In-orbit performance verification of the Soft X-ray Imaging Telescope Xtend onboard XRISM for two observation modes

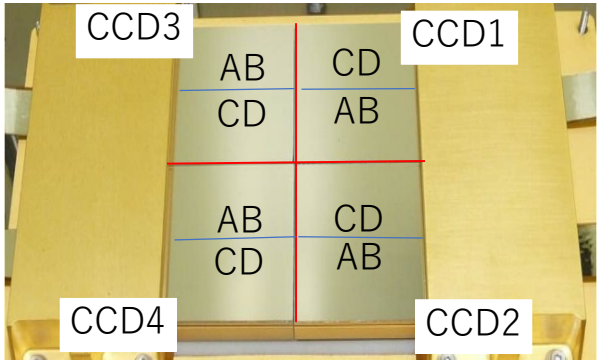
Kota Takayama (Kindai University)

Kumiko Nobukawa, Masayoshi Nobukawa, Yuma Aoki, Yamato Ito,
Koji Mori, Hiroshi Murakami, Hiroshi Nakajima, Tsunefumi Mizuno
on behalf of the Xtend team

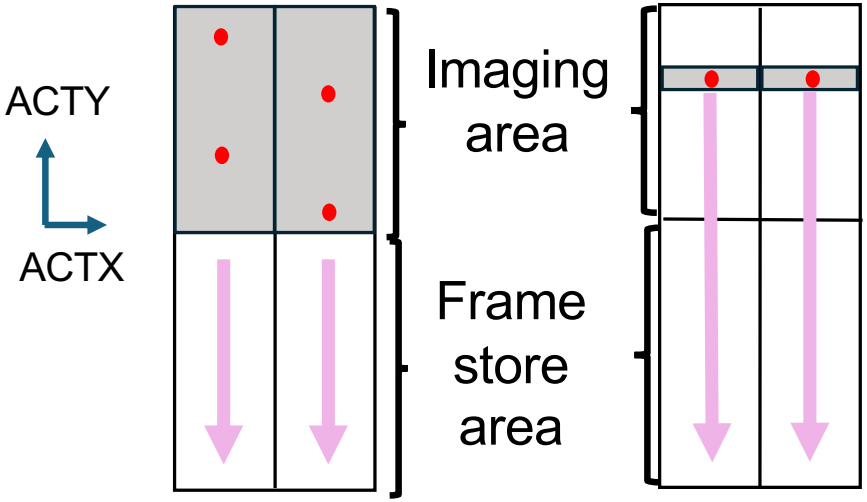
17th IACHEC meeting

Introduction

4 CCDs of Xtend



Full window mode 1/8 window mode



- Xtend has 4 CCDs, arranged in a 2 x 2 array.
- Each CCD has 640 x 640 binned pixels and two segments (AB and CD) corresponding to read out nodes.
- The nominal operation mode is called the “Full Window (No Burst)” mode.
  - Frame exposure is 3.96 seconds.
- To reduce the likelihood of pile-up events when observing bright sources, users can select the “1/8 Window No Burst” mode.
  - Only 80 CCD rows (1/8 of the full logical pixels) are read out.
  - Readout time is reduced by 1/8 of the full window mode.
- To verify in-orbit performance of the normal and the 1/8 window modes, we measure the difference in X-ray flux between the two modes by analyzing the data of Cygnus loop and N132D.

Data and Analysis

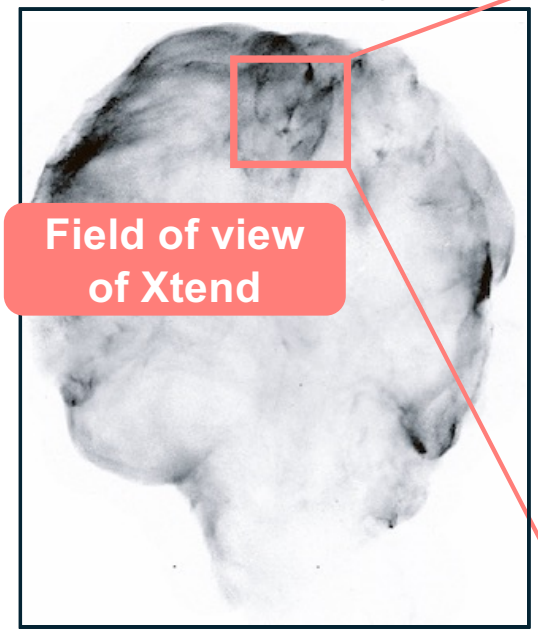
Observation logs and file names of the analysis data

Mode	OBSID	Object	Right Ascension (°)	Declination (°)	Exposure Time (s)	Start Time (UT)	End Time (UT)	Event File
Full	100008010	CygnusLoop	312.689	31.8836	37909	2024/04/18 06:26:04	2024/04/19 06:00:04	xa100008010xtd_p03000000a0_cl.evt
1/8	100008020	CygnusLoop	312.689	31.8838	37794	2024/04/19 06:00:04	2024/04/20 09:04:04	xa100008020xtd_p031100010_cl.evt
Full	000126000	N132D	81.2593	-69.6405	93560	2023/12/03 22:01:04	2023/12/07 00:01:04	xa000126000xtd_p030000010_cl.evt
1/8	000128000	N132D	81.2596	-69.6406	54113	2023/12/09 09:53:04	2023/12/11 03:46:04	xa000128000xtd_p031100010_cl.evt

- Each of Cygnus Loop and N132D was observed by the full and 1/8 window modes with the same pointing direction to reduce the uncertainties in the effective areas of the mirror and detector.
- We analyzed cleaned event files (rev3 data).
  - Data during the exposure time when the Xtend was pointing at the sources were analyzed.
  - Only X-ray Grade events were extracted.
  - Charge Injection (CI) rows and 2 rows in front and behind (=5 rows) were removed.
- We analyzed the data of the on-axis segment (CCD2CD).
  - Flickering pixels due to cosmic ray echoes are negligible in CCD2CD.
- Count rates of the two observation modes were measured in common energy band (0.5−2 keV) and region (ACTY = 439−478, 484− 513).

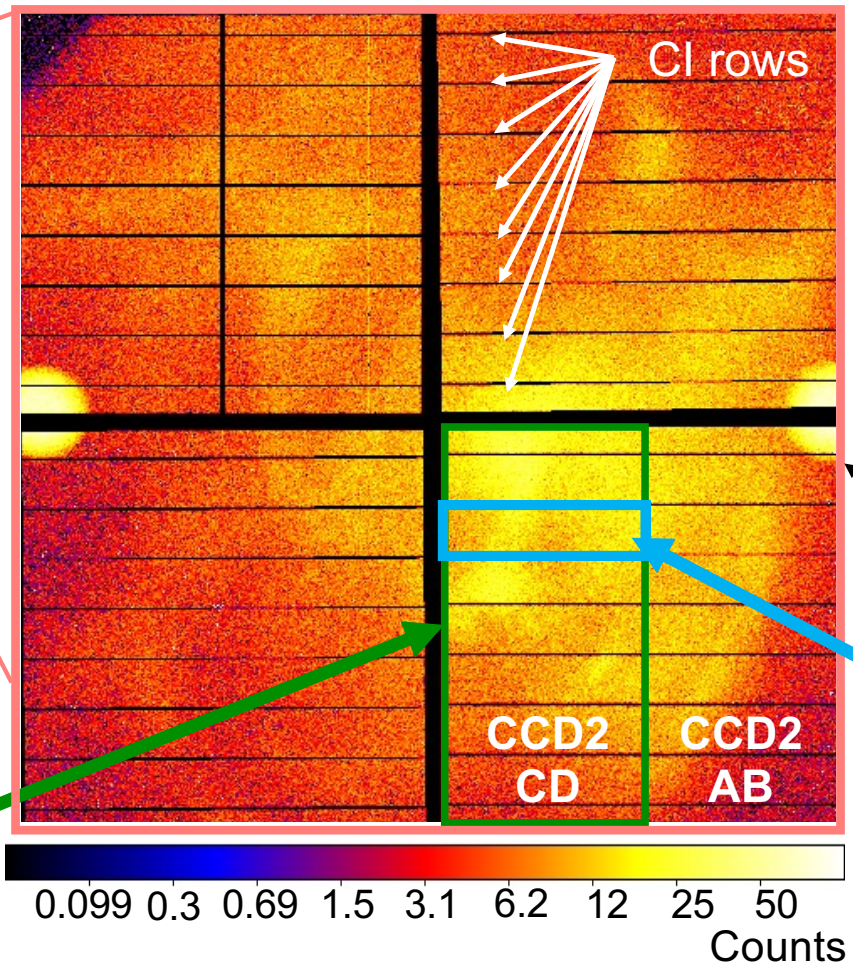
Cygnus Loop

ROSAT image



Levenson & Graham (2005)

Xtend image
in DET coordinate display



Normal mode

- Whole area of the CCDs is irradiated by X-rays from the celestial object.
- Data of 1/8 window mode were obtained by the same pointing as the full window mode.
- Image of the 1/8 window mode is just like the blue square region.

Calibration source
(55Fe)

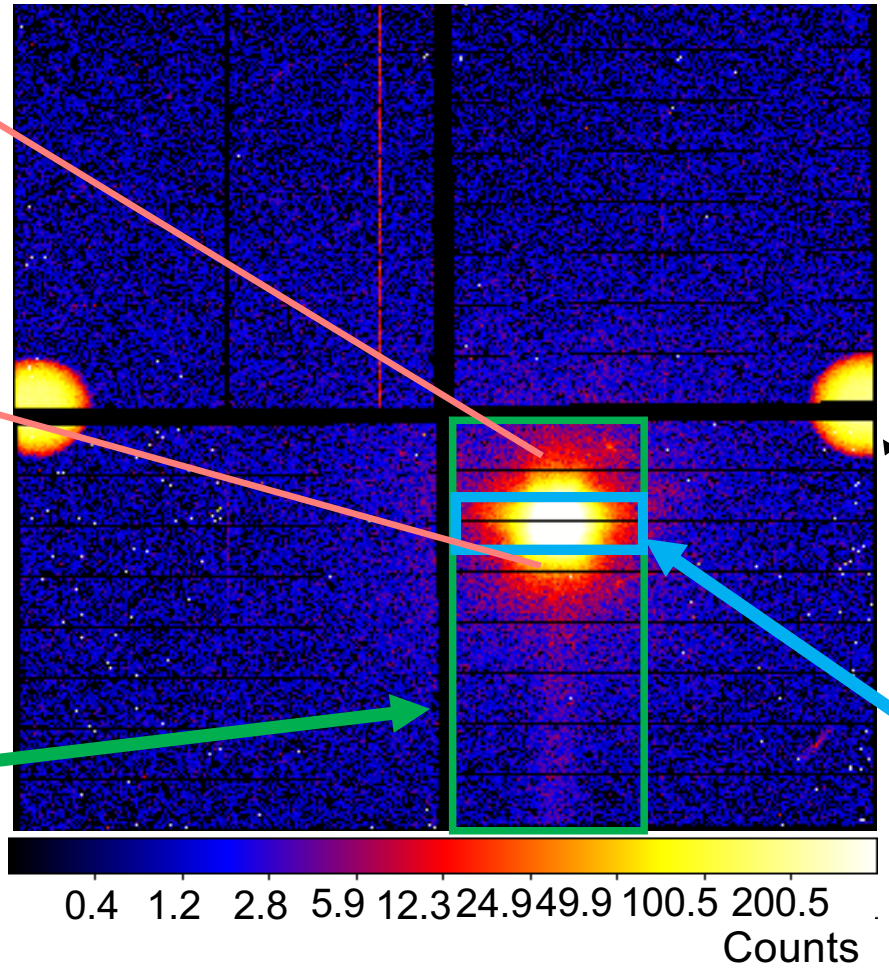
1/8 window mode

N132D

Chandra image

Borkowski et al. (2007)

Xtend image
in DET coordinate display



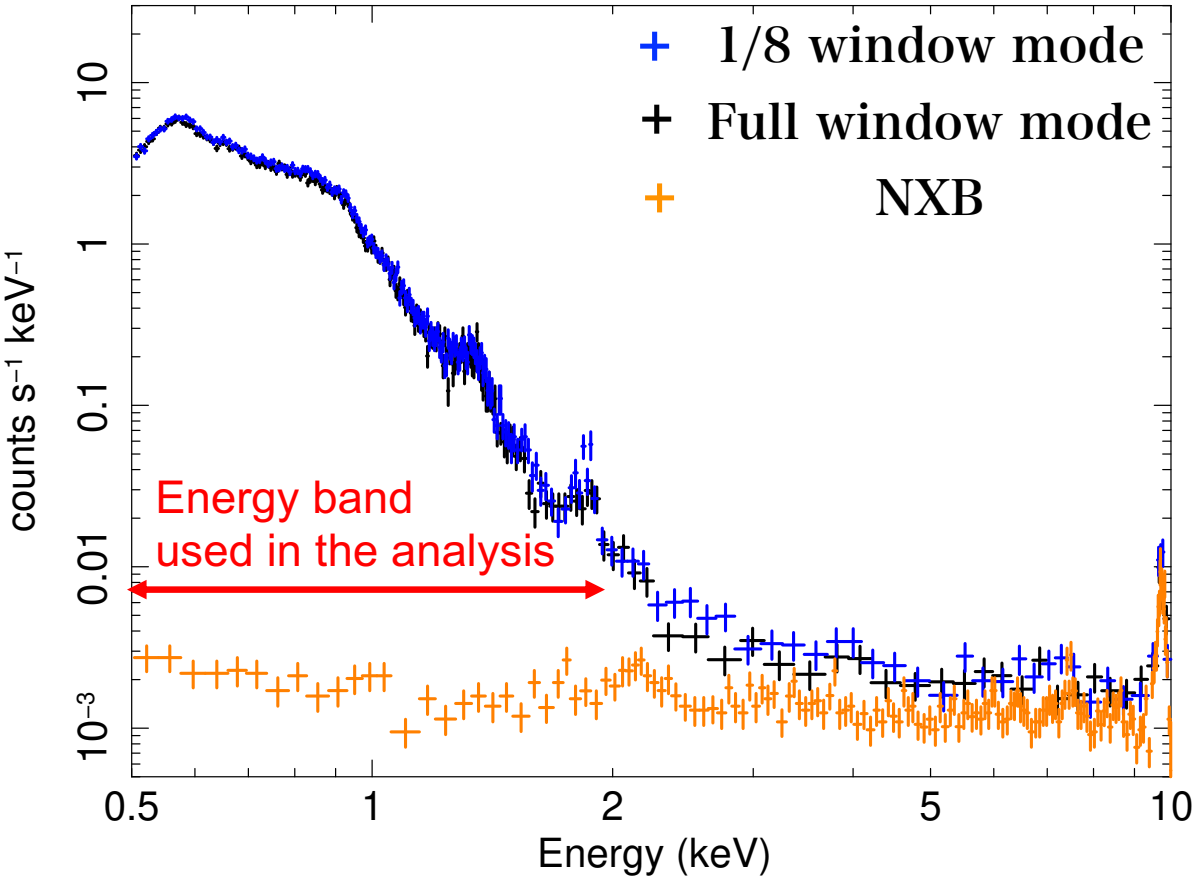
- N132D is within CCD2CD.
- In the same way as Cygnus Loop, the data of 1/8 window mode were obtained by the same pointing as the full window mode.
- Image of the 1/8 window mode is just like the blue square region.

Calibration source
(55Fe)

Normal mode

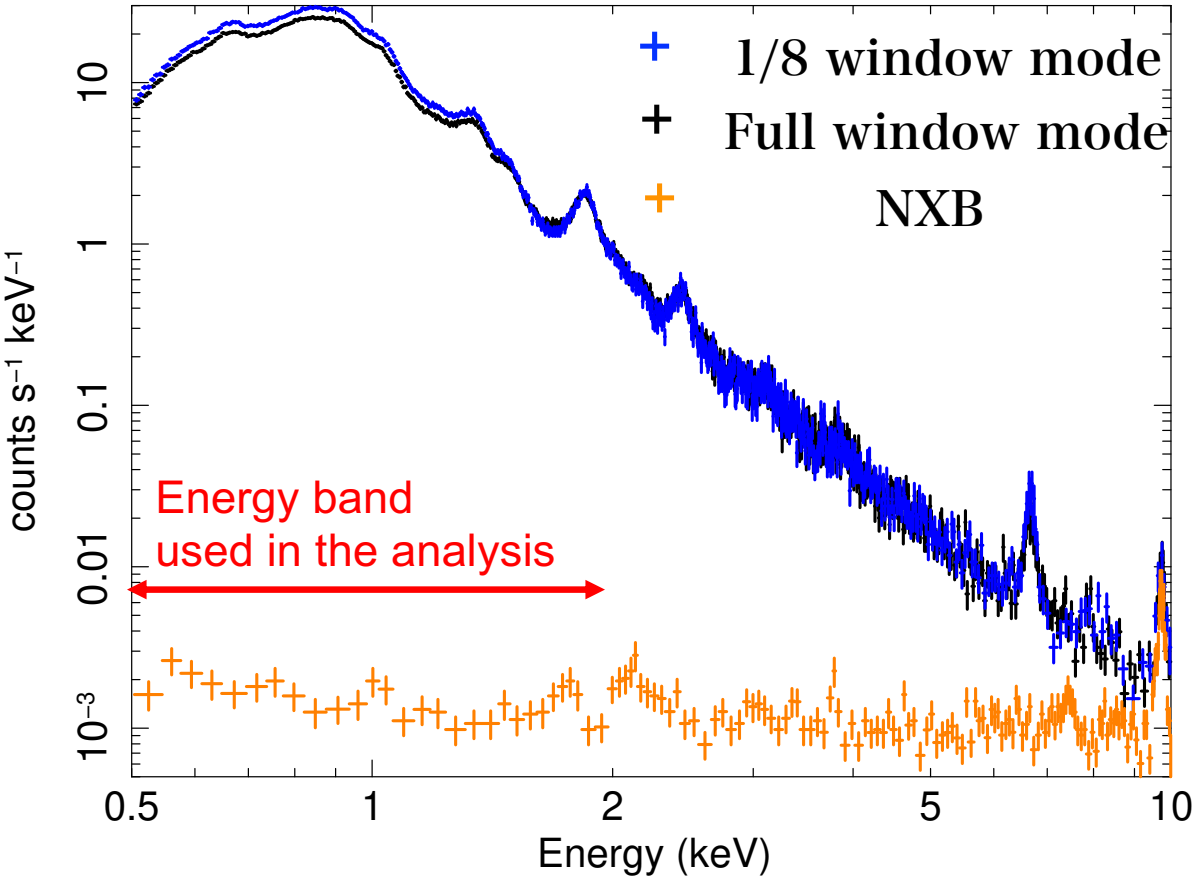
1/8 window mode

Spectrum: Cygnus Loop



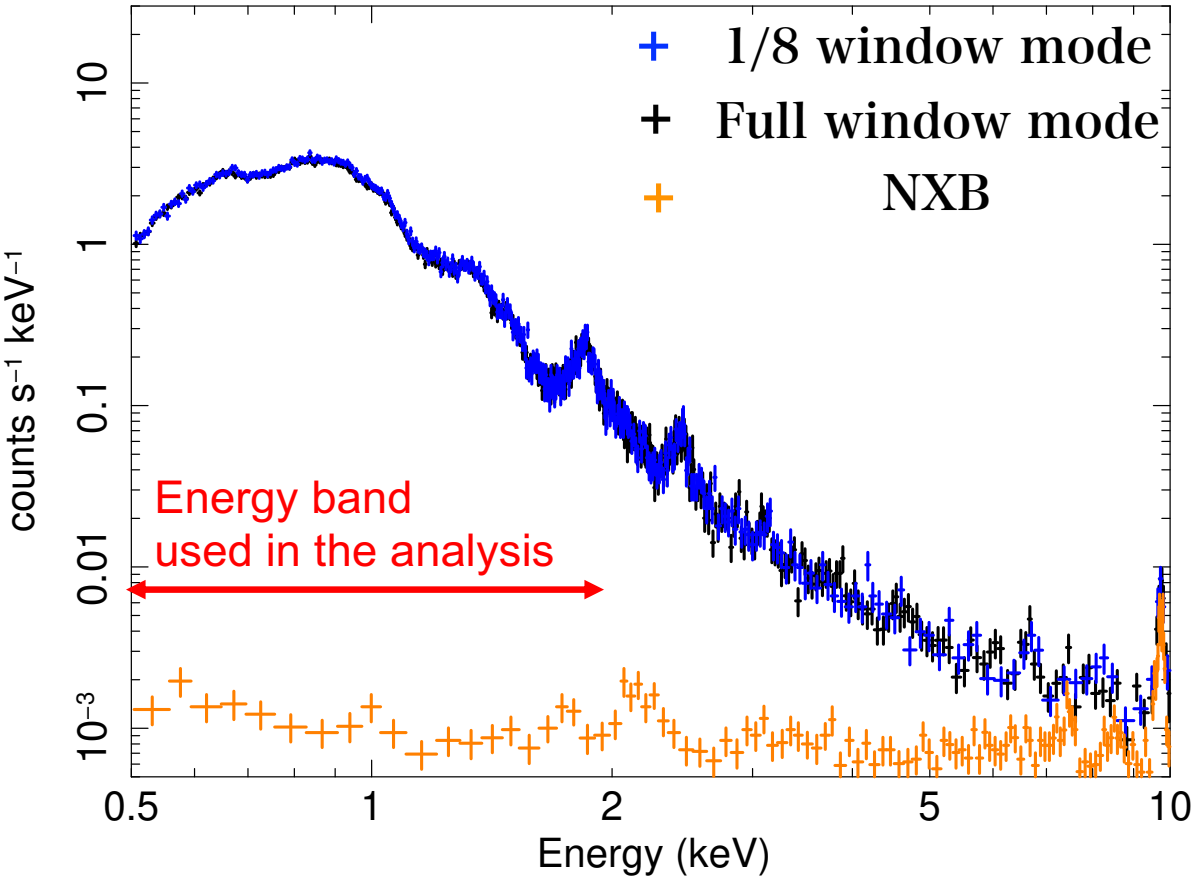
- NXB spectrum is obtained by running xtdnxbgen with the NXB Database (DB) provided by the XRISM team.
- NXB DB is for full-window mode only, but the NXB levels are expected to be comparable between the full window and 1/8 window modes.
- NXB is not negligible in the energy band above 2 keV, so only the count rates in the 0.5−2 keV energy band were measured.

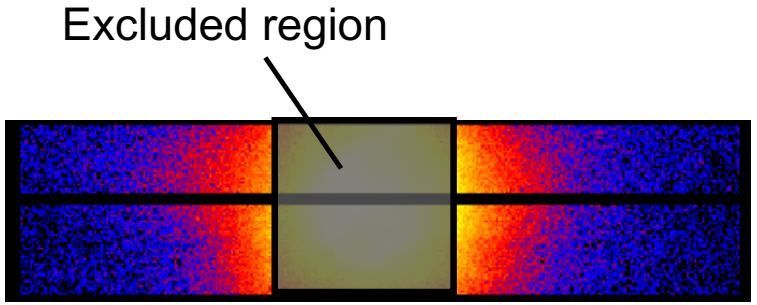
Spectrum: N132D



- NXB spectrum is obtained by the NXB Database (DB) for full window mode.
- NXB is negligible in the the 0.5−2 keV energy band.
- Spectrum of the 1/8 window mode is higher than that of the full window mode in the low-energy band whereas the both spectra are comparable to each other in the high-energy band.
  - It indicates that the full window spectrum is affected by pile-up events.

Spectrum: N132D





- We extracted spectra excluding the N132D region.
- Large discrepancy the two spectra in the low-energy band was improved.
- Count rates in the 0.5−2 keV energy band were measured excluding the N132D region.

Results

Count rates (cts/s) of the analyzed regions (NXB is not subtracted).

0.5–2 keV	Full window	1/8 window	diff.
Cygnus Loop	1.752 ± 0.002	1.843 ± 0.006	$5.2 \pm 0.4\%$
N132D	1.825 ± 0.004	1.882 ± 0.005	$3.1 \pm 0.5\%$

- Difference of count rates between the two modes are calculated by:

$$\text{diff.} = \frac{C_{1/8} - C_{full}}{C_{full}}$$

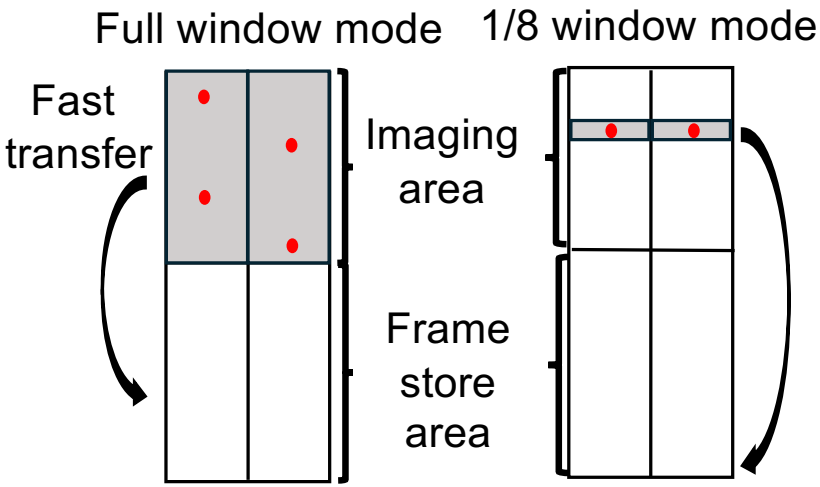
  here $C_{1/8}$ and C_{full} are count rates of the 1/8 window and full window modes.

- 1/8 window mode has a higher count rate than the full window mode by 3−5%.

Discussion: possible causes of the discrepancy

(1) “Out-of-time” events during fast transfer

- In the case of the Cygnus loop, X-rays fall on the whole area of the CCD.
- 1/8 window mode is more affected by “out-of-time” events because the ratio of fast transfer time to exposure time is larger, which may produce a higher count rate in the 1/8 window mode.



	Exposure time (s)	Fast transfer time (s)	Time ratio (fast transfer / exposure)
Full	3.96	0.03	0.8%
1/8	0.46	0.03	6.5%

(2) Pile-up events

- Since the exposure time of the full window mode is longer than the 1/8 window mode by 8 times, the full window mode is more affected by pile-up events and its count rate may be suppressed.

Discussion: comparison with FM ground test

- We compared the results with that of a FM ground test.

Count rates (cts/s) of CCD2CD.

^{55}Fe	Full window	1/8 window	diff.
Ground test	16.89 ± 0.02	17.34 ± 0.03	$2.6 \pm 0.2\%$

- Size of the analyzed region above is almost comparable to that of Cygnus Loop analysis.
- X-rays from ^{55}Fe fall on the whole area of the CCD.
- Count rates of the ground test are an order of magnitude higher than both Cygnus Loop and N132D.
- However the difference of the count rates between the two modes is < 3%, which is comparable to or less than the in-orbit results (3–5%).
- “Out-of-time” or pile-up events alone cannot explain the difference in count rates between the two modes in orbit.
- We will continue to investigate the causes of the difference in count rates by analyzing other sources and simulations.

Summary

- We Investigated the difference in count rates between the full window and 1/8 window modes of Xtend by analyzing the data of N132D and Cygnus loop.
- Difference of count rates between the two observation modes are found to be 3–5%.
- Possible causes of the difference are “out-of-time” and pile-up events.
- In the ground test, X-rays from 55Fe fall on the whole area of the CCD, and the count rate is an order of magnitude higher than Cygnus Loop and N132D, but the difference in count rate (< 3%) is less than the results of in-orbit observations.
- We will continue to investigate the causes of the the difference in count rates by analyzing other sources and simulations.