Kinematical Characterization of Intensity Fluctuations Observed in STEREO EUVI Images

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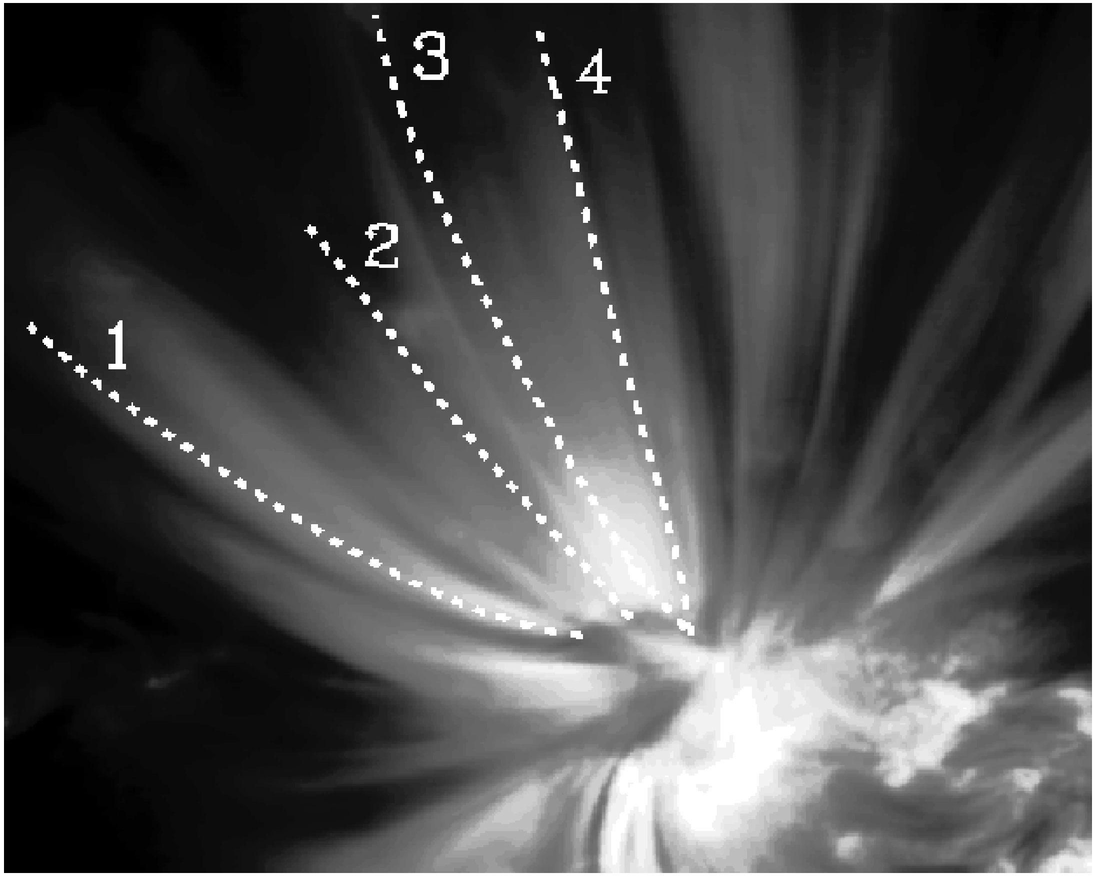
Motivation - Robbrecht Waves

Slow Magnetoacoustic Waves in Coronal Loops: EIT and TRACE
E. Robbrecht, E. Verwichte, D. Berghmans, J. Hochedez, S. Poedts, V. Nakariakov
A&A, Vol 370, pp. 591-601, 2001.



Telescopes: SOHO/EIT and TRACE
Projected Speed: 65 - 150 km/s
True Speed: ??

- May 13th, 1998 JOP Campaign.

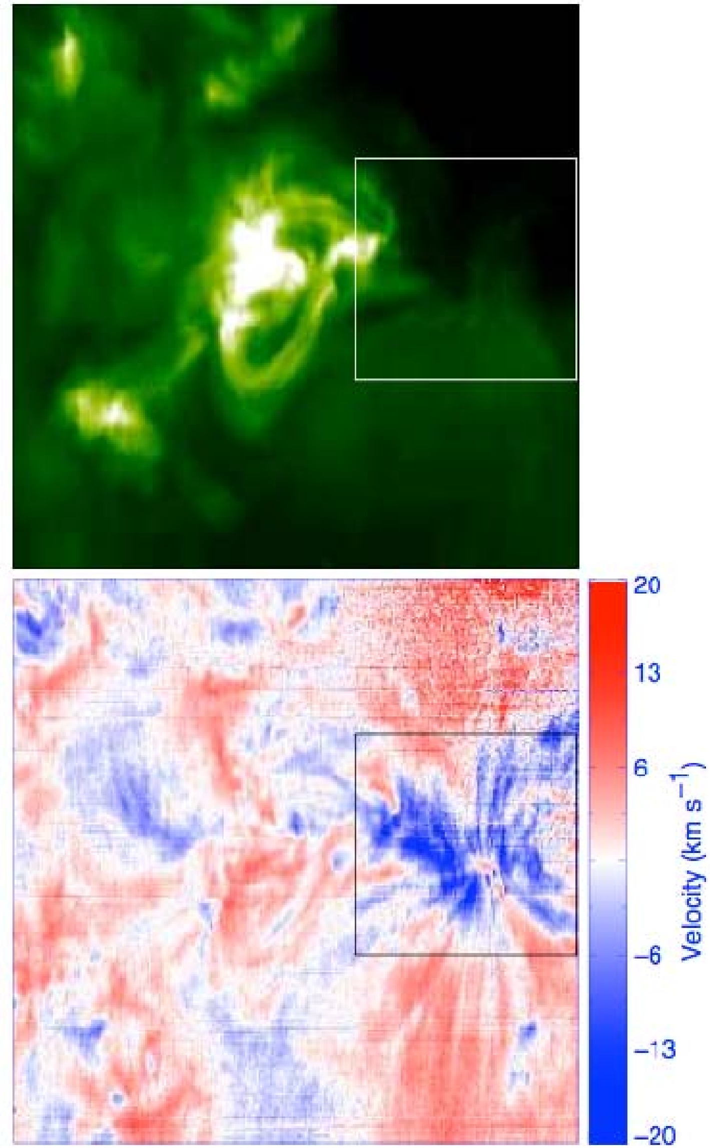
Motivation - Doschek Outflows

- Outflows from the Sun somehow make up the slow solar wind.
- Doppler-shifted EIS measurements to validate result.
- Also, analyzes a Dec 11, 2007 AR.
- **Top**: FeXII 195.12 A intensity for August 23, 2007 AR
- **Bottom**: Doppler Map (blue is towards the observer) obtained with the Extreme-ultraviolet Imaging Spectrometer (EIS) on the Hinode S/C.

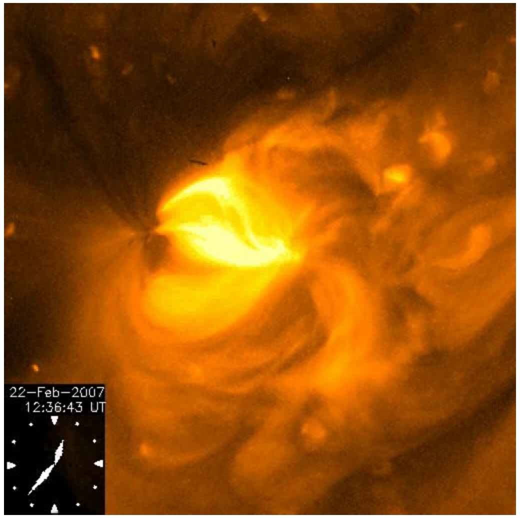
Flows and Non-thermal Velocities in Solar Active Regions Observed with Hinode/EIS: A Tracer of Active Region Sources of Heliospheric Magnetic Fields?

G. Doschek, H. Warren, J. Mariska, K. Muglach, J. Culhane , H. Hara, T. Watanabe
ApJ, Vol 686, pp. 1362-1371, 2008.

Telescope: HINODE/EIS
LOS Speed: 20-50 km/s
True Speed: ?



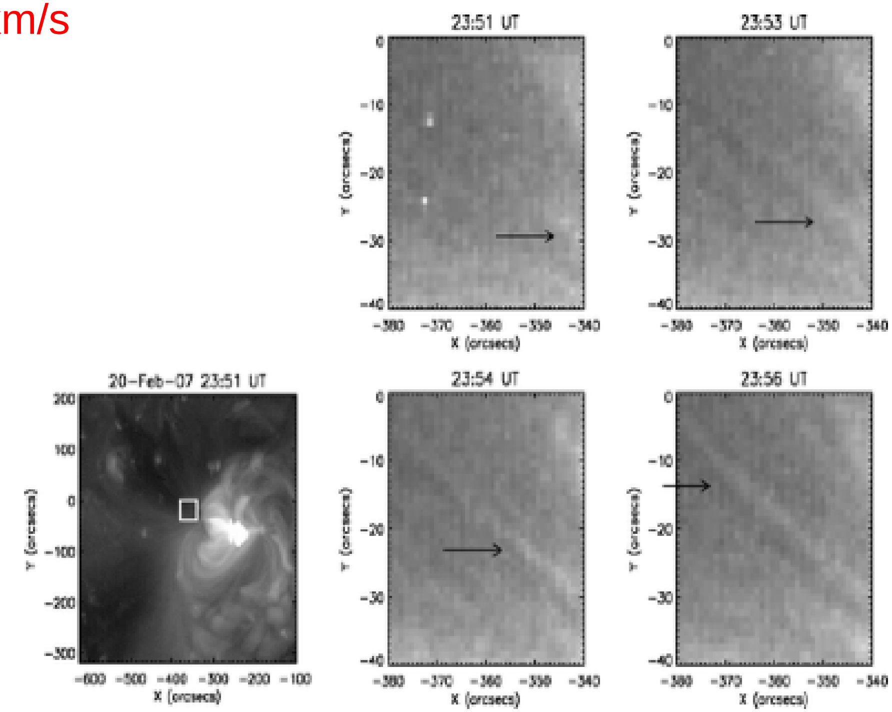
Motivation - Harra Outflows



Outflows at the Edges of Active Regions: Contributions to Solar Wind Formation?
L. Harra, T. Sakao, C. Mandrini, H. Hara, S. Imada, P. Young, L. Van Driel-Gesztelyi, D. Baker
ApJ, Vol 676, pp. L147-L150, 2008.

Telescope: Hinode/XRT
LOS Speed: 20-50 km/s
True Speed: >100 km/s

- The outflows are the major contributor to the slow solar wind.
- Outflow occurs at EDGES of active regions.
- Large scale loops lie over active region and open to interplanetary space.
- Doppler shifted EIS measurements were used as comparison.



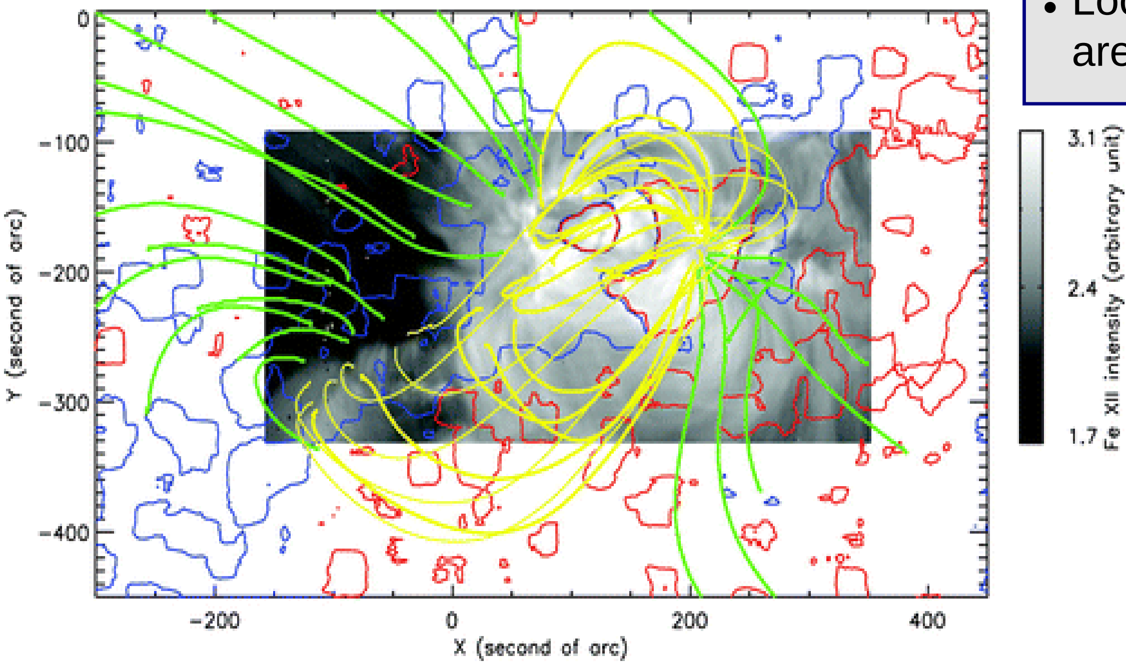
Motivation - Marsch Outflows

Plasma Flows Guided by Strong Magnetic Fields in the Solar Corona

E. Marsch, H. Tian, J. Sun, W. Curdt, T. Wiegelmann

ApJ, Vol 685, pp. 1262-1269, 2008.

Telescope : Hinode/EIS
Contours : Force-free magnetic field model
LOS Speed: ??
True Speed: ??



- Photospheric convection drives a global "coronal circulation".
- Most blue shifted occurrences are associated with open or large looped field lines.
- Agrees with Harra et al. - mass outflow is contributing to the slow solar wind through "open" field lines.
- Using force-free magnetic field model to define open/closed lines.
- Loops of specified height (~100,000km) are considered open field lines.

Why STEREO/EUVI ?

STEREO Advantage

• **Continuous coverage**:

EUVI data does not suffer from small FOV/telemetry problems of Hinode payload.

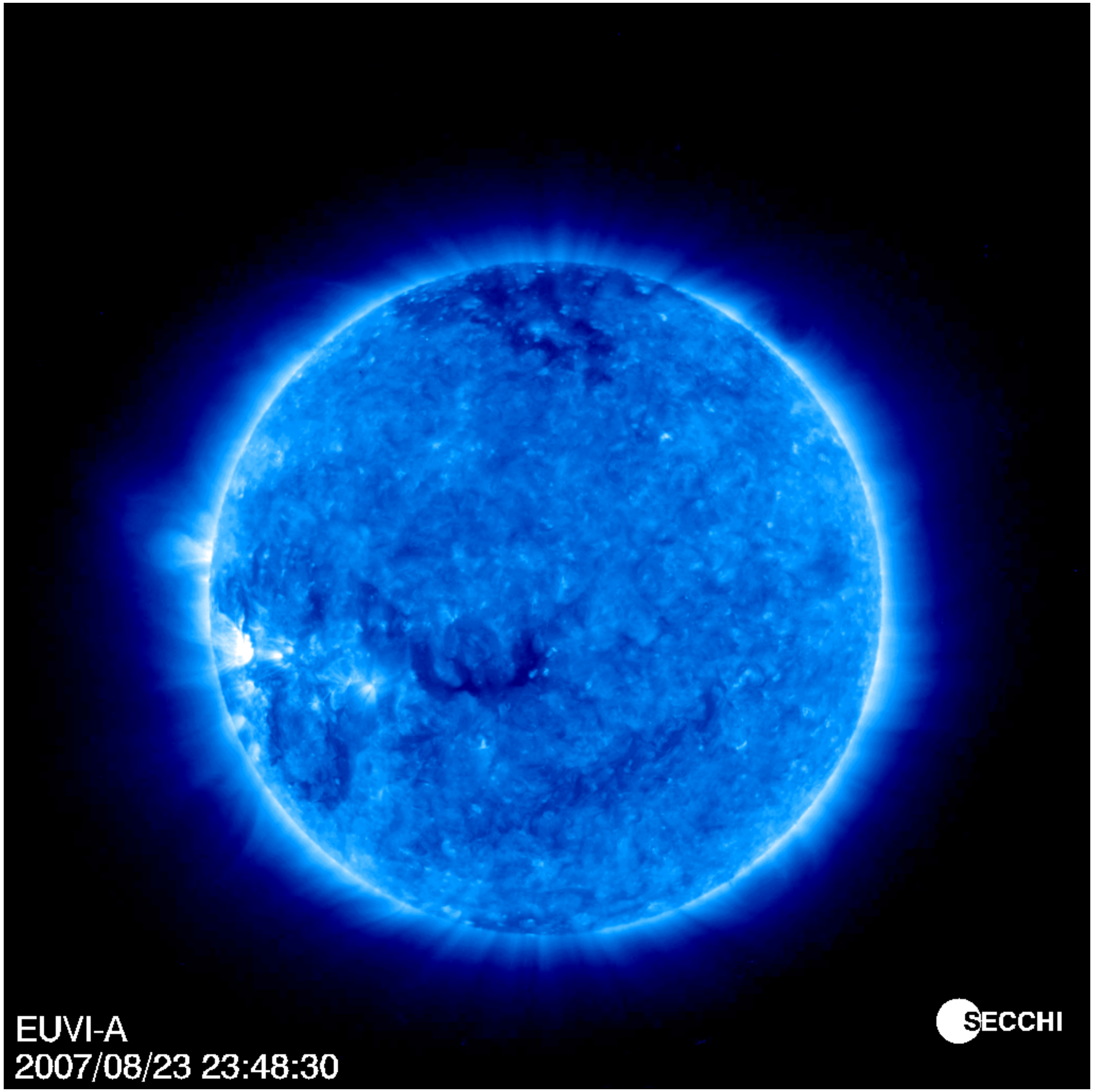
• **Suitable temporal resolution**

• **Constant bandpass**

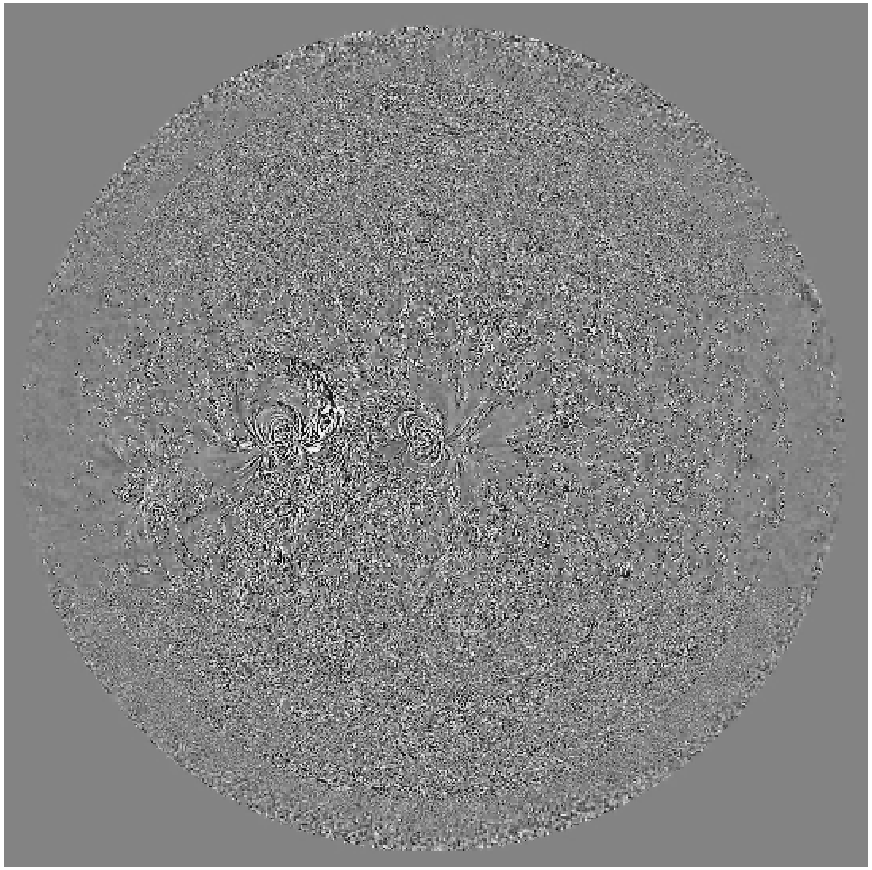
allows us to follow brightness fluctuations directly, without using Doppler analysis.

• **3D capabilities**

allow true speed calculations.



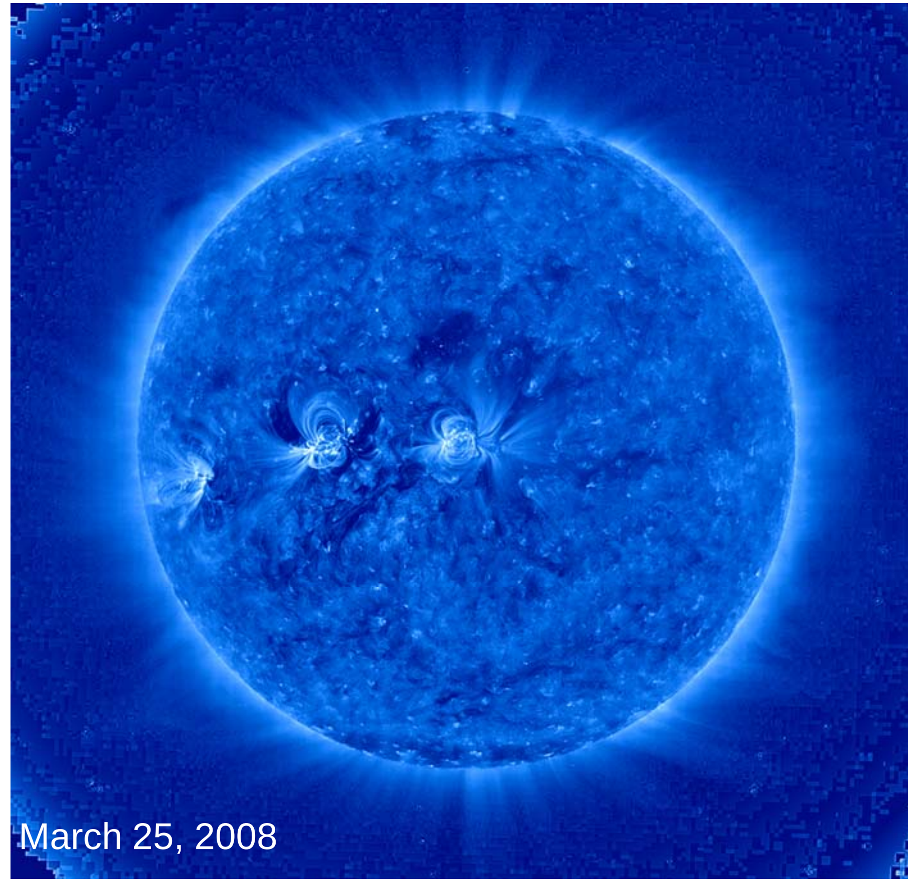
Does STEREO/EUVI see something similar?



EUVI 171 B

Running difference of wavelet-cleaned images

Cadence: 1.5 min



Details of the wavelet-cleaning and -enhancing algorithm at

A Fresh View of the Extreme-Ultraviolet Corona from the Application of a New Image-Processing Technique

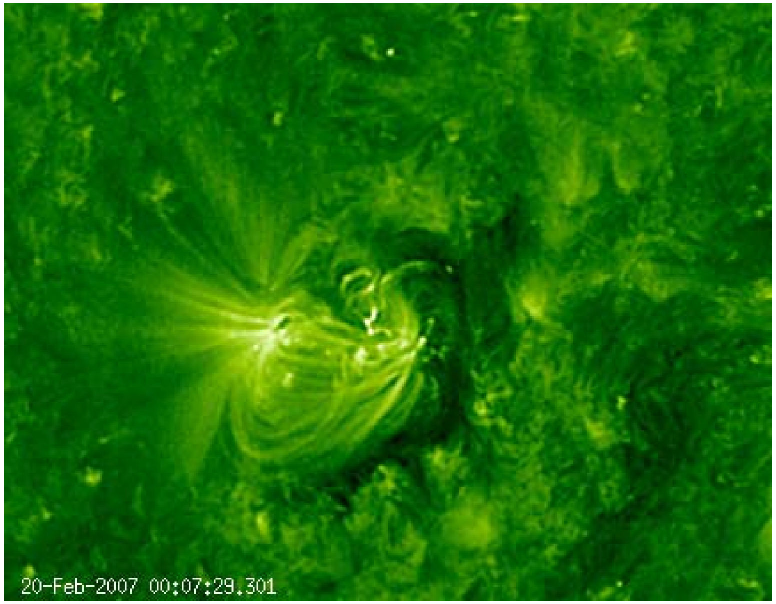
Stenborg, G.; Vourlidas, A.; Howard, R.

ApJ, Vol 674, Issue 2, pp. 1201-1206.

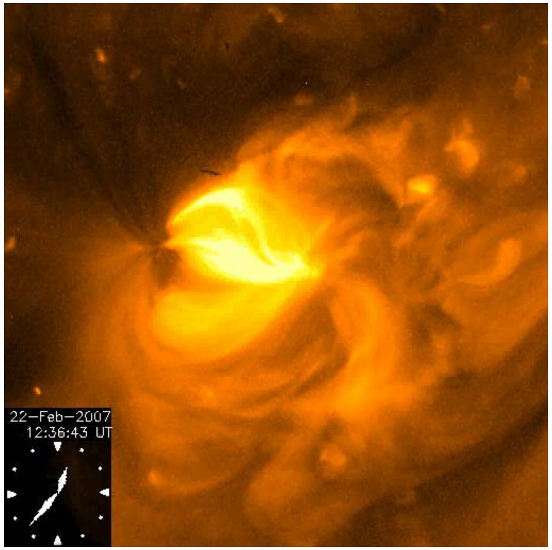
☐A few words on the wavelet technique

What does STEREO/EUVI observe on February 20, 2007

Outflows at the Edges of Active Regions: Contributions to Solar Wind Formation?
L. Harra, T. Sakao, C. Mandrini, H. Hara, S. Imada, P. Young, L. Van Driel-Gesztelyi, D. Baker
ApJ, Vol 676, pp. L147-L150, 2008.

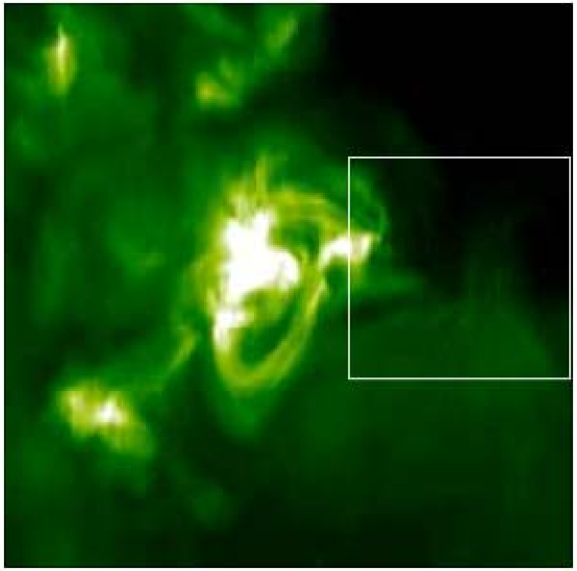


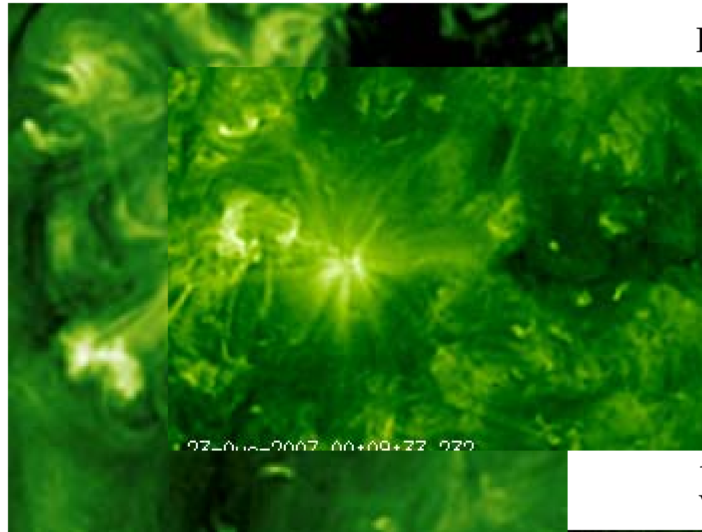
EUVI B 195 wavelet processed snapshot movie
(time span 8 hs, cadence 10 min)
of a comparable area to that
observed by HINODE/XRT



HINODE/XRT

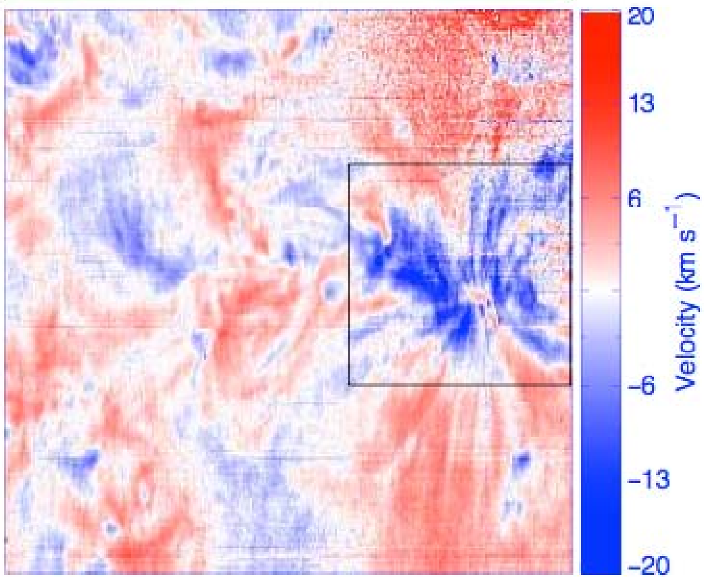
August 23, 2007





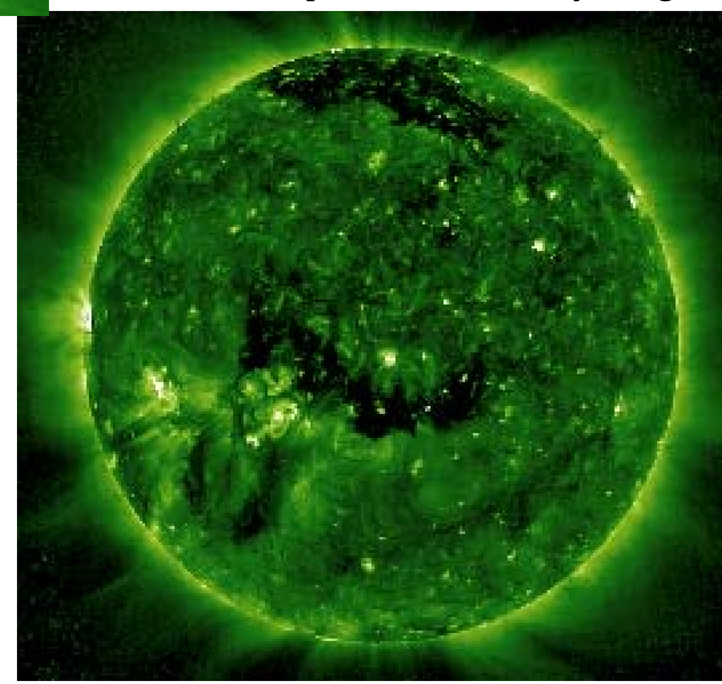
EUVI B 195 (06:55 UT)
wavelet processed snapshot
of the disk region shown in
Doschek et al paper

Full-Disk EUVI B 195 (06:55 UT)
wavelet processed intensity image



Top: FeXII 195.12 A intensity

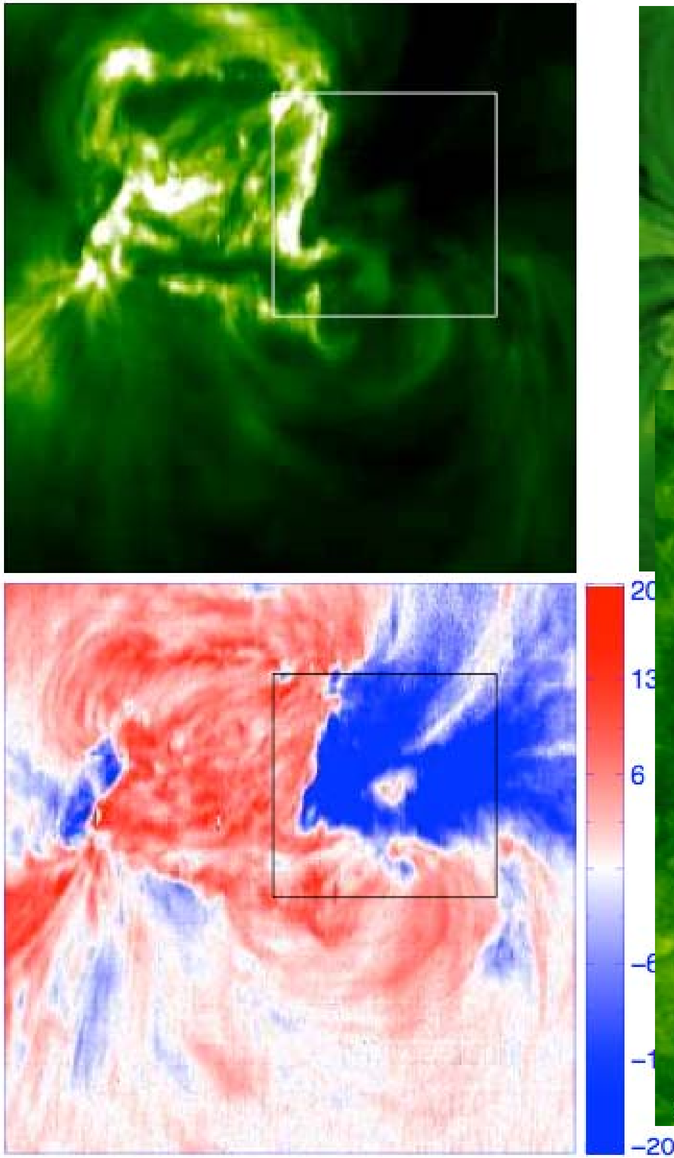
Bottom: Doppler Map (blue is towards the observer) obtained with Hinode/EIS.



From Doschek, et al., ***ApJ***, 686, 1362, 2008

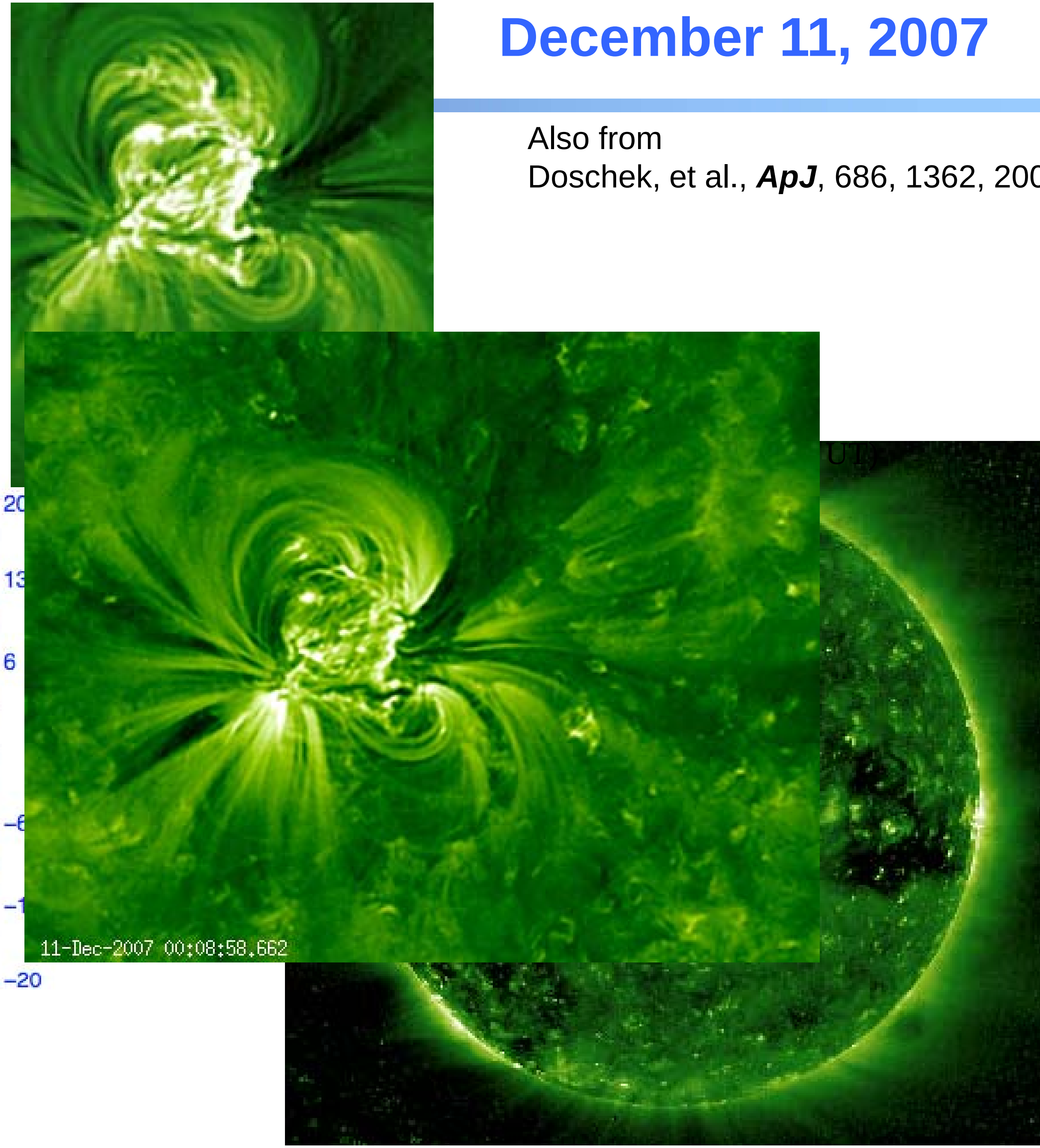
December 11, 2007

Also from
Doschek, et al., ***ApJ***, 686, 1362, 2008



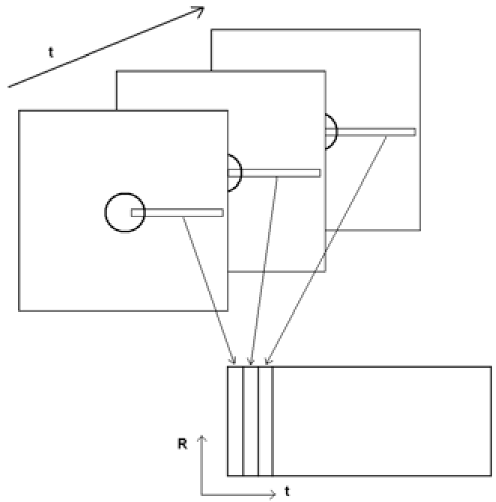
Top: FeXII 195.12 A intensity

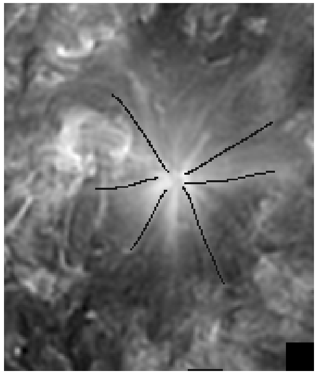
Bottom: Doppler Map (blue is towards the observer) obtained with the HINODE/EIS.



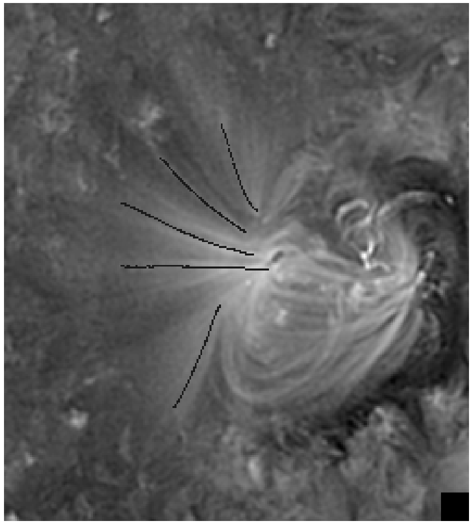
How can we measure the speed of the disturbances?

Original idea: Use of Height-Time Maps (J-maps) Sheeley et al. 1999, 2000
available in solar software



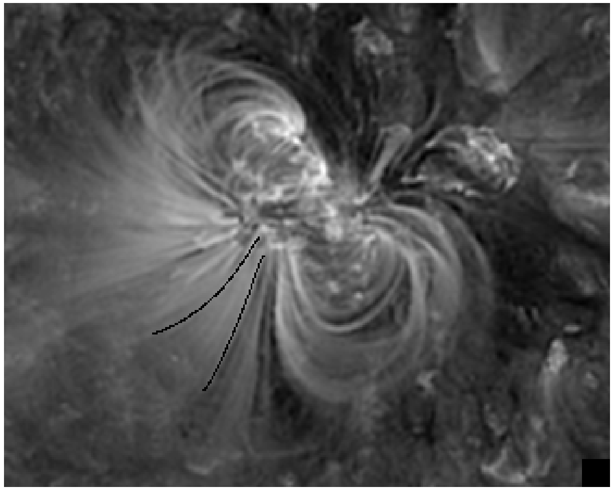


2007/08/23 EUVI B 171

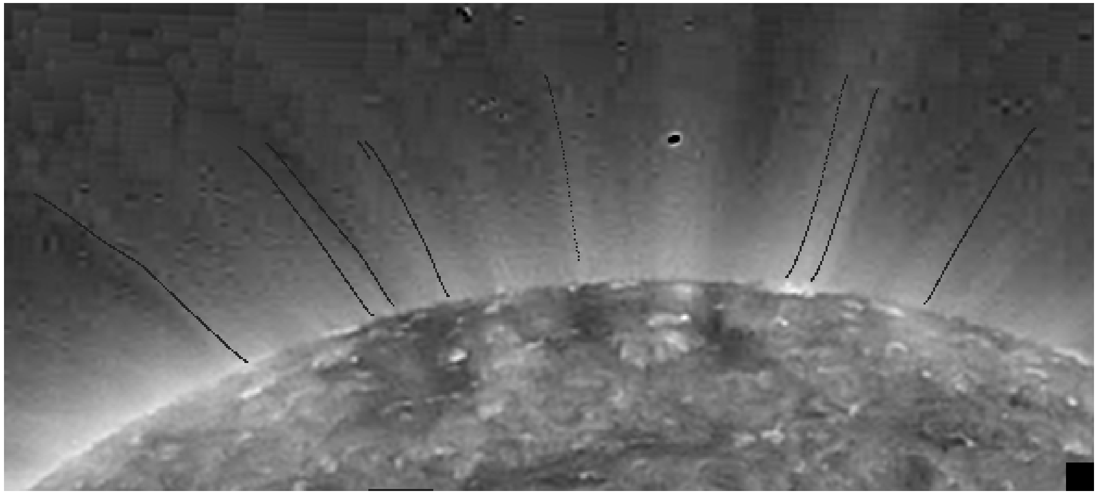


2007/02/20 EUVI B 171

2007/12/09 EUVI B 171



2008/03/25 EUVI B 171

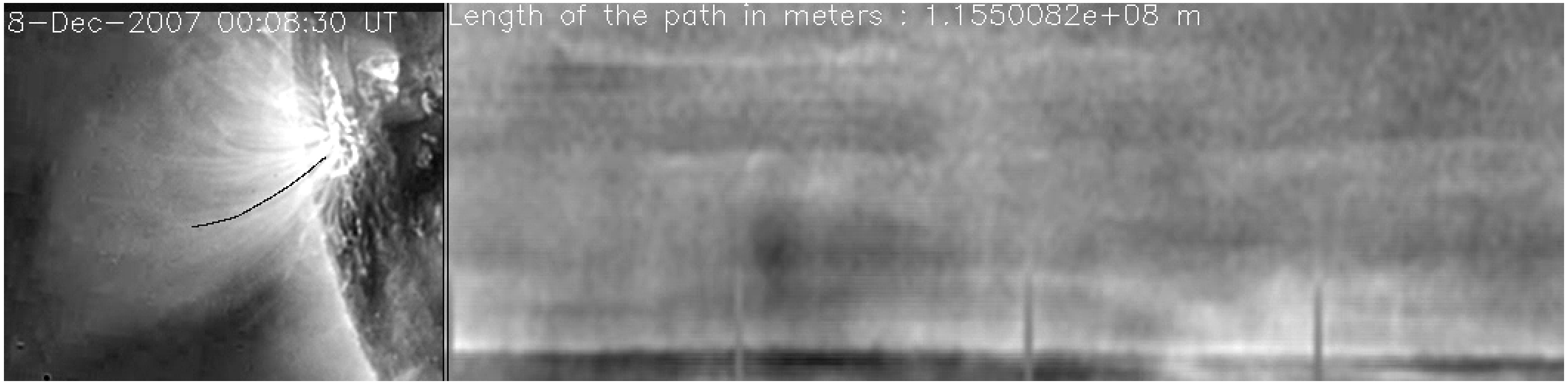


K maps

1) Wavelet-processed images are de-rotated by 8 hour segments.
2) Paths manually defined by point-and-click on the Region of Interest
3) K-maps created through each 8 hour segments.

Time

S/C A



Distance along the path

S/C A

Distance along the path

Time

- Using the K-maps we are able to find the **projected** speed of the density enhancements.
- Before speed assessment we determine if tracked features remain <u>constant</u> throughout the 8 hour de-rotation period. If not constant, then speed cannot reliably be found.

Kinematical characterization

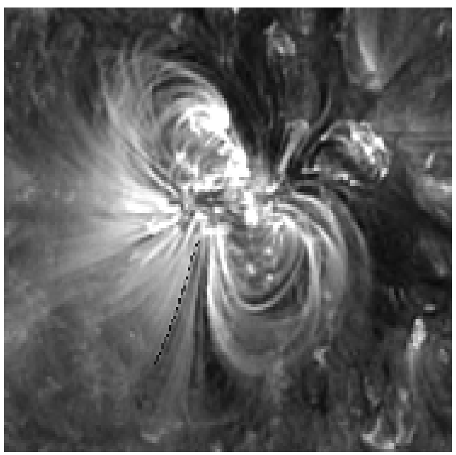
*** On the intensity variations observed along pseudo-open field lines nearby AR**

A **qualitative** analysis of the days processed so far showed that, the traveling disturbances are stronger (i.e., better discerned against the background) when:

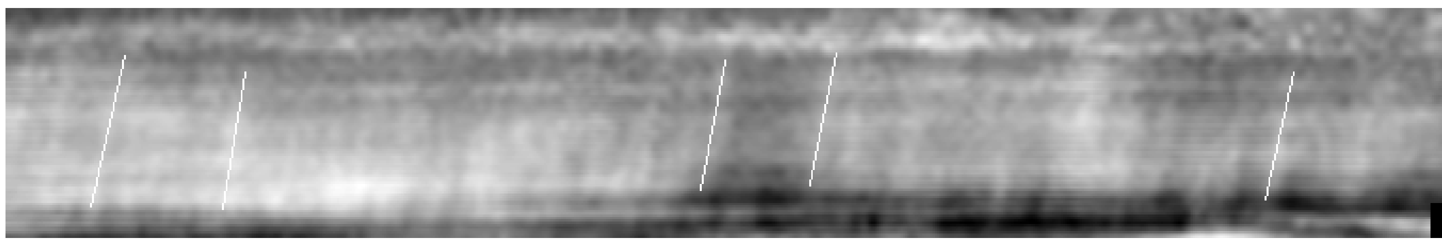
i) closed field lines are nearby apparently open field lines,

ii) closed field lines are nearby another closed field lines that end up on different foot points.

Example of **quantitative** analysis



December 9, 2007 [00:00 UT - 08:00 UT]

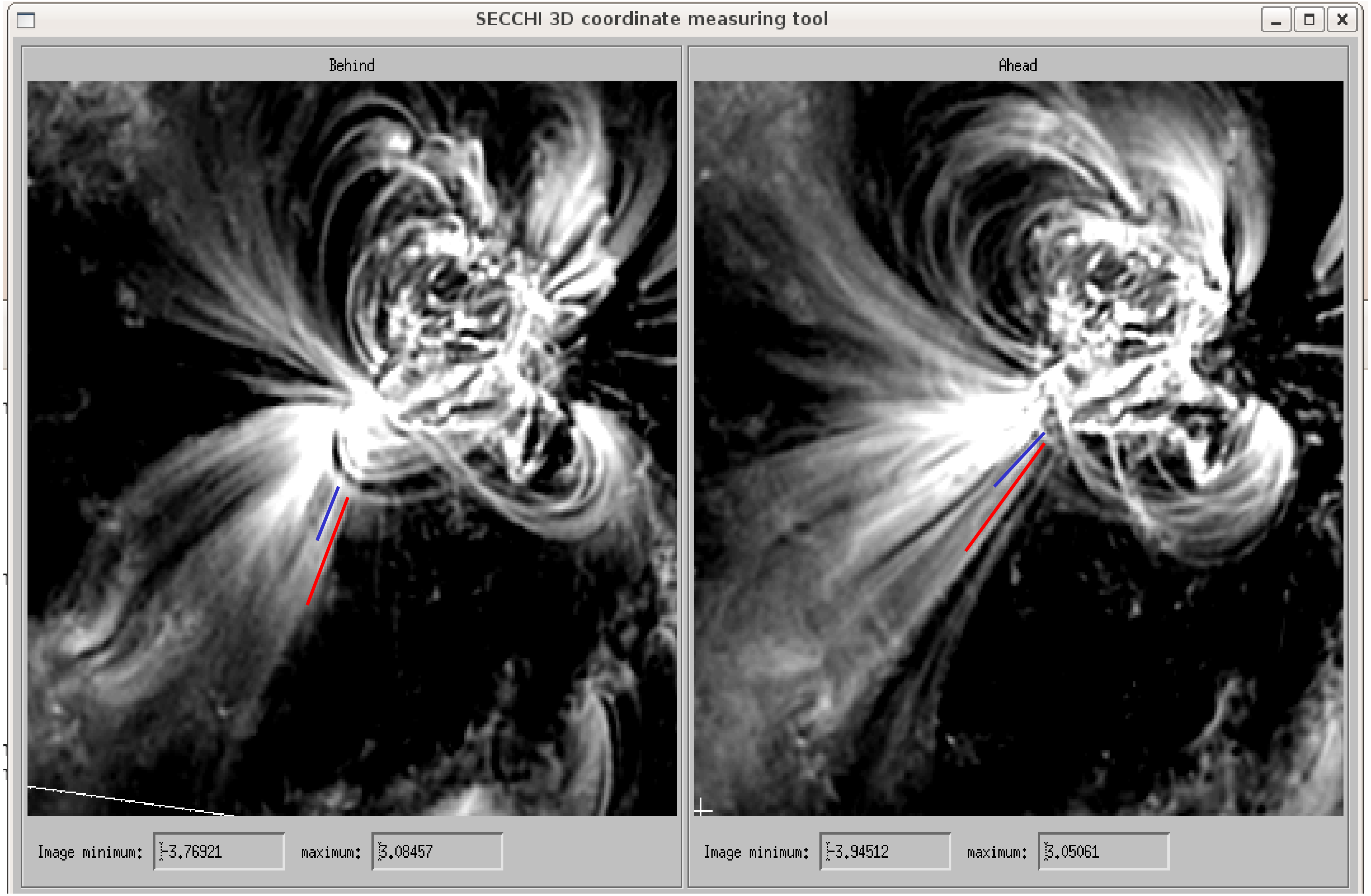


95 km/s 120 km/s 115 km/s 100 km/s 95 km/s

--- Projected Speed of a sample of intensity variations as they move along the selected ray ----

The seven cases analyzed (including “on-disk” and “off-limb” cases) result in projected speeds in the range 50 - 140 km/s

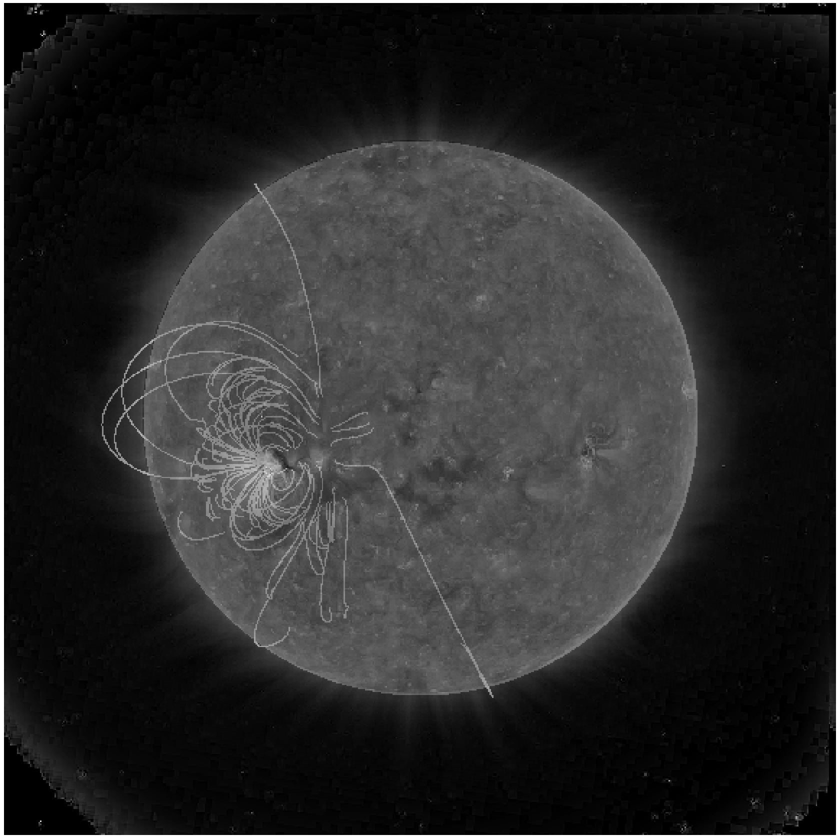
Future Work: I) Tie-Point to infer the true speed?



Future Work: II) Magnetic Topology

Do these intensity variations exist anywhere else on the disk with closed field lines?

- Do the variation exist along plumes with open field lines?
- How does magnetic topology relate to flow strengths?

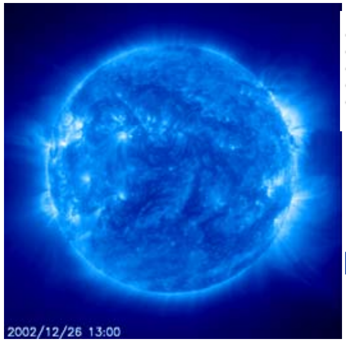


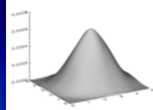
- Infer the topology of the magnetic field where the flows are observed by comparing with magnetic field models

Issues to Consider

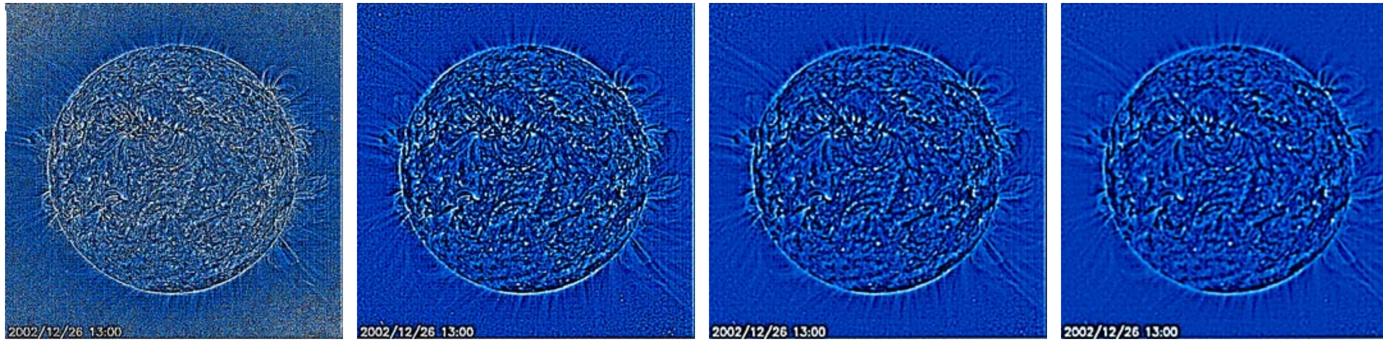
- Reliability of feature tracking using point-and-click method
- Accuracy of feature tracking between STEREO-A to STEREO-B
- Are the flows inside closed (but long) loops or inside open magnetic field extending into the heliosphere?
- Physical Interpretation: Are the observed intensity fluctuations mass outflows or waves?
- How is the magnetic field topology where the intensity fluctuations exist?
- Are the observed intensity fluctuations observed above the polar coronal holes caused by the same mechanism as those observed in pseudo-open field lines nearby AR?

The 2D “a trous” algorithm

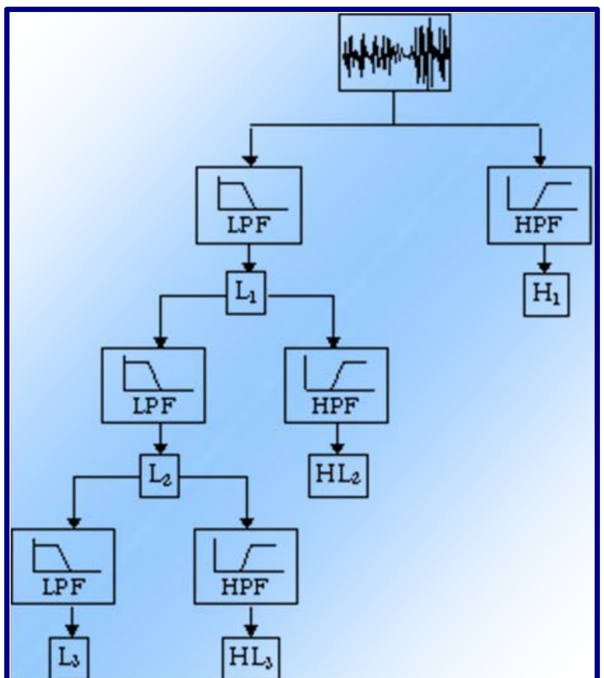




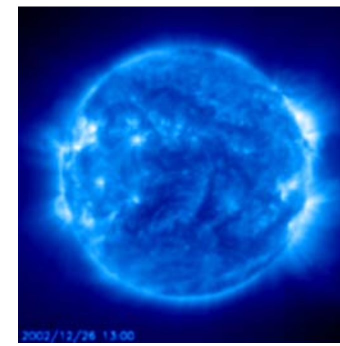
2D
B_3-spline



Wavelet scales 1 to 4 (W_i)



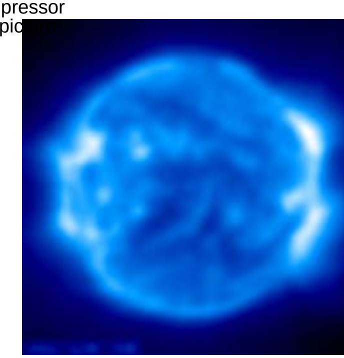
Smoothed image corresponding to decomposition based on 25 scales



QuickTime™ and a
YUV420 codec decompressor
are needed to see this picture.

$$I_k^{treated} = \left[\log(I_k) - \log\left(R^i\right)\right] + \sum \alpha_j . \left(\omega_j - W_j^i\right)$$

For comparison, smoothed image corresponding to decomposition based on 50 scales



☐ Back