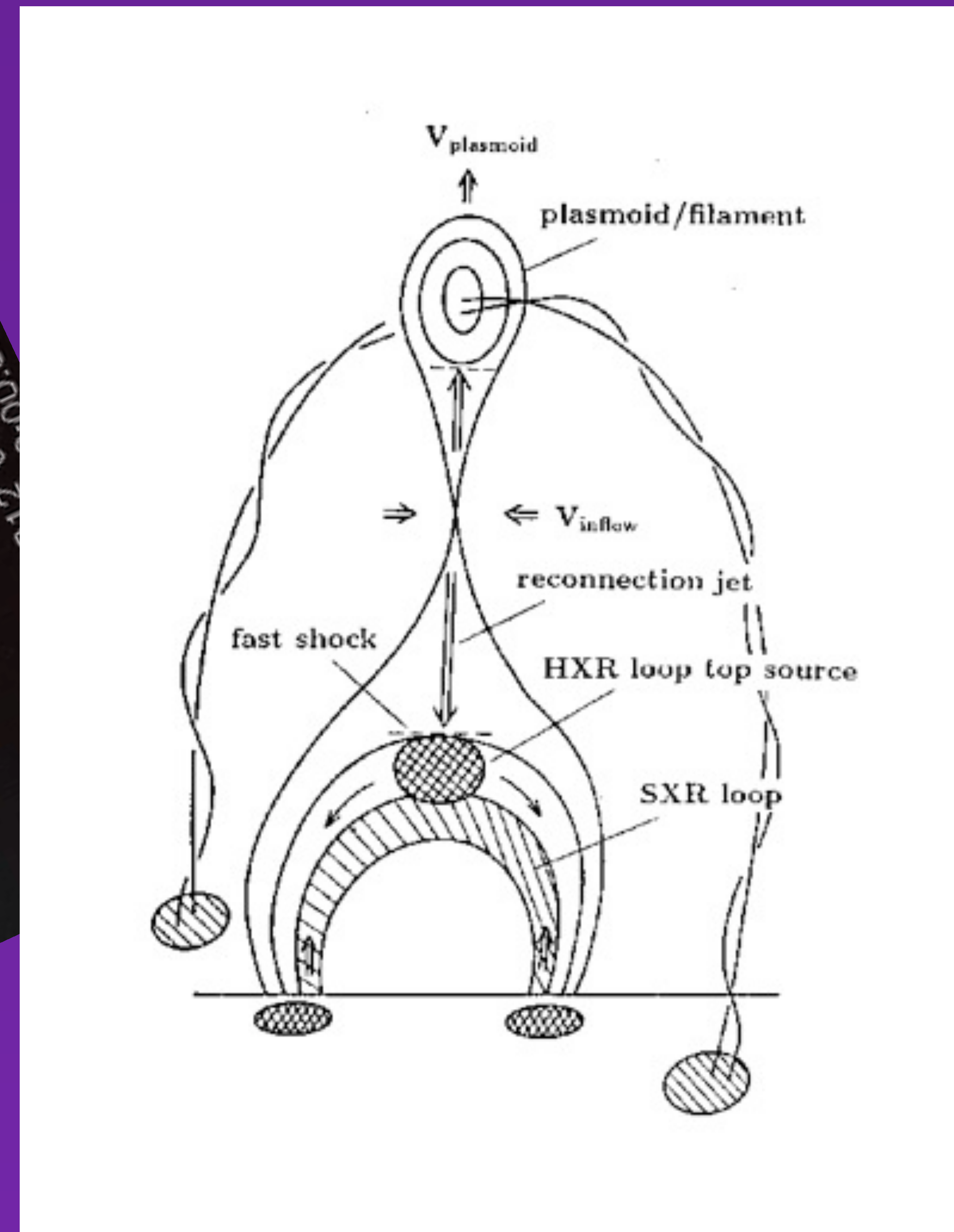
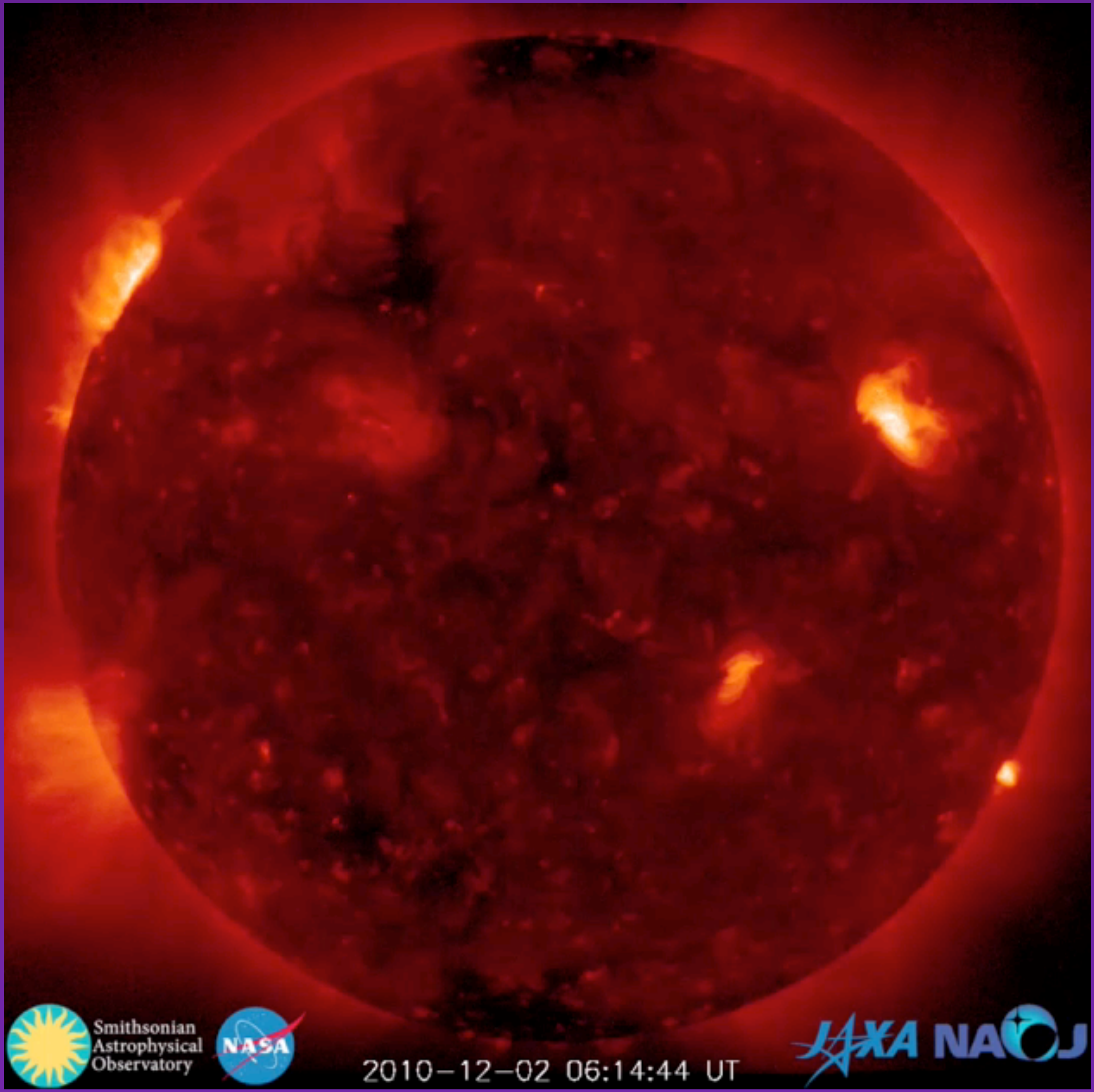
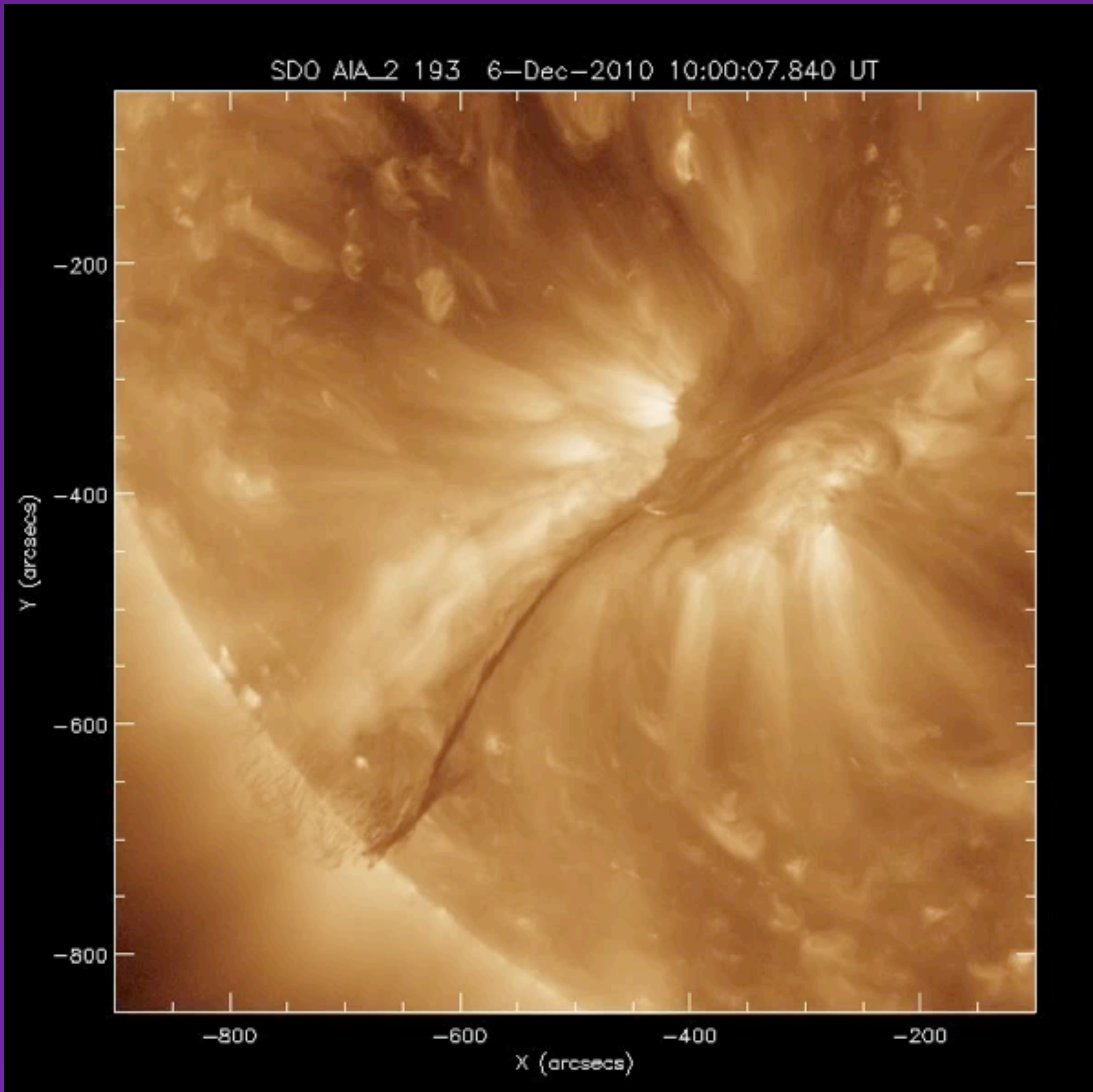
00:00:00 UT

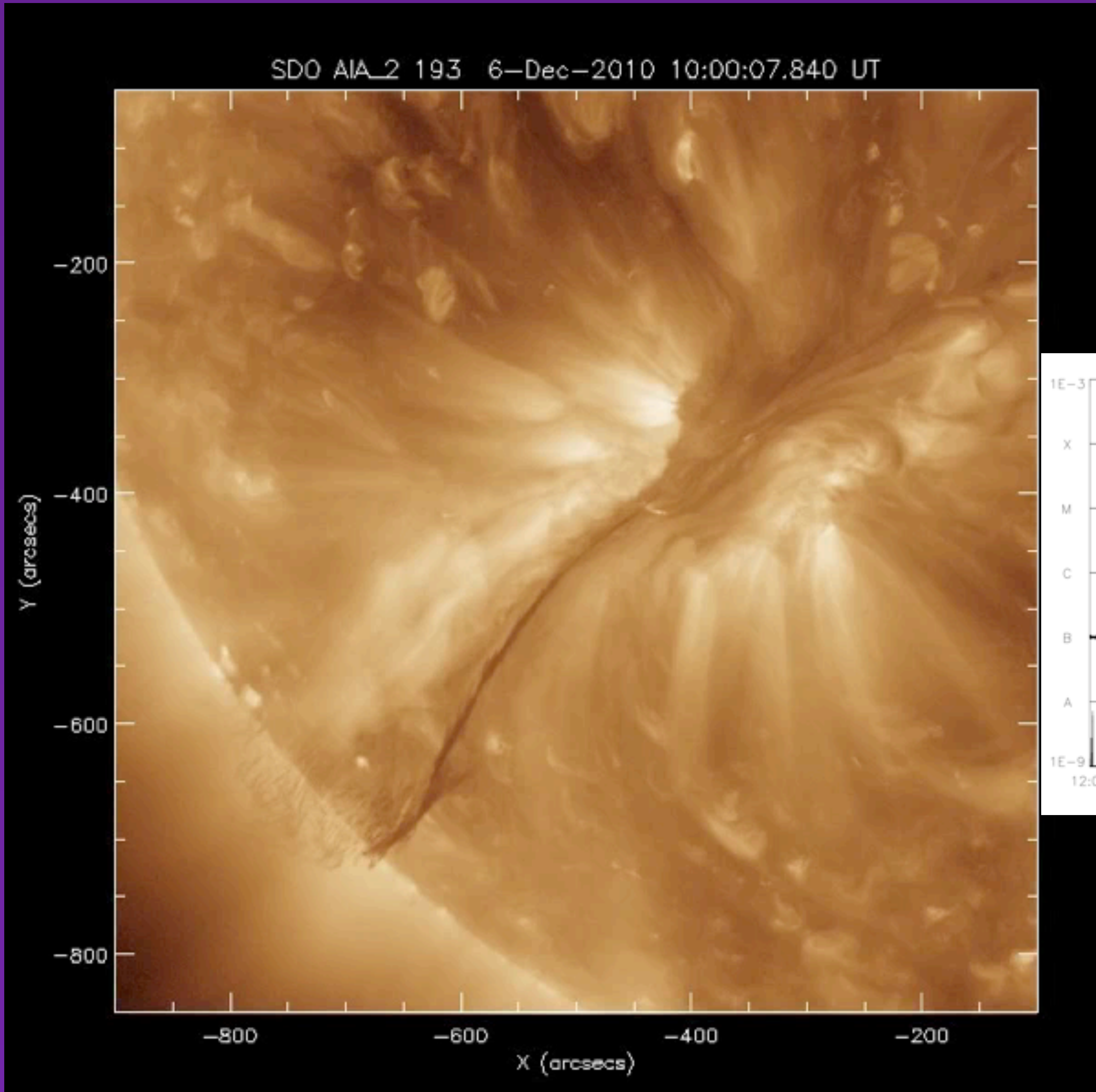

$V_{plasmoid}$
plasmoid/filament
V_{inflow}
reconnection jet
fast shock
HXR loop top source
SXR loop



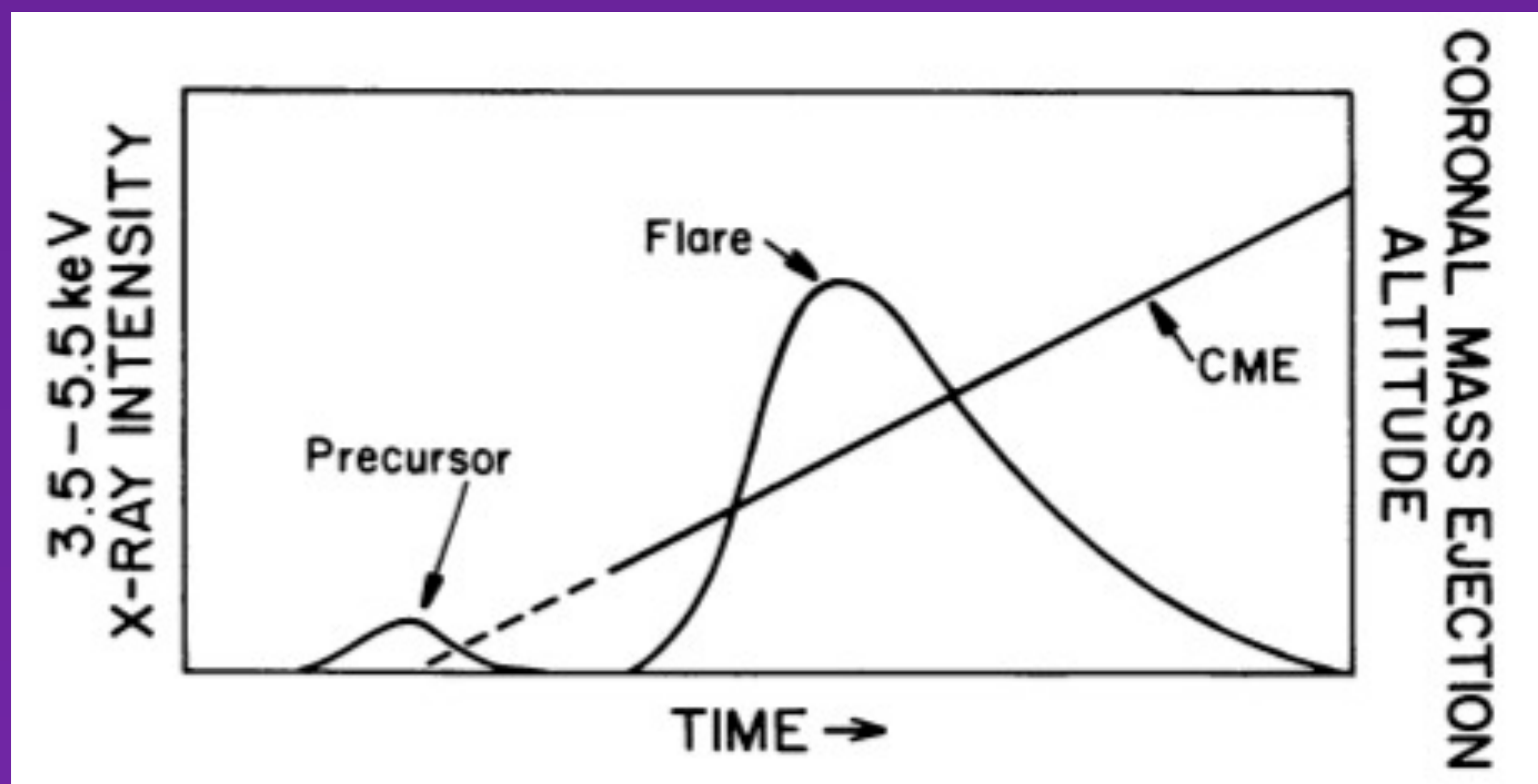
A. Sterling, Sep 2015, Solar-C, Belfast



A. Sterling, Sep 2015, Solar-C, Belfast

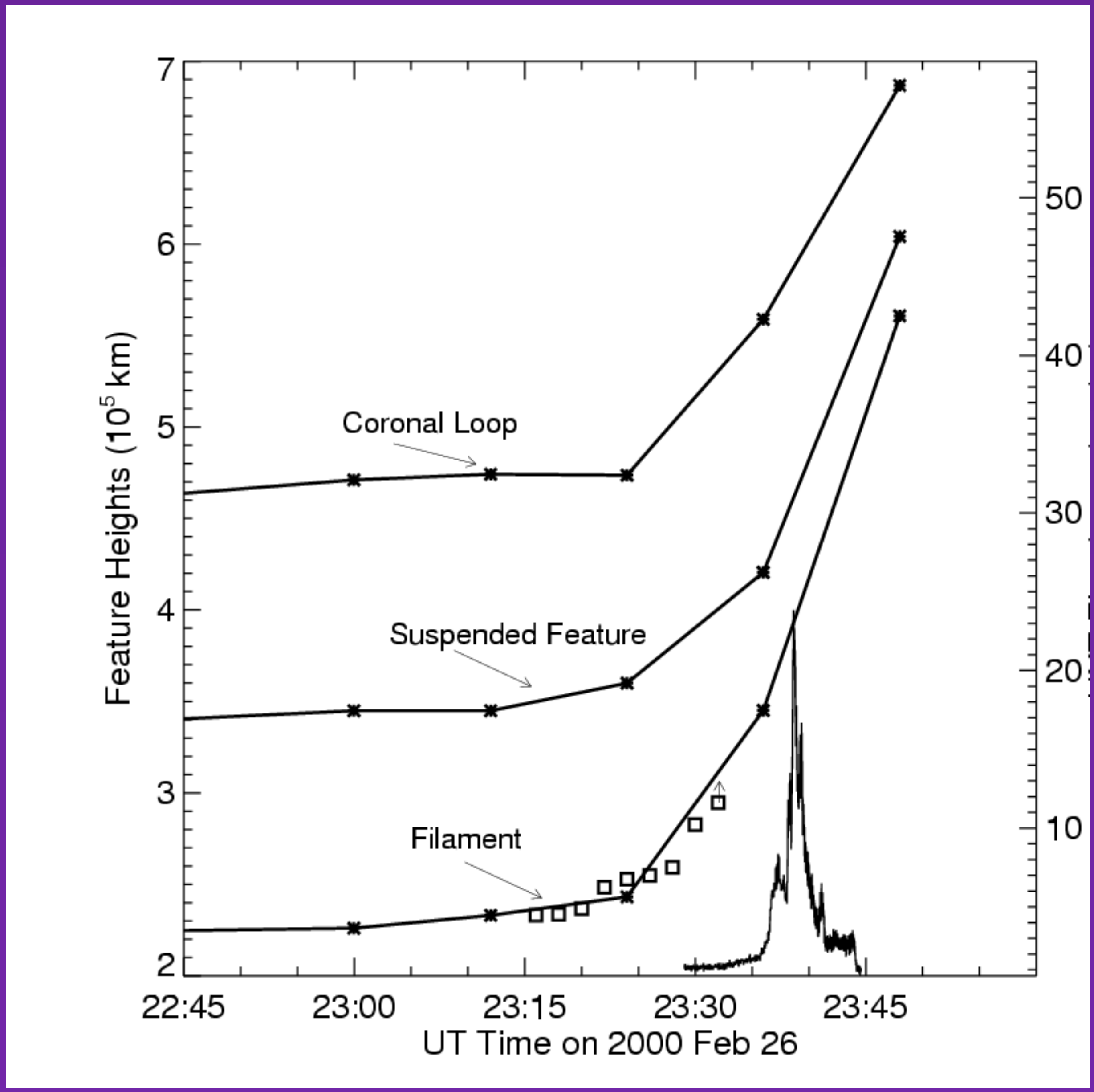

SDO AIA_2 193 6-Dec-2010 10:00:07.840 UT
Y (arcsecs)
X (arcsecs)
-200
-400
-600
-800
-800
-600
-400
-200


GOES 15 X-Rays:
1E-3
X
M
C
B
A
1E-9
12:00
15:00
18:00
21:00
00:00
03:00
06:00
Start Time (06-Dec-10 11:59:58)



Harrison (1986)

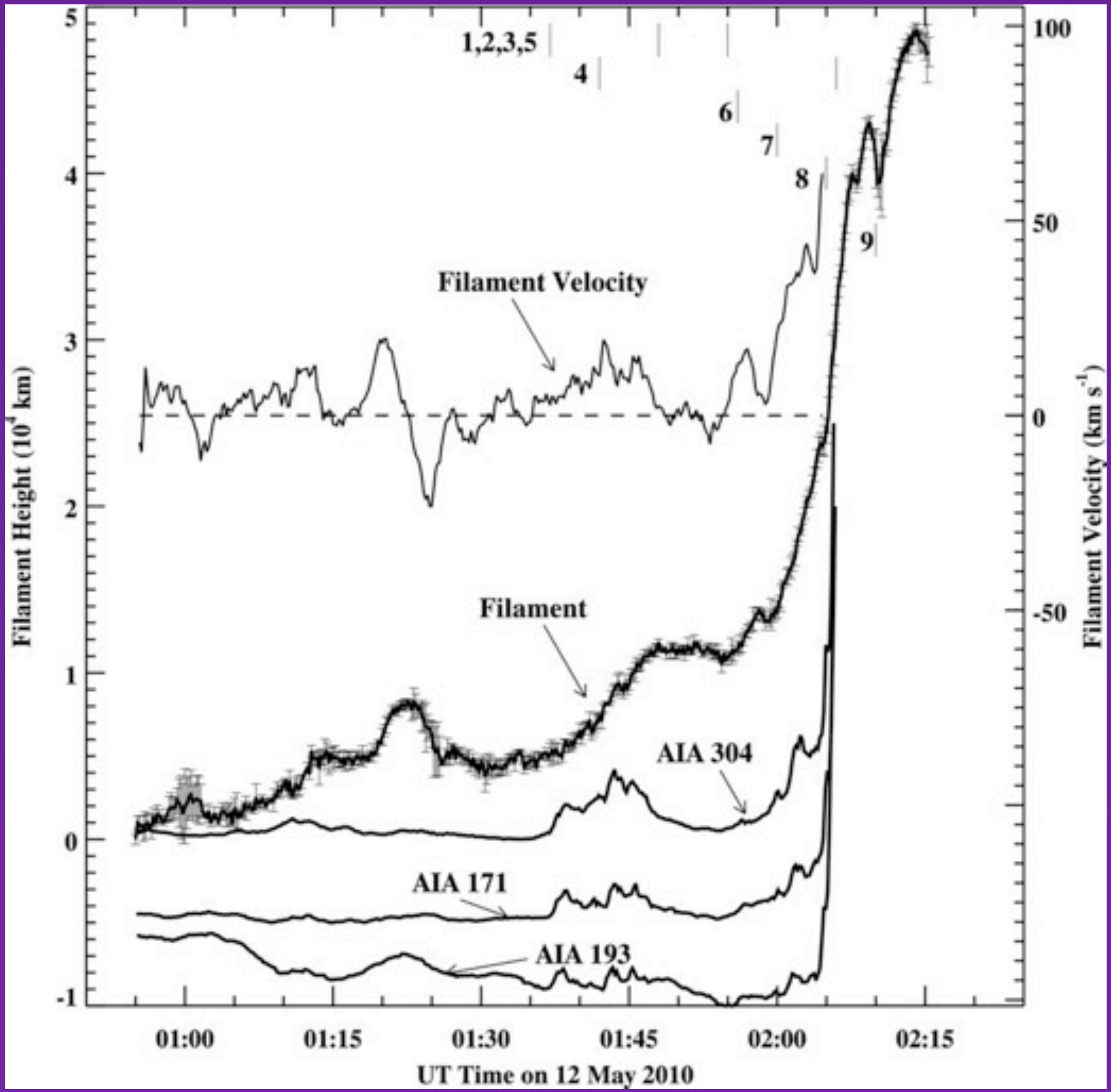
Also see "slow rise" (activation, etc) in active regions, but time-scales are shorter.



Sterling & Moore (2004)

Trajectories: SOHO/EIT+Hα
Flux: Yohkoh/HXT Lo (14-23 keV)

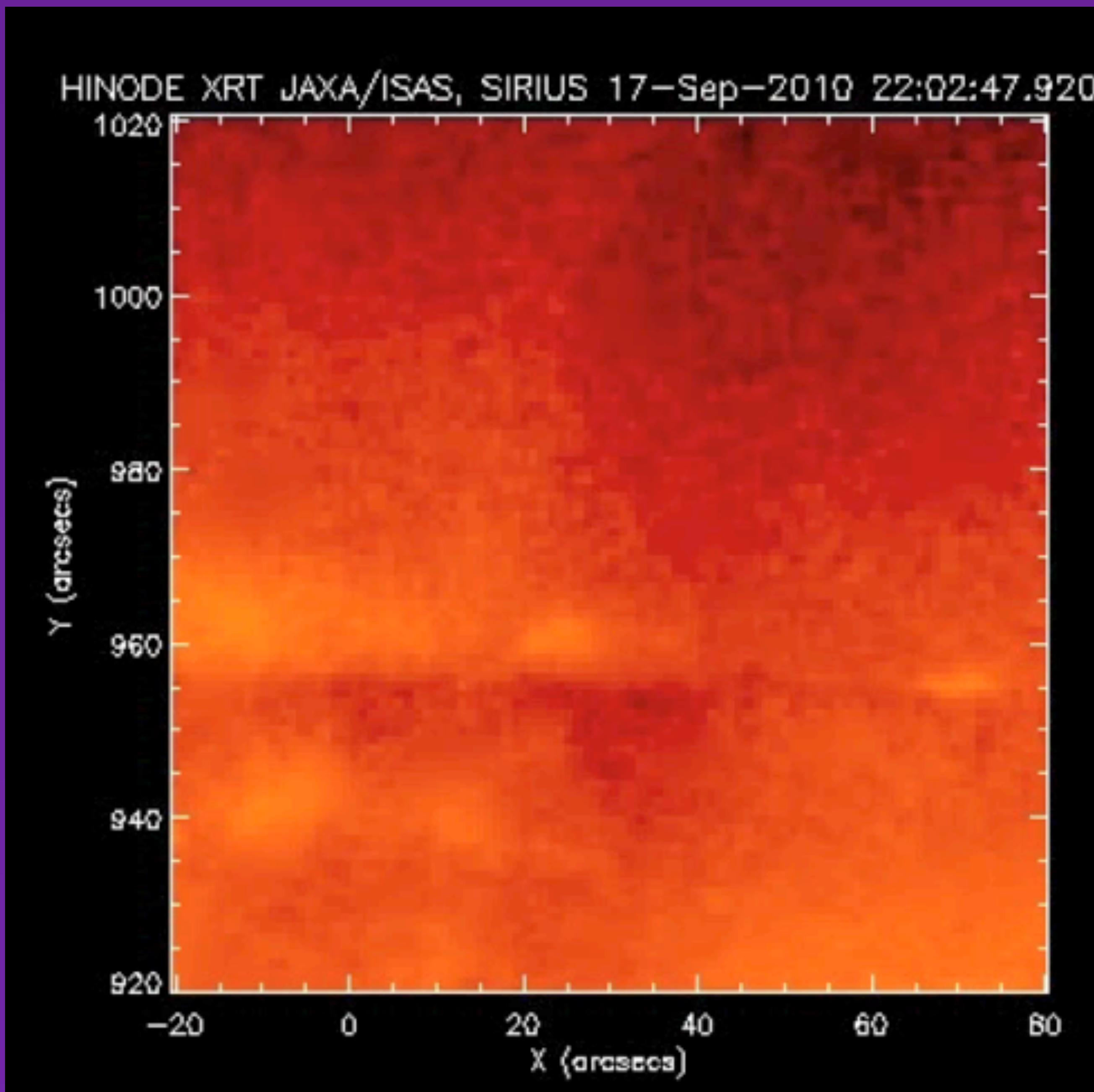
A different active region eruption:



Sterling, Moore, & Freeland (2011)

XRT

AIA 193

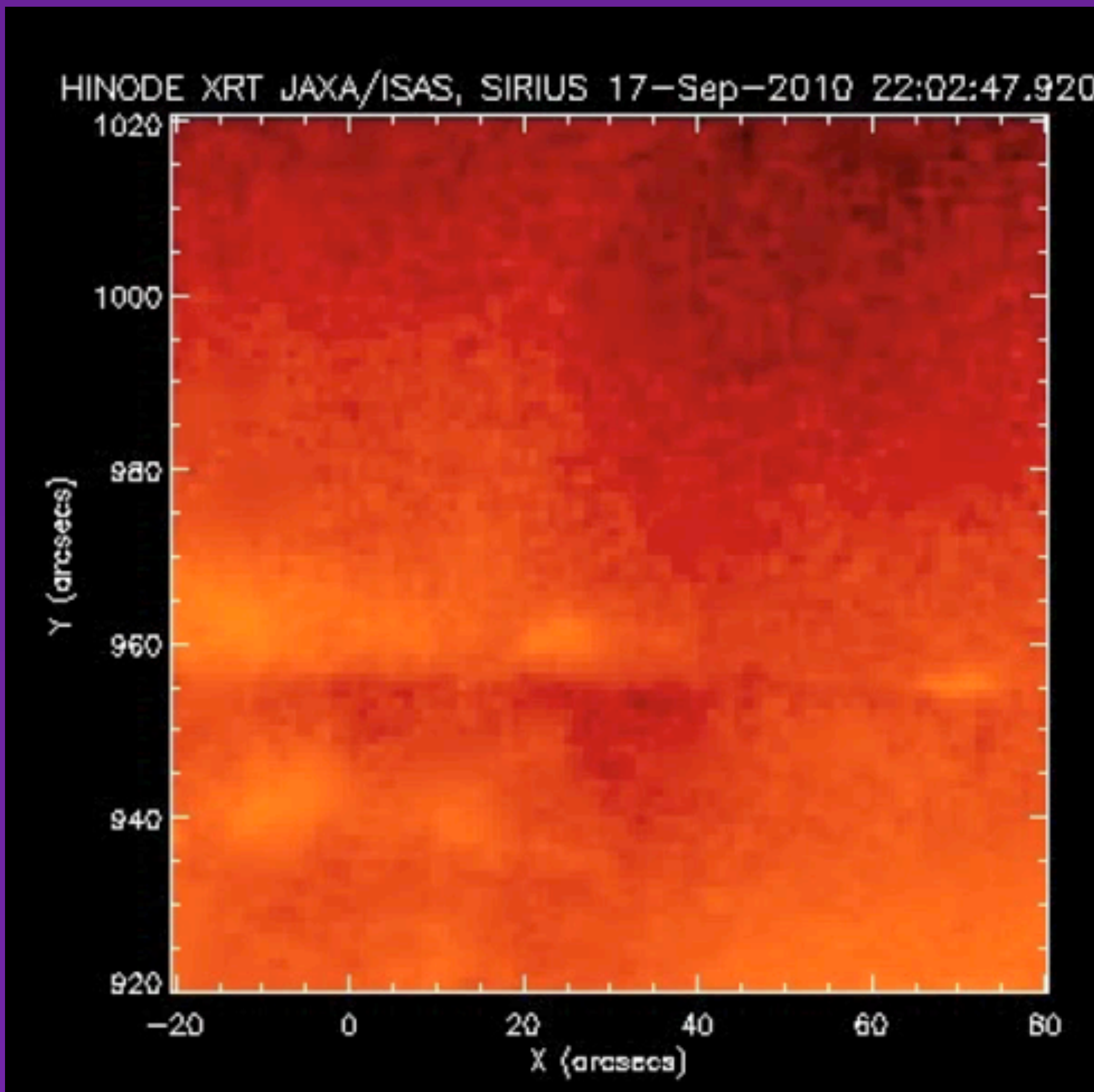


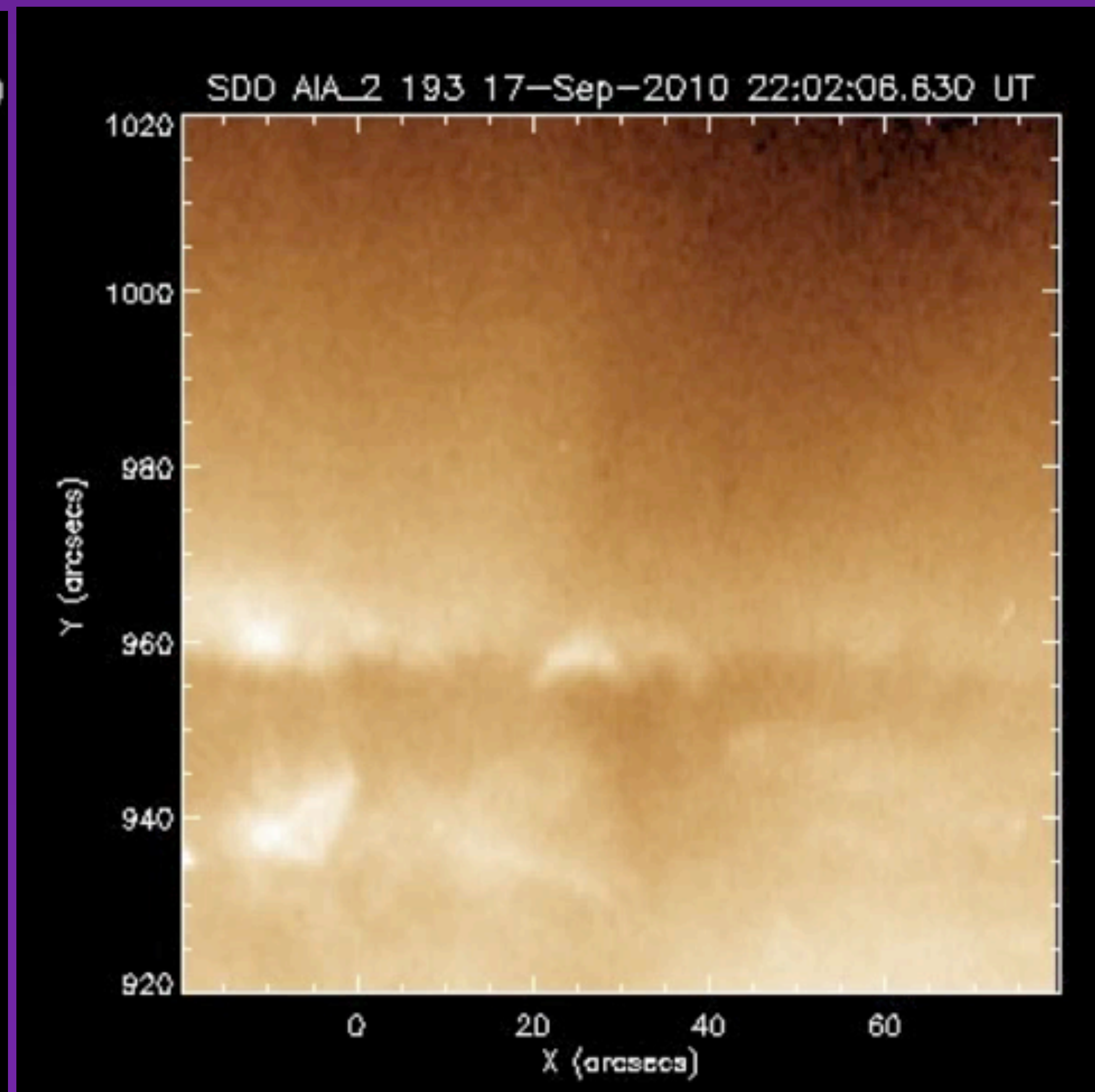
Sterling et al. (2015) Event 18

A. Sterling, Sep 2015, Solar-C, Belfast

XRT

AIA 193



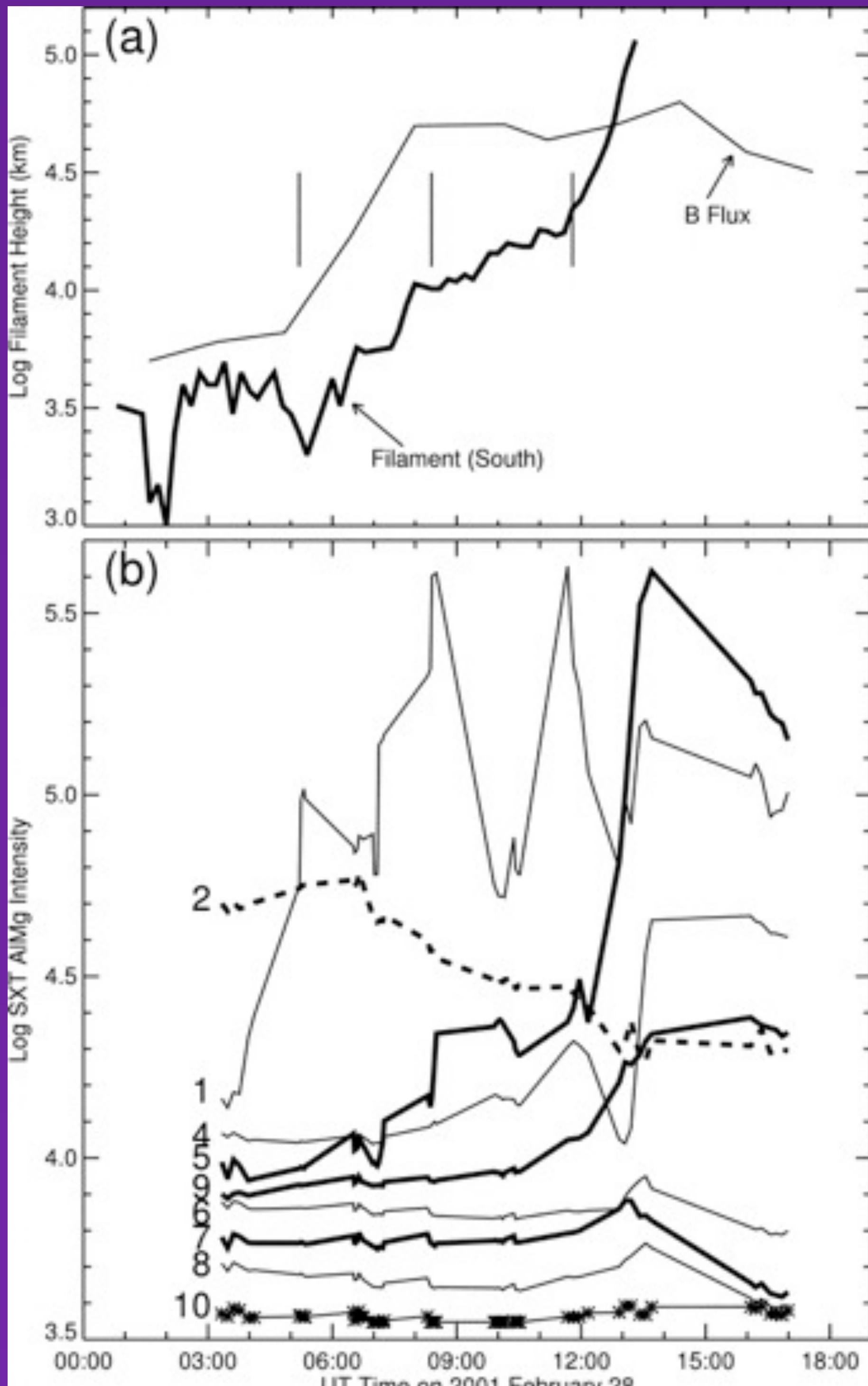


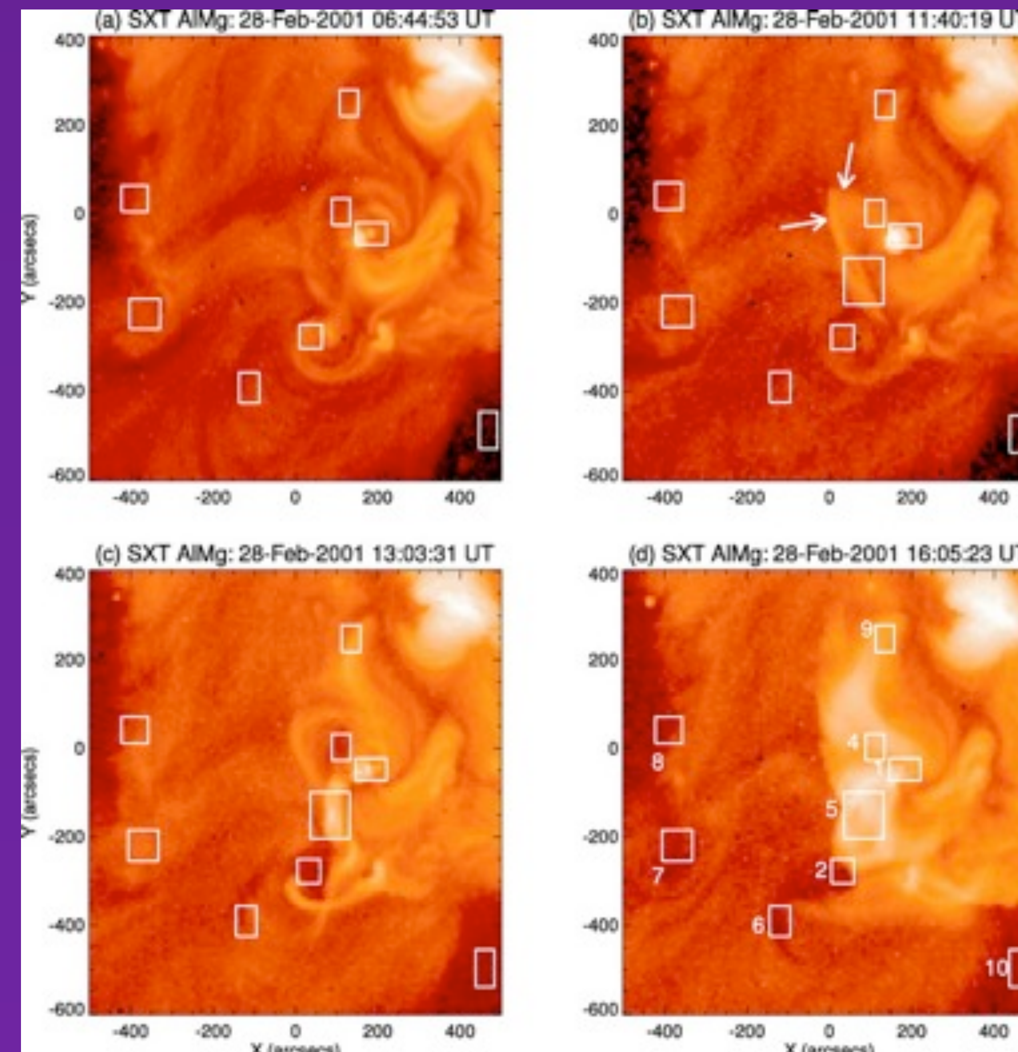
Sterling et al. (2015) Event 18

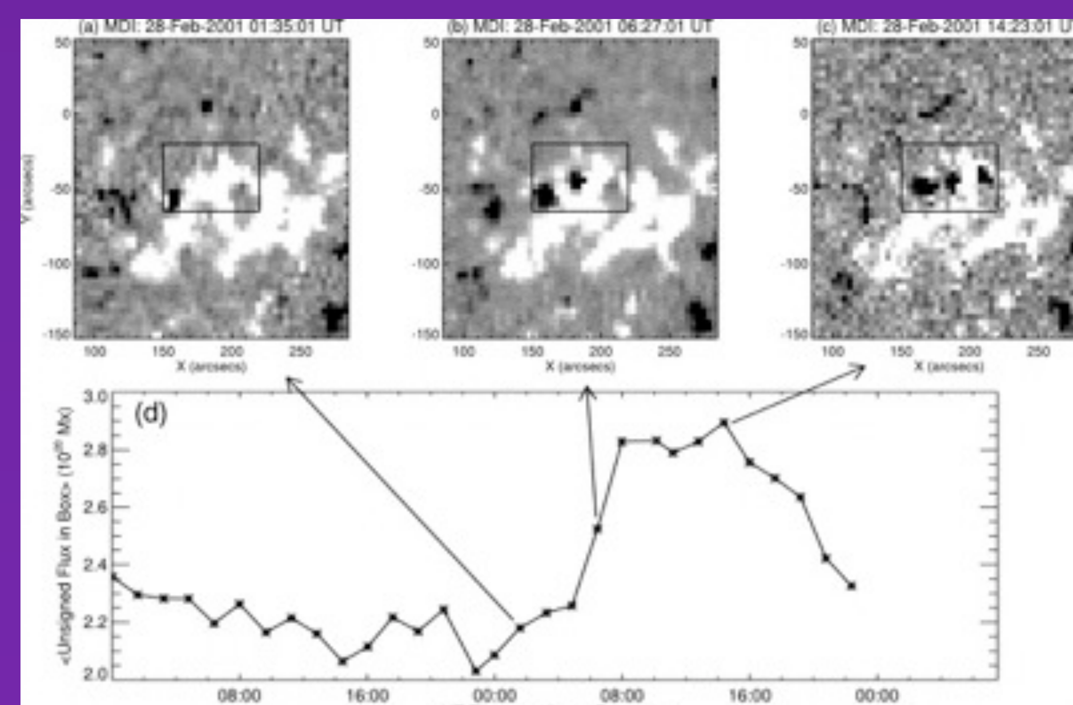
What Causes Eruption Onset?

- At least for many events...
- Evidence consistent with some destabilizing agent causing the slow-rise onset.
- Then, fast-rise starts when “flare reconnection” kicks in (e.g., Antiochos et al., Kusano et al., others), or MHD instability takes over (e.g., Lin & Forbes, Amari, Mikíc, & Linker 2010)

- Slow-rise onset can start from a variety of circumstances: Flux emergence (Chen & Shibata 2000 for theory; many observed examples, e.g., Feynman & Martin 1995; Sterling, Harra, & Moore 2007).
- Flux cancelation (many examples)
- And newly-recognized (although long suspected): triggering by remote events (e.g., Schrijver & Title 2011; Török et al. 2011 for theory). (“Lid removal”; e.g., Cheng et al. 2011, Sterling et al. 2014.)
- Other ideas, e.g. helicity injection (Yan et al. 2014).





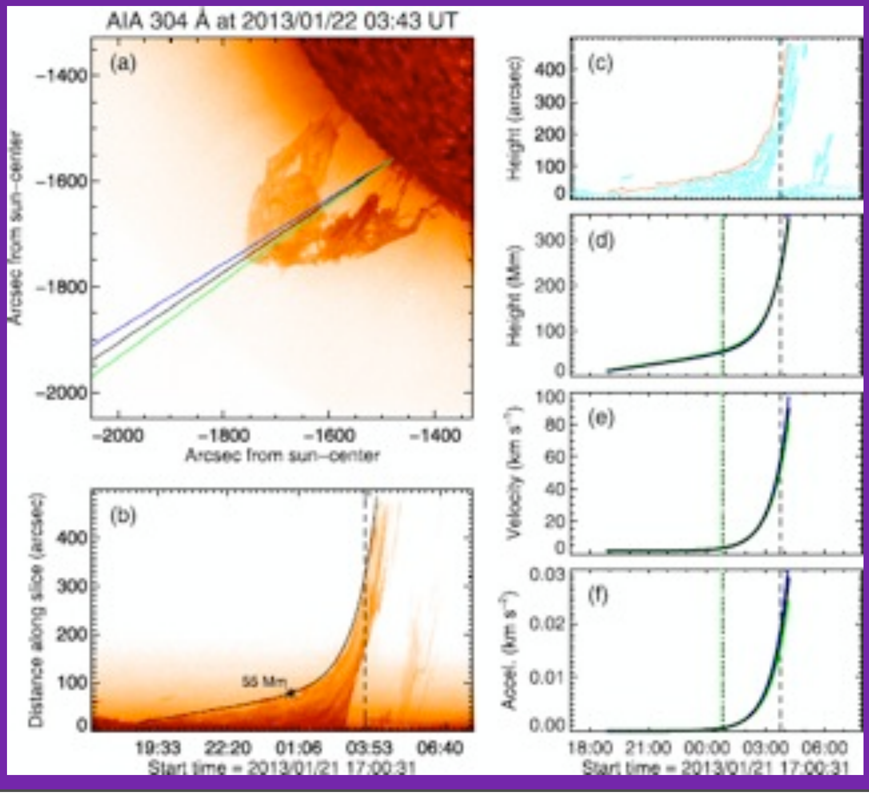


A. Sterling, Sep 2015, Solar-C, Belfast

Duration of Slow Rise

- Many individual studies study individual processes.
- Quiet-Sun: Several hours.
- Active regions, ~30 min.

- McCauley et al. (2015):
  - Studied 106 limb events with AIA.
  - Sample favored events outside of active regions.
  - Average is 4.4 hours.
  - Span (68% confidence level) is 1.2---8.0 hours.



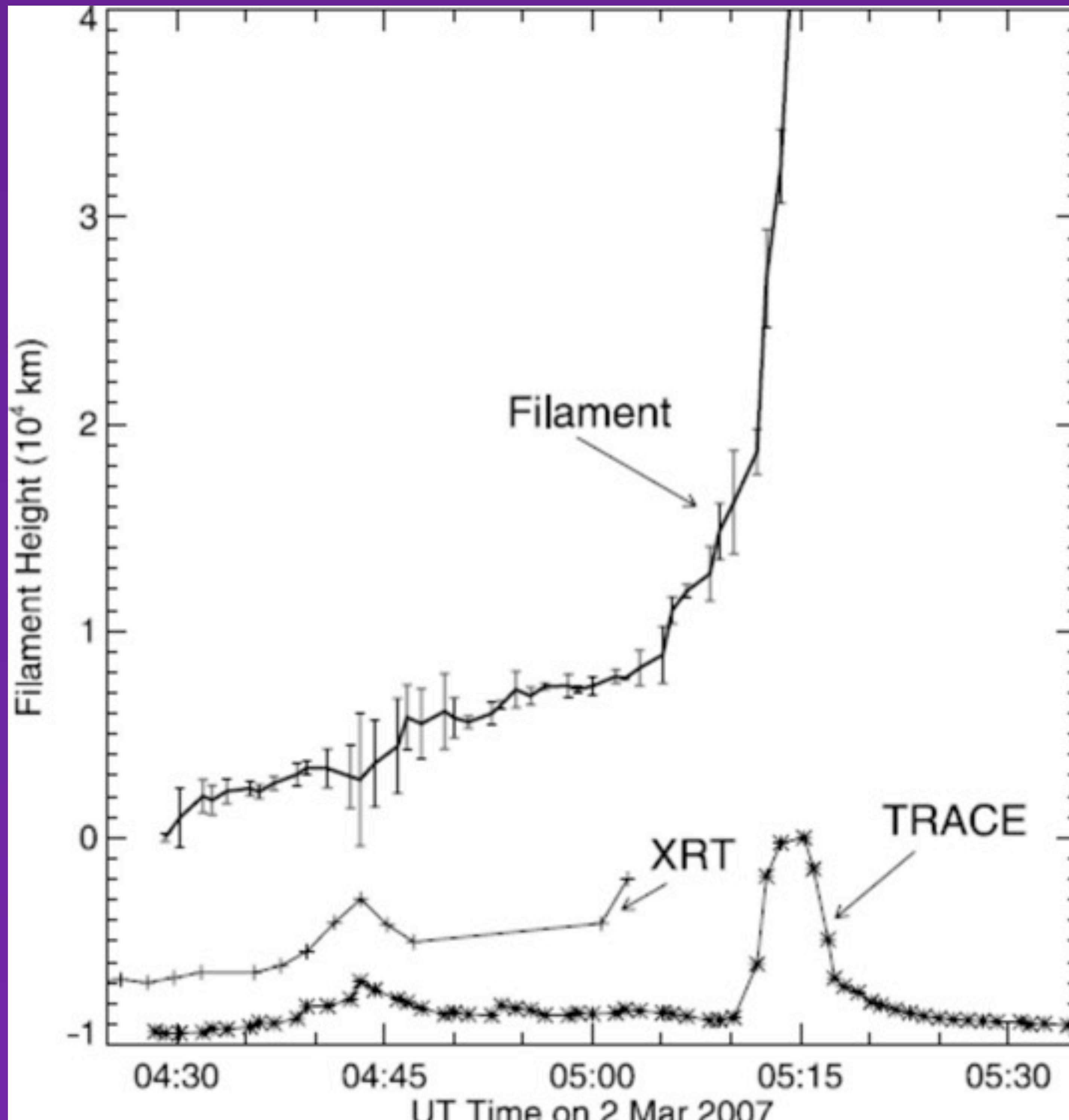
A. Sterling, Apr 2015, Solar-C, Belfast

What is Needed to decipher onset mechanisms?

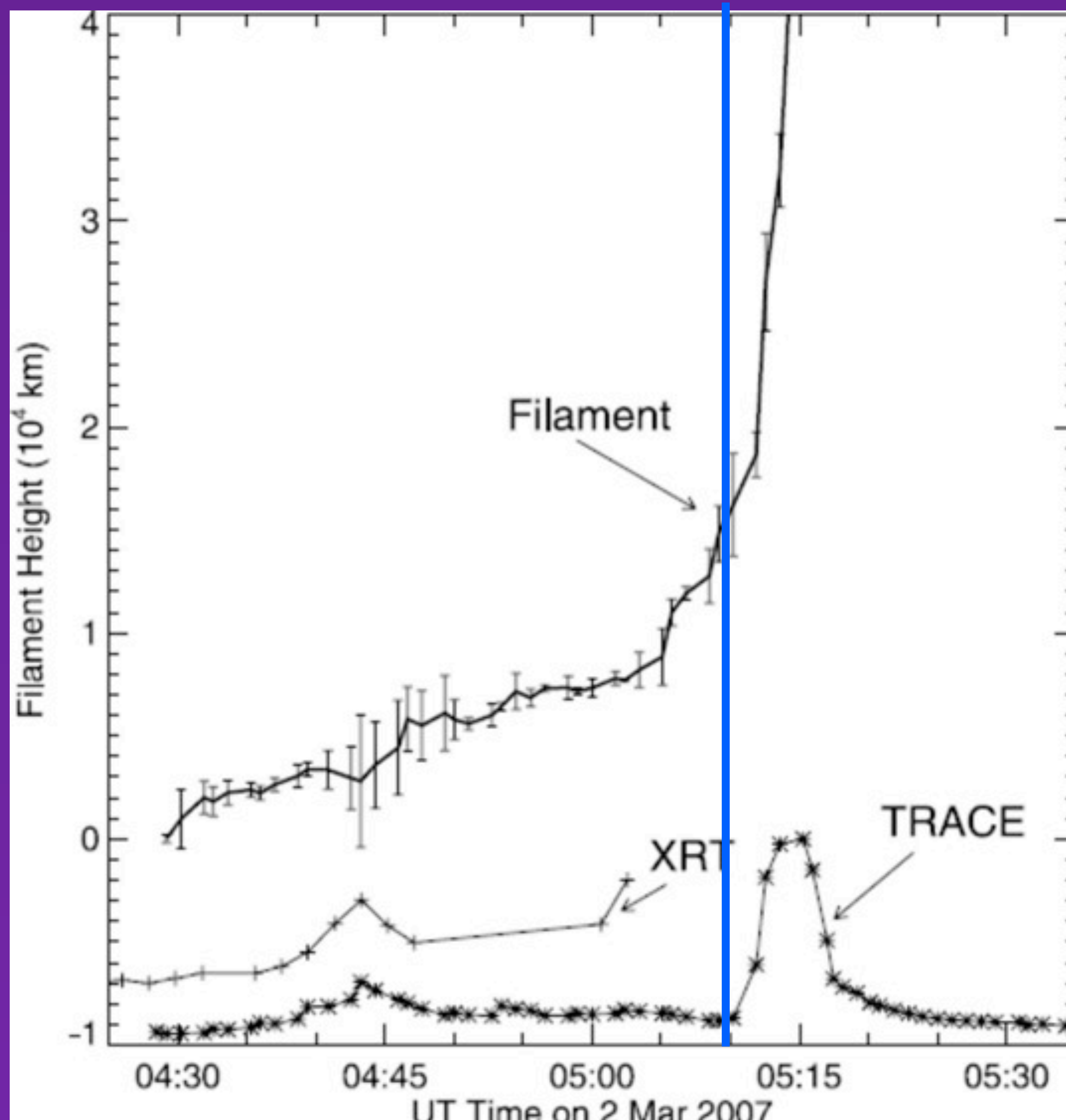
- Assuming limited FOV, so have to focus on a filament, and then watch it until it erupts! (Synoptic type.) Processes discussed by e.g. van Ballegooijen & Martens (1989) may lead to eruption over long time scales.
- Very small FOV might miss the initial trigger, if that trigger is off of the main neutral line (e.g., remote flux emergence).
- Need high-level observations "long" before flare brightening. This means 10s of minutes as a minimum in active regions. For quiet regions, many hours. Currently Hinode uses only a few minutes (e.g. ~4 for XRT, depending on the program).
- Need complementary instrumentation for larger-scale FOV coverage (e.g., AIA and HMI), because the trigger might be remote (sympathetic, lid removal, etc).

Solar-C Can Address:

- Onset mechanism of erupitons, by observing filaments from the time of onset of slow rise (or even earlier).
- These observations require long-term focus with full implementation of observing modes.
- Full-disk capability is important; can be from complementary mission.
- In addition to the main flare brightenings, also expect that "precursor brightenings" result from reconnection. This reconnection is key to the stability disruption that results in the eruption. Can study these reconnections.
- Observing magnetic field in chromosphere can help test whether reconnection ideas are valid.
- Smaller-scale filament eruptions (e.g., minifilaments of X-ray jets) are expected to result from similar processes. Studying these smaller scale, more compact systems might clarify some aspects of eruptions in general.
- A rapid-response operations approach can facilitate chances of catching eruption onsets.



Filament
XRT
TRACE
Filament Height (10^4 km)
4
3
2
1
0
-1
04:30
04:45
05:00
05:15
05:30
UT Time on 2 Mar 2007



4
3
2
1
0
-1
Filament Height (10⁴ km)
Filament
XRT
TRACE
04:30
04:45
05:00
05:15
05:30
UT Time on 2 Mar 2007