Gyrokinetic continuum simulations of plasma turbulence in the Texas Helimak

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Simple magnetized tori (SMT) experiments, such as the Texas Helimak, use vertical and toroidal field coils to create open, helical magnetic-field-line configurations with curvature and shear. With dimensionless parameters and magnetic geometry similar to the SOL, these devices can be used to compare analytic and numerical models of SOL turbulence to experimental data. Prior to this work, only fluid simulations had been performed of the Helimak. These fluid models reproduced some key experimental features and may explain SMT and tokamak-SOL plasmas well in some collisional parameter regimes. However, kinetic models are required to capture effects that can be significant in lower-collisionality parameter regimes, such as trapped particles, some non-linear wave–particle interactions, and non-Maxwellian features in the particle distribution functions.

Building on work by Shi *et. al.* using the computational plasma physics framework Gkeyll[1, 2, 3], we present the first continuum gyrokinetic simulations of plasma turbulence in the Texas Helimak[4, 5] The device has features similar to the scrape-off layer region of tokamaks, such as bad curvature-driven instabilities and sheath boundary conditions on the end plates, which are included in our model. A bias voltage can be applied across conducting plates to drive $\mathbf{E}\times\mathbf{B}$ flow and study the effect of velocity shear on turbulence suppression. We performed simulations of grounded[4] and limiter-biased scenarios[5]. Comparisons between simulations and measurements from the experiment show good qualitative similarities, including equilibrium profiles and fluctuation amplitudes that approach experimental values, but also some important quantitative differences. We discuss how including additional physical and geometric effects in our model, such as real ion-to-electron mass ratio and vertical $\mathbf{E}\times\mathbf{B}$ flow could improve agreement with experiment. Both experimental and simulation results exhibit turbulence statistics that are characteristic of blob transport, and, overall, results demonstrate good progress towards modeling turbulence on helical open-field lines in tokamak SOL-like conditions with gyrokinetic equations.

Acknowledgements

This work was supported by the U.S. Department of Energy SCGSR program under contract DE-SC0014664, by DOE Contract DE-FG02-04ER-54742, through the Institute of Fusion Studies at the University of Texas at Austin, and DOE contract DE-AC02-09CH11466, through the Princeton Plasma Physics Laboratory (PPPL).

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