Case Studies of Magnetic Topology Evolution in Active Regions

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Abstract. We give a preliminary report on the evolution of the magnetic field topology extrapolated in the current-free approximation for two solar active regions observed through an MOF imaging magnetograph.

1. Introduction

Two active regions (AR8015 and AR8016) of the old and new cycle respectively were observed through a Sodium Magneto-Optical Filter (MOF) imaging magnetograph installed at the Kanzelhöhe Solar Observatory in Austria (Cacciani et al. 1997). The filter was in a setup phase and only full-disk, low-resolution (∼ 8.2 x 6.5 °/pixel) dopplergrams and longitudinal magnetograms were taken. Such preliminary observations did not allow high quality quantitative measurements to be carried out, as the instrument was just installed at the time of the observations and the (already developed) calibration procedures (Cacciani & Moretti 1997, Moretti 1997) are now under test. Nevertheless, the opportunity to observe active regions with simple magnetic configurations favoured, on one hand, the (heuristic) analysis of the time evolution of its topology and, on the other hand, the identification of operating features that needed to be properly taken into account and tuned. Despite the prototypal characteristics of the installed MOF, such observations indicate the potentialities of this instrument for the analysis of the magnetic topology in fast evolving phenomena under suitable hypotheses. For the purposes of this preliminary analysis we selected ten frames per each region corresponding to a time sampling cadence of two images/hour, which is consistent with the observed evolution. The online SOHO and Kanzelhöhe solar data archives were used to pick up reference images at different wavelengths. To reconstruct the magnetic field lines above the active regions we adopted a very simple current-free model (Nakagawa & Raadu 1972) which resulted in a simplified numerical scheme to derive the potential Ψ, on a 3-D mesh inside a box located over the region under consideration, from the observed longitudinal magnetic field values as boundary conditions. The gradient
of the potential $\nabla \Phi$ was computed as an average over five points, consistently with the resolution of the original image. Finally, the field lines were displayed through the Streamline Module of the Advanced Visualization System package. The visualization box was oriented so as to have the reference plane (from which the lines originate) just over the observed region and interactively rotated until a satisfactory perspective view was found. Intensive computations and processing were performed at CASPUR in Rome.

2. Morphological Evolution of AR8015

Optical Features AR8015 appeared on the disk on 29 January and was last observed at the West limb on 7 February 1997. During its whole life it showed a bipolar spot configuration (magnetic class B). At the time of our observation (30 January) the region was one day old and in white-light the leading and the following spots were the most prominent features.

Global Magnetic Features The sequence of longitudinal magnetograms 10:03-14:03 UT (Figure 1) shows a relatively weak field in both polarities during the whole temporal evolution, whose strength was increasing with time. The negative polarity was predominant but of the same order of magnitude as the positive one.

Magnetic Topology Evolution Initially, a double structure was visible with four, almost parallel, elongated regions of interconnected alternate opposite polarities and similar intensities. This pattern matches the H$\alpha$ and EIT He II 30.4 nm features. At a later time, the upper (in our pictures) negative region was disrupted and the central negative one strengthened and intruded into the positive ones. Finally a further expansion and intensification of the negative region occurred as well as of the upper positive region.

3-D Magnetic Field Lines Reconstruction Even under the very limiting assumptions of the current-free model which obliges to take into account all the due "caveat", the reconstruction of the magnetic field over the AR might be helpful to follow, as it shows an evolution leading to the formation of a well developed closed loop system. Indeed a loop system is clearly visible in the EIT Fe ix/x 17.1 nm and in the Yohkoh SXT pictures.

3. Morphological Evolution of AR8016

Optical Features AR8016 appeared on the disk on 2 February and was last observed at the West limb on 10 February 1997. It evolved from a bipolar spot configuration (magnetic class B) during the first four days to a single polarity spot (class A). At the time of our observation (2 February) the region was just born and in white-light the leading and the following spots were the most prominent features as well as a small central feature.

Global Magnetic Features The sequence of longitudinal magnetograms 11:03-15:03 UT (Figure 2) shows a relatively weak field in both polarities during the
Figure 1. Initial and final stages of the magnetic topology evolution in AR8015. The longitudinal magnetograms (lower panels; dark grey shades and continuous contours - positive field; light grey shades and dashed contours - negative field) show intensification and development of both magnetic polarities. The relevant 3-D field reconstructions in the current-free approximation (upper panels) correspondingly show the formation of a closed loop system.
Figure 2. Initial and final stages of the magnetic topology evolution in AR8016. The longitudinal magnetograms (lower panels; dark grey shades and continuous contours - positive field; light grey shades and dashed contours - negative field) show an intensification of the predominant positive polarity and a weakening of the most prominent negative one. The correspondent 3-D field reconstructions in the current-free approximation (upper panels) show an expansion of closed loop systems with time.
whole temporal evolution, whose strength was increasing with time. The positive polarity was predominant and about three times more intense than the negative one at its maximum development state.

**Magnetic Topology Evolution** Three main regions were visible where the external ones were positive and the inner one negative. The leftmost positive region was the most intense. During the evolution, the latter became strongly reinforced and expanded, whereas the central negative region was only slightly intensified. Finally a further expansion and intensification of the leftmost positive region occurred as well as a slight weakening of the central negative one.

**3-D Magnetic Field Lines Reconstruction** The reconstructed potential field lines show closed loop systems since the very beginning, while intensifications and loop expansion appear in the last frames. In such a case the choice of the proper perspective view was quite difficult and the last frame shown in Figure 2 was displayed with a slightly different rotation angle with respect to the previous one.

4. **Comments and Conclusions**

We reported on the evolution of the topology of the longitudinal magnetic field for two active regions observed through an MOF imaging magnetograph when the instrument was in a setup phase. The low-resolution images were used to generate 2-D maps of the longitudinal component of the field in a sequence of 5 frames with a time lag of 1 hour. The first set of measurements (AR8015) is uncalibrated but the second one (AR8016) was calibrated according to the procedure set up by Cacciani and Moretti (1997) which minimizes some of the problems related to such kind of observing technique. Adopting a simplified current-free model, we reconstructed the 3-D magnetic field above the active regions in the attempt to follow the time evolution of the topology. Despite the low resolution and the limiting assumptions, the derived magnetic patterns seem to match to some extent the observations at different wavelengths, but, of course, this does not allow any quantitative interpretation at this preliminary stage. A final setup of the MOF system installed at Kanzel will allow to exploit the full potentialities of this technique for the mapping of the magnetic field on short timescales by applying the most recent procedure for the calibration of the measurements.

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