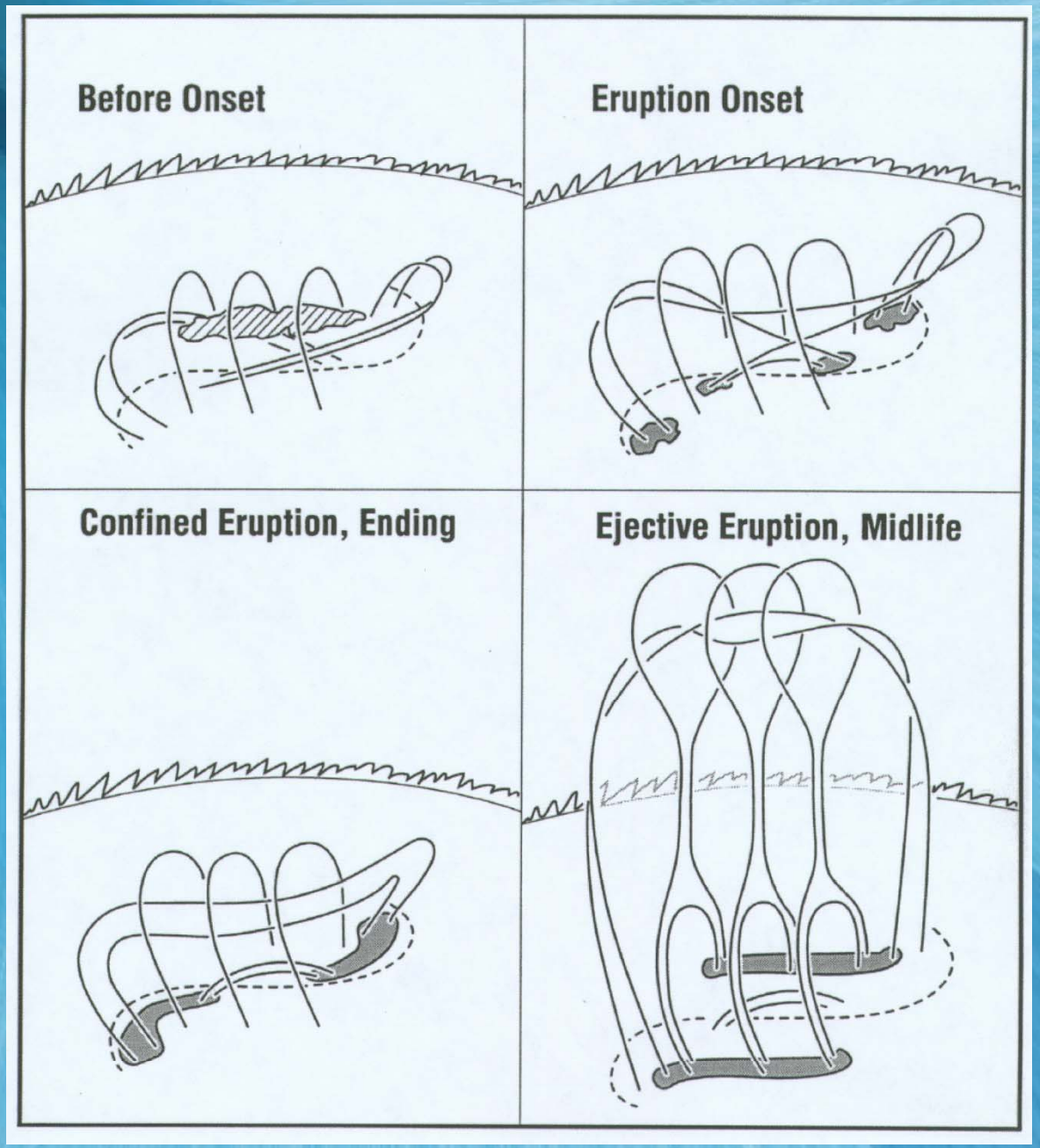
Filament Eruption Onset

Alphonse C. Sterling, NASA/MSFC, JAXA/ISAS
Ronald L. Moore, NASA/MSFC
et al.

(Moore et al. 2001)



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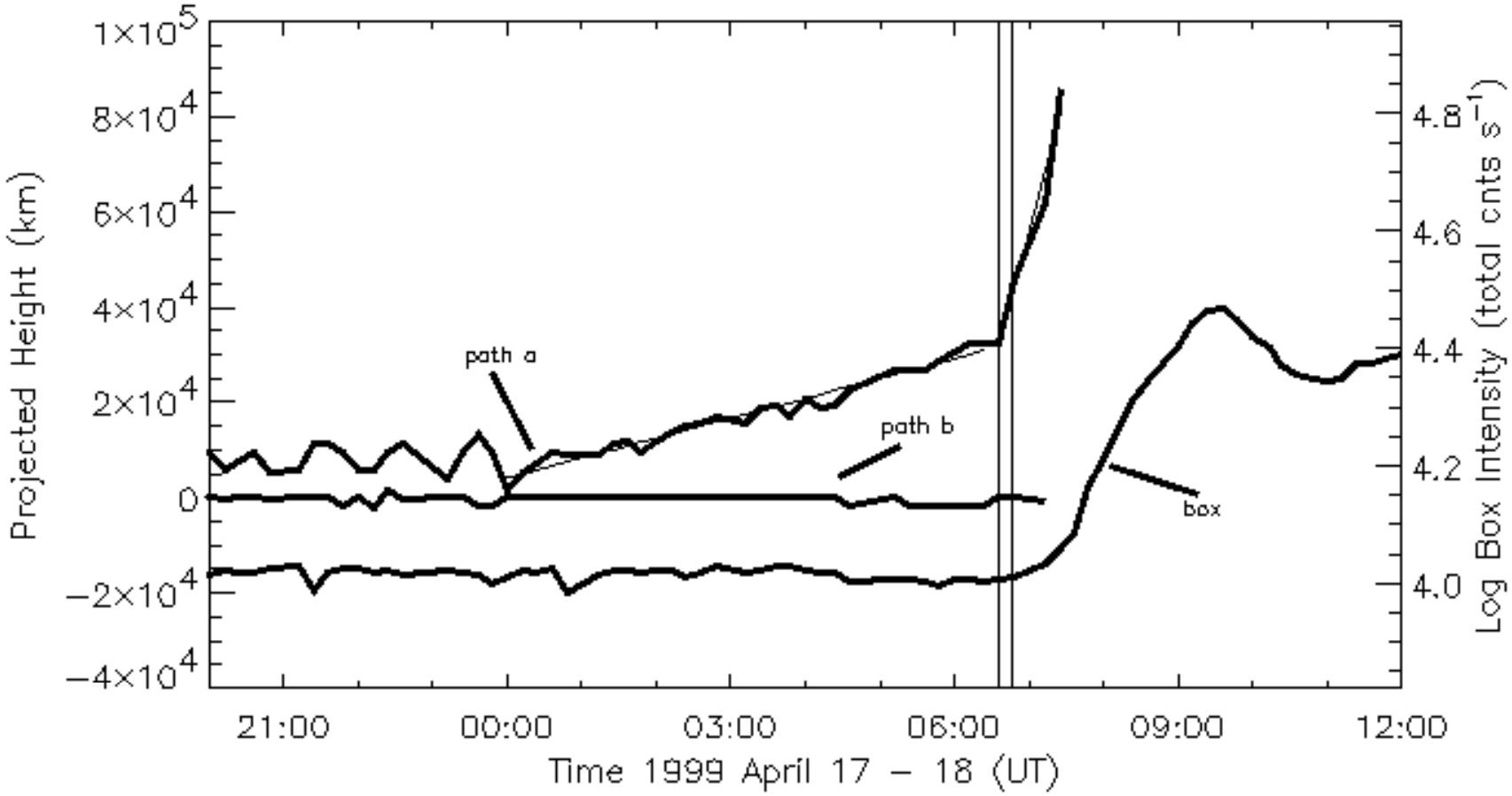

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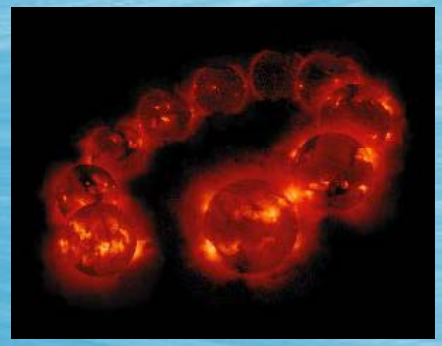
Introduction



- We have been investigating filament eruptions in recent years (Sterling, Moore, et al.).
- Use *filament eruptions* as markers of the coronal field evolution.
- Data from SoHO, Yohkoh, TRACE, Hinode, and other sources.
- We and others have observed:
  - Filaments often show slow rise, followed by fast rise (e.g.,Roy et al. 1975, Martin 1980, Tandberg-Hannen et al. 1980; Kahler et al. 1988; Nagashima et al. 2007; Isobe et al. 2007; Cheng et al 2010, Xu et al. 2010, Joshi & Srivastava 2011; Sterling, Moore, et al.)
  - Brightenings, preflares, microflares (many workers); during slow rise (Sterling, Moore, et al.)
  - Magnetic evolution in hours prior to eruption onset (e.g., Martin et al. 1985 van Ballegooijen & Martens 1989, Wang & Shi 1993, Moore et al. 2001.)

- What do Hinode and SDO show for filament eruptions?

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An AR-event example from Hinode

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

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TRACE

QuickTime™ and a
YUV420 codec decompressor
are needed to see this picture.

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TRACE on MDI

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Hinode XRT

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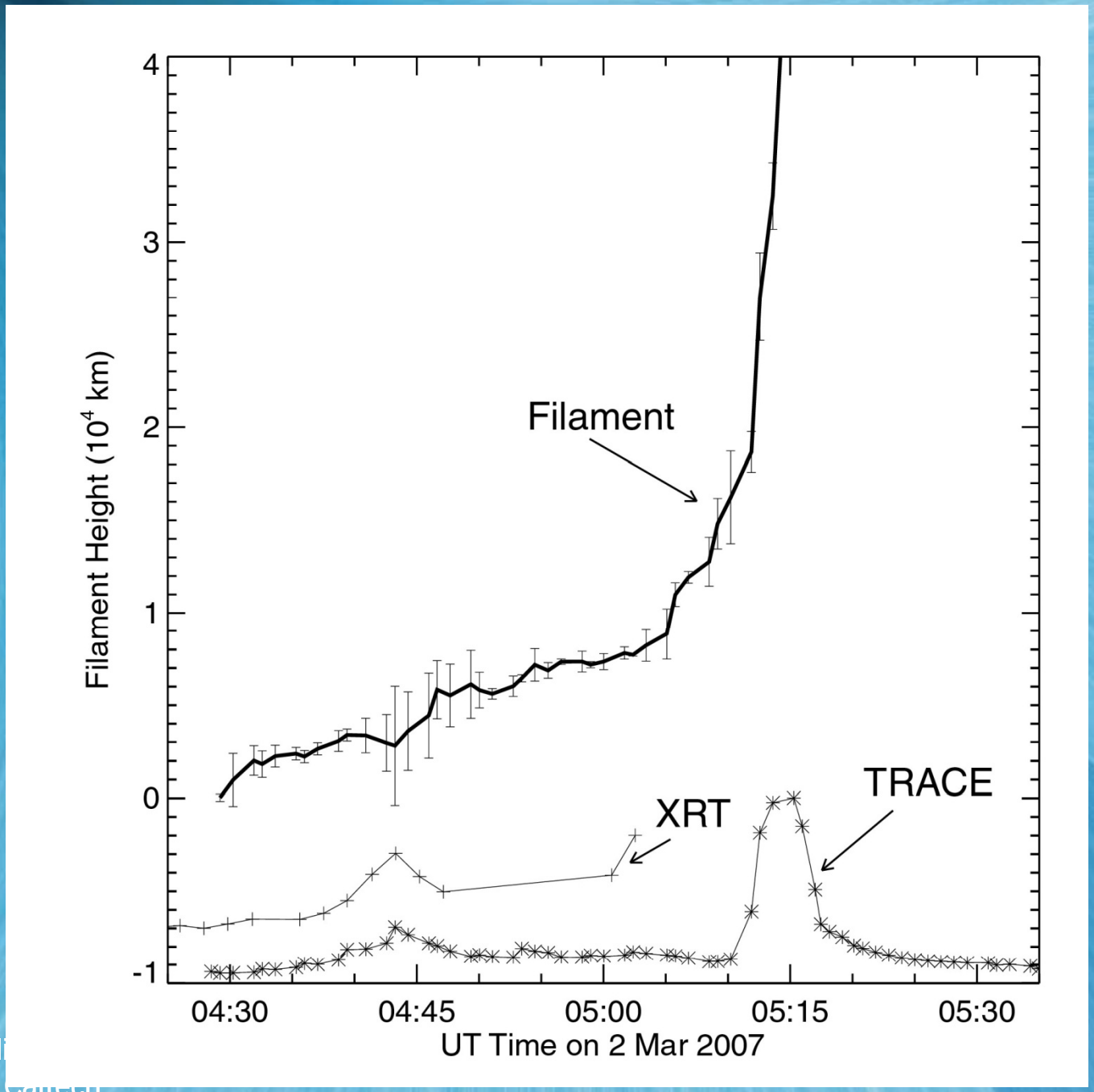

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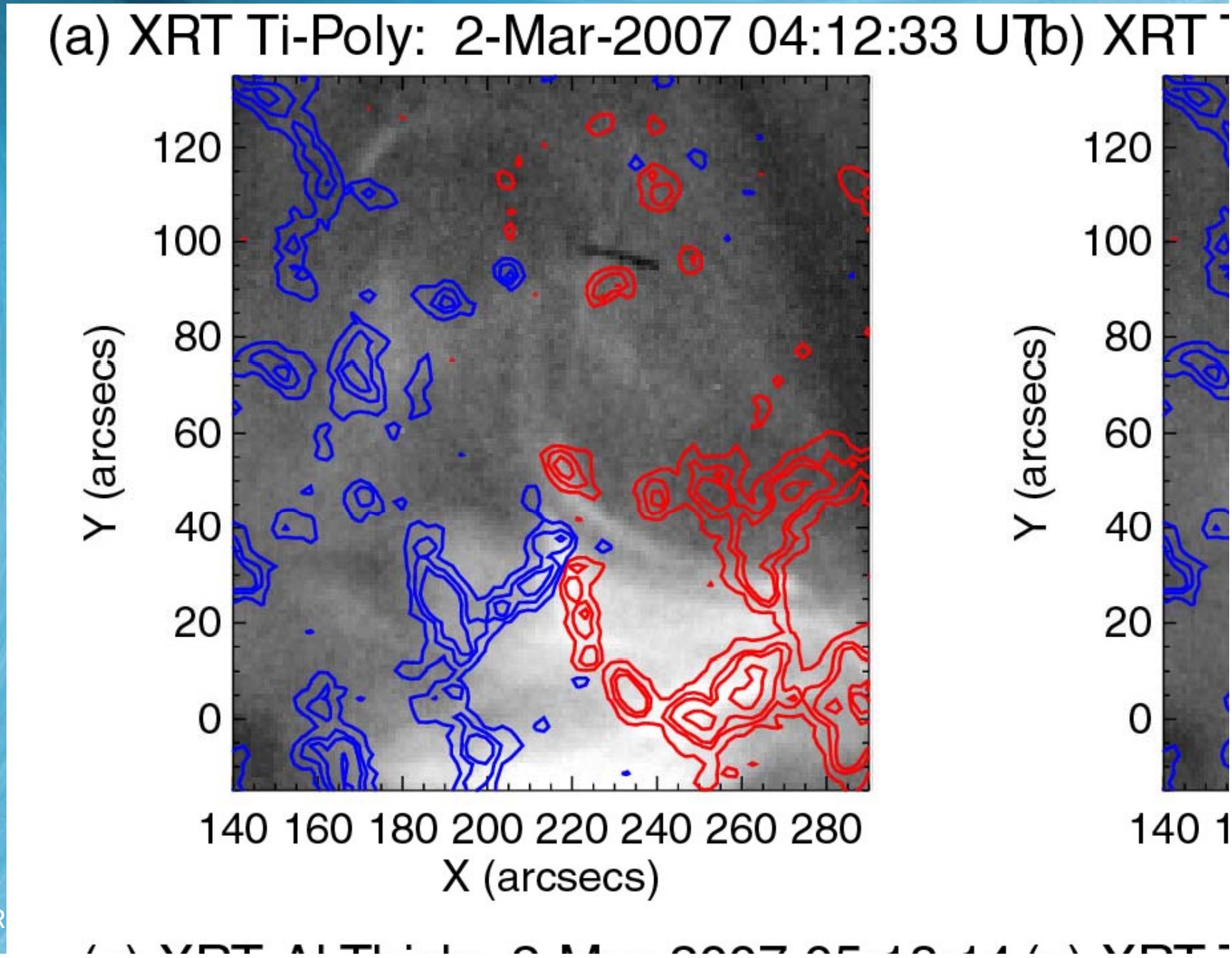
XRT on MDI



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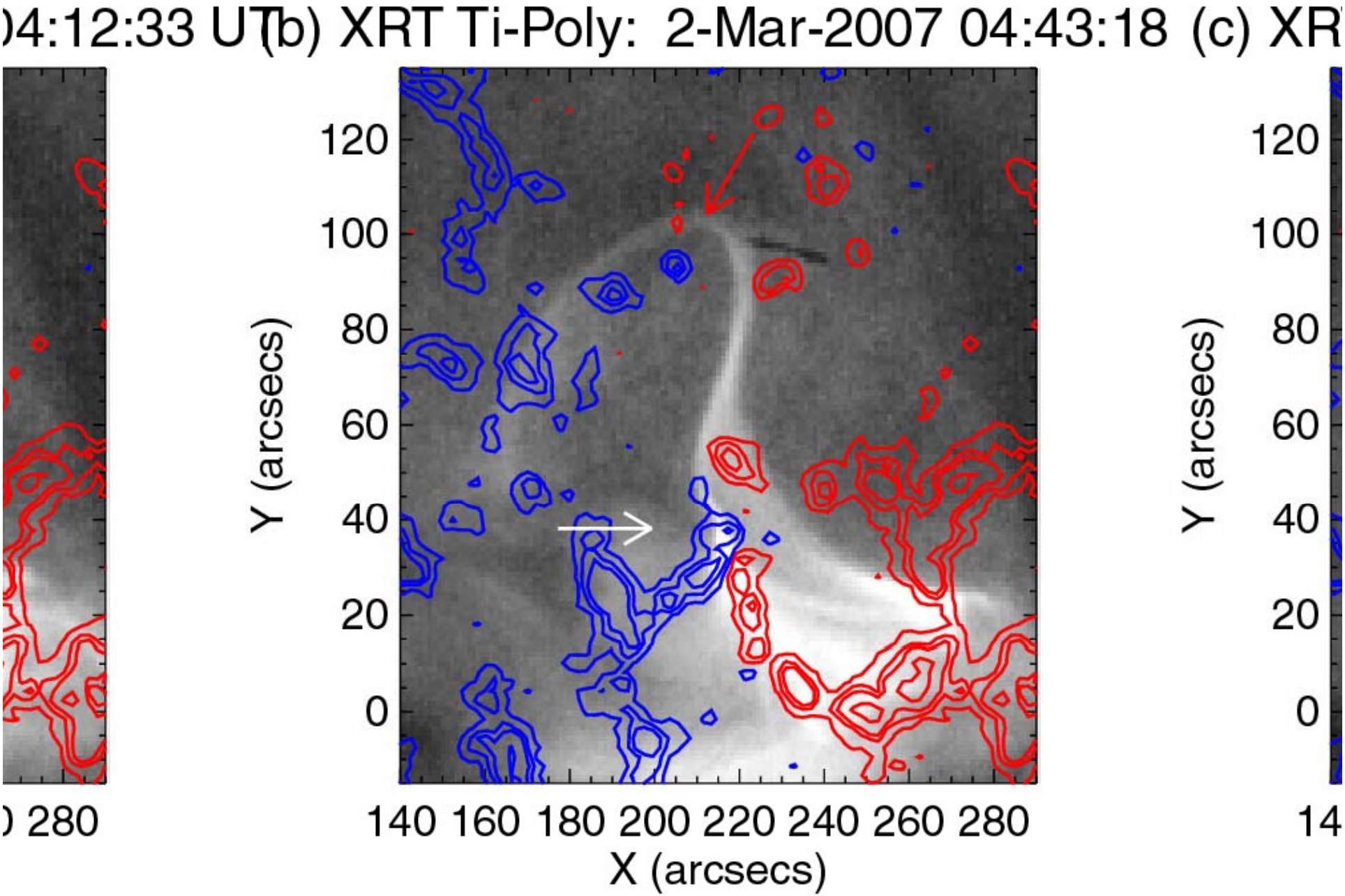
XRT on MDI


04:12:33 UT
(b) XRT Ti-Poly: 2-Mar-2007 04:43:18
(c) XR
120
100
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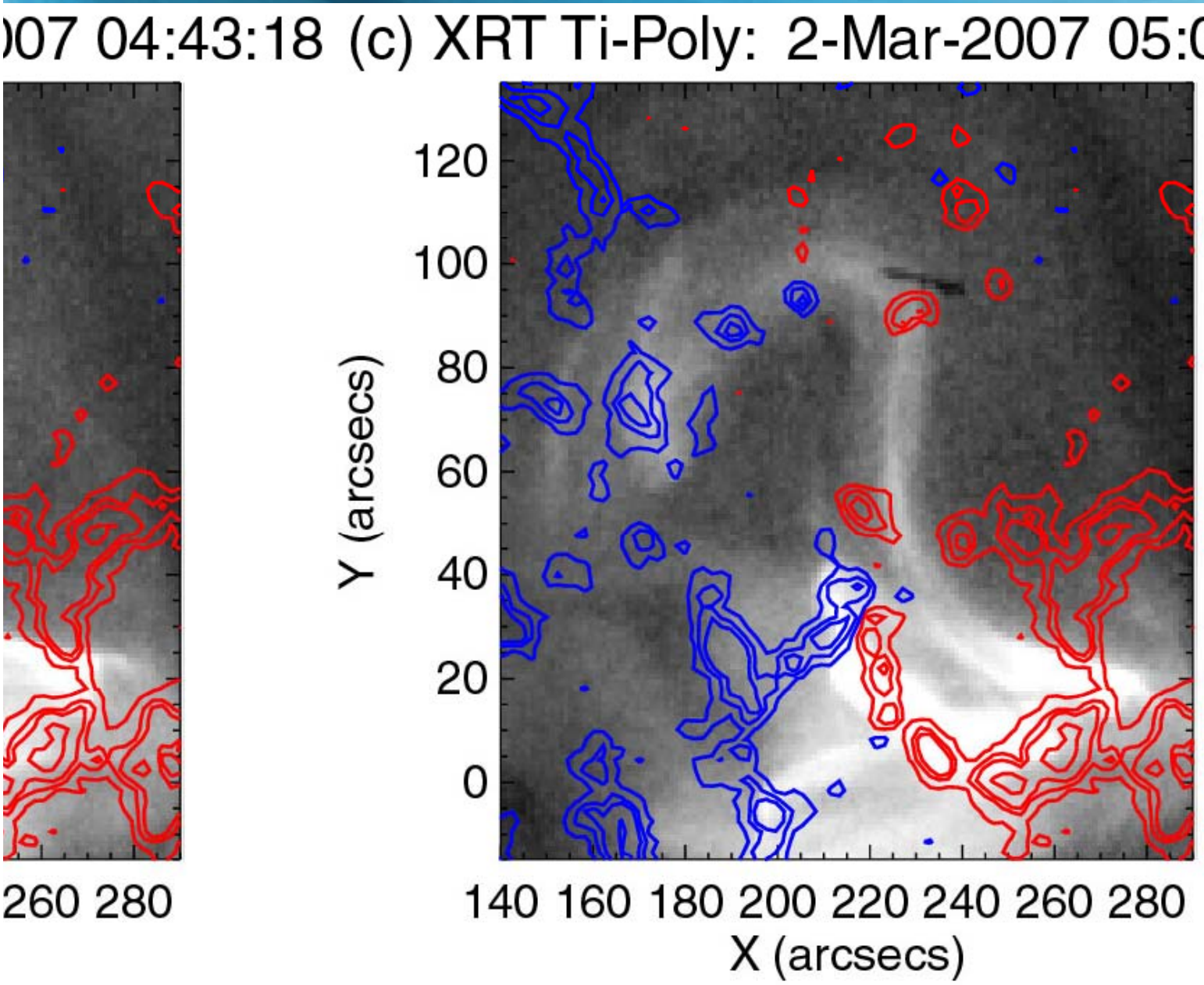
Y (arcsecs)
0 280
140 160 180 200 220 240 260 280
14
X (arcsecs)

XRT on MDI


)07 04:43:18 (c) XRT Ti-Poly: 2-Mar-2007 05:02:
120
100
80
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40
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0
Y (arcsecs)
260 280
140 160 180 200 220 240 260 280
X (arcsecs)

SOT FG V magnetogram

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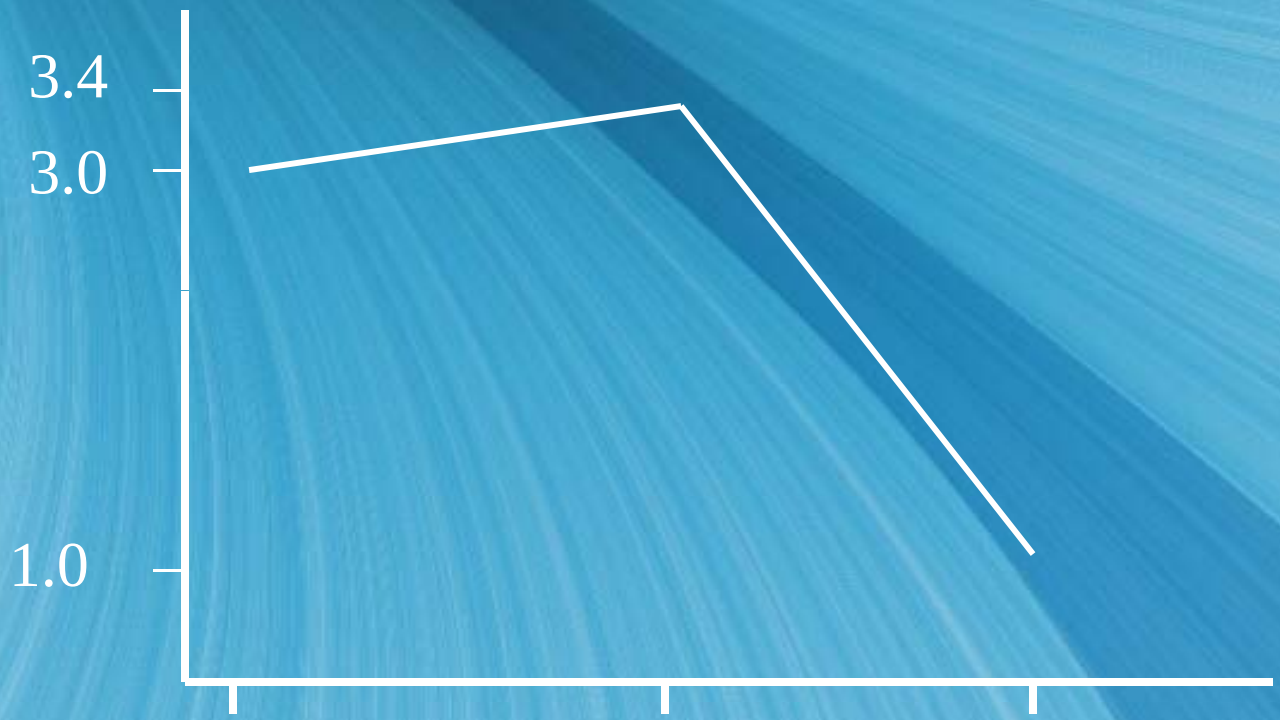

(Cf. flux of whole region: ~ 10^{21} Mx)

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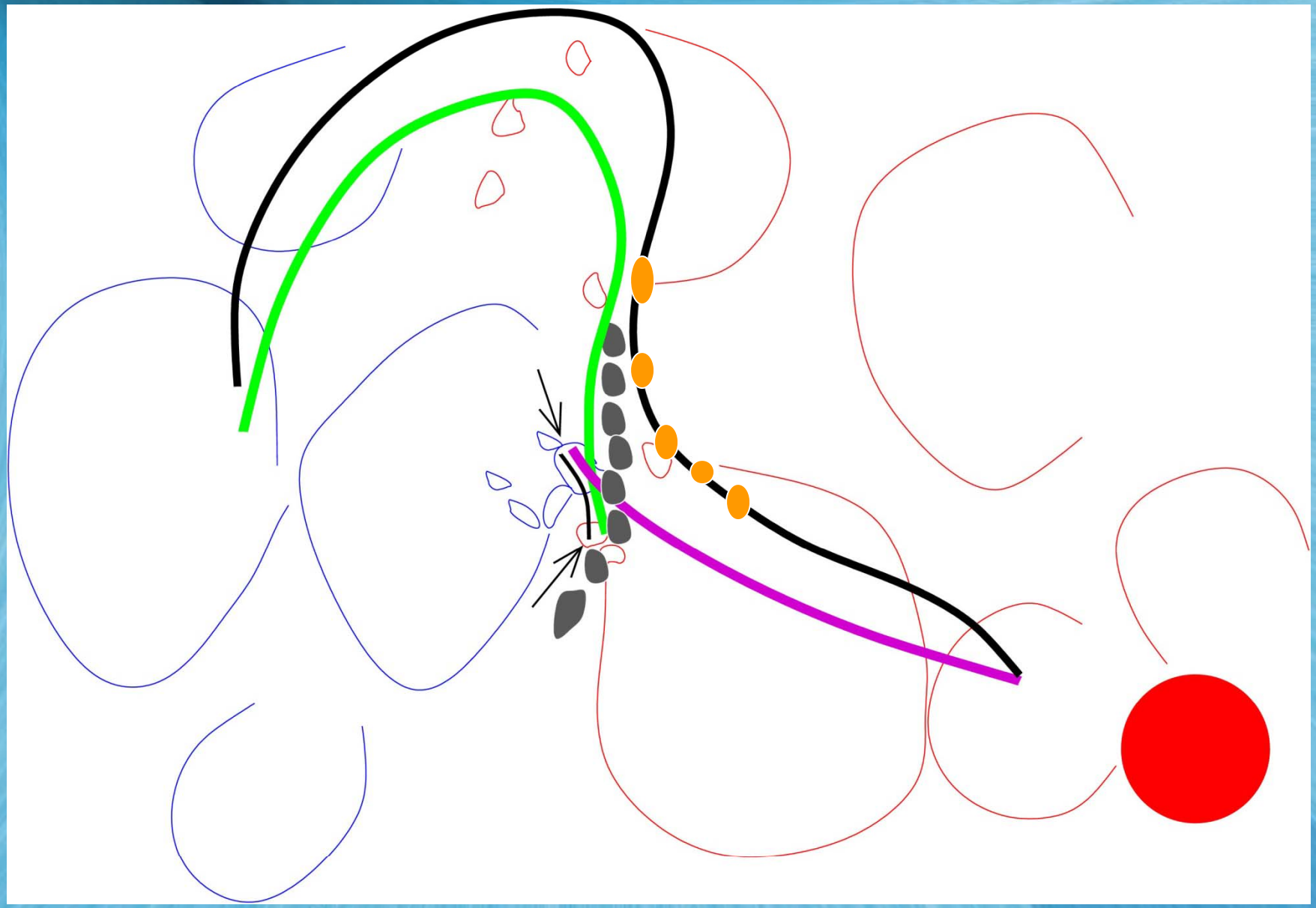

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Conclusions from this Hinode Event

- 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).
- During pre-eruption period, $\Delta\Phi \sim 10^{19}$ Mx
  = ~ 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.
- SXR sigmoid formation. (E.g., Rust, Kumar; Pevtsov; Mckinzie, Canfield; Gibson, Fan, et al.; Green et al.; Sterling, Hudson, Moore.)
- 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.)

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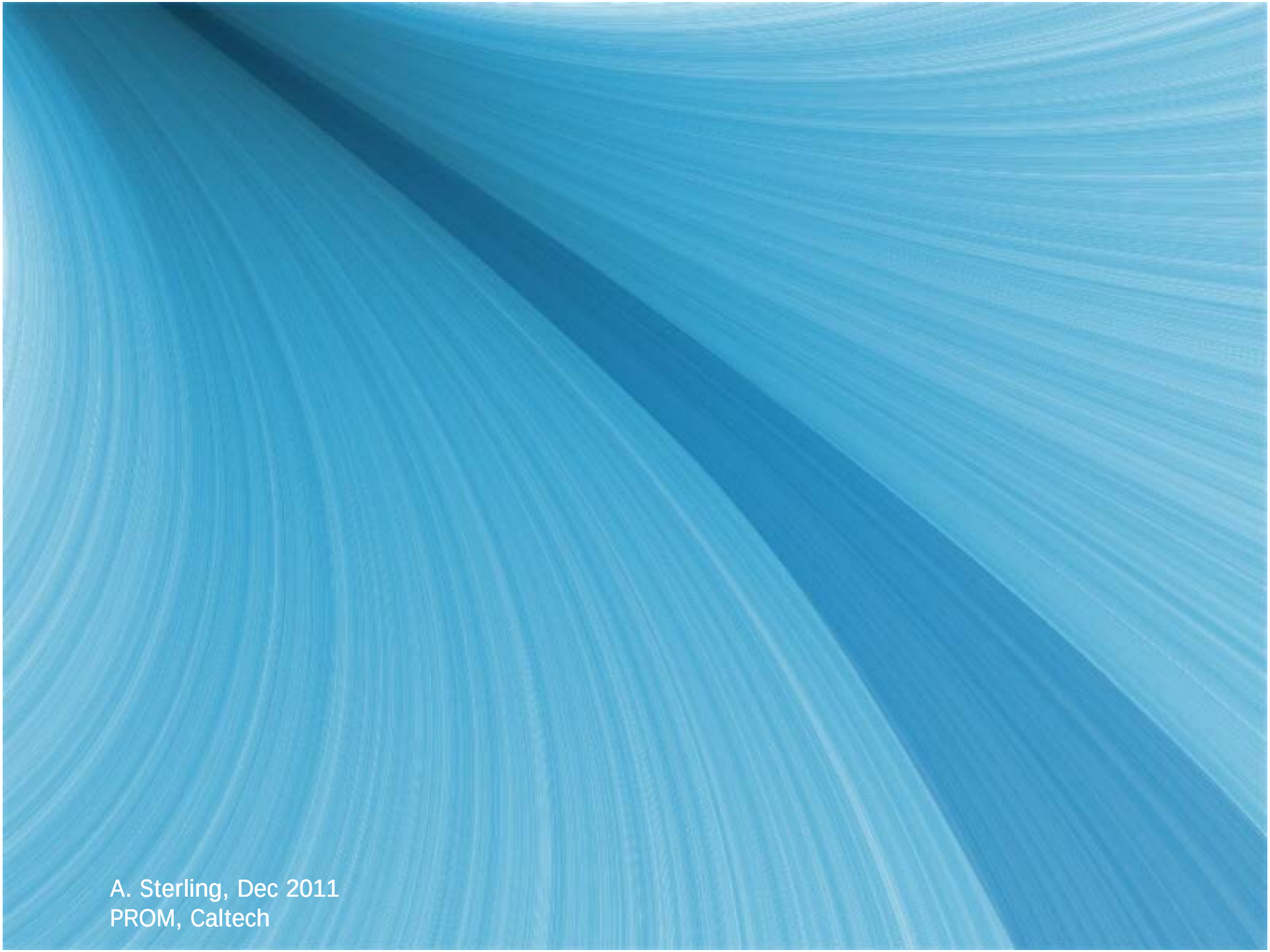

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An AR Confined ("Failed") Eruption from SDO

- Active region, near-limb filament eruption of 12 May 2010.
- Confined eruption; no CME detected.
- GOES class B1.5 flare.
- SDO/AIA, various filters (94, 131, 171, 193, 211, 304, 335 Ang.)
- High time cadence (12 s) and high spatial resolution (0".6 pixels).
- SDO/HMI, selected-time, line-of-sight magnetograms.
- Sterling, Moore, & Freeland (2011).

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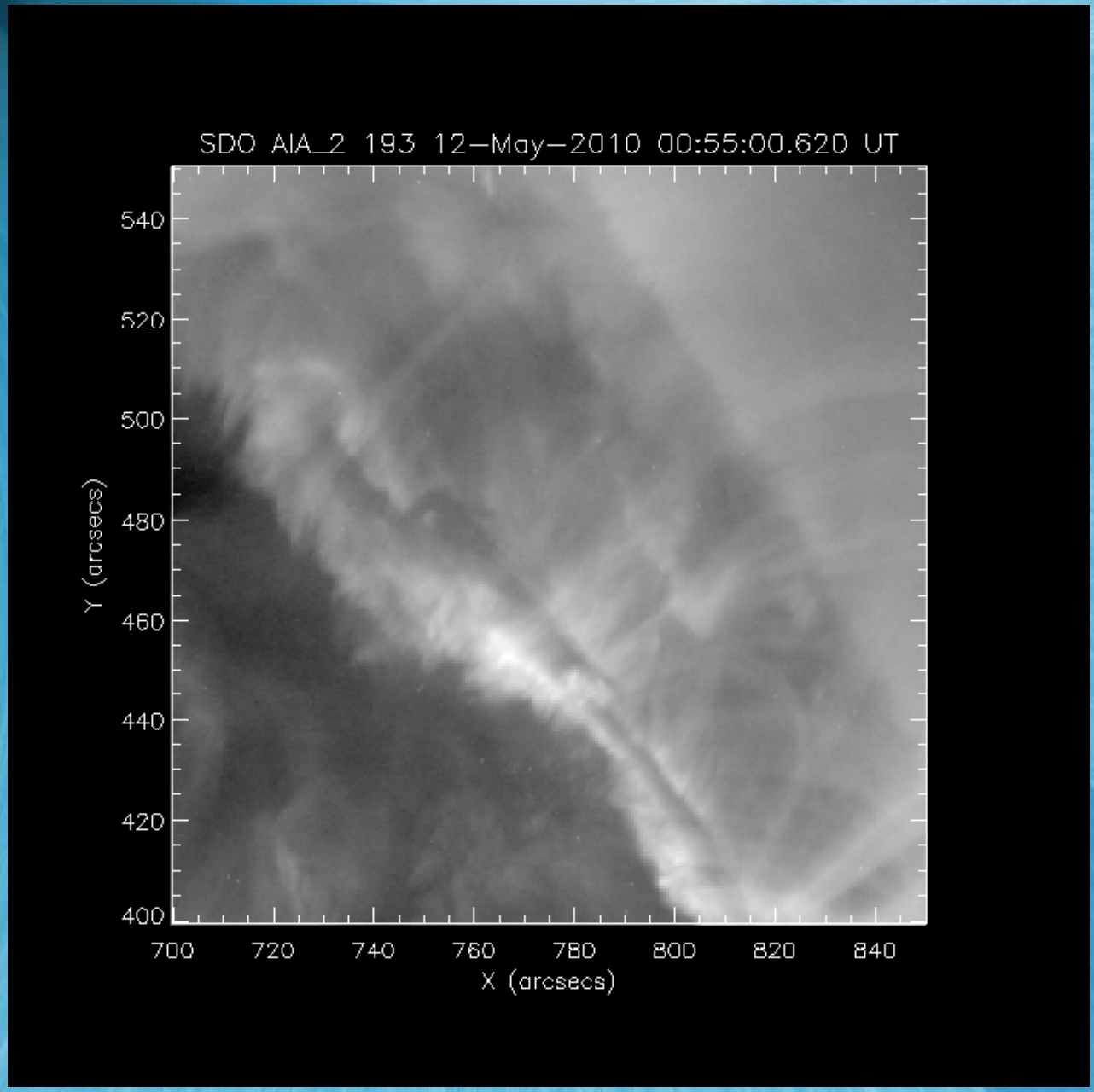

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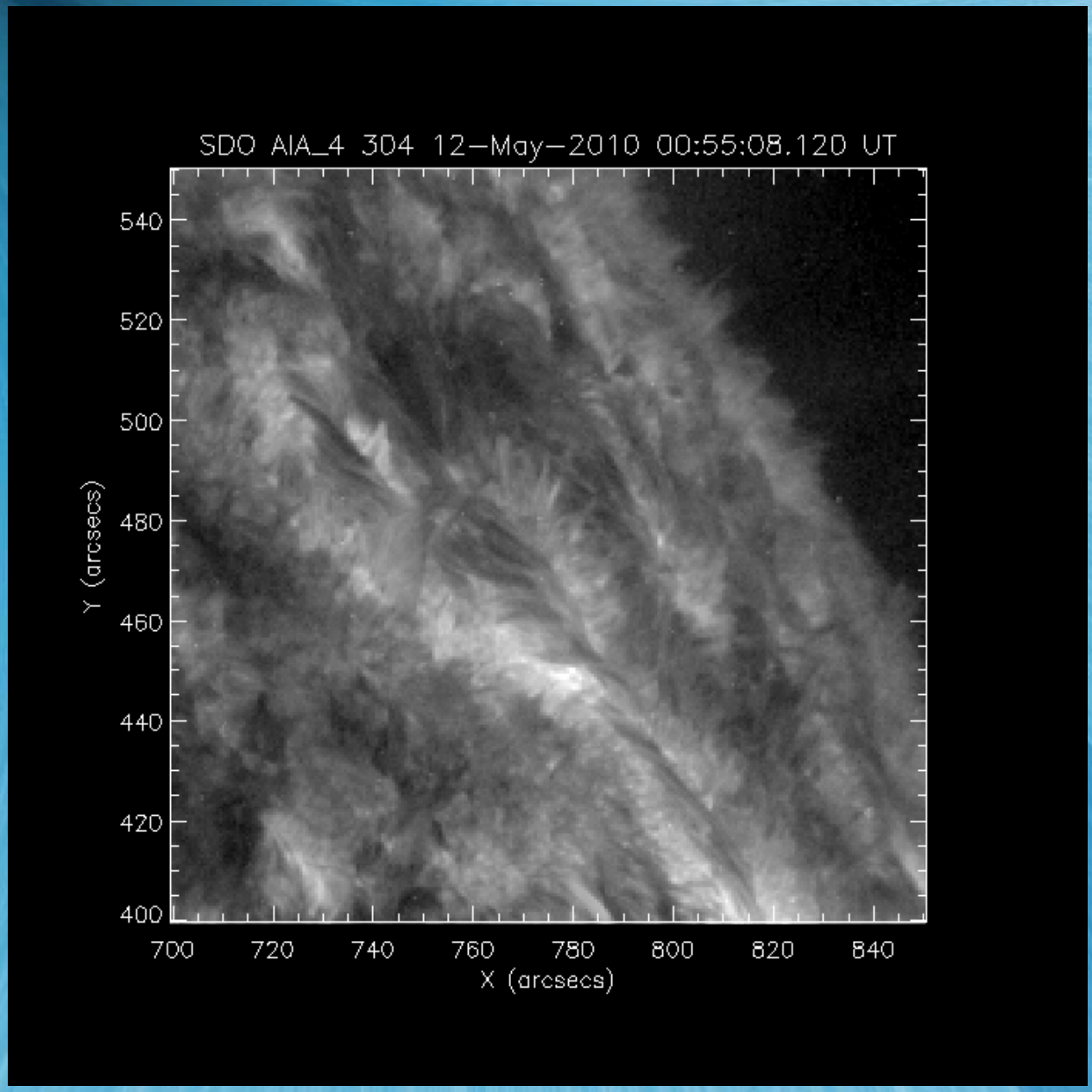

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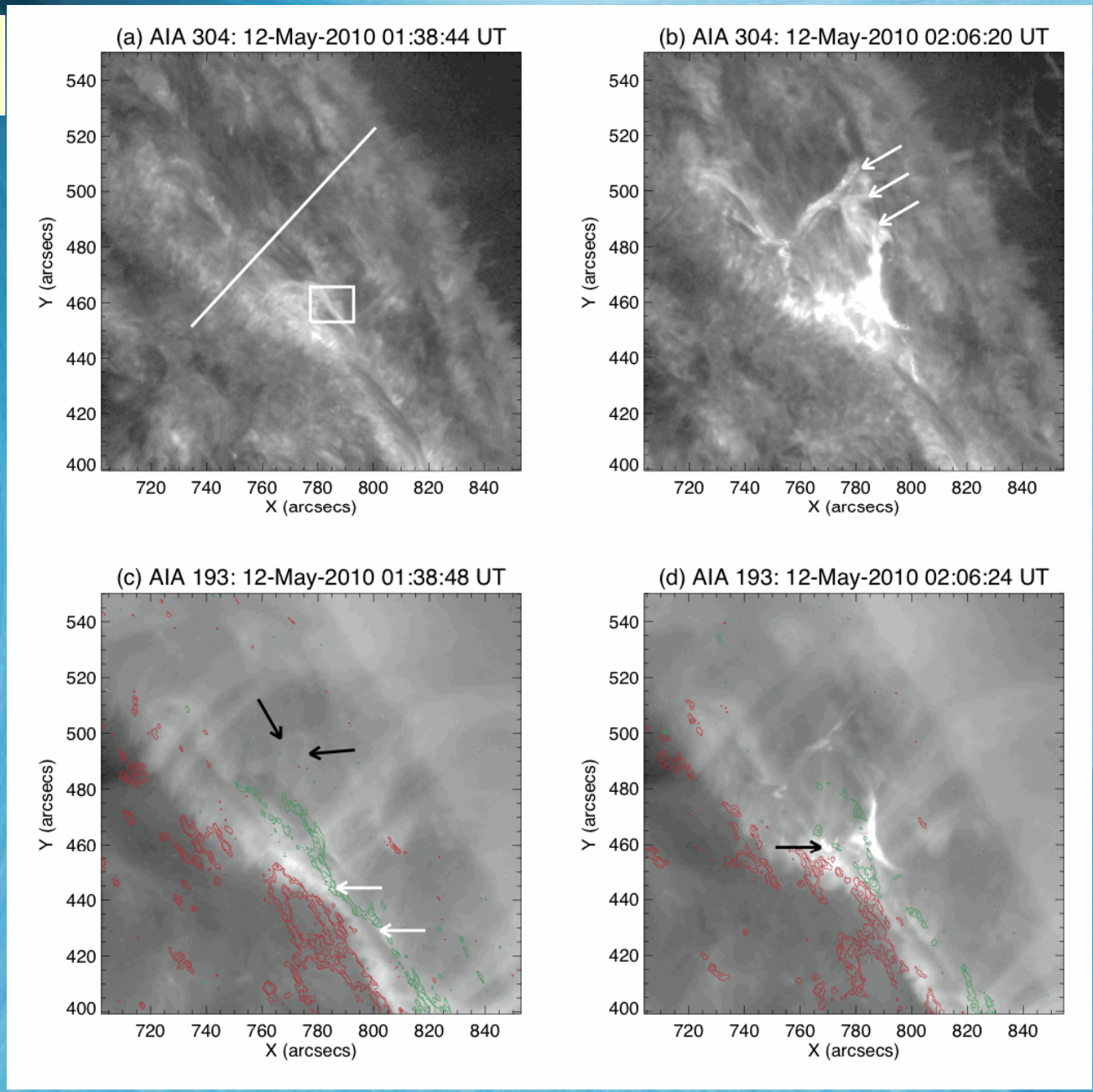
-**Preflare & TC.**

-B cancelation.



A. Sterling, Dec 2011 Sterling, Moore, & Freeland (2011)
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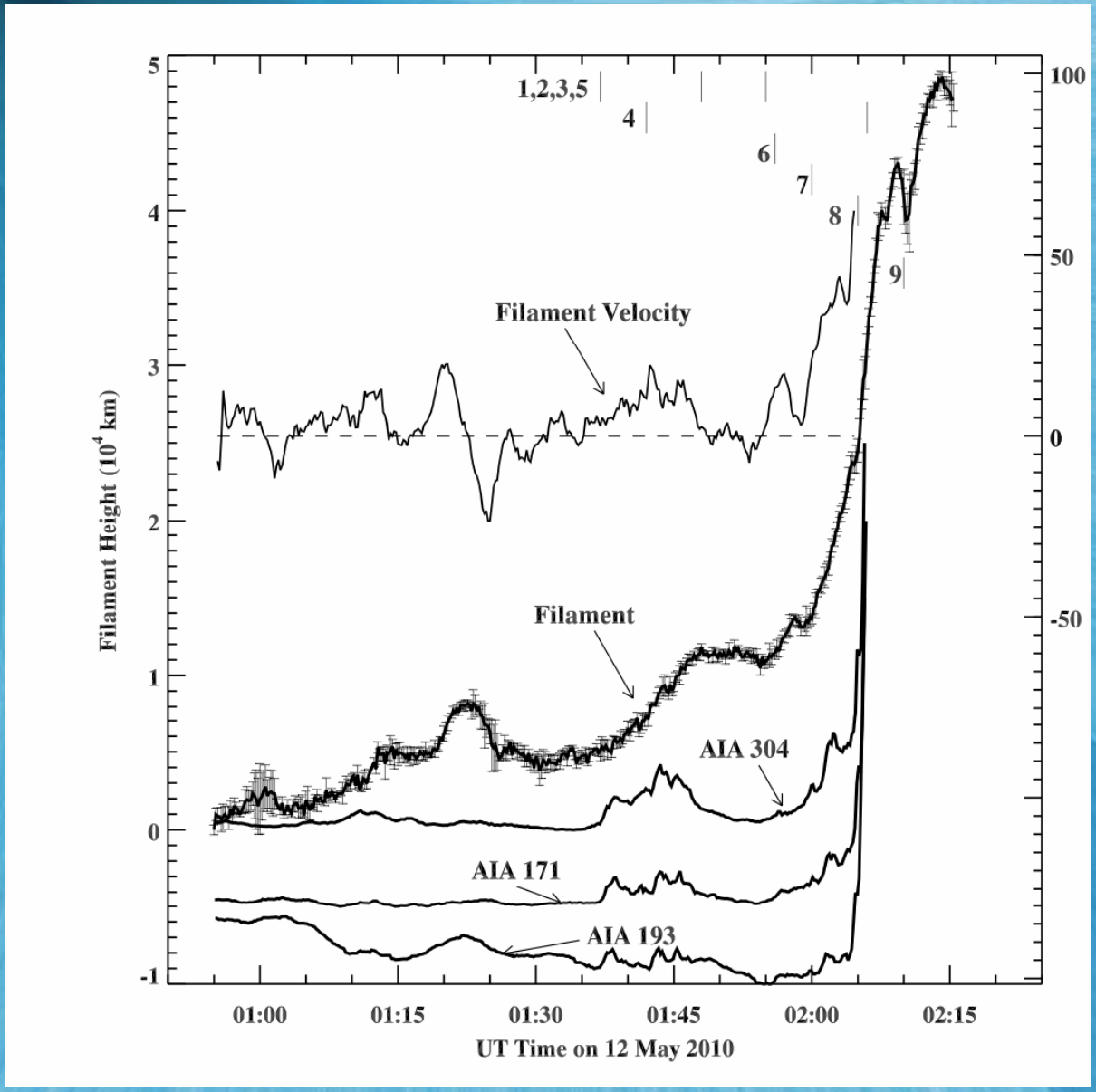

Sterling, Moore, & Freeland (2011)

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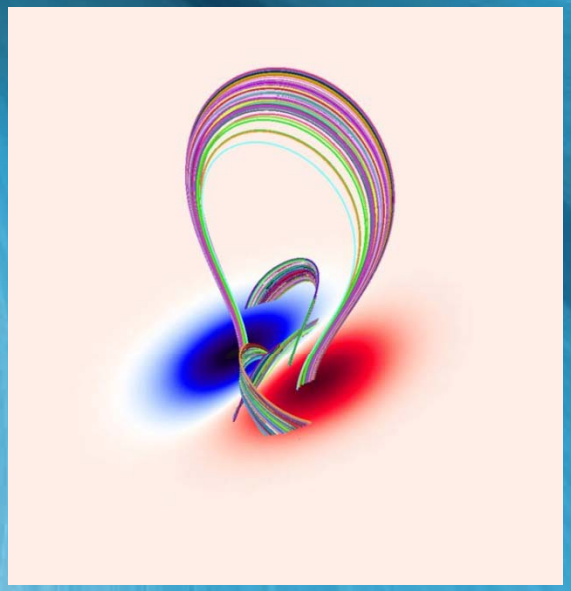

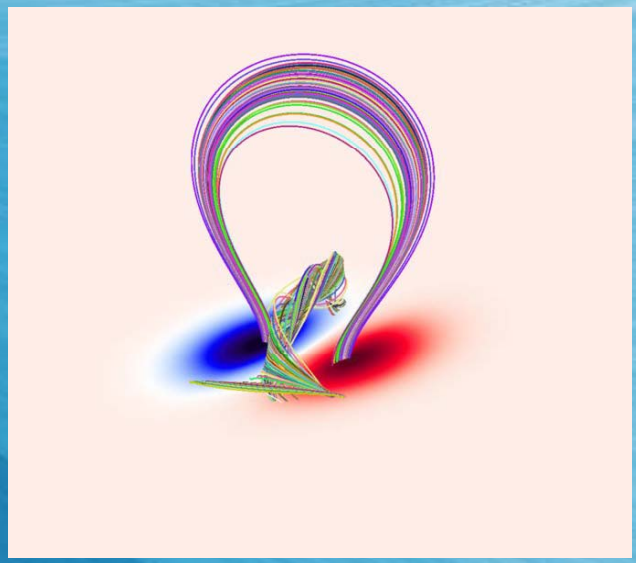

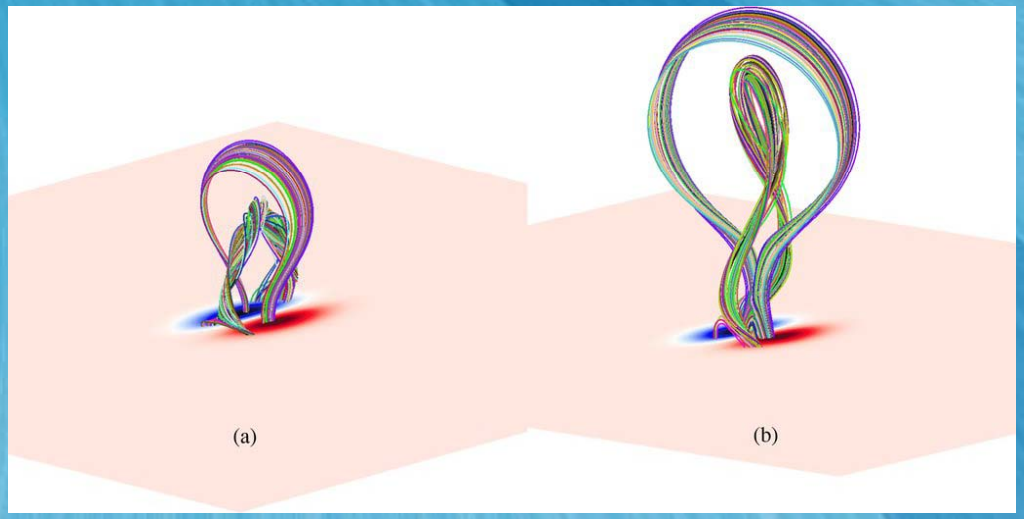

Amari et al. (2010) -- Flux Cancelation

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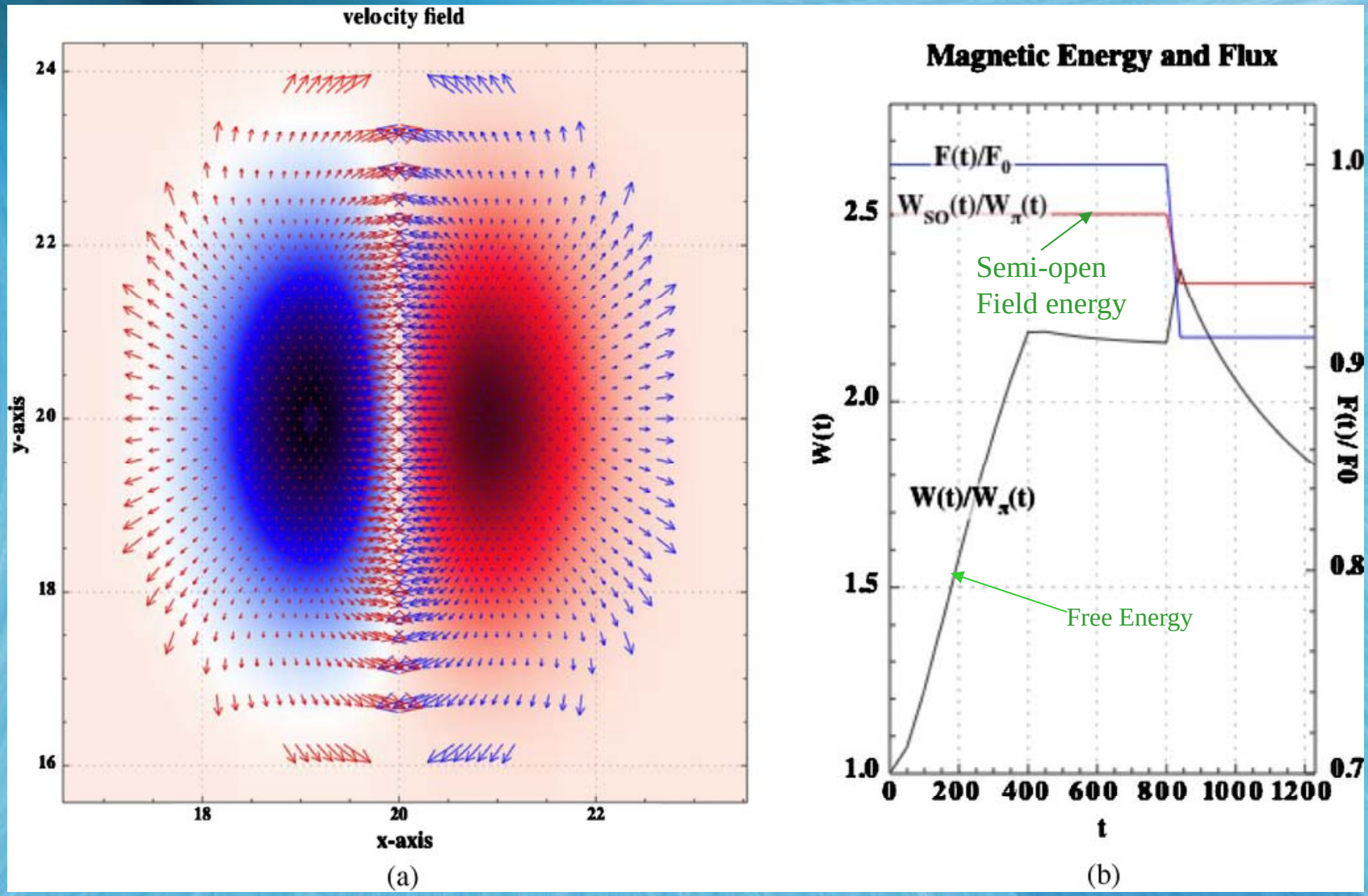

Amari et al. (2010) -- Flux cancelation

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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 (cf., Torok & Kliem 2005, Williams et al. 2005, Fan & Gibson 2007).
- Amari et al. simulation: time from cancelation onset until eruption: ~ $38\tau_A$.
- SDO event:
  - L ~ 30,000 km
  - Guess: v_A ~ 300 km/s
    => $\tau_A = L/v_A$ ~ 100 s; $38\tau_A$ ~ 60 min.
  - Observed time from preflare brighteing to eruption ~ 20 min.
- So observations are comparable to simulations.

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Summary

- Location of preflare brightening vs. tether cutting.
- Potential-field flare?
- Twisting/distortion start with preflare brightening (cancelation/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.
  - EUV “cocoon.”
  - Collapsing envelope field --> main flare loops.
  - Eruption arrested in this case.

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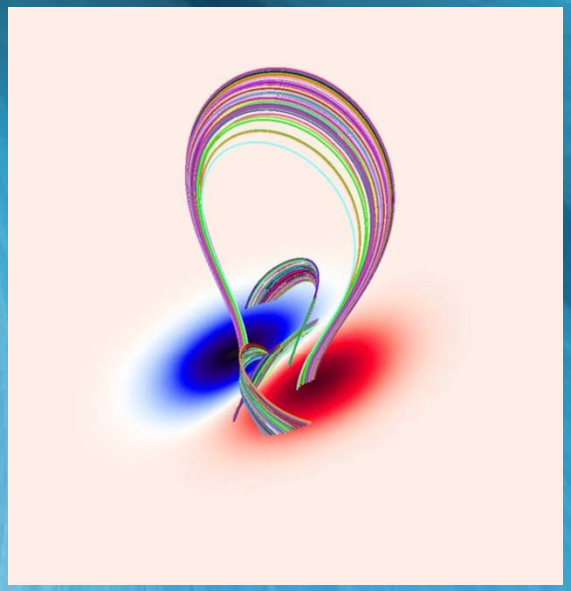

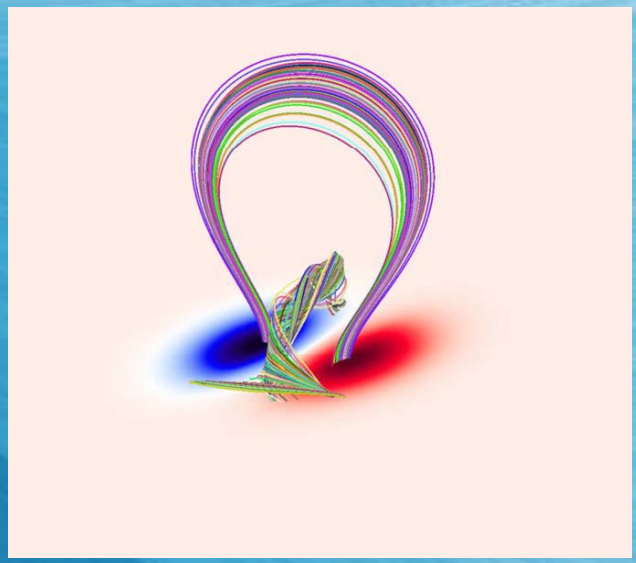

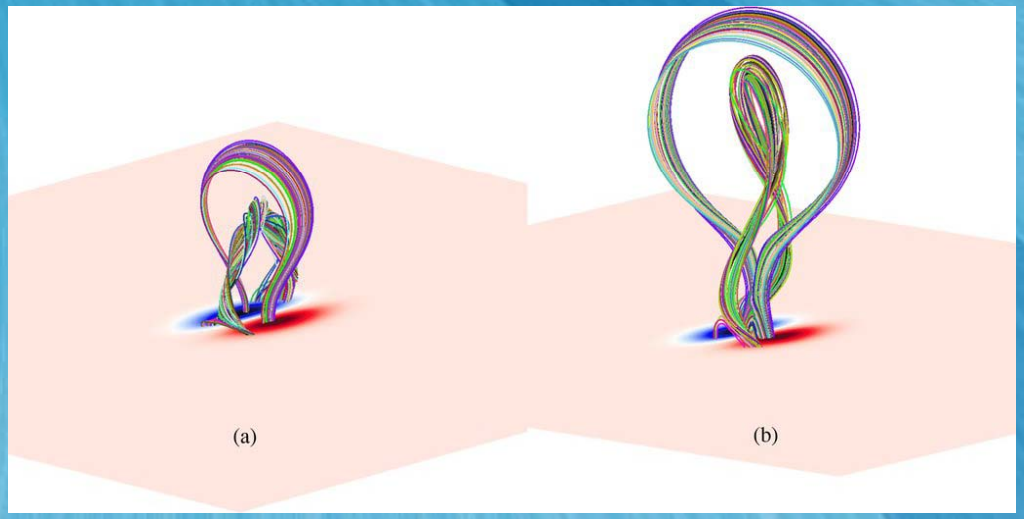

Amari et al. (2010) -- Flux Cancelation

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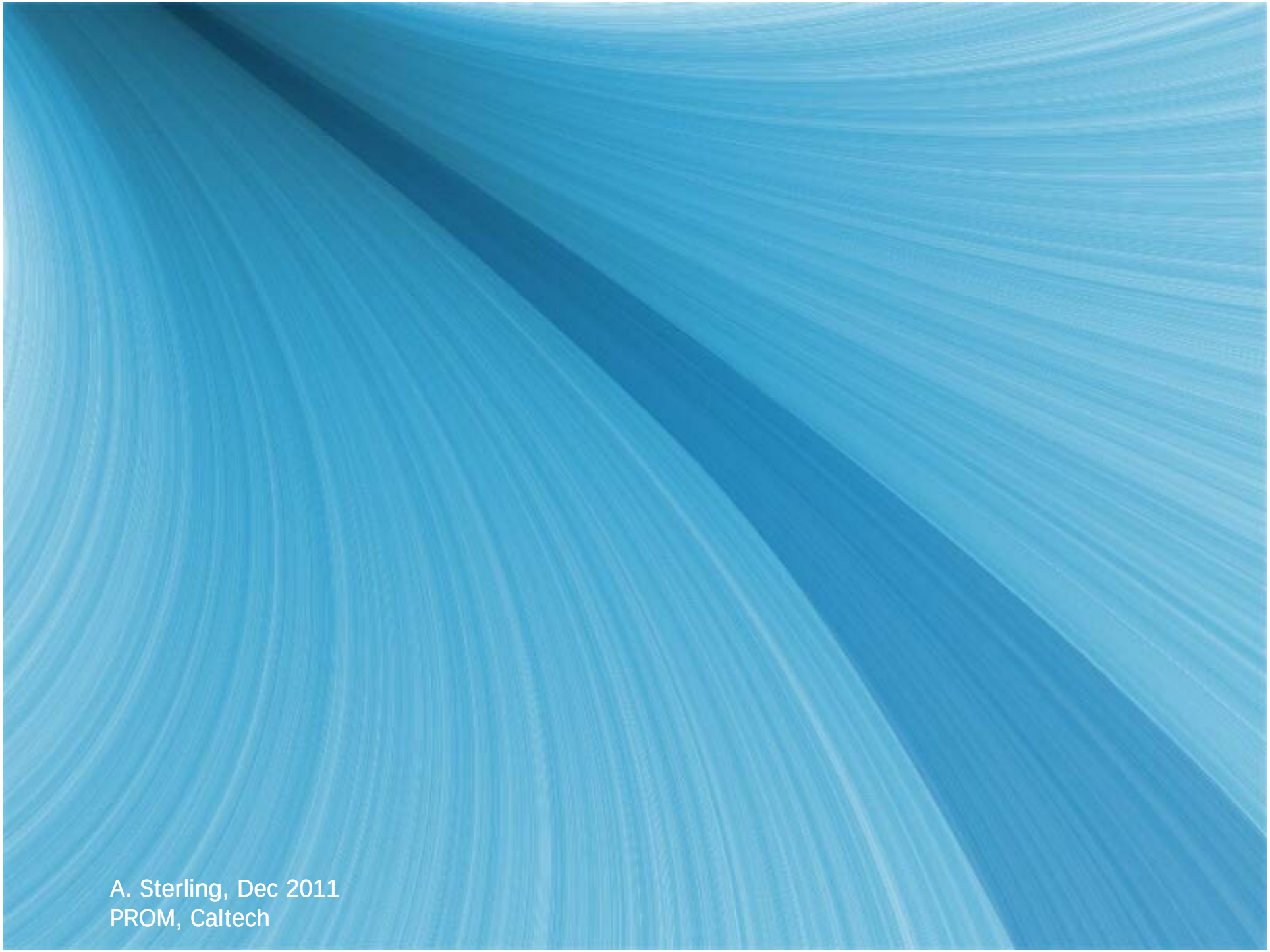

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An AR Ejective Eruption from SDO and Hinode

- Active region eruption of 1 June 2011.
- Confined eruption; no CME detected.
- GOES class C4.1 flare.
- SDO/AIA, various filters (94, 131, 171, 193, 211, 304, 335 Ang.)
- High time cadence (24 s) and high spatial resolution (0”.6 pixels).
- SDO/HMI line-of-sight magnetograms.
- Hinode observed the onset, and the later decay phase.

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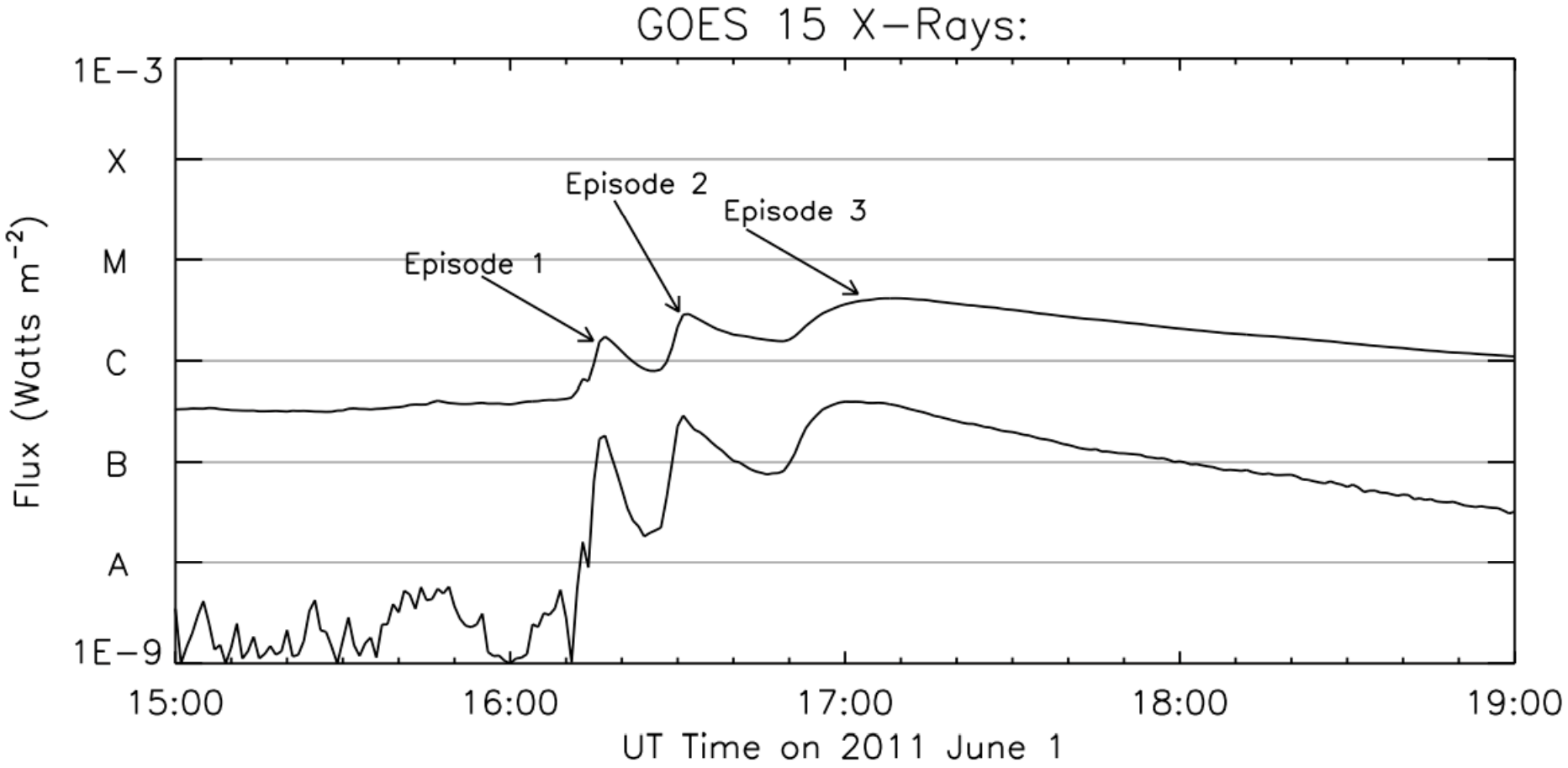

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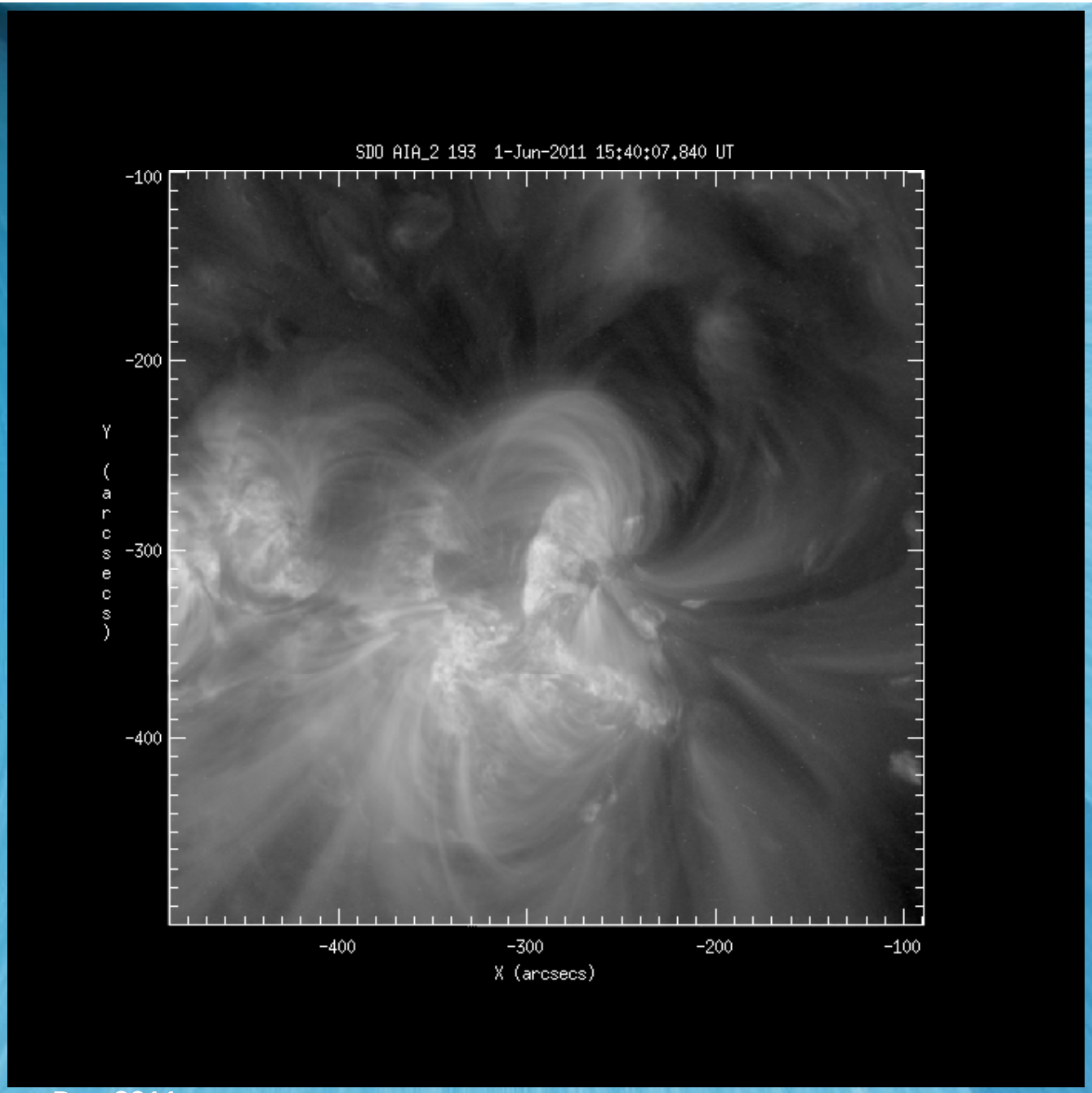

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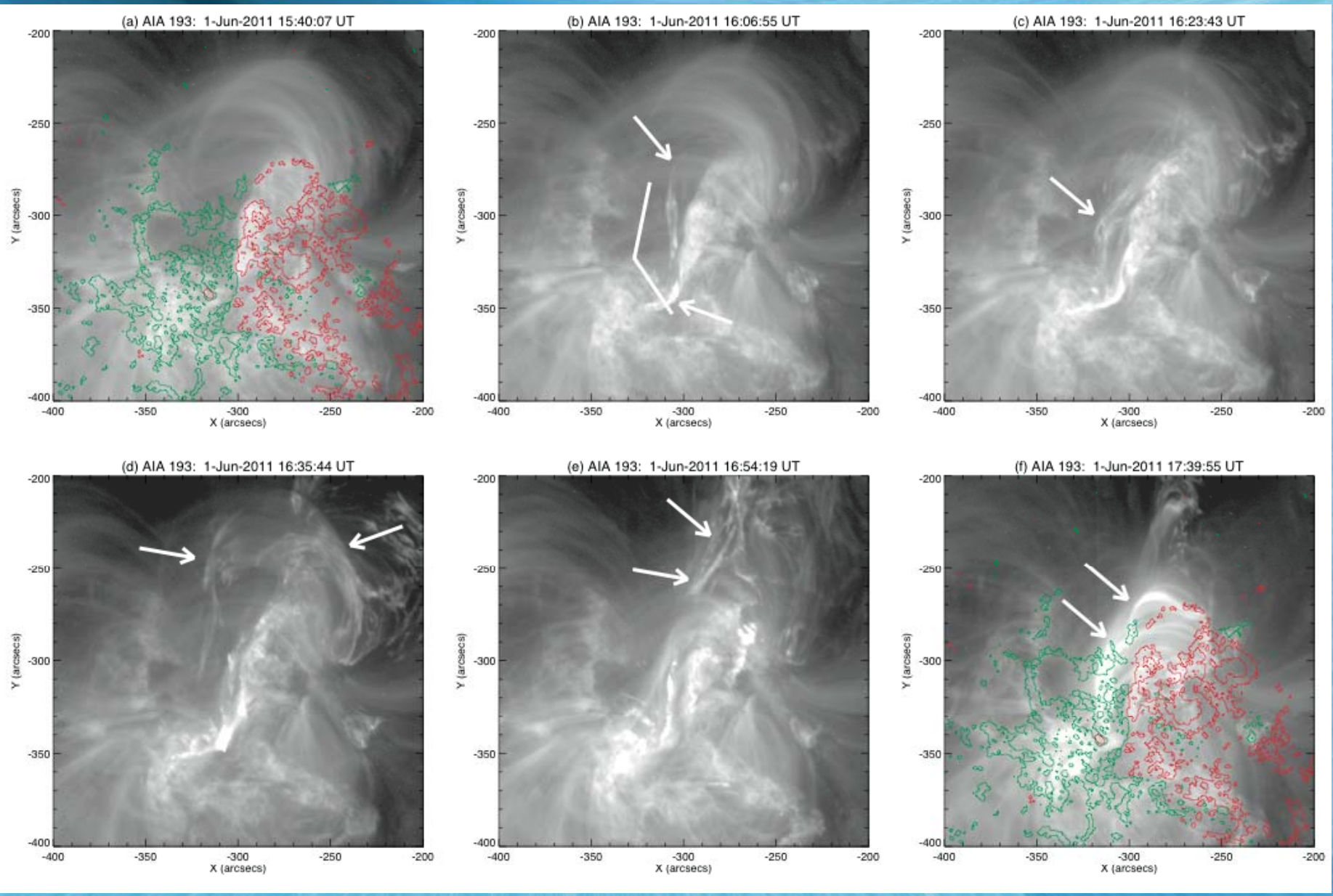

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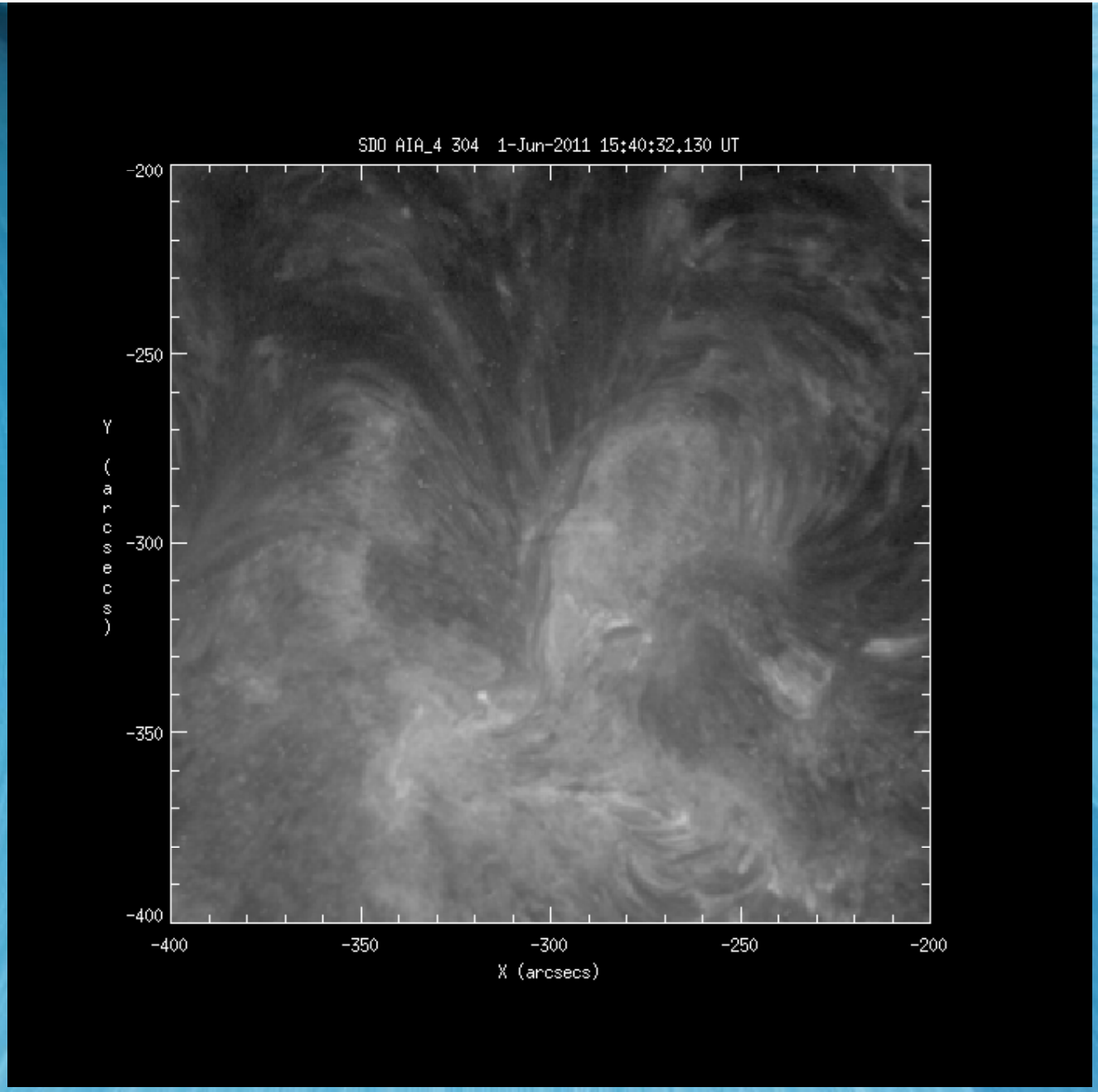

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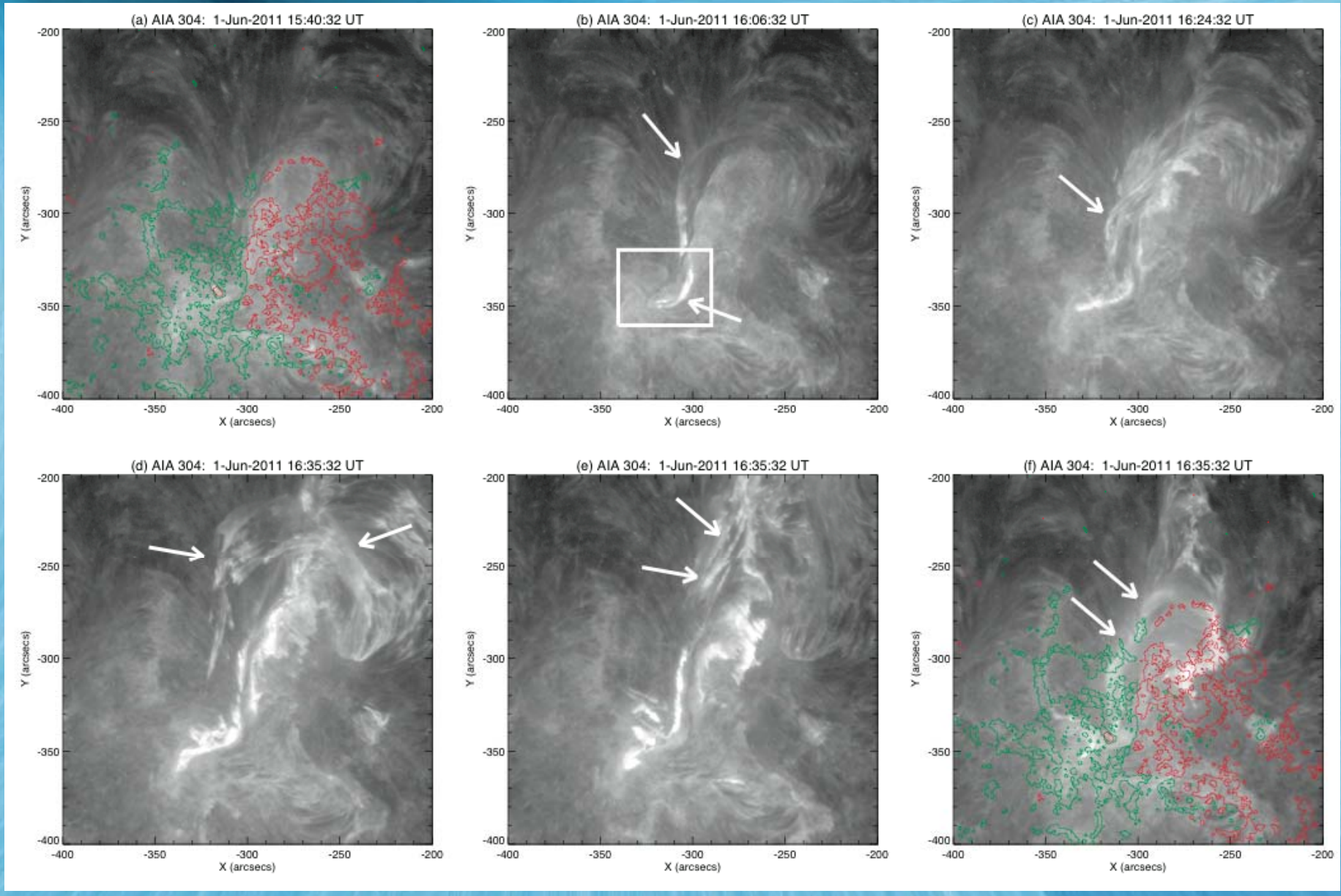

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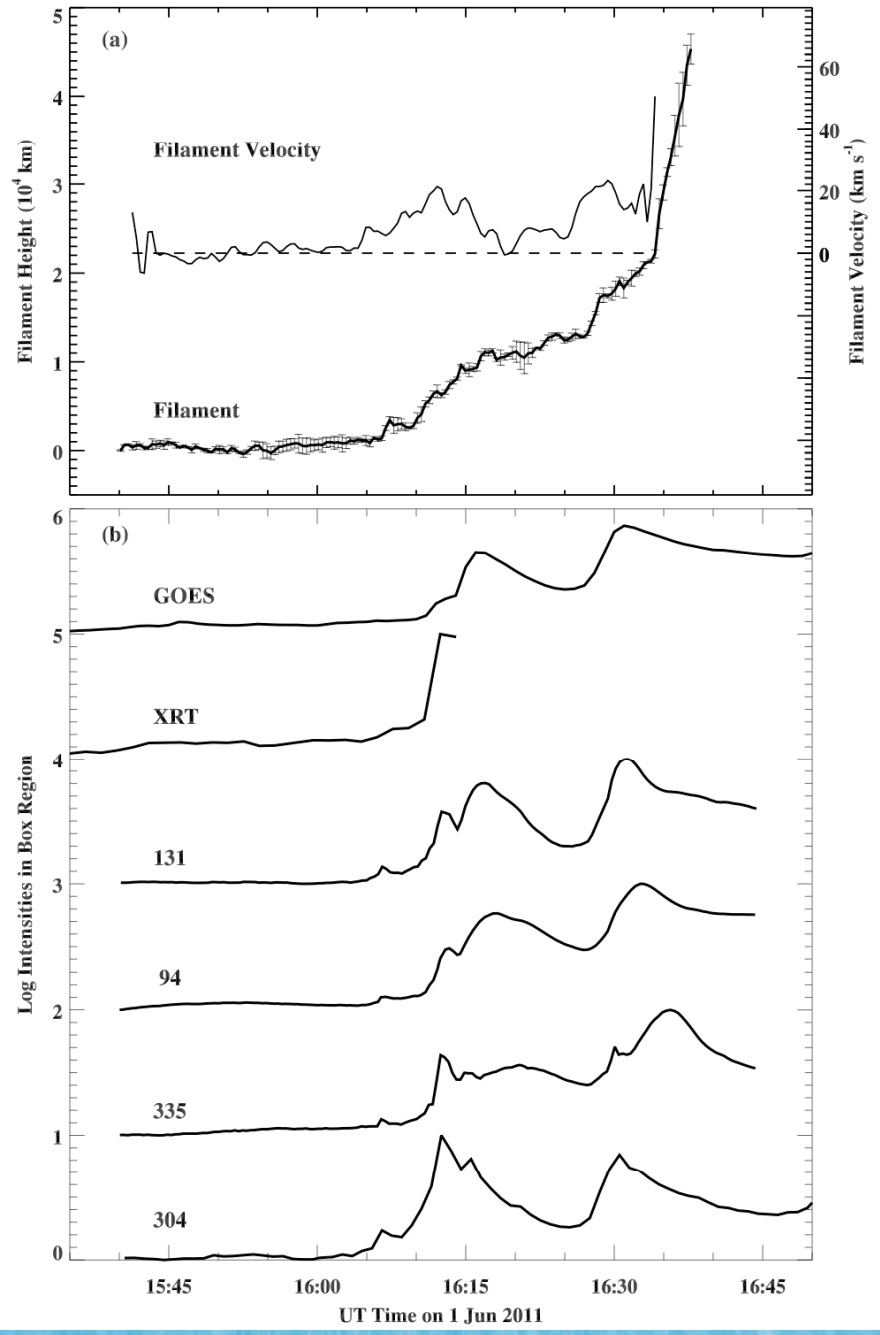

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- Filament slow rise has steps, as in several previous cases.
- Goes “episodes” play role of “microflares” in other events; that is, filament jumps <=> intensity peaks.
- Last episode is the main flare; flare loops.
- There may be a ``cocoon’’ counterpart.

What goes on at the S base, where the eruption seems to start?

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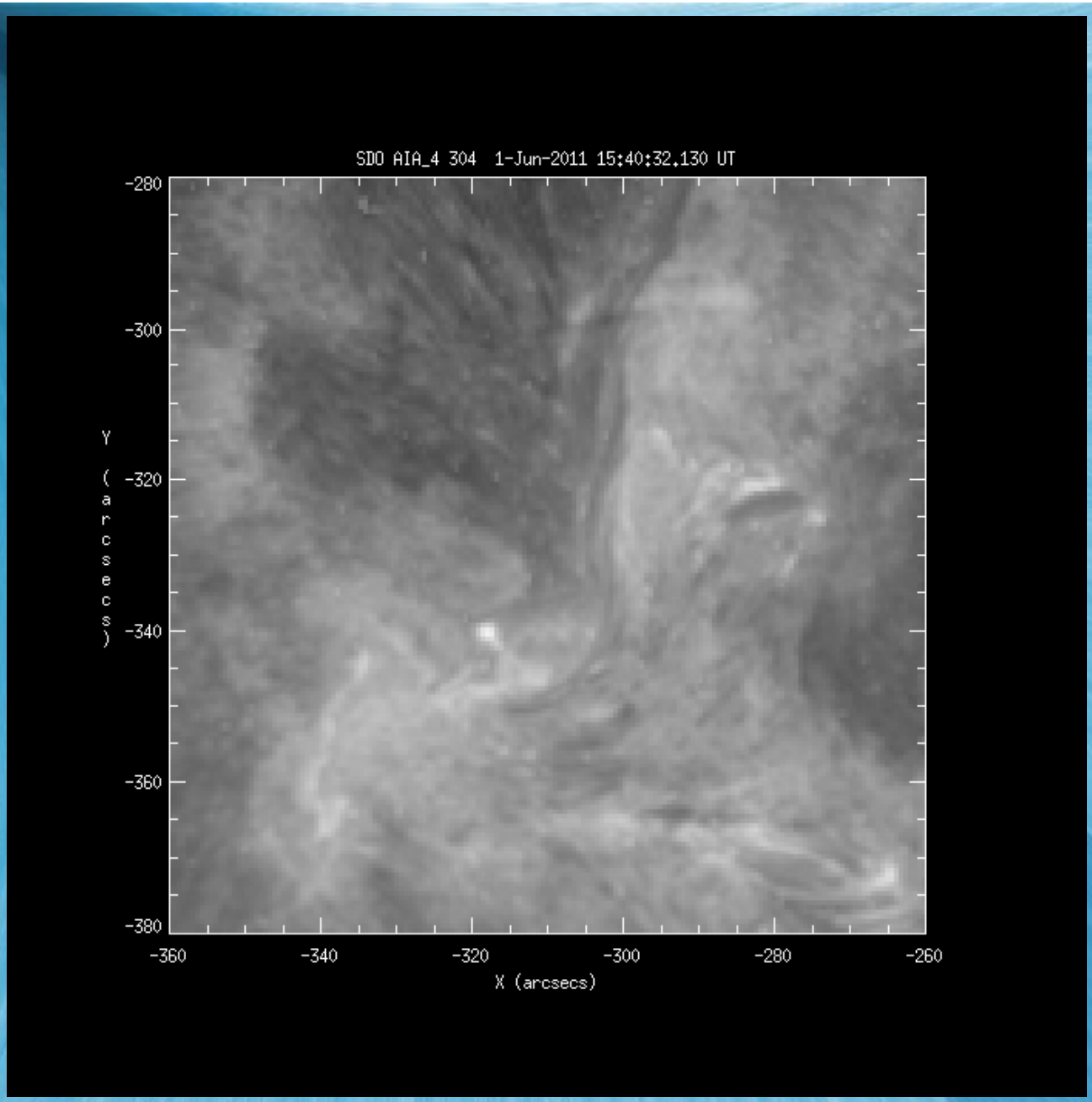

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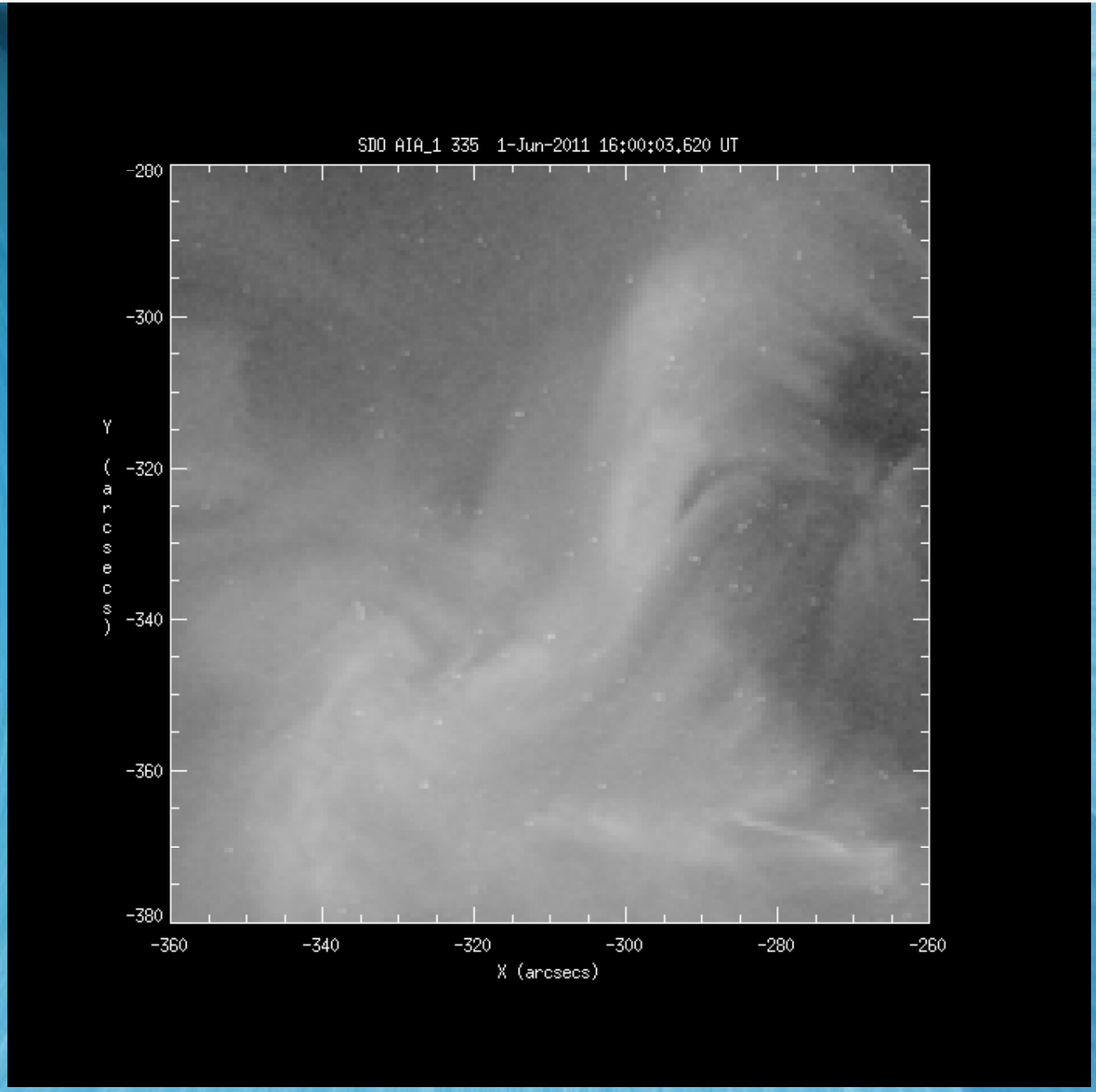

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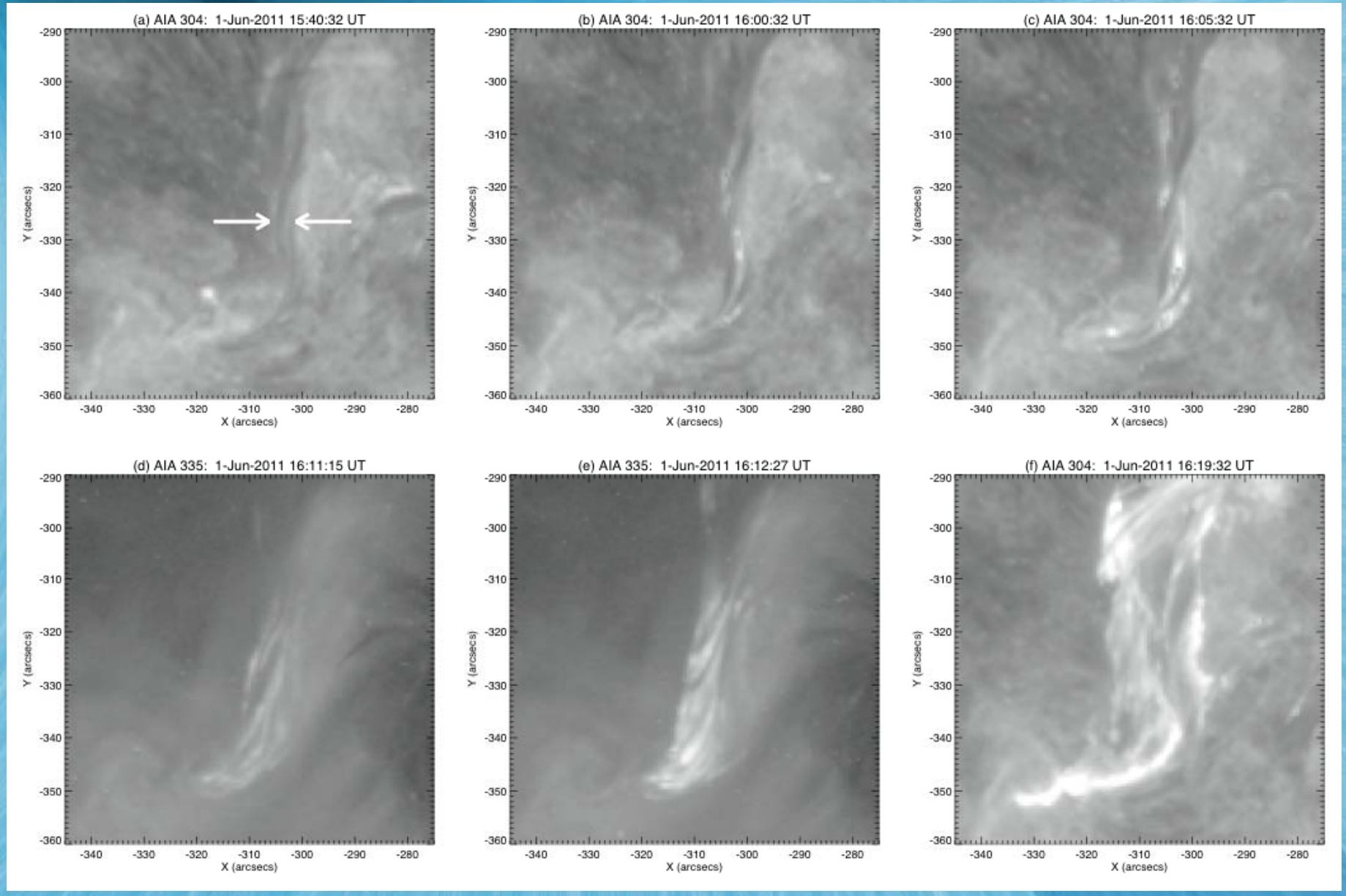

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Can this drive the entire eruption sequence?

Estimate amount of free energy in newly-twisted field:

$$B_{norm} \approx B_{par}$$

$$E_{free} \approx E_{pot} \sim B_z^2 / 8\pi \times (\pi r^2 L)$$

$$\sim 10^{29} \text{ ergs}$$

where we have taken L and r = 50, 3 arcsec.

Energy of the total system is likely 10^{30} ergs or more.
So "no" is answer to question.

Additional energy comes from remainder of sheared large loop, shear (free energy) of second filament, etc. (Normally assumed situation.)

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What causes the initial reconnection at the base?

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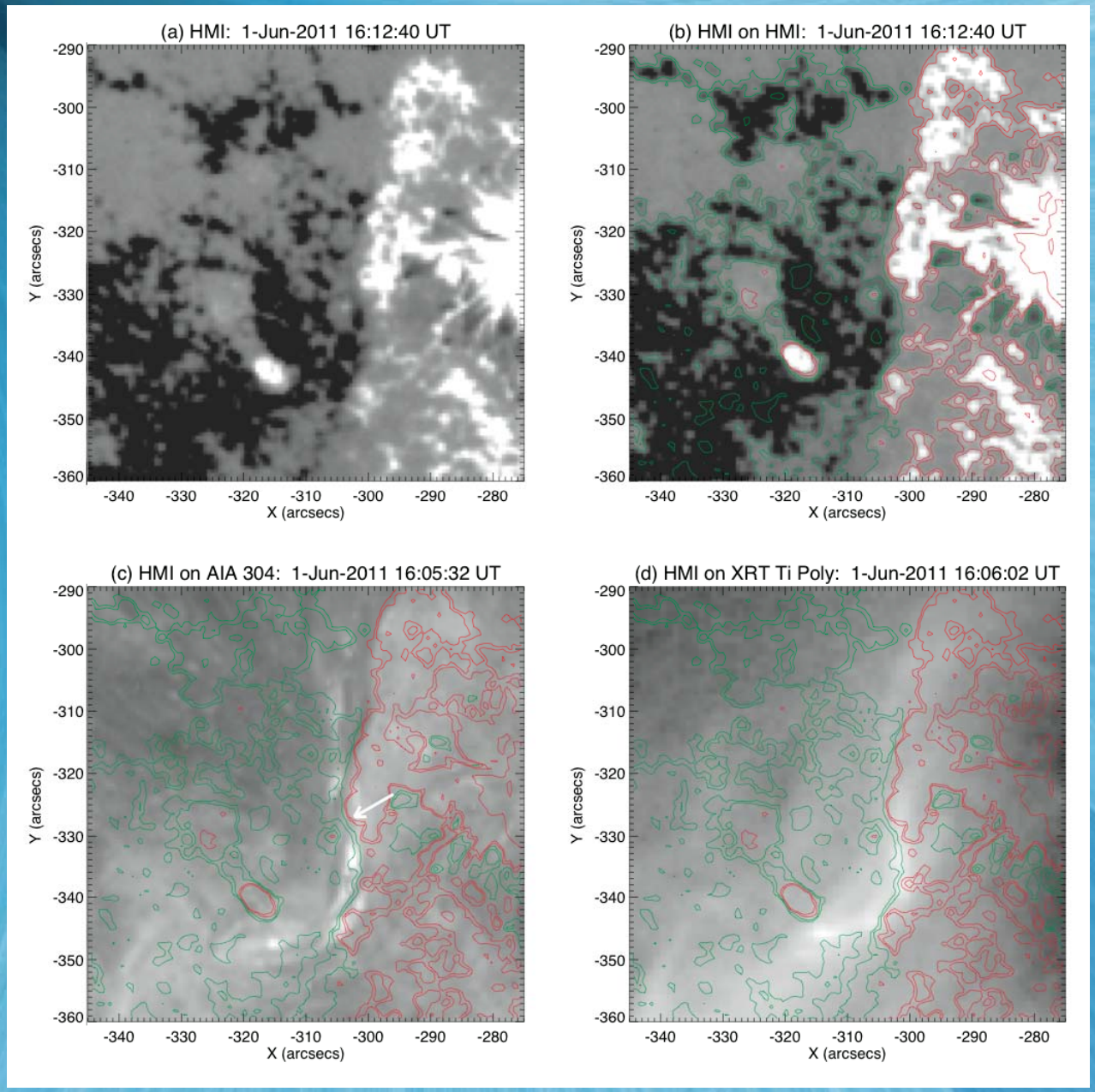

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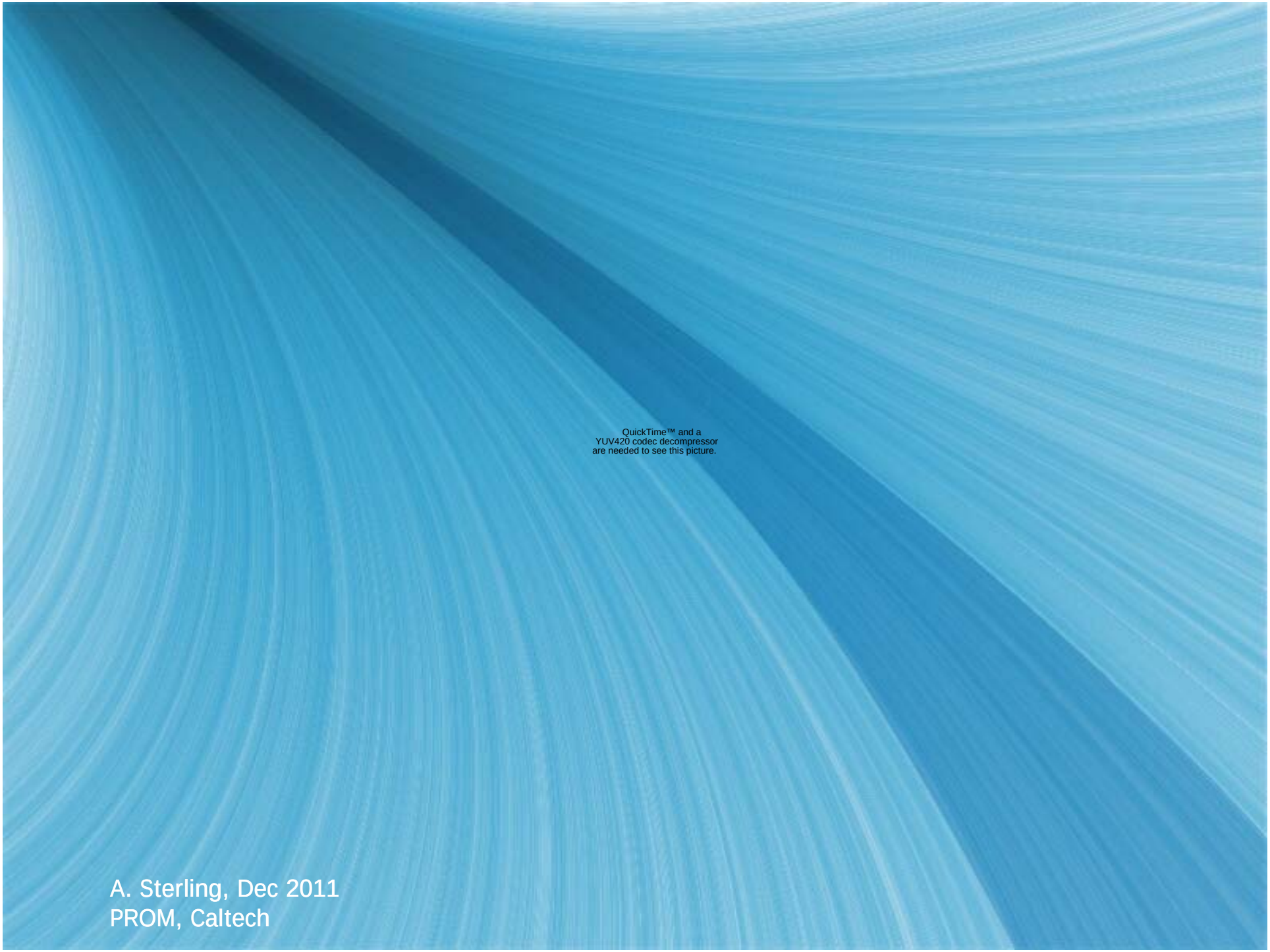

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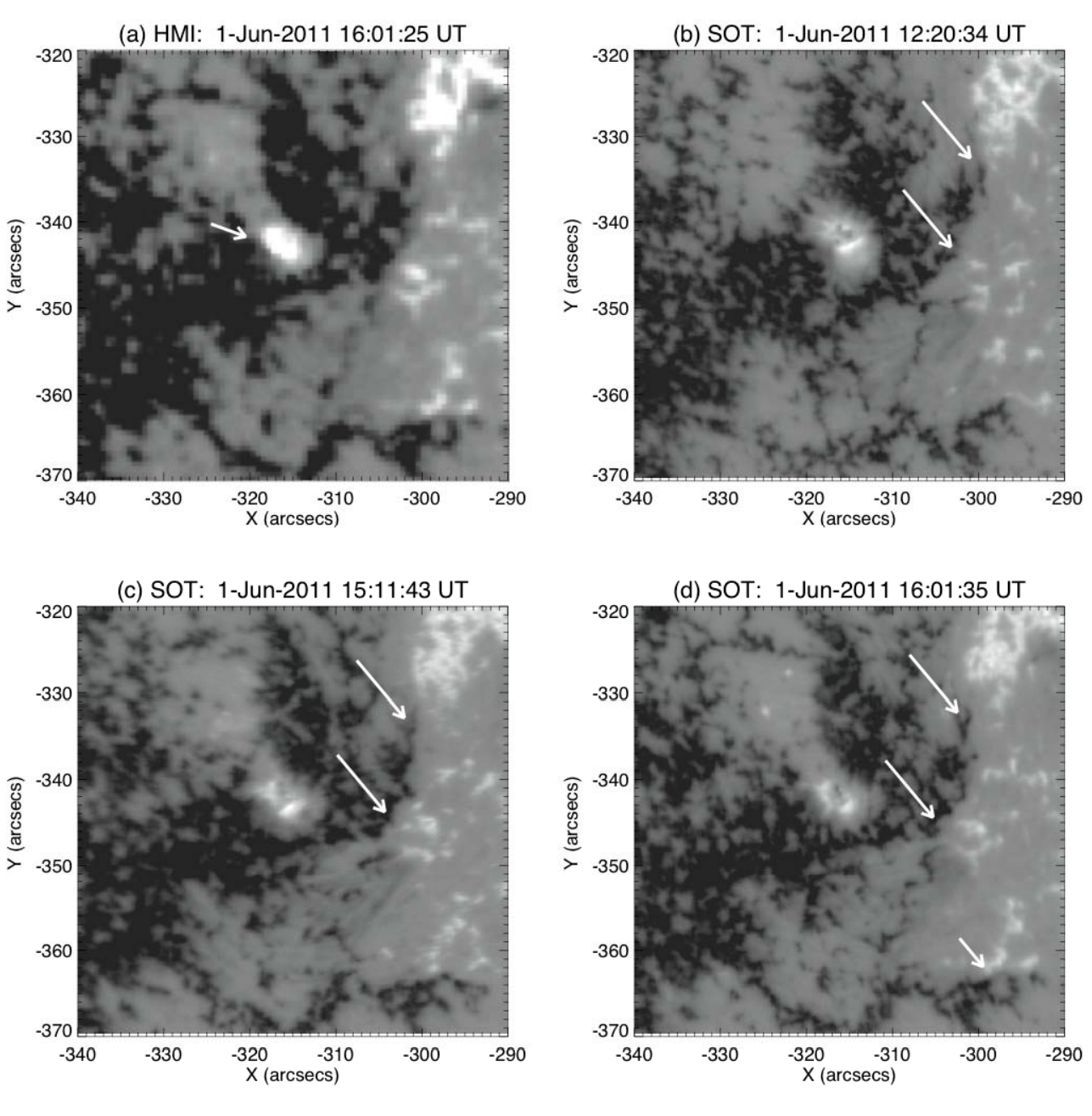

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Conclusions (2011 Jun 1 event)

- Something leads to reconnection; not totally clear what.
- Reconnection -> twisted flux rope in ~20 min; first microflare and filament jump.
- Twist -> writhe, ~ 20 min; filament plateau. (E.g., Torok, Kliem; Gilbert et al.; Fan, Gibson; Srvastava et al.)
- Writhe -> jump and eruption of filament 1, via instability; second microflare. (E.g., ditto; also Williams et al.)
- First eruption -> second filament eruption (e.g., Sterling, Moore; Liu et al.; Torok et al.; Schrijver & Title)

The presented events all involve twist, and likely instability.

But there may be other types of events too…

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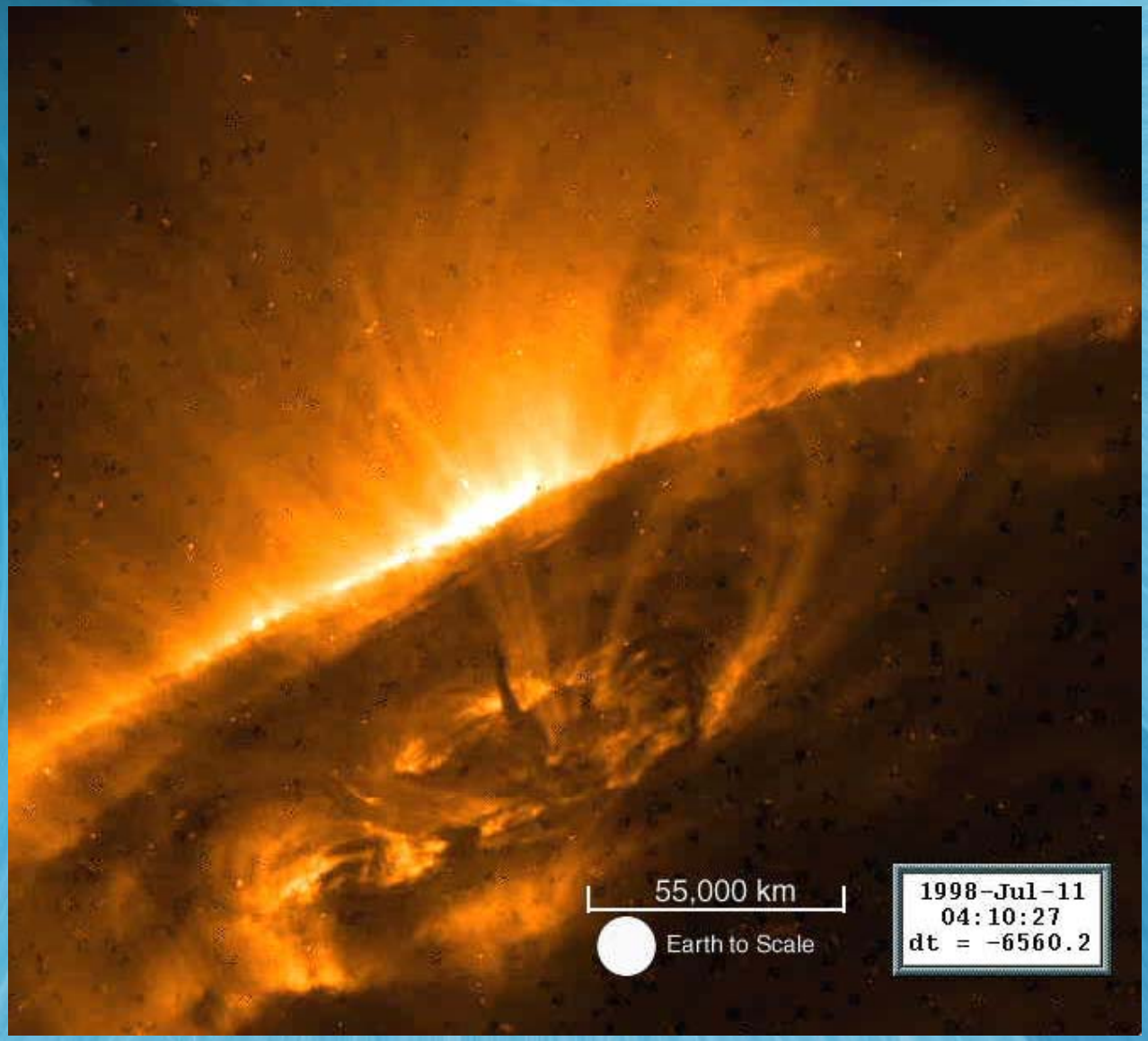

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