Collisional Electrostatic and Collisionless Electromagnetic Simulations with the Global Gyrokinetic $\delta f$ Particle-in-Cell Code ORBS


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1. Introduction

The global PIC gyrokinetic code ORBS [1], based on $\delta f$-method, is upgraded with:
- Linearized intra- and inter-species Landau collision operators for ions and electrons [2].
- A novel background switching scheme in the frame of the $\delta f$ PIC approach [3].
- A coarse graining procedure for avoiding the weight spreading [3].
- An electromagnetic solver [4].

Numerical results:
- Global neoclassical equilibria with self-consistent electric fields [2], [5] are obtained and used as starting point for carrying out simulations of electrostatic ITG microturbulence with collisional effects.
- The crucial issue of numerical noise is addressed by showing that the coarse graining procedure makes it possible to run relevant collisional turbulent simulations.
- Global collisionless electromagnetic simulations show the influence of $j$ on heat transport.

2. Two-Weight Scheme

- The gyro-averaged particle distribution function is split into a Maxwellian background $f_0$ and a perturbed part $f = f_0 + \delta f$.
- Marker distribution in gyrocenter phase space: $g(A, v, \mu, t)$.
- In a collisional system, $g$ is not constant along trajectories $\mathcal{M}=\{f_0(v)\}$, $\rho_t(v) = \frac{\rho_0(v)}{g(A, v, \mu)}$.

4. Electrostatic Collisionless Simulations [8]

- Gradient-driven simulations, CYCLONE base case, adiabatic electrons. Two temperature gradients considered: $R_E/L_E = 5.3$ and $R_T/L_T = 6.9$. Total ion heat diffusivity in general increased by collisions.
- Temperature profiles with wide gradients are used ($\Delta T \sim 0.6a$), except for figures showing the time traces of the shearing rate (bursts more visible in a more local configuration, $\Delta T \sim 0.3a$).

5. RH test, effects of gradients

- Collisionless simulations: the residual value of the zonal flow is proportional to the initial amplitude of the perturbation.
- Collisional simulations: the zonal flow converges towards the neoclassical equilibrium, regardless of the initial electric field amplitude.

7. Electromagnetic Collisionless Simulations [9]

- CYCLONE base case, $r^* = 1/184$, $m_i/m_e = 1000$.
- Left: Time evolution of the ion thermal diffusivity for an electromagnetic $i_{\|} \sim 0.3\%$ simulation (red), and electrostatic simulation with kinetic trapped and adiabatic passing electrons (black, dashed) and with all electrons adiabatic (blue).
- Right: Ion thermal diffusivity as a function of $i_{\|}$ sources applied. The red point: different initial conditions (white noise), $\chi_i$ averaged over radius and time (moving average).

8. Conclusions

- Non-negligible collisional effects on turbulence.
- Kinetic electrons increase ITG heat diffusivity.
- Future work: Collisional TEM simulations.

References: