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Electrostatic Solitary Waves in Degenerate Relativistic Quantum Plasmas

Authors : Sharmin Sultana, Reinhard Schlickeiser

Abstract : A degenerate relativistic quantum plasma (DRQP) system (containing relativistically degenerate electrons, degenerate/non-degenerate light nuclei, and non-degenerate heavy nuclei) is considered to investigate the propagation characteristics of electrostatic solitary waves (in the ionic scale length) theoretically and numerically. The ion-acoustic solitons are found to be associated with the modified ion-acoustic waves (MIAWs) in which inertia (restoring force) is provided by mass density of the light or heavy nuclei (degenerate pressure of the cold electrons). A mechanical-motion analog (Sagdeev-type) pseudo-potential approach is adopted to study the properties of large amplitude solitary waves. The basic properties of the large amplitude MIAWs and their existence domain in terms of soliton speed (Mach number) are examined. On the other hand, a multi-scale perturbation approach, leading to an evolution equation for the envelope dynamics, is adopted to derive the cubic nonlinear Schrödinger equation (NLSE). The criteria for the occurrence of modulational instability (MI) of the MIAWs are analyzed via the nonlinear dispersion relation of the NLSE. The possibility for the formation of highly energetic localized modes (e.g. peregrine solitons, rogue waves, etc.) is predicted in such DRQP medium. Peregrine solitons or rogue waves with amplitudes of several times of the background are observed to form in DRQP. The basic features of these modulated waves (e.g. envelope solitons, peregrine solitons, and rogue waves), which are found to form in DRQP, and their MI criteria (on the basis of different intrinsic plasma parameters), are investigated. It is emphasized that our results should be useful in understanding the propagation characteristics of localized disturbances and the modulation dynamics of envelope solitons, and their instability criteria in astrophysical DRQP system (e.g. white dwarfs, neutron stars, etc., where matters under extreme conditions are assumed to exist) and also in ultra-high density experimental plasmas.

Keywords : degenerate plasma, envelope solitons, modified ion-acoustic waves, modulational instability, rogue waves
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