Full Kinetic Simulation on Plasma Flow Response to a Meso-scale Magnetic Dipole

H. Usui*[1], M. Umezawa[1], Y. Miyake[1], M. Matsumoto[2], T. Moritaka[3] and M. Nishino[4]

[1]Graduate School of System Informatics, Kobe University, 1-1 Rokkoudai, Nada-Ku, Kobe 657-8501, Japan
h-usui@port.kobe-u.ac.jp,

[2] Information Technology Center, The university of Tokyo, 2-11-16 Yayoi, Bunkyo-ku, Tokyo 113-8658, Japan

[3]Institute of Laser Engineering, Osaka University, 2-6 Yamadaoka, Suita, Osaka 565-0871, Japan

[4]Solar-Terrestrial Environment Laboratory, Nagoya University, Furo-cho, Chikusa-ku, Nagoya 464-860, Japan

Abstract

We have been studying plasma flow response to a meso-scale magnetic dipole by means of full kinetic simulations using Particle-In-Cell method. The plasma flow response to a magnetic dipole and the resulting formation of a magnetosphere depends on the intensity of the magnetic moment of the dipole. The size of a magnetic dipole immersed in a plasma flow is characterized by a distance L from its center at which the equilibrium is satisfied between the pressure of the dipole magnetic field and that of the plasma flow. We particularly focused on a meso-scale magnetic dipole which implies that L is comparable to or somewhat smaller than the ion Larmor radius or the inertial length. In this case, plasma kinetics such as finite Larmor radius effect will play an important role to determine the plasma response to the magnetic dipole.

Contrary to the case of the Earth's magnetosphere, we found that difference of dynamics between ions and electrons in the meso-scale dipole field plays an important role in the magnetosphere formation. In other words, electron-ion coupling through dipole fields becomes important. However, very little analysis has been done so far on the interactions between meso-scale dipole field and a plasma flow because plasma kinetics should be taken into account. To fully include the plasma kinetics in the analysis, we have been performing particle simulations for the investigation on the interactions between the solar wind and meso-scale dipole magnetic fields.

The simulation results show that electron response to the local magnetic field is important in the process of meso-scale magnetosphere formation. Within the distance of L from the dipole center, charge separation occurs because of the difference of dynamics between magnetized electrons and unmagnetized ions in the meso-scale dipole fields. Then intense electrostatic field is induced inside the dipole region. It turns out that incoming ion flow to the dipole fields is eventually influenced by this intense electric field and the ions' trajectories are largely distorted. In two-dimensional simulations, we found the incoming ions are reflected by the electrostatic field at the distance L in the upstream region of the dipole. At the ion reflection point, magnetic fields are compressed, forming a magnetopause. The width of the boundary current layer as well as the spatial gradient of the local magnetic field compression found on the dayside magnetopause can be characterized by the electron Larmor radius and is independent of ion's spatial scale.

We also examined the solar wind interactions with a magnetic anomaly called Reiner Gamma on the lunar surface. Since the magnetic field is almost perpendicular to the solar wind, increase of plasma and magnetic field densities is found at the dayside region. One of the interesting findings is that the solar wind ions hardly reach the moon surface in Reiner Gamma due to the interaction with the local field. Most ions are reflected back to the sunward direction at the magnetopause even though the ion Larmor radius is larger than L. We will discuss this point by considering the plasma dynamics as well as the electrostatic field observed over the Reiner Gamma region.

References

T. Moritaka, Y. Kajimura, H. Usui, M. Matsumoto, T. Matsui and I. Shinohara, "Momentum transfer processes of solar wind plasmas in a kinetic scale artificial magnetosphere", *Physics of Plasmas*,19, 032111, 2012.