Derivation and application of the fully magnetized kinetic equations

C. Dong$^{1,2}$, D. Li$^{1,2,3}$, W. Zhang$^{1,2,3}$, J. Cao$^{1,2}$

1. Institute of Physics, Chinese Academy of Sciences, Beijing
2. University of Chinese Academy of Sciences, Beijing
3. University of Science and Technology of China, Hefei

Email: dli@cashq.ac.cn

In the magnetized and laser fusion plasma, space and astrophysical plasma, the particles’ gyro-radii can be smaller than the Debye length when there is a strong magnetic field. This will have a significant influence on collision dynamics and many physical processes such as parallel velocity slowing down, temperature relaxation, particle diffusion, thermal transport, and so on..

The fully magnetized Fokker-Planck equation is derived by including a uniform magnetic field in the collision term as follows:

\[
\frac{\partial f_a(v_\alpha, \tau)}{\partial \tau} + \Omega_\alpha v_\alpha \times \hat{e}_z \cdot \frac{\partial f_a(v_\alpha, \tau)}{\partial v_\alpha} = - \frac{\partial}{\partial v_\alpha} \cdot [(\Delta V_\alpha) f_a(v_\alpha, \tau)] + \frac{1}{2} \frac{\partial^2}{\partial v_\alpha \partial v_\alpha} \cdot [(\Delta V_\alpha \Delta V_\alpha) f_a(v_\alpha, \tau)]
\]

Where the magnetized Fokker-Planck coefficients \((\Delta V_a)\) and \((\Delta V_\alpha \Delta V_\alpha)\) have been derived explicitly within the binary collision model and the fully magnetized Landau equation is obtained:

\[
\frac{\partial f_a(v_\alpha, \tau)}{\partial \tau} + \Omega_\alpha v_\alpha \times \hat{e}_z \cdot \frac{\partial f_a(v_\alpha, \tau)}{\partial v_\alpha} = \frac{\partial}{\partial v_\alpha} \cdot \sum_{\beta} \frac{q_\alpha^2 q_\beta^2}{m_\alpha} \int_{-\infty}^{\tau} dt_1 \int d^3k \int d^3v_\beta \\
\times \Phi_\beta(k) \exp\left[i \cdot (H_\alpha(t_2) - H_\alpha(0)) \cdot v_\alpha \right] - i k \cdot [H_\beta(t_1) - H_\beta(0)] \cdot v_\beta - i \omega(t - t_1) \right] \\
\times \left( \frac{1}{m_\alpha} \frac{\partial}{\partial v_\alpha} - \frac{1}{m_\beta} \frac{\partial}{\partial v_\beta} \right) [f_a(v_\alpha, \tau) f_\beta(v_\beta, \tau)]
\]

It is shown that the impact of strong magnetic field is significant on transport processes such as stopping power and temperature relaxation etc.

References

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