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Dynamics and evolution of emerging active regions

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Abstract. In the framework of the study on active region emergence, we report the results obtained from the analysis of two ARs (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 instruments (IOACT, DOT, BBSO, MDI/SOHO, EIT/SOHO, TRACE). The results obtained have provided indications on the atmospheric layers where the first manifestations of the emerging AR are evidenced, on the rate of emergence of magnetic flux, on the upward velocity of AFS, on asymmetries in downward motions in the AFS legs.

Key words. Sun: activity – Sun: sunspots – Sun: magnetic field

1. Introduction

It is now well established that the appearance of active regions on the Sun is due to the emergence of magnetic flux tubes from subphotospheric layers: several small (r ∼ 200 Km), intense (500 G) flux tubes, initially separated, become clustered and form pores and sunspots.
However, despite the detailed knowledge we have today 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 a fully developed active region, or they will disappear within few hours/days.
In the framework of this study, using data acquired during two observational campaigns at THEMIS telescope in IPM mode, coordinated with other ground- and space-based instruments (INAF-OACT, DOT, BBSO, MDI/SOHO, EIT/SOHO, TRACE), we have analyzed the first evolutionary phases of two active regions (NOAA 10050 e NOAA 10407), characterized by different lifetimes: recurrent the former and short-lived the latter. More precisely, we have determined the morphological and magnetic evolution of these two ARs , as well as the velocity fields associated with their magnetic structures (AFS, pores, spots).

2. Observations

The recurrent active region NOAA 10050 is firstly observed to appear in the upper solar atmosphere (EIT 304 Å image) on 26 July 2002 at 1:00 UT; the first record of the relevant sunspot group is instead at 16:15 UT

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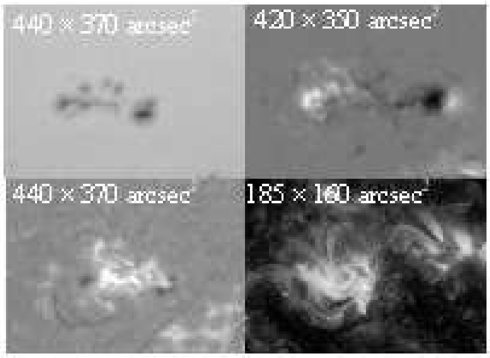

Fig. 1. The active region NOAA 10050 in different atmospheric layers. From top to bottom and from left to right: (a) photosphere (WL), (b) MDI magnetogram, (c) chromosphere (H_α), (d) corona (171 Å). The numbers in each image indicate its field of view.

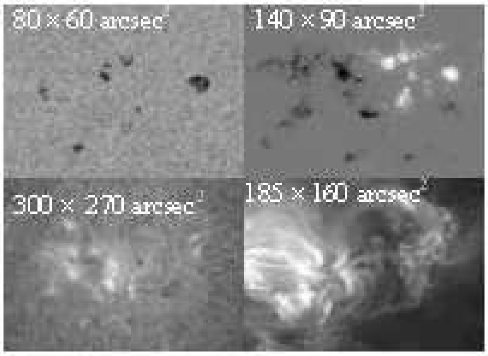

Fig. 2. The active region NOAA 10407 in different atmospheric layers. From top to bottom and from left to right: (a) photosphere (WL), (b) MDI magnetogram, (c) chromosphere (H_α), (d) corona (171 Å). The numbers in each image indicate its field of view.

(MDI image), with heliographic coordinates S06, E31. This region develops considerably and is present for more than three rotations on the Sun, before completely decaying (see Fig. 1).

The short-lived active region NOAA 10407 is firstly observed to appear in the transition region and lower corona (EIT 195 Å image) on 11 July 2003 at 8:48 UT, while the first record of the relevant sunspot group is at 16:00 UT (MDI image), with heliographic coordinates N09, E29. The active region is observed on the solar disc only for 7 days, before completely decaying (see Fig. 2).

3. Data analysis

Several series of monochromatic images of the solar photosphere and chromosphere have been acquired. One series is acquired along the 6562.92 H_α line and is formed by 12 images. The other series is acquired along the 5576.012 Fe I line and is formed by 6 images; each series is completed by a continuum image. We corrected the THEMIS/IPM data applying the standard dark current and flat field corrections. In order to calculate the values of velocity along the line of sight (los) in photosphere and chromosphere, 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 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 $\cdot$ s^{-1} and 1 Km $\cdot$ s^{-1} for the Fe I and H_α line, respectively.

4. A comparison between the two active regions

The common features observed in both long-lived and short-lived active regions are:

- the first signatures of these ARs emergence are initially observed in the outer atmospheric layers (transition region and corona) and later on (i.e. with a time delay of 6 - 7 h) in chromosphere;
- the ARs appearance in the outer atmospheric layers seems to be synchronous with the sudden increase of magnetic flux in photosphere;
- the loops of the AFS observed in chromosphere are characterized by a decreasing upward motion during the AR's lifetime;

Fig. 3. Velocity map plotted over an image of NOAA 10050, acquired in the center of the Hα line on July 27, 2002 at 9:32 UT. Thick contours indicate upward plasma motions, while thin contours indicate downward plasma motions. The velocity contours are drawn every 2 km $\cdot$ s^{-1}.

Fig. 4. Velocity map plotted over an image of NOAA 10407, acquired in the center of the Hα line on July 14, 2003 at 9:22 UT. Thick contours indicate upward plasma motions, while thin contours indicate downward plasma motions. The velocity contours are drawn every 1 km $\cdot$ s^{-1}.

– the downward plasma motion in the AF's loop legs is asymmetrical.

The differences observed between the long-lived and short-lived active regions are:

– the short-lived AR appearance in photosphere is almost synchronous with that in chromosphere, while there is a time delay of $\sim$ 8 hours between the long-lived AR appearance in chromosphere and photosphere.
– during the AR formation the magnetic flux increases by about one order of magnitude in the long-lived AR and by only a factor 2 in the short-lived AR;
– 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;
– in the short-lived AR the higher plasma downflow is measured in the preceding leg, while in the long-lived AR it is observed in the following leg.

5. Conclusions

We have analyzed the morphology, magnetic characteristics and dynamics of two active regions characterized by different lifetimes and we have found several common points and several differences between them, which might be important in recognizing the kind of evolution an active region will have, since its first manifestations in the solar atmosphere.
Moreover, we would like to stress that all these observational signatures fit quite well a scenario where 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

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