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ORIGINAL ARTICLE

Soliton and shocks in pair ion plasma in presence of superthermal electron

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Abstract Solitons and shocks are addressed in a pair ion plasma in the presence of a kappa distribution. The dissipation is taken care of through the kinematic viscosity of both positive and negative ions in the plasma. The Kadomtsev–Petviashvili–Burger (KPB) equation is derived using the small amplitude expansion method. The Abel equation is obtained from the KPB equation and a solution is obtained by using the factorization method. The effect of the parameters κ and β (temperature ratio of ion species) is observed. Analytically we can find both solitons and shocks. The change of profile from soliton to shocks is shown in the figures. This study may be of wide relevance for the study of the formation of shocks and solitons in laboratory-produced pair ion plasmas.

Keywords Pair ion · Superthermal electron

1 Introduction

Plasma physics has been developing day by day in the previous two decades in different fields such as planetary rings, cometary tails, interplanetary medium and interstellar clouds, and the lower parts of the earth's ionosphere (Shukla et al. 2002; Verheest 2000; Mendis and Rosenberg 1994). In most cases of these observations one assumed a Maxwellian velocity distribution of the plasma species, but numerous studies on space environment clearly indicate that these particles have a velocity distribution which deviates from Maxwellian behavior (Asbridge et al. 1983; Divine and Garret 1983; Krimigis et al. 1983; Sahu 2010). The kappa or the generalized Lorentzian distribution is used as a versatile tool to study the kinetic modeling of waves and instabilities in space plasma, but these plasmas only have been considered in so far as they have been unmagnetized or they had wave propagation parallel to the ambient magnetic field. This distribution obeys an inverse power law at high velocities, and for all velocities the Maxwellian distribution behaves as a special case of the kappa distribution. The kappa distribution is highly favored in any kind of space plasma modeling where a reasonable physical background is not apparent. The family of kappa distributions is obtained from the positive definite part $12 \leq \kappa \leq \infty$, corresponding to $-1 \leq q \leq 1$ of the general statistical formalism. If we take a generalized Lorentzian or kappa distribution as $f_0(v) = (1 + v^2/(\kappa/\theta^2))^{-(\kappa+1)}$ where $V = V_x^2 + V_y^2 + V_z^2$ and θ is the effective thermal speed related to usual thermal speed $V_{\mathrm{th}} = (2K_B T/m)^{1/2}$ by $\theta^2 = [(\kappa - 3/2)/\kappa]V_{\mathrm{th}}^2$ and κ is the spectral index, a measure of the slope of the energy spectrum of the superthermal particles forming the tail of the velocity distribution (Chatterjee et al. 2010; Choi et al. 2011). This velocity distribution approaches the Maxwellian one at very large values of κ, while at low values of κ, they act as a harder energy spectrum with a strong non-Maxwellian tail, having a power law form at high velocities. Typical values of κ for the space plasma lie between 2–6.

The pair plasma plays a significant role in plasma physics due to numerous astrophysical environments such as the pulsar magnetosphere, active galactic nuclei, neutron stars etc., where intense energies create electron positrons through pair production and annihilation. The physics of the pair plasma became more interesting when it descended from its astro-

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