Mem. S.A.It. Suppl. Vol. 19, 97

Memorie della
Supplementi

Spectropolarimetric analysis of the solar Active Region NOAA11005 by inversion techniques: preliminary results

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Abstract. We present the preliminary results of spectropolarimetric observations and analysis of a disk-center region containing a pore. The dataset was acquired on 2008/10/15 by the SOT spectropolarimeter onboard the Solar-B (Hinode) mission. It consists of high spatial and spectral (2.15 *pm*) resolution full Stokes imaging scans in the iron doublet at 630 *nm*, in Fast Map Mode (0.3×0.32 $arcsec^2$ pixel scale), with 0.1% polarimetric accuracy. The analysis of a 60×60 $pxls^2$ area around the pore was performed by inversion techniques using the SIR code. We gave in input an initial atmospheric model with a single magnetic component, but accounting for stray light contamination. The code is capable of retrieving the full Stokes syntetized profiles and the inverted atmospheric parameters, like plasma temperature, magnetic field vector etc., for each depth and resolution element. We show and comment the magnetic field reconstruction maps (field strengths and inclinations) as inferred from SIR inversion procedure, comparing to what emerges from the linear polarization maps.

Key words. Techniques: Spectropolarimetry COG magnetogram Inversions

1. Introduction

Improvements in spectropolarimetry help to understand the physical nature and the evolution of solar magnetic fields, and their connection to the dynamics of atmospheric plasma. This technique consists in the analysis of the Stokes spectra, that represent the observables associated to polarized light.
Polarization is generated by the high degree of anisotropy that characterizes the magnetic field filled solar plasma. As magnetic field vector and plasma thermodymamics confer unique properties and distinctive features to Stokes spectra, one can infer informations about the physical parameters of the magnetized atmosphere by solving the Radiative Transport Equations (RTE) for polarized light (Landi Degl'Innocenti & Landolfi , 2004). Unfortunatly, this task is not so easy: solutions may be found analitically by introducing a set of approximations, or numerically. Several inversion codes have been realized to approach this problem (Skumanich & Lites 1987, Ruiz Cobo & Del Toro Iniesta 1992, Sanchez Almeida, 1997).
In this paper we present preliminary results of the spectropolarimetric analysis of the Active Region NOAA11005, observed by

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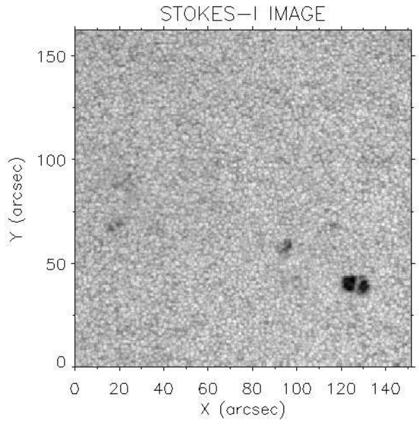

Fig. 1. Continuum intensity image of the observed region.

SOT spectropolarimeter on board Hinode on 2008 October 15th. The dataset, restricted to a 60×60 $arcsec^2$ region sorrounding a pore, is processed using SIR inversion code (Ruiz Cobo & del Toro Iniesta , 1992), which works in LTE hypothesis.
We show only the retrieved magnetic field strength and inclination. Further analysis and investigations on the other physical quantities will be the subjects of forthcoming papers.

2. Hinode observations

The dataset was acquired by SOT telescope in SP (spectropolarimeter) Fast Map mode (0.3×0.3 $arcsec^2$ spatial resolution), with high spectral resolution ($2.1 \cdot 10^{-3}$ nm) and 0.001 polarimetric accuracy. It consists of full Stokes 150×162 $arcsec^2$ scans for each wavelength (112 in total) of the photospheric FeI doublet at 630 nm. In this configuration a complete scan of the observed area, takes about 30 minutes, hindering any dynamical study. The AR NOAA11005 is quite close to the disk center, having heliocentric coordinates [10.0° E, 25.2°N] and heliocentric angle cosine μ = 0.93.
In figure 1 the observed full region is shown.

3. The data analysis

We renstricted our analysis to a region about 60×60 $arcsec^2$ containing the pore visible in the lower right corner of figure 1.
The analysis was performed by means of inversion techniques using the SIR code, which works into two steps: synthesis, computing the Stokes spectra by solving the RTE for polarized light, and inversion, looking for the atmospheric and magnetic parameters that minimize the differences between observed and synthetized Stokes spectra (Bellot Rubio , 2003).
We used a guess input atmospheric model with a single magnetic component (magnetic filling factor set to 1), but accounting for local straylight contamination. Only the pixels whose Stokes Q, U , or V amplitudes are larger than 4.5×10^{-3} the continuum intensity have been inverted (Orozco Suàrez et al. , 2007). This threshold selected 20000 pixels to be processed.

4. Results

In figure 2 we show the magnetic field strength map produced by SIR inversions in the selected area. The code reproduces the structured field and its radial gradient in the pore (Giordano et al. , 2008), from the central 2500 G to the boundary hecto Gauss field strength, and the kG field strength in the network. In order to compare the magnetic field strength and inclination retrieved by the SIR code, we computed the COG magnetogram (Rees & Semel , 1979) and a linear polarization map (figure 2). The line of sight flux is averaged over the resolution element.
Linear polarization has been inferred from the dataset, and computed as:

$$\int (Q^2 + U^2)^{1/2} \frac{d\lambda}{I_c}$$

where I_c is the continuum intensity of the quiet Sun, averaged over a substantially unpolarized area far from the pore.
We can now compare the linear polarization with the field inclination map (bottom panels of figure 2). It is evident how the SIR code retrieves inclined fields only where the linear

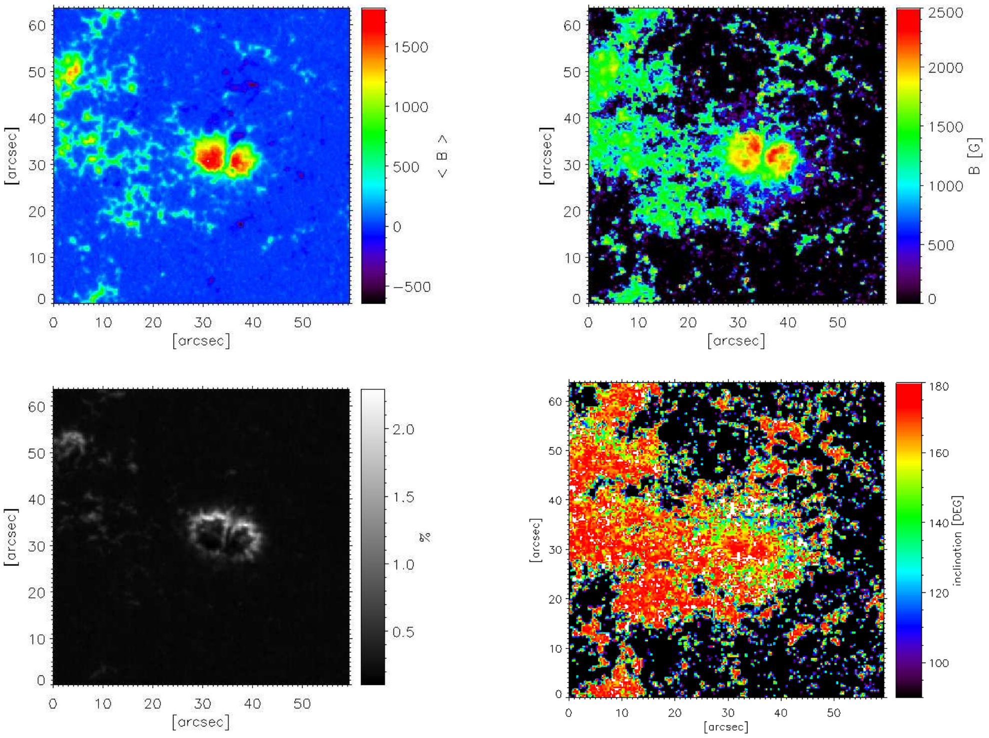

Fig. 2. *Upper Left:* COG magnetogram of the region 60×60 $arcsec^2$ containing the AR NOAA11005. The image represents the magnetic field line of sight component averaged on the resolution element. *Upper Right:* Inverted magnetic field strength map in the selected. Black pixel have not been inverted because their Stokes profiles was below the adopted threshold. *Lower Left:* Percentage of linear polarization in the considered region (see the text). The most prominent signals are associated to the upper part of the pore. *Lower Right:* Inverted magnetic field inclination map.

polarization is above 1%. As intense Stokes V signals dominated the field of view, most of the retrieved magnetic fields are interpreted as vertical by SIR.

5. Conclusions and discussion

The SIR code retrieves, as expected, the *kG* field distributions in the plage and pore regions.

The inclination map shows a predominantly line of sight magnetic field, except for a small region in the upper part of the pore, where the field inclination with respect to the line of sight may be seen. Also in the network, the retrieved magnetic concentrations are essentially line of sight, with a faintly visible inclination on some pixels at the edges.

More details of the physical nature of the region will be given in forthcoming publications. The inversion techniques are very powerful tools to investigate the physical nature of the solar magnetized atmosphere, starting from the leading of the radiative transport equations for polarized radiation.

Nevertheless, it is necessary to take extra care in the analysis of the inversion results. They are dependent on the chosen atmospheric model that represents the solar photosphere. The Marquardt algorithm on wich SIR is based, searches for absolute minimum of the multi-parametric surface χ^2 (Press et al. , 1987). This implies that adopting a model which is not close enough to reality may results in a collapse onto a wrong χ^2 minimum. This and other code capabilities are now being tested on simulations using simple atmospheres. One fact that clearly emerges from them is the loss of information in the resolution element: also in a very simple condition the magnetic flux as inferred from inversions tends to spread widely, and the total measured flux likely understimates the real one.

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