XMM-Newton CCF Release Note

XMM-CCF-REL-300

EPIC-pn Long-Term CTI

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1 CCF Components

Name of CCF	VALDATE	EVALDATE	Blocks Changed	CAL Version	XSCS Flag
EPN_CTI_0028.CCF	2000-01-01T00:00:00		LONG_TERM_CTI		NO

2 Changes

Over time, the EPIC-pn shows a steady increase in charge transfer inefficiency (CTI). Event energies are corrected for this through an empirical modelling of the non-long-term CTI corrected line centroid trends, obtained from exposures illuminated by the on-board calibration source (*CalClosed* exposures). Full details of the method may be found in [1]. This CCF contains the correction parameters which have been modified to reflect all available calibration data up to revolution 2421.

The correction method is illustrated in Fig. 1, which shows the Full Frame mode Mn-K_α line centroids as determined without any long-term CTI correction, and the best fit model from which the values of the long-term CTI correction parameters are derived. The data used are single pixel events without precursors, which are events for which the energy reconstruction is most accurate. Furthermore, in order to optimise the energy reconstruction for targeted sources the data selected for CCD 4 are restricted to an area around the boresight (RAWY in the range [181..200]). For the other CCDs, data from the complete chips are used, although areas with an excessive fraction of out-of-time events are excluded.

Similar modelling of Extended Full Frame mode line centroids allows the determination of long-term CTI correction parameters for this mode (see Fig. 2).

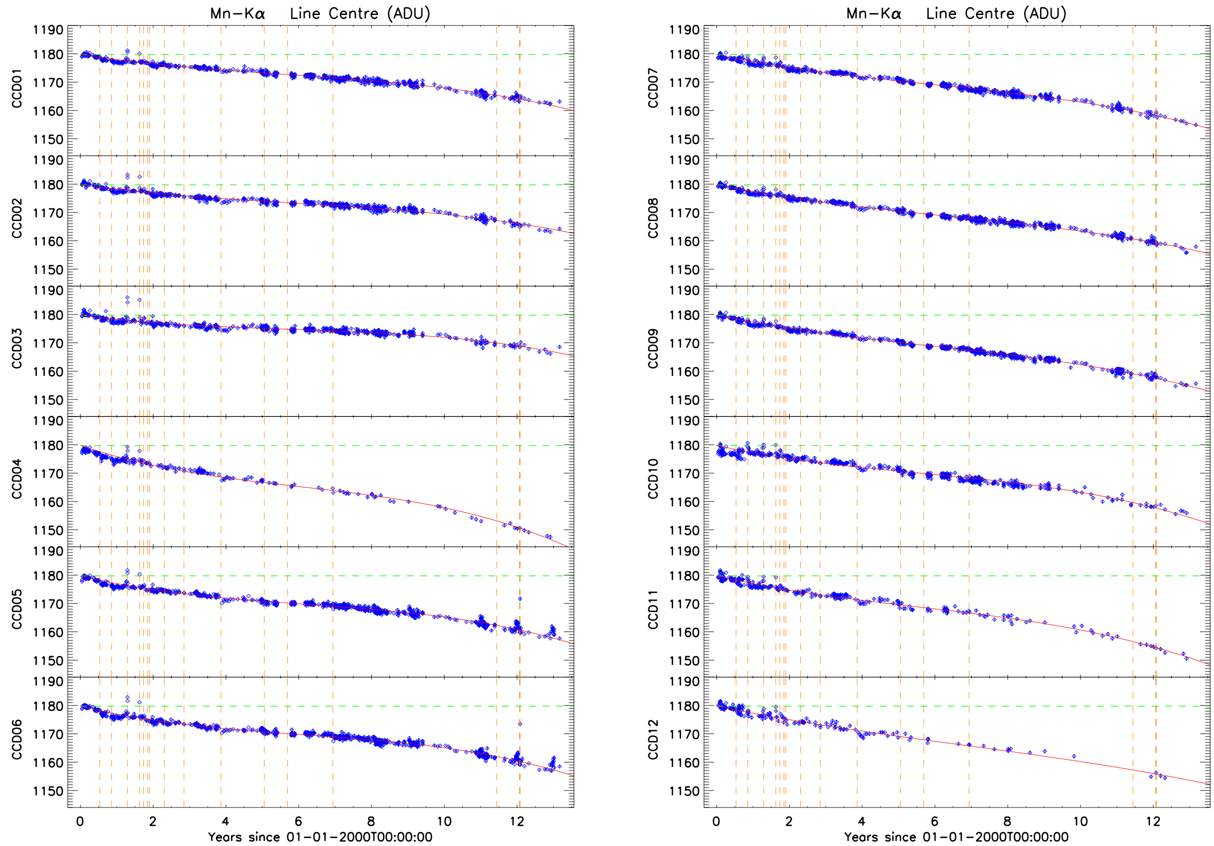

Figure 1: Mn-K$_\alpha$ line centroid energies (in ADU) as determined from Full Frame mode *CalClosed* observations, without applying any long-term CTI correction. The horizontal green dashed line shows the theoretical line energy, the vertical dashed lines indicate the times of major solar coronal mass ejections. The best fit empirical model is overlaid in red; this is used to derive the parameter values of the long-term CTI correction. The data shown here were extracted from the well illuminated areas of the complete CCDs, except for CCD 4, where the data were extracted from a 20-row region around the boresight.

Large Window, Small Window, Timing and Burst modes are not designed for full-frame illumination, thus complicating the interpretation of *CalClosed* data. As an approximation, for these modes the Full Frame mode parameter values are used.

3 Scientific Impact and Estimated Quality

The following plots show the reconstructed Mn-K$_\alpha$ line centroid energies from *CalClosed* data (first-single events) extracted from the complete CCD area, except for CCD 4 where the data are extracted from around the boresight. The results obtained with the new CCF, issue 0028, are compared with those of the previous version, issue 0027.

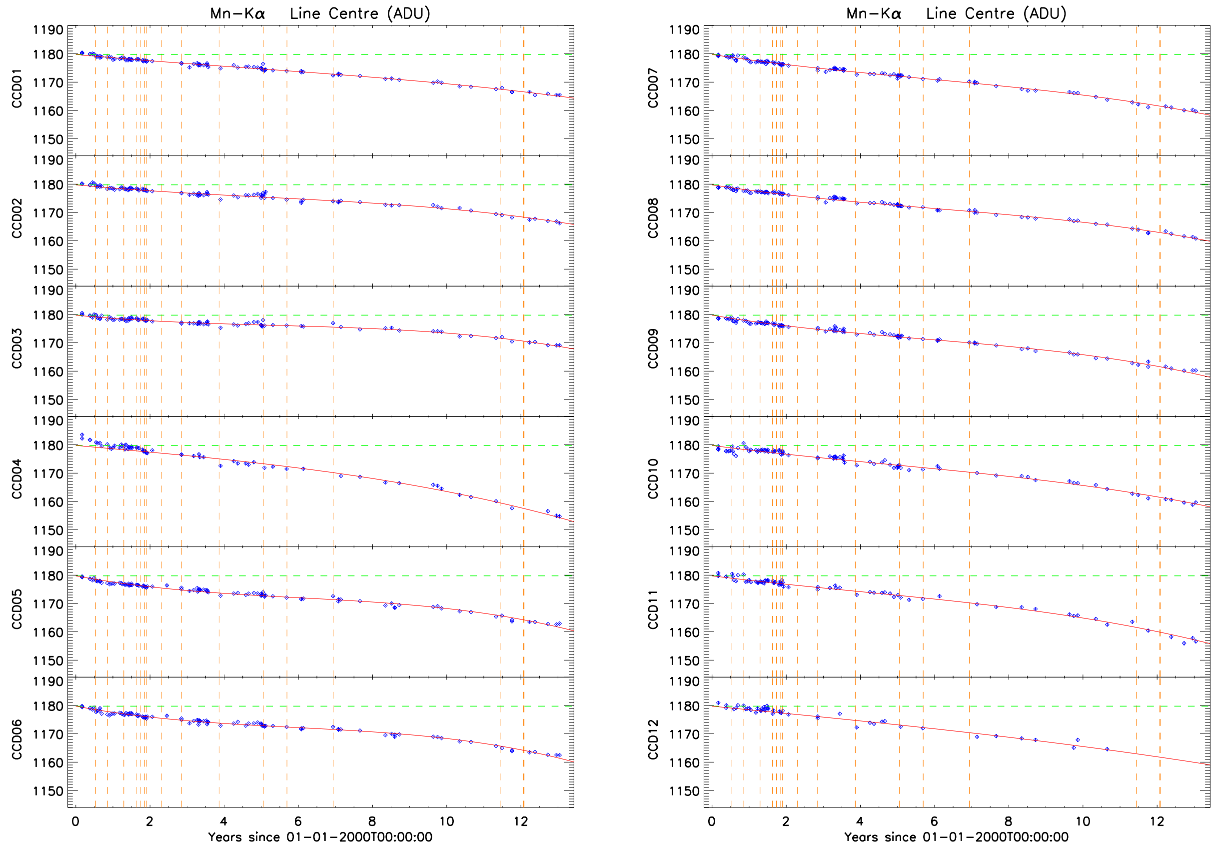

Figure 2: As Fig 1, for Extended Full Frame mode.

3.1 Full Frame mode, *CalClosed* data

The Full Frame mode results are shown Fig. 3 (CCDs 1 - 6) and Fig. 4 (CCDs 7 - 12); data for the old and new CCFs are shown in the left and right panels respectively.

For several CCDs, the reconstructed Mn-K_α line energies obtained with the previous CCF issue show systematic deviations from the theoretical energy from the beginning of 2012 onwards. The deviations range from approximately -4 ADU to $+4$ ADU (equivalent to -20 eV to $+20$ eV; the conversion is: 1 ADU = 5 eV), depending on the CCD. In particular, the line reconstruction at the boresight location shows an over-correction of up to 3 ADU.

Using the new CCF, the systematic deviations seen in recent observations have been reduced. Over the course of the mission, the Mn-K_α reconstructed line energies are in general within ± 2.5 ADU (± 12.5 eV) of the theoretical value. Larger deviations occur in distinct epochs up to approximately 2001, and in other exposures often associated with periods of increased solar activity.

For the boresight location the accuracy of the *CalClosed* energy reconstruction over the course of the mission is summarised in Table 1.

Event patterns	$\overline{E}_{measured} - E_{theoretical}$	
	Al-K$_\alpha$ ($E_{theoretical} = 1.486$ keV)	Mn-K$_{\alpha 2}$ ($E_{theoretical} = 5.888$ keV)
singles only	-7 <5> eV	-2 <6> eV
singles and *doubles*	-6 <5> eV	$+11$ <7> eV

Table 1: Summary of the energy reconstruction accuracy at the boresight location for Full Frame mode *CalClosed* exposures over the course of the mission. Values shown are the mean and standard deviation of the differences between measured line centroid and theoretical energy, and are derived from observations with exposure times ≥ 25 ks.

3.2 Extended Full Frame mode, *CalClosed* data

The results for Extended Full Frame mode are shown in Figs. 5 and 6. The new CCF yields an energy reconstruction stability within ± 2 ADU of the theoretical energy at Mn-K$_\alpha$. The standard deviation of the line centre distribution less than 1.0 ADU for all CCDs except those of quadrant 3 which show standard deviations of $1.1 - 1.3$ ADU.

3.3 Impact on measurements of the Fe-K$_\alpha$ line in astrophysical sources

The new CCF was tested on a number of recently observed Seyfert Galaxies which are known to exhibit narrow Fe-K$_\alpha$ fluorescent lines: Ark 120 (observation start date: February 18, 2013); ESO198-G1 (February 24, 2013) and Swift2127.4+5654 (November 4, 2012). In all cases, the application of the new CCF yields a shift of the best-fit centroid of the line towards lower energies by 14 ± 7 eV (ESO198-G1) to 21 ± 20 eV (Ark 120, Swift2127.4+5654), with the statistical error on the measurements at the 90% confidence level for one interesting parameter. This shift brings the line centroid closer to values expected in a scenario where the line is produced by fluorescence from neutral or mildly ionized Fe. In ESO198-G1 the simultaneous EPIC-MOS observation allows a comparison of line centroid energy with that measured by EPIC-pn: $E_{pn} - E_{MOS} = 21 \pm 10$ eV.

4 The "2.3 keV" feature in EPIC-pn spectra

EPIC-pn spectra of bright objects occasionally exhibit a bright emission-like feature at $\simeq$2.3 keV, corresponding to the energy region where the Au-edge creates a particularly steep gradient in the effective area. Formally, this feature can be attributed to a systematic excess in the energy scale by $20 - 30$ eV. However, applying the new CCF to spectra of recently observed bright AGN does not yield any significant improvement in the quality of the fits in this band (see Fig. 8). Work is ongoing to understand and calibrate this feature.

5 Expected Updates

The EPIC-pn CTI will continue to develop in time. Model parameters will likely have to be adjusted to new calibration data as sufficient observations become available.

6 Test Procedures and Results

Verification of functionality of EPN_CTI_0028.CCF with SAS 12: `calview`, `cifbuild`, `epproc`.

7 Acknowledgements

We thank G. Matt for kindly allowing the use of proprietary data of observations mentioned in Sections 3.3 and 4.

8 References

[1] Smith, M.J.S., et al., 2010, XMM-SOC-CAL-SRN-0271
(`http://xmm2.esac.esa.int/docs/documents/CAL-SRN-0271-1-0.ps.gz`)

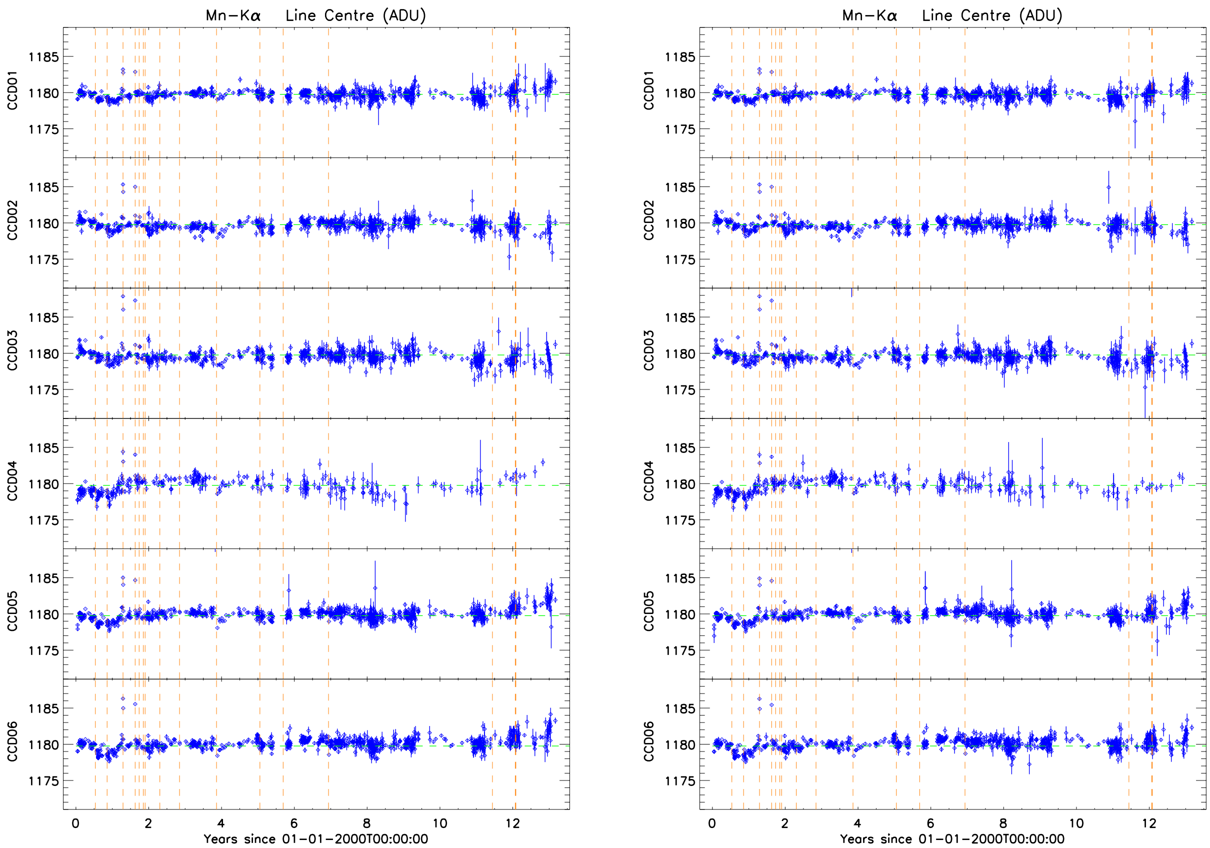

Figure 3: Full Frame mode Mn-K_α line centroid energy reconstruction for CCDs 1 - 6. Results of the old and new CCFs are shown in the left and right panels respectively. The data were extracted from the well illuminated parts of the complete CCDs, except for CCD 4, where the data are obtained from around the boresight only. The green dashed line shows the theoretical energy. Vertical dashed lines indicate the times of major solar coronal mass ejections.

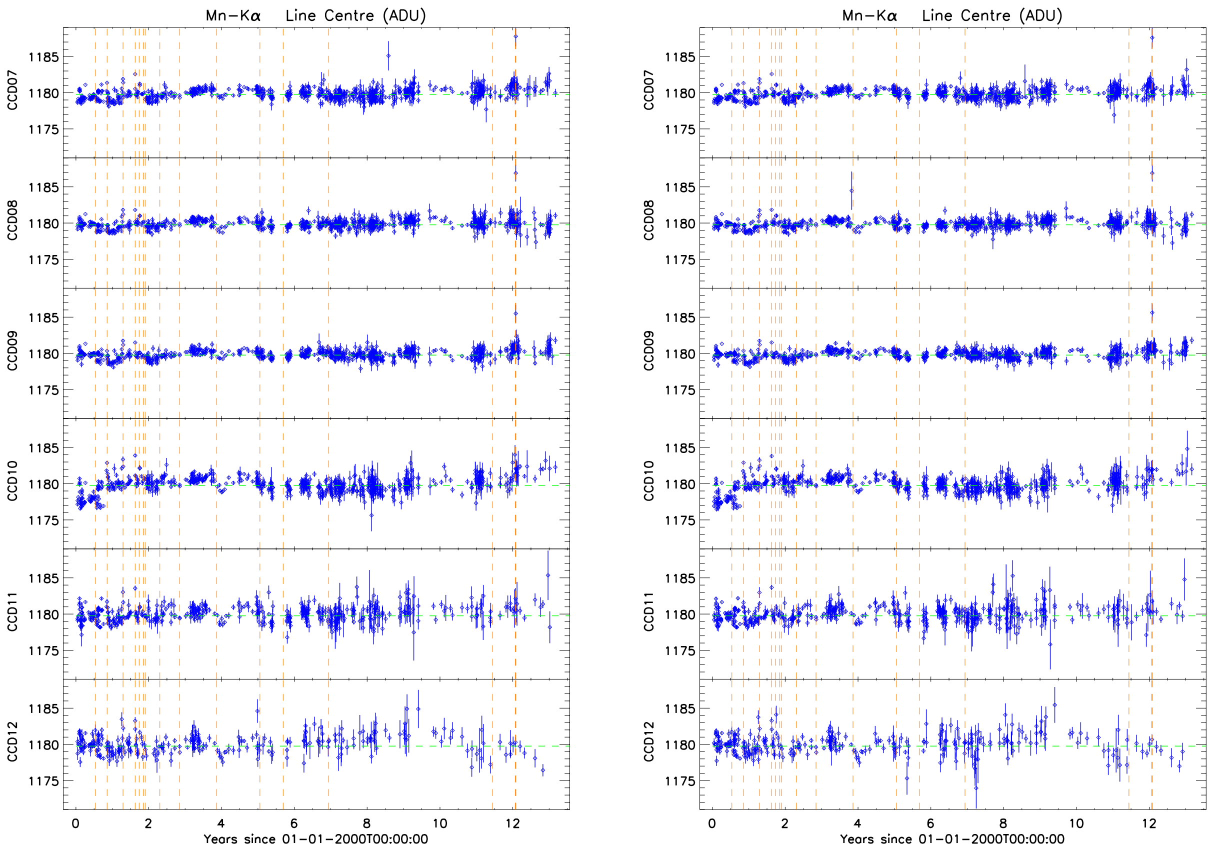

Figure 4: As Fig. 3, for CCDs 7 - 12. Results obtained with the old CCF are shown in the left panel, and with the new CCF in the right panel.

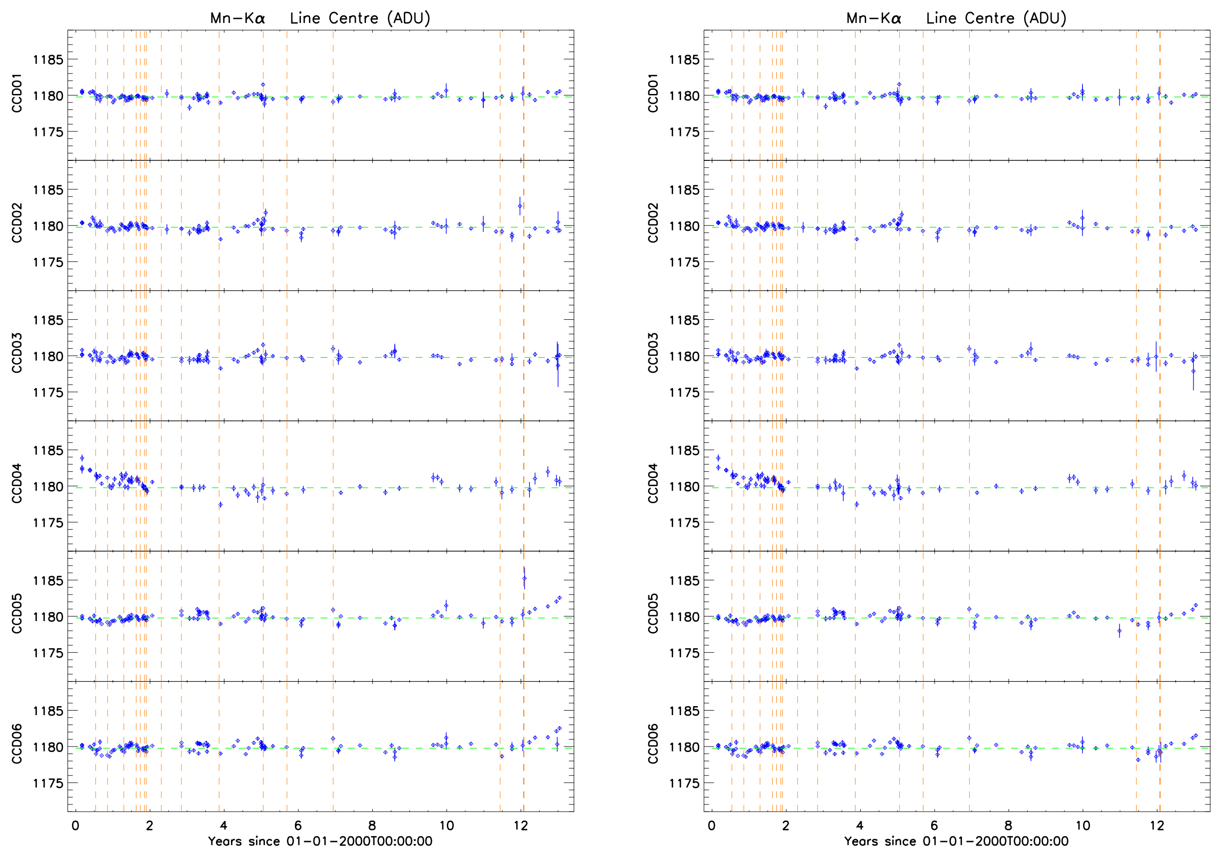

Figure 5: As Fig. 3, for Extended Full Frame mode.

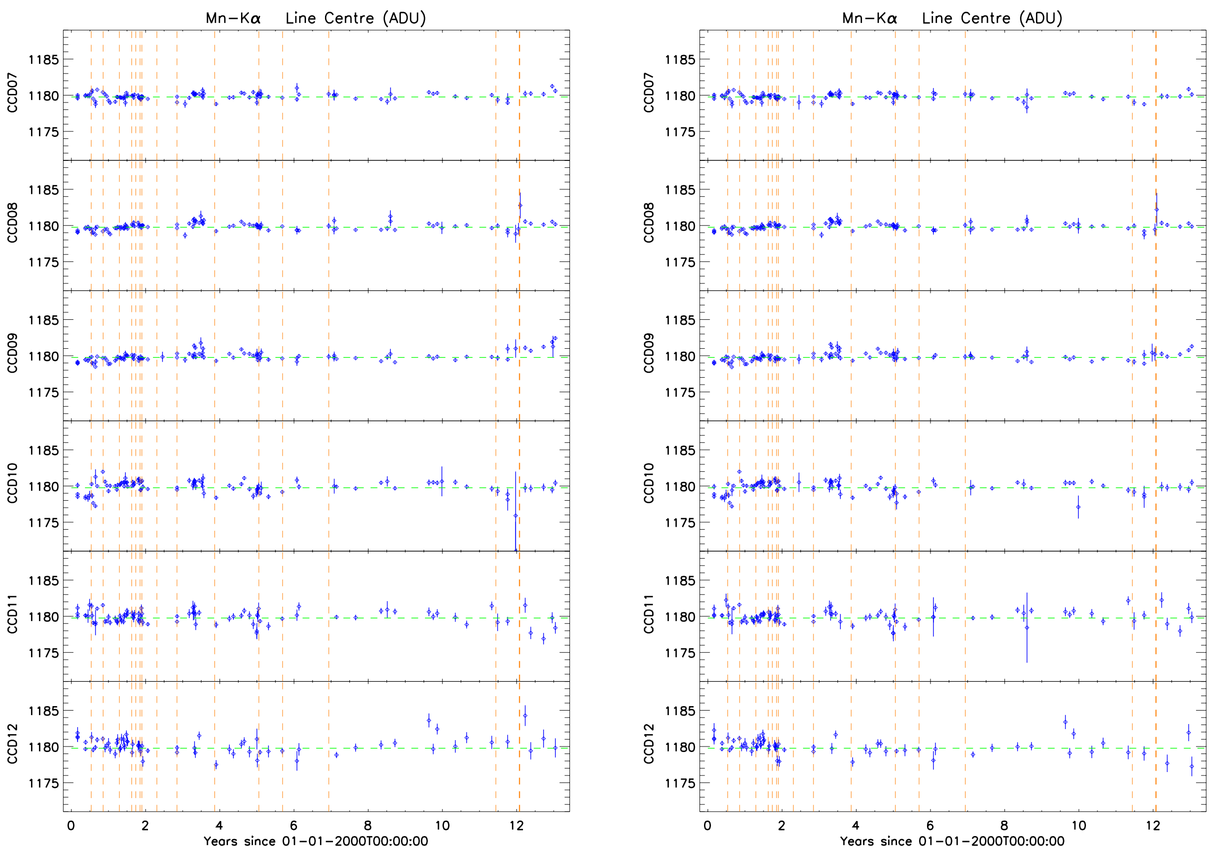

Figure 6: As Fig. 4, for Extended Full Frame mode.

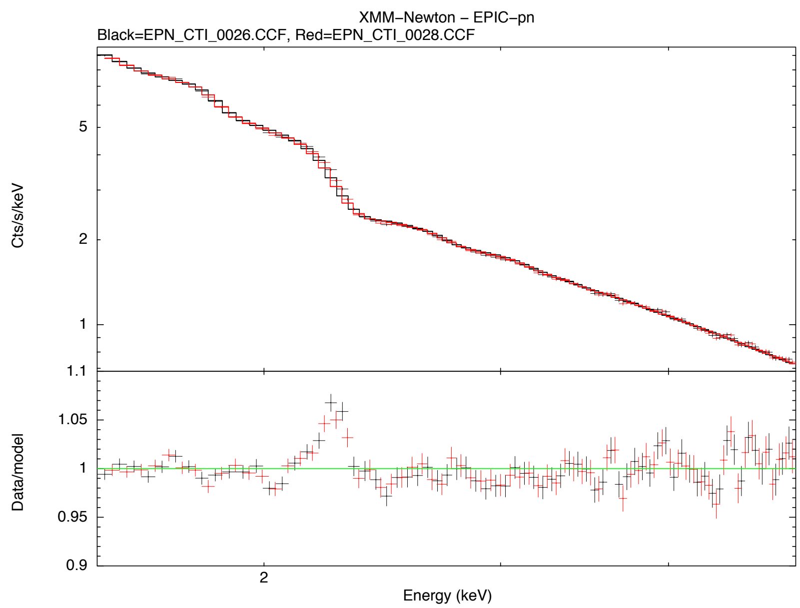

Figure 7: Spectra (*upper panel*) and residuals (*lower panel*) against a photoelectrically absorbed power-law model in the 1.5 − 5 keV energy band when the public issue 0027 (*black*) and the new issue 0028 (*red*) CCFs are used. Data are of a bright Seyfert Galaxy observed in January 2013.