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ORIGINAL ARTICLE

Electron acoustic soliton energy of the Kadomtsev-Petviashvili equation in the Earth's magnetotail region at critical ion density

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Abstract The nonlinear properties of small amplitude electron-acoustic solitary waves (EAWs) in a homogeneous system of unmagnetized collisionless plasma consisted of a cold electron fluid and isothermal ions with two different temperatures obeying Boltzmann type distributions have been investigated. A reductive perturbation method was employed to obtain the Kadomstev-Petviashvili (KP) equation. At the critical ion density, the KP equation is not appropriate for describing the system. Hence, a new set of stretched coordinates is considered to derive the modified KP equation. Moreover, the solitary solution, soliton energy and the associated electric field at the critical ion density were computed. The present investigation can be of relevance to the electrostatic solitary structures observed in various space plasma environments, such as Earth's magnetotail region.

Keywords Electron-acoustic solitary waves · Reductive perturbation · Kadomstev-Petviashvili (KP) equation

1 Introduction

The nonlinear electron acoustic solitary waves (EAWs) have been observed in laboratory devices when the plasma consisted of two temperature electrons, referred to as hot and cold electrons (Ikezawa and Nakamura 1981; Karlstad et al. 1984). Another type of EAWs have been observed in electron-ion plasma with ions hotter than electrons (Fried and Gould 1961; Kakad et al. 2009). In practice, the hot electrons may not follow a Maxwellian distribution due to the formation of phase space holes caused by the trapping of hot electrons in a wave potential (Mamun and Shukla 2002; Shukla et al. 2004). Electron-acoustic mode have been observed in the Earth' magnetosphere by many satellites, e.g. Viking, FAST etc. (Dubouloz et al. 1991, 1993; Cattell et al. 1998; Ergun et al. 1999; Pottelette et al. 1999; Miyake et al. 2000). Several other studies have been devoted before to study the nonlinear propagation of EAWs in an unmagnetized plasma, see Singh and Lakhina (2004), Sahu and Roychoudhurya (2006), El-Shewy (2007), Elwakil et al. (2007), Kakad et al. (2007), Pakzad and Tribeche (2010). Kakad et al. (2009) studied the effect of two temperature ions on the nonlinear evolution of small amplitude EAWs for the three-component plasma consisting of cold electron, low and high temperature ions. They showed that the estimated electric field of the electrostatic structure is in good agreement with the observed solitary wave structures in the Earth's plasma sheet boundary layer. Lakhina et al. (2009, 2011) explained the electron acoustic solitons and double layers in a four-component plasma system consisting of core electrons, two counter streaming electron beams, and one type of ions, to investigate the electrostatic solitary waves observed by CLUSTER satellite in the magnetosheath region. Pakzad and Tribeche (2010) studied the effect of electron nonthermality on the existence and possible realization of electron-acoustic solitary waves using Sagdeev's pseudopotential technique. Sahu and Roychoudhurya (2012) have studied the nonlinear wave structures of electron acoustic waves (EAWs) in an unmagnetized quantum plasma consisting of cold and hot electrons and ions. They used the quantum hydrodynamic model to study the quantum correction of the EAWs and examined the effects of quantum diffraction and Mach number on the nonlinear properties of EA solitary waves. Recently, number of investigations have

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