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Simulation of particles trajectory around the fine particles by using GRAPE
重力多体問題専用計算機を用いた微粒子周辺の粒子軌道シミュレーション

Yasunori Mizuno, Hiromi Matsunaga and Hiroshi Inuzuka
水野　保則、松永　寛海、犬塚　博

Shizuoka University
3-5-1, Jyouhoku, Naka-ku, Hamamatsu, Shizuoka, 432-8561, Japan
静岡大学 〒432-8561　浜松市中区城北3-5-1

We are trying to use GRAPE for gravity calculation at a high speed, to reproduce on a computer Debye shielding phenomenon in the plasma. We reproduced in three dimensions plasma various phenomena ever. This time, to track the trajectory of the electrons around in the fine particle, we observe the motion of the electrons leading to Debye shielding. The electrons contributing to Debye shielding are pivoting center the fine particle, and the electrons to elastic collision to the fine particle are neutralized the fine particle.

1. Introduction

We are using a special purpose computer for the gravitational N-body problem named GRAPE-6 and it computing speed has reached 985[GFLOPS] per unit. This computer is achieved a high speed of the calculation by connecting a lot of parallel pipeline processors [1][2].

GRAPE is the computer of the gravitational interaction, but only modify some of the parameters, can be converted to the calculation of Coulomb interaction. We are subjected to plasma particles simulation fast by applying the calculation of Coulomb interaction this GRAPE. We have achieved the exact calculation result at a high speed until today, by applying plasma oscillations and diffusion of electron cloud, the particles of the dust plasma simulation[3][4].

We are necessary to solve the problem the next in order to apply the GRAPE to the plasma particle simulations. 1) Attractive and repulsive forces acts on the charged particles. 2) Plasma particles calculation requires a large number of particles compared to the gravity calculation. 3) Potential of the particles is shielded. We reproduce Debye shielding phenomenon on a computer, while maintaining the fast computation of GRAPE, by using a large number of particles. By reproducing Debye shieling on the computer, we evaluate the movement of the particles leading to Debye shielding, as well as evaluation from the electric potential distribution the effect of shielding, by tracking the trajectory of the electrons around a fine particle. The divergence of electrons held by imposing the boundary conditions, and total energy is kept constant.

2. Method of the simulation

We observe the electric potential distribution from the time variation of the distribution of the electron by place the one charged fine particles from 10 to 10^4 [C/e] in the center of the electron cloud distributed uniformly. In this simulation, the density of electrons is set to 10^{23}[m^{-3}] and the electron temperature is set to 2.6[eV]. Furthermore, divergence of the electron is suppressed by using a boundary condition and adopted the individual time step calculation method. The number of electrons that used to calculate are the actual 10^2 - 10^4 pieces, initial electron distribution is distributed uniformly, and each electrons also exert Coulomb repulsion to each other. Figure 1 shows the initial distribution of the electron.

3. Result of the simulation

Figure 2 shows the electron distribution of the 10^3 steps after the case of simulation of conditions in the previous. In the figures, λ_e represents Debye length of the electrons. Electrons are attracted strongly to the center of the fine particle in the figure, and the electron density decreases toward the radially outward around the fine particle. Potential distribution that has been calculated from the density distribution of the electron is in good agreement with the decay curve theoretical considering Debye shielding. Figure 3 shows the trajectories of electrons around the fine particle to Debye shielding phenomenon.

Electrons contributing to the Debye shielding are pivoted a fine particle, and form the electron cloud around it. The electrons proceed linearly to elastic collision in the fine particle travels through the fine particle in this simulation. Therefore, it is not observed in the simulations, we considered electrons elastically colliding particles to contribute to the neutralization of the particles.

We reported in a poster session on the day details of this simulation.

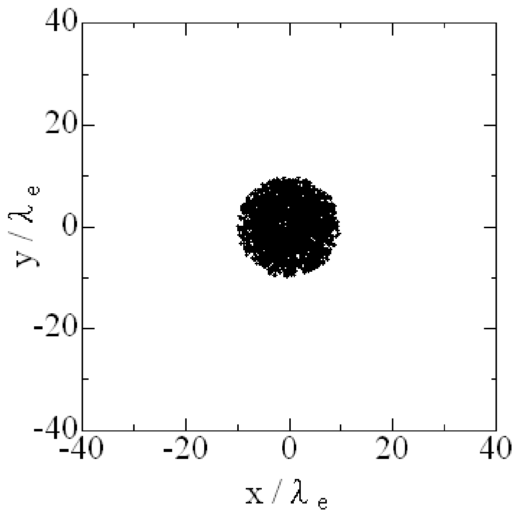

Fig. 1. Initial distribution of charged particles.

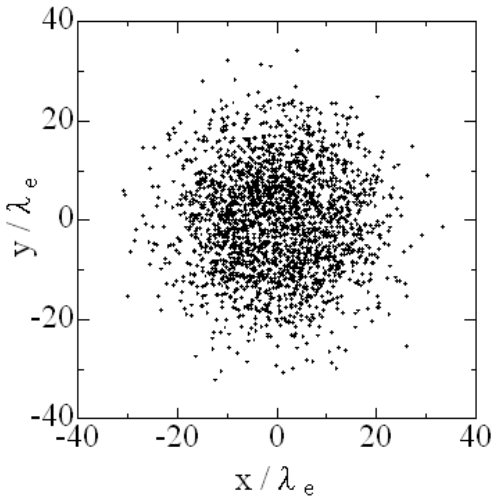

Fig. 2. Charged particles distribution after 10^3 steps using the boundary conditions.

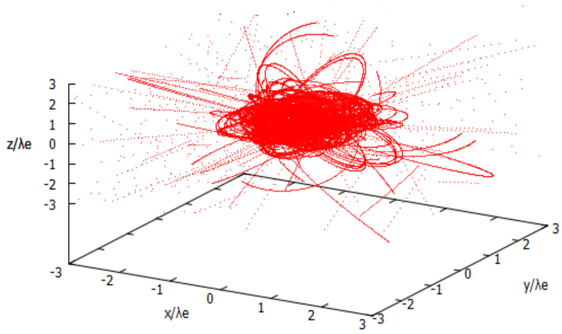

Fig. 3 Trajectories of electrons around the fine particle to Debye shielding phenomenon.

4. Conclusion

- The simulation of Debye shielding phenomenon around a fine particle was done by using GRAPE.
- An increase in the number of steps from 10^3 to 10^6, the particles around the fine particles are diffused, and the potential distribution is no longer consistent with theoretical value.
- The simulation that boundary condition of particle creation and destruction become the closest to the theoretical value, and it is stable for a long time.
- The electrons contributing to Debye shielding are pivoting center the fine particle, and the electrons to elastic collision to the fine particle are neutralized the fine particle.

References

[1] M. Taiji and J. Makino, A special-purpose computer system for astro-physical many-body simulation, Jpn. Plasma Fusion Res. 72(1996) 920-925.

[2] J. Makino, T. Fukushige, M. Koga and K. Namura,GRAPE-6: Massively-Parallel Special-Purpose Computer for Astrophysical Particle Simulation, Publ. Astron. Soc. Jpn. 55 (2003) 1163-1187.

[3] Y. Mizuno, Y. Cao, K. Yamamoto, H. Inuzuka, Y. Liu and K. Yazawa, How to compute the plasma particle movement using a special-purpose computer for gravitational many-body problems, IEEJ Trans. FM, 124 (2004) 344-345.

[4] K. Yamamoto, Y. Mizuno, S. Hibino, H. Inuzuka, Y. Liu and K. Yazawa, Simulation of dusty plasma using a special-purpose computer system designed for gravitational N-body problems, Phys. Plasmas, 13 (2004) 344-345.