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DISCRETE ALFVÉN WAVES IN SOLAR PROMINENCES: PRELIMINARY STUDIES

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It is shown that the Discrete Alfvén wave can explain the natural oscillations of solar prominences by considering the existence of a current flow. Discrete Alfvén waves are a new class of Alfvén waves which is described by the inclusion of finite ion cyclotron frequency ($\omega/\omega_{ci} \neq 0$) and/or the equilibrium plasma current. In this paper we consider only the current effect since in prominences $\omega/\omega_{ci} \approx 0$. We have modeled the prominences as a cylindrical plasma, surrounded by an ideally conducting wall (corona), with L >> a where L and a are the plasma column length and radius, respectively. We have shown the spectrum of the discrete Alfvén waves as function of the plasma current.

ONDAS DE ALFVÉN DISCRETAS EM PROEMINÊNCIAS SOLARES: ESTUDOS PRELIMINARES – É mostrado que a onda de Alfvén discreta pode explicar as oscilações naturais das proeminências solares ao considerar a existência de uma corrente. Ondas de Alfvén discretas são uma nova classe das ondas de Alfvén que é descrita pela inclusão da frequência ciclotrônica de íon ($\omega/\omega_{ci} \neq$ 0) e/ou devido a corrente de plasma. Neste trabalho consideramos somente o efeito da corrente desde que em proeminências $\omega/\omega_{ci} \approx 0$. O modelo utilizado para proeminência é um plasma cilíndrico limitado por uma parede condutora (corona) com L >> a, onde L e a são, respectivamente, comprimento e raio da coluna de plasma. Mostramos que o espectro das ondas de Alfvén discretas é uma função da corrente de plasma.

1. INTRODUCTION

The discrete Alfvén waves are a new class of Alfvén waves which is described by the inclusion of the finite ion cyclotron frequency ($\omega/\omega_{ci} \neq 0$) terms and considering the equilibrium plasma current (Appert & Vaclavik, 1987). These waves are sensitive to the equilibrium magnetic field geometry. Experimental (De Chambrier et al., 1982) and numerical (Ross et al., 1982) results concerning the antenna loading of tokamak plasmas show the evidence of resonance peaks at frequencies just below the Alfvén continuum (Appert et al., 1982a). The resulting peaks are related to the excitation of discrete eingenmodes of the Alfvén wave. In solar plasmas the evidence of global oscillations that might be associated with discrete Alfvén waves were reported by Balthazar et al. (1986) and Kouthchmy et al. (1983).

Since it is reasonable to assume that a current is flowing along the solar prominences (Tandberg-Hansen, 1974) and that it allows the propagation of the discrete Alfvén modes, we propose that this propagation is the cause of the natural oscillations of prominences. It should also be mentioned that no completely convincing theory for oscillations in prominences has yet appeared. The CGS system of units is used throughout this paper.

In Section 2 we discuss the Alfvén wave dispersion relation for the case of small magnetic twist. In Section 3 we show the conclusions.

2. ALFVÉN WAVES IN A COLD CURRENT CARRYING HOMOGENEOUS PLASMA: SMALL TWIST ($B_\theta / B_Z << 1$)

In this paper, we are interested in exploring the possibility of the existence of these modes in the solar prominences. Therefore, rather than introducing the complicated magnetic field structure, we adopt a simple model yet the essence of physics can be brought out. We will show that, within MHD theory, when a bounded plasma is assumed, there will be new discrete modes besides the shear Alfvén and magnetosonic modes with the angular frequency ω a little below the shear Alfvén frequency. The spectrum of these modes depend on ω/ω_{ci} and the plasma current, as a first order quantity. We take as model for the solar prominence a straight magnetized cylindrical plasma with radius a and length L with current I flowing along its length and surrounded by an ideally

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conducting wall (corona). Since in prominences ω/ω_{ci} is very small we consider it as negligible, so wen can use the MHD theory. We assume two components of the magnetic field; one along the axis of the cylinder, B_z, and the other in the azimuthal direction, B_θ. The latter one is due to the plasma current. The magnetic field lines are then twisted around the cylinder.

In this section we consider that the current is relatively small (although in absolute value this may be large) so that $B_\theta/B_z << 1$, that is, the twist is small.

Assuming the time and space dependence of the perturbation quantities as $f(r) \exp[i(k_{/\!/} z + m\theta - \omega t)]$, in cylindrical coordinates, and using the approximation $\partial/\partial r \approx ik_r$, known as "WKB" approximation, Appert et al. (1982b) reported the following dispersion relation, for the small shear (or small twist) case:

$$[\omega^2 - k_{/\!/}^2 v_A^2] [\omega^2 - v_A^2 (k_r^2 + k_\perp^2 + k_{/\!/}^2)] \,.$$

$$[\omega^2 - k_{/\!/}^2 v_A^2 + \frac{(2B_{\theta o}/a)^2 k_{/\!/}^2 = B_{zo}^2}{(k_r^2 + k_\perp^2)(4\pi\rho v_A^2)}] = 0 \,, \qquad (1)$$

where

$$k_\perp = (m/r) B_{zo}/B_o - k B_{\theta o}/B_o \,,$$

$$k_{/\!/} = kB_{zo}/B_o + (m/r) B_{\theta o}/B_o \,,$$

$$k = k_{/\!/} B_o/B_{zo} - (m/r) B_{\theta o}/B_{zo} \,,$$

$$v_A = B/(4\pi\rho)^{1/2}, \; B_{\theta o} = B_\theta(r=a),$$

ρ is the plasma mass density.

There are three eigenmodes, the first (the first bracket) representing the shear Alfvén, the second (second bracket) the magnetosonic and the last the discrete Alfvén. Rewriting the dispersion relation of the discrete Alfvén mode and setting it equal to zero we have

$$\omega^2 = \omega_A^2 - \frac{(2B_{\theta o}/a)^2 k_{/\!/}^2 B_{zo}^2}{(k_r^2 + k_\perp^2)(4\pi\rho v_A^2)} \qquad (2)$$

where $\omega_A^2 = k_{/\!/}^2 v_A^2$ is the shear Alfvén wave angular frequency.

For a better understanding of eq. (2) we can write it as follows:

$$\omega^2 = \omega_A^2 \{1 - [\frac{2B_{\theta o}}{B_{zo}}]^2 \frac{1}{a^2 (k_r^2 + k_\perp^2)}\}$$

Assuming that

$1/a \cong k_r$ and $k_r \cong k_\perp$, we obtain:

$$\omega^2 \cong \omega_A^2 [1 - 2 [\frac{B_{\theta o}}{B_{zo}}]^2] \qquad (3)$$

We see from eq. (3) that the shear in the equilibrium magnetic field ($B_{\theta o} \neq 0$) produces a new eigenmode for the cylindrical plasma, with the angular frequency below the shear Alfvén frequency by a factor $[1 - 2(B_{\theta o}/B_{zo})^2]$. The shear term $-2(B_{o\theta}/B_{oz})^2$ in actual prominence is not necessarily small which means that we need numerical calculations to obtain the dispersion relation for the discrete Alfvén wave. This is the subject for the next paper.

Equation (3) is the main result of this section. We can clearly see from this equation that the field twist due to the plasma current will lower the Alfvén frequency. The frequency mismatch $\Delta\omega^2 = \omega_A^2 - \omega^2$ could be a good index quantity to be used to calculate the magnetic shear of the solar prominence, and so, the plasma current along with it. In other words the decrease of ω is directly related to the increase of current (that implies the increase of $B_{\theta o}$). It means that, if the current flow in the prominence is increasing in time, it might be possible to observe the decrease of ω in time. We might way that it is a good proposal to observe the variation of ω with time since it could be a nice way to diagnose the presence of currents in prominences and also to infer their values. We have clearly shown that the variations in ω is caused by variations in the equilibrium current flow in the prominence.

3. CONCLUSIONS

We have shown that the current flow in prominences is responsible for the existence of the discrete Alfvén wave as an eigenmode of that structure. This new mode may explain the natural oscillations of prominences with frequencies which vary with the equilibrium current and lie below the shear Alfvén continuum.

We have also shown that the frequency mismatch between the lower edge of the Alfvén continuum and the discrete Alfvén eigenfrequency increases as the current increases and could be a good quantity to infer the magnetic field twist of solar prominences.

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REFERENCES

APPERT, K., GRUBER, R., TROYON, F. & VACLAVIK, J. – 1982a – Excitation of global eigenmodes of the Alfvén wave in tokamaks. Plasma Phys., **24**: 1147-1159.

APPERT, K., GRUBER, R., TROYON, F. & VACLAVIK, J. – 1982b – AERH - A new heating scheme? Presented at the 3rd Joint Varenna, Grenoble International Conference on Heating in Toroidal Plasma, Grenoble.

APPERT, K. & VACLAVIK, J. – 1987 – Low frequency RF heating on TCA using Alfvén waves. Invited paper presented at the 1987 International Conference on Plasmas Physics, Kiev, April 6-12.

BALTHAZAR, H., KNOLKER, M., STELLMACHER, G. & WIEHR, E. – 1986 – Evidence for quasi-periodic Doppler motions in solar prominences. Astron. Astrophys., **163**: 343-346.

DE CHAMBRIER, A., CHEETHAM, A.D., HEYM, A., HOLFMAN, F., JOYE, B.; KELLER, R., LIETTI, A., LISTER, J.B. & POCHELON, A. – 1982 – Alfvén waves coupling experiments on the TCA tokamak. Plasma Phys., **24**: 893-902.

KOUTHCHMY, S., ZUGZDA, Y.D. & LOCANS, U. – 1983 – Short period coronal oscillations: observations and interpretation. Astron. Astrophys., **120**: 185-191.

ROSS, W.D., CHEN, G.L. & MAHAJAN, J.M. – 1982 – Kinetic description of the Alfvén wave heating. Phys. Fluids, **25**: 652-667.

TANDBERG-HANSEN, E. – 1974 – Solar prominences. Reidel Co., 318 pp.

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