XMM-Newton CCF Release Note

XMM-CCF-REL-269

CCF implementation of RGS-pn rectification

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1 CCF components

Name of CCF	VALDATE	List of Blocks changed	XSCS flag
RGS1_EFFAREACORR_0008	2001-01-01T00:00:00	RECTIFICATION	NO
RGS2_EFFAREACORR_0008	2001-01-01T00:00:00	RECTIFICATION	NO

2 Changes

The first half of 2010 saw the release of two important new independent calibration items:

- a new RGS effective area model [1];
- a revision of the EPIC-pn redistribution [2].

Once these were in place, a systematic comparison of RGS and EPIC-pn models was made [3], to which the reader is referred for details of the procedures followed. In particular, a set of wavelength-dependent rectification factors was applied to the RGS model in simultaneous XSPEC fits of a few dozen spectra in the XCal archive in order to reconcile the instruments. The best-fit values of the rectification factors show the discrepancies between the independent calibrations of EPIC-pn and RGS. Although these factors are applied to the RGS, they are in reality determined by a combination of effects from the calibration of each instrument coupled with details of the modelling, including accuracy of the physical models used and the statistical methods employed. XSPEC was run following the standard XCal use of the Chi-Squared statistic with standard weights calculated from observed counts. The results summarised in Figure 12 of [3] are reproduced here in Figure 1. No evidence was found of any time dependence.

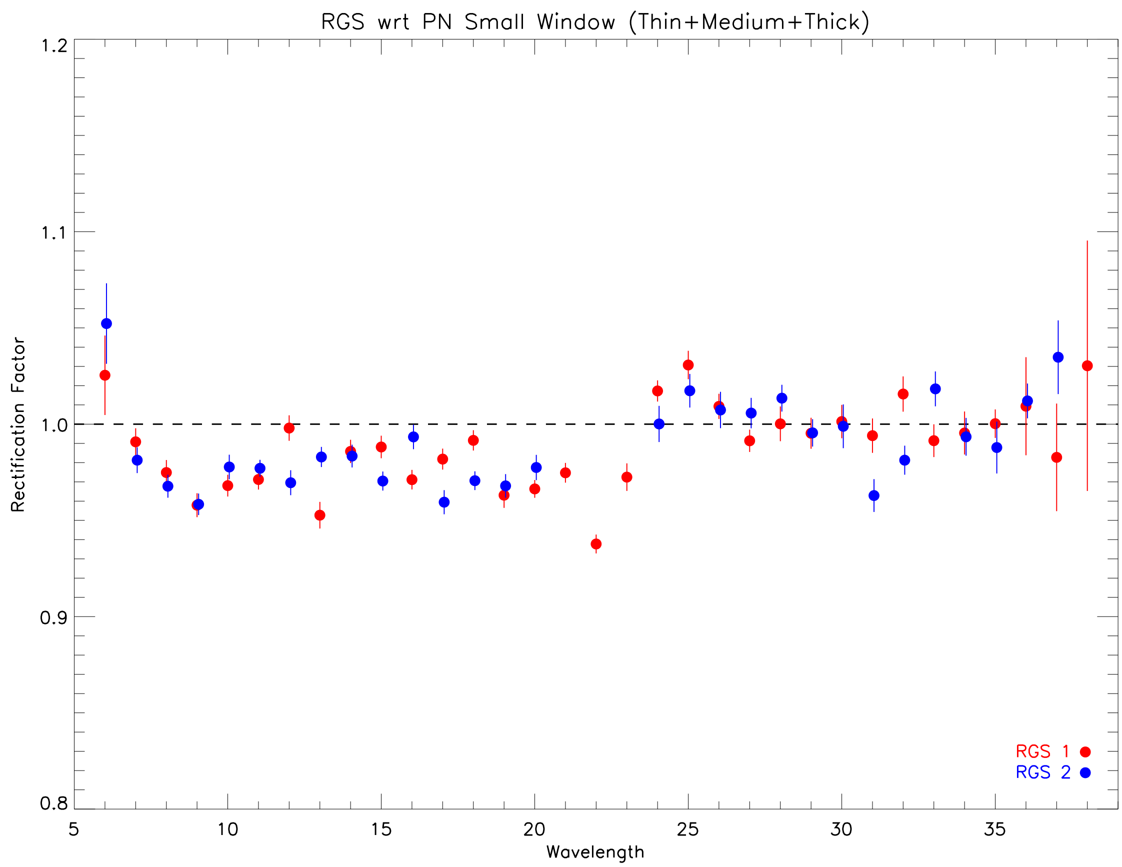

Figure 1: Average RGS1-pn and RGS2-pn rectification factors in 1Å intervals for XCal models of a standard sample of AGN including 3C273, PKS2155-304, H1426+428 and other sources. This is Figure 12 from [3] and suggests that a smooth approximation could be provided by a step function at the oxygen edge, separately for RGS1 and RGS2.

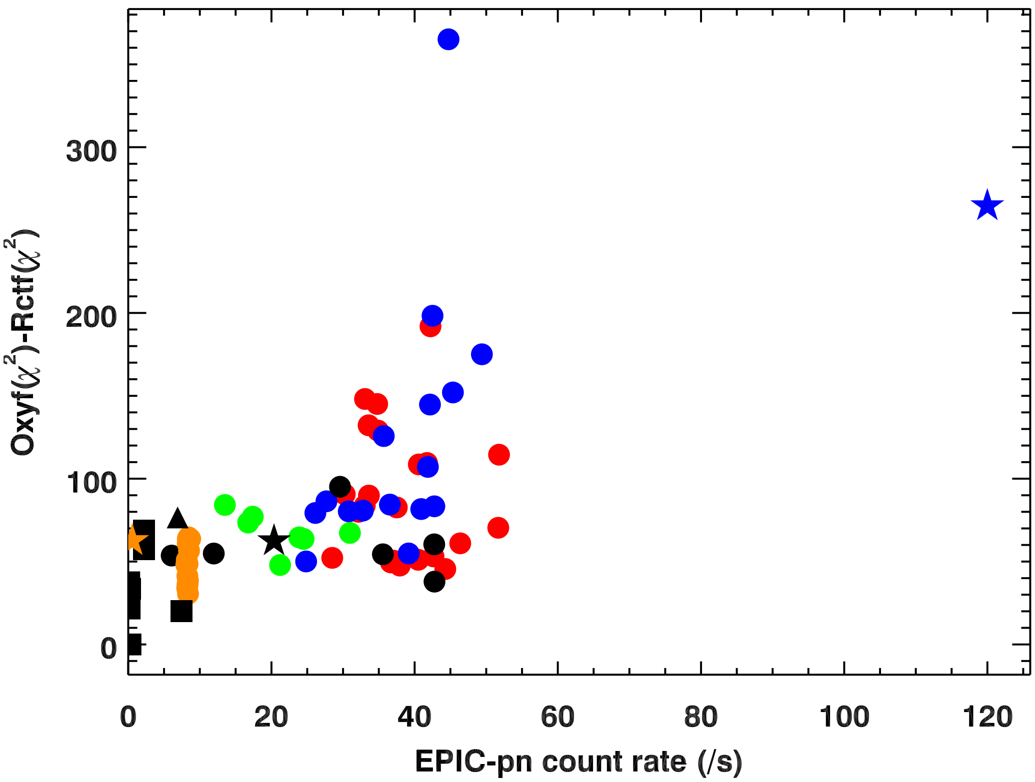

Figure 2: Difference in χ^2 for the XCal source sample of AGN and RXJ1856.6-3754 between a detailed Rctf rectification model with independent factors at 1Å intervals and a step-function Oxyf approximation with about 50 fewer degrees of freedom. The small difference justifies use of the rectification model. Colours represent different sources, including the neutron star RXJ1856.6-3754 in orange, for example. Symbols represent EPIC-pn modes, the majority small-window mode by circles and timing mode by stars.

The task here is how best to make these results available to observers through the CCF, taking into account the recommendations of the 2010 XMM Users Group. The form of the individual wavelength-dependent rectification factors in Fig.1 suggests that a simple step function at the oxygen edge would be a good smooth approximation and this proves to be justified on statistical grounds: Fig. 2 shows the difference in χ^2 between the rectified and "oxyfied" models: the individual 1Å factors of the rectified models are constrained in the oxyfied models to a single value between 7.5 and 23.5 Å on one side of the oxygen edge and a single value between 23.5 and 37.5 Å on the other. The reduction of χ^2 between the original XCal models and the rectified models are changed by between about 50 and 200 for 50 fewer degrees of freedom.

Restricting analysis to the majority EPIC-pn small window mode, simplified step-function rectification factors were calculated for the 51 observations of AGN shown in Fig. 3. The median values used to construct the CCF `RECTIFICATION` tables were as follows :

	$7.5 < \lambda(\text{Å}) \leq 23.5$	$23.5 < \lambda(\text{Å}) \leq 37.5$
RGS1	0.9716	1.0021
RGS2	0.9753	1.0028

Table 1: Simplified rectification factors for RGS1 and RGS2 calculated from 51 XCal EPIC-pn small-window observations of AGN with smooth continuum spectra.

The close similarity of the factors independently estimated for RGS1 and RGS2, both in comparison with the same EPIC-pn instrument, gives confidence in both the calibration of each RGS spectrometer and the robustness of the rectification procedure.

An alternative smoothing scheme was considered in which the discontinuous step at the oxygen edge was replaced by a smooth exponential step, initially of width 1Å. For a sample of 48 spectra of brighter XCal AGN, this model delivered higher χ^2 values in every case, increasing between +8.7 and +588.3. The high resolution of the RGS is evidently able to distinguish between these smoothing schemes. In a few examples in which the exponential width and position were treated as free parameters, the width tended to zero and the position of the step remained consistent with the oxygen edge. A more rigorous simultaneous analysis of the whole sample in order to constrain properly these parameters was not possible due to XSPEC limitations of the number of simultaneous high-resolution matrices. The comparison with previous calibration reported in section 6 and particularly Fig. 16 of the detailed rectification report [3] suggests the reality of a sharp jump at the oxygen edge.

During testing of the v7 CCFs, attention was drawn to the shortest wavelength bin of Fig. 1 which, although relatively uncertain, appears to deviate from the otherwise constant value on this side of the oxygen edge. In order to reproduce this, a modification was introduced into the XSPEC rectification model of a taper between 7 and 6 Å, linear in energy, between the short wavelength values of Table 1 and the rectification value, F6, at 6 Å. In a sample of 54 AGN spectra, the addition of this extra free parameter reduced the median χ^2 fit statistic of simultaneous EPIC-pn and RGS models from 4470.79 by a median of 2.7. The weighted mean values of F6 shown in Table 2 were used to generate the linear energy taper in v8 CCFs, which are those proposed for release.

RGS1	1.052
RGS2	1.065

Table 2: Rectification factors, F6, at 6 Å for RGS1 and RGS2 calculated from observations of AGN with smooth continuum spectra for linear interpolation in energy between 6 and 7 Å.

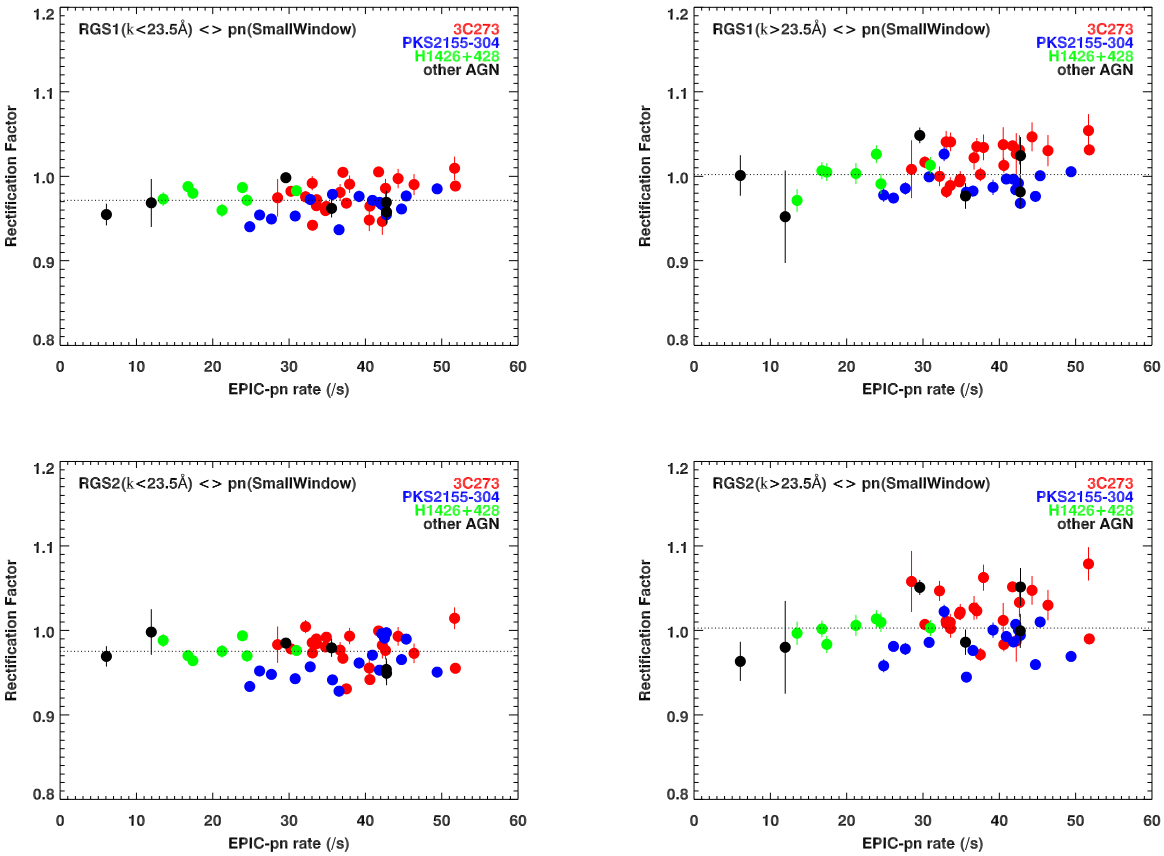

Figure 3: Parameters of the simplified step-function rectification model for RGS1 and RGS2 for an XCal sample of 51 observations of AGN in EPIC-pn small-window mode. For each observation, best-fit values are calculated independently for RGS1 and RGS2 rectification factors either side of the oxygen edge. The median values shown by the horizontal dotted lines were used to fill the CCF RECTIFICATION tables.

3 Scientific Impact of this Update

The main purpose of offering the rectification procedure is to allow models of improved consistency to be constructed of models of simultaneous RGS and EPIC-pn data.

4 Estimated Scientific Quality

This CCF, when activated by the `rgsproc` switch `withrectification=yes`, causes the empirical `RECTIFICATION` correction factors, to be applied to RGS effective area to bring simultaneous models of RGS and EPIC-pn spectra into agreement by reducing apparent systematic errors to the level of better than about 1%.

5 Test procedures & results

For comparison with the default unrectified RGS RMFs from SAS v10, a set of rectified RGS RMFs was calculated for the XCal AGN sample with the new RGS EFFARACORR v7 CCFs and the SAS v10 switch `withrectification=yes`. The XCal versions were as follows:

RGS*_EFFAREACORR_0006 `xmmsas_20100423_1801-10.0.0_release`

RGS*_EFFAREACORR_0007 `xmmsas_20100423_1801-10.0.0_RGSrectify`

As the v8 CCFs differ from the v7 CCFs by a few percent only below 7 Å, the judgement was made that the tests did not need to be repeated.

Table 3 shows the results of comparative spectral analysis of the same XCal archive data of an example observation of PKS2155-304 before and after rectification. As the implemented CCF average rectification factors from Table 1 will in general not be equal to the optimum values for a particular combination of observation and model, best-fit rectification factors are also shown. In this example, CCF rectification improved the apparent quality of the fit by $\Delta\chi^2 = -82.7$, accompanied by small revisions to the best-fit model. The optimum rectification factors for this observation, which give a fit statistic reduced by a further $\Delta\chi^2 = -33.7$, differ from the mean CCF values by 1 or 2% with very little further change in the model.

`XSPEC> model Tbabs*bknpower`			
$N_H(cm^{-2}) = 1.24 \times 10^{20}$	XCal	CCF	`rgsrectify`
α_1	2.6579 ±0.0019	2.6509 ±0.0019	2.6539 ±0.0020
E_{break}(keV)	1.305 ±0.052	1.244 ±0.034	1.264 ±0.035
α_2	2.7886 ±0.0060	2.7905 ±0.0056	2.7907 ±0.0067
normalisation	0.032796±0.000047	0.033036±0.000049	0.032984±0.000058
RGS1 $F_{6-23.5}$		0.9716	0.9652 ±0.0034
RGS1 $F_{23.5-38}$		1.0021	0.9919 ±0.0039
RGS2 $F_{6-23.5}$		0.9753	0.9911 ±0.0035
RGS2 $F_{23.5-38}$		1.0028	0.9990 ±0.0038
χ^2	7603.7	7521.0	7487.4
NPHA	6335	6335	6336
NDOF	6331	6331	6328

Table 3: Best-fit XSPEC parameter values for the XCal model of PKS2155-304 in 0174_0080940101 for a simultaneous analysis of EPIC-pn, RGS1 and RGS2 shown with 1σ errors calculated with the `XSPEC> error` command. No EPIC-MOS data were used. The statistical methods and the absorbed broken-powerlaw model were adopted from the XCal archive. The best-fit parameters in the XCal column are those with no rectification; those labelled CCF used RGS RMFs rectified with the new CCFs and the SAS v10 `rgsproc` switch `withrectification=yes`; and those labelled `rgsrectify` used an XSPEC user model to optimise the RGS rectification factors in this observation, F, with the best-fit values reported.

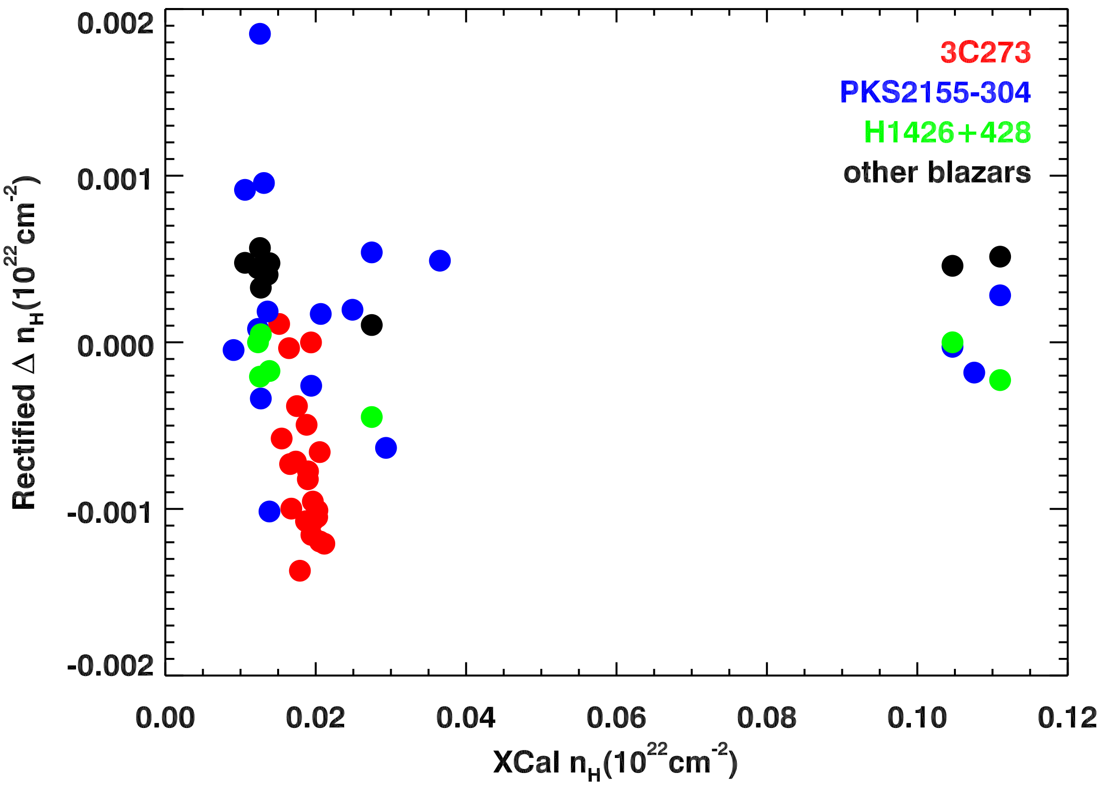

Figure 4: Differences between best-fit values of the galactic column density, n_H, treated as a free parameter, between RGS RMFs with and without rectification in simultaneous EPIC-pn and RGS models of AGN spectra.

In order to assess how much rectification with a jump of 3% at the oxygen edge affects absorption estimates, the column densities of the AGN sample were treated as free parameters and the values compared in simultaneous EPIC-pn and RGS models using default and rectified RGS RMFs. The results are shown in Fig. 4. The changes are model-dependent but small, at a level of less than about 10^{19}cm^{-2} or a few percent.

6 Expected Updates

A small issue remains to be resolved concerning details of the SAS interpolation scheme, only detected through a point-by-point comparison of the RGS effective area with and without rectification. More generally, updates are expected to follow, for example, new releases of the effective area of any of the XMM-Newton X-ray instruments; availability of a larger XCal cross-calibration sample; or improvements in spectral models.

References

[1] The RGS effective area incorporating exponential contamination and a mechanism for rectification, XMM-CCF-REL-262
`http://xmm.esac.esa.int/docs/documents/CAL-SRN-0262.ps.gz`

[2] Refinement of pn redistribution, XMM-CCF-REL-266
`http://xmm.esac.esa.int/docs/documents/CAL-SRN-0266-1-0.ps.gz`

[3] An investigation into RGS-pn rectification, XMM-SOC-CAL-TN-89
`http://xmm.esac.esa.int/docs/documents/CAL-TN-0089-1-0`