Observations from *Hinode* and *SDO* of a Twisting and Writhing Start to a Solar-filament-eruption Cascade

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An AR Ejective Eruption from SDO and Hinode

- Active region eruption of 1 June 2011.
- Ejective eruption.
- 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.

We will: Overview the full eruption sequence.
Main focus: What is going on in the onset phase?

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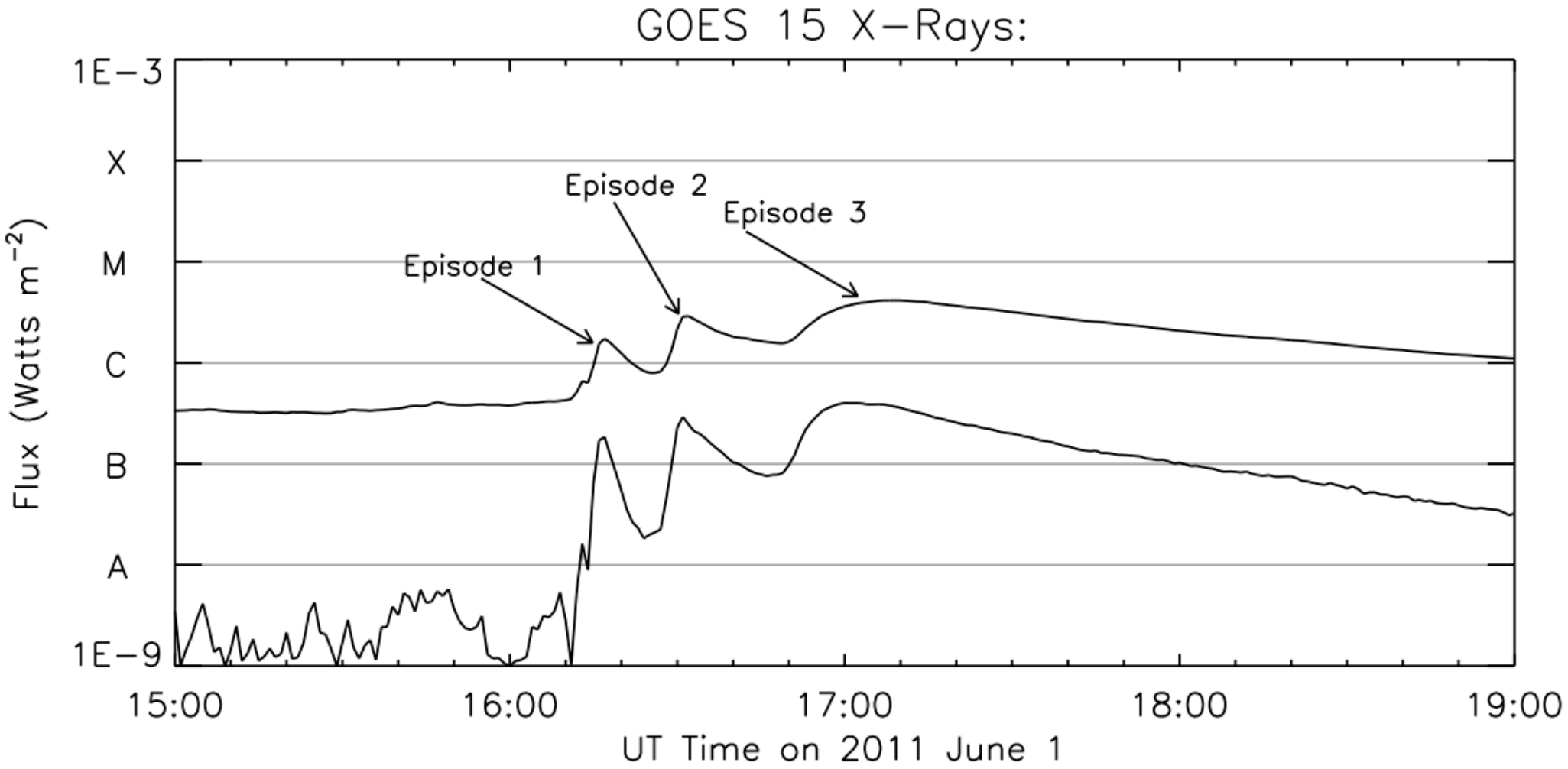

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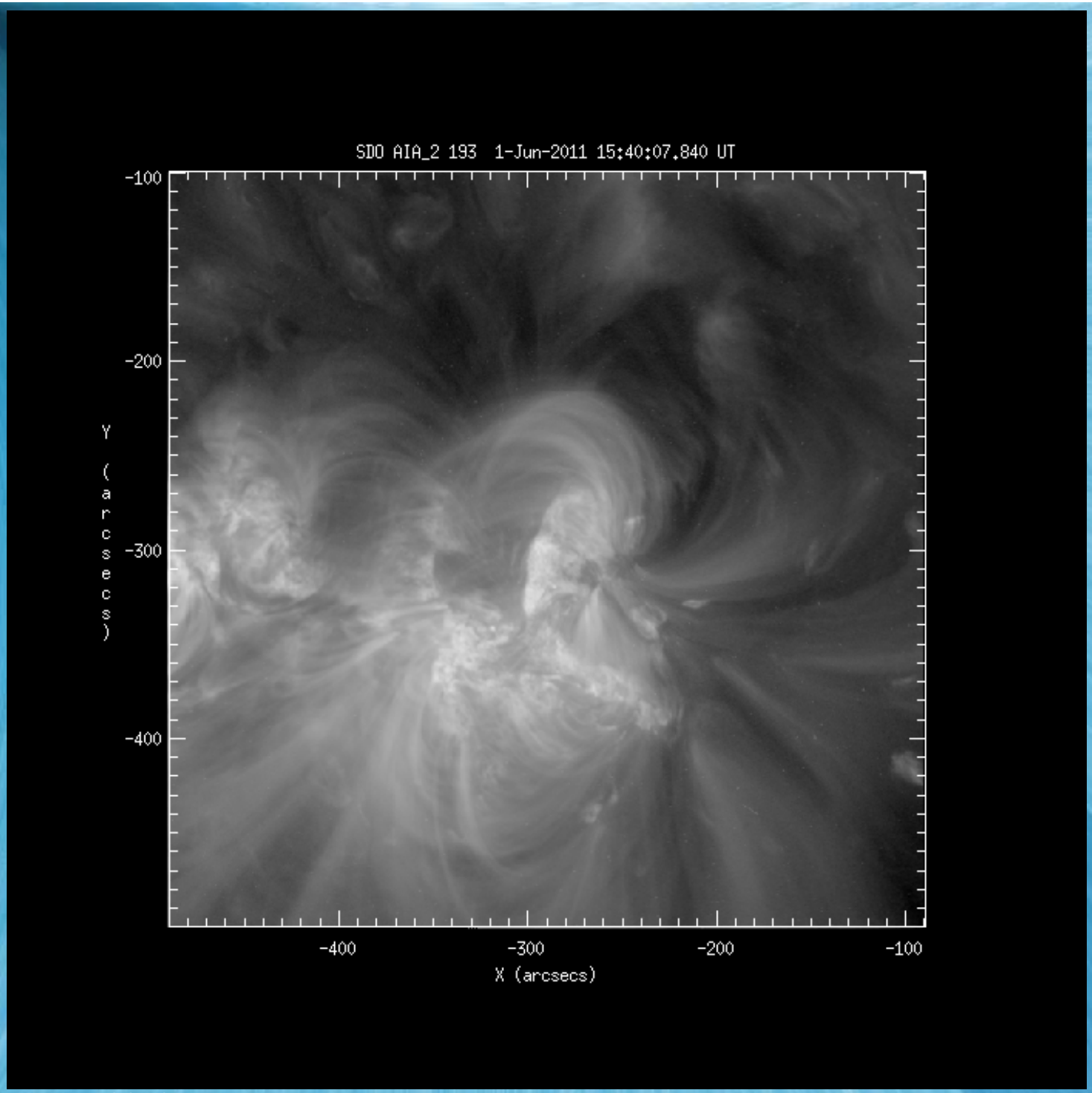

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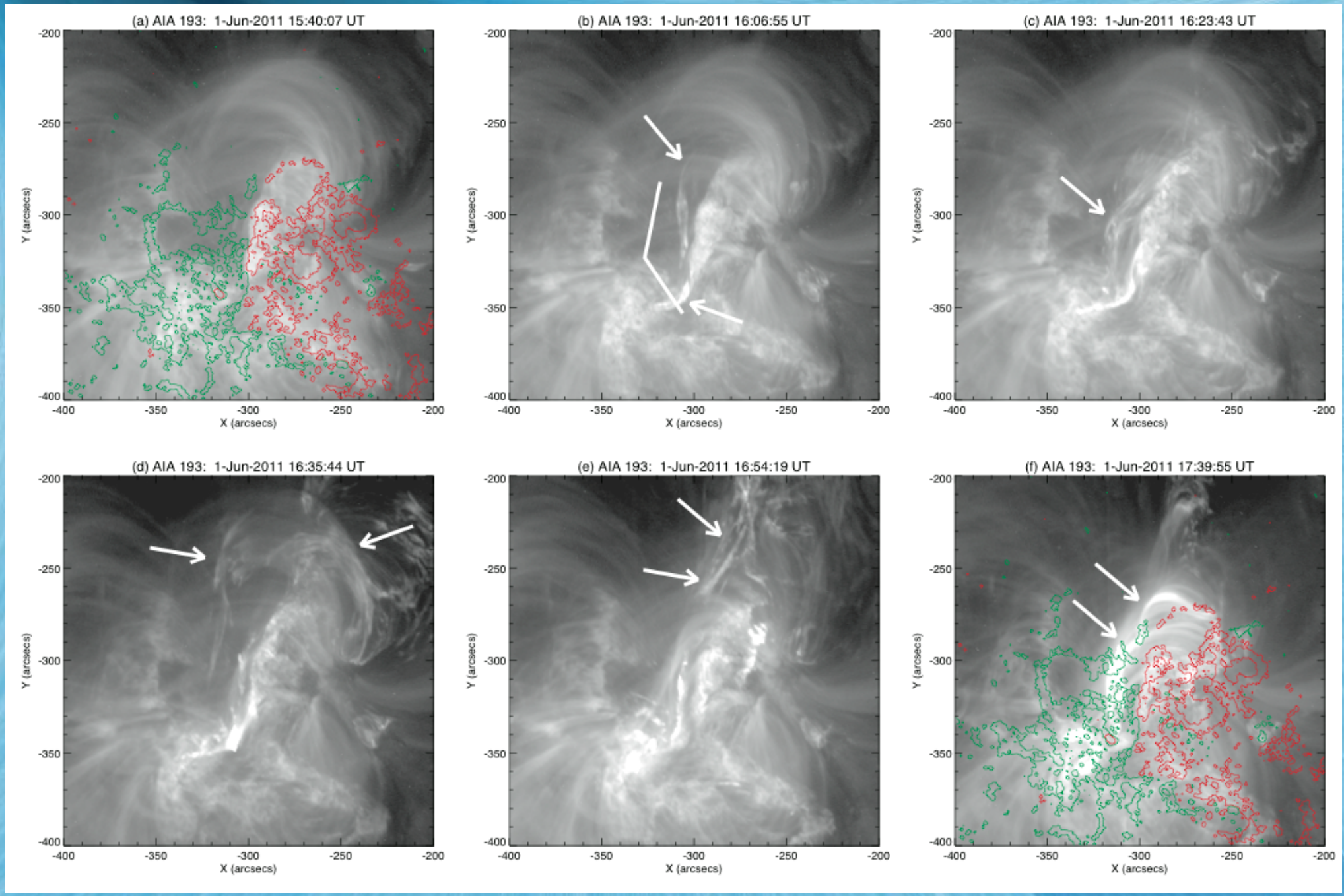

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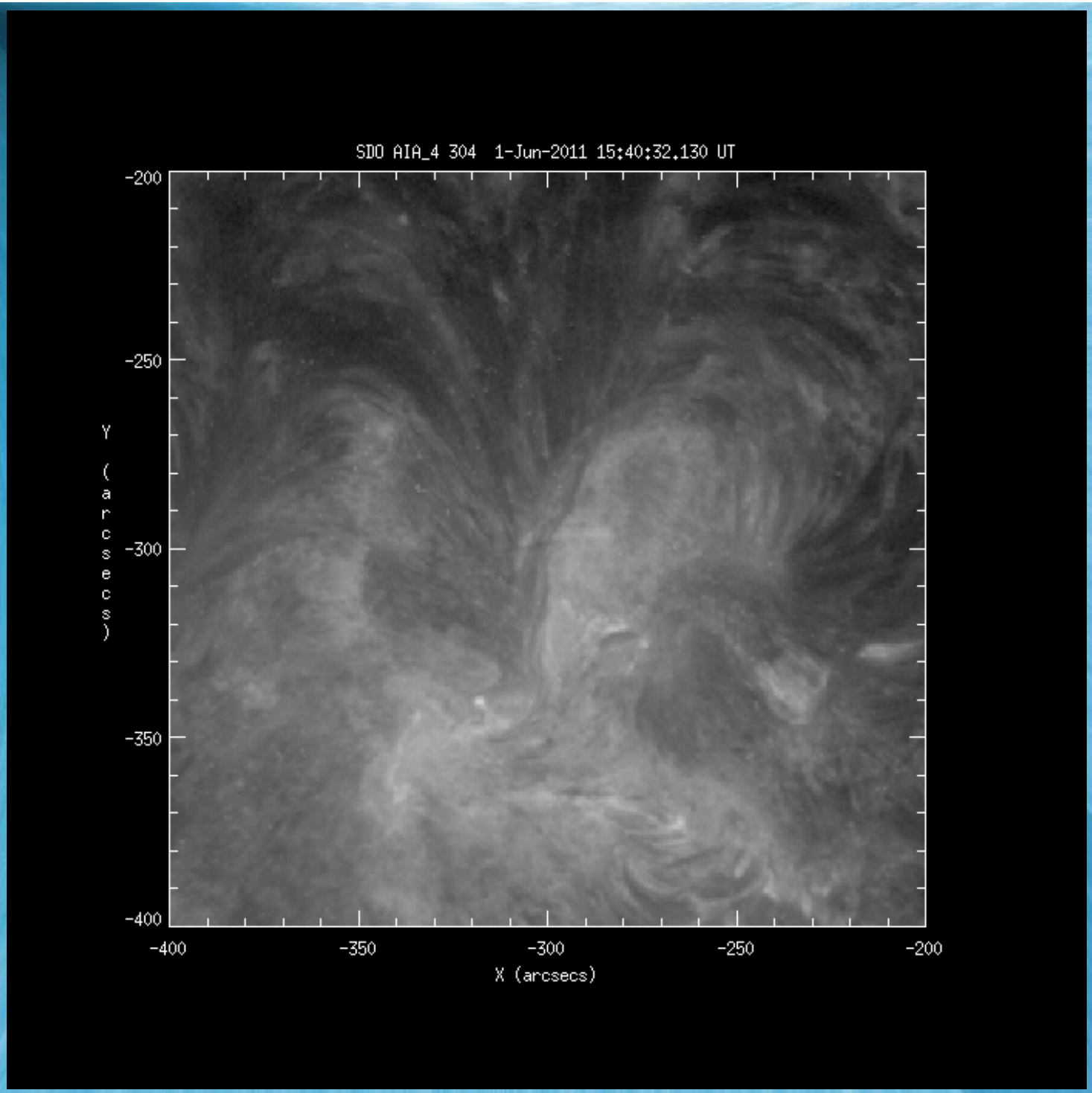

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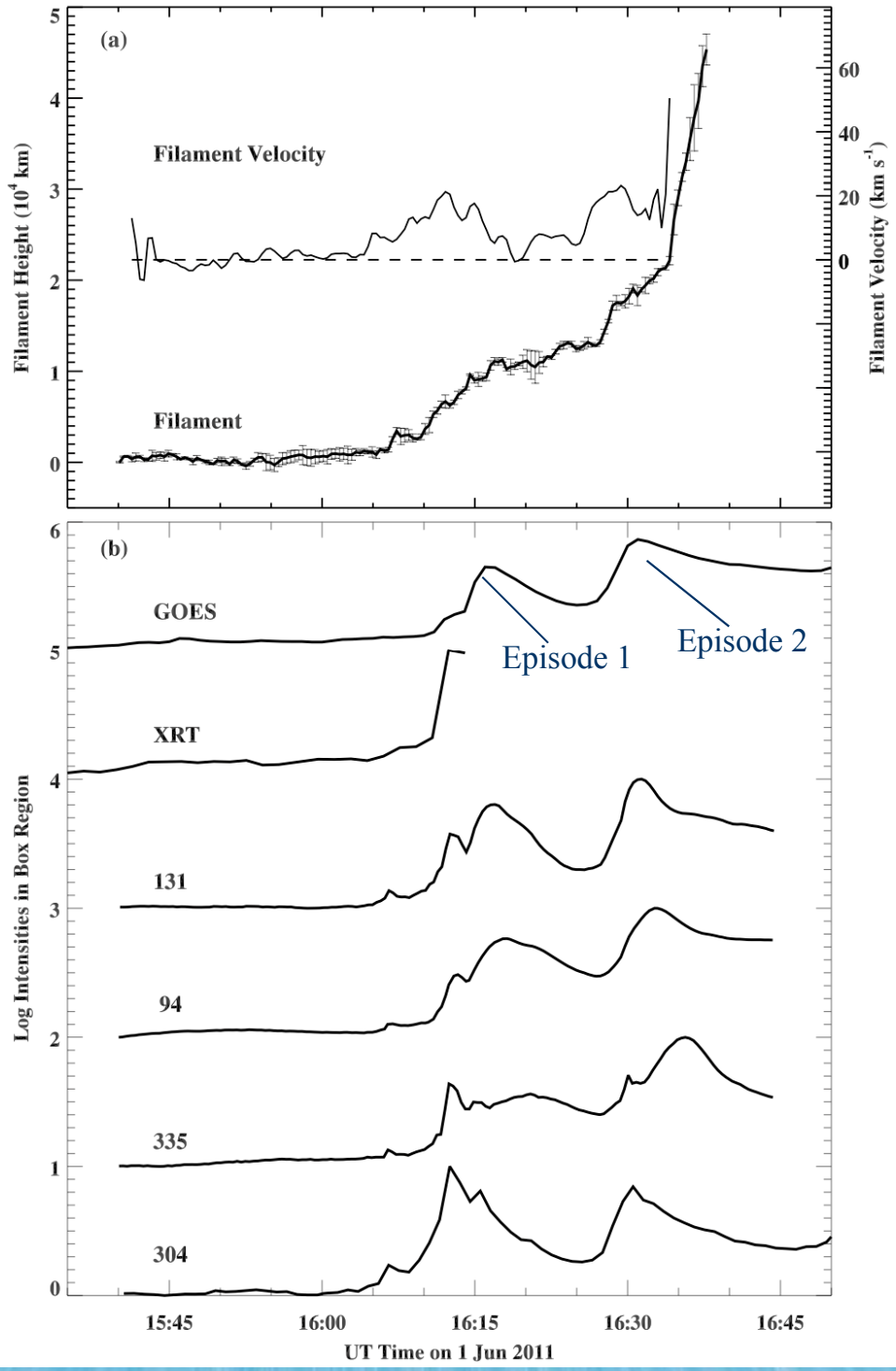

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• There are two filament eruptions (filament 1 and filament 2).

• Filament 1 has slow rise with steps, as in several previous cases. GOES "episodes" play role of "microflares" in other events; that is, filament jumps <=> intensity peaks.

• Episode 1 brightening: Accompanied by filament 1's initial motions. (Rest of talk.) Filament 1 becomes unstable, and…

• Episode 2 brightening: Flare ribbons following filament 1's fast liftoff. This destabilizes neighboring filament 2, and…

• Episode 3 brightening: Flare ribbons of whole system following filament 2's eruption.

What goes on at the southern end, near time of Episode 1 brightening?

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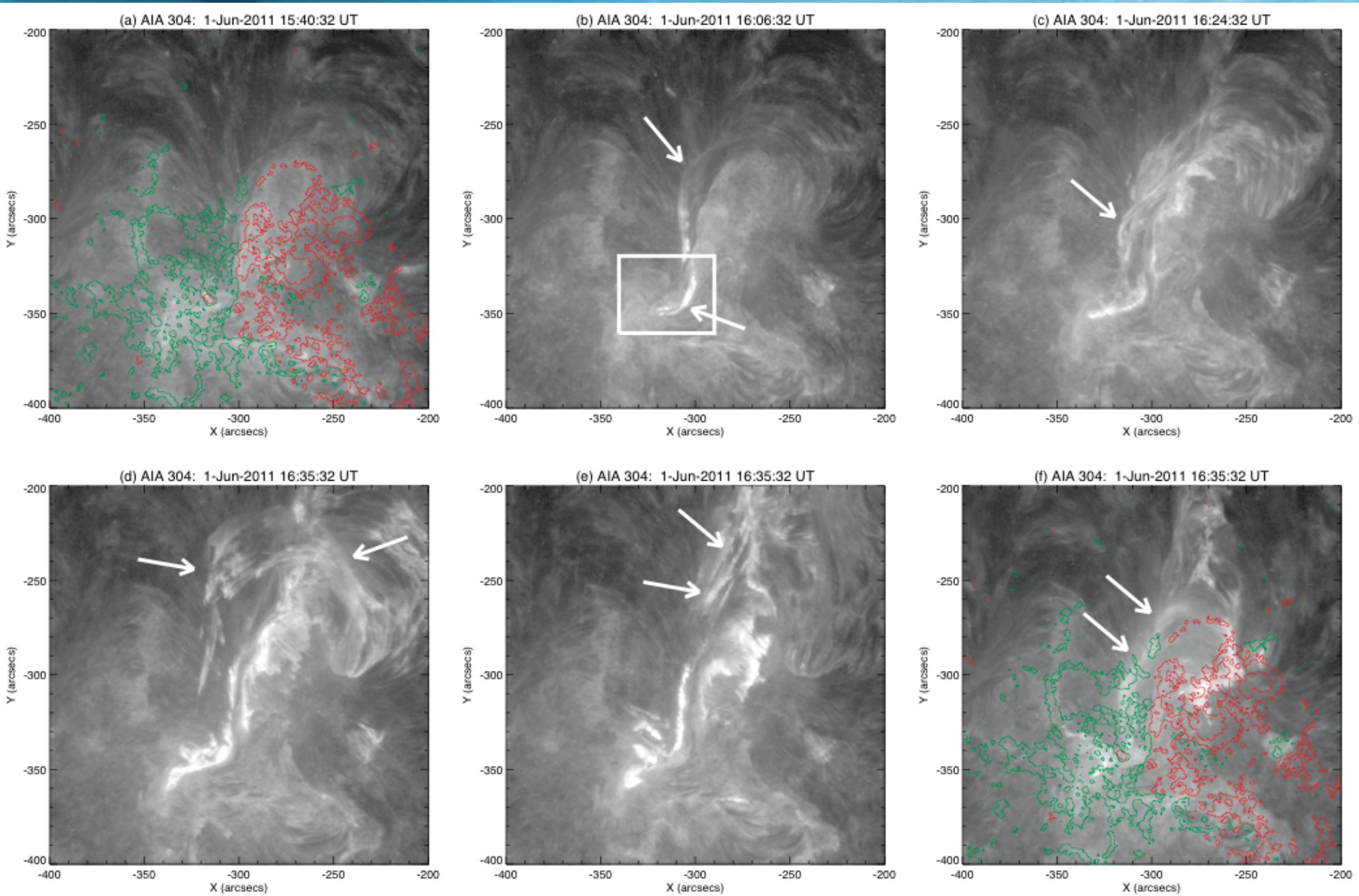

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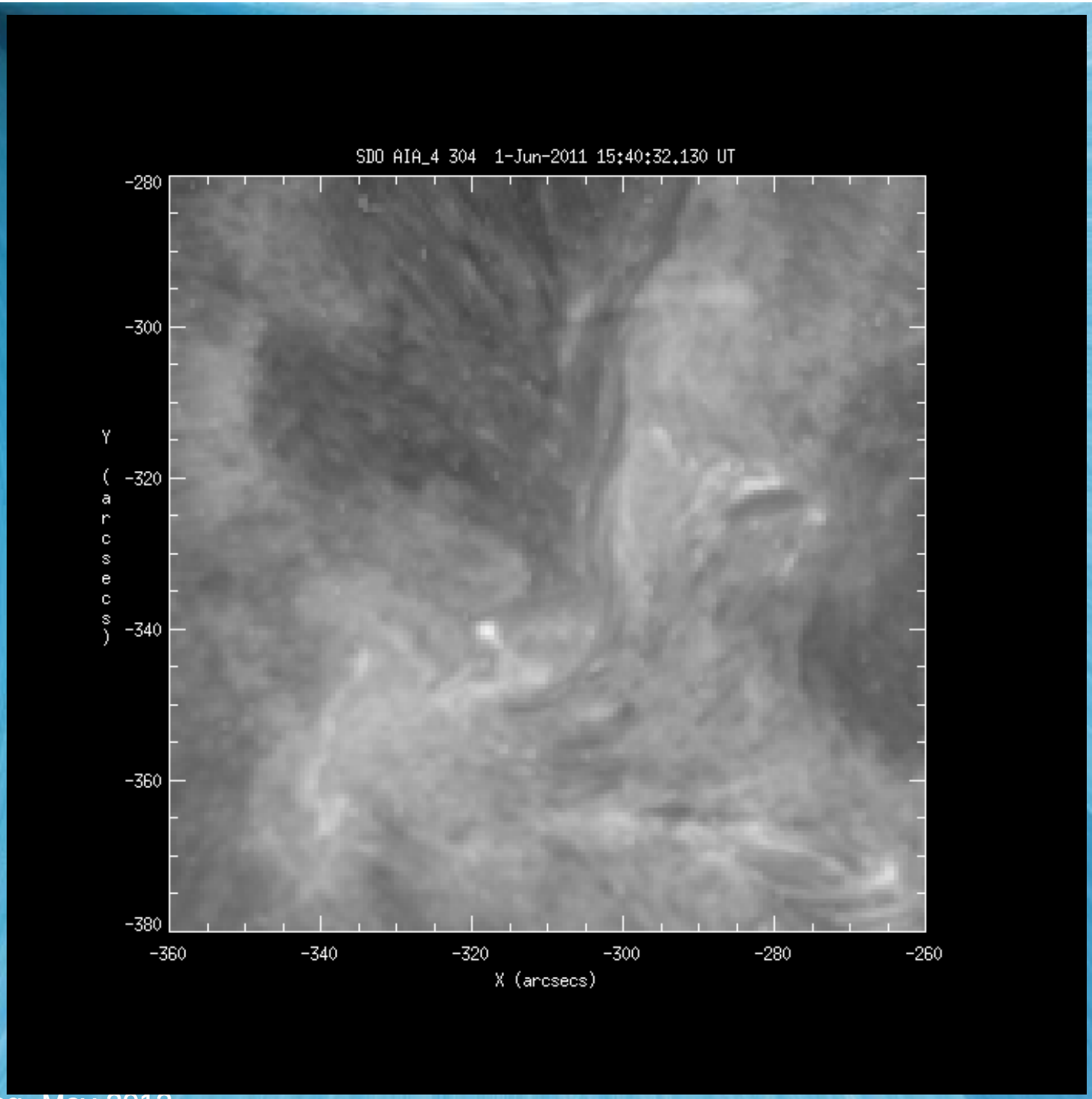

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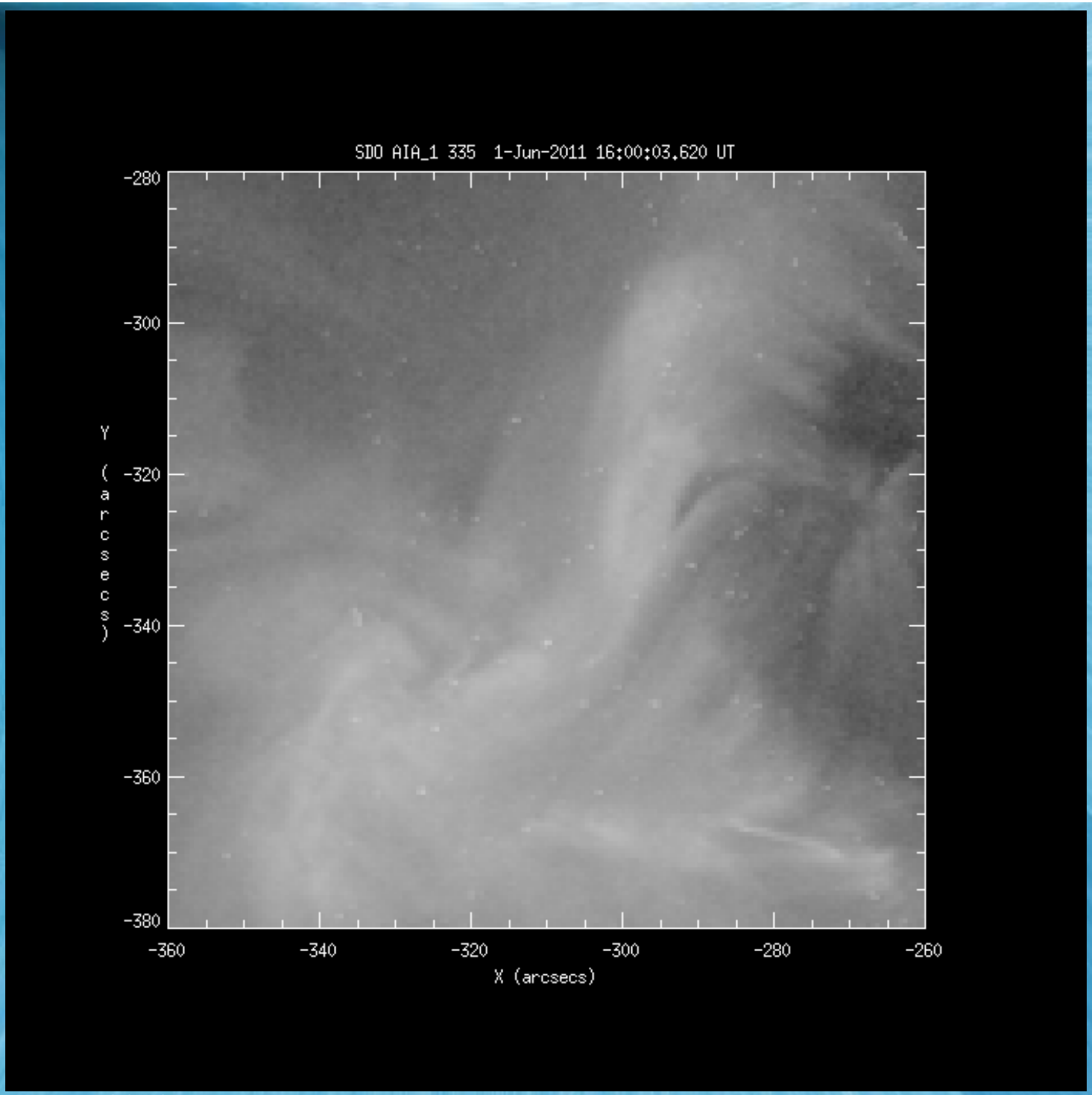

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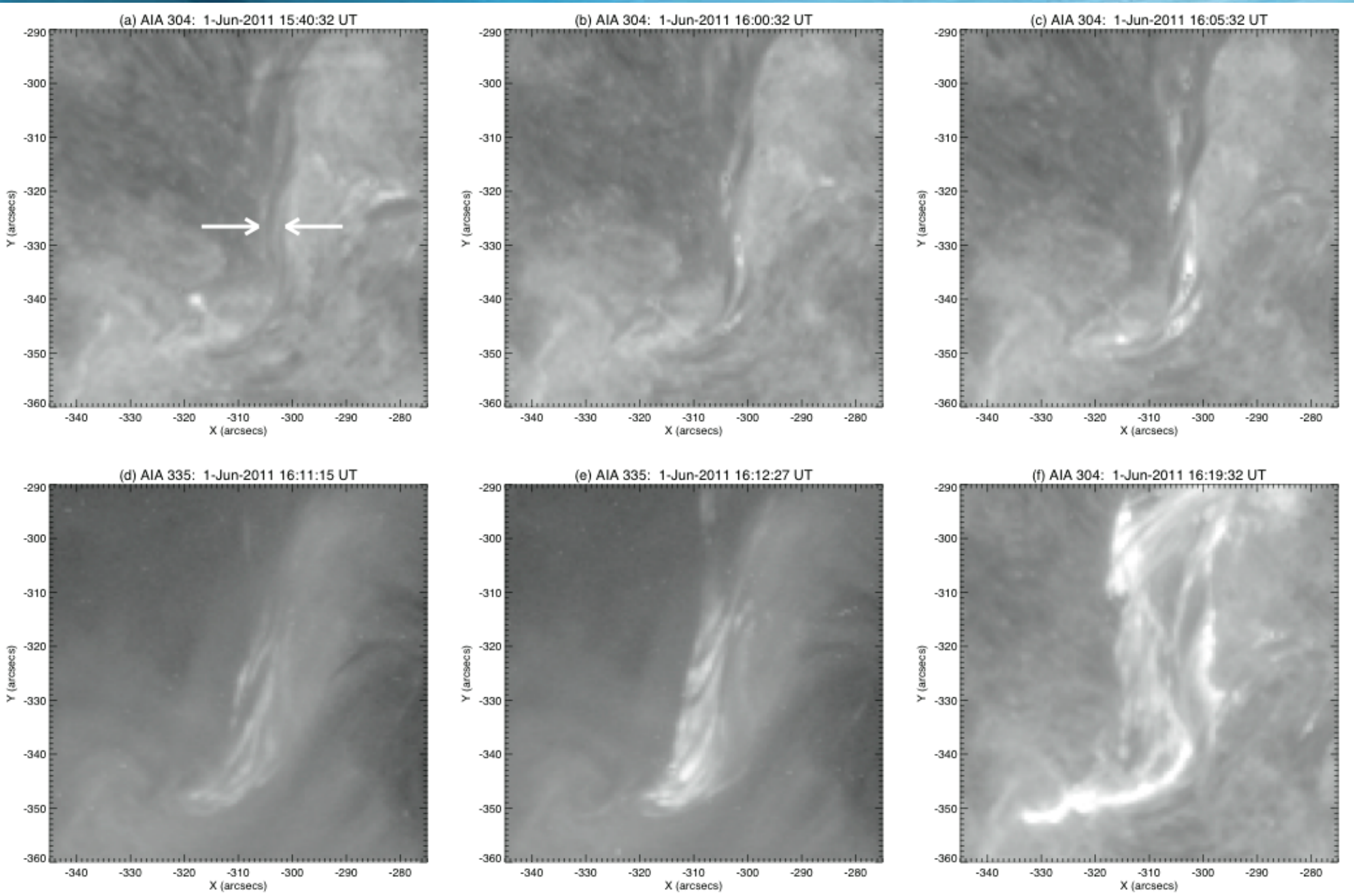

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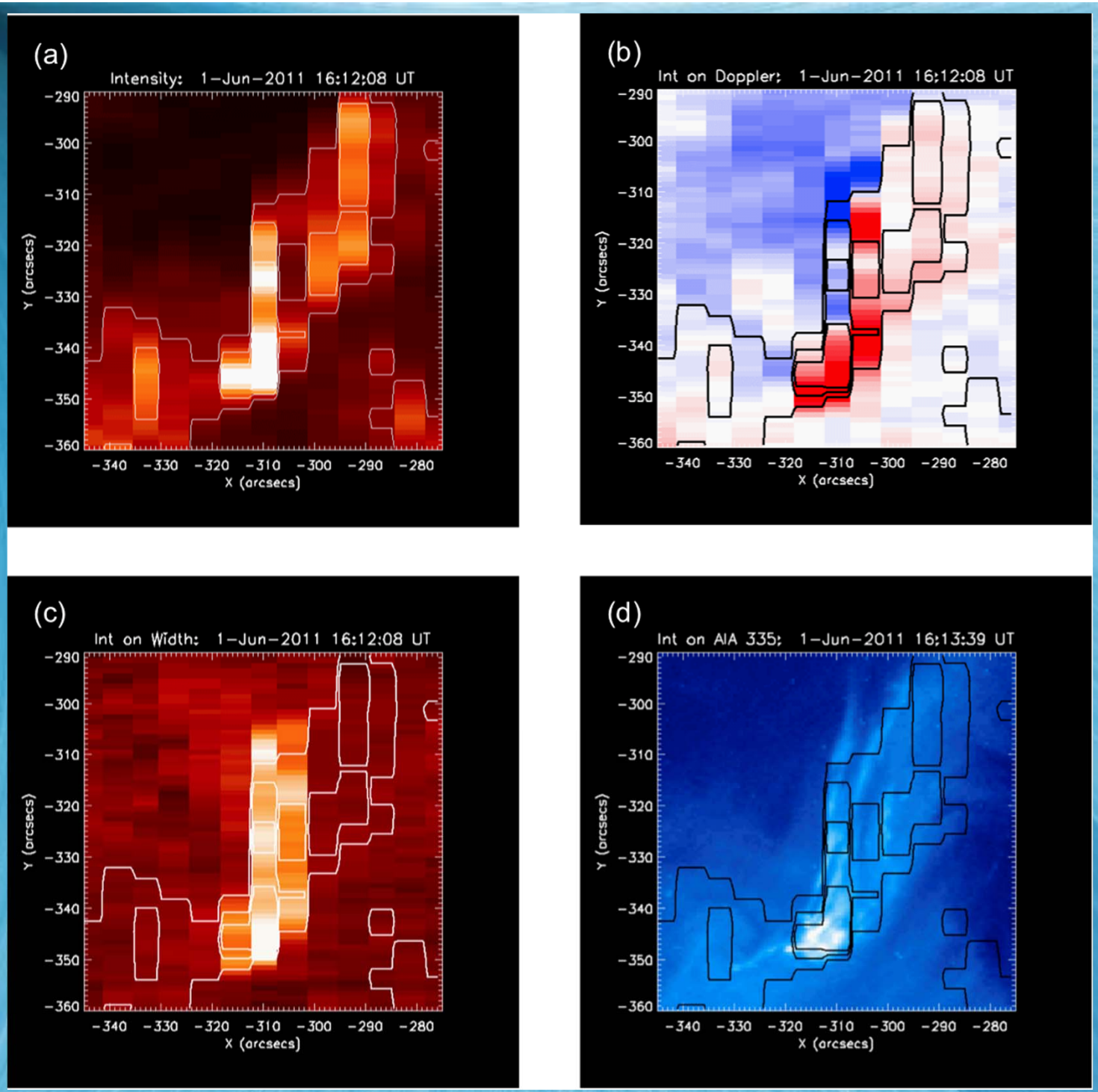

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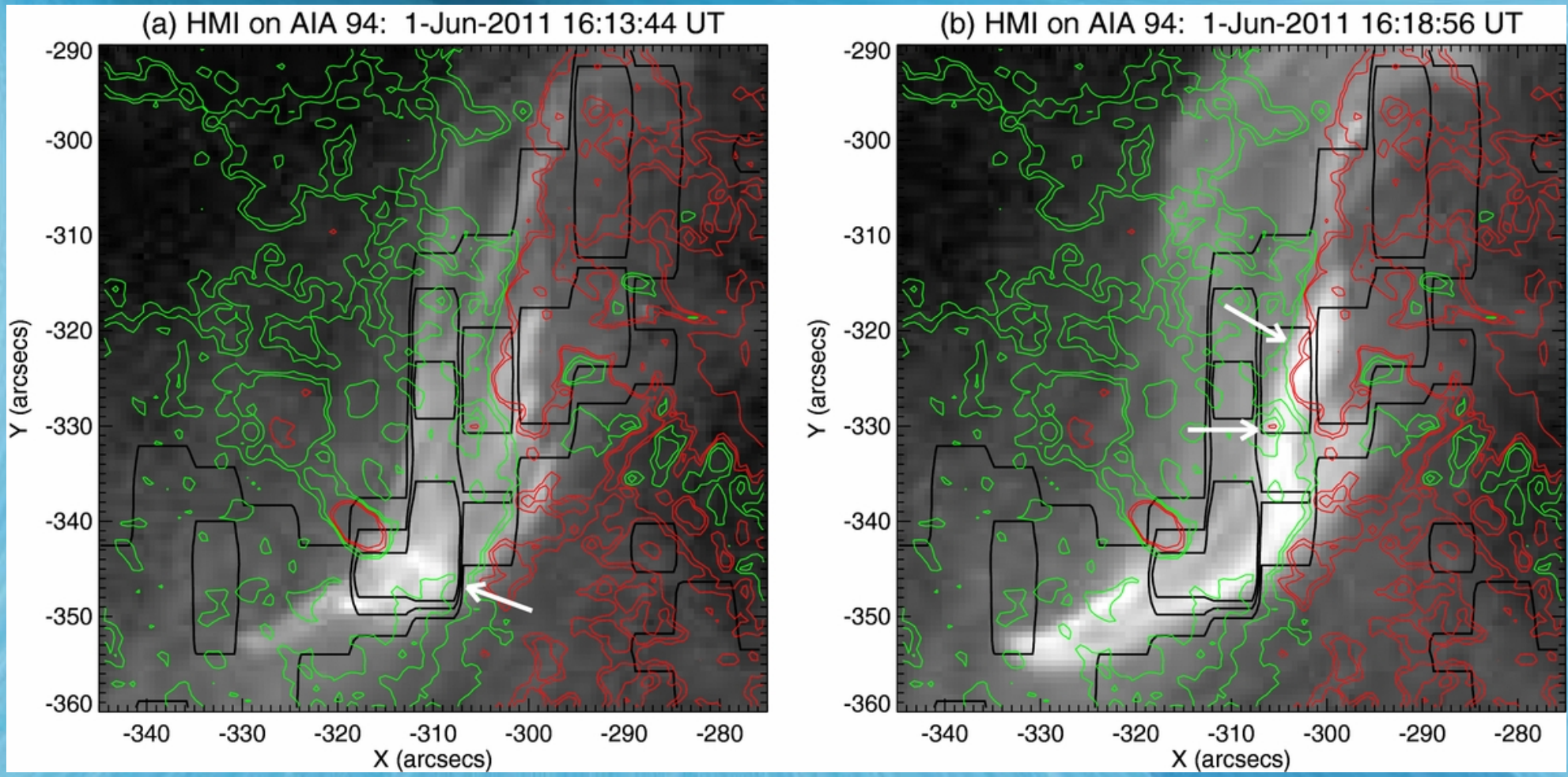
EIS Spectral Properties

- "Picket fence" mode; 1" in N-S, ~6" in EW
- Slit crosses ROI ~ 16:13:36 UT
- Alignment good to ~3", based on intensity matching
- Doppler velocities:
  - Max blue in E strip ~ 23+-17 km/s
  - Max red in S, ~ 85+-60 km/s
  - Max red in W strip ~ 62+-25 km/s
- Non-thermal velocities:
  - ~ 70 km/s in two strips
  - ~ 125 km/s in s
  - These max are similar to C- and M-flares of Kay et al. (2006)
- What leads to blue and red Doppler shifts?
  - Not twisting....
  - Maybe "flare" loops?



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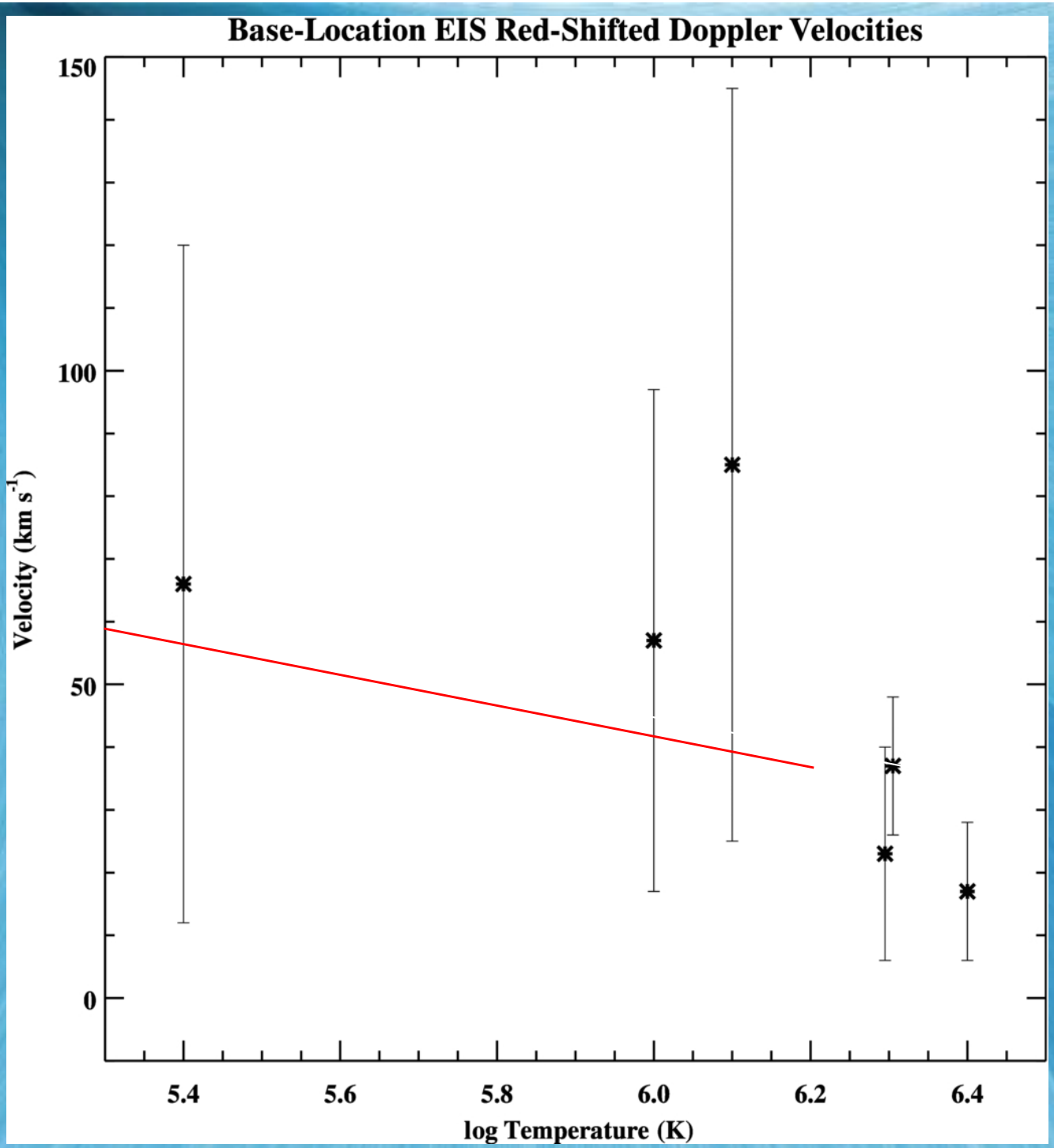

Red= Milligan & Dennis (2009), Evaporation red shift.

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Is the "Flux Rope" Structure Twist-Unstable?

Some history of twist-induced instability in filament eruptions:
e.g., Sakurai, Török & Kliem, Fan & Gibson, Gilbert et al.,
van Driel-Gesztelyi et al.

Criterion : Kink instability for line-tied tube (Hood & Priest): 2.5π;
for Titov & Démoulin loop (Török et al): ~3.5π

We observe here: ~1.5 turns (3.0π) over ~50″
=> consistent with kink instability acting.

(Cf. Srivastava et al. (2010): Small flare seen in TRACE and
Hinode: ~6.0π)

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Can this drive the entire eruption sequence?

Estimate amount of free energy in newly-twisted field (cf. Moore 1988):

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

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

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

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.)

What causes the initial reconnection at the base?

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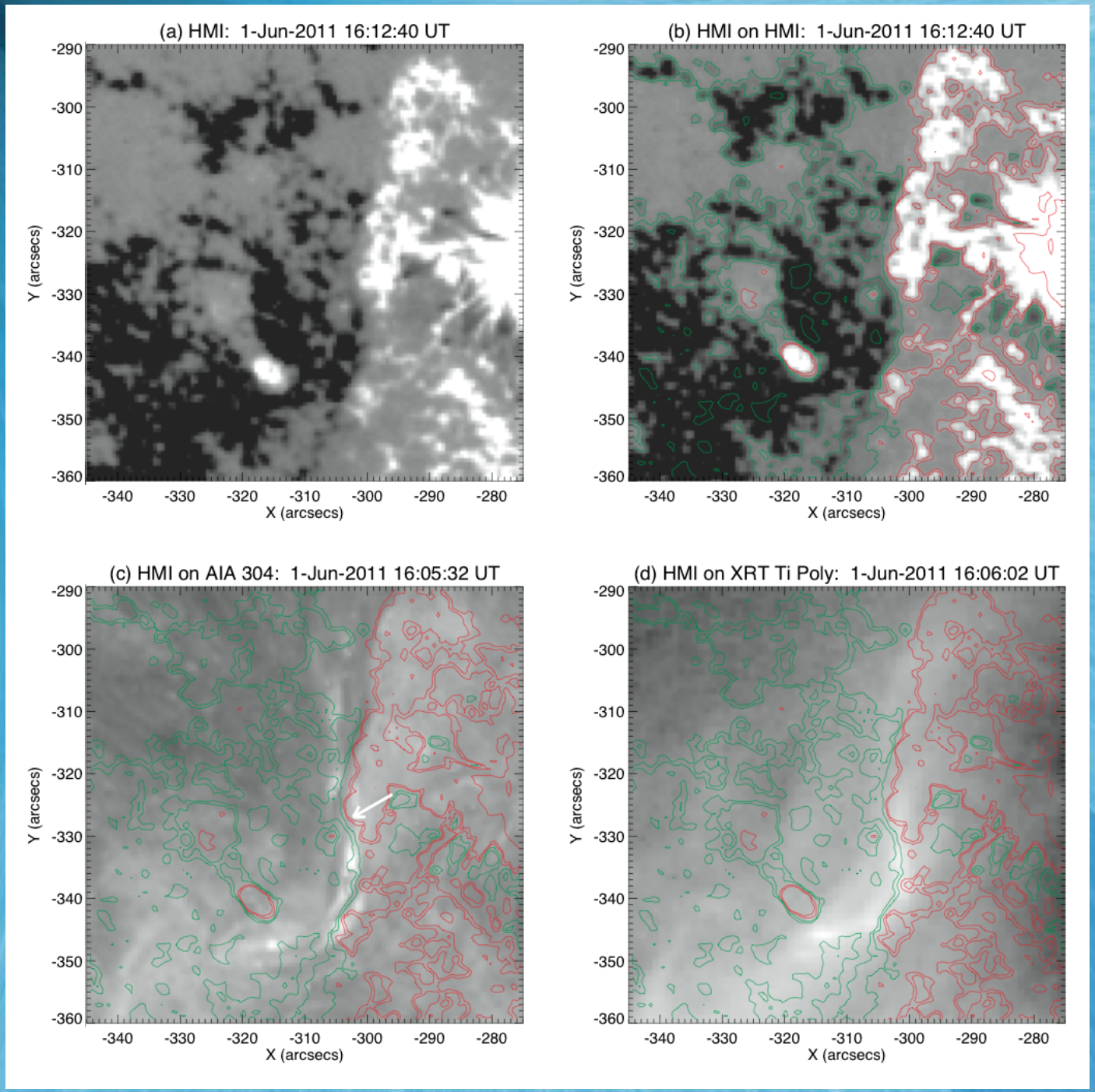

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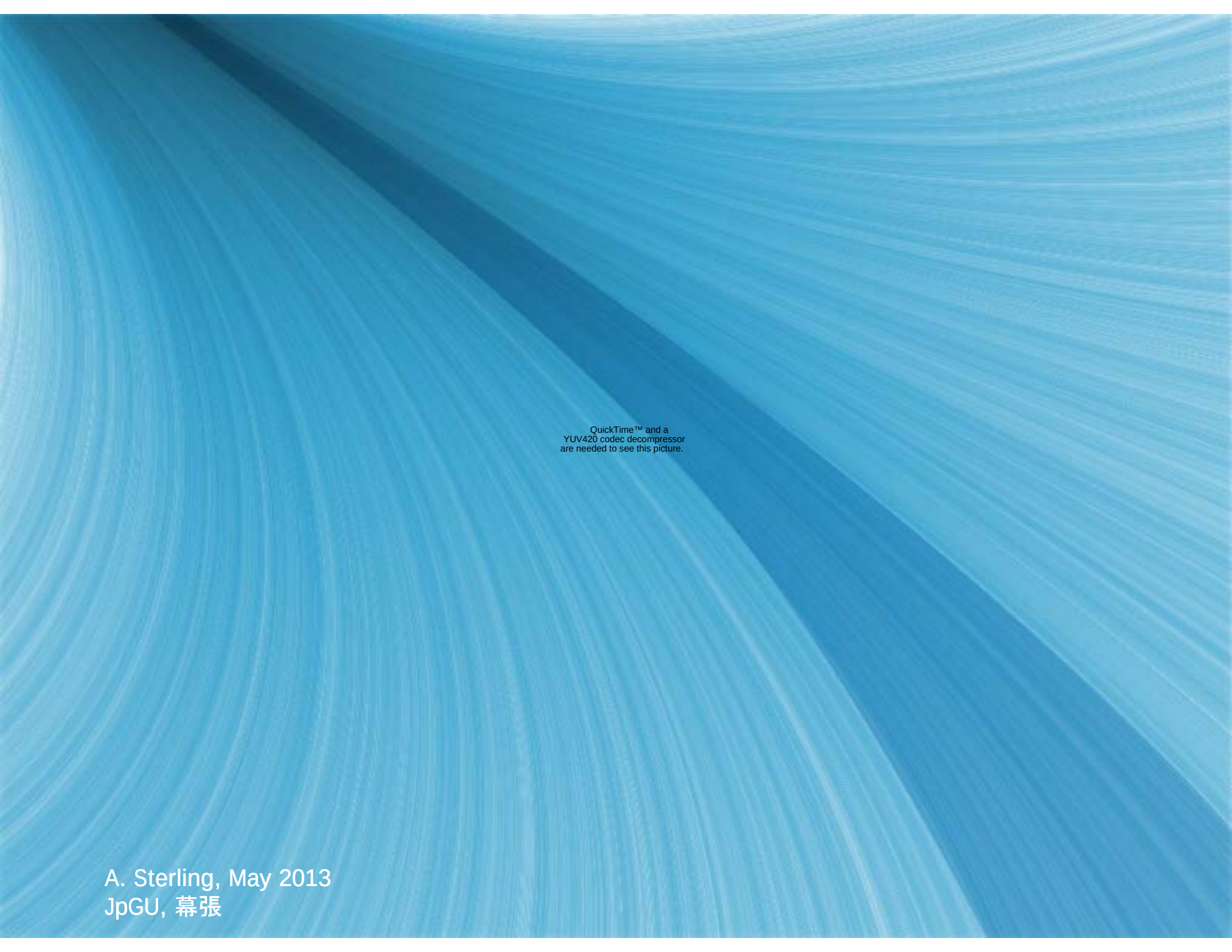

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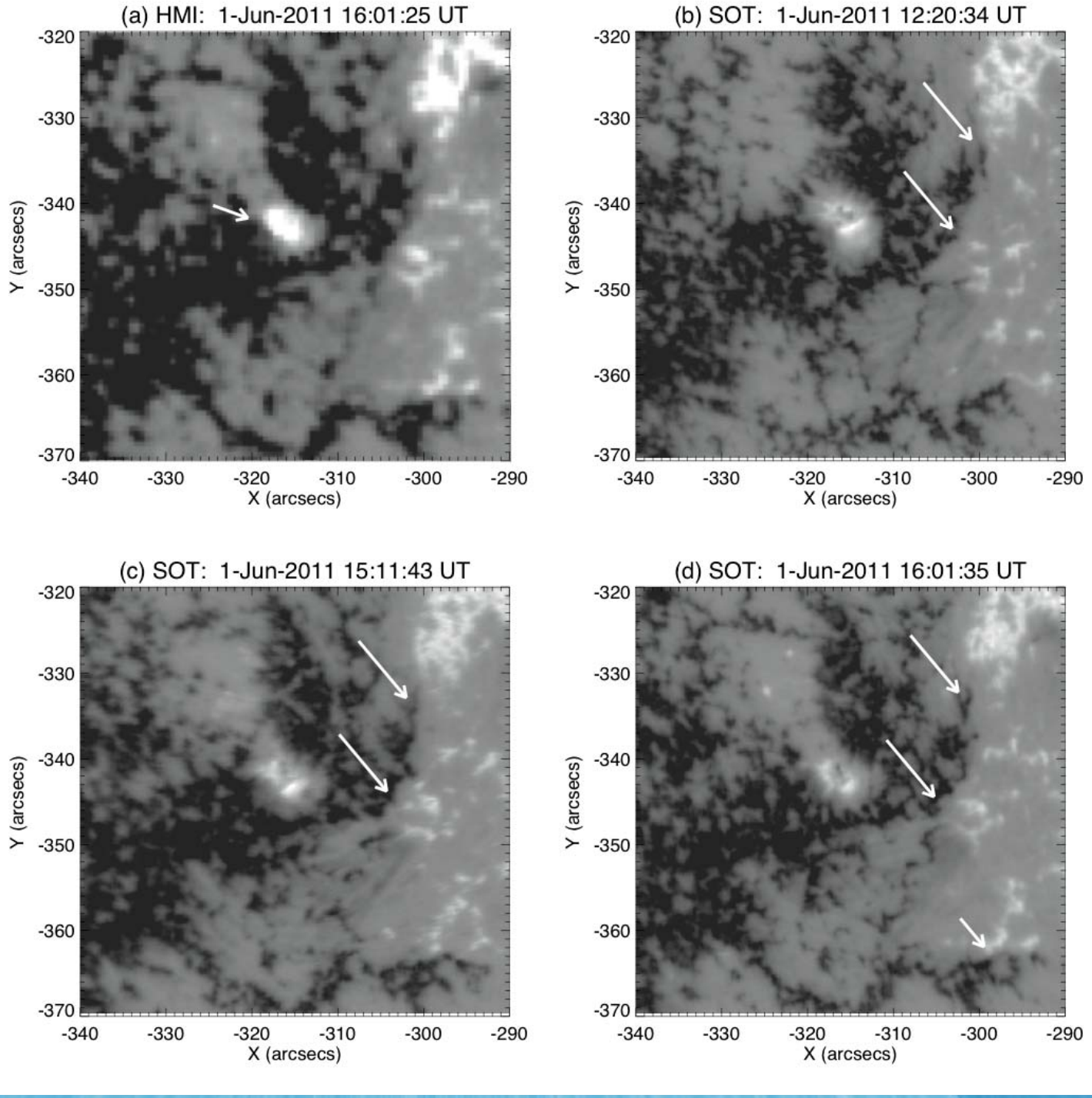

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Conclusions (2011 Jun 1 event)

- Something leads to reconnection; not totally clear what.
- Reconnection -> twisted flux rope in ~20 min; episode 1 microflare (flare ribbons; TC) and filament jump.
- Twist -> writhe, via kink instability; filament-trajectory plateau, ~ 20 min.
- Writhe -> jump and eruption of filament 1, via instability; episode 2 microflare (flare ribbons; TC). (E.g., Williams et al.)
- First eruption -> second filament eruption (episode 3 flare ribbons; TC). (E.g., Sterling, Moore; Liu et al.; Torok et al.; Schrijver & Title.)

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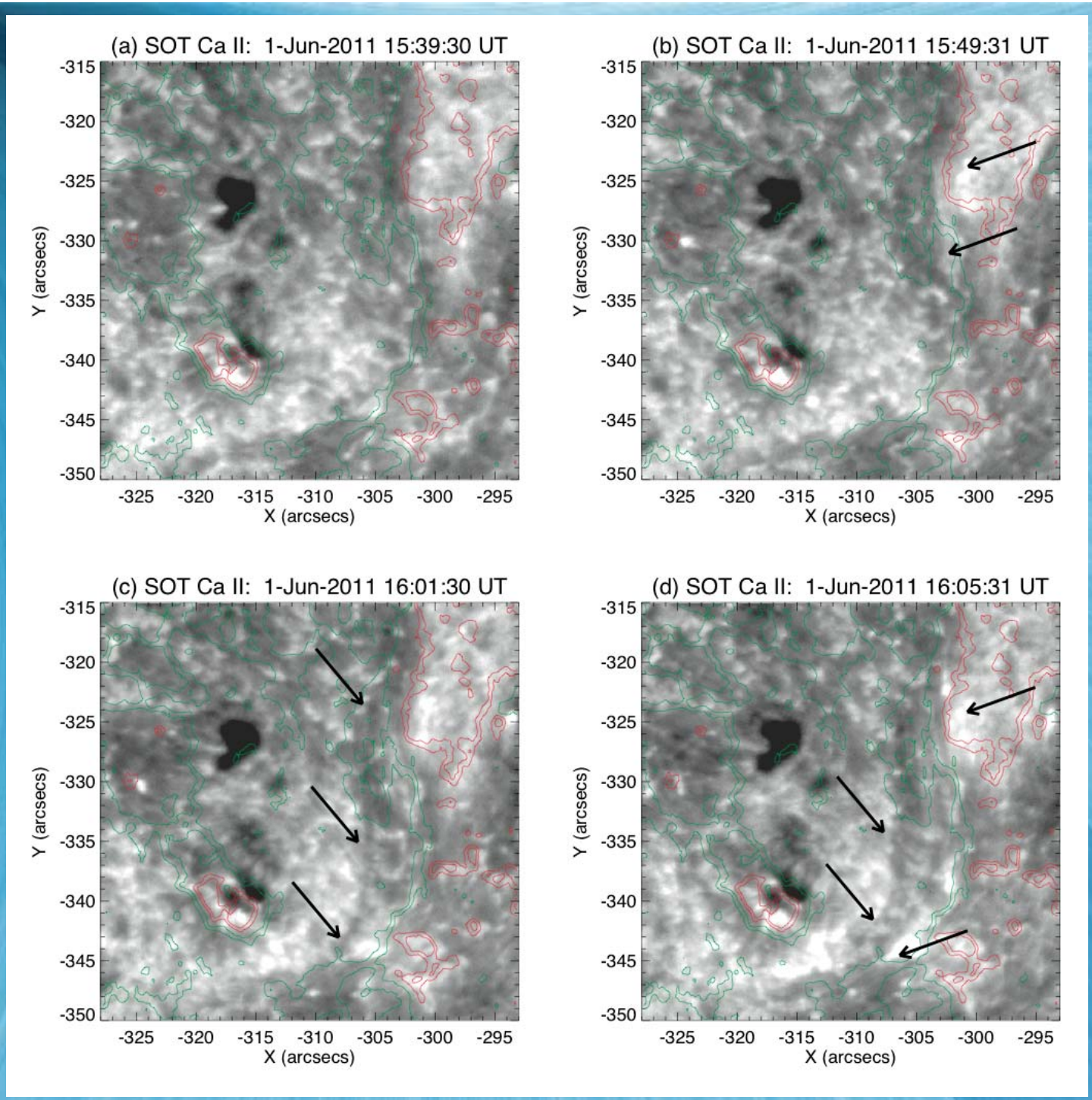

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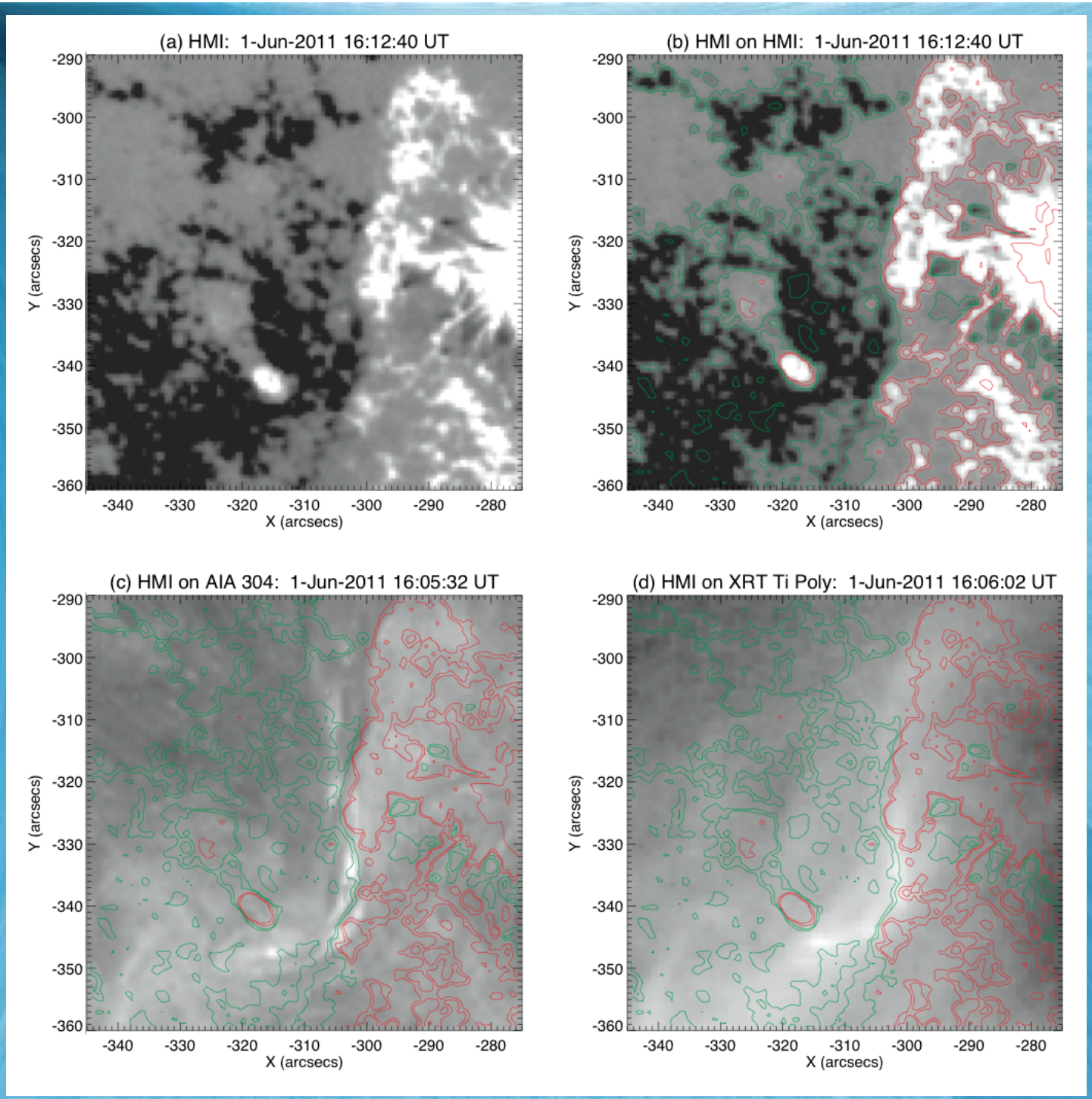

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