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The Magnetic Structure of Solar Prominence Cavities: New observational signature revealed by coronal magnetometry

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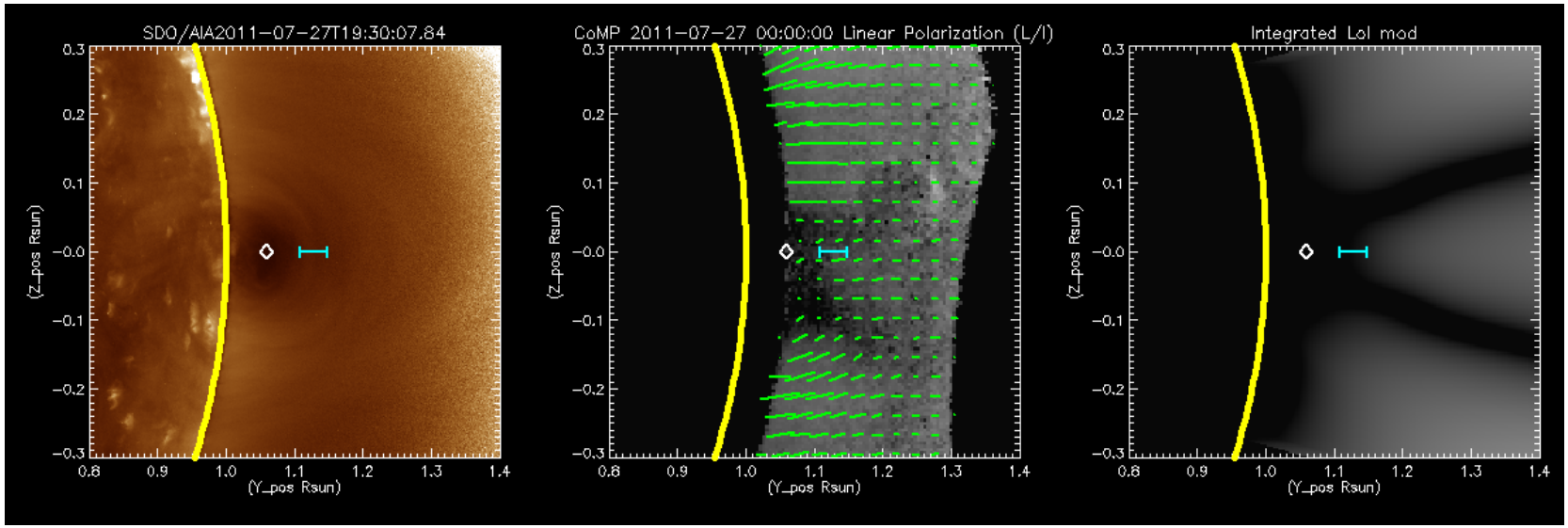
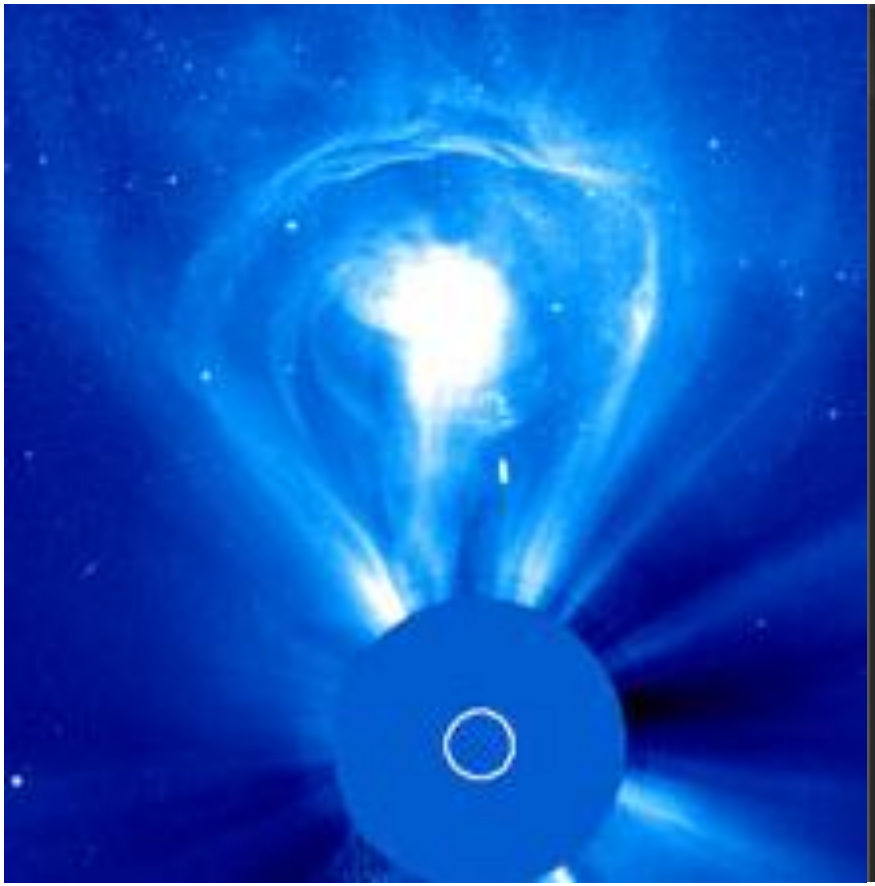
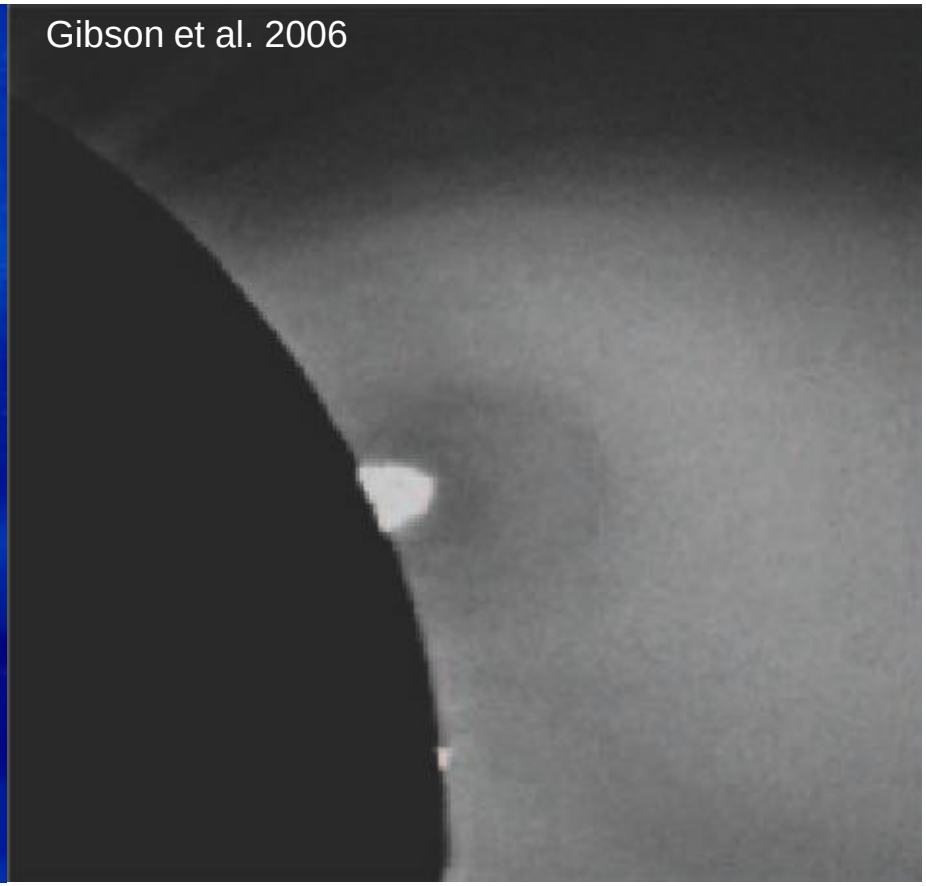
Christian Bethge, Blake Forland, Laurel Rachmeler



Coronal cavities



Illing & Hundhausen 1986



Vaiana et al. 1973
Tandberg-Hanssen 1974

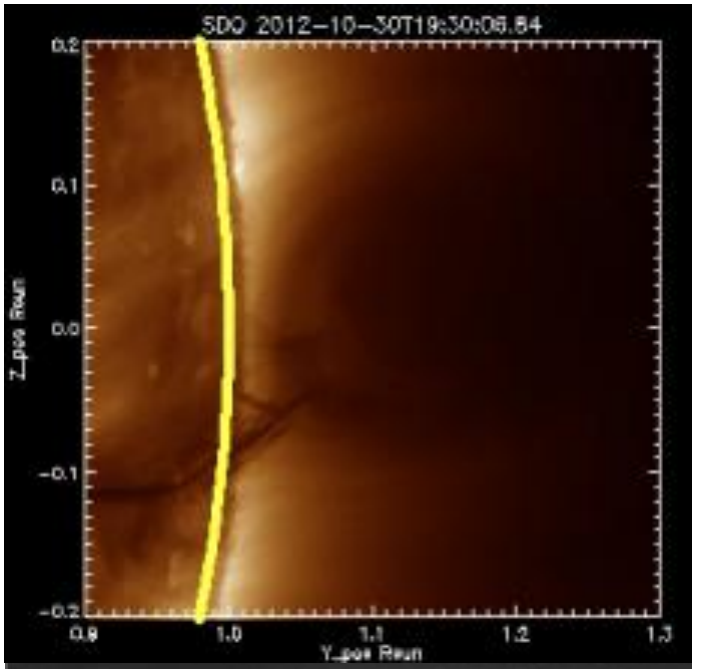
Coronal cavities

Coronal cavities are elliptical regions of rarefied density (Fuller & Gibson 2009; Gibson et al. 2010)

Typically exist in a low corona (< 1.6 $R_{\odot}$)

Observed in:

- WL (Gibson et al. 2006),
- radio (Marque et al. 2002; Marque 2004),
- SXR and EUV (Hudson et al. 1999; Hudson & Schwenn 2000; Sterling & Moore 2004; Heinzel et al. 2008, Berger et al. 2012; Reeves et al. 2012)



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Coronal cavities

- Cavities observed in the polar crown regions surround quiescent prominences (Tandberg-Hanssen 1995). They are long-lived, their structure changes slowly with time.

- Eruption of a previously quiescent white-light cavity as a CME (Maričić et al., 2004; Gibson et al. 2006, Regnier et al. 2011).

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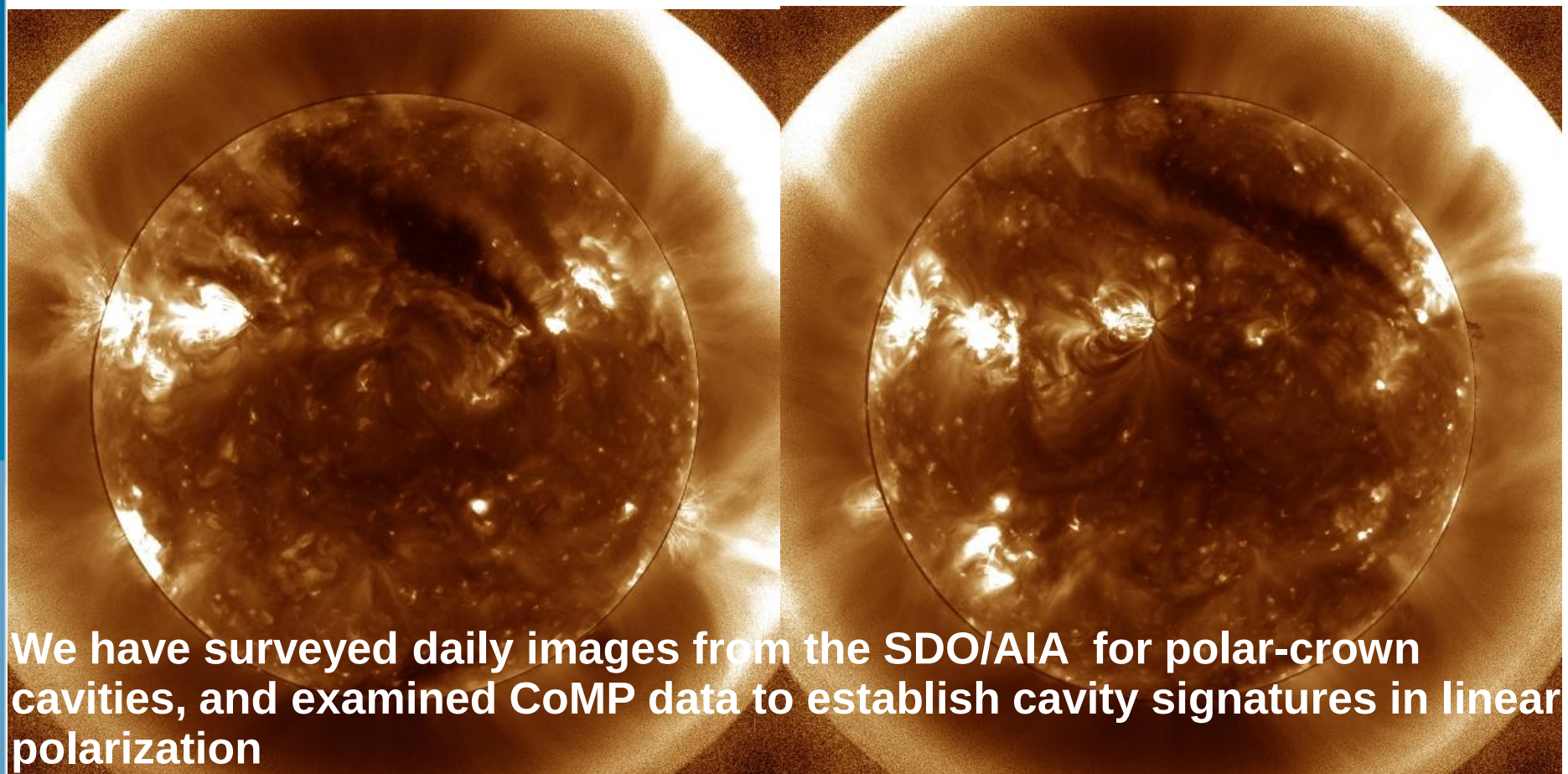
Coronal cavities

They have been modeled as magnetic flux ropes (Low & Hundhausen 1995) .

Understanding the magnetic structure of those cavities is important for understanding pre-CME configurations.



We have surveyed daily images from the SDO/AIA for polar-crown cavities, and examined CoMP data to establish cavity signatures in linear polarization

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Coronal Multi-channel Polarimeter (CoMP)

Tomczyk, et al. 2008

Information about the magnetic field, plasma density and motion.

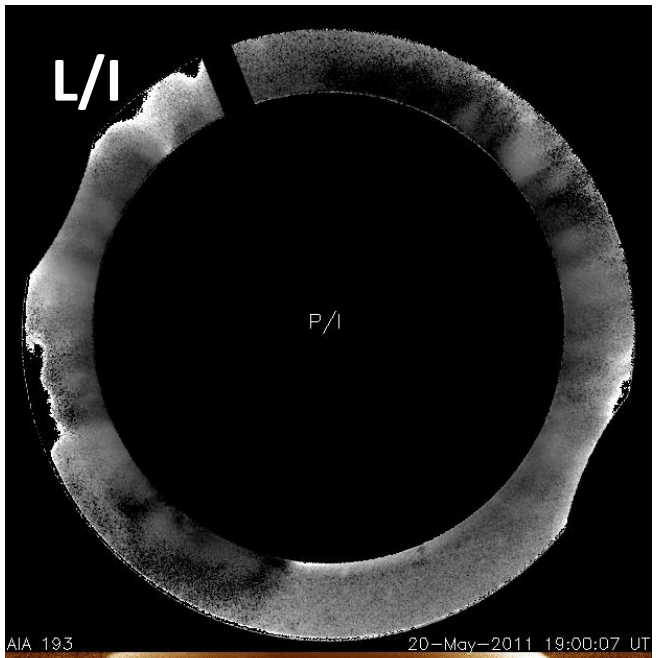
- FOV ~1.04 to 1.4 $R_{\odot}$
- Location: Mauna Loa Solar Observatory - daily observations since October 2010
- CoMP records the intensity and the linear and circular polarization (Stokes I,Q,U,V) of the forbidden lines of Fe XIII at 1074.7 nm and also at 1079.8 nm.
- CoMP also measures the LOS plasma velocity from Doppler observations in the wings of the line intensity (Stokes I), and the POS density from the ratio of the lines at 1074.7 and 1079.8 nm.

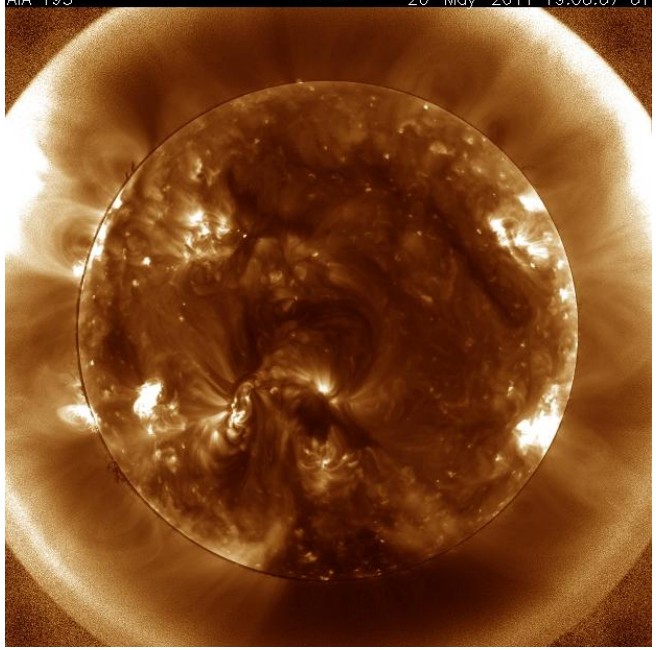
Polarization

- Circular Polarization (V): Line-of-Sight Magnetic Field Strength from Longitudinal Zeeman effect
- Linear Polarization (Q,U) from resonance scattering effect (saturated Hanle effect)
  - Degree of linear polarization: *p*
  - Azimuth of B (Plane-of-Sky Magnetic Field Direction): Φ

$$p = (Q^2 + U^2)^{1/2}/I$$

$$\phi = \tfrac{1}{2}\tan^{-1}(U/Q)$$





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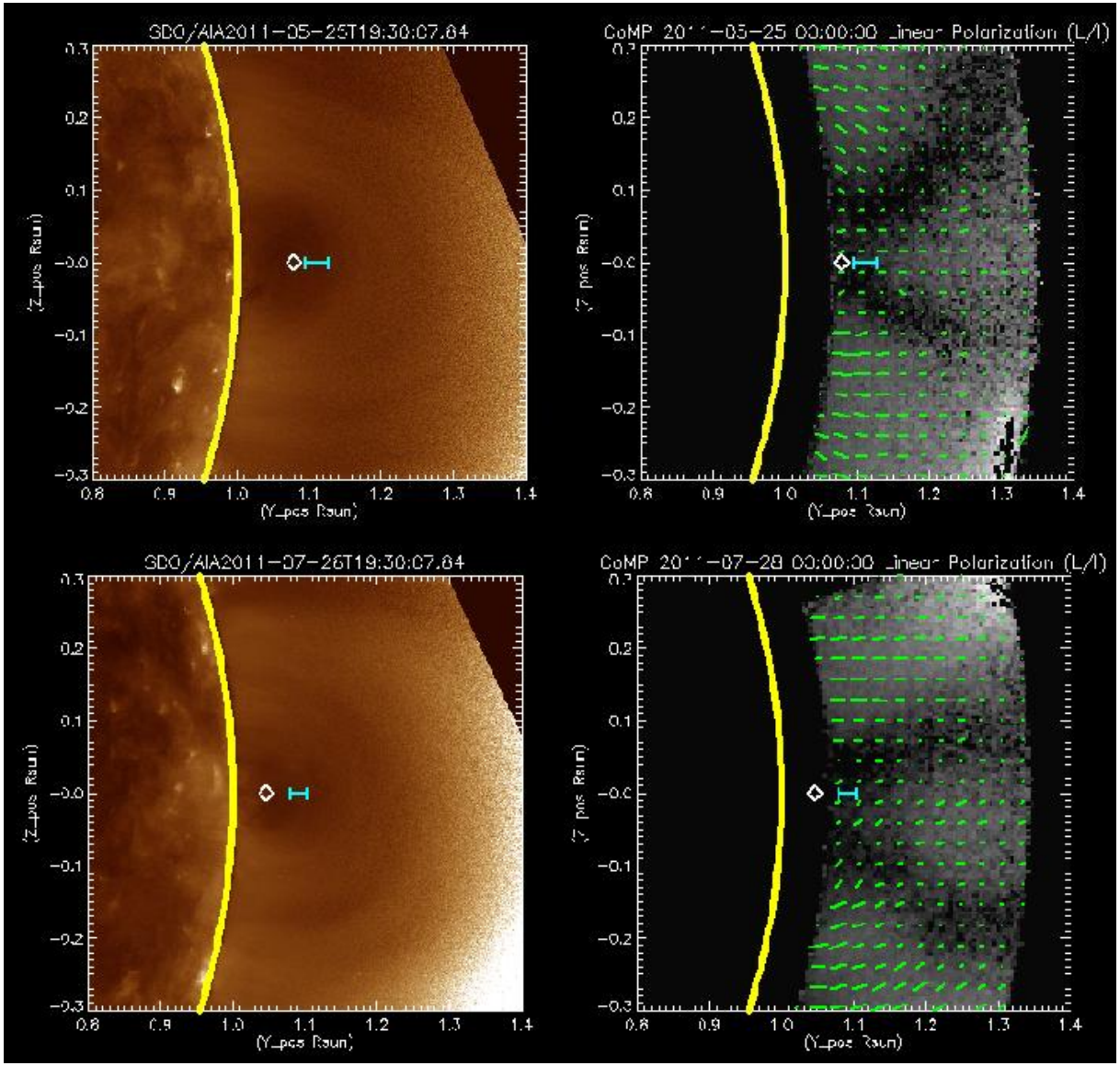
Observations in linear polarization



How can we interpret these observations?

Forward modeling

Gibson et al. 2010

Numerical model	+	Forward calculation of polarization	=	Synthetic CoMP-like data

http://people.hao.ucar.edu/sgibson/FORWARD/

Linear Polarization: B direction in the POS

$L/I \sim \sin^2\Theta$

strong signal: $\Theta=90°$, POS field

L=0 provides the most useful informations

weak signal: $\Theta=0°,180°$
weak signal: Van Vleck inversion at $\vartheta=54°.7$

see also: Rachmeler et al., 2012; Rachmeler et al., 2013

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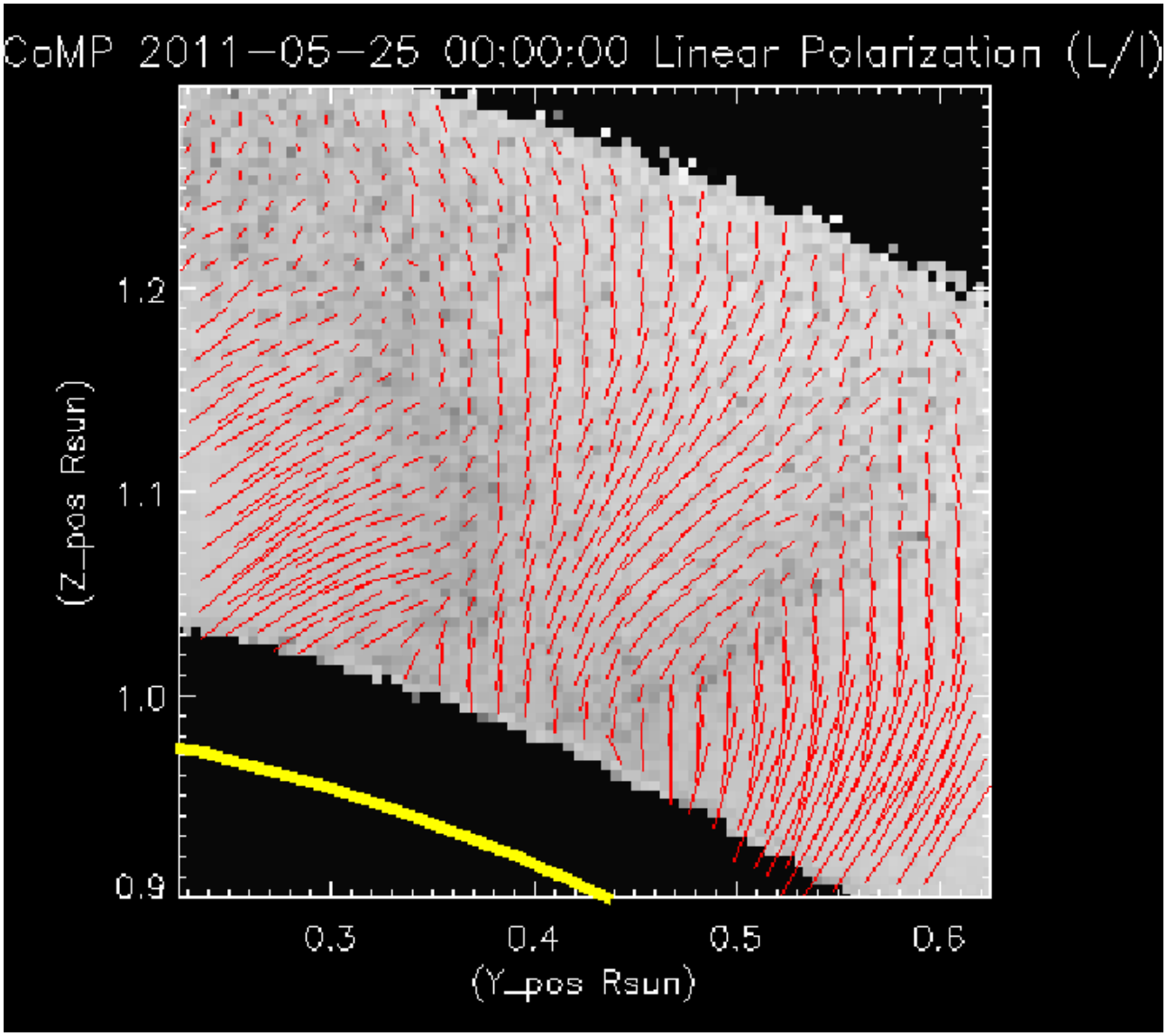
Linear Polarization: B direction in the POS



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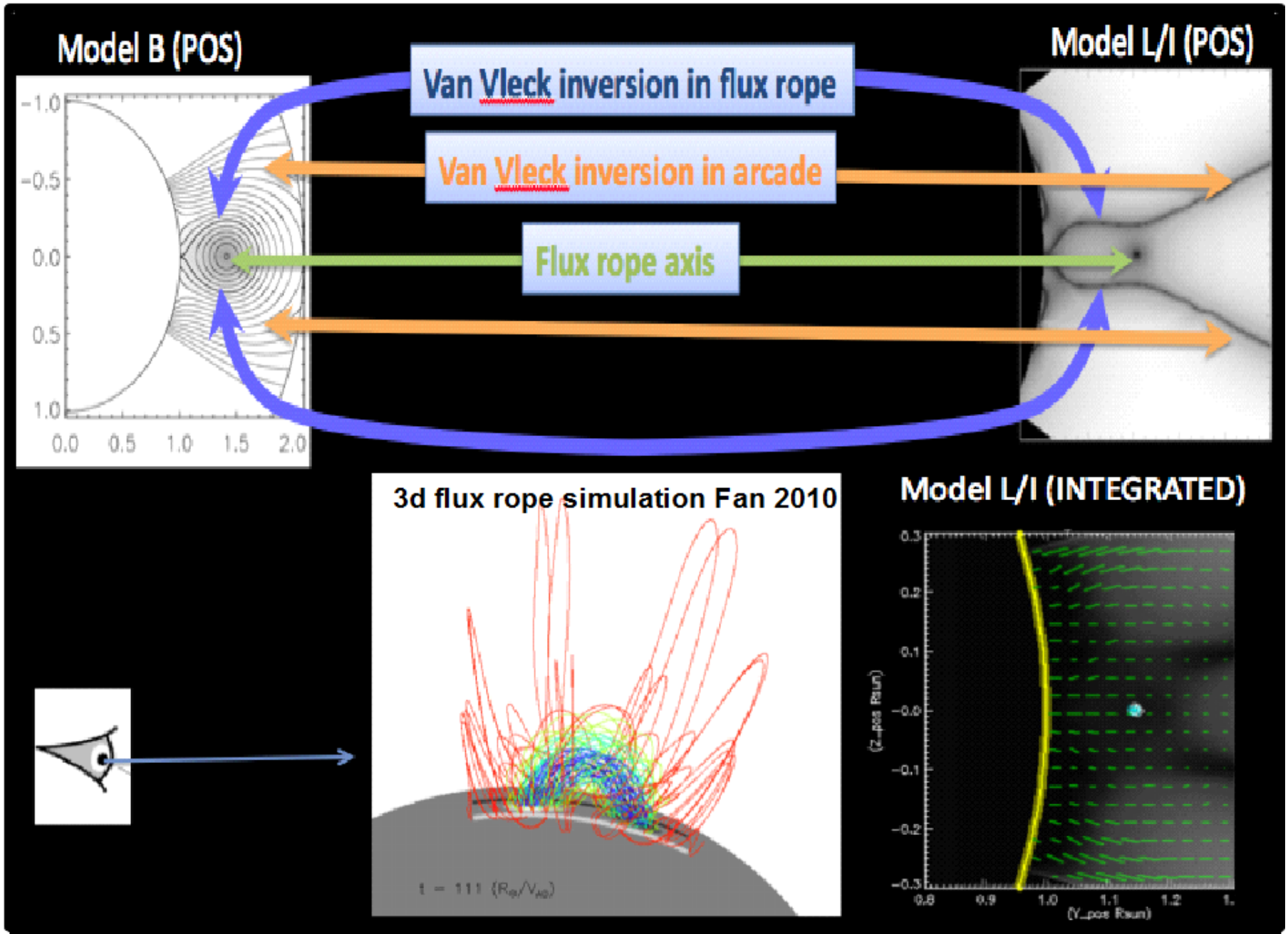
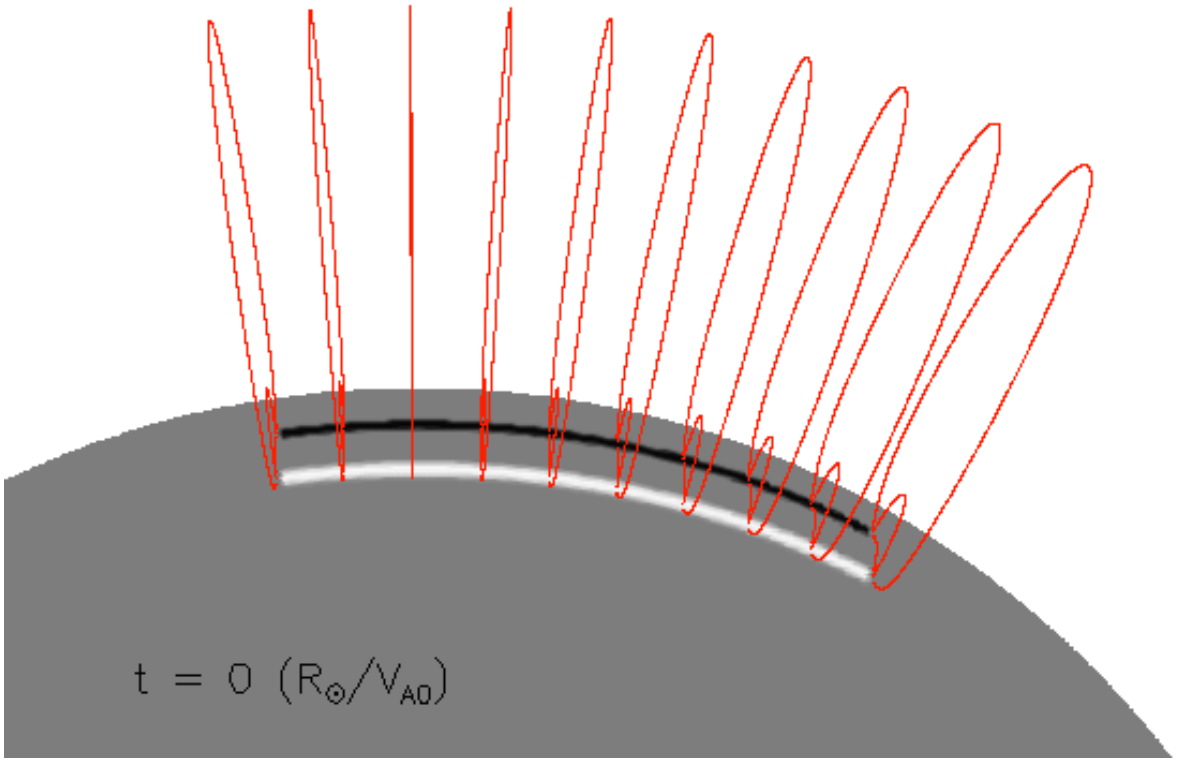
Magnetic flux rope polarization signatures





Fan 2010 - 3d flux rope simulation

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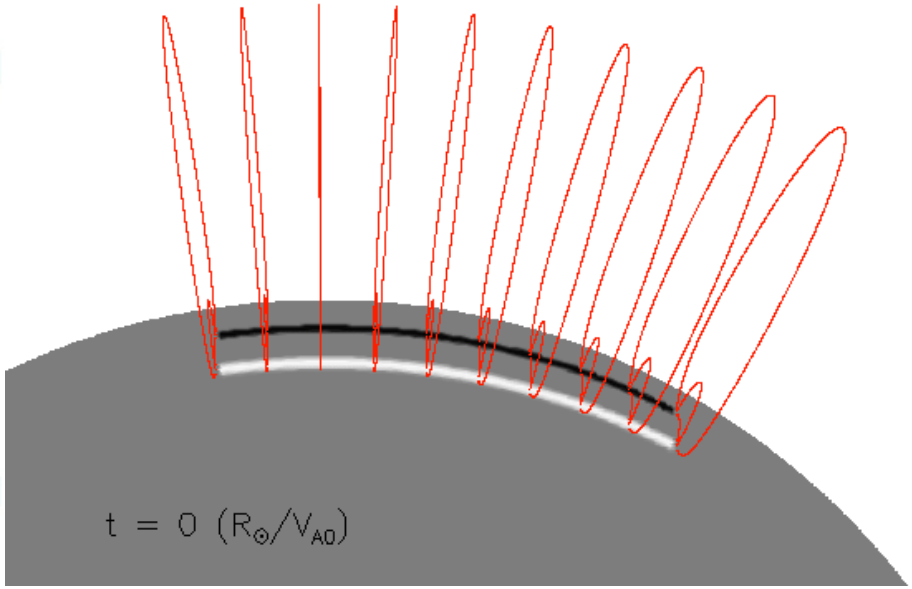
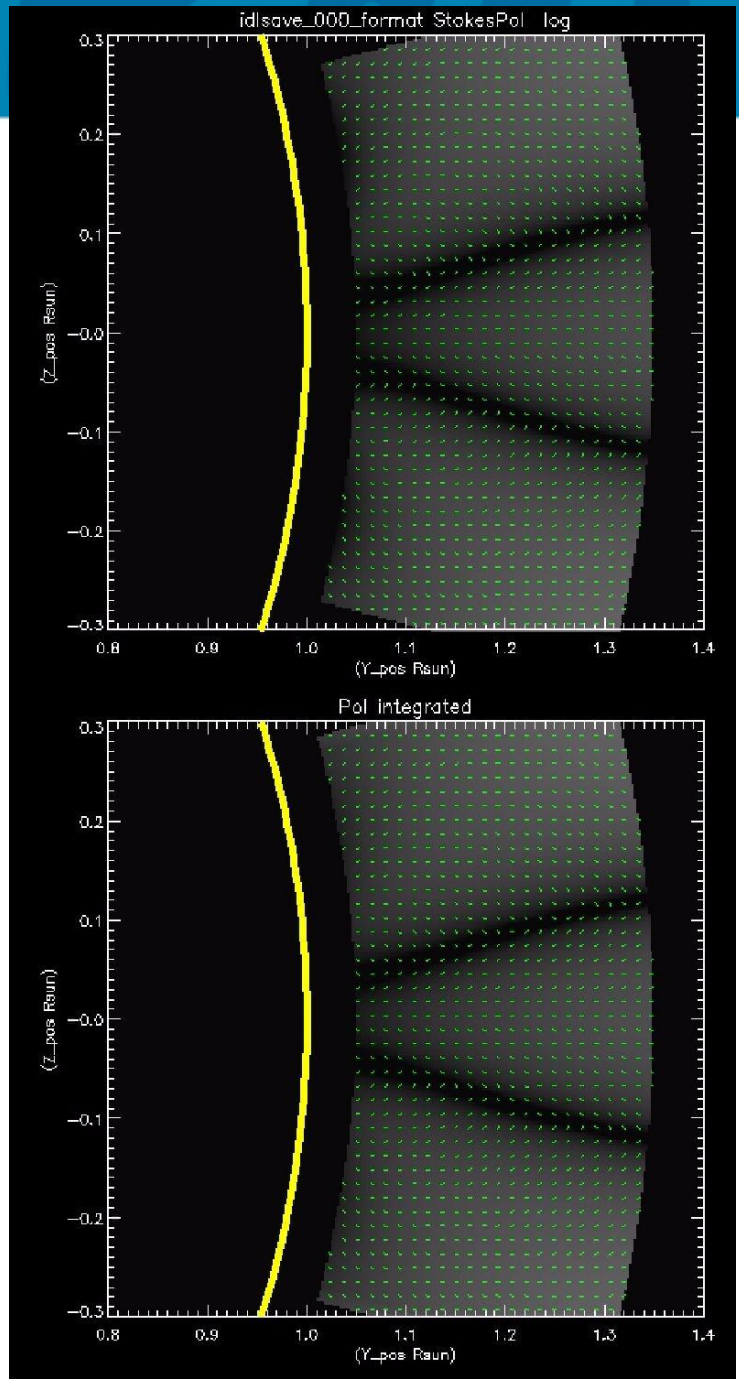


Fan 2010 - 3d flux rope simulation

Model L/I POS



Model L/I LOS

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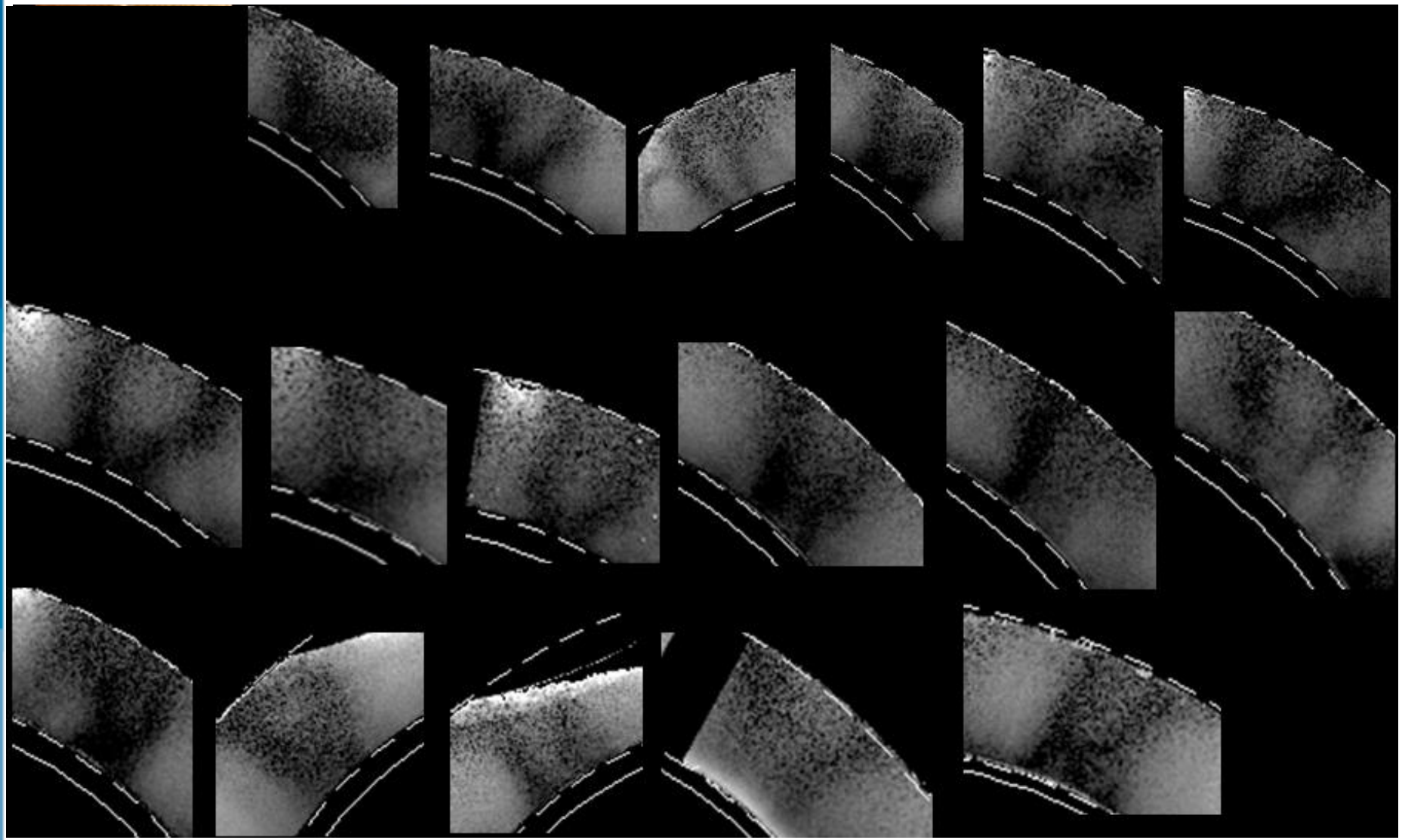
Coronal cavities in linear polarization



May 2011- December 2012 – 59 structures observed during 69 days

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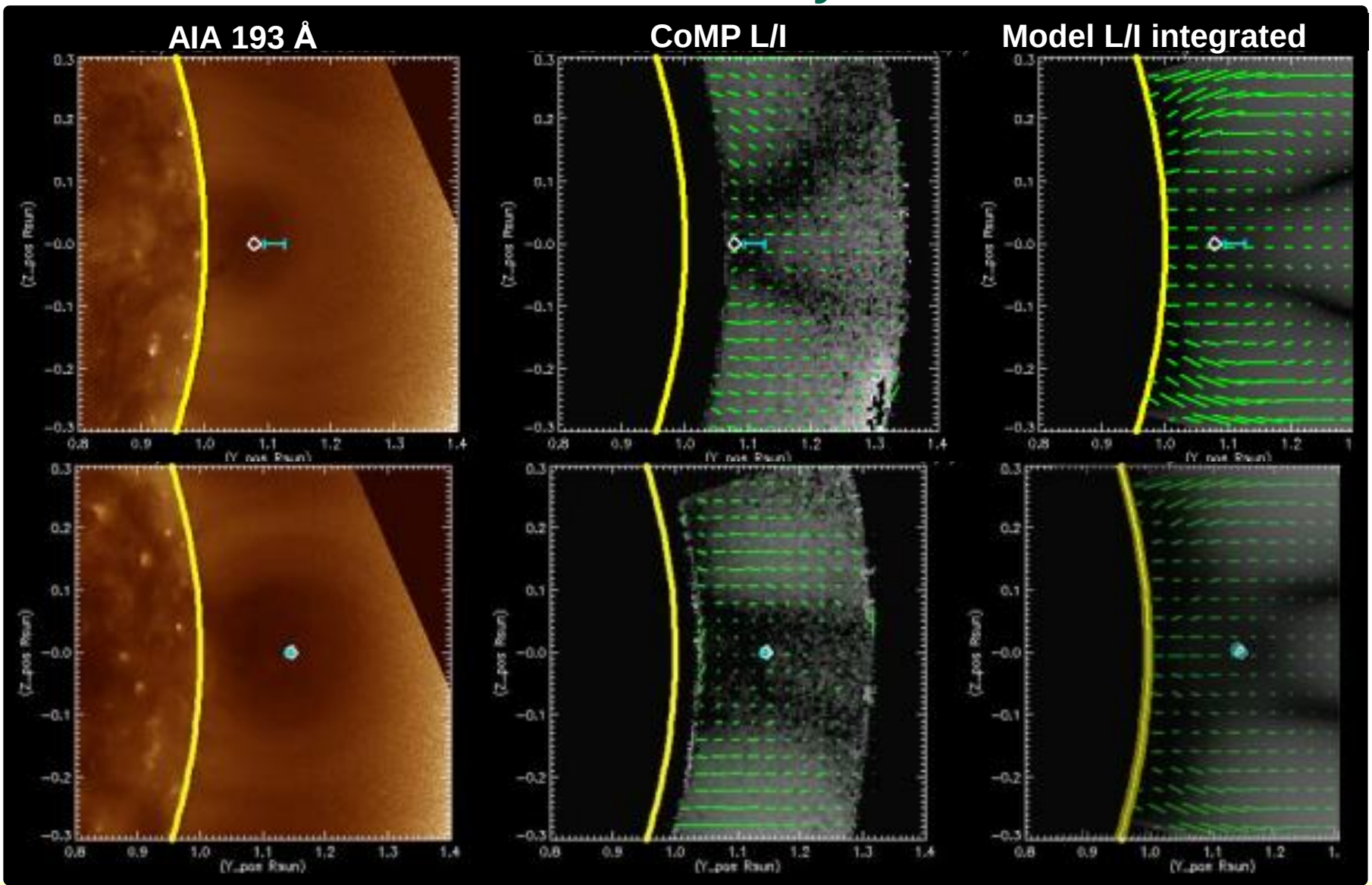
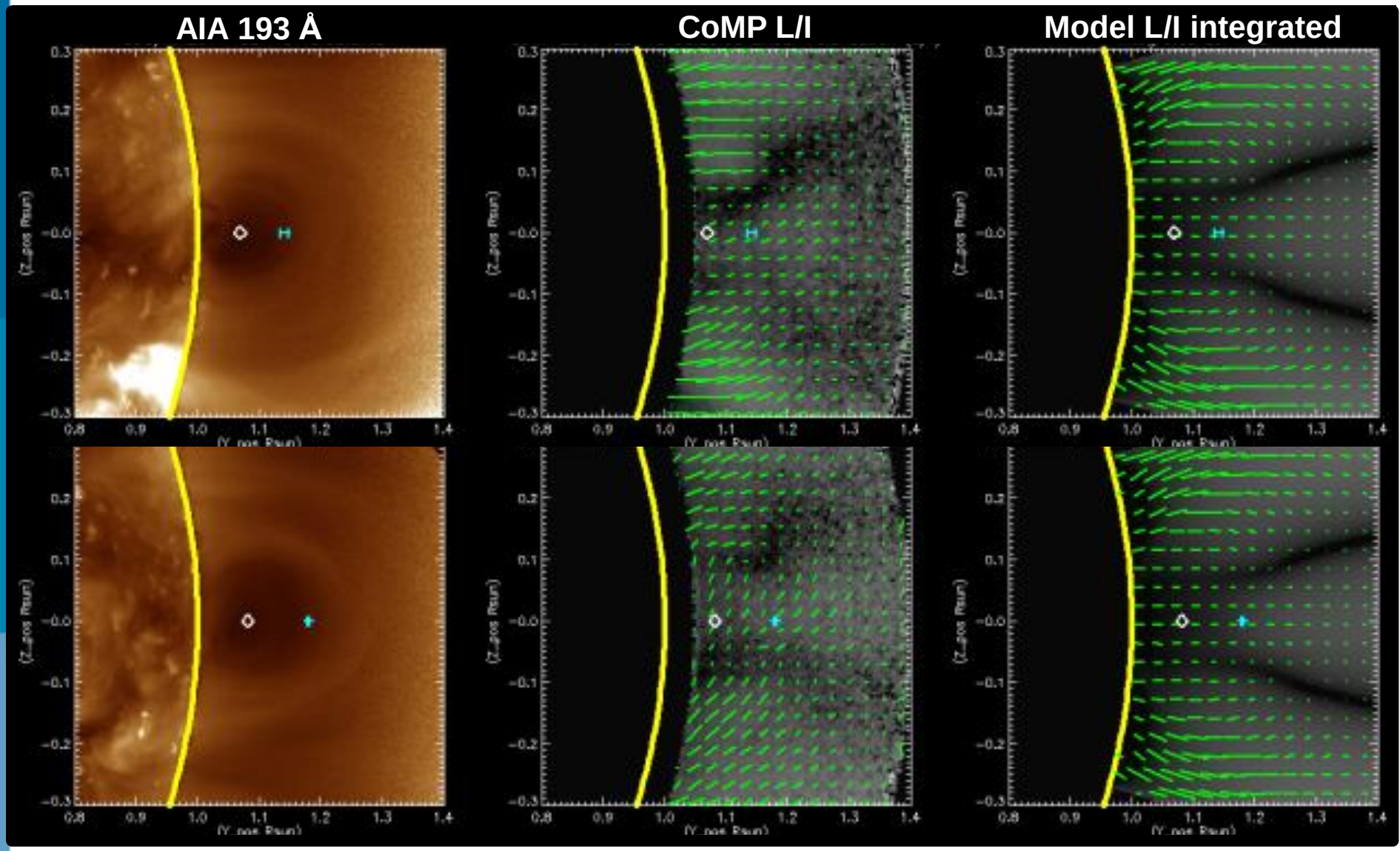
Structures seen on linear polarization scales with the cavity size




AIA 193 Å
CoMP L/I
Model L/I integrated

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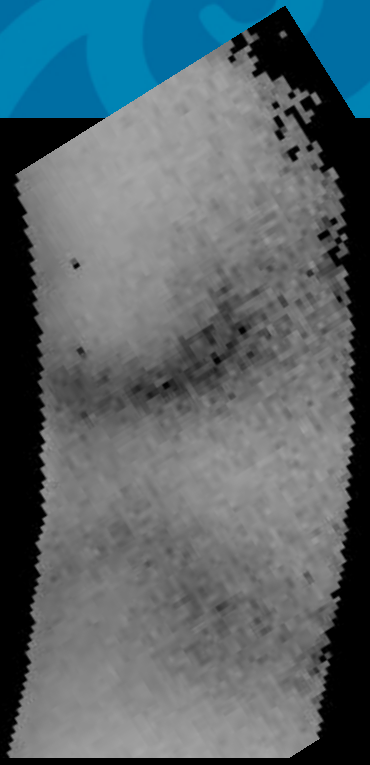
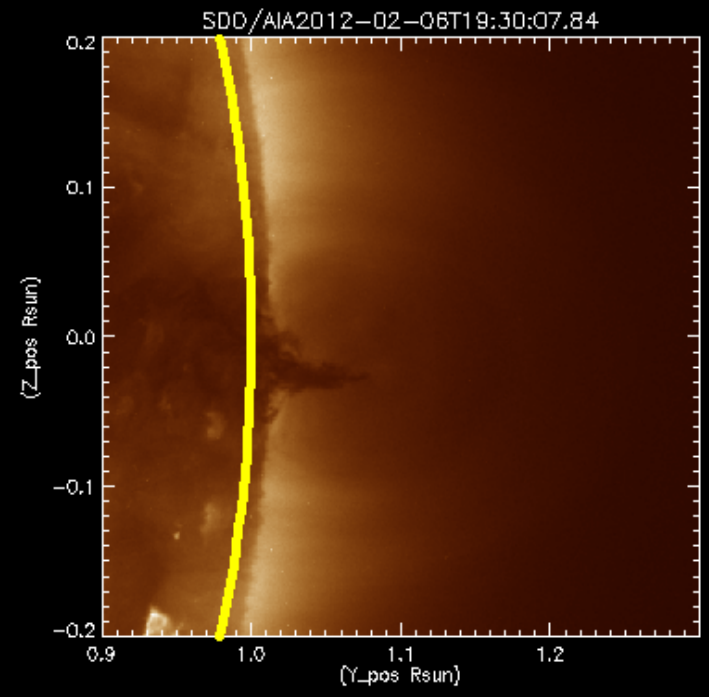
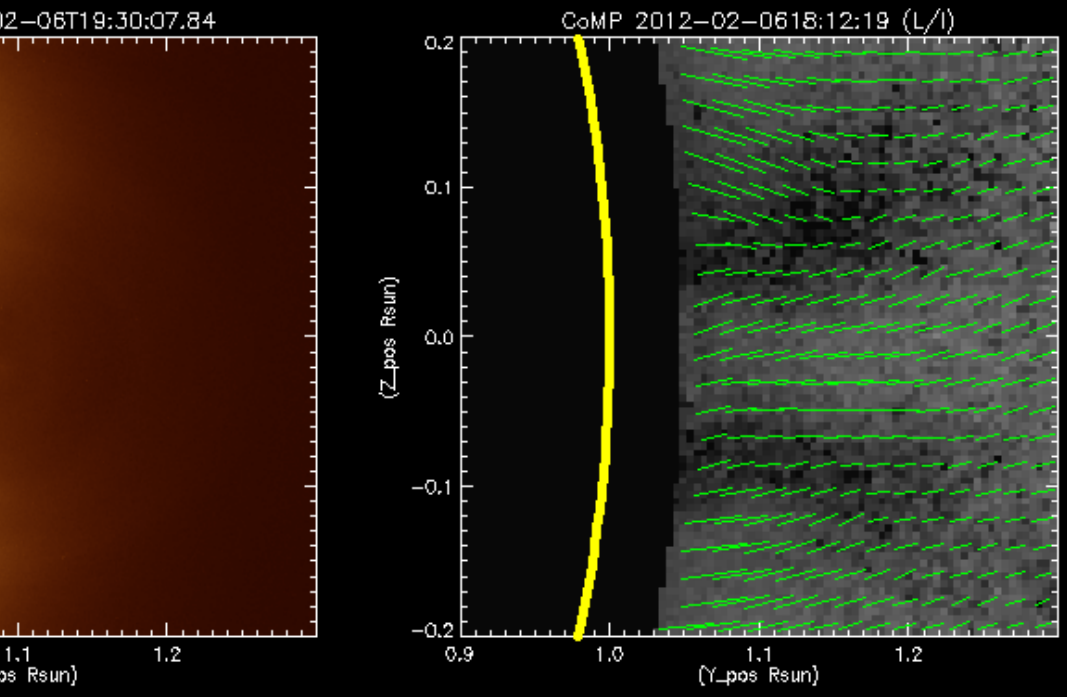
Other examples

5 Feb 2012

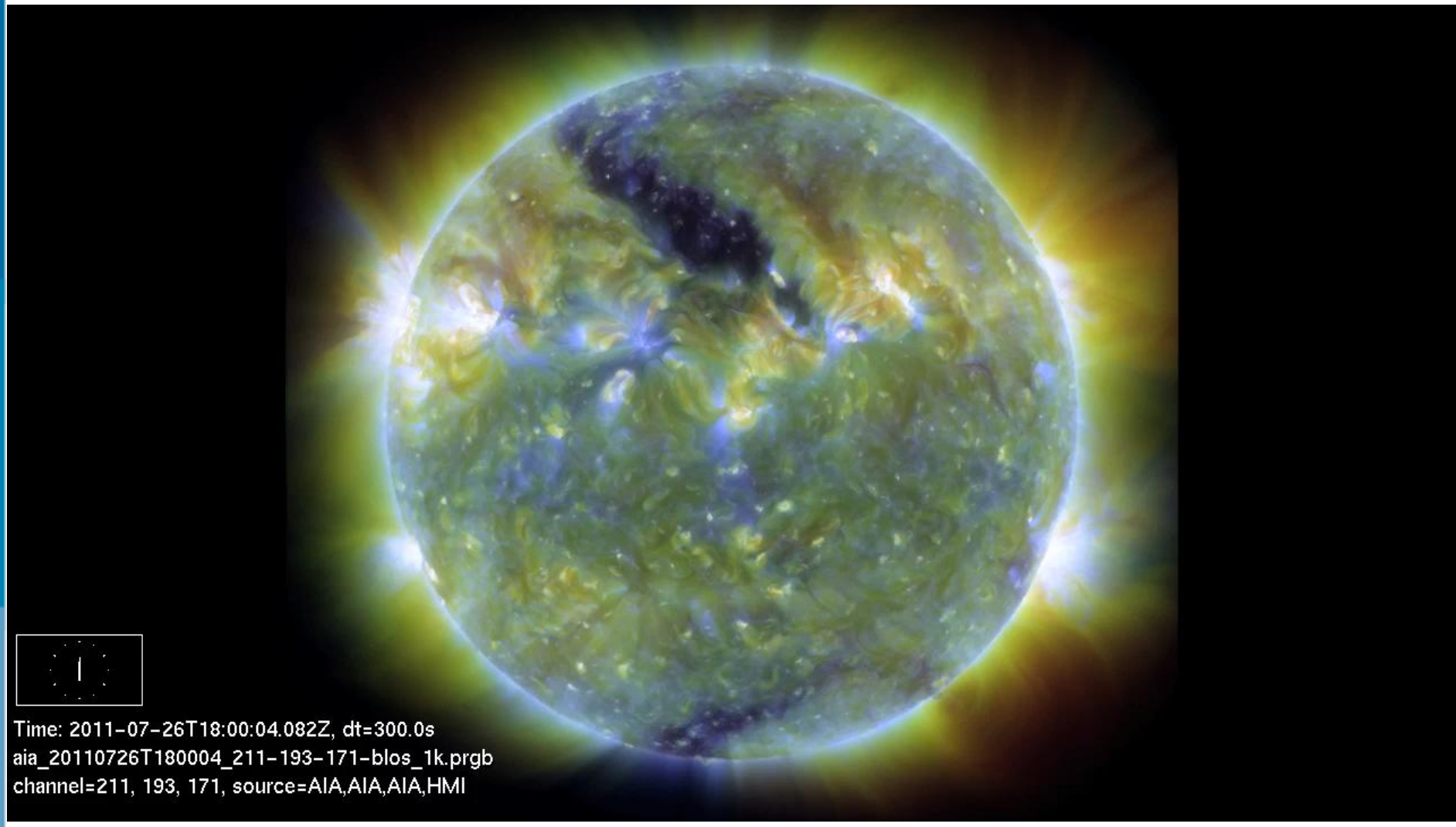


6 Feb 2012





2 cavities - July 27, 2011



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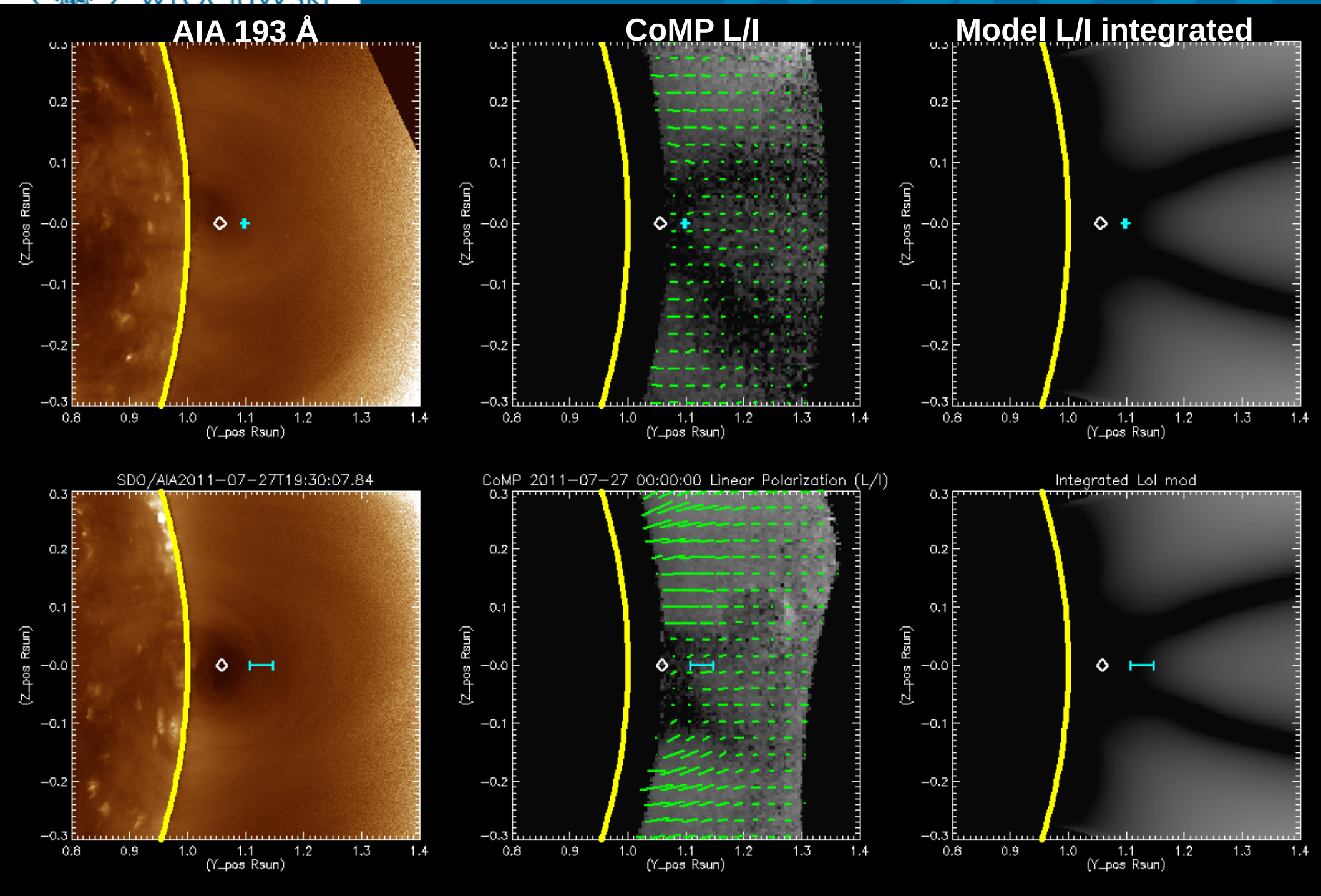
July 27, 2011



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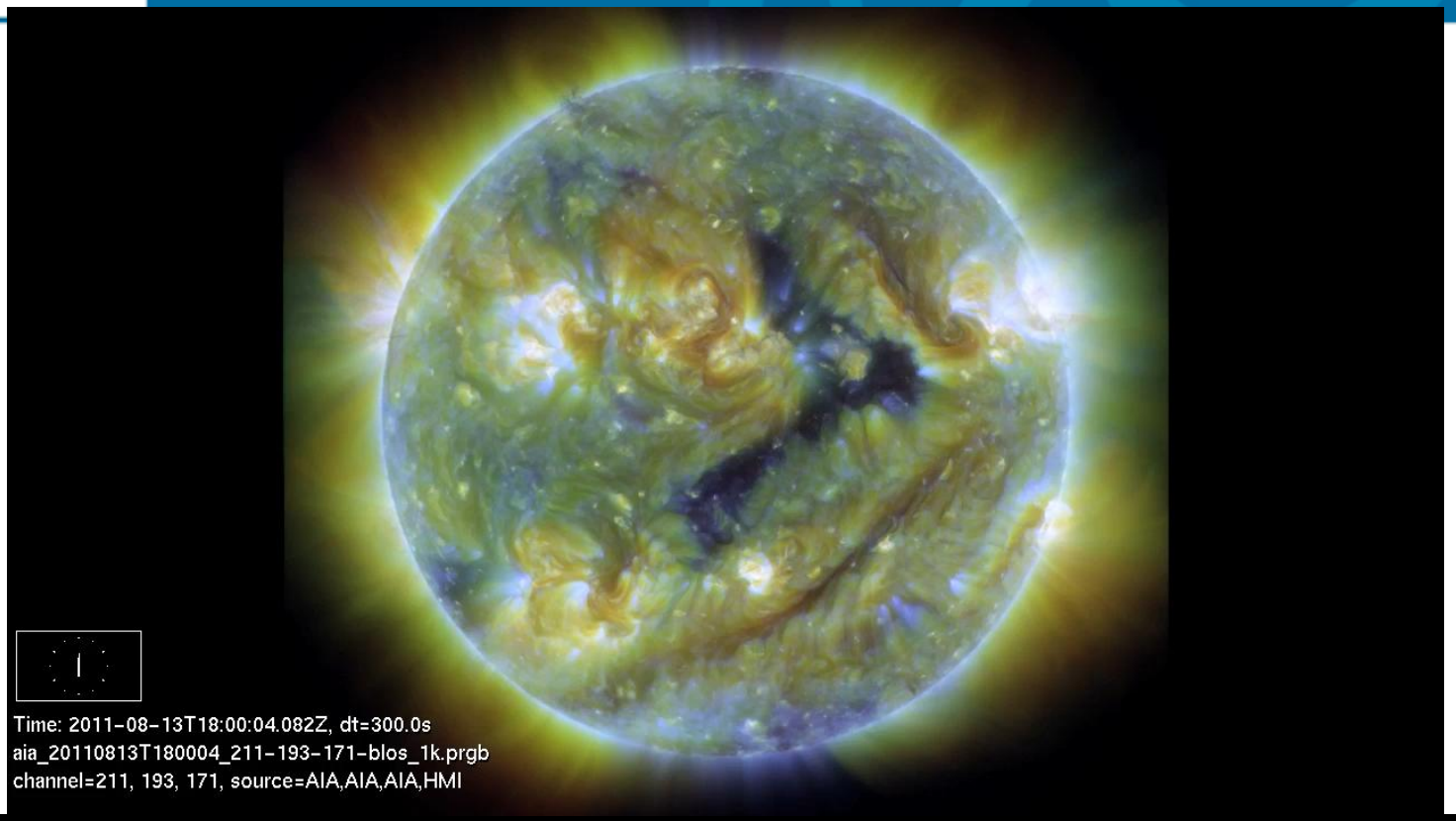
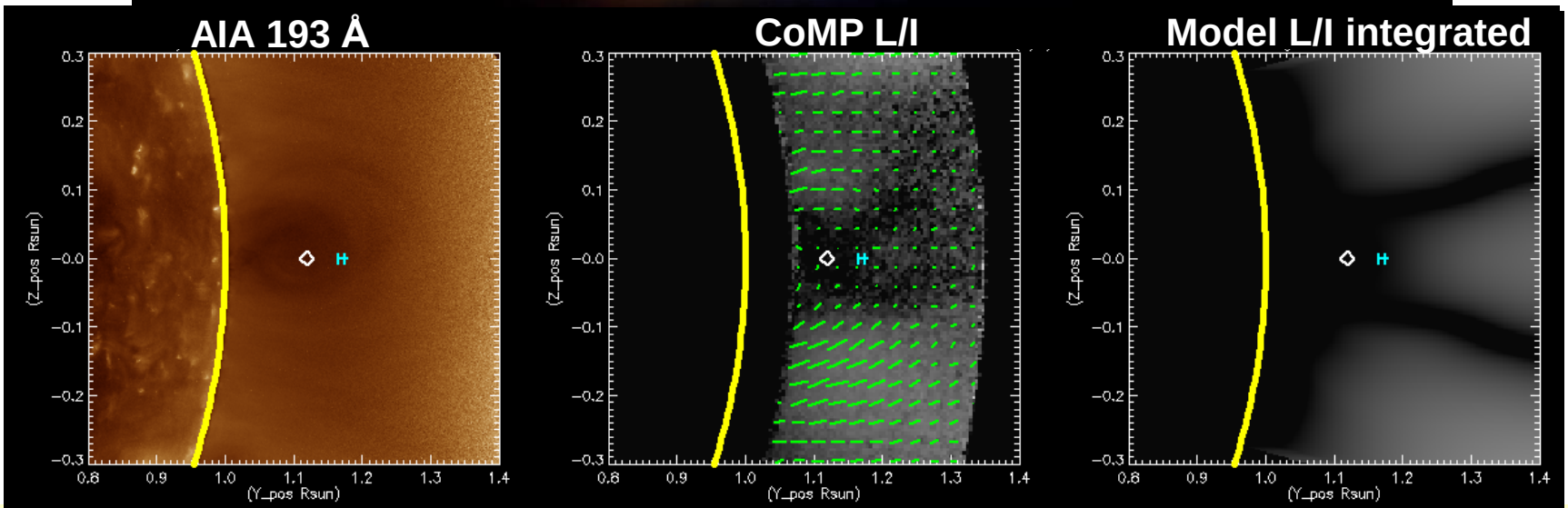
August 14, 2011





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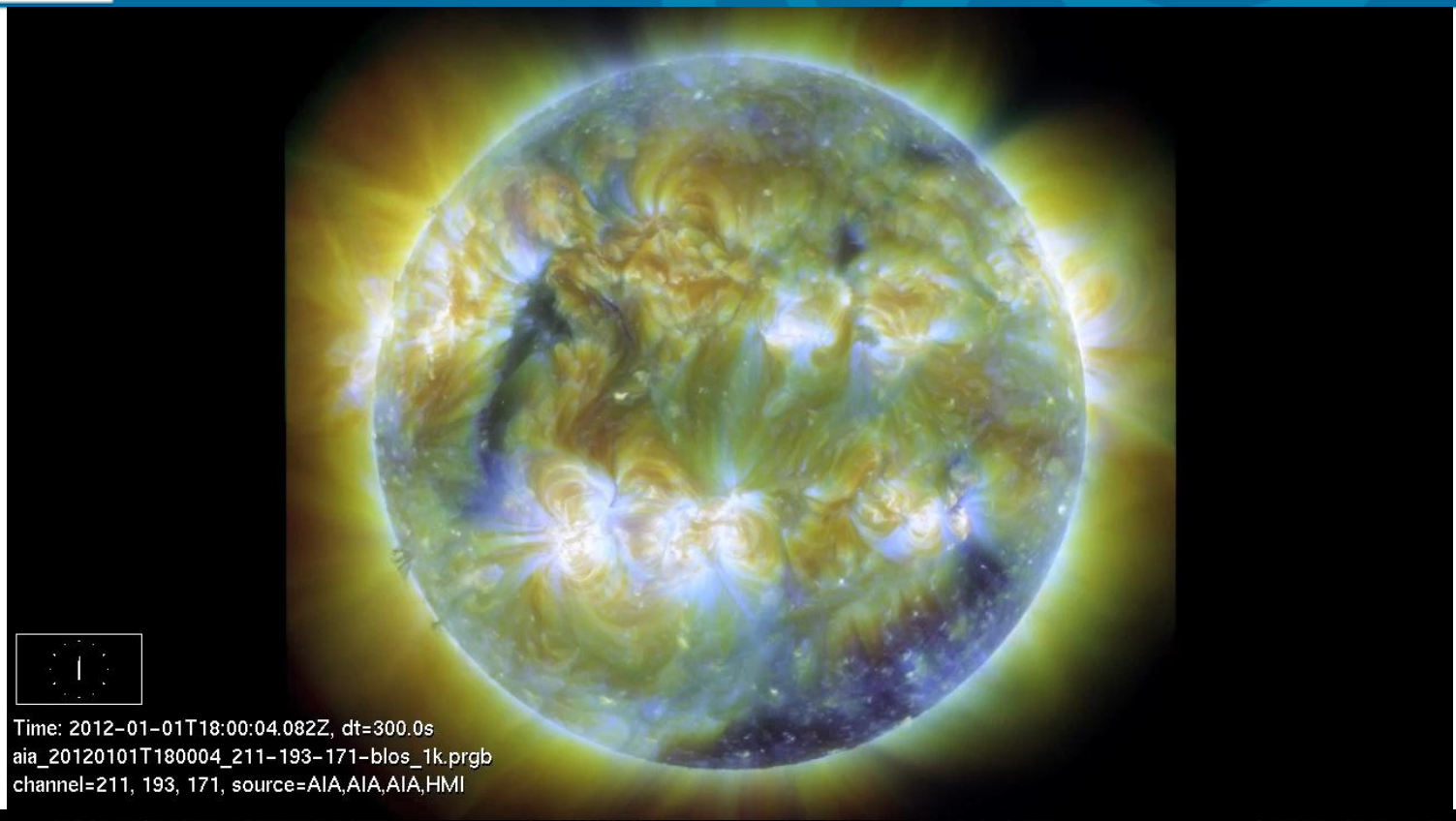
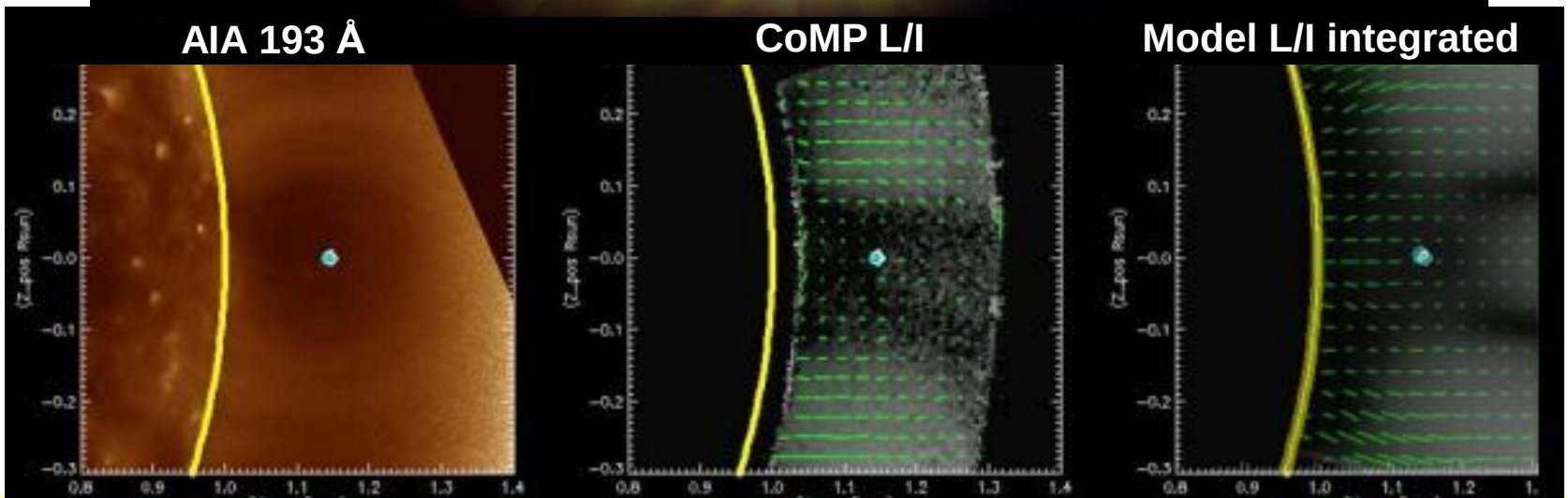
January 2, 2012





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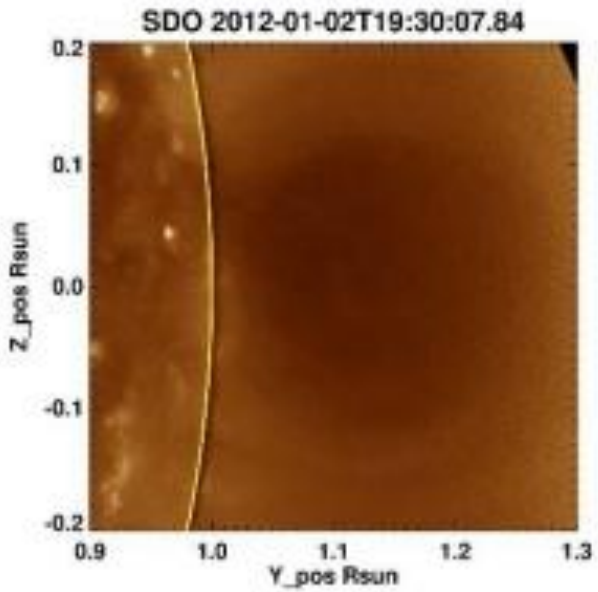
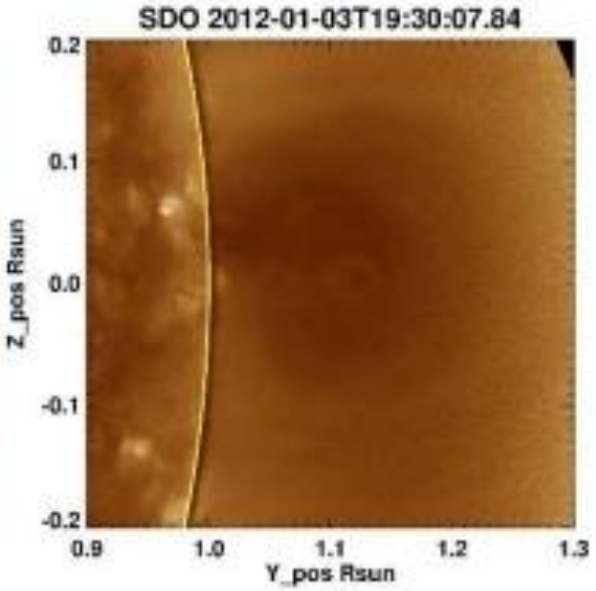
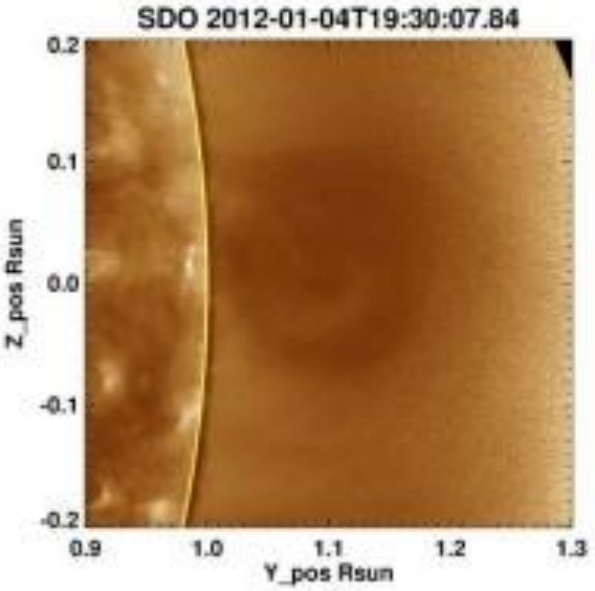
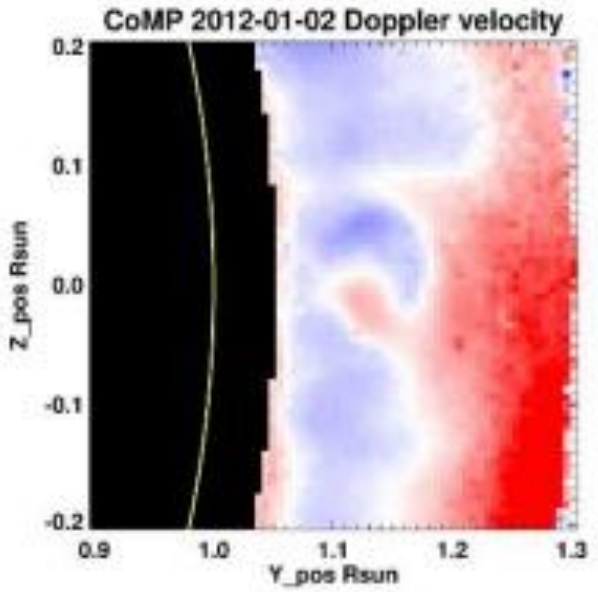
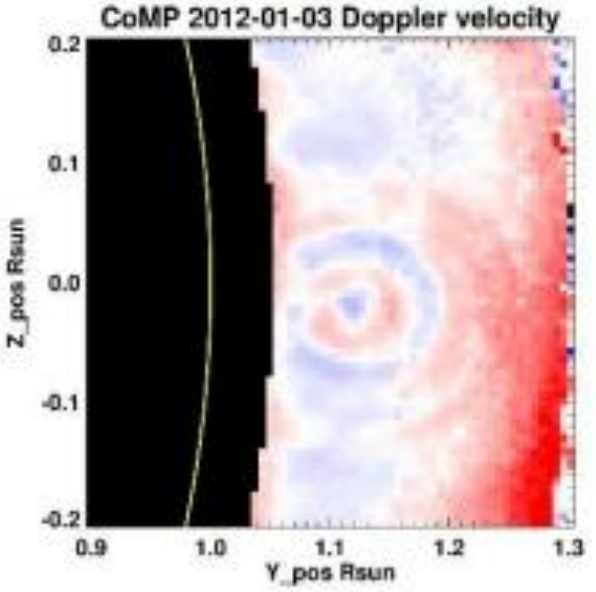
January 2, 3, 4

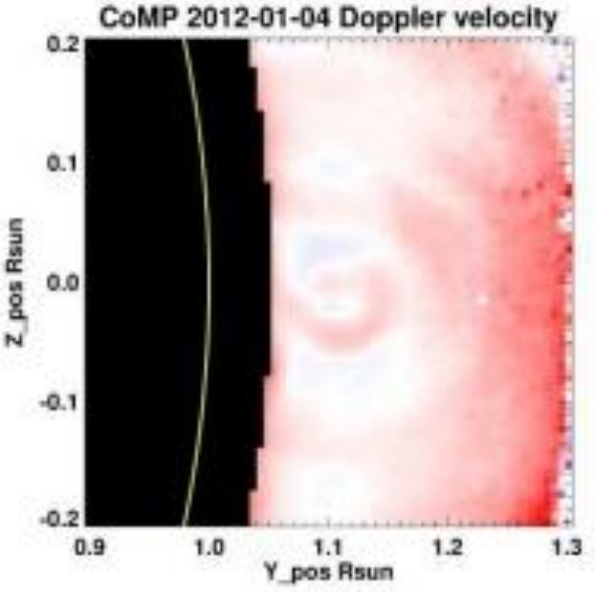












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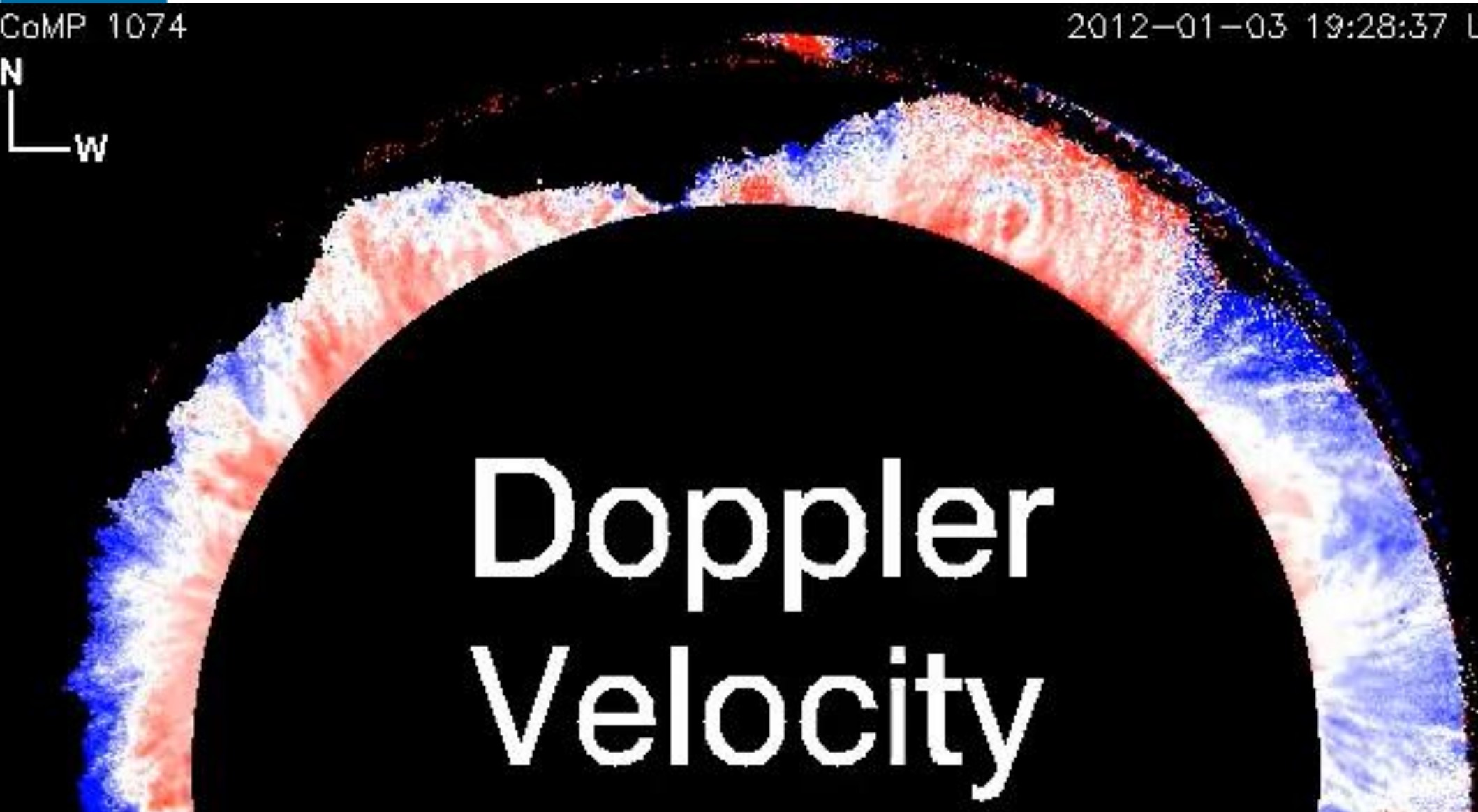
January 3, 2012



Conclusions

- Using new CoMP observations we've found, that polar crown cavities are commonly associated with „rabbit heads". We found 59 rabbit heads during 69 days.
- Observed structures can be explained with flux rope model.
- Spatial size of rabbits scales with cavity size.
- Line-of-sight velocity shows "bulls-eye" - consistent with flows along flux surfaces of magnetic flux rope.
- Flux rope or sheared arcade? Forward modeling technique applied to different models (Rachmeler et. al, 2013)

Stokes V or direction of polarization vectors may be required

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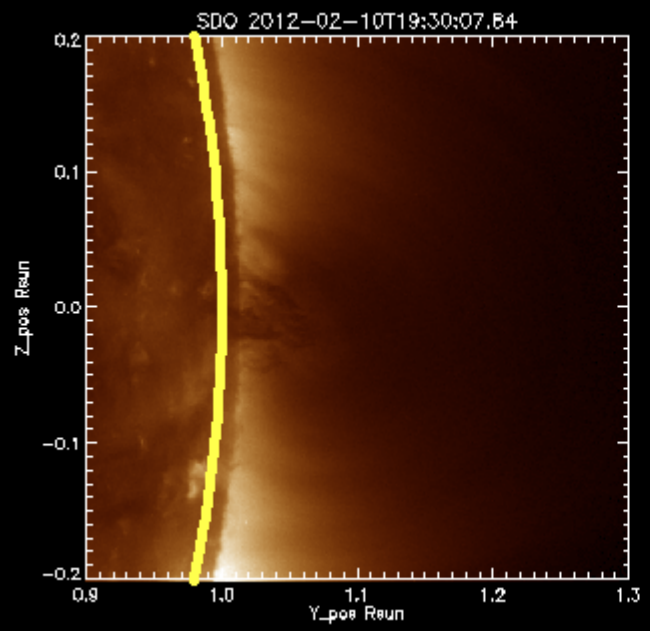

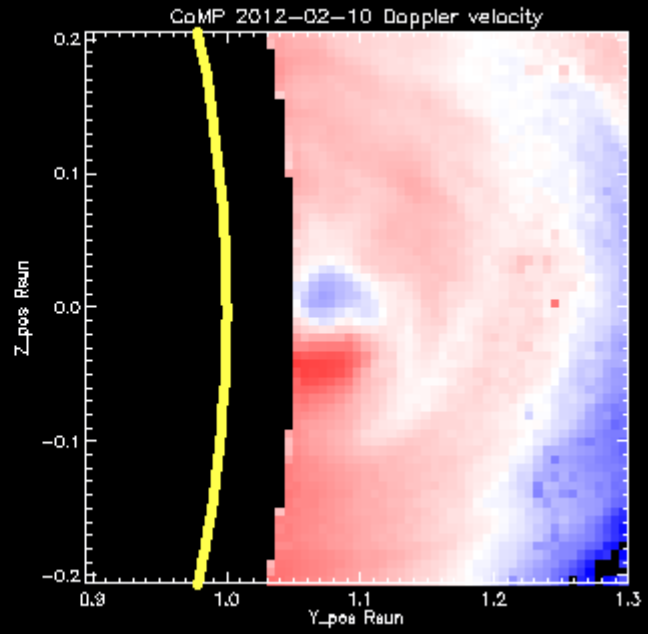

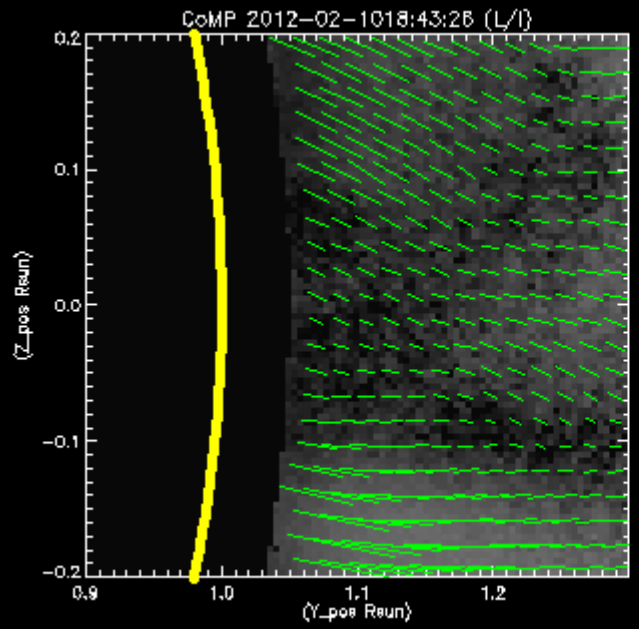

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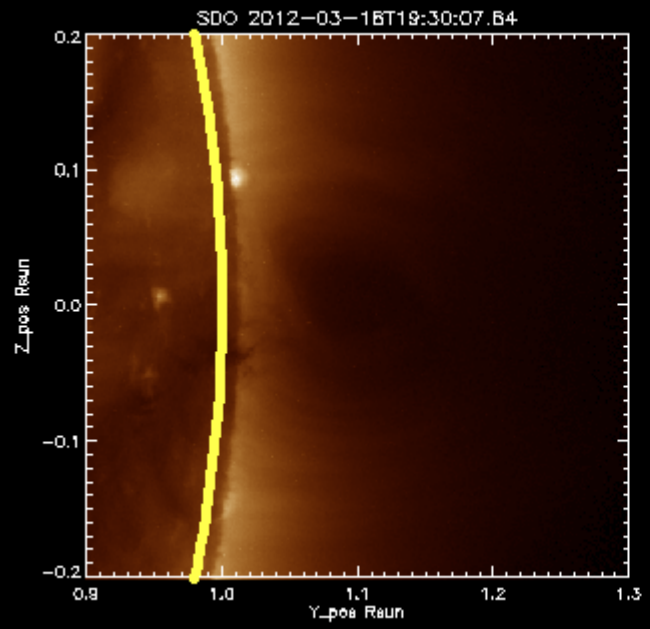

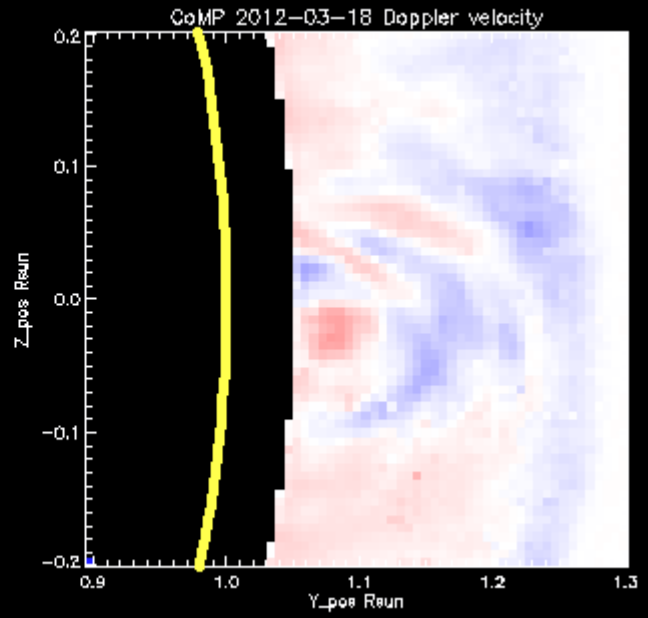

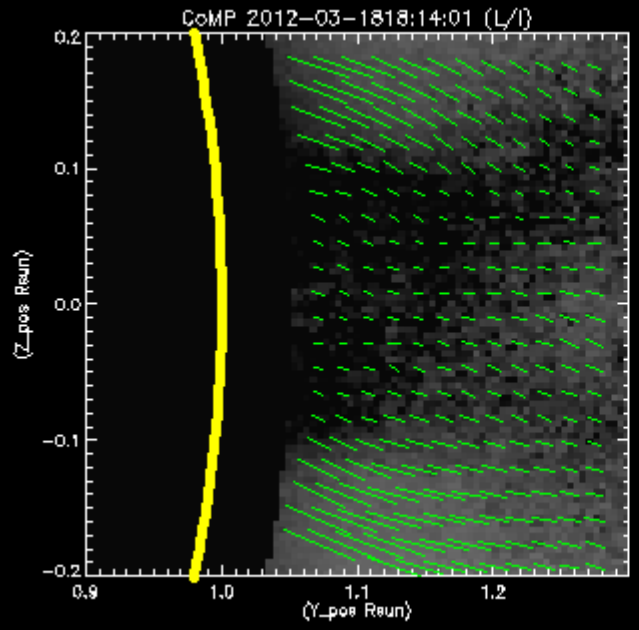

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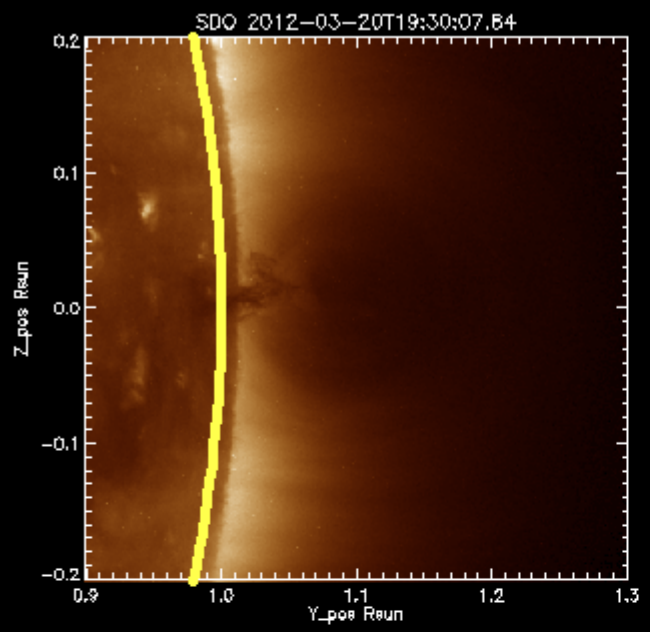

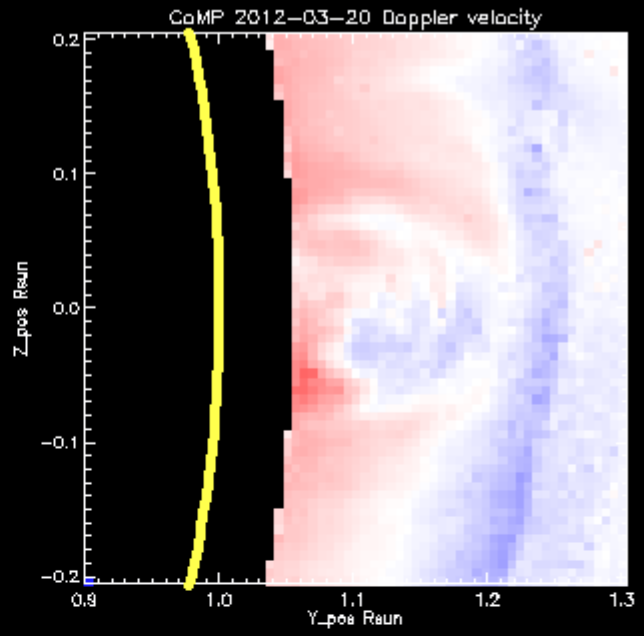

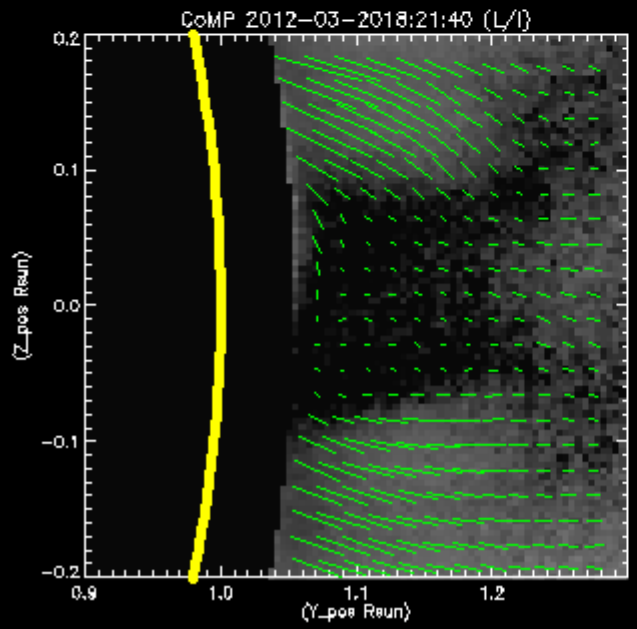

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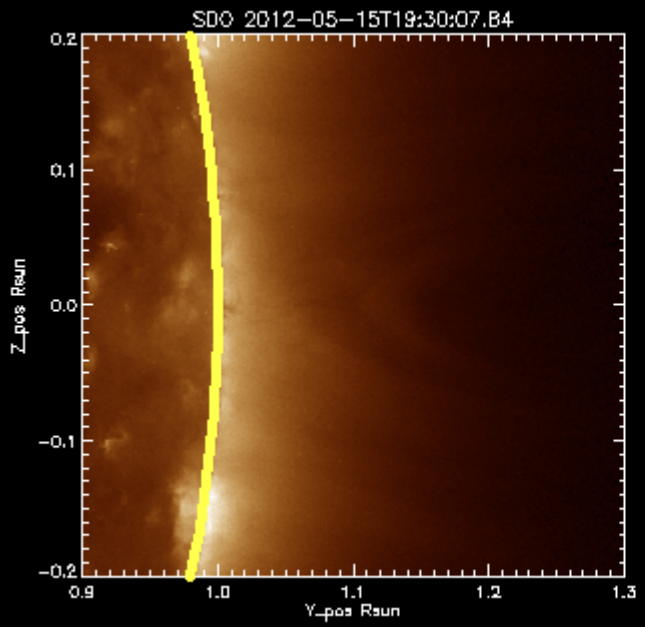

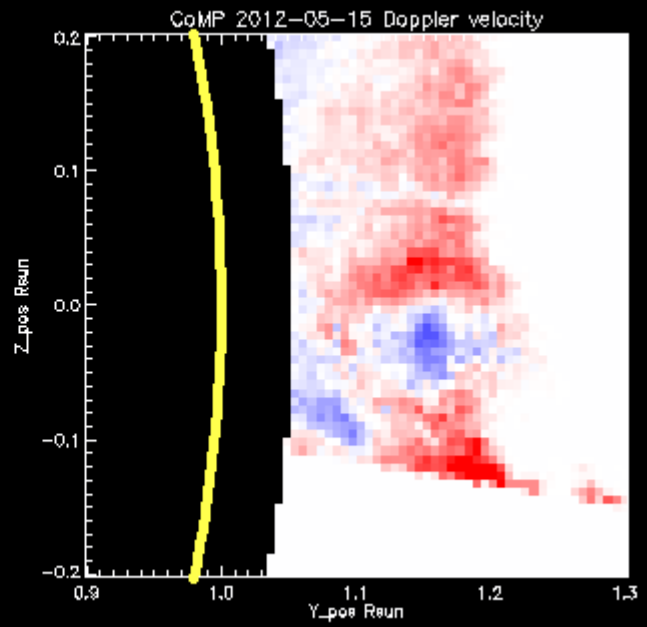

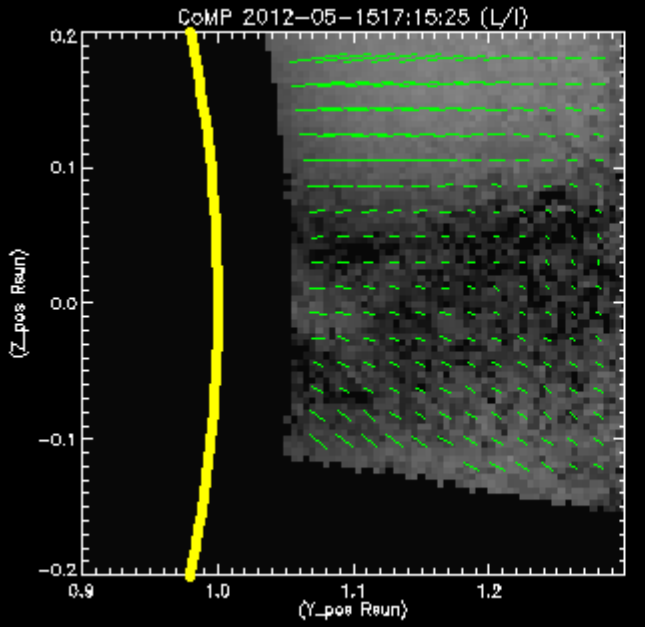

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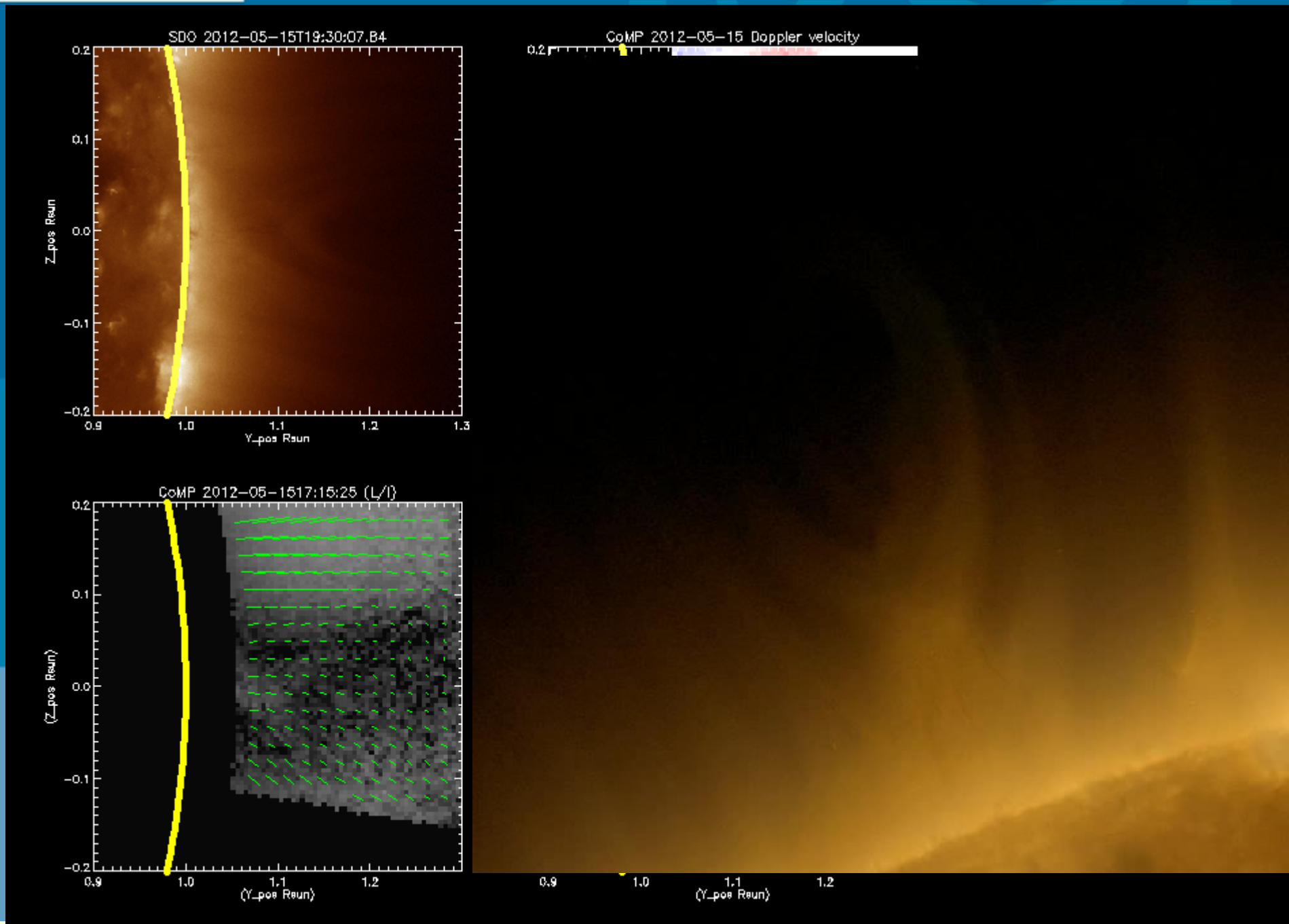

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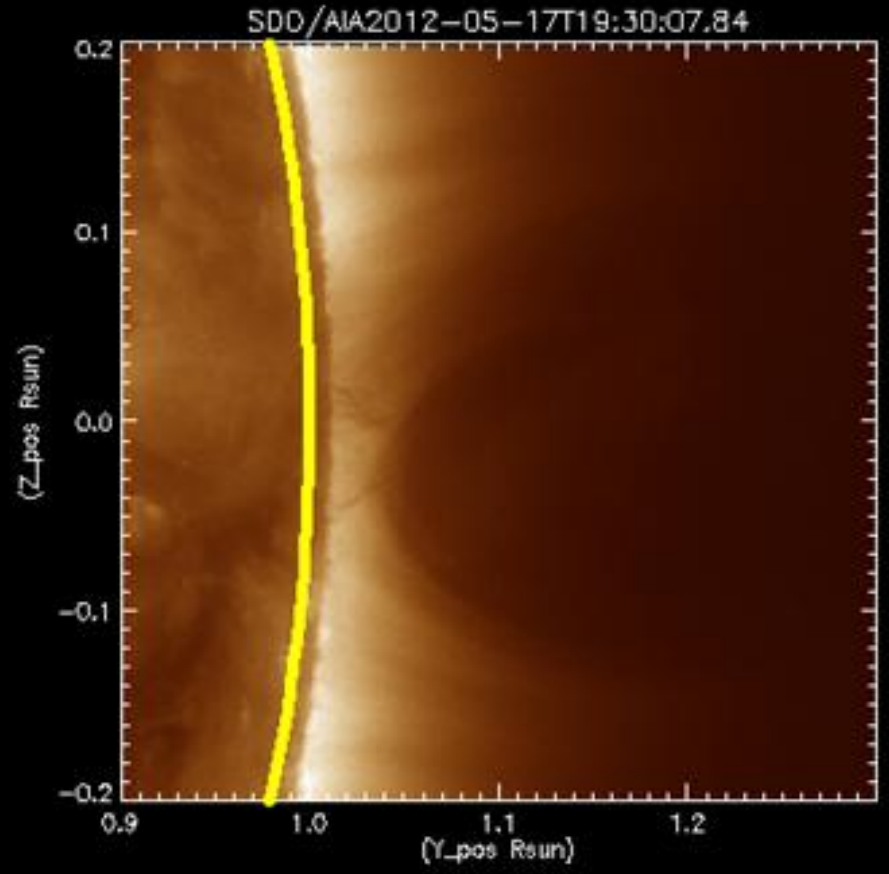

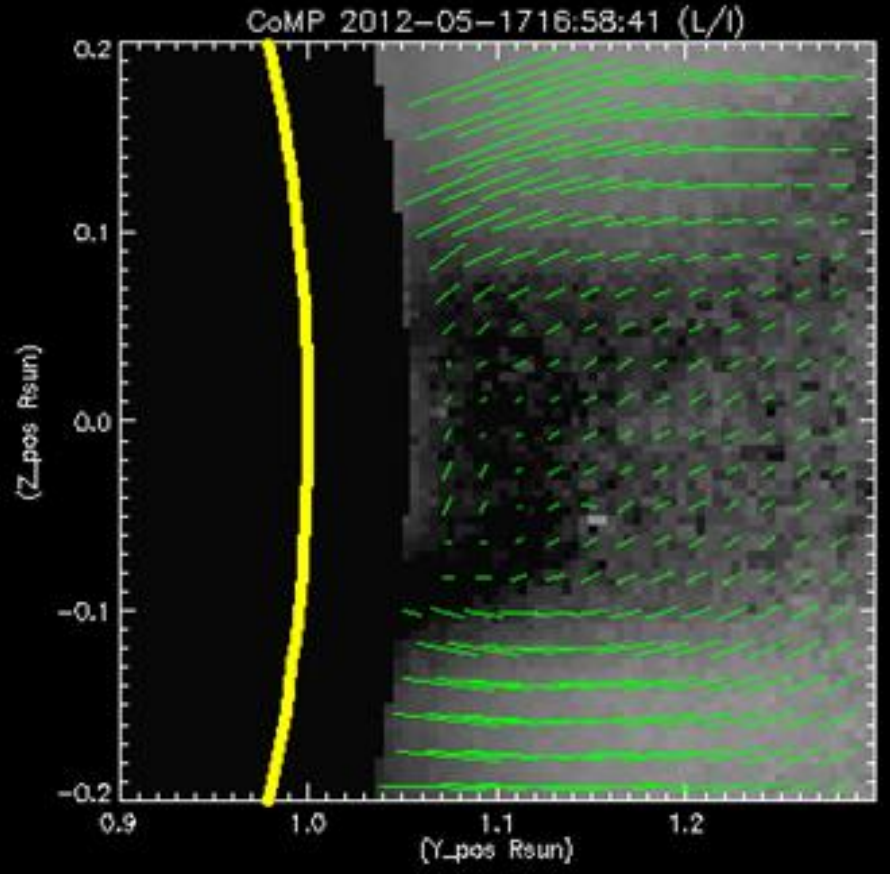

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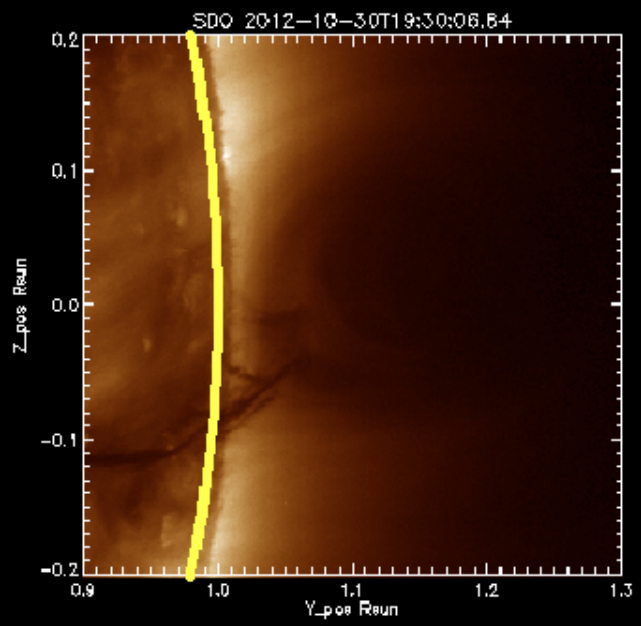

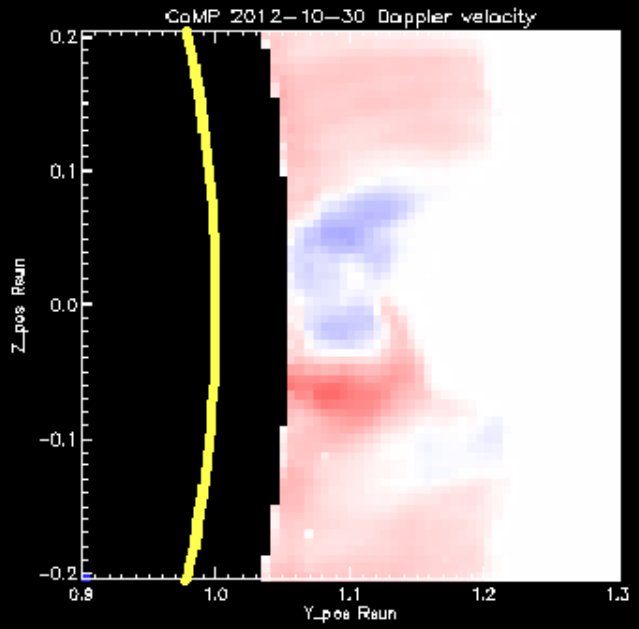

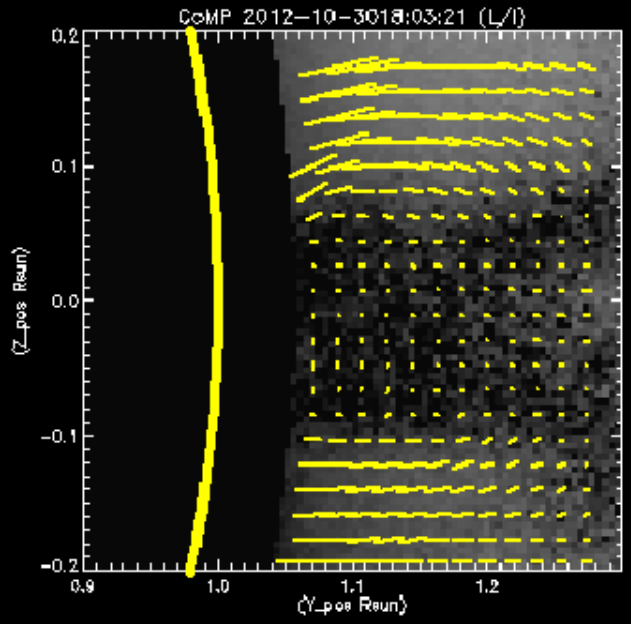

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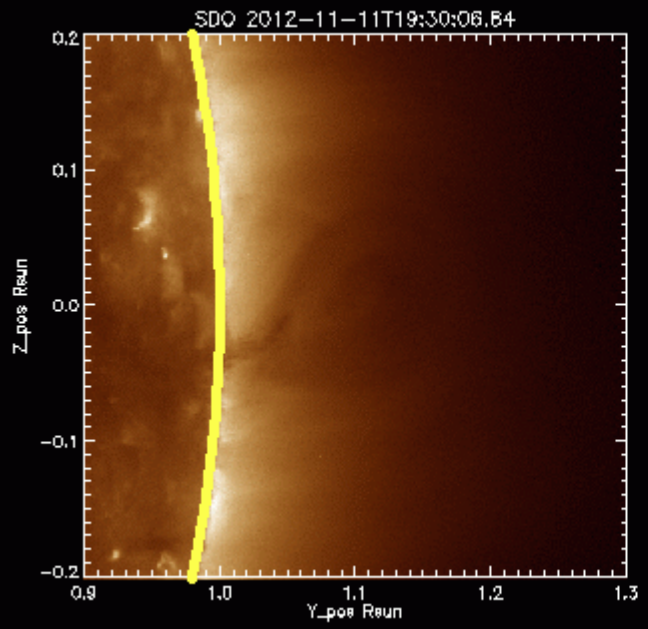

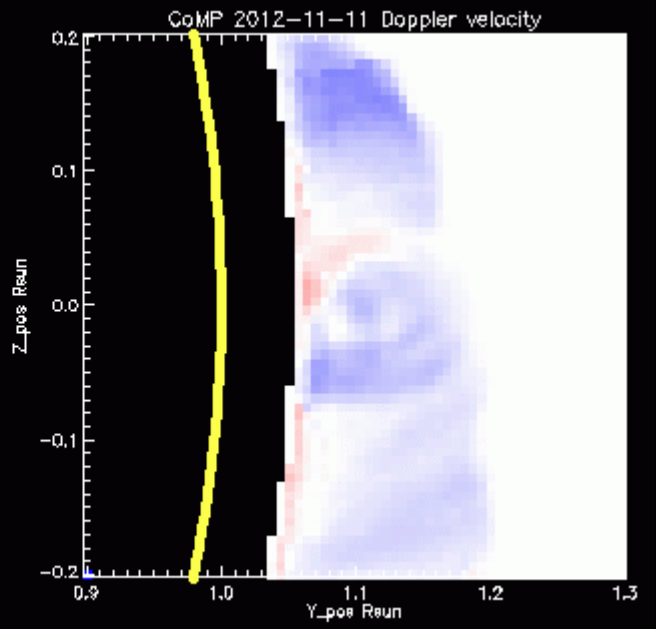

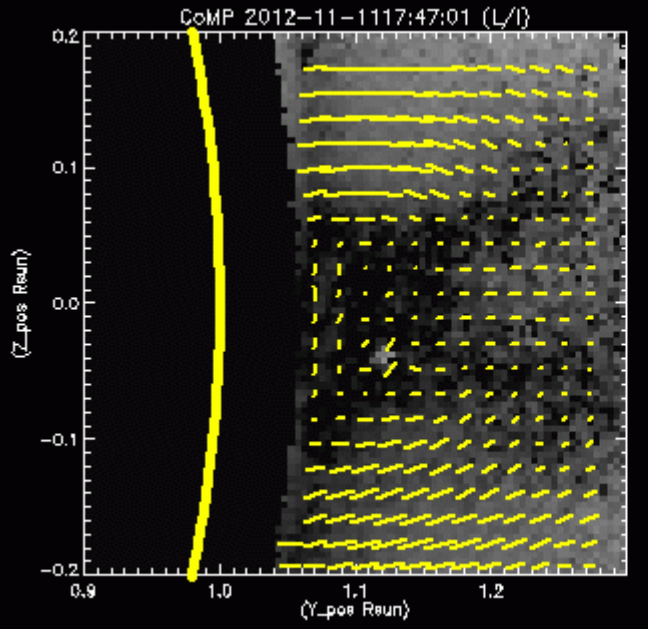

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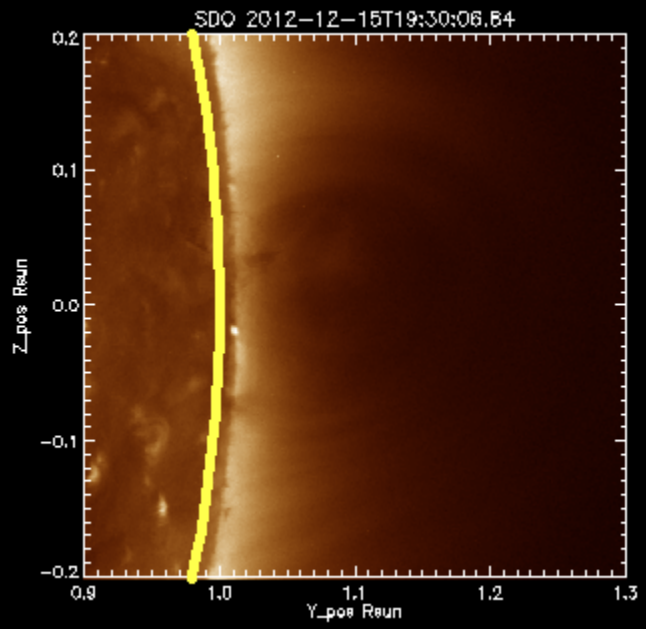

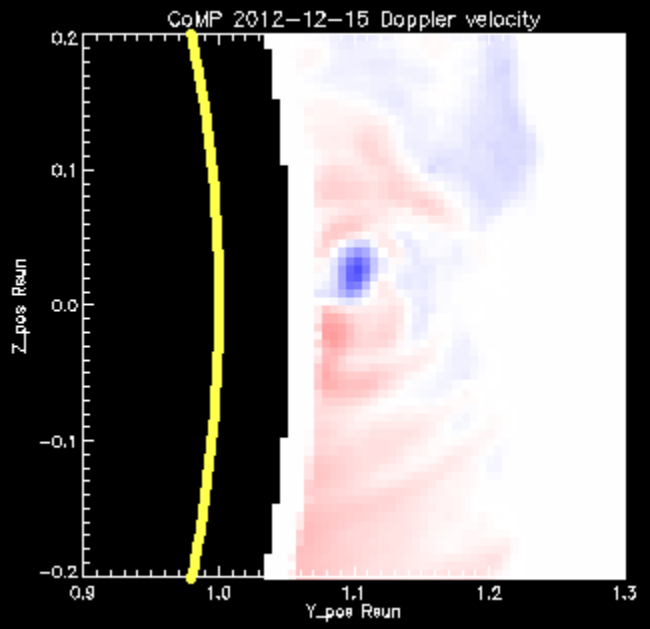

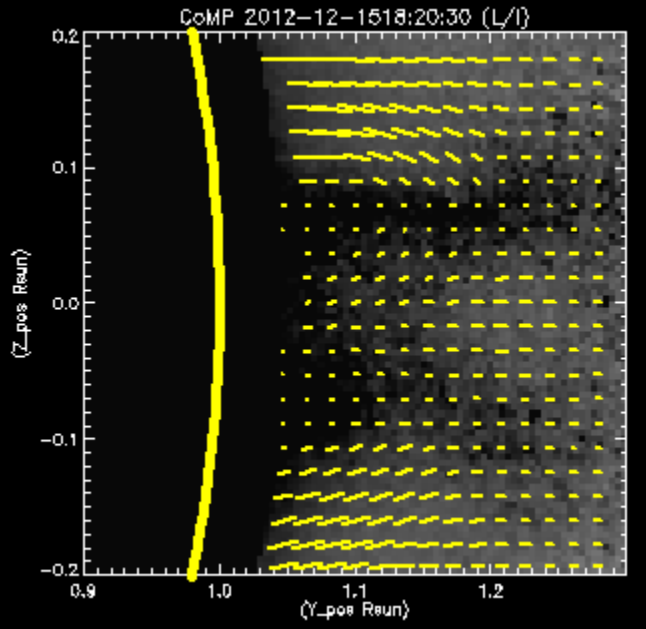

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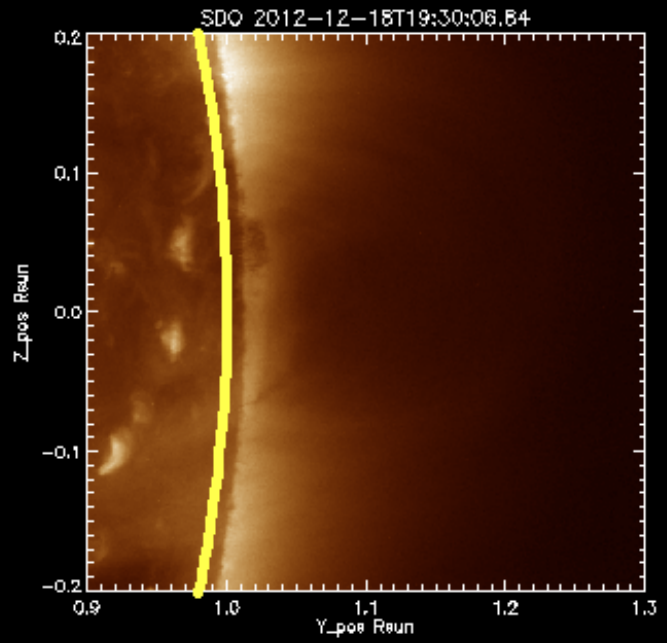

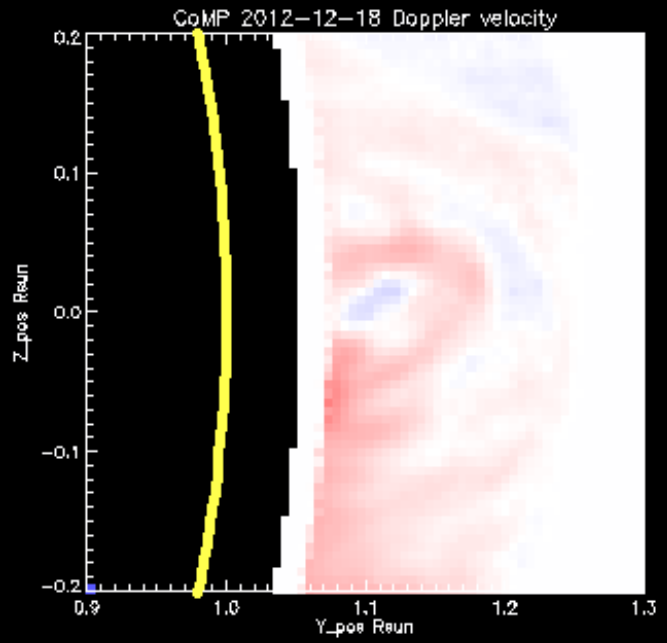

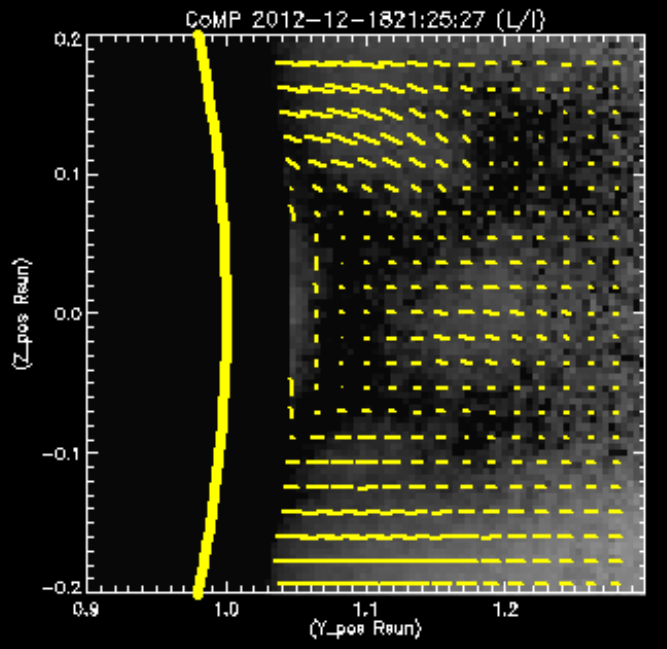

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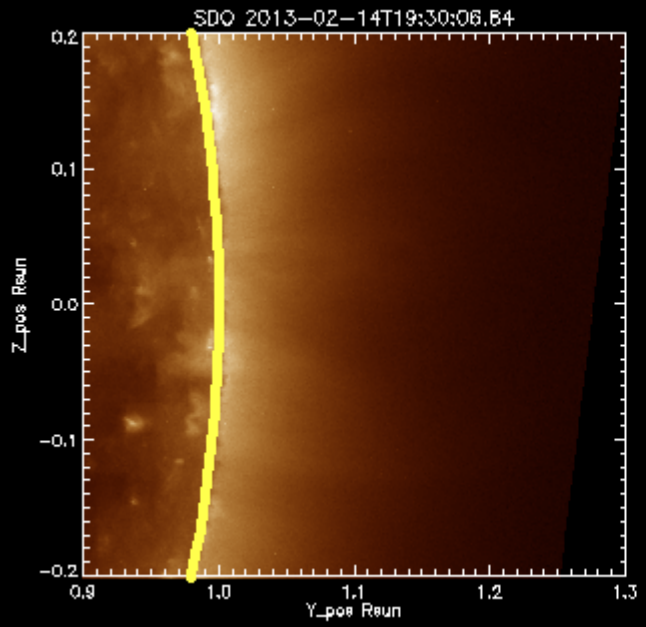

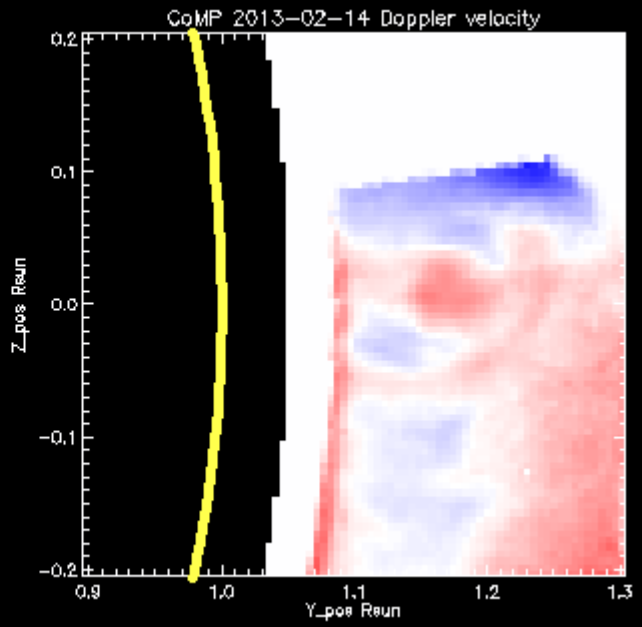

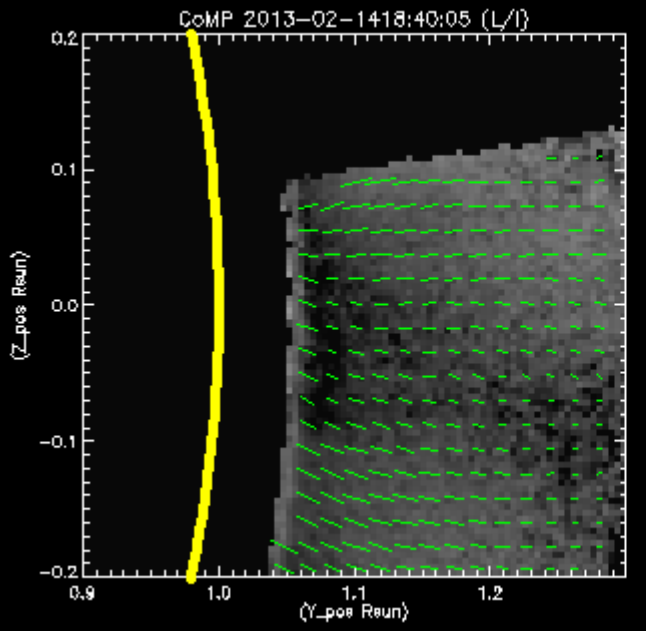

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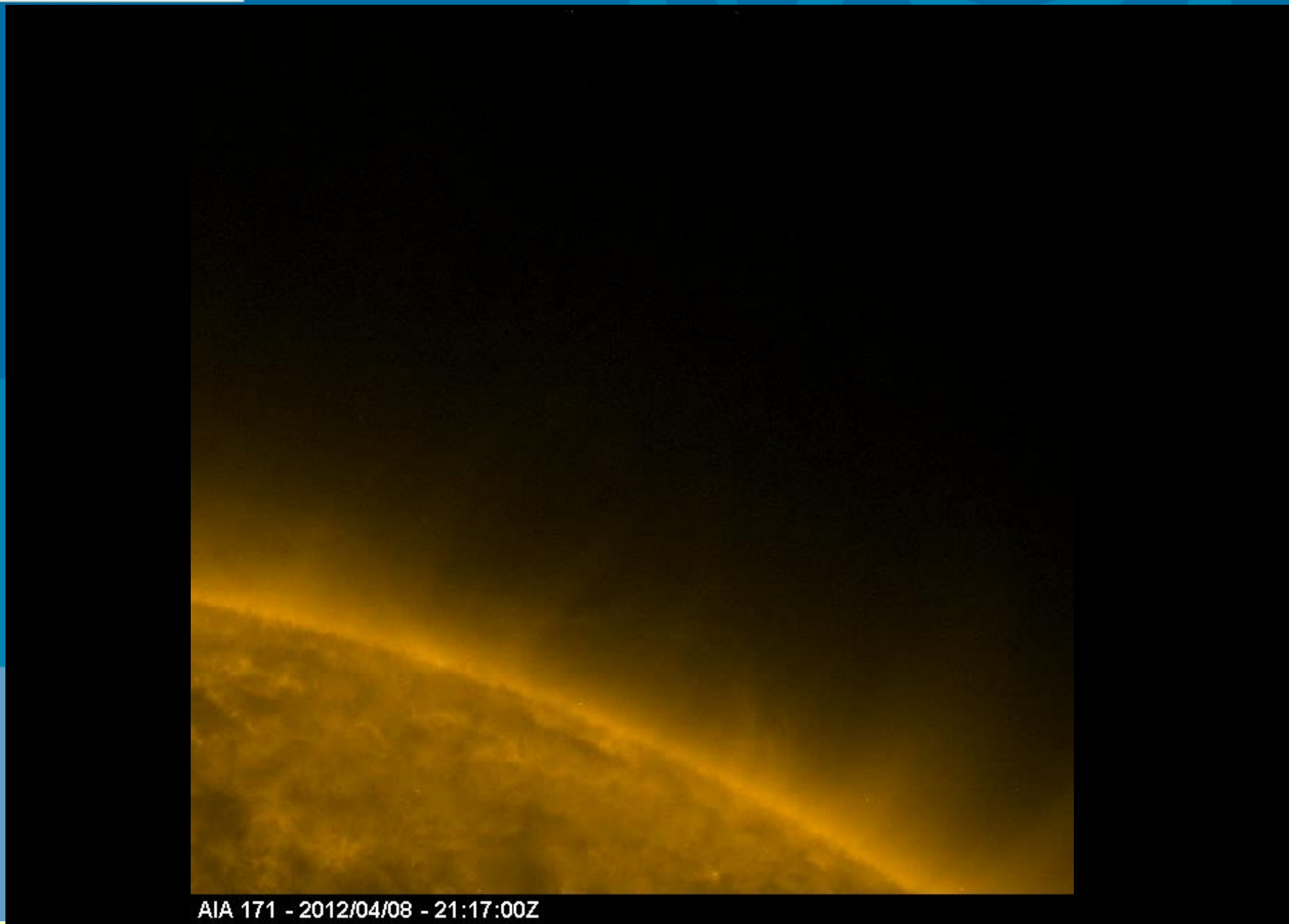
Eruptions



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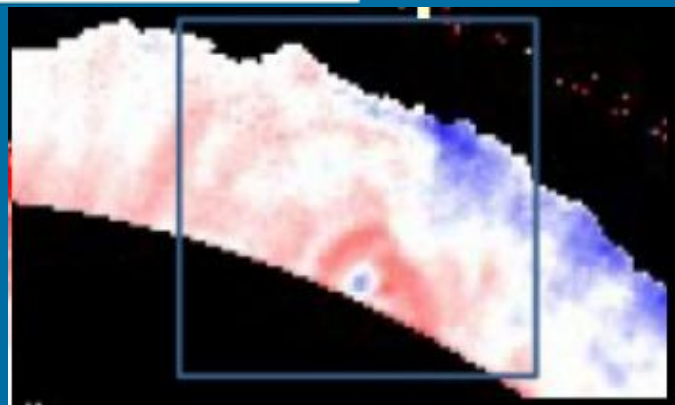
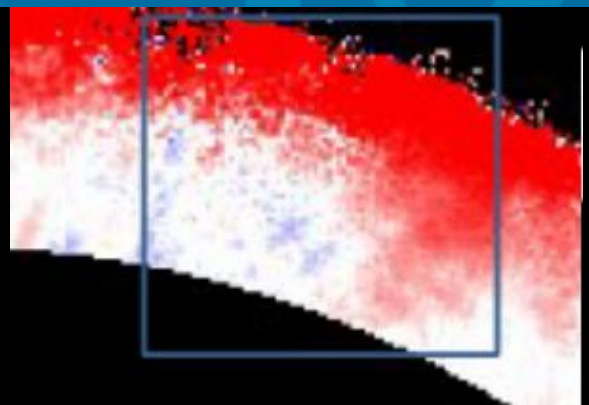
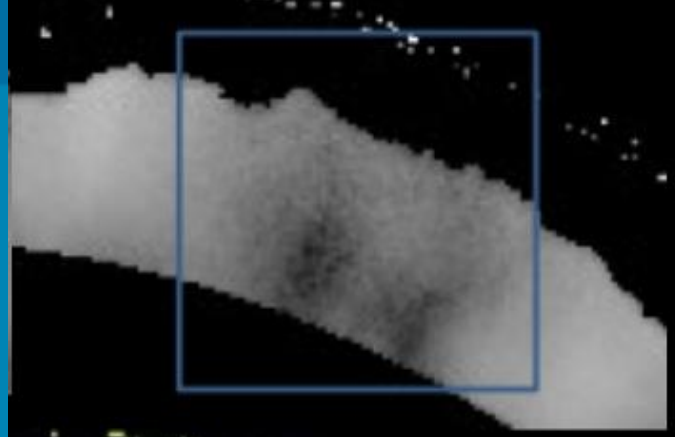
Eruptions

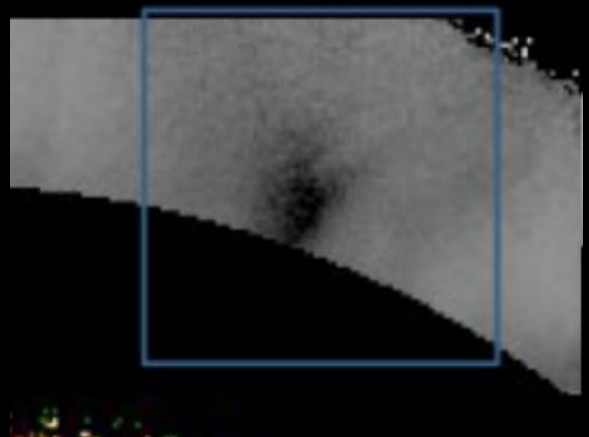


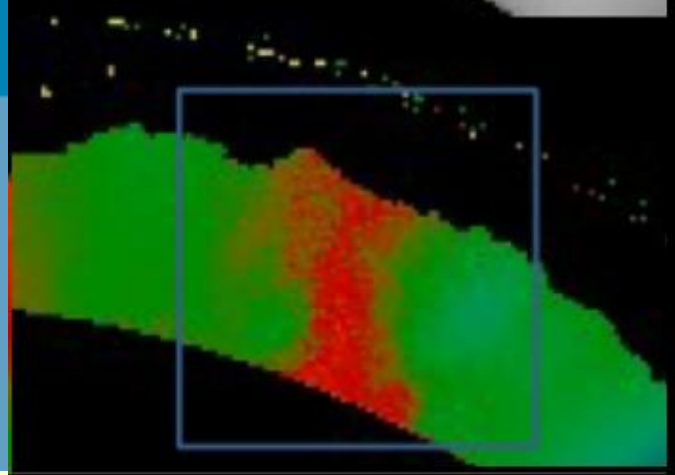
Before – 11 Apr 2012

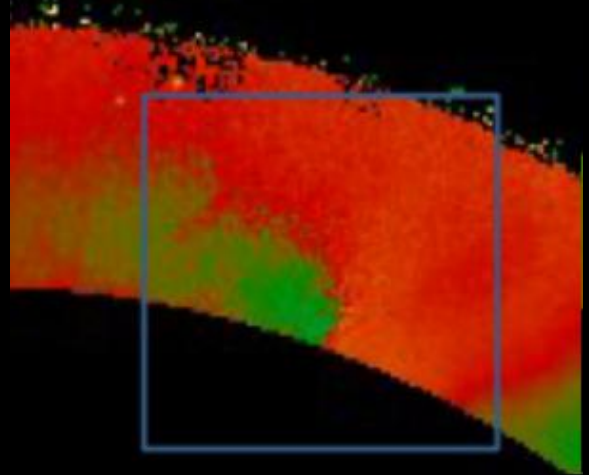


After – 12 Apr 2012









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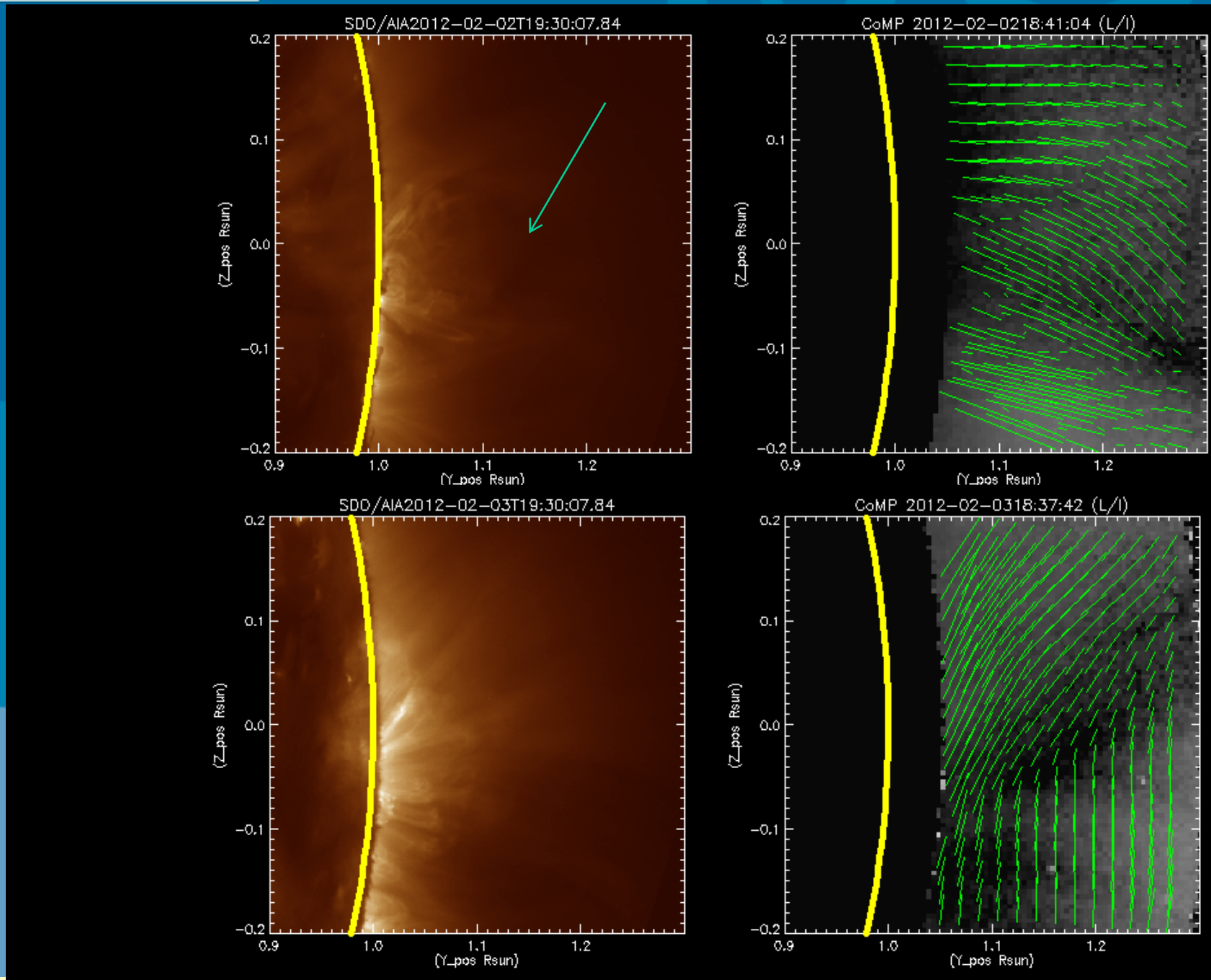
Eruptions



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