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ORIGINAL ARTICLE

Korteweg-de Vries equation for ion acoustic soliton with negative ions in the presence of nonextensive electrons

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Abstract Korteweg-de Vries (KdV) equation for electrostatic ion acoustic wave in a three component plasma containing positive and negative ions along with the nonextensive electrons is derived. Fast and slow ion acoustic modes which propagate with different velocities are excited. The effects of variation of quantities like q (nonextensive parameter), Q (mass ratio of positive to negative ion), μ (electron to positive ion number density ratio), θ_i (positive ion to electron temperature ratio) and θ_n (negative ion to electron temperature ratio) have been presented for fast and slow ion acoustic modes. Both compressive and rarefactive solitons are observed. It is found that the solitary excitations strongly depend on the mass and density ratios of the positive and negative ions as well as on nonextensive electron parameter.

Keywords Nonextensive electrons · KdV equation · Reductive perturbative technique · Positive and negative ions

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1 Introduction

Recently, nonlinear wave propagation in plasmas has become one of the most important subjects of plasma physics. There are different types of differential equations e.g., the Korteweg-de Vries (KdV) equation, modified Korteweg-de Vries equation (mKdV) and nonlinear Schrödinger equation (NLSE) (Dodd et al. 1982) which are helpful in understanding the properties of these nonlinear plasma waves. Nonlinear wave structures such as solitons, shocks and double layers are formed due to competition between nonlinearity, dispersion and dissipation present in the system. Among the most investigated nonlinear structures are ion-acoustic solitary waves (IAWs). Washimi and Taniuti (1966) were the first to derive the KdV equation for ion acoustic (IA) solitons in a plasma. Since then, the plasma physics community has been actively involved in soliton theory and nonlinear phenomena related structures, instabilities, wave-wave interaction, wave-particle interaction and methodologies related to plasma modes (Davidson 1972). The pseudopotential approach and reductive perturbation method have been applied to study these waves in the arbitrary and small amplitude limits, respectively. The reductive perturbation method (RPM) has frequently been used to study theoretically ion acoustic solitons which were later on verified experimentally by a number of researchers (Lonngren 1998; Saitou and Nakamura 2005).

Most of the studies have been carried out, by considering the plasma systems in thermal equilibrium. The plasma species in thermal equilibrium follow the Maxwellian-Boltzmann distribution. But this ideal thermal equilibrium assumption is no longer valid where some external agents (e.g., force field present in natural space plasma environments, wave-particle interaction, turbulence, etc.) disturb the thermal equilibrium of the plasma environments. Spatial observations revealed the existence of non-Maxwellian