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

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Introduction

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 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.

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]. 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 [6]. 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 [7], 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, rather than 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.

Preliminary Analysis and Results

Figure 2 shows an ARTEMIS observation from November 11, 2011 of pickup ions within the terrestrial magnetotail lobe. The presence of these pickup ions at energies above 100eV, as well as the $\approx 45-90°$ pitch angles, suggests that a small convective velocity must be present, as the lunar surface is not expected to reach potentials higher than $\approx$ 10 to 20 V [8]. Ions generated near the surface will be accelerated parallel to the magnetic field lines by the electrostatic potential difference in the

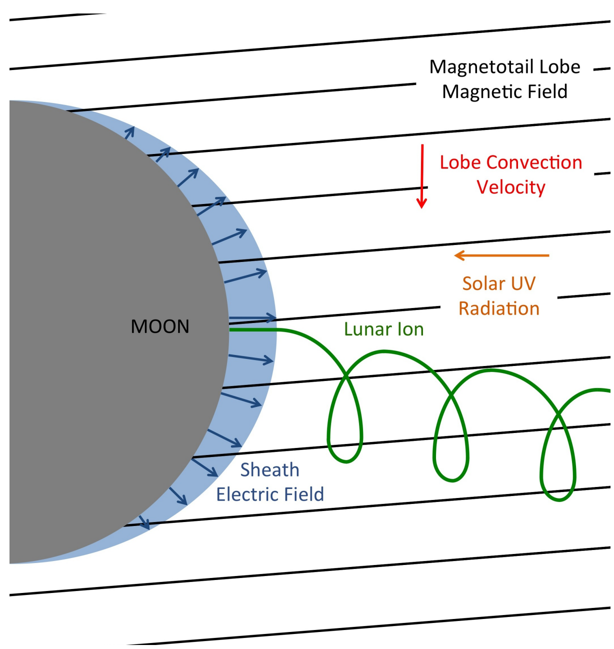

Figure 1: A cartoon showing the various field and particle populations present in the ARTEMIS observations. The magnetotail lobe magnetic field (black) convects with velocity v_c past the moon. Solar ultraviolet radiation (orange) photoionizes the lunar surface and generates a photoelectron sheath, including a near-surface sheath electric field (blue). Shown in green is a depiction of an ion's trajectory after photodesorption by incoming solar UV radiation at the lunar surface and pickup by the convection electric field, E = -v_c x B_{lobe}

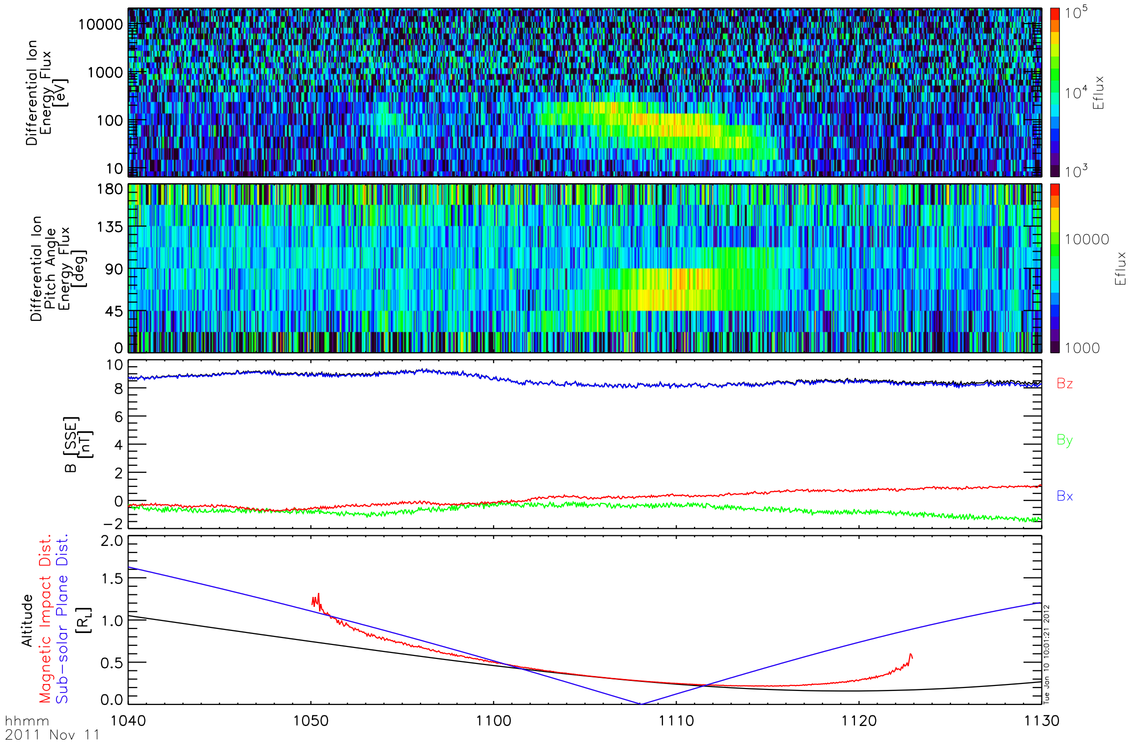

Figure 2: An ARTEMIS observation on November 11, 2011 of pickup ions above the dayside lunar surface within the terrestrial magnetotail lobe. The panels show the differential ion energy flux, differential pitch-angle energy flux, the magnetic field components, and the altitude, magnetic impact distance, and distance from the subsolar plane, from top to bottom, respectively. Energy fluxes are shown in units of eV/s/cm^2/str/eV.

photoelectron sheath. Correspondingly, magnetospheric lobe convection and any component of the sheath electric field perpendicular to the magnetic field will accelerate ions perpendicular to the magnetic field. Analysis of the energy, pitch angle, and gyrophase distributions of these ions may yield information about both the surface electrostatic environment and the convection properties of the magnetospheric lobes. In order to assist our analysis, we will present a variety of pickup ion measurements in the lobes, along with the results of both forward and backward ion tracing simulations with the goal of constraining both the masses and source regions of the ions.

References

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