Full PIC simulations of the surface charging on the night side of Phobos

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We calculated the surface charging on the night side of Phobos caused by the solar wind interaction and analyzed the charging process.
It is known that the surface soils of airless bodies exposed to the solar wind are altered by space weathering. This process at Phobos is important for determining its origin using surface remote sensing and sample analysis by the Martian Moons Exploration (MMX) mission. Meanwhile, the solar wind, a supersonic plasma flow, makes complicated plasma structure around these bodies. Among these structures, surface charging has a close relation with space weathering processes.
Previous studies suggested that there are many types of current systems associated with the surface charging: Solar wind current, photoelectron current and secondary electron current. In order to keep a current balance on the surface, the surface charges up in a steady state. The charging process is different between the dayside and nightside of bodies. While the dayside surface potential is determined by the balance of the solar wind and photoelectron currents, the nightside charging process is complicated. When solar wind plasmas flow into small airless bodies, most of them are absorbed by the dayside of the surface. This removal of plasma at the dayside results in a wake region in the downstream. Then, solar wind ions are accelerated and go into the wake region by ambipolar electric field. While a previous theoretical analysis suggested that the nightside surface potential charged up to several hundred volts, details of electromagnetic field and density distribution around bodies have not been clarified.
In order to understand the process of surface charging, we calculated the plasma environment around a small body by self-consistent 2-D particle-in-cell simulations.
In this study, we calculated a quasi-steady state solution of the electric potential around Phobos in the solar wind by self-consistent PIC simulations. Though Phobos' mean radius is about 11 km, we changed it to 1 km in the simulations to save computational resources. To reveal charging mechanism of Phobos, we adjusted the ratios of the solar wind bulk velocities to thermal velocities and Phobos radius to gyro radii to real ones. 2-D electrostatic PIC simulations were performed under a southward interplanetary magnetic field condition. Compared with theoretical analysis, we found that the surface potential nearly corresponds to theoretical results at the shallow wake region. However, at the deep wake region, the result of simulation shows different potential. This result suggests that the surface potential is affected by not only ambipolar diffusion but also plasma void and non-neutral regions around the wake.
To evaluate the dependence of the surface potential on the solar wind condition, we calculated two types of conditions: Nominal and strong solar wind conditions. While previous studies showed that the surface is charged strongly in the strong solar wind condition, our calculation showed an opposite result at the deep wake region.

Keywords: charging, Phobos, plasma wake, ambipolar difusion, self-similar solution, particle-in-cell simulation

