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Magnetohydrodynamic (MHD) waves driven by cosmic rays in magnetized self-gravitating dusty molecular clouds

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The equipartition of energy density between interstellar medium, magnetic field and galactic cosmic rays (CRs) imply strong interaction with each other [1,2]. Galactic CRs play a crucial role in the heating and ionization of the dust grains in the molecular clouds. In the photo-dissociation region (PDRs), CRs generate ultraviolet (UV) photons which results in charging of dust grains [2]. The charged dust grains interact with CRs and drive MHD waves. In this work, the influence of galactic cosmic rays (CRs) on low-frequency magnetohydrodynamic (MHD) waves and linear gravitational instability in a typical dusty plasma environment of molecular clouds (MCs) is examined in terms of CR pressure and parallel CR diffusion. The dusty fluid model is developed by incorporating the equations governing magnetized electrons, ions, and dust particles while accounting for CR effects. The interaction between CR fluid and gravitating magnetized dusty plasma is analyzed through the modified dispersion properties of MHD waves and instabilities using a hydrodynamic fluid–fluid (CR–plasma) approach.

CR diffusion influences the coupling between the CR pressure-driven mode and the dust-Alfvén MHD mode, leading to damping in MHD waves. This effect persists along the magnetic field direction while diminishing in the perpendicular direction. The phase-speed diagram shown in Figure 1 (left) indicates that for super-Alfvénic waves, the slow mode transitions into the intermediate Alfvén mode.

In a self-gravitating clouds, while the fundamental Jeans instability criterion remains unaffected by CR effects, in the absence of CR diffusion, the contributions of dust-acoustic speed and CR pressure-driven wave speed become evident in the instability criterion. CR pressure is found to have a stabilizing effect, whereas CR diffusion enhances the growth rate of Jeans instability, significantly impacting the gravitational collapse of dusty MCs. These findings are discussed in the context of gravitational instability in the dusty PDRs of MCs[4]. The work is supported by Science and Engineering Research Board (SERB), New Delhi, India under project no. CRG/2022/000591.

References
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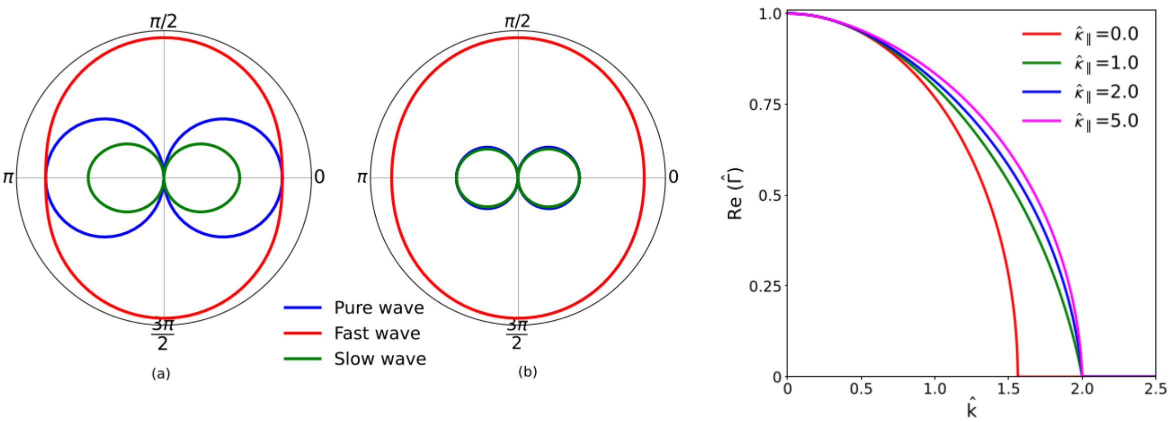

Figure 1. Friedrich diagram of the phase speed (left) is depicted for the case of (a) sub- Alfvénic and (b) super-Alfvénic case. On the right, the growth rate of Jeans instability (Γ) is plotted against wavenumber (k) to show the impact of CR diffusion coefficient ($\boldsymbol{\kappa}_{/\!/}$) considering CR pressure = 0.4 $V_A/(\gamma_{cr}\rho_{d0})$, where V_A is the Alfvén speed, γ_{cr} is the adiabatic index of CRs and ρ_{d0} is the dust density.