Effective Date: 2026-07-21

INSTRUMENT CALIBRATION REPORT

XTEND REDISTRIBUTION MATRIX

XRISM_XTEND_CALDB_RMFPARAM

REVISION (-)

X-ray Imaging and Spectroscopy Mission (XRISM) Project

Goddard Space Flight Center
Greenbelt, Maryland

National Aeronautics and
Space Administration

Signature/Approval Page

Prepared by: A. Nagao, K. Shima, Y. Ode, M. Yoshimoto, M. Hanaoka, T. Hakamata, A. Miyamoto, H. Odaka, H. Matsumoto, K. Hayashida, H. Noda, H. Uchiyama, the XRISM Science Operation Center, and the XRISM Xtend Team

Reviewers/Approvers:

Eric Miller
Tahir Yaqoob
Michael Loewenstein

Change History Log

Revision	Effective Date	Description of Changes
-	2026-07-21	Initial release

NOTE to editors: These documents are updated as needed, e.g. when the relevant CALDB files, or the relevant calibration data analysis, is revised.

This document must include the CalDB file name, an explanation of how the data were collected and the analysis conducted and, if using standard Ftools, the software version number. All revisions are consolidated into the same document to maintain a full record of all changes.

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1 Introduction

1.1 Purpose

This document describes how the parameters for the redistribution or "response" matrix (the gain and the line spread function) of Xtend onboard the XRISM satellite in the CalDB file are prepared.

1.2 Scientific Impact

The events regarded as X-rays are selected with the Grade method in the same way as for Suzaku/XIS. The line spread function of good grade events is understood to have several components besides the Primary Gaussian, Secondary Gaussian, and Constant components, as well as Si escape and Si Kα line (Figure 1). The CalDB file provides the line width and the relative intensity of each component as a function of the incident X-ray energy. The line center and line width estimation influence the physical parameters of observed celestial X-ray sources, such as redshift and gas motion along the line of sight, respectively. The intensity of the constant component also affects the flux measurement of the continuum emission from astronomical objects.

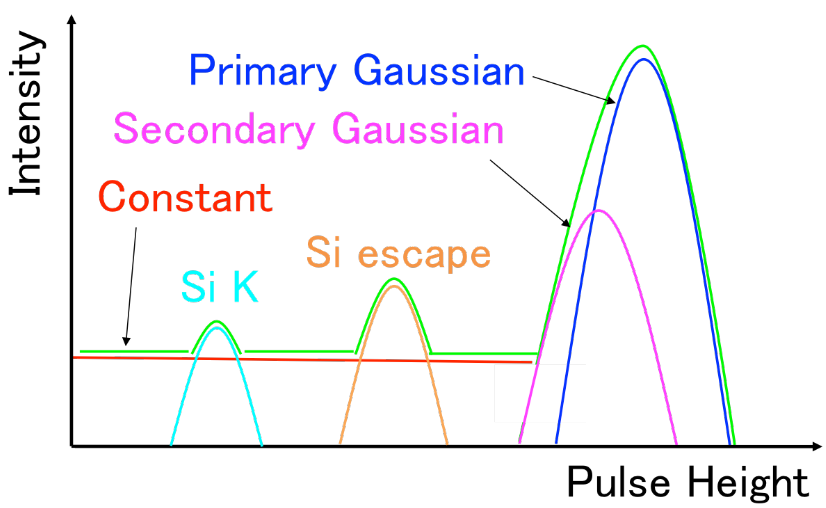


Figure 1: Schematic line spread function of SXI for monochromatic X-rays.

The CCD chips have several regions with relatively low CTE (charge transfer efficiency). The line spread function consists of the events extracted from these regions different from those in the other regions. We define the border of these regions using the data obtained with the flight model camera. When a user specifies a photon-extracting region across the border, the parameters of the line spread function will be weighted averages according to the number of X-ray events in each region.

The parameters in this CalDB file are used to generate a response matrix file (RMF) of Xtend.

2 First Delivery 20200831, Release CalDB 20210927

The following information pertains to the delivered and released files.

CalDB Filename	Validity date	File(s) as delivered	Delivery date	Comment
xa_xtd_rmfparam_20190101v002.fits	20190101 00:00 UT	xa_xtd_rmfparam_20200827.fits	20200831	

This CalDB file first appeared in the Build 4 CalDB release (20210927). Prior to that, the rmfparam files consisted of Hitomi data (as in the Hitomi/SXI CalDB 20160310), in the same format, except that the keywords and column names were modified for XRISM. The values in the rmfparam CalDB file released on 20210927 are also based on Hitomi/SXI but with some important additions/modifications compared to the previously released Xtend CalDB file. This new version is still mainly intended to test the analysis tools. The detailed description of the parameters in this version is described in ASTH-SXI-CALDB-RMFPARAM Version 0.4.[1] The file structure is different from that of the corresponding Hitomi/SXI file on two points:

- First, a column called "PRIMARY_CENTER" is added. Suzaku/XIS has a jump in the relation between the incident X-ray energy E_X and the peak of its pulse height PI_{peak} around the Si K edge (for details, see [1]). To deal with this phenomenon, we add this new column and use a discontinuous relation between E_X and PI_{peak} in the RMF generator.
- Second, the number of rows is increased from that in the Hitomi/SXI rmfparam file. The energy bin widths of the Hitomi/SXI rmfparam file are not fine enough to describe the complex structure around the Si K edge. To make the energy grid fine enough, we increased the number of rows (energies) in the CalDB file.

Note that this CalDB file is based on Hitomi/SXI ground measurements. The CalDB file based on XRISM/SXI ground measurements will be delivered later.

3 Delivery 20220228, Release CalDB 20220630

CalDB Filename	Validity date	File(s) as delivered	Delivery date	Comment
xa_xtd_rmfparam_20190101v003.fits	20190101 00:00 UT	xtend_caldb_rmfparam_20220228.fits	20220228	Build 5 CalDB

3.1 Data Description

This CalDB file is based on experimental data from the Xtend FM CCD chip calibration test conducted at Osaka University in April 2021. Radioisotopes and an X-ray generator were used to irradiate the CCD chip with the characteristic X-rays shown in Table 1. Frame data were taken in the experiment. The CCD chips were cooled to -110°C. Note that the noise level (and thus energy

[1] https://heasarc.gsfc.nasa.gov/docs/hitomi/calib/caldb_doc/asth_sxi_caldb_rmfparam_v20160310.pdf

resolution) may differ from the actual FM setup because the CCD was not installed in the FM body for this calibration. This will be corrected later using the integrated test data.

Table 1: Irradiated characteristic X-rays in the calibration test of the FM CCD chips.

Line	Energy (keV)	Line	Energy (keV)
O K$\alpha_{1,2}$	0.525	Mn K$\alpha_{1,2}$	5.895
F K$\alpha_{1,2}$	0.677	Mn K$\beta_{1,2}$	6.490
Al K$\alpha_{1,2}$	1.487	Np L$\alpha_{1,2}$	13.93
Si K$\alpha_{1,2}$	1.740		

3.2 Data Analysis

Pulse height corrections for "even-odd", "charge trail", and "charge trail inefficiency" were applied before the analysis. To create this CalDB file, the relative strengths and widths of the subcomponents (secondary, escape, fluorescence, and constant components) to the primary Gaussian were assumed to be the same as those of Hitomi/SXI (see ASTH-SXI-CALDB-RMFPARAM Version 0.4). Using the Hitomi/SXI response (RMF), we fitted the spectral data with a phenomenological model (Figure 2). Segment AB/CD of each chip was analyzed separately.

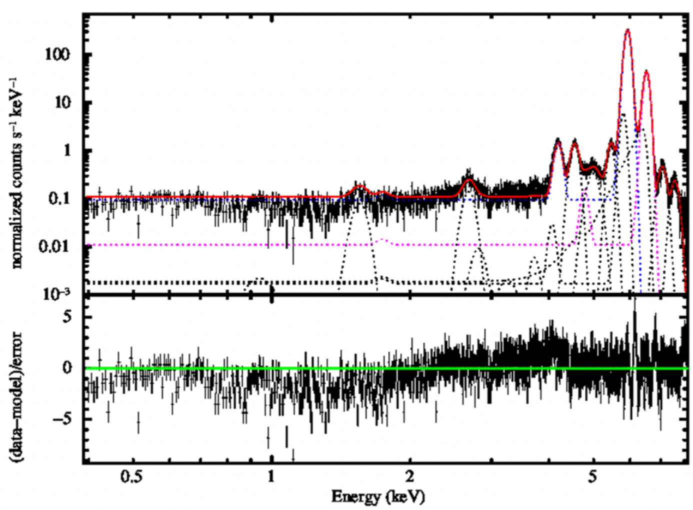


Figure 2: ^{55}Fe spectrum of the CCD1 segment AB with the phenomenological model.

3.3 Results

The obtained relationship between the additional width $\Delta\sigma(E)$ from that of Hitomi/SXI and energy E was modeled as shown in Figure 3. Using the relationship between the width of the primary Gaussian of Hitomi/SXI to the energy $\sigma_{SXI}(E)$, that of XRISM/Xtend $\sigma_{Xtend}(E)$ was calculated as $\sigma_{Xtend}(E) = \sqrt{\sigma_{SXI}(E)^2 + \Delta\sigma(E)^2}$ (Figure 4). In this CalDB file, the position dependence of the response was assumed to be flat on the segment. For the 1/8-window mode, the value obtained for the full-window mode is tentatively used for now.

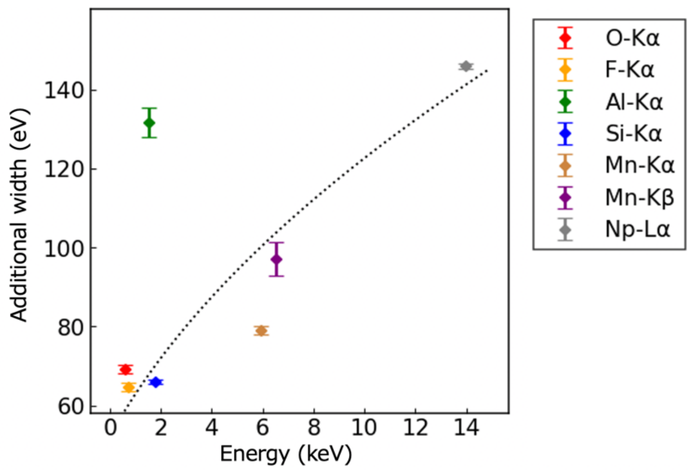


Figure 3: The obtained relationship between the additional width and energy for CCD1 segment AB (data points). It was modeled as the dotted line.

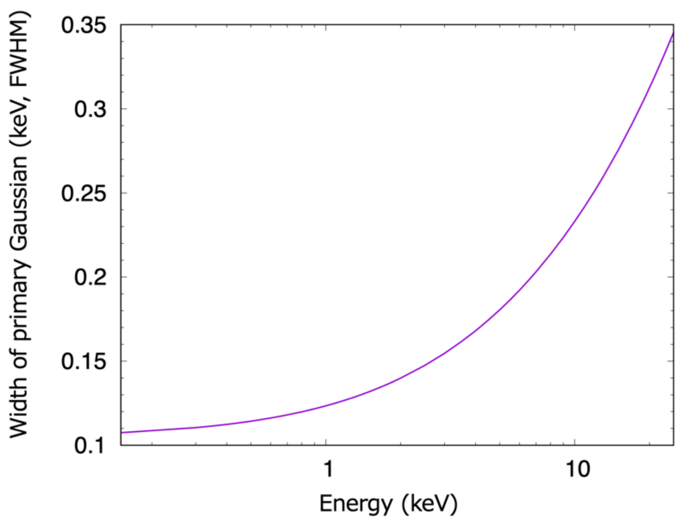


Figure 4: The relationship between the width of the primary Gaussian and energy for CCD1 segment AB in the v003 CalDB file.

3.4 Final Remarks

The RMF parameter file will be further updated later based on the ground tests.

4 Delivery 20220730, Release CalDB 20221201

CalDB Filename	Validity date	File(s) as delivered	Delivery date	Comment
xa_xtd_rmfparam_20190101v004.fits	20190101 00:00 UT	xtend_caldb_rmfparam_20220730.fits	20220730	Build 5a CalDB

4.1 Data Description

This CalDB file is based on experimental data from the FM SXI-S cooling test conducted at TKSC in September 2021. In this experiment, the CCD chips were installed in the FM body. A ^{55}Fe radioisotope was used to irradiate the CCDs. Frame data were taken in the experiment. The CCD chips were cooled to -110°C.

4.2 Data Analysis

Pulse height corrections for "even-odd", "charge trail", and "charge trail inefficiency" were applied before the analysis. Segment AB/CD of each chip was analyzed separately. The data of the full- and 1/8-window modes were analyzed respectively. We fitted the spectral data with a phenomenological model and measured the width of the primary Gaussian in the Mn K α line. Note that, using the data of the Xtend FM CCD chip calibration test conducted at Osaka University in April 2021 (see section 3.1), we examined the position dependence of the primary Gaussian width and found no significant position dependence within a segment (Figure 5). Therefore, this CalDB file does not contain the position dependence of the primary Gaussian width.

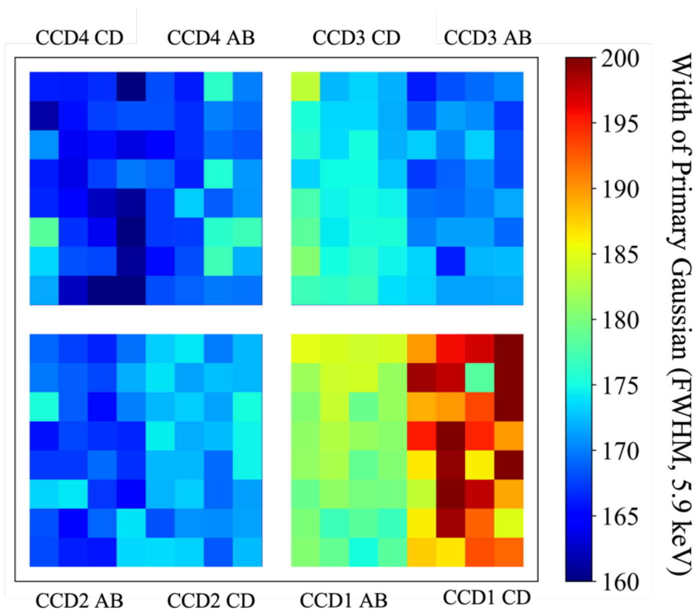


Figure 5: The position dependence of the primary Gaussian width.

4.3 Results

The relationship between the width of the primary Gaussian to the energy was modeled as $\sigma_{CCD}(E) = \sqrt{m_1 + m_2 E}$ using the data of the FM CCD chip calibration test (see the previous delivery 20220228, Section 3). The constant m_1 was updated to m_1' such that it reproduces the σ_{SXI-S}(5.9 keV) obtained from the Mn Kα line data of the FM SXI-S cooling test. It adjusts for the difference in noise level between CCD calibration and the actual FM setting.

Figure 6 shows the additional widths required to fit the Mn Kα and Kβ lines in SXI-S cooling test data with the phenomenological model using the RMF generated with this CalDB file. The Mn Kα lines in the full window mode are well reproduced while those in the 1/8-window mode and Mn Kβ lines require additional widths. The cause of this systematic error is under investigation. Note that the reproducibility of the RMF at the low energy band was not confirmed because only ^{55}Fe was irradiated in the FM SXI-S cooling test. High systematic error might exist there.

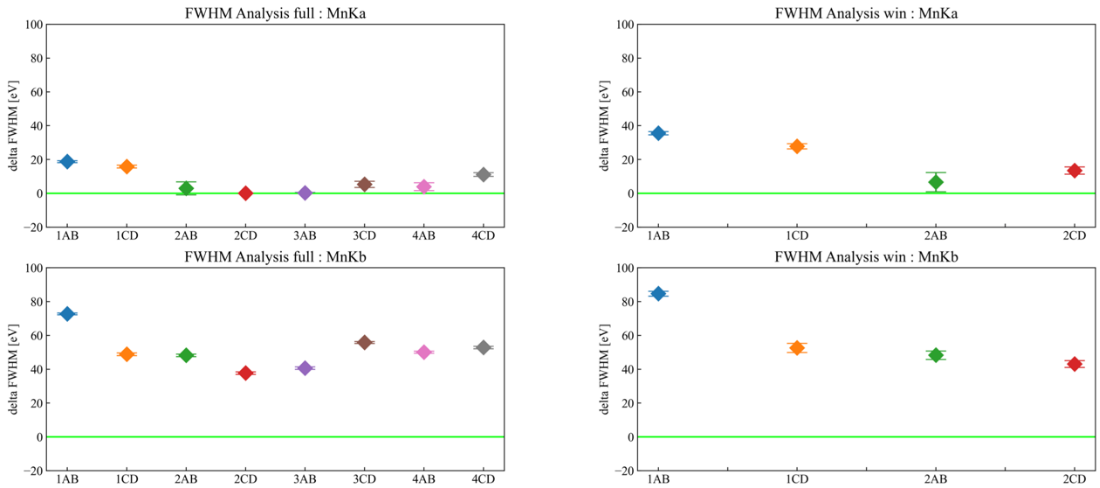


Figure 6: The additional widths required to fit the Mn Kα and Kβ lines in SXI-S cooling test data as a function of segment with the phenomenological model using the RMF generated with the v004 CalDB file.

4.4 Final Remarks

This CalDB file is the final released version before the launch.

4.5 Additional Information

Analysis of the PV data revealed that the response files generated from this rmfparam CalDB fail to adequately represent the spectral resolution in the low-energy band (below 3 keV). This CalDB file should not be used for the analysis of in-orbit observation data. Therefore, in the XRISM CalDB 8 release (20240315), the "rmfparam" file was replaced by xa_xtd_rmfparam_20190101v006.fits, which is simply a copy of the Hitomi-based file xa_xtd_rmfparam_20190101v002.fits that was released pre-launch in CalDB 20210927. Note that the file xa_xtd_rmfparam_20190101v005.fits was never released because it only had an inconsequential keyword change compared to xa_xtd_rmfparam_20190101v004.fits.

5 Delivery 20240831, Release CalDB 2024115

CalDB Filename	Validity date	File(s) as delivered	Delivery date	Comment
xa_xtd_rmfparam_20190101v007.fits	20190101 00:00 UT	xtend_caldb_rmfparam_20240831.fits	20240831	CalDB 10

5.1 Data Description

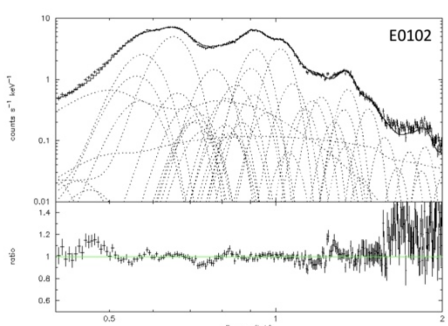
This CalDB file was constructed using in-orbit observations of 1E 0102.2-7219 and the Perseus Cluster, acquired during the performance verification phase, as listed in Table 2.

Table 2: The in-orbit data during the performance verification used to create the v007 CalDB file.

	Full window		1/8 window	
OBSID	000136000	000154000	100010010	000155000
Object Name	1E0102.2-7219	Perseus_CAL1	1E0102.2-7219	Perseus_CAL2
Obs Start Date	2023-12-24	2024-01-21	2024-02-19	2024-01-22
Exposure (ks)	74.5	50.4	41.1	52.7

5.2 Data Analysis

Pulse height corrections for “even-odd,” “charge trail,” and “charge trail inefficiency” were applied prior to the analysis. However, the parameters for these corrections were based on ground experiment results, not on in-orbit calibration data. The spectra of 1E 0102.2-7219 and the Perseus Cluster were extracted from the on-axis CCD2CD chip segment only. The Xtend spectra of these objects were fitted using calibration models, namely the IACHEC calibration model for 1E 0102.2-7219 [2] and a phenomenological model in the highly ionized iron band constructed from fits to the Resolve spectrum. The energy dependence of the FWHM of the primary Gaussian component was modeled as $\sigma_{CCD}(E) = \sqrt{m_1 + m_2 E}$. The parameters m_1 and m_2 were determined to simultaneously reproduce the spectra of 1E 0102.2-7219 and the Perseus Cluster using the calibration models. These analyses were performed separately for the full-window and 1/8-window mode data. The best-fit results are shown in Figures 7 and 8.



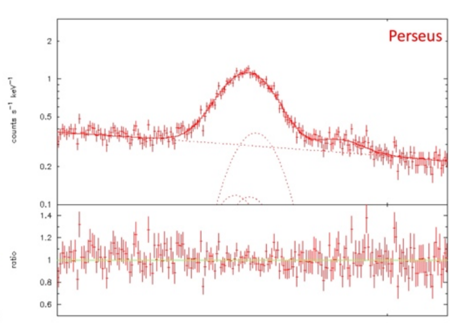


Figure 7: The spectra of E0102 and Perseus in full-window mode with the best-fitting models, for the v007 CalDB file analysis.

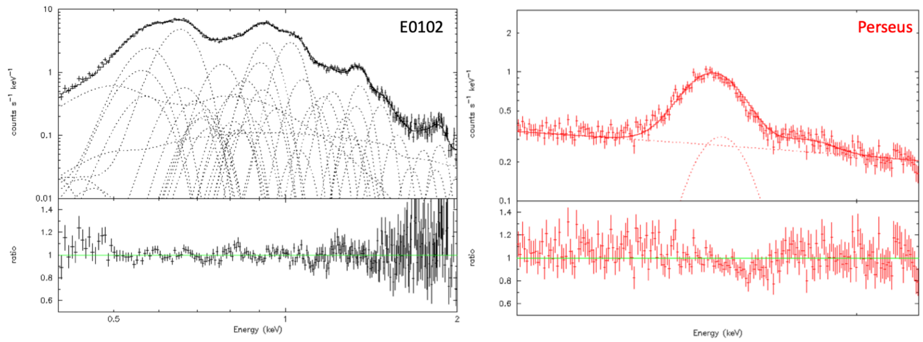


Figure 8. The spectra of E0102 and Perseus in 1/8 window mode with the best-fitting models, for the v007 CalDB file analysis.

5.3 Results

The obtained energy dependence of the FWHM of the primary Gaussian is shown in Figure 9.

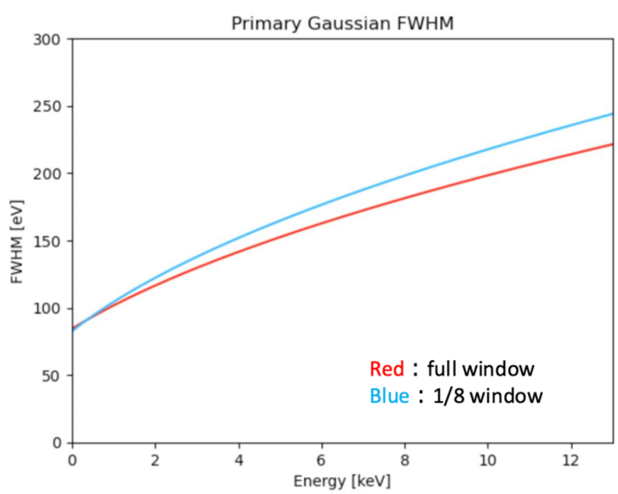


Figure 9. The energy dependence of the FWHM of the primary Gaussian for the v007 CalDB file.

5.4 Final Remarks

This rmfparam CalDB file is intended to be used together with the charge trail and CTI CalDB files, xa_xtd_chtrail_20190101v003.fits and xa_xtd_cti_20190101v002.fits, which are derived from ground experiment results.

Only the on-axis segment (CCD2CD) is calibrated in this CalDB file. For the other off-axis segments, the same values as those of the on-axis segment are applied. Even for the on-axis segment, the mid-energy band (2–6 keV) is not calibrated. Therefore, the response in this band may have larger uncertainties than the calibrated regime. The values in this CalDB file are constant over time.

6 Delivery 20250507, Release CalDB 20250915

CalDB Filename	Validity date	File(s) as delivered	Delivery date	Comment
xa_xtd_rmfparam_20190101v008.fits	20190101 00:00 UT	xtend_caldb_rmfparam_20250507.fits	20250507	CalDB 12

6.1 Data Description

This CalDB file is based on the in-orbit data during the performance verification (PV) phase, as shown in Table 3. The on-axis segment CCD2CD was calibrated based on the data of E0102, N132D, Perseus, W49B (full window), and Circinus (1/8 window). The other segments were verified using the data of the ^{55}Fe calibration sources and the Perseus cluster.

Table 3: The in-orbit data during the performance verification used to create the v008 CalDB file.

OBSID	Object Name	Obs Start Date	Exposure (ks)
Full window			
000136000	1E0102.2-7219	2023-12-24	74.5
000154000	Perseus_CAL1	2024-02-19	50.4
000126000	N132D	2023-12-03	91.2
300055010	W49B_East	2024-04-23	272.7
(Trend achieve)	Calibration source ^{55}Fe		
1/8 window			
100010010	1E0102.2-7219	2024-02-19	33.6
000128000	N132D	2023-12-09	52.6
000155000	Perseus_CAL2	2024-01-22	45.2
000162000	Circinus_Galaxy	2024-02-28	286.8

6.2 Data Analysis

Pulse height corrections for “even-odd,” “charge trail,” and “charge trail inefficiency” were applied before the analysis. The parameters for these corrections were derived from the results of the PV phase.

For the on-axis segment CCD2CD, the Xtend spectra were fitted using calibration models. These include the IACHEC calibration models for 1E 0102.2-7219 [2] and N132D, together with phenomenological models constructed by fitting the Resolve spectra of Perseus, W49B, and Circinus in the highly ionized iron band. The energy dependence of the FWHM of the primary Gaussian component was modeled as $\sigma_{CCD}(E) = \sqrt{m_1 + m_2 E}$. The parameters m_1 and m_2 were determined to explain these spectra with the calibration models simultaneously. were determined to simultaneously reproduce these spectra with the calibration models. The analysis was performed separately for the full-window and 1/8-window mode data. The best-fit results are shown in Figures 10 and 11.

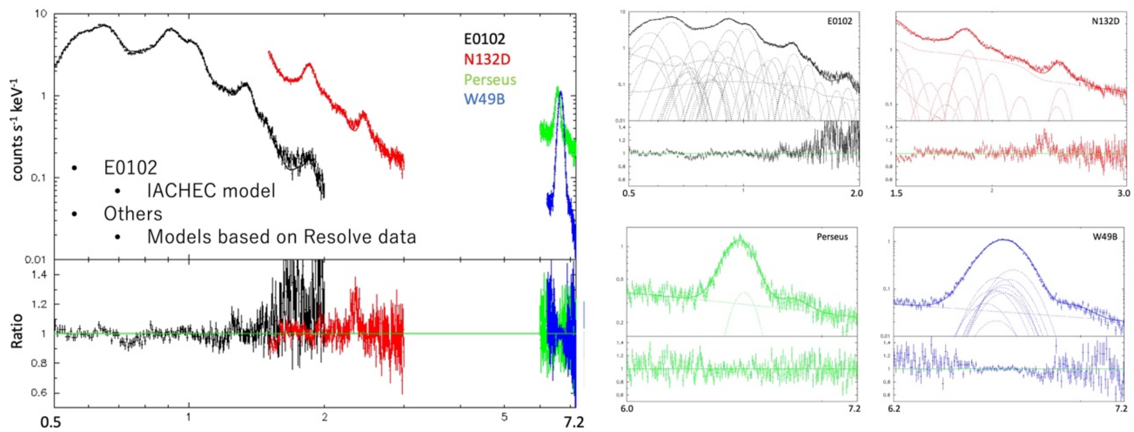


Figure 10: The on-axis spectra in the full window mode with the best-fitting models, for the v008 CalDB file analysis.

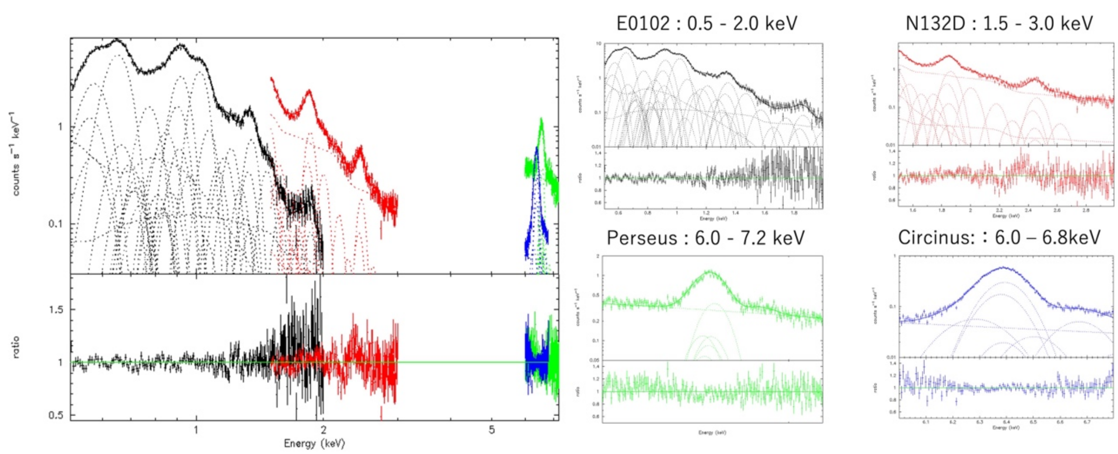


Figure 11: The on-axis spectra in the 1/8 window mode with the best-fitting models, for the v008 CalDB file analysis.

For the other segment, the calibration parameters were assumed to be identical to those of the on-axis segment. Using these parameters, RMF files were generated, and the Mn Kα line (5.9 keV) in the calibration source and the Fe XXV Heα line (6.7 keV) in Perseus were fitted with phenomenological models to validate the RMF. Examples of the best-fitting results are shown in Figure 12.

6.3 Results

The energy dependence of the FWHM of the primary Gaussian component obtained for the on-axis segment is shown in Figure 13. For the other segments, for which the RMF parameters were assumed to be identical to those of the on-axis segment, no significant discrepancy was found between the data and the models for the Mn Kα line (5.9 keV) in the calibration source and the Fe XXV Heα line (6.7 keV) in Perseus.

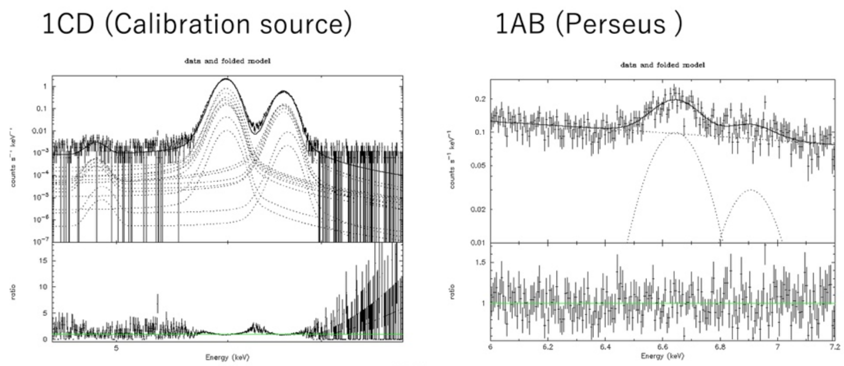


Figure 12: The off-axis spectra in the full window mode with the best-fitting models, for the v008 CalDB file analysis.

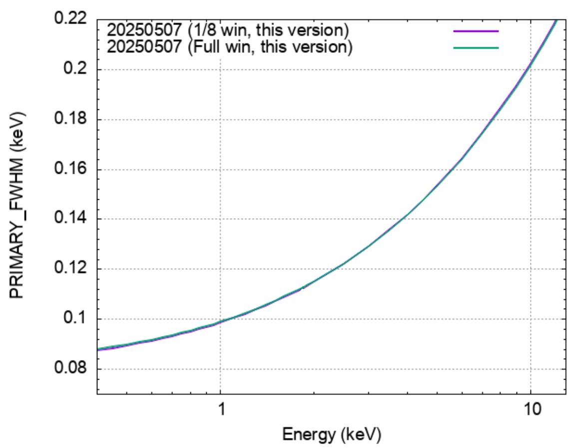


Figure 13. The energy dependence of the FWHM of the primary Gaussian for the v008 CalDB file.

6.4 Final Remarks

This rmfparam CalDB file should be used with the charge trail, CTI and gain CalDB files delivered on 2025-05-07, which are based on PV observations. The on-axis segment (CCD2CD) is calibrated over a wide energy band of 0.5–7 keV. For the other segments, verification has been performed only around the Fe line energy, and the low-energy response may therefore be uncertain. The values in this CalDB file are constant over time.

6.5 Additional Information

The validity of this rmfparam CalDB was verified using spectra corrected with the new charge trail and CTI files in the CalDB 20260315 release. We found that the on-axis spectra of E0102 (OBSID 102005010 and 10200601[0,1,2]; 2025 October), N132D (OBSID 001012010; 2025 September), and the Perseus Cluster (OBSID 10101[1,2]010; 2025 July), corrected with the new charge trail and CTI CalDBs, were well fitted by RMFs based on this CalDB file (see Figures 14 and 15). In contrast, the response uncertainty for the other off-axis segments remains unclear.

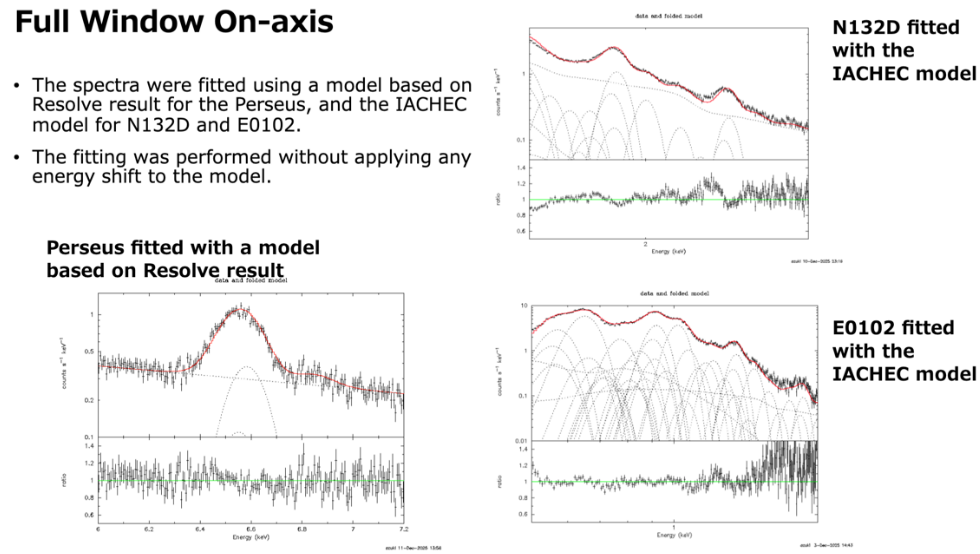


Figure 14 : The verification of the validity of the v008 rmfparam CalDB file for the full-window on-axis data corrected with the new charge trail and CTI files in the CalDB 20260315 release.

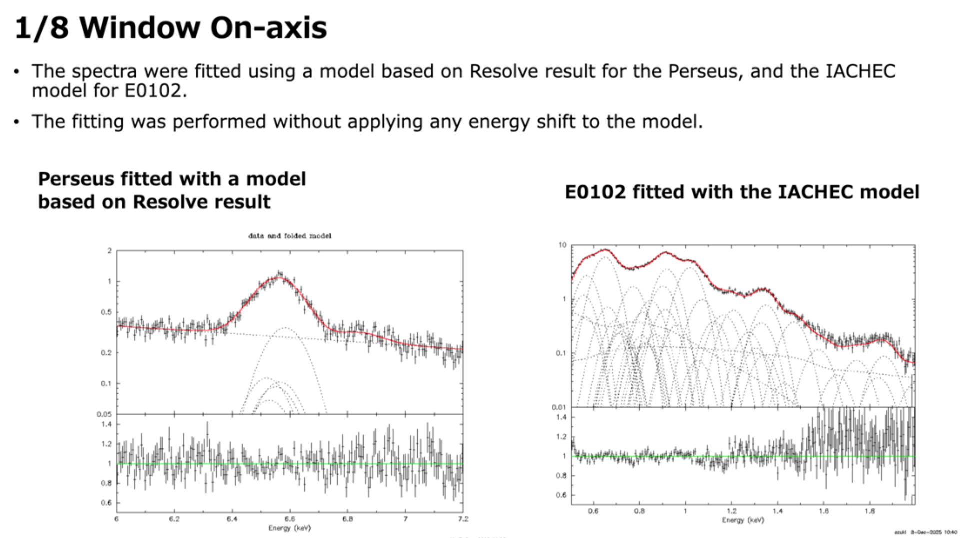


Figure 15 : The verification of the validity of the v008 rmfparam CalDB file for the 1/8-window on-axis data corrected with the new charge trail and CTI files in the CalDB on 20260315 release.

7 References

[1] "The spectral response of X-ray CCDs in the energy band around Si-K edge: a solution to the Si-K edge problem for the XIS onboard Suzaku," Okazaki, K., et al. Proc. SPIE, 10709, 107091F (2018)
[2] "SNR 1E 0102.2-7219 as an X-ray calibration standard in the 0.5-1.0 keV bandpass and its application to the CCD instruments aboard Chandra, Suzaku, Swift and XMM-Newton," Plucinsky, P., et al. A&A, 597, A35 (2017)