New Aspects of a Lid-Removal Mechanism in the Onset of an Eruption Sequence that Produced a Large Solar Energetic Particle (SEP) Event

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An Active Region Ejective Eruption

- Active region eruption of 2012 January 23.
- Ejective eruption.
- GOES class M8.7 flare.
- CME has ``complexities.'' Very fast: 2100 km/s.
- Results in strong Solar Energetic Particle (SEP) event. (1 MeV proton flux of $>10^3$ pfu for 43 hrs.)

- Only ~1%---2% of all CMEs generate SEPs, so this event is "special."
- SEPs not the focus here. See Joshi et al. (2013). Also see Liu et al. (2013) for other interplanetary aspects.
- ("Lid removal" discussion to follow in a bit.)

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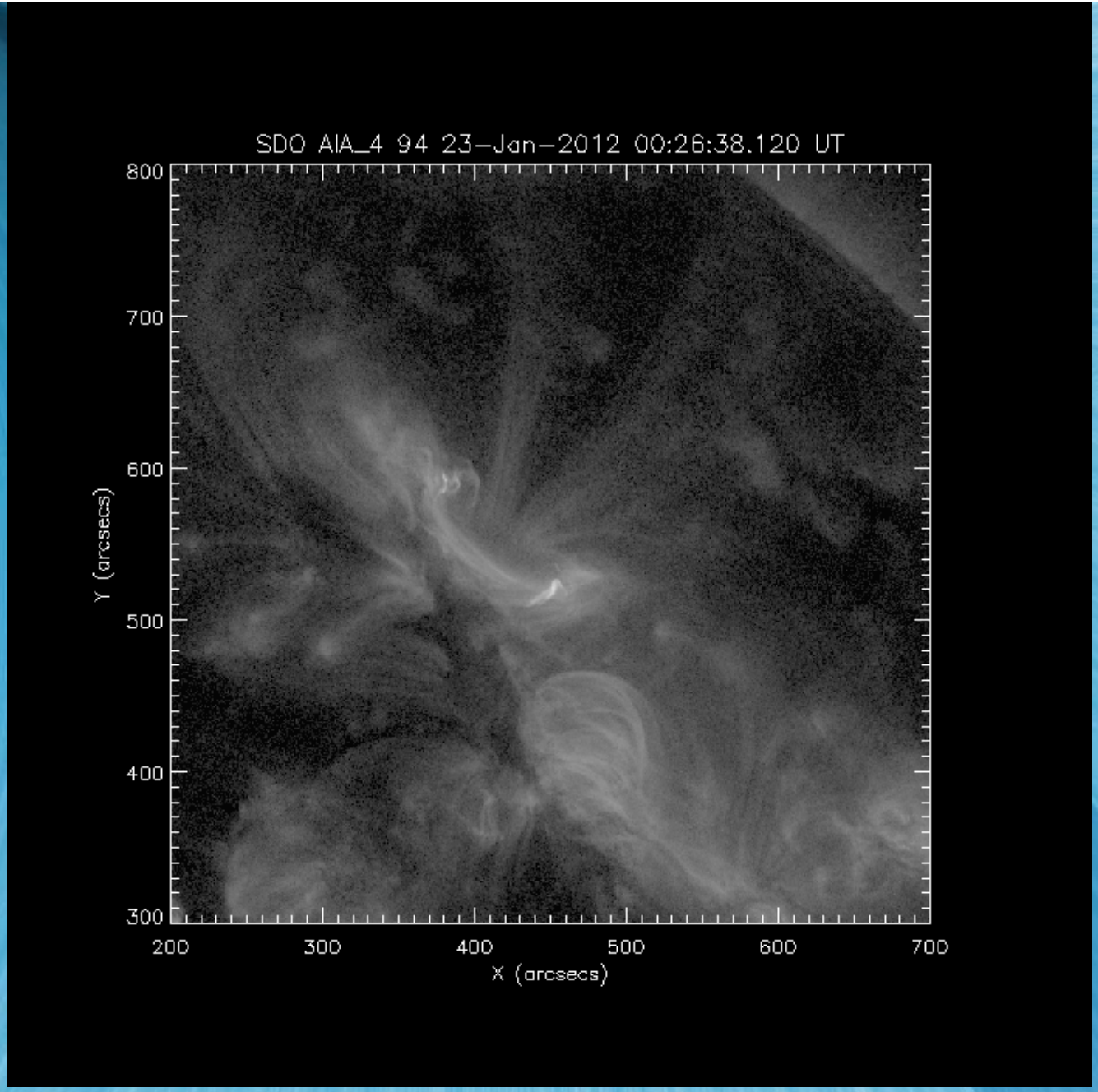
Our Focus: Overview of the eruption onset: Eruption dynamics and magnetic topology

- AIA: Adequate time cadence (145 s) and high spatial resolution (0”.6 pixels).
- SDO/HMI line-of-sight magnetograms.
- On-disk from SDO; limb event from STEREO A.
- SDO/AIA, various filters (304, 171, **193**, 211, 131, 335, **94** Ang).
- Two distinct eruptions (“two flux ropes,” Li & Zhang 2013, Cheng et al. 2013); Eruption 1 and Eruption 2.
- Eruption 2 includes eruption of a filament.



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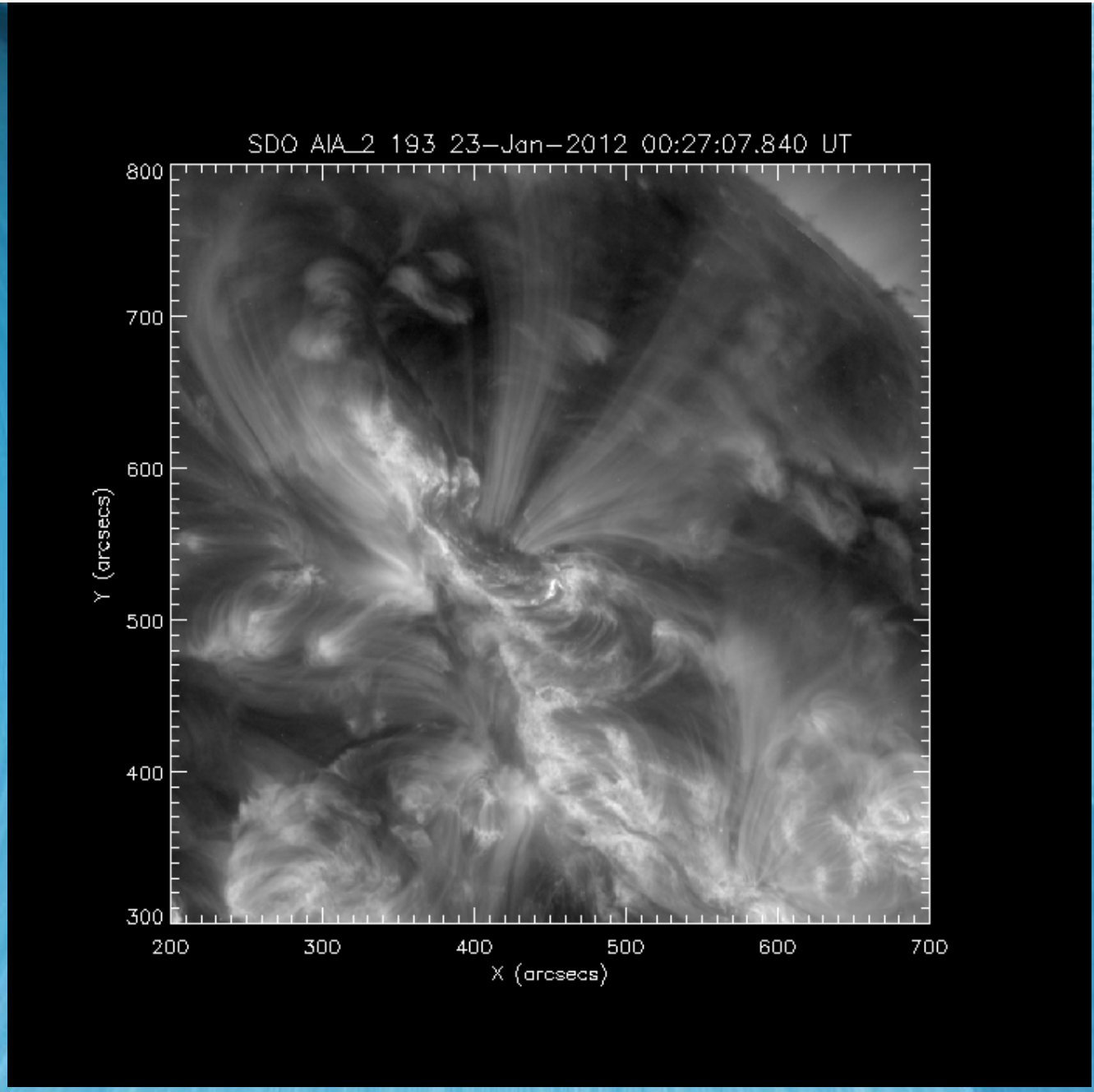

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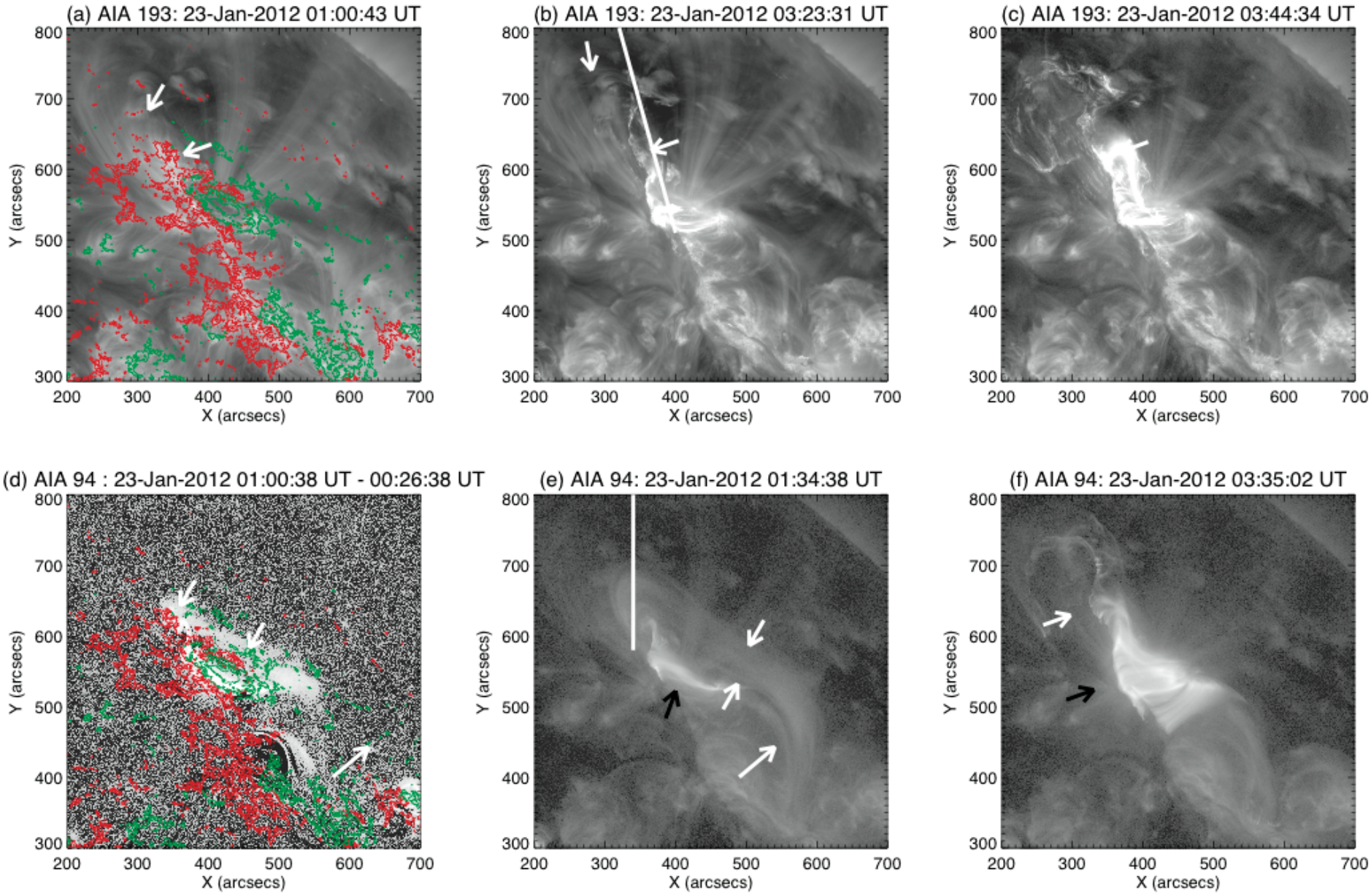

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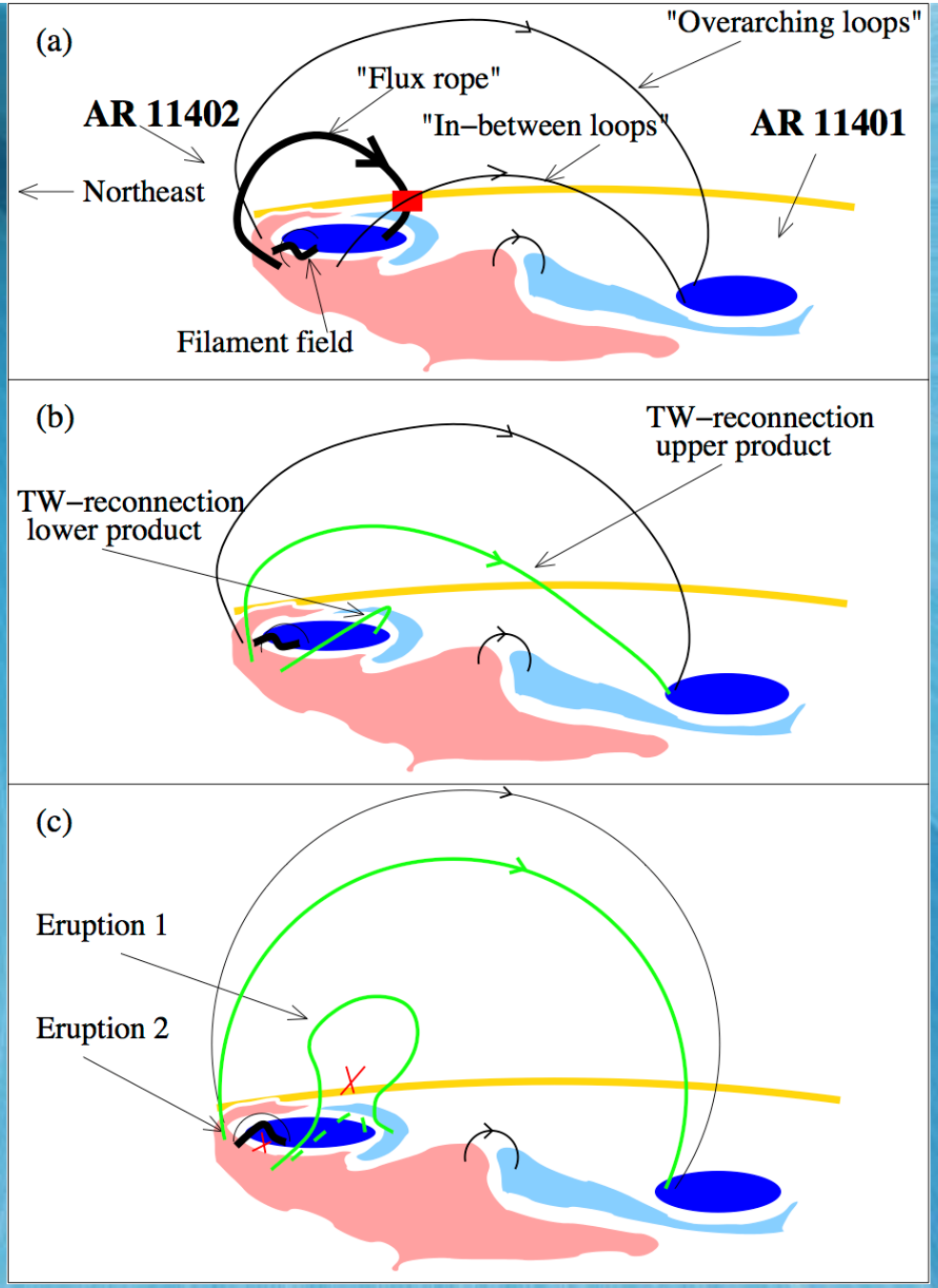

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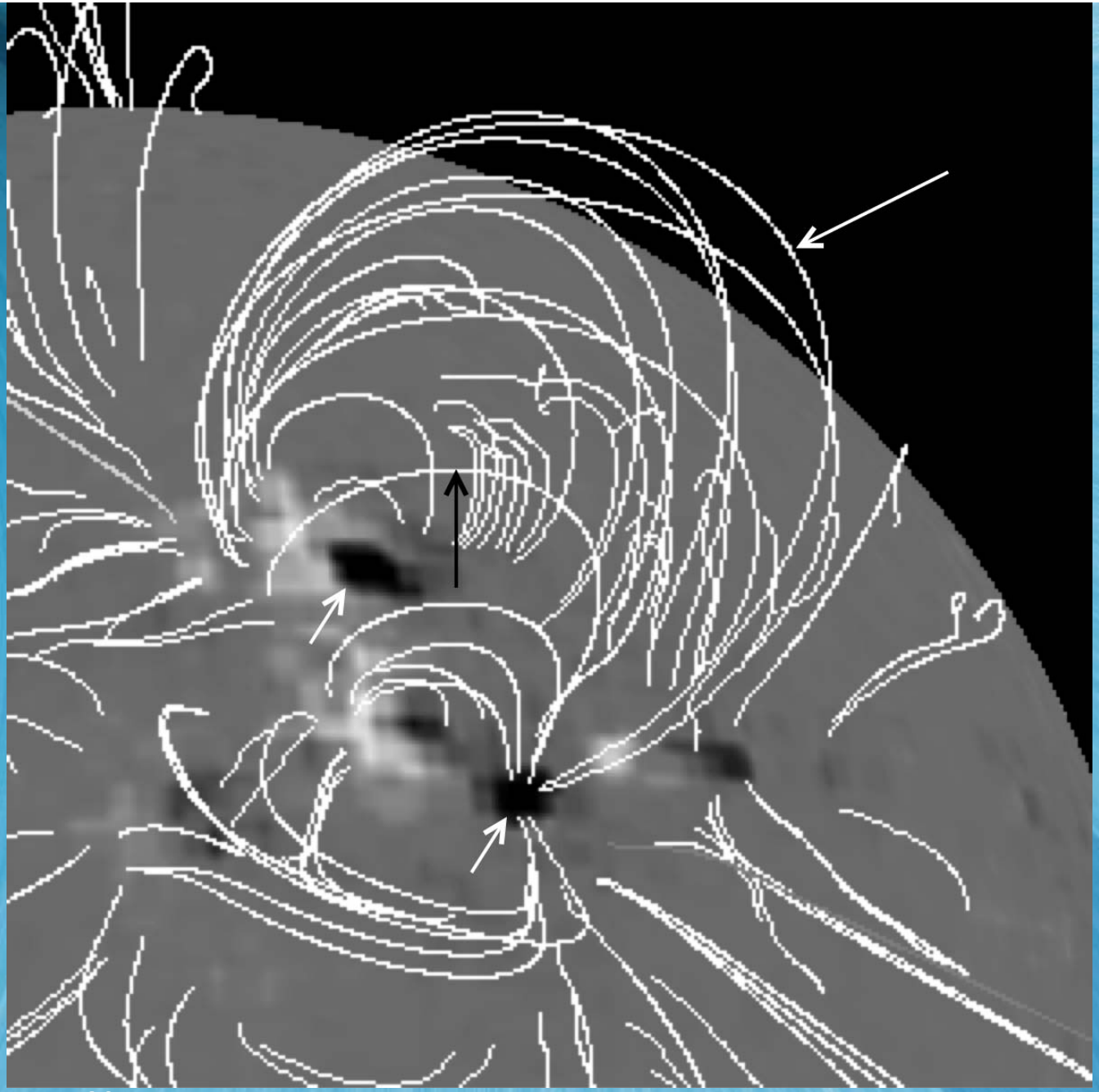

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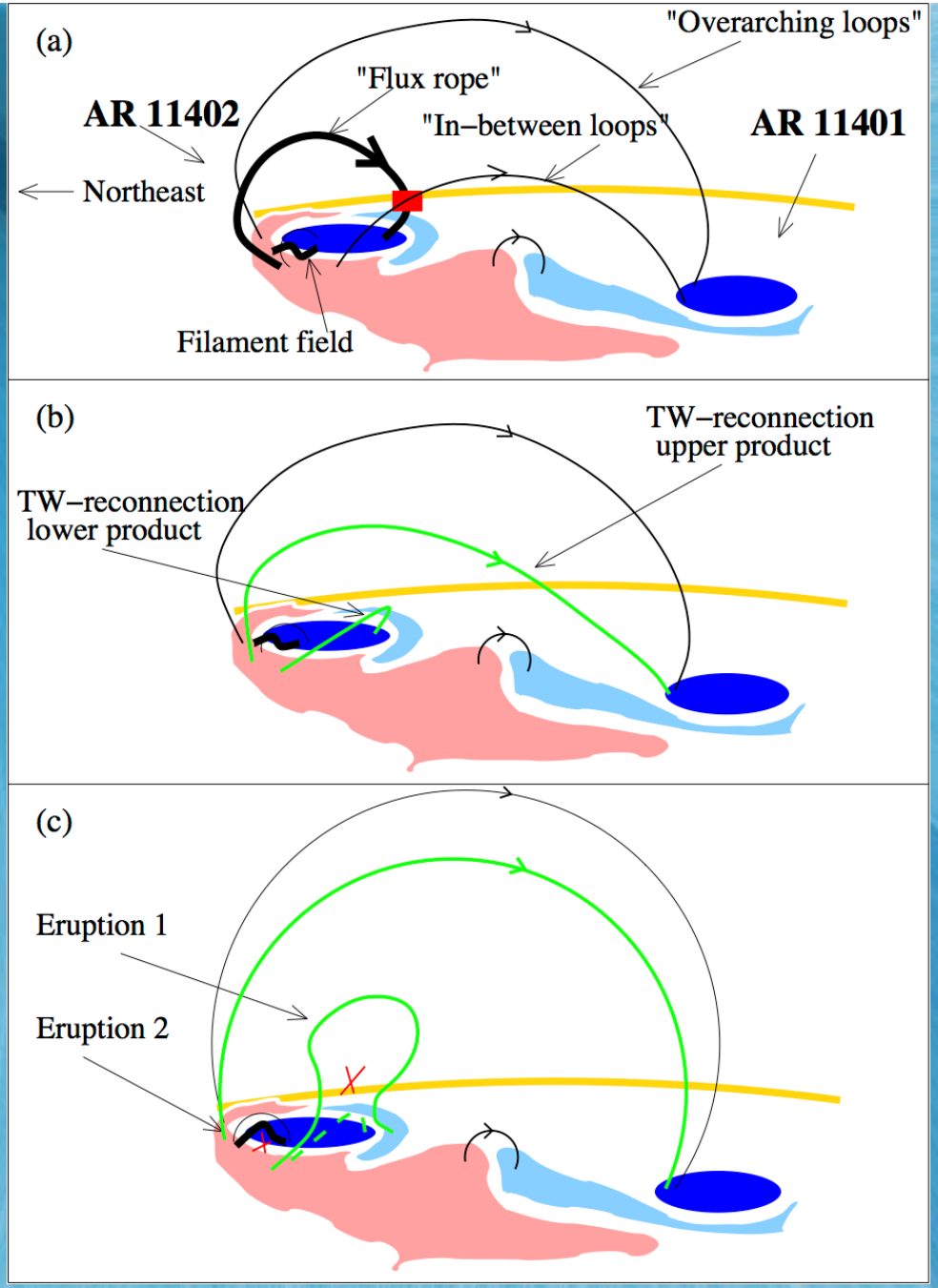

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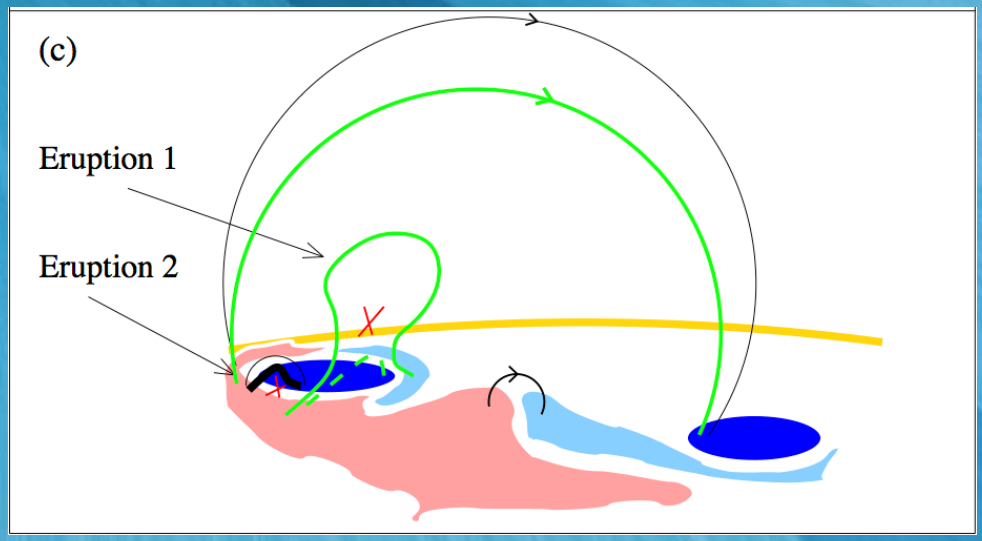
Eruption 2 Via "Lid Removal"

- Cheng et al. (2013) describe how Eruption 1 removes field above the Eruption 2 flux rope.
- They show B gradient with height is steep enough for Eruption 2 flux rope to be subject to torus instability, allowing its eruption. (Eruption due to ideal MHD instability.)
- We call their explanation for Eruption 2 (including filament) "lid removal."
- Fundamentally different from eruption-trigger mechanisms we have examined (e.g., tether cutting, breakout...).
- Similar however to other observations/descriptions (e.g., Schrijver & Title 2011, Török et al. 2011).

Can Lid Removal Work with Eruption 1 Flare Arcade?

- Standard flare model => Eruption 1 flare loops should form over filament arcade, perhaps preventing Eruption 2 ("confined eruption"). (S. Antiochos 2013, private comm.)



- Look to see what happens.
- Need "hot" AIA to see Eruption 1; need "cool" AIA to see filament.
- Use mixture; 70% hot (=131 Ang), 30% cool (=193 Ang).

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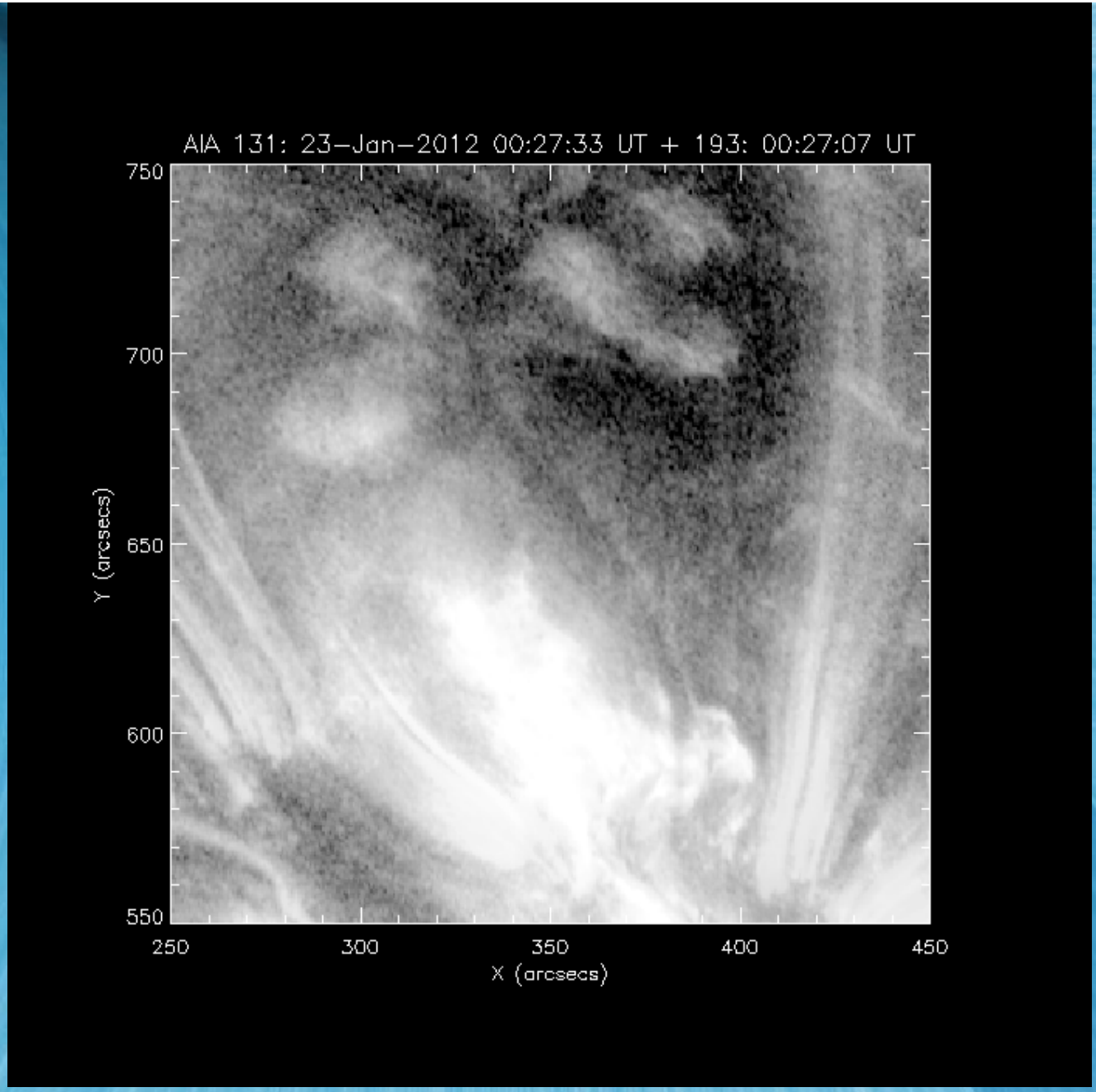

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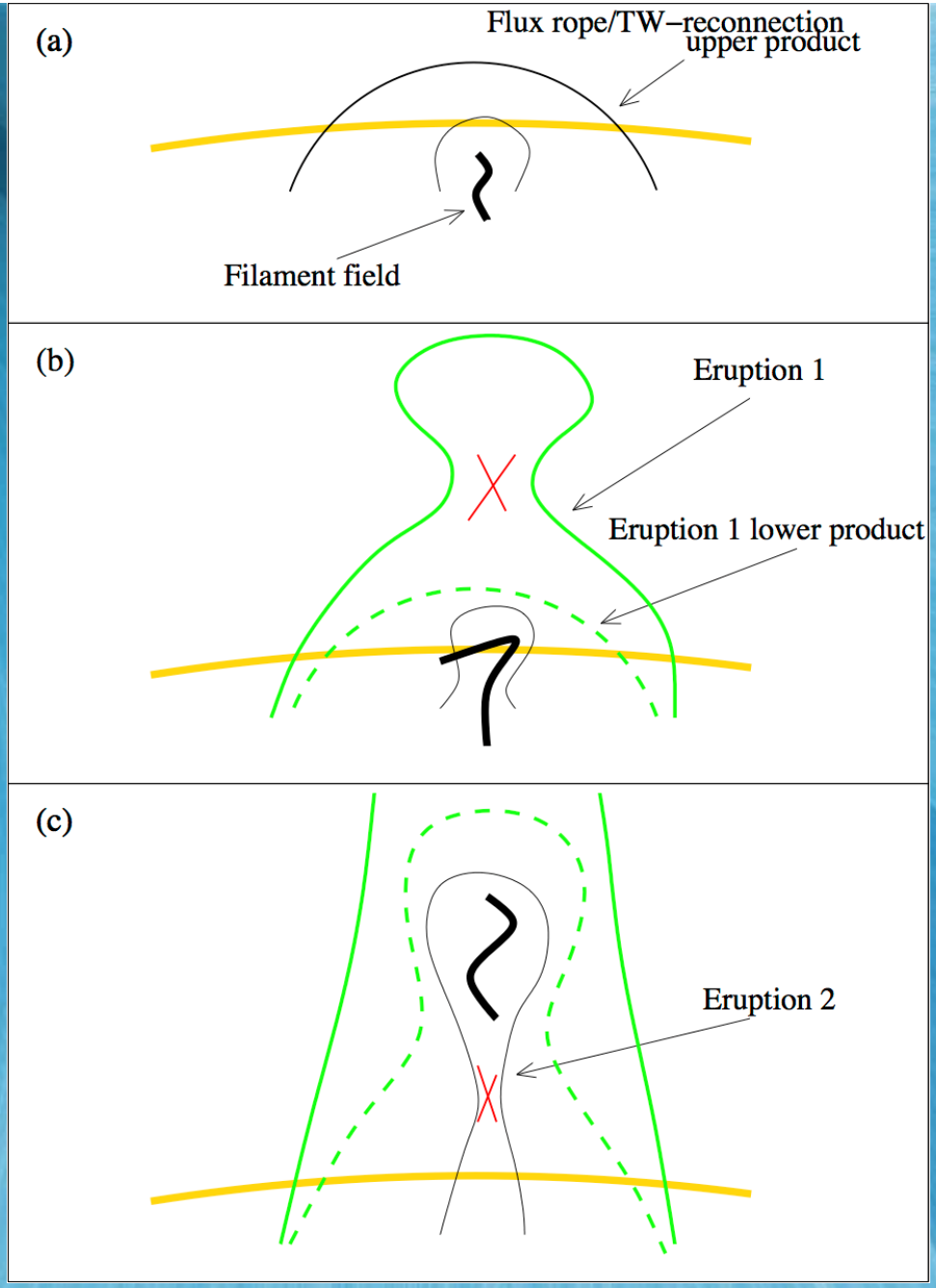

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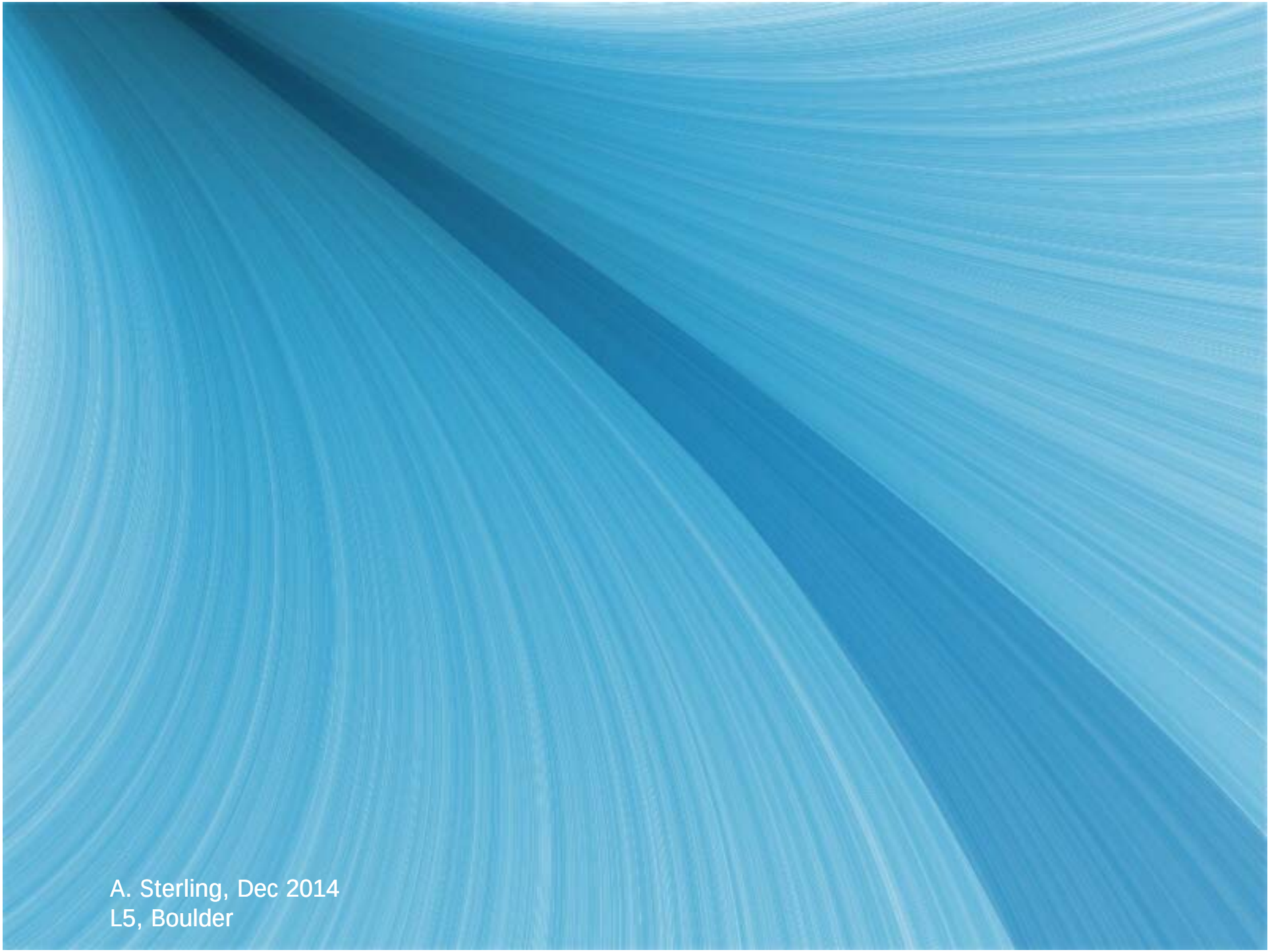
Summary (2012 Jan 23 event)

- Two eruptions, with first only seen in AIA hot channels.
- Eruption 1 field reconnects with neighboring region, ("tether-weakening reconnection," Moore et al. 1992).
- Eruption 1 removes field above filament arcade, leading to destabilization and onset of eruption 2; *Lid Removal*.
- Eruption 2 blows out Eruption 1 flare loops.
- Regarding SEPs: Double CMEs likely critical (e.g., Kahler 2001; Gopalswamy et al. 2002, 2003, 2004; Li et al. 2012). Effects on above points not yet known.
- Sterling et al. (2014) provide more details.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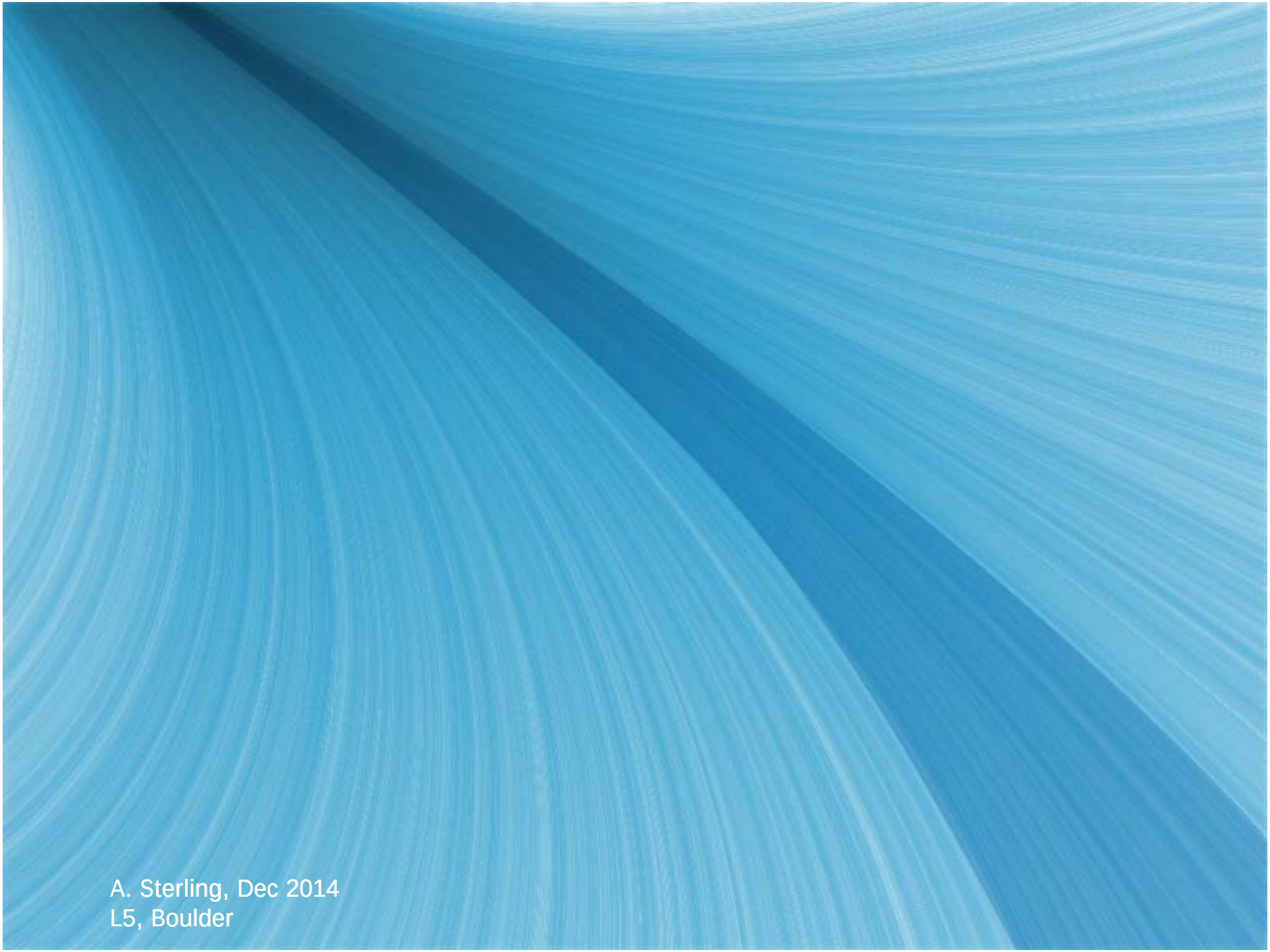
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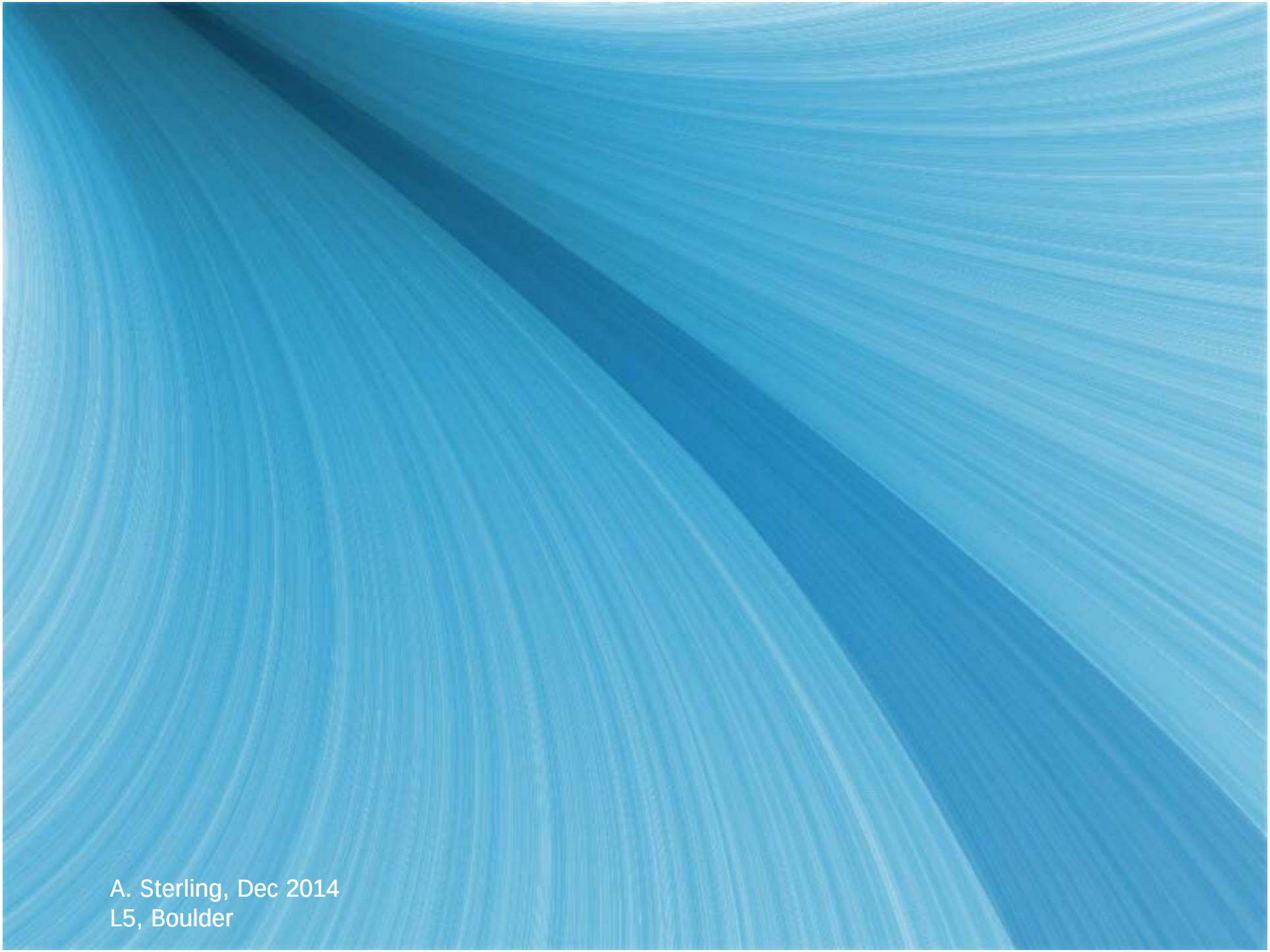
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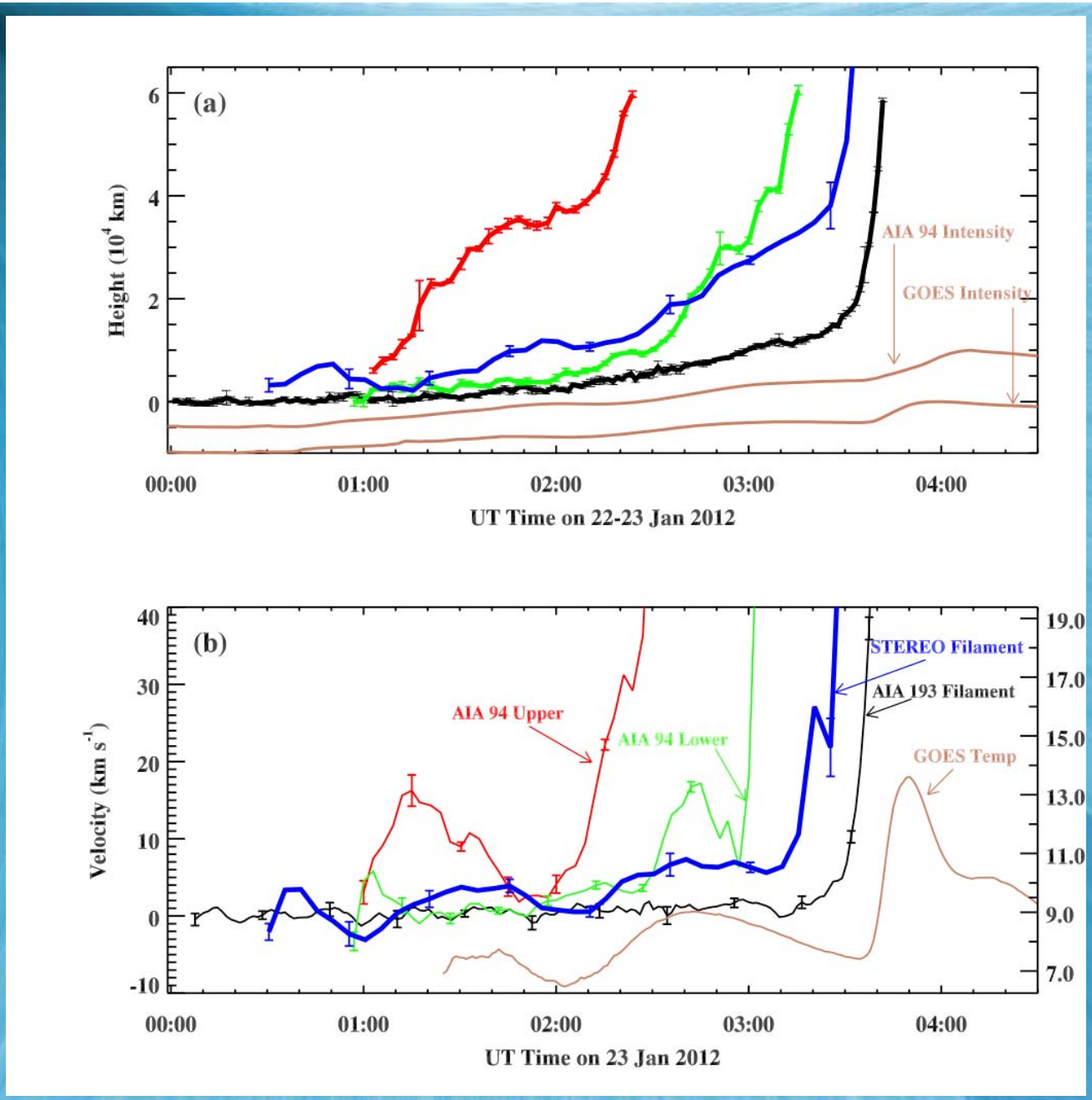

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What causes Eruption 1 onset?

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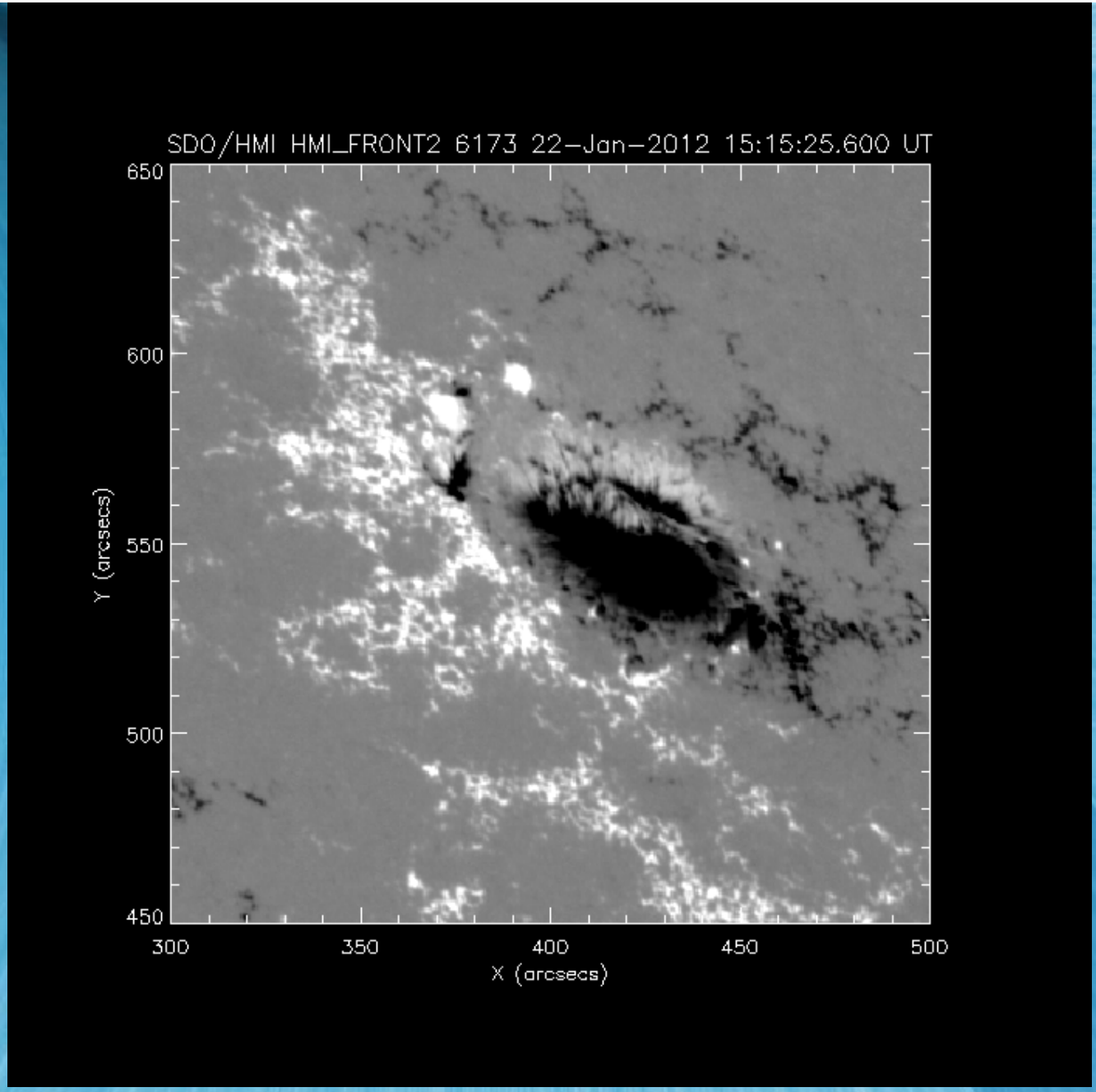

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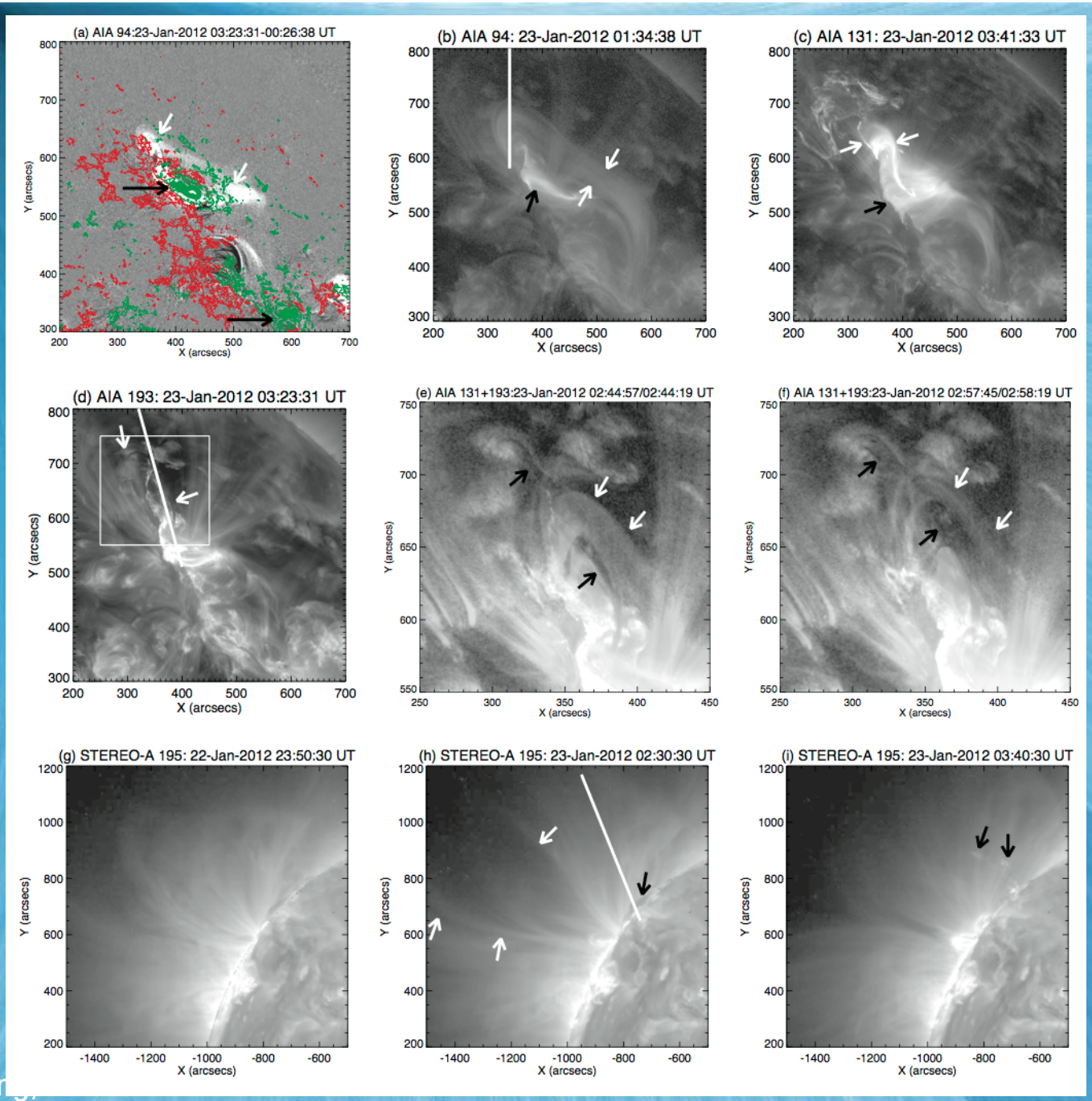

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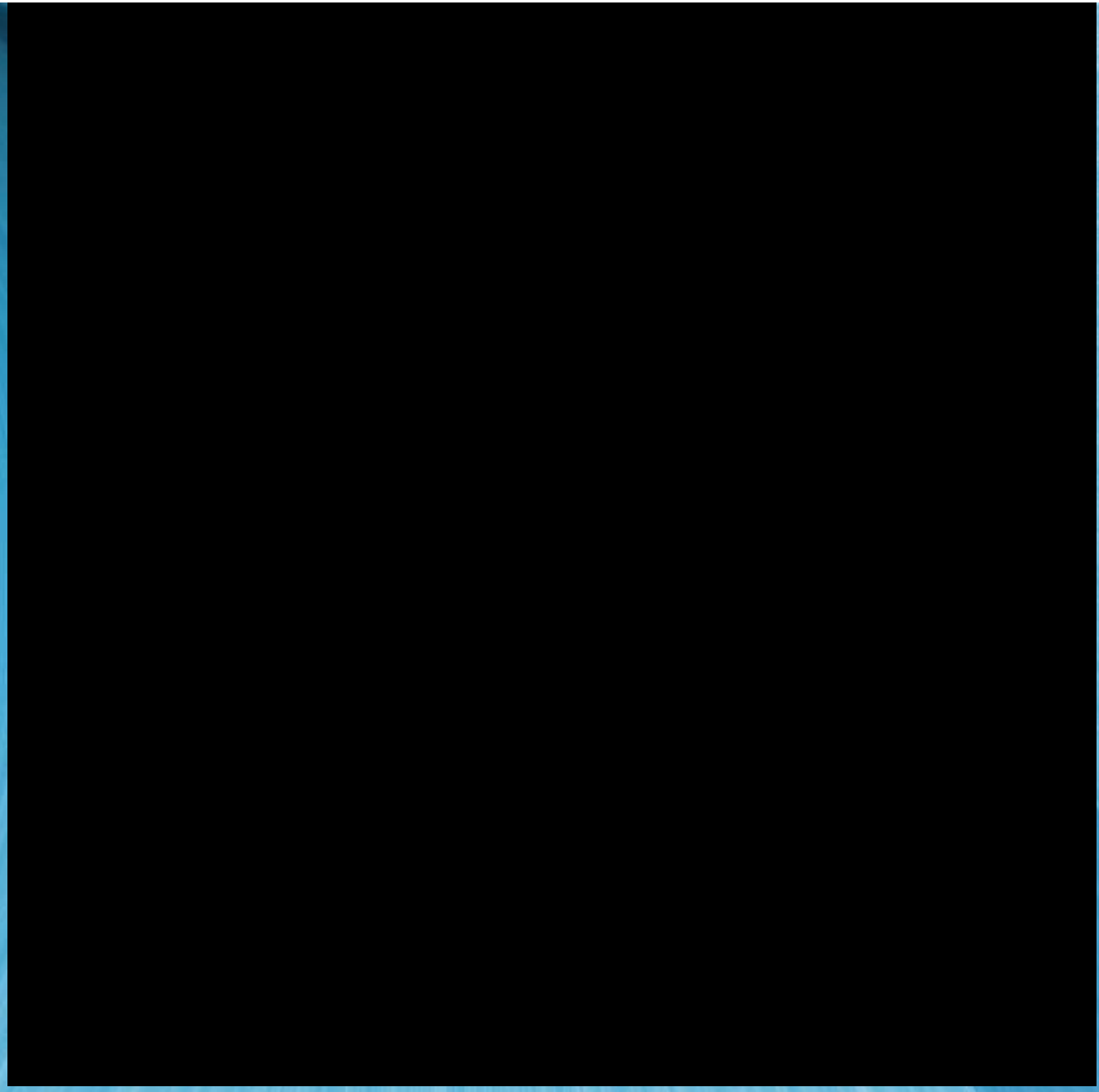

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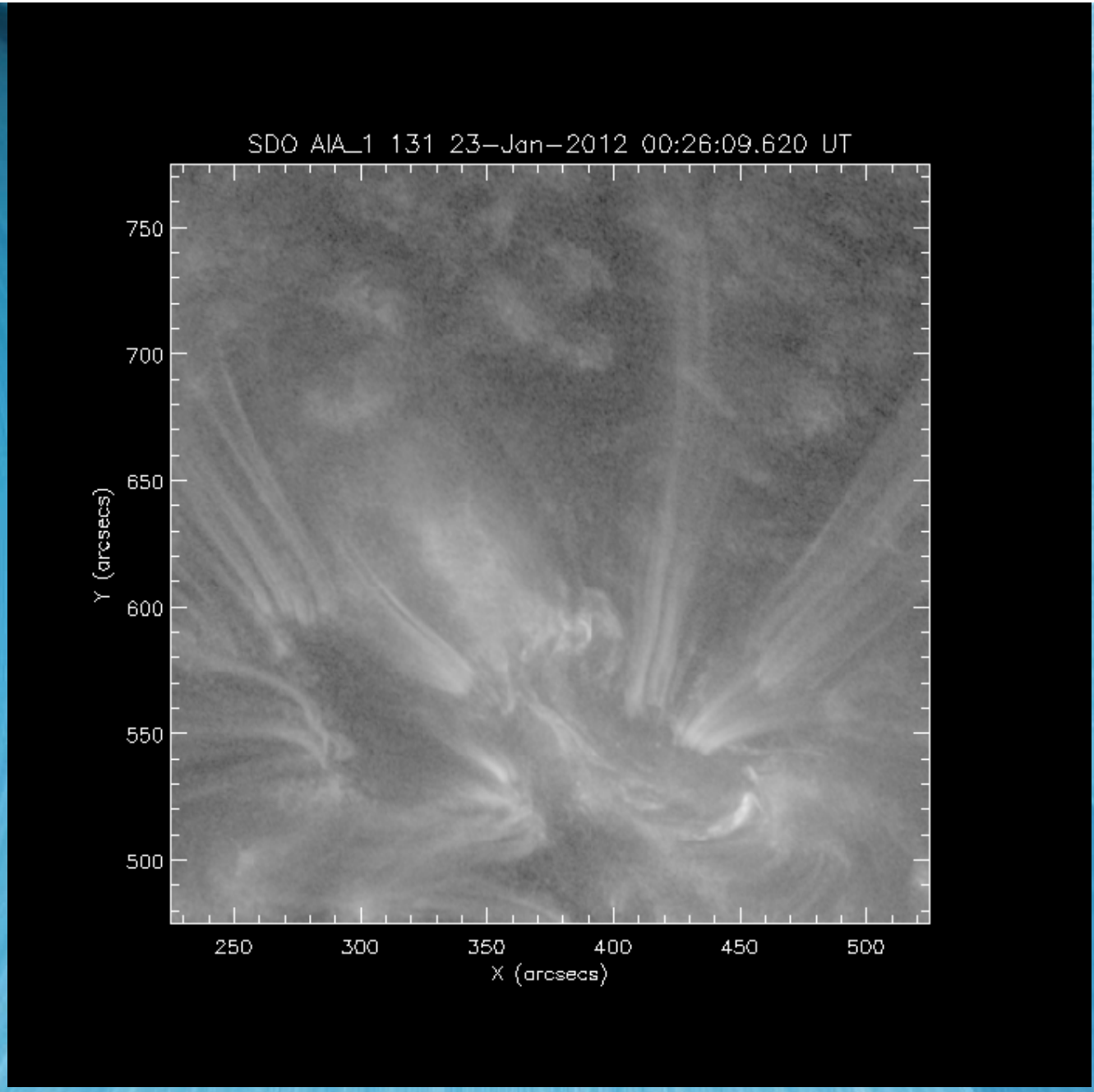

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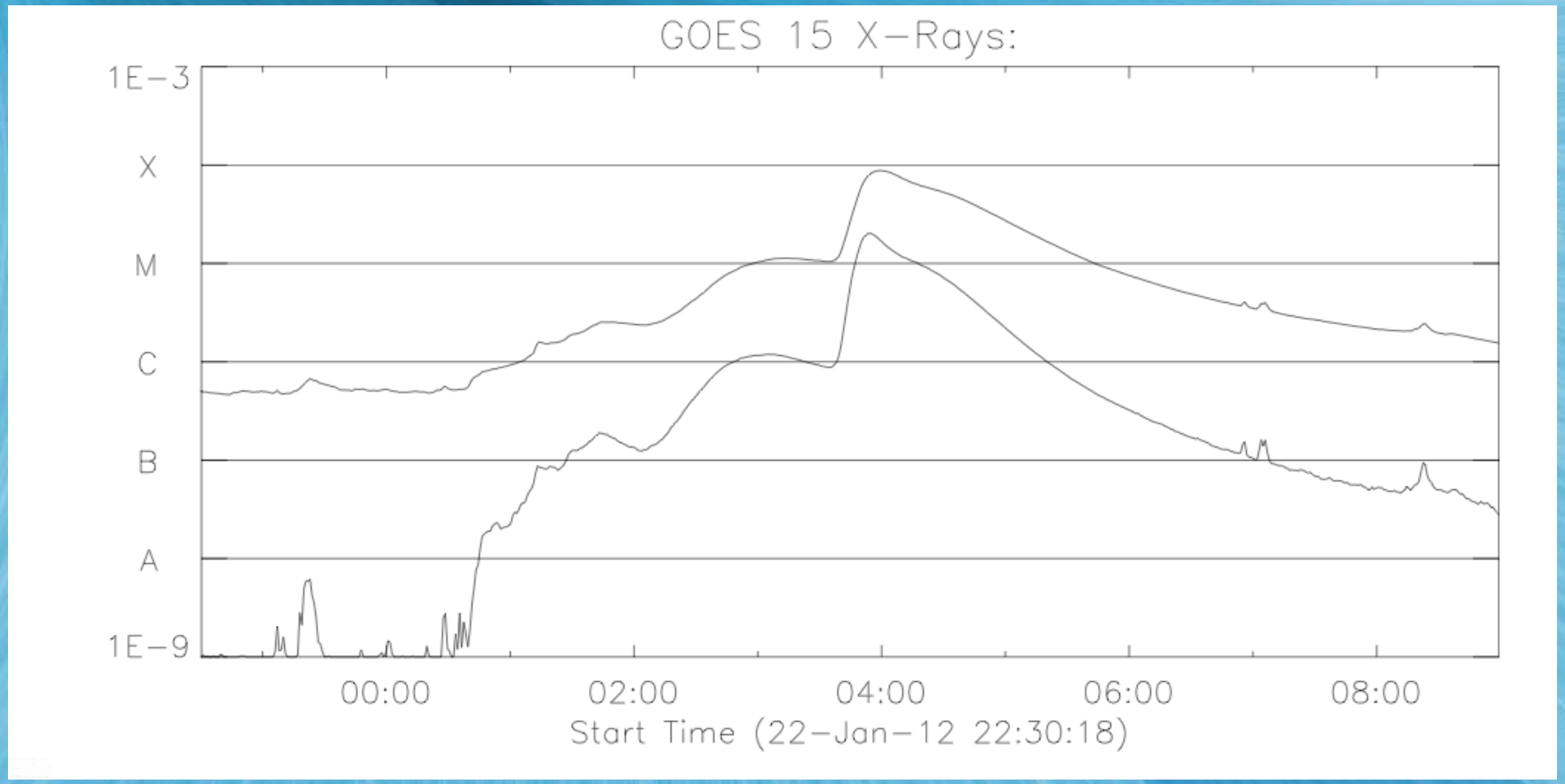

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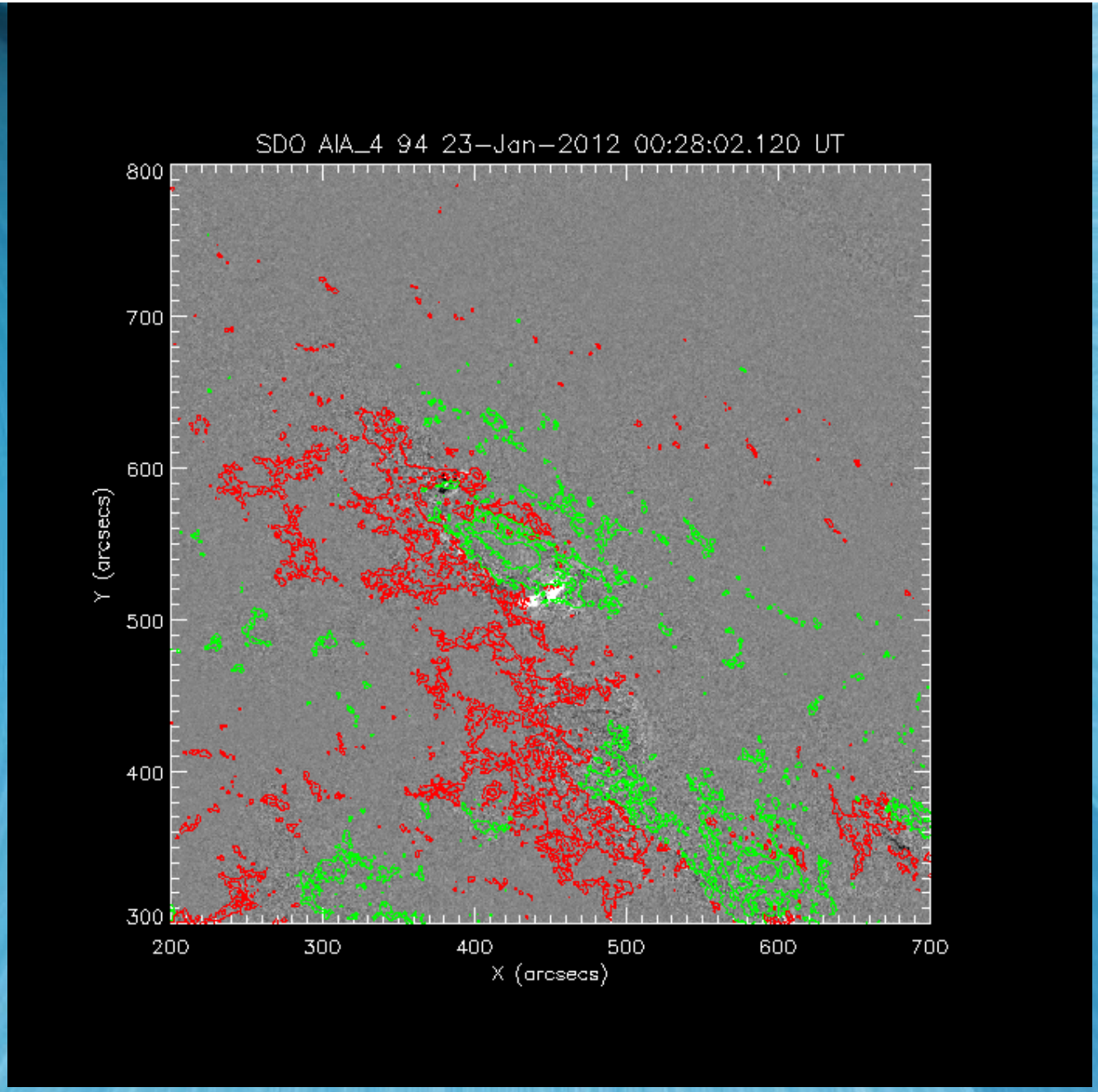

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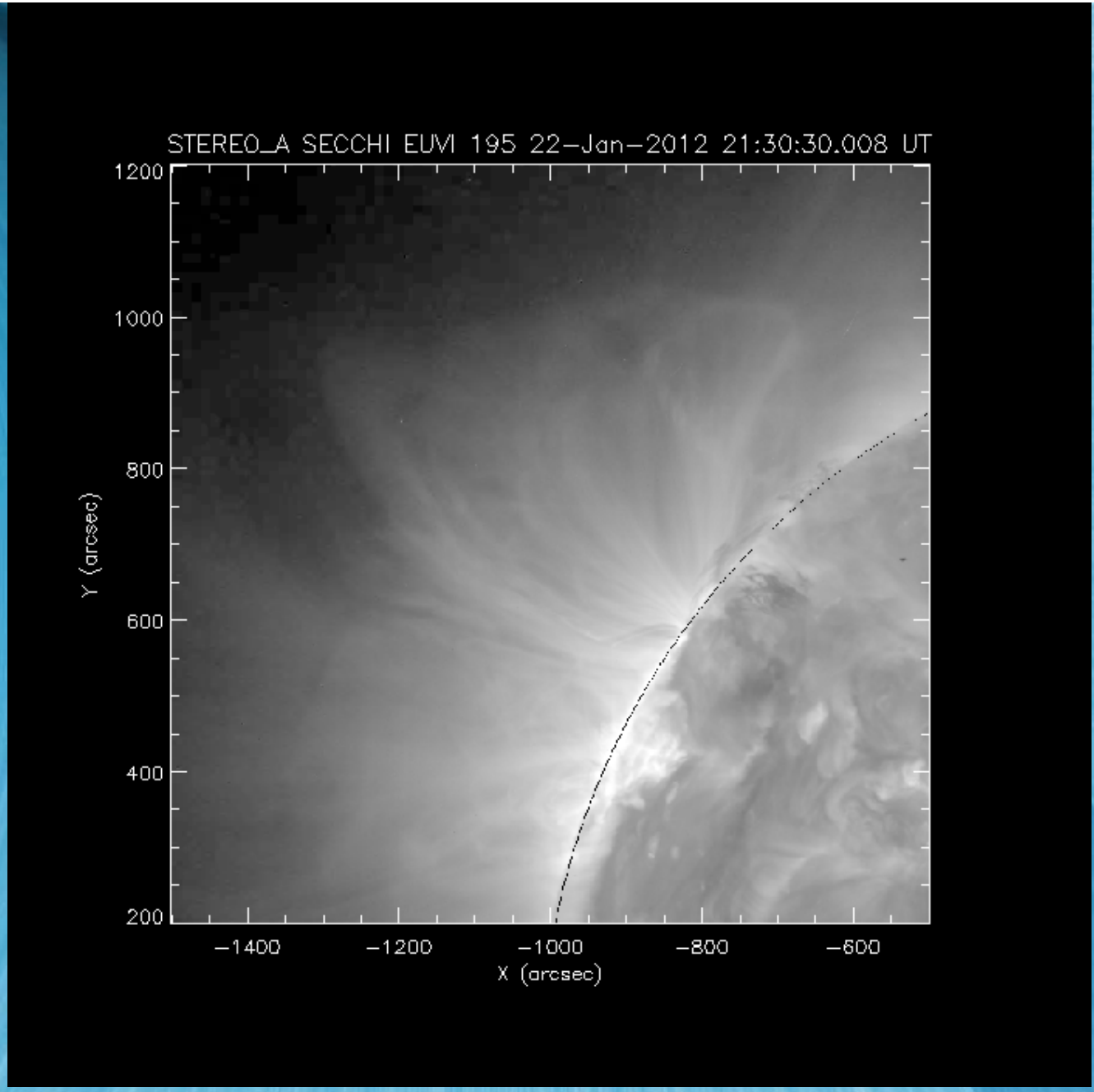

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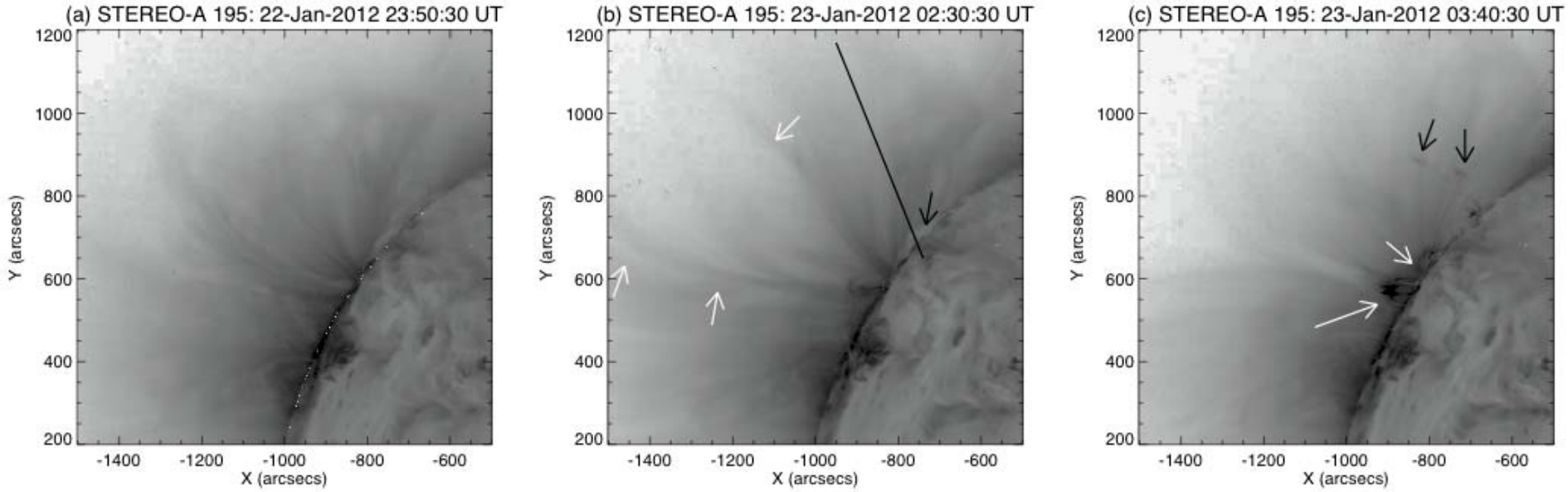

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- There are two eruptions (“eruption 1” and “eruption 2”), the latter including the filament. (Both components visible in LASCO CME images.)

- Eruption 1 nearly invisible in cooler on-disk EUV images, but appears as field opening in limb view (STEREO A).

- An even earlier brightening is due to ``merging reconnection’’ (and eruption 1 flare).

- Filament eruption (eruption 2) is due to removal of overlaying flux by eruption 1.

- This ``Lid Removal’’ mechanism is a *candidate* for an ideal, non-resistive trigger. NB., it differs from the breakout mechanism.

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Conclusions (2012 Jan 23 event)

- Something causes eruption 1; could be flux cancelation from MMFs.
- Eruption 1 field merges with neighboring region, with hot-plasma signature (``merge reconnection'').
- Eruption 1 removes field above filament arcade.
- This leads to destabilization and onset of eruption 2, creating the strongest and hottest GOES flare via *Lid Removal*.
- Candidate for ideal onset mechanism.
- Similar processes: E.g. Schrijver & Title (2011); also Török et al. (2012).

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