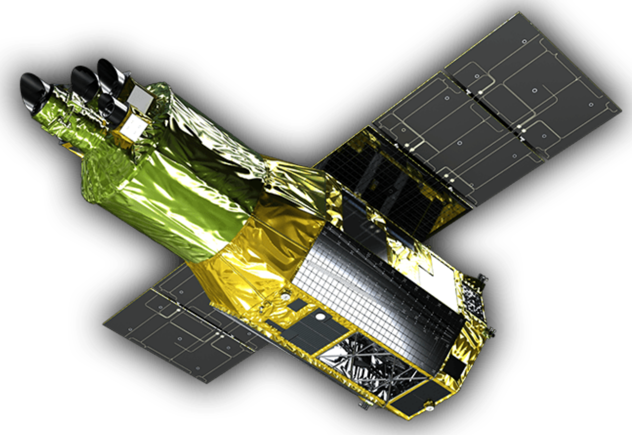
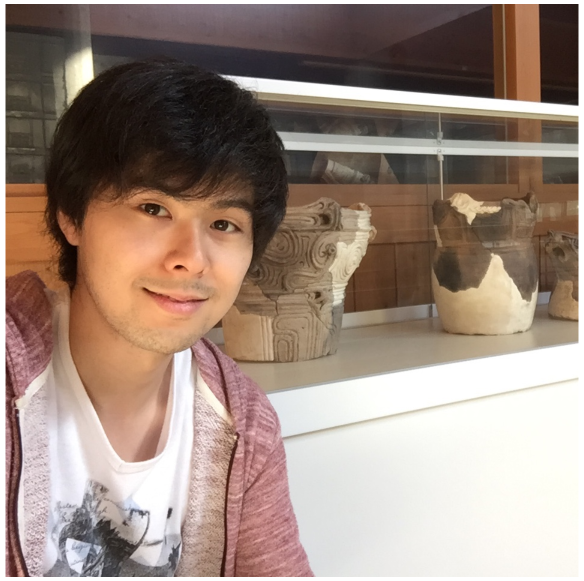
XRISM
X-Ray Imaging and Spectroscopy Mission



# Xtend overview



**Hiromasa Suzuki**
**(Konan-U, JP)**
on behalf of the XRISM/Xtend team

KONAN

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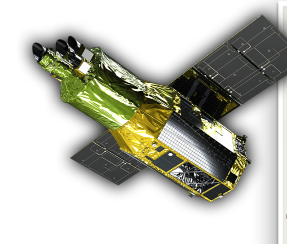
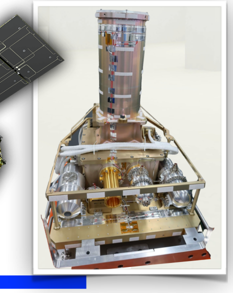
# XRISM Xtend team

**14 institutes**
**> 50 members**

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- **Tokyo University of Science**
  S. B. Kobayashi, T. Kohmura
- **The University of Tokyo** K. Hagino
- **Kanto Gakuin University**
  **H. Nakajima (sub-PI)**
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- **Advisors**
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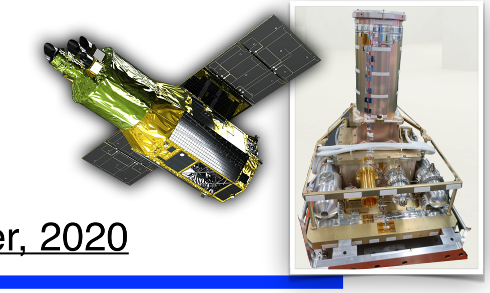
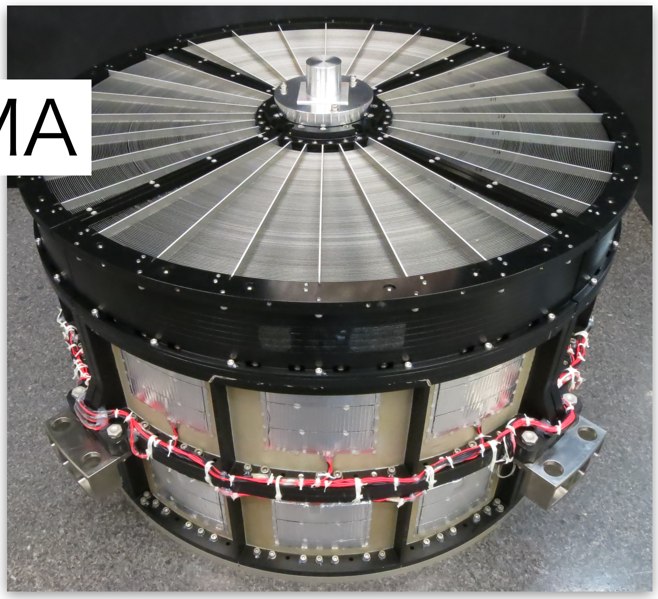
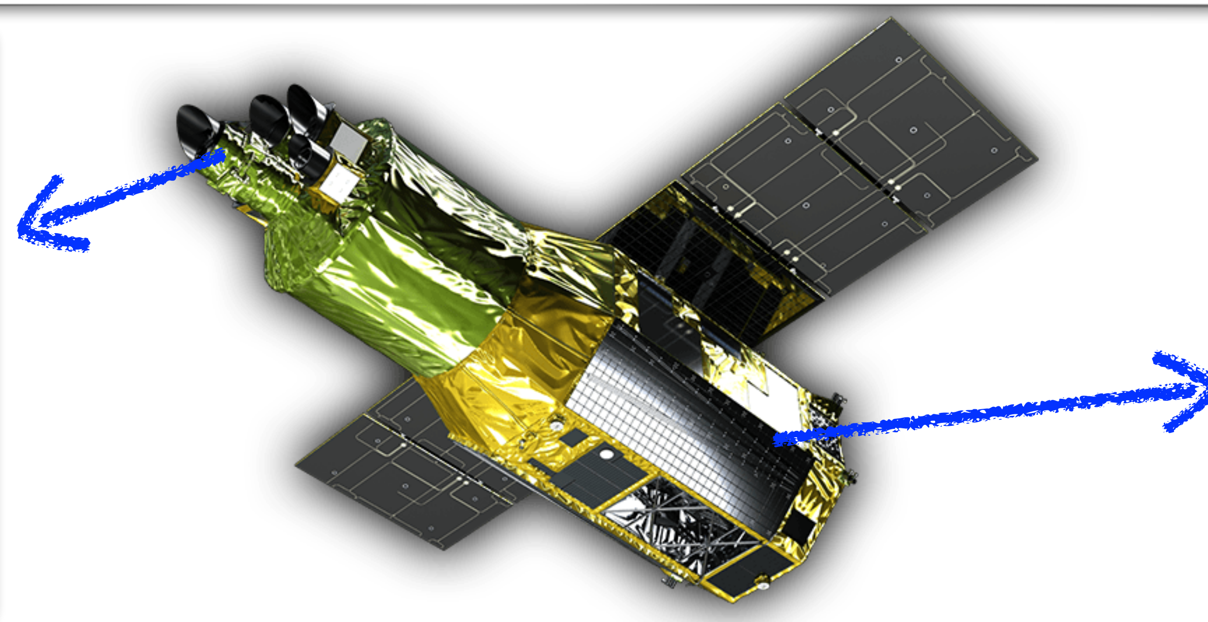
# XRISM Xtend

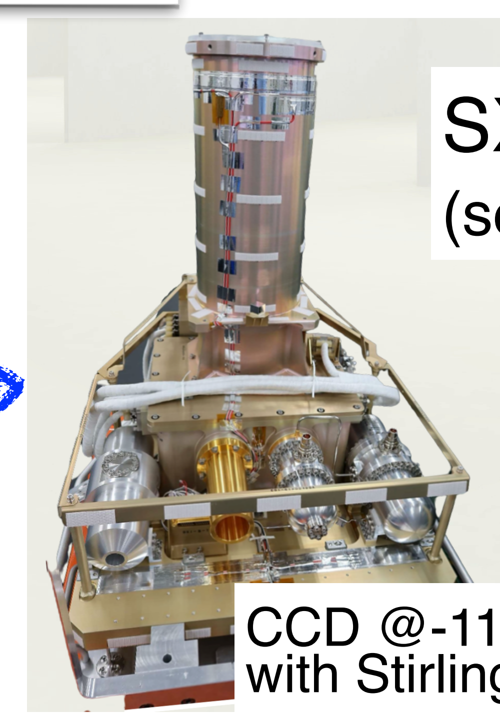


XRISM white paper, 2020

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






- **XMA**：Wolter type I mirror optics

  ✓similar to Hitomi SXT

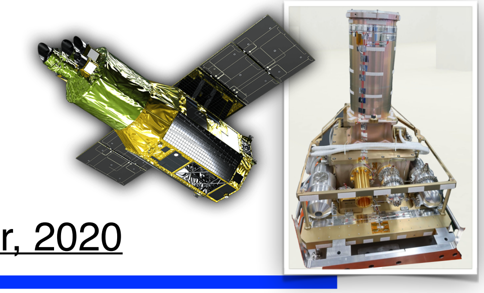
- **SXI**：X-ray CCDs

  ✓similar to Hitomi SXI
  ✓fully-depleted back-illuminated
  P-channel CCD

- Energy range：0.4–13 keV
- FoV：38’ × 38’
- Energy resolution：< 200 eV @5.9 keV
- Ang. resolution：< 1.7’ (Half Power Diameter)

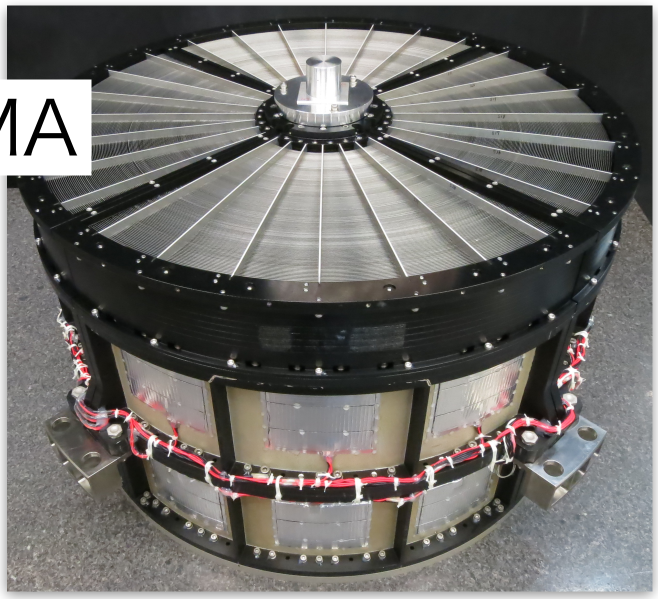
# XRISM Xtend

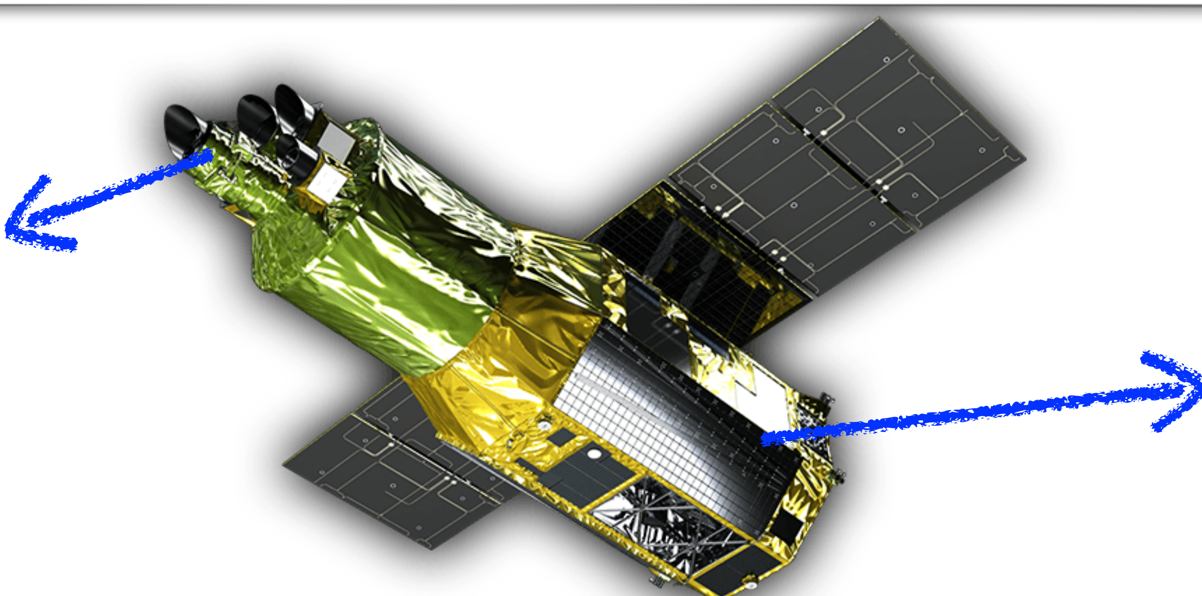
XRISM white paper, 2020

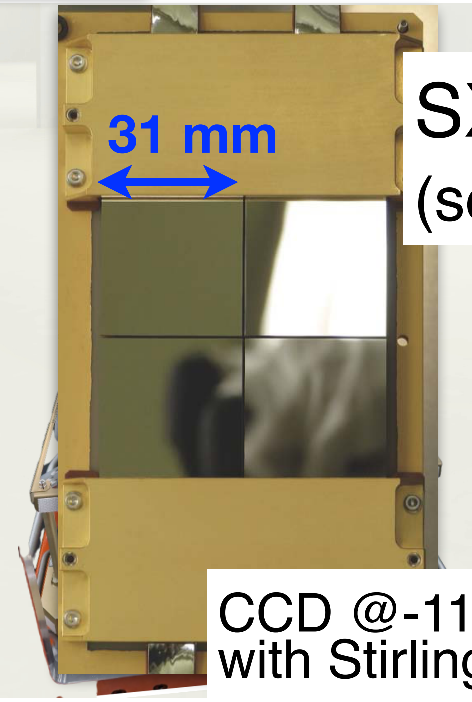


Xtend = XMA (X-ray Mirror Assembly) + SXI (Soft X-ray Imager)

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
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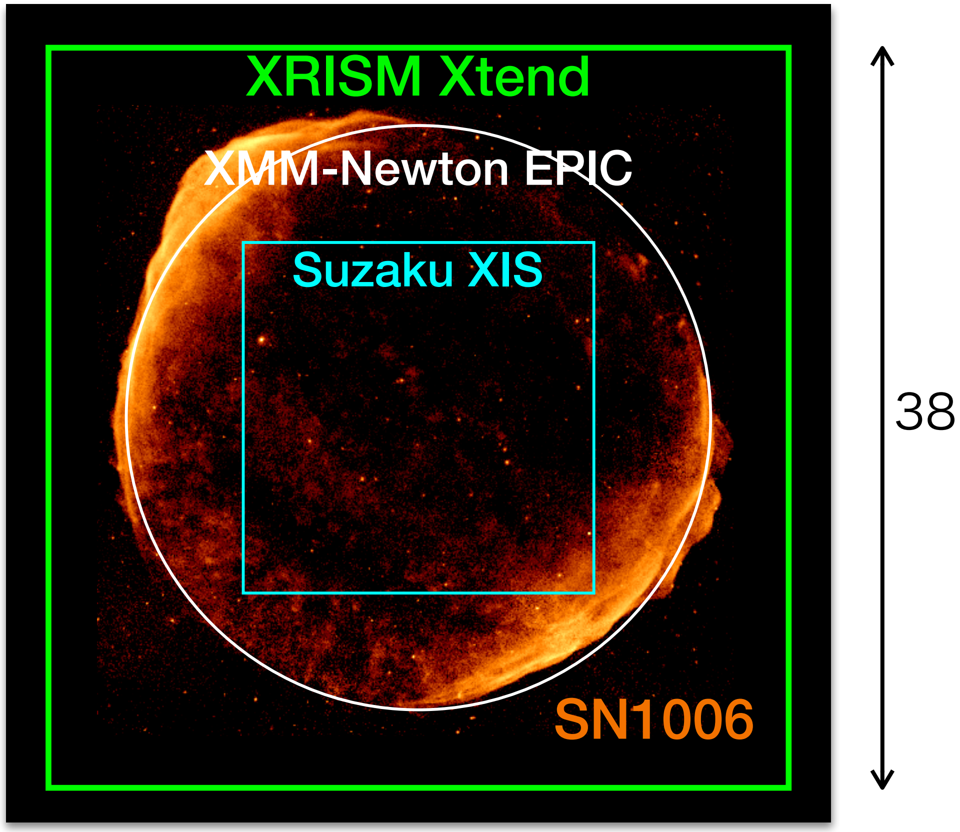
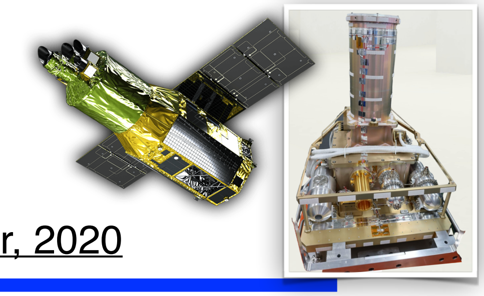
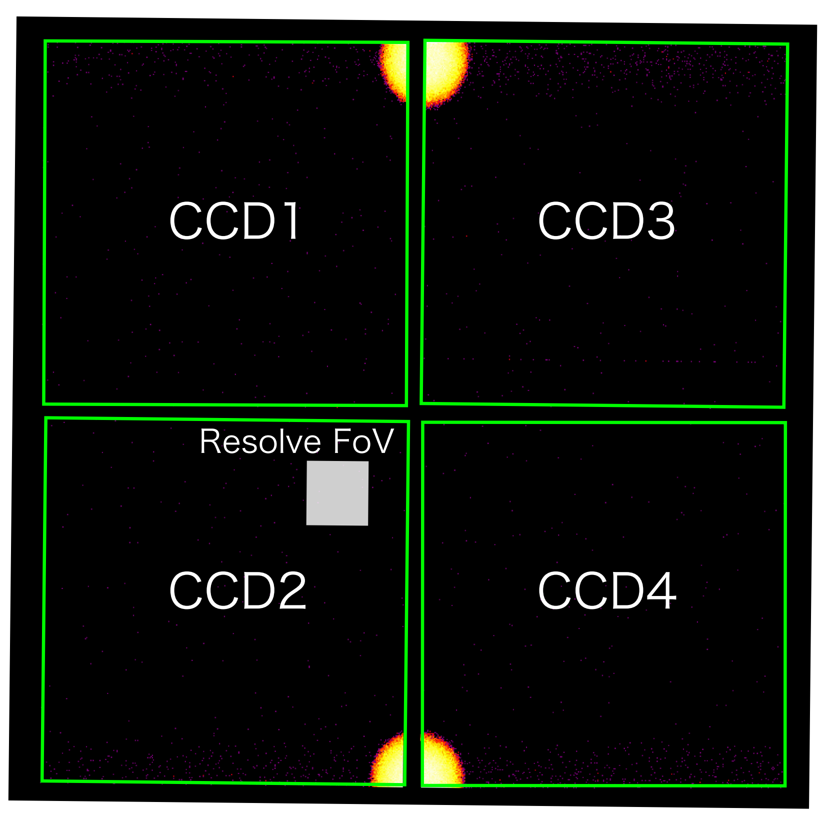


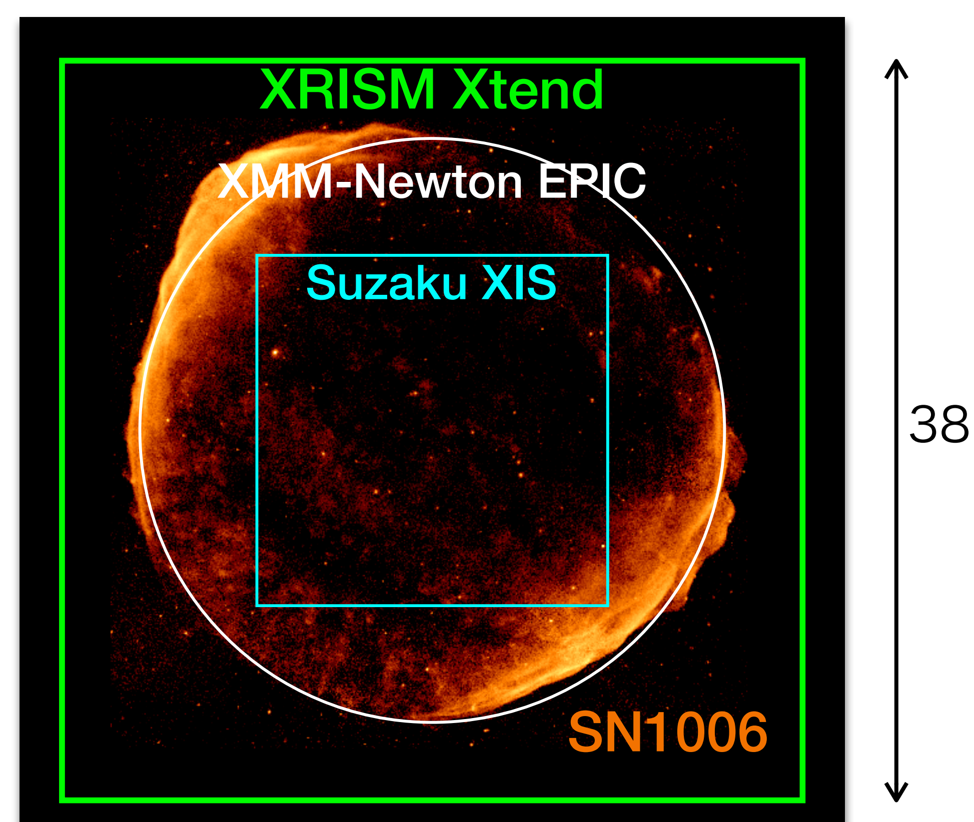
# Roles of Xtend



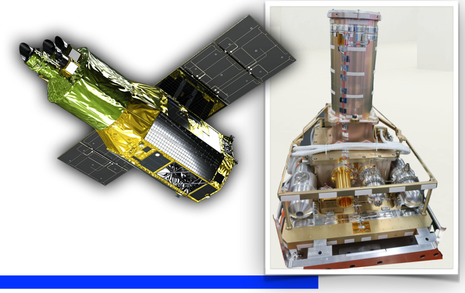
XRISM white paper, 2020

- **Monitor large area around Resolve FoV**
  → Clarify contribution of sources around target
    - sky background
    - contribution of other bright 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



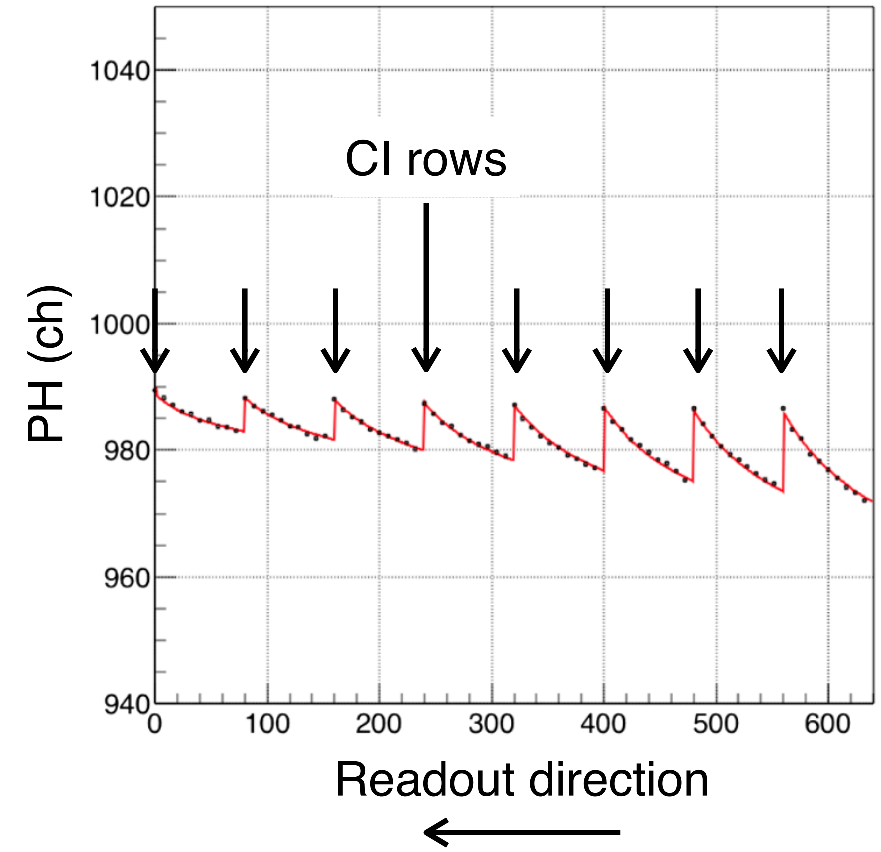



# CCDs of SXI

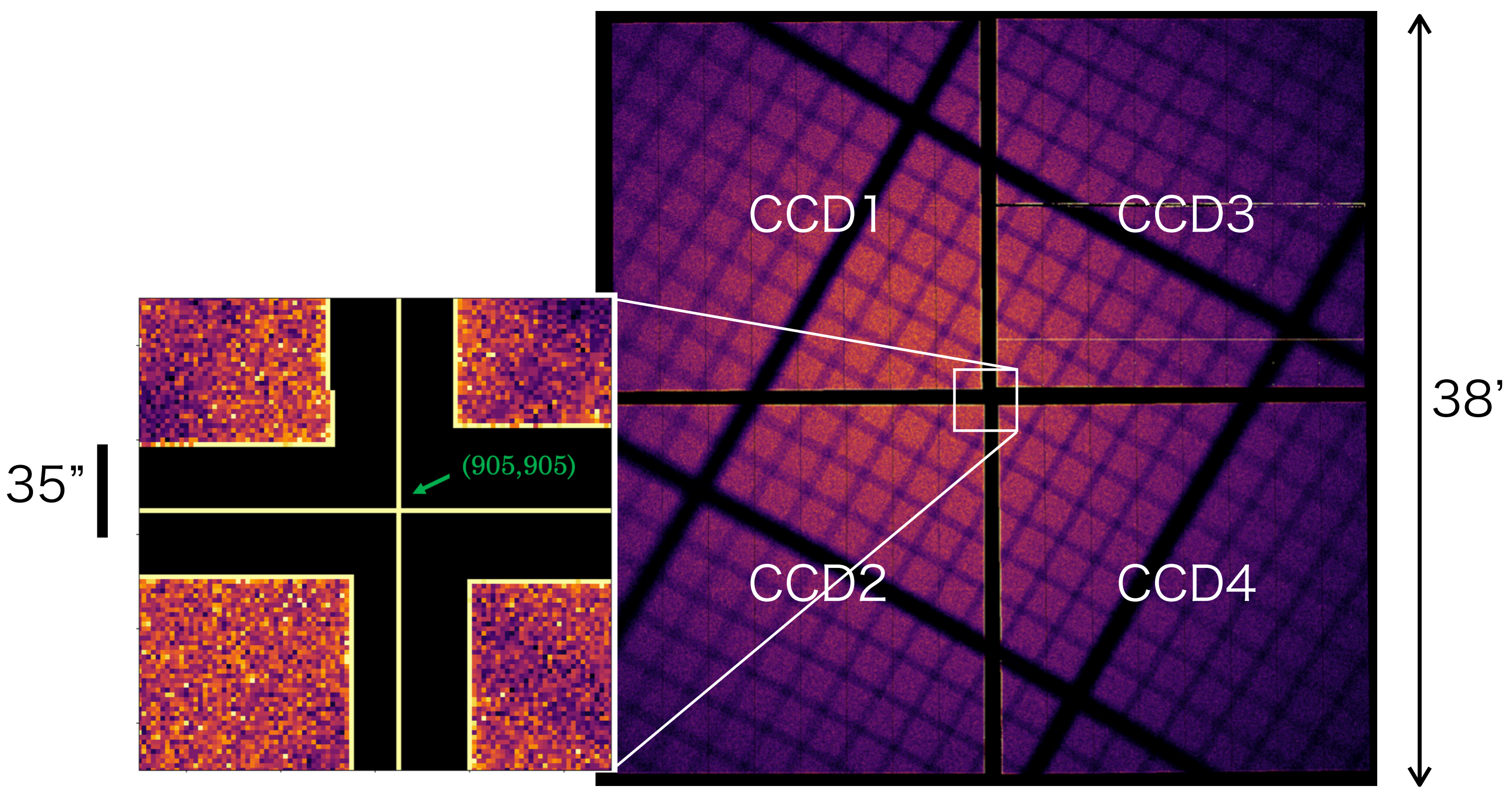


Tanaka et al. 2018

- 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

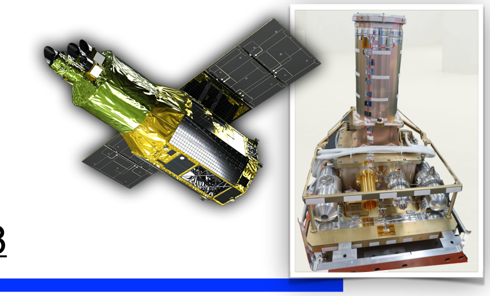



- Mind the gaps between CCDs!!
  - 40”–60”
  - Point sources may fall into the gaps



# Observations

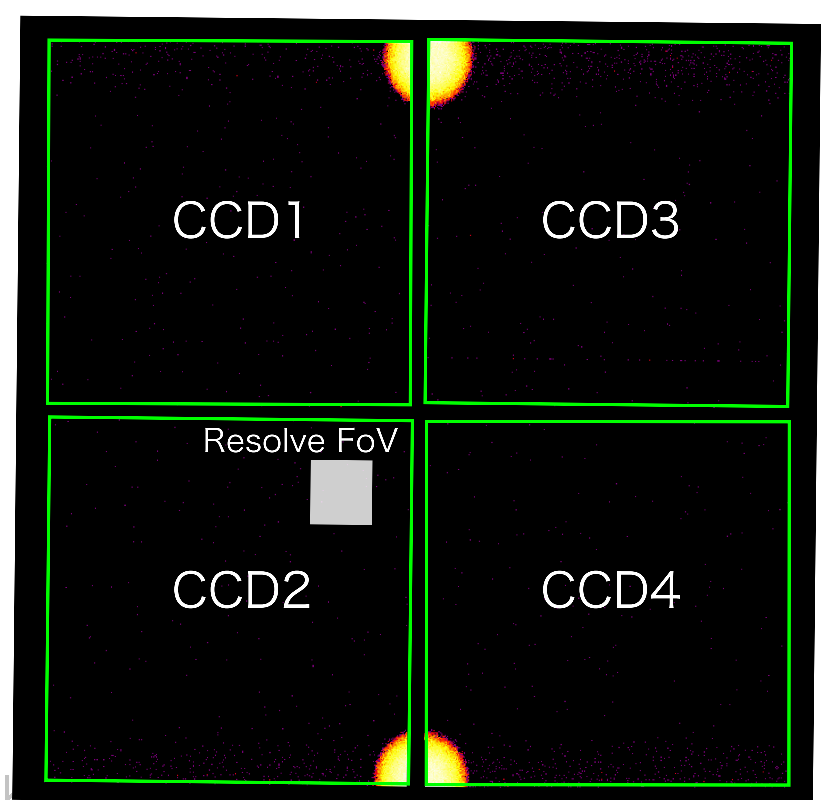
Tanaka et al. 2018

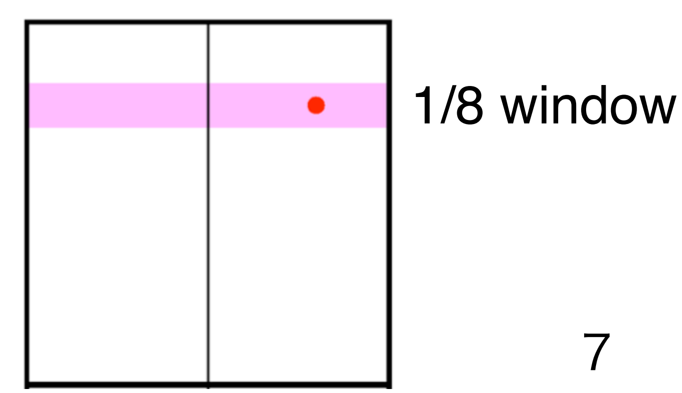


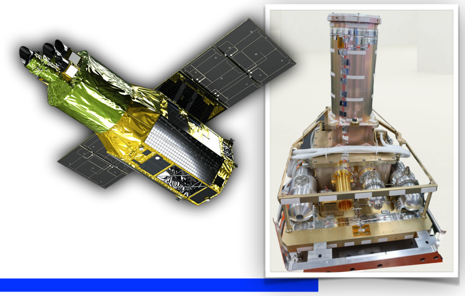
- Observation modes

| Mode | Region size | Frame exposure | Time resolution | Live time fraction | Purpose |
|---|---|---|---|---|---|
| **Full window** | 1 | 4.0 sec | 4.0 sec | ~1 | General |
| **1/8 window** | 1/8 | 0.46 sec | 0.46 sec | ~1 | Bright/variable sources (against pile-up, etc.) |
| **1/8 window + 0.1-s burst** | 1/8 | 0.06 sec | 0.06 sec | 0.13 | Bright/variable sources (against pile-up, etc.) |
| **0.1-s burst** | 1 | 0.06 sec | 0.06 sec | 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.)

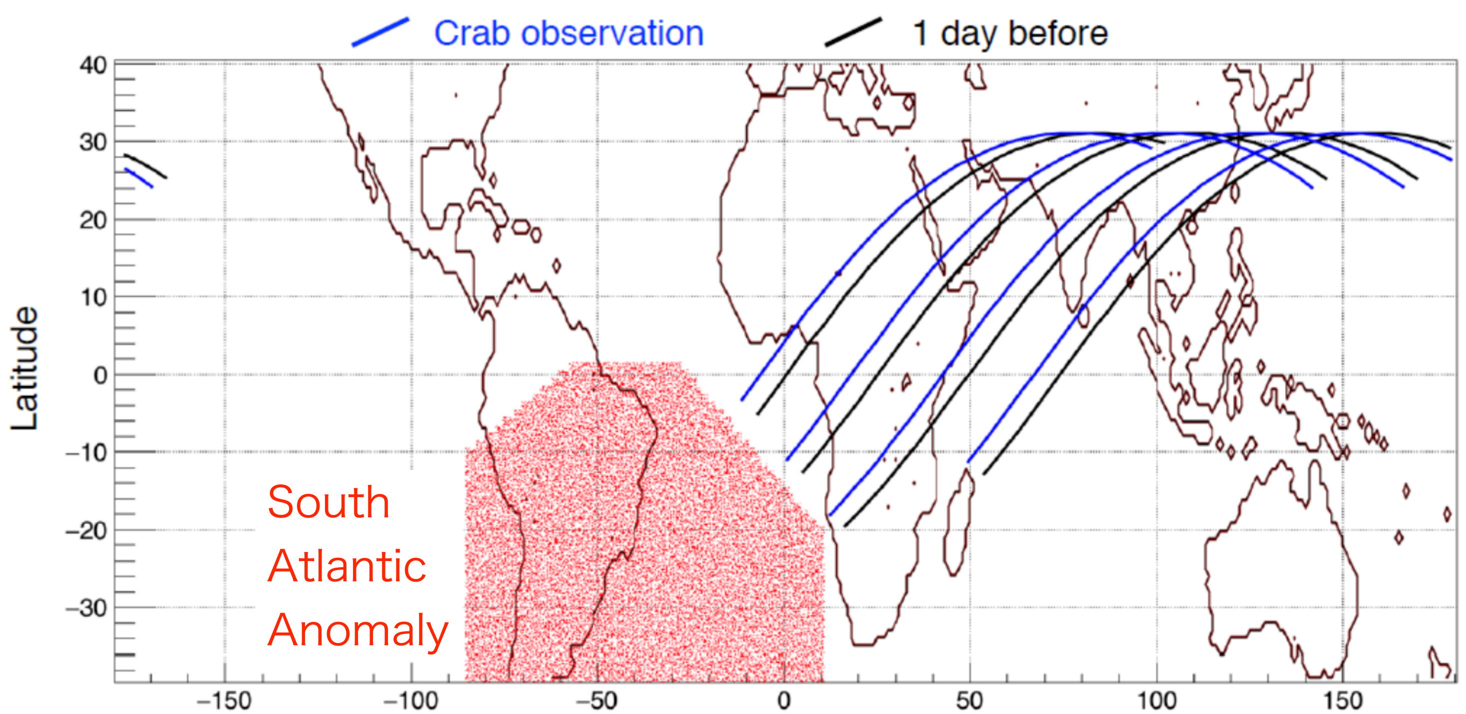




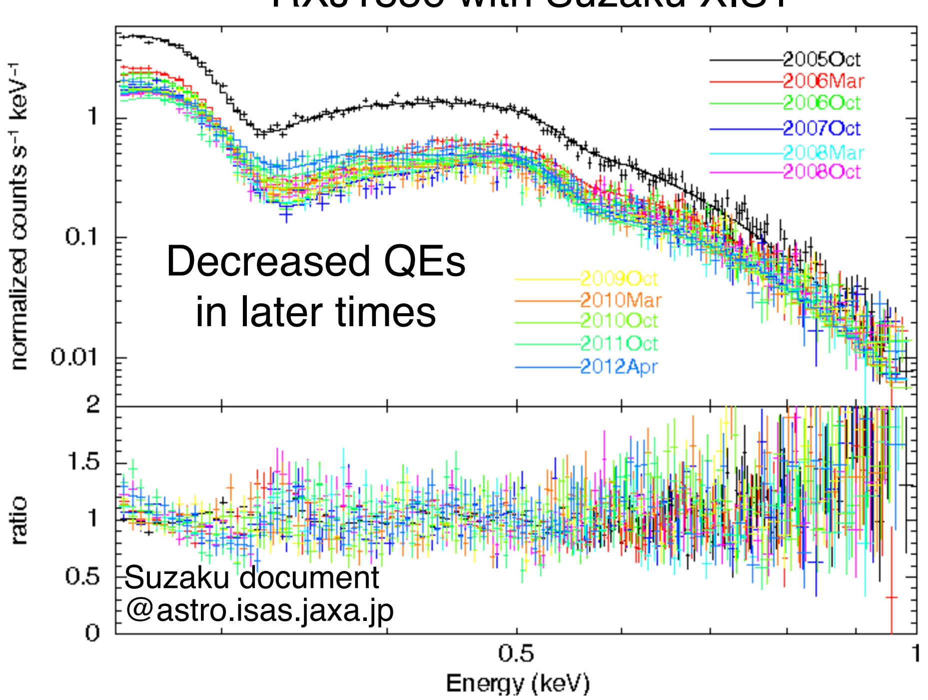
# Observations

- 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 in low energies




Hitomi collaboration 2018

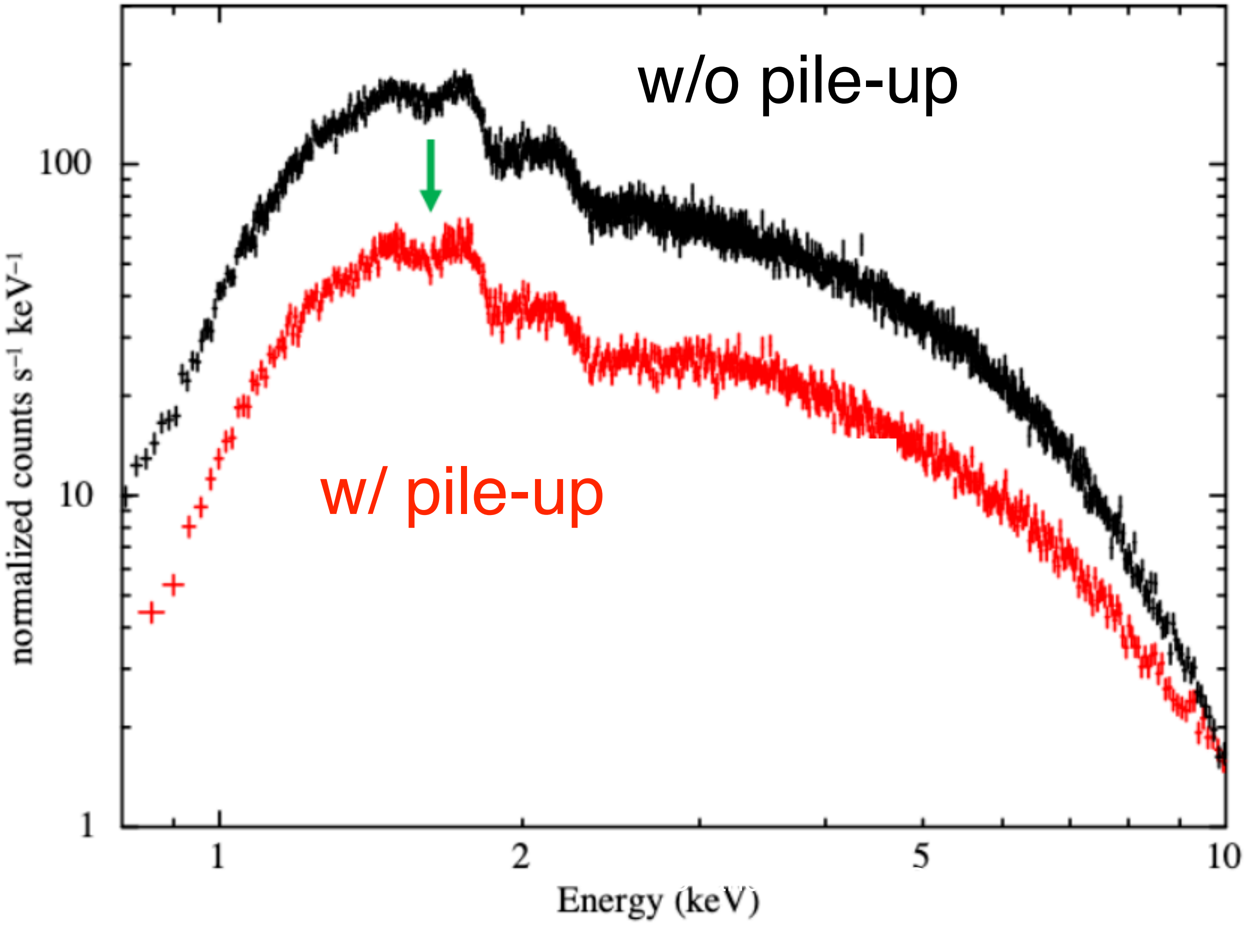
RXJ1856 with Suzaku XIS1



# Observing bright point sources

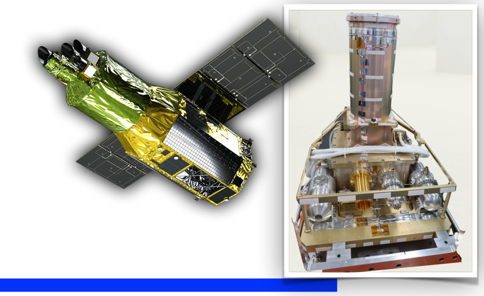
Tamba et al. 2022

- Consider pile-up of photons
- In Xtend, this happens if sources brighter than ~1 mCrab
- Choose suitable obs. mode to avoid pile-up
    - ~1/8 photons if 1/8 window mode, ~1/70 if window-burst mode
- Pile-up estimator will be provided to observers
    - i.e., choose target's flux & power-law index → check pile-up

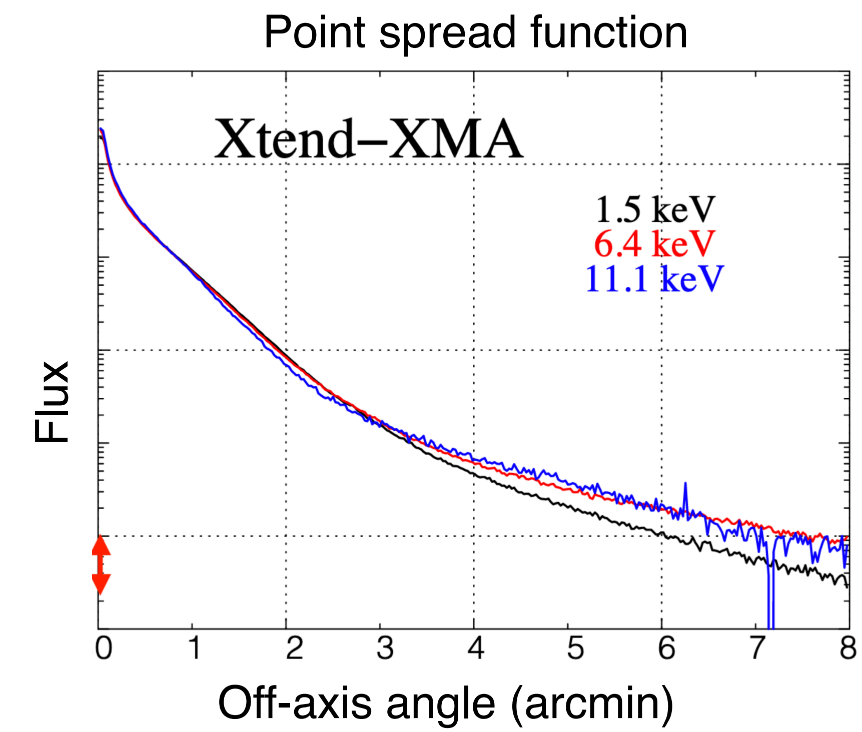


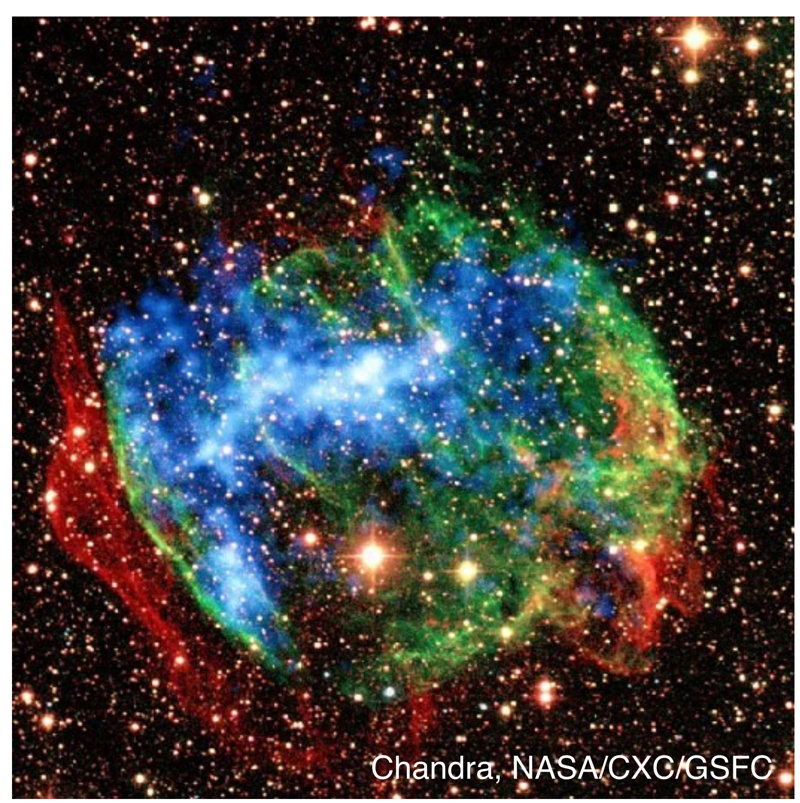

(0.5 Crab, 8 sec frame exposure)

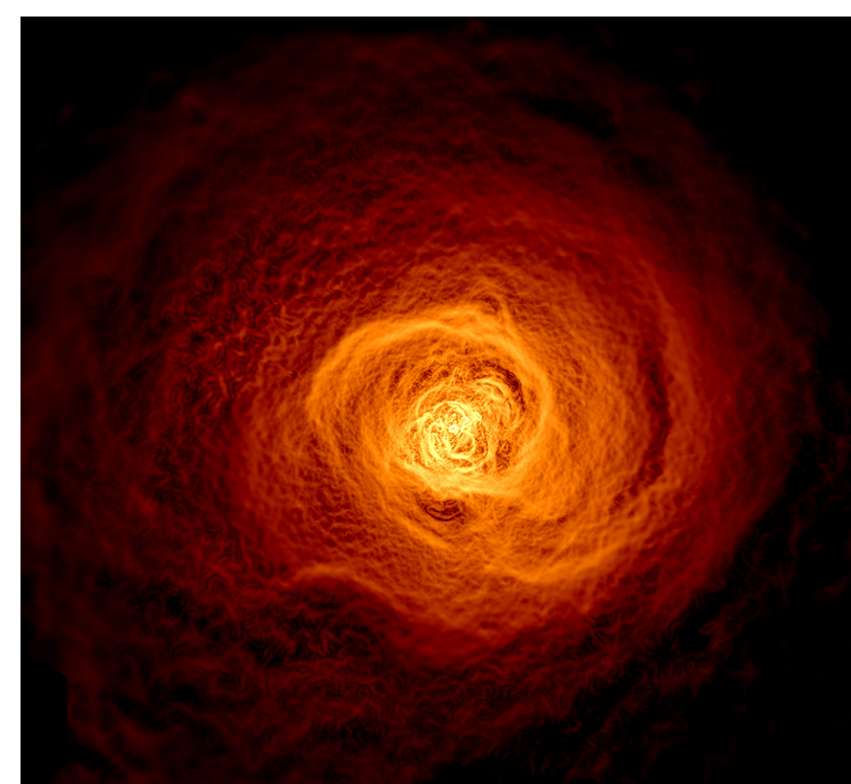
# Observing extended sources



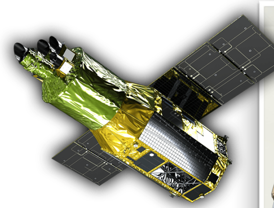
- Consider…
  - Bright sources around the target
  - Sky / detector backgrounds affect more than for point sources

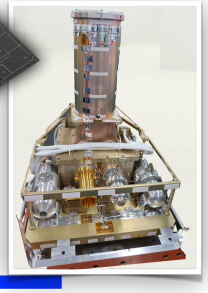


# Analysis procedure

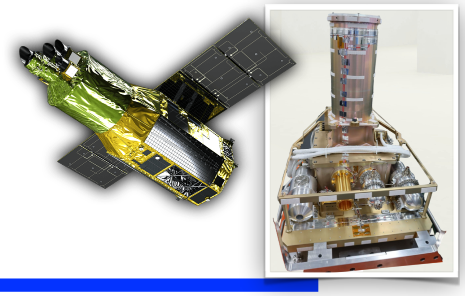




Refer to Hitomi Analysis Guide, Step-by-Step guide
Will be updated for XRISM

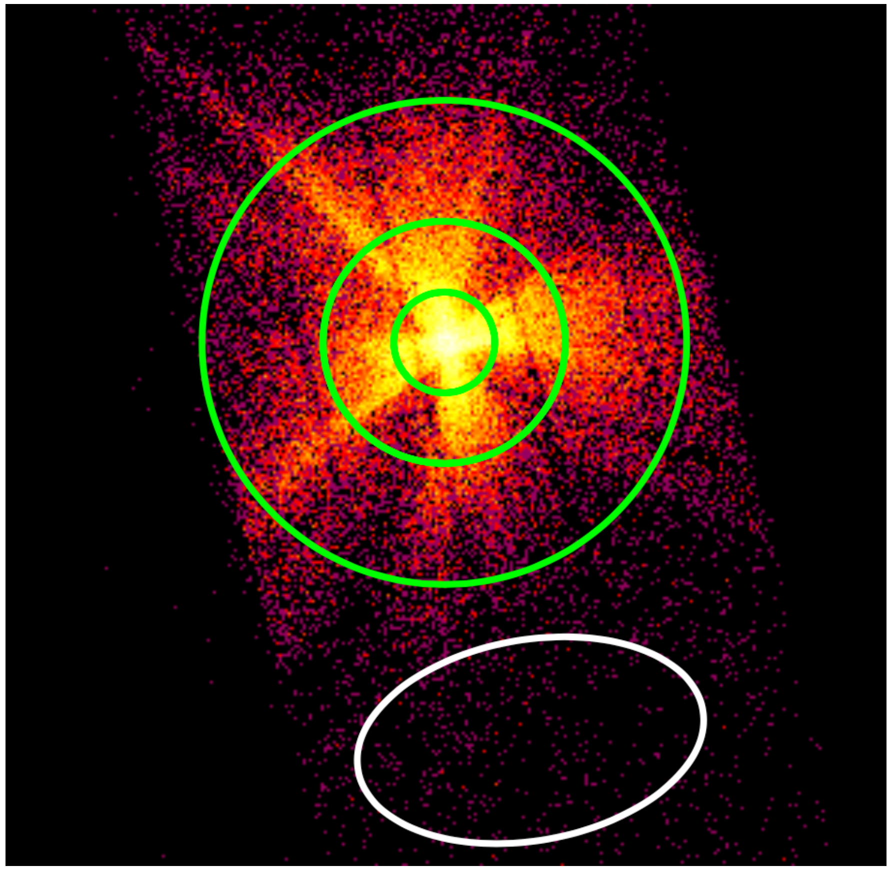
- Similar to Suzaku XIS & Hitomi SXI

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!!

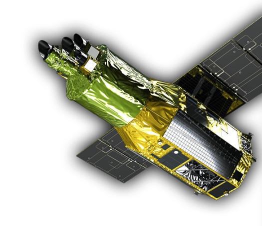
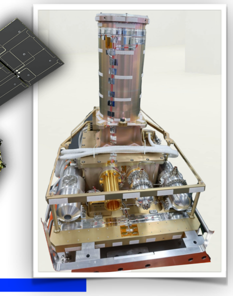


# Analyzing bright point sources

- If so bright that pile-up affects data…
  - first try to avoid this!!  but sometimes need good statistics, data might 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



# Analyzing extended sources

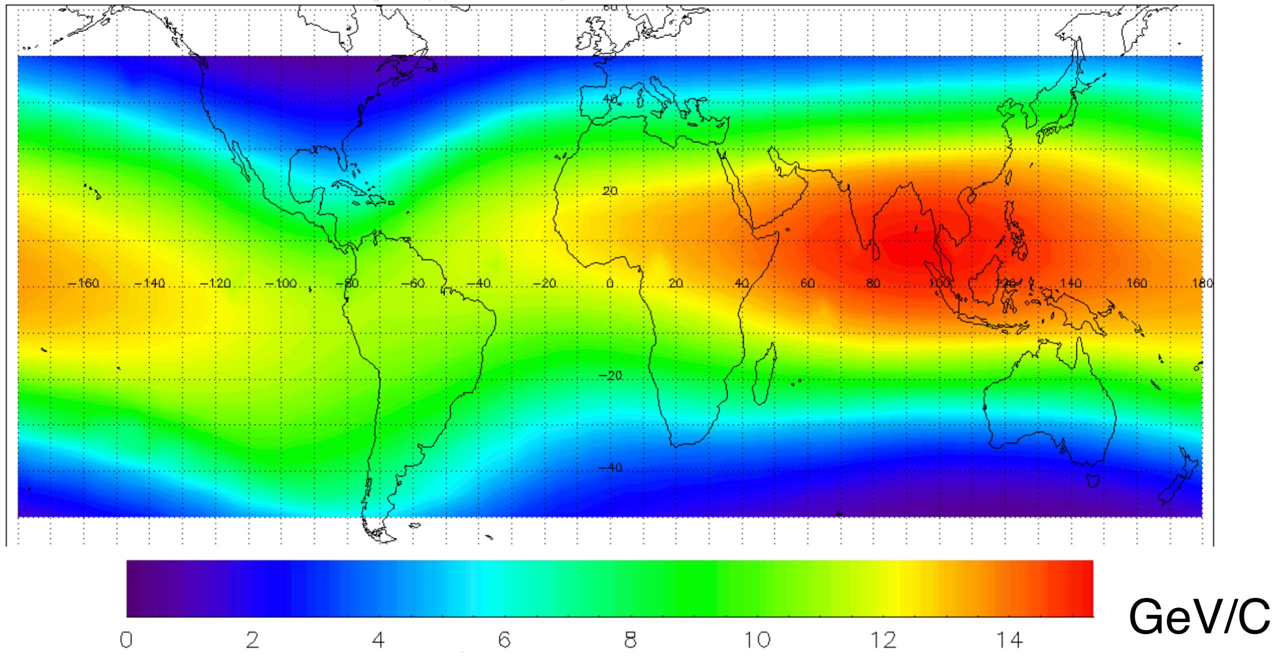
- Both source & background should be stable… but check light curves!!
- Detector background (similar to Suzaku XIS/Hitomi SXI)
  → Following pages

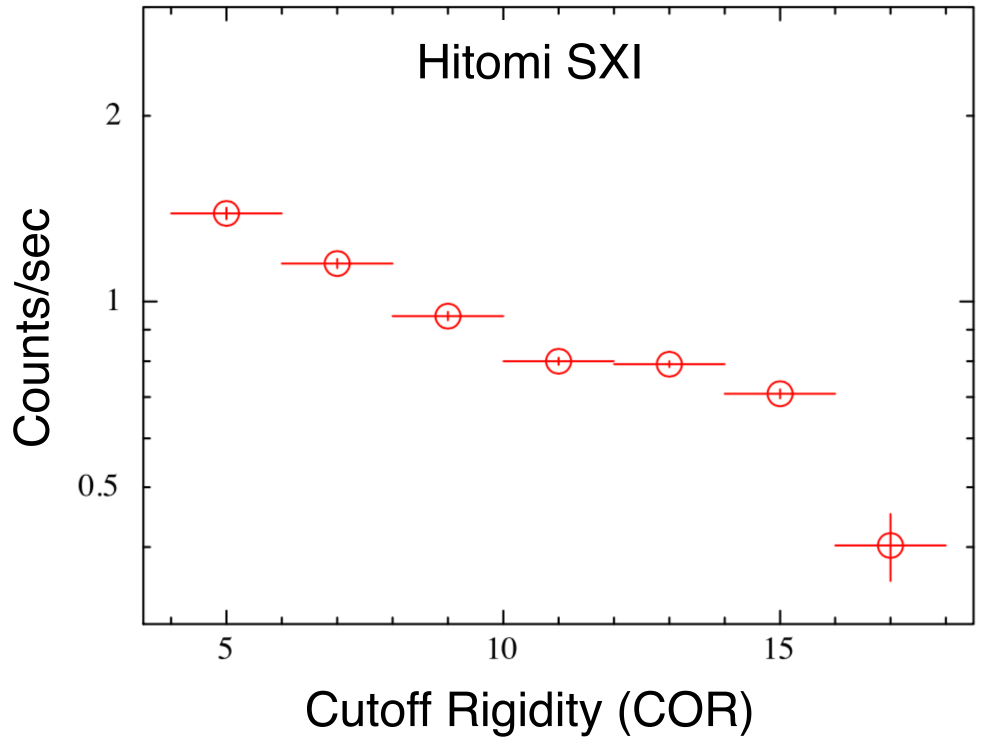
- Sky background
  - Many contribute, many depends on sky coordinates & time
  - Local Hot Bubble/Foreground Emission e.g., Snowden et al. 1998; Kuntz & Snowden 2000; Yoshino et al. 2009; Masui et al. 2009; Ueda et al. 2022
  - Milky Way Halo/Transabsorption Emission e.g., Kuntz & Snowden 2000; Yoshino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

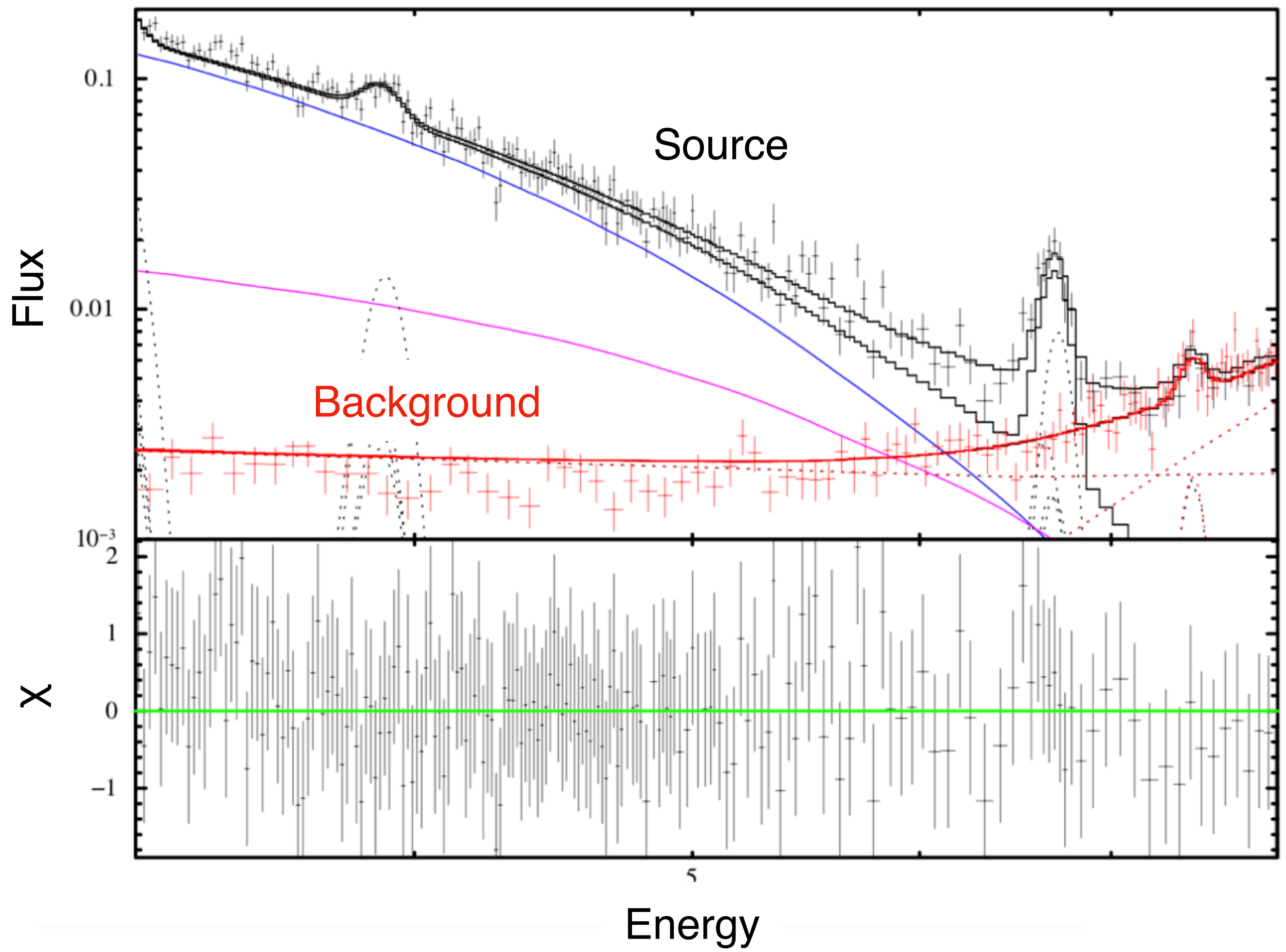
Color: Cutoff Rigidity (COR)



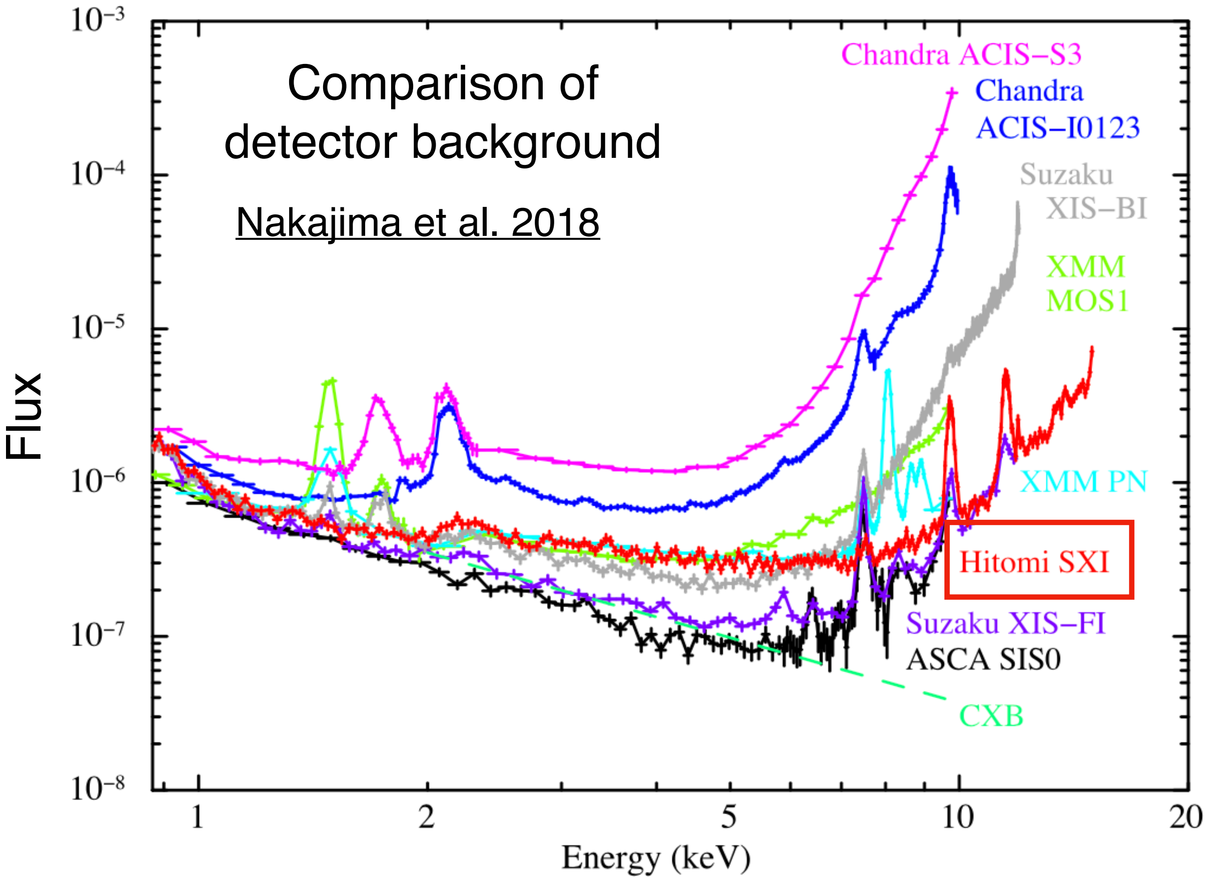
# Detector background

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

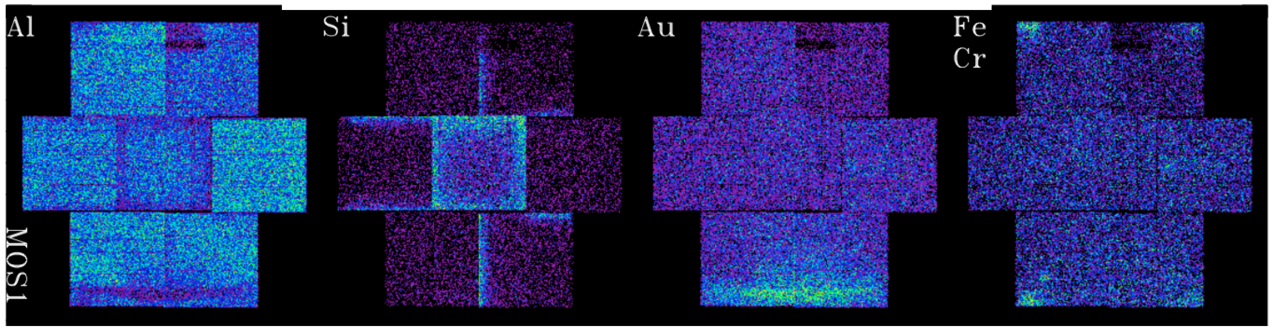


# Compare to other satellite missions

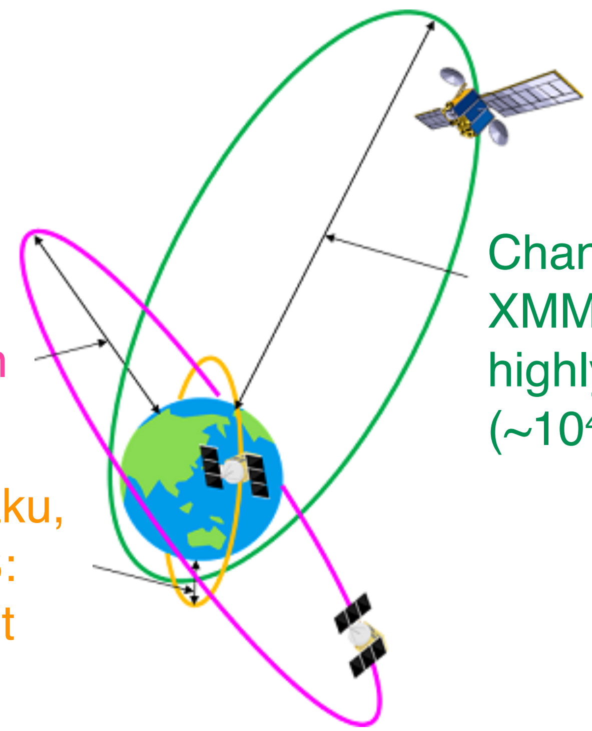
- LL of ASCA, Suzaku, XMM, Chandra, Hitomi have been considered
  - suppressed stray light, background, contamination, CCDs operated at lower temperature




XMM MOS detector background



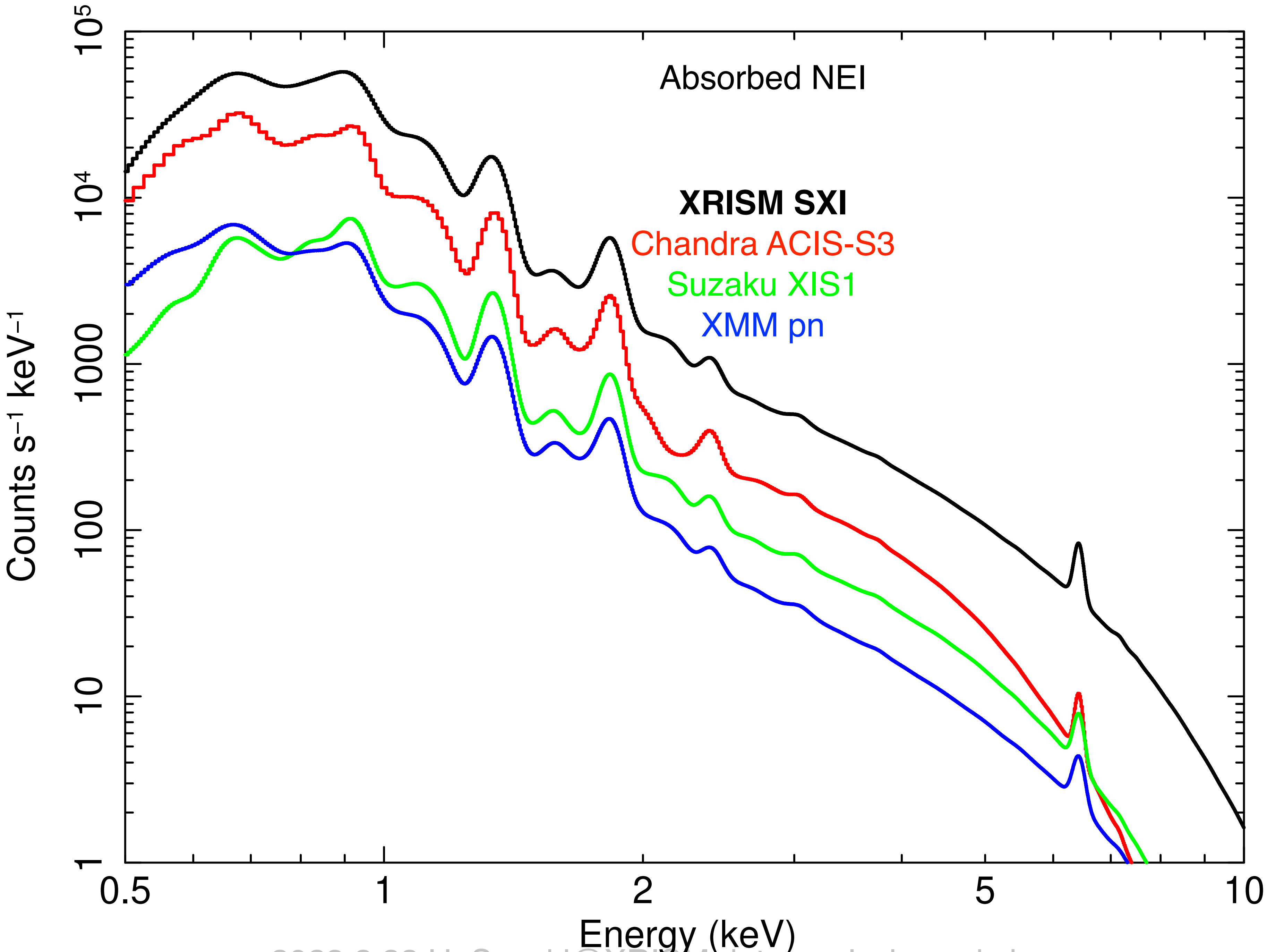

Kuntz & Snowden 2008

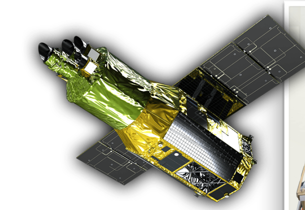
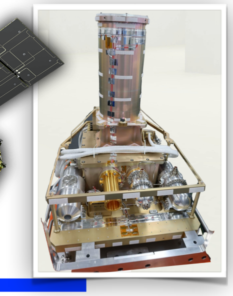



SRG/eROSITA: L2

# Compare to other satellite missions

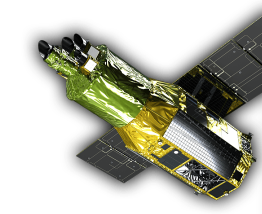
- Detector response
  - basically as good as other X-ray CCDs on satellites
  - moderate energy resolutions at low energies

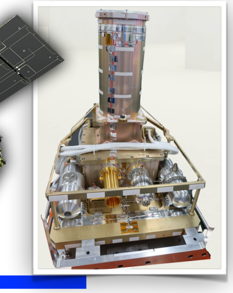


# Some other notes

- Transient source search
  - observers' option at proposal submission (yes/no)
  - if yes, XRISM team members see observation data before passed to observers, to search for transient sources
  - if a transient found, XRISM team members post a telegram





# Key takeaways

**When observing / analyzing 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
- Ang. resolution ~1.5’ (HPD)→care about surrounding sources
- Sky/detector background
  - coordinate (sky/detector) / time dependence
  - in spectral studies, use W-stat or Source & background simul. modeling w/ C-stat
- Pile-up for bright point sources
  - try to avoid pile-up
  - pile-up estimator will be provided