Effective Date: 11/25/2024
Expiration Date: 11/25/2029

XRISM/ Resolve
CMO
11/25/2024
RELEASED

INSTRUMENT CALIBRATION REPORT

DEFINITION OF SAA

RESOLVE-SCI-RPT-0176

REVISION (-)

XRISM-GEN-CALDB-SAA-102

X-ray Imaging and Spectroscopy Mission (XRISM) Project

NASA/GSFC Code 461

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RESOLVE-SCI-RPT-0176
Revision-
Effective Date: 11/25/2024

DEFINITION OF SAA

Signature/Approval Page

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Preface

This document is an XRISM Project signature-controlled document. Changes to this document require prior approval of the applicable Product Design Lead (PDL) or designee. Proposed changes shall be submitted in the Technical Data Management System (TDMS) via a Signature Control Request (SCoRe) along with supportive material justifying the proposed change. Changes to this document will be made by complete revision.

All of the requirements in this document assume the use of the word "shall" unless otherwise stated.

Questions or comments concerning this document should be addressed to:
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Change History Log

Revision	Effective Date	Description of Changes (Reference the SCoRe Approval Date)
(-)	11/25/2024	Describes initial delivery of SXS_SAA and SXI_SAA region definitions and first two updates. Release per RESOLVE-SCoRe-0574

NOTE to editors: The document name will be XRISM-CAL-RPT-XXXX, where XXXX is assigned by the TDMS system. The document will be cross-referenced in TDMS to the filename in the format XRISM-XXX-CALDB-FILEDESC-NN where XXX is the instrument or component (e.g. RESOLVE), FILEDESC refers to a specific calibration report (e.g., rmfparams) and NN the corresponding number assigned to that report by the SDC. For example the calibration report addressing the Resolve LSF calibration may be assigned XRISM-RESOLVE-CALDB-RMFPARAMS-01, that addressing the Resolve gain calibration XRISM-RESOLVE-GAINPIX-CALDB-02, etc. (where the numbers are to be provided by the SDC).

These documents are updated as needed, e.g. when the relevant CALDB files, or the relevant calibration data analysis, is revised. The document version will be assigned by the TDMS system. The tracking tool should be used to record changes.

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.

Table of Contents

1 Introduction

1.1 Purpose

The SAA CalDB file defines the borders of the South Atlantic Anomaly, which is a region on the Earth's surface where there is a high flux of energetic particles. XRISM passes through the SAA 8-9 times lasting for ~3-30 minutes each in a day of 15-16 rotations around the Earth. *Resolve* continues to operate in observation mode during the SAA passages, thus events are collected during SAA. The events must be removed (screened) using good-time-interval (GTI) windows based on the position of the spacecraft projected on the Earth surface ("longitude-latitude cut"). Xtend is not operated during SAA, and the high voltage of the Modulated X-ray Source of Resolve is reduced while in SAA. For these operational and data-processing motives, the SAA borders must be defined in CalDB and updated as they shift.

1.2 Scientific Impact

If the SAA is not properly defined, the number of background events could increase or the health of the instruments could be put at risk.

1.3 Formalization

Two SAA regions per instrument (called SAA and SAA2) are defined and implemented in CalDB. "SAA" is used for the default SAA region for each instrument. "SAA2" is used for a wider SAA region for tighter screening, after which fewer events are left. All are defined as a set of (LON, LAT) positions for the vertices of one or more polygons and are stored in "xrism/gen/bcf/xa_gen_saa_*.fits" HDU[2] (SAA_VERTICES) and HDU[3] (SAA2_VERTICES). Each extension has two columns, one defined for Xtend (soft x-ray imager, or SXI) and one for Resolve (soft x-ray spectrometer, or SXS). The two columns are SXI_SAA and SXS_SAA for extension SAA_VERTICES and SXI_SAA2 and SXS_SAA2 for extension SAA2_VERTICES.

2 First Delivery

CalDB Filename	Validity date	File(s) as delivered	Delivery date	Comment
xa_gen_saa_20190101v001.fits	20140101 00:00 UT	ah_gen_saa_20140101v002.fits	20151010	Carry-over from Astro-H

2.1 Data description

For the first delivery to the XRISM CalDB, the SXI_SAA, SXS_SAA, SXI_SAA2, and SXS_SAA2 from the final SAA definitions for Astro-H were imported without alteration. The SXI and SXS columns are identical within each of the two extensions. The SXI_SAA and SXS_SAA regions were defined for Astro-H before launch. A new operational definition had been adopted for Astro-H based on the count rate of the SXS anti-co, but a corresponding change was not made within the Astro-H CalDB.

These initial definitions are captured in Tables 2-1 and 2-2.

Table 2-1 Values for SXI_SAA and SXS_SAA in v001

Longitude (deg)	-85	-55	-29.28	10	10	-85
Latitude (deg)	-10	2	2	-20	-1000	-1000

Table 2-2 Values for SXI_SAA2 and SXS_SAA2 in v001 (3 distinct polygons)

Longitude (deg)	100	160	160	100
Latitude (deg)	-26	-26	-1000	-1000

Longitude (deg)	-170	-100	-100	-62	-32	0	50	50	170
Latitude (deg)	-23	-23	-10	5	5	-5	-10	-1000	-1000

Longitude (deg)	-200	-180	-100	-85	-70	-70	-200
Latitude (deg)	26	20	5	5	30	1000	1000

3 Revision for XRISM CalDB 8 Release (20240315)

CalDB Filename	Instrument	Validity date	File(s) as delivered	Delivery date	Comment
xa_gen_saa_20190101v002.fits	Resolve	20190101 00:00 UT	SAA_3.csv	20240306	
	Xtend	20190101 00:00 UT	Initial SAA definition used for XRISM operations – vertices supplied by email from Xtend team to SDC	20231223	

3.1 Resolve

For this first revision based on XRISM in-flight data, only SXS_SAA is updated for Resolve. The following subsections document these updates.

SXS_SAA2 is unchanged from the Astro-H version and should not be used for screening Resolve data without reassessment by the user. As shown in Fig. 3-6, SXS_SAA2 defines a large area, resulting in an aggressive cut that clearly would result in lower background than SXS_SAA, but its borders have not been optimized for XRISM.

3.1.1 Resolve data description

We define the SAA region based on mapping the event rate of the anti-co detector in the orbit. We use the Resolve detector array data to evaluate the choice of anti-co detector threshold used to define the SAA regions. The position of the spacecraft projected on the Earth surface was taken from the orbit file distributed as a part of the XRISM pipeline products.

For the anti-co data, we used all the anti-co detector events taken from October 11, 2023 to December 6, 2023. We removed events in the time intervals of the ADR recycles, calibration x-ray illumination, and night earth elevation smaller than -5 degrees. Anti-co events were cleaned using the following conditions:

1. AC_ITYPE==0 for selecting event data.
2. PSP_ID = A1 for selecting only one of the two readout channels
3. PHA ≥ 71 and DURATION ≥ 2 for selecting particle-induced events.

For the corresponding Resolve detector array data, we used the same period and applied the standard event screening.

After determining candidate SAA regions using the data described above, we used OBSID 00014000 (ABELL2319_BS2), an extended data set dominated by the instrumental background, also known as the non-X-ray background (NXB), to evaluate the proposed SAA regions.

3.1.2 Resolve data analysis

Anti-co count rate threshold

We first determined the threshold by evaluating the NXB count rate and the energy resolution of the ^{55}Fe calibration source in pixel 12. Figures 3-1 and 3-2 show the two metrics as a function of the count rate. As the anti-co count rate increases, the NXB rate increases, and the energy resolution of the Mn Kα line degrades. Based on these plots, we chose to investigate potential anti-co rate thresholds of $\leq 4\ s^{-1}$ for defining SAA.

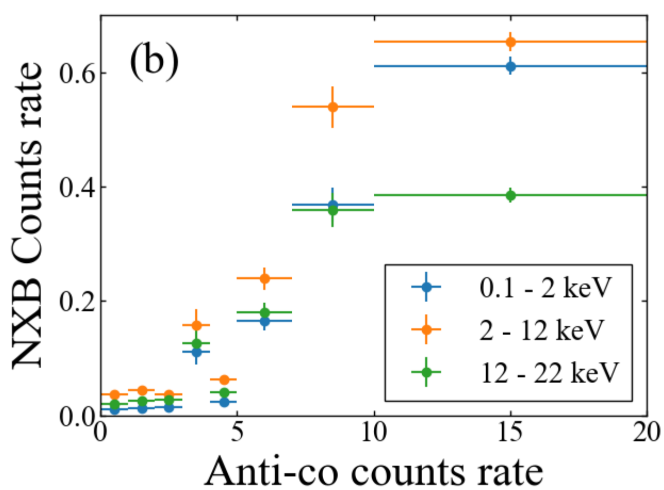

Figure 3-1 The NXB count rate of all pixels except for pixel 11, 12, and 13 (calibration pixel and its cross-talk neighbors) and all grade events. The rates in three different energy bands are shown in different colors.

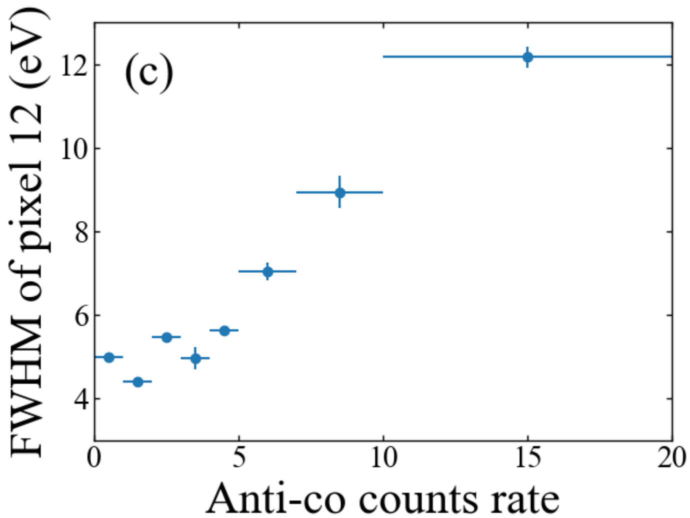

Figure 3-2 The energy resolution in FWHM of the Mn Ka line of pixel 12.

Next we used OBSID 00014000 (ABELL2319_BS2) to compare anti-co and array light curves with cut-off-rigidity (COR) curves and candidate definitions of the SAA GTI. Data were processed using the BUILD 7 pipeline tools. We started with the unfiltered events file so that data during eclipses and SAA could be retained. Other than these exceptions, we applied standard cleaning to the data. This included: [PI>600&&PI<60000&&((RISE_TIME>=40&&RISE_TIME<=60&&ITYPE<4)||(ITYPE==4)) &&STATUS[4]==b0]. To make the resulting file smaller, events occurring while the anti-co rate was > 50 s^{-1} were removed, preserving the SAA edges for analysis. We created 30s anti-co and array light curves using commensurate binning. The following limits were applied to the input to these light curves:

- Anti-co: ≥ 30 keV, DURATION 2 -19
- Array: H+Mp event grades, 0.3 - 20 keV

Using the bins of these light curves, we plotted array rate vs anti-co rate (Fig. 3-3), like Fig. 3-2, but for this one OBSID. Outside of SAA, the anti-co rate is modulated by COR. Fig. 3-4 shows that the transition from COR-modulated to SAA-modulated rates occurs at an anti-co rate of ~ 2 s^{-1}, which is also seen in the increased density of points in Fig. 3-3 below 2 s^{-1}. To define GTI based on SAA and COR separately, the SAA definition must be based on an anti-co rate threshold ≥ 2 s^{-1}. We fitted the relationship between array rate and anti-co rate to be able to plot the light curves scaled accordingly, as a visual guide for evaluating the candidate SAA definitions. Fig. 3-5 is an example SAA crossing from 000014000, showing GTI boundaries from the proposed SAA definitions for anti-co rates of 2, 3, and 4 s^{-1}. These were checked against the light curves and each other. The SAA passages of 000014000 sampled the features of the boundaries of the proposed regions reasonably well. For this CalDB delivery, a border corresponding to 3 s^{-1} was chosen because the resulting crossings resulted in well behaved GTIs, and the edges corresponded generally to < 3 s^{-1} .

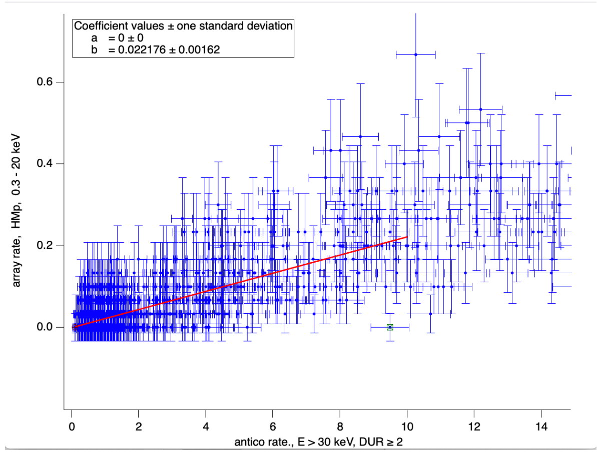

Figure 3-3 Fit of relationship between array rate and anti-co rate in NXB-dominated data (000014000)

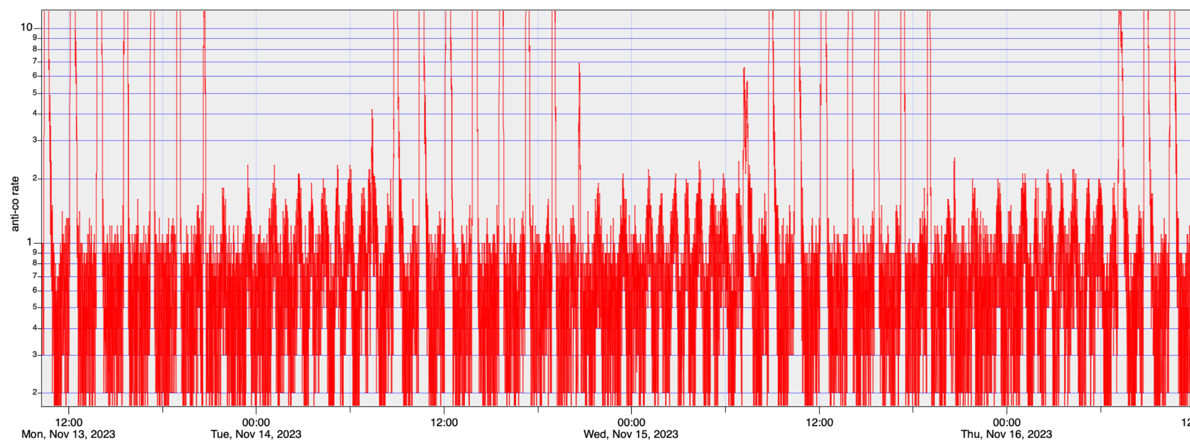

Figure 3-4 Light curve of the anti-co rate, showing that modulation outside of SAA stays below ~ 2 s^{-1}.

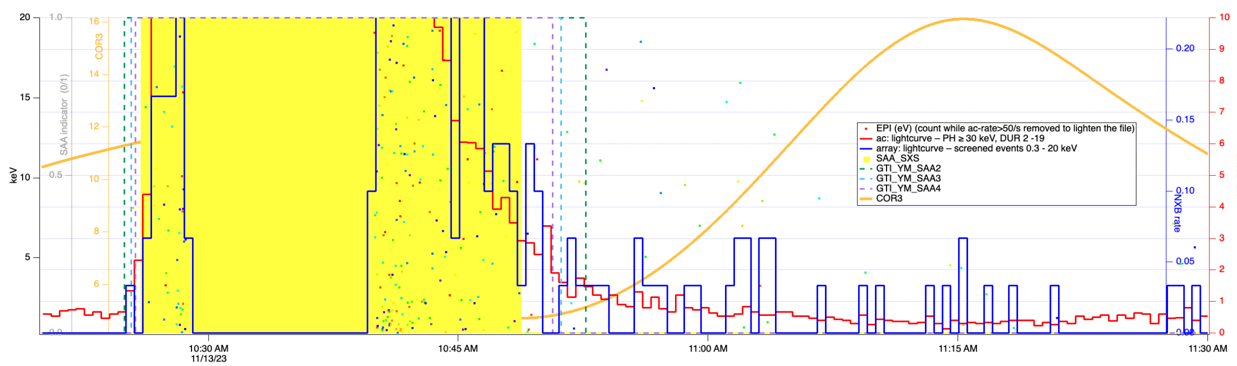

Figure 3-5 Example SAA crossing from 000014000. Yellow shading shows the Astro-H definition of SAA. The axes of the anti-co and array light curves, in red and blue, respectively, are scaled so array and anti-co rates align (using fitted scale factor of 0.0222). Also plotted are COR (orange) and individual X-ray points (dots colored according to pixel ID). GTI boundaries using SAA regions defined using anti-co rates of 2, 3, or 4 s^{-1} are indicated in the legend as GTI_YM_SAA2, GTI_YM_SAA3, and GTI_YM_SAA4.

SAA region

Figure 3-6 shows the anti-co count rate in a 1 s bin averaged over a 2x2 degree grid. We defined the SXS_SAA region enclosed by the blue lines in Figure 3-6, which corresponds to an anti-co count rate $> 3\ s^{-1}$.

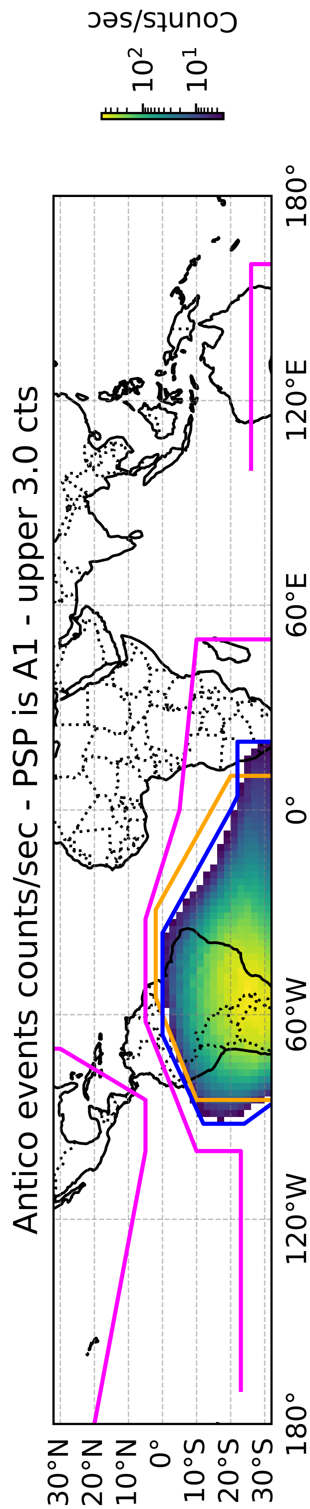

Figure 3-6 Anti-co count-rate map averaged over a 2x2 degree grid. XRISM SXS_SAA (blue) region, defined using anti-co rate > 3 s^{-1}, compared to the ASTRO-H SXS_SAA (orange) and SXS_SAA2/SXI_SAA2 (purple) regions [1], [2].

3.2 Xtend

As mentioned in Section 2.1, the initial SAA definitions for both Xtend and Resolve were taken from the final Astro-H CalDB file, but these were Astro-H pre-launch values that had never been updated. However, an update to the operational definition of SAA had been made for Astro-H based on the SXS anti-co rate. The final CalDB and operational definitions from Astro-H became the corresponding initial values for XRISM, and their mismatch was a problem for Xtend that needed adjustment.

In operation, Xtend data acquisition is stopped during SAA passages to protect the CCDs and to avoid obtaining useless data. Just after each passage, SXI resumes nominal operations after a dedicated clocking mode ("erasing" mode) to wipe out charges stored during the passage. Since it was found that it may take some time for the CCDs to return to the nominal performance, a GTI selection based on the time after SAA passage (T_SAA_SXI) is useful to improve the quality of the data. T_SAA_SXI and other SAA-related parameters in the extended housekeeping (EHK) file are calculated from the SAA vertices in the CalDB file by the pipeline program "xamkehk", thus the CalDB definition and the operations definition should be consistent with each other.

This update changes only SXI_SAA. SXI_SAA2 is unchanged from the Astro-H version and should not be used for screening Xtend data without reassessment by the user. As shown in Fig. 3-6, SXI_SAA2 a large, aggressive cut that clearly would result in lower background than SXI_SAA, but its borders have not been optimized for XRISM.

3.2.1 Xtend data description

In this update, the operational definition developed for Astro-H and used from the start of operations on XRISM was adopted as the definition for SXI_SAA. Table 3-2 describes the exact SAA definition for SXI after this correction.

3.2.2 Xtend data analysis

The operational definition was adopted without modification.

3.3 Results

Tables 3-1 and 3-2 are the coordinates of SXS_SAA and SXI_SAA. Note that the fourth and fifth entries (in red italics) of Table 3-2 were not provided by the Xtend instrument team, but were inserted by the SDC along the line between vertices to make the number of coordinate pairs identical for SXS_SAA and SXI_SAA, which is a requirement of the formatting.

Table 3-1 SXS_SAA

Longitude (deg)	-84	-92	-92	-66	-36	0	4	20	20
Latitude (deg)	-35	-24	-12	0	0	-20	-22	-22	-35

Table 3-2 SXI_SAA

Longitude (deg)	-95	-95	-60	*-50*	*-40*	-30	0	30	30
Latitude (deg)	-35	-11	2	*2*	*2*	2	-15	-20	-35

3.4 Remarks

None.

4 Revision for Xtend (20241115)

CalDB Filename	Instrument	Validity date	File(s) as delivered	Delivery date	Comment
xa_gen_saa_20190101v003.fits	Xtend	20241115 01:09 UT	xa_gen_saa_20190101 v002.fits SXS_SAA	20240306	

4.1 Resolve

No updates were made for Resolve in this version.

4.2 Xtend

The Xtend, XRISM operations, and Resolve teams agreed to change the operational definition of SAA to match Resolve's definition in CalDB file v002, and it was necessary to change the CaldDB definition for Xtend to match this.

This update changes only SXI_SAA. SXI_SAA2 remains unchanged from the Astro-H version and should not be used for screening Xtend data without reassessment by the user.

4.2.1 Xtend data description

With this revision, the operational and Xtend definitions are made identical to the Resolve definition (SXS_SAA) of v002.

4.2.2 Xtend data analysis

The Resolve definition was adopted without modification.

4.3 Results

Table 4-1 shows the shared definition of SXS_SAA, SXI_SAA, and operational SAA.

Table 4-1 SXI_SAA and SXS_SAA

Longitude (deg)	-84	-92	-92	-66	-36	0	4	20	20
Latitude (deg)	-35	-24	-12	0	0	-20	-22	-22	-35

4.4 Remarks

Table 4-2 captures the history of the re-use of SAA definitions in different contexts from the intent of their original release, including operations. The operational definition is not tracked in the CalDB file, but in the table is associated with the contemporaneous CalDB version. Red, blue and green text is used to emphasize the definitions that are identical.

Defintion name	**v001**	**v002**	**v003**
SXS_SAA	Astro-H pre-launch, identical to SXI_SAA	Updated based on Resolve anti-co rate	Same as v002
SXI_SAA	Astro-H pre-launch, identical to SXS_SAA	Copied from v001-era operations	Copied from v002 SXS_SAA
Operations (Resolve MXS HV on/off and Xtend CCD acquisition on/off)	Developed for Astro-H operations, based on SXS anti-co rate.	Same as v001	Copied from v002 SXS_SAA

5 References

[1] Astro-H Science Data Center, INSTRUMENT CALIBRATION REPORT RIGIDITY AND SAA ASTH-GEN-CALDB-SAA
[2] Mochizuki, Y. *et al.* Optimization of x-ray event screening using ground and in-orbit data for the Resolve instrument onboard the XRISM satellite. in *Space Telescopes and Instrumentation 2024: Ultraviolet to Gamma Ray* (SPIE, Yokohama, Japan, 2024). doi:10.1117/12.3019453.