Multilevel Monte Carlo for diffusive Kinetic Equations in Plasma Edge Simulations

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When designing tokamak fusion reactors, two sets of particles need to be modeled. The electromagnetically constrained plasma, which harbors the reaction, is generally modeled as a fluid. This fluid model is coupled with a kinetic equation modeling neutral particles. When the collision rate of neutrals with the background is high, a well-defined limiting equation exists. High-dimensionality of the position-velocity phase-space means that particle-based Monte Carlo becomes a go-to approach in many cases. These methods become very expensive, however, when approaching the high-collisional limit as small time steps are required to resolve the collision dynamics.

The multilevel Monte Carlo method combines simulations with different discretization accuracies to compute results with the accuracy of the finest discretization at a reduced computational cost. In this presentation we introduce a class of methods called asymptotic-preserving multilevel Monte Carlo methods, and demonstrate the speed up they achieve on test-problems. We then discuss the challenges involved in applying these methods to more physically realistic problems and how these challenges can be addressed.