Calibration Description: Lucy L'Ralph Linear Etalon Imaging Spectral Array
V1.0: Amy Simon, May 9, 2024

Introduction

The Lucy Mission to the Trojan asteroids in Jupiter's orbit carries an instrument named L'Ralph, a visible/near infrared multi-spectral imager and a short wavelength infrared hyperspectral imager. This document describes the Linear Etalon Imaging Spectral Array (LEISA) half of the instrument. LEISA is an imaging spectrometer that operates from ~0.97 to 3.97 microns with 40.75 microrad spatial resolution. The full array of the detector is 1024 spatial pixels x 1472 wavelength channels. LEISA uses 3 linear variable filters to cover the full spectral range, and targets are scanned using an internal scan mirror across the 1472 pixels in the wavelength direction (the mirror can scan in either direction). As the target moves along the wavelength channels, a frame is readout every integration time allowing the later reconstruction of image cubes at a single wavelength. The cross-track (XT) readout size can be reduced to lower data volume or to allow for shorter integration times. It is also possible to readout subsets of wavelength channel (or along track, AT, pixels). A 2x2 sum mode may also be employed, reducing both the spatial and spectral resolution by a factor of 2 with onboard summing. Key words in the header provide information about the pixels that were recorded and if summing was applied. File size will be XT * AT * N frames, or XT/2 * AT/2 * N for summed frames. More instrument details can be found in Reuter et al. 2023 *Space Science Reviews* **219**, 69. DOI: 10.1007/s11214-023-01009-2

The ground calibration pipeline converts the Level 0 data to physical units. Several processing and calibration steps are performed on the raw data to produce a Level 2 spectrum:

1. Subtract the average background (dark current) level
2. If 2x2 summing was employed, count and divide by the number of good pixels in each 2x2 sum in both the science and calibration frame
3. Calculate the actual integration time
4. Convert to radiance units

Calibrated data products produced by this calibration pipeline are indicated with a filename containing the filed "sci". Further description of the LEISA pipeline and its products is provided in the Lucy LEISA SIS, Document 22668.07-LEISA-SIS-01_R2_C1.

1. Background Subtraction

Background levels are dependent on the detector temperature. Deep space frames acquired in the same mode, at similar detector temperature, are used to calculate the average background level (Space File). As sequences are not calling separate observation blocks for this purpose, 10 frames of the science observation, before the target has crossed the FOV, are averaged and used for this purpose. Note that the very first frame is often corrupted (until the first detector reset) so the first few frames are discarded. These corresponding space files are manually generated and validated to ensure that there is no target in the FOV. Corrected counts, $C_{i,j}$, are simply the raw counts $DN_{i,j}$, minus the average background:

$$C_{i,j} = DN_{i,j} - \frac{1}{10}\sum_{3}^{12} DN_{i,j}$$

The space data are saved into files with names matching the science file but denoted by "space". This file name appears in the headers, and the data are also written into the L2 file as an extension.

2. 2x2 Sum Adjustment

If pixels have been summed onboard, the bad pixel map ($BPM_{i,j}$) was used to determine if a pixel belonged in the sum. The counts at Level 0 must be averaged by the number of pixels in the sum (0 to 4). To determine the true data number, $C_{i,j}$ are corrected for the number of pixels using the corresponding bad pixel map ($BPM_{i,j}$). In flight, all science data use the BPM generated at 115K from thermal vacuum testing data.

$$C_{i,j} = \frac{C_{i,j}}{\sum BPM_{i,j}}$$

Note: If summing was applied, then the radiometric coefficients will be similarly averaged for calibration.

3. Integration Time Calculation

Integration times are commanded in milliseconds, but the detector frame readout values are quantized depending on how much of the detector is read out in the XT direction and may vary slightly from the commanded value. In the flight software, the commanded time is rounded down to the nearest integer "drop frame", DF. The actual integration time, t, is then found by:

$$t = (XT + 3 + (2048 - XT) / 144 + DF) * 0.72 \text{ ms}$$

4. Radiance Unit Conversion

Corrected counts are converted to radiance units, $I_{i,j}$, in W/cm^2/sr/micron by first dividing by exposure time, t, to get counts/s. They are then multiplied by the appropriate Radiometric Conversion File, $R_{i,j}$:

$$I_{i,j} = \frac{CO_{i,j}}{t} * R_{i,j}$$

Nominal operating temperature is 103K, but calibration files were generated between 90K and 117K. The file name used in the pipeline is in the header, and the calibration coefficient are also written into a L2 file extension.

Data notes:

- Data acquired when detector is above the nominal operating temperature range have decreased long wavelength sensitivity and will not be calibrated at those wavelengths.

- Level 2 science data will often show optical fringes, likely due to a small internal reflection between detector and filter. Because the effect varies with illumination, and other factors, a correction cannot be included in the calibration pipeline. Please see the separate post-pipeline processing document for more details.
- Cosmic ray cleaning has not been performed.
- Scans are sometimes performed at rates different than 1 pixel/int time. For Dinkinesh the mirror moved at ~1.53 pixels per integration time.