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ORIGINAL ARTICLE

Nonlinear dust acoustic waves in a charge varying complex plasma with nonthermal ions featuring Tsallis distribution

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Abstract The concept of ion nonthermality is generalized within the theoretical framework of the Tsallis thermostatistics. In this connection, a physically meaningful ion distribution function is outlined. As the nonextensive character of the nonthermal ions increases, the distribution shoulders may become less or more prominent and high energy states are less or more probable than in the extensive nonthermal case. Variable charge dust acoustic waves are then addressed. We first consider the case of adiabatic dust charge variation and discuss later the case when the nonadiabatic charge variations are self-consistently included. Our results may complement and provide new insight into previously published work in nonthermal space plasmas.

Keywords Dusty plasmas · Dust charge variation · Nonthermality · Nonextensivity · Dust acoustic waves · Solitons · Shock waves

1 Introduction

Recently, low-temperature plasmas containing, in addition to electrons and ions, finite-sized highly charged particulate matter have been studied by many authors because of the frequent occurrence of such plasmas in laboratory, space, and astrophysical plasma environments, such as cometary tails, asteroid zones, planetary rings, interstellar medium, earth's ionosphere and magnetosphere (Goertz 1989; Mendis and Rosenberg 1994; Horanyi 1996; Verheest 2000; Shukla and Mamun 2002). While the importance of such interest cannot be overemphasized, in recent years there is a phenomenal growth in research activities in this area. Because of the high charge and large mass of the grain particulates compared to those of ions, new time and space scales come into play, giving rise to new waves instabilities in the dusty plasmas. It has been found both theoretically and experimentally that the presence of static charged dust grains modifies the existing plasma wave spectra. On the other hand, it has been shown that the dust charge dynamics introduces new eigenmodes, such as, dust-acoustic (DA) mode (Rao et al. 1990), dust ion-acoustic (DIA) mode (Shukla and Silin 1992), dust Bernstein-Greene-Kruskal (DBGK) modes (Tribeche et al. 2000)...etc. Among the host of new dusty modes discussed in the literature, the dust-acoustic wave (DAW) has received wide attention (Mamun 1999a, 1999b; Ghosh et al. 2001; El-Labany et al. 2002, 2008, 2010; Rahman et al. 2008; Pakzad 2010; Das and Devi 2010; Tribeche and Benzekka 2011) as well as experimental confirmation (Barkan et al. 1995) in several low-temperature dusty plasma devices. The later arises due to the restoring force provided by the plasma thermal pressure (electrons and ions) while the inertia is due to the dust mass.

Numerous observations clearly indicated the presence of energetic particles (electrons and ions) as ubiquitous in a variety of astrophysical plasma environments and measurements of their distribution functions revealed them to be highly nonthermal (Goldman et al. 1999). Nonthermal electron-ion distributions turned out to be a very common and characteristic feature of space plasmas where coherent nonlinear waves and structures (Davidson 1972) are expected to play an important role. Such nonthermal populations may be distributed isotropically in velocities or possess a net streaming motion with respect to the background plasma, and their presence has been confirmed by

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