Astrophys Space Sci
DOI 10.1007/s10509-013-1766-x

ORIGINAL ARTICLE

Modulational instability of dust ion acoustic waves in dusty plasmas with superthermal electrons

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Received: 17 September 2013 / Accepted: 20 December 2013

Abstract The propagation of dust ion acoustic waves is studied in plasmas composed of superthermal distributed electrons and stationary dust particles. The nonlinear Schrödinger equation is derived using the reductive perturbation technique and the modulational instability of dust ion acoustic waves is analyzed. Parametric investigations indicate that the presence of superthermal distributed electrons significantly modify the modulational instability and its growth rate. The effect of particle relative density on the wave characters is also investigated.

Keywords Dust ion acoustic waves · Dusty plasma · Superthermal electrons · Modulational instability

1 Introduction

Nonlinear waves associated with the dust ion acoustic waves (DIAW) (Fechting et al. 1979; Rao et al. 1990; Mendis and Rosenberg 1994) and particularly, the dust ion-acoustic envelope solitary waves (Nakamura and Sharma 2001; Amin et al. 1998) have received a great deal of attention in plasma physics because of their importance in the environment of space and Earth as well as in laboratory activities (Mendis and Horanyi 1991; Pieper and Goree 1996; Shukla 2000; Rosenberg and Merlino 2007; Goertz 1989; Whipple et al. 1989). Shukla and Silin (1992) have first theoretically shown 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_{e0}, n_{d0}, and n_{i0} are equilibrium density of electron, dust and ion, Z_d is the number of electrons residing onto the dust grain surface and e is the magnitude of the electronic charge) a dusty plasma with negatively charged static dust can support low-frequency dust ion-acoustic (DIA) waves (DIAWs) with phase speed much smaller (larger) than the electron (ion) thermal speed. The DIAWs have also been observed in laboratory experiments too (Merlino and Goree 2004; Barkan et al. 1996). Theoretically, Mamun and Shukla (2002, 2005) have investigated DIASWs in unmagnetized dusty plasmas consisting of cold ion fluid, isothermal electrons and negatively charged static dust particles. Mamun (2008) discussed the propagation of nonlinear one-dimensional DIASWs in unmagnetized dusty plasmas containing adiabatic ions and electrons with negatively charged static dust grains. More recently a great deal of attention has been devoted to the study of ion acoustic and dust-ion acoustic waves in plasmas (Ghosh et al. 2012; Samanta et al. 2013a, 2013b; Ghorui et al. 2013). On the other hand the nonlinear wave propagation is generically subject to an amplitude modulation due to the carrier wave self-interaction which is a well-known harmonic generation mechanism. The standard multiple scale technique (Taniuti and Yajima 1969; Asano et al. 1969) which is employed in the study of this mechanism, leads to a nonlinear Schrodinger-type equation (NLSE) describing the evolution of the wave envelope. Under certain conditions, the wave may undergo a Benjamin–Feir-type (modulational) Instability (MI) i.e., its envelope may collapse under the influence of external perturbations. In addition the analysis of the NLSE which occurs in a variety of physical contexts (Remoissenet 1994;

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Published online: 08 January 2014