New Horizons Alice Instrument Overview

This document is an overview of the New Horizons' Alice Ultraviolet Imaging Spectrograph Instrument. This Alice description was originally adapted from Slater et al. (2005) and Stern et al. (2005). During migration to PDS4, this current copy was adapted from the PDS3 Alice instrument catalog file, providing light edits to the text, format, and flow.

Instrument Overview

The New Horizons Alice instrument is a lightweight (4.4 kg), low-power (4.4 Watt) imaging spectrograph aboard the New Horizons mission to Pluto/Charon and the Kuiper Belt. Its primary job is to determine the relative abundances of various species in Pluto's atmosphere. Alice also is used to search for an atmosphere around Pluto's moon Charon, (486958) Arrokoth (2014 MU69), as well as the Kuiper Belt Objects (KBOs) that New Horizons hopes to fly by after Pluto-Charon-MU69. It makes ultraviolet (UV) surface reflectivity measurements of all these bodies as well. The instrument incorporates an off-axis telescope feeding a Rowland-circle spectrograph with a 520-1870 Angstrom (A) spectral passband, a spectral point spread function of 3-6 A FWHM, and an instantaneous spatial field-of-view that is 6 degrees long. Different input apertures that feed the telescope allow for both airglow and solar occultation (SOCC) observations during the mission. The focal plane detector is an imaging microchannel plate (MCP) double delay-line detector with dual solar-blind opaque photocathodes (KBr and CsI) and a focal surface that matches the instrument's 15-cm diameter Rowland-circle.

Specifications

NAME:	Alice
DESCRIPTION:	Ultraviolet Mapping Spectrograph
PRINCIPAL INVESTIGATOR:	Alan Stern, SwRI (Southwest Research Institute)
WAVELENGTH RANGE:	520 - 1870 Angstrom
FIELD OF VIEW:	1.7 x 70 mRad (Note 1); 35 x 35 mRad (Note 2)
ANGULAR RESOLUTION:	1.7 x 5.2 mRad
WAVELENGTH OFFSET:	229.5+/-1.5 Angstrom at first pixel
WAVELENGTH RESOLUTION:	1.815+/-0.004 Angstrom/pixel
ACTIVE PIXELS:	~780 pixels (Note 3)

Note 1: Slit
Note 2: Solar occultation aperture/channel; SOCC
Note 3: Starting at an offset of 130 pixels from the first pixel

Description

The New Horizons Alice is a lightweight (4.4 kg), low-power (4.4 W), ultraviolet spectrograph based on the Alice instrument previously flown aboard the European Space Agency's Rosetta spacecraft. Its primary job is to detect a variety of important atomic and molecular species in Pluto's atmosphere, and to determine their relative abundances so that a complete picture of Pluto's atmospheric composition can be determined for the first time. Alice also is used to search for an atmosphere around Pluto's moon Charon, 2014 MU69, as well as the Kuiper Belt Objects (KBOs) New Horizons plans to fly by after Pluto-Charon-MU69.

Light can enter the telescope section through either a 40 mm x 40 mm entrance aperture (i.e., the airglow channel) or a stopped-down 1-mm diameter entrance aperture and flat relay mirror (i.e., the SOCC) and is collected and focused by an off-axis paraboloidal (OAP) primary mirror onto the spectrograph entrance slit. The OAP has a 120 mm focal length.

Scientific Objectives

1. Upper atmospheric temperature and pressure profiles of Pluto.
2. For atmospheric densities greater than ~10^9 cm^{-3}, temperature and vertical temperature gradients should be measured to ~10% at a vertical resolution of ~100 km.
3. Search for atmospheric haze at a vertical resolution <5 km.
4. Mole fractions of N_2, CO, CH_4 and Ar in Pluto's upper atmosphere.
5. Atmospheric escape rate from Pluto.
6. Minor atmospheric species at Pluto.
7. Search for an atmosphere of Charon.
8. Constrain escape rate from upper atmospheric structure.

Calibration

Alice instrument calibration considerations include the following:

- Dark count rate.
- Spectral offsets i.e., which wavelength is sampled by each pixel.
- Spectral and spatial resolution and point-spread function.
- Scattered light characteristics, including H Lyman-alpha.
- Absolute effective area.

See Stern et al. (2008) for details.

Operational Considerations

The New Horizons Alice UV spectrograph was successfully launched on 19 January 2006 and is operating normally in space. All in-flight performance tests to date have shown performance within specification; the pointing and airglow sensitivity tests completed in September 2006 were nominal. The main remaining tests to be performed were the testing of the solar occultation aperture after it was opened, and instrument mutual noise susceptibility testing.

May 2007, Inter-instrument interference test:

The Alice contribution to the interference test was completed successfully. No interference was found in any of the three acquisitions. The retrieved housekeeping (HK) data for temperatures, HVPS (high-voltage power supplies), and countrate were all nominal and no outliers were observed. In particular, the background count rate had returned to normal after the elevated count rate at Jupiter.

July 2007, SOCC door opening:

Open status was confirmed by detection of the star Bellatrix close to the center of the box in the Y (along slit) direction. Events coincident with the door opening also were detected by the Student Dust Counter (SDC) instrument, i.e., the movement of the door caused impact-like events to be measured by the SDC.

All further tests during the ACOs (Annual CheckOuts, 2007-2014) were nominal.

Detectors

The detector is a 2-dimensional (2-D) array of 1024 spectral pixels by 32 spatial pixels.

Although there are 1024 spectral pixel columns across the detector array, only about 780 are active, starting at an offset of 130 columns from the first spectral column.

The spectral passband quoted above only refers to the active pixels.

See Stern et al. (2008) for details.

Electronics

Major electronic subsystems are

- Low-Voltage Power Supply Electronics.
- Command-and-Data-Handling Electronics.
- Decontamination Heaters.
- High Voltage Power Supplies.

See Stern et al. (2008) for details.

Optics

Summary information is above; see Stern et al. (2008) for details.

Operational Modes

Optics Aperture Modes

Alice has two separate entrance apertures that feed light to the telescope section of the instrument: an 'airglow' aperture, which allows measurement of emissions from atmospheric constituents, and an 'occultation' aperture, when either the Sun or a bright star is viewed through the atmosphere producing absorption by the atmospheric constituents. The Alice occultation mode will be used just after New Horizons passes behind Pluto and looks back at the Sun through Pluto's atmosphere.

Data Acquisition Modes

Alice has three data taking modes: (i) PixelList Mode; (ii) Histogram Imaging Mode; (iii) High Cadence Count Rate (HCCR). The Alice flight software controls all the modes. Data are collected in a dual-port acquisition memory that comprises two separate 32kx16-bit memory channels. In both PixelList and Histogram Imaging modes, the instrument is turned on and photons hitting a pixel on the detector, that result in analog pulses above a set threshold level, generate photon events that are then transferred to the flight software. Each photon event contains the pixel location of the event. The difference between PixelList and Histogram Imaging modes is in how the flight software stores the photon events in the memory channels.

PixelList Mode: continuous 1-D stream of photon events and time hacks

In PixelList Mode (PLM), the 2-D pixel array location of each single photon event from the detector is transferred from Alice to the spacecraft memory as a stream of data; the data stream is also interspersed with timing information (time hacks) that can be used to constrain the time of each photon event.

In PLM, each Alice memory channel acts as a linear data stream buffer: while one memory channel is being written to with detector data, the other is written to spacecraft memory. Once the instrument fills the first memory channel, the roles switch and the detector data go to the second channel while the first channel is written to spacecraft memory. This double-buffering - called 'ping-pong' acquisition - allows continuous readout and storage of detector event data.

In this mode, a single event is represented by one 16-bit word in instrument memory and can be either a detector photon event or a time hack event. Photon events occur stochastically in time and are generated by photons hitting the detector. Time hack events, referred to simply as 'time hacks,' occur at regular intervals in time and are generated by the Alice flight software. The time hack interval is programmable and can be as short as 4ms. The PLM data stream comprises photon event locations interspersed with time hack values. Time hacks can be converted to timestamps in the series of events and may be used to provide temporal information about the PLM data stream and to constrain the time that any photon event occurs.

Histogram Imaging Mode: summing of photon events into a 2-D spectrogram

In Histogram Imaging Mode (HIM), the Alice flight software sums detector photon event counts for each pixel over a specified period (exposure) and then writes the result out as a 2-D array i.e., a spectral-spatial image or spectrogram. In this mode, the 1-D 32k memory channel is treated as a 2-D 1024x32 array; each memory channel location thus accumulates the photon event count acquired at its corresponding pixel location in the detector array. While some have found it confusing to call this a histogram, it is only an extension of the normally 1-D arrangement of histogram bins into pixels representing bins in two dimensions.

Note that the timing information present in the time hacks of the PLM data stream is neither generated nor saved in HIM. Therefore, while the PLM data stream can be analyzed to generate the equivalent of the HIM spectrogram, the HIM data cannot be used to generate the PLM data.

Besides the collection and binning of detector events, HIM collects pulse-height distribution (PHD) data from the detector electronics. These PHD data are collected and binned into a 64-bin histogram that is stored within the first two rows of the detector histogram, in a location where no physical pixel within the detector active area exists (therefore, the PHD data does not interfere with the collected detector data). During ground processing, the Science Operations

Center pipeline software reads these PHD data and then zeroes the relevant area of the input array before creating the data products.

The same Alice instrument software that controls the PLM ping-pong acquisitions also controls the HIM.

High-Cadence Count Rate Mode: detector/photons events

High-Cadence Count Rate (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 rates. High-Cadence Count Rate mode acts as a UV photometer and discards all spatial and spectral information, so it provides a low downlink data volume collection mode. The FSW update (loaded on the spacecraft in August 2021) to provide the HCCR allows it to be executed via the nominal ALICE pixellist science acquisition commanding. Since the number of counts in a sample period are given in single 8-bit bytes, the maximum number of counts in a sample is 255 and any higher incident count rate is reported as 255; so the range of measurable incident count rates ranges from 51 Hz (at 4.96 s sample period) to 12,750 Hz (at 0.02 s sample period). A standard Alice pixellist science frame, on which the HCCR data are based, is 65,536 bytes. The HCCR data has an extended frame header of 12 bytes, which provides metadata that allows the HCCR data to be identified uniquely from a regular pixel list acquisition.

See Stern et al. (2008) for further details.

Measured Parameters

PixelList Mode

Each 16-bit word in the PLM data stream represents either the detector location of a photon event or the time of a time hack.

One bit in each word identifies that word as a photon event or as a time hack. The meaning of the remaining fifteen bits depends on which type of event the word represents. Photon events use ten bits for the spectral detector position (0 to 1023) and five bits for the spatial detector (0 to 31). Time hack events use all fifteen bits to represent the number of 4 ms time intervals since either the instrument was turned on or the most recent rollover of the time hack counter.

Histogram Imaging Mode

Accumulated count of photon events, which each generated an analog pulse above the set threshold, at each pixel location for the duration of each exposure.

A MCP PHD histogram is created when detector electronics digitize the analog amplitude of each detected event and send them to the Command & Data Handling subsystem.

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