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Memorie della

THEMIS observational hits in 2006

A. López Ariste

THEMIS – CNRS UPS 853, C/ Vía Láctea s/n, 38280 La Laguna, Spain
e-mail: arturo@themis.iac.es

Abstract. We describe some of the most remarkable observational results reached by THEMIS in 2006, stressing the instrumental improvements that have allowed them, in particular the arrival of the new IXON CCD detectors, and the T3 tip-tilt system. The selected observations are the measurement of Na emission in Mercury's exosphere during daylight, the polarimetry at 10^{-5} on the 2nd solar spectrum, the observation of the spatial variation over the photosphere in the resonance scattering polarization of the SrI line and the simultaneous observation of the two He lines D_3 and 10830 over prominences.

Key words.

1. Introduction

This brief report summarizes some of the remarkable observations made with THEMIS in 2006 thanks in most to the arrival of the new IXON CCD detectors and the commissioning of the T3 tiptilt system. Each one of them pushes on its own the limits of solar observations; together they place THEMIS as the best present telescope for solar spectropolarimetry and extending into the inner Solar System.

The observations here presented, because of their novelty, have been made possible thanks to a strong commitment from the technical team at each moment. In many cases however the principal investigator is external to the THEMIS team. This report will therefore avoid any scientific use of the data presented while expressing the deepest thanks to the respective PI's to allow us to use a few of their data to exemplify to observational possibilities opened to THEMIS.

Send offprint requests to: A. López Ariste

2. Li and 2nd solar spectrum observations

The arrival of the tiptilt has succeed in stabilizing the solar limb during long burst of images at less than 1 arcsec in or off the limb. The main driver for such observations is the measurement of the polarization arising from resonance scattering, also called the 2nd solar spectrum (Stenflo,& Keller 1996). With the improved stability the signal has improved in quality and also the burst can be longer thus increasing the signal-to-noise ratio to values of typically 10^5. Beyond those sensitivity levels the data reduction process seems to be unable to tackle all the spurious (or non-spurious) signals seen almost everywhere. An example of such observations is shown in Fig. 1 where the linear polarization due to resonance scattering is shown for the spectral region around 6708Å. A prominent (compared to the neighborhood) signal appears at the wavelength corresponding to the Li I D_1 and D_2 lines. While the spectral line is barely identifiable as a tiny ripple of the continuum, it is unmistakably present in linear

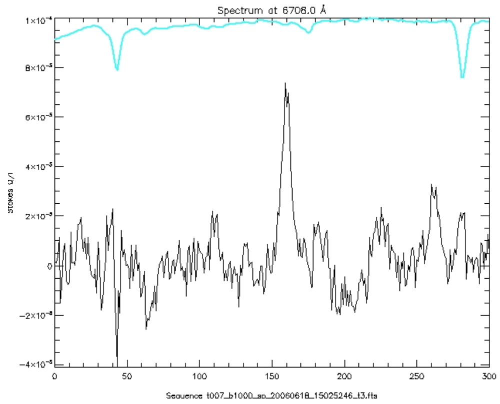

Fig. 1. Linear polarization observed at the solar limb of the spectral region around 6708Å. The most prominent feature corresponds to polarized emission from the D lines of Li I, barely visible in the intensity spectrum as a tiny ripple of the continuum. A signal-to-noise ratio of 10^5 is needed to observe such feature.

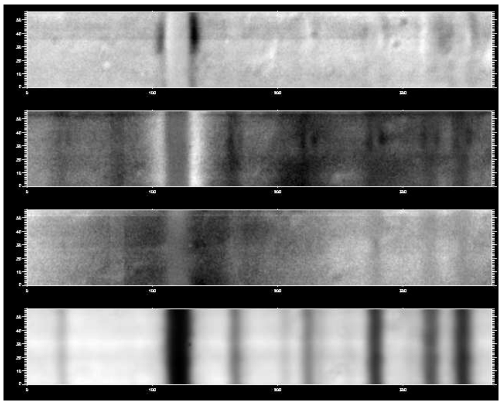

Fig. 2. From top to bottom, Stokes V (circular), Q and U (linear) and intensity profiles of the BaII D2 line (the strongest absorption line to the left of the image). The Q signature is typical of the resonance scattering polarization processes of this line, while the Stokes V is an anomalous signature that remains unexplained

polarization when sensibilities of 10^{-5} are attained.

A second example can be seen with a line of strong diagnostic interest, the Ba II D2 line. This line shows a strong signal of resonance scattering polarization (see Fig.2), with spectral features highly dependent on the magnetic field in which the Ba atoms are embedded. The data, obtained in collaboration with A. Asensio Ramos, R. Manso Sainz and M. Derouich (Instituto de Astrofísica de Canarias, Spain), shows nicely the strong linear polarization signals and also an anomalous signal of circular polarization not due to Zeeman effect and which remains unexplained.

3. The spatial variation of polarization in the Sr line. Data from J.-M. Malherbe (LESIA. Paris Observatory)

The Sr I line at 4607 has been known for some time to produce a strong polarization signal in conditions of resonance scattering (Wiehr 1981; Stenflo 1982). It is furthermore a line formed in an atomic system which can be acceptably well modeled with just 2 levels thus making computations extremely straightforward (Faurobert-Scholl 1993). Because of the easiness in the modelling and the strong signal, it has been proposed to observe the spatial variations of the polarization signal in the quiet sun of the photosphere. THEMIS excels in those measurements and here we will show just an example of those measurements performed by J.-M. Malherbe (LESIA. Paris Observatory) last fall.

In Fig.3 we show the Stokes Q and V profiles of the spectral region around the Sr line at 4607Å. The thick line corresponds to an average over the intergranules and the thin line to an average over the granules. Granules and intergranules are defined here as the brighter-than-average and darker-than-average structures as seen in the continuum of this dataset taken at 40 arcsec inside the solar limb. We observe that the Sr shows a linear polarization stronger in the intergranules than in the granules, but also a stronger amplitude in the characteristic antisymmetric profile of circular polarization due to Zeeman effect. This may seem contradictory at first sight, since the amplitude of Stokes V is roughly proportional to amount of field, while stronger field tends to depolarize Stokes Q through Hanle effect. It appears therefore that the Hanle effect implies

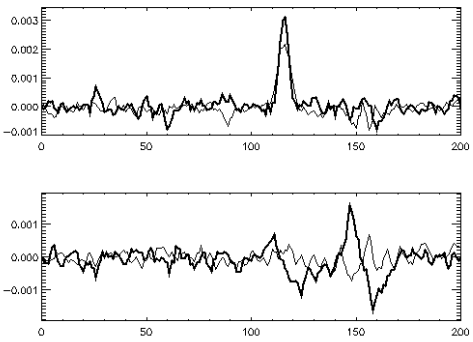

Fig. 3. Stokes Q (top) and V(bottom) profiles of the spectral region around the Sr I line at 4607Å. The Sr line is the only one showing a prominent Q signal. In Stokes V, a second line shows up to the right in the plot corresponding to an Fe line very sensitive to the Zeeman effect. The thick lines correspond in both cases to an average over darker-than-average, intergranular regions, while the thin lines correspond to brighter-than-average granular regions, as observed at 40 arcsec inside the solar limb. Data courtesy of J.M. Malherbe (LESIA. Paris Observatory).

that the magnetic field is stronger in granules than in intergranules, while the Zeeman effect implies right the opposite. The solution to the riddle comes through the realization that Zeeman effect in circular polarization is sensitive only to **net** fields over the resolution element, while Hanle effect is sensitive to all fields, independent of their sign. One should therefore call for the presence of a distribution of fields in the resolution element of the observations (roughly 1000 by 1000 km in area). The fields are in our case stronger over the granular regions, thus depolarizing more the Sr line Stokes Q signal, but they are also better balanced leaving no net field to be seen in Stokes V. The intergranules, on the other side, have a weaker field but some of those fields are unbalanced introducing a relatively strong Zeeman signature in Stokes V.

4. The He D_3 and 10830Å lines observed simultaneously in prominences.

A fundamental particularity of THEMIS is its ability to do spectropolarimetry in many spectral domains simultaneously. THEMIS do so through the use of a predispersor that projects a first order-low dispersion spectra over a focal plane at which the pre-selected domains are allowed to pass and enter the main echelle grating. The physical space at that focal plane places therefore a limit to the maximum separation of the spectral domains observed, a limit which is known to be of roughly 3000Å. Altough big, the limit was a big drawback for the observation of the two main lines of the triplet system of HeI in prominences, separated by 5000Å. But the instrument is flexible enough to allow for the modifications needed for the purpose. Thanks therefore to that flexibility and the to the arrival of the new IXON CCD cameras, with an increased sensitivity in the infrared, THEMIS has been the very first telescope to do the simultaneous observation and full polarimetry of the 2 He lines over prominences, thus opening an enormous window into the diagnostic of prominence magnetic fields.

5. The exosphere of Mercury (in collaboration with A. Doressoundiram (LESIA, Paris Observatory), F. Leblanc (Service d'Aéronomie. France) and J.L. Bougeret (LESIA, Paris Observatory).

Different from all other previous solar telescopes, THEMIS is not made of a coelostat but it is a true telescope able to point anywhere over the celestial sphere and thermally protected from the intense power input from direct sunlight. THEMIS can therefore be used for non-solar astronomical observations as well, although it is severely penalized by its small 90-cm mirror. The small mirror however may be the smallest drawback if THEMIS can provide an advantage which is not available in any other astronomical instrument. This is the case

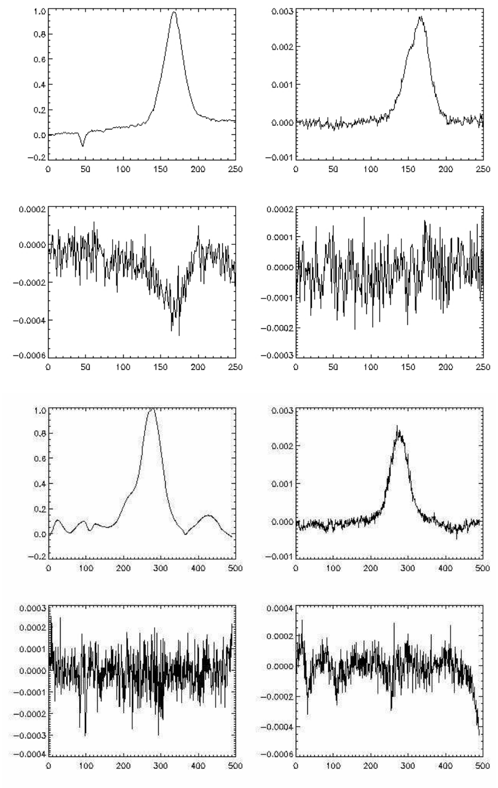

Fig. 4. Simultaneous spectropolarimetry of the He lines D_3 (top 4 panels) and 10830Å (bottom four panels) over a low-lying prominence. Each one of the 4 panels set shows Stokes I and Q on the top from left to right, and Stokes U and V on the bottom.

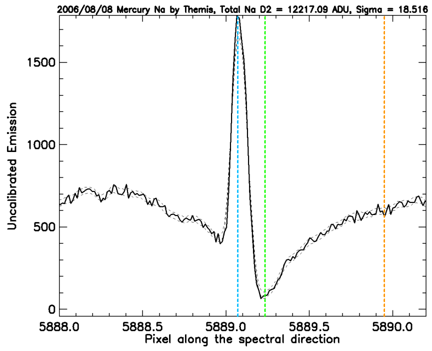

Fig. 5. Na emission in Mercury's exosphere. The figure shows the intensity profile over Mercury measured on August 8th, 2006 during daylight. The absorption feature shows the Na line from the solar spectra reflected in Mercury's planetary surface and whose line center is marked by the central dashed line. The solar spectrum itself, scattered by the Earth's atmosphere has already been subtracted, but presented the same Na line centered in the rightmost dashed vertical line. The distance between both dashed lines (central and rightmost) is a measure of the relative velocity of Mercury respect to the Earth on that date (roughly 40 km/s). Inside the absorption feature, a strong and narrow emission feature, marked with the leftmost dashed vertical line, due to Na in Mercury's exosphere. Courtesy of F. Leblanc (Service d'Aeronomie. CNRS France)

of Mercury. The planet is so near the Sun that normal night telescopes can only point at it for a few days on the year (coinciding with the maximum elongations of the planet) and then only for the few minutes in which the planet is visible before or after the sun rises or sets, at any rate always very near the horizon with all the disturbances of a long optical path across the Earth's atmosphere. THEMIS on the other hand can observe it any time of the year as long as the planet is not behind the solar disc, and this all day long, thus increasing both the day and the year coverage. Such a huge advantage compensates for the relatively small mirror, if appropriate detectors are used with high enough sensitivity.

The new IXON CCD cameras provided us with the appropriate detection system and we tried a proof-of-concept observation in August 2006. Fig.5 shows the excellent result attained. The goal was not to see the planet itself, but the emission in Na from the rarefied exosphere around Mercury. The planet is too small to retain a gaseous atmosphere, but still a variety of physical process results in the presence of different gases around the planet. Such gases are dragged by the solar wind and abandon the planet's neighborhood in a comet's shaped exosphere. In Fig5 one can see the absorption line of Na D_2 reflected over Mercury's planetary surface (and Doppler-shifted accordingly to the relative speed of Mercury respect to the observer in that date) and a narrow emission feature inside the absorption line corresponding to the cold emission of Na from the exosphere. The observations were done at noon, at the moment of minimum airmass since the planet was near to the local zenith, thus opening *de facto* a new science case for THEMIS

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