NONLINEAR SURFACE ALFVÉN WAVE PROPAGATION IN SOLAR ATMOSPHERE

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The paper deals with the surface wave propagation in the solar atmosphere. The plasma motion is supposed to be described by magnetohydrodynamic equations. In the first part of the paper the surface wave propagation on a single magnetic interface in the solar corona is considered. The plasma is assumed to be cold. Using the reductive perturbation method we derive the equation governing the evolution of nonlinear small-amplitude surface waves as follows

$$\frac{\partial h}{\partial x} - R\left\{\frac{\partial}{\partial t}\left(H\left(h\frac{\partial h}{\partial t}\right) - hH\left(\frac{\partial h}{\partial t}\right)\right) - \frac{\partial h}{\partial t}H\left(\frac{\partial h}{\partial t}\right)\right\} - \frac{\partial^2 h}{\partial t^2} = 0 \qquad (1)$$

This equation is written in a coordinate system moving with the phase velocity of linear waves. Dimensionless variables are used. The symbol H denotes the Hilbert transform. The shape of the interface is defined by the equation $z = h(t,x)$ in the Cartesian coordinates x, y, z. The Reynolds number R determines the relative contributions of nonlinearity and viscosity. We take a source radiating a sinusoidal wave. Then the wave evolution is calculated numerically. We get that at large R the wave steepening takes place. This steepening leads to a strong increase of wave damping.

In the second part we study wave propagation on the magnetic structure consisting of three magnetic interfaces parallel each other. The fluid is considered to be incompressible. The viscosity is not taken into account. In the long-wavelength approximation the dispersion equation is approximately as follows $f = ck + ak|k| + bk^3$. There are some singular directions of wave propagation for which $a = 0$. Using the reductive perturbation method we derive for waves propagating in a singular direction the governing equation similar to (1). The solutions of this equation in the form of algebraic solitary waves are found.

E. R. Priest and V. Krishan (eds.), Basic Plasma Processes on the Sun, 237–238.

DISCUSSION

ROBERTS: Have you considered applying your interface studies to the field-free magnetic interface on the penumbra of a sunspot, using appropriate speeds for that region?

RUDERMAN: Considering surface wave propagation on a single magnetic interface, I used the cold-plasma approximation that is convenient for the corona but inappropriate for the penumbra. Therefore my study cannot be applied to the field-free magnetic interface on the penumbra of a sunspot.

BUTI: (i) What is your small parameter ε ?
(ii) Are you getting solitary waves to second order in ε ?

RUDERMAN: (i) The non-dimensional wave amplitude is used as a small parameter.
(ii) No, I get solitary waves only to first order in ε .

HOLLWEG: I am pleased to see the inclusion of coronal viscosity and of course nonlinearity. But if you put in coronal numbers (viscosity coefficient = $10^{-16}T^{5/2}$ cgs and velocity amplitude $\approx$ 30-40 km/s), can you in fact get the waves to dissipate in a few loop lengths?

RUDERMAN: Estimates show that surface wave propagation can be described by the MHD equations provided their periods are larger or of the order of 5s. On the other hand the plasma can be considered to be homogeneous (outside the magnetic interface) provided wave periods are smaller than about 50s. Linear theory shows that the rate of wave damping depends very strongly on the undisturbed plasma parameters and the direction of wave propagation. In particular, there is a small region of these values for which waves with periods from 5 to 50s damp significantly in a few loop lengths. As the nonlinearity increases the rate of wave damping, it expands this region: the larger the nonlinearity, the wider this region of parameters. The observed velocity amplitudes of the order of 30-40 km/s are large enough. In some cases the inclusion of nonlinearity can increase the damping rate by up to 10 times for waves with such amplitudes.