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ORIGINAL ARTICLE

# Effect of quantum corrections on the Jeans instability of self-gravitating viscoelastic dusty fluid

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**Abstract** In this paper we investigate the effects of quantum correction on the Jeans instability of self-gravitating viscoelastic dusty electron-ion quantum fluids. The massive self-gravitating dust grains are assumed to be strongly coupled and non-degenerate having both viscous and elastic behavior while the inertialess electrons and ions are considered as weakly coupled and Fermi degenerate. The hydrodynamic model is modified and a linear dispersion relation is derived employing the plane wave solutions on the linearized perturbation equations for the considered system. It is observed that the dispersion properties are affected due to the presence of viscoelastic effects and quantum statistical corrections. The modified condition of Jeans instability and expression of critical Jeans wavenumber are obtained. Numerically it is shown that viscoelastic effects, dust plasma frequency and quantum statistical effects all have stabilizing influence on the growth rate of gravitationally Jeans mode. The growth rates are also compared in kinetic and hydrodynamic limits and it is found that decay in the growth of unstable Jeans mode is larger under the kinetic limits than the hydrodynamic limits. The results are discussed for the understanding of formation of dense degenerate dwarf star through gravitational collapsing which is assumed to be strongly coupled dusty quantum fluid where the strongly coupled dust provides inertia and Fermi degenerate electron and ions provide quantum statistical effects.

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## 1 Introduction

The dusty or complex plasmas have an extensive range of applications in molecular cloud formation, planetary rings, fusion plasmas, low-temperature laboratory plasmas, and processing plasmas in the semi-conductor industry. The dust grains with average potential energy greater than kinetic energy (so called strongly coupled complex plasma) emerge new area of research in laboratory experiments, simulation studies and in astrophysical systems. The properties of strongly coupled dusty plasma (SCDP) deal with so many exciting and important phenomena which cover the gain about formation of plasma crystal, dense dwarf stars, neutron star and interior of heavy planets (Ohta and Hamaguchi 2000; Rosenberg and Kalman 1997; Kalman et al. 2000). The variation in coupling parameter $\Gamma = q^2/(4\pi\varepsilon_0 a T_d)$ (where $q$, $a$ and $T_d$, are the dust charge, the intergrain distance and dust temperature respectively) over a wide range ($1 \le \Gamma \le 2000$) shows many interesting phenomenon and applications of SCDP. In this direction, the collective behavior of an SCDP liquid ($\Gamma_c \gg \Gamma \gg 1$) and the resulting low-frequency modes and instability have been already investigated theoretically (Sorasio et al. 2003).

Moreover, the temperature in some complex systems are reported extremely low providing new interesting phenomena. At extremely low temperature ($T \ll T_F$, where $T_F$ is the Fermi temperature) the de-Broglie wavelength of the charge particle ($\lambda_{Bj} = h/2\pi m_j V_{Tj}$, where $j = e, i$, $m_j$ is mass of electron and ion, $V_{Tj}$ is thermal velocities of electron and ion) becomes comparable to the dimension of the system ($\lambda_{Bj} \ge \lambda_{Dj}$, where $\lambda_{Dj}$ is the Debye length of the charge particles) and thus the quantum

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