Seminar

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Institute for Plasma Research

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Title: Analytical and computational studies of some nonlinear wave processes in plasmas

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Date: 19th April 2024 (Friday)

Time: 3.30 PM

Venue: Seminar Hall, IPR

Abstract

Plasma is a typical nonlinear dynamical system with many degrees of freedom. The dynamics of nonlinear wave is one of the most important subject of plasma physics because of its many applications in laboratory and astrophysics. The transport processes of these nonlinear waves are usually described through the model dependent nonlinear partial differential equations (NLPDE). To tackle these problems analytically, we have employed reductive and multi-scale perturbation techniques. Moreover, the derived NLPDEs are simulated using MATLAB-based PDE solver, the split-step Fourier and pseudo-spectral schemes on the basis of the experimental and astrophysical plasma parameters.

The dynamics of a modulated ion acoustic wave (IAW) excited by a steadily moving obstacle in a collisionless plasma is shown to be governed by a forced/driven nonlinear Schrödinger equation (NLSE). This NLSE is solved exactly for some special analytic forms of the driven term. The computational results using MATLAB-based PDE solver are noteworthy, which predict the excitation of collisionless shock at supersonic relative speed of the obstacle. The results are in well agreement with the observations in low altitude auroral plasmas.

The dynamics of the modulated electron plasma in presence of Kappa distributed non-thermal electrons is shown to be governed by a nonlocal NLSE. The nonlinear Landau damping process is responsible for the nonlocal term. The analytical results predict far ($3/2<\kappa<5/2$) and near ($5/2<\kappa<\infty$) equilibrium regions (κ is the spectrum of the distribution), which are in exact agreement with the statistical analysis of the Kappa distribution in space plasmas. In the far equilibrium, a new dispersive correction of the wave is observed. A 2nd order split-step Fourier scheme is developed for computation which demonstrate the orbit deviation of the recurrence cycles in Akhmediev breather. Similar kinds of phenomena are observed in water tank experiment in the presence of dissipation.

The dynamics of the modulated IAW at critical non-thermal parameter is studied by deriving a NLSE. At the boundary of the parameter space, a modified NLSE is derived to study the modulation characteristics. A higher order pseudo-spectral scheme is developed to simulate the modified NLSE and the results reveal that the IAW is modulationally unstable at the boundary.

The dynamics of the weakly nonlinear electrostatic ion cyclotron wave in the presence of Schamel distributed trapped electrons is shown to be governed by a Schamel-Ostrovsky type equation in a collisionless plasma. Analytical and numerical results reveal the collapse of a solitary (localized) pulse at a critical time that depends on the trapping parameter and the strength of the magnetic field. The computational results using pseudo-spectral scheme is noteworthy, which predict the wave packet (wave group) formation beyond the critical time. The results are in good agreement with the astrophysical observations in auroral plasmas.