Fast downflows in the chromosphere seen by He I 1083 nm lines

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Chromospheric downflows

- He I triplet lines (1082.909 nm, 1083.025 nm and 1083.034 nm) are sensitive to dynamic phenomena in the solar atmosphere due to their narrow line width and various studies have reported downflows in these lines (e.g., Muglach et al. 1997; Solanki et al. (2003) and Lagg et al. (2004)).
- Dual flows (one subsonic and one supersonic) were reported by Schmidt et al. (2000) and Lagg et al. (2007) with the fast downflow (> 10 km/s) component showing redshifts of up to 42 km/s.

Our goal is to characterize the dual flows seen in the He triplet and investigate their relation with the magnetic field. We present a few results of our preliminary analysis in this direction.

Analysis tool - HELIX$^+$

- HE-Line Information extractor$^+$ inversion code (Lagg et al. 2004, 2009).
- Stokes profiles synthesis is carried out in a Milne Eddington type atmosphere.
- Model parameters are B, inclination, azimuth, line-of-sight velocity, Doppler width, damping constant, ratio of line center to continuum opacity, gradient of the source function.
- Merit function minimization done using PIKAIA algorithm.
- Can handle arbitrary number of atmospheric components and spectral lines.

Observations

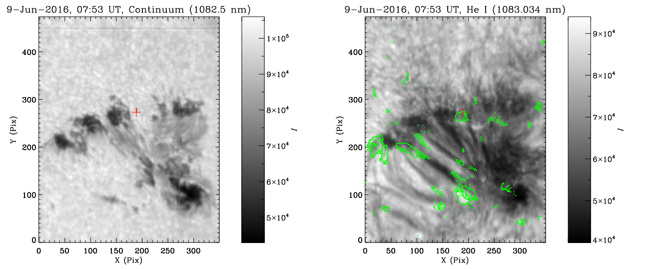


Figure 1: Intensity images of the active region NOAA 12552 in continuum (left) and in He I 1083.034 nm line core (right).

- Observations recorded by GREGOR Infrared Spectrograph (GRIS) mounted on the 1.5 m solar telescope GREGOR at the Observatorio del Teide of the active region NOAA 12552 on 9 June 2016 between 07:53 - 08:28 UT.
- Coordinates of the active region: x=+573", y=+243" ($\mu = 0.75$).
- Spatial resolution is approximately 0.45" and the rms noise is typically $1 \times 10^{-3} I_c$.

Line-of-sight velocities

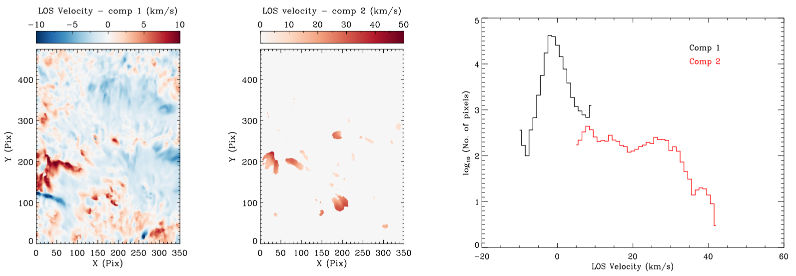


Figure 2: Line-of-sight velocity maps retrieved from two component inversions for the slow component (left), fast component (middle) and their histograms (right). The locations of these two component flows are marked by green contours in Figure 1.

Criteria for second component selection

- The second component must be shifted by at least 8 km/s relative to the first.
- The filling factor of the second component must be greater than 20%.
- Fitness from the two component inversion must be greater than at least 10% that of the one component inversion.
- Peak value of $|V|$ larger than $2 \times \sigma(V)$ or $|Q|$ larger than $2 \times \sigma(Q)$ or $|U|$ larger than $2 \times \sigma(U)$.

$\sigma(Q) = 1.23 \times 10^{-3} I_c$
$\sigma(U) = 1.39 \times 10^{-3} I_c$
$\sigma(V) = 1.33 \times 10^{-3} I_c$

Magnetic field strength and inclination

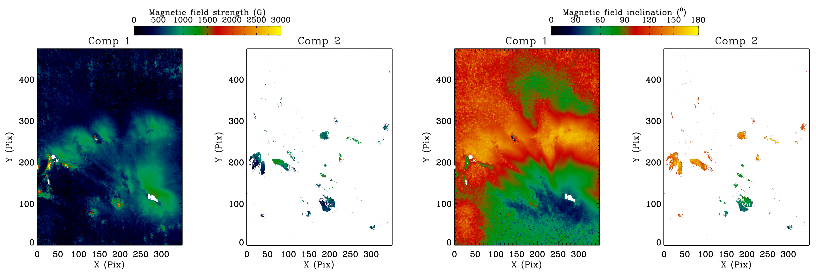


Figure 3: Magnetic field strength and inclination maps for the slow and fast components.

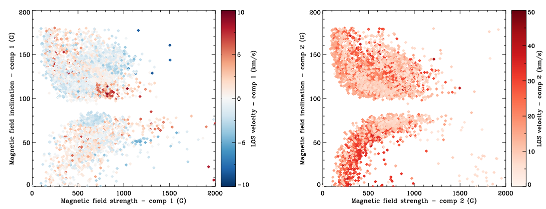
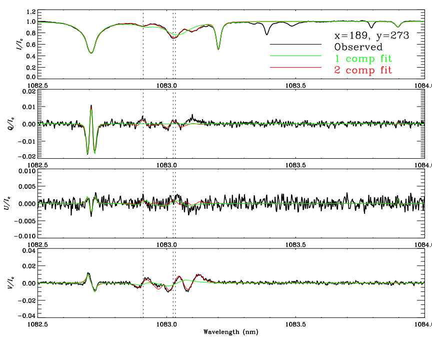


Figure 4: Correlation between the magnetic field strength, inclination and velocities at locations where both slow and the fast components are present.

Stokes profiles at dual flow locations



Two component model

- $v_1 = -0.4$ km/s
- $v_2 = 19.9$ km/s
- $B_1 = 587$ G
- $B_2 = 553$ G
- $\gamma_1 = 111°$
- $\gamma_2 = 132°$

Inversion with just one component is clearly not sufficient to fit the observed Stokes profiles at dual flow locations.

Figure 5: Comparison between the observed Stokes profiles (black), the fit from the 1 component inversion (green) and the fit from the 2 component inversion (red) at a pixel marked by red '+' in Figure 1, where two component flows are detected. Vertical dotted lines indicate He triplet positions.

Summary and outlook

- The preliminary analysis of the active region NOAA 12552 reveals that the supersonic downflows in the chromosphere are rather uncommon.
- About 4 percent of the analyzed pixels show two component flows with the fast component having supersonic velocities up to 42 km/s.
- The two component flows with one having supersonic velocities are located at the footpoints of the magnetic loops.
- The magnetic fields at the locations of dual flows are having strengths below 2 kG and slightly different inclinations with respect to the line-of-sight.

This analysis will be extended to a large dataset consisiting of different targets such as sunspots, pores, emerging flux regions etc. recorded by GRIS.

References

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Downflows in the solar chromosphere

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In earlier studies employing observations from VTT, a population of supersonic downflows with speeds up to 40 $\mathrm{km\,s^{-1}}$ coexisting with a second slow population were reported. Magnetic field was found to have different strength and orientation for the two populations. In this work, we carry out a statistical analysis of these downflows in observations recorded by the GRIS instrument at GREGOR in the He I 10830 Å triplet. Using multi-component and multi-line inversions of the spectropolarimetric data assuming Milne-Eddington-type atmospheres, we derive the velocities and magnetic vector for several data sets. Making use of the line-of-sight velocity and magnetic field vector maps retrieved from inversions, we investigate the velocity structure and its relation with the magnetic fields in the chromosphere where the He lines are formed (8000–10000 K).