Lunar Atmosphere

and Dust Environment Explorer

(LADEE)

Project

Ultraviolet and Visible Spectrometer Planetary Data System Software Interface Specification

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CONFIGURATION MANAGEMENT FOREWORD

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REVISION HISTORY

Rev.	Description of Change	Author(s)
2014/9/17	First UVS PDS delivery.	A.C., J.K., M.S., K.V.
2014/9/17	Second PDS delivery. Added Derived-level data products.	A.C., J.K., M.S.

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1 PURPOSE AND SCOPE OF DOCUMENT

This Software Interface Specification (SIS) describes the data archived in the Planetary Data System (PDS) by the Lunar Atmosphere and Dust Environment Explorer (LADEE) Ultraviolet and Visible Spectrometer (UVS) team. The document serves both as UVS's Data Product SIS and its Archive Volume SIS. It is written for scientists, software engineers, and others who wish to understand the contents of the UVS Archive, including users associated with the project and those in the general planetary science community. It explains the structure and contents of the archive, including a detailed description of the spectral data products and how they were generated. It describes the UVS instrument, its observational activities, and the data products produced by the UVS team and the steps used to derive them. It is intended to provide the information necessary to use and reproduce the data products.

1.1 Applicable documents and constraints

The LADEE UVS SIS complies with the following documents:

- PDS4 Concepts, Version 1.0.0, May 1, 2013
- Planetary Data System Standards Reference, Version 1.0.0, May 1, 2013
- LADEE Data Management and Archive Plan, Revision A, September 5, 2013, document number C10.LADEE.SDMAP
- LADEE UVS Science Team and PDS Atmospheres Node Interface Control Document, Version 1.0, August 20, 2013

The descriptions of the instrument, settings, observational activities, raw data products, calibration, and relationship with the LADEE spacecraft are derived from the:

- LADEE PDS Mission Description, Revision 1.4, May 6, 2014, document number 12.LADEE.PMD
- LADEE PDS Spacecraft Description, Revision 1.2, March 14, 2013, document number 11.LADEE.PDSSD
- Colaprete, A., Vargo, K., Shirley, M., Landis, D., Wooden, D., Karcz, J., Hermalyn, B., & Cook, A. 2014, *An overview of the LADEE Ultraviolet-Visible Spectrometer*, Space Science Reviews, 185, 63–91, hereafter referred to as *UVS Instrument Document*

1.2 Relationship with other interfaces

The UVS data products are stored in multiple locations according to the LADEE Project Data Management and Archive Plan (DMAP). Copies are stored at Ames Research Center for use by the UVS Science Team. These copies are the source versions of the products generated by UVS for delivery to the PDS. The LADEE project will also deliver a SPICE Archive containing spacecraft trajectory, attitude and clock information to the Navigation and Ancillary Information Facility (NAIF, `http://naif.jpl.nasa.gov`) at JPL. The products in the UVS PDS archive contain a wide variety of view geometry information derived from this SPICE Archive, including spacecraft position and attitude at the time of every UVS observation. This information is the best currently available at the time the UVS Archive was delivered to the PDS. Users wanting the best possible information, however, are encouraged to check with the NAIF for updates.

2 DATA PRODUCT CHARACTERISTICS AND ENVIRONMENT

2.1 Instrument Overview

The UVS instrument was carried aboard the LADEE mission to perform spectral characterization of the lunar atmosphere, including gases and dust at several wavelengths. This characterization entailed measuring the relative concentrations of certain species, including Na and K, and noting the spatial and temporal distributions of those species. Searches for other possible gas species, including O, Mg, Al, Si, Ti, Fe, OH, Ca, and H_2O and the forward or backward scatter from dust were also conducted as were searches for sunlight extinction at low altitude due to dust. This table summarizes the key parameters:

Wavelength Range	230 to 810 nm
Spectral Resolution	$\lambda/\Delta\lambda \sim 900$ at 500 nm
Detector	Hamamatsu S7030/S7031 series CCD
Fiber	45-cm length, 300-micron core-diameter, bifurcated glass optical fiber
Two active apertures	Telescope: circular FOV, 0.5° half-angle
	Solar Viewer: circular FOV, 0.5° half-angle

The main components of the UVS system are an ultraviolet/visible/near-infrared spectrometer (230 – 810 nm), a limb viewing telescope and a solar viewing optic. The instrument is shown in Figure 1.

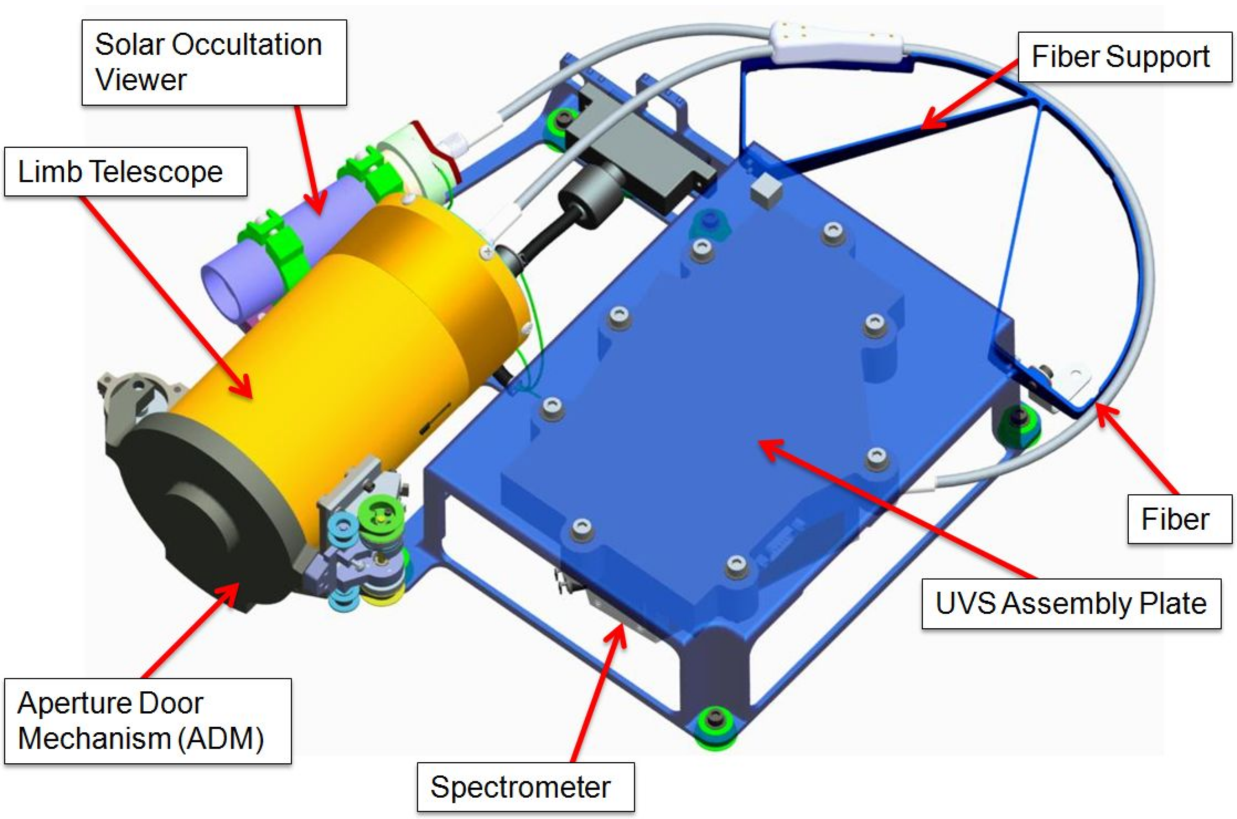

Figure 1: Components of the UVS instrument

The UVS limb telescope and the solar viewer are connected with fiber optic cables to the spectrometer. The limb telescope is a 3-inch diameter Cassegrain design with a 1° field-of-view (FOV). A small lens at the primary pass-through helps to minimize the incident angle at which the light enters the fiber, thereby maximizing throughput of the telescope-to-fiber system. Baffling at the secondary and primary pass-though, roughening of the telescope tube interior, and the arrangement of the fiber interface are responsible for off-axis light rejection. Additional mediation of in-flight off-axis scatter was performed by adjusting observation timing and location relative to off-axis sources, including lit lunar surface and the sun.

During integration, testing, and launch, the limb telescope aperture was protected by a spring-loaded deployable door, called the Aperture Door Mechanism (ADM). This door was permanently opened by a pin-puller early in the commissioning phase of the mission.

The solar viewer is constructed of a series of six cylindrical segments, each having a 1 mm aperture. In series, these segments create a 1° FOV for the solar viewer. At the fiber end, a diffuser attenuates the solar input and diffuses it across the fiber entrance.

The limb telescope and solar viewer share the spectrometer, and hence their fiber connectors merge and are projected onto the spectrometer slit. There is no switch or gate. This impacts operations: in general, when gathering data with one optic, the other should not be pointed at a significant source of light. This issue is largely mitigated by the solar viewer attenuator (designed to reduce the solar brightness to the spectrometer's mid-range while using an integration time of ~20 ms).

The spectrometer uses a 1044 x 64 pixel Hamamatsu charge-coupled device (CCD) array. 1024 x 58 pixels are active light-detecting pixels used for measuring spectra; the rest are overscan, mask, and bevel pixels. See additional discussion in Section 2.2. The slit is projected along the horizontal axis (the 1044-pixel direction) of the CCD. The spectrometer and the telescope are not imaging systems, so all active vertical pixels (58) are co-added and a single 1044 x 1 spectrum is output. Co-adding across the vertical (64 pixel) direction increases the signal.

The detector is cooled with a thermoelectric cooler (TEC) to a user specified set point up to 45 °C of cooling relative to the temperature of the spectrometer body. During normal operations, the set point was configured once at the beginning of an activity and held constant until the activity finished. As power dissipation caused the spectrometer body to heat up, the detector temperature was held close to the set point until the temperature differential across the cooler reached ~45 degrees, at which point, the detector temperature also increased. Both the set point and the detector temperature are available in the product labels.

Further information about the UVS instrument may be found in the *UVS Instrument Document*.

2.2 Operations Overview

The basic unit of UVS operations was an Activity, each of which was one pass through these steps: turn on, (configure instrument settings, collect data), turn off. The parenthesized steps could be repeated several times. Over the duration of the LADEE mission, UVS executed 1890 activities, collecting over 1 million spectra. Activities are numbered in the order they occurred. However, the activity number immediately after occultation activities are skipped due to a subtlety involving the numbering of files by LADEE Flight Software. Within each activity, each spectrum was assigned a second sequence number. The pair of activity number and sequence number uniquely identifies each spectrum. These numbers appear in the labels for each spectrum and are used to name the spectrum table and label file.

Each activity had a specific type and purpose. These were:

Activity Type	Purpose
Limb	An observation with the telescope looking just above the moon's limb and pointing along the orbit track, either ram or anti-ram, looking for lit gasses. This was the most common observation type and was used to look for gasses and dust.
Occultation	An observation with the solar viewer at the sunrise terminator of the sun setting due to orbital motion looking for extinction or forward scattering due to dust. In this attitude, the telescope is pointed at the surface, and care must be taken to select spectra at times when the surface within the field-of-view is unlit.
North/South	An observation with the telescope looking just above the moon's limb, pointing north or south, looking for lit gasses and dust.

Sodium Tail	An observation with the spacecraft in shadow and with the telescope pointed (approximately) anti-sun. These observations looked for sodium atoms pushed away from the moon by the solar wind.
Almost Occultation	A variant of an occultation such that the solar viewer was off-sun and the telescope had approximately the same angles to the sun and to the surface as in a normal occultation. This was used to assess the effects of sunlight scattered into the telescope.
Almost Limb	A second variant of occultations such that the solar viewer was off-sun and the telescope crossed the limb shortly after umbra entry. This was used to look for dust above the limb.
Calibration	One of several kinds of calibration activity

Most activities were planned to occur at a particular solar longitude, that is a position along the orbit relative to the sun or, stated equivalently, at a particular local time-of-day for the point on the surface below the spacecraft. Occultations always occurred over the sunrise terminator (solar longitude = 270 deg), and Sodium Tail observations always occurred over the night side [0,90] deg and [270-360) deg. Limb observations, however, occurred at many places across the day side and at places over the night side while looking toward the lit sunrise or sunset limb. Each label contains the latitude and longitude of LADEE in a selenocentric, sun-fixed frame (solar longitude) at the time the spectrum was captured; these values can be used to distinguish which kind of limb observation was made.

The activities were limited to 20 minutes duration, after which UVS was allowed to cool off. Detector temperature was the primary limiting factor, although power usage was also a consideration. No more than three activities were scheduled within one orbit.

The data collection step of each activity consisted of these substeps:

1. Configure UVS
2. Collect a sequence of similar spectra
3. Configure again and repeat

The configuration parameters were:

Parameter	Description
Integration Time	Duration of data collection for a single spectrum, in milliseconds
Duration	Length of a sequence of spectrum integrations, in seconds

Period	Time between successive integration starts, in milliseconds
TEC Setpoint	The target detector temperature for the thermo-electric cooler

The label for each spectrum contains the configuration settings that were in effect when the spectrum was collected.

Understanding the observation geometry is crucial to understanding the spectra. This starts with placement of the instrument on the spacecraft (Figure 2: UVS Placement on LADEE's Radiator Panel):

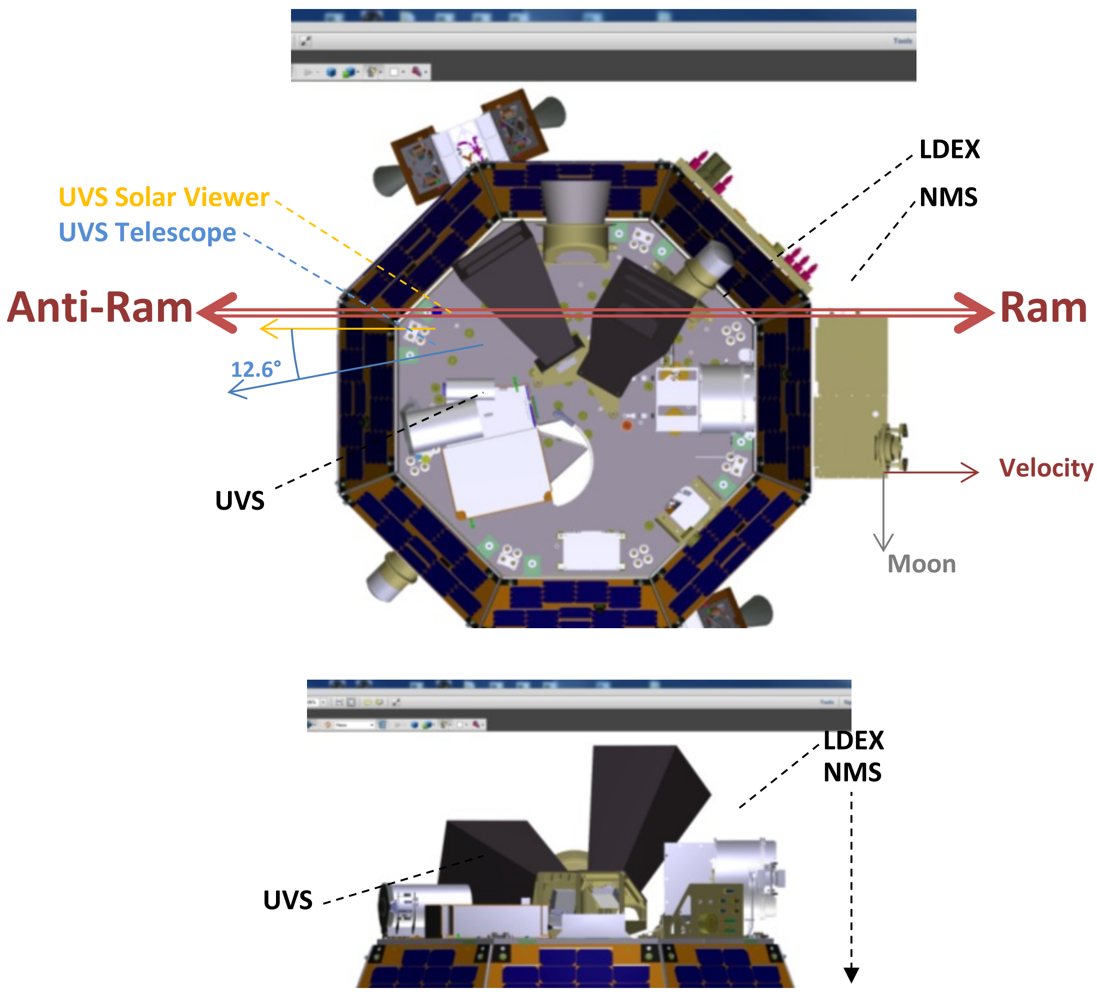

Figure 2: UVS Placement on LADEE's Radiator Panel

The upper figure shows a top view of LADEE, looking down on the radiator panel. Black dashed lines indicate the position of UVS and the Lunar Dust Experiment (LDEX). The Neutral Mass Spectrometer (NMS) is positioned further down, on the side of the spacecraft. The large red arrows indicate LADEE's direction of motion when in its default orientation. Ram indicates the direction of motion, and anti-ram, the opposite. In this orientation, the moon's center was down in the figure. Most observations were made in or near this default attitude. LDEX and NMS, in-situ instruments whose apertures faced the ram direction so gasses or dust would enter their apertures. The UVS solar viewer (yellow dashed line) faced anti-ram and the telescope faced 12.6° from anti-ram toward the moon. This angle was selected to point the telescope just above the moon's limb when LADEE was at an altitude of 50 km, reducing the need to rotate away from this attitude when performing limb observations.

The attitude of the spacecraft is given in the labels as a quaternion in J2000 frame, and the position is given in rectangular coordinates and as Latitude/Longitude/Altitude, both with respect to the Lunar Mean Earth frame. Many other quantities describing the viewing geometry are also provided, like grazing altitudes and phase angles. These are described in Appendix 7.1.

These geometric quantities were calculated using the final versions of the LADEE trajectory and attitude history produced by the mission and submitted to the PDS Navigation Node in SPICE format. Those products are available from the NAIF for recreating the information in the UVS labels, for updating them should the trajectory be updated, and for calculation new quantities of interest. Spectra should be associated with the spacecraft state by their timestamps. The timestamps in the labels have been corrected to UTC. Uncorrected timestamps are also provided for use with the SPICE clock kernel should that require updating.

Note that once the Aperture Door was opened, both UVS apertures were always active, with the light through both apertures added to make a single spectrum. Activities intending to use one aperture could be impacted by light entering through the other aperture. Due to the solar viewer's diffuser, light through it can be safely ignored during telescope-oriented activities. The reverse, however, isn't always true. Light admitted through the telescope must be accounted for during observations with the solar viewer.

2.3 Data Product Overview

UVS provides a single type of observational data: a spectrum containing 1044 pixels from approximately 230 to 810 nm. The UVS PDS archive provides three observational product collections that are based on these data One collection contains the 1044 pixel spectra as raw counts (digital numbers or DN) and a second contains 1024 pixel calibrated radiance spectra derived from the raw counts after omitting edge and blank pixels. The third collection contains two products, which provide spectral radiances (line strengths) for sodium and potassium derived for many of the spectra. Taken together there are approximately 2 million UVS data products. Each UVS PDS product consists of one spectrum, plus its label.

2.4 Data Processing

2.4.1 Data Processing Level

The LADEE mission uses the data processing level terminology defined in the PDS4 standard (Table 1). The UVS team has delivered products at three of the DMAP levels: Raw, Calibrated, and Derived. The UVS products are summarized in Table 2.

Table 1: PDS data processing levels.

Product	**Description**
Packet Data	Telemetry data stream as received at the ground station, with science and engineering data embedded.
Raw	Original data from an instrument. If compression, reformatting, packetization or other translation has been applied to facilitate data transmission or storage, those processes will be reversed so that the archived data are in a PDS approved archive format.
Reduced	Data that have been processed beyond the raw stage but which are not yet entirely independent of the instrument.
Calibrated	Data converted to physical units entirely independent of the instrument.
Derived	Results that have been distilled from one or more calibrated data products (for example, maps, gravity or magnetic fields, or ring particle size distributions). Supplementary data, such as calibration tables or tables of viewing geometry, used to interpret observational data should also be classified as derived data if not easily matched to one of the other three categories.

Table 2: Contents of each data product level.

Product level	**Data**	**Format**
Raw	Raw counts for each pixel.	ASCII table of 16-bit integers; one column; pixel # implicit
Calibrated	Radiance for each pixel	ASCII table of single-precision floats; one column; pixel # implicit
Derived	Spectral radiance (line strength) for Na and K	ASCII table; eleven columns containing line strength along with associated metadata; one row per observation

2.4.2 Data Product Generation

All UVS PDS data products were produced by the UVS instrument team. The SPICE products that much of the supporting metadata depends on were produced by the LADEE Flight Dynamics Team and the LADEE Science Operations Center (SOC). Both sets of products were available to the UVS Science Team during the mission and validated by use during data analysis.

2.4.3 Data Flow

Figure 3 illustrates how data flows from the UVS instrument to the PDS. This figure focuses on the spectra and internal instrument metadata. Trajectory, attitude and clock calibration information used to calculate viewing geometry is received from the LADEE SOC and inserted at the Data Processing Pipeline stage. Currently, no spacecraft-specific telemetry is used in UVS data processing or analysis, other than attitude.

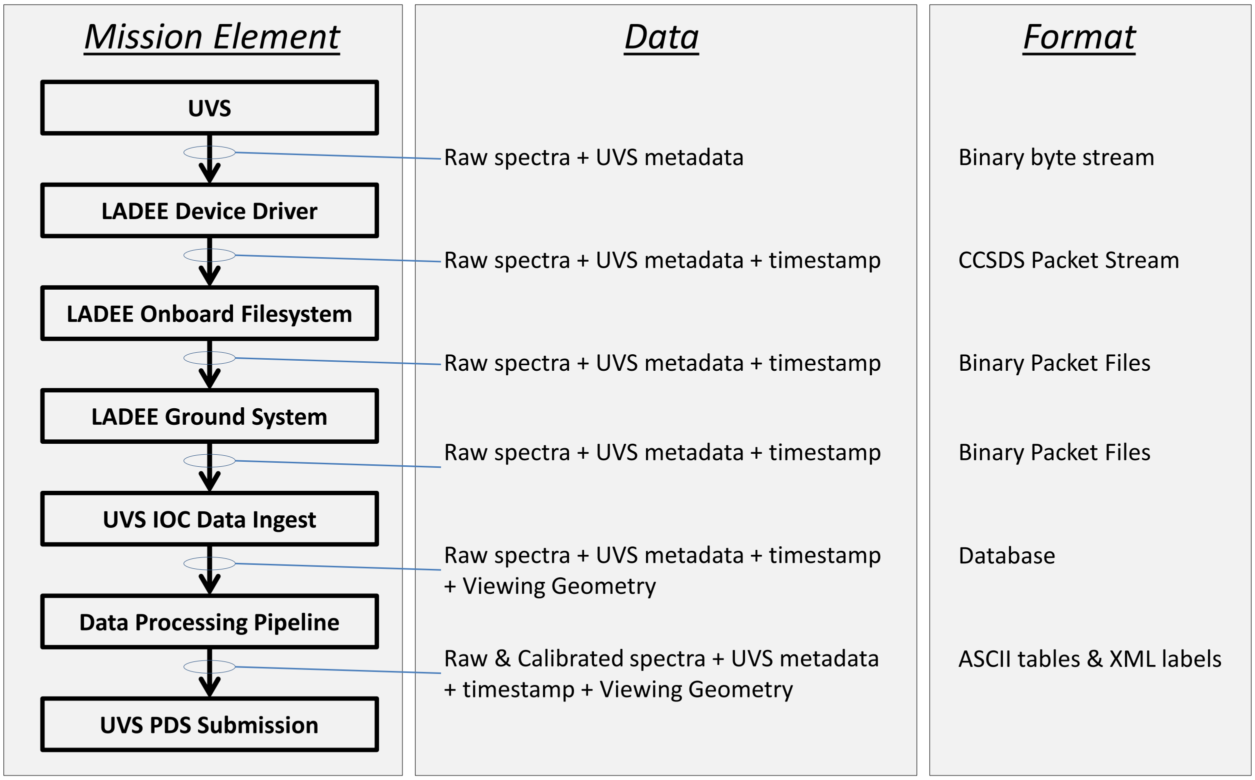

Figure 3: Dataflow Overview

The binary files received at the UVS Instrument Operations Center (IOC) contain packets which themselves contain all commands sent to UVS and all bytes received from UVS, in time order. The byte stream received from UVS is completely unprocessed except that it is partitioned into responses to configuration commands, spectra and associated internal metadata, and other 'out-of-band' bytes received by the spacecraft device driver when they are not expected. Capturing out-of-band bytes was done for diagnostic purposes, and ~300 bytes were transmitted every time UVS powered on, but at no other times. The commands sent and the out-of-band data were checked to ensure the integrity of the RS-422 link between the device driver and UVS but they play no role in processing the spectra. There is no other housekeeping data received from the instrument except the data attached to each spectrum.

The UVS IOC Data Ingest and Data Processing Pipeline programs are custom software that perform three functions: calculate viewing geometry, apply UVS' calibration function, and identifies cosmic ray hits.

2.4.3.1 Viewing Geometry

The Data Ingest program uses SPICE and custom code to perform the viewing geometry calculations. It also uses LRO Lunar Orbiter Laser Altimeter (LOLA) Digital Elevation Map products to do terrain-related calculations. The viewing geometry parameters themselves are described in Appendix 7.1, and the operations section of the *UVS Instrument Document* gives figures that can help in understanding what the parameters mean.

2.4.3.2 Calibration

Raw spectra contain 1044 pixels whose values are 16-bit unsigned integers [0, 65535]. The pixels are either lit, bevel or blank as described in *Table 3*.

Table 3: The meaning of pixel ranges in raw spectra

Pixel Range	Description
0-3	Blank pixels. These are extra shift-registers embedded within the detector substrate and do not correspond to active light-sensing detector elements. They can be used to estimate the read current in the lit pixels.
4-9	Bevel pixels. These are a result of the back thinning of the CCD detector and are unused.
10-1023	Lit pixels. These contain spectral data
1024-1039	Bevel pixels. These are a result of the back thinning of the CCD detector and are unused.
1040-1043	Blank pixels. These are extra shift-registers embedded within the detector substrate and do not correspond to active light-sensing detector elements. They can be used to estimate the read current in the lit pixels.

The calibration function calculates radiance from instrument counts. The function has these steps:

1. Subtract an estimate of the dark current

2. Correct for higher-order harmonics generated by the grating as it spreads the spectrum across the detector

3. Multiply corrected-counts by the gain which is a function of pixel number

The result is radiance.

The dark current is estimated in two steps. First, the global dark current is estimated across all pixels at the time of the spectrum by averaging the counts of pixels 1040-1042 within a set of spectra before, including and after the spectrum being processed, after throwing out outliers. This set of spectra is chosen to include 21 spectra, 10 before and 10 after the spectrum being processed. Dark current is temperature dependent, and this sample is a compromise between reducing noise in the estimated dark current and using samples that vary too much in temperature.

This global estimate corrects most of the 3000-4000 counts measured without any light hitting the detector. The second step is to apply a per-pixel correction to this estimate of the dark current called a 'bias' spectrum. The 'bias' spectrum is a measure of an instrument signal offset from zero. The bias spectrum is generated from a set of 10 millisecond scans whose global dark current estimate has also been subtracted. These scans should be essentially free of thermal noise. For each pixel, the average counts over this set is calculated after throwing out outliers. The result is a single, averaged 'bias' spectrum that reflects the per-pixel dark current. This is also subtracted from the spectrum being processed.

The grating disperses light multiple times across the detector according to the grating equation. The first and second order dispersions are of enough strength to be significant. The third and higher grating orders were determined to be insignificant and thus ignored. The function giving the strength of the second order dispersion is in the calibration section of the *UVS Instrument Document*.

Once the counts have had the dark current and second-order grating dispersion accounted for, they are multiplied by gain as a function of pixel number. This function is also given in the calibration section of the *UVS Instrument Document*.

2.4.3.3 Cosmic Ray Detection

The UVS detector received radiation hits at an average rate of approximately 0.5 per second over the mission. These hits temporarily produced artificially high counts in one or more pixels in captured spectra. Cumulative damage to the silicon substrate, mainly during the radiation belt passages, permanently raised the read current of some pixels and is the primary perturbation that estimating and subtracting the per-pixel dark current is intended to correct.

The UVS team is developing products in which every pixel of every spectrum has been flagged as containing a possible cosmic ray hit. This initial data delivery includes these flags, but the algorithm that produced them has not yet been tuned and the flags should not yet be relied on. The remainder of this section describes the detection algorithm at the time of this release.

The flags appear in 17 label attributes, each of which contains a 16-bit integer reflecting the bit flags for a range of pixels. The attributes are "ladee:cosmic_ray_hit_pixel_n" where n is a two-digit decimal number from 00 to 17. The following function returns a "1" indicating a potential cosmic ray hit or a "0" indicating none was found:

```
flagged(pixel) = (Attribute(Floor(pixel/16)) & 2^Mod(pixel,16)) != 0
```

`Floor` rounds down to the nearest integer. `Mod` returns the remainder of its first argument divided by its second argument. `Attribute` returns the value of the ladee:cosmic_ray_hit_pixel_n attribute where n is its argument. ^ is exponentiation.

The cosmic ray identification algorithm involves these steps:

1. Generate read noise statistics for each pixel at -25 C.

2. For each pixel, select two thresholds. If a pixel's value is above the first threshold with respect to surrounding spectra, it will be flagged

3. Flag pixels across the dataset

4. For each flagged pixel, examine the pixel in immediately following spectra. If its value is above the second threshold with respect to surrounding spectra, the flag the new pixel and continue until either a pixel's value is under the second threshold or more than 2 minutes lies between spectra.

The first step involves assembling a corpus of spectra taken with a detector temperature from [-26 to -24C]. For each pixel, calculate the median of its values, then a standard deviation-like distance from that median. Remove any values that are greater than 5 times the distance from the median to eliminate obvious cosmic ray hits from the corpus. With the remaining set, calculate the mean and standard deviation. The flags in the labels were calculated using 4 sigma as threshold 1 and 2 sigma as threshold 2.

2.4.3.4 Line strengths

The following section describes the derivation of sodium and potassium emission line strengths from UVS "noon-time" observations (see the *UVS Instrument Document*). The line strengths are calculated on the raw (non-radiometrically calibrated) data as there are known calibration features in the radiance calibration at around the principle potassium lines that interfere with the linear continuum fitting (see below). The raw spectral data has otherwise had the usual processing steps described in 2.4.3.2. After the line strength has been derived from the raw data the radiance calibration is applied to produce line strengths in physical units. To improve signal-to-noise a moving average (in time) across six spectra is applied within each UVS observation activity, and the analysis performed on this spectrum average. All metadata for each activity is also averaged across this period, with their average values reported at the middle of each averaging interval. The first and last spectrum number for this averaging interval is reported.

In the wavelength range for sodium and potassium D1 and D2 emissions there is significant contamination to the spectrum from scattering of solar surface reflectance. Local lunar sodium and potassium emission lay atop solar Fraunhofer absorption features, partially filling them in. To derive the lunar sodium and potassium emission line strength the solar component is subtracted off from the total measured radiance. For the solar component a high resolution solar spectrum model[1] is convolved with the UVS instrument response function. The emission line strength is then computed by subtracting the spectrum continuum, defined as the average of two points two either side of the emission line feature, from the spectrum value at the emission line center. The sodium D1 and D2 doublet lines at 589.16 nm and 589.76 nm are unresolved by the UVS instrument (which has a resolving power of approximately 0.5 nm), so a convolution of both lines with the UVS instrument response function is used to derive the sodium line strength. The D1 and D2 potassium doublet lines at 770.1 nm and 766.7 nm respectively are resolved by UVS. The D2 line has better signal-to-noise (SNR) and is thus used by itself to compute the potassium emission line strength.

The total uncertainty in line strength values is divided into systematic (radiance calibration) and relative (random error in one measurement to the next, associated with the measurement SNR). The systematic error is estimated from pre-launch radiance calibration repeatability (uncertainty introduced in calibration setup, random or systematic from measurement to measurement) plus the published error for the calibration lamp (*UVS Instrument Document*). While the calibration error is also a combination of systematic and random error, because it is a constant value with respect to converting instrument counts to radiance, it has a systematic effect across all derived line strengths. The variance across five radiance calibrations (using the same laboratory setup—described in *UVS Instrument Document*—but separated in time by several weeks) was about 6% and 4% for Na and K wavelengths respectively. The published uncertainty in the lamp

[1] Chance, K. & Kurucz, R.L. 2010, *An improved high-resolution solar reference spectrum for earth's atmosphere measurements in the ultraviolet, visible, and near infrared*, J. Quant. Spectrosc. Radiat. Transf., 111, 1289–1295

calibration at both of these wavelengths was about 2.5%. These uncertainties are added in quadrature.

For the relative error, that is the error from one set of measurements to the next, the standard deviation of the instrument counts is calculated across the spectrum continuum points used in the calculation of the line strength. This standard error is then divided by the average continuum value (in counts) to get a total fractional error. This analysis also demonstrates that the variability in the line strength (in time) is much greater than the variability (in time) of the continuum points. Using this approach the relative error for Na and K are about 5% (1-sigma, and using a 6-spectrum running average) and 4% respectively. This is consistent with what would be expected from Poisson statistics for background counts in the ~500 range, typical for the period over which these observations were made.

2.4.4 Data product identification

Each UVS data product is uniquely identified by a PDS4 logical identifier (LID).

The LIDs for Raw- and Calibrated-level products are constructed from their data-processing level, activity number, and sequence number within the activity. The identifiers have the form

`urn:nasa:pds:ladee_uvs:[level]:[activity]_[sequence]`

where `[level]` can either be `raw` or `cal`, `[activity]` is a four digit decimal integer with leading zeros followed by a single letter code indicating the activity type (Table 5), and `[sequence]` is also a four digit decimal integer with leading zeros.

The LIDs for the Derived-level products have the form

`urn:nasa:pds:ladee_uvs:derived:[species]`

where `[species]` is either "sodium" or "potassium."

The data products are stored in the archive's Data Product collection, which is described in Section 0.

Table 4: Definition of activity type codes which appear in Raw- and Calibrated-level observational data product file names. For details, see Section 2.2 and the *UVS Instrument Document*.

Code	**Activity type**
`A`	Almost Limb
`C`	Calibration
`D`	Dark Calibration
`F`	Forward Limb
`G`	Surface Calibration
`L`	Backward Limb

Code	Activity type
N	North Limb
O	Occultation
R	Ram-only
S	South Limb
T	Sodium Tail
U	Unknown

2.5 Standards used in generating data products

2.5.1 PDS standards

UVS data products comply with Planetary Data System standards for file formats and labeling as listed in section 1.1.

2.5.2 Time standards

All absolute times contained in UVS products are expressed in Coordinated Universal Time (UTC). The primary timestamp for each spectrum reflects the time UVS stopped integrating light for that spectrum. The integration time and a start timestamp are also provided. Labels also contain a raw timestamp, which is the spacecraft clock at the time flight software received each spectrum from UVS. The relationships between these timestamps are:

```
stop_time = raw_timestamp + clock_correction – 0.1 sec
start_time = stop_time - integration_time/1000
```

where clock_correction adjusts the spacecraft clock to true UTC and is applied on the ground, after the fact, and 0.1 seconds is the data transmission time between UVS and LADEE flight software and integration_time is expressed in milliseconds. Here, raw_timestamp, integration_time and clock_correction are independent variables, and the other values are calculated.

One more timestamp is provided for each spectrum which is generated by UVS. These instrument timestamps are relative to when UVS firmware last booted and are in milliseconds. They give supporting information about the time deltas between spectra but are from a clock that has not been corrected to UTC.

2.5.3 Coordinate systems

The UVS data products contain metadata information related to spacecraft position, instrument pointing, etc. expressed in terms of spatial coordinates. Most such coordinates are expressed in the LRO Mean Earth/Polar Axis (ME) frame, as described in "A Standardized Lunar Coordinate System for the Lunar Reconnaissance Orbiter, LRO Project White Paper, 451-SCI-000958, Version 4, May 14, 2008."

The UVS data products also express some locations in terms of solar latitude and longitude, which are angles in a Moon-centered, Sun-synchronous frame. The solar frame is defined such that solar latitude increases with LADEE's retrograde orbit. Local midnight is 0° solar latitude 0° solar longitude, and the subsolar point is 0° solar latitude, 180° solar longitude. Solar latitude increases with seleographic latitude, but solar longitude increases in the *opposite* sense as seleographic longitude.

Altitude above terrain for the LADEE spacecraft and the UVS instrument is defined with respect to a Digital Elevation Map generated by LRO's LOLA instrument. This DEM can be accessed via LOLA's page on the Planetary Data System website: http://geo.pds.nasa.gov/missions/lro/lola.htm. The specific version used is product_id=LDEM_64, data_set_id= LRO-L-LOLA-4-GDR-V1.0, product_version_id= V1.03. Altitude above terrain for the UVS telescope and solar viewer boresight grazing points is generated by calculating a grazing point above the lunar reference sphere and then adjusting for the terrain height at that point.

3 DETAILED DATA PRODUCT SPECIFICATIONS

UVS data products are stored in PDS4 formats. Each spectrum has two associated data products– one product each for the Raw and Calibrated data-processing levels. There are only two Derived-level products—line strengths for sodium and potassium—but each contains entries for a large fraction of UVS's observations. The archive also contains two calibration products: a product which provides the mapping between detector bin number and calibrated wavelength and one which provides the mapping from instrument counts to radiance.

3.1 Data Product structure and organization

Each product consists of two files, one containing an Extensible Markup Language (XML) PDS4 label describing the product and one containing the data object. For a Raw- or Calibrated-level observational product, the label contains information identifying the observation and provides descriptive metadata essential for interpreting the spectrum. The data object file contains the spectrum in a human-readable tabular form. For each Derived-level product, the label describes the product, and the data object file provides the line strengths and their associated metadata. For calibration products, the label describes the product, and the data file contains a list providing the calibration mapping.

3.2 Labels

The PDS4 label associated with each Raw- and Calibrated-level observational data product identifies the observation, describes the observational field and state of the instrument, and describes the contents of the data objects. It includes the time of the observation, pointing information, instrument settings, and defines the record types of the columns of the measurement data. The labels are instances of the PDS4 *Product_Observational* class. The contents of the label fields are described in detail in an appendix, Section 7.1.

The Derived-level and calibration data product labels are also of *Product_Observational* class but contain no mission-specific metadata fields.

3.3 Data format description

Each data object file consists of a PDS4 *Table_Character* listing the spectral, line-strength, or calibration data in PDS4 *repeating_record_structure* format. The layout of a particular data table is defined in its corresponding label. A detailed definition of the table format may be found in the PDS4 Concepts document.

3.3.1 Raw-level observational products

A Raw-level data table has a single column containing 1044 record lines—one for each detector bin, including the masked calibration pixels. Each record contains the raw measurement from the corresponding bin. The contents and sizes of the records are listed in Table 4. Record lines are delimited by an ASCII carriage return followed by a linefeed. The pixel types of each of the detector bins are shown in Table 3.

Table 5: Raw-level data table contents.

Field	Number	Location	Data type	Length	Unit	Description
Value	2	6	ASCII_NonNegative_Integer with range [0, 65535] if the instrument is set to accumulate one scan during an activity; range [0, 4,294,967,295] if the accumulation count is set to > 1.	5 or 10	Digital number (DN)	Unmodified measurement.

3.3.2 Calibrated-level observational products

A Calibrated-level table consists of a single column. Each table has 1024 records—one for each observational spectral bin. Each record contains the radiance of the corresponding bin. The contents of the records are described in Table 6.

Table 6: Calibrated-level data table columns.

Name	Data type	Field length	Unit	Description
Radiance	ASCII_Real	11	Watt nanometer^{-1} meter^{-2} steradian^{-1}	The radiance of the observed spectrum.

3.3.3 Derived-level observational products

A Derived-level table consists of eleven columns. Each table has 1024 records—one for each observational spectral bin. Each record contains the radiance of the corresponding bin. The contents of the records are described in Table 6.

Table 7: Derived-level data table columns.

Name	Data type	Field length	Unit	Description
activity_number	ASCII_NonNegative_Integer	4		Unique UVS mission activity number.
day_of_year	ASCII_NonNegative_Integer	6	Day	Day of year for the activity, UTC.

Name	Data type	Field length	Unit	Description
seconds_into_day	ASCII_Non Negative_Integer	10	Second	Number of seconds since the start of the day, UTC.
lowest_sequence_number	ASCII_Non Negative_Integer	4		Lowest sequence number of the spectra used to calculate the line strength.
highest_sequence_number	ASCII_Non Negative_Integer	4		Highest sequence number of the spectra used to calculate the line strength.
solar_longitude_grazing_point	ASCII_Real	7	Degree	Solar longitude of the field-of-view (FOV) grazing point.
grazing_altitude	ASCII_Real	7	Kilometer	Altitude of the line-of-site at the FOV grazing point.
spacecraft_altitude	ASCII_Real	7	Kilometer	Altitude of the spacecraft above the lunar surface.
grazing_latitude	ASCII_Real	7	Degree	Selenographic latitude at the FOV grazing point in the LRO ME frame.
grazing_longitude	ASCII_Real	7	Degree	Selenographic longitude at the FOV grazing point in the LRO ME frame.
spacecraft_latitude	ASCII_Real	7	Degree	Selenographic latitude of the spacecraft in the LRO ME frame.
spacecraft_longitude	ASCII_Real	7	Degree	Selenographic longitude of the spacecraft in the LRO ME frame.
line_strength	ASCII_Real	12	Microwatt centimeter^{-2} nanometer^{-1} steradian^{-1}	Line strength (spectral radiance) of sodium or potassium.
dn_at_line	ASCII_Real	9	Digital number (DN)	Average of total instrument counts at continuum points.

3.3.4 Wavelength calibration product

The wavelength calibration product consists of two columns containing 1024 records—one for each active observational spectral bin. Each record provides the bin number and the corresponding wavelength. The contents of the records are described in Table 8.

Table 8: Wavelength calibrated data table columns.

Name	Data type	Field length	Unit	Description
Bin	ASCII_Non Negative_Integer	4	Dimensionless	Detector bin number

Name	Data type	Field length	Unit	Description
Wavelength	ASCII_Real	7	Nanometer	Wavelength corresponding to the bin.

3.3.5 Radiance calibration product

The radiance calibration product consists of three columns containing 1044 records. Each record provides the mapping from counts to radiance and data for removing the second order diffraction. The contents of the records are described in Table 9.

Table 9: Radiance calibrated data table columns.

Name	Data type	Field length	Unit	Description
Correction	ASCII_Real	10	Dimensionless	Fraction of the magnitude of the pixel given in the Source Bin column which must be subtracted from the current bin (row) to correct for second-order diffraction from the grating
Bin Number	ASCII_Non Negative_Int eger	4	Dimensionless	Index of the pixel which corresponds to the wavelength of light contributing to the counts in the current pixel through second-order diffraction
Radiance	ASCII_Real	9	Watt $Nanometer^{-1}$ $Meter^{-2}$ $Steradian^{-1}$	Coefficient mapping counts to radiance for each bin

4 ARCHIVE VOLUME CONTENTS

This section contains the contents of the UVS Archive volumes, including the file names, file contents, file types, and organization responsible for providing the files.

4.1 Root directory

The root directory contains files describing the bundle and sub-directories containing six collections. The contents are listed in Table 10.

Table 10: Contents of the root directory

File or directory	Contents
`bundle_ladee_uvs.xml`	PDS label for the UVS bundle.
`readme.txt`	Text description of the contents of the bundle.
`data_raw/`	Raw spectra collection.
`data_calibrated/`	Calibrated spectra collection.
`data_derived/`	Derived product collection.
`calibration/`	Calibration collection.
`document/`	Document collection.

File or directory	Contents
context/	Context collection. (PDS labels for PDS4 objects related to the UVS archive.)
xml_schema/	XML schema for XML labels in the archive.

4.2 Observational data directories

The structure of the Raw- and Calibrated-level collections are identical. Their contents are shown in Table 11. Both contain data products for every UVS observation during the mission. Because of the large number of observations during the mission, the products are stored in subdirectories grouped by the day-of-year of the observations.

Table 11: Contents of `data_raw/` and `data_calibrated/`.

File or directory	Contents
collection_uvs_data_[calibrated or raw].xml	Label for the collection; describes collection_uvs_[calibrated or raw]_inventory.tab.
collection_uvs_data_[calibrated or raw]_inventory.tab	List of spectral products in the collection.
[year]_[day]/	All products for a given day of the year.
[year]_[day]/UVS_[level]_[activity number][activity type]_[sequence number].XML	Label for a data product. The field "[level]" can be either "RAW" or "CAL." The field "[activity number]" indicates the observational activity for which the spectrum was collected, and "[sequence number]" indicates when during the activity the observation occurred. The possible values of "[activity type]" are shown in **Error! Reference source not found.**.
[year]_[day]/UVS_[level]_[activity number][activity type]_[sequence number].TAB	Data table containing a spectrum from an observation..

The contents of the Derived-level collection are show in Table 12. It contains only two products.

Table 12: Contents of `data_derived/`.

File or directory	Contents
collection_uvs_data_derived.xml	Label for the collection; describes collection_uvs_derived_inventory.tab.
collection_uvs_data_derived_inventory.tab	List of products in the collection.

File or directory	Contents
potassium.xml	Label for the potassium line strength product.
potassium.tab	Potassium line strength data table.
sodium.xml	Label for the sodium line strength product.
sodium.tab	Sodium line strength data table.

4.3 Calibration directory

The structure of calibration collection is shown in *Table 13*. It contains two data products—the mapping between active spectral bin number and calibrated wavelength, and the mapping between raw detector DN and radiance.

Table 13 Contents of the calibration data product collection.

File or directory	Contents
collection_uvs_calibration.xml	Label for the collection; describes collection_uvs_calibration.tab.
collection_uvs_calibration_inventory.tab	List of products in the collection.
wavelength.xml	Label for the wavelength mapping product.
wavelength.tab	Data table for the wavelength mapping product.
radiance.xml	Label for the radiance calibration data file.
radiance.tab	Table of radiance calibration data.

4.4 Document directory

The document collection contains files describing the mission, instrument, activities conducted by UVS, and the observational data. The contents are listed in Table 14.

Table 14: Contents of document/, the document collection. Each document file also has an associated PDS4 XML label file.

File or directory	Contents
collection_uvs_document.xml	Label for the collection; describes collection_uvs_document_inventory.tab.
collection_uvs_document_inventory.tab	List of products in the documentation collection.
UVS_SIS.pdf	This document—the UVS Software Interface Specification.
instrument_uvs.pdf	UVS instrument description.
activity_log.csv	Description of all observations conducted by UVS, in comma-separated-value format.

File or directory	Contents
activity_log.pdf	Activity log in archival Portable Document Format.
activity_log.xls	Activity log in Microsoft Excel 97–2003 format.

4.5 Context directory

The context collection contains PDS label files describing PDS objects of relevance to the LADEE mission and UVS investigation. The contents are listed in Table 15.

Table 15: Contents of `context/`, the context collection.

File or directory	Contents
collection_uvs_context.xml	Label for the collection; describes collection_uvs_context_inventory.tab.
collection_uvs_context_inventory.tab	List of products in the context collection.

4.6 Schema directory

The document collection contains XML schema files for the PDS4 labels throughout the rest of the archive. The contents are listed in Table 16.

Table 16: Contents of `xml_schema/`, the schema collection. Each schema file also has an associated PDS4 XML label file.

File or directory	Contents
collection_uvs_xml_schema.xml	Label for the collection; describes collection_uvs_xml_schema_inventory.tab.
collection_uvs_xml_schema_inventory.tab	List of products in the XML schema collection.

5 ARCHIVE VOLUME GENERATION

The UVS archive bundle, including all of the data products, instrument-level documentation, and PDS labels, were generated by the UVS instrument team. The plans for product and archive generation were developed in coordination with the PDS Atmospheres Node and the LADEE Data Analysis Working Group (DAWG), with oversight by the DAWG.

UVS data will be provided to the PDS in two stages. The first delivery, which occurred in August, 2014, included the data products from spacecraft checkout through the mission's primary science period—the data through the first 100 days of science operations. The second delivery, which is scheduled to occur one year later, will include all UVS observations from the entire LADEE mission.

Each delivery of the archive bundle will be made to the Atmospheres Node via File Transfer Protocol (FTP) and verified through separately sent checksums. The first delivery contains 1,038,103 spectra and occupies ~ 40 GB.

The products and archive were validated by peer review during the development process. There are three planned reviews: 1) a pre-launch review of a draft UVS SIS, simulated sample products, and archive, conducted March 12, 2013, 2) a review prior to the first PDS delivery, conducted May 21, 2014, and 3) a review prior to the second, final delivery of the archive. The instrument team is responsible for resolving errata and liens found during the reviews.

6 ROLES AND RESPONSIBILITIES

Table 17: Cognizant people for the UVS PDS archive

Name	Role	Mailing Address	E-mail address and phone Number
Dr. Anthony Colaprete	UVS Principal Investigator	Mail Stop 245-3 NASA Ames Research Center Moffett Field, CA 94035	anthony.colaprete-1@nasa.gov (650) 604-2918
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Dr. Mark Shirley	UVS Software Lead	Mail Stop 269-2 NASA Ames Research Center Moffett Field, CA 94035	mark.h.shirley@nasa.gov (650) 604-3389
Kara Vargo	UVS Calibration Lead	Mail Stop 240A-2 NASA Ames Research Center Moffett Field, CA 94035	kara.e.vargo@nasa.gov (650) 604-6227
Lyle Huber	PDS Atmospheres Node UVS representative	New Mexico State University Department of Astronomy P.O. Box 30001/MSC 4500 Las Cruces, NM 88003	lhuber@nmsu.edu (575) 646-1862

7 APPENDICES

7.1 Data-product label fields

The UVS data product labels contain fields providing metadata about each observation. Some are standard PDS4 fields and others are UVS-specific. The metadata attribute fields contained in the Raw- and Calibrated-level labels are identical. They are listed in Table 18 through Table 23, broken down by the major sections in a PDS4 label. The fields in most of the tables are standard attributes included in all PDS 4 product labels. The fields in Table 23 are UVS-specific. They indicate the purpose of the observation and provide relevant instrument and spacecraft state and settings.

Table 18: Data product label `Identification_Area` fields.

Field	Description
logical_identifier	Unique identifier for the product. See section 2.4.4.

Table 19: Data product label `Observation_Area/Time_Coordinates` fields.

Field	Description
start_date_time	Corrected UTC time of the start of integration.
stop_date_time	Corrected UTC time of the end of integration.

Table 20: Data product label `Observation_Area/Investigation_Area` fields.

Field	Description
Name	LADEE
Type	Mission

Table 21: Data product label `Observation_Area/Observing_System` fields.

Field	Description
Name	UVS
observing_system_component_type	Instrument

Table 22: Data product label `Observation_Area/Target_Identification` fields.

Field	Description
Name	Name of the observation's primary target. UVS has two active apertures at all times, and this value doesn't distinguish which aperture can view this target. Elements within Mission_Area disambiguate this.
Type	The type of the primary target

Table 23: Data product label `Observation_Area/Mission_Area` fields.

Field	Type	Description
ladee:activity_number	ASCII_Integer	Activities are the main units of data collection for UVS. Each activity number derived from the automatic numbering of UVS data files onboard the spacecraft. Occultation activities generate enough spectra to span two data files, so the activity number following each occultation is unused. Other than those gaps, activity numbers correspond to a running counter of the instrument power cycles.
ladee:activity_type	ASCII_String	A short string describing the nature of each activity. Permissible values include "BackwardLimbWithNod", "ForwardLimbWithNod", "NorthLimbWithNod", "SouthLimbWithNod", "BackwardLimbWithoutNod", "ForwardLimbWithoutNod", "NorthLimbWithoutNod", "SouthLimbWithoutNod", "Occultation", "DarkCal",

Field	Type	Description
		"StarCal", "SolarCal", "SolarBoresightCal", "TelescopeBoresightCal", "RamOnly", "SodiumTail", and "SurfaceCal".
ladee:altitude	ASCII_Real	Spacecraft altitude above the lunar reference sphere (radius=1737.4 km) in km
ladee:altitude_above_terrain	ASCII_Real	Spacecraft altitude above terrain in km
ladee:average_counts	ASCII_Real	Average of all pixel values (range 0-1043) in DNs or calibrated units
ladee:cosmic_ray_hit_count	ASCII_Integer in hex	The number of cosmic ray hits identified within the spectrum. The values of all cosmic-ray related fields were generated by a preliminary version of the detection algorithm and shouldn't be relied upon. See section 2.4.3.3.
ladee:cosmic_ray_hit_pixel_00	ASCII_Integer in hex	16 bits of a 1044-bit vector giving the location of hits
ladee:cosmic_ray_hit_pixel_01	ASCII_Integer in hex	16 bits of a 1044-bit vector giving the location of hits
ladee:cosmic_ray_hit_pixel_02	ASCII_Integer in hex	16 bits of a 1044-bit vector giving the location of hits
ladee:cosmic_ray_hit_pixel_03	ASCII_Integer in hex	16 bits of a 1044-bit vector giving the location of hits
ladee:cosmic_ray_hit_pixel_04	ASCII_Integer in hex	16 bits of a 1044-bit vector giving the location of hits
ladee:cosmic_ray_hit_pixel_05	ASCII_Integer in hex	16 bits of a 1044-bit vector giving the location of hits
ladee:cosmic_ray_hit_pixel_06	ASCII_Integer in hex	16 bits of a 1044-bit vector giving the location of hits
ladee:cosmic_ray_hit_pixel_07	ASCII_Integer in hex	16 bits of a 1044-bit vector giving the location of hits
ladee:cosmic_ray_hit_pixel_08	ASCII_Integer in hex	16 bits of a 1044-bit vector giving the location of hits
ladee:cosmic_ray_hit_pixel_09	ASCII_Integer in hex	16 bits of a 1044-bit vector giving the location of hits
ladee:cosmic_ray_hit_pixel_10	ASCII_Integer in hex	16 bits of a 1044-bit vector giving the location of hits
ladee:cosmic_ray_hit_pixel_11	ASCII_Integer in hex	16 bits of a 1044-bit vector giving the location of hits
ladee:cosmic_ray_hit_pixel_12	ASCII_Integer in hex	16 bits of a 1044-bit vector giving the location of hits
ladee:cosmic_ray_hit_pixel_13	ASCII_Integer in hex	16 bits of a 1044-bit vector giving the location of hits
ladee:cosmic_ray_hit_pixel_14	ASCII_Integer in hex	16 bits of a 1044-bit vector giving the location of hits
ladee:cosmic_ray_hit_pixel_15	ASCII_Integer in hex	16 bits of a 1044-bit vector giving the location of hits
ladee:cosmic_ray_hit_pixel_16	ASCII_Integer in hex	16 bits of a 1044-bit vector giving the location of hits

Field	Type	Description
ladee:drive_current	ASCII_Real	TEC Drive current in mA
ladee:emission_angle	ASCII_Real	If the UVS telescope boresight intersects the lunar reference sphereoid, this is the angle at the intersection between the surface normal and the vector to LADEE in degrees. 0 otherwise. Calculated by SPICE ilumin_c().
ladee:in_sun	ASCII_Integer	An integer representing three bits. Each bit represents a geometric calculation asking whether the upper limb of the sun is above the lunar limb (including terrain) at (bit 0) the spectrum's timestamp, (bit 1) 1 second before the start of data collection, and (bit 2) 1 second after the end of data collection. The 1 second buffers were chosen to be slightly conservative. A value of 0 means 'definitely in shadow' and 7 means 'definitely in sun'. Intermediate reflect intermediate knowledge.
ladee:integration_time	ASCII_Integer Range: [0, 65535]	The detector integration time for each scan, in milliseconds.
ladee:latitude	ASCII_Real	Latitude of the sub-spacecraft point in ME frame.
ladee:longitude	ASCII_Real	Longitude of the sub-spacecraft point in the ME frame.
ladee:moon_fixed_vx	ASCII_Real	X velocity of the spacecraft in ME frame in km/sec
ladee:moon_fixed_vy	ASCII_Real	Y velocity of the spacecraft in ME frame in km/sec
ladee:moon_fixed_vz	ASCII_Real	Z velocity of the spacecraft in ME frame in km/sec
ladee:moon_fixed_x	ASCII_Real	X position of the spacecraft in ME frame in km
ladee:moon_fixed_y	ASCII_Real	Y position of the spacecraft in ME frame in km
ladee:moon_fixed_z	ASCII_Real	Z position of the spacecraft in ME frame in km
ladee:peak_counts	ASCII_Real	Maximum value in the spectrum, either in DNs or in calibrated units
ladee:phase_angle	ASCII_Real	If the UVS telescope boresight intersects the lunar reference sphereoid, this is the angle at the intersection between the sun vector and the vector to LADEE, in degrees. 0 otherwise. Calculated by SPICE ilumin_c().
ladee:predicted_attitude_flag	ASCII_Integer Range: [0,1].	A small number of spectra in the last activity were captured at times during which no spacecraft attitude information is available. Metadata for these spectra was calculated using the commanded quaternions rather than actual quaternions. A value of 1 means that commanded quaternions were used.
ladee:quaternion_w	ASCII_Real	Uncorrected attitude, estimated on-board
ladee:quaternion_x	ASCII_Real	Uncorrected attitude, estimated on-board
ladee:quaternion_y	ASCII_Real	Uncorrected attitude, estimated on-board
ladee:quaternion_z	ASCII_Real	Uncorrected attitude, estimated on-board
ladee:raw_timestamp	ASCII_Integer	Uncorrected timestamp applied by the s/c in subseconds (2^-16 sec) from J2000 epoch.
ladee:scan_number	ASCII_Integer Range: [0,65535]. Counts to 65535 then wraps back to 0.	This is a sequence number assigned to each spectrum by the instrument. It starts at 0 every time the instrument is commanded to capture a stream of spectra. Within a single activity, this number can reset to 0 several times.
ladee:sequence_number	ASCII_Integer	This is a sequence number within each UVS activity. This

Field	Type	Description
		number does not reset within an activity, so the activity_number, sequence_number pair forms a unique identifier for each spectrum just as each spectrum's timestamp is unique.
ladee:solar_incidence_angle	ASCII_Real	If the UVS telescope boresight intersects the lunar reference sphereoid, this is the angle at the intersection between the sun vector and surface normal. 0 otherwise. Calculated by SPICE ilumin_c().
ladee:solar_latitude	ASCII_Real	Latitude of the sub-spacecraft point in a selenocentric, sun-synchronous frame.
ladee:solar_longitude	ASCII_Real	Longitude of the sub-spacecraft point in a selenocentric, sun-synchronous frame.
ladee:solar_viewer_boresight_me_x	ASCII_Real	X coordinate of the normalized solar-viewer boresight vector in lunar Mean Earth frame
ladee:solar_viewer_boresight_me_y	ASCII_Real	Y coordinate of the normalized solar-viewer boresight vector in lunar Mean Earth frame
ladee:solar_viewer_boresight_me_z	ASCII_Real	Z coordinate of the normalized solar-viewer boresight vector in lunar Mean Earth frame
ladee:solar_viewer_fov_graze_altitude_above_terrain	ASCII_Real	The circular edge of the solar viewer field-of-view corresponds to a cone rooted at the spacecraft. This value is the closest approach of that cone to terrain in km, or 0 if the cone intersects.
ladee:solar_viewer_graze_altitude	ASCII_Real	The closest approach of the solar-viewer boresight vector to the lunar reference sphere, or 0 if it intersects
ladee:solar_viewer_graze_altitude_above_terrain	ASCII_Real	The closest approach of the solar-viewer boresight vector to terrain in km, or 0 if it intersects
ladee:solar_viewer_graze_latitude	ASCII_Real	Latitude in ME frame of the intersection of the solar viewer boresight vector and the LRO lunar reference sphere or the closest point on the reference sphere to that vector.
ladee:solar_viewer_graze_longitude	ASCII_Real	Longitude in ME frame of the intersection of the solar viewer boresight vector and the LRO lunar reference sphere or the closest point on the reference sphere to that vector.
ladee:solar_viewer_graze_solar_latitude	ASCII_Real	Latitude in a selenocentric, sun-synchronous frame of the intersection of the solar occultation viewer boresight vector and the lunar reference sphere or the closest point on the reference sphere to that vector.
ladee:solar_viewer_graze_solar_longitude	ASCII_Real	Longitude in a selenocentric, sun-synchronous frame of the intersection of the solar occultation viewer boresight vector and the lunar reference sphere or the closest point on the reference sphere to that vector.
ladee:solar_viewer_solar_elongation	ASCII_Real	Angle between the solar viewer boresight and the sun vector, in degrees
ladee:solar_viewer_target	ASCII_String	A short string describing what is in the solar viewer's field-of-view. Values are: "Unknown", "Limb", "LitMoon", "UnlitMoon", "Sun", "Earth", "DarkSky".

Field	Type	Description
ladee:sun_graze_altitude_above_terrain	ASCII_Real	The circular limb of the sun corresponds to a cone rooted at the spacecraft. This value is the closest approach of that cone to terrain in km, or 0 if the cone intersects terrain.
ladee:tec_cold	ASCII_Real	Thermo-electric cooler cold-side temperature, which is the best estimate of the temperature of the detector., in degrees centigrade
ladee:tec_enabled	ASCII_Boolean	Indicates whether the Thermo-electric cooler is active. Values are "True" and "False"
ladee:tec_hot	ASCII_Real	Thermo-electric cooler hot-side temperature, in degrees centigrade
ladee:tec_setpoint	ASCII_Real	The target temperature, in degrees C, to which the UVS' thermo-electric cooler has been configured to drive the detector temperature.
ladee:telescope_boresight_me_x	ASCII_Real	X coordinate of the normalized telescope boresight vector in lunar Mean Earth frame
ladee:telescope_boresight_me_y	ASCII_Real	Y coordinate of the normalized telescope boresight vector in lunar Mean Earth frame
ladee:telescope_boresight_me_z	ASCII_Real	Z coordinate of the normalized telescope boresight vector in lunar Mean Earth frame
ladee:telescope_earth_elongation	ASCII_Real	Angle between the telescope boresight vector and the Earth vector, in degrees
Ladee:telescope_ecliptic_declination	ASCII_Real	Angle between the telescope boresight vector and the plane of the ecliptic
ladee:telescope_fov_graze_altitude_above_terrain	ASCII_Real	Altitude above terrain in km of the vector through the edge of the telescope field of view closest to the moon center or 0 if the vector intersects terrain
ladee:telescope_graze_altitude	ASCII_Real	Altitude above the reference sphere in km of the telescope boresight vector or 0 if the vector intersects the reference sphere
ladee:telescope_graze_altitude_above_terrain	ASCII_Real	Altitude above terrain in km of the telescope boresight vector or 0 if the vector intersects terrain
ladee:telescope_graze_lattitude	ASCII_Real	Latitude in ME frame of the intersection of the telescope boresight vector and the LRO lunar reference sphere or the closest point on the reference sphere to that vector.
ladee:telescope_graze_longitude	ASCII_Real	Longitude in ME frame of the intersection of the telescope boresight vector and the LRO lunar reference sphere or the closest point on the reference sphere to that vector.
ladee:telescope_graze_solar_lattitude	ASCII_Real Range [-90,90]	Latitude in a selenocentric, sun-synchronous frame of the intersection of the telescope boresight vector and the lunar reference sphere or the closest point on the reference sphere to that vector.
ladee:telescope_graze_solar_longitude	ASCII_Real Range [0, 360)	Longitude in a selenocentric, sun-synchronous frame of the intersection of the telescope boresight vector and the lunar reference sphere or the closest point on the reference sphere to that vector.
ladee:telescope_solar_elongat	ASCII_Real	Angle between the telescope boresight and the sun vector

Field	Type	Description
ion		in degrees
ladee:telescope_sun_azimuth	ASCII_Real	Azimuth in degrees of the sun vector in UVS telescope frame. This is approximately the angle between the Telescope boresight and the sun vector projected onto the LADEE radiator panel
ladee:telescope_sun_elevation	ASCII_Real	Elevation in degrees of the sun vector in UVS telescope frame. This is approximately the angle between the sun vector and the LADEE radiator on which UVS is mounted
ladee:telescope_target	ASCII_String	A short string describing what is in the telescope's field-of-view. Values are: "Unknown", "Limb", "LitMoon", "UnlitMoon", "Sun", "Earth", "DarkSky".
ladee:uvs_timestamp	ASCII_NonNegative_Integer	A timestamp applied to the spectrum by the UVS instrument, in msec since UVS' firmware booted. This provides a way to measure relative time that is independent of the spacecraft clock. It is not synchronized with that clock, and it starts at 0 during every UVS activity.
ladee:valid_checksum	ASCII_String	True if the packet received by the spacecraft from UVS contained one spectrum with a valid checksum, False otherwise.
ladee:occulation_view_vector	Float3Vector	Vector from the spacecraft to the intersection of the solar occultation viewer boresight vector and the lunar reference sphere or, if there is no intersection, the point along the boresight vector closest to the reference sphere. In meters.
ladee:occultation_grazing_altitude	ASCII_Real	Distance, in meters,from the point specified by (ladee:occultation_grazing_point_latitude, ladee:occultation_grazing_point_longitude) and the ladee:occultation_view_vector.
ladee:telescope_grazing_point_longitude	ASCII_Real	Longitude, in ME frame, of the intersection of the telescope boresight vector and the LRO lunar reference sphere or the closest point on the reference sphere to that vector.
ladee:telescope_grazing_point_solar_latitude	ASCII_Real	Solar latitude, in ME frame, of the intersection of the telescope boresight vector and the LRO lunar reference sphere or the closest point on the reference sphere to that vector.
ladee:telescope_grazing_point_solar_longitude	ASCII_Real	Solar longitude, in ME frame, of the intersection of the telescope boresight vector and the LRO lunar reference sphere or the closest point on the reference sphere to that vector.
ladee:telescope_target	ASCII_String	Symbolic description of field-of-view. One of 'lit-moon', 'unlit-moon', 'sky', 'sun', 'door'
ladee:telescope_view_vector	Float3Vector	Cartesian vector from the spacecraft to the intersection of the telescope boresight vector and the lunar reference sphere or, if there is no intersection, the point along the boresight vector closest to the reference sphere, in meter

Field	Type	Description
		in the ME frame.
ladee:scan_number		
ladee:spacecraft_timestamp	ASCII_NonNegative_Integer	Spacecraft clock time at which the observation was received from the instrument by the spacecraft, in units of 2^-16 seconds ("subseconds") since the mission epoch (200-001-11:58:56.818).
ladee:spectrometer_timestamp	ASCII_NonNegative_Integer	Time, in milliseconds, since the instrument's processor booted.
ladee:integration_start_time	ASCII_Date_Time_UTC	Corrected UTC time at which the integration started.
ladee:tec_enabled	ASCII_Boolean	"True" indicates that the thermoelectric cooler (TEC) is enabled; "False" indicates that it is not.
ladee:tec_hot_side_temp	ASCII_Integer Range: [-700, 700]	Thermoelectric cooler hot-side temperature. The temperature, T, is related to the returned value, s, through $T = s * 0.1$ °C.
ladee:tec_setpoint	ASCII_IntegerRange: [-200, 70]	Thermoelectric cooler temperature setpoint to which the cooler tries to drive the detector temperature. The setpoint temperature, T, is related to the returned value, s, through $T = s * 0.1$ °C.
ladee:valid_checksum	ASCII_Boolean	"True" indicates that the checksum sent by the instrument was correct; "False" indicates otherwise.
ladee:occultation_target	ASCII_String	Symbolic description of field-of-view. One of 'lit-moon', 'unlit-moon', 'sky', 'sun', 'door'
ladee:telescope_grazing_altitude	ASCII_Real	Distance, in meters, from the point specified by (ladee:telescope_grazing_point_latitude, ladee:telescope_grazing_point_longitude) and the ladee:telescope_view_vector.
ladee:telescope_grazing_point_latitude	ASCII_Real	Latitude, in ME frame, of the intersection of the telescope boresight vector and the LRO lunar reference sphere or the closest point on the reference sphere to that vector.

7.2 Abbreviations and acronyms

ASCII American Standard Code for Information Interchange

CCD Charge-coupled device

CCSDS Consultative Committee for Space Data Systems

DAWG Data Analysis Working Group

DMAP Data Management and Archive Plan

DN Digital number

FOV Field of view

FTP File Transfer Protocol

LADEE Lunar Atmosphere and Dust Environment Explorer

LDEX	Lunar Dust Experiment
LOLA	LRO Lunar Orbiter Laser Altimeter
LRO	Lunar Reconnaissance Orbiter
ME	LRO Mean Earth / Polar Axis frame
NAIF	Navigation and Ancillary Information Facility
NMS	Neutral Mass Spectrometer
PDS	Planetary Data System
PDS4	PDS Version 4
SIS	Software Interface Specification
SPICE	"Spacecraft Planet Instrument C-matrix Events" NAIF geometry system
TEC	Thermoelectric cooler
UVS	Ultraviolet and Visible Spectrometer
UTC	Coordinated Universal Time
XML	Extensible Markup Language

7.3 Example PDS labels

7.3.1 Raw-level observational data product label


```
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<?xml-model href="http://pds.nasa.gov/pds4/pds/v1/PDS4_PDS_1101.sch"?>
<Product_Observational
    xmlns="http://pds.nasa.gov/pds4/pds/v1"
    xmlns:pds="http://pds.nasa.gov/pds4/pds/v1"
    xmlns:ladee="http://pds.nasa.gov/pds4/ladee/v1"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xsi:schemaLocation="http://pds.nasa.gov/pds4/pds/v1
http://pds.nasa.gov/pds4/pds/v1/PDS4_PDS_1101.xsd http://pds.nasa.gov/pds4/ladee/v01
http://pds.nasa.gov/pds4/ladee/v1/ladee_1100.xsd">
  <Identification_Area>
    <logical_identifier>urn:nasa:pds:ladee_uvs:raw:0000d_0000</logical_identifier>
    <version_id>1.0</version_id>
    <title>Spectrum 0 in activity 0 (DarkCal)</title>
    <information_model_version>1.1.0.1</information_model_version>
    <product_class>Product_Observational</product_class>
    <Modification_History>
      <Modification_Detail>
        <modification_date>2014-09-16</modification_date>
        <version_id>1.0</version_id>
        <description>First version of UVS products</description>
      </Modification_Detail>
    </Modification_History>
  </Identification_Area>
  <Observation_Area>
    <Time_Coordinates>
      <start_date_time>2013-09-14T20:10:12.493Z</start_date_time>
      <stop_date_time>2013-09-14T20:10:12.503Z</stop_date_time>
    </Time_Coordinates>
    <Primary_Result_Summary>
      <purpose>Science</purpose>
      <processing_level>Raw</processing_level>
      <description>
        One raw UVS spectrum.  Each row provides counts for one spectral pixel (bin), including
both lit and unlit pixels.
        Wavelengths corresponding to each pixel can be found in the calibration collection.
      </description>
      <Science_Facets>
        <wavelength_range>Ultraviolet</wavelength_range>
        <wavelength_range>Visible</wavelength_range>
        <domain>Atmosphere</domain>
        <discipline_name>Atmospheres</discipline_name>
        <facet1>Structure</facet1>
      </Science_Facets>
    </Primary_Result_Summary>
    <Investigation_Area>
      <name>LADEE</name>
      <type>Mission</type>
      <Internal_Reference>
        <lid_reference>urn:nasa:pds:context:investigation:mission.ladee</lid_reference>
        <reference_type>data_to_investigation</reference_type>
      </Internal_Reference>
    </Investigation_Area>
    <Observing_System>
      <name>LADEE</name>
      <description>Description of LADEE</description>
      <Observing_System_Component>
        <name>UVS</name>
        <type>Instrument</type>
        <Internal_Reference>
          <lid_reference>urn:nasa:pds:context:instrument:instrument.uvs__ladee</lid_reference>
          <reference_type>is_instrument</reference_type>
        </Internal_Reference>
      </Observing_System_Component>
```

```
    </Observing_System>
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      <type>Satellite</type>
      <Internal_Reference>
        <lid_reference>urn:nasa:pds:context:target:satellite.moon</lid_reference>
        <reference_type>data_to_target</reference_type>
      </Internal_Reference>
    </Target_Identification>
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      <ladee:longitude>29.782817300194</ladee:longitude>
      <ladee:solar_latitude>-10.8306574390756</ladee:solar_latitude>
      <ladee:solar_longitude>211.667815013808</ladee:solar_longitude>
      <ladee:altitude>410898.354597349</ladee:altitude>
      <ladee:altitude_above_terrain>410900.820097349</ladee:altitude_above_terrain>
      <ladee:activity_number>0</ladee:activity_number>
      <ladee:activity_type>DarkCal</ladee:activity_type>
      <ladee:cosmic_ray_hit_count>0</ladee:cosmic_ray_hit_count>
      <ladee:cosmic_ray_hit_pixel_00>0</ladee:cosmic_ray_hit_pixel_00>
      <ladee:cosmic_ray_hit_pixel_01>0</ladee:cosmic_ray_hit_pixel_01>
      <ladee:cosmic_ray_hit_pixel_02>0</ladee:cosmic_ray_hit_pixel_02>
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      <ladee:cosmic_ray_hit_pixel_08>0</ladee:cosmic_ray_hit_pixel_08>
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      <ladee:cosmic_ray_hit_pixel_15>0</ladee:cosmic_ray_hit_pixel_15>
      <ladee:cosmic_ray_hit_pixel_16>0</ladee:cosmic_ray_hit_pixel_16>
      <ladee:drive_current>1947</ladee:drive_current>
      <ladee:emission_angle>0</ladee:emission_angle>
      <ladee:in_sun>7</ladee:in_sun>
      <ladee:integration_time>10</ladee:integration_time>
      <ladee:moon_fixed_vx>0.203707603310866</ladee:moon_fixed_vx>
      <ladee:moon_fixed_vy>1.28666813536813</ladee:moon_fixed_vy>
      <ladee:moon_fixed_vz>0.00576773523738627</ladee:moon_fixed_vz>
      <ladee:moon_fixed_x>349878.706084187</ladee:moon_fixed_x>
      <ladee:moon_fixed_y>200238.106373922</ladee:moon_fixed_y>
      <ladee:moon_fixed_z>-88078.702061081</ladee:moon_fixed_z>
      <ladee:peak_counts>3899</ladee:peak_counts>
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      <ladee:quaternion_w>0.979008754305308</ladee:quaternion_w>
      <ladee:quaternion_x>-0.203061681519636</ladee:quaternion_x>
      <ladee:quaternion_y>0.00354397524526591</ladee:quaternion_y>
      <ladee:quaternion_z>-0.0171829197591436</ladee:quaternion_z>
      <ladee:raw_timestamp>28341795347999</ladee:raw_timestamp>
      <ladee:scan_number>0</ladee:scan_number>
      <ladee:sequence_number>0</ladee:sequence_number>
      <ladee:solar_incidence_angle>0</ladee:solar_incidence_angle>
      <ladee:solar_viewer_boresight_j2000_x>-
0.937690664104142</ladee:solar_viewer_boresight_j2000_x>

<ladee:solar_viewer_boresight_j2000_y>0.319544406887849</ladee:solar_viewer_boresight_j2000_y>

<ladee:solar_viewer_boresight_j2000_z>0.136482931088933</ladee:solar_viewer_boresight_j2000_z>
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      <ladee:solar_viewer_boresight_me_y>0.756953613085413</ladee:solar_viewer_boresight_me_y>
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<ladee:solar_viewer_fov_graze_altitude_above_terrain>410900.820097349</ladee:solar_viewer_fov_gra
ze_altitude_above_terrain>
      <ladee:solar_viewer_graze_altitude>410898.354597349</ladee:solar_viewer_graze_altitude>
```

```
<ladee:solar_viewer_graze_altitude_above_terrain>410900.820097349</ladee:solar_viewer_graze_altit
ude_above_terrain>
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      <ladee:solar_viewer_graze_longitude>29.7828173001865</ladee:solar_viewer_graze_longitude>
      <ladee:solar_viewer_graze_solar_latitude>-
10.8306574390756</ladee:solar_viewer_graze_solar_latitude>

<ladee:solar_viewer_graze_solar_longitude>211.667815013808</ladee:solar_viewer_graze_solar_longit
ude>
      <ladee:solar_viewer_solar_elongation>12.2708502259793</ladee:solar_viewer_solar_elongation>
      <ladee:solar_viewer_target>DarkSky</ladee:solar_viewer_target>

<ladee:sun_graze_altitude_above_terrain>410900.820097349</ladee:sun_graze_altitude_above_terrain>
      <ladee:tec_cold>-19.9</ladee:tec_cold>
      <ladee:tec_enabled>true</ladee:tec_enabled>
      <ladee:tec_hot>13.6</ladee:tec_hot>
      <ladee:tec_setpoint>-20</ladee:tec_setpoint>
      <ladee:telescope_boresight_j2000_x>-0.99045942455795</ladee:telescope_boresight_j2000_x>
      <ladee:telescope_boresight_j2000_y>0.128991081995875</ladee:telescope_boresight_j2000_y>
      <ladee:telescope_boresight_j2000_z>0.0484915360642303</ladee:telescope_boresight_j2000_z>
      <ladee:telescope_boresight_me_x>0.474774280186807</ladee:telescope_boresight_me_x>
      <ladee:telescope_boresight_me_y>0.879714921379595</ladee:telescope_boresight_me_y>
      <ladee:telescope_boresight_me_z>-0.0262876392092036</ladee:telescope_boresight_me_z>
      <ladee:telescope_earth_elongation>145.506490792696</ladee:telescope_earth_elongation>
      <ladee:telescope_ecliptic_declination>0</ladee:telescope_ecliptic_declination>

<ladee:telescope_fov_graze_altitude_above_terrain>410900.820097349</ladee:telescope_fov_graze_alt
itude_above_terrain>
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      <ladee:telescope_graze_longitude>29.7828173001865</ladee:telescope_graze_longitude>
      <ladee:telescope_graze_solar_latitude>-
10.8306574390756</ladee:telescope_graze_solar_latitude>

<ladee:telescope_graze_solar_longitude>211.667815013808</ladee:telescope_graze_solar_longitude>
      <ladee:telescope_solar_elongation>0.43537272946784</ladee:telescope_solar_elongation>
      <ladee:telescope_sun_azimuth>0.151385588596471</ladee:telescope_sun_azimuth>
      <ladee:telescope_sun_elevation>0.408206081641714</ladee:telescope_sun_elevation>
      <ladee:telescope_target>Sun</ladee:telescope_target>
      <ladee:uvs_timestamp>143321</ladee:uvs_timestamp>
      <ladee:valid_checksum>true</ladee:valid_checksum>
    </Mission_Area>
  </Observation_Area>
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      <reference_type>data_to_document</reference_type>
    </Internal_Reference>
  </Reference_List>
  <File_Area_Observational>
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      <local_identifier>raw_data_file</local_identifier>
      <creation_date_time>2014-09-16T23:41:40.310Z</creation_date_time>
      <file_size unit="byte">7308</file_size>
      <records>1044</records>
    </File>
    <Table_Character>
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      <offset unit="byte">0</offset>
      <records>1044</records>
      <record_delimiter>carriage-return line-feed</record_delimiter>
      <Record_Character>
        <fields>1</fields>
        <groups>0</groups>
        <record_length unit="byte">7</record_length>
        <Field_Character>
          <name>Counts</name>
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          &lt;field_location unit="byte"&gt;1&lt;/field_location&gt;
          &lt;data_type&gt;ASCII_Integer&lt;/data_type&gt;
          &lt;field_length unit="byte"&gt;5&lt;/field_length&gt;
          &lt;unit&gt;Counts&lt;/unit&gt;
          &lt;description&gt;Counts&lt;/description&gt;
        &lt;/Field_Character&gt;
      &lt;/Record_Character&gt;
    &lt;/Table_Character&gt;
  &lt;/File_Area_Observational&gt;
&lt;/Product_Observational&gt;
```

7.3.2 Calibrated-level observational data product label


```
<?xml version="1.0" encoding="UTF-8"?>
<?xml-model href="http://pds.nasa.gov/pds4/pds/v1/PDS4_PDS_1101.sch"?>
<Product_Observational
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    xmlns:pds="http://pds.nasa.gov/pds4/pds/v1"
    xmlns:ladee="http://pds.nasa.gov/pds4/ladee/v1"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xsi:schemaLocation="http://pds.nasa.gov/pds4/pds/v1
http://pds.nasa.gov/pds4/pds/v1/PDS4_PDS_1101.xsd http://pds.nasa.gov/pds4/ladee/v01
http://pds.nasa.gov/pds4/ladee/v1/ladee_1100.xsd">
  <Identification_Area>
    <logical_identifier>urn:nasa:pds:ladee_uvs:cal:0000d_0000</logical_identifier>
    <version_id>1.0</version_id>
    <title>Spectrum 0 in activity 0 (DarkCal)</title>
    <information_model_version>1.1.0.1</information_model_version>
    <product_class>Product_Observational</product_class>
    <Modification_History>
      <Modification_Detail>
        <modification_date>2014-09-17</modification_date>
        <version_id>1.0</version_id>
        <description>First version of UVS products</description>
      </Modification_Detail>
    </Modification_History>
  </Identification_Area>
  <Observation_Area>
    <Time_Coordinates>
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      <stop_date_time>2013-09-14T20:10:12.503Z</stop_date_time>
    </Time_Coordinates>
    <Primary_Result_Summary>
      <purpose>Science</purpose>
      <processing_level>Calibrated</processing_level>
      <description>
        One calibrated UVS spectrum.  Each row provides a radiance for one illuminated spectral
pixel (bin).
        Wavelengths corresponding to each pixel can be found in the calibration collection.
      </description>
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        <wavelength_range>Ultraviolet</wavelength_range>
        <wavelength_range>Visible</wavelength_range>
        <domain>Atmosphere</domain>
        <discipline_name>Atmospheres</discipline_name>
        <facet1>Structure</facet1>
      </Science_Facets>
    </Primary_Result_Summary>
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      <type>Mission</type>
      <Internal_Reference>
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        <reference_type>data_to_investigation</reference_type>
      </Internal_Reference>
    </Investigation_Area>
    <Observing_System>
      <name>LADEE</name>
      <description>Lunar Atmosphere and Dust Environment Explorer</description>
      <Observing_System_Component>
        <name>UVS</name>
        <type>Instrument</type>
        <Internal_Reference>
          <lid_reference>urn:nasa:pds:context:instrument:instrument.uvs__ladee</lid_reference>
          <reference_type>is_instrument</reference_type>
        </Internal_Reference>
      </Observing_System_Component>
    </Observing_System>
    <Target_Identification>
      <name>Moon</name>
      <type>Satellite</type>
      <Internal_Reference>
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```

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        <reference_type>data_to_target</reference_type>
      </Internal_Reference>
    </Target_Identification>
    <Mission_Area>
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      <ladee:longitude>29.782817300194</ladee:longitude>
      <ladee:solar_latitude>-10.8306574390756</ladee:solar_latitude>
      <ladee:solar_longitude>211.667815013808</ladee:solar_longitude>
      <ladee:altitude>410898.354597349</ladee:altitude>
      <ladee:altitude_above_terrain>410900.820097349</ladee:altitude_above_terrain>
      <ladee:activity_number>0</ladee:activity_number>
      <ladee:activity_type>DarkCal</ladee:activity_type>
      <ladee:cosmic_ray_hit_count>0</ladee:cosmic_ray_hit_count>
      <ladee:cosmic_ray_hit_pixel_00>0</ladee:cosmic_ray_hit_pixel_00>
      <ladee:cosmic_ray_hit_pixel_01>0</ladee:cosmic_ray_hit_pixel_01>
      <ladee:cosmic_ray_hit_pixel_02>0</ladee:cosmic_ray_hit_pixel_02>
      <ladee:cosmic_ray_hit_pixel_03>0</ladee:cosmic_ray_hit_pixel_03>
      <ladee:cosmic_ray_hit_pixel_04>0</ladee:cosmic_ray_hit_pixel_04>
      <ladee:cosmic_ray_hit_pixel_05>0</ladee:cosmic_ray_hit_pixel_05>
      <ladee:cosmic_ray_hit_pixel_06>0</ladee:cosmic_ray_hit_pixel_06>
      <ladee:cosmic_ray_hit_pixel_07>0</ladee:cosmic_ray_hit_pixel_07>
      <ladee:cosmic_ray_hit_pixel_08>0</ladee:cosmic_ray_hit_pixel_08>
      <ladee:cosmic_ray_hit_pixel_09>0</ladee:cosmic_ray_hit_pixel_09>
      <ladee:cosmic_ray_hit_pixel_10>0</ladee:cosmic_ray_hit_pixel_10>
      <ladee:cosmic_ray_hit_pixel_11>0</ladee:cosmic_ray_hit_pixel_11>
      <ladee:cosmic_ray_hit_pixel_12>0</ladee:cosmic_ray_hit_pixel_12>
      <ladee:cosmic_ray_hit_pixel_13>0</ladee:cosmic_ray_hit_pixel_13>
      <ladee:cosmic_ray_hit_pixel_14>0</ladee:cosmic_ray_hit_pixel_14>
      <ladee:cosmic_ray_hit_pixel_15>0</ladee:cosmic_ray_hit_pixel_15>
      <ladee:cosmic_ray_hit_pixel_16>0</ladee:cosmic_ray_hit_pixel_16>
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      <ladee:emission_angle>0</ladee:emission_angle>
      <ladee:in_sun>7</ladee:in_sun>
      <ladee:integration_time>10</ladee:integration_time>
      <ladee:moon_fixed_vx>0.203707603310866</ladee:moon_fixed_vx>
      <ladee:moon_fixed_vy>1.28666813536813</ladee:moon_fixed_vy>
      <ladee:moon_fixed_vz>0.00576773523738627</ladee:moon_fixed_vz>
      <ladee:moon_fixed_x>349878.706084187</ladee:moon_fixed_x>
      <ladee:moon_fixed_y>200238.106373922</ladee:moon_fixed_y>
      <ladee:moon_fixed_z>-88078.702061081</ladee:moon_fixed_z>
      <ladee:peak_counts>3899</ladee:peak_counts>
      <ladee:phase_angle>0</ladee:phase_angle>
      <ladee:predicted_attitude_flag>0</ladee:predicted_attitude_flag>
      <ladee:quaternion_w>0.979008754305308</ladee:quaternion_w>
      <ladee:quaternion_x>-0.203061681519636</ladee:quaternion_x>
      <ladee:quaternion_y>0.00354397524526591</ladee:quaternion_y>
      <ladee:quaternion_z>-0.0171829197591436</ladee:quaternion_z>
      <ladee:raw_timestamp>28341795347999</ladee:raw_timestamp>
      <ladee:scan_number>0</ladee:scan_number>
      <ladee:sequence_number>0</ladee:sequence_number>
      <ladee:solar_incidence_angle>0</ladee:solar_incidence_angle>
      <ladee:solar_viewer_boresight_j2000_x>-
0.937690664104142</ladee:solar_viewer_boresight_j2000_x>

<ladee:solar_viewer_boresight_j2000_y>0.319544406887849</ladee:solar_viewer_boresight_j2000_y>

<ladee:solar_viewer_boresight_j2000_z>0.136482931088933</ladee:solar_viewer_boresight_j2000_z>
      <ladee:solar_viewer_boresight_me_x>0.653001062324207</ladee:solar_viewer_boresight_me_x>
      <ladee:solar_viewer_boresight_me_y>0.756953613085413</ladee:solar_viewer_boresight_me_y>
      <ladee:solar_viewer_boresight_me_z>-0.0247151823864698</ladee:solar_viewer_boresight_me_z>

<ladee:solar_viewer_fov_graze_altitude_above_terrain>410900.820097349</ladee:solar_viewer_fov_gra
ze_altitude_above_terrain>
      <ladee:solar_viewer_graze_altitude>410898.354597349</ladee:solar_viewer_graze_altitude>

<ladee:solar_viewer_graze_altitude_above_terrain>410900.820097349</ladee:solar_viewer_graze_altit
ude_above_terrain>
      <ladee:solar_viewer_graze_latitude>-12.3248355268455</ladee:solar_viewer_graze_latitude>
      <ladee:solar_viewer_graze_longitude>29.7828173001865</ladee:solar_viewer_graze_longitude>
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10.8306574390756</ladee:solar_viewer_graze_solar_latitude>
```

```
&lt;ladee:solar_viewer_graze_solar_longitude&gt;211.667815013808</ladee:solar_viewer_graze_solar_longit
ude>
      &lt;ladee:solar_viewer_solar_elongation&gt;12.2708502259793&lt;/ladee:solar_viewer_solar_elongation&gt;
      &lt;ladee:solar_viewer_target&gt;DarkSky&lt;/ladee:solar_viewer_target&gt;

&lt;ladee:sun_graze_altitude_above_terrain&gt;410900.820097349&lt;/ladee:sun_graze_altitude_above_terrain&gt;
      &lt;ladee:tec_cold&gt;-19.9&lt;/ladee:tec_cold&gt;
      &lt;ladee:tec_enabled&gt;true&lt;/ladee:tec_enabled&gt;
      &lt;ladee:tec_hot&gt;13.6&lt;/ladee:tec_hot&gt;
      &lt;ladee:tec_setpoint&gt;-20&lt;/ladee:tec_setpoint&gt;
      &lt;ladee:telescope_boresight_j2000_x&gt;-0.99045942455795&lt;/ladee:telescope_boresight_j2000_x&gt;
      &lt;ladee:telescope_boresight_j2000_y&gt;0.128991081995875&lt;/ladee:telescope_boresight_j2000_y&gt;
      &lt;ladee:telescope_boresight_j2000_z&gt;0.0484915360642303&lt;/ladee:telescope_boresight_j2000_z&gt;
      &lt;ladee:telescope_boresight_me_x&gt;0.474774280186807&lt;/ladee:telescope_boresight_me_x&gt;
      &lt;ladee:telescope_boresight_me_y&gt;0.879714921379595&lt;/ladee:telescope_boresight_me_y&gt;
      &lt;ladee:telescope_boresight_me_z&gt;-0.0262876392092036&lt;/ladee:telescope_boresight_me_z&gt;
      &lt;ladee:telescope_earth_elongation&gt;145.506490792696&lt;/ladee:telescope_earth_elongation&gt;
      &lt;ladee:telescope_ecliptic_declination&gt;0&lt;/ladee:telescope_ecliptic_declination&gt;

&lt;ladee:telescope_fov_graze_altitude_above_terrain&gt;410900.820097349</ladee:telescope_fov_graze_alt
itude_above_terrain>
      &lt;ladee:telescope_graze_altitude&gt;410898.354597349&lt;/ladee:telescope_graze_altitude&gt;

&lt;ladee:telescope_graze_altitude_above_terrain&gt;410900.820097349</ladee:telescope_graze_altitude_ab
ove_terrain>
      &lt;ladee:telescope_graze_latitude&gt;-12.3248355268455&lt;/ladee:telescope_graze_latitude&gt;
      &lt;ladee:telescope_graze_longitude&gt;29.7828173001865&lt;/ladee:telescope_graze_longitude&gt;
      &lt;ladee:telescope_graze_solar_latitude&gt;-
10.8306574390756&lt;/ladee:telescope_graze_solar_latitude&gt;

&lt;ladee:telescope_graze_solar_longitude&gt;211.667815013808&lt;/ladee:telescope_graze_solar_longitude&gt;
      &lt;ladee:telescope_solar_elongation&gt;0.43537272946784&lt;/ladee:telescope_solar_elongation&gt;
      &lt;ladee:telescope_sun_azimuth&gt;0.151385588596471&lt;/ladee:telescope_sun_azimuth&gt;
      &lt;ladee:telescope_sun_elevation&gt;0.408206081641714&lt;/ladee:telescope_sun_elevation&gt;
      &lt;ladee:telescope_target&gt;Sun&lt;/ladee:telescope_target&gt;
      &lt;ladee:uvs_timestamp&gt;143321&lt;/ladee:uvs_timestamp&gt;
      &lt;ladee:valid_checksum&gt;true&lt;/ladee:valid_checksum&gt;
    &lt;/Mission_Area&gt;
  &lt;/Observation_Area&gt;
  &lt;Reference_List&gt;
    &lt;Internal_Reference&gt;
      &lt;lid_reference&gt;urn:nasa:pds:ladee_uvs:document:DPSIS&lt;/lid_reference&gt;
      &lt;reference_type&gt;data_to_document&lt;/reference_type&gt;
    &lt;/Internal_Reference&gt;
    &lt;Internal_Reference&gt;
      &lt;lidvid_reference&gt;urn:nasa:pds:ladee_uvs:raw:0000d_0000::1.0&lt;/lidvid_reference&gt;
      &lt;reference_type&gt;data_to_raw_product&lt;/reference_type&gt;
    &lt;/Internal_Reference&gt;
    &lt;Internal_Reference&gt;
      &lt;lidvid_reference&gt;urn:nasa:pds:ladee_uvs:calibration:wavelength::1.0&lt;/lidvid_reference&gt;
      &lt;reference_type&gt;data_to_calibration_product&lt;/reference_type&gt;
    &lt;/Internal_Reference&gt;
  &lt;/Reference_List&gt;
  &lt;File_Area_Observational&gt;
    &lt;File&gt;
      &lt;file_name&gt;UVS_CAL_0000d_0000.TAB&lt;/file_name&gt;
      &lt;local_identifier&gt;calibrated_data_file&lt;/local_identifier&gt;
      &lt;creation_date_time&gt;2014-09-17T00:28:46.605Z&lt;/creation_date_time&gt;
      &lt;file_size unit="byte"&gt;13312&lt;/file_size&gt;
      &lt;records&gt;1024&lt;/records&gt;
    &lt;/File&gt;
    &lt;Table_Character&gt;
      &lt;local_identifier&gt;cal:0000d_0000_table&lt;/local_identifier&gt;
      &lt;offset unit="byte"&gt;0&lt;/offset&gt;
      &lt;records&gt;1024&lt;/records&gt;
      &lt;record_delimiter&gt;carriage-return line-feed&lt;/record_delimiter&gt;
      &lt;Record_Character&gt;
        &lt;fields&gt;1&lt;/fields&gt;
        &lt;groups&gt;0&lt;/groups&gt;
        &lt;record_length unit="byte"&gt;13&lt;/record_length&gt;
        &lt;Field_Character&gt;
```

```
          <name>Flux</name>
          <field_number>1</field_number>
          <field_location unit="byte">1</field_location>
          <data_type>ASCII_Real</data_type>
          <field_length unit="byte">11</field_length>
          <unit>Watt * Nanometer**-1 * Meter**-2 * Steradian**-1</unit>
          <description>Radiance</description>
        </Field_Character>
      </Record_Character>
    </Table_Character>
  </File_Area_Observational>
</Product_Observational>
```

7.3.3 Derived-level observational data product label

```xml
<?xml version="1.0" encoding="UTF-8"?>
<?xml-model href="http://pds.nasa.gov/pds4/pds/v1/PDS4_PDS_1101.sch"?>
<Product_Observational
    xmlns="http://pds.nasa.gov/pds4/pds/v1"
    xmlns:pds="http://pds.nasa.gov/pds4/pds/v1"
    xmlns:ladee="http://pds.nasa.gov/pds4/ladee/v1"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xsi:schemaLocation="http://pds.nasa.gov/pds4/pds/v1
http://pds.nasa.gov/pds4/pds/v1/PDS4_PDS_1101.xsd http://pds.nasa.gov/pds4/ladee/v01
http://pds.nasa.gov/pds4/ladee/v1/ladee_1100.xsd">
  <Identification_Area>
    <logical_identifier>urn:nasa:pds:ladee_uvs:derived:potassium</logical_identifier>
    <version_id>1.0</version_id>
    <title>Potassium line strengths</title>
    <information_model_version>1.1.0.1</information_model_version>
    <product_class>Product_Observational</product_class>
    <Modification_History>
      <Modification_Detail>
        <modification_date>2015-04-13</modification_date>
        <version_id>1.0</version_id>
        <description>Release of UVS Derived-level data products</description>
      </Modification_Detail>
    </Modification_History>
  </Identification_Area>
  <Observation_Area>
    <Time_Coordinates>
      <start_date_time>2013-09-14T20:10:12.493Z</start_date_time>
      <stop_date_time>2014-04-18T04:22:38.129Z</stop_date_time>
    </Time_Coordinates>
    <Primary_Result_Summary>
      <purpose>Science</purpose>
      <processing_level>Derived</processing_level>
      <description>
        Potassium line strengths derived from UVS spectra.  Each row provides a
        line strength along with metadata indicating the spectra from which it
        was derived along with some information about the location of the
        spacecraft and pointing of the instrument during the observations.
        Each also includes the corresponding number of instrument counts,
        which provides an indication of the amount of light scattered into
        the instrument.
      </description>
      <Science_Facets>
        <wavelength_range>Ultraviolet</wavelength_range>
        <wavelength_range>Visible</wavelength_range>
        <domain>Atmosphere</domain>
        <discipline_name>Atmospheres</discipline_name>
        <facet1>Structure</facet1>
      </Science_Facets>
    </Primary_Result_Summary>
    <Investigation_Area>
      <name>LADEE</name>
      <type>Mission</type>
      <Internal_Reference>
        <lid_reference>urn:nasa:pds:context:investigation:mission.ladee</lid_reference>
        <reference_type>data_to_investigation</reference_type>
      </Internal_Reference>
    </Investigation_Area>
    <Observing_System>
      <name>LADEE</name>
      <description>Description of LADEE</description>
      <Observing_System_Component>
        <name>UVS</name>
        <type>Instrument</type>
        <Internal_Reference>
          <lid_reference>urn:nasa:pds:context:instrument:instrument.uvs__ladee</lid_reference>
          <reference_type>is_instrument</reference_type>
        </Internal_Reference>
      </Observing_System_Component>
    </Observing_System>
    <Target_Identification>
```

```
      <name>Moon</name>
      <type>Satellite</type>
      <Internal_Reference>
        <lid_reference>urn:nasa:pds:context:target:satellite.moon</lid_reference>
        <reference_type>data_to_target</reference_type>
      </Internal_Reference>
    </Target_Identification>
  </Observation_Area>
  <Reference_List>
    <Internal_Reference>
      <lid_reference>urn:nasa:pds:ladee_uvs:document:DPSIS</lid_reference>
      <reference_type>data_to_document</reference_type>
    </Internal_Reference>
    <Internal_Reference>
      <lid_reference>urn:nasa:pds:ladee_uvs:document:derived</lid_reference>
      <reference_type>data_to_document</reference_type>
    </Internal_Reference>
  </Reference_List>
  <File_Area_Observational>
    <File>
      <file_name>potassium.tab</file_name>
      <local_identifier>raw_data_file</local_identifier>
      <creation_date_time>2015-06-30T11:26:57.622Z</creation_date_time>
      <file_size unit="byte">25923384</file_size>
      <records>233544</records>
    </File>
    <Table_Character>
      <local_identifier>derived:potassium_table</local_identifier>
      <offset unit="byte">0</offset>
      <records>233544</records>
      <record_delimiter>carriage-return line-feed</record_delimiter>
      <Record_Character>
        <fields>14</fields>
        <groups>0</groups>
        <record_length unit="byte">111</record_length>
        <Field_Character>
          <name>Activity</name>
          <field_number>1</field_number>
          <field_location unit="byte">1</field_location>
          <data_type>ASCII_NonNegative_Integer</data_type>
          <field_length unit="byte">4</field_length>
          <description>The unique UVS mission activity number.</description>
        </Field_Character>
        <Field_Character>
          <name>day_of_year</name>
          <field_number>2</field_number>
          <field_location unit="byte">6</field_location>
          <data_type>ASCII_NonNegative_Integer</data_type>
          <field_length unit="byte">4</field_length>
          <description>Day of the year for the activity, UTC.</description>
        </Field_Character>
        <Field_Character>
          <name>seconds_into_day</name>
          <field_number>3</field_number>
          <field_location unit="byte">11</field_location>
          <data_type>ASCII_Real</data_type>
          <field_length unit="byte">10</field_length>
          <description>Seconds since the start of the day, UTC.</description>
        </Field_Character>
        <Field_Character>
          <name>lowest_sequence_number</name>
          <field_number>4</field_number>
          <field_location unit="byte">22</field_location>
          <data_type>ASCII_NonNegative_Integer</data_type>
          <field_length unit="byte">4</field_length>
          <description>Lowest sequence number of the spectra used to calculate the line
strength.</description>
        </Field_Character>
        <Field_Character>
          <name>highest_sequence_number</name>
          <field_number>5</field_number>
          <field_location unit="byte">27</field_location>
```

```
          <data_type>ASCII_NonNegative_Integer</data_type>
          <field_length unit="byte">4</field_length>
          <description>Highest sequence number of the spectra used to calculate the line
strength.</description>
        </Field_Character>
        <Field_Character>
          <name>solar_longitude_grazing_point</name>
          <field_number>6</field_number>
          <field_location unit="byte">32</field_location>
          <data_type>ASCII_Real</data_type>
          <field_length unit="byte">7</field_length>
          <unit>degree</unit>
          <description>Solar longitude of the field-of-view grazing point.</description>
        </Field_Character>
        <Field_Character>
          <name>grazing_altitude</name>
          <field_number>7</field_number>
          <field_location unit="byte">40</field_location>
          <data_type>ASCII_Real</data_type>
          <field_length unit="byte">7</field_length>
          <unit>kilometer</unit>
          <description>Altitude of the line of sight as it crosses the grazing
point</description>
        </Field_Character>
        <Field_Character>
          <name>spacecraft_altitude</name>
          <field_number>8</field_number>
          <field_location unit="byte">48</field_location>
          <data_type>ASCII_Real</data_type>
          <field_length unit="byte">7</field_length>
          <unit>kilometer</unit>
          <description>Altitude of the spacecraft above the lunar surface.</description>
        </Field_Character>
        <Field_Character>
          <name>grazing_latitude</name>
          <field_number>9</field_number>
          <field_location unit="byte">56</field_location>
          <data_type>ASCII_Real</data_type>
          <field_length unit="byte">7</field_length>
          <unit>degree</unit>
          <description>Selenographic latitude of the field-of-view grazing point in the LRO Mean
Earth / Polar Axis frame.</description>
        </Field_Character>
        <Field_Character>
          <name>grazing_longitude</name>
          <field_number>10</field_number>
          <field_location unit="byte">64</field_location>
          <data_type>ASCII_Real</data_type>
          <field_length unit="byte">7</field_length>
          <unit>degree</unit>
          <description>Selenographic longitude of the field-of-view grazing point in the LRO Mean
Earth / Polar Axis frame.</description>
        </Field_Character>
        <Field_Character>
          <name>spacecraft_latitude</name>
          <field_number>11</field_number>
          <field_location unit="byte">72</field_location>
          <data_type>ASCII_Real</data_type>
          <field_length unit="byte">7</field_length>
          <unit>degree</unit>
          <description>Selenographic latitude of the spacecraft in the LRO Mean Earth / Polar
Axis frame.</description>
        </Field_Character>
        <Field_Character>
          <name>spacecraft_longitude</name>
          <field_number>12</field_number>
          <field_location unit="byte">80</field_location>
          <data_type>ASCII_Real</data_type>
          <field_length unit="byte">7</field_length>
          <unit>degree</unit>
          <description>Selenographic longitude of the spacecraft in the LRO Mean Earth / Polar
Axis frame.</description>
```

```
        </Field_Character>
        <Field_Character>
          <name>line_strength</name>
          <field_number>13</field_number>
          <field_location unit="byte">88</field_location>
          <data_type>ASCII_Real</data_type>
          <field_length unit="byte">12</field_length>
          <unit>microwatt centimeter^-2 nanometer^-1 steradian^-1</unit>
          <description>Potassium line strength (spectral radiance).</description>
        </Field_Character>
        <Field_Character>
          <name>dn_at_line</name>
          <field_number>14</field_number>
          <field_location unit="byte">101</field_location>
          <data_type>ASCII_Real</data_type>
          <field_length unit="byte">9</field_length>
          <unit>Counts</unit>
          <description>Average total instrument counts at continuum points.</description>
        </Field_Character>
      </Record_Character>
    </Table_Character>
  </File_Area_Observational>
</Product_Observational>
```

7.3.4 Wavelength calibration product label


```
<?xml version="1.0" encoding="UTF-8"?>
<Product_Observational xmlns="http://pds.nasa.gov/pds4/pds/v1"
                       xmlns:ladee="http://pds.nasa.gov/pds4/ladee/v01">
  <Identification_Area>
    <logical_identifier>urn:nasa:pds:ladee_uvs:calibration:wavelength</logical_identifier>
    <version_id>1.0</version_id>
    <title>Mapping between spectrometer sensor bin number and calibrated wavelength</title>
    <information_model_version>1.1.0.1</information_model_version>
    <product_class>Product_Observational</product_class>
    <Modification_History>
      <Modification_Detail>
        <modification_date>2014-05-21</modification_date>
        <version_id>1.0</version_id>
        <description>First version of UVS products</description>
      </Modification_Detail>
    </Modification_History>
  </Identification_Area>
  <Observation_Area>
    <Time_Coordinates>
      <start_date_time>2013-09-07T03:27:00.000Z</start_date_time>
      <stop_date_time>2014-04-18T05:00:00.000Z</stop_date_time>
    </Time_Coordinates>
    <Investigation_Area>
      <name>LADEE</name>
      <type>Mission</type>
      <Internal_Reference>
        <lid_reference>urn:nasa:pds:context:investigation:mission.ladee</lid_reference>
        <reference_type>data_to_investigation</reference_type>
      </Internal_Reference>
    </Investigation_Area>
    <Observing_System>
      <name>LADEE</name>
      <description>Description of LADEE</description>
      <Observing_System_Component>
        <name>UVS</name>
        <type>Instrument</type>
        <Internal_Reference>
          <lid_reference>urn:nasa:pds:context:instrument:instrument.uvs__ladee</lid_reference>
          <reference_type>is_instrument</reference_type>
        </Internal_Reference>
      </Observing_System_Component>
    </Observing_System>
    <Target_Identification>
      <name>Moon</name>
      <type>Satellite</type>
        <Internal_Reference>
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    </Target_Identification>
  </Observation_Area>
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      <reference_type>data_to_document</reference_type>
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        <groups>0</groups>
        <record_length unit="byte">13</record_length>
        <Field_Character>
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          <field_location unit="byte">1</field_location>
          <data_type>ASCII_NonNegative_Integer</data_type>
          <field_length unit="byte">4</field_length>
          <description>Detector bin number.</description>
        </Field_Character>
        <Field_Character>
          <name>WAVELENGTH</name>
          <field_number>2</field_number>
          <field_location unit="byte">6</field_location>
          <data_type>ASCII_Real</data_type>
          <field_length unit="byte">6</field_length>
          <unit>NANOMETER</unit>
          <description>Calibrated wavelength corresponding to the bin.</description>
        </Field_Character>
      </Record_Character>
    </Table_Character>
  </File_Area_Observational>
</Product_Observational>
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