**Bandwidth Optimisation of STIX Low Latency Calibration Spectra**

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## Introduction

The STIX detector calibration parameters, in particular offset and gain, are likely to vary over many timescales, as the temperature changes. These must therefore be continually characterized by fitting low latency background spectra taken over the duration of roughly a day, with spectral lines at known energies. As the calibration of all 32 x 12 x 1024 (~ 4e5) detector/pixel/channel combinations must be maintained and telemetry is limited, the strategy for reducing the needed bandwidth is that each spectrum will be telemetered as a set of up to eight sub-spectra with varying resolution in the binning of ADC channels, rather than sending the full calibration spectrum of all 1024 channel accumulators for each of the 384 detector/pixels.

These sub-spectra are characterized by their starting channel, the channels per data bin, and the total number of channels. These sub-spectra must then be combined and decompressed to give an approximation of the full calibration spectrum that is then fit to determine the positions of the calibration lines at 31 and 81 keV, and hence the offset and gain for each detector pixel.

As there are so many detector/pixel elements to evaluate, it is critical to determine a minimum set of sub-spectra that are needed, so that a reliable calibration can be determined, using as few sub-spectra and data bins as possible to minimize the telemetry required.

### Detector Grouping

The purpose of the procedure stx\_calib\_groups.pro is to identify which detectors to group together as sub-spectra using the same parameters, so that they use the same full resolution channel sets (1 for 30.85 keV and 1 for 81 keV for each) over a limited range in ADC channel number. That is, detectors with similar expected locations for the calibration line peaks are grouped together with full resolution binning of 1 bin per ADC channel only performed in the range where these detectors all have their expected peak locations. As the offset and gain is mostly determined by measuring the positions of the two major calibration lines and the majority of the counts accumulated away from these lines is dominated by background, high resolution data is only needed in ADC channel ranges close to the line peaks.

If a small number of these groups can be appropriately defined these sub-spectra can be sent in a reduced number of telemetry packets and hence reduce the total telemetry needed for calibration. In the current, initial, procedure, 3 groups of detectors are defined, all including their individual pixel units. The starting point for these estimations is the data taken when testing the flight unit detectors in the thermal vacuum chamber These data were taken as part of the STIX PFM (Proto Flight Model) thermal tests which included measurement of the performance of the Caliste SO. These tests were performed at the University of Bern Thermal Vacuum Facility with the relevant data accumulated between 21:01 28-May-2017 and 20:16 31-May-2017. Further details of the test procedure are described in STIX-TR-0108-FHNW.

This full resolution data was taken with the detectors cooled and represents the best data set for estimation of the calibration and sub-spectral parameters to use before commissioning data is available from the instrument in flight.

The detector groups are defined by first starting with the ADC channels expected to correspond to 29, 33, 79, 83 keV based on the current calibration estimates. Then the minimum and maximum expected peak ADC values over all pixels for a given detector are calculated. Expected ranges around the peak values of the 30.85 keV line are then considered.

The detectors are then divided into three groups based on a simple model. First, the maximum and average differences between the minimum and maximum channel for the 31 keV line energy range for each detector are calculated. These were found to be 30.4 and 47.6 ADC channels respectively. The maximum and minimum range over all detectors was found to be 306.2 to 402.1. Bounds using these values with a buffer of 3 ADC channels were used to test if all detectors could be placed into 3 groups. A test width of 50 was used and three groups defined one starting from the lowest bound, one starting from the lowest bound + 25 and the third starting from 25 before the highest bound. These boundaries were determined to be 303.2 - 353.2, 328.2 - 378.2 and 380.1 - 430.1.

Detectors are then matched with the provisional groups by comparing the center of the range for each detector with the centers of the defined ranges for the three groups. This initial test determines that it is possible to group all detectors in groups with width of 50 channels, with the majority (28) being assigned to the center group and 2 detectors each being assigned to the edge groups.

To refine these groupings a plot showing the range for each detector, along with bands of width 10 ADC channels between 300 and 420 was made (Figure 1). By inspection the boundaries of the groups were refined to be 305 - 365, 330- 390 and 360 – 410. The detectors were then assigned to these groups by determining which bounds fully contained the maximum and minimum values for each detector. Again, the majority (25) were assigned to the central group with 3 and 4 detectors being placed in the lower and higher groups respectively. The boundaries were then further refined by using the maximum and minimum values for the detectors assigned to a given group, with an additional buffer of 1 channel at either end giving: 305 – 358, 331 – 388 and 359 – 403 as the channel boundaries for the three groups.



Figure 1: The range of expected ADC values between 29 and 33 keV for each detector are determined by taking the maximum and minimum values over all individual pixels in a detector. To initially evaluate the groupings bands with width 10 ADC channels are defined between 300 and 420.

The boundaries around the 81 keV lines were then checked by using the same groupings as previously defined and determining the maximum and minimum channel values for each group of detectors, with an additional buffer of 3 channels at either end.

To maximize flexibility in selecting sub-spectra outside of the peak ranges, the upper boundaries of the initial groups are increased so that the number of channels between the 31 keV and 81 keV bands is divisible by 4 for each group. Thus the final boundaries are 305 – 360, 331 – 389 and 359 – 403 for the bands around the 31 keV line (Figure 2) and correspondingly 420 – 478, 445 – 508 and 475 – 521 for the bands around the 31 keV line (Figure 3).

The procedure also defines additional sub-spectra for each of the three groups above the 81 keV and below the 31 keV band. These are also assigned a width divisible by 4.



Figure 2: The three groups defined for the 30.85 keV line. The detector energy ranges are determined as with Figure 1. The lines showing the detector ranges and the bounds for the full resolution binning are coloured red, green and blue corresponding to the lower, central and upper groups.



Figure 3: The three groups defined for the 81 keV line. The detector energy ranges are determined as with Figure 1. The lines showing the detector ranges and the bounds for the full resolution binning are coloured red, green and blue corresponding to the lower, central and upper groups.