Seminar

Institute for Plasma Research

Title: A global gyrokinetic study of microinstabilities driven by steep profile gradients in ADITYA-U Tokamak

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Abstract

In an MHD-stable fusion plasma, turbulence driven by microinstabilities poses a major challenge to achieving sustained confinement in tokamaks by enhancing radial transport of heat and particles. These instabilities are driven by gradients in temperature, density, and magnetic geometry, and evolve on spatial scales comparable to the ion Larmor radius and on time scales much slower than the gyrofrequency. This Thesis presents a systematic gyrokinetic investigation of electrostatic and low-β electromagnetic microinstabilities using experimentally relevant profiles of the ADITYA-U tokamak [1]. The work is organized into three main parts. In the first part, electrostatic simulations are performed using gyrokinetic ions and adiabatic electrons in an ad-hoc concentric circular equilibrium. Linear simulations reveal two distinct branches: the standard ion temperature gradient (ITG) mode at $k_\theta\rho_s \approx 0.4$ and a short-wavelength ITG (SWITG) mode at $k_\theta\rho_s \approx 1.2$, favored under steep gradient conditions. Although SWITG modes exhibit higher linear growth rates, nonlinear simulations show reduced transport due to enhanced zonal-flow shearing, which limits their saturation amplitude [2]. The second part extends the study to realistic magnetic equilibria. Electrostatic linear and nonlinear simulations of ITG-SWITG modes demonstrate that magnetic shaping (elongation and triangularity) reduces growth rates, shifts the unstable spectrum toward higher mode numbers, and lowers heat transport. In addition, electrostatic linear simulations with drift-kinetic electrons reveal the emergence of trapped electron modes (TEMs), which propagate in the electron diamagnetic direction at higher mode numbers [3]. In the final part, electromagnetic ITG-TEM turbulence is studied using gyrokinetic ions and drift-kinetic electrons in realistic equilibria, including collisions. At low-β and relatively high collisionality relevant to ADITYA-U, TEMs are stabilized due to collisional detrapping, and turbulence is dominated by ITG and SWITG modes. Nonlinear simulations show that finite-β and collisions together substantially reduce ion heat transport compared to the electrostatic case [4]. Findings provide qualitative insight and quantitative estimate of transport arising out of interplay between ITG, SWITG, TEMs, finite-beta effects, collisions and magnetic geometry in steep temperature gradient tokamaks such as ADITYA-U. All simulations are performed using global gyrokinetic codes GLOGYSTO [5] and ORB5 [6].

References

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[5] S. Brunner and J. Vaclavik, Phys. Plasmas 5, 3929–3949 (1998).
[6] Lanti E *et al* 2020, Comput. Phys. Commun. 251 107072.