Seminar

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Institute for Plasma Research

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Title:	A global gyrokinetic study of microinstabilities driven by steep profile gradients in ADITYA-U Tokamak
Speaker:	Mr. Amit Kumar Singh Institute for Plasma Research, Gandhinagar
Date:	28^{th} July 2025 (Monday)
Time:	10:30 AM
Venue:	Seminar Hall, IPR

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, arising from gradients in temperature, density, and magnetic geometry, evolve on time scales slower than the charged particle gyrofrequency and occur at Larmor-radius scales.

This thesis work numerically investigates the linear and nonlinear characteristics of electrostatic and low β electromagnetic microinstabilities, using experimental profiles and parameters of ADITYA-U tokamak [1], a medium-sized device. This study is structured in three parts, as outlined below. In the first part of this work, the standard Ion Temperature Gradient driven modes (ITG) and Short Wavelength ITG (SWITG) modes are found and analyzed for experimental profiles and parameters of ADITYA-U tokamak. Linear global gyrokinetic simulations reveal two distinct growth rate peaks: one around $k_\theta \rho_s \approx 0.4$ corresponding to the standard ITG mode, and another around $k_\theta \rho_s \approx 1.2$, indicative of the SWITG mode. Notably, the existence of SWITG is naturally favored under the steep density and temperature gradients in ADITYA-U. While the SWITG mode is linearly more unstable than the conventional ITG mode in certain regimes, nonlinear simulations reveal that its contribution to ion heat transport is significantly reduced, due to enhanced zonal flow shearing rate in steep gradient regime, which reduces the nonlinear saturation amplitude of SWITG [2]. The second part of the study explores how magnetic equilibrium shaping specifically, elongation and triangularity affects ITG and SWITG behavior. Using exact magnetic equilibria for shaped plasmas in ADITYA-U, a reduction in growth rate is observed, along with a shift of the growth rate spectrum to higher mode numbers and a broadening of the unstable range. The heat flux is noticeably reduced when using true circular MHD magnetic equilibria instead of ad hoc con centric circular ones. Additionally, the inclusion of drift-kinetic electrons (both trapped and passing) leads to enhanced ITG growth rates and the emergence of a mode propagating in the electron diamagnetic direction at high toroidal mode numbers known as Trapped Electron Modes (TEMs) [3]. In the final part, the electrostatic studies are extended to include electromagnetic perturbations and electron-ion collisional effects. At low plasma beta and in a high collisionality regime characteristic of ADITYA-

U plasmas, it is found that the TEMs are completely stabilized. Only ITG and SWITG modes are found survive. Nonlinear simulations comparing electrostatic and electromagnetic cases, with and without collisions, suggest that finite β and collisionality together may reduce ion heat transport [4]. In this talk, details of the above said work and several open problems will be discussed. All simulation studies in thesis work have been performed using global gyrokinetic codes namely GLOGYSTO [5] and ORB5 [6].

References

[1] Tanmay Macwan *et al* 2021 Nucl. Fusion 61, 096029.

[2] Amit K. Singh *et al* 2023 Nucl. Fusion 63 086029.

[3] Amit K. Singh *et al* 2024 Nucl. Fusion 64 106005.

[4] Amit K. Singh *et al* Electromagnetic gyrokinetic simulation of turbulence in ADITYA-U with collisions, (to be submitted, 2025).

[5] S. Brunner and J. Vaclavik, Phys. Plasmas 5, 3929–3949 (1998).

[6] Lanti E *et al* 2020, Comput. Phys. Commun. 251 107072.