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ORIGINAL ARTICLE

Self-gravitational instability in magnetized finitely conducting viscoelastic fluid

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Abstract The linear self-gravitational instability of finitely conducting, magnetized viscoelastic fluid is investigated using the modified generalized hydrodynamic (GH) model. A general dispersion relation is obtained with the help of linearized perturbation equations using the normal mode analysis and it is discussed for longitudinal and transverse modes of propagation. In longitudinal propagation, we find that Alfven mode is uncoupled with the gravitating mode. The Jeans criterion of instability is determined which depends upon shear viscosity and bulk viscosity while it is independent of magnetic field. The viscoelastic effects modify the fundamental Jeans criterion of gravitational instability. In transverse mode of propagation, the Alfven mode couples with the acoustic mode, compressional viscoelastic mode and gravitating mode. The growth rate of Jeans instability is compared in weakly coupled plasma (WCP) and strongly coupled plasma (SCP) which is larger for SCP in both the modes of propagations. The presence of finite electrical resistivity removes the effect of magnetic field in the condition of Jeans instability and expression of critical Jeans wavenumber. It is found that Mach number and shear viscosity has stabilizing while finite electrical resistivity has destabilizing influence on the growth rate of Jeans instability.

Keywords Self-gravitational instability · Viscoelastic fluid · Magnetic field · Dense stars · Finite electrical resistivity

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1 Introduction

The formation of stellar objects through gravitational fragmentation leads to the well known self-gravitational (Jeans) instability. This process occurs in the structuring of stars, spiral arms of galaxies, nebula, comets, interstellar media (ISM), intergalactic medium which is first discussed by Jeans (1902). In this direction, many researchers have investigated the Jeans instability in various kinds of plasma environment e.g. gaseous plasma, fluid plasma, dusty plasma and Fermi degenerate quantum plasma (Chandrasekhar 1961; Mace et al. 1998; Ren et al. 2009). Along with this there are so many objects which exist in strongly coupled state viz. atmosphere of neutron star, dwarf star, interior of planets and ultra cold neutral plasma (Rosenberg and Shukla 2011). In these systems the Coulomb potential energy is much greater than the average thermal energy of the plasma particles. The ratio of the Coulomb potential energy to the thermal energy is called the coupling parameter which is represented by $\Gamma = q^2/4\pi\varepsilon_0 a k_B T$ (where q is charge of particles and a is Wigner-Seitz radius) thus for strongly coupled plasma $\Gamma \gg 1$. These objects are supposed to be composed of viscoelastic fluid which is strongly coupled and show both viscous and elastic behaviour.

In recent past years, the waves and instability of dense strongly coupled systems is analyzed by many authors. The stability of such systems is discussed using the generalized hydrodynamic (GH) model in which the coefficient of viscosity behaves like viscoelastic operator (Frenkel 1946). An extensive work has been carried out to investigate the stability of strongly coupled plasma (SCP) in both theoretical and experimental ways. Using this model, Kaw and Sen (1998) have discussed the low frequency wave modes in strongly coupled dusty plasma (SCDP) and found that for the well known dust acoustic mode strong correlations provide new