Full PIC simulation analysis on the plasma dynamics in a small-scale magnetosphere

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The objectives of this research is to study a small magnetosphere formed by the interaction between a weakly magnetized small body and the solar wind and to understand plasma dynamics at the orbit level of the particle by performing three-dimensional particle simulation. As examined in the previous works, Mercury has weak intrinsic magnetic field and a small-scale magnetosphere is created due to the interaction with the solar wind. The previous spacecraft observation revealed that the dipole moment of the Mercury’ s intrinsic magnetic field is around 1/2000 of that of the Earth and it causes a small (i.e. 1/20 of that of the Earth) magnetosphere. The proportion occupied by the Mercury body in the magnetosphere is large. The Mercury magnetosphere has been studied by MHD and hybrid particle simulation so far. However, plasma kinetics have not much considered in those previous simulations.
In this study, we performed three-dimensional full particle simulations to understand the plasma dynamics including particle trajectories in the small magnetosphere. In the simulation model, the weakly magnetized small body is set in the center, and the solar wind having the southward IMF is injected from the boundary of the simulation domain. When we define Dp as the distance between the dipole center and a position where the solar wind dynamics pressure balances the magnetic pressure at the dayside, the ratio of Dp to ion inertia length λi can be more than 10 in the Mercury model. In the present study, in order to emphasize the kinetic effect, we set $\lambda i/Dp=1$. When we define R_b as the radius of sphere, we took a relatively large proportion of sphere in the magnetosphere as $R_b/Dp=0.6$. We reported that dawn-dusk asymmetry characteristics of the plasma spatial distribution are found in the equatorial plane. In the present study, we examined the formation of the asymmetry distribution by considering the plasma dynamics including analysis about particle orbit. We particularly focused on the electron acceleration in the region where the southward IMF and the magnetospheric magnetic field cancel each other and the magnetic field intensity becomes zero. We also focused on the plasma dynamics in the cusp and the tail region of the magnetosphere and analyzed how the plasma particles behave in the inner magnetosphere near small body. In addition, we investigated surface charging and electric field by considering the amount of plasma flux flowing into the surface of the body. The knowledge is important for understanding the distribution of ion (Na+) and its acceleration in the Mercury magnetosphere. In the future research, we will consider the contribution of heavy ions and photo-electrons with a certain scale height, and analyze their dynamics in the Mercury environment.

Keywords: Particle-in-cell simulation, Weakly magnetized airless body, small-scale magnetosphere, plasma dynamics

