
Sunny Beach, 2 June 2015

Prediction of the orientation of the Bz component of ICMEs inside and at 1AU

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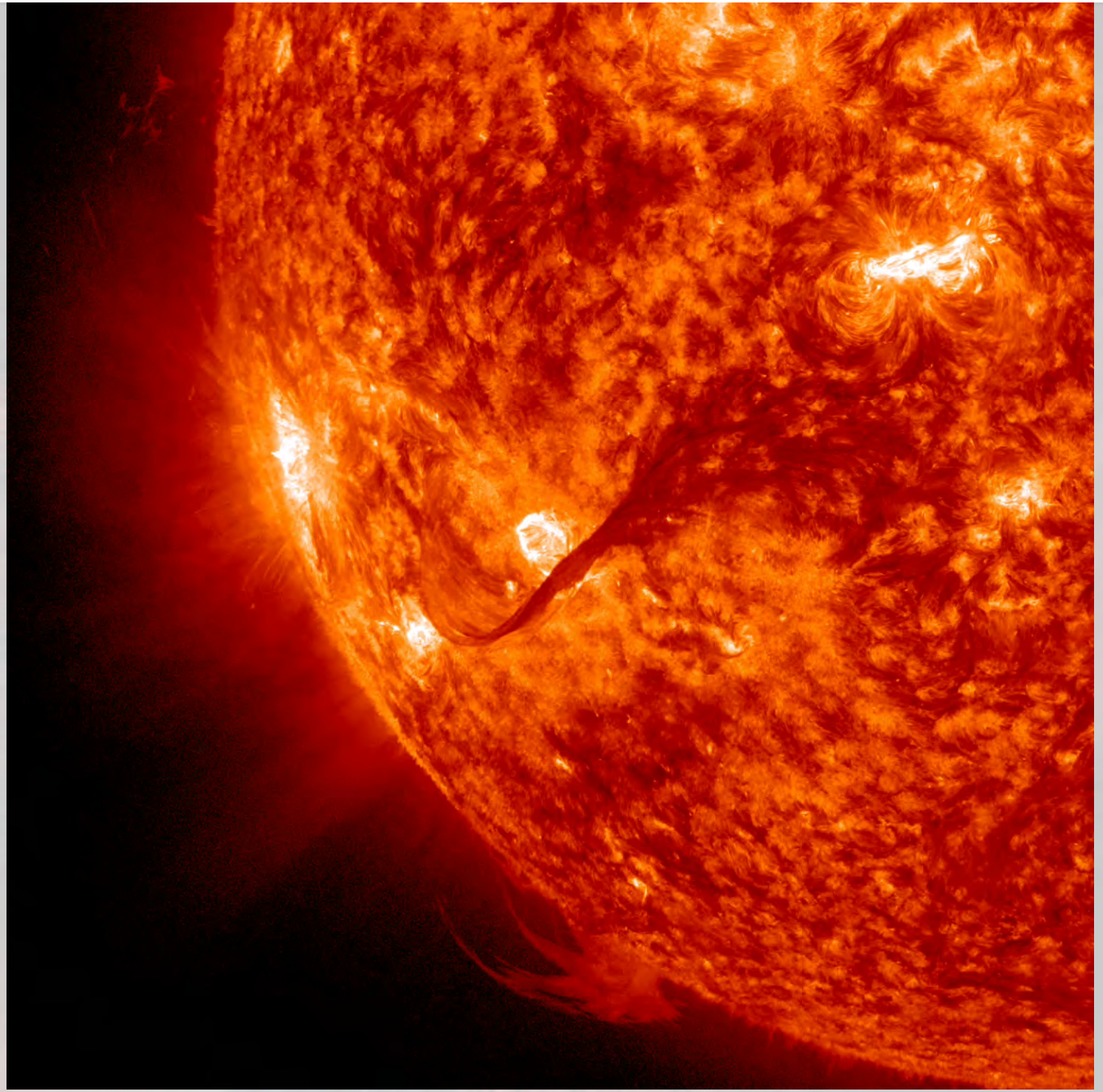
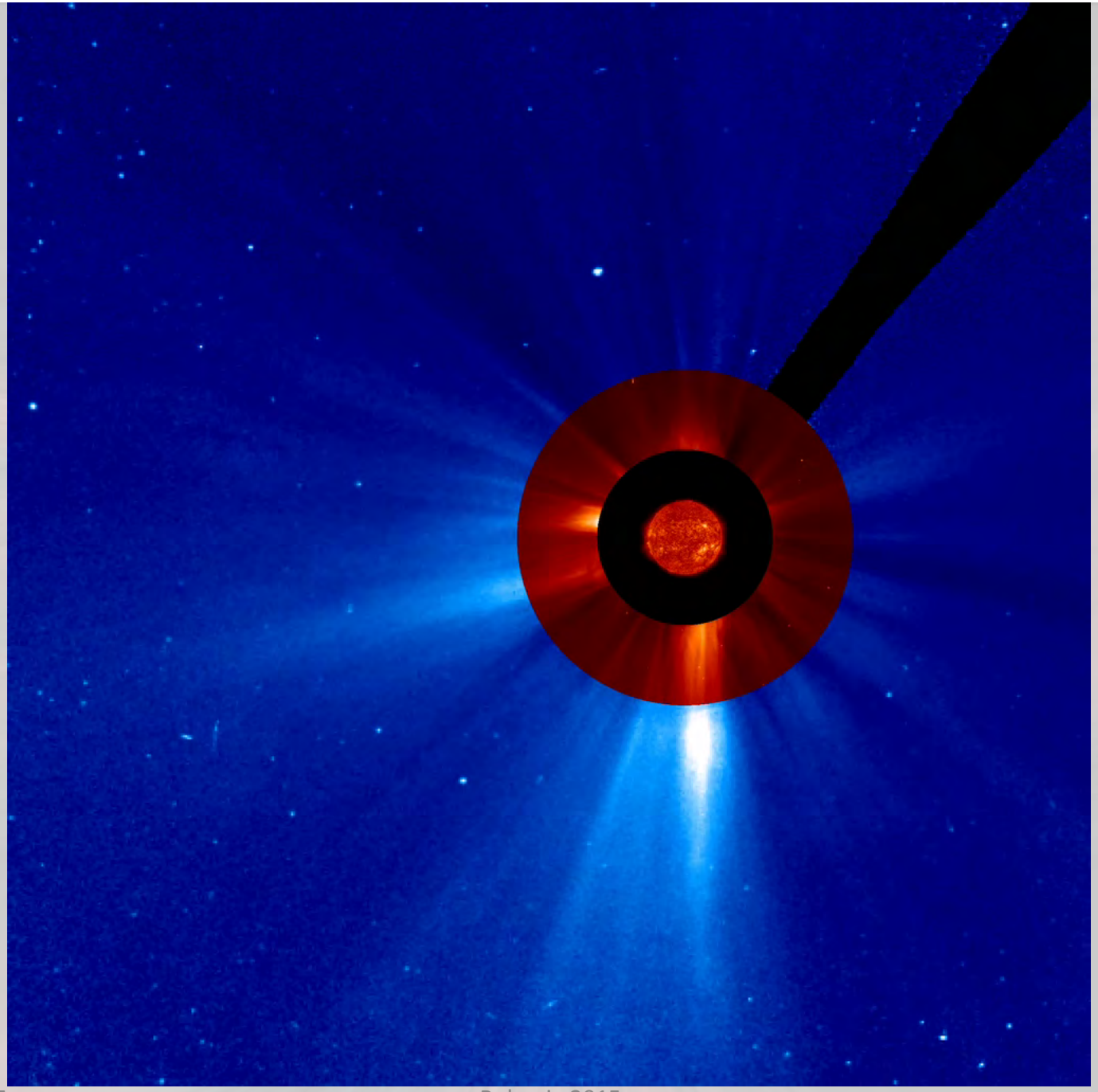
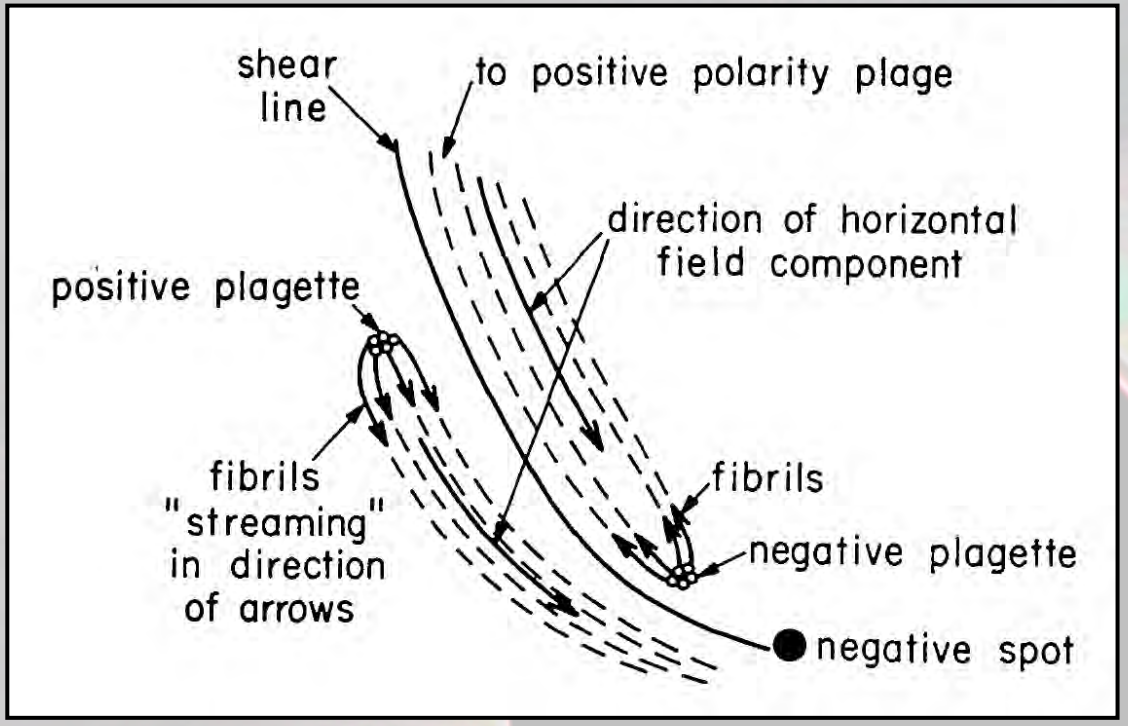
The direction of the axial component of the magnetic field of a pre-eruptive filament and of the corresponding CME caused by filament eruption may be established observationally. This is a fundamental component in determining the geo-effectiveness of Interplanetary (I)CMEs. Filament channels, filaments, and the CME and ICME are all part of a multi-scale chiral system (i.e. possessing chirality) and the analysis of such chiral systems is a powerful tool to determine the topology of the magnetic fields involved in eruptive solar events later seen in space as ICMEs. There is a body of observational and data analysis work which allow the development of step by step methods to determine the sign of helicity (chirality) of filaments and filament channels (dextral or sinistral). These methods can be turn into a simple empirical predictor of CME geo-effectiveness (improve predictions of the relative strength of southward and northward components of the magnetic field in ICMEs) and have the ability for predictions inside 1 AU, e.g., at Mercury (MESSENGER) or future missions (e.g., Solar Orbiter, Solar Probe Plus).





Before eruptions…

1. Direction of the chromospheric fibrils
2. Direction of the filament barbs
3. Direction of the coronal cells
4. The skew of the coronal arcade above the filament channel can give answer about the chirality of the filament under this arcade

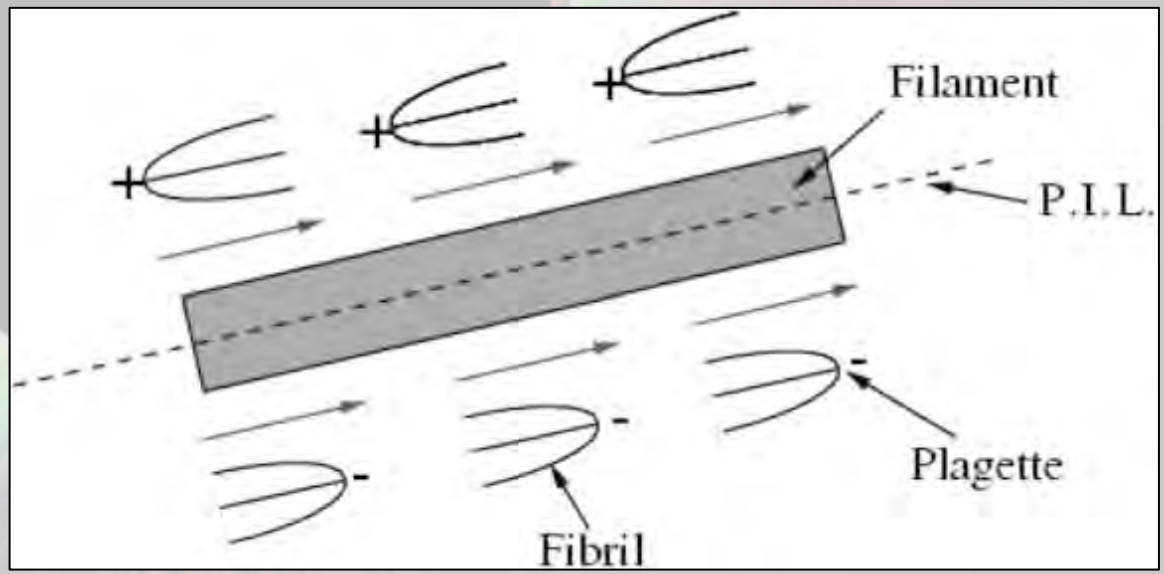


Filament channel is a region around PIL where the chromospheric fibrils are aligned - the "streaming" of the chromospheric fibrils inside filament channels.

The horizontal component of the magnetic field must point in the same direction on either side of the channel

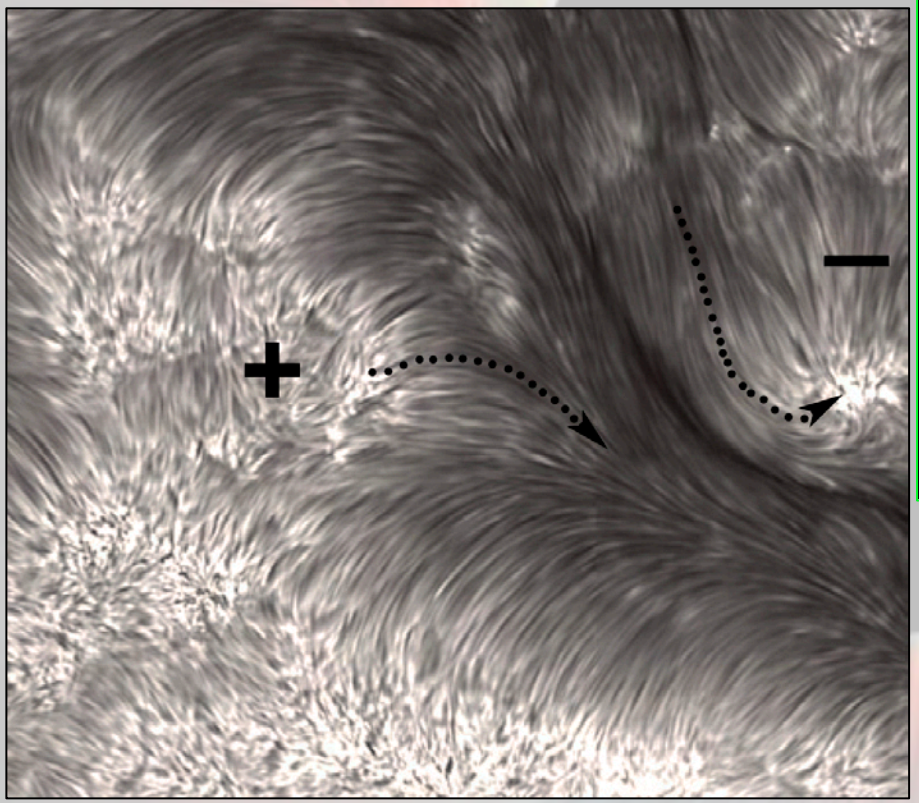
Martres et al. 1966,

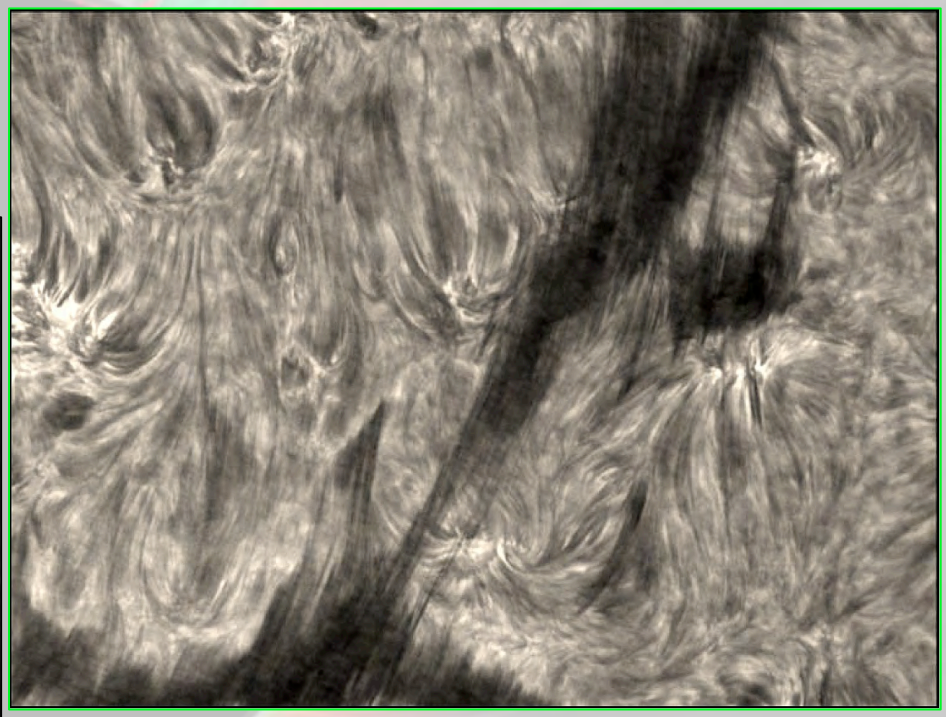
Foukal 1971



Vial and Engvold 2015

From this fibril alignment it can be deduced that filament channels, the birth ground of filaments, are locations of strong magnetic shear and highly non-potential magnetic fields. Solar filaments which lie in the corona are believed to be embedded in the filament channel field which extends up into the corona.

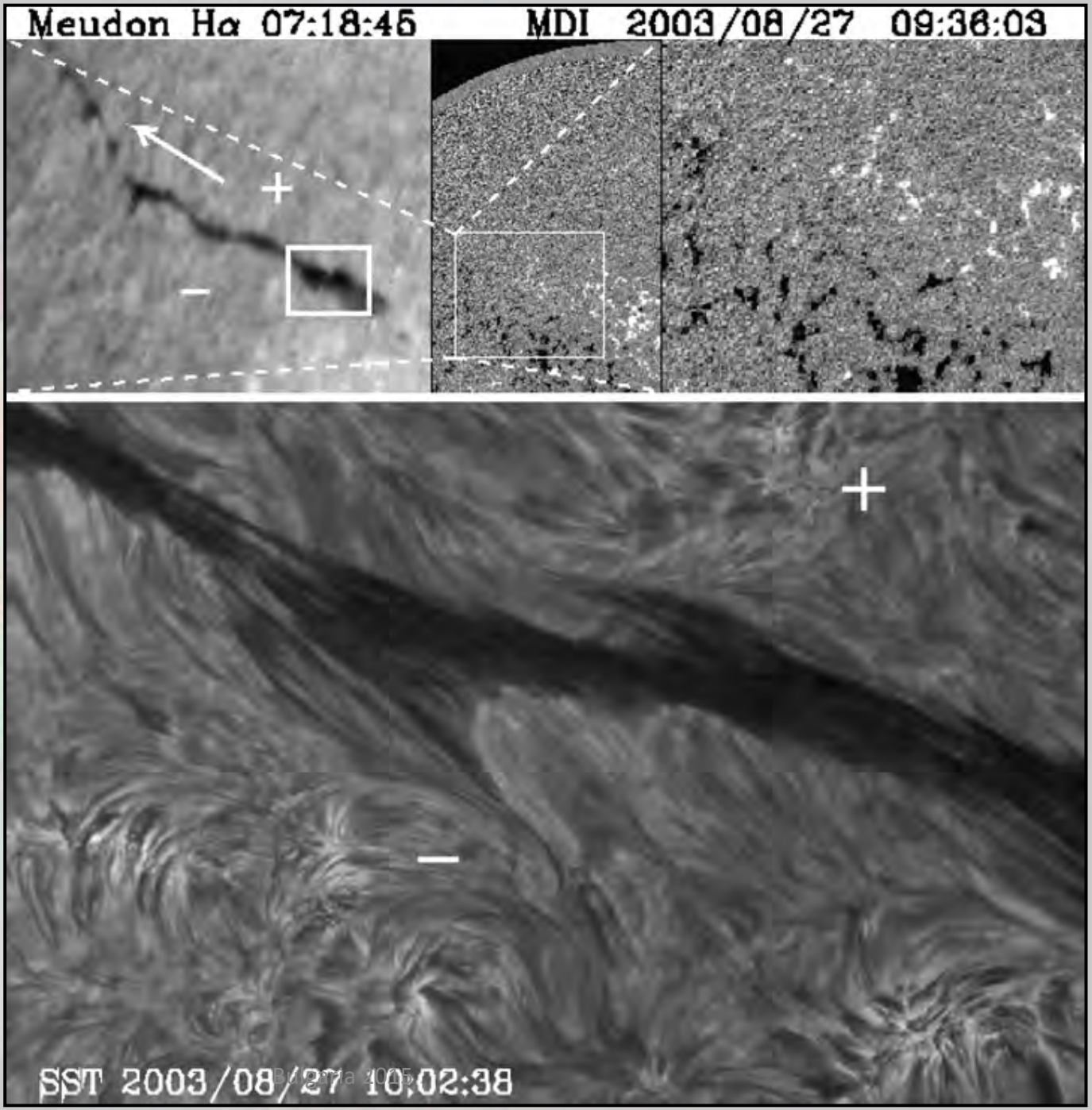




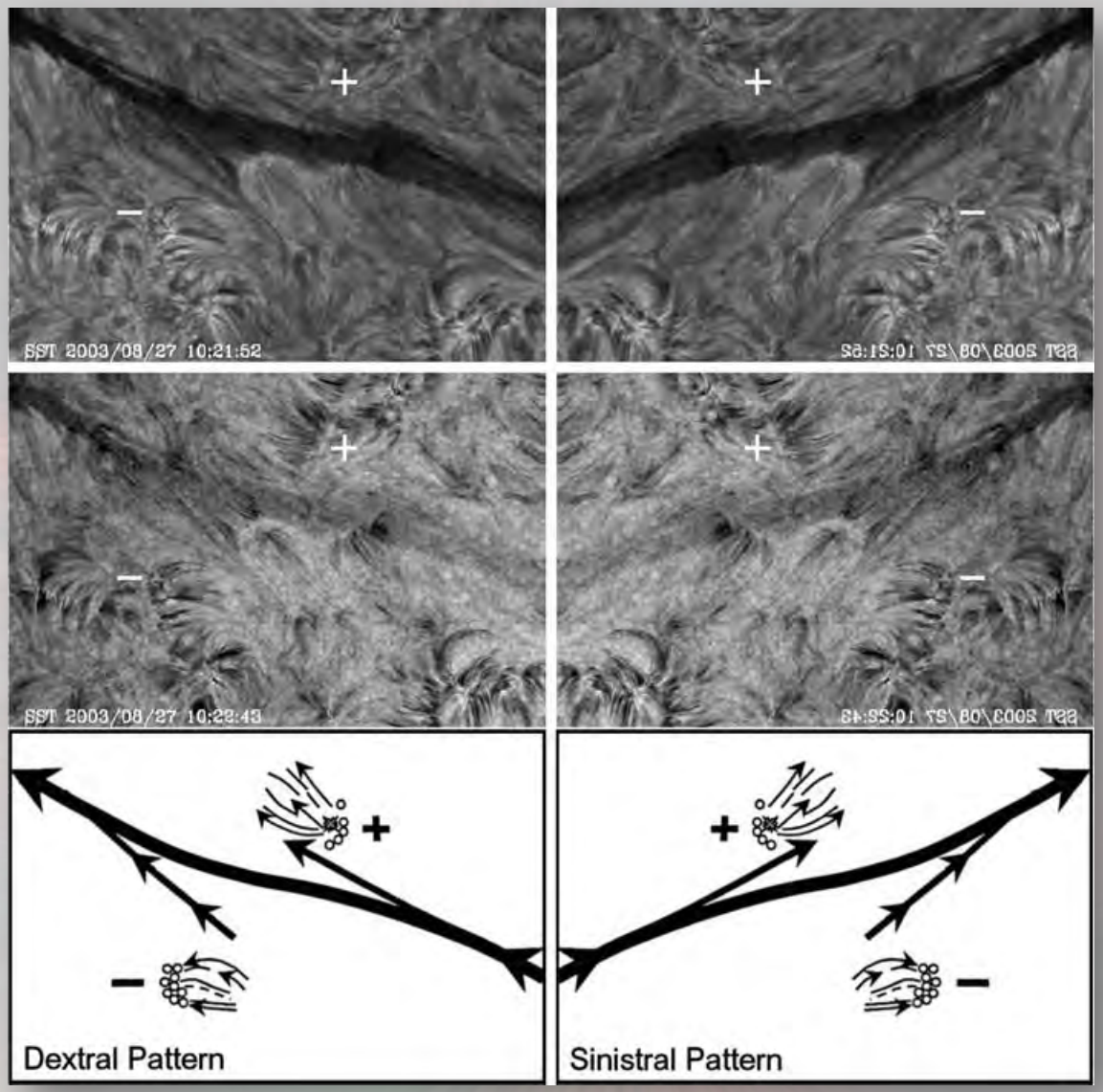
SST 2003-08-26 09:53 UT

Left panel: NSO/Sacramento Peak,
the Interferometric Bidimensional Spectrometer
(IBIS), 2010 Aug 3, Ca II 8542 Å

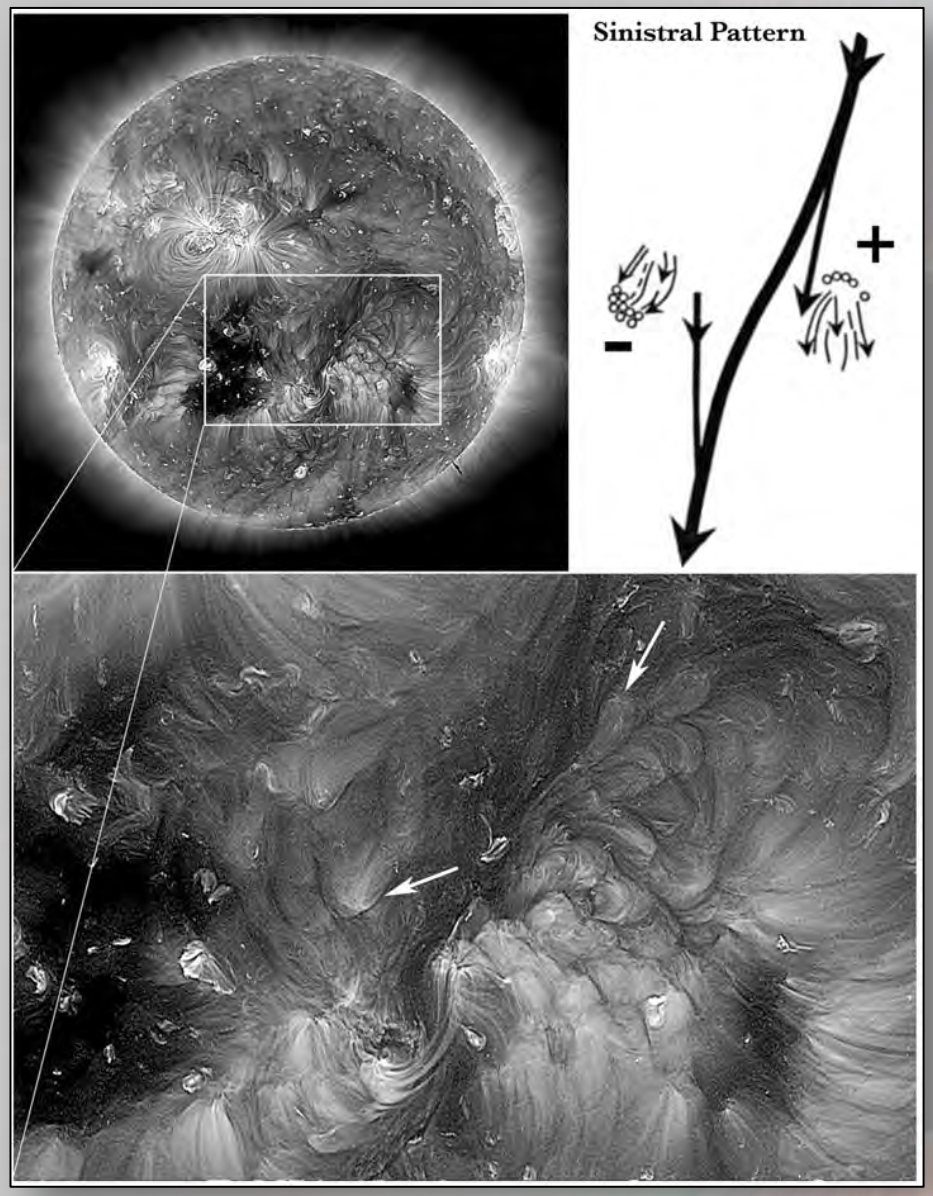
Direction of the filament barbs



Note: Leenaarts, Carlsson and Rouppe van der Voort (2012) work supports the commonly held notion that H-alpha threads indeed trace the magnetic field.



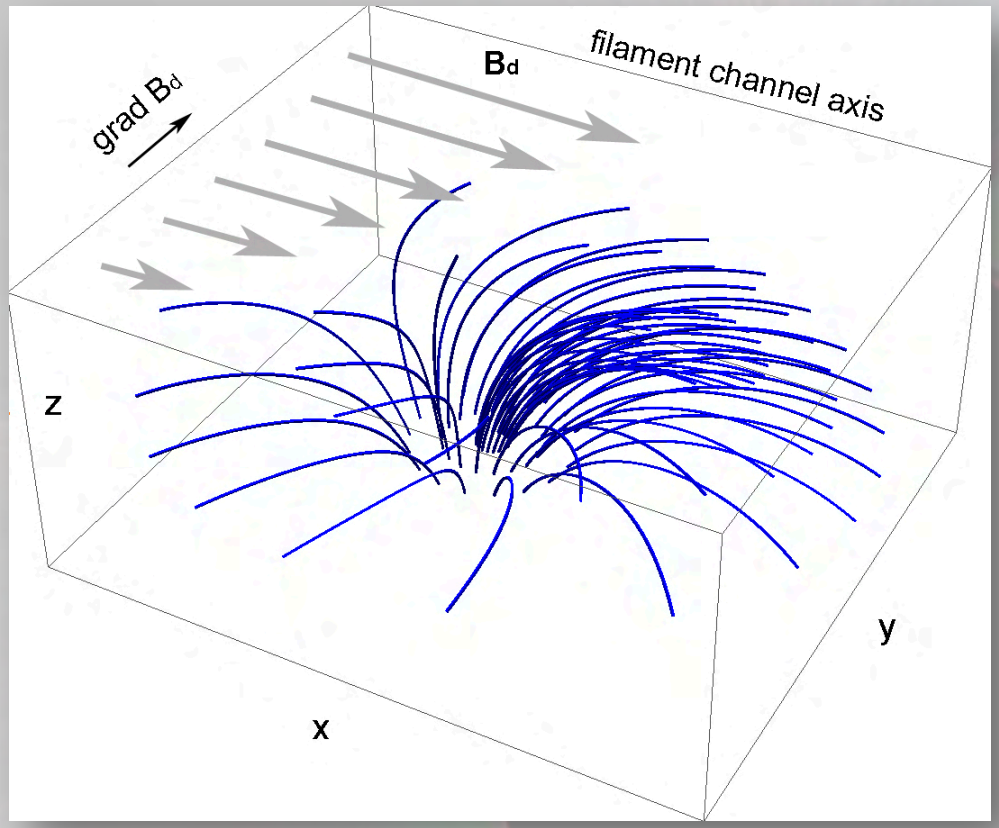
Martin, Lin and Engvold 2008

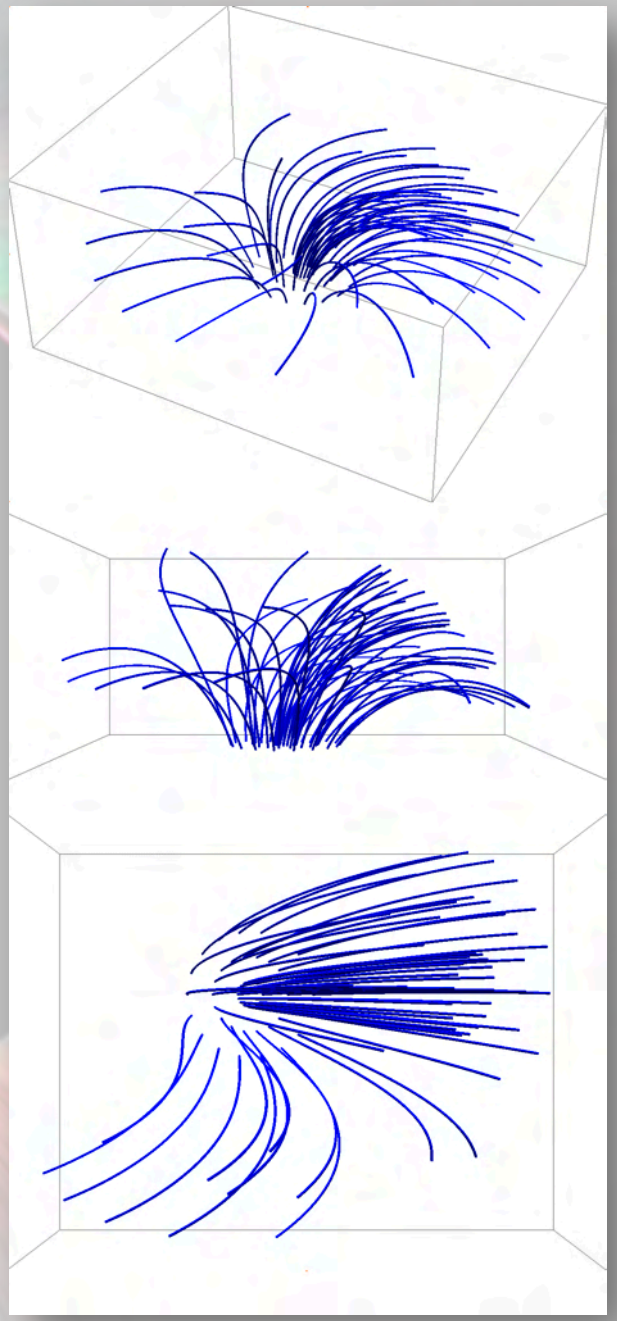


(Panasenco et al. 2013)

Coronal cells

(Sheeley and Warren, 2012; Sheeley et al. 2013)





Model of coronal cell magnetic field lines (blue) in the presence of a horizontal directed "filament channel" field (gray) along the x-axis and gradient along the y-axis.

(Panasenco et al. 2016)

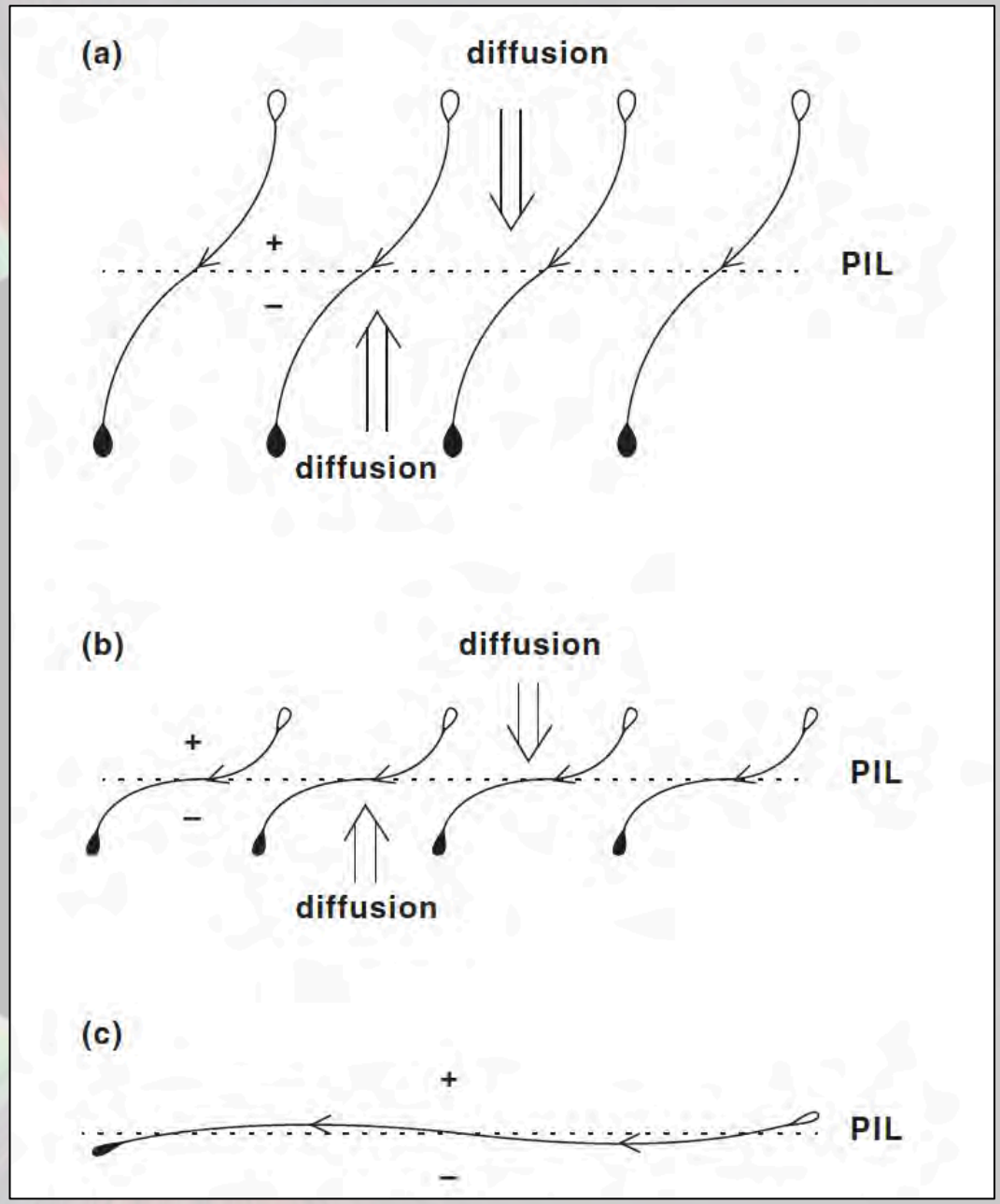
Diffusion (random walk in the supergranular flow field) and cancellation of opposite-polarity flux elements linked by reverse-S field lines.

As the flux elements converge on the PIL, the transverse field component decreases and the reverse-S structures shorten and rotate clockwise; their necks thus become aligned with the PIL and merge to form an axial field having dextral chirality.

- The axial field (B_x) becomes stronger and stronger with time relative to the vertical field on either side of the PIL.

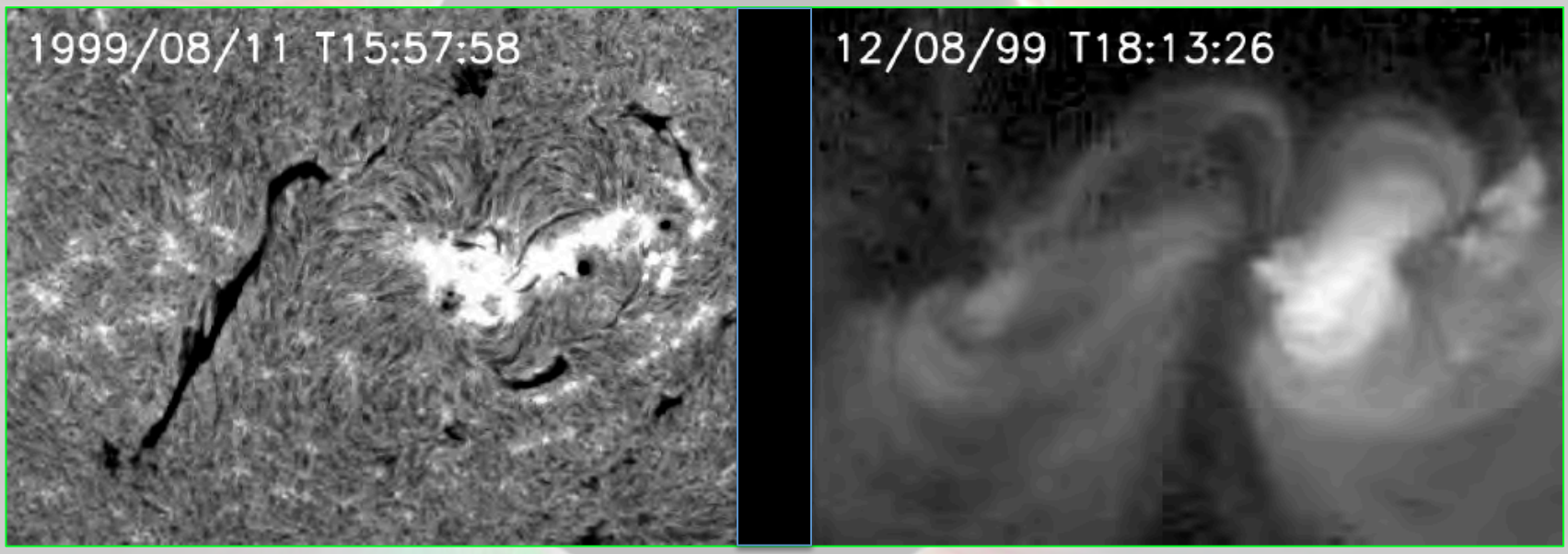
$$\frac{B_x(0,t)}{B_z(\langle y\rangle,t)} \sim \alpha\sqrt{\frac{4\kappa t}{\pi}} \propto t^{1/2}$$

(Y.-M. Wang et al. 2013)

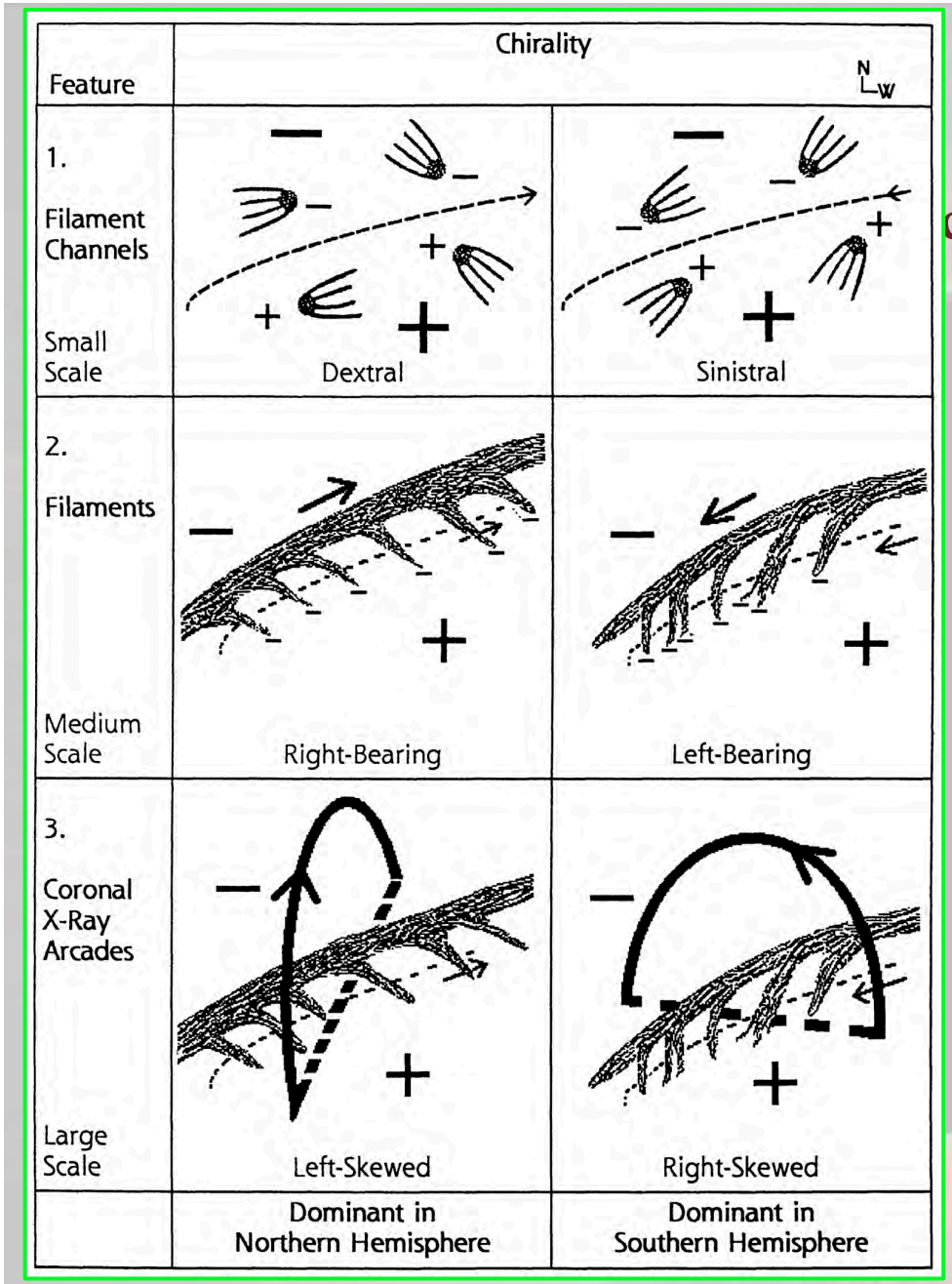


Before eruption…

4. The skew of the coronal arcade above the filament channel can give answer about the chirality of the filament under this arcade.



A sinistral filament in the southern hemisphere (left image) and the right skewed arcade above it (right image).



All chiralities are interrelated: filament channel's, filament's and coronal arcade's above the filament channel

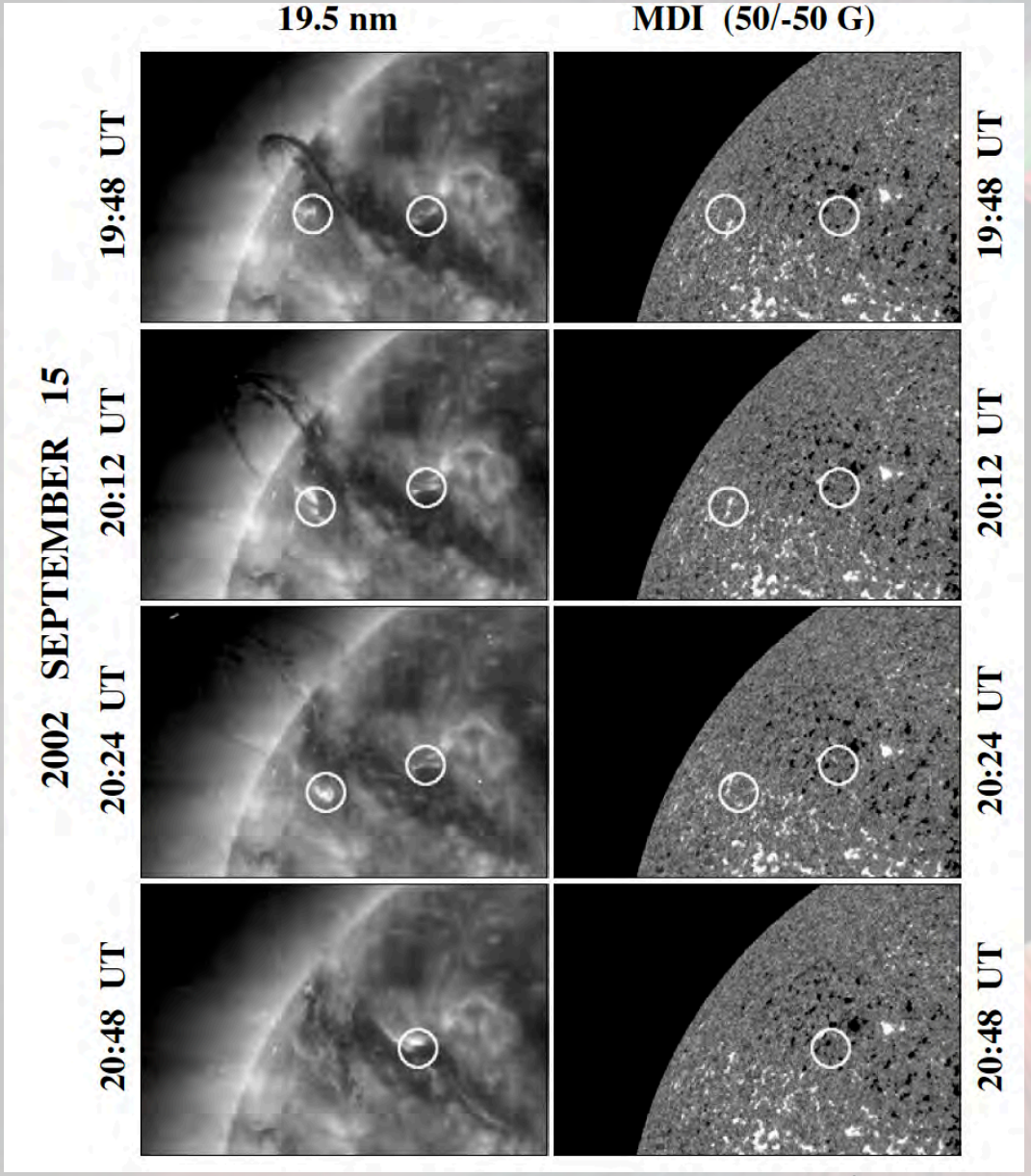
One-to-one chirality relationships for

(a) fibril and coronal cell patterns,
(b) filament spines and barbs, and
(c) overlying arcades of coronal loops,
are shown in each column.

The patterns in the left column are dominant in the northern hemisphere and those in the right column are dominant in the southern hemisphere. Exceptions exist to this hemispheric preference but there are no known exceptions within the sets of chirality relationships.

(Martin 1998)

During eruptions…



5. Y.-M. Wang et al. (2009): bright points appear on both sides of the filament channel near the sites where filament feet are anchored, so we can learn about the magnetic field direction along the filament spine and therefore can determine the chirality.

Eruption of a filament near the northeast limb on 2002 September 15.

The locations of the endpoint brightenings are circled.

After eruptions…

6. The direction of the offset of two flare ribbons relative to the polarity boundary between them can give the answer, because the offset is directly related to the coronal arcade skew;

7. The skew of the post eruptive bright arcade will be the same as the skew of the coronal arcade and therefore can give the answer on chirality.

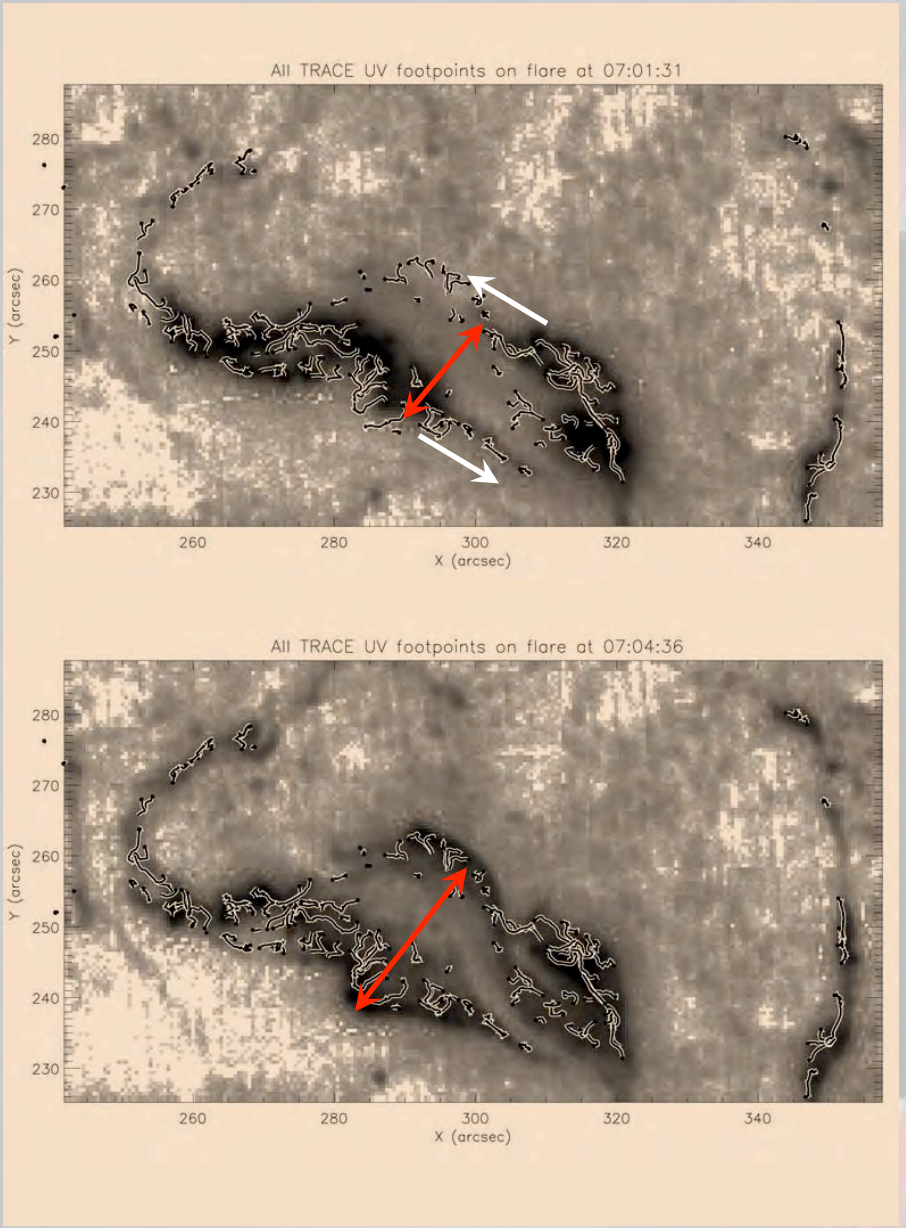
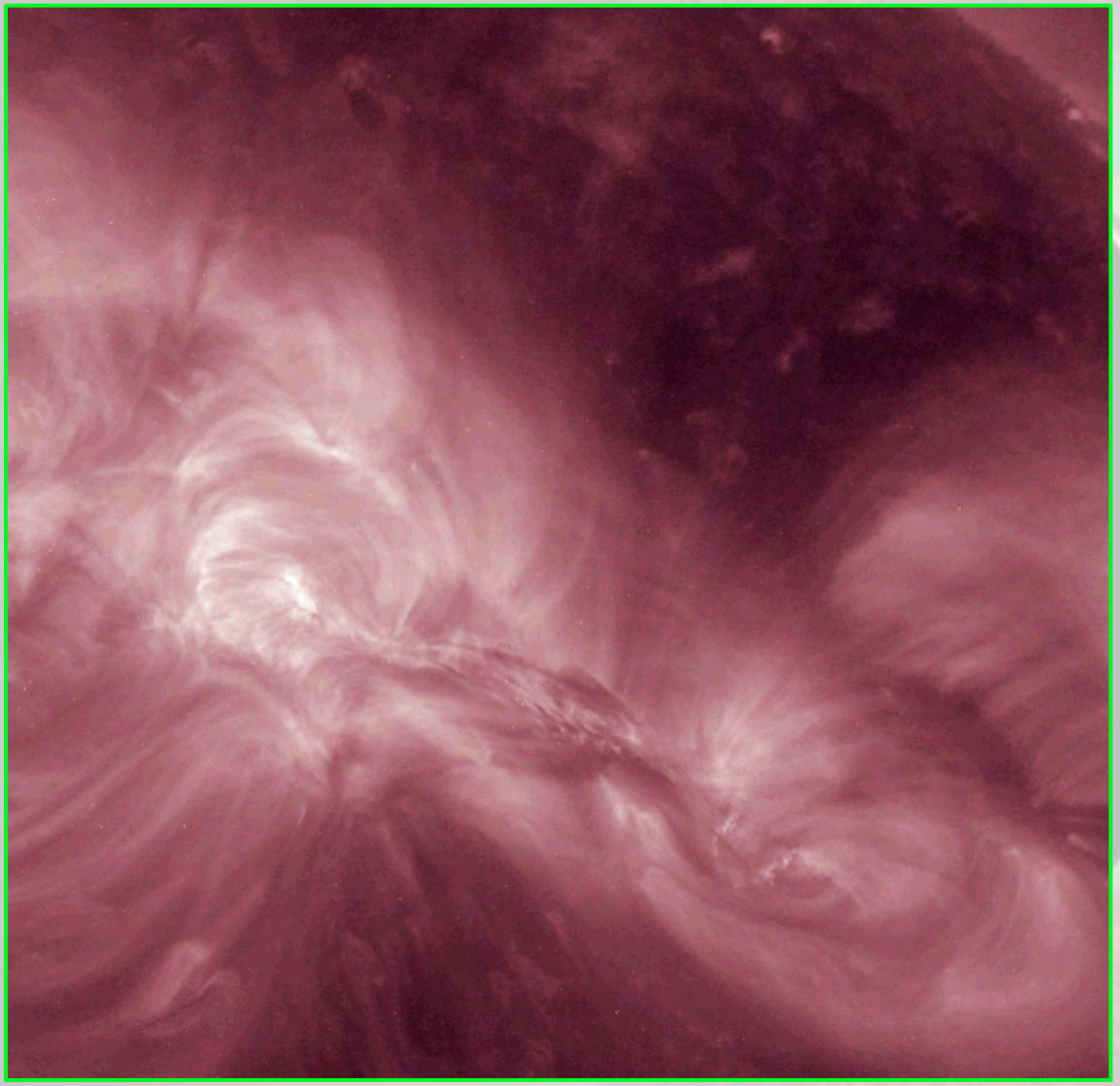
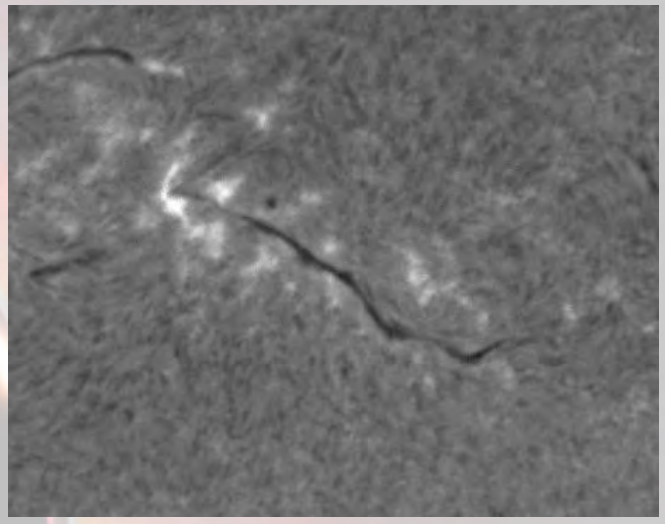


Figure shows the tracks superposed on a flare image at the beginning and at the end of the tracking period, illustrating the relationship between motion of individual UV sources and the ribbons as a whole.

Fletcher, Pollock & Potts, 2004, Solar Phys., 222, 279

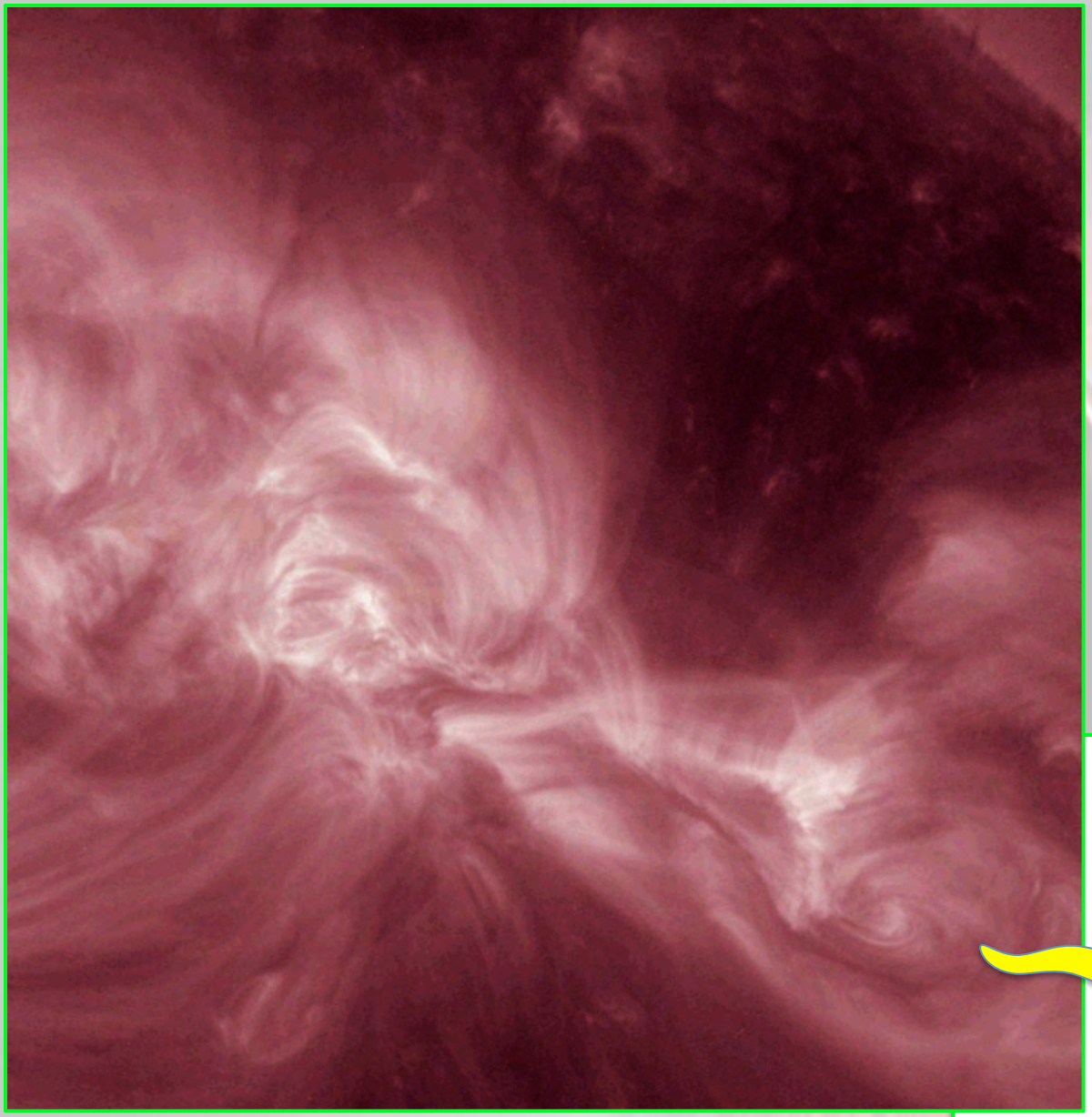
Offset of two flare ribbons

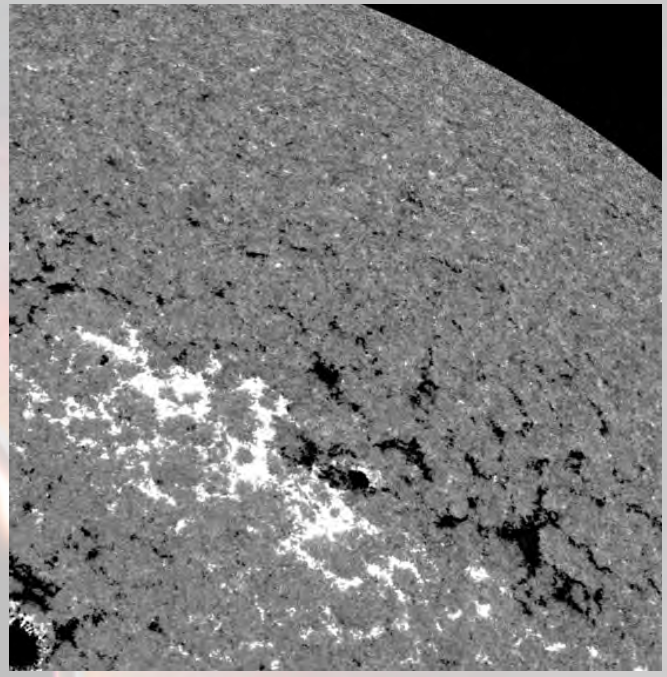


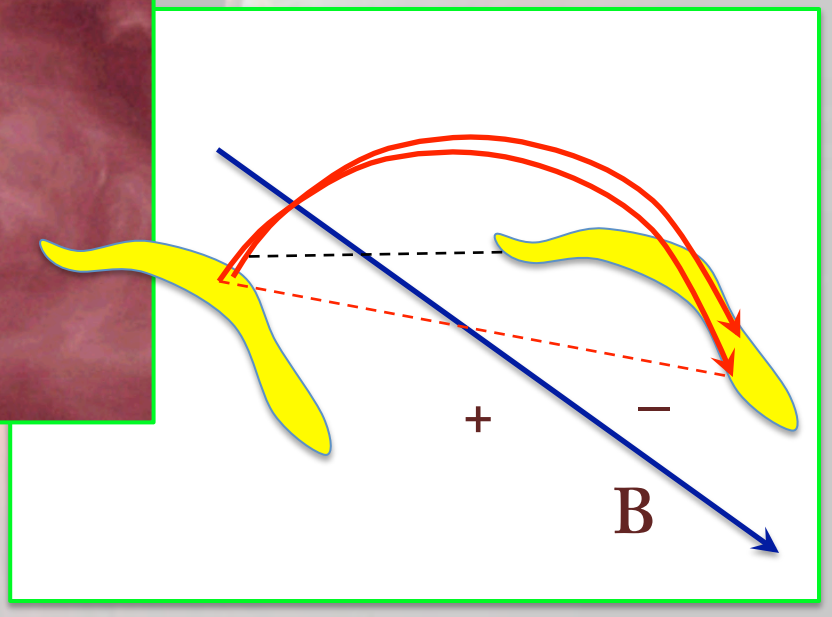


H-alpha

2011-04-01
SDO/AIA 211Å



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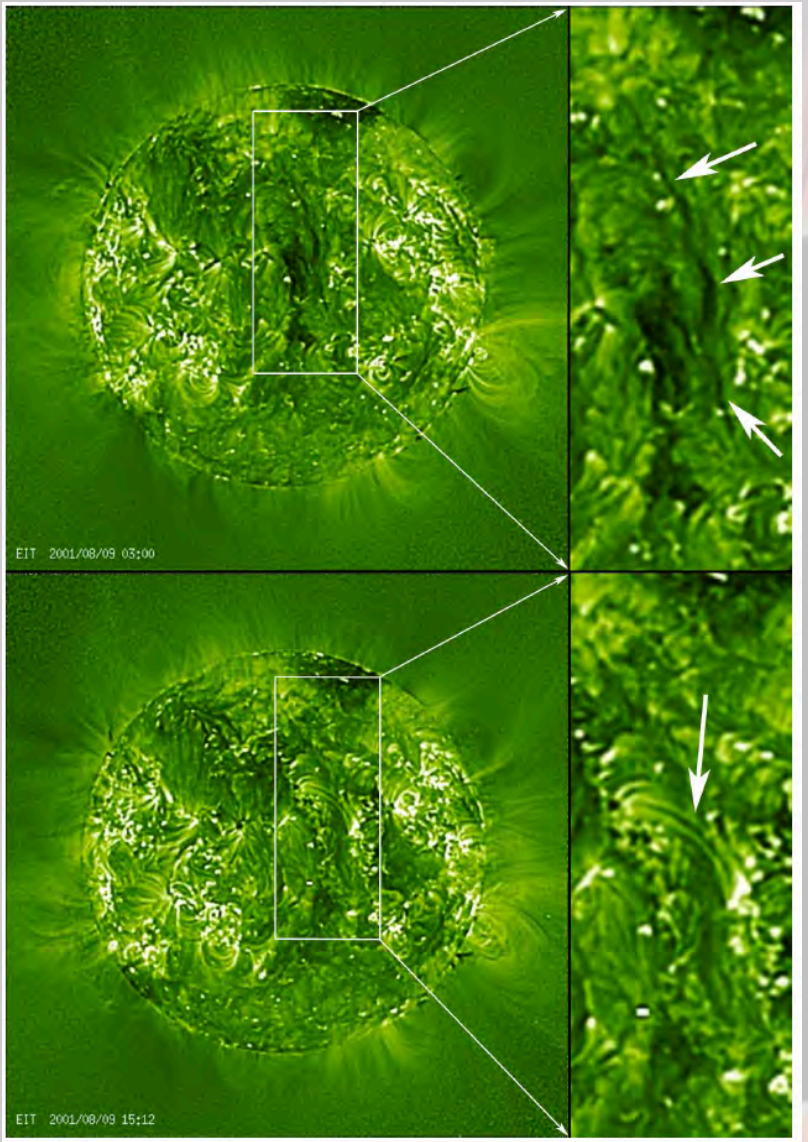
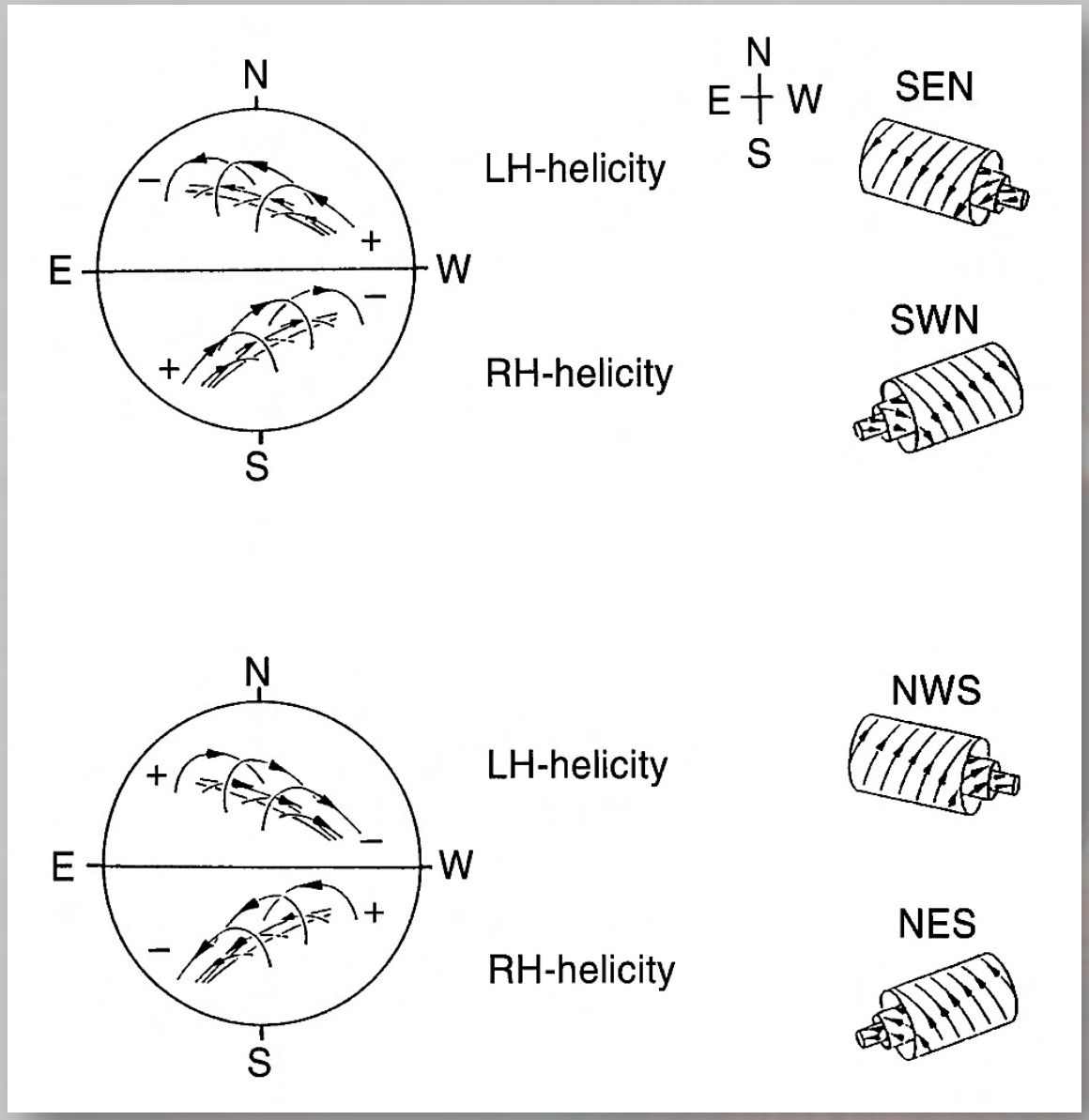


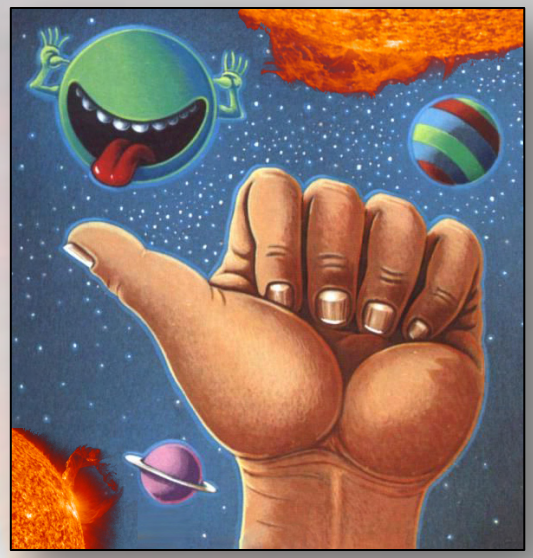
Figure 4. SOHO/EIT 195Å wavelet-enhanced images before (top row) and after the eruption (bottom row). Upper row: at the left shown the filament channel before the eruption inside a white box; at the right, white arrows point to the 195Å dark linear feature identifying the filament channel (August 09, 2001 at 03:00 UT). Bottom row: filament channel soon after the eruption; A white arrow points to flare-like loops above the filament channel. The left-skew of these loops corresponds to dextral chirality (August 09, 2001 at 15:12 UT).

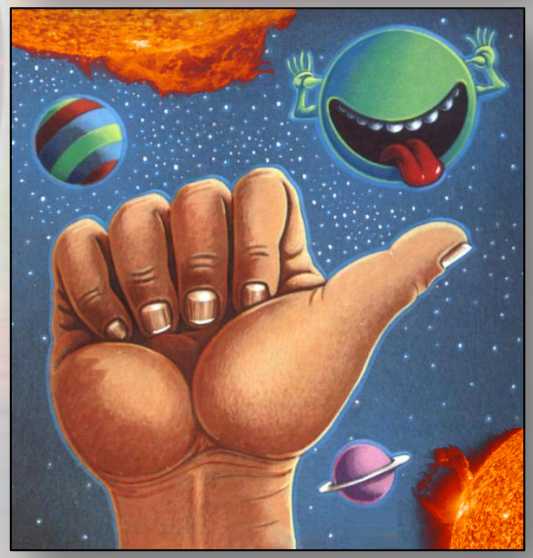
The skew of the post eruptive bright arcade will be the same as the skew of the coronal arcade and therefore can give the answer on chirality.

Pevtsov, Panasenco & Martin, 2011

8. Chirality of ICME (measured in-situ) is the same as the chirality of the coronal arcade above the filament channel from where ICME originated.



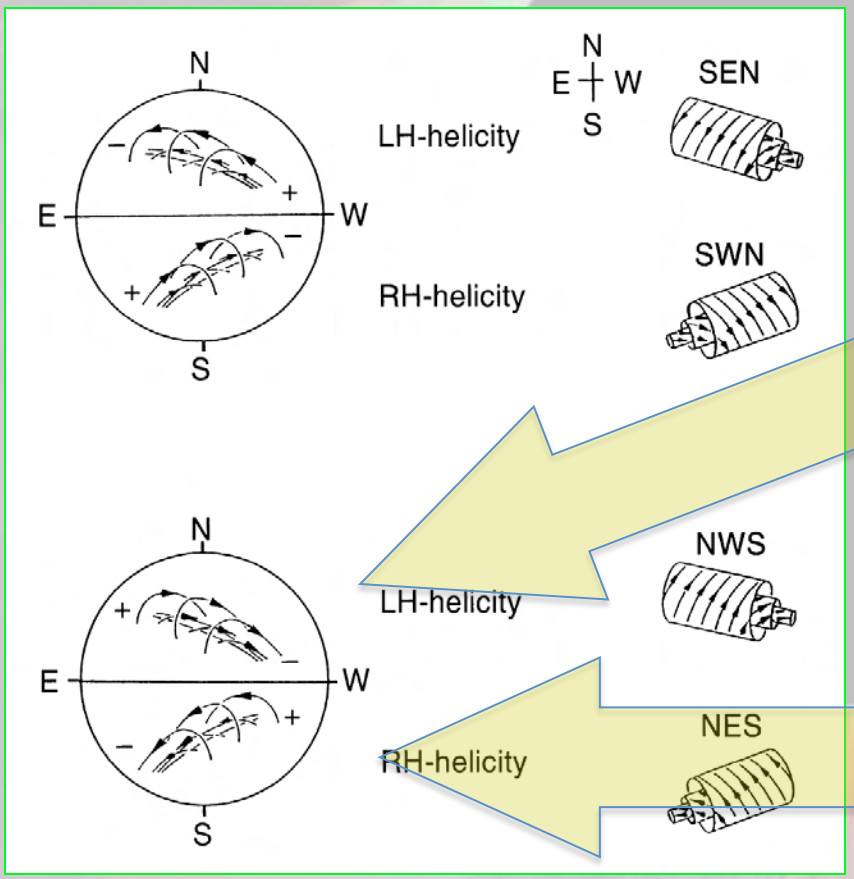


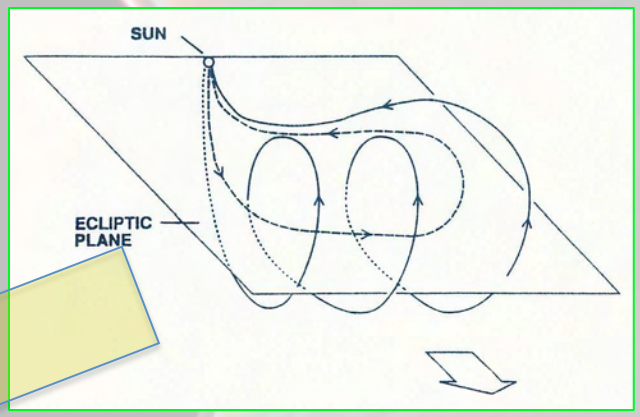


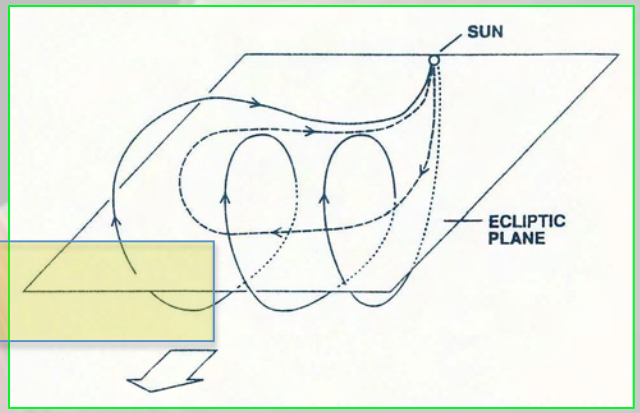
Bothmer and Schwenn 1998

After eruption…

7. Chirality of ICME (measured in-situ) is opposite in chirality to the filament channel and filament from where this ICME originated, but is the same as the chirality of the coronal arcade.

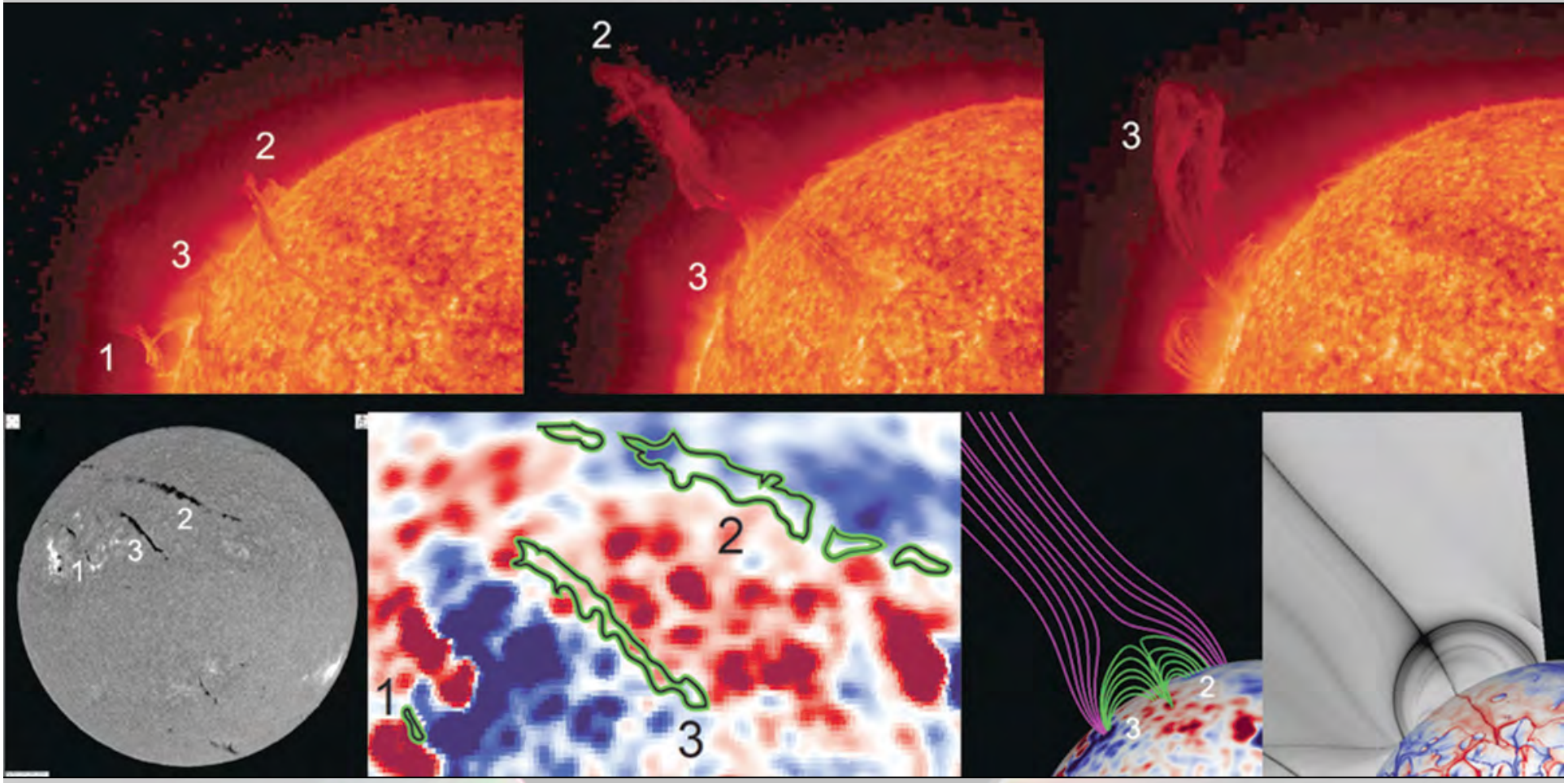




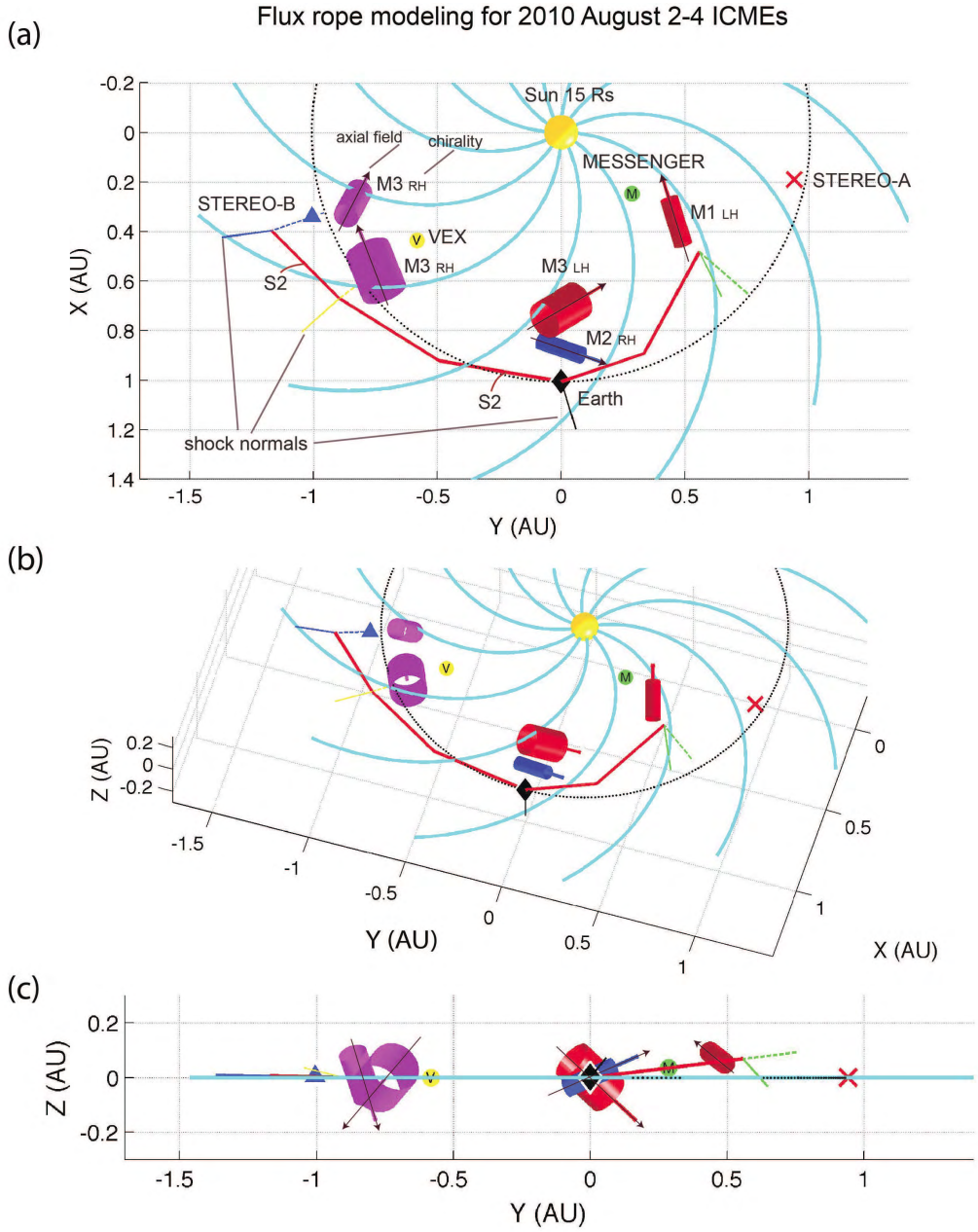


Bothmer & Schwenn, 1998

Gosling, 1990

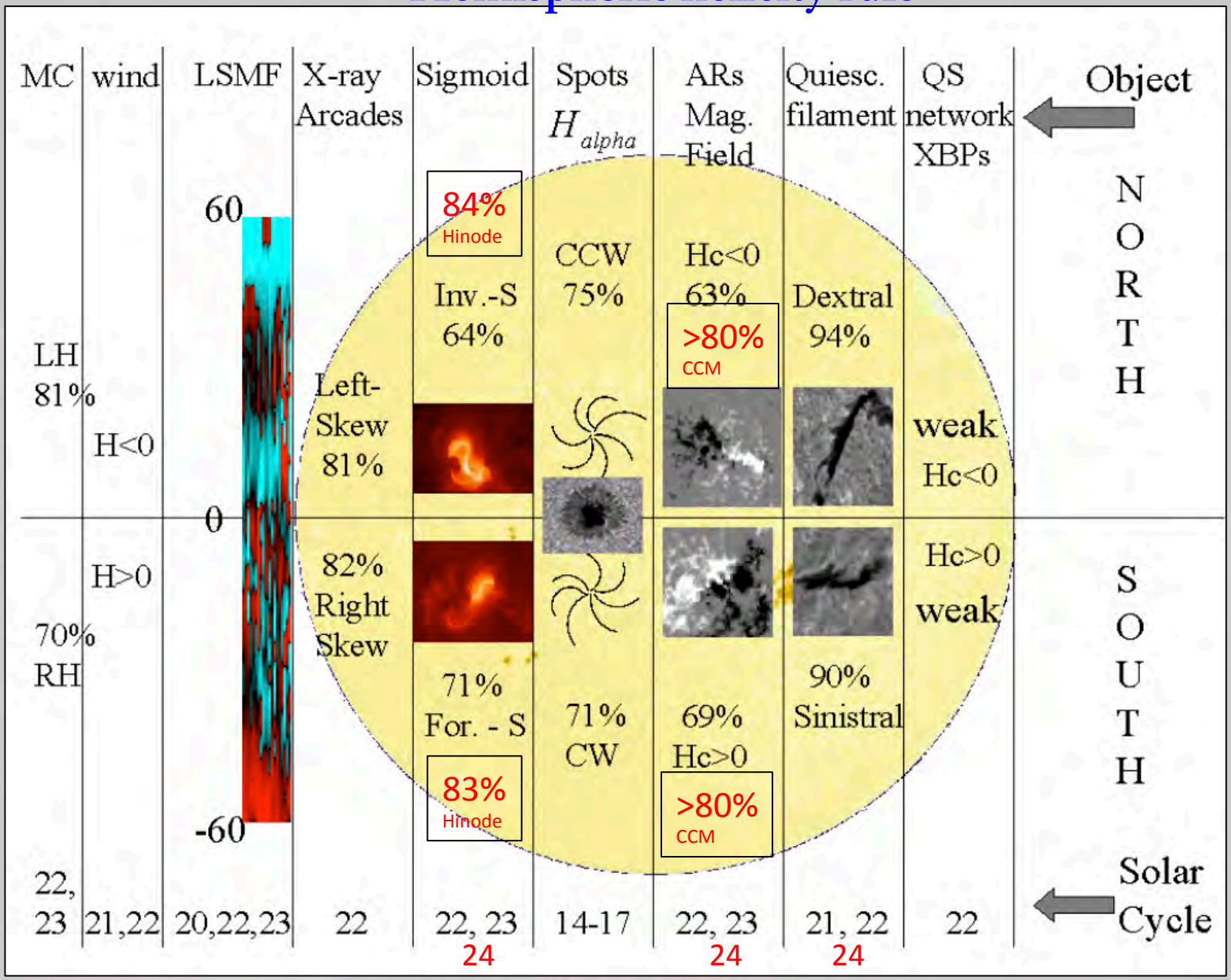


Torok et al., 2011



Mostl et al., 2012

Hemispheric helicity rule



(Pevtsov 2002; revised by Panasenco for cycle 24)

How is filament chirality related to the interplanetary Bz and geo-effectiveness?

If we know the chirality of the filament/filament channel and the magnetic polarity on either of its sides, we can unambiguously determine the direction of the axial magnetic field along the channel. When looking from the positive (negative) polarity side of the filament the axial field will be directed towards the right (or left) for dextral (sinistral) filaments respectively. The direction of the axial field of the filament is the same as the axial magnetic field of the coronal arcade above the channel. This arcade becomes part of the CME flux-rope during eruption and carries the same axial field it had before the eruption. The chirality then determines the sense of rotation of the flux-rope CME field around the magnetic axis. Therefore the axial field direction of the CME, together with the chirality, i.e. the sense of rotation of the field around this magnetic axis, and knowledge of the 3D position of ICME in space, its deflections/rotation, will determine the direction of the Bz field of the corresponding ICME as it travels to 1 AU.