ON THE HYDROMAGNETIC MODELS OF THE COMET TAILS

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Ershkovich *et al.* (1972) proposed a model of type-1 comet tail as a plasma cylinder separated from the solar wind by a tangential discontinuity surface. This model was shown to be in accordance with observations of helical waves in the plasma tails (Ershkovich, 1977). Indeed, for long wavelengths, the transition from the cometary plasma in the cylindrical central tail to the solar wind (with mutual contamination of the cometary and solar wind flows, plasma inhomogeneities, streamers, etc.) may be considered as a discontinuity surface (Ershkovich, 1979). The corresponding dispersion equation does not depend on the direction of the comet tail magnetic field, and a neutral sheet (separating magnetic fields of equal magnitude and opposite direction) is also included. The θ-shaped surface current encircling the tail produces approximately uniform magnetic field throughout the cross-section of each hemi-cylinder. This field evaluated from the pressure balance through the tangential discontinuity surface turns out to be of the order of the interplanetary magnetic field (Ershkovich *et al.*, 1972). Analysis of the observations of both the helical waves and the 'folding phenomenon' of streamers supports this estimate (Ershkovich, 1976, 1977, 1978).

In contrast to this, Mendis (1978) recently proposed a model in which the cross-tail current closes through the entire volume of the comet tail lobes. In this model the magnetic field is assumed to be of the order of 100γ near the tail axis (according to Ip and Mendis (1976) it even reaches 1500γ), decreasing outwards to interplanetary field values far enough from the axis. It will be shown that this assumption contradicts the equilibrium pressure balance across the tail.

Let us consider the MHD momentum equation

$$\rho\left(\frac{\partial \mathbf{v}}{\partial t} + (\mathbf{v}\cdot\nabla)\mathbf{v}\right) = -\nabla\left(p + \frac{B^2}{8\pi}\right) + \frac{1}{4\pi}(\mathbf{B}\cdot\nabla)\mathbf{B}. \tag{1}$$

The magnetic field in the tail cannot be force-free if it is non-uniform across the field lines (Ershkovich, 1978), and the magnetic force cannot be eliminated from (1).

The term

$$(\mathbf{B}\cdot\nabla)\mathbf{B} = (\mathbf{B}\cdot\operatorname{grad} B)\frac{\mathbf{B}}{B} + \mathbf{n}\frac{B^2}{R_c}, \tag{2}$$

where $\mathbf{n}$ is a unit vector of the principal normal to the field line and R_c is the radius of curvature of the field line, has no component normal to the magnetic field $\mathbf{B}$ if $R_c = \infty$. The same concerns the term $(\mathbf{v}\cdot\nabla)\mathbf{v}$ if $\mathbf{v} \parallel \mathbf{B}$. Calculations by Schmidt and Wegmann

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(1976) with $\mathbf{B} \perp \mathbf{v}$ in the unperturbed solar wind show that far enough from the nucleus the streamlines become approximately parallel to the tail axis. Then we obtain $(\mathbf{v} \cdot \nabla)\mathbf{v} \simeq 0$. Hence with $\partial/\partial t = 0$ the total pressure $p + B^2/8\pi$ is constant across straight fan-shaped magnetic field lines in the conventional model proposed by Alfvén (1957) (cylindrical tail is a central part of this configuration). Surfaces normal to the field lines in this model necessarily come into the solar wind, whence one obtains

$$\left(p + \frac{B^2}{B\pi}\right)_T = \text{const.} = \left(p + \frac{B^2}{8\pi}\right)_s, \tag{3}$$

where indices T and s refer to the comet tail and the solar wind, respectively. The gas-kinetic pressure in the solar wind, p_s, is usually of the order of the magnetic pressure, $B_s^2/8\pi$. Hence we arrive at the inequality

$$B_T \lesssim \sqrt{2} B_s \lesssim 10\gamma \quad \text{at} \quad 1 \text{ a.u.} \tag{4}$$

The pressure balance (3) follows from the fundamental principle of momentum conservation and it does not depend on the specific model of comet tail. It also holds if the transition from the cylindrical central tail to the solar wind is considered as a discontinuity surface. This result is obvious for the case of tangential discontinuity. The total pressure is approximately continuous across the rotational or contact discontinuity as well since the normal component of the magnetic field at the tail boundary should be small. Although Mendis (1978) has also used the continuity of the total pressure across the comet tail he failed to obtain the inequality (4) because of the algebraic mistake following his pressure balance.

With $B \lesssim 10\gamma$ in the comet tail the acceleration mechanism (due to Alfvén waves of large amplitude) proposed by Mendis (1978) is ineffective, and the plasma velocity in the tail remains $\lesssim 6\,\text{km s}^{-1}$ even with large amplitude $b/B = 1.4$ assumed in this paper. It is not a surprise, since large accelerations are observed in type-1 comet tails much more frequently than the waves of large amplitude. Therefore such a mechanism cannot be responsible for the observed accelerations. Besides, the wave amplitudes are much less than those accepted by Mendis (1978). Maximum amplitudes of the observed helical waves are of about 0.3 tail radii (this corresponds to the value $b/B \approx 0.3$ with the observed values $kR \sim 1$, where k is the wave number and R is the tail radius). These values are in accordance with a mechanism of non-linear stabilization of the Kelvin–Helmholtz instability (Ershkovich, 1977). A natural explanation of the observed accelerations in type-1 comet tails in terms of momentum transfer due to viscous interaction between the solar wind and the comet tail plasma was given in Pérez-de-Tejada *et al.* (1977).

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