Face to face collision of dust acoustic kinetic Alfvén waves in a dusty plasma

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In dusty plasmas, various kinds of forces act on a dust particle, such as electromagnetic force, drag force, gravitational force, thermophoretic force and radiation pressure force. Over the last many years, there has been an increasing interest in the study of influence of polarization force on different kinds of nonlinear structures in a dusty plasma. The polarization force in dusty plasmas arises due to the change in plasma density on two sides of the dust grains. This can occur due to finite dust pressure. As a result of this density non-uniformity, the Debye shield of dust grains no longer remains spherical. This leads to a partial charge separation, thus creating an electric field. This electric field can oppose or enhance the external electric field, which is parallel electric field in the present investigation. Over the last many years, a great deal of attention has been focussed to study the linear and non-linear structures of dust kinetic Alfven (DKA) waves in a dusty plasma. Dust grains are very sensitive to the perturbations in the external applied magnetic field which is naturally available in most of the space plasmas and in laboratory plasmas. The perturbations in the magnetic field generate the dust kinetic Alfven waves (DKAWs) via polarization drift of dust fluid. Dust dynamics modifies the dispersion relation for the kinetic Alfven waves. In a dusty plasma, when the dust is considered as cold and stationary, dust modified kinetic Alfven waves arise with frequency in the range. But, for finite dust temperature, dust kinetic Alfven waves arise with frequency less than the dust cyclotron frequency. For dusty plasmas, comprising of negatively (positively) charged dust grains, the Debye shielding distance is determined by the number density and temperature of positively charged ions (electrons). However, for a fixed value of other parameters, the strength of polarization force remains the same for a plasma, containing either positively or negatively charged dust grains, and is always directed opposite to the electric field. Thus, the polarization force is independent of the nature of the charge on dust grains.

The observations of various satellite missions have confirmed the omnipresence of non-Maxwellian particles with suprathermal tails at higher energies in most of the astrophysical and space plasma environments. Such kinds of nonthermal particles are naturally found in solar wind, Jupiter, and Saturn environments. The non-Maxwellian hybrid distributions involving two commonly adopted distribution functions for describing the plasmas are the kappa distribution (first time introduced by Vasyliunas for modelling the OGO 1 and OGO 2 solar data), and the highly non-Maxwellian distribution profile with bump-on the tail proposed by Cairns et al. The kappa distribution has the power-law form and deviates only moderately in the tail from the Maxwellian profile, while the distribution of Cairns et al. exhibits non-monotonic features in the suprathermal components. The main non-linear phenomenon, in various plasma environments, is an interaction of solitary waves. The interaction of two or more solitary waves occurs due to propagation towards each other and then exchanges their energies and separates off after the collision. In the whole process of collision, the solitary waves remain stable and conserve their shapes and sizes, and each solitary wave gains a positive or a negative phase shift. The phase shift physically means the energy utilization by solitary waves to preserve their shape and size after collision. In order to obtain the two KdV equations to analyse phase shifts after head-on collision, an extended Poincare-Lighthill-Kuo method is employed. Most importantly, in the presence of external periodic perturbations, the periodic solitonic behaviour is transformed to quasiperiodic and chaotic oscillations. In this investigation, the effect of polarization force on dust kinetic Alfven solitary waves (DKASWs) in a magnetized dusty plasma consisting of dust fluid, electrons, and positively charged ions is studied. By incorporating density non-uniformity and polarization force in the fluid model equations, KdV equation is derived. Only rarefactive DKASWs at sub- and super-Alfvenic speeds are observed. These waves are significantly affected by varying polarization force, angle of propagation, plasma beta. This study may form the basis for the diagnostics of dust in laboratory and space/astrophysical plasmas where plasma density has some amount of non-uniformity and ion-dust interaction causes the polarization of the dust Debye sphere. The phase portrait analysis of the nonlinear KAW has also been presented. The numerical analysis of nonlinear KAWs from periodic to quasi-periodic and to chaos has also been presented in the presence of external perturbation. The investigation may be useful for understanding the energy transport phenomena of nonlinear KAW in space and laboratory plasmas.

References

[1] M. Singh et. al., Phys. Plasmas **25**, 023705 (2018).
[2] K. Singh et. al., Phys. Plasmas **25**, 033705 (2018).
[3] S. Mahmood et. al., J. Phys. Soc. Jpn.**89**, 034501 (2020).