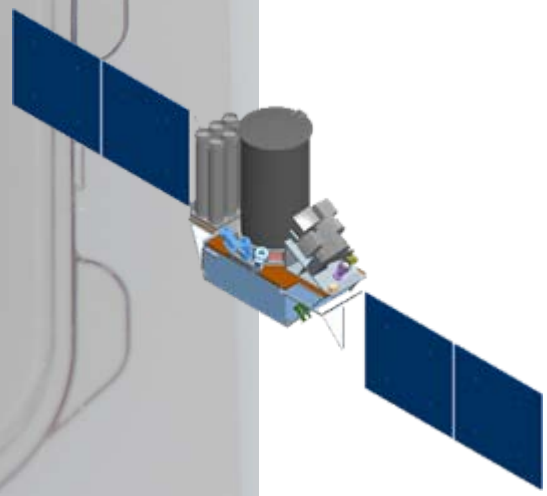
eROSITA

Norbert Meidinger



Outline

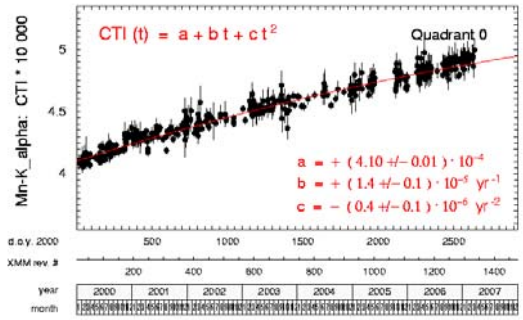
I. eROSITA project
II. Telescope
III. pnCCD camera
IV. Characteristics
V. Outlook

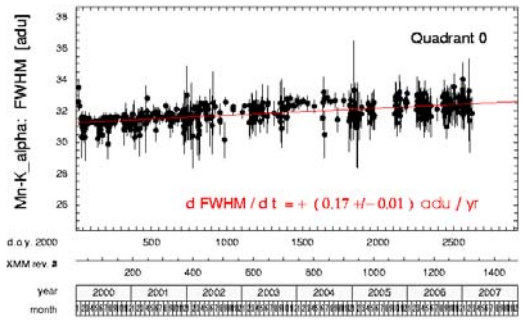
I. eROSITA background

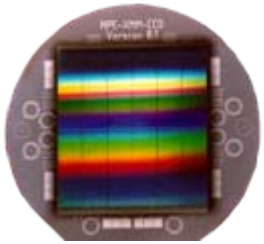
pnCCD development for **spectroscopy and imaging of X-rays**:
→ ESA's **XMM-Newton** X-ray astronomy satellite (12/1999):
XMM-pnCCD X-ray camera (by MPE & HLL)

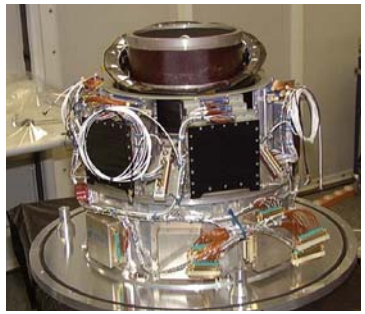
X-ray detection	→ E = [0.3 keV; 10 keV] with QE≳90%
Image area	→ 6 cm x 6 cm (full frame mode)
Pixel size	→ 150 x 150 μm² pixel
Time resolution	→ 73 ms (fullframe, standard)
Noise	→ 5 electrons rms @ -90°C
Energy resolution	→ FWHM(5.9keV)=155eV (single events!)
Long-term stability	→ after >7 years in space: FWHM(5.9 keV) = 155 eV → 161 eV

XMM-Newton operation extended until 2008, probably 2010









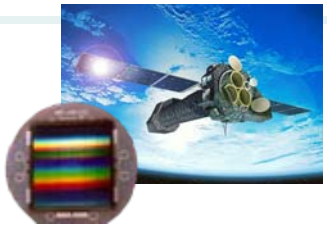
I. eROSITA project: Background

ROSAT
1990-1998

First X-ray all-sky survey with an imaging telescope

PSPC
gas counter
camera

XMM-Newton
1999 –
Pointed observations



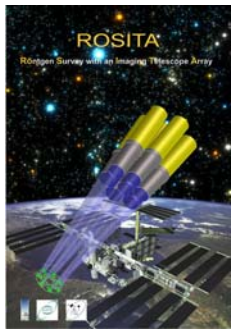
XMM pnCCD
camera

ABRIXAS
1999

To extend the all-sky survey towards higher energies

XMM pnCCD
camera
† satellite
power system

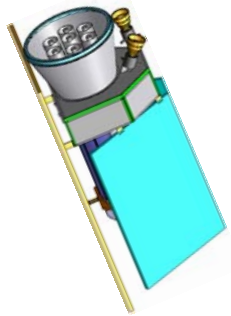
ROSITA
2002



ABRIXAS science
on the
International
Space Station

7 cameras
256 x 256 pixel
FS pnCCD

DUO
2004

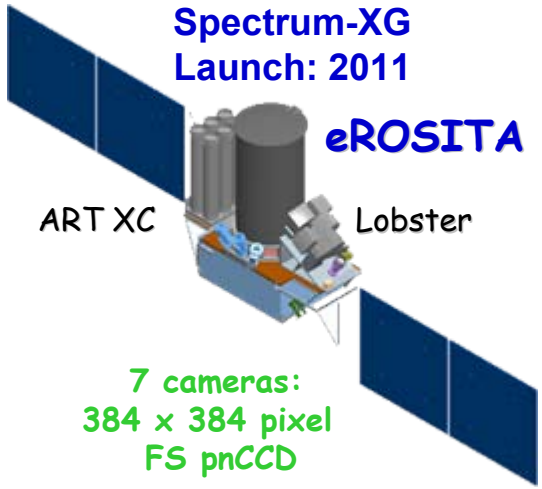


Dark Energy
10^4 Clusters of Galaxies

7 cameras:
256 x 256 pixel
FS pnCCD

NASA SMEX
proposal
† 01/2005

Spectrum-XG
Launch: 2011



7 cameras:
384 x 384 pixel
FS pnCCD

ABRIXAS & DUO science
10^5 Clusters of Galaxies

DLR grant 04/2007

I. eROSITA project

eROSITA = ROSITA + DUO

(extended ROentgen Survey with an Imaging Telescope Array)

Main scientific goals:

First imaging all-sky survey (1 y exposure time) 0.3 keV up to 10 keV

→ systematic detection of all obscured accreting Black Holes in nearby galaxies and new active galactic nuclei in the hard band.

Wide and deep survey (3 y + 0.5 y): observation of dedicated sky regions to detect 100.000 clusters of galaxies.

Follow-up pointed observations (0.5 y) to map out LSS in Universe

→ nature of Dark Energy and Dark Matter (96% of Universe) ; model of inflation + re-observation of interesting targets

⇒ total: 5 y

Satellite: Spectrum-XG

Launch: 2011, Baikonur

600 km circular orbit, 30° inclination, 96 min. orbit

Launch vehicle: Soyus-2/Fregat

II. eROSITA project

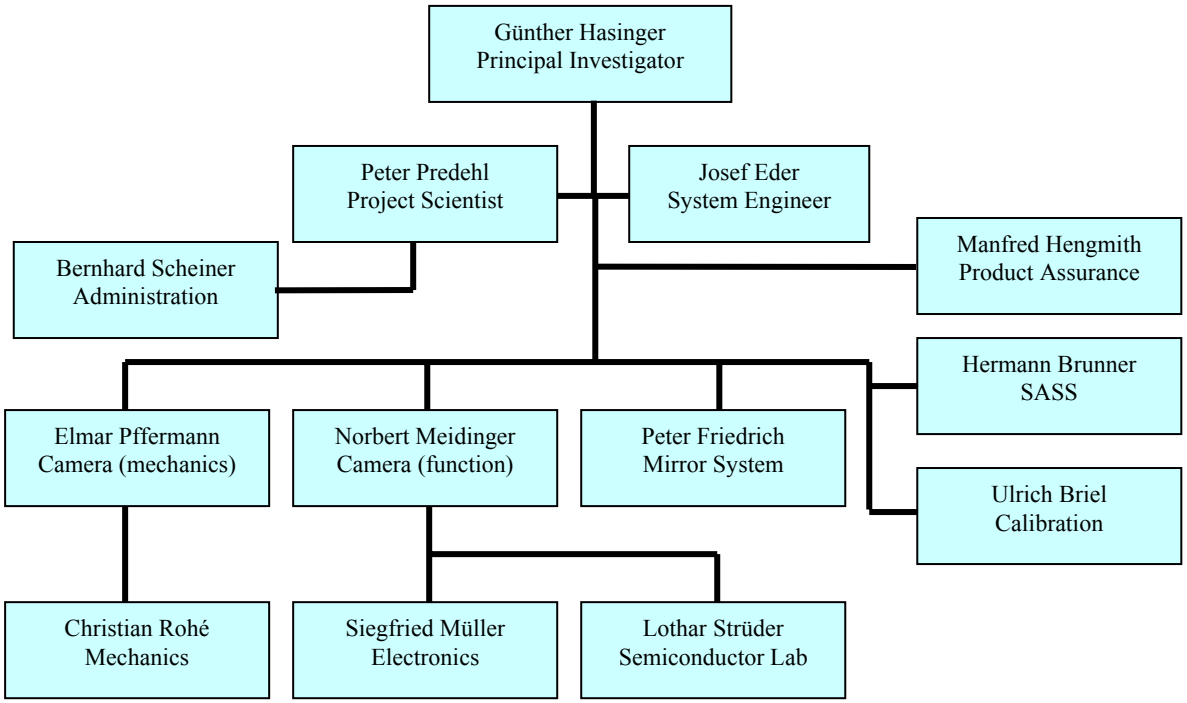
04/2007:

- **Memorandum of understanding** signed by **DLR** and **ROSKOSMOS** for cooperation:
  eROSITA aboard Russian satellite Spectrum-X-ray-Gamma
- **Funding by DLR granted** (until launch): **21 Mio. €**

Consortium:

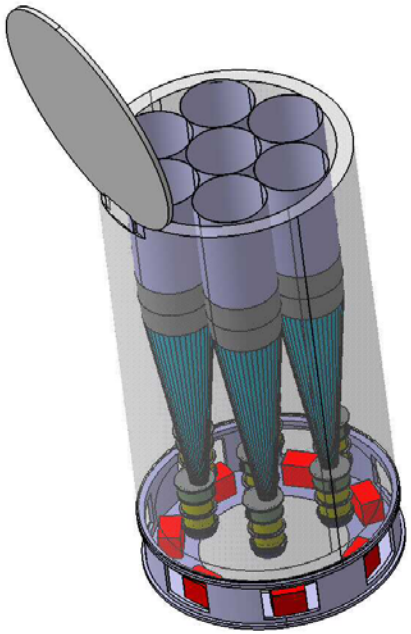
led by: **MPE**

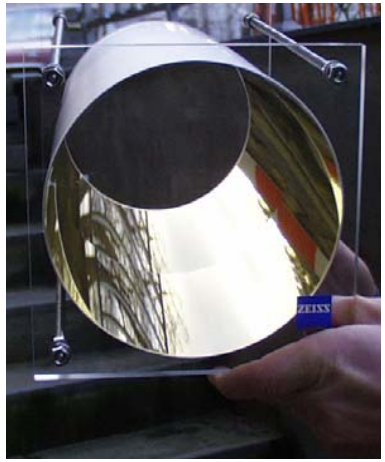
IAAT (Tübingen),
FAU (Erlangen),
AIP (Potsdam),
UH (Hamburg),
MPA (Garching),
IKI (Moscow)



II. Telescope

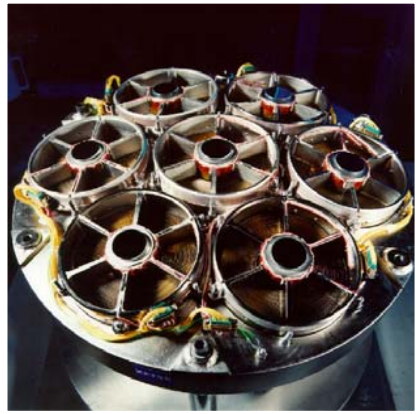
Telescope =
7 x (mirror system
+ pnCCD camera in focus)





mirror shell

ABRIXAS:



7 mirror systems

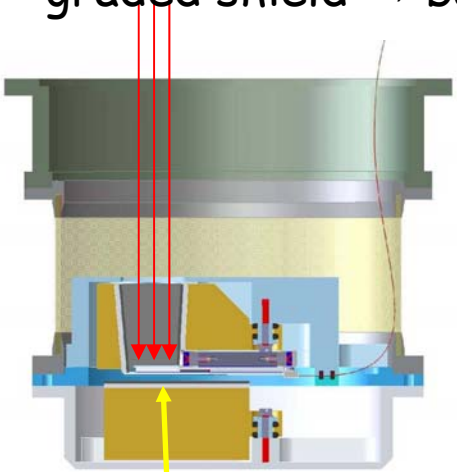
- 7 mirror systems
  with parallel optical axes
- 54 nested mirror shells
  Wolter-I type
  (ABRIXAS 27 shells qualified)
- focal length: 1.6 m
- FoV: ∅ = 1°
- angular res. <15`` HEW
  (1 keV, on-axis)
- gold coating on nickel shell
- nickel-galvanoplating process
  (similar XMM-Newton)
  → Media Lario Srl
  + Carl Zeiss AG
  + Kayser-Threde GmbH

II. Telescope

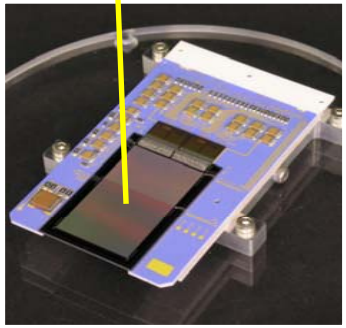
7 identical pnCCD cameras

active cooling → TECs + radiator

graded shield → background



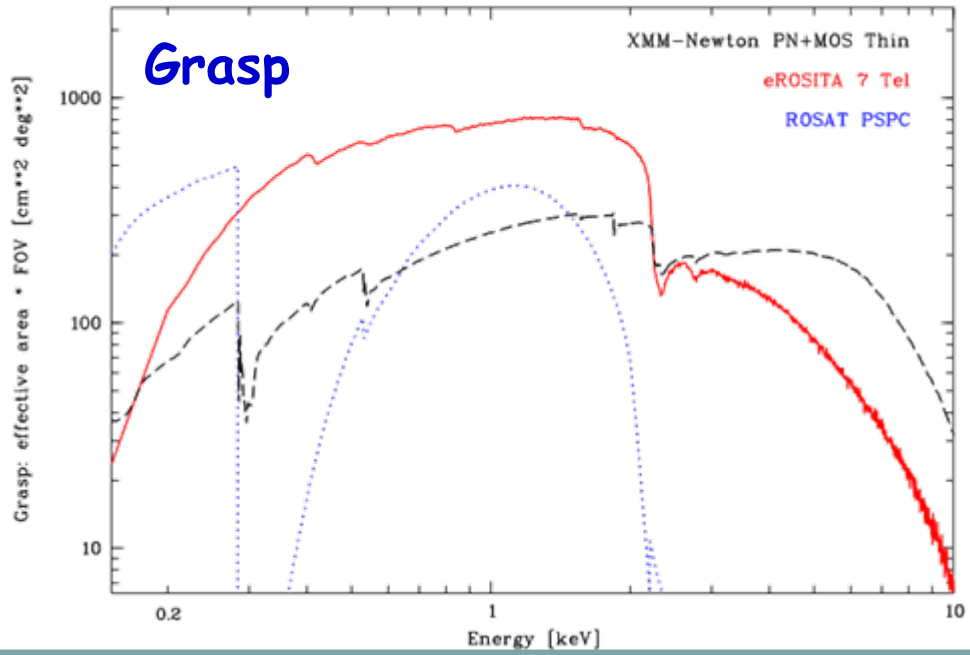
pnCCD camera



pnCCD detector module

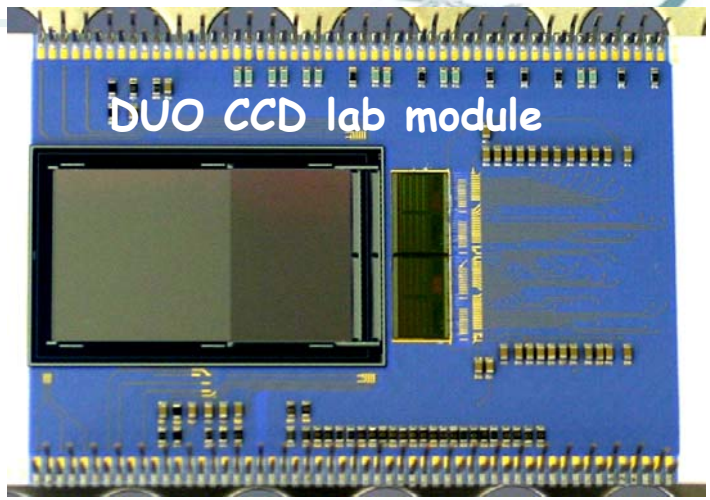
Detector requirements:

- Image area 28.8 mm x 28.8 mm
  = 384 x 384 pixel → FoV: ∅ = 1°
- Pixel size: 75 μm x 75 μm
- Time resolution: 50 ms ↔ frame rate: 20 images / s
- Energy range: 0.3 keV – 10 keV
- Energy resolution ≈ 138 eV @ 6 keV
- Power consumption in f.p. ≈ 0.6 W
- Operating temperature ≈ -80°C
- On-chip optical + UV filter
- Long term stability > 5 y
- ...



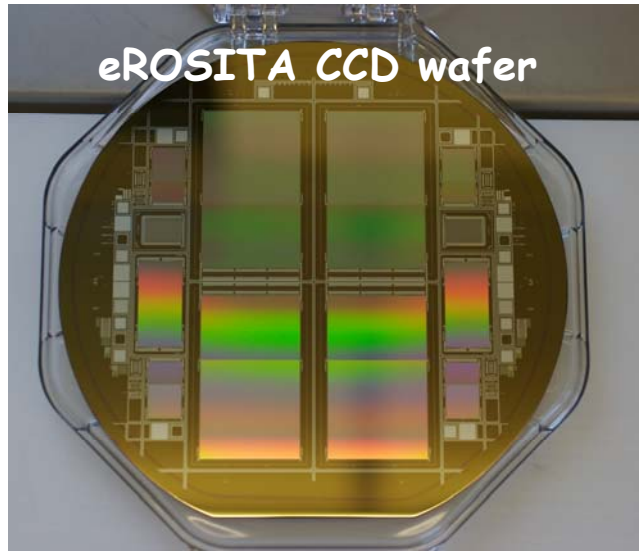
III. pnCCD camera

pnCCD:
DUO pnCCDs (C11) = prototype CCDs of eROSITA
256 x 256 pixel, BCB, light filter
tested extensively 2005 - 2007

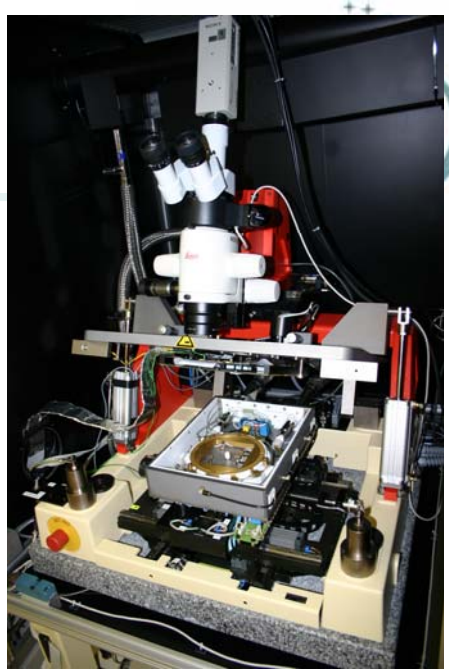


eROSITA flight pnCCDs (C12):
production started 07/2006 – 10/2007 (?)
standard process technology – low risk
changes:
- number of pixels
- MOS gate to control charge reset

9 wafers x 4 pnCCDs
→ 3 lab/breadboard + 2 QM + 7 FM
+ 4 FS CCD modules

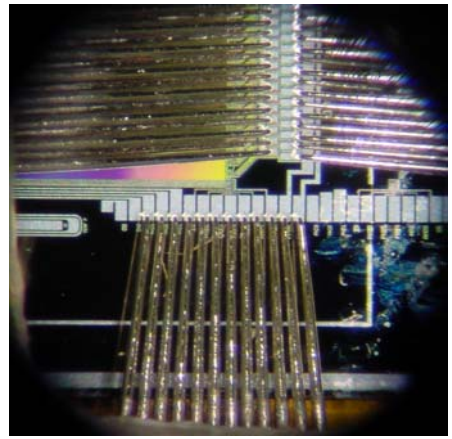


III. pnCCD camera



pnCCD:
selection by Kaltprober:
→ spectrocopic performance tests
just with wafer/chip - no module
(Necessary: Probecard + single needles → alignment, darkness, cooling, Fe55 source, complete electronics, DAQ system)

- successful test with a DUO CCD wafer
→ modification for larger eROSITA CCDs



CAMEX ASICs: readout of eROSITA pnCCD
fabrication started 02/2007 – 06/2007 (?)

changes:
- 6 → 8 `` wafer, new process techn., e.g. thinner gate oxides
- linearity + speed of output buffer + bandwidth
- control of ref. currents by CAMEX programming
- 2 CAMEX types: conservative + innovative
- fallback: present CAMEX chips

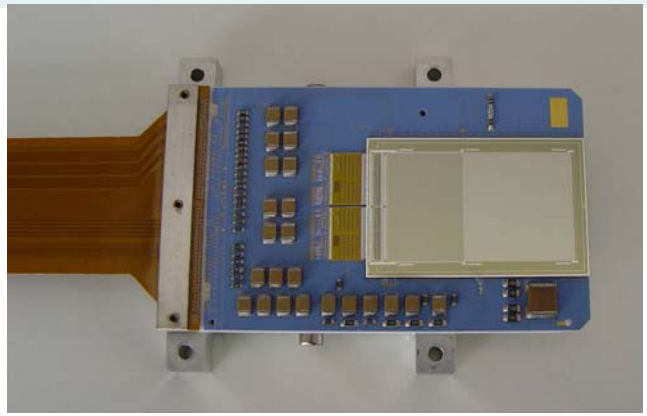
→ 25. April: CAMEX Electronics (Sven Herrmann)

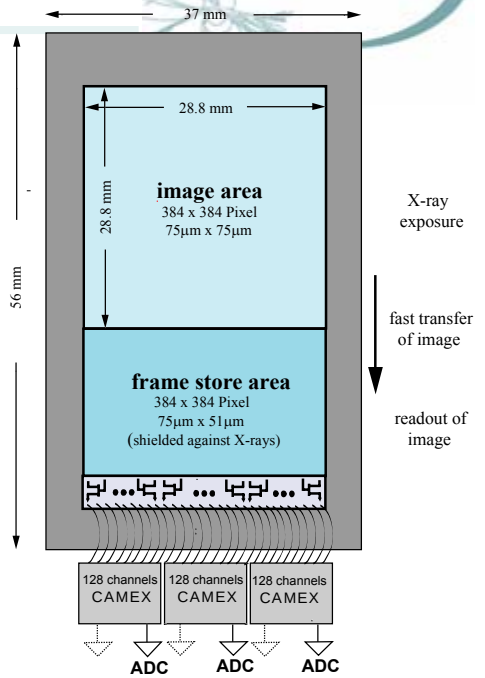
III. pnCCD camera

pnCCD module:

Ceramic PCB:

5+1 layers; thick film technlogy;
CCD, CAMEXes, SMD C's + R's
wedge bonding

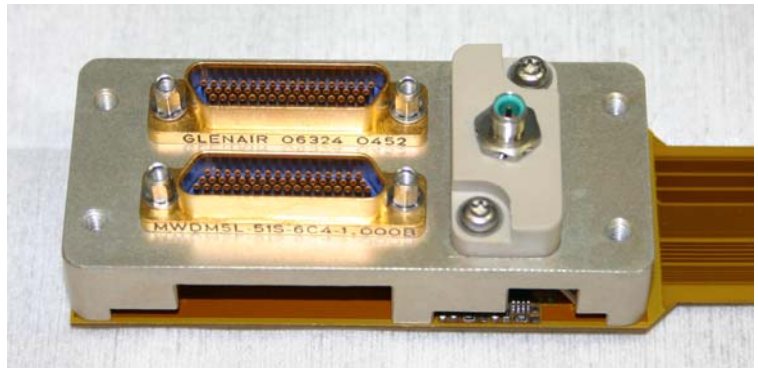




used + successfully tested for 20 y
esp. in all lab. pnCCD detector tests
→ adopted for **eROSITA flight camera**

Flex lead:

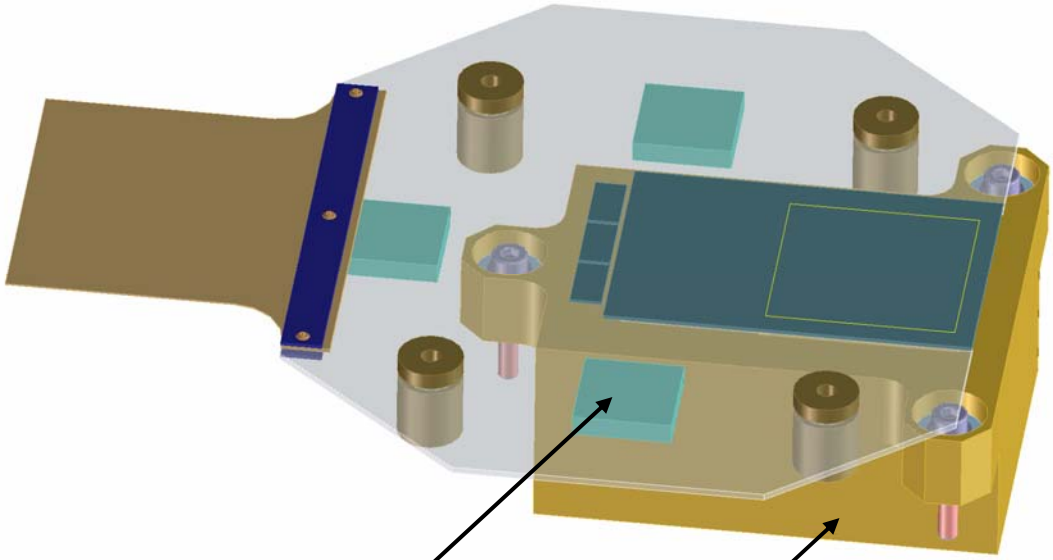
- connects CCD module to camera electronics
→ wedge bonds and soldering to connectors
- analog CCD clock pulses generated on flex
- analog output buffer (ADC)

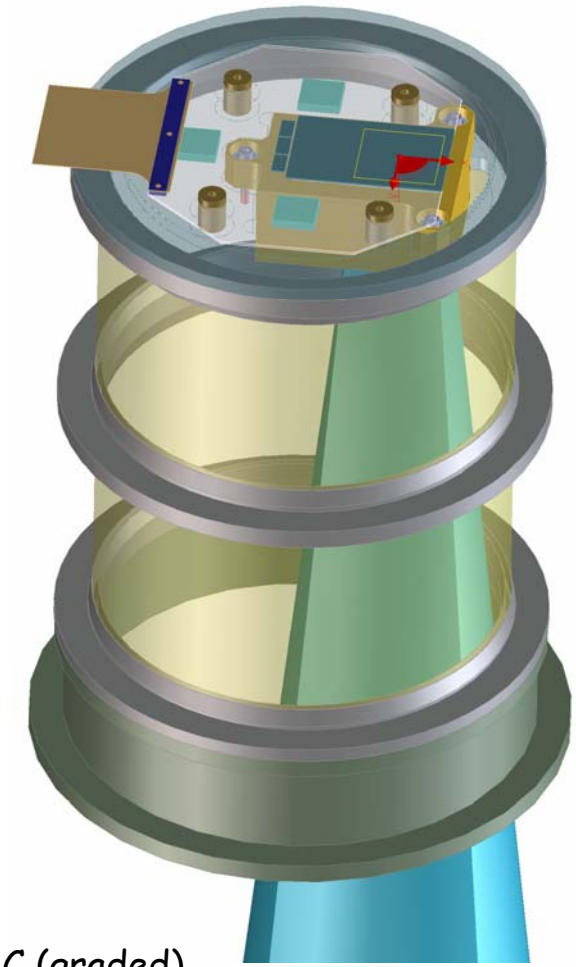


Status prototype pnCCD module
- tested with CAMEX
- soon with CCD

III. pnCCD camera

pnCCD camera:
pnCCD module + mechanical + thermal

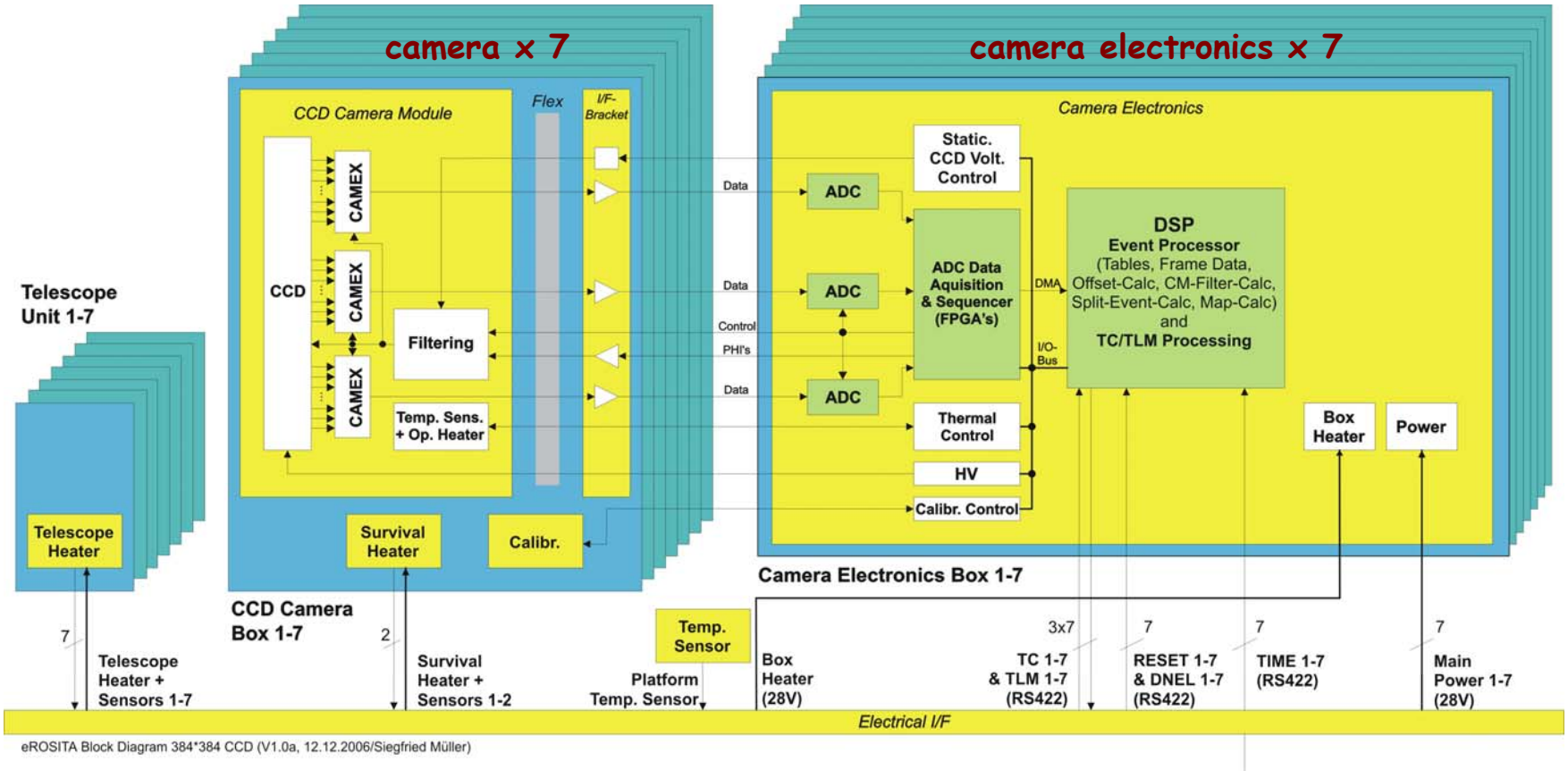




shielding: Cu (proton) + Al_2O_3 + BC (graded)

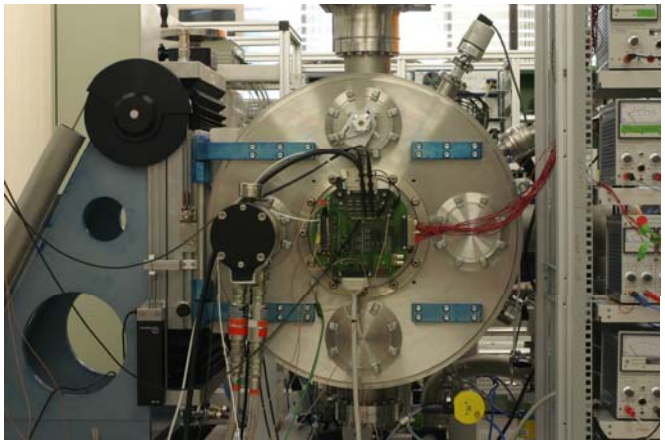
III. pnCCD camera

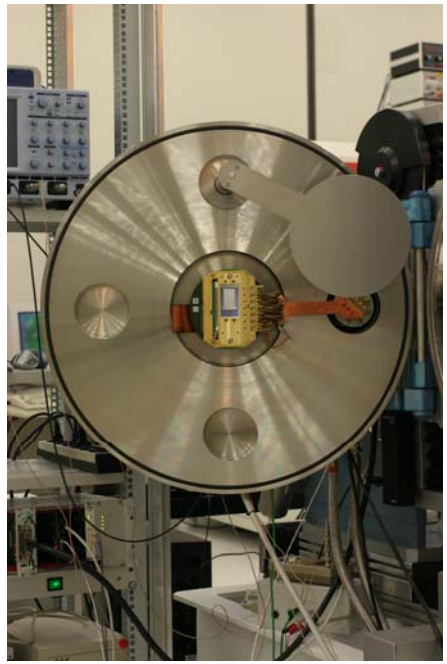
7 x camera electronics (outside camera)
ADCs, DSP event analyzer, power supplies, FPGA sequencer, HK controller, …



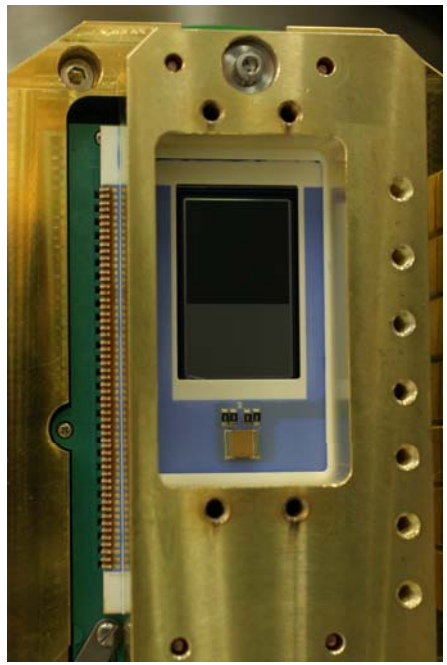
→ lab DAQ → TRoPIC camera at PANTER for telescope cal. → flight prototype → flight

IV. Performance



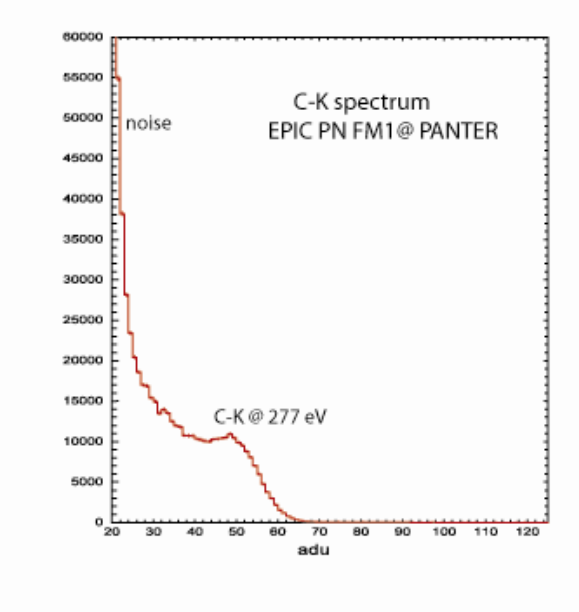


ROESTI @ HLL:
performance tests of
lab. prototype pnCCD modules
256 x 256 pixel CCD



IV. Performance

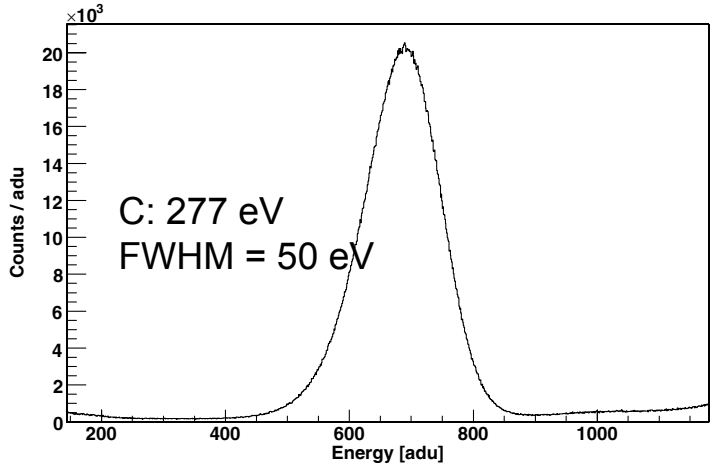
XMM-Newton: pnCCD

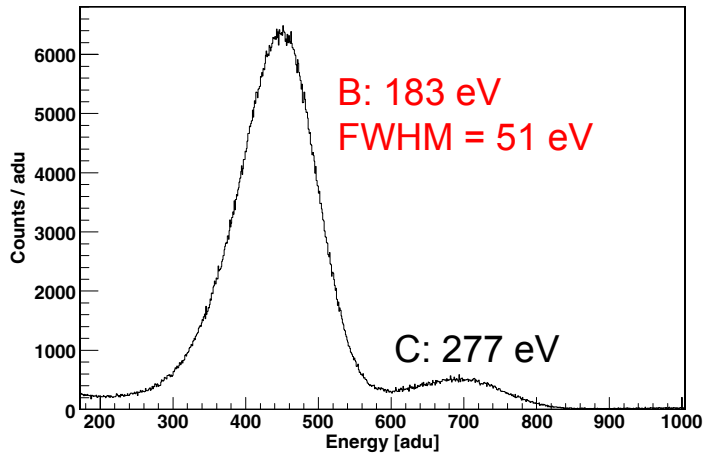


24. April:
lower energy – same pnCCD →
„pnCCDs at FLASH" (Christian R.)

„Data analysis" (Robert A.)

eROSITA: frame store pnCCD





„eROSITA conditions":
T = -80°C; frame rate 20 images/s; light filter

IV. Characteristics

pnCCD	eROSITA	XMM-Newton
# Cameras	7	1
# pixels per pnCCD Total # pixels	294,912 2,064,384	153,600 153,600
Operation mode	frame store	fullframe
Out of time (image smearing)	0.4 %	6 %
# pixel transfers	[385;768]	[1;200]
Pixel size	75 x 75 μm^2	150 x 150 μm^2
Sens. depth	450 μm	300 μm
Operating temperature	-80°C	-90°C
Read noise	2 el. rms	5 el. rms
CTI	2×10^{-5}	50×10^{-5}
FWHM@5.9keV	all events: 138 eV	singles: 155 eV
FWHM@277eV or 183 eV	all events: 50 eV	-

V. Outlook

eROSITA is now a project !!!

Project with **highest priority** at MPE-group of HLL and X-ray group of MPE

Cameras are built **by MPE & HLL** (no industry – in contrast to mirror systems)

Camera schedule:

breadboard construction + concept phase	presently
Final design	→ 12/2007
DM manufacturing and assembly + test	→ 06/2008
EQM manufacturing + assembly + test	→ 12/2008
FM1 manufacturing, assembly, test	→ 22.04.2009
FM2 manufacturing, assembly, test	→ 17.06.2009
FM3 manufacturing, assembly, test	→ 12.08.2009
FM4 manufacturing, assembly, test	→ 07.10.2009
FM5 manufacturing, assembly, test	→ 02.12.2009
FM6 manufacturing, assembly, test	→ 27.01.2010
FM7 manufacturing, assembly, test	→ 24.03.2010
Calibration, integration into satellite, final tests	
Satellite launch:	2011

thanks to the whole team