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ORIGINAL ARTICLE

Influence of arbitrarily charged dust and trapped electrons on propagation of localized dust ion-acoustic waves

H. Alinejad

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Abstract A theoretical investigation is developed to study the existence, formation and basic properties of arbitrary amplitude dust ion-acoustic solitary potentials in a dusty plasma consisting of warm ions, trapped electrons and immobile negative (positive) dust particles. It is found a definite interval for the Mach number for which solitary waves exist and depend sensitively on the ion temperature and negative (positive) dust concentration. In addition, the effects of ion temperature, two oppositely charged dust species and resonant electrons on the shape of the solitary waves are also investigated extensively. For both cases of negative and positive dust grains, the effect of ion temperature is found to be destructive for the formation of localized structures. Further, the amplitude of the solitary structures decreases (increases) with the increase in the negative (positive) dust concentration.

Keywords Trapped electrons · Negative (positive) dust concentration · Ion temperature · Solitary waves

1 Introduction

The physics of charged dust particles, which are ubiquitous in laboratory (Homann et al. 1997), astrophysical and space environments (Mendis and Rosenberg 1994; Shukla and Mamun 2002), has received a great deal of interest in understanding linear and nonlinear propagation of electrostatic excitations that are observed in space environments and laboratory devices. In dusty plasmas, due to the presence of a high density of dust grains, different types of collective processes exist and very rich wave modes can be excited. One of these is the low-frequency dust ion-acoustic (DIA) waves in an unmagnetized dusty plasma. Shukla and Silin (1992) were the first to report theoretically the existence of DIA waves. They showed that due to the conservation of equilibrium charge density $n_{e0} + Z_d n_{d0} = n_{i0}$, and the strong inequality $n_{e0} \ll n_{i0}$ (where n_{s0} is the particle number density of the species with $s = e(i)d$ for electrons (ions) dust particles, Z_d is the number of electrons residing on the dust grain surface), a dusty plasma with negatively charge static dust grains supports DIA waves. Later, these waves have been observed in laboratory experiments (Nakamura et al. 1999). In the DIA waves, the restoring force comes from the pressures of inertialess electrons, whereas the ion mass provides the inertia similar to the usual ion acoustic waves in an electron-ion plasma. Thus, the DIA waves is characterized by a phase speed much larger (smaller) than the ion (electron) thermal speed, and a frequency much higher than the dusty plasma frequency.

In the commonly used charging model, the dust grains would be essentially charged by the capture of the more mobile electrons; hence, they become negatively charged. Moreover, the presence of positively charged dust particles has been also observed in different regions of space, viz. cometary tails, upper mesosphere, Jupiter's magnetosphere, etc. (Shukla and Mamun 2002). There are a number of principle mechanisms by which a dust grain becomes positively charged. These are: secondary emission of electrons from the surface of the dust grains, photo electron emission by UV radiation, thermionic emission, field emission, impact

H. Alinejad (✉)
Department of Physics, Faculty of Basic Science, Babol University of Technology, Babol 47148-71167, Iran
e-mail: alinejad@nit.ac.ir

H. Alinejad
Research Institute for Astronomy and Astrophysics of Maragha, P.O. Box 55134-441, Maragha, Iran
Fax: +98-111-3234201