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ORIGINAL ARTICLE

Electron-acoustic solitary structures in two-electron-temperature plasma with superthermal electrons

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Abstract The propagation of nonlinear electron-acoustic waves (EAWs) in an unmagnetized collisionless plasma system consisting of a cold electron fluid, superthermal hot electrons and stationary ions is investigated. A reductive perturbation method is employed to obtain a modified Korteweg–de Vries (mKdV) equation for the first-order potential. The small amplitude electron-acoustic solitary wave, e.g., soliton and double layer (DL) solutions are presented, and the effects of superthermal electrons on the nature of the solitons are also discussed. But the results shows that the weak stationary EA DLs cannot be supported by the present model.

Keywords Superthermal electrons · Electron-acoustic solitary waves · Double layers · mKdV equation

1 Introduction

The EAWs can either exist in a two temperature (cold and hot) electron plasma (Watanabe and Taniuti 1977; Yu and Shukla 1983) or in an electron-ion plasma with ions hotter than electrons (Fried and Gould 1961). EAWs are typically high-frequency (by comparison with the ion plasma frequency), dispersive plasma waves where the relatively cold inertial electrons oscillate against a thermalized background of inertialess hot electrons which provide the necessary restoring force. In the long-wavelength approximation, the dispersion relation of EAWs is given as $\omega = k(n_{c0}/n_{h0})^{1/2}\mathrm{v}_{th}$, where $\mathrm{v}_{th} = (\kappa_B T_h/m_e)^{1/2}$ is the hot electron thermal speed, κ_B is the Boltzmann constant, and n_{c0} (n_{h0}) are the cold (hot) equilibrium electrons densities. The phase speed $c_s = (n_{c0}/n_{h0})^{1/2}\mathrm{v}_{th}$ of EAWs must be intermediate between cold and hot electron thermal velocities so that the Landau damping is avoided. In the Maxwellian plasmas, Gary and Tokar (1985) performed a parameter survey and found that the hot electron component constitutes a non-negligible fraction of the total electron density (more than $\sim$20%) for the existence of the EAWs. And for the Lorentzian plasmas, Mace and Hellberg (1990) showed that the EAWs were usually strongly Landau damped by the hot electrons, unless $n_{c0}/n_{h0} \ll 1$.

In the nonlinear wave studies, the propagation of solitary waves is important as it describes the characteristics of interaction between waves and plasmas. Solitary waves are localized nonlinear wave phenomena which arise due to a delicate balance between nonlinearity and dispersion. Among the best known paradigms used to investigate small-amplitude nonlinear wave behavior are different versions of KdV equation (Washimi and Taniuti 1966), or nonlinear Schrödinger equation (NLSE) (Hasegawa 1975). Some form of reductive perturbation technique is used to derive such equations. The KdV or mKdV describes the evolution of unmodulated wave, while the NLSE governs the dynamics of a modulated wave packet. In addition, for the arbitrary amplitude solitary waves, the Sagdeev pseudopotential method (Sagdeev 1966) is used too. Electrostatic solitary structures are often observed in the space and laboratory plasma environment. EA soliton has been considered as one of the possible candidates for some of the observed solitary structures.

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