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ORIGINAL ARTICLE

Ion acoustic solitary and shock waves with nonextensive electrons and thermal positrons in nonplanar geometry

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Abstract The nonlinear wave structures of ion acoustic waves (IAWs) in an unmagnetized plasma consisting of nonextensive electrons and thermal positrons are studied in bounded nonplanar geometry. Using reductive perturbation technique we have derived cylindrical and spherical Korteweg-de Vries-Burgers' (KdVB) equations for IAWs. The presence of nonextensive q-distributed electrons is shown to influence the solitary and shock waves. Furthermore, in the existence of ion kinematic viscosity, the shock wave structure appears. Also, the effects of nonextensivity of electrons, ion kinematic viscosities, positron concentration on the properties of ion acoustic shock waves (IASWs) are discussed in nonplanar geometry. It is found that both compressive and rarefactive type solitons or shock waves are obtained depending on the plasma parameter.

Keywords Ion acoustic waves · Electron-positron-ion plamsa · Solitary or shock waves

1 Introduction

The study of linear and nonlinear wave propagation of electron-positron plasmas attracted a considerable interest during the last few decades due to their presence in Van Allen radiation belts and near the polar cap of fast rotating neutron stars (Michel 1991; Lightman 1982; Burns and Lovelace 1982; Zdziarski 1987), active galactic nuclei (Miller and Witta 1987; Goldreich and Julian 1969), quasars and pulsar magnetosphere (Reynolds et al. 1996; Hirotani et al. 1999; Michel 1982), semiconductor plasmas (Shukla et al. 1986), intense laser fields (Berezhiani et al. 1992), etc. Also it has been found that positrons can be produced in tokamaks due to the collision of runaway electrons with plasma ions and thermal electrons (Helander and Ward 2003). A great deal of research has been made to study the electron-positron and electron-positron-ion plasmas during the last three decades (Nejoh 1996; Verheest et al. 1995; Sarby et al. 2009; Salahuddin et al. 2002; Mahmood and Akhtar 2008; Shukla et al. 2004; Pakzad 2011a).

It is well-known, Maxwellian distribution in Boltzmann-Gibbs (B-G) statistics is believed valid universally for the macroscopic ergodic equilibrium systems. However, numerous observation of space plasmas (Vasyliunas 1968; Leubner 1982; Armstrong et al. 1983) are often characterized by a particle distribution function with high energy tail and they may thus deviate from Maxwellian. For the systems with the long-range interactions, such as plasma and gravitational systems, where the non-equilibrium stationary states exist, Maxwellian distribution might be inadequate for the description of the systems. In the experiment for measuring the ion acoustic waves, the energy distribution of electrons may actually be not the Maxwellian one and hence it is hard to determine the valid electron temperature (Alexeff and Neidigh 1963). The non-Maxwellian velocity distributions for electrons in plasma were already measured in the experiment where the temperature gradient was steep (Sarris et al. 1981; Williams et al. 1988). A few examples of physical systems where the standard Boltzmann-Gibbs approach seems to be inadequate are self-gravitating systems and some kinds of plasma turbulence. A growing body of evidence suggests that the q-entropy may provide a convenient frame for the analysis of many astrophysical scenarios, such as stellar polytropes, solar neutrino problem, and peculiar velocity distribution of galaxy clusters. It has been

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