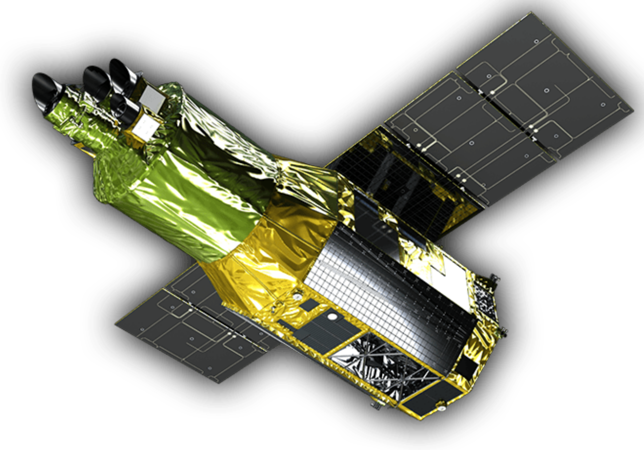
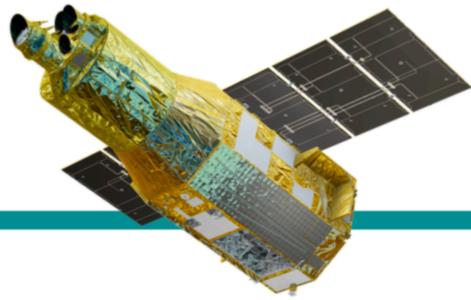
XRISM
X-Ray Imaging and Spectroscopy Mission



Xtend overview

Kenji Hamaguchi
(XRISM GOF)
H. Suzuki & the Xtend team

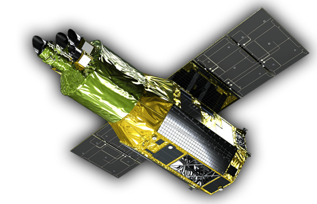
XRISM / Xtend Team



- **Tohoku Gakuin University**
  H. Murakami
- **Tokyo University of Science**
  S. B. Kobayashi, T. Kohmura
- **The University of Tokyo**
  K. Hagino
- **Chuo University**
  T. Yoneyama (← ISAS/JAXA)
- **Kanto Gakuin University**
  H. Nakajima (***sub-PI***)
- **ISAS/JAXA**
  H. Tomida (***Instrument Manager***),
  T. Yoshida, Y. Maeda, H. Suzuki (← Konan U.)
  Y. Kanemaru, M. Ishida
- **Shizuoka University**
  H. Uchiyama
- **Nagoya University**
  K. Yamaoka
- **Kyoto University**
  H. Uchida, T. G. Tsuru
- **Nara University of Education**
  M. Nobukawa
- **Kindai University**
  K. K. Nobukawa
- **Osaka University**
  K. Hayashida, H. Noda, H. Matsumoto,
  H. Odaka (MOPT → Xtend)
- **Konan University**
  T. Tanaka
- **University of Miyazaki**
  K. Mori (***PI***), M. Yamauchi, I. Hatsukade
- **NASA's GSFC**
  T. Okajima, Y. Soong, T. Hayashi

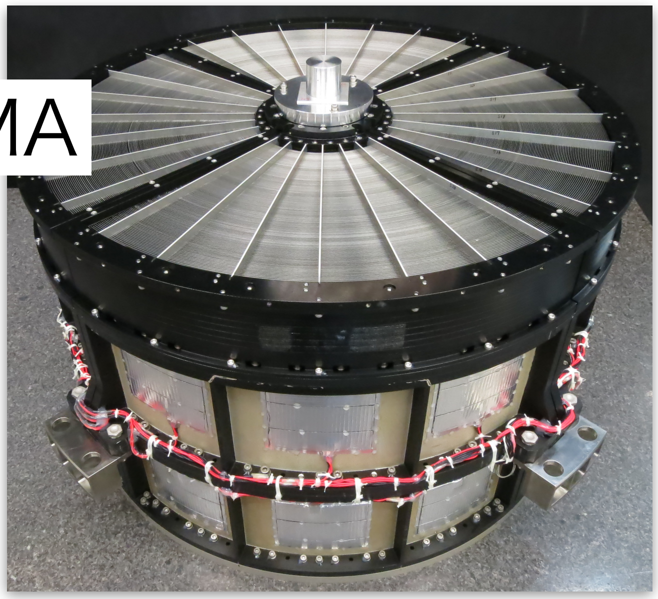
- **Students**
  Y. Aoki, Y. Ito, H. Yokosu, W. Yonemaru, Y. Otsuka, H. Nakano,
  K. Ichikawa, R. Takemoto, T. Matsushima, M. Yoshimoto,
  T. Hakamata, M. Aoyagi, K. Shima, R. Azuma, N. Terano,
  M. Fukuda, D. Aoki,
- **Advisors**
  J. S. Hiraga, M. Ozaki, T. Dotani, H. Tsunemi
- **MOPT/SOC (joint work)**
  T. Mizuno, N. Sakamoto (**Hiroshima University**)

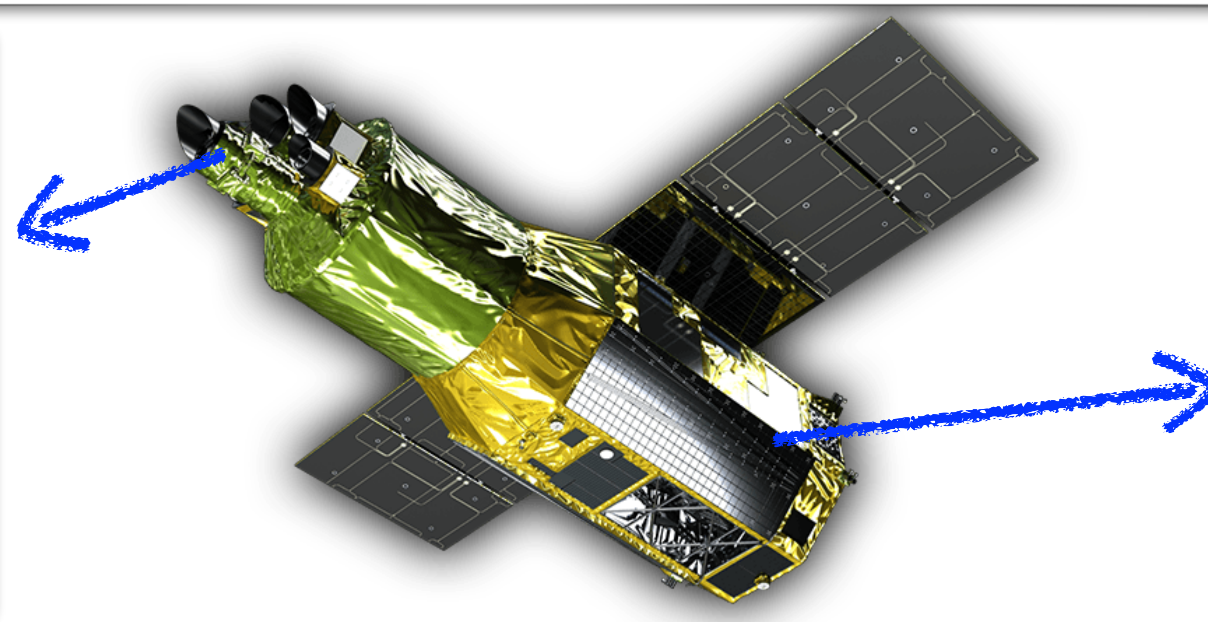
Xtend

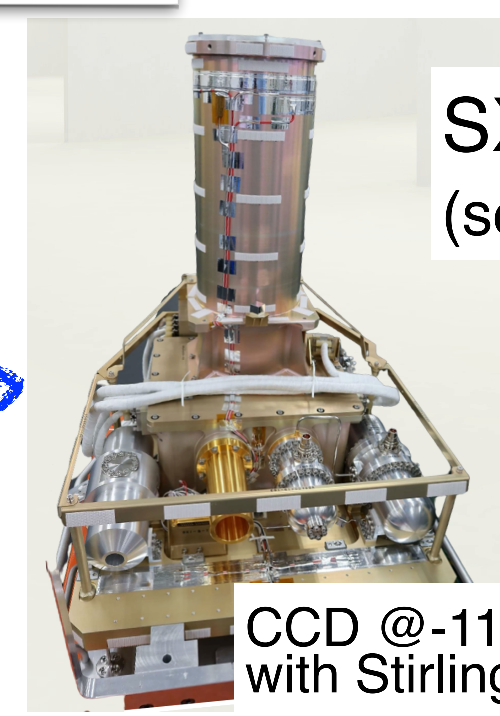


XRISM white paper, 2020

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







- **XMA** : Conically approximated Wolter type I mirror

  ✓identical to Resolve XMA

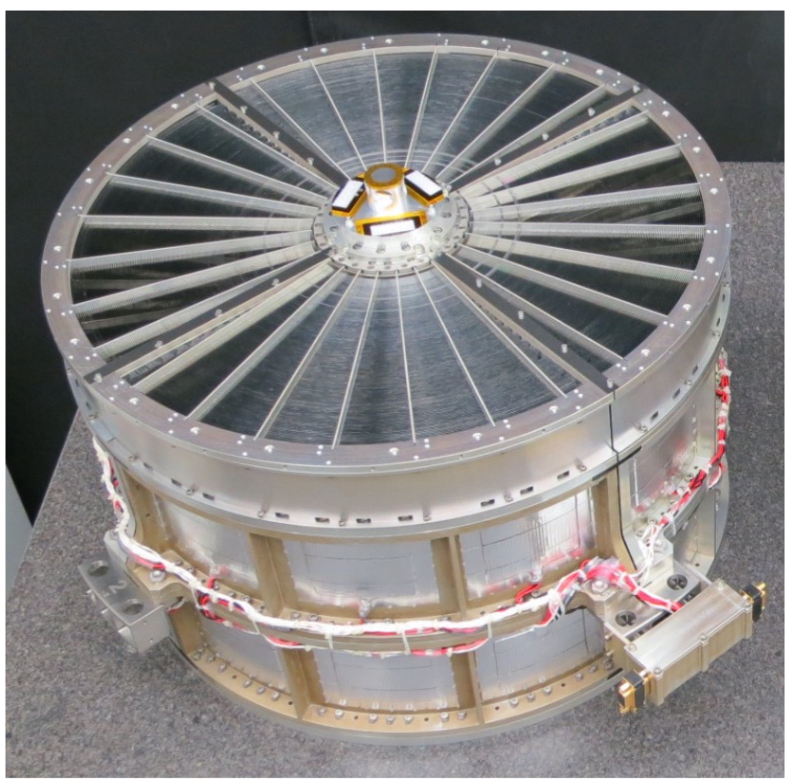
- **SXI** : X-ray CCDs

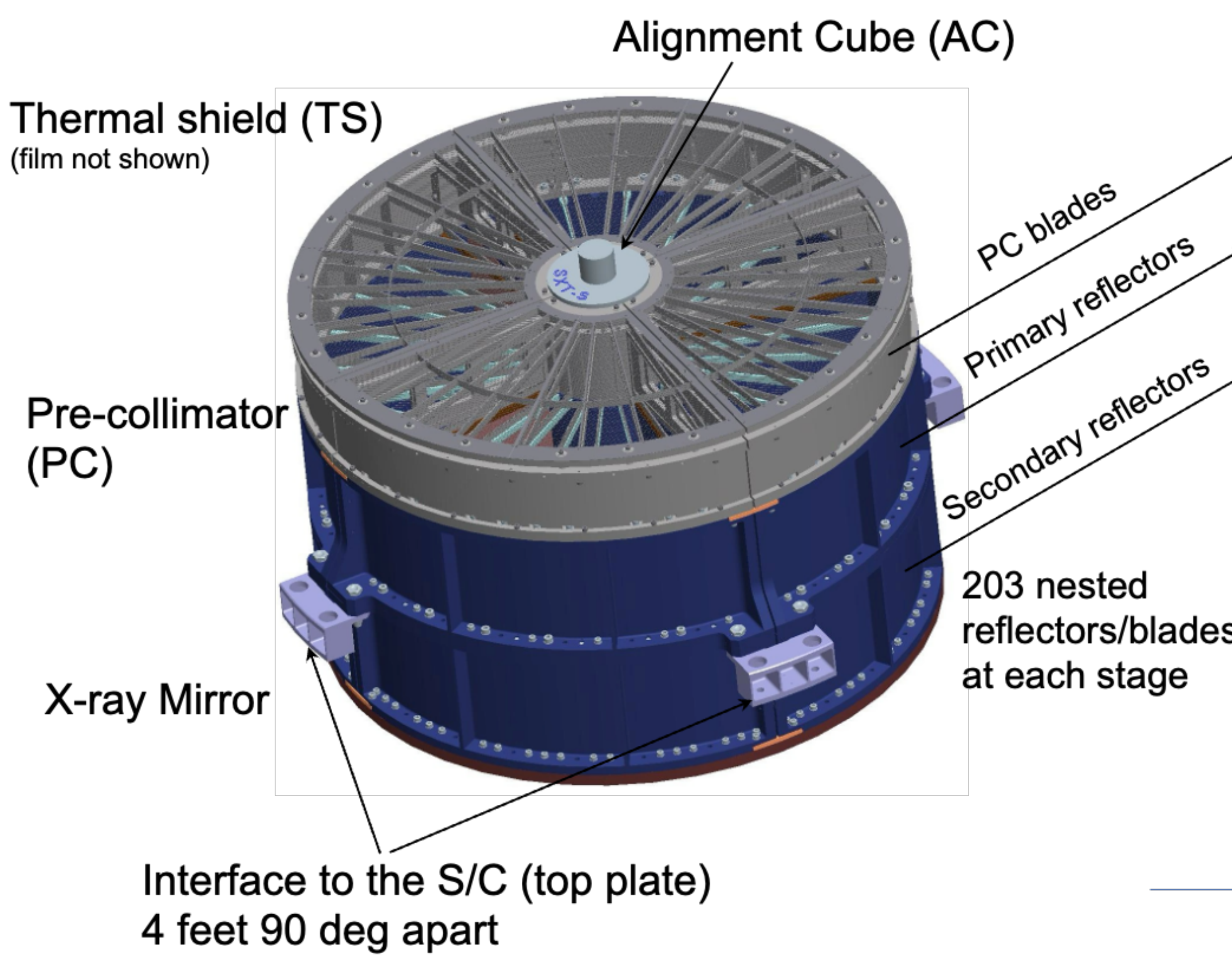
  ✓fully-depleted back-illuminated
  P-channel CCD

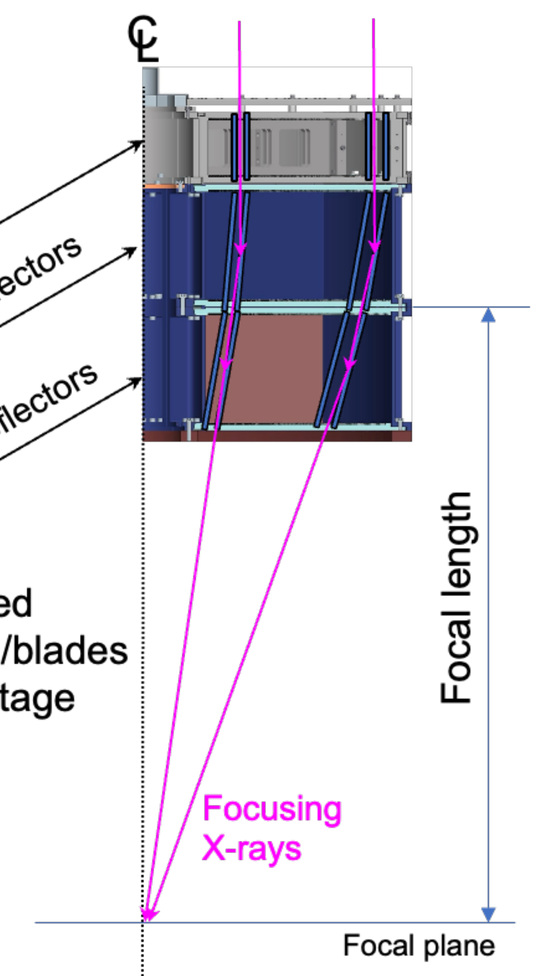
- Energy range : 0.4–13 keV
- FoV : 38’ × 38’
- Energy resolution : ~180 eV@5.9 keV
- Ang. resolution : < 1.47’ (Half Power Diameter)

Brief XMA overview

- Conically approximated Wolter I grazing incident optics (203 nested shells)
- Gold surface coating for X-ray reflection
- Focal length = 5.6 m
- Two almost identical mirrors, one for Resolve and one for Xtend.

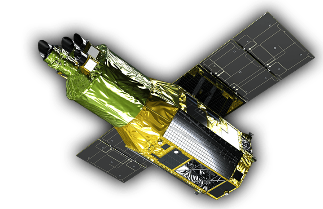


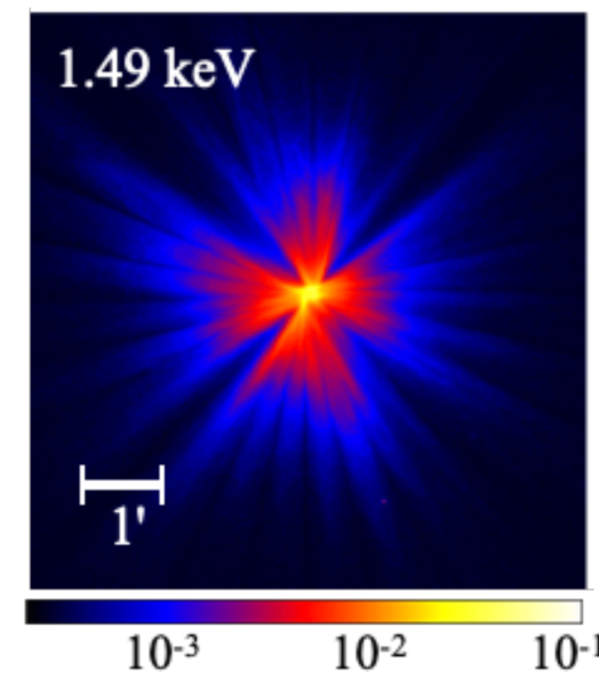




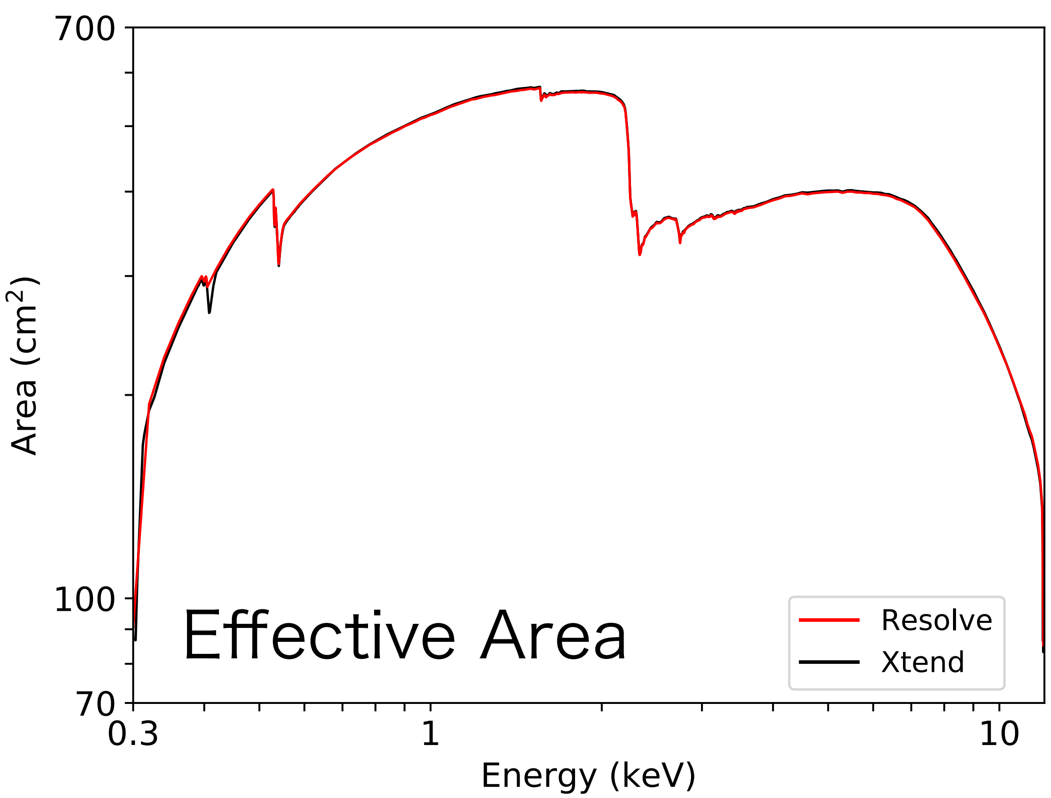
Brief XMA overview

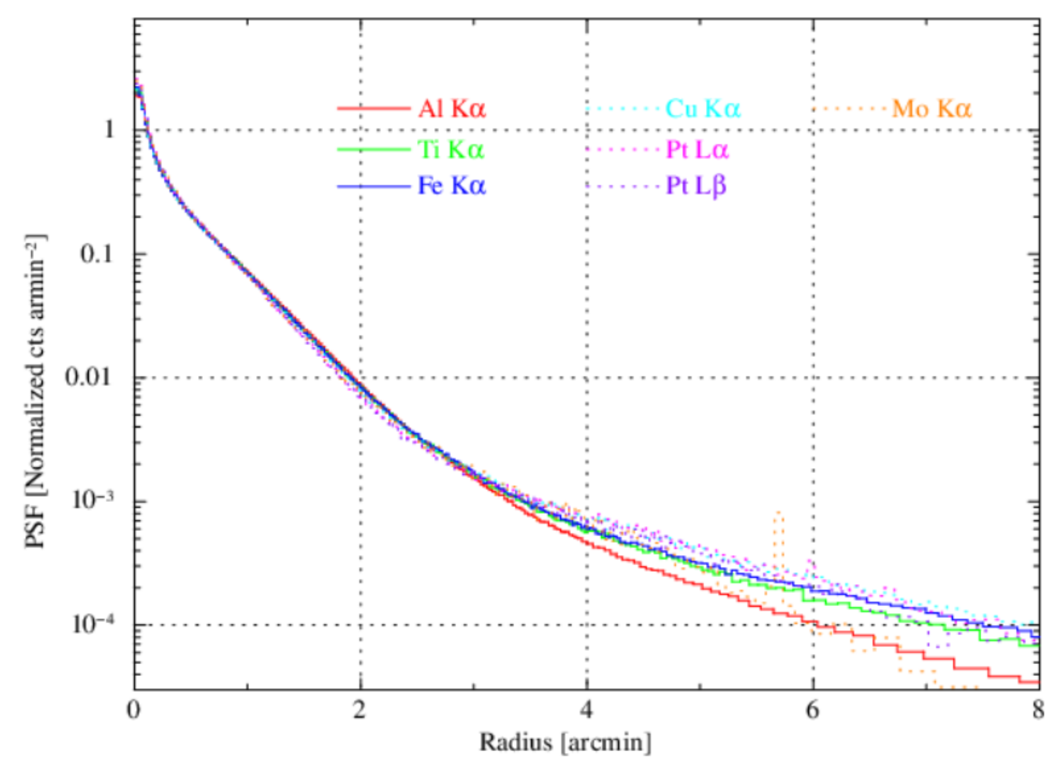
- The in-orbit performance is roughly consistent with the ground calibration.
- Point Spread Function (small energy dependence)
  - Resolve: 1.3' (HPD)
  - Xtend: 1.5’ (HPD), 7” (FWHM)
- Effective area
  - ~418 cm² @6.4 keV, ~587 cm² @1.5 keV

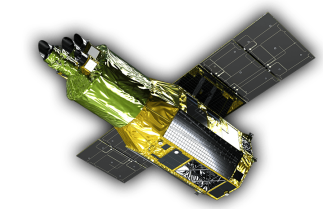




PSF



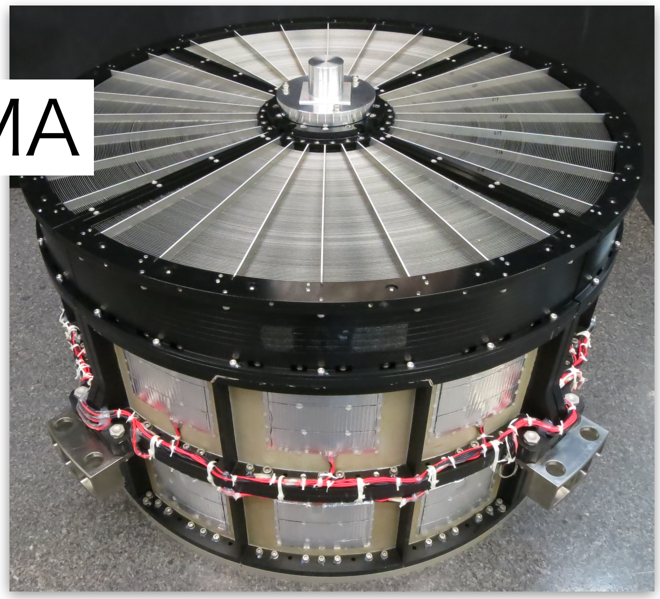


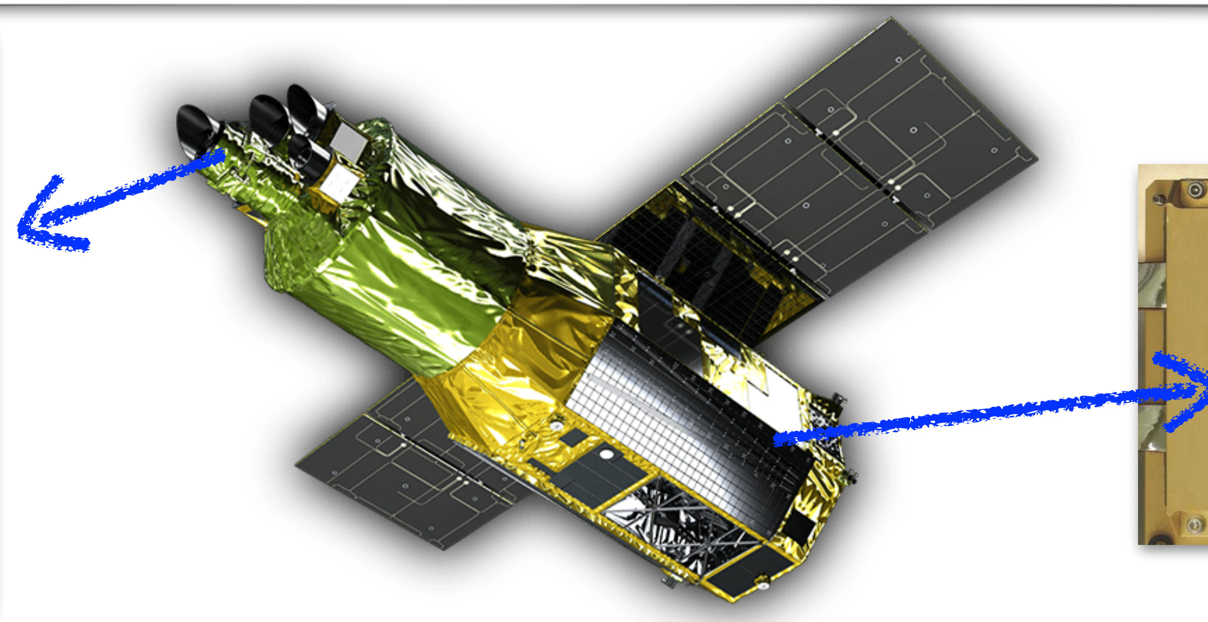


Xtend

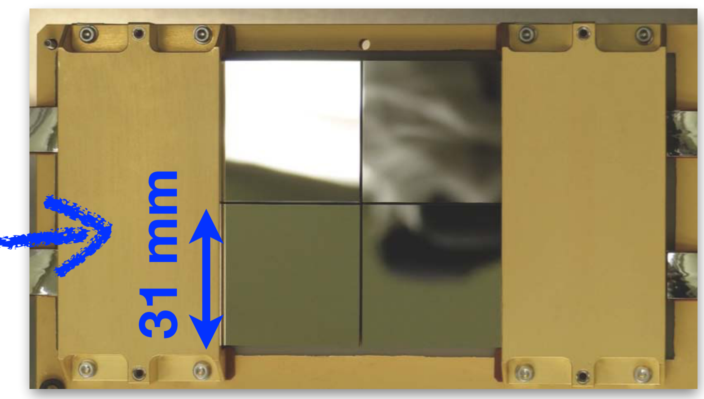
XRISM white paper, 2020

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



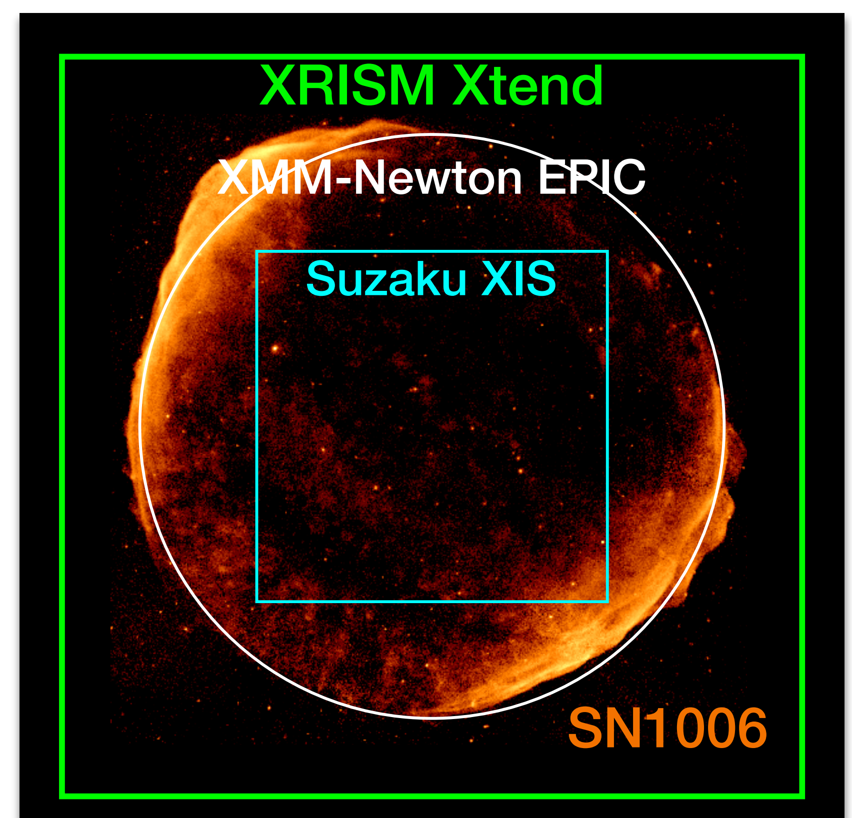


SXI-S
(chips)



CCD @-110 degC
with Stirling cooler

- **XMA**：Wolter type I mirror optics
  - ✓almost identical to Resolve XMA
- **SXI**：X-ray CCDs
  - ✓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)

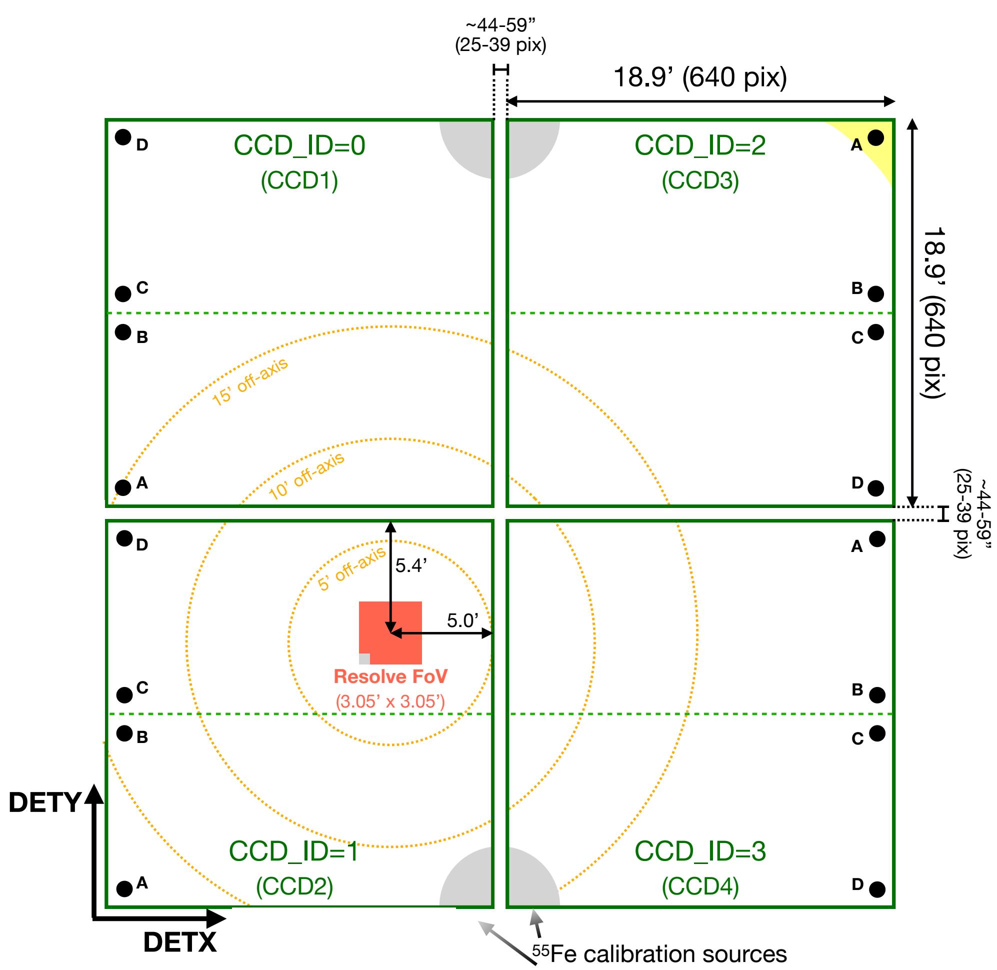


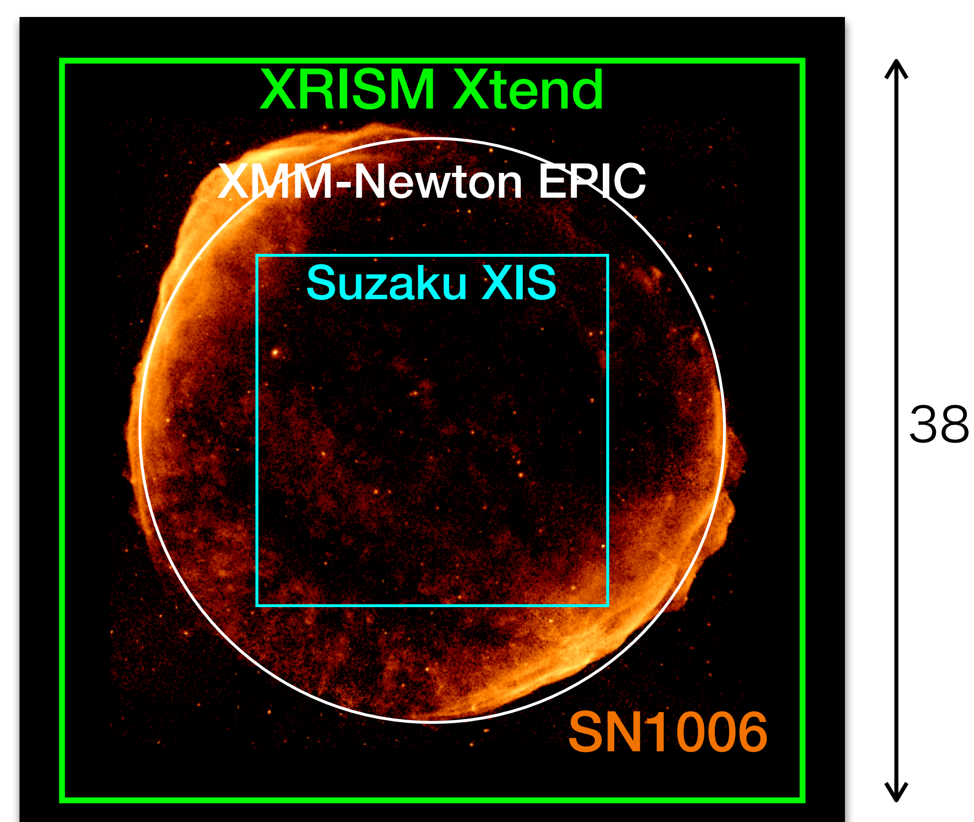
38’

Strength

XRISM white paper, 2020

- **Observe moderately extended faint objects**
  - Cover a large FoV (~x2 XMM EPIC)
  - Low & stable particle background
- **Monitor bright sources outside of Resolve field of view**
  - Resolve FoV ~ 3'x3', while the PSF tail extends to a few arcmin.
  - Bright sources outside Resolve FoV may contribute to Resolve data.
  - Xtend can monitor surrounding source fluxes.

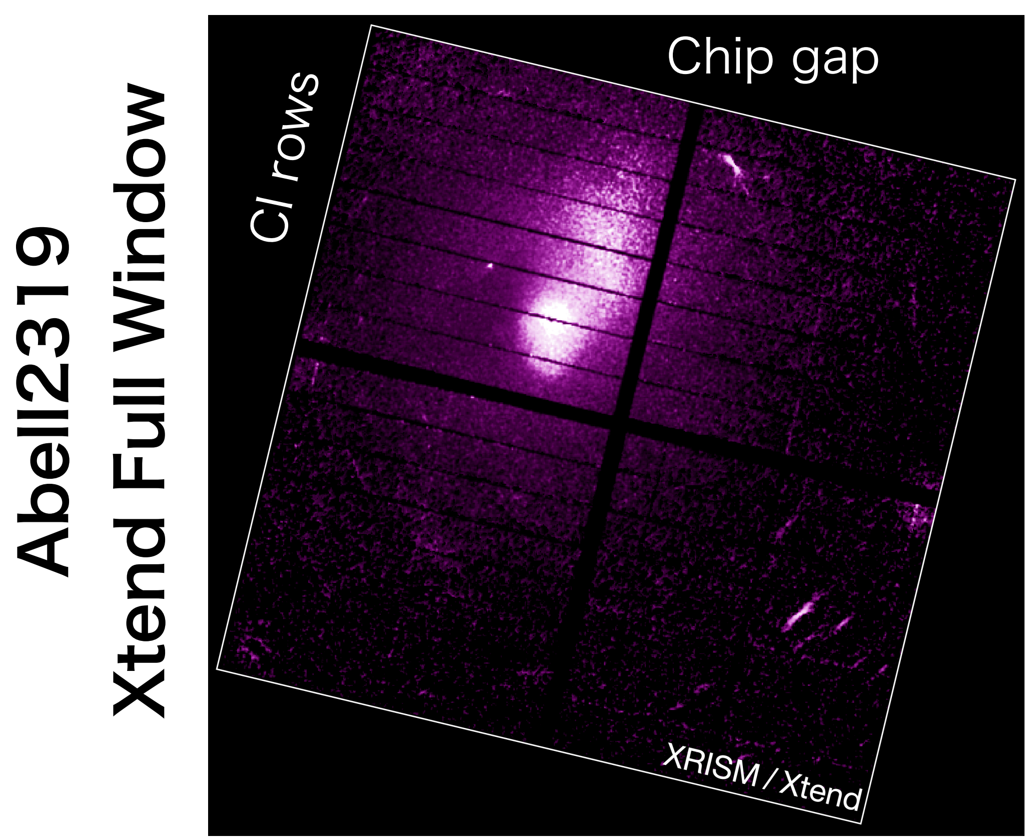


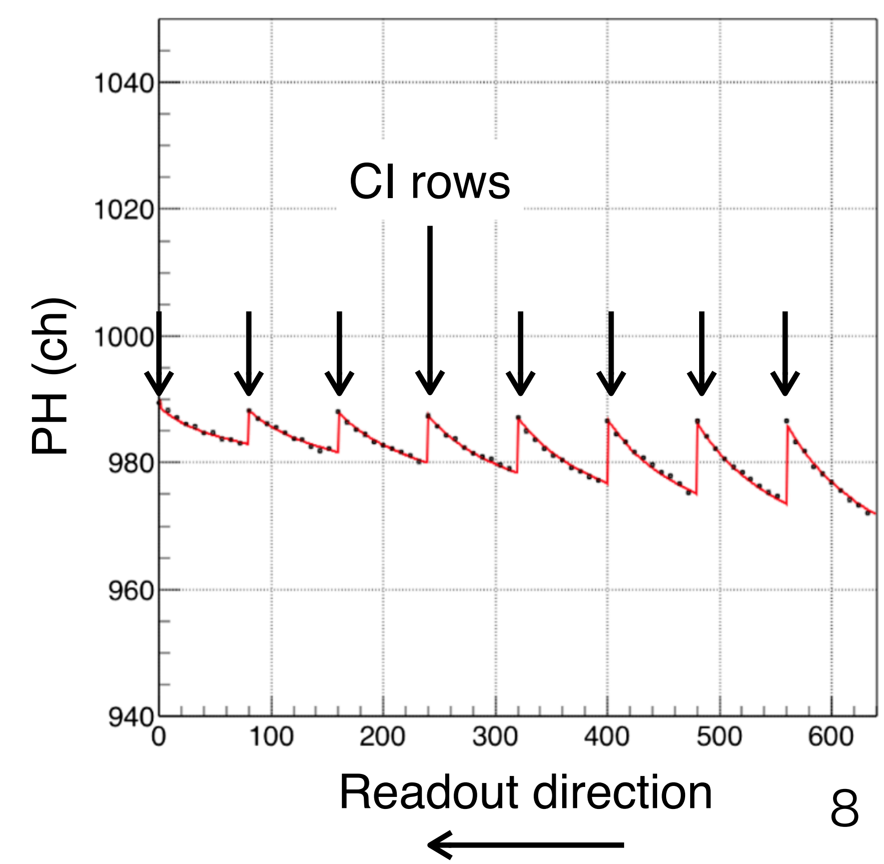


SXI CCDs

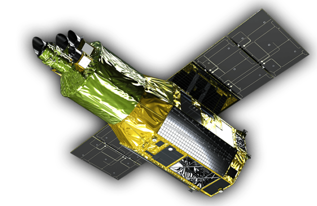
Tanaka et al. 2018

- It's working great so far!
- Frame exposure cycle: 4 sec (full), 0.5 sec (1/8)
- Charge Injection (CI) technique:
  - Inject charges to every 80 rows to improve energy resolution
- Data gaps - some point sources may fall into.
  - Chip gaps: 44"–59"
  - No X-ray sensitivity at CI (+/-1) rows, equivalent to ~5"

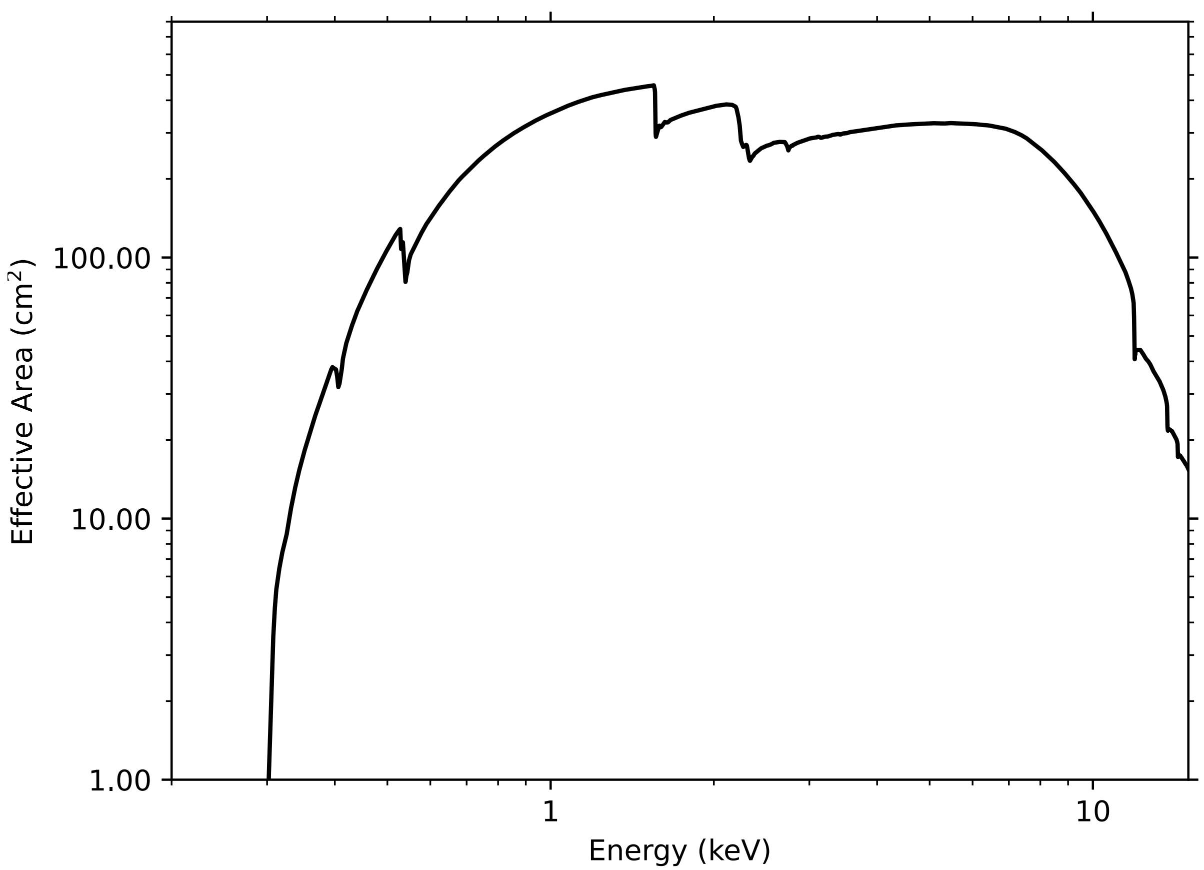


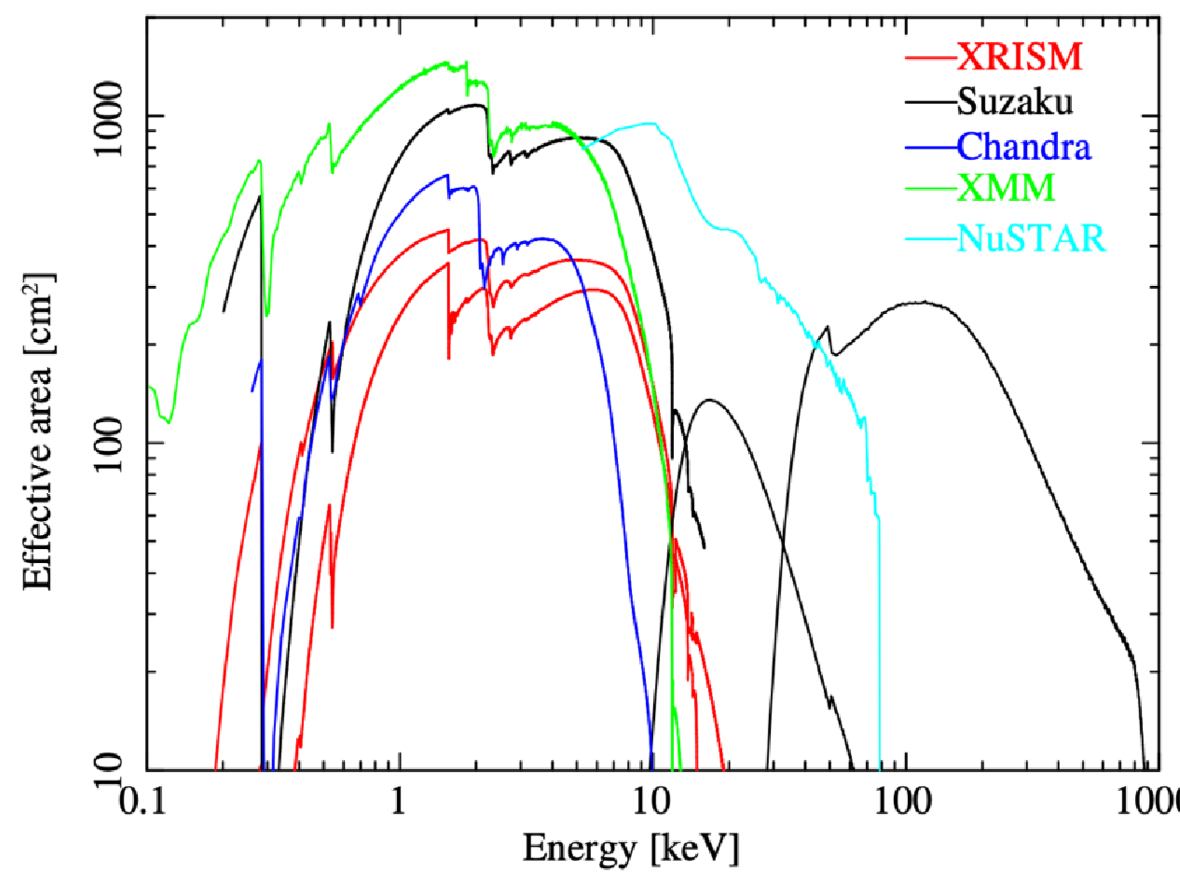


Effective Area



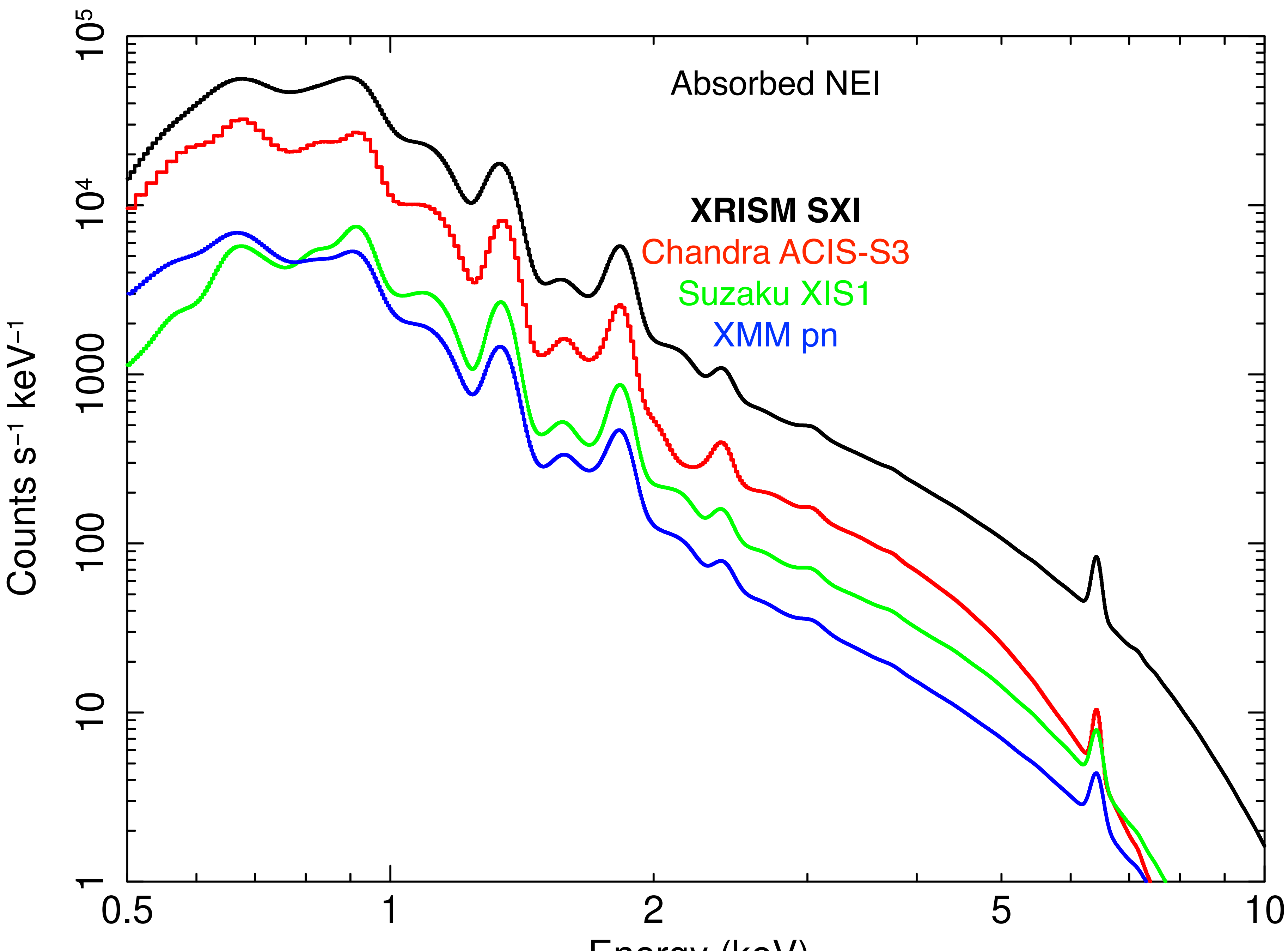
- Mirror's collecting area multiplied by the detector's quantum efficiency and filter transmission.





Detector Response

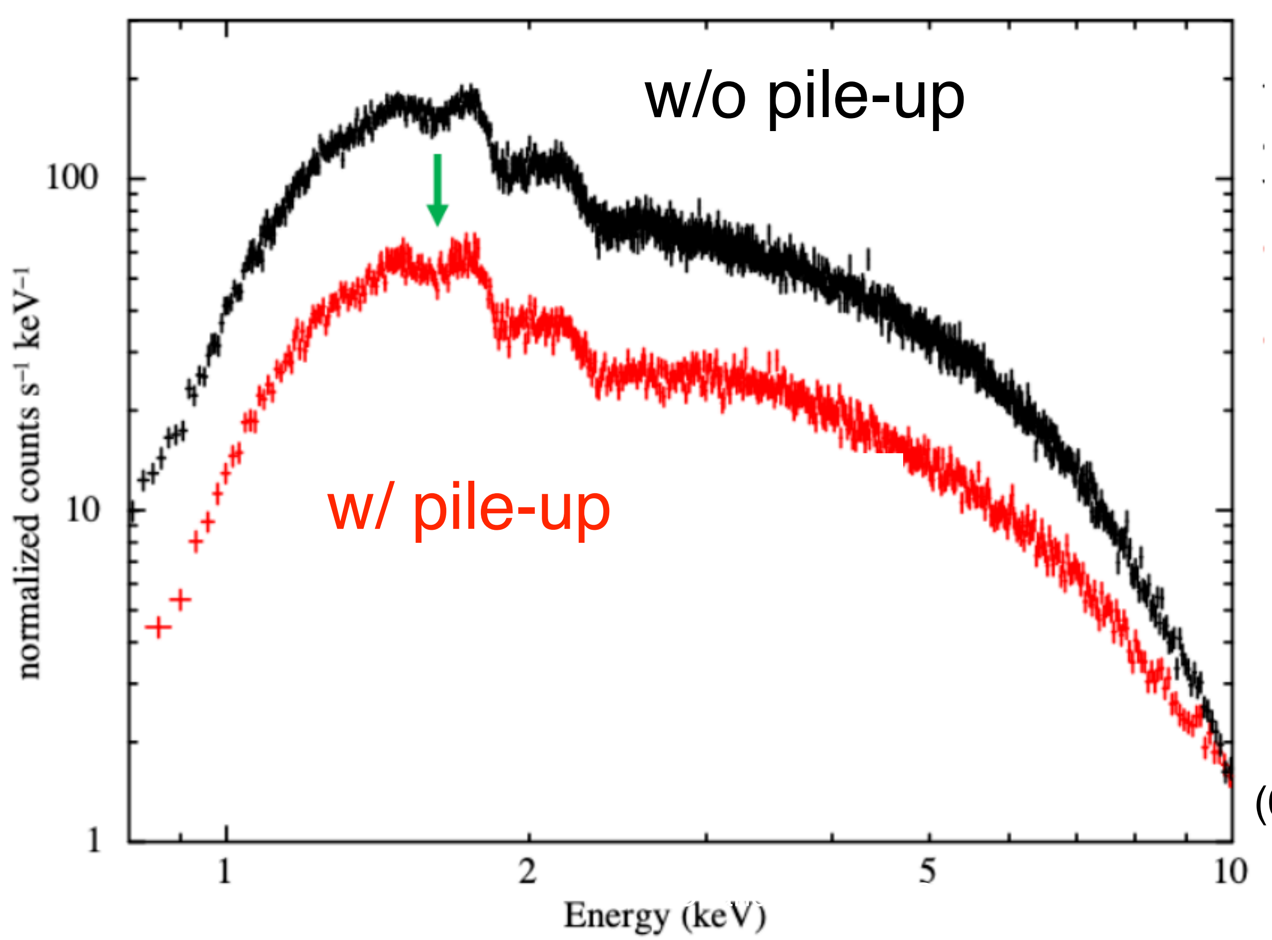
- Energy Resolution: ~180 eV@5.9 keV
  - Hard X-rays: as good as X-ray CCDs on earlier or active satellites
  - Soft X-rays: slightly worse than those on *Suzaku* or *Chandra*



Bright Source Observations

Tamba et al. 2022

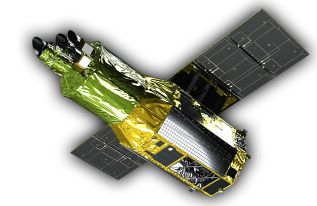
- Photon pileup
  - Two X-ray photons fall in 3x3 pixels in a single frame exposure
  - They are counted as a single X-ray event or none.
  - It occurs for sources with >2.5 mCrab.



(0.5 Crab, 8 sec frame exposure)

How to avoid pileups

- Reduce the frame exposure time
  - Xtend provides two additional observing modes.



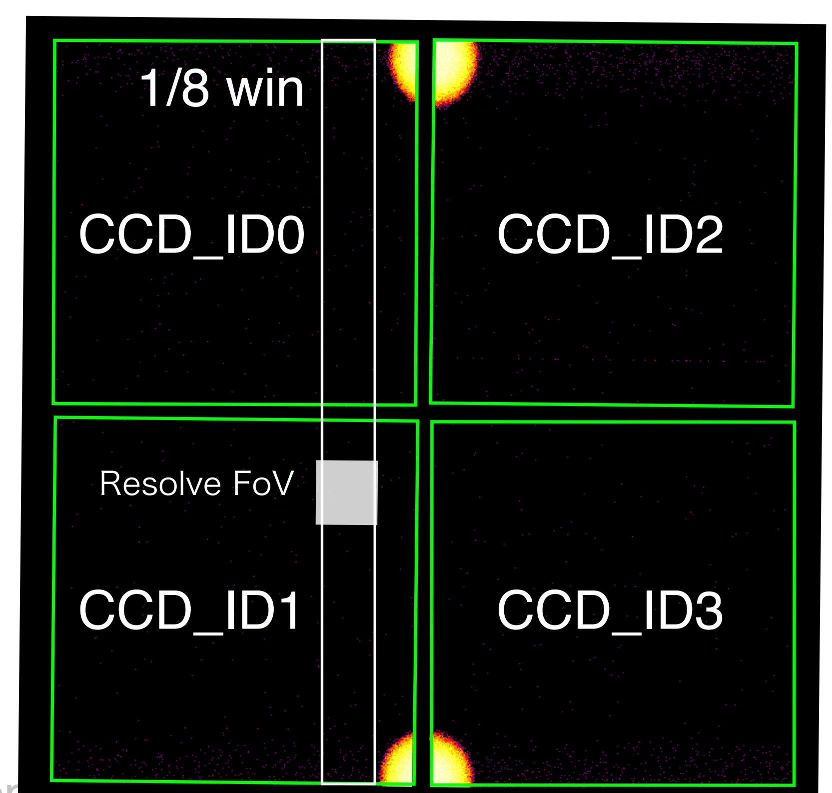
Observation Mode

Tanaka et al. 2018

- Observation mode of CCD_ID = 0 & 1

Mode	Region size (per CCD)	Frame Exp (sec)	Time Res (sec)	Live time fraction	Pileup Limit (mCrab)	Purpose
Full window	640x640	4.0	4.0	0.99	2.5	General
1/8 window	640x80	0.46	0.46	0.93	21	Bright src
1/8 window + 0.1-s burst	640x80	0.06	0.46[a]	0.12	160	Very bright src
Full win 0.1-s burst	640x640	0.06	4.0	0.015	160	Inst team only

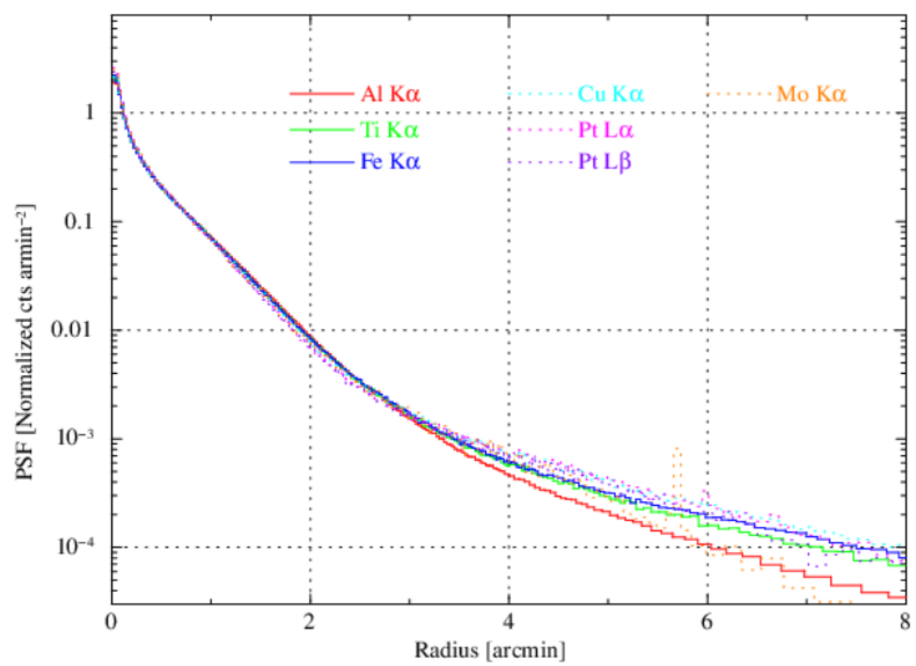
- CCD_ID = 0 & 1 run with the same observation mode.
- CCD_ID = 2 & 3 always run with the full window mode.
- [a]Burst mode data have 0.06 sec exposure window information, which should help pulsation search.



How to avoid pileups

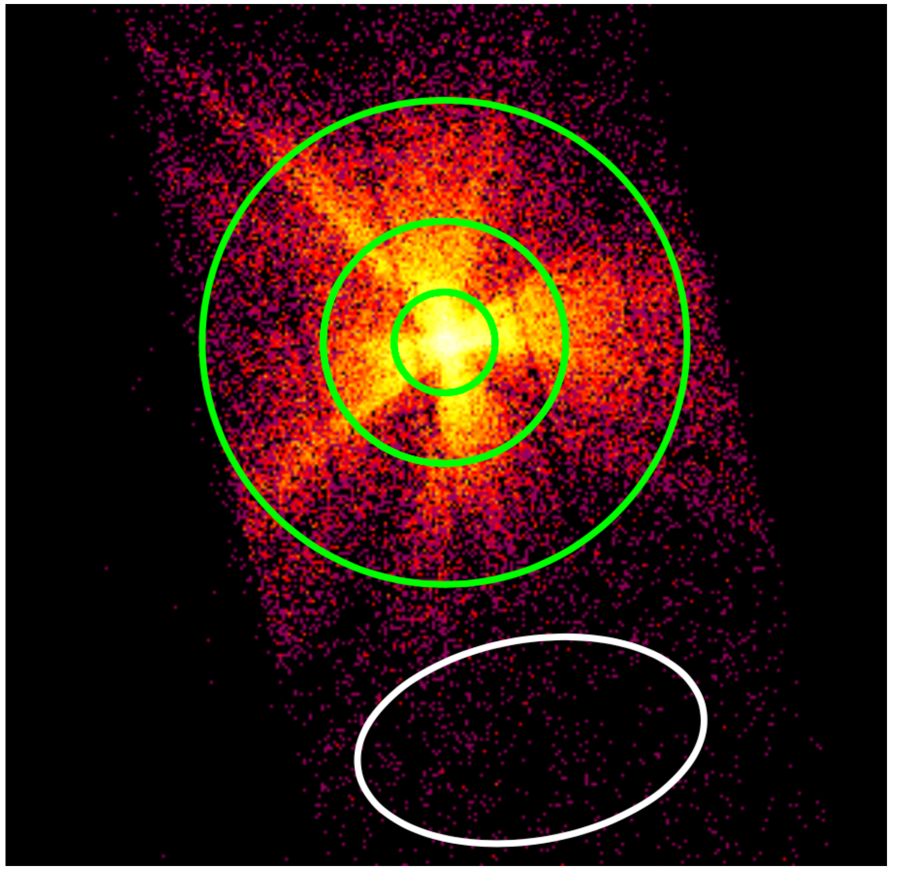
- Reduce the frame exposure time
  - Xtend provides two additional observing modes.
- Use the full window mode and exclude the PSF core
  - Xtend PSF has a sharp core, where pileups occur.
  - The PSF tail may not suffer pileups.
  - The pileup estimator, pileest, helps find pileup pixels.

Point spread function

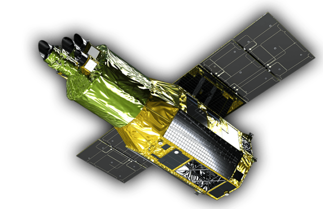


Angle from the PSF core (arcmin)

Tamba et al. 2022

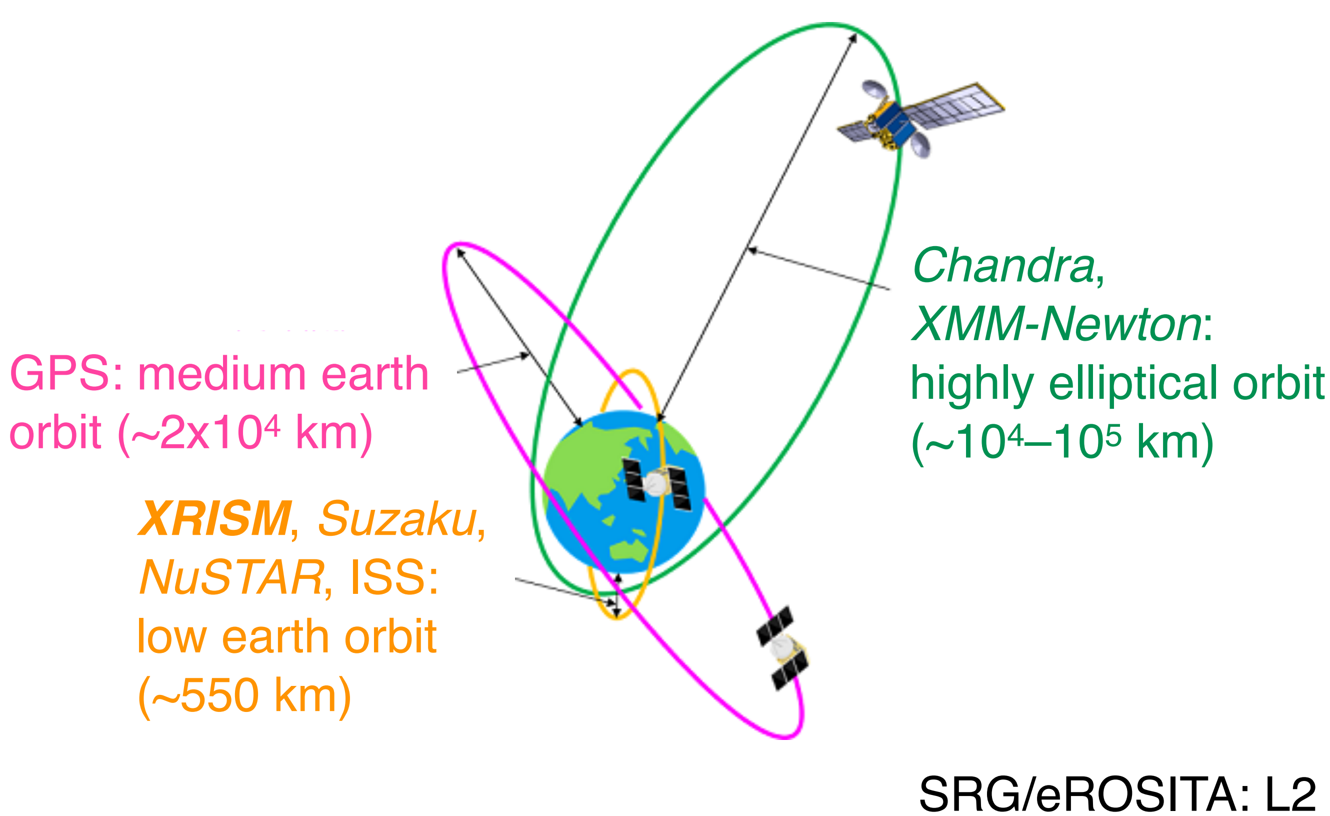


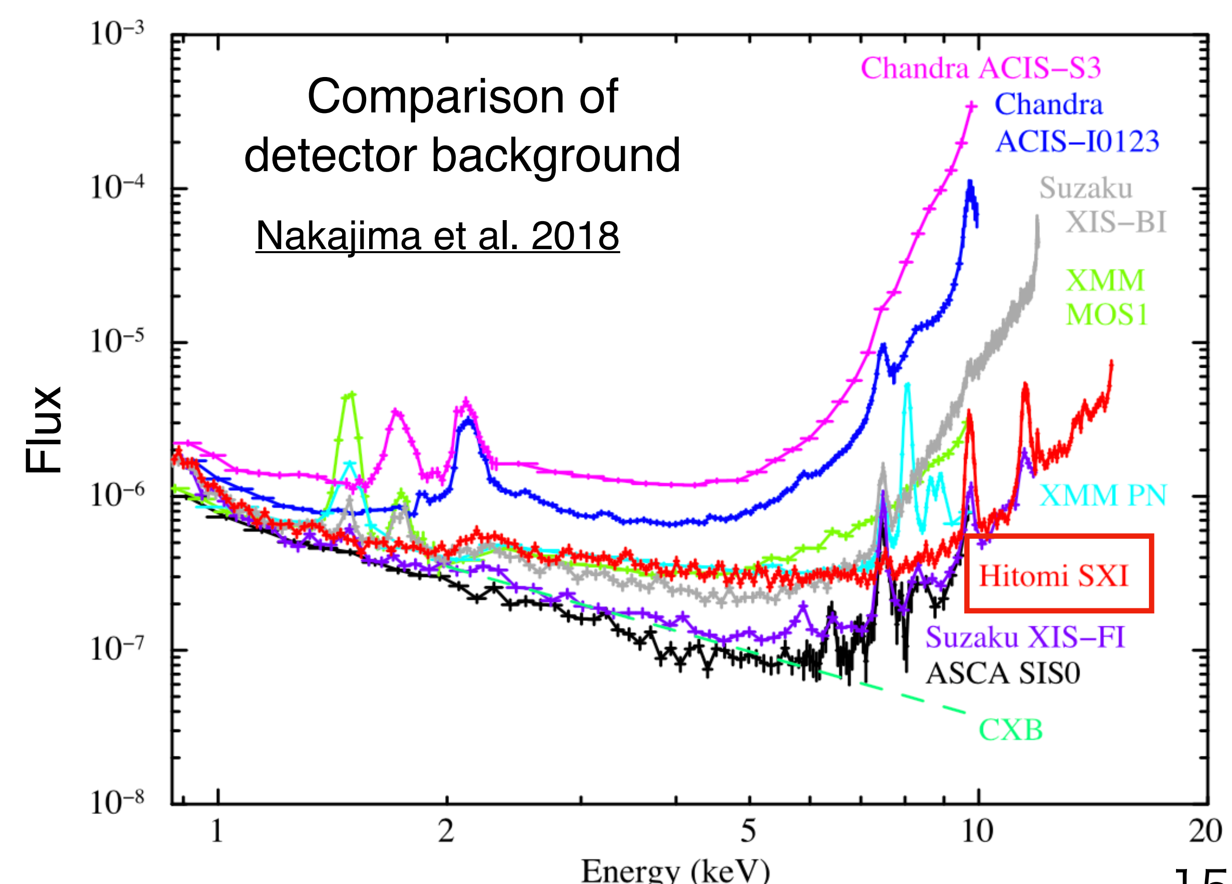
Non X-ray Background (NXB)



- Cosmic ray particles
  1. produce ionization charges when they traverse CCD chips.
  2. excite fluorescence X-rays, which the SXI may detect.
  - Event selection excludes most cosmic ray events but not all.
- Earth's magnetosphere alleviates cosmic ray radiation.
  - *XRISM* is in a low-Earth orbit.
  - Less charged particles than *Chandra or XMM-Newton*

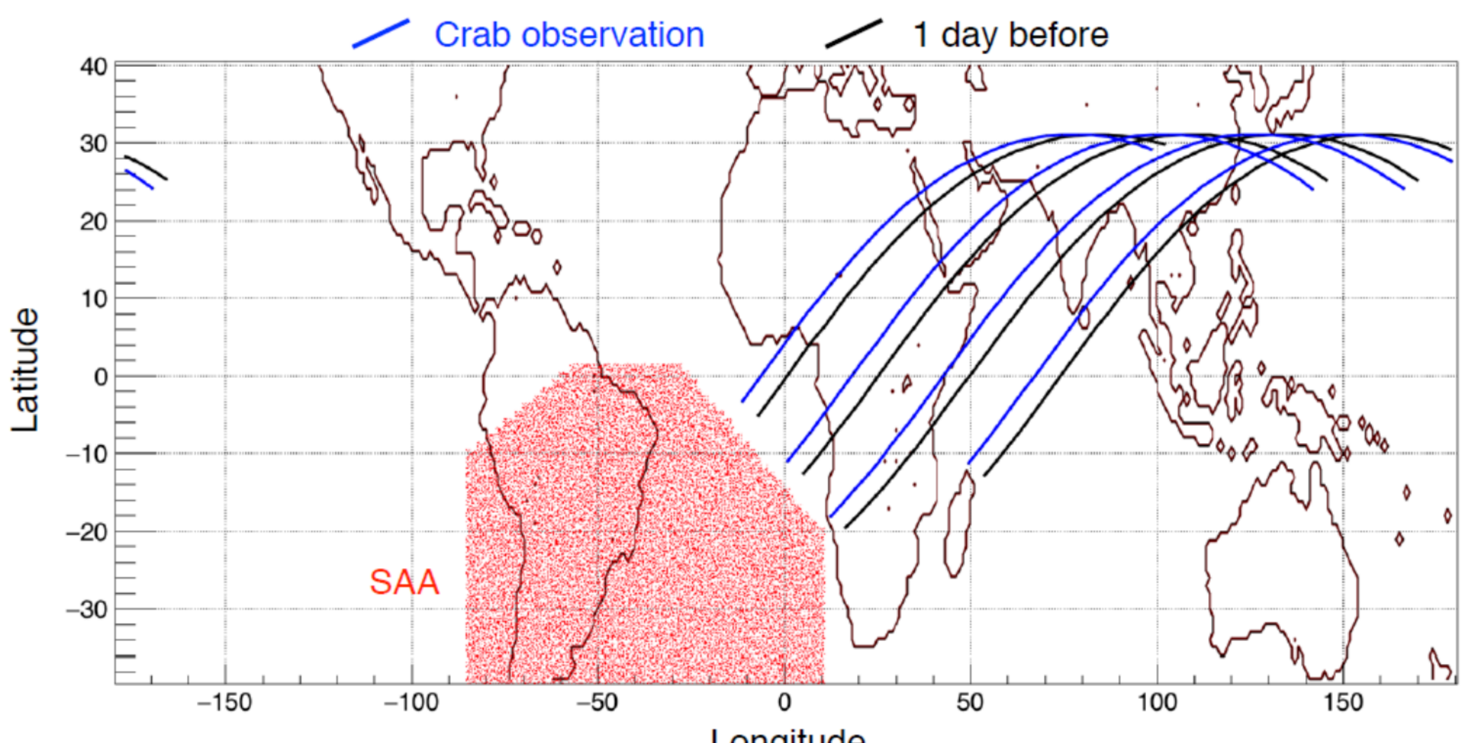
Nakajima et al. 2018



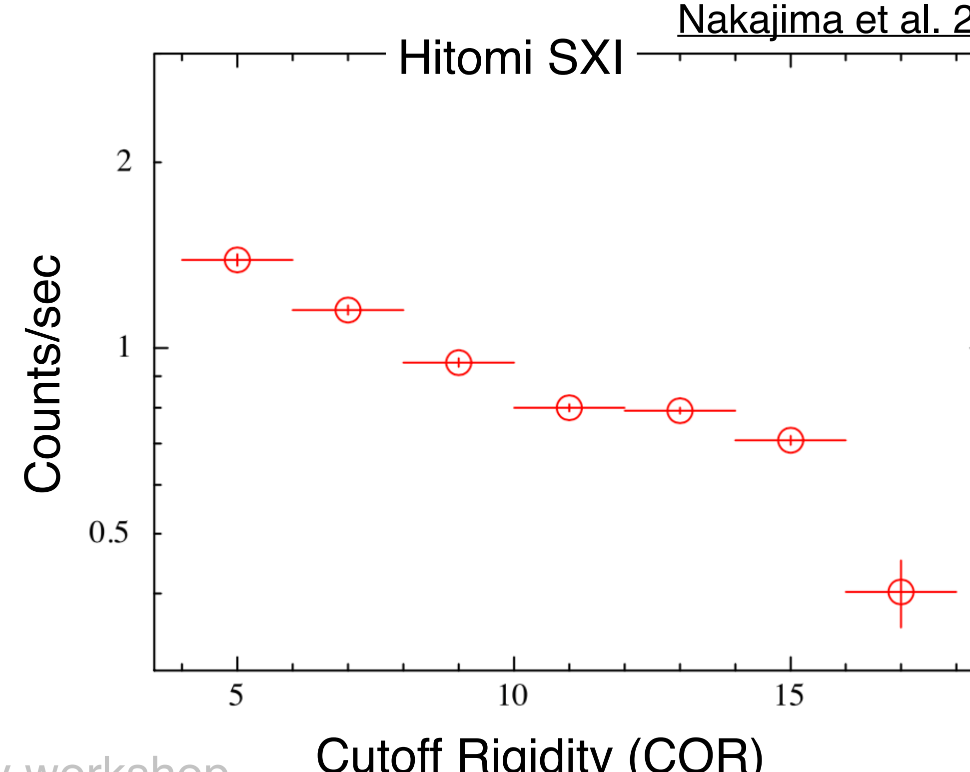


Non X-ray Background (NXB)

- No astronomical data during SAA with lots of charged particles.
- Cutoff Rigidity dependence
  - Total CR flux varies w/o changing spectral shape
  - Distribution changes on timescale of years
- More background in CCD rows far side from the readout.
- Xtend team collect NXB data from night earth observations and store them in CALDB. The data are accessible through `xtdnxbgen`.
- The team also provides a template NXB spectral model for c-stat fittings.

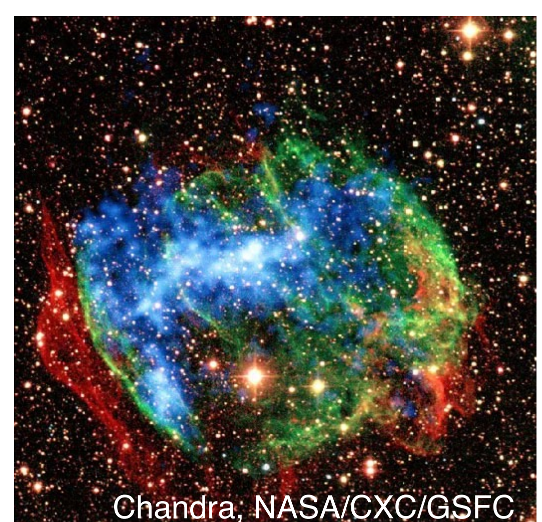


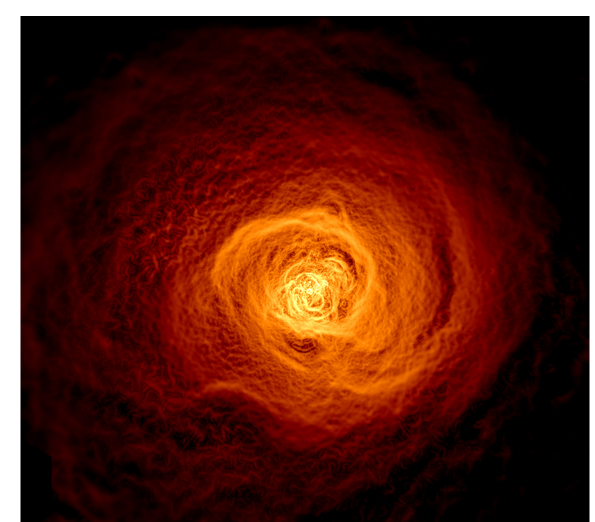
Nakajima et al. 2018

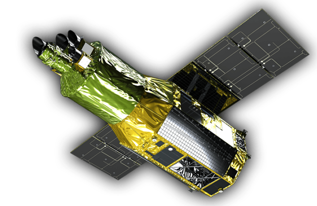


Sky Background

- The contribution may be non-negligible for extended sources
  - 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 e.g., Kuntz & Snowden 2000; Yoshino et al. 2009; Masui et al. 2009
  - 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
- They could also be interesting science objects (i.e., signals)!


Chandra, NASA/CXC/GSFC





Analysis procedure

- Similar to Suzaku XIS & Hitomi SXI

1. Reprocess data with the latest CALDB (`xapipeline`, `xtdpipeline`)
2. Extract image, spectrum, light curve (`xselect`, `fselect`, astropy, etc.) more filtering if needed (good time intervals, attitudes, etc.)
3. Make response files for spectral studies (`xtdrmf`, `xaexpmap`, `xrtraytrace`, `xaarfgen`)
4. Other procedures (`barycen`, detector background (`xtdnxbgen`), etc.)
5. Enjoy imaging/spectral/timing studies!

Transient Source Search

- The *XRISM* team will monitor Xtend data for transient sources before delivering data to the observers.
- The search is automatic, and the team will only analyze sources that show unusual brightness increases.
- If it's worth rapid announcements to the community, the team posts the findings to the Astronomer's Telegram or other appropriate sources.
- The observers are invited to the author list.
- If you don't want the team to touch your data, you can opt out by choosing "no" to the inquiry on the proposal form.

Questions?