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ORIGINAL ARTICLE

Head—on collision of nonlinear dust—acoustic solitary waves in dusty plasmas with dust of opposite polarities

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Abstract The propagation and the head—on collision of nonlinear dust—acoustic solitary waves (DASWs) in dusty plasmas consisting of electrons, ions and negative as well as positive dust particles are investigated. Applying an extended Poincaré-Lighthill-Kuo (PLK) method, Kortwege-de Vries equations and analytical phase shifts after the head-on collision of two DASWs in dusty plasmas are obtained. Analytically and numerically, the relevance of the phase shifts and trajectories to the positive-to-negative dust number density ratio, the ratio of the ion number density to negative dust number density, negative-to-positive dust particle mass ratio, and the ion-to-electron temperature ratio effects is explicitly demonstrated. Moreover, the current findings are applied to different regions of space, viz. cometary tails, mesosphere, Jupiter's magnetosphere.

Keywords The head-on collision · Nonlinear dust-acoustic solitary waves · The extended Poincaré-Lighthill-Kuo method · The phase shifts and trajectories

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1 Introduction

In the last years, the investigation of nonlinear waves and structures in dusty plasmas (fully or partially ionized low temperature gases comprising of neutral gas molecules, electrons, ions, and submicron- and micron-sized charged dust grains) has become one of the most important activities of plasma physics because of their vital role in the study of the astrophysical and space environment (Horányi et al. 1993; Mendis and Rosenberg 1994; Horányi 1996; Havnes et al. 1996; Mamun 1999; El-Labany et al. 2002, 2008, 2009; Shalaby et al. 2010), as well as in the laboratory (Barkan and Merlino 1995; Barkan et al. 1996). The presence of charged dust grains in plasma can modify the collective behavior of a plasma, as well as excite new modes and new nonlinear phenomena, such as dust-ion–acoustic solitary waves (DIASWs), dust-acoustic solitary waves (DASWs), dust lattice waves (DLWs), etc. It should be mentioned here that, one of the most famous and important dusty plasma wave modes is the DASWs which were first presented through the theoretical model of Rao et al. (1990). The phase velocity of the DASWs is much smaller than the electron and ion thermal speeds. Accordingly, the inertialess electrons and ions establish equilibrium in the DASWs potential. Here the pressure gradient is balanced by the electric force, leading to Bolthmann electron and ion number density. Therefore, the creation of DASWs is evaluated due to the restoring force which comes from the pressures of the inertialess electrons and ions, while the dust mass provides the inertia (Shukla and Mamun 2002).

Owing to various processes, dusty plasmas containing grains of opposite polarities may be occur naturally in space. For examples, there have been observations of the coexistence of negative and positive dust in the Earth's magnetosphere and cometary tails (Mendis and Rosenberg