Large Scale Particle-In-Cell Simulations of Steady State Microturbulence in Tokamaks

R. Ganesh[1] , J.Chowdhury[2] , W. X. Wang[3], W. W. Lee[3] , S. Ethier[3] and J. Manickam[3]

[1]*Institute for Plasma Research, Bhat, India;*

[2]*Univ. of Boulder, Colorado, USA;*

[3]*Princeton Plasma Physics Laboratory, Princeton, NJ, USA 08543*

An efficient and physically meaningful formulation of Vlasov-Maxwell equations suitable for microturbulence simulations in tokamaks followed by the advent of large scale computing resources world-wide has led to an unprecedented level of advancement in the understanding of global, electrostatic/electromagnetic gyrokinetic toroidal turbulence driven by ion and electron temperature gradients & trapped electron physics. Depending on the physics problem, a number of methods and codes are now available, such as phase space Eulerian methods, Lagrangian & Semi-Lagrangian methods and Monte-Carlo δf methods, to mention a few. In particular, δf Particle-in-Cell (PIC) methods pioneered by Lee and co-workers [1] has the important advantage of using modest resources to scale up to realistic systems size to estimate steady state transport. Traditionally, in the δf formulation, a single weight Klimontovich-Dupree formulation representing only the microturbulence evolution has been considered. However, in tokamaks, in reality, zeroth-order inhomogeneity which drives the microturbulence also needs to be evolved self-consistently. Another important open question is to address the physics of energetic particle redistribution in the presence of Ion temperature gradient (ITG) turbulence and Trapped electron mode (TEM) turbulence.

In this presentation, these three important and related questions are addressed, namely: 1. The use of a generalized weight-based particle simulation scheme suitable for simulating tokamak plasmas [2], where the zeroth-order inhomogeneity is important 2. The transport of energetic particles as passive tracers. 3. The retardation of the linear growths of ITG modes due to the presence of the equilibrium zonal flows generated by the finite Larmor radius (FLR) effects of the ions, which give rise to extra ion charge density [1]. In particular, a new scheme, based on the concept of multiscale expansion that can simulate both the perturbed distribution (δf-) and the full distribution (full-F-) within the same code is developed and implemented. For energetic particle transport, test particle diagnostics implemented in GTS [Wang et al, Phys. Plasmas 13, 092505 (2006)] code and corresponding simulation studies for relevant initial energy of fast particles carried out on the state-of-the-art massively parallel computers, for ITG and TEM turbulence [3] is presented. A comparison with previous work on profile relaxation [4] and the physics of steady state transport in tokamaks using GTC [Lin et al, Science 1998] as well as the comparisons between the Dimits shift [Dimits, PoP 2000] of ITG modes, which is nonlinear in nature, and the linear retardation described above [1] , which has been initially studied recently [5] will also be discussed.

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