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ORIGINAL ARTICLE

Higher-order corrections to ion acoustic waves in degenerate electron-positron-ion plasmas

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Abstract The nonlinear propagation of ion acoustic waves in ideal plasmas consisting of degenerate electrons and positrons, and isothermal ions is investigated. The Korteweg de Vries (K-dV) equation that contains the lowest order nonlinearity and dispersion is derived from the lowest order of perturbation and a linear inhomogeneous (K-dV type) equation that accounts for the higher order nonlinearity and the dispersion relation is obtained. The stationary wave solution for these equations has been found using the renormalization method**.** Also, the effects of electrons and positrons densities and ion temperature on the amplitude and width of solitary waves are investigated, numerically. It is seen that higher order corrections significantly change the properties of the K-dV solitons. Also, it is found that both compressive and rarefactive solitary waves can be propagated in such plasma system.

Keywords Ion acoustic waves · Degenerate plasmas · e-p-i Plasmas · Renormalization method

1 Introduction

The nonlinear wave propagation in plasma is one of the most important subjects of plasma physics. There are large classes of nonlinear partial differential equations to interpret and explore a variety of nonlinear phenomena observed in space and astrophysical plasma as well as laboratory experiments (Bailung and Nakamura 1998; Nakamura et al. 1999; Nakamura and Sarma 2001). The K-dV equation historically, was first derived by Korteweg-de Vries (Korteweg and de Vries 1895) in relation to the problem of along surface waves in water in a channel of constant depth. Washimi and Taniuti (1966) have shown that K-dV equation gives a weakly nonlinear description of one-dimensional ion sound wave disturbances traveling near the ion sound speed. The solution of K-dV equations, describes the evolution of a non-modulated waves, i.e., a bare pulse with no fast oscillations inside the packet.

The electron-positron (e-p) plasma is believed to exist in a pulsar magnetosphere (Ginzburg 1971; Sturrock 1971; Ruderman and Sutherlond 1975; Manchester and Taylor 1977; Michel 1982, 1991) in active galactic nuclei (Miller and Waiita 1987) and in the early universe (Gibbons et al. 1983). Since many of the astrophysical plasmas contain ions besides the electrons and positrons—the presence of ions leads to the existence of several low frequency waves which otherwise do not propagate in (e-p) plasmas—thus it is important to study the dynamics of the nonlinear wave motions in an electron-positron-ion (e-p-i) plasma (Rizzato 1988). Linear and nonlinear wave's propagation in (e-p) and (e-p-i) plasmas have been studied by many authors (Hasegawa et al. 2002; Salahuddin et al. 2002; Mahmood et al. 2003; Saleem et al. 2003; Saleem and Mahmood 2003; Mahmood and Akhtar 2008; Popel et al. 1995; Nejoh 1996; Shukla and Shukla 2007). However most of these studies are confined to Maxwell-Boltzmann plasmas, in which there are so many plasma systems in astrophysical bodies, such as white dwarfs (Shapiro and Teukolsky 1983) and under laboratory conditions in laser fusion (Lebo and Tishkin 2006) and micropinch (Mererovich 1999) experiments, where's the electrons and positrons have very high

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