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Can Coronal Magnetic Structures be Quasi-Static?

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Abstract. The recent work of Heyvaerts and Priest (1992) shows that d.c. flows in the photosphere produce turbulent heating in the corona. The associated turbulent resistivity precludes quasi-static coronal structures. Estimates are presented of the expected coronal flow velocities based on the assumption that the corona is indeed heated by the turbulent dissipation.

1. Introduction

Coronal magnetic structures are assumed to be in equilibrium because of their large lifetimes. These are further assumed to be in static equilibrium on account of the very small value of the plasma resistivity which implies a very slow diffusion. However, it is this same low resistivity that poses a problem for the conversion of mechanical energy into thermal energy in the corona. Turbulent resistivity is one way out of this problem.

A larger resistivity implies, however, a shorter diffusion time. For example, if one assumes the value of resistivity implied by equation (98) of Heyvaerts and Priest (1992), then one ends up with a diffusion time scale of 1000 s to 10000 s which is smaller than the lifetime of coronal structures. Thus, if the corona is indeed heated by means of turbulent diffusion, then long lived structures must be in dynamic rather than static equilibrium.

2. Estimates of the velocity

We will exactly follow the analysis of Heyvaerts and Priest (1992) to come up with estimates of the flow in the structures which are in dynamical equilibrium. Heyvaerts and Priest (1992) assumed a Cartesian coordinate system wherein the y axis is the symmetry axis along which there is no variation (cf figure in Heyvaerts and Priest, 1992). This is assumed to lie along the polarity inversion line of a magnetic arcade. The direction normal to the y axis in the photospheric plane is chosen as the x axis. The arcade is assumed to have a finite extent in this direction. The direction along the field line spanning the inversion line is chosen as the z axis, with $z = 0$ lying at the apex of the arcade. The value of z is assumed to have positive values in the portion of the field line from the apex to its footpoint rooted in the negative or south-polarity region of the arcade and negative values in the portion from the apex to the footpoint rooted in the north-polarity region of the arcade.

The boundary flow at the footpoints is assumed to be along the y direction with the magnitude of the velocity varying as a function of x. The present paper discusses the extrapolation of this velocity to the higher regions of the solar atmosphere.

In the analysis of Heyvaerts and Priest (1992), the boundary flow and magnetic field are Fourier analyzed in the x direction. The z variation of each Fourier component is then calculated using the MHD equations. In this way, the flow and magnetic field can be extrapolated from the photosphere to the corona. Using the value of resistivity implied by equation (98) of Heyvaerts and Priest (1992), we find from their equation (45a) that the flow velocity varies linearly with height. If the boundary velocity is a few $km\ s^{-1}$, then the flow in the corona will continue to be of this order except at the very top where it will vanish from symmetry considerations.

3. Discussions and Conclusions

The problem of coronal heating is still open. New ideas even reject the concept of a hot corona in the conventional sense (Scudder 1992 a,b). However, if the turbulent heating scenario is valid, then this paper points out that one signature of this scenario would be a measurable flow velocity. In other words, coronal structures cannot be quasi-static if turbulent resistivity is important. More efforts towards observing steady flows in the corona and transition region are needed. Theoretically, the introduction of a steady flow increases the degrees of freedom in the problem of the extrapolation of coronal magnetic fields. Careful observations of the photospheric velocity fields along with magnetic fields seem necessary for constraining the extra degrees of freedom.

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References

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