The dynamics of a solar arch filament system from the chromosphere to the photosphere

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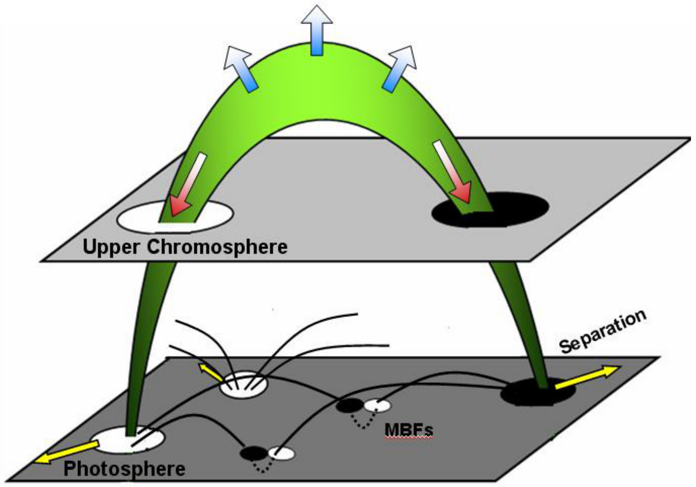
We study the dynamics of plasma along the legs of an arch filament system (AFS) from the chromosphere to the photosphere, observed with high-cadence spectroscopic data from two ground-based solar telescopes: the GREGOR telescope (Tenerife) using the GREGOR Infrared Spectrograph in the He I 10830 Å range and the Swedish Solar Telescope (La Palma) using the CRisp Imaging Spectro-Polarimeter to observe the Ca II 8542 Å and Fe I 6173 Å spectral lines. The temporal evolution of the draining of the plasma was followed along the legs of a single arch filament from the chromosphere to the photosphere. The average Doppler velocities inferred at the upper chromosphere from the HeI 10830 Å triplet reach velocities up to 20–24 km s^{-1}, and in the lower chromosphere and upper photosphere the Doppler velocities reach up to 11 km s^{-1} and 1.5 km s^{-1} in the case of the Ca II 8542 Å and Si I 10827 Å spectral lines, respectively. The evolution of the Doppler velocities at different layers of the solar atmosphere (chromosphere and upper photosphere) shows that they follow the same line-of-sight (LOS) velocity pattern, which confirms the observational evidence that the plasma drains toward the photosphere as proposed in models of AFSs. The observations and the nonlinear force-free field (NLFFF) extrapolations demonstrate that the magnetic field loops of the AFS rise with time.

Context of the research

1. Emerging flux regions (EFRs) are seen as magnetic concentrations in the photosphere of the Sun. EFRs are visible in the chromosphere in the form of magnetic loops loaded with cool plasma. Nowadays, we refer to them as an arch filament system (AFS), which connects two different polarities.

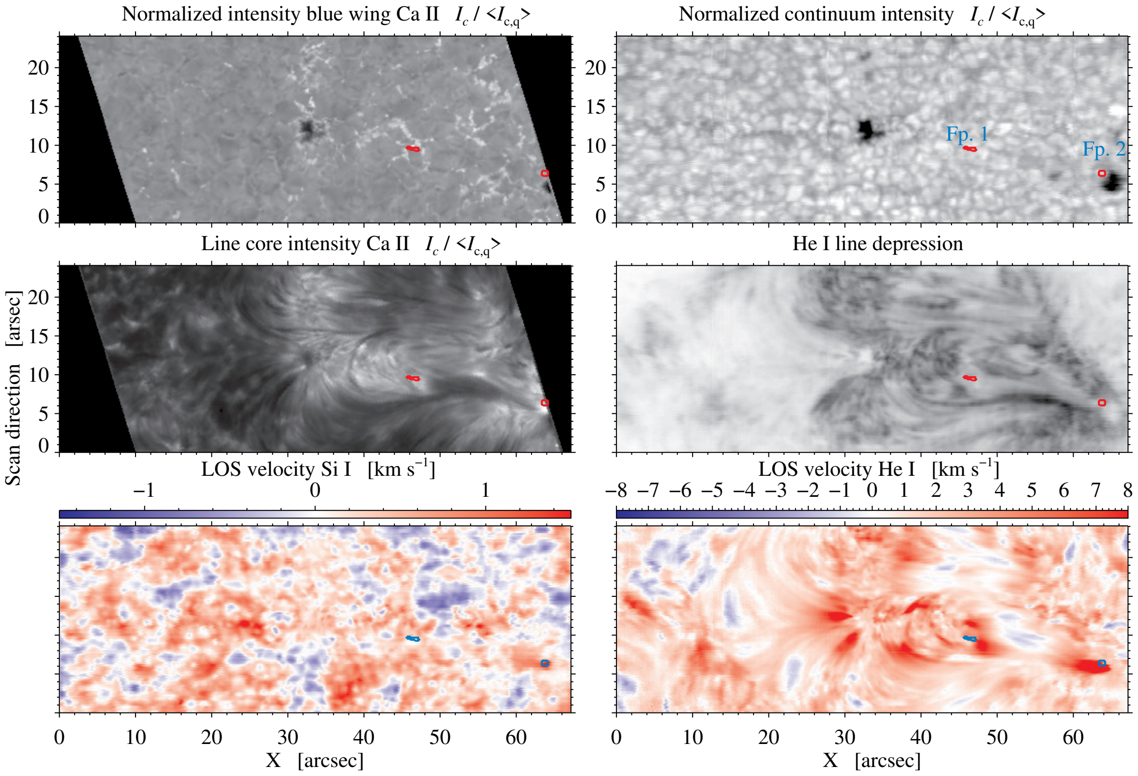


Xu et al. 2010, A&A 520, A77

2. Essentially, these structures develop with upflows in the midpoint of the loops and downflows at the footpoints

3. Supersonic velocities at this chromospheric heights are considered above v > 10 km s^{-1}

4. Goal: follow the evolution of the plasma flows across several heights at the footpoints of an AFS.



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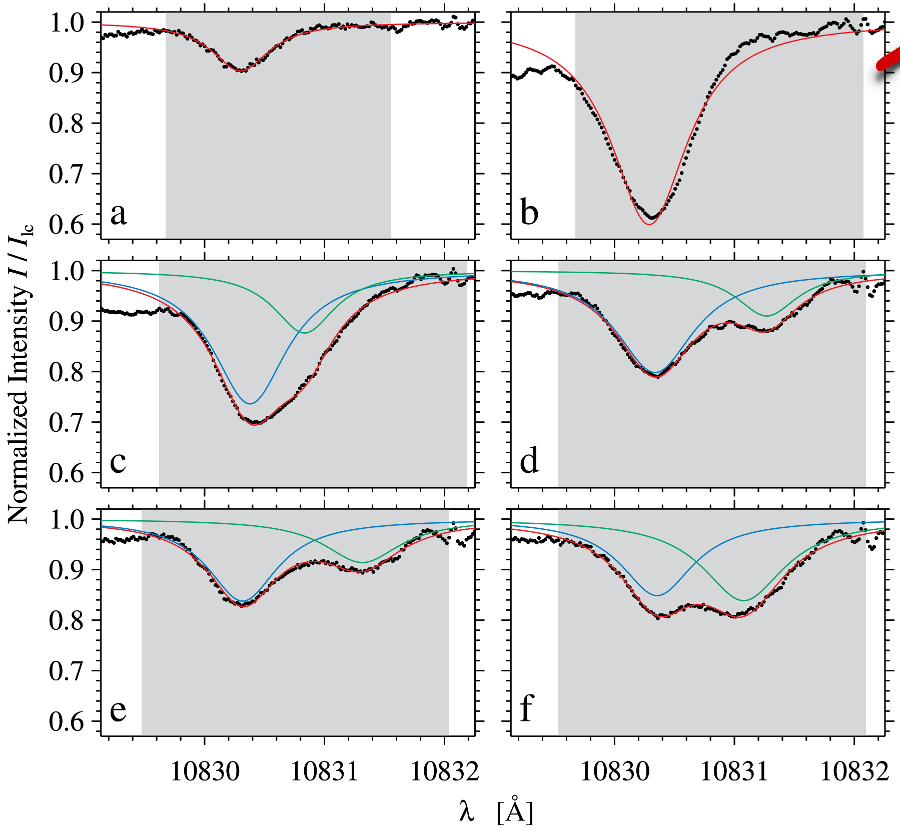
Observations

Telescope and date	Instrument	λ (Å)	Time (UT)	mode
GREGOR **2015 April 17**	Infrared Spectograph (GRIS)	He I 10830 Si I 10827 Ca I 10839	08:16 - 09:20	Spectroscopic
SST **2015 April 17**	CRisp Imaging Spectro-Polarimeter (CRISP)	Ca II 8542 Fe I 6173	08:47 - 9:20	Spectropolarimetric

Methodologies



González Manrique et al. 2016, AN, 337, 1057

Upper Chromosphere	He I 1083.0 nm	1 or 2 Lorentzian
Lower Chromosphere Upper photosphere	Ca II 854.2 nm	NICOLE inversions average values log $\tau \in [-2.4,-3.0]$
Upper photosphere	Si I 1082.7 nm	Fitting the core, gaussian
Lower photosphere	Fe I 617.3 nm Ca I 1083.9 nm	Fitting the core, gaussian

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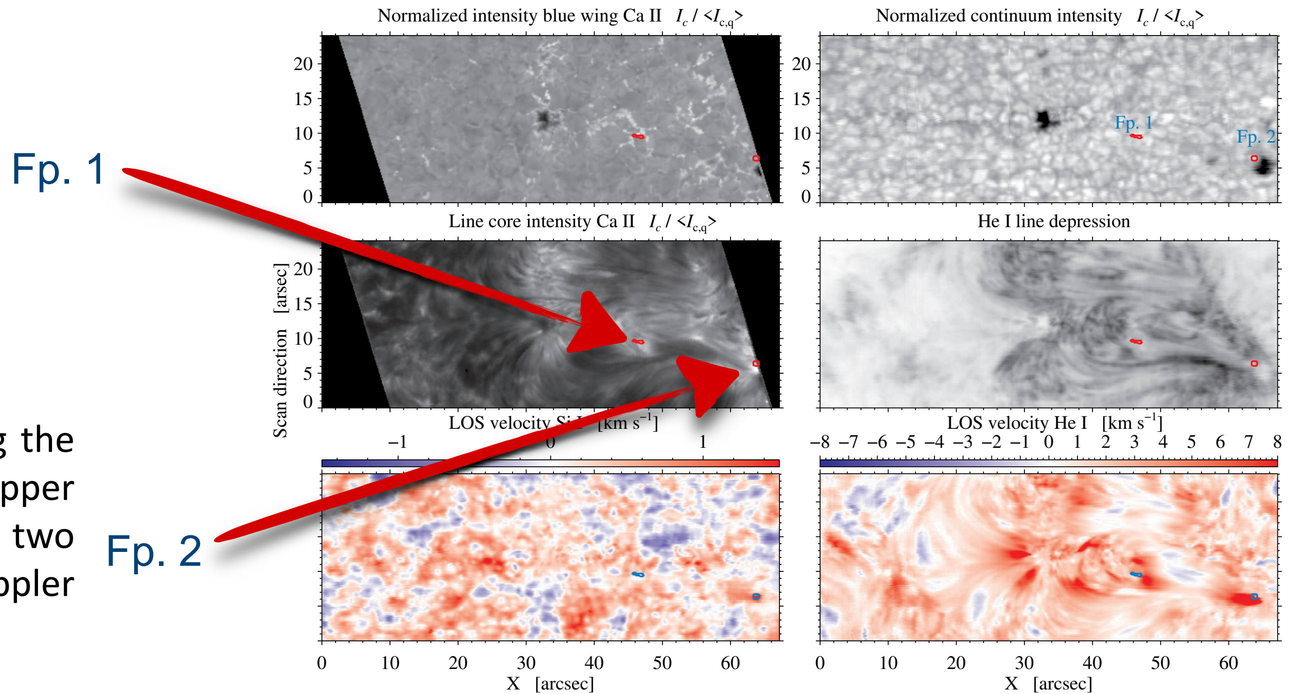
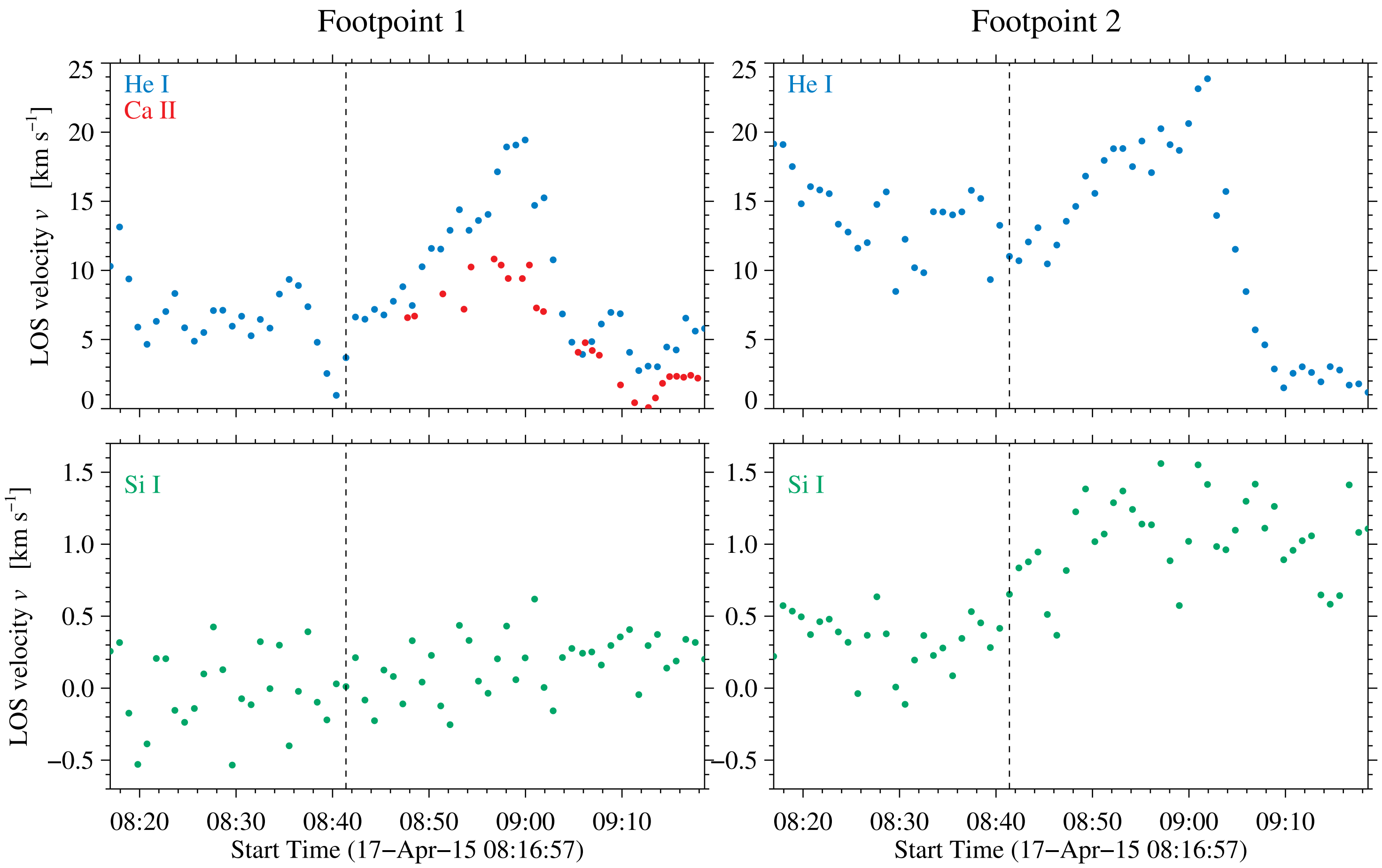


We investigate the height dependence of the draining flows along the AFS across different layers of the solar atmosphere, from the upper chromosphere down to the photosphere. We selected the two footpoints of a single arch filament and computed the average Doppler velocities within the area of the contours of Fp. 1 and Fp. 2

Results



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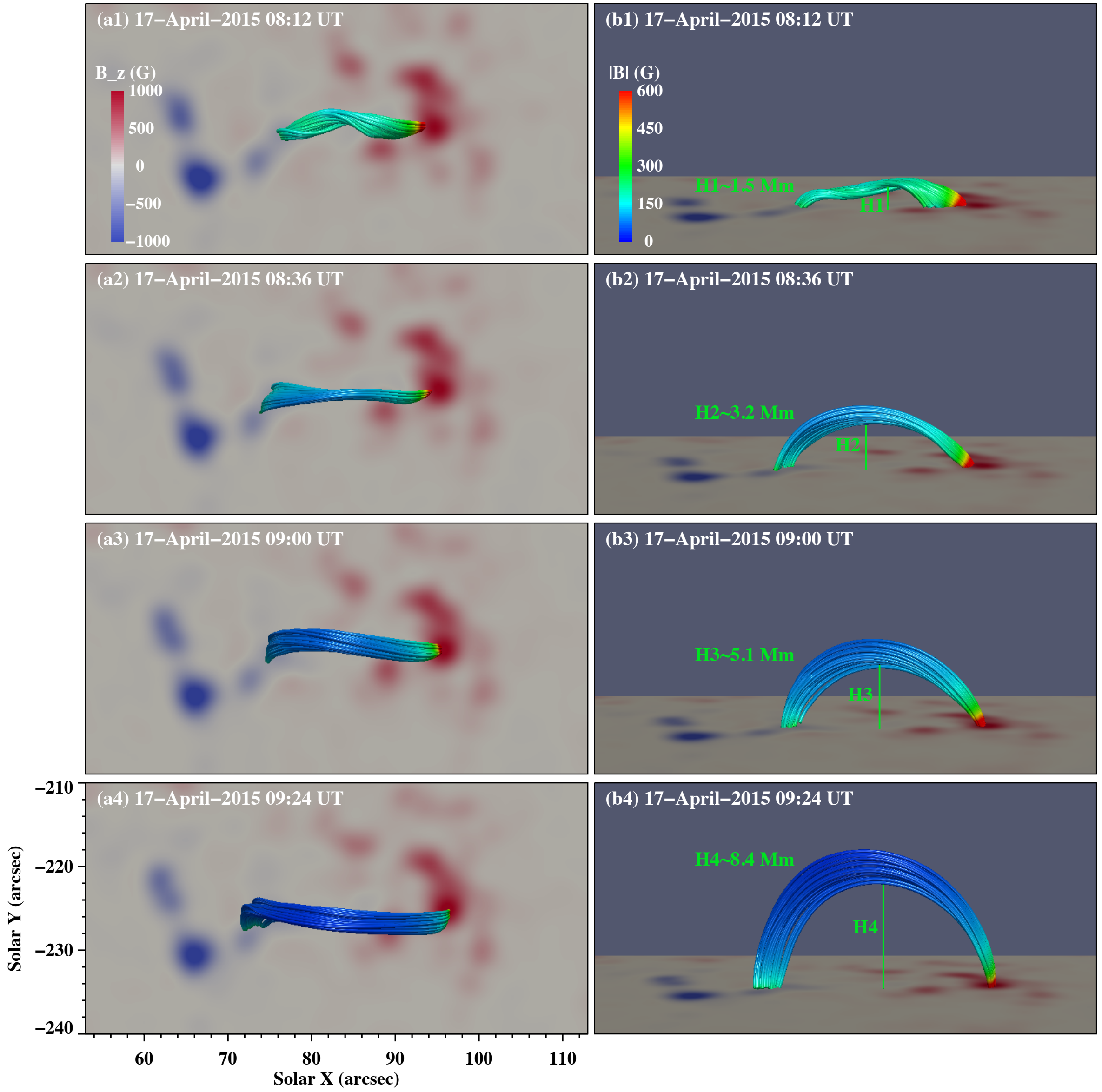
- ☑ We show the temporal evolution of the Doppler velocities for the He I, Ca II, and Si I for the Fp. 1 and Fp2.
- ☑ Blue He I (upper chromosphere), red Ca II IR (Lower chromosphere), and green Si I (upper photosphere).
- ☑ Constant supersonic LOS velocities at the beginning of the time series (He I).
- ☑ After 25 min sudden increase of the LOS velocities. At the end decay.
- ☑ 08:41 UT the mean Doppler velocities increased, reaching a maximum of about 20-24 km s^{-1} (He I), 11 km s^{-1} (Ca II), 1.5 km s^{-1} (Si I).
- ☑ Doppler velocities drop drastically at the end of the time series.
- ☑ Clear correlation between He I, Ca II, and Si I.
- ☑ Fe I and Ca I photospheric spectral lines do not show any correlation.
- ☑ Asymmetries between Fp. 1 and Fp. 2.

Results



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- ☑ To investigate the evolution of the 3D magnetic topology of the AFS, we perform nonlinear force-free field (NLFFF) extrapolations.
- ☑ We use the “weighted optimisation” method (Wiegelmann 2004; Wiegelmann et al. 2012).
- ☑ The boundary conditions for the NLFFF extrapolation is given by an HMI photospheric vector magnetogram with an image scale of 0.5” pixel^{-1}. Preprocessed by a procedure developed by Wiegelmann et al. (2006) to satisfy the force-free condition.
- ☑ The NLFFF extrapolations were modeled for four different times to associate the flows to the magnetic field topology (08:12 UT, 08:36 UT, 09:00 UT, and 09:24 UT). The time range covers our ground-based observing time.
- ☑ The observations and the NLFFF extrapolations demonstrate that the magnetic field loops of the AFS rise with time.
- ☑ At the end of the time series, the height of the magnetic loop continued to increase up to 8.4 Mm.

Conclusions

- ☑ We scrutinized how the plasma flows along the footpoints of an AFS connecting two different polarities through different layers of the solar atmosphere. In both footpoints the dynamic shows similar LOS velocity pattern at different atmospheric layers, the upper chromosphere and the upper photosphere. This similar behavior of the plasma flows at different layers.
- ☑ To confirm the plasma reaching the upper photosphere at Fp. 2, we used He I and Si I (GRIS), while at Fp. 1, we also used Ca II (CRISP).
- ☑ we do not detect the plasma reaching the upper photosphere with the Doppler velocities inferred from the Si I spectral line at Fp. 1 while at Fp. 2 they are well detected.
- ☑ The plasma decelerated with height.
- ☑ The NLFFF extrapolations demonstrate why the plasma decelerated with height and the velocity asymmetries between Fp. 1 and Fp. 2.
- ☑ All figures and the complete study can be read in González Manrique et al. 2020, ApJ, 890, 82: https://iopscience.iop.org/article/10.3847/1538-4357/ab6cee/pdf