Wave Energy Dissipation in The Solar Atmosphere

Zhou Aihua
(Purple Mountain Observatory, Academia Sinica,
Nanjing, P.R.C.)

ABSTRACT. There are two regions of rapid dissipation when Alfvén waves propagate from the transition region to the corona. They occur respectively in a range of several hundred kilometers above the base of the transition region and in the corona at about 1-3R⊙. The heating of the atmosphere by wave dissipation could be one order of magnitude larger than heat conduction in the coronal part with a lower temperature and density and stronger magnetic field. Wave heating could also become more important when the magnetic field divergence becomes stronger.

Basic Equations and Results

Alfvén wave heating in the transition region has previously estimated (Zhou (1988,1989)). In this paper we discuss its dissipation in corona. The equation of motion for the mean flow is (Jacques (1977))

$$\rho \frac{dU}{dt} = - \nabla \left[P + \frac{B^2}{8\pi} \right] + (B \cdot \nabla) \frac{B}{4\pi} - \nabla \cdot P + \rho g, \tag{1}$$

In the case of Alfvén waves the wave stress tensor is $P_w = WKK - WI/2$ (Li *et al* (1984)) and W is the wave energy density. The energy equation is

$$\frac{\partial E}{\partial t} + \nabla \cdot G = 0; \tag{2}$$

where

$$E = \rho U^2 + P/(r-1) + B^2/(8\pi) + W; \tag{3}$$

$$G = [\rho U^2 + rP/(r-1) - \rho GM_{\odot}/R]U - (U \times B) \times B/(4\pi) + VaW + U \cdot P_w + G_1 \tag{4}$$

and G_1 represents the contribution to G from processes such as radiation and heat conduction (Vanveberen and De Loore (1976); Rosner and Tucker (1978)). The equation of continuity is

$$\frac{\partial \rho}{\partial t} \nabla \cdot (\rho U) = 0, \tag{5}$$

and the equation of wave action density is (Jacques (1977))

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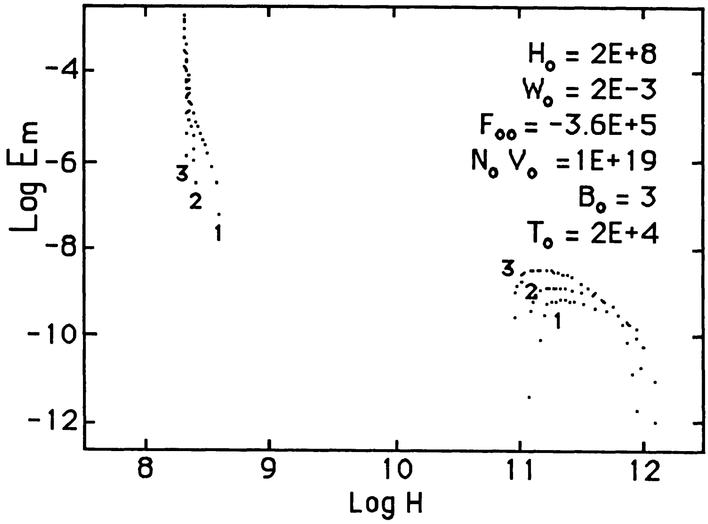

Figure 1. The distributions of Em for radial flow for $N_0 = 1.3 \times 10^{10}$ (1), 1.8×10^{10} (2) and 3×10^{10} (3).

$$\nabla \cdot (VaS) = -VaS/d, \quad (6)$$

where S is the wave action density and d is the Alfvén wave damping length (Kaplan and Tsytovich (1973)).

The results show that Alfvén waves have two dissipation regions in the transition region and in corona at about 1-3Ro. As T_0 and N_0 decrease and B_0 increases, Alfvén wave heating by the dissipation becomes more important and the height ranges of the dissipation move to larger heights. Also, when the magnetic field becomes more divergent, the ratios of the wave heating to the heat conduction Em/Ec become larger. This nonradial effect could explain coronal-hole cycle variations of the basic heliosphere quantities (Zhou (1990)).

References

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