

The PANTER Long Beam X-ray Test Facility

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X-ray **DE**tector Technologies for **P**hysics (XDEP)

Overview

- PANTER X-ray test facility
 - Overview
 - Detectors
- Optics & Telescope Testing at PANTER
 - X-ray Optic
 - SVOM
 - Einstein Probe
 - IAXO
- Summary

A Brief PANTER History

PANTER was built to better understand the physical properties (shape, microroughness) of X-ray optics and develop metrology and analysis methods for optimising them.

1977 A 20 m facility was setup for rocket experiments and **EXOSAT**

1982 The 120 m X-ray beamline was setup in preparation for the **ROSAT** mission

1985 A large Instrument chamber and clean room added to the beamline for **ROSAT** and **SAX**

1991 Testing of **SOHO/CDS**

1994 Instrument Chamber enlarged to a length of 12 m for **XMM-Newton** Mirrors, CCD detector, grating development and calibration, also for the **AXAF (Chandra)** LETG

2001 CAST Axion telescope at CERN based on an **ABRIXAS MM**

2002 Calibration and „end to end test“ of the **SWIFT** X-ray telescope

2007 Beginning of **eROSITA** Mirror development

2012-... X-ray beamline extended by 13 m to allow $f=20\text{m}$ **IXO** type Silicon Pore optics

and Slumped Glass Optics to be measured in focus $\rightarrow f=12\text{ m}$... **ATHENA** type optics now for **newATHENA**

2012-2015 Acceptance and Calibration of the **eROSITA** X-ray 8 Mirror Modules

2015-2022 Testing and Calibration of the **SVOM** Optic and Telescope

2019-2022 Testing and Calibration of the **Einstein-Probe FXT and WXT** X-ray Mirror Modules

2023 OGRE rocket experiment testing OPG gratings and JET-X + PSO optics

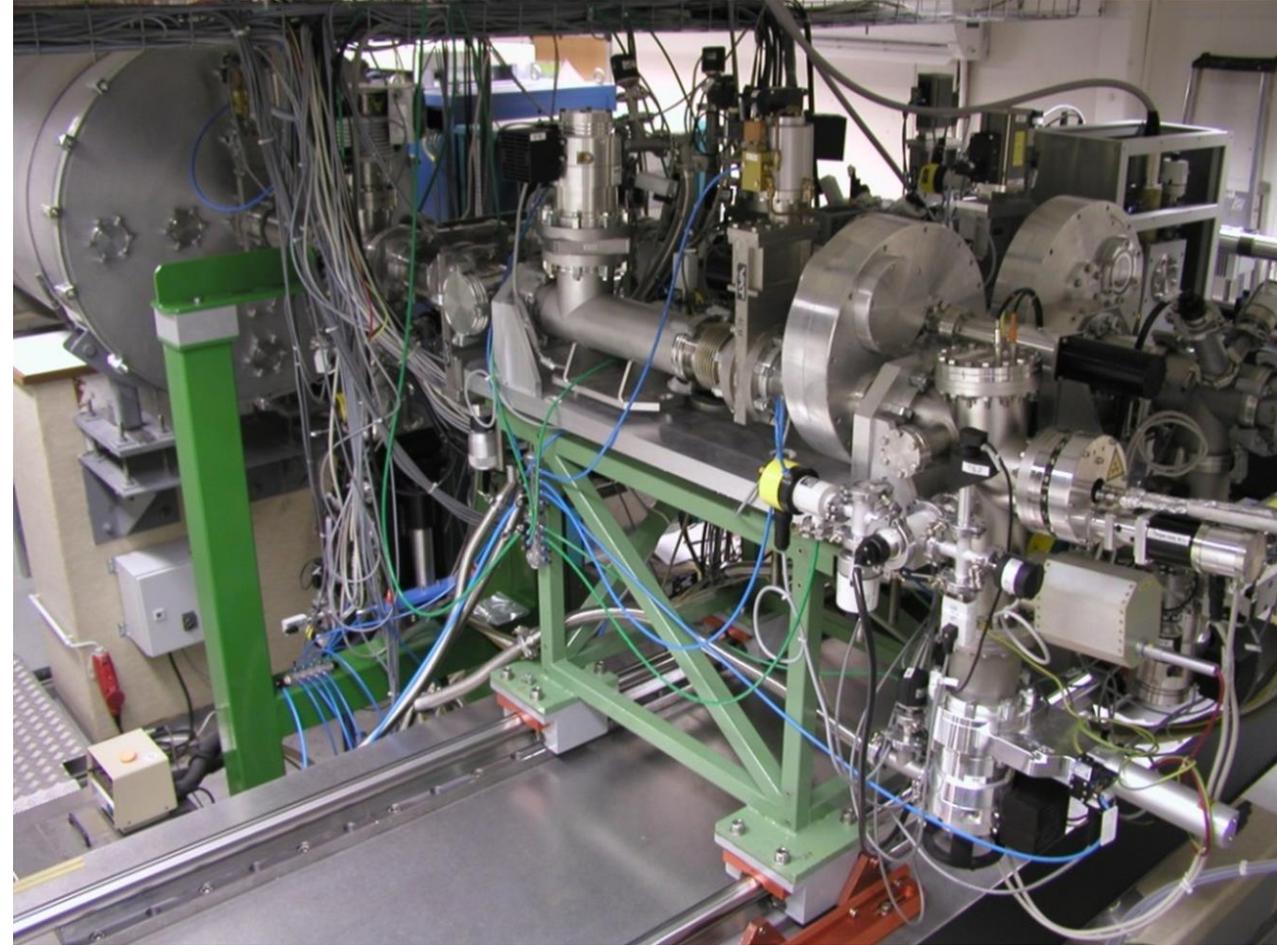
The MPE PANTER X-Ray Test Facility

- Located in Neuried, south west of Munich
- 120 m X-ray beamline, 1 m diameter
- 12 m instrument chamber, 3.5 m diameter
- Large cleanroom for handling X-ray optics
- Movable 10 m extension with 0.25 m diameter and a 3 m instrument chamber, 1.2 m diameter
→ for focal lengths up to $f = 20$ m



The MPE PANTER X-ray Sources

- Standard Energies
→ B-K (0.18 keV) through Ge-K β (11.0 keV)
- Homogeneous Beam → up to 1m diameter
- Source size → 200 – 300 μm
- Filters available to reduce continuum around characteristic lines
- Open Multi target electron impact source
- Seifert closed X-ray source (< 40 keV)
- X-ray Monochromators
 - Double Crystal (polarised)
 - Reflection Grating



The MPE PANTER X-ray Sources

TRoPIC : Single photon counting

CCD camera

256 x 256 pixels

75 μ m x 75 μ m pixels

f.o.v. 19.2 mm x 19.2 mm

PIXI : Integrating pnCCD Camera

1300 x1340

20 μ m x 20 μ m pixels

f.o.v. 26.0 mm x 26.8 mm

New PANTER eROSITA/EP type camera:

Single photon counting pnCCD

384 x 384 pixels

75 μ m x 75 μ m pixels

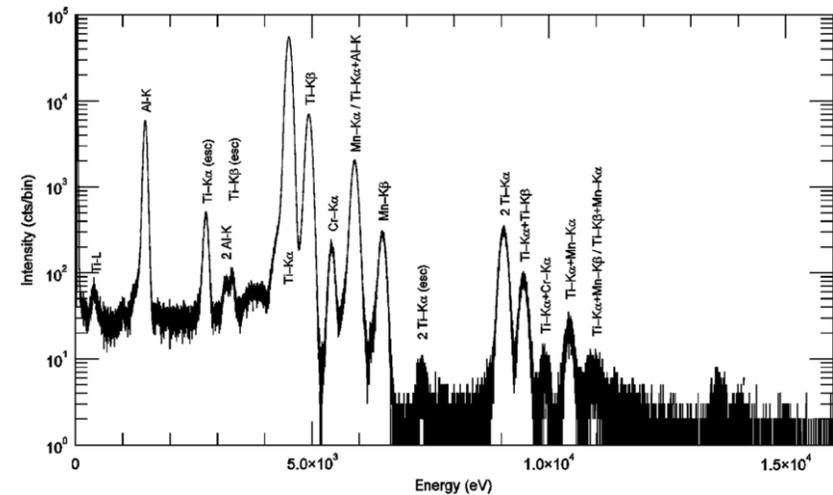
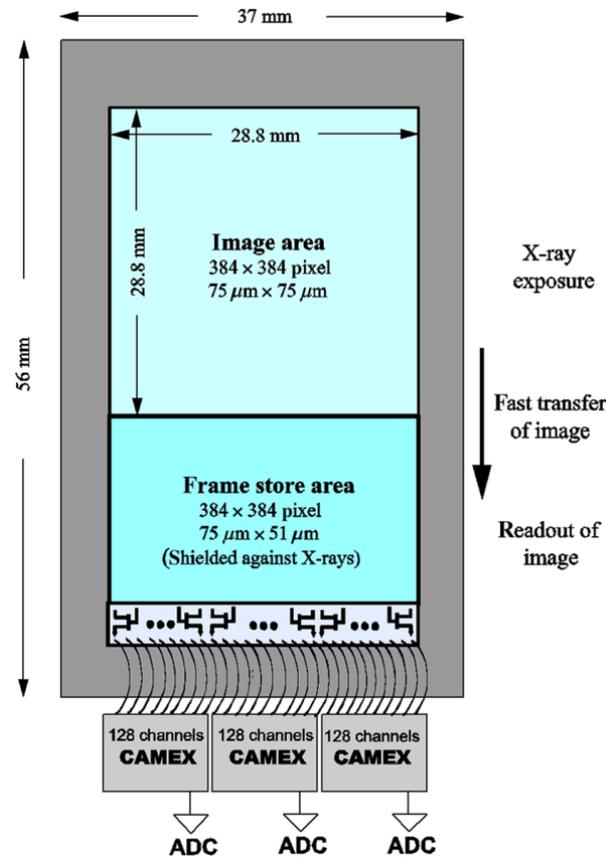
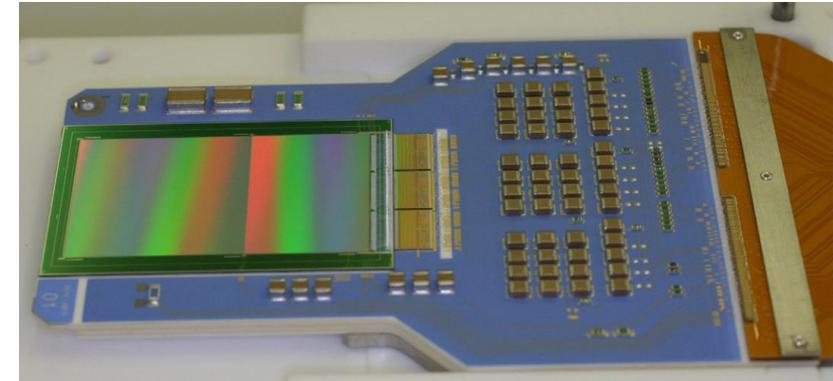
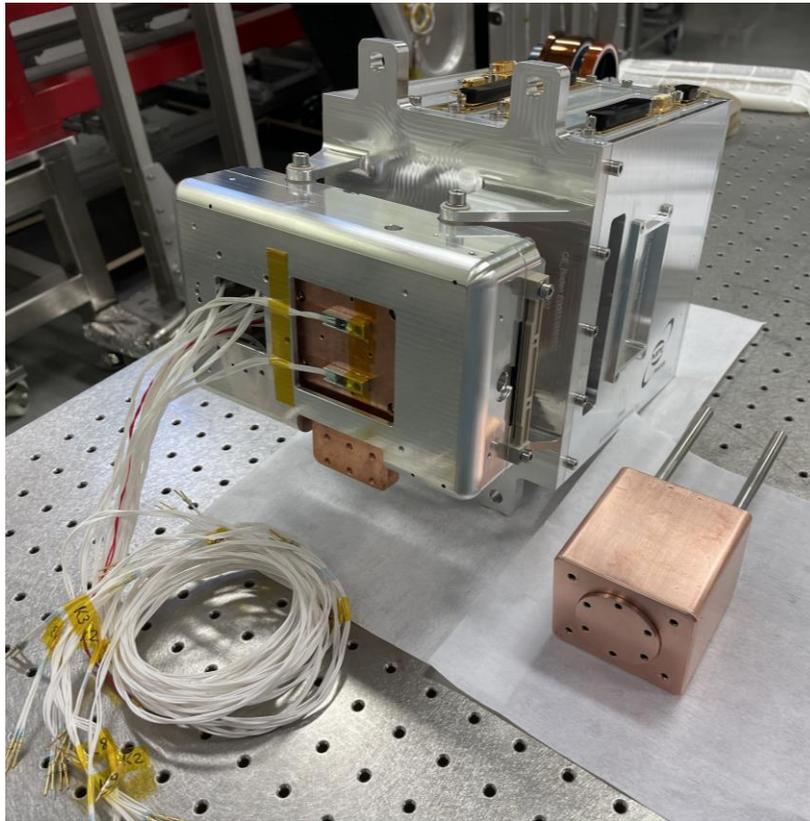
f.o.v. 28.8 mm x 28.8 mm

Monitor counter :

Amptek XR-100 SDD



The new MPE PANTER eROSITA type Detector



Camera housing prepared for a thermal Test before integration of the pnCCD.

The eROSITA Detector ground calibration results

Energy resolution

Spectral line energy	TM1 FWHM (eV)	TM2 FWHM (eV)	TM3 FWHM (eV)	TM4 FWHM (eV)
C-K: 277 eV	58.2 ± 0.3	57.8 ± 0.3	57.7 ± 0.4	57.8 ± 0.3
O-K: 525 eV	63.9 ± 0.2	65.2 ± 0.3	65.7 ± 0.3	63.5 ± 0.2
Cu-L: 930 eV	70.0 ± 0.3	74.0 ± 0.3	72.3 ± 0.3	69.8 ± 0.3
Al-K: 1.49 keV	77.4 ± 0.3	81.8 ± 0.3	80.0 ± 0.3	77.0 ± 0.3
Ti-K α : 4.51 keV	118.2 ± 0.5	125.1 ± 0.6	122.1 ± 0.6	118.2 ± 0.6
Fe-K α : 6.40 keV	137.9 ± 0.6	145.4 ± 0.7	142.0 ± 0.7	137.8 ± 0.6
Cu-K α : 8.04 keV	158.3 ± 0.7	166.6 ± 0.7	163.1 ± 0.7	158.5 ± 0.7
Ge-K α : 9.89 keV	177.5 ± 1.0	181.0 ± 1.0	182.0 ± 1.1	173.4 ± 1.1

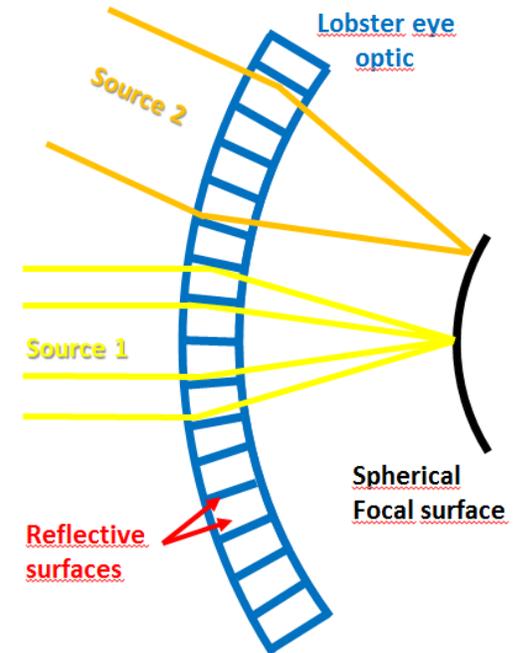
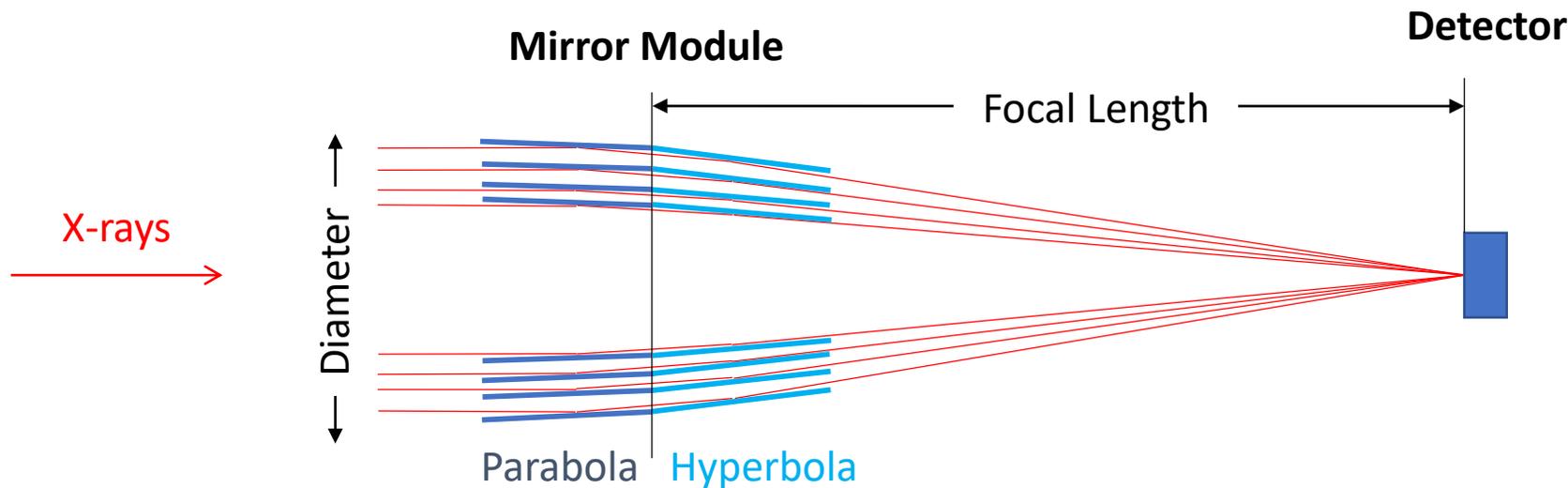
QE with 200 nm Al on chip Filter

Spectral line energy	QE TM1 to TM4, TM6 (%)
C-K: 277 eV	12.4
O-K: 525 eV	42.2
Cu-L: 930 eV	80.0
Al-K: 1.49 keV	94.0
Ti-K α : 4.51 keV	97.9
Fe-K α : 6.40 keV	98.9
Cu-K α : 8.04 keV	99.3
Ge-K α : 9.89 keV	96.9

Meidinger et al., 2021 JATIS DOI:10.1117/1.JATIS.7.2.025004

X-ray Telescope Mirrors: how they work

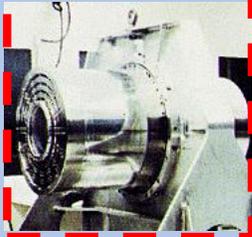
- X-rays are reflected at grazing incidence angles
- Surfaces have to be superpolished rms < 0.5 nm
- Nested Mirrors → larger collecting area



X-ray Telescope Mirrors

*Glas-
Zerodur*

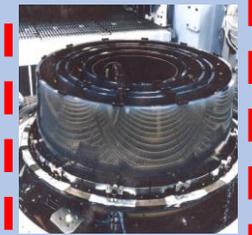
Einstein



ROSAT



Chandra

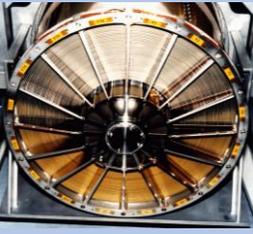


Electroformed Nickel

BeppoSax



XMM/IA XO



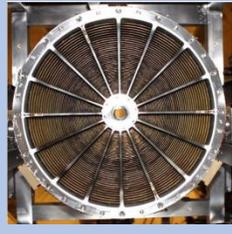
Jet-X/Swift



NICER



**CAST /
eROSITA / EP**



ART-XC

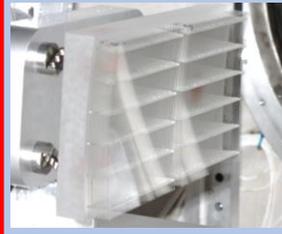


Slumped Glass

NuStar

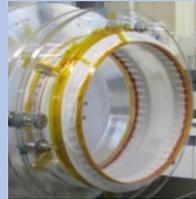


„IXO“ / IA XO



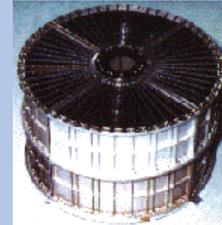
Thin Glass Shells

WFXT / Lynx



Coated Foils

ASCA



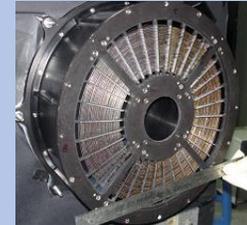
Hitomi/XRISM



Suzaku

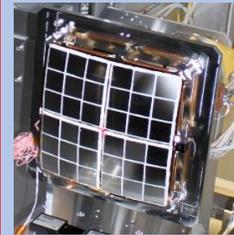


AstroSat

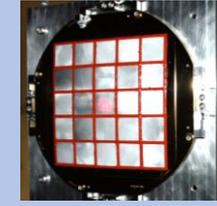


Micropore /Lobster Eye

LEIA/EP-WXT

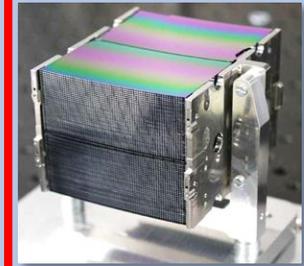


**SVOM / SMILE
LEXI / THESEUS**



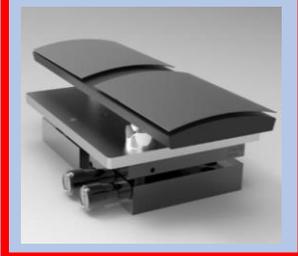
*Silicon
Pore optics*

Athena/Arcus



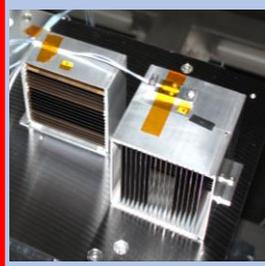
*Polished
Silicon optics*

Star-X / Lynx



*Kirk Patrick
Baez optics*

Cubesats

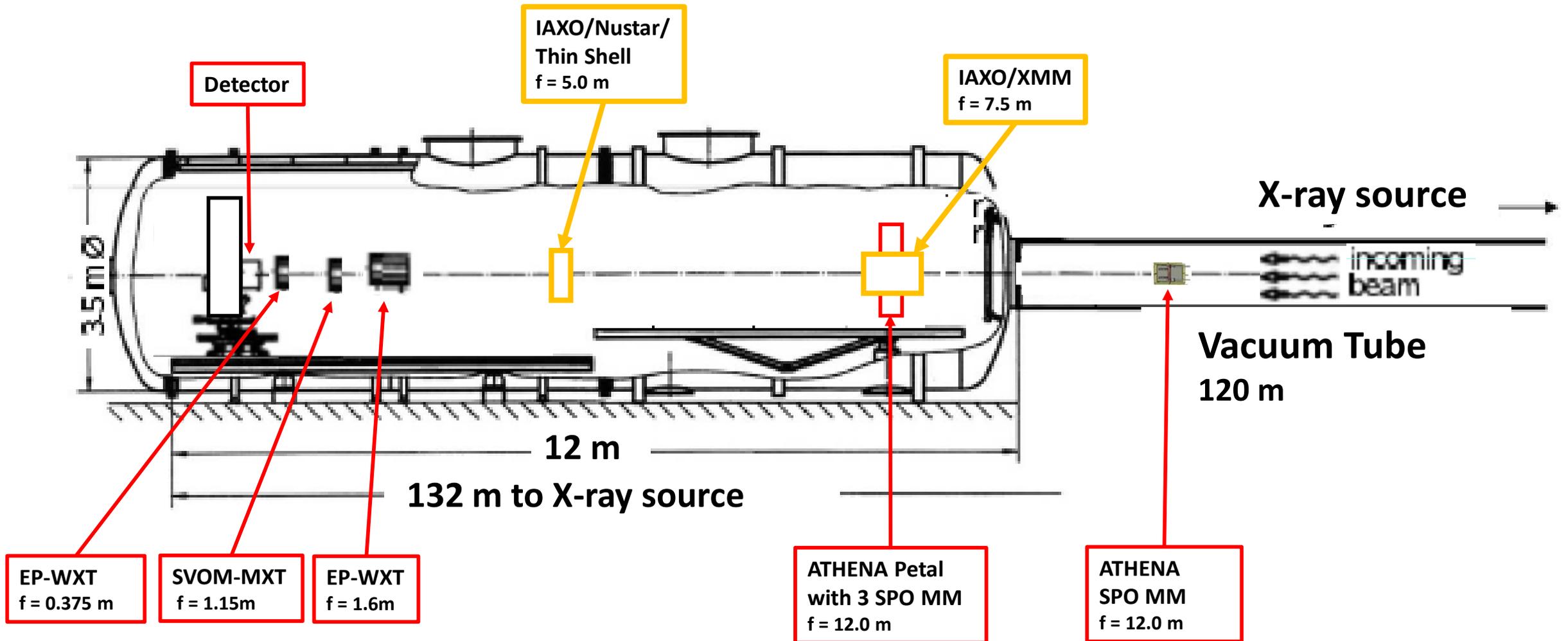


**Active
Missions**

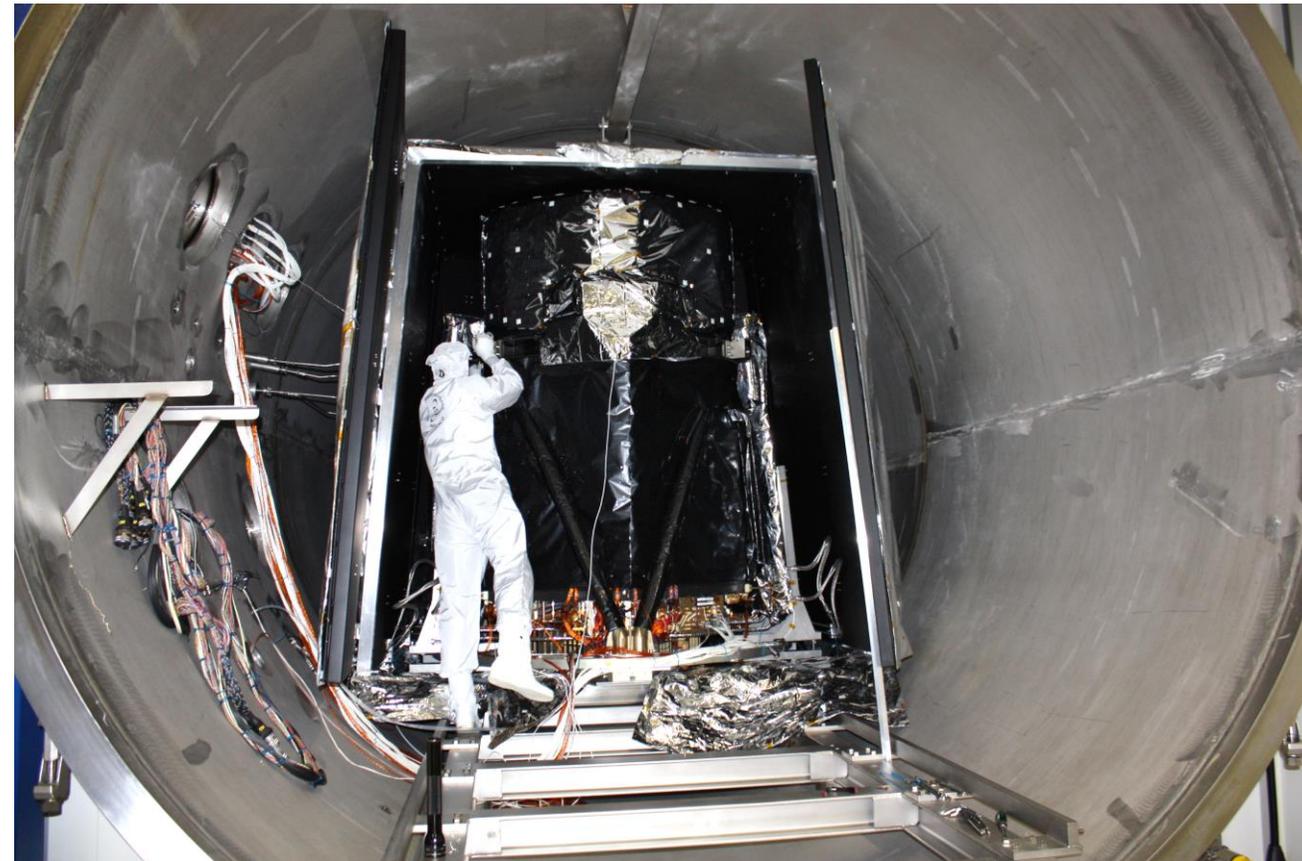
**Upcoming
Missions**

**Tested at
PANTER**

The Location of Optics in PANTER chamber



Cleanroom access to the PANTER chamber



eROSITA

DE survey

- Launched July 2019
- 4.5 All-sky surveys completed until end of Feb 2022
- Since then eROSITA is in safe mode
→ falls under EU sanctions
- German half of the first All-Sky-Survey made public
 - Publically available since Jan 31, 2024
 - With source catalogs
 - >50 papers published by the eROSITA consortium



SVOM MXT at PANTER

Optics level Measurements

- QM optic
→ Tested Nov. 2019
- FM optic
→ Calibrated Jan. 2021
- FS optic
→ Calibrated Mar 2022

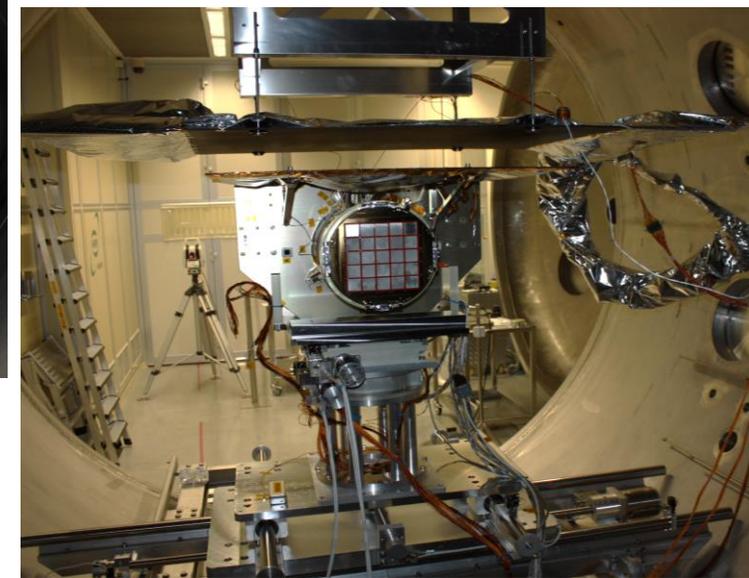
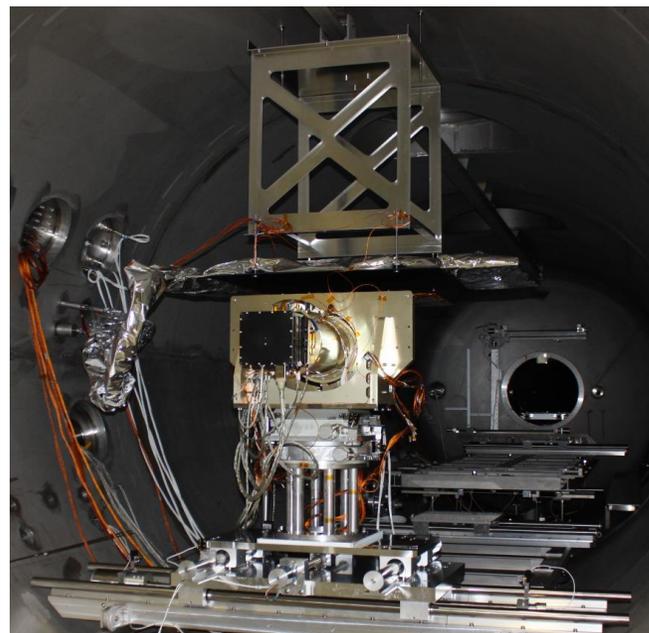
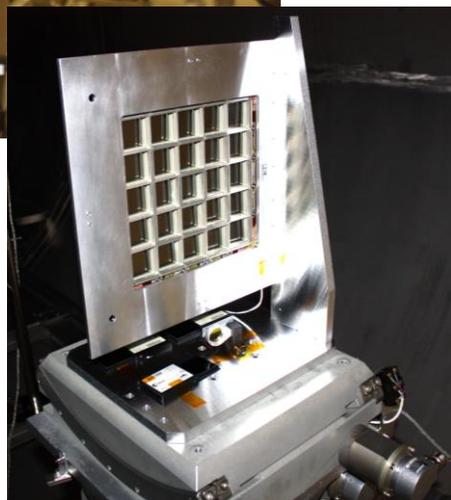
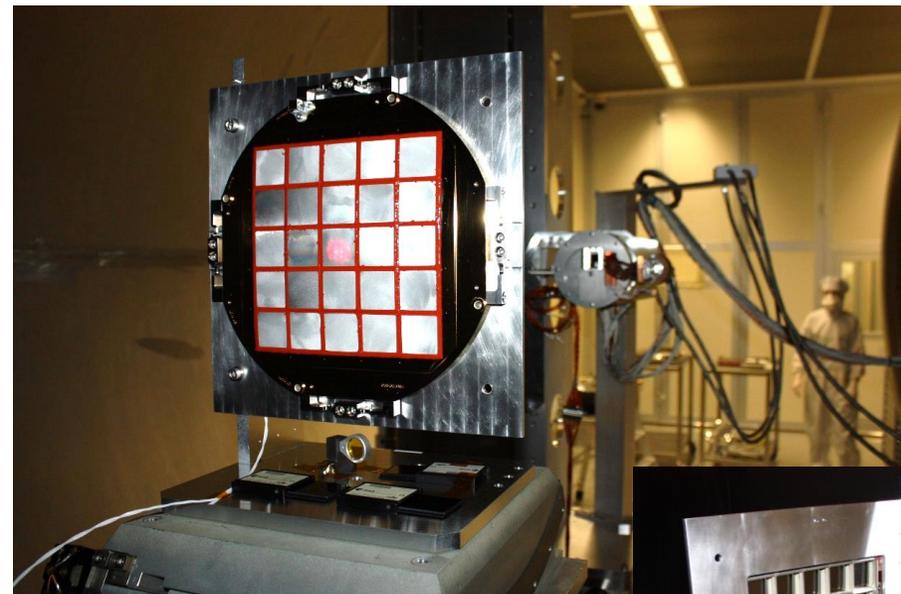
Telescope level Measurements

- PANTER Model End to End test
→ completed in Jan.- Feb 2020
 - QM Optic
 - EM Camera
- FM Model End to End test
→ completed Oct. – Nov. 2021
 - FM Optic
 - FM Camera

SVOM MXT at PANTER: Setup

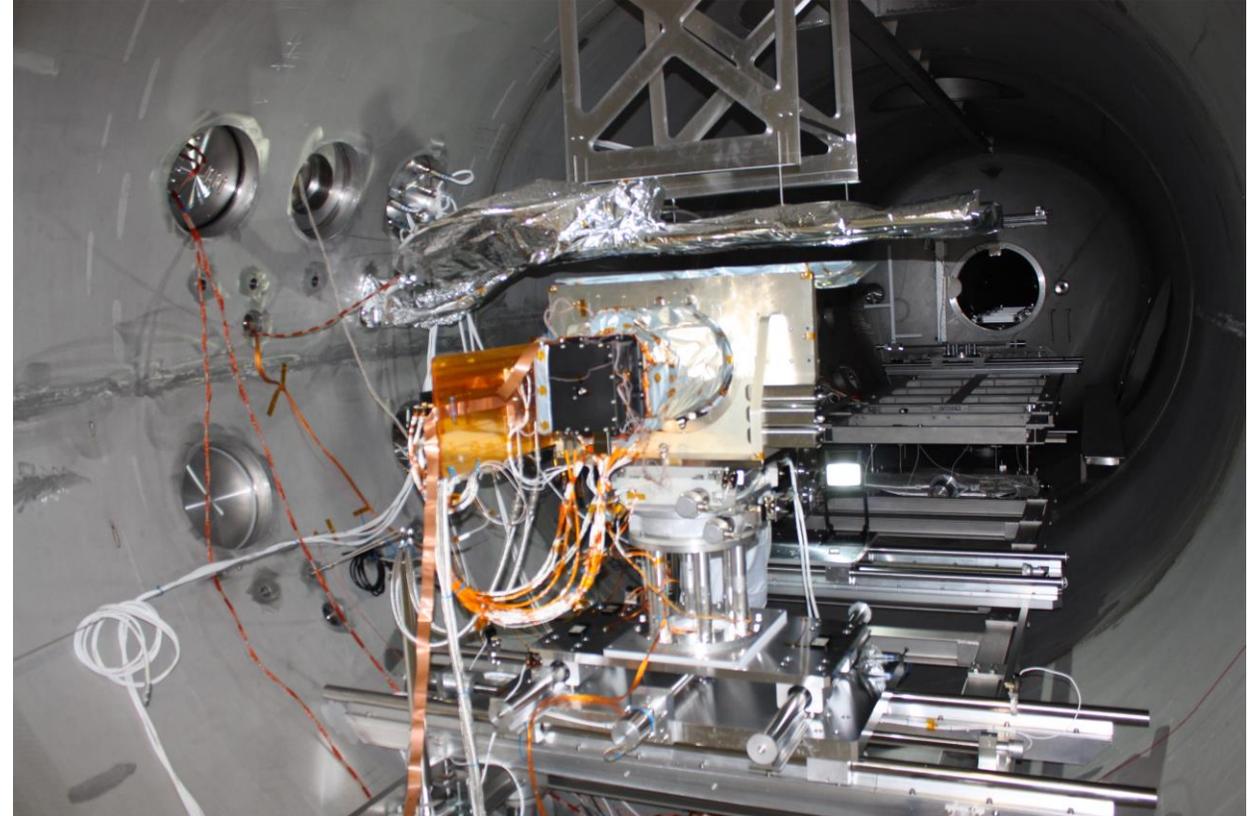
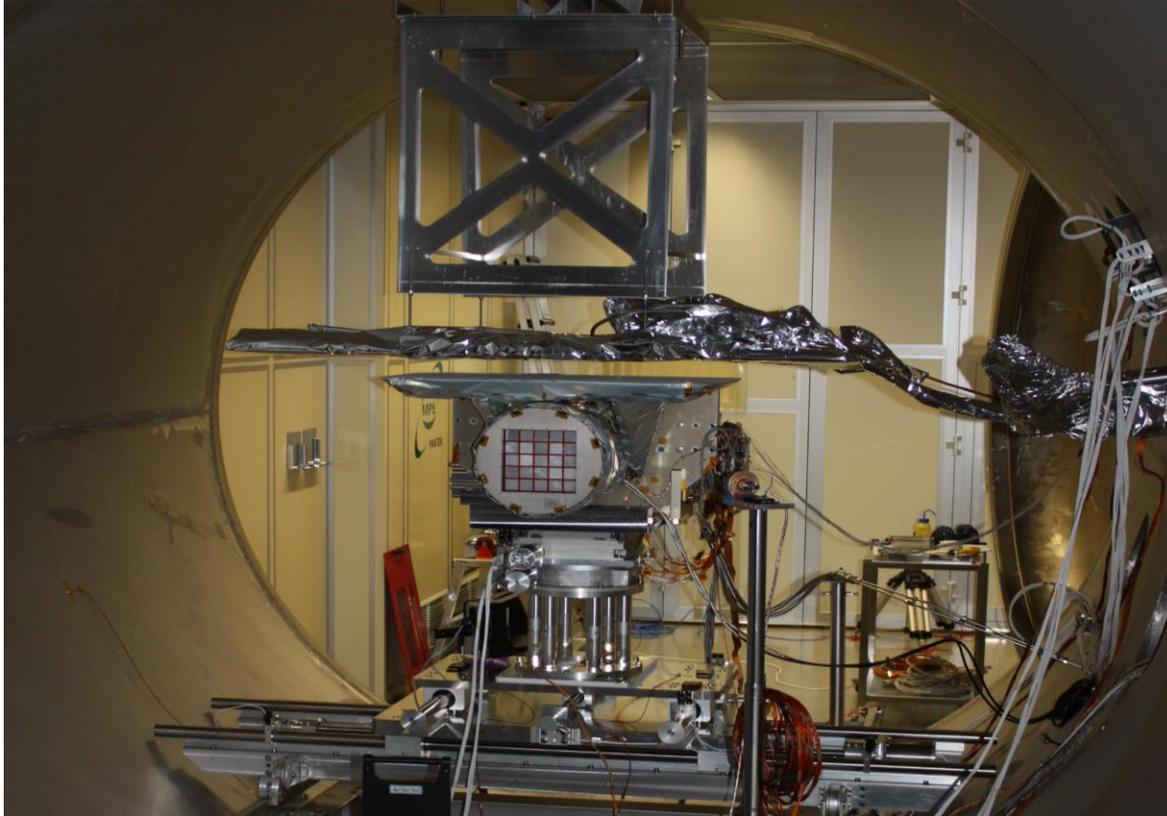
Optics Test

Telescope Test



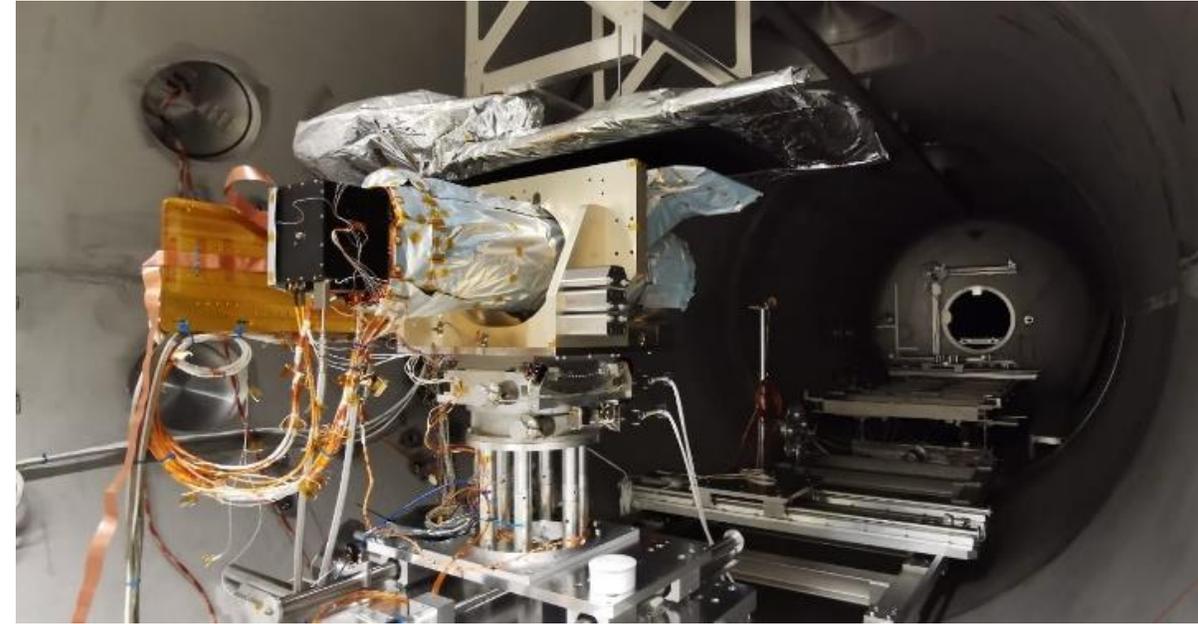
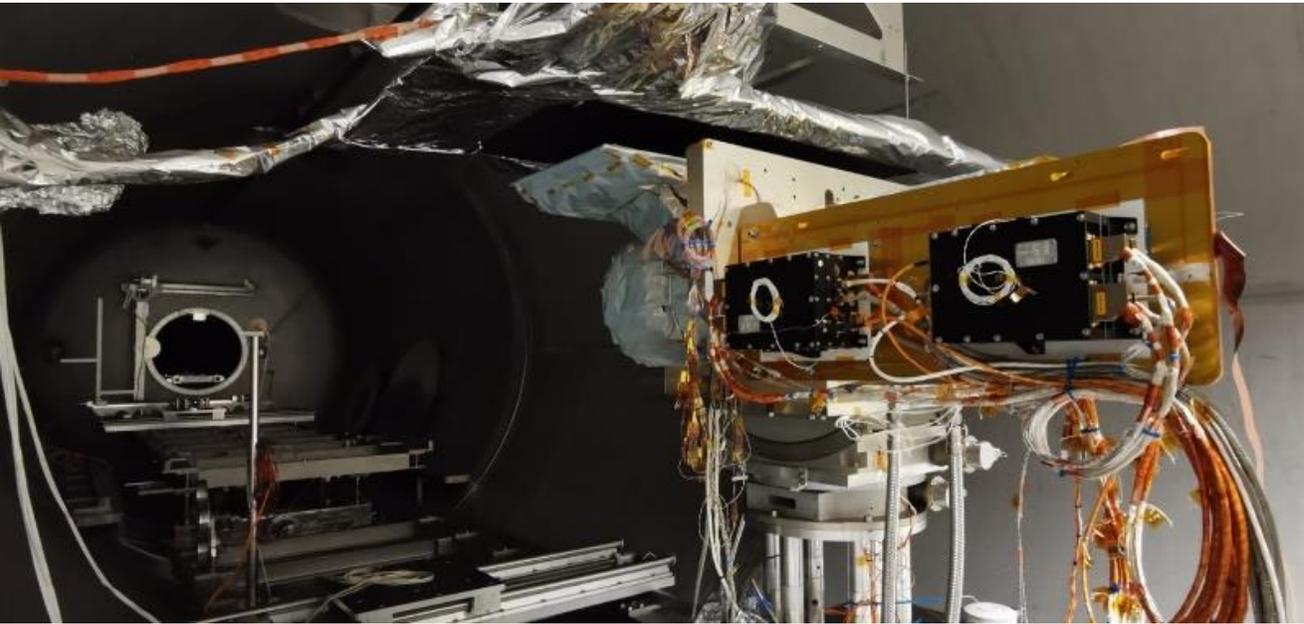
Testing the SVOM-MXT Telescope in PANTER

Setup in the vacuum chamber for Flight Model test



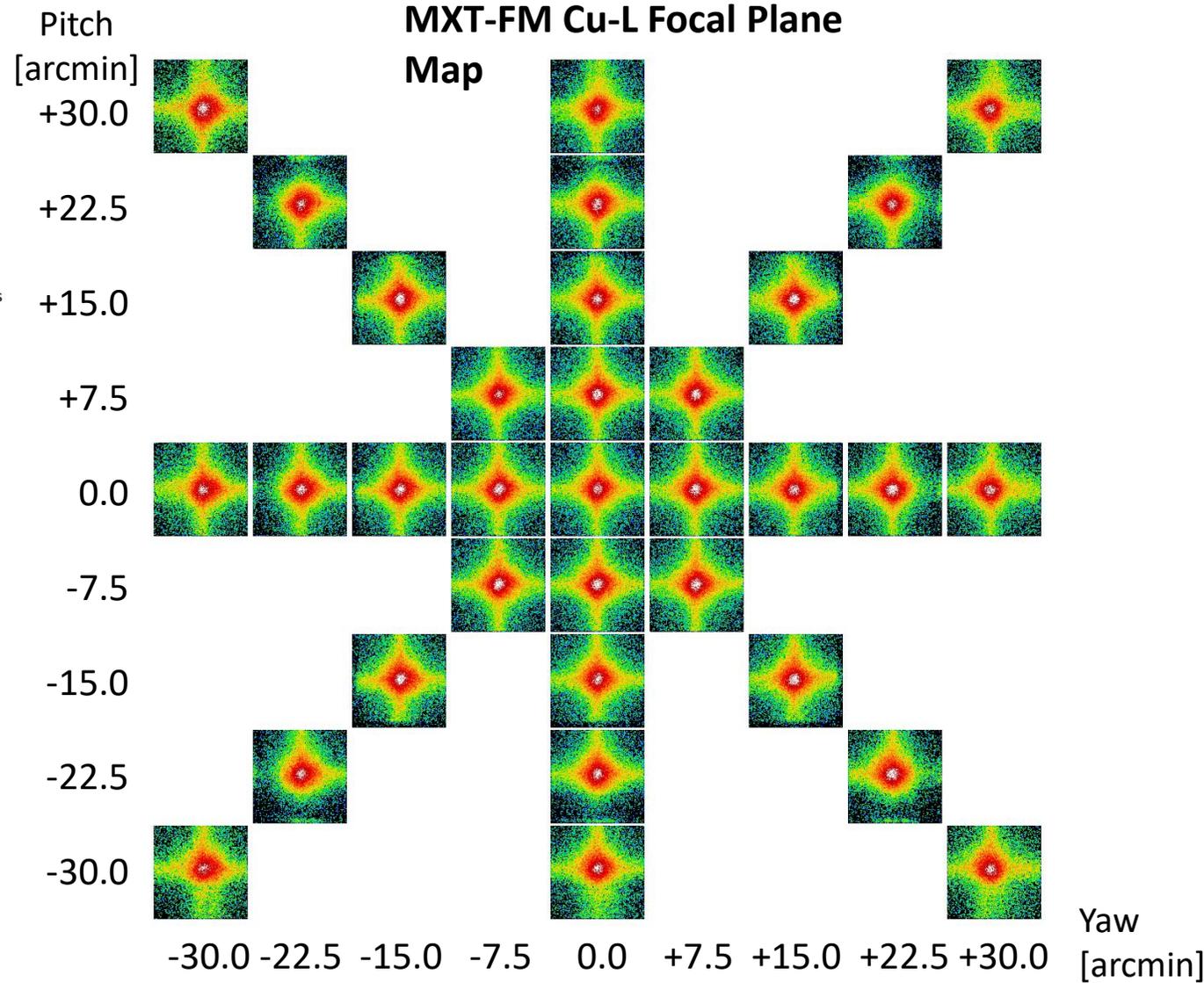
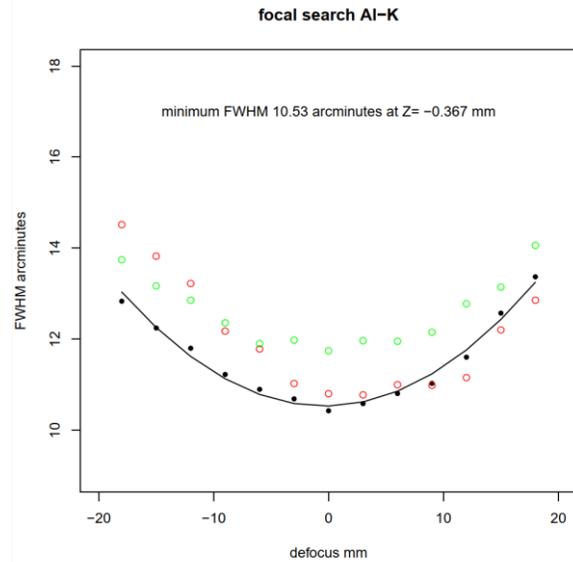
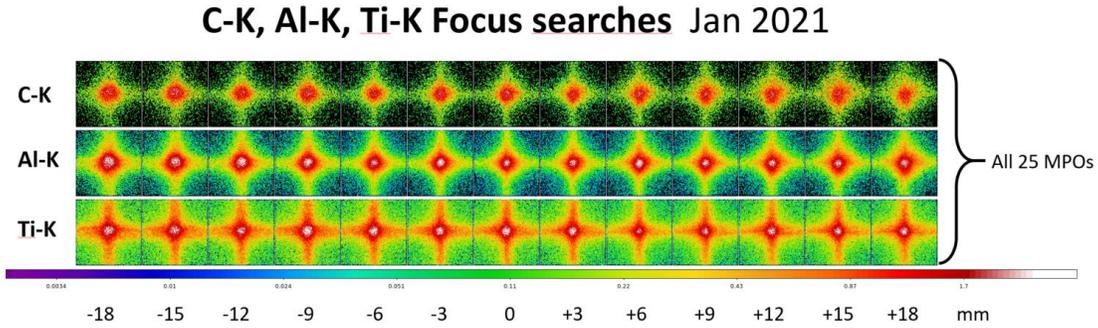
Testing the SVOM-MXT Telescope in PANTER

Setup in the vacuum chamber for Flight Model test



SVOM MXT at PANTER: Measurements

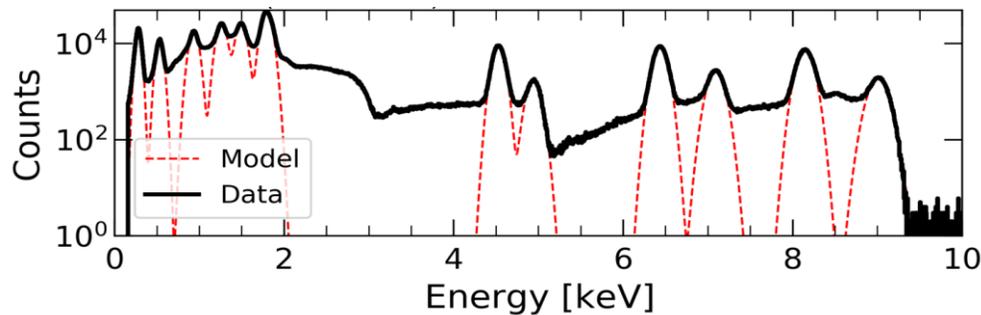
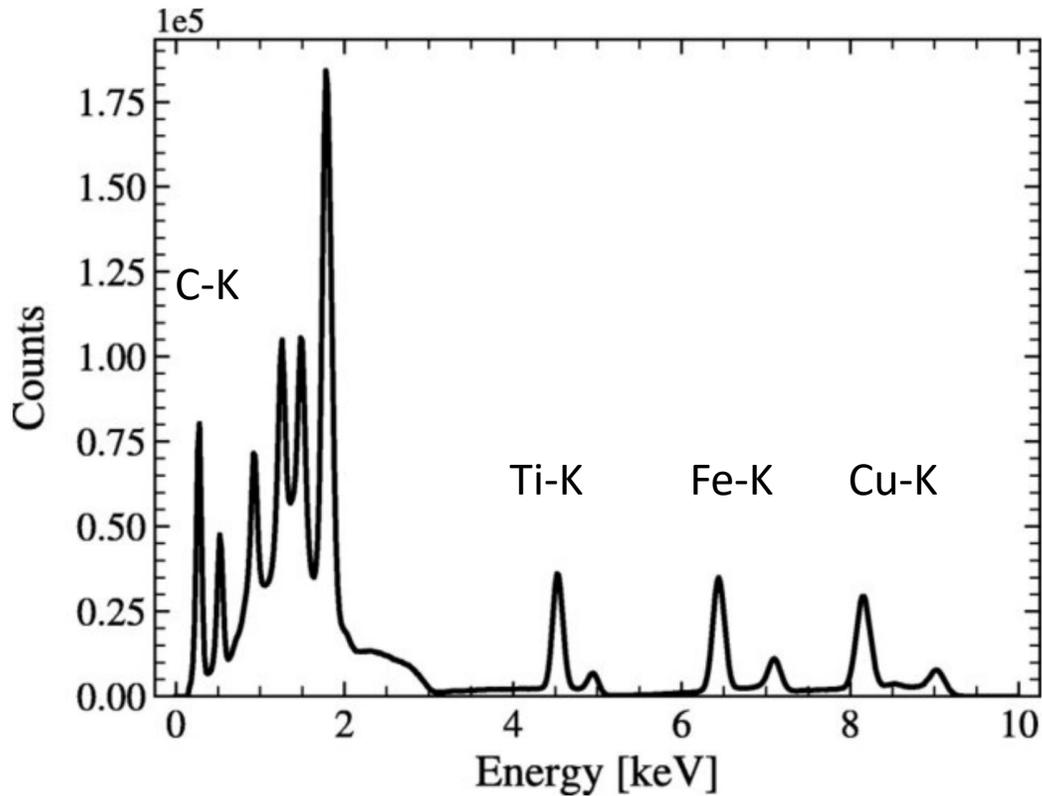
Optics Test



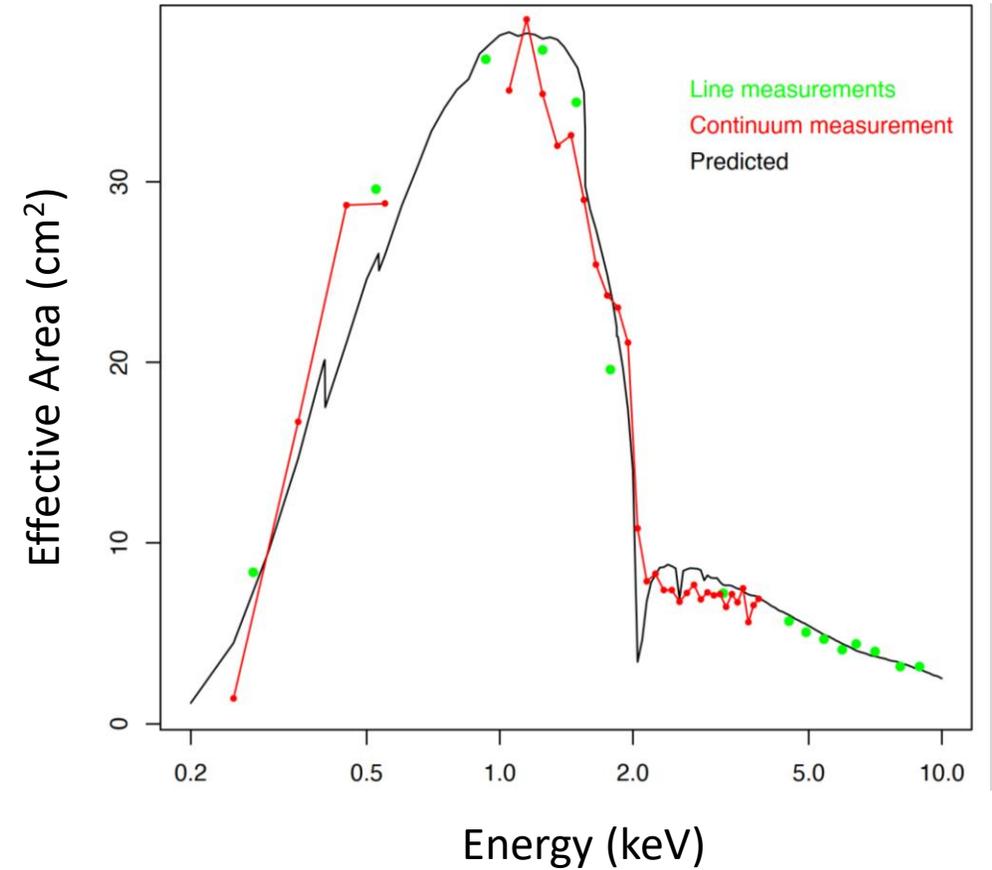
Courtesy Willingale

SVOM MXT at PANTER: Spectral Measurements

Camera



Telescope Effective Area



Courtesy Willingale

Einstein Probe Optics at PANTER

Follow-up X-ray Telescope (FXT)

eROSITA type MM $f = 1.6$ m (54 Nickel Shells)

- STM optic
 - MM Acceptance test Nov. 2019
 - MA Acceptance test Dec. 2019
 - Post Vibration Apr. 2020
 - Post Thermal cycling May 2020
- QM / FS optic
 - MM Acceptance test May 2021
 - MA Acceptance test June 2021
 - MA Post Vibration July 2021
 - MA Post Thermal cycling/calibration
→ planned Aug. 2021
- FM optic planned Dec. 2021 – May 2022
 - MM Acceptance test
 - MA Acceptance test
 - MA Post Vibration test
 - MA Post Thermal cycling test / Calibration

MM – Mirror Module

MA – Mirror Assembly = MM + X-ray Baffle

Wide field X-ray Telescope (WXT)

Micropore optics (Lobster eye design)

- QM Optic
 - Test and Calibration of all four quadrants
→ Launched as LEIA July 2022
- FM5 Optic Oct.-Dec., 2022
 - Test and Calibration of all four quadrants

Einstein Probe

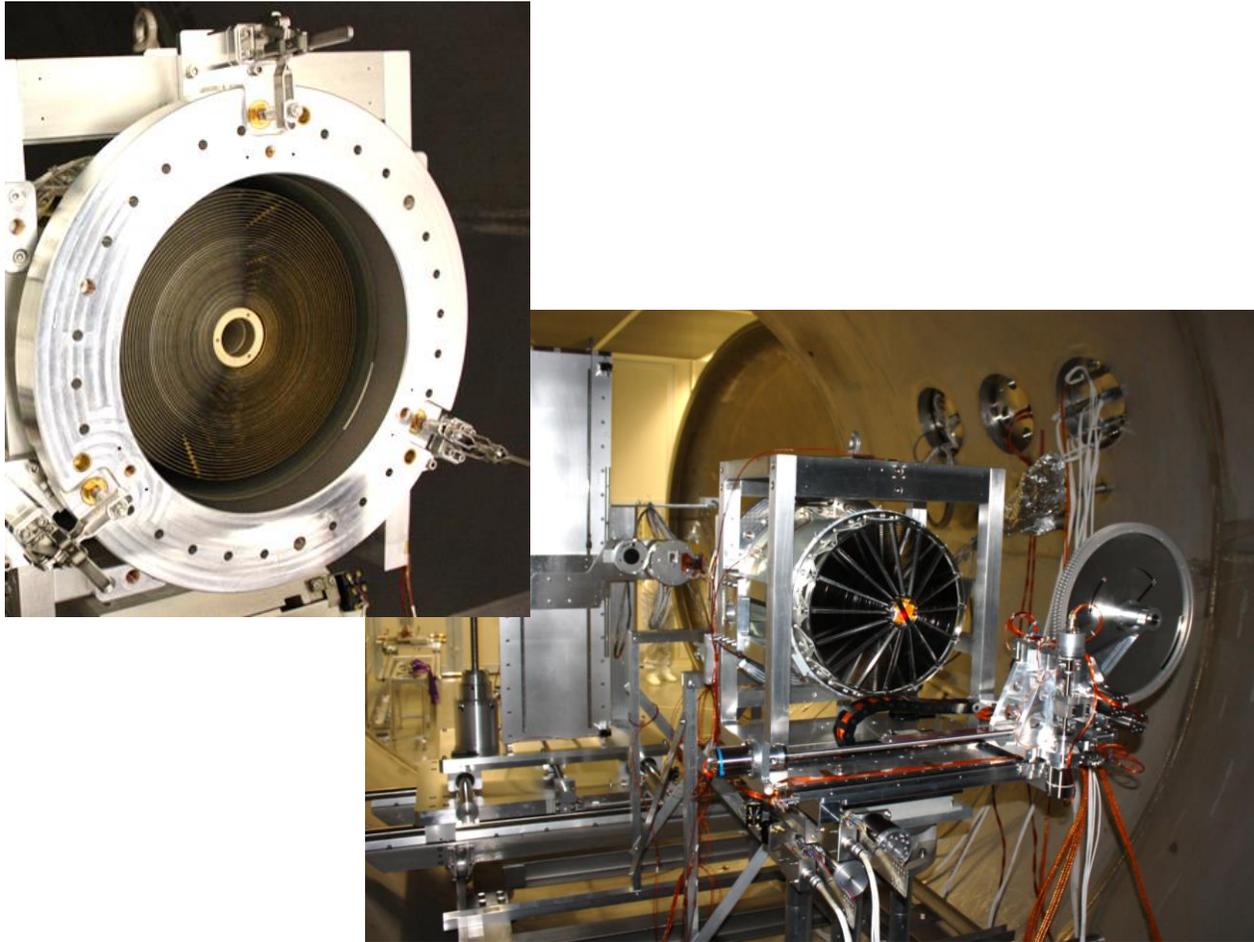
Launched successfully

→ Jan. 9, 2024



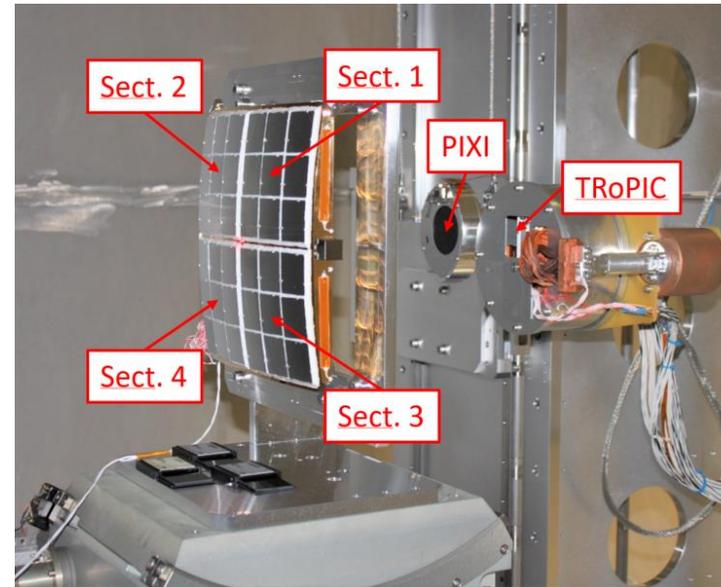
Einstein Probe Optics at PANTER: Setup

Follow-up X-ray Telescope (FXT)



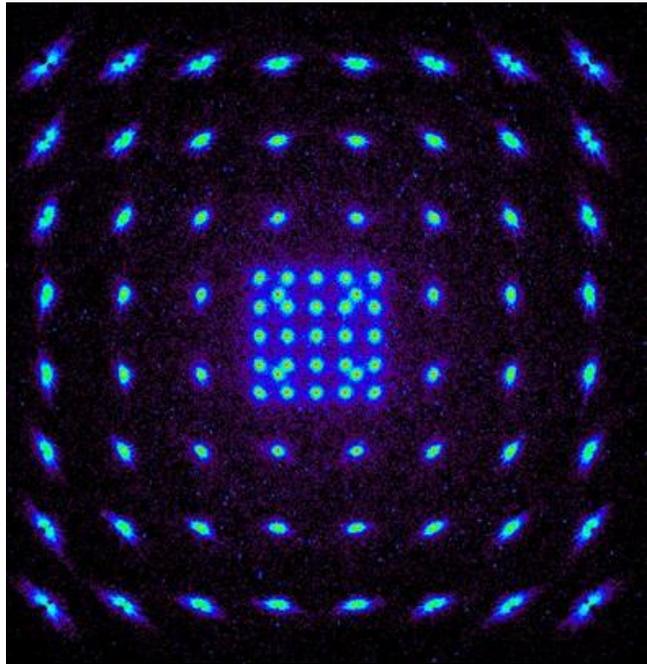
Wide field X-ray Telescope (WXT)

- QM Optic in the PANTER Chamber April 2020



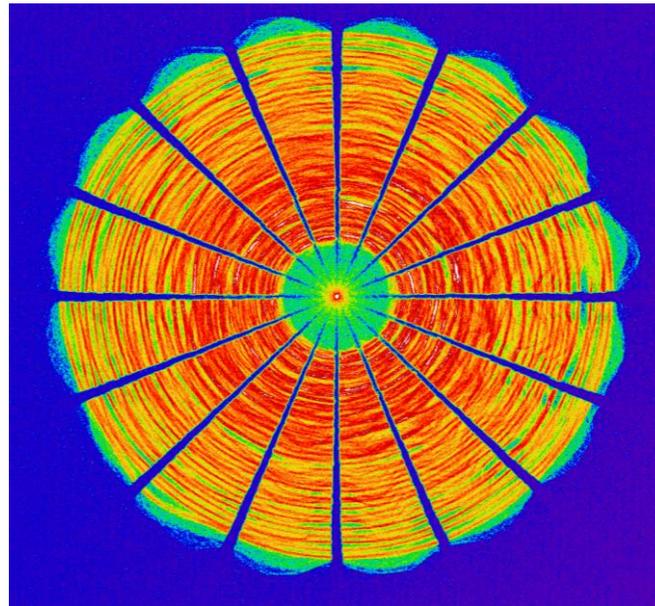
Einstein Probe Optics at PANTER: Measurements

Follow-up X-ray Telescope (FXT)



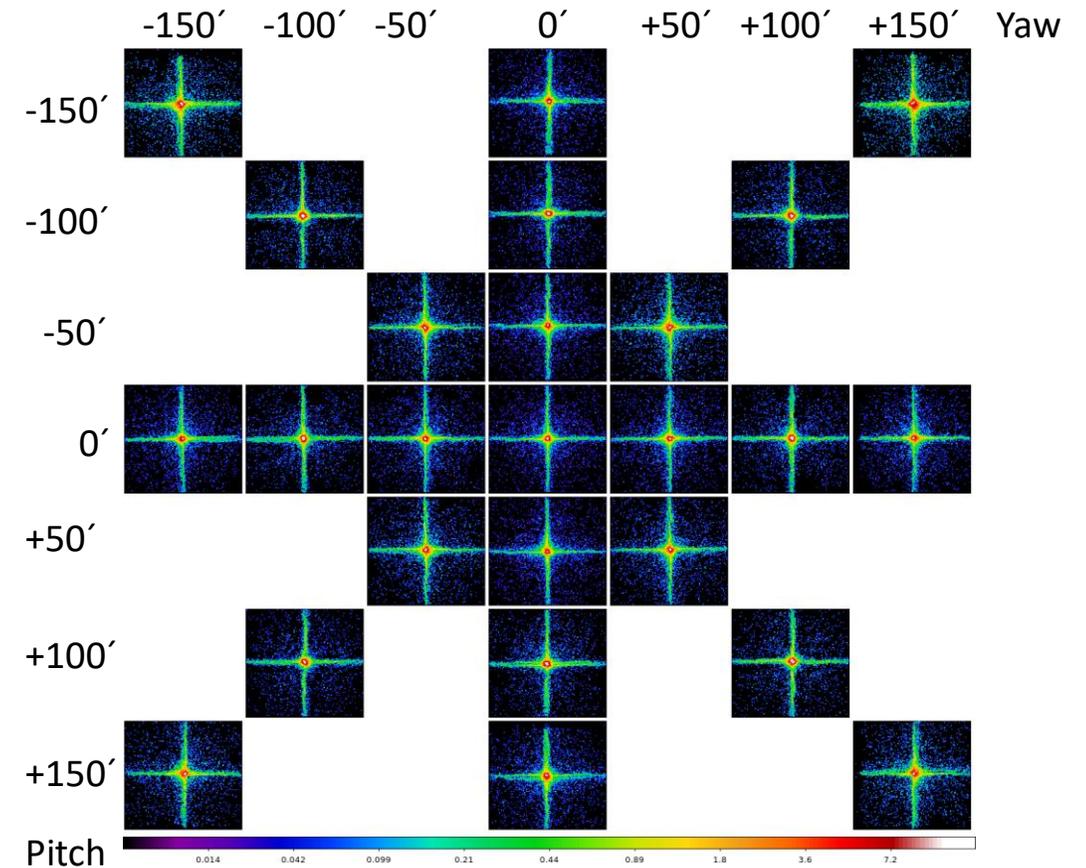
FOV Vignetting study

Extra focal image

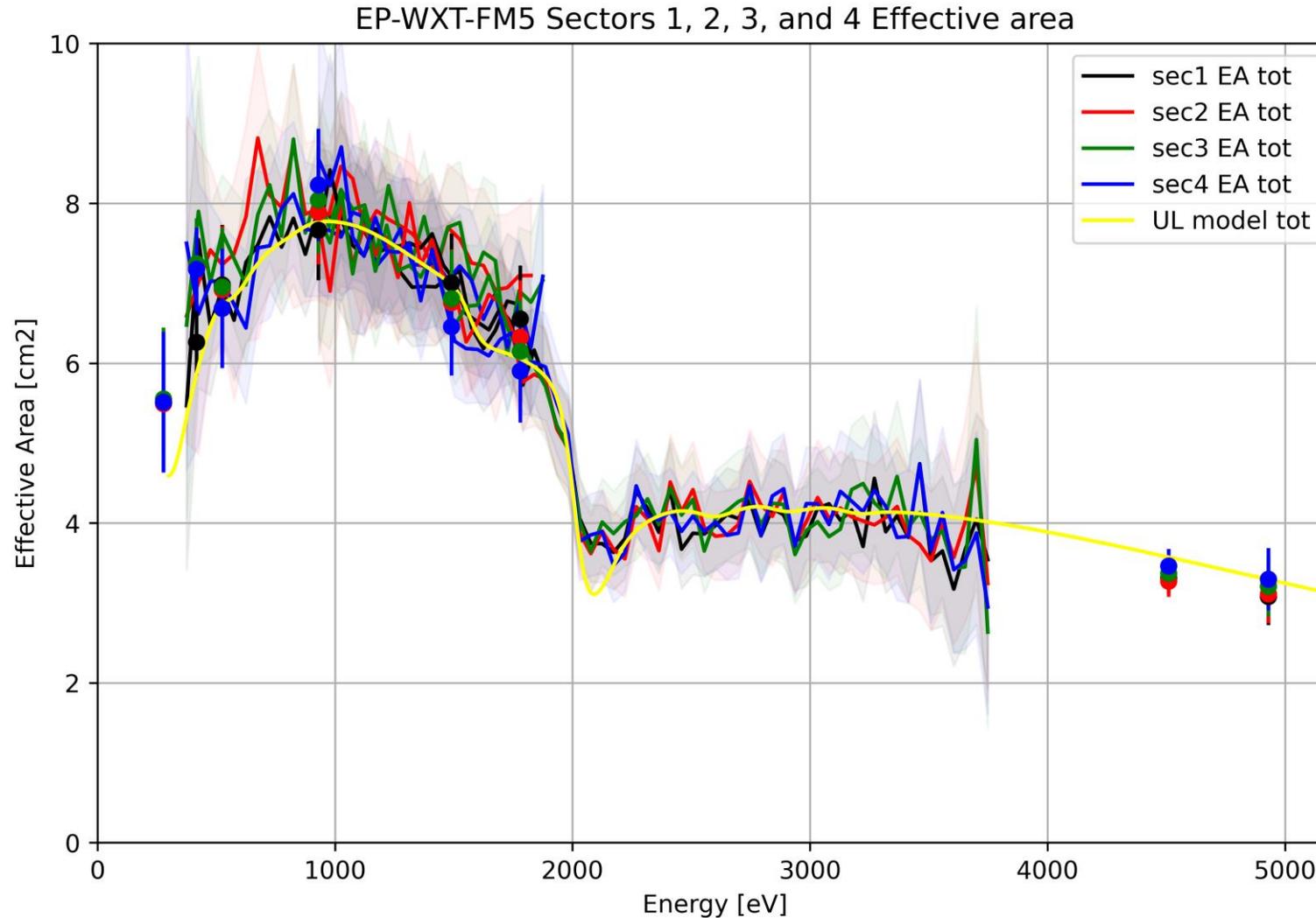


Wide field X-ray Telescope (WXT)

○ QM Optic Sector #1 Cu-L in the PANTER Chamber



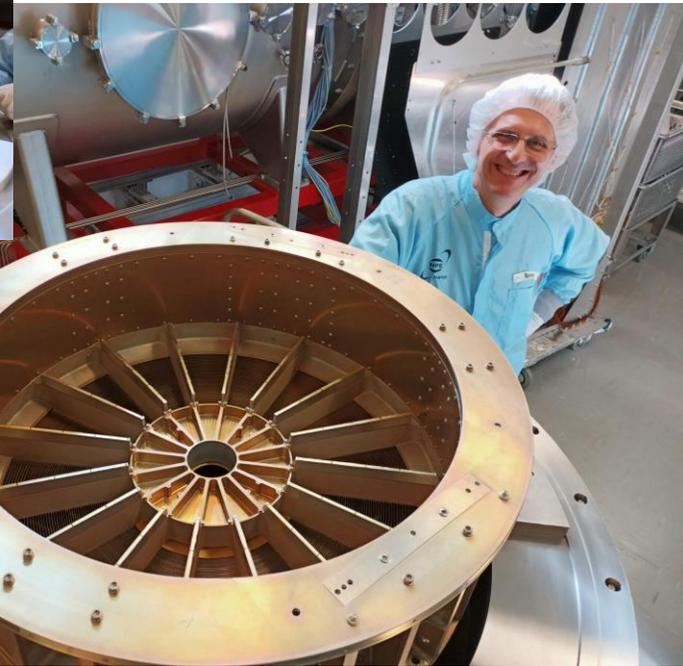
Einstein Probe WXT on Axis Effective Areas



Effective Area

- total E.A = double + single + direct
- two lower points (at 4 cm²) of sectors 3 and 4 to avoid confusion
- gain of the IEbc data by 0.955 so the edge in the data and matches the theoretical edge position.
- the Leicester model smoothed with a sigma=100eV gaussian and scaled up by 3 %

IAXO: Unpackaging the XMM-MM-FM5



IAXO: Overview the XMM-MM-FM5

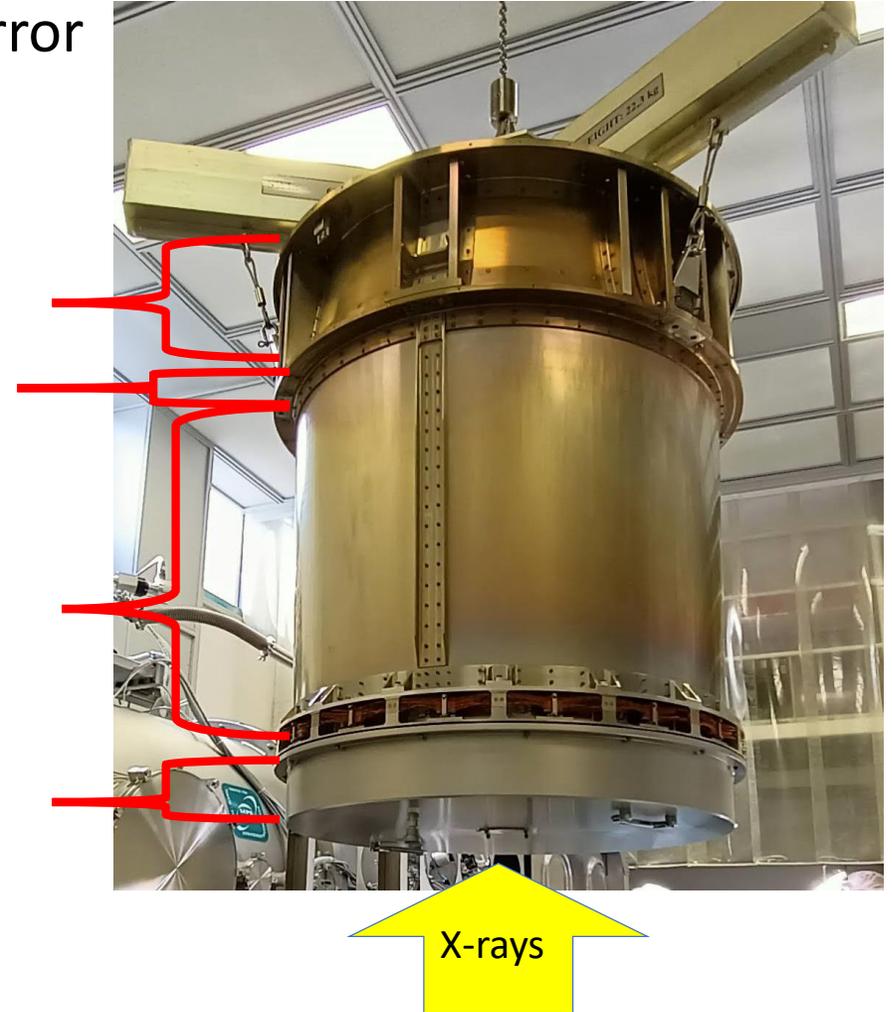
The Mirror assembly is a true flight like mirror assembly with:

Exit baffle

Magnetic spider (inside) can be removed

Mirror

X-ray sieve plate baffle



XMM-MM-FM5 in it vacuum MGSE



It works for FM5 but not for FM1

IAXO: Move the XMM-MM-FM in to the vacuum chamber

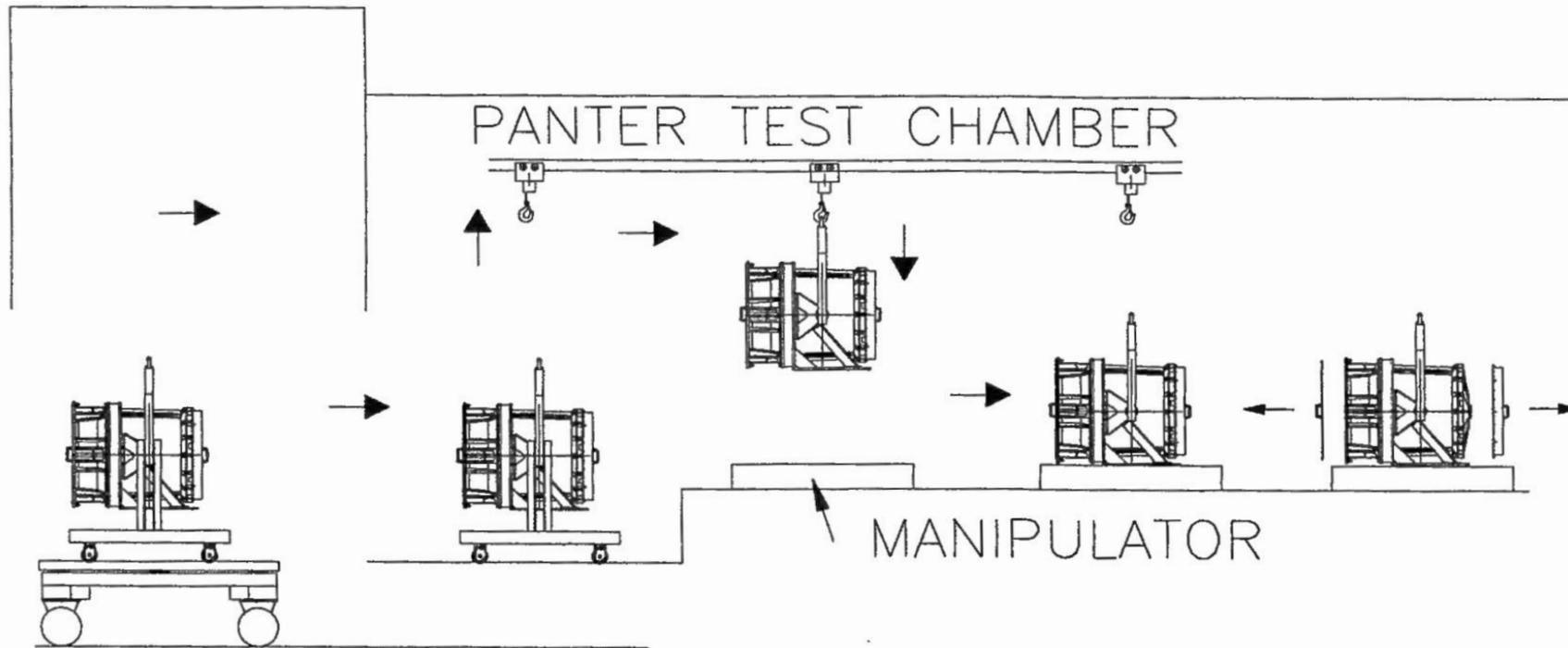


Fig. A.3-1 Installation of the Mirror Model at Panter Test Facility

KT-FO-E-0009-01-00

Iss.: 3 Rev.: -

Datei: MM-KT-PR-015-3 Step.doc

A.3-1

IAXO: The XMM-MM-FM5 and the PANTER Team

From left to right:
Vadim, Thomas, Suri, Thomas, Gisela, Stefan, Bernd



Summary

- eROSITA
 - First All-Sky-Survey German data and catalogues released Jan. 31, 2024
- SVOM
 - QM and FM optics were tested/calibrated successfully
 - The PANTER FM Telescope End to End Test was completed successfully
- Einstein Probe
 - FXT STM, QM, FM tests just about complete, FM test start end of 2021
 - WXT QM test successful → launched with the QM Detector as LEIA in July 2022
 - WXT FM test also due end of 2022
- IAXO
 - XMM Mirror ready for testing at PANTER