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THE DYNAMIC EVOLUTIONARY PROCESSES OF THE MAGNETIC FIELDS IN THE SOLAR ACTIVE REGION BOULDER 5395

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ABSTRACT In this paper, based on observational information we proposed an opening bipolar magnetic field model and studied numerically the dynamic evolutionary processes of the magnetic fields by solving a complete set of MHD equations. The aim is to discuss one of the mechanisms of energy build up of solar flares produced in the active region Boulder 5395.

The dynamic evolutionary processes of a magnetic field configuration in a solar active region play an important part in solar eruptive events, which are correlated to the energy stored and released in the solar active region. The dynamic evolution of the magnetic field in the solar atmosphere is mainly studied by using numerical simulations, e.g., Xinping Liu et al. (1981), Krall et al. (1982), Xinping Liu et al. (1985), Xinping Liu (1988).

Recently, the active region Boulder 5395 was one of the most productive and best observed flaring regions of the 22nd solar cycle's observation period. From its emergence on March 6, 1989 until its disappearance over the solar limb on March 19, it produced a lot of large flares, including 195 optical flares, 106 X-ray flares and 240 microwave outburst events. Figure 1 shows one of the vector magnetograms that was observed by the solar magnetic field telescope of Huairou Solar Observing Station in Beijing. The active region was characterized by the presence of strong rotations from March 9 to 15 and strong magnetic shear structure. According to the character of the active region Boulder 5395 we proposed an intergrowth magnetic flow tube model by twisting the magnetic field (see Liu Xinping et al. 1990) and an opening bipolar magnetic field model (see Figure 2). In this paper, by means of numerical methods we first obtained the initial configuration of the opening bipolar magnetic model, and then studied the evolution of the opening bipolar magnetic field configuration by shearing the magnetic field.

The initial boundary-value problem of a complete set of magnetohydrodynamics is solved by using a fully implicit continous Eulerian scheme. The

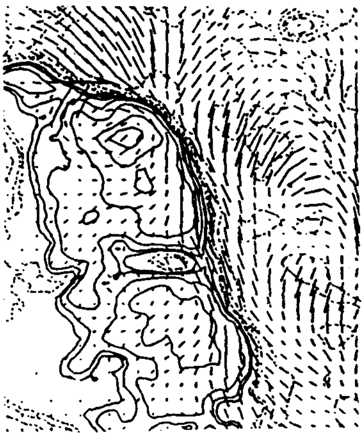

Fig.1 The vector magnetogram in 5395 on March 13, 1989. Time: 03:33:07 UT

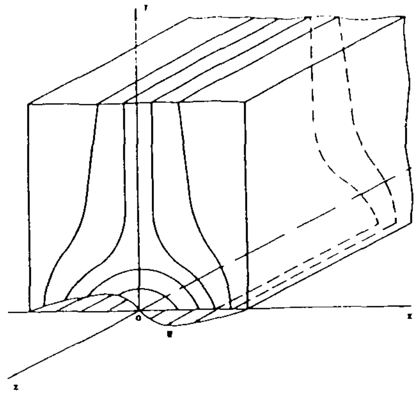

Fig.2 An opening bipolar magnetic field model for energy storage by shearing.

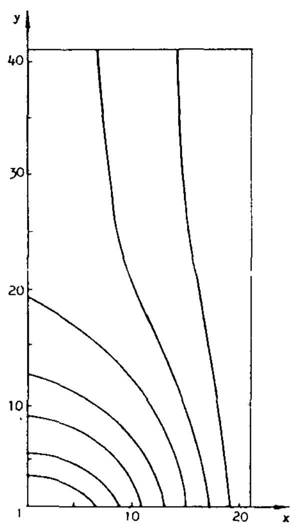

Fig.3 The computational configurations of the magnetic field at $\tau = 0$.

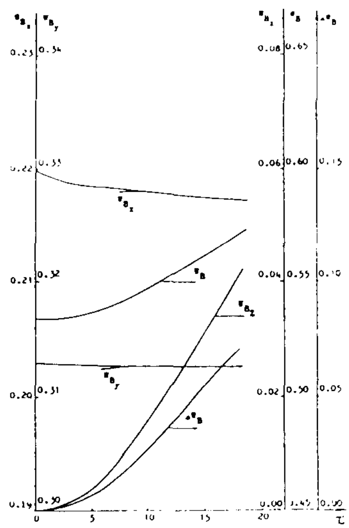

Fig.4 Magnetic energy versus time.

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equilibrium equation is solved to obtain the initial magnetic field with the super-relaxation method.

The computational configuration of the initial magnetic field is given in Figure 3. It can be seen that there is a current sheet near the Y-type neutral point in the computational configuration. Correlations between the magnetic energy and time are presented in Figure 4, where W_{Bx}, W_{By}, W_{Bz} express the magnetic energy of magnetic field components in the directions of x, y, z, respectively. W_B expresses the total magnetic energy of the magnetic field. ΔW_B denotes the total magnetic energy growth rate, which is the difference between the energy at some time τ and the initial energy over the initial energy. The net increase of magnetic energy may be on the order of $2.3 \times 10^{24} J$ during a day if it increases at the same rate as before. Meanwhile the increase in magnetic energy is stored in the local active region 5395. The computational kinetic energy varies only slightly with time and its value is several orders of magnitude less than the magnetic energy. The gravitational energy shows little variation with time.

The computational results show the dynamic evolutionary processes of the typical magnetic configuration in the active region Boulder 5395, which is caused by the shear motion of plasma at the feet points. They also give the quantitative coupling relationship between non-linear flow and magnetic field in the active region 5395. The results show that the dynamic evolutionary processes for the magnetic energy build up (see Figure 4) by the shearing magnetic field in the active region are very important processes even at a small velocity (less than 1 km/s). However, some researchers drew the conclusion that dynamical processes are not important when the shearing velocity is below 1 km/s (Wu et al. 1984). In this paper we propose that for the flare-producing active region, dynamic evolutionary processes of the magnetic field configuration play an important part in magnetic energy storage at small velocities.

From vector magnetograms it can be seen that the vector magnetic fields of the active region 5395 continuously evolve. On March 13th the transverse components of the photospheric magnetic field were aligned along the polarity inversion line, which is evidence of the formation of magnetic shear in the active region (see Figure 1).

In this paper an opening bipolar magnetic field configuration with a current sheet near the Y-type neutral point (where the magnetic field vanishes, see Figure 2) was obtained, which may be one of the configurations of the active region. Because there is the current sheet near the Y-type neutral point and an opening of some of the magnetic force lines in the configuration, energy of the magnetic field shored by shearing the magnetic field is converted efficiently into heat and bulk kinetic energy, and particles can be accelerated to high energies. Thus, many high energy events, X-ray flares, and larger flares frequently occur in the active region Boulder 5395.

The active region Boulder 5395 is a very complex super-active region, with sunspot area larger than any observed in previous cycles. In this paper we discuss one possibility of its magnetic energy build up; others will be discussed in later articles.

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