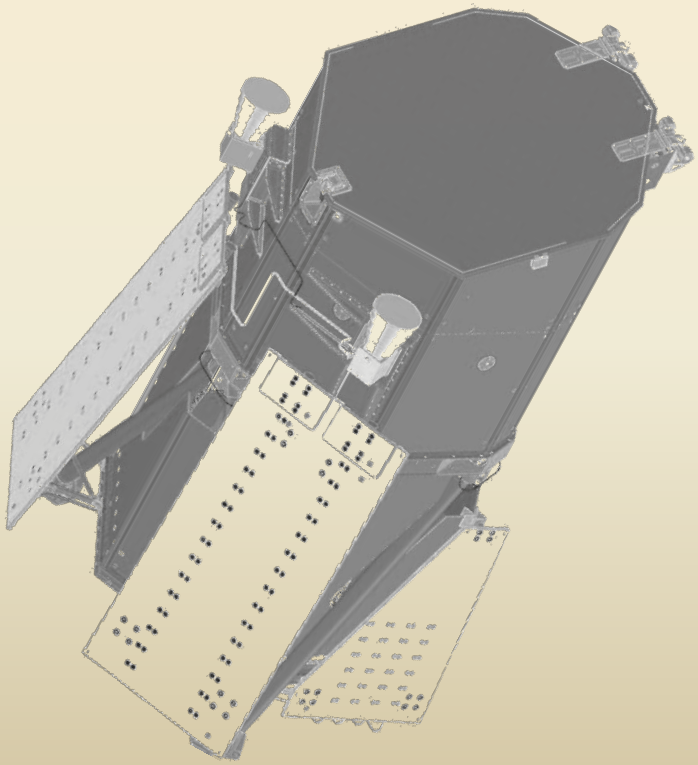
eROSITA
on Spectrum-Rentgen-Gamma (SRG)

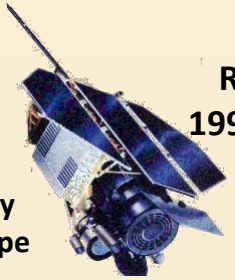
Vadim Burwitz on behalf of the eROSITA team
Max-Planck-Institut für extraterrestrische Physik



Historical Development

Negotiations between Roskosmos and ESA on a "new" Spectrum-XG mission (2005)

MoU between Roskosmos and DLR (2007)
„Detailed Agreement“ (2009)

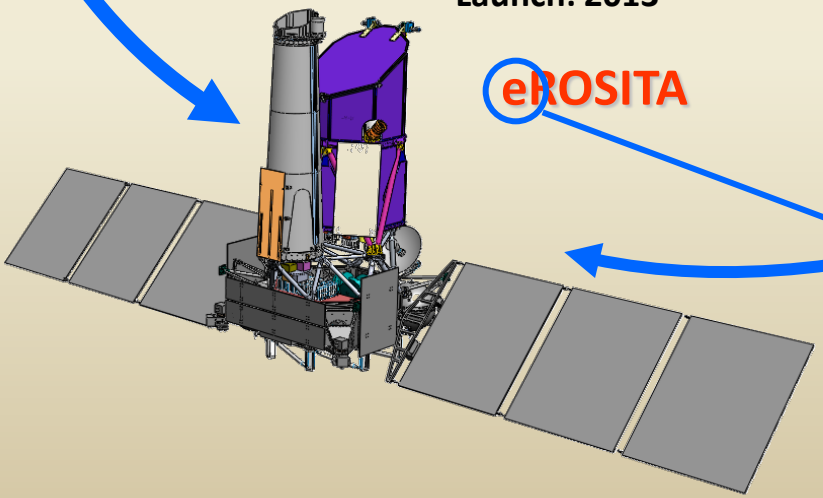


ROSAT
1990-1998

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

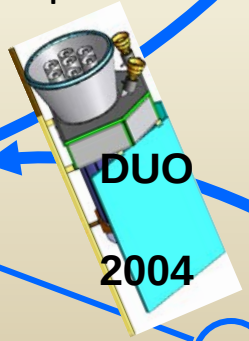
Bundle of 7 small telescopes
To extend the all-sky survey towards higher energies

SRG
Launch: 2013



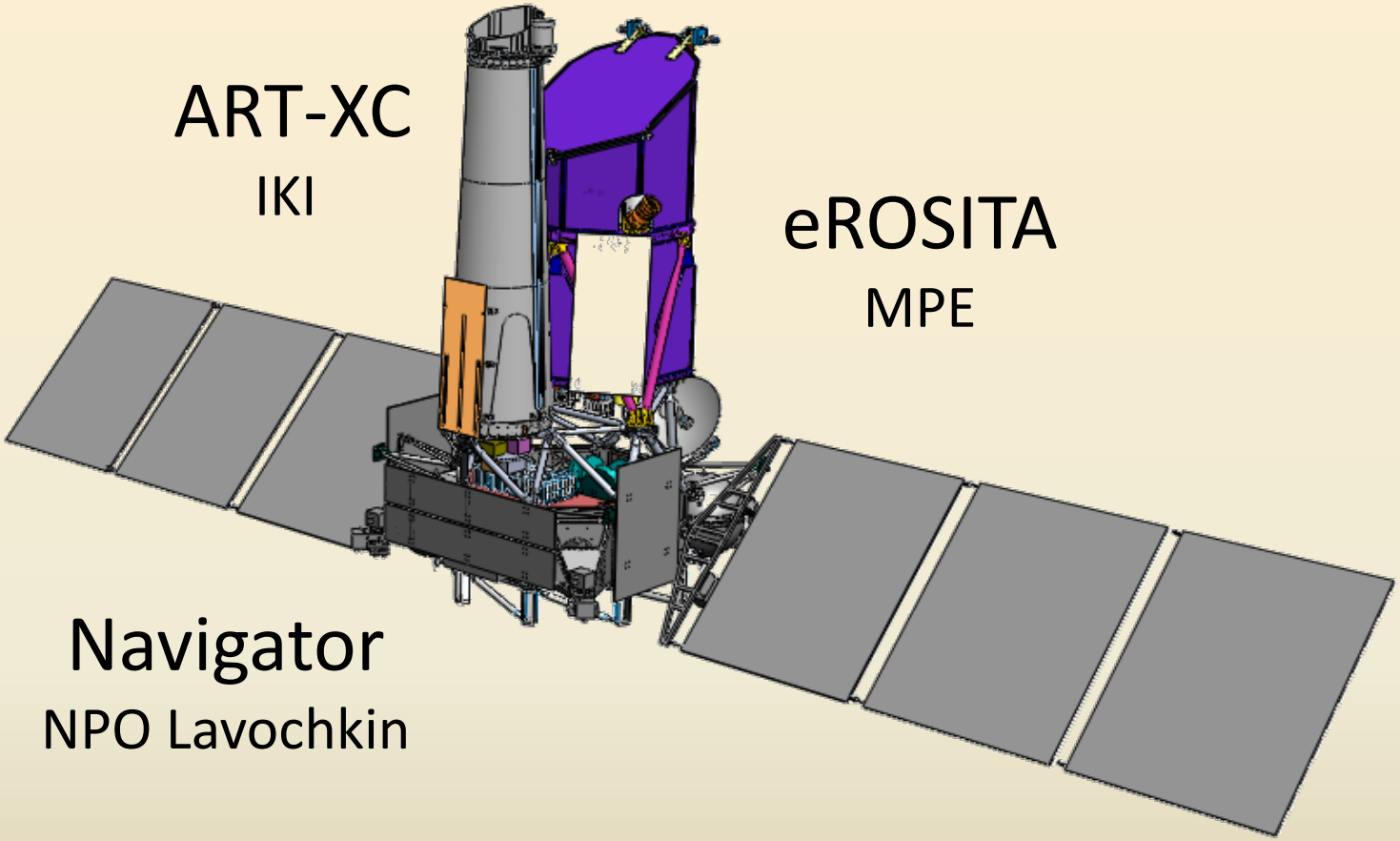
eROSITA

ABRIXAS science on the International Space Station



Dark Energy
10^5 Clusters of Galaxies

SRG



Launch from Baikonur with Zenit-FREGAT, Nov. 2013

Zenit-Fregat-Navigator = standard configuration, also used for Elektro-L (Jan 2011) and Radiastron (Jul 2011).

eROSITA Collaboration

Core Institutes (DLR funding):
MPE, Garching/D
Universität Erlangen-Nürnberg/D
IAAT (Universät Tübingen)/D
SB (Universität Hamburg)/D
Astrophysikalisches Institut Potsdam/D

Co-I Institutes:
MPA, Garching/D
IKI, Moscow/Ru
USM (Universität München)/D
AIA (Universität Bonn)/D

Industry:

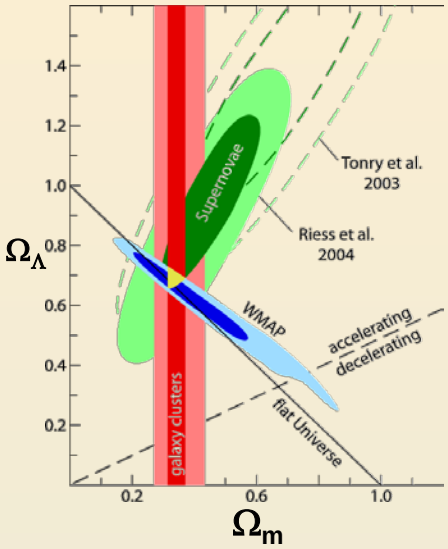
Media Lario/I	Mirrors, Mandrels
Kayser-Threde/D	Mirror Structures
Carl Zeiss/D	ABRIXAS-Mandrels
Invent/D	Telescope Structure
pnSensor/D	CCDs
IberEspacio/E	Heatpipes
RUAG/A	Mechanisms
HPS/D,P	MLI

+ many small companies

MPE: Scientific Lead Institute, Project Managment
Instrument Design, Construction, Integration & Test
Data Handling & Processing, Archive etc.

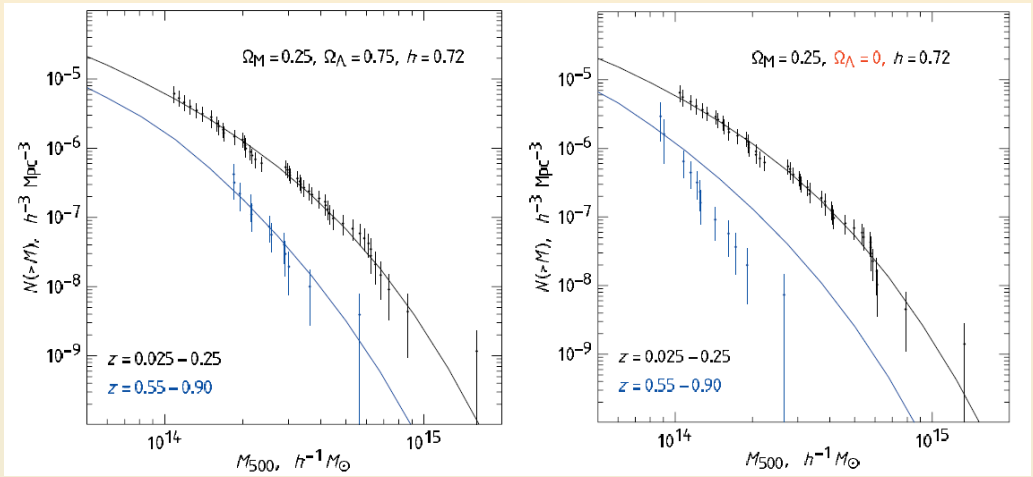
More than 50 people are working for eROSITA at MPE

Observational Constraints



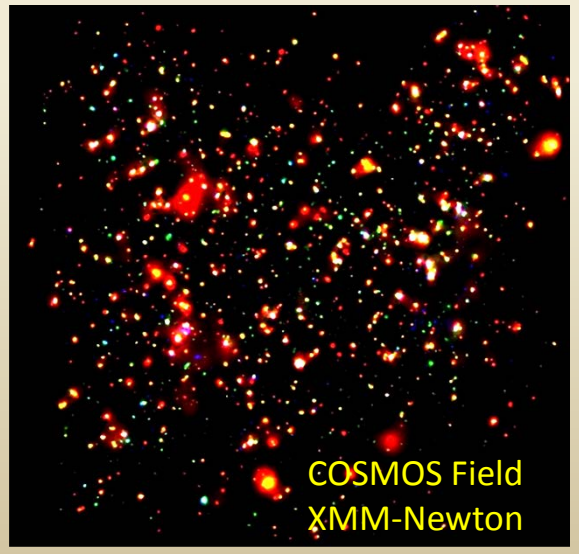
WMAP results from Spergel et al. 2003

REFLEX results from Schuecker et al. 2003



Vikhlinin et al., 2009

WMAP	→ Flat Universe
SN Ia	→ Accelerated Expansion
Clusters	→ Matter density



Clusters of galaxies are the largest gravitationally bound entities in the universe

In X-rays we see clusters as one continuous entity

Design Driving Science

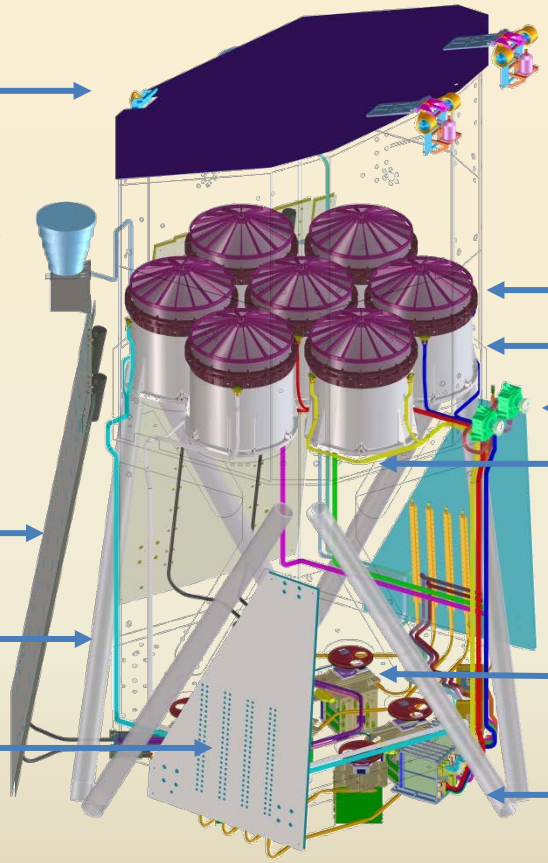
- Constrain parameters of Dark Energy

- Detectability of 100.000 Clusters of Galaxies, z < 1.5
  - All-sky survey with sensitivity 6×10^{-14} erg cm^{-2} s^{-1}
  - Deep survey field(s) (~100 sqdeg) with 1×10^{-14} erg cm^{-2} s^{-1}
  - Individual pointed observations

- Instrument:

  - Moderate angular resolution (< 28 arcsec, aver. over FoV)
  - Large collecting area (> 2000 cm^2 @ 1keV)
  - Large FoV (1° Ø)
  - Long duration (survey 4 years ← → 1/2 year (ROSAT)

Instrument



7 identical Mirror Modules	Field of View	1° Ø
54 nested Mirror Shells each	Angular Resolution	15 arcsec on-axis
7 identical pnCCD Cameras	Energy Range	0,5 - 10 keV

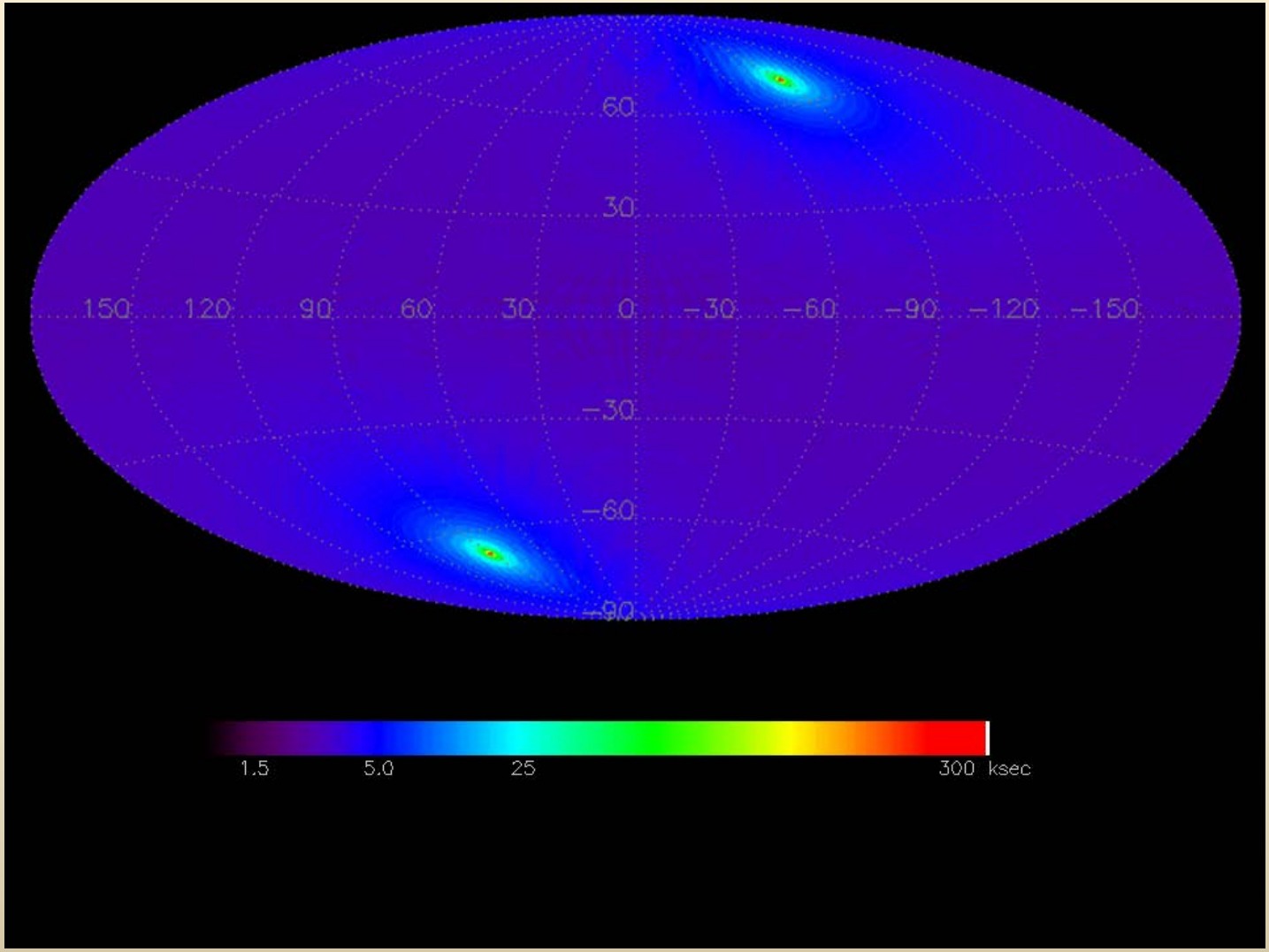
Mission Profile

Orbit around L2 (~ ½ yr)

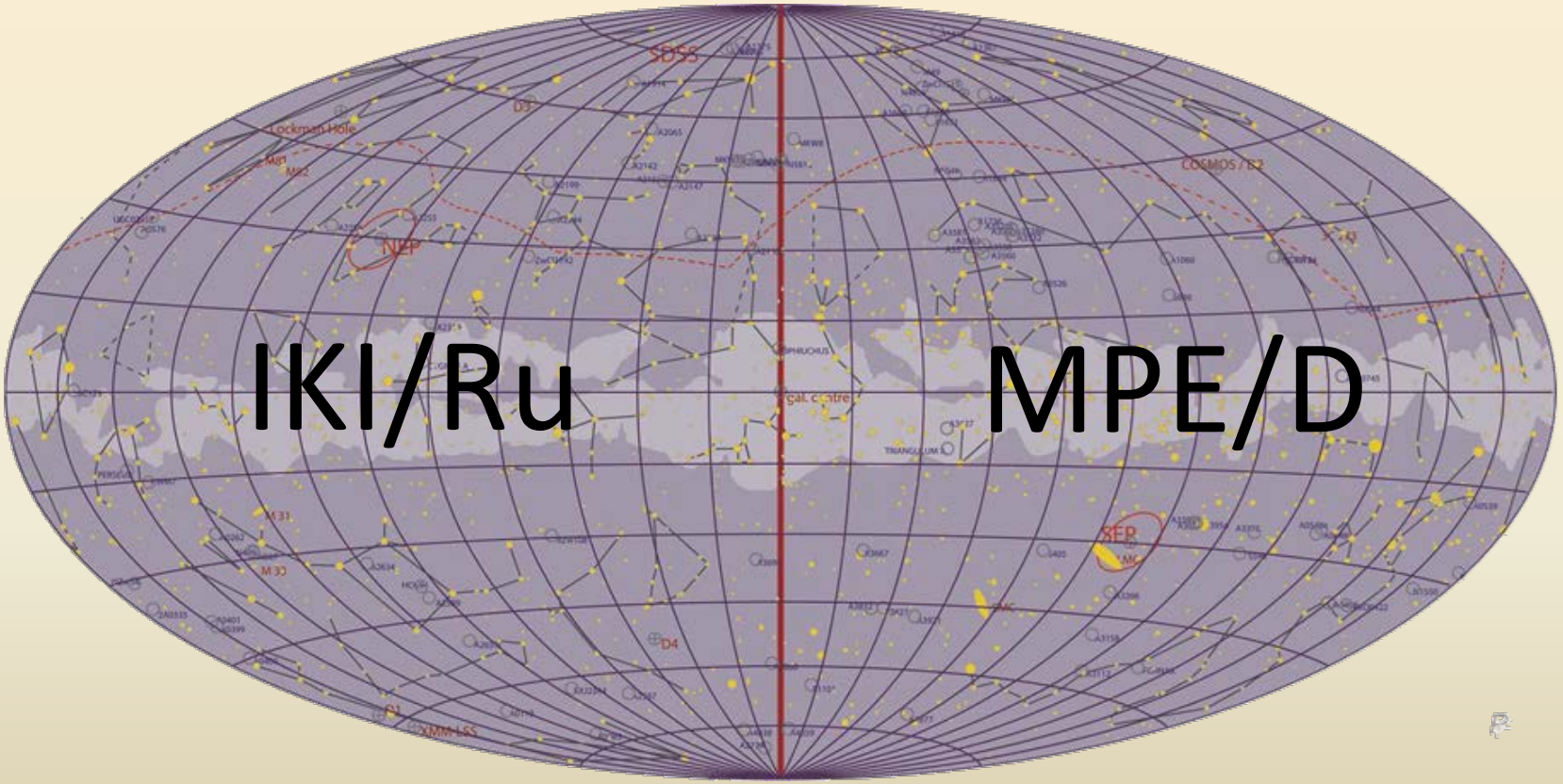
Continously rotating during Survey, ~ 4 hours / revolution

4 years all-sky survey, 3 years pointing

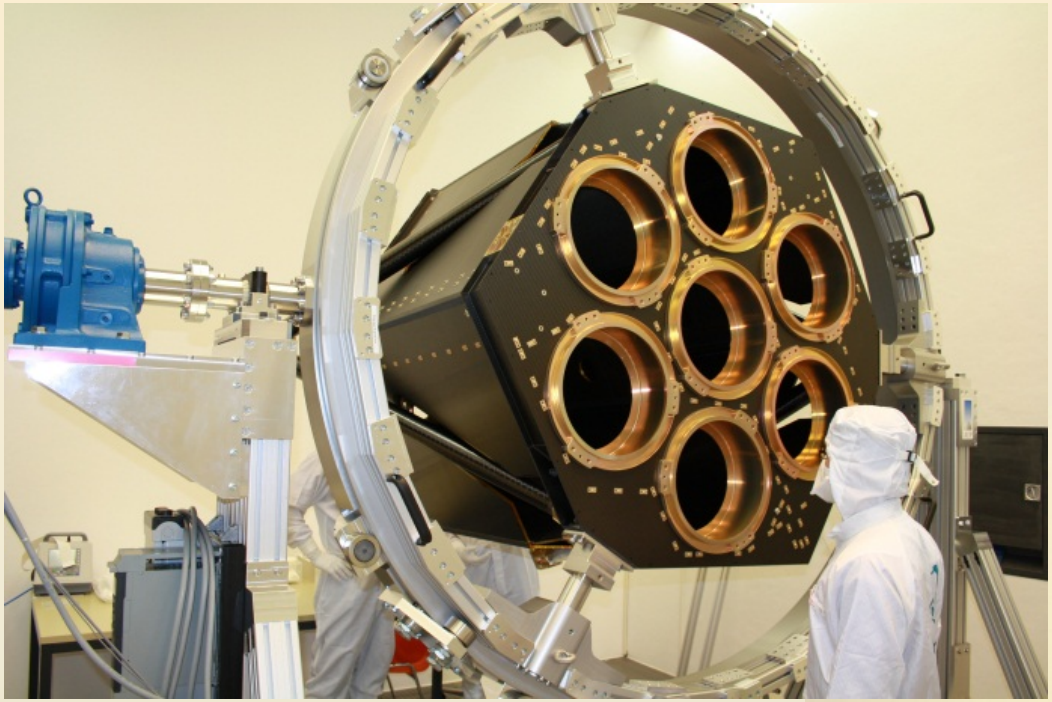
Exposure Map



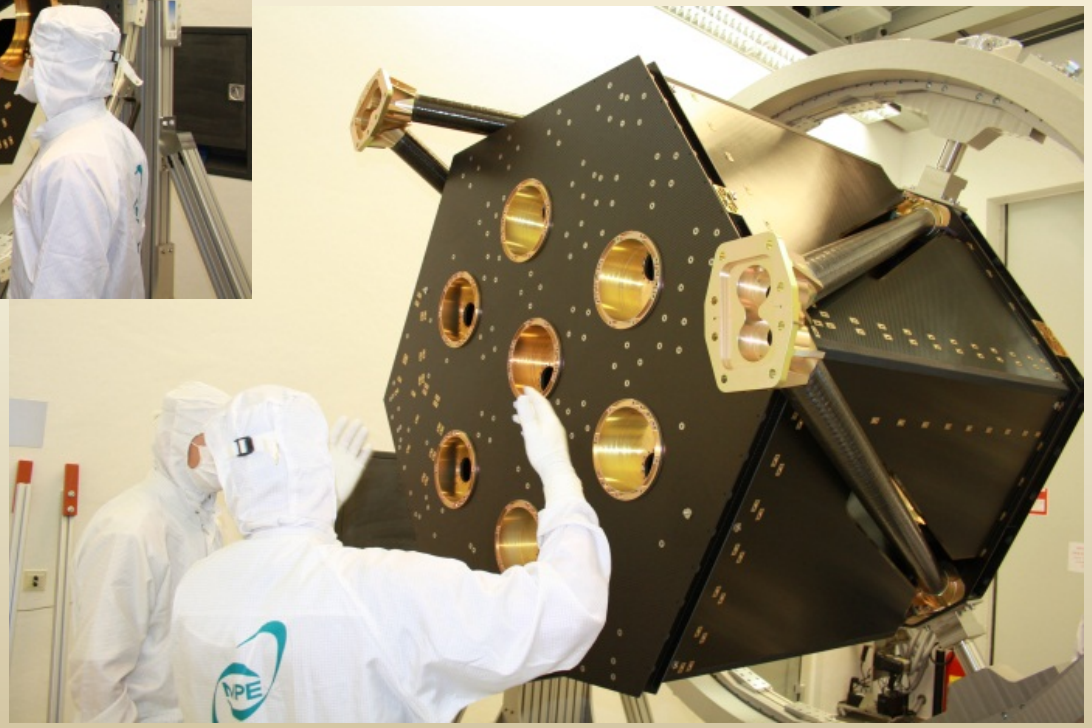
Sky Division



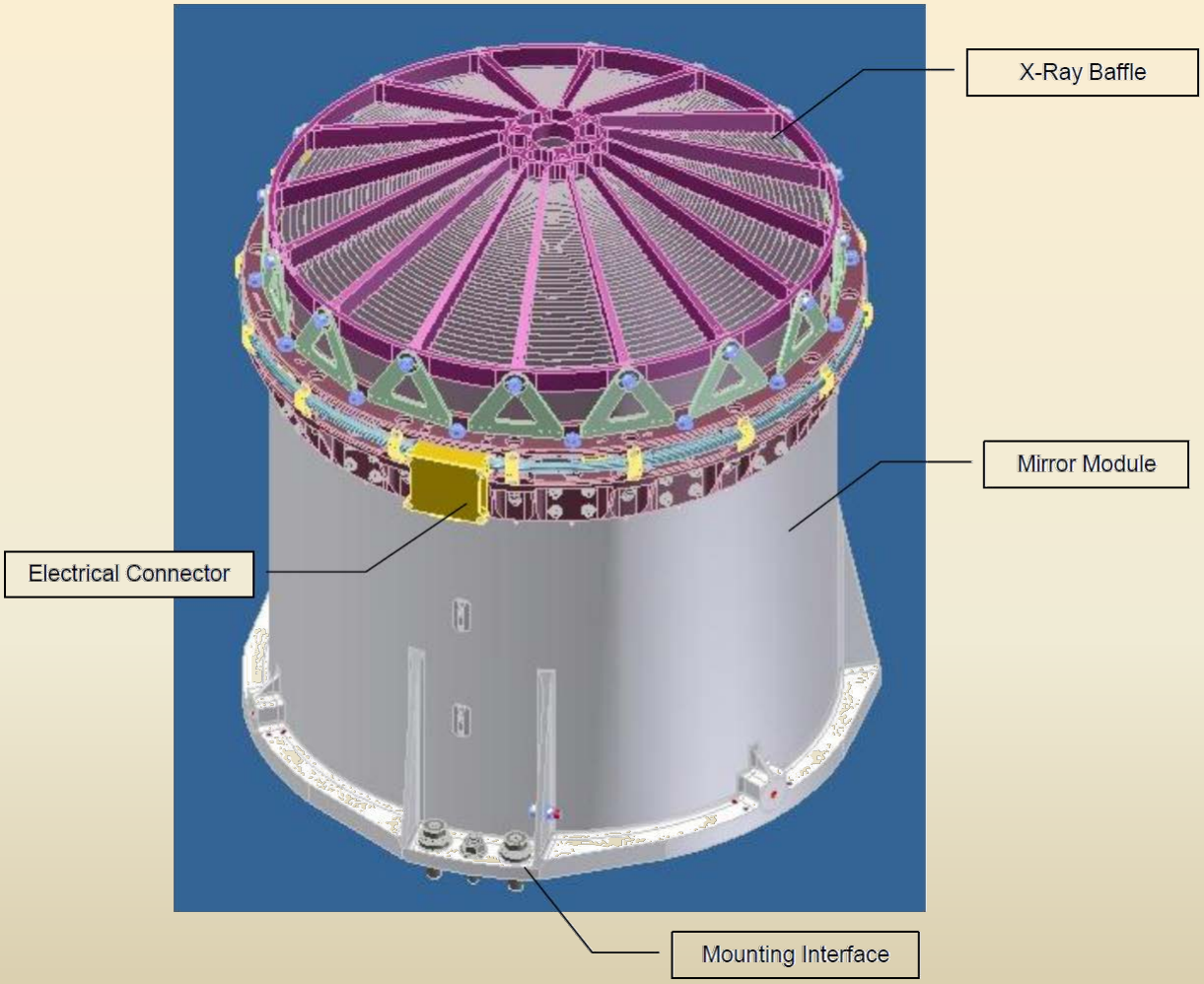
eROSITA H/W: Telescope Structure

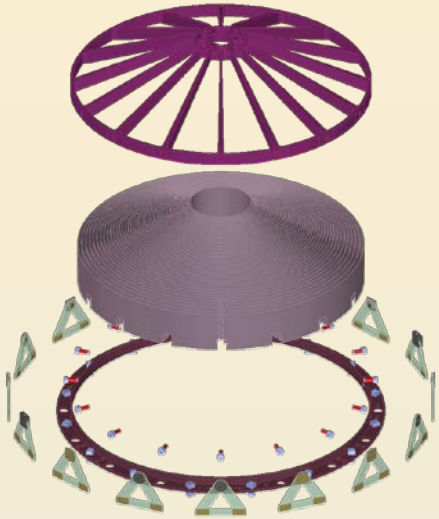


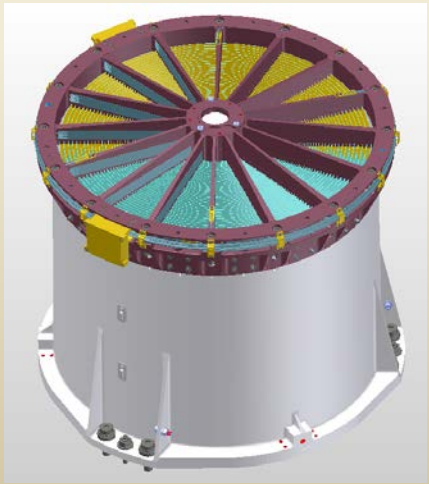
Telescope Structure
prior integration of
subsystems and components



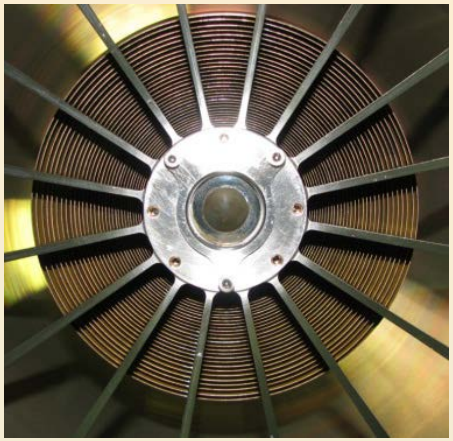
Mirror Assembly (x 7)







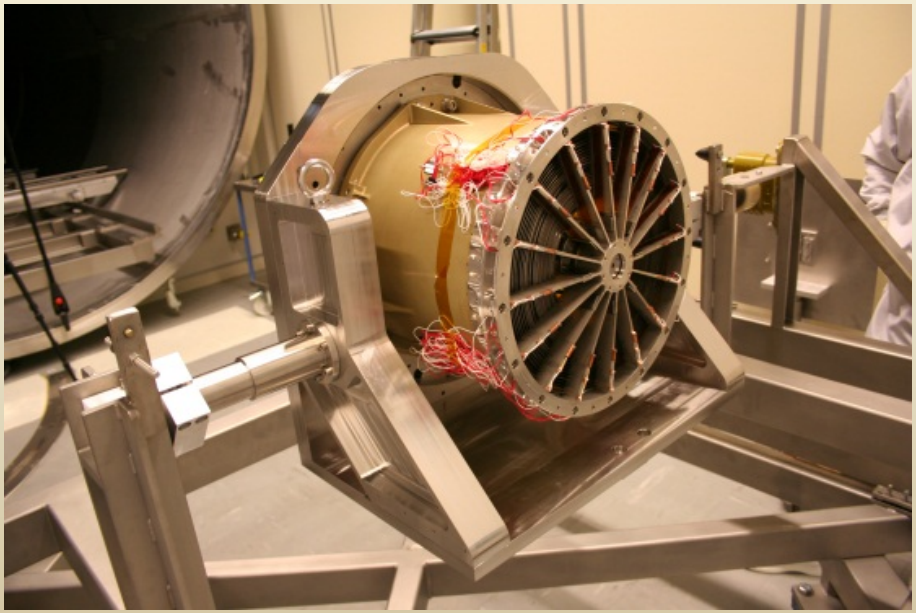
eROSITA H/W: Mirror Assembly

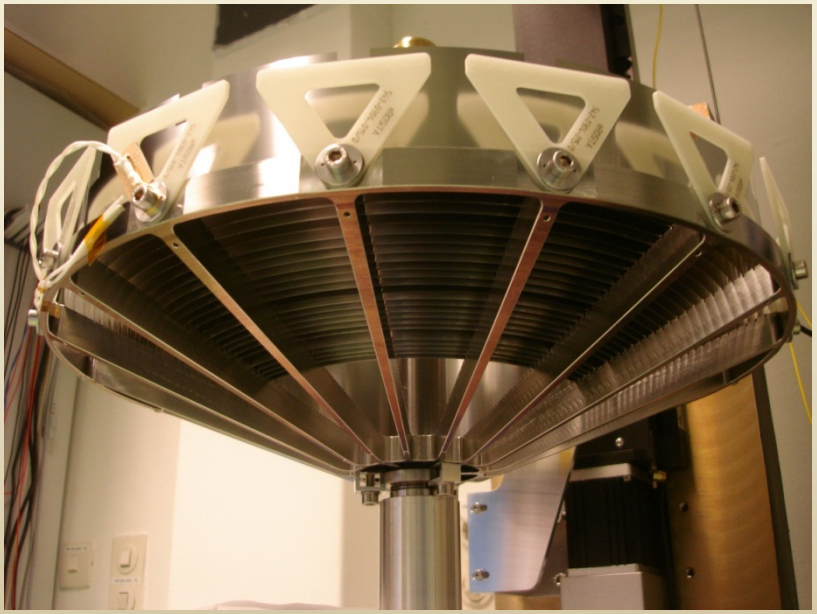


Mirror Modules

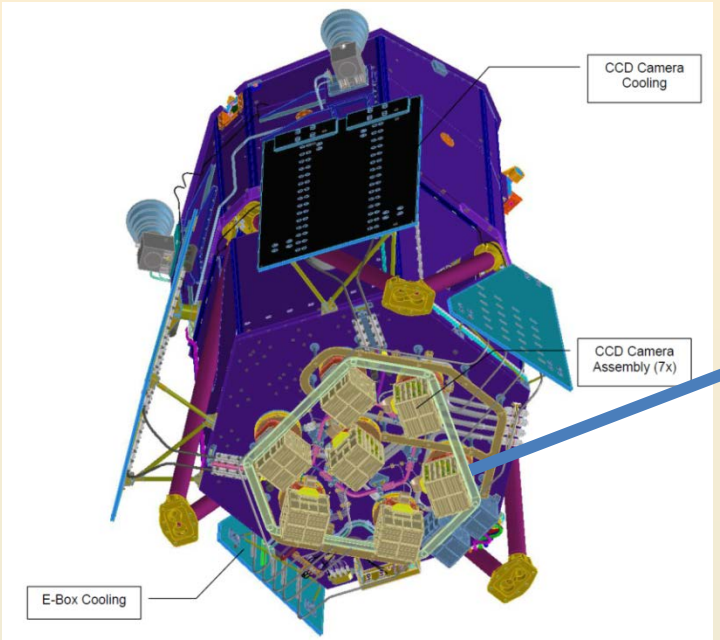
FM-production running

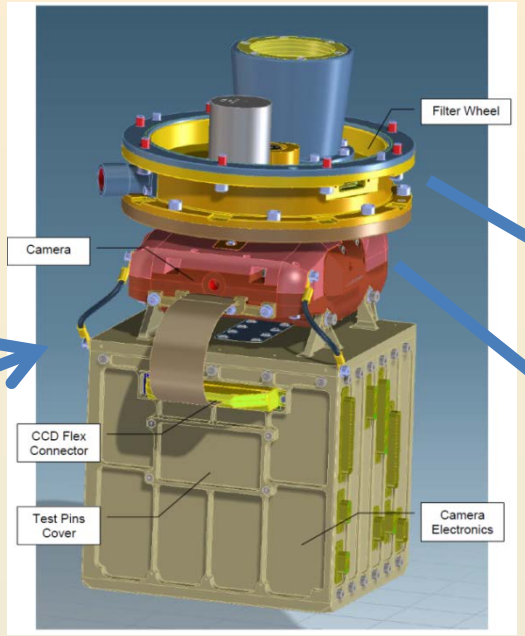
15 arcsec HEW, on-axis

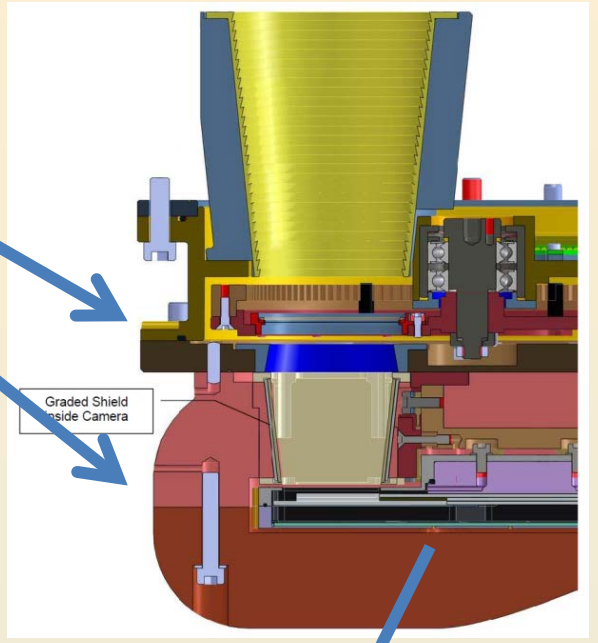




Camera Assembly (x 7)

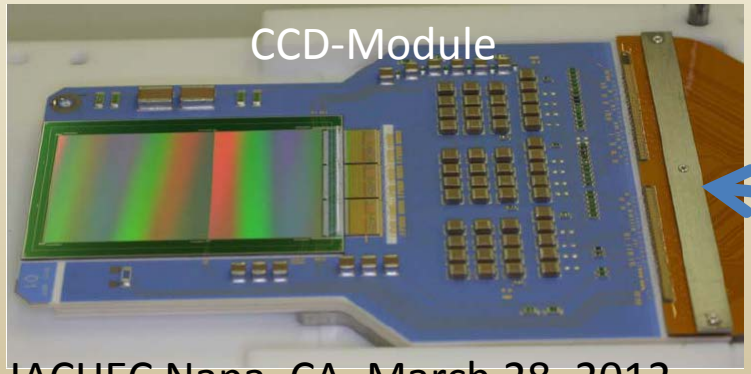


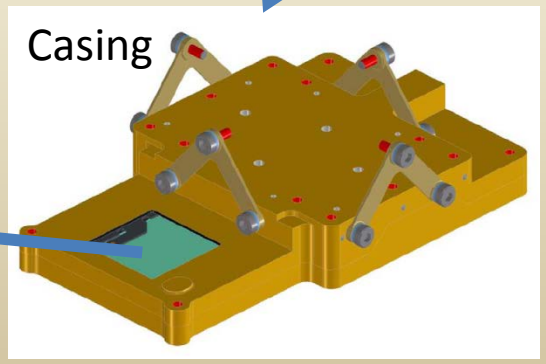




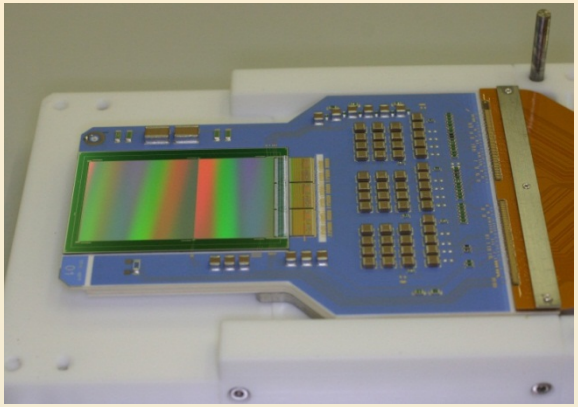
warm (roomtemperature)

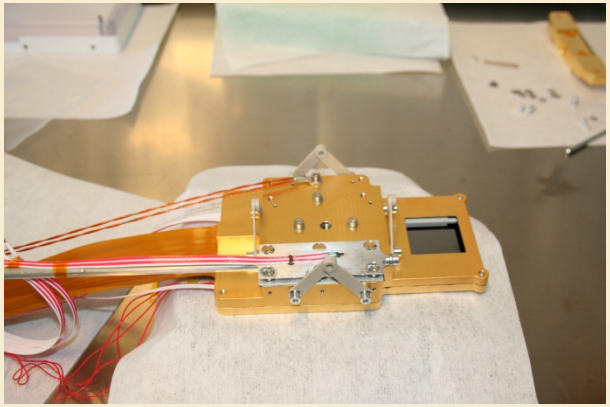
cold (-95°, goal)

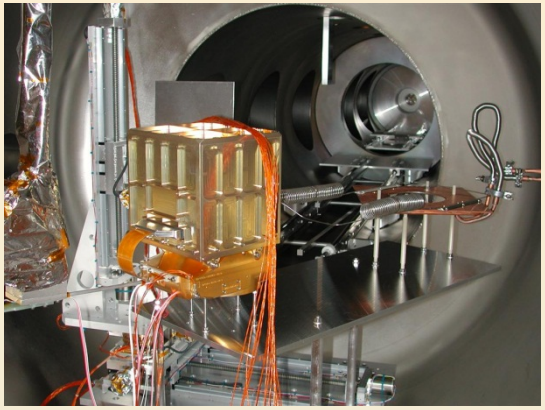


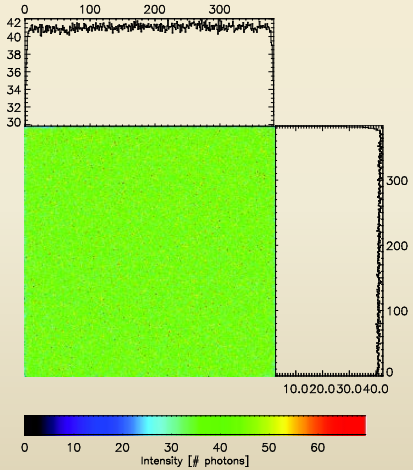


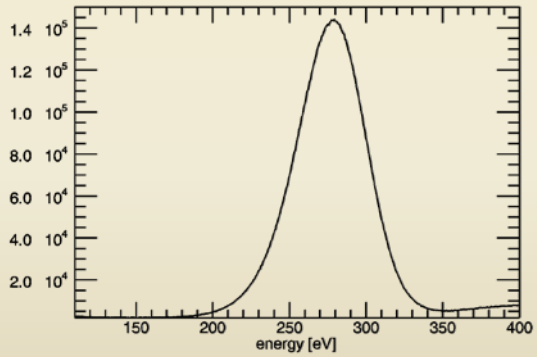
pnCCD-Camera







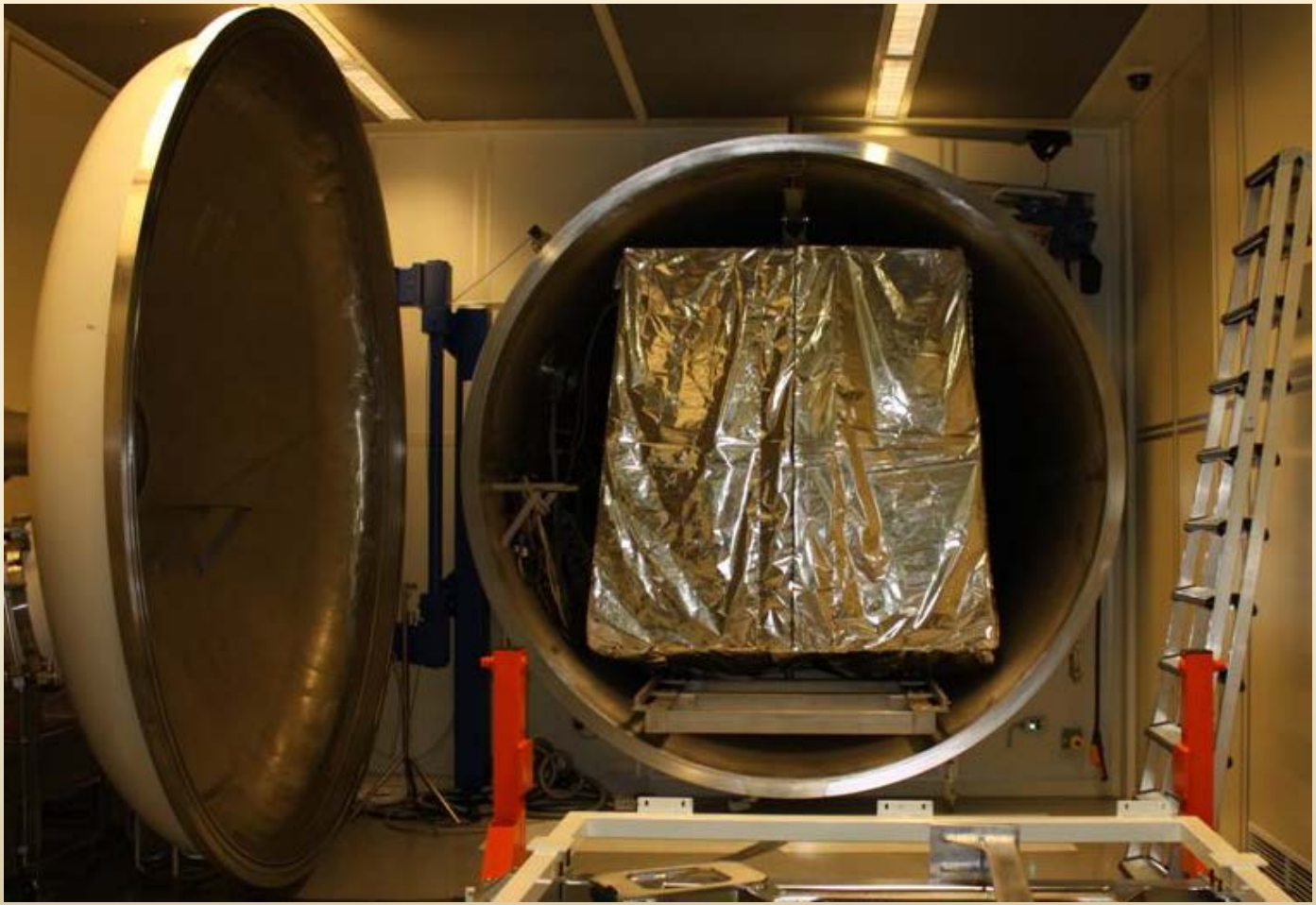




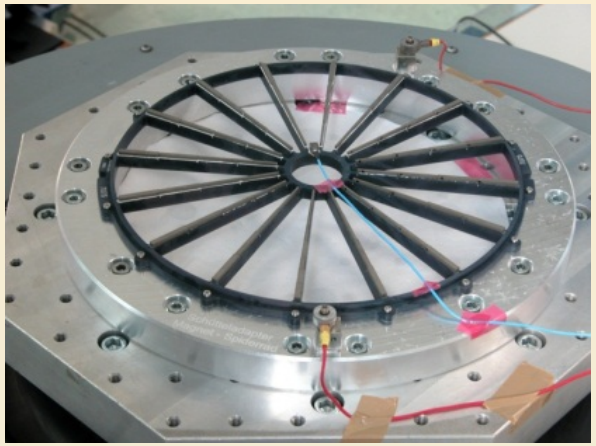
pnCCD Module working since 2010, in spec

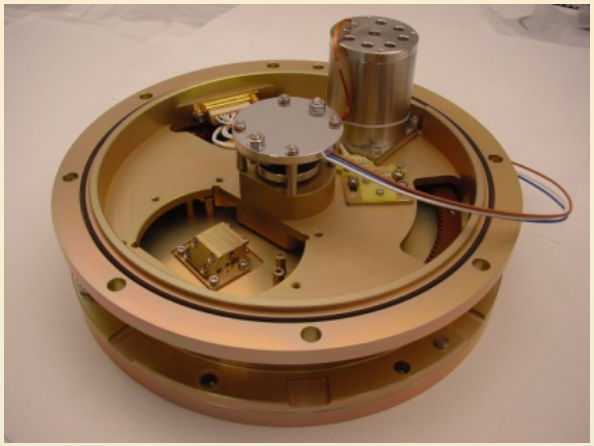
size:	384 × 384 pixels = 28.8 × 28.8 mm^2
cycle time:	50msec
energy resolution	138eV @ 6 keV

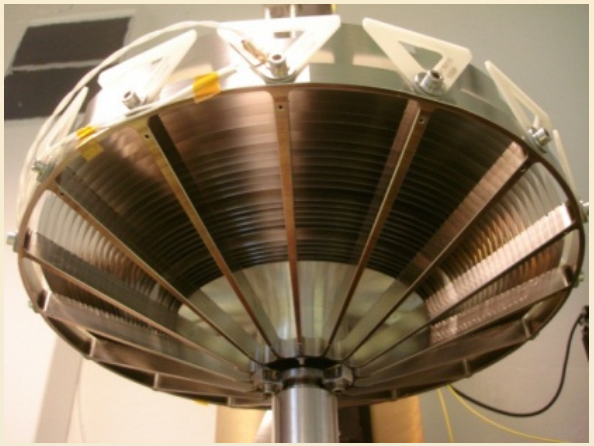
Thermal Tests

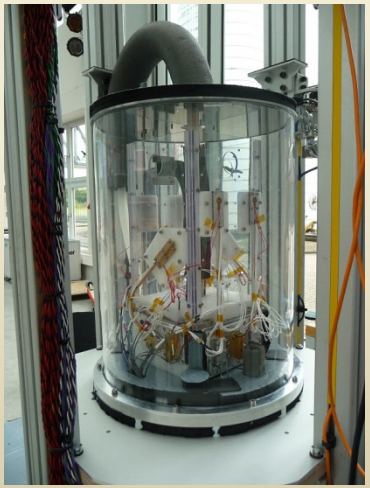


Miscellaneous







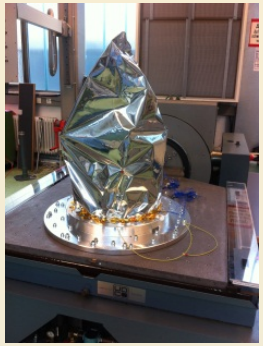


Magnetic Electron Deflector	qualified
Filterwheel	qualified
X-ray baffle	qualified

cryogenic heatpipes tested last year at the Drop Tower in Bremen, 10sec µg

MPE Test Facilities

- hundreds of individual tests to be conducted
- 9 vacuum chambers continuously in operation + shaker + other equipment



Calibration

device	*process*	*signal*	*characteristic properties*	
telescope	reflection (scattering)	*photon [eV]*	effective area (E,φ) point spread function (E,φ) field of view (FOV) boresight	collecting area, reflectivity, vignetting mirror quality focal length, detector geometry, plate scale alignment
filter	absorption		transmission (E) contamination (E,t)	
CCD	charge release	*charge [e^-]*	charge splitting low energy threshold	**patterns** (singles, doubles, triples, quadruples, invalid..)
			contaminating effects	**pile-up** (single pixel, pattern) **photon background** (fluorescence, optical loading)
			quantum efficiency (QE) energy resolution (ΔE)	**particle induced background** (soft protons, MIPs) **detector induced background** (noise, bright pixels)
	charge transfer		charge transfer loss (CTI) pattern migration	**trap saturation** due to photons and particles **charge transfer noise** **threshold induced charge loss** reemission, charge diffusion, charge splitting
	charge readout	*pulse height amplitude [adu]*	readout noise amplification ('gain')	non-linear gain, also dependence of the "apparent" gain on threshold(!) dependence on energy, temperature, time
on-board data processor	signal processing	*event [bit]*	energy offsets (offset map) common mode correction signal extraction MIP suppression	**restrictions likely due to limitations in on-board computing power and telemetry** (low energy threshold, MIPS..)

court. K. Dennerl

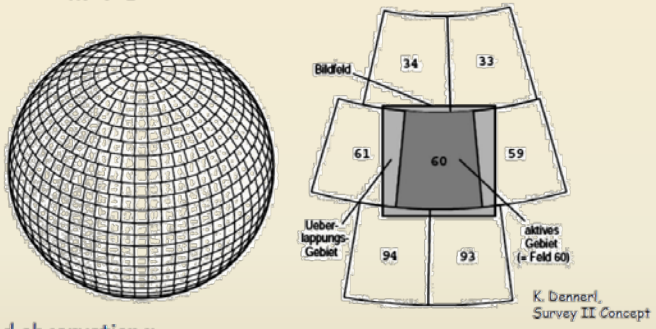
NRTA & SASS & Catalogues

- NRTA (Near Real Time Analysis)
- SASS (Standard Analysis Software System)

The SASS pipeline processes all-sky survey and pointed data:

All-sky survey:

- Sky is divided into 5839 equatorial equal-area fields of approx. 3°x3°
- After event-calibration, incoming data stream is split and accumulated in same number of overlapping 3.6°x3.6° fields, centred on each of these fields (local, parallel projection sky maps)
- Source detection and further source-level analysis is performed on these sky maps



Pointed observations:

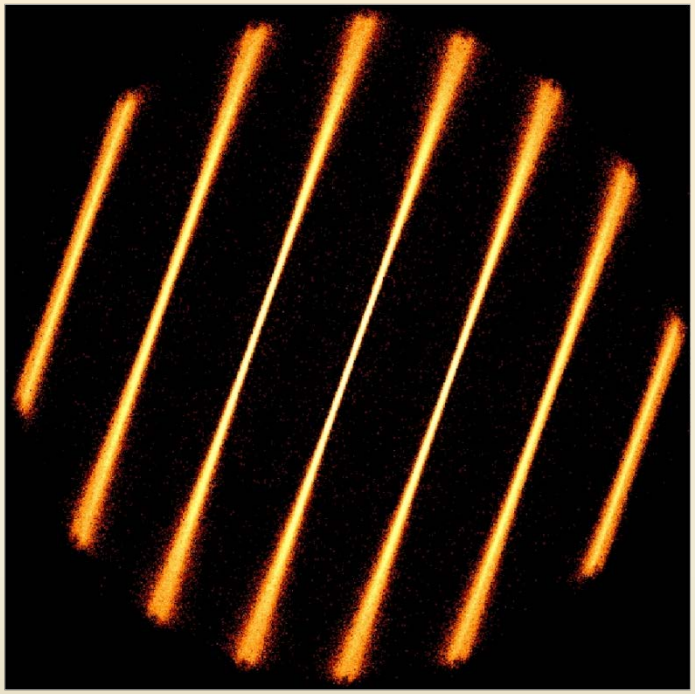
- Incoming data stream is split in different pointings (←timeline)
- Source detection is performed on 1.6°x1.6° fields, centred on pointing

- **Calibrated event files**
  FITS extensions: EVENTS, EXPOSUREn, GTIn, BADPIXn, OFFSETn
- **Image products**
  Sky image in four non-overlapping energy bands (E_{min}-0.5, 0.5-2, 2-5, 5-10 keV); energy bands should be science driven (to be discussed in WG)

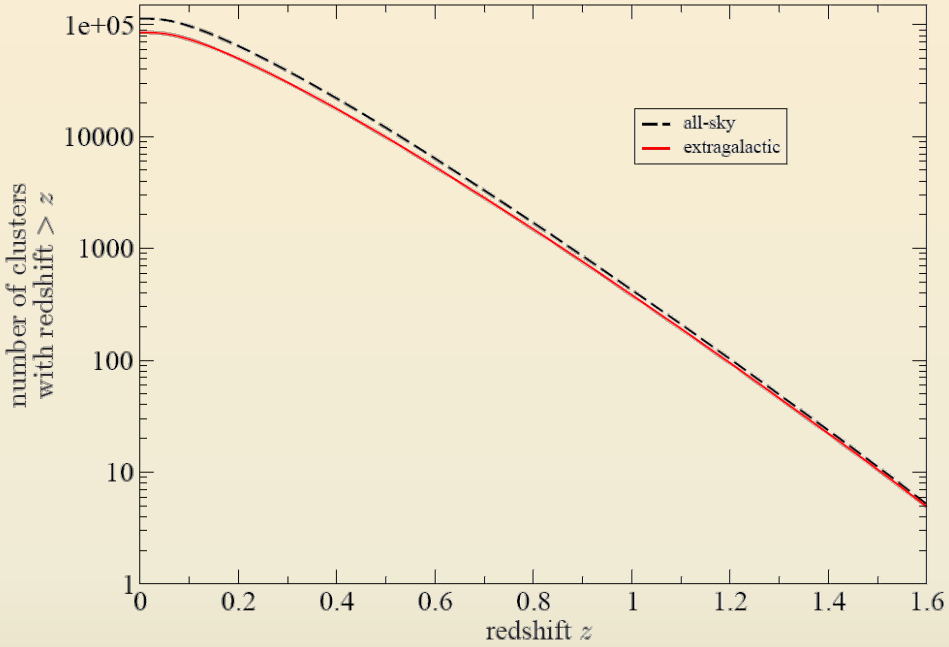
  Image pixel size: 4" (tbd)
  Image size survey: 3.6^0 x 3.6^0
  3240 x 3240 pixels
  pointed obs.: 1.6^0 x 1.6^0
  1440 x 1440 pixels

  Corresponding exposure & backgr. maps
- **Source Lists**
  XMM-style (emldetect) source lists
  ds9 region files of detected sources
- **Source specific products**
  Extracted spectra (source & backgr., suitable for spectral fitting) and time series for all sources with more than tbd counts (FITS & PDF); under discussion: include simple model fits (PL?)
- **Index or summary file (ASCII)**
  Observation and instrument config. summary, high backgroud warning, important warnings and errors from pipeline processing, automatic & interactive quality screening flags, list of files in dataset
- **Pipeline parameter file**
  Allows the user to re-run the pipeline
- **Other products**
  Attitude file (FITS) & histogram plot, backgr. Lightcuvre (FITS/PDF), opt. cross-ID products, selected HK files

Simulations



Off-axis blurring of a Wolter-I telescope →
PSF has to be averaged over the FoV
15 arcsec on-axis → 28 arcsec averaged



100.000 Clusters of Galaxies
400 with z > 1

Working Groups

„Science Working Groups“:	Chairs
Clusters and Cosmology	H. Boehringer, J. Mohr, T. Reiprich
AGN, Blazars	K. Nandra
Normal Galaxies	F. Haberl
Compact objects	A. Schwope, A. Santangelo
Stars	J. Robrade, J. Schmitt
Solar System	K. Dennerl
Diffuse emission, SNR	W. Becker, M. Freyberg, M. Sasaki

„Infrastructure Working Groups“:	
Time Domain Astrophysics	J. Wilms, I. Kreykenbohm
Data analysis, source extraction, catalogs	H. Brunner
Multi-wavelength followup	J. Mohr
Calibration	K. Dennerl
Background	M. Freyberg

Follow-up Observations

Needs for follow up:

- Enabling studies of cosmology and cluster physics:

  Redshift: phot-z + spec-z, Mass Estim.: weak lens. + velocity disersions
- Evolution of AGN Population

  Redshift estim., phot-z, spec-z
- Galactic Sources