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Particle-In-Cell simulation on the interactions between the solar wind and a magnetic anomaly on the moon

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The objectives of the current research is to reveal the plasma environment in terms of plasma distribution and field enhancement caused by the interactions between the solar wind and magnetic anomaly found on the moon surface by considering the plasma kinetics. We perform plasma particle simulations for the current study. To increase the spatial resolution at the high density region of magnetic field as well as plasma, we utilize our new particle code called PARMER in which adaptive mesh refinement is incorporated. First, we analyzed simple cases where small-scale magnetic dipole is immersed in a plasma flow. Then we examined a case of magnetic anomaly found in Reiner Gamma on the moon and analyzed the solar wind interactions.

If we define the dipole size L as the distance between the dipole center and a position where the solar wind dynamic pressure balances the magnetic pressure, L of our interest is in the meso-scale which implies the size smaller than the ion's inertia length and sufficiently larger than the electron Larmor radius in the solar wind. Contrary to the Earth's magnetosphere, difference of dynamics between ions and electrons with respect to the local magnetic field play an important role in the magnetosphere formation. In other words, electron-ion coupling through a dipole field becomes important.

The simulation results obtained with the plasma particle simulations we performed so far show that electron interactions are important in the process of meso-scale magnetosphere formation. Around the distance of L from the dipole center, charge separation occurs because of the difference of dynamics between electrons and ions. Then intense electrostatic field is induced and ions, which can be assumed unmagnetized in the present dipole size, are eventually influenced by this electric field.

In the case of magnetic anomaly found in Reiner Gamma, the magnetic field is almost perpendicular to the solar wind. In such a situation, increase of plasma and magnetic field densities is found at the dayside region in the simulation results. When the direction of IMF changes, their increase fluctuates because of the magnetic field reconnection. One of the interesting findings is that the solar wind ions do not reach the moon surface in Reiner Gamma. We will discuss this point by considering the plasma dynamics as well as the electrostatic field observed over the Reiner Gamma region.

Keywords: Plasma particle simulation, magnetic anomaly, small-scale magnetic dipole, solar wind, Reiner Gamma