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Remote Sensing of Surface Electric Potential on the Moon: A New Technique Using ENAs for Future Missions

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Abstract

Electric potential at lunar surface provides essential information for understanding fundamental science and environment of the Moon, which directly impacts on future lunar exploration. Here we present a new technique of remote sensing of surface electric potential at the Moon [4]. The technique relies on the energy spectra of the energetic neutral atoms (ENAs) backscattered from the Moon. We applied this technique to the existing dataset of ENAs, and created the first 2-D image of the electric potential distribution near a magnetic anomaly. The result revealed that the magnetized area provides a preferable landing site of the Moon, while strong surface potential exists.

1. Introduction

The electrostatic potential between the Moon surface and space is a key parameter that is fundamental for lunar science and human exploration on the Moon. Many investigations of electric potential and associated electric fields have been conducted theoretically and experimentally from the surface and orbits using solar wind plasma since the Apollo era [1,2,5,6,9,11]. In summary, high energy electron flux results in -400 V potential in the nightside of the Moon. In the dayside, due to the photoelectron emission the surface tend to charge positively with +5–+20 V, while near the magnetic anomaly, potential more than +100 V is expected.

2. Electric Potential Mapping

The new technique depends on the empirical fact that the characteristic energy of the ENAs backscattered from the lunar surface depends only on the impinging proton velocity at the surface (Figure 1) [4]. When the characteristic energy, T_{BS}, is measured, the impinging proton energy at the surface, E_S, is immediately derived. Provided the existence of the surface potential, the impinging proton energy at the surface is modified from the energy in the solar wind by the surface potential. Since the solar wind energy, E_{SW}, is also a measurable quantity, the surface potential (Φ) is now obtained as a difference of them: $\Phi = E_{SW} - E_S$. More detailed description of the technique is also available in [4].

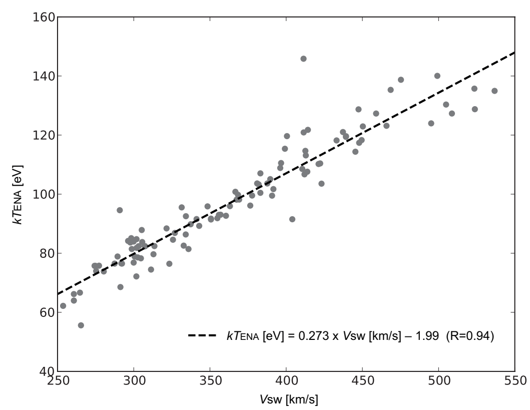

Figure 1: Correlation between the solar wind velocity (equivalent to the energy) and the characteristic energy of the backscattered ENAs measured by Chandrayaan-1/SARA instrument. The figure is taken from Futaana et al., 2012 [3].

3. Application

We applied the above described electric potential mapping method to the region over a lunar magnetic anomaly (Figure 2). We can immediately identify a strong electrostatic potential inside the magnetic anomaly (inside the inner circle in Figure 2A). The potential is positive with strength more than 150 V. It spreads over as wide area as the magnetic anomaly. On the other hand, the area surrounding the magnetic anomaly (between dashed circles in Figure 2; enhanced region) shows no electric potential, while the ENA flux increases. The ENA flux increase is attributed to higher solar wind proton flux at the lunar surface caused by the deflection of the ion flow above the magnetic anomaly [13]. However, the lack of electrostatic potential in the enhanced region indicates that there is no electric potential formed above the enhanced region. Therefore, the deflection above the anomaly is mainly caused by magnetic forces, and the previously suggested mini bow shock [7] is evidently not formed.

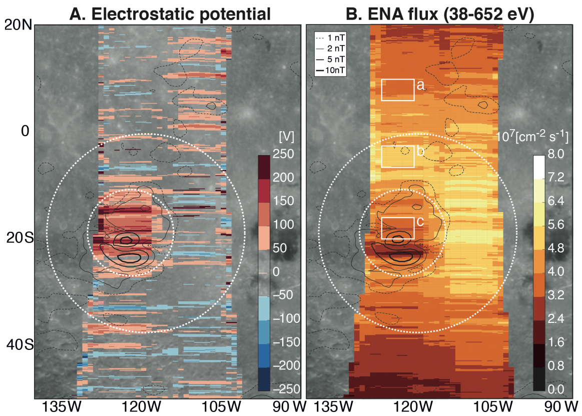

Figure 2: A) Electrostatic potential distribution near the Gerasimovic magnetic anomaly derived from the proposed new technique by ENAs. B) The backscattered ENA flux, which is proportional to the impinging solar wind flux at the lunar surface. The field strength at 30 km is drawn by black lines [8]. Two circles separate characteristic regions (a-c) of the interaction. Figures are taken from Futaana et al., 2013 [4].

4. Impact on exploration

The relatively large amplitude (150 V) and wide-spread electrostatic potential above the magnetic anomaly does not pose any significant challenges for human and robotic activities on the Moon. The wide structure suggests a formation of weak electric field. For example, let us assume a 150V potential with a spatial extent of 200 km. The corresponding electric field becomes 0.8 mV/m, which is of the same order of the solar wind convection electric field at the Moon orbit. For the vertical field, when we assume 10 km of the scale height, the electric field becomes 15 mV/m. This is still not strong enough to influence the human and robotic activities, for example discharging. Therefore, a region under a magnetic anomaly is still a good candidate site for landing and future exploration of the Moon. However, secondary effects, e.g., dust levitation due to the electric field and its adsorption to any components [10], should be carefully assessed for robotic activities, but such effects are commonly seen regardless of the magnetization.

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