Photospheric and Chromospheric Magnetic Structure of a Sunspot

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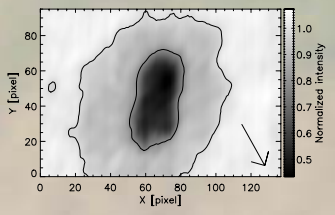
Abstract

The magnetic field of sunspots has been well studied in their photospheric layers, but is poorly known in the upper chromosphere. Here we present state-of-the-art inversions of the full stokes vectors of the He I triplet at 1083~nm and other infrared line which give us a map of the full magnetic vector in the upper chromosphere, as well as in the photosphere. These maps are analyzed to discuss the differences between the photospheric and the chromospheric magnetic structure of sunspots.

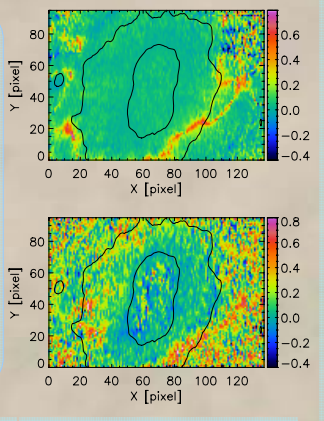
Observations and data analysis

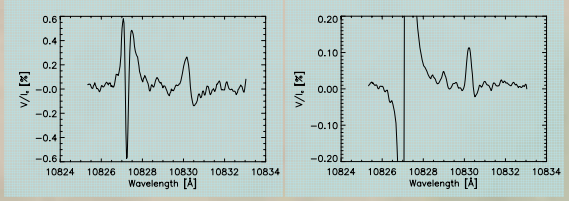
An isolated Sunspot at μ=0.88 was recorded on September 28, 2002 with the Tenerife Infrared polarimeter on the Vacuum Tower Telescope at the Teide observatory on Tenerife. The wavelength range contains one photospheric line (Si 1082.7 nm) and the chromospheric He I triplet at 1083~nm. The analysis of both lines is based on inversion techniques (Frutiger 2000; A. Lagg et al. 2003).



Continuum map of the Sunspot. The arrow points to the solar limb. The Sunspot is almost round.

The Stokes V area asymmetry, δA, for Silicon (top) and Helium (bottom), clearly shows the position of the neutral line on the sunspot in Silicon and Helium. The Silicon line is sensitive to strong gradients in B present in the penumbra (e.g. Borrero et al. 2005). The Helium, formed in the upper chromosphere, also shows broad-band polarization, suggesting the presence of strong gradients also at these layers. The black contour marks the umbra-penumbra boundaries.

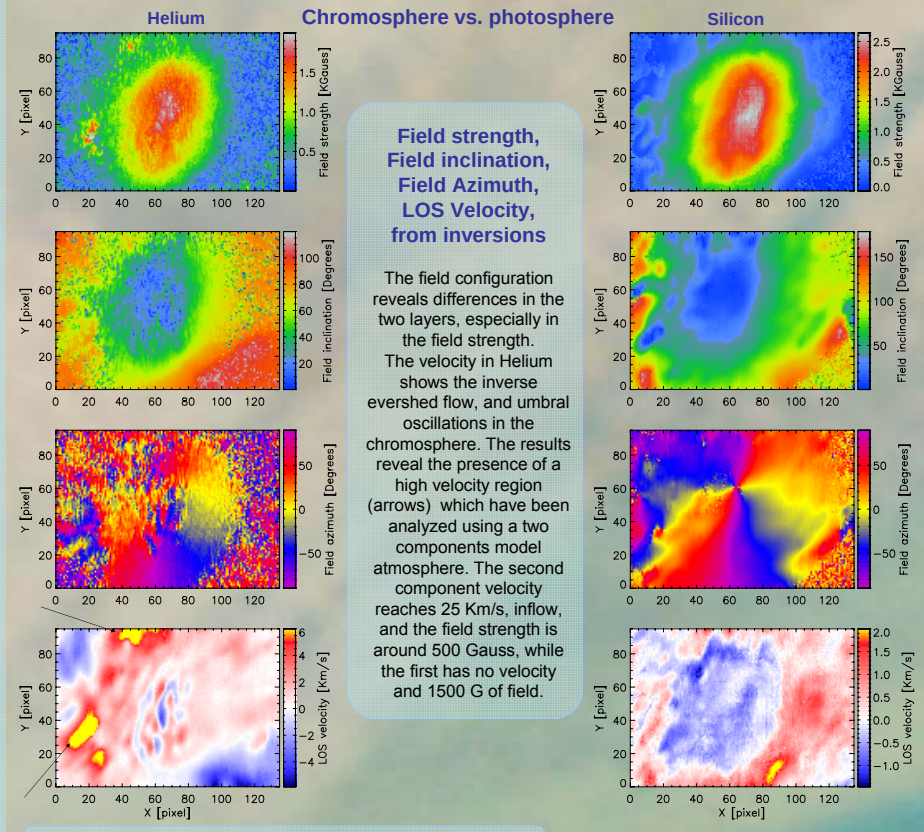




Example of an asymmetric Stokes V profile for Silicon, left, and an average over 15 profiles around the Helium neutral line, right. The second shows a negative field in Silicon while the Helium shows a mainly positive and asymmetric profile.

Inversion results

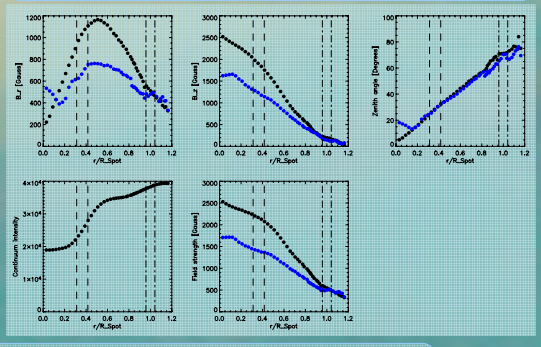
The Helium line has been inverted for a Milne-Eddington atmosphere model considering the Zeeman splitting in the incomplete Paschen-Back regime (Socas-Navarro et al. 2004), and the Silicon line using a model with a gradient in the magnetic field strength and five nodes in line of sight velocity and temperature, the other atmospheric parameters like the field inclination and azimuth have been forced to be constant. The influence of stray light was carefully tested and can be neglected in both models. The inferred results for Silicon have been taken at optical depth unity. Both results have been projected to the local reference frame.



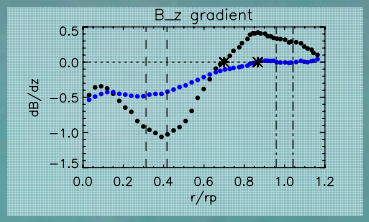
Field strength, Field inclination, Field Azimuth, LOS Velocity, from inversions

The field configuration reveals differences in the two layers, especially in the field strength. The velocity in Helium shows the inverse evershed flow, and umbral oscillations in the chromosphere. The results reveal the presence of a high velocity region (arrows) which have been analyzed using a two components model atmosphere. The second component velocity reaches 25 Km/s, inflow, and the field strength is around 500 Gauss, while the first has no velocity and 1500 G of field.

Azimuthal averages. The vertical lines represent the umbral and penumbral boundaries. The black points refer to the photosphere, the blue points to the chromosphere



Field strength gradient in the photosphere (black), and gradient between the photosphere and chromosphere assuming a formation height of 2000 Km for He I (blue). The Si I gradient agrees with the result from Westendorp Plaza (2001) for visible lines.



References

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