XMM-Newton CCF Release Note

XMM-CAL-SRN-0304

Post-XRL Rate-Dependent CTI correction for EPIC-pn Timing Mode

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1 CCF components

Name of CCF	VALDATE	EVALDATE	Blocks changed	XSCS flag
EPN_CTI_0029.CCF	2000-01-01		RATE_DEPENDENT_CTI	NO

This CCF constituent includes an update of the Rate-Dependent CTI (RDCTI) correction for EPIC-pn Timing Mode. This change is required by the implementation of the "X-Ray Loading (XRL)" correction, described in an accompanying CCF Release Note (Guainazzi & Smith 2013). It has been recently discovered that almost all the offset maps taken in scientific filters prior to exposures in EPIC-pn Fast Modes (Burst and Timing) are contaminated by the pointed source (see Guainazzi et al., 2012 for a discussion of this effect). XRL distorts the energy scale in PHA space. This means that the calibration of the RDCTI publicly available so far was based on data, whose energy scale was corrupted in a rate-dependent way.

This CCF fixes this issue. The RDCTI has been now calibrated using XRL-corrected spectra.

As of the $23rd$ of May 2012, offset maps prior to EPIC-pn exposures in Fast Modes (Burst and Timing) are taken in `CLOSED` filters to avoid XRL. The recalibration of the RDCTI is adequate for these exposures as well.

2 Changes

The principle of the RDCTI calibration are described in the original CCF RN (Guainazzi et al. 2009). Readers are referred to this document for a description of the data reduction and analysis, as well as of the algorithm.

The RDCTI calibration embedded in this CCF constituents was based on an updated sample of 49 sources with featureless spectra in the 1.5–3 keV energy band, covering the

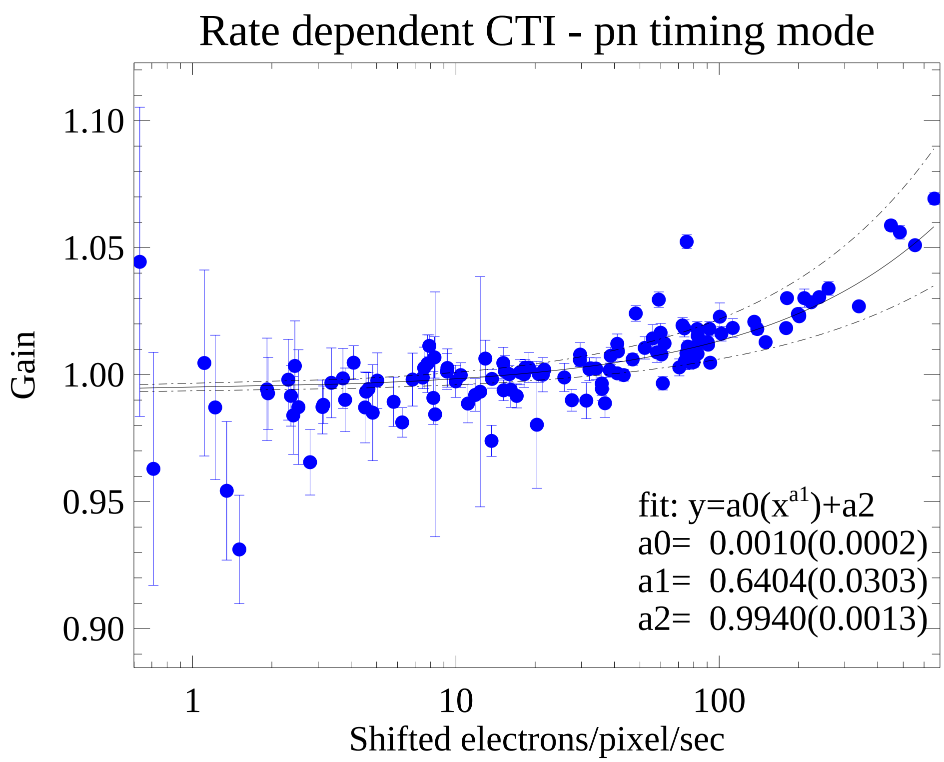

Figure 1: RDCTI calibration curve in `EPN_CTI_0029.CCF`. The *solid line* represent the best-fit function (*inset label*): the *dashed lines* represent the envelope of the same function corresponding to the 1σ error on the best-fit parameters (in brackets in the *inset*).

a_0	a_1	a_2
0.0010 ± 0.0002	0.640 ± 0.030	0.9940 ± 0.0013

Table 1: Parameters of the RDCTI calibration function (and 1σ statistical uncertainties) in `EPN_CTI_0029.CCF`

whole mission up to April 2012. The sample does not include either sources with a count rate exceeding the pile-up limit (800 counts per second on the 9-pixel `RAWY` extraction region), nor observations whose ODF does not contain an offset map, because the XRL correction is not reliable in these cases (Guainazzi & Smith 2013).

The RDCTI calibration curve is shown in Fig. 1. The data points were fit with the function: $G = a_0(N_e)^{a_1} + a_2$, where G is the gain factor (calculated around the Si and Au instrumental edges, *i.e.* around 2 keV), N_e is the total number of shifted electrons (a proxy for for the source count rate), and a_i are fit parameters. The best-fit parameters are listed in Tab. 2 (the CCF contains only the best-fit values, not the associated statistical uncertainties).

3 Scientific Impact of this Update

Together with the associated calibration of the XRL correction (Guainazzi & Smith 2013), the update of the RDCTI calibration is intended to finalise a full recalibration of the energy scale in EPIC-pn Timing Mode.

4 Estimated Scientific Quality

Together with the associated calibration of the XRL correction (Guainazzi & Smith 2013), the update of the RDCTI calibration is expected to yield a reconstructed energy scale in EPIC-pn Timing Mode better then 25 eV on most of the calibrated energy bandpass (0.7–10 keV) and for any level of count rate below the pile-up limit ($\simeq$800 total counts per second).

Doubts have been expressed on the accuracy of the energy-dependence of the RDCTI (Walton et al. 2012). As this correction is calibrated at $\simeq$2 keV, a wrong energy-dependence could yield significant errors at the iron line energies. Admittedly, the true origin of the RDCTI is unknown. It is therefore possible that the assumptions underlying its algorithm could yield mistakes in the energy reconstruction at energies different from those where the RDCTI had been calibrated. We address this point from an experimental perspective in §5–6. If the rate-dependent correction to the energy scale is due to a CTI effect, and taking into account the known dependence of EPIC-pn CTI with energy as measured through the calibration source (K.Dennerl, in preparation), we estimate that the systematic error due to the energy dependency of the RDCTI algorithm is lower than 10 eV. This is within the residual systematic uncertainties of the energy scale in EPIC-pn Timing Mode. On the other hand, not applying the RDCTI (*i.e.*, not correcting the EPIC-pn Timing Mode event list with `epfast`) may yield errors on the energy scale as large as a few hundreds eV. Extreme care should be exercised in deriving scientific conclusions on RDCTI-uncorrected spectra, especially in case of complex continua, because the spectral deconvolution could be completely falsified.

5 Test procedures and results

The performances of the new RDCTI have been tested using two metrics:

- the deviation between the energy scale in the data and in the calibration at the Au edge, applying the same algorithm to calibrate the RDCTI on spectra extracted from `epfast`-corrected event list. The results are summarised in the top panel of Fig. 2. The energy scale is accurate within $\pm$10 eV up to count rates below the pile-up threshold, with a scatter of $\pm$20 eV

- the measured energies of atomics transitions over the whole energy range between 1

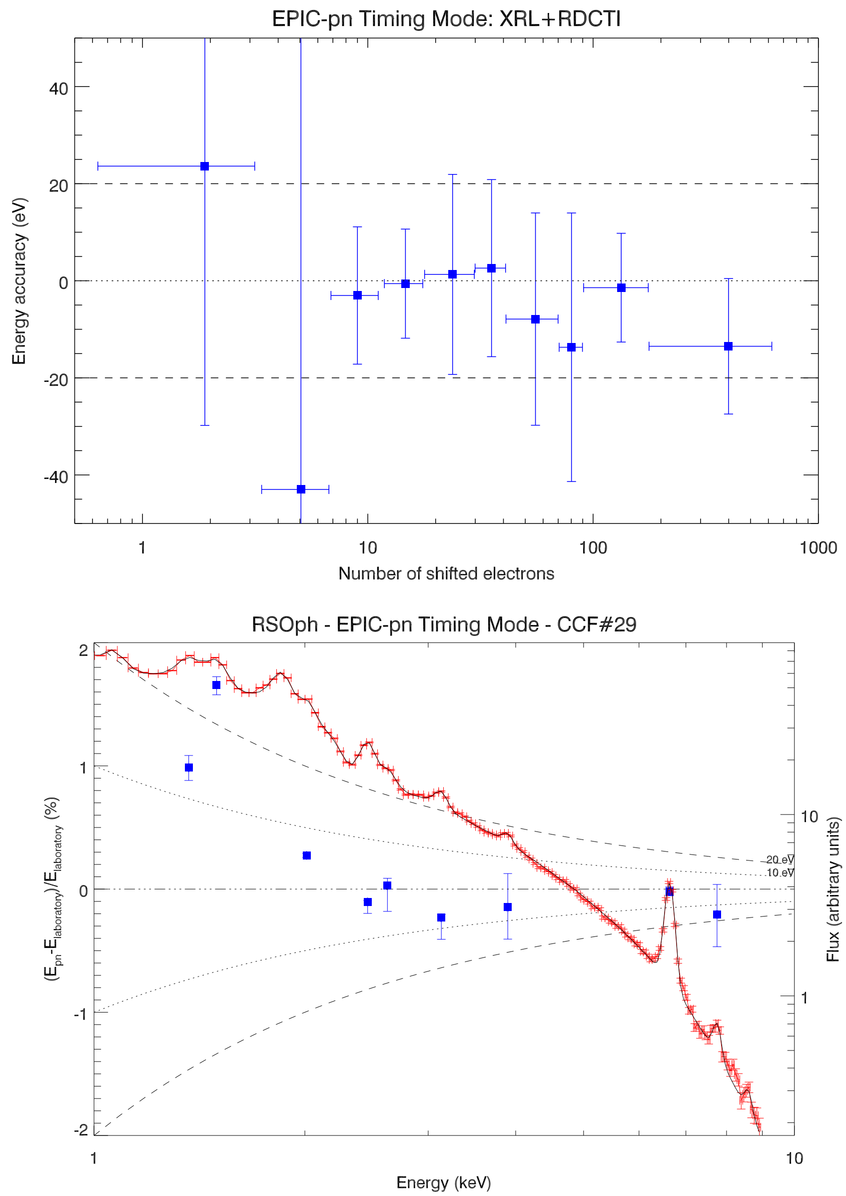

Figure 2: *Top panel*: accuracy of the energy scale at the Au edge ($\simeq$2.3 keV) as a function of N_e. *Bottom panel*: percentage difference between the centroid and the laboratory energy for a number of atomic transitions observed in the spectrum of the outbursting nova RSOph (Obs.#0410180101; *blue points*). The *red crosses* indicate the observed spectrum (scale on the *left y-axis*)

and 8 keV in the spectrum of the outbursting nova RSOph observed by XMM-Newton in February 2006 (Obs.#0410180101; cf. the bottom panel in Fig. 2). The difference between the energies measured by the EPIC-pn Timing Mode spectrum and the laboratory energies of the closest transition is within 10 eV from Si to Ni. A larger difference (≤25 eV) is measured for MgXI and MgXII. It is possible that uncertainties in the spectral deconvolution associated to the degraded resolution play a role. At lower energies Ne IX and NeX could constrain the energy scale. It is, however, difficult to constrain these features given the level of photoelectric absorption in this source ($N_H \simeq 8\times10^{21}$ cm^{-2}).

6 Expected updates

Guainazzi (2013) describes another algorithm to correct for the intrinsic rate-dependence of the energy scale: the Rate-Dependent PHA correction (RDPHA). It is intended to eventually replace the RDCTI, because it acts on the spectra in PHA, and it is independent on any astrophysical assumptions. Its calibration is, however, not mature enough yet. In the meantime, the RDCTI correction have been therefore updated, not to delay unnecessarily the public delivery of an energy scale correction consistent with the XRL correction. Studies are ongoing to make the RDPHA publicly available in a SAS version later than 13.0.2.

A study is ongoing to directly measure the energy-dependence of the RDCTI using a sample of X-ray binaries exhibiting absorption lines in the Fe band. This study may lead to a further enhancement of the RDCTI (or of the RDPHA) in a future SAS version.

7 References

Guainazzi M., 2013, XMM-SOC-CAL-SRN-0299
(available at: http://xmm2.esac.esa.int/docs/documents/CAL-SRN-0299-1-1.ps.gz)

Guainazzi M. & Smith M., 2013, XMM-SOC-CAL-SRN-0302
(available at: http://xmm2.esac.esa.int/docs/documents/CAL-SRN-0302-1-5.pdf)

Guainazzi M., et al., 2012, XMM-SOC-CAL-TN-0083
(available at: http://xmm2.esac.esa.int/docs/documents/CAL-TN-0083.pdf)

Guainazzi M. et al., 2009, XMM-CCF-REL-256
(available at: http://xmm2.esac.esa.int/docs/documents/CAL-SRN-0256-1-0.ps.gz)

Walton D., et al., 2012, MNRAS, 422, 2510