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ORIGINAL ARTICLE

The characteristics of ion acoustic shock waves in non-Maxwellian plasmas with (G'/G)-expansion method

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Abstract Korteweg-de-Vries-Burger (K-dVB) equation is derived for ion acoustic shock waves in electron-positron-ion plasmas. Electrons and positrons are considered superthermal and are effectively modeled by a kappa distribution in which ions are as cold fluid. The analytical traveling wave solutions of the K-dVB equation investigated, through the (G'/G)-expansion method. These traveling wave solutions are expressed by hyperbolic function, trigonometric functions are rational functions. When the parameters are taken special values, the shock waves are derived from the traveling waves. It is observed that the amplitude ion acoustic shock waves increase as spectral index κ and kinematic viscosity $\eta_{i,0}$ increases in which with increasing positron density β and electron temperature σ the shock amplitude decreases. Also, numerically the effect different parameters on the nonlinearity A and dispersive B terms and wave velocity V investigated.

Keywords Non-Maxwellian plasmas · Ion acoustic shock waves · (G'/G)-expansion method

1 Introduction

The propagation of linear and nonlinear waves and their stability properties in Maxwellian plasmas have been investigated by many authors (Lonngren 1983; Nakamura et al. 1985, 1993; Chatterjee and Roychoudhury 1997; Kourakis and Shukla 2003). However, in many cases such as solar wind, magnetosphere and auroral zone plasmas particles are often characterized by velocity distributions are not Maxwellian and modeled by a Kappa (or generalized Lorentzian) distribution function (Vasyliunas 1968; Leubner 2002; Pierrard and Lazar 2010; Hellberg et al. 2000, 2009; Baluku and Hellberg 2008). The three-dimensional isotropic κ velocity distribution is given by (Leubner 2002; Baluku and Hellberg 2008; Hellberg et al. 2009)

$$f_k(v) = \frac{n_0}{(\pi\kappa\theta^2)^{3/2}} \frac{\Gamma(\kappa+1)}{\Gamma(\kappa-1/2)} \left(1 + \frac{v^2}{\kappa\theta^2}\right)^{-(\kappa+1)} \tag{1}$$

where n_0 is the species equilibrium number density, $\theta = [(1-3/(2\kappa))(2k_B T/m)]^{1/2}$ is the characteristic velocity, T is the kinetic temperature and m is the species mass. Here $v^2 = v_x^2 + v_y^2 + v_z^2$ obviously denotes the square velocity norm of the velocity v, $\Gamma(x)$ is the usual gamma function and κ is the spectral index that measuring deviation from Maxwellian equilibrium. We shall note that the effective thermal speed θ is only defined for $\kappa > 3/2$, and thus when considering physical quantities derived from (1), such as the density, we shall use $\kappa > 3/2$. For large values of κ (in limit $\kappa \to \infty$) Kappa distributions reduces to Maxwellian distribution.

Kappa distribution was first suggested by Vasyliunas (1968) to model space plasmas. Applications of the κ distribution function include, for example, an interpretation of observations in the earth's foreshock (for $3 < \kappa < 6$) (Feldman et al. 1982) and solar wind models with coronal electrons satisfying $2 < \kappa < 6$ (Pierrard and Lemaric 1996). Recently the propagation waves in the presence of a Kappa distribution with excess superthermal particles investigated by many authors. Hellberg and Mace (2002) observed a generalized plasma dispersion function for a plasma with a Kappa velocity distribution. They the effects of superthermal electrons and ions on nonlinear ion acoustic waves have investigated. Arbitrary amplitude ion acoustic waves excitations

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