The Hanle and Zeeman Effects in Solar Spicules

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in collaboration with

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Summary

- Preliminary results about observing campaign on Spicules in the He-D3 line at IRSOL, Locarno
- 53 full-Stokes spectropolarimetric measurements during 15 days
- **Goal:** magnetic field diagnostics via inversion of the Stokes profiles based on the quantum theory of the Hanle and Paschen-Back effects.
Outline

- Theoretical Modelling and Inversion
- The instrumentation
- The observations
- Preliminary results
- Conclusions
The Theoretical Model and the Inversion Method

The Model Atom for Helium

5 lowest triplet terms
The Helium D3-multiplet

5875.97 Å (weak red component)

5875.60–5875.64 Å (strong blue component)

Not scaled!
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Not scaled!

Typical Intensity Profile of Spicules
Theoretical Model: basic features

- Atomic polarization due to the anisotropic illumination induces emission of polarized radiation.

- In particular, coherences between fine-structure levels within each atomic term are completely accounted for, allowing for the treatment of both the Hanle and Zeeman regimes, including level crossings (incomplete Paschen-Back effect).


- Spicules are assumed to be optically thin.
The inversion

- Database containing profiles for different magnetic field orientations and strengths is created for a given limb distance.
- The best fitting theoretical profiles are carefully searched in the database.
Instrumentation

- **Telescope**: Gregory - Coudé, evacuated
  - Diameter of primary mirror: 45 cm
  - Total focal length: 25 m
ZIMPOL2-polarimeter (*Zurich Imaging Polarimeter*, developed at ETH-Zurich) allows precise measurements free from seeing induced spurious effects (modulation 42 kHz).

Limb tracker keep constant the distance between the spectrograph slit position and the limb.

Instrumental polarization is small and almost constant over one day of observations (easy to correct)
The observations

- 53 measurements during 15 days from November 2004 to June 2005.
- Different positions and limb distances.
- Total integration time per measurement from 10 to 50 minutes.
Corrections: Crosstalks

I → Q, U, V determined through measurements in quiet regions at the center of the solar disc

Q → V and U → V measured with a linear polariser sheet applied at the entrance window of the telescope.

V → Q and V → U deduced from the symmetries of the theoretical Müller Matrix and the Q → V and U → V measured crosstalks.
The scattered light

- The emission intensity profile of spicules (*signal*) has to be separated from the scattered light (*background*).
- An intensity spectrum measurement is taken on the solar disc (usually near the measured spicules) and we assume that the scattered light has the same shape (approximation).
- The scattered light may be slightly polarized (linear polarization usually $\sim 10^{-3}$). Corrections are applied in the data analysis assuming that the degree of polarization ($P/I$) of the scattered light is wavelength independent.

**Sources of scattered light:**
- **Earth atmosphere** → influenced by meteorological conditions and zenith angle, but practically unpolarized.
- **Telescope** → scattered light may be polarized.

![Signal and background](image-url)
The Results (preliminary)

Example: The observations of the 18th June 2005

- Very good observing conditions (clear sky and good seeing)
- Exposure time for each measurements about 30 minutes
- Measurements at ~3 arcsec from limb
Measurement in a quiet region (m2)
Stokes profiles

Region 1
Fitted profile: $B = 7$ Gauss, $\theta = 58^\circ$, $\phi = -101^\circ$

Region 2
Fitted profile: $B = 6$ Gauss, $\theta = 54^\circ$, $\phi = -90^\circ$

~ 10 gauss
Also all other analyzed Stokes profiles obtained from measurements in quiet regions indicate $B \sim 10$ gauss \textit{(in agreement with the results obtained by Trujillo Bueno et al. (2005) via the He I 10830 multiplet)}
Example: The observations of the 18\textsuperscript{th} June 2005
Spicules at ~2.5 arcsec from W limb (active region) 18 June 05
Stokes profiles

Near active region we found ~ 50 gauss!
Conclusion

- At IRSOL, we could obtain several interesting full-Stokes spectropolarimetric measurements of Spicules in the He-D3 line with ZIMPOL2.

- Inversions of the Stokes profiles observed in spicules near quiet regions give $B \sim 10$ gauss.

- In one case (near active region) we obtained $B \sim 50$ gauss.

- Analysis is preliminary:
  - Not all data have been fully analyzed yet
  - Ambiguities are under study
  - We shall improve the model to account for the broadening of the intensity profiles in the wings.