§26. Evolution of Eruptive Flares II. The Occurrence of the Locally Enhanced Resistivity in the Preflare Phase

Magara, T. (Kyoto Univ. Sci.)
Shibata, K. (NAOJ)

We study the resistive process running in the preflare phase of eruptive flares by means of the 2.5-dimensional MHD numerical simulation. According to the detailed observation of solar flares, their evolution is characterized by several phases, each of which has a prominent feature. In the first phase, some kinds of radiation begin to be enhanced gradually, which implies the occurrence of the preflare heating. Then, at a certain time, this gradual energy-release phase is replaced by the explosive phase in which a huge amount of energy is released in various forms. So far, the nature of this violent phase and its later phase has been well studied by using a flare model based on the fast magnetic reconnection (see Magara et al. 1996[1], 1997[2]), though such problems as the preflare heating and the transition from the gradual energy-release phase to the violent one have not been sufficiently discussed yet. In order to clarify these problems, we start with a 2.5-dimensional force-free current sheet under an uniformly distributed resistivity, associated with a very small random velocity perturbation. Then the evolution enters on the linear stage of the tearing instability and later a sufficient amount of thermal energy is produced in the nonlinear stage, which is considered to have a relation with the preflare heating. As the nonlinear evolution proceeds, the magnetic field perpendicular to the sheet (perpendicular magnetic field) flows away from X-points formed in the sheet and eventually a current-sheet collapse occurs at such points. That collapse makes the thickness of the sheet reduced into the range of microscopic values if the magnetic Reynolds number is quite large and the plasma beta is quite low. Since the formation of that thin current sheet leads to the occurrence of the locally enhanced resistivity (anomalous resistivity), the transition from the gradual energy-release phase under an uniformly distributed resistivity to the violent one under a locally enhanced anomalous resistivity can be accomplished, which causes the fast magnetic reconnection responsible for various explosive phenomena in the sun.

In the following, we take one example of our simulation cases to show how the drift velocity, v_d, which plays a key role in the local enhancement of resistivity and the perpendicular magnetic field, B_y, vary their distributions with time.

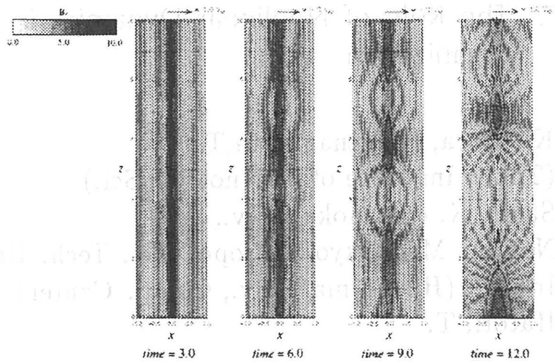

Fig. 1. Evolution of the standard case ($\beta = 0.15$ and $R_m = 1000$). Contour lines, arrows, and color map represent the magnetic field lines, velocity field, and perpendicular magnetic field projected onto the (x, z)-plane. Elapsed times are t = 3, 6, 9, and 12 from left to right.

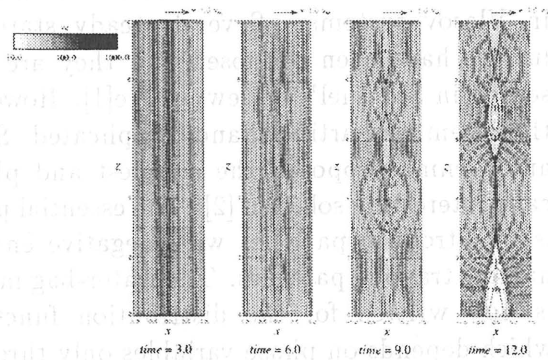

Fig. 2. Evolution of the standard case ($\beta = 0.15$ and $R_m = 1000$). Contour lines, arrows, and color map represent the magnetic field lines, velocity field, and v_d projected onto the (x, z)-plane. Elapsed times are t = 3, 6, 9, and 12 from left to right.

Comparing Figure 1 with Figure 2, it is found that there is a prominent anticorrelation between the distributions of v_d and the perpendicular magnetic field, that is, the region of weak perpendicular magnetic fields corresponds to the region where v_d is large. A particularly remarkable region of this tendency is found around the so-called X-point, which appears around (x, z) = (4.1, 0) and (7.5, 0) at t = 9 and around (x, z) = (4.1, 0) and (8.5, 0) at t = 12.

Reference

1) Magara, T., Mineshige, S., Yokoyama, T., and Shibata, K. : ApJ, 466, 1054 (1996)
2) Magara, T., Shibata, K., & Yokoyama, T. : ApJ, 487, 437 (1997)