LOBSTER – New Space X-ray Telescopes

R. Hudec, M. Skulinová and V. Šimon, Astronomical Institute, Academy of Sciences of the Czech Republic, Ondrejov, Czech Republic

L. Pína and L. Švéda, Faculty of Nuclear Science, Czech Technical University, Prague, Czech Republic

A. Inneman and V. Semencová, Center of Advanced X-Ray Technologies, Reflex s.r.o., Prague, Czech Republic

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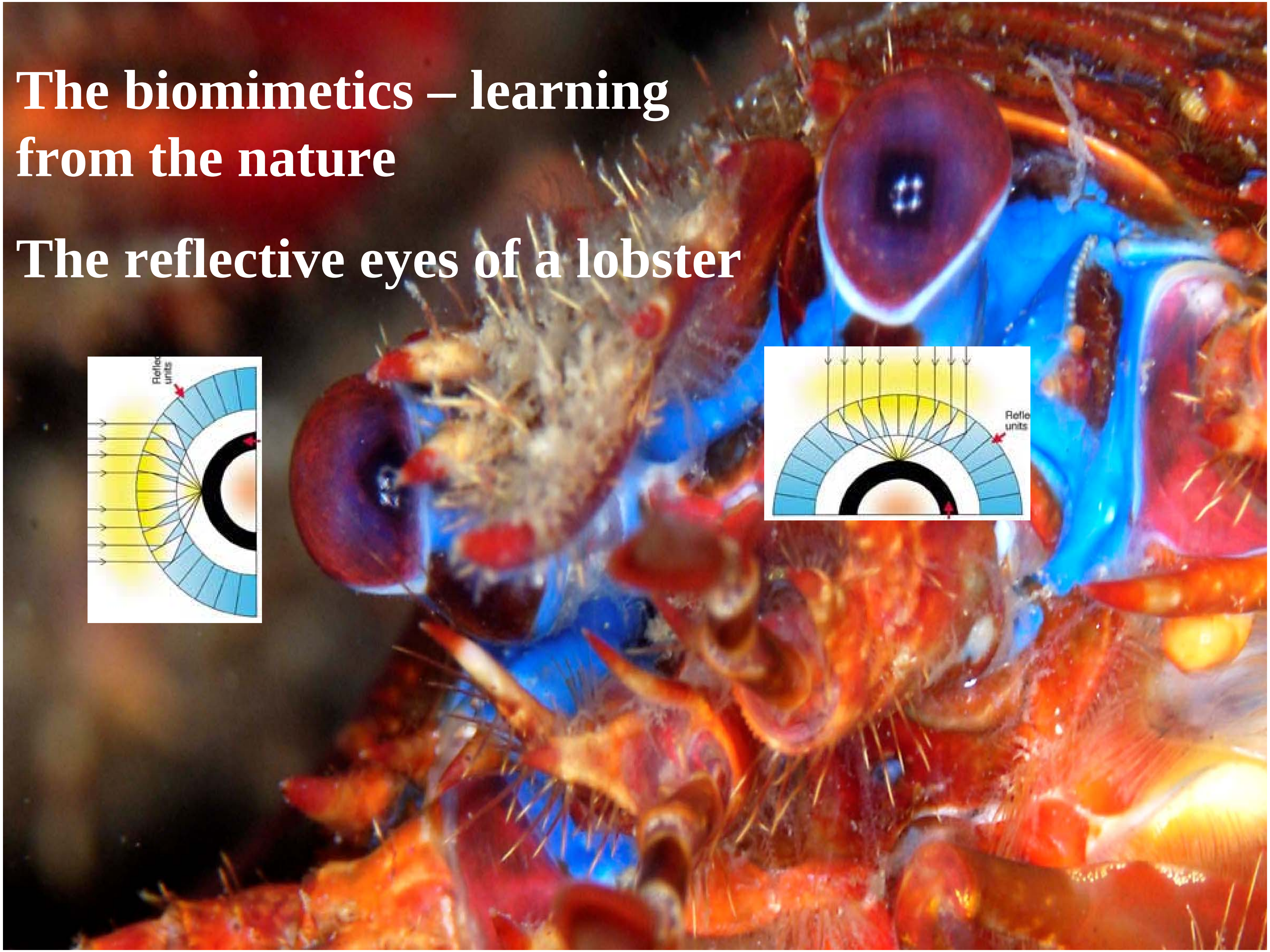
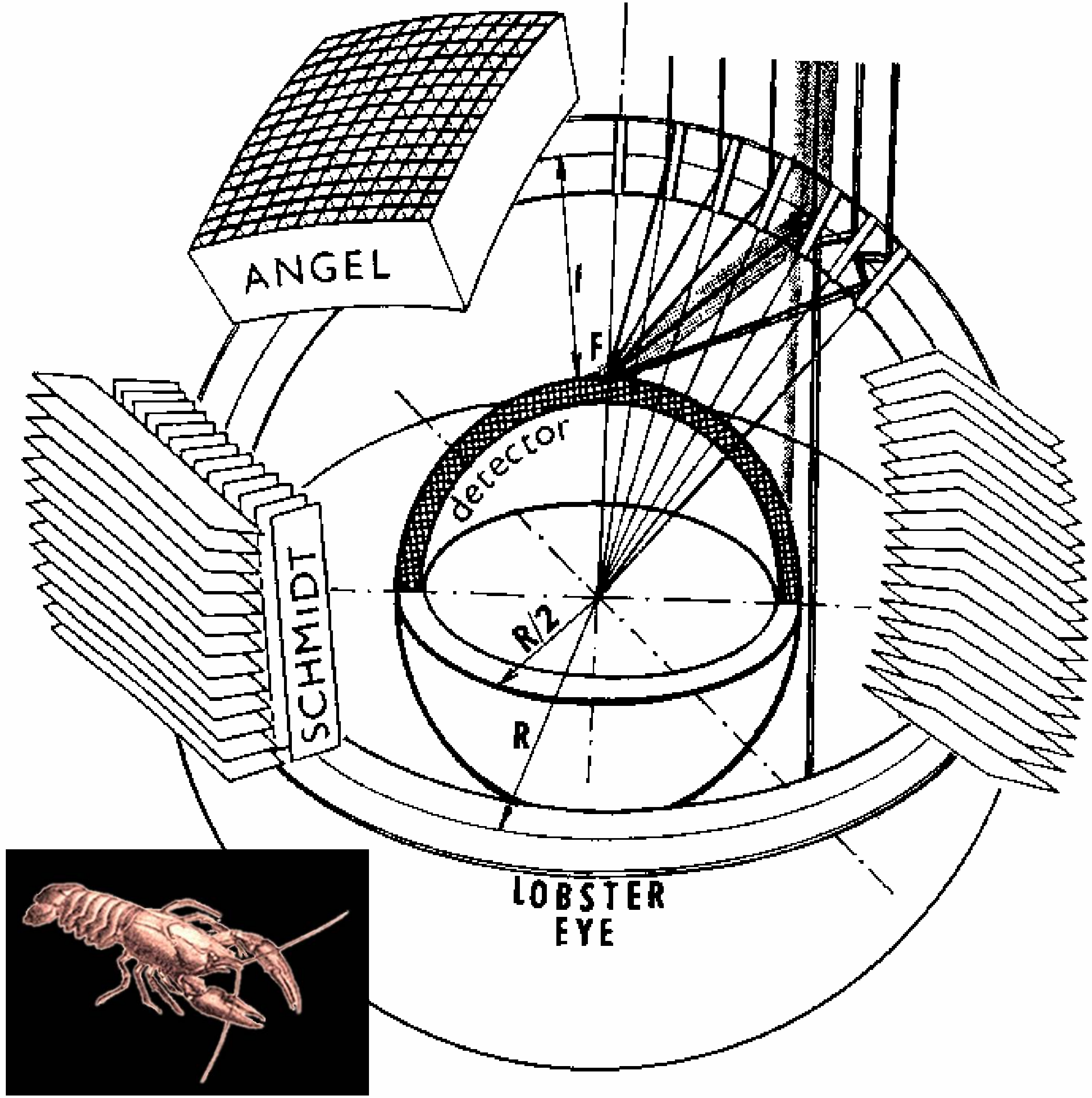
Lobster-Eye (LE)

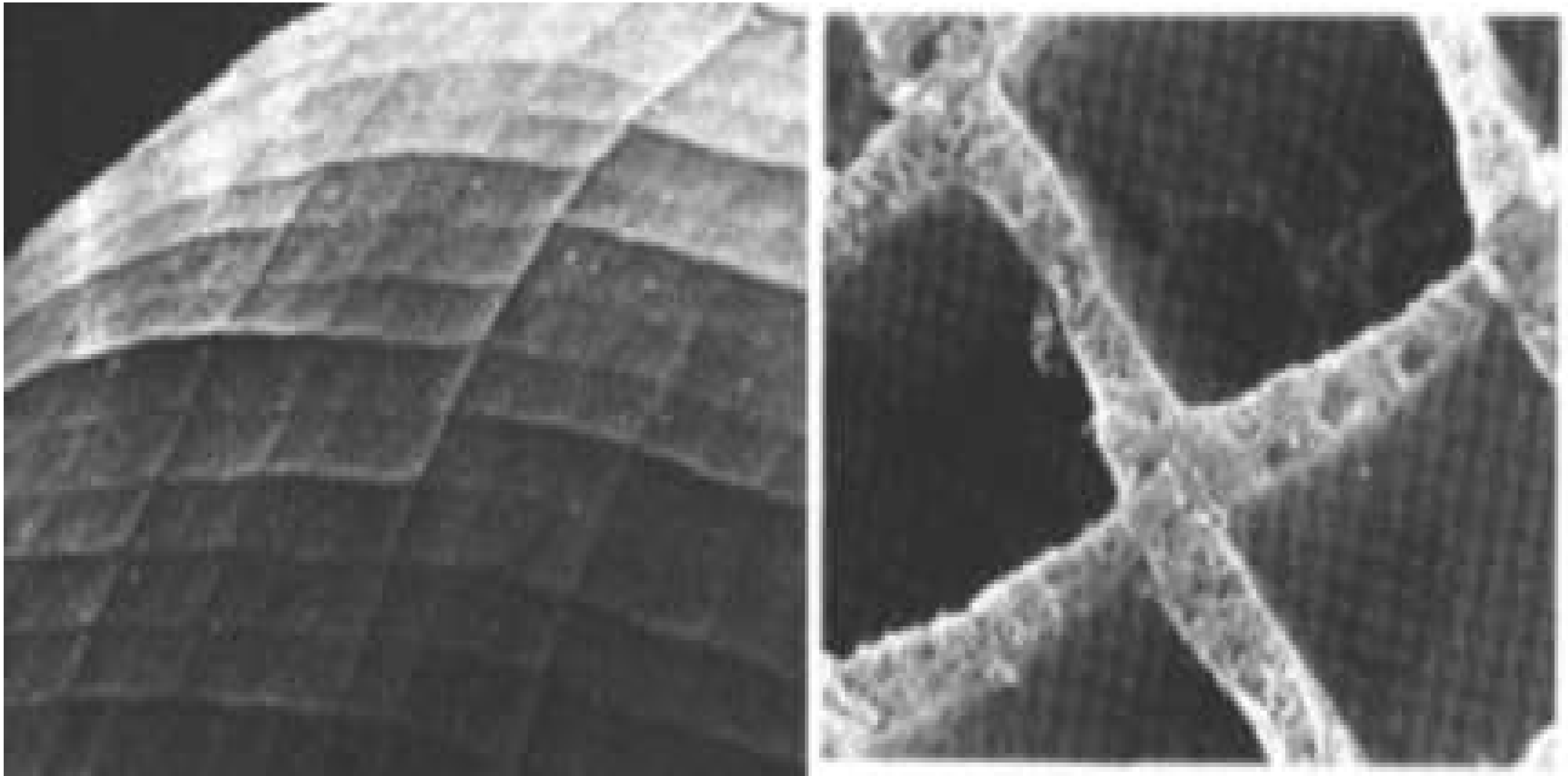
- Novel Wide Field X-ray Telescopes
- FOV of 100 sq. deg. and more easily possible (classical X-ray optics only 1 deg or less)
- Analogy with lobster eyes
- Designed for astronomy, but laboratory applications also possible

The biomimetics – learning from the nature

The reflective eyes of a lobster

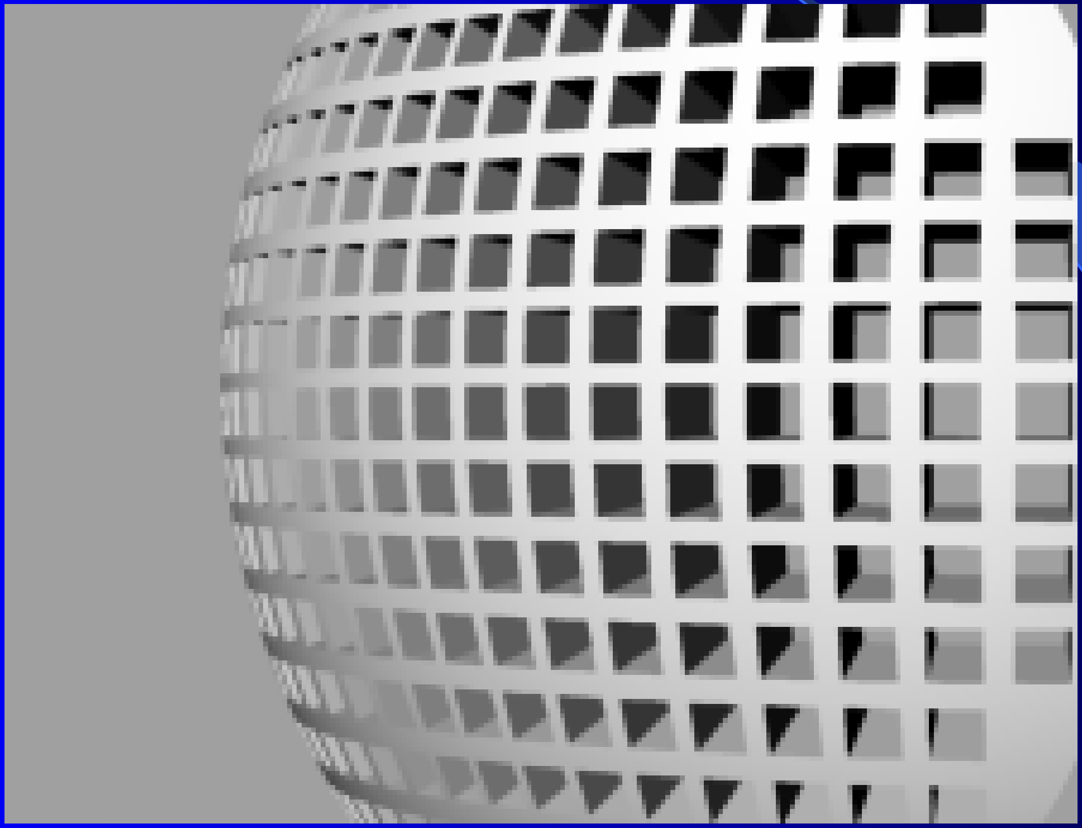



ANGEL
SCHMIDT
detector
F
f
R/2
R
LOBSTER
EYE



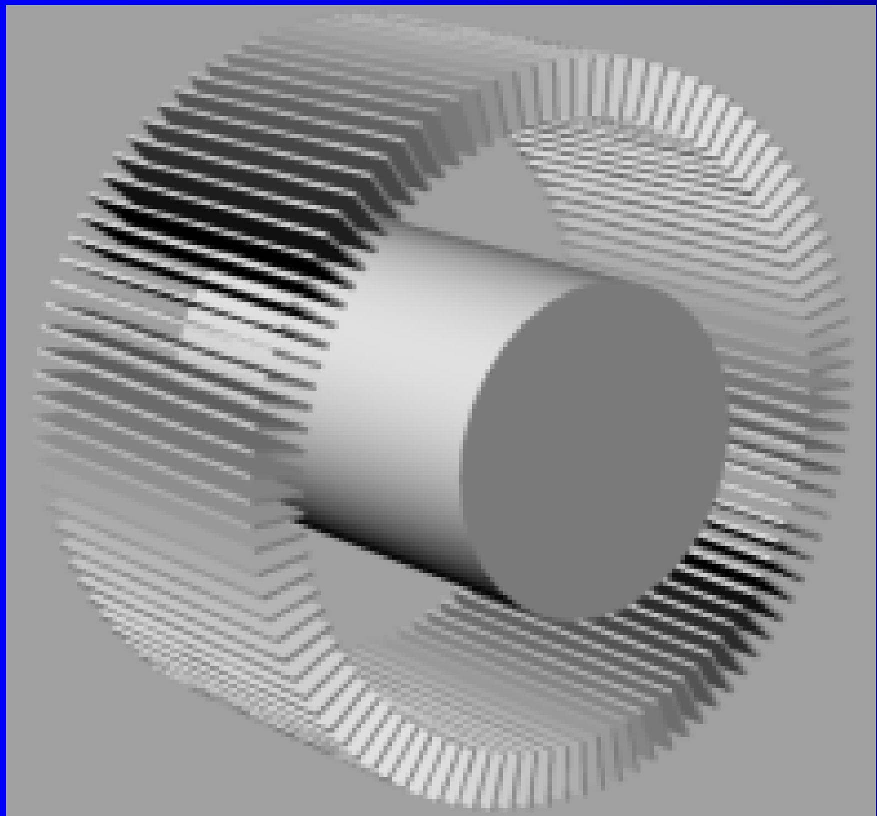
The eye of a lobster, viewed with a microscope. Right: closeup of a small area of the eye. The eye consists of millions of square "channels"; each channel measures approximately 20 microns (or two hundredths of a millimetre) across..

Lobster Concept

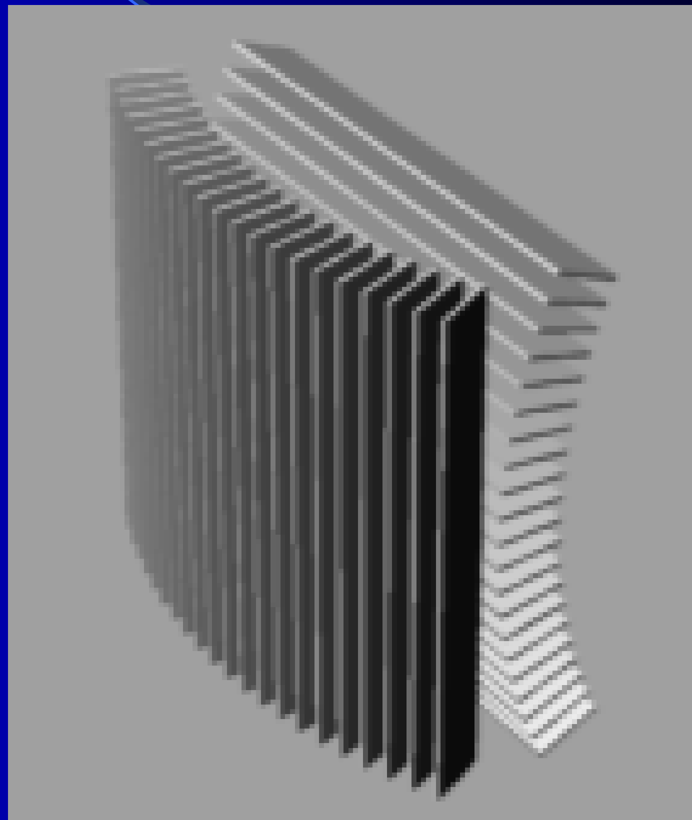


Angel arrangement

Lobster Concept



1D Schmidt



2D Schmidt

LE International Space Station (ISS) like design

MCP design

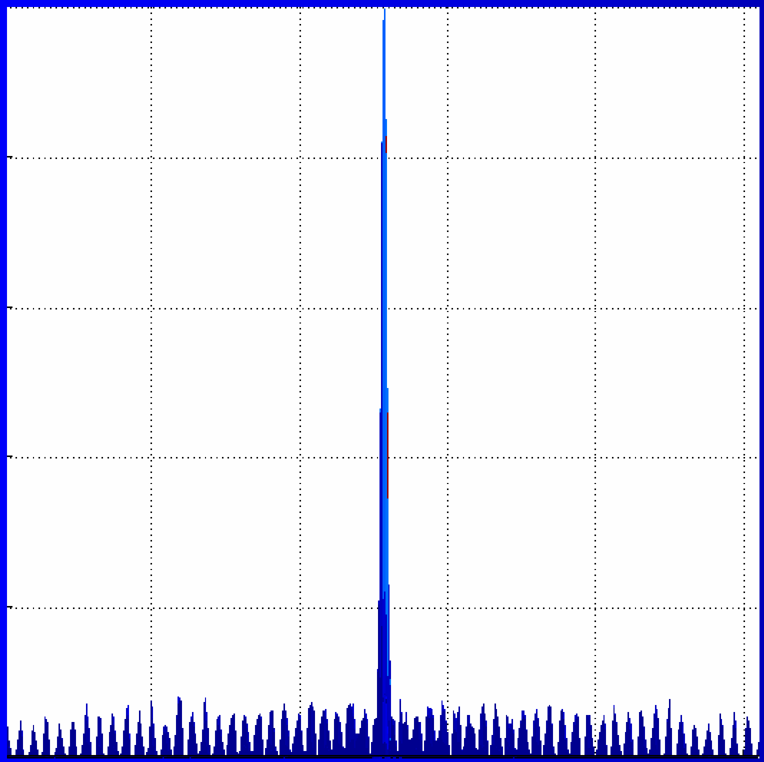
(microchannel plate)

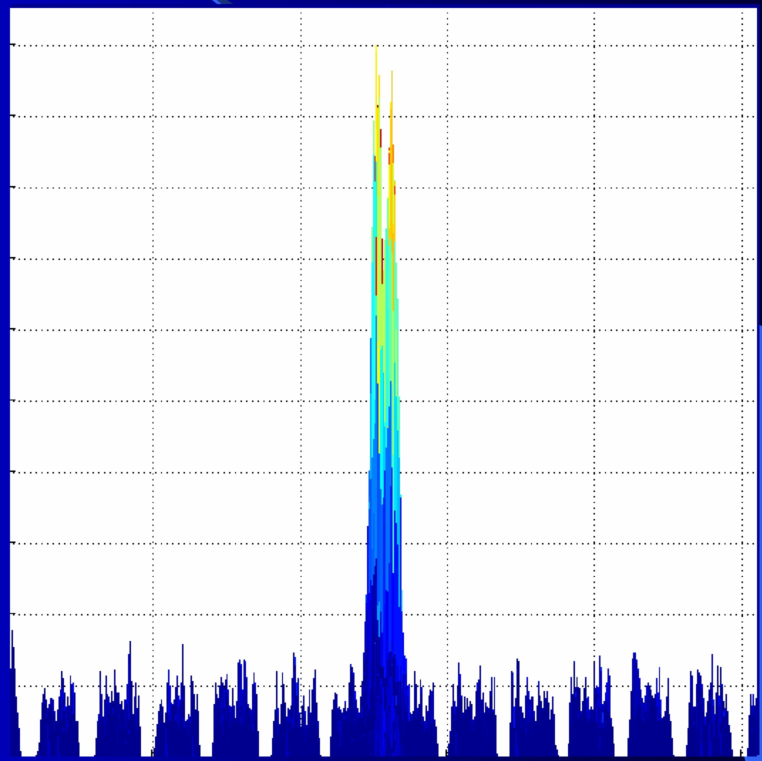
UK - Univ. of Leicester - collab.

Angel arrangement

Thin foil design - Multi Foil Optics (MFO)
(this talk)
CZ- collaboration
prototypes already available and tested
high gain ~ 600
better energy range - up to 10 keV
Schmidt arrangement

Simulated pointed observations



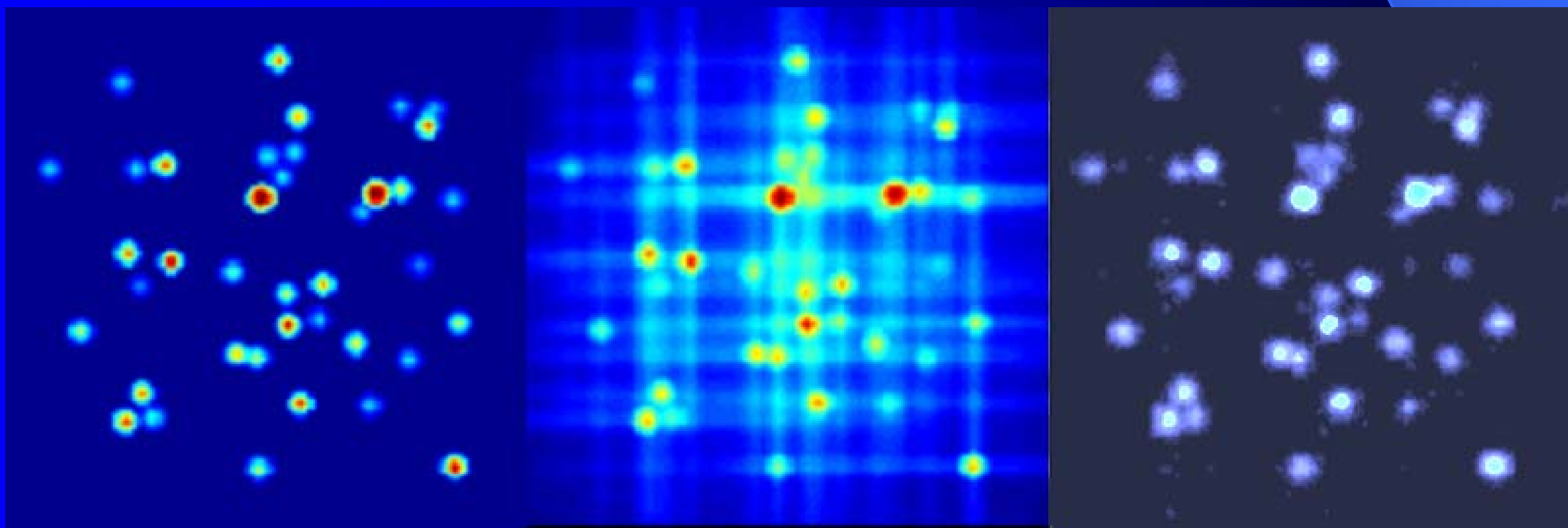


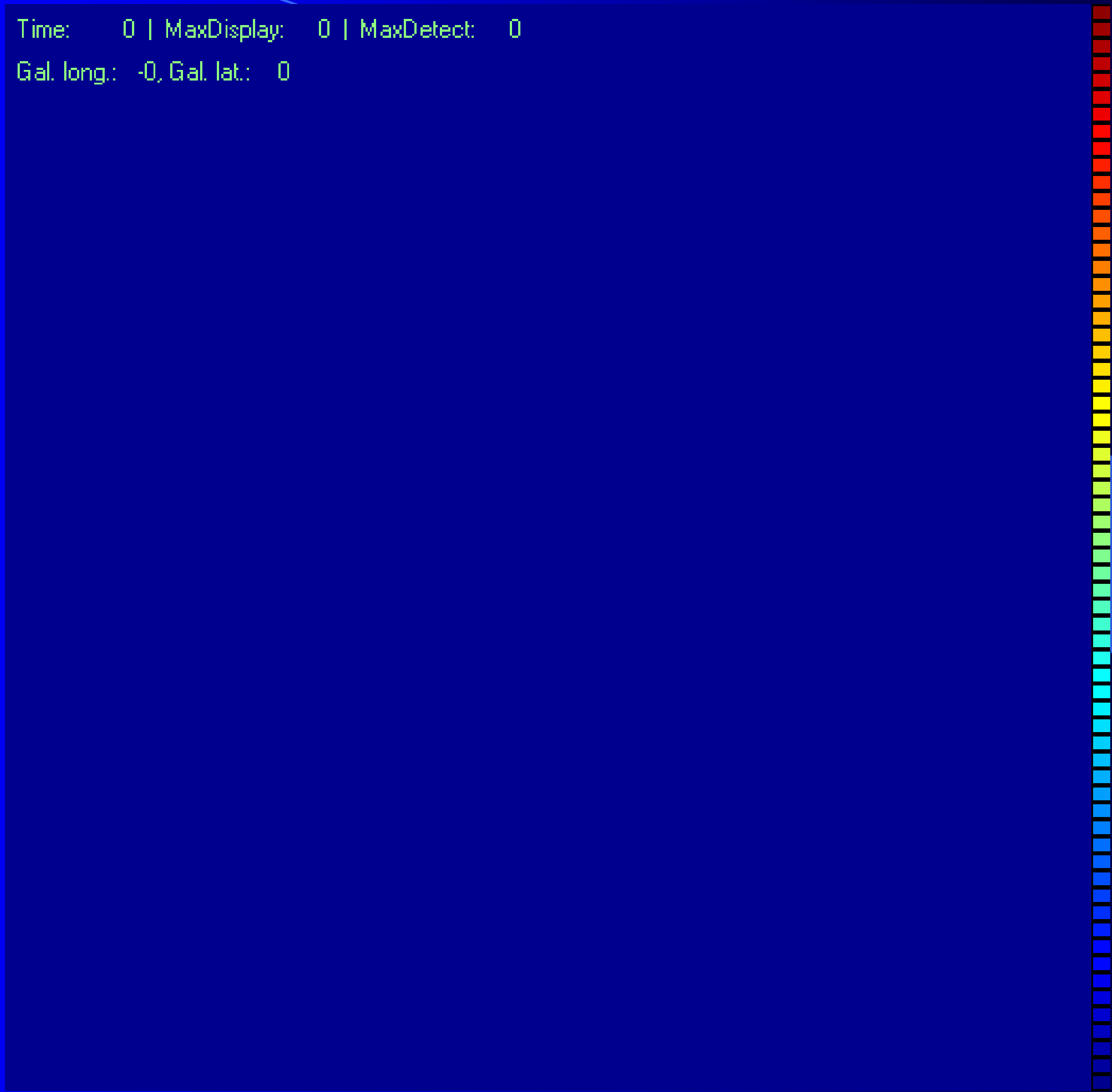
PSF – 5 keV photons, golden layered plates, 78 mm x 11.5 mm x 100 μm plates, 300 μm spacing

Simulated pointed observations

- for low energies (cross faint relative to the central peak) standard deconvolution techniques can be used successfully
- for strong cross structures PSF subtraction was successfully used
- 5 keV PSF & PSF subtraction example at the figure below

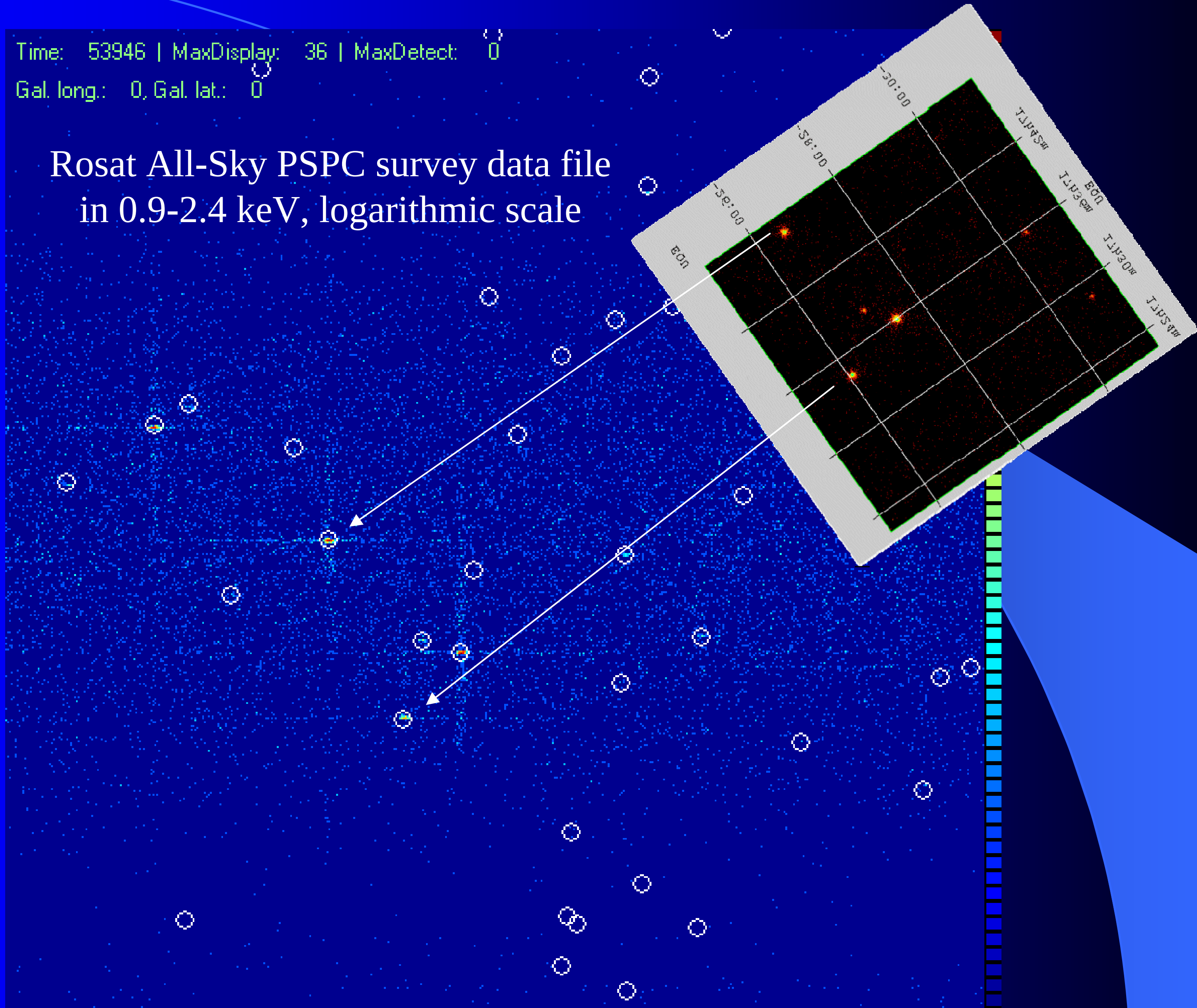
Test field Convolved Deconvolved





logarithmic scale

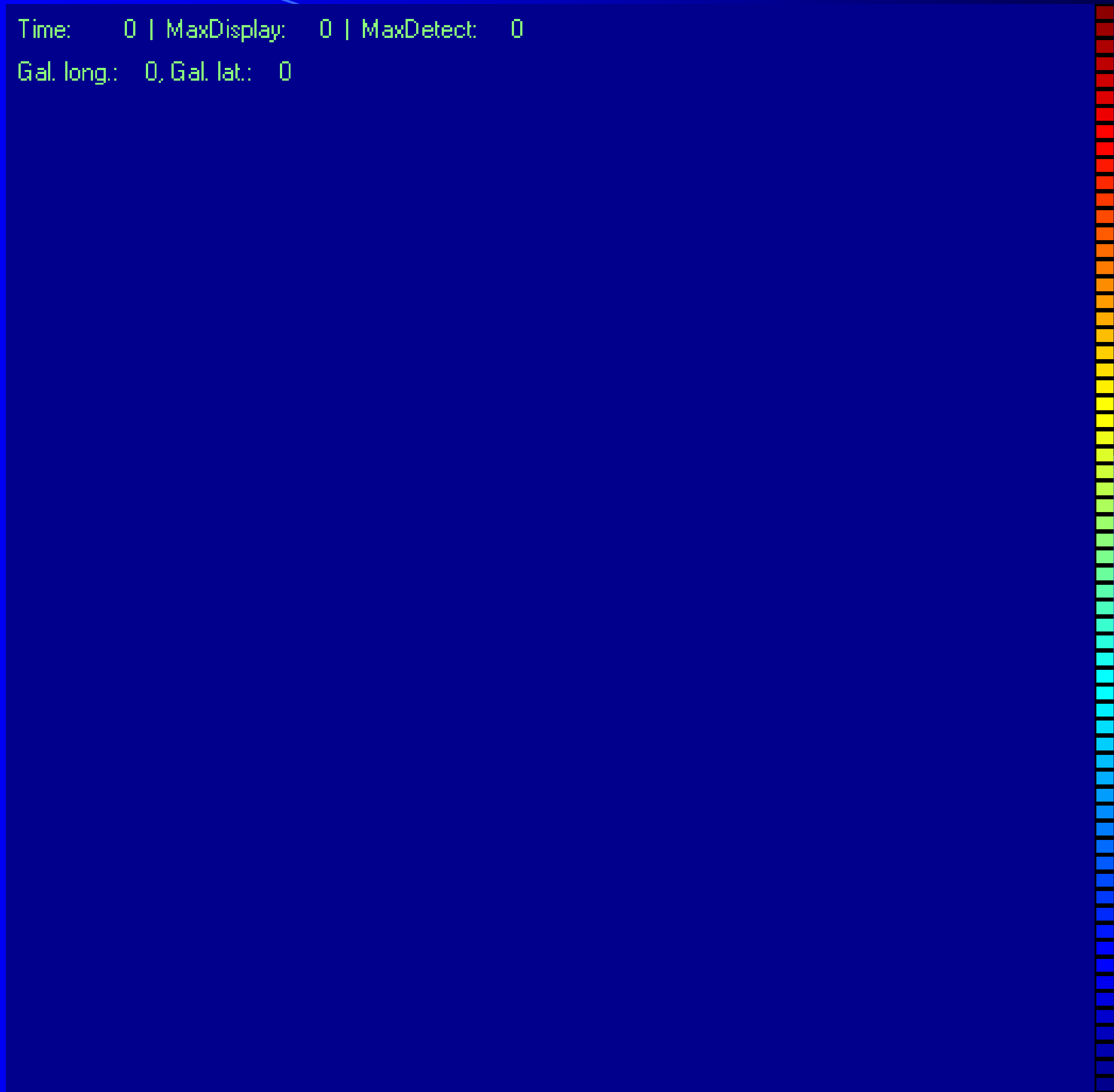
Rosat All-Sky PSPC survey data file
in 0.9-2.4 keV, logarithmic scale



logarithmic scale

Simulated scanned observations

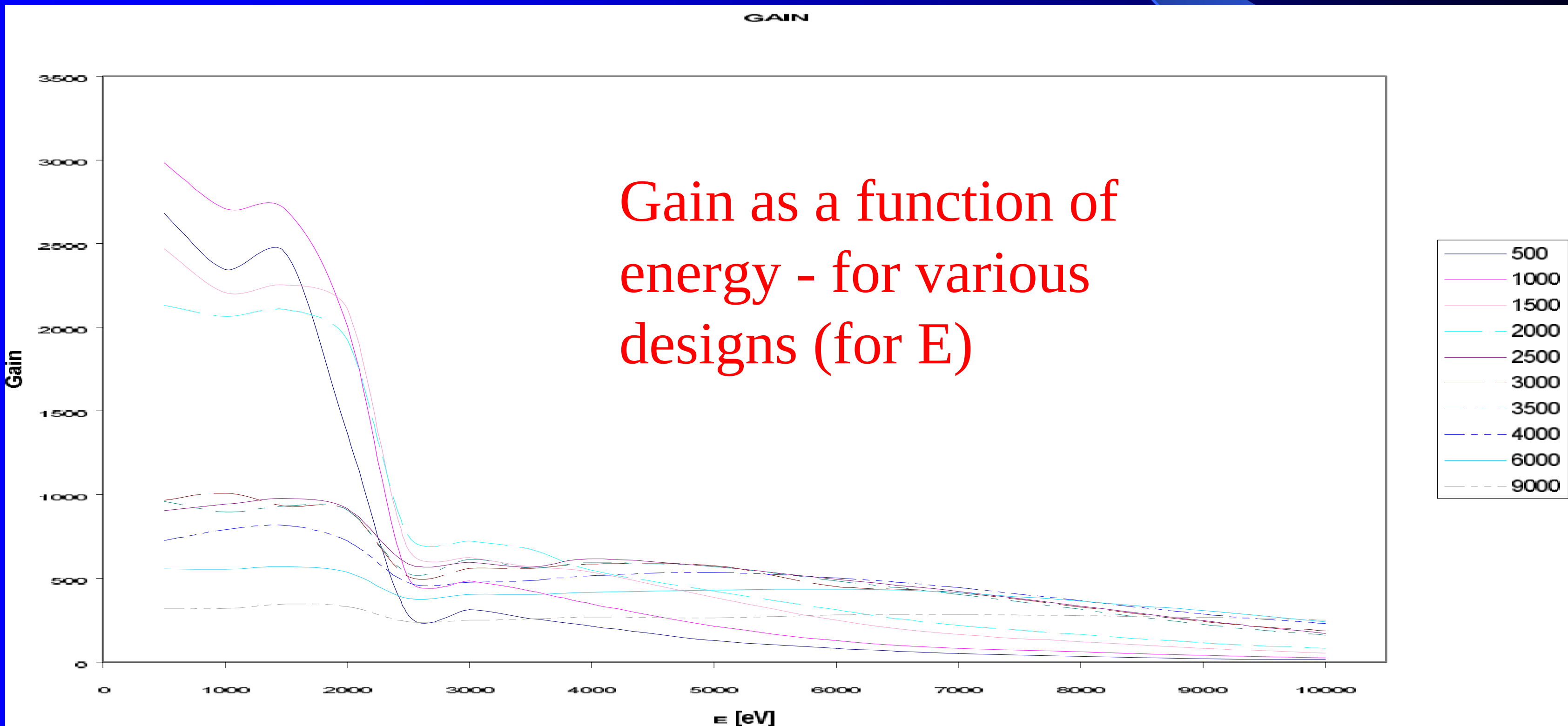
- **Data taken from The ROSAT All-Sky Survey Bright Source Catalogue (1RXS)**
- **Source count rate scaled to get [ct s^{-1} cm^{-2}] by the ROSAT effective area**
- **Galactic plane scans, 105 min / revolution**
- **78 mm x 11.5 mm x 100 μm plates, 300 μm spacing**



logarithmic scale

Gain

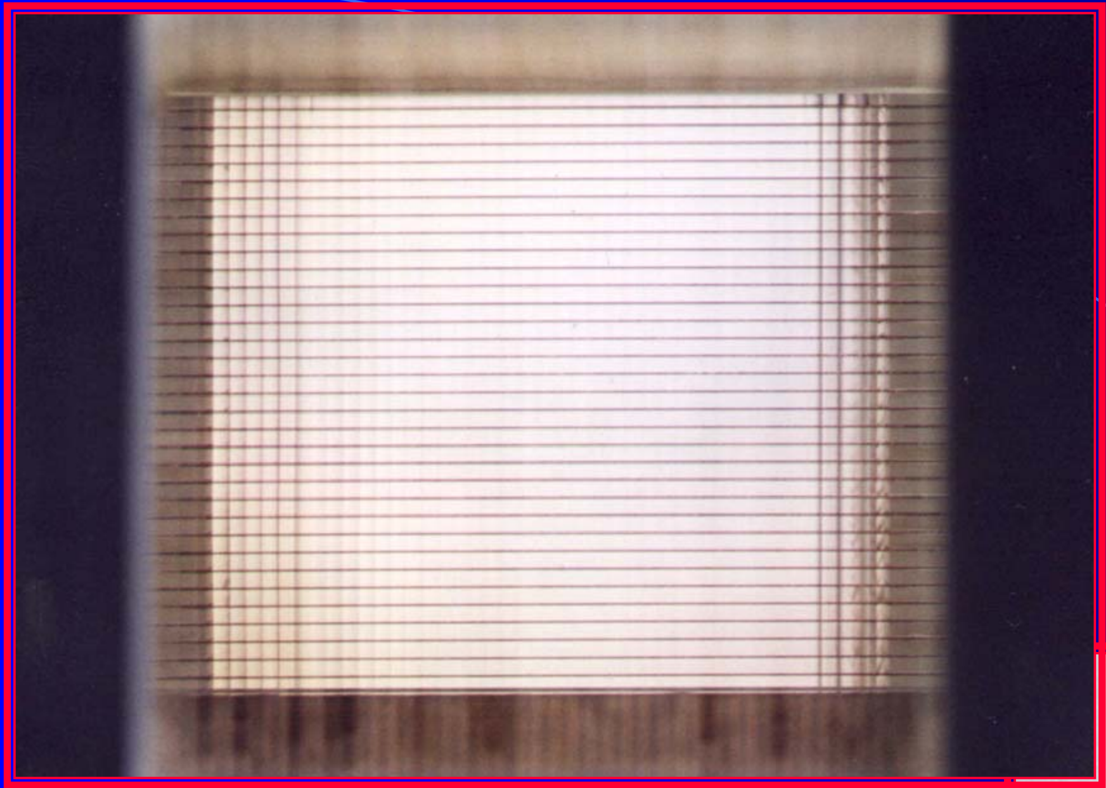
$$G = \frac{\text{number of photons detected inside the FWHM circle with the LE}}{\text{number of photons detected inside the FWHM circle without the LE}}$$



X-ray Optics LE prototypes (Schmidt geometry) developed and tested so far

MODULE	size	plate thickness	distance	length	eff. angle	focal length	resolution	field of view	energy
	d(mm)	t(mm)	a(mm)	l(mm)	a/l	f(mm)	r(arcmin)	(°)	(keV)
macro	**300**	0.75	10.80	300	0.036	6000	7	16	3
middle	**80**	0.3	2	80	0.025	400	20	12	2
mini 1	**24**	0.1	0.3	30	0.01	900	2	5	5
mini 2	**24**	0.1	0.3	30	0.01	250	6	5	5
micro	**3**	0.03	0.07	14	0.005	80	4	3	10

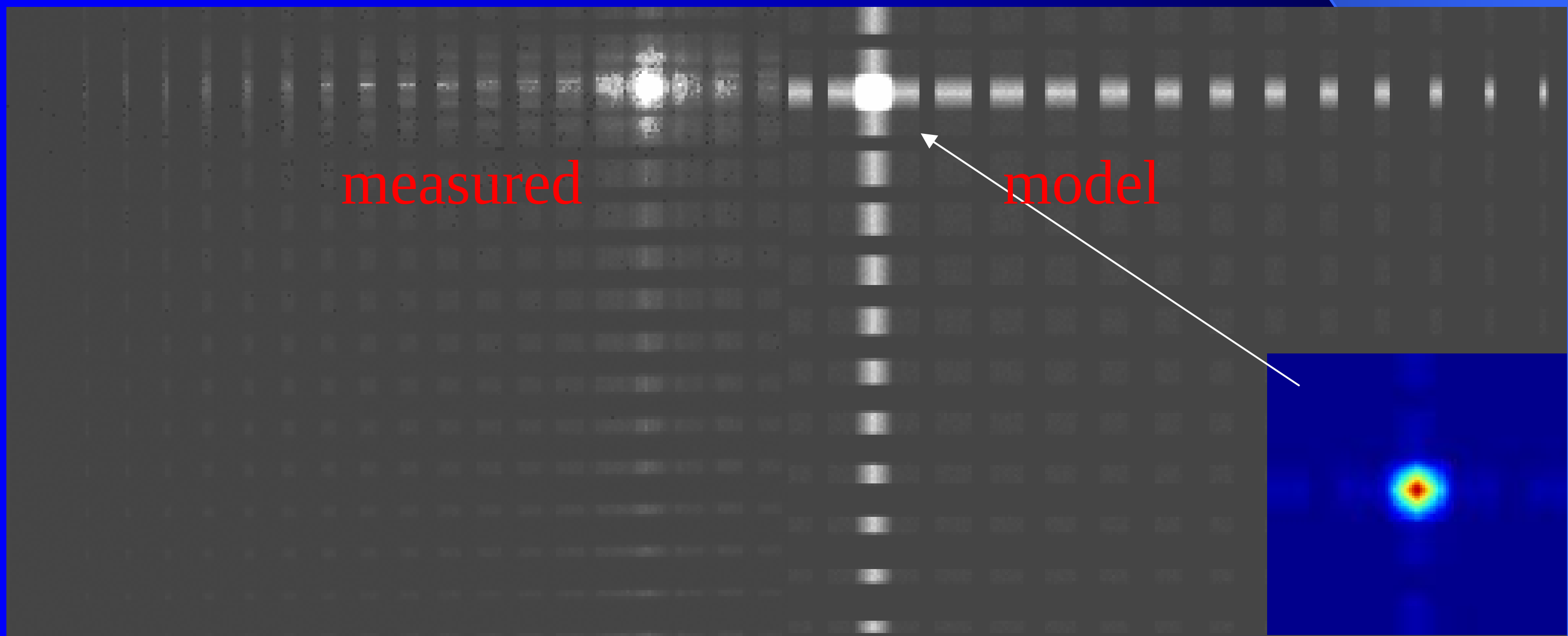
5 prototype LE telescopes have been already designed, developed, and tested



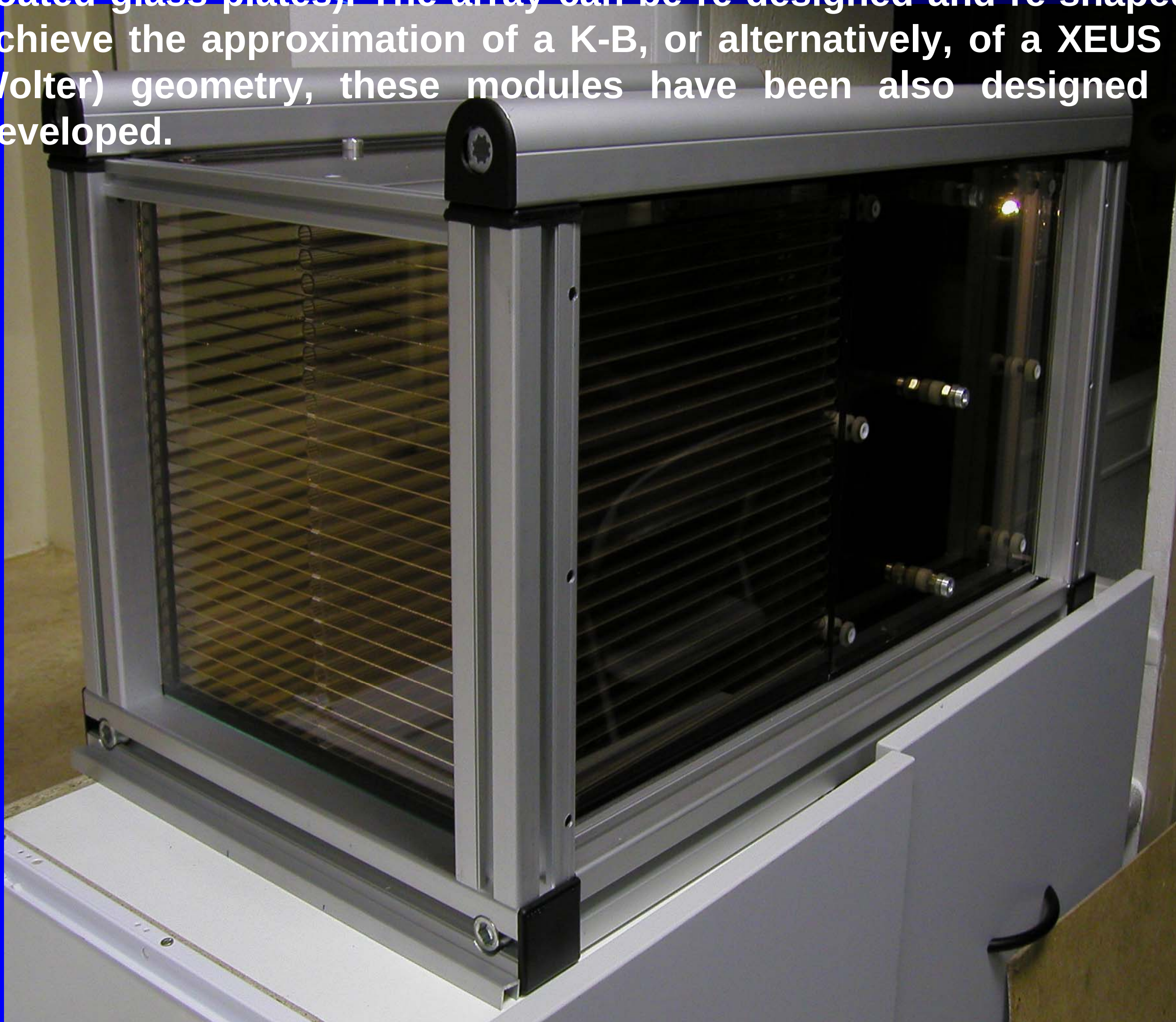
The front wiew of the mini - lobster module, Schmidt arrangement, based on 100 micron thick plates spaced by 300 microns, 23 x 23 mm each

X-ray experiment vs. simulation

- Point-to-point focusing system, LE Schmidt mini
- source-detector distance 1.2 m, 8 keV photons
- image width: 2x512 pixels, 24 µm pixel
- Gain: ~570 (measured) vs. ~584 (model)



The large (30 x 30 x 60 cm) LE 2 D module (0.75 mm thick gold coated glass plates). The array can be re-designed and re-shaped to achieve the approximation of a K-B, or alternatively, of a XEUS (i.e. Wolter) geometry, these modules have been also designed and developed.

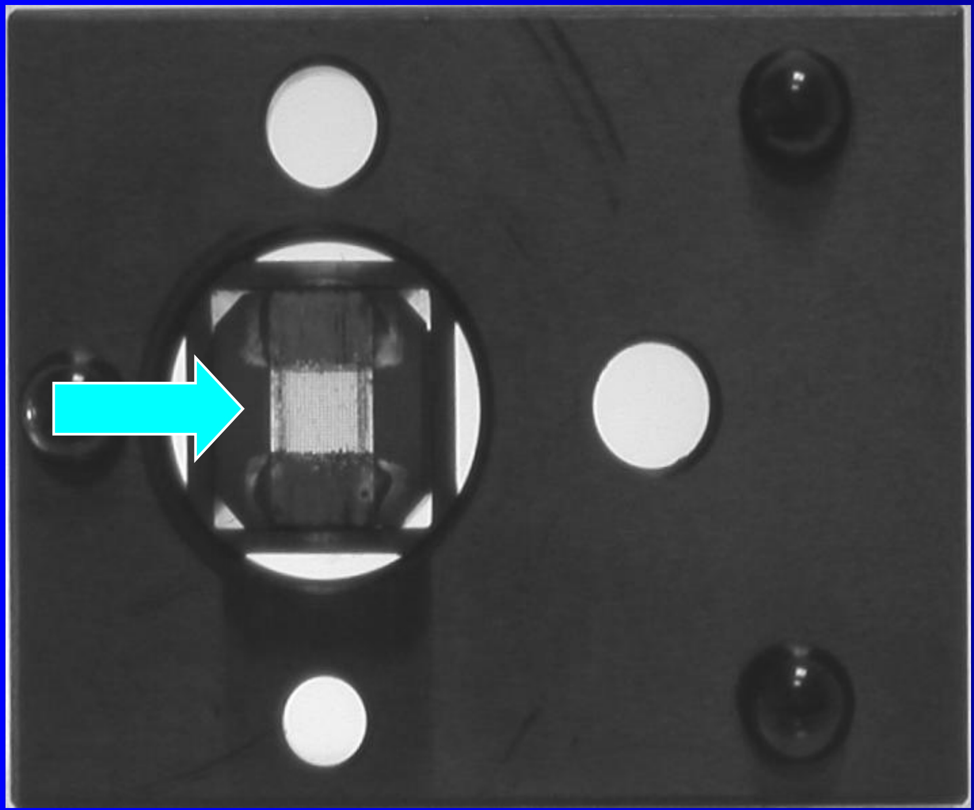


The focal plane image from the large (30 x 30 cm) LE 2 D module (0.75 mm thick glass plates, visible light).

Micro LE: **3 x 3 x 14 mm module**

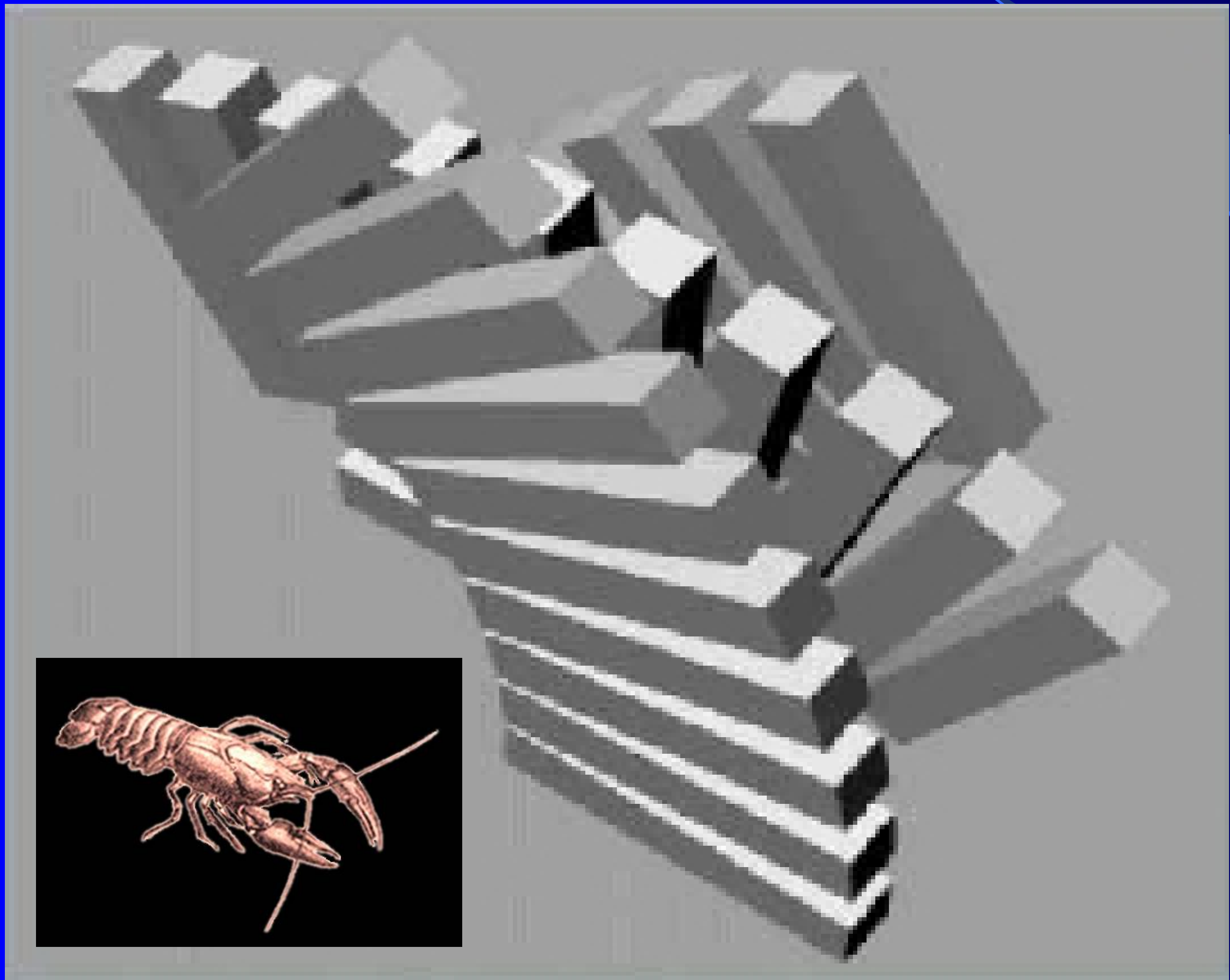
glass foils 30 microns thick

separated by 70 microns

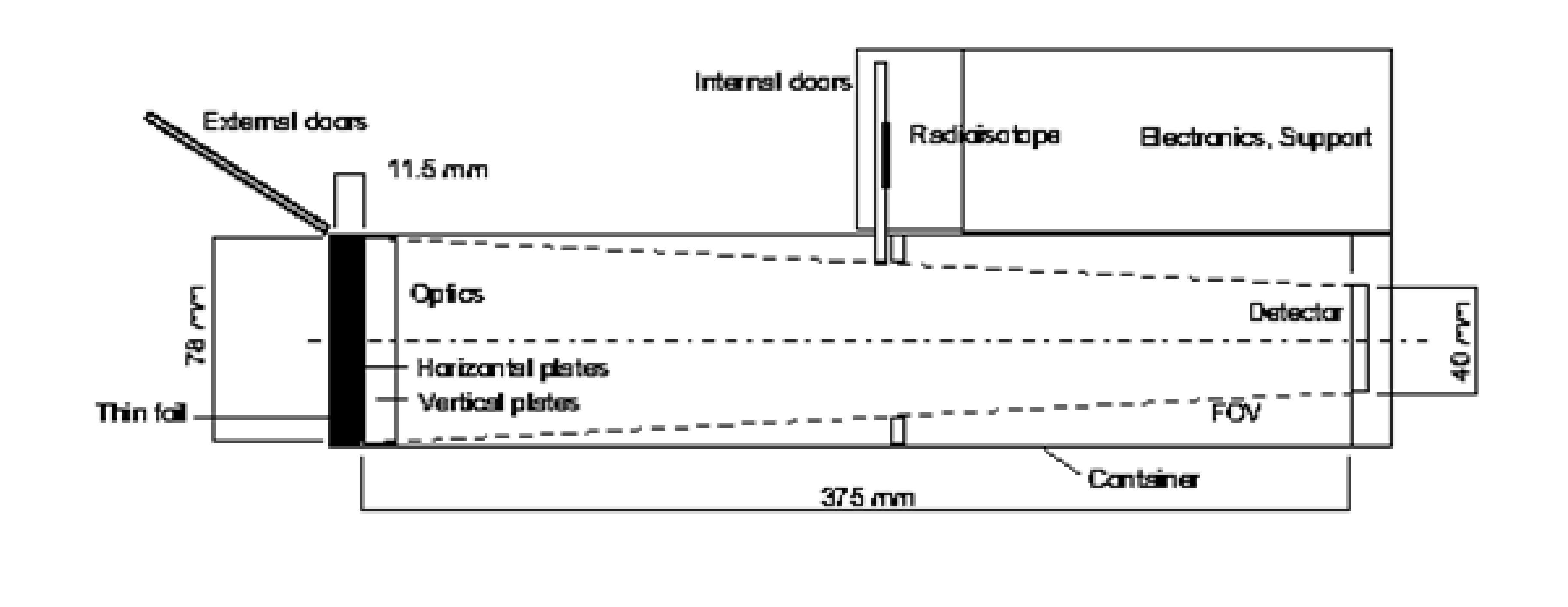


Focal image, 8 keV

LE All Sky Monitor - Proposal



- Modular concept
- Design for ISS
- Easy modification for EXIST, HXMT or other satellites



LE Modular Concept - 1 module

LE ASM ISS = 30 modules

French/Cninese XRA satellite = 3 modules

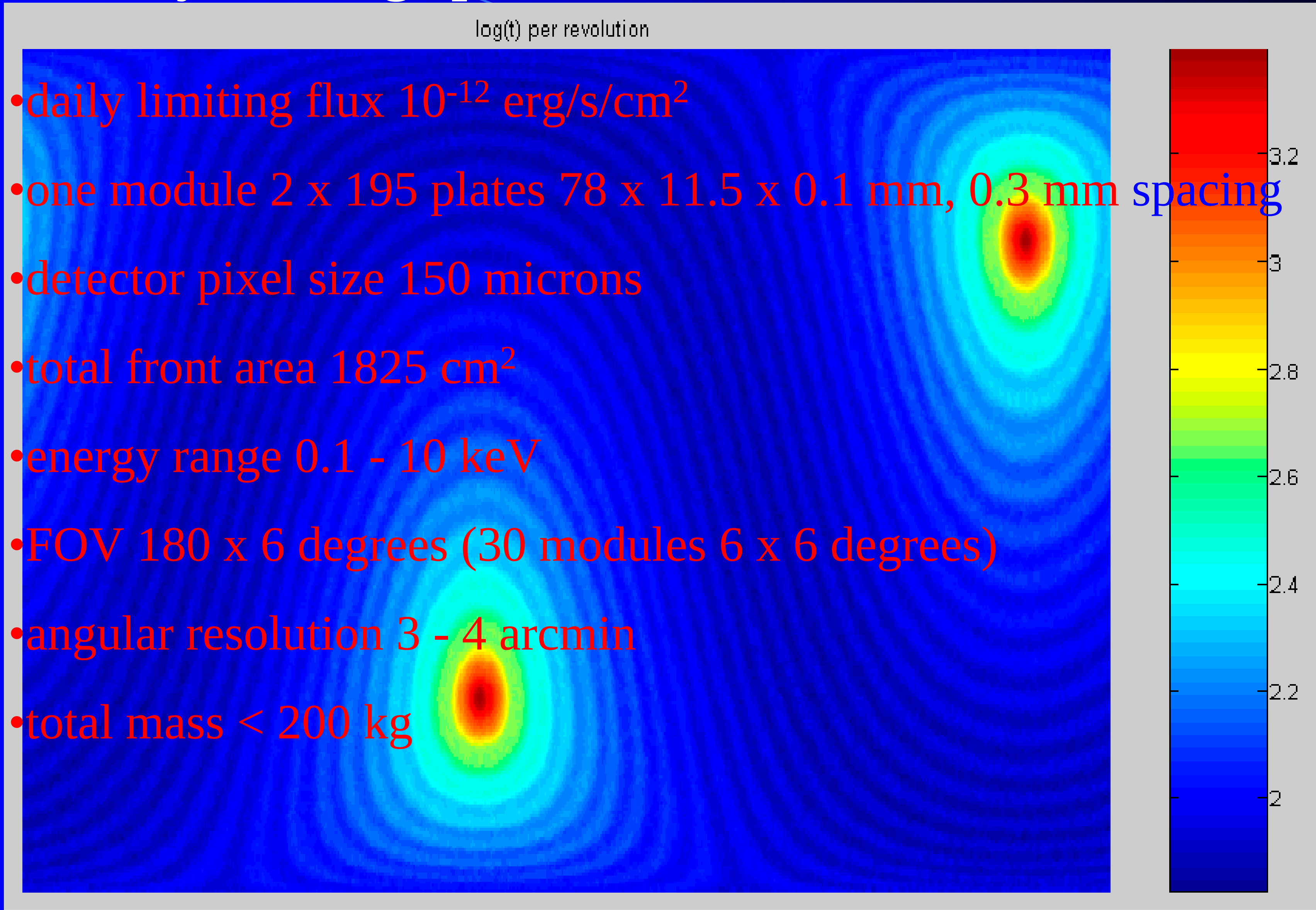
Easy modification for HXMT & other space projects

The Detector

The detector with dimensions 40 x 40 mm^2 with pixel size 100 x 100 μm^2 is needed for each of the modules. The detector has to be able to work as a photon counting device, with time resolution better than 1 second.

Fast X-Ray CCDs like Epic-PN detector on XMM-Newton or newly developing detectors based on the MOS technology seems to be the optimal choice.

LE Sky coverage per revolution



- daily limiting flux 10^{-12} erg/s/cm^2
- one module 2 x 195 plates 78 x 11.5 x 0.1 mm, 0.3 mm spacing
- detector pixel size 150 microns
- total front area 1825 cm^2
- energy range 0.1 - 10 keV
- FOV 180 x 6 degrees (30 modules 6 x 6 degrees)
- angular resolution 3 - 4 arcmin
- total mass < 200 kg

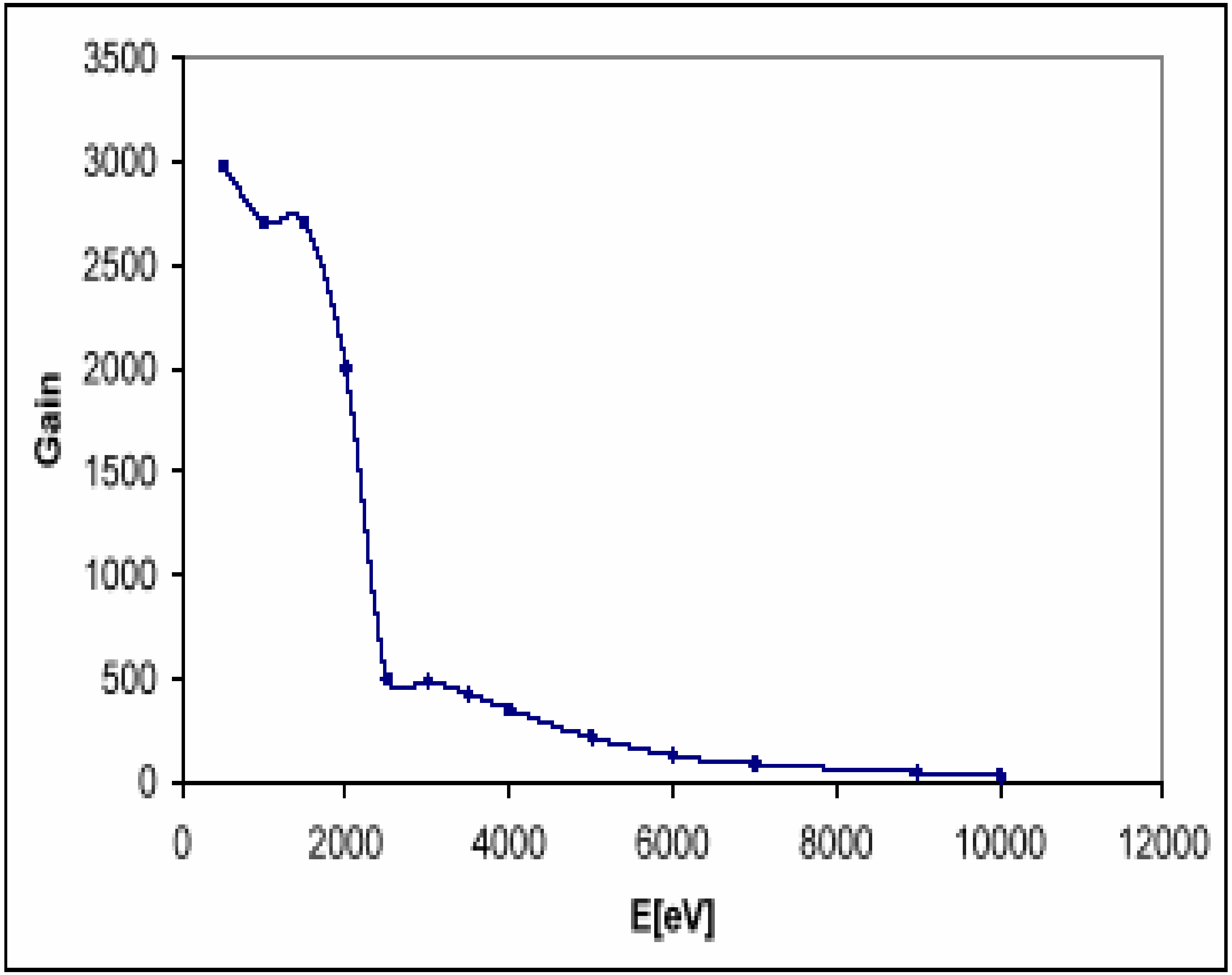


Figure 7: The gain computed from the ray-tracing simulation

Scientific goals

1. Alert System for X-ray transients

fast recognition of new X-ray sources and/or sudden changes in X-ray flux of known sources, prompt emission study, precise positioning, alert system for narrow-field instruments

- **GRB prompt and afterglow X-ray emission (20-60 triggers/year)**
- **X-ray flashes (> 8 triggers/year)**
- **orphan GRBs (detectable in X-rays but not in gamma)**
- **SNe prompt emission (thermal flash) 10-20 triggers/year**
- **X-ray binary & CVs flux changes**
- **Stellar events in the Sun's vinicity**

2. Long-term X-ray source monitoring

long-term monitoring of large number of X-ray sources with sampling of hours to days (depending on the source flux). Light curves for all the sources together with rough spectra (continuum monitoring, strong lines, iron detectable). In the list below we assume the limiting flux of 10-12 erg/s/cm2 (but we can go deeper):

- **X-ray binaries ~ 700 triggers**
- **Cataclysmic Variables ~ 200 triggers**
- **stars ~ 600 triggers**
- **AGN ~ 4 000 triggers**
- **galaxy clusters ~ 400 triggers**
- **SN remnants**

When the LOBSTER will go to space?

1. UK Leicester led collaboration (with our participation)

LOBSTER ISS, RSG with Russia

2. Czech collaboration

Balloon experiment?

LE channel on Chinese HXMT satellite?

LE channel on EXIST and/or analogous satellites?

Small French-Chinese satellite (proposal delivered)

Small Czech scientific satellite?

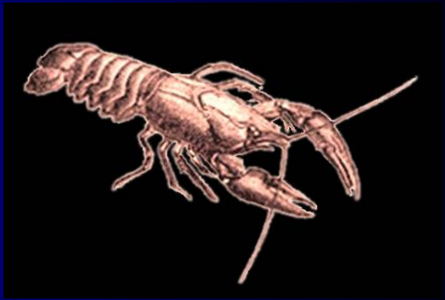
We offer the technology to Italy and China for their space programs

LE Balloon experiment

- For celestial X-ray sources
- For atmospheric X-ray sources (red sprites/above active thunderstorms/terrestrial gamma-ray flashes)

Positions of terrestrial gamma-ray flashes observed by RHESSI

Conclusion



The LE ASM will very significantly contribute to various regions of recent astrophysics

The necessary technical background is already available, making proposals for space project based on Lobster Eye optics possible

Applications also in other areas, e.g. atmospheric science

Space Lobster projects recently considered by ESA and by the Chinese Space Agency


The End

Table 1: ASM main features

Energy Range	$0.1 - 10.0$ keV
Angular Resolution	$\sim 3 - 4$ arcmin
FOV	180×6 deg
Orbit	LEO
Survey	$\sim 100\%$ sky coverage each orbit
Daily Limitting Flux	$\sim 10^{-12}$ erg/s/cm^2
Number of modules	30
Number of detectors	30
Detector Pixel Size	150×150 μm
Energy Resolution	$E/dE > 10$
Total Detector Area	480 cm^2
Total Front Area	1825 cm^2
Total Mass	< 200 kg
Data Transfer Rate	~ 30 kbps
Mission Lifetime	> 2 years