New Horizons Alice KEM1 Encounter Raw Data Overview

During the migration to the Planetary Data System's (PDS) PDS4 data standards, this current description was adapted from the PDS3 Alice dataset catalog file, providing light edits to the text, format, flow, and to make the description to better conform to this PDS4 data collection.

Abstract

This data set contains Raw data taken by the New Horizons Alice Ultraviolet Imaging Spectrograph instrument during the KEM1 ENCOUNTER mission phase.

This version includes data acquired by the spacecraft between 08/14/2018 and 05/01/2022. All Alice data obtained before 05/01/2022 were fully successfully downlinked before that date.

This dataset contains data from Arrokoth's encounter.

These data were migrated from the previously released PDS3 data set NH-A-ALICE-2-KEM1-V6.0.

Data Set Overview

This data set contains Raw data taken by the New Horizons Alice Ultraviolet Imaging Spectrograph instrument during the KEM1 ENCOUNTER mission phase.

PERSI-Alice (P-ALICE; also ALICE) is a spectrograph on the New Horizons spacecraft that is sensitive to extreme and far UltraViolet (UV) light (520-1870 Angstroms). The ALICE instrument comprises a telescopic optics section and a spectrograph section that includes a diffraction grating and a photosensitive two-dimensional (2-D) detector. The optics and diffraction grating physical arrangement configure one detector dimension as a spatial dimension and the other as spectral. ALICE has two separate entrance apertures that feed light to the telescope section of the instrument: the AirGlow Channel (AGC) aperture; the Solar Occultation Channel (SOCC) aperture. Both apertures pass light to the detector through a lollipop-shaped slit comprising two contiguous sections: a narrow, rectangular slit with a Field Of View (FOV) of 0.1 by 4.0 degrees; a fat, square slit with FOV 2.0 x 2.0 degrees. ALICE has three data-taking modes: PixelList mode records each detector/photon event location (pixel, i.e., spectral and spatial), interleaved with time sequence events (hacks), allowing sub-second resolution of the photon events; histogram mode summarizes the per-pixel photon event counts into a 2-D histogram over all detector pixels, collected over an extended time which can range from a few seconds to several days; High-Cadence CountRate (HCCR) mode stores only the number of detector/photon events recorded during each regular sampling interval that can be chosen from 0.02 seconds up to 4.96 seconds, yielding a time series of global detector event count rate. From both PixelList and histogram modes, the common data product is the histogram (derived on the ground in the PixelList case), which is functionally equivalent to a spectral-by-

spatial spectrogram (2-D image); High-Cadence CountRate mode discards all spatial and spectral information. Other data products are also provided and described in this data set.

Every observation provided in this data set was taken as a part of a particular sequence. A list of these sequences has been provided in file that can be found within the PDS (with PDS4 LID: urn:nasa:pds:nh_documents:alice:seq_alice_kem1). N.B. Some sequences provided may have no corresponding observations.

Version History

Each subsection below details the major changes between the prior versions of this data set, listing the newest versions before older versions.

PDS4 v1.0 (migration from PDS3 V6.0)

This data collection was migrated from Planetary Data System's (PDS) PDS3 archive standards to the PDS4 archive standards, which involved changing the PDS formatted product labels. The products themselves have remained unchanged. The major changes from the PDS3 V6.0 data set are:

- the calibration files, documents, and data products were reorganized into separate collections of calibration files, documents, and data products, instead of being in a single package as it was in prior PDS3 data set versions.
- the geometry keywords were recalculated using the most recent spice kernels available at the time and updated in the PDS4 labels only. Note that the FITS headers have not been updated.

PDS3 V6.0 (NH-A-ALICE-2-KEM1-V6.0)

This version includes data acquired by the spacecraft between 08/14/2018 and 05/01/2022. All Alice data obtained before 05/01/2022 were fully successfully downlinked before that date.

This version includes data from a flight software (FSW) update that provided a new mode called High-Cadence CountRate (HCCR), data from the in-flight verification tests of the new FSW and HCCR mode, Wakeup activities, Decontaminations, Darks, High Energy ElecTron (HEET), Lyman Alpha Sky Emission Dense Map for one sector, IPM Scans, Cosmic UV Background, Point-to-Point IPM Measurements with LRO, and Button-up.

PDS Citation Information: Stern, A., NEW HORIZONS RAW ALICE KEM1 V6.0, NH-A-ALICE-2-KEM1-V6.0, NASA Planetary Data System, 2023.

PDS3 V5.0 (NH-A-ALICE-2-KEM1-V5.0)

Version 5.0 of this data set included data acquired by the spacecraft between 08/14/2018 and 03/01/2021. It only included data downlinked before 03/01/2021.

This version included High Voltage (HV) dark tests, Airglow observations of ASTEROID 486958 Arrokoth (2014 MU69), Approach Solar Unocculted SOCC Histogram, Departure Solar Unocculted SOCC Histogram, Stellar Occultation Airglow, Stellar Occultation SOCC, a map of the Lyman Alpha Sky Emission, IPM Observations, and Pointing and Flux Verifications.

Some data files may not contain housekeeping data because the housekeeping packets were not downloaded by the time of archive creation. In the level 3 (calibrated) dataset, some files may have a countrate extension with 0 values caused by a high voltage and dark test in which the housekeeping sample rate was changed.

The following two data files were acquired as part of a wake-up sequence before time synchronization was fully active, making them appear to be part of an earlier sequence (i.e. REQID and other time-based information is not correct):

> 20200414_044930/ali_0449301885_0x4b1_*.fit
> 20200415_044930/ali_0449301963_0x4b1_*.fit

PDS Citation Information: Stern, A., NEW HORIZONS RAW ALICE KEM1 V5.0, NH-A-ALICE-2-KEM1-V5.0, NASA Planetary Data System, 2022.

PDS3 V4.0 (NH-A-ALICE-2-KEM1-V4.0)
Version 4.0 of this data set included data acquired by the spacecraft between 08/14/2018 and 04/30/2020. It only included data downlinked before 05/01/2020.

This version included High Voltage (HV) dark tests, Airglow observations of Arrokoth, Approach Solar Unocculted SOCC Histogram, Departure Solar Unocculted SOCC Histogram, Stellar Occultation Airglow, Stellar Occultation SOCC, a map of the Lyman Alpha Sky Emission, IPM Observations, and Pointing and Flux Verifications.

Some data files may not contain housekeeping data because the housekeeping packets were not downloaded by the time of archive creation. In the level 3 (calibrated) dataset, some files may have a countrate extension with 0 values caused by a high voltage and dark test in which the housekeeping sample rate was changed.

PDS Citation Information: Stern, A., NEW HORIZONS RAW ALICE KEM1 V4.0, NH-A-ALICE-2-KEM1-V4.0, NASA Planetary Data System, 2021.

PDS3 V3.0 (NH-A-ALICE-2-KEM1-V3.0)
Version 3.0 of this data set included data acquired by the spacecraft between 08/14/2018 and 07/31/2019. It only included data downlinked before 08/01/2019.

This version included High Voltage (HV) dark tests, Airglow observations of Arrokoth, Approach Solar Unocculted SOCC Histogram, Departure Solar Unocculted SOCC Histogram, Stellar Occultation Airglow, Stellar Occultation SOCC, and a map of the Lyman Alpha Sky Emission.

PDS Citation Information: Stern, A., NEW HORIZONS RAW ALICE KEM1 V3.0, NH-A-ALICE-2-KEM1-V3.0, NASA Planetary Data System, 2020.

PDS3 V2.0 (NH-A-ALICE-2-KEM1-V2.0)
Version 2.0 of this data set included data acquired by the spacecraft between 08/14/2018 and 01/31/2019. It only included data downlinked before 02/01/2019.

This version included High Voltage (HV) dark tests, Airglow observations of Arrokoth, Departure Solar Unocculted SOCC Histogram, Stellar Occultation Airglow, and Stellar Occultation SOCC.

An EXTENSION_HK_TABLE was added to several fits files as compared to V1.0. An EXTENSION_CT_RATE_VEC_HK_ARRAY was added to several fits files as compared to V1.0.

Two digits of precision have also been added to the EXPOSURE_DURATION value in all data labels after V1.0.

PDS Citation Information: Stern, A., NEW HORIZONS RAW ALICE KEM1 V2.0, NH-A-ALICE-2-KEM1-V2.0, NASA Planetary Data System, 2020.

PDS3 V1.0 (NH-A-ALICE-2-KEM1-V1.0)
This version includes data acquired by the spacecraft between 08/14/2018 and 12/31/2018. It only includes data downlinked before 01/01/2019.

This version includes High Voltage (HV) dark tests, and Airglow observation of 2014 MU69.

Citation Information: Stern, A., NEW HORIZONS RAW ALICE KEM1 V1.0, NH-A-ALICE-2-KEM1-V1.0, NASA Planetary Data System, 2019.

General statement about data set versions after V1.0
The pipeline (see Processing below) was re-run on these data for each version since the first (V1.0). A pipeline rerun usually changes the FITS headers but not the FITS data of raw data sets. In some cases, calibrated FITS data may change because the calculated geometry of an observation has changed. See data set version-specific sections above for significant exceptions to this general statement, i.e., changes to pipeline processing, calibration processing, and data delivered.

Note that even if this is not a calibrated data set, calibration changes are listed as the data will have been re-run and there will be updates to the calibration files, to the documentation and to the steps required to calibrate the data.

Processing
The data in this data set were created by a software data processing pipeline on the Science Operations Center (SOC) at the Southwest Research Institute (SwRI), Department of Space Operations. This SOC pipeline assembled data as FITS files from raw telemetry packets sent down by the spacecraft and populated the data labels with housekeeping and engineering values, and computed geometry parameters using SPICE kernels. The pipeline did not resample the data.

Data
The observations in this data set are stored in data files using standard Flexible Image Transport System (FITS) format. Each FITS file has a corresponding detached PDS label file, named according to a common convention. The FITS files may have image and/or table extensions.

See the PDS label plus the document collection for a description of these extensions and their contents.

This Data section comprises the following sub-topics:

- Filename/Product IDs
- Instrument description
- Other sources of information useful in interpreting these Data
- Visit Description, Visit Number, and Target in the Data Labels

Filename/Product IDs

The filenames and Local product Identifiers (LID) of observations adhere to a common convention, e.g.:

```
ali_0123456789_0x4b0_eng.fit
^^^ ^^^^^^^^^^ ^^^^^ ^^^\__/
 |      |        |    |   ^^
 |      |        |    |    |
 |      |        |    |   +--File type (includes dot)
 |      |        |    |       - .FIT for FITS file
 |      |        |    |       - .LBLX for PDS label
 |      |        |    |       - not part of LID
 |      |        |    |
 |      |        |   +--ENG for CODMAC Level 2 data
 |      |        |      SCI for CODMAC Level 3 data
 |      |        |
 |      |       +--Application ID (ApID) of the telemetry data
 |      |           packet from which the data come
 |      |           N.B. ApIDs are case-insensitive
 |      |
 |     +--MET (Mission Event Time) i.e. Spacecraft Clock
 |
+--Instrument designator
```

Instrument Designator(s):

Instrument Designator	Description
ALI	Alice

See SOC Instrument Interface Control Document (ICD) within the PDS for more details (PDS4 LID: urn:nasa:pds:nh_documents:mission:soc_inst_icd).

Mission Event Time (MET)

Note that, depending on the observation, the Mission Event Time (MET) in the data filename and in the LID may be similar to the MET of the actual observation acquisition, but should not be used as an analog for the acquisition time. The MET is the time that the data are transferred from the instrument to spacecraft memory and is therefore not a reliable indicator of the actual observation time. The PDS labels are better sources to use for the actual timing of any observation. The specific keywords for which to look are:

- start_date_time
- stop_date_time
- start_clock_count
- stop_clock_count

Application ID (ApID)

Here is a summary of the types of files generated by each ApID (N.B. ApIDs are case-insensitive) along with the instrument designator that go with each ApID:

ApIDs	Data product description/Prefix(es)
0x4b0	ALICE PixelList Lossless (CDH 1)/ALI
0x4b1	ALICE PixelList Packetized (CDH 1)/ALI
0x4b4	ALICE PixelList Lossless (CDH 2)/ALI
0x4b5	ALICE PixelList Packetized (CDH 2)/ALI
0x4b2	ALICE Histogram Lossless (CDH 1)/ALI
0x4b3	ALICE Histogram Packetized (CDH 1)/ALI
0x4b6	ALICE Histogram Lossless (CDH 2)/ALI
0x4b7	ALICE Histogram Packetized (CDH 2)/ALI
0x4c0	ALICE High-Cadence CountRate Lossless (CDH 1)/ALI
0x4c1	ALICE High-Cadence CountRate Packetized (CDH 1)/ALI
0x4c4	ALICE High-Cadence CountRate Lossless (CDH 2)/ALI
0x4c5	ALICE High-Cadence CountRate Packetized (CDH 2)/AL

Note 1: CDH 1 and CDH 2 refer to the spacecraft redundant Command and Data Handling systems in general, and here specifically to their respective Solid State Recorders (SSRs) 1 and 2, where Alice data be stored and prepared for downlink. Alice can send data to SSR 1 or to SSR 2, or, for mission-critical data, to both redundantly. Alice shares its channel to the SSRs with the Long-Range Reconnaissance Imager (LORRI), so both instruments cannot store data simultaneously. Alice has the capability to store histogram data to instrument-internal storage, and to transfer it to the SSR(s) later; such an operation is called a Held Histogram, and it allows Alice to take data at the same time that LORRI is taking and writing data to the SSR(s).

Note 2: Packetized (i.e. uncompressed in PDS4) and Lossless refer to the method used on-board to convert raw, high-speed instrument data on the SSR to low-speed data ready for downlink. The conversion process is generally referred to as compression, even though Packetized conversion does not reduce the data volume. In practice, PixelList data always use Packetized compression. Histogram and High-Cadence CountRate (HCCR) data may use Packetized or Lossless compression. Depending on the actual data contents, Lossless compression reduces Histogram data volume by 60 to 90% or more; for nominal science data a factor of 3 or more is normal. Tests show HCCR data do not compress much. Lossless compression is used whenever possible to reduce downlink data volume. There is no difference, between Packetized and Lossless compression, in the resultant FITS files after processing by the Science Operations Center (SOC) data pipeline.

There are other ApIDs that contain housekeeping values and other values. See SOC Instrument ICD for more details: urn:nasa:pds:nh_documents:mission:soc_inst_icd

Please note that not all ApIDs may be found in this data set.

Instrument description

Refer to the following files for a description of this instrument.:

- New Horizon Alice instrument overview:
  `urn:nasa:pds:nh_documents:alice:alice_inst_overview`
- Alice Space Science Review (SSR) paper:
  `urn:nasa:pds:nh_documents:alice:alice_ssr`
- SOC Instrument ICD: `urn:nasa:pds:nh_documents:mission:soc_inst_icd`
- Alice SPICE Instrument Kernel: `urn:nasa:pds:nh_documents:alice:nh_alice_ti`

Other sources of information useful in interpreting these Data

Refer to the following files for more information about these data:

- NH Mission Trajectory Table:
  `urn:nasa:pds:nh_documents:mission:nh_mission_trajectory`
- Field of View Illustration: `urn:nasa:pds:nh_documents:mission:nh_fov`
- Alice SPICE Instrument Kernel: `urn:nasa:pds:nh_documents:alice:nh_alice_ti`

Visit Description, Visit Number, and Target in the Data Labels

The observation sequences were defined in Science Activity Planning (SAP) documents and grouped by Visit Description and Visit Number. The SAPs are spreadsheets with one Visit Description & Number per row. A nominal target is also included on each row and included in the data labels but does not always match with the target name field's value in the data labels. In some cases, the target was designated as right_ascension_angle, declination_angle pointing values in the form "right_ascension_angle, declination_angle =123.45,-12.34" indicating Right Ascension and Declination, in degrees, of the target from the spacecraft in the Earth Equatorial J2000 inertial reference frame. This indicates that either the target was a star, or the target's ephemeris was not loaded into the spacecraft's attitude and control system which in turn meant the spacecraft could not be pointed at the target by a body identifier and an inertial pointing value had to be specified as Right Ascension and Declination values. PDS-SBN practices do not allow putting a value like right_ascension_angle, declination_angle =... in the PDS target name keyword's value. In those cases, the PDS target purpose value is set calibration. Target name may be None for a few observations in this data set; typically, that means the observation is a functional test so None is an appropriate entry for those targets, but the PDS user should also check the nh:observation_description and nh:sequence_id keywords in the PDS label, plus the provided sequence list (`urn:nasa:pds:nh_documents:alice:seq_alice_kem1`) to assess the possibility that there was an intended target. These two keywords are especially useful for star targets as often stars are used as part of instrument calibrations and are included as part of the sequencing description which is captured in these keywords.

Specifically for Alice observations, any observation that has an observation description or sequence ID that includes the words dump or held will usually have None as its target, but that indicates the observation was actually taken as part of an earlier sequence and held locally in instrument memory (i.e. a Held Histogram; see the Notes in the Data section below), and the

Dump sequence represents the commands that transferred the instrument data onto the spacecraft Solid-State Recorders (SSRs). In the cases of Held Histograms, the user should check the previous sequence in the sequence list. For other cases note that if the characters _P_, _C_, or _PC_ are in the sequence ID, then the intended target was likely Pluto, Charon, or Pluto and Charon together, respectively.

Ancillary Data

The geometry items included in the data labels were computed using the SPICE kernels archived in the New Horizons SPICE data set, NH-J/P/SS-SPICE-6-V1.0.

Every observation provided in this data set was taken as a part of a particular sequence. The sequence identifier and description are included in the PDS label for every observation.

N.B. While every observation has an associated sequence, every sequence may not have associated observations. Some sequences may have failed to execute due to spacecraft events (e.g., safing). No attempt has been made during the preparation of this data set to identify such empty sequences.

Time

There are several time systems, or units, in use in this dataset: New Horizons spacecraft MET (Mission Event Time or Mission Elapsed Time), UTC (Coordinated Universal Time), and TDB Barycentric Dynamical Time.

This section will give a summary description of the relationship between these time systems. For a complete explanation of these time systems the reader is referred to the documentation distributed with the Navigation and Ancillary Information Facility (NAIF) SPICE toolkit from the PDS NAIF node, (see http://naif.jpl.nasa.gov/).

The most common time unit associated with the data is the spacecraft MET. MET is a 32-bit counter on the New Horizons spacecraft that runs at a rate of about one increment per second starting from at value of zero at "19.January, 2006 18:08:02 UTC" or "JD2453755.256337 TDB."

The leapsecond adjustment (DELTA_ET = ET - UTC) was 65.184s at NH launch, and the first four additional leapseconds occurred at the ends of 12/2009, 06/2012, 06/2015, and 12/2016. Refer to the NH SPICE data set, NH-J/P/SS-SPICE-6-V1.0, and the SPICE toolkit documentation, for more details about leapseconds.

The data labels for any given product in this dataset usually contain at least one pair of common UTC and MET representations of the time at the middle of the observation. Other portions of the products, for example tables of data taken over periods of up to a day or more, will only have the MET time associated with a given row of the table.

For the data user's use in interpreting these times, a reasonable approximation (+/- 1s) of the conversion between Julian Day (TDB) and MET is as follows:

```
JD TDB = 2453755.256337 + ( MET / 86399.9998693 )
```

For more accurate calculations the reader is referred to the NAIF/SPICE documentation as mentioned above.

Reference Frame

Geometric Parameter Reference Frame

Earth Mean Equator and Vernal Equinox of J2000 (EMEJ2000) is the inertial reference frame used to specify observational geometry items provided in the data labels. Geometric parameters are based on best available SPICE data at time of data creation.

Epoch of Geometric Parameters

All geometric parameters provided in the data labels were computed at the epoch midway between the start_date_time and stop_date_time label fields.

Software

The observations in this data set are in standard FITS format with PDS labels and can be viewed by a number of PDS-provided and commercial programs. For this reason, no special software is provided with this data set.

Confidence Level Overview

During the processing of the data in preparation for delivery with this volume, the packet data associated with each observation were used only if they passed a rigorous verification process including standard checksums.

In addition, raw (CODMAC Level 2) observation data for which adequate contemporary housekeeping and other ancillary data are not available may not be reduced to calibrated (CODMAC Level 3) data. This issue is raised here to explain why some data products in the raw data set may not have corresponding data products in the calibrated data set.

Data coverage and quality

Every observation provided in this data set was taken as a part of a particular sequence.

Refer to the Confidence Level Overview section above for a summary of steps taken to assure data quality.

The lollipop-shaped fuzz in images of some Alice spectra, seen as high signal levels at the box end of the slit around Hydrogen Lyman-alpha (H Lya) wavelengths, is due to a characteristic of the detector and aperture. To make the Micro Channel Plate (MCP) more sensitive to UV light, it was coated with potassium bromide (KBr) photocathodes from 520 to 1180 Angstrom and with cesium iodide (CsI) photocathodes from 1250 to 1870 Angstrom. A vertical strip - a spectral band of 70 Angstrom centered at ~1216 Angstrom - of the MCP was masked and left uncoated to reduce the sensitivity of the detector to H Lya radiation. In the slit portion of the aperture (0.1deg wide x 4deg high), the diffraction grating keeps the strong H Lya line within that uncoated band. However, in the 2x2 degree box portion of the aperture designed to

capture the Sun during occultations, the H Lya spreads out beyond the uncoated 70-Angstrom band over another ~55 Angstroms of more sensitive photocathode-coated detector on either side. The quantum efficiencies of the photocathode- coated surfaces are about an order of magnitude more sensitive to H Lya wavelengths than the bare, uncoated glass, which gives rise to high signal levels from the box area of the slit i.e. the lollipop fuzz.

Observation descriptions in this overview file

Some users will expect to find descriptions of the observations in this data set here. This data set follows the more common convention of placing those descriptions under the Data Set Overview section of this overview file.

Caveat about target name in PDS labels and observational

The downlink team on New Horizons has created an automated system to take various uplink products, decode things like Chebyshev polynomials in command sequences representing celestial body ephemerides for use on the spacecraft to control pointing, and infer from those data what the most likely intended target was at any time during the mission. This works well during flyby encounters and less so during cruise phases and hibernation.

The user of these PDS data needs to be cautious when using the target name and other target-related parameters stored in this data set. This is less an issue for the plasma and particle instruments, more so for pointed instruments. To this end, the heliocentric ephemeris of the spacecraft, the spacecraft-relative ephemeris of the inferred target, and the inertial attitude of the instrument reference frame are provided with all data, in the J2000 inertial reference frame, so the user can check where that target is in the Field Of View (FOV) of the instrument.

Finally, note that, within the FITS headers of the data products, the sequence tables, and other NH Project-internal documents used in this data set, informal names are often used for targets instead of the canonical names used within the PDS labels. For example, during the Pluto mission phase, instead of the target name '15810 ARAWN (1994 JR1)' there might be found any of the following: 1994JR1; 1994 JR1; JR1. However, within the context of this data set, these project abbreviations are not ambiguous (e.g. there is only one NH target with 'JR1' in its name), so there has been, and will be, no attempt to expand such abbreviations where they occur outside formal PDS keyword values.

Contact Information

For any questions regarding the data format of the archive, contact the New Horizons Alice Principal Investigator: Alan Stern, Southwest Research Institute

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