Magnetic Field Vector Measurements with THEMIS

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Abstract. The aim of the present work is twofold: a) to validate the Milne- Eddington UNNOFIT inversion by comparing its results with those of the SIR inversion, which is in LTE but does not assumes the Milne-Eddington atmosphere; b) to present a decrease of the network local average magnetic field strength in the vicinity of a filament/prominence, observed before its disappearance, suggesting that the disappearance results from a weakening of the magnetic support.

1. Introduction

The present paper is aimed to present some recent results obtained from THEMIS observations. The THEMIS telescope has the original feature of being “polarization free,” i.e., the polarization analysis is performed on axis, before any oblique reflection. The second original feature of THEMIS is being able to simultaneously record several spectral windows, in order to probe the solar atmosphere as a function of depth, because the different lines simultaneously observed are formed at different altitudes. A more detailed description of the THEMIS instrument can be found in Arnaud, Mein, & Rayrole (1998), although it has to be updated with the tip-tilt correction, which has been modified and is now operational, and the polarization analyzer quarter-wave plate positions that are now free to take any position needed.

Recently, a Milne-Eddington inversion code, UNNOFIT, has been successfully tested and applied to THEMIS spectropolarimetric data (Bommier et al. 2007). After having recalled the main results of this first inversion (§2.), results are presented about the comparison of the UNNOFIT inversion results with the SIR inversion results (§3.). In the SIR inversion (Ruiz Cobo & del Toro Iniesta
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1992), LTE but not Milne-Eddington is assumed. This is a way to test the Milne-Eddington approximation.

In § 4., we report a result of a network field evolution observed before a prominence/filament disappearance: the network field strength has been observed to decrease during the two days preceding the disappearance.

2. UNNOFIT Inversion

Based on the Levenberg-Marquardt algorithm applied to the analytical Unno-Rachkowsky solution that describes the polarization emerging from a Milne-Eddington atmosphere embedded in a homogeneous magnetic field, the initial UNNOFIT (Landolfi, Landi Degl’Innocenti, & Arena 1984) retrieves 8 parameters from the inversion: 1) the line strength $\eta_0$; 2) the Zeeman splitting $\Delta \lambda_H$ that provides the magnetic field strength; 3) the Doppler absorption profile width $\Delta \lambda_D$; 4) the $\gamma$ damping parameter of the Voigt function; 5) one single $b$ parameter describing the Milne-Eddington $\tau$-dependence along the atmosphere vertical with $b = \mu B_1/B_0$, where $B_0$ and $B_1$ are the usual parameters describing the Milne-Eddington atmosphere, and $\mu$ is the cosine of the line-of-sight inclination angle; 6) the line central wavelength (providing thus the Doppler shift), 7) and 8) the magnetic field inclination and azimuth angles. Bommier et al. (2007) have added a ninth free parameter, the magnetic filling factor $\alpha$. The same atmosphere parameters have been assumed in the magnetic and non-magnetic components.

However, the tests realized in the conditions of the Fe I 6302.5 Å line observation with THEMIS have shown that the magnetic filling factor and the magnetic field strength are not separately recovered, but that their product $\alpha B$ that we call the “local average magnetic field” (which is not the same as the magnetic flux that depends on the longitudinal component only), is recovered.

The UNNOFIT inversion was then applied to some THEMIS data (NOAA 517 observed on 7 December 2003). The coherence of the results obtained in two different lines, Fe I 6302.5 Å and 6301.5 Å, has led to the conclusion of the co-existence of two field classes: a) the network field, located at the supergranules frontiers and in active regions, rather vertical and having a local average magnetic field strength of hundreds of Gauss; b) the internetwork field which is “turbulent,” i.e., changing in direction from pixel to pixel, and is weaker with a local average magnetic field strength of about 20 Gauss. These two classes are clearly visible in Figure 16 of Bommier et al. (2007), which displays the map of local average magnetic field strength of these data.

3. Comparison with SIR Inversion

The SIR inversion (Ruiz Cobo & del Toro Iniesta 1992) has been applied to small maps extracted from the map studied by Bommier et al. (2007): a) the sunspot; b) a small quiet region. The line was Fe I 6302.5 Å. As UNNOFIT provides only the local average magnetic field strength $\alpha B$, the SIR inversion was performed with one single magnetic component, with a homogeneous field. The 11 free parameters of SIR were in this case: a) the temperature (5 nodes); b) the microturbulent velocity; c) the macroturbulent velocity; d) the line-of-sight
velocity (the line position); e) the magnetic field strength; f) and g) the magnetic field inclination and azimuth angles. The results of the comparison, that are displayed in Figures 1–4, show a good agreement between both inversions,
validating thus the Milne-Eddington approximation for this line, a feature already expected from the linear behavior around $\tau = 1$ of the line source function reported in Figure 8 of Bommier et al. (2007).

As can be seen in Figures 2 and 4, the inclination and azimuth angles agree between the two inversions within 20° for the sunspot and 30° for the quiet region, the azimuth map of the quiet region being more noisy because of the weakness of the linear polarization in this region. These discrepancies between UNNOFIT and SIR inversions are of the same order of magnitude as the UNNOFIT accuracy determined from prepared data (Bommier et al. 2007), so that we consider that the UNNOFIT inversion is now validated by the SIR inversion.

The validity of this line for magnetic field determination has been put in question by Martínez González, Collados, & Ruiz Cobo (2006) from SIR inversion with two components, one magnetic and one non-magnetic. The answer of the present study could be that this line correctly provides the local average magnetic field strength $\alpha B$, but is unable to provide $\alpha$ and $B$ separately, in the intermediate field range where these two quantities act in the same way on the $V/I$ profile amplitude. In the strong field regime of the Zeeman effect their actions would not be the same so that the two parameters could be separately determined. With visible lines this regime is reached in sunspots only, whereas IR lines are more sensitive to the Zeeman effect and better adapted to a separate determination of $\alpha$ and $B$.

4. Network Field Evolution Observed Before a Prominence or Filament Disappearance

A filament was observed with THEMIS and its surrounding magnetic field was mapped, on 24 and 25 August 2006. On 26 August it had disappeared. The vector magnetic field maps, superimposed to the filament Hα images (simulta-
Figure 5. Filament located at S25 observed with THEMIS on 24 (top) and 25 (bottom) August 2006: Hα image in background. Superimposed: the vector magnetic field map. The longitudinal field is drawn with colors (warm colors — yellow, red — for the field going out of the Sun, cold colors — blue, green — for the field entering the Sun). The transverse field is drawn with dashes of a proportional length, without arrows because the 180° ambiguity is not solved.

neously recorded), are given in Figure 5 for both days. The corresponding local average magnetic field strength is plotted in Figures 6 and 7, in which it can be seen that the network local average magnetic field strength decreases from about 400 Gauss (on the 24th) to about 100 Gauss (on the 25th), before the filament/prominence disappearance, suggesting that the disappearance results from a weakening of the magnetic support.

5. Conclusion

The main conclusion of the present work is the validation of the Milne-Eddington UNNOFIT inversion by comparison with the LTE SIR inversion, in one single line Fe I 6302.5 Å and for the local average magnetic field vector, which is the product of the magnetic field vector with the magnetic filling factor. This validates the series of vector magnetic field maps now available at the THEMIS database BASS2000, where UNNOFIT has
been implemented, as well as the maps visible in the first author’s web page http://amrel.obspm.fr/bommier/. The BASS2000 web address is http://bass2000.bagn.obs-mip.fr/pagef3.html. All these data constitute a basis for the study of the solar vector magnetic field and the understanding and forecasting of solar activity. As an example of the use of such data, a decrease of the network local average magnetic field strength from about 400 Gauss to about 100 Gauss before the disappearance has been observed with THEMIS on 24–25 August 2006, suggesting that the filament/prominence disappearance results from a weakening of its magnetic support.

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Figure 7. Local average magnetic field strength 3D map corresponding to the vector magnetic field map of Figure 5 (bottom).

References


