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Full Particle-In-Cell 3D simulation on the solar wind response to a lunar magnetic anomaly

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The objectives of the current research is to reveal the plasma environment disturbed by the magnetic anomaly found on the moon surface by considering the plasma kinetics. In this study, by performing three-dimensional full Particle-In-Cell simulations, we will discuss the plasma response to Reiner Gamma which is one of the typical and famous magnetic anomalies on the moon. The size of a magnetic anomaly is characterized by distance L from its center at which the equilibrium is satisfied between the pressure of the magnetic field of the dipole and that of the solar wind. In the Earth's magnetosphere, L implies the magnetopause location. We particularly focused on meso-scale magnetic dipoles in which L is smaller than the gyroradius of ions in the solar wind but larger than the electron Larmor radius. 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 show that a meso-scale magnetosphere is clearly created even if the ion gyroradius is larger than L. We found that electron dynamics 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 locally induced and ions, which are assumed unmagnetized in the meso-scale magnetic dipole, are eventually influenced by this electric field. We also examined the plasma dynamics at dayside magnetosphere. Ions which encounter the magnetic anomaly start to gyrate around the local magnetic field. However, electrons which are basically magnetized make drift motion with ExB velocity. This difference of the plasma dynamics causes intense boundary current in the dayside region. In the case of 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 in the dayside region in the simulation results. We are also interested in the plasma response when the direction of IMF changes because the magnetic field reconnection occurring in the dayside region will affect the formation of the meso-scale magnetosphere. 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: Magnetic anomaly, Reiner Gamma, Meso-scale magnetic dipole, Solar wind response, Plasma particle simulation