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電子縮退プラズマ中の電子–イオン温度緩和率
Electron-ion temperature equilibration rate in electron degenerate plasmas

杉田昂平[1]、中尾安幸[1]、城﨑知至[2]
Kohei Sugita[1], Yasuyuki Nakao[1], and Tomoyuki Johzaki[2]

[1]九大院工、[2]広大院工
[1]Kyushu Univ., [2]Hiroshima Univ.

1. Introduction

The temperature equilibration between electrons and ions in dense plasma is one of the most important phenomena for inertial confinement fusion (ICF) [1], and then its calculation model has been modified recent years [2-6]. The rate of electron-ion temperature relaxation is determined by the magnitude and frequency of electron-ion interaction and is affected by various physical processes. In highly-compressed plasmas as realized in ICF implosions, the effect of electron degeneracy becomes non-negligible [3]. However this effect has not been discussed sufficiently yet and the evaluation based on more rigorous treatment is necessary. Thus we evaluated the rate parameter of electron-ion temperature relaxation from the time variation of detailed energy distribution of ions coexisting with degenerate electrons.

2. Model

The equilibration of electron and ion temperature (T_e, T_i) via collisions is often described by

$$\frac{dT_e}{dt} = -\gamma_{ei}(T_e - T_i), \quad (1) \qquad \frac{dT_i}{dt} = -\gamma_{ie}(T_i - T_i), \quad (2)$$

where the parameter γ_{ei} (γ_{ie}) is equal to the reciprocal of the relaxation time and have been evaluated using various methods, for example, Brown, Preston, and Singleton (BPS) used the dimensional continuation method [3-5]. However their formula does not incorporate real time variation of temperature and detailed energy distribution of particles, therefore we solved the equation for distribution function of ions coexisting with degenerate electrons [8] and evaluated γ_{ie} from the time variation of ion temperature in order to remove vagueness as many as possible.

3. Results and discussion

Supposing fully ionized deuterium plasmas at various temperature ($T_i \neq T_e$) as the initial values and fixing the distribution function of electrons, we evaluated the parameter γ_{ie} by fitting obtained time variation of ion temperature to Eq.(2). Figure 1 presents the parameter γ_{ie} as a function of electron temperature at electron number density n_e = 10^{26} cm^{-3}. The points are obtained from the time variation of ion temperature and dashed curves are from BPS formula. The red points and curve are results in the case considering the effect of electron degeneracy and the blue ones are obtained ignoring the degeneracy effect. For comparison, we plotted the results from other models [2,6,7]. At this density, BPS formula is accurate above 0.5 keV [4], and except its neighborhood, our calculation gives similar results as the BPS model. The parameter γ_{ie} decreases with temperature because the frequency of electron-ion interaction decreases. In addition, it can be seen that the electron degeneracy slows temperature equilibration and this tendency become more significant at lower temperature. This is because Pauli's exclusion principle reduces the frequency of electron-ion interaction in the degenerate region.

However each result shown in Fig.1 does not include strongly coupling plasma effects, which are important below about 0.2 keV, and it becomes incorrect at very low temperatures.

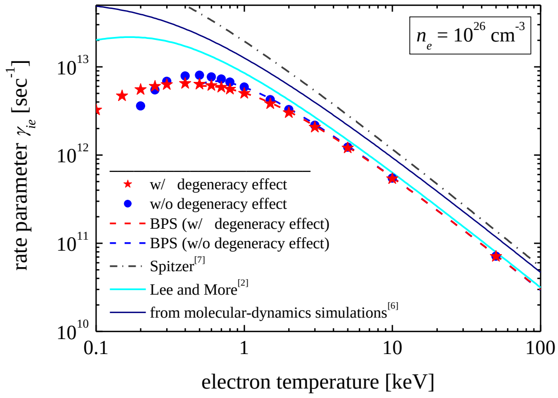

Fig. 1 The electron-ion temperature equilibration rate at n_e = 10^{26} cm^{-3}. All calculations start from T_i = $T_e/2$ as the initial value.

4. Conclusion

Evaluating the rate of electron-ion temperature relaxation from the time variation of ion temperature, we have found that the electron degeneracy decreases it. Besides, comparing our results and BPS ones, we could confirm the accuracy of our and their models except at very low temperatures.

References

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