Reconnection Outflows in the Extended Corona and Magnetotail

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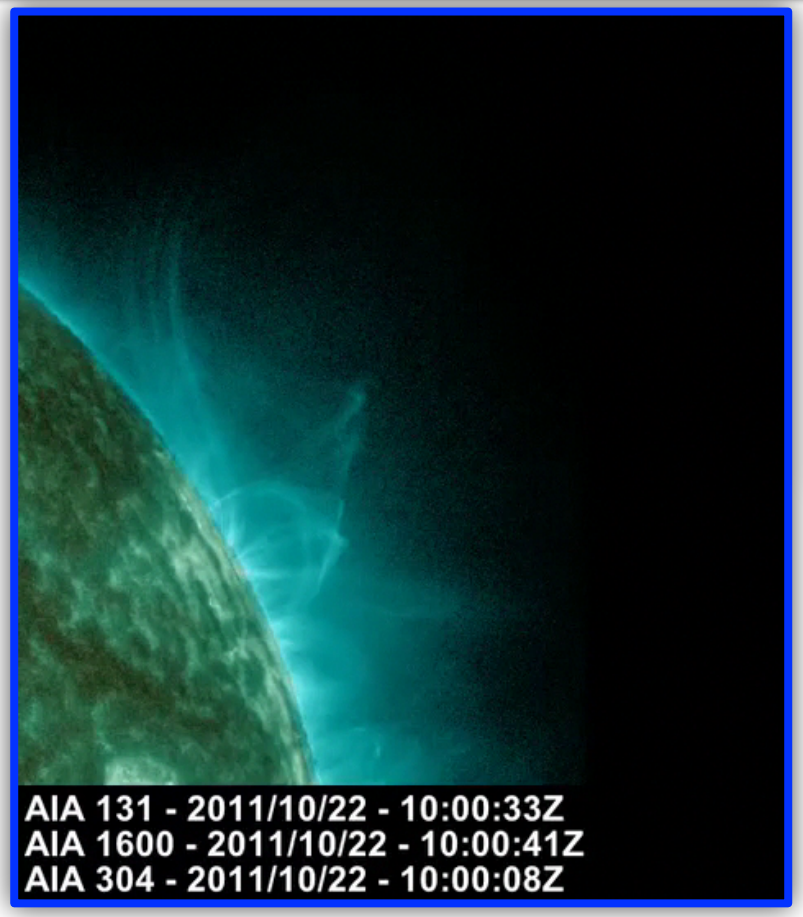
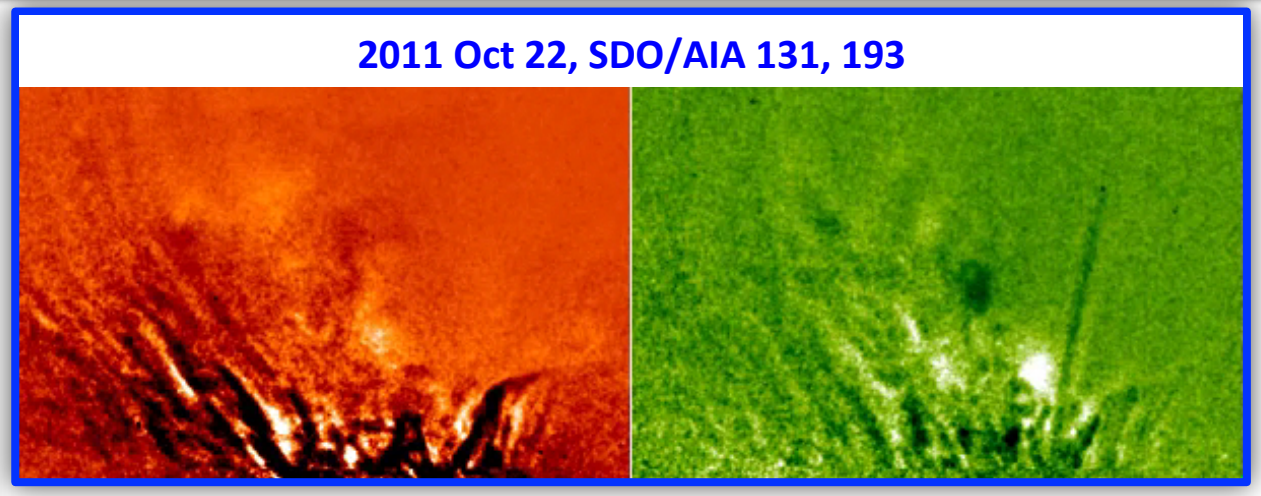
*Considerable contributions from K. Reeves & D. McKenzie

Supra-Arcade Downflows (SADs) and Downflowing Loops (SADLs) Observations

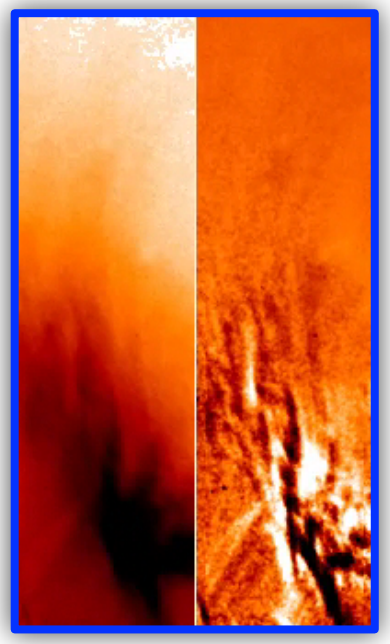




Hot AIA channels. (2-10 MK)

Run-mean-differenced

Reverse-scaled



SADs appear as voids carved out in the plasma sheet by the SADLs.

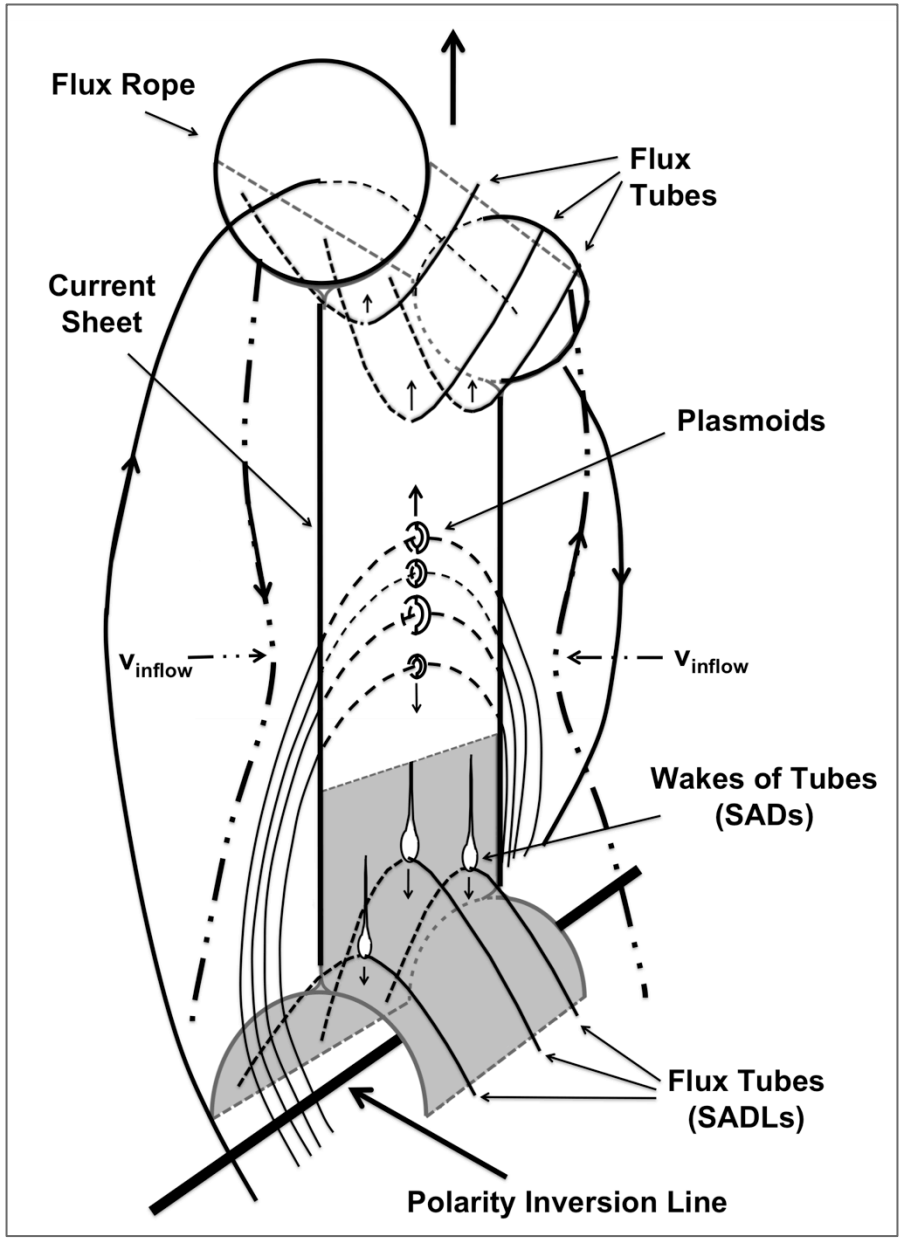
Courtesy D. McKenzie

Savage et al. 2012

SADs + SADLs

- **Key features**
  - Different from plasmoids
  - Observationally associated with inflows (as outflows)
  - Significant correlations with particle acceleration and heating (temporally and spatially), thanks to RHESSI and radio observations

Fig 1



Basic reconnection scenario, post initial flux rope formation and release.

- Field lines reconnect across the current sheet to form outflowing flux tubes while plasmoids form along the current sheet.
- SADs are formed as the flux tubes (SADLs) retract through hot plasma in the fan (*otherwise, only SADLs are observed*).

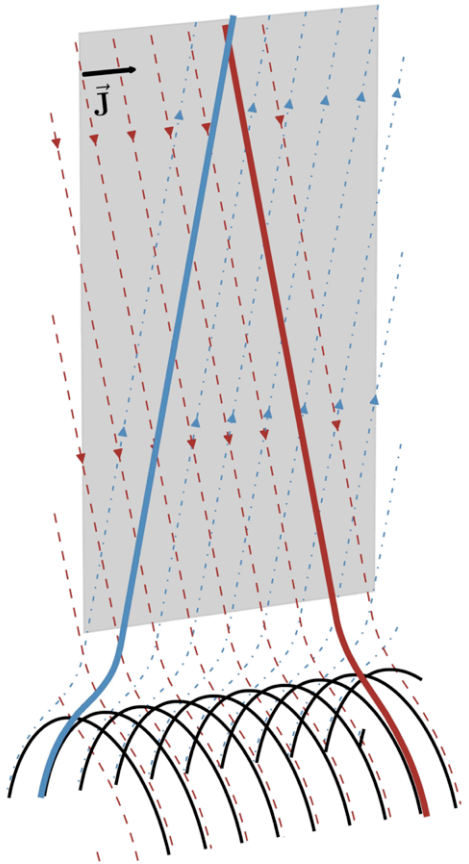


Fig 1: Savage et al. 2012

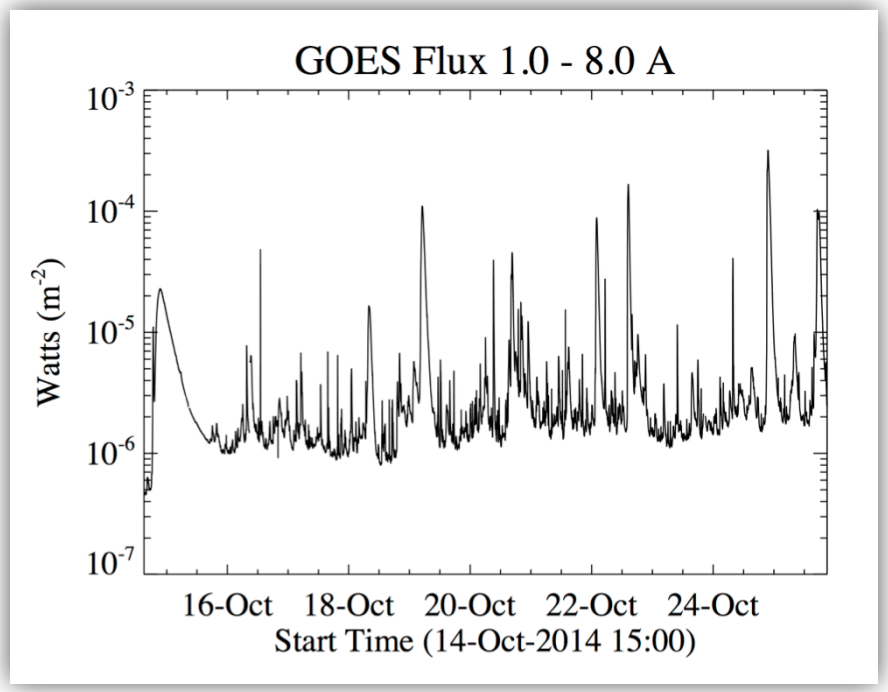
Fig 2: A. Kobelski

SADs in the Extended Corona…

SADs in the lower corona are typically observed well after reconnection has occurred.

In the extended corona, we are better able to observe the migrating reconnection sites.

WL coronagraphs allow us to see reconnection develop behind the CME while looking directly at the density.



"Giant Arches" Flare – 2014 Oct 14

Fig 1

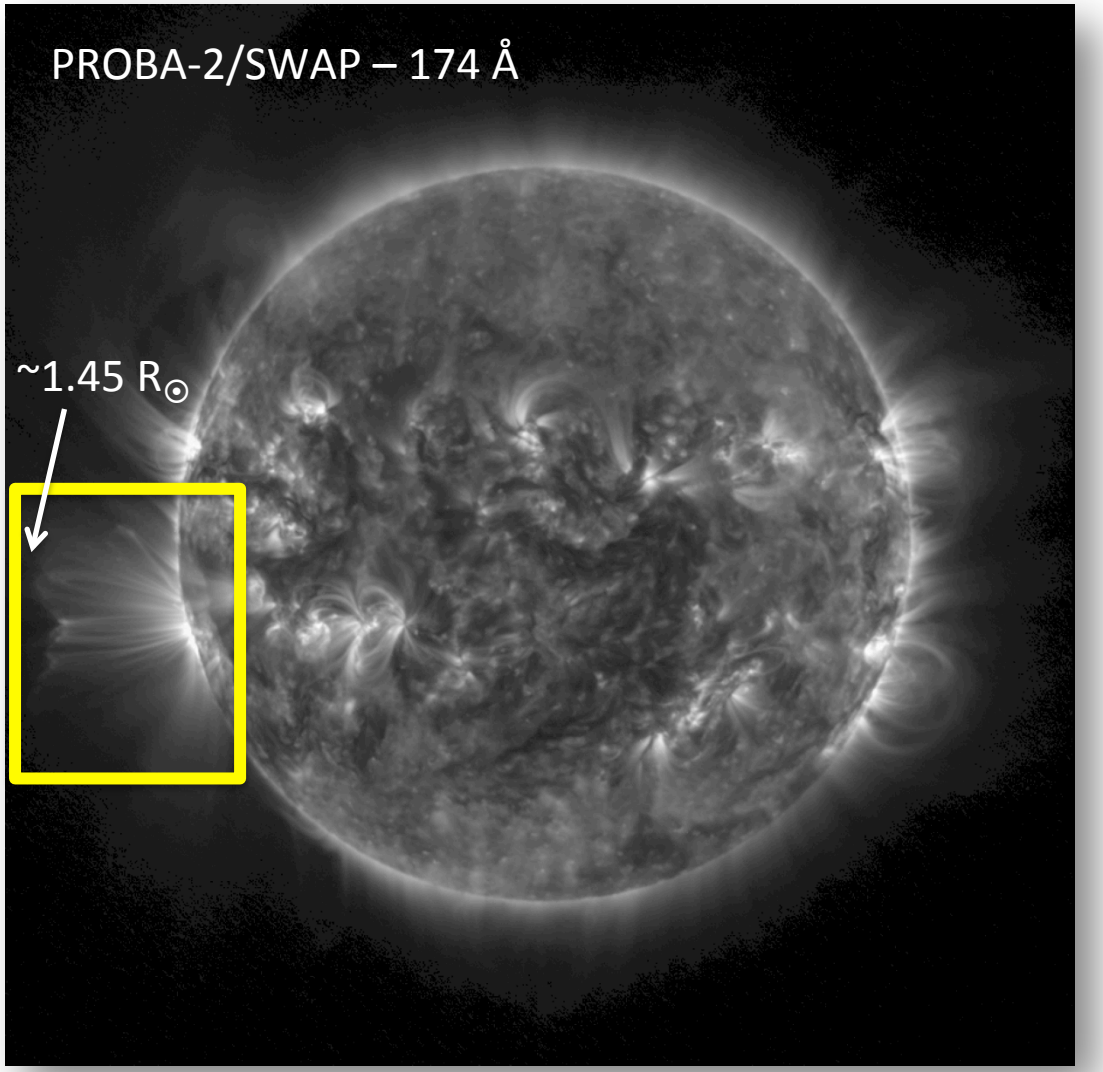


Fig 1: West & Seaton 2015

SADs in the Extended Corona…

LASCO C2
PROBA-2/SWAP
AIA 131 Å

A: Flattened from a year's worth of data

Cleaned (cosmic rays, background stars, planets)

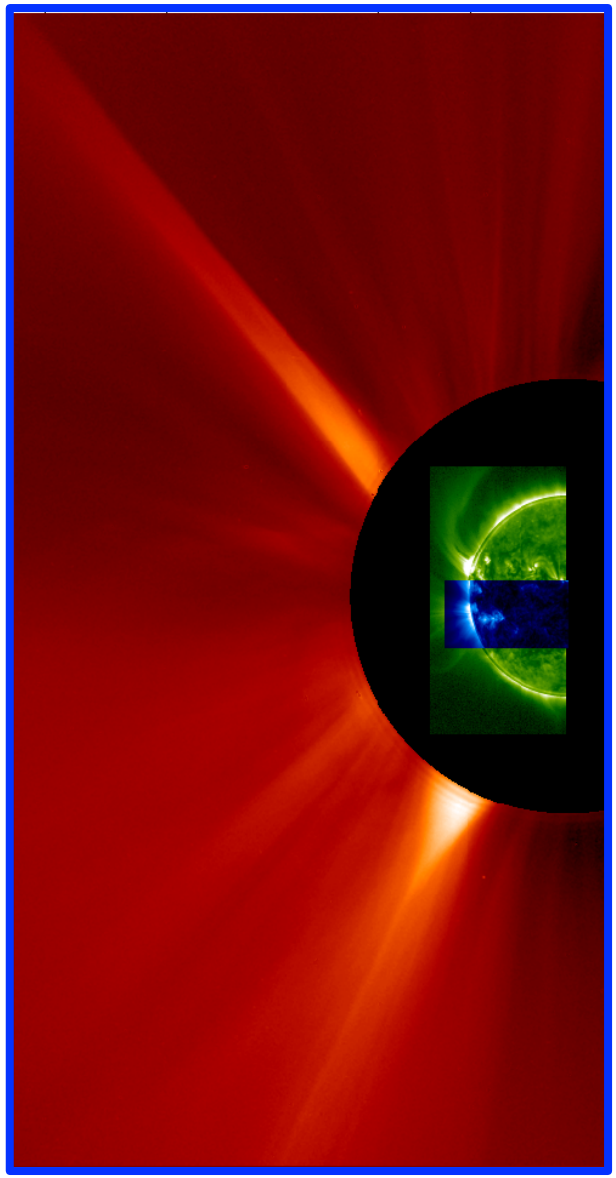
Attenuated disk

B: All that + Run-mean-differenced

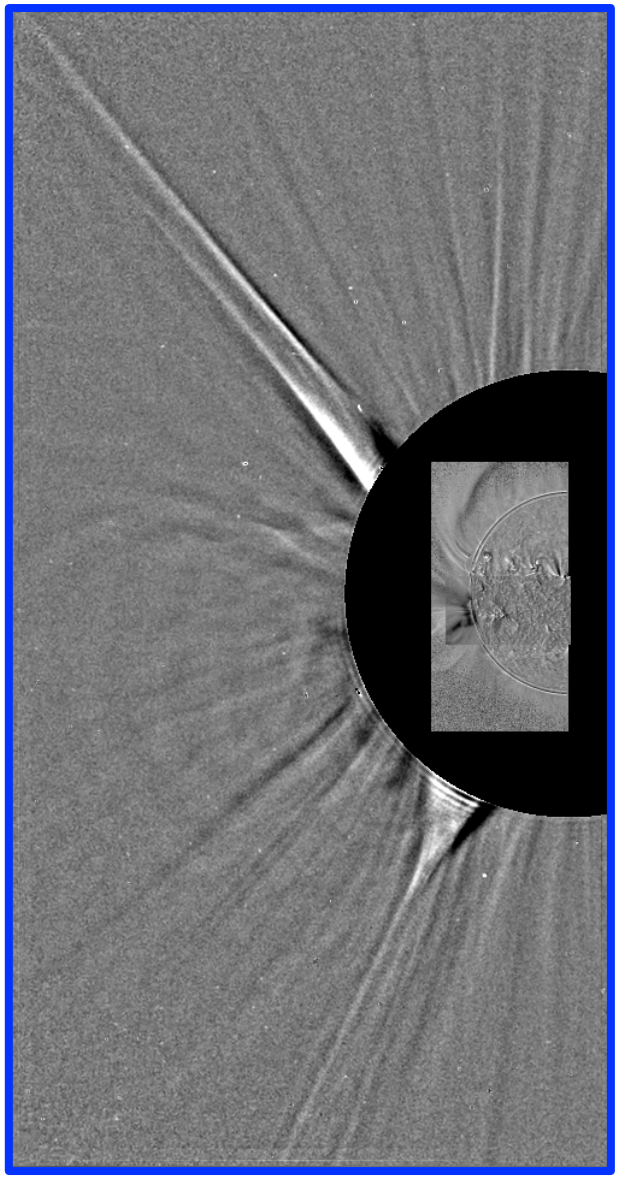
- Both Scaled

Downflows in C3 as well!

A



B

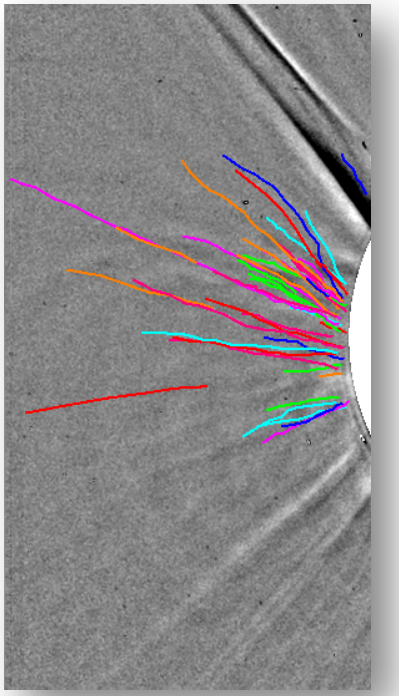


PROBA-2/SWAP GI: Savage, West, and Seaton in prep.

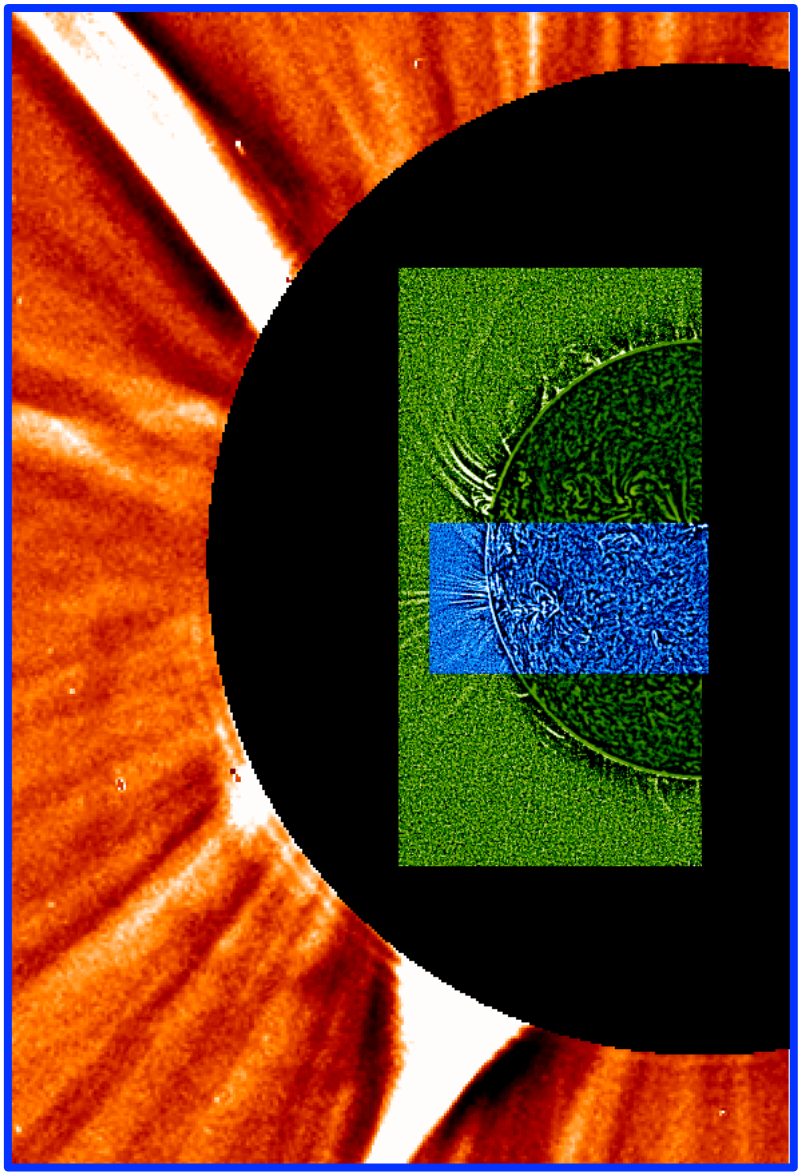
SADs in the Extended Corona…

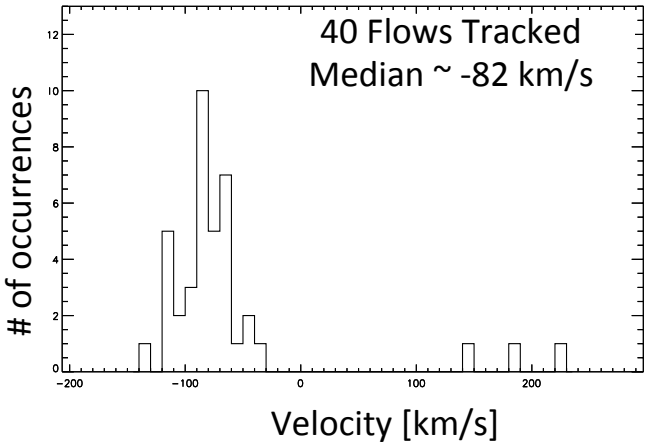
LASCO C2
PROBA-2/SWAP
AIA 131 Å

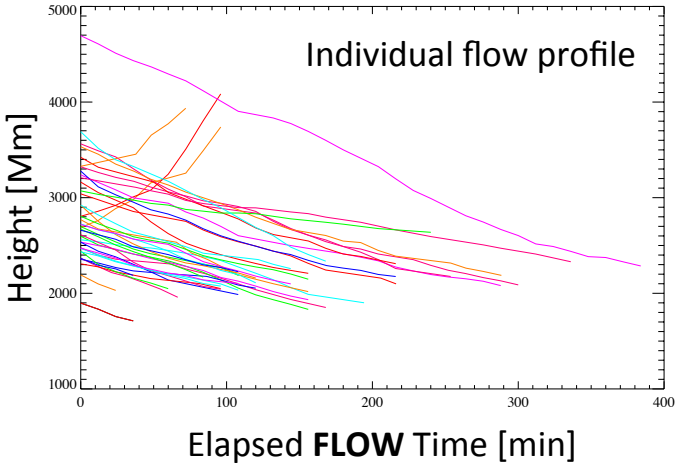
C: Smooth-Differenced
Extracted
Scaled



C







\+ Initial heights increased with time.

PROBA-2/SWAP GI: Savage, West, and Seaton in prep.

Strong potential analogy with magnetotail substorms

(e.g., Reeves et al. 2008)

Fig 1

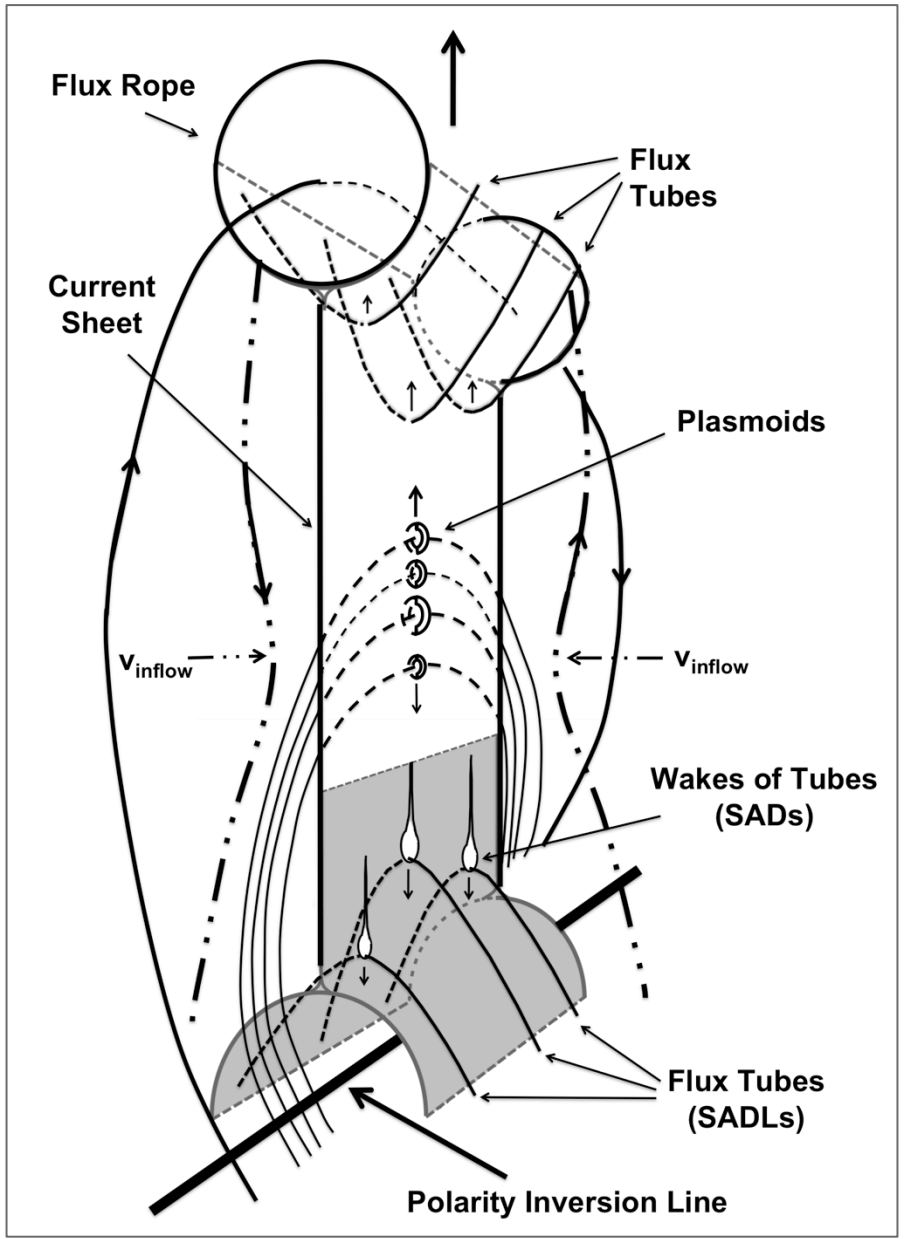


Fig 2

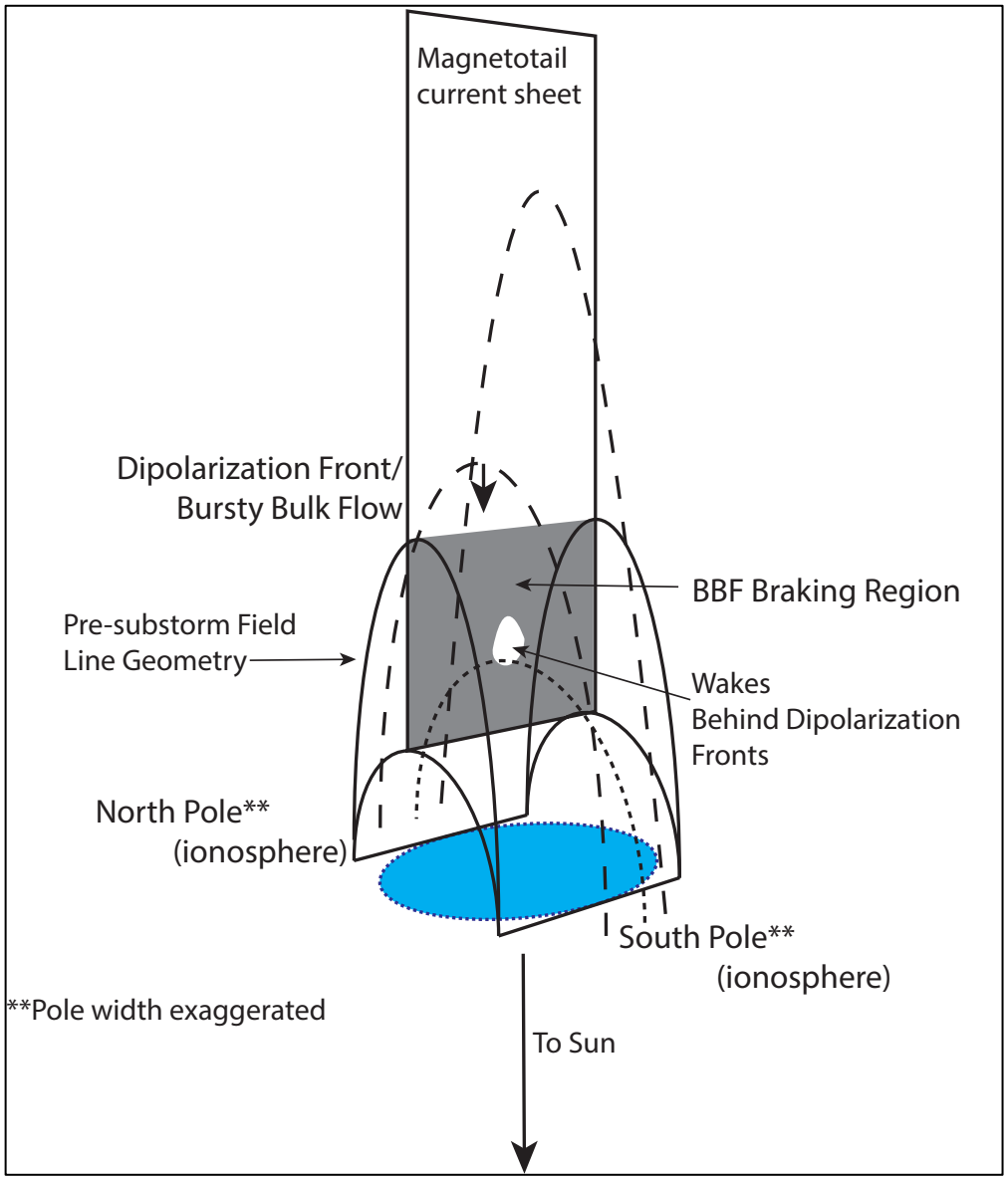
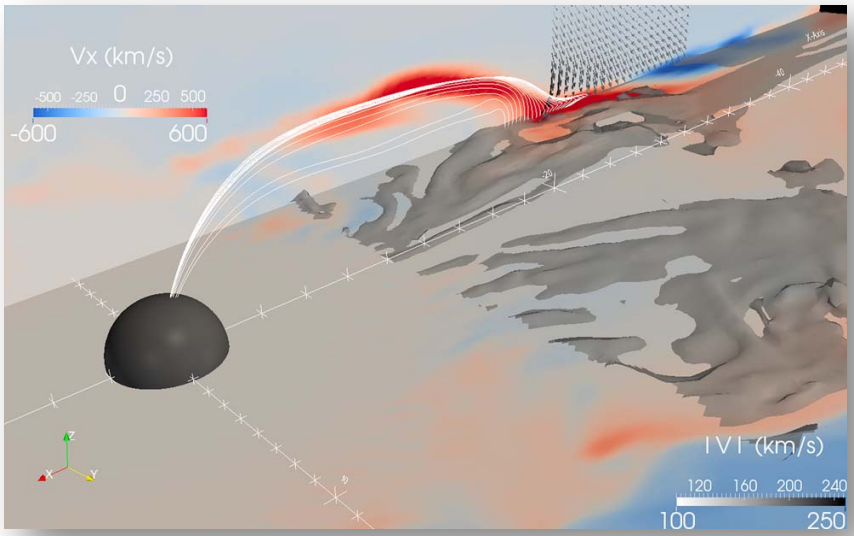
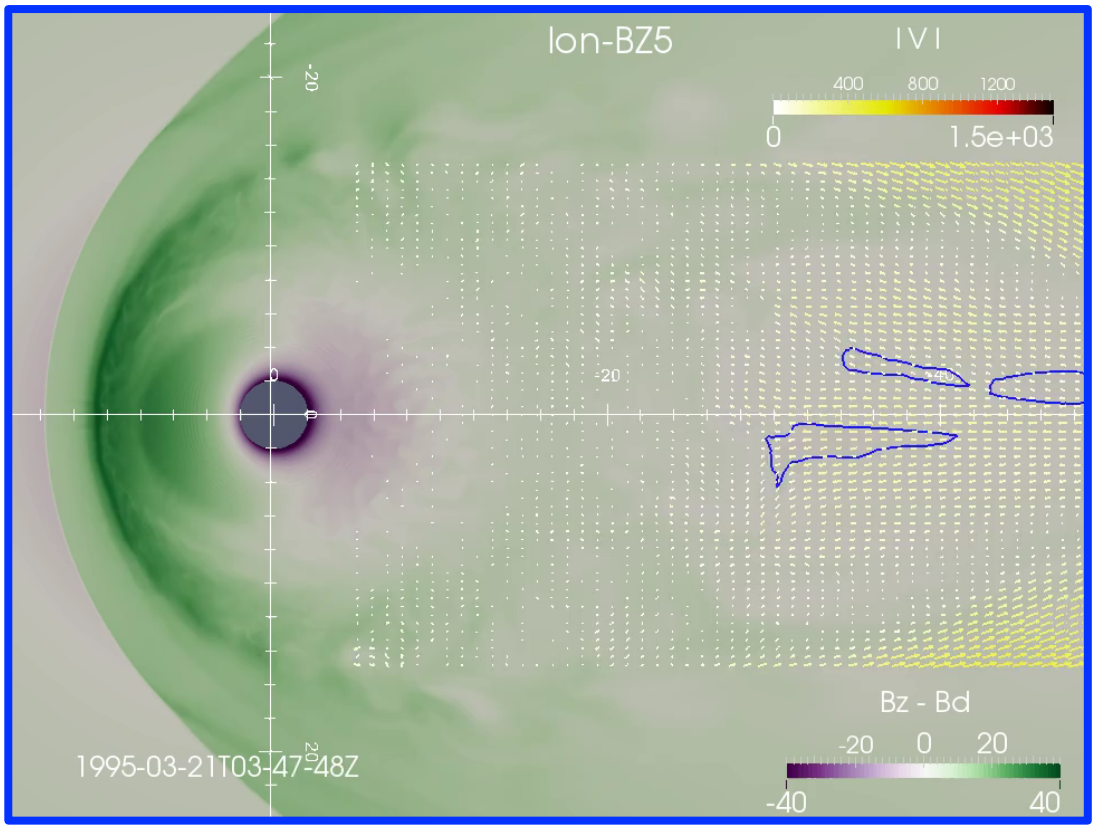


Fig 1: Savage et al. 2012

Fig 2: Courtesy of A. Kobelski, Reeves et al. 2008

Using THEMIS for comparison to *in situ* data





Wiltberger et al. 2015

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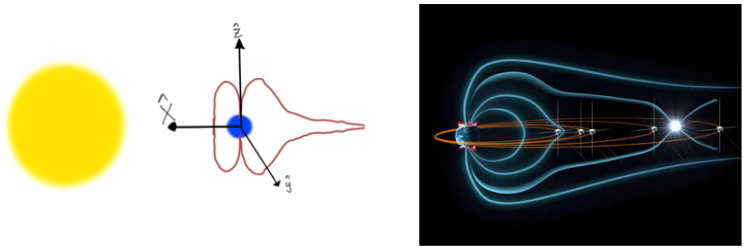
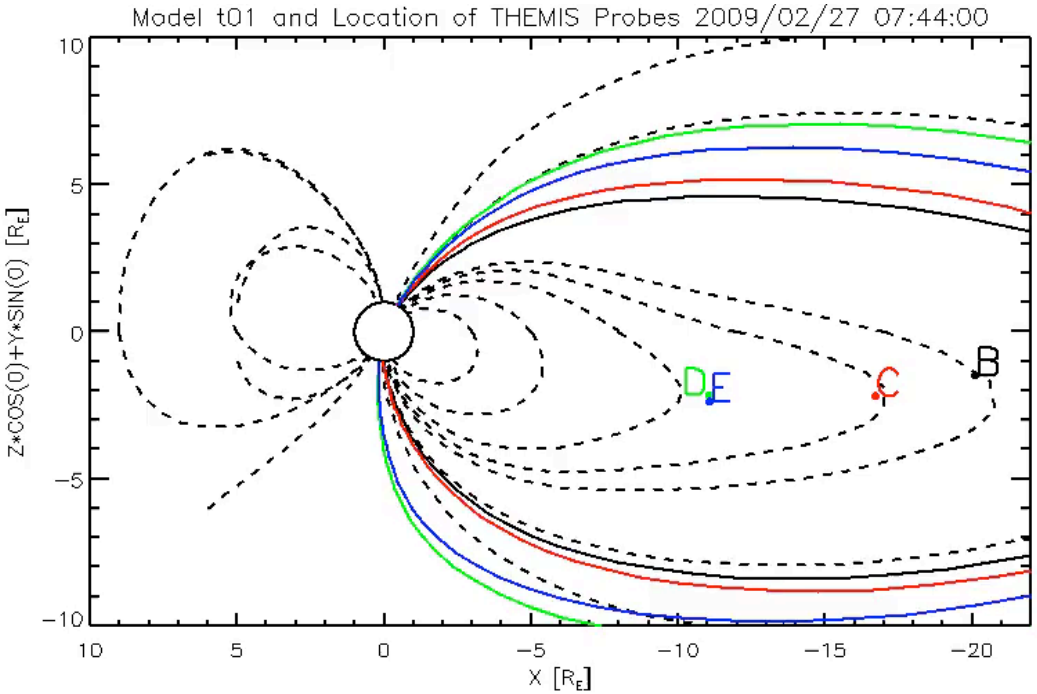
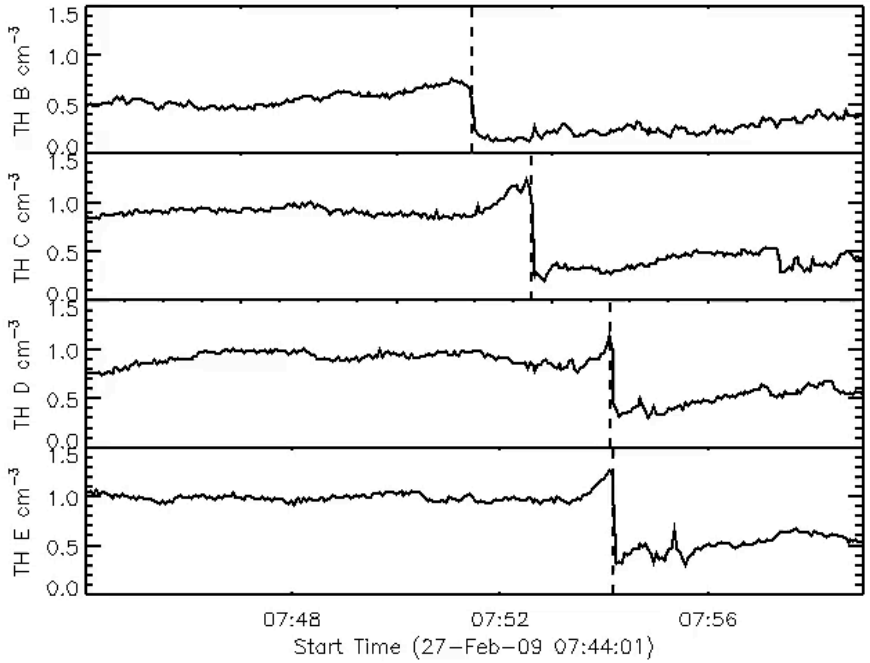




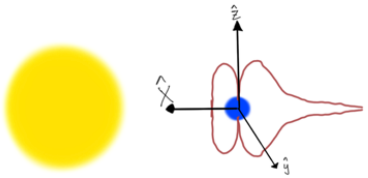
Density at each spacecraft

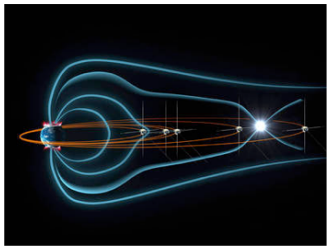


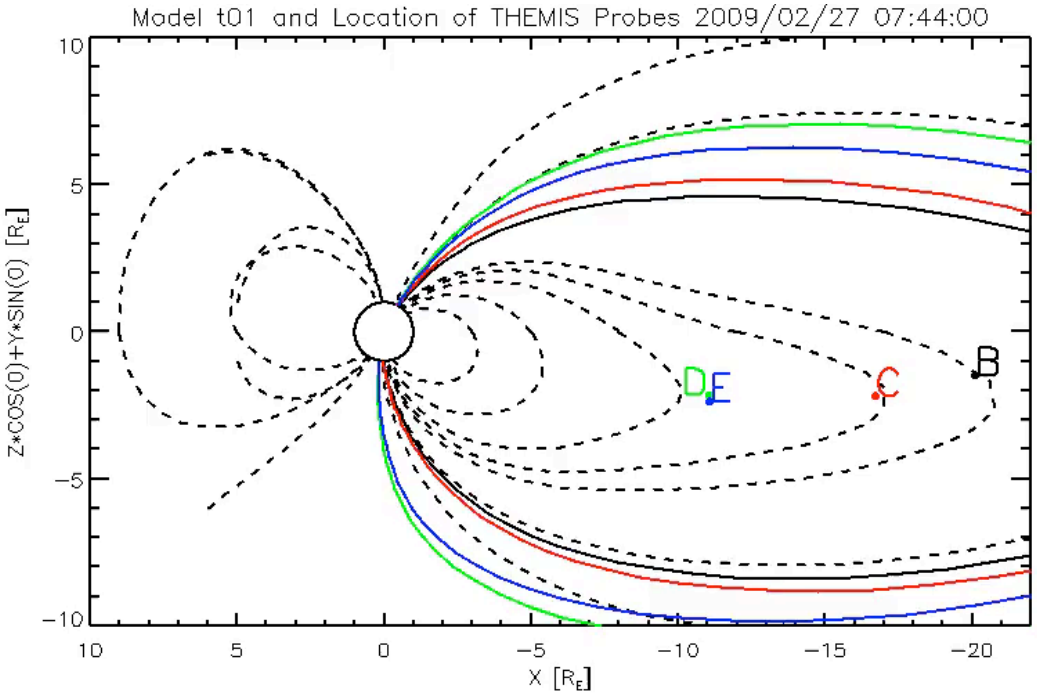
Substantial density drop following the dipolarization event!

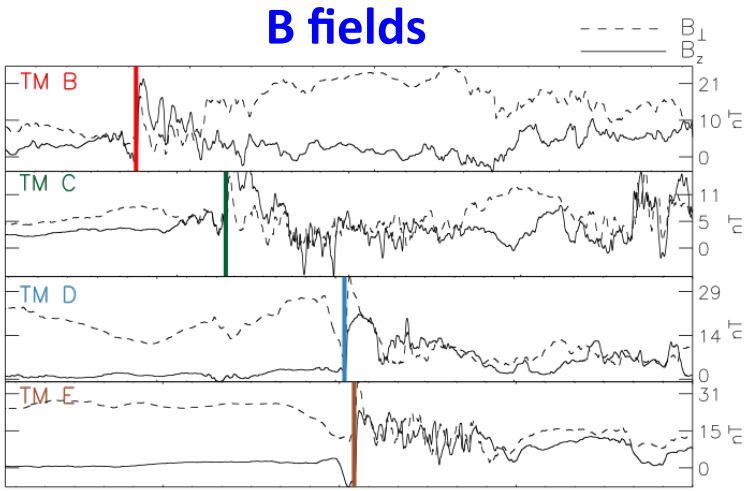
Courtesy of Adam Kobelski and David Malaspina based on analysis from Runov et al., 2011

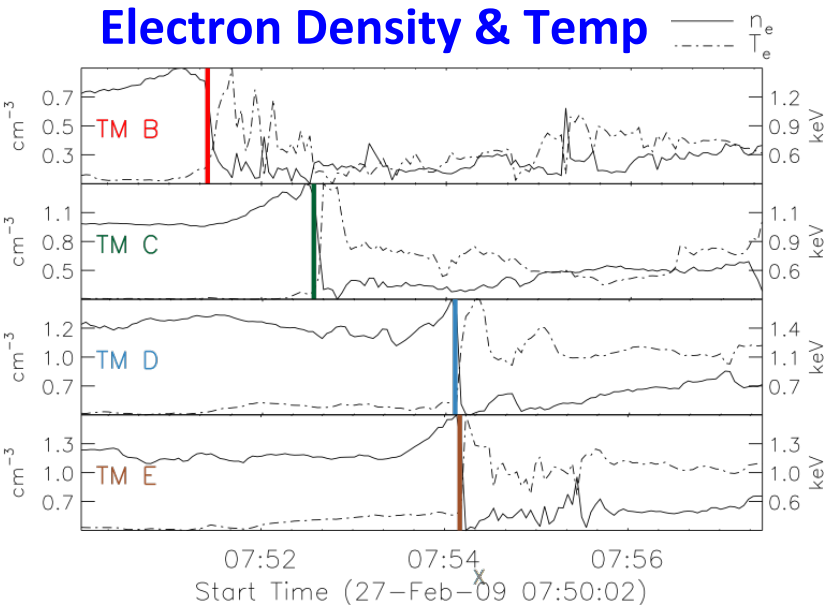
Using THEMIS for comparison to *in situ* data









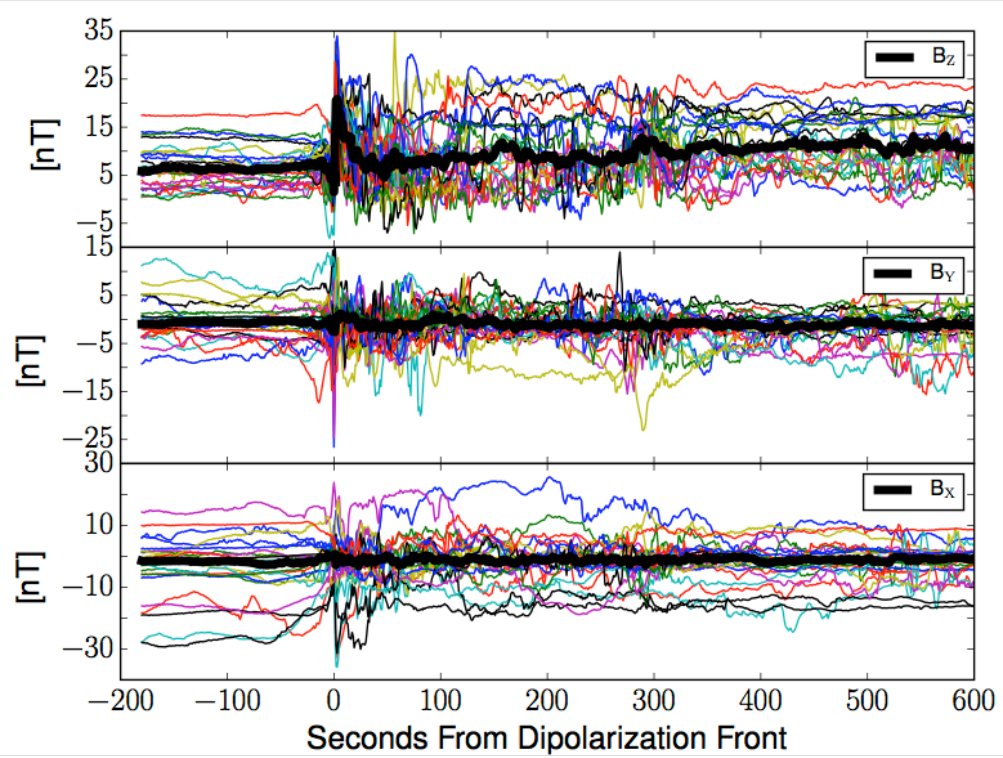


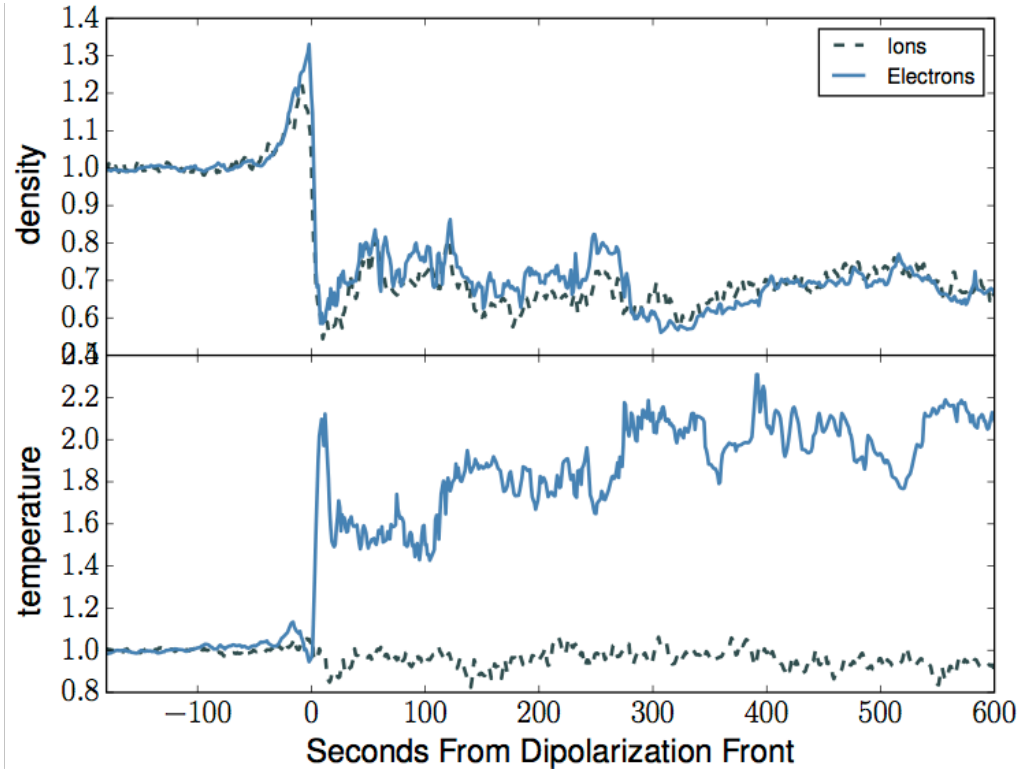
Dipolarization fronts defined by reversal in B field.

Electron densities drop. Temperatures increase as front passes.

Courtesy of Adam Kobelski and David Malaspina based on analysis from Runov et al., 2011

Using THEMIS for comparison to *in situ* data



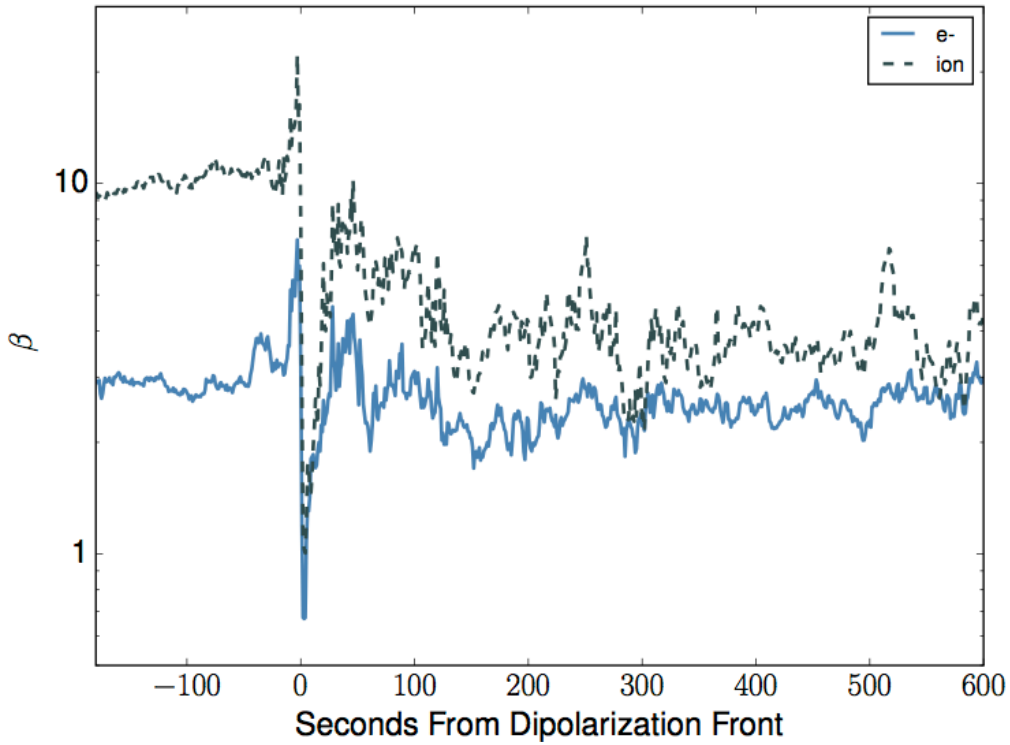


Combination of 6 events observed by up to 5 THEMIS spacecraft
(listed in Runov et al., 2011)

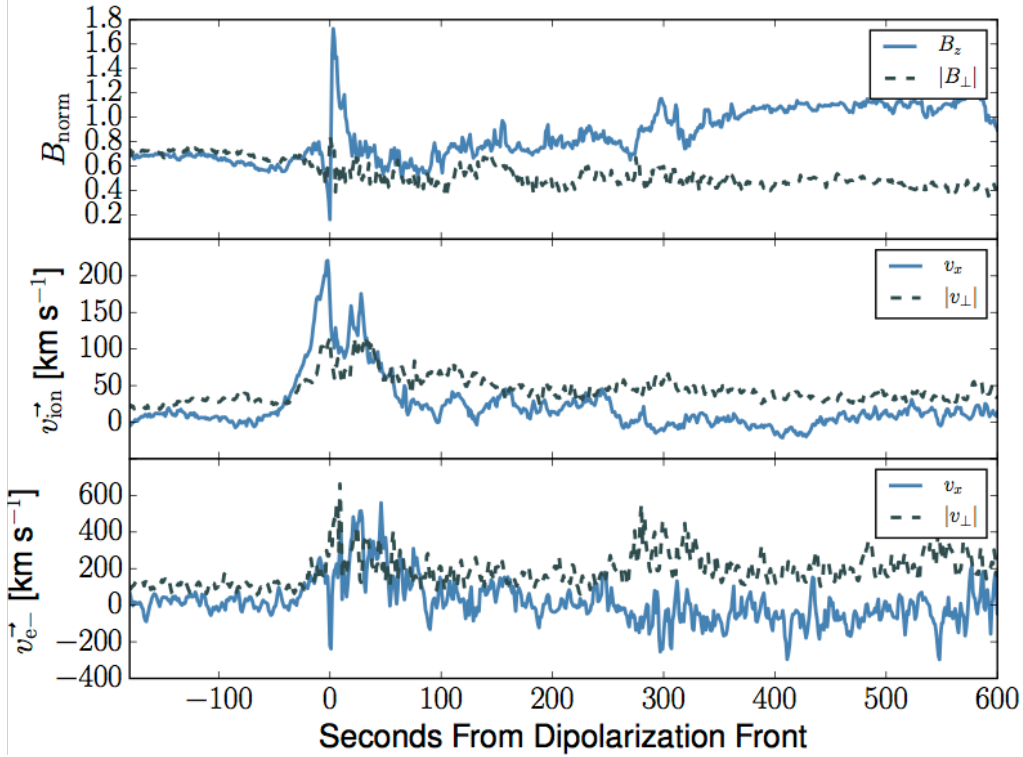
Courtesy of Adam Kobelski and David Malaspina based on analysis from Runov et al., 2011

Using THEMIS for comparison to *in situ* data

Plasma Beta



B_{norm}, Ion velocity, Electron velocity



Combination of 6 events observed by up to 5 THEMIS spacecraft
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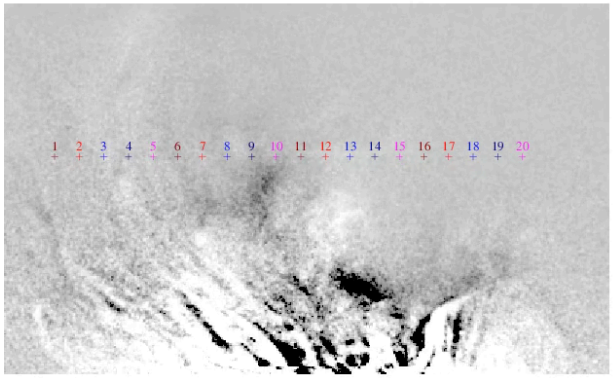
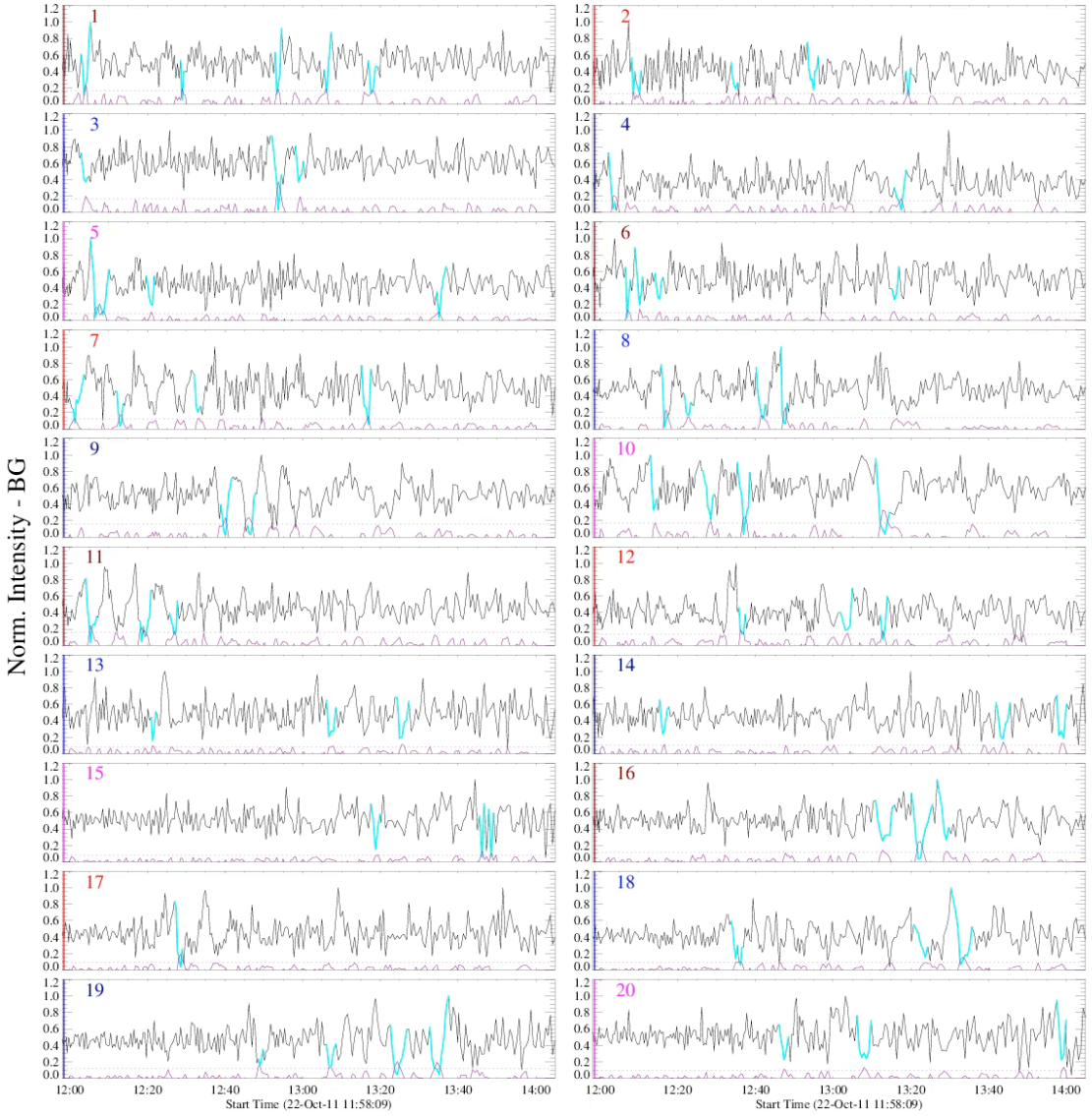
Mimicking *in situ* data sets in the corona



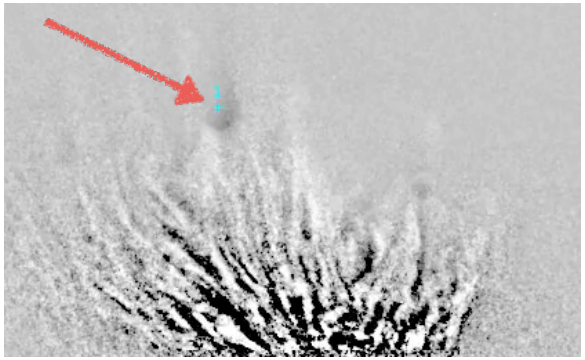
Fake "satellites" placed in the fan.

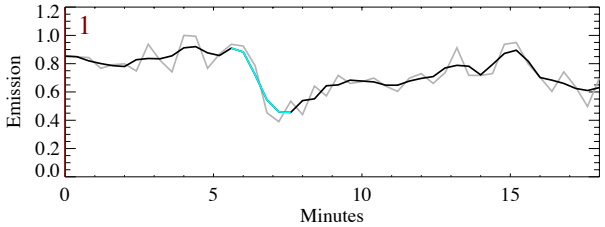
- Lightcurves measured and normalized via smoothing
- Convolution function used to automatically detect SAD profiles in lightcurves (cyan indicates a detection)
- Lightcurve plots trace density changes
- Not perfect, but neither is *in situ* data

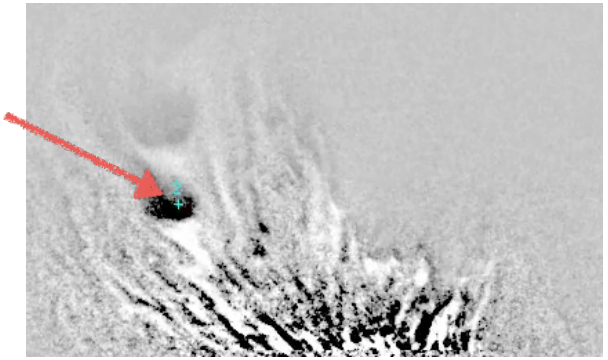


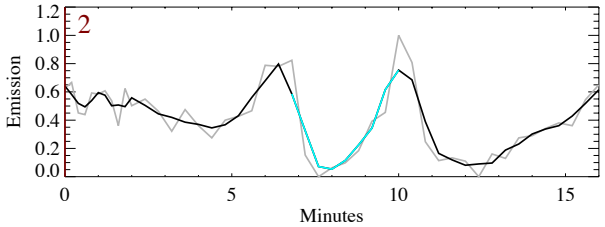
Kobelski, Savage, and Malaspina in prep.

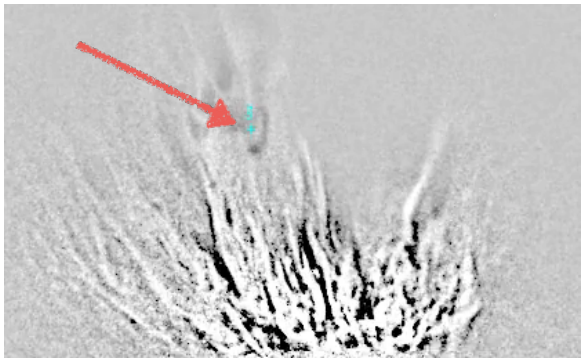
Mimicking *in situ* data sets in the corona

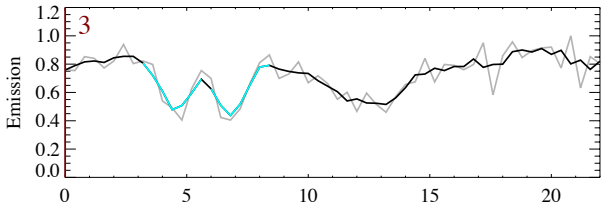


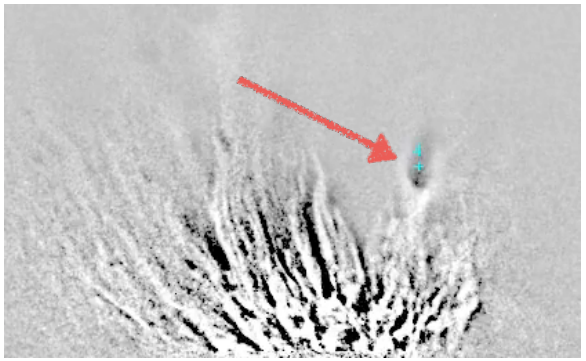


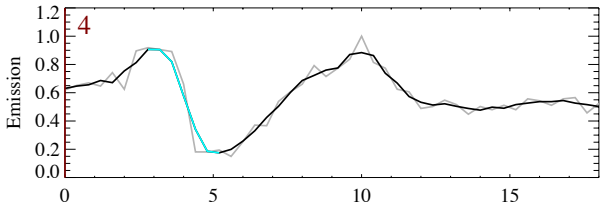








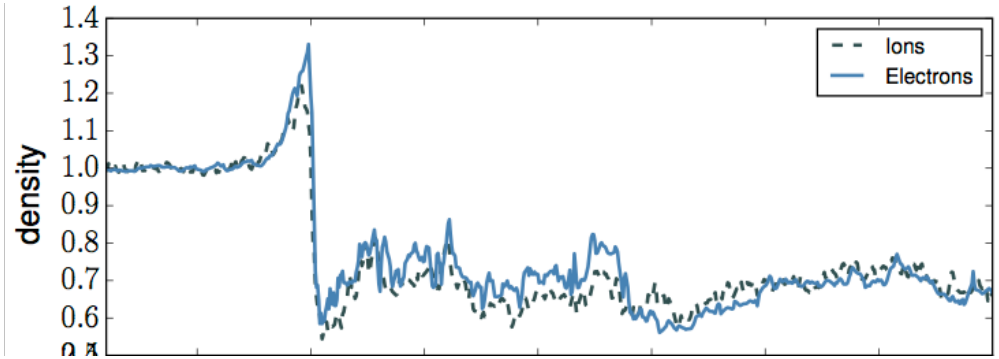




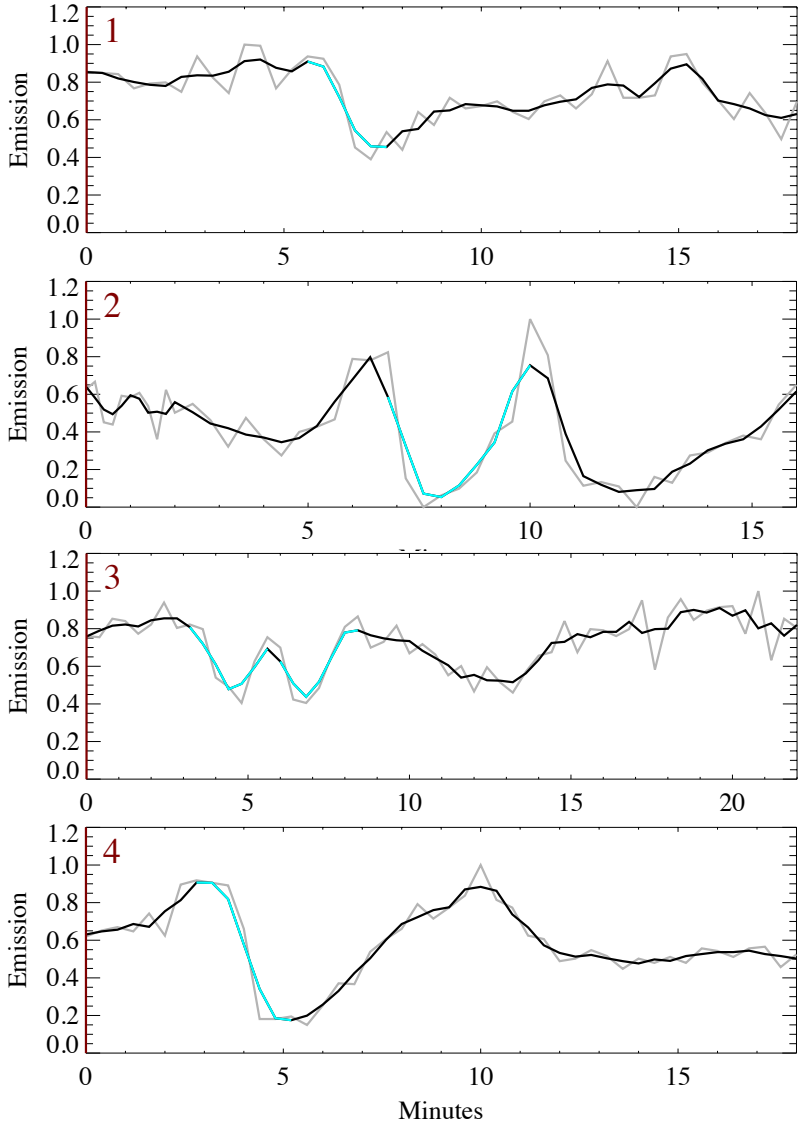
Kobelski, Savage, and Malaspina in prep.

Quick comparison

Dipolarization Fronts



SADs

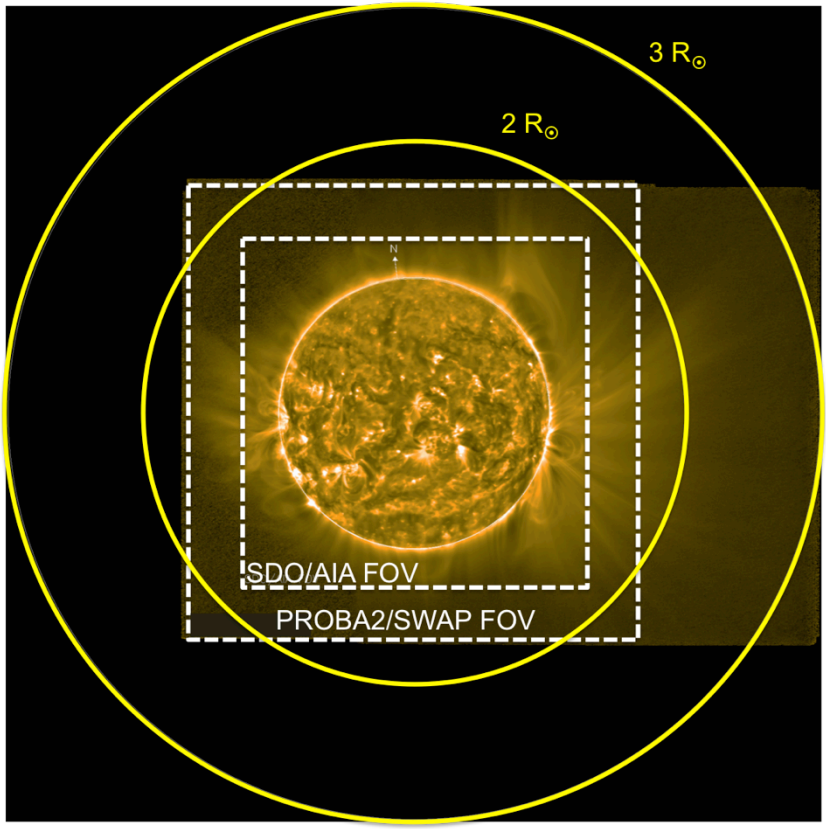


Immediate future… Temperatures.

Kobelski, Savage, and Malaspina in prep.

Take aways

- **Continuation of shrinking loops can impart energy into the current sheet long after the eruption and high into the corona.**
- ***In situ* magnetotail data being used to inform remote sensing coronal data (and eventually vice versa…)**
- **COSIE instrument would immensely add to our transitional corona knowledge**



Kobelski, Savage, and Malaspina in prep.

Savage, West, and Seaton in prep.