

Nonlinear electron plasma waves in fully relativistic plasmas

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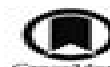
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Abstract

Propagation of nonlinear electron plasma waves is investigated in a fully relativistic electron-ion plasma using two-fluid hydrodynamic model. The relationship between pressure and density is assumed to be of polytropic form for relativistic electrons. The conditions for the validity of adiabatic equation of state for electron fluid is also discussed. The well-known pseudopotential approach is employed for arbitrary amplitude wave analysis and superluminous and subluminous wave phase speed cases are discussed in two special frames of references transformed under Lorentz-transformation. The set of model equations is solved analytically as well as numerically to obtain nonlinear periodic wave structures of electron plasma waves in a fully relativistic plasmas. A special case of solitary wave structure formed in subluminal phase speed case is also discussed in detail, which has not been done in the previous published literature. The effects of electron temperature and phase speed of the plasma wave (i.e., for subluminal and superluminous wave phase speed cases) on the amplitude of nonlinear periodic wave and solitary wave structures are also presented with its possible applications to the astrophysical environment.

Keywords: plasma physics, special theory of relativity, astrophysics, Lorentz transformation, plasma waves

(Some figures may appear in colour only in the online journal)

1. Introduction

There has been a great deal of interest among plasma physics community to study the electron plasma waves [1–5]. The breaking of nonlinear periodic plasma waves in a cold relativistic framework was investigated by Chian *et al.* [6] using the pseudopotential technique. Breaking of electron plasma waves in a relativistic was also investigated for a warm plasma [7]. Buti [8] discussed the damping of linear electron plasma waves in a relativistic plasma using kinetic theory. The breaking of electron plasma waves, using the electron trapping condition, (having phase speed equal to the speed of light) with water-bag distribution for electrons was investigated [5]. Haas and Kourakis [9] discussed the effect of relativistic parameter $(3\hbar^2\pi^2n_{e0})^{1/2}/(2\pi m_e c)$ on the propagation of linear and nonlinear plasma waves in a fully degenerate relativistic plasma, where $\hbar$ is the Planck's constant, m_e is the electron mass, c is the speed of light and n_{e0} is the electron equilibrium density. Recently the dynamical

behaviour of nonlinear ion acoustic solitary waves (NLASW's) in an unmagnetized weakly relativistic collisionless plasma system was studied by G. Haque [10], using the Schamel Korteweg-de Vries (SKdV) equation. Also, the propagation of ion acoustic shock and solitary wave in a weakly relativistic plasma with the effects of trapping efficiency of superthermal electrons and kinematic viscosity of ions was studied by G. Haque [11].

In literature, plasmas with electron thermal energy $K_B T_e/m_e c^2$ (where K_B is the Boltzmann constant and T_e is the electron temperature) roughly lying in the following range $10^{-3} < K_B T_e/m_e c^2 < 1$ are termed as warm plasma [7]. The relativistic warm plasmas are ubiquitous in astrophysical environments e.g., the typical temperature of the order 10^7 – 10^8 K exists in the intercluster medium [12]. Observations of x-rays emissions from binary sources indicate a temperature of 10^7 K whereas, the diffuse x-rays emissions from intergalactic medium indicates a temperature of the order of 10^8 K [12]. After big bang most of the Helium was

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