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MISMA inversion of HINODE SOT/SP data

Preliminary results

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Abstract. We analyze full Stokes observations of a quiet Sun region at disk center taken with the spectropolarimeter of the Solar Optical Telescope aboard the HINODE satellite. We present the preliminary results derived from the MISMA inversion of the observed Stokes *I* and *V* profiles. The complete analysis has as a final goal the definition of probability density function for the statistical description of the quiet Sun magnetic field vector for a direct comparison with recently published results.

Key words. Sun: photosphere – Sun: magnetic fields

1. Introduction

The study of the magnetic field in quiet Sun regions is an extremely important topic in solar physics. In fact, quiet Sun regions cover more than 90% of the solar surface, indipendently of the phase of the solar cycle (Harvey-Angle 1993), and contain a large fraction of the photospheric magnetic flux and magnetic energy of the solar photosphere (e.g., Schrijver & Title 2003).

The Probability Density Function (PDF) of quiet Sun magnetic field strengths, $P(B)$, is a major tool for the description of quiet Sun regions. In fact, it carries information about the mean unsigned flux density and the mean magnetic energy density related to the first and second moments of the $P(B)$, respectively.

Different PDFs have been proposed to describe quiet Sun magnetic fields. Most of them have been defined by analyzing the Stokes profiles in the spectral regions around the Fe I lines at 6300 Å and 15650 Å (e.g. Domínguez Cerdena et al. 2006; Martínez González et al. 2008). Recently, Orozco Suárez et al. (2007) proposed a PDF for quiet Sun magnetic fields obtained from the inversion of Stokes profiles for the couple of Fe I lines in the visible observed with the HINODE satellite. The inversion was performed under Milne Eddington hypothesis.

Here, we illustrate the preliminary results of the inversion of Stokes *I* and *V* profiles, observed with the HINODE satellite, under the MISMA hypothesis (Sánchez Almeida et al. 1996).

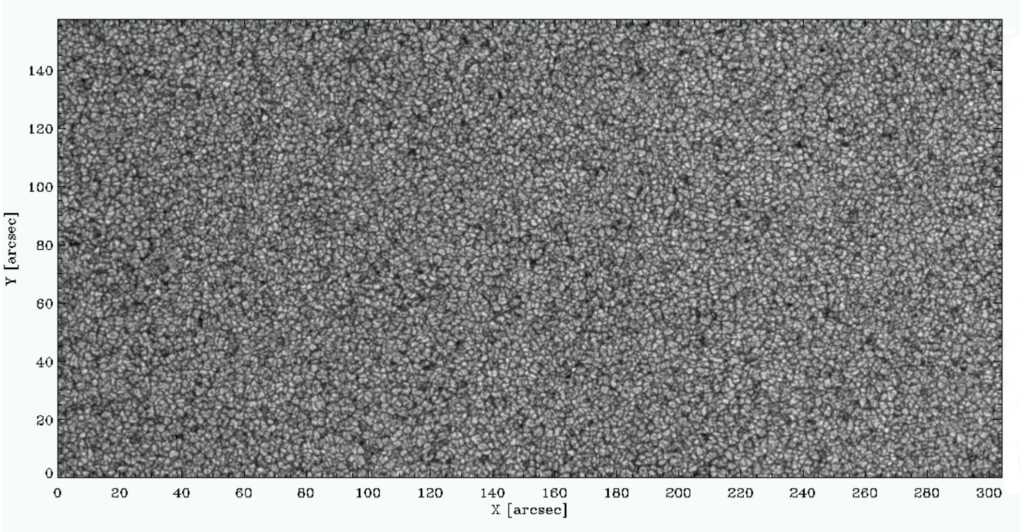

Fig. 1. Continuum intensity I_c from the dataset. The image has been obtained by averaging the intensity profiles in the spectral range 6302.92 – 6303.14 Å.

2. Dataset

The selected dataset consists of full Stokes measurements of a quiet Sun region of about $302'' \times 162''$ at the disc center. The spectropolarimeter aboard of HINODE obtains polarization profiles of Fe I lines at 6301.5 Å and 6302.5 Å with a wavelength sampling of 2.15 pm pixel^{-1} and a scanning step is of $0.1476''$.

The data reduction and calibration have been performed by the `sp_prep.pro` routine (Lites 2008). To obtain a correct wavelength calibration a correction for the gravitational redshift of 613 m s^{-1} is needed.

The calculated noises for Stokes profiles are of $1.1{\times}10^{-3}I_c$ for Stokes V and $1.2{\times}10^{-3}I_c$ for Stokes Q and U. Continuum intensity I_c and total polarization maps are shown in Figs. 1 and 2.

3. Inversion hypothesis and strategy

The inversion of Stokes I and V profiles is performed under the MISMA hypothesis. It states that the photospheric magnetic fields is structured on scales smaller than the mean photon free path at the solar photosphere (Sánchez Almeida et al. 1996; Sánchez Almeida 1997). Starting from this hypothesis, Sánchez Almeida & Lites (2000) proposed ten MISMA models representative of the typical profiles observed in quiet Sun regions. Each model has three distinct components with different temperatures, pressures, and magnetic field vectors. With their constraints, the models provide the degree of realism required to invert the complex polarization profiles emerging in quiet Sun regions by controlling 20 free parameters (see the references above for an exhaustive description of the models).

At the present state the inversion strategy is extremely simple. We refer to a subset of seven models selected among the ten MISMA models of Sánchez Almeida & Lites (2000) as starting models to invert each observed profile. The model atmosphere considered representative of each inverted profile is the one able to fit the profile with the minimum χ^2 among the seven different inversion performed. Once selected the model atmosphere we are able to obtain information about the magnetic field strength at the photosphere. Two examples of the inversion of observed profiles, and of the model atmosphere obtained from the same in-

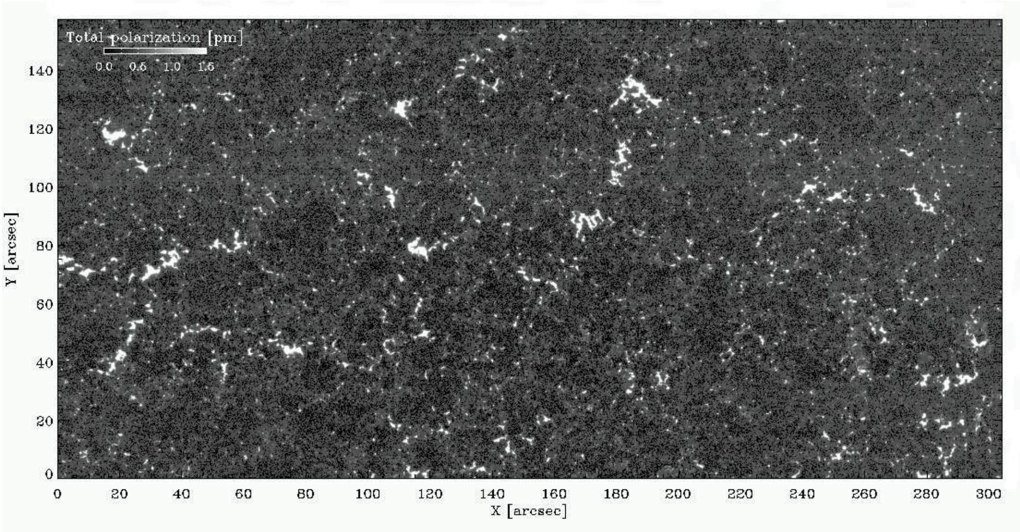

Fig. 2. Total polarization $\int (Q^2 + U^2 + V^2)^{1/2} d\lambda / I_c$ signal from the dataset. The gray scale bar reported in the figure is expressed in pm and saturates at 1.5 pm. Null polarization is associated to the regions where the maximum amplitude of polarization is smaller than three times the associated noise level. The polarization signals above zero cover about 84% of the total image.

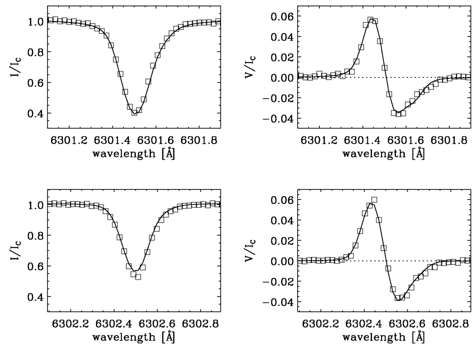

Fig. 3. Inversion of Stokes I and V profiles for the Fe I lines at 6301.5 Å and 6302.5 Å. The synthetized profiles are represented with solid lines while the data are represented with squares.

version, are reported in Fig. 3 and Fig. 4 respectively. Deriving the magnetic field strength at the base of the photosphere in a model as the one shown in Fig. 4 is straightforward. Because of the lateral pressure balance with the non-magnetic quiet Sun, the base corresponds to the height where the total pressure $P_g = 1.3{\times}10^5$ dyn cm^{-2}. Till now the inversion procedure has been successfully applied to invert a total of 1000 profiles randomly selected in the whole data set.

4. Conclusions and future plan

In this paper we illustrate the preliminary results of the inversion of Stokes I and V profiles, observed with the HINODE satellite. The inversion was performed under the MISMA hypothesis (Sánchez Almeida et al. 1996) that provides the degree of realism required to invert the complex polarization profiles emerging in quiet Sun regions.

The simple strategy illustrated in §3 worked for the inversion of a sample of 1000 profile. For this reason we are planing to follow the same procedure to analyze a definitive sample of ~10000 profiles to reliably define the statistical properties of the quiet Sun region represented in Fig. 2.

Since the inversion of Stokes I and V alone allows to set only the magnetic field strength along the line of sight, the next step of the analysis will be the inversion of full Stokes data to

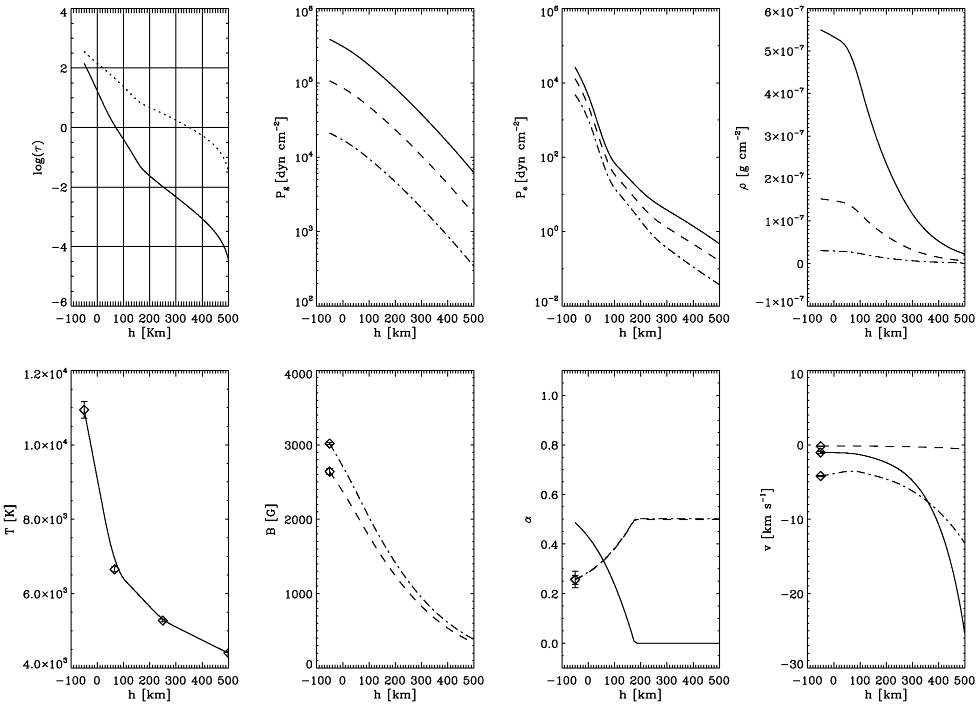

Fig. 4. Model MISMA retrieved from the inversion of the profiles in Fig. 3. The logarithm of the continuum optical depth (solid line) and the line center optical depth (dotted line) are reported in the top-left panel. The remaining panels represent the stratification of gas pressure P, electron pressure P_e, gas density ρ, temperature T, magnetic field strength B, occupation fraction α and plasma velocity along the line of sight v for the different components of the model MISMA. Each component is represented with different type of line.

obtain information about the magnetic vector in quiet Sun regions.

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