17th European Fusion Theory Conference

9 - 12 October 2017, Athens - Greece

EFTC 2017

Multi-Scale Gyrokinetic Simulation of L and H-mode Plasma Conditions in the Alcator C-Mod Tokamak

N. T. Howard[1], C. Holland[2], A. E. White[1], M. Greenwald[1], J. Candy[3], P. Rodriguez- Fernandez[1], and A. J. Creely[1]

[1]*Massachusetts Institute of Technology (MIT), Cambridge MA 02139, USA*
[2]*University of California – San Diego (UCSD), La Jolla, CA 92093, USA*
[3]*General Atomics (GA), San Diego, CA 92121, USA*

Referred to as the, "great unsolved problem of tokamak transport physics" [1], electron thermal transport is often anomalous in the tokamak core. It has been speculated that short wavelength ETG turbulence plays a key role, but due to extreme computational requirements this hypothesis has only recently been tested quantitatively using a model that captures coupling between long wavelength ITG/TEM and short wavelength ETG. In Alcator C-Mod, simulations of long wavelength turbulence often fail to explain experimental electron heat fluxes [2], suggesting that electron-scale turbulence and cross-scale coupling may play an important role. Dedicated experiments have been performed in Alcator C-Mod L-mode plasmas and ITER-relevant, ELM-y H-mode plasmas to validate nonlinear gyrokinetic simulations. Building off of previous work [3] full-physics, multi-scale simulations of tokamak plasmas have been performed using the GYRO code. The simulations capture coupled ITG/TEM/ETG turbulence ($k_\theta\rho_s$ < 48.0), use experimental inputs, impurities, real geometry, electromagnetic effects, ExB shear, collisions, and realistic electron mass (mi/me = 3600) while pushing the limits of high-performance computing. These multi-scale simulations reveal the complex interplay between ion and electron-scale turbulence in real plasma conditions. ETG streamers are found to coexist and strongly interact with ITG turbulence, modify the direction of energy cascades, and nonlinearly couple with zonal flows in the core tokamak plasmas. This nonlinear cross-scale coupling enhances both ion and electron heat flux, resulting in simulations that quantitatively reproduce experimental ion and electron heat flux levels and measured values of electron profile stiffness. In some experimental conditions, multi-scale simulation is found to predict heat fluxes up to a factor of 10 greater than corresponding ion-scale simulation, which may call into question existing ITER predictions based solely on long wavelength simulation. To begin to probe the importance of cross - scale coupling in ITER, multi-scale simulations of high performance, Alcator C-Mod, H-mode conditions were performed. These simulations predict extremely stiff transport and demonstrate that cross-scale coupling plays a critical role in reproducing experimental heat fluxes and electron profile stiffness in ITER-like conditions as well. The role of multi-scale plasma turbulence in real experimental conditions and the implications of cross-scale coupling on predicting turbulence and transport in current and future experiments will be discussed.

References

[1] D. A. Batchelor et al. Plasma Science and Technology 9 (2007)
[2] N. T. Howard et al. Nuclear Fusion 53 (2013) 123011
[3] N. T. Howard et al. Physics of Plasmas 21, (2014) 112510