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Collisionless Reconnection in the Structure and Dynamics of Active Regions

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Abstract. On the basis of the Yohkoh data on the site and mechanism of magnetic energy transformation into thermal and kinetic energies of superhot plasmas and accelerated particles, a model is developed that explains observed properties of collisionless 3D reconnection in active regions. The model makes intelligible the observed relation between the S-like morphology and eruptive activity.

1. Evidence of Reconnection in Active Regions

X-ray observations on board *Yohkoh* suggest that reconnection is responsible for many phenomena in active regions. In particular, in flares reconnection appears to take place. The following properties of observed X-ray structures are consistent with the 'standard model' of reconnection in flares and therefore allow us to assume that flare energy release proceeds via reconnection: (a) the coronal hard X-ray (HXR) source discovered by Masuda et al. (1994) can be understood if the source of energy is located somewhere above the soft X-ray (SXR) loops, (b) the increasing separation of the HXR double footpoint sources (Sakao et

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al. 1998), (c) the slow rising motion of the flaring loop together with the 'above-the-loop-top' HXR source observed during some impulsive flares and some LDEs that can be interpreted in terms of accumulation of reconnected magnetic field lines below a reconnection place (Somov et al. 1999); (d) a 'loop-with-a-cusp' structure (Tsuneta et al. 1997); (e) unexpected structures and their changes in the preflare stages as well as during arcade flares observed on the limb (Uchida et al. 1998), (f) HXR observations of superhot plasma and accelerated particles support the idea of collisionless 3D reconnection in flares (Somov et al. 1998).

When the photospheric magnetic field has been extrapolated into the corona it was found (e.g., Bentley et al. 2000) that the active region magnetic field was very close to being potential. The basic ingradients for reconnection to occur and to produce flares are present. The observed photospheric evolution is expected to drive reconnection in such active regions.

2. Topological Model of Reconnection and S-type morphology

The existing models of reconnection in the solar atmosphere can be classified in two groups: global and local ones (Kosugi and Somov, 1998). The global models are used to describe active regions on the Sun in different approximations and with different accuracies (e.g., Gorbachev and Somov, 1989; Ranns et al. 2000). The main advantage of the global models is a direct comparison between the results of computation and the observed large-scale patterns. For example, the so-called topological model of a solar flare (Gorbachev and Somov, 1990; Somov, 1992) is used to reproduce the main features of the observed field in the photosphere related to the four most important sunspots. As a consequence, the model reproduces the large-scale features of the actual field, related to these sunspots.

Figure 1 shows, as a well studied example from Gorbachev and Somov (1990), a picture of potential field lines crossing the region of primary energy release $\mathcal{E}$, which is situated somewhere near the apex of the separator. The flare ribbons FR_1 and FR_2 are formed where these field lines cross the photosphere. The model demonstrates that the flare energy is released during the reconnection process at the separator which is placed in the corona in a definite way relatively sunspots, allows us to determine the shape of coronal loops observed in the X-rays and the shape of flare ribbons in the chromosphere where these ribbons are visible best of all in the hydrogen line Hα.

The model predicts that the reconnecting magnetic fluxes are distributed in the corona in such a way that the *two loops may look like that they interact with each other*. That is why the SXR observations demonstrating such structures are usually considered as direct evidence of the model of two interacting loops. When the spatial resulution in SXR is not sufficient, we observe one huge S-flux tube as the main feature of an active region. Note that the S structures are usually interpreted in favour of non-potential fields. As we see in Figure 1, however, the S structure $C\mathcal{E}B$ connecting the bright points C and B results from the computations of the potential field in the frame of the topological model.

Hudson et al. (1998), Canfield et al. (1999), Glover et al. (2000) studied active regions characterised by S or inverse-S morphology in SXR and have found these regions to possess a high probability of eruption. Incorporating data from

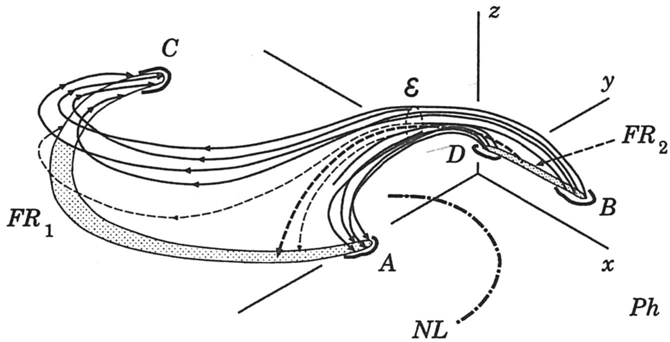

Figure 1. The topological model of the active region AR 2776 where the solar flare of 1980 November 5 occured.

SOHO, this survey found the 'sigmoid-to-arcade' development a common feature of active regions associated with the onset of a CME.

We assume that the S morphology results from the 3D reconnection process in a high-temperature turbulent-current sheet located at the separator of a quadrupolar-type magnetic field of an active region, as illustrated in Figure 1. Since the pre-CME 'sigmoid' disappears leaving a SXR arcade and two 'transient coronal holes' (Sterling & Hudson 1979), I assume that the second important element of the CME onset is opening a closed configuration (Syrovatskii and Somov 1980; Syrovatskii 1982), which drives collisionless reconnection at the separator.

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