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Gyrokinetic Theory and Simulation of Experiments[1]

GREGORY W. HAMMETT, Princeton Plasma Physics Laboratory

There has been interesting and important progress recently in the development of 5-dimensional continuum and PIC gyrokinetic simulations of turbulent transport in tokamaks [1-3]. The mechanisms driving this turbulence will be illustrated with intuitive physical pictures and visualizations from simulations. This also gives insight into methods to reduce turbulence that are being studied in experiments and simulations. 5-dimensional plasma turbulence is a very challenging problem, but is becoming feasible because of the exponential growth in computer power and advances in algorithms and theory. These advances include the gyrokinetic equations themselves (a rigorous expansion of the full equations that average over high-frequency gyromotion while retaining nonlinearities) and computational techniques such as high-order algorithms, efficient field-aligned coordinates, and implicit methods. The most comprehensive of these codes treat all transport channels and now include all the effects thought important for realistic calculations of the drift-wave microturbulence that occurs in the core of tokamaks: fully gyrokinetic ions and electrons, electromagnetic fluctuations, collisions, realistic geometry, ExB shear stabilization, and finite rho-star effects that can break gyro-Bohm scaling and provide non-local transport. These codes are increasingly being used to compare with and understand experimental data. Remaining challenges will also be described, including more extensive comparisons (such as with non-steady-state phenomena and fluctuation measurements), multiscale couplings (such as low-n MHD and turbulence), and the complex edge of fusion devices.

[1] W. Dorland, F. Jenko, M. Kotschenreuther, B.N. Rogers, Phys. Rev. Lett. (2000)
[2] J. Candy, R.E. Waltz, Phys. Rev. Lett. (2003)
[3] Y. Chen, S.E. Parker, B.I. Cohen, A.M. Dimits et al., Nucl. Fus. (2003)

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