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ORIGINAL ARTICLE

Effect of electron trapping and background nonextensivity on the ion-acoustic soliton energy

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Abstract Weak ion-acoustic (IA) solitary wave propagation is investigated in the presence of electron trapping and background nonextensivity. A physically meaningful distribution is outlined and a Schamel-like equation is derived. The role a background electron nonextensivity may play on the energy carried by the IA soliton is then examined. It is found that nonextensivity may cause a soliton energy depletion. An increase of the amount of electron trapping leads to a net shift towards higher values of the soliton energy.

Keywords Ion-acoustic solitary wave · electron trapping · Nonextensivity · Schamel-like equation · soliton energy

1 Introduction

Recently (Tribeche et al. 2012), we have investigated solitary ion-acoustic (IA) wave propagation in the presence of electron trapping and background nonextensivity. A physically meaningful Schamel-like distribution has been outlined. Our results revealed the existence of localized IA structures in a plasma with trapped nonextensive electrons. In the small-amplitude limit and for $-1 < q \leq 1$, where q stands for the nonextensive parameter, the nonlinear dispersion relation has been derived and solved to get an expression which exhibits in a simple manner the parameter dependences of the phase velocity. For a given amplitude and trapping state, the solitary structure narrows as the electron nonextensivity decreases. Moreover, we have derived the evolution equation for small but finite amplitude IA solitary waves (IASWs). The suggestion has been made that the main quantities (amplitude and width) of the weak IASWs may be drastically affected by nonextensive effects. This leads us to wonder about the possible role the electron nonextensivity (for a given trapping state) may play on the energy carried by the IA soliton. Let recall that interacting solitons may split, fuse, and exchange energies during collision. A large number of investigations have been made on the soliton energy for different plasma situations (Singh and Honzawa 1993; Malik et al. 1994; Mushtaq et al. 2006; Singh and Malik 2007; El-Shewy 2007; Khan et al. 2008; Pakzad and Javidan 2011; El-Shewy et al. 2011; Pakzad 2012; Elwakil et al. 2013; Zahran et al. 2013). The Tsallis statistical mechanics (Tsallis 1988) and the ensuing generalized statistics have been employed with some success in plasma physics (Lima et al. 2000; Du 2004; Valentini 2005; Liyan and Du 2008; Liu et al. 2009; Liu and Du 2009; Tribeche et al. 2010; Amour and Tribeche 2010; Tribeche and Djebarni 2010; Ait Gougam and Tribeche 2011). The statistical description of nonextensive systems demands a generalization of the well-known Boltzmann-Gibbs (BG) thermostatistics. Habitually, the statistical equilibrium of a system is described based on the BG entropy defined as $S_{BG} = -k_B \sum_i p_i \ln(p_i)$, where k_B is the Boltzmann constant, and p_i the probability of the i-th microstate. Let us now consider two independent systems, namely, A and B. The probability of the system $(A + B)$ of being in a microstate $(i + j)$, where i is a microstate of A and j a microstate of B, is therefore $p_{i+j}^{A+B} = p_i^A p_j^B$ and the BG entropy is said extensive in the sense that it satisfies $S_{BG}^{A+B} = S_{BG}^A + S_{BG}^B$. However, an increasing amount of experimental, computational and theoretical evidence, shows that the BG formalism fails to describe systems with long

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