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ORIGINAL ARTICLE

Magnetoacoustic solitons in dense astrophysical electron-positron-ion plasmas

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Abstract Nonlinear magnetoacoustic waves in dense electron-positron-ion plasmas are investigated by using three fluid quantum magnetohydrodynamic model. The quantum mechanical effects of electrons and positrons are taken into account due to their Fermionic nature (to obey Fermi statistics) and quantum diffraction effects (Bohm diffusion term) in the model. The reductive perturbation method is employed to derive the Korteweg-de Vries (KdV) equation for low amplitude magnetoacoustic soliton in dense electron-positron-ion plasmas. It is found that positron concentration has significant impact on the phase velocity of magnetoacoustic wave and on the formation of single pulse nonlinear structure. The numerical results are also illustrated by taking into account the plasma parameters of the outside layers of white dwarfs and neutron stars/pulsars.

Keywords Electron-positron-ion · Quantum plasmas · Pulsars · Magnetoacoustic wave

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1 Introduction

During last decade, the study of quantum plasmas has gained interest due its application in astrophysical objects such as compact stars and in future laser plasma experiments (Marklund and Shukla 2010). The electron-positron (e-p) plasmas are believed to exist around astrophysical objects such as active galactic nuclei (AGN), quasars, neutron stars/pulsars (Beskin 2006). The positrons are created in laboratory experiments and used for a wide range of applications, including the study of atomic and molecular physics (Iwata et al. 1997), antihydrogen formation (Charlton et al. 1994), plasma physics (Greaves and Surko 1995) and the characterization of materials and surfaces (Schultz and Lynn 1988). Surko et al. (1989) performed an experiment to describe trapping and confinement of positrons gas sufficiently cold and dense to exhibit classical plasma like behavior. Greaves and Surko (2002) described a method to create a low density, electron-positron plasma ($\sim 10^7\ \mathrm{cm}^{-3}$) for basic plasma physics studies that uses a combination of radio-frequency and magnetic confinement. Many researchers have already explained the existence of positrons in the astrophysical objects like pulsars and magnetors (Beloborodov and Thompson 2007; Ruderman and Sutherland 1975; Arons and Scharlemann 1979; Harding and Muslimov 2002). In the atmosphere around these objects, beside electron-positron pairs a small number of heavy ions is also likely to be present (Mahajan et al. 1998). For example, the magnetosphere of the neutron stars is filled with electron-positron (e-p) plasma, however, it is believed that it may have some fraction of ions as well. The presence of some fraction of ions in the neutron star magnetosphere is assumed to be originated from some interior source such as a result of evaporation or seismic processes on the surface of neutron star. The ions can also enter in the magnetosphere of neutron/pulsar from outside in the process