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Interaction between the Moon and the Earth's magnetosphere

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Abstract

Interaction between the Moon and the Earth's magnetosphere is investigated using the low energy ion and electron data observed around the Moon. We will report two examples of newly observed phenomena. One is the detection of ions originating from the Moon surface / exosphere. These ions were detected in the lobe region on the dayside of the Moon especially when the solar zenith angle was below 40deg. These ions often show characteristic variation of the flux and energy that presumably correlates with the lunar surface structure or composition. The other is different plasmoid / plasma sheet signatures observed on the dayside and the night-side of the Moon. On the night side of the Moon, ions accelerated by the spacecraft potential and the electrons accelerated by the potential difference between the lunar surface and the spacecraft were simultaneously observed. It enables us to determine the night side lunar surface potential and spacecraft potential only using the observed data.

1. Introduction

The Moon stays in the Earth's magnetosphere for 3 ~ 4 days every month. The hot plasma-sheet plasmas in the Earth's magnetosphere can directly impact the lunar surface since the Moon has neither global intrinsic magnetic field nor thick atmosphere. The interaction between the Earth's magnetosphere and the Moon has been investigated in terms of the lunar surface charging [4], [1], [2]. Analyzing Lunar Prospector electron data, Halekas et al. [1], [2] found the lunar surface potentials of ~-100 V in the terrestrial magnetotail lobes and potentials of ~-200 V to ~-1 kV in the plasma sheet on the night side of the Moon. On the lunar dayside, Halekas et al. found that the potential is smaller than ~20 V, except in the plasma sheet, where they observed negative potentials of several hundred volts at times. Recently, low energy ion data have also become available by lunar orbiters, Kaguya, Chandrayaan-1 and Chang'E-1. Magnetic field and Plasma experiment - Plasma energy Angle and Composition Experiment (MAP-PACE) on Kaguya (SELENE) measured lunar plasmas in polar orbit with altitude of 100km, 50km, and in an elliptical orbit with perilune altitude as low as 10km for nearly 1.5 years [5]. Although the plasma density in the Earth's magnetosphere around the Moon orbit (at about 60Re) was quite low, MAP-PACE sensors succeeded in measuring characteristic ion / electron distributions in the Earth's magnetosphere including lobe cold ions, fast flowing ions associated with plasmoids, and cold ion acceleration in the plasma sheet / lobe boundaries. According to MAP-PACE observations, several characteristic phenomena caused by the interaction between Earth's magnetosphere and the lunar surface were so far found: 1) Ions originating from the Moon surface / exosphere [6], 2) Gyro-loss effect of electrons in the lobe / plasma sheet [3], and 3) Plasmoid / plasma sheet signature that is different on the day-side and night-side of the Moon.

2. Ions originating from the Moon surface / exosphere

The ions originating from the Moon surface / exosphere were observed both in the solar wind [7] and in the Earth's magnetosphere [6]. The mass profile of these ions shows heavy-ion peaks including C^+, O^+, Na^+, K^+, and Ar^+ that indicates that these ions are the Moon origin. In the Earth's magnetosphere, these ions were clearly observed on the dayside of the Moon in the lobe especially when the solar zenith angle was below 40deg. Since the convection electric field in the lobe region is much weaker than in the solar wind, the ions originating from the Moon surface / exosphere are possibly accelerated by the potential difference between the lunar surface and Kaguya. These ions often show characteristic

variation of the flux and energy that presumably correlates with the lunar surface structure or composition. If these ions are accelerated by the potential difference between the lunar surface and Kaguya, the energy variation reflects the surface potential distribution on the lunar surface.

3. Plasmoid/plasma sheet signature

In the Earth's magnetotail, Kaguya encountered the plasmoid / plasma sheet many times. The encounter was characterized by the transition between the lobe cold ions, cold ion acceleration in the plasma sheet / lobe boundaries, and hot plasma sheet ions or fast flowing ions associated with plasmoids. Different from the previous measurements made in the magnetotail, the ions were affected by the existence of the Moon. On the dayside of the Moon, tailward flowing cold ions and their acceleration were observed (as usual in the magnetotail). However, on the night side, tailward flowing cold ions could not be observed since the Moon blocked them. In stead, ion acceleration by the spacecraft potential and the electron beam accelerated by the potential difference between lunar surface and spacecraft were simultaneously observed. These data enabled us to determine the night side lunar surface potential and spacecraft potential from the observed data for the first time.

4. Summary and Conclusions

The plasmas around the Moon observed in the Earth's magnetosphere are gradually unveiling their characteristics. The newly obtained knowledge about the lunar plasma environment by Kaguya must contribute to the understanding of the plasma environment around non-magnetized solar system objects.

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