Astrophys Space Sci
DOI 10.1007/s10509-013-1681-1

ORIGINAL ARTICLE

Velocity shear effect on the longitudinal wave in a strongly coupled dusty plasma

S. Garai · D. Banerjee · M.S. Janaki · N. Chakrabarti

Received: 4 September 2013 / Accepted: 27 October 2013

Abstract The characteristics of longitudinal dust acoustic wave (DAW) in presence of velocity shear have been investigated in a strongly coupled dusty plasma using the generalized hydrodynamic (GH) model. In the hydrodynamic regime ($\omega\tau_m \ll 1$), i.e. when characteristic time τ_m is slower than inverse of wave frequency, the viscosity in the GH model plays the usual role of wave damping, whereas in the kinetic regime ($\omega\tau_m \gg 1$), i.e. when characteristic time τ_m is larger than inverse of wave frequency, viscosity shows energy storing property in the wave. In the kinetic regime, we have studied the longitudinal mode $\omega^2 = k^2(c_d^2 + c_l^2)$ (where ω is the frequency, k is the wave number, c_d is the dust acoustic velocity and c_l is the longitudinal velocity that arises due to viscosity) in presence of velocity shear. It is shown that velocity shear can destabilize this mode. Both nonmodal and modal techniques are employed to demonstrate the growth rate of the instability.

Keywords Strongly coupled dusty plasma · Dust acoustic mode · Velocity shear · Non modal

S. Garai (✉) · D. Banerjee · M.S. Janaki · N. Chakrabarti
Saha Institute of Nuclear Physics, 1/AF Bidhannagar,
Kolkata 700064, India
e-mail: sudip.garai@saha.ac.in

D. Banerjee
e-mail: debabrata.banerjee@saha.ac.in

M.S. Janaki
e-mail: ms.janaki@saha.ac.in

N. Chakrabarti
e-mail: nikhil.chakrabarti@saha.ac.in

1 Introduction

The physics of strongly coupled plasma (SCP)—in which the average potential energy per particle dominates over the average kinetic energy—is of great interest because of its potential applications to a large number of physical systems starting from laboratory to interstellar space plasma. A complex (dusty) plasma in a laboratory (Fortov et al. 2006; Rosenberg 2001) is an example of such a system. Different astrophysical systems such as the ion liquid in white dwarf interiors (Verheest 2000), neutron star crusts, supernova cores and giant planetary interiors; condensed matter systems such as molten salts and liquid metals as well as degenerate electron or hole liquids in two-dimension or layered semiconductor nano-structures are known to exist in SCP state (Kalman et al. 1998). The collective modes in such plasmas have been studied to characterize the physics of the mode and also for making wide application to the laboratory and space plasmas (Mendis and Rosenberg 1994; D'Angelo 1995; Zobaer and Mamun 2013; Xie and Yu 2000).

In a dusty plasma, beside the electrons and the most abundant ion species, there is an additional species with a different mass and charge. The presence of the new species is expected to result in new effects in the collective-mode behavior of the plasma as compared to those in a simple electron-ion plasma (Ghosh and Bharuthram 2008; El-Awady and Djebli 2012). Due to the large amount of charge on a single dust particle, the effect of correlations become important because of which the dust fluid can show strong viscous properties even leading to viscoelastic behavior (Kaw and Sen 1998). The strength of the coupling is characterized by the Coulomb coupling parameter (Ikeji 1986) $\Gamma = q_d^2/(k_B T_d a)$, where q_d is the charge on the dust grains, $a(\simeq n_d^{-1/3})$ is the average distance between them, n_d, T_d are the density

Published online: 07 November 2013