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ORIGINAL ARTICLE

Dust acoustic soliton and double layers with streaming dust and superthermal particles

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Abstract Dust acoustic waves are investigated in plasma system containing dynamic and streaming dust, superthermal electrons and ions. Linear and nonlinear studies are carried out and elaborated with the help of parameters taken for Saturn's F-ring. An energy integral equation is obtained by using the Sagdeev potential approach, and results are displayed by solving it analytically and numerically. The dependence of nonlinear structures on κ values, the ratio of electron to dust equilibrium densities μ_{ed}, Mach number M, and dust streaming speed v_{d0} have been presented. The streaming speed appears as a destructive partner for the Mach number M in the pseudoenergy equation and hence plays a dominant modifying role in the formation of nonlinear structures. It plays a destructive role for some of the solitons and works as a source, for the emergence of new solitons (region). Formation of double layers are also investigated and shown that the amplitude, width and existence of double layers structures are predominantly affected by the presence of superthermal electrons, ions, and streaming dust beam.

Keywords Streaming instabilities · Saturn's F-ring · Dust acoustic double layers

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1 Introduction

The plasma containing normal electron-ion with an additional highly charged component of small micron or submicron sized extremely massive charged particulates is named as dusty plasma which is ubiquitous in the universe, e.g., in interstellar clouds, interplanetary space, cometary tails, ring systems of giant planets (like Saturn F-ring's), mesospheric noctilucent clouds, as well as in many Earth bound plasma (Shukla and Mamun 2003; Verheest 2000). Other applications range from astrophysics to strongly coupled dusty plasmas and dusty plasma crystals to technology plasma etching and deposition (Horonyi 1996; Mendis and Rosenberg 1994; Shukla and Mamun 2003; Verheest 1996). In a dusty plasma, the dust grains may be charged negatively by plasma electron and ion currents or positively by secondary electron emission, UV radiation, or thermionic emission (Whipple 1981; Horonyi 1996). In most of the situations, it has been observed that due to higher thermal speed of electrons than ions, they quickly approach the dust grains and make them acquire negative charge in low temperature laboratory dusty plasma (Barkan et al. 1994).

Because of the addition of this new component, plasma system is forced to behave differently from the usual electron-ion plasma. The dust particles have a large mass, i.e., about million times heavier than ions and hence introduce new time scales of interest in the plasma system. The presence of such heavier species makes it possible for the plasma system to sustain novel ultra-low-frequency waves as well, the most notable of which, is the dust-acoustic wave (DAW). The DAW was first theoretically predicted by Rao et al. (1990) and have been experimentally confirmed by various studies (Angelo 1990; Barkan et al. 1995; Chu et al. 1994; Pieper and Goree 1996; Prabhuram and Goree 1996; Thomas and Watson