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ORIGINAL ARTICLE

Head-on collision of ion-acoustic solitons in an ultracold neutral plasma

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Abstract Properties of ion acoustic solitons head-on collision in an ultracold neutral plasma composed of ion fluid and non-Maxwellian electron distributions are investigated. For this purpose, the extended Poincare-Lighthill-Kuo (PLK) method is employed to derive coupled Kortweg-de Vries (KdV) equations describing the system. The nonlinear evolution equations for the colliding solitons and corresponding phase shifts are investigated both analytically and numerically. It is found that the polarity of the colliding solitons strongly depends on the type of the non-Maxwellian distribution (via nonthermal or superthermal electron distributions). Especially the phase shift due to solitons collision is strongly influenced by the non-Maxwellian distribution. A new critical nonthermal parameter β_c, characterizing the nonthermal electron distribution, and which is not present for superthermal particle distributions, allows the existence of double polarity of the solitons. The phase shift increases below β_c for compressive solitons, but it decreases above β_c for rarefactive soliton. For superthermal distribution the phase shift increases rapidly for low spectral index κ, whereas for higher values of κ, the phase shift decreases smoothly and becomes nearly stable for $\kappa > 10$. Around β_c and small values of κ, the deviation from the Maxwellian state is strongest, and therefore the phase shift has unexpected behavior due to the presence of more energetic electrons that are represented by the non-Maxwellian distributions. The nonlinear structure, as reported here, could be useful for controlling the solitons that may be created in future ultracold neutral plasma experiments.

Keywords Ion-acoustic solitons · Ultracold neutral plasmas · Non-Maxwellian electron distributions · PLK method

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1 Introduction

Laboratory ultracold neutral plasmas (UNPs) (Simien et al. 2004; Killian 2007; Killian et al. 2007; Killian and Rolston 2010; Castro et al. 2012), sometimes also referred to as the Rydberg plasma (Mendonca and Shukla 2011), are

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