THE MODEL OF SIGMOIDAL FLARE STRUCTURE

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There are two simple mechanisms of formation of current structure in the solar atmosphere: the longitunal (along the neutral line of the magnetic arcade) shift of photospheric plasma and the transversal one. In the second case the neutral line bends, taking the S-form, i.e. the sigmoidal magnetic structnre appears. Last time these structures are of great interest (Rust and Kumar, 1996; Canfield et al., 1999) due to their close correlation with the flare activity and CME. Theoretically it is clear that the strong deformation of the neutral line of the system can result in the appearence of large electric currents and exitation of anomalous resistance leading to the flare release of the free magnetic energy. The relaxation of the system to the potential state results also in the change of magnetic field distribution in the photospheric layer. It is a tipycal event for large "two-ribbon" flares (Priest, 1982).

Here we present the new analytical model for the force-free sigmoidal arcade based on the original solution obtained earlier (Mikhalyaev, 1986).

Let us introduce the cartesian coordinates X, Y, Z by such a way that the plane (Y, Z) coincides with the photosphere, and the axis X is vertical and directed up. The force-free field is given by the next expression (Mikhalyaev, 1986)

$$\mathbf{B_0} = B_0 e^{-z}(-sin(y - arctg\, bz)\mathbf{e}_x + cos(y - arctg\, bz)\mathbf{e}_y), \tag{1}$$

where $y = Y/L$, $z = z/L$ are the dimensionless coordinates, B_0 and L are the scale parameters. The parameter b gives the magnitude of the neutral line curvature. The equation of the neutral line in that structure is $y = arctg\, bz$. The force–free parameter of the field is given by the expression

$$\alpha = \frac{d\, arctg\, bz}{dz}.$$

The electirc current density is

$$j = \frac{\alpha c}{4\pi} B_0 e^{-x},$$

here $x = X/L$, and reaches its maximum at the origin, where the bend occurs. While the parameter b as well as α and j are great enough, the process of the fast reconnection of magnetic field lines can be initiated, and the force-free magnetic structure can relax toward the potential one with the same geometrical S–form of its neutral line

$$\mathbf{B}_1 = B_1 e^{-x}(-\sqrt{1 + b^2 z^2} sin(y - arctg\, bz)\mathbf{e}_x +$$
$$+\sqrt{1 + b^2 z^2} cos(y - arctgbz)\mathbf{e}_y) - b\, cos\, y\, \mathbf{e}_z. \tag{2}$$

We can describe the initial and final (after the reconnection) states of the field in the active region using equations (1) and (2). In particular, we can derive the value of the released magnetic energy W. Choosing the constants B_0 and B_1 so that the magnetic field B is fixed on the vertical boundary $z = \pm a$, we obtain

$$W = \frac{1}{8} a L^3 B_0^2 \left[1 - \frac{1 + b^2/2 + a^2 b^2/3}{1 + a^2 b^2} \right]. \tag{3}$$

If $B_0 \approx 102\ G$, $L \approx 4 \times 10^9\ cm$, $a = 3$, $b = 1$, then $W \geq 10^{32}\ ergs$.

References

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