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Magnetoacoustic gravity surface waves with flows

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Abstract. The effect of uniform flows on the characteristics of magneto acoustic-gravity surface waves at a single interface when both the magnetic field and the propagation vector are parallel to each other is studied. The region above the interface is permeated by a uniform horizontal magnetic field. The lower region is field free. The temperature on both sides of the interface is assumed to be uniform, with a discontinuity along the interface. The dispersion relation for the fluid which is compressible and having large conductivity is derived in the linear context. Depending on the temperature structure, the interface supports one or two surface modes in the absence of gravity. Certain limiting cases are discussed.

Key words : MHD Waves, Flows

1. Introduction

The solar atmosphere is strongly structured by magnetic field and stratification by gravity from the photosphere to the corona. The propagation of MHD waves is quite complicated. The importance of MHD modes in the Sun with flows has been considered by Nakariakov et al. (1996,1998). Satya Narayanan (1996,1997) studied the properties of surface waves for non parallel propagation in the absence of gravity and shear flows. In this study, we discuss surface waves for parallel propagation with gravity and shear (uniform). The non-parallel propagation will be taken up in future studies.

Let z = 0 be the interface between two compressible media. The region above the interface is permeated by a uniform magnetic field and shear while the lower region is field free. Region z > 0 is denoted by region 1 and z < 0 as region 2. The magnetic field is $B(z) = (B_0(z),0,0)$

The magneto hydrostatic balance is determined by $\frac{d}{dz}(p(z) + \frac{B_0^2(z)}{2\mu}) = -\rho(z)g$ where p, B_0, ρ and g are pressure, magnetic field, density and the acceleration due to gravity.

The solution of $v_x(z)$ from the wave equation the regions 1 and 2 given by

$$v_x(z) = d_1 \exp\{\frac{1}{2H_1}[1-(1-4A_1H_1^2)^{1/2}]z\}, \quad d_2 \exp\{\frac{1}{2H_2}[1+(1-4A_2H_2^2)^{1/2}]z\},$$

respectively with the assumption that $4A_1H_1^2 \leq 1$ and $4A_2H_2^2 \leq 1$.

Applying the matching conditions that the normal component of velocity and the total pressure be continuous along the interface one gets the dispersion relation

$$\frac{\rho_1(c_1^2 + v_A^2)(\Omega^2 - k^2 c_T^2)}{(k^2 c_1^2 - \Omega^2)} \left\{\frac{1}{2H_1}\left[1 - (1 - 4A_1H_1^2)^{1/2}\right]\right\} - \frac{k^2 g\rho_1 c_1^2}{(k^2c_1^2 - \Omega^2)}$$

$$= \frac{\rho_2 c_2^2\, \omega^2}{(k^2 c_2^2 - \omega^2)}\left\{\frac{1}{2H_2}\left[1 + (1 - 4A_2H_2^2)^{1/2}\right]\right\} - \frac{k^2 g\rho 2 c_2^2}{(k^2c_2^2 - \omega^2)}$$

$$A_1 = -m_1^2 + \frac{gk^2}{(c_1^2 + v_A^2)(k^2c_T^2 - \Omega^2)} + \frac{gk^2 c_1^2 m_1^2}{H_1(\Omega^2 - k^2c_1^2)(k^2v_A^2 - \Omega^2)}$$

$$A_2 = -m_2^2 + \frac{gk^2}{\omega^2(\omega^2 - k^2c_2^2)} + \frac{gk^2 c_2^2 m_2^2}{H_2\omega^2(\omega^2 - k^2c_2^2)}$$

$$m_1^2 = \frac{(k^2c_1^2 - \Omega^2)(k^2v_A^2 - \Omega^2)}{(c_1^2 + v_A^2)(k^2c_T^2 - \Omega^2)} \quad m_2^2 = \frac{\omega^2(k^2c_2^2 + \omega^2)}{c_2^2\omega^2}, \quad \Omega = \omega - kU, \quad c_T^2 = \frac{c_1^2 v_A^2}{c_1^2 + v_A^2}$$

Limiting Cases :

In the absence of gravity and shear the dispersion relation reduces to

$$\frac{\rho_1(c_1^2 + v_A^2)(\omega^2 - k^2 c_T^2)}{(k^2 C_1^2 - \omega^2)}\left\{\frac{1}{2H_1}\left[1 - (1 - 4A_1H_1^2)^{1/2}\right]\right\} = \frac{\rho_2 c_2^2\, \omega^2}{(k^2 c_2^2 - \omega^2)}\left\{\frac{1}{2H_2}\left[1 + (1 - 4A_2H_2^2)^{1/2}\right]\right\}$$

$A_1 = -m_1^2$ $\qquad$ $A_2 = -m_2^2$

The above relation can be simplified to yield $\rho_1(k^2v_A^2 - \omega^2)m_1 - \omega^2\rho_2 m_2 = 0$.

In the incompressible limit, $c_1, c_2 \rightarrow \infty$, $m_1^2, m_2^2 = k^2$, the dispersion relation reduces to $\frac{\omega^2}{k^2} = \frac{v_A^2}{1+R}$, where $R = \rho_2/\rho_1$.

2. Discussion

It is easy to realise that the surface waves exist only when $\Omega \neq kc_1$, $\Omega \neq kc_2$ with the condition $4A_1H_1^2 \leq 1$, $4A_2H_2^2 \leq 1$. For the non gravity case, both the fast and slow magneto acoustic surface waves propagate only when $c_2 > c_1$ and $v_A > c_1$. The effect of shear is to increase the phase velocity of the surface wave at low wavenumbers. However, in the limit $kH_2 \rightarrow \infty$, only one mode, the slow surface wave propagates. This asymptotically approaches the phase speed of the bulk wave in the long wavenumber limit. It will be interesting to study the characeteristics of surface waves when the propagation vector is not parallel to the magnetic field. This study is being taken up and will be reported later.

References

Nakariakov V. M., Roberts B., Mann G.,1996 A&A, 311, 311.

Nakariakov V. M., Roberts B., Murawski K., 1998 A&A, 332, 795.

Satya Narayanan A.,1996 BASI, 24, 371

Satya Narayanan A.,1997 A&A 324, 977