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Chromospheric polarity reversal on sunspots: New insight from spectro-polarimetric measurements

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Abstract. We present here spectro-polarimetric observations of chromospheric and photospheric lines on an active region. We show that the presence of polarity reversal between photosphere and chromosphere cannot be detected relying on magnetograms and broad band and even narrow band filters only. We demonstrate that opposite signs in CaII magnetograms in sunspots compare to photospheric magnetograms are not due to a reversal of the magnetic field, but rather due to the presence of line core emission as suggested from theoretical arguments by Sánchez Almeida (1997).

Key words. Sun: magnetic field – Sun: photosphere – Sun: chromosphere

1. Introduction

Most of the solar magnetic field observations concern the photospheric magnetic field. The chromospheric magnetic field deserves less attention maybe due to intrinsic difficulties to measure and interpret. It is however evident that a better knowledge of the chromospheric magnetic field would be of fundamental importance, for example to study the details of the magnetic flux emergence from the low layers of the solar atmosphere to the corona, or to investigate magnetic field topology changes in active region (especially in regions giving eruptive events).

Among the few observational studies, the presence of "polarity reversal" between the photosphere and chromosphere was mentioned by Wang & Shi (1992), Li & Zhang (1994). Sánchez Almeida (1997) points out that such reversal may not be due to true magnetic field reversal but rather to the presence of emission in the line core. The arguments were based on theoretical simulation and sofar no new observations confirmed this hypothesis.

In this work we provide observational evidence supporting that the reversal is due to lie emission.

2. Observation

Observations on active region NOAA 0019 were performed between July 2nd and July 6th 2002 with the spectro-polarimetric mode of the THEMIS telescope[1]. It allows to obtain 2-dimensional maps of the solar active region. Four lines were recorded simultaneously. We report here results on the photospheric (FeI 630.2 nm) and the chomospheric (Hα 656.3 nm and CaII 854.2 nm) line profiles. The sunspot was located W39–S17 the first day of observation and reached E08–S17 the last day. The region was scanned with step of 0.5″ (the size of the spectrograph entrance slits width).

The spatial sampling along the slit is 0.5″/pixel. The spectral sampling is 35 mÅ/pixel for CaII, 27 mÅ/pixel for Hα and 22 mÅ/pixel for FeI. The exposure time for all wavelengths was 300 msec. Seeing conditions limited the spatial resolution to about 1″.

The so-called $2 \times 1'$ THEMIS spectro-polarimetric configuration was used: the two beams with orthogonal polarization exiting the analyzer are directed into a single camera. The field of view covered by the entrance slits of the spectrograph is 1′. Beam inversion was performed for the linear polarization Q: the top part of the camera received sequentially $I + Q$, $I - Q$, $I + U$ and $I - V$ while the bottom part recorded $I - Q$, $I + Q$, $I - U$, $I + V$.

This observing strategy allows to reduce the errors coming from uncertainties on the flat-field, to correct for the cross-talk between Stokes parameters (applying a known demodulation matrix) and to reduce the impact of the seeing induced cross-talk due to the time delay between to successive polarimetric measurements: 1 s (Skumanich et al. 1997).

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[1] THEMIS is operated on the island of Tenerife by INSU-CNRS/CNR in the Spanish Observatorio del Teide of the Instituto de Astrofísica de Canarias.

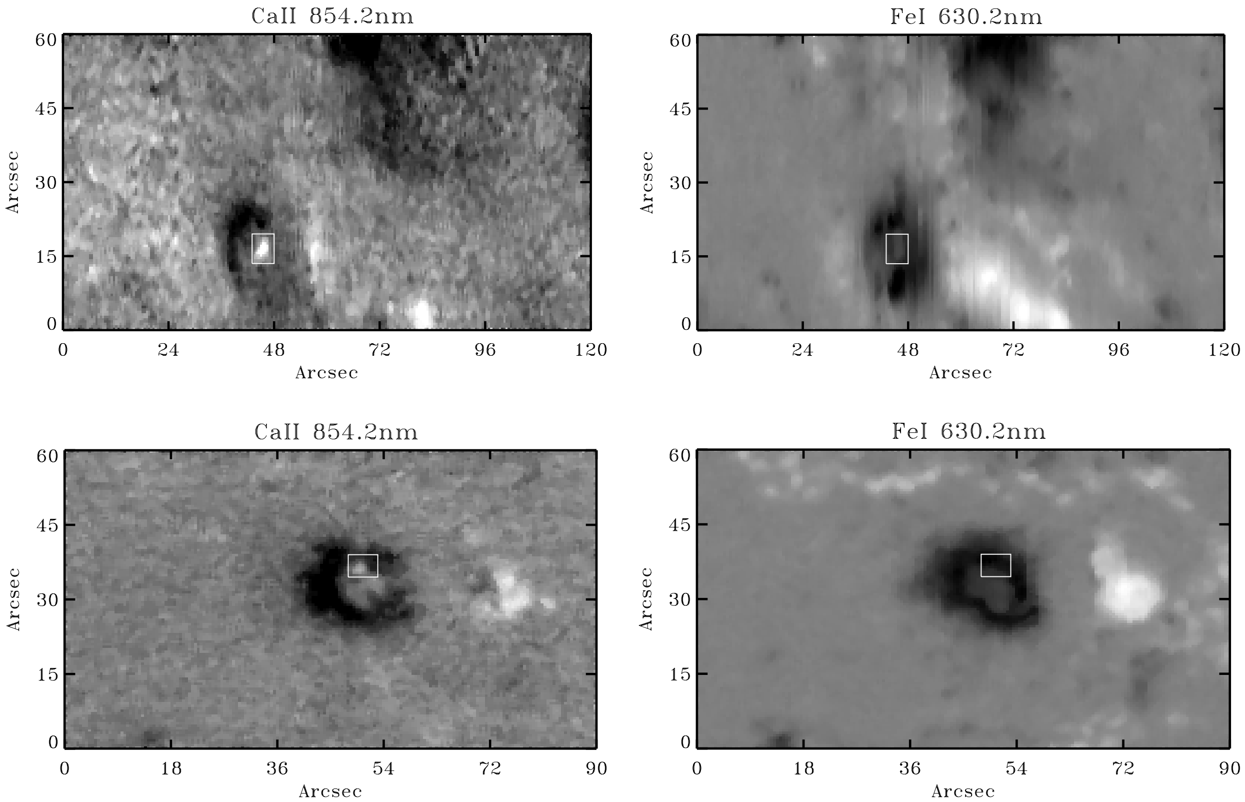

Fig. 1. Magnetograms in CaII (top) and FeI (bottom) from data obtained on June 2nd 2002 at 15h11 UT (left) and June 6th 2002 at 08h20 UT (right). The rectangles underlines the area where a "polarity reversal" seems to be present on the sunspot.

The final error of the measurements is: $S/I_c = 10^{-3}$ for FeI and 5×10^{-3} for the two chromospheric lines (S stands for one of the Q, U or V Stokes parameter and I_c stands for the intensity of the continuum in Quiet Sun region).

The Landé factor of the FeI 630.2 nm line is 2.5, of the CaII 854.2 nm line is 1.1 and of Hα is 1. All lines exhibit a normal Zeeman pattern with two lobes of opposite polarities for Stokes V.

2.1. Line of sight magnetograms reconstruction

All intensity maps were reconstructed at line center, simulating filter with a narrow bandwidth of 125 mÅ. Magnetograms presented in the following sections were drawn from a fixed pixel position corresponding to the blue peak of Stokes V of each spectral lines. Such reconstruction technique does not try to give any absolute value of the line of sight magnetic field. Rather it mimics the operation of a magnetograph and allows to show apparent reversal of the Stokes V peak.

In the weak field approximation, Stokes V is related to the magnetic field by the following formula:

$$V = 4 \times 10^{-13} g_{\rm eff} \lambda^2 \alpha B_{\rm los} \frac{{\rm d}I^{\rm m}}{{\rm d}\lambda} \quad (1)$$

where $g_{\rm eff}$ is the effective Landé factor, α the filling factor, $B_{\rm los}$ the magnetic field along the line of sight and $I^{\rm m}$ the Stokes I coming from the magnetic element. For this expression to be valid, $I^{\rm m}$ and V have the same units and wavelength and magnetic fields have to be expresssed in Angstrom and Gauss, respectively. A change of sign of V can result either from a change of $B_{\rm los}$ or from the presence of emission core in Stokes I profile that induces a change on the sign of $\frac{{\rm d}I^{\rm m}}{{\rm d}\lambda}$.

3. Data analysis

3.1. Evidences of polarity reversals?

In a first attempt, the magnetograms from CaII and FeI are compared. Two examples are presented in Fig. 1. It is clear that a small area (in the rectangles of the previously mentioned figure) shows opposite sign in the photosphere and the chromosphere. Note that the two magnetograms correspond to the same observed region (the phenomenon is thus stable over many days). However, as explained in the previous section, this phenomenon can also result from an emission in the line core. To check if the region presents activity we display its intensity maps (drawn as described in Sect. 2.1) in Fig. 2.

Such maps (even if obtained at line centre) do not exhibit a specific chromospheric activity, or at least do not strongly show if the intensity profile is or not in emission. Such kind of argument was used by Wang & Shi (1992) to prove the real nature of the polarity reversal from chromosphere to photosphere.

Another way to put in evidence the presence of a polarity reversal could be to look at the CaII Stokes V parameter. Indeed, two photospheric lines are present at about 0.3 Å on the blue wing (see also Fig. 3). Once again, we could conclude of the presence of a polarity reversal in this region.

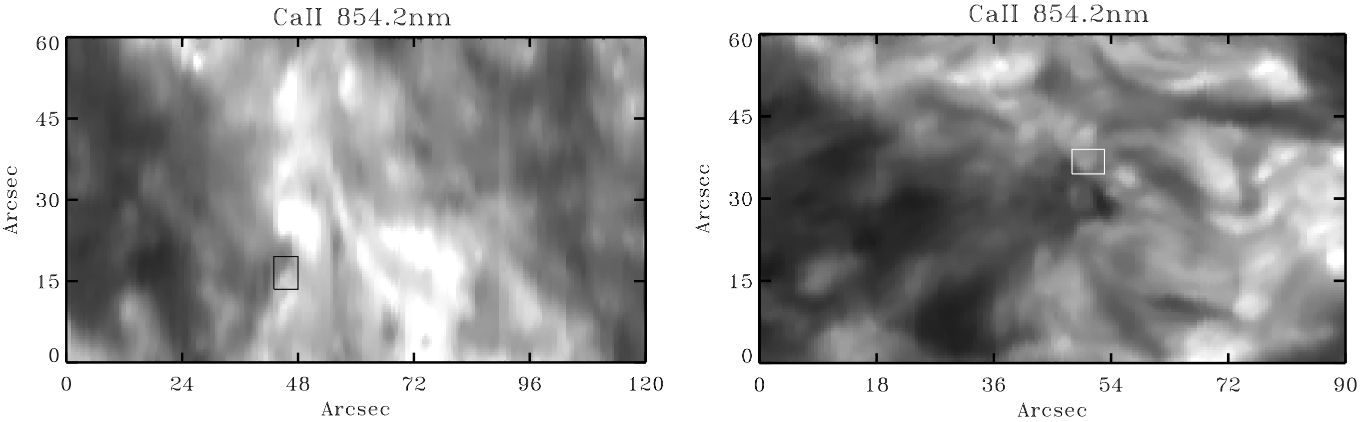

Fig. 2. Intensity reconstructed maps from the CaII IR line core corresponding to the magnetograms of Fig. 1. The rectangle underline the areas where opposite signs are detected on the magnetograms. Intensity maps are in linear scale.

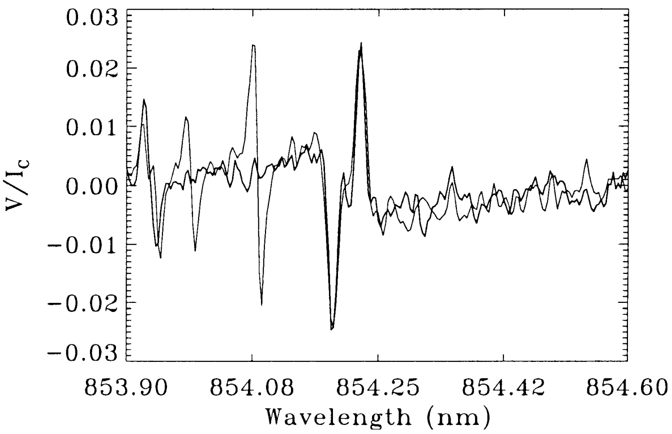

Fig. 3. Comparison between the measured Stokes *V* (thick) and Stokes *V* obtained with the weak field approximation. Both profiles are very similar for the CaII lines. The discrepancy in amplitude for the FeI line at 853.8 nm comes from the multiplicative factor that was used to adjust the CaII line (non fitted lines are telluric lines). The two lines on the blue wing of CaII are iron lines.

However, we will show in the following that this "polarity reversal" does not really exists.

3.2. Evidences for misinterpretation

To test the presence or not of a polarity reversal, we compare the observed Stokes *V* profiles with the *V* profiles coming from the weak field approximation formula. With such approach, if a polarity reversal is indeed present, the sign of the fit would be incorrect for the chromospheric lines but correct for the photospheric structures. Figure 3 shows the comparison between the Stokes *V* obtained from the weak field approximation and the observed Stokes *V*. The correct fitting of both CaII and photospheric lines shows that the reverse sign of the peak of Stokes *V* is not due to a magnetic field reversal.

As argued by Sánchez Almeida (1997), the line core emission can be undetected if it occurs in a dark structure of a sunspot. And, indeed, Fig. 4 (middle panel on right) shows the Stokes *I* profile of CaII which clearly exhibits such emission profile.

Finally, Fig. 4 presents another case of reversal of the Stokes *V* peaks for CaII together with FeI and Hα. CaII line presents an apparent reversal of the Stokes *V* peak, while Hα does not. An interpretation in terms of magnetic field reversal is hardly possible since the two lines are formed almost at the same solar height. The only way to explain this discrepancy is that the opposite sign of the Stokes *V* peaks in CaII and Hα is only due to the presence of an emission in the CaII core while Hα does not exhibit such a feature.

4. Conclusions

At first glance, chromospheric magnetic field measurement seems to show a polarity reversal of the magnetic field compared to the orientation at photospheric level. However, we have presented here several evidences from observational data that such phenomena is not real, but mainly due to the presence of core emission of an absorption line. We must quote that the results are representative of the whole set of data running from the July 2nd to July 6th 2002. We found several areas with such phenomena in CaII IR line, but we never found evidence of Stokes *V* peak reversal (compare to the photospheric lines) from Hα line except in region of flares. This difference between the two lines is easily explained by the difference of sensitivity of the two lines in respect to the temperature.

The reality of the existence of polarity reversal (or "transient events") was already discussed and rejected from observational point of view (Lotzitskaya & Lozitskií 1982; Patterson 1984). However, these studies discussed the subject based on photospheric lines in case of flares. The study presented here afford new arguments from spectro-polarimetric observations of photospheric and chromospheric lines measured strictly simultaneously, in active region away from flares. It gives observational evidences for the theoretical conjecture of Sánchez Almeida (1997).

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Letter to the Editor

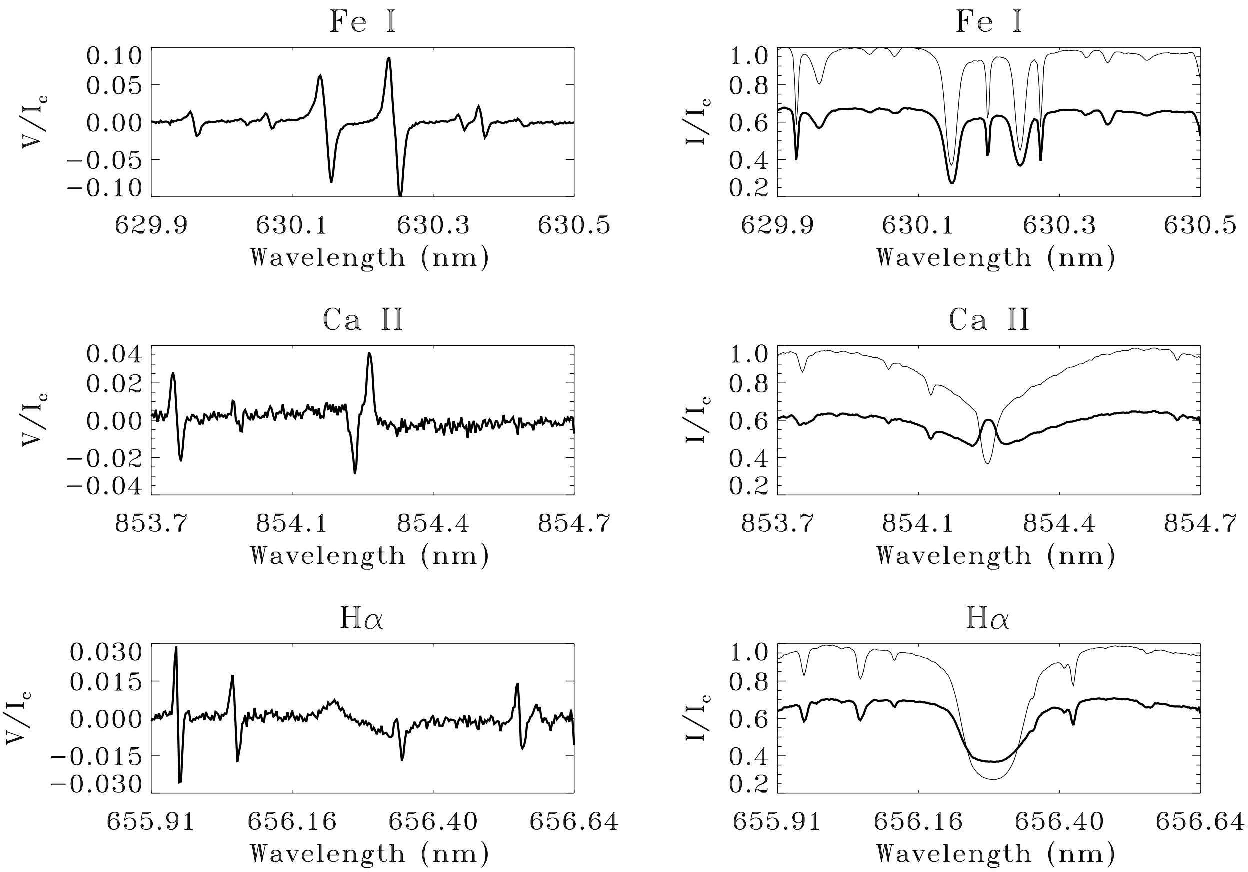

Fig. 4. Stokes V (left) and I (right) for FeI, CaII and Hα (from top to bottom), relatively to the quiet sun intensity continuum. Also superimposed on Stokes I, the intensity in a quiet Sun region around the "polarity reversal" area.

References

Li, W. A., & Zhang, H. 1994, Sol. Phys., 151, 1

Lotzitskaya, N. I., & Lozitskií, V. G. 1982, Soviet Ast. Lett., 8(4), 270

Patterson, A. 1984, ApJ, 280, 884

Sánchez Almeida, J. 1997, A&A, 324, 763

Skumanich, A., Lites, B. W., Martínez Pillet, V., & Seagraves, P. 1997, ApJS, 110, 357

Wang, J., & Shi, Z. 1992, Sol. Phys., 140, 67