SWIFT-XRT-CALDB-09

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SWIFT XRT CALDB RELEASE NOTE SWIFT-XRT-CALDB-09: Response matrices and Ancillary Response Files

Table 1: Files to be released:

Filename	Mode	Grade	Substrate* voltage (V)	Start time°	End time°	Release Date
swxpc0to12s0_20070301v011.rmf †	PC	0-12	0	01-Mar-2007	31-Aug-2007	03-Dec-2009
swxpc0to12s0_20070901v011.rmf †			0	01-Sep-2007		
swxpc0to12s6_20070301v011.rmf ‡			6	01-Mar-2007	31-Aug-2007	
swxpc0to12s6_20070901v011.rmf			6	01-Sep-2007		
swxpc0s0_20070301v011.rmf †	PC	0	0	01-Mar-2007	31-Aug-2007	03-Dec-2009
swxpc0s0_20070901v011.rmf †			0	01-Sep-2007		
swxpc0s6_20070301v011.rmf ‡			6	01-Mar-2007	31-Aug-2007	
swxpc0s6_20070901v011.rmf			6	01-Sep-2007		

*The substrate voltage was permanently raised from $V_{ss} = 0\,\mathrm{V}$ to $V_{ss} = 6\,\mathrm{V}$ on 2007 August 30 (see Section 4).

° Start and end validity time when the RMFs should be used.

† At present, the $V_{ss} = 0\,\mathrm{V}$ RMFs are identical to the $V_{ss} = 6\,\mathrm{V}$ RMFs.

‡ The epoch 20070301 RMFs are identical to the epoch 20070901 RMFs but are required to ensure a similar file-naming scheme to the previously released WT broadened RMFs.

1 Scope of Document

This note describes the release of the *Swift*-XRT Photon Counting epoch-dependent redistribution matrix (RMF v011) (see Table 1) which complement the Windowed Timing epoch-dependent RMFs released back in April (see SWIFT-XRT-CALDB-09_v12).

The XRT effective area is made by three main components: the mirror effective area, the CCD quantum efficiency (QE) and the filter transmission. The QE is included directly in the redistribution matrix files (RMFs). The auxillary response files (ARFs) contain the mirror effective area, the filter transmission, as well as the vignetting correction and the Point Spread Function (PSF) correction (which depends on the source location and of the size of the extraction region, as well as on defects on the CCD). Here we report on the CALDB RMF and ARF files which represent the effective area of the telescope for a nominal on-axis observation (no vignetting correction) and for an infinite region of interest (no correction for PSF losses). RMF files do not include the PSF correction and do not depend on the source position on the detector. The CCD soft energy response is sufficiently uniform within the central 200x200 pixels (see e.g. previous RMF release notes), therefore there is just one RMF file per mode and grade selection and per epoch. The ARF files, instead, need vignetting and PSF corrections and, therefore, need to be built for each observation. To produce the observation-specific ARF files, the XRTMKARF task (XRTDAS-HEADAS software) has been developed. This task corrects the nominal ARF file for the vignetting and, optionally (psfflag=yes), for PSF losses. This task includes corrections for CCD defects with the inclusion of an exposure map automatically generated by the data analysis pipeline (expofile=filename.img). The adopted calibration method implies that we include the residual correction of the CCD quantum efficiency in the CALDB ARF files, accounting for why the nominal ARF files are different for different grade selection.

Motivations of this release:

Radiation and high-energy proton damage on the CCD (the imaging area, the store frame area and the serial register) over time result in the build-up of charge traps (i.e. faults in the Si crystalline structure of the CCD). The deepest faults are responsible for the line FWHM degradation, the line shape then showing a more pronounced low energy wing (see Section 2). The most serious of these charge traps can cause a loss of up to 350 eV from the incident X-ray energy.

In this release, the PC RMFs are newly computed files including an epoch-dependent broadened kernel handling the evolution of the line broadening over time (see below), while the WT RMFs and the WT & PC ARFs are the same as those issued in the previous releases SWIFT-XRT-CALDB-09_v12 and SWIFT-XRT-CALDB-09_v11, respectively.

File naming scheme:

On 2007 August 30 (at 14:28UT), the CCD substrate voltage was raised from $V_{ss} = 0\,\text{V}$ to $V_{ss} = 6\,\text{V}$. The change was made in order to reduce the thermally induced dark current in the CCD, which allows the XRT to collect useful science data at slightly higher temperatures (3 to 4 C) than was possible before the change. The change in substrate voltage has made it necessary to release two sets of RMF/ARF files, now distinguished by the characters 's0' and 's6' in their file names. At the moment the $V_{ss} = 6\,\text{V}$ files are placeholders and identical to the 0V files (see the previous release SWIFT-XRT-CALDB-09_v11 and see Table 1).

To model the evolution of the XRT spectral response over time, we release three sets of PC RMFs (for both grade 0 and grades 0-12). The first set of PC RMFs are unbroadened RMFs, and they are the same as those issued in the previous releases SWIFT-XRT-CALDB-09_v11 & SWIFT-XRT-CALDB-09_v12. They should be used for data collected from launch to 2007 February 28 (**swxpc0to12s0_20010101v011.rmf** and **swxpc0s0_20010101v011.rmf**). The second and third sets of PC RMFs including an epoch-dependent broadened kernel should be used for data collected from 2007 March 1 to 2007 August 31 (**swxpc0to12s0_20070301v011.rmf** & **swxpc0s0_20070301v011.rmf**) and from 2007 September 01 onwards (**swxpc0to12s6_20070901v011.rmf** & **swxpc0s6_20070901v011.rmf**) (see Table 1). A similar nomenclature was used for the WT RMFs (see SWIFT-XRT-CALDB-09_v12).

2 RMF generation

The Response Matrix Files (RMFs) are created by a Monte-Carlo simulation code (Godet et al. 2009, A&A, 494, 775, Godet et al. 2007, SPIE, 6686, 6686OA1). This code models: transmission of the incident X-rays through the CCD electrode structure; photo-absorption in the active layers of the device; charge cloud generation, transportation and spreading; silicon fluorescence and its associated escape peak; surface loss effects; mapping of the resultant charge-cloud to the detector pixel array; charge transfer efficiency; addition of electronic read-out noise; event thresholding and classification according to the specific mode of operation.

Past improvements: In the release SWIFT-XRT-CALDB-09, in orbit observations of the soft calibration sources were used to refine the surface loss function in order to better match the spectral redistribution at low energies. While for heavily absorbed sources, the parameterisation of the redistribution of high energy X-rays down to low energies was improved for both PC and WT modes (using SNR G21.5, SGR 1900+14 & NGC 7172 for PC, and

GROJ1655-40, 4U1608-52, XTE J1701-462 & GX17+2 for WT) by including a correction to the loss-shelf (see the release note SWIFT-XRT-CALDB-09_v2). For PC mode, a new charge-cloud spreading model was implemented following the theory of Pavlov & Nousek (1999 NIMA 428 348), which better accounts for sub-threshold losses seen in the more energetic multi-pixel events (see the release SWIFT-XRT-CALDB-09_v2). In the release SWIFT-XRT-CALDB-09_v11, a slight change in the loss function parameters between 1 keV and 2 keV in WT mode was implemented to suppress the 10% residuals around 0.9-1 keV only visible in high statistical spectra. A new set of PC and WT ARFs were also released along with the release of the WT gain file SWXWTGAINS0_20010101v008.FITS. For both modes, updated Charge Transfer Inefficiency (CTI) values were used, which are more appropriate for the CTI degradation suffered in orbit during the middle of 2006. In the release SWIFT-XRT-CALDB-09_v12, we released two sets of WT RMFs with an epoch-dependent broadened kernel handling the evolution of the line broadening over time.

Improvements specific to this release:

We computed PC RMFs including an epoch-dependent broadened kernel enabling us to handle the line broadening seen over time (see the release note SWIFT-XRT-CALDB-09_v12 for an explanation).

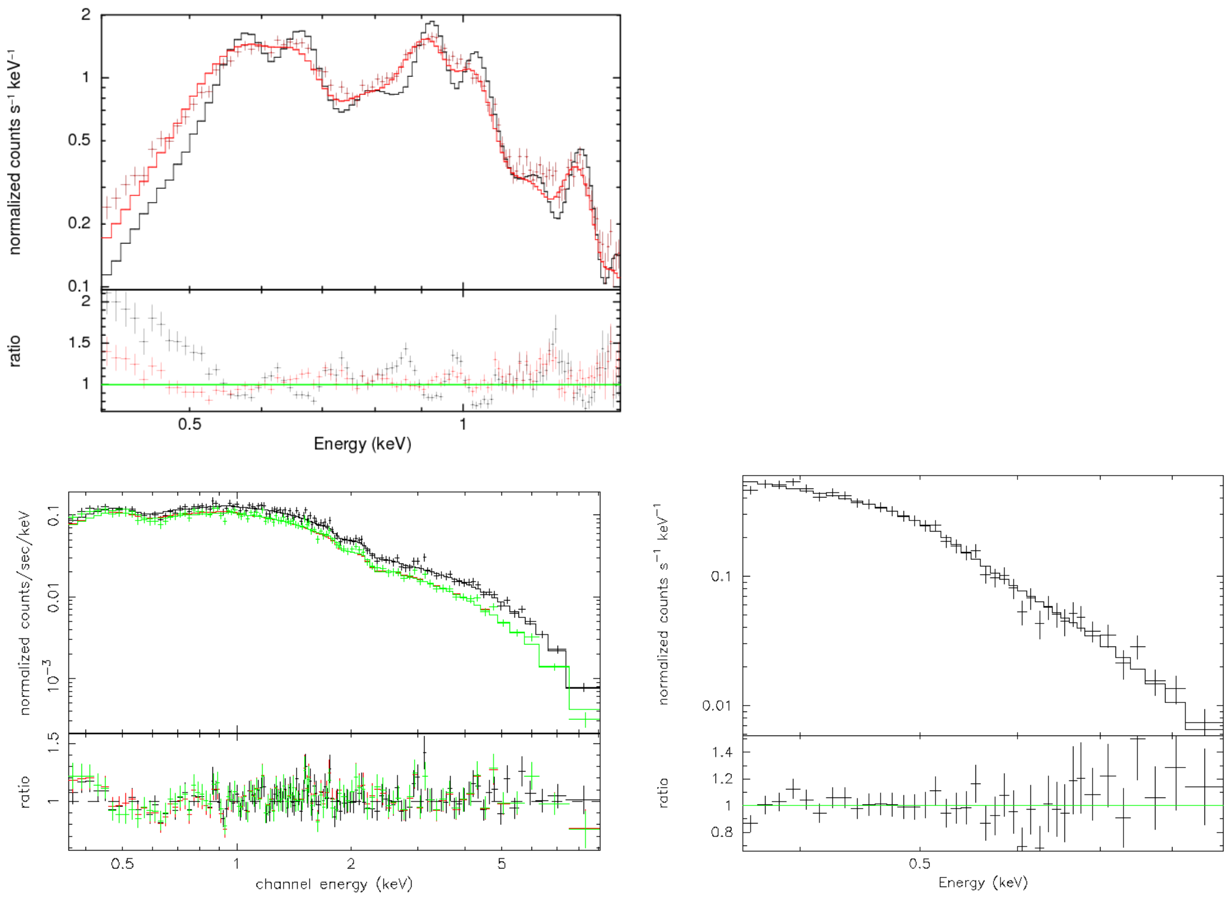

Figure 1: Spectral performance of the broadened kernel PC RMFs. Top panel - SNR E0102-72.3 from September 2007 data (red: grade 0-12 RMF **swxpc0to12s6_20070901v011.rmf**; black: grade 0-12 unbroadened RMF **swxpc0to12s6_20010101v011.rmf**). The spectral model is based on an XMM/RGS-PN model (see Plucinsky et al. 2008, Proc. SPIE, arXiv0807:2176). The spectra were extracted using data when the source was not located on the bad columns. Bottom left panel - 3C279 from December 2008 data fitted using the new broadened kernel PC grade 0-12 RMF **swxpc0to12s6_20070901v011.rmf** (black) and the new broadened kernel PC grade 0 RMF **swxpc0s6_20070901v011.rmf** (red). The fit of the PC grade 0 spectrum using the unbroadened v011 PC g0 RMF **swxpc0s6_20010101v011.rmf** is shown in green. Bottom right panel - RXJ 1856.4-3754 from July 2008 g0 data using the new broadened PC RMFs (**swxpc0s6_20070901v011.rmf**). The spectrum is fitted using the model described in Beuermann et al. (2006, A&A, 458, 541). The normalisation relative to that given in the Beuermann et al. model is $C = 1.02 \pm 0.03$; which is close to that derived using 2005-2006 data of RX J1856.4-3754 ($C = 0.96 \pm 0.03$).

To produce these new PC RMFs, we used a method similar to that described in SWIFT-XRT-CALDB-09_v12 *i.e.* we convolved each of the 2400 monochromatic line input spectra of the unbroadened v011 PC RMFs **swxpc0s0_20010101v011.rmf** and **swxpc0to12s0_20010101v011.rmf** (see Godet et al., 2009, A&A, 494, 775) with a function f. The profile of the function f should depend on several parameters related to the physical behaviour of charge traps on the CCD such as i) the position of the charge traps on the CCD; ii) their depth (i.e. their energy shifting effect); iii) the photon energy; iv) the CCD temperature which could affect the time relaxation of the trapped charges; v) the source count rates which, if too high, can fill completely the charge traps so that their effects on the spectral response are no longer visible. However, most of this information is unknown, and therefore it is not possible to work out the exact profile of the function f with energy. So, we defined an empirical function f, its energy-dependent width was calibrated using an iterative method based on fits of several datasets: 3C279 (December 2008), the SNR E0102-72.3 (from June 2007 to August 2008), RX J1856.4-3754 (from June 2007 to August 2008). Fig. 1 shows the performance of these new PC RMFs when compared with these obtained using the unbroadened v011 PC RMFs (designed for data collected before 2007 February 28). In all cases, the residuals are flattened. These new PC RMFs also enable to retrieve a value of the normalisation relative to that given in the Beuermann et al. (2006, A&A, 458, 541) model ($C = 1.02 \pm 0.03$ from July 2008 instead of 0.76 ± 0.03 using the unbroadened v011 PC RMF (**swxpc0s0_20010101v011.rmf**)) close to that derived using 2005-2006 data of RX J1856.4-3754 ($C = 0.96 \pm 0.03$).

3 Current limitations and future prospects

We recommend to fit the XRT WT and PC spectra in the 0.3-10 keV energy range with these epoch-dependent XRT response files (version 11). The following considerations apply to both WT and PC mode observations:

- 10-15% spectral fit residuals in the 1.5-2 keV energy band can be visible in high statistical quality spectra (mostly in WT mode, because the sources observed are much brighter) using the v011 response files (also visible using previous versions). This is due to an overestimation of the effective area in that region induced by the change of the substrate voltage from 0 V to 6 V, which slightly reduced the depletion depth. The creation of both PC and WT RMFs including the effective area correction is under investigation and will be released as soon as possible.

- The v011 WT & PC RMFs with a broadened kernel are designed to model the averaged behaviour of the line broadening in a given time interval. We have investigated the effects of source count rates (below 50 counts s^{-1}), CCD temperatures (from -70°C to -50°C) and location of the sources in the WT & PC windows (from column 200 to column 400) during the calibration of the v011 WT RMFs. Even if these latter parameters are in the ranges considered (and on the calibration sources considered they seem to have a second order effect), we cannot guarantee that the broadening of the WT & PC RMF kernel will be suitable in every case. In particular, the broadening scheme adopted in this release treats only the average behaviour of the increasing charge traps. Individual traps may affect specific datasets more strongly.

- Prospects to implement a column by column description of the bias correction in the ground software enabling to correct for the effects of traps are under investigation for PC and WT data after June 2007 (see Fig.4 in the release SWIFT-XRT-CALDB-09_v11 and Godet et al. 2009, A&A, 494, 775).