Particle-In-Cell simulations of circularly polarised Alfven wave phase mixing: a new mechanism for electron acceleration in collisionless, kinetic plasmas

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MAIN RESULTS:

The study of interaction of Alfven waves (AWs) with plasma inhomogeneities is important for both astrophysical and laboratory plasmas. This is because both AWs and inhomogeneities often coexist in a number of these physical systems. AWs are believed to be good candidates for plasma heating, energy and momentum transport. On one hand, in many physical situations AWs are easily excitable (e.g. through convective motions of the solar interior) and they are present in a number of astrophysical systems. On the other hand, these waves dissipate on shear viscosity as opposed to compressive fast and slow magnetosonic waves which dissipate on bulk viscosity. In astrophysical plasmas shear viscosity is extremely small as compared to bulk one. Hence, AWs are notoriously difficult to dissipate. One of the possibilities to improve AW dissipation is to introduce progressively decreasing spatial scales into the system. Heyvaerts and Priest have proposed (in astrophysical context) one such mechanism called AW phase mixing [1]. It occurs when a linearly polarised AW propagates in the plasma with one dimensional, transverse to the uniform magnetic field density inhomogeneity. In such situation initially plane AW front is progressively distorted because of different Alfven speeds across the field. This creates progressively strong gradients across the field (effectively in the inhomogeneous regions transverse scale collapses to zero), and thus in the case of finite resistivity, dissipation is greatly enhanced. Hence, it is believed that phase mixing can provide significant plasma heating. A significant amount of work has been done in the context of heating open magnetic structures in the solar corona. All phase mixing studies so far have been performed in the MHD approximation, however, since the transverse scales in the AW collapse progressively to zero, MHD approximation is inevitably violated, first, when the transverse scale approaches ion gyro-radius and then electron gyro-radius. Thus, we proposed to study phase mixing effect in the kinetic regime, i.e. we go beyond MHD approximation. Particle-In-Cell simulations of a circularly polarised Alfven wave interaction with one dimensional, across the uniform magnetic field, plasma density inhomogeneity (phase mixing) in collisionless plasmas were performed for the first time. In our preliminary work we reported discovery of a new electron acceleration mechanism [2]. In this mechanism, progressive distortion of Alfven wave front, due to the differences in local Alfven speed, generates oblique (nearly parallel to the magnetic field) electrostatic fields, which accelerate electrons through the Landau resonance. We report detailed study of this novel effect, including analysis of broadening of ion distribution function due to the presence of Alfven waves and the generation of compressive perturbations due to weak non-linearity and plasma density inhomogeneity in [3]. The AW amplitude decay law in the inhomogeneous regions, in the kinetic regime, is shown to be the same as in the MHD approximation described by [1], which is novel and unexpected [2,3]. The discovered mechanism has important implications for various space and laboratory plasmas, e.g. coronal heating problem and acceleration of solar wind.

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