§26. Like-particle Collision Model for δf Particle Simulation

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Collisions between ions and electrons can be simply modeled by employing the large mass ratio approximation. Here we present a linear like-particle collision model, accurately conserving all of particle number, momentum and energy for δf particle simulation.

Our like-particle collision model reads

$$C^l(f_1) = C_0^l + [P_1 + Q_1 + P_2 + Q_2] f_M, \quad (1)$$

where

$$C_0^l(f_1) = C_{TP}(f_1) + P f_M, \quad (2)$$

$$P(\vec{r},\vec{v}) = \vec{A}\cdot\frac{d}{dt}\langle\vec{v}\rangle_{TP} + B\frac{d}{dt}\langle v^2\rangle_{TP},$$

$$P_1(\vec{r},\vec{v}) = \vec{A}\cdot\frac{d}{dt}\langle\vec{v}\rangle_{TP+P} + B\frac{d}{dt}\langle v^2\rangle_{TP+P},$$

$$Q_1(\vec{r},\vec{v}) = D\frac{d}{dt}\langle v^0\rangle_P,$$

$$P_2 = \vec{A}\cdot\frac{d}{dt}\langle\vec{v}\rangle_{TP+P+P_1+Q_1} + B\frac{d}{dt}\langle v^2\rangle_{TP+P+P_1+Q_1},$$

$$Q_2(\vec{r},\vec{v}) = D\frac{d}{dt}\langle v^0\rangle_{P+P_1+Q_1},$$

$$\vec{A} = -6\sqrt{\frac{\pi}{2}}\phi\frac{v_{th}\vec{v}}{v^3}, \quad B = -2\sqrt{\frac{\pi}{2}}\left[\phi - \frac{d\phi}{dx}\right]\frac{1}{v v_{th}},$$

$$D(\vec{x},\vec{v}) = 3\sqrt{\frac{\pi}{2}}\left[\phi - \frac{d\phi}{dx}\right]\frac{v_{th}}{v} - 1,$$

$\phi(x)$ is Maxwellian integral with $x = v^2/v_{th}^2$. The $C_{TP}(f_1)$ is drag and diffusion part that describes the test particle (f_1) collisions with Maxwellian field particles (f_M), and is readily implemented by Monte Carlo method. The Pf_M works for compensating $\frac{d}{dt}\langle\vec{v}\rangle_{TP}$ and $\frac{d}{dt}\langle v^2\rangle_{TP}$, the averaged momentum and energy loss due to C_{TP}. Pf_M and the other rest terms of Eq.(1) can be implemented by weight method in δf simulation. C_0^l represents the previous collision operator[1,2]. In the implementation of C_0^l, there are still considerable non-vanishing $\frac{d}{dt}\langle\vec{v}\rangle_{TP+P}$, $\frac{d}{dt}\langle v^2\rangle_{TP+P}$ and $\frac{d}{dt}\langle v^0\rangle_P$ due to numerical errors, and the numerical errors may get so enlarged as to distort simulation results. The compensation terms are developed to restore conservations. For example, $P_1 f_M$ is introduced to compensate the momentum and energy loss, $\frac{d}{dt}\langle\vec{v}\rangle_{TP+P}$ and $\frac{d}{dt}\langle v^2\rangle_{TP+P}$, and $Q_1 f_M$ to compensate $\frac{d}{dt}\langle v^0\rangle_P$, the numerical particle loss due to Pf_M. As shown in Fig.1, the conservations of all three quantities are greatly improved by using present collision operator. A shifted Maxwellian solution of ion drift kinetic equation under $\nabla T = 0$, which gives zero particle and energy flux, is recovered (Fig.2) owing to the utilize of the improved operator

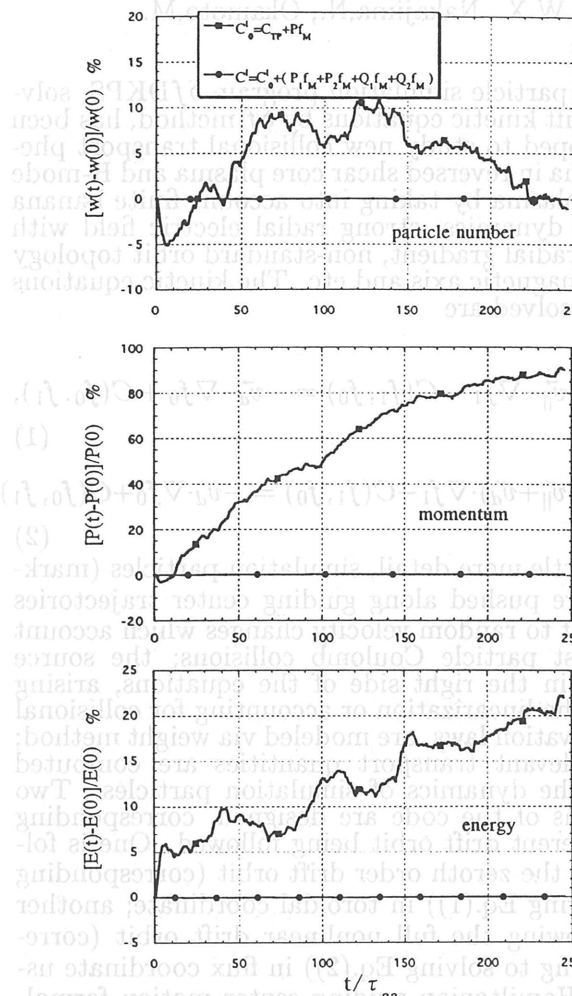

Fig.1 The time history of three conservations

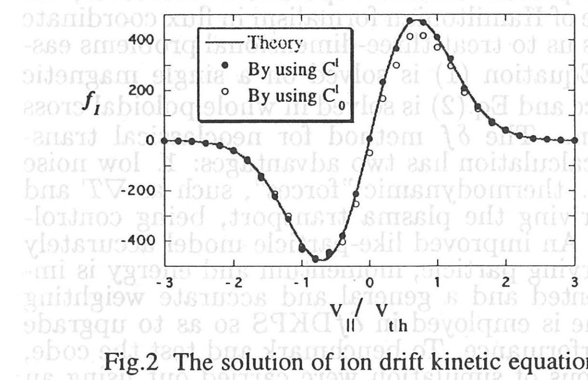

Fig.2 The solution of ion drift kinetic equation

References

1) Dimits,A.M. and Cohen,B.I., Phys. Rev. E 49 (1994) 709.

2) Lin,Z., Tang,W.M. and Lee,W.W., Phys. Plasmas 2 (1995) 2975.