Turbulence, transport and self-consistent profiles via global Eulerian gyrokinetic simulations*

J. Candy

General Atomics, P.O. Box 85608
San Diego, California 92186-5608

Abstract

In this presentation we discuss algorithms devised, and obstacles faced, throughout the development of the global Eulerian gyrokinetic code, GYRO. The purpose of GYRO, in the most general sense, is to explore the dependence and character of turbulent transport in tokamaks on equilibrium parameters (temperature gradient, magnetic shear, and many others). To address the general problem of transport and associated profile stiffness, GYRO also has an operational mode which can predict the self-consistent radial profiles of density and temperature in a given discharge by balancing the computed turbulent power flow with the experimentally-measured power flow. This is done using an iterative, transport-timescale relaxation scheme. From the point of view of comprehensiveness, GYRO is unsurpassed in the breadth of physical effects that are included in each calculation: standard ion-temperature-gradient (ITG) mode turbulence, trapped and passing electrons with pitch angle collisions, finite-β fluctuations, real flux-surface shape, linear and nonlinear $\mathbf{E} \times \mathbf{B}$ rotation, parallel flow shear, and arbitrary radial variation of all equilibrium quantities. GYRO operates at finite $\rho_* = \rho_i/a$ using a WKB-like formulation to treat the small $1/n$ corrections due to radial variation of ω_*, η_i, s, etc, not present in the flux-tube approximation. A special technique[1] to remedy the troublesome Ampère cancellation problem[2] is critical to the finite-β mode of operation. The choice of an Eulerian rather than a PIC discretization scheme allows us to perform very-long-time simulations $(c_s/a)t \gg 1000$ with no noise-related accuracy degradation, and moreover, no instability and/or artificial secular or explosive growth of $n = 0$ modes. Electron advection is treated implicitly, and all other physics explicitly, to full second-order accuracy using a so-called implicit-explicit Runge-Kutta integrator[3]. The scheme is consistent, accurate and strong-stability-preserving in the stiff limit $(m_i/m_e \to \infty)$. One effect of the scheme is to couple the Poisson and Ampère equations, and further to regularize them at long wavelength. In previous work, we have reproduced the nonlinear, flux-tube Cyclone benchmarks[4] over the full range of R/L_T. Also, we have shown systematically how to recover gyroBohm-scaled transport in the small-ρ_* limit with both quasi-periodic and non-periodic boundary conditions.[5] More recently, we have carried out simulations which match, well within experimental error bounds, the turbulent transport levels observed in a pair of DIII-D L-mode discharges [6].

*Work supported by the U.S. Department of Energy under Grant Nos. DE-FG03-95ER54309 and the SciDAC Plasma Microturbulence Project.

---

[1]J. Candy and R.E. Waltz, General Atomics Report GA-A23876, November 2001.

[2]F. Jenko, private communication (2001).

[3]L. Pareschi and G. Russo, in *Hyperbolic Problems: Theory, Numerics, Applications* (Springer) 2002.

[4]A.M. Dimits, *et al.*, Phys. Plasmas **7**, 969 (2000).

[5]R.E. Waltz, J. Candy and M.N. Rosenbluth, Phys. Plasmas **9**, 1938 (2002).

[6]J. Candy and R.E. Waltz, submitted to Phys. Rev. Lett.