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Study of magneto acoustics waves at various angles

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Abstract: In the present paper, I would like to discuss the damping rate and wavelength of slow-mode and fast-mode magnetoacoustic waves. For the slow-mode waves, I have found that as the value of k increases, after a certain value, called kc, the slow mode disappears. The change in magnetic field does not affect the damping rates of slow mode waves. These waves can propagate with velocity of sound cs, which is independent of magnetic field. For the fast mode waves the graph is similar in qualitative nature.

Introduction:

As the temperature of solar corona (within $1\text{–}2R\Theta$) is being maintained at the value of the order of 10^6 K, the problem of solar coronal heating is yet unsettled. Many of scientists have investigated the problem of solar coronal heating through MHD waves by using the same set of MHD equations. They got different results for the damping rate and wavelength of slow-mode and fast-mode magnetoacoustic waves. For the propagation of MHD waves in a homogeneous, magnetically structured, compressible, and low-β plasma, the basic equations are [1][2]

$$\frac{\partial \rho}{\partial t} + \nabla.(\partial v) = 0 \qquad (1)$$

$$\rho\frac{\partial v}{\partial t} + \rho(v.\nabla)v = -\nabla p + \frac{1}{4\pi}(\nabla \times B) \times B - \nabla.\pi \qquad (2)$$

$$\frac{\partial B}{\partial t} = \nabla \times (v \times B) \qquad (3)$$

$$\frac{Dp}{Dt} + \gamma p(\nabla.v) = (\gamma - 1)[Q_{th} + Q_{vis} - Q_{rad}] \qquad (4)$$

$$p = \frac{2\rho k_B T}{m_p} \qquad (5)$$

For this set of equations (1)–(5), the dispersion relation is (Kumar et al. 2006; Chandra et al. 2010):

$$\omega^5 + iA\omega^4 - B\omega^3 - iC\omega^2 + D\omega + iE = 0$$

Where

$$A = c_0 + \frac{\eta_0}{3\rho_0}(k_x^2 + 4k_z^2)$$

$$B = \frac{c_0\eta_0}{3\rho_0}(k_x^2 + 4k_z^2) + (c_s^2 + v_A^2)k^2$$

$$C = \frac{3\eta_0}{\rho_0}c_s^2 k_x^2 k_z^2 + \frac{c_0 p_0 k^2}{\rho_0} + v_A^2 c_0 k^2 + \frac{4\eta_0 v_A^2 k_z^2 k^2}{3\rho_0}$$

$$D = \frac{3c_0 p_0 \eta_0 k_x^2 k_z^2}{\rho_0^2} + \frac{4\eta_0 c_0 v_A^2 k_z^2 k^2}{3\rho_0} + v_A^2 k_z^2 k^2 c_s^2$$

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$$E = \frac{p_0 c_0 v_A^2 k_z^2 k^2}{\rho_0}$$

Kumar et al. (2006) and Chandra et al. (2010) derived a fifth degree polynomial in ω and, for the real values of k, they discussed about the fast-mode and slow-mode magnetoacoustic waves. The obtained five roots are of the form:

$$i\alpha_{1i}, \quad \alpha_{2r} \pm i\alpha_{2i}, \quad \alpha_{3r} \pm \alpha_{3i}$$

The pure imaginary root corresponds to the thermal wave, whereas the other two complex roots correspond to the fast-mode and slow-mode waves. The real part of the root for the fast-mode wave is larger than that for the slow-mode wave. The real and imaginary parts of ω respectively give the frequency of the wave and its damping rate.

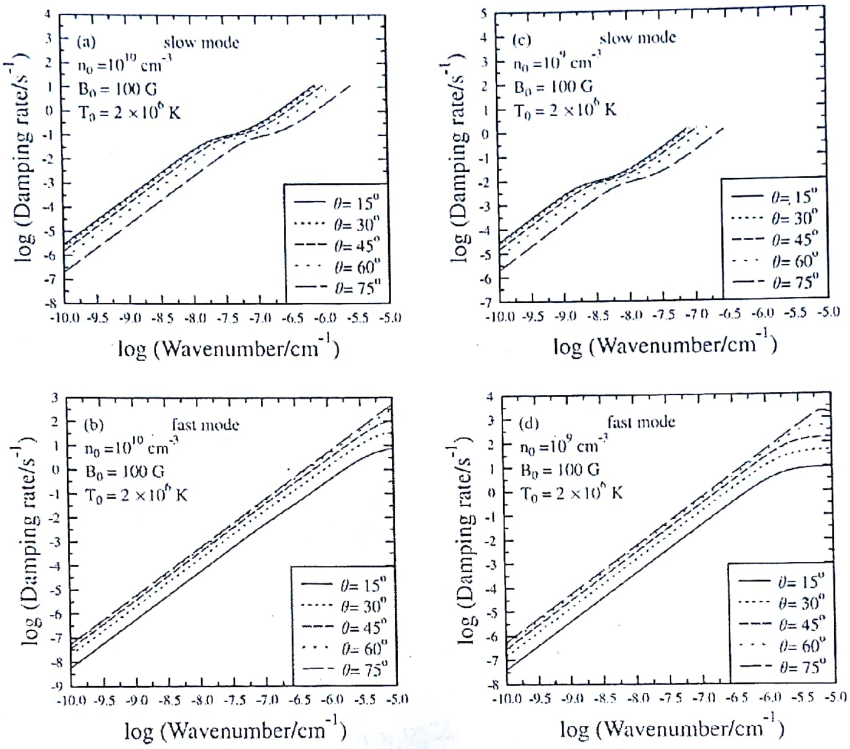

Figure 1: Variation of damping rate as a function of wavenumber for (a) slow-mode wave and (b) fast-mode wave. Parameters values are written in the graph.

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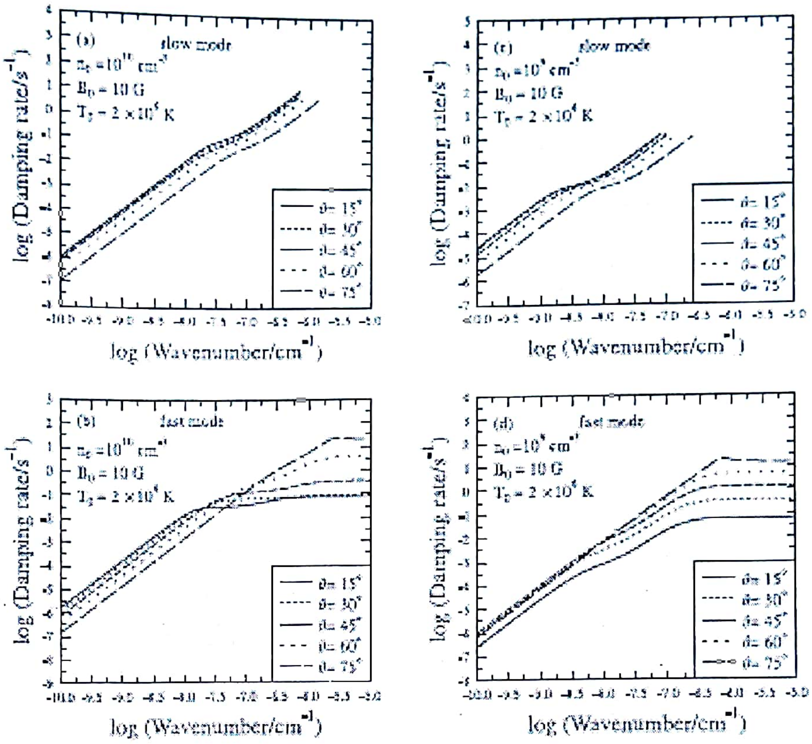

Figure 2: Variation of damping rate as a function of wavenumber for (a) slow-mode wave and (b) fast-mode wave. Parameters values are written in the graph.

Discussion

For the slow-mode waves, I have found that as the value of k increases, after a certain value, called k_c, the slow mode disappears. For the fast mode waves the graph is similar as shown by Kumar et al. [1] in their Figures 1(b) and 2 (b).

Figure 2 is similar to Figure 1, where the magnetic is taken 10G. One can compare Figures 1(a) and 1(c) with Figures 2(a) and 2(c). It gives; the change in magnetic field does not affect the damping rates of slow mode waves. Because of the slow mode waves can propagate with velocity of sound c_s, which is independent of magnetic field (Narain & Agarwal [8]). For the fast mode waves the graph is similar in qualitative nature as shown by Kumar et al. [1] in their Figures 4(a) and 4(b).

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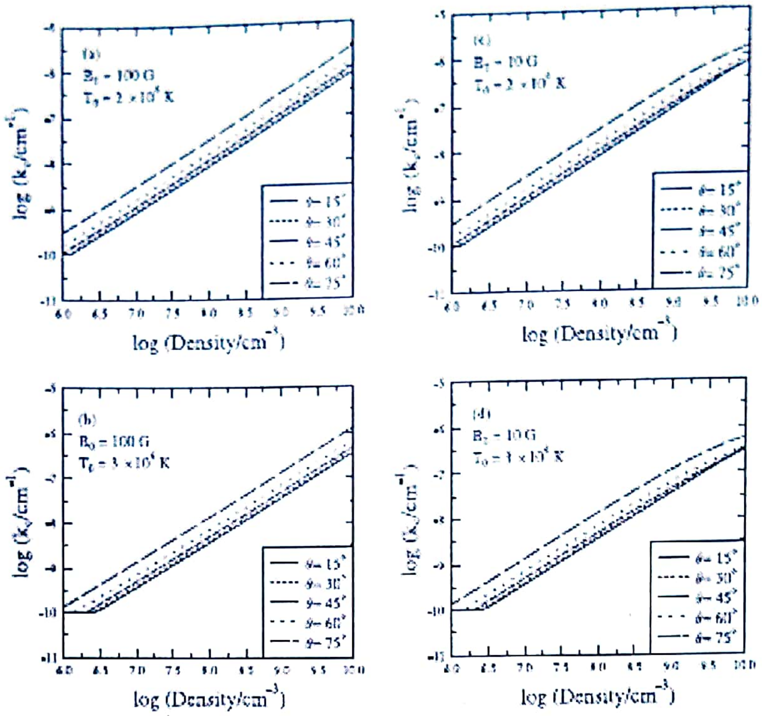

Figure 3: variation of k_c versus density for slow mode waves. Parameter values are written in the graph.

In Figure 3, we have plotted k_c versus density for slow-mode waves for: (a) $T_0 = 2\times10^6$ K and $B_0 = 100$ G, (b) $T_0 = 3\times10^6$ K and $B_0 = 100$ G, (c) $T_0 = 2\times10^6$ K and $B_0 = 10$ G and (d) $T_0 = 3\times10^6$ K and $B_0 = 10$ G. In the figures, we have taken $\theta = 15^o, 30^o, 45^o, 60^o, 75^o$. At larger values of number density ($n_0 \sim 10^{10}$ cm^{-3}) and low values of magnetic field

(B = 10G) the values of k_c become equal for angle less than or equal to 60^o (i.e., $\theta = 15^o, 30^o, 45^o, 60^o$) which gives different values for angle greater than 60^o (i.e., $\theta = 75^o$).

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