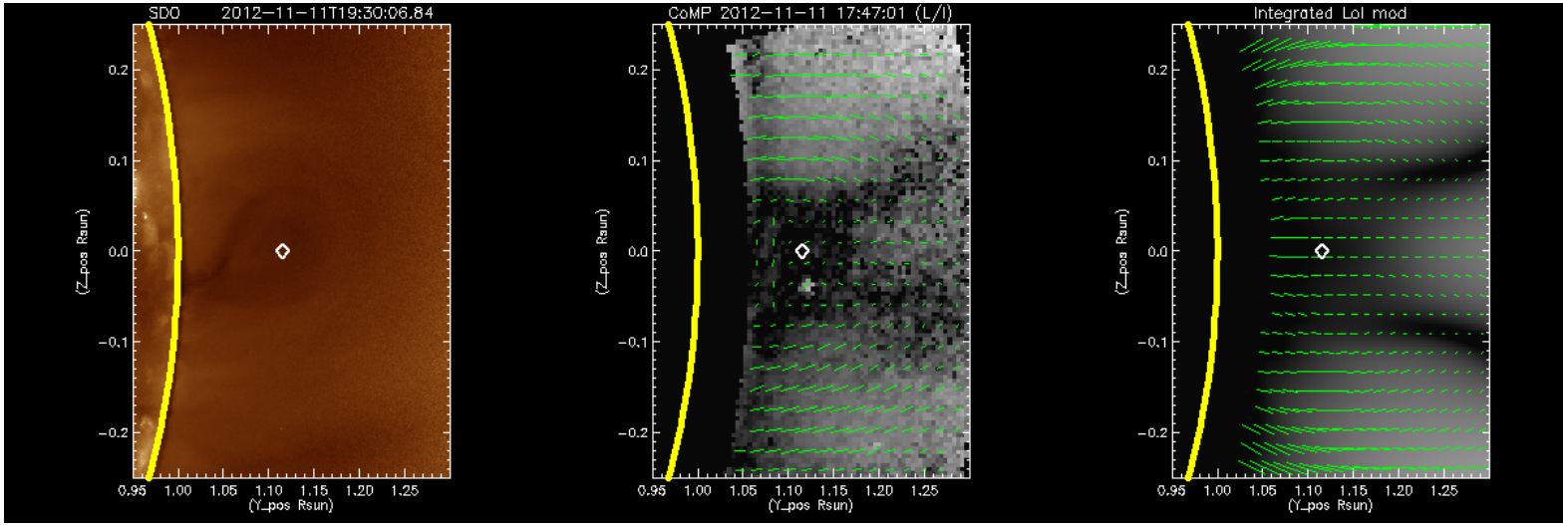
Uniwersytet Wrocławski

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

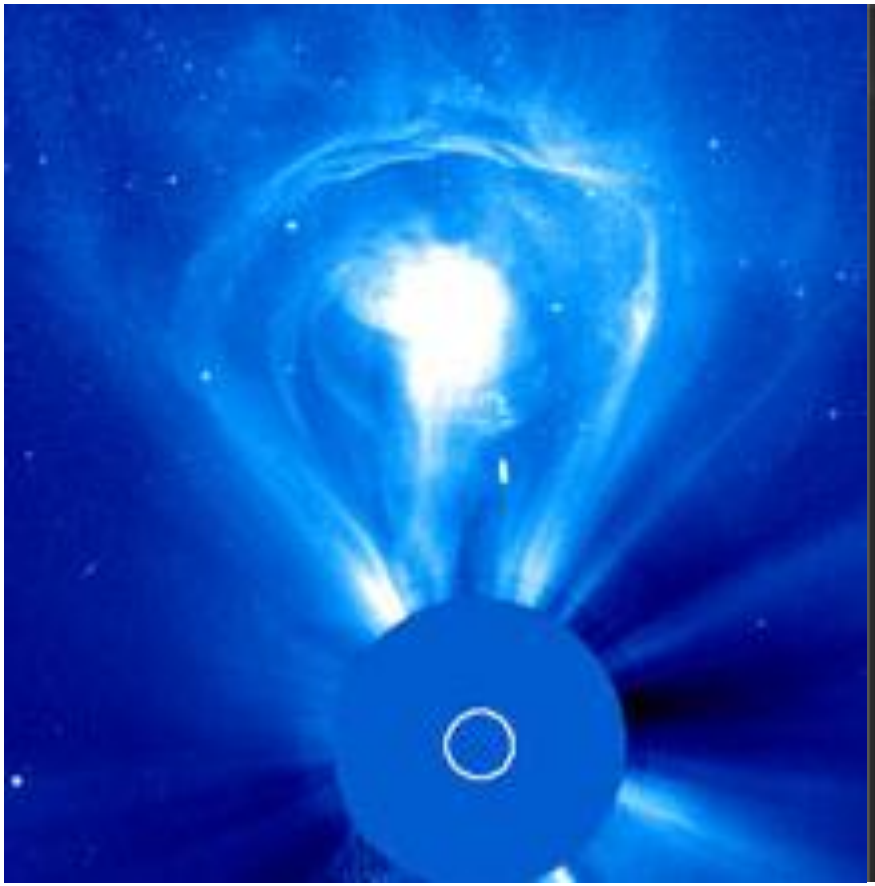
Urszula Bąk-Stęślicka[1], Sarah Gibson[2], Yuhong Fan[2],
Christian Bethge[2], Blake Forland[3], Laurel Rachmeler[4]

[1]Astronomical Institute, University of Wrocław, Poland; [2] High Altitude Observatory, NCAR, Boulder, CO, USA;
[3] Metropolitan State College of Denver, USA, [4] Royal Observatory of Belgium, Brussels

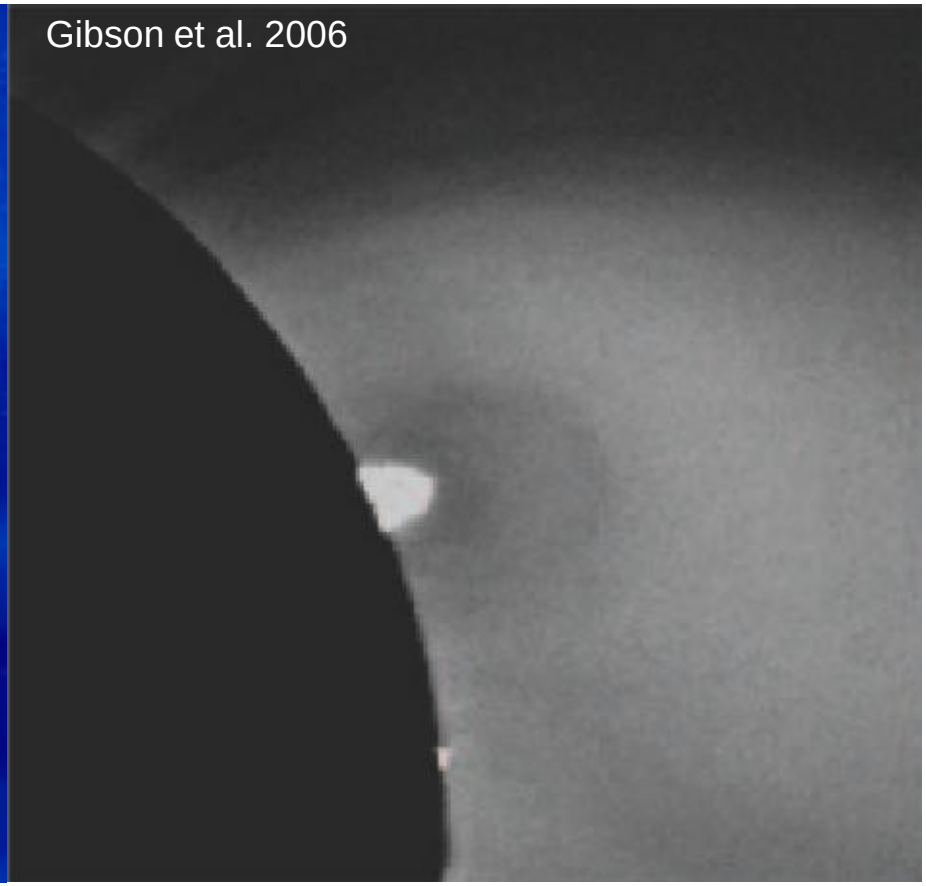


Kanzelhöhe Observatory Colloquium, October 8-10 2013

Coronal cavities



Illing & Hundhausen 1986

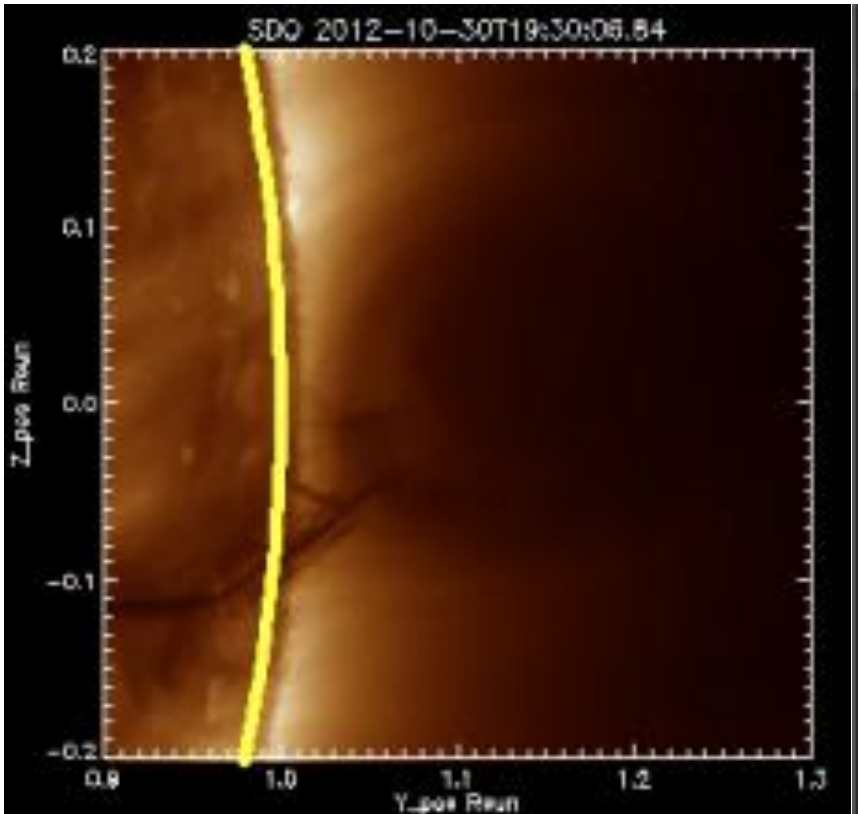


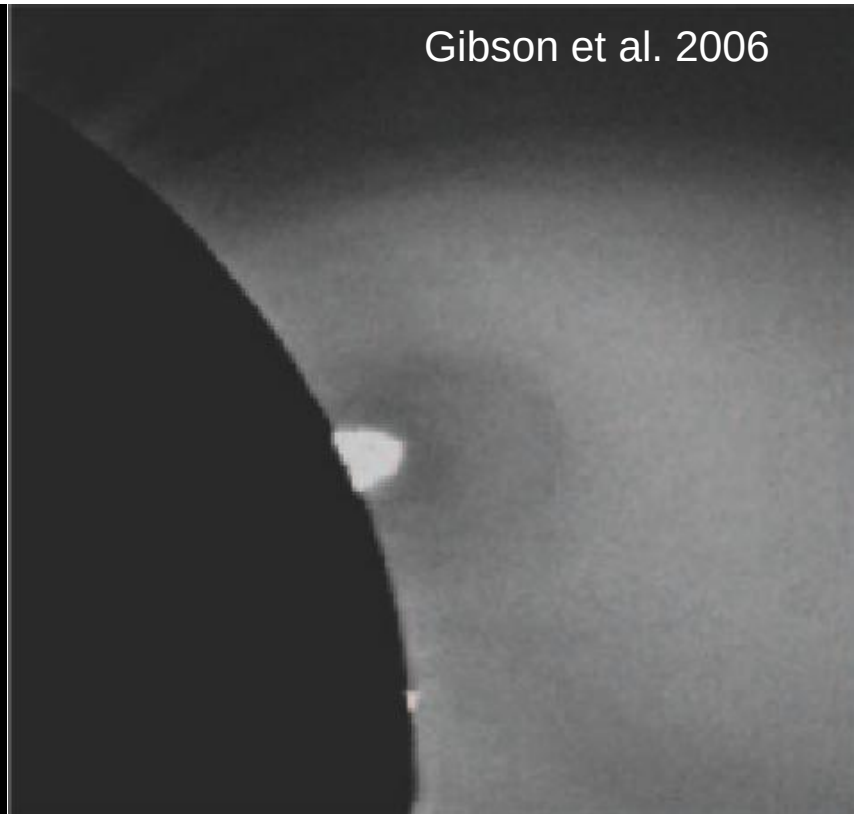
Vaiana et al. 1973
Tandberg-Hanssen 1974

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 $R_{\odot}$)

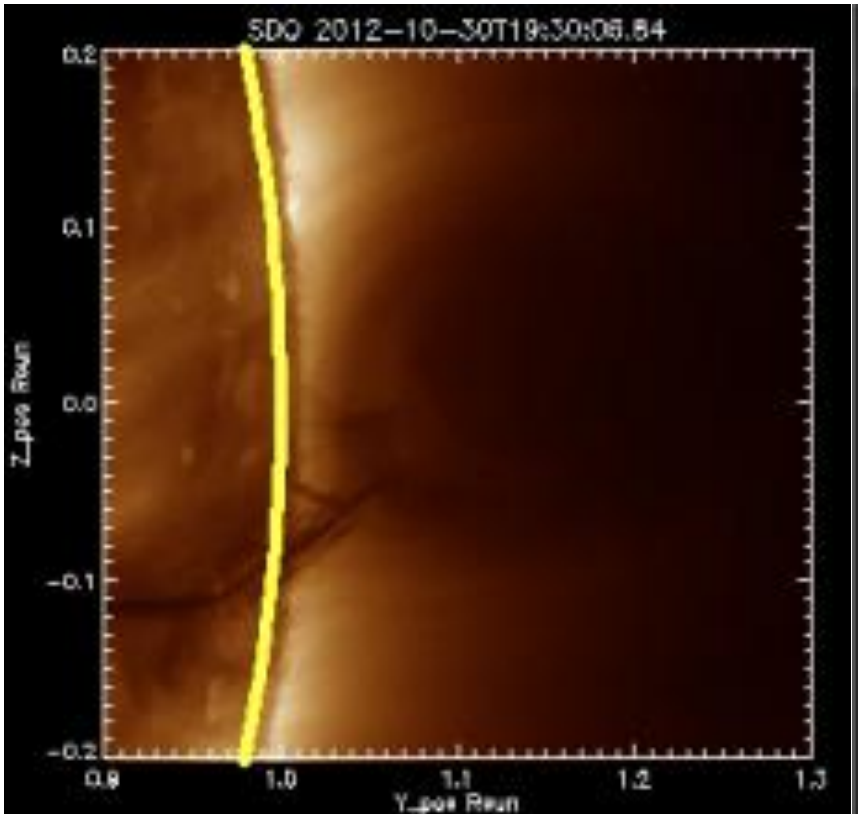


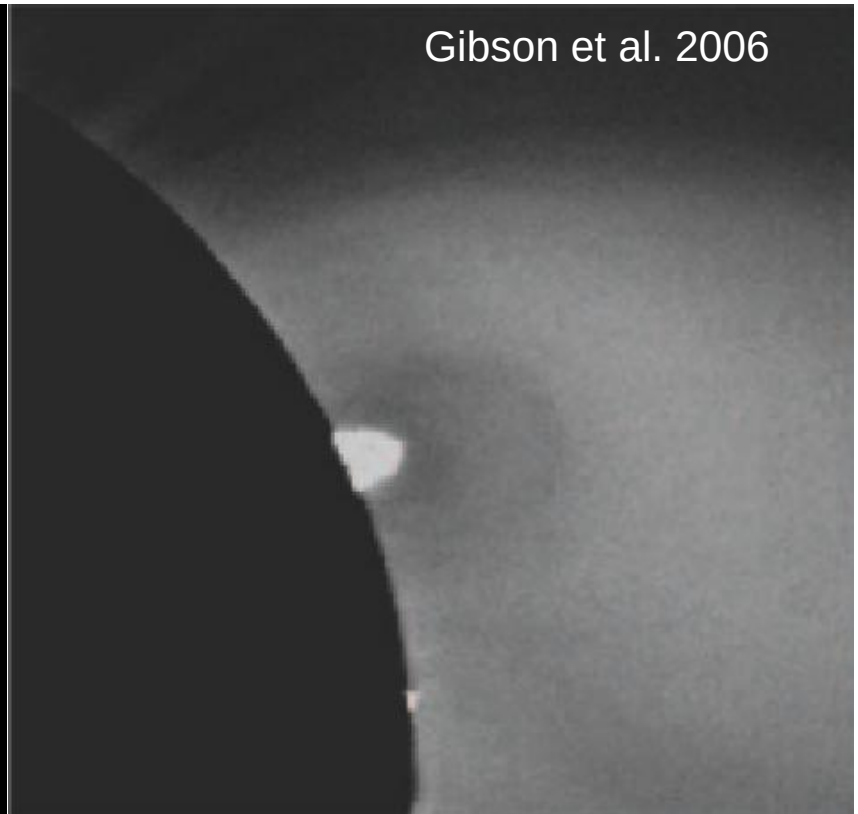


Coronal cavities

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)





Uniwersytet Wrocławski

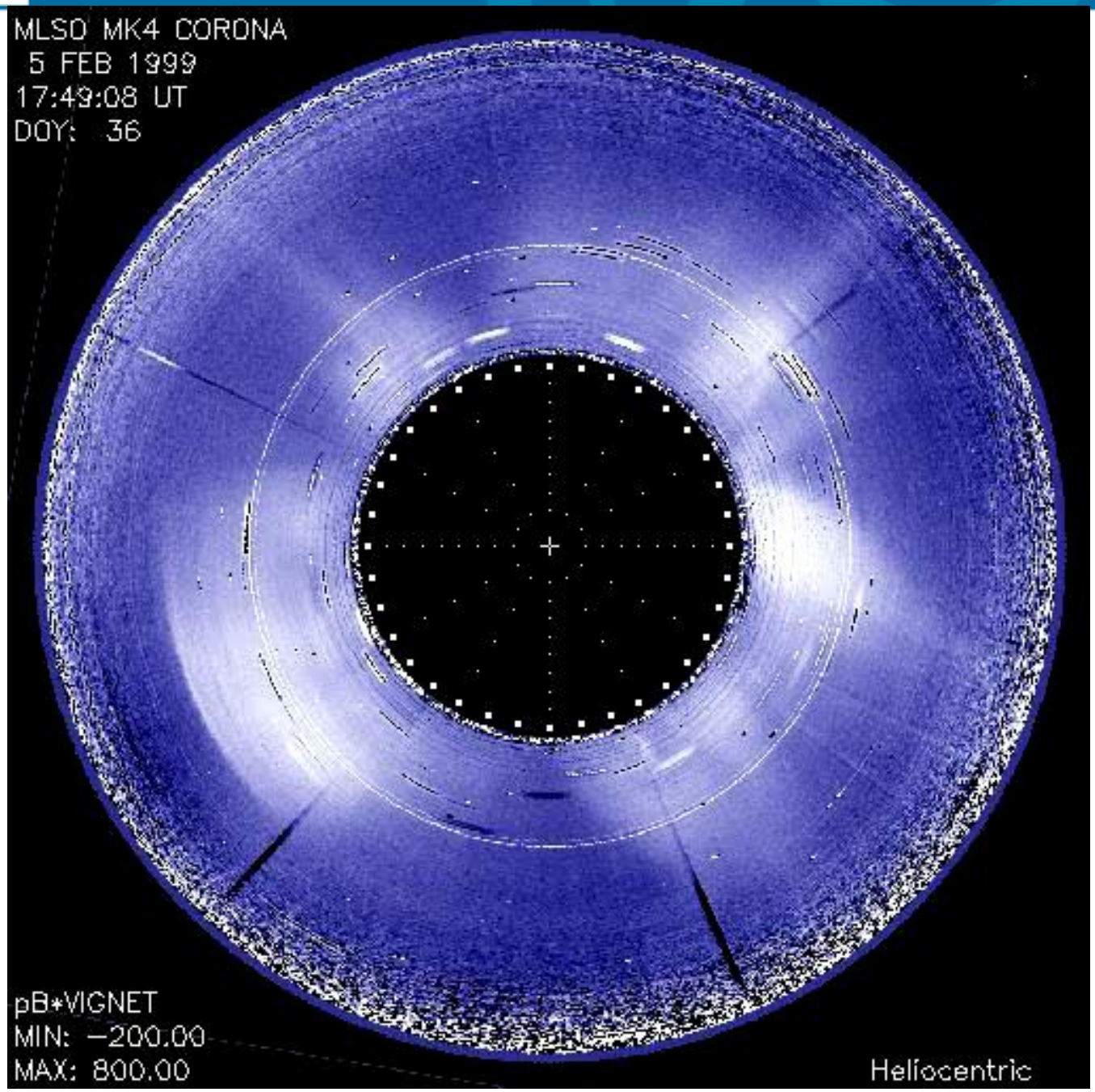
Coronal cavities

- 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).

Uniwersytet Wrocławski

Coronal cavities

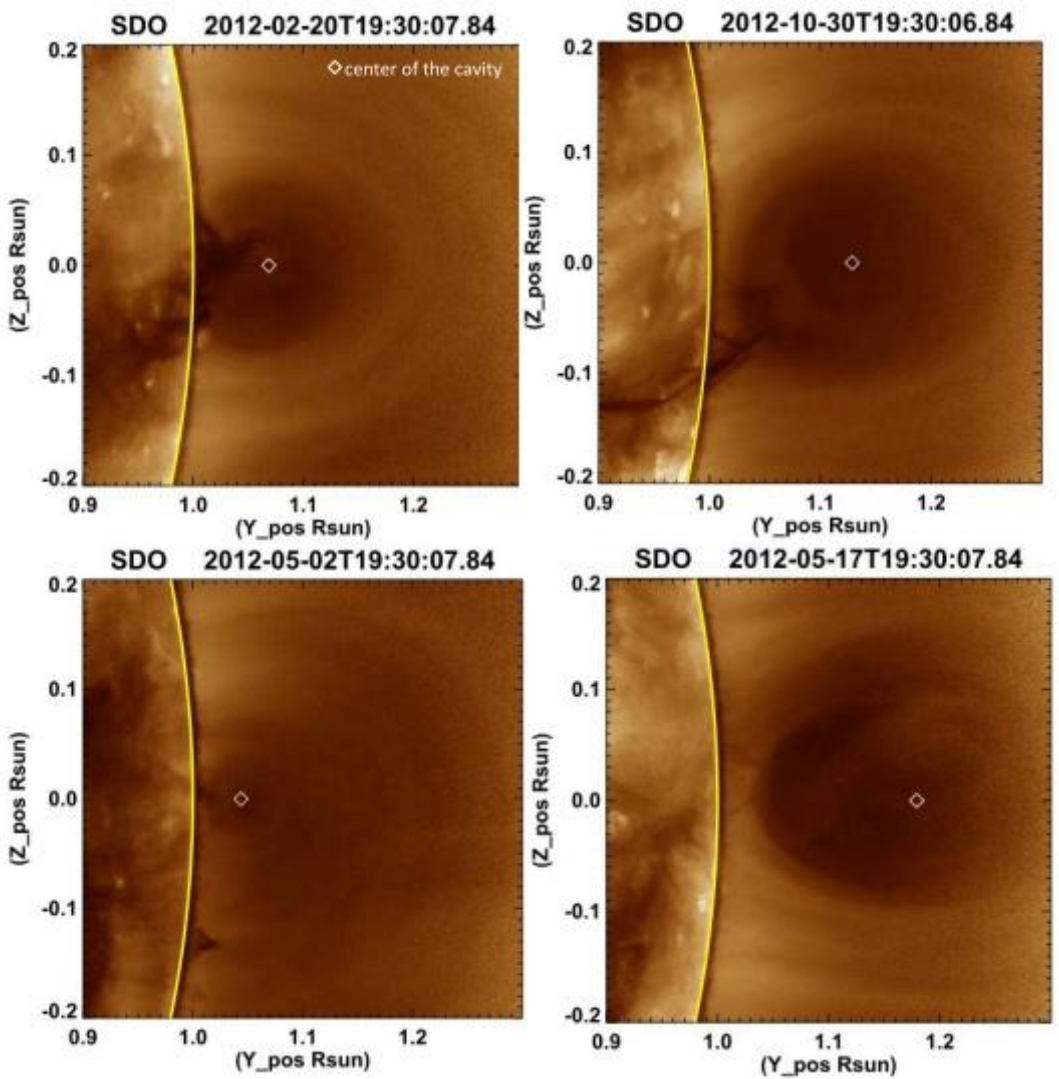


Gibson et al. 2006

Uniwersytet Wrocławski

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

Bąk-Stęślicka et al. 2013, ApJL, 770, 28

Uniwersytet Wrocławski

Coronal Multi-channel Polarimeter (CoMP)

Tomczyk, et al. 2008

Information about the magnetic field, plasma density and motion.

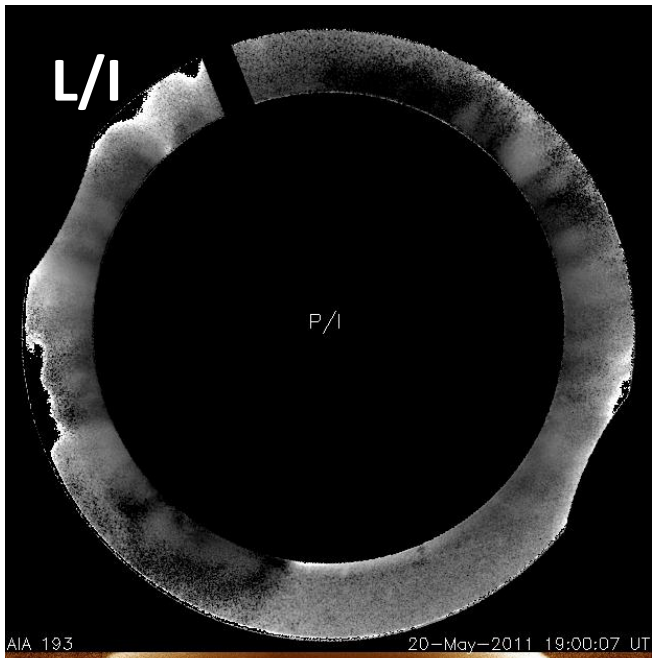
- FOV ~1.04 to 1.4 $R_{\odot}$
- Location: Mauna Loa Solar Observatory - daily observations since October 2010
- CoMP records the intensity and the linear and circular polarization (Stokes I,Q,U,V) of the forbidden lines of Fe XIII at 1074.7 nm and also at 1079.8 nm.
- CoMP also measures the LOS plasma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

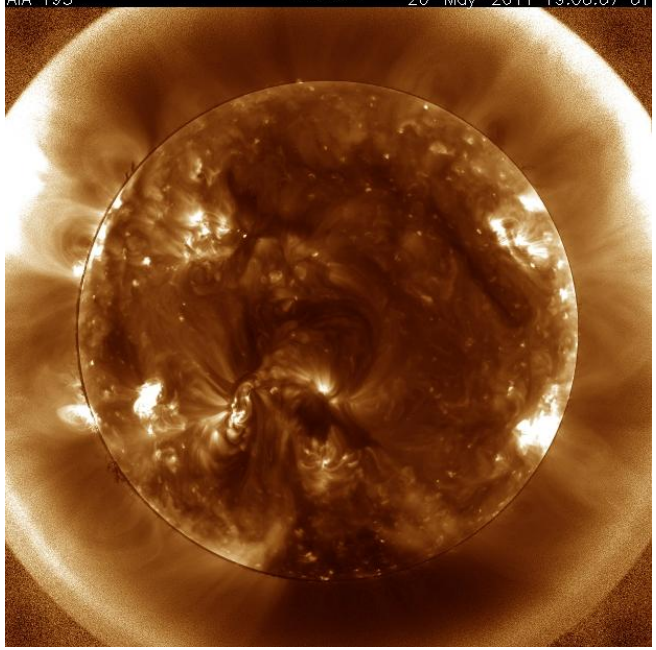
Polarization

- 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

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

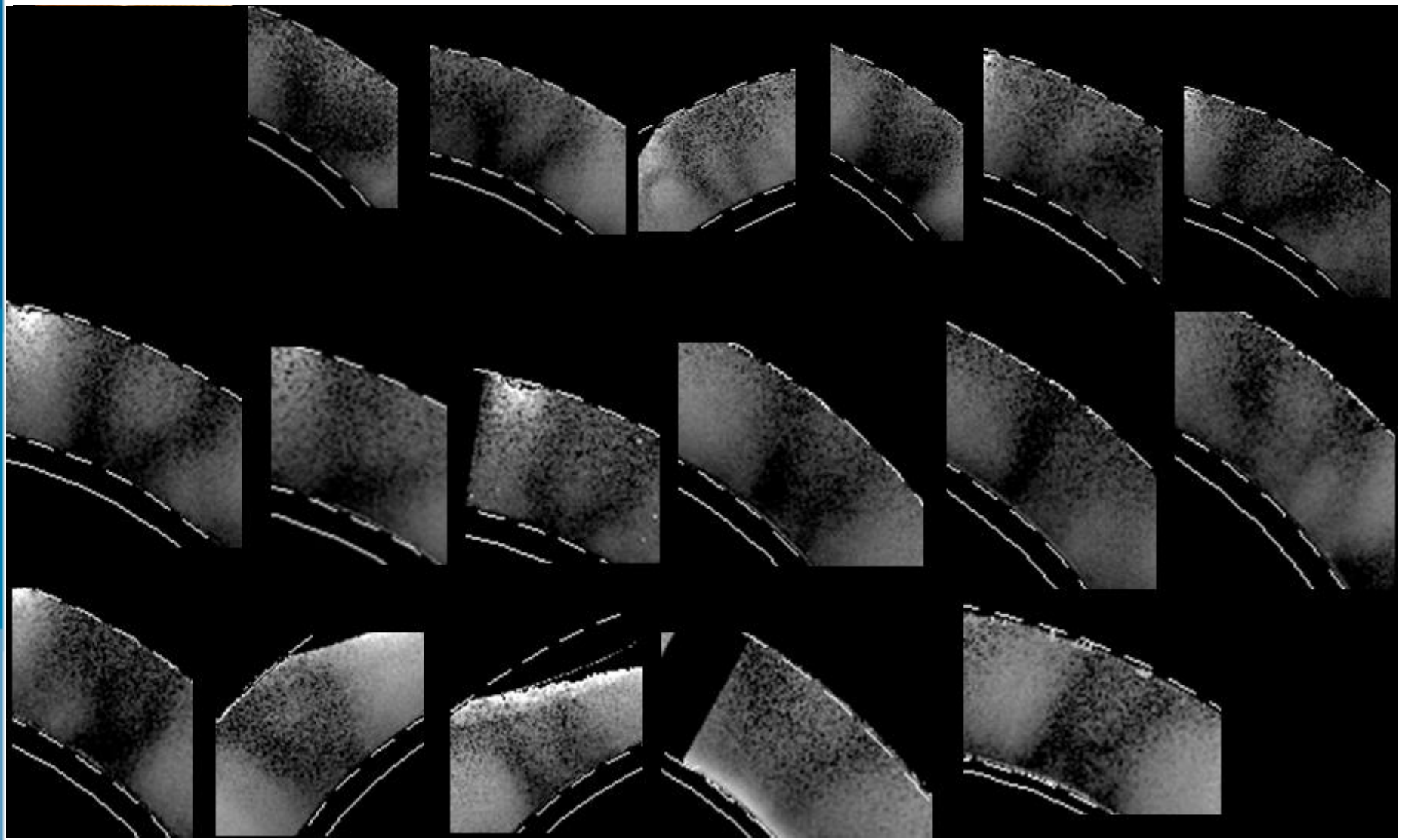
$$\phi = \tfrac{1}{2}\tan^{-1}(U/Q)$$





Uniwersytet Wrocławski

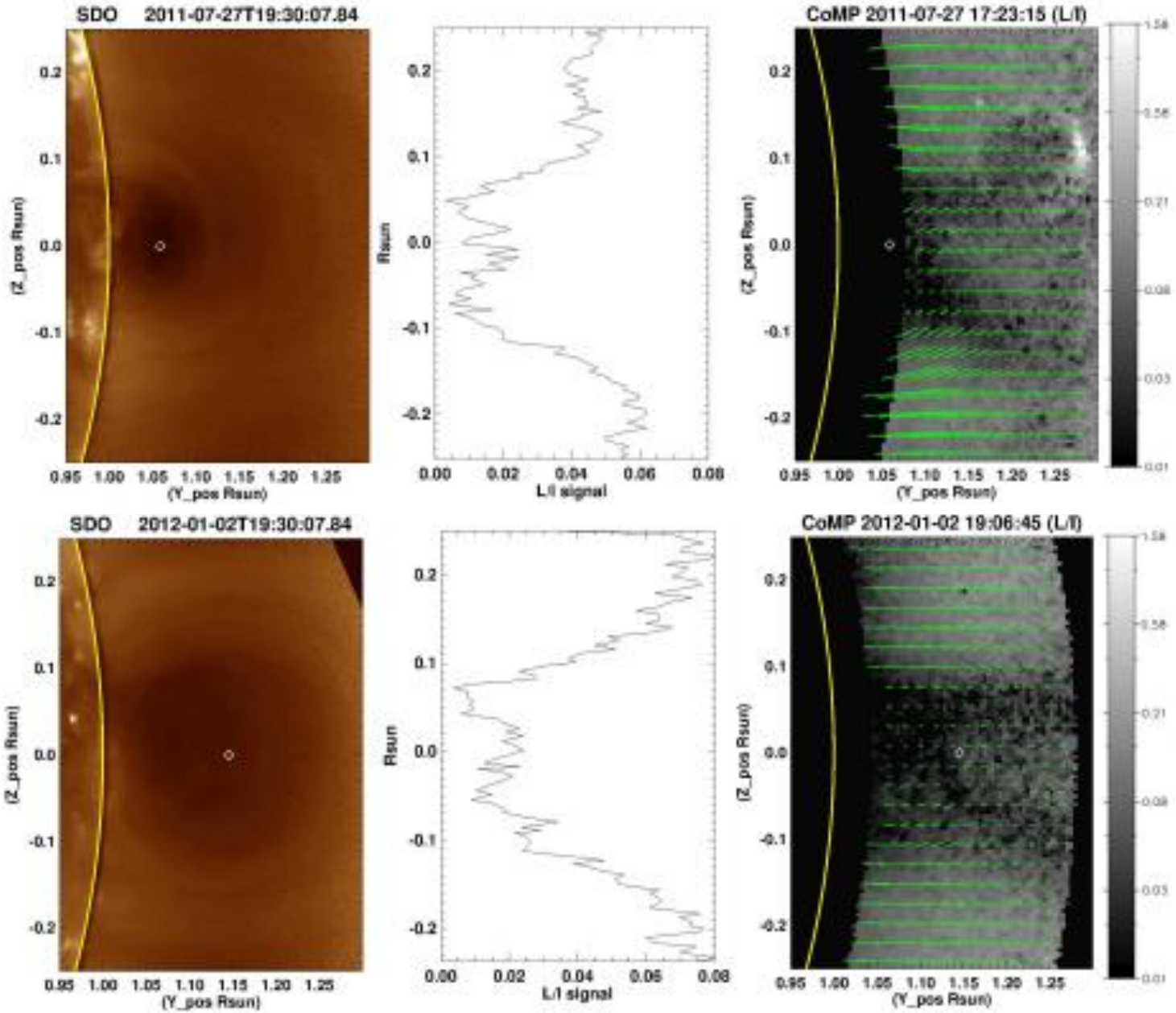
Coronal cavities in linear polarization



May 2011- December 2012 – 68 structures observed during 78 days

Uniwersytet Wrocławski

Observations in linear polarization



Bąk-Stęślicka et al. 2013, ApJL, 770, 28

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

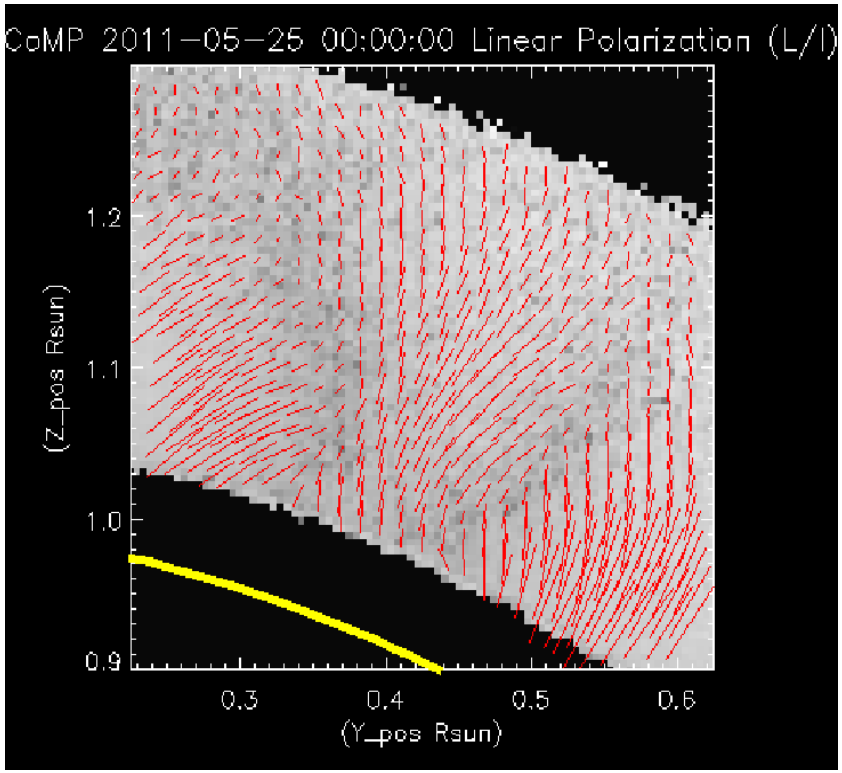
$L/I \sim \sin^2\Theta$

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

L=0
provides the most useful informations

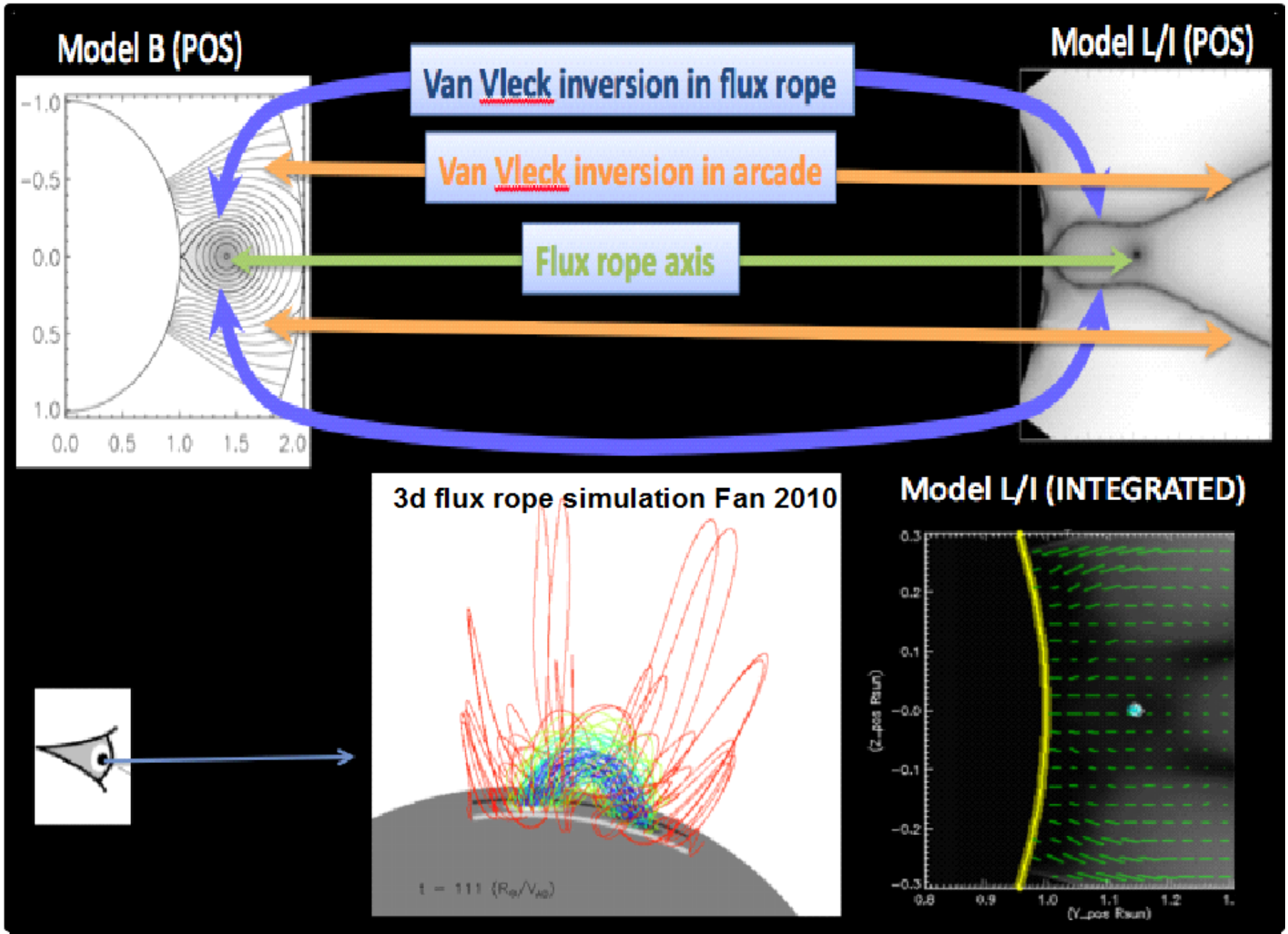
weak signal: $\Theta=0°,180°$
weak signal: Van Vleck inversion at $\vartheta=54°.7$

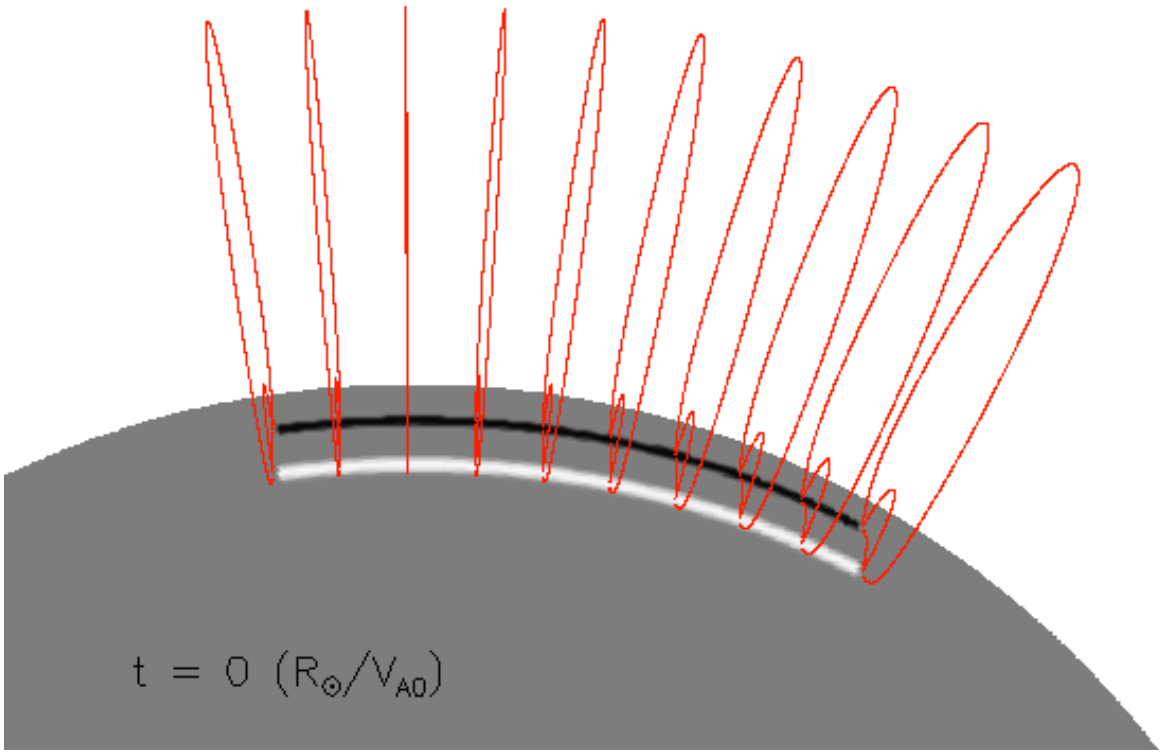
see also: Rachmeler et al., 2012; Rachmeler et al., 2013



Uniwersytet Wrocławski

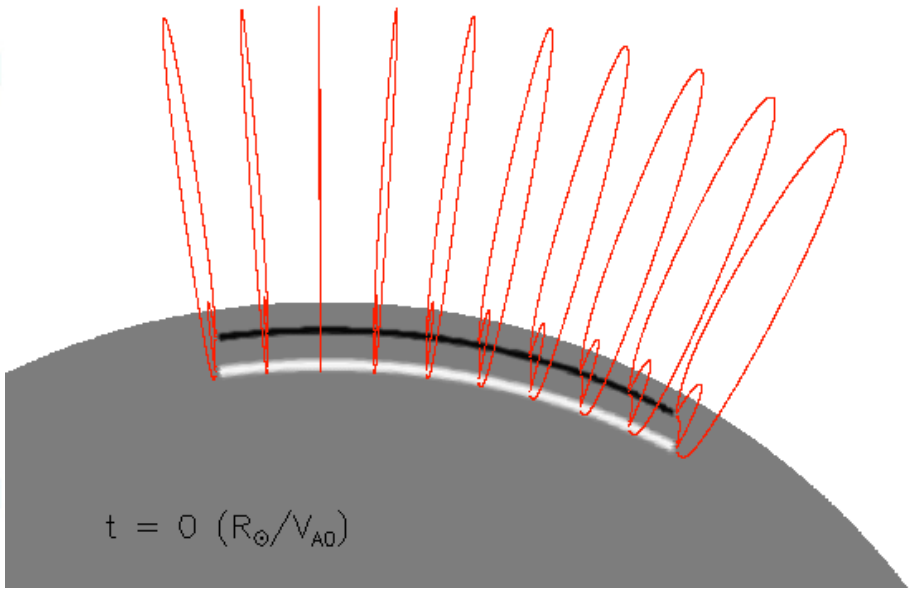
Magnetic flux rope polarization signatures





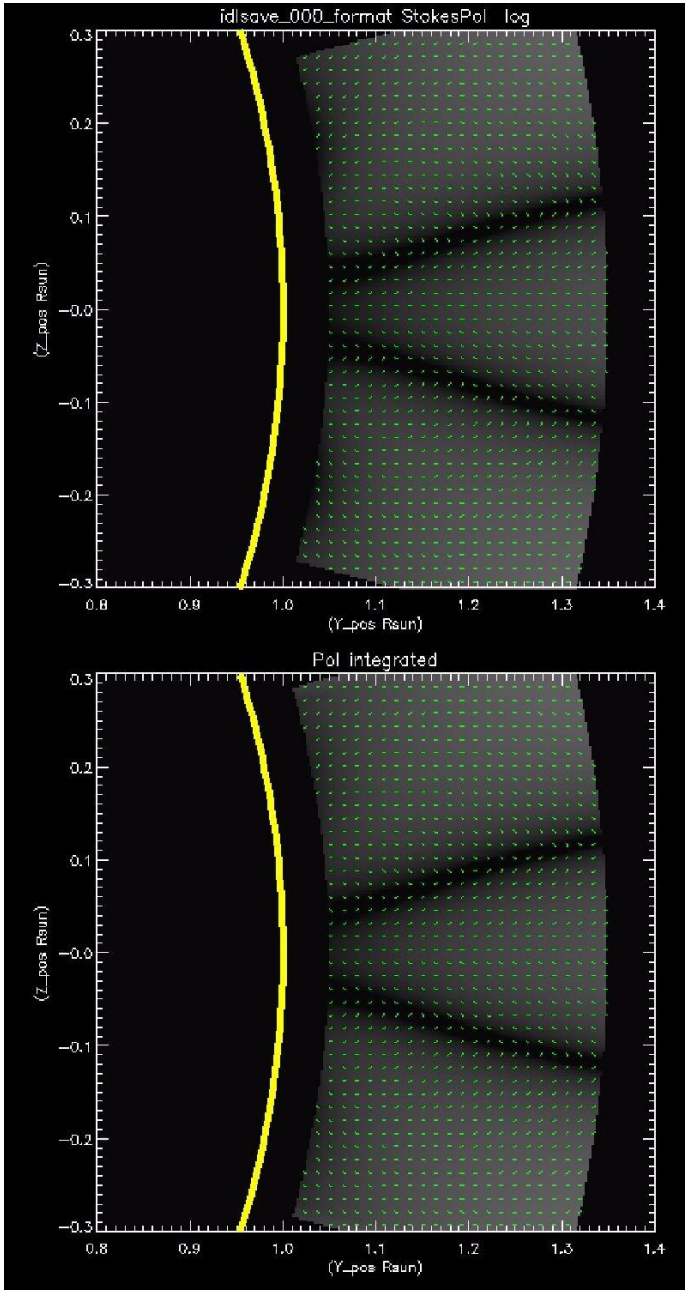
Fan 2010 - 3d flux rope simulation

Uniwersytet Wrocławski



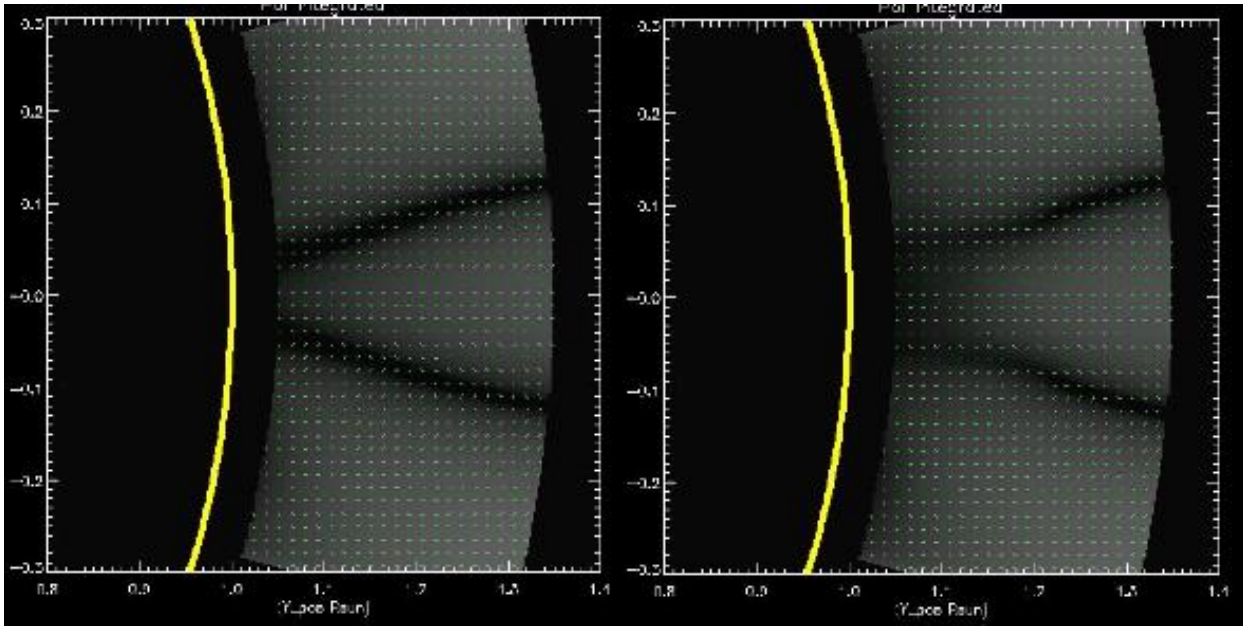
Fan 2010 - 3d flux rope simulation

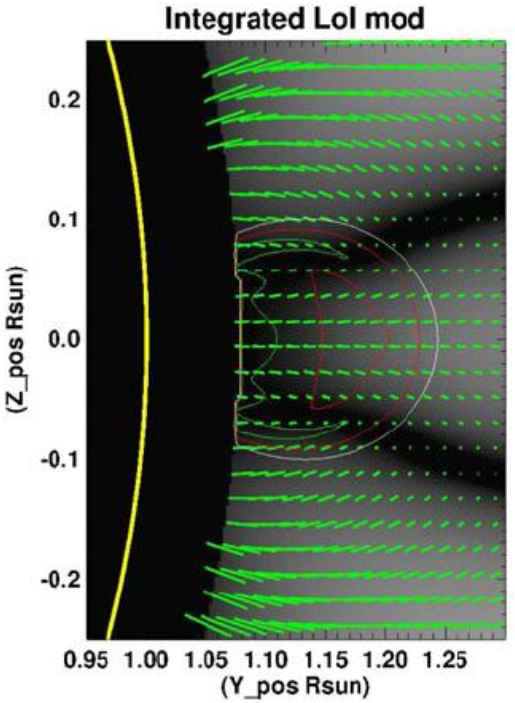
Model L/I POS



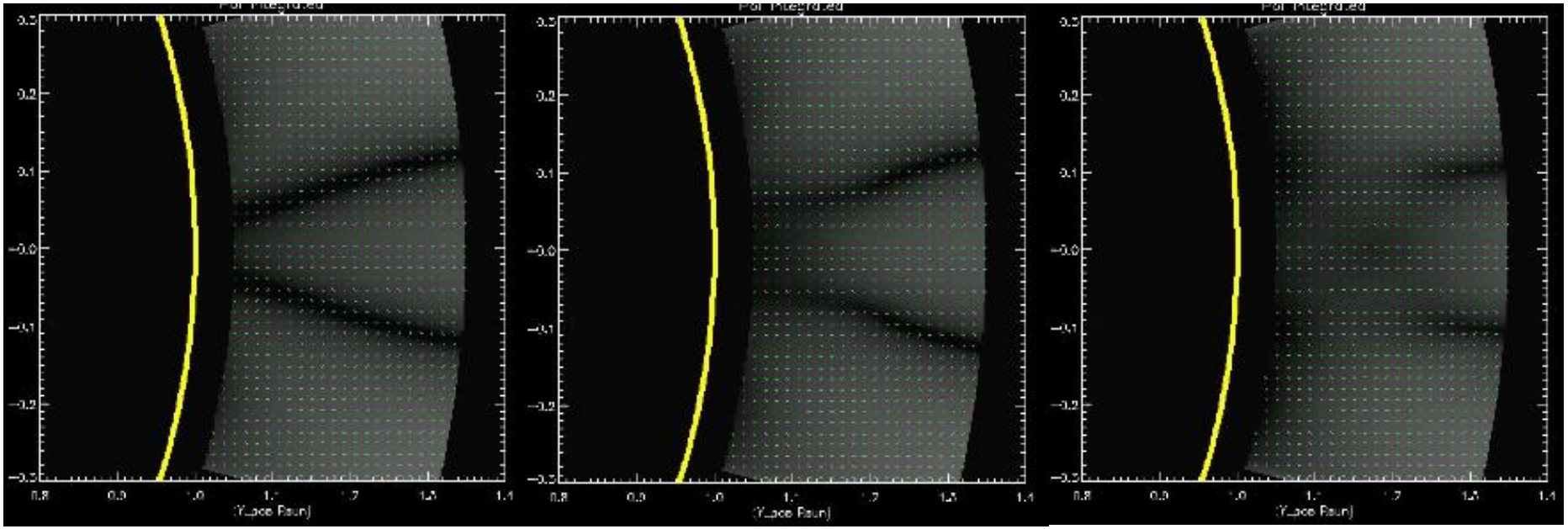
Model L/I LOS

Forward model

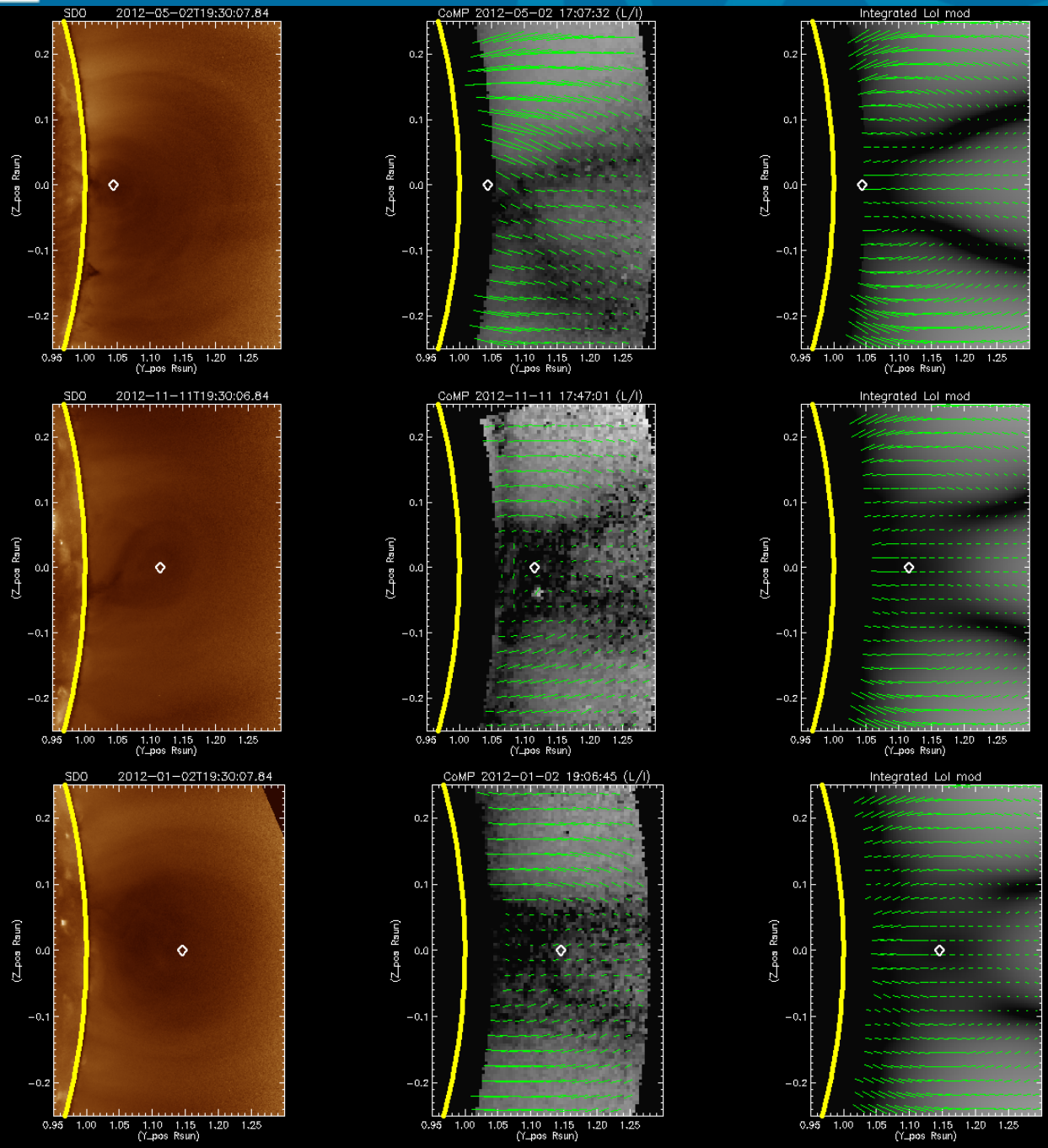




Forward model



Uniwersytet Wrocławski

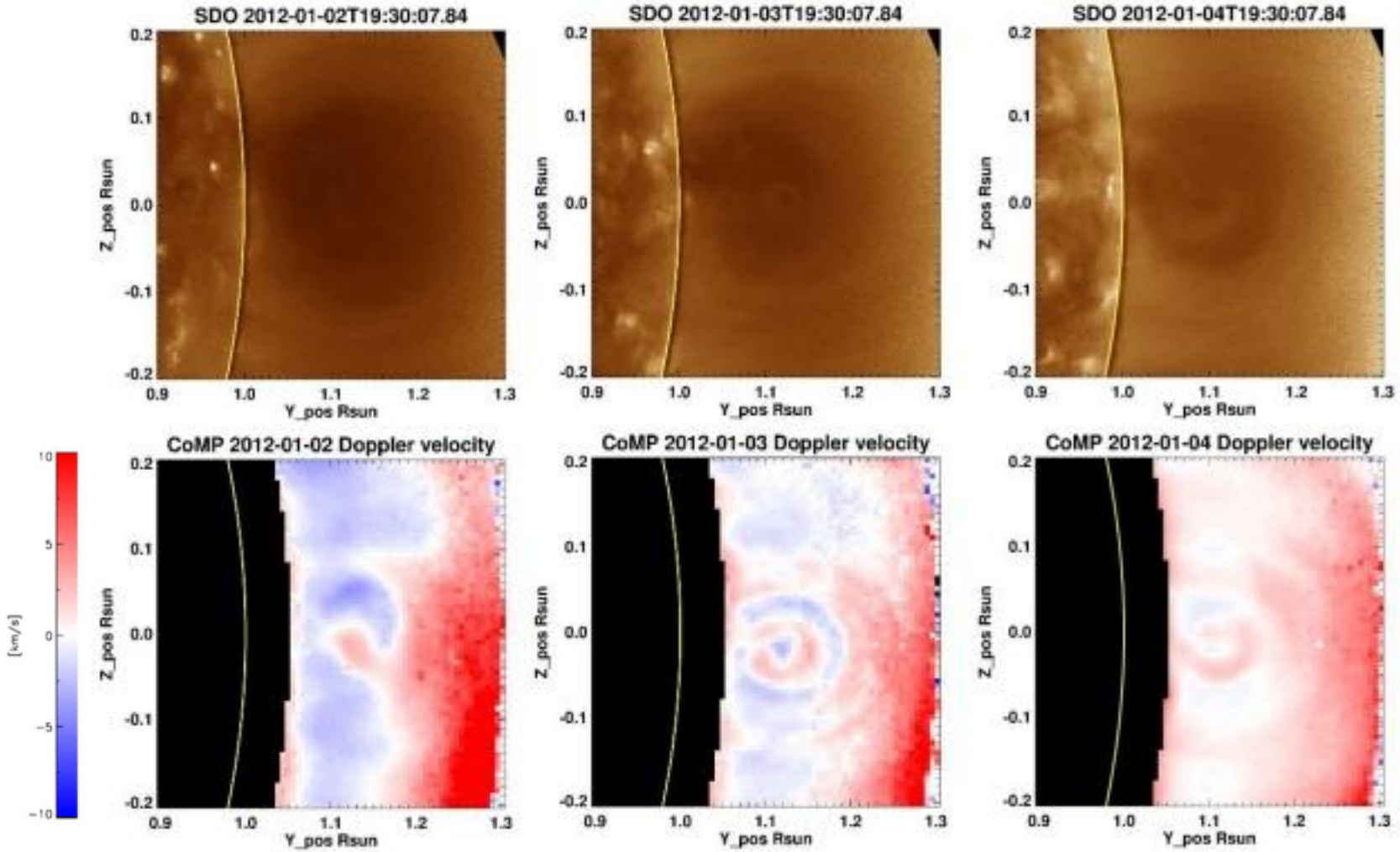


Uniwersytet Wrocławski

Doppler velocity

Schmit et al. (2009) found Doppler velocities of 5–10 km s^{-1} within a coronal cavity.

January 2, 3, 4

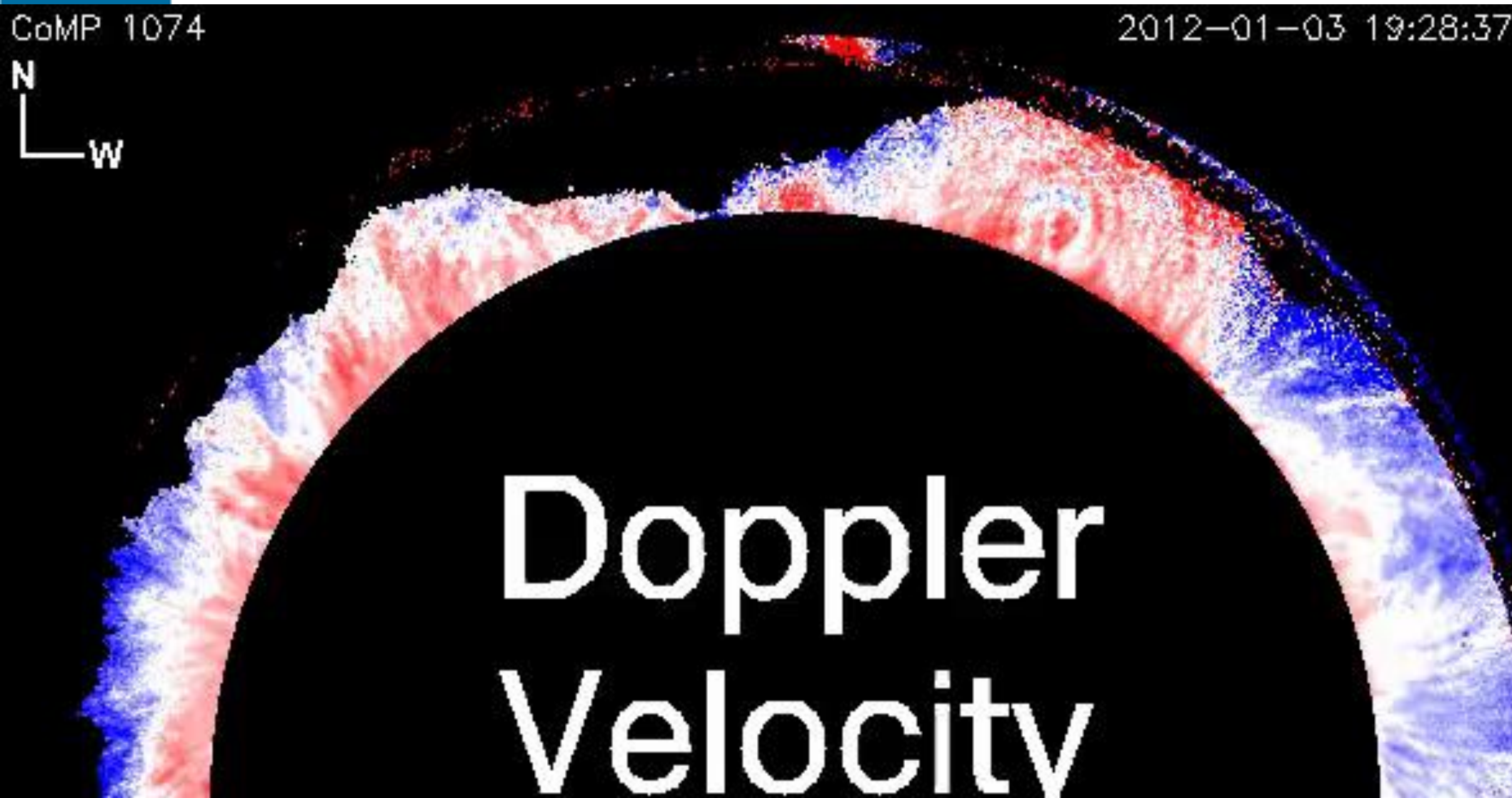


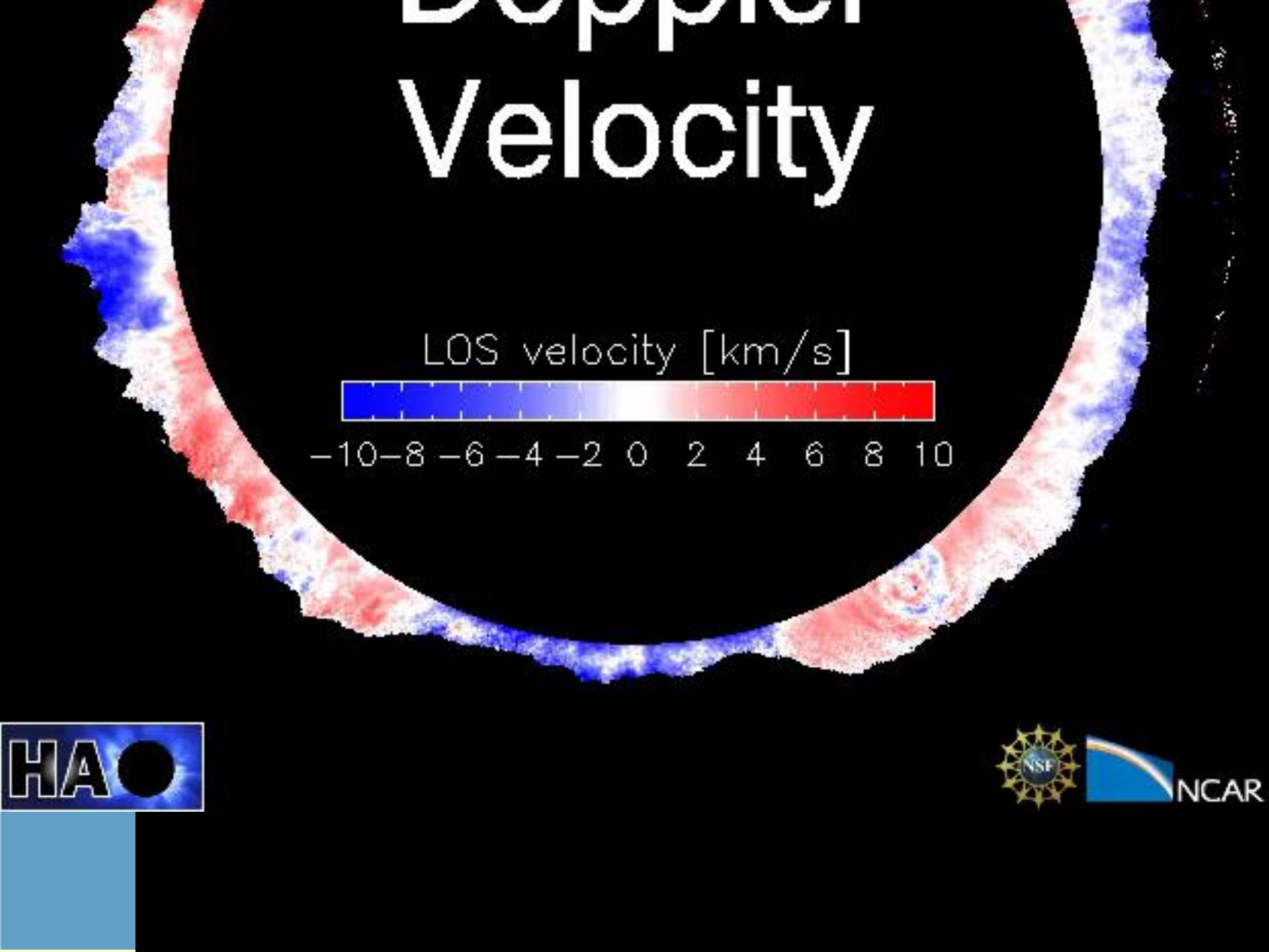
Bąk-Stęślicka et al. 2013, ApJL, 770, 28

Uniwersytet Wrocławski

Doppler velocity

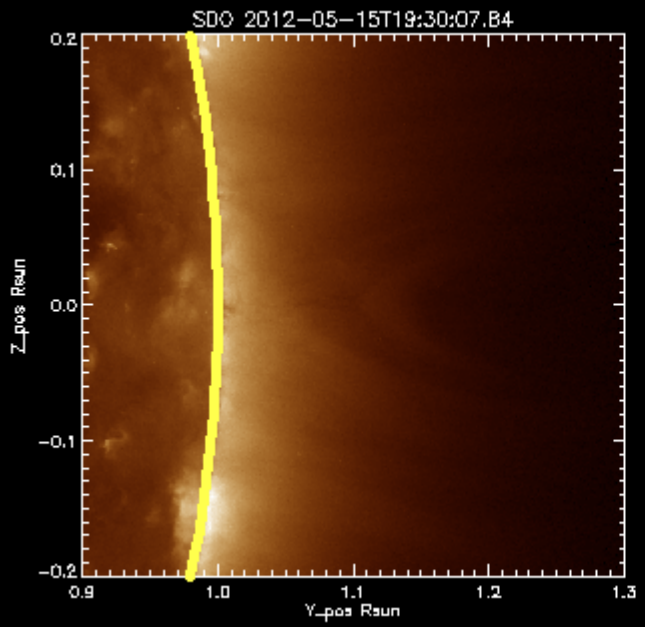
2012 January 3

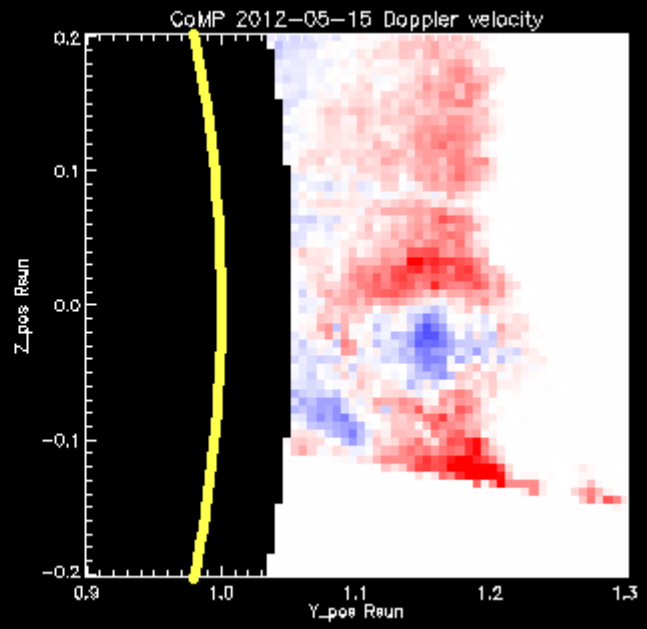


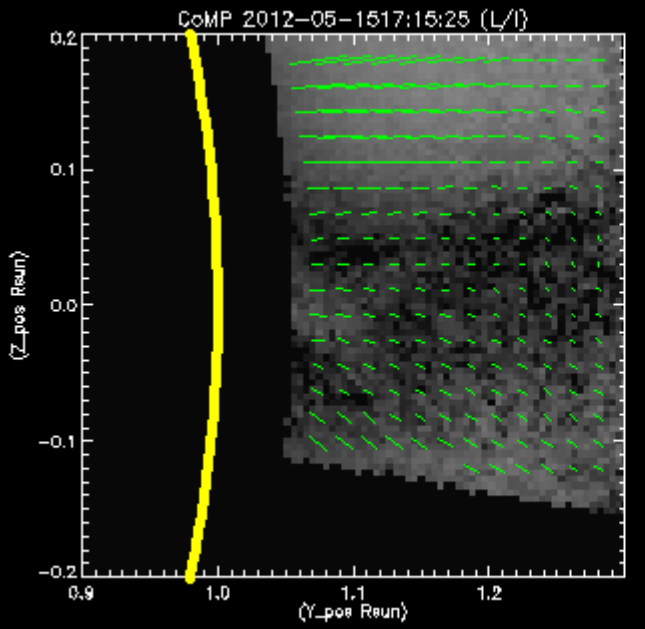

Doppler
Velocity
LOS velocity [km/s]
−10 −8 −6 −4 −2 0 2 4 6 8 10
HAO
NSF
NCAR

Uniwersytet Wrocławski

Doppler velocity

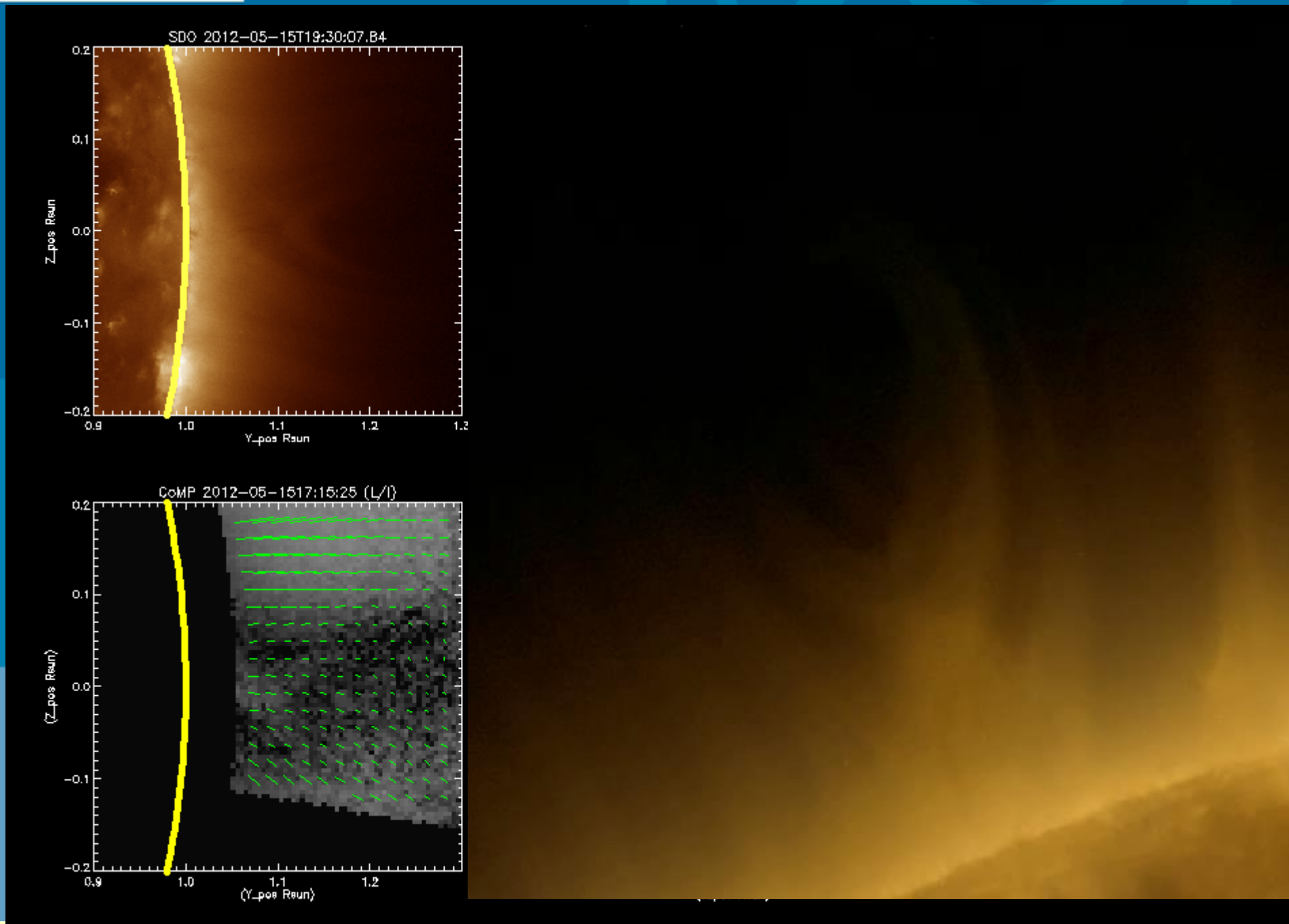






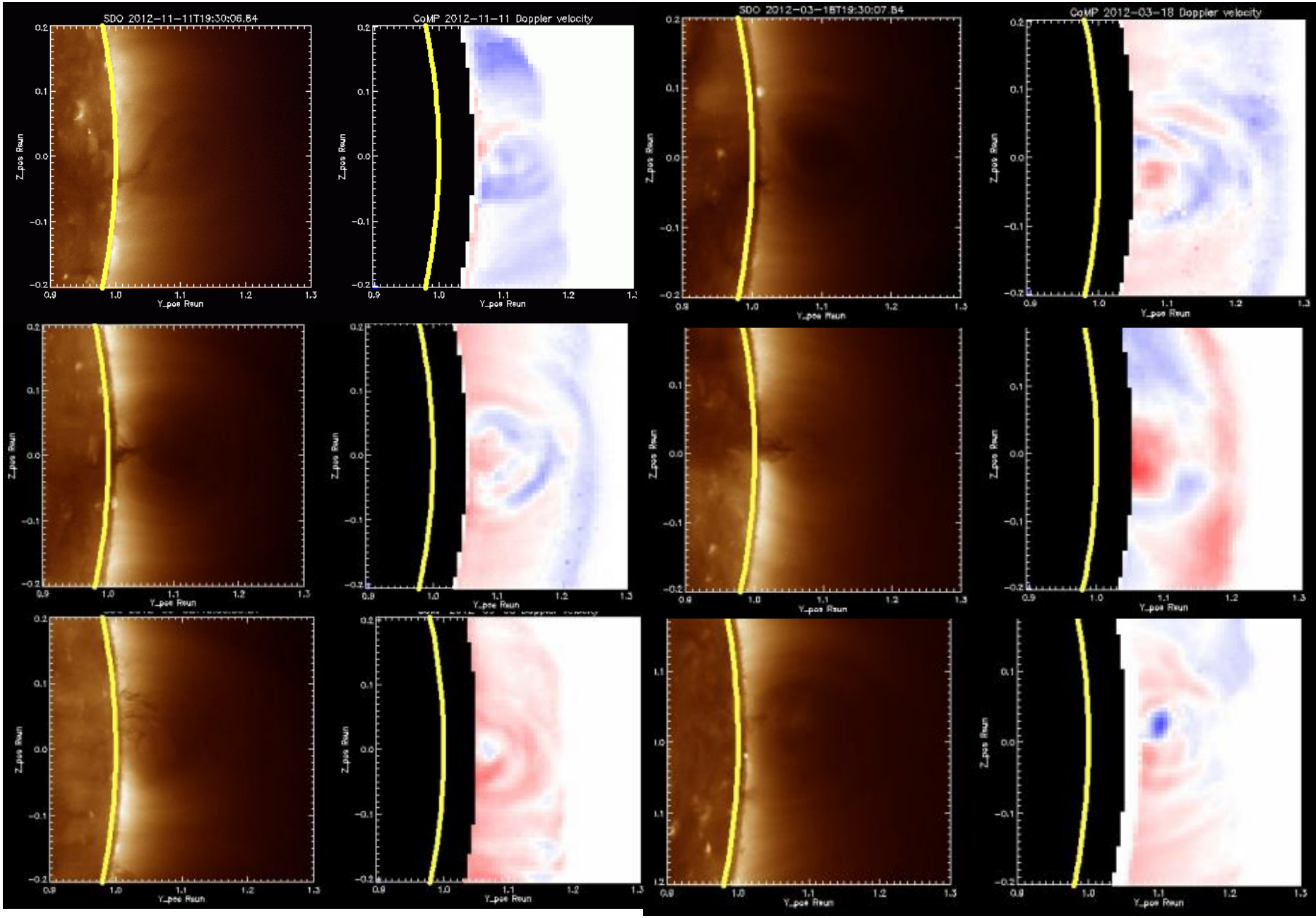
Uniwersytet Wrocławski

Doppler velocity



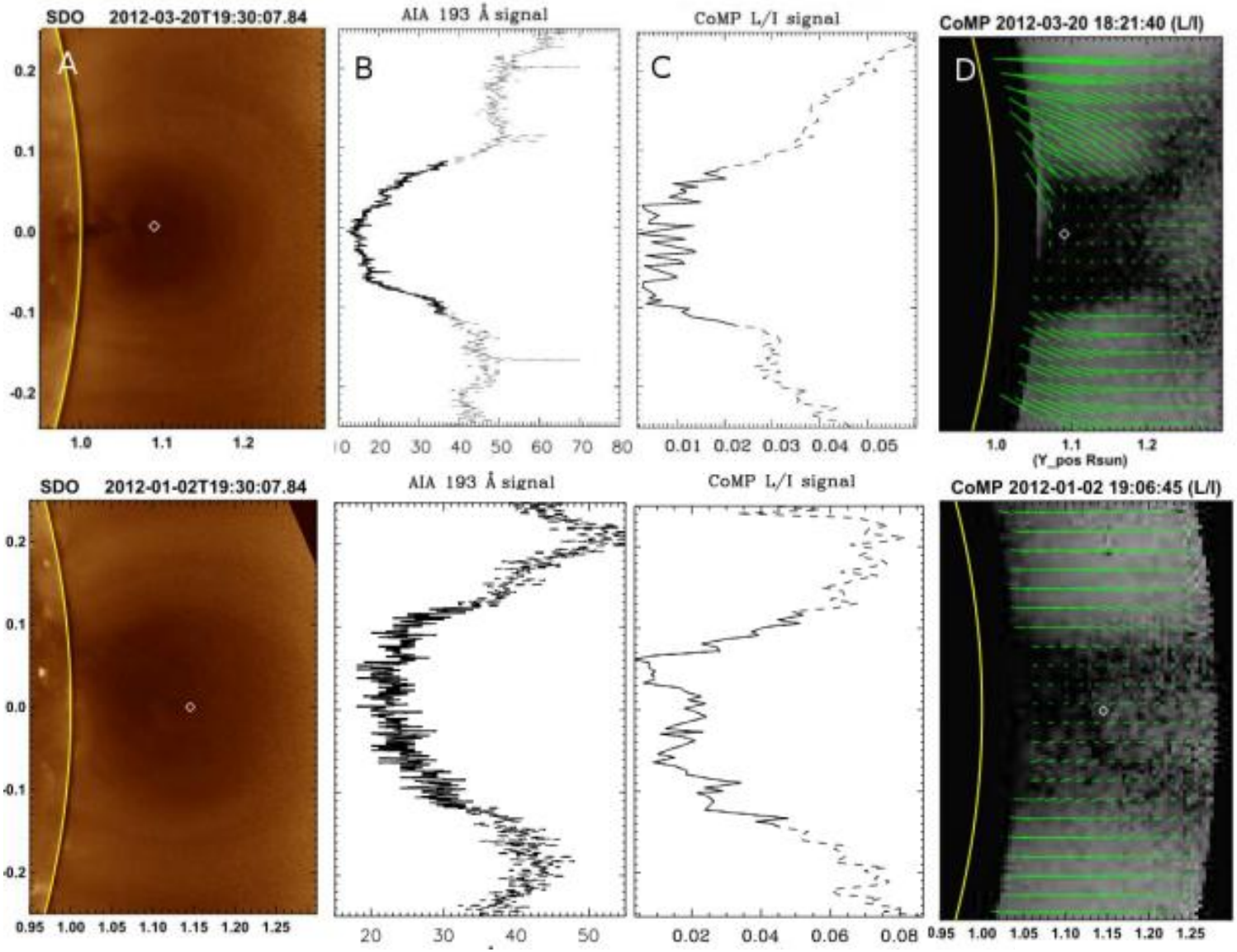
Uniwersytet Wrocławski

Doppler velocity



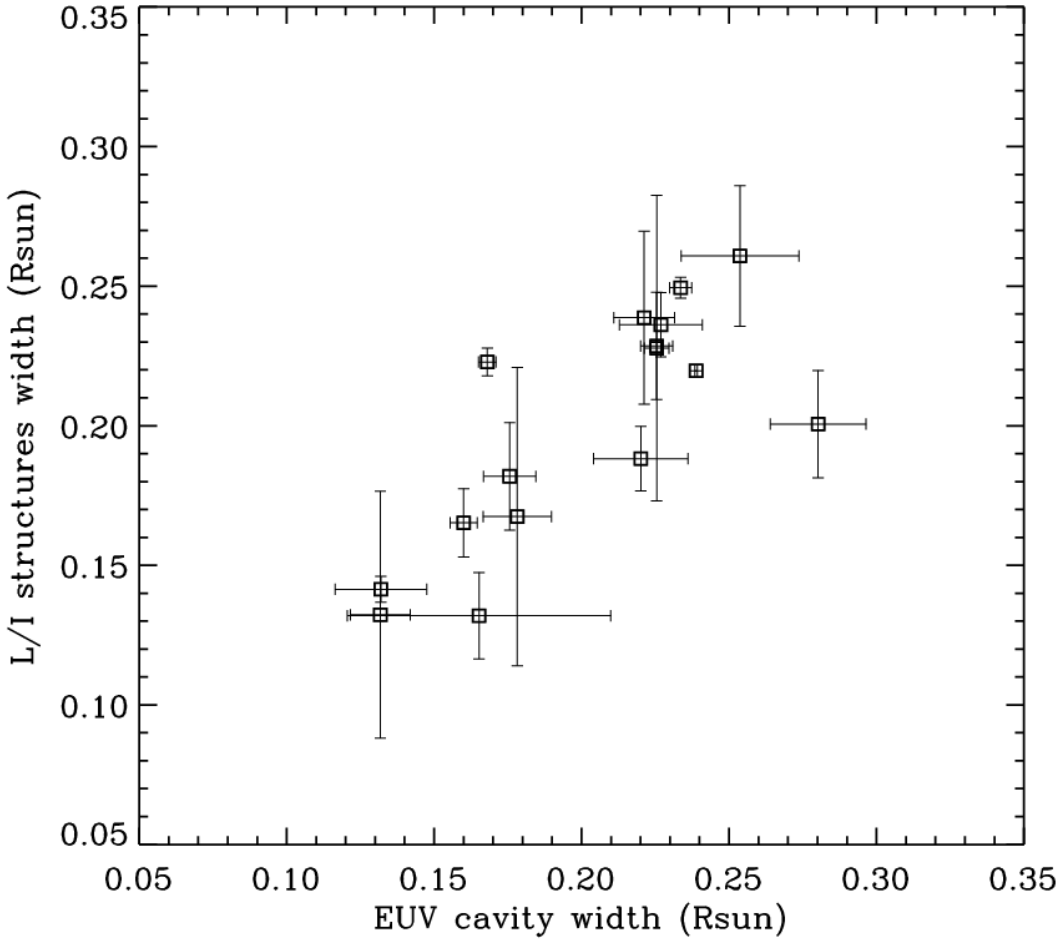
Uniwersytet Wrocławski

The spatial relation between EUV cavities and linear polarization signatures



Uniwersytet Wrocławski

The spatial relation between EUV cavities and linear polarization signatures



Bąk-Stęślicka et al., 2013, Nature of Prominences and their Role in Space Weather Proceedings IAU Symposium No. 300 , *in press*

Conclusions

- Using new CoMP observations we've found, that polar crown cavities are commonly associated with lagomorphic structures. We found 68 different structures during 78 days.
- Observed structures can be explained with flux rope model.
- Line-of-sight velocity shows ring-like structures - consistent with flows along flux surfaces of magnetic flux rope.
- Size of the lagomorph structure scales with the size of the cavity.

Uniwersytet Wrocławski

Thank you