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Multi-line spectro-polarimetry on active region NOAA 9125(*)

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Summary. — We present here some preliminary results of observations performed with the spectro-polarimetric mode of the THEMIS telescope on active region NOAA 9125 on August 2000. We show the presence of high-velocity downflows located at the edge of a filament and stress on the non-stationary character of these flows. Flaring activities were also observed: we just present here some spectro-polarimetric profiles of these regions, more accurate magnetic-field configuration determination being performed latter on.

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1. – Introduction

All the results presented here are based on observations performed with THEMIS telescope(1) during campaign 2000. The goal of the campaign was to study the emergence and evolution of active regions. In this paper, we will present some preliminary results concerning mainly flows in filaments and flares.

Filaments are composed of a cold plasma embedded in a hot atmosphere, frozen in the chromospheric magnetic field. They appear along neutral ligne separating regions of opposite polarity. During the quiescent phase of the filament, only small upper motions are noticed [1, 2]. However, strong perturbations of the filament velocity map are usually seen during the activating phase, giving rise to flares [3, 4]. We report here some preliminary results on the presence of perturbating phase of some quiescent filaments. The correlation between the appearance of strong up- and downflows and flares is still under study.

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(1) Operated on the island of Tenerife by CNRS-CNR in the Spanish Observatorio del Teide of the Instituto de astrofisica de Canarias.

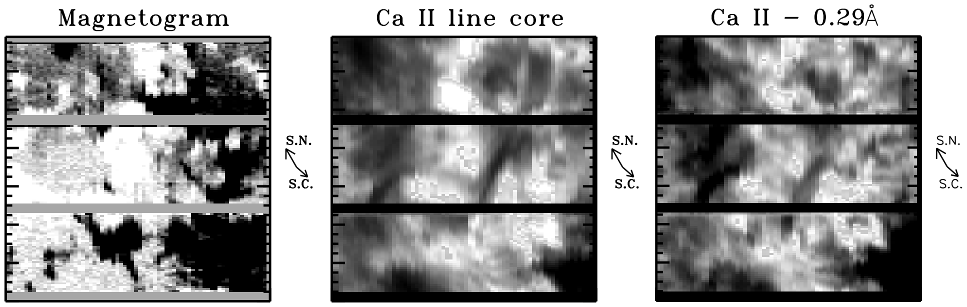

Fig. 1. – Magnetogram and Ca II intensity map of NOAA 9125 for the two wavelengths indicated on the top of each image. The top right filament shows a sub-structure with an arch filament shape (compare the two Ca II images) *which is not seen in Hα line* (not shown here). Also indicated the Solar North direction (S.N.) and the Sun Center direction (S.C.).

Section **2** presents briefly the observations performed and the data reduction employed. Section **3** presents the results obtained: in **3**˙1 the details on the high, non-stationary, downflows detected at the edges of filaments and in **3**˙2 some brief results on the spectro-polarimetric measurements of the flaring region. Finally, sect. **4** provides the conclusions.

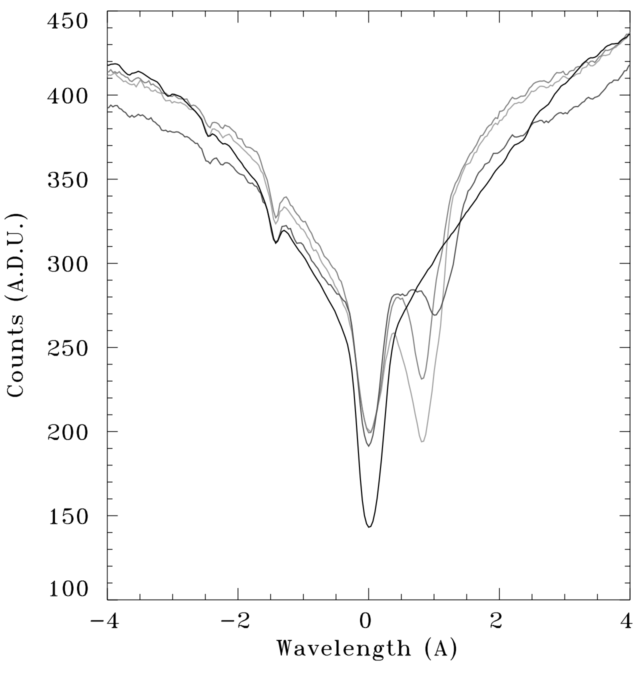

Fig. 2. – Example of λ8542 Ca II profiles showing the peculiar absorption in the red wing. A plasma falling down with a velocity of about 45 km s^{-1} seems to be superimposed to a quiet-Sun background (note that the Ca II core line is not shifted).

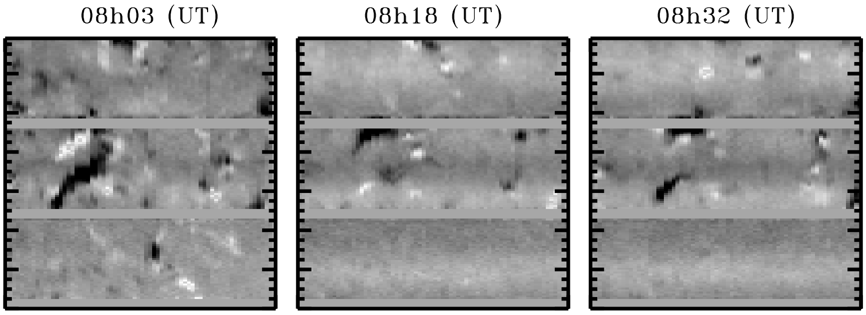

Fig. 3. – Longitudinal velocity maps obtained for Ca II core ±0.8 Å, *i.e.* representing 28 $\mathrm{km\,s^{-1}}$ (black being downwards motion), for three successive scans on the region. Strong velocity shear is noticeable at footpoints of the filaments. After almost complete disappearance of the strong downflows (second map), it is once again present on the last map.

2. – Observations and data reduction

2˙1. *Instrumental configuration.* – THEMIS is equipped with three different modes to performed polarimetric measurements (see THEMIS web page for their description http://www.themis.iac.es). For these observations, we prefered the "Grid Method" as described in [5]. The grid, located at the entrance of the polarimeter, selects different fields of view of 16 arcsec width. The entrance slit of the spectrograph was 0.7 arcsec and three of these fields of view were recorded simultaneously on a single CCD camera.

Three spectral lines were recorded simultaneously: the photospheric λ6302 Fe I, and the two chromospheric λ6563 Hα and λ8542 Ca II.

The region was scanned by steps of 0.7 arcsec. One scan of 91 × 85 arcsec, with the four Stokes parameters recorded, took about 15 minutes.

The region has been observed for 4 days (from August 11th to August 15th, 2000). The results we present here concerned mainly August 15th for which the seeing was the best and activity was quite remarkable.

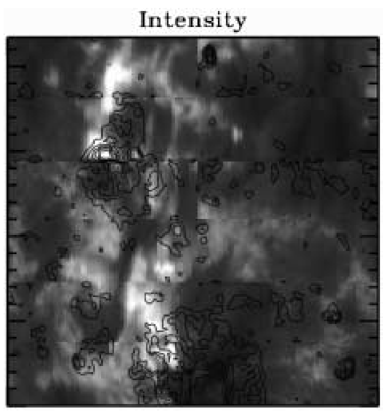

Fig. 4. – Map of the whole active region as seen in Ca II (91×85 arcsec^2). Fe I intensity contours are overplotted. A large activity appears in the top sunspot. Another intense activity has been noted close from the sunspot located on the lower right part of the image.

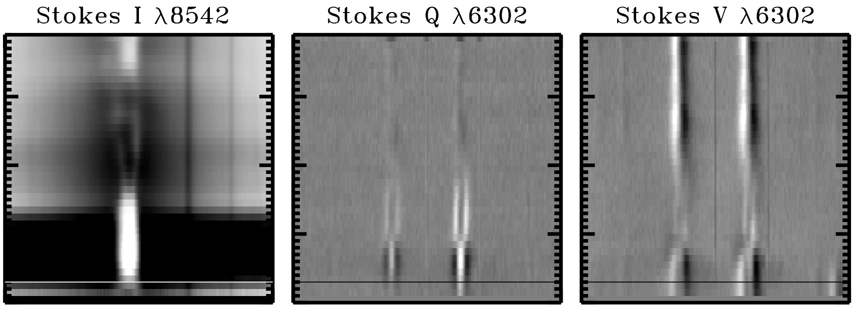

Fig. 5. – Ca II Stokes I together with Fe I Stokes Q and V on the flaring region. Stokes U presenting almost no signal is not presented here. The horizontal line on each spectra shows where the profiles of fig. 6 have been extracted.

2·2. *Data reduction.* – Data reduction is based on the well-known formula

$$I^{\mathrm{c}} = \frac{I^{\mathrm{r}} - \mathrm{dark}}{\mathrm{flat} - \mathrm{dark}}\,, \tag{1a}$$

where I^{c} stands for the corrected image, I^{r} for the raw image, *flat* for the flat-field image and *dark* for the dark current image.

The first step to obtain the flat field is to sum 100 images (acquired when the telescope was moving). Spectral lines must be removed from the image before the flat field is applied. Since spectral lines are slightly inclined and curved, it is necessary to first applying a bending correction to the spectral lines. Then, the mean spectral profile is extracted from this image and used to remove all spectral information from the average image. The flat-field image to be applied contains only defects from which the image must be corrected (fringes, dust,..., etc.).

Dark current is obtained only by averaging 25 dark current images.

The bending correction deduced from the flat-field image is applied to each individual data of the scanning before eq. (1a) is applied.

3. – Results

3·1. *Non-stationary longitudinal downflows in filaments.* – At observing time, NOAA 9125 was located at (E13, N21) that is very close from the solar meridian ($\mu = 0.96$). Figure 1 shows the region as seen in Ca II at two different wavelengths together with the magnetogram obtained from iron line.

Individual Hα and Ca II profiles reveal the presence of strong downflows: a Doppler-shifted profile is superimposed to a "quiet Sun" profile (cf. fig. 2). This suggests the presence of plasma moving downwards in an almost static atmosphere (or moving horizontally, which cannot be detected here).

All these profiles are correlated with the presence of filaments. Downflows at the footpoints of quiescent filaments are well-known phenomena [6, 7, 1, 8]. Most of the preceeding results were based on data with a moderate spectral resolution. The results we present here are based on spectroscopic data having a high spectral resolution (700000). This allows us to also identify fine velocity structures in the filament.

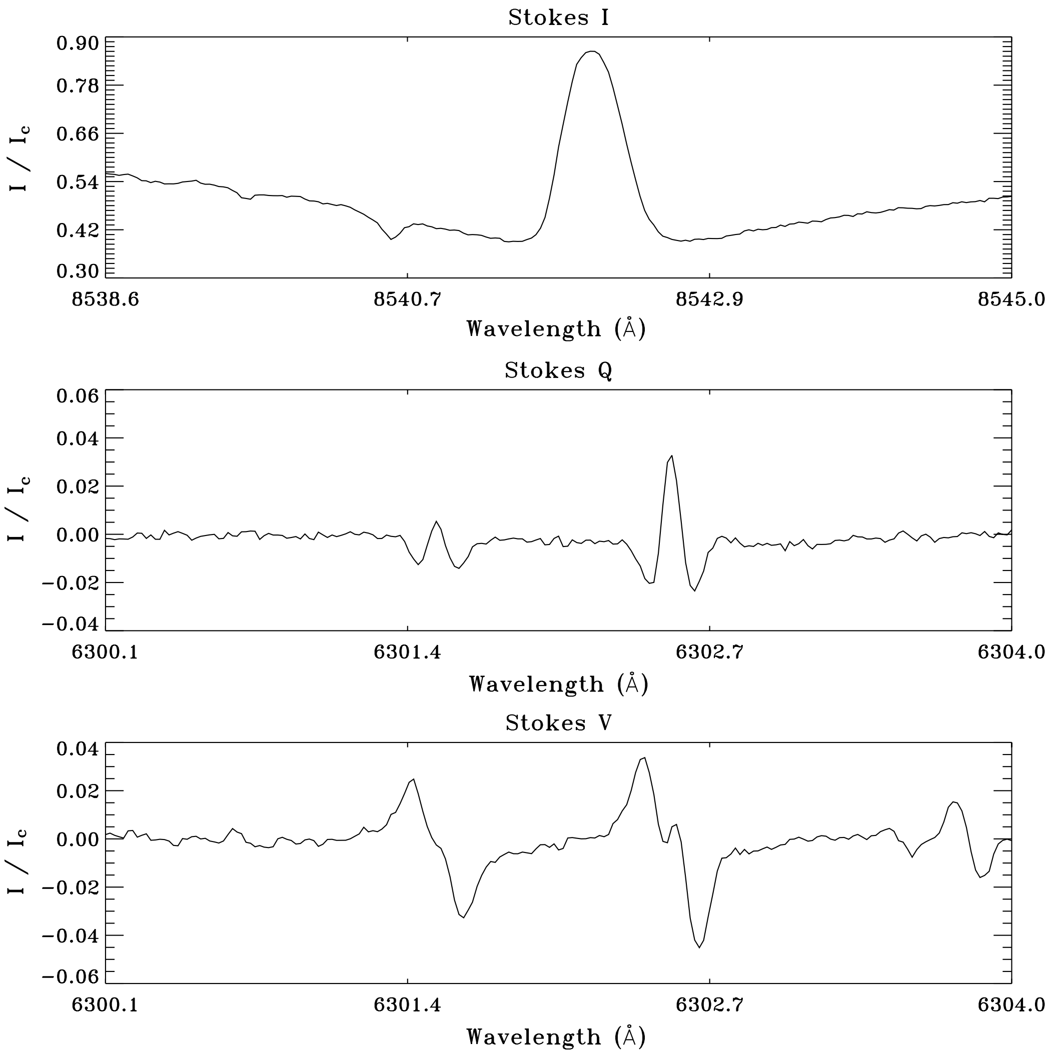

Fig. 6. – Profiles close from the flaring region. Magneto-optical effects are well seen on the Stokes V parameters. Polarimetric precision on a single profile: $2 \cdot 10^{-3}$ with an exposure time of 300 ms.

Figure 3 shows velocity maps of the region, at ±0.8 Å from the line core, underlying velocities of $\pm 28\ \mathrm{km\,s^{-1}}$. Most of the flows present a symmetrical behavior with the presence of a down- and an upflow. The most prominent feature is the strong (in value and spatial extension) downflow associated with the filament of the middle left part of the image. If other noticeable flows are mainly concentrated at the filament footpoints, this one appears most likely at filaments edges. Velocities up to $-45\ \mathrm{km\,s^{-1}}$ have been noticed. This suggests a free-fall process.

Data are not corrected for perspective effects. However, the region being close to the disk center, their influence must be reduced. We cannot conclude yet on the presence of acceleration of the flow, while falling down, even if the strongest downflows have been detected on the lower layers of the filaments. The time series we have allows us to point out the non-stationary character of the downflow phenomenon. Figure 3 sketchs the flows at three different times. It is evident that the strong downflow previously mentioned is not always present (in black): very strong at 08h03, it almost completly disappears at 08h18 and appears again at 08h32. Velocity field from Hα line shows the same behavior. It is noteworthy that the magnetic field (longitudinal or transversal) on the photosphere below the filament should be very weak since no noticeable polarities appear on the magnetogram. An accurate determination of the magnetic-field configuration is however necessary and will be performed later on using inversion codes.

These figures show that the presence of strong magnetic field in filamentary structure is not permanent during the lifetime of the structure but appears maybe recurrently. More specific observations on the subject are necessary with a better temporal resolution.

A quick look at the data obtained latter on shows a complete transformation of the filament. The whole data set must be reduced to check if any flare is present at or close to the filament position, as suggested by Jiang *et al.* [3, 4].

3·2. *Flaring activity in a sunspot*. – Many flares or sub-flares appear on the region. The most prominent one was located in one of the sunspots (cf. fig. 4). Figures 5 and 6 show some example of Stokes spectra and profiles recorded during the flaring phase. It is noteworthy that polarity in Stokes V and Q change appears *in the sunspot, almost at the maximum flare location.*

It lasted for at least half an hour. At first glance, we notice a diminution of the negative polarity at photospheric level during the flare evolution (from the magnetograms deduced from the iron line—not shown here). A more accurate determination of the magnetic configuration will be performed latter on with an inversion code.

4. – Conclusions

The present set of data obtained with THEMIS telescope during the campaign 2000 is very important to study the disturbance of filaments and the correlation with flare appearance. The accurate polarimetric measurements allow us to derive the magnetic field at photospheric levels. Some attempts will be done also to get the magnetic field at chromospheric level, at least where the magnetic field is strong enough.

Another important item is to study the time evolution of the region over the 5 observing days.

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