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ORIGINAL ARTICLE

Higher order corrections to dust-acoustic ZK-solitons in a magnetized quantum dusty plasma

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Abstract Nonlinear propagation of two dimensional dust-acoustic solitary waves in a magnetized quantum dusty plasma whose constituents are electrons, ions, and negatively charged heavy dust particles are investigated using quantum hydrodynamic model. The Zakharov-Kuznetsov (ZK) equation is derived by using reductive perturbation technique (RPT). The higher order inhomogeneous ZK-type differential equation is obtained for the correction to ZK-soliton. The dynamical equation for dressed soliton is solved by using renormalization method. The effects of obliqueness (l_x) of the wave vector, magnetic field strength (B_0), quantum parameter for ions (H_i), soliton velocity (θ) and Fermi temperature ratio (σ) on amplitudes and widths of the ZK-soliton and as well as of the dressed soliton are investigated. The conditions for the validity of the higher order correction are described. Suitable parameter ranges for the existence of compressive and rarefactive dressed solitons are also discussed.

Keywords Dust-acoustic waves · Dressed soliton · Quantum magnetized plasma · RPT method · ZK-equations

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1 Introduction

When the plasma is cooled to extremely low temperatures or the densities are very high enough then it is sufficient to consider the plasma as degenerate. Generally electrons are considered to be degenerate because of their small masses but to make the system more accurate, we also consider the degenerate ions. Since the de-Broglie wavelength of the charge carriers becomes comparable to the scale lengths, such as Debye length or Larmor radius in the system, and in such systems, the ultracold dense plasma would behave as a Fermi gas and quantum mechanical effects play a crucial role in the behavior of charged particles of these plasmas. Quantum effects in such plasmas become important when the thermal de Broglie wavelength (λ_{Bj}) is comparable to or larger than the average inter-particle distance $n_j^{-1/3}$ i.e. when $n_j\lambda_{Bj}^3 \geq 1$. Where $\lambda_{Bj} = \frac{\hbar}{\sqrt{m_j K_B T}}$ is the thermal de-Broglie wavelength for the j-th species, $\hbar$ is the Planck's constant divided by 2π, K_B is the Boltzman constant and T is the system temperature. As the dust particles are heavier than both ions and electrons, we consider that the dust particles behaves classically. In microelectromechanical system, ultra small electronic devices etc. impurities play the role of dust particles (Kremp et al. 1999). Thus the existence of dust plays an important role to modify the plasma dynamics. Progress of dusty plasma research has seen increasing interest due to its relevance in space, laboratory, and astrophysical plasma environments (Mendis and Rosenberg 1994; Verheest 2000; Shukla and Mamun 2002). Propagation of nonlinear dust acoustic (DA), ion-acoustic (IA), electron-acoustic (EA), dust-ion-acoustic (DIA) waves in both magnetized and unmagnetized quantum dusty plasmas has been studied theoretically by many authors (Hass et al. 2003; Shukla and Eliasson 2006; Masood et al. 2007; Misra et al. 2008; Shukla 2008; Sah and Manta 2009;