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ORIGINAL ARTICLE

Planar Gardner solitons and double layers in dusty electronegative plasmas with kappa distributed electrons

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Abstract A theoretical investigation has been made on the Dust ion-acoustic (DIA) Gardner solitons (GSs) and double layers (DLs) in electronegative plasma consisting of inertial positive and negative ions, super-thermal (kappa distributed) electrons, and negatively charged static dust. The standard reductive perturbation method is employed to derive the Korteweg-de Vries (K-dV), modified K-dV (mK-dV), and standard Gardner equations, which admits solitary waves (SWs) and DLs solutions. It have been found that GSs and DLs exist for α around its critical value α_c, where α_c is the value of α corresponding to the vanishing of the nonlinear coefficient of the K-dV equation. The parametric regimes for the existence of both the positive as well as negative SWs and negative DLs are obtained. The basic features of DIA SWs and DLs are analyzed and it has been found that the polarity, speed, height, thickness of such DIA SWs and DLs structures, are significantly modified due to the presence of two types of ions and spectral index (κ) of super-thermal electrons. It has also been found that the characteristics of DIA GSs and DLs, are different from that of the K-dV solitons and mK-dV solitons. The relevance of our results to different interstellar space plasma situations are discussed.

Keywords Dusty plasma · Super-thermal electrons · Gardner solitons · Electronegative plasma

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1 Introduction

Recently, there have been up-growing interests for researchers in understanding the non-linear features of electronegative plasmas (plasmas with significant amount of negative ions) (Berezhnoj et al. 2000; Franklin 2002; Mamun et al. 2010; Rahman et al. 2011; Plihon and Chabert 2011; Mannan and Mamun 2012). Electronegative plasmas (ENP) have attracted a great deal of attention not only because of their potential applications in microelectronic and photoelectronic industries (Lieberman and Lichtenberg 2005) but also because of their occurrence in both laboratory devices (Jacquinot et al. 1977; Weingarten et al. 2001; Ichiki et al. 2002) and space environments (Meige et al. 2007; Coates et al. 2007; Plihon and Chabert 2011). ENP are contaminated by solid impurities (dust). Therefore, ENP are also called dirty or dusty ENP (Kim and Merlino 2006; Merlino and Kim 2006; Mamun et al. 2009a).

The nonlinear features of the dust ion-acoustic (DIA) waves in ENP have been analyzed by many authors (Mamun et al. 2009a, 2009b, 2009c; Kim and Hershkowitz 2009; Rahman et al. 2011). Rahman et al. (2011) have studied the dust ion-acoustic solitary waves and their multi-dimensional instability in a magnetized dusty electronegative plasma with trapped negative ions. Sayed et al. (2008) studied dust ion-acoustic solitary waves in a dusty plasma with positive and negative ions. Mamun et al. (2010) investigated the effects of adiabaticity of electrons and negative ions on solitary waves and double layers in an electronegative plasma.

According to the various observations (Feldman et al. 1973; Formisano et al. 1973; Scudder et al. 1981; Marsch et al. 1982), the presence of super-thermal electron and ion structures is ubiquitous in a variety of astrophysical plasma environments. Due to the effect of external forces acting on the natural space environment plasmas or because of