MODEL-DATA COMPARISONS OF LADEE/LDEX OBSERVATIONS OF LOW-ENERGY LUNAR DAYSIDE IONS A. R. Poppe[1], J. S. Halekas[1], J. R. Szalay[2], M. Horányi[2], and G. T. Delory[1] [1]Space Sciences Laboratory, Univ. of California at Berkeley, Berkeley, CA, 94720 (poppe@ssl.berkeley.edu), [2]Laboratory for Atmospheric and Space Physics, Univ. of Colorado at Boulder, Boulder, CO, 80304

Introduction: The lunar exosphere is a tenuous, collisionless combination of various neutral species derived from a variety of sources, including charged particle sputtering, micrometeoroid impact vaporization, internal gas release, and photon-, electron-, and thermally-stimulated desorption. Solar irradiation will photoionize these neutrals which are in turn picked up by the ambient interplanetary magnetic and electric fields and lost to interplanetary space. The Lunar Dust EXperiment (LDEX) onboard the Lunar Atmospheric and Dust Environment Explorer (LADEE) is currently searching for the signature of charged, sub-micron sized dust grains lofted to kilometer altitudes above the lunar surface, but such measurements are also sensitive to ambient, low-energy ions including those of lunar exospheric origin. Here, we report on a comparison between LDEX dayside low-energy current observations and a model for heavy pick-up ion fluxes from the lunar exosphere.

LDEX Observations: The Lunar Dust Experiment is an impact-ionization dust detector designed to measure the density of micron and sub-micron sized dust grains in the near-lunar environment. The instrument has two main methods of detecting dust grains: (1) direct, individual detection of an impact plasma plume for grains with radii approximately greater than 0.5 μm and (2) measurement of the collective electrical current for charged dust grains smaller than 0.5 μm. The latter measurement is also sensitive to low-energy ions, including both solar wind protons that have reflected off of the lunar surface or crustal magnetic anomalies and heavy pick-up ions of lunar exospheric origin. Importantly, the current measurements are only sensitive to low-energy ions due to a series of electrical grids in the instrument used for accelerating impact charge ions into the detector.

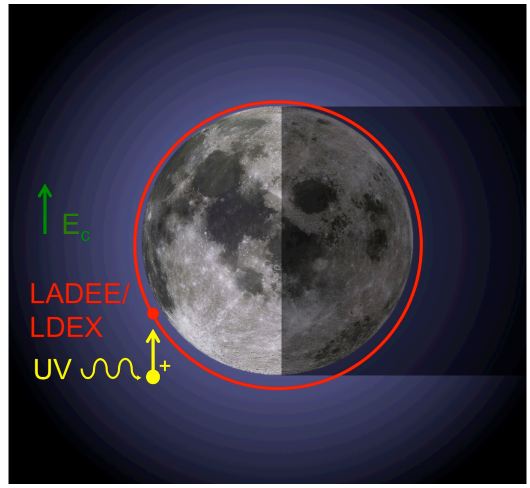

Figure 1: An cartoon of the geometry of the dayside lunar pick-up ion observations by LADEE/LDEX. UV-photoionized neutrals (yellow) follow the interplanetary convection electric field (green) upon birth and are detected by LDEX aboard LADEE (red) provided that they have not been accelerated to very high energies.

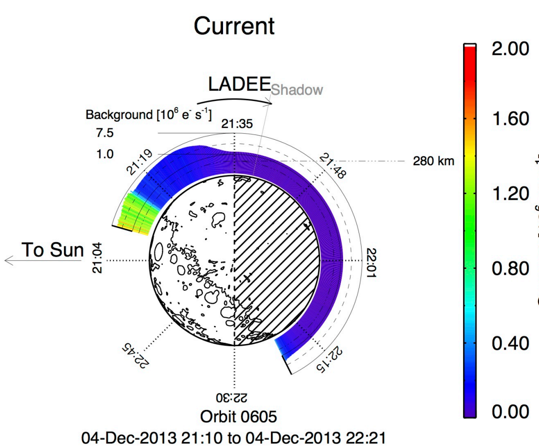

Figure 2: An example of current measurements taken by the LADEE LDEX instrument for orbit 605 on December 4, 2013. The observation begins at approximately 21:09 with elevated, temporally variable levels of current before diminishing near 21:15.

Heavy pick-up ions are continuously produced from the lunar neutral exosphere via solar photoionization [1-3]. Once ionized, these ions are accelerated along the interplanetary convection electric field and begin to undergo cycloidal motion around the interplanetary magnetic field. Energies of these heavy pick-up ions depends on both the strength of the convection electric field and the ion mass and can reach several tens of keV for the heaviest ions. Therefore, LDEX's relatively low maximum observable ion energy implies that any measured ions must be produced fairly close to the instrument. Figure 2 shows an example measurement of temporally variable currents as measured by LDEX. At approximately 21:09, LDEX turned on for orbit 605 on the lunar dayside and immediately measured an elevated current (yellow-green portion of the orbit). This continued for approximately five minutes before abruptly shutting off and falling to low levels (blue-purple) before LADEE passed behind the Moon into shadow. The elevated levels of current are hypothesized to be heavy pick-up ions entering LDEX along the convection electric field.

Exospheric Pick-up Ion Modeling: In order to quantify the heavy pick-up ion current into the LDEX instrument, we have constructed a time-series model of the pick-up ion fluxes from the lunar exosphere and calculated the predicted LDEX response. We use a neutral exospheric model based on both previous observations and recent modeling that includes solar wind sputtering, micrometeoroid impact vaporization, photon-stimulated desorption, and thermal desorption as sources (note that we currently restrict comparisons to periods when the Moon and LADEE are in the solar wind) [4,5]. Laboratory-based photoionization rates are used to establish absolute pick-up ion production rates [6]. Finally, we use observations of the interplanetary magnetic and electric fields by the Acceleration, Reconnection, Turbulence, and Electrodynamics of the Moon's Interaction with the Sun (ARTEMIS) mission [7] and the LADEE position and LDEX pointing vector to calculate a net heavy pick-up ion current.

Figure 3 shows the results of our model for the LADEE/LDEX orbit shown in Figure 2. Panel 3(a) shows the ARTEMIS-observed convection electric field components and magnitude. During this period, the IMF and electric field underwent several rotations with a slightly decreasing magnitude overall. Panel 3(b) shows the cosine of the angle between the convection electric field and the LDEX boresight. The lower red line denotes the period when LADEE/LDEX was on the lunar dayside and the vertical dotted line in all panels denotes when LDEX turned on (~21:09). Panel 3(c) shows the modeled pick-up ion current into LDEX integrated over all photo-ion species, showing that during this particular orbit, the current steadily increased until approximately 21:15, where a rotation in the IMF and convection electric field caused the pick-up ions to no longer enter the LDEX instrument. This scenario qualitatively matches the LDEX current measurements presented in Figure 2. This agreement suggests that a further study of LDEX current measurements on the lunar dayside may allow us to understand and identify this current signature as heavy pick-up ions. Eventually, we aim to both subtract heavy pick-up ion signals out from the LDEX current to aid in the detection of sub-micron lofted dust grains while also studying the density, distribution, and dynamics of the lunar exo- and ionosphere.

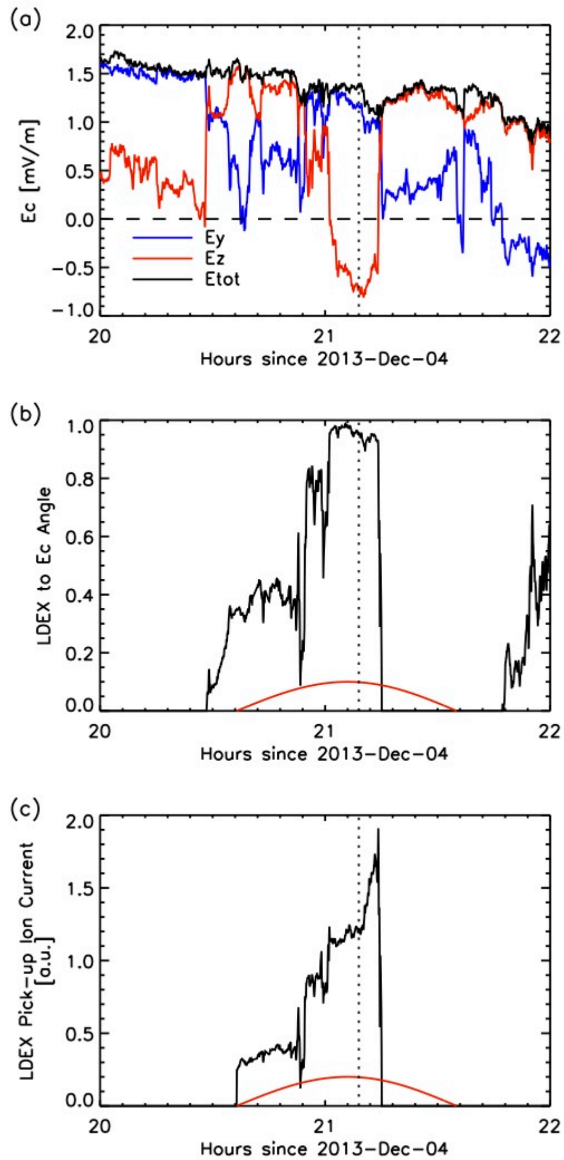

Figure 3: (a) The convection electric field components (colored lines) and magnitude (black line) as measured by the ARTEMIS spacecraft. (b) The cosine of the angle between the convection electric field and the LDEX instrument boresight. (c) The model-predicted pick-up ion current into the LDEX instrument in arbitrary units for approximately one orbit on December 4, 2013. The red semi-circle denotes the period when LADEE/LDEX was on the lunar dayside.

References: [1] Yokota, S. et al. (2009), *Geophys. Res. Lett.*, **36**(L11201) [2] Halekas, J. S. et al. (2012), *J. Geophys. Res. Planets*, **117**(E06006) [3] Poppe, A. R. et al. (2012) *Geophys. Res. Lett.*, **39**(L17104) [4] Sarantos, M. et al. (2012) *J. Geophys. Res.*, **117**(A03103) [5] Poppe, A. R. et al. (2013) *J. Geophys. Res. Planets*, **118** [6] Huebner, W. F. et al. (1992) *Astrophys. Space Sci.*, **195** [7] Angelopoulos, V. (2011) *Space Sci. Rev.*