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ORIGINAL ARTICLE

Energy of electron acoustic solitons in plasmas with superthermal electron distribution

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Abstract The propagation of nonlinear waves in plasmas consisting of cold electron fluid and superthermal hot electrons and stationary ions is studied. The Korteweg-de Vries (KdV) equation is derived using the reductive perturbation theory. It is found that only the rarefractive solitons can be created. Moreover, the linear dispersion relation and energy of solitary waves in the presence of hot superthermal electrons are derived. Our investigation is of wide relevance to astronomers and space scientists working on interstellar space plasmas.

Keywords Electron-acoustic waves · Solitary waves · Superthermal electrons · Soliton energy

1 Introduction

The electron-acoustic wave, which is one of the basic wave processes in plasmas, is a high-frequency (in comparison with the ion plasma frequency) wave that occurs in plasmas having, in addition to positively charged ions, two electron components with widely disparate temperatures (Watanabe and Taniuti 1977; Tokar and Gary 1984; Gary and Tokar 1985). The electron acoustic solitary waves (EASWs) can also be generated by electron and laser beams (Gary and Tokar 1985; Montgomery et al. 2001). Recently, a great deal of interest has been shown in the studies on the propagation of EASWs. They have been observed in space and laboratory plasmas. On the other hand, they are investigated because of their importance in interpreting electrostatic component of the broadband electrostatic noise (BEN) observed in the cusp region of the terrestrial magnetosphere (Tokar and Gary 1984; Singh and Lakhina 2001), in the geomagnetic tail (Schriver and Ashour-Abdalla 1989), in the dayside auroral acceleration region (Dubouloz et al. 1977; Pottelette et al. 1999) and etc. The propagation of EASWs in a plasma system has been studied by several investigators in an unmagnetized two-electron plasma (Dubouloz et al. 1977; Chatterjee and Roychoudhury 1995; Berthomier et al. 2000; Mamun and Shukla 2002) as well as in magnetized plasmas (Mace and Hellberg 2001; Mamun et al. 2002; Berthomier et al. 2003; Shukla et al. 2004). On the other side, space plasma observations indicate clearly the presence of electron populations which are far away from their thermodynamic equilibrium (Gill et al. 2006; El-Shewy 2007b; Vasyliunas 1968; Leubner 1982; Younsi and Tribeche 2010; Pakzad and Tribeche 2010; Sahu 2010b; Armstrong et al. 1983). Numerous observations of space plasmas (Feldman et al. 1973; Formisano et al. 1973; Scudder et al. 1981; Marsch et al. 1982) clearly prove the presence of superthermal electron and ion structures as ubiquitous in a variety of astrophysical plasma environments. Superthermal particles may arise due to the effect of external forces acting on the natural space environment plasmas or because of wave-particle interactions. Plasmas with an excess of superthermal (non-Maxwellian) electrons are generally characterized by a long tail in the high energy region. It has been found that generalized Lorentzian of k distribution can be modeled such space plasmas, better than the Maxwellian distribution (Hasegawa et al. 1985; Thorne and Summers 1991; Summers and Thorne 1991; Summers and Thorne 1994; Mace and Hellberg 1995b). Kappa distribution has been used by several authors (Hellberg and Mace 2002; Podesta

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