HIGH RESOLUTION OBSERVATIONS OF EMERGING ACTIVE REGIONS CARRIED OUT AT THE THEMIS TELESCOPE

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ABSTRACT

Using data acquired during two observational campaigns at THEMIS telescope in IPM mode, coordinated with other instruments (IOACT, BBSO, TRACE, EIT/SOHO, MDI/SOHO), the first evolutionary phases of some active regions have been analysed, in order to study the morphology and dynamics of some magnetic structures (pores, spots, AFS) during their emergence. The results obtained have provided indications on the atmospheric layers where the first manifestations of the emerging ARs are evidenced, on the upward velocity of the AFS and on asymmetries in downward motions in the AFS legs. These results have been interpreted in the framework of rising flux tube models.

Key words: Sun: activity; Sun: sunspots; Sun: magnetic fields.

1. INTRODUCTION

It is widely accepted that the formation of active regions in the solar atmosphere is caused by the emergence of small (r ~ 200 Km) and intense (500 G) magnetic flux tubes from subphotospheric layers.

However, despite the detailed knowledge we have today (see, e.g., van Driel-Gesztelyi 2002, for a review) on the formation and emergence of active regions, it is not yet possible to forecast whether newly emerging magnetic flux tubes will give rise to an active region with a typical lifetime of ~ 1 – 2 months, or they will diffuse in a short time (1–4 days).

In this framework, we report the results obtained from the analysis of two active regions (NOAA 10050 and NOAA 10407), characterized by different lifetimes: recurrent the former and short-lived (7 days) the latter. The data used were acquired during two observational campaigns carried out at THEMIS telescope in IPM mode, coordinated with other ground- and space-based instruments (IOACT, BBSO, TRACE, EIT/SOHO, MDI/SOHO). The results obtained have provided indications on their morphological and magnetic evolution and on the velocity fields associated with their magnetic structure.

Figure 1. The active region NOAA 10050 in different atmospheric layers. From bottom to top: (a) MDI magnetogram (fov ~ 295 x 245 Mm²), (b) photosphere (fov ~ 310 x 260 Mm²), (c) chromosphere (fov ~ 310 x 260 Mm²), (d) corona (fov ~ 130 x 110 Mm²).

Figure 2. The active region NOAA 10407 in different atmospheric layers. From bottom to top: (a) MDI magnetogram (fov ~ 100 x 65 Mm²), (b) photosphere (fov ~ 55 x 40 Mm²), (c) chromosphere (fov ~ 210 x 190 Mm²), (d) corona (fov ~ 130 x 110 Mm²).
2. OBSERVATIONS

Active region NOAA 10050 (see Fig. 1) was characterized by a lifetime greater than 2 months. It was firstly observed in the transition region and lower corona (EIT 304 Å image) on 26 July 2002 at 1:00 UT, while the first record of the relevant sunspot group was at 16:15 UT (MDI image), with heliographic coordinates S06, E31. This active region had a very complex evolution during its first transit on the solar disc, with an extended preceding spot, two following spots, some pores and several large filaments. Moreover it showed an intense flare activity (GOES-8 recorded 16 C-class flare events)(see Spadaro et al. 2004, for a more detailed analysis of this AR).

The active region NOAA 10407 (see Fig. 2) had a lifetime of 7 days. It was firstly observed in the upper atmosphere (EIT 195 Å image) on 11 July 2003 at 8:48 UT, while the first record of the relevant sunspot group was at 16:00 UT (MDI image), with heliographic coordinates N09, E29. This active region showed a very simple evolution, characterized by the formation of a single spot, several pores and some small filaments. It did not show any flare activity (see Zuccarello et al. 2005, for a more detailed analysis of this AR).

The images acquired in the centre of the Hα line showed that the main characteristic of the early phases of formation of both active regions was an arch filament system (AFS) connecting the two emerging magnetic polarities (see Figs.3a and 4a). These AFS were composed by several arch filaments (AF) grouped in bundles, approximately parallel and located across the polarity inversion line (PIL).

3. DATA ANALYSIS

The images obtained by the THEMIS telescope operating in IPM mode were acquired in 18 spectral points, 12 along the profile of the Hα line (6562.92 Å) and 6 along the Fe I line (5576.012 Å). At the same time images in broad band centered at 5380.960 Å were acquired.

The THEMIS/IPM data were corrected applying the standard dark current and flat field corrections (e.g., Contarino et al. 2003). In order to determine the values of velocity along the line of sight (los) in photosphere (through Fe I line) and chromosphere (through Hα line), we considered the Doppler shift of the centroid of the line profiles in each spatial point with respect to the median of the centroid in the whole field of view. The median is used as wavelength reference, since there is no absolute wavelength reference in IPM. We estimated the uncertainty affecting the velocity measurements in a statistical way, considering the standard deviation of the centroids of the line profiles estimated in all points of the whole field of view. The so estimated errors in the velocity are ±0.2 Km s⁻¹ and ±1 Km s⁻¹ for the Fe I and Hα line, respectively.

In order to study the rate of emergence of magnetic flux in these two active regions, we selected one MDI full disc magnetogram every 90 min and determined in each mag-

netogram both the positive and negative flux, taking into account the corrections required by the projection effects.

4. DISCUSSION AND CONCLUSIONS

The results obtained indicate that the arches of the AFS forming in both active regions show an upward motion at their tops and downward motions at their extremities (see Figs. 3b and 4b). Moreover, the values of upflow velocities decrease during the evolution of the active regions (see Fig. 5). Upward motion on the top of the AFS is indicative of the buoyancy of the magnetic flux tubes and of their rise towards higher atmospheric levels (Shibata et al. 1989, Caligari et al. 1995, Moreno-Insertis 1997). However the values of both upflow and downflow velocities measured in the AFS are lower than those reported in literature.

Results of recent numerical simulation of the emergence of a twisted flux tube in the solar atmosphere show that
the field lines (arches) appear to be twisted and not parallel in the innermost layers and have a fan shape in the higher layers (Archontis et al. 2005). This behaviour is particularly evident in the loops of the recurrent AR 10050.

On the basis of our analysis, we can compile two lists: the former including the common features between the short-lived active region and region that undergoes a complete evolution and the latter including the differences.

The common features observed in both long-lived and short-lived active regions are:
- the ARs are initially observed (as a brightness increase) in the outer atmospheric layers (transition region and corona) and later on (i.e. with a time delay of ~ 6 - 7 hrs) in the chromosphere;
- the AR appearance in the outer atmospheric layers is synchronous with the sudden increase of magnetic flux in the photosphere;
- the arches of the AFS forming in the chromosphere are characterized by a decreasing upward motion during the AR’s lifetime;
- the plasma downflow velocity is asymmetrically distributed between the two AFS legs.

The differences observed between the long-lived and short-lived active regions are:
- while the short-lived AR appearance in photosphere is almost synchronous with that in chromosphere, the time delay between the long-lived AR appearance in chromosphere and photosphere is ~ 8 h;
- the magnetic flux increase during the AR formation is about one order of magnitude in the long-lived AR and only a factor 2 in the short-lived AR (see Fig. 6);
- the displacement of the center of symmetry of each polarity in the short-lived AR is mainly directed westward, while it is diverging from the neutral line in the recurrent AR;
- the higher downflow velocity is measured on the f-side in the long-lived AR and on the p-side in the short-lived AR;
- in the long-lived AR the arches forming the AFS are not parallel, but some seem to cross each other (greater twist).

We conclude that all these observational signatures might indicate that the short-lived active region is not anchored in the toroidal, subphotospheric magnetic field and is therefore more subject to turbulence than a long-lived, strongly anchored active region.

REFERENCES