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ORIGINAL ARTICLE

Nonlinear propagation of dust-acoustic waves in a magnetized nonextensive dusty plasma

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Abstract A theoretical investigation has been made of obliquely propagating dust-acoustic solitary waves in a magnetized three-component dusty plasma, which consists of a negatively charged dust fluid, ions, and nonextensive electrons. The reductive perturbation method has been employed to derive the Korteweg-de Vries equation which admits a solitary wave solution. It has been shown that the combined effects of external magnetic field (obliqueness), ions, and electron nonextensivity change the behavior of these electrostatic solitary structures that have been found to exist with positive and negative potential in this dusty plasma model. The implications of our results in astrophysical and cosmological scenarios like vicinity of the Moon, magnetospheres of Jupiter and Saturn, dark-matter halos, hadronic matter, quark-gluon plasma, protoneutron stars, stellar polytropes etc. have been mentioned.

Keywords Dust-acoustic solitary waves · Korteweg-de Vries equation · Nonextensive electrons · Reductive perturbation method · External magnetic field

1 Introduction

In dusty plasma, there has been a great deal of attraction in understanding different types of collective processes in dusty plasmas (Shukla and Mamun 2002; Verheest 2000; Asaduzzaman 2012; Asaduzzaman and Mamun 2011, 2012c, 2012d; Masud et al. 2013; Tasnim et al. 2013) with extremely massive and negatively charged dust grains, because of its important role in the study of astrophysical and space environments (Goertz 1989; Horanyi 1996), such as cometary tails, asteroid zones, planetary rings, interstellar medium, lower ionosphere of the Earth, etc. About two decades ago, Rao et al. (1990) theoretically predicted the existence of dust-acoustic (DA) solitary waves (SWs) (Tanjia and Mamun 2008; Asaduzzaman and Mamun 2012e), in which the dust particle mass provides the inertia and the pressures of the inertialess electrons and ions provide the restoring force. The laboratory experiments (Barkan et al. 1995; Thompson et al. 1999) have conclusively verified the theoretical prediction of Rao et al. (1990) and reported some nonlinear features of the DA waves.

Nonlinear propagation of DA waves, particularly the DA SWs are consistent with equilibrium plasma system. Total energy of such plasma system is considered to be extensive, i.e., Maxwellian distribution in Boltzmann Gibbs statistics is believed to be valid universally for the thermal equilibrium systems (Moslem 2006; Alinejad 2011b, 2011a; Asaduzzaman and Mamun 2012a, 2012b; Pervin et al. 2013). Space plasmas (Tsallis 1988; Leubner 1982; Plastino and Plastino 1993; Feron and Hjorth 2008; Gervino et al. 2012; Lavagno and Pigato 2011) clearly indicate the particles which follow non-Maxwellian distribution function with high energy tails, and that tails strongly deviate from simple Maxwellian due to the anisotropy of the temperature and long range interactions caused by the coupling between plasmas and external fields. Such particles, following non-Maxwellian distribution function point to a class of Tsallis's velocity distribution (Tsallis 1988) that is well known as q-distribution, which characterizes the nonextensivity of any plasma species.

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