The magnetic flux ropes: theory and observations

A.A. Soloviev

Kalmyk State University, Elista, Russia

The brief review of the theory of the twisted magnetic flux tubes (ropes) applying to the solar activity fenomena is given. First, the problem of equilibrium of the cylindric flux ropes with the magnetic field $\mathbf{B} = (0, B_\varphi(r), B_z(r))$ in the rarefied plasma of solar corona is once more discussed. It is shown that the external magnetic field is needed to mantain the equlibrium of the rope trough its cross–section. While the external magnetic field is quasi–homogenious the equlbrium along the length takes place at twisting $k = 2\beta \approx 0.1$, where β is the plasma parameter, k is the ratio of the mean square (over the rope cross–section) of the $B_\varphi(r)$–field to the mean square of the $B_z(r)$. (In the absence of the B_{ex}, when the force balance is mantained by the gas pressure difference, the equilibrium value of k is equal to 2). This equilibrium is stable, and the oscillations of the rope, as a whole, near this stable state can be exited. Under given amplitude of the non–linear oscillations one could easily find the energy related with the oscillations. Taking into account that the cylindrical surface of the oscillating rope is the origin of the driven Alfven oscillations (of the same initial amplitude) propagating outward through the external field, we can find the flux of wave–energy spreading away per second. Dividing the reserve of oscillatory energy to the flux we derive the estimation of the time τ, which is the relaxation time of the system due to the radiative looses. The preliminary results show that τ turns out to be only several times greater then the period T of the free oscillations. Thus, the quality of the oscillatory system is low enough in accordance with the observational data obtained by TRACE telescope. Second, the axisymmetric models of the magnetic flux rope of variable cross–sections, with three component of the field, $\mathbf{B} = (B_r(r,z), B_\varphi(r,z), B_z(r,z))$, were elaborated by author for more realistic modelling of the observed plasma structures. These models are based on the new class of non–linear magnetohydrostatic solutions describing the vertical axially symmetric and uniformly twisted magnetic flux tube of varying cross–section embedded in the hydrostatic atmosphere. In the solution one of the following functions can be set arbitrarily: the distribution of plasma density with height or the geometric shape of magnetic surface. In particular, this approach allowes to obtain easily the solution for the magnetic flux rope with the cross–section constriction in equilibrium. The solution obtained can serve as the foundation for justification of Alfven–Karlquist idea concerning the nature of solar flare. The essence of the idea is that the electric current along the filament can be "locked up" when the certain critical current density is attained. As a sequence of abrupt increasing of ohmic resistance in some part of the electric circuit the large amount of magnetic energy can be released in the different forms. In the flare model based on the present solution the small relatively quasistatic alteration in twisting of quasivertical basements (legs) of magnetic loop fixed in the photosphere can lead to the significant growth of the local field constriction. In this region two conditions are reached simultaneously: the decreasing of plasma density and the increasing of current density. It can result in the excitement of plasma instabilities and the appearance of the anomalous plasma resistance exceeding by several orders of the normal one.