X-Ray Imaging and Spectroscopy Mission

Inflight calibration status of the XMA on XRISM

17th IACHEC meeting

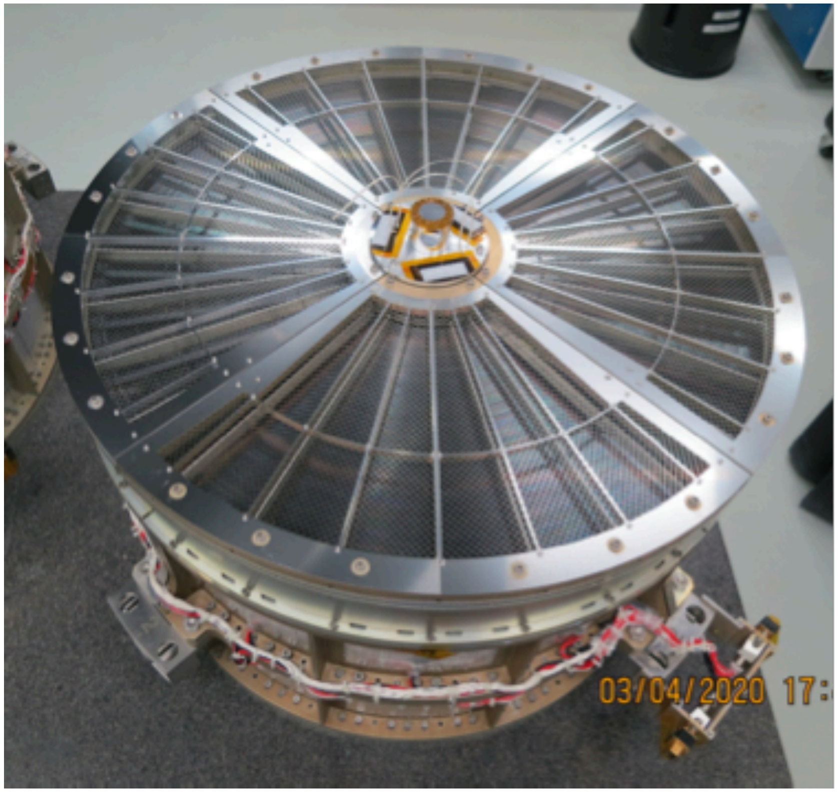
Takayuki Hayashi (GSFC&UMBC)

on behalf of XMA team, XRISM IF-CP WG

X-ray Mirror Assembly (XMA)

XRISM X-Ray Imaging and Spectroscopy Mission

- XMA
  - Resolve-XMA (Microcalorimeter)
  - Xtend-XMA (CCD Camera)
- Multi-nested thin foil optics
  - 5.6m focal length
  - 45cm diameter
    - Grazing angle 0.15 - 0.57 deg
  - 203 nested reflectors (Au surface)
    - Thickness of the reflectors 0.16mm, 0.24mm, 0.32mm
  - Precollimator (PC: stray baffle)



XMA On-Orbit Calibration Items

- Point Spread Function (PSF)
  - NGC 4151 (Xtend 1/8 CCD mode)
  - 3C273 (Resolve)
- Effective Area (cross-calibration)
  - 3C273
  - PKS2155-304
  - G21.5-0.9

  <— Eric Miller's talk
- Optical Axis Search
  - Abel 2029 (Xtend)
  - (GX3+1 (Resolve)) Not observed yet

Resolve optical axis search is very difficult because of Resolve's small FoV (3'x3') in comparison with XMA's vignetting (FWHM ~ 14'@6.4 keV). Moreover, we need updates of data process and/or detector calibration.

- Off-Axis Point Spread Function (PSF)
  - Cyg X-2
  - PKS 2155-304
- Stray Light
  - Crab nebula (60' off)

After mention PSF, concentrate on Xtend's optical axis search and Stray light in this talk

Point Spread Function (Xtend)

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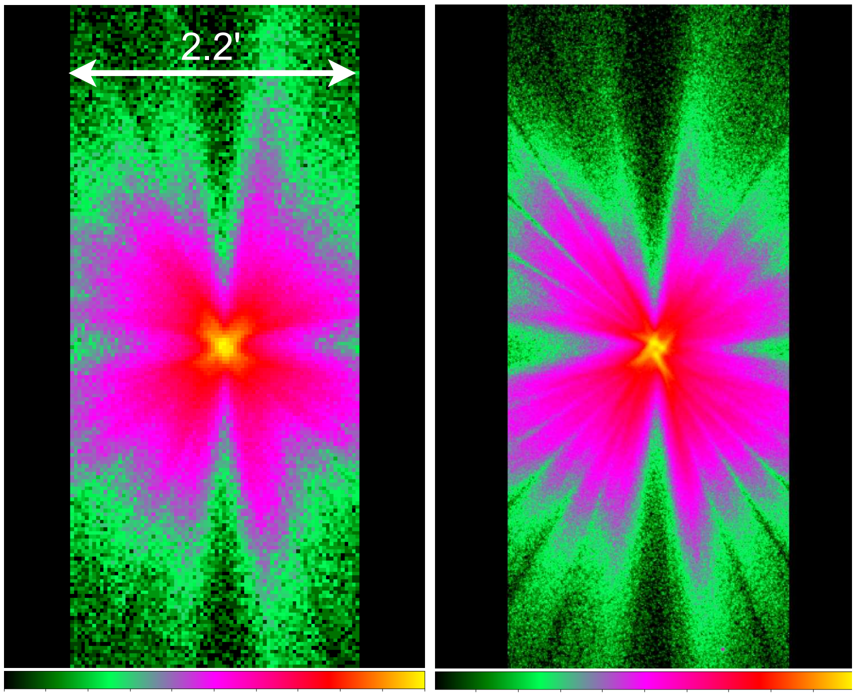
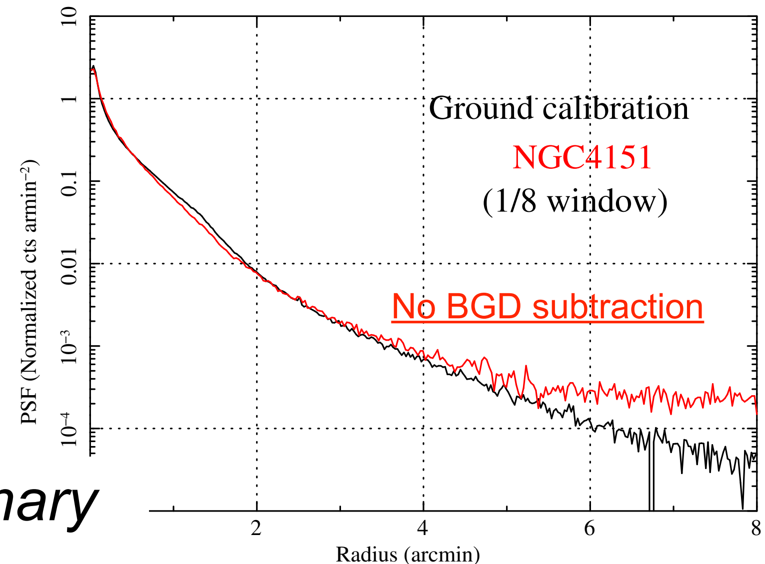
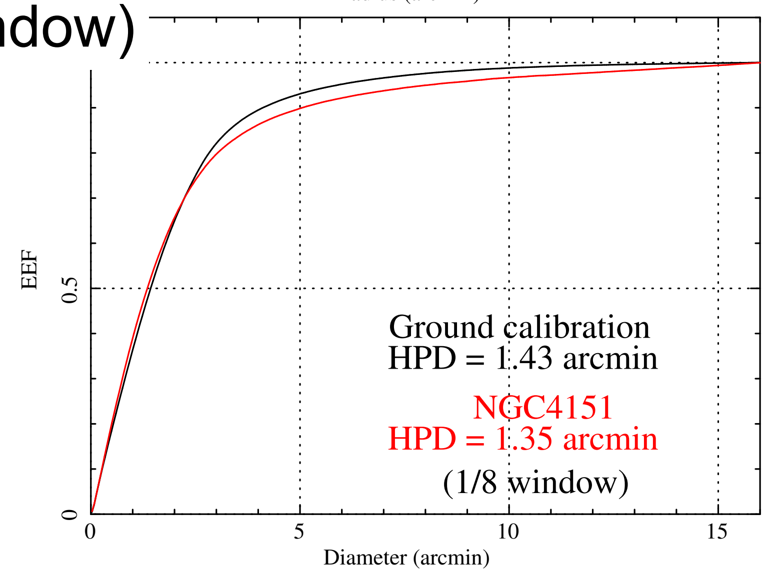
NGC 4151 (6-7keV) | Ground Calibration (6.4 keV)



Preliminary

(1/8 window)





- No degradation in the Xtend-XMA imaging performance was observed in 1/8 Window mode
- Detailed calibration requires high S/N full window mode data

Point Spread Function (Resolve)

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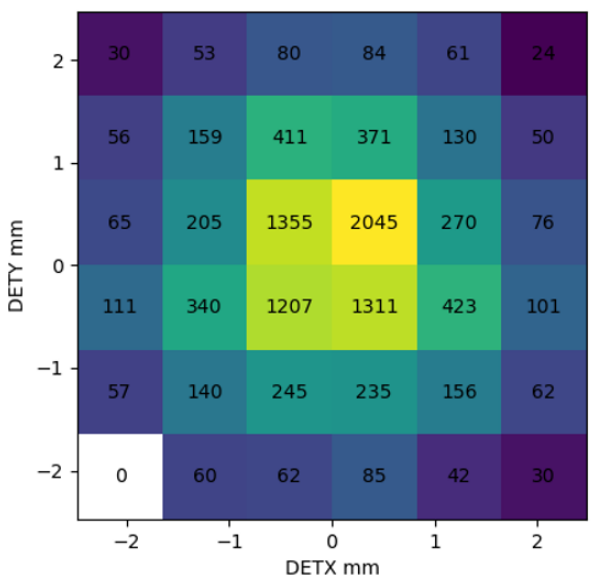
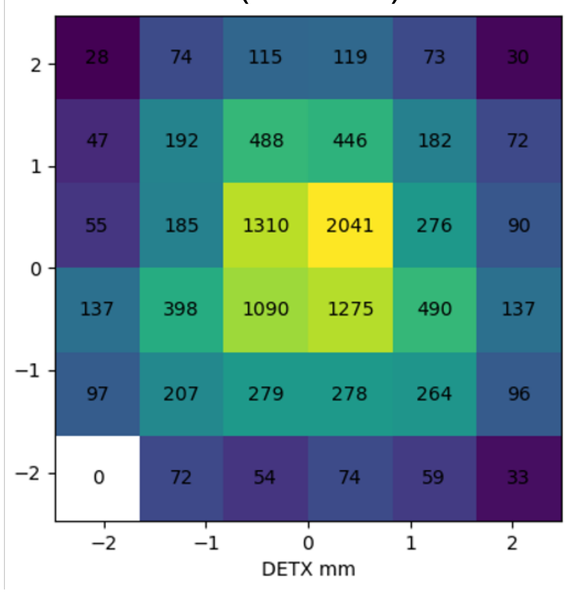
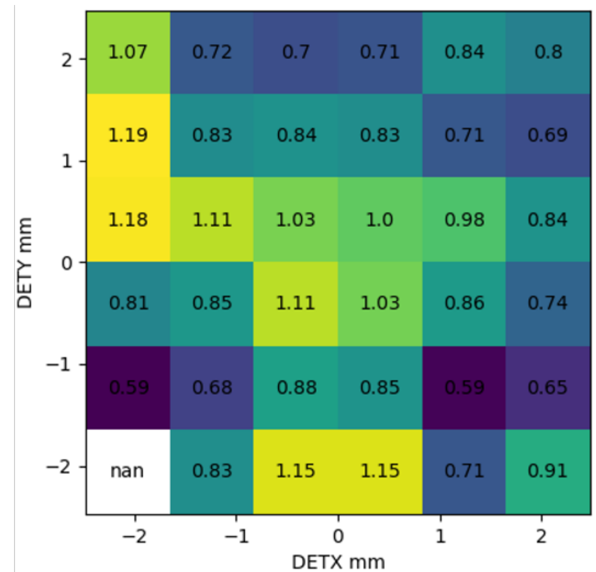
3C 273 on orbit
(6-7keV)



Calculation from the Ground Calibration result
(6.4 keV)



Ratio (On orbit / Ground Cal.)
(6.4 keV)

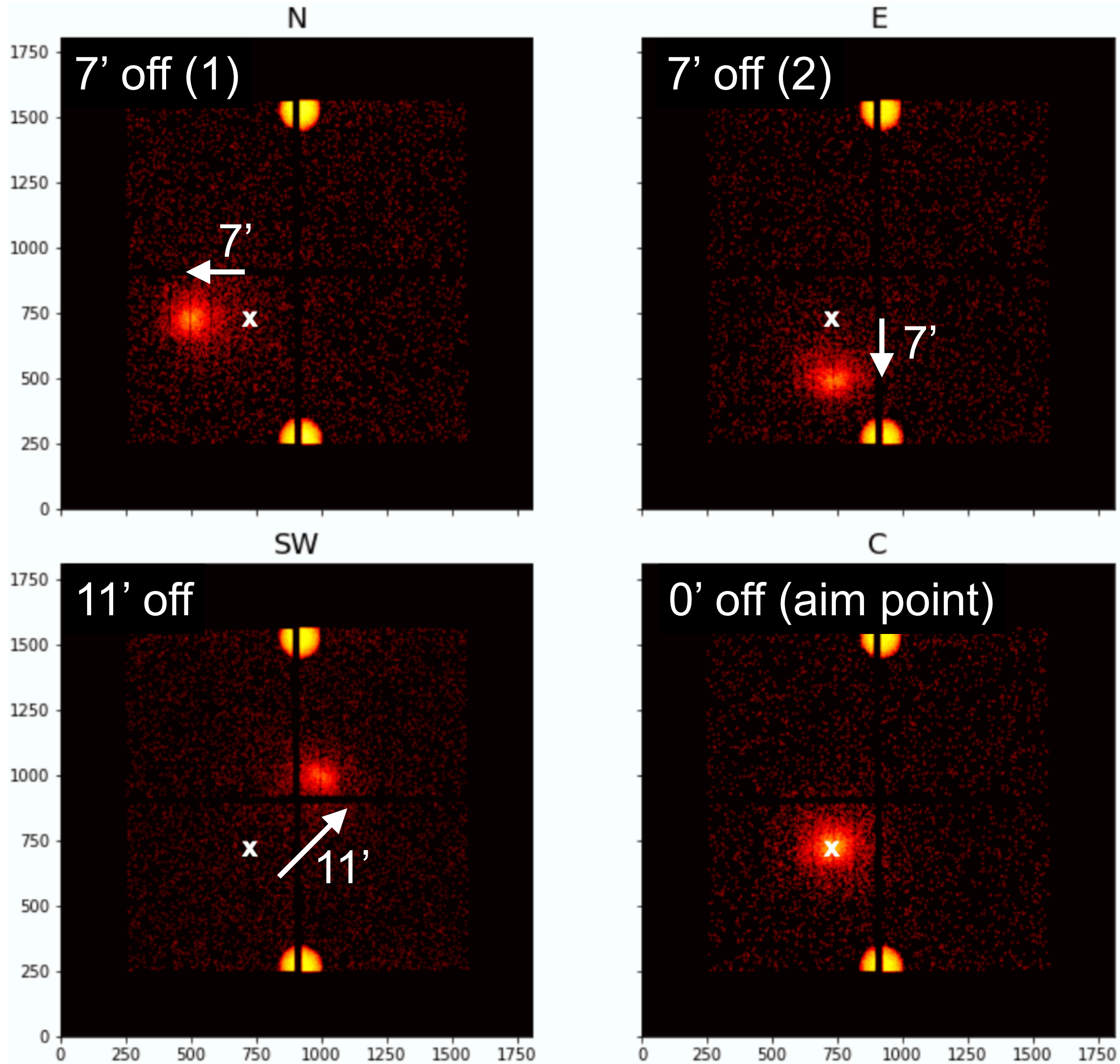


- There is no significant change in the imaging performance
- Detailed calibration requires updates of data process and/or detector calibration

Optical Axis Search (Xtend)

7 points of Abell 2029 (size ~30”)
Xtend optical axis search (4 points) + Scientific purpose (3 points)

4 observations
for Xtend optical axis search

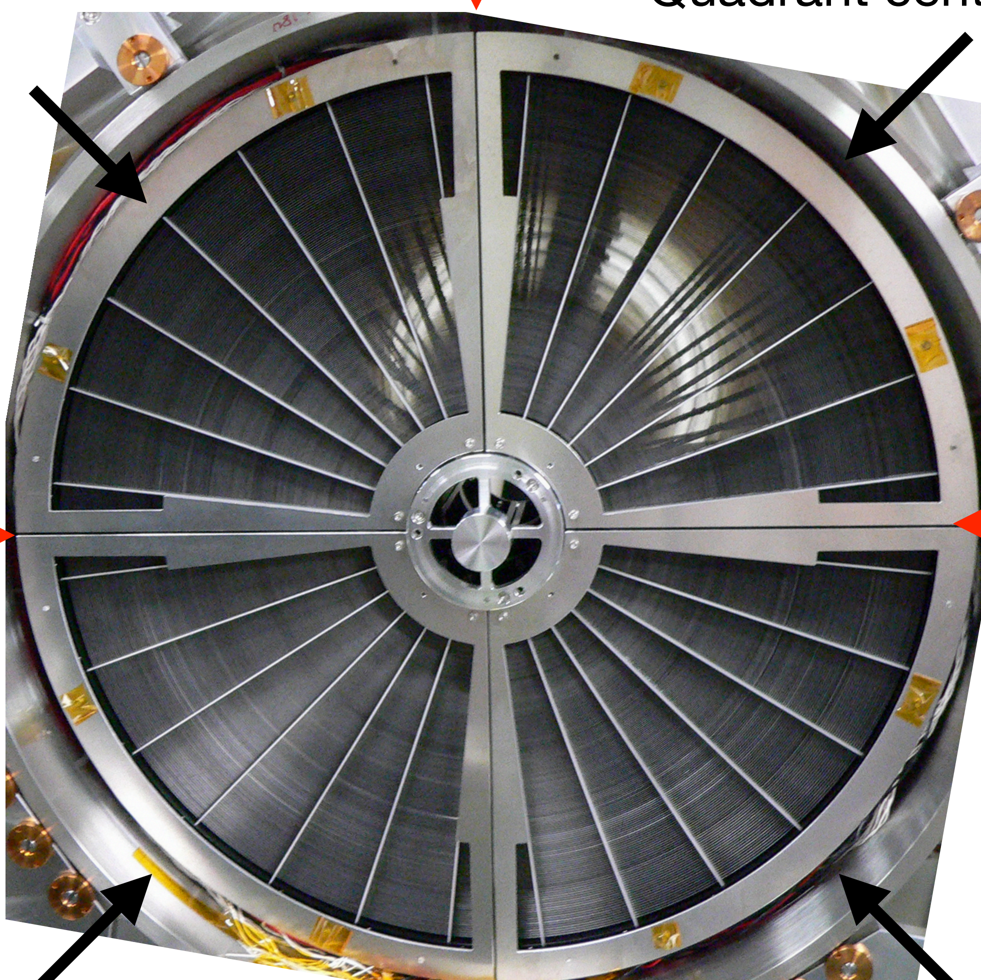


Asymmetry of vignetting

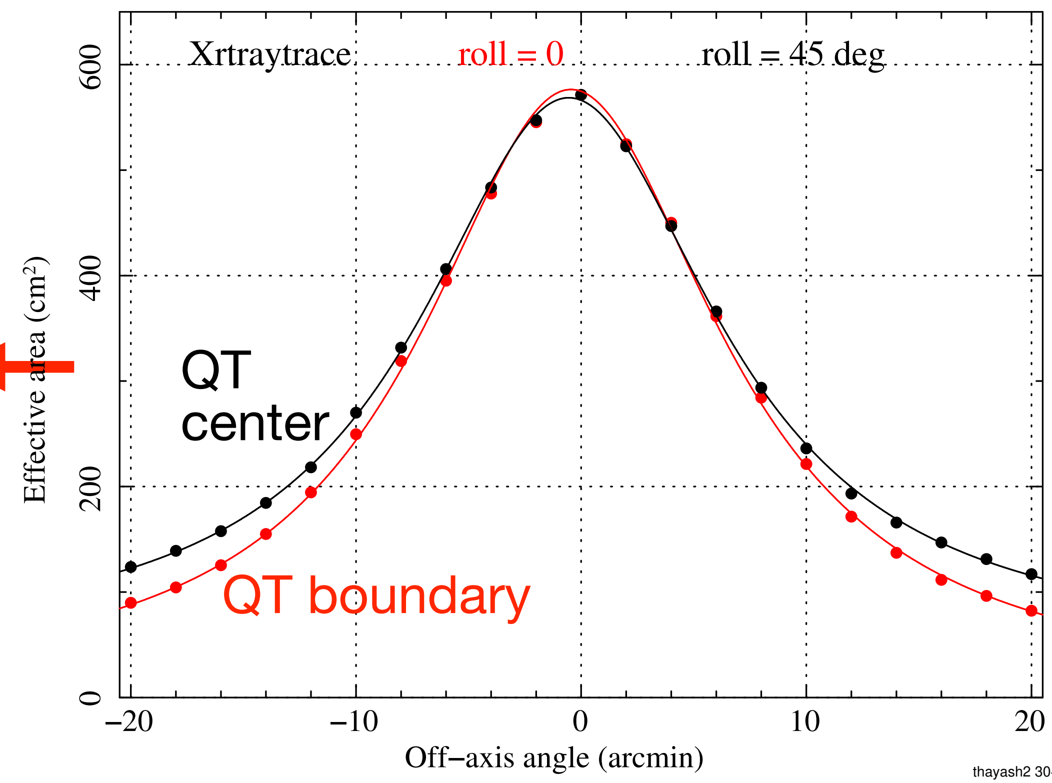
Azimuthal asymmetry is made by the QT boundaries

Quadrant boundary → Narrower

Quadrant center → Wider



- Vignetting



Need to consider asymmetry for optical axis measurement

Asymmetric 2D Vignetting model

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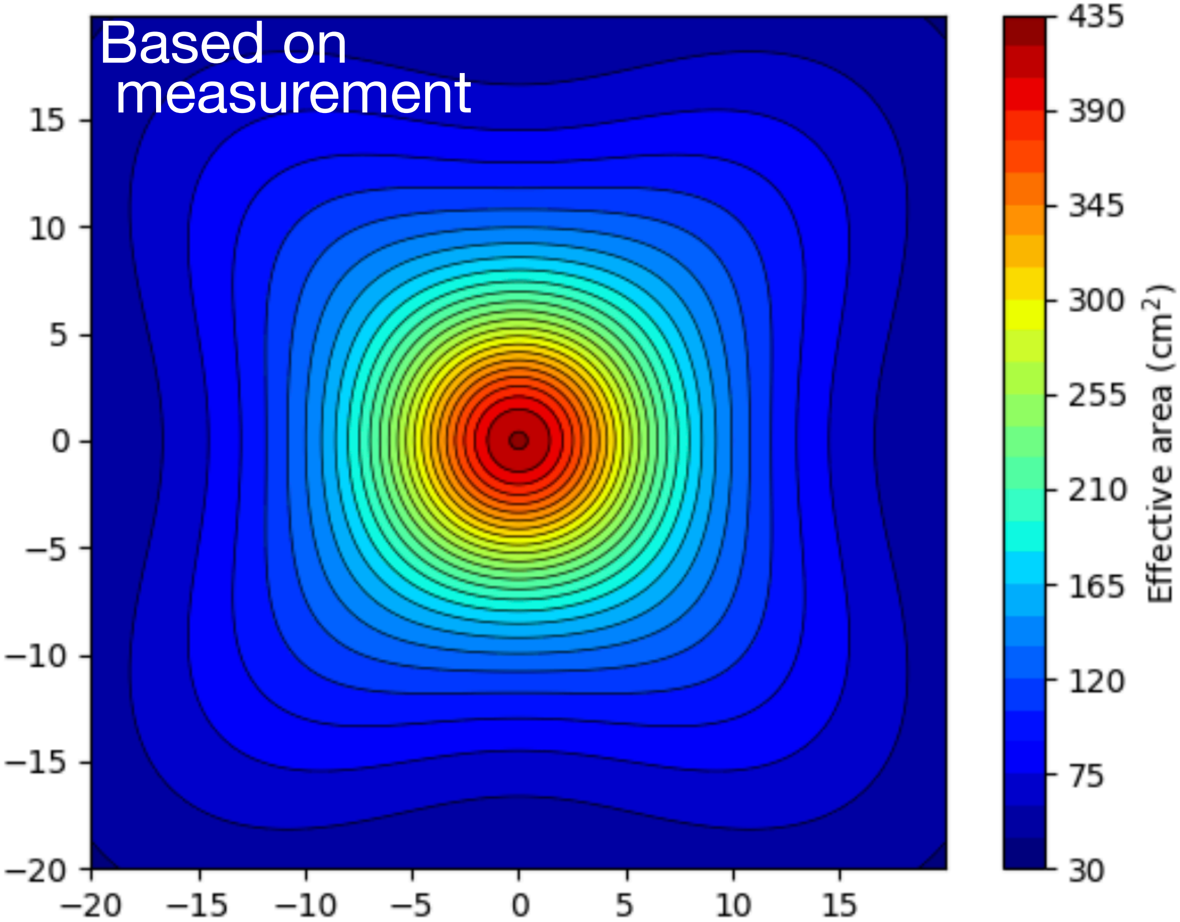
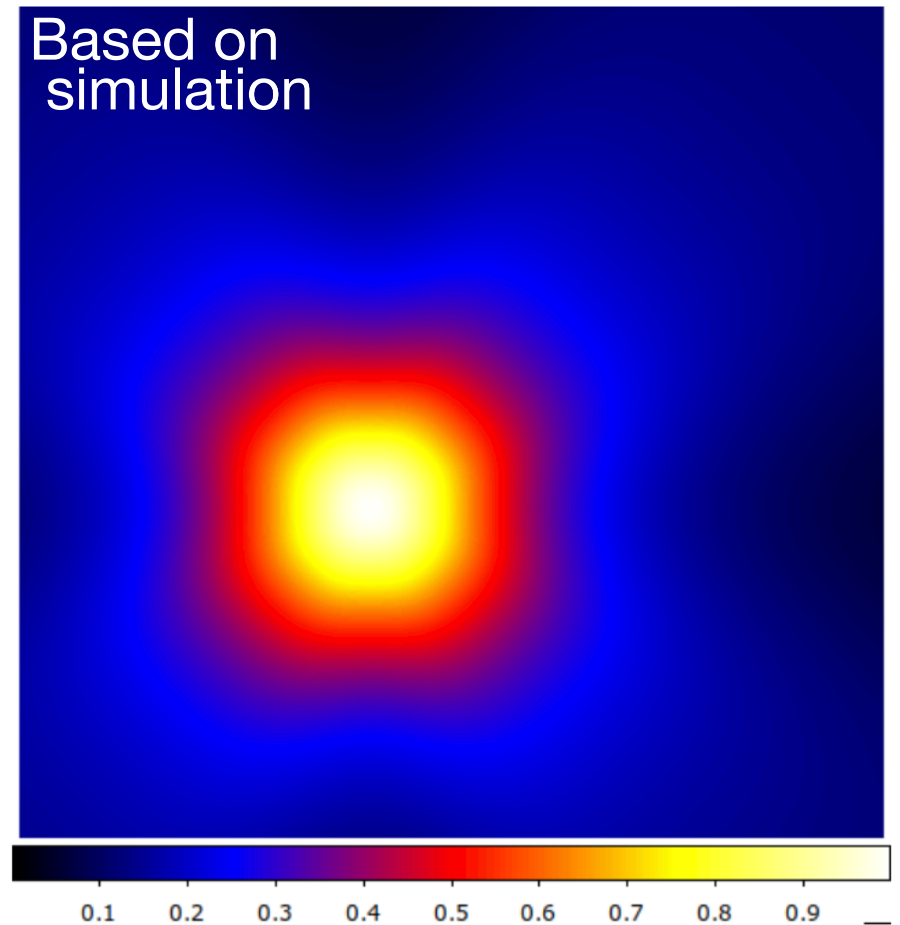
2D vignetting profile models





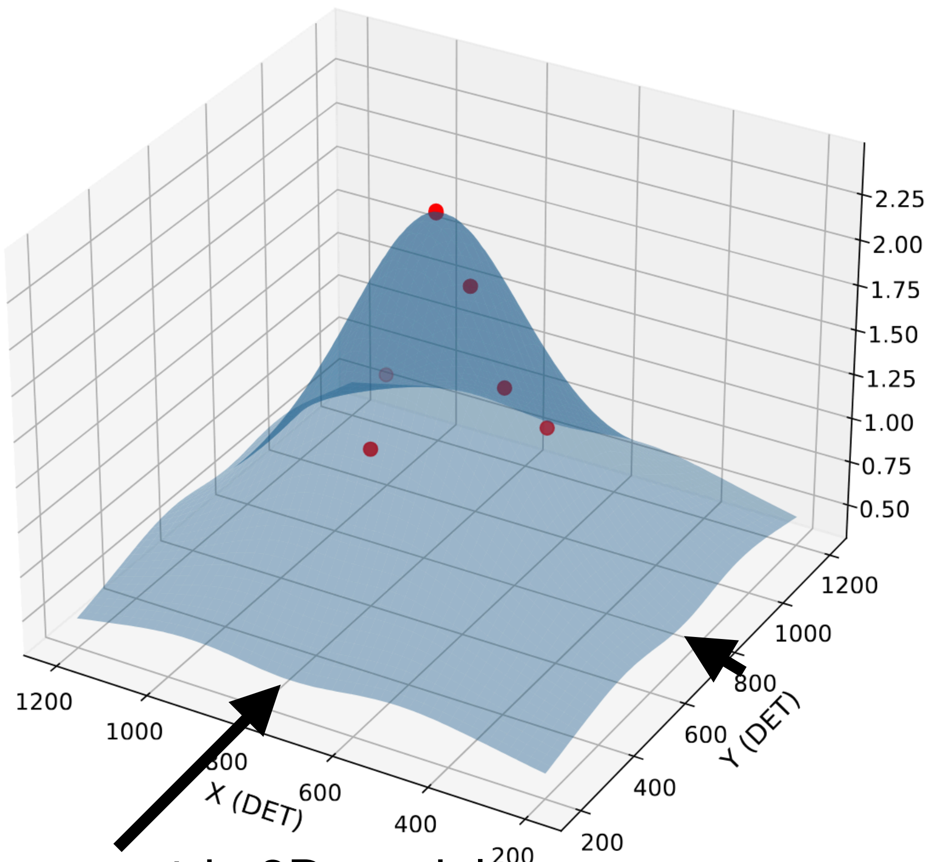
Two complementary 2D vignetting models were developped

Based on
- Ground measurement (higher accuracy)
- Simulation with CalDB (denser data points)

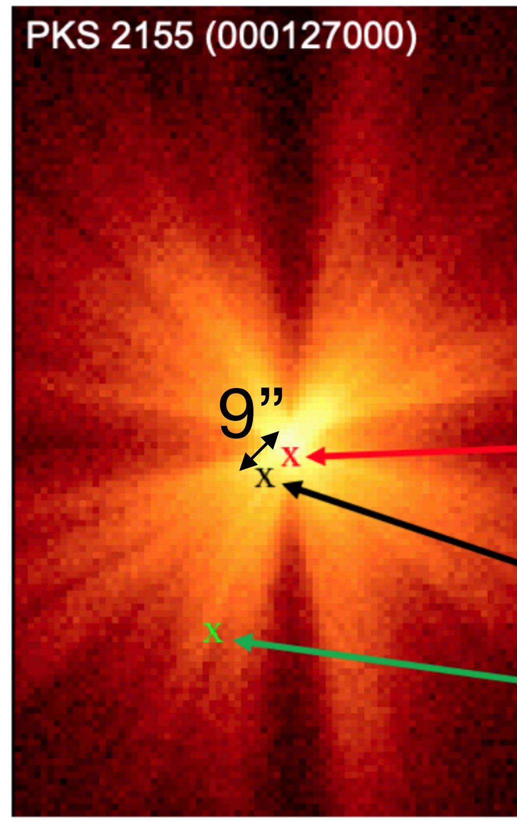
→ Fit these models to the Abell2029 observations

Result of Optical Axis Search

- 2D model fitting to the Abell2029 observations



Asymmetric 2D model
→ Vignetting peak = Optical axis

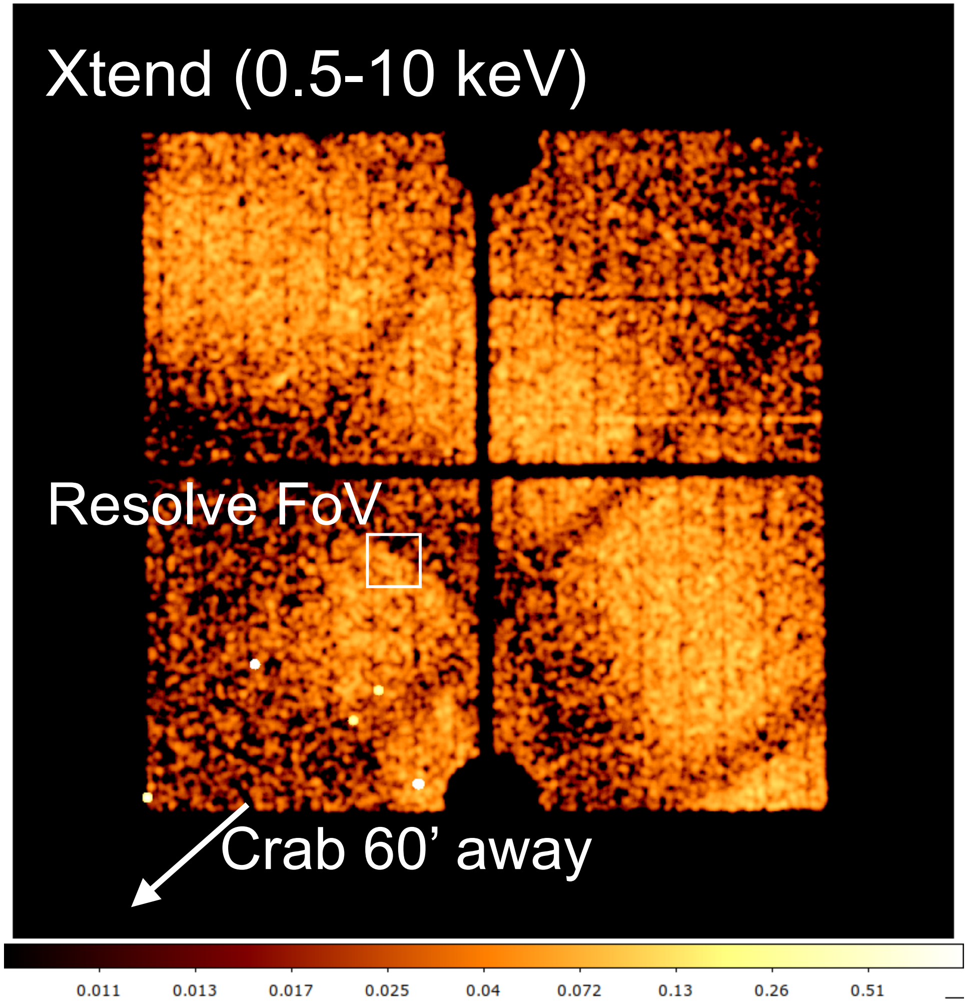


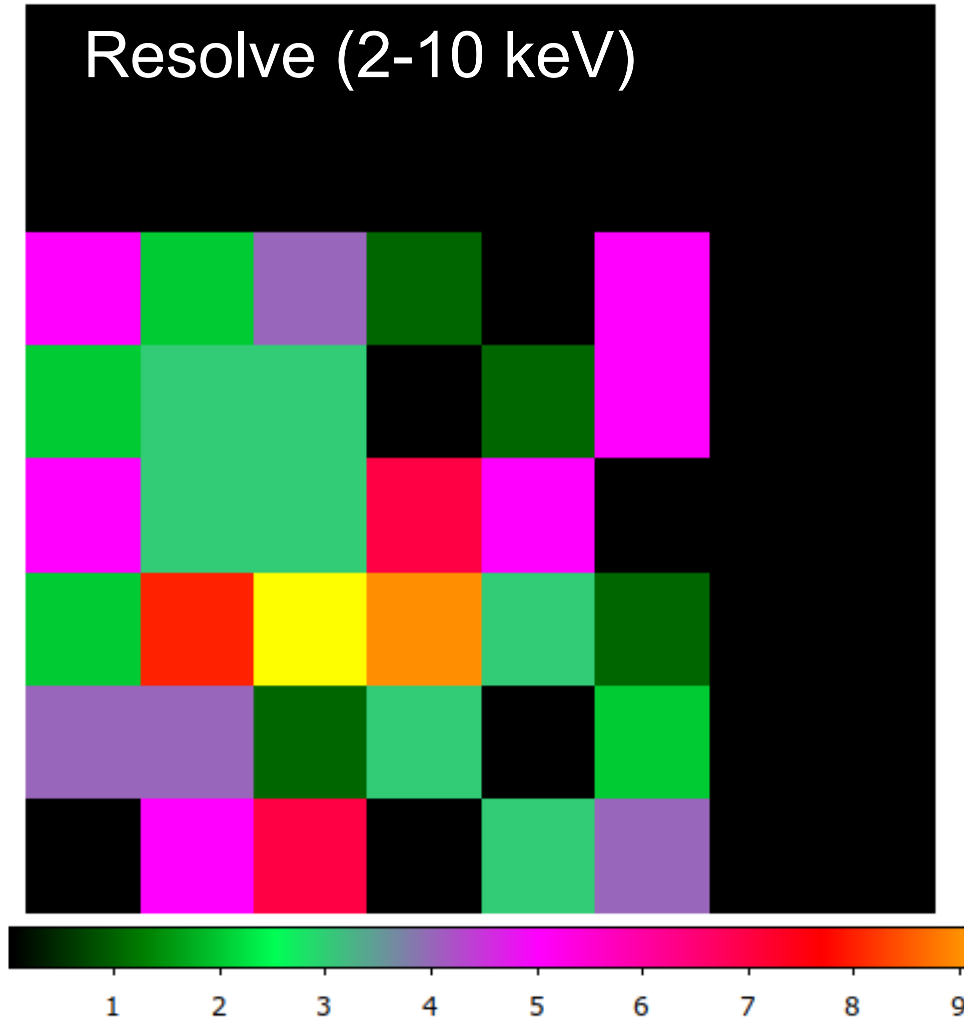
Optical axes by asymmetric 2D models are consistent
and are close to the aimpoint (~9”) —> Current CalDB

(cf. Symmetric 2D (Lorentzian) model gives an offset of 30”)

Stray (images)

Crab 60'-off

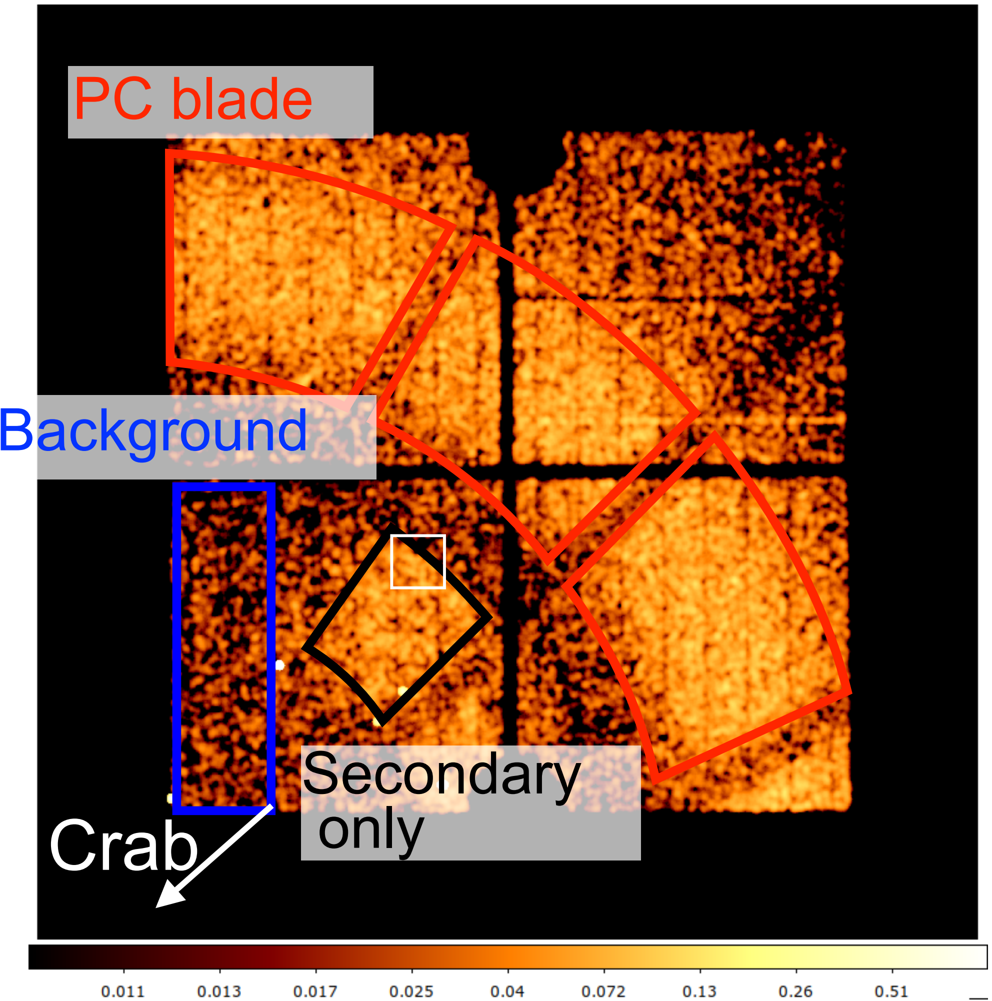


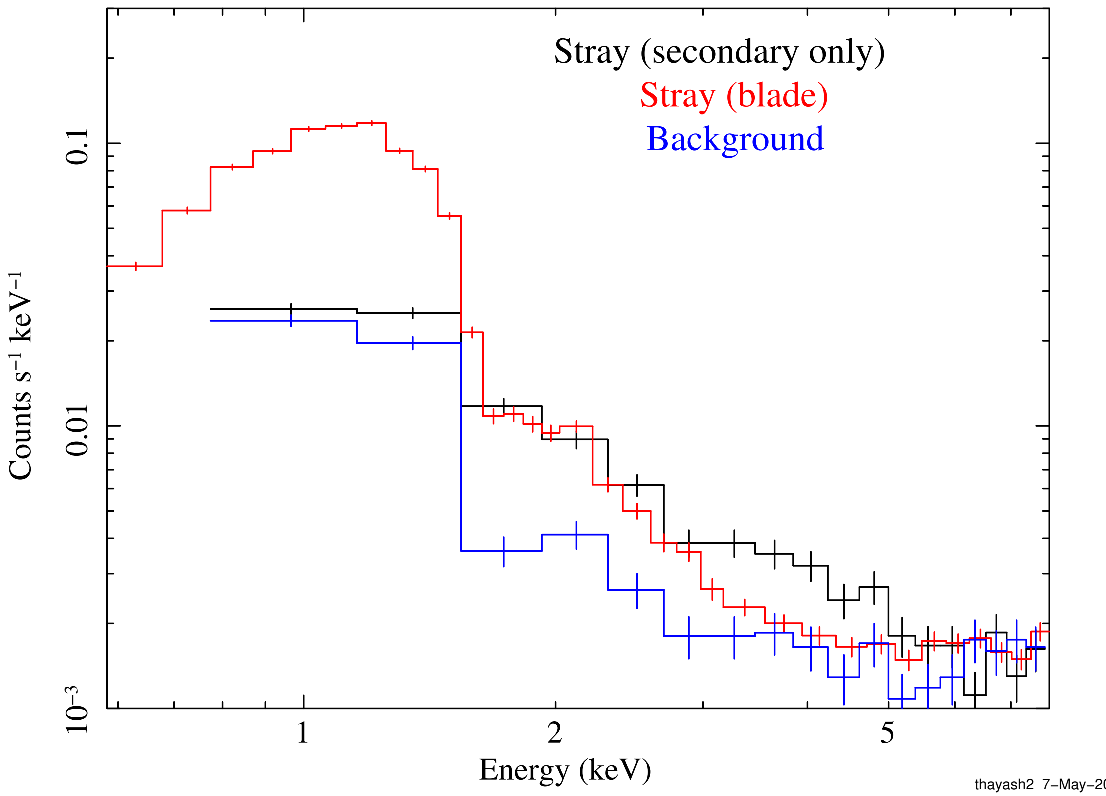


- Characteristic stray pattern in Xtend
- No obvious stray pattern in Resolve

Stray (Xtend spectrum)

Crab 60'-off



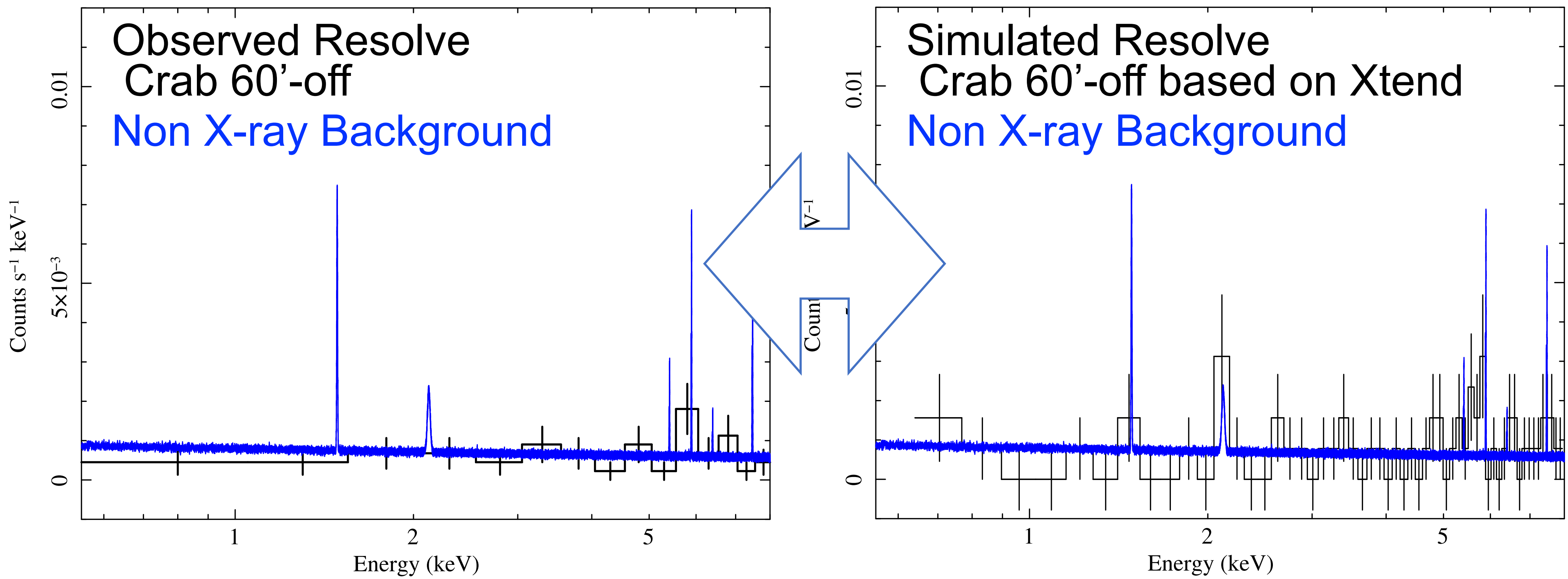


- 2 types (Outer ring → Scattering by blades of precollimator (PC)
  Soft: bright around 1 keV
  Inner ring → Single reflection by secondary reflectors
  Hard: reaches 5 keV & **Overlaps with Resolve FoV**

Stray (Resolve spectrum)

XRISM X-Ray Imaging and Spectroscopy Mission

10 ks & Gate Valve closed



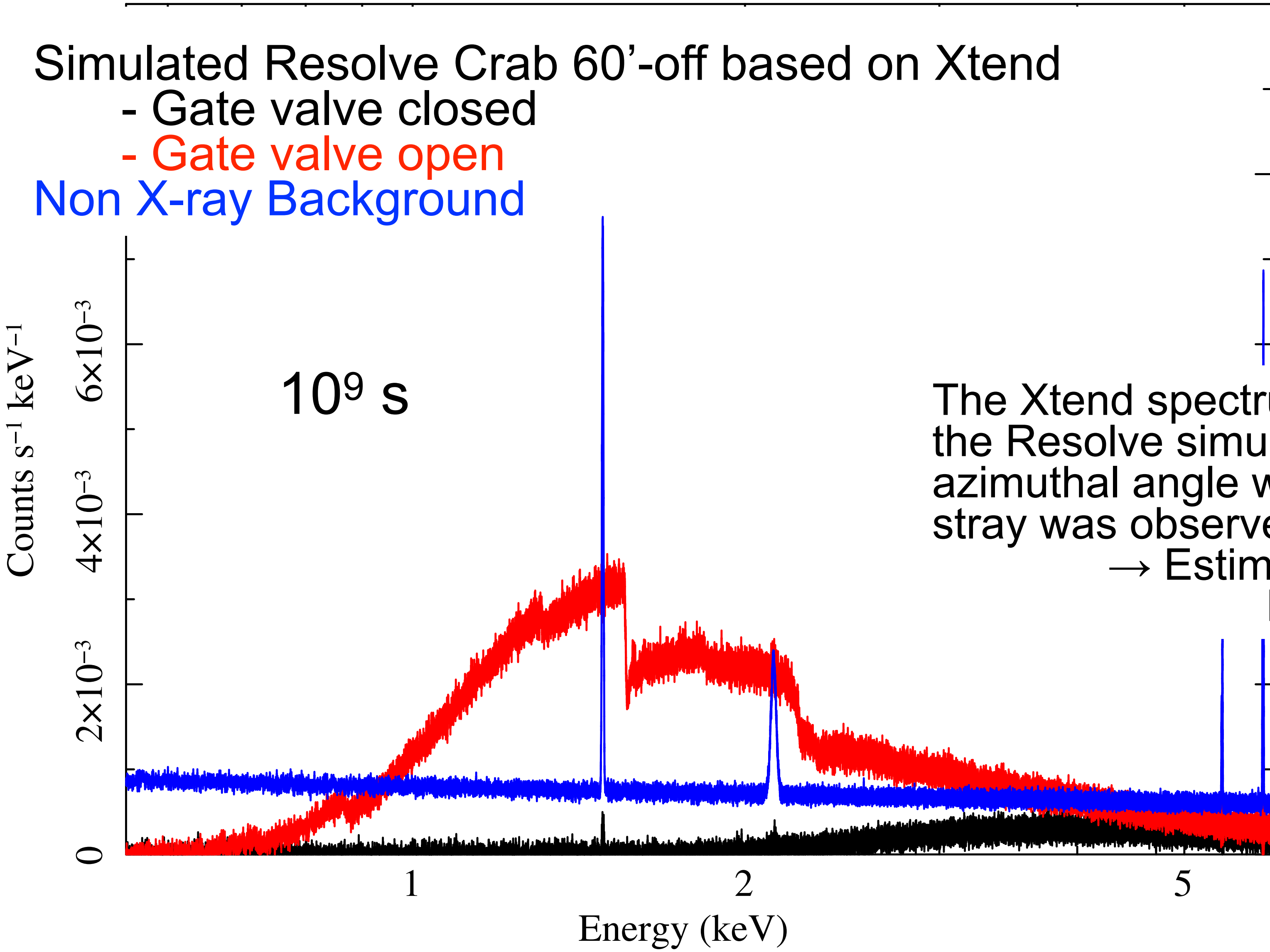
- Observed 60'-off Crab spectrum (10 ks&gate valve closed) by Resolve is consistent with NXB
- Simulation based on Xtend secondary-only spectrum verified the observation which is consistent with NXB

Stray (Resolve spectrum estimate)

XRISM X-Ray Imaging and Spectroscopy Mission

Simulated Resolve Crab 60'-off based on Xtend
- Gate valve closed
- Gate valve open

Non X-ray Background



The Xtend spectrum that is the base of the Resolve simulation was taken at the azimuthal angle where the strongest stray was observed on ground
→ Estimate of the strongest Resolve stray

Gate valve closed: stray < NXB by a factor of a few at most
Gate valve open: stray > NXB by a factor of a few at most
→ will be observed after gate valve open (September)

Note: PC is desinged to reduce stray at 30'-off → Stray is weaker at off-axis angle < 60'

Summary

- Point Spread Function
  - Xtend: No degradation in the the imaging performance was observed in 1/8 Window mode
  - Resolve : No performance degradation was observed
- Optical Axis Search
  - Xtend: Optical axis was measured by asymmetric 2D vignetting model
    Deviation of optical axis from the aim point is ~9”
    (cf. 30” by symmetric 2D model (Lorentzain))
  - Resolve: Measurement of GX 3+1 is proposed
- Stray light measurements
  - Xtend: Obvious stray pattern was taken
    2 types
    Precollimator blade: soft
    Secondary only: hard and overlapped with Resolve FoV
  - Resolve: no obvious stray pattern & spectrum is consistent with NXB
    Simulation based on the Xtend stray spectrum
    → Gate valve
    Closed (until September at least): Stray < NXB
    Open: Stay > NXB by a factor of ~4 at most
    Will be observed after gate valve open

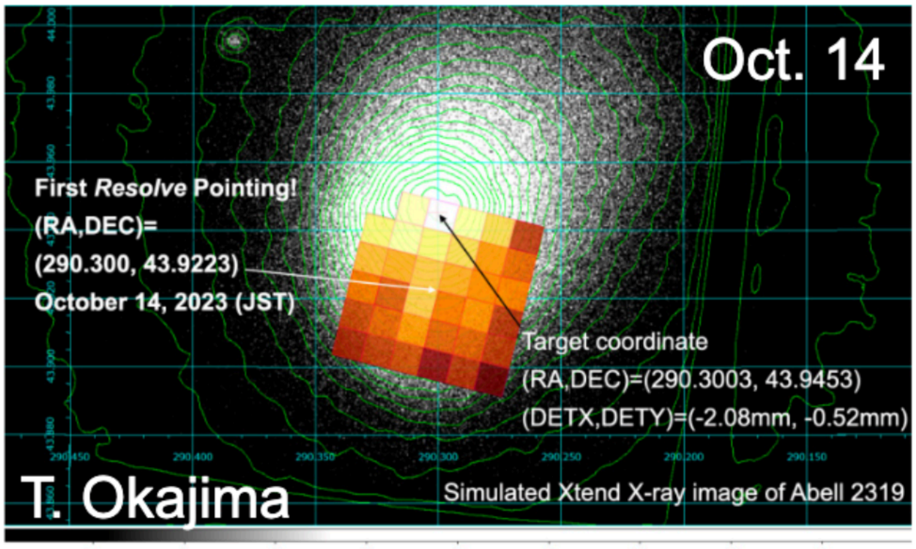
Aim Point Search I (Course)

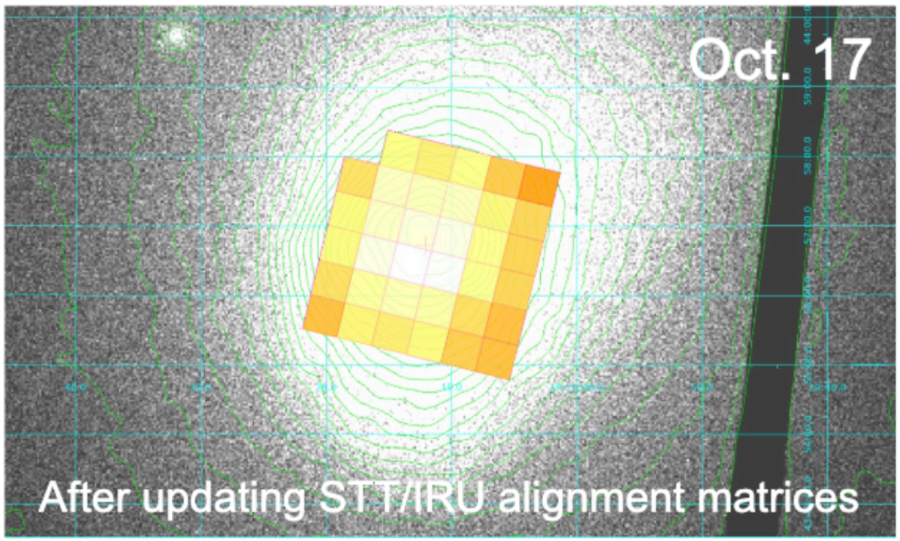
XRISM X-Ray Imaging and Spectroscopy Mission

Required accuracy is 1.5mm (55")

2023 Oct. Abel 2319

Roughly adjusting the ACS using the extended source



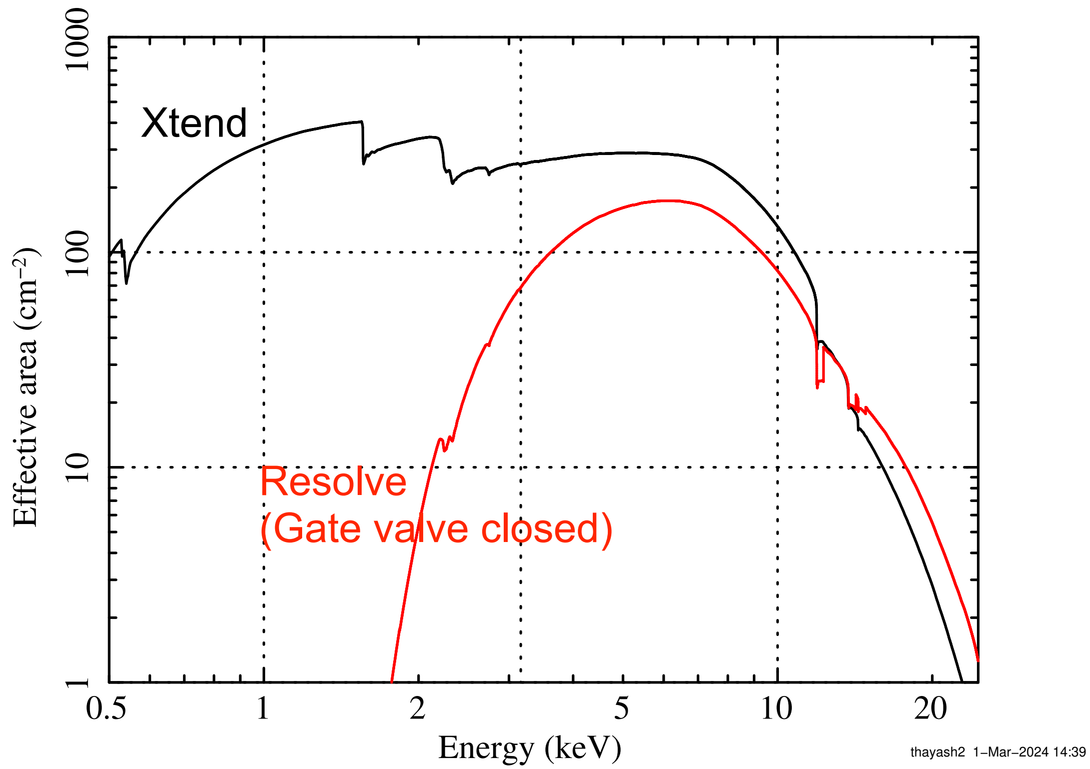


Verifying that the Able 2319 comes to the center of Resolve's field of view

On-Axis Effective Area

XRISM X-Ray Imaging and Spectroscopy Mission

On Axis effective area Calculated using CalDB (Build 7)



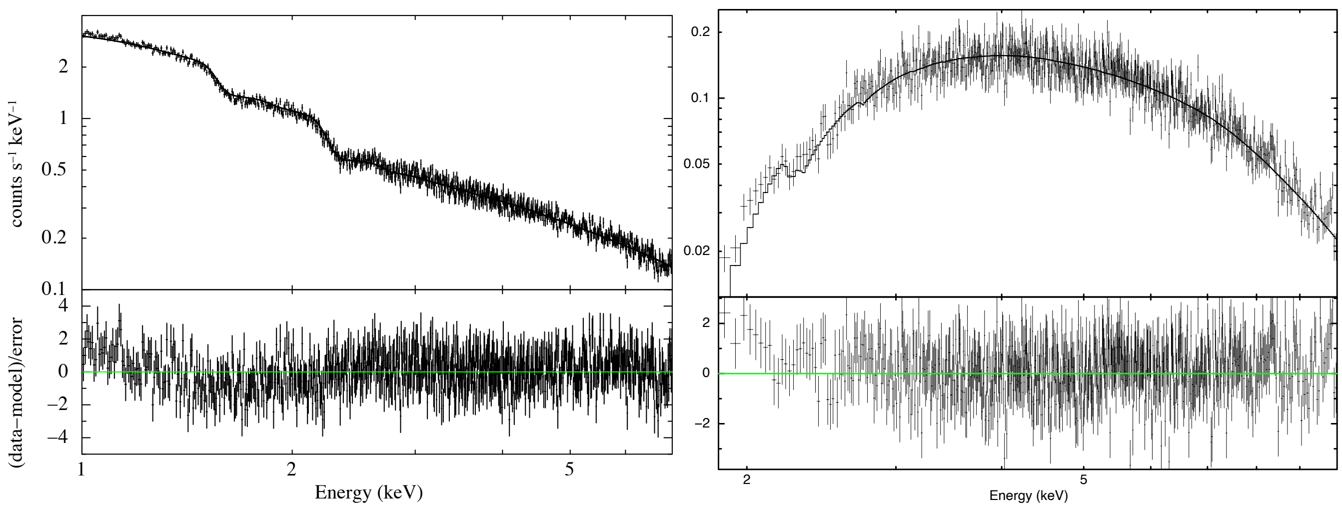
The gate valve is still not open at this time.
At energy below 1.8 keV, the effective area is not sufficient for observation.

On-Axis Effective Area

X-Ray Imaging and Spectroscopy Mission

X-ray Spectra of 3C 273

Xtend (r < 2')   Resolve (All FOV)



- Fit the spectra with the model (Power law * TBabs)(Preliminary)
- Absorption model (N_H, abundance, cross-section) are fixed to that in Madsen et al. 2015

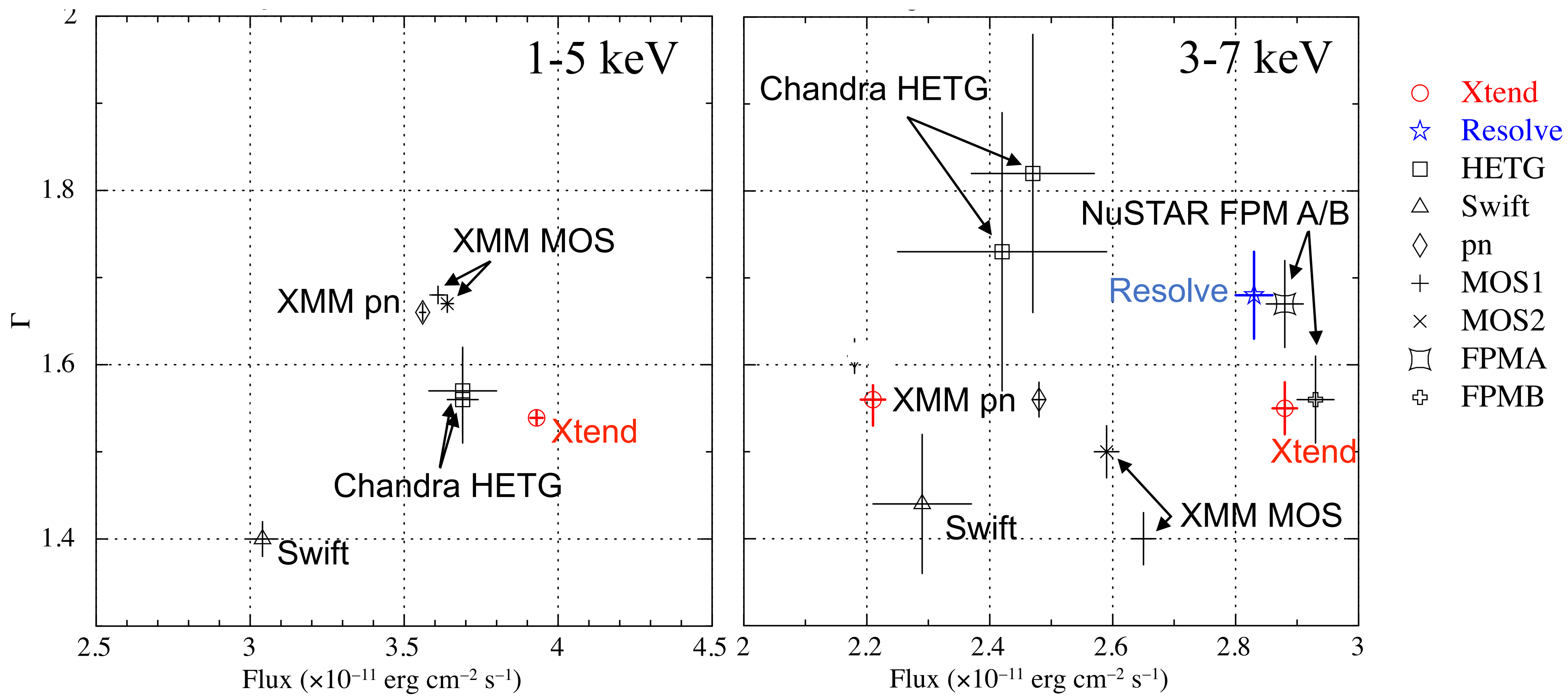
	Xtend (1-5keV)	Xtend (3-7 keV)	Resolve (3-7 keV)
Γ	1.546 ± 0.008	1.54 ± 0.02	1.68 ± 0.05
Flux [erg cm^{-2} s^{-2}]	$(4.08 \pm 0.02)\times10^{-11}$	$(2.98 \pm 0.02)\times10^{-11}$	$(2.83 \pm 0.03)\times10^{-11}$

On-Axis Effective Area

XRISM X-Ray Imaging and Spectroscopy Mission

Comparison of X-ray spectra obtained by various satellites (Preliminary)

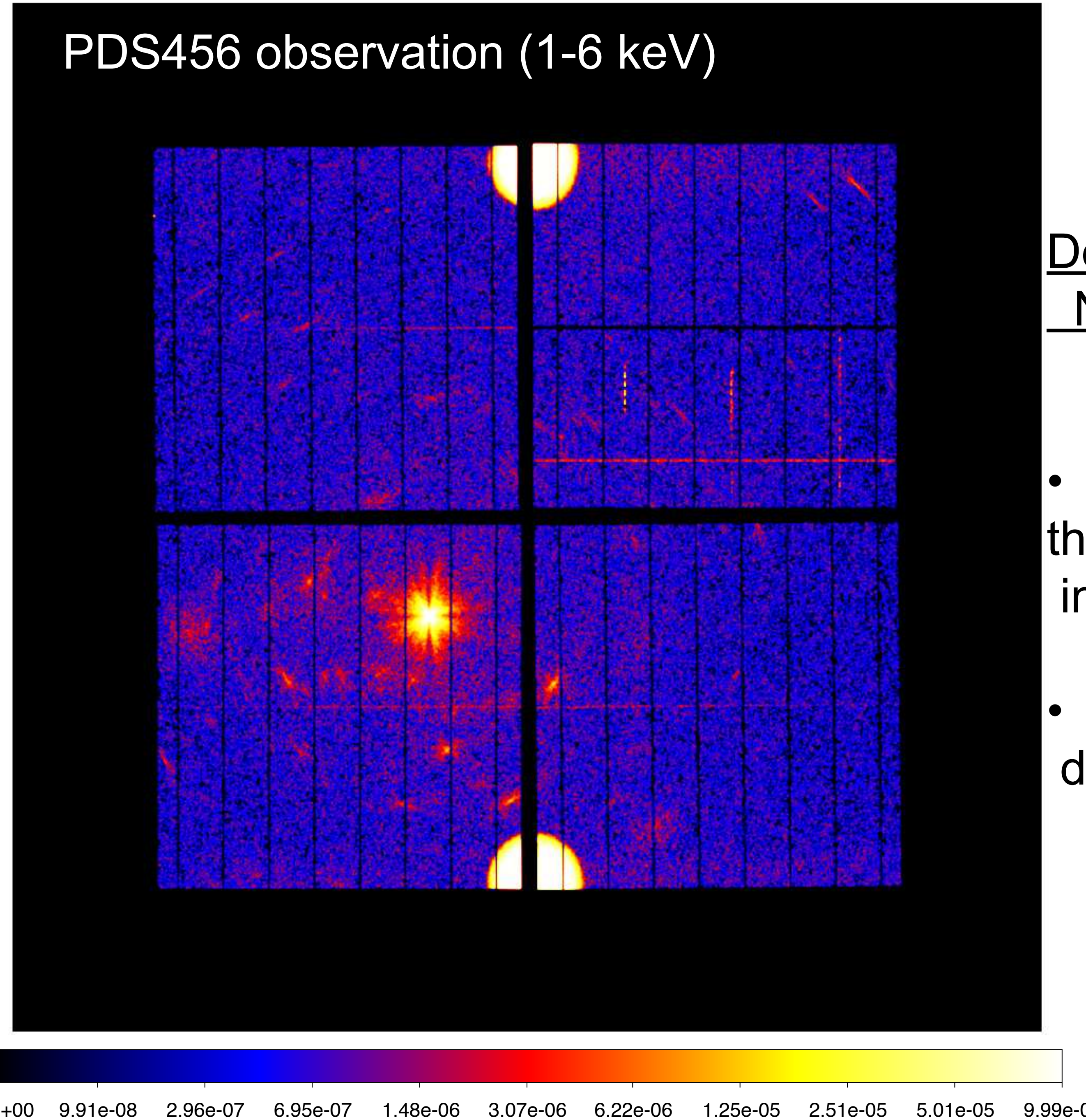
Simultaneous observation of 5 satellites



Both Xtend and Resolve Results are within the variation of the other satellite results.

Off-axis PSF (Xtend)

XRISM X-Ray Imaging and Spectroscopy Mission



<u>Dedicated observation is NOT performed or planned so far</u>

- A lot of sources around the main target (Resolve FoV) in large FoV of Xtend
- To calibrate off-axis PSF & EA dedicated observations are needed

Off-axis PSF (Resolve)

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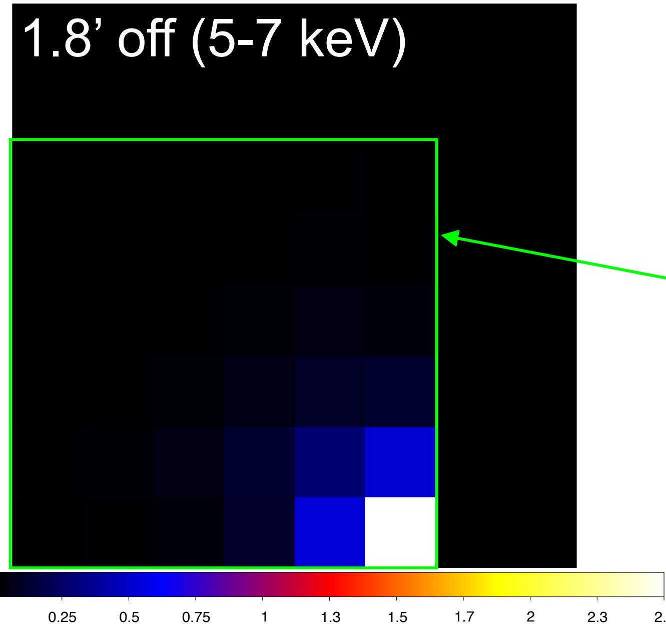
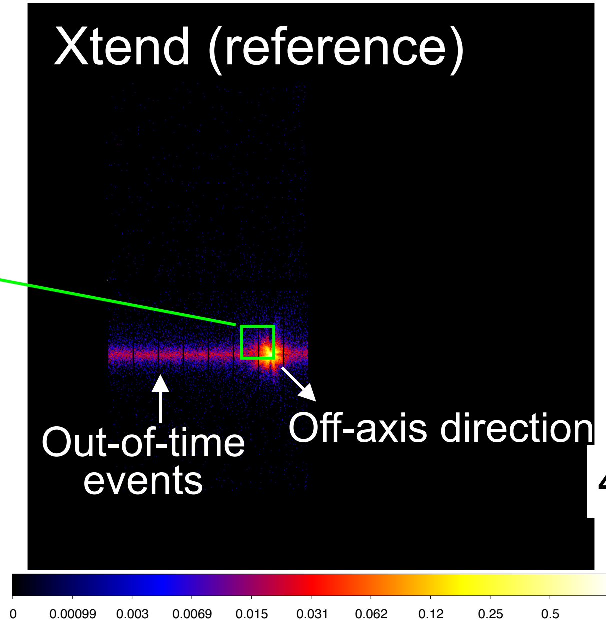
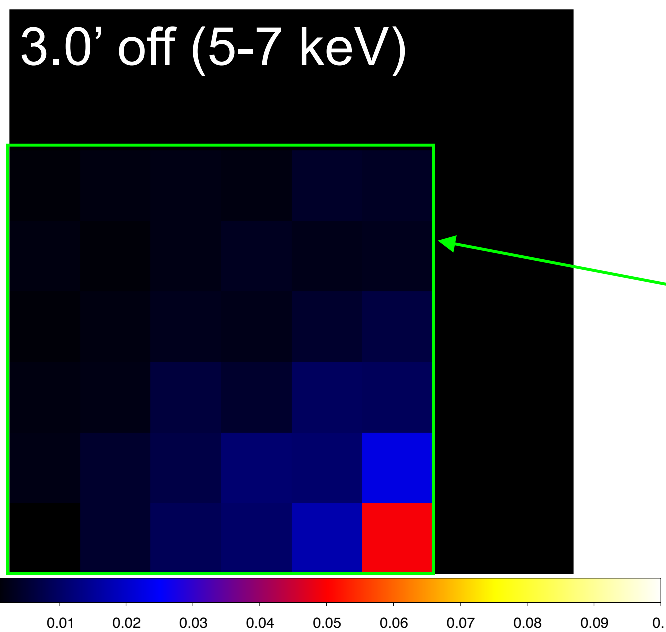
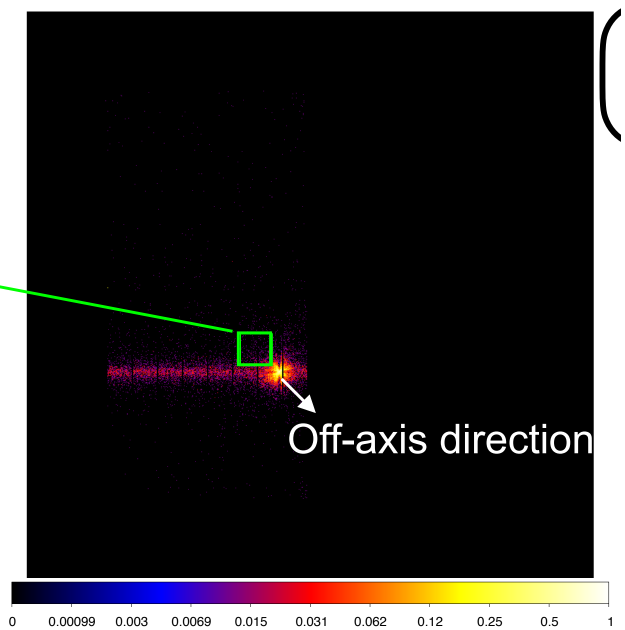
Cyg X-2 off-axis along QT center direction



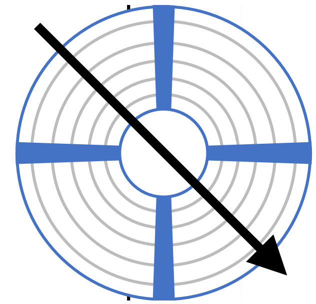






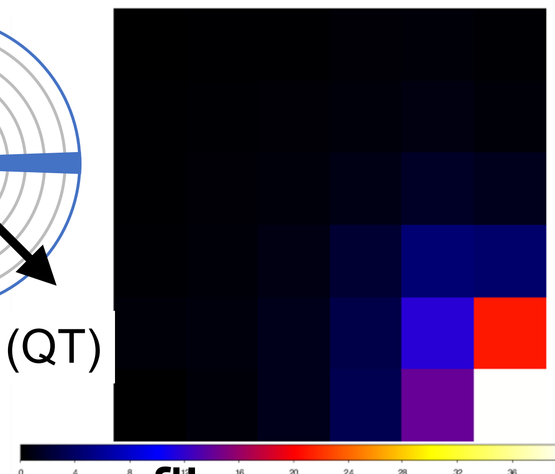
Ground calibration

XMA aperture



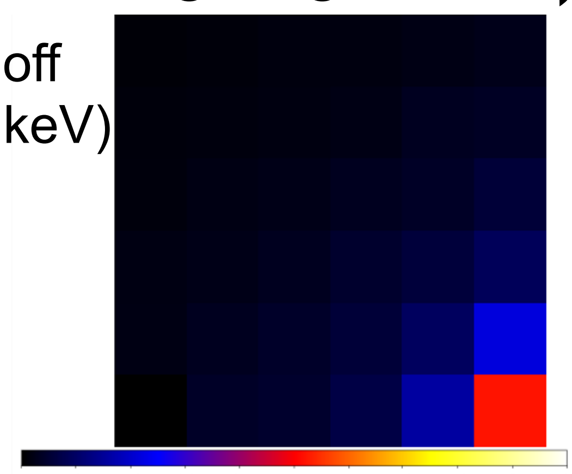
4xQuadrant (QT)

1.8’ off (6.4 keV)



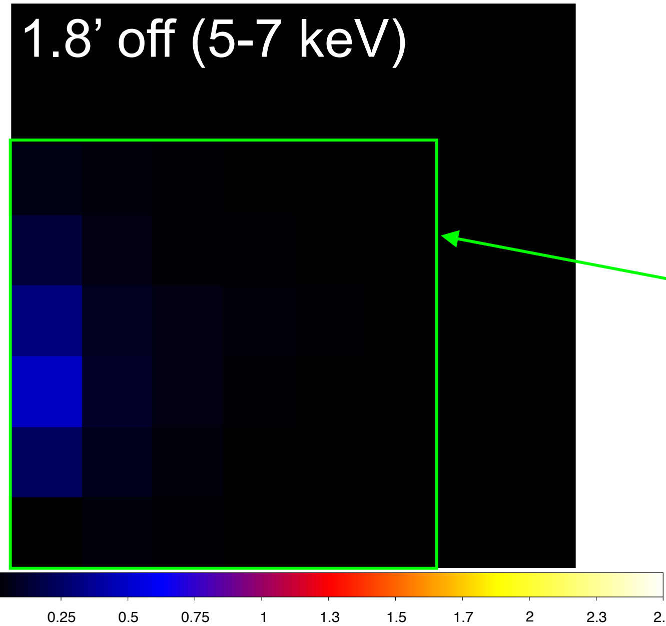
- Similar profile
  (quantitative comparisons are ongoing)

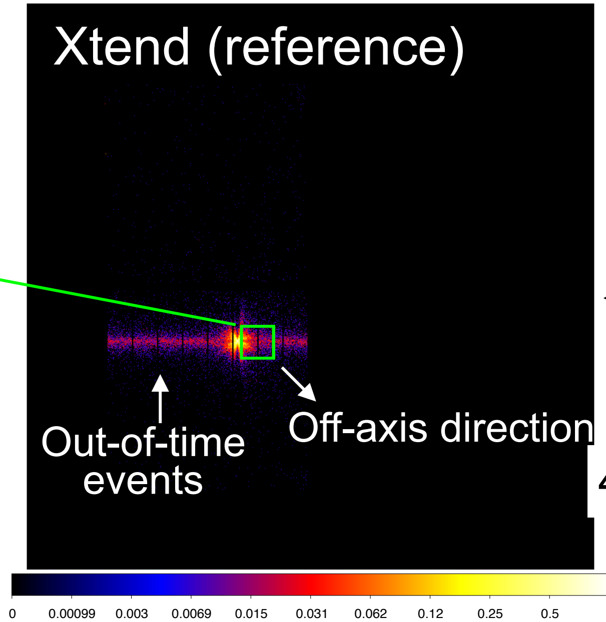
3’ off (6.4 keV)

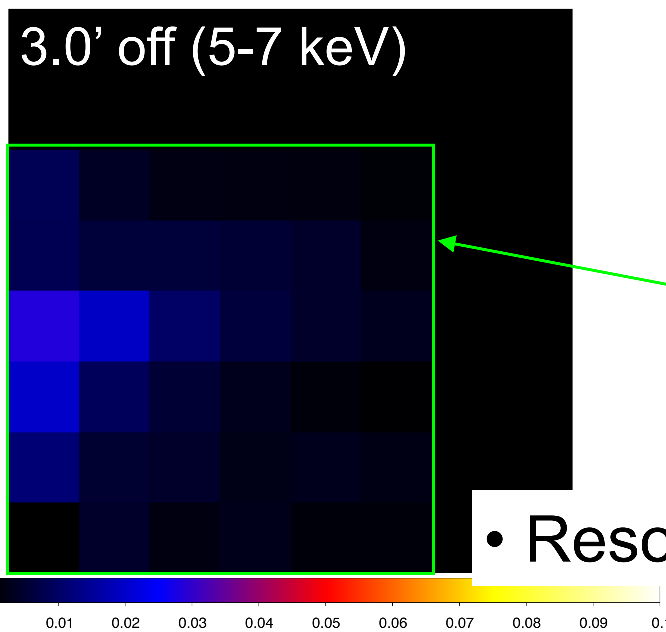


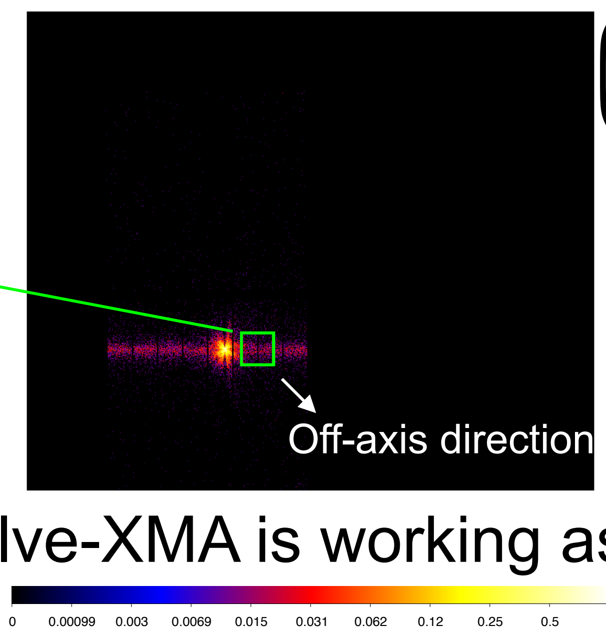
Off-axis PSF (Resolve)

Cyg X-2 off-axis along QT boundary



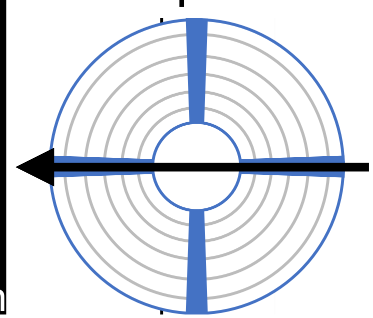


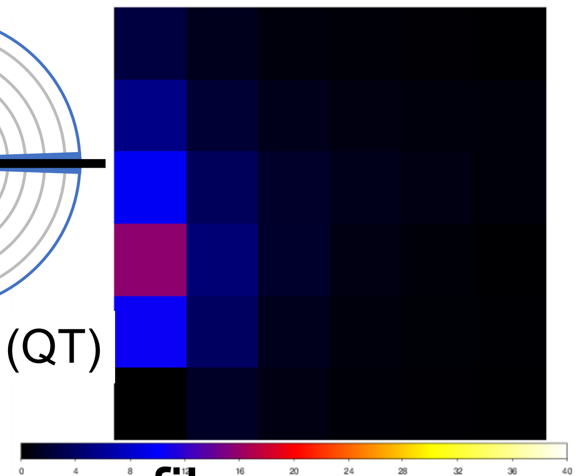




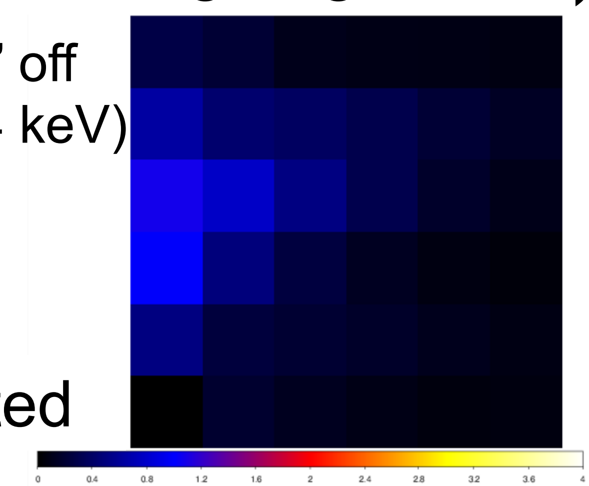
- Resolve-XMA is working as expected

Ground calibration





- Similar profile
(quantitative comparisons are ongoing)

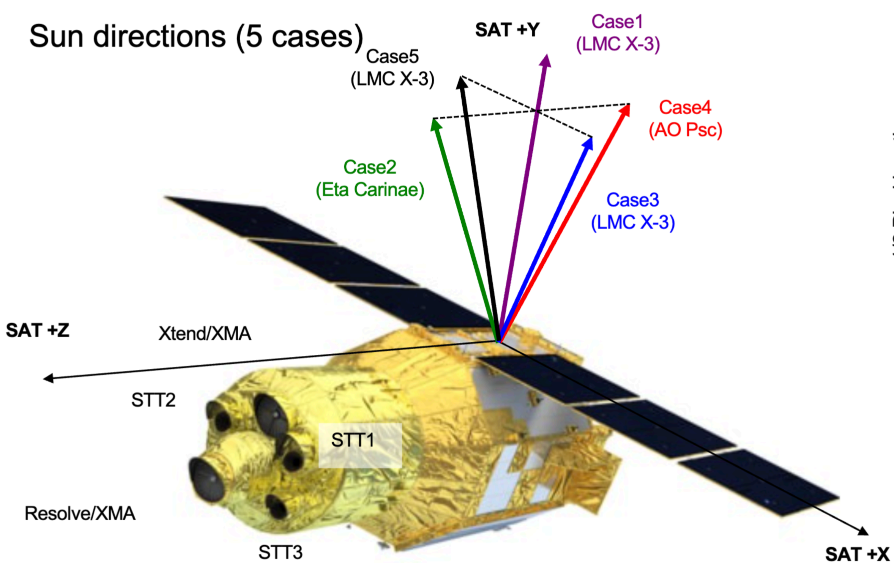


Aim Point Search

Previous talk (Kanemaru-san) for detail

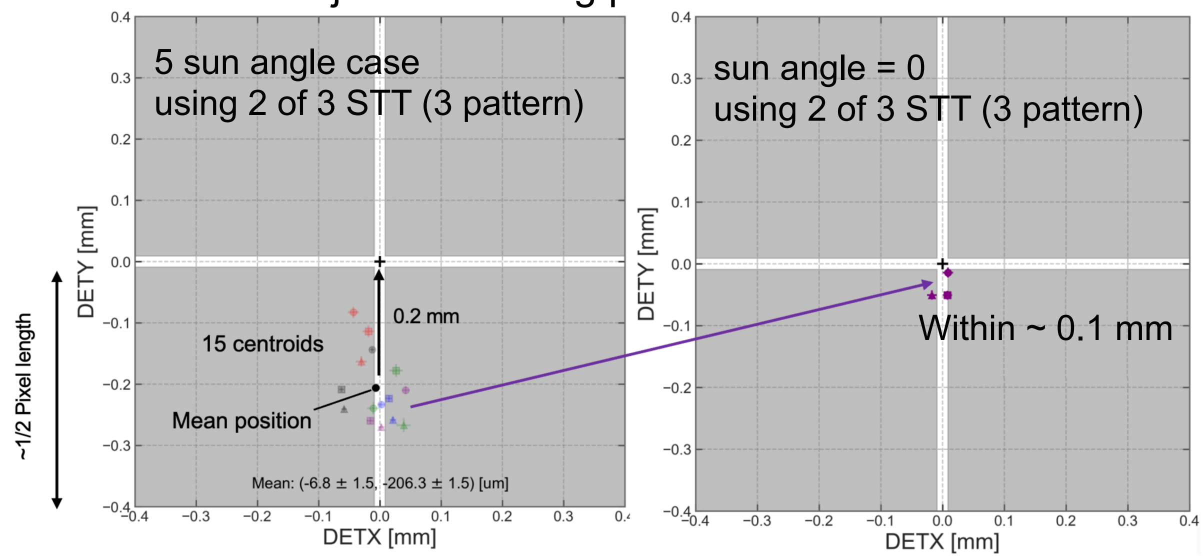
Rough alignment in 2023 Oct. (Abell 2319)

Roughly adjusting the ACS using the extended source



Fine alignment in 2023 Nov. (LMC X-3, AO Psc, η-Car)

Precise adjustment using point sources

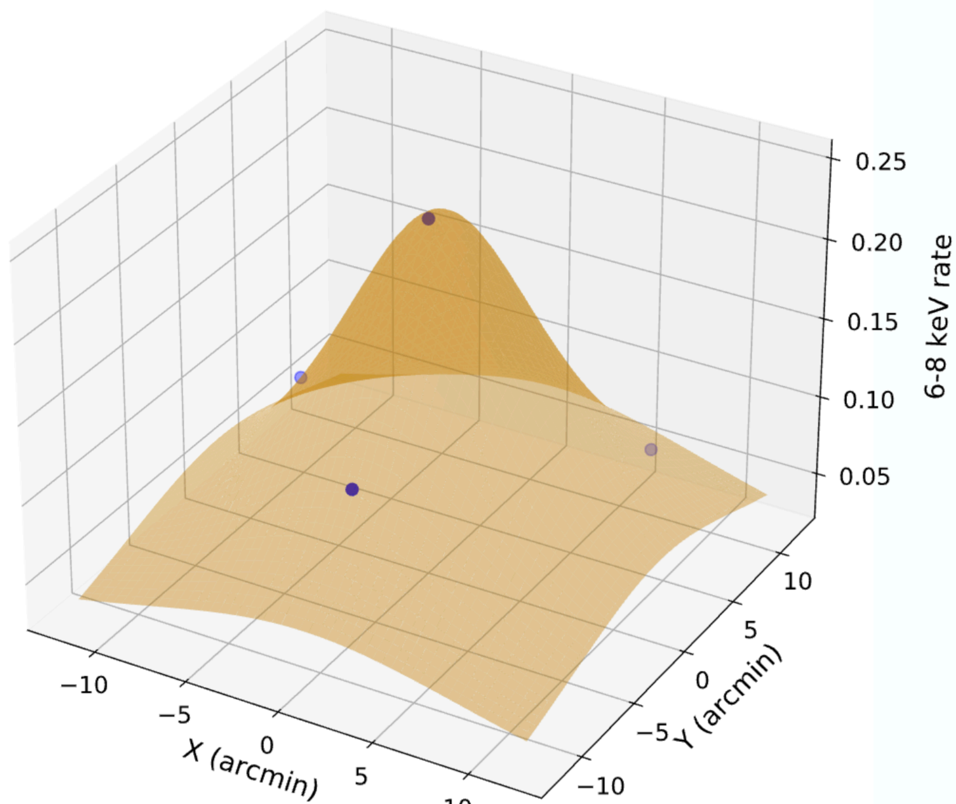


- Deviation from the center of Resolve FOV = 0.2mm (7.4”) after rough alignment

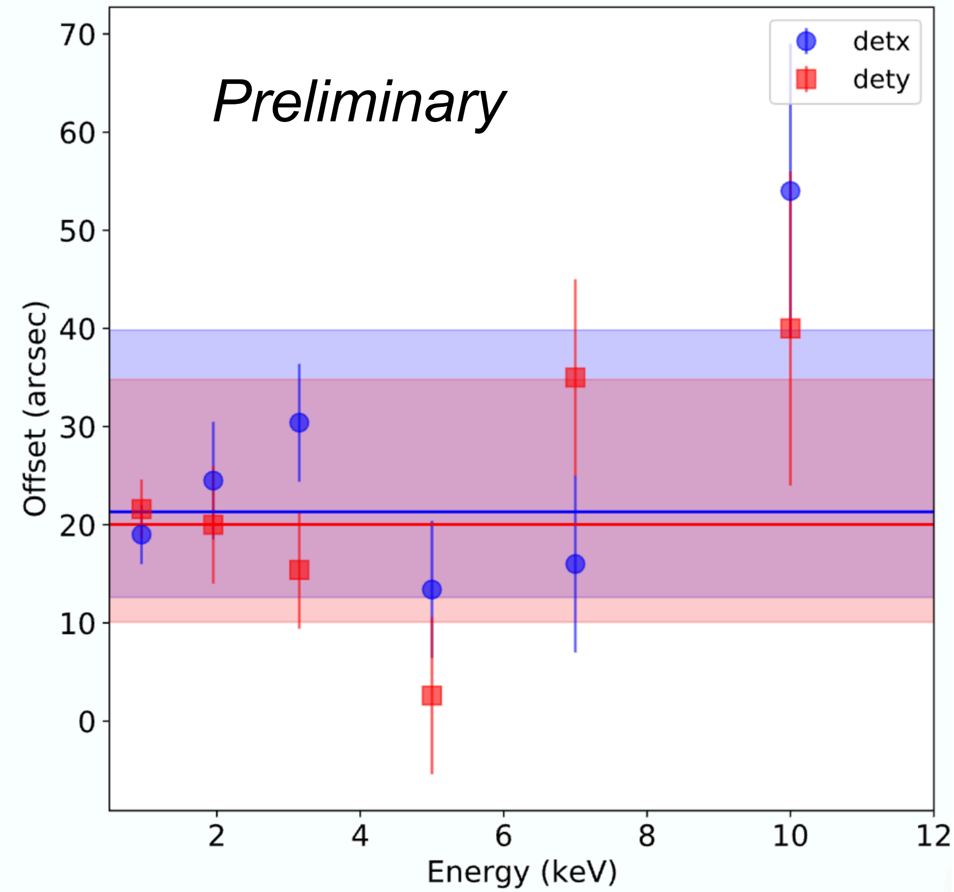
After fine Adjustment ➡ <~ 0.1 mm ~ 5” (During using STT)

Optical Axis (Xtend)

The Xtend-XMA optical axis was calculated as peak in the EA at the 4 points



2D Lorentzian fit (amplitude, width, x_off, y_off all free parameters)



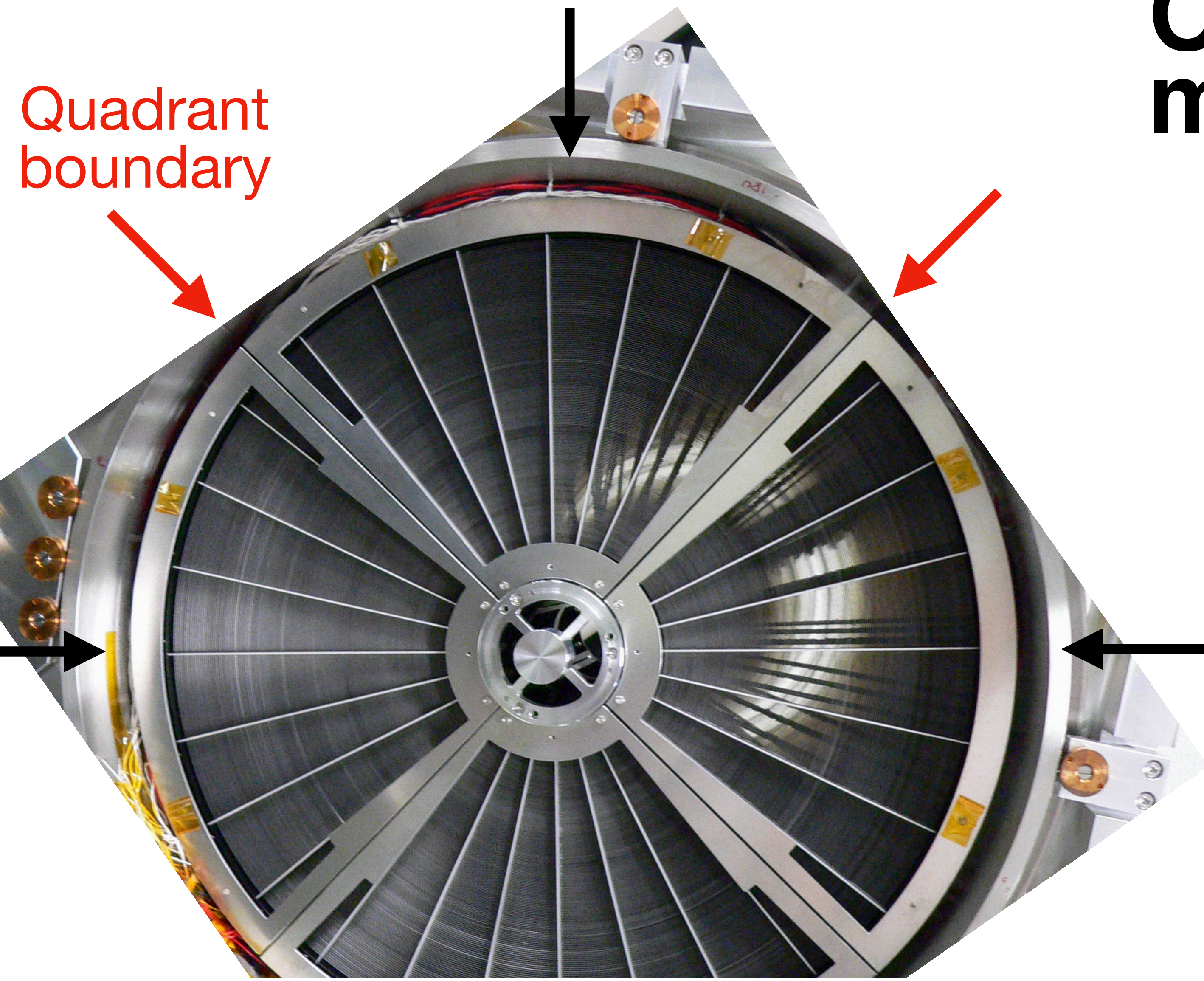
Caution: No background subtraction! Count rates estimated from 1.8' circle in SKY coordinates (based on Chandra centroid). Extended source, no raytracing (yet).

- Off-axis angle at the aim point is about 30" (A. Simionescu et al.)

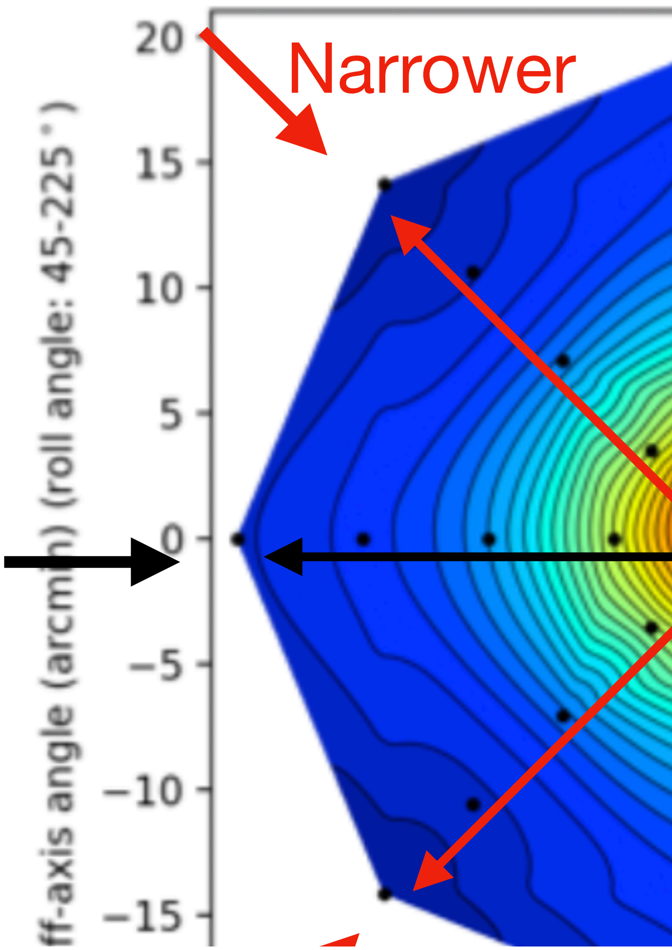
Asymmetry of vignetting

Quadrant center

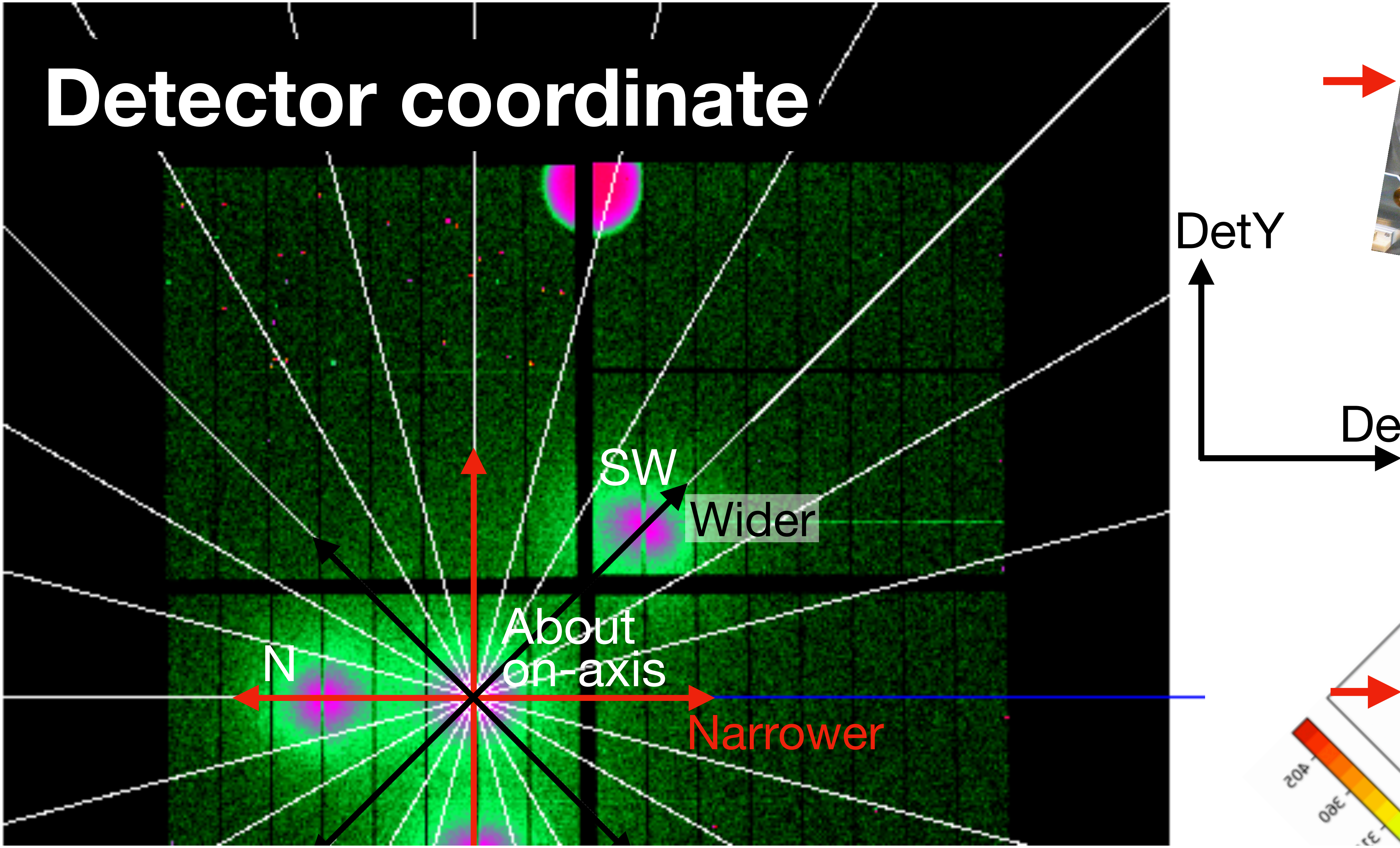
Quadrant boundary



On-ground measurement

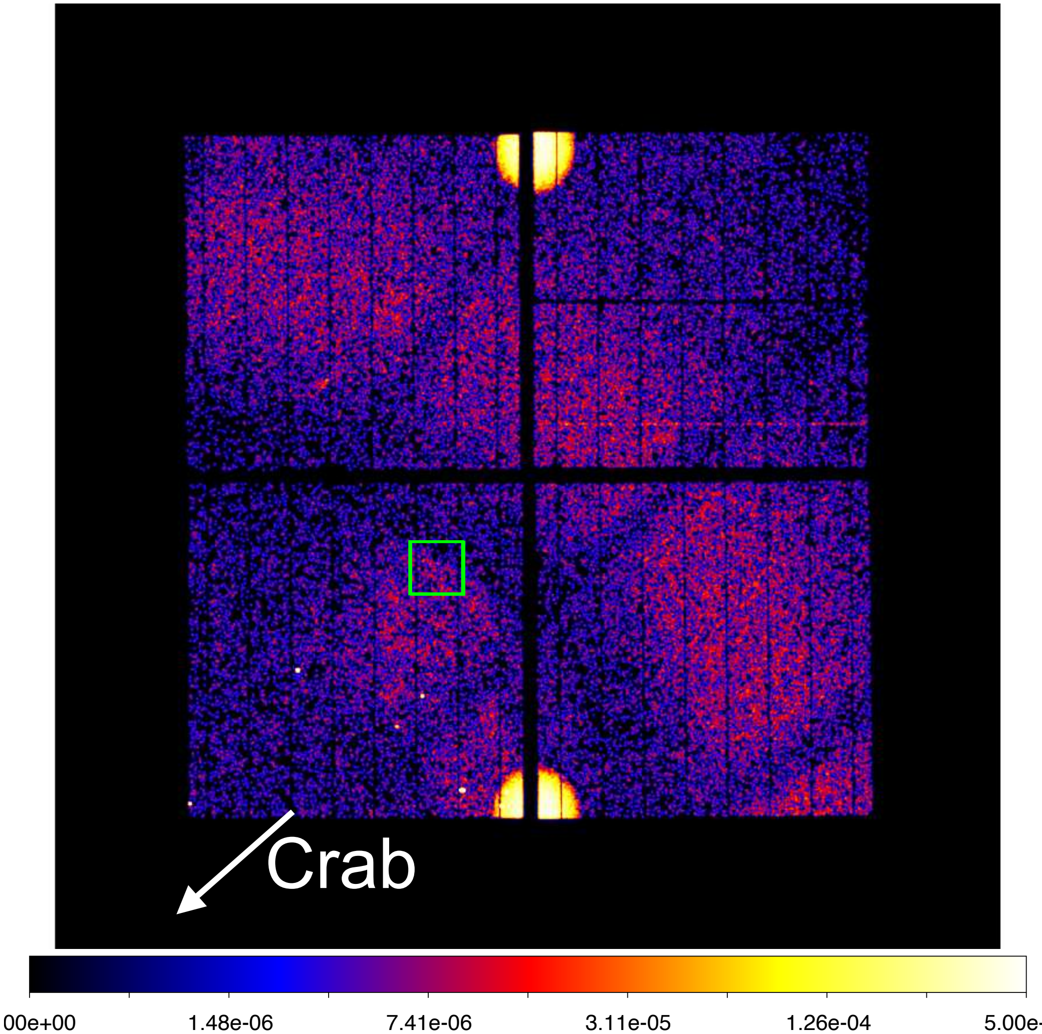


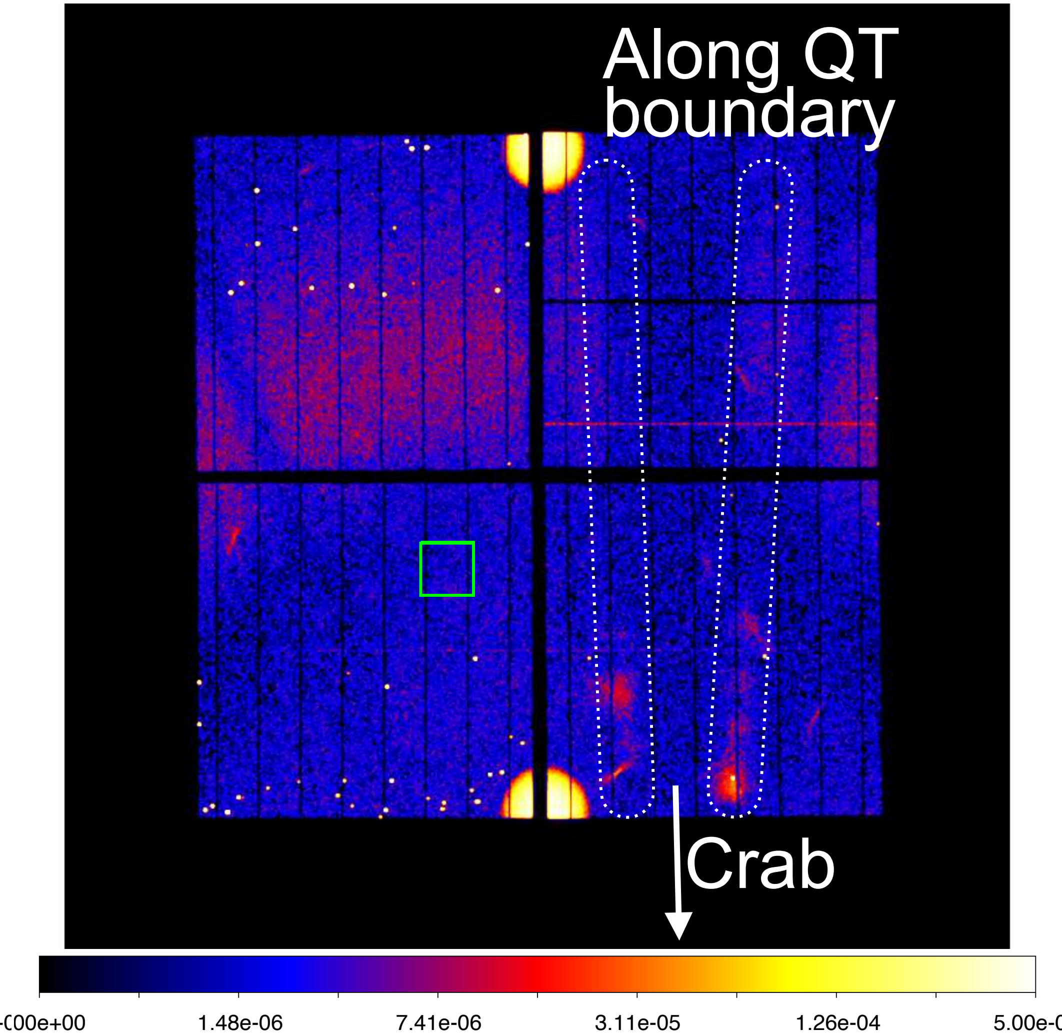
Optical Axis (Xtend)



Stray (Xtend)

<u>Crab 60'-off in two azimuthal directions</u>





- Characteristic patterns
- Structure along QT boundary
- Comparisons with ground calibration are ongoing

Stray (Resolve)

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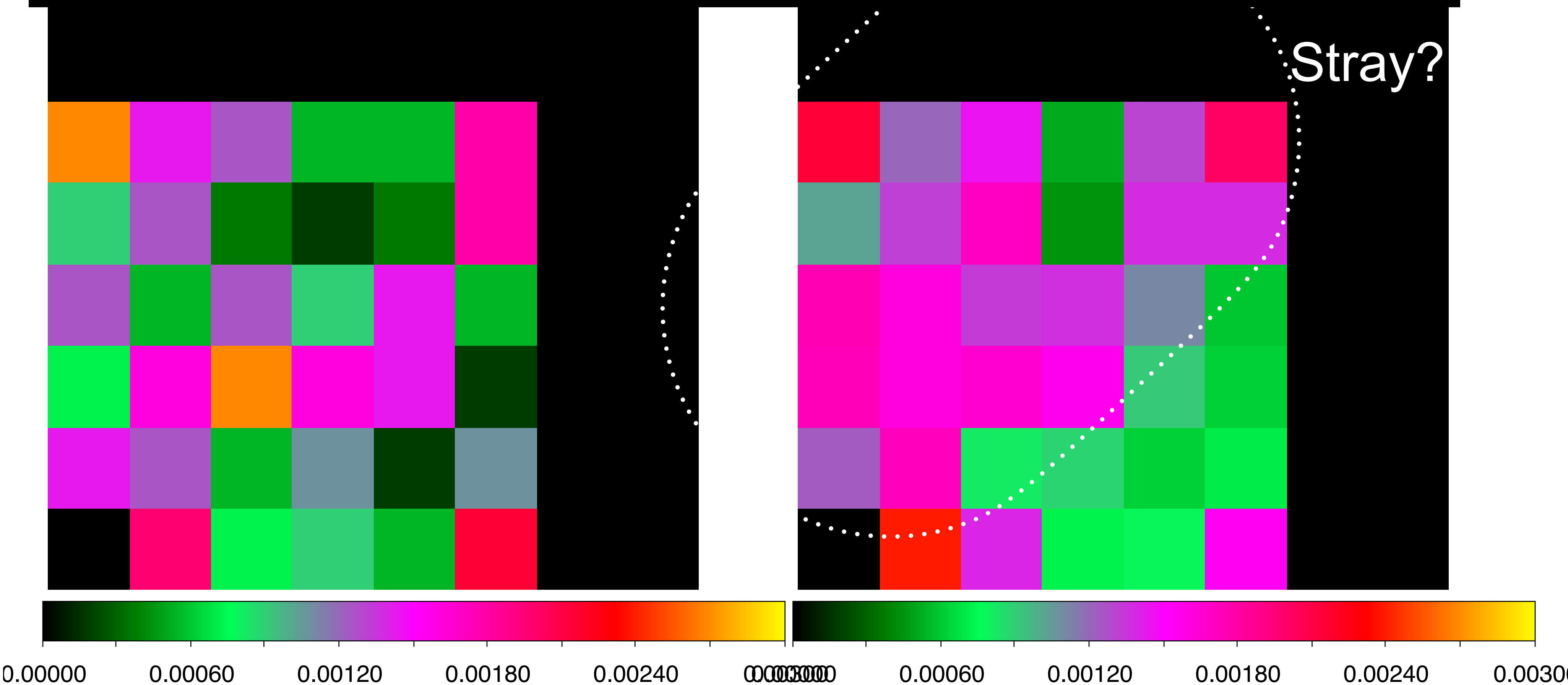
Crab 60'-off in two azimuthal directions (the same observations as the previous slide)

Note: Stray pattern can be different between Resolve and Xtend



- Hard to identify by the characteristic pattern because of Resolve's small FoV (3') and large pixel (0.5')
- Comparisons with ground calibration are ongoing