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The appearance of the luminous matter in the solar corona is in many cases due to the condensation of the coronal plasma. This relatively cool and dense matter appears as prominences inside a very hot and rarified plasma. We consider here the apparent motion of the condensations along the magnetic field.

Let us suppose that the temperature drops in some region of a hot plasma in the magnetic field. For the condensation process the number of the recombinations highly increased and so does the energy radiated into surrounding space. The temperature may drop from about 10^6 K to $2 \cdot 10^4$ K or less. Since the plasma is in the magnetic field the heat flow across the magnetic field is strongly reduced, because $\varkappa_\perp / \varkappa_\parallel \ll 1$, where $\varkappa_\perp$ and $\varkappa_\parallel$ are thermal conductivities in the directions perpendicular and parallel to the magnetic field. If the inward energy flow is low enough the cool region will spread along the magnetic field into the hot one. This problem we treat similarly as it is treated the problem of the propagation of flame above an inflammable liquid in a canal[1]. In this case the hot region moves into the cold one.

We assume that the magnetic field is oriented along the z axis. Let Δz be the width of the zone in which the cooling of the plasma is taking place. Δz is approximately the distance on which the temperature drops from T_1 to T_2 where T_1 is the temperature of the hot plasma and T_2 is the temperature in the condensation. The time τ_E in which the temperature drops from T_1 to T_2 is approximately equal to the energy relaxation time for the electrons flowing along the magnetic field into the condensation from the hot region. Similarly as in the problme of an inflammable liquid we get

$$\Delta z = (\varkappa_\parallel^e / \tau_E)^{1/2} \qquad (1)$$

where $\varkappa_\parallel^e$ is the temperature conductivity of the electrons along the magnetic field. The thermal conductivity is given by the relation[2]

$$\varkappa_\parallel^e = \frac{k^2 T_e}{e^2} \cdot \sigma_\parallel^e$$

$\sigma_\parallel^e$ is the electrical conductivity parallel to the field. Treating the electron gas as an ideal one we get

$$\varkappa_\parallel^e = \frac{2}{3} \frac{kT_e}{e^2 n_e} \cdot \sigma_\parallel^e \qquad (2)$$

Taking for the $\sigma_\parallel^e$ the expression

$$\sigma_\parallel^e = \frac{e^2 n_e \cdot \tau_e}{m_e}$$

we get

$$\varkappa_{\parallel}^e = \frac{2}{3} \frac{kT_c}{m_e} \cdot \tau_e \qquad (3)$$

where τ_e is the mean collision time for the electrons. From the Eqs. (1) and (3) we get for the apparent velocity of the propagation of a condensation along the magnetic field

$$v_a = (2kT_e \cdot \tau_e / 3m_e \tau_E)^{1/2} \qquad (4)$$

Let us use this equation to calculate the velocity v_a in a prominence in the solar corona. For T_e we take a typical value $T_e = 2 \cdot 10^4$ K. The energy relaxation time τ_E is much longer than the mean collision time τ_e. We can take for the hydrogen plasma $\tau_e / \tau_E = 10^{-2}$. For v_a we get $v_a = 45$ km/s. Velocities of similar magnitude have really been measured[3]. If $v_a = 0$ it does not mean that the matter is flowing along the field lines. This is the velocity of the region of the enhanced radiation. In majority of the moving prominences the matter really moves along the magnetic field.

References:

1) Landau, L.D., and Lifshitz, E.M.,Fluid Mechanics, Pergamon Press Inc., New York, 1963.

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3) Kaplan, S.A., Pikelner, S.B., Tsytovich V.N., Plasma Physics of Solar Atmosphere, (in Russian), Nauka, Moscow 1977.