Seminar

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Institute for Plasma Research

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Title: Vlasov Maxwell simulations of whistler mode interaction with bulk and beam plasma

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Date: **20th November 2024 (Wednesday)**

Time: **11.00 AM**

Venue: Seminar Hall, IPR

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Abstract

Phenomena like tokamak disruption and solar flare generate energetic particles. In case of solar flares underlying mechanism is magnetic reconnection which involves anisotropic velocity distribution functions (VDFs) that destabilize electromagnetic perturbations. In case of magnetized laboratory plasmas or in a large tokamak experiment like ITER, one of the major challenges is to control the energetic or runaway electrons. In tokamak disruption event, bulk plasma temperature drops to a very low value, as a result large toroidal electric field is generated forcing a fraction of electrons to detach from bulk plasma and accelerate. At high velocities, the collisions become rare, so the collisional mechanism fails to thermalise the system and an avalanche of runaways is generated. Recent estimates suggest that the upper hybrid mode remains stable for large size tokamak like ITER while the whistlers may not. The later may be self-excited and prevent the beam from growing. This is considered to be a potential reason for a threshold in the magnetic field for the runaway electrons to be generated. The destabilized whistlers also enter a nonlinear stage where the system operates in a state of marginal stability.

The kinetic treatment of such nonequilibrium systems are required to study these linear and nonlinear processes and validation of the existing analytical estimates. In this view, the outstanding issue of energetic electrons both in fusion reactors and in space plasmas, and to perform relevant analysis, grid based electromagnetic Vlasov simulation framework is developed along with an advanced linear dispersion solver [1, 2, 3]. By implementing these tools, the thesis addresses the following three problems, (a) The stability analysis of systems involving anisotropic VDFs is done with respect to external magnetic field and temperature of the electrons with verification of the linear result. From simulation, the nonlinear behaviour with external magnetic field and phase space evolution for isotropic core with anisotropic beam plasma system is studied [1]. (b) The marginal stability of the beam plasma system is tracked. A marginal stability condition is also derived analytically and its validity is examined for the regime of stability where saturation is attained following a nonlinear evolution. It is shown how the collisionless scattering depends on the wavelength of whistlers and the nonlinear saturation is developed by marginally stable state of the instability, relevant for both space and fusion plasmas. Stability of the beam plasma system with the core temperature, beam density and beam anisotropy is also simulated [2]. (c) The isotropic Maxwellian and Kappa VDFs are treated both by analytics and simulations. The electron temperature effect on the linear dispersion of the coherent whistler excitation is treated from the dynamical behaviour of the velocity space distribution using pure Maxwellian electrons. The long time behaviour of wave magnetic field for the Maxwellian and Kappa VDFs is simulated showing the nonlinear process of particle trapping in wave magnetic field resulting into wave amplitude oscillations, the corresponding phase space dynamics is illustrated [3].

References

[1] Anjan Paul and Devendra Sharma. Whistler heat flux instability governed interaction of anisotropic beam electrons in electromagnetic vlasov simulations. Physics of Plasmas, 30(10), 2023.
[2] Anjan Paul and Devendra Sharma. Kinetic instability of whistlers in electron beam-plasma systems. Physics of Plasmas, 31(3), 2024.
[3] Anjan Paul and Devendra Sharma. Microscopic structure of electromagnetic whistler wave damping by kinetic mechanisms in hot magnetized vlasov plasmas. Physica Scripta, 99(06), 2024.