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ARTEMIS observations of lunar pickup ions in the magnetosphere tail-lobes

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Abstract

We report observations by the twin-probe mission ARTEMIS of pick-up ions of lunar origin obtained during times when the Moon was transiting the terrestrial magnetotail lobes. These ions were detected as a two separate, pitch angle and gyro-phase focused beams between 0.1 and 1.0 lunar radii above the dayside lunar surface. Analysis of these beams has shown that they possess both field-aligned and field-perpendicular velocities, implying the presence of electric fields both parallel and perpendicular to the magnetotail lobe magnetic field. We suggest that the sources of these two electric fields are (a) the electric field generated by the magnetotail lobe convection velocity and (b) the near-surface electric field due to the lunar photoelectron sheath. Additionally, by analyzing the energy spectra and observed location of these ions, we can make preliminary constraints on the composition and source regions of the observed ions.

1. ARTEMIS Observations

Due to its tenuous nature, direct measurements of the lunar surface-bounded exosphere (SBE) are difficult [1]; however, measurement of ionized exospheric constituents as pickup ions represents an indirect, yet powerful, method of observing the SBE [2]. These ions typically originate from the dayside lunar surface or exosphere, via a variety of production mechanisms, including electron- or photon-stimulated desorption, ion sputtering, meteoroid bombardment or charge exchange [2]. Measurements of the density and composition of pickup ions near the Moon can yield information about the nature and composition of the lunar surface and SBE, as well as the generation and loss processes in effect.

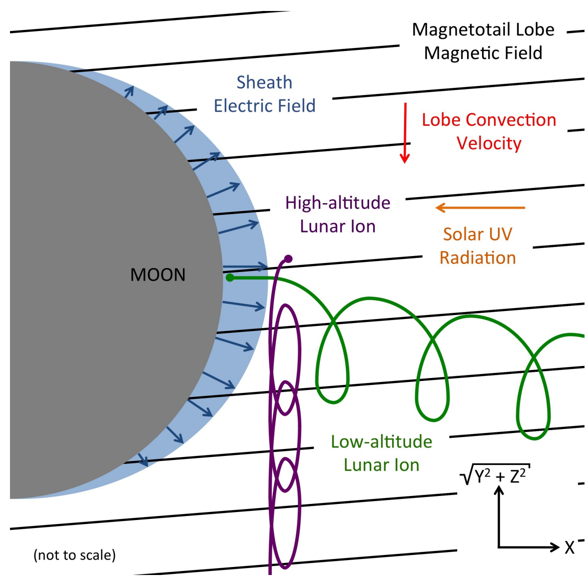

Figure 1: A cartoon outlining the various particles and fields relevant to the ARTEMIS lunar pickup ion observations.

A majority of pickup ion observations come while the Moon is in the solar wind, where the relatively large solar wind convection speed implies a strong electric convection field, which in turns accelerates newly born ions to very high energies ($>$ 10 keV) perpendicular to the magnetic field [3, 4, 5, 6]. The terrestrial magnetosphere, where the Moon spends approximately 20% of its orbit and is shielded from the solar wind, is not typically expected to be an ideal environment for the creation of pickup ions, although the KAGUYA spacecraft has recently made measurements of a tenuous ion population above the lunar dayside in the magnetotail [7]. These ions were measured with energies approaching 400 eV, which the authors attributed to acceleration by the dayside lunar surface potential and not pickup due to magnetospheric convection. Additionally, using an on-board mass spectrometer, KAGUYA determined the composition of these heavy ions to be a mix of exospheric and surface-generated species and suggested their most likely source to be photon-stimulated desorption.

ARTEMIS, a twin-probe plasma mission currently in orbit around the Moon [8], has recently made a series of observations within the terrestrial magnetotail lobes of a similar population of ions to those measured by KAGUYA; however, these ions have pickup characteristics, including cycloidal, non-field aligned motion and gyrophase bunching, in addition to characteristics expected from surface potential acceleration. Figure 1 is a cartoon displaying the various processes believed to be responsible for the generation of these pickup ions within the magnetotail lobes. By analyzing the energy spectra and observed location of these ions, we aim to place constraints on the composition, source region, and source processes responsible for the generation of these ions, as well as the source and loss processes of the neutral lunar exosphere.

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