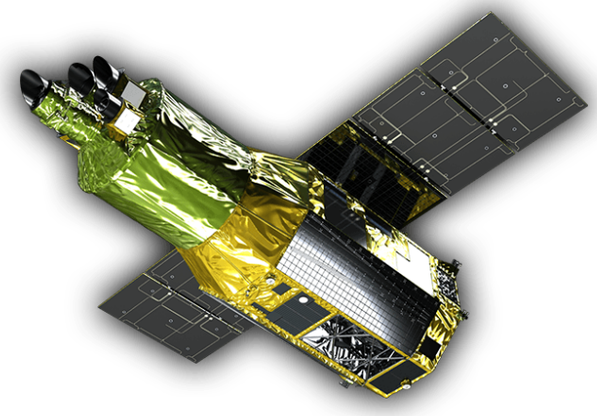
X-Ray Imaging and Spectroscopy Mission

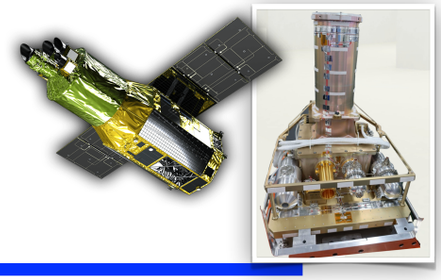


Xtend overview

Kenji Hamaguchi

Hiromasa Suzuki, Eric Miller and the *XRISM*/Xtend Team

XRISM Xtend team



18 institutes
> 50 members

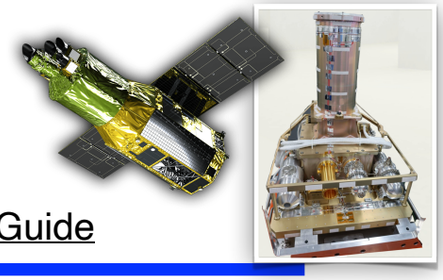
- **Tohoku Gakuin University**
  H. Murakami
- **Tokyo University of Science**
  S. B. Kobayashi, T. Kohmura
- **Kanto Gakuin University**
  H. Nakajima (sub-PI)
- **ISAS/JAXA**
  H. Suzuki, Y. Kanemaru, D. Ishi, T. Yoshida, H. Tomida, Y. Maeda, M. Ishida
- **Meiji University**
  T. Sato
- **Shizuoka University**
  H. Uchiyama
- **Nagoya University**
  K. Yamaoka
- **Kyoto University**
  H. Uchida, T. G. Tsuru
- **Nara University of Education**
  M. Nobukawa

- **Chuo University**
  T. Yoneyama
- **Kindai Universityo**
  K. K. Nobukawa
- **the University of Tokyo**
  K. Hagino
- **Tohoku University**
  H. Noda
- **Osaka University**
  H. Matsumoto, H. Odaka, K. Hayashida
- **Konan University**
  T. Tanaka
- **University of Miyazaki**
  K. Mori (PI), M. Yamauchi, I. Hatsukade
- **NASA's GSFC**
  T. Okajima, Y. Soong, T. Hayashi, K. Tamura
- **University of Maryland**
  R. Boissay-Malaquin
- **Students**

  R. Azuma, H. Asahina, S, Nakamura, T. Kamei, S. Fukuda, M. Yoshimoto, T. Hakamata, M. Aoyagi, K. Shima, S. Inoue, Y. Aoki, Y. Ito, D. Aoki, K. Ninoyu, Y. Shimizu, M. Higuchi, Y. Otsuka, H. Yokosu, W. Yonemaru, K. Ichikawa, H. Nakano, R. Takemoto, T. Matsushima, R. Urase, J. Kurashima, K. Fuchi
- **Advisor, MOPT/SOC (joint work)**

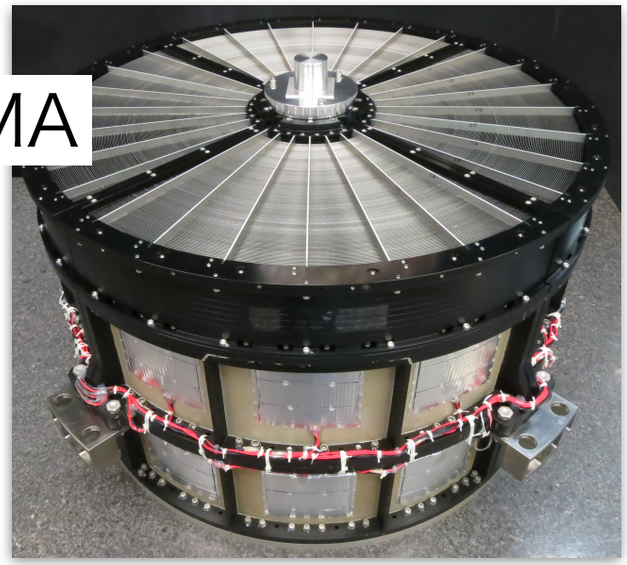
  J. S. Hiraga, M. Ozaki, T. Dotani, H. Tsunemi, T. Mizuno

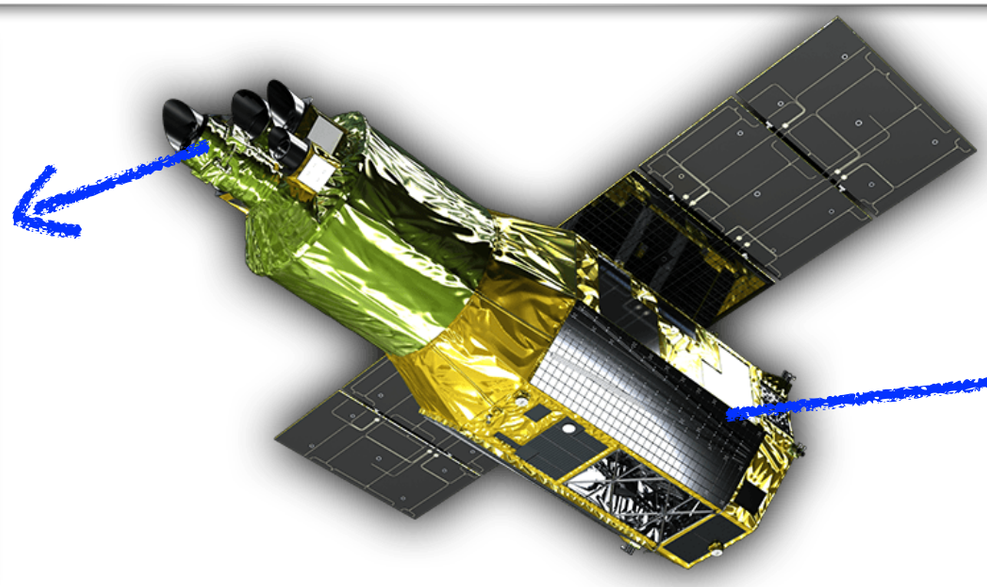
XRISM Xtend



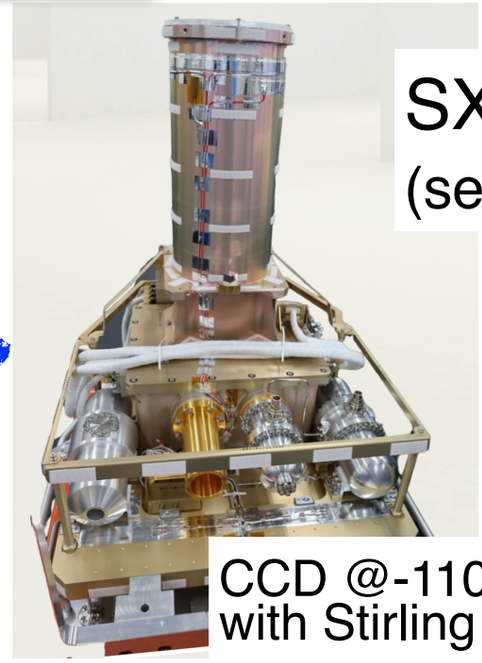
Xtend = XMA (X-ray Mirror Assembly) + SXI (Soft X-ray Imager)

XMA





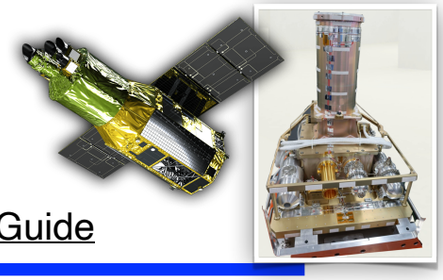
SXI-S
(sensor)



CCD @-110 degC
with Stirling cooler

- **XMA**：Wolter type I mirror optics
  - ✓nearly identical to Hitomi SXT
- **SXI**：X-ray CCDs
  - ✓nearly identical to Hitomi SXI
  - ✓fully-depleted back-illuminated P-channel CCD
- Energy range：0.4–13 keV
- FoV：38’ × 38’
- Energy resolution：~180 eV @5.9 keV
- Ang. resolution：~1.47’ (Half Power Diameter)

XRISM Xtend



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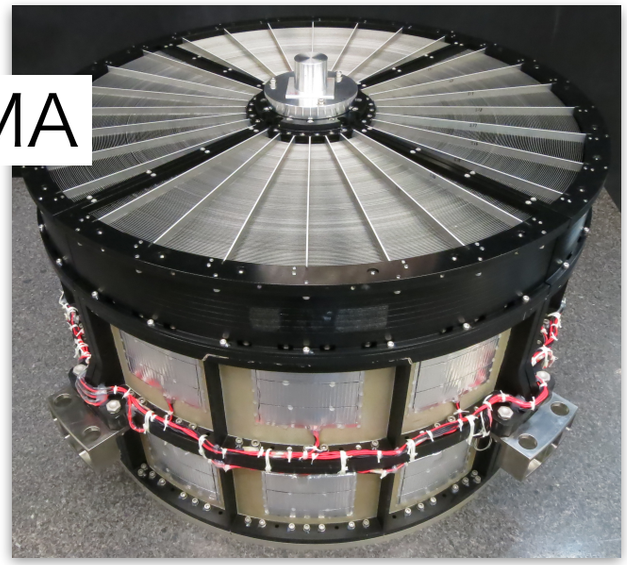
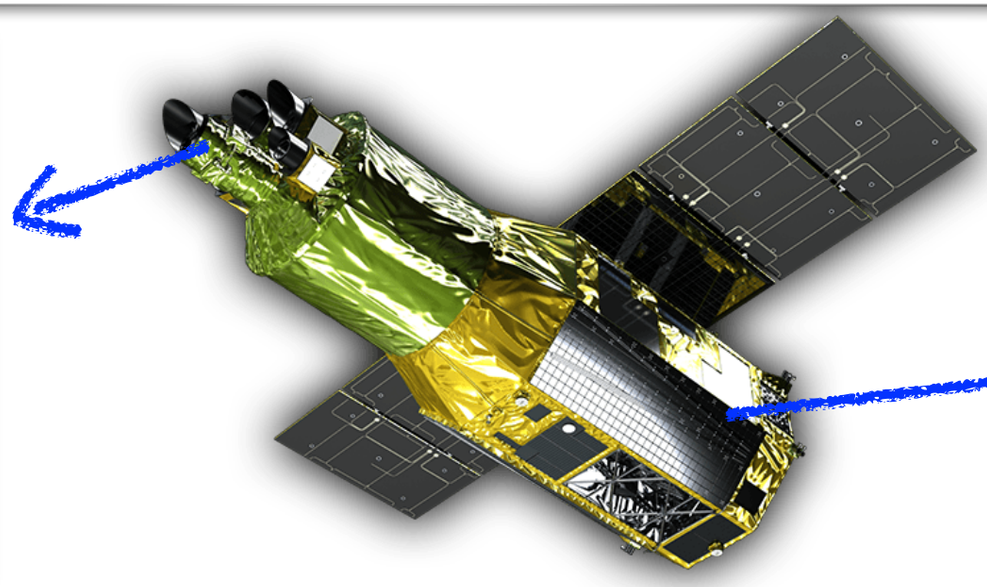
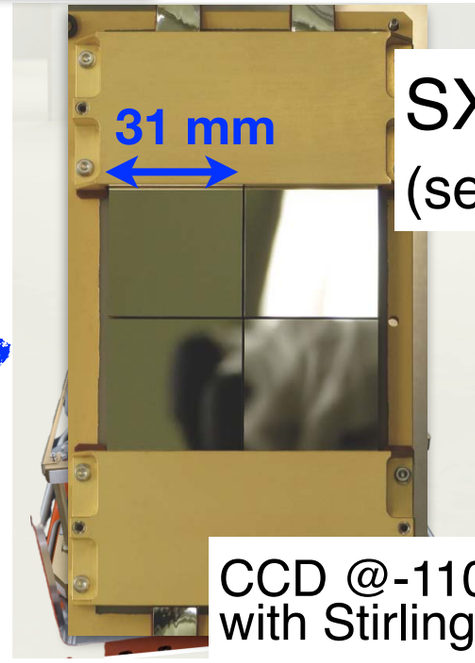
XMA







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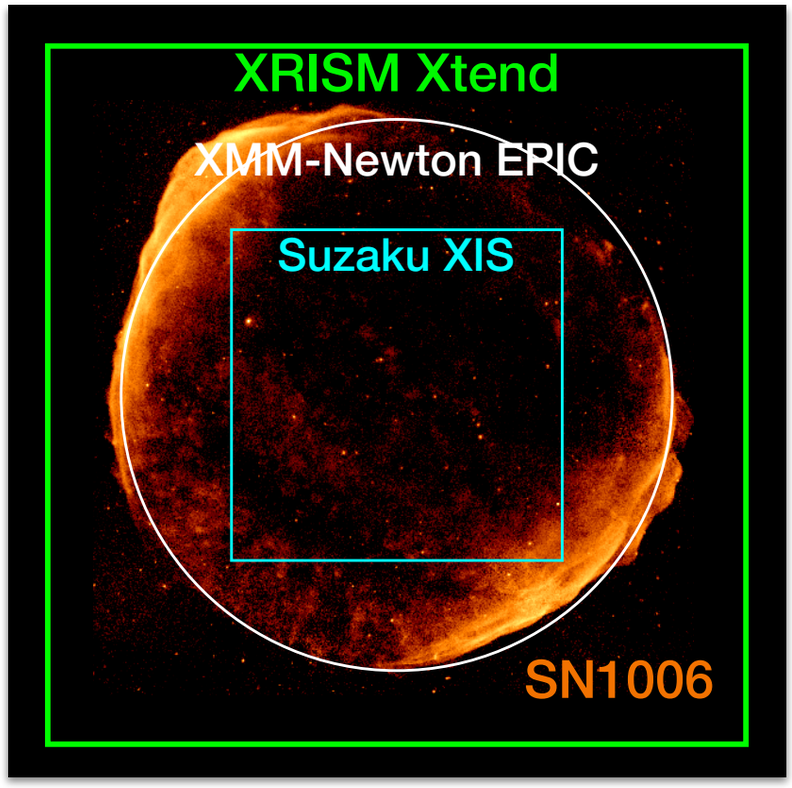
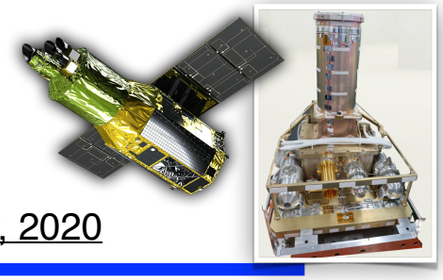
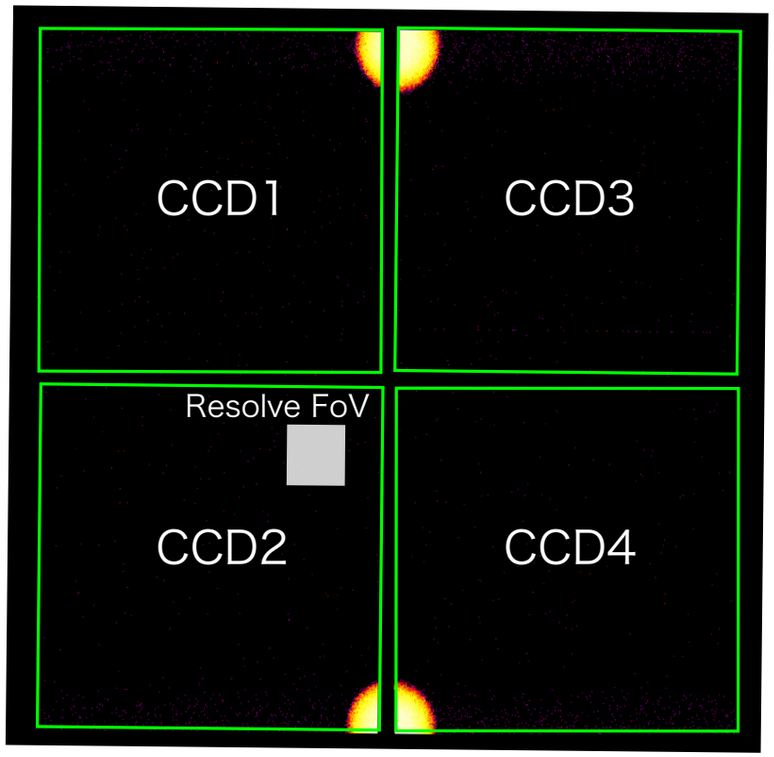


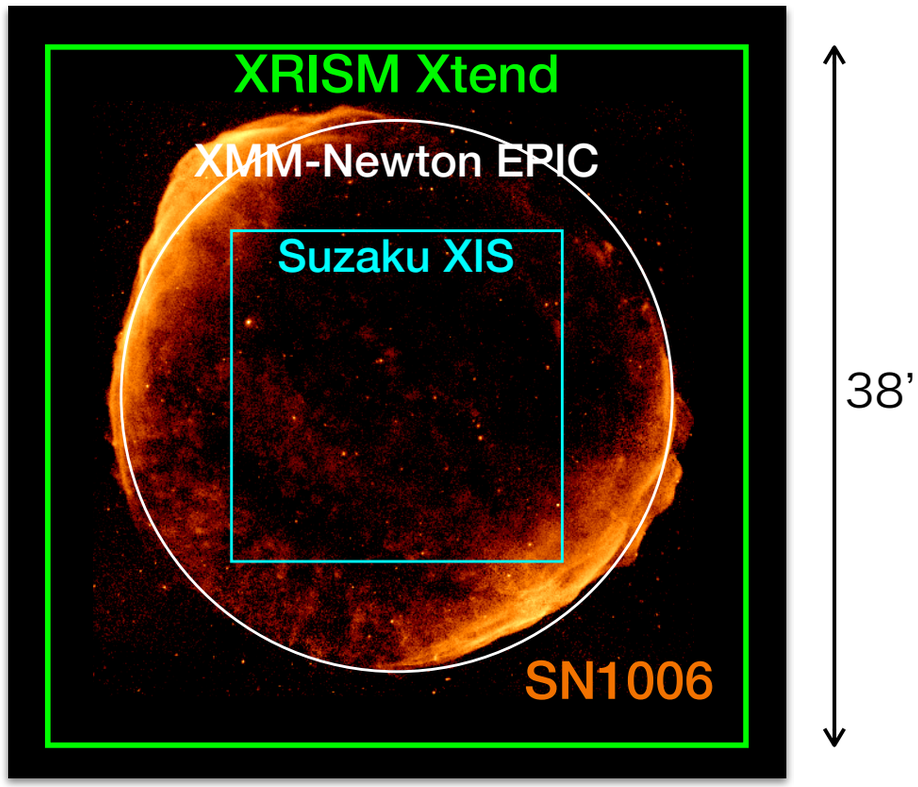
Xtend Characteristics

XRISM white paper, 2020

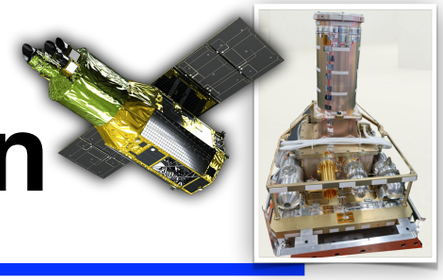


- **A large field of view (FOV)**
  → Xtend can find sources outside Resolve FOV.
- **Better pixel resolution than Resolve**
  → Xtend can resolve extended source structure better.
- **Sensitivity down to 0.4 keV**
  → Xtend provides soft X-ray (<1.7 keV) spectra and light curves

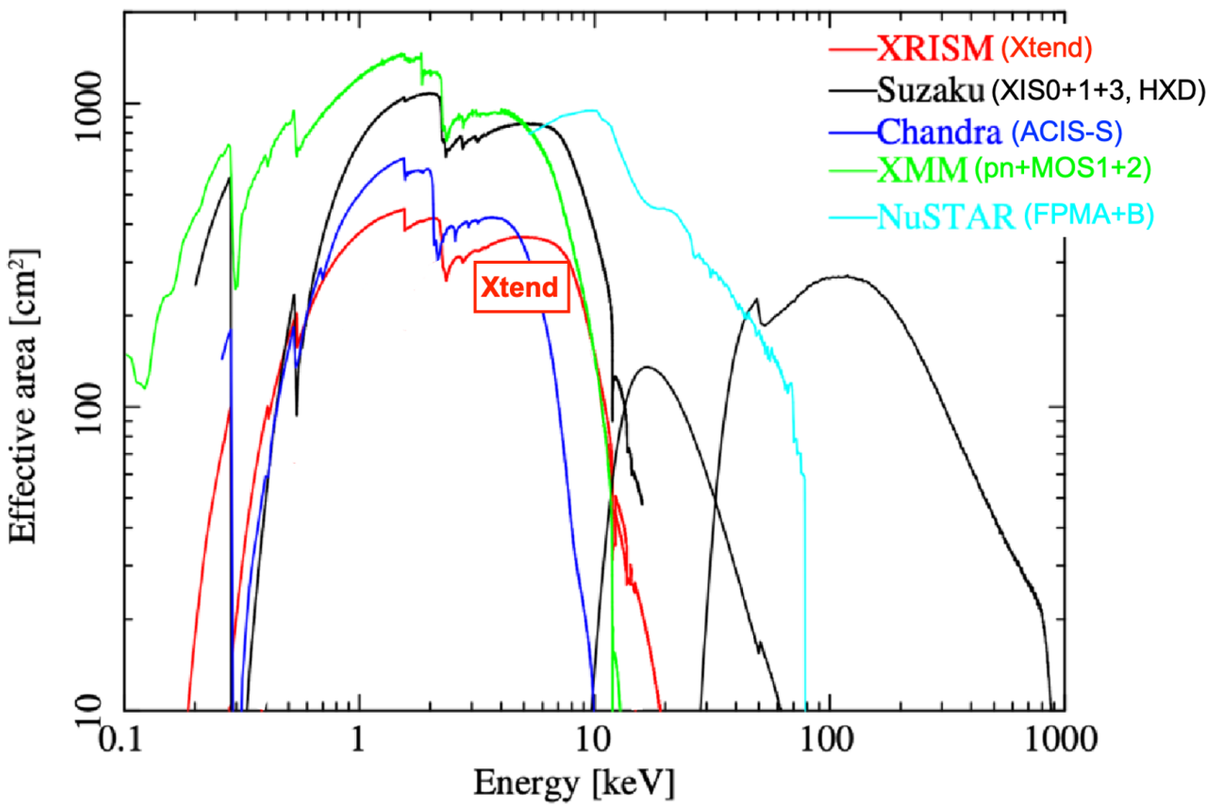


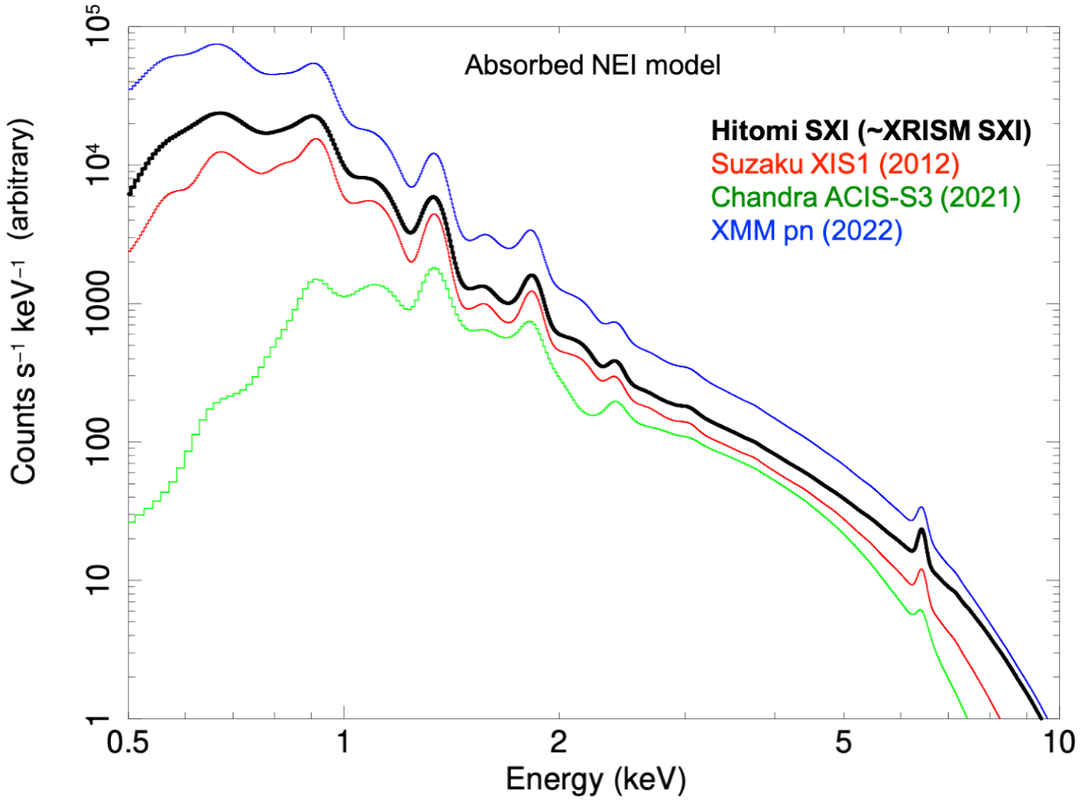


Effective Area & Energy Resolution



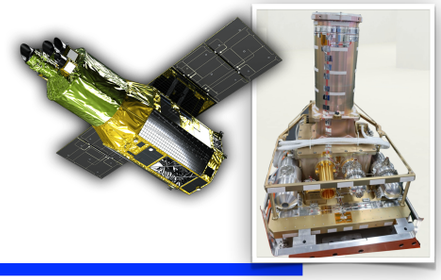
- Effective area
  - Soft band: ~*Chandra*/ACIS
  - Hard band*: ~XMM*/EPIC
- Energy Resolution
  - Similar to CCDs on other X-ray observatories



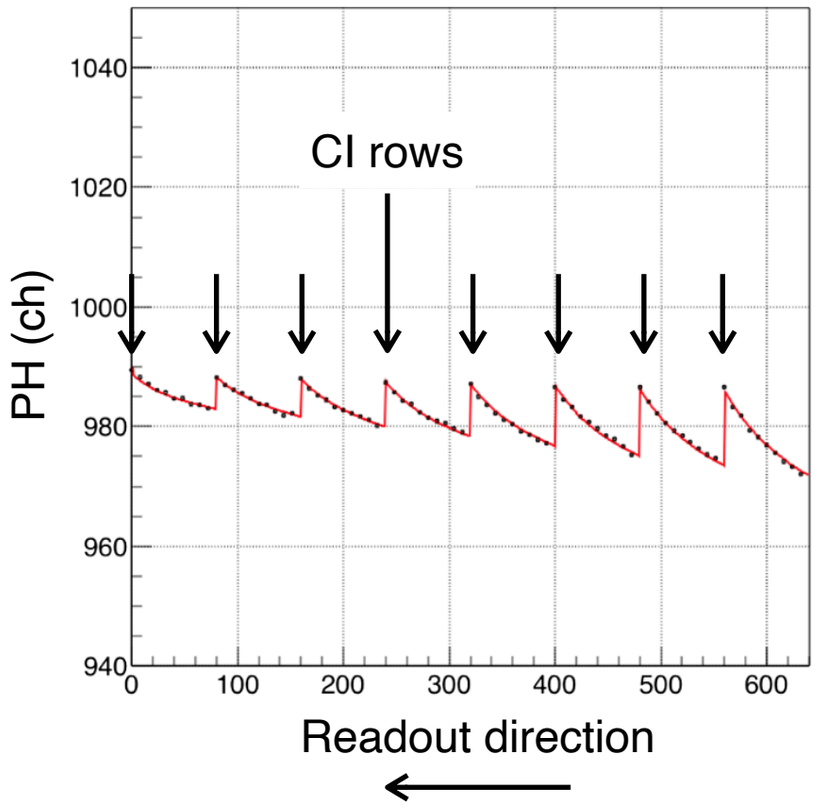


CCDs

Tanaka et al. 2018



- Frame exposure time: 0.06–3.96 sec, depending on the modes.
- Charge Injection (CI) technique:
  - injects artificial charges to minimize charge transfer inefficiency
  - used for *Suzaku* XIS/*Hitomi* SXI



- Mind the gaps between CCDs
  - 40”–60”
- Point source PSF cores may fall into them.

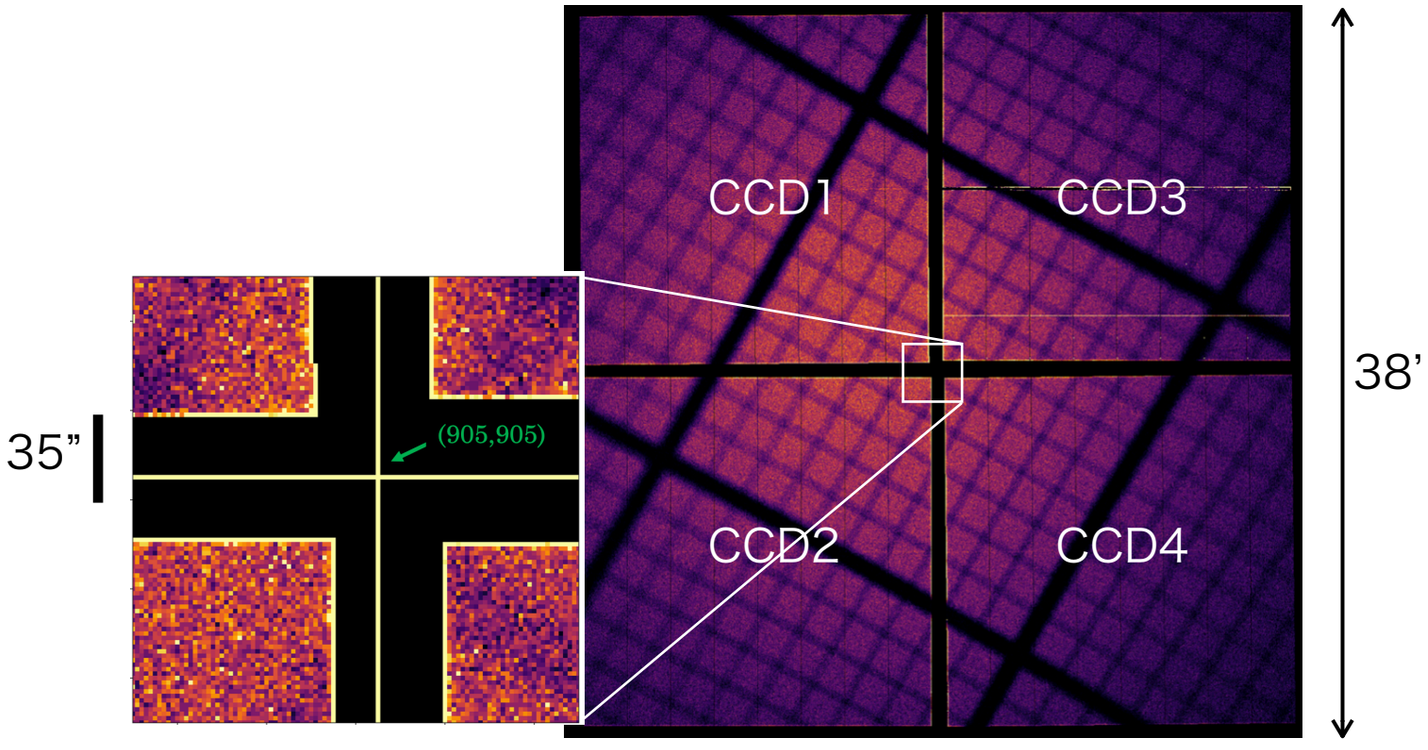
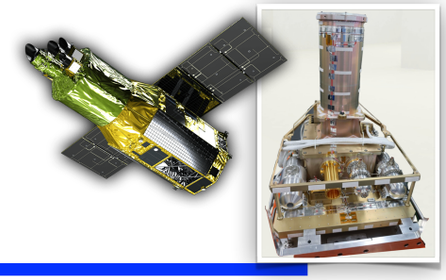


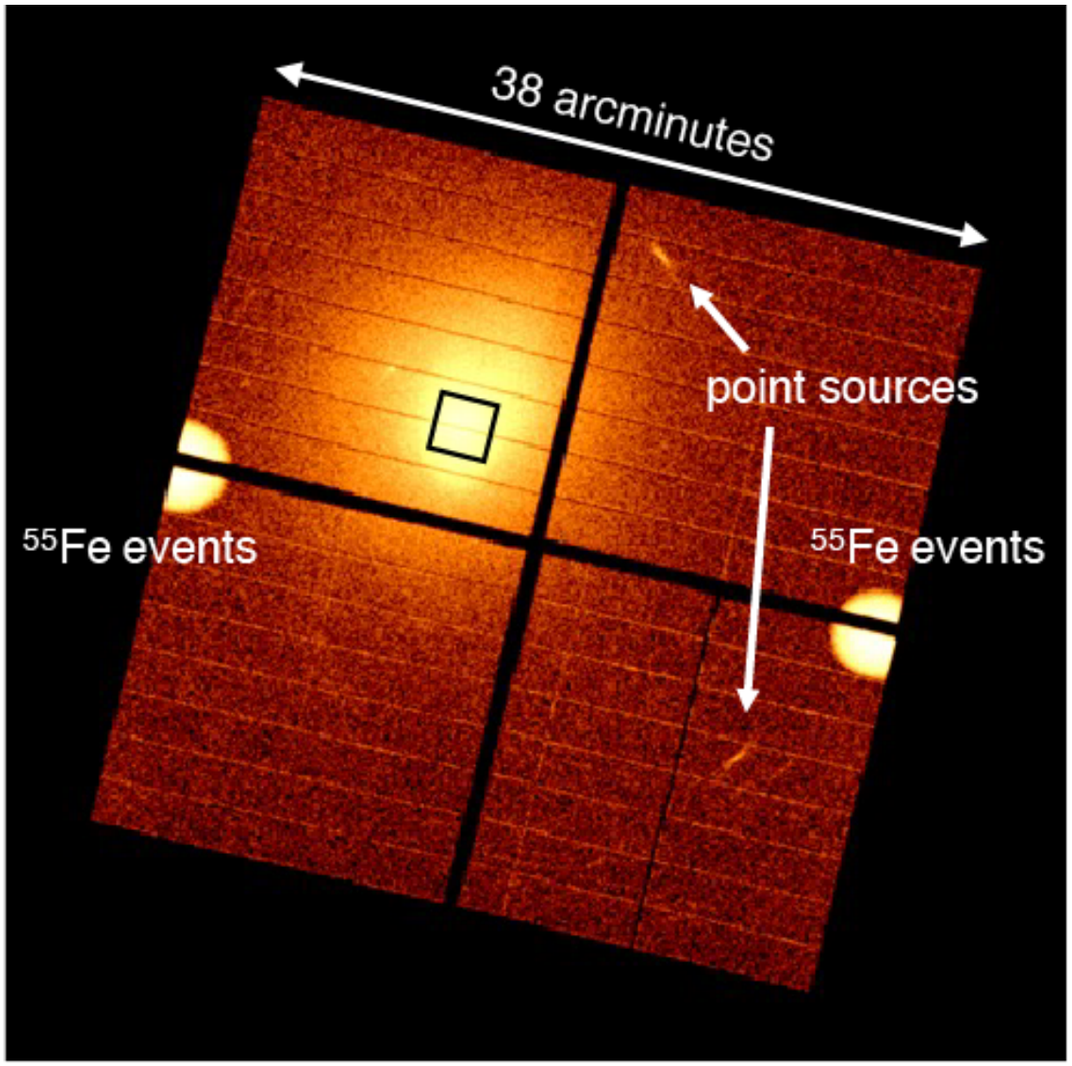
Image (First Light)

Mori et al. 2024

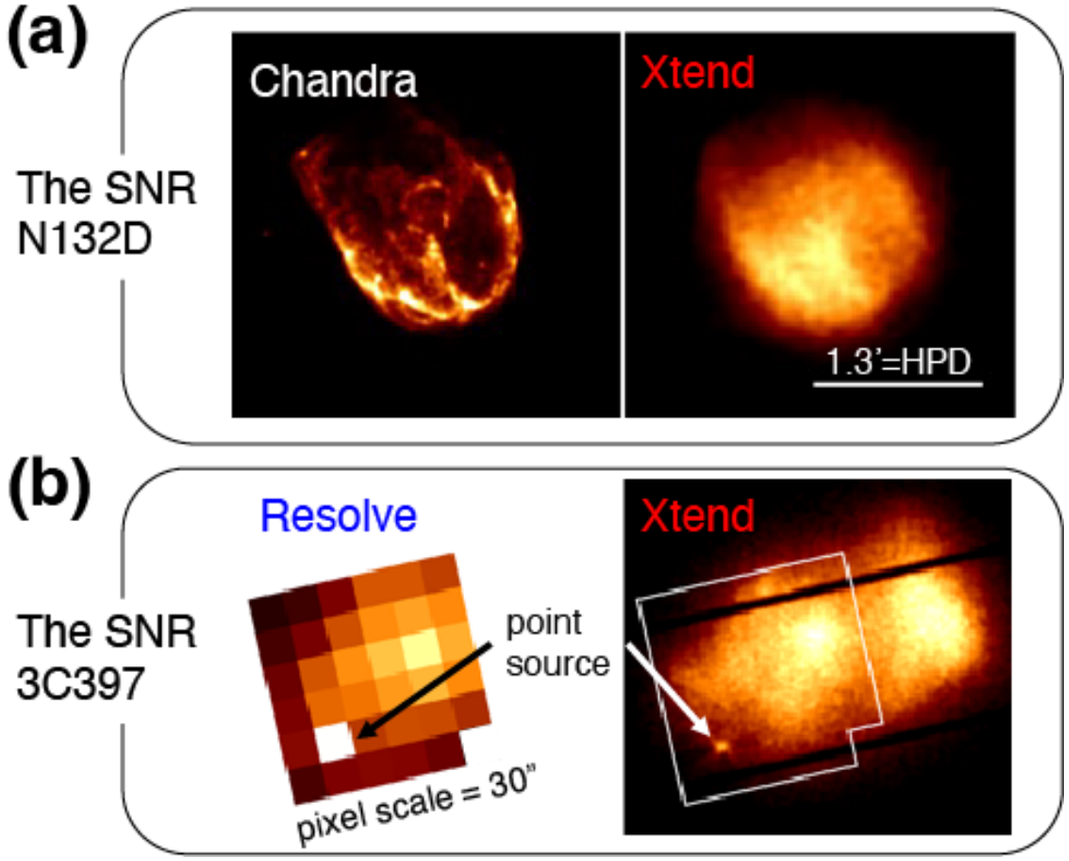
Tamura et al. 2022



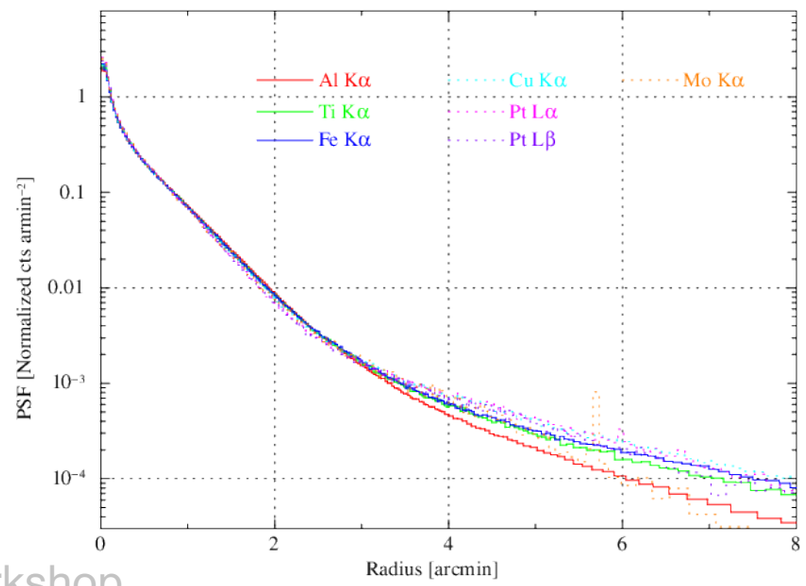
- Abell 2319



- N132D

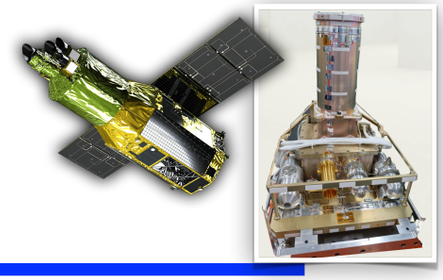


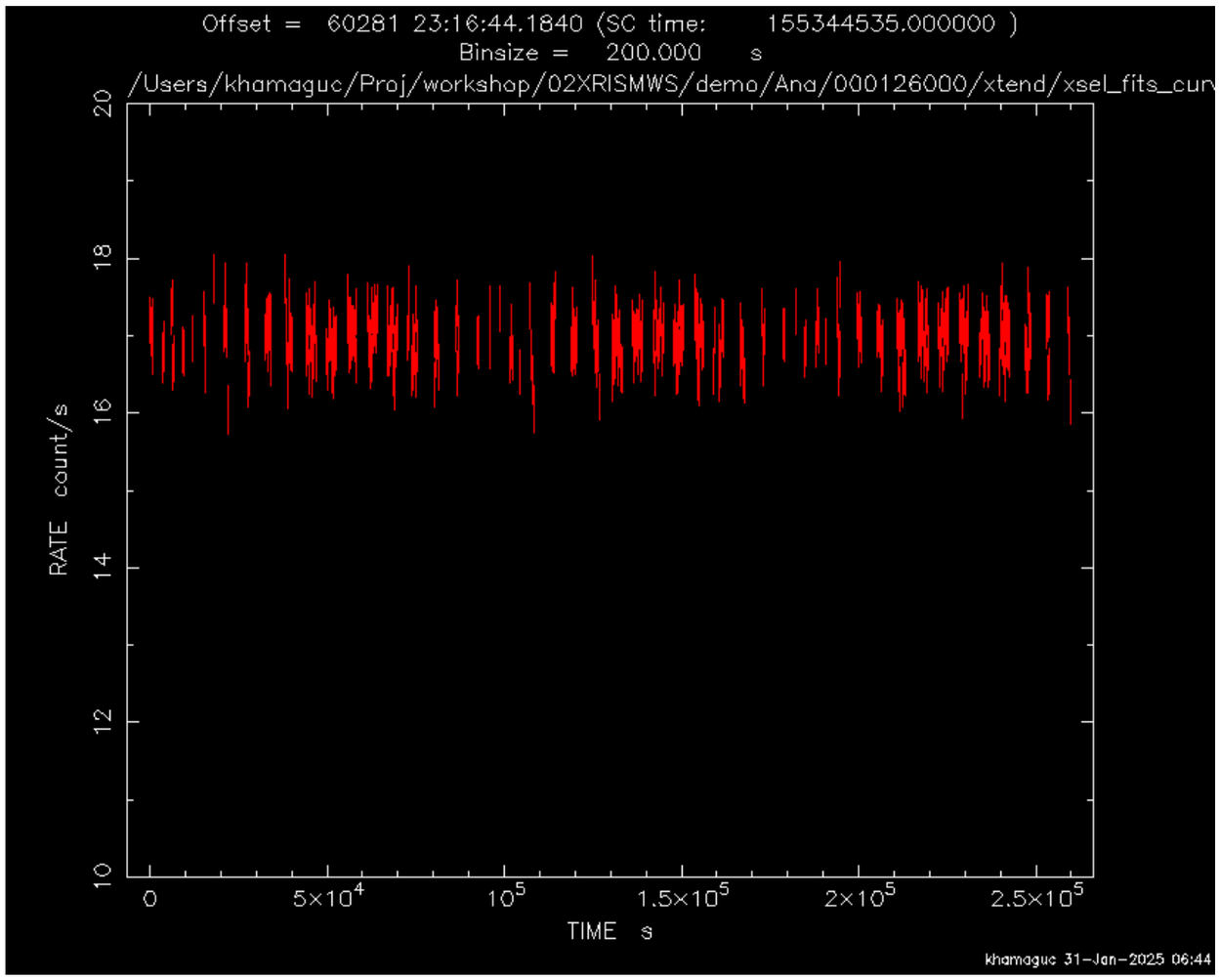
- PSF

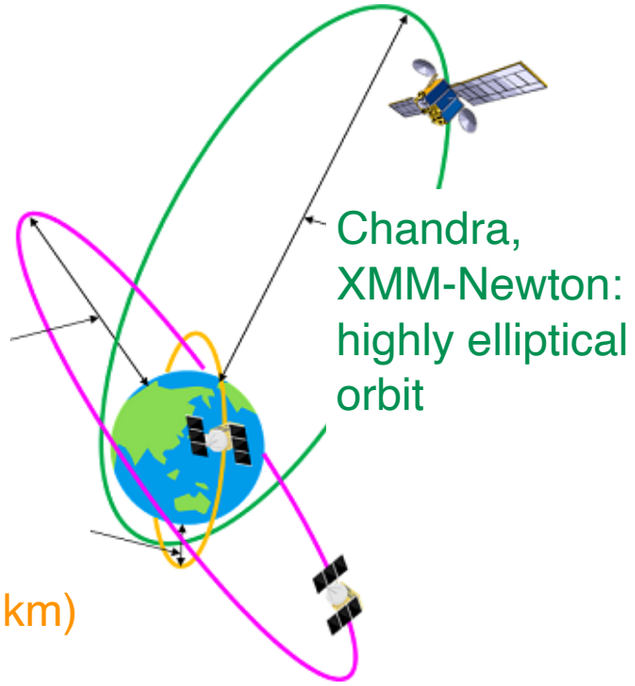


- A Charge injection row went over the aim point…
  - The team shifted the rows later.

Light Curve

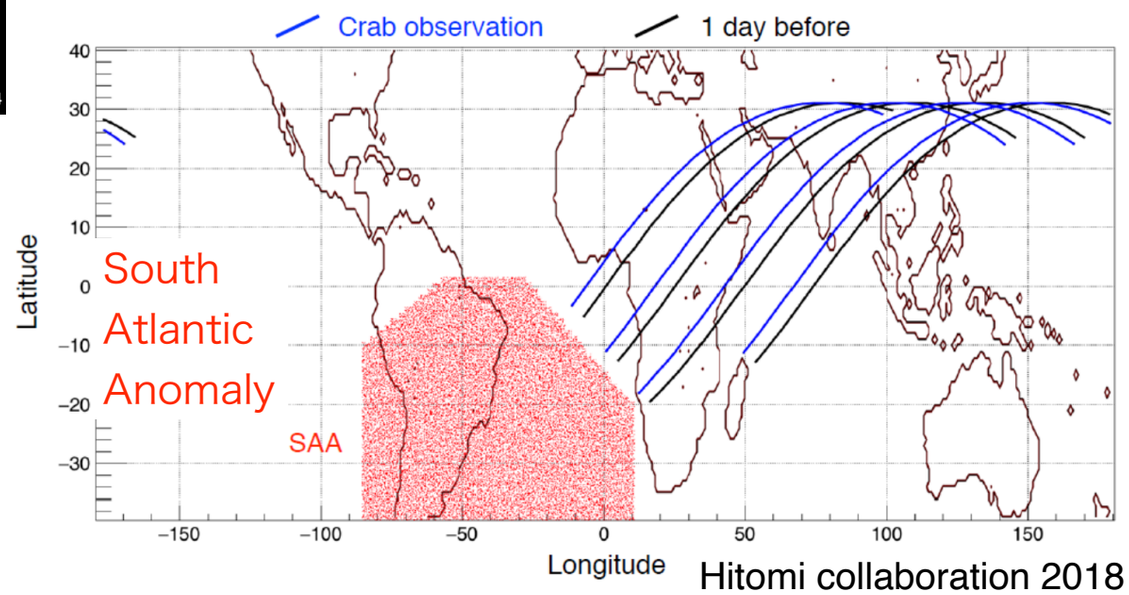






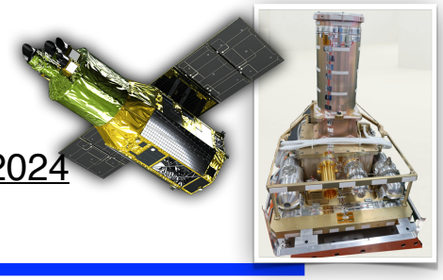
A gap every XRISM low Earth orbit (*P* ~96 min).

- Earth occultation
- Day Earth
- South Atlantic Anomaly

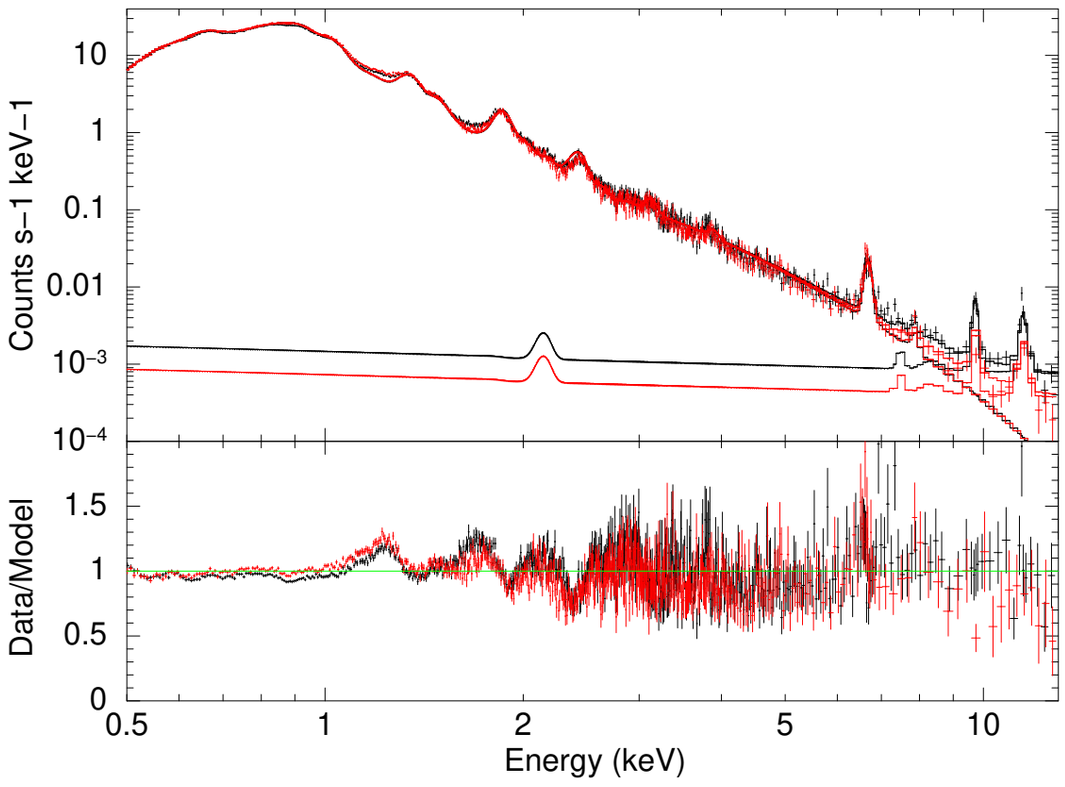


Hitomi collaboration 2018

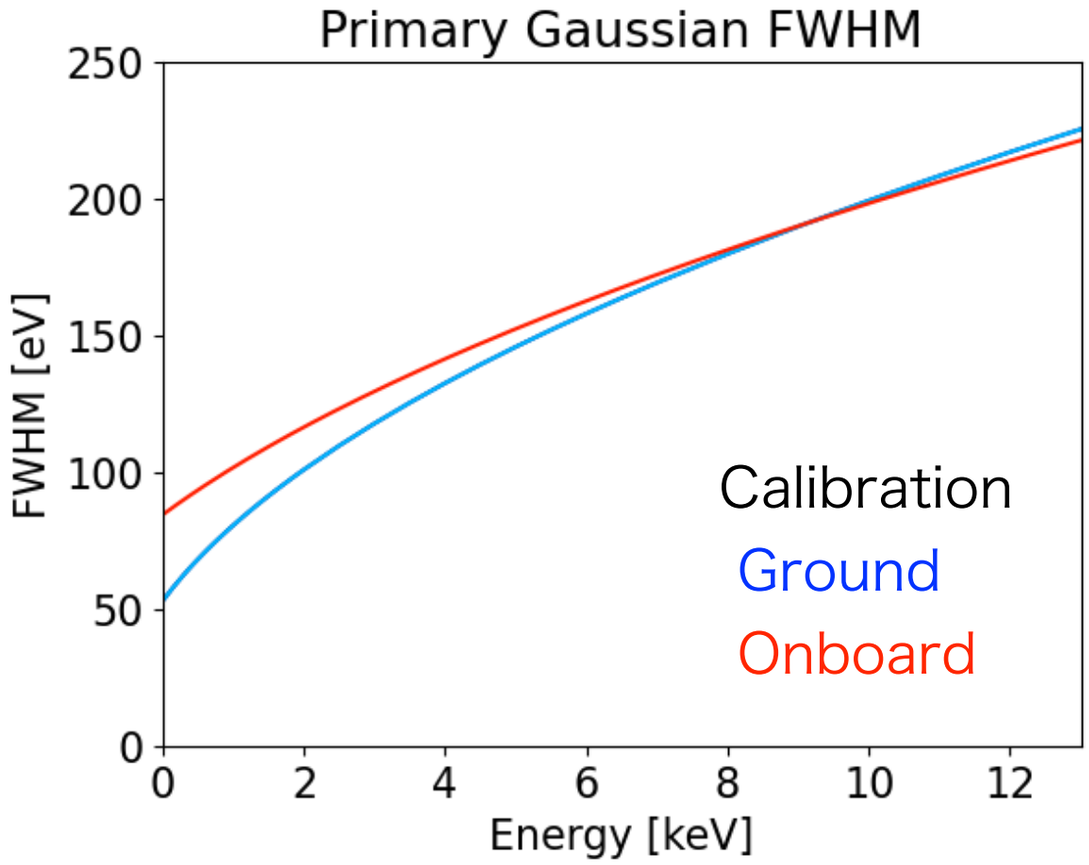
Spectrum



- N132D



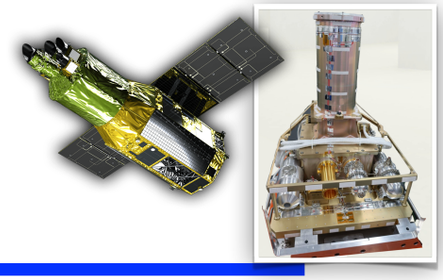
- Energy Resolution Calibration



- Xtend can resolve multiple emission lines.

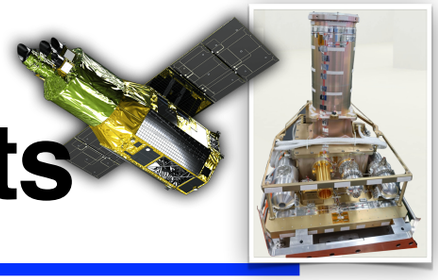
- The onboard calibration is partly included in CALDB241115.
- More updates are coming in the future CALDB release.

Hot / Flickering Pixels



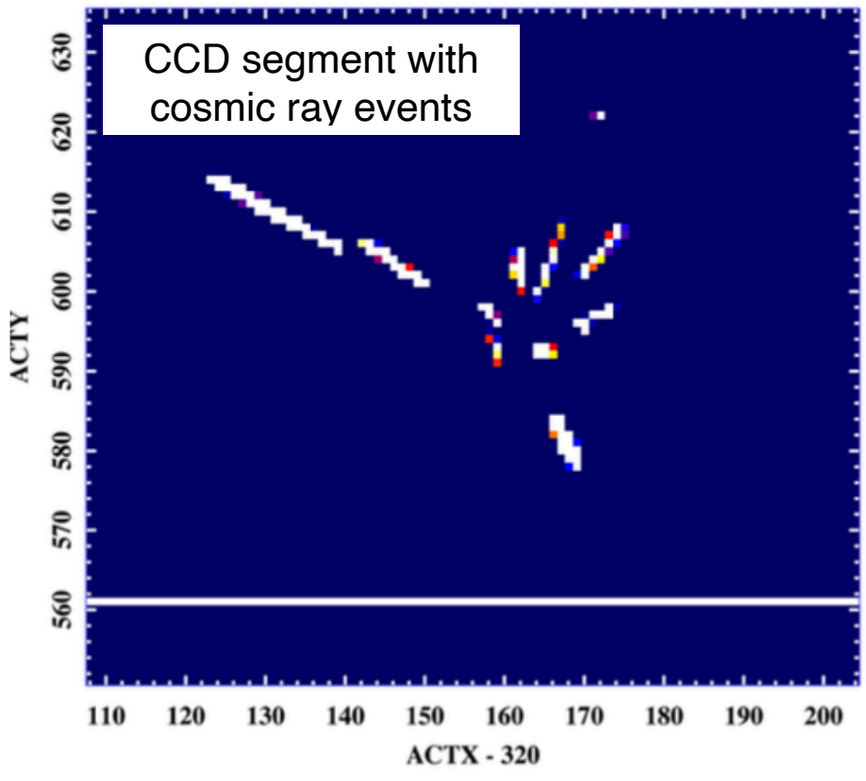
- Defects in the CCD silicon lattice produce charge currents without X-ray or particle events.
  - Hot pixels/columns: permanent.
    - The instrument team registers the locations in a CALDB file.
  - Flickerling pixels: occasional
    - The tool `searchflickpix` searches for flickering pixels in a given dataset and finds pixels detected above a threshold defined from statistical probability.
- The Xtend team has not seen many hot pixels yet.

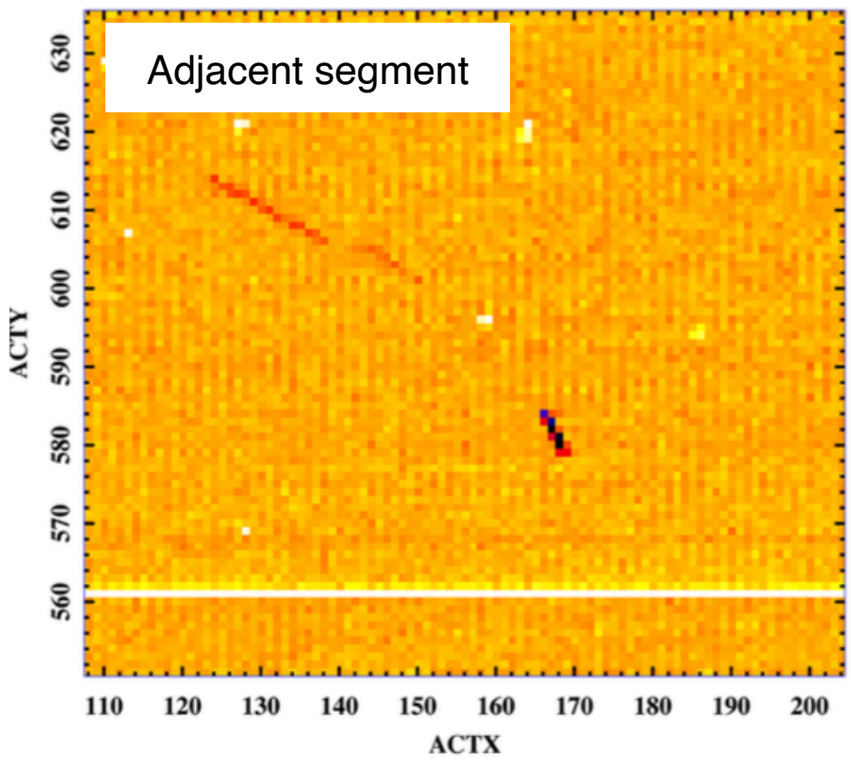
Cosmic Ray Echo (Crosstalk) Events



- Crosstalk with cosmic-ray signals shifts the dark (zero) levels of pixels in the adjacent segment to negative values.
- The net pulse heights are consistently above the event threshold.
- Those pixels detect events until a dark level reset after a day.
- The Xtend team is preparing HEASoft tools to mitigate or correct the problem.

Crosstalk due to cosmic ray events





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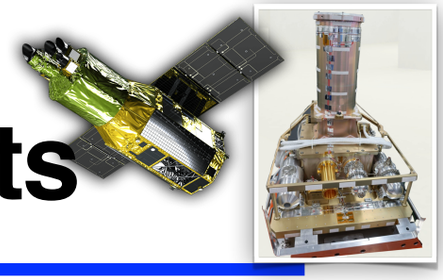
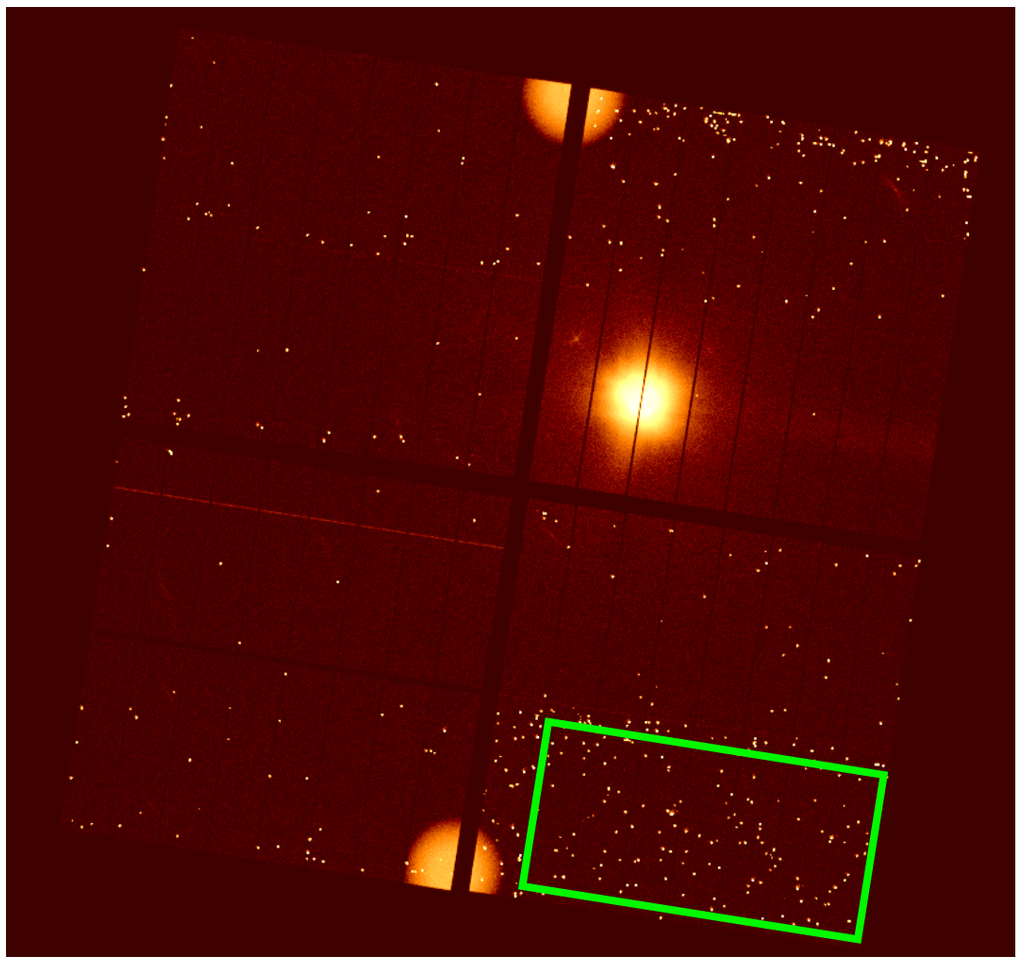
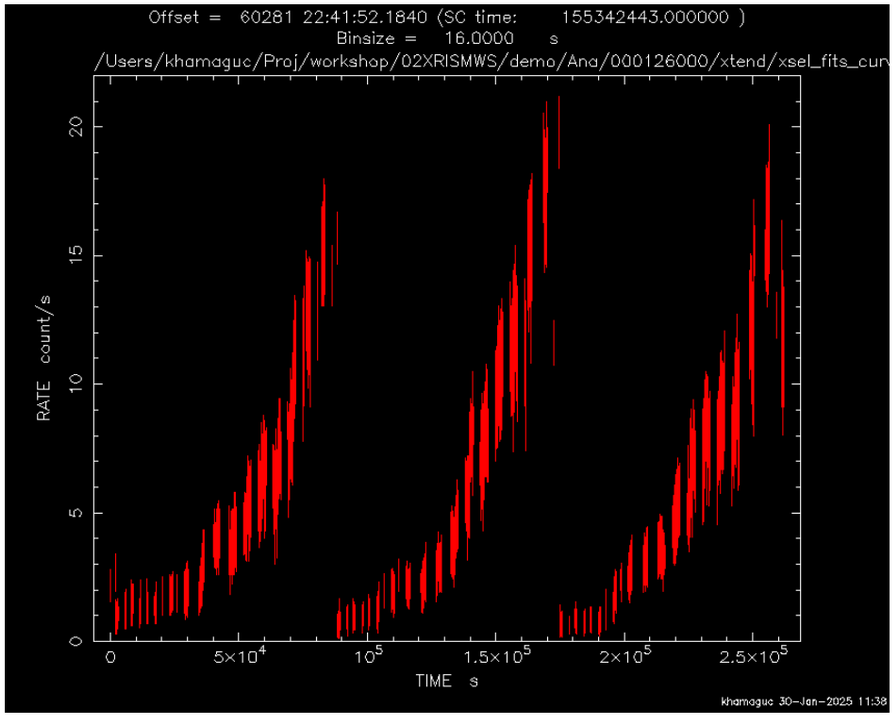
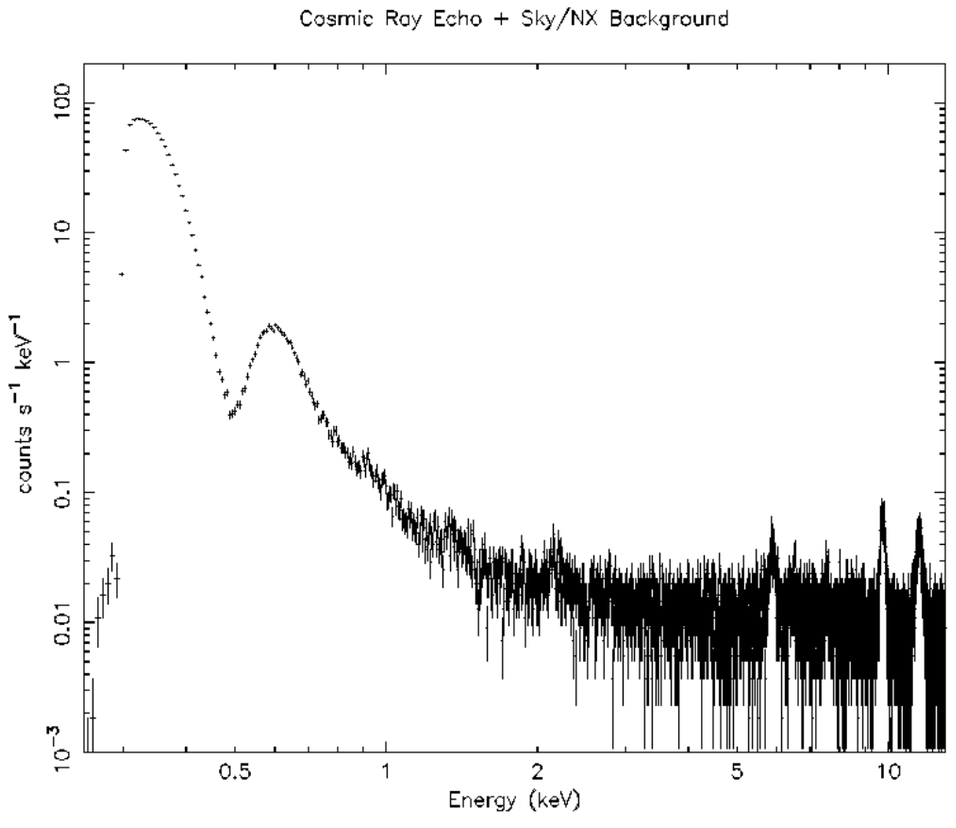


- Few cosmic ray echo pixels near the aim point
- Those events are seen mostly below ~0.4 keV

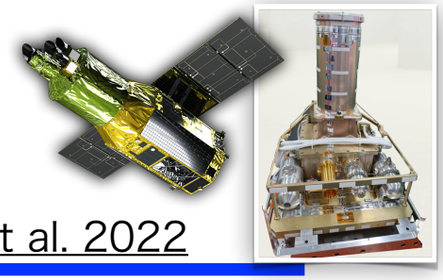


N132D (ObsID: 000126000)
no energy filter



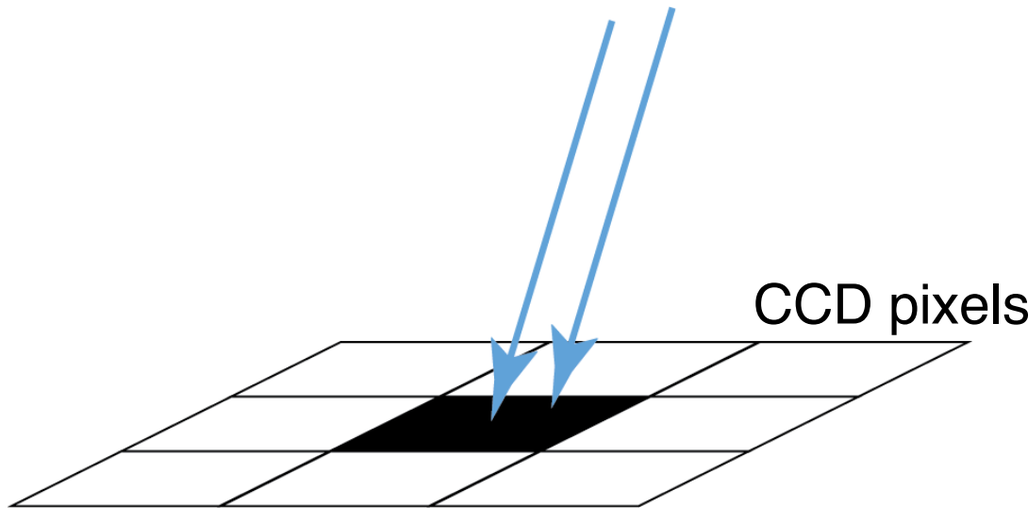


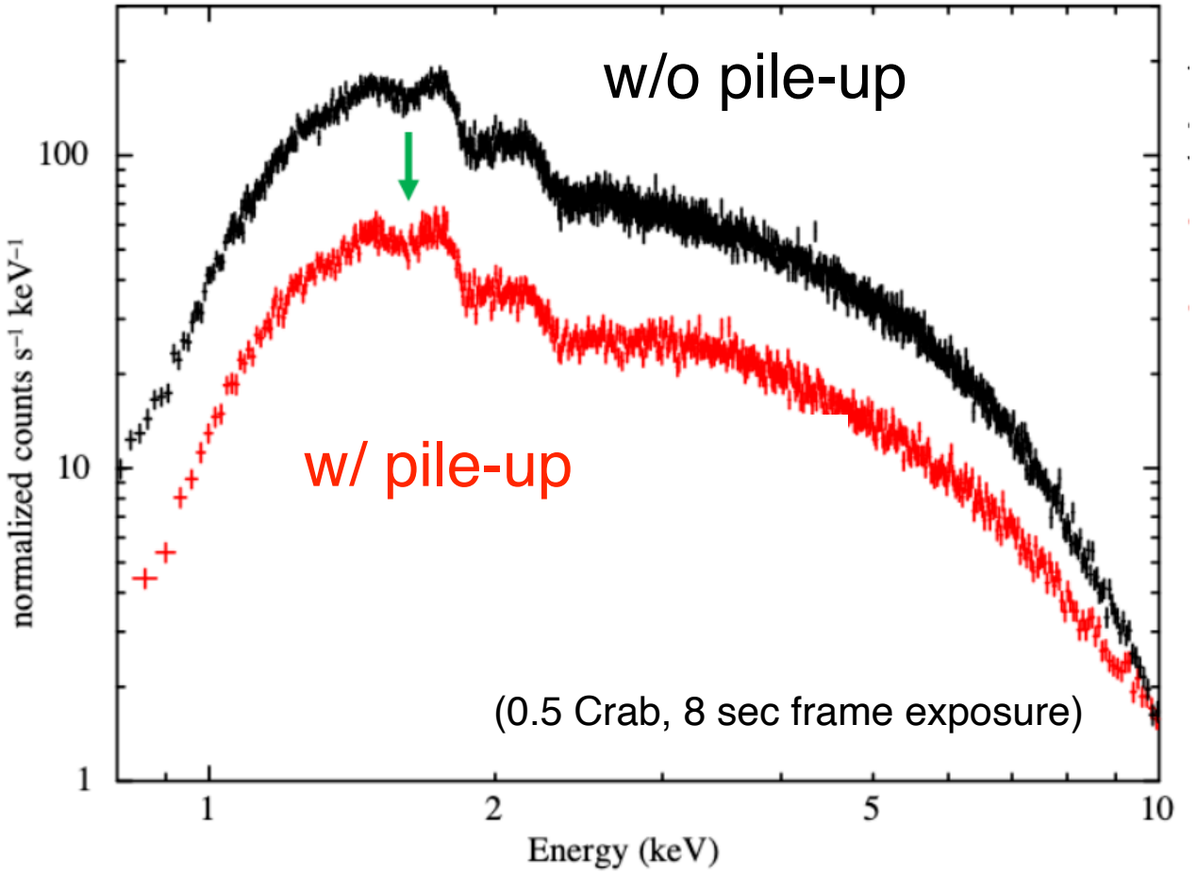
Bright Point Source Data



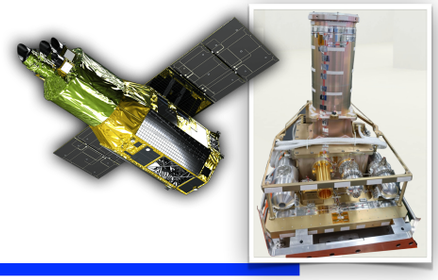
Tamba et al. 2022

- Photon Pile-ups
  - Two photons hit a 3x3 (or 5x5) pixel in a single exposure (4 sec).
  - Full frame mode: >~2.5mCrab
  - 1/8 window (burst) mode has a shorter frame exposure, tolerable to brighter sources.



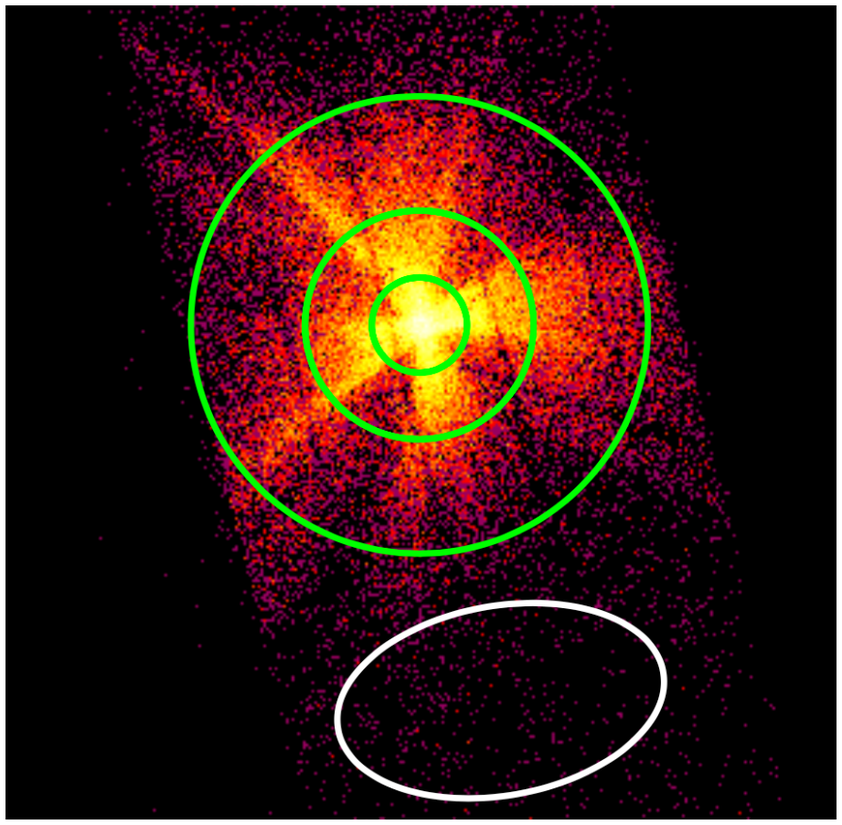


Analyzing Bright Point Sources

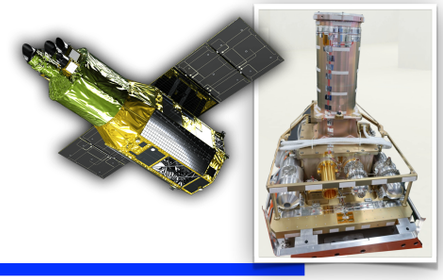


- If a source suffers photon pile-ups,
  - try to avoid this with an appropriate observation mode.
  - exclude the PSF core with pile-up events.
  - use a simulator or pile-up model, which isn't provided.

Tamba et al. 2022



Observations

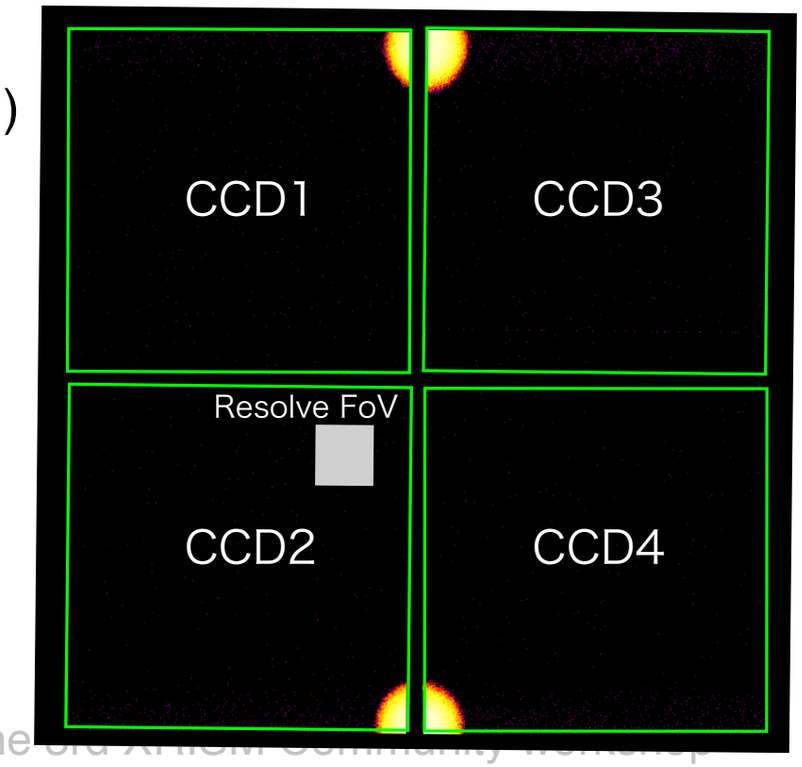


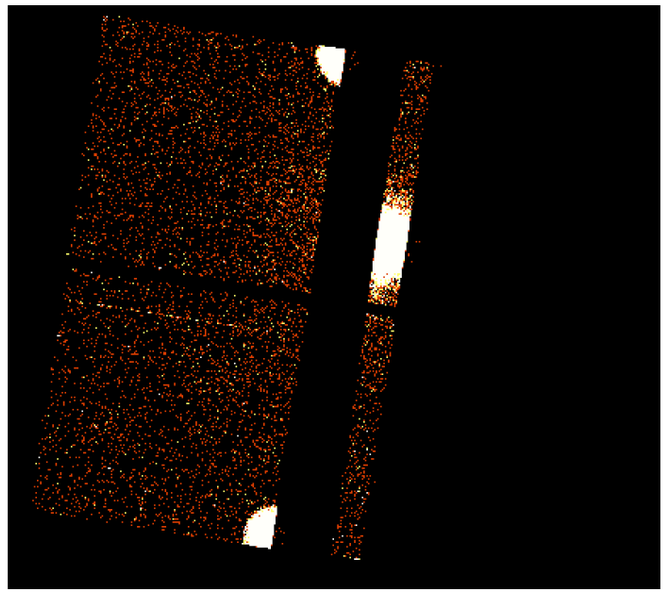
Mori et al. 2024

- Observation modes

Mode	Region size	Frame exposure	Time resolution	Exp per Frame	Live time fraction	Purpose
Full window	1	3.96 sec	4.0 sec	1	0.99	General
1/8 window	1/8	0.46 sec	0.46 sec	8	0.93	Bright/variable sources
1/8 window + 0.1-s	1/8	0.06 sec	0.06 sec	8	0.12	Bright/variable sources
0.1-s burst	1	0.06 sec	0.06 sec	1	0.015	Crab mode, not for users

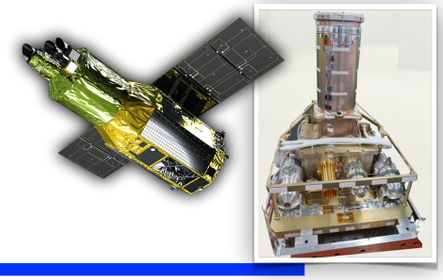
* 1/8 win. & win.+burst: only applied to CCDs 1 & 2 (i.e., CCDs 3 & 4 are Full win.)





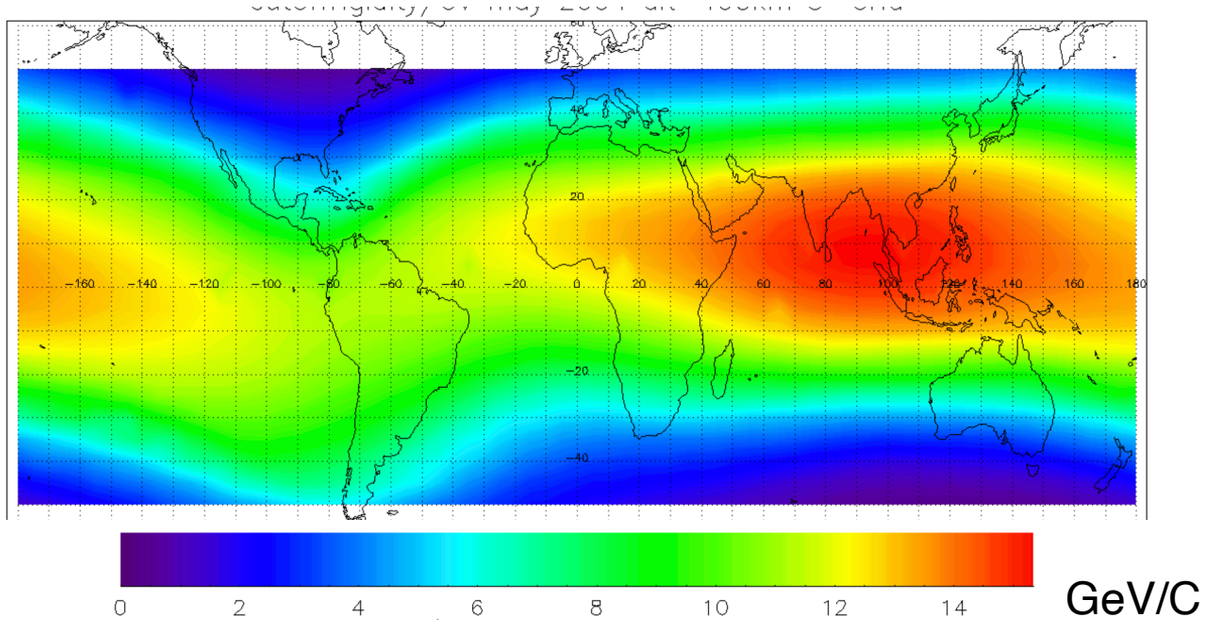
1/8 window

Non X-ray Background

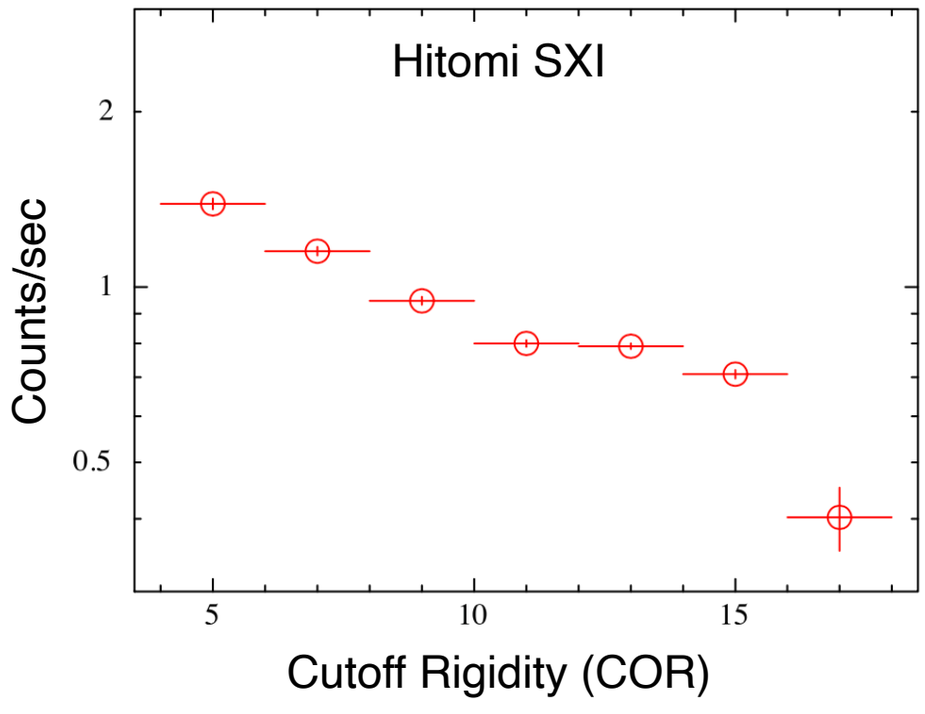


- Cosmic ray particles
  - produce charges in CCD pixels on their tracks, and
  - stimulate instrument bodies, which emit fluorescent X-rays.
  - These components are called Non-X-ray Background, or NXB
- Event screening removes most NXB events but not all of them.
- NXB intensity varies with
  - cutoff rigidity value
  - detector coordinates along the readout direction
  - the solar activity (occasionally).

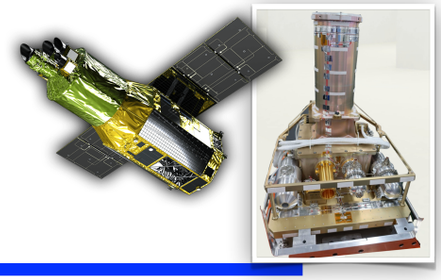
Color: Cutoff Rigidity (COR)



Nakajima et al. 2018

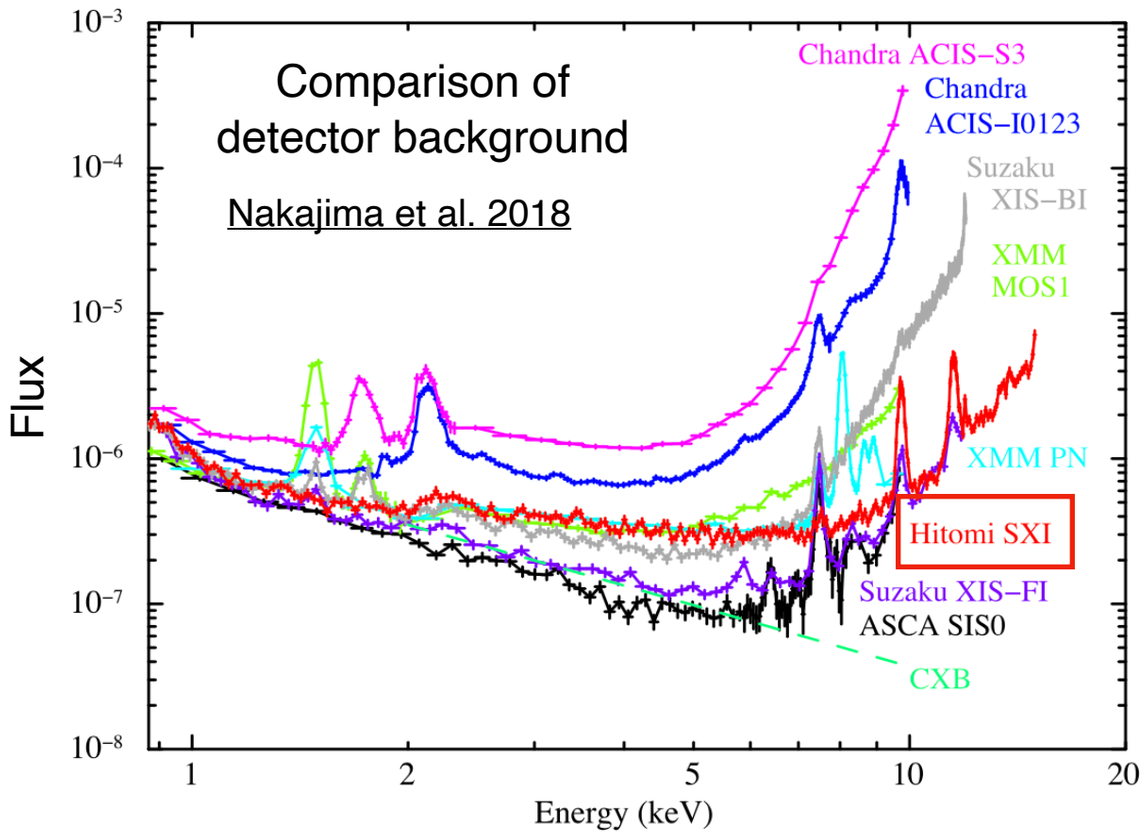


Non X-ray Background

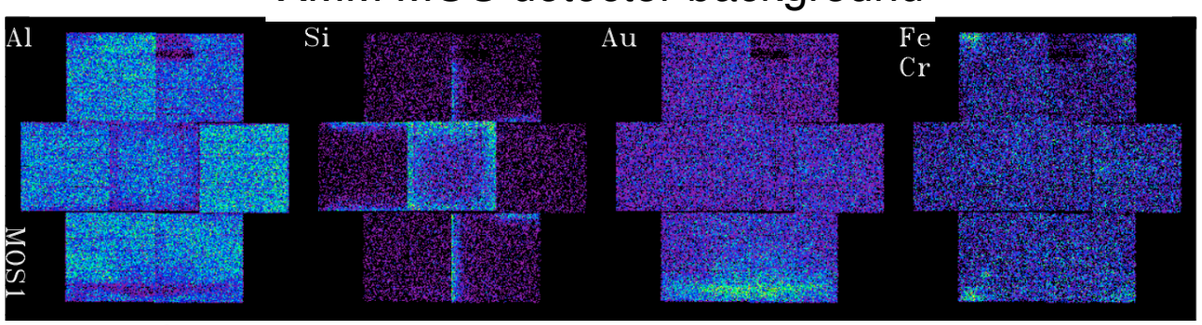


- Earth's magnetosphere blocks cosmic-ray particles

➡ Relatively small NXB constitution

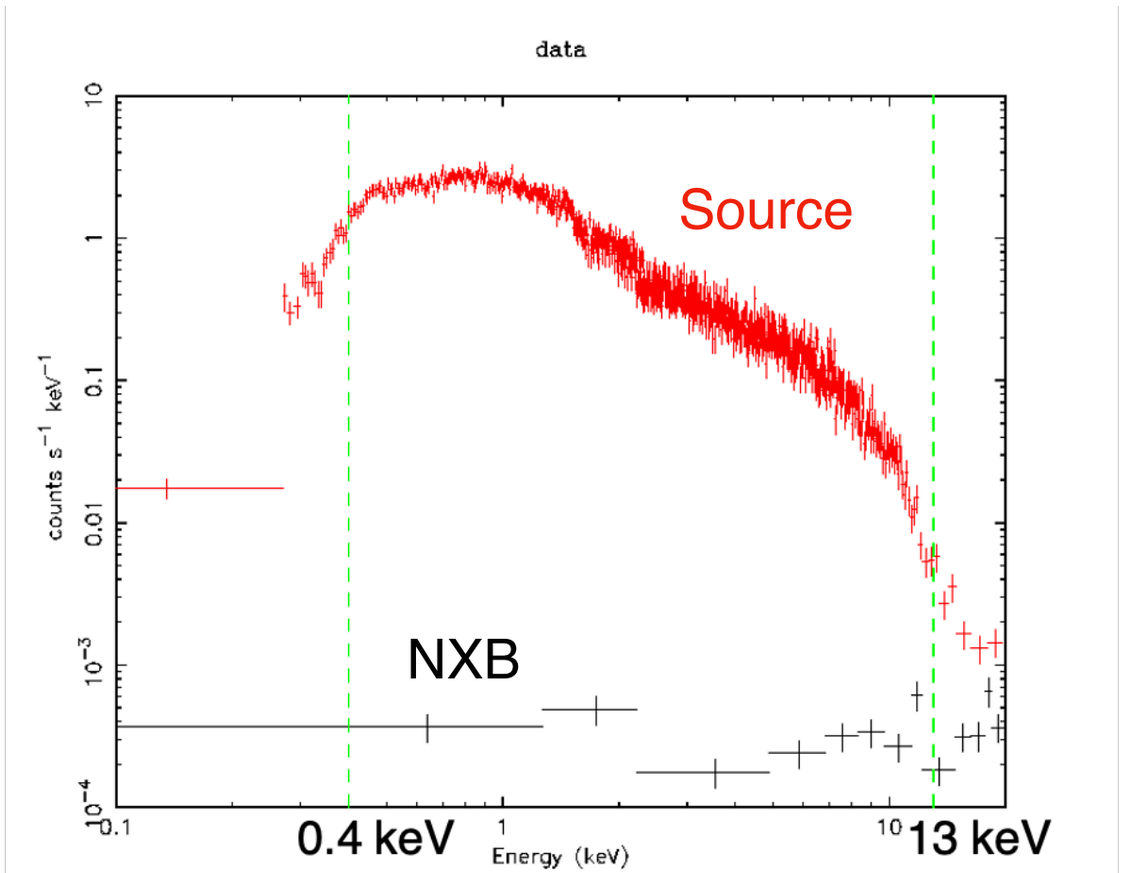


XMM MOS detector background



Kuntz & Snowden 2008

- We accumulate data when *XRISM* sees night Earth.
- `Xtdnxbgen` estimates NXB during on-source observations using the data.

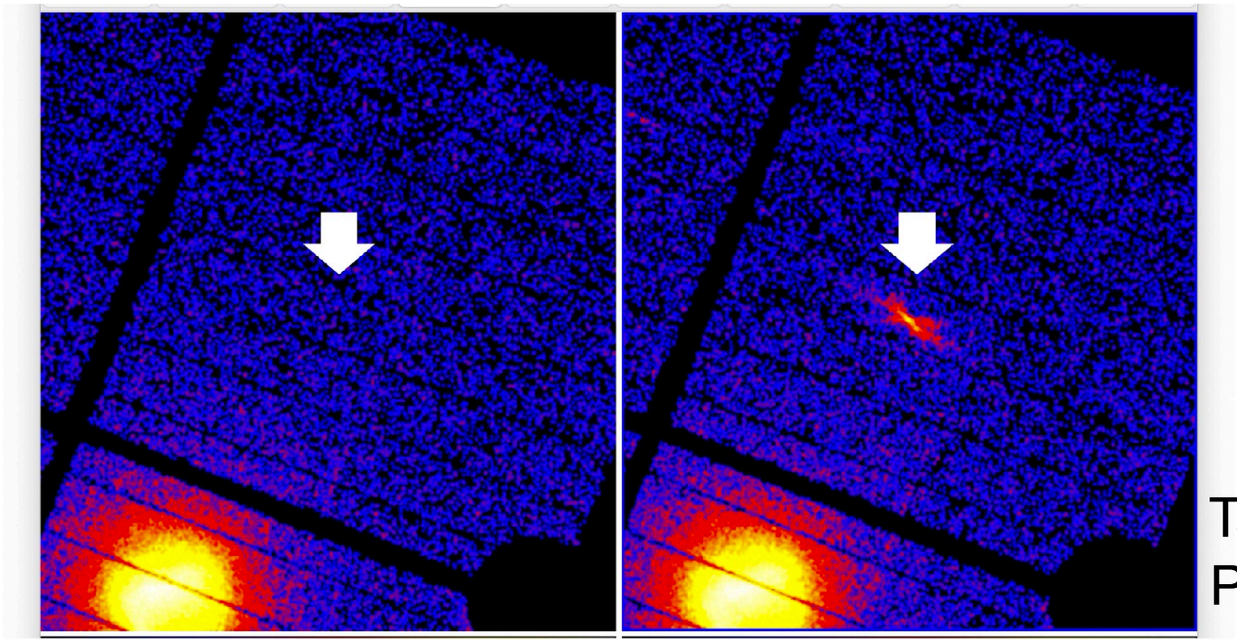


A 3C 273 Xtend spectrum

Mori et al. 2024

Contribution in time-domain astronomy: XRISM XTS (Xtend Transient Search) system

- Xtend data, with a wide FOV, are used for semi-automatic transient search.
- Note: the search could be ~24h after the observation or earlier.



Tsuboi et al., Proc. SPIE, 2024

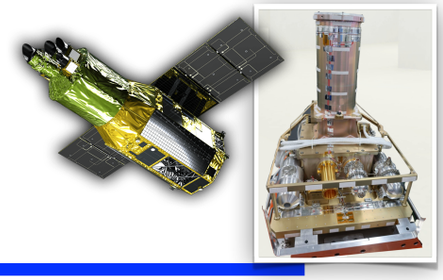
Figure 4. The Xtend images of AX J1910.7+0917 before (*left*) and after (*right*) the outburst reported as the ATel #16607 (see Table 1)

ATel#	Date	Type	Counterpart (species)	Time lag (hour)†
16532	2024-03-15	Stellar Flare	LP 593-21 (M dwarf binary)	168
16558	2024-03-28	Stellar Flare (?)	4XMM J190821.5+06585 (?)	36
16561	2024-03-31	Stellar Flare	SSTGLMC G335.2665-00.0151? (YSO candidate)	20
16592	2024-04-17	Stellar Flare	UCAC4 476-091023 (spectroscopic binary)	123
16607	2024-05-01	Outburst	AX J1910.7+0917 (NS HMXB)	67
16632	2024-05-28	Supernova	SN2024iss (Super Nova)	N/A‡
16652	2024-06-14	Stellar Flare	Cl Collinder 228 113 (spectroscopic binary)	91
16683	2024-07-02	Stellar Flare	MS Ser (BY Dra type variable)	19
16685	2024-07-03	Stellar Flare	MS Ser (BY Dra type variable)	15

† Time lag between the transient and the ATel submission.

‡ Not triggered but followed up by XTS.

Key takeaways



Xtend has a

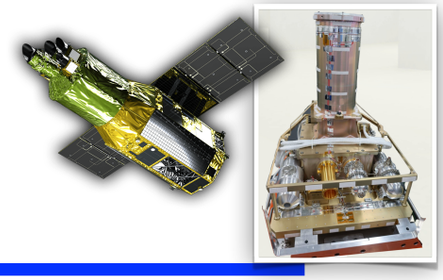
- good sensitivity down to 0.4 keV,
- good pixel resolution and,
- wide field of view.

Don’t Forget to Analyze Xtend Data!

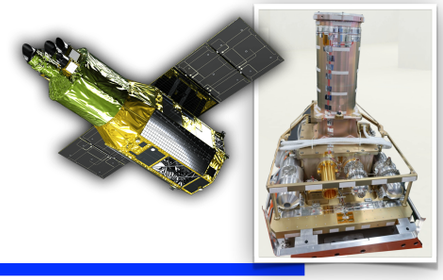
Papers using Xtend data

- 1st XRISM collabo. paper on supernova remnant N132D: narrow-band Fe maps
  - https://ui.adsabs.harvard.edu/abs/2024PASJ...76.1186X/abstract
- Plasma diagnostics of supernova remnant Sagittarius A East: contamination evaluation for a bright point source outside Resolve FoV
  - https://ui.adsabs.harvard.edu/abs/2024arXiv241200676X/abstract
- Detection of faint diffuse emission around microquasar V4641 Sgr: 1st science results using full performance of Xtend
  - https://ui.adsabs.harvard.edu/abs/2025ApJ...978L..20S/abstract

Back up



Analyzing extended sources

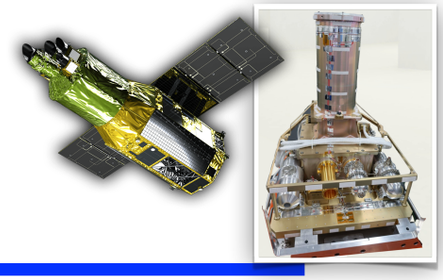


- Both source & background should be stable… but check light curves!!
- Detector background (similar to Suzaku XIS/Hitomi SXI)
  → Following pages

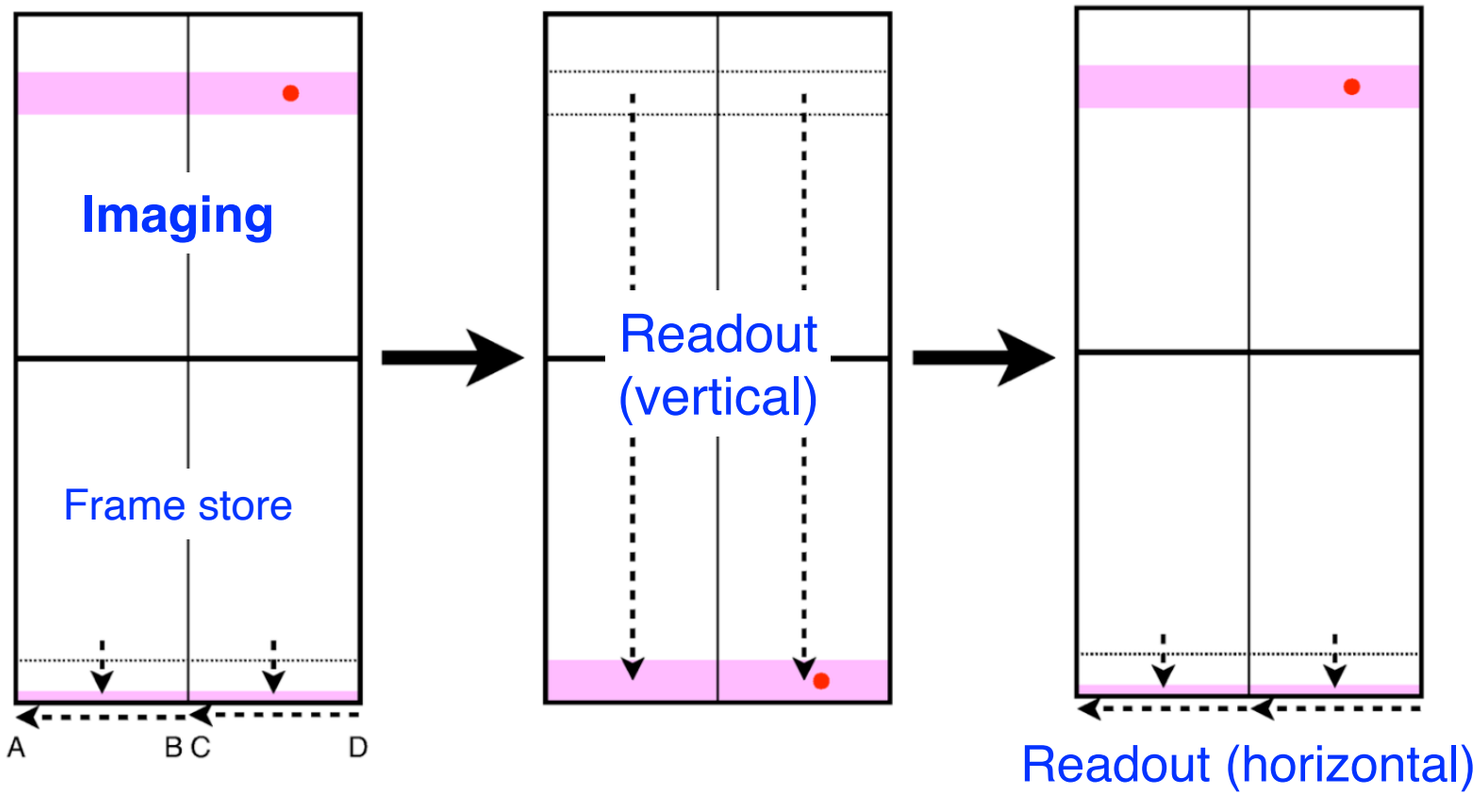
- Sky background
  - Many contribute, many depends on sky coordinates & time
  - Local Hot Bubble/Foreground Emission e.g., Snowden et al. 1998; Kuntz & Snowden 2000; Yoshino et al. 2009; Masui et al. 2009; Ueda et al. 2022
  - Milky Way Halo/Transabsorption Emission e.g., Kuntz & Snowden 2000; Yoshino et al. 2009; Masui et al. 20
  - Solar Wind Charge eXchange e.g., Cravens et al. 2001; Koutroumpa et al. 2007
  - Near Galactic center e.g., Uchiyama et al. 2013; Koyama 2018; Nobukawa & Koyama 2021
    - Galactic Ridge X-ray Emission
    - Galactic Center X-ray Emission
    - …
  - Cosmic X-ray Background e.g., Kuntz & Snowden 2000; Kushino et al. 2002

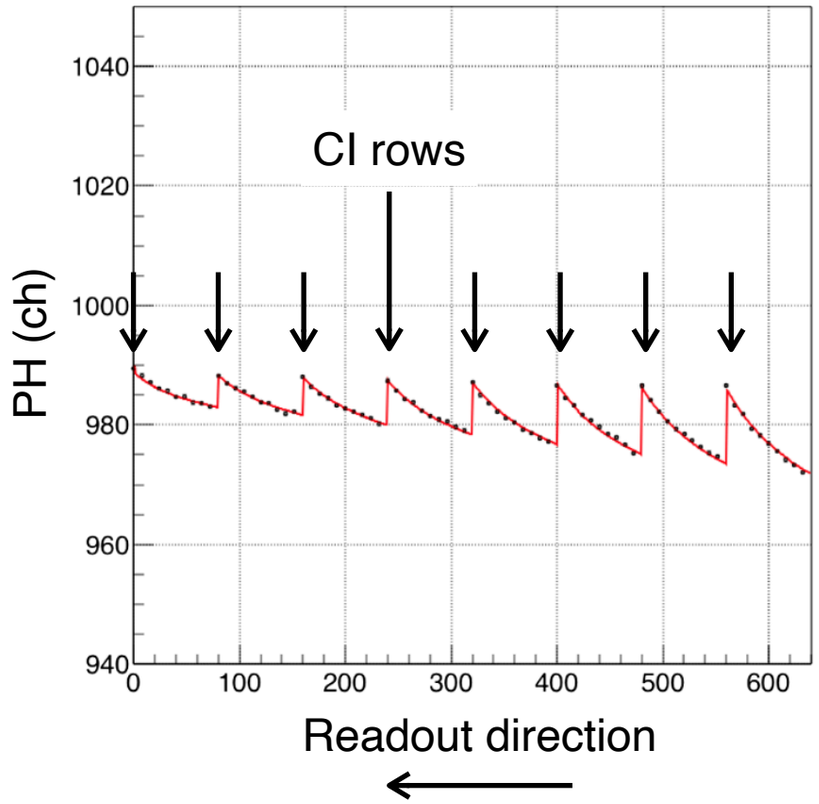
CCDs of SXI

Tanaka et al. 2018

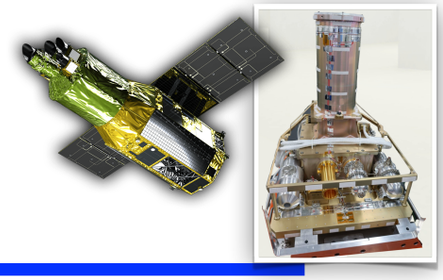


- Frame exposure time: 0.06–3.96 sec (depends on obs. modes)
- Charge Injection (CI) technique:
  - give artificial charges to minimize charge transfer inefficiency
  - similar to Suzaku XIS/Hitomi SXI

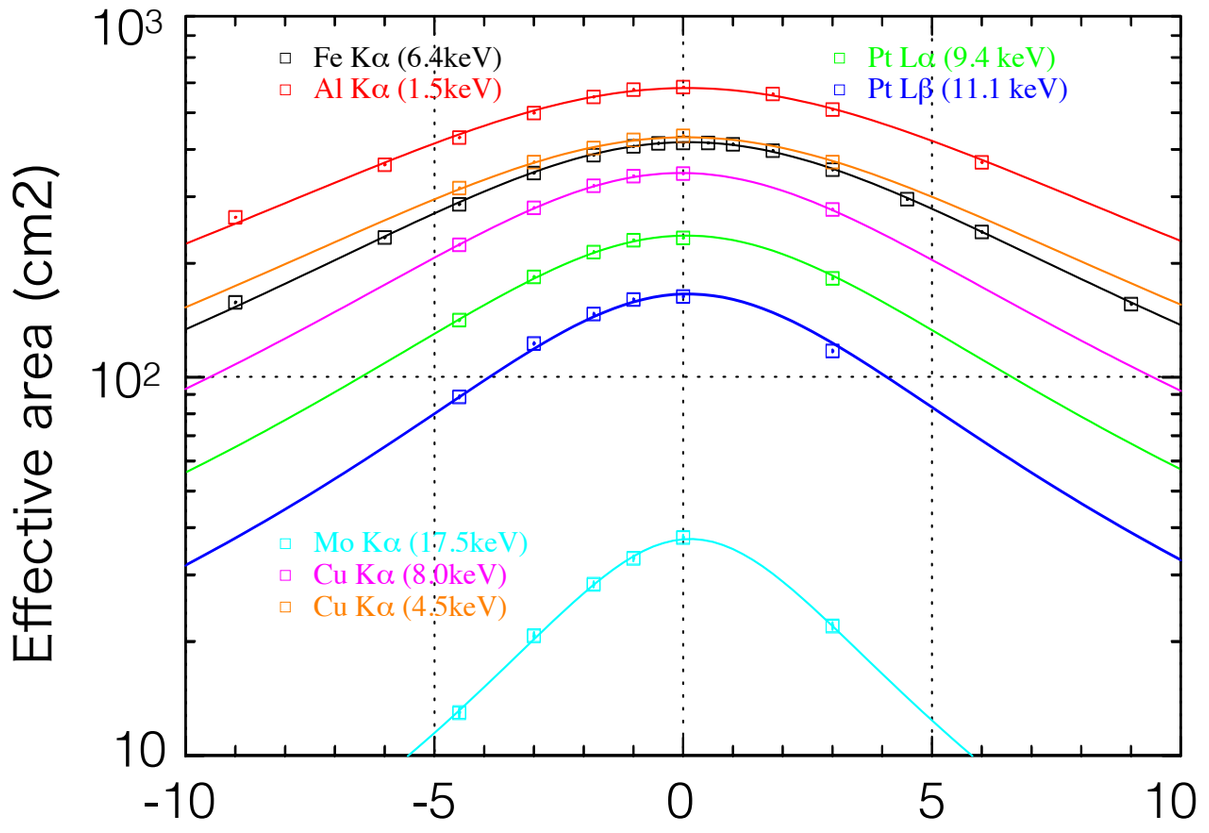




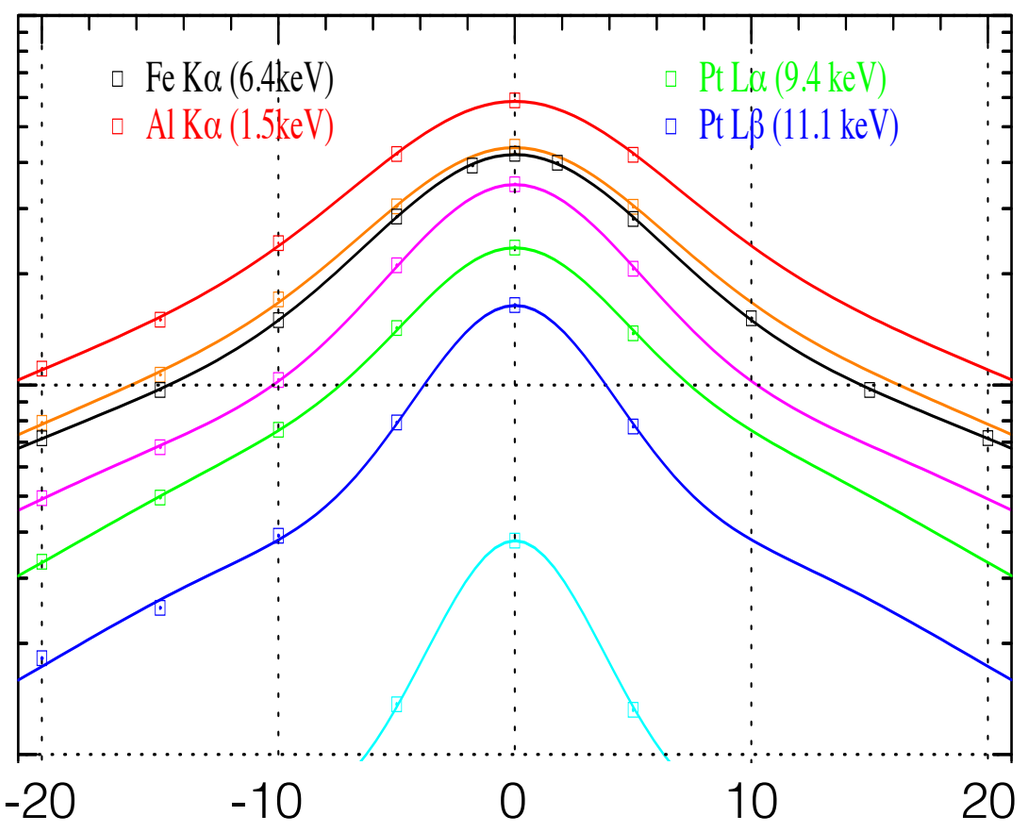
Off-axis effective areas



Resolve XMA (mirrors)



Xtend XMA (mirrors)



Off-axis angle (arcmin)

Sky background