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EVOLUTION OF THE SOURCE REGION OF THE INTERPLANETARY MAGNETIC CLOUD OF 18-20 OCT. 1995

L. van Driel-Gesztelyi[1,2,3], B. Schmieder[1,4], and T. Baranyi[5]

[1] *Observatoire de Paris, Section de Meudon, F-92195 Meudon Principal Cedex, France*
[2] *Konkoly Observatory, H-1525 Budapest, Pf. 67, Hungary*
[3] *MSSL, University College London, Holmbury Saint Mary, Dorking, Surrey, RH5 6NT, UK*
[4] *University of Oslo, P.O.Box 1029 Blindern, N-0315 Oslo, Norway*
[5] *Heliophysical Observatory, H-4010 Debrecen, Pf. 30, Hungary*

ABSTRACT

We follow the evolution and activity of the reversed polarity AR 7912 using multi-wavelength observations. We find that the presence of high shear increased by flux emergence led to the occurrence of a long-duration eruptive flare on 14 October 1995, which was manifested in the SXR corona by an arcade of expanding sigmoidal loops. A twisted magnetic cloud was observed at 1 AU between October 18-20. We propose that it was ejected from this reversed polarity AR, and it was associated with the expanding sigmoids.

INTRODUCTION

The appearance of S-shaped soft X-ray loops (sigmoids) in solar active regions indicates the presence of important twist or helicity (Pevtsov *et al.* 1997) and suggests an increased probability of CME activity (Canfield et al. 1999). When, due to magnetic evolution, the magnetic non-potentiality becomes too high in a sheared arcade, it is likely to get unstable and loops start moving upward. This drives magnetic reconnection in the arcade creating long twisted loops connecting the external parts of the arcade and under-lying shorter loops in its centre. The long twisted (sigmoidal) loops continue to expand (Titov & Démoulin, 1999). Such expansion of X-ray loops have indeed been observed (e.g. Manoharan *et al.* 1996). They carry magnetic flux and helicity into the interplanetary space (Low, 1996).

A magnetic cloud was observed with the Solar Wind Experiment and the Magnetic Field Instrument on board of the WIND spacecraft at 1 AU in the period of 18-20 October 1995 (Lepping *et al.* 1997). Smith *et al.* (1997) identified its solar source as a region between two interacting active regions (ARs NOAA 7912 and NOAA 7910), where soft X-ray dimming and type IV metric radio bursts were observed. In this paper, through an evolutionary study of the reversed polarity AR 7912, we take another look at the series of soft X-ray events related to the ejection of the magnetic cloud and suggest that the cloud was actually launched *from AR 7912*, where due to the high non-potentality, magnetic loops swelled up, reconnecion created sigmoidal loops which then expanded into the interplanetary space. The expanding loops interacted with neighbouring magnetic systems of ARs 7910 and AR 7913, leading to the observed radio bursts.

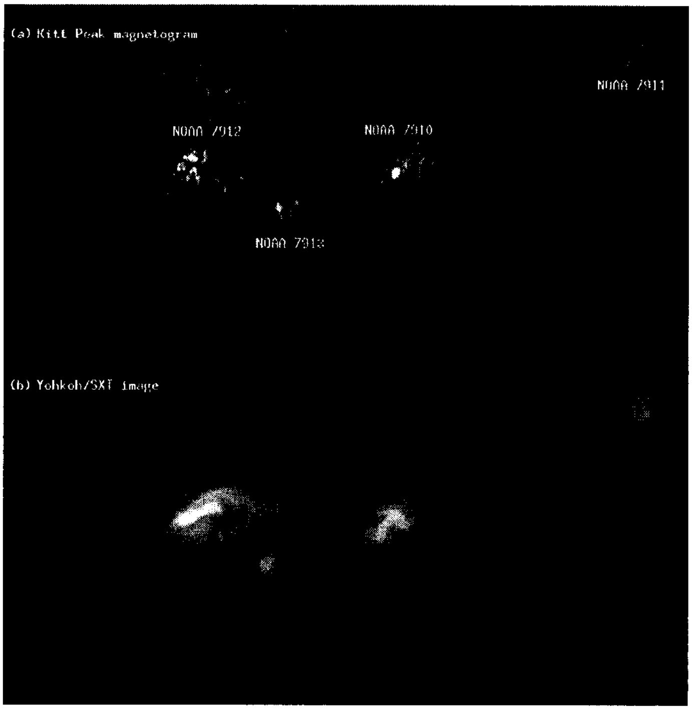

Figure 1: Kitt Peak magnetic map (upper panel) and Yohkoh soft X-ray image (Al.1 filter) taken on 14 Oct. 1995. Note the S-shaped loops (sigmoids) in the reversed polarity active region NOAA 7912. The loops are in expansion in the X-ray image, which was taken before the peak of the LDE. At the western edge of the expanding loops an X-point, well known from the reconnection theory, appears to form, indicating that the swelling loops encounter and reconnect with neighbouring magnetic system(s).

OBSERVATIONS

Magnetic evolution and sunspot motions of AR 7912

The AR consisted of a round leading and smaller dispersed trailing spots with a few parasitic (included) polarities disturbing the bipolar structure (Fig. 1). This South hemispheric AR had reversed polarity. On 11 Oct., in the following, positive polarity part of the AR two new bipoles emerged, one with reversed, another with normal polarity, but with a high inclination. These new bipoles were involved in a series of flares. The negative polarity spots of the diverging new bipoles gradually cancelled with the positive polarity magnetic environment and disappeared by 17 October. Sunspot proper motions were interesting; the leading spot moved along a curved path and some following spots moved westward instead of their usual eastward direction. The unusual sunspot motions and the high inclination of the bipoles provide indications that the new flux emerged with inherent currents, increasing the non-potentiality in the reversed polarity AR (van Driel-Gesztelyi & Leka, 1994; Leka *et al.* 1996).

X-ray observations

AR 7912 showed a vortex-like appearance soft X-rays (Fig.1), indicating the presence of electric currents. The X-ray loops had a sigmoidal shape with a positive helicity corresponding to the global south-hemispheric helicity.

The region was quite flare-active but it did not produce very important flares: there was no X-flare, but three M-flares and dozens of smaller flares originated from the region during its disc passage. On 14 October a C1.6 long-duration event (LDE) started after 05 UT, reached maximum at 9:21 UT according to the SGD

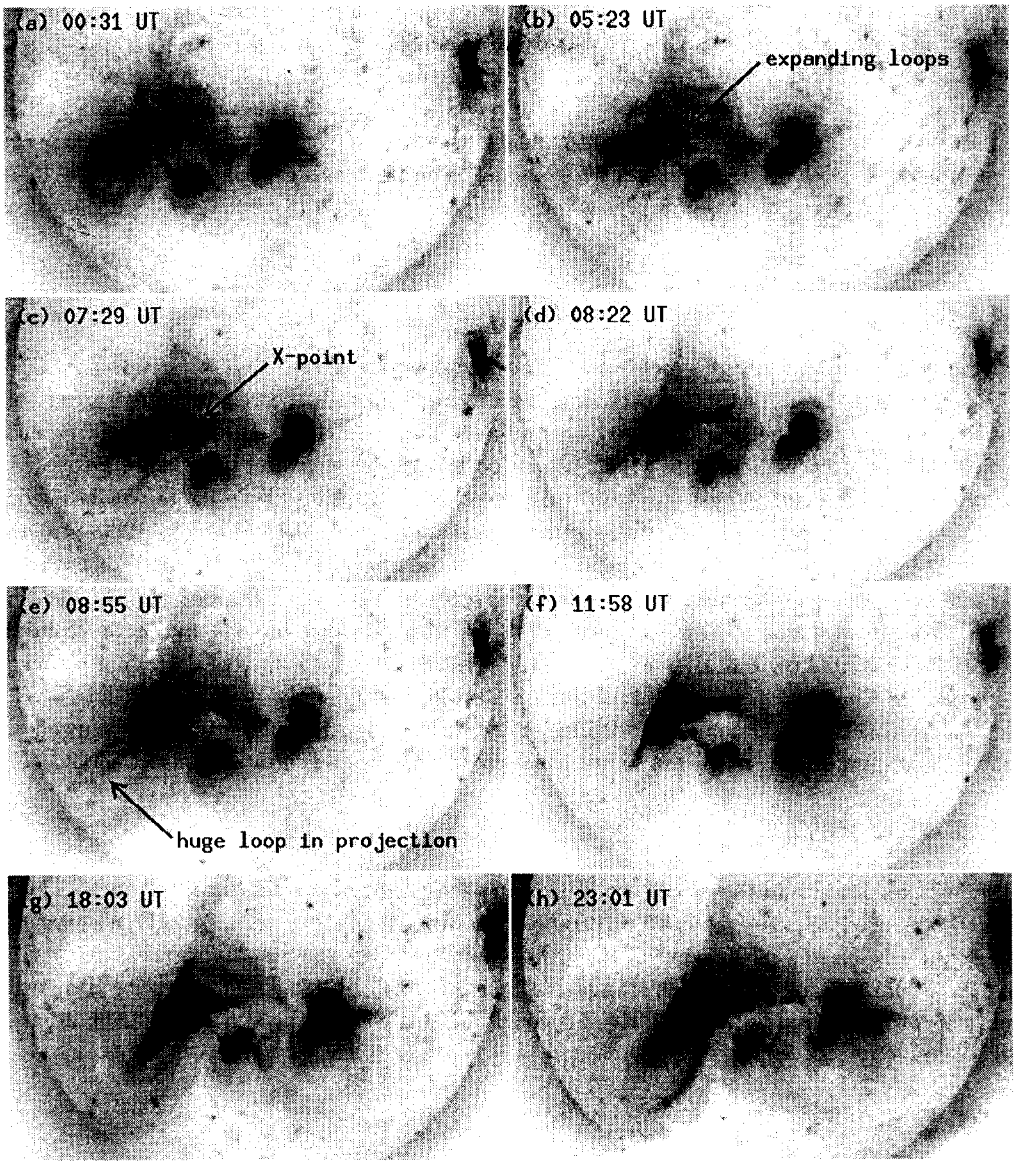

Figure 2: Evolution of the soft X-ray structures on 14 Oct. 1995. Expansion of the coronal loops starts soon after 05 UT. By 07:29 UT bright, short sigmoidal loops appear in the centre of the AR, and the external loops of the expanding arcade encounter with the magnetic fields of neighbouring regions and an X-point forms, indicating reconnection. The continuing expansion of the AR 7912 loops are seen at 08:22 and especially at 08:55 UT. The Yohkoh/SXT images were taken with the thin Al filter and, in order to increase the dynamic range, we combined images taken with long and short exposures. The novelty of the information in the present figure as compared to Figure 5 by Smith et al. (1997), that the increased dynamic range of the present images reveal the existence of the huge expanding sigmoidal loop, which originated from AR 7912.

and lasted for at least 15 hours longer. The GOES curve of the LDE is very spiky, several flares occurred in the same and neighbouring ARs during its duration. The LDE started with loop brightenings (Fig. 2). Expansion of the sheared loops were seen already at 05:23 UT. By 07:29 UT bright short sigmoidal loops appeared in the centre of the AR, presumably due to reconnection in the sheared arcade, and the external expanding loops encountered with the magnetic fields of neighbouring regions and an X-point formed, indicating reconnection with external magnetic systems. The continuing expansion of the AR 7912 loops was seen at 08:22 and especially at 08:55 UT, when the span of the loops in projection became comparable to the solar radius.

CONCLUSIONS

We propose that the magnetic cloud which passed the Earth between 18-20 October was actually launched *from AR 7912*, where due to non-potentality, increased by small-scale twisted flux emergence, the system became MHD unstable and the loops started expanding. The expansion drove magnetic reconnection in the sheared arcade and created sigmoids which expanded into the interplanetary space (Titov & Démoulin, 1998). The related X-ray event was a long-duration event of C1.6. The dimming region noticed by Smith et al. (1997) among the three ARs is a well-known signature of erupting sigmoids. The expanding loops interacted with neighbouring magnetic systems, leading to the observed radio bursts. We propose that the large-scale reconnection events helped the expansion by removing (i.e. opening) some of the large-scale over-lying field lines (Antiochos et al. 1999), but the bulk of the interplanetary magnetic cloud originated from the sigmoidal AR 7912 region. Bleybel et al. (1999) found that both the total magnetic energy and the helicity decreased in AR 7912 after this LDE. Such a decrease could only be achieved if twisted magnetic flux was ejected from the AR. Magnetic modelling of the interplanetary magnetic cloud showed that it had positive helicity (Lepping et al. 1997) matching the helicity sign of the sigmoids in AR 7912.

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