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Simulation of charged particles motion around a fine particle by using GRAPE.

重力多体問題専用計算機を用いた微粒子近傍の荷電粒子運動シミュレーション

Yasunori Mizuno, Takeshi Yokitani, Kosuke Sawamoto, Hiroshi Inutsuka and Hiroshi Yamaguchi*
水野保則, 斧谷毅，澤本晃佑，犬塚　博，山口　浩*

*Shisuoka Univ., Hamamatsu Metrix Co., Ltd.**
3-5-1, Johoku naka-ku, Hamamatsu, Shizuoka, 432-8561, Japan
*1-4-10-10, Shinmiyakoda, kita-ku, Hamamatsu, Shizuoka, 431-2103, Japan**
静岡大学 〒432-8561　浜松市中区城北3-5-1
浜松メトリックス株式会社　〒431-2103　浜松市北区新都田1-4-10-10*

We performed a simulation of charged particles motion around a fine particle using a special purpose computer for the gravity named GRAPE. It is fast to calculate the gravitaional interaction on 1 TFlops. The distribution of the charged particles around a fine particl is simulated by using the individual time step method. The charged particles distribution of the simulation results are close to the actual physical phenomenon without spread out greatly.

1. Introduction

The gravity simulator named GRAPE-6 (G6) is achieved, by connecting a lot of pipeline processors for special use of the gravity, computing speed to 985Gflops (≒1 Tflops) per unit. It includes many large-scale integration chips for calculation of specific analytical expression such as $1/r^2$ interactions. G6 is currently being used for the simulation of star and star cluster interactions, as well as galaxy and galaxy group interactions [1][2].

Our group has used G6 for simulation of Coulombic interactions, which have the same central-force form as gravitational interaction. These simulations have been conducted to investigate particle motion in plasmas. Three-dimensional simulations using the gravitational force as a proxy for the Coulomb force have proved successful. This approach has been used to simulate the diffusion of electron clouds, plasma oscillations in terms of particle motion, the behavior of dust clouds in micro-gravity environments, and the simulation of a Coulomb crystal [3][4].

When G6 is applied to a plasma phenomenon, the simulation must solve a problem peculiar to plasma such as having much number of the particles and Debye shielding phenomenon.

Therefore we try the reproduction of Debye shielding phenomenon on the computer now using G6.

In our Debye shielding simulation, we reproduce the cover effect which has the tens of thousands of neighboring charged particles for one charged fine particle on the computer. Because an charged particle has large acceleration as it approaches to fine particles, the charged particle is splashed at high speed in the infinite distance. As a result, most charged particles are scattered by the simulation of long time, and there becomes no charged particles around the fine particle. Therefore we devised a method to add mechanism of the charged particles generation and extinction to this simulation. Furthermore, we devised the method to reflect an charged particle on a spherical boundary. However, in actual plasma space, the presence of the plasma boundary is hard to consider.

So, this time we focus on the motion of each charged particle, and we report the result of simulations with individually time step for each particle updates.

2. Method of the simulation

The initial distribution of simulation is distributed in the spherical space of the radius $10\lambda_e$ (Debye length) by 3058 (density of charged particles 10^{23}[m^{-3}]) charged particles uniformly. A positively-charged fine particle is put in the center of the spherical space. A time step (△t) of the simulation was made $1/100\,\omega_{pe}$ (plasma frequency). The spatial distribution of charged particles around a fine particle calculated 10^3 steps is compared with the initial distribution or others.

Furthermore, the simulation time step of the charged particles which approached a center fine particle was short, and the simulation time step of the charged particles which leave a center fine particle was extended. Short time step is set up in 1/2 of the extended time step, at this time. From now on, this is written with the individual time step method.

3. Result of the simulation

The result of the simulation is shown in figure 2 and 3. The distribution of the three-dimensional charged particles is projected on the x-y plane, and it is drawing on all the figures. Figure 1 shows the initial distribution of charged particles before the simulation. Charged particles are distributed with $10\lambda_e$ around the fine particle uniformly.

The distribution of charged particles after 10^3 steps is shown in the figure 2. The scale of x and y axis is being indicated by a same scale to compare with a figure 1. Spatial distribution of the charged particles spreads out greatly because an charged particle may get the repulsive force of the charged particles and acceleration for the outside due to the interaction with a center fine particle.

Figure 3 is the result of the simulation which used the individual time step method. The charged particles within $5\lambda_e$ from the center fine particle is being simulated in the step of 1/2⊿t and those outer of $5\lambda_e$ from it is calculating in the step of 1.0 ⊿t. A result of simulation by the individual time step doesn't spread out greatly, and it is distributed in the form which is close to the actual plasma phenomenon. Details of the electrical potential distribution and energy distribution are reported in a poster.

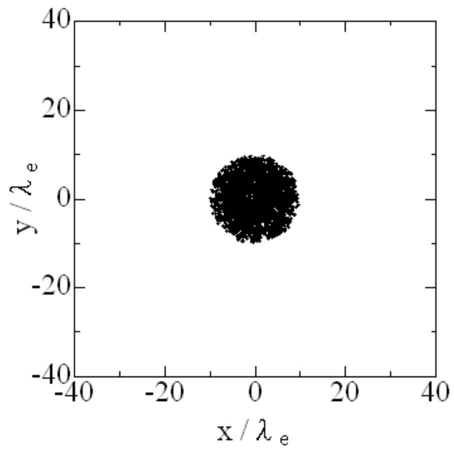

Fig.1. Initial distribution of charged particles.

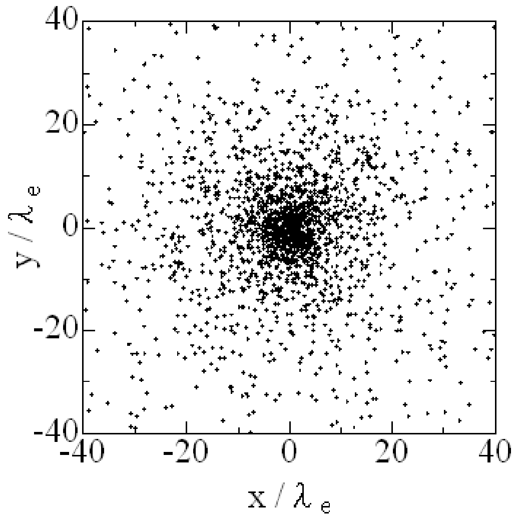

Fig. 2. Charged particles distribution after 10^3 steps.

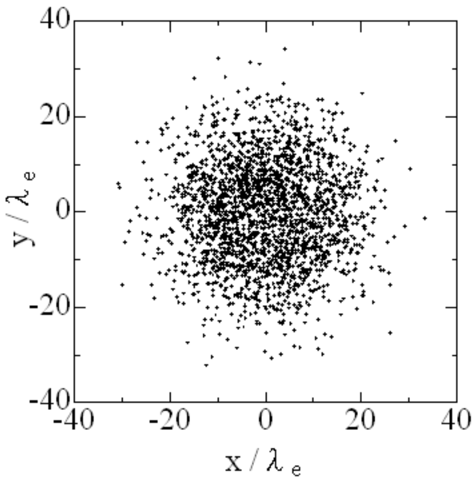

Fig.3. Charged particles distribution after 10^3 steps using the individual time step method.

References

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