Abstract for an Invited Paper
for the APR99 Meeting of
The American Physical Society

Theory Based Models of Turbulence and Anomalous Transport

GREGORY W. HAMMETT, Princeton Plasma Physics Laboratory[1]

Turbulence has been an important topic in plasma physics research both because of its fundamental interest as a complex nonlinear phenomenon, and because of the effects of turbulence on the behavior of astrophysical and laboratory plasmas. The performance of fusion experiments has often been limited by the turbulent loss of heat from the plasma, though recent experiments have found various ways to significantly reduce the turbulence, which could help lead to more attractive fusion reactor designs. Some of the essential physics that drive turbulence in magnetically confined plasmas can be demonstrated by simple physical pictures such as the classic Rayleigh-Taylor gravitational instability (for a heavy fluid supported by a light fluid), or the simple instability of an inverted pendulum. Significant progress has been made in direct 3-D simulations of turbulence in magnetically confined plasmas using both fluid and particle techniques. This has been made possible by theoretical advances and experimental evidence that help guide relevant approximations, by innovations in computational algorithms, and by the growth of computer power. Present simulations appear to be able to explain important scalings of turbulence in tokamak experiments in many parameter regimes. Interesting features of the turbulence, which will be demonstrated by computer visualizations, include marginal-stability behavior (similar to turbulence in the convection zone of the sun), self-regulation of turbulence via generation of sheared zonal flows, regimes of self-sustained turbulence driven by nonlinear instabilities, and various methods to reduce the turbulence. While significant progress has been made, present computer simulations are not yet complete enough to predict plasma turbulence in all parameter regimes relevant in a fusion device, and there are various sources of uncertainty in projecting to larger devices. But the progress made to date strongly suggests that relatively complete simulations should be achievable in the near future, made possible by further theoretical and experimental work, and by the power of the next generation of massively parallel supercomputers.

[1]This work supported by DOE Contract DE-AC02-76CH03073, by the Numerical Tokamak Turbulence Project, a DOE computational Grand Challenge Project, and by the National Energy Research Supercomputer Center.