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Observation of the solar wind protons and alpha particles over lunar magnetic anomalies

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Lunar surface is directly affected by solar wind because the Moon has neither thick atmosphere nor global magnetic field. However, there exist locally magnetized regions called lunar magnetic anomalies on the lunar surface. Strong lunar magnetic anomalies can prevent solar wind from impacting the lunar surface. Research on the interaction between solar wind and lunar magnetic anomalies has been carried out by in-situ observations, numerical simulations and laboratory experiments, since the discovery of the lunar magnetic anomalies in 1960s. Since lunar magnetic anomalies greatly affect the incident solar wind plasma and plasma around the Moon, investigation on the interaction between solar wind and lunar magnetic anomalies is quite important.

The solar wind consists of protons as a major component and several percent of alpha particles as a second major component.

The flux of the magnetically reflected solar wind ions is about several tens percent of the incident solar wind ion flux. So far, nobody has ever investigated the reflected solar wind ions over lunar magnetic anomalies in terms of the ion species. Since more than 90% of the solar wind ions are protons, the current knowledge of the interaction between solar wind ions and lunar magnetic anomalies is highly dependent on the behavior of protons. Note that the incident solar wind alpha particles can be detected clearly, but the reflected alpha particles are not easily observed. Thus analysis of both proton and alpha particles will led us to more detailed understanding of the plasma structure over lunar magnetic anomalies.

In this study, we have analyzed mass identified low energy ion data observed by a low energy ion mass spectrometer MAP-PACE-IMA on Kaguya. We have newly found that reflected protons and reflected alpha particles show significantly different behaviors over lunar magnetic anomalies. In most cases, the bulk velocity of the reflected ions is slightly reduced from the incident solar wind bulk velocity, and the temperature of the reflected ions is higher than the incident solar wind ions. We have found that the bulk velocity of the reflected alpha particles is much lower than the bulk velocity of the reflected protons. We have also found that the ratio of the reflected alpha particle flux to the incident solar wind alpha particle flux is much less than the ratio of the reflected proton flux to the incident solar wind proton flux. There seems to be multiple reasons why the existence of the reflected alpha particles were not clear; 1) there exists large difference in E/q (E: kinetic energy, q: charge) between incident solar wind alpha particles and the reflected alpha particles and 2) the reflected alpha particle flux is quite low. It clearly shows that the reflection of the solar wind ions is not an ideal magnetic mirror reflection but the reflection includes non-adiabatic processes.

Keywords: Moon, plasma, solar wind, magnetic anomaly