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ORIGINAL ARTICLE

Effects of two-temperature superthermal electrons on dust-ion-acoustic solitary waves and double layers in dusty plasmas

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Abstract Dust-ion-acoustic (DIA) waves in an unmagnetized dusty plasma system consisting of inertial ions, negatively charged immobile dust, and superthermal (kappa distributed) electrons with two distinct temperatures are investigated both numerically and analytically by deriving Korteweg–de Vries (K-dV), modified K-dV (mK-dV), and Gardner equations along with its double layers (DLs) solutions using the reductive perturbation technique. The basic features of the DIA Gardner solitons (GSs) as well as DLs are studied, and an analytical comparison among K-dV, mK-dV, and GSs are also observed. The parametric regimes for the existence of both the positive as well as negative SWs and negative DLs are obtained. It is observed that superthermal electrons with two distinct temperatures significantly affect on the basic properties of the DIA solitary waves and DLs; and depending on the parameter μ_c (the critical value of relative electron number density μ_{e1}), the DIA K-dV and Gardner solitons exhibit both compressive and rarefactive structures, whereas the mK-dV solitons support only compressive structures and DLs support only the rarefactive structures. The present investigation can be very effective for understanding and studying various astrophysical plasma environments (viz. Saturn magnetosphere, pulsar magnetosphere, etc.).

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Keywords Dust-ion-acoustic waves · Superthermal electrons · Kappa distribution · Two-electron-temperature · Solitary waves · Double layers

1 Introduction

Dusty plasmas have opened up a completely new and fascinating research area, because of their vital applications in understanding various collective processes in space environments (Shukla 2001; Mendis and Rosenberg 1994; Shukla and Mamun 2002) and laboratory devices (Barkan et al. 1995, 1996; Merlino et al. 1998; Homann et al. 1997). The presence of highly negatively charged and massive grains of dust particles in an electron ion plasma is responsible for the appearance of new types of waves, depending on whether the dust grains are considered to be static or mobile. One type of these waves is the dust-ion-acoustic (DIA) wave, which is the usual ion-acoustic wave modified by the presence of dust grains. In DIA waves, ion mass provides the inertia and restoring force comes from the thermal pressure of electrons. The phase speed of such DIA waves is much larger (smaller) than the ion (electron) thermal speed.

Shukla and Silin (1992) have first theoretically shown the existence of low frequency DIA waves in a dusty plasma system. Barkan et al. (1996) and Nakamura et al. (1999) have observed the DIA waves in laboratory experiments. Nowadays, the linear properties of the DIA waves in dusty plasmas are well understood from both theoretical and experimental points of view (Shukla and Mamun 2002; Barkan et al. 1996; Merlino et al. 1998; Shukla and Silin 1992; Shukla and Rosenberg 1999). Recently, the nonlinear waves particularly the DIA solitary waves (DIA SWs) have received an impressive interest in realizing the basic properties of localized electrostatic perturbations in space and