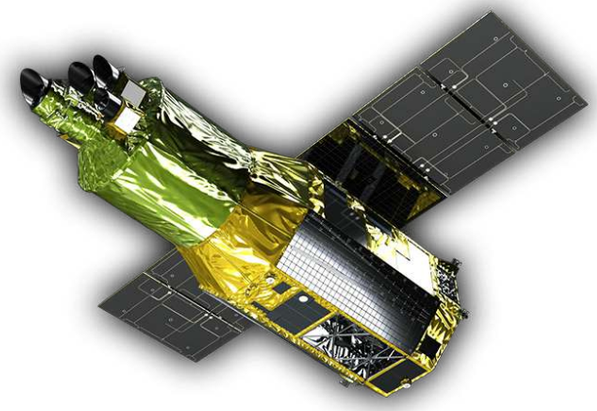
XRISM
X-Ray Imaging and Spectroscopy Mission

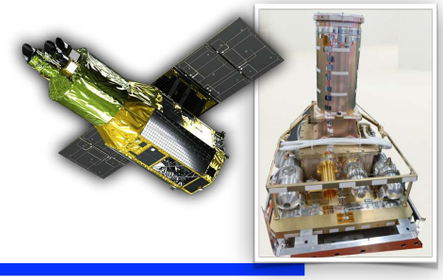


In-orbit operations, calibration, and performance of Xtend

Hiromasa Suzuki
(ISAS/JAXA, JP)
on behalf of the XRISM/Xtend team

This work was supported by JSPS Core-to-Core Program
(grant number:JPJSCCA20220002).

XRISM Xtend team



15 institutes
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- **Tokyo University of Science**
  S. B. Kobayashi, T. Kohmura
- **The University of Tokyo**
  K. Hagino
- **Chuo University**
  T. Yoneyama
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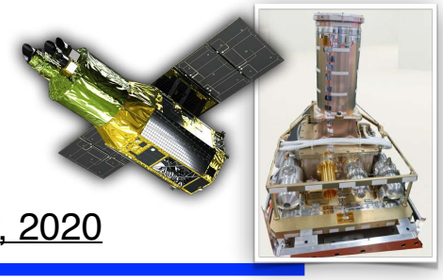
  K. K. Nobukawa
- **Osaka University**
  H. Noda, H. Matsumoto, H. Odaka, K. Hayashida
- **Konan University**
  T. Tanaka
- **University of Miyazaki**
  K. Mori (PI), M. Yamauchi, I. Hatsukade
- **NASA's GSFC**
  T. Okajima, Y. Soong, T. Hayashi

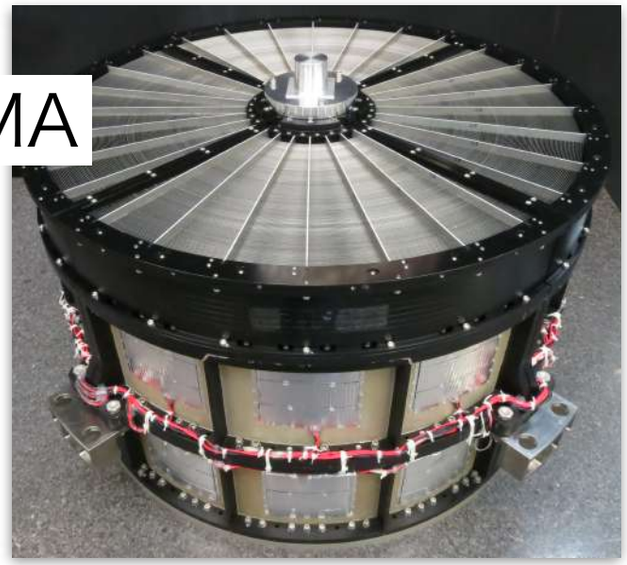
XRISM Xtend

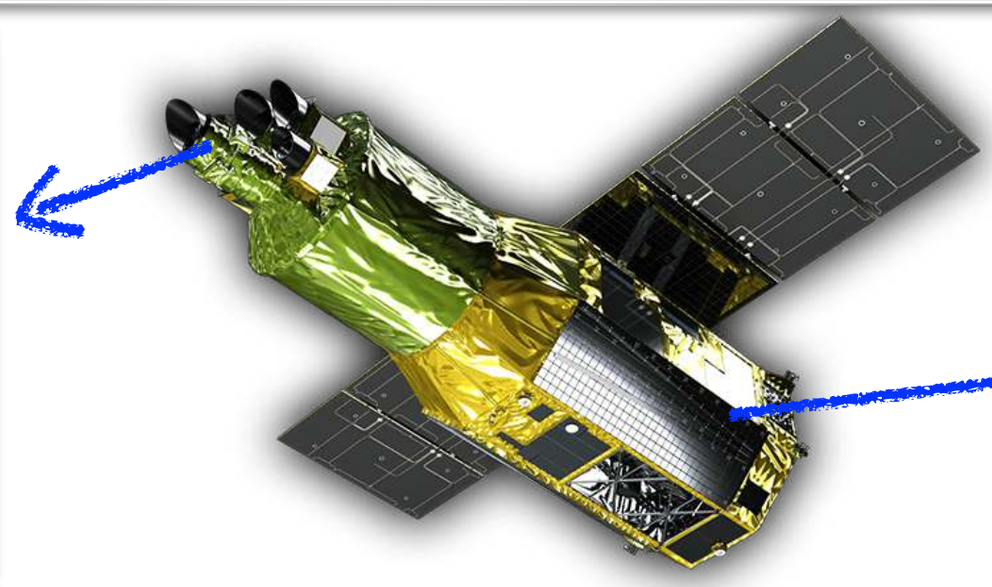
XRISM white paper, 2020



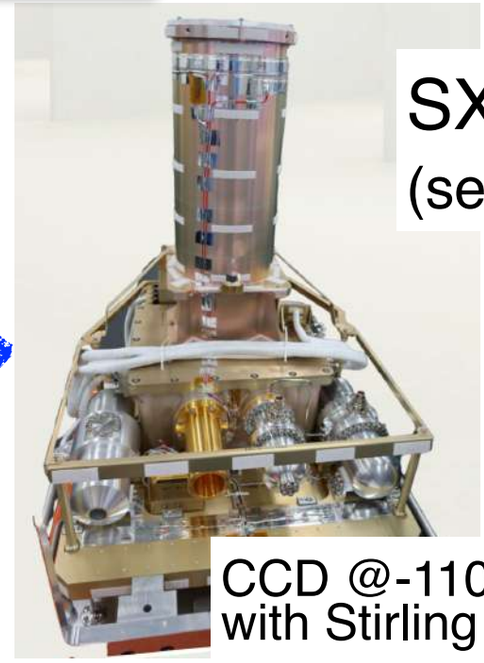
Xtend = XMA (X-ray Mirror Assembly) + SXI (Soft X-ray Imager)

XMA





SXI-S
(sensor)

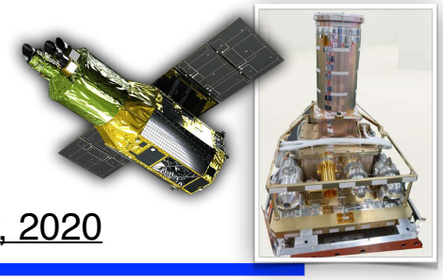


CCD @-110 degC
with Stirling cooler

- **XMA**：Wolter type I mirror optics
  - ✓similar to Hitomi SXT
- **SXI**：X-ray CCDs
  - ✓similar to Hitomi SXI
  - ✓fully-depleted back-illuminated P-channel CCD
- Energy range：0.4–13 keV
- FoV：38 arcmin × 38 arcmin
- Energy resolution：< 200 eV @5.9 keV (requirement)
- Ang. resolution：< 1.7’ (Half Power Diameter) (requirement)

XRISM Xtend

XRISM white paper, 2020



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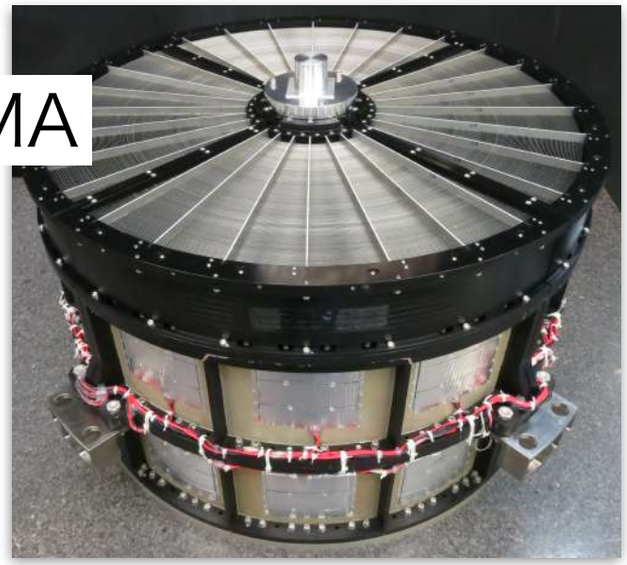

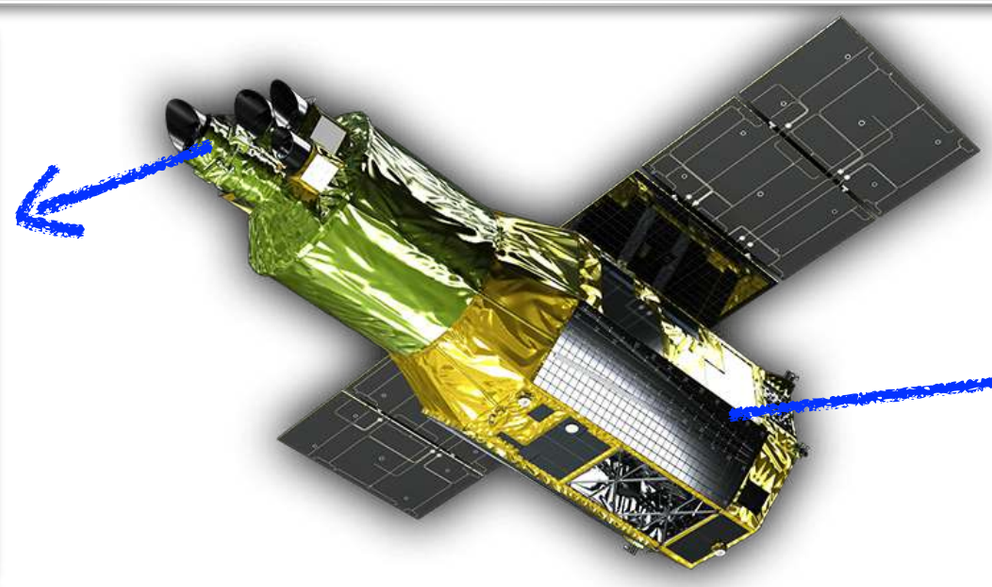

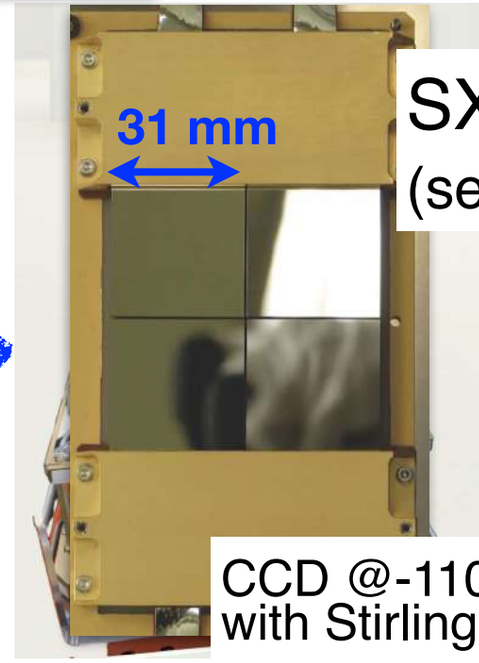

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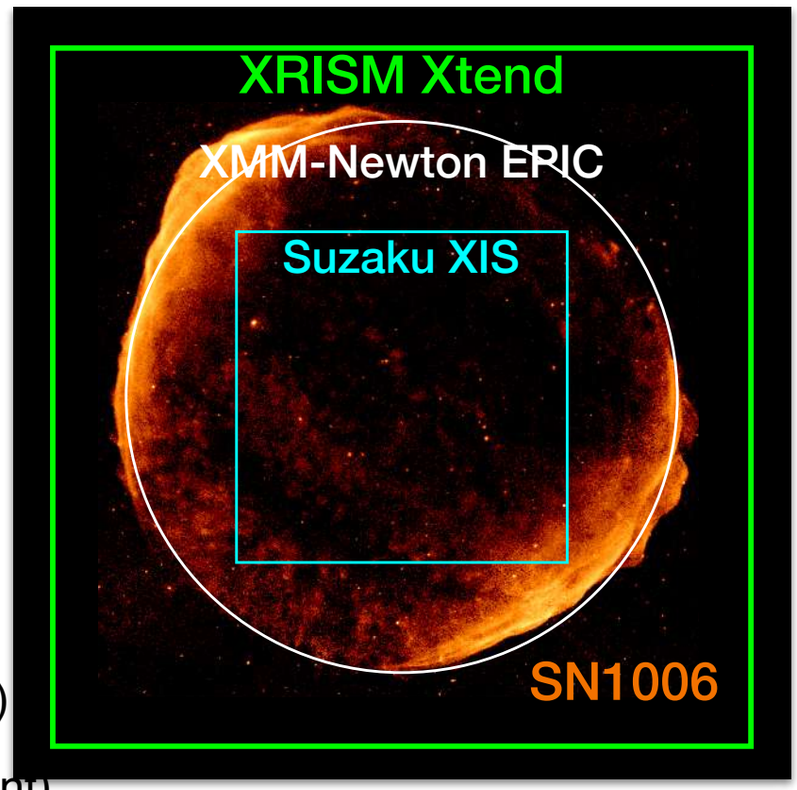
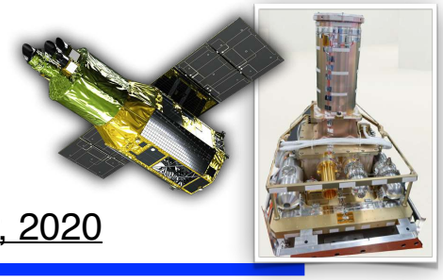
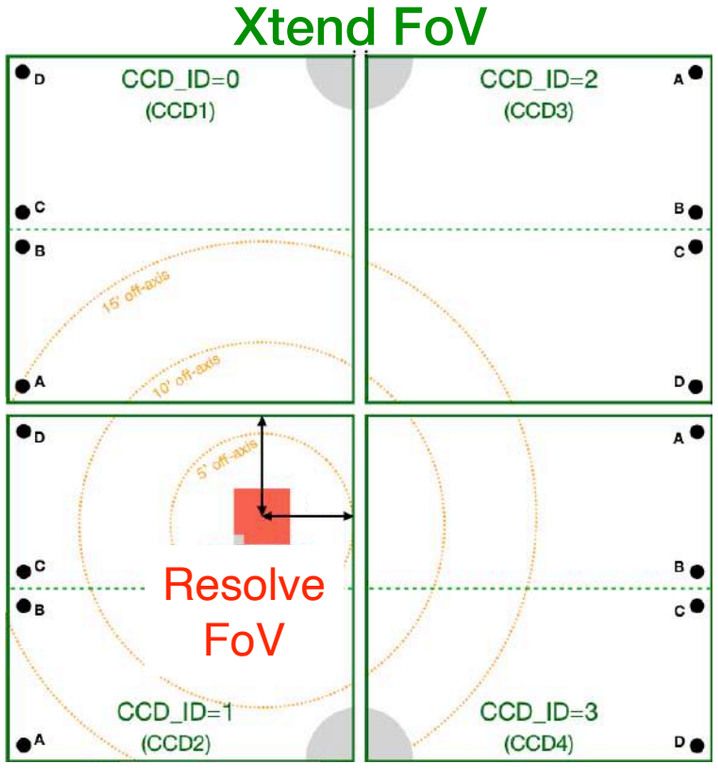


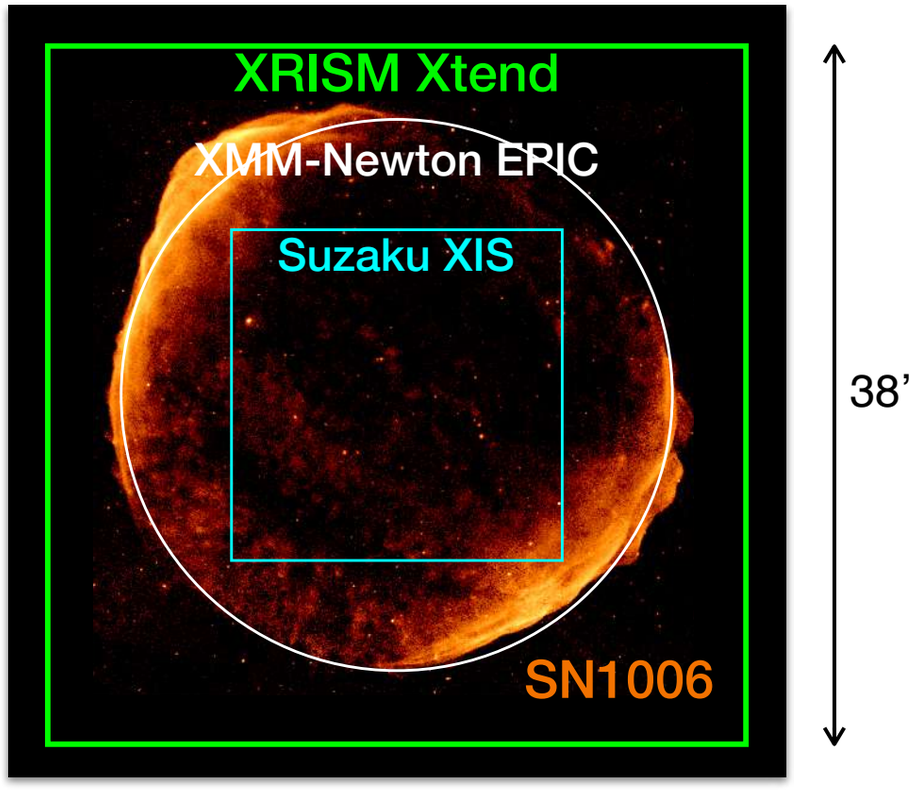
Strength



XRISM white paper, 2020

- **Monitor large area around Resolve FoV**
  → Clarify contribution of sources around target
    - sky background
    - contribution of bright/variable sources
- **Xtend itself will produce scientific achievements**
    - CCDs' good energy resolution
    - Low & stable detector background similar to Suzaku XIS/Hitomi SXI
    - 2x larger FoV than XMM-Newton
    - Semi-automatic transient search system: time-domain astrophysics!

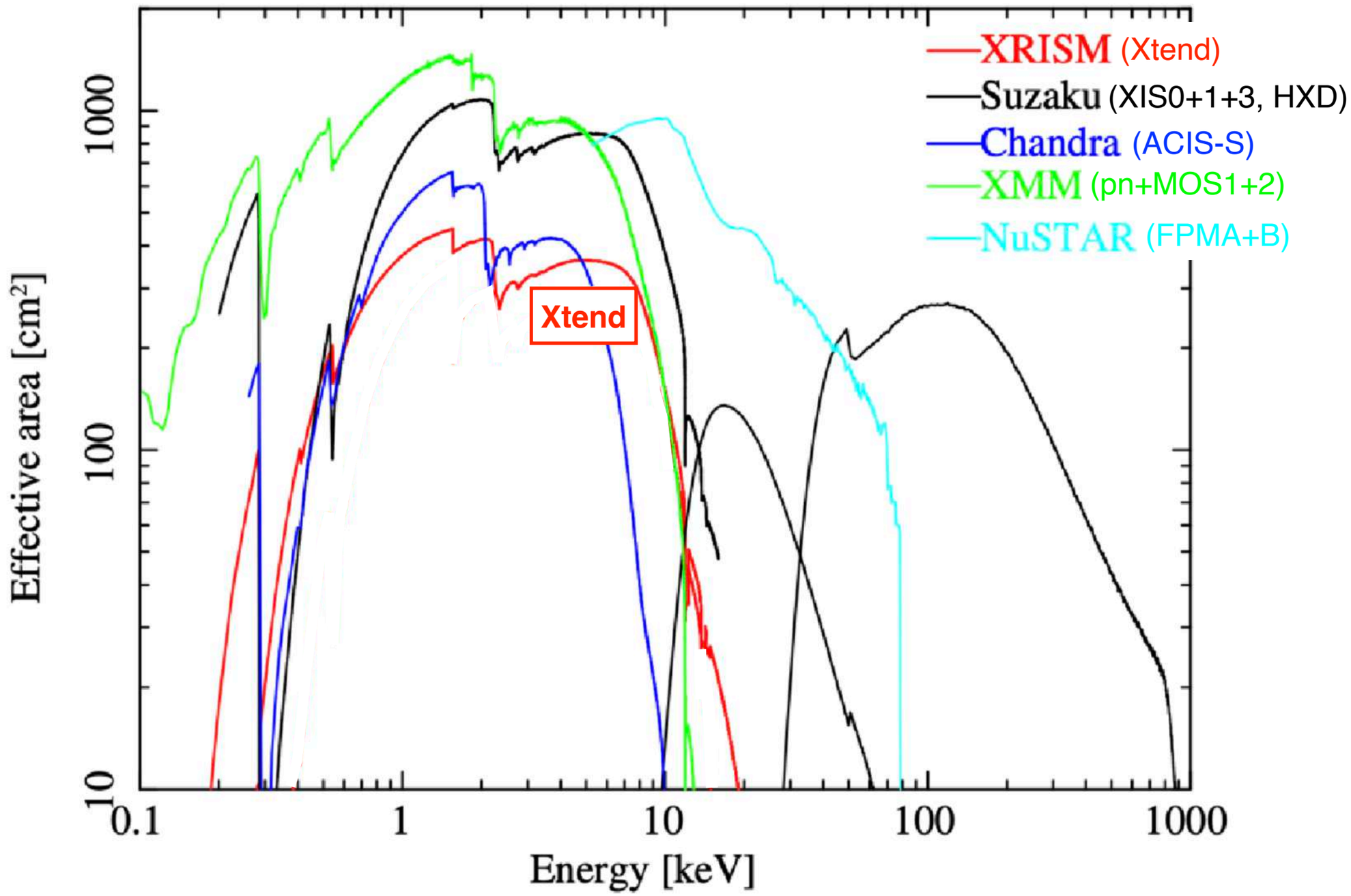




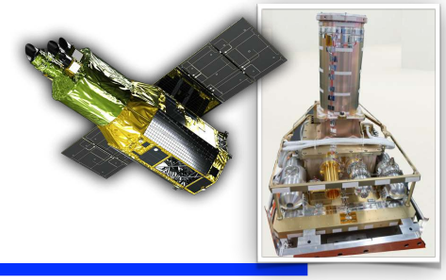
Effective area

XRISM Quick Reference, 2022

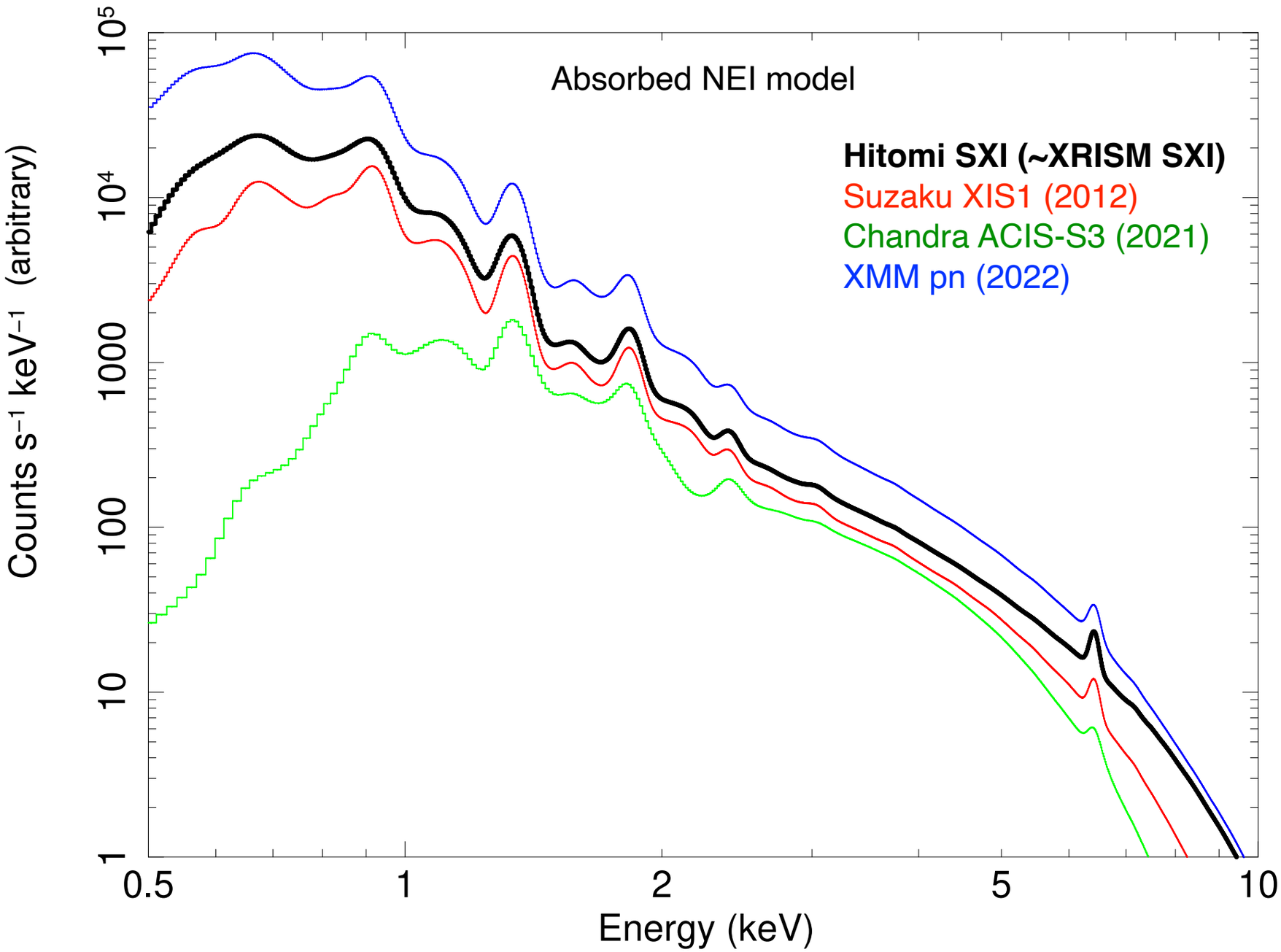
- Similar to Suzaku x0.4



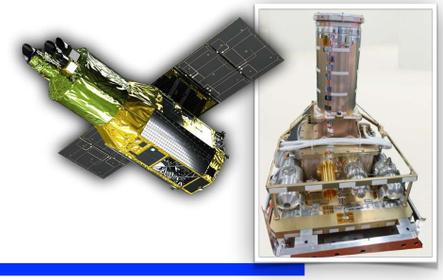
Detector response



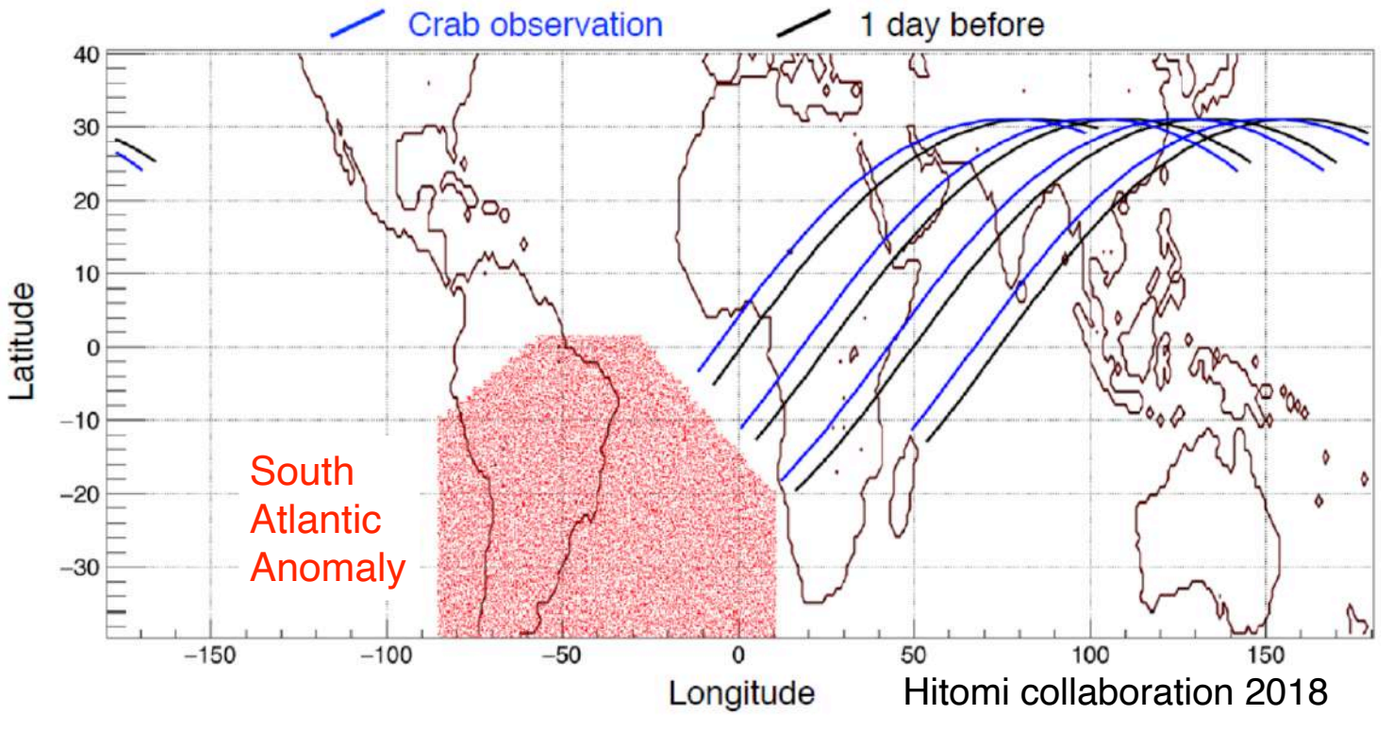
- Similar spectroscopic capability to other X-ray CCDs in orbit expected

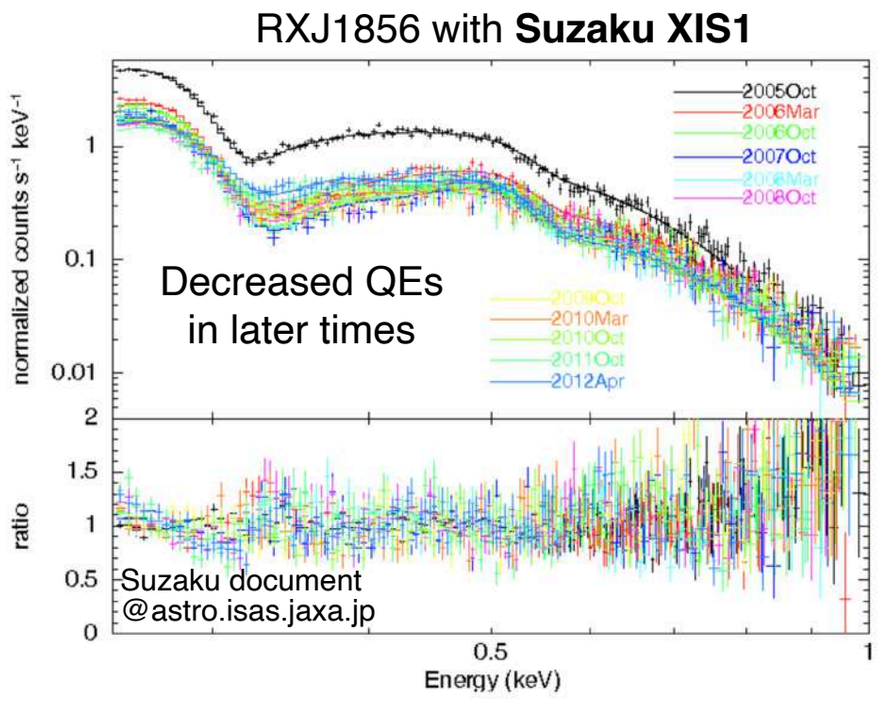


General notes on observations



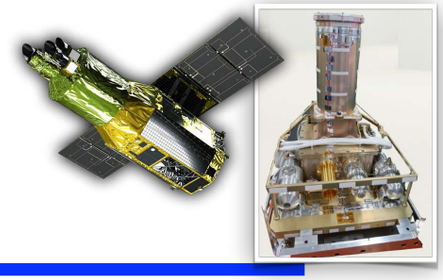
- Observation efficiency in low earth orbit
  - Earth occultation & day earth give dead times (~50%)
- Degradation of CCDs
  - Increasing Charge Transfer Inefficiency, bad pixels due to radiation
  - Increasing contamination due to outgas
    = lower quantum efficiencies at low energies
  - Note: no such evidence for Xtend up to now





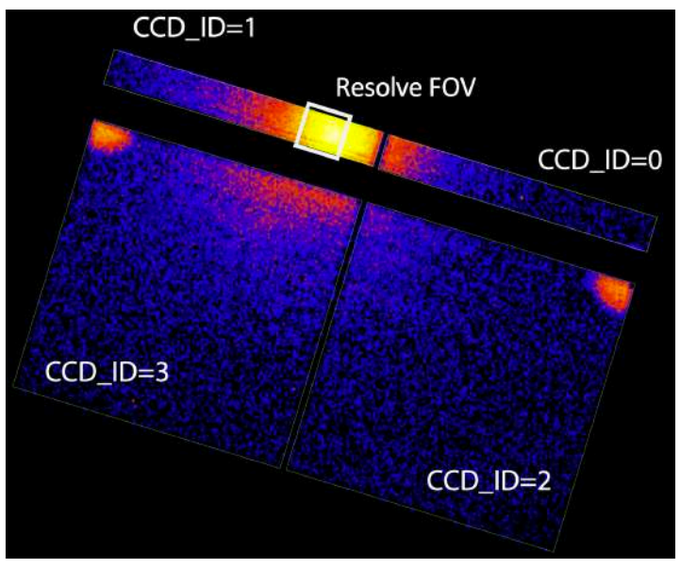
Observation modes

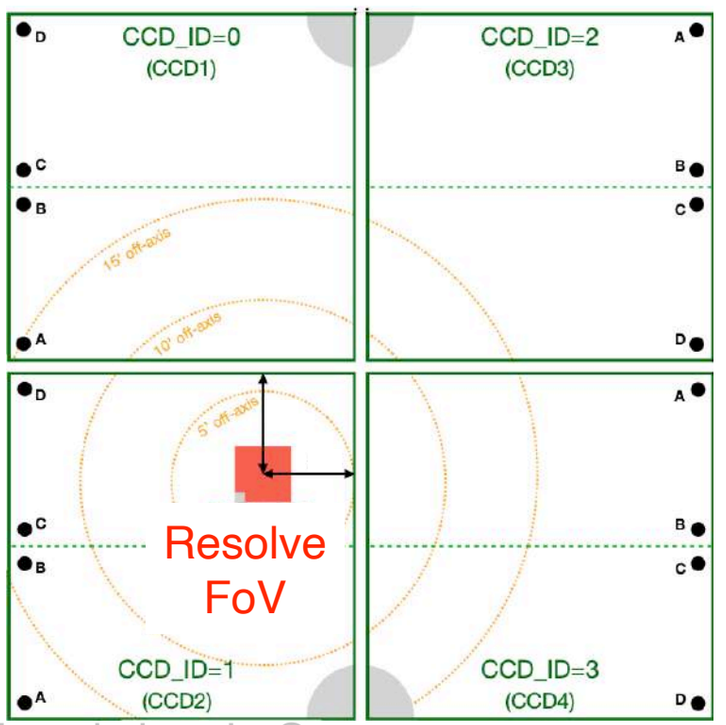
Tanaka et al. 2018



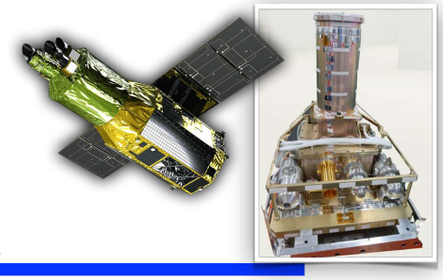
Mode	Region size	Frame exposure	Live time fraction	Purpose
Full window	1	4.0 sec	0.99	General
1/8 window	1/8	0.46 sec	0.93	Bright/variable sources (against pile-up, etc.)
1/8 window + 0.1-s burst	1/8	0.06 sec	0.12	Bright/variable sources (against pile-up, etc.)
0.1-s burst	1	0.06 sec	0.015	Crab mode, not for users

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





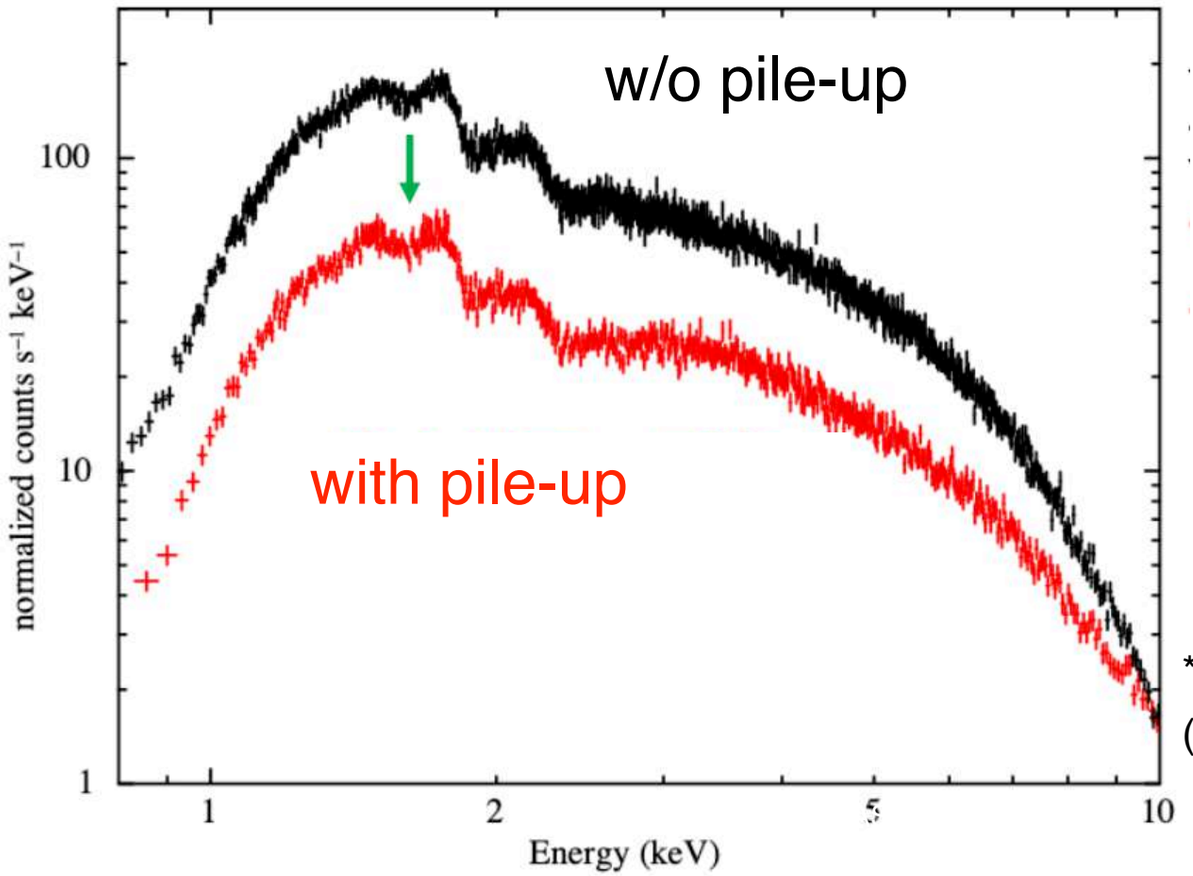
Bright source observations



Tamba et al. 2022

Proposer's guide (to be announced)

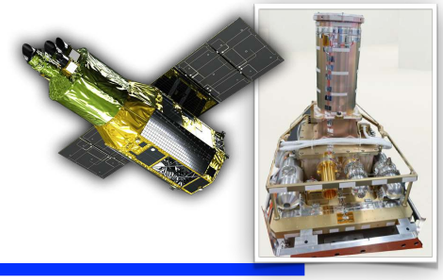
- Consider pile-up limits (depends on spectral shape)
  - Full win.: ~2.5 mCrab
  - 1/8 win.: ~20 mCrab
  - 1/8 win. + burst: ~190 mCrab
- Pile-up estimator will be provided to observers
  - i.e., choose target's flux & power-law index → check pile-up



*Extreme case

(0.5 Crab, 8 sec frame exposure)

Analysis procedure

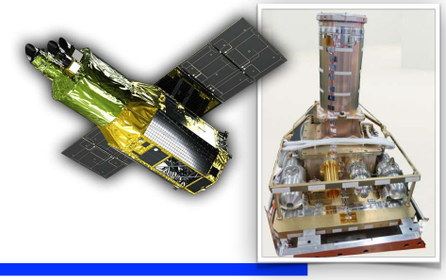


Refer to Hitomi Analysis Guide, Step-by-Step guide
Will be updated for XRISM

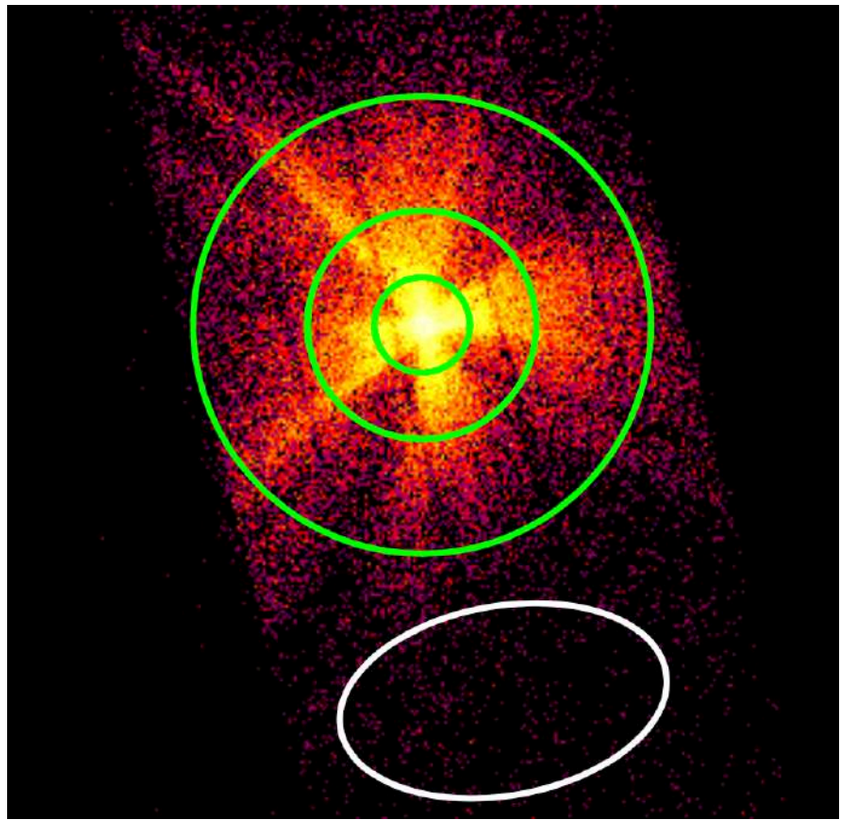
- Similar to Suzaku XIS & Hitomi SXI

1. Reprocess data with latest CALDB (`xapipeline`, `xtdpipeline`)
2. Extract image, spectrum, light curve (`xselect, fselect`, astropy, etc.) with 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!!

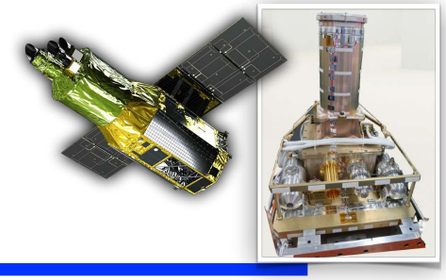
Analysis of bright sources



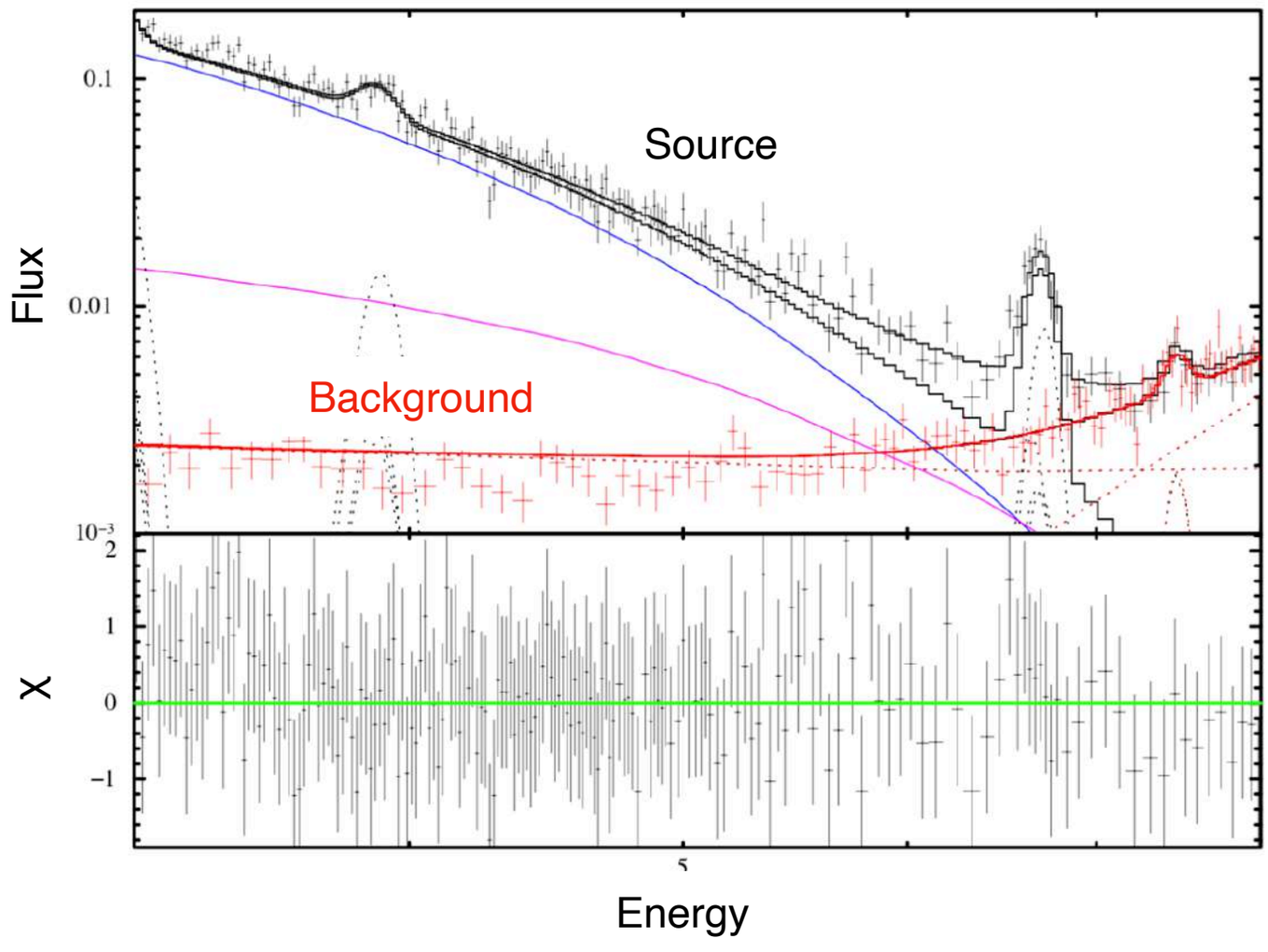
- If so bright that pile-up affects data…
  - first try to avoid this!! but sometimes need good statistics, unluckily affected by solar flares, …
  - conventional “core exclusion” method still is a good way
  - simulator-based method is another option, but will not generally provided to users Tamba et al. 2022



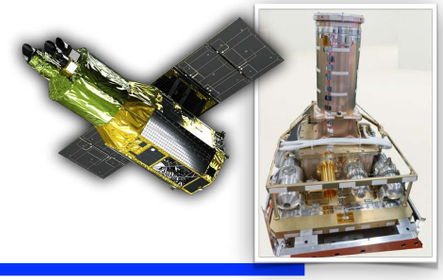
Detector background



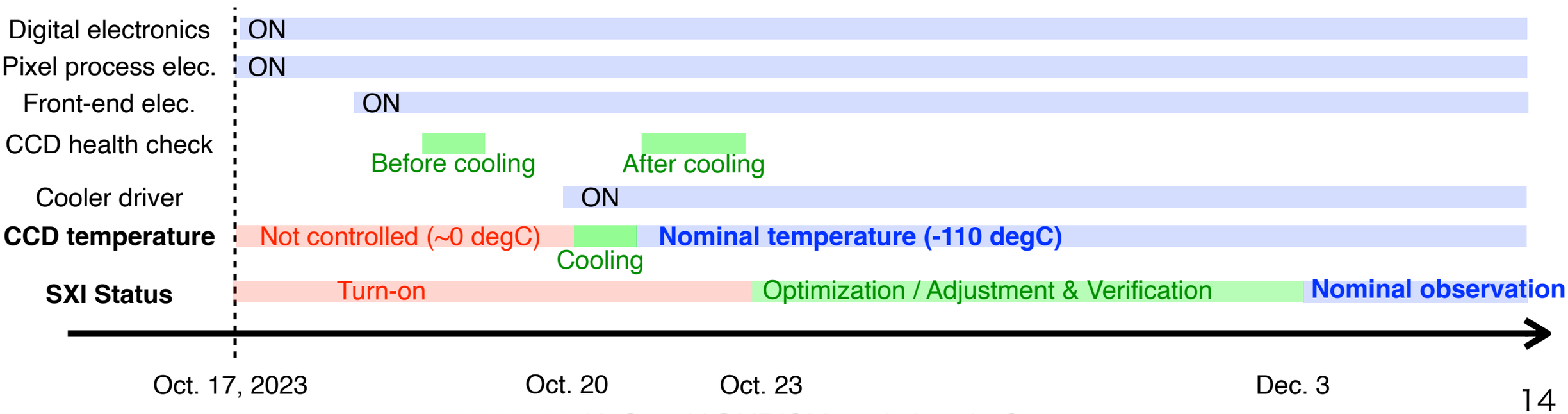
- Background spectra generating tool (`xtdnxbgen`)
- Use C-stat/W-stat in spectral studies XSPEC manual
- W-stat or “Source & Background” better than “Source – Background”



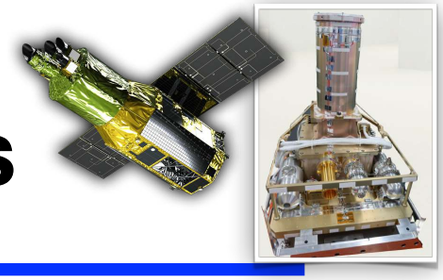
Initial operations



- **Oct. 17–23, 2023: Power-on operations of SXI**
  - CCD health check before cooling
  - cooling of CCDs
  - CCD health check at -110 degC
- **Oct. 23–Dec. 3, 2023: Parameter optimization/adjustment & verification**
  - optimize power of cooler driver
  - optimize observation parameters
  - adjust imaging region for 1/8-win mode
  - adjust operations for SAA/day-earth passages
- **Dec. 3–: (Almost) Nominal observation**



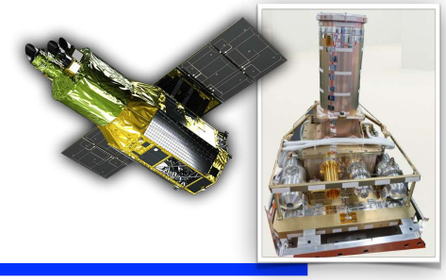
In-orbit performance & calibration status

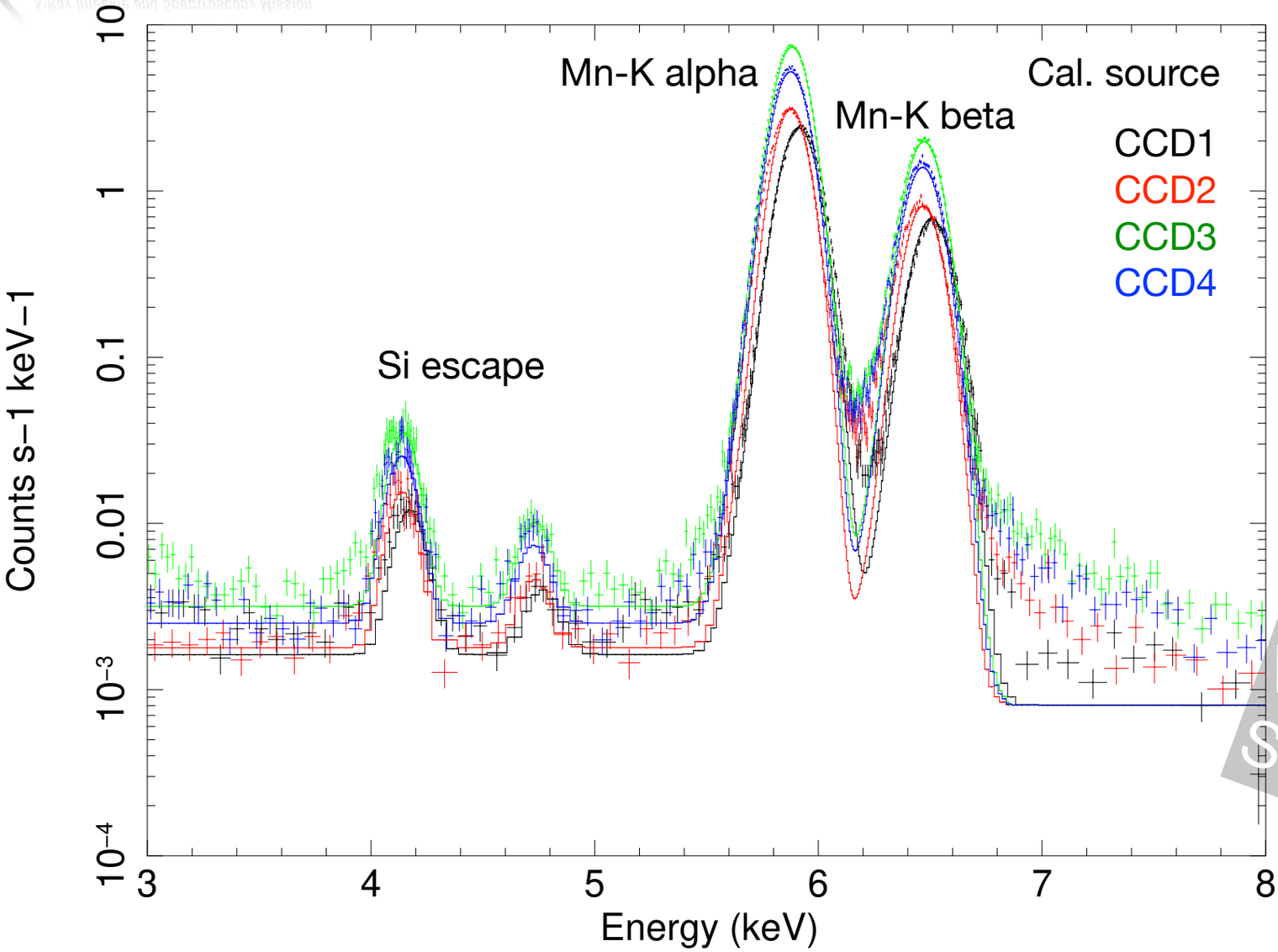


Very preliminary!!
Subject to change!!

- Energy resolution
- Effective area
- Point spread function
- Background level
- Other topics
  - contamination
  - stability after SAA passage
  - Xtend transient search

Energy resolution





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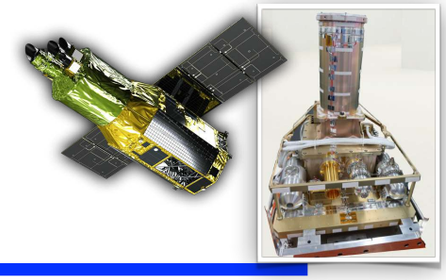
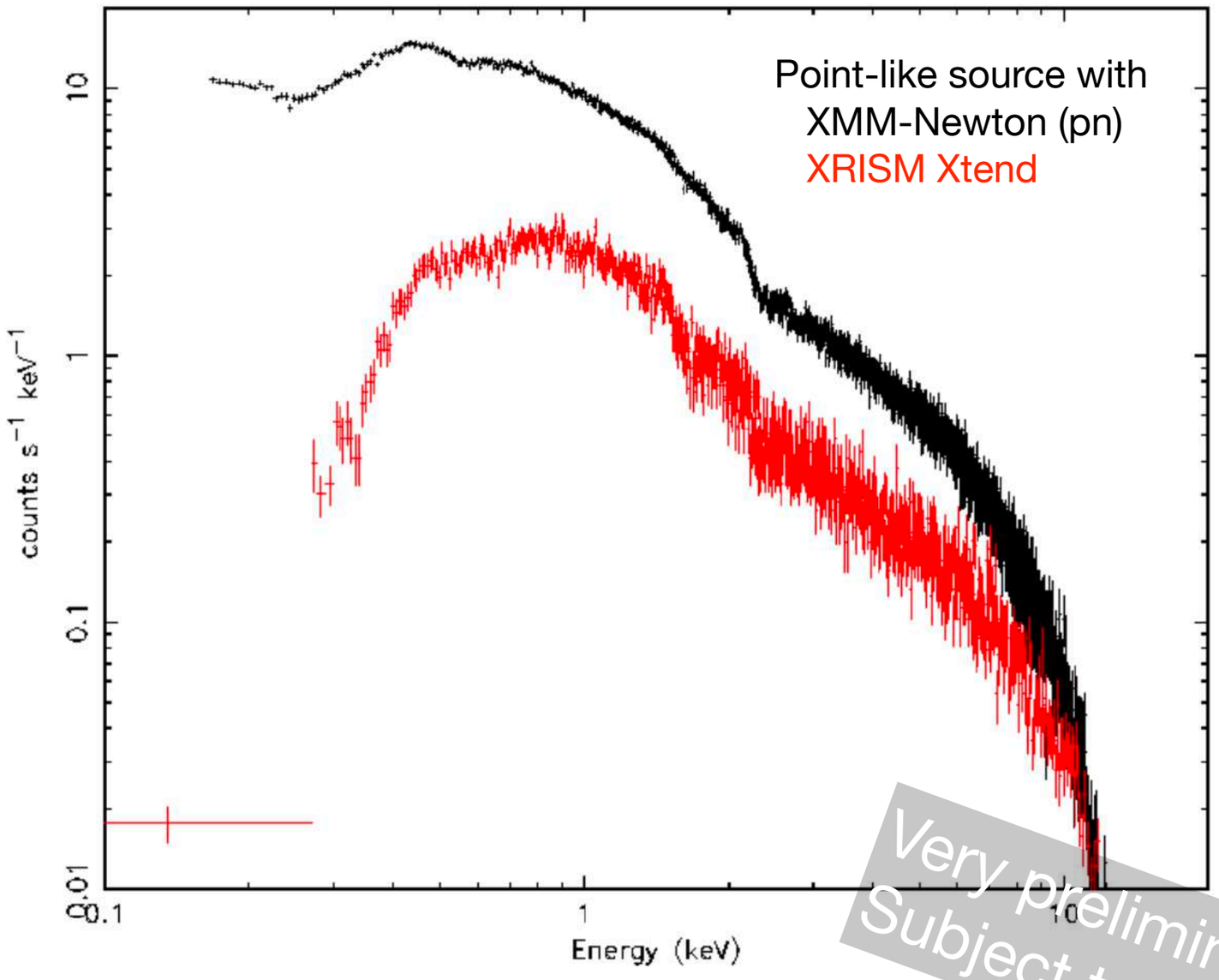
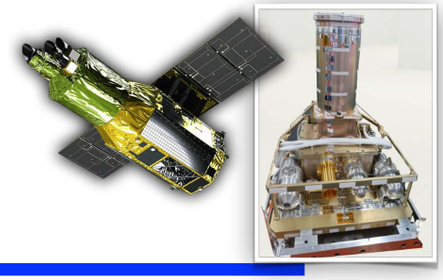
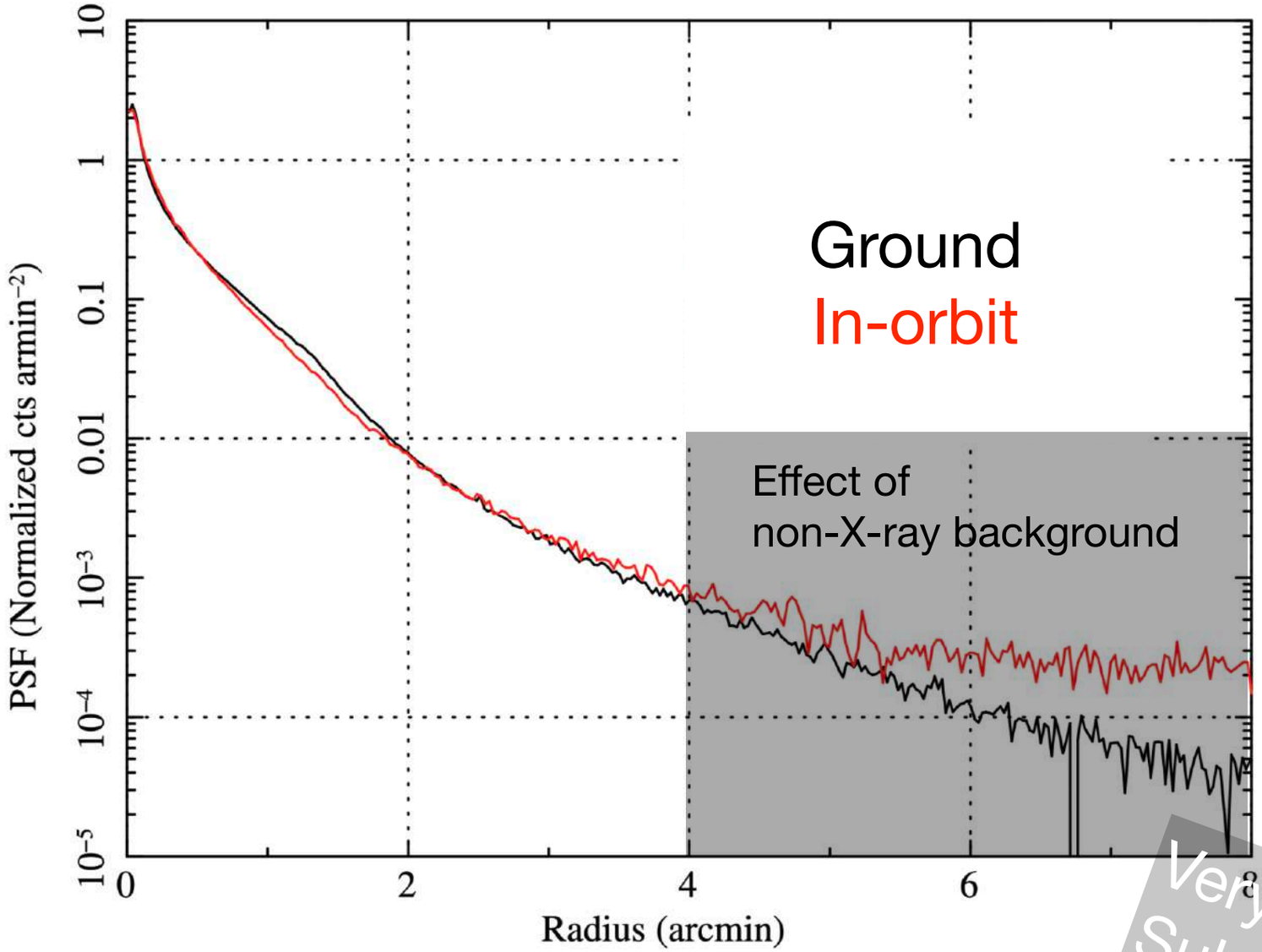




Very preliminary!!
Subject to change!!

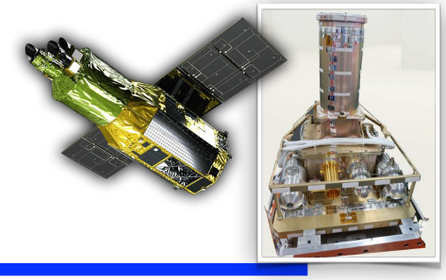
Point spread function

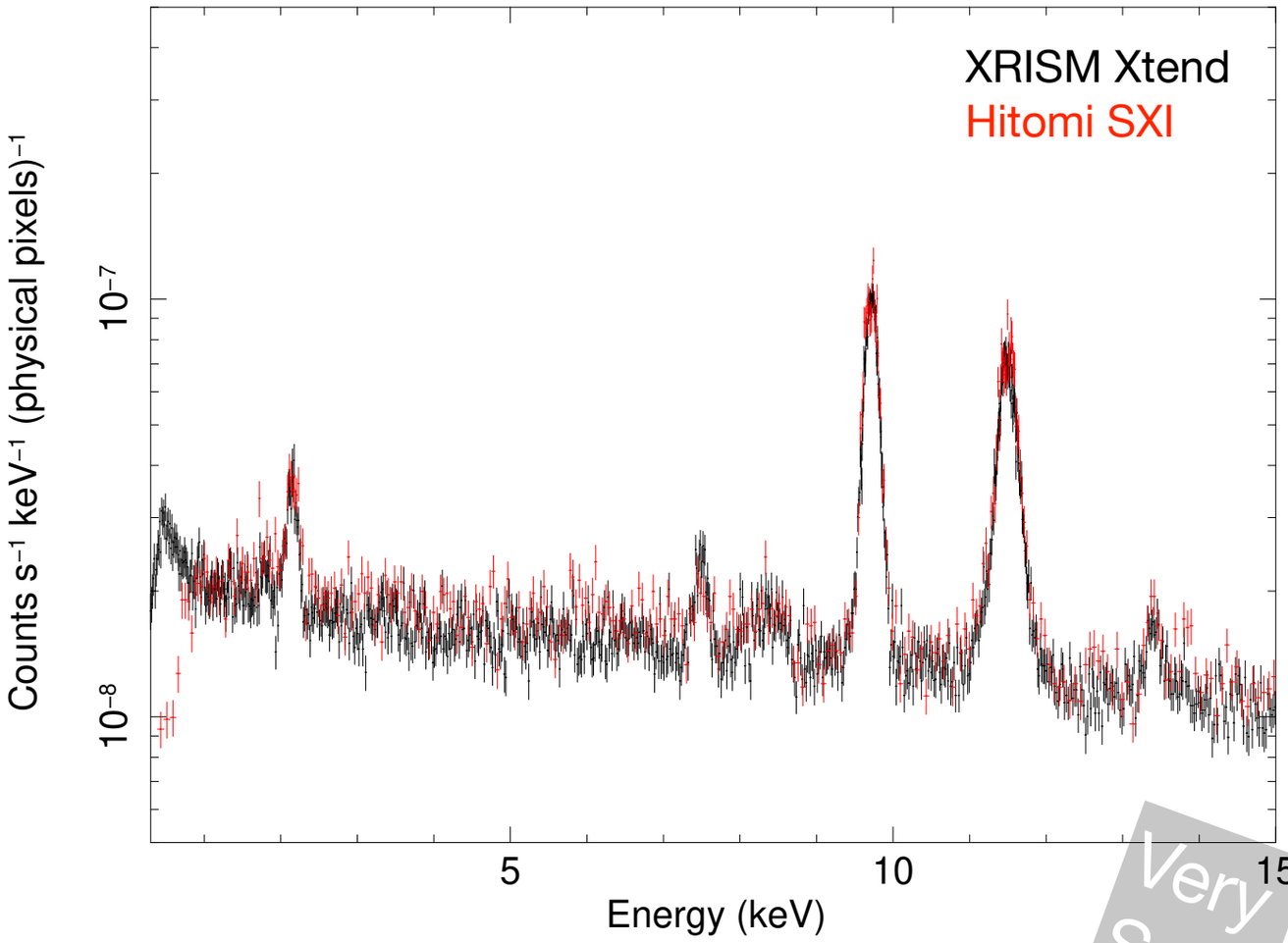




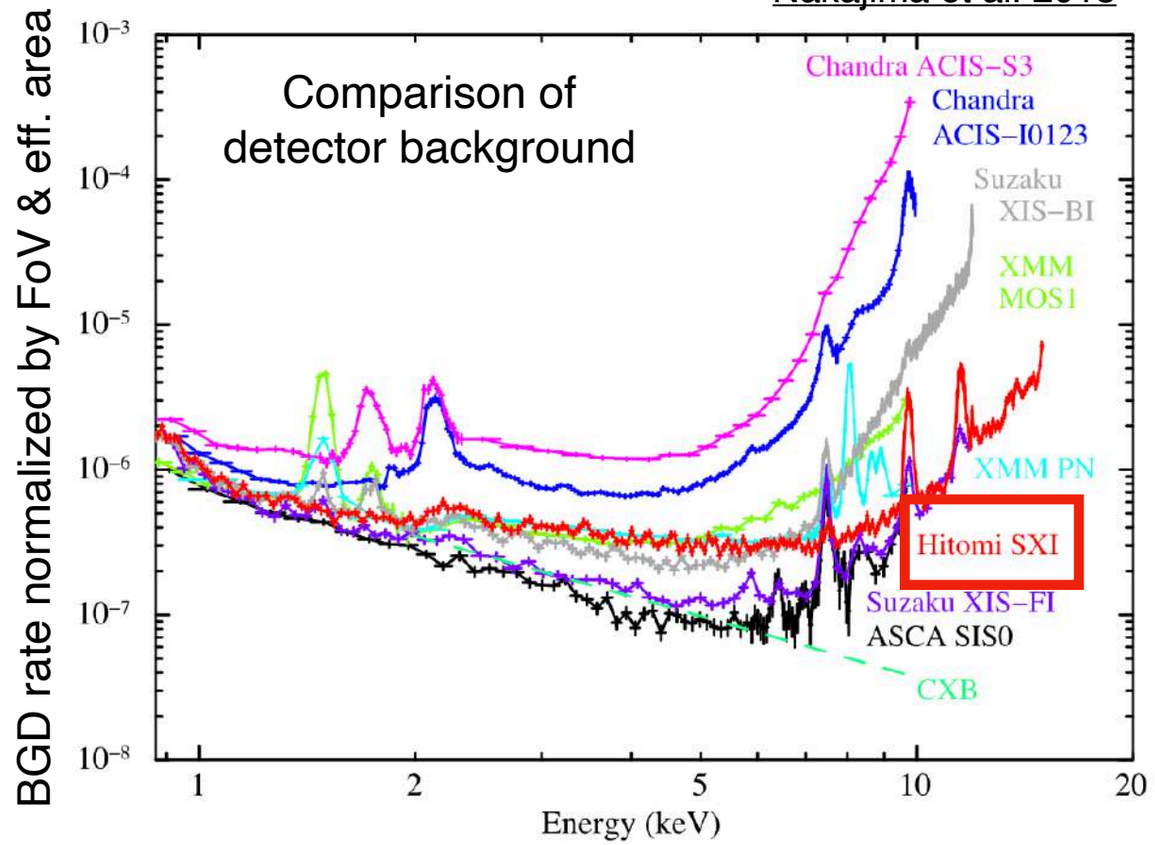
Very preliminary!!
Subject to change!!

Non-X-ray Background level



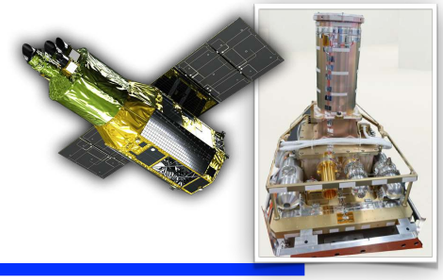


Nakajima et al. 2018



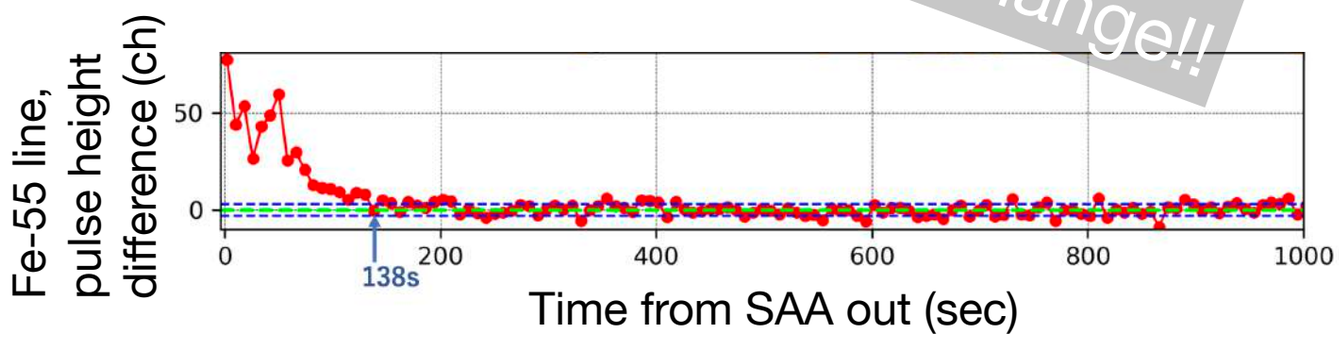
Very preliminary!!
Subject to change!!

Other topics



- Contamination
  - no evidence for contamination on CCDs right now
- Stability after SAA passage

Very preliminary!!
Subject to change!!



- Xtend transient search (XTS) system: Contribution to time-domain astrophysics!
  - observers' option at proposal submission (yes/no)
  - if yes, XRISM team members look at data (every day) before passed to observers, to search for transient sources (only for QL, exclude Resolve FoV)
  - if found, XRISM team posts a telegram
  - system under construction & verification

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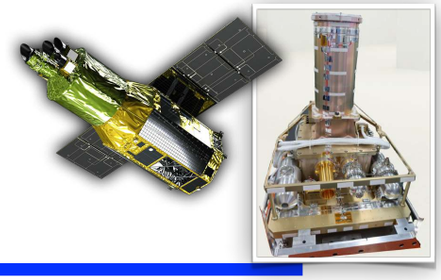
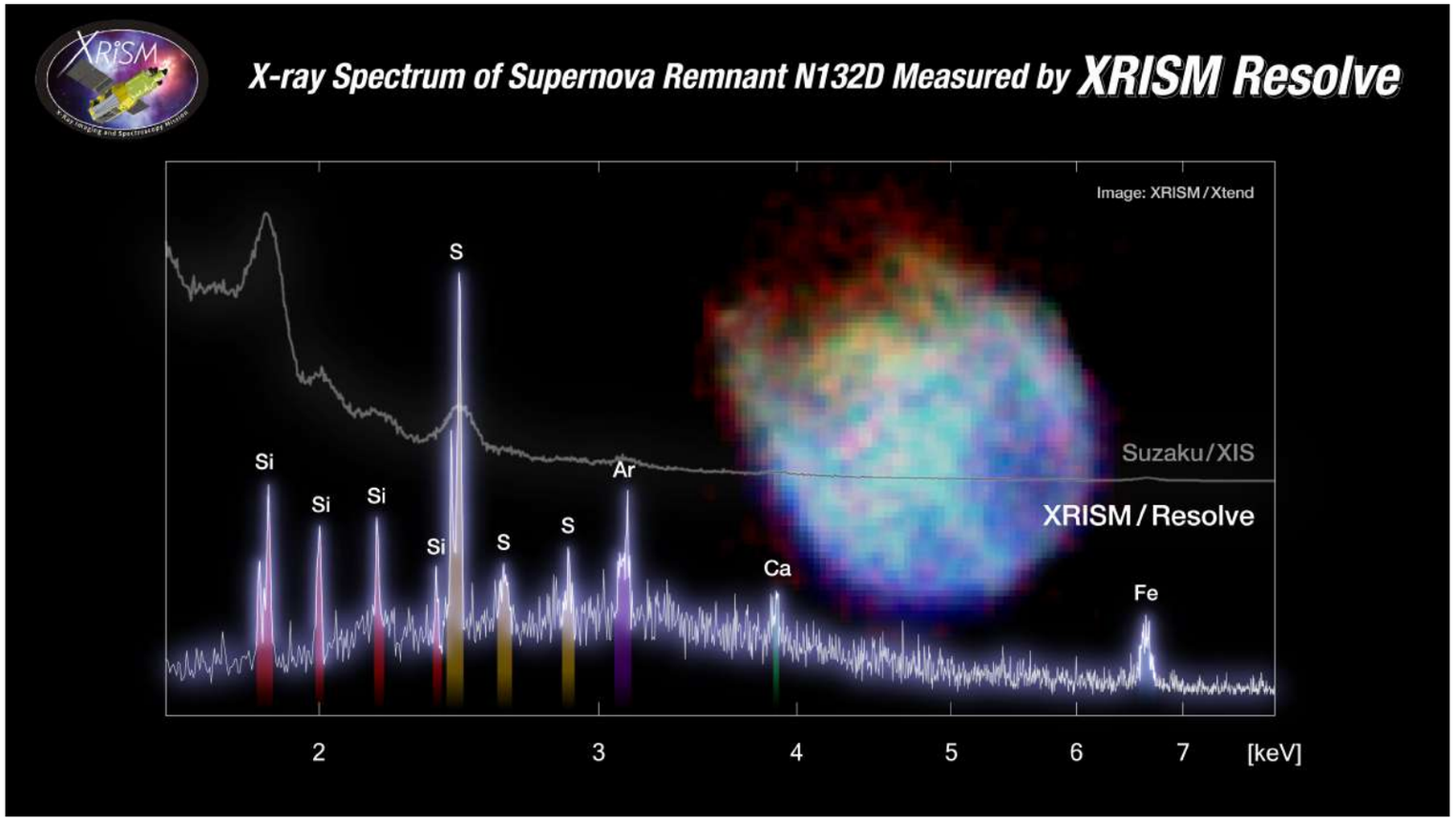
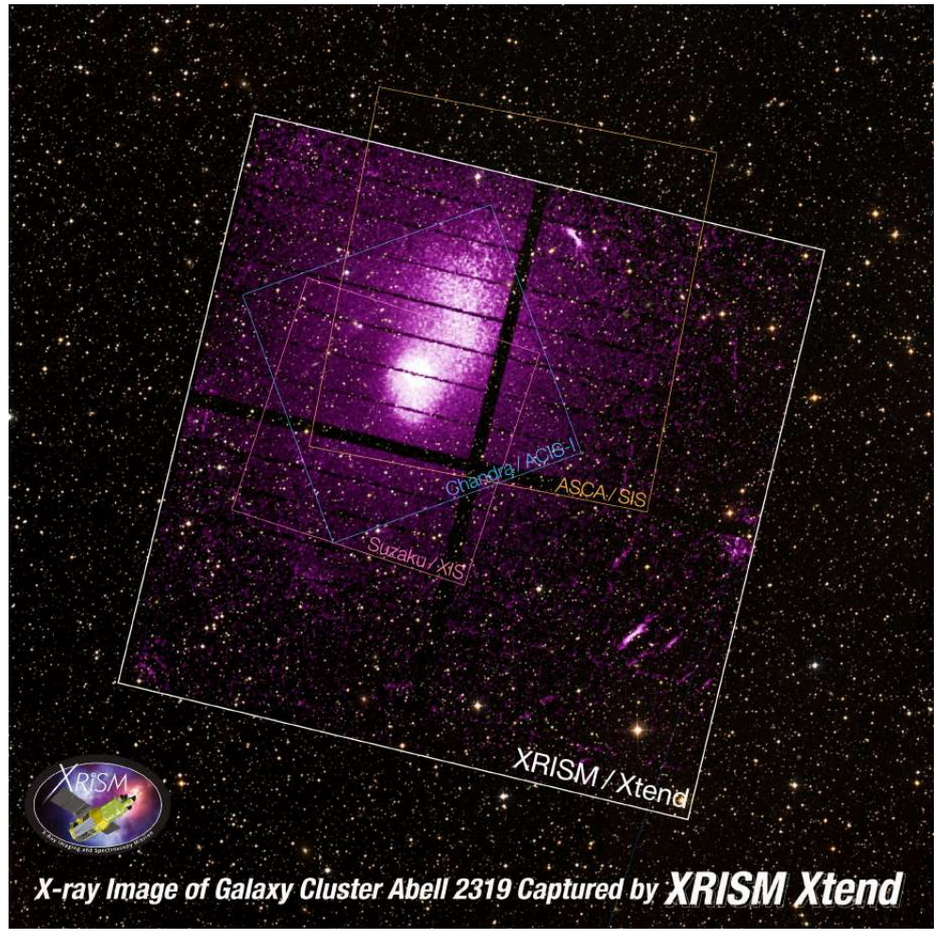
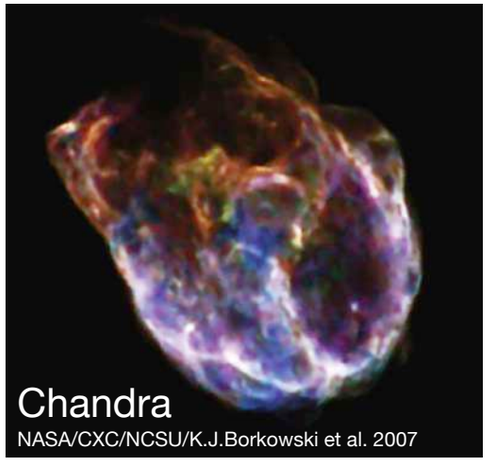
X-Ray Imaging and Spectroscopy Mission

First light

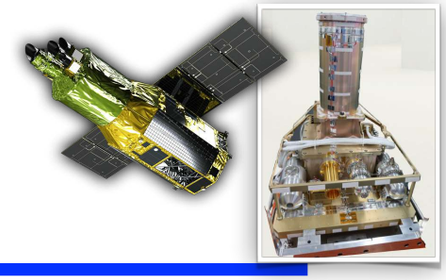


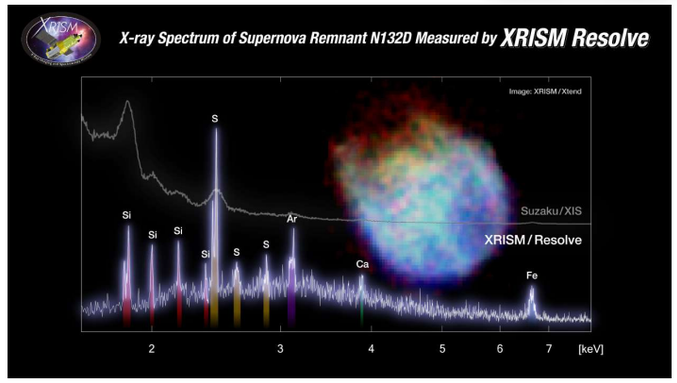






Key takeaways



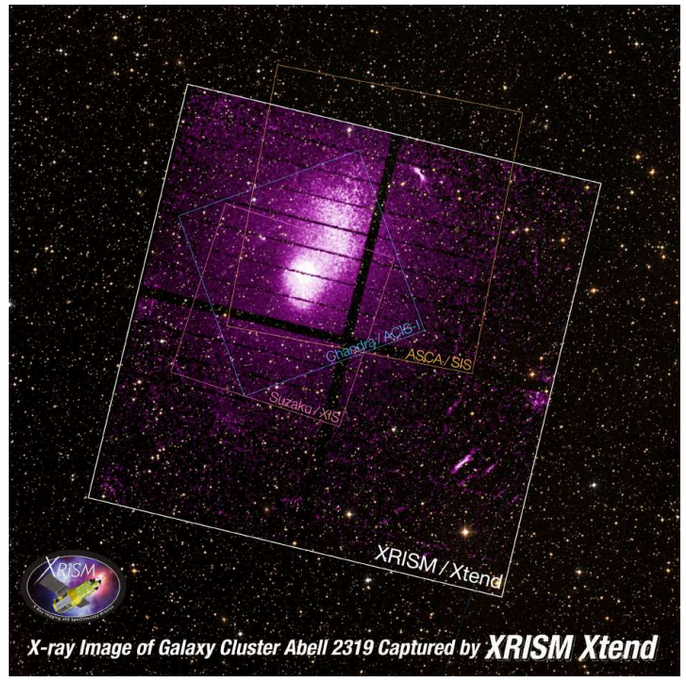


When observing with Xtend, consider…

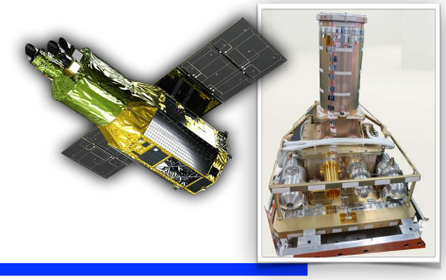
- CCD gaps (40–60”)
- Moderate energy resolution at low energies
- 3 observation modes (full win., 1/8 win., 1/8 win+burst)
- ~50% observation efficiency due to low earth orbit
- Sky/detector background
  - coordinates (sky/detector) / time dependence
    - use W-stat or Source & background simul. spec. modeling
- Pile-up for point sources with > ~2.5 mCrab
  - try to avoid pile-up, use pile-up estimator

In-orbit performance (very preliminary!!)

- Requirements satisfied:
  Energy resolution, Angular resolution,
  Effective area, Low & stable background
  similar to Hitomi SXI
- Calibration still ongoing, stay tuned!

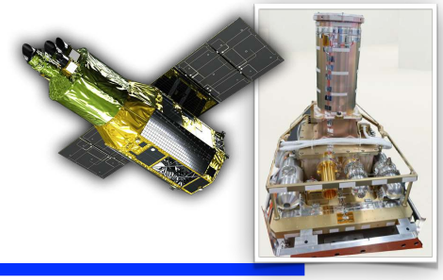


Back up

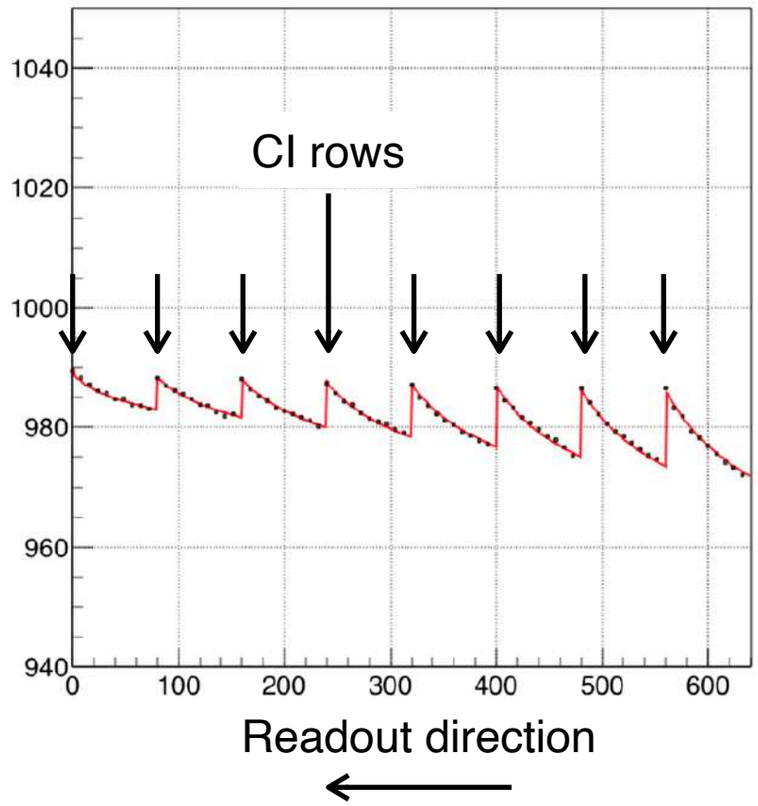


CCDs of SXI

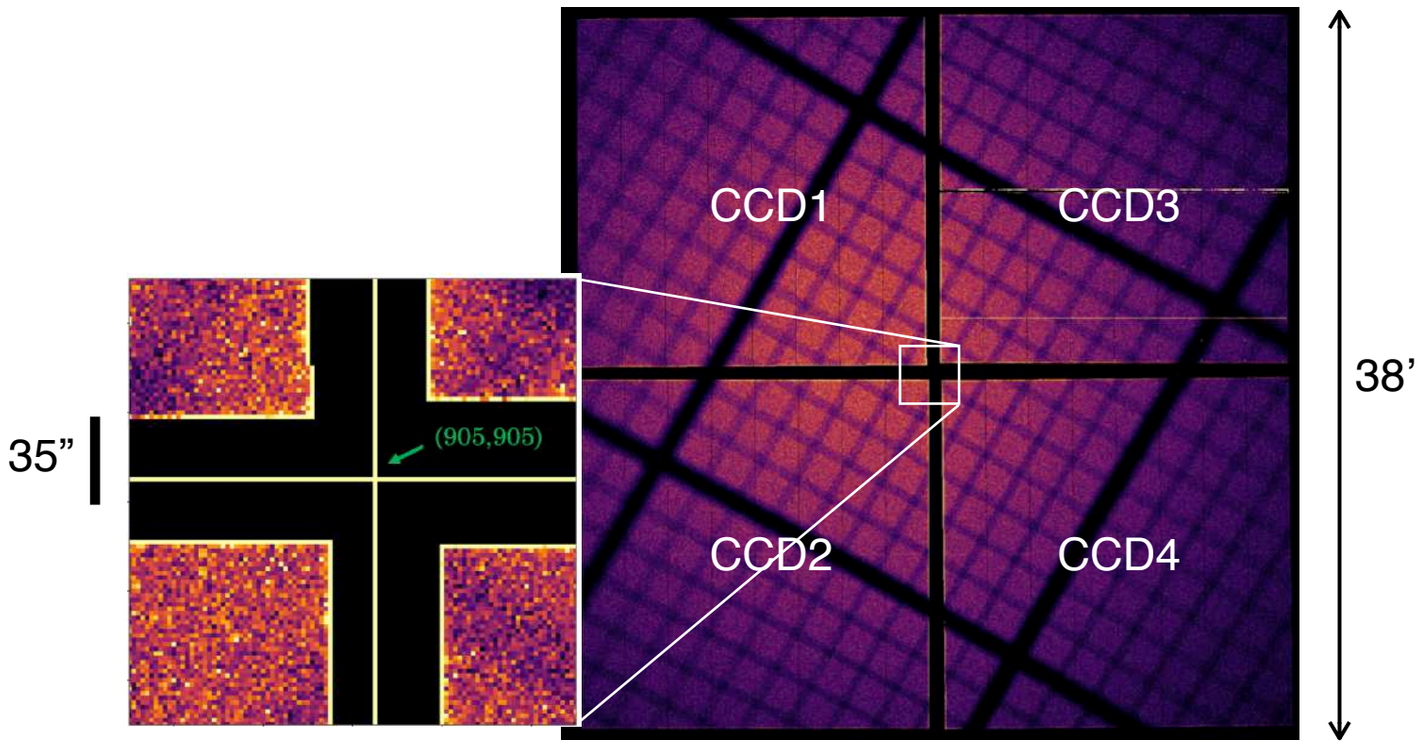
Tanaka et al. 2018



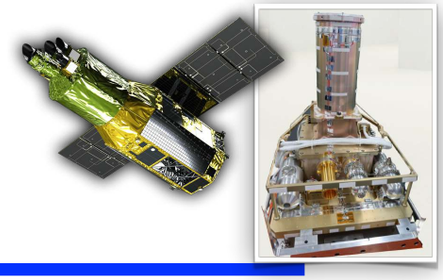
- Frame exposure time: 0.06–3.96 sec (depends on obs. modes)
- Charge Injection (CI) technique:
  - give artificial charges to minimize charge transfer inefficiency
  - similar to Suzaku XIS/Hitomi SXI



- Mind the gaps between CCDs!!
  - 40”–60”
  - Point sources may fall into the gaps

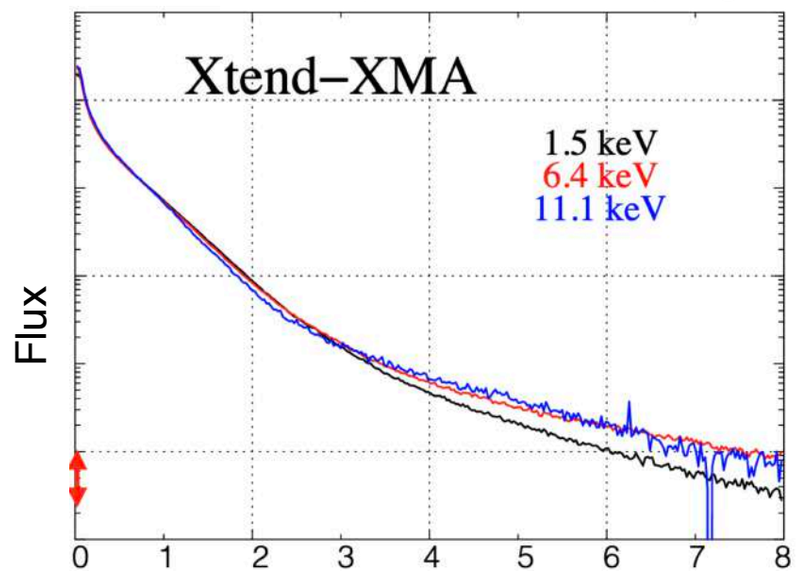


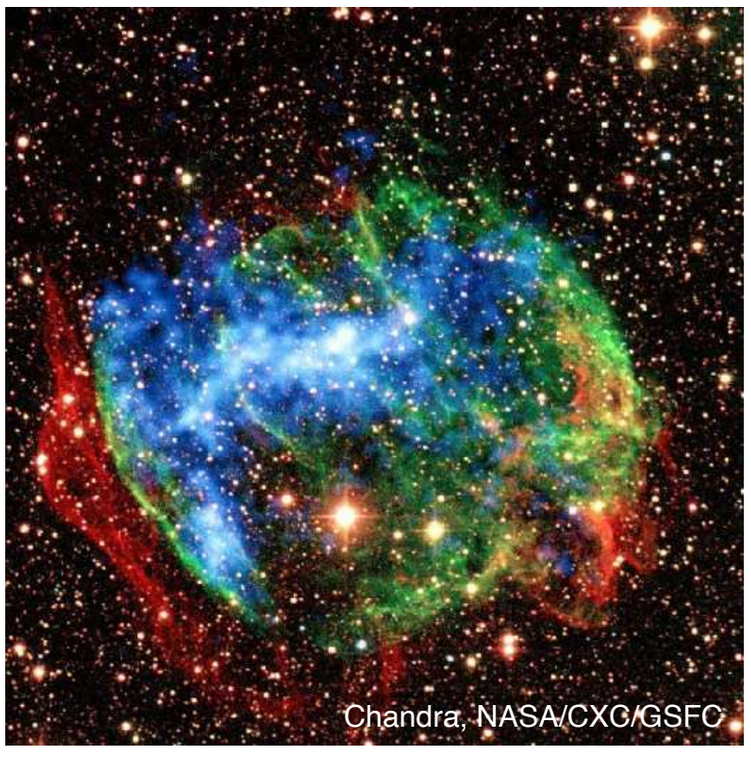
Observing extended sources

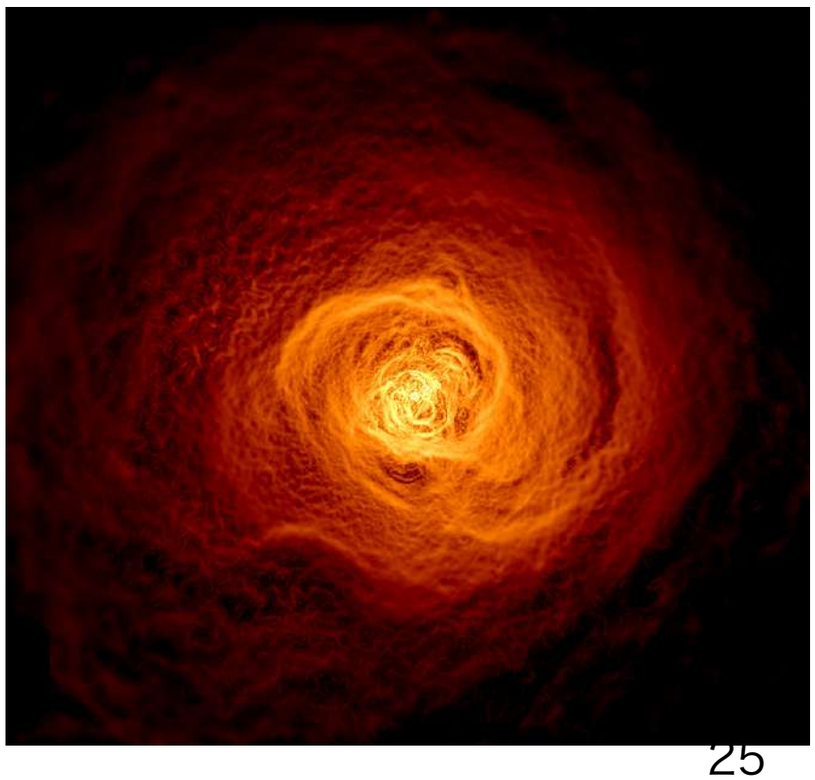


- Consider…
  - Bright sources around the target
  - Sky / detector backgrounds affect more than for point sources

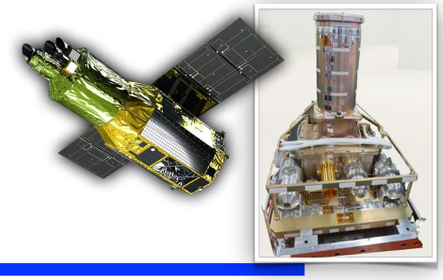
Point spread function (on ground)







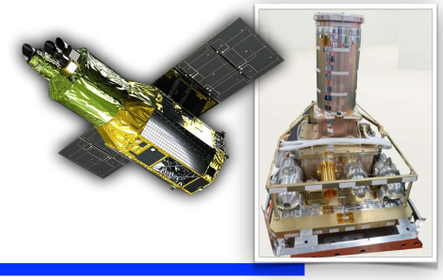
Analyzing extended sources



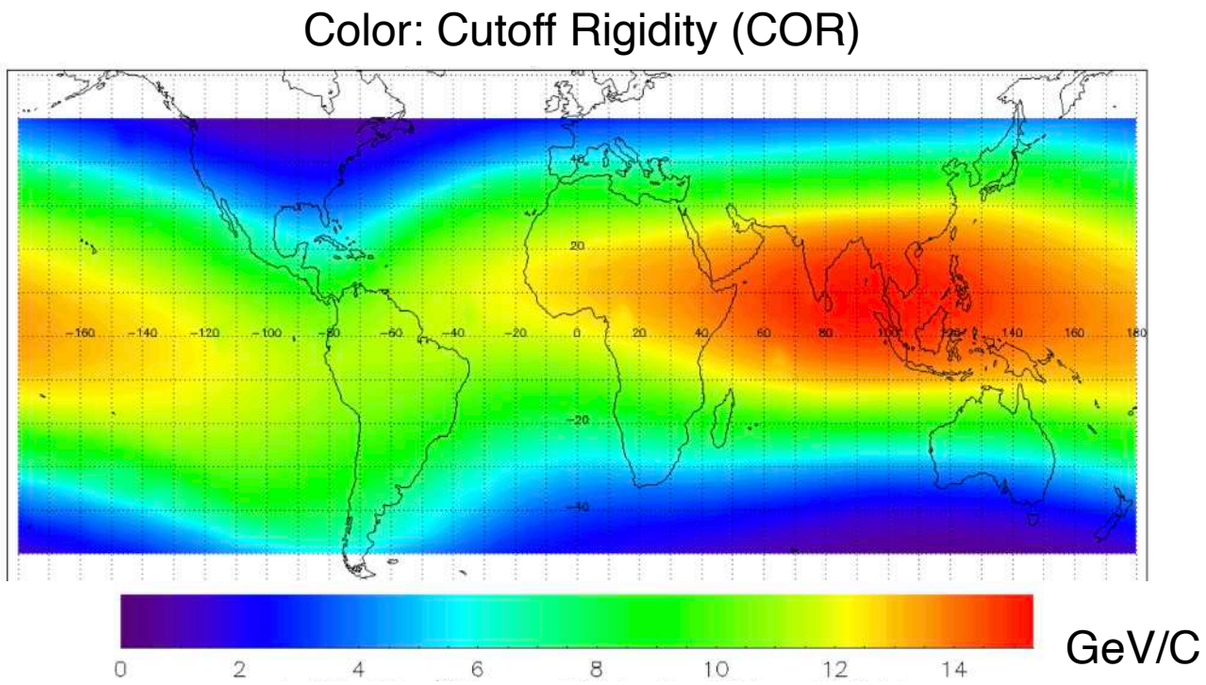
- Both source & background should be stable… but check light curves!!
- Detector background (similar to Suzaku XIS/Hitomi SXI)
  → Following pages

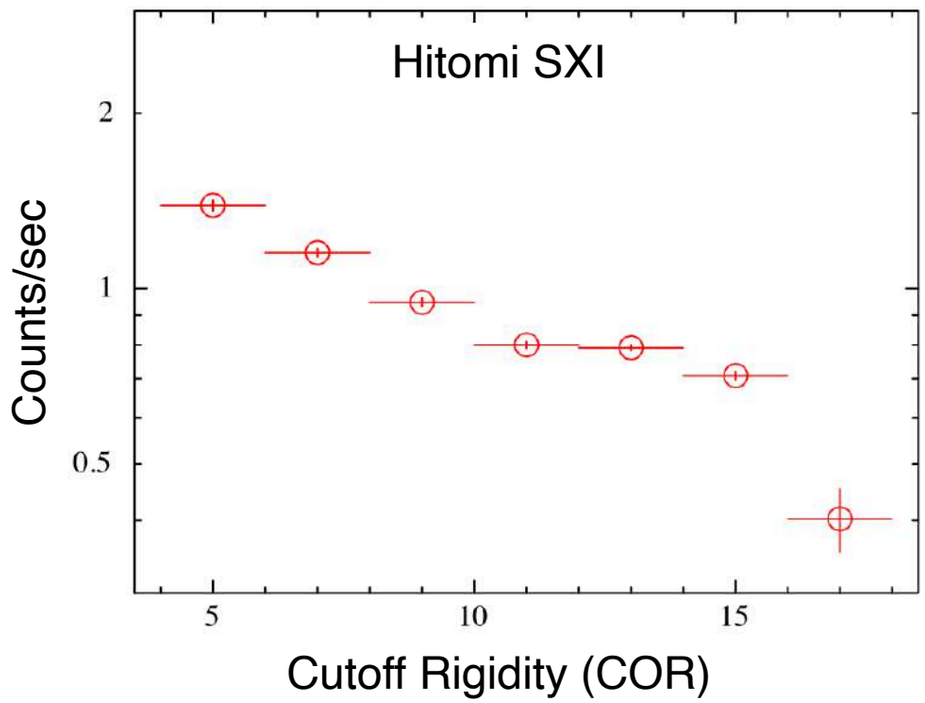
- Sky background
  - Many contribute, many depends on sky coordinates & time
  - Local Hot Bubble/Foreground Emission e.g., Snowden et al. 1998; Kuntz & Snowden 2000; Yoshino et al. 2009; Masui et al. 2009; Ueda et al. 2022
  - Milky Way Halo/Transabsorption Emission e.g., Kuntz & Snowden 2000; Yoshino 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

Detector background



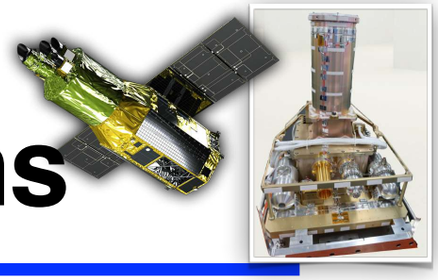
- Due to cosmic ray particles
  - Direct hits & stimulate fluorescence
  - Affect if left after event selection
- Dependence on Cutoff Rigidity Nakajima et al. 2018
  - Total flux varies w/o changing spectral shape
  - Note on year-scale movement of Cutoff Rigidity
- Depends on detector coordinates along readout direction Nakajima et al. 2018
- Effect of solar cycle almost ignorable



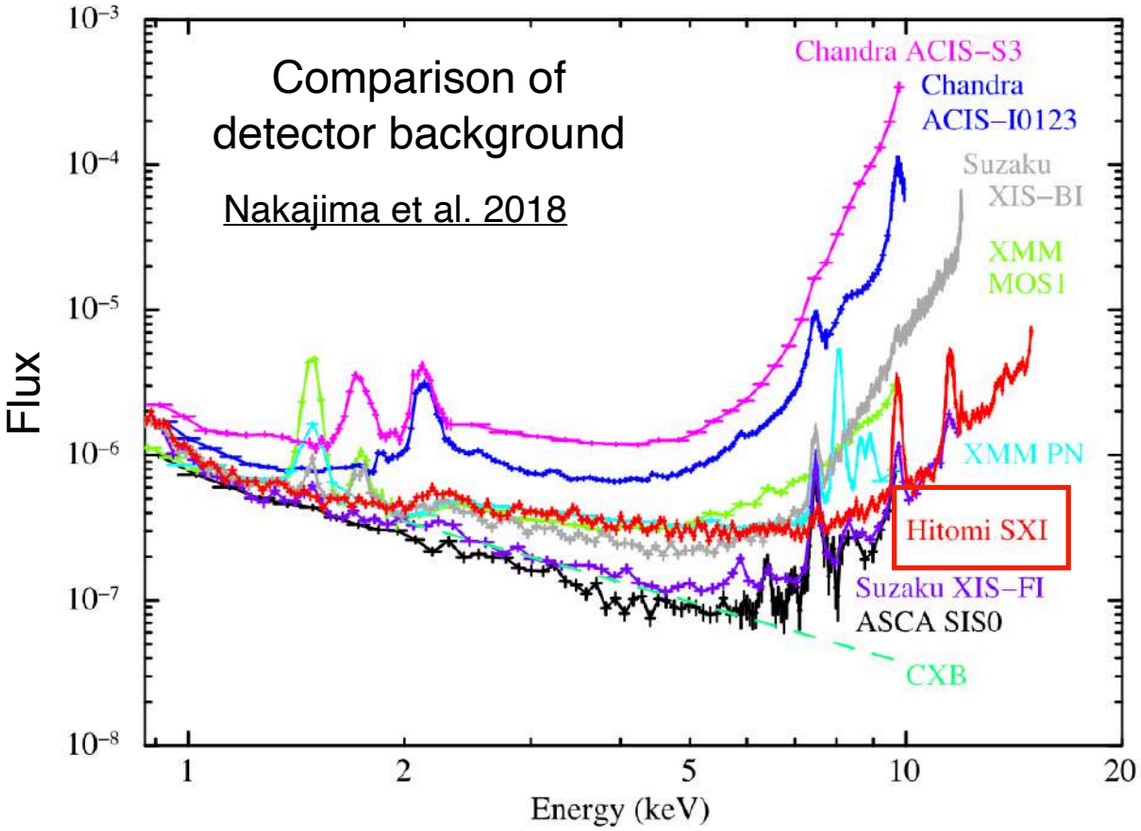


XRISM Compare to other satellite missions

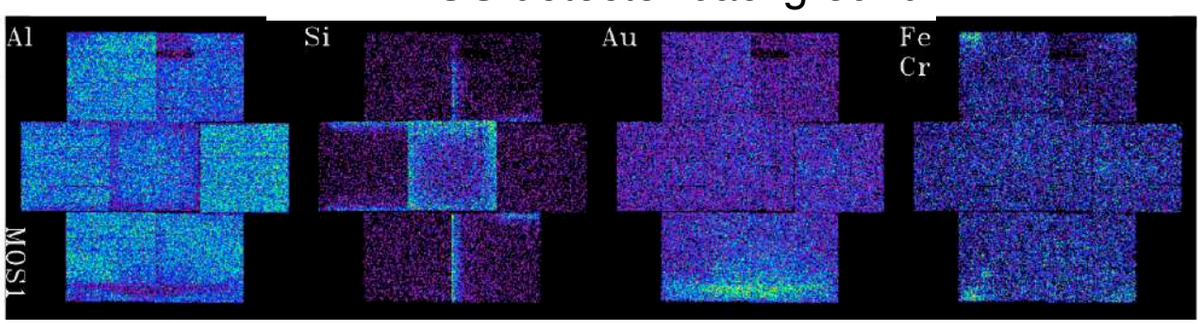
X-Ray Imaging and Spectroscopy Mission



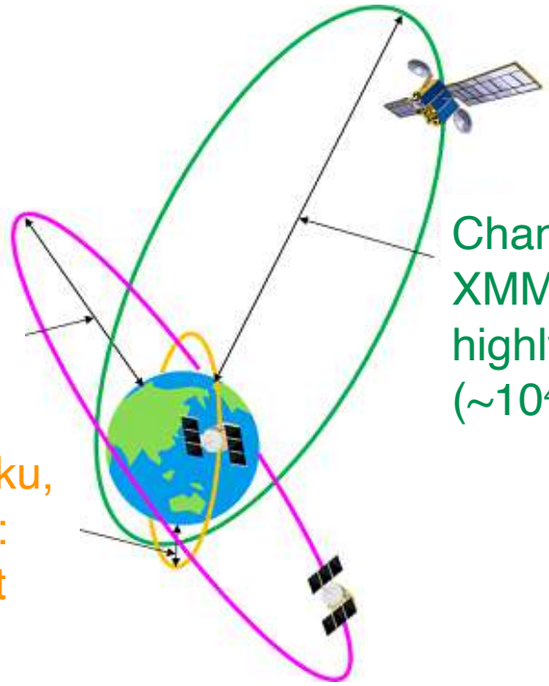
- LL of ASCA, Suzaku, XMM, Chandra, Hitomi have been considered
  - suppressed stray light, background, contamination, CCDs operated at lower temperature



XMM MOS detector background



Kuntz & Snowden 2008



GPS: medium earth orbit (~2x10^4 km)

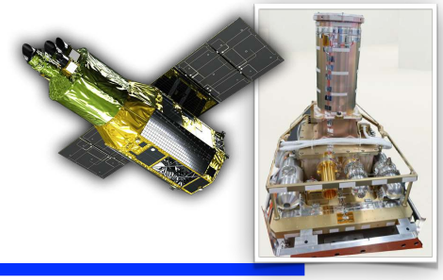
XRISM, Suzaku, NuSTAR, ISS: low earth orbit (~500 km)

Chandra, XMM-Newton: highly elliptical orbit (~10^4–10^5 km)

SRG/eROSITA: L2

CCDs of SXI

Tanaka et al. 2018



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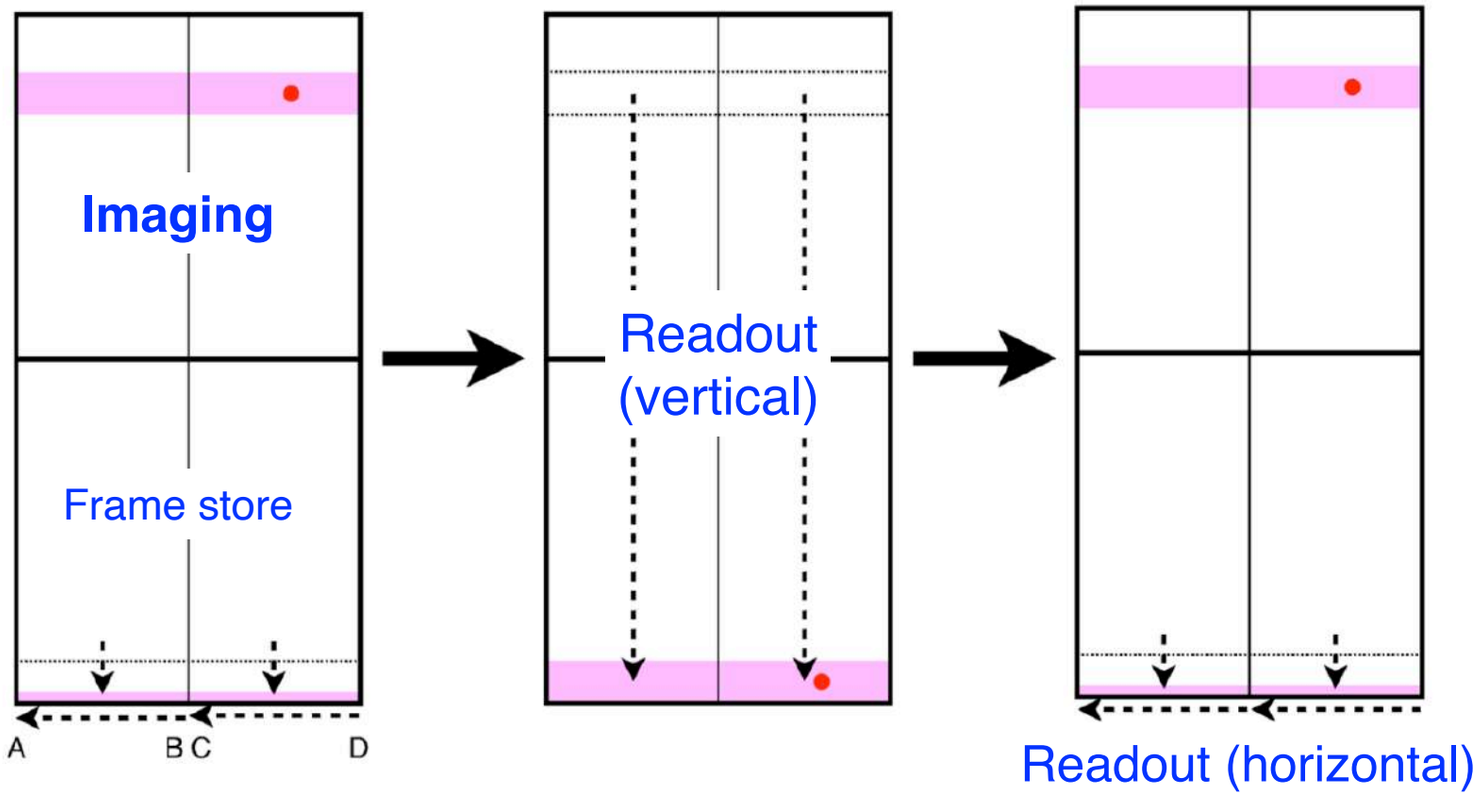
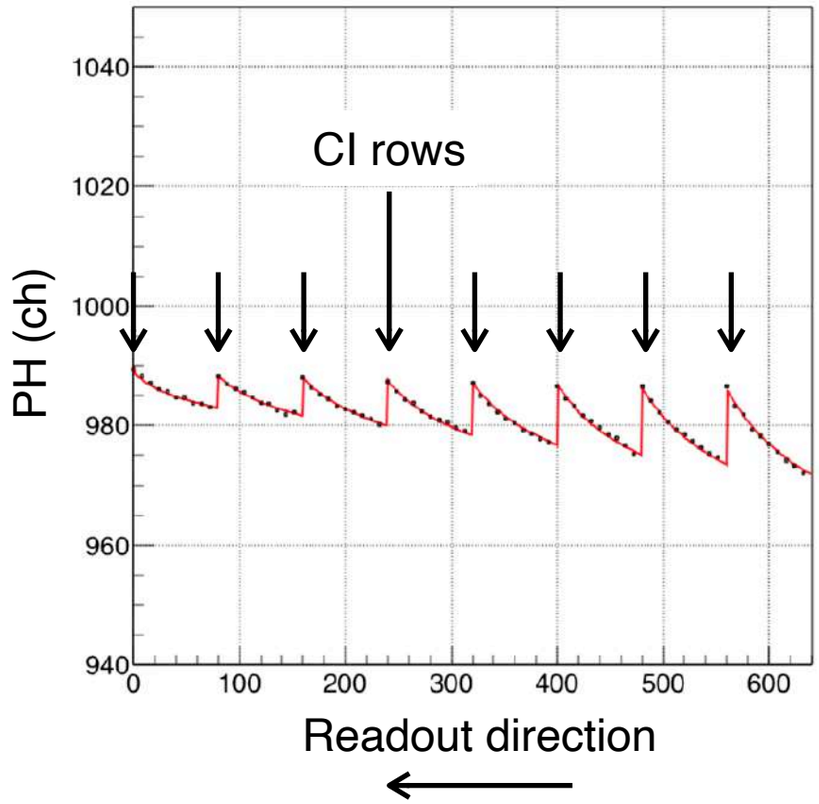
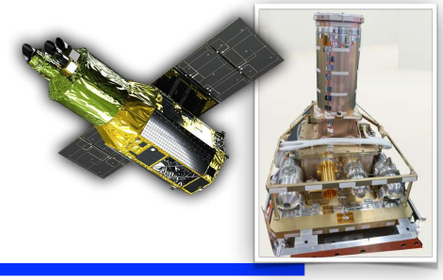
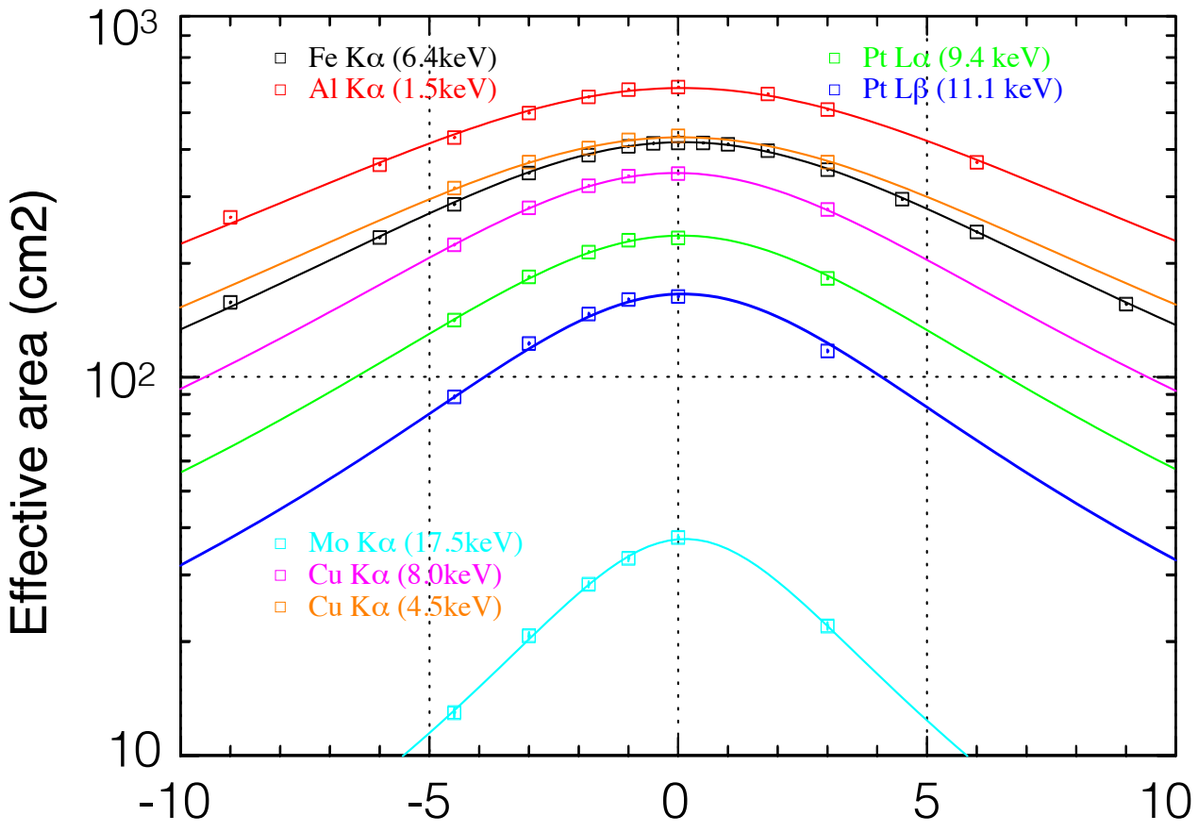




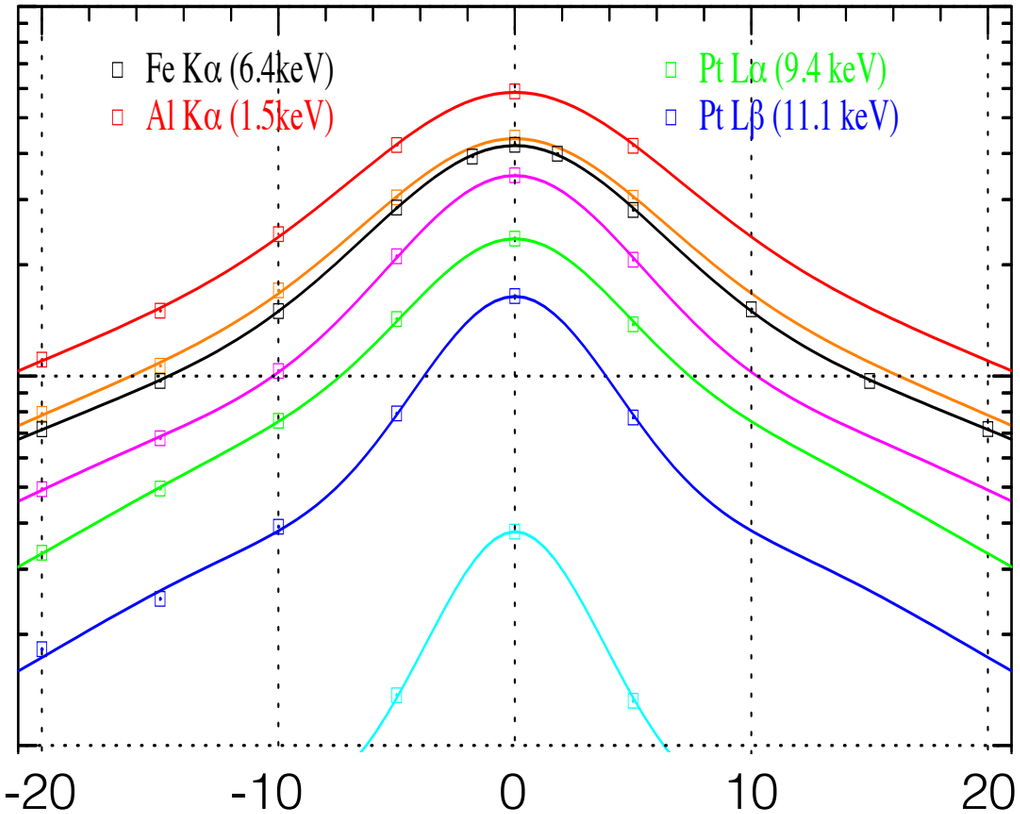
Off-axis effective areas



Resolve XMA (mirrors)

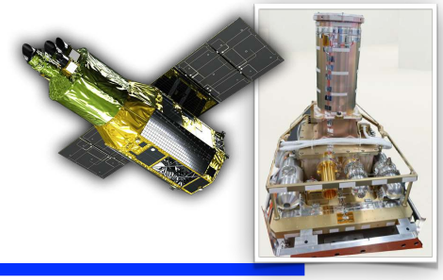


Xtend XMA (mirrors)



Off-axis angle (arcmin)

Analyzing extended sources



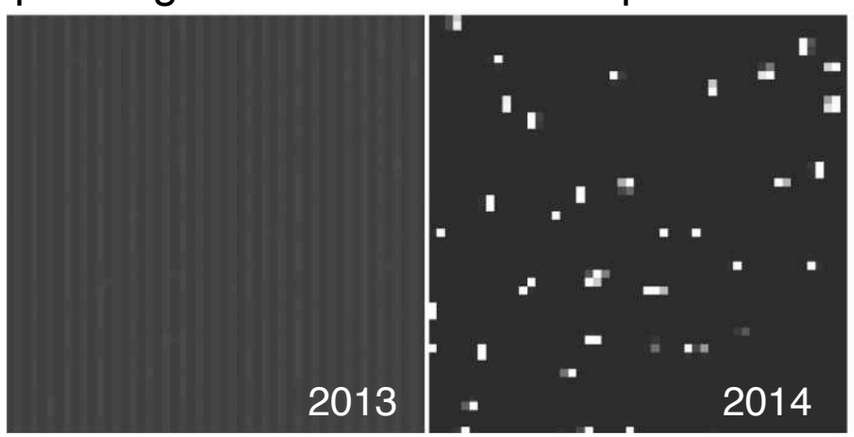
- Sky / detector background (similar to Suzaku XIS/Hitomi SXI)
  → Following pages
- Both source & background should be stable… but check light curves!!

- Pinholes (optical light leak) → bad pixels
- Crosstalk due to cosmic ray events
  → many pseudo events → bad pixels

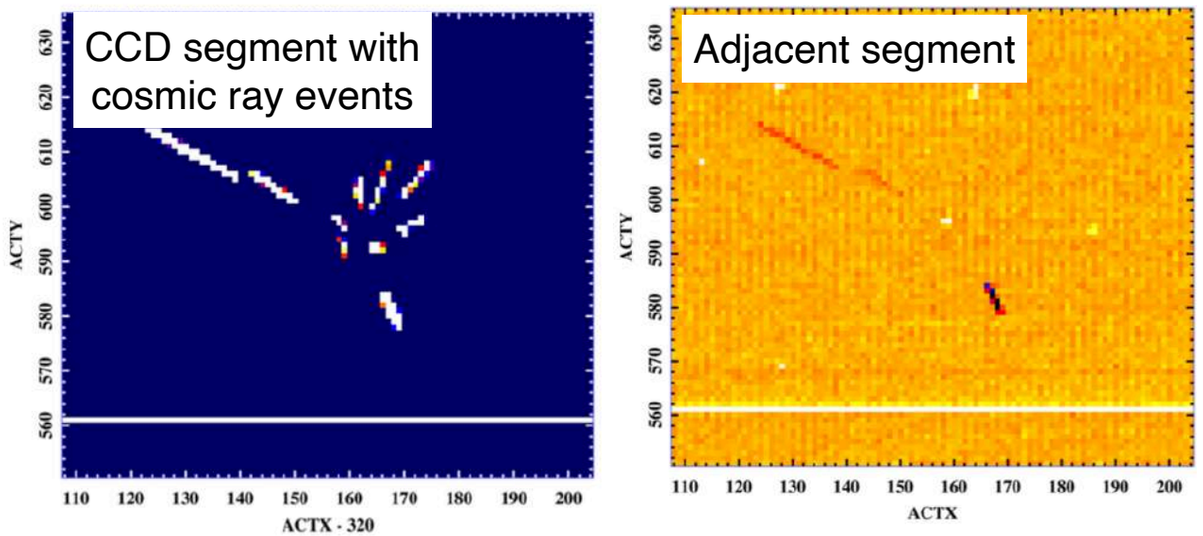
} problem in Hitomi SXI, should be fixed in XRISM SXI

Nakajima et al. 2018

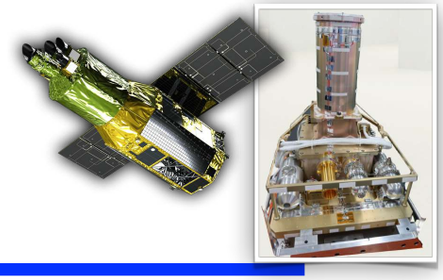
Optical light illumination. White: pinholes



Crosstalk due to cosmic ray events

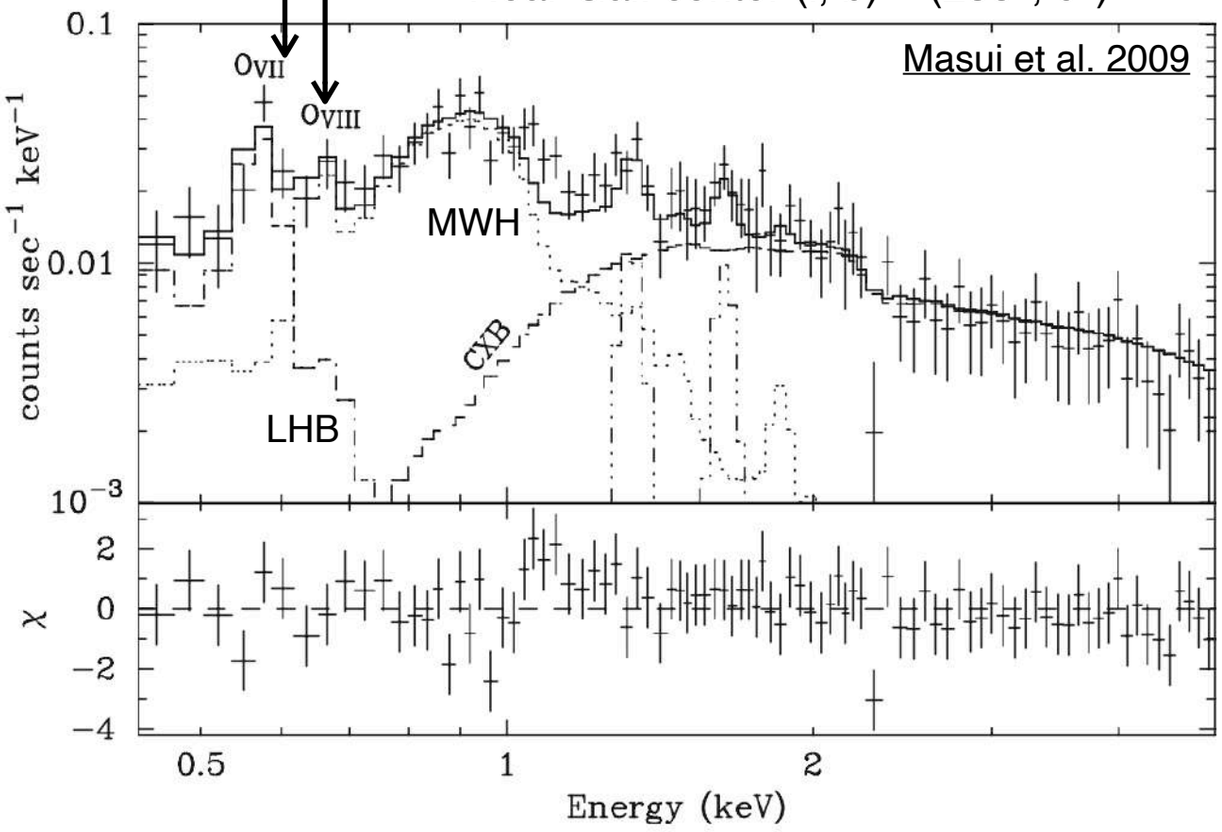


Sky background

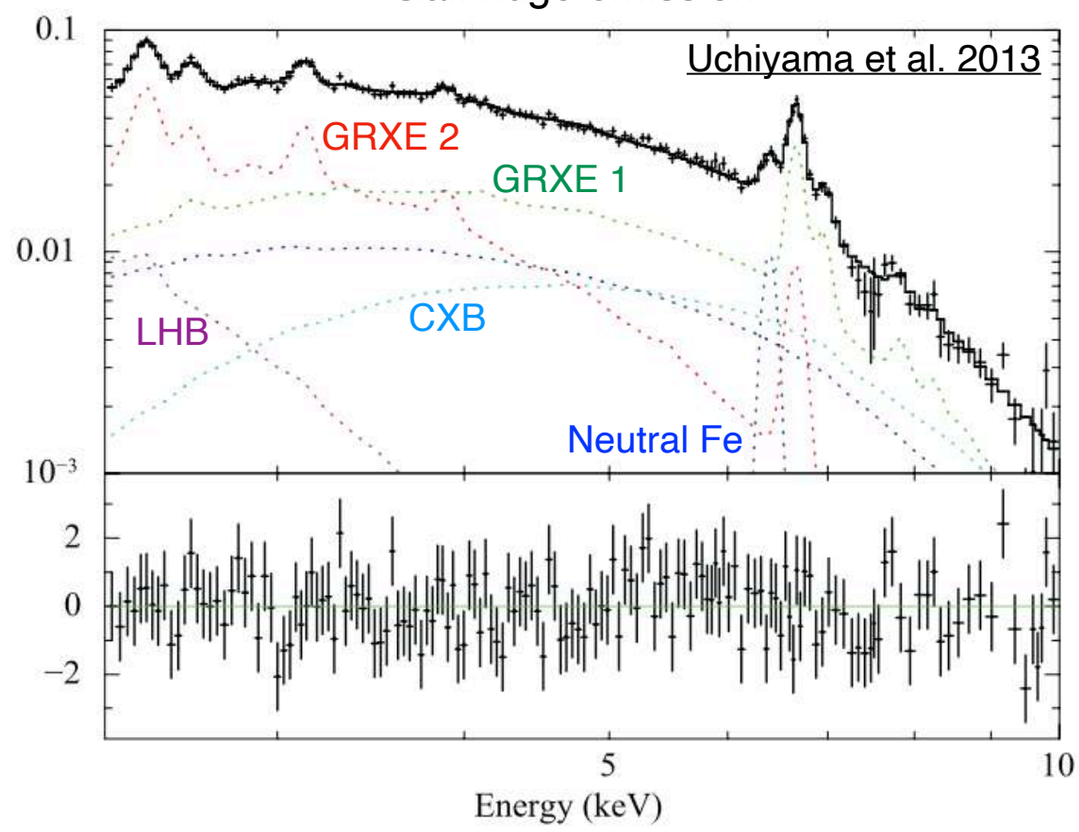


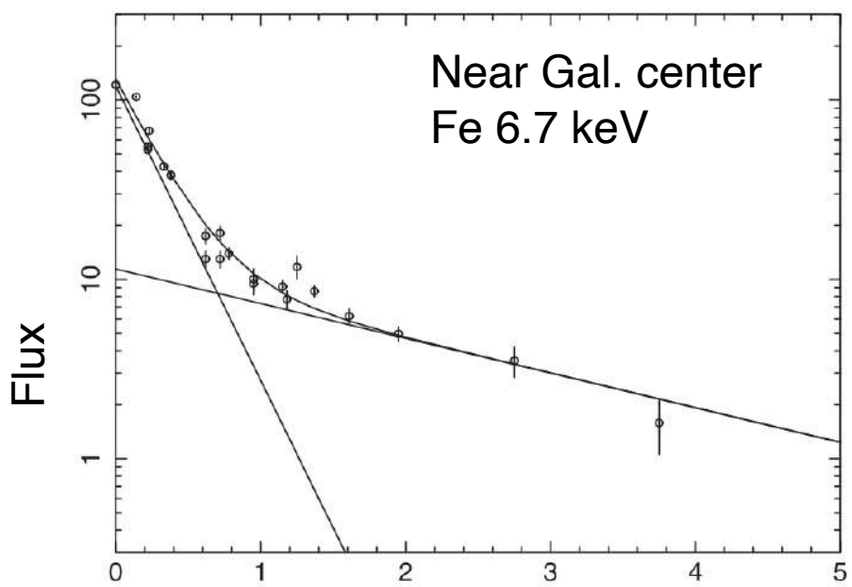
SWCX

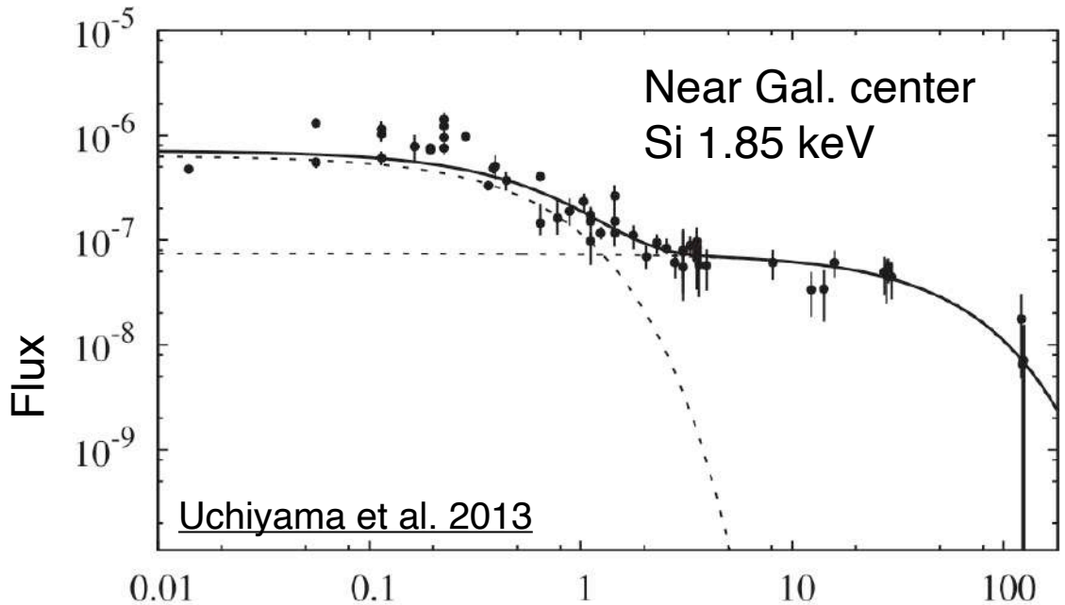
Near Gal. center (l, b) = (235°, 0°)



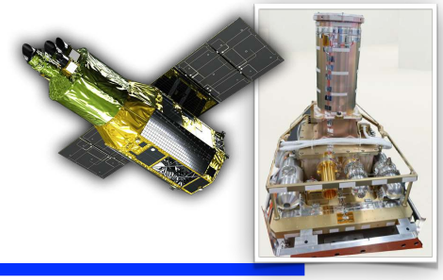
Gal. ridge emission







Detector background



- Depends on detector coordinates Nakajima et al. 2018
  - Along readout direction, due to cosmic-ray events in frame store regions
- SXI turned off in SAA but background possibly high just before/after SAA
- Almost ignorable effect of solar cycle