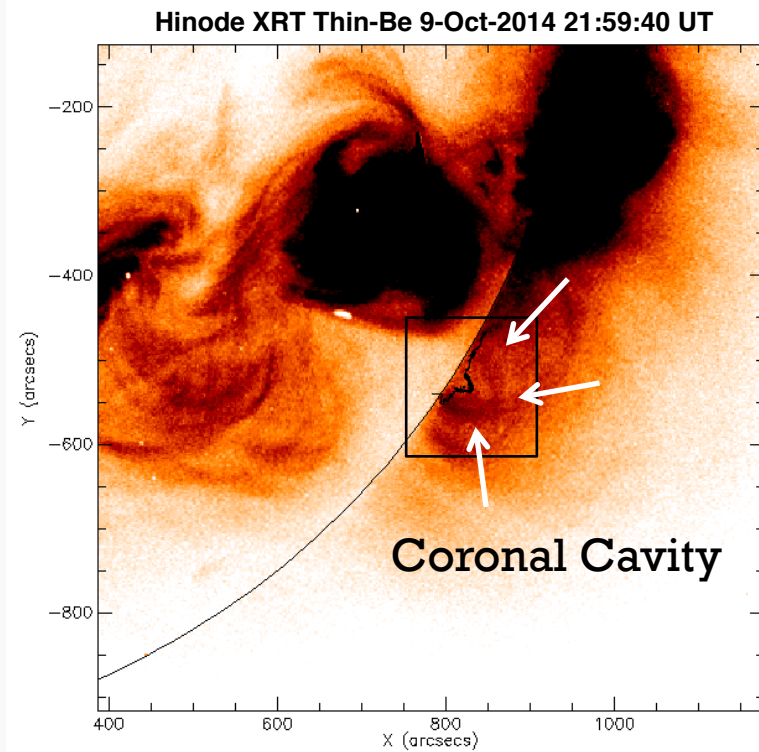
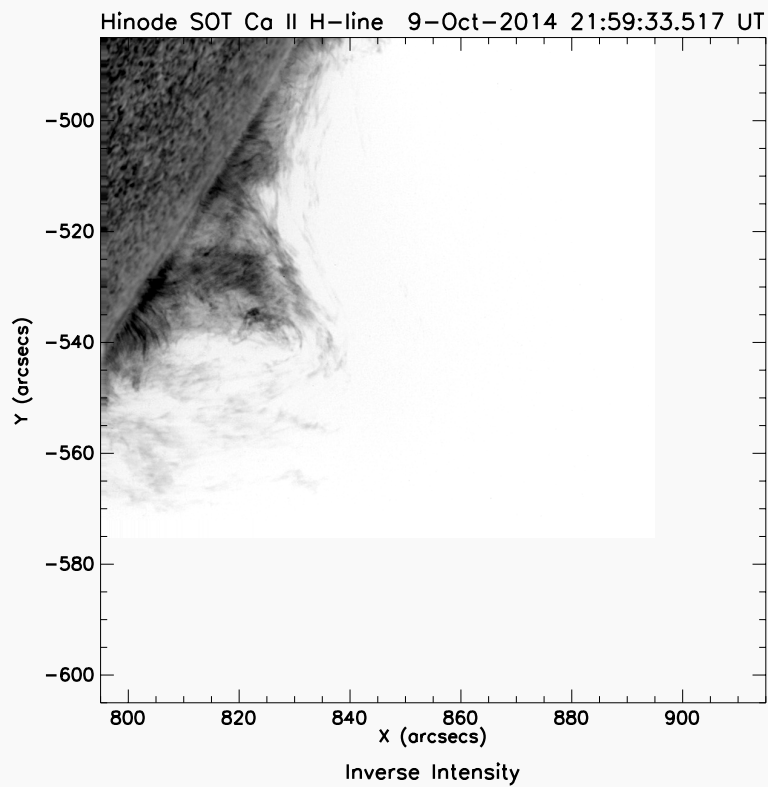


# Evidence for a Magnetic Flux Rope in Observations of a Solar Prominence-Cavity System

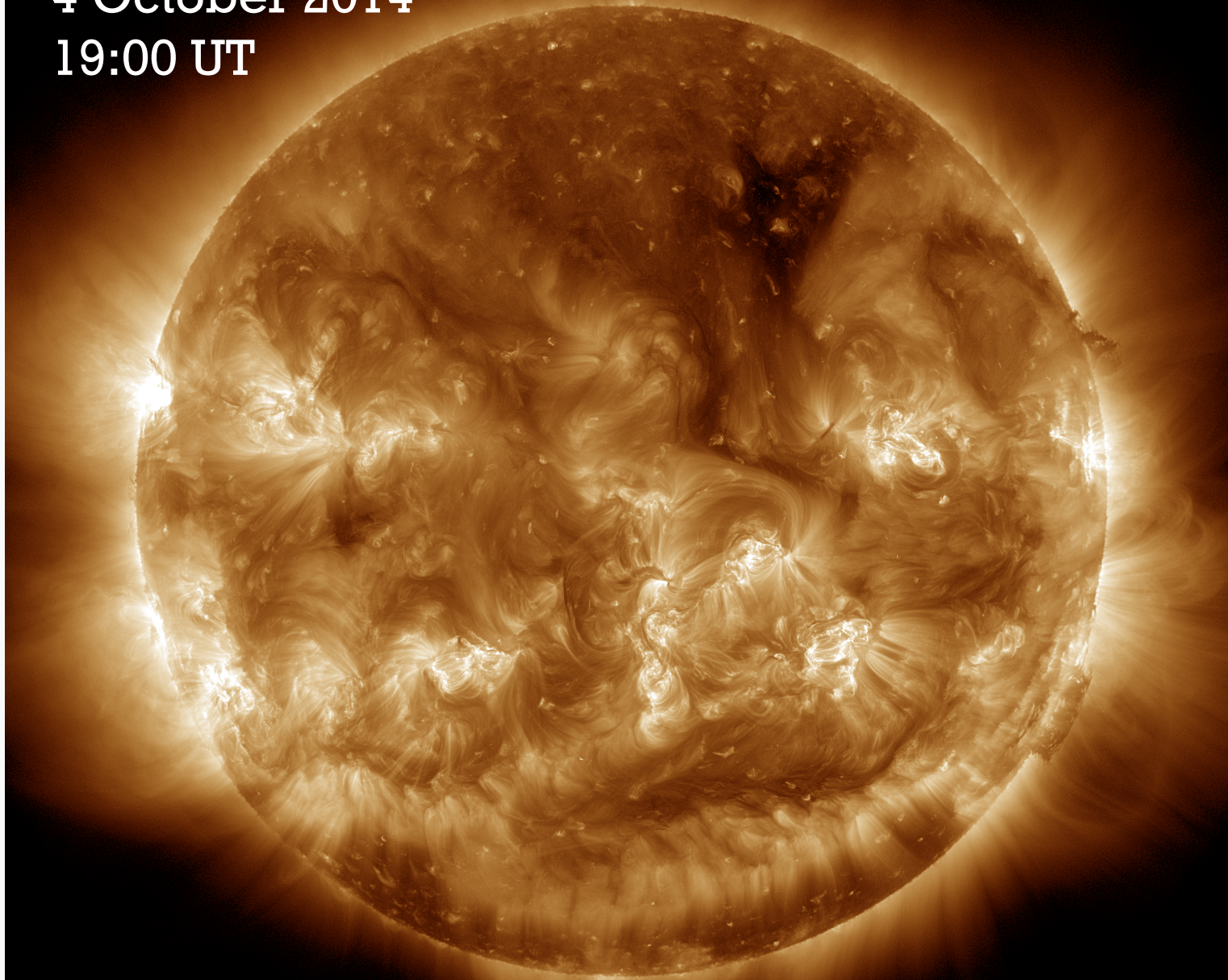
P. R. Jibben, K. K. Reeves, & Su, Y.,  
Frontiers in Astronomy & Space  
Sciences, 3:10.

[www.frontiersin.org](http://www.frontiersin.org)

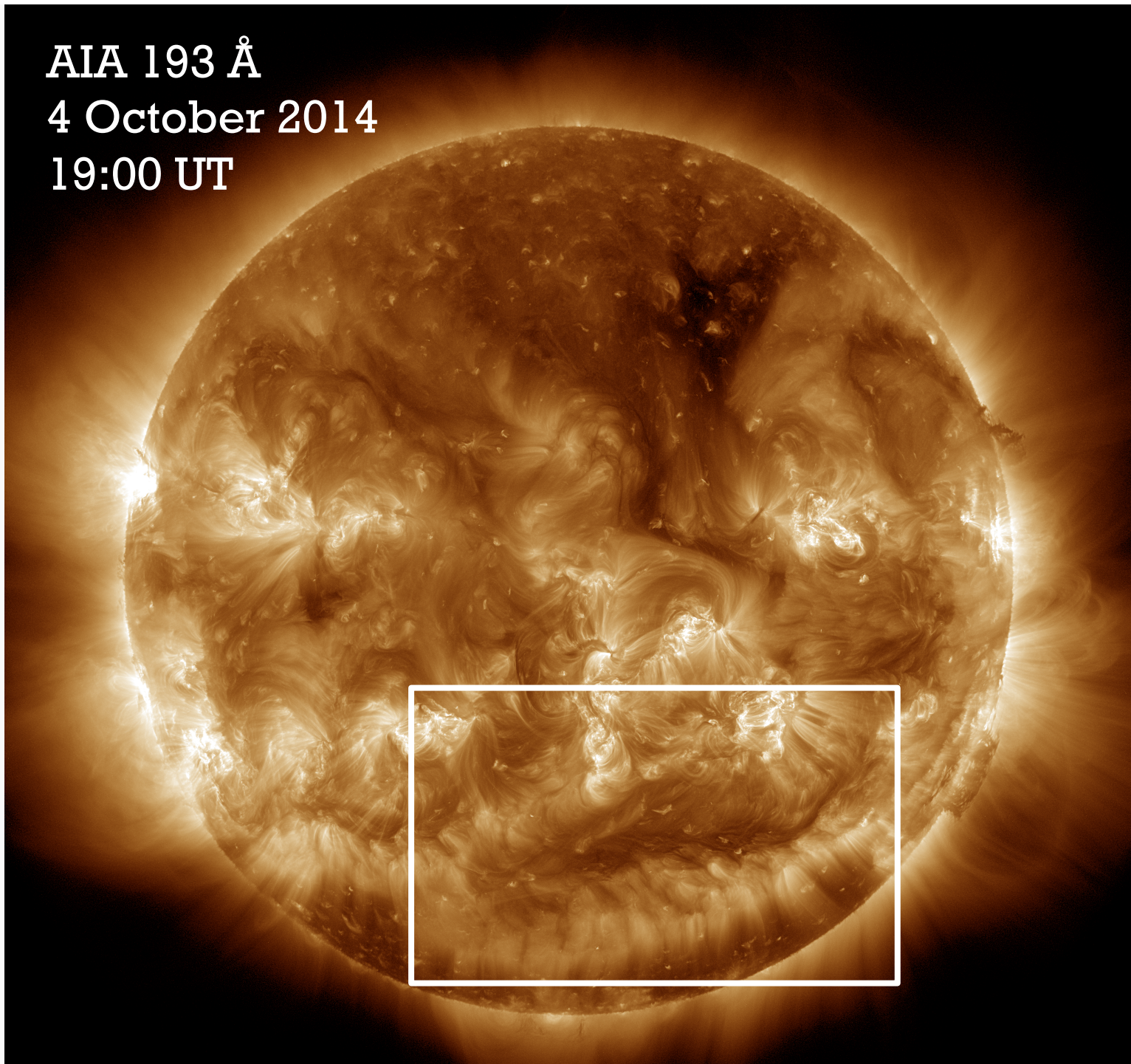
# Prominence-Cavity System



AIA 193 Å  
4 October 2014  
19:00 UT

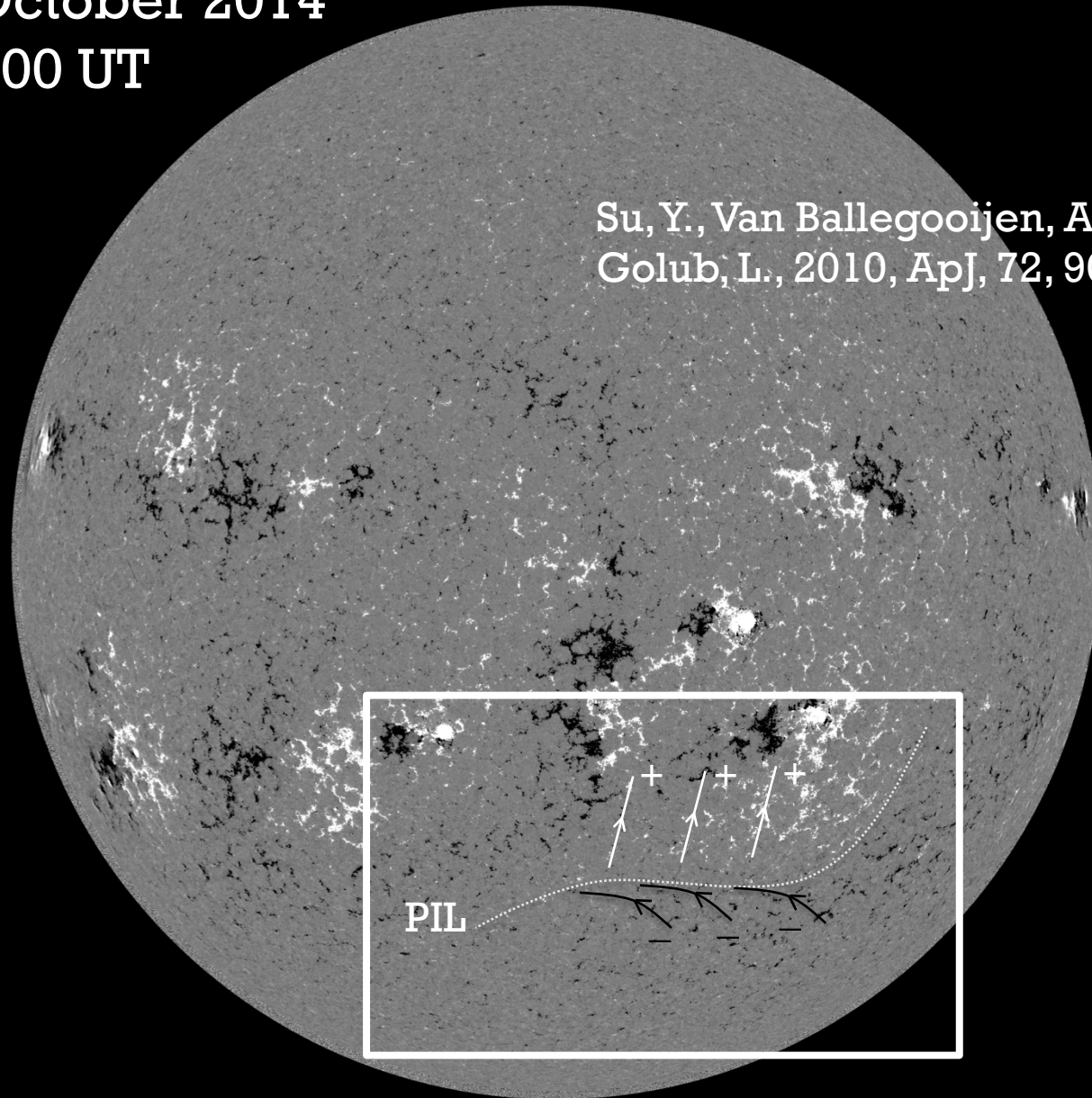


AIA 193 Å  
4 October 2014  
19:00 UT



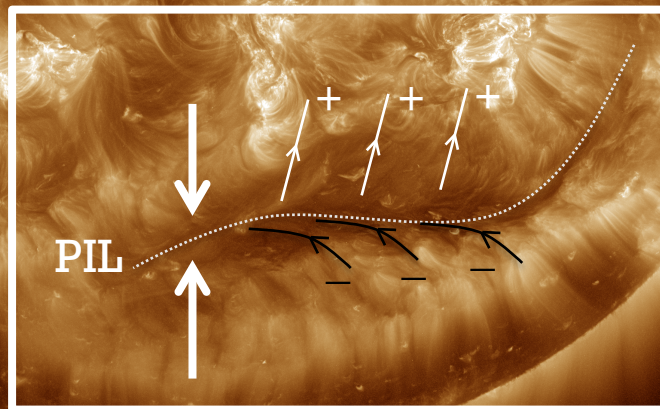
HMI LOS  
4 October 2014  
19:00 UT

Su, Y., Van Ballegooijen, A.,  
Golub, L., 2010, ApJ, 72, 901



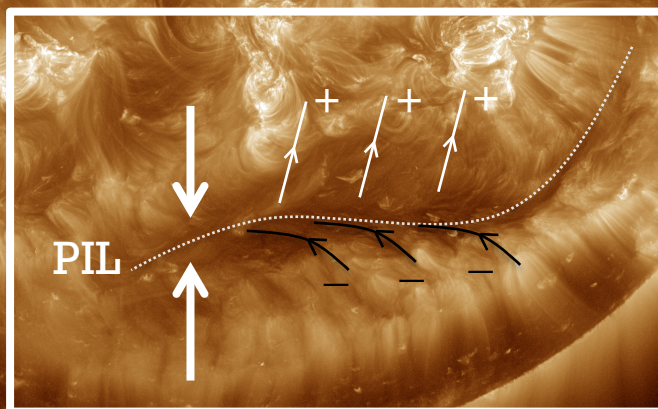
AIA 193 Å  
4 October 2014  
19:00 UT

Su, Y., Van Ballegooijen, A.,  
Golub, L., 2010, ApJ, 72, 901



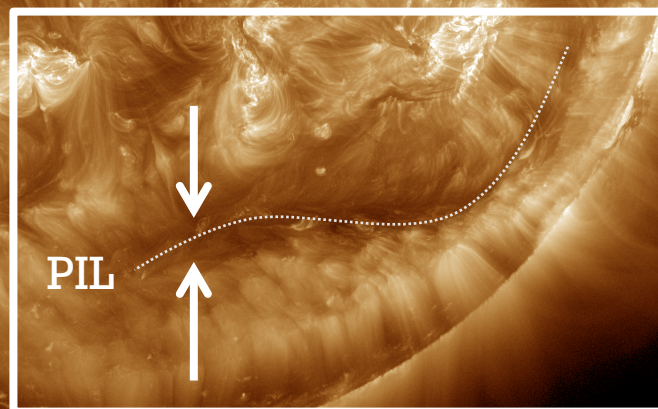
AIA 193 Å  
4 October 2014  
19:00 UT

Su, Y., Van Ballegooijen, A.,  
Golub, L., 2010, ApJ, 72, 901



AIA 193 Å  
5 October 2014  
19:00 UT

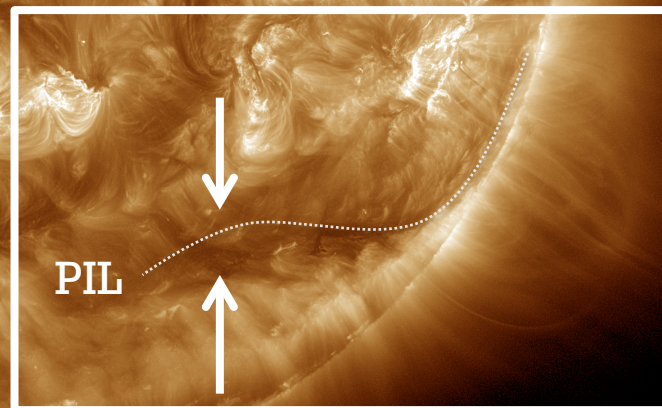
Su, Y., Van Ballegoijen, A.,  
Golub, L., 2010, ApJ, 72, 901





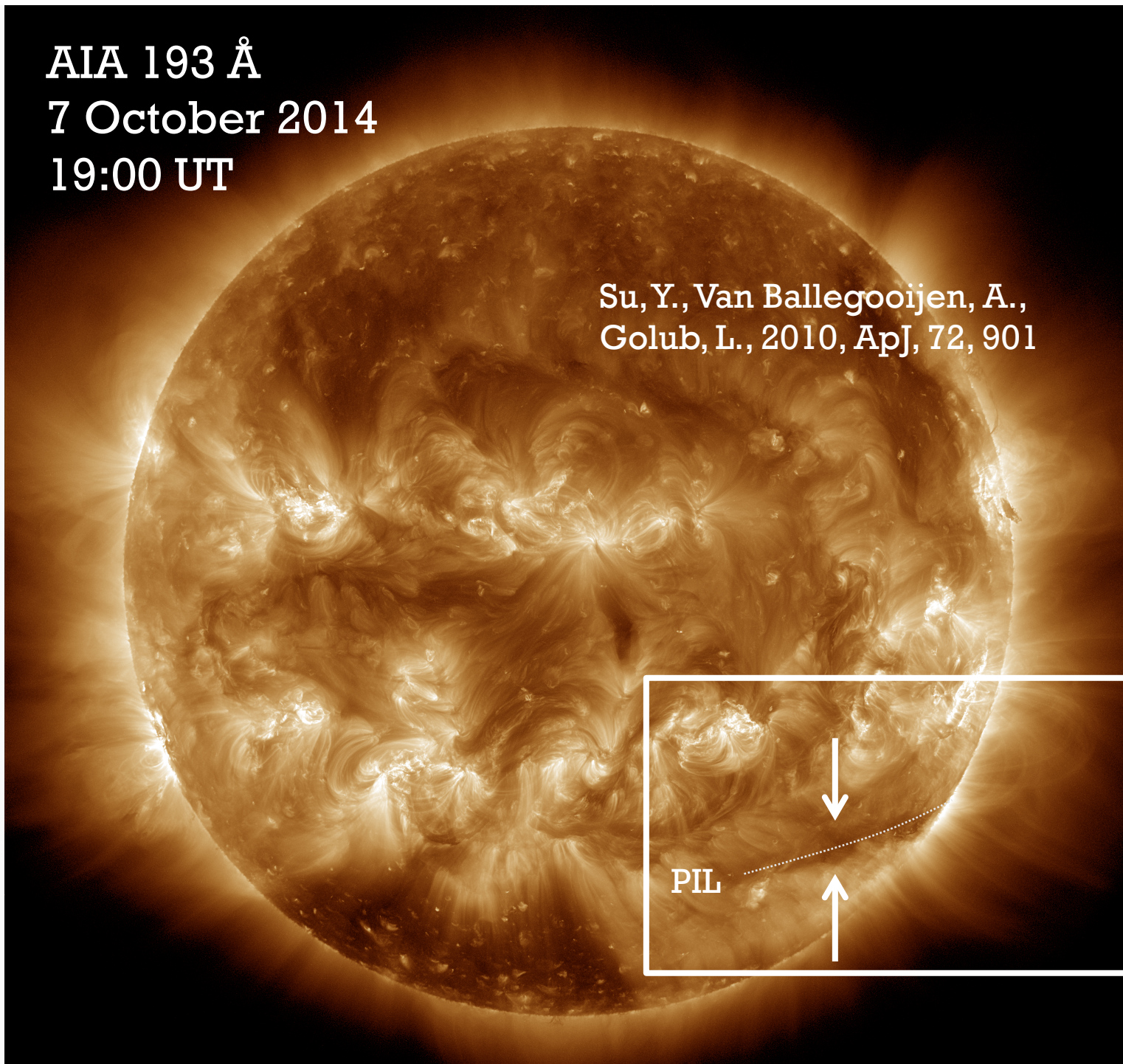
AIA 193 Å  
6 October 2014  
19:00 UT

Su, Y., Van Ballegooijen, A.,  
Golub, L., 2010, ApJ, 72, 901



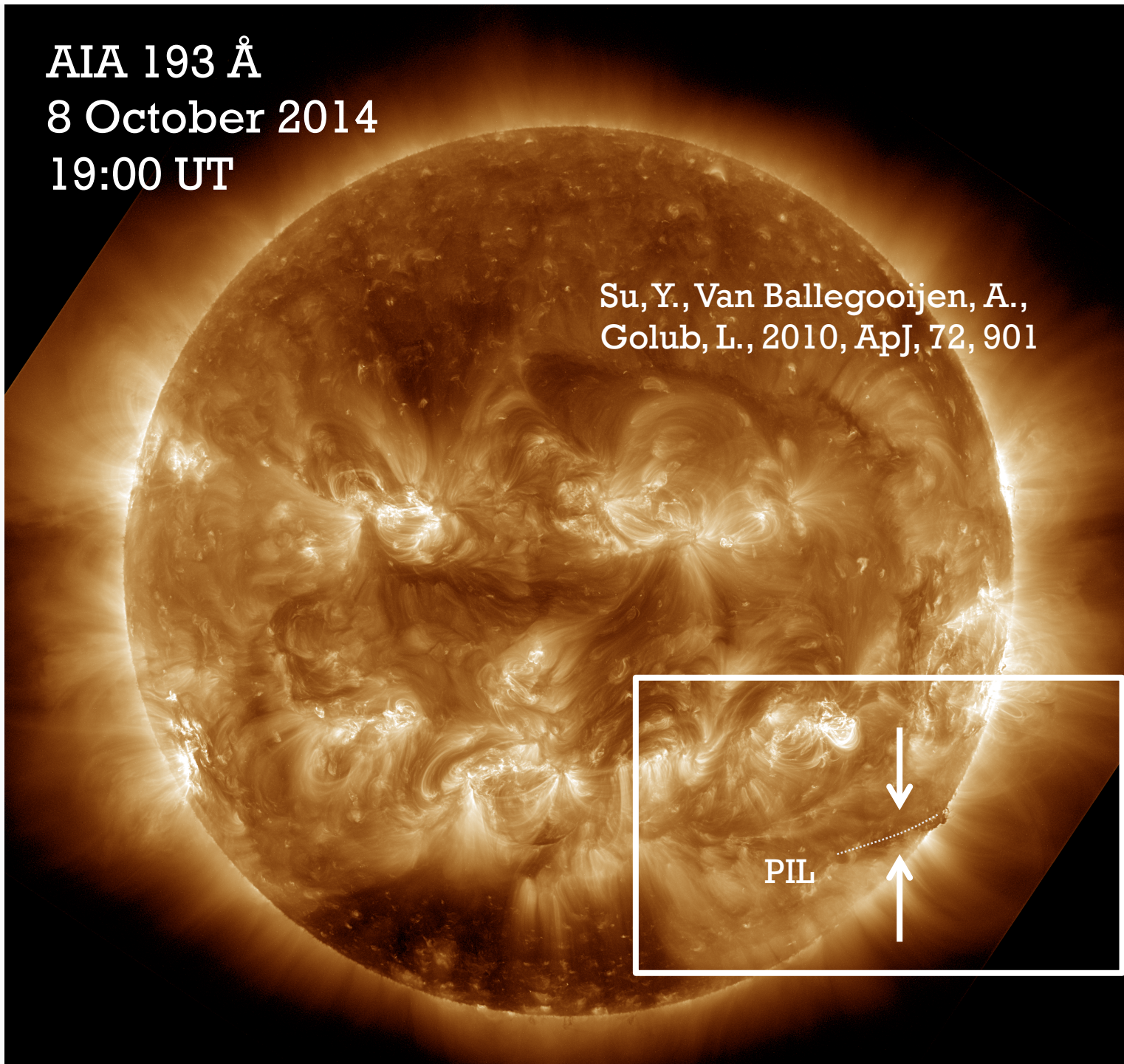
AIA 193 Å  
7 October 2014  
19:00 UT

Su, Y., Van Ballegooijen, A.,  
Golub, L., 2010, ApJ, 72, 901

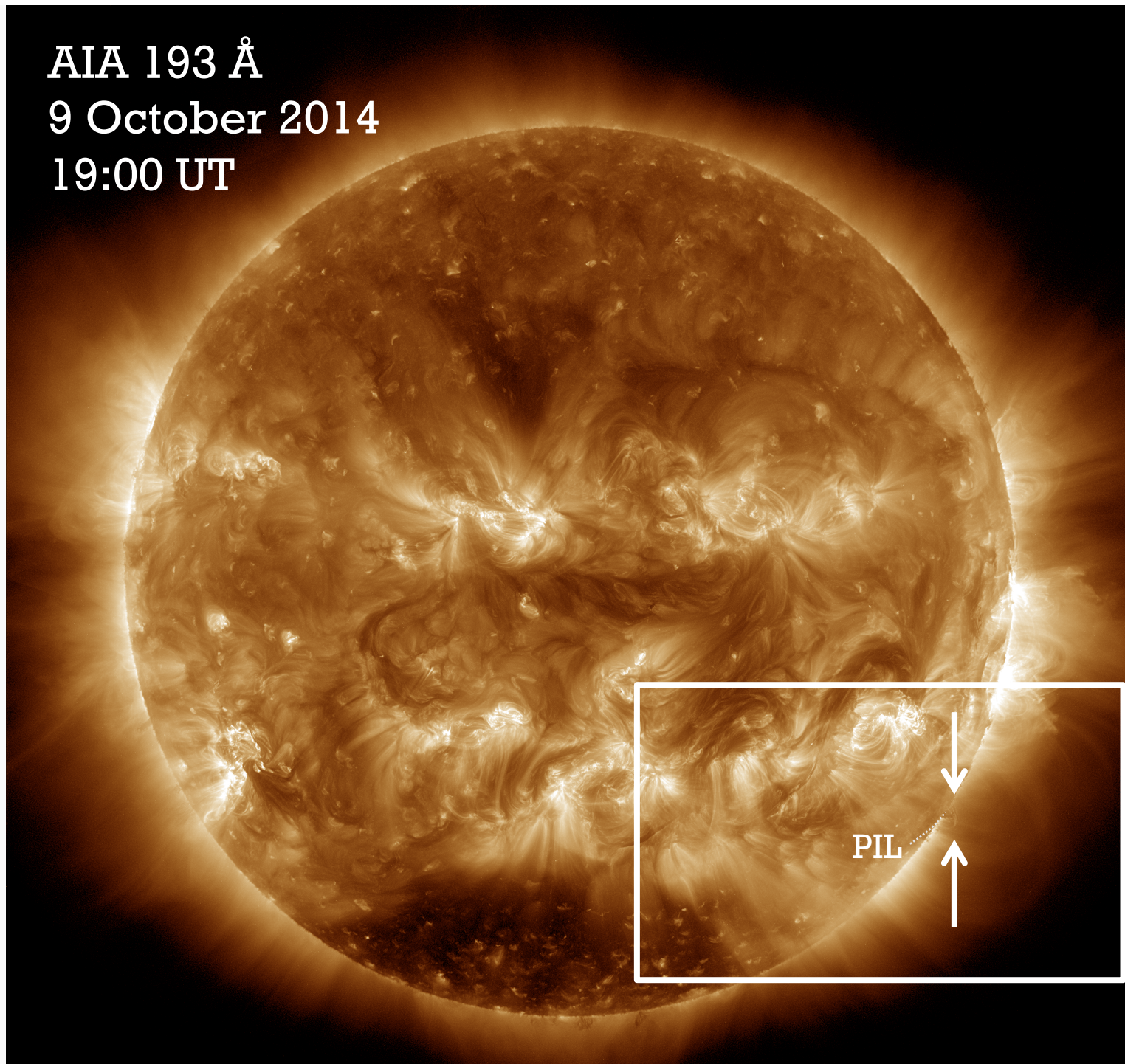


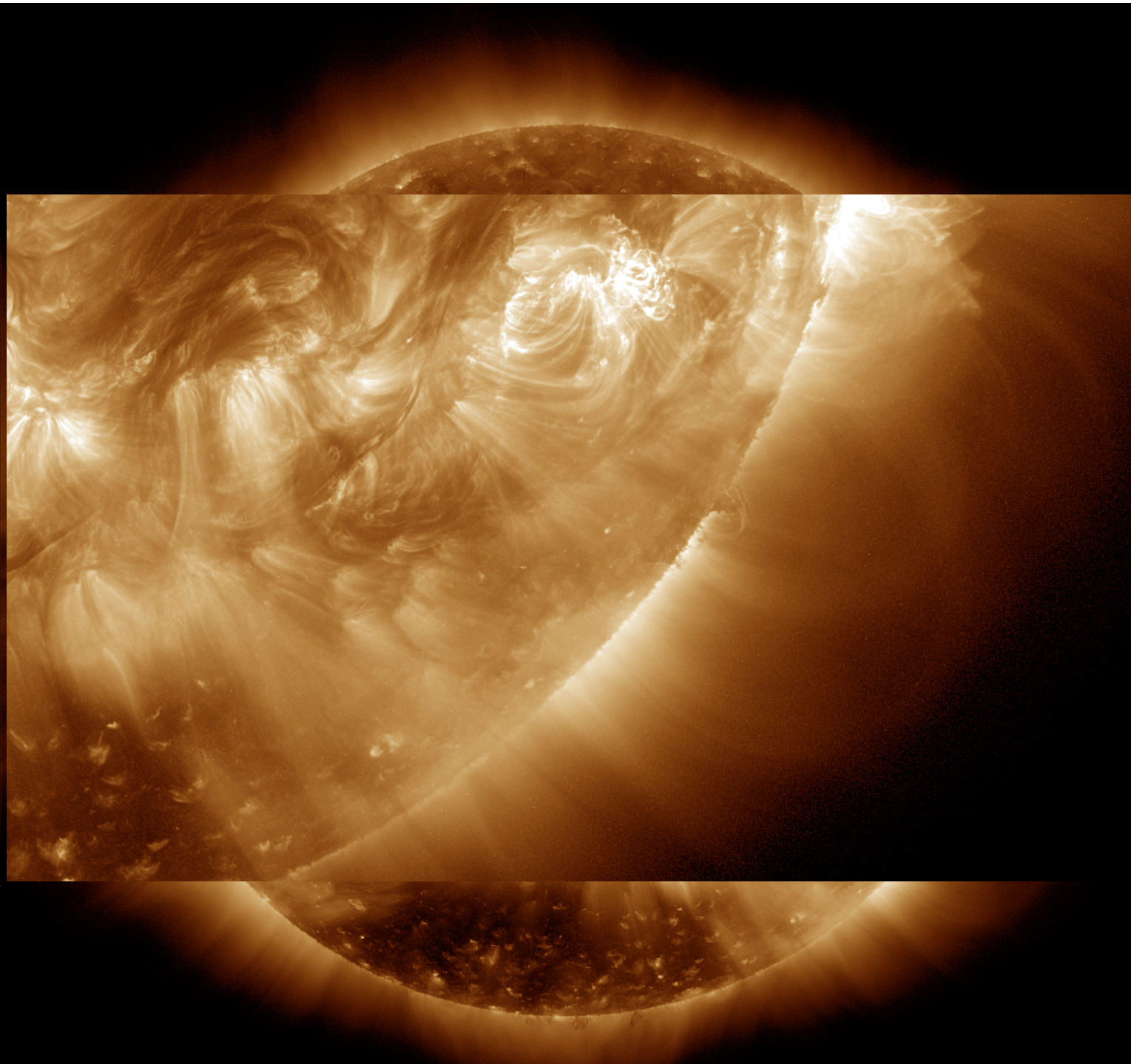
AIA 193 Å  
8 October 2014  
19:00 UT

Su, Y., Van Ballegooijen, A.,  
Golub, L., 2010, ApJ, 72, 901



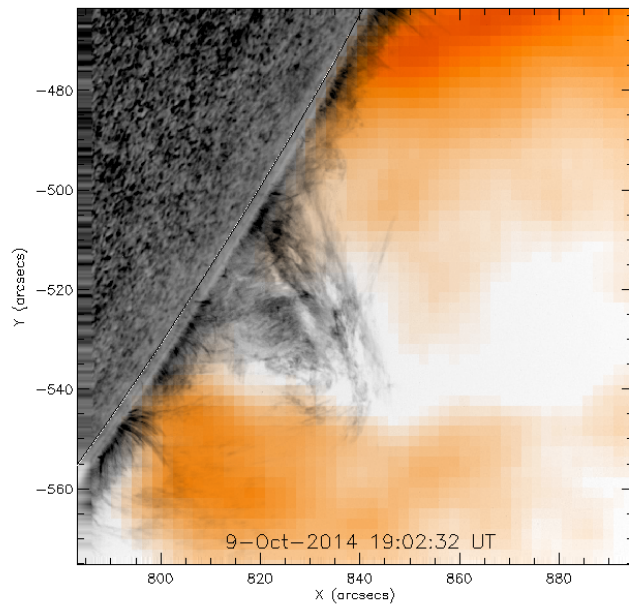
AIA 193 Å  
9 October 2014  
19:00 UT





# Before Eruption

Hinode XRT & SOT

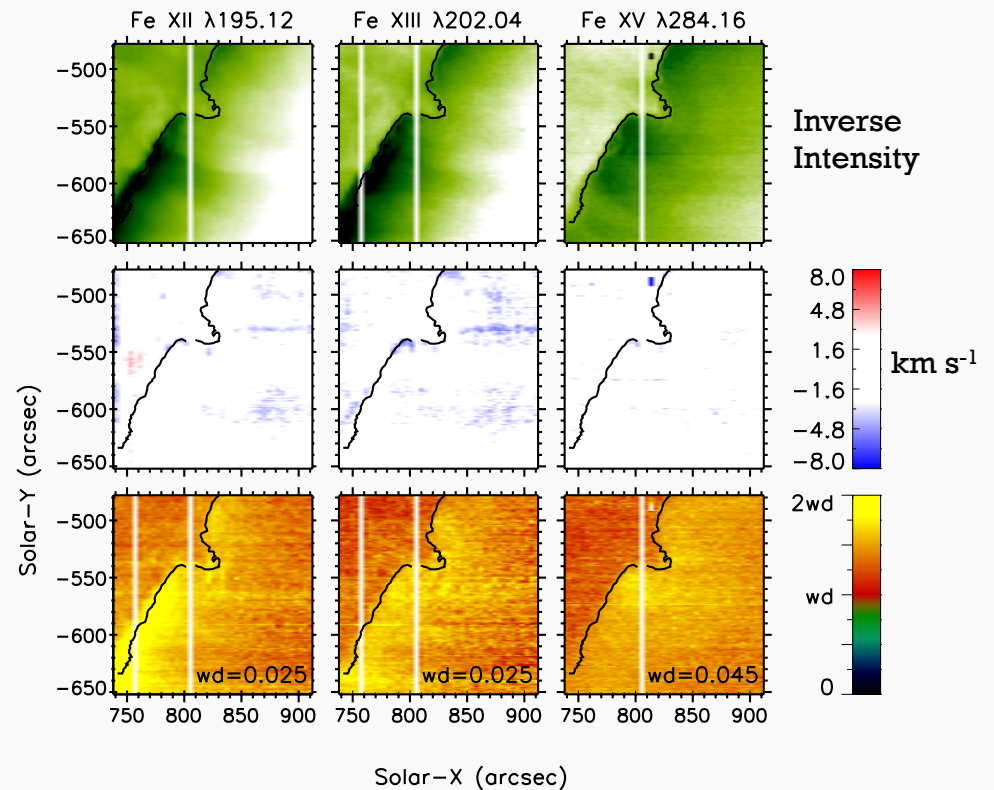


Orange: XRT Thin-Be (1-10 MK)

Grayscale: Ca II H-line

Cavity is at least 5 times dimmer than surroundings

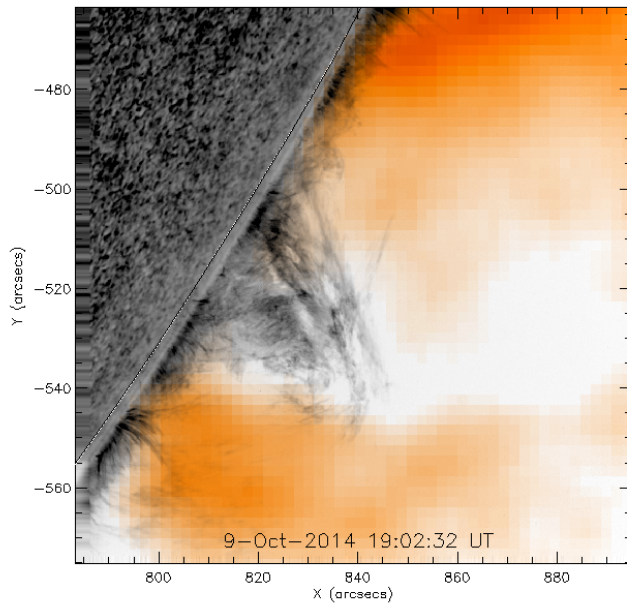
Hinode EIS Raster Scan



18:16-19:21UT

# During Eruption

Hinode XRT & SOT

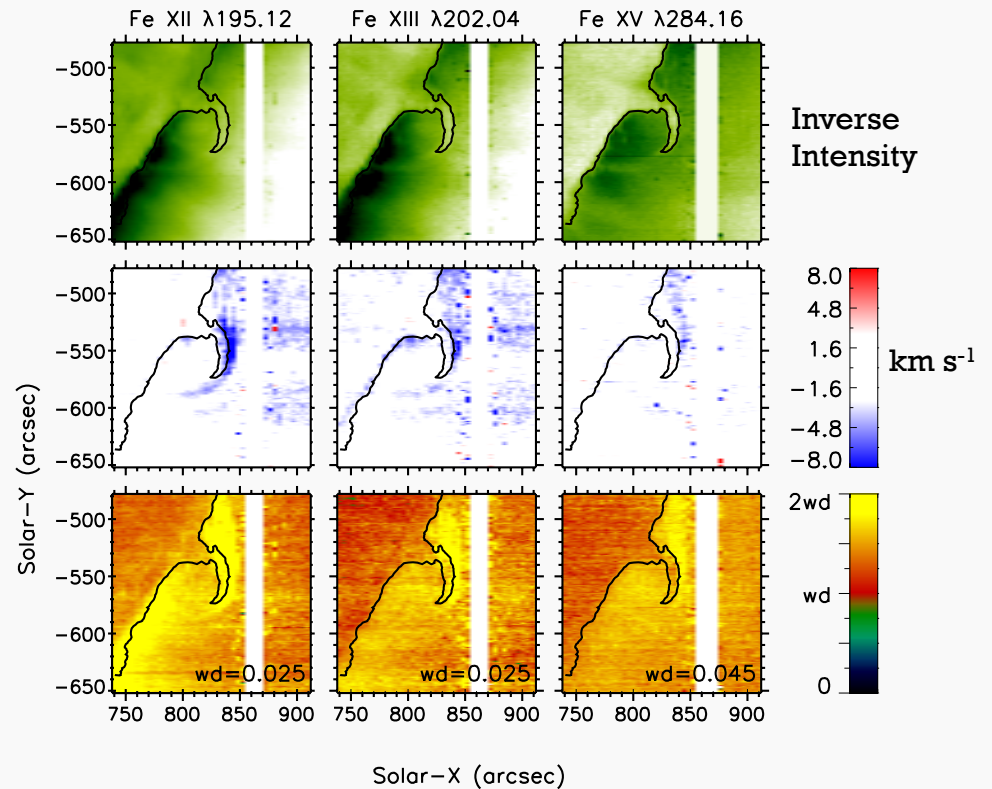


Orange: XRT Thin-Be (1-10 MK)

Grayscale: Ca II H-line

Cavity is at least 5 times dimmer than surroundings

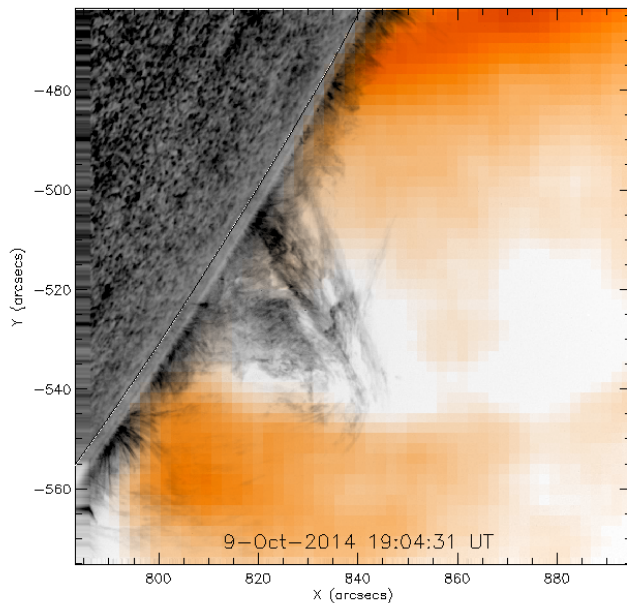
Hinode EIS Raster Scan



18:16-19:21UT

# During Eruption

Hinode XRT & SOT

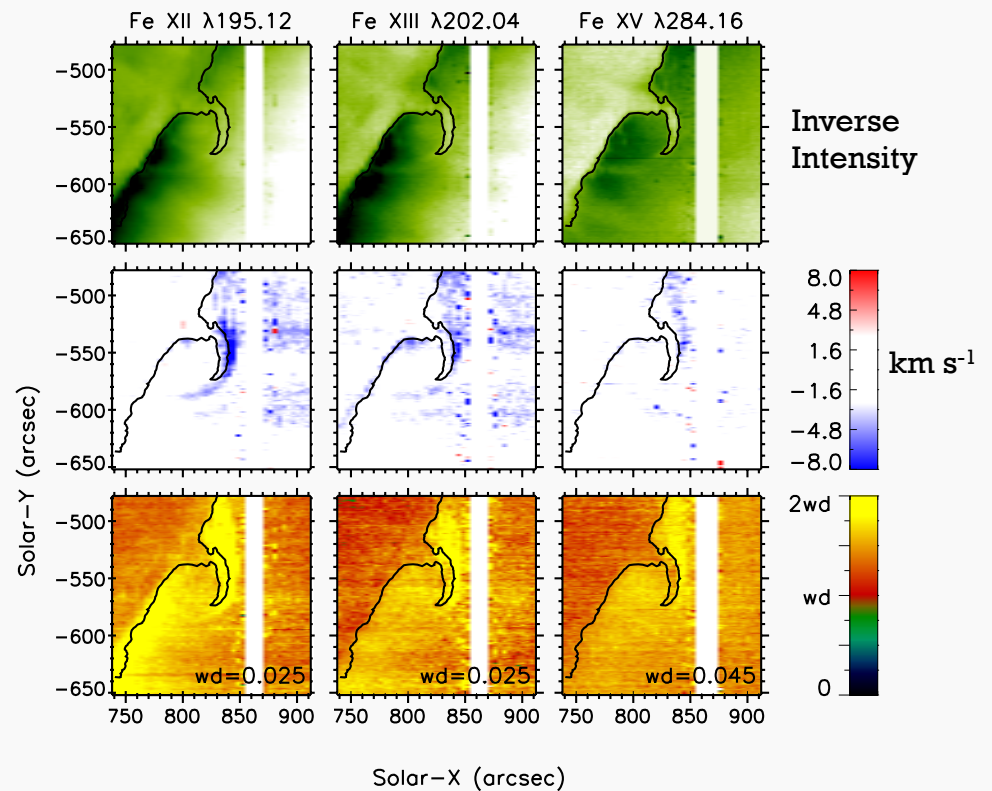


Orange: XRT Thin-Be (1-10 MK)

Grayscale: Ca II H-line

Cavity is at least 5 times dimmer than surroundings

Hinode EIS Raster Scan

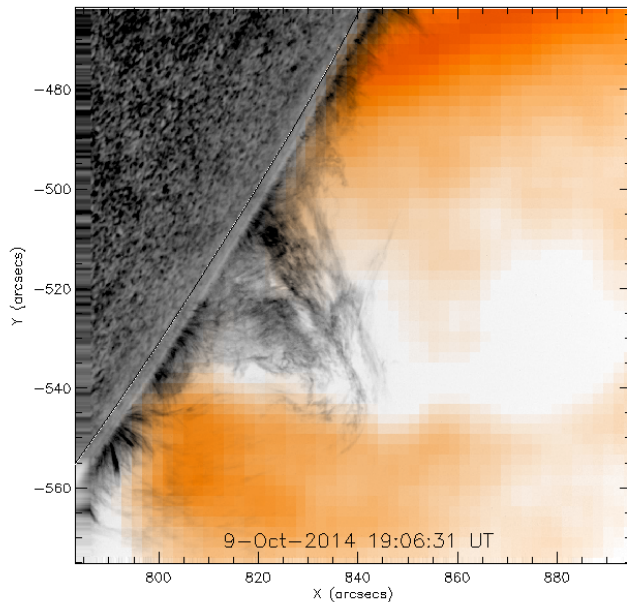


18:16-19:21UT



# During Eruption

Hinode XRT & SOT

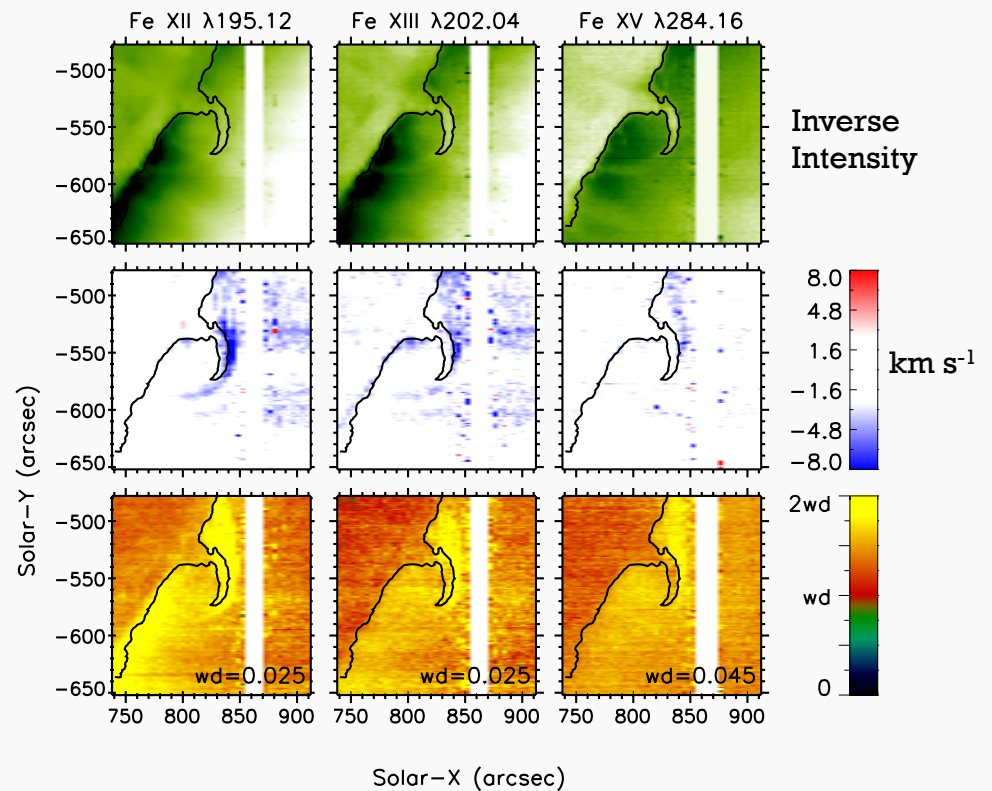


Orange: XRT Thin-Be (1-10 MK)

Grayscale: Ca II H-line

Cavity is at least 5 times dimmer than surroundings

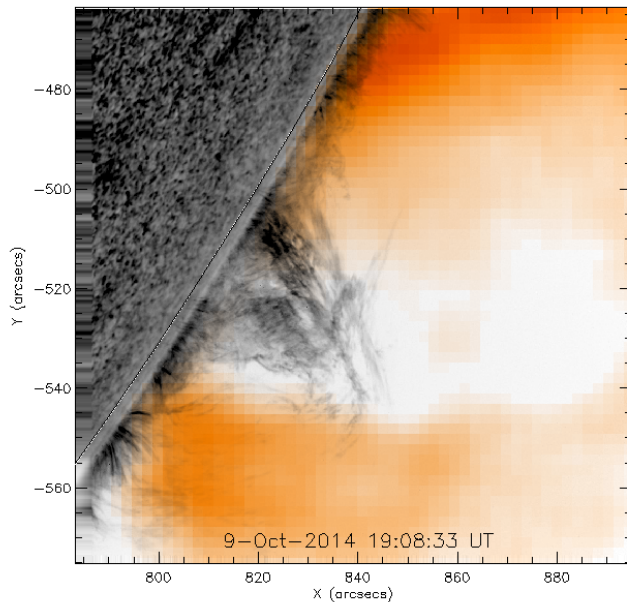
Hinode EIS Raster Scan



18:16-19:21 UT

# During Eruption

Hinode XRT & SOT

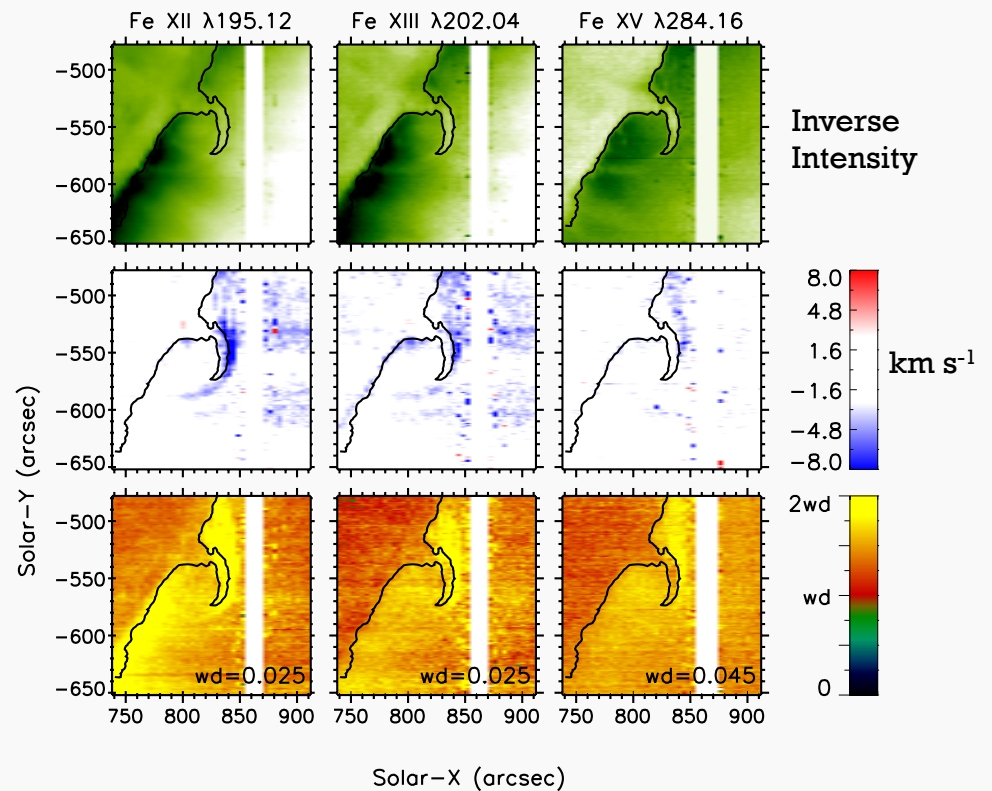


Orange: XRT Thin-Be (1-10 MK)

Grayscale: Ca II H-line

Cavity is at least 5 times dimmer than surroundings

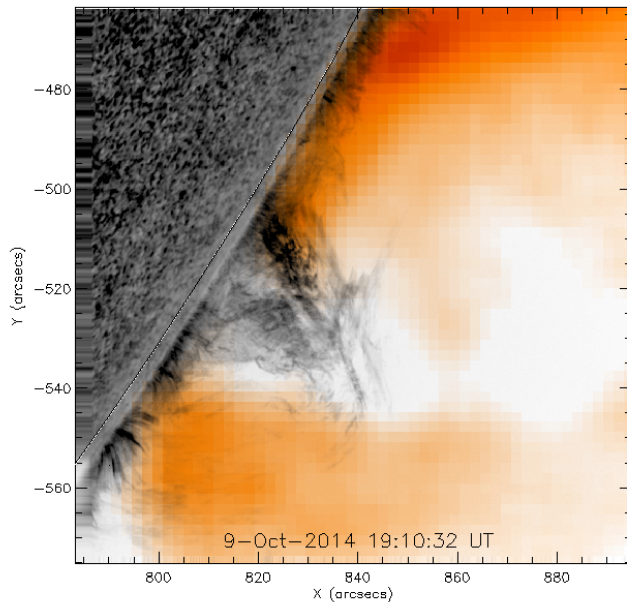
Hinode EIS Raster Scan



18:16-19:21 UT

# During Eruption

Hinode XRT & SOT

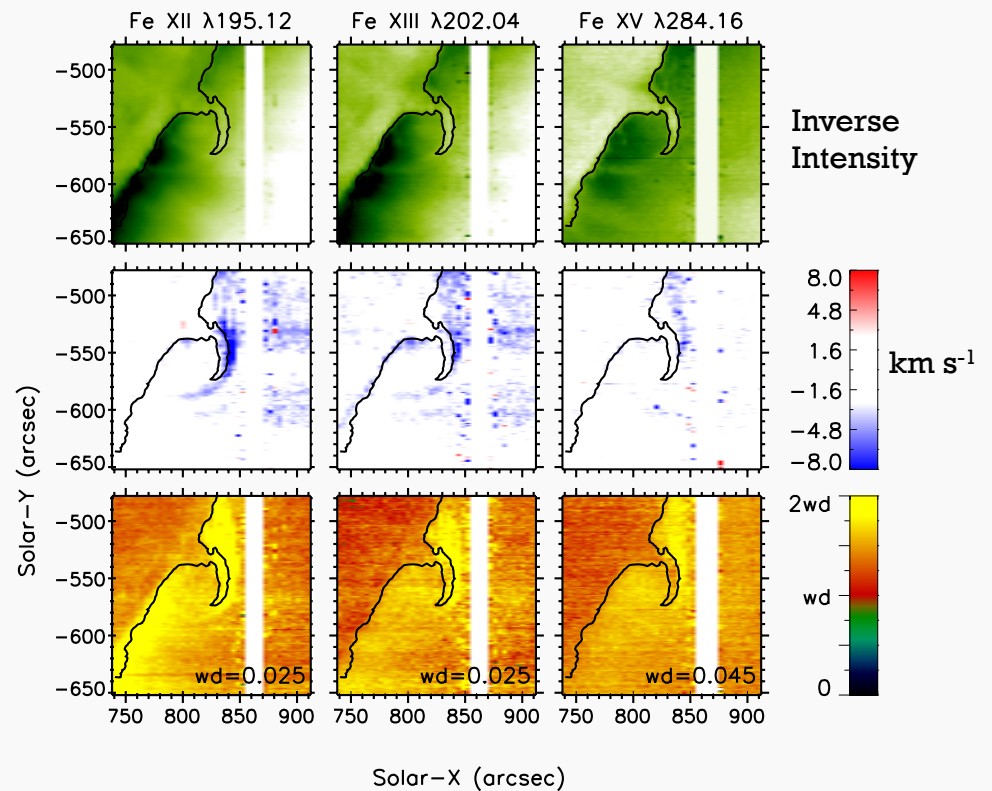


Orange: XRT Thin-Be (1-10 MK)

Grayscale: Ca II H-line

Cavity is at least 5 times dimmer than surroundings

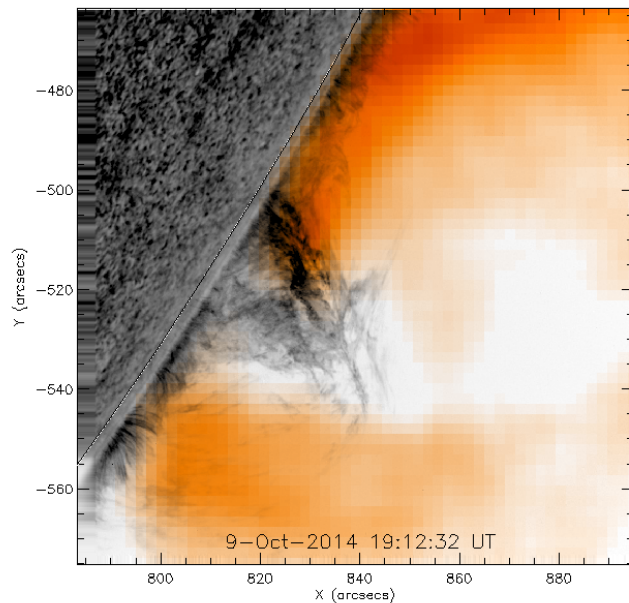
Hinode EIS Raster Scan



18:16-19:21UT

# During Eruption

Hinode XRT & SOT

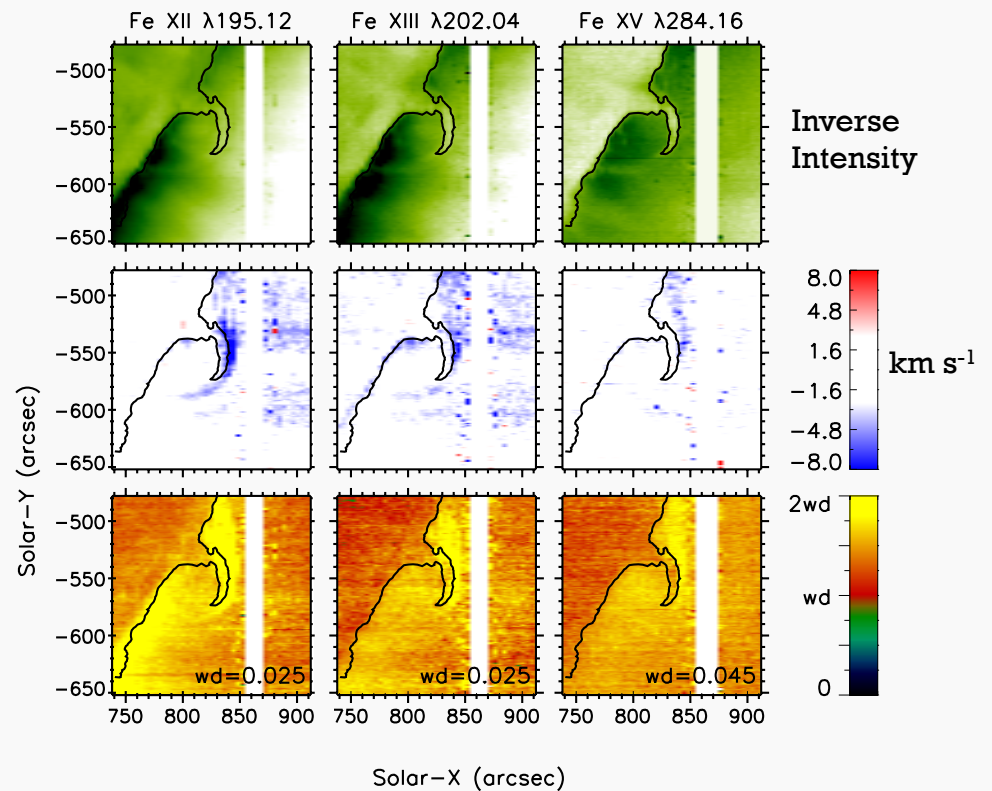


Orange: XRT Thin-Be (1-10 MK)

Grayscale: Ca II H-line

Cavity is at least 5 times dimmer than surroundings

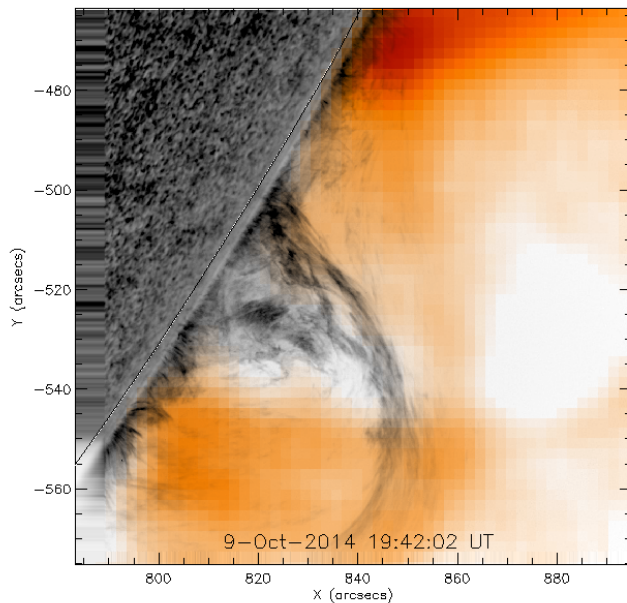
Hinode EIS Raster Scan



18:16-19:21UT

# During Eruption

Hinode XRT & SOT

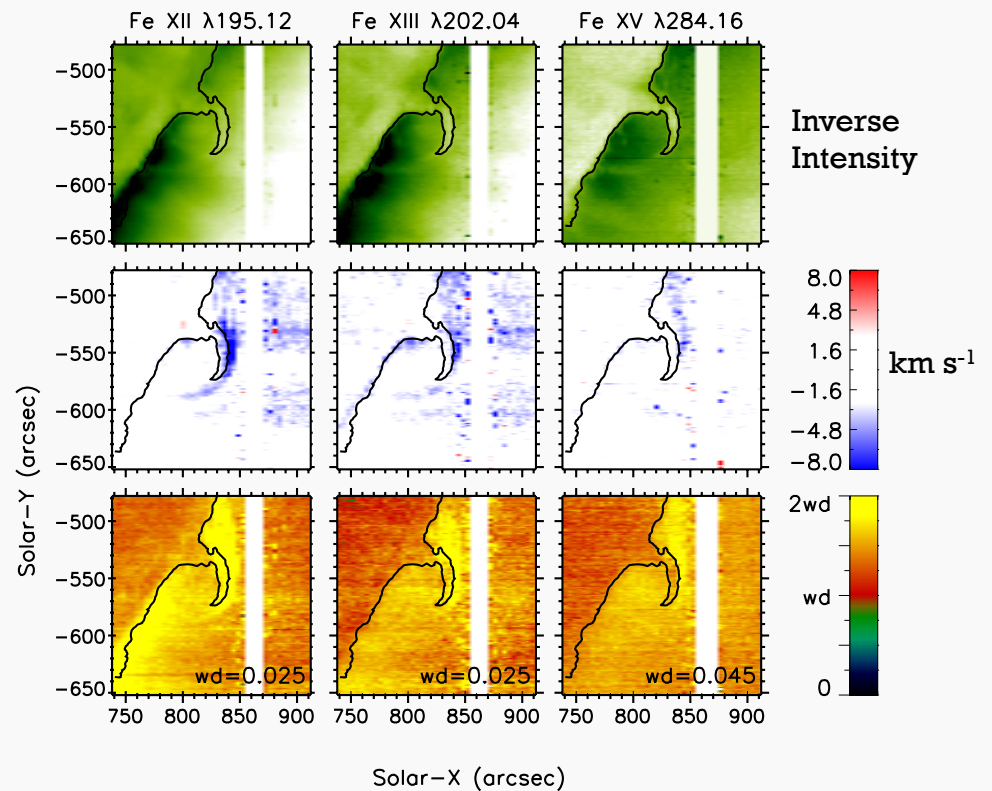


Orange: XRT Thin-Be (1-10 MK)

Grayscale: Ca II H-line

Cavity is at least 5 times dimmer than surroundings

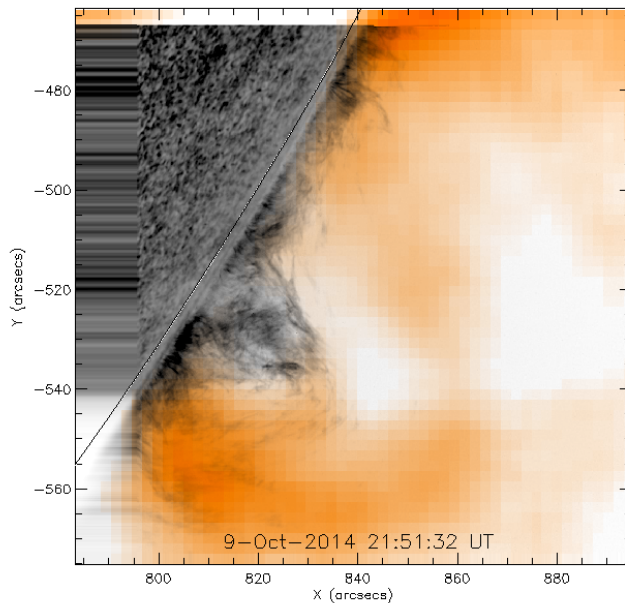
Hinode EIS Raster Scan



18:16-19:21 UT

# After Eruption

Hinode XRT & SOT

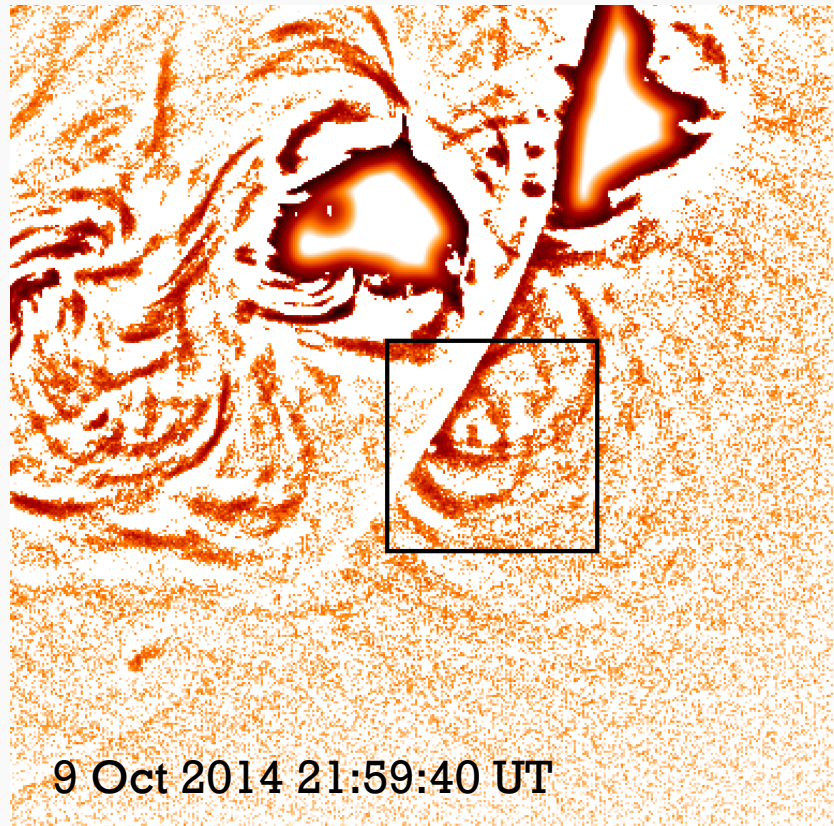


Orange: XRT Thin-Be (1-10 MK)

Grayscale: Ca II H-line

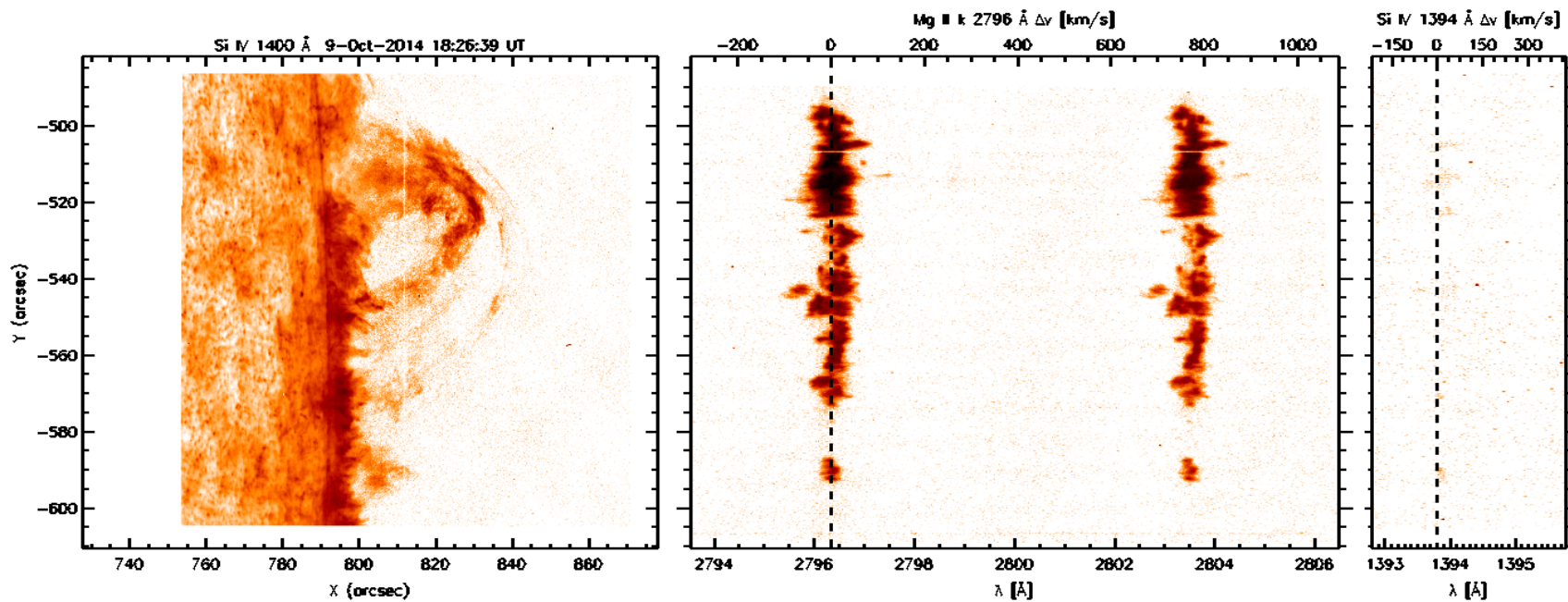
Cavity is at least 5 times dimmer than surroundings

XRT Thin-Be Wavelet



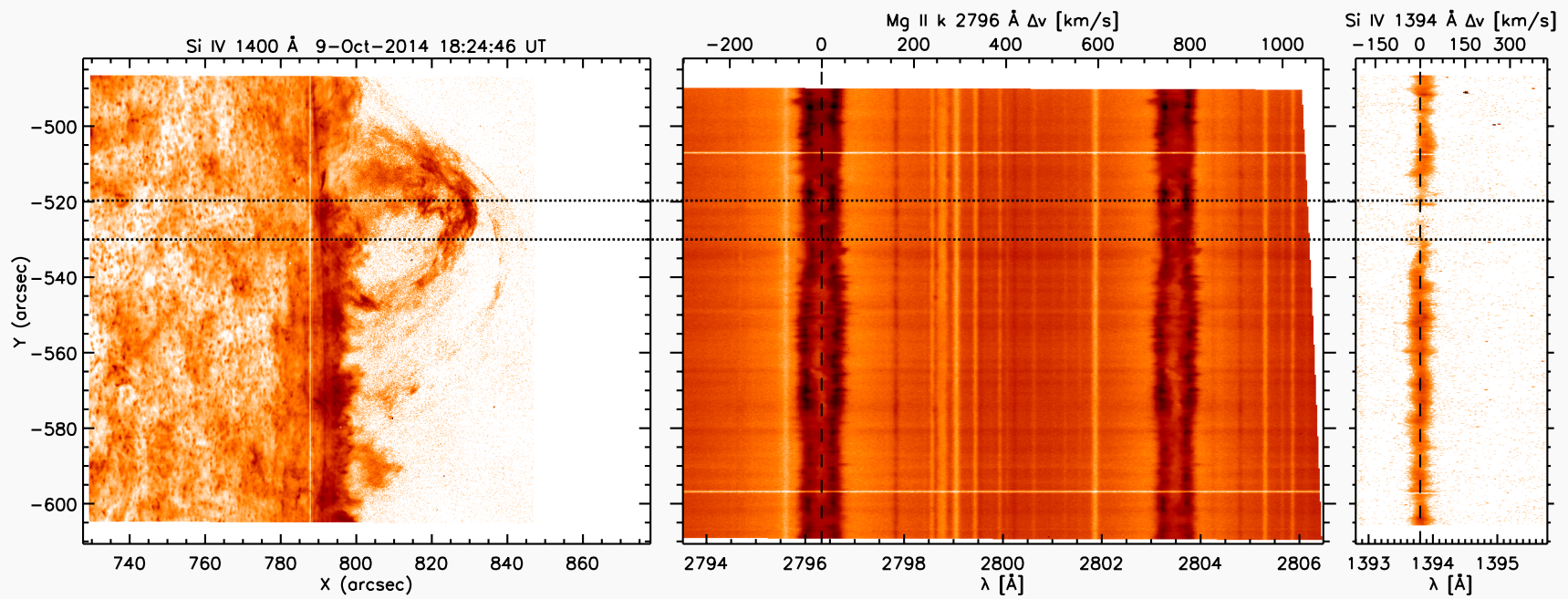
*à trous* wavelet transform with a cubic spline  
Stark & Murtagh (2002)

# IRIS Observations



Hinode XRT & SOT movie of eruption available with online publication.

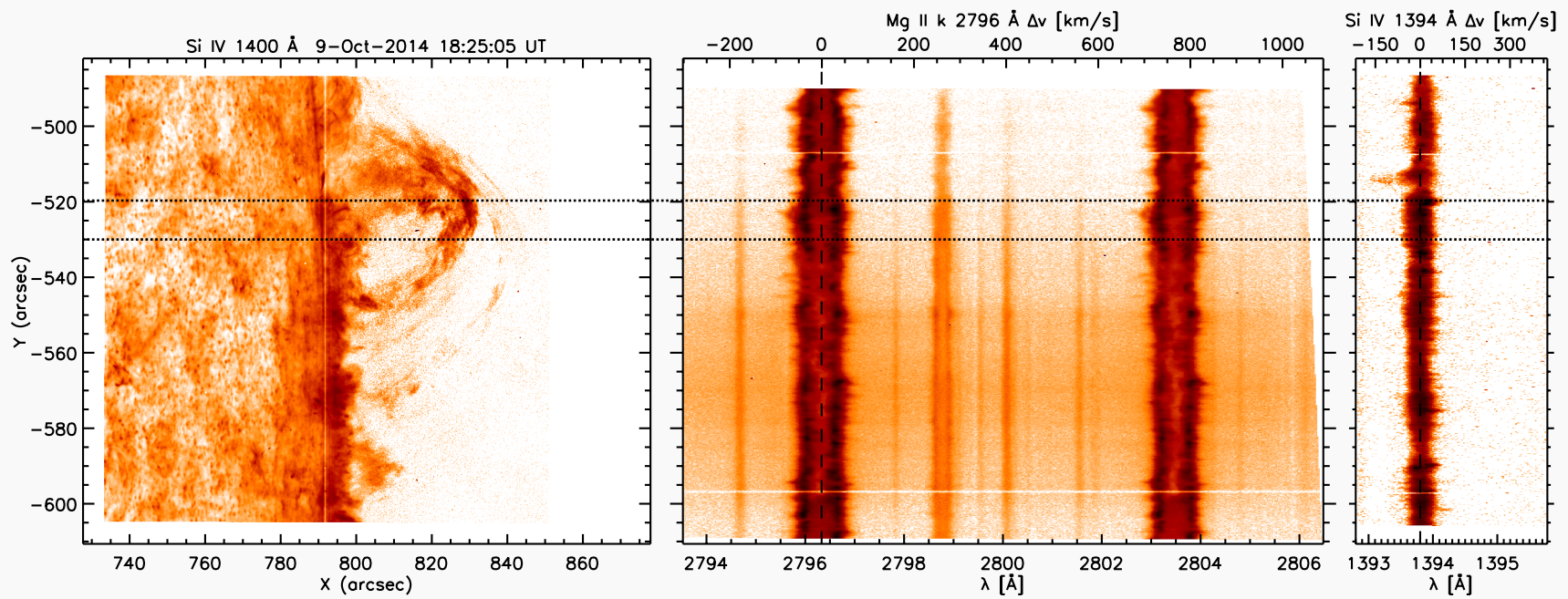
# IRIS Spectra



Raster position: 0  
On Disk

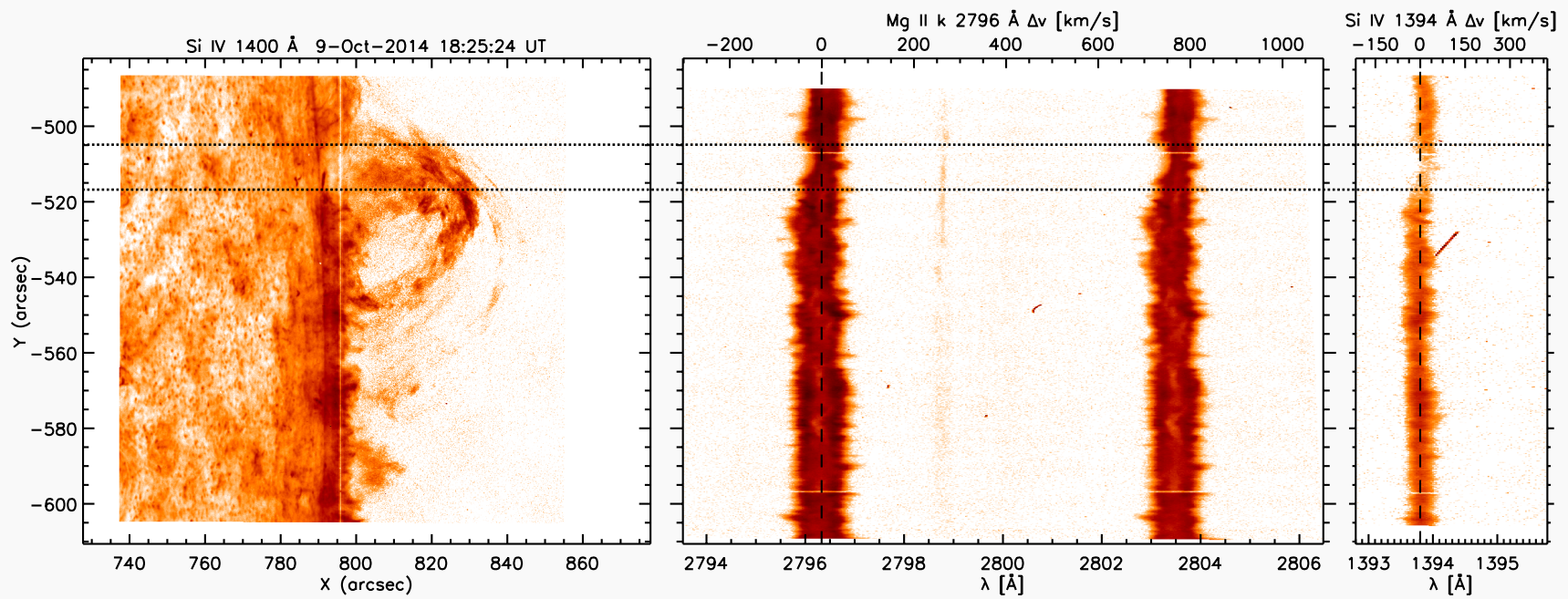


# IRIS Spectra



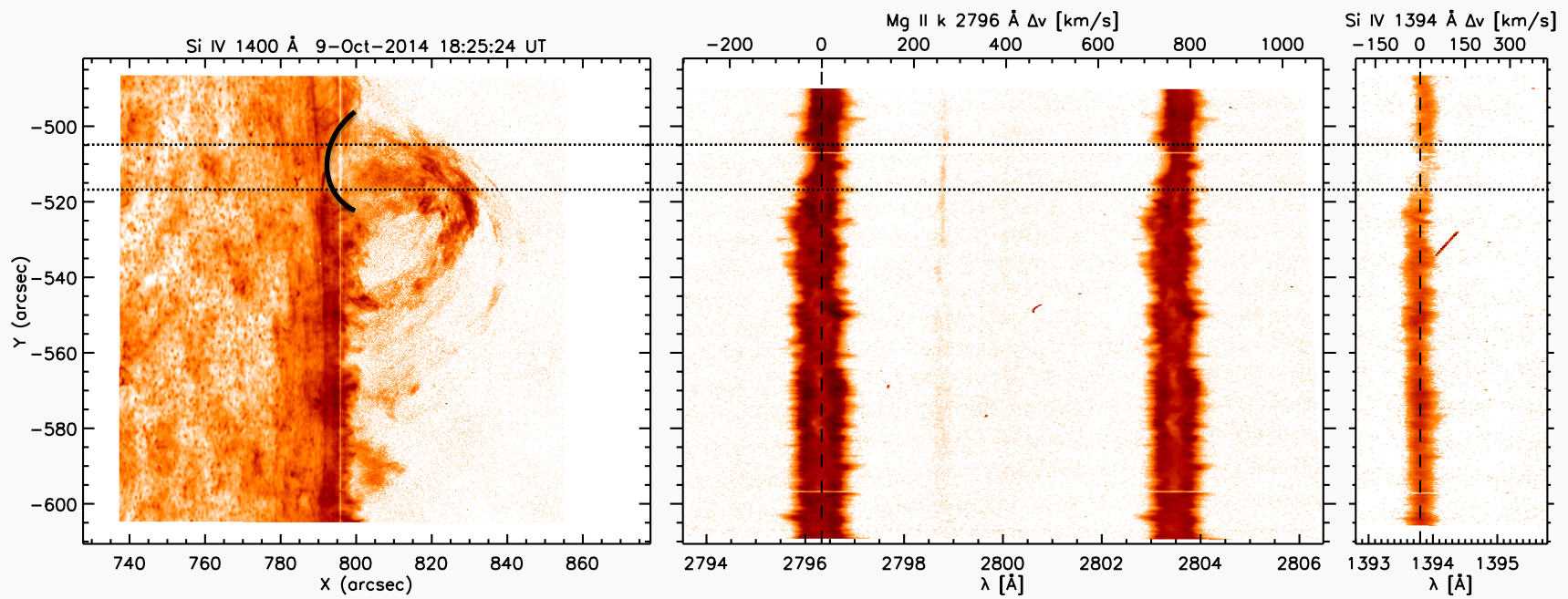
Raster position: 2  
Limb

# IRIS Spectra



Raster position: 4  
Spicule Region

# IRIS Spectra



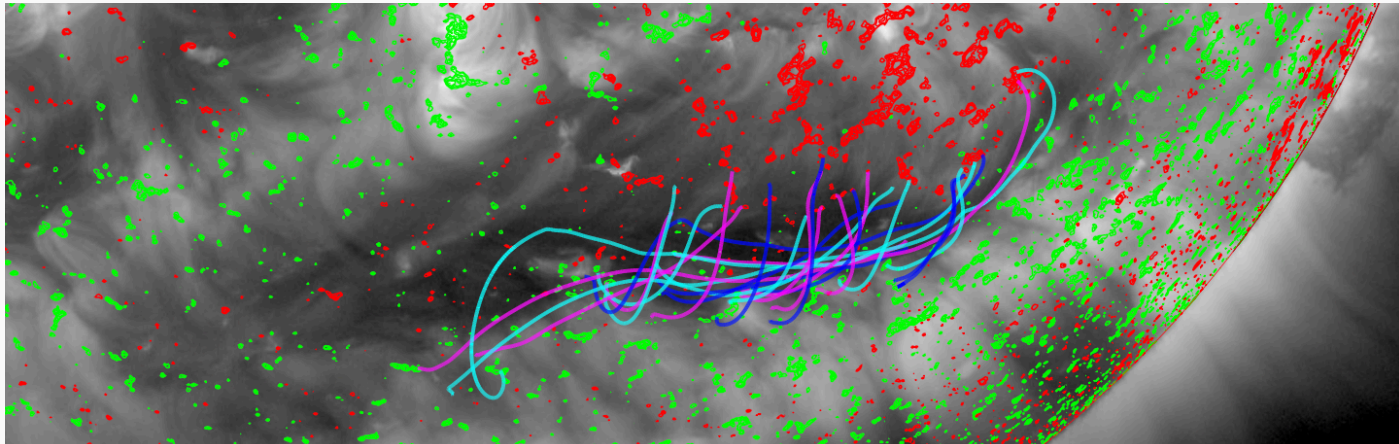
Raster position: 4  
Spicule Region

# Summary of Observations

- Eruption reveals a coronal cavity surrounding the prominence
- Evidence of heating within the cavity
- Velocities show material moving toward observer and over the coronal cavity
- Reduced spicule activity near prominence

# 3D Magnetic Flux Rope Model

SDO/HMI LOS magnetic map & SDO/AIA 193 Å



Red: + radial field  
Green: - radial field

Coronal Modeling System (CMS)  
van Ballegoijen (2004)  
Su et al., 2009, 2011;  
Su & van Ballegoijen (2012)

- Overlying arcade
- Flux rope
  - Lower boundary condition defined by magnetogram
  - Initial axial & poloidal fluxes

# Model Development

- Vary initial fluxes
  - **Magnitude of the fluxes**
  - **Left/right handed poloidal flux**
  - Constant vs. variable axial flux along PIL
- Vary length of flux rope

## Axial Flux

- Size of the flux rope

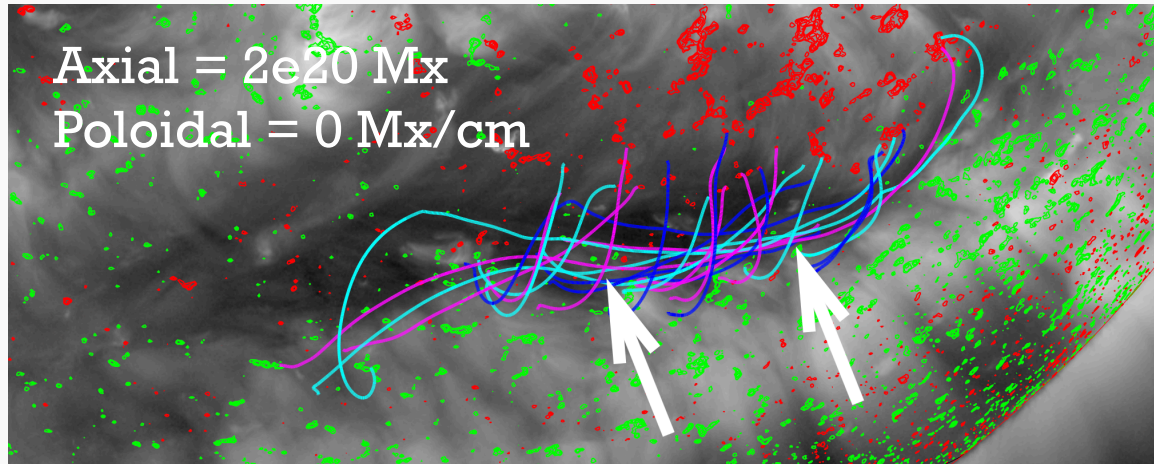
## Poloidal Flux

- Twist of flux rope

## Flux Rope Chirality

- Dextral/Sinstral

## Weakly Twisted -> Dextral Flux rope



## Highly Twisted

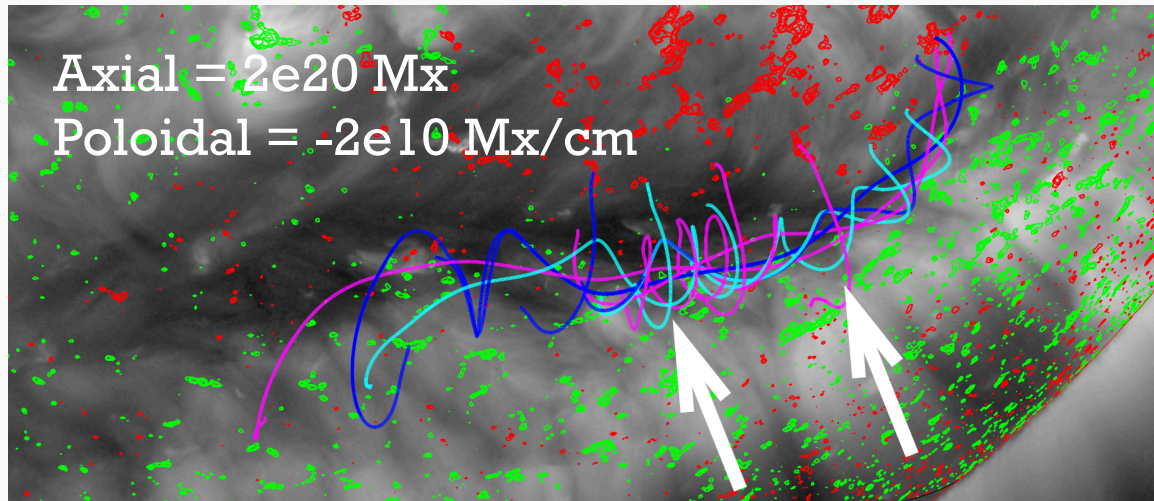


Fig. 9

Bipoles within the PIL exhibit a bald-patch topology

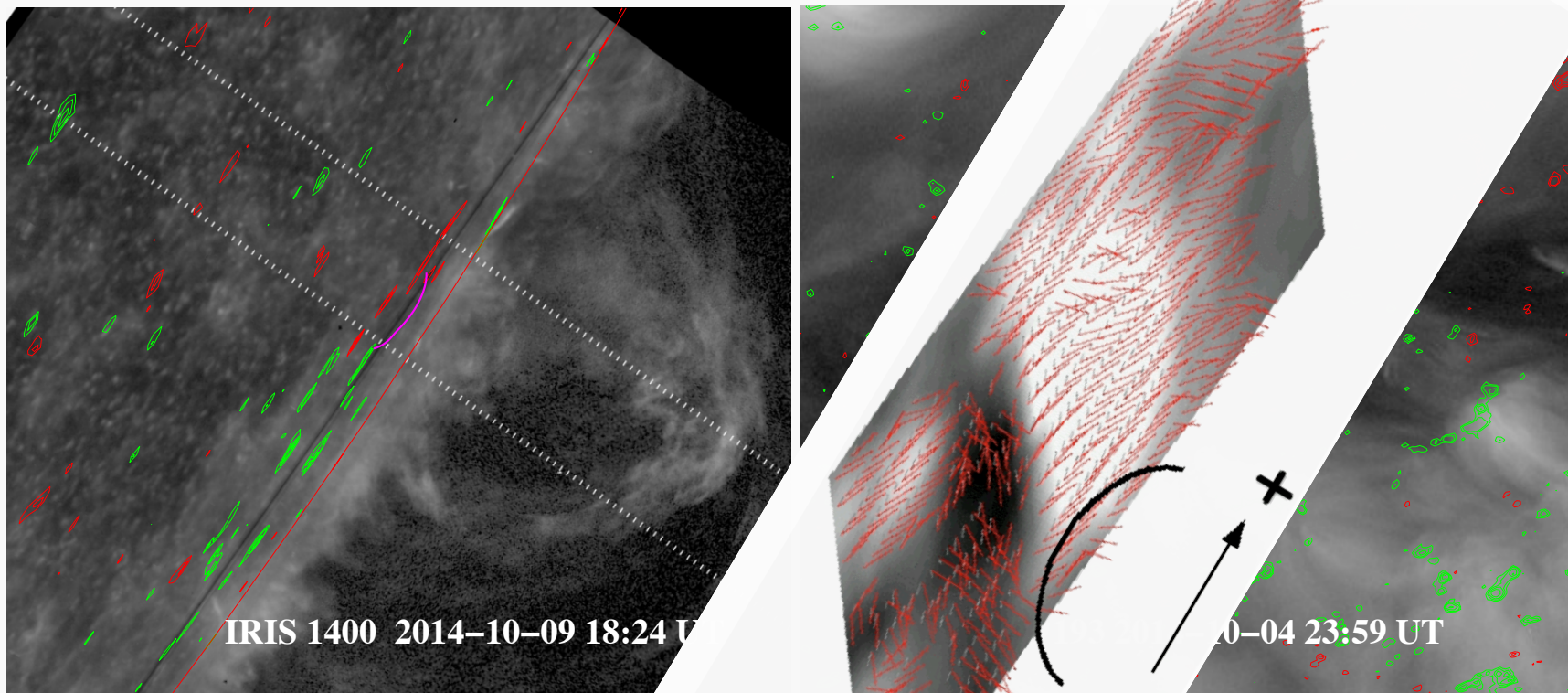


Fig. 11.

Fig. 14. Lopez Ariste, A., et al. *Astron. Astrophys.*, (2006) 456



# Model Summary

A Magnetic Model of a weakly twisted flux rope can explain

- Path of eruption & LOS velocities
- Reduced spicule activity near prominence & PIL (BP topology)
- Heating within cavity
  - Current sheet formed within BPSS
    - Fan & Gibson, 2006

## Coronal Multi-Channel Polarimeter (CoMP)

QuickInvert data Fe XIII 1074.7 nm

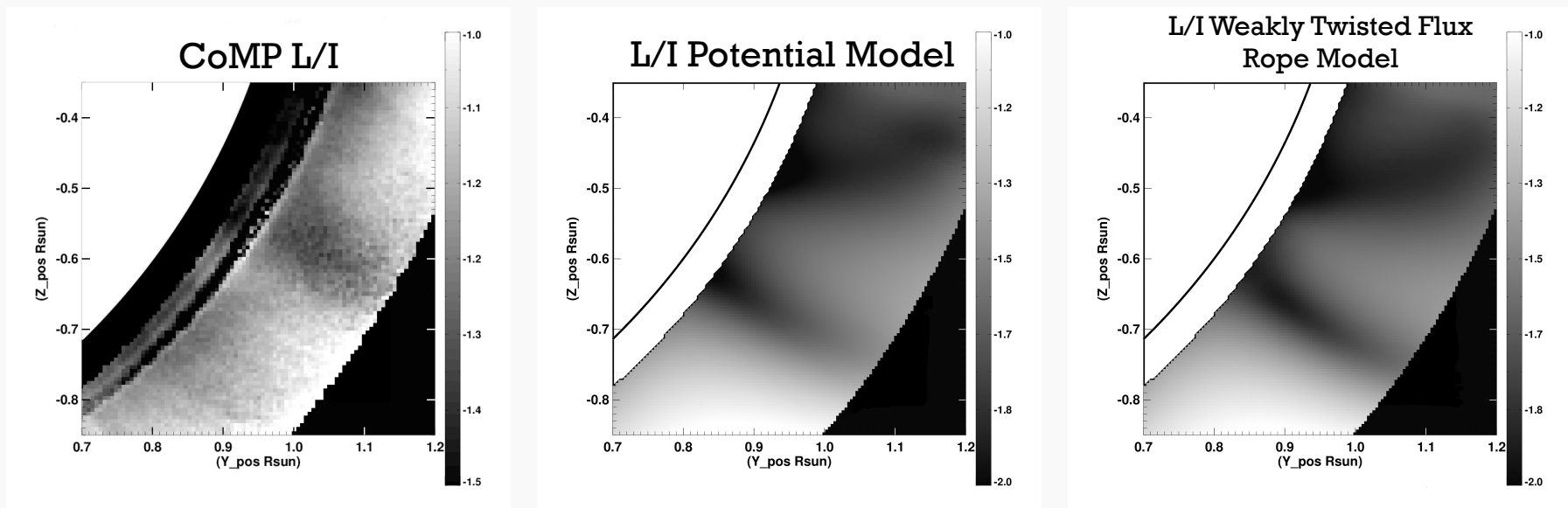
- Stokes I, Q, U, & V
- L = linear polarization
- Magnetic field azimuth

Utilized the FORWARD toolset  
(Gibson et al. 2016)



$$L \propto \sin^2 \Theta$$

$\Theta$  is the angle between the LOS and the local magnetic field vector.



(Log scale)

Bright areas: POS ( $\Theta=0^\circ, 180^\circ$ )

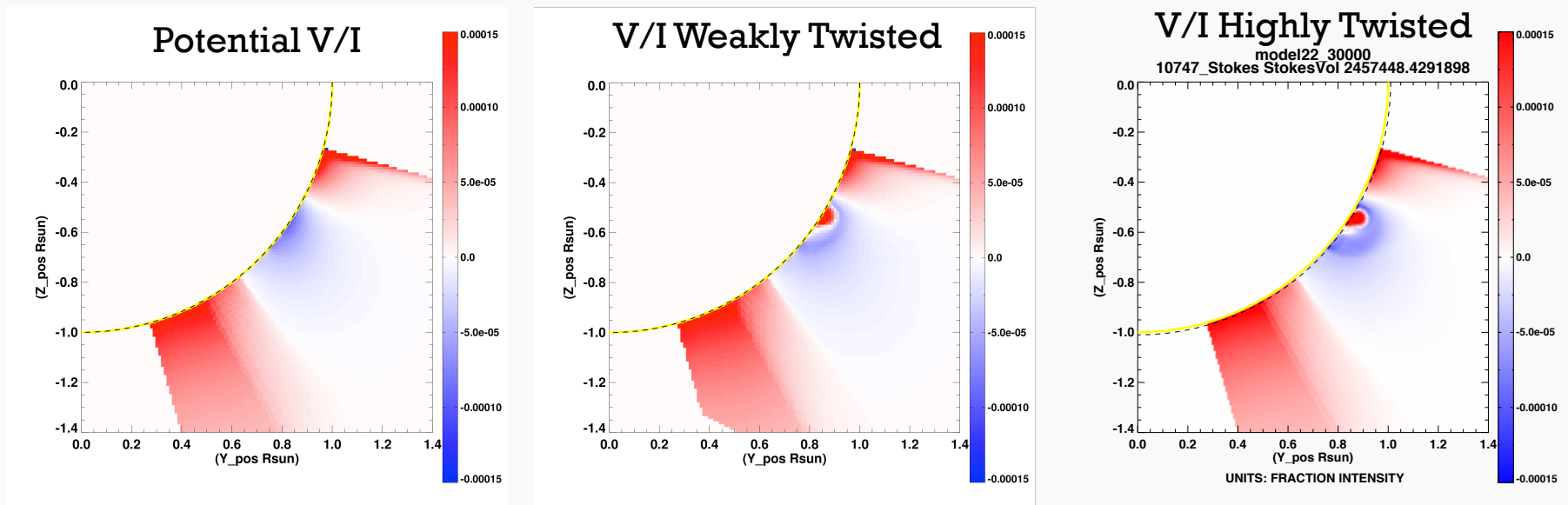
Dark areas: LOS ( $\Theta=90^\circ$ )

\*dark linear features: Van Vleck angle ( $54.7^\circ$ )

Rachmeler, Casini, & Gibson, 2012

$$V \propto -\cos \Theta$$

$\Theta$  is the angle between the LOS and the local magnetic field vector.

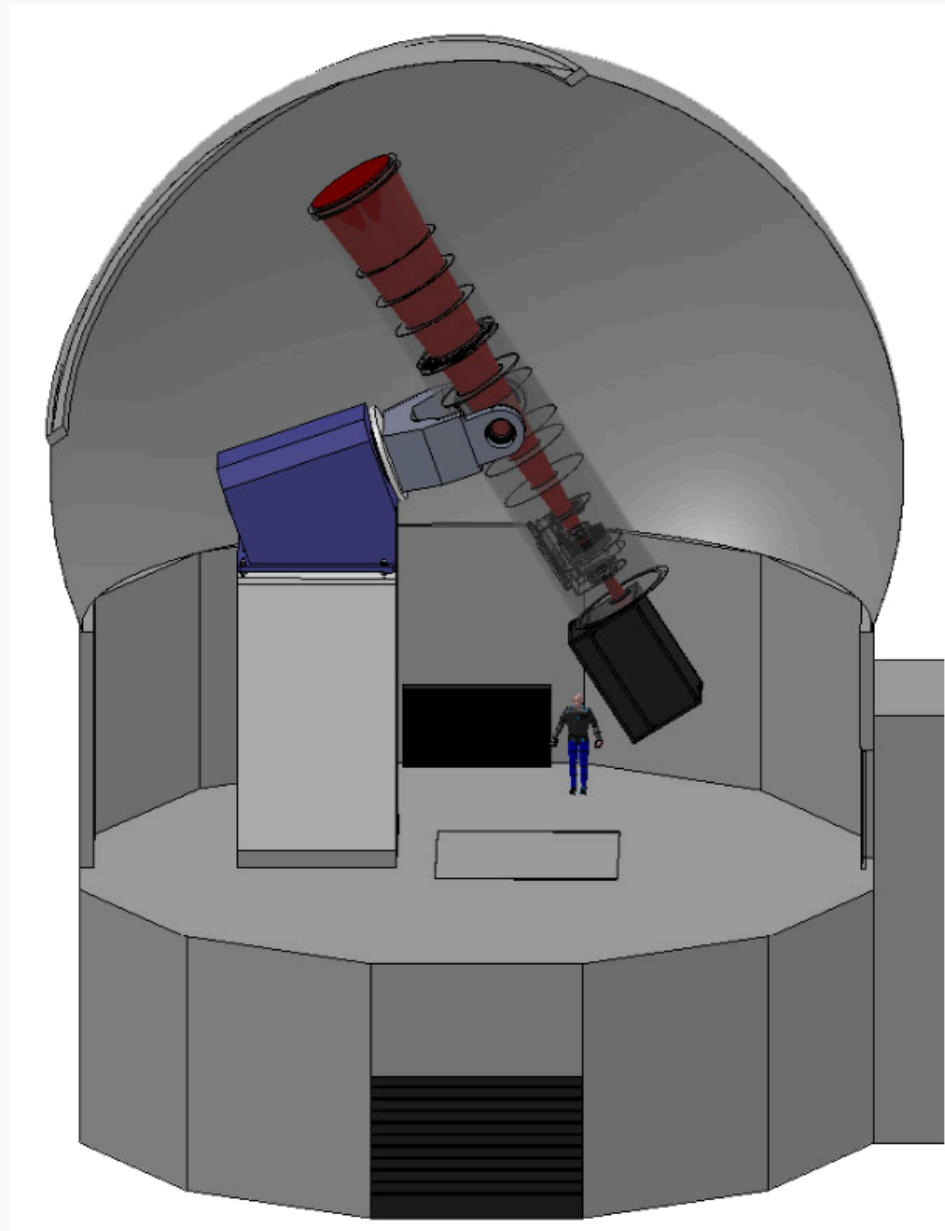


Blue:  
Toward the observer

## **COronal Solar Magnetism Observatory (COSMO)**

- Chromospheric & Prominence Magnetometry (ChroMag)
- Electron scattered K-corona (K-cor)
- Large Coronagraph (LC)

NCAR/UCAR & HAO



<https://www2.hao.ucar.edu/cosmo/large-coronagraph>

# Conclusions

- Observations show evidence of
  - Heating within cavity.
  - Blue-shifted coronal & chromospheric velocities.
  - Reduced spicule activity around PIL.
    - > Bald-patch topology
- The best magnetic model
  - Weakly twisted dextral flux rope
- $L/I$  cannot constrain flux rope, need  $V/I$