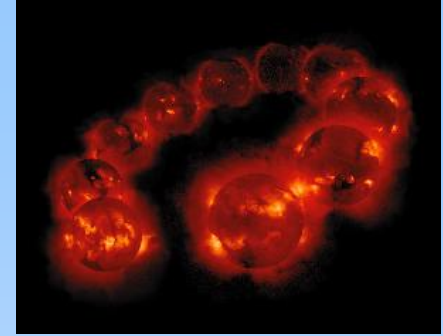


# Filaments Away!

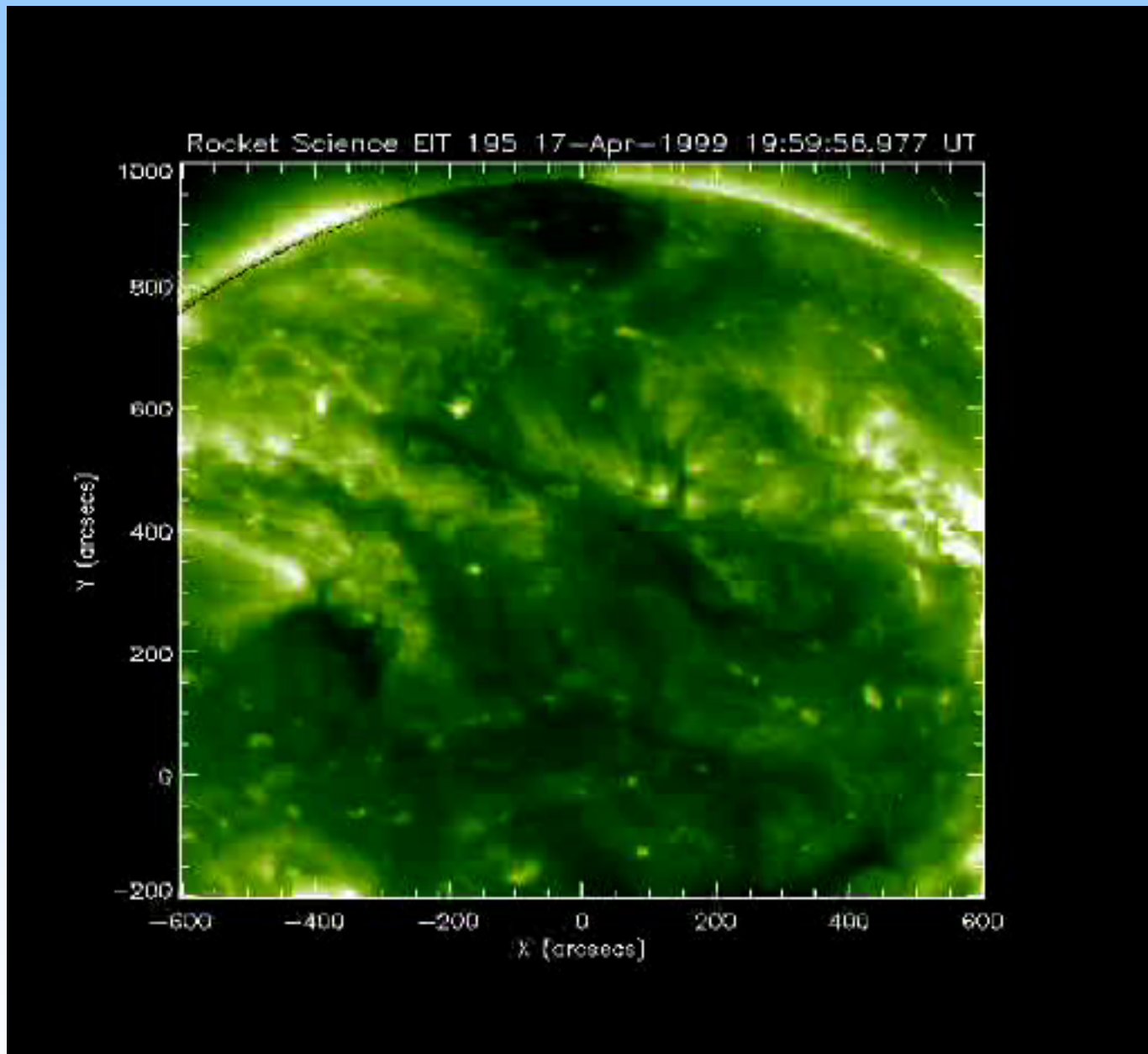
Alphonse C. Sterling

NASA/MSFC/NSSTC/JAXA/ISAS

# Introduction

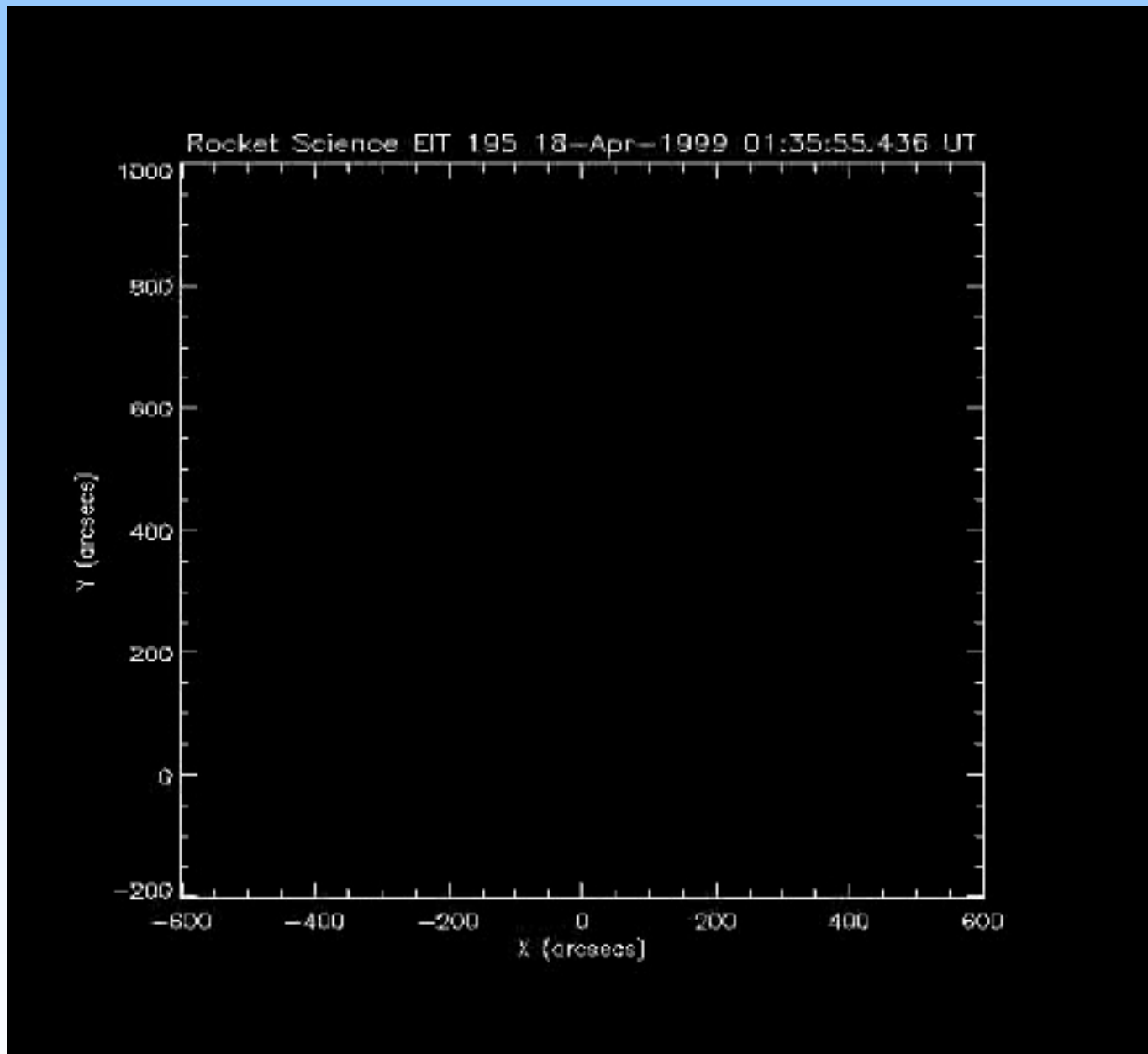


- Eruptions on the Sun involve the sudden release of large amounts of energy.
- Why do eruptions occur? Basic mechanism is magnetic, and can often include coronal mass ejections (CMEs), flares, and filament eruptions.
- In recent years we (Sterling, Moore + Harra,..) have been investigating the build-up to eruption.
- Use *filament eruptions* as markers of the more-general eruption.

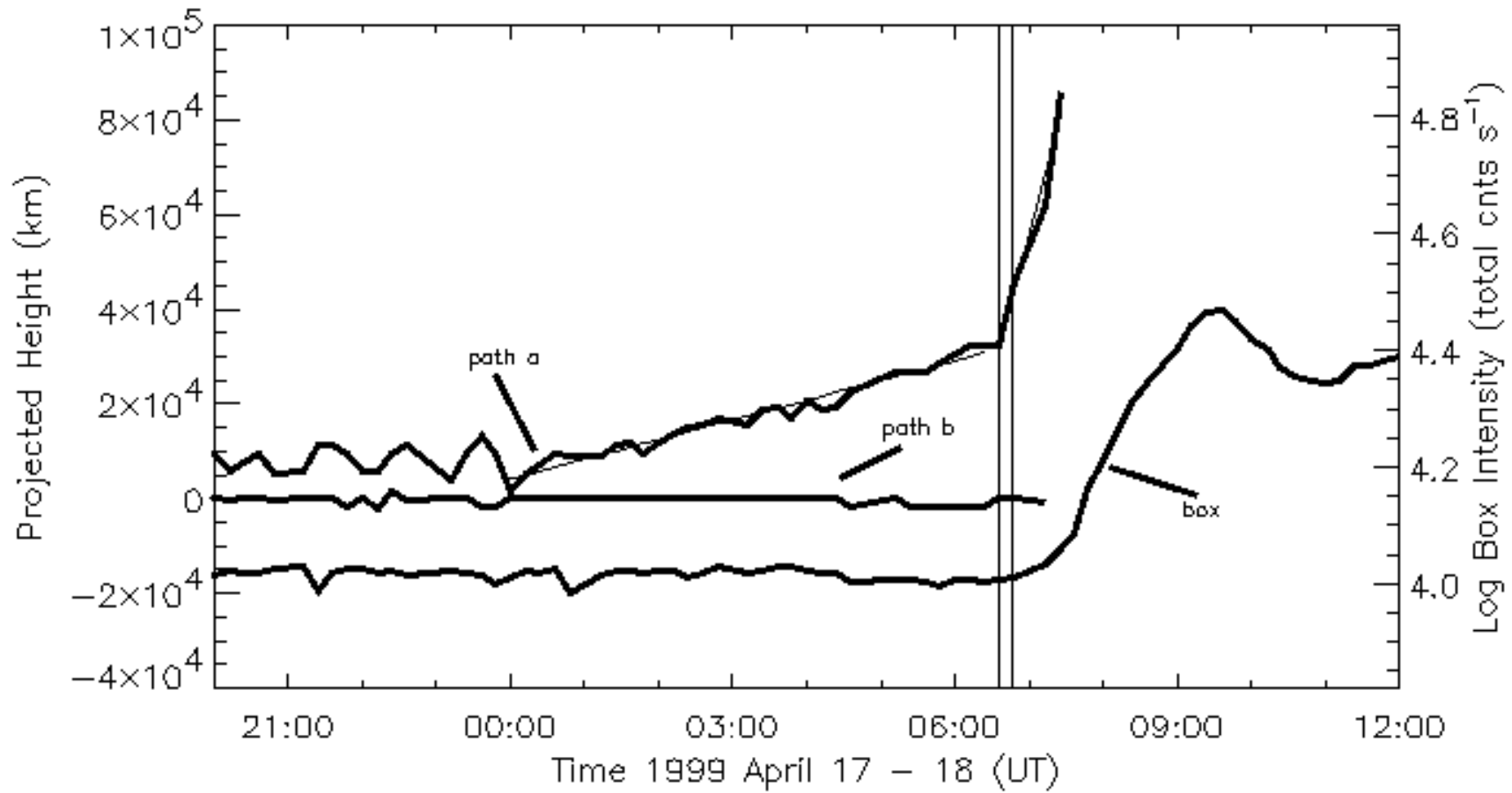


A. Sterling, Feb '11  
Filaments Away!

Sterling, Moore, & Thompson (2001)



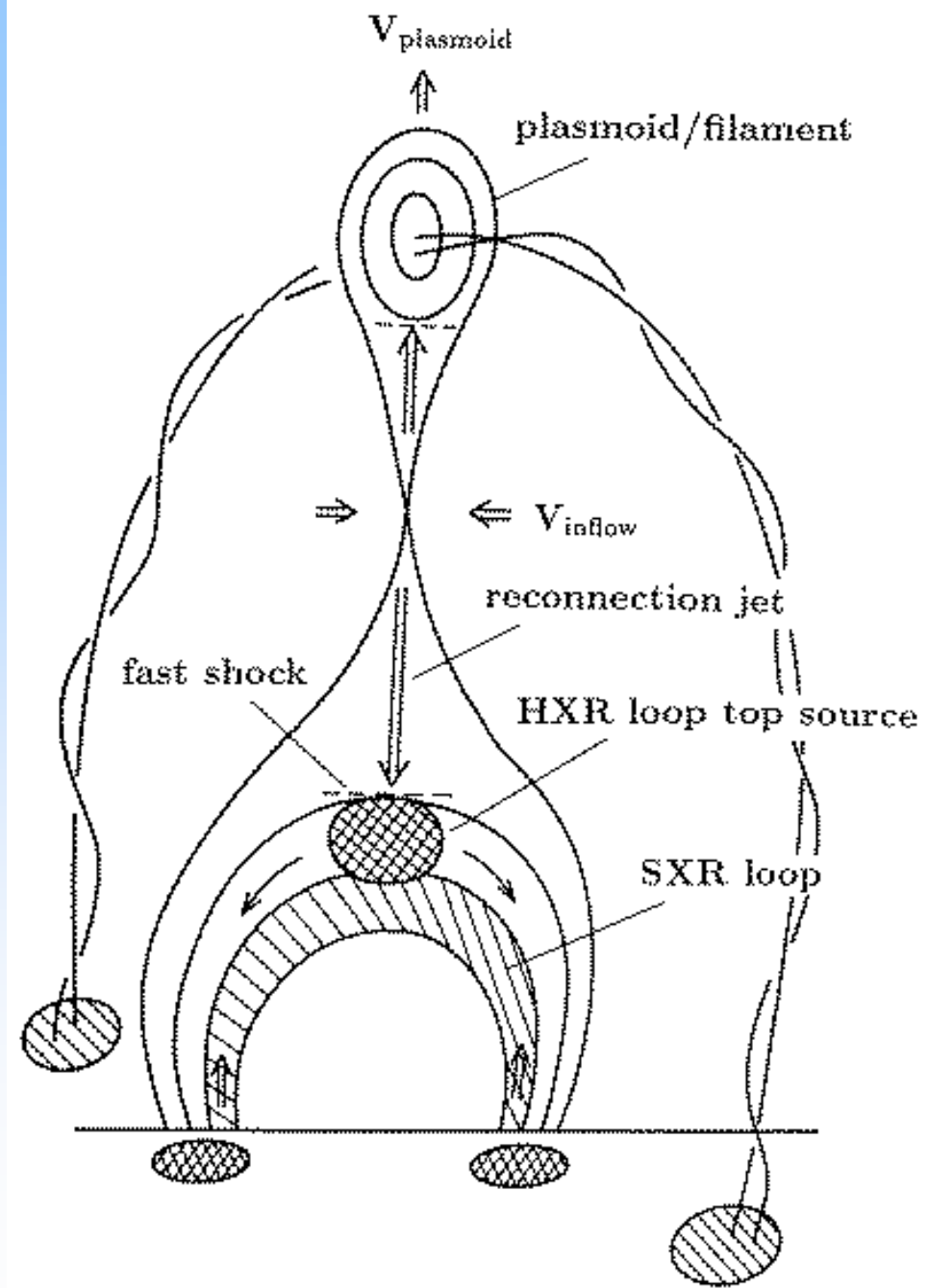
A. Sterling, Feb '11  
Filaments Away!



Sterling, Moore, Thompson (2001)

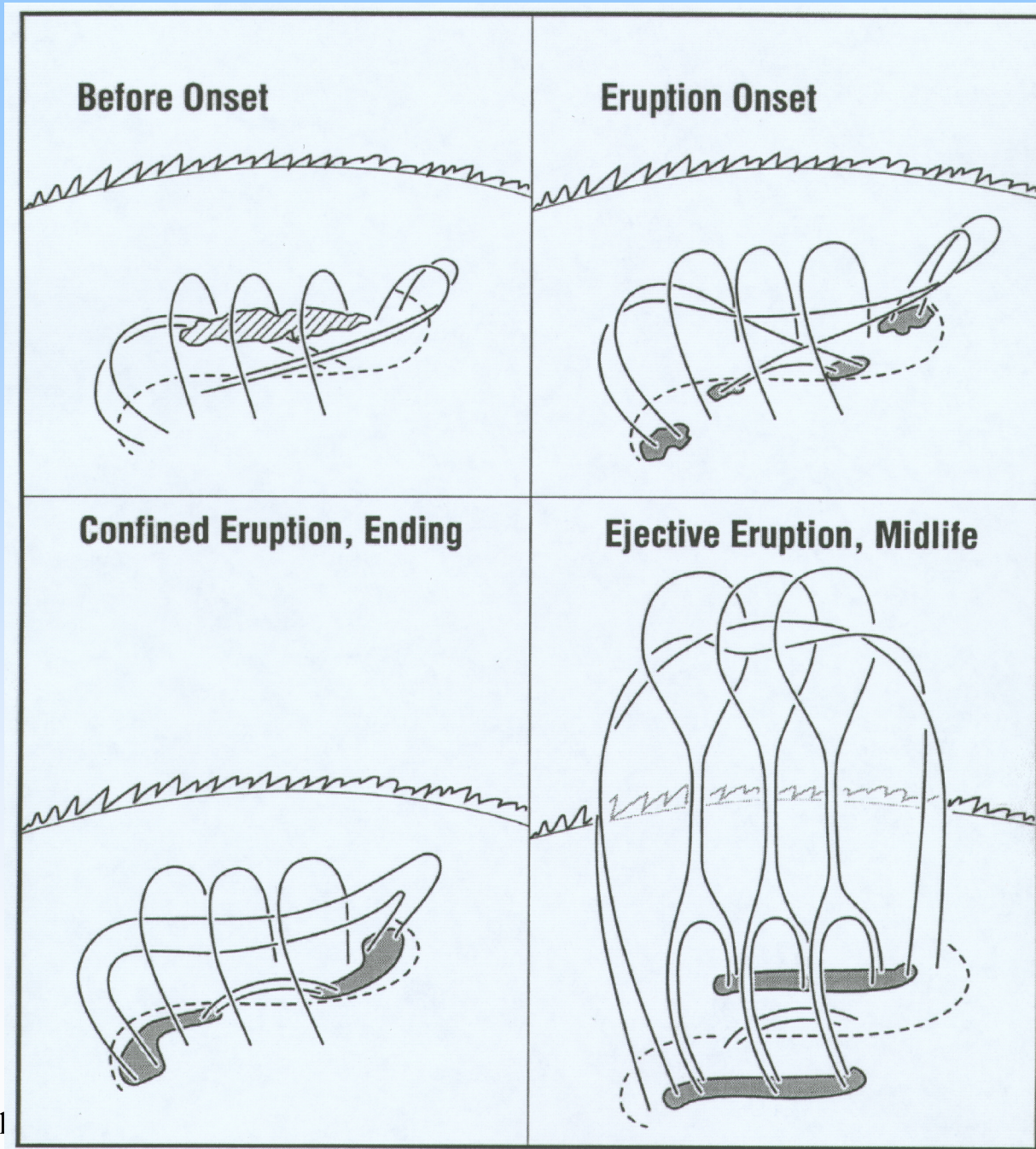
A. Sterling, Feb '11  
Filaments Away!

Shibata et al. (1995)

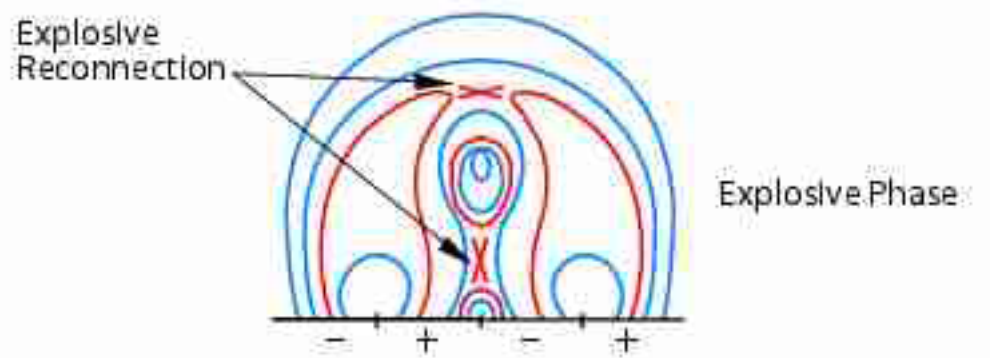
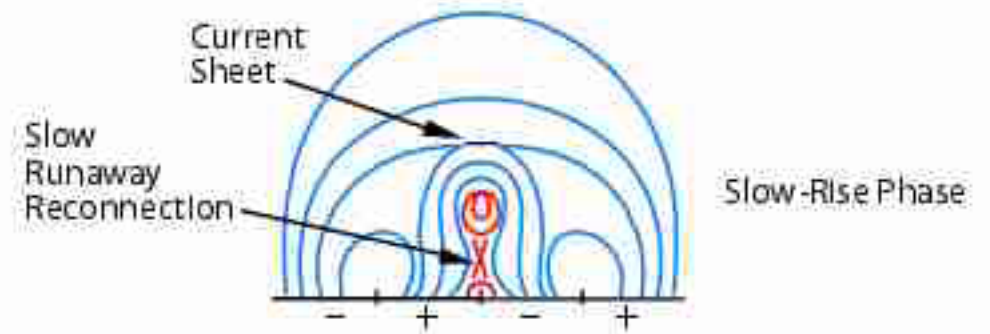
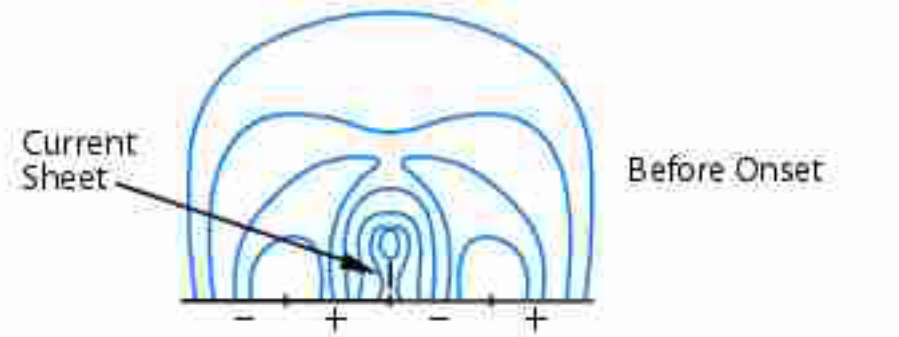
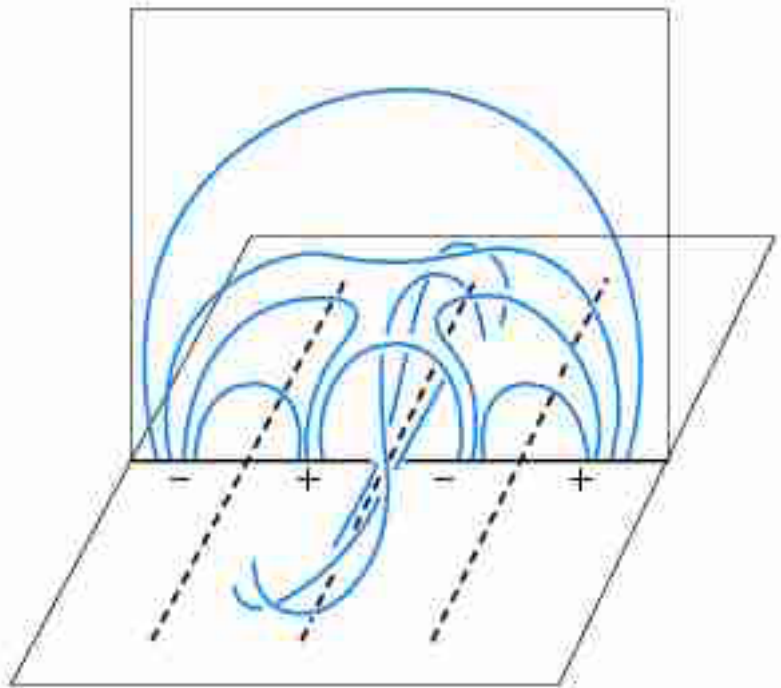


A. Sterling, Feb '11  
Filaments Away!

(Moore et al. 2001)



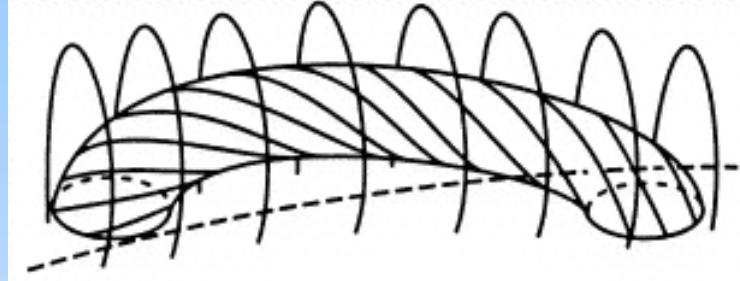
A. Sterling, Feb '11  
Filaments Away!



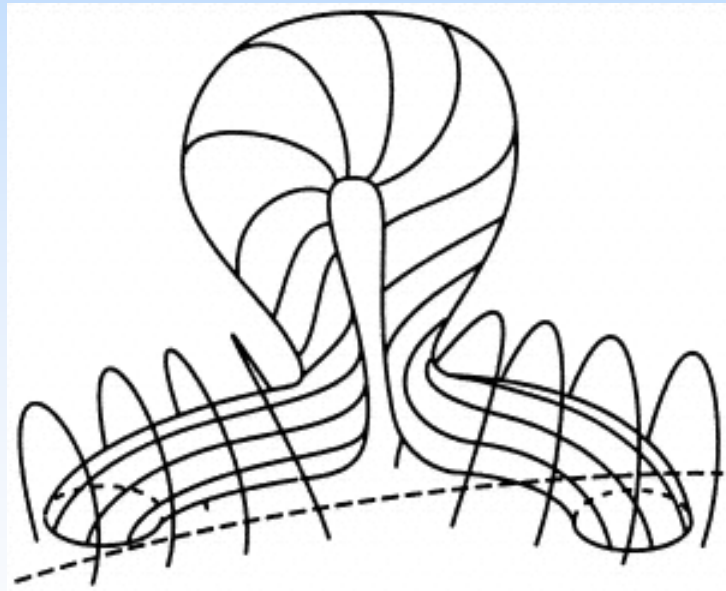
A. Sterling, Feb '11  
Filaments Away!

Moore & Sterling 2006





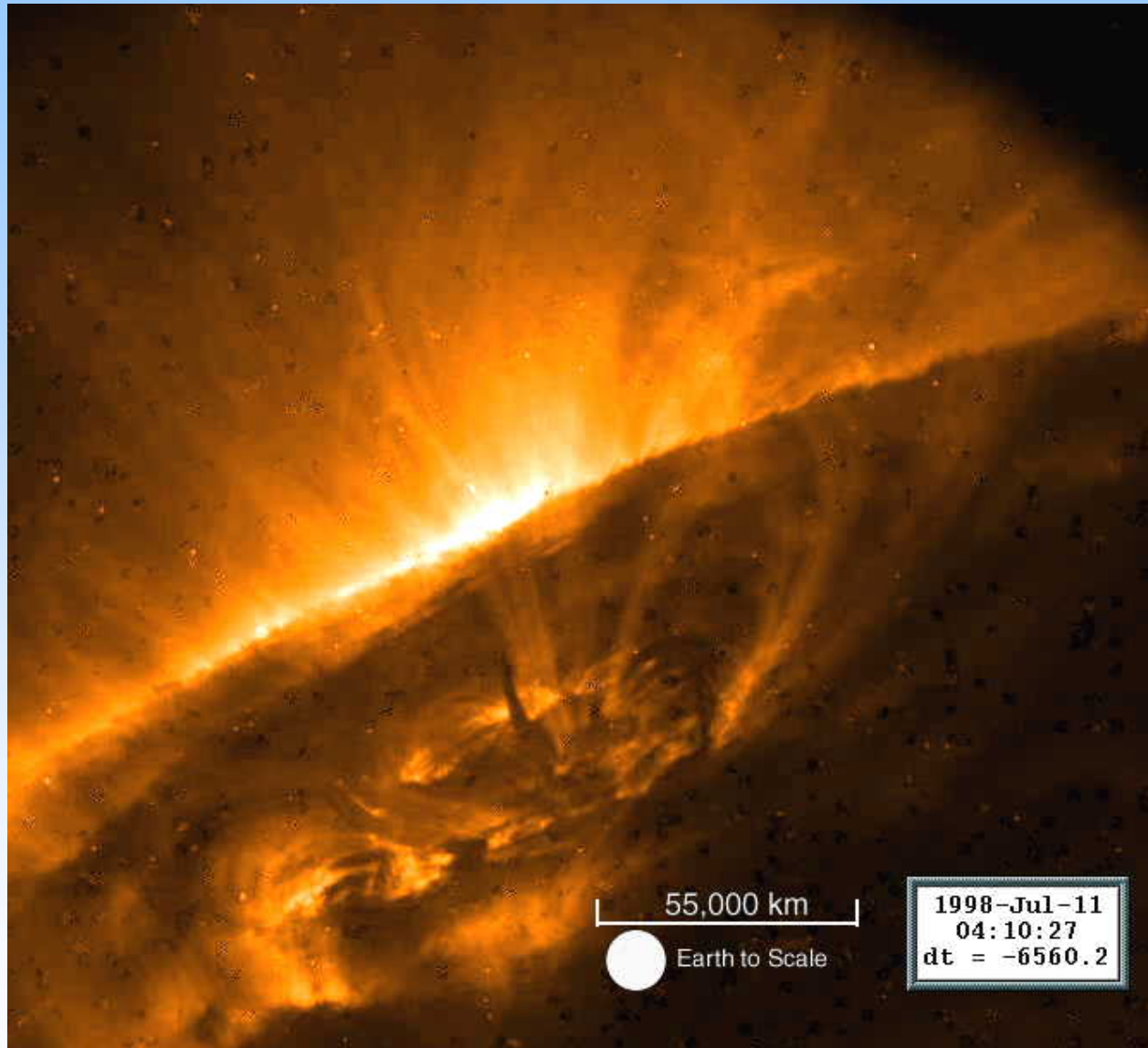
(Sturrock et al.  
2001).



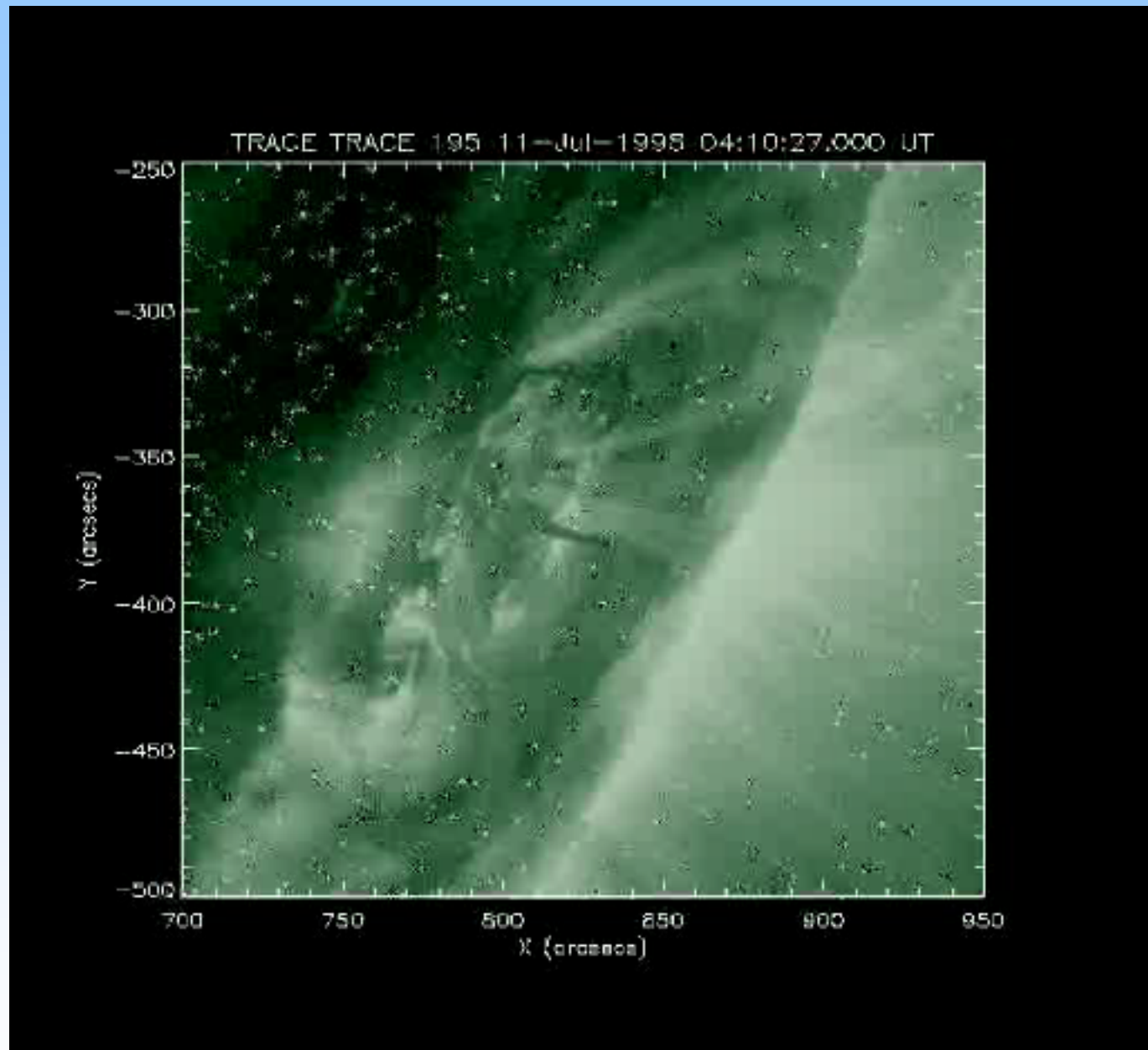
Also, e.g.:  
Sakurai 1976,  
Török & Kliem 2005  
Fan & Gibson 2003  
Van Driel-Gesztelyi 2000  
Williams et al. 2005

# An AR-event example from TRACE

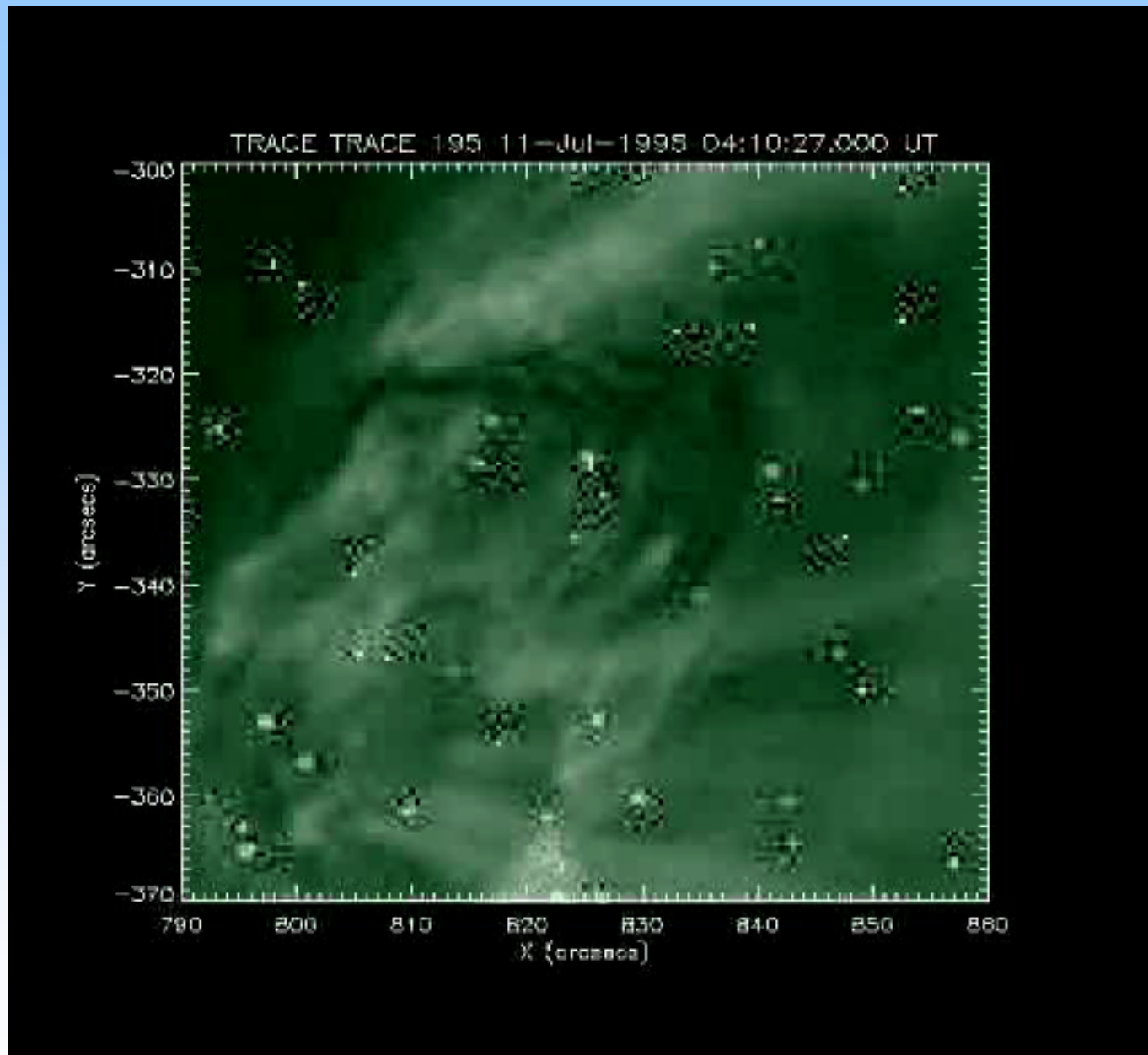
- Active Region Near-limb filament eruption of 11 July 1998.
- TRACE.
- Yohkoh SXT and HXT.
- SOHO/MDI magnetograms.
- Sterling & Moore (2005)



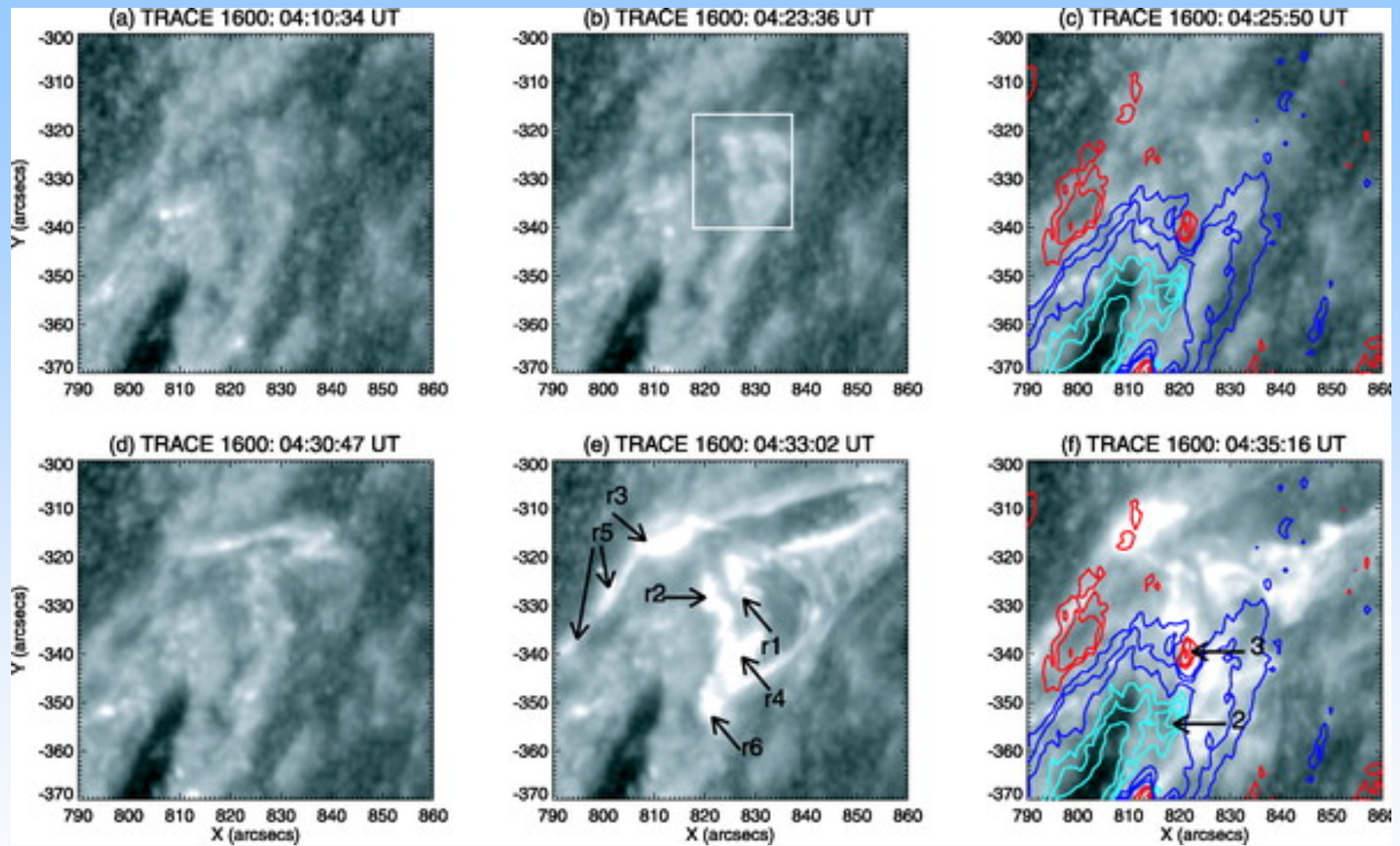
A. Sterling, Feb '11  
Filaments Away!



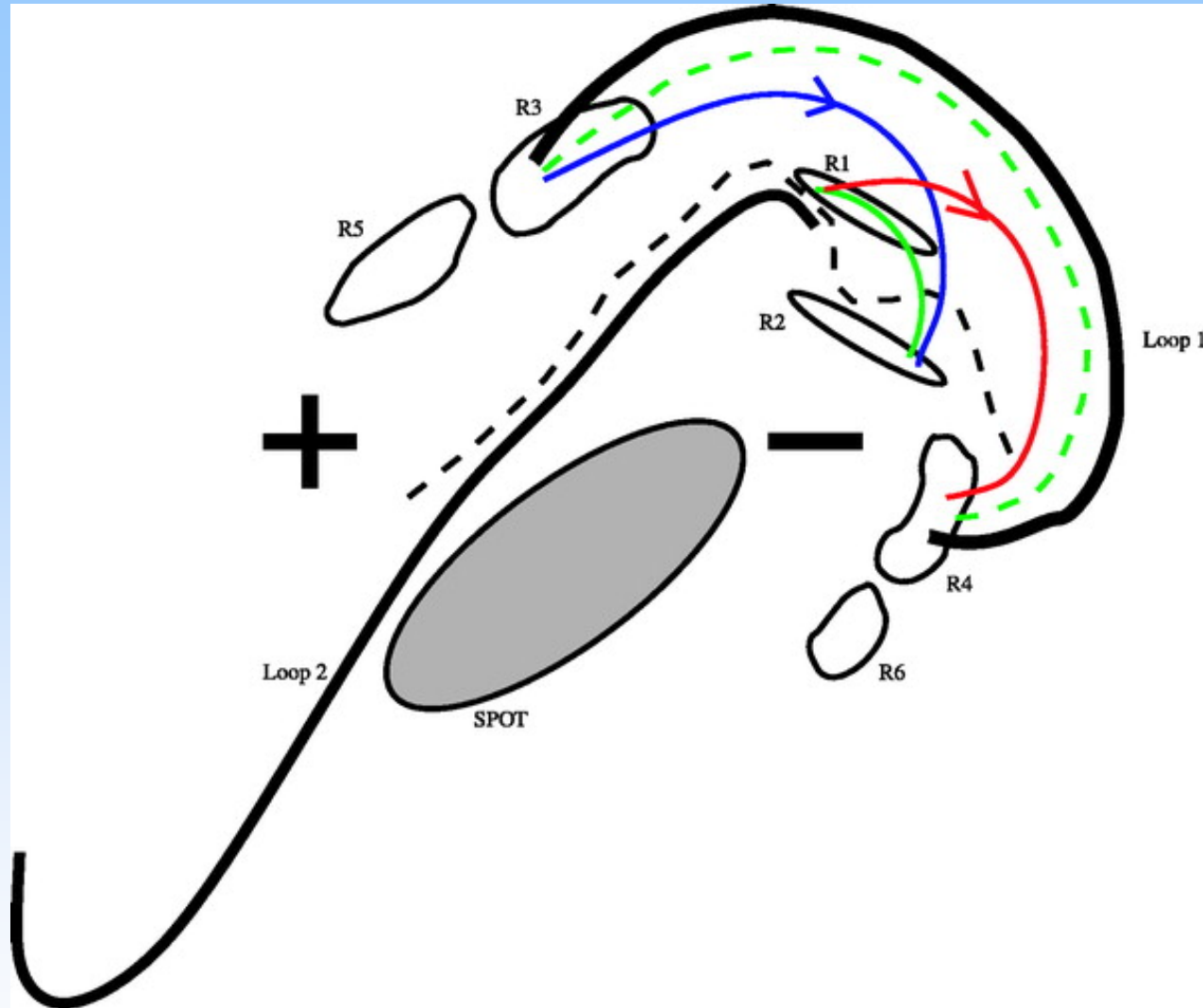
A. Sterling, Feb '11  
Filaments Away!



A. Sterling, Feb '11  
Filaments Away!

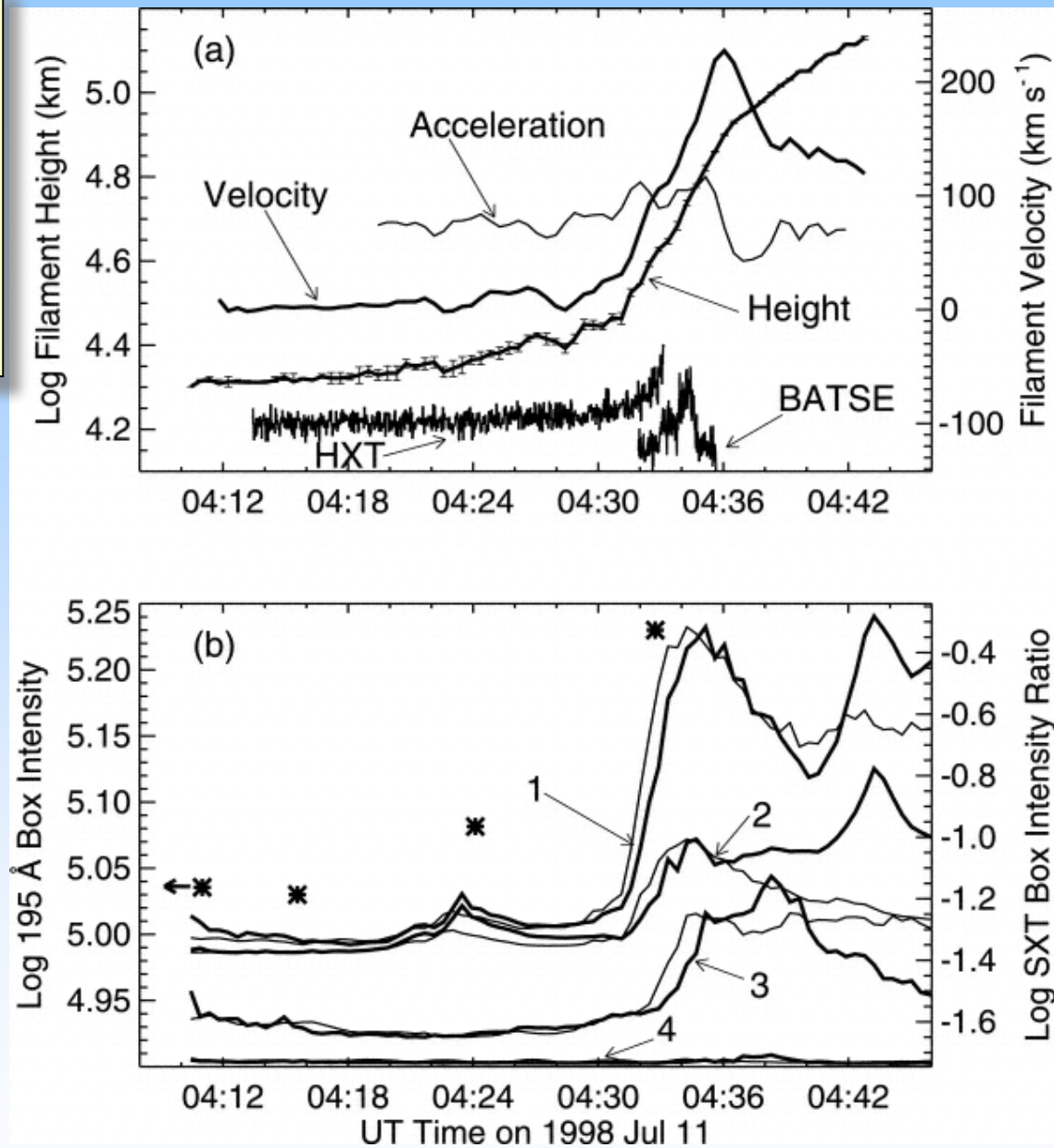


A. Sterling, Feb '11  
 Filaments Away!



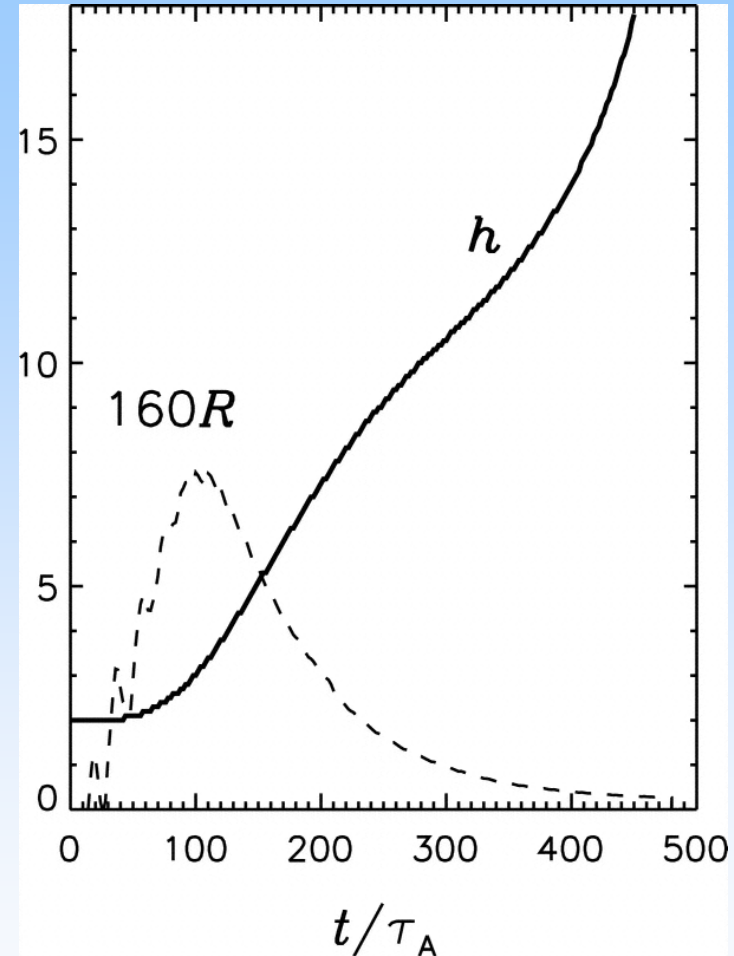
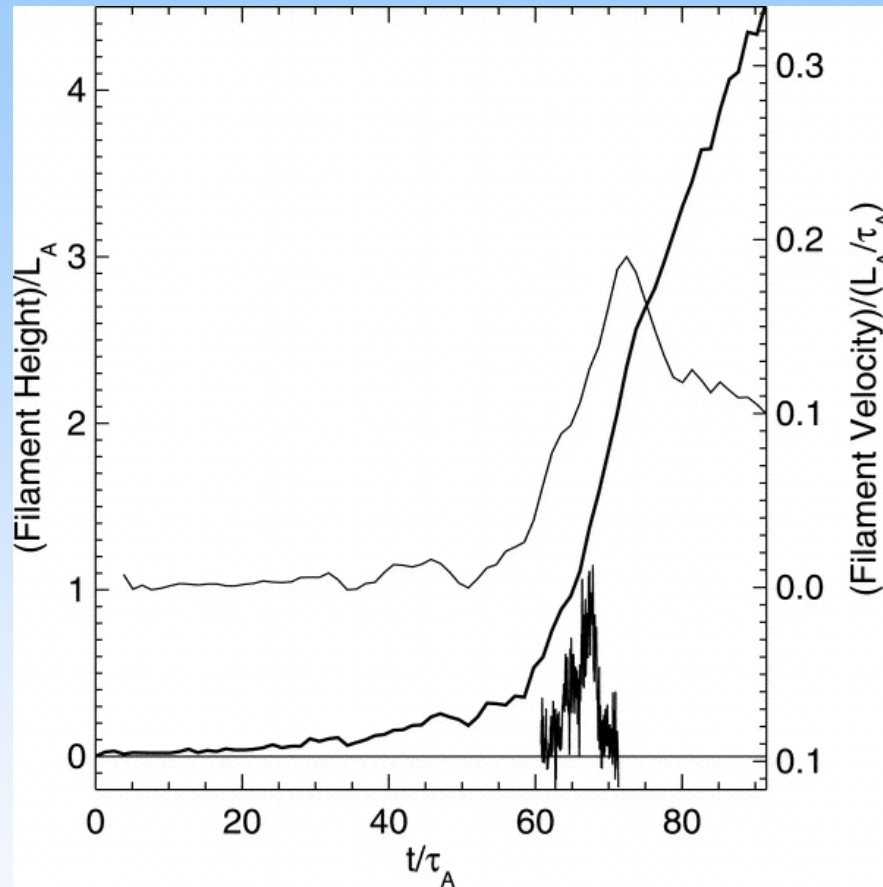
A. Sterling, Feb '11  
 Filaments Away!

- Slow rise.
- Preflare brightening.
- HXR near start of fast rise.





# Compare observations with emerging flux simulation

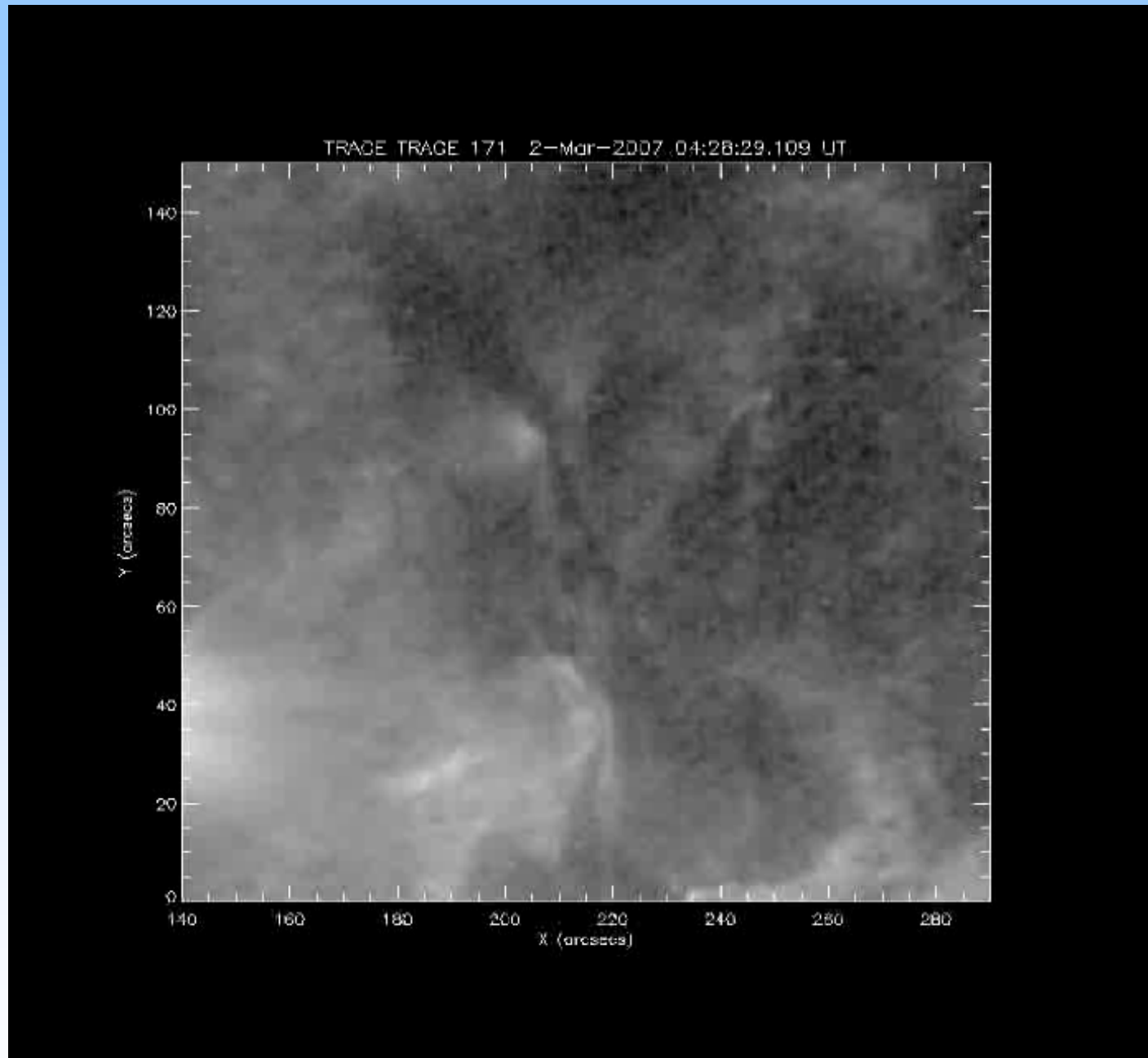


Sterling & Moore (2005), Chen & Shibata (2000)

- Comparison OK in general
- In detail: What about slow rise phase?

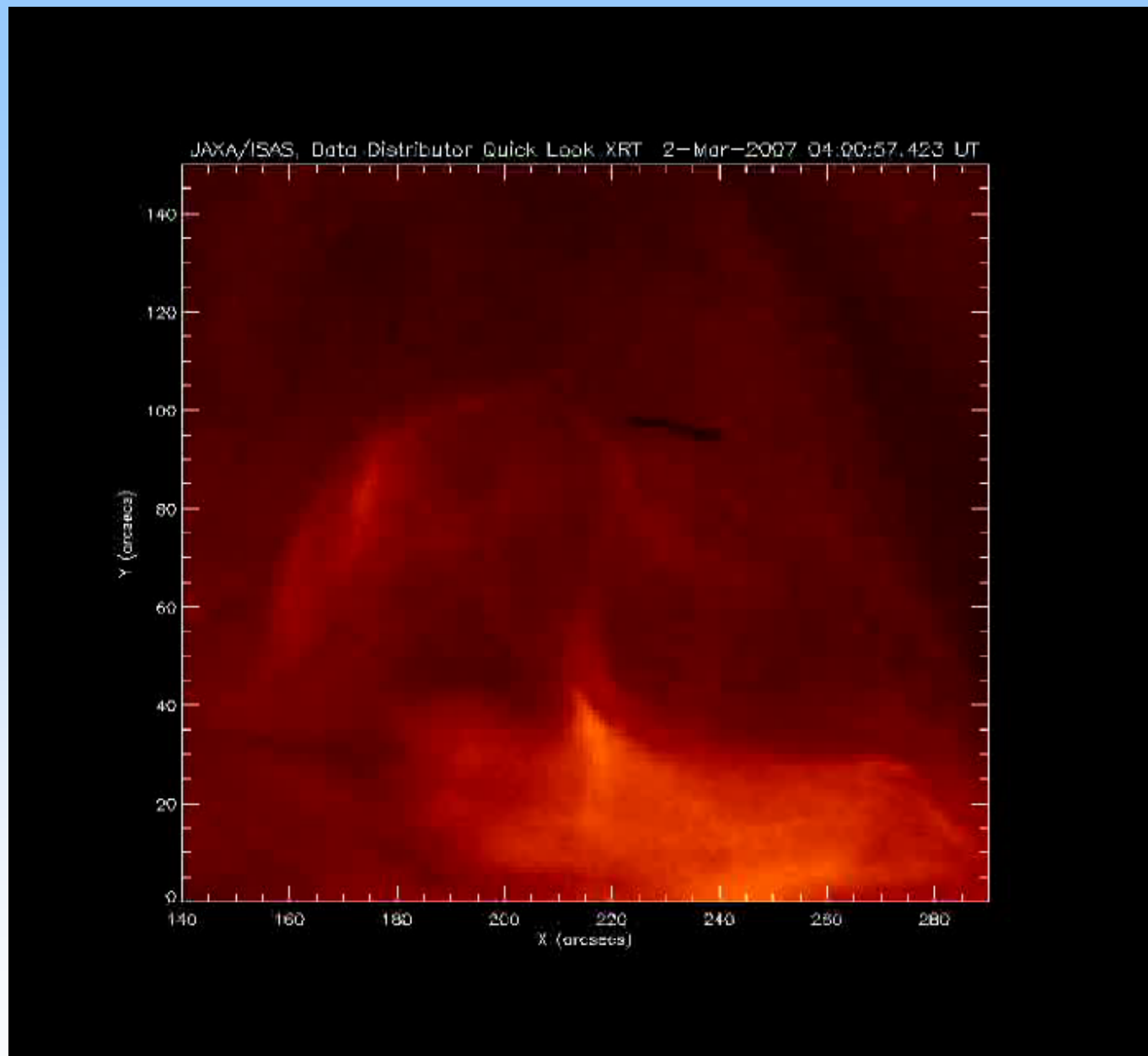
# An AR-event example from Hinode

- On-disk filament eruption of 2 March 2007, seen with TRACE, STEREO.
- Hinode:
  - SOT (FG V magnetogram), etc.
  - SXR from XRT.
- Also use MDI magnetogram.
- Sterling et al. (2007).

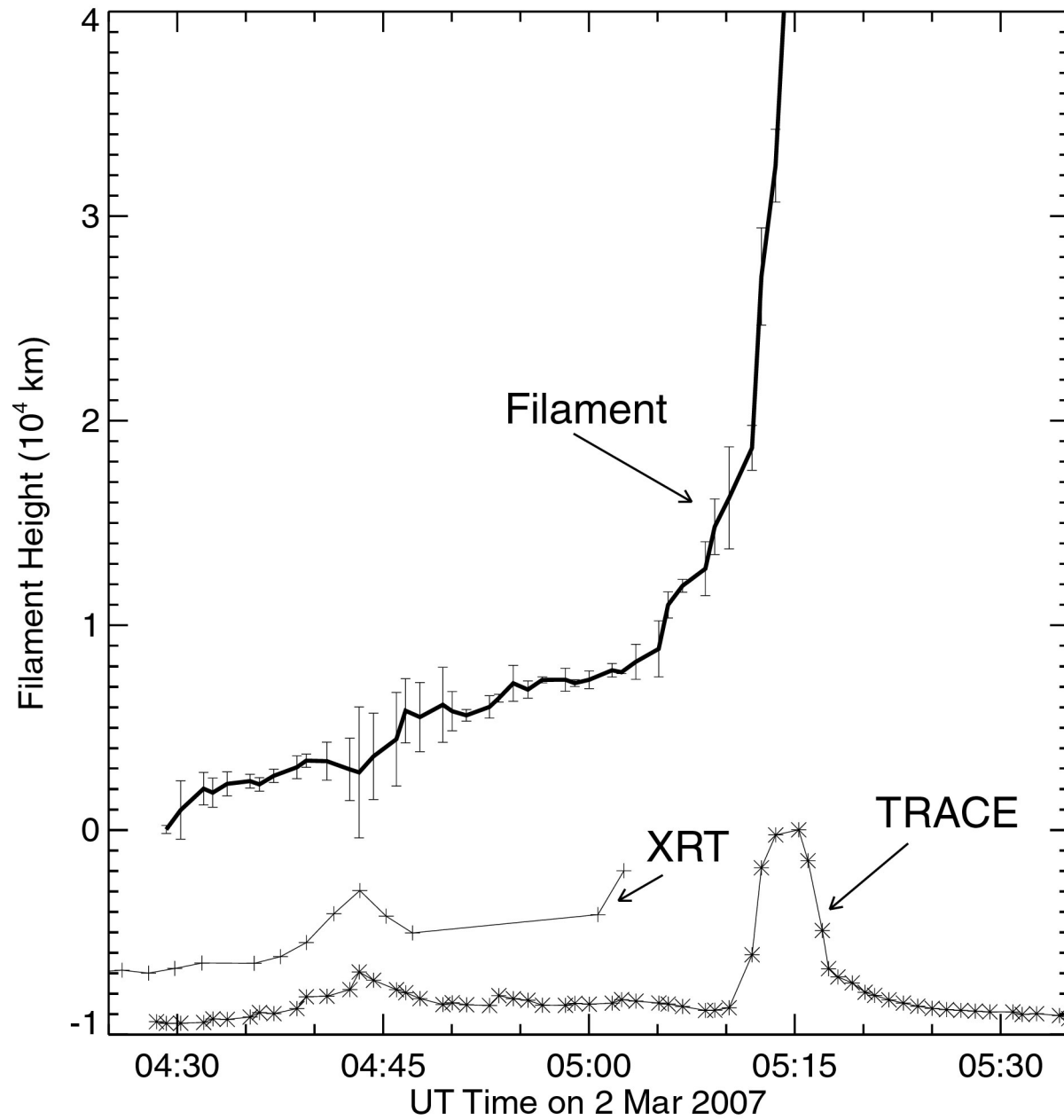


A. Sterling, Feb '11  
Filaments Away!

Sterling et al. (2007)



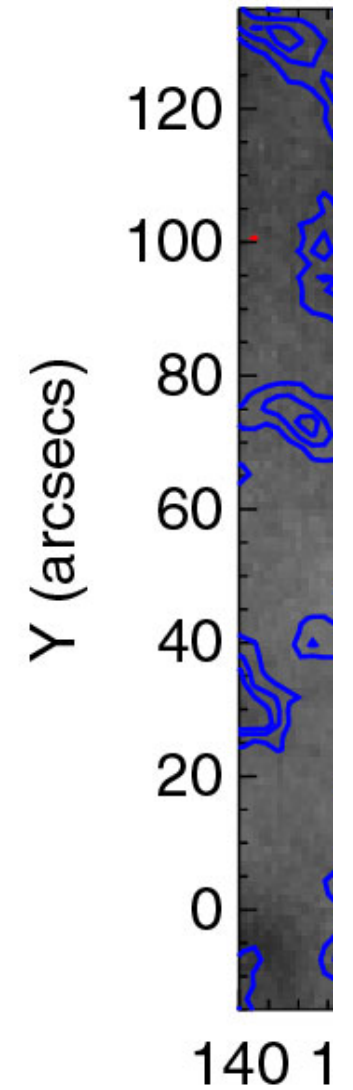
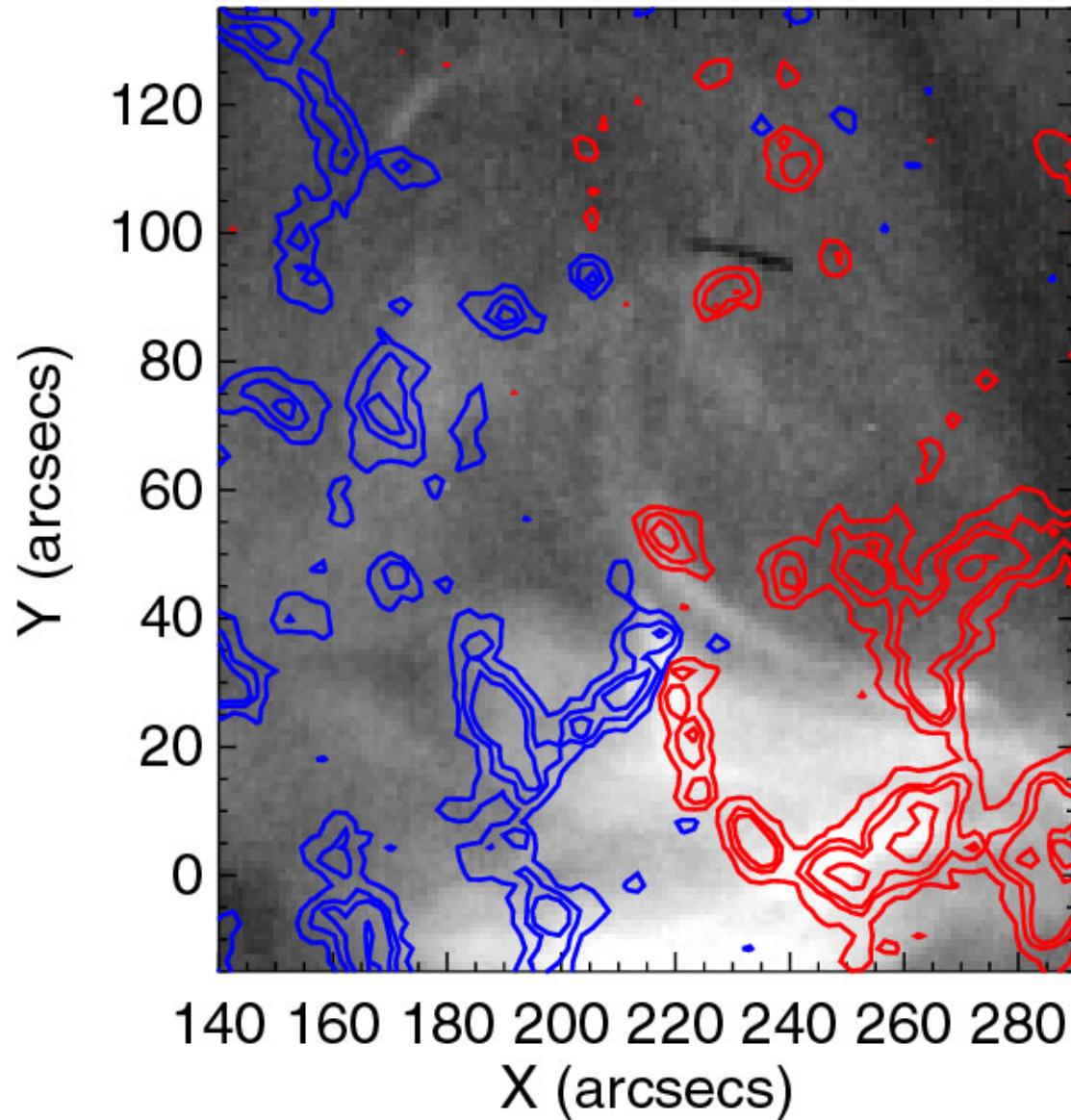
A. Sterling, Feb '11  
Filaments Away!



A. Sterli  
Filaments away:

# XRT on MDI

(a) XRT Ti-Poly: 2-Mar-2007 04:12:33 UT (b) XRT

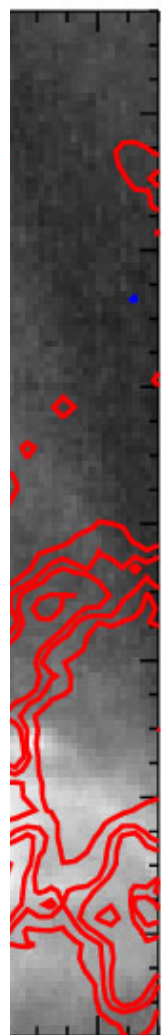


A.  
Fil.

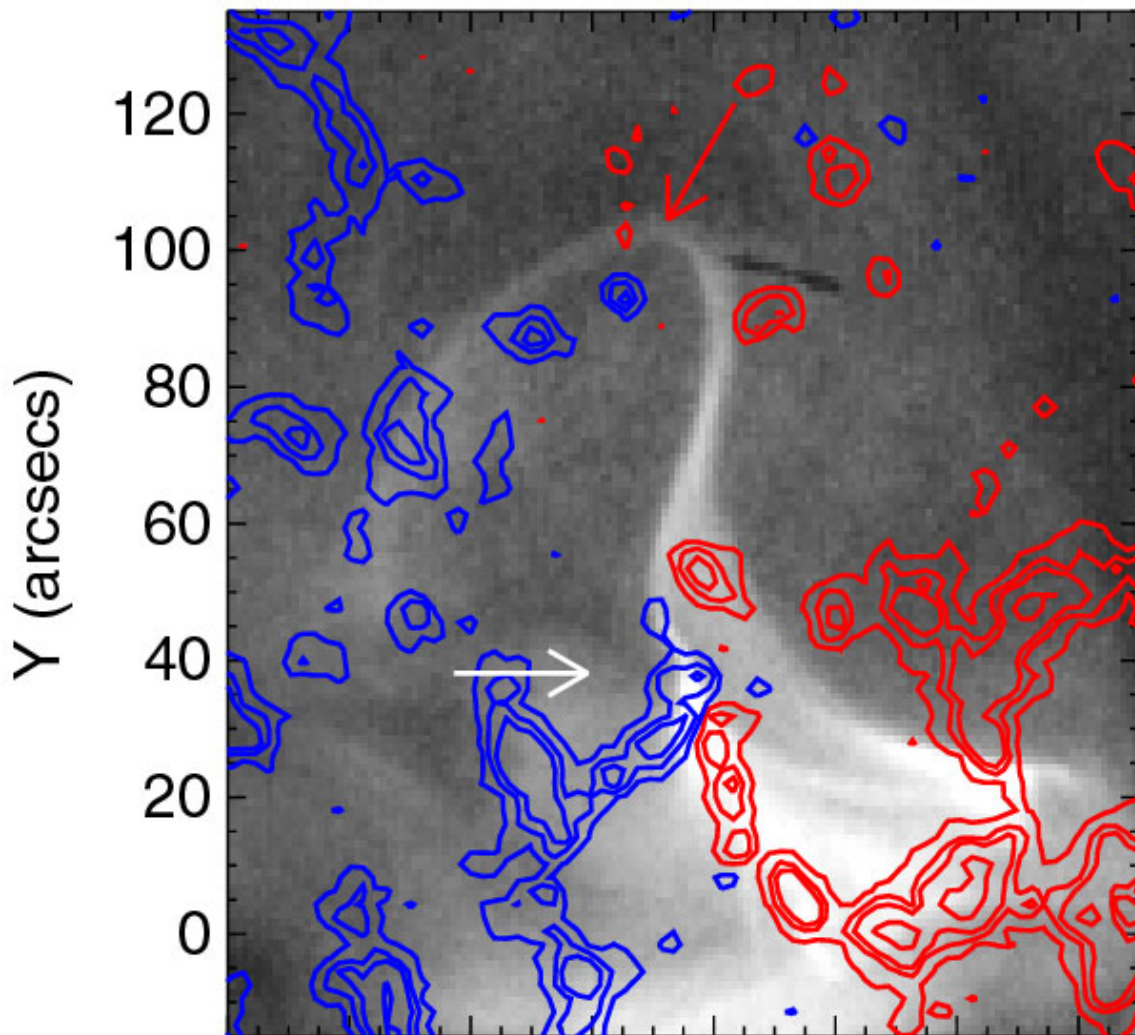
(c) XRT Al-Ti: 2-Mar-2007 05:10:14 UT (d) XRT

# XRT on MDI

04:12:33 UT (b) XRT Ti-Poly: 2-Mar-2007 04:43:18 (c) XRT



280

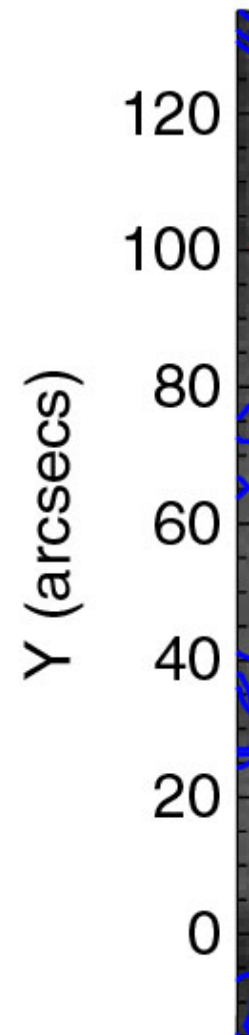


Y (arcsecs)

120  
100  
80  
60  
40  
20  
0

140 160 180 200 220 240 260 280

X (arcsecs)



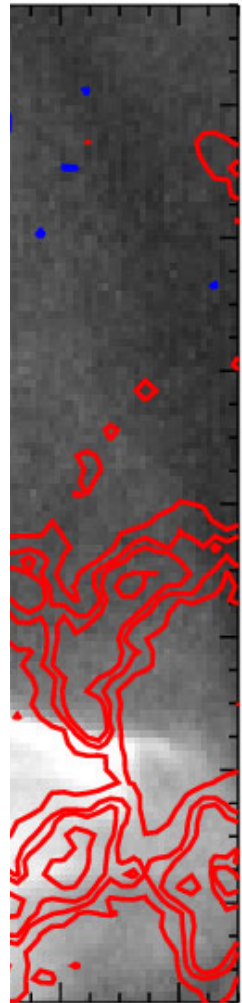
Y (arcsecs)

120  
100  
80  
60  
40  
20  
0

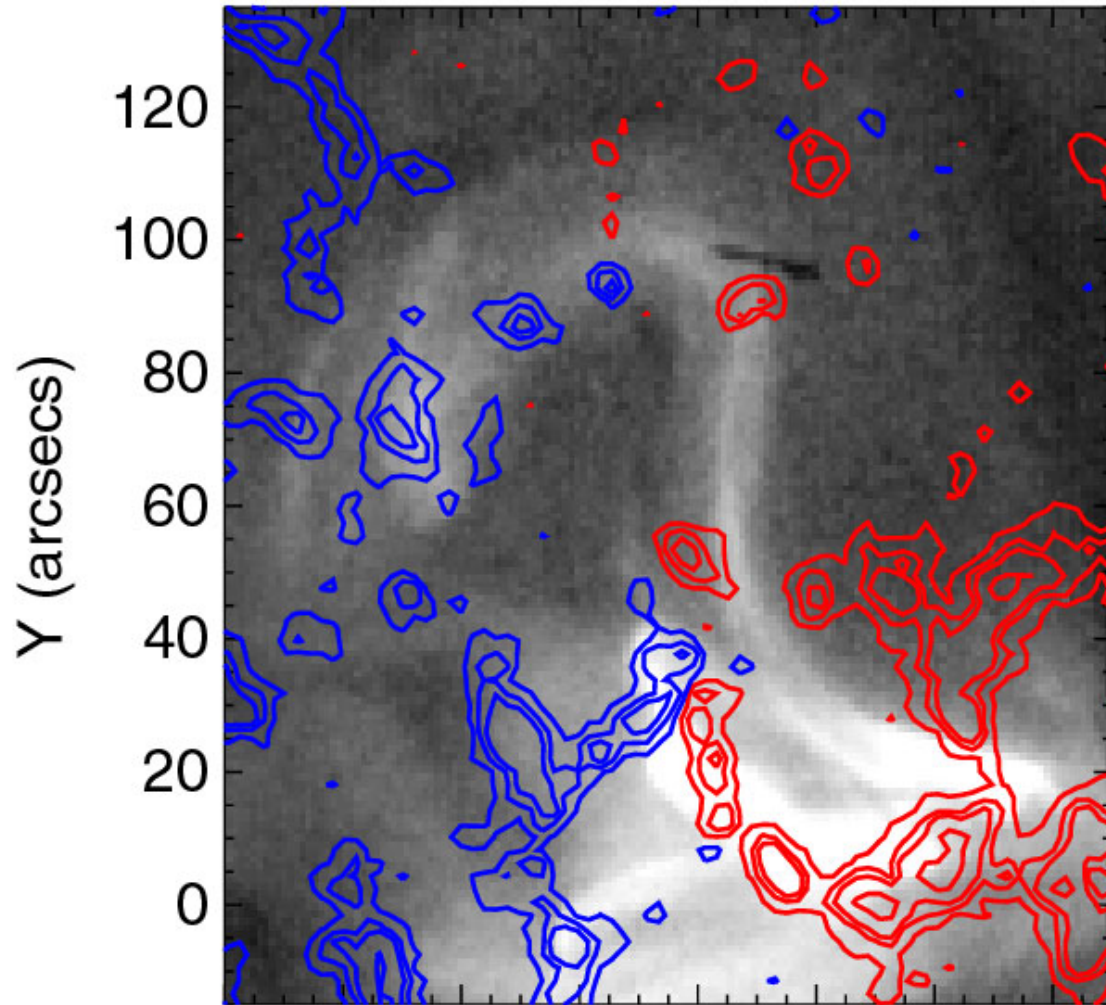
14

# XRT on MDI

2007 04:43:18 (c) XRT Ti-Poly: 2-Mar-2007 05:02:



260 280

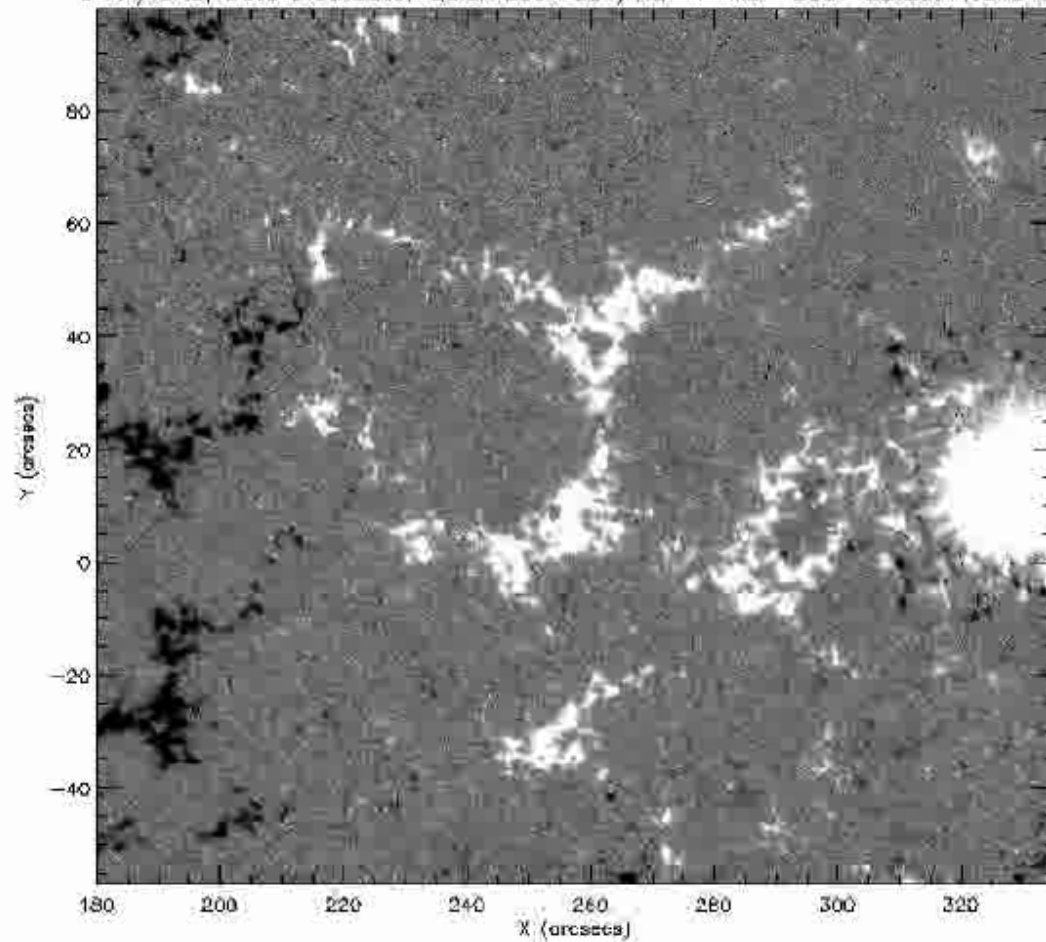


140 160 180 200 220 240 260 280

X (arcsecs)

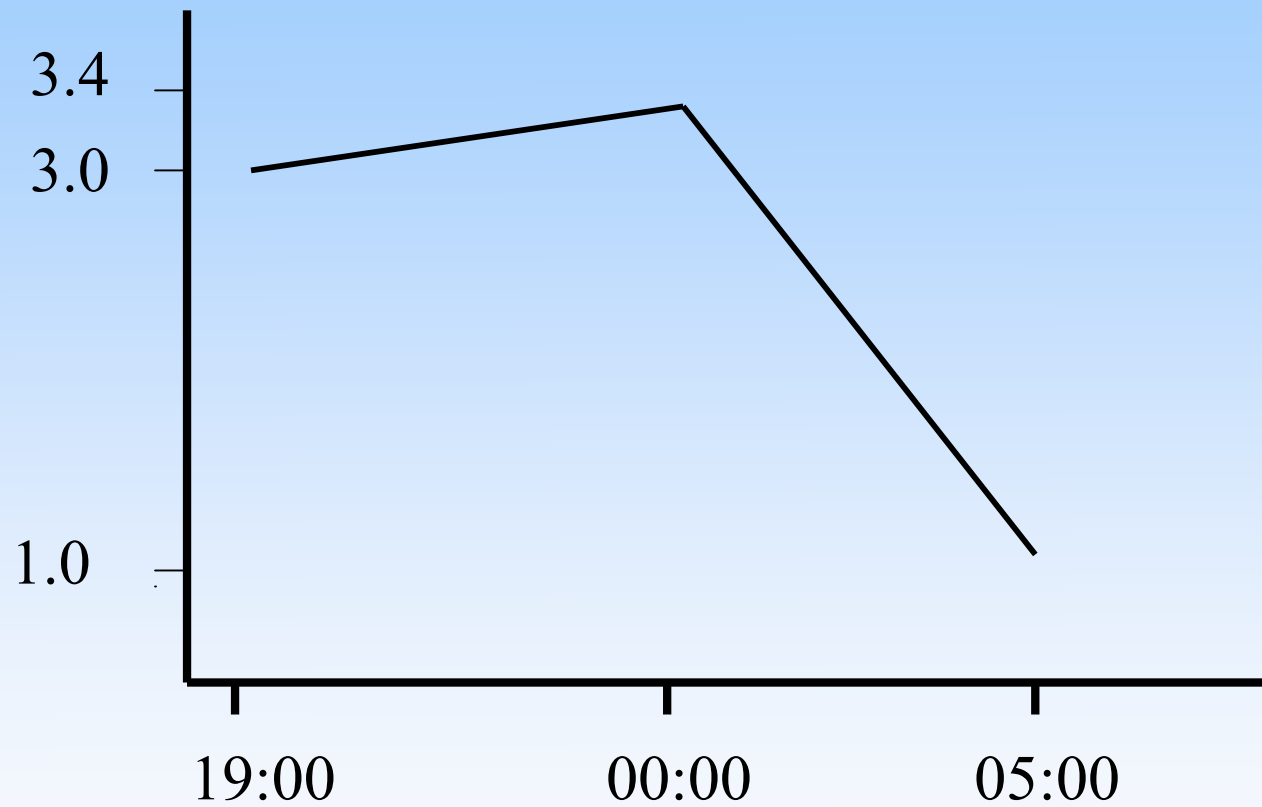


JAXA/ISAS, Data Distributor Quick Look SOT/NB 1-Mar-2007 22:20:41.04B.UT

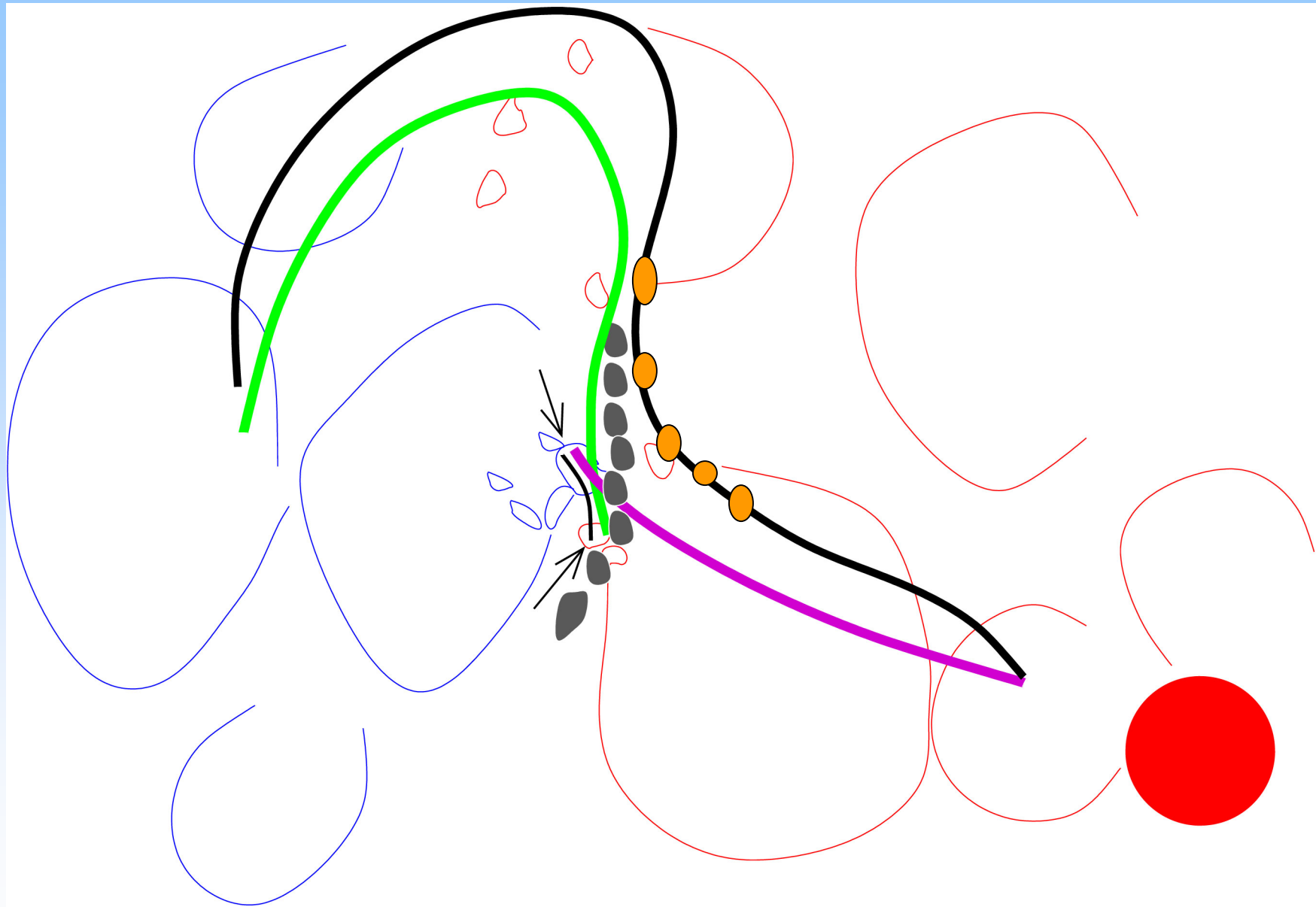


A. Sterling, Feb '11  
Filaments Away!

# Magnetic Flux in box ( $\times 10^{19}$ Mx)



UT Time on 1-2 Mar 2007  
(Cf. flux of whole region:  $\sim 10^{21}$  Mx)



A. Sterling, Feb '11  
Filaments Away!

# Discussion

This initial observation from Hinode of a filament eruption supports the idea that flux changes in or near the eruption site are responsible for pre-explosive phase (e.g., slow-rise phase) dynamics.

Flux changes = flux emergence and/or flux cancelation (also: tether weakening, slow tether cutting).

(E.g., van Ballegooijen & Martens 1989, Moore & Roumeliotis 1992, Rust & Kumar 1996, Lin & Forbes 2000, Chen & Shibata 2000, Feynman & Ruzmaikin 2004, Williams et al. 2005, Sterling, Harra & Moore 2007, Mikic et al. 2007.)

# Hinode First Event Discussion: Continued

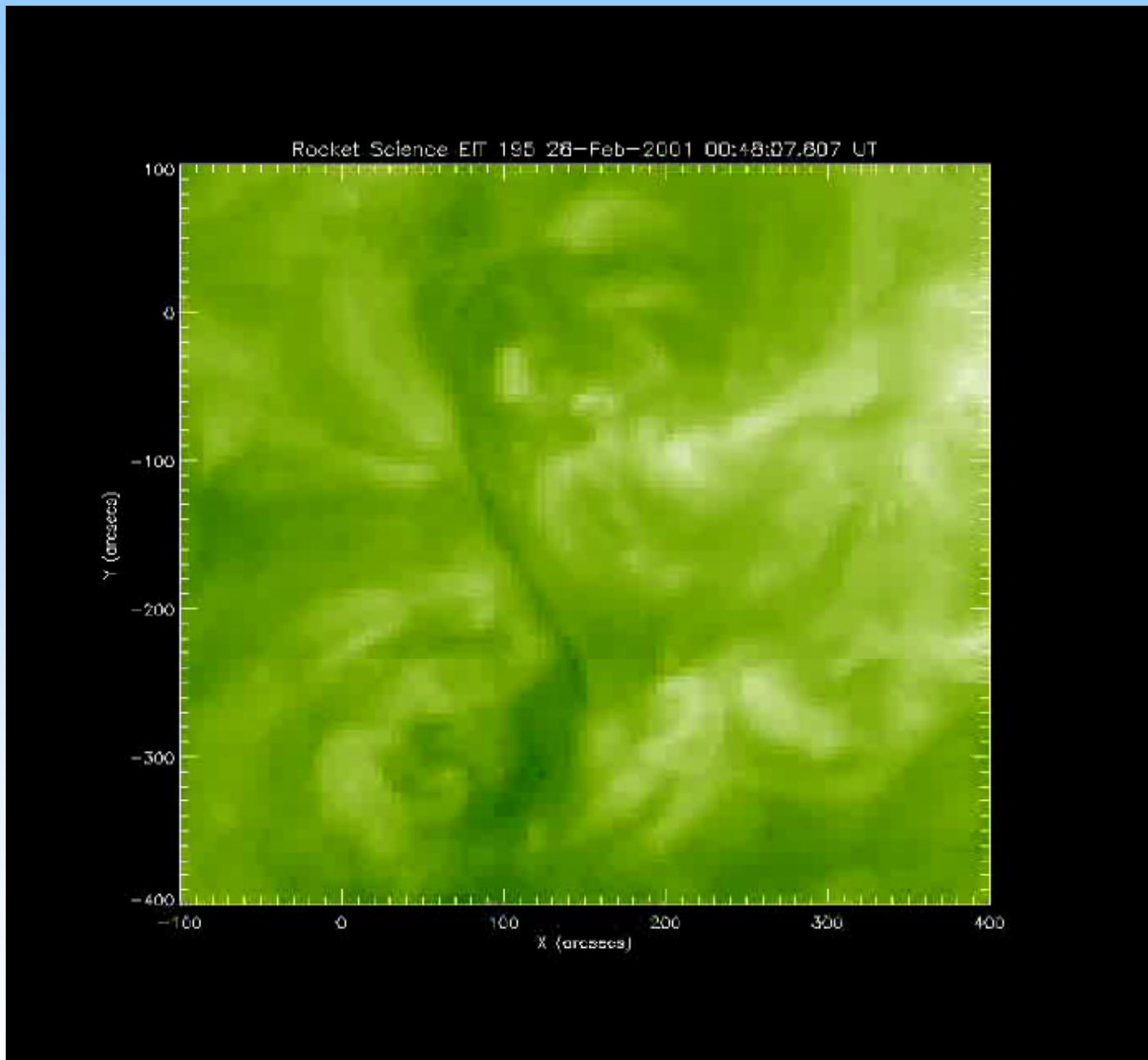
- Supports that pre-eruption (pre-flare) **filament slow-rise phase** is due to early flux changes (in this case: cancelation; slowly-driven tether-cutting reconnection).
- See sigmoid develop during eruption (e.g., cf. Pevtsov 2002, Green et al. 2011).
- During pre-eruption period,  $\Delta\Phi \sim 10^{19} \text{ Mx}$   
=  $\sim 5\%$  of flux of total erupting system.

Therefore, the cancelation triggers release of the energy contained in the sheared field; it does not power the eruption.

- (Sterling et al. 2010 found  $\sim 10\%$  of total flux canceled over a 24 hr period for a different eruption. (Cf.  $\sim 30\%$  for a region of Green et al. 2011, over a longer period.)
- A question: What triggers the **fast-rise phase**? Hard to determine; see, e.g., Moore & Sterling 2006, Chifor et al. 2007. (Also, Liu et al. 2008, ApJ; suggest kinking plus internal tether cutting.)

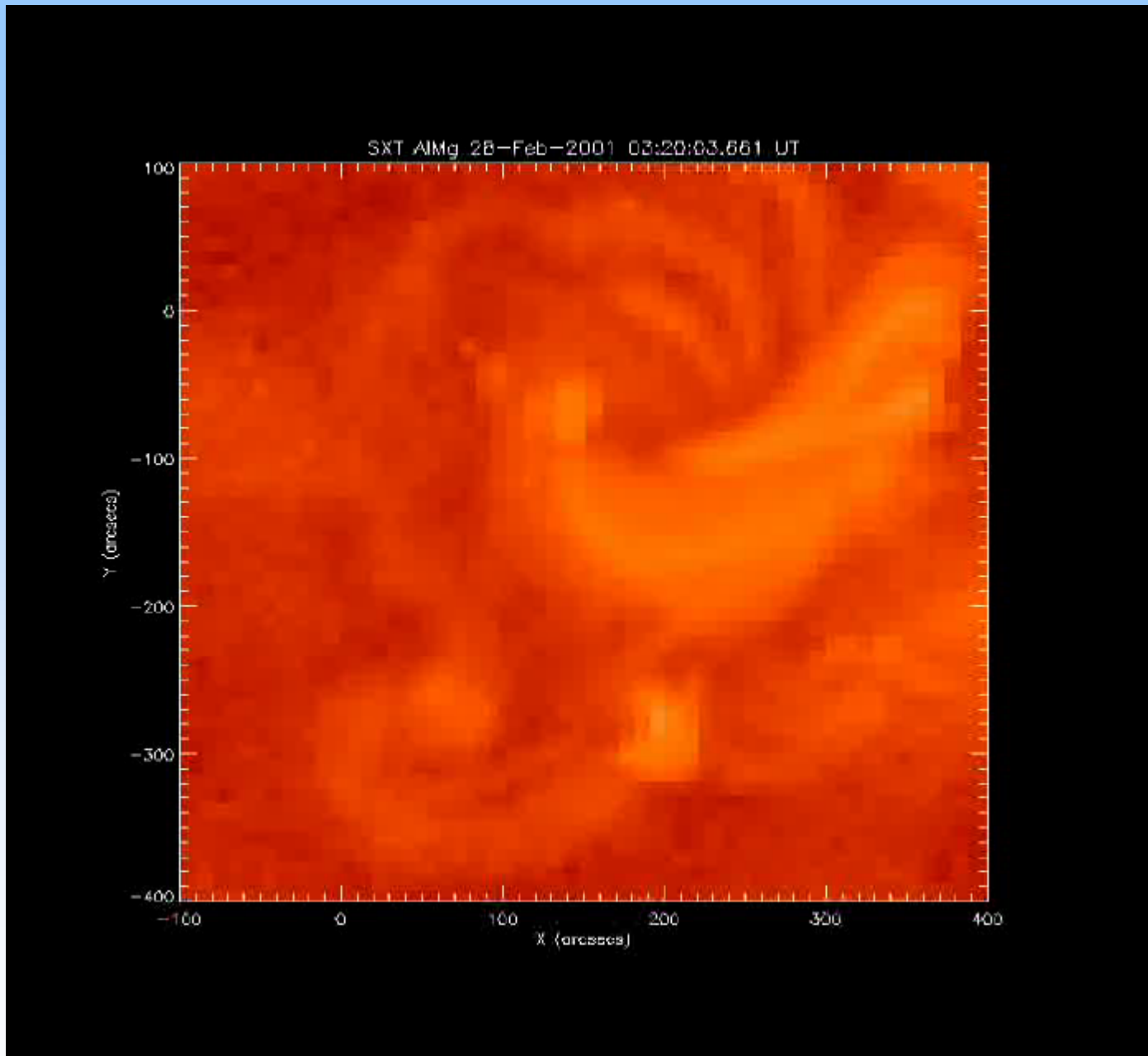
# EFR-Abetted QS Eruption

- Quiet-region filament eruption of 28 Feb 2001.
- SOHO/EIT and Yohkoh/SXT
- SOHO/MDI magnetograms.
- Sterling, Harra, & Moore 2007 (same event as Marque et al. 2002).



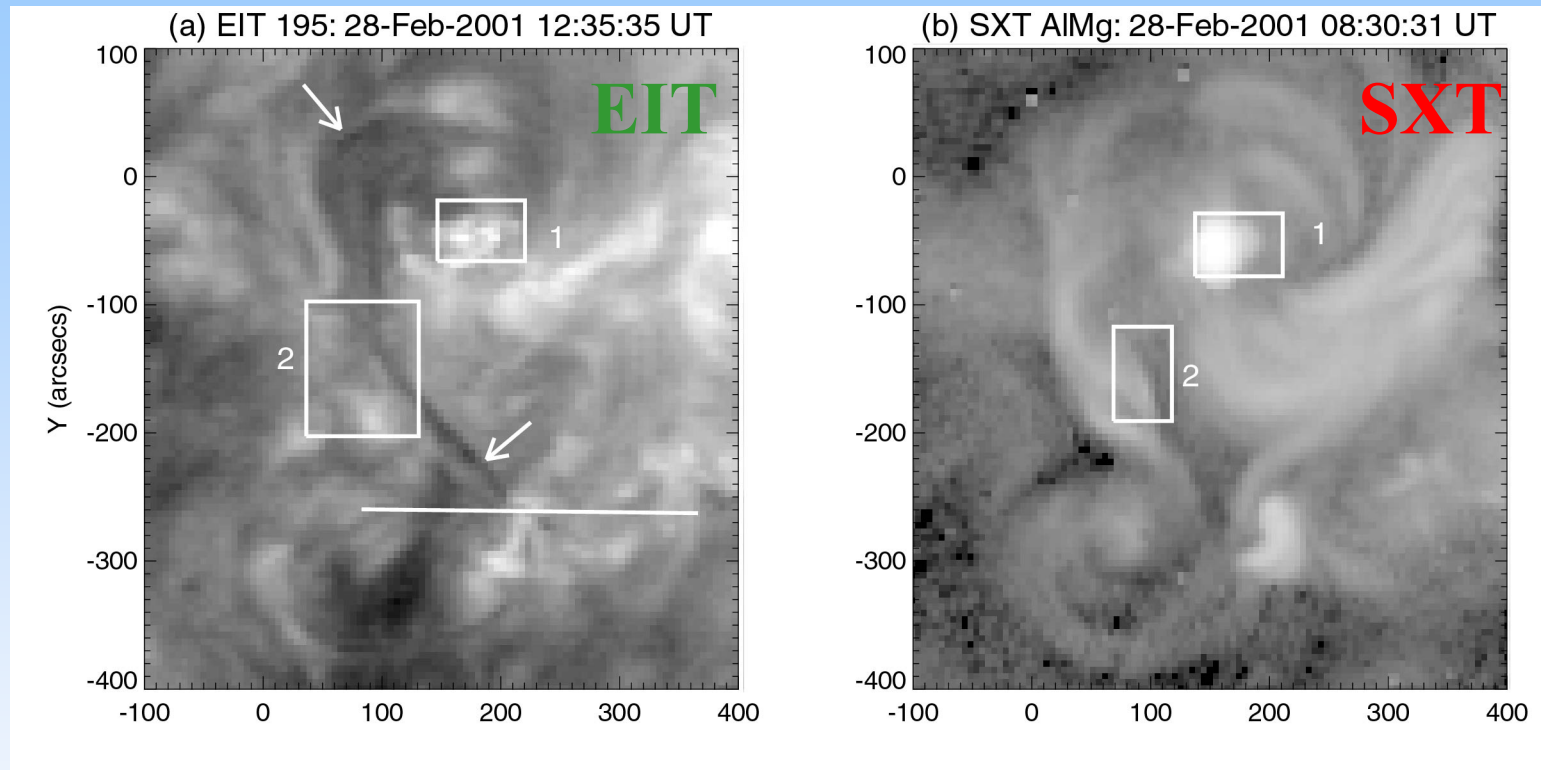
A. Sterling, Feb '11  
Filaments Away!

Sterling, Harra, & Moore (2007)



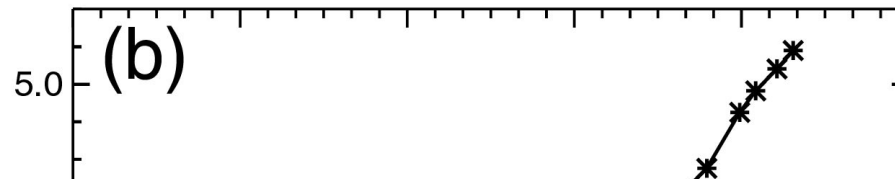
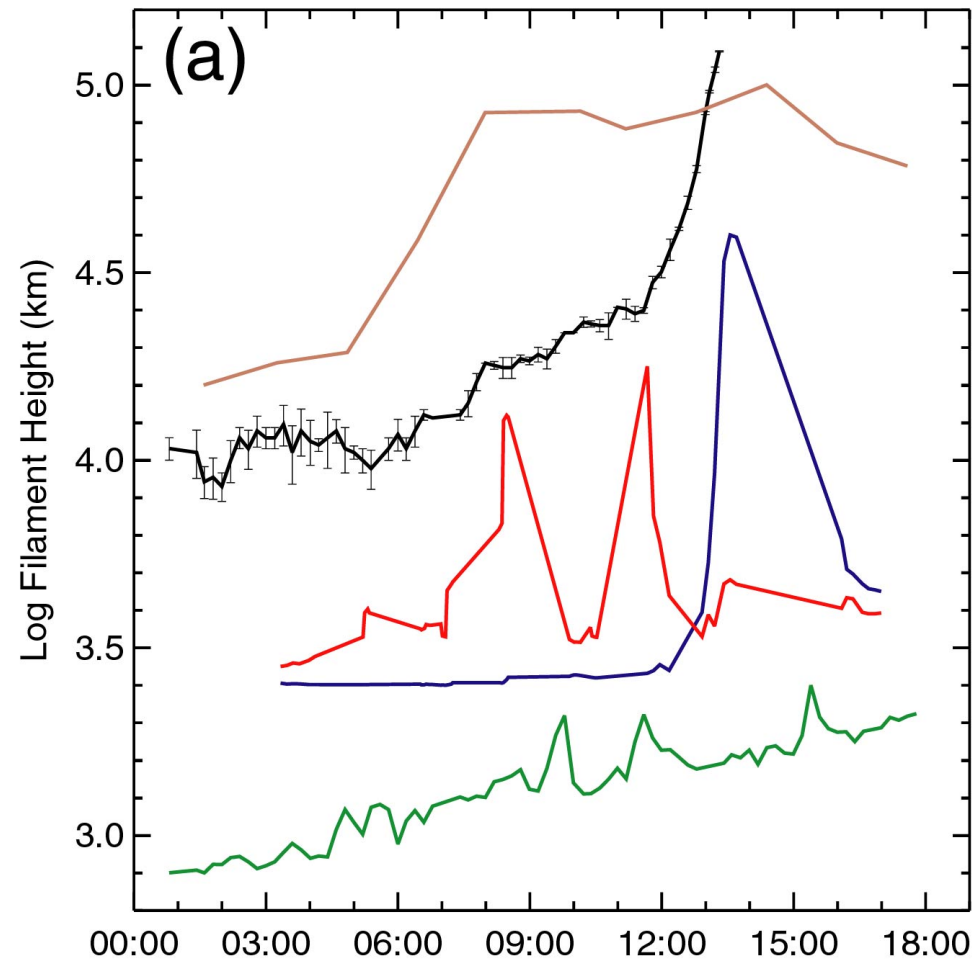
A. Sterling, Feb '11  
Filaments Away!



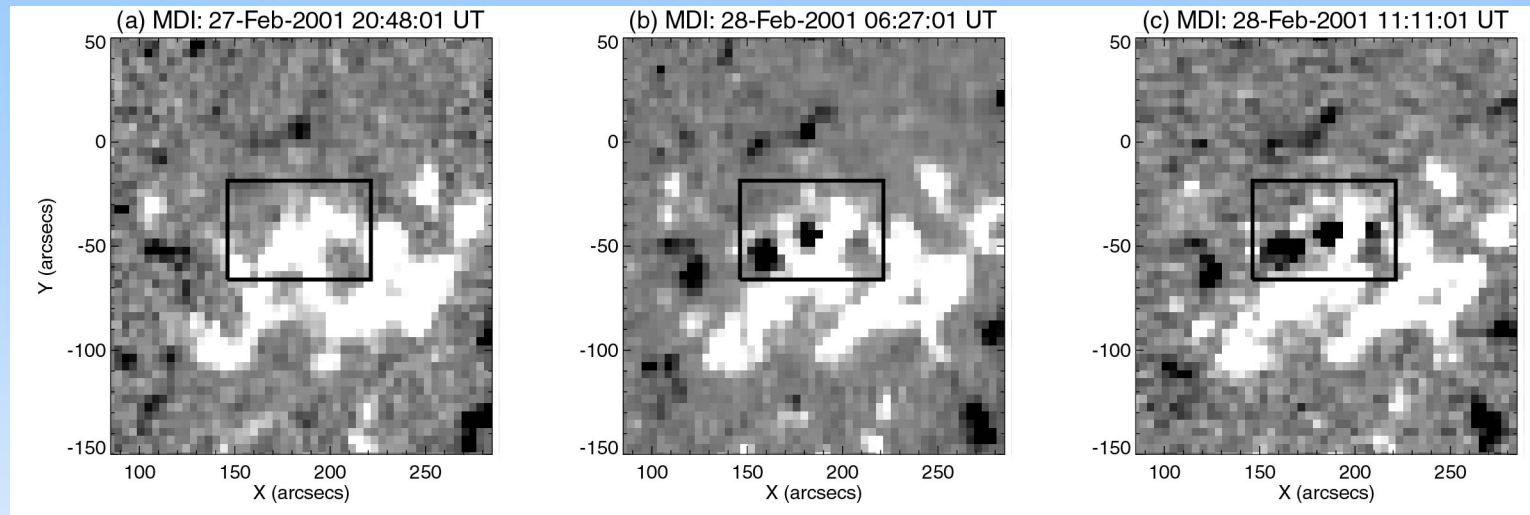


Sterling, Harra, & Moore (2007)

A. Sterling, Feb '11  
Filaments Away!



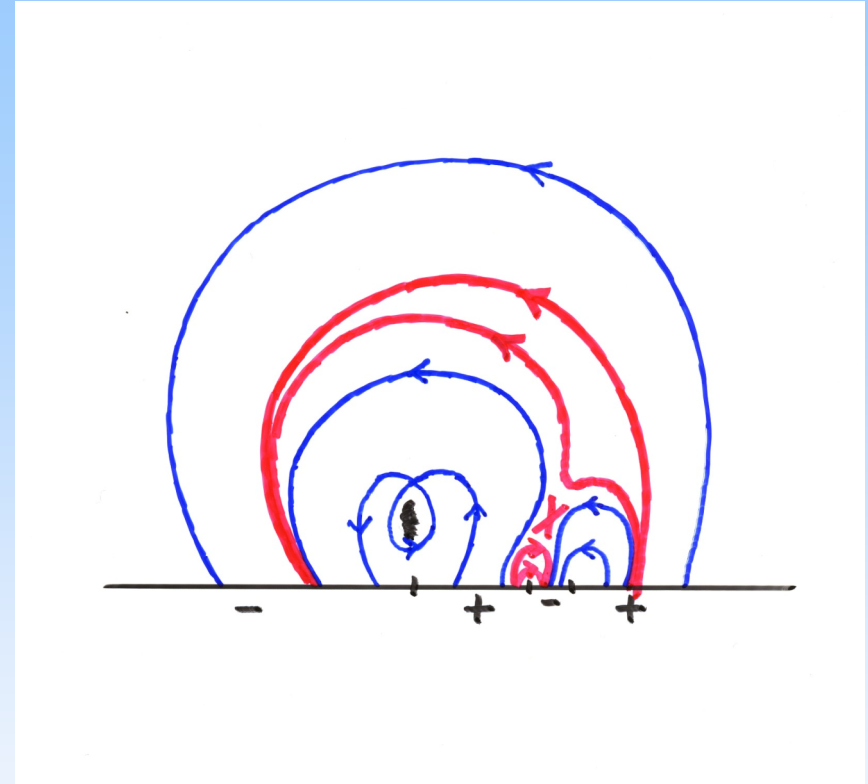
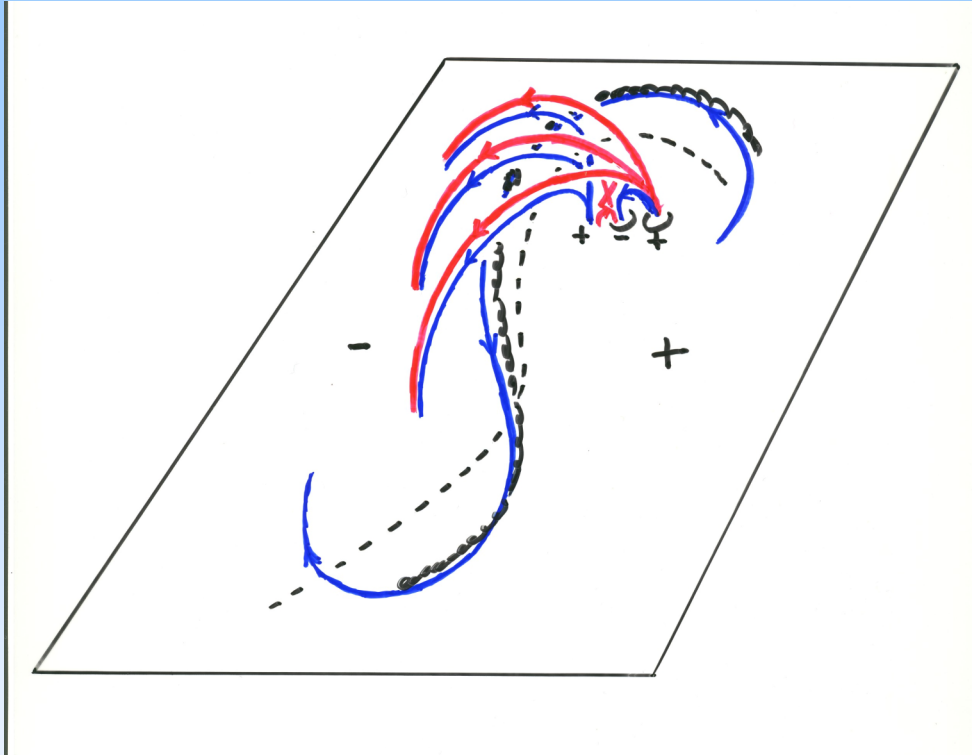
A. Sterling, Feb '11  
Filaments Away!



Cf. Feynman & Ruzmaikin (2004)  
(also, e.g., Li et al. 2006, and many others).

A. Sterling, Feb '11  
Filaments Away!

## Slow-rise phase: Tether-Weakening Reconnection?



Sterling, Harra, Moore (2007)

A. Sterling, Feb '11  
Filaments Away!

# Some Questions, and Objectives

- How common is the slow-rise phase?
- What triggers the fast-rise phase? (TC, breakout, instability, something else?)
- What triggers the slow-rise phase? I suspect B cancelation and/or emergence.
- Examination of several more good events needed.
- More broadly:
  - Larger-scale consequences of slow rise phase (e.g., hints for breakout?).
  - Dimmings and remote connections (dittio).
- Need:
  - More good e.g.s (AR or QS).
  - B data.

# An AR Confined (“Failed”) Eruption from SDO

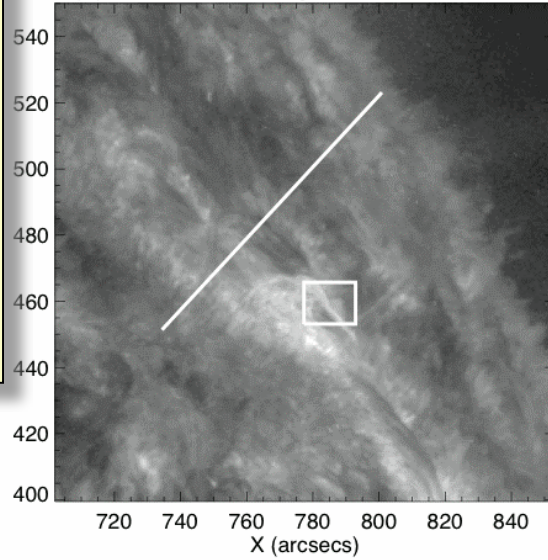
- Active Region Near-limb confined filament eruption of 12 May 2010.
- SDO/AIA, various filters.
- SDO/HMI, selected magnetograms.
- Sterling, Moore, & Freeland (2011).

-preflare  
brightening.

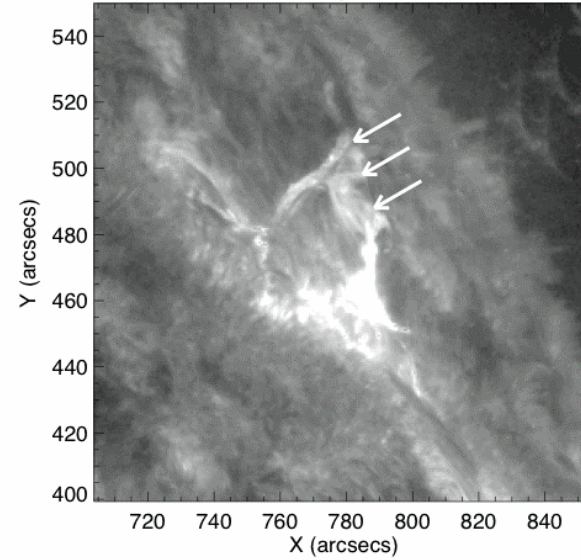
-Enveloping  
loop.

-- B 変更 .

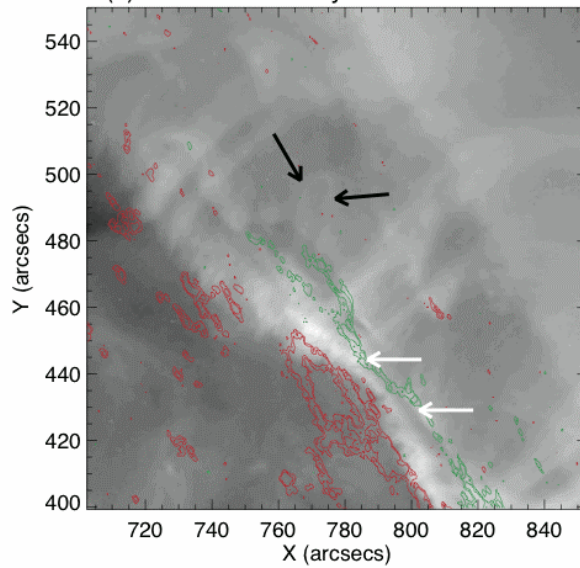
(a) AIA 304: 12-May-2010 01:38:44 UT



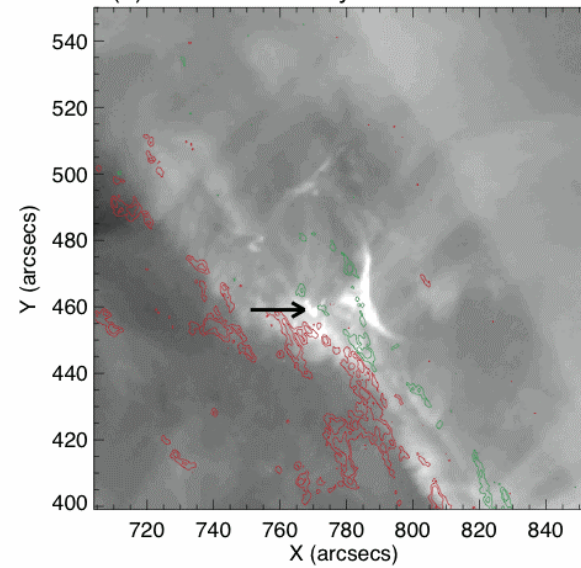
(b) AIA 304: 12-May-2010 02:06:20 UT



(c) AIA 193: 12-May-2010 01:38:48 UT

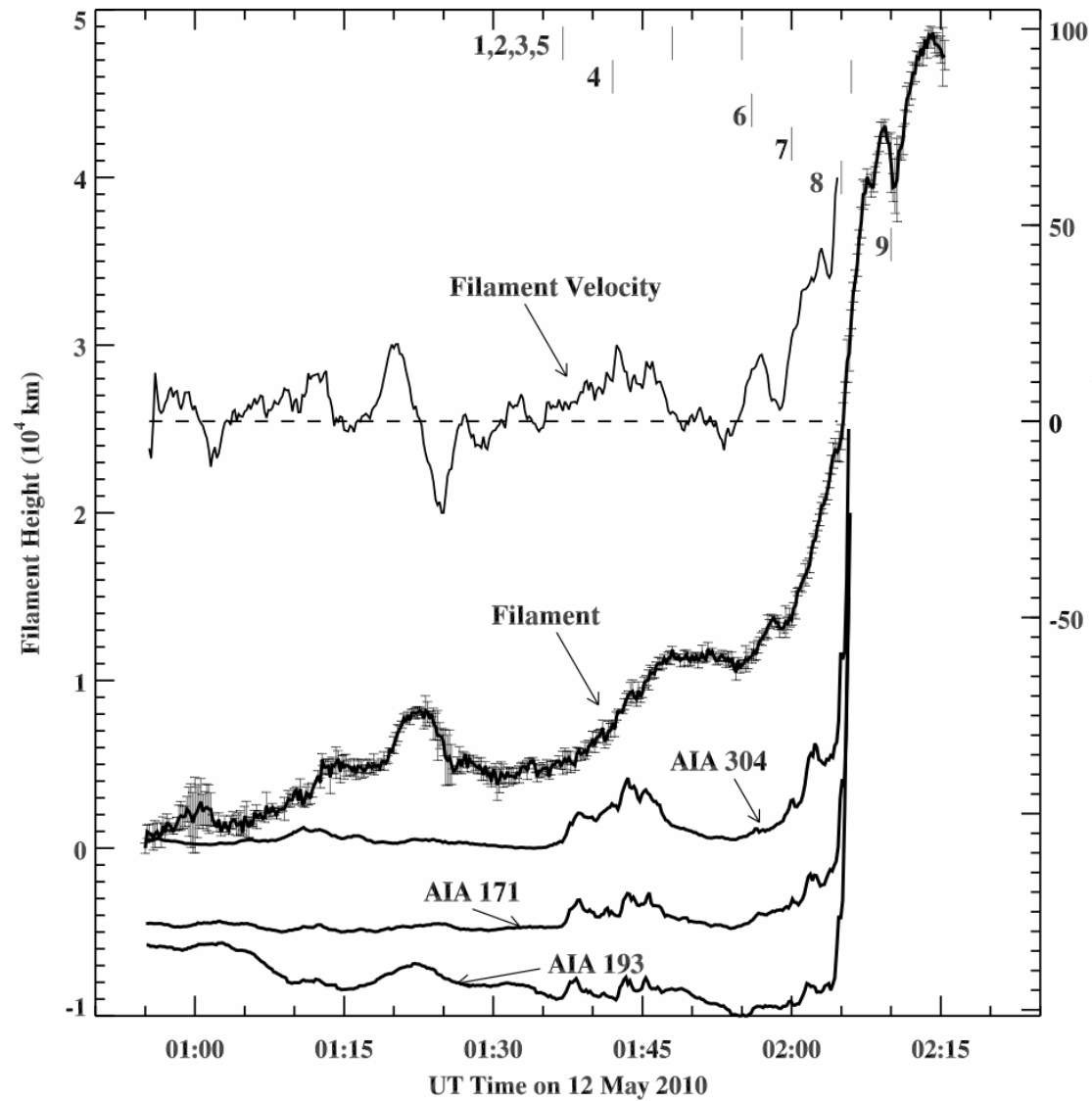


(d) AIA 193: 12-May-2010 02:06:24 UT



A. Sterling, Feb '11  
Filaments Away!

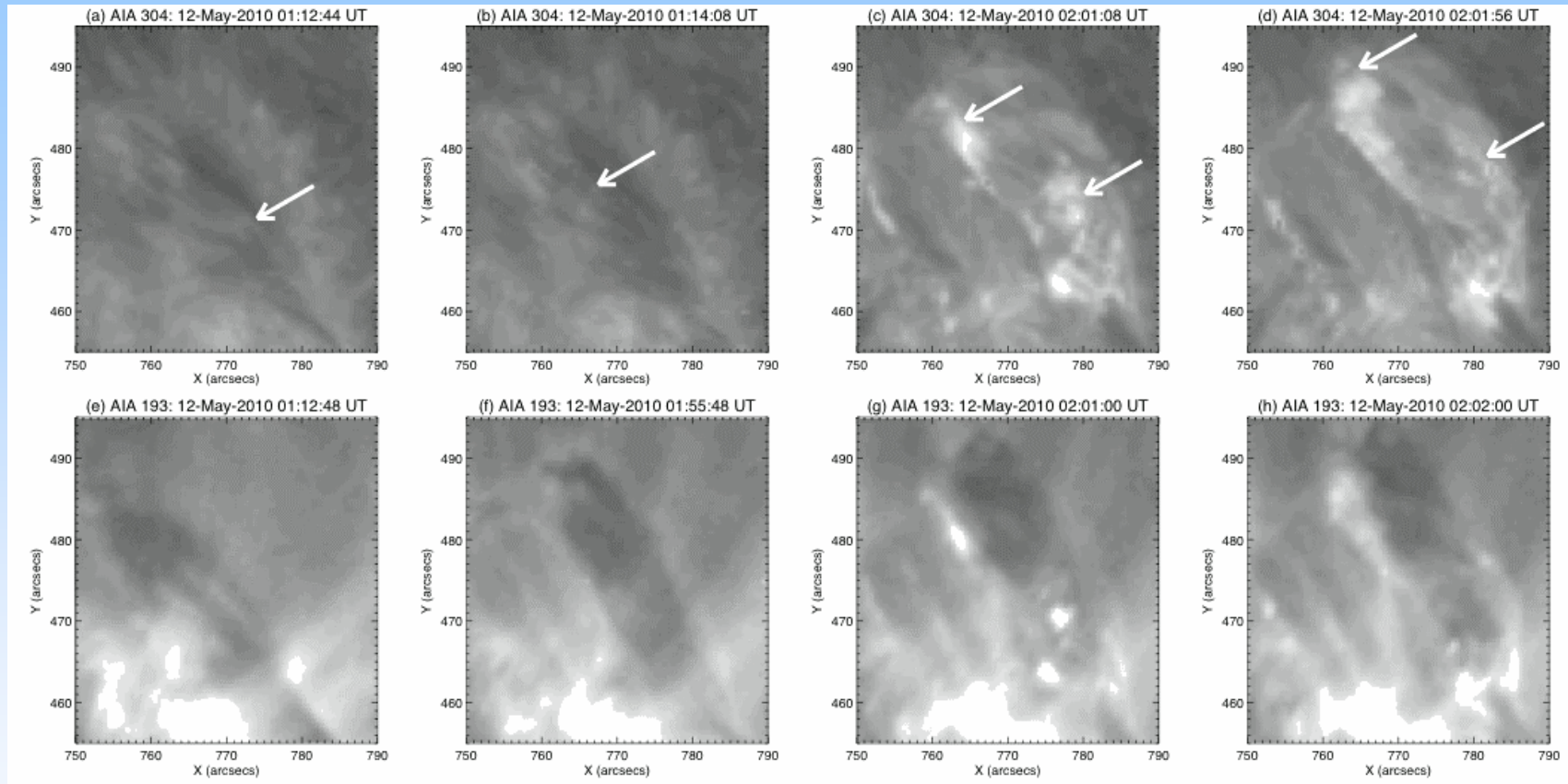
Sterling, Moore, & Freeland (2011)



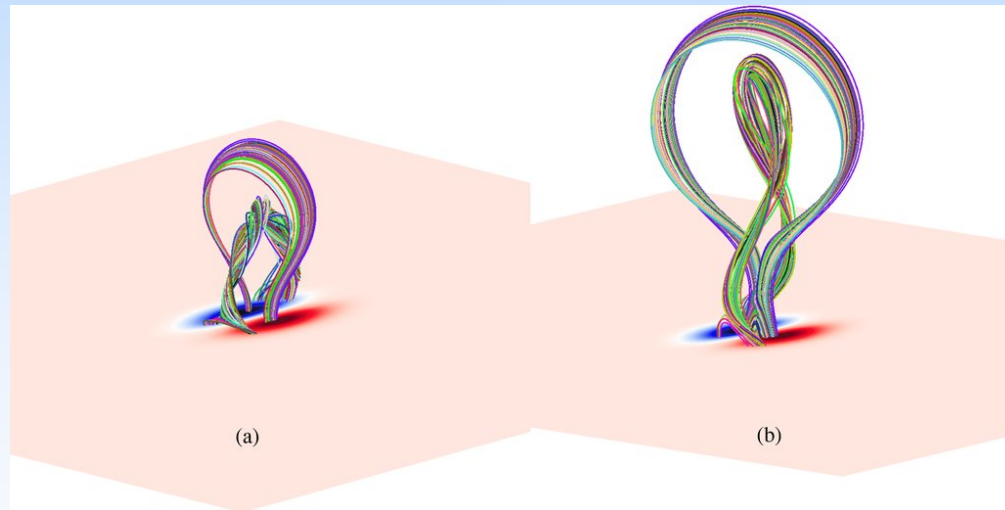
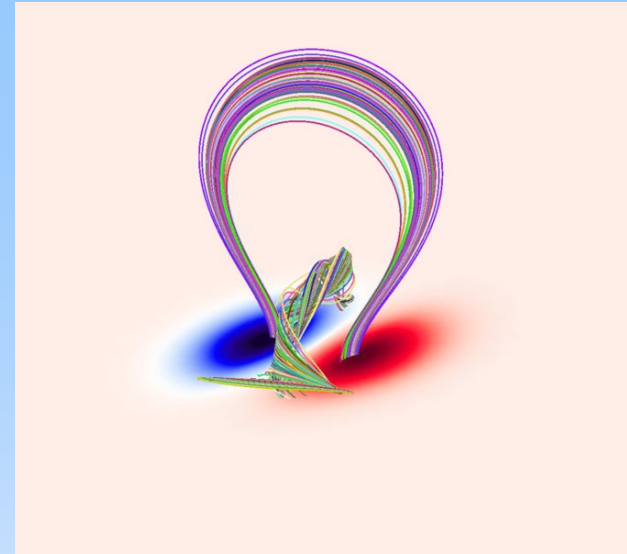
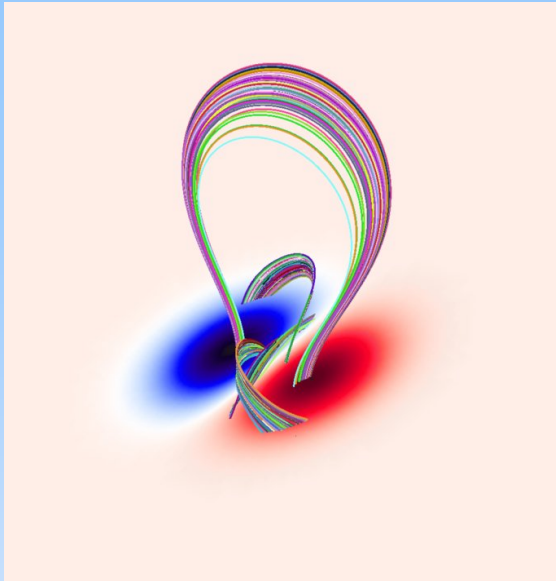
Sterling, Moore, & Freeland (2011)

A. Sterling, Feb '11  
Filaments Away!



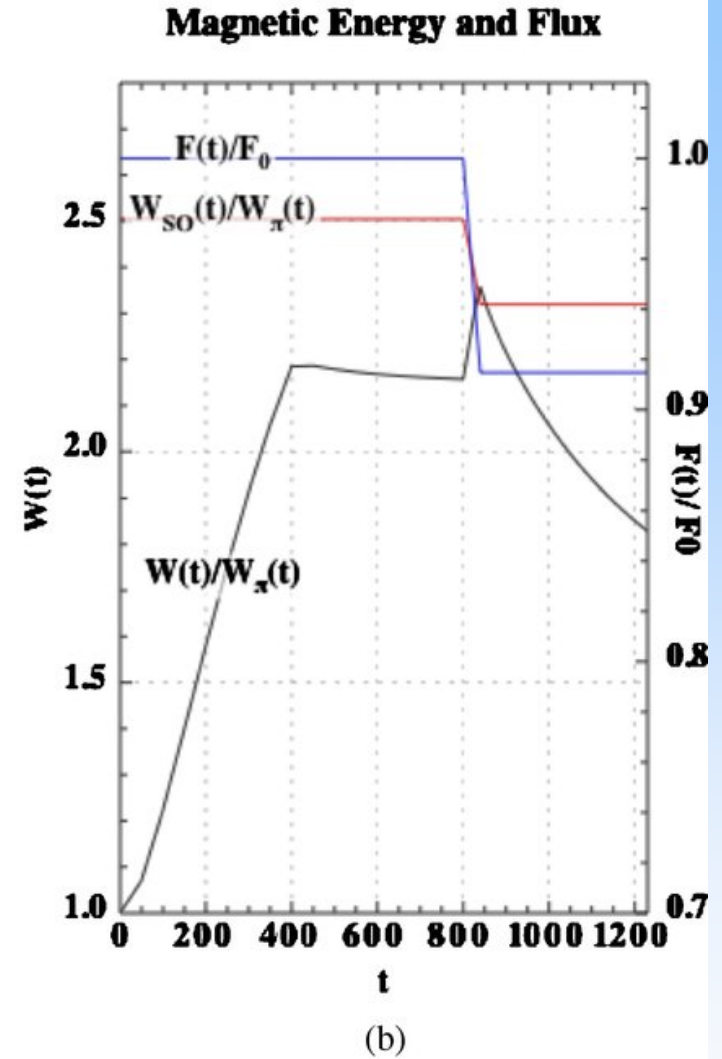
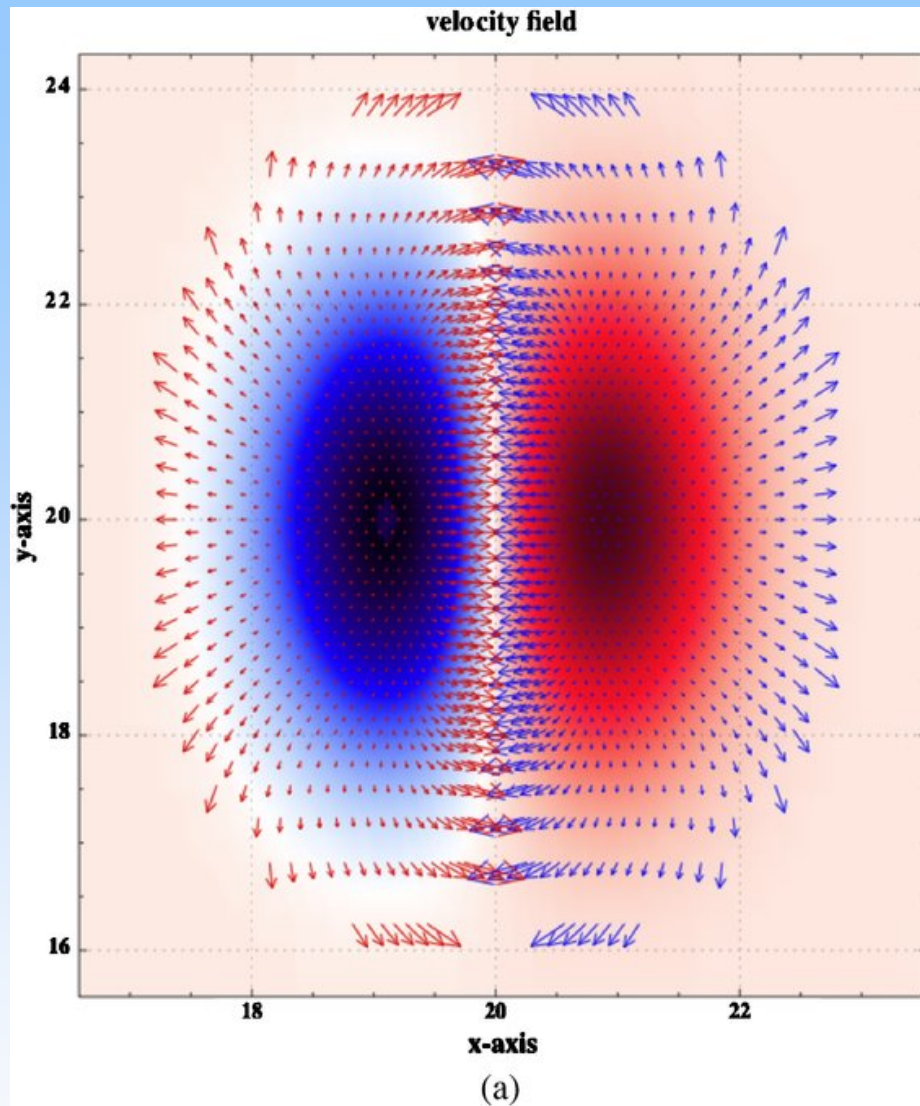


A. Sterling, Feb '11  
 Filaments Away!



## Amari et al. (2010) -- Flux Cancellation

A. Sterling, Feb '11  
Filaments Away!



Amari et al. (2010) -- Flux cancellation

A. Sterling, Feb '11  
Filaments Away!

# Compare Amari et al and our SDO event

- We observe twisting or helical distortion from pre-flare brightening onset, so may have Amari et al.-type cancelation followed by kink instability:
- Amari et al. simulation: time from cancelation onset until eruption:  $\sim 38\tau_A$ .
- SDO event:
  - $L \sim 30,000$  km
  - Guess:  $v_A \sim 300$  km/s  
 $\Rightarrow \tau_A = L/v_A \sim 100$  s;  $38\tau_A \sim 60$  min.
  - Observed time from preflare brightening to eruption  $\sim 20$  min.
- So observations are comparable to simulations.

# Summary

## SDO Event: What We've Seen (Before)

- Converging (or emerging) fields
- Slow (unsteady) rise prior to eruption.
- Flare kicking in when eruption fully underway.
- Preflare brightening, “affecting” filament trajectory.
- Activation (new clues?)
- EUV-brightening “cocoon.”
- Twisting or distorting of filament field. Hints of timing of twist onset.

# Summary

## SDO Event: Some Questions

- Location of preflare brightening vs. TC.
- Potential-field flare?
- Twisting/distortion start with preflare brightening (cancellation/EF reconnection)?
- Looks like this, but is it correct (can it be verified)?:
  - Gradual flux cancelation.
  - Builds flux rope and leads to slow rise.
  - Bursts of aborted runaway reconnection result in slow-rise steps.
  - MHD instability and/or runaway TC --> fast eruption.
  - Collapsing envelope field --> main flare loops.
  - Eruption arrested in this case.

A. Sterling, Feb '11  
Filaments Away!

A. Sterling, Feb '11  
Filaments Away!



A. Sterling, Feb '11  
Filaments Away!