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Three dimensional particle simulation for pulsar mangetosphere with GRAPE-DR

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Pulsar is known as a highly magnetized(~10^12 gauss) and rapidly rotating(~0.1 sec) neutron stars with pulsating electromagnetic radiation.
The rotating neutron star is regarded as a unipolar dynamo; it induces a large voltage(10^15 volt). The plasmas are boosted up to ultra-relativistic regime by the induced electric field and emit high-energy Gamma-rays(~GeV). Successively, the Gamma-rays converts into electron-positron pairs via pair-creation process. The accelerated plasmas also form relativistic outflow from the magnetosphere, which eventually becomes persistent source of surrounding synchrotron nebula.
The pulsation of the electromagnetic wave with a rotating period of neutron star indicates that the accelerating region of plasma is co-rotating with the star. Although the local acceleration region is believed to maintain in a context that pair plasma in the magnetosphere controls its acceleration, there is a longstanding problem how and where the particles are accelerated in the such magnetosphere.
In the pulsar magnetosphere, the ideal magneto-hydrodynamics approximation may not be necessarily to be guaranteed, and the effect of plasmas generated by pair creation and particle inertia of the plasma will be important. To treat such problems, global particle simulation is one of the valid approach. Conventional Particle in Cell method is restricted only in the local area for the computational time and required size of memory. Focusing on a steady solution of the pulsar magnetosphere, we simulated entire region of magnetosphere with omitting of the effects of time-varying field. Well known as N-body problem, the number of calculation of interaction between each particles is proportional to the total particle number squared, indicating it may be difficult to carry out N-body simulation for the multi-body plasma system. However, GRAPE-DR enables us to simulate the plasma system likewise N-body problem. The GRAPE-DR is successor to GRAPE-6, which is special purpose computer for gravitational N-body problem and the peak speed is over 1T flops. The interaction between plasmas with GRAPE can be achieved by treating the charge of each plasma such as the mass of the particles for the gravity N-body problem.
We developed a 3 dimensional electro-magneto static numerical code, which can treat several million particles in the region of simulation. In the code, (1) the electromagnetic field at each point is obtained by the steady Maxwell equations by equation of motion, (2) the interaction between the particles, which is N^2 times calculation per every step, are calculated with GRAPE-DR, and (3) the time step of individual particle is adjusted individually to the period of the gyro motion of each particle with parallel computing of the host computer. In the paper, we report the three-dimensional structure obtained above conditions of the simulation.
In the future, we will treat more realistic pair-process by taking into account the mean-free path and by tracing the propagation of the gamma-ray photos, for which GPGPU Hybrid-method will be useful. We also report the results of and the test run in which the propagation of each gamma-ray is traced.

Keywords: plasma, N-body, neutron star, GRAPE, GPGPU