THE LUNAR GAS AND DUST EXOSPHERE AS REVEALED BY THE LADEE MISSION.

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NASA's Lunar Atmosphere and Dust Environment Explorer, LADEE, performed a fully successful investigation of the Moon's tenuous gas and dust atmosphere. LADEE hosted three science instruments to address atmospheric and dust objectives: an ultraviolet-visible spectrometer (UVS), a neutral mass spectrometer (NMS), and a lunar dust experiment (LDEX) are available [1,2,3,4]. In its low-altitude, retrograde lunar orbit, LADEE carried out observations over a wide range of local times and altitudes. Here we describe some of the initial results.

Lunar Exospheric Dust: LDEX measured a tenuous but persistent "cloud" of small dust grains, from ~0.3 to >0.7 μm in radius [5]. The number density of these grains maximizes over the morning side of the Moon, the hemisphere on the "upstream" side of the Moon's motion about the sun. The cloud, with observed densities ranging between $0.4 – 4 \times 10^{-3}$ m^{-3}, is made up of ballistic ejecta from micrometeoroidal impacts on the lunar surface. The cloud density increases as the Earth-Moon system passes through known meteoroid streams, such as the Geminids, which are derived from cometary debris trails. LDEX data found no evidence for electrostatically-lofted dust down to altitudes of a few kilometers [6].

Lunar Exospheric Structure and Composition: LADEE's NMS instrument measured exospheric helium (^4He), neon (^{20}Ne) and argon (^{40}Ar), revealing systematic variations in density and scale height for these three noble gas species [7]. The diurnal variation of helium, neon and argon are largely controlled by surface temperature. Helium density closely tracks the input of He^{++} from the solar wind; loss is by way of thermal escape. ^{20}Ne is a minor solar wind constituent, but it has a long lifetime at the Moon and builds up to significant densities in the lunar atmosphere. These three are the most abundant species in the lunar exosphere. ^{40}Ar density maximizes over the western maria, in particular the KREEP-rich Mare Imbrium and Oceanus Procellarum areas, part of the PKT [7,8]. There is also an overall, many-lunation variation in argon density, perhaps reflecting changes in the rate of release out of the subsurface, either the interior diffusive source or impacts.

NMS's ion mode revealed multiple species that are ionized by solar EUV and accelerated by the solar wind electric field, as measured in the lunar neighborhood by ARTEMIS [9]. These species include H_2^+, He^+, $^{20}Ne^+$, Na^+, K^+ and $^{40}Ar^+$, as might be expected, but include $^{12}C^+$, $^{14}N^+$ and mass 28, which could be Si^+, N_2^+ or most likely CO^+. Masses 17 and 18 (OH^+ and H_2O^+), also observed in ion mode, are probable outgassing artifacts in the local spacecraft "coma".

Remote Sensing of Na and K: LADEE's UVS measured the sodium and potassium exospheres. The former exhibits a systematic variation with lunar phase, peaking near Full Moon, but with temporal structure in the density that suggests solar wind sputtering (absent in the geomagnetic tail) is an important process. Meanwhile, mobile Na atoms that are not lost to photoionization can be trapped on the cold nightside, and recycled into the atmosphere after sunrise. As the Moon leaves the geomagnetic tail, sputtering resumes and the abundance rises with newly-released Na atoms. There is a long-term trend to the sodium, with an overall decline similar to ^{40}Ar [10]. Shower-generated sodium enhancements (eg., Geminids) may persist for many lunations.

The potassium exosphere is similar to that of sodium but there is less evidence for magnetotail-related drops in density. There are indications of regional enhancements related to surface composition, with higher values of K over the PKT.

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