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ORIGINAL ARTICLE

Formation of obliquely propagating dust-ion-acoustic shock waves due to dust charge fluctuation in magnetized nonthermal dusty plasma

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Abstract A theoretical investigation is made on the formation as well as basic properties of dust-ion-acoustic (DIA) shock waves in a magnetized nonthermal dusty plasma consisting of immobile charge fluctuating dust, inertial ion fluid and nonthermal electrons. The reductive perturbation method is employed to derive the Korteweg-de Vries-Burgers equation governing the DIA shock waves. The combined effects of external static magnetic field, obliqueness, nonthermal electron distribution and dust charge fluctuation on the DIA shock waves are also investigated. It is shown that the dust charge fluctuation is a source of dissipation, and is responsible for the formation of the DIA shock waves. It is also observed that the combined effects of obliqueness, nonthermal electron distribution and dust charge fluctuation significantly modify the basic properties of the DIA shock waves. The implications of our results in space and laboratory dusty plasma situations are briefly discussed.

Keywords Dust-ion-acoustic waves · Shock waves · Nonthermal electrons

1 Introduction

Dusty plasma is an electron-ion plasma with an additional component of small micron sized highly charged dust (Shukla and Mamun 2002). The presence of this charged dust component does not only modify the existing plasma wave spectra, but also introduces new eigenmodes, such as dust- acoustic (DA) mode (Rao et al. 1990; Melandso et al. 1993; Rosenberg 1993; Barkan et al. 1995; D'Angelo 1995), dust- ion acoustic (DIA) mode (Shukla and Silin 1992), dust cyclotron mode (Shukla and Rahman 1998), dust drift mode (Shukla et al. 1991), dust lattice mode (Melandso 1996; Farokhi and Shahmansouri 2009; Shahmansouri and Farokhi 2012), etc. The DIA mode, which is one of the most important low frequency electrostatic dust associated modes, is first predicted theoretically by Shukla and Silin (1992), and observed experimentally by Barkan et al. (1996). The experimental observation of the DIA waves is more convenient than that of the DA waves. These waves exist not only in laboratory devices, but also in various space and astrophysical plasma systems. Therefore, the DIA waves have attracted a great deal of attention in the last few decades.

The electron distribution function may be significantly modified by the localized dust- ion-acoustic potential structures via generating fast or energetic or nonthermal electron population. The electrostatic solitary structures associated with density depression have been observed by the Viking spacecraft (Boström 1992) and Freja satellite (Shukla and Mamun 2002) at the lower part of in the magnetosphere or upper part of the ionosphere. These observations motivated Cairns et al. (1995) to study the effect of nonthermal electrons on the nature of ion acoustic solitary waves. Their results were in good agreement with those observed by Viking and Freja. The influence of nonthermal distribution of plasma particles on the collective processes in plasma has been discussed by a number of authors (Ghosh et al. 2002; Ghosh et al. 2004; Zhang and Xue 2005; El-Taibany and Sabry 2005; Zhang and Wang 2006; El-Taibany and Kourakis 2006; Roy et al. 2006; El-Taibany

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