XMM-Newton CCF Release Note

XMM-CCF-REL-5

EPIC Energy Scale

D Lumb

October 3, 2000

1 CCF components

Name of CCF	VALDATE	List of Blocks changed	CAL VERSION	XSCS flag
EMOS1_ADUCONV_0008	2000-01-01T00:00:00	ADUCOEFF OFFSET_GAIN ENERGY_COMBINE		YES
EMOS2_ADUCONV_0008	2000-01-01T00:00:00	ADUCOEFF OFFSET_GAIN ENERGY_COMBINE		YES
EPN_ADUCONV_0009	2000-01-01T00:00:00	ADUCOEFF OFFSET_GAIN GAIN_HIGH REEMISSION REEMISSION1		YES
EMOS1_CTI_0005	2000-01-01T00:00:00	CTI CTI_EXTENDED		NO
EMOS2_CTI_0005	2000-01-01T00:00:00	CTI CTI_EXTENDED		NO
EPN_CTI_0008	2000-01-01T00:00:00	CTI CTI_EXTENDED HOT_PIXELS DISCARDED_PIXELS CTI-HIGH		NO

2 Changes

First release

A number of factors are involved in determining the photon's energy. The intrinsic silicon photoelectric conversion process, the losses of charge during transfer to the output node, the on- and off-chip amplifications and the event processing. As far as possible we aim to keep a physical representation of all these items within the calibration files.

Although it is not the recommended practice for spectral fitting, we adopt a PI channel (i.e. corrected apparent energy) domain analysis. This eases considerably the co-addition of data from multiple CCDs, while the oversampling of energy resolution is probably sufficient to allow this approach in practice.

The silicon conversion process is inherently linear, although some theoretical models predict departure from linearity, especially at low energies and near the Si K absorption edge (1.84 keV). Such features may be masked by other processes though.

Charge transfer losses are in principle measured, calibrated and monitored by using an internal calibration source. This has Mn K α and β lines of 5.89 and 6.4 keV, with a fluorescent Alk target line of 1.49 keV. Other much weaker fluorescent contaminants can also be detected. However all these lines do not provide good leverage on energy-dependent CTI effects for low signal packet magnitudes. In addition the calibration source flux is relatively large compared with most astronomical image scenes, thus a systematic discrepancy due to a count-rate dependency might be encountered.

For the PN camera, the charge loss per transfer is significantly higher. Fortunately, an extremely detailed model has been developed to account for energy and count rate dependence. This means that single pixel events which are the first read out of a frame, can be corrected with the same fidelity as the MOS camera. To the accuracy we can determine there has been (nor was there expected to be) no degradation since launch. Furthermore, the response generation also has (at present) high fidelity only for "first singles" events. These represent about 70% of all X-ray data, so the situation is thought to be acceptable for the first calibration.

In the EPIC data-handling units, events are selected for transmission. A common occurrence is the splitting of events between pixels. The energy determination is degraded by a combination of noise quadrature summation and sub-threshold charge loss. The amount of charge splitting itself is energy dependent. These effects are incorporated in the response matrix, however the on-board and SAS processing makes the best attempt to reconstruct true energy in the first place. As part of the in-orbit verification process, distenangling the effects of gain and response matrix is somewhat complicated, and maintaining coherence between event processing algorithms, and their resulting response distributions is not yet complete.

3 Scientific Impact of this Update

First release

4 Estimated Scientific Quality

For the MOS camera, the pre-lauch CTI was good enough that a typical charge loss from CCD edge to an on-axis target location was only 3–5 eV, largely correctable. Since launch, degradation has been about this amount again, so that this portion of the energy determination budget is well in hand. However the Small change in CTI with time is included in the CTI calibration files as an avergae change over all CCDs, because the individual error measurement on the small change is larger than the change itself.

The association of measured ADC value to an energy should be a linear translation due to amplifier gain. However there are still episodic discrepancies at ≥5eV, which can be due to a number of causes. A readout mode dependence has still to be ruled out, for we are only just starting to gather enough data on modes other than full-frame with the calibration sources. The effect of light loading can be present. For example if a blocking filter is chosen which is too thin, each optical photon detected in a pixel produces a 3.6eV energy equivalent offset. In the PN camera this is in principle calculated on a pixel-by-pixel basis, though associated noise must also be considered. In the MOS a row/column average value is subtracted, so that local deviations can be considerable. Such offsets can be checked for in the raw data files by histogramming E3 and E4 values around the target of interest, and checking for gross deviations from zero. (of course the PSF for optical photons is comparable with X-ray PSF's, so energy discrepancy will be significantly greater for the pixels at the PSF core).

However, having laid bare all these caveats, the current experience is that energy determination is generally good to about 5eV. Use of low energy SNR emission lines in principle are able to supplement this knowledge, but plasma emission code uncertainties and scientific interpretation start to play. In case of suspicious data, it is suggested that the user can double check gain values by looking in the raw data for optical contamination, AND by checking parasitic emission lines in the background (e.g. Al K (1.487keV) and Cu Kα (8.048 keV) are relatively uniform in the focal plane and in long exposures should be centroided with reasonable accuracy).

For MOS Timing Mode, the gain was incorrect in hardware from mission start until ca. September 2000. Currently it is 10% incorrect.

5 Expected Updates

For EPIC MOS, the revision of the *rmfgen* code to match the low energy response may need some modification of the low energy gain determination. This may be performed by reconciling the low energy RGS emission line spectra with MOS.

When the MOS timing mode is properly calibrated the files will be updated.

For PN there will be changes due to the further analysis of mode and count rate dependence. Only the FULL FRAME PN camera mode is properly calibrated, and future updates will address the mode dependence. On ground this calibration for full frame mode required millions of photons at a wide range of energies. In-orbit for the other modes we are restricted to the limited emission line set of the in-flight calibration source, which is necessarily faint.