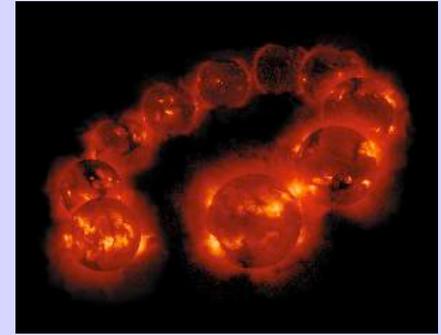


CME Eruption Onset Observations: Dimmings

Alphonse C. Sterling
NASA/MSFC/NSSTC

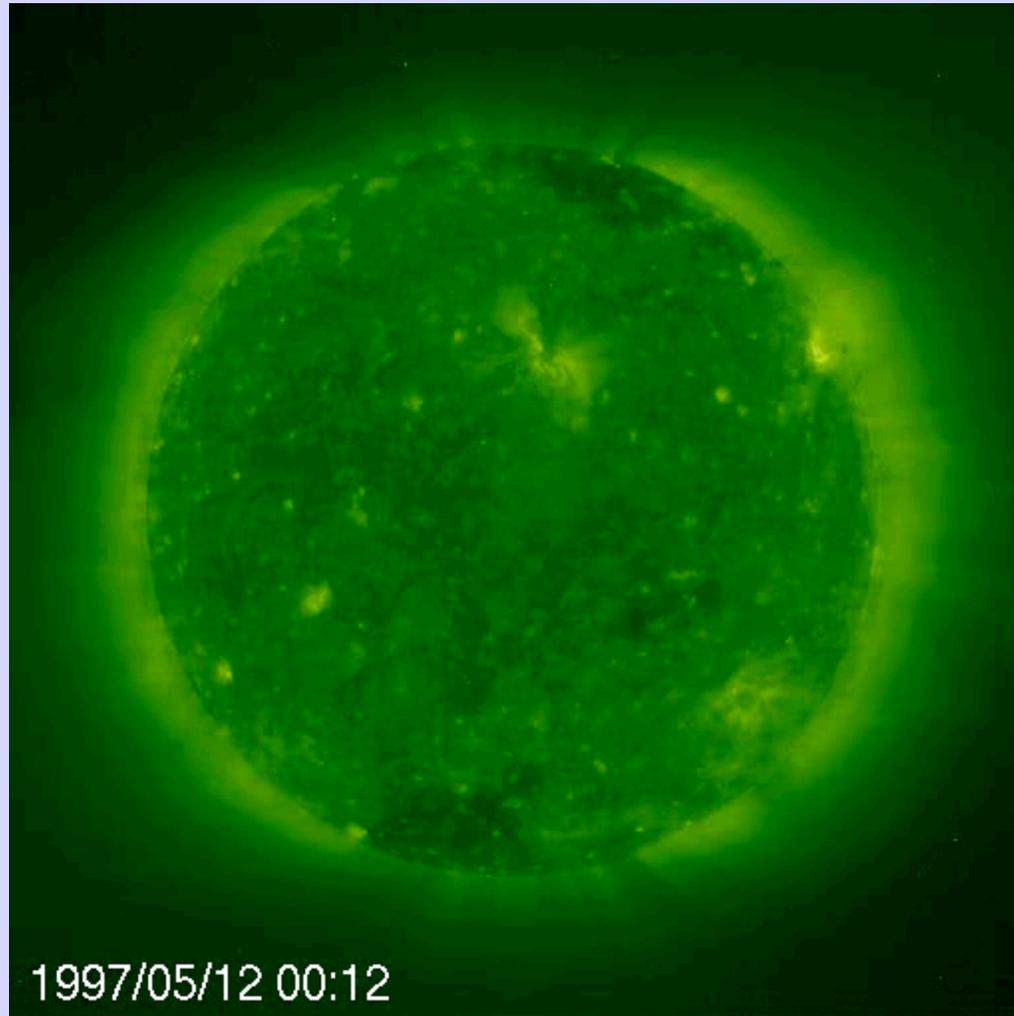
Introduction



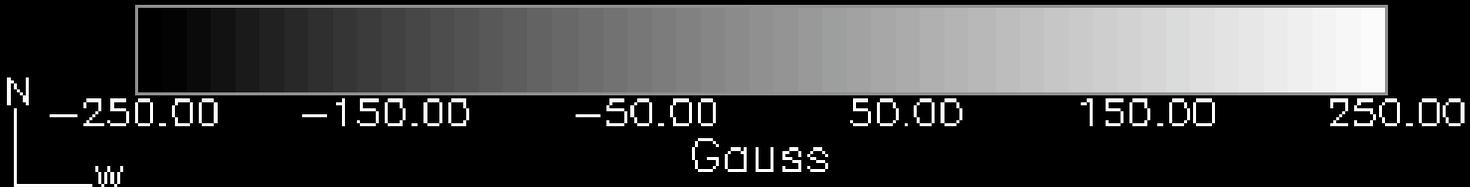
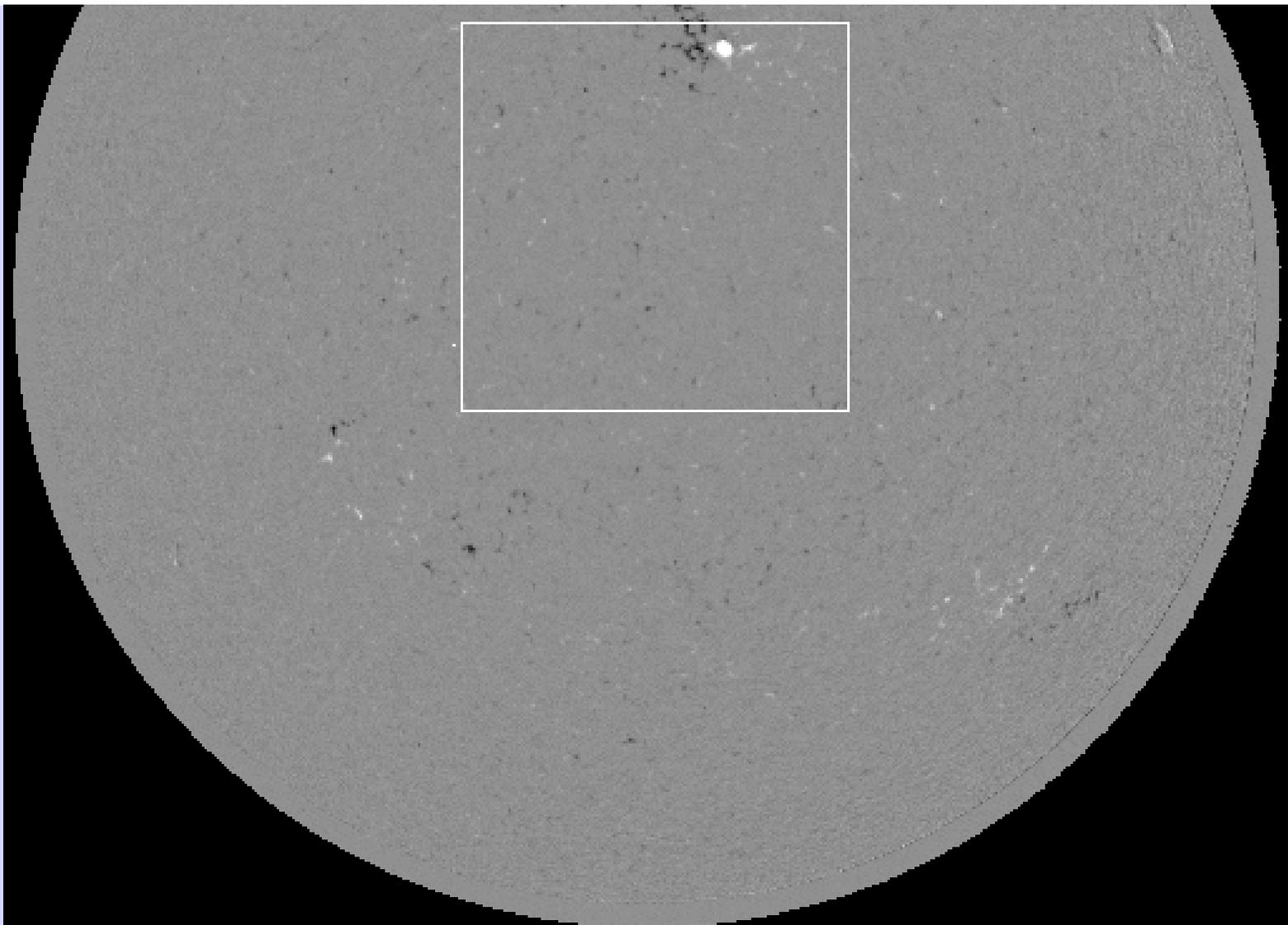
- Intensity “dimmings” are often associated with eruptions.
- Originally seen in white-light coronagraphs.
- Recent studies: SXT, EIT, TRACE, and CDS.
- One objective: Examine CME source regions.
- This talk: EIT, SXT, and CDS dimmings; consider implications for CME eruption mechanism, and consider early dimmings.
- Not a comprehensive review, => more topics for discussion.

“Typical” (Simple) Dimming

- Roughly symmetric, double dimming pattern.
- Seen in SXT and EIT (some early e.g.s, Manoharan et al. 1996; Sterling & Hudson 1997; Hudson et al. 1998; Thompson et al. 1998, 2000; Gopalswamy et al. 1998, 2000; etc.)
- Simple pattern likely due to simple bipole magnetic geometry (details yet to be verified!).



Thompson et al. 1998, etc.

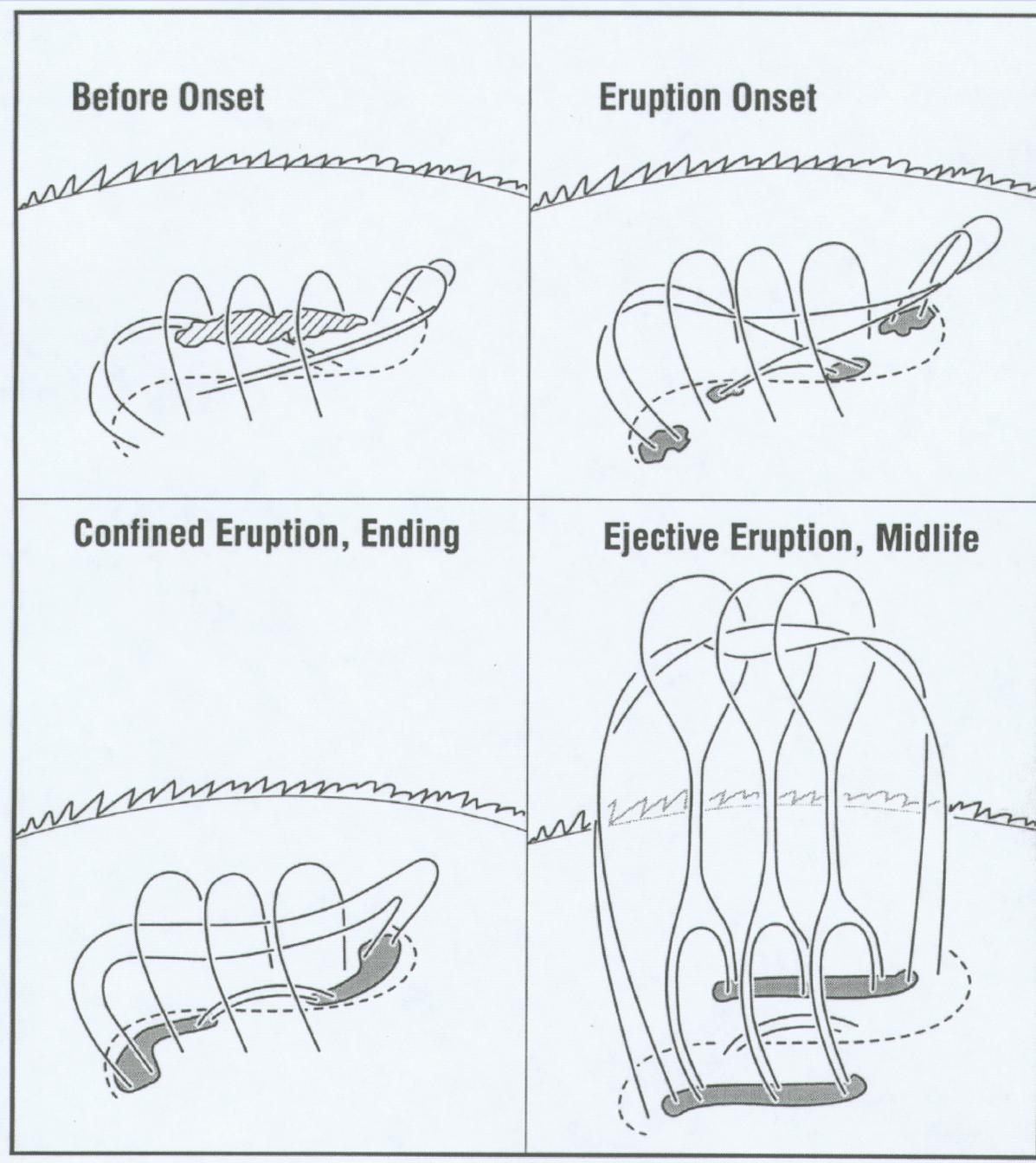


Shine 20

SOI / MDI

Stanford Lockheed Institute for Space Research

(Moore et al. 2001)



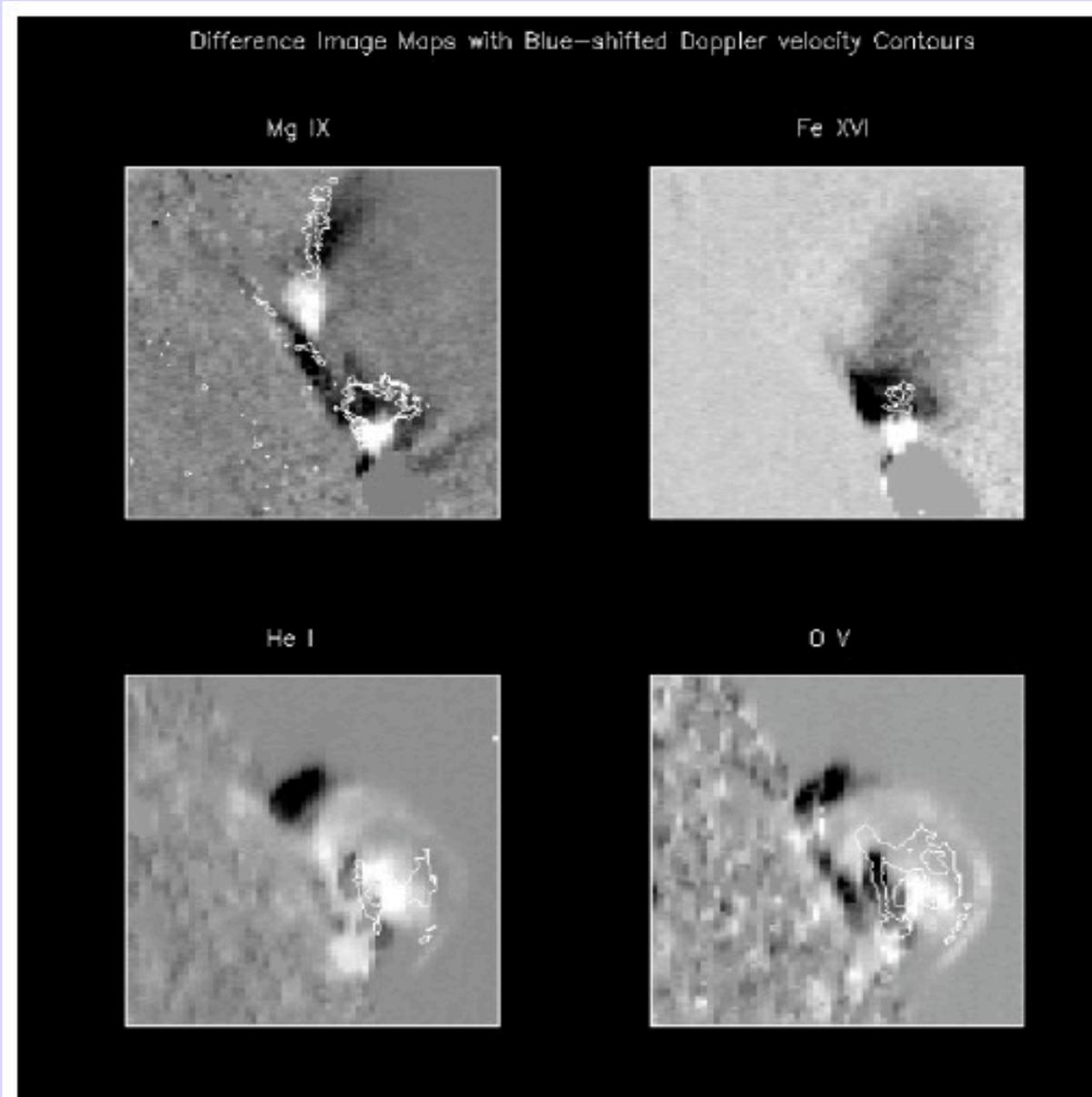
Shine 2004, A. Sterli

Dimmings: Mass Loss or ΔT (?)

- Often due to mass loss:
- Dimmings seen in both SXT and EIT (Zarro et al. 1999; Gopalswamy & Thompson 2000; Sterling & Moore 2003a).
- Evidence for outflows from dimming regions from CDS (Harra & Sterling 2001).
- More evidence from CDS (Harrison & Lyons 2000; Harrison et al. 2003; Howard & Harrison 2004).

EUV Dimmings

- Howard & Harrison (2004) looked at dimmings in CDS and in EIT. In EIT, 5 of 9 CMEs have dimming, 4 of 9 do not have dimming (counted 9 “certain” cases with on-disk sources), => some CMEs have no EUV dimming signature.
- CDS ions:
 - He I: 20,000 K
 - Ov: 250,000 K
 - Mg ix: 1 MK
 - Fe xvi: 2 MK
 - Two Si x lines: 1.3 MK



Shine 2004, A. Sterling

Harra & Sterling (2001)

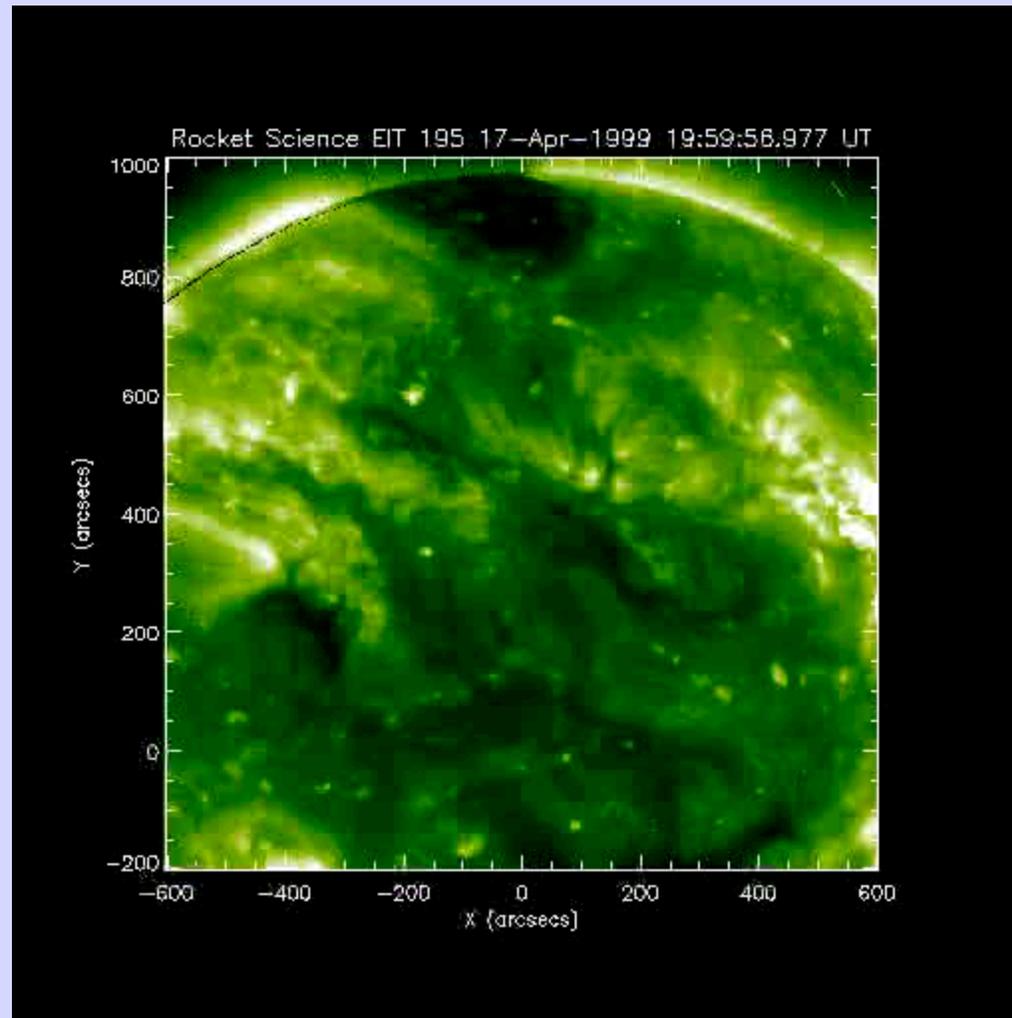
Dimmings and Eruption Properties

Will use:

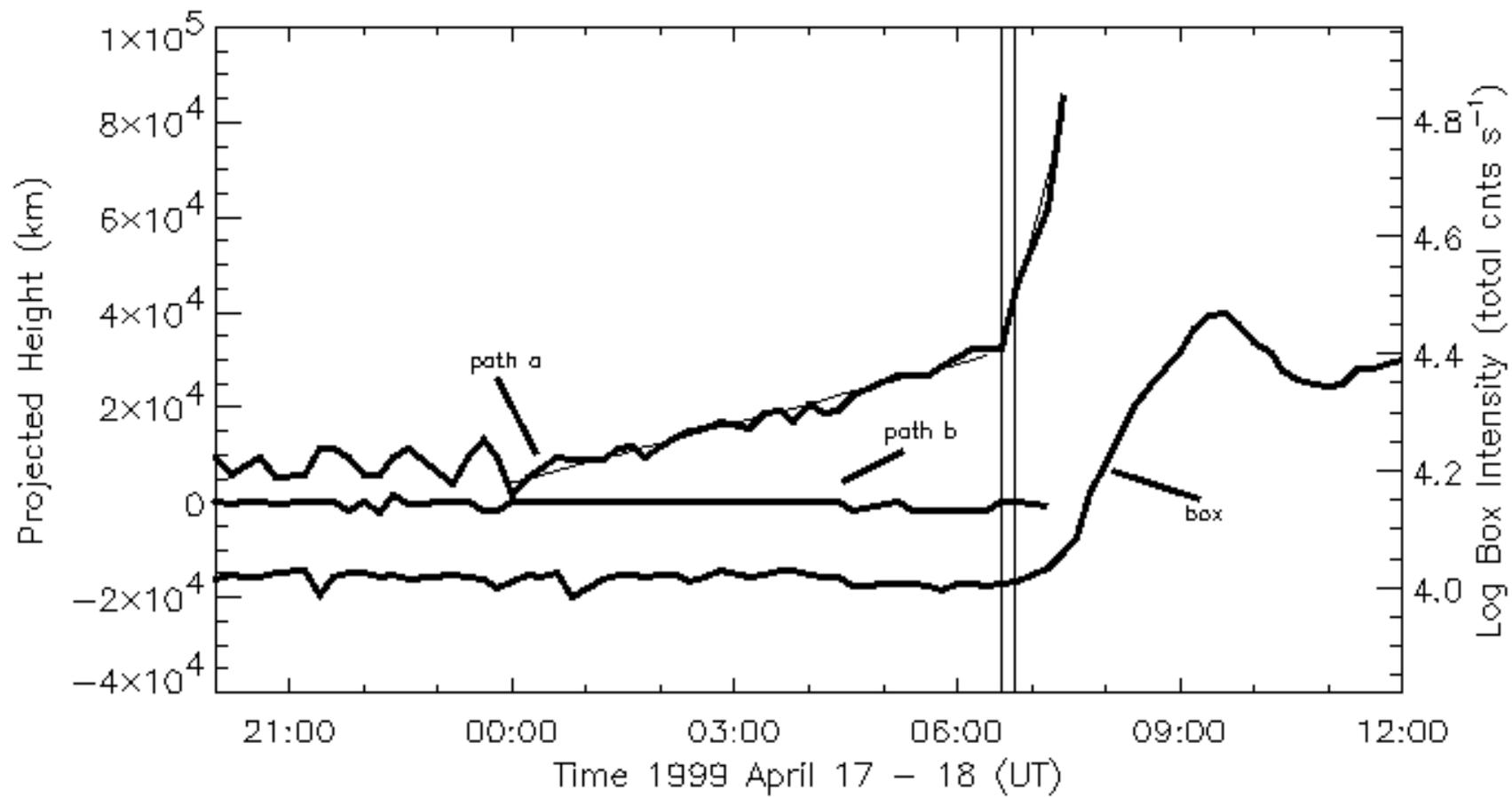
- Slow eruptions (combat EIT cadence).
- Filament eruption events (“see” **B**).

Example 1 of 3: 18 April 1999

(Sterling, Moore, & Thompson 2001;
Sterling & Moore 2004a)



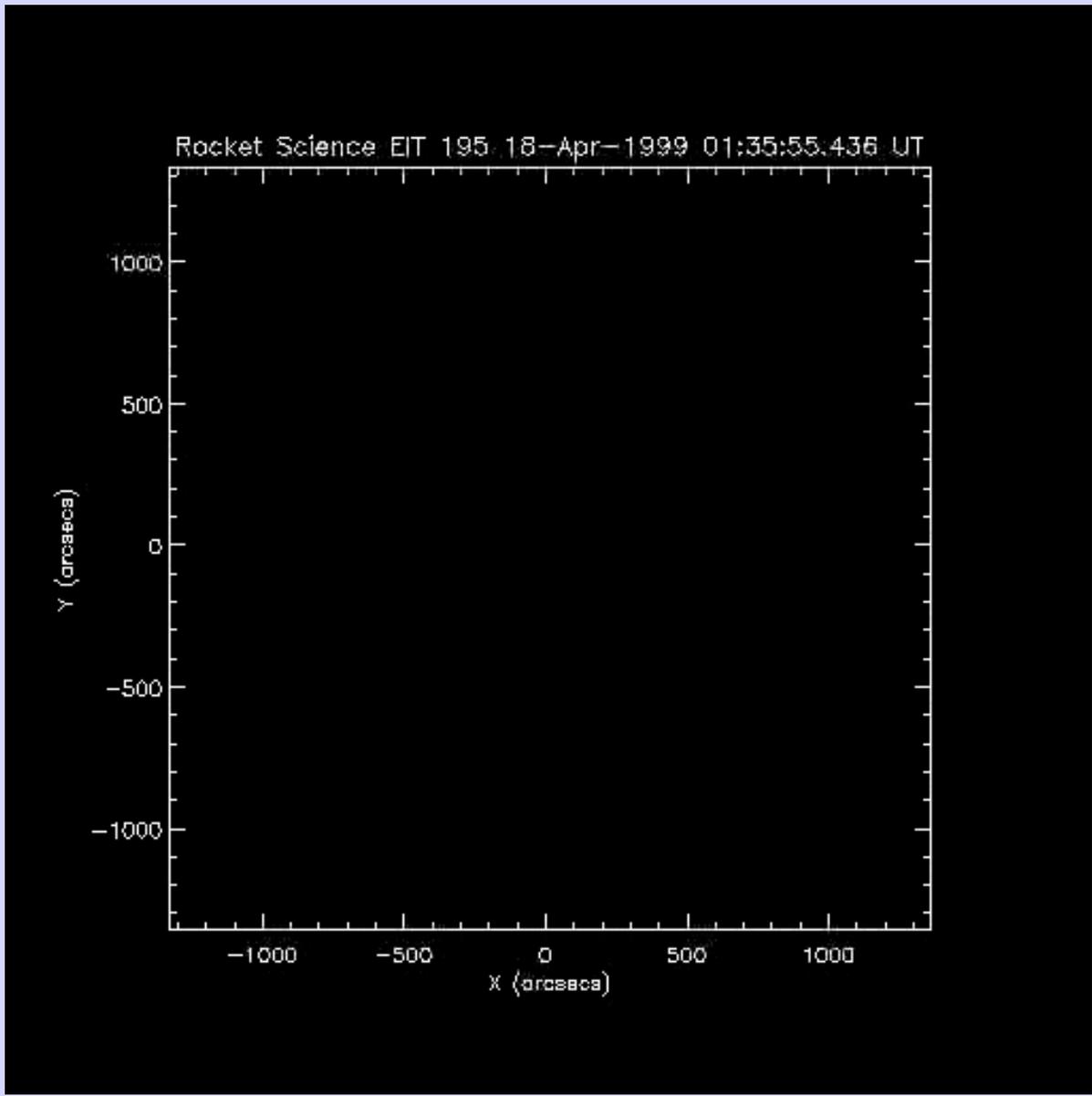
Shine 2004, A. Sterling



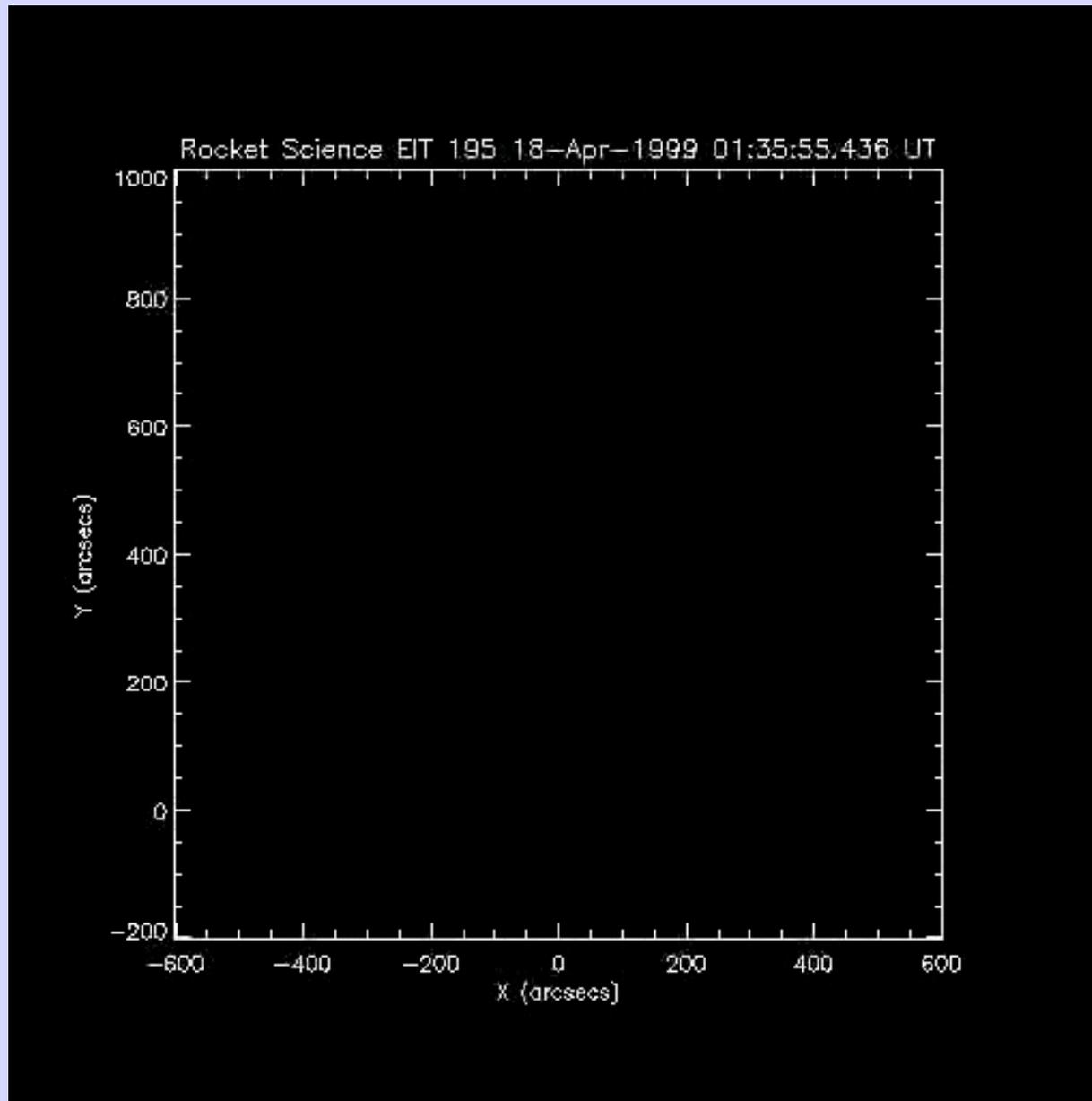
Sterling, Moore, Thompson (2001)

Beware of False Dimmings!

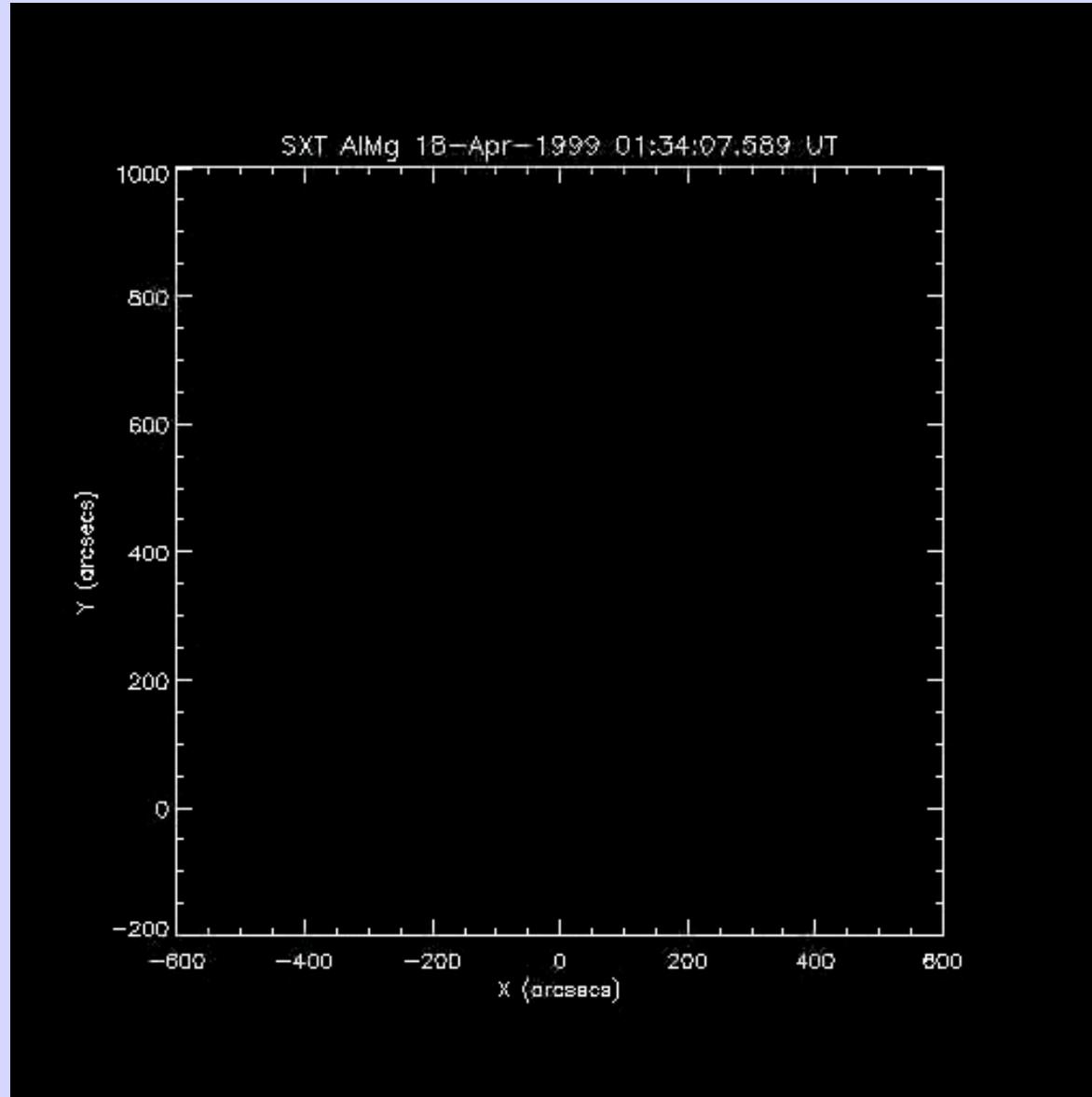
- Can occur in long, fixed-dimming runs.
- Get false dimming in East, false brightening in West.
- Due to combination of solar rotation and limb brightening.
- More prominent in EIT than in SXT.



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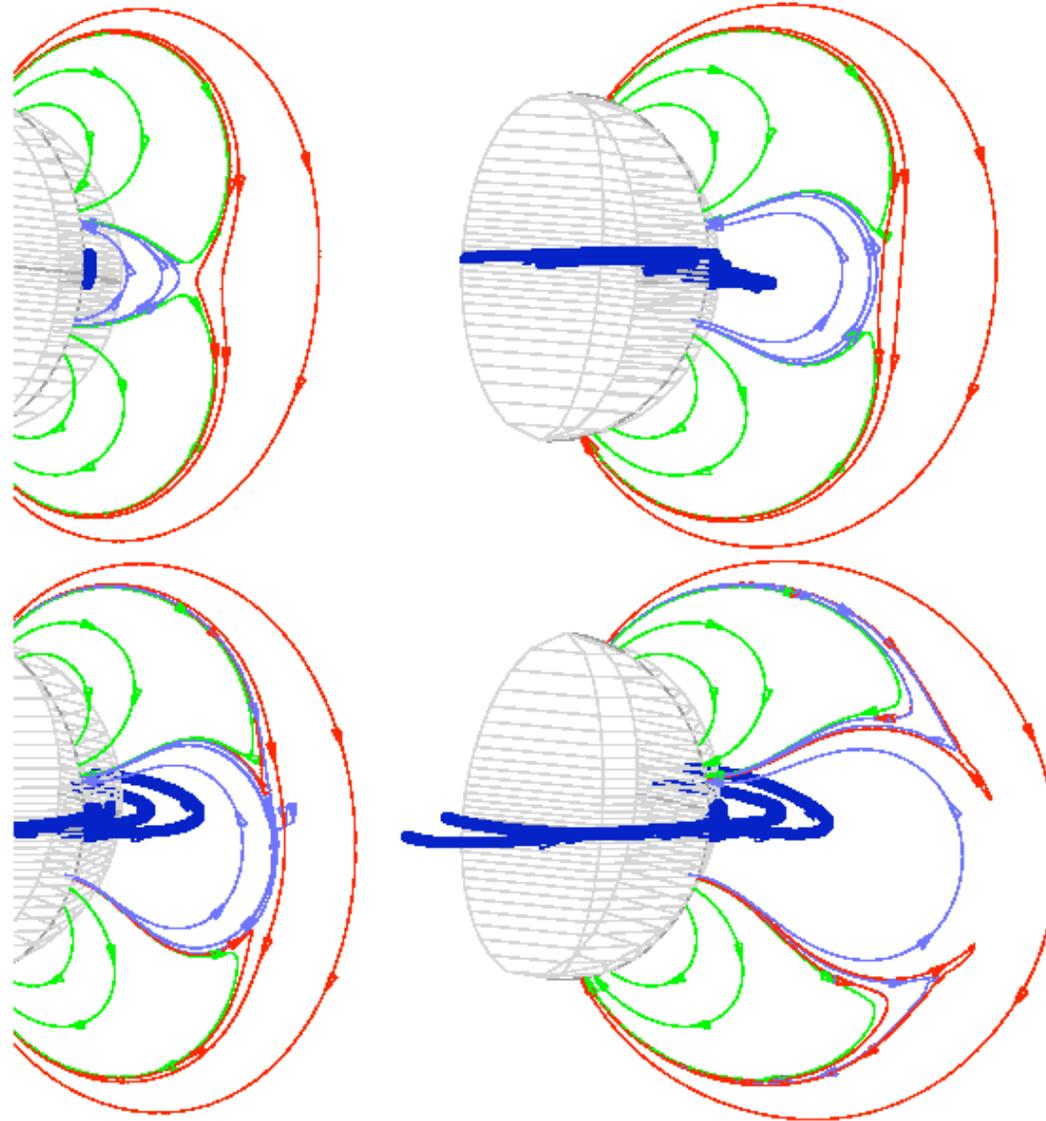


Shine 2004, A. Sterling

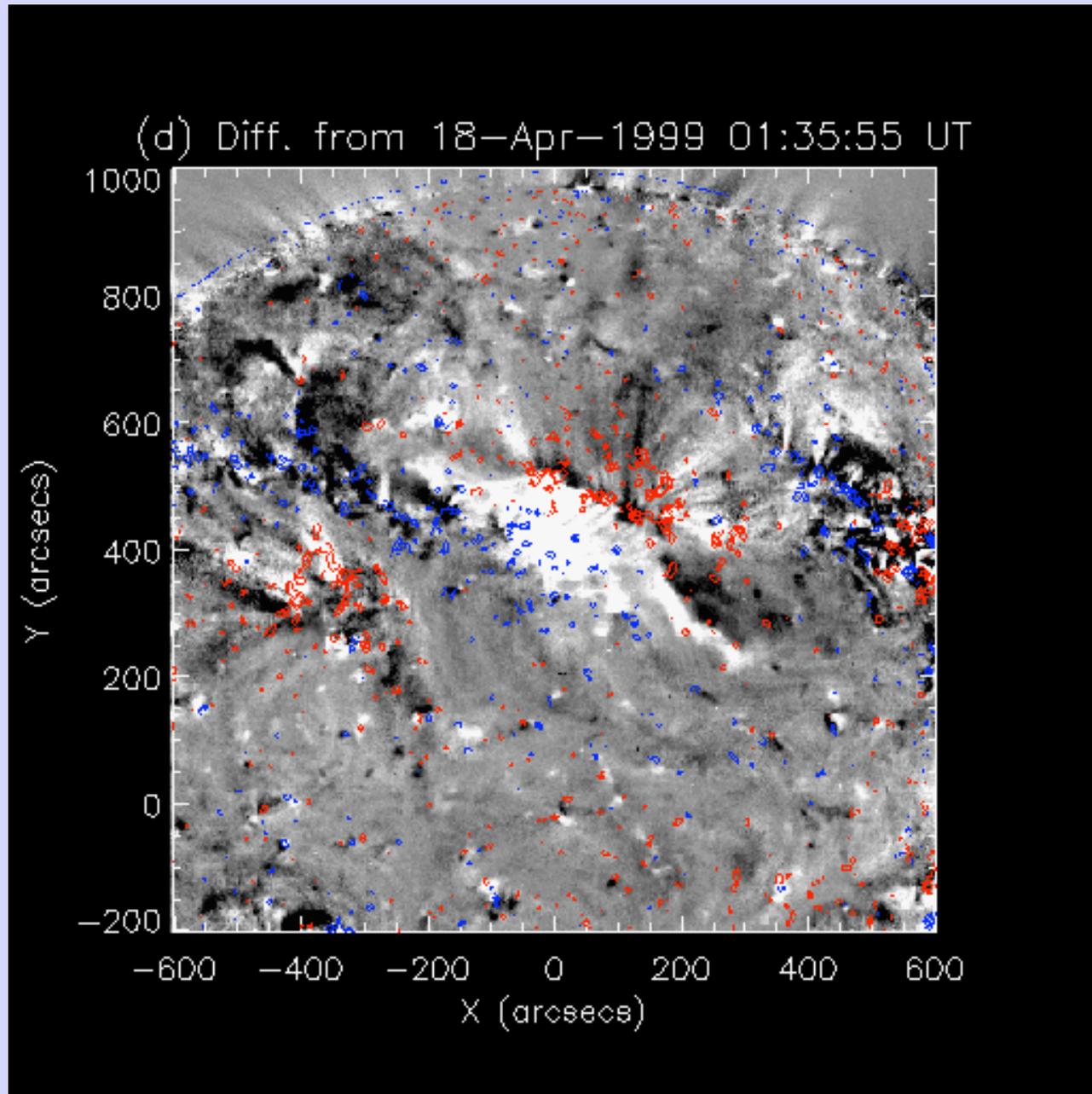


Shine 2004, A. Sterling

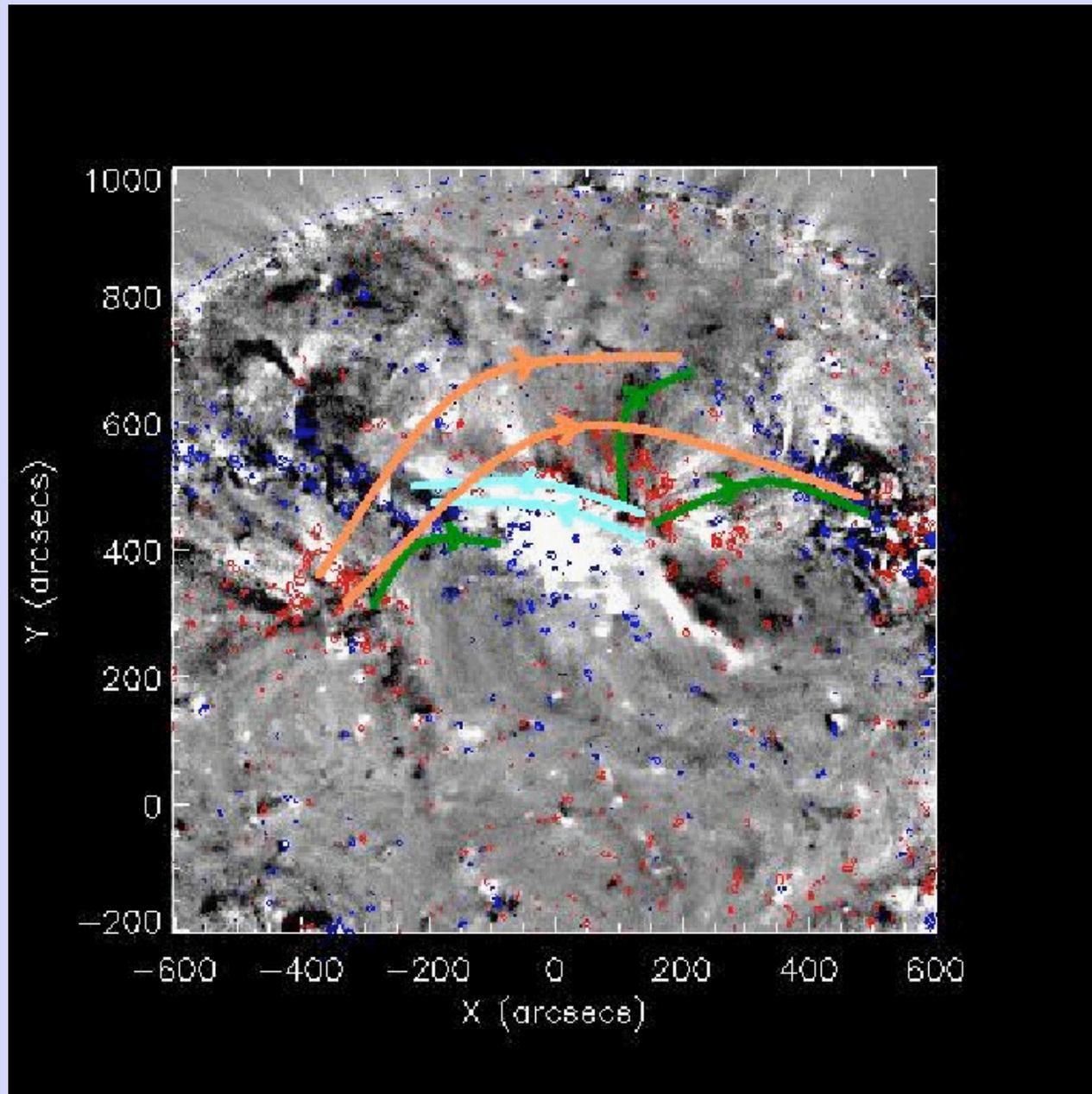
Antiochos
et al. (1999)



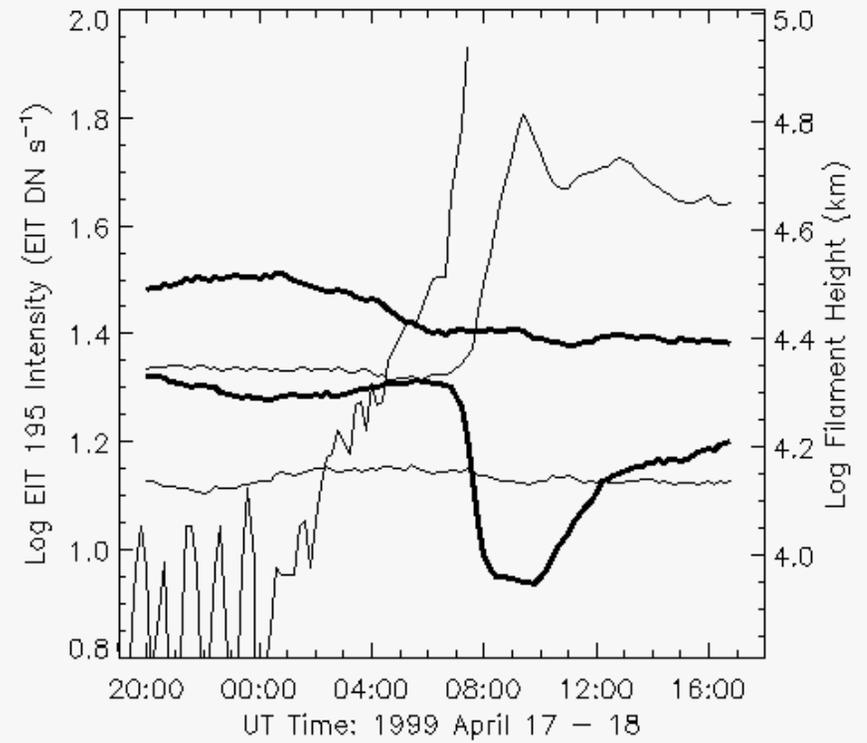
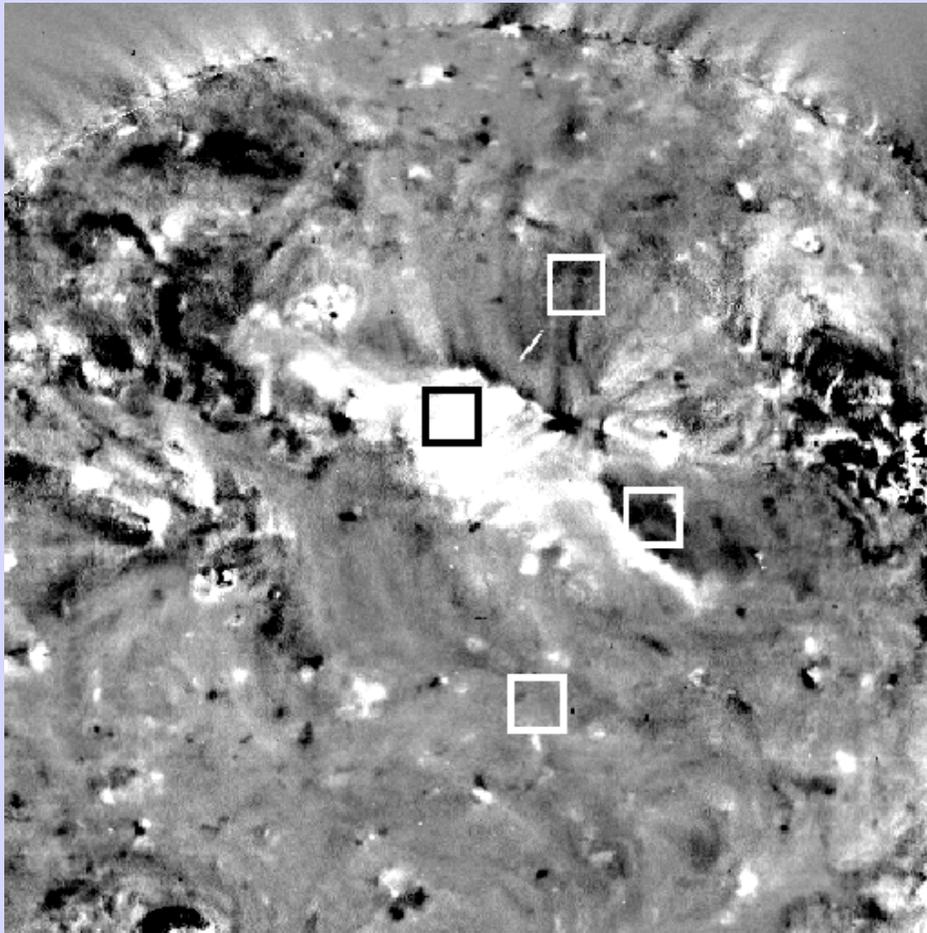
Shine 2004, A. Sterling,



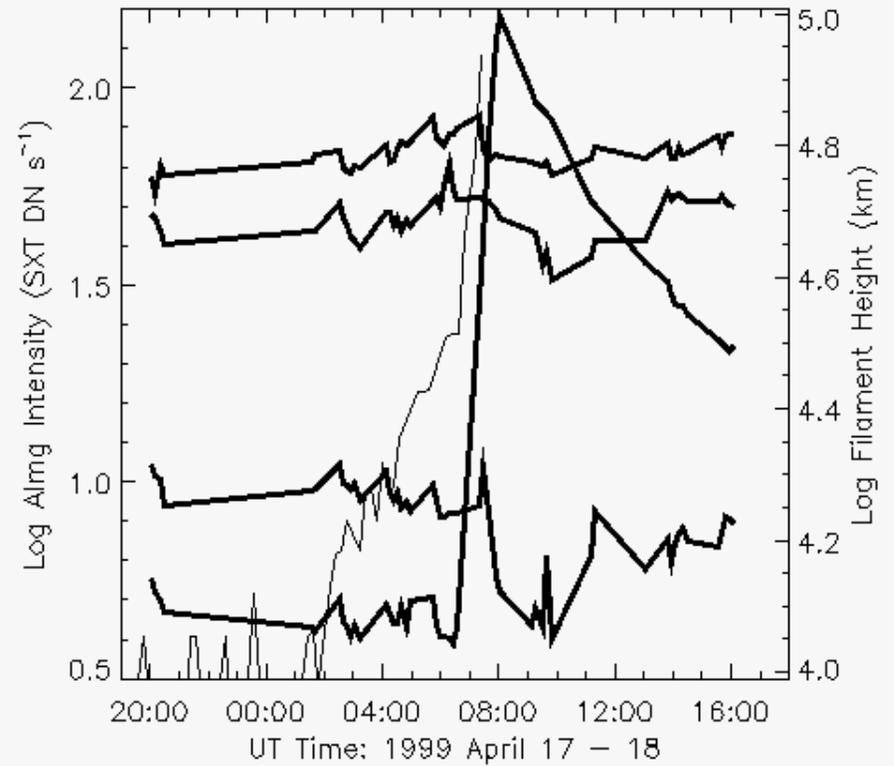
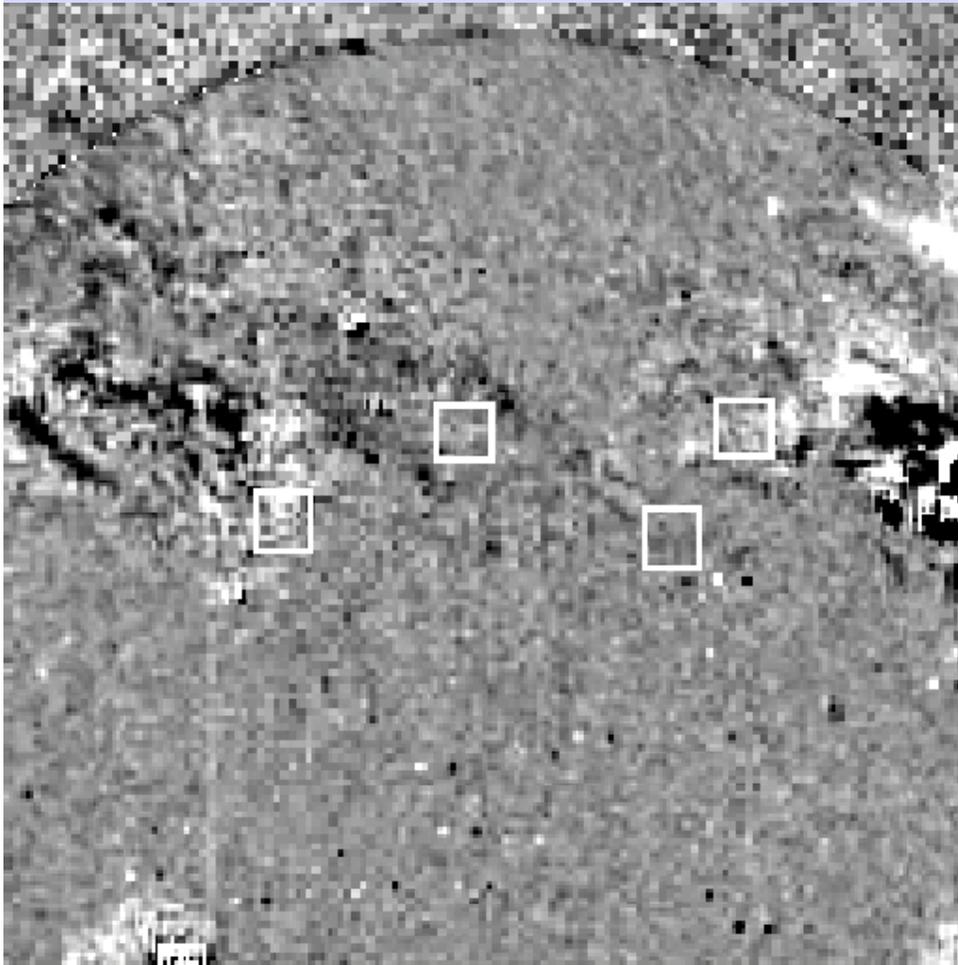
Shine 2004, A. Sterling



Shine 2004, A. Sterling



EIT 195 Ang: 12:12 UT – 01:36 UT 1999 Apr 18.



SXT AlMg: 06:00 UT – 01:37 UT 1999 Apr 18.

Shine 2004, A. Sterling

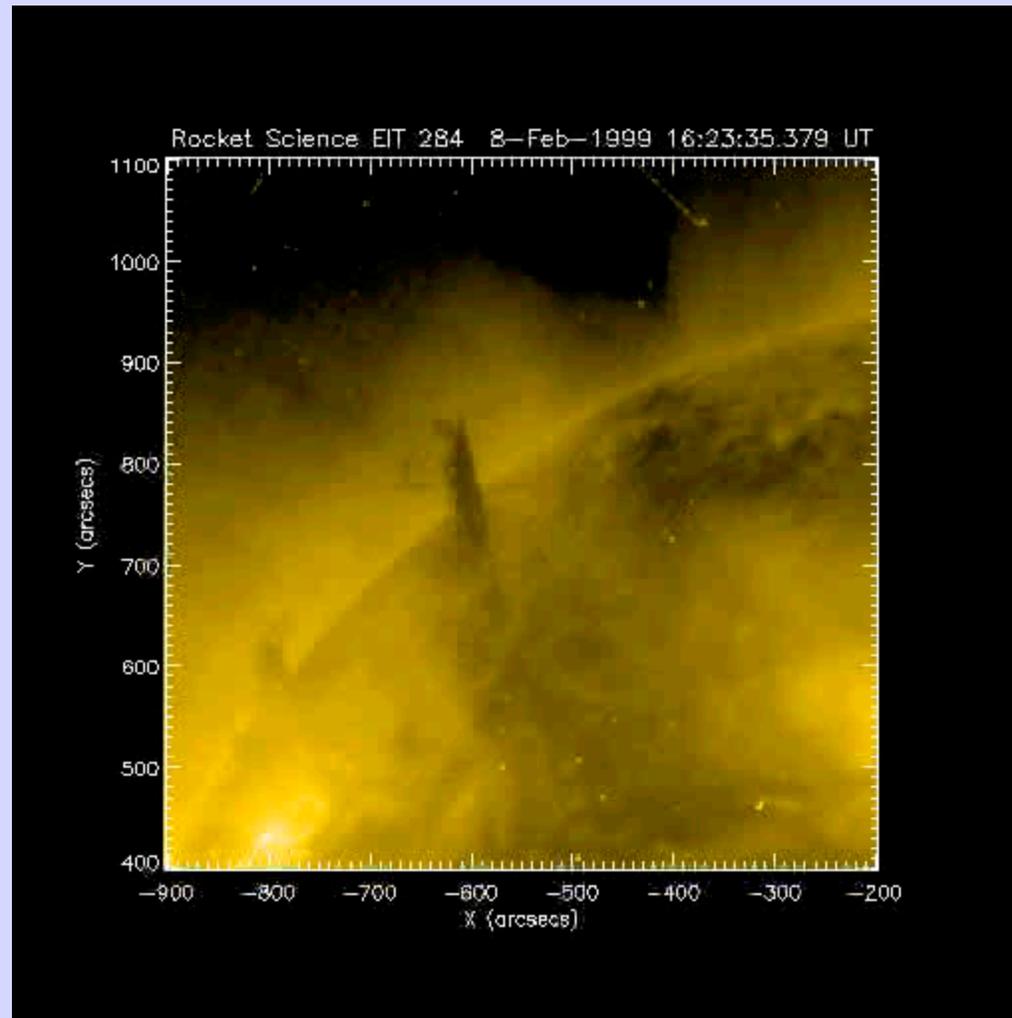
Event 1 Summary

- Slow pre-eruption rise, followed by fast eruption. (Seen by many; cf. Zhang et al. 2001.)
- Main dimmings occur at fast-rise and flare onset; location consistent with base of opening field.
- Pre-eruption dimmings are weak, but show field expansion, and possible breakout signatures.
- Non-breakout explanations are possible.

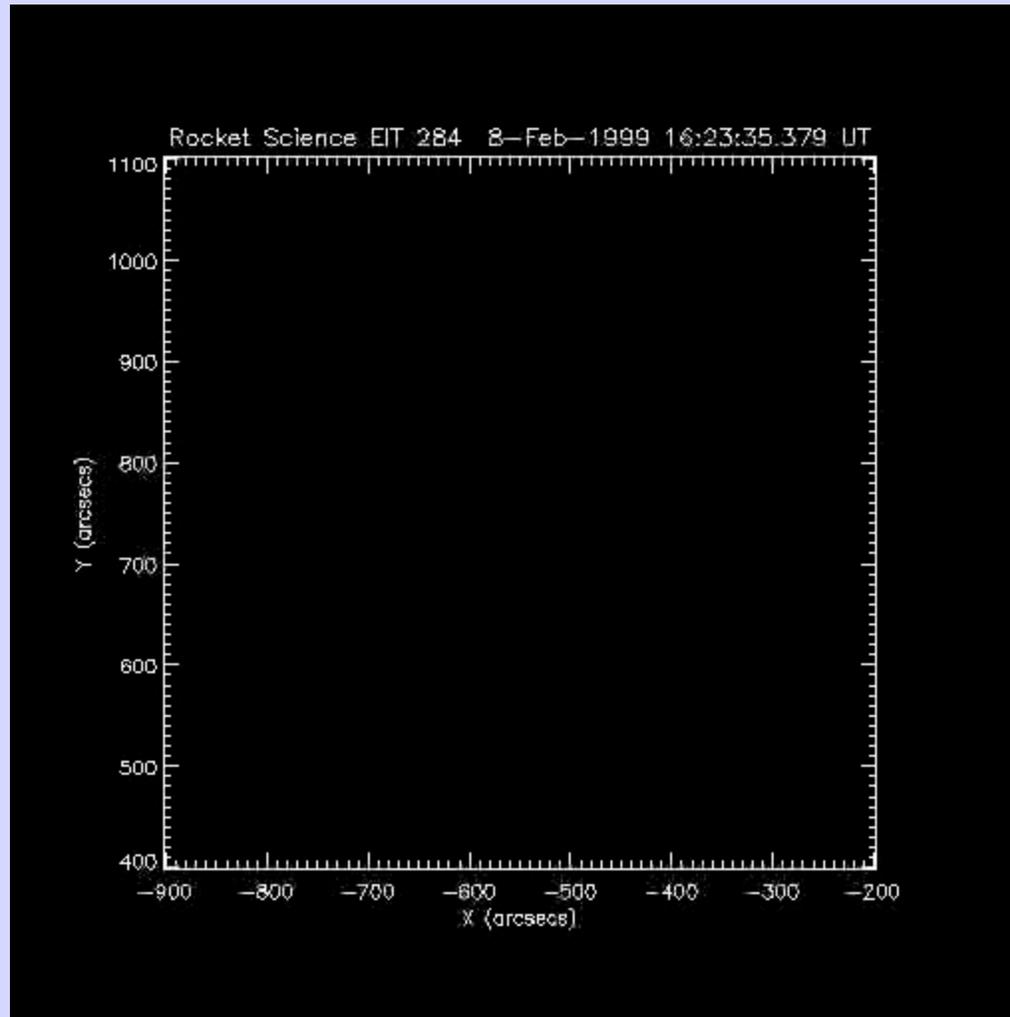
Dimmings and Eruption Properties

Example 2 of 3: 17 April 1999

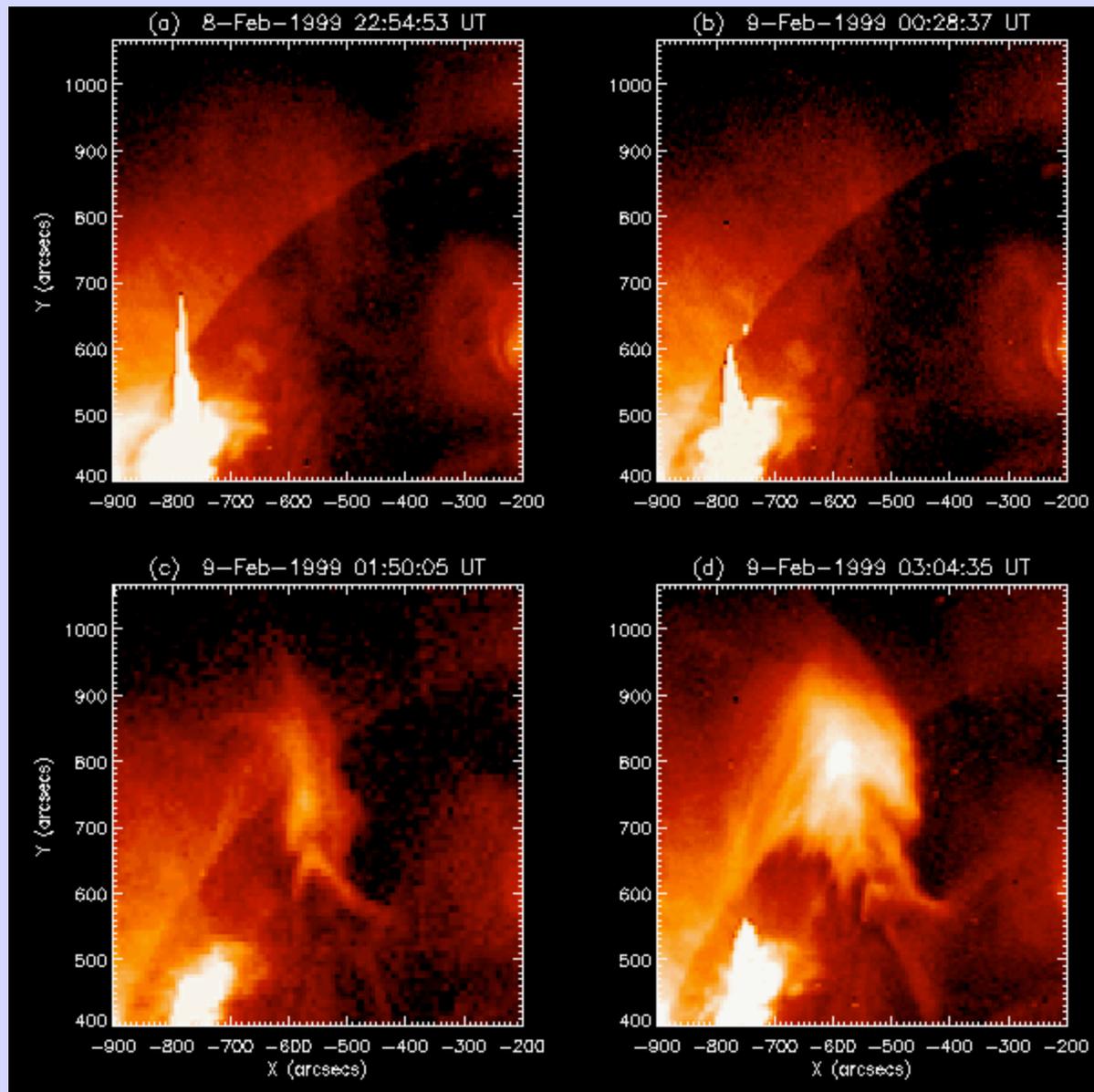
(Sterling & Moore 2003)



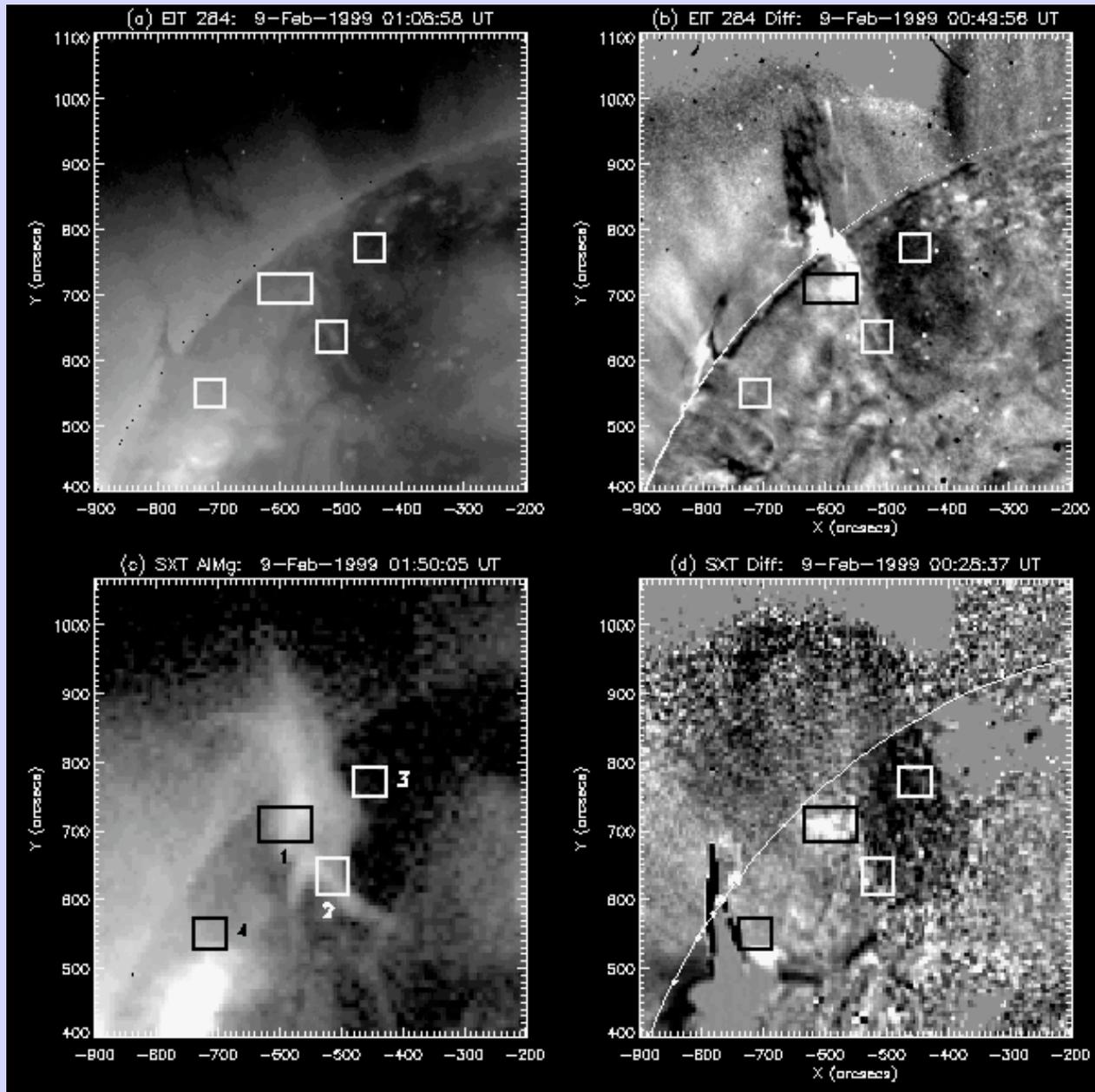
Shine 2004, A. Sterling



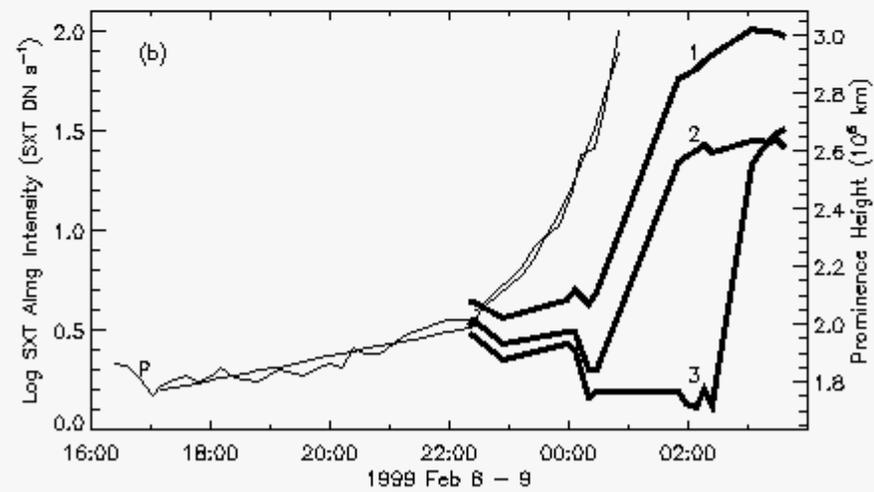
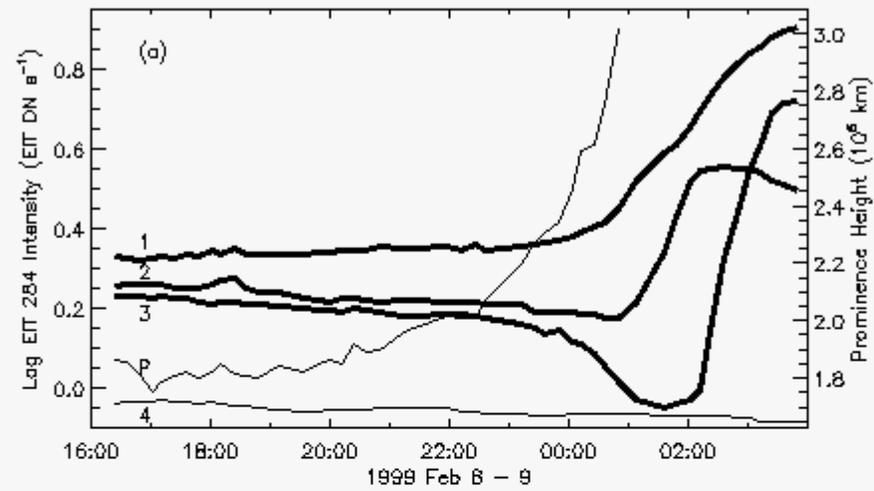
Shine 2004, A. Sterling



Shine 2004, A. Sterling



Shine 2004, A. Sterling



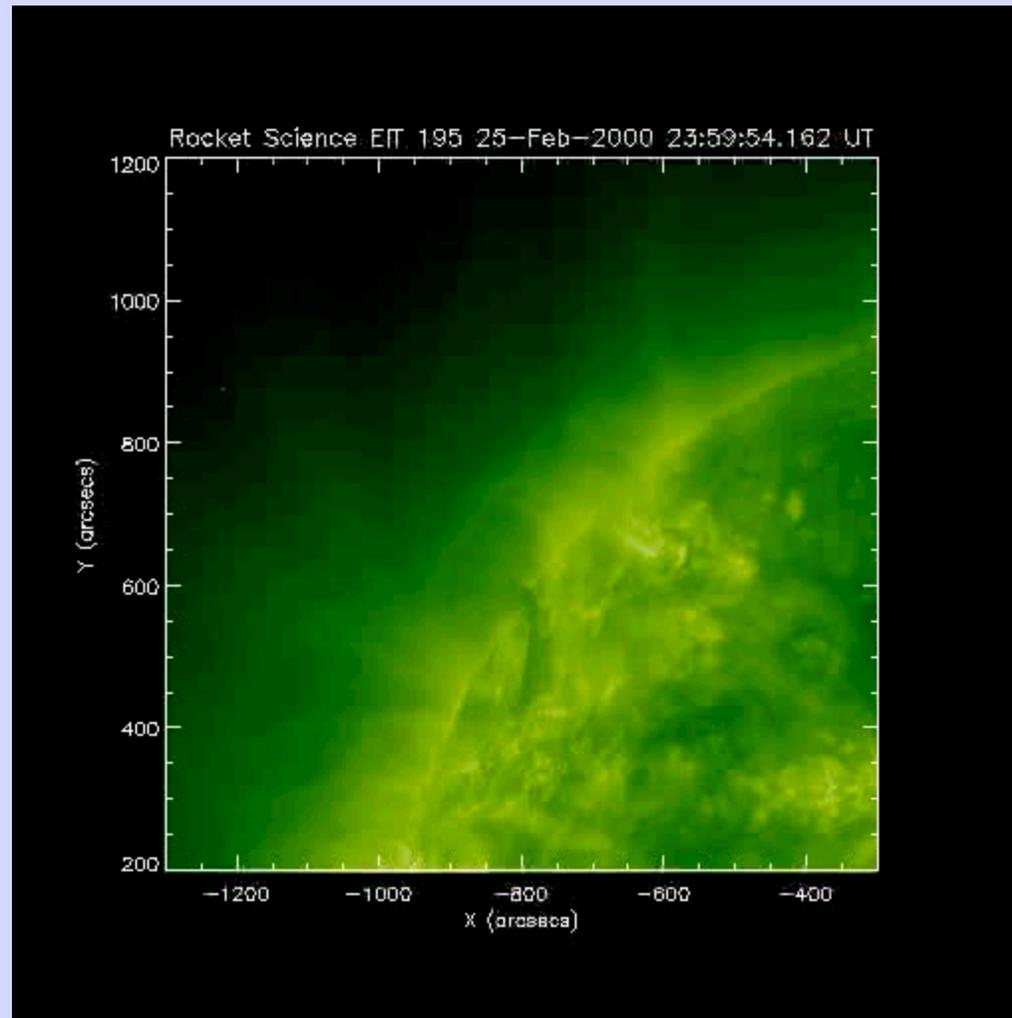
Event 2 Summary

- Slow pre-eruption rise, followed by fast eruption.
- Main dimmings occur at fast-rise and flare onset; consistent with base of opening fields.
- Pre-eruption dimmings exist but are weak; they show field expansion associated with slow rise.

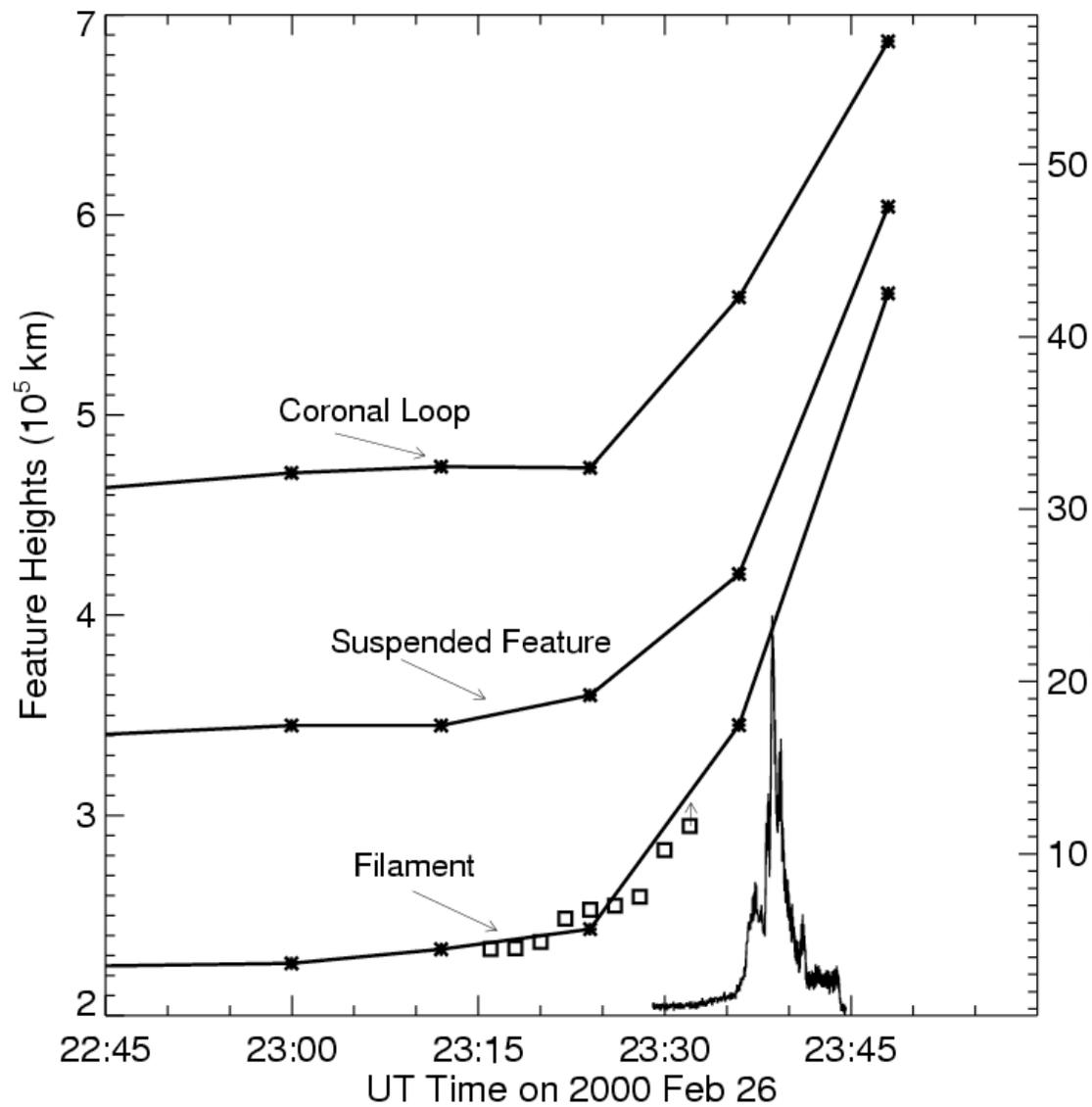
Dimmings and Eruption Properties

Example 3 of 3: 26 February 2000

(Sterling & Moore 2004b;
Choudhary et al. 2004, this meeting)

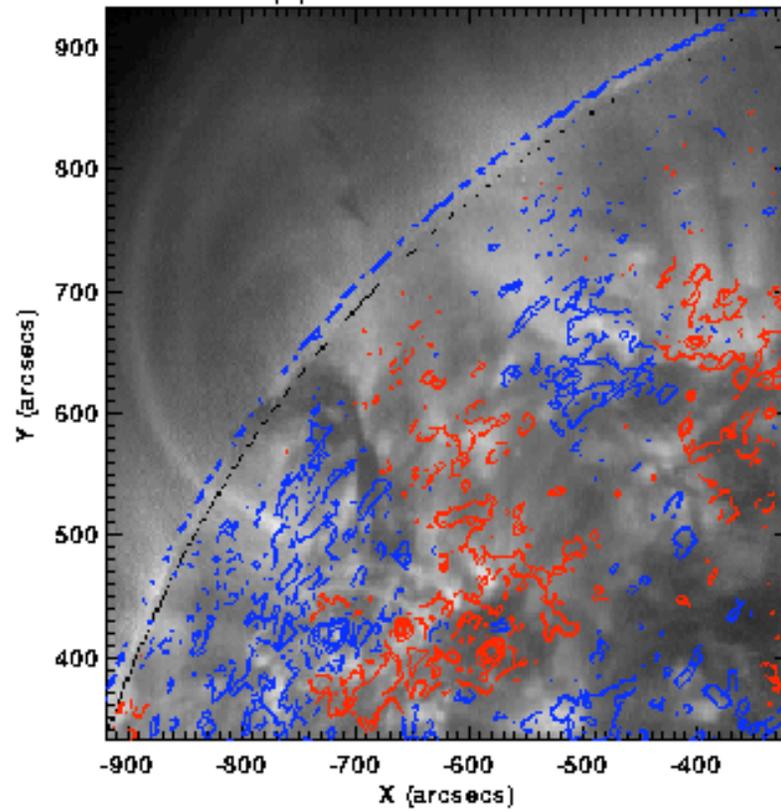


Shine 2004, A. Sterling

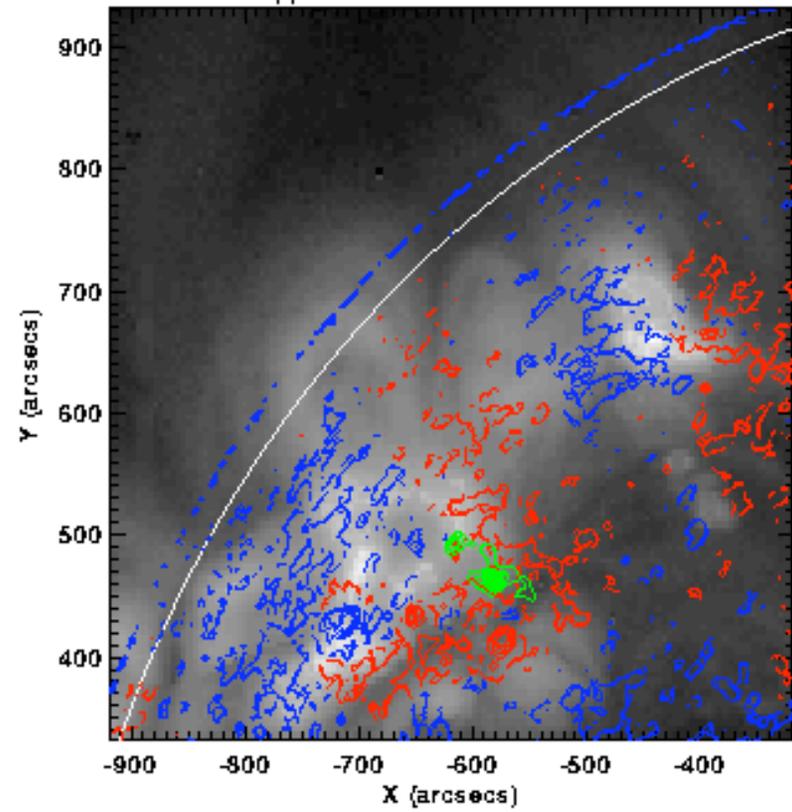


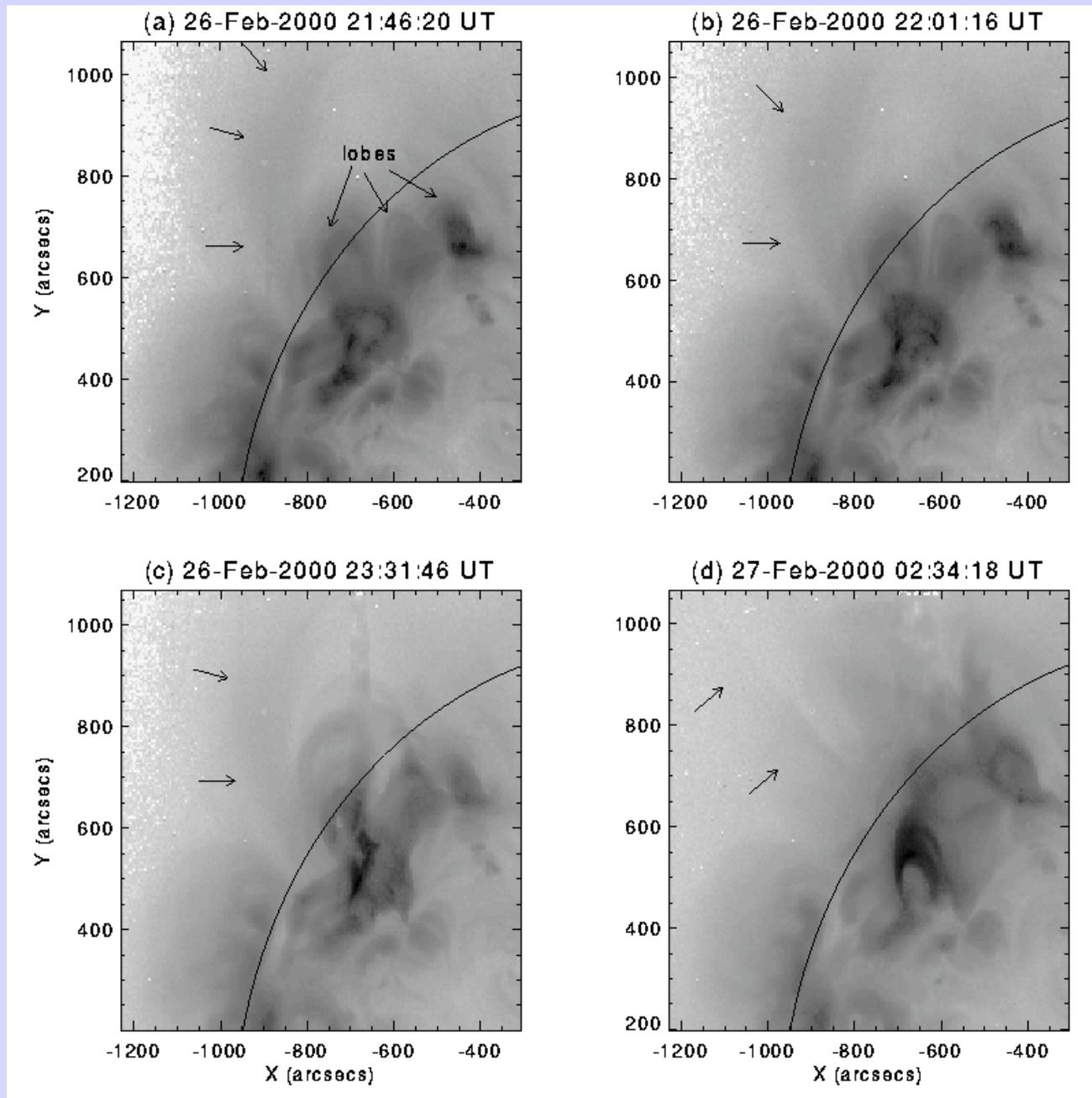
HXT Lo
14 – 23 keV

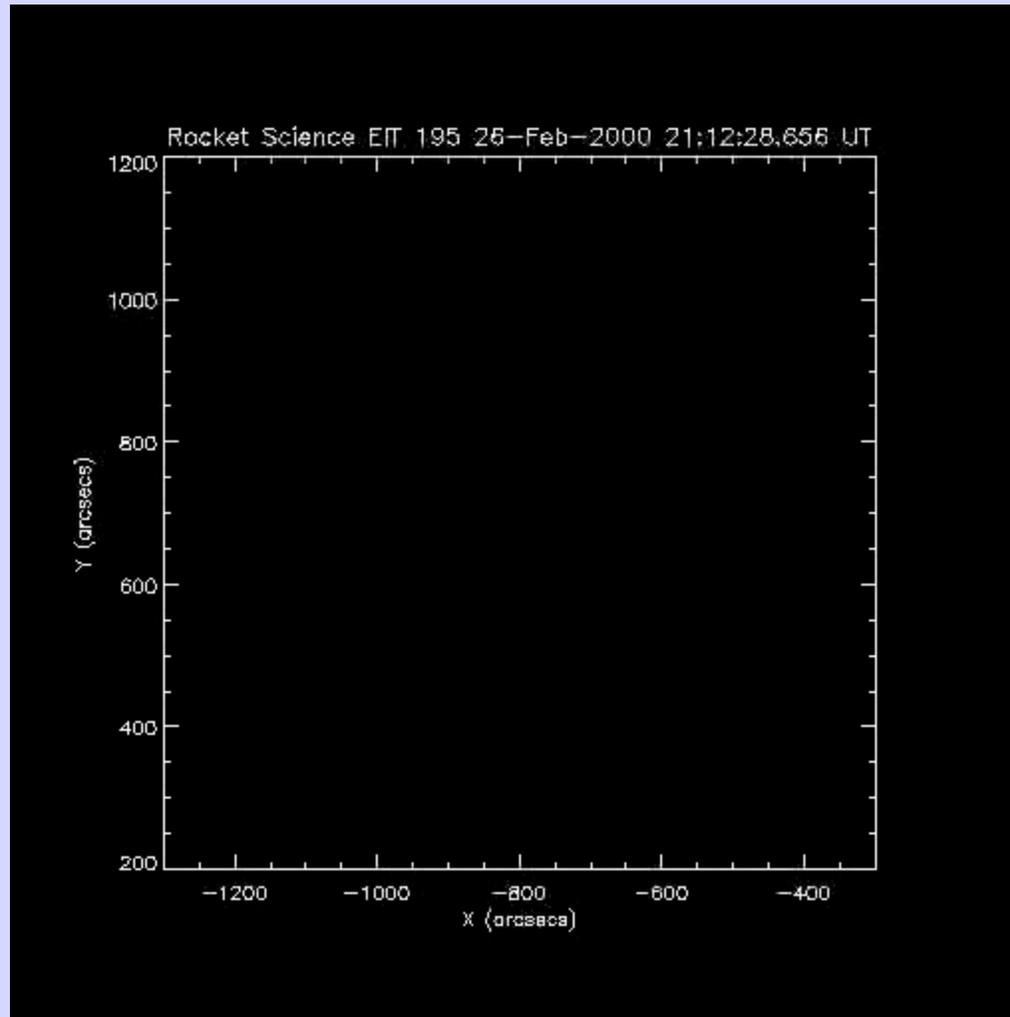
(e) MDI contours on EIT



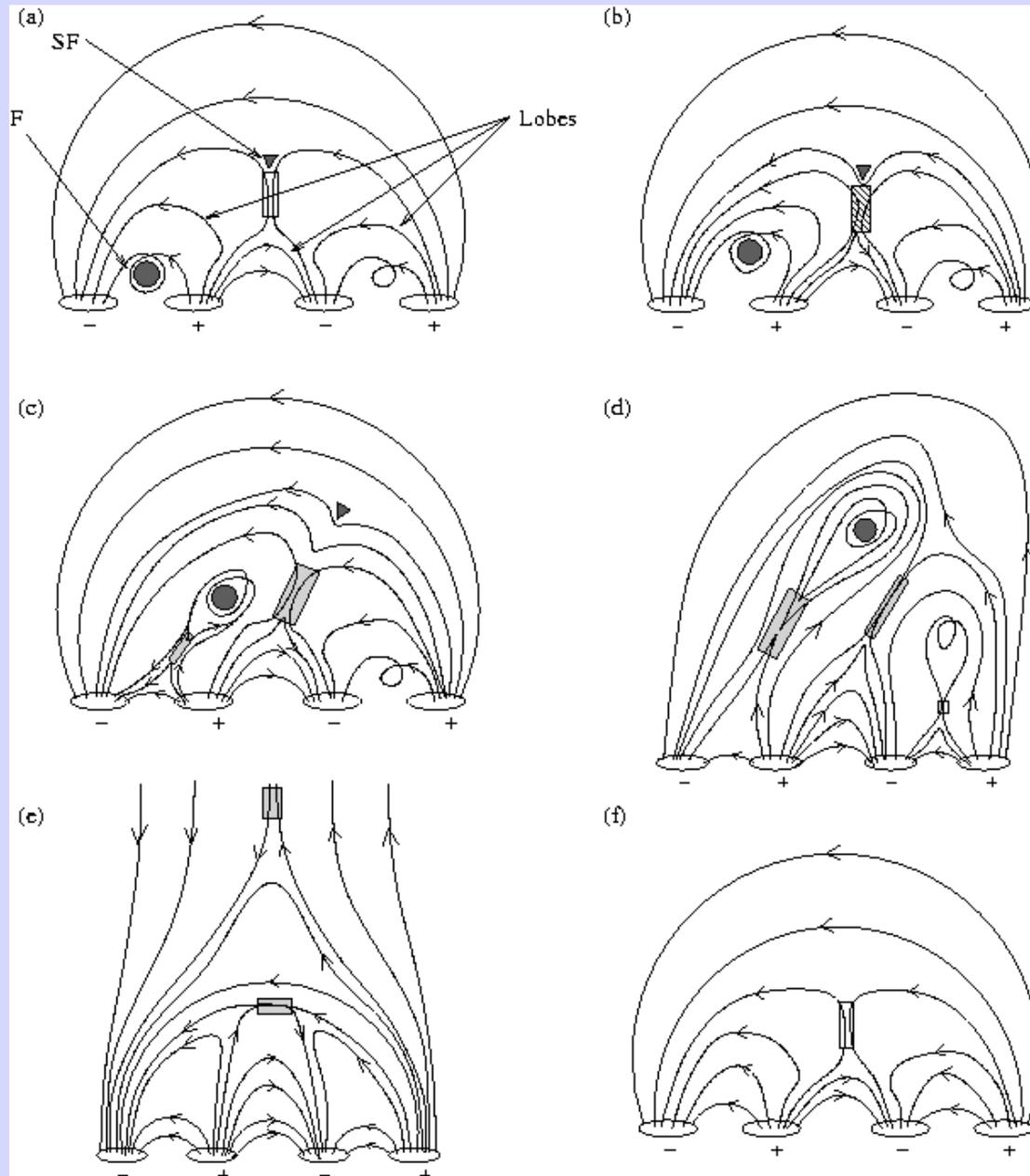
(f) MDI contours on SXT







Shine 2004, A. Sterling



Event 3 Summary

- Slow pre-eruption rise, followed by fast eruption.
- Breakout-like characteristics.
- Main dimmings occur at fast-rise and flare onset; consistent with base of large cavity.
- Secondary eruption initiated by first eruption (seemingly “kicked off” by dimming).
- Sets constraints on tether cutting, and could be a model case for testing breakout.

Early (Pre-Eruption and Pre-Flare) Strong Dimming

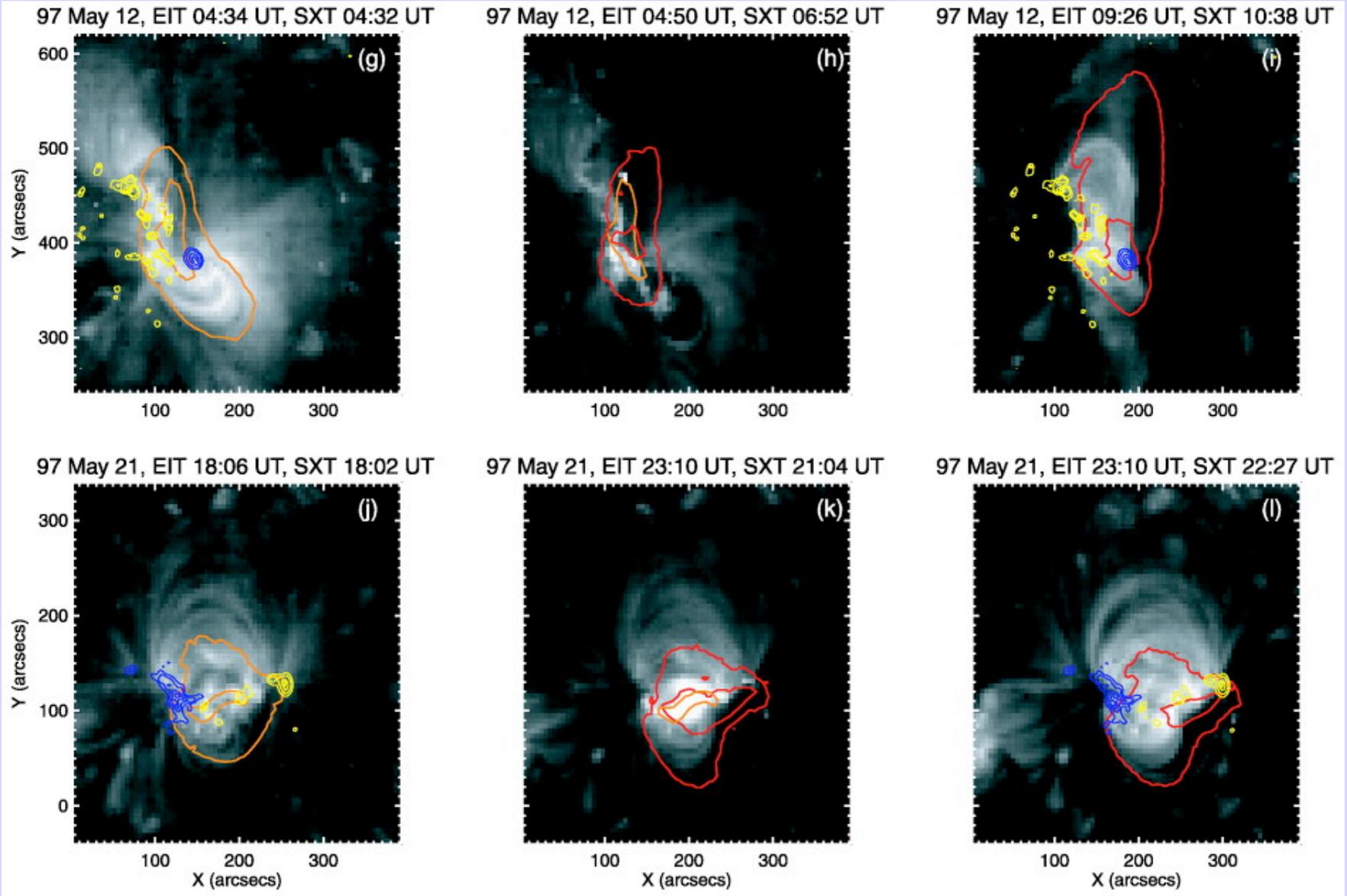
- A few examples of very early (pre-flare; pre-eruption) dimmings are reported.
- Gopalswamy et al. (1999) present an excellent example of a pre-flare strong dimming in both SXT and EIT; EIT dimming start (max) two hours (5 min) before GOES X1 flare onset. Is this different from other events? 

Gopal's Early-Dimming Event: Eruption Cascade?

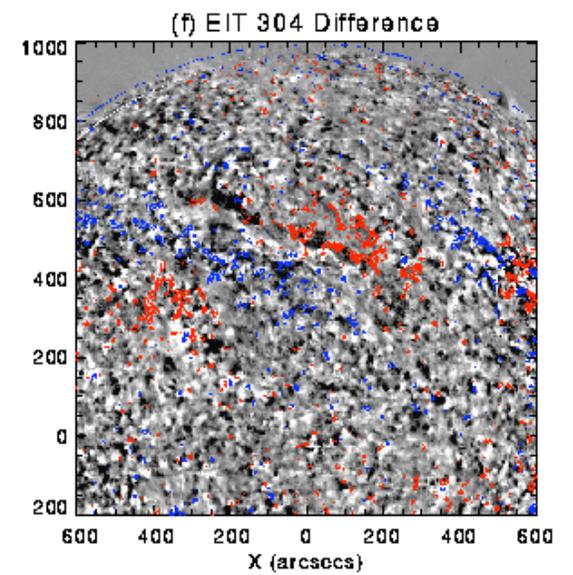
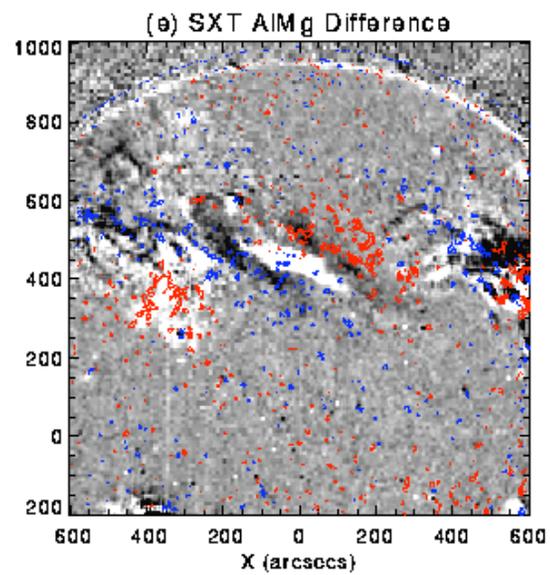
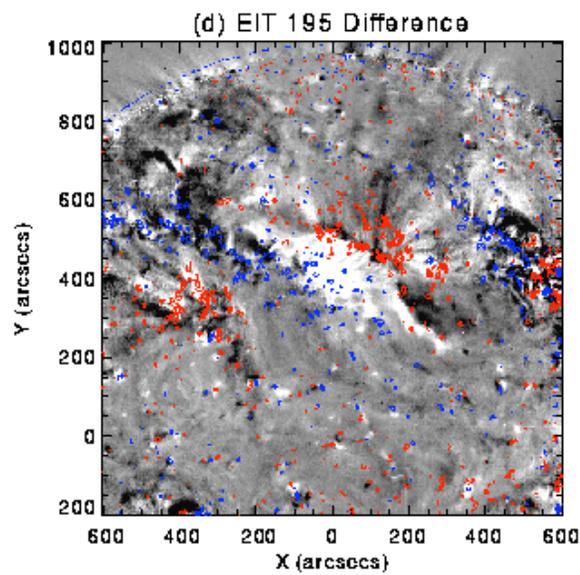
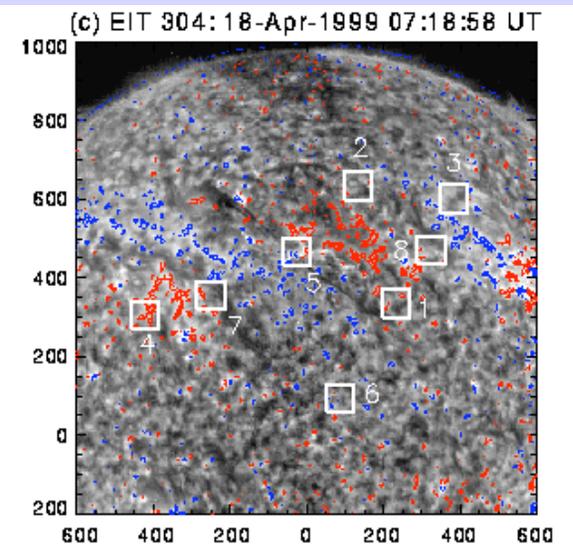
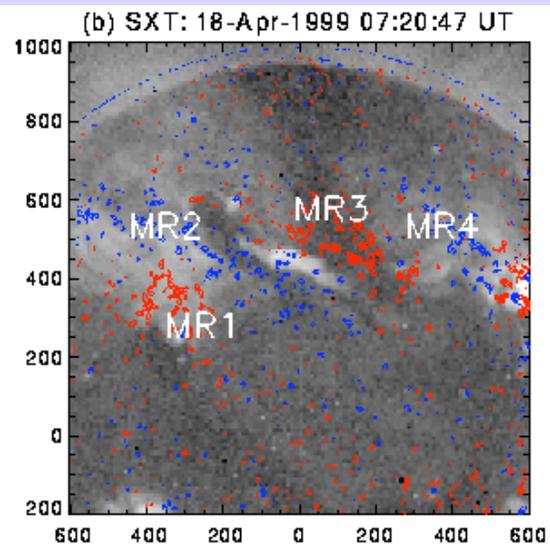
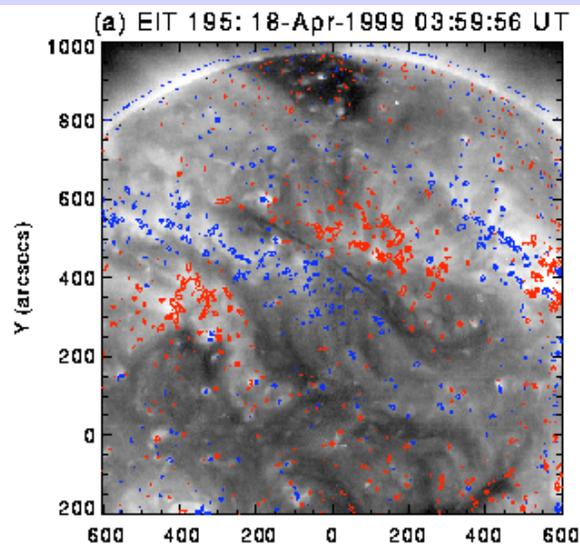
- Activity occurs in flare region concurrent with pre-flare dimming.
- Alfvén speed of 1000 km/s \Rightarrow travel time of about 5 min ($<$ EIT cadence), so activity could have caused the pre-flare dimming.
- Could this be an eruption cascade?
Activity \rightarrow pre-flare dimming \rightarrow flare.

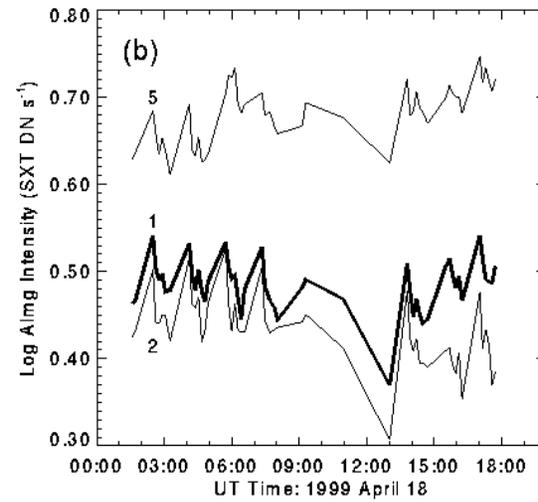
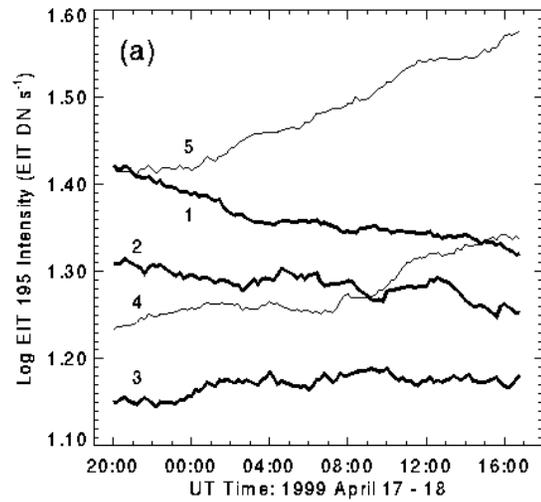
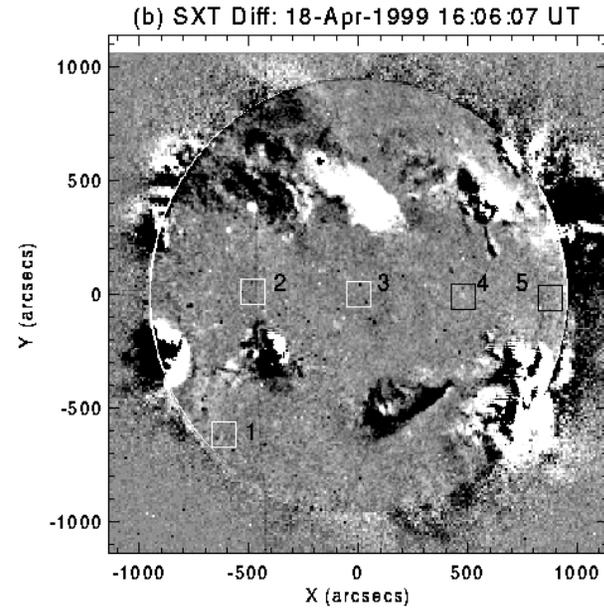
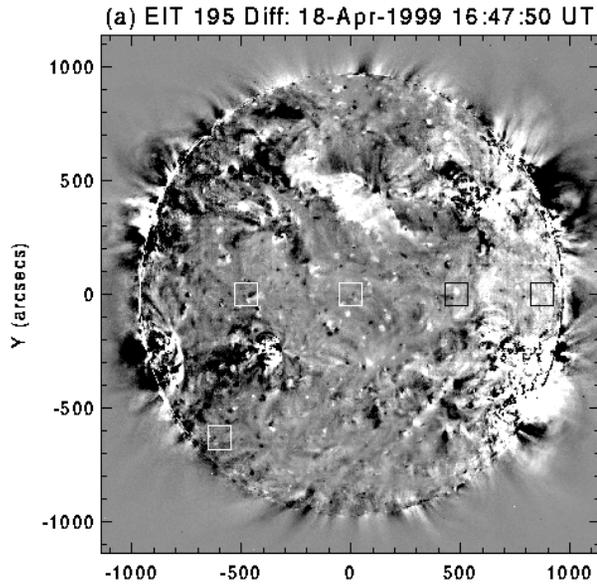
Overall Summary

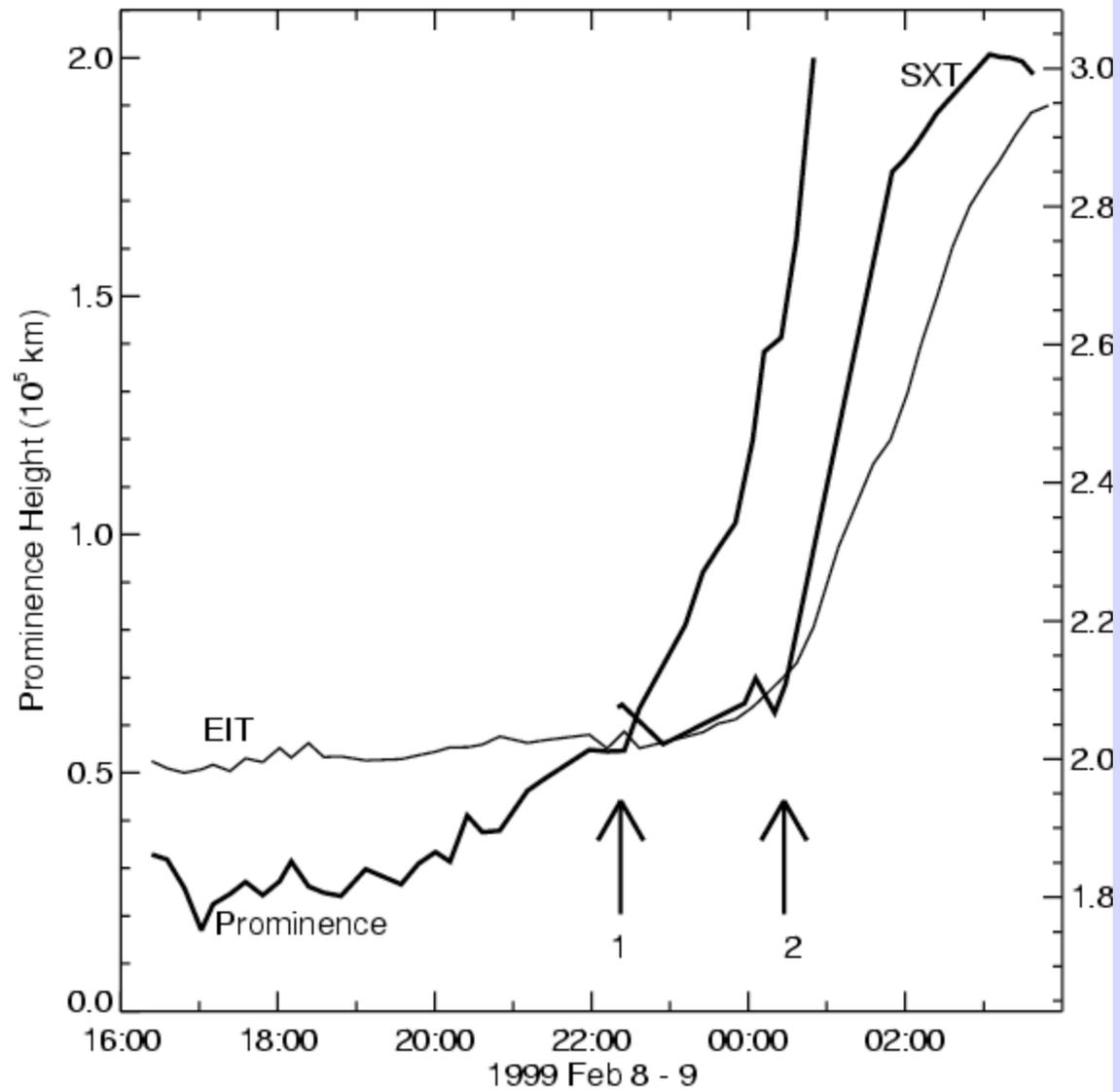
- Dimmings are often a signature of mass depletion during eruption; some CMEs have no dimming.
- Nature of dimming relates to **B** environment.
- Main dimming onset concurrent with fast-eruption (and flare) onset.
- Seemingly, dimmings can “kick start” secondary eruptions.
- Early (pre-eruption) dimmings are weak (field expansion), or “special” (Gopal et al. e.g.).
- These examples provide constraints on models.



(Sterling et al. 2000)





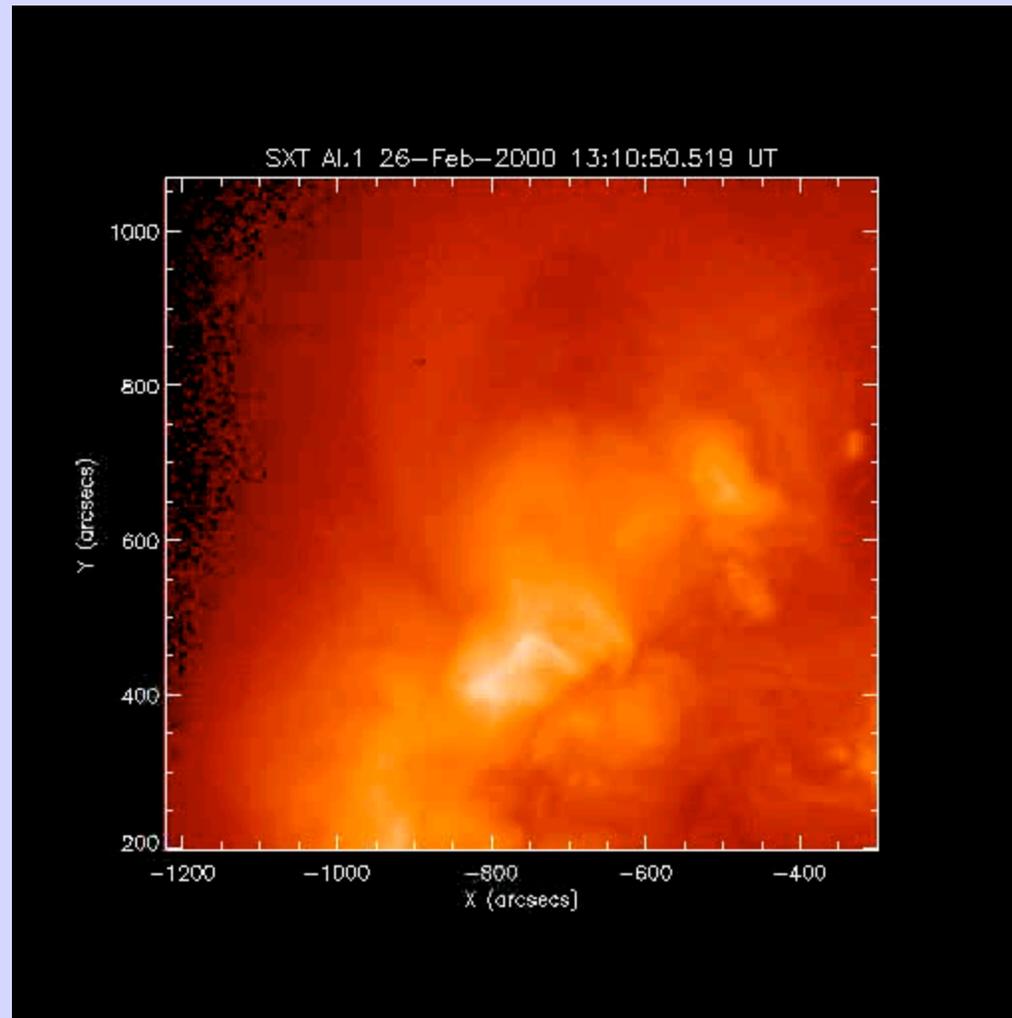


Sterling (2004)

Shine 2004, A. Sterling

The amount of thermal energy (based on SXT) for one hour near Time 2 is $\sim 10^{28} - 10^{29}$ ergs. This emission is barely visible in SXT at Time 2 ($10^5 - 10^7$ ergs $\text{cm}^{-2} \text{s}^{-1}$, for a small box over the estimated duration of tether-cutting reconnection; Sterling & Moore 2003).

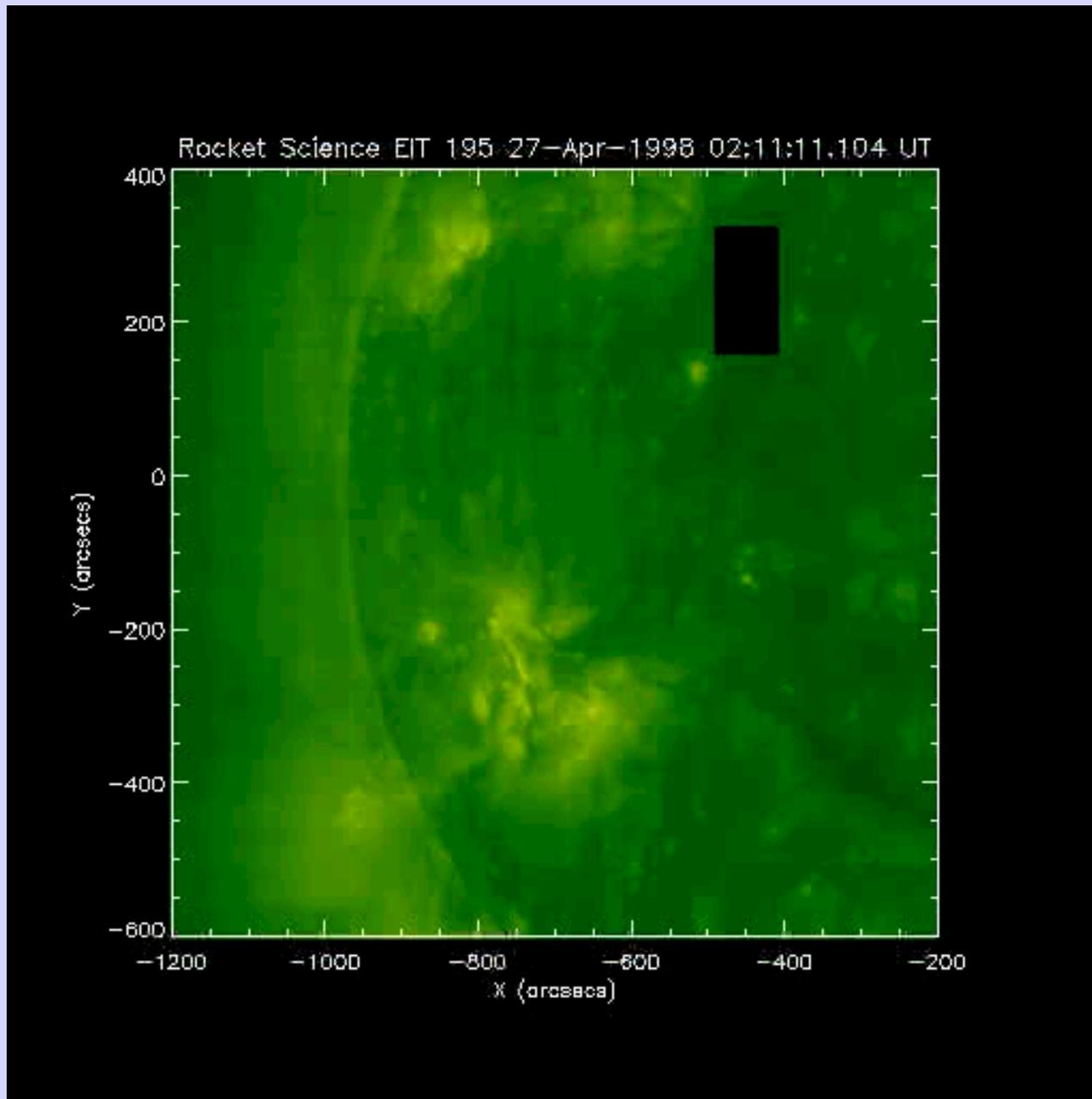
If the heating energy due to tether-cutting reconnection scales approximately linearly with the prominence height (gravitational energy), then expect much weaker soft X-ray emission near Time 1.



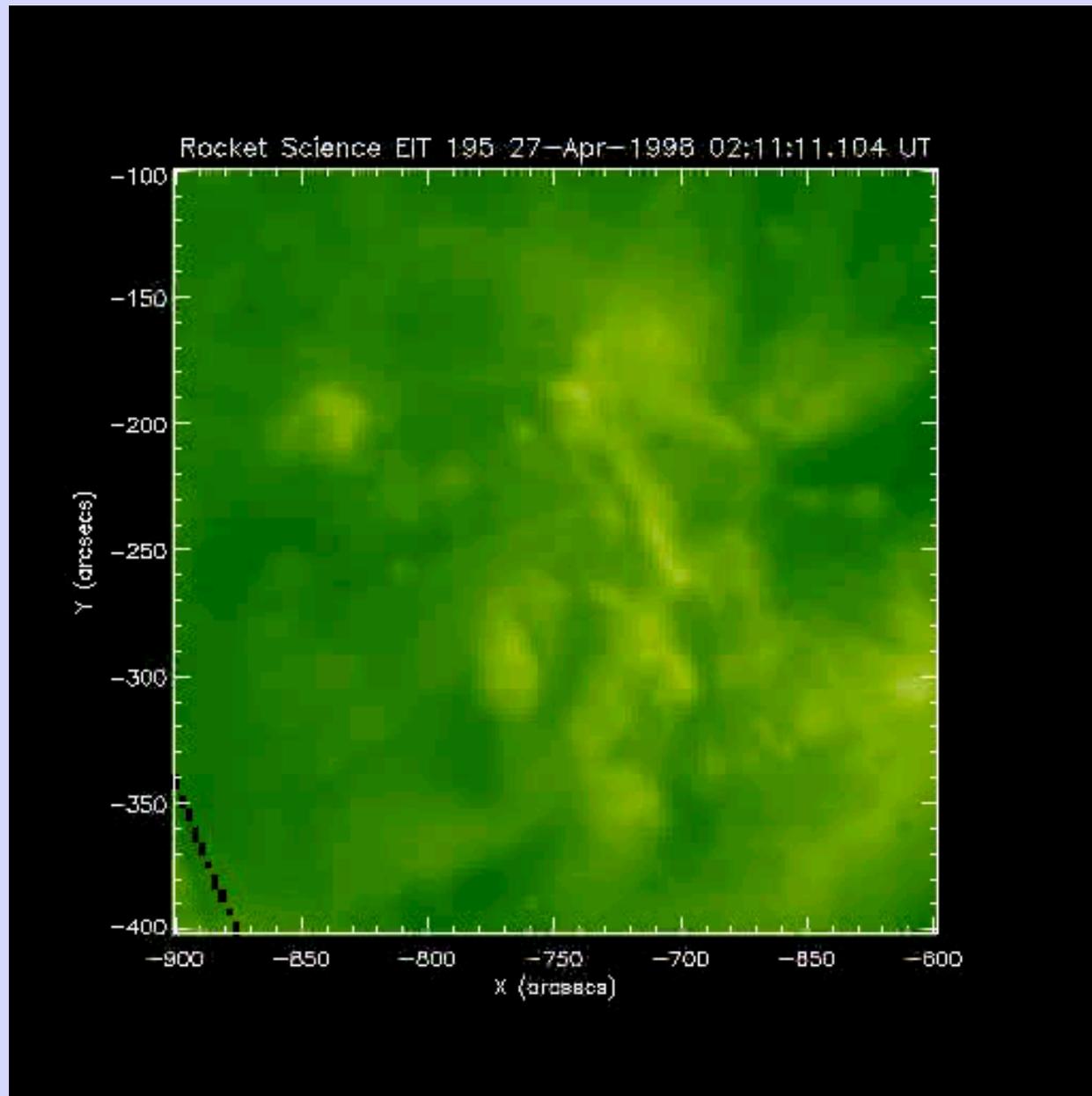
Shine 2004, A. Sterling

Howard & Harrison (2004, Solar Physics)

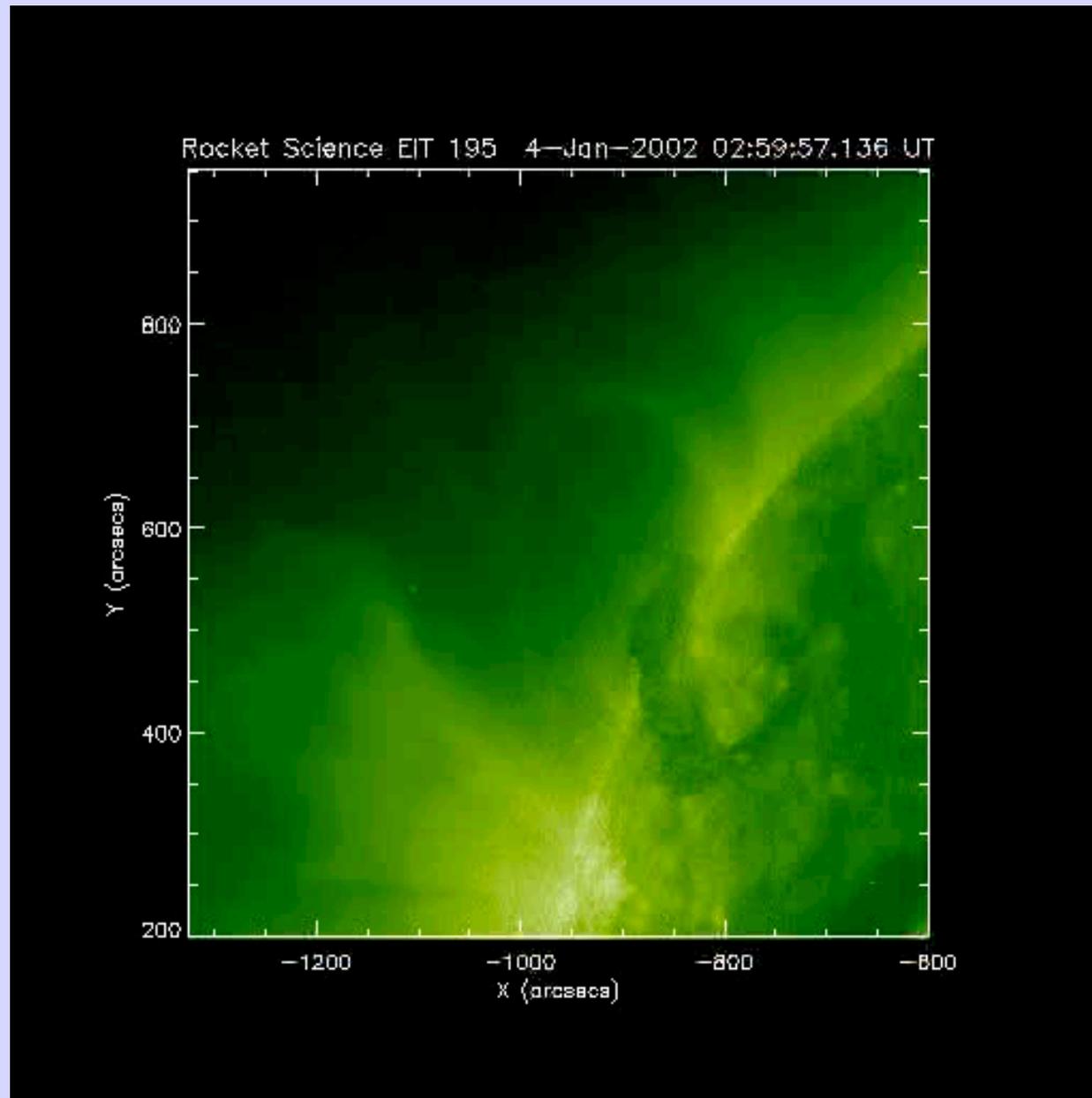
- Dimmings in CDS and in EIT.
- CDS: Range of ions (He I, .02 MK; O v, .25 MK; Mg ix, 1 MK; Fe xvi, 2 MK; Two Si x lines, 1.3 MK).
- With EIT, 5 of 9 CMEs have dimming, 4 of 9 do not have dimming (counted 9 “certain” cases with on-disk sources), => some CMEs have no EUV dimming signature.
- Four events (out of 21 certain CMEs, some over the limb) are CDS heating or cooling (=> dimmings due to temperature??).



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Shine 2004, A. Sterling



Shine 2004, A. Sterling

