eROSITA

Instrument & Science – an Overview

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on behalf of the eROSITA-Collaboration

Outline

1. Design Driving Science
2. Instrument Design
3. Instrument Performance
4. Science with eROSITA
5. Instrument Status

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

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

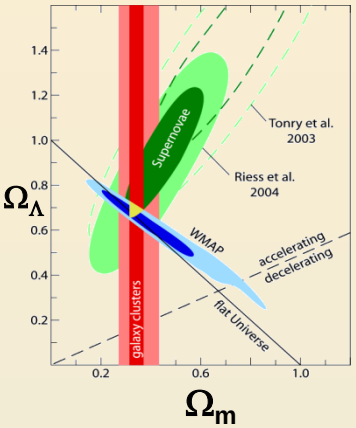
Industry:

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
Moog/USA	Valves
MAP/F	Painting
Laserjob/D	X-ray Baffles
NPOL/Ru	Spacecraft, Mission

+ many other (small) companies

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

Cluster Cosmology Design Driving Science



WMAP: Spergel et al. 2003
ROSAT: Schuecker et al. 2003

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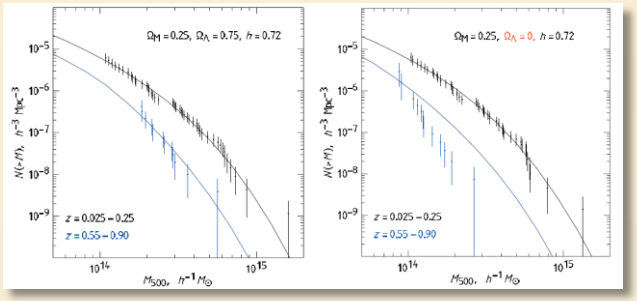

Vikhlinin et al., 2009

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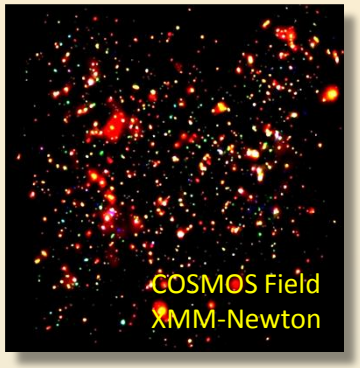


Clusters of galaxies are the largest gravitationally bound entities in the universe.

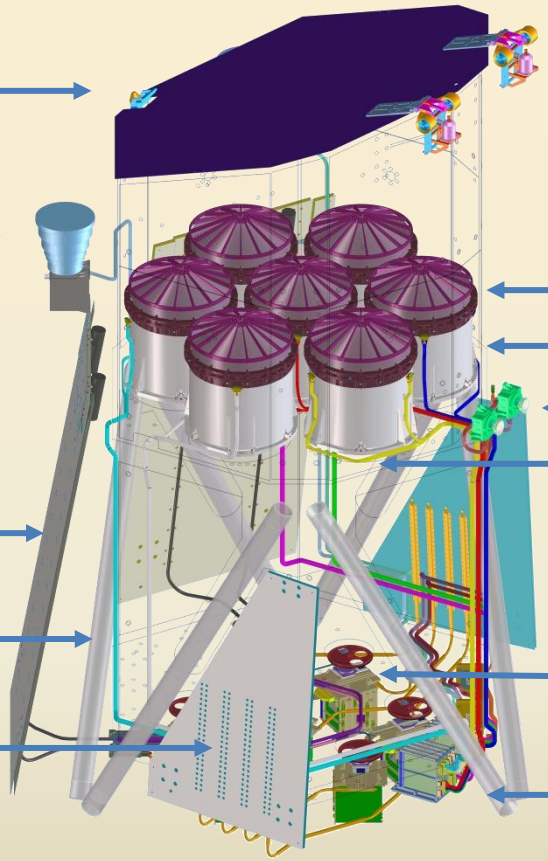
In X-rays we see clusters as one continuous entity.

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

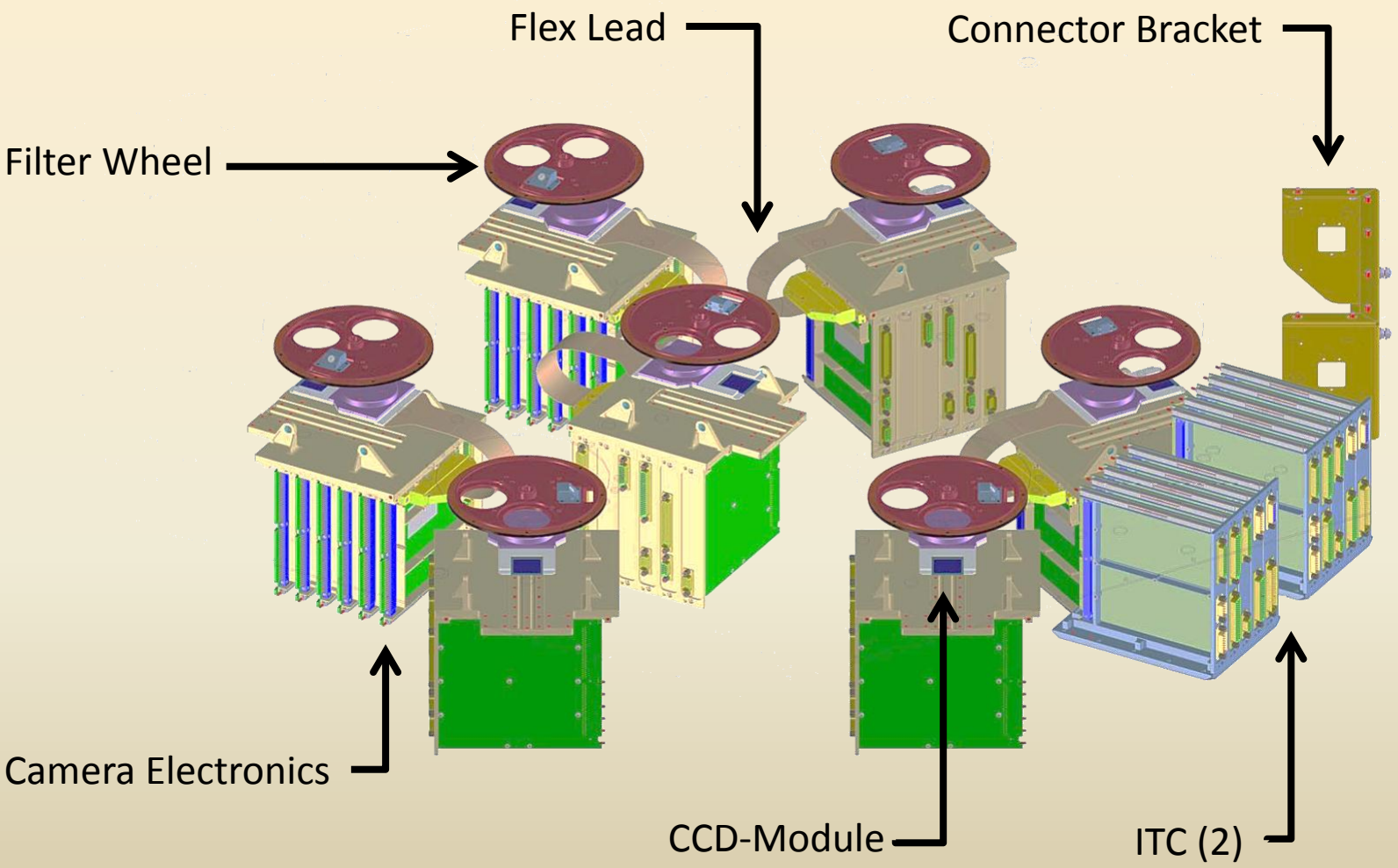
- Moderate angular resolution (< 28 arcsec, aver. over FoV)
- Large collecting area (> 2000 cm^2 @ 1keV)
- Large FoV (1° Ø)
- Long duration (survey 4 years ← → 1/2 year (ROSAT)

Instrument

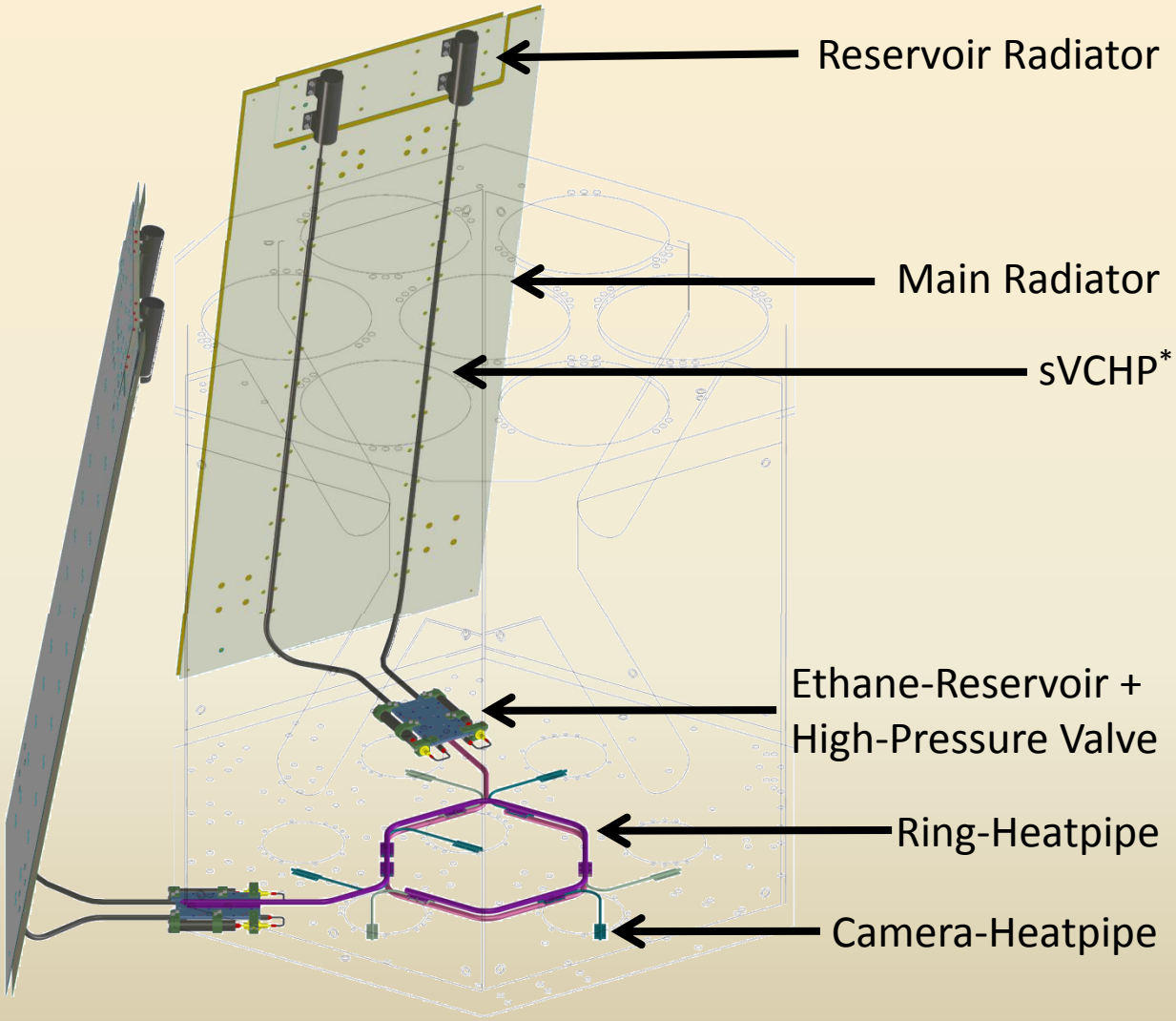


7 identical Mirror Modules	Field of View	1° Ø
54 nested Mirror Shells each	Angular Resolution	15 arcsec on-axis
7 identical pnCCD Cameras	Energy Range	~0,3 - 10 keV

Cameras


Flex Lead
Connector Bracket
Filter Wheel
Camera Electronics
CCD-Module
ITC (2)

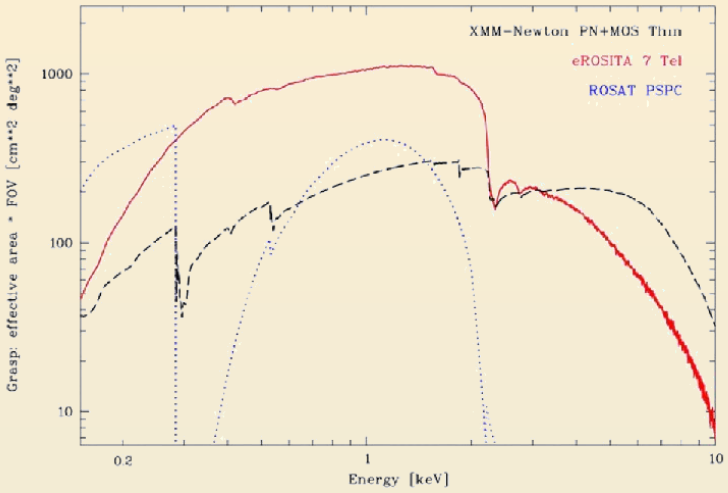
Cooling System



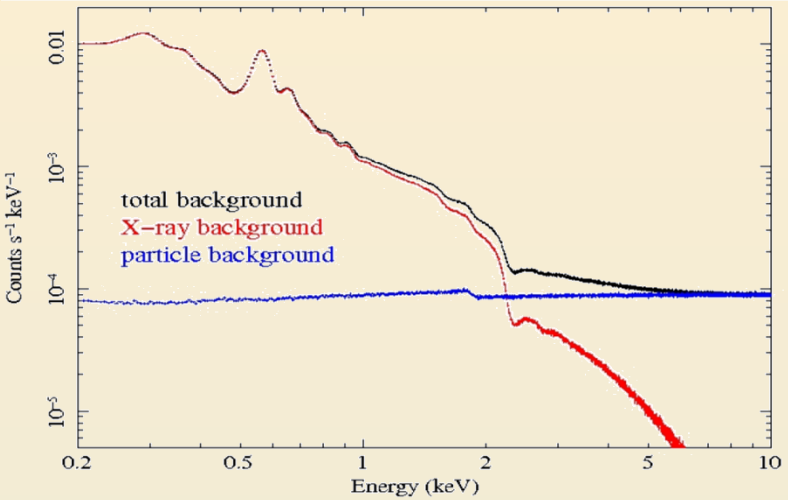
* switchable Variable Conductance Heatpipe

eROSITA Performance

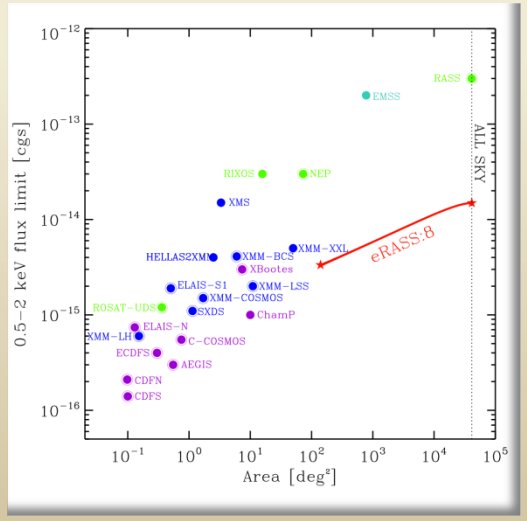
Grasp



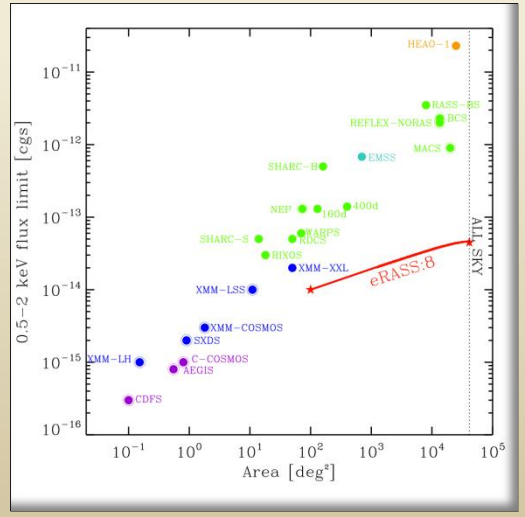
Background



Point Source Sensitivity

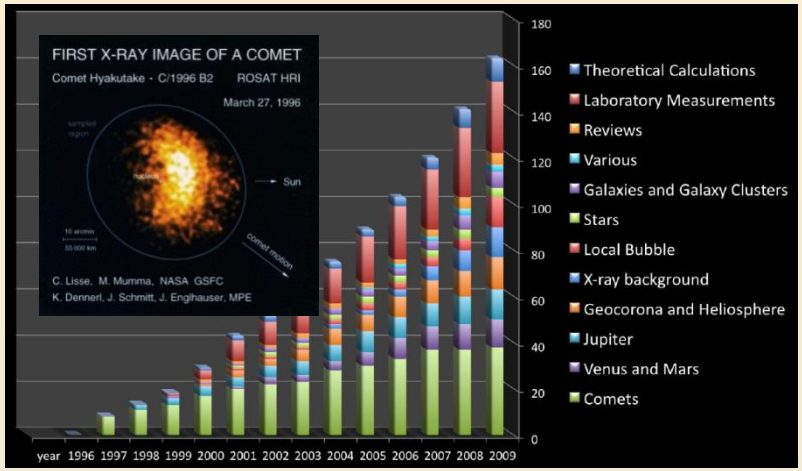


Cluster Sensitivity



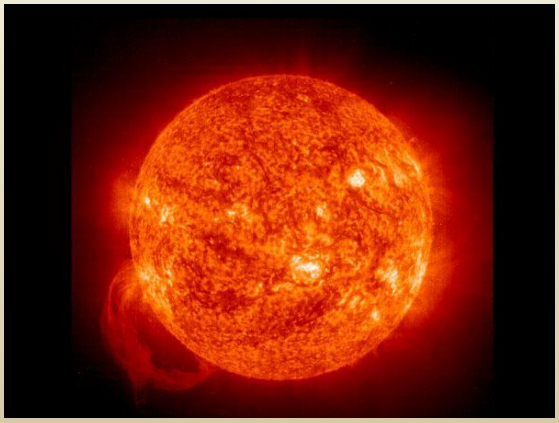
Science: Cold Universe

Charge Exchange



court. K. Dennerl

Schmitt et al. 1990

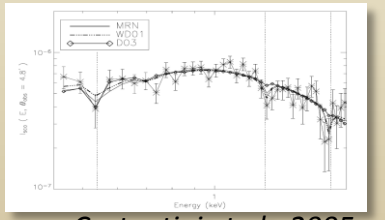


Cool Stars

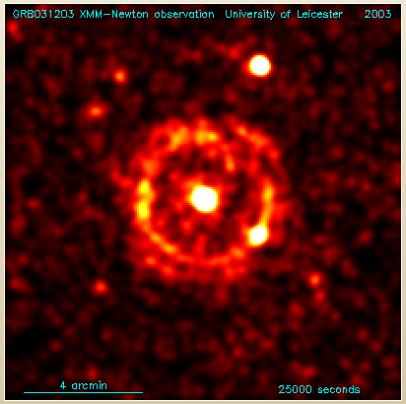
magnetic activity
coronae

Interstellar Dust

scattering
spectroscopy
chemistry



Costantini et al., 2005



Vaughan et al., 2003

Stars

0.3 – 0.5 Mio. Stars

- Cool Stars (late A to late M-type, magnetic activity, coronae)
- Hot Stars (O to early B-type incl. WR Stars, wind shocks)
- other

log L_X	stars	distance limit
26.0	late M dwarf	10 pc
26.5	active VLM (M9) star	20 pc
27.0	Sun, Altair (A7), Prox Cen (M5)	30 pc
28.0	Procyon (F5), Eps Eri (K2)	100 pc
29.0	low-mass CTTS, active M dwarf	300 pc
30.0	EK Dra (active G2)	1 kpc
31.0	Algol, bright TTS, early B star	3 kpc
32.0	WR1, O type star	10 kpc
33.0	θ^1 Ori C (mag. O5)	30 kpc

Stellar population studies
- activity vs. age, rotation, mass, eff.temperature
- Lx/Lbol relation along hot star sequence

Dynamo theory
- study of (super-) saturation effects and Lx/Lbol evolution
- transition effects at fully convective boundary

Local star formation history & galactic structure
- young nearby stellar population
- early evolution of planetary systems

Properties of individual SFR
- masses, IMF, star formation history
- modes of star formation & scenarios

court. J. Robrade

SNR + ISM

- SNRs:
  - Search for new SNR candidates (radio quiet / X-ray bright)
  - Large SNRs in Milky Way

- Hot Interstellar Medium:
  - Globally (LMC, SMC)
  - Particular Sources (superbubbles, SNR)

  → Strong shocks, T, densitities, ionization stages, chem. abund., NE effects

  ← XMM-Newton and Chandra spectra show inconsistencies with collisional ionizing equilibrium and common non-equilibrium ionizing models

- Background:
  - Local Hot Bubble (origin? state? CEI or NEI?, cooling curves?, etc.)
  - Loop I (CE relevant?)
  - Galactic Halo (by shadowing → 3d picture of contribution and properties)

Compact Objects

- Accretion
  - via RLOF (CVs, LMXBs, BHs…)
  - via stellar wind (HMXBs)
  - via disk (BE)
  - from ISM (INS, IBH)
  - Cyclotron lines features
  - Heavily obscured binary systems
- Thermonuclear
  - Novae, Bursts
- Cooling, remnant heat
  - WDs, NSs
- Magnetic Fields
  - AXPs, Magnetars
- Spin-down
  - Pulsars
- Other

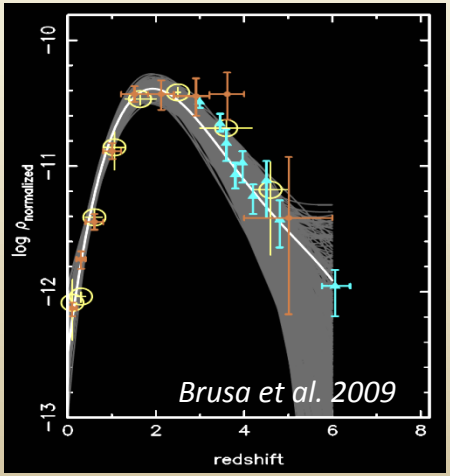
court. A. Schwope

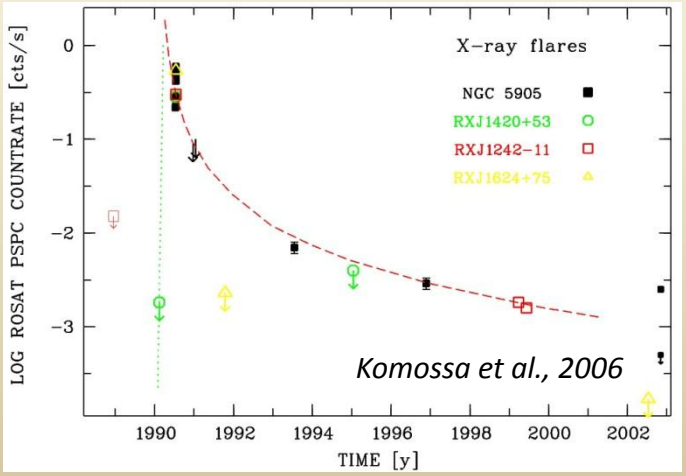
100s INS

AGN

3 Mio. AGN

- Accretion History: XLF, obscured vs. unobscured
- LSS: AGN ACF, AGN/Galaxy CCF, AGN/Cluster CCF
- AGN host Galaxies: Morphology, SFR, Obscuration
- Sub-Populations:
  - High Redshift (z>6)
  - Extreme Luminosity
  - Compton thick AGN
- Spectra: Obscuration, Continuum, Soft Excess, Iron Lines
- Variability: Var. vs. L, L/L_{edd}, z, Tidal Disruptions





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
Diffuse emission, SNR	W. Becker, M. Freyberg, M. Sasaki
Stars	J. Robrade, J. Schmitt
Solar System	K. Dennerl

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

Status 1/3

- Telescope Structure:
  - qualified in parts (vibration), complete
- Mirrors:
  - QM qualified (thermal, vibration, X-rays)
  - 7 FMs + 1 FS: Mechanical Structures complete, Shell Integration 66%
- Cameras:
  - EM/STM qualified (thermal, vibration, X-rays, proton-radiation damages)
  - FM-CCDs 100%, 7 FM + 1FS-mechanics & electronics in manufacturing
- Cooling System:
  - EM qualified
  - QM/parts of FM complete
- X-ray Baffles:
  - qualified (vibration, thermal, X-rays)
  - 7 FMs + 1 FS: Integration started 4/12, 1 shell/day
- Electron Deflectors:
  - qualified (vibration, thermal)
  - 7 FMs + 1FS: Structures 100%, magnets 100%, integration 70% (5)
- Filterwheels:
  - Qualified (vibration, thermal, acoustic noise)
  - 7 FMs + 1 FS: motors 100%, mechanics in manufacturing
  - Cal-Source (Fe55) optimised for three lines (Al-Kα, Ti-Kα, Mn-Kα)

Status 2/3

- Electronics (10 E-boxes):
  - qualified (thermal, vibration)
  - EM 9/12, FM+FS open

- MGSE
  - Integration Stand — in operation
  - Transport Container — ready
  - Other equipment — all ready

- EGSE
  - Power Suppies — 100% available
  - Data Aquisition Tools — 100% available
  - Computers — 100% available
  - Software — 60% ready (except checkout sequences)

- „Technological Model“ — In preparation, delivery to Lavochkin 10/2012
  - Mechanics — ready
  - Electronics — ready 9/2012
  - Software — in preparation/test until 10/12

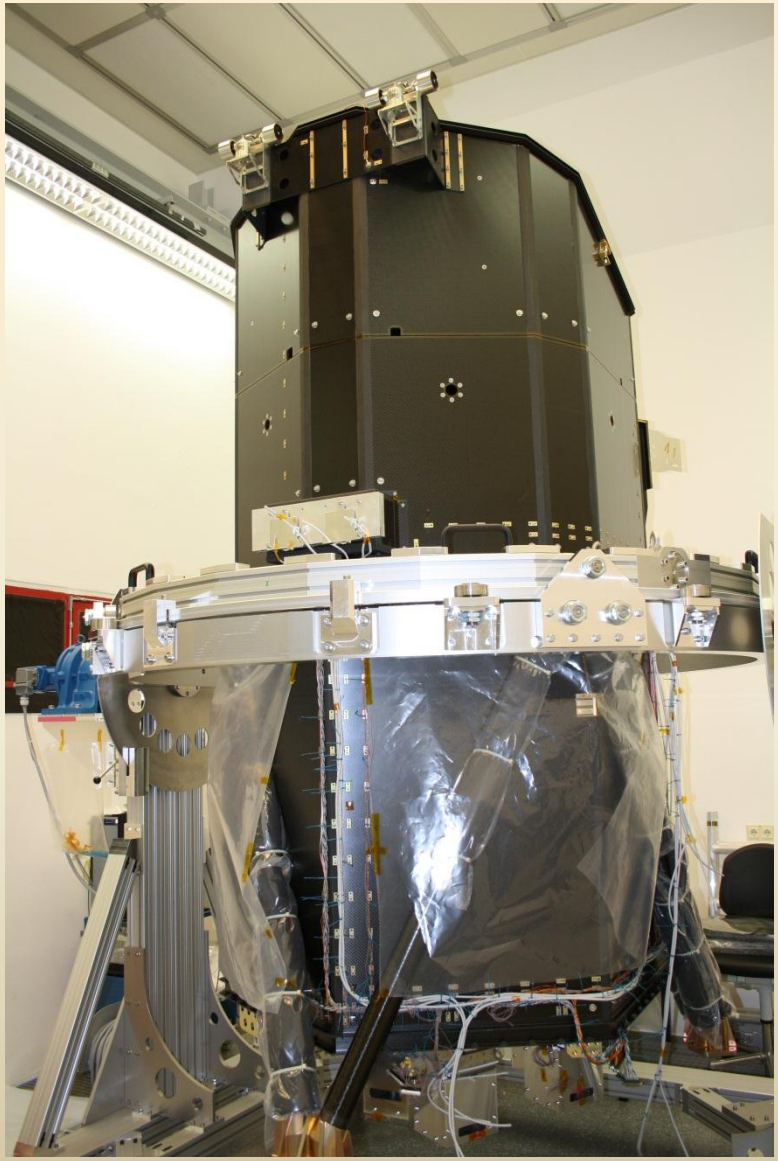
Status 3/3

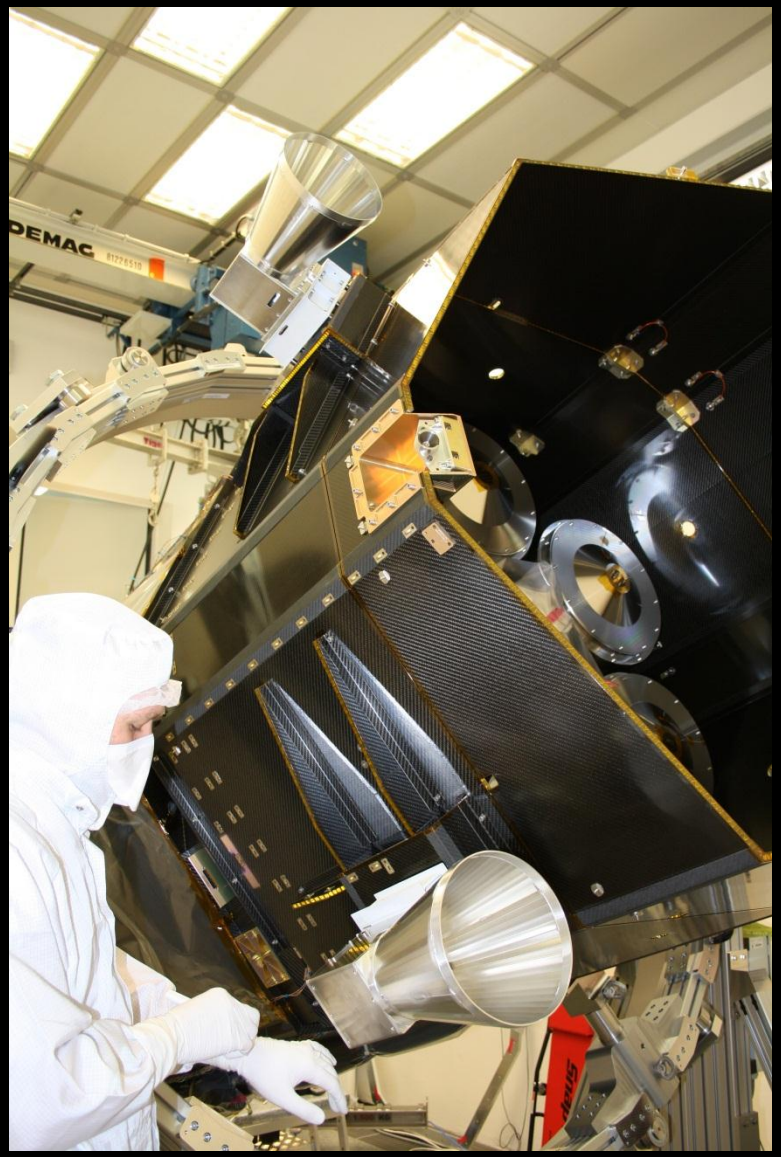
- Ground Software:
  - Near Real Time Analysis (NRTA), Standard Analysis Software System (SASS)
  - Based on ROSAT and XMM-Newton
  - Readiness: integrated tests have started
- Calibration CCD-Camera:
  - ongoing since 2007 (TRoPIC-CCD), 2010 (eROSITA-CCD)
  - completely in spec (energy resolution, quantum efficiency etc.)
- Calibration Mirrors:
  - manufacturing of FM-Mirrors witnessed by frequent X-ray measurements:
  - FM-1a 15/54 shells HEW @ 1,5 keV = 13,1 arcsec
  - FM-2a 15/54 shells HEW @ 1,5 keV = 13,9 arcsec
  - FM-3c 39/54 shells HEW @ 1,5 keV = 16,4 arcsec
  - FM-1b 30/54 shells HEW @ 1,5 keV = 15,4 arcsec
  - Problems with shell #1 and #2 in teststructure, but shell #6 has 13,4 arcsec
- Calibration Telescopes:
  - Plan: Calibration of each Mirror Module + ass. Camera in Testbench (PANTER Facility)
  - Time needed for all 7 Telescopes: 1×4 + 6×2 = 16 weeks
- End-to-End Test eROSITA:
  - PANTER facility with thermal shroud, instrument upright (heatpipes!) → no X-rays possible
  - Complete functional tests, Cooling System, 7 Cameras, ITC
  - Checkout Sequences, Typical Mission scenarios, in-Orbit Calibration, Failure Modes, etc.
  - Time needed: 10 Weeks

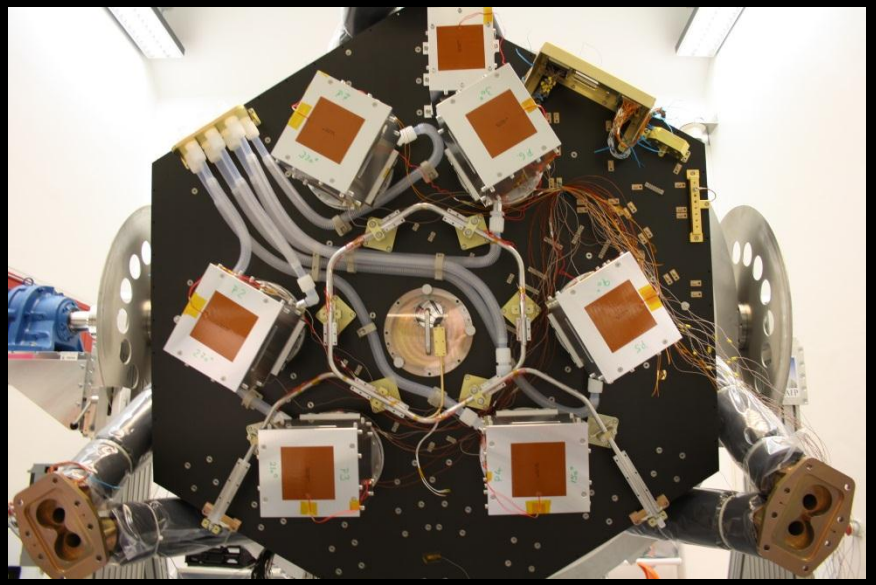
Qualification Tests @ IABG

- 45 days test campaign, starting on October 8th, 2012
- Tests:
  - Mass property measurement
  - Vibration test
  - Shock test
  - Acoustic test
  - Space simulation test
  - ´End-to-End test´ test (PANTER)
- Configuration:
  - Complete PFM Structure
  - 1 Mirror Module + 6 Dummies
  - 1 Camera + Electronics (STM) + Filterwheel + 6 Dummies
  - Complete Cooling System (PFM, QM)
  - Front Cover Mechanisms (PFM)

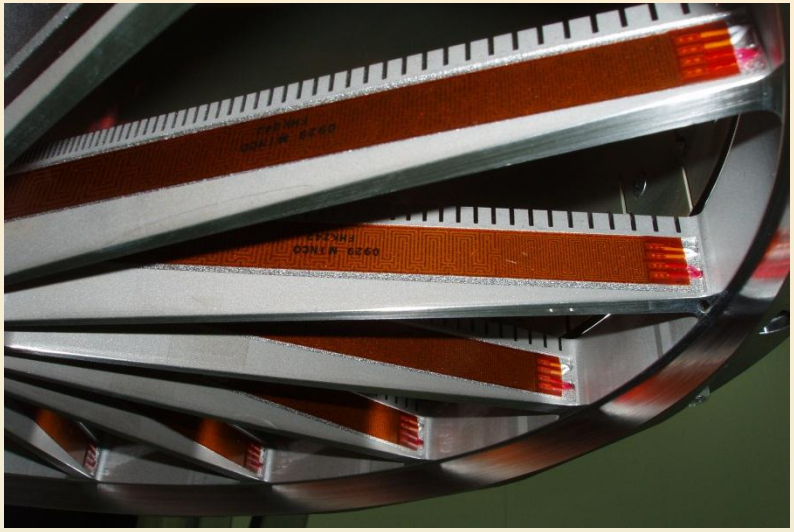
Telescope Structure



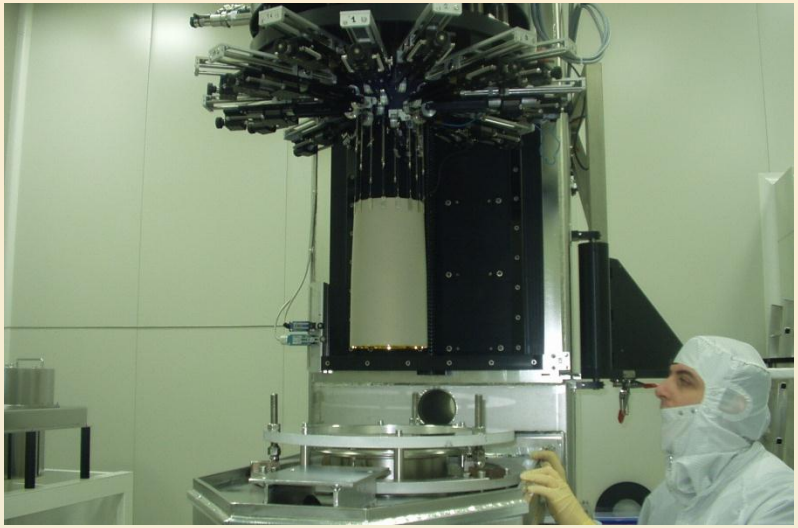

DEMAC



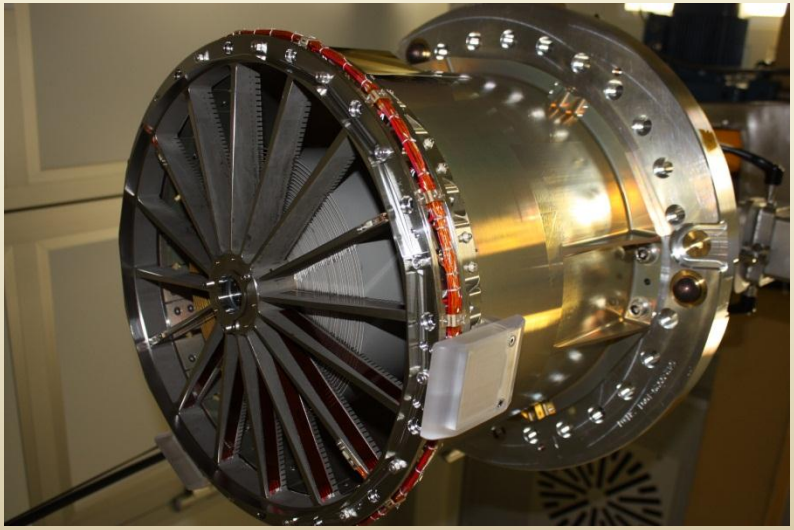
Mirror System



Spider Wheel with heaters integrated



VOB in action: Integration of a Shell

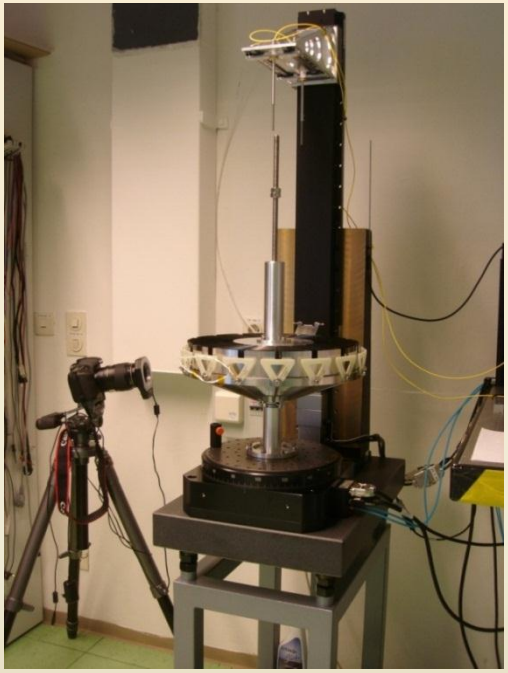


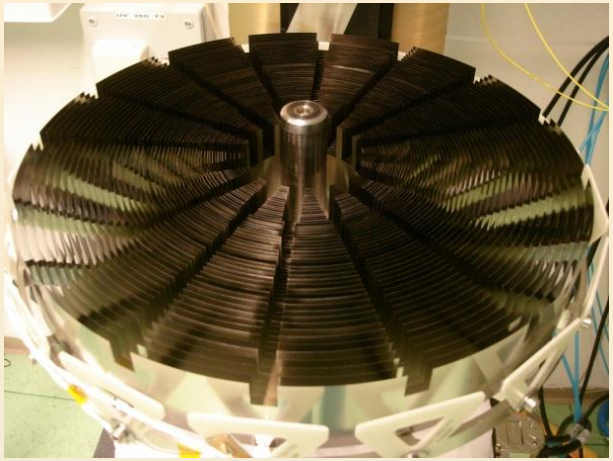
FM-3 Mirror Module with 39/54 shells

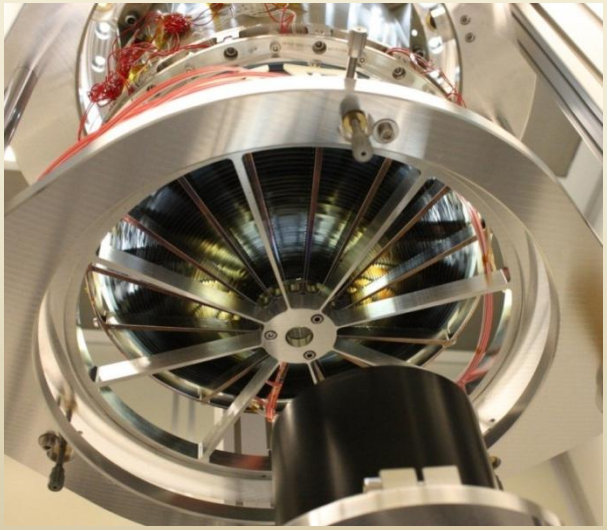
Preparation of PANTER X-ray Tests (FM-3c)

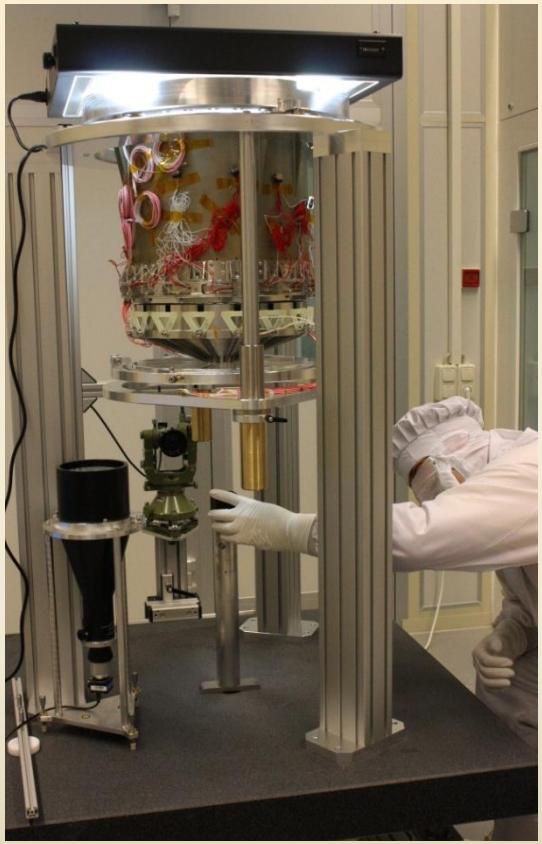
X-ray Baffle

Stand for Integration and Metrology of Baffle Shells



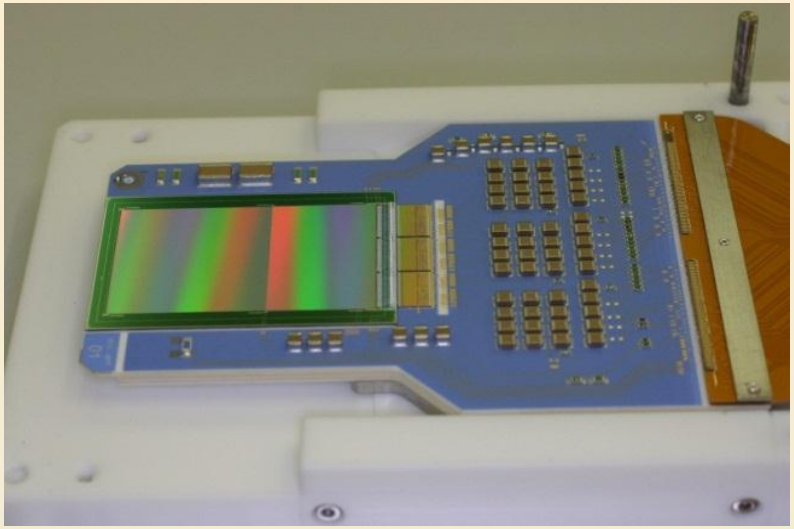




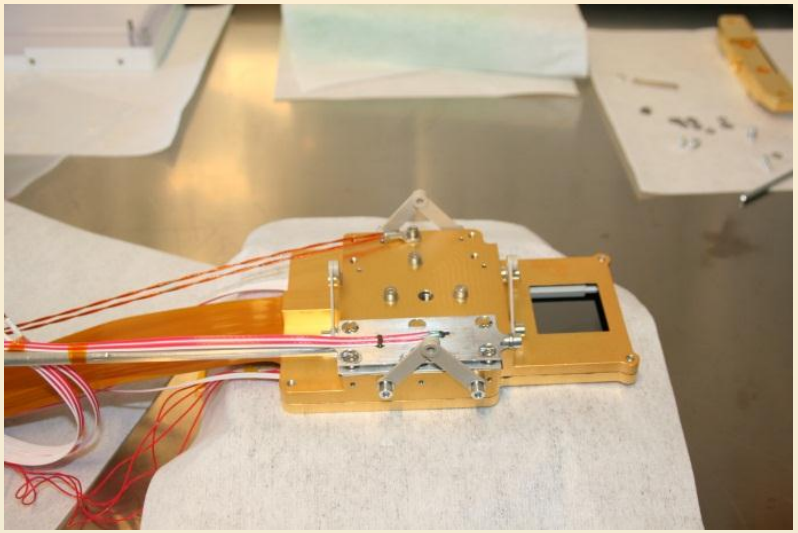


Integration and Metrology of X-ray Baffle onto Mirror Module

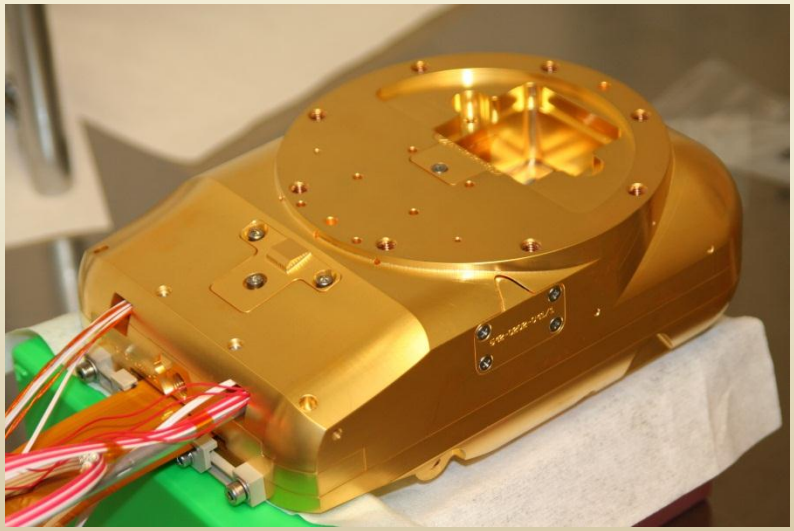
Camera



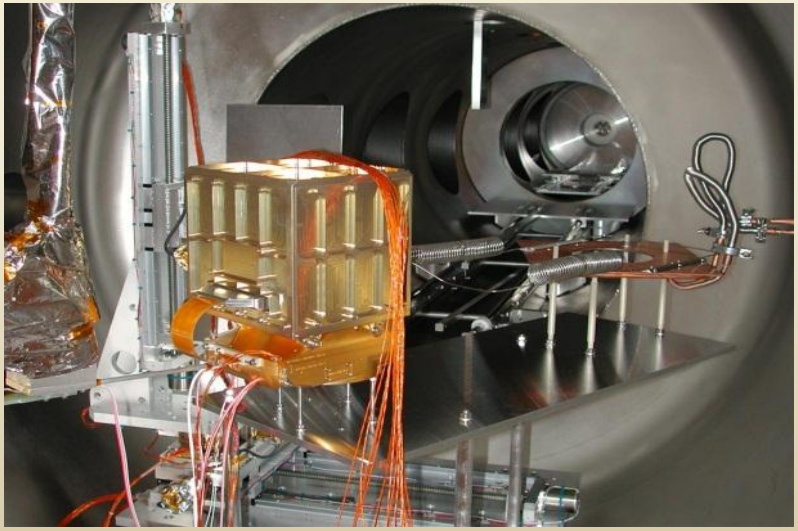
Heart of the Camera: CCD-Module



Cold part of Camera (with test sensors)

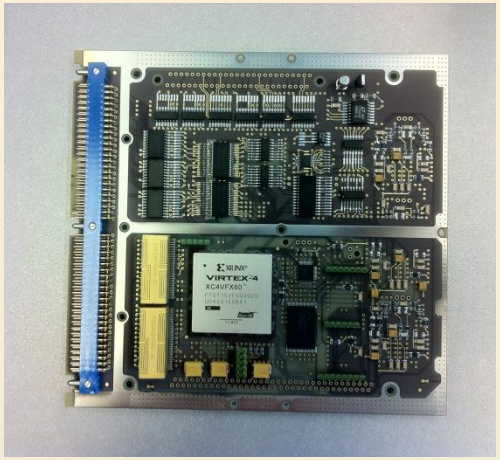


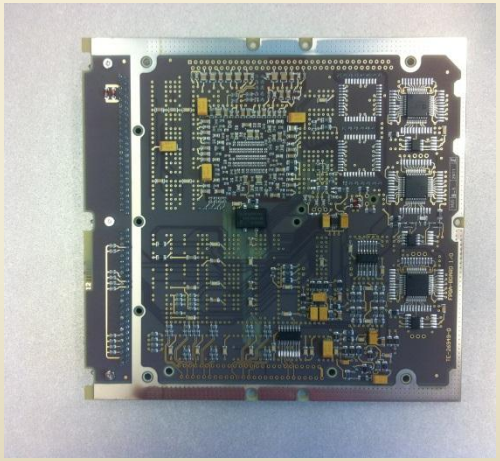
Integrated Camera (with massive Copper Housing)

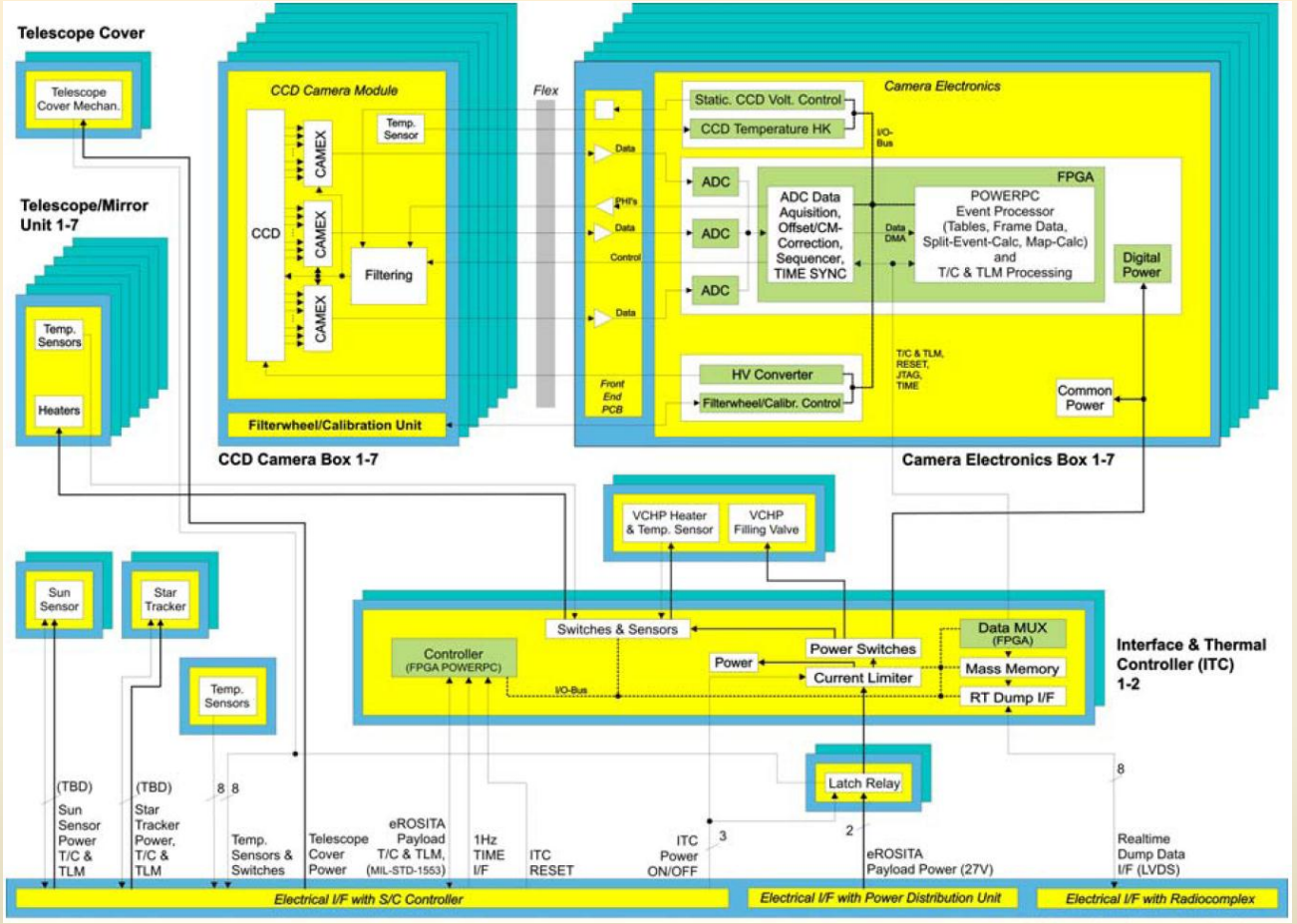


Preparation of Thermal Test

Electronics

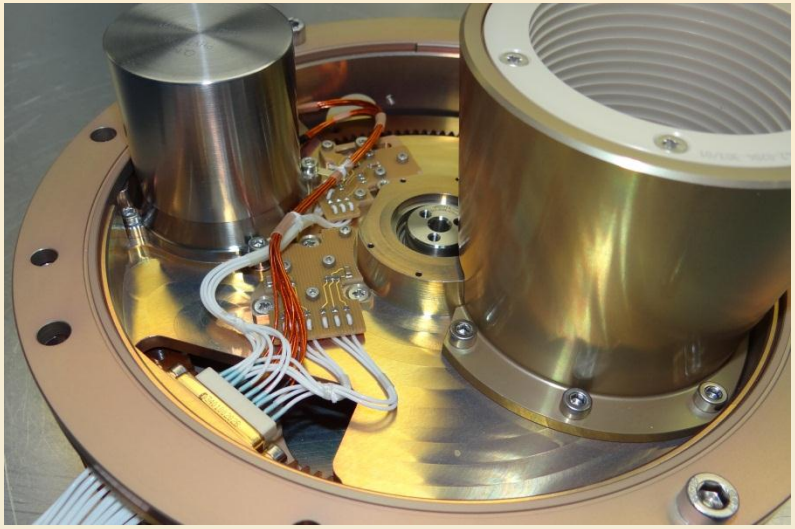




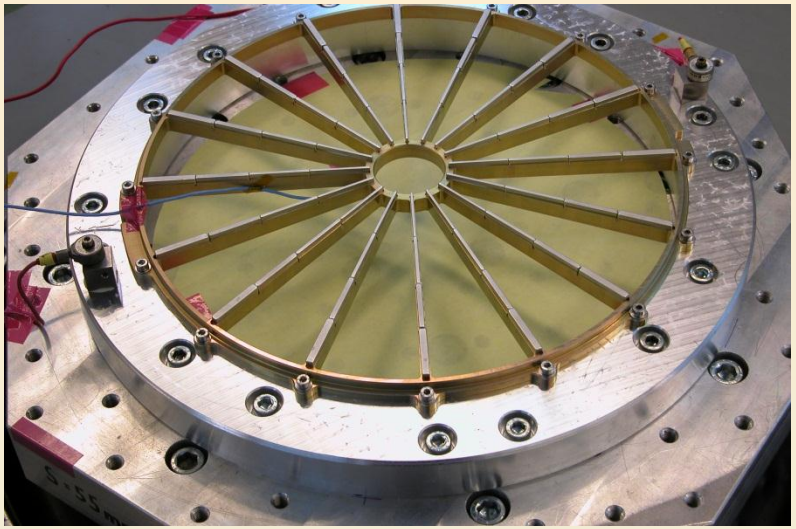


54 PCBs in total, up to 12-fold multilayer

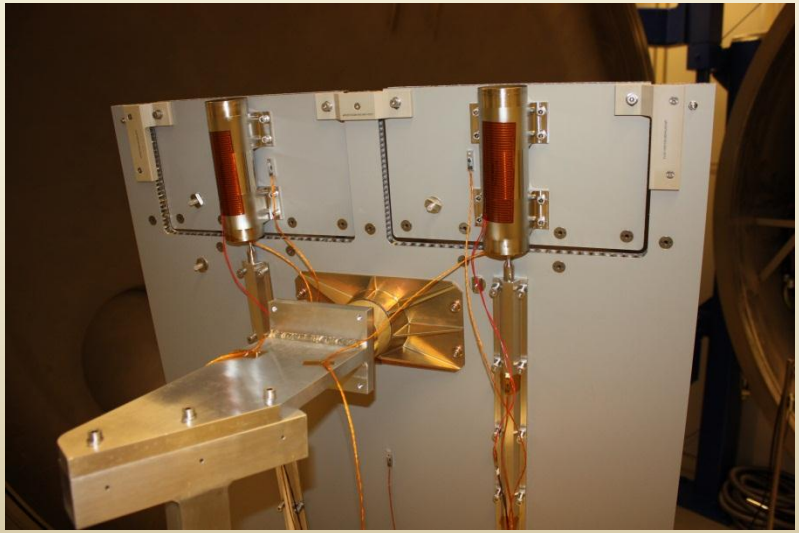
Miscellaneous



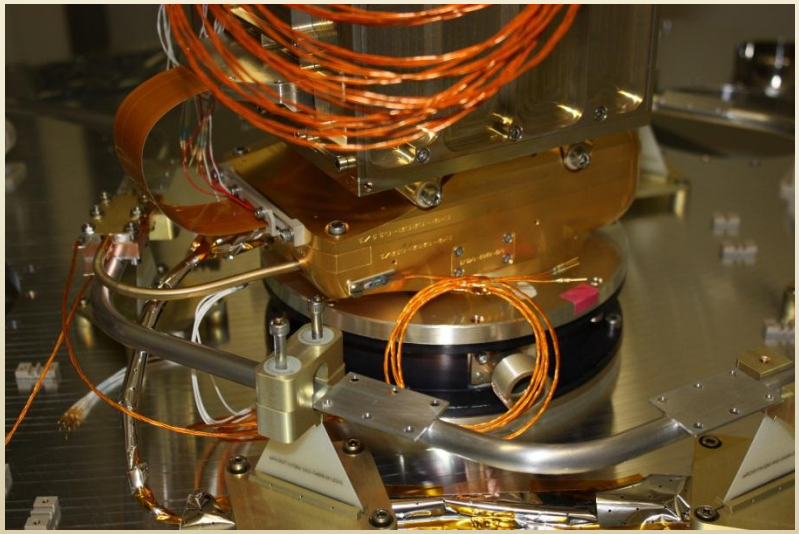
Filter Wheel



Electron Deflector (on Shaker)

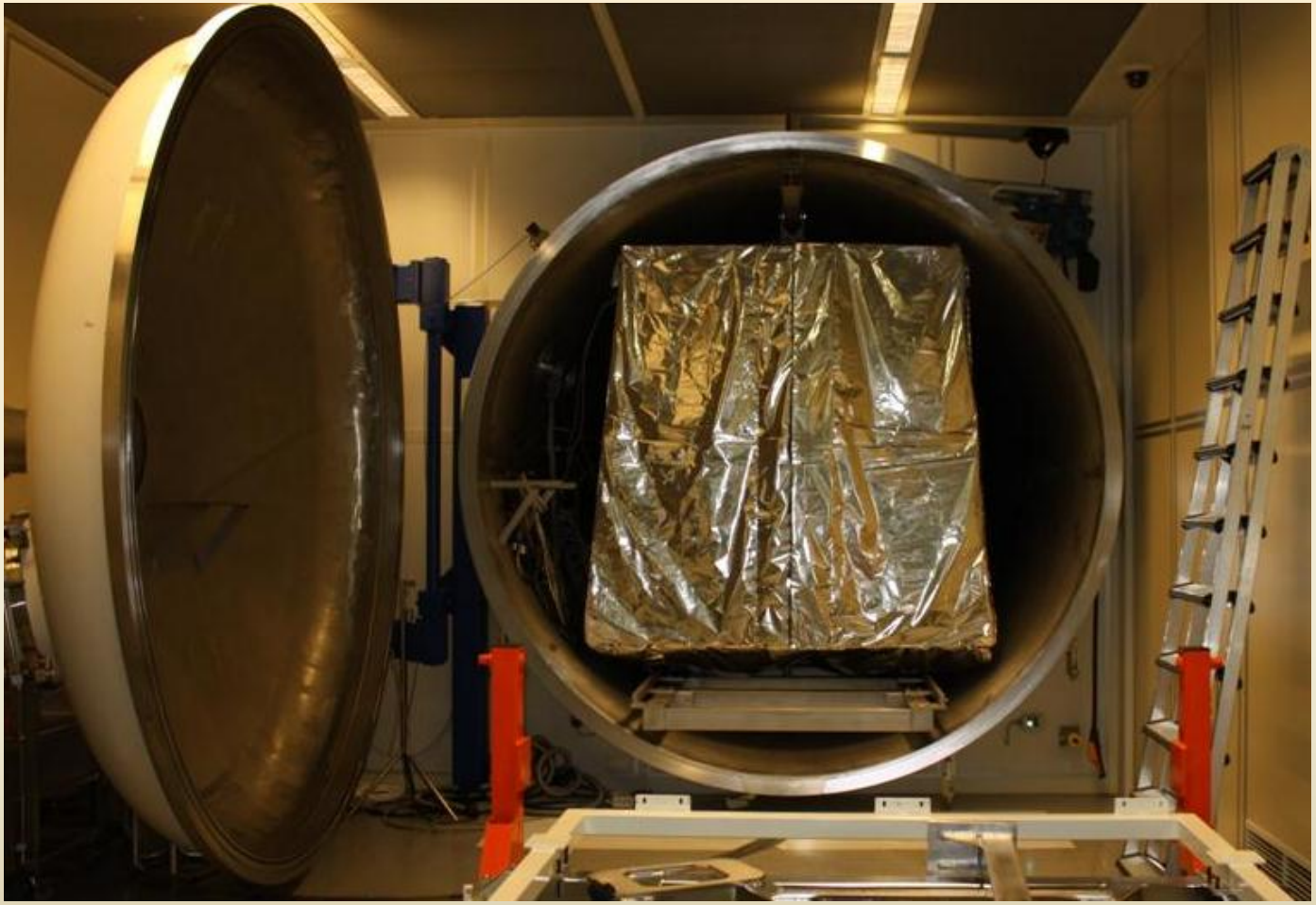


Camera Radiator, upper part with VCHP-Reservoirs



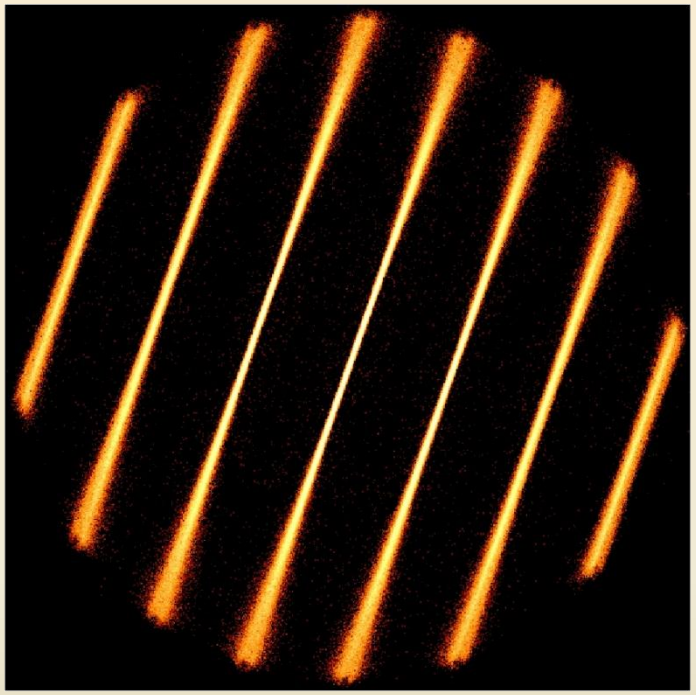
Preparation of Thermal Test with Heatipe System

Thermal Tests



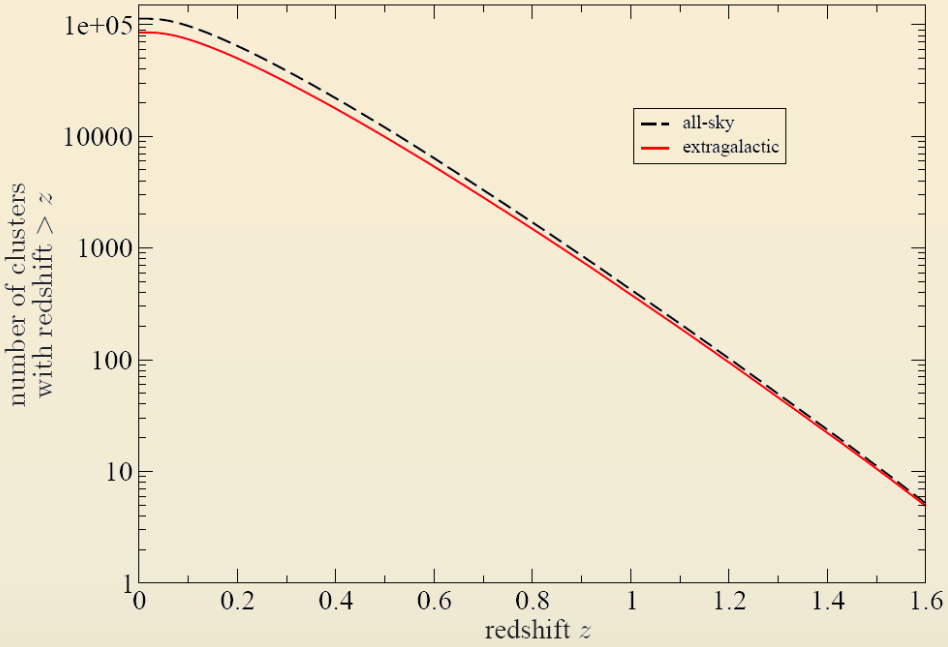
… just before closing the 3,5m PANTER door (Thermal Shroud seen only)

Simulations



court. Chr. Schmid

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



M. Mühlegger, 2010

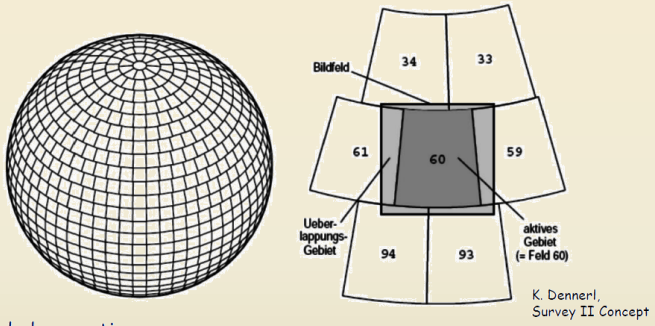
100.000 Clusters of Galaxies
400 with z > 1

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

court. H. Brunner

Follow-up Observations

1. Needs for followup:
   - 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

2. Follow up Context for eROSITA (List not complete!)
   - Shallow Multiband OIR Surveys 2MASS, PanSTARRS, SDSS
   - Deep Multiband OIR Surveys VISTA, DES
   - Optical Spectroscopic Surveys SDSS, BOSS
   - Proposed Optical Spectroscopic Surveys 4MOST, SPIDERS, WEAVE
   - Future OIR Imaging Surveys LSST, Euclid

3. Radio, MM Surveys

2014 in Байконур