eROSITA Status
Calibration plans

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for the eROSITA team
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Shonan Village, Japan

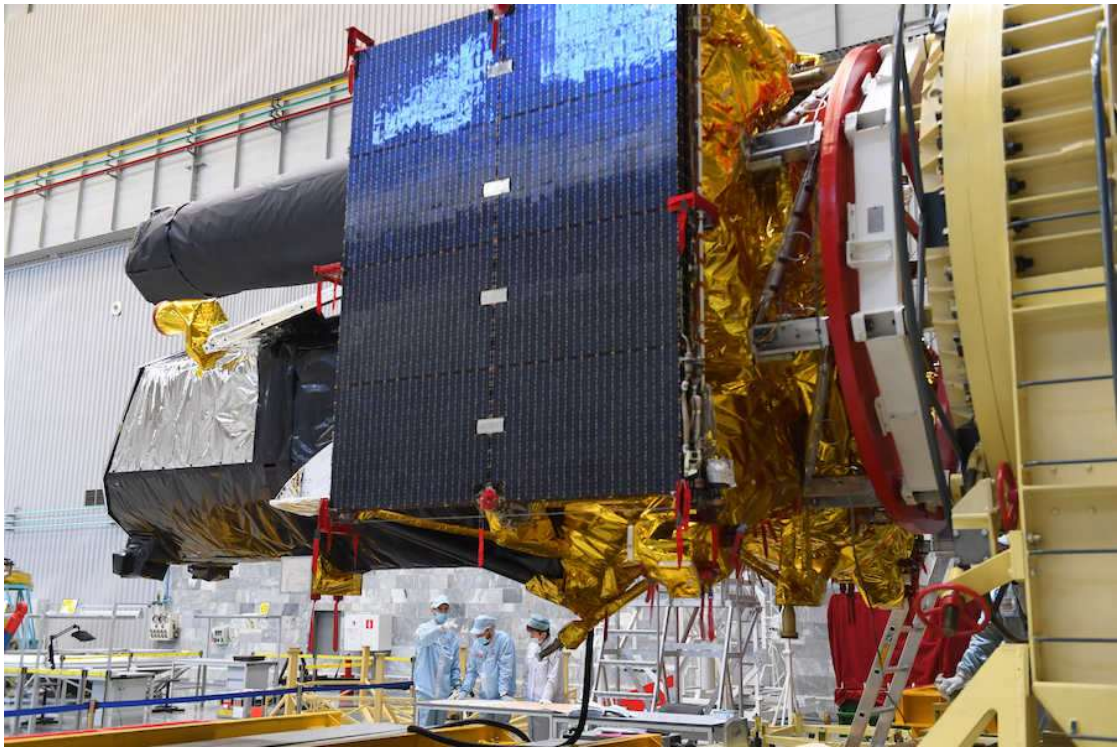
Overview

- Current status of eROSITA on Spektr-RG
- eROSITA ground calibration
- ART-XC on Spektr-RG ground cross-calibration at PANTER
- Planned in orbit activities
  - Comissioning
  - Calibration
  - Performance verification
  - Cross-calibration

Current status of eROSITA

- eROSITA is now in Baikonur together with ART-XC mounted on the Spektr-RG satellite platform after spending 2 ¼ years in Moscow.
- In Baikonur Spektr-RG has now been unpacked and redied for integration on the Proton launcher and Block-D upperstage.
- Removal of last red tag items is planned for next week → end of May
- Launch is still scheduled for Friday June 21st, 2019
  → in just over 1 month time

Packing in Moscow



Arrival of Spektr-RG in Baikonur

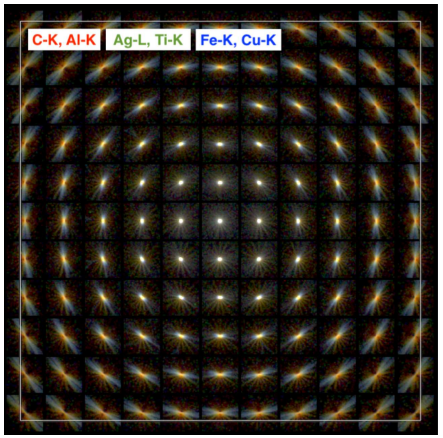


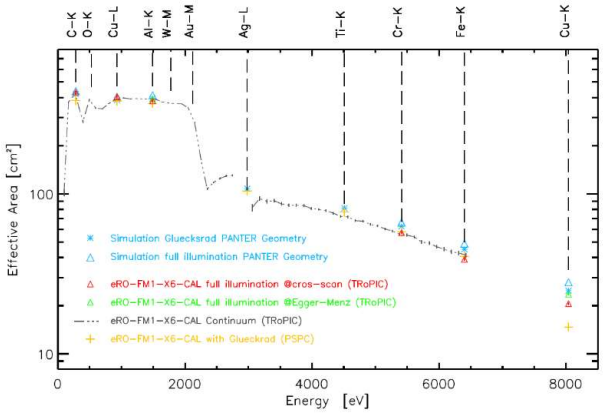


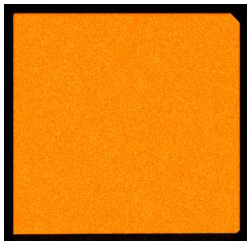


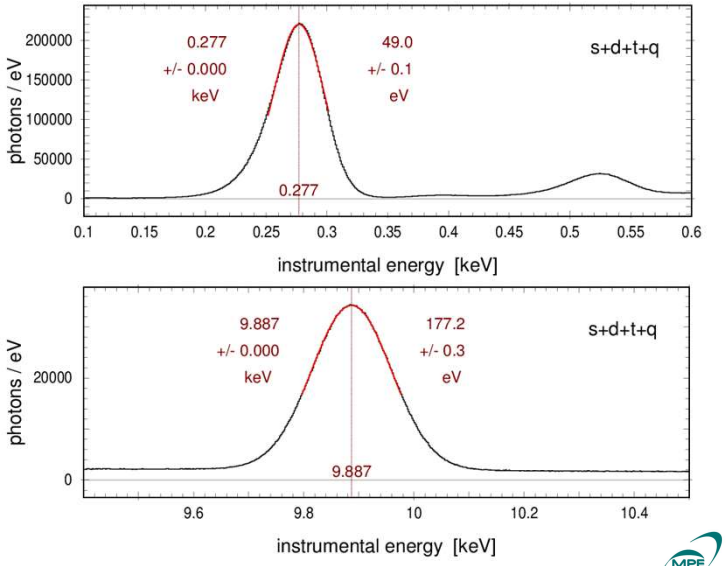
eROSITA Ground Calibration

- eROSITA Ground calibration of the Mirrors and Detectors (flight + spare)
  → was performed at PANTER and PUMA respectively in the 1 half of 2016
- For the Mirrors the on- and off-axis PSF shapes and effective areas were determined at energies ranging from 0.18 keV up to 10 keV
- For the detectors especially the energy resolution in the range 0.18 keV to 10 keV was also determined.

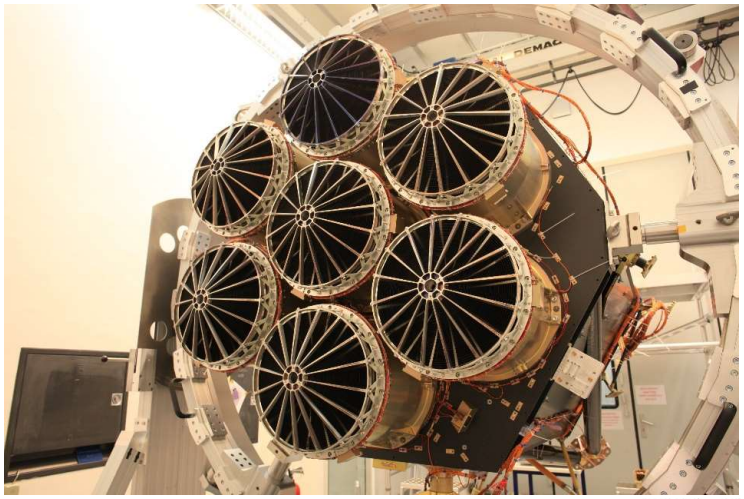


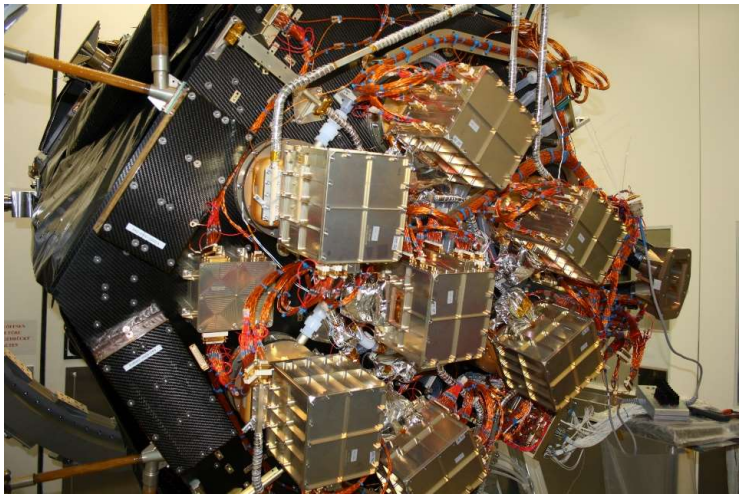




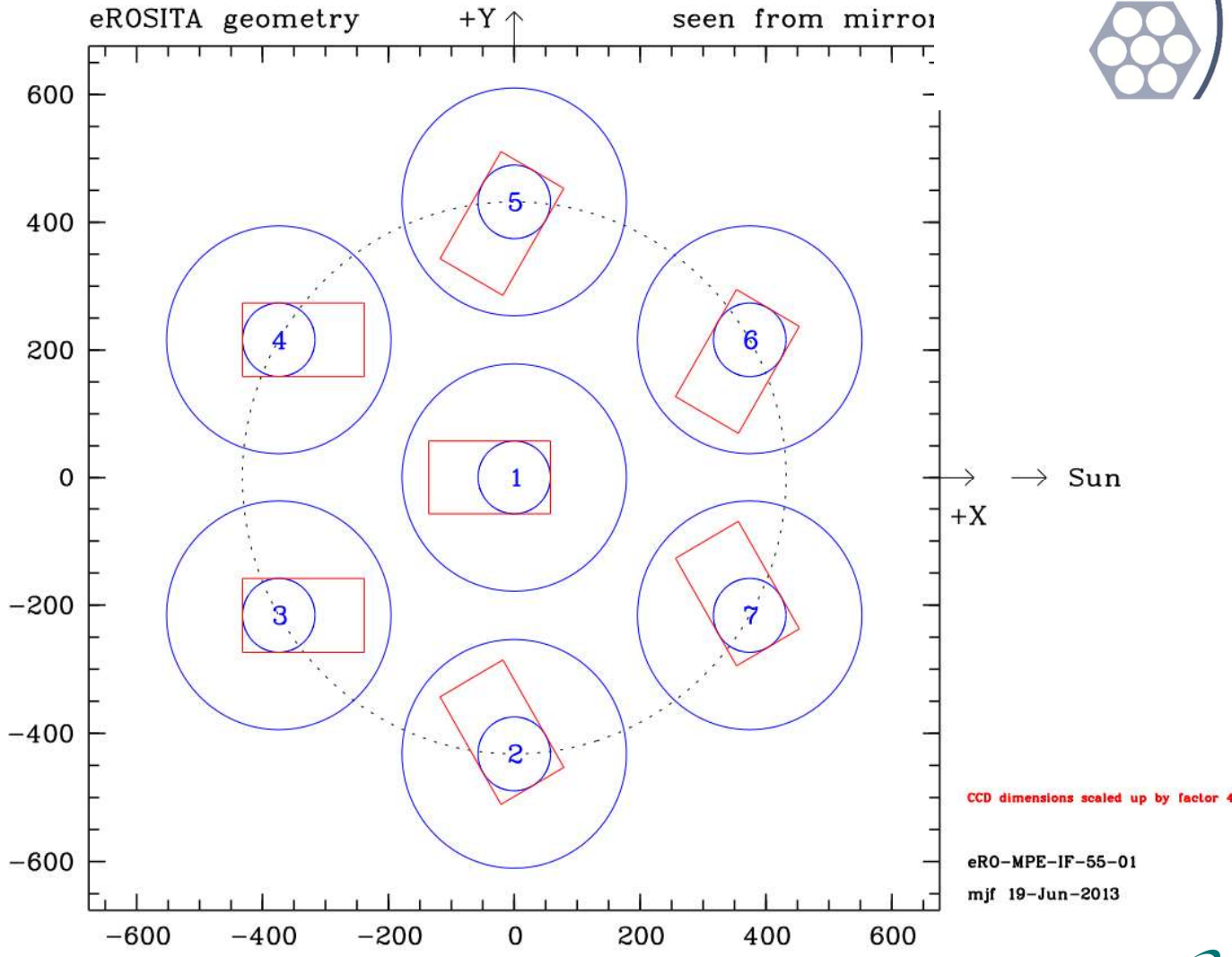


eROSITA geometry: mirror modules and cameras





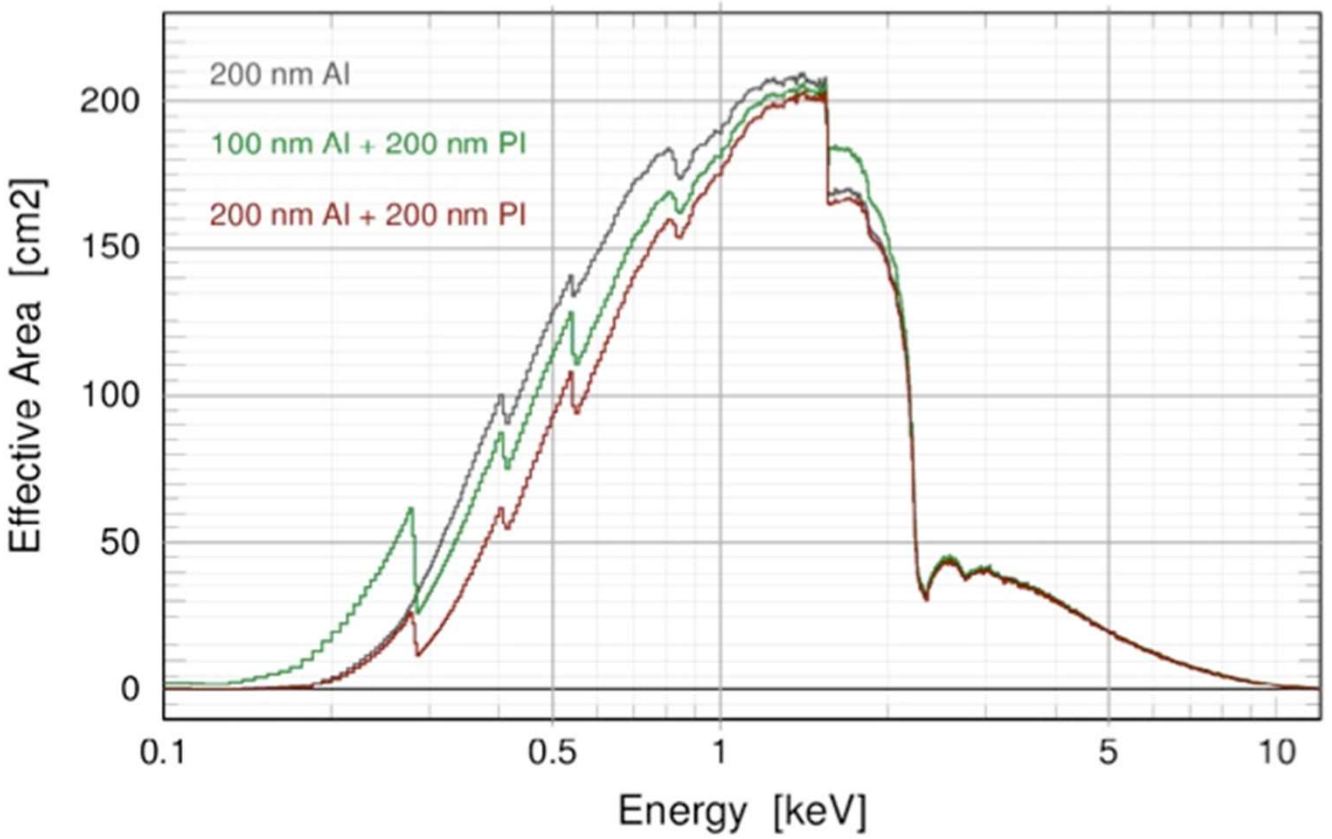
ART−XC ←



eROSITA ground calibration input for the CALDB

Telescope Module (CALDB position)	Units	1	2	3	4	5	6	7
Mirror Assembly (FM)	**[#]**	**2**	**3**	**5**	**4**	**6**	**7**	**1**
HEW @ Al-Kα (1.49 keV)	[arcsec]	16.0	15.5	16.5	15.9	16.1	15.6	17.0
HEW @ Cu-Kα (8.04 keV)	[arcsec]	14.5	15.1	15.6	16.3	15.1	16.2	14.7
Effective area @ Al-Kα	[cm²]	391	393	388	369	378	392	392
Effective area @ Cu-Kα	[cm²]	24.8	25.1	24.1	23.8	25.1	25.0	24.8
Scattering @ Cu-Kα	[%]	11.1	11.0	13.2	12.1	11.2	12.8	10.2
Camera Assembly (FM)	**[#]**	**3**	**2**	**7**	**4**	**5**	**6**	**1**
FWHM @ C-Kα (0.277 keV)	[eV]	58	58	58	58	50	58	49
FWHM @ O-Kα (0.525 keV)	[eV]	64	65	66	64	57	63	56
FWHM @ Cu-L (0.93 keV)	[eV]	70	74	72	70	68	70	68
FWHM @ Al-Kα (1.49 keV)	[eV]	77	82	80	77	75	77	77
FWHM @ Ti-Kα (4.51 keV)	[eV]	118	125	122	118	116	118	117
FWHM @ Fe-Kα (6.40 keV)	[eV]	138	145	142	138	135	138	136
FWHM @ Cu-Kα (8.04 keV)	[eV]	158	167	163	159	155	159	156
FWHM @ Ge-Kα (9.89 keV)	[eV]	178	181	182	173	170	174	175
ext. Filter (frame)	**[#]**	**23**	**10**	**7**	**24**	**20**	**1**	**19**
ext. Filter (PI)	[nm]	205.0	207.7	209.9	204.5	219.5	212.5	203.1
ext. Filter (Al)	[nm]	(200)	(200)	(200)	(200)	103.3	(200)	102.3

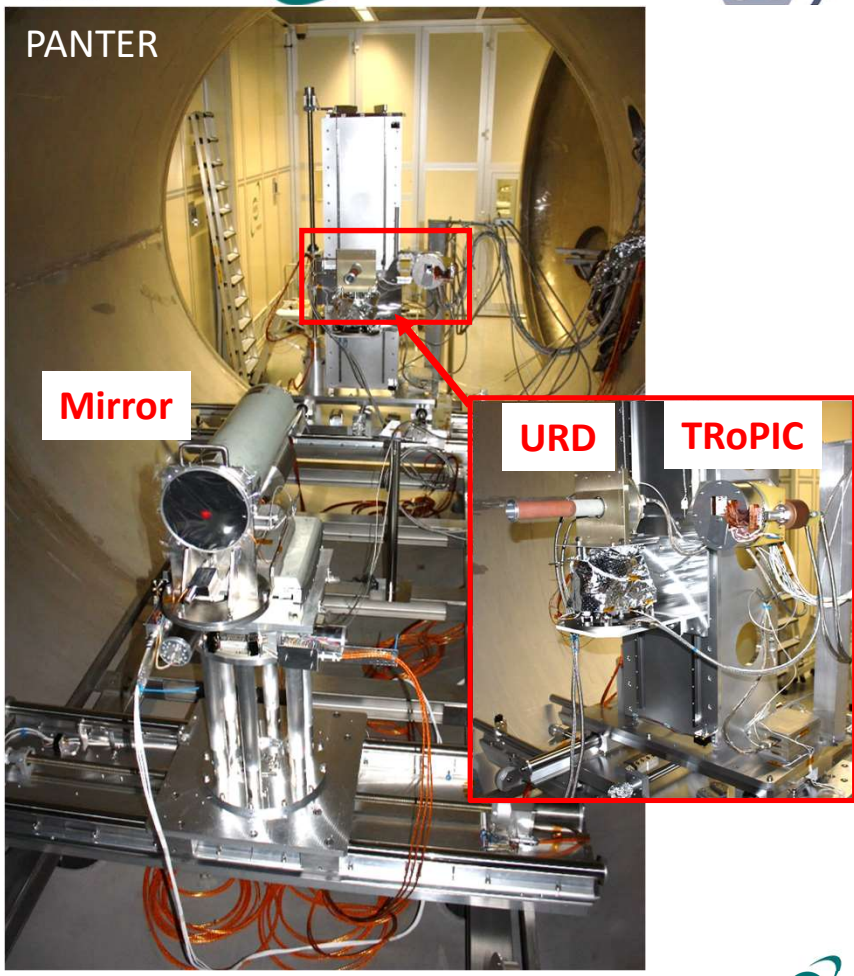
Expected Telescope Survey Effective Area



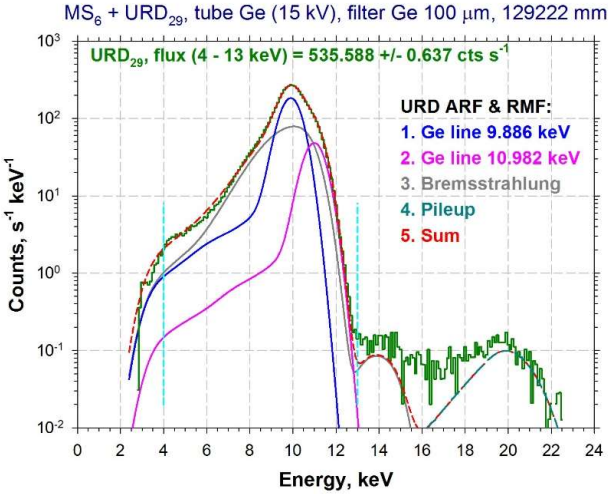
Effective areas of the three filter combinations for one eROSITA camera, composed of the expected effective area of one mirror assembly (averaged over the FoV), the filter transmissions, and the CCD quantum efficiency. All values are preliminary.

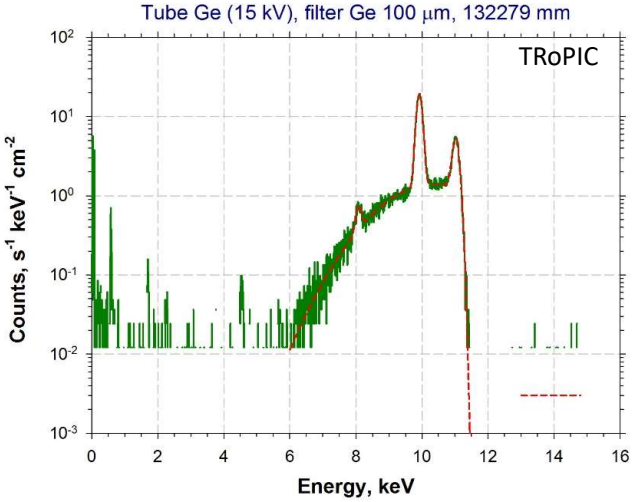
ART-XC tests at PANTER

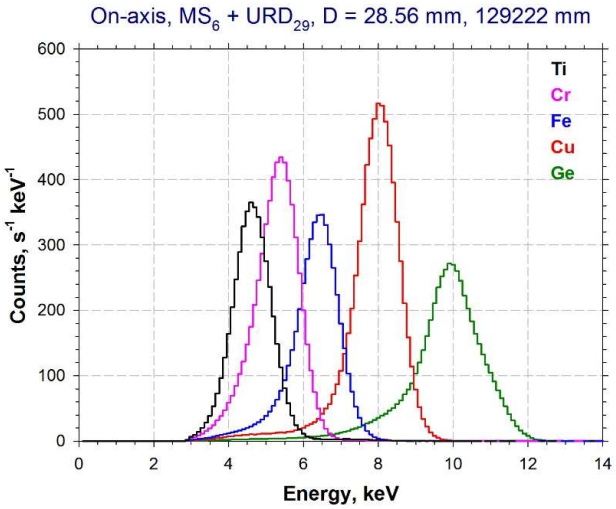
- Took place Oct. 11-26, 2018 at PANTER
- Mirror and Detector flight spare were tested specifically in the overlapping ART-XC - eROSITA ~4 to 10 keV energy range using PANTERs TRoPIC pn-CCD camera:
  - Either behind the optics.
  - or in paralell with the ART-XC detector.
- Like this it was possible to check the FM calibration measurements obtained the test facilities in Marshall SLF and at IKI in Moscow.
- The tests were successful and we know have a cross-calibration of the ART-XC Mirrors and URD detectors with respect to our TRoPIC pn CCD camera

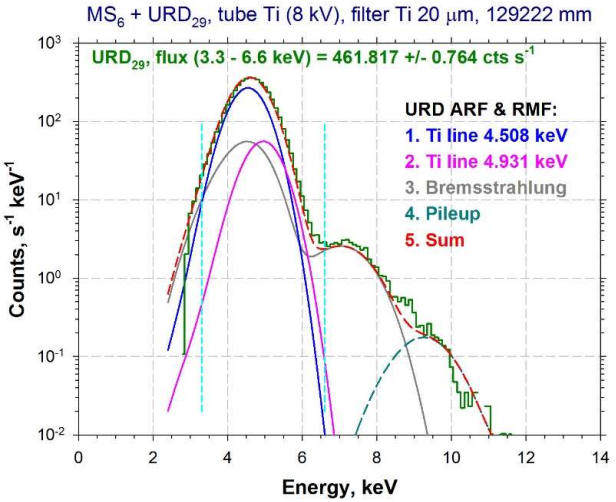


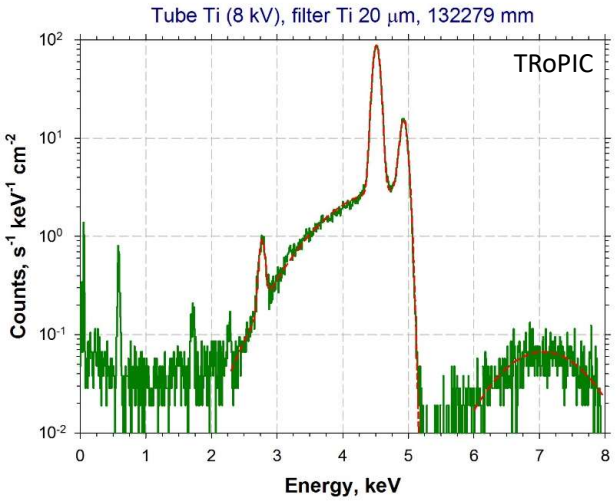
Results from the ART-XC PANTER Campaign











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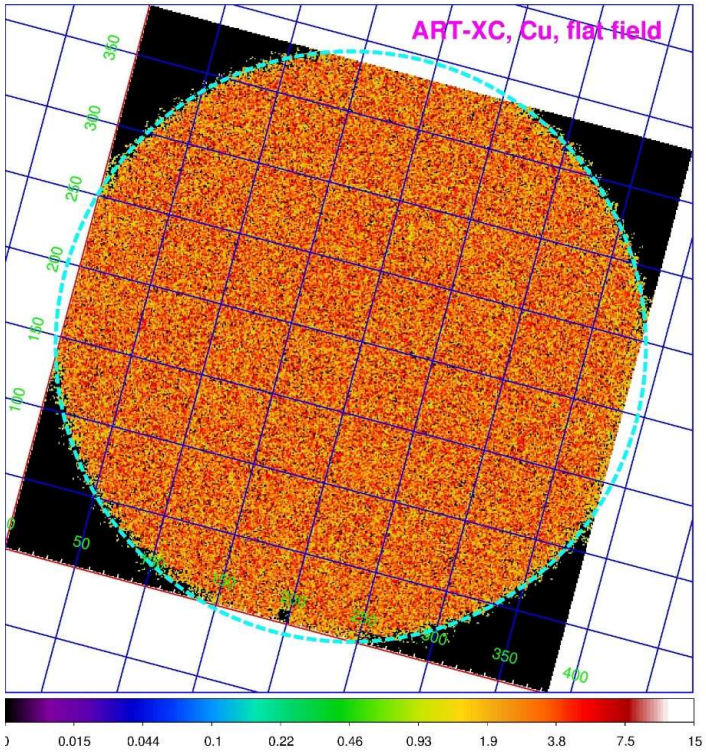
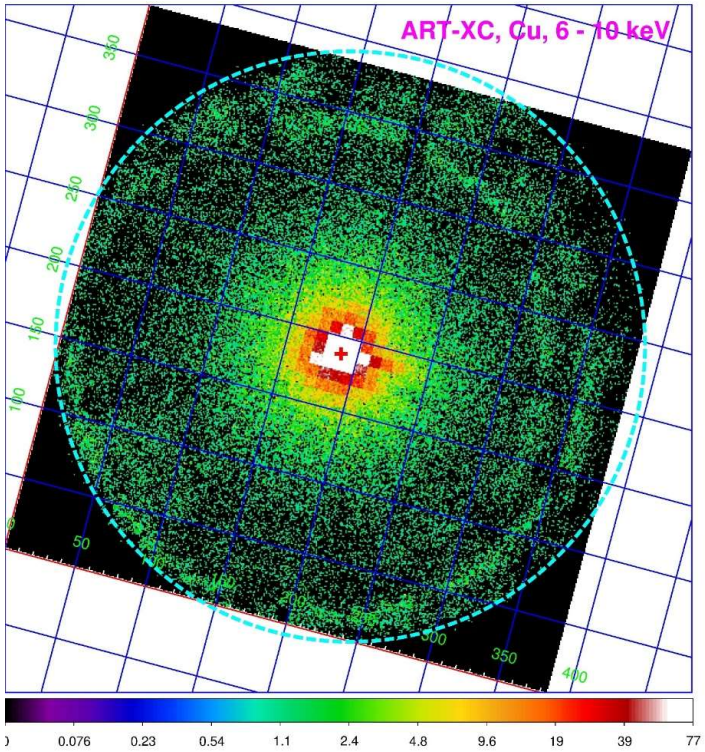
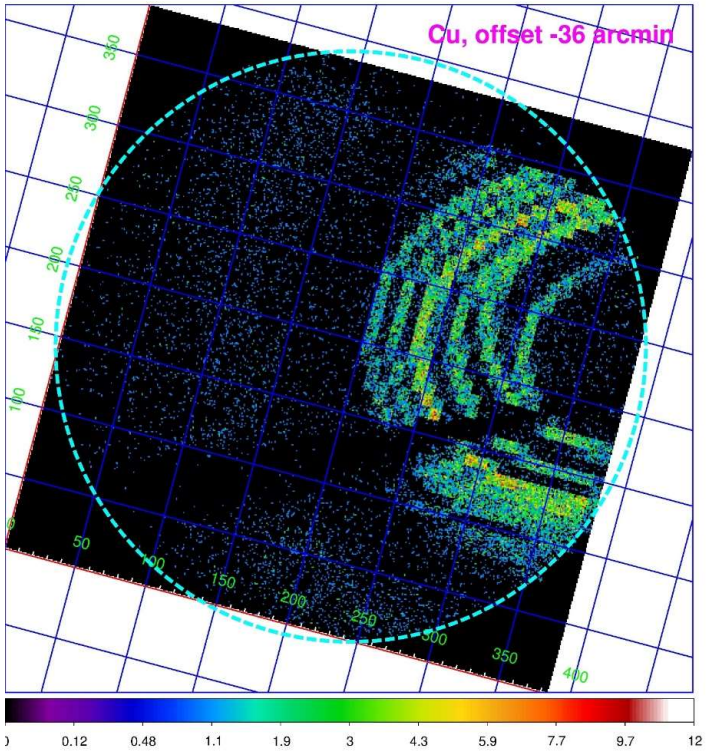




Effective Area Measurements



Single reflection contribution study

eROSITA post-launch baseline schedule

- Launch date June 21/22 2019 with backup July 12/13 20__
- Now with complementary visibility windows to previously assumed (preferred) Mar./Apr. or Sept./Oct. launch windows
- Min. 2 wks outgassing (telescope cover, filter wheel, cooling)
- 4 wks commissioning (1 + 2 + 2 + 2 cameras per week),
- 4 wks calibration (Cal) phase interleaved with
- 3 wks performance verification (PV) phase,
- 4 yrs survey(s) (90◦/h like XMM-Newton Slew Survey) interleaved with monitoring,
- 3+ yrs pointed programme (GO)

eROSITA post-launch schedule

- eROSITA: start calibration and performance verification observations,
  interleaved (enhance visibility),
  time-line dependant,
  In-flight calibration (+PV) plan documents:
  https://wiki.mpe.mpg.de/eRosita/PvPhase
- make use of communication sessions during ground contacts
- reach quasi-periodic orbit around L2
- End-of-CalPV Review ~ T0+ 66 days (Aug 27)
- start survey operations ~ T0+105 days

- complete calibration (if needed)
- monitoring observations (Fe-55/Closed and celestial sources)
- orbit corrections (station keeping)
  every 40 – 70 days
  (eROSITA mode to be finalized), survey rotation has to be stopped,
  use this occasion for pointed monitoring observations (RXJ 1856, 1E 0102)
- reaction wheel unloading (eROSITA observing, attitude may be degraded)

Main In-orbit calibration topics

- Commissioning
- Background (graded shield, calibration and monitoring, “Closed”, etc.)
- Plate scale and boresight of the 7 modules (star-trackers vs. mirror assembly)
- Filter integrity (launch, micrometeorites)
- Soft X-ray (and XUV) response and contamination monitoring
- Gain and CTI (calibration and monitoring, “CalClosed” Fe-55), RMF
- PSF (on-axis, off-axis, survey)
- Effective area, QE, flat-fielding, and vignetting
- Optical loading by point sources (energy shift, spurious sources)
- X-ray baffle (Sco X-1 visible until 22-SEP)
- Absolute and relative timing (and operational tests e.g., ROSAT-like “mini-survey” for time-delays between star tracker and X-ray cameras, attitude reconstruction)
- Power-law type spectrum (high-energy cross-calibration)
- clusters of galaxies (general cross-calibration, IACHEC)
- Monitoring every 6 months: RXJ1856 (contamination), 1E0102 (low-energy gain): highly recommended by IACHEC

Commissioning: 4 weeks

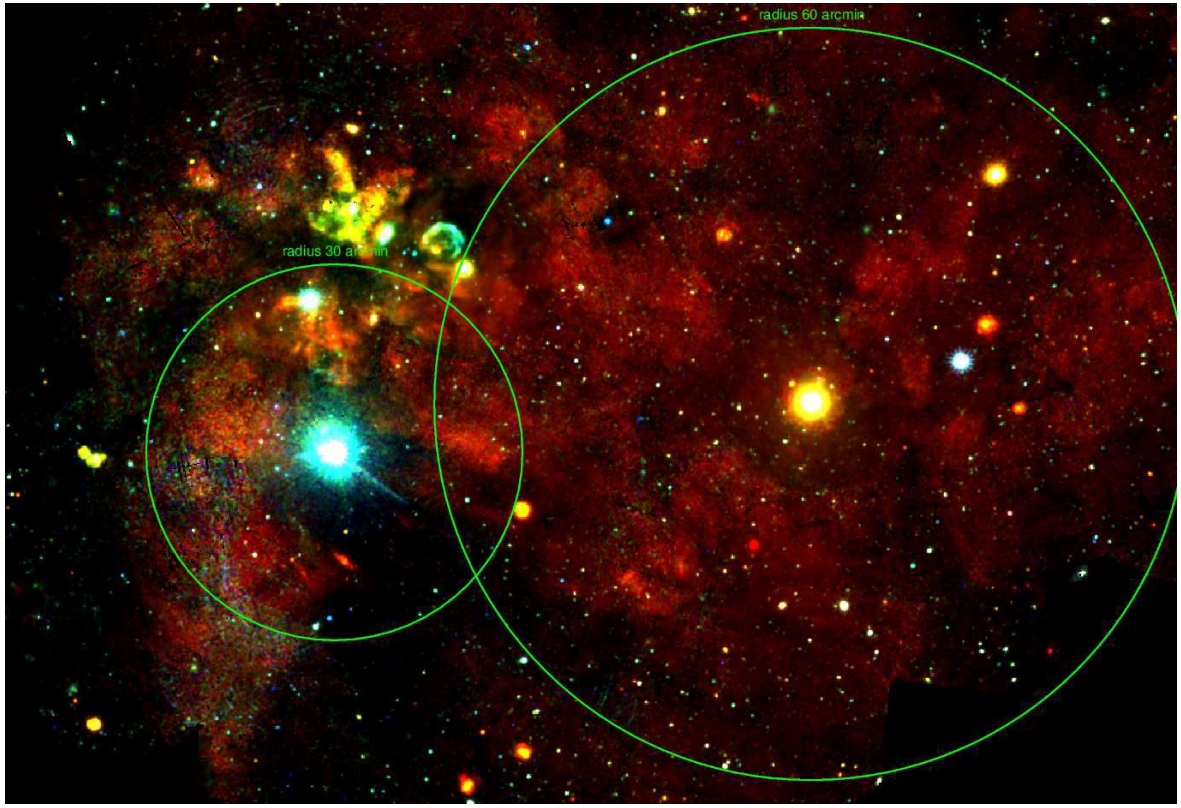
- closed (4 mm Al), calclosed (Fe-55), (low-gain mode like for EPIC-pn not implemented), “open” (i.e., filter): “Commissioning Light”
- Why as soon as possible:
  - immediate quicklook of :
  - background from sky (soft protons !)
  - filter integrity, optical loading,
  - mirror module health, PSF,
  - baffle performance,
  - single-reflections,
  - bore-sight, ...
- helps to optimize set-up for following “open” (filter) scientific CalPV observations
  (save weeks of time to possibly adapt on-board software, but also eSASS)

“Commissioning Light” (XMM-Newton EPIC image courtesy F.Haberl)

- Preferred target: LMC:
  30 Dor region / SN1987A
  (observable “at any time”)

Target name	RA (2000)	Decl. (2000)	l (deg)	β (deg)	Remark	Exp. (ks)
LMC (30 Dor)	053842.4	−690102	279.37	−86.827	each camera	40

- Minimum:
  - after commissioning of first camera (on-chip, TM6)
  - after commissioning of second camera (off-chip, TM5)
  - after commissioning of all cameras
- Commissioning phase determines and fixes the setup for the CalPV (and survey) phase



Looking forward to launch on June 20/21 and the eROSITA version of this image end of Aug 2019

Summary (nominal 21/22 June 2019):

```
launch T_0                    = DOY 172/173 = 21/22 June 2019
cooling of CCDs: T_0 + 41d    = DOY 213/214 = 1/2 Auguyst 2019
commissioning light #1 +5d    = DOY 218/219 = 6/7 August 2019
commissioning light #2 +9d    = DOY 222/223 = 10/11 August 2019
commissioning light #7 +24d   = DOY 237       25 August 2019
CalPV start       T_0 + 66d   = DOY 238       26 August 2019
CalPV end         T_0 + 125d  = DOY 297       24 October 2019
Survey start      T_0 + 126d  = DOY 298       25 October 2019
```

Summary (nominal 21/22 June 2019):

Omega Cen	(visibility ends!)	26.8.2019	20 ks * 4 positions
NGC 2516	(boresight #1)	27.8.2019	20 ks * 4 positions
PSR J1119-6127	(408 ms period)	1.9.2019	80 ks + overhead
PG 1634+706	(PSF, 1 source)		40 ks * 13 positions
RXJ 1856	(contamination #1)	13.9.2019	80 ks + overhead
1E 0102-72	(gain on-axis)	14.9.2019	60 ks + overhead
Mini-Survey	(Sco X-1)	15.9.2019	6 great circles
1E 0102-72	(gain off-axis +20')	16.9.2019	60 ks + overhead
1E 0102-72	(gain off-axis -20')	17.9.2019	60 ks + overhead
3C 58	(gain on-axis)	18.9.2019	80 ks + overhead
3C 58	(vignetting 12')		50 ks + overhead
3C 58	(vignetting 18')		50 ks + overhead
3C 58	(vignetting 24')		50 ks + overhead
1E 0102-72	(vignetting 12')		50 ks + overhead
1E 0102-72	(vignetting 18')		50 ks + overhead
1E 0102-72	(vignetting 24')		50 ks + overhead
Stars	(optical loading)	ground contacts (just offset map)	

Summary (nominal 21/22 June 2019):

A2199	(cluster X-cal)		60 ks
EXO0422	(cluster X-cal)		100 ks
MS0419.3+1943	(power-law)		40 ks
Mkn 3	(power-law)		40 ks
Vela SNR	(CTI)		60 ks
PG 1658+441	(XUV on-axis))	22.10.2019	40 ks + overhead
PG 1658+441	(XUV off-axis 20')	22.10.2019	40 ks + overhead
NGC 2516	(boresight #2)	23.10.2019	80 ks + overhead
RXJ 1856	(contamination #2)	24.10.2019	80 ks + overhead
1E 0102-72	(gain)	24.10.2019	40 ks

Monitoring:

Survey #1		25.10.2019	180 days
RXJ 1856	(contamination monit.)	(11.3.2020 - 22.4.2020)	80 ks
1E 0102-72	(gain monit.)	(11.3.2020 - 1.7.2020)	80 ks
Closed filter	(background)	1 camera per day	
CalClosed filter	(gain/CTI)	1 camera per day	