Continuous upflow of material in an AR filament from the photosphere to the corona

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Abstract

Using spectropolarimetric data of an Active Region (AR) filament we have carried out inversions in order to infer vector magnetic fields in the photosphere (Si line) and in the chromosphere (He line). Our filament lies above the polarity inversion line (PIL) situated close to disk center and presents strong Zeeman-like signatures in both photospheric and chromospheric lines. Pore-like formations, see below (Fig. 4), with both polarities are identified in the continuum under the PIL. The azimuth ambiguity is solved at both heights using the AZAM* code. A comparison between the photospheric and chromospheric vector magnetic fields revealed that they are well aligned in some areas of the filament. However, especially at chromospheric heights, the magnetic field is mostly aligned with the dark threads of the filament. Velocity signatures indicating upflows of field lines are found at both heights.

The combination of all our results strongly suggest an emerging flux rope scenario.

*Lites et al. 1995, ApJ, 446, 877

Observations & Inversions

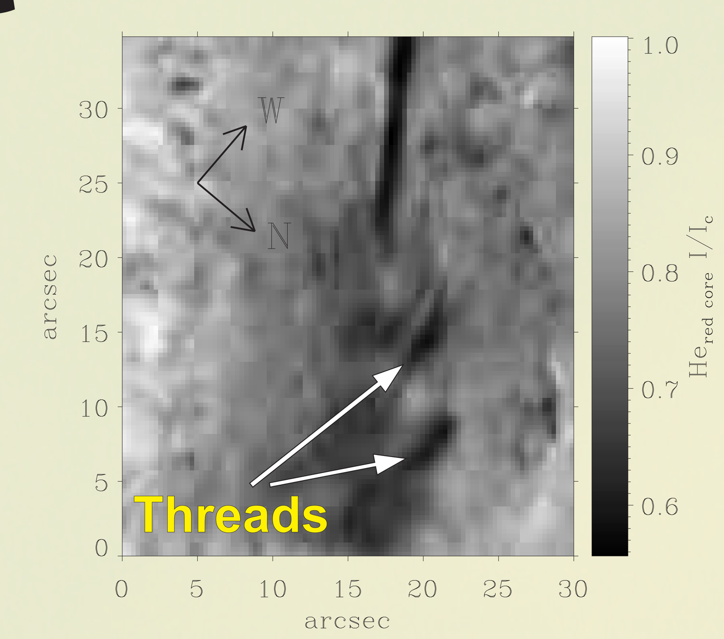

Fig. 3: He I (red core centered line) slit-reconstructed intensity I/I_c image.

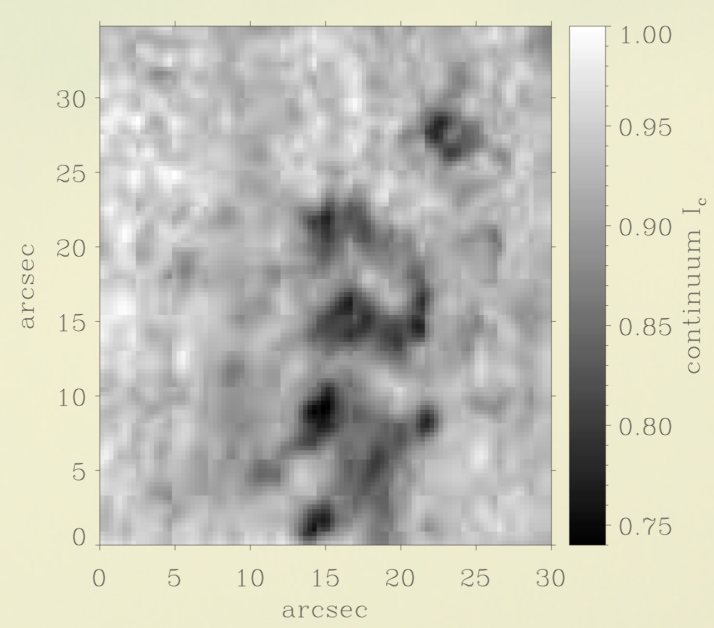

Fig. 4: Continuum slit-reconstructed image. Pores and penumbral-like structures can be identified.

Table 3: Used inversion codes.

	He I	Si I
Code	MELANIE[1] (*Milne-Eddington*)	SIR[2] (*Stokes Inversions based on Response functions*)

[1]Socas-Navarro, H. 2001, ASPC, 236, 487
[2]Ruiz Cobo, B., & del Toro Iniesta, J.C. 1992, ApJ, 398, 375

Ion	λ (Å)
Si I	10827.09
He I	10829.09
He I	10830.25
He I	10830.34

Table 2: NIST atomic data.

Days (July 2005)	3rd	5th
μ	0.97	0.92
# Maps	2	7
FOV (arcsec)	34 X 30	

Table 1: Observations.

From the ME inversions we have inferred strong chromospheric magnetic fields in the filament, between **600 – 800 G**, predominantly transversal.

At photospheric, as well as chromospheric, heights we found very high inclinations (between 80° and 100°) with respect to the LOS thus confirming **strong transverse fields** in this AR filament. For a more detailed description of the observations and inversions see Kuckein et al. (2009, 2010).

Velocities

Using the inversion code MELANIE (SIR), we inferred the chromospheric (photospheric) velocities.

In order to understand if the field lines in the filament are moving up or down, we refer the velocities in them to those obtained in the faculae (which acts as our zero of velocity). Below we present the velocities (Δv) of the filament with respect to the faculae.

He I 10830

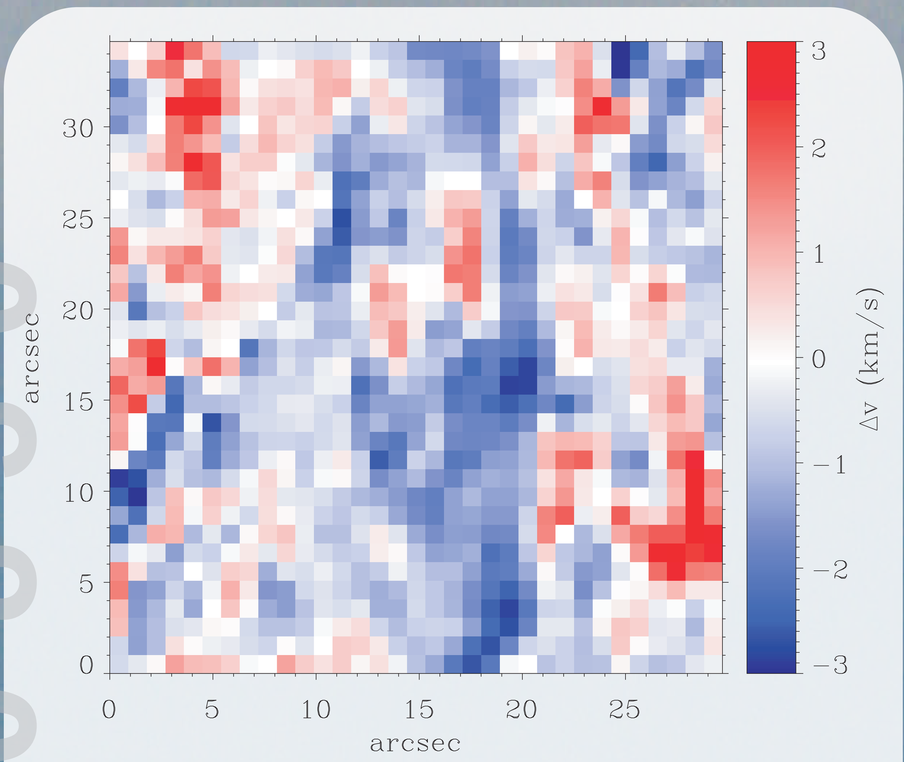

Fig.6: He I velocity map Δv with respect to the mean faculae velocity of the map. Individual upflows (*blue*) up to 2.8 km/s can be seen at the position of the filament (at the center of the map). All the filament is rising with a mean velocity of ~ 1.1 km/s.

Si I 10827

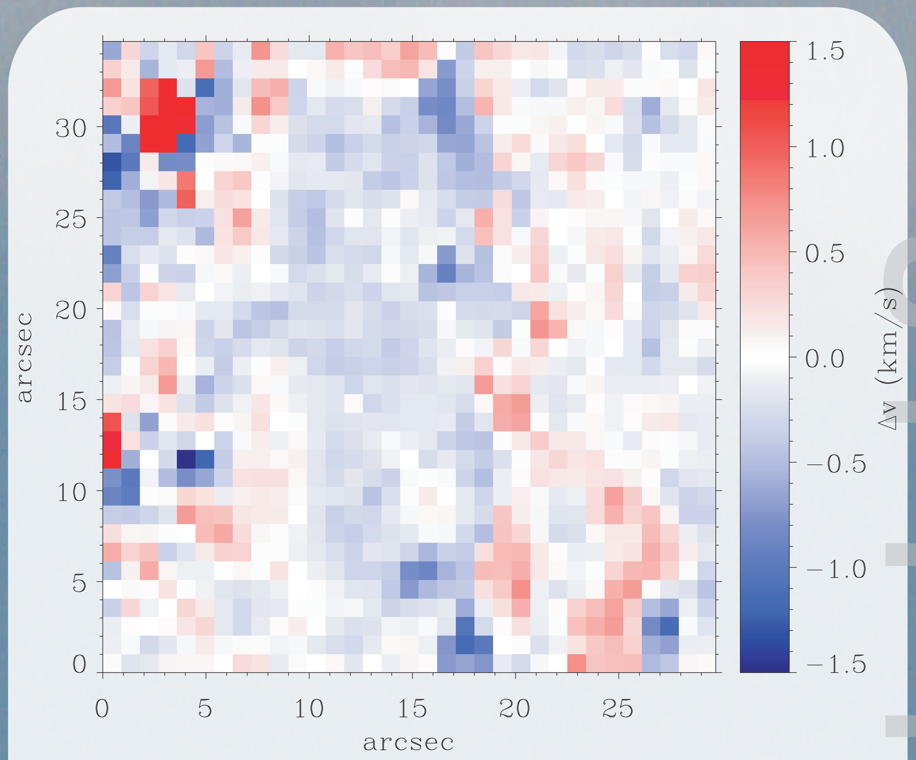

Fig.7: Photospheric (Si I) velocity map Δv with respect to the mean faculae velocity of the map. Small upflows with a mean velocity of ~ 0.1 km/s are present at the position of the filament.

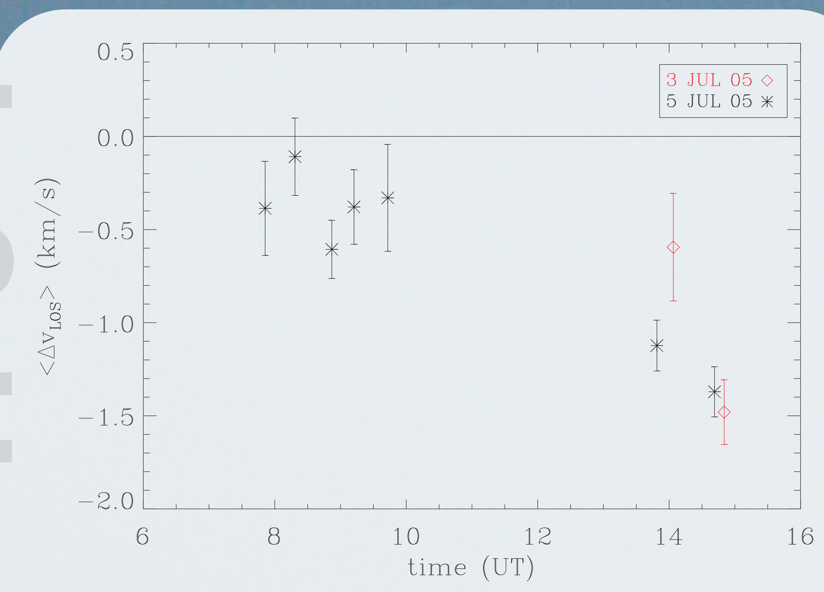

Fig. 8: Chromospheric (He I) mean LOS velocities (Δv) of the filament with respect to the faculae mean velocity. We have calculated the Δv of 9 maps and all show clear upflows as seen in this figure. The X-axis show the time when the data was acquired.

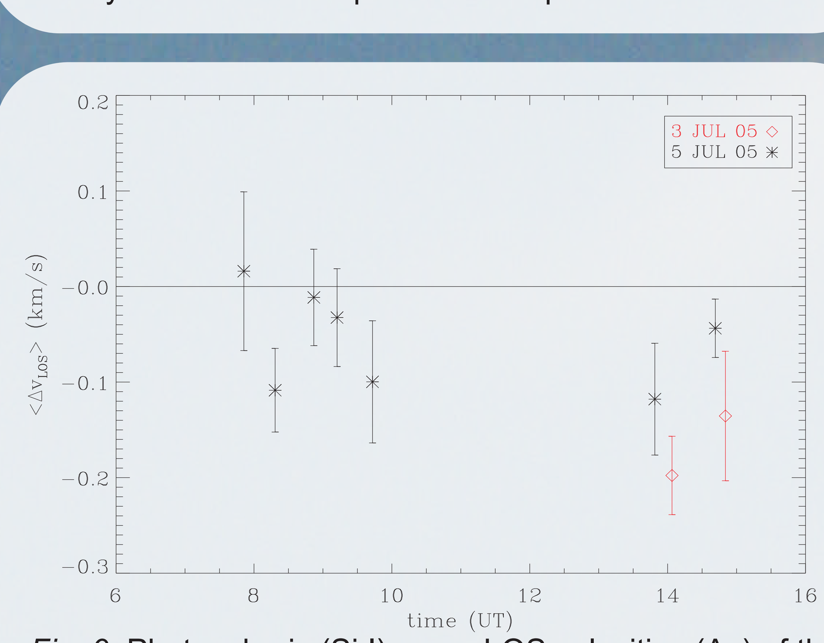

Fig. 9: Photospheric (Si I) mean LOS velocities (Δv) of the filament with respect to the faculae mean velocity. At this height the filament is also predominantly moving upward.

	Criteria
Filament	He I red core intensity $I_{He}/I_c < 0.6$
Faculae	Si I ($\log \tau = -2$) inclination $\theta < 10^\circ$ or $\theta > 170^\circ$

Table 4: Criteria used for calculating the mean velocities of the filament and faculae.

Vector magnetic field

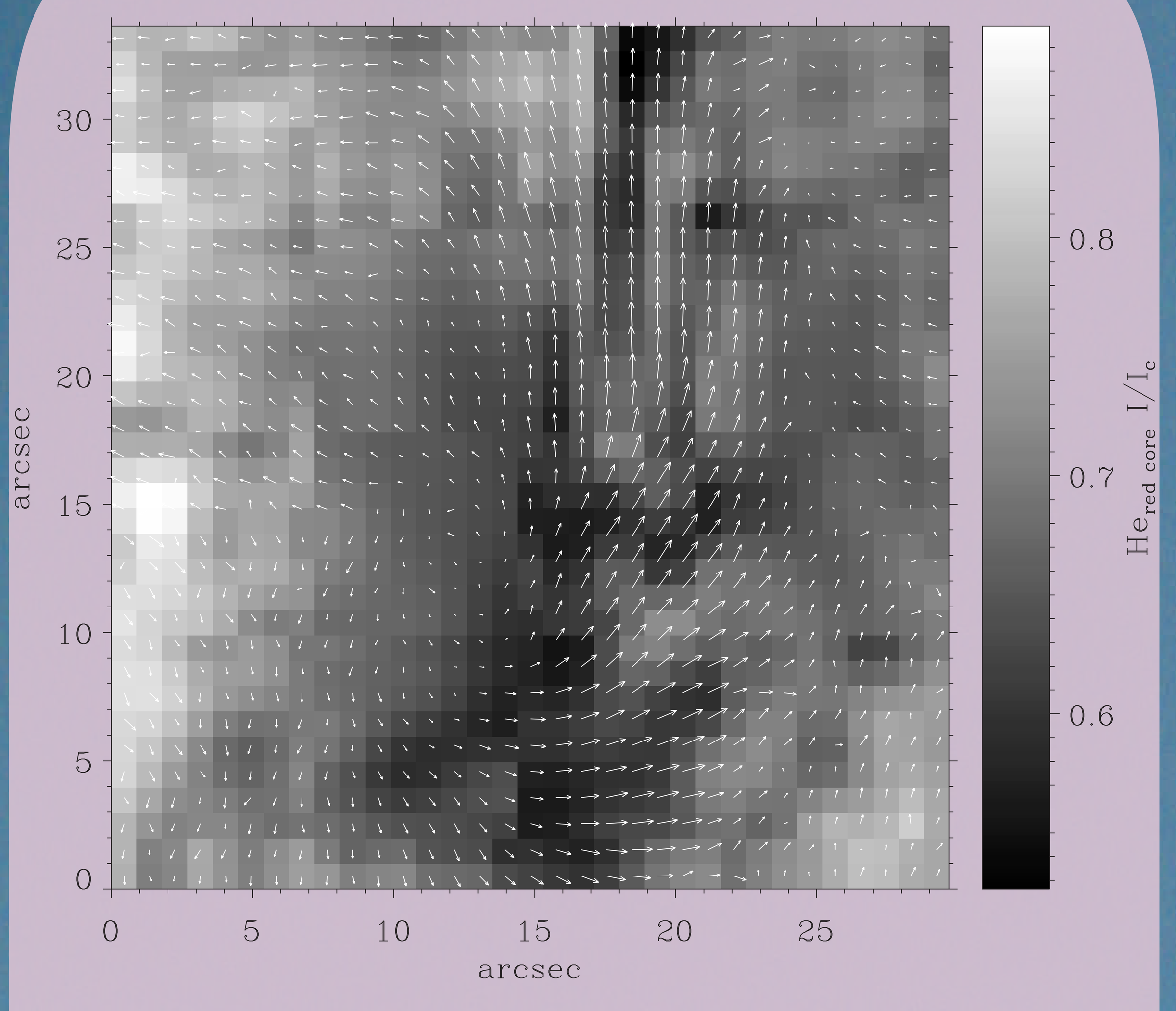

Fig. 1: The white arrows show the 180º resolved He I 10830 Å vector magnetic field. In the background image we can see the continuum normalized intensity of the He red core line. The dark threads represent higher concentrations of He.

The magnetic field is well aligned with the dark threads. This behavior is common to the other maps of the 5th of July. The field lines are moving upward as can be seen in Figure 6.

Note that the polarities distribution, He I threads orientation together with the azimuth of the field lines pointing upward, imply dips in a flux rope topology.

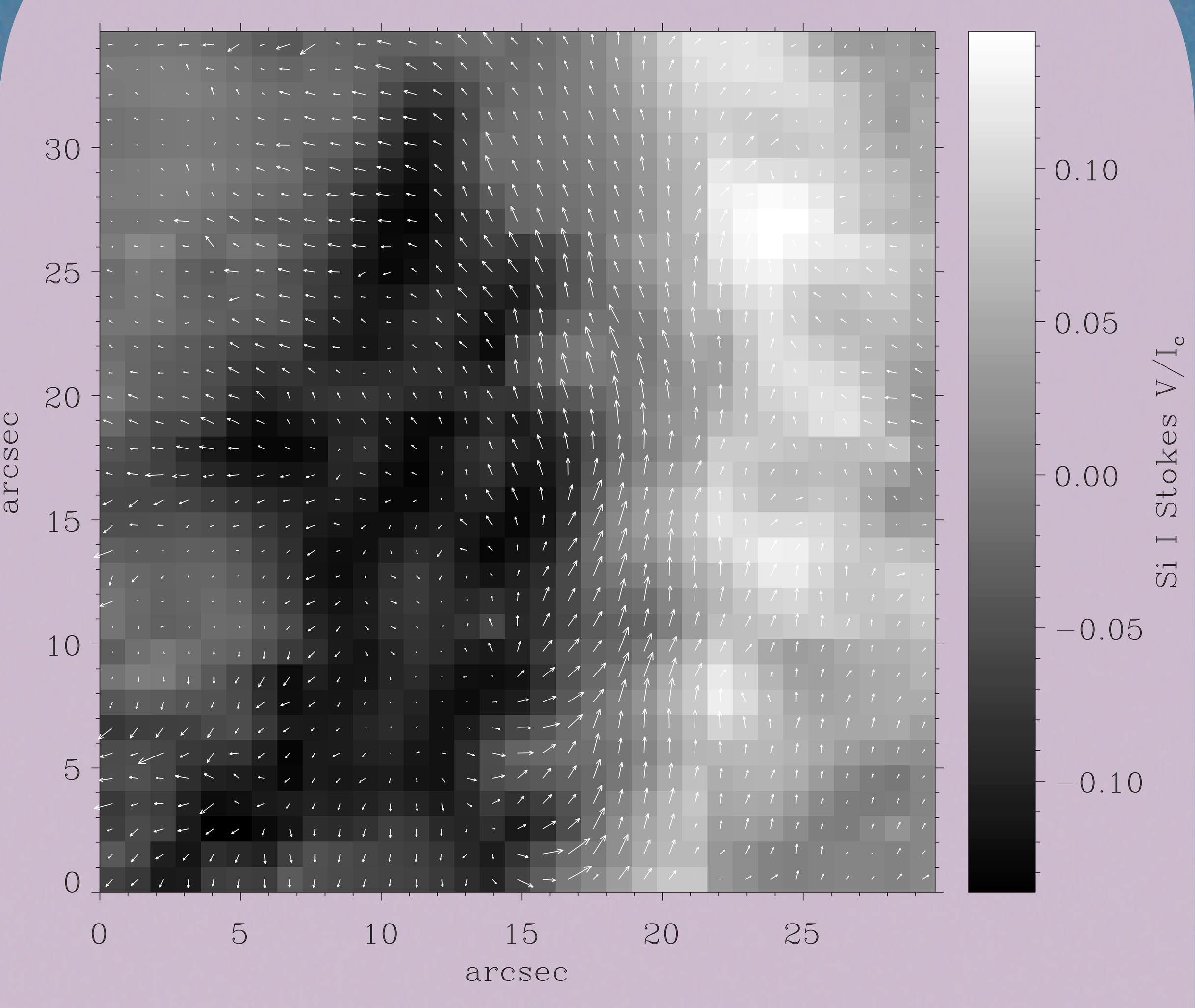

Fig. 2: Photospheric Si I 10827 Å (at a height of $\log \tau = -2$) vector magnetic field arrows over-plotted to the Si I Stokes V/I_c image. The opposite polarity fluxes are into close contact with each other.

Looking at the figure, one can identify a clear alignment of the magnetic field with the PIL indicating a highly sheared magnetic field which, taking into account the results of the inferred velocities (see below), is emerging slowly compared to the chromospheric velocities into the corona.

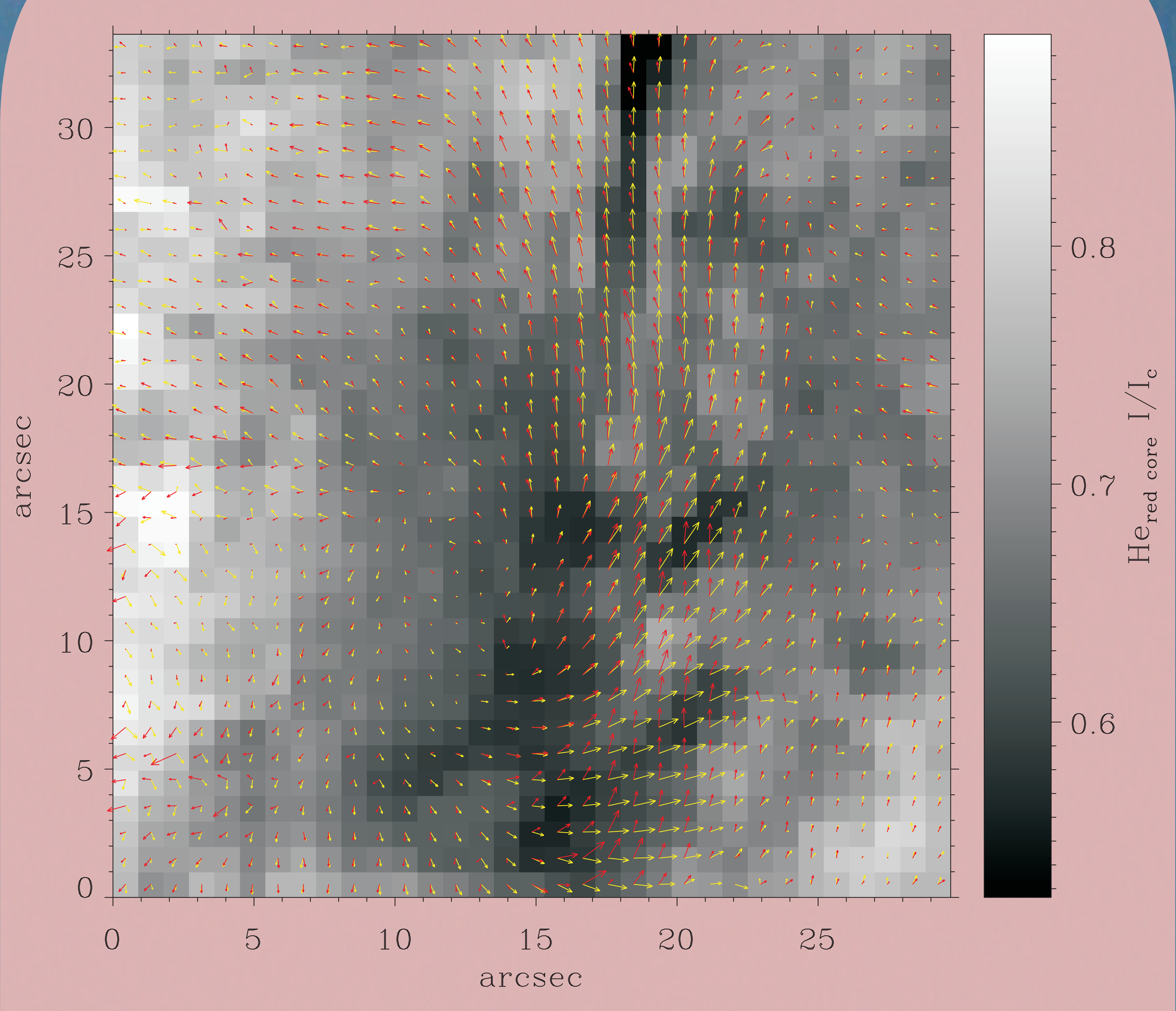

Fig. 5: He I (*yellow*) over-plotted to Si I (*red*) vector magnetic field arrows. In the background we show the He $I_{red\ core}/I_c$ intensity map. Chromospheric fields are systematically less sheared than photospheric fields in the bottom part of the filament. Typically by at least 10-20 degrees. At the top part of the filament, photospheric and chromospheric fields are more aligned with each other.

Conclusions

- Upflows in He I (chromosphere)
- Small upflows in Si I (photosphere)
- He I vector magnetic field aligned with He I dark threads, suggestion of a twisted flux rope
- Si I vector magnetic field aligned with PIL, highly sheared magnetic field lines.

An emerging flux rope scenario is suggested from the combination of observed velocities and vector field distribution.

Future work

- Nonlinear force-free field extrapolations
- Time evolution of the filament

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References

- Kuckein, C., Centeno, R., Martínez Pillet, V., Casini, R., Manso Sainz, R., & Shimizu, T. 2009, A&A, 501, 1113
- Kuckein, C., Centeno, R., & Martínez Pillet, V. 2010, MmSAI, in press (arXiv:1001.2434)