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Spectropolarimetric Investigations of the Deep Photospheric Layers of Solar Magnetic Structures

N. Oklay,[1] A. Gandorfer,[1] S. K. Solanki,[1] M. Bianda,[2] and R. Ramelli[2]

[1]*Max-Planck-Institut für Sonnensystemforschung, Max-Planck-Straße 2, 37191 Katlenburg-Lindau, Germany*

[2]*Istituto Ricerche Solari Locarno, Via Patocchi - Prato Pernice, CH - 6605 Locarno Monti, Switzerland*

Abstract. Solar surface magnetism manifests itself in a variety of structures with sizes often comparable or even below our spatial resolution capabilities. Nevertheless, sub-resolution information about the intrinsic atmospheric structure can be obtained via indirect techniques. We use state-of-the-art spectropolarimetric observations in carefully selected photospheric lines which include C I (5380.3 Å) as well as strong lines of Fe I, Ti I covering also the deep layers of the photosphere and obtain ratios of their Stokes V amplitudes. From there we deduce that the temperature within magnetic features is higher at locations of smaller magnetic flux.

1. Introduction

The continuum brightness of small-scale magnetic elements determined by the temperature in lower layers of the photosphere is interesting for a number of applications. We aim to provide a spatial-resolution independent estimate of this quantity based on a comparison of the Stokes V profiles of C I 5380.323 Å, which is formed deep in the photosphere, to other lines (Solanki & Brigljević 1992). By considering many more profiles we strongly improve the statistics compared to earlier work.

2. Observations

Our observations were made at IRSOL (Istituto Ricerche Solari Locarno) between June 3rd and June 8th 2007 with the Gregory Coudé Telescope. The ZIMPOL II polarimeter (Gandorfer et al. 2004) was used in combination with the Czerny-Turner spectrograph. During this period we observed three active regions (AR 10958, AR 10959 and AR 10960) near solar disk center avoiding both sunspots and pores. Our spectral sampling is 6.3 mÅ/px and the spatial scale is $1.3''$/px; typical noise levels are 5×10^{-4} of the intensity. An example of an observed spectrum and a sample of spectral profiles are presented in Fig. 1 and in Fig. 2.

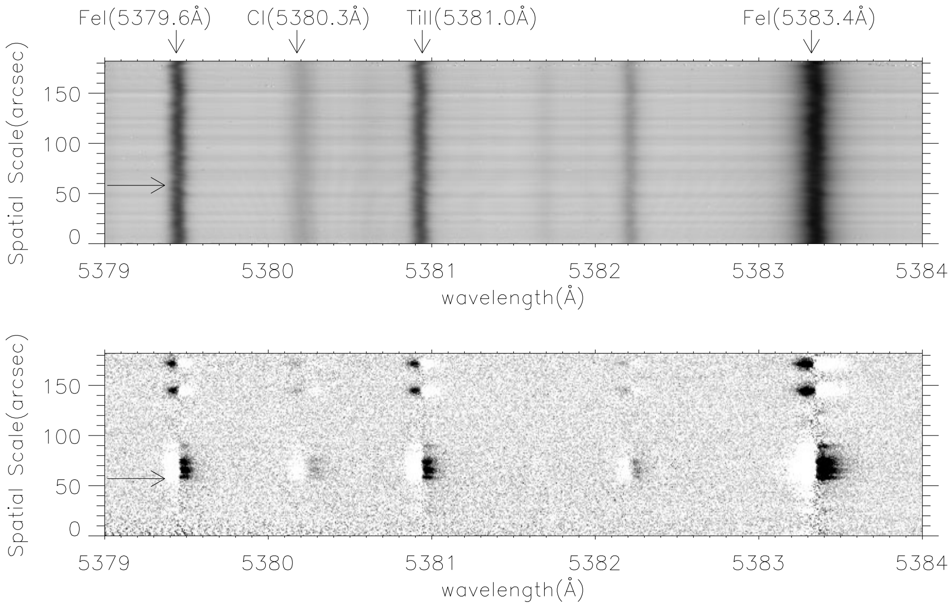

Figure 1. 2D spectrum of Stokes I and Stokes V/I. The upper panel shows the Stokes I spectrum of the selected spectral region. The lines used for the analysis are marked at the top of the spectrum. The lower panel shows the corresponding Stokes V/I spectrum (grayscale is set to ± 1%). The slit covers $182''$. Images are taken with an exposure time of 0.5s. The arrows at the left mark the position of the example spectrum shown in Fig. 2.

3. Data Analysis

For our analysis we used only those spectra, in which the Stokes V/I amplitudes in all lines are larger than three times the noise level. This provides us with a data set of 185 individual spectra. In this data set we calculated the following quantities as defined in Solanki (1987) for the spectral lines C I (5380.3 Å), Fe I (5379.6 Å), Ti II (5381.0 Å) and Fe I (5383.4 Å):

- Sum of Stokes V amplitudes: $a_b + a_r$
- Relative Stokes V amplitude asymmetry: $\delta a = \frac{a_b - a_r}{a_b + a_r}$
- Sum of Stokes V areas: $A_b + A_r$
- Relative Stokes V area asymmetry: $\delta A = \frac{A_b - A_r}{A_b + A_r}$,

where a_b is the amplitude of the blue wing, A_b is the area of the blue wing, while a_r and A_r are the same quantities for the red wing of the Stokes V profile.

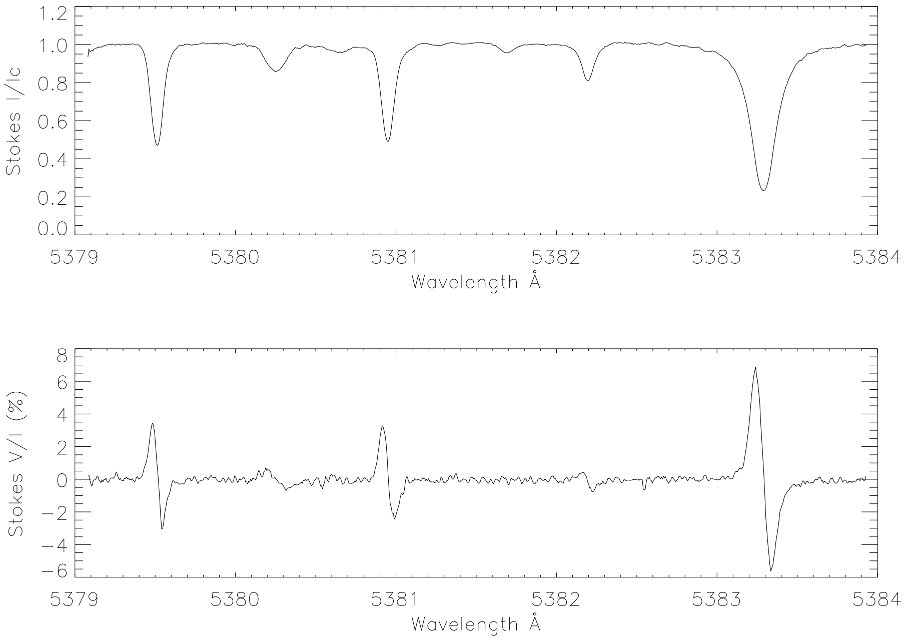

Figure 2. Example spectra of Stokes I/I_c and Stokes V/I at the position marked by arrows in Fig. 1.

In order to determine the individual behavior of the spectral lines, in Fig. 3 the ratios of Stokes V amplitudes (left panel) and area (right panel) of C I 5380.3 Å to Fe I 5379.6 Å (top), Ti II 5381.0 Å (middle), Fe I 5383.4 Å (bottom) are plotted vs. the Stokes V amplitude (left) and area (right).

4. Results

The decrease in ratio of the Stokes V amplitude or area of C I 5380.323 Å relative to the other lines with increasing Stokes V amplitude or area of those lines (Fig. 3) shows that the magnetic features in regions with little magnetic flux are on average hotter and brighter than in regions with higher flux. This confirms and extends the results of Solanki & Brigljević (1992) to a much larger number of data points, at considerably higher spatial resolution.

5. Future Work

The observed Stokes V ratios will be compared to forward calculations in different atmospheric models, including realistic 3D numerical radiation MHD simulations of the solar photosphere with varying magnetic activity. Inversions of the data using the SPINOR code (Frutiger et al. 2000) are also planned.

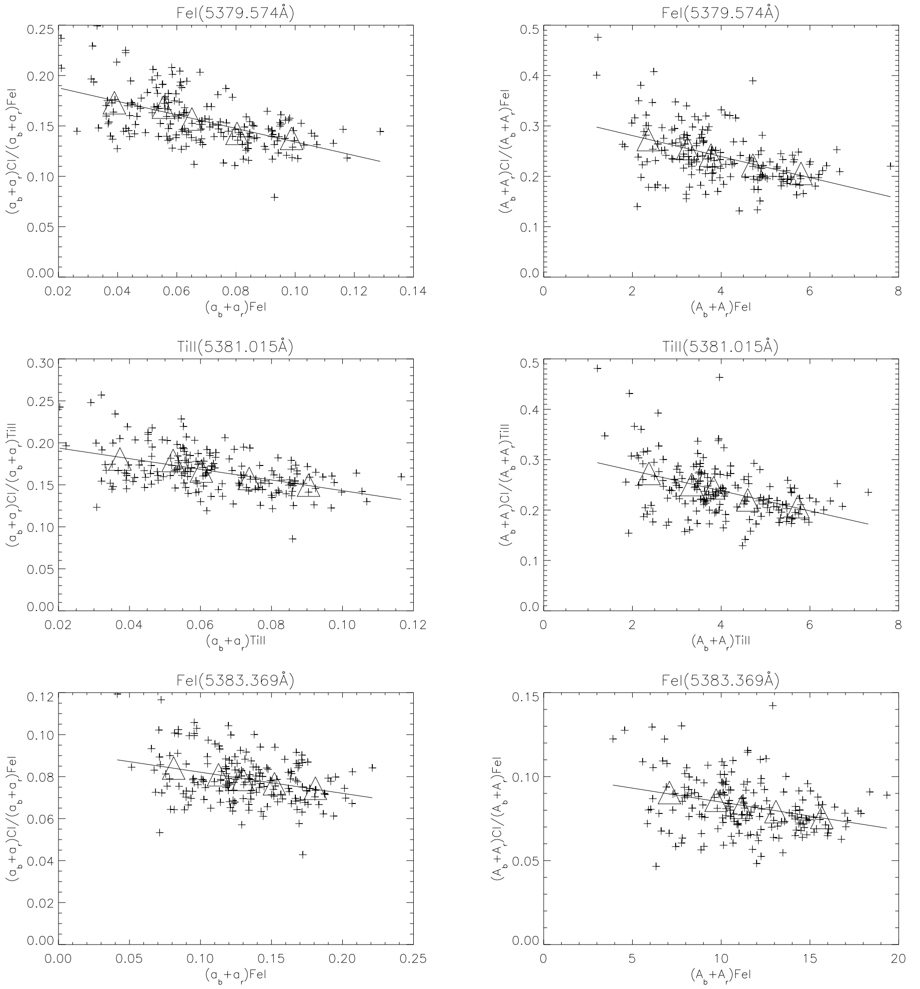

Figure 3. Stokes V amplitude (left) and area (right) ratios of C I (5380.3 Å) to Fe I 5379.6 Å (top), Ti II 5381.0 Å (middle) and Fe I 5383.4 Å (bottom). A_b: area of Stokes V/I blue wing, A_r: area of the Stokes V/I red wing, a_b: amplitude of the Stokes V/I blue wing, a_r: amplitude of the Stokes V/I red wing. The line shows the linear fit to the data points. Triangles represent 37 point averages.

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