The Microchannel X-ray Telescope

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Max-Planck-Institut für extraterrestrische Physik

cnes CENTRE NATIONAL D'ÉTUDES SPATIALES

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On behalf of the MXT Team

Presentation Plan

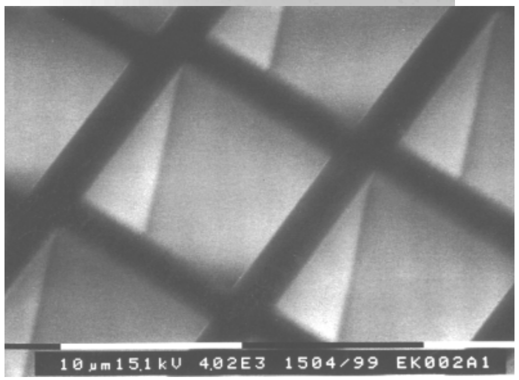
- MXT scientific performance
  - Design
  - Sensitivity
  - GRB Localization capabilities
  - Spectral capabilities

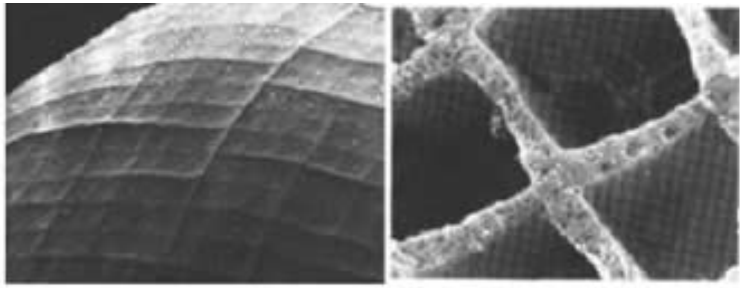
- MXT on-board data processing and data format

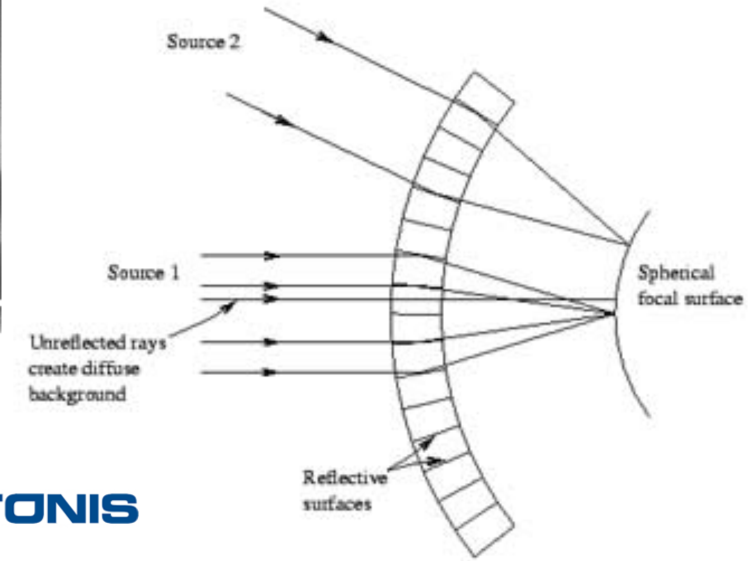
- Conclusions

Microchannel X-Ray Telescope

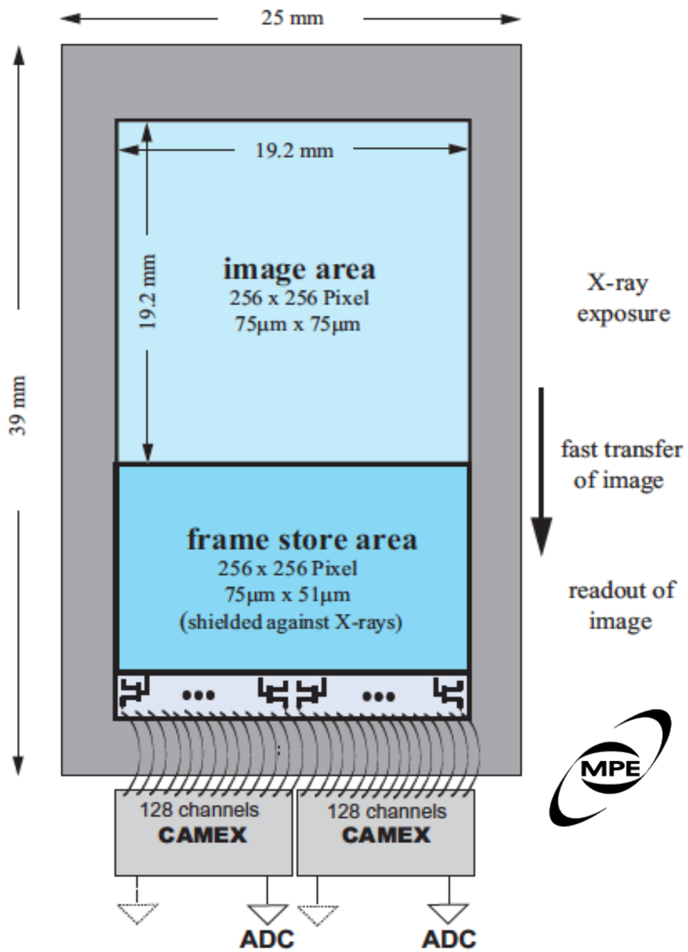
Micro Channel Plate (MPOs) Optics of 40 microns in a "Lobster Eye" configuration





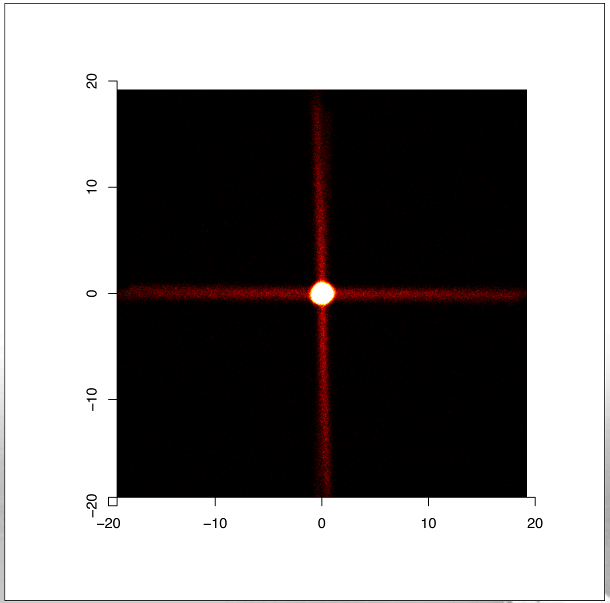


« DUO » pnCCD



Operated in PC mode at 100 ms frequency

Point Spread Function



- 0 or even # of reflections from opposite sides of pore

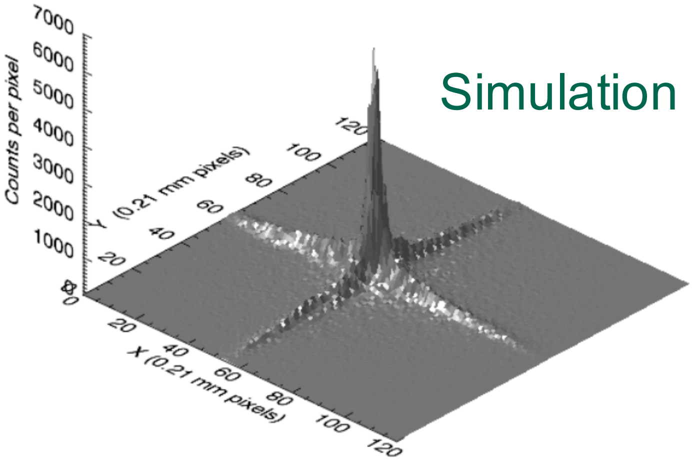
-> Diffuse flux, no imaging , ~8% flux

- Odd # of reflections from opposite sides of pore

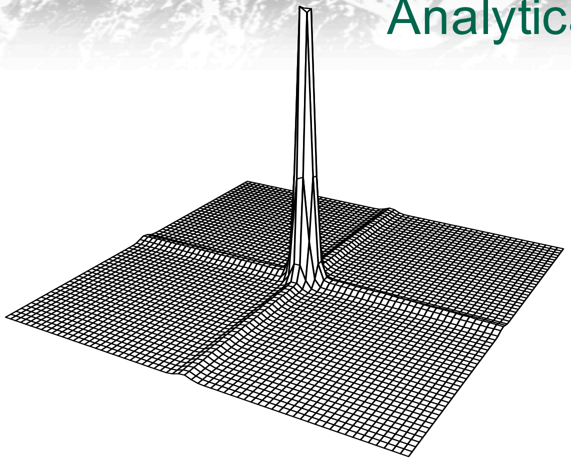
-> Line focus ~2x21% of flux

- Even # reflections from adjacent sides of pore

-> 2-D focus central spot ~50% flux



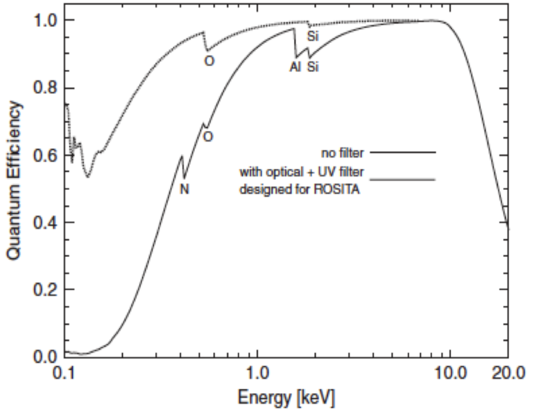
Simulation



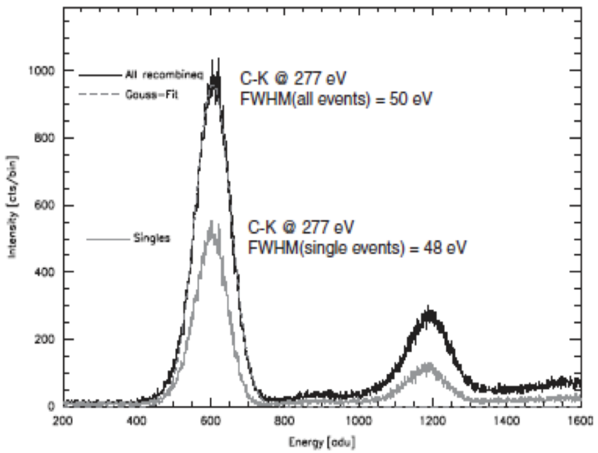
Analytical model

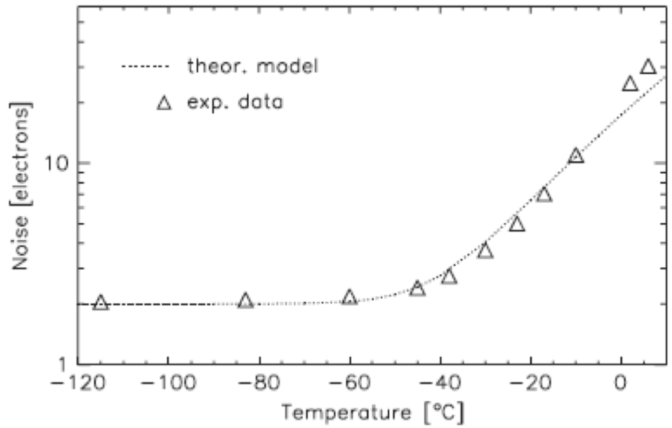
MPE DUO CCD performance

- The MXT optics are most efficient below 2 keV (short focal length)



The DUO CCD has an excellent low energy response (QE, en. resolution and low noise)



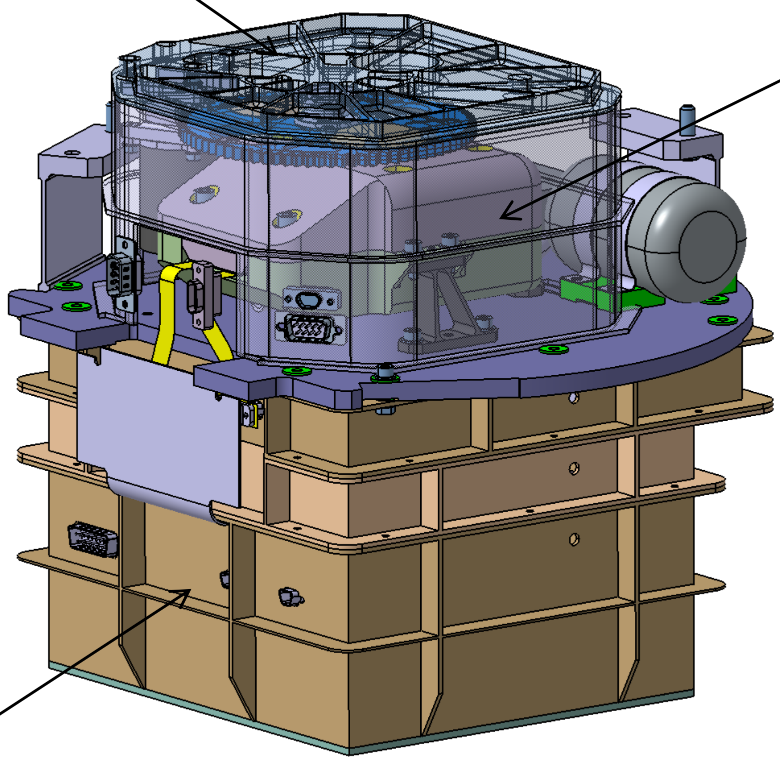


Meidinger+06

Camera mechanical design

Wheel assembly

Focal plane assembly



Front-end electronics

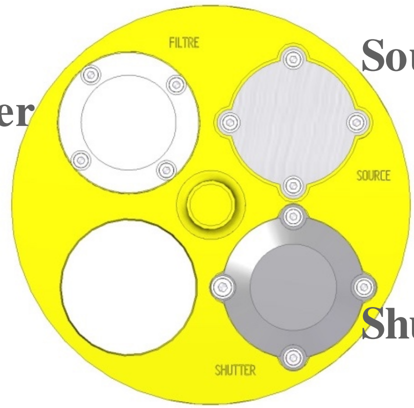
Opt/UV Filter

Source

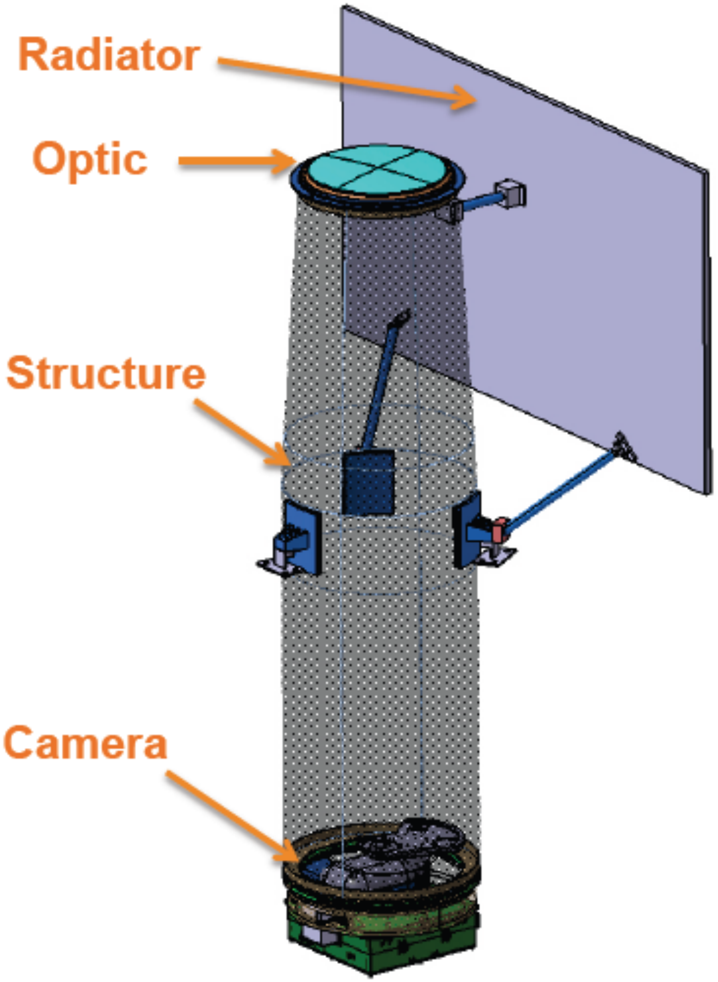
$^{55}Fe + Al$

Open

Shutter

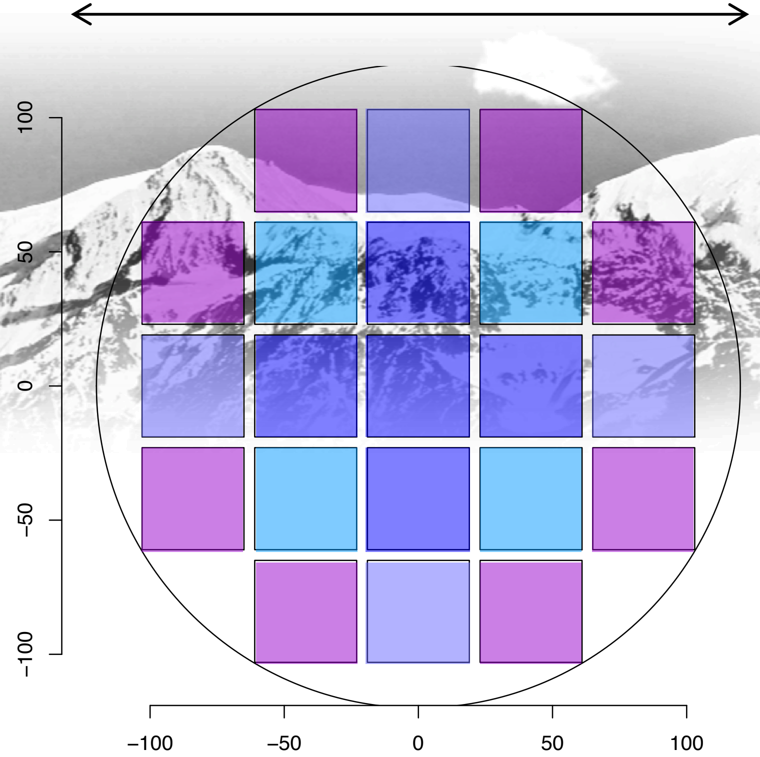


MXT telescope layout



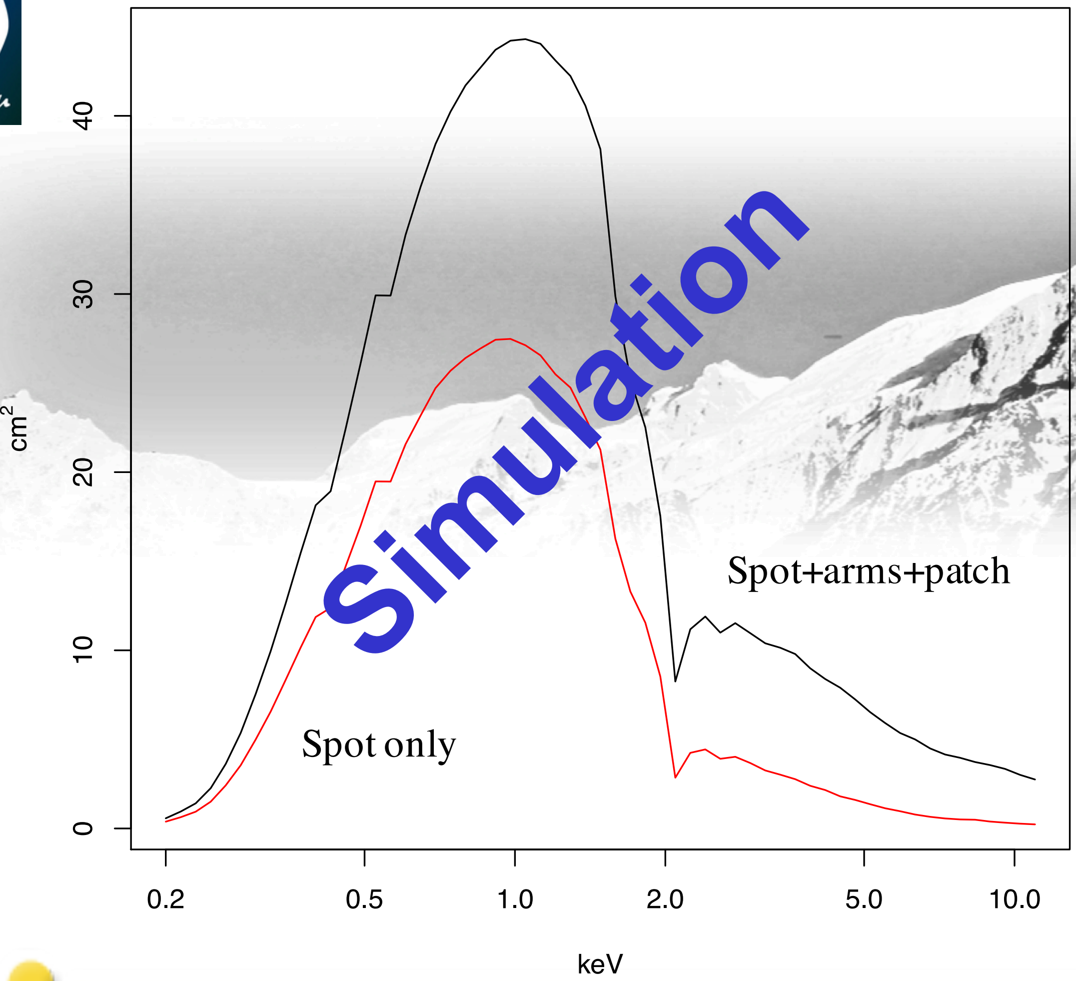
Few mm thickness
(channel lenght)

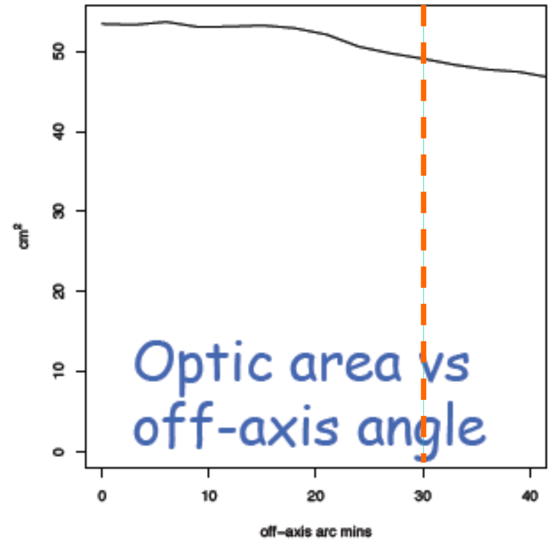
240 mm



MXT Requirements: Effective Area

Aeff @ 1 keV 27 cm^2, PSF width ~4.5 arc min, very small vignetting

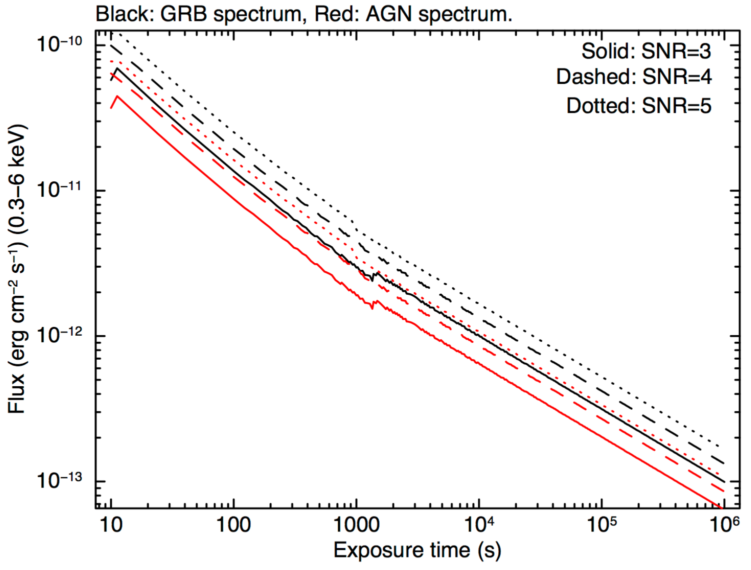


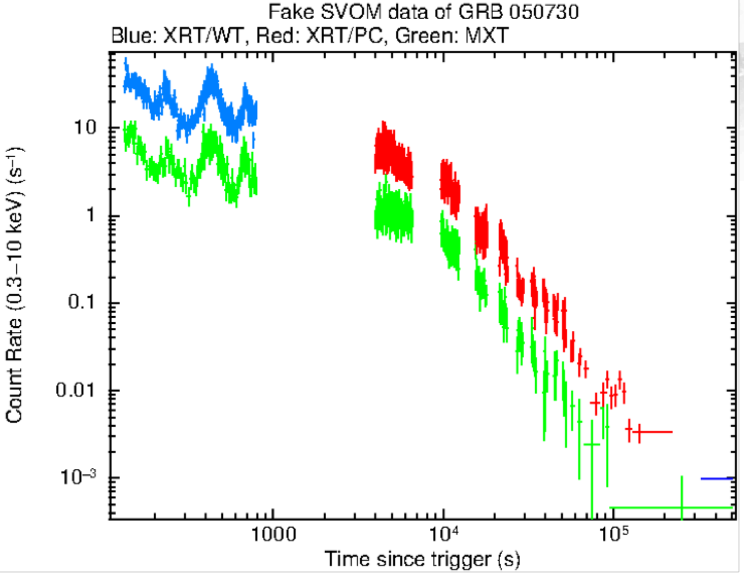


MXT Sensitivity (GRBs)

Simulations show that:

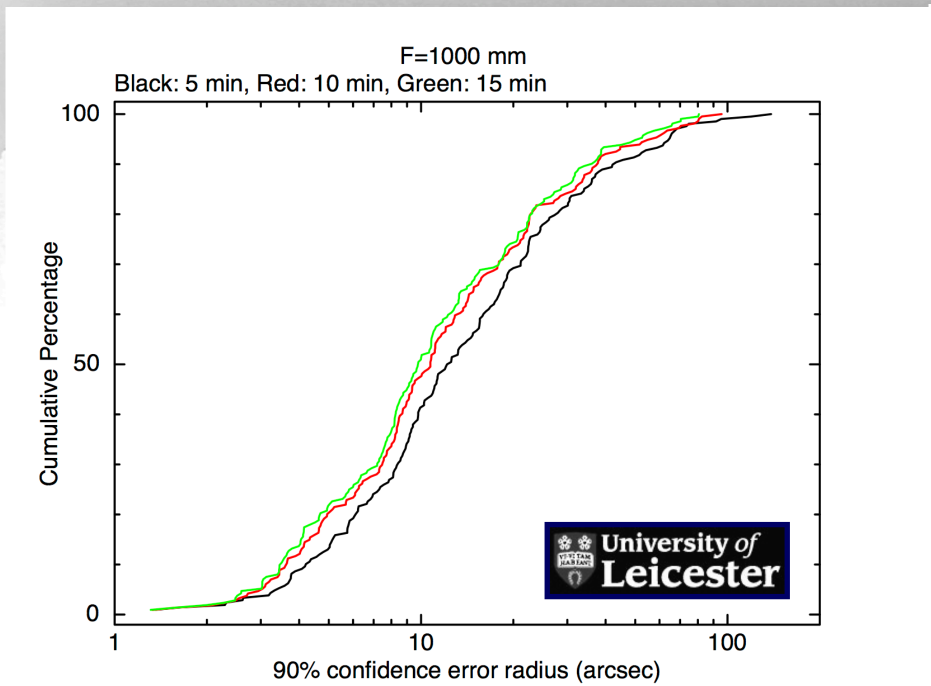
- Virtually all the GRBs detected by ECLAIRs will be detected and localized by MXT, given that they are pointed sufficiently early (1^{st} orbit)
- even for faint GRB afterglows a detection is expected up to 10^5 s after the T_0 (i.e. up to ~18 orbits, provided integration over a few orbits), while after that time the chances of detecting the afterglow are small.

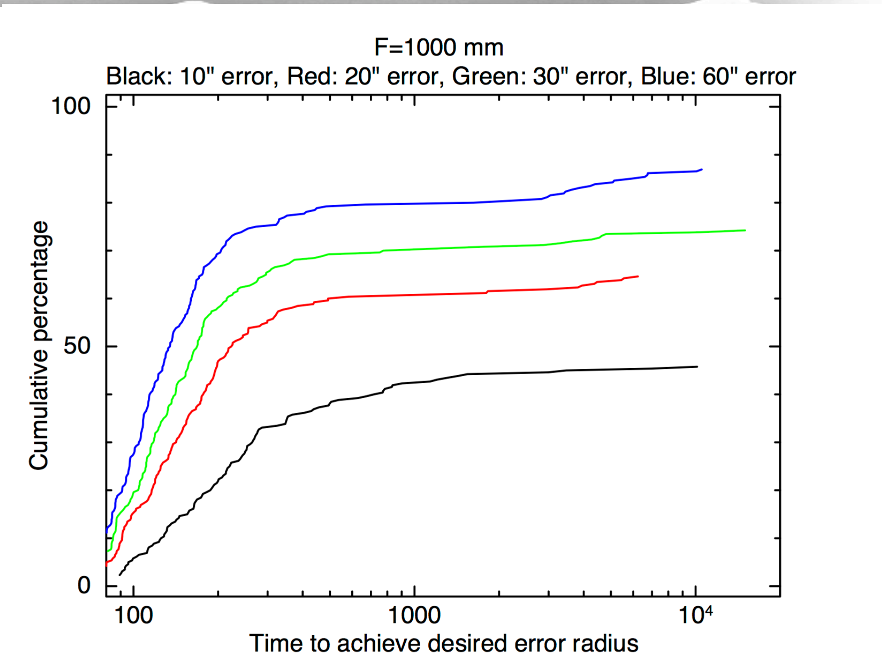




Localization Simulations Results

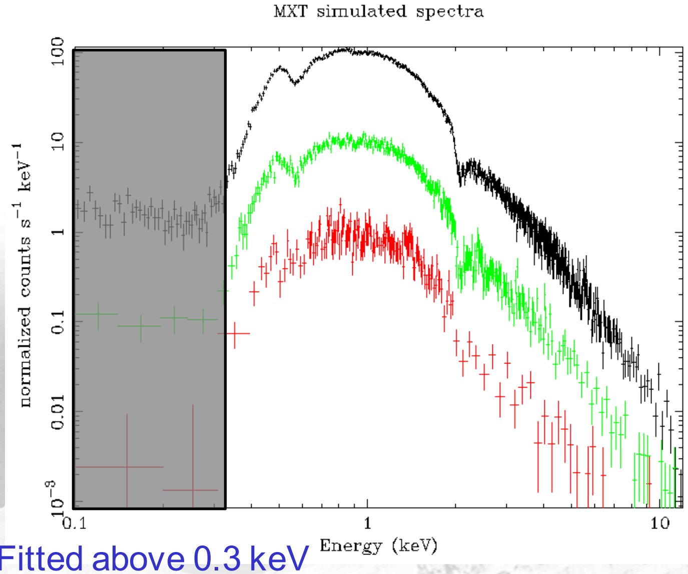
- Compared to all bursts detected at the time (**statistical error only!**):
- – 50% of sources have R90 < 12” at 5 min after trigger (83% det)
- – 90% of sources have R90 < 43” at 5 min after trigger
- – 50% of sources have R90 < 11” at 10 min after trigger (84% det)
- – 50% of sources have R90 < 10” at 15 min after trigger (85% det)
- Detection algorithm not yet optimised to use larger bkg region (counts cumulated on 10x10 arc min spot)





MXT Spectral resolution & summary

MXT will have state of the art CCD spectral resolution dE = 75 eV (FWHM) at 1.5 keV at launch.



Fitted above 0.3 keV

Derived spectral parameters at 90% c.l.:

Crab

Parameter	Confidence Range		Input
N_H	0.340	0.347	0.345
Γ	2.07	2.11	2.1
Norm.	8.85	9.04	9

100 mCrab

Parameter	Confidence Range	
N_H	0.33	0.35
Γ	2.02	2.13
Norm.	8.7e-1	9.3e-1

10 mCrab

Parameter	Confidence Range	
N_H	0.31	0.37
Γ	1.87	2.24
Norm.	7.5e-2	9.0 e-2

Energy Range	0.2-10 keV
Field of view	64×64 arc min
Point Spread Function	4.5 arc min (FWHM @ 1.5 keV)
Sensitivity (5 σ)	$\sim 10^{-10}$ erg cm^{-2} s^{-1} in 10 s $\sim 2\times10^{-12}$ erg cm^{-2} s^{-1} in 10 ks
Throughput	1 mCrab ∼0.20 ct/s for N_H=4.5x10^{21} cm^{-2}, photon index = 2.08
Energy Resolution	∼75 eV (FWHM @ 1 keV)
Time Resolution	100 ms

MXT Science simulator (L. Gosset)

Produces event files and spectra (central spot)
Includes X-ray bcakground (CXB and galactic)
Constant & time variable sources (declining spectra as t^{-alpha}; periodic sources (sinusoidal variation))
Up to date spectral and spatial response (incl. vignetting), pile-up

Not yet: Particle background (after pattern recognition)
Patterns (mainly doubles)
Detector and optics defects

e.g. 10 mCrab source in 2000 s.
Total number of counts 6620.

File Edit Tools Help

Select	TIME	Y	Z	PHA	E	PATTERN	PHOT_ORIGIN	PILE_UP
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3	1.000000014901E-01	125	127	529	4.575152E+00	0	0	1
4	1.000000014901E-01	124	122	207	1.451751E+00	0	0	0
5	1.000000014901E-01	134	95	181	1.251239E+00	0	0	0
6	1.000000014901E-01	127	126	181	1.251239E+00	0	0	0
7	1.000000014901E-01	125	125	160	1.094926E+00	0	0	0
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9	1.000000014901E-01	172	168	92	6.233402E-01	0	0	0
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11	1.000000014901E-01	82	130	133	9.013546E-01	0	0	0
12	1.000000014901E-01	126	3	167	1.146470E+00	0	0	0
13	1.000000014901E-01	126	129	231	1.643695E+00	0	0	0
14	1.000000014901E-01	84	220	250	1.800317E+00	0	0	0
15	1.000000014901E-01	127	127	81	5.520187E-01	0	0	0
16	1.000000014901E-01	127	176	209	1.467495E+00	0	0	0
17	1.000000014901E-01	130	208	164	1.124311E+00	0	0	0
18	2.000000029802E-01	129	204	117	7.905761E-01	0	0	0
19	2.000000029802E-01	126	126	127	8.594700E-01	0	0	0
20	2.000000029802E-01	132	144	133	9.013546E-01	0	0	0

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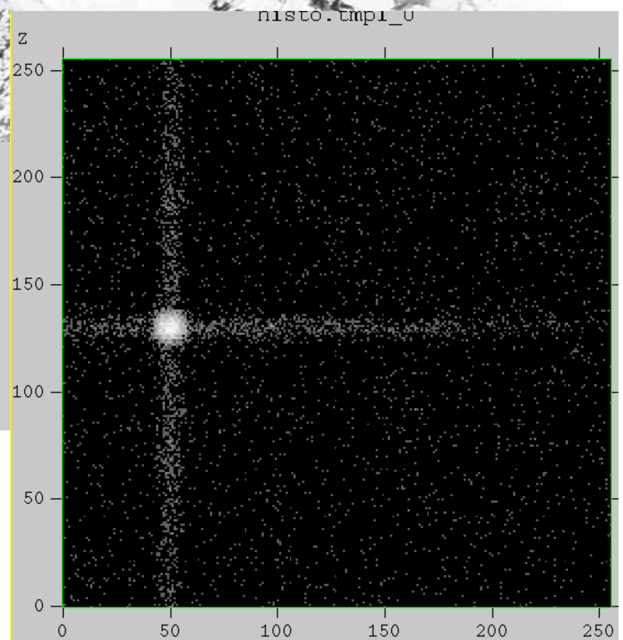

On board processing and data products

- MXT will autonomously localize the GRB counterparts on board and send their position to ground via the VHF channel, and to the VT to created finding charts and sub-images (pattern recognition and barycentering will be done on the fly on board by the M-DPU)
  - A first 2 sec image will be computed (chance mode) once the instrument is stabilized after the satellite slew
  - The image will incrementally updated every 30 s -> position amelioration
  - The timeout is the end of the second orbit
  - Pre-stabilization frames could also be used
- MXT will generate VHF data packets: about 180 counts (detector position, energy, pattern) will be sent to ground through the VHF channel. They can be used as diagnostic on the position computed on board
  - MXT VHF data download could be activated on request for peculiar observation, like MM-TOO (proposal under evaluation)
- MXT X-band data will be composed of photon lists (complete patterns) extracted from the 100 ms frames. MXT has a single "photon counting" mode

Conclusions

- MXT is a small, light (~35 kg vs hundreds of kg for ROSAT, Swift/XRT or eROSITA) and compact X-ray telescope
- It's design has been tailored to fit the GRB needs on a small class mission like SVOM
- It can reach a sensitivity of about < 1 mCrab in a few ks, which makes it a valuable tool to follow-up different kind of transients during their early phases
- It can provide long term X-ray monitoring of sources in the B1 law configuration, and snapshots of the galactic plane sources
- Its large FOV/grasp is adapted for the follow-up of non-photonic alerts (see C. Lachaud's presentation)