

Seminar

Institute for Plasma Research

Title: Gyrokinetic Investigation of Transport in Weak Temperature Gradient Tokamak Plasmas

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Abstract

Transport in tokamak plasmas is largely driven by microturbulence associated with drift-wave instabilities caused by radial gradients in plasma density and temperature. In most tokamaks, temperature-gradient-driven modes such as the ion temperature gradient (ITG) mode and the trapped electron mode (TEM) dominate turbulent transport. However, experiments such as the Lithium Tokamak Experiment (LTX) at PPPL, US have demonstrated nearly flat temperature profiles with lithium-coated inner walls [1,2]. This raises an important question: when the temperature gradient is very small, does anomalous transport still occur, and if so, which instabilities are responsible?

This thesis investigates microturbulence and transport in weak-temperature-gradient plasmas using the global gyrokinetic code ORB5 [3]. Even without temperature gradients, density gradients alone destabilize drift-wave instabilities, namely the passing-electron-driven universal drift mode (UDM) and the trapped-electron-driven ubiquitous mode (UM), the latter found to be dominating in simplified equilibria. A parametric study demonstrate that the instability strength mainly depends on the density gradient and the trapped-electron fraction [4]. The UM is then examined in realistic LTX-like plasmas using CHEASE-generated equilibria [5]. Linear analysis confirms unstable UM modes over a range of toroidal mode numbers, while nonlinear simulations reveal an inverse spectral cascade toward lower mode numbers through mode coupling [6]. Zonal-flow (ZF) shearing remains weak, and weak temperature gradients produce only a marginal increase, consistent with the weak dependence of UM growth rates on temperature gradients. Even when kinetic passing electrons enhance transport, UM-driven turbulence remains the dominant source of particle and energy transport in LTX-like plasmas.

The influence of plasma shaping and reverse magnetic shear configurations is also investigated. Negative triangularity significantly reduces particle diffusivity due to lower UM growth rates despite ZF shearing comparable to positive triangularity, while reverse shear configuration also reduces transport by locally stabilizing the instability in the negative-shear region, accompanied by poloidalharmonic collapse and stationary corrugated structures near the shear-reversal layer [7]. Finally, motivated by the recent LTX upgrade with neutral beam heating [8], the interaction between energetic particles and plasma instabilities is studied. Simulations show the expected transition from the internal kink mode to the fishbone instability above a critical energetic-particle fraction, while nonlinear dynamics reveal strong self-

generated zonal flows that alter energetic-particle phase-space evolution, with implications for redistribution, transport barriers, and turbulence regulation in fusion plasmas [9].

References:

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