**An Examination of LADEE UVS Spectral Variability Associated with the Geminid Meteor Shower.**
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**Introduction:** The Lunar Atmosphere and Dust Environment Explorer (LADEE) was an orbital lunar science mission designed to address the goals of the 2003 National Research Council decadal survey, the Lunar Exploration Analysis Group Roadmap, and the "Scientific Context for Exploration of the Moon" (SCEM) report, and has been recommended for execution by the 2011 Planetary Missions Decadal Survey. The LADEE mission goal was to determine the composition of the lunar atmosphere and investigate the processes that control its distribution and variability, including sources, sinks, and surface interactions. LADEE monitored variations in known gasses, such as sodium, potassium, argon and helium, and searched for other, as-yet-undetected gasses of both lunar and extra-lunar origin. LADEE also examined whether dust is present in the lunar exosphere, and revealed the processes that contribute to its sources and variability. LADEE launched September 6, 2013, entered lunar orbit on October 6, 2013 and operated until April 17, 2014.

Examined here are spectral variability at around the time of the Geminid meteor shower (at around December 13-14, 2014). UVS made standard limb observations at the Sunrise and Sunset terminators, as well as observation looking anti-sun on the dark side of the moon (the so called "Sodium-Tail" observation type). The before, during and after spectra are compared to look for variability in line emissions.

**The Ultraviolet-Visible Spectrometer (UVS):** One of three science instruments on LADEE, the Ultraviolet and Visible Spectrometer (UVS) was designed to make observations of the lunar exosphere and search for dust (Figure 1). UVS consisted of a CCD spectrograph and two fore-optics: a three-inch telescope and a solar viewing optic. Both fore-optics are fed to the spectrometers via optical fibers [1].

UVS deployed its limb-viewing telescope door on October 17 and began a series commissioning activities, including pointing, wavelength and preliminary radiometric calibrations. UVS made its first lunar limb observations on October 23, 2013, making over 1 million spectral observation over the lifetime of the mission. UVS has been routinely monitoring two previously measured atmospheric species, potassium and sodium, and has been making observations to search for other, previously-sought species including OH, $H_2O$, Si, Al, Mg, Ca, Ti, and Fe. UVS is also able to detect the scattered light from lofted dust between the altitudes of a few km up to 50 km using its limb telescope, as well as search for dust very near the surface using solar occultation measurements. The UVS instrument operated between 230 – 810 nm with a spectral resolution of <1 nm. The spectrometer has been operating nominally.

**Observations:** UVS has two sets of optics: a "Limb Telescope" and a "Solar Occultation Viewer". Limb observations, using the UVS three-inch telescope, have been made on a routine basis, with limb "stares" at 20 km at the terminators, and 40 km at around local noon time. At the terminators the spacecraft "nods" the telescope between the surface and about 50 km. At noon it was found that near-surface scatter precluded observations below about 30 km, so nods are not performed then. There were a mix of both "backward" looks (stares that point in the anti-velocity direction of the spacecraft), and "forward" looks (which flip the spacecraft to allow UVS to look in the velocity direction). This permits observations both in and away from the direction of the sun.

Sodium and potassium are regularly measured in all activities, except for occultations. Trends in these measurements are made both spatially and temporally, and correlations with specific events, such as meteor streams, and surface composition are examined.

During terminator observations the spacecraft observes the illuminated lunar atmosphere while the spacecraft is in lunar umbra. At these times lunar surface and solar scatter is absent, thus very faint emissions or scattering signatures can be searched for in the data. Likewise, periodically, "Sodium-Tail" observations are made. These observations look roughly anti-sun while on the dark-side of the Moon, typically beginning around midnight and lasting until "dawn" (over the sunset terminator). It is these observations, the

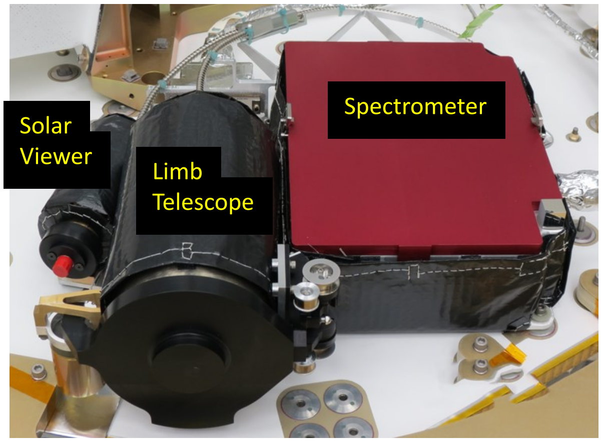

Figure 1. The LADEE UVS instrument showing the spectrometer, limb telescope, and solar viewer, integrated onto the top-deck of the LADEE spacecraft.

SC-dark sunrise and Sodium-Tail observations that are compared here.

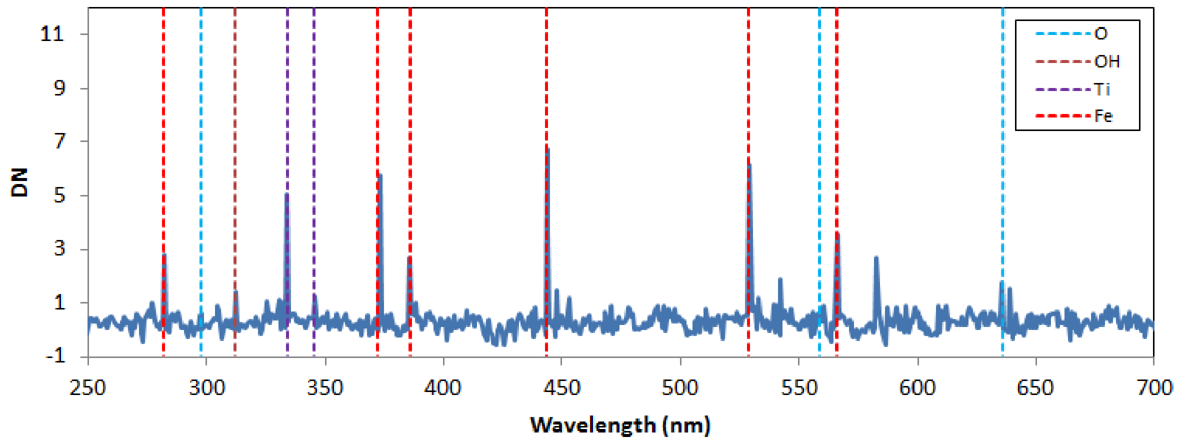


Figure 2. Example of Gemind shower spectra cpmparison. Shown is the difference of measurments taken during (Dec 13, 2014) and prior (Dec 8, 2014) to the Geminid shower. Tenative line identification is shown.

**Analyses:** Spectra from activities prior to, during (if available), and after the Geminid meteor shower are analyzed. In each activity there are typically around 512, two-second exposures. For “sunrise” activities only spectra taken while the SC was in shadow (lunar umbra) were used. And of these spectra only those with a solar longitude (the position of the telescope filed-of-view grazing point) between 275-300 deg were used. For all measurements, the dark current and instrument bias was corrected for, and “hot pixels” (identified through a series of on orbit dark calibrations) were removed. In most instances >100 spectra could be co-added to improve the signal-to-noise ratio. Shown in Figure 2 is an example of the Geminid before-after difference of “Sunrise” observations. Several lines show increased strength during or just after the Geminid showers: specifically iron, titanium and possible oxygen. In “Sodium-Tail” comparisons, sodium also shows an increase from just before to during/just-after the shower.

**Discussion:** Comparing spectra associated with an event, such as the Geminid meteor shower, is an effective way to examine the lunar exosphere as subtle instrumental effects can be largely mitigated. The observations presented here show significant changes in some line intensities, several of which had yet to be measured. These observations will help constrain the relative importance of meteoritic impacts as a source of exospheric dust, however, care is needed as a range of other variables are at play (e.g., changes in lunar phase, SC selenographic longitude, etc.).

**References:** [1] Colaprete A. et al (2015) *SPAC, 90,* in press.