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ORIGINAL ARTICLE

Interaction of ion beam with dust grains produces dust-acoustic solitary waves in Herbig-Haro objects

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Abstract Properties of dust-acoustic solitary waves in a warm dusty plasma are analyzed by using the hydrodynamic model for massive dust grains, electrons, ions, and streaming ion beam. For this purpose, Korteweg-de Vries (KdV) equation for the first-order perturbed potential and linear inhomogeneous KdV-type equation for the second-order perturbed potential have been derived and their analytical solutions are presented. In order to show the characteristics of the dust-acoustic solitary waves are influenced by the plasma parameters, the relevant numerical analysis of the KdV and linear inhomogeneous KdV-type equations are obtained. The dust-acoustic solitary waves, as predicted here, may be associated with the nonlinear structures caused by the interaction of polar jets with the interstellar medium, which is known as Herbig-Haro objects.

Keywords Dusty plasma · Ion beam · Solitary waves · Herbig-Haro objects

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1 Introduction

The study of dusty plasmas represents one of the most rapidly growing branches of plasma physics. Interest in dusty plasmas ranges since the Voyager observation in the early 1980s, that showed phenomena in the rings of Saturn, which could not really be explained on purely gravitational ground alone. Telltales were the spokes in the B ring and the braids in the F ring, the latter ring itself being discovered by these missions. Other examples in the solar system are circumsolar dust rings, noctilucent clouds in the Arctic troposphere as the closest natural dusty plasmas, or even in the flame of a humble candle. Other dusty plasmas occur in the asteroid belt, in cometary comae and tails, in the rings of all the Jovian planets and in the interstellar dust clouds (Verheest 2000). On the other hand, the growing interest in the physics of dusty plasmas not only because of dust being omnipresent ingredient of our universe, but also because of its vital role in understanding collective processes in astrophysical and space environments, such as wave modification, new waves, and coherent structures. One of these waves is the low-frequency dust-acoustic wave (DAW). The existence of the DAWs in an unmagnetized dusty plasma was predicted theoretically by Rao et al. (1990) and was conclusively verified in a many laboratory experiments (see e.g. Barkan et al. 1995). Extensive work has been devoted to the study of the DAWs in unmagnetized dusty plasmas. For example, Mamun et al. (1996) reported that only negative potential structures associated with the nonlinear DAWs can exist in a two-component plasma of ions and dust particles. Xie et al. (1999) studied the dust-acoustic solitary waves (DASWs) and double layers in dusty plasma with variable dust charge and two-temperature ions. They have shown that both compressive and rarefactive solitons, as well as double layers could exist. Also, the amplitudes of