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ORIGINAL ARTICLE

Nonlinear electrostatic coherent structures: solitary and shock waves in a dissipative, nonplanar multi-component quantum plasma

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Abstract The nonlinear propagation of ion-acoustic solitary and shock waves in a dissipative, nonplanar quantum plasma comprised of electrons, positrons, and ions are studied. A modified Korteweg-de Vries Burgers equation is derived in the limit of low frequency and long wavelength by taking into account the kinematic viscosity among the plasma constituents. It is shown that this plasma system supports the propagation of both compressive and rarefactive nonlinear waves. The effects of variation of various plasma parameters on the time evolution of nonplanar solitary waves, the profile of shock waves, and the nonlinear structure induced by the collision of solitary waves are discussed. It is found that these parameters have significant effects on the properties of nonlinear waves in cylindrical and spherical geometries, and these effects for compressive and rarefactive nonlinear waves are obviously different.

Keywords Quantum plasma · Nonplanar geometry · Ion-acoustic wave

1 Introduction

A multi-component plasma system is a fully or partially ionized mixed gas consisting of arbitrary number of charged and neutral species satisfying the condition of quasi-neutrality. In general, there are three types of widely studied multi-component plasma systems, which are multi-ion plasma containing more than one type of ions, dusty plasmas containing heavy dust particles besides electrons and ions (Hasan et al. 2013), and electron-positron-ion ($e-p-i$) plasma which contain the antiparticle of electron, i.e., positron, besides the conventional electrons and ions (Ghosh and Chatterjee 2013; Chatterjee et al. 2012; Valiulina and Dubinov 2012; Ghosh and Bharuthram 2011; Pakzad and Javidan 2011). The investigation of collective phenomena in electron-positron ($e-p$) plasmas has attracted considerable attention during the past decade (Saberian and Esfandyari-Kalejahi 2013; Ridgers et al. 2012; El-Taibany and Mamun 2012; Shukla et al. 2011; Nerush et al. 2011). Electron-positron pairs, a fully ionized gas composed of electrons and positrons having equal masses and charges with opposite polarity, is found near the polar caps of pulsars, in active galactic nuclei, in the earlier universe, in magnetospheres of neutron stars, and in the inner region of accretion discs in the vicinity of black holes, will always be created in a system whose temperature exceeds twice the electron rest mass (∼1.2 MeV) (Tajima and Taniuti 1990). These plasmas are also observed in laboratory experiments in which the positrons can be used to probe the particle transport in tokamak plasmas (Greaves and Surko 1995). In the $e-p$ pair, the plasma frequency ω_p is modified (Saleem et al. 2003), i.e., it is $\omega_p^2 = 2\omega_e^2$, where $\omega_e^2 = n_0 e^2/\epsilon_0 m_e$, as well as other quantities such as the Debye length, the Alfvén velocity, etc.

However, because of the rather long life time of positrons compared to the ion time scale, most of the astrophysical and laboratory plasmas become an admixture of electrons, positrons, and ions (here referred as $e-p-i$). Such $e-p-i$ plasmas are rather widespread in astrophysical systems, in space environments, as well as in laboratory plas-

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