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ORIGINAL ARTICLE

Nonplanar dust ion-acoustic solitary and shock excitations in electronegative plasmas with trapped electrons

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Abstract It is shown that the three-dimensional cylindrical Kadomtsev-Petviashvili (CKP) and the extended cylindrical Kadomtsev-Petviashvili (ECKP) equations can describe the propagation of nonplanar dust ion-acoustic excitations in a dusty plasma composed of positive ions, negative ions, stationary dust particles, as well as trapped electrons or a small percentage of trapped electrons. It is found that the solution of the CKP equation supports only solitary pulses, while the ECKP equation describes the propagation of both solitary and shock excitations. The effects of physical parameters, namely negative ions density, dust grains density, positive-to-negative mass ratio, direction cosine of the wave propagation on the pulses profile are examined. Furthermore, the existence regions of either localized or shock pulses are investigated. The relevance of nonlinear structures in the Earth's ionosphere and plasma experiment is discussed.

Keywords Plasma · Electronegative plasma · Nonplanar geometry · Solitary structure · Shock structure

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1 Introduction

It is well known that dust particles are common in the universe and they represent much of the solid matter in it. Dust particles often contaminate fully ionized or partially ionized gases and form the so-called 'dusty plasma', which occurs frequently in the nature. In astrophysics, in the early 1930s, dust was shown to be present in the interstellar clouds where it appears as a selective absorption of stellar radiation interstellar reddening. Dust particles play a very important role in the solar system, in cometary tails, in planetary rings, and also in the evolution of the solar system from its solar nebula to its present form. They are also found in environments such as production processes, flames, rocket exhausts, etching experiments, and experiments on dust plasma crystals. The dust particles are of micrometer or submicrometer size and their mass is large compared to the masses of the ion species. Also these dust grains can be positively or negatively charged according to the type of the charging process. The inclusion of dust component in a plasma introduces new collective modes and instabilities, for example, dust-acoustic waves, dust ion-acoustic waves (DIAWs), dust Coulomb waves, and dust lattice waves (Shukla and Mamun 2002). Shukla and Silin (1992) were the first to report theoretically the existence of DIAWs in unmagnetized dusty plasmas. Barkan et al. (1996) observed the DIAWs experimentally. Furthermore, many efforts have been made to understand the properties of linear and nonlinear DIAWs in