Rosetta Alice Data Calibration Cookbook

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This document is intended to provide a high-level description of the steps that are performed by the Alice calibration pipeline. A detailed desciption of the Alice instrument is given by Stern et al. (2007), and the unsupported source code for the Alice pipeline is provided in the DOCUMENT directory.

The general data calibration procedure is as follows:

1. Create a 2-D wavelength image
2. Correct for detector dead time
3. Subtract dark counts
4. Divide by exposure time
5. Divide by flat field image (not currently applied)
6. Divide by effective area
7. Divide by $\Delta\lambda$ (LIN data only)
8. Interpolate data onto common linear wavelength scale (LIN data only)

1 Create a 2-D Wavelength Image

Changes in the resistivity of the detector electronics (primarily due to thermal variations) cause the mapping of a location on the detector in physical space, [x,y], to data space, [X,Y], to vary. This results in an effective change in the dispersion of the data. To correct for this, the detector electronics can produce simulated photon events, known as "stim" pulses, at two known locations in physical space on opposite ends of the detector. The location of the two stim pulses can be used to define a common reference frame

(CRF) for all data. Data obtained with an arbitrary plate scale can then be corrected and re-mapped into this CRF using the following equation:

$$P_X = S_{X1} + \left(P'_X - S'_{X1}\right)\left(\frac{S_{X2} - S_{X1}}{S'_{X2} - S'_{X1}}\right) \tag{1}$$

where P_X is the location of an event in the CRF, S_{X1} and S_{X2} are calibration constants that define the CRF, P'_X is the location of the event in the uncorrected data frame, and S'_{X1} and S'_{X2} are the locations of the stim pulses in the data frame (Wilkinson et al., 2001).

Unfortunately, on *Rosetta* Alice, the second stim pulse (corresponding to the short wavelength end of the detector) is typically mapped into the last column in data space (1023) regardless of the state of the detector electronics, rendering it ineffective as a wavelength fiducial. Since photons of a given wavelength will always fall on the same location, in physical space, on the detector, the location of spectral feature, in pixel space, can serve as a proxy for the second stim pulse. Lyman-α is present in almost all of the Alice data, so it is a good proxy for the second stim pulse. The Alice pipeline determines the centroid of the Lyman-α feature in three separate rows and uses the average value for S'_{X2}.

The current wavelength solution, the wavelength of the detector columns as a function of detector for Alice (v006) is based on a 20^{th}-order polynomial fit to the locations of spectral features (in the CRF) in Alice spectra of Mars, Earth, the Moon (i.e. a reflected solar spectrum), C/2002 T7 LINEAR, α Gru, γ Gru, ζ Cas, ρ Leo, HD 93521, G191-B2B, and BD +28° 4211. Wavelengths for these features come from spectra from IUE, HUT, HST, UARS, TIMED/SEE, and various models.

The 2-D wavelength image for a particular data file is created by solving Eq. 1 for P'_X and then applying a row-dependent offset to compensate for the curved appearance of the Alice entrance slit as seen by the detector. This curvature is the result of optical distortion, primarily coma, and is measured by comparing the centroid of Lyman-β in a given row to that in row 15.

2 Detector Dead Time

When a charge pulse from the MCP hits the DDL readout anode, the detector electronics converts the signal into a 10-bit X location and a 5-bit Y location. This process takes a small, but non-zero, amount of time, during which the detector can not process any additional events. This introduces a non-linearity into the detector response, especially at high signal rates.

The dead time behavior of the Alice detector exhibits both paralyzable and non-paralyzable components.

Non-paralyzable deadtime is conceptually simpler. If the detector starts to process an event at time $t = 0$, then it will not be able to process any additional events until time $t = \tau_n$, i.e. it is “dead”. If an additional event occurs between $t = 0$ and $t = \tau_n$, the event is simply ignored. Likewise, In the case of paralyzable deadtime, the detector cannot process any additional events until time $t = \tau_p$. However, if a new event occurs between $t = 0$ and $t = \tau_p$, it “resets” the clock and the detector will not become “live” again until a time, τ_p, later.

For systems exhibiting both paralyzable and non-paralyzable dead times, the count rate observed by the detector electronics,r_{out}, is given by:

$$r_{out} = \frac{r_{in}}{\exp\left(r_{in}\tau_p\right) + r_{in}\tau_n} \tag{2}$$

where r_{in} is the count rate input to the detector electronics, and τ_p and τ_n are the paralyzable and nonparalyzable dead time constants (Lampton and Bixler, 1985). Lab tests on the *Rosetta* Alice flight spare detector showed that $\tau_n = 15.7\mu$s and $\tau_p = 11.3\mu$s. The Alice data are multiplied by the scalar detector deadtime correction factor r_{in}/r_{out}. For an observed count rate of 1000 counts/s this correction factor is 1.03, while for 10,000 counts/s the deadtime correction is 1.39. After the deadtime correction, the data are in units of input counts.

3 Dark Count Subtraction

Even when the Alice aperture door is closed and no UV photons can enter the instrument, Alice detects some background counts at a low rate. Presently, the dark rate is approximately 34 counts/s over the whole detector. However, this rate appears to be increasing approximately linearly with time at a rate of 2.7 counts/s/year.

Alice has obtained dark exposures during most of the observing epochs to date. Since there appears to be no time-variable structure in the spatial distribution of dark counts, individual dark exposures are summed together–after correcting for the location of the stim pixels–to create a “superdark” image. To remove dark counts from Alice data, the “superdark” is scaled to the dark count rate for the particular observing epoch times the exposure time of the data. The resulting 2-D dark image is then subtracted from the data.

4 Exposure Time

The Alice data are then divided by the scalar value of the exposure time. Ordinarily this would be a very simple operation. However, because of the interaction between the way Alice checks to see if the commanded exposure time has elapsed and the actual command time line, sometimes the aperture door was closed before the exposure ended. To correct for this, the Alice pipeline code checks, when available, the housekeeping "event" files for aperture door motion events during an exposure. HK event files can be identified by the extension "*EVNT_ENG.TXT". The total time the instrument aperture door was open during an exposure is recorded as "OPENTIME" in the primary header of the FITS file. Similarly, "CLOSTIME" is the total time during an exposure that the aperture door was closed. "OPENTIME" + "CLOSTIME" = "EXPTIME", the total length of time of the exposure. Since dark counts have already been subtracted from the data (using the value of "EXPTIME") any remaining counts should be due to UV photons coming through the aperture, so the data are divided by the value of "OPENTIME". Note, if *Rosetta* is in an environment with a high flux of MeV electrons, which can penetrate the 0.7mm thick instrument housing and be detected by Alice, this may not be a valid assumption. After this step, the data are in units of counts s^{-1}.

5 Flat Field Correction

At this point, the data would be divided by a flat field correction. To correct for spatial variations in the Alice sensitivity. Two methods have been used to derive the flat field response in flight: scanning a star (i.e. a point source) along the length of the slit and scanning the moon (which fills the width of the slit) along the length of the slit. After correcting for the changing width of the slit and the different input spectra, the two methods yield similar results.

At this time, the flat field correction is not applied by the Alice calibration pipeline.

6 Effective Area Correction

The data are then divided by the effective area of the instrument, A_{eff}. A_{eff} is a function of wavelength and is derived from comparison of Alice spectra of hot stars with reference spectra. A 2-D A_{eff} image is created by interpolating the A_{eff} vs. wavelength curve for each pixel in the 2-D wavelength image. The Alice data are then divided by the A_{eff} image, after which they have units of photons cm^{-2} s^{-1}.

This is the last step in the calibration of the CODMAC level 3 data (SCI files).

7 $\Delta\lambda$ Correction

CODMAC level 4 data, (LIN files) undergo two additional steps in the calibration process. First, the data are divided by a 2-D image containing the width of each pixel in wavelength space, $\Delta\lambda$. After this step, the data have units of photons cm^{-2} s^{-1} Å^{-1}.

8 Interpolation Onto Common, Linear Wavelength Scale

Finally, the LIN data files are interpolated onto a CRF that is linear in wavelength. The row-dependent positional offsets introduced by the instrument optics are included, such that a spectral feature in the interpolated data should appear in the same column for all rows. This makes it much easier to compare data. To ensure that the total flux is conserved through the interpolation process, the interpolated data are multiplied by the ratio of total pre-interpolation flux to total post-interpolation flux. This correction is usually of order 0.1% or less.

References

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