pB2

STUDY OF ALFVEN WAVES IN STELLAR PLASMAS AND IN PLASMAS OF MAGNETIC CONFINMENT (TOKAMAK)

Amel BENAHMED et Abdelaziz SID
PRIMA Laboratory, Physics Department, Faculty of Sciences, University of Batna
E-mail: amel_benahmed@yahoo.fr

ABSRACT: Alfvèn waves are low frequency magnetohydrodynamics plasma waves or oscillations which propagate in the direction of the magnetic field. Alfvèn waves are of fundamental importance in the behavior of many laboratory and space plasmas. They play important roles in the heating, stability and transport of plasmas. Solar plasmas are structured and stratified both vertically and horizontally. The stability is discussed of the drift-Alfvèn wave which is driven by the equilibrium density gradient, collisional solar plasma, including the effects of both hot ions and a finite ion Larmor radius. An analytical mode analysis is used for the description of the waves in spatially unlimited plasma. In the analysis of modes, the exchange of identity between the electrostatic and electromagnetic modes is demonstrated. The results are applied to coronal and chromospheric plasmas.

KEYWORDS: Alfvèn waves, instabilities, magnetized plasmas, stellar plasmas

1. Model and derivations:

The momentum equations for ions and electrons are:

$$m_i n_i\left[\frac{\partial v_i}{\partial t}+(v_i.\nabla)v_i\right]=en_i\left(-\nabla\phi-\frac{\partial A_Z}{\partial t}e_z+v_i\wedge B\right)-kT_i\nabla n_i-\nabla.\Pi_i-m_i n_i\nu_i v_i \qquad (1)$$

$$m_e n_e\left[\frac{\partial v_e}{\partial t}+(v_e.\nabla)v_e\right]=en_i\left(-\nabla\phi-\frac{\partial A_Z}{\partial t}e_z+v_e\wedge B\right)-kT_e\nabla n_e-\nabla.\Pi_e-m_e n_e(\nu_e v_e-\nu_{ei}v_i) \qquad (2)$$

The parallel electron dynamics, in the limit when ion motion is predominantly polarized in the perpendicular plain, is described by:

$$\left(\frac{\partial}{\partial t}+v_{e0}\nabla_\perp\right)A_{z1}+\frac{\partial\phi_1}{\partial z}-\frac{kT_e}{n_{e0}e}\frac{\partial n_{e1}}{\partial z}-\frac{m_e\nu_e}{\mu_0 e^2 n_{e0}}\nabla_\perp^2 A_{z1}=0 \qquad (3)$$

and by using the Ampere law, the electron continuity becomes:

$$\frac{\partial n_{e1}}{\partial t}+\frac{1}{B_0}(e_z\wedge\nabla_\perp\phi_1).\nabla_\perp n_{e0}+\frac{1}{\mu_0 e}\frac{\partial}{\partial z}\nabla_\perp^2 A_{z1}=0 \qquad (4)$$

By the same method, the ion continuity equation is finding and combined by (4) using the quasi-neutrality to obtain:

$$\left(\frac{\partial}{\partial t}+\nu_i\right)\nabla_\perp^2\phi_1+c_a^2\frac{\partial}{\partial z}\nabla_\perp^2 A_{Z1}+\frac{kT_i}{en_0}\left(\frac{\partial}{\partial t}+\nu_i\right)\nabla_\perp^2 n_1-\rho_i^2\frac{\partial}{\partial t}\nabla_\perp^4\left(\phi_1+\frac{kT_i}{en_0}n_1\right)=0 \qquad (5)$$

The given set of Eqs (3), (4) and (5) will be used in the description of "The drift-Alfvèn waves in solar plasma".

2. Waves in unlimited plasma:

In Cartesian geometry, for perturbations $\approx \exp(-i\omega t + ik_y y + ik_z z)$. Eqs (3), (4) and (5) yield

$$\omega^3 - \omega^2\left[\omega_{*e} + \omega_{*i} - i\left(\delta + \frac{\nu_i}{1+k_y^2\rho_i^2}\right)\right] + i\frac{\nu_i}{1+k_y^2\rho_i^2}\left[\omega_{*e}\omega_{*i} - k_y^2 k_z^2 c_a^2\left(\rho_s^2+\rho_i^2\right)\right] = 0 \qquad (6)$$

2.1. Coronal plasma:

To discuss the roots and increments/decrements, we solve eq (6) numerically by taking parameters values that are typical for the solar atmosphere (Fig1, 2 and 3)

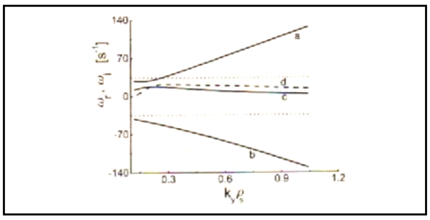

Figure 1: Frequencies ω_r and increment ω_i in terms of the couplingterms $k_y\rho_s$.

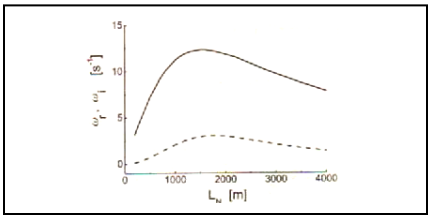

Figure 2 : The drift wave frequency (full line), and its increment (dashed line) in terms of the density scale lengh.

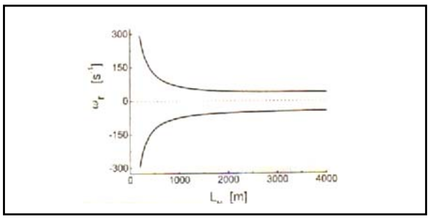

Figure 3: The frequency of the kinetic Alfvèn modes corresponding to the drift mode in Fig.2.

2. 2. Application to the chromosphere:

Equation (6) is solved also for the quiet sun parameters of "The chromospheric plasma".

3. Confinement and heating of plasmas by Alfvèn waves in the Tokamak:

What's Tokamak?

The word Tokamak is an acronym for the Russian words **T**oroidal'naya **K**amera **M**agnitnoi **K**atushki, meaning toroidal chamber and magnetic coil.

3.1. Plasma heating:

The most efficient way to heat a tokamak plasma is by passing through it a current induced by the primary coil (as seen from Fig. 4) This coil is the primary circuit of a transformer in which the plasma ring constitutes the secondary circuit. It works like an electric heater, the amount of heat generated depending on the current and the resistance of the plasma.

Unfortunately, the plasma resistivity decreases as the temperature rises and the heating process becomes less effective. The maximum temperature that can be achieved in tokamaks by the resistance heating (or homic heating) method is about $3{*}10^7$ k, twice the temperature in the center of the sun but less than needed to startup a reactor, about 10^8 K. In tokamak experiments auxiliary heating is used to reach temperatures currently as high as $5*10^8$ k (more than 30 times the temperature at the sun-center). The two main methods of additional heating is by the injection of high-energy neutral particle beams and radiofrequency waves of various types.

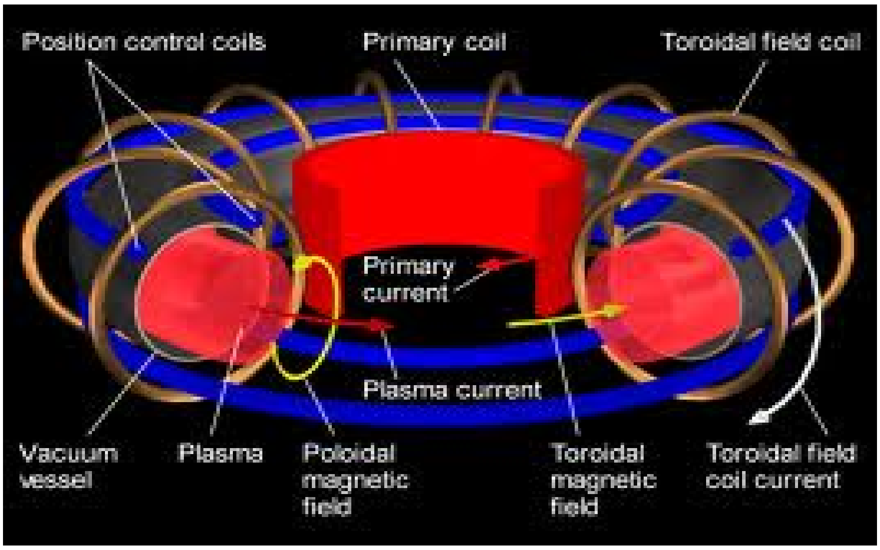

Figure 1: Main components of the tokamak

Conclusion:

The frequency of Alfvèn waves modes depends on the density gradients (as seen from 1, 2 and 3), and on the coupling with the corresponding drift mode which is driven by the density gradient. The change in the frequency of the Alfvèn modes should be taken into account in the analysis of observed modes in the solar corona. In fact, this introduces a certain freedom in the fitting of observations into the theorical modeling. We note in the particular that the widely used one-fluid (MHD) model is intrinsically unable to describe these phenomena.

References:

[1] Bostick, Winston H and Morton A; *Experimental Demonstration in the laboratory of the Existence of Magneto-Hydrodynamic Waves in Ionized Helium* **87** 671-677 (1952).
[2] Berthod, Harris and Hope H; *World-Wide Effects of Hydro magnetic waves Due to Argus* **65** 2233(1960).
[3] Alfven H; *Cosmic Plasma*, Holland (1981).