A new hybrid-Lagrangian gyrokinetic scheme for tokamak edge plasmas

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Objectives

- Tokamak edge is in a non-thermal state, and requires an in-depth kinetic understanding for predictive ITER-critical physics
  - Edge confinement determines the core fusion performance
- A more efficient and robust scheme needs to be developed for the difficult gyrokinetic simulation of tokamak edge plasmas
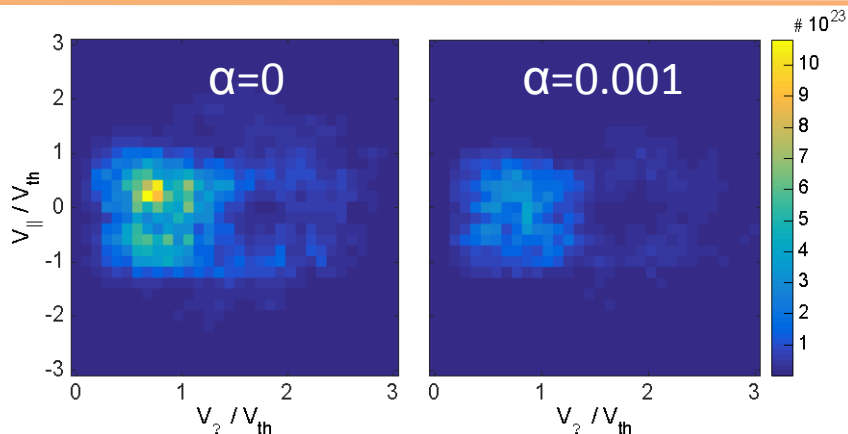

Fig. 1. Square mean of particles weights (Monte Carlo noise) on velocity grid at two different particle-to-grid conversion rate: (left) $\alpha=0$, and (right) $\alpha=0.001$. Reduction in particle noise by factor of 4 is achieved with $\alpha = 0.001$

Impact

- The new scheme will enable faster progress in the gyrokinetic understanding of tokamak edge plasmas on leadership class computers.

Challenges

- Edge non-thermal plasmas are subject to scale-inseparable multiphysics
  - Neoclassical physics, turbulence and instabilities, neutral particles, radiative loss, and wall loss need to be simulated together
- Such non-thermal plasmas are difficult to study from the existing gyrokinetic schemes
  - Each schemes have pros and cons
  - Can we combine the pros?

Accomplishments

- A new hybrid-Lagrangian gyrokinetic scheme has been invented, by combining the phase space grid into the PIC scheme: implemented in the edge gyrokinetic code XGC1
- The coarse-grained phase space grid contains evolution of the slowly varying non-Maxwellian particle distribution function f_0, while the δf marker particles describe the fast-varying physics
- A small fraction, α, of δf particle weight is converted to grid f_0 at every simulation time step to mitigate the growing-weight issue (Fig 1)
- Marker particles provide the parallel scalability on leadership class computers, while the coarse-grained grid f_0 reduces the Monte Carlo noise

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