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Characteristics of Bernstein Greene Kruskal modes in Superthermal Space Plasmas

Harikrishnan Aravindakshan(1),Amar Kakad(1), and Bharati Kakad(1)
(1) Indian Institute of Geomagnetism, New Panvel, Navi Mumbai, 410218, India.

1 Extended Abstract

Bernstein, Greene, and Kruskal (BGK) have developed the theory for one-dimensional stationary nonlinear electrostatic waves in a collisionless plasma [2]. It is a nonlinear kinetic theory formulated in the one-dimensional Vlasov-Poisson framework of equations. If the solution obtained after the BGK analysis is positive, it is a model of a one-dimensional electrostatic coherent structure, usually called a BGK wave. There are certain structures called a phase space holes that develop because of particle trapping in a potential, which is a phase space manifestation of BGK wave. As these structures in phase space have a lower density at the center than the rim, they are "Phase Space Holes". Depending on which species trapped, phase space holes are further classified as Electron Holes (EHs) and Ion Holes (IHs). Most of the coherent electrostatic structures encountered in space plasmas modeled in terms of these different phase space holes. However, these models assume the space plasma in thermal equilibrium, described by the Maxwell distribution [3]. Several spacecraft data observations reveal that the plasmas in space cannot be assumed to be in thermal equilibrium and these plasmas are best-modelled using generalized Lorentzian distribution or kappa distribution [4]. Hence, a nonlinear kinetic theory for superthermal plasma is an essential component to study the the coherent wave structures in space plasmas. We develop a first ever one-dimensional model of superthermal plasma keeping ions stationary in the electrostatic limit. We have derived the analytical expression for trapped electron density and distribution function of trapped electrons. We find a significant difference in the trapped electron density and distribution function. We find that superthermal plasma is more prone to trapping and as a result, the distribution function in superthermal plasma found steeper and denser than the trapped distribution in thermal plasma. EHs formed in a superthermal plasma are found to have a smaller size than the EHs formed in thermal plasma for same perturbation. The width and amplitude of perturbation play an important role in the development of holes and deciding their characteristics. The analytical expression for width – amplitude inequality relation that decides the stability of EHs has been derived [1]. We have observed that the parametric regime of amplitude and width (perturbation) that supports stable BGK EH solutions in superthermal plasma is less than that of weakly superthermal plasma. It can be observed that both an increase in width and amplitude of wave potential cause an augmentation in the trapping of particles. The amplitude plays a dominant role in the trapping of maximum energetic particles whereas width plays role in deciding the density of particles at the center of the EHs. Thus this theory provides a generalized platform to study BGK modes developed in both thermal and Superthermal background plasma conditions.

References

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