Collisional Effects On Ion-Acoustic Solitary Waves Propagation

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Solitary structures, which are identified as solitary and well-defined pulses in the signal shape, are ubiquitous in Nature and can be easily observed in several plasma systems, as, for example, the Solar Wind [1]. Focusing on solitary waves of ion-acoustic nature, their excitation is essentially due to small scale charge separation effects that produce dispersive effects in the wave dispersion relation. Moreover, the propagation of solitary waves can be affected by kinetic effects, as the Landau damping, and the presence of electrostatic solitary waves is in general connected to the presence of trapped particles and phase space holes [2].

Here, we focus on solitary waves of ion-acoustic nature [3]. The excitation and the propagation of solitary waves are analyzed by means of kinetic Eulerian simulations, in both collision-free and collisional plasmas, composed of kinetic warm protons and linear Boltzmannian electrons. The process of soliton formation is discussed in detail through the description of the time evolution of the electrostatic potential and of the associated phase space portraits of the proton distribution function.

In order to include the collisional effects, one should consider the three dimensional Landau collisional integral. However, since the Landau operator is nonlinear and multidimensional, numerical simulations of the full Landau equation are a hard goal to achieve. Therefore, simplified collisional operators of reduced dimensionality, as the one-dimensional nonlinear Dougherty operator [4], are commonly employed. Although these simplified operators change, in principle, the physics of the particle collisions and surely lack of many details compared to the full Landau operator, they have been successfully used to model collisionality in physical systems whose dynamical evolution is intrinsically one dimensional [5,6].

Here, we study the effects of collisions on the propagation of solitary waves, by modeling proton-proton interactions through the Dougherty operator. We show how, in a case of non-negligible collisionality, short spatial scales in the electrostatic potential are dissipated in time and the phase space structures, observed in the distribution function in absence of collisions, are significantly smoothed out.

Finally, by exploiting the analogy between ion-acoustic waves in neutral infinite plasma and Trivelpiece-Gould waves in nonneutral plasmas columns, a recipe to observe solitary structures in nonneutral plasma devices is proposed.

[1] A. Mangeney, et. al., *Ann. Geophys.* **17**, 307 (1999)
[2] F. Valentini, et. al., *Phys. Rev. Lett.* **106**, 165002 (2011)
[3] O. Pezzi, et. al., *Eur. Phys. J. D* (accepted for publication)
[4] J. P. Dougherty, *Phys. Fluids* **7**, 1788 (1964)
[5] O. Pezzi, et. al., *Phys. Plasmas* **20**, 092111 (2013)
[6] O. Pezzi, et. al., *Phys. Plasmas* **21**, 019901 (2014)