Two Types of Magnetic Flux Cancelation in The Solar Eruption of 2007 May 20

Alphonse Sterling, Ronald Moore, Helen Mason

We study a solar eruption of 2007 May 20, in an effort to understand the cause of the eruption's onset. The event produced a GOES class B6.7 flare peaking at 05:56 UT, while ejecting a surge/filament and producing a coronal mass ejection (CME). We examine several data sets, including H-alpha images from the Solar Optical Telescope (SOT) on Hinode, EUV images from TRACE, and line-of-sight magnetograms from SoHO/MDI. Flux cancelation occurs among two different sets of flux elements inside of the erupting active region: First, for several days prior to eruption, opposite-polarity sunspot groups inside the region move toward each other, leading to the cancelation of ~10^{21} Mx of flux over three days. Second, within hours prior to the eruption, positive-polarity moving magnetic features (MMFs) flowing out of the positive-flux spots at ~1 km/s repeatedly cancel with field inside a patch of negative-polarity flux located north of the sunspots. The filament erupts as a surge whose base is rooted in the location where the MMF cancelation occurs, while during the eruption that filament flows out along the polarity inversion line between the converging spot groups. We conclude that a plausible scenario is that the converging spot fields brought the magnetic region to the brink of instability, and the MMF cancelation pushed the system ``over the edge," triggering the eruption.

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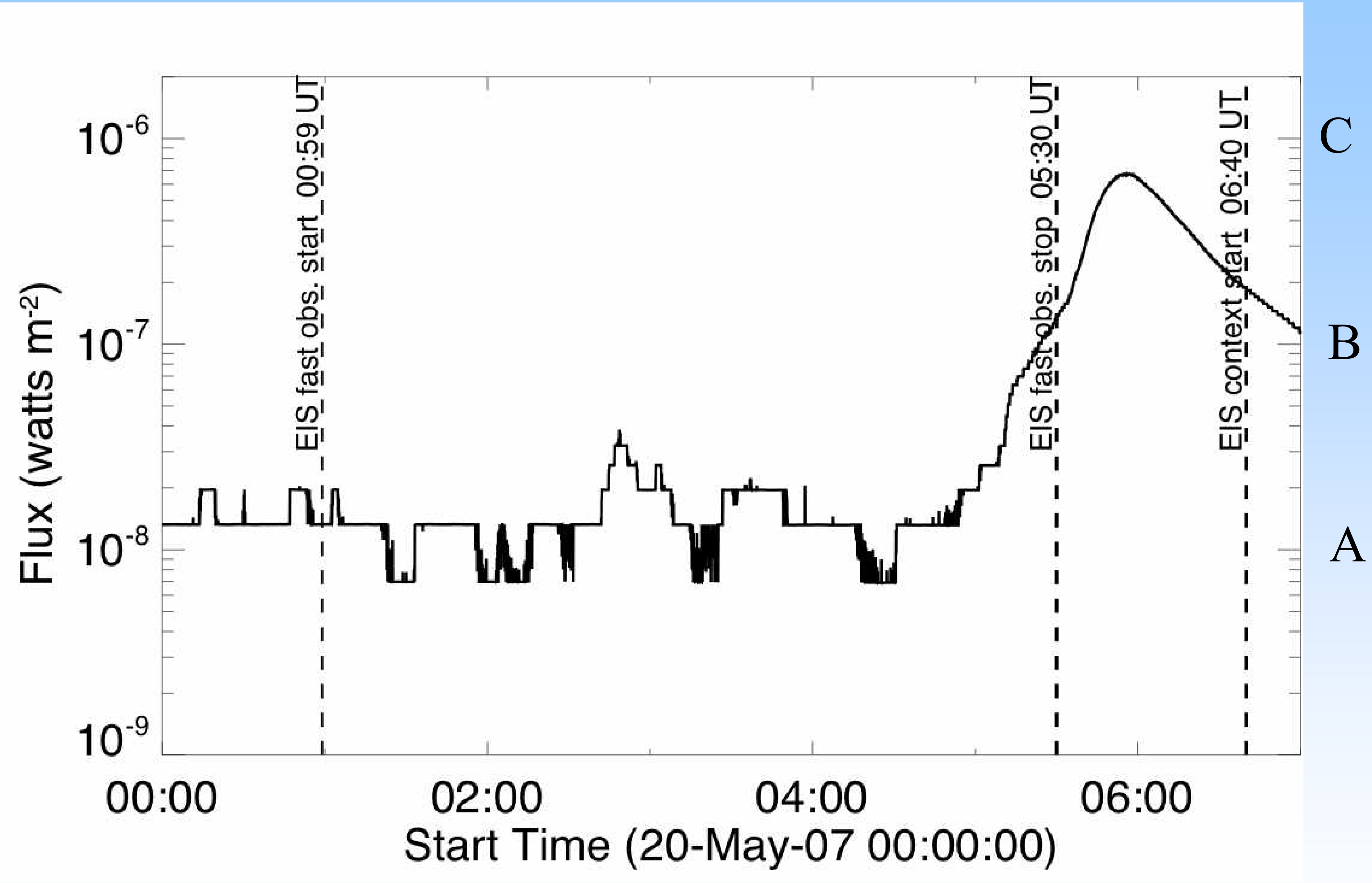
Introduction

- Trying to understand the **onset** of solar eruptions, especially those with filaments.
- Detailed examination of several individual events (Sterling, Moore, et al., 2001 - 2008…).
- Continuing this work in the Hinode/STEREO era.
- Present one event today…
- Eruption of 20 May 2007. (Chifor, Sterling, Mason, Moore, & Young 2008, A&A, in press.)

Event of 20 May 2007

- Peaks at GOES B7 level in SXRs.
- Surge-like filament erupts.
- TRACE, STEREO (EUV), SOHO/MDI (magnetograms), Hinode/SOT (Ca II H), Hinode/XRT (SXRs), Hinode/EIS (EUVspectroscopy).
- Hinode SOT and Hida ground-based (H-alpha).



Flux (watts m-2)
10-6
10-7
10-8
10-9
EIS fast obs. start 00:59 UT
EIS fast obs. stop 05:30 UT
EIS context start 06:40 UT
00:00
02:00
04:00
06:00
Start Time (20-May-07 00:00:00)
C
B
A

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

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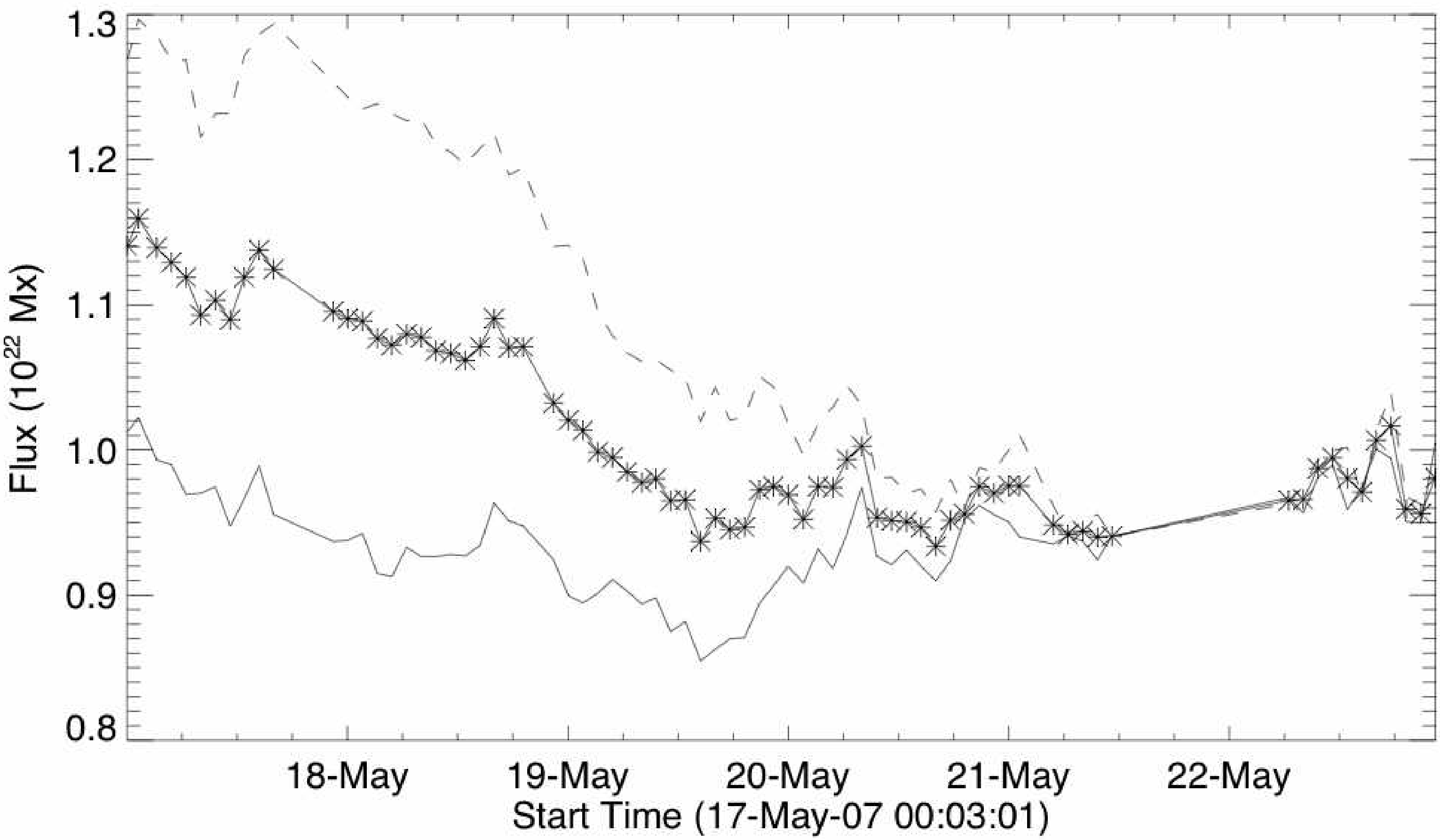

Flux decrease of ~10% in 24 hrs from 18 May 12 UT.

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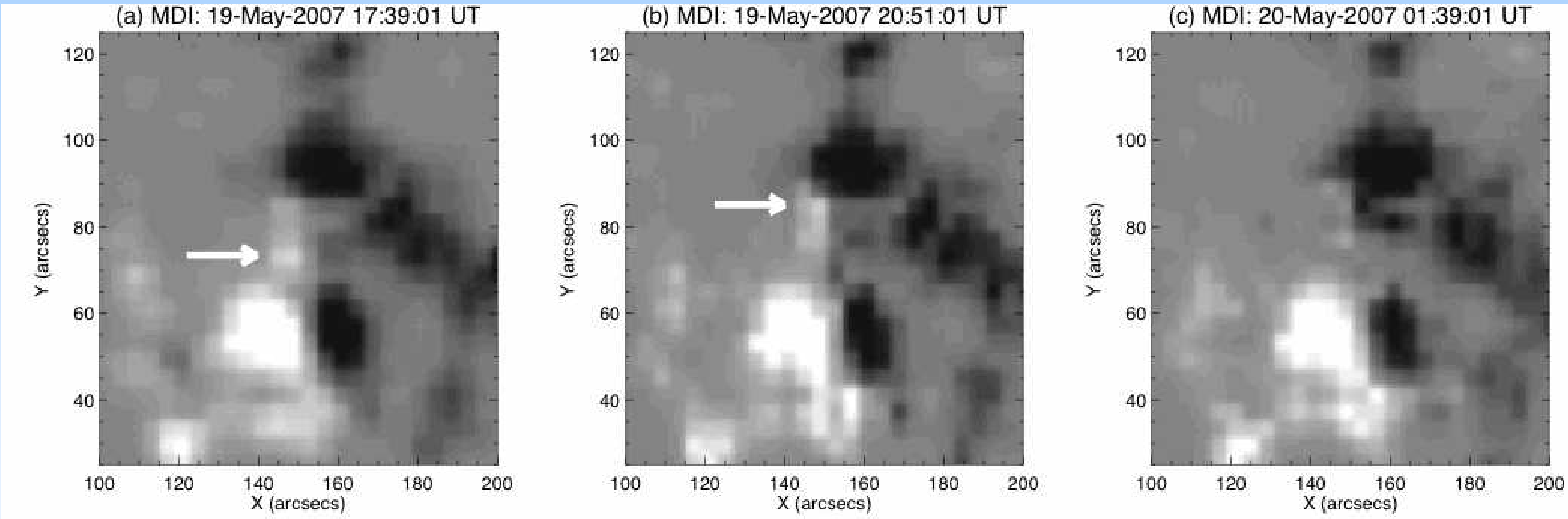
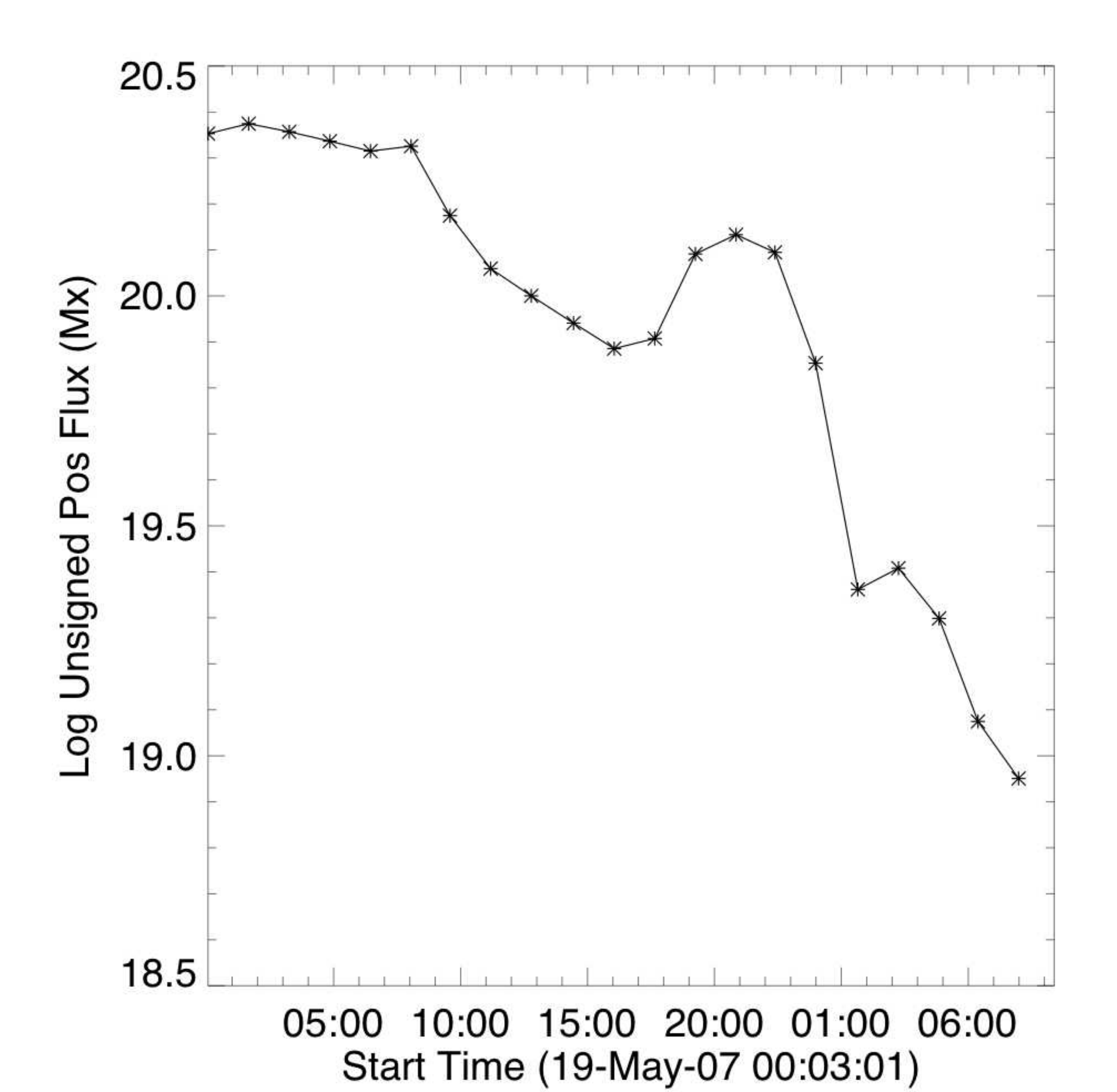
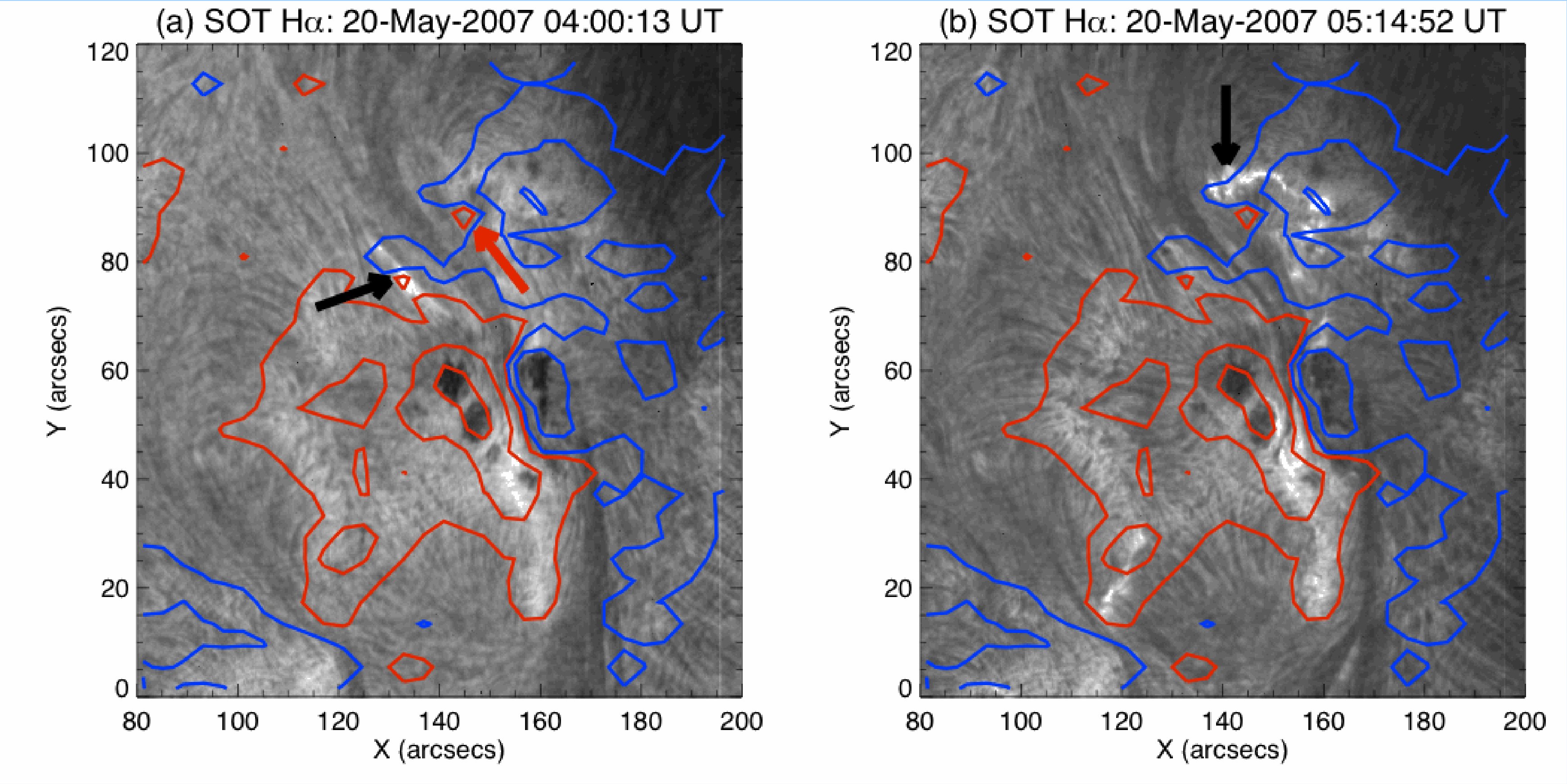


vel ~ 0.5 --- 1.0 km/s

Moving Magnetic Features (MMFs; Harvey & Harvey 1973)

Log positive flux entering box in north.





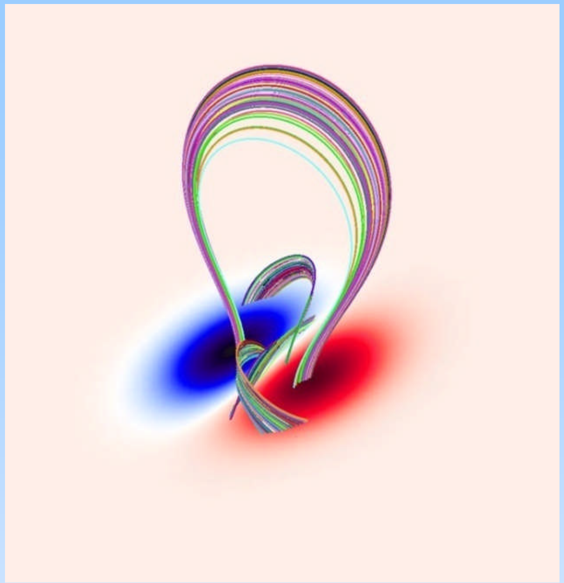
(a) SOT Hα: 20-May-2007 04:00:13 UT
(b) SOT Hα: 20-May-2007 05:14:52 UT
Y (arcsecs)
X (arcsecs)
0
20
40
60
80
100
120
80
100
120
140
160
180
200

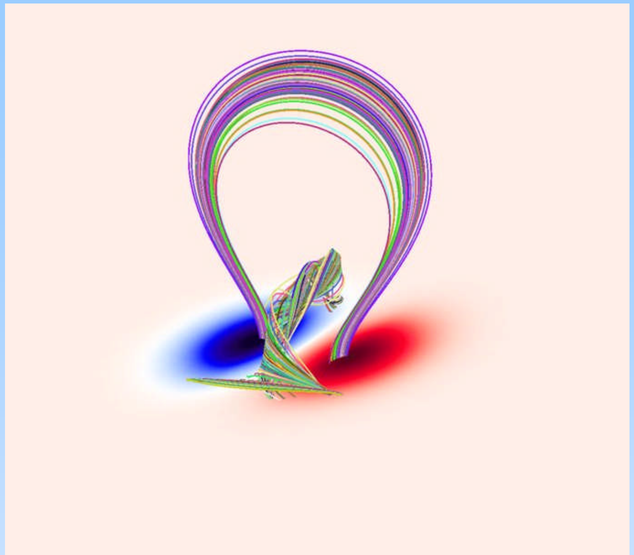
Summary

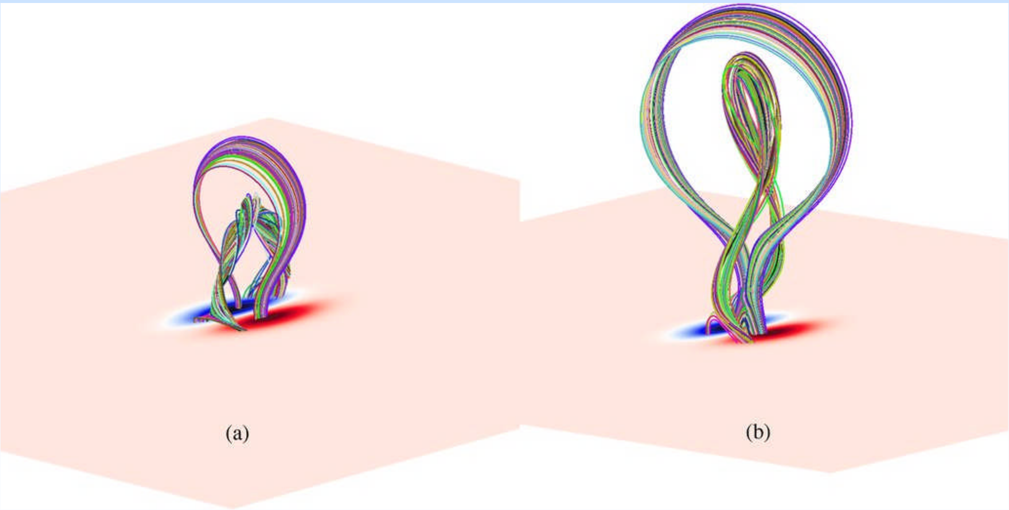
- At least **two magnetic motions** play key roles in triggering the eruption of 20 May 2007:
  - Spots move together and cancel flux along main neutral line.
  - Positive flux "flows" of ~1 km/s from spot region and cancels with negative patch in the north.
- We speculate that the **canceling spot flux driven by photospheric flows gradually destabilizes the sheared-core arcade, bringing it to the "brink of eruption." Then, localized magnetic flux cancelation in the north sets off a surge-like ejection and kicks the system "over the edge,"** resulting in the large-scale eruption.
- A small amount (~10%) of change to total flux of region can lead to eruption of field. Flux changes can be due to cancelation, or flux emergence (shown elsewhere). Energy built up in field over time prior to eruption trigger.
- Preliminary spectroscopic diagnostics with EIS show enhancements in flows, line broadenings, and densities at specific locations (neutral lines and EUV brightenings) in the neighborhood of the base of the surge.

Broader Discussion

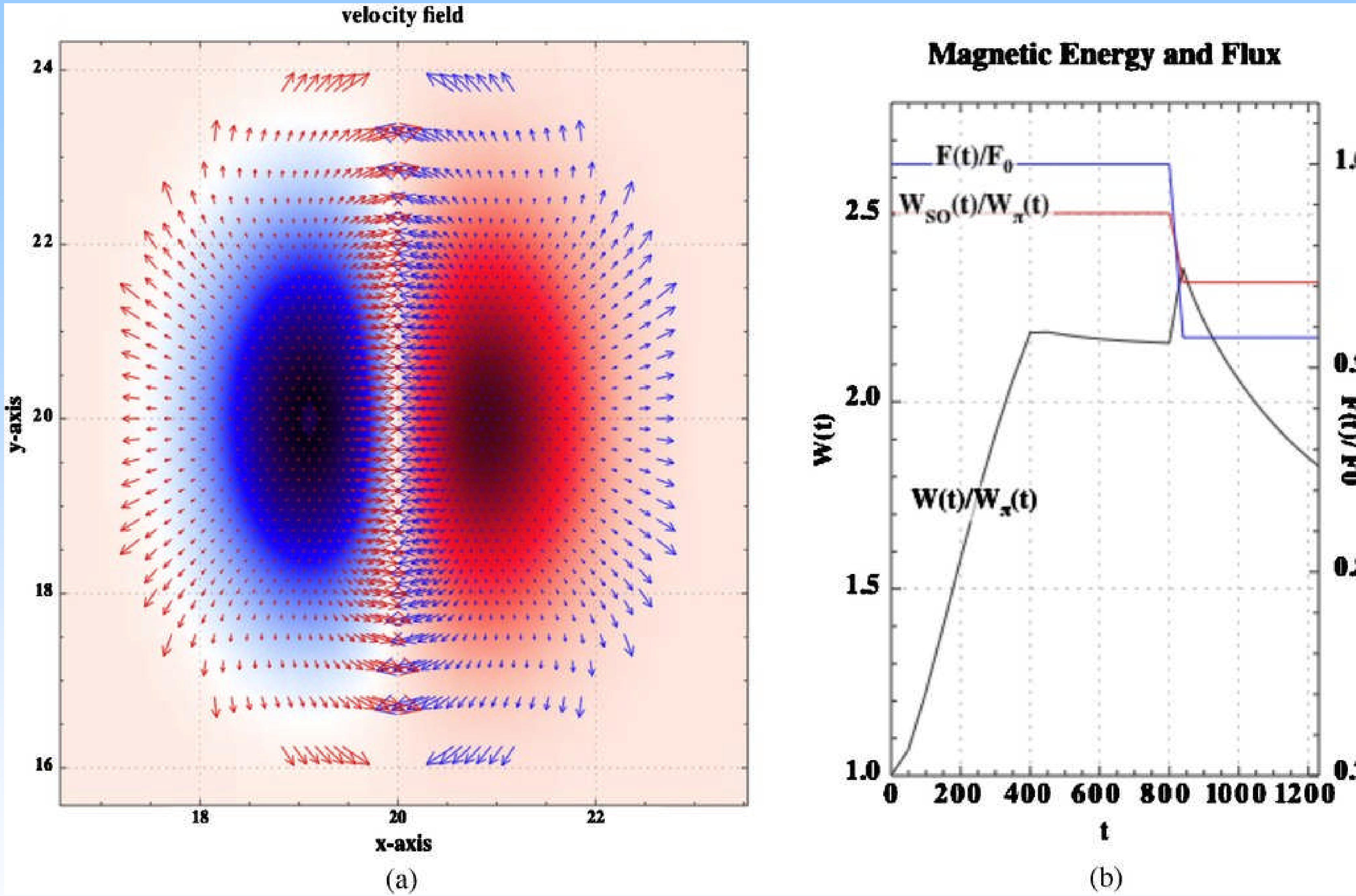
- Flux cancelation plays an important role in eruptions.
- Flux cancelation discussed by many (e.g., Martin et al. 1985).
- Van Ballegooijen & Martens (1989): Cancelation due to reconnection leads to eruption. Emphasize the cancelation continuing over an extended period prior to eruption. This is similar to what we observe here.
- (Tether cutting, e.g. Moore & LaBonte 1980, is similar concept: Release of tension in sheared core field above the polarity inversion line of the arcade.)
- Flux cancelation of ~5% during eruption of 2 Mar 2007 (Sterling et al. 2007).
- Numerical simulations by Amari et al. (2010) show that a sheared arcade can erupt when only about 6% of flux is canceled.







Amari et al. (2010)



Amari et al. (2010)

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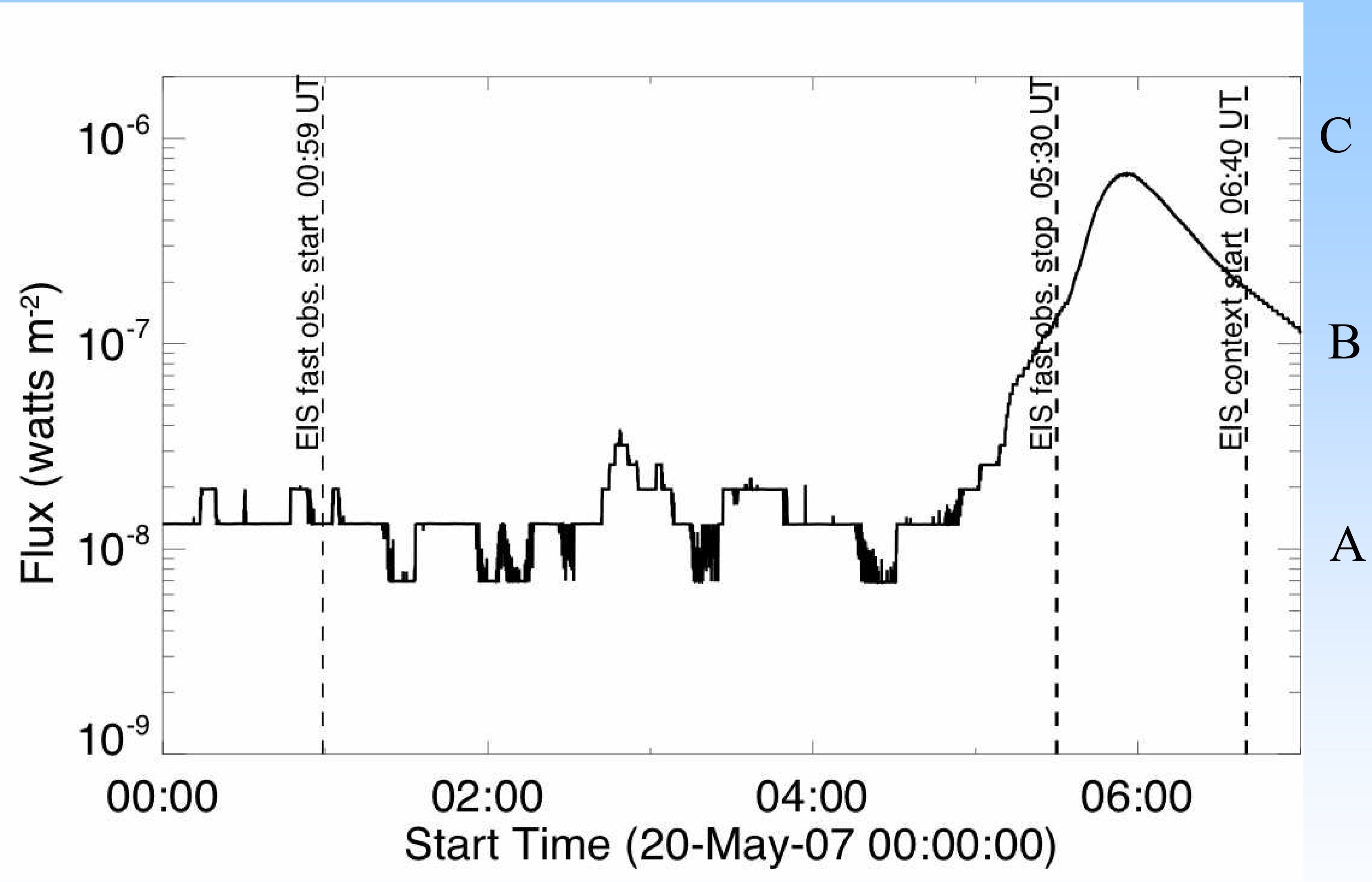

C
B
A
10^-6
10^-7
10^-8
10^-9
Flux (watts m^-2)
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00:00
02:00
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Start Time (20-May-07 00:00:00)

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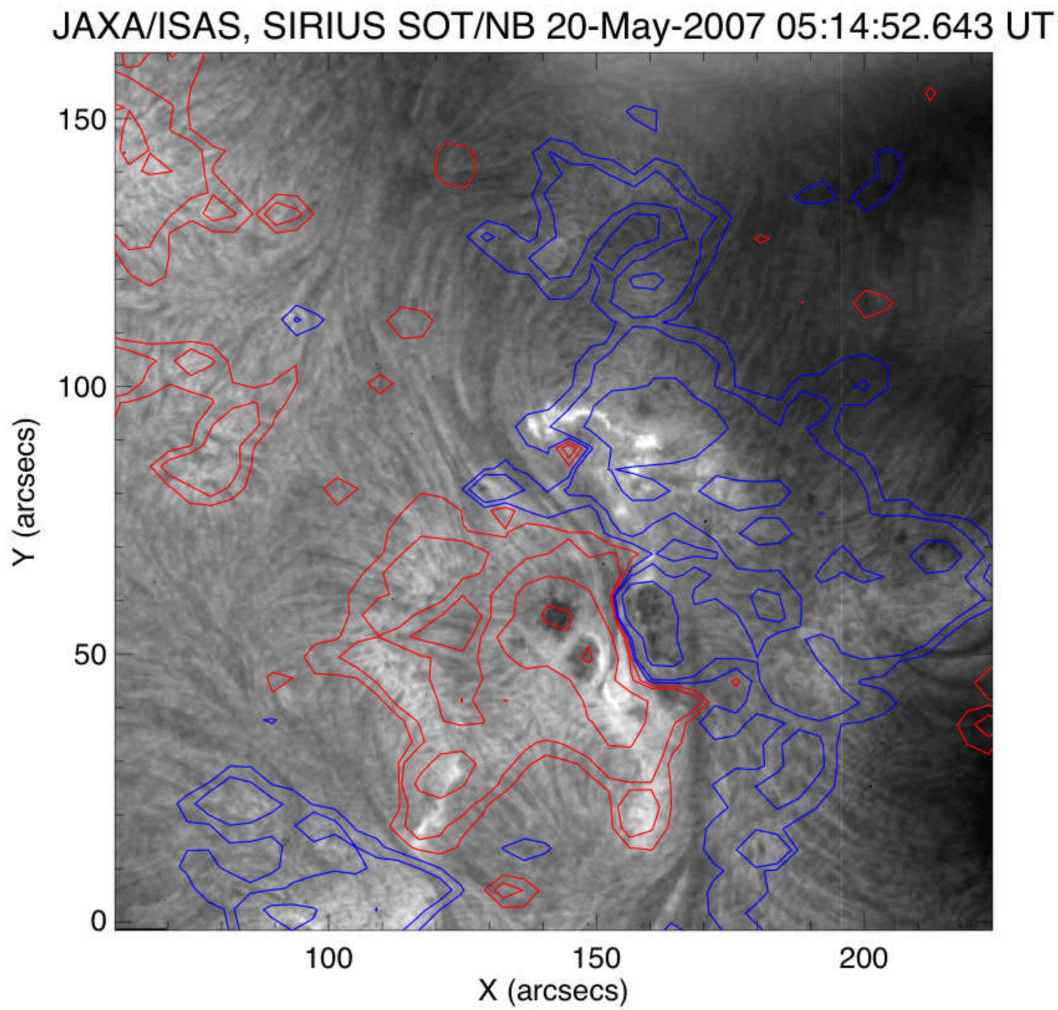
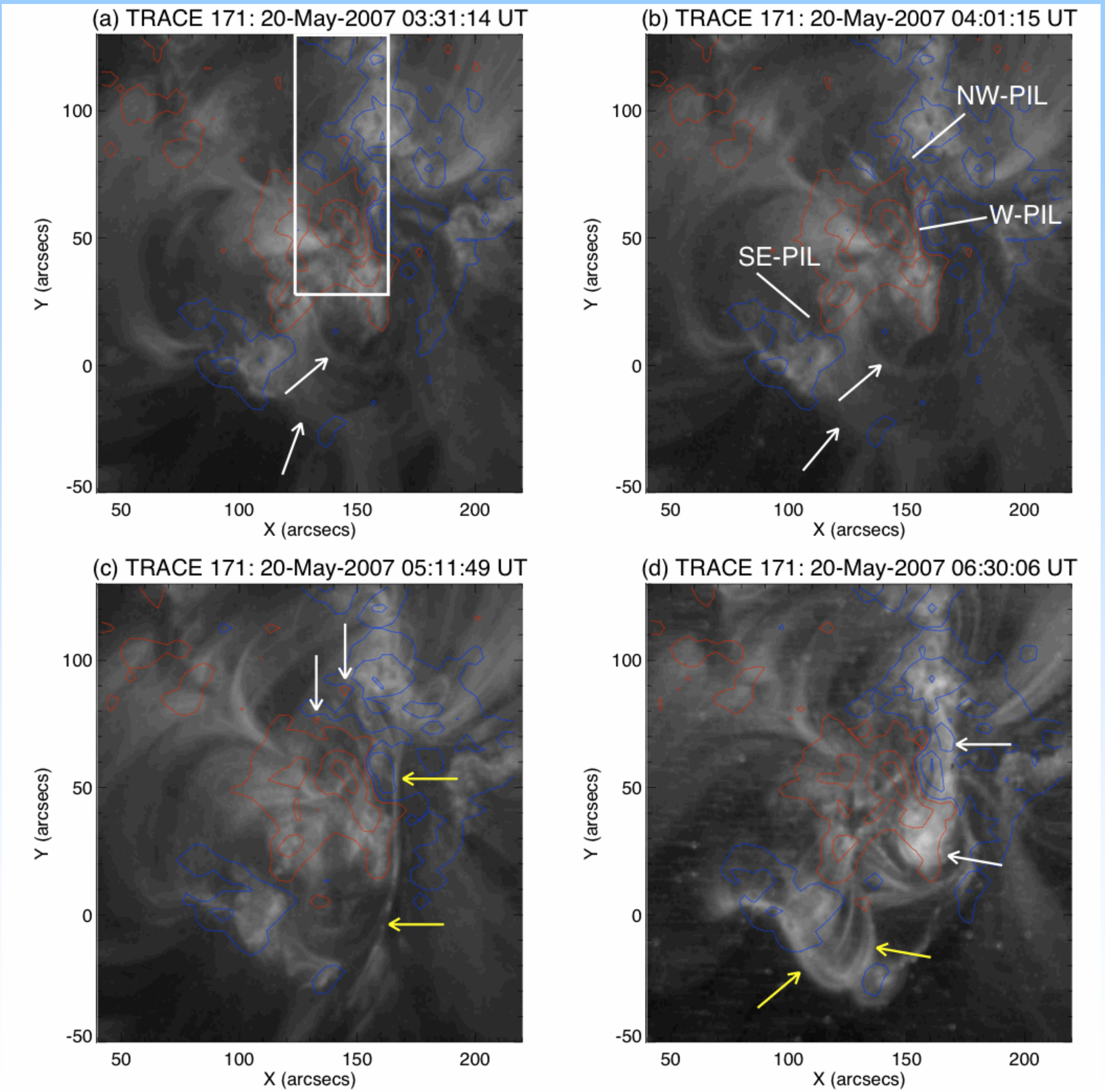
SOT H-alpha & MDI




(a) TRACE 171: 20-May-2007 03:31:14 UT
(b) TRACE 171: 20-May-2007 04:01:15 UT
NW-PIL
W-PIL
SE-PIL
(c) TRACE 171: 20-May-2007 05:11:49 UT
(d) TRACE 171: 20-May-2007 06:30:06 UT
Y (arcsecs)
X (arcsecs)

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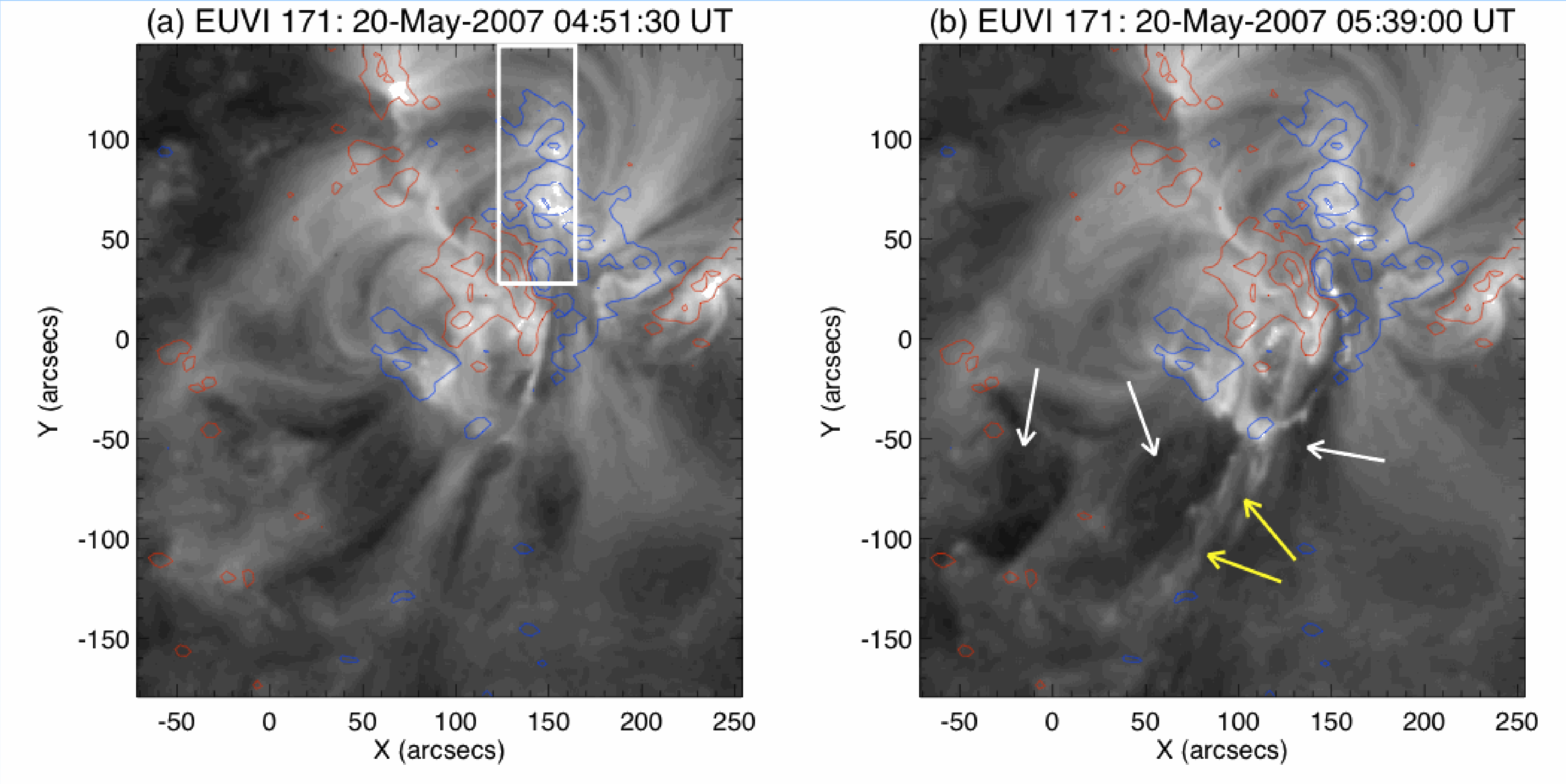

(a) EUVI 171: 20-May-2007 04:51:30 UT
(b) EUVI 171: 20-May-2007 05:39:00 UT
Y (arcsecs)
X (arcsecs)
100
50
0
-50
-100
-150
-50
0
50
100
150
200
250

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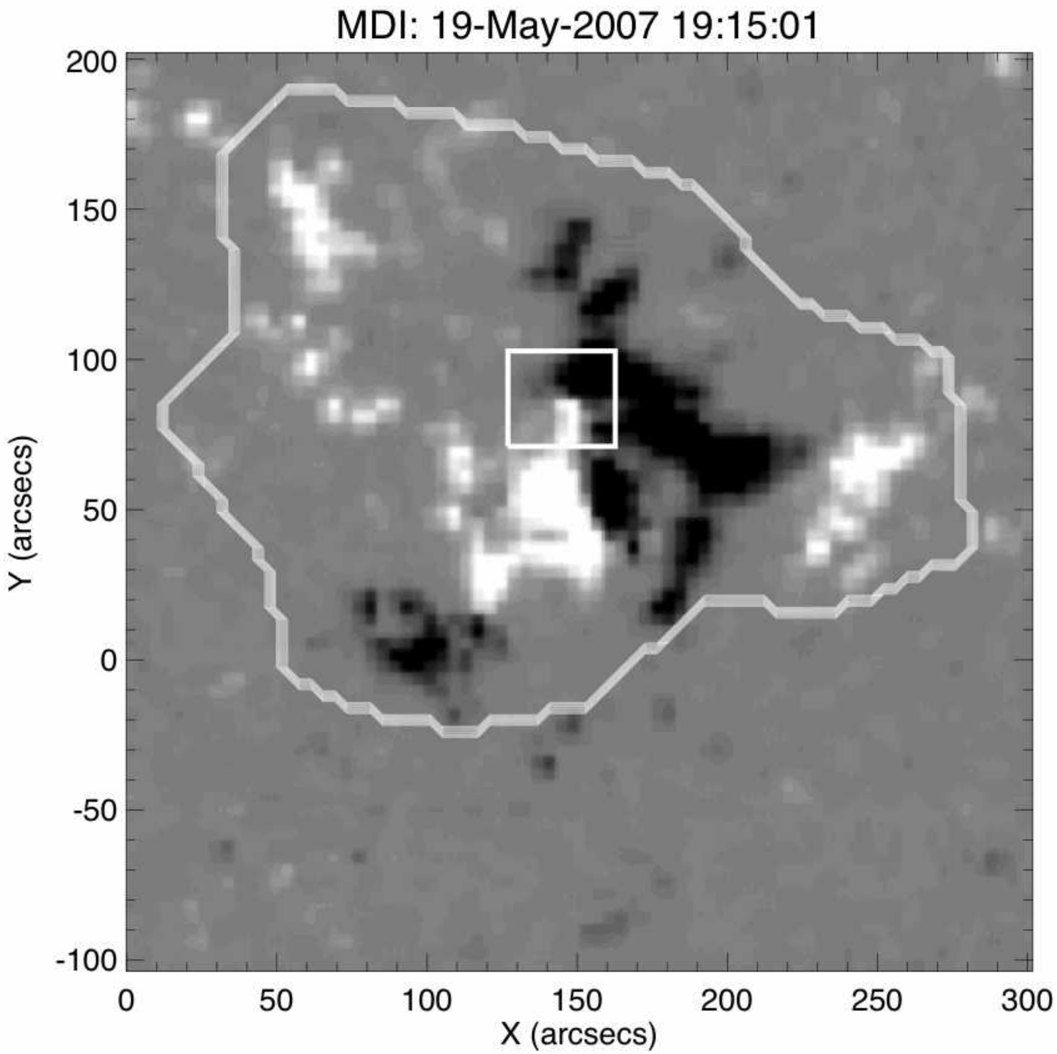
MDI: 19-May-2007 19:15:01
Y (arcsecs)
X (arcsecs)
200
150
100
50
0
-50
-100
0
50
100
150
200
250
300

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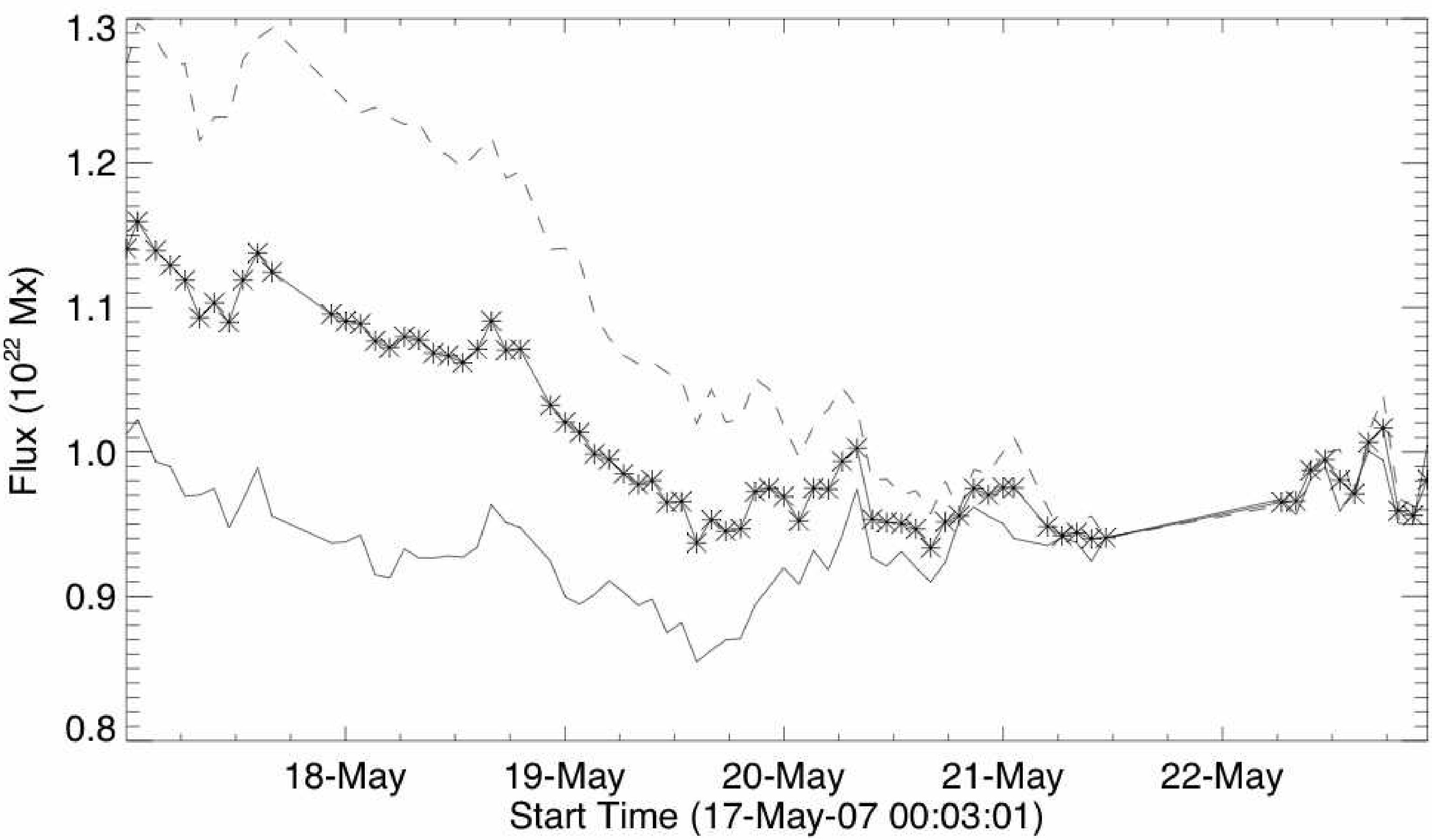

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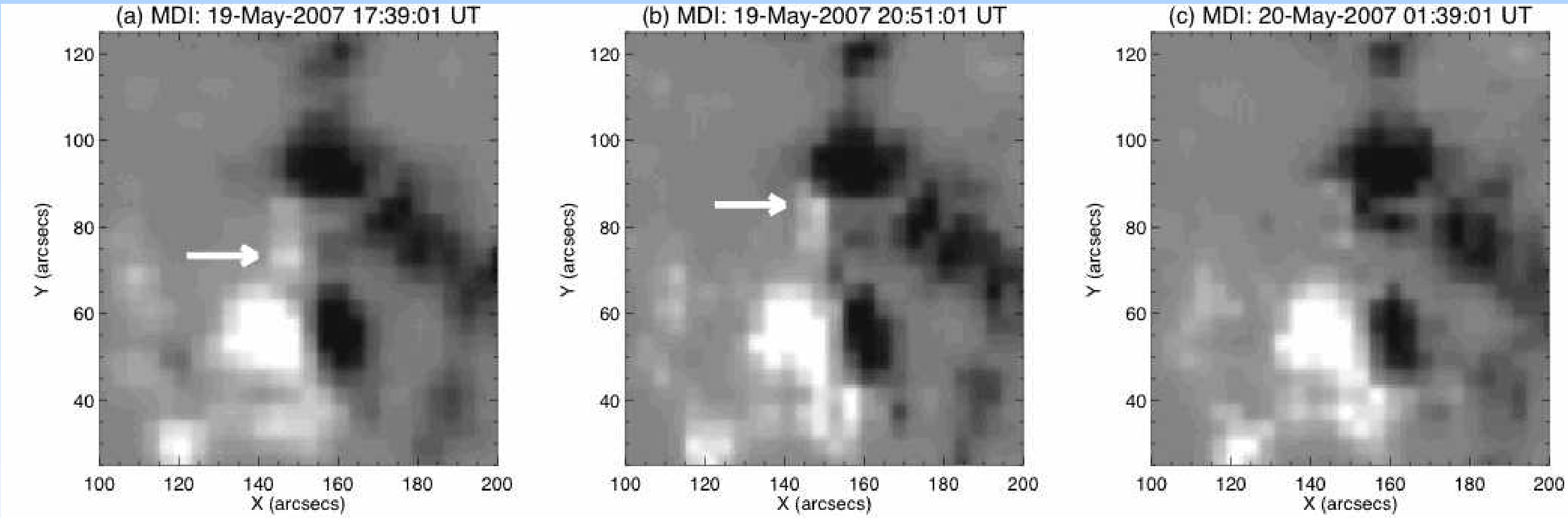

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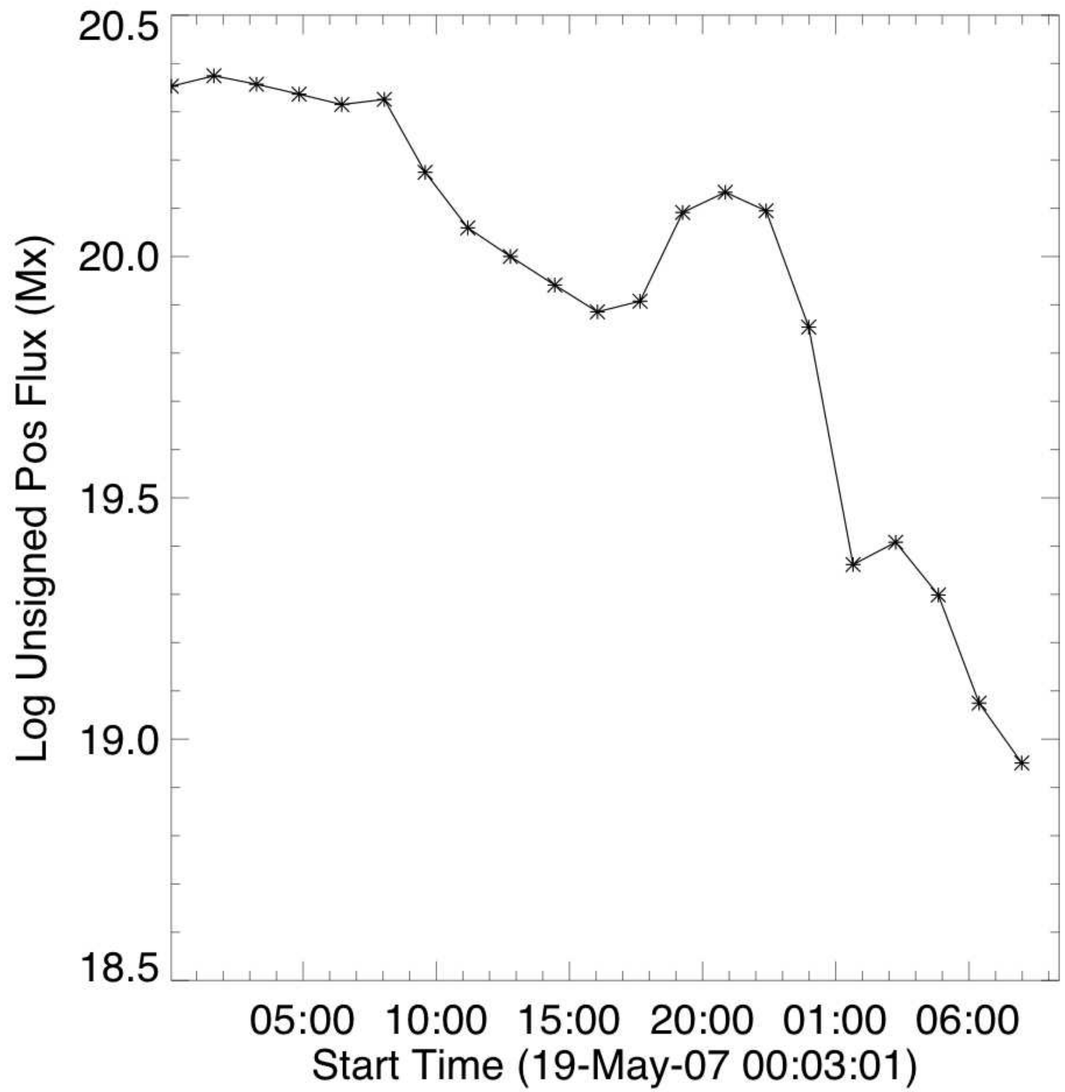

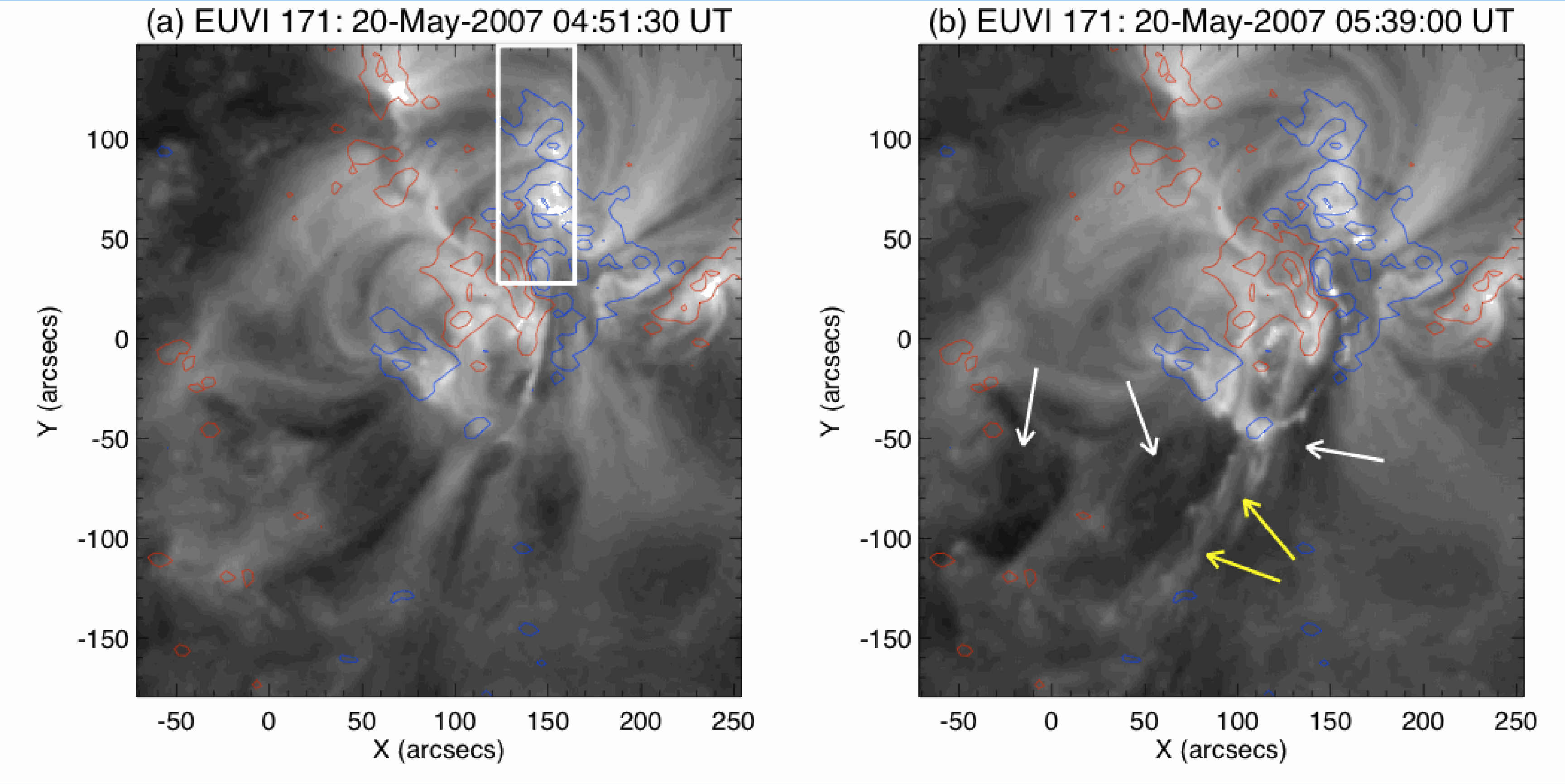
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(b) EUVI 171: 20-May-2007 05:39:00 UT
100
50
0
-50
-100
-150
Y (arcsecs)
-50
0
50
100
150
200
250
X (arcsecs)

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Some Preliminary EIS Findings

- Small-scale transient brightenings were observed in the region prior to eruption at both transition region and coronal temperatures. These were at the base of the surge-ejection site, and in some cases at sites of mixed (canceling) polarity.
- Persistent red-shifted flows (Fe XII), and non-thermal line-broadening along the main polarity inversion line (spot-merging region), and a negative region in the north (surge-source region).
- A brightening along neutral line in E has mixed lineshifts and strong non-thermal Fe XII broadenings.
- Strongest lineshifts are ~20 km/s.
- Typical densities are a few $\times 10^9$ cm^{-3}. Find density enhancements that are localized, and changing with time along the polarity inversion lines.

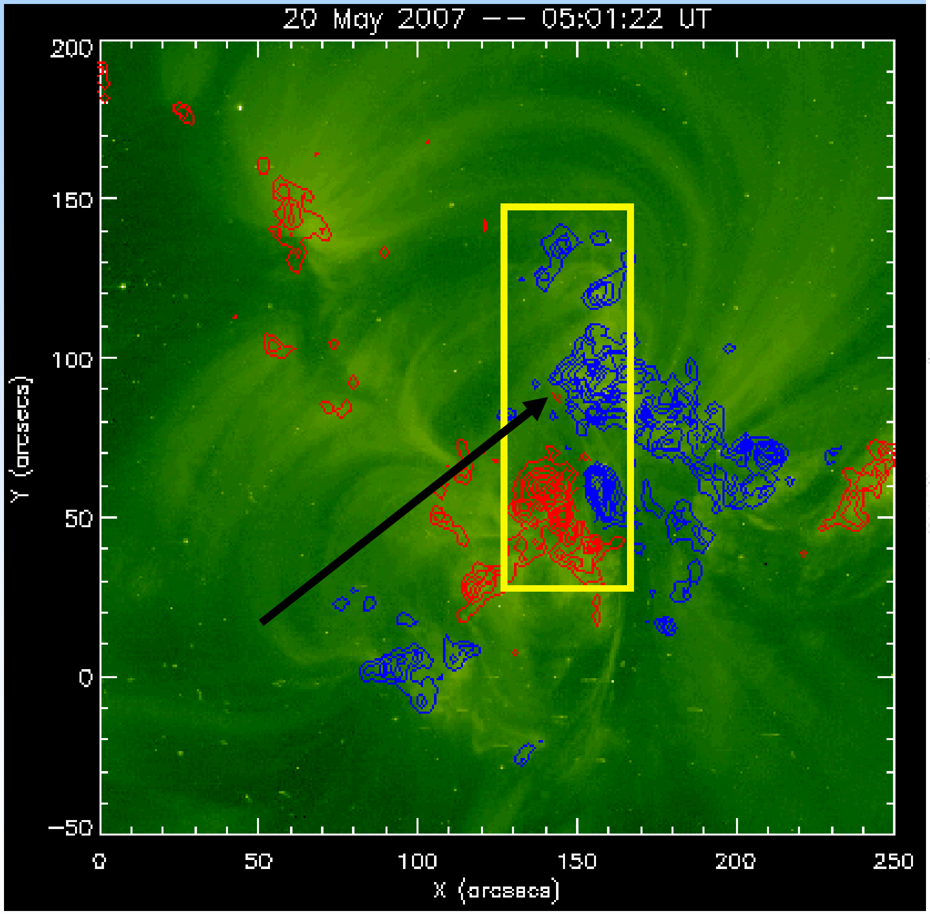
EIS Observed Eruption Region

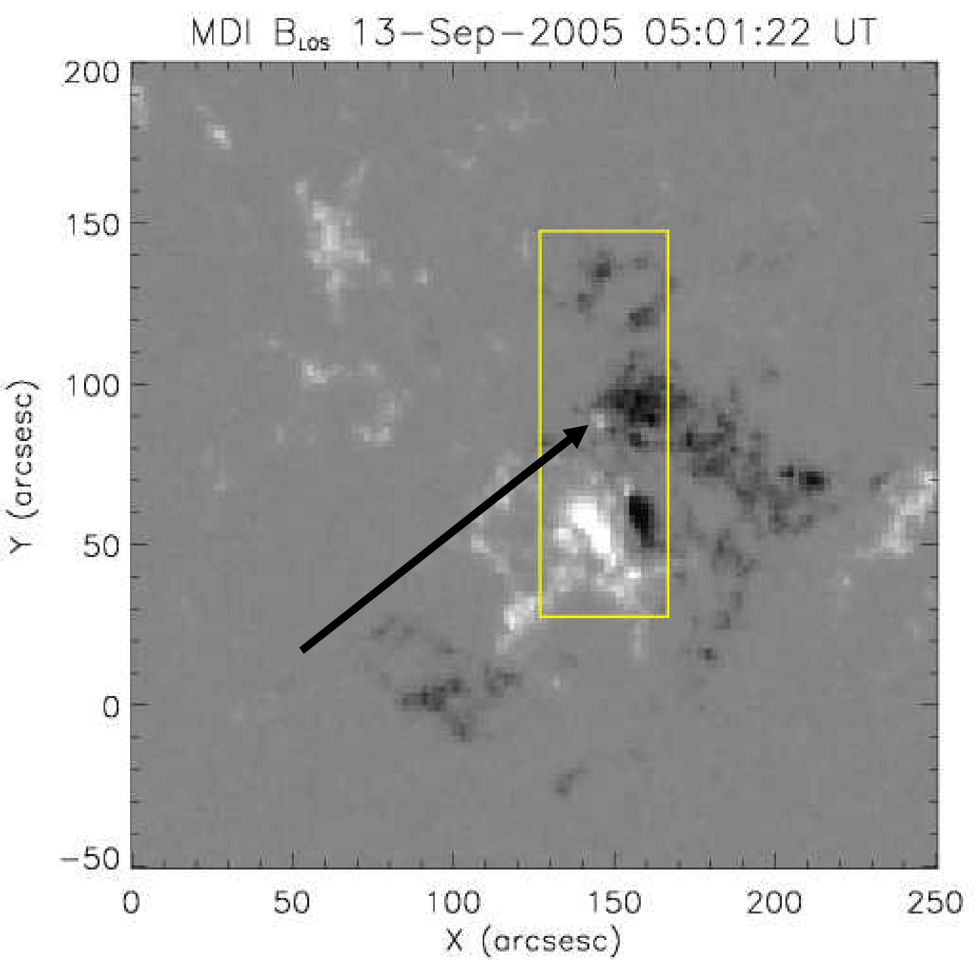
- Used common brightenings seen in TRACE, STEREO, XRT, and SOT to align EIS data.
- Hinode was in spacecraft night during the eruption peak, but observed much prior to and after the peak.
- ‘CAM_ARTB_RHESSI’ sequence.
  - Series of fast-cadence (~3.5 min, 40”x120” FOV) rasters, followed by context (~20 min, 240”x204”) raster, both with 2” slit.
  - Includes several strong TR and coronal lines over wide temperature range.

- Can obtain information on flows, line widths, and density.

EIS FOV + TRACE+MDI

Arrow shows position of the 'intruding' positive polarity





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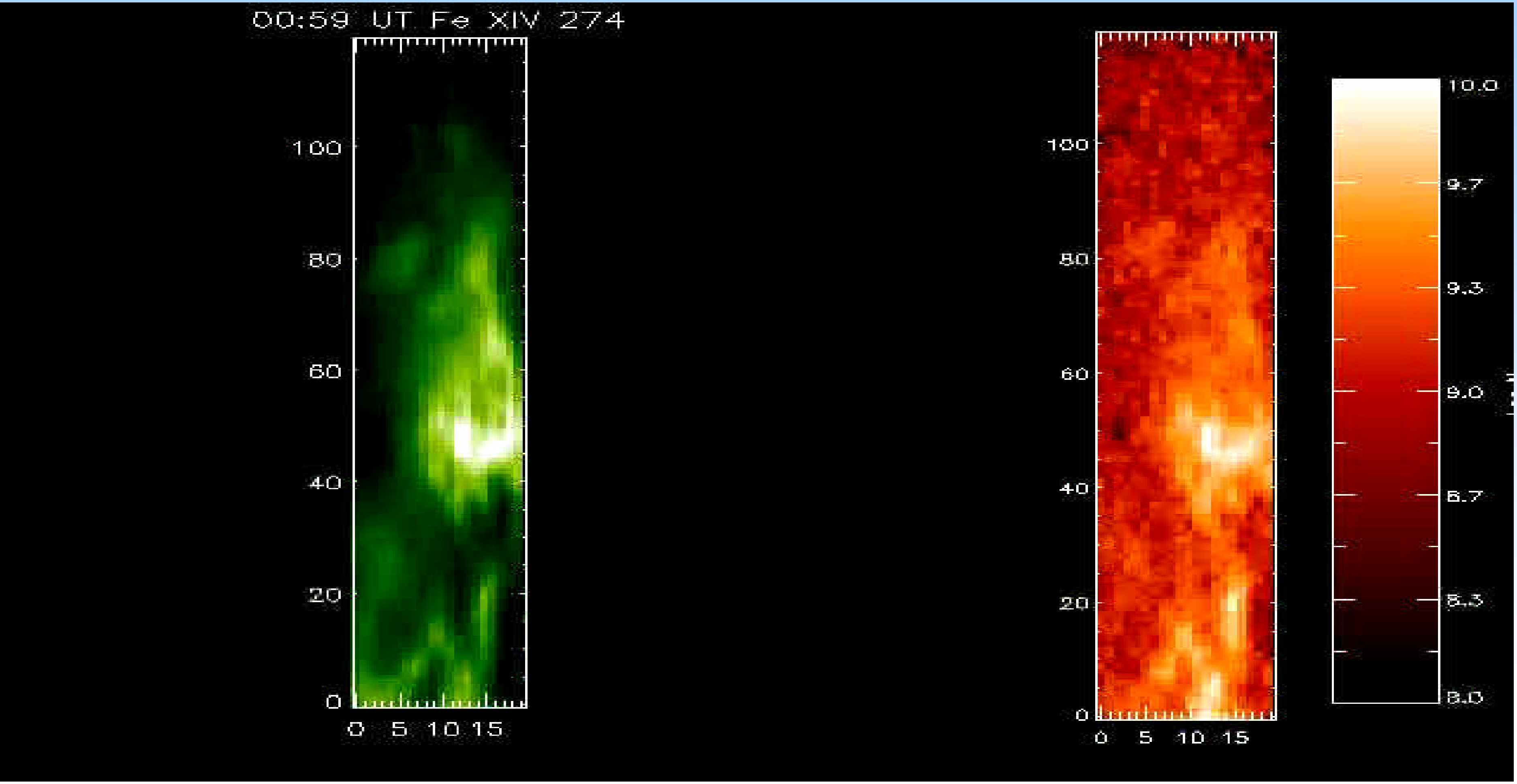
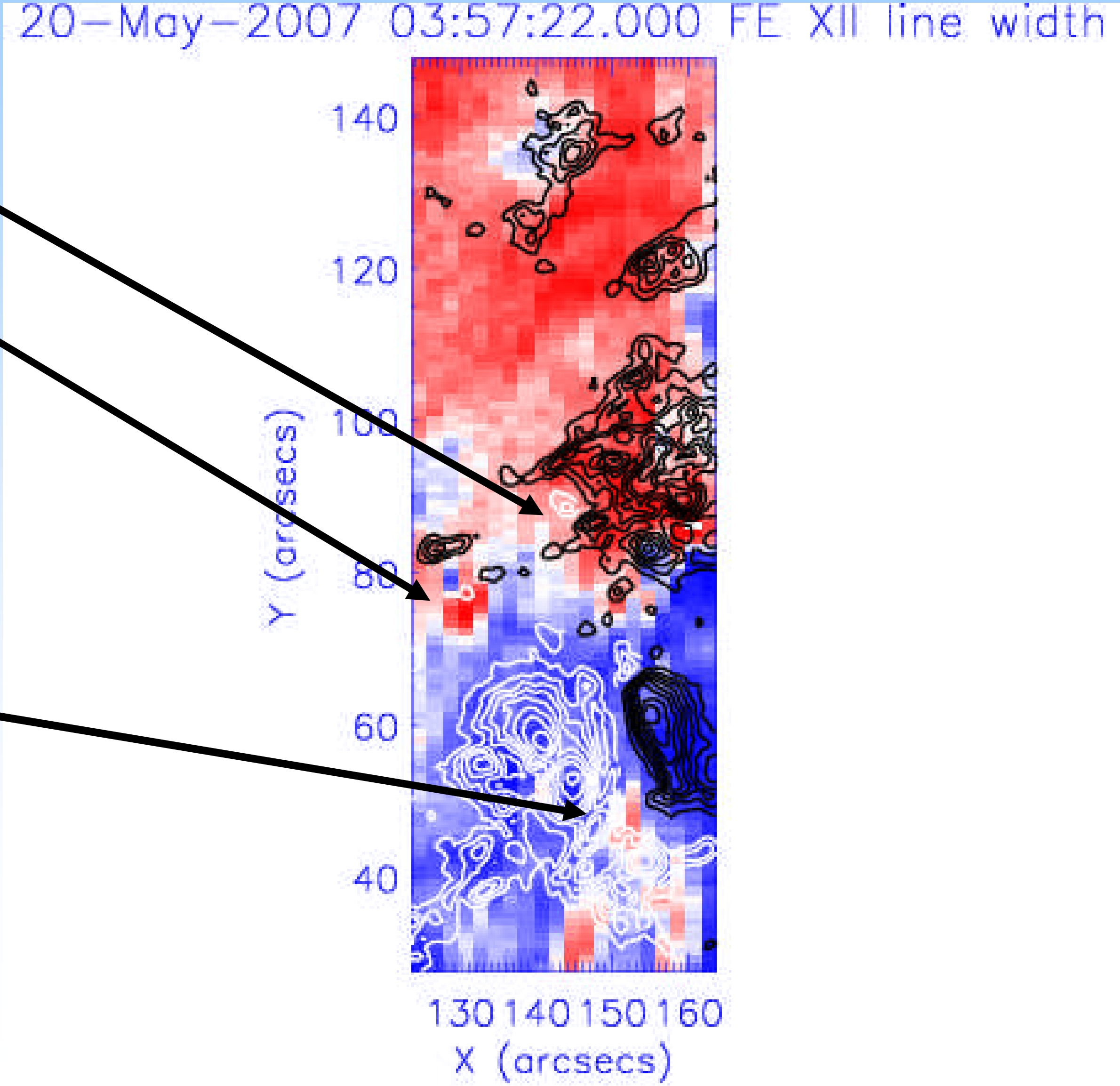
Density from Fe XIV (274/264)



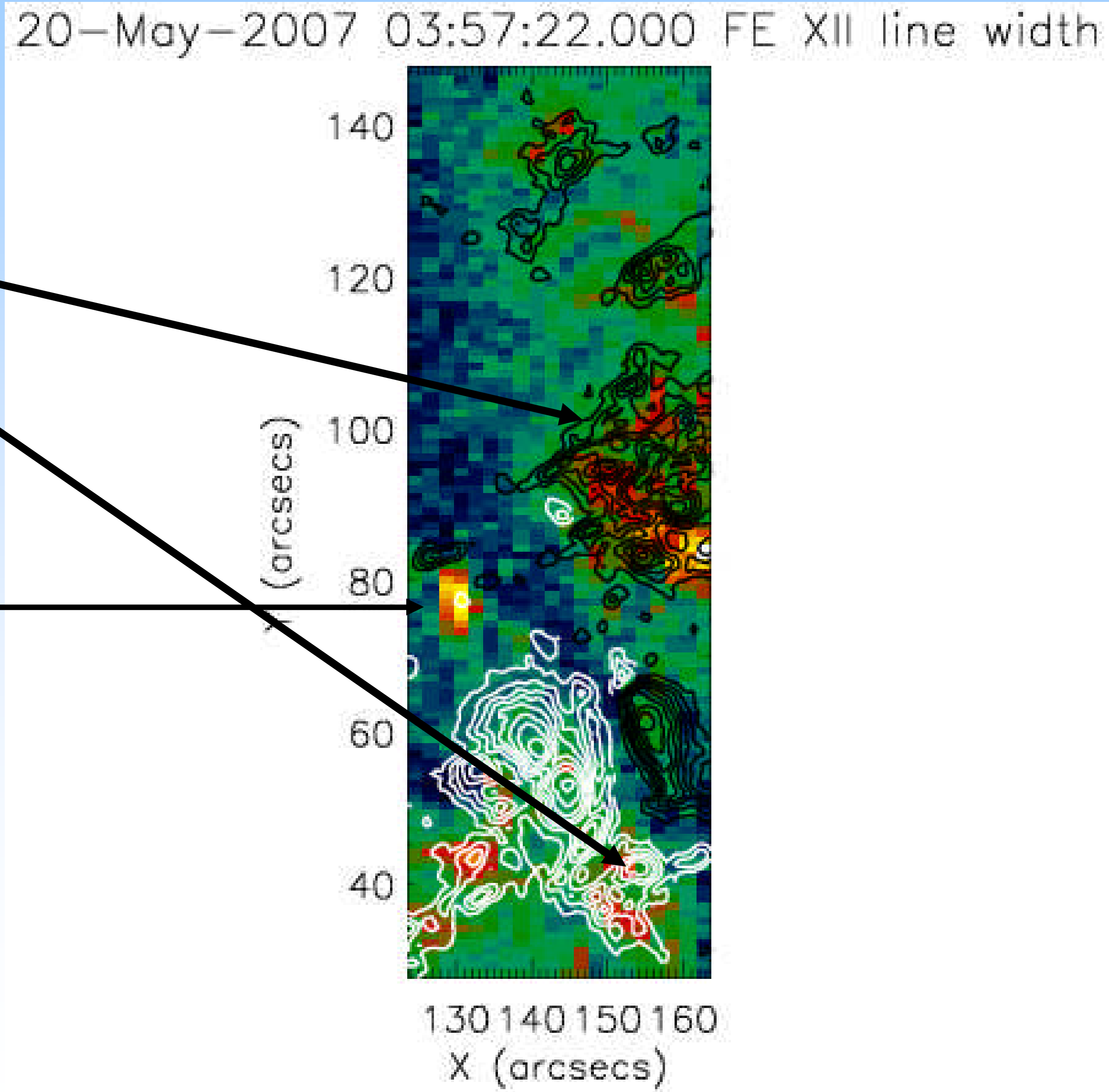
MDI + EIS Fe XII 03:57 UT Doppler shift

- The intruding positive polarity.
- The preflare ‘co-alignment brightening’ is seen close to a small magnetic bipole. It seems associated with a bipolar flow (?).
- Persistent redshifts along the neutral line.



MDI + EIS Fe XII 03:57 UT line broadening

- Persistent line broadening in the negative flux region and along neutral line.
- The preflare brightenings are associated with strong nonthermal broadening of the line.



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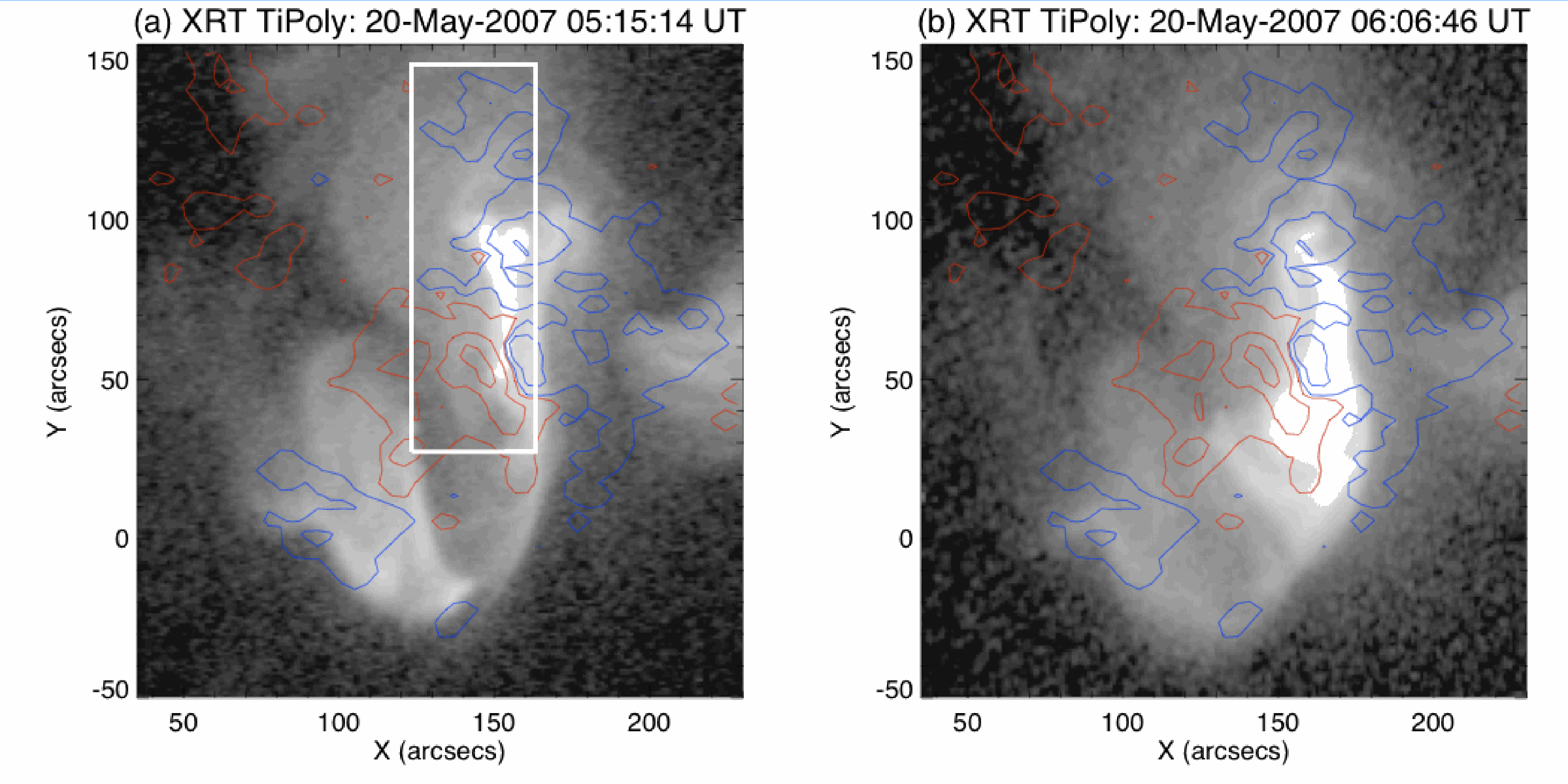
(a) XRT TiPoly: 20-May-2007 05:15:14 UT
(b) XRT TiPoly: 20-May-2007 06:06:46 UT
Y (arcsecs)
X (arcsecs)
150
100
50
0
-50
50
100
150
200

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XRT

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

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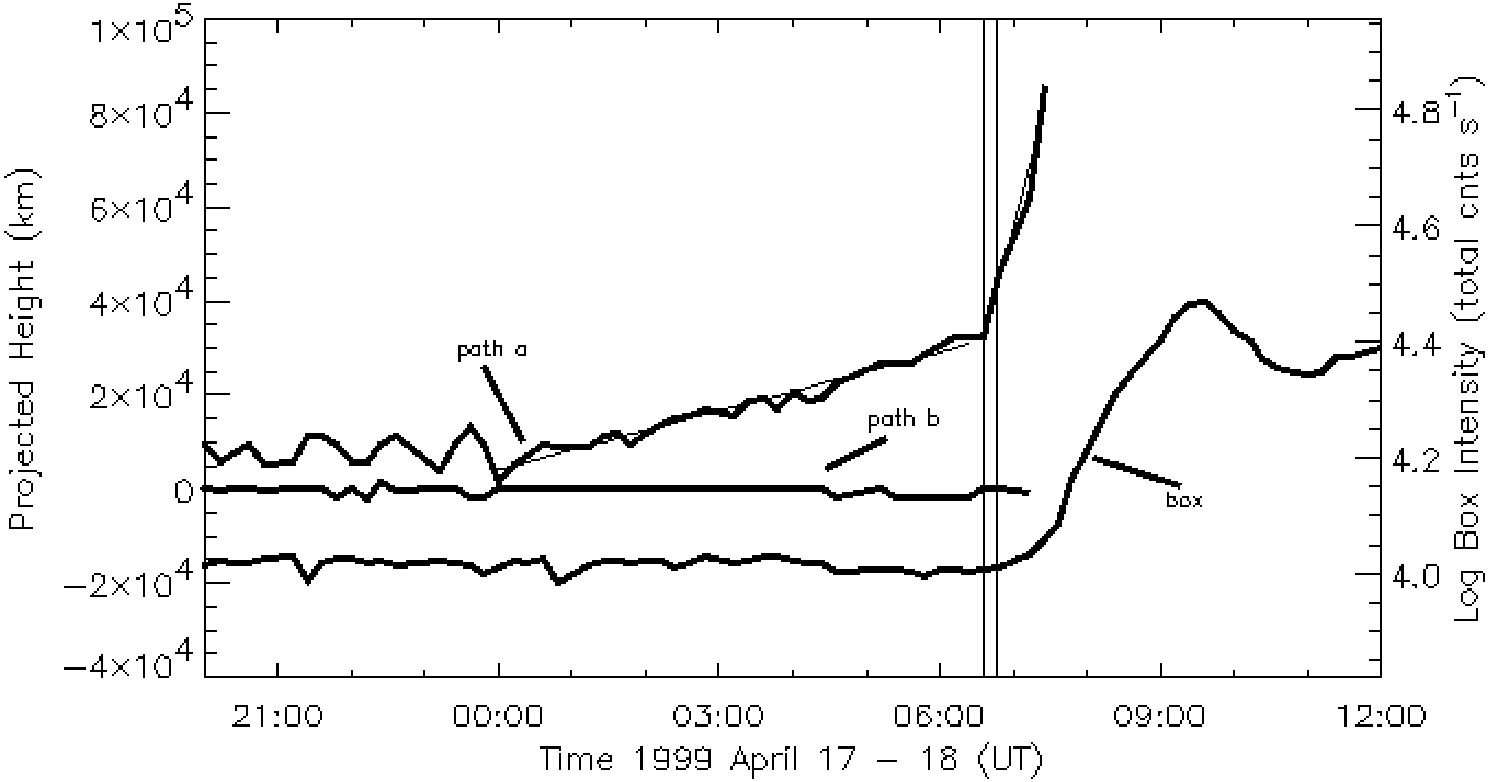
Event of 2 March 2007

- On-disk filament eruption of 2 March 2007. GOES class B 2.5.
- Seen with TRACE, Hinode (STEREO too).
- Use TRACE for filament.
- Hinode:
  - SOT (FG V magnetogram), etc.
  - SXRs from XRT
- Also use MDI magnetogram.
- Can address what occurs during the pre-eruption **slow rise** of filaments, using Hinode.

Image Alignment

- TRACE on MDI: both alignments known.
- Match SOT and MDI magnetograms => SOT on MDI, TRACE.
- XRT onto SOT: Internal Hinode studies (H. Hara, N. Narukage; private communication), plus “by eye.” => XRT onto MDI, TRACE.

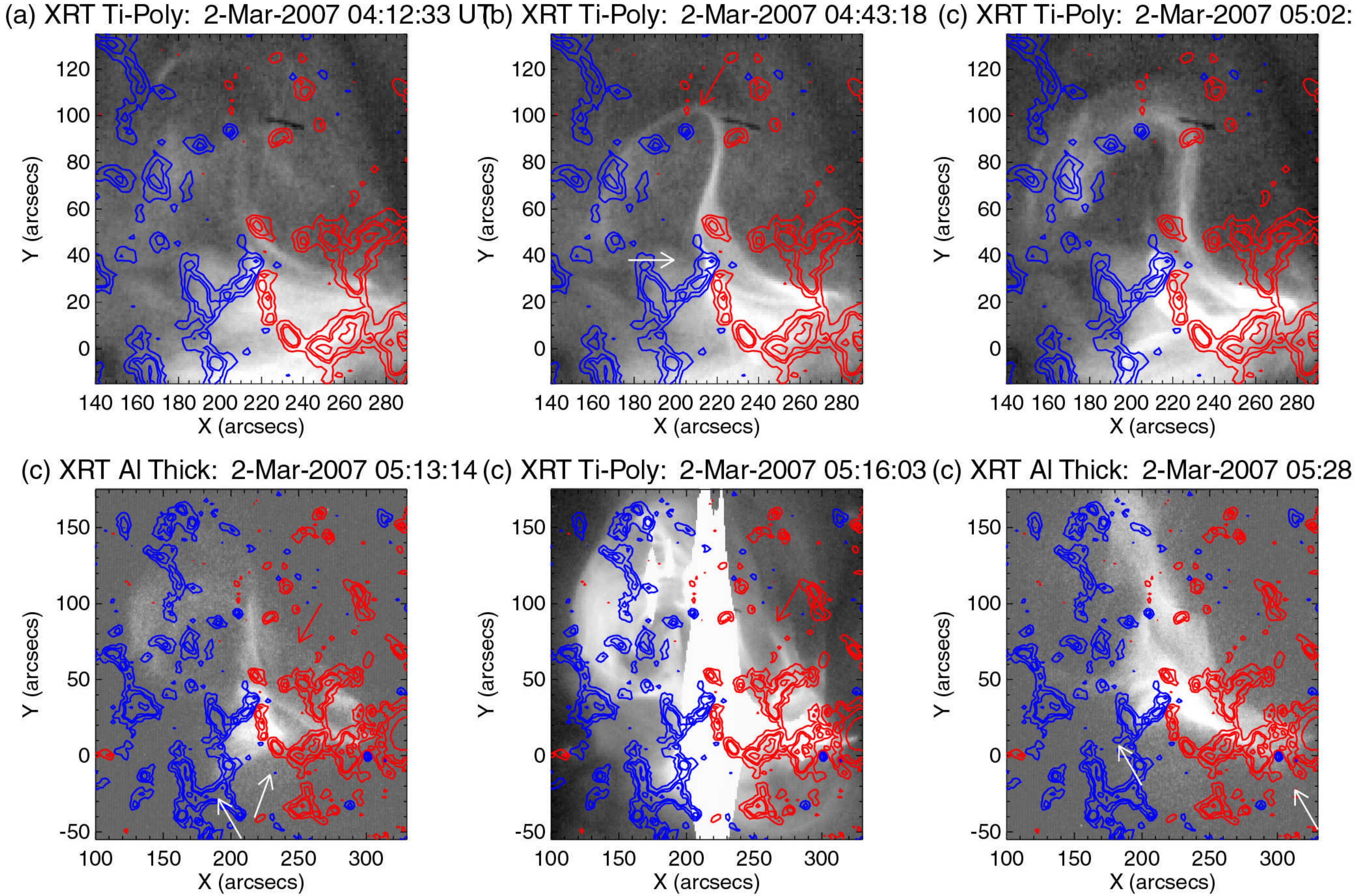
Filament pre-eruption, pre-flare **slow-rise phase**



Sterling, Moore, Thompson (2001)

(e.g., Tandberg-Hanssen et al. 1980, Kahler et al. 1988)

XRT on MDI



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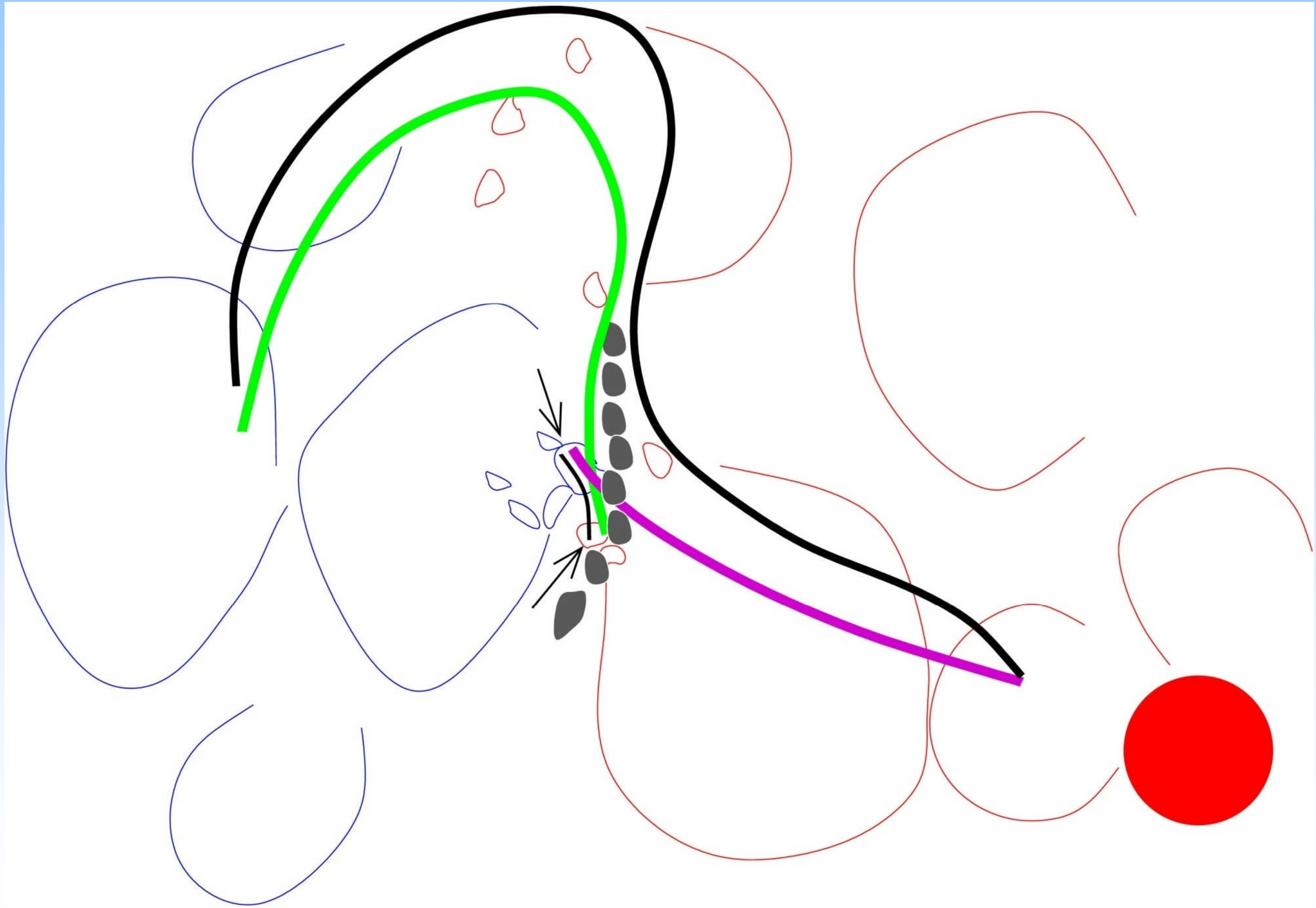

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