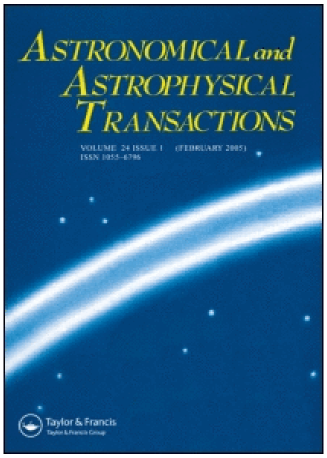

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THE MECHANISM OF X-RAY BRIGHT POINT APPEARANCE

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The mechanism X-ray bright point (XBP) production is simulated in a numerical MHD experiment. The anisotropy of the plasma thermal conductivity in the magnetic field is taken into account. It is shown that plasma heating can be produced by magnetic line reconnection around the neutral line. The long time hot plasma confinement is provided by a magnetic trap configuration of the magnetic field.

KEY WORDS Sun, X-ray bright points (XBP), solar activity

There are two fundamental problems associated with XBPs: the source of local heating of the corona, and long-time existence of very hot plasma (of order 10 hours) in a small restricted region in spite of the high thermal corona conductivity. Many observational data show that an XBP appears at the emergence of a new weak magnetic flux. It is natural to assume that plasma heating is produced by reconnection of such flux with the oppositely directed magnetic field in the vicinity of a neutral line. If the emerging flux is not too strong, all arriving magnetic field lines should reconnect, and a powerful current sheet should not be produced.

For a point diameter of $d \sim 5 \times 10^8$ cm, a plasma temperature of $T \sim 1000$ eV, and a density of $n \sim 10^9$ cm^{-3}, the time of plasma cooling can be estimated as $t \sim d^2/\kappa_0 \sim 0.1$s. Here $\kappa_0 = \lambda^2/\tau_{ei} \sim 10^{20}T^{5/2}/n$, T is the electron temperature in eV, and n is the plasma density in cm^{-3}. The energy loss due to thermal conductivity is $W \sim nkTd^3/t \sim 10^{27}$ erg s^{-1}, which is comparable to a solar flare power.

These estimates contradict the observed data. The long existence of an XBP with a slow energy release can be achieved only by effective magnetic thermal isolation. The configuration of the magnetic field in the vicinity of a neutral line (Figure 1*a*) corresponds to a well-known thermonuclear magnetic trap with the field increasing toward the periphery (Podgorny and Sumarokov, 1960). It has been shown that plasma cooling along the magnetic lines in such a configuration is possible only through very narrow slits along the separatrix. The slit width is of the order of the ion cyclotron radius. This scenario of plasma heating and hot plasma confinement around the neutral line is demonstrated in a numerical experiment in the resistive

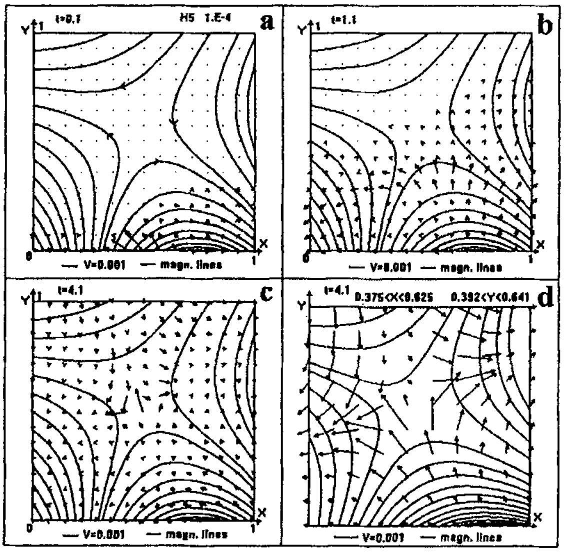

Figure 1 Magnetic field lines and velocity vectors for different moments of time.

MHD approximation (Podgorny and Podgorny, 2000). Here we present some new results. The strong anisotropy of the thermal conductivity in the magnetic field has been taken into account. A new version of the PERESVET code is used.

The system of MHD equations is numerically solved with the following dimensionless parameters. The magnetic Reynolds number is 10^4, the Reynolds number is 100, the Peclet number is 1000, $\beta = 10^{-6}$, and the radiation loss is calculated according Cox and Tucker (1969). The conductivity and thermal conductivity are determined by Coulomb collisions. All results are presented in dimensionless units: L is the dimension of the region, ρ is the coronal density, B_0 is the magnetic field on the photosphere, the Alfvenic velocity V_A is the velocity unit, $t = L/V_A$ is the time unit. If the average magnetic field on the photosphere is 100 Gauss, the plasma density in the corona is 10^7 cm^{-3}, and the neutral line is situated at 5×10^9 cm above the photosphere, we have $L = 10^{10}$ cm, $V_A = 3 \times 10^9$ cm s^{-1}, and $L/V_A = 3$s.

The initial magnetic field is obtained by superposition of the homogeneous field $B = 0.5$ inclined to the photosphere ($\alpha = 30°$) and the fields of two vertical dipoles placed under the photosphere ($\mu_1 = 4.5$, $X = 0.6$, $Y = -1.5$ and $\mu_2 = -4.5$, $X = 1.1$, $Y = -1.5$). The field configuration is shown in Figure 1*a*. The magnetic disturbance is set by the field of a horizontal dipole placed under the photosphere ($X = 0.5$, $Y = -0.2$). Its magnetic moment is increased from $\mu_3 = 0$ to $\mu_3 = 0.0005$. The time of increase is 0.1 s. The magnetic field increasing on the photosphere is $\Delta B/B \sim 0.01$.

It has been shown that energy transference from the photosphere to the vicinity of a neutral line occurs by Alfvenic and magnetosound waves. The velocity vectors are perpendicular to the magnetic lines. Magnetic field lines and distributions of

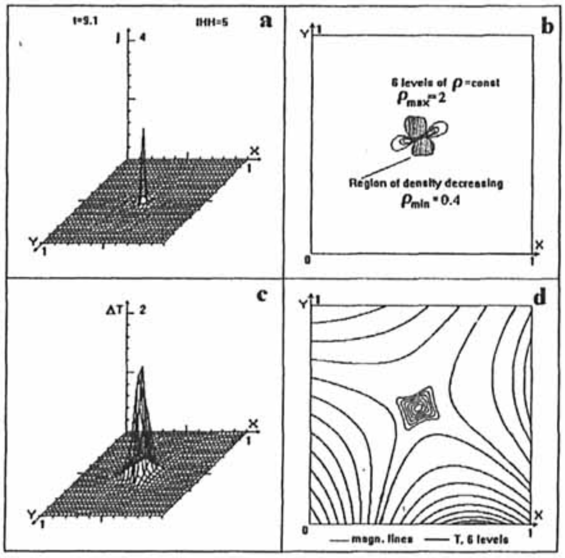

Figure 2 (a) The distribution of the current density; (b) Levels of ρ = const; (c) Distribution of the temperature; (d) Magnetic field lines and levels of T = const (in the center). All data are presented for $t = 9.1$.

velocity for $t = 0.1$, 1.1, and 4.1 are shown in Figure 1*a*, *b*, *c*. The maximum plasma velocity is ~ 0.001. At $t \sim 4$ the front of disturbance is reached by the neutral line, and reconnection occurs. The typical pattern of flow for reconnection is presented in Figure 1*d* in extended scale. Here, plasma inflows from above and below. After reconnection in the neutral line, plasma outflows to the right and left. A strong current sheet does not appear. The current distribution (Figure 2*a*) shows that the current sheet width is comparable with its thickness. So, all magnetic lines that arrived at the neutral line reconnect, and considerable magnetic energy storage is not found.

The plasma density slightly drops in the inflow region, but increases in the vicinity of the neutral line in the outflow region (Figure 2*b*). The temperature around the neutral line increases. The maximum of the temperature is very sharp (Figure 2*c*). The role of anisotropy of the thermal conductivity is distinctly seen in Figure 2*d*, where the levels of T = const and magnetic lines are presented. The lines of T = const are directed along the magnetic lines. This picture does not change for a long time, but when $t > 50$ a noticeable artifact appears, because of numerical errors on the photosphere boundary.

Apparently, XBP are responsible for solar cosmic ray generation during the minimum of solar activity, when the number of X-ray bright points increases by an order of magnitude (Golub *et al.*, 1979). For an inflow velocity $V_{\text{in}} = 0.001\ V_A$ and $B \sim 10$ Gauss, the electric field along the neutral line is $E = -VB/c \sim 0.5$ V cm^{-1}. If the point diameter is $\sim 5 \times 10^8$ cm, the particle can be accelerated to ~ 100 MeV.

Acknowledgments

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