

Ground Calibration of the X-ray Mirror Assembly for the X-Ray Imaging and Spectroscopy Mission (XRISM) III - Performance variation across the aperture



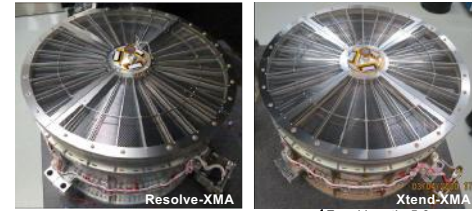
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Introduction

- X-ray Mirror Assembly (XMA)

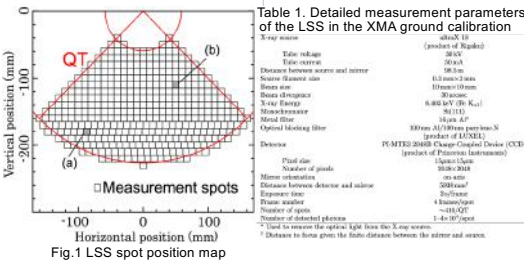
The X-ray mirror of the X-Ray Imaging and Spectroscopy Mission¹ (XRISM). The XRISM has two observational instruments: Resolve (Resolve-XMA + micro-calorimeter with non-dispersive $\Delta E = 5-7$ eV) & Xtend (Xtend-XMA + X-ray CCD with FoV = $38^\circ \times 38^\circ$). The XMA has been developed at NASA's Goddard Space Flight Center (GSFC).



- Mirror Thermal shield² (stabilizes temperature)
- Pre-collimator³ (reduces stray light)
- Mirror part (collects & focuses X-rays)
- Quadrant $\times 4$ (QTs: Q1, Q2, Q3 & Q4)
- 203 pairs of primary and secondary reflectors
- Reflector support structures $\times 7$ per reflector and plane (i.e., pri-top & -bottom, sec-top & -bottom)

- Local Spot Scan (LSS) Measurement⁶

The XMA global parameters such as effective area (EA) and Half Power Diameter (HPD) are ensembles of performances of small parts of the XMA aperture. To fully characterize the XMA, we performed an LSS by tiling 1600 snapshots with a 1 cm^2 pencil beam across the entire aperture. The local performance acquired with the LSS will be compiled into the CalDB file and enhance the CalDB accuracy.



Measurement

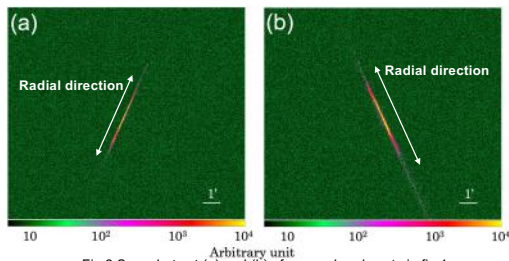
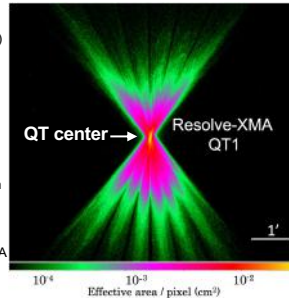


Fig.2 Snapshots at (a) and (b) of gray-colored spots in fig.1.

Each spot image radially extends (fig.2)
 All the snapshots (~410/QT) are summed up
 Total QT image is bow-tie shaped in general (fig.3)
 The node is defined as the QT center
 Used as the benchmark for each spot image position

Fig.3 Total image of Resolve-XMA taken with the LSS.



Performance maps

- Analysis

Three local performance metrics acquired the LSS:
 EA: Calculated with total number of photon per spot
 Image shift: Defined as the offset of the spot image center from the QT center
 Corresponds to local shift in the focal length
 Image profile: Quantified with the Half Power Diameter (HPD)
 Corresponds to the figure error of the reflectors

Taking the radial profiles (fig.4), the three metrics are extracted

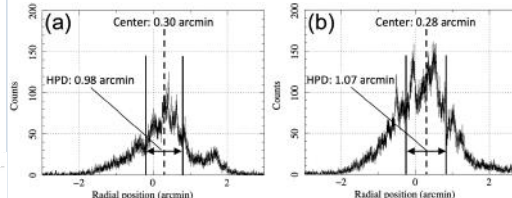


Fig.4 Radial profiles (projections) of the spot images of (a) and (b) in fig.2
 Origin of the horizontal axis corresponds to the QT center.

- Effective area map

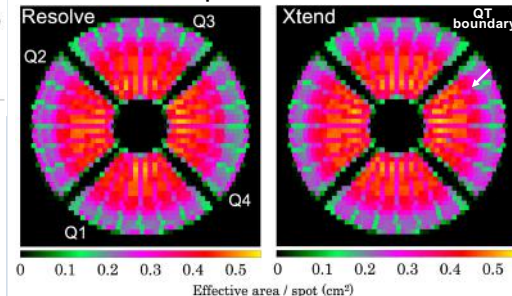


Fig.5 Apertures of Resolve- and Xtend-XMAs colored by the local EA.
 The four black radiating regions in each XMA correspond to the QT boundaries.
 - 7 Reflector support structures per QT \rightarrow Radiating darker lines (But two end ones are not clear)
 - All the QTs are very similar to each other
 - Inner most local EA $\sim 0.5\text{ cm}^2$ vs Outer most local EA $\sim 0.25\text{ cm}^2$
 Inner most reflectors: Incident angle ~ 0.15 deg \rightarrow reflectivity $\sim 93\%$
 Outer most reflectors: Incident angle ~ 0.57 deg \rightarrow reflectivity $\sim 65\%$ (Assuming: micro-roughness = 7Å)
 Considering the double reflection, $0.93^2 \cdot 0.65^2 = 0.86 : 0.42 \sim 2 : 1$
 \rightarrow explains the difference in EA between the innermost and outermost regions
 Note: geometrical efficiency (i.e., the fraction of the reflective) is better for outer reflectors but the difference is $\sim 10\%$

- Image shift map

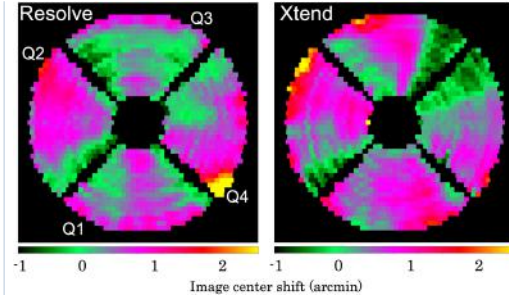


Fig.6 The same maps as fig.5 except for being colored by the image shift.

- Quite different per QT
- Entirely tends to be positive
 \rightarrow With our definition of "+" and "-", local EA entirely longer than design
 1' image shift $\rightarrow \sim 150\text{ mm}$ and $\sim 40\text{ mm}$ difference in the FL at the innermost and outermost reflectors, respectively
- Several alignment structures split the image shift (e.g., obvious in Q3 of Xtend)
 \rightarrow alignment of alignment structures significantly affect the reflector alignment but no obvious correlation with the local EA (cf. fig.5)

- HPD map

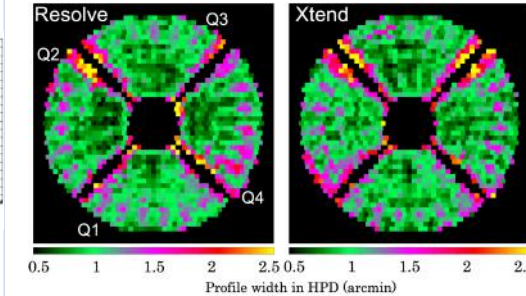


Fig.7 The same maps as fig.5 except for being colored by the HPD.

- Similar across all the QT in contrast to the image shift
- Better in inner region than in outer region
 \rightarrow Conical approximation: better in inner region $\sim 0.15^\circ$ than in outer region $\sim 0.4^\circ$
- Figure error: better in inner region $\sim 0.4''-0.5''$ than in outer region $\sim 0.6''-0.7''$, considering the double reflection
- Correlates with the alignment structures in certain radial range
 \rightarrow the alignment structures somewhat affect the figure error but not major

Summary

- The local spot scan (LSS) revealed detailed local performance of Resolve- and Xtend-XMAs of XRISM satellite
- Local EA Map is very similar across all the QTs
 Different between inner and outer reflectors by a factor of 2, which is explained by the X-ray reflectivity at shallower incident angles
- Local image shift Map is quite different per QT
 Determined by the reflector alignment structures
 Shows the local FL is entirely longer than the design
- Local image profile Map is similar across all the QTs
 Narrower (better in HPD) in inner reflectors than outer ones because the conical approximation and figure error are better in inner reflectors

REFERENCES

1. Tashiro et al. SPIE (2018)
2. Tawara et al. SPIE (2011)
3. Mori et al. SPIE (2012)
4. Boissay-Malaquin et al. SPIE (2022)
5. Tamura et al. SPIE (2022)
6. Sato et al. SPIE (2014)