

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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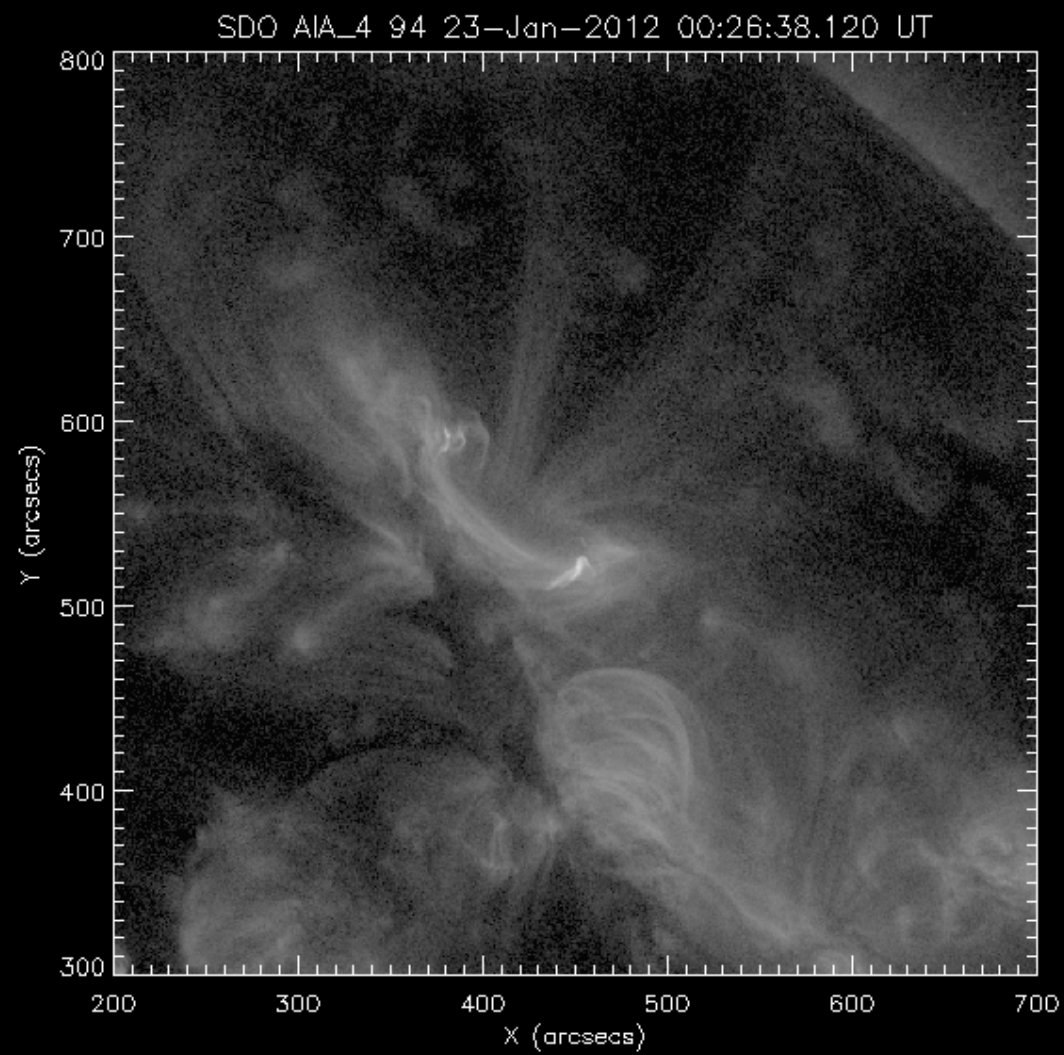
An Active Region Ejective Eruption

- ◆ 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.)

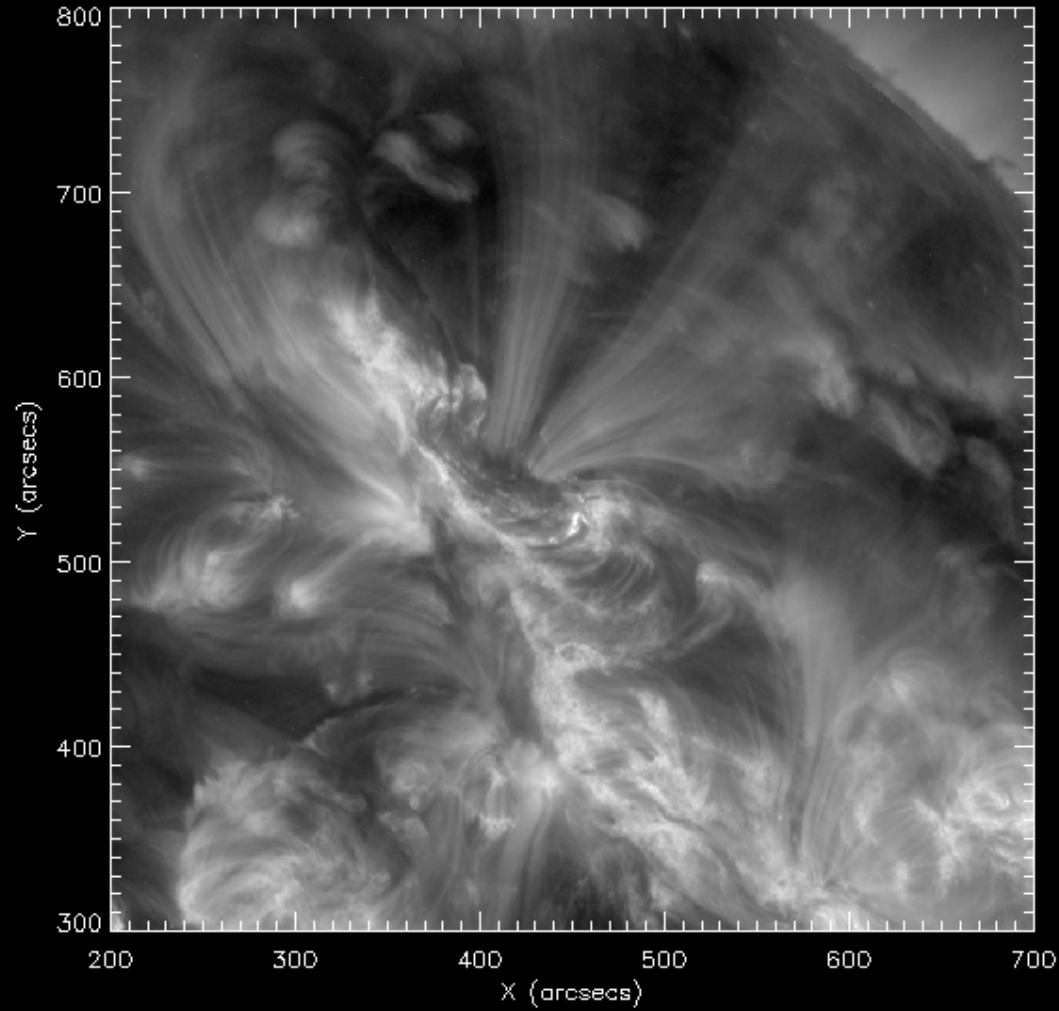
Our Focus: Overview of the eruption onset: Eruption dynamics and magnetic topology

- ◆ 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.

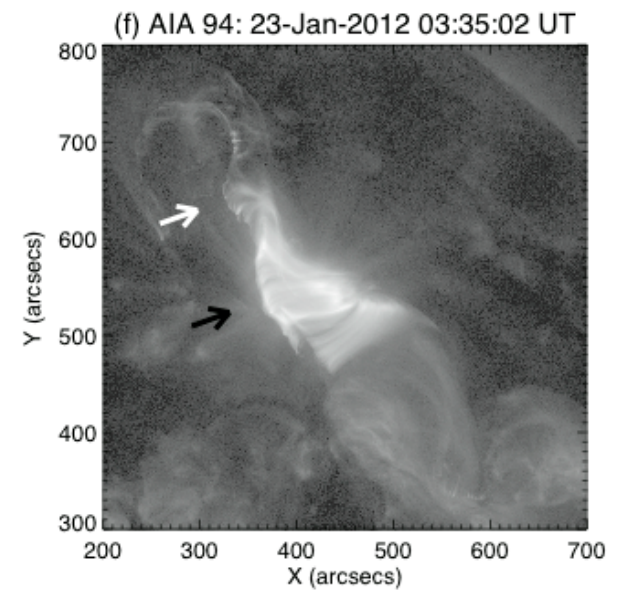
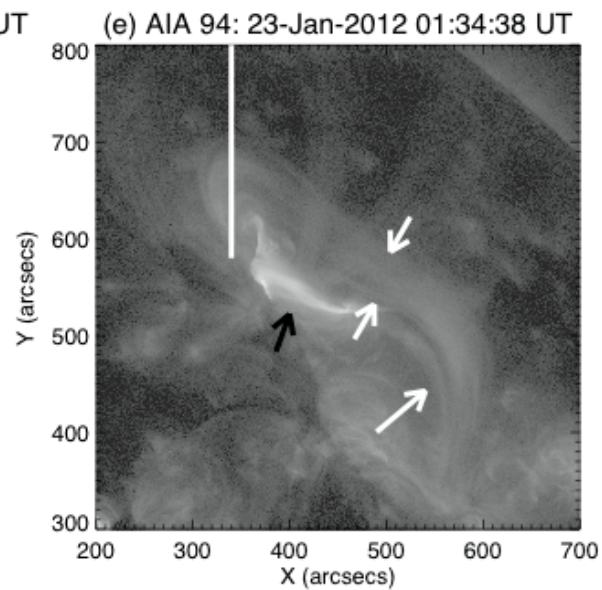
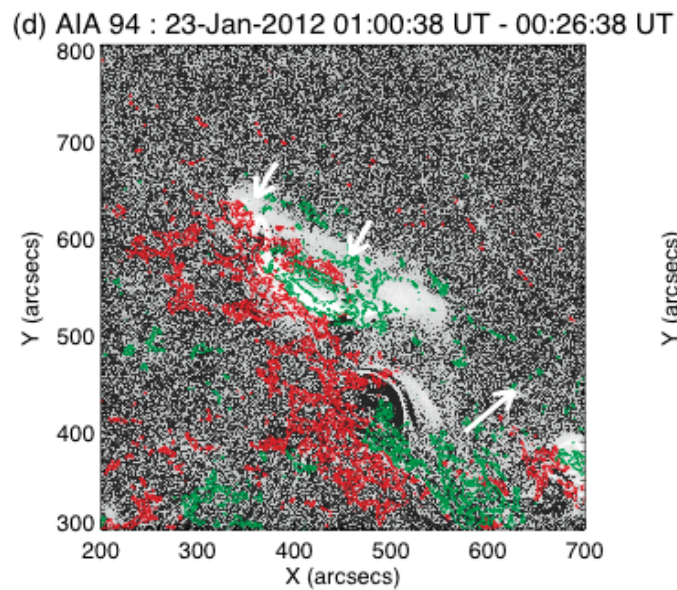
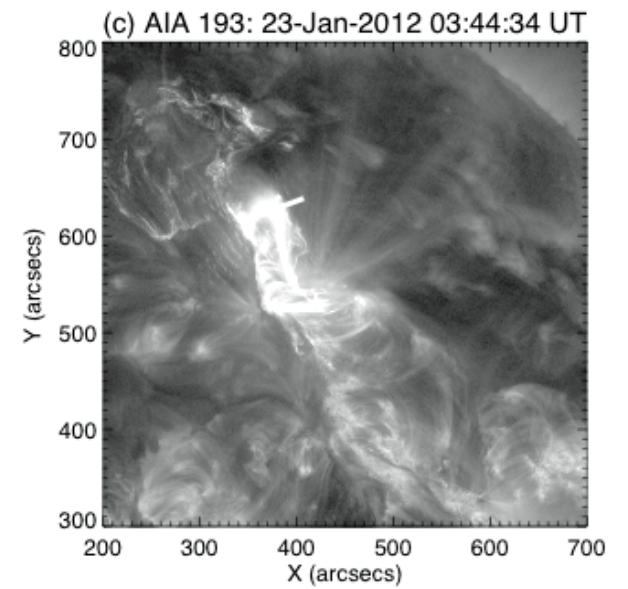
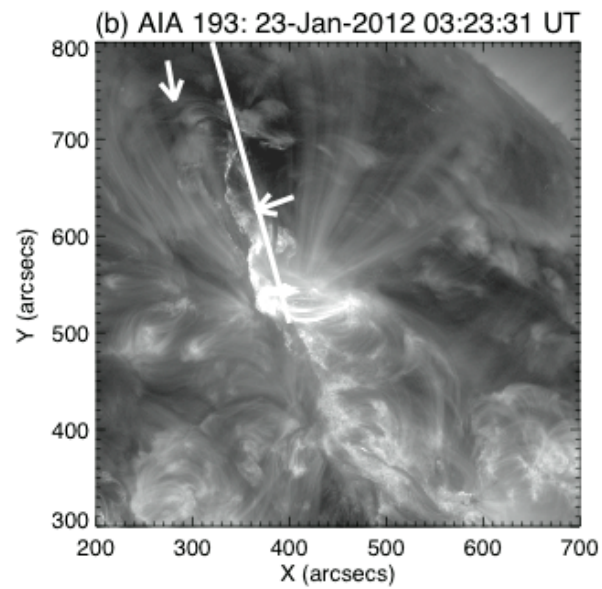
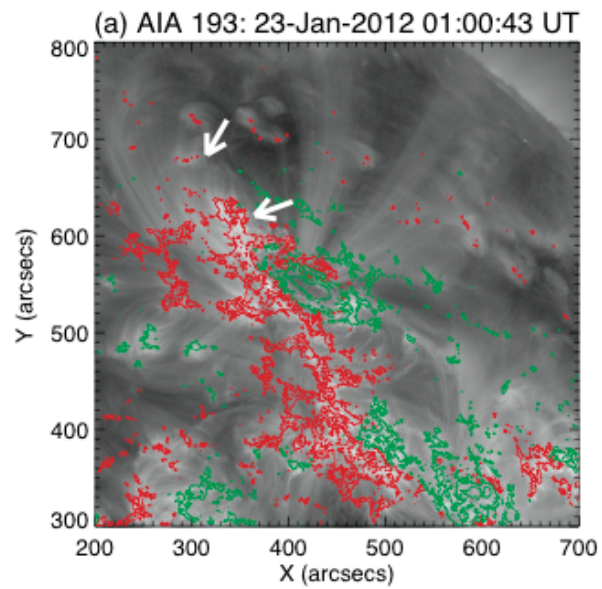


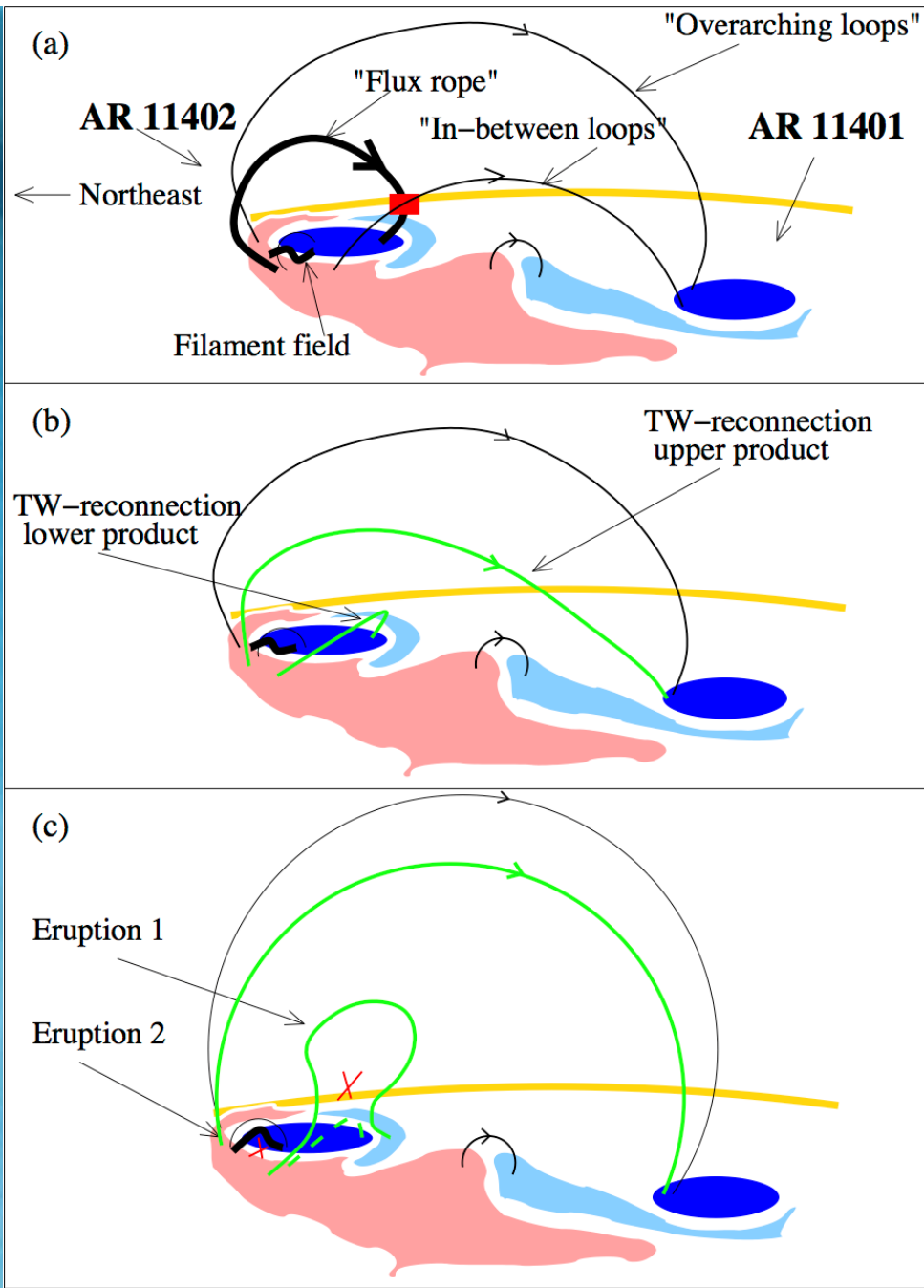
A. Sterling, Dec 2014
L5, Boulder

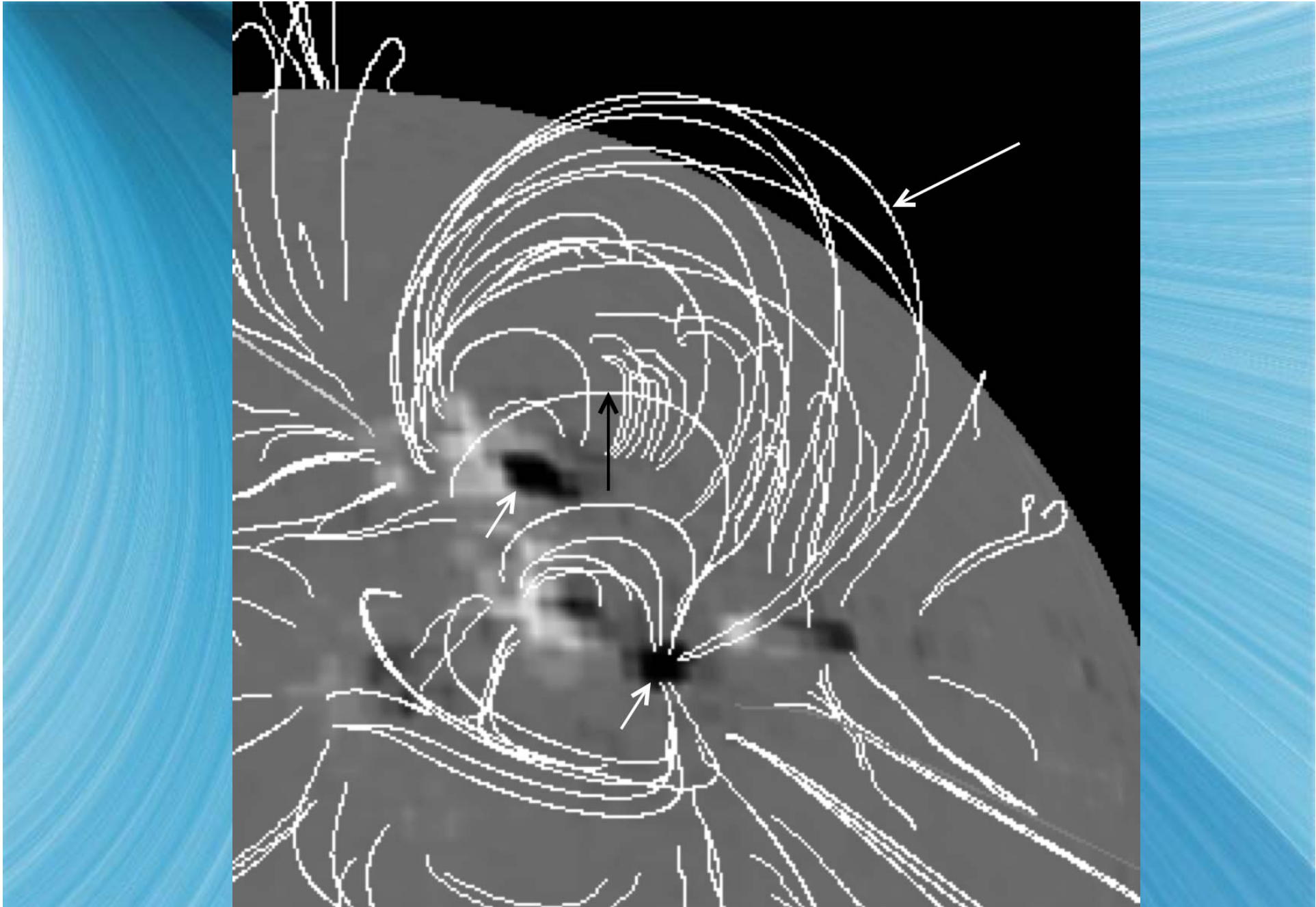
SDO AIA_2 193 23-Jan-2012 00:27:07.840 UT



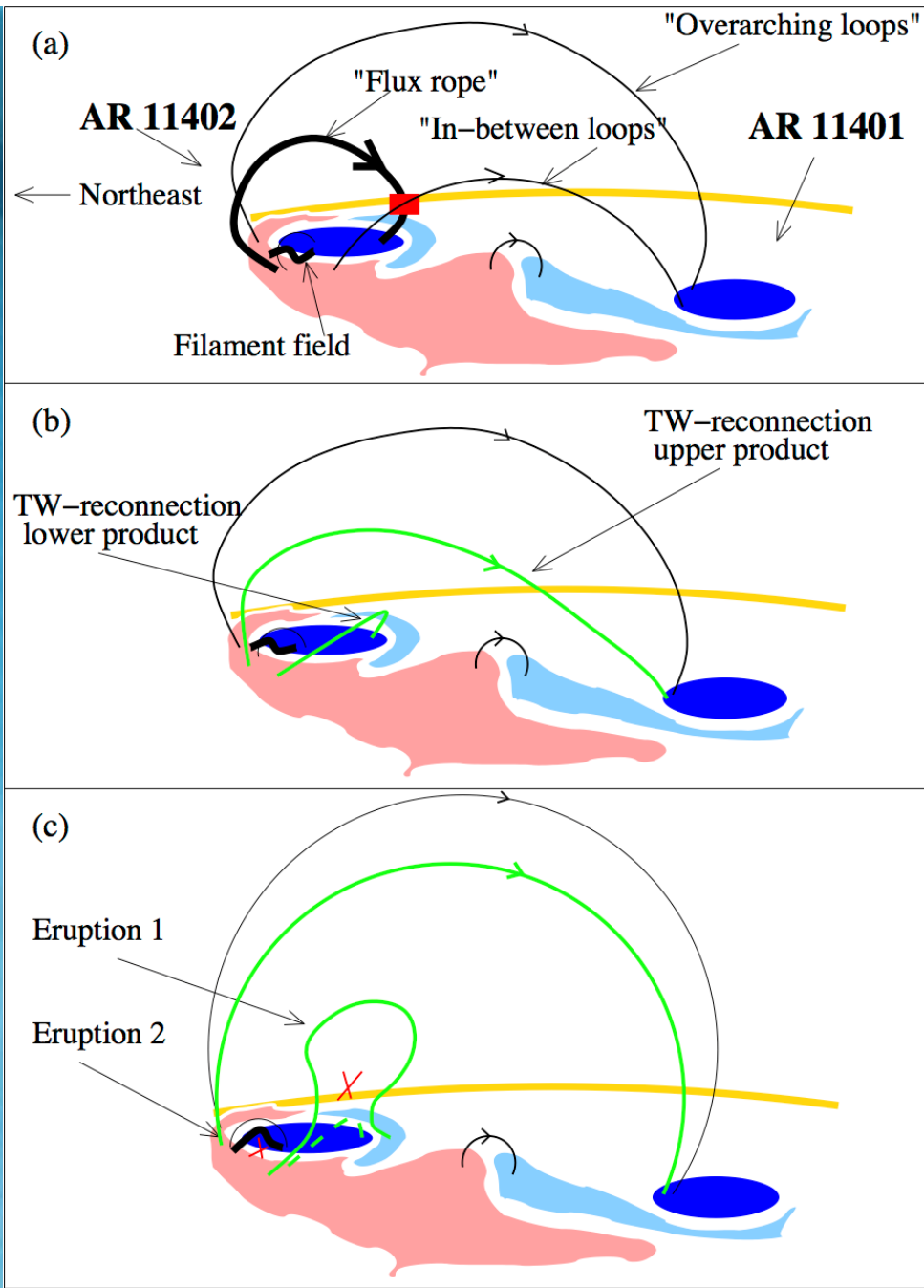
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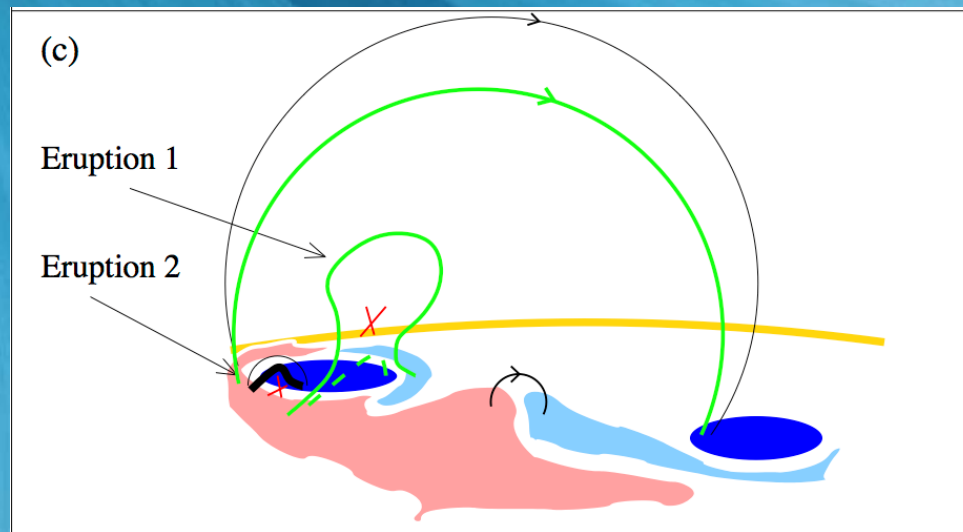


Eruption 2 Via “Lid Removal”

- ◆ 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).

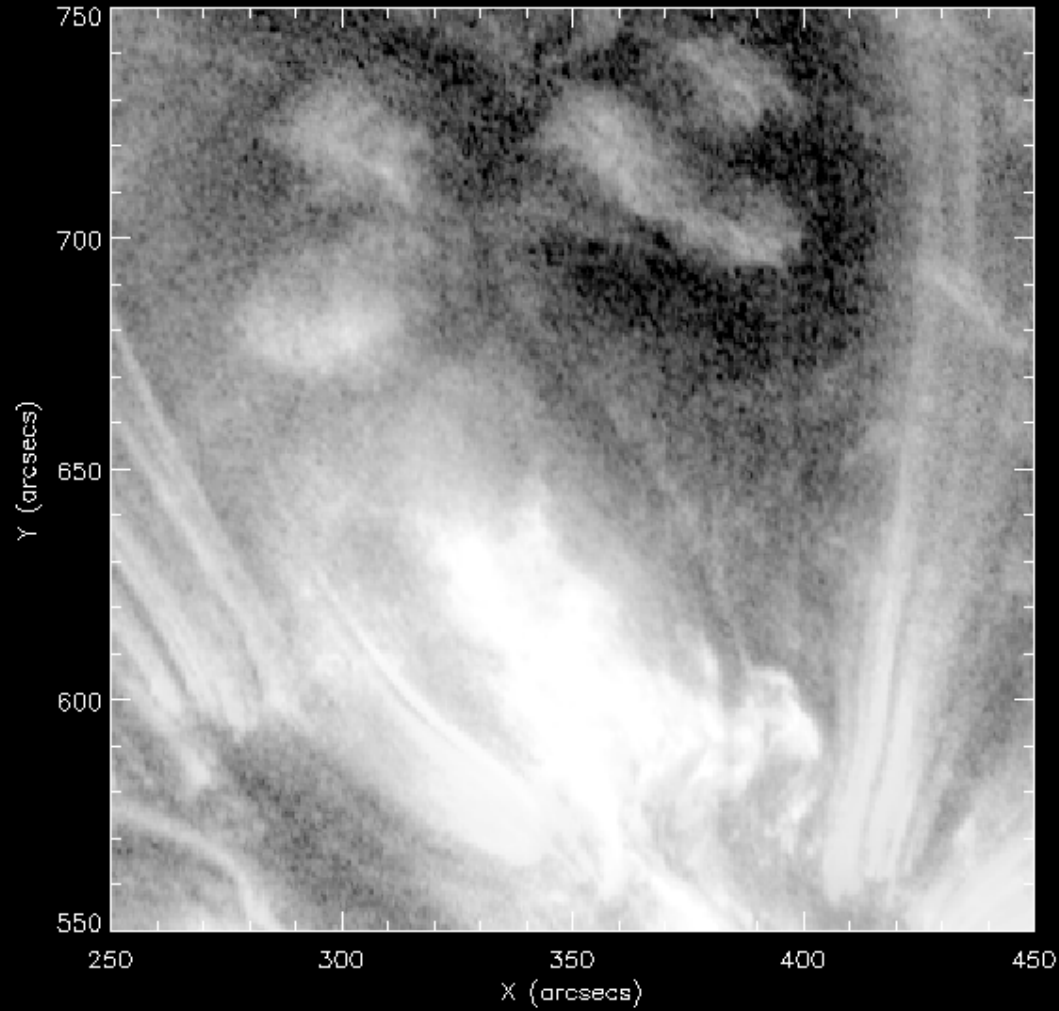
Can Lid Removal Work with Eruption 1 Flare Arcade?

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

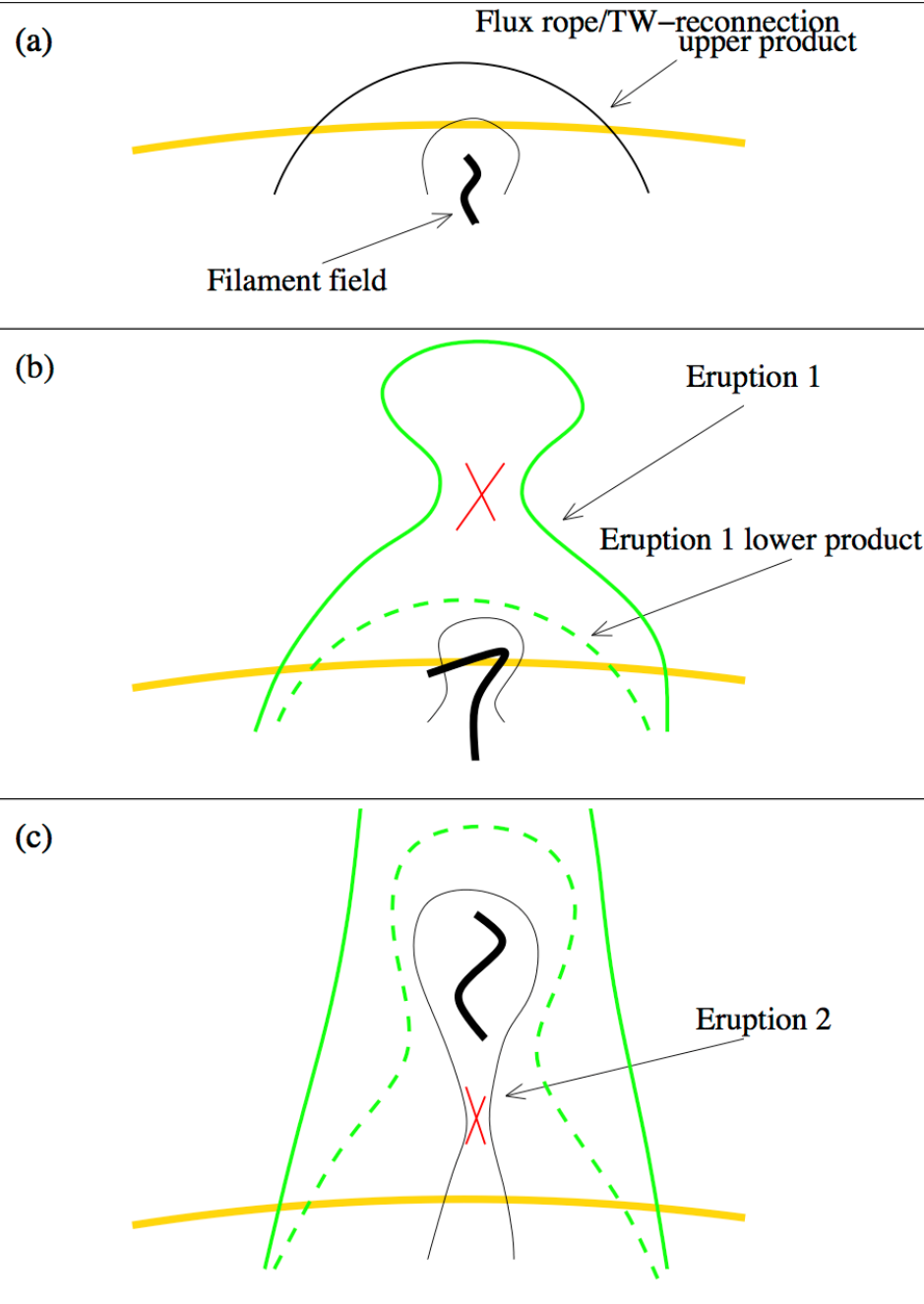


- Look to see what happens.
- Need "hot" AIA to see Eruption 1; need "cool" AIA to see filament.
- Use mixture; 70% hot (=131 Ang), 30% cool (=193 Ang).

AIA 131: 23-Jan-2012 00:27:33 UT + 193: 00:27:07 UT

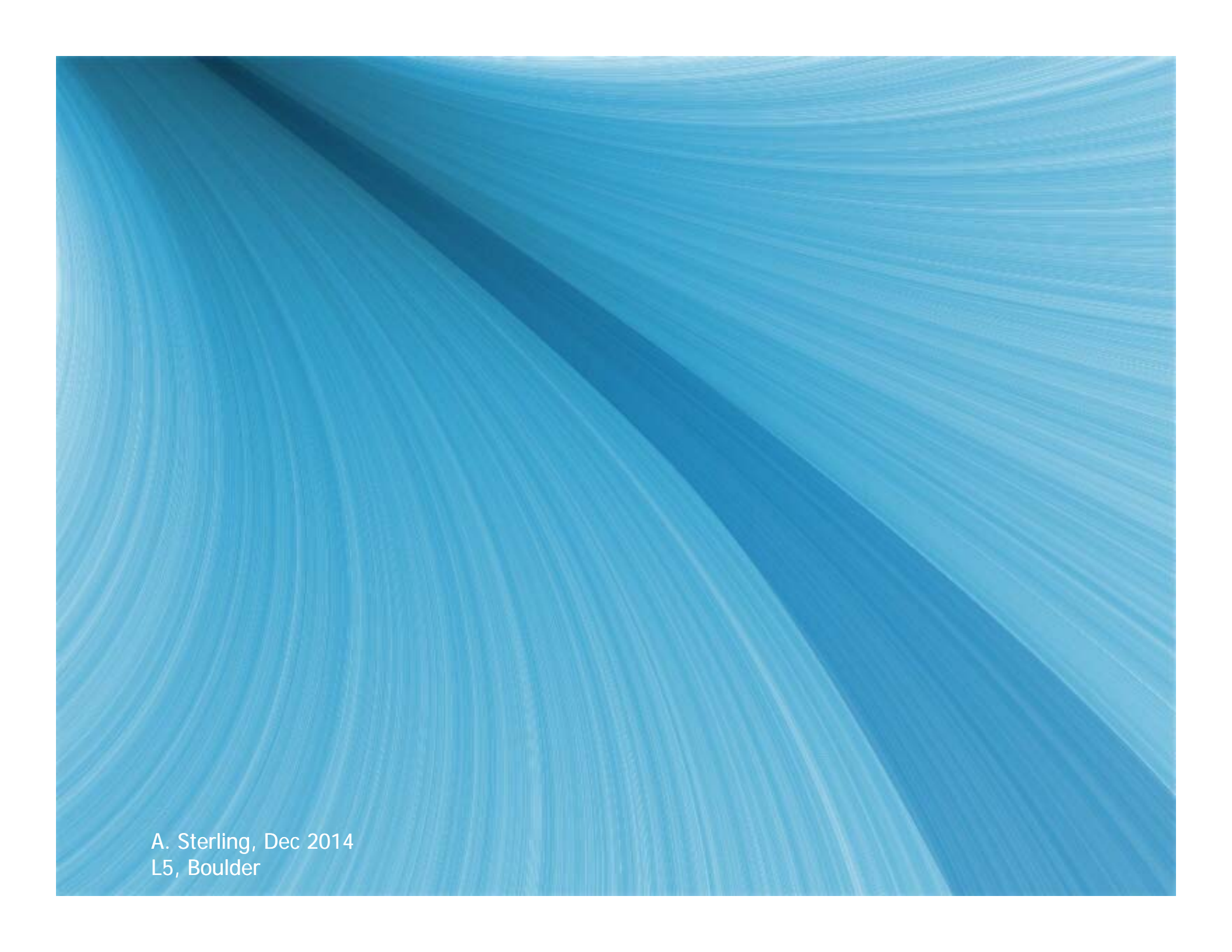


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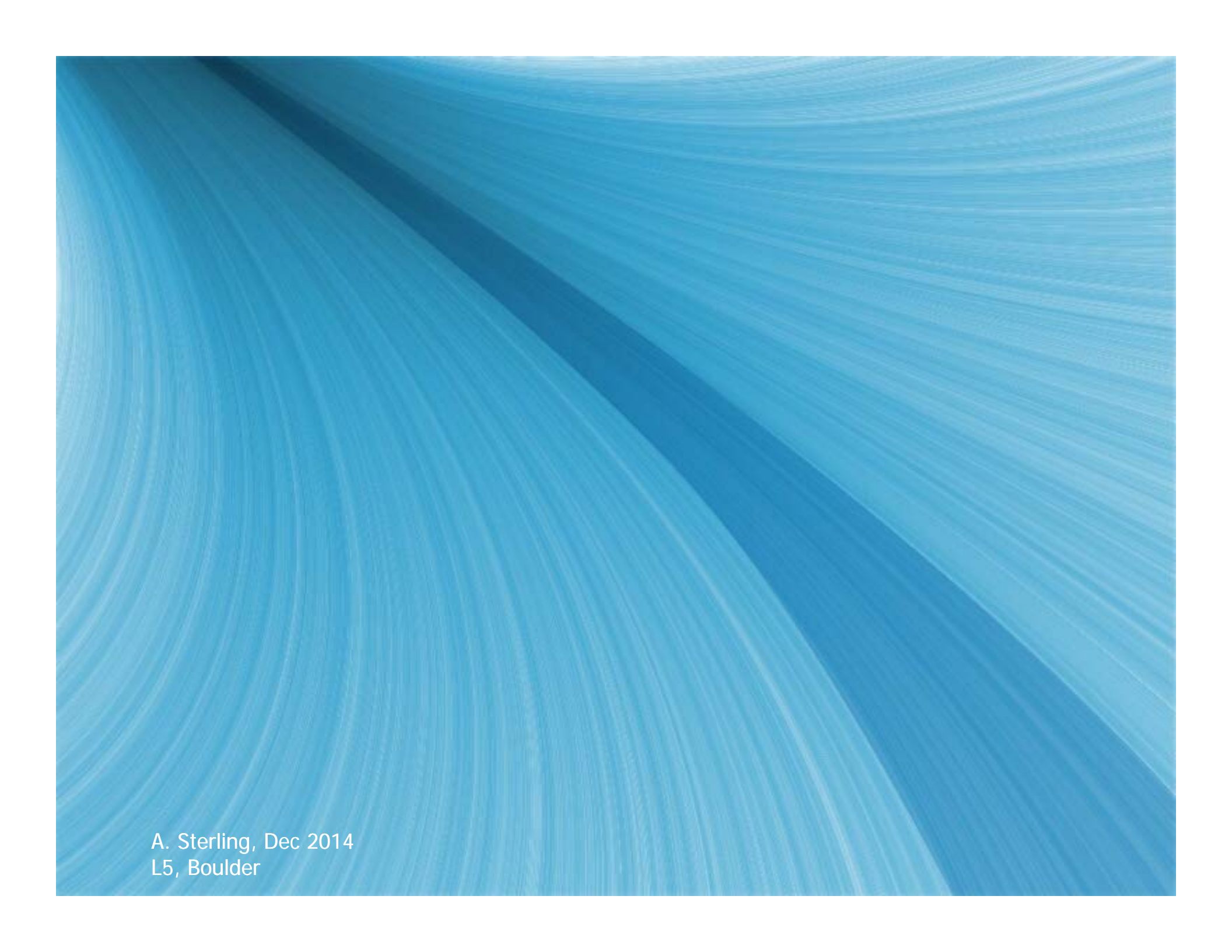


Summary (2012 Jan 23 event)

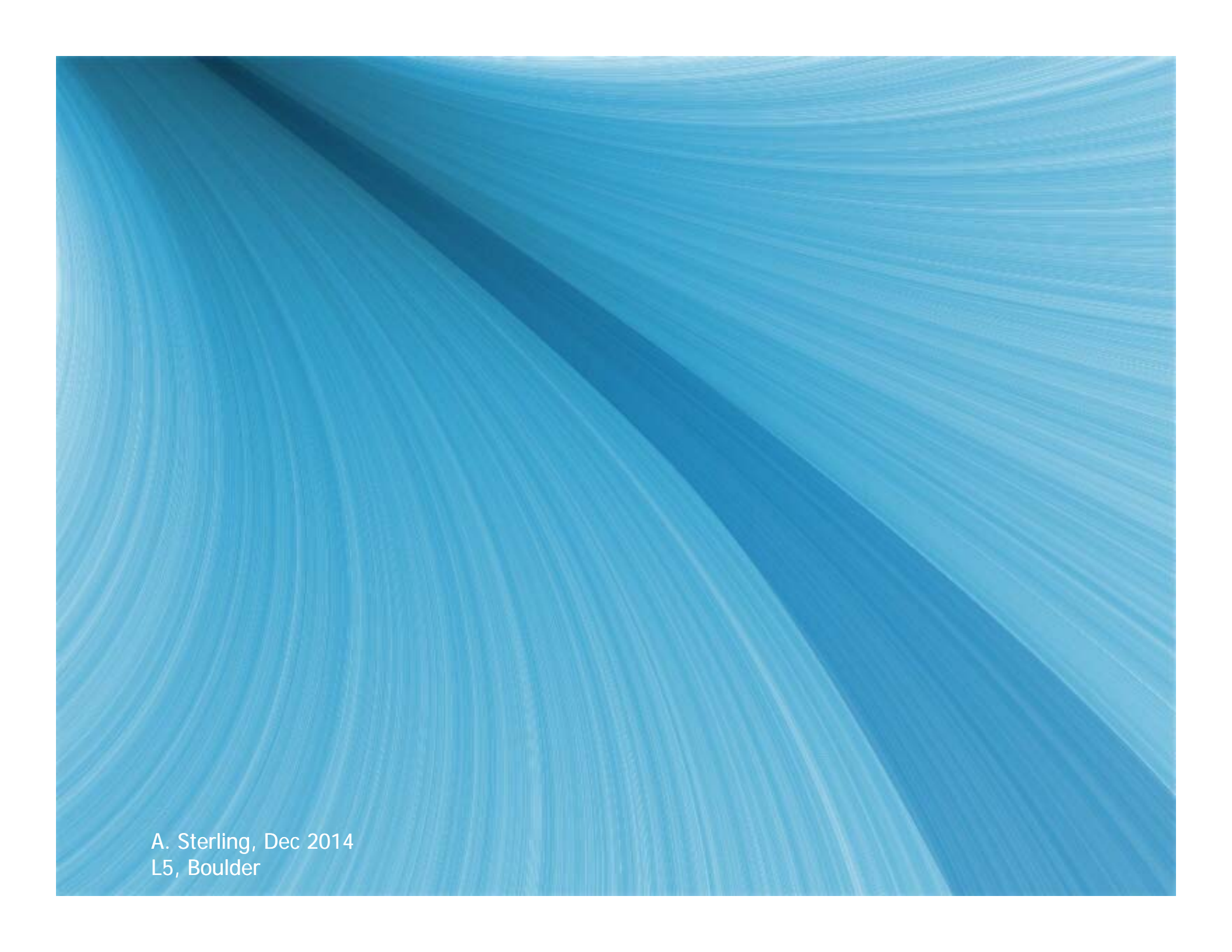
- ◆ Two eruptions, with first only seen in AIA hot channels.
- ◆ Eruption 1 field reconnects with neighboring region, (“tether-weakening reconnection,” Moore et al. 1992).
- ◆ Eruption 1 removes field above filament arcade, leading to destabilization and onset of eruption 2; *Lid Removal*.
- ◆ Eruption 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.

The image features a solid blue background with a prominent diagonal band of a darker shade of blue running from the top-left towards the bottom-right. The entire surface is covered with fine, wavy, horizontal lines that create a textured, brush-stroke-like effect. The lines are more pronounced in some areas and more subtle in others, adding depth and movement to the composition.

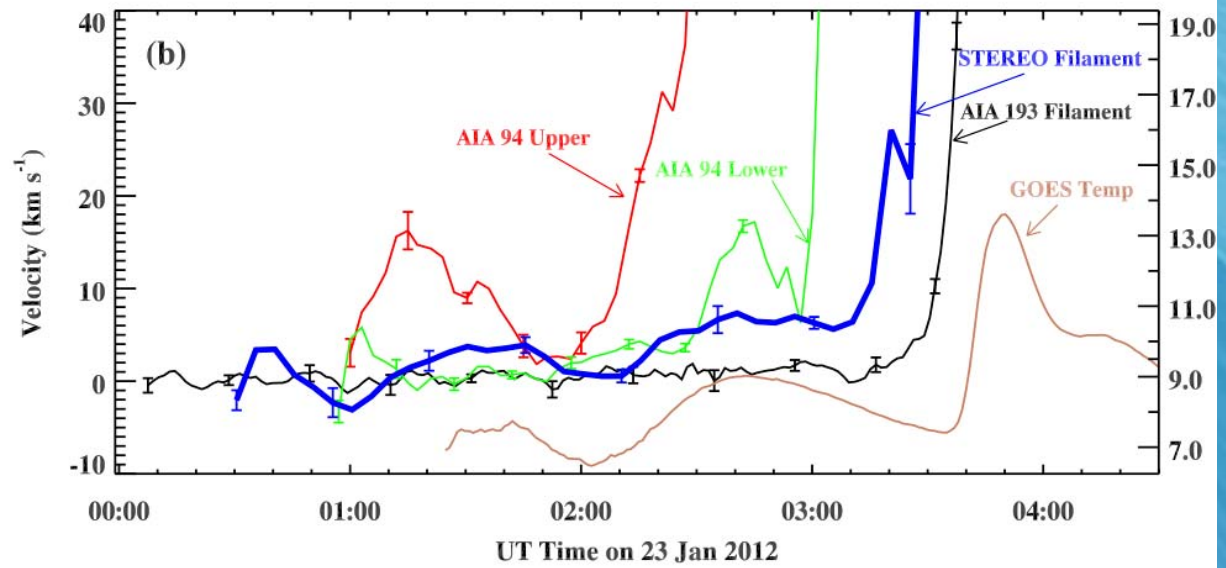
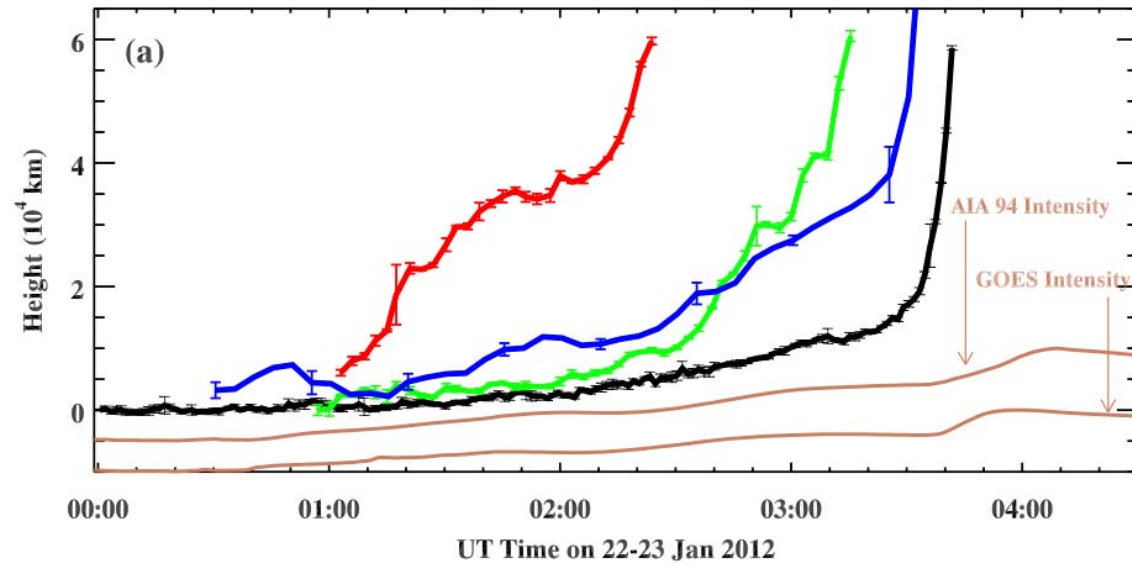
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The image features a solid blue background with a prominent diagonal band of a darker shade of blue running from the top-left towards the bottom-right. The entire surface is covered with fine, wavy, horizontal lines that create a textured, brush-stroke-like effect. The lines are more densely packed in some areas, particularly along the diagonal band, and more sparse in others, contributing to a sense of depth and movement.

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The image features a solid blue background with a prominent diagonal band of a darker shade of blue running from the top-left towards the bottom-right. The entire surface is covered with fine, wavy, horizontal lines that create a textured, brush-stroke-like effect. The lines are more densely packed and darker in some areas, particularly along the diagonal band, and more sparse and lighter in others.

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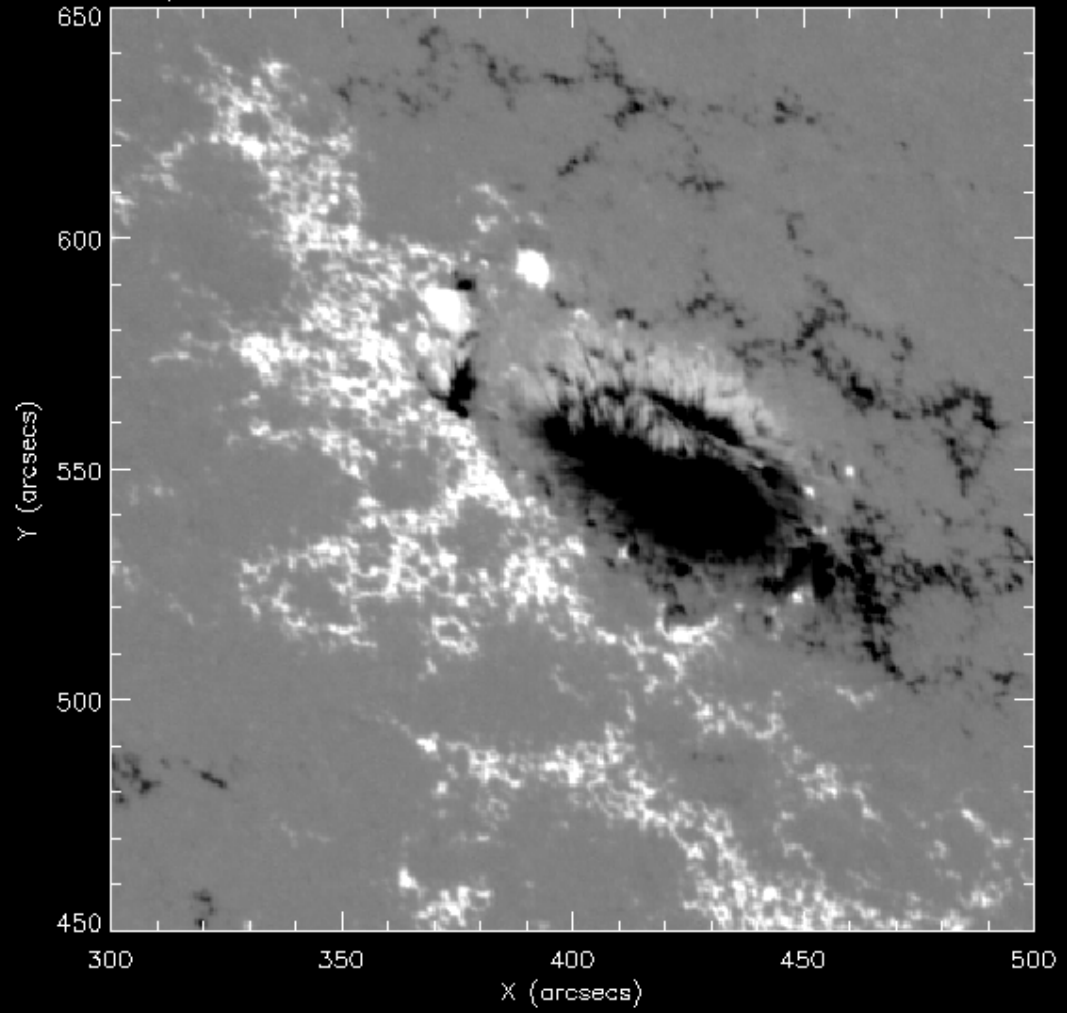


Goes Temp (MK)

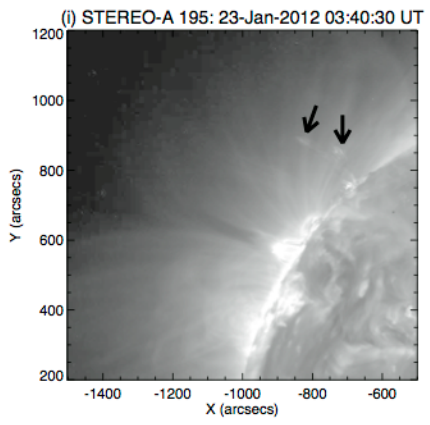
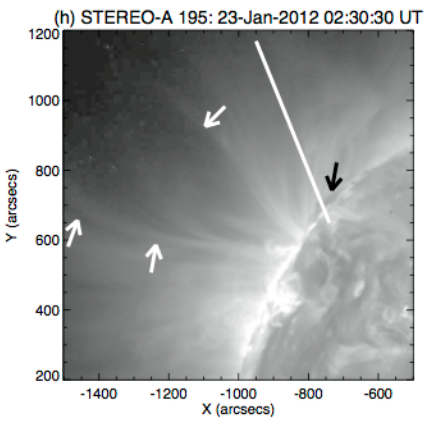
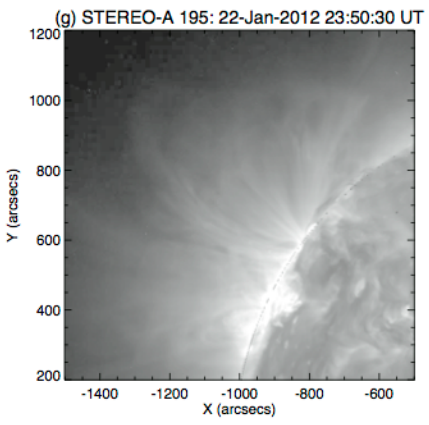
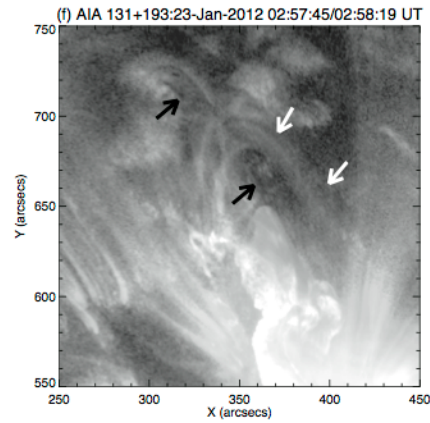
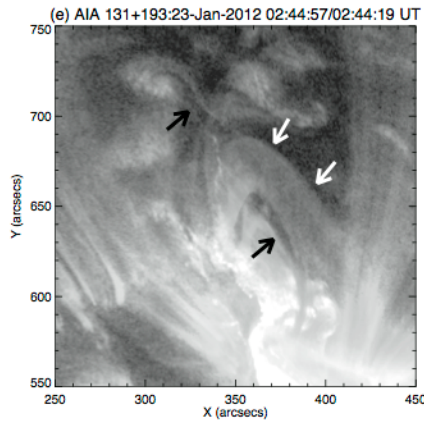
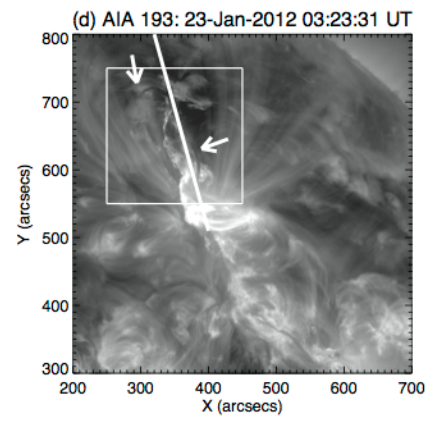
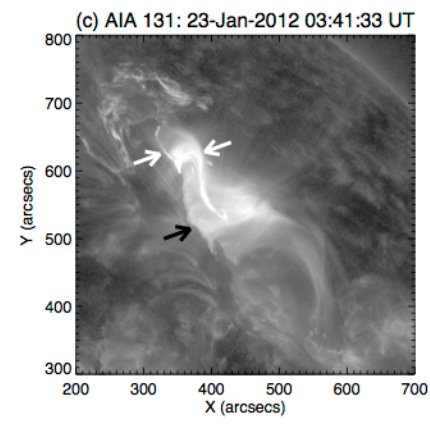
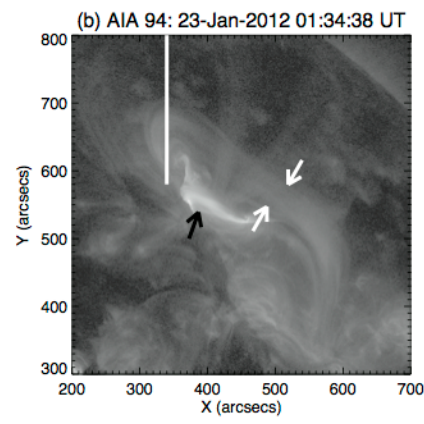
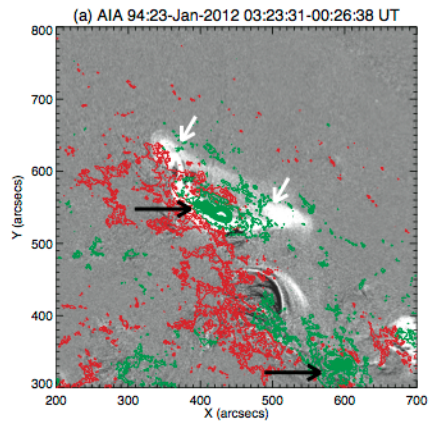
What causes Eruption 1 onset?

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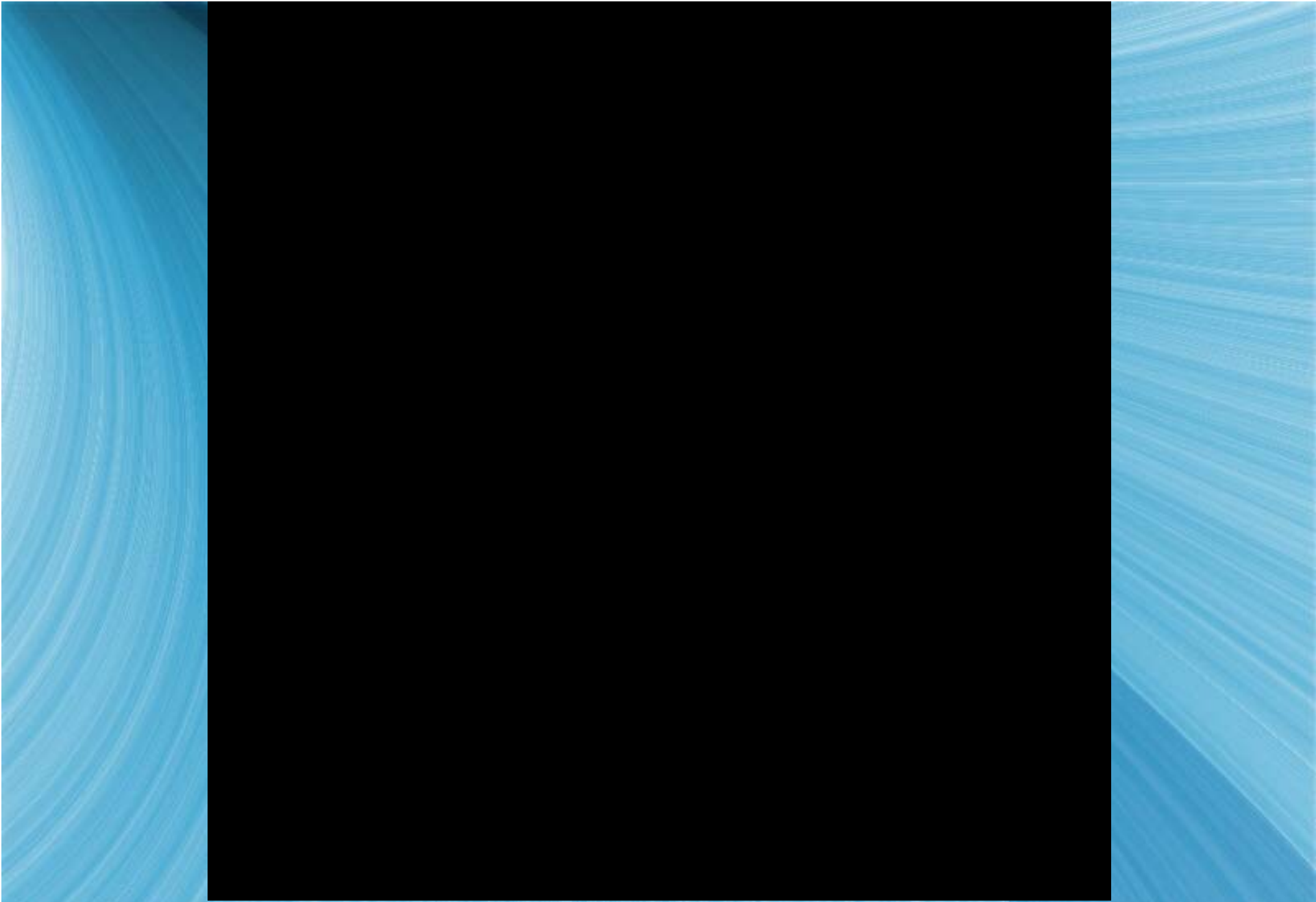
SDO/HMI HMI_FRONT2 6173 22-Jan-2012 15:15:25.600 UT



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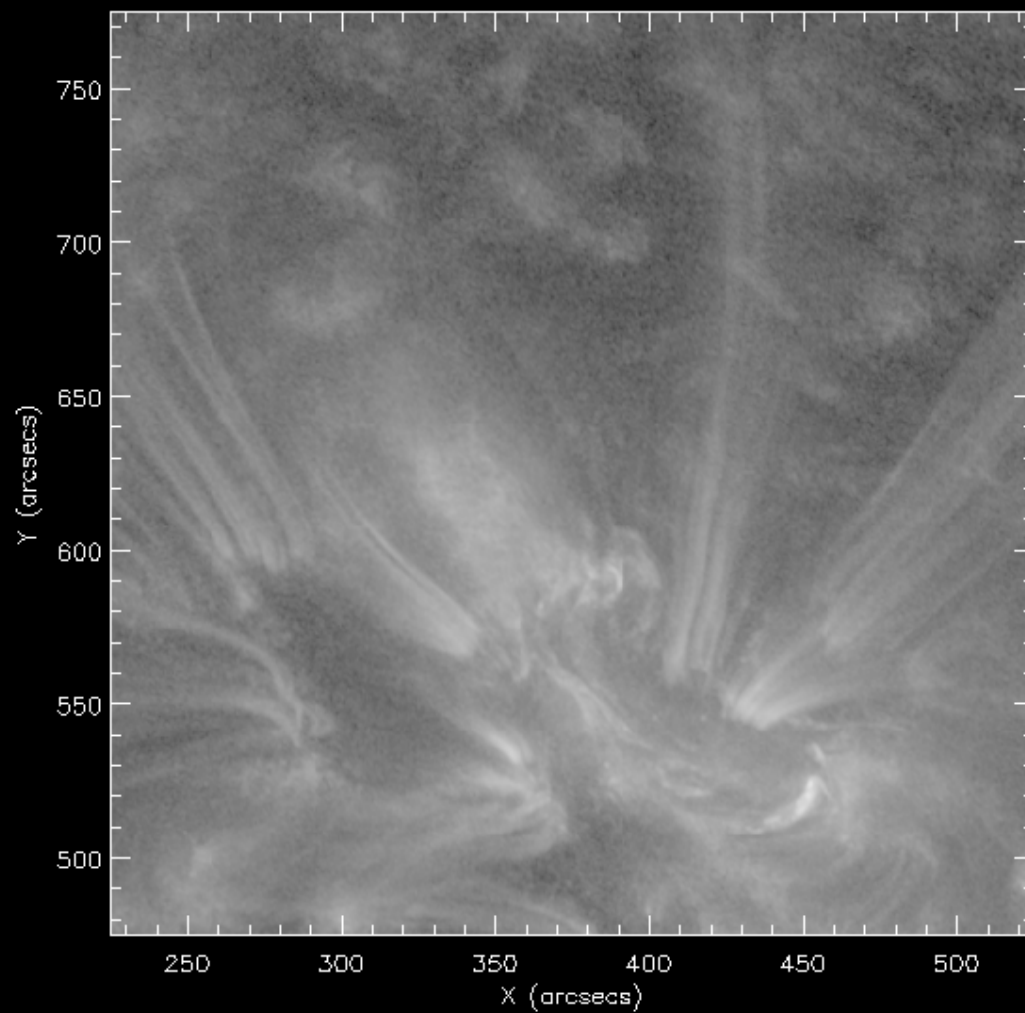


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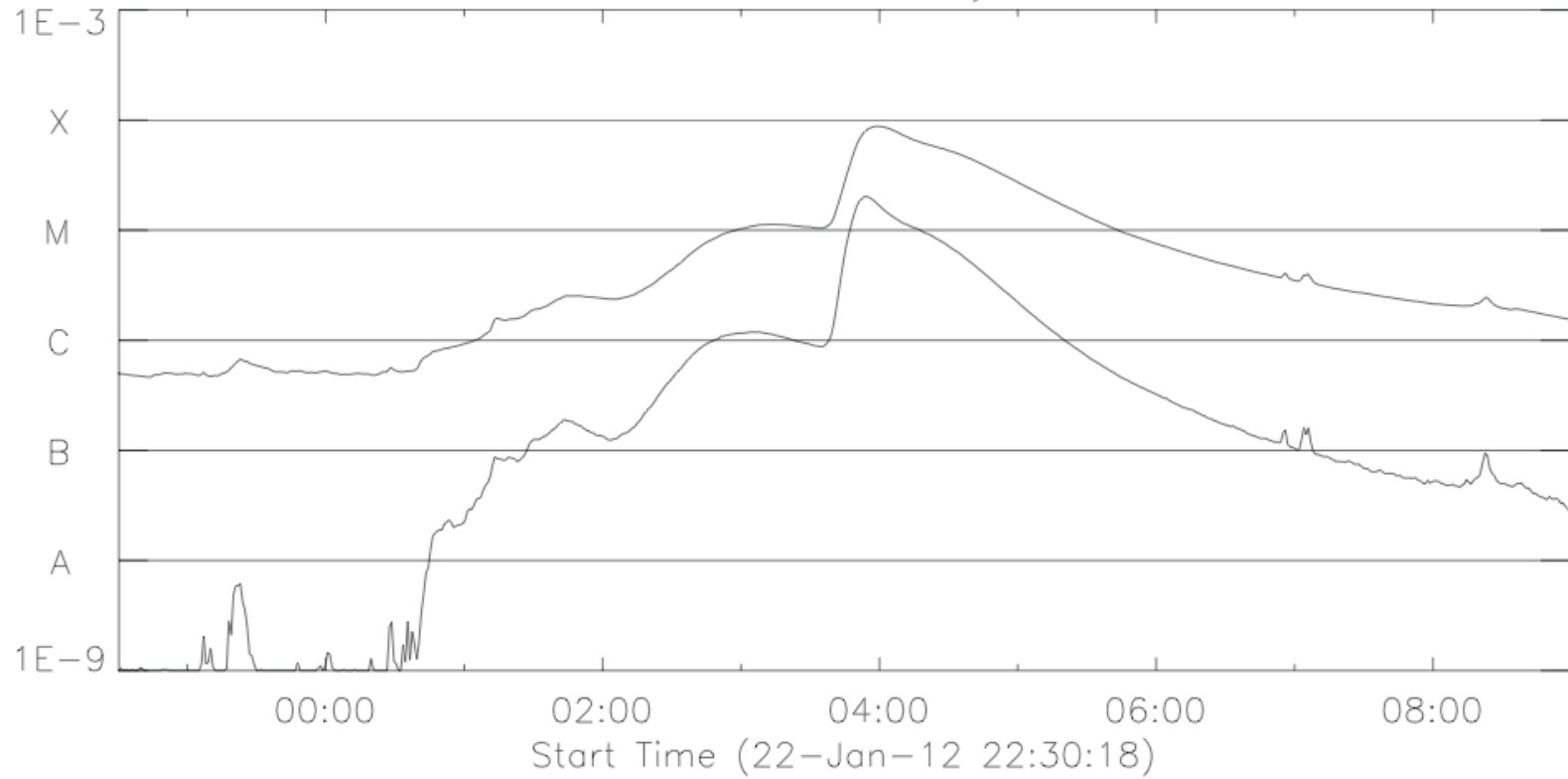
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SDO AIA_1 131 23-Jan-2012 00:26:09.620 UT



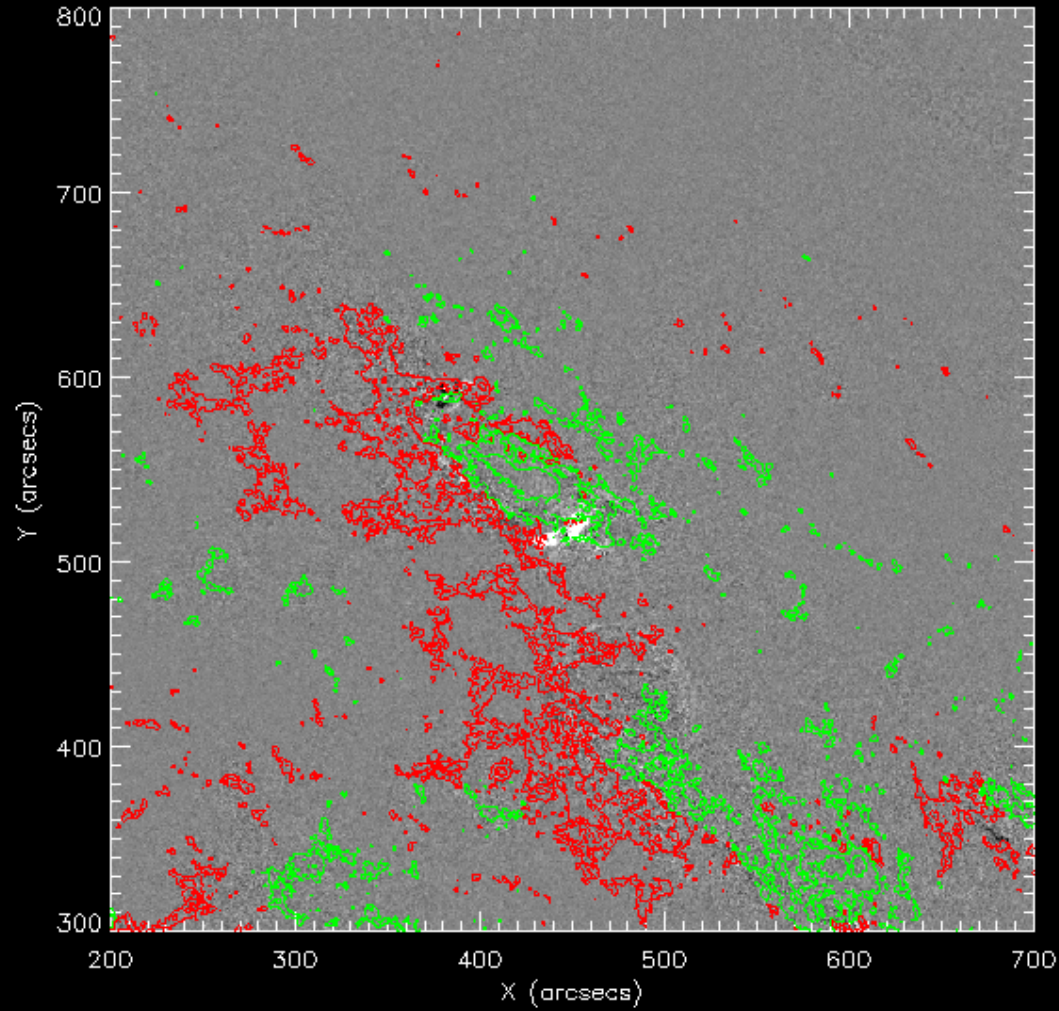
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GOES 15 X-Rays:



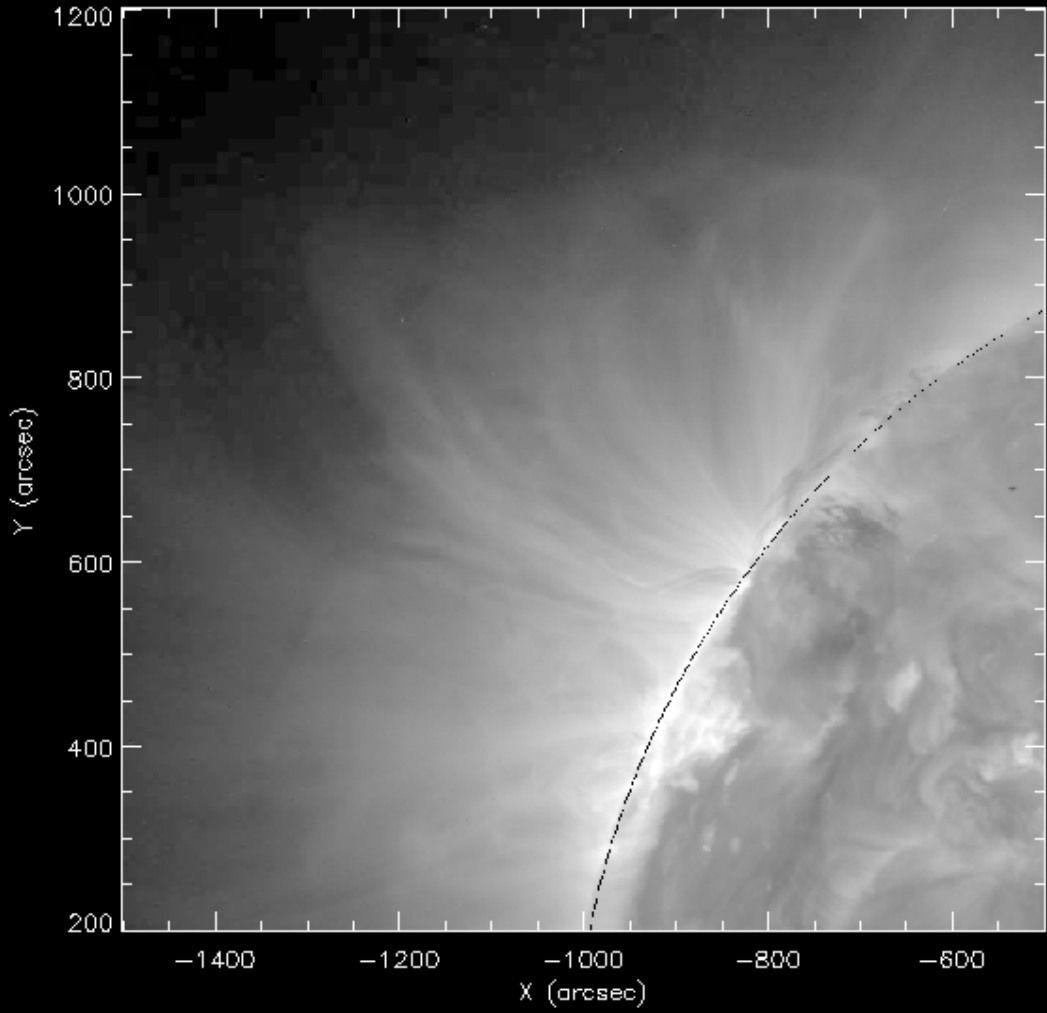
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SDO AIA_4 94 23-Jan-2012 00:28:02.120 UT



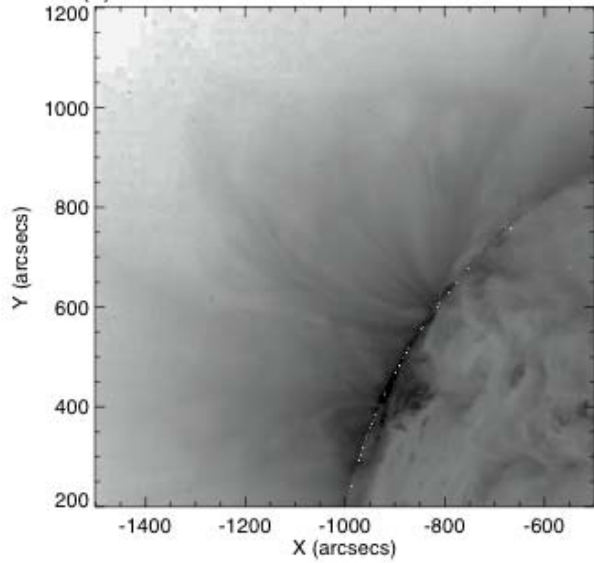
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STEREO_A SECCHI EUV 195 22-Jan-2012 21:30:30.008 UT

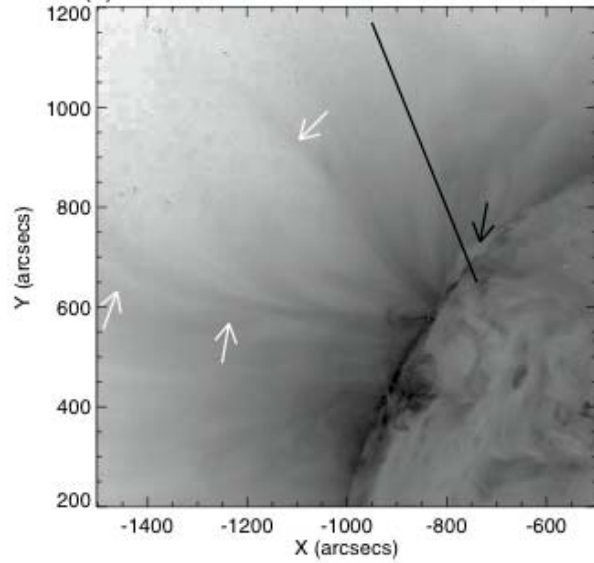


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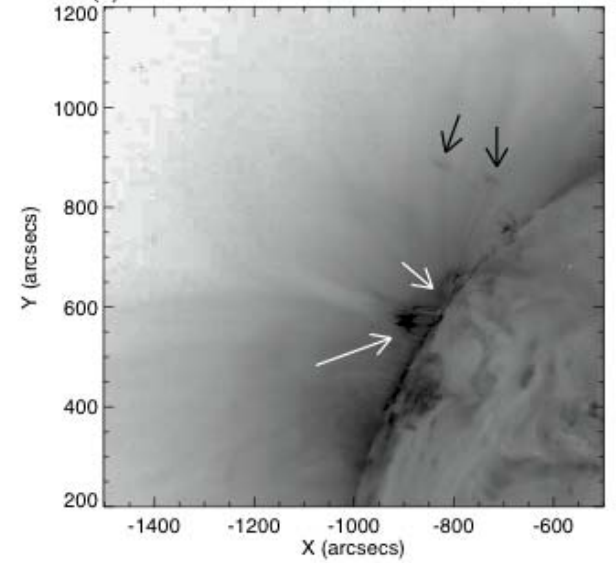
(a) STEREO-A 195: 22-Jan-2012 23:50:30 UT



(b) STEREO-A 195: 23-Jan-2012 02:30:30 UT



(c) STEREO-A 195: 23-Jan-2012 03:40:30 UT



- 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.

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).