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DYNAMICS IN RESTRUCTURING ACTIVE REGIONS OBSERVED DURING SOHO/YOHKOH/GBO CAMPAIGNS

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ABSTRACT

JOP17 and JOP 33 are SOHO Joint Observing Programs in collaboration with Yohkoh/SXT and ground based observatories (GBO's), dedicated to observe dynamical events through the atmosphere. During runs of these programs we observed in restructuring active regions (ARs), surges, subflares, bright knots, but not large flares and jets. From these observations we have been able to derive some of the responses of the coronal and chromospheric plasma to the evolution of the photospheric magnetic field. Emerging flux in an AR led to the formation of Arch Filament Systems in the chromosphere, hot loops and knots in the transition region, and X-ray loops. Frequent surges have been observed in relation to parasitic or mixed polarities, but coronal jets have not yet been found. We discuss the possible mechanisms acting during the restructuring of the active regions (reconnection or "sea-serpent" geometries).

INTRODUCTION

The evolution of active regions is mainly due to emerging flux, while in For the decaying phase nothing is really clear in this "boiling" magnetic field (review of van Driel-Gesztelyi, 1998). The concept of emergence due to an Ω - loop is relatively classical. Another interesting effect that should be considered in this great activity is the emergence of a U-loop (Parker 1984, Spruit et al. 1987). U-loops are horizontal subsurface flux tubes which have two ends in the photosphere. Small sections of the horizontal loop can be brought up by turbulence and create mixed polarity fields through a "sea serpent" process. In moat regions around sunspots this phenomena is well observed. It could be responsible for filament formation (Low 1996). We present two active regions which were the seat of constant emerging flux.

OBSERVATIONS

Two solar active regions were mainly observed by SOHO/MDI (full disk magnetograms with a time step of 96 minutes), by Yohkoh/SXT (full disk soft X-ray images), by SOHO/EIT (full disk images in HeII 304 Å, FeIX-X 171 Å, FeXV 284 Å and FeXII 195 Å) and by the large telescope at Bialkow (Poland). Magnetograms and white light images were obtained in Huairou and Debrecen, respectively (Schmieder et al. 1998).

<u>AR 8048</u> was mainly stable in the sense that the flux stayed constant but its area was increasing, which is a sign that the AR is in its decaying phase (van Driel-Gesztelyi, 1998). Following the evolution of the magnetic field, we find three interesting zones which could be places suitable for ejections. Around the leading spot a moat region is evolving. Such a region is generally related to surge and X-ray jet activity (Canfield et al., 1996). The moat region consists of bipolar elements moving radially away from the spot. The outer edge of the moat cell has the same negative polarity as the sunspot. When the leading cells of positive polarity reach the boundary they merge and disappear (Fig. 1).
In the middle of the AR we observe some dark fibrils in the Hα line and bright X-ray loops (EIT, CDS and Yohkoh images in Schmieder et al., 1998). This is the signature of emerging flux at the centre of the AR.

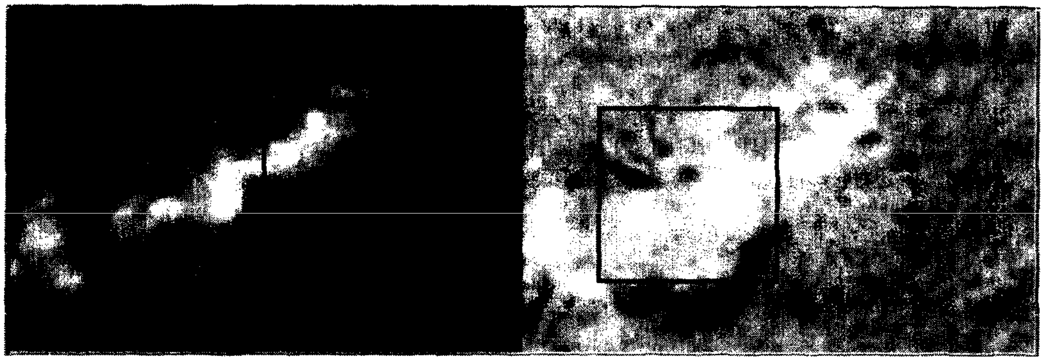

Figure 1: AR 8048 in HeII 304 Å (EIT) (left panel) and in Hα observed with the Meudon spectroheliogram (right panel) on June 5 1997. The box of each image represents the CDS field of view (see figure 2).

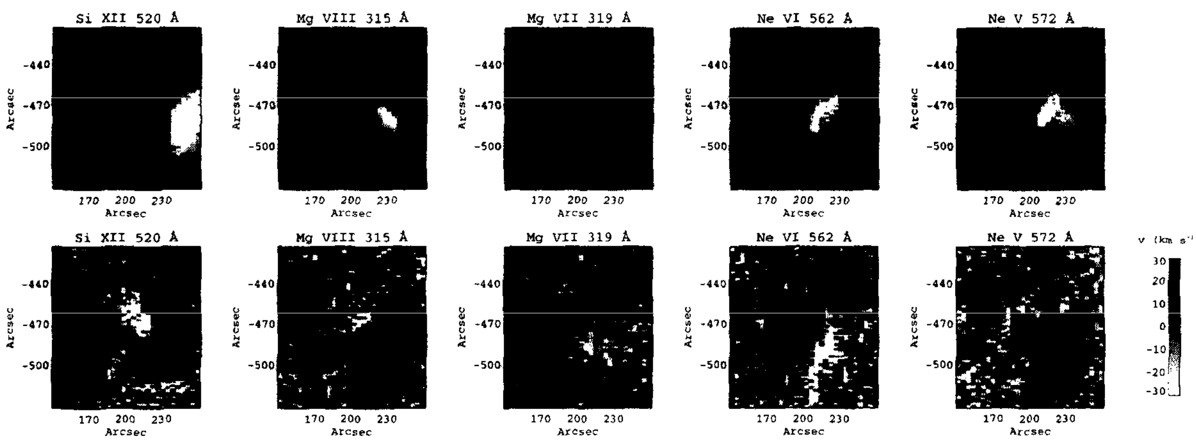

Figure 2: Intensity and velocity maps of AR 8048 observed with SOHO/CDS on June 5, 1997 (with the color table). The CDS field of view (120"×120") is centered on the following sunspot of the AR. The coordinate origin is the disk center.

At the footpoints of the hot loops bright intermittent features were observed by CDS in transition region emission lines (e.g. O V and Ne V $\sim 2.5\times10^5$ K) with a relatively high electron density (2-6 10^{10} cm^{-3}). The velocity field of these structures shows respectively blue and red shifts along the main axis suggesting some twisting effect, like in a surge (Fig. 2).
At the South-East of the main bipole another pre-existing bipolar region with some facula is present. The interaction of these two bipoles leads to the formation of a filament. According to Low (1996), this can occur between two ARs when they belong to the same subphotospheric flux tube. When they emerge in the middle of two Ω structures, dense material rises horizontally forming filamentary structures (Fig. 1).
Apparently the field in these three zones is potential and they do not show any jets, only some surge-like events around the following spot on June 5 1997.

AR 7968 appears on June 3, 1996, entering its decaying phase by June 10 (the magnetic flux becomes weaker) and dies 5 days after. A round negative spot forms inside a bipolar facular region on June 3, 1996. The AR central meridian passage occurs on June 6, being located at N02 in its transit through the disk. Between June 5 and June 6 constant emergence of flux is observed at the central portion of the AR (Fig. 4). The magnetic inversion line, which is perpendicular to the solar equator on June 4, becomes nearly parallel to it on June 6 and 7, coming back to its initial position by June 8. During this whole period (June 5 to 9) we have observed AFS and dark fibrils anchored in Hα bright zones in the middle of the AR (Fig. 4), while bright loops in UV lines and X-rays overlay the region in EIT and SXT images (Fig. 3). The main changes observed after that are due to the growth of parasitic polarities at the South of the following spot. On June 9 we observed a surge at 06:42 UT and a small flare at 09:06 UT. We have found no jet associated

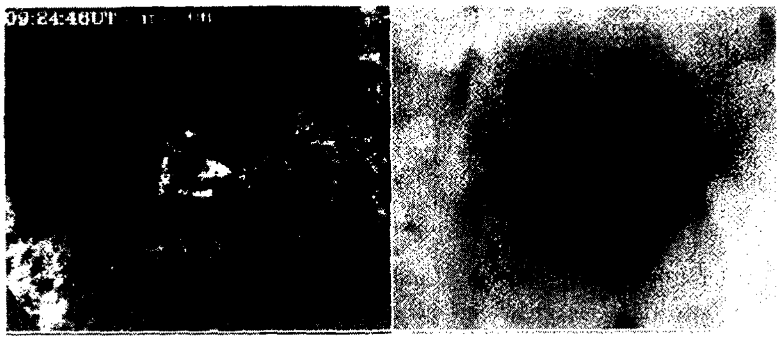

Figure 3: Arch filament system in Hα and hot loops (EIT 195 Å) above AR 7968 (259" $\times$ 216 ")

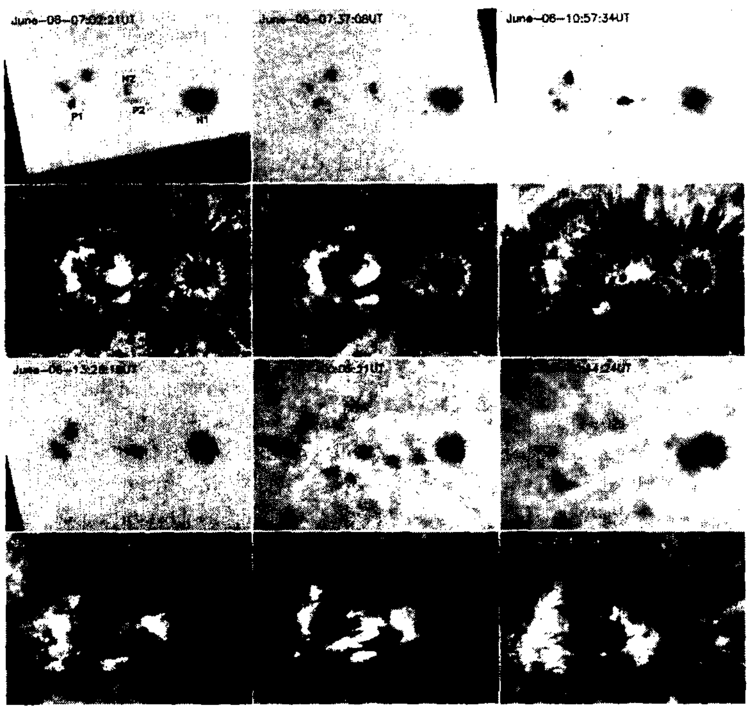

Figure 4: Debrecen white light images and Hα observations of AFS in AR 7968 (Courtesy of Debrecen and Wroclaw observatories)

with the surge. In fact, the SXT image was taken before the surge ejection so that can be one reason; the second one is that generally jet densities are low (10^9 cm^{-3}) and, therefore, they are difficult to detect in an AR (Schmieder et al., 1995).

MAGNETIC FIELD EVOLUTION

The two active regions have a global potential configuration during all the observational period, according to the extrapolated of magnetic field lines and their comparison with the large loops in Yohkoh and EIT (171-195 Å) images.

The small magnetic structures are nevertheless in a "boiling" activity. Emergence and cancellation of flux occurs all the time. In AR 7968, the polarities have fast horizontal velocities reaching 0.45 km^{-1}. Concentrating our attention in the AFS evolution on June 6, 1996, we could identify emergence and cancellation of flux. We show in Figure 4 three examples where these phenomena occur and lead to the connection of small fibrils. We can identify the polarities which cancel (parts of N2 and P2 between the 2 first images in Fig 4) and which are responsible of the long fibril visible at 07:59:18 UT in Hα.

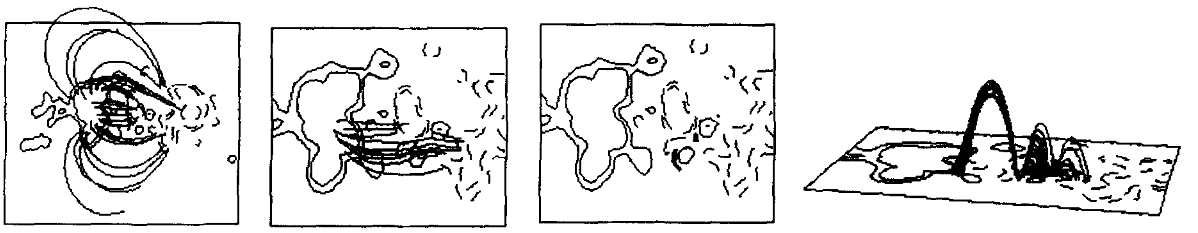

Figure 5: Magnetic field model of AR 7968 on June 6 (linear force free approx. with α = -0.0063 Mm^1). The panels show from left to right: large scale field lines (compare with EIT-195 at 11:07:39 UT in Fig.3), short scale field lines and the location of "dips" (thick lines) at the photosphere in a reduced field-of-view located to the West of the leading spot, a 3-D arbitrary point of view of the lines associated to the "dips"to be compared with the AFS visible in Hα (Fig. 4 at 06 07:59 UT). Isocontours of the field are: $\pm$ 40, 100, 500 G.

DISCUSSION AND CONCLUSION

Restructuring leads often to ejections of material: surges or small dynamical events visible in transition lines. These events could be due to reconnection processes. We did not detect jets, even in the case of AR 8048, where the moat region was favoring that phenomenon. The potentiality of the ARs did not allow for enough storage of energy. The emergence of magnetic flux leads to quasi-static events which we identify as the formation of a filament or long fibrils in AFS. These occur in the moat region around the sunspot, or inside a dipole or in a quadrupolar region. Two mechanisms could be involved in such restructuration: reconnection of magnetic field lines or emergence of a "sea serpent".

In order to distinguish between the two possible explanations we have observations in hotter lines. In the case of reconnection we should see some heating. Apparently with the data set that we have (the time step is large) we cannot detect any heating in the observed loops with EIT or Yohkoh. For AR 7968, the extrapolation of the magnetic field according to the method developed by Démoulin et al. (1997) shows the presence of "dips" (Fig. 5) in field lines at photospheric level (bald patches) at the place of the cancelling flux. This would favour the existence of a submerged horizontal flux tube that is lifted up by turbulence, giving place to the strongly absorbing fibril seen in $H\alpha$ at 07:59:18 UT on June, 6 1996.

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