THE ASTROPHYSICAL JOURNAL, 514:456–471, 1999 March 20

EVOLUTION OF ERUPTIVE FLARES. II. THE OCCURRENCE OF LOCALLY ENHANCED RESISTIVITY

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Received 1998 June 8; accepted 1998 October 20

ABSTRACT

In this paper we study resistive processes in the preflare phase of eruptive flares by means of the 2.5-dimensional MHD numerical simulation. According to many detailed observations of solar flares, their evolution is characterized by several phases, each of which has a distinct nature. 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, that gradual energy-release phase is replaced by the violent energy-release phase in which a huge amount of energy is released in various forms. So far, the nature of this violent energy-release phase has been well studied by using a flare model based on the fast magnetic reconnection, although those problems of the preflare heating and the transition from the gradual energy-release phase to the violent one have not been sufficiently discussed yet. In this paper, in order to tackle these problems, we start with a 2.5-dimensional force-free current sheet under a uniformly distributed resistivity, which is subject to a very small random velocity perturbation. At first the evolution enters on the linear stage of 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. In this nonlinear stage, the component of magnetic fields perpendicular to the sheet (perpendicular magnetic fields) flows away from X-points formed in the sheet and eventually the *current sheet collapses* at these points. This collapse strongly reduces the thickness of the sheet if the magnetic Reynolds number is quite large and the plasma beta is quite low. Since the formation of thin current sheet leads to the occurrence of locally enhanced resistivity (anomalous resistivity), the transition from the gradual energy-release phase under a 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.

Subject headings: MHD — Sun: corona — Sun: flares — Sun: magnetic fields

1. INTRODUCTION

Explosive phenomena are often observed in the solar corona, which are now widely believed to be energy conversion processes from the magnetic energy to the other types of energy. Since the corona is generally a good conductive medium, any dynamical evolution in the corona is usually described within the context of ideal MHD theory, where the effect of resistivity is negligible. It is therefore necessary to investigate the small-scale region where the magnetic energy can be efficiently converted into the other types of energy when we consider any explosive phenomenon in the corona. That region in which a certain component of magnetic fields changes abruptly across the sheet so that a large amount of currents can flow through it is known as current sheet. Owing to this enhancement of current density, the Ohmic dissipation efficiently works in current sheet, compared with other normal regions in the corona.

From this viewpoint, many authors have tried to explain various coronal explosive phenomena by using the concept of current sheet. For example, Heyvaerts, Priest, & Rust (1977) presented a flare model, in which a current sheet was formed between the emerging subphotospheric magnetic field and the overlying coronal magnetic field. This flare model was lately investigated in detail by Shibata et al. (1989, 1992) and Yokoyama & Shibata (1996) who performed two-dimensional MHD numerical simulations and clarified many interesting features of this type of flares. As for the model of the so-called two-ribbon flares, Mikic, Barnes, & Schnack (1988), Biskamp & Welter (1989), Finn, Guzdar, & Chen (1992), Inhester, Birn, & Hesse (1992), Kusano et al. (1994), Choe & Lee (1996), and Amari et al. (1996) succeeded to develop a model in which a current sheet is formed within a magnetic arcade by imposing a particular photospheric motion in either the single-arcade or the multiple-arcade system. Forbes & Priest (1983), Forbes, Malherbe, & Priest (1989), and Forbes & Malherbe (1991) performed two-dimensional MHD numerical simulations in order to study the physical structure of the two-ribbon flares. They found that a closed magnetic structure was formed in the lower part of a current sheet and that structure well reproduced several observational features of postflare loops. With respect to the coronal heating, Parker (1994) discussed that current sheets were spontaneously formed as singular layers in the corona where a sufficient amount of thermal energy for the coronal heating is produced by the Ohmic dissipation. Recently, Karpen, Antiochos, & DeVore (1996) showed an interesting simulation result that many current sheets are distributed all over an active region.

When we study the natures of solar flares, we have an important problem with their timescale. Since the magnetic Reynolds number in the corona is quite large, diffusive processes in current sheet proceed very slowly, which cannot explain such a short timescale as is observed in real flares. This problem has prompted solar physicists to consider a rapid energy-conversion mechanism in the current sheet,

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