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Dust Correlation Effects on Dust Density Waves in Presence of Streaming Magnetized Background Ions

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The complex plasma medium is a system of ionized gas where the collective effects are determined by the charge, mass, temperature, and strength of interaction of microparticles. The strength of interaction categorizes the medium as weakly, moderately, or strongly coupled. Strongly coupled complex plasmas have recently gained attention due to their ability to achieve strong coupling at room temperature, leading to long-range order and changes in collective dynamics. [1]

In this study, we focus on Dust Density Waves (DDWs), which can be self-excited in the presence of streaming ions. The presence of a sheath electric field or an externally applied electric field to levitate the dust cloud in laboratory settings is usually responsible for the ion drift. [2] We study the DDWs in the strongly correlated regime using the Generalized Hydrodynamics (GH) model, which considers correlations among the dust particles phenomenologically using a viscoelastic operator. [3]

Additionally, we consider the impact of an external magnetic field that magnetizes the streaming ions on DDWs, as such experiments are being performed in various experimental facilities like the MDPX and also due to the resemblance of such magnetized systems with various astrophysical environments and fusion plasmas where magnetic fields are present.[4] We derive a dispersion relation and discuss the effect of streaming magnetized ions on DDWs, considering the effect of strong correlations of the dust in the hydrodynamic regime. Furthermore, we discuss the general condition of the ion-streaming instability across a broad parameter regime. We consider the streaming ions in two limits: (a) strongly magnetized and (b) unmagnetized, and our results indicate that a critical Mach number or an electric field is required to excite the wave at a given pressure and magnetic field. We also theoretically estimate the critical instability conditions in both the limits and compare them to the exact numerical values and are found to correctly predict the conditions to a very good approximation as shown in Figure 1. We observe that the magnetized ions influence the instability conditions and the wave phase velocity for a range of dust coupling regimes.

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References

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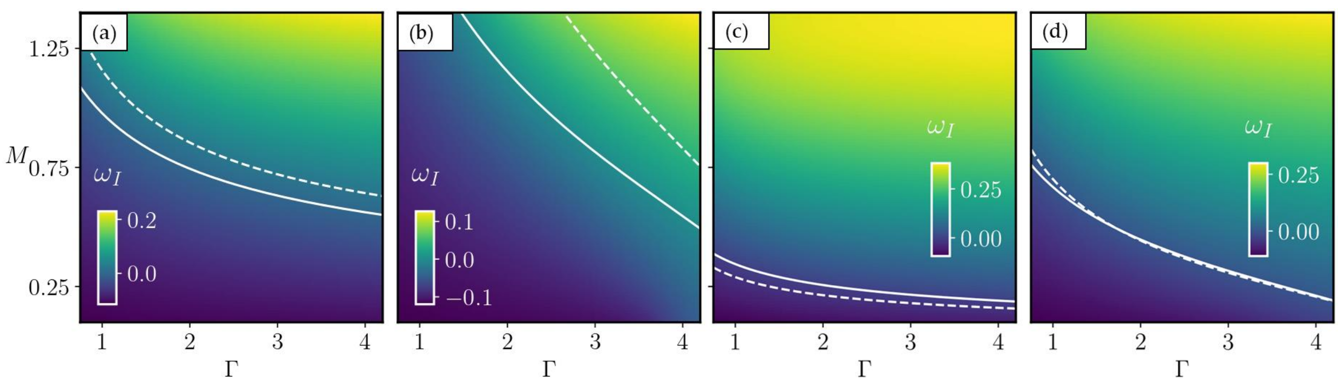

Figure 1. The exact growth rate of the DDW is plotted in the (Γ, M) plane for different values of κ, for unmagnetized: (a) 1.5, and (b) 2.5, and strongly magnetized limits: (c) 1.5 and (d) 2.5 The white line denotes the (Γ, M) values for which $\omega_i = 0$ and the dashed line denotes the exact numerical values of the cut off ion thermal Mach number for the onset of the instability.