Status of Continuum Edge Gyrokinetic Code Physics Development*

X. Q. Xu, Z. Xiong, M. R. Dorr, J. A. Hittinger, G. D. Kerbel,
W. M. Nevins, B. I. Cohen, and R. H. Cohen
Lawrence Livermore National Laboratory, CA 94550

We are developing an edge gyro-kinetic continuum simulation code to study the boundary plasma over a region extending from inside the H-mode pedestal across the separatrix to the divertor plates. A 4-D $(\psi, \theta, \epsilon, \mu)$ version of this code is presently being implemented, en route to a full 5-D version. A set of gyrokinetic equations[1] are discretized on computational grid which incorporates X-point divertor geometry. The present implementation is a Method of Lines approach where the phase-space derivatives are discretized with finite differences and implicit backwards differencing formulas are used to advance the system in time. A fourth order upwinding algorithm is used for particle cross-field drifts, parallel streaming, and acceleration. Boundary conditions at conducting material surfaces are implemented on the plasma side of the sheath. The Poisson-like equation is solved using GMRES with multi-grid preconditioner from HYPRE. A nonlinear Fokker-Planck collision operator from STELLA[2] in $(v_\parallel, v_\perp)$ has been streamlined and integrated into the gyro-kinetic package using the same implicit Newton-Krylov solver and interpolating F and $dF/dt|_{coll}$ to/from (ϵ, μ) space.

With our 4D code we compute the ion thermal flux, ion parallel velocity, self-consistent electric field, and geo-acoustic oscillations, which we compare with standard neoclassical theory for core plasma parameters; and we study the transition from collisional to collisionless end-loss. In the real X-point geometry, we find that the particles are trapped near outside midplane and in the X-point regions due to the magnetic configurations. The sizes of banana orbits are comparable to the pedestal width and/or the SOL width for energetic trapped particles. The effect of the real X-point geometry and edge plasma conditions on standard neoclassical theory will be evaluated, including a comparison of our 4D code with other kinetic neoclassical codes (such as NCLASS[3] and XGC[4]) and experiments.

References

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