The Magnetic and Velocity Fields of Solar Active Regions
ASP Conference Series, Vol. 46, 1993
Harold Zirin, Guoxiang Ai, and Haimin Wang (eds.)

NONLINEAR MODE COUPLING OF RESISTIVE INSTABILITY AND THE FLARES OF FEBRUARY 4 and 6, 1986

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ABSTRACT In this paper, we propose a mechanism of solar flare based on the 3-D nonlinear mode coupling of resistive tearing instability. The results show that the nonlinear coupling of tearing modes leads the rapid destabilization of some high modes. Furthermore, tearing mode turbulence is formed and anomalous resistivity is produced, which in turn, quickens the development of tearing instability and accelerate the magnetic reconnection process. It is suggested that the fast magnetic reconnection as a mechanism of solar flare may be associated with this self-excited process caused by the nonlinear mode coupling of tearing instability in the solar corona. Using our model, we successfully explain all the main typical characters of the flares of February 4 and 6, 1986.

1. FUNDAMENTAL EQUATIONS AND NUMERICAL METHOD

The basic MHD equations are (Strauss, 1976)

$$\left(\frac{\partial}{\partial t}+\mathbf{V}\cdot\nabla\right)u=\boldsymbol{B}\cdot\nabla J_z+\nu\nabla_\perp^2 u, \tag{1}$$

$$\frac{\partial\psi}{\partial t}=\boldsymbol{B}\cdot\nabla\phi-\eta J_z+E_z, \tag{2}$$

where ψ and ϕ are z-components of the potential function of magnetic field $\boldsymbol{B}$ and the stream function of plasma velocity $\mathbf{V}$.

The magnetic field equilibrium is given by the parametrization of the safety factor q

$$q(r)=q_0\left[1+\left(\frac{r}{r_0}\right)^{2p}\right]^{\overline{p}}, \tag{3}$$

We use a finite difference in radial direction, a Fourier series expansions in poloidal and axial coordinates and a rigid edge condition at $r=1$.

2. NUMERICAL RESULTS

We take $S=6\times10^3$, $q_0=1.2$, $p=4$ and $r_0=0.6$.

Fig.1 shows that the time-evolutions of growth rates in single and multi helicity cases. In the single-helicity case (Fig. 1 (a)), the growth rate of 3/2 mode (dash), as the same as 2/1 mode (real), decreases when it enters the nonlinear stage, and finally the magnetic island width saturates, the growth rates of 4/3 and 5/3 modes are very small. In multi-helicity case (Fig.1 (b)), when 2/1 and 3/2 magnetic islands overlap, the $(m=3,\ n=2)$ mode is strongly destabilized by $(m=2,\ n=1)$ mode, and its nonlinear growth rate increases and exhibits a strong peak about $t=0.028T_r$, 4/3, 5/3 and other high modes are also non-linearly generated and strongly destabilized and the island widths are larger than that in the single-helicity approximation.

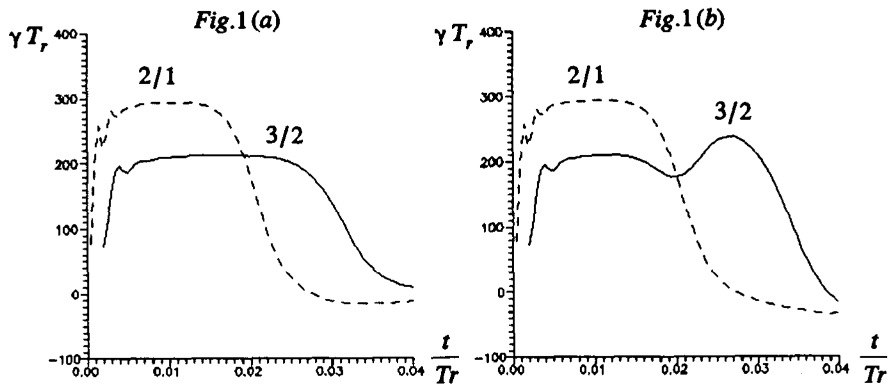

Fig.1 The time-evolution of normalized growth rate in single(a) and multiple(b) helicity respectively.

The proliferation of higher modes duo to the mode coupling process is shown in Fig.2.

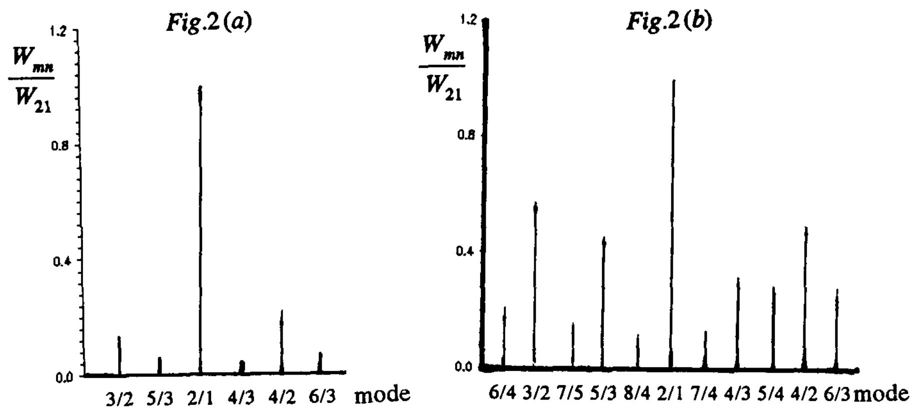

Fig.2 The normalized widths for different modes before (a) and after (b) the overlap.

Before the magnetic island overlap, there are well-formed magnetic surface, after the overlap, the magnetic surface are broken, and the magnetic line are scattered within a finite area, which represents the region of stochastic field lines (Carreras,

https://doi.org/10.1017/S025292110002950X Published online by Cambridge University Press

et al., 1980; Spicer, 1977). This mean that the nonlinear mode interaction of low modes leads to the generation of high mode tearing turbulence, and produces a large anomalous resistivity (Stix, 1976), which in turn, may accelerate the development of tearing instabilities and quicken the process of magnetic reconnection.

3. CONCLUSIONS AND DISCUSSIONS

In this paper, we suggest that the fast magnetic reconnection as a mechanism of solar flare may be associated with this self-excited process caused by the nonlinear mode coupling of tearing instability in the solar corona.

One of the obvious advantages of our model is that mode coupling can lead to large regions of ergodic magnetic field lines, form tearing mode turbulence and produce an large anomalous resistivity. In two dimensions, tearing modes occur but do no produce turbulence, tearing mode turbulence occurs when magnetic island of different helicity overlap and this can only occur when three-dimensional perturbation are allowed; The second is that the development of the resistive tearing instability driven by the current gradient only requires that the quantity $K \cdot B_0$ van ishs, it is not necessary to need opposite directed magnetic fields, so reconnection can occur in any sheared magnetic field configuration, such as an arch or filament.

On February 4 and 6, 1986, two consecutive major flares occurred in the same region during the period of minimum solar activity. The Rotations of sunspot group was observed and the flare obviously resulted from the arch-shaped dark filament and was restricted by the filament in its beginning and the primary bright points were located in two plages, which were correspondent to the different magnetic polarities.

The rotation of the foot points in photosphere twists and distorts the coronal magnetic field, and a current sheet is formed (Strauss, 1988), which is unstable to tearing instability, the above stated self-excited process caused by mode coupling produces a rapid release of magnetic energy, and the electric field resulted from development of tearing modes accelerates the electrons and ions which stream downward along guiding magnetic field line and impact on the dense chromosphere, heating the cold chromosphere plasma and producing most of the bremsstrahling there. Our model is also in agreement with the VLA observation that the primary energy release of a flare, having an impulsive character, occurs in side a magnetic loop, joining the regions of opposite magnetic polarity at the photosphere and the observations that the flares tend to appear in the place with sufficiently high current density and that if there were steep magnetic gradients in the region, considerable activity might be expected (Zirin, 1988).

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https://doi.org/10.1017/S025292110002950X Published online by Cambridge University Press