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ORIGINAL ARTICLE

Linear and nonlinear propagation of ion-acoustic waves in a multi-ion plasma with positrons and two-temperature superthermal electrons

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Abstract Linear and fully nonlinear features of ion-acoustic waves (IAWs) have been investigated by normal mode analysis (which is valid for extremely small amplitude limit) and pseudopotential approach (which is valid for arbitrary amplitude waves). The plasma is assumed to be composed of nonthermally κ (kappa)-distributed two-temperature electrons (termed as hot and cold), Maxwellian positrons, inertial ions and immobile negatively charged heavy ions. The pseudo-energy balance equation is derived from the fluid dynamical system of equations, and the properties of arbitrary amplitude ion-acoustic wave (IAW) excitations are examined. The basic features (width, amplitude, polarity, critical Mach number, speed, etc.) of IAWs are found to be significantly modified by the effects of positrons, heavy ions as well as by the effects of κ-distributed two-temperature superthermal electrons. The analytical and numerical results presented in this manuscript could be useful for explaining and understanding the basic features of solitary structures in astrophysical environments, where two-temperature superthermal electrons and thermal positrons exist.

Keywords mIAWs · Superthermal electrons · Heavy ions · Positrons

1 Introduction

The analysis of solitary wave characteristics has become an interesting topic of research to plasma physicists during last few decades. The presence of mobile ions in an electron-positron plasma (Goldrich and Julian 1969; Michel 1982) can generate a low frequency acoustic mode due to the inertial effect of ions mass. The characteristics of solitary wave excitations (arises due to the balance between the nonlinearity and dispersion) in such plasma (i.e. electron-positron-ion (epi) plasma) have been investigated by many authors (Berezhiani et al. 1994; Popel et al. 1995; Rizzato 1988; Esfandyari-Kalejahi et al. 2012; Roy et al. 2012a, 2012b; El-Tantawy et al. 2011; Jehan et al. 2009). It is worth to mention that the most of the space plasma environments (such as Saturn's rings, Halleys comet, etc.) consist of massive charged particles (heavy ions or dust particles of constant charge (Shukla and Mamun 2002; Roberts et al. 1987).

A large number of theoretical (Rao et al. 1990; Esfandyari-Kalejahi et al. 2012; Roy et al. 2012a, 2012b; El-Tantawy et al. 2011; Ali and Shukla 2006; Jehan et al. 2009; Baluku et al. 2010) and experimental (Thompson et al. 1997; Nakamura and Sharma 2001; Nakamura et al. 1999) investigations have shown that the presence of negatively charged dust particles or heavy ions modifies the nonlinear propagation of IAWs waves significantly. Also many theoretical research has been carried out to investigate the properties of dust-ion-acoustic waves (DIAWs) (El-Tantawy et al. 2011; Dubinov et al. 2012) and dust-acoustic waves (DAWs) (Esfandyari-Kalejahi et al. 2012; Jehan et al. 2009) in dust-electron-positron-ion (depi) plasmas. It is noted here that the existence of two-temperature electrons has been confirmed by many investigations (Sheridan et al. 1991; Passoni et al. 2004). The wave properties may be influenced due to the presence of negatively charged heavy ions and due to the presence of two-temperature electrons in an epi plasma. We note that in the modified IAWs (mIAWs), the inertia is provided by positive ion mass, the restoring force is provided by the thermal pressures of positrons/two-temperature elec-

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