Japan Geoscience Union Meeting 2012
(May 20-25 2012 at Makuhari, Chiba, Japan)

PPS25-P23 Room:Convention Hall Time:May 23 17:15-18:30

Angular dependence of the solar wind protons scattered at the lunar surface

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Since the Moon does not have neither global intrinsic magnetic field nor thick atmosphere, it is well known that the solar wind directly impacts the lunar surface. The behavior of low energy electrons around the moon has been investigated by the satellite observations such as Apollo Project and Luna Prospector. Previously there was almost no observation of the low energy ions around the Moon, and the solar wind ions after impacting the lunar surface was not understood. When arguing about the interaction of the lunar surface and the solar wind ions, the behavior of the solar wind ions after impacting the lunar surface has been regarded to be absorbed by the lunar surface from the knowledge obtained by laboratory experiments.

MAP-PACE on Kaguya (SELENE) observed scattering of the solar wind ions at the lunar surface. MAP-PACE on Kaguya (SELENE) completed observation of the low energy charged particles around the Moon from low altitude (less than 100km) polar orbit. MAP-PACE consists of 4 sensors: two electron sensors (ESA-S1, ESA-S2) and two ion sensors (IMA, IEA). Since each sensor has a hemispherical field of view, two electron sensors and two ion sensors that are installed on the spacecraft panels opposite to each other can make full 3-dimensional measurements of low energy electrons and ions. Initial analysis found that the scattered ions were almost protons and 0.1%~1% of the solar wind protons were scattered at the lunar surface. Although the feature of the scattered ions at the satellite altitude became clear by initial analysis, understanding the scattering characteristics at the lunar surface, such as a scattering angle, was not clear.

In order to understand the scattering characteristics at the lunar surface, we have investigated the relation between the incidence angle of the solar wind to the lunar surface and the output angle of the scattered protons from the lunar surface using the high angle resolution mode data of MAP-PACE-IMA. We also investigated the relation between the output angle and the energy. As a result, we have found that the protons are scattered back to the direction opposite to the incidence vector of the solar wind for all the incidence angles and they are scattered back inside a scattering cone with 40 degrees around the center axis. The energy loss of the scattered proton is largest along the axis of the scattering cone and it is smaller at the edge of the cone. In addition, we have succeeded in explaining these characteristics by a scattering model that considers the microscopic surface of the lunar regolith.

Keywords: solar wind, lunar surface, scattering