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Simulations of Electromagnetic Microtubulence with Kinetic Electrons[1]

Y. Chen and S. E. Parker[2]
University of Colorado, Boulder, CO 80309

A new numerical algorithm has recently been developed that allows for simulation of electromagnetic tokamak microturbulence with drift-kinetic electrons, experimental values of plasma β, and realistic mass ratios using gyrokinetic δf particle-in-cell (PIC) simulation methods[3]. PIC methods of this type have the computational advantage of resolving particle-wave resonance effects using only a three-dimensional spatial grid. Such simulations can use a very large number of particles ($10^8 - 10^9$) thereby providing a useful tool to determine if fine phase space resolution is needed for the microturbulence problem. The new algorithm solves a long-standing problem in gyrokinetic particle simulation when kinetic electrons and finite-β effects are introduced[4]. The problem is associated with the electron current of the zero-order distribution (Maxwellian in terms of parallel canonical momentum) which typically far exceeds the total perturbed current. It is solved here by evaluating this current using the same marker particles and the same particle shape as that used for the perturbed distribution to get near exact numerical cancellation. The simulation uses three-dimensional toroidal field-line-following flux-tube geometry and includes electron-ion collisional effects. Linear benchmarks show good agreement with continuum codes[5]. It is found that for H-mode parameters, the nonadiabatic effects of kinetic electrons increase linear growth rates of the Ion-Temperature-Gradient-Driven (ITG) modes, mainly due to trapped-electron drive. The ion heat transport is also increased from that obtained with adiabatic electrons. The ion heat transport decreases to below the adiabatic electron level when finite plasma β is included due to finite-β stabilization of the ITG modes. This may help explain why past H-mode results predicted transport levels much too high[6].

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[2]with Summit Framework collaborators: B. I. Cohen, A. M. Dimits, W. M. Nevins, D. Shumaker, LLNL; V.K. Decyk, J.N. Leboeuf, UCLA

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