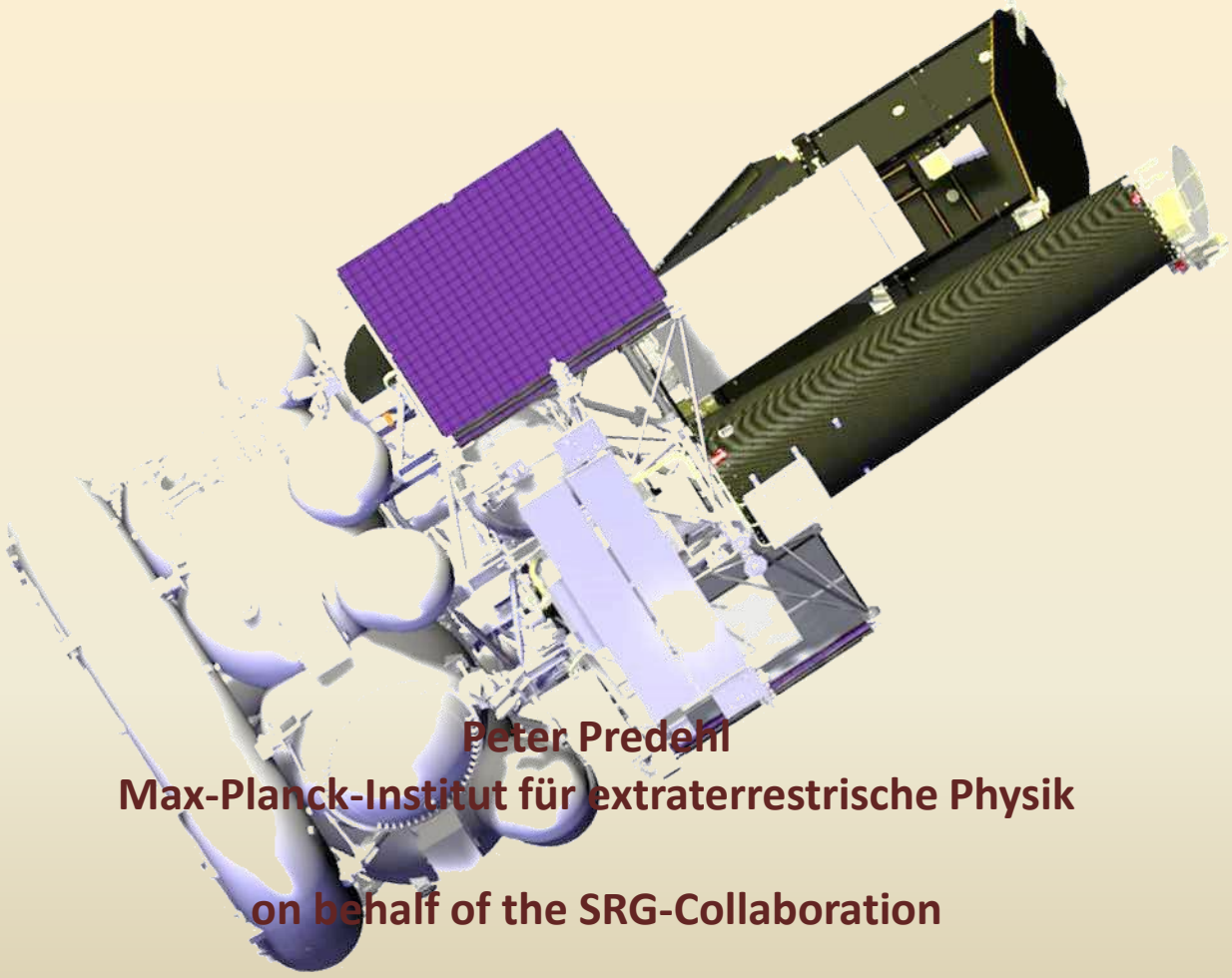
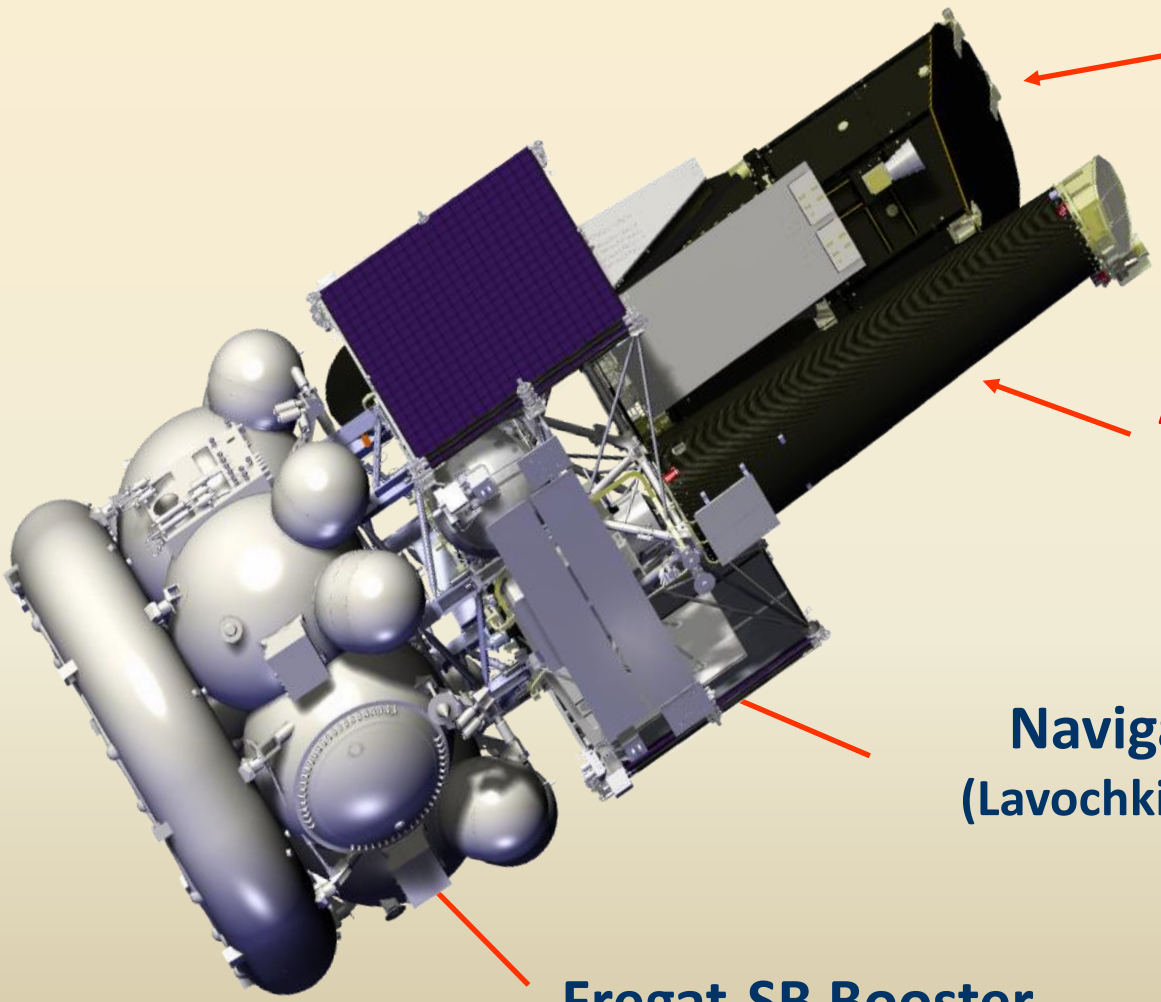
Spektr-Rentgen-Gamma



Peter Predehl
Max-Planck-Institut für extraterrestrische Physik

on behalf of the SRG-Collaboration

Spektr-Rentgen-Gamma



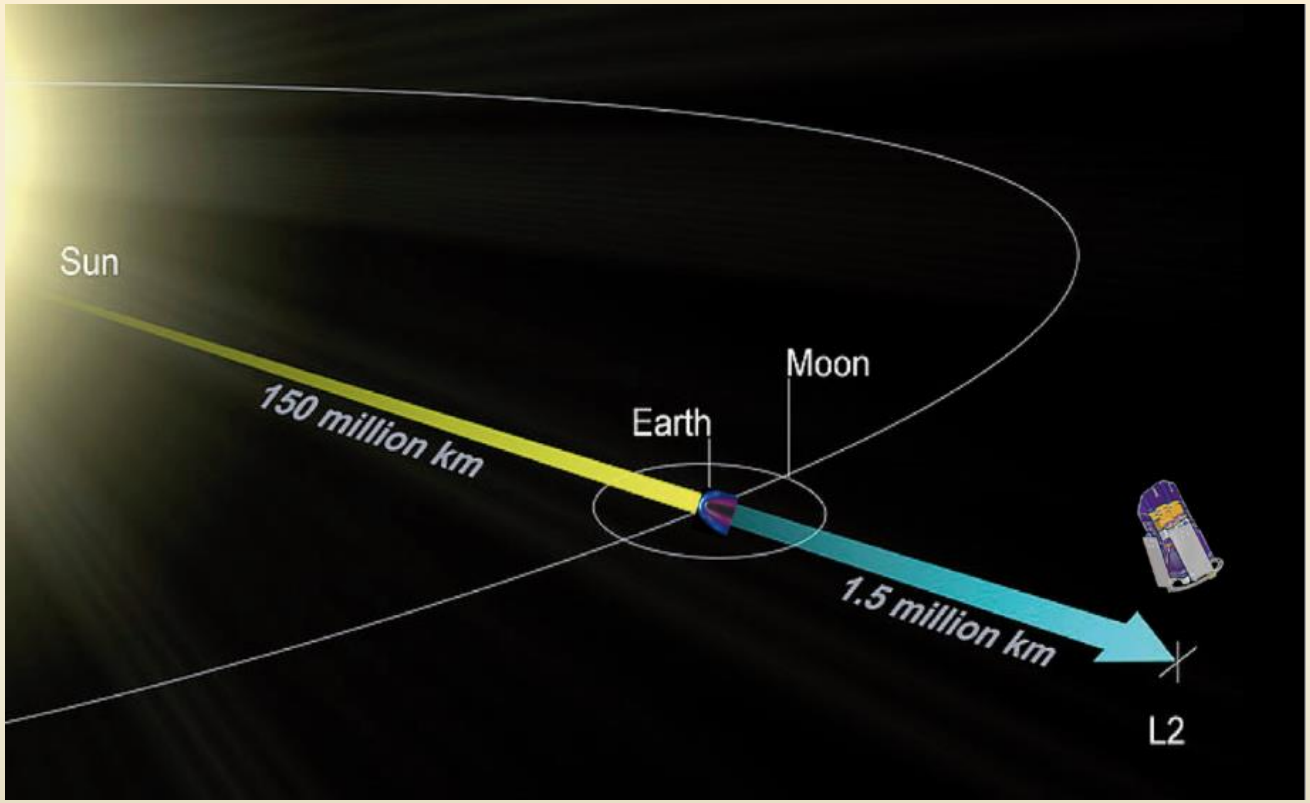
eROSITA
(MPE)

ART-XC
(IKI)

Navigator
(Lavochkin Ass.)

Fregat-SB Booster

Spektr-Rentgen-Gamma



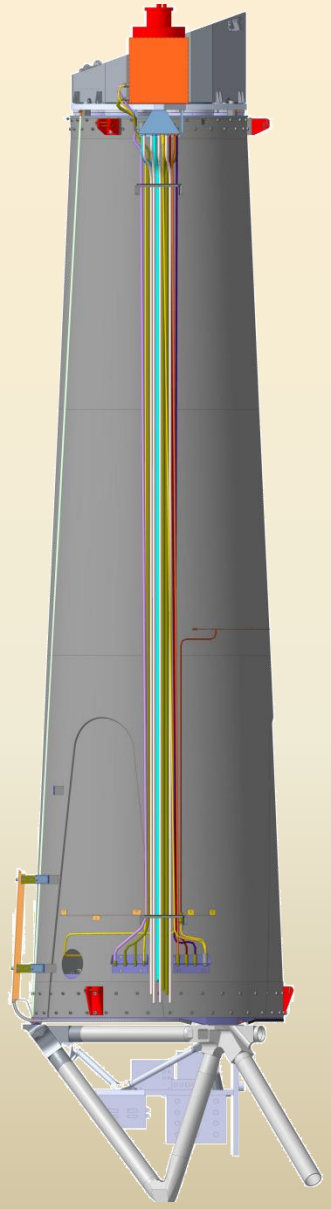
Launch from Baikonur with Zenit-Fregat, 2016 (March 26)

- 3 months: flight to L2, verification and calibration phase

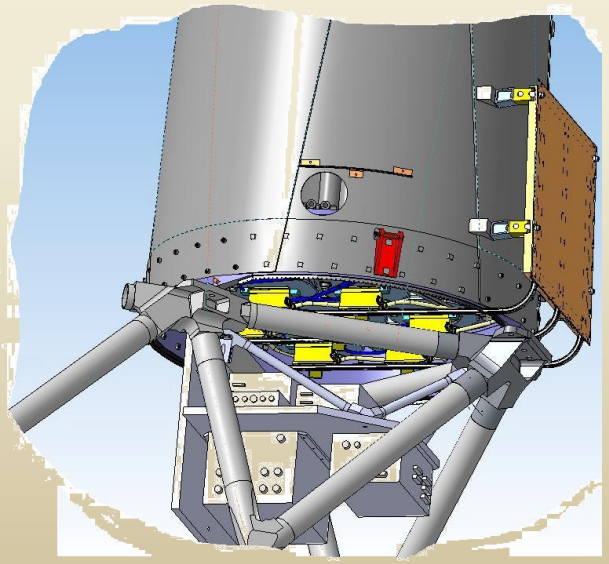
- 4 years: 8 all sky surveys (scanning mode: 6 rotations/day, 1 degree advance per day)

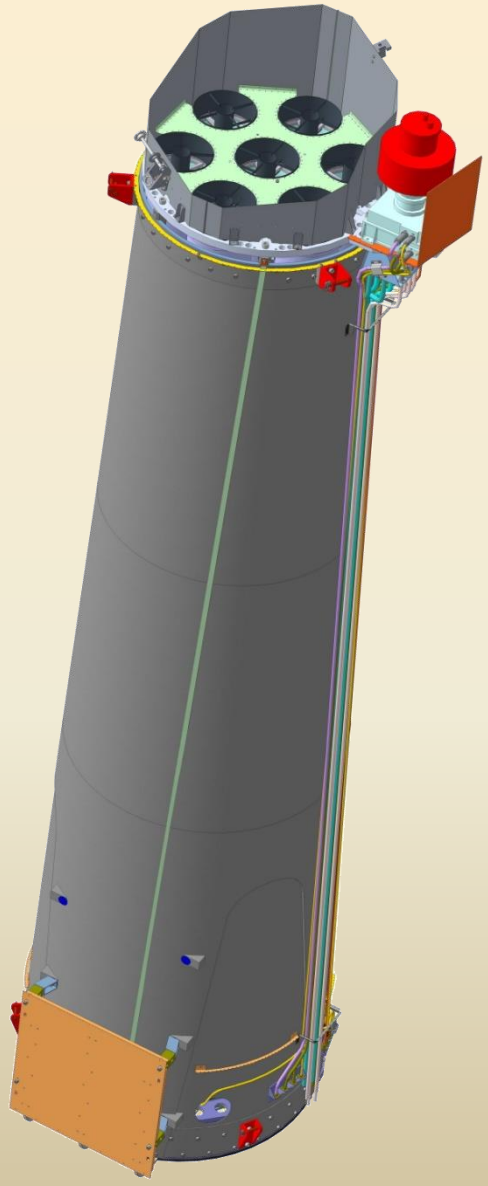
- 3 years: pointed observation phase, including ~20% of GTO. 1 AO per year

ART-XC



1) Energy range 5 – 30 keV
2) FOV ∅34′
3) On-axis resolution ≤1′
4) Total weight 350 kg
5) Power consumption 300 W





ART-XC Collaboration

1) **VNIIEF, Sarov – design of telescope, QM X-ray mirror systems, structure, tests, AIT**
2) **IKI, Moscow – CdTe DSSD X-ray detectors, aboard computer and memory, thermal balance system control block, star sensor, X-ray ground calibration of detectors and mirror systems**
3) **MSFC/NASA – FM X-ray mirror systems and their ground calibration**
4) **Lavochkin Association, Khimki – MLI, heat pipes, pyropin**
5) **Obninsk Research and Production Enterprise "Technologiya“ – carbon fiber structure**

eROSITA Collaboration

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

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

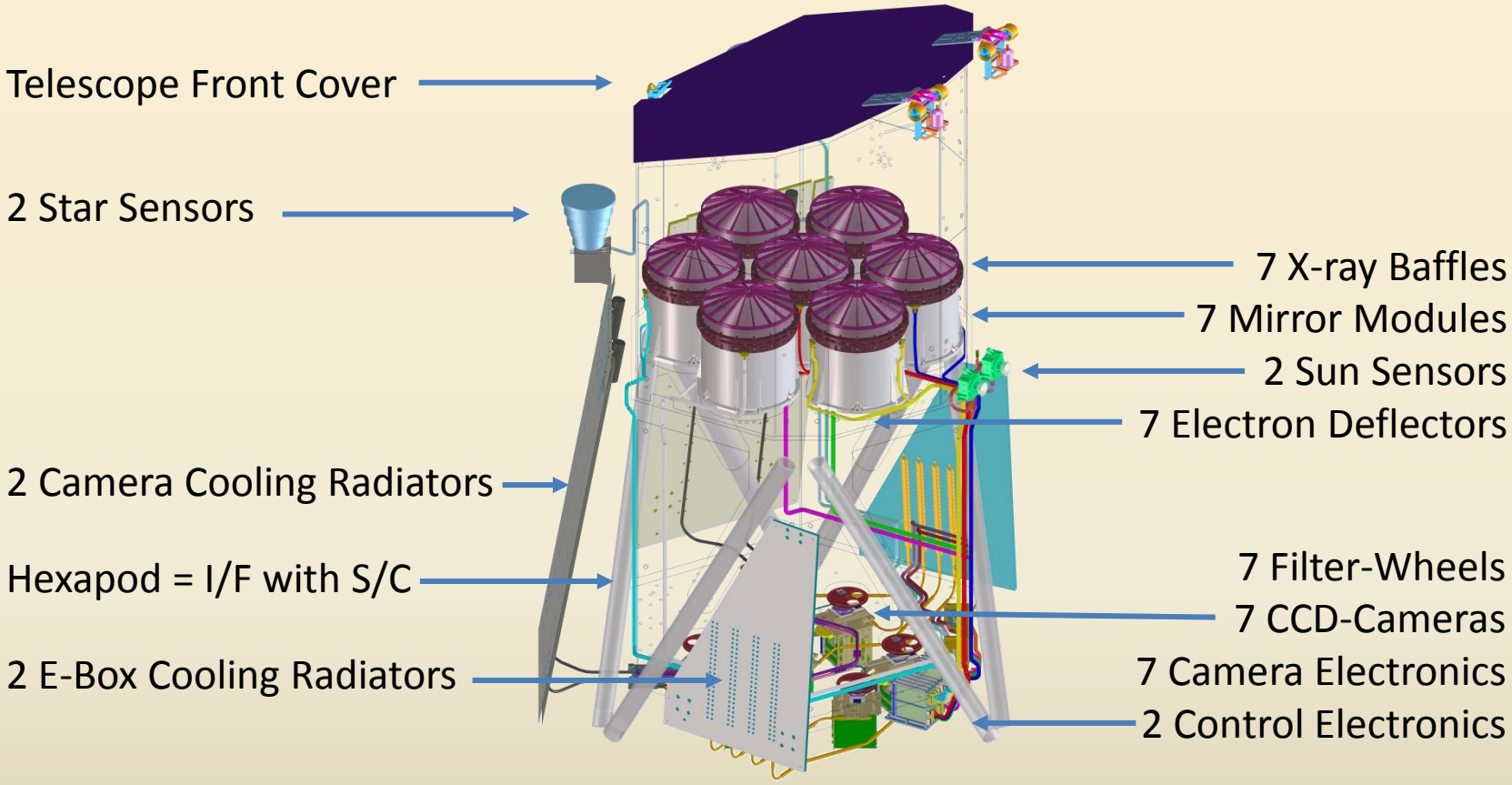
Industry:

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

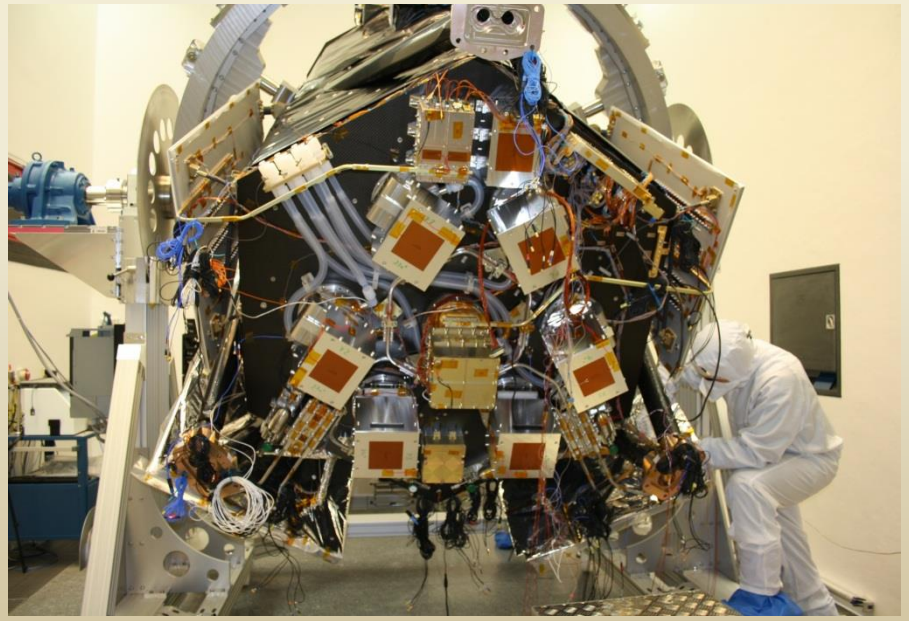
MPE: Scientific Lead Institute, Project Management
Instrument Design, Manufacturing, Integration & Test
Data Handling & Processing, Archive etc.

eROSITA



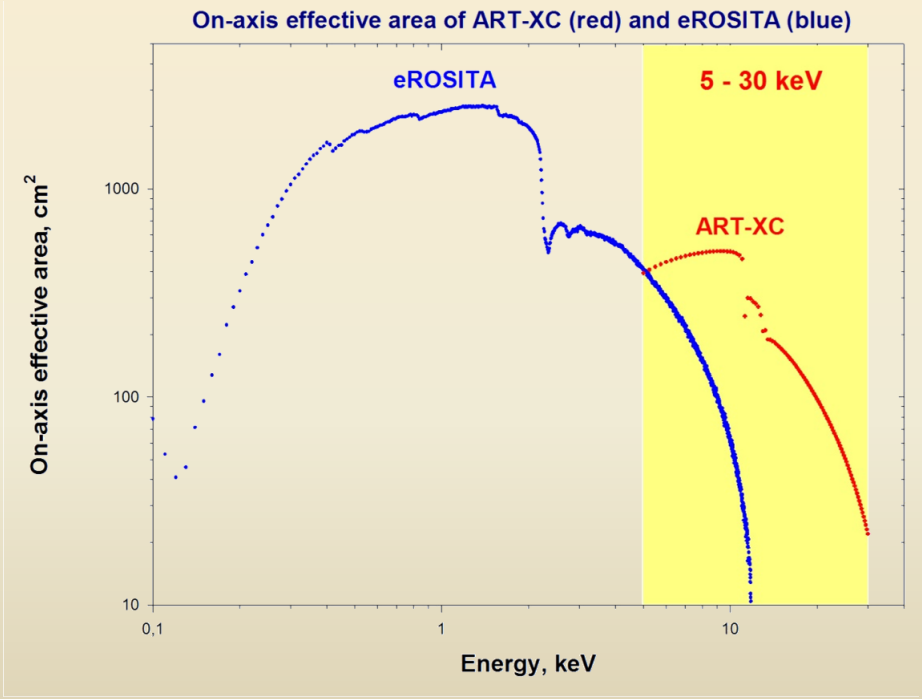
7 identical Mirror Modules	Field of View	1° Ø
54 nested Mirror Shells each	Angular Resolution	~16 arcsec on-axis
7 identical pnCCD Cameras	Energy Range	~0.3 - 10 keV


MPE



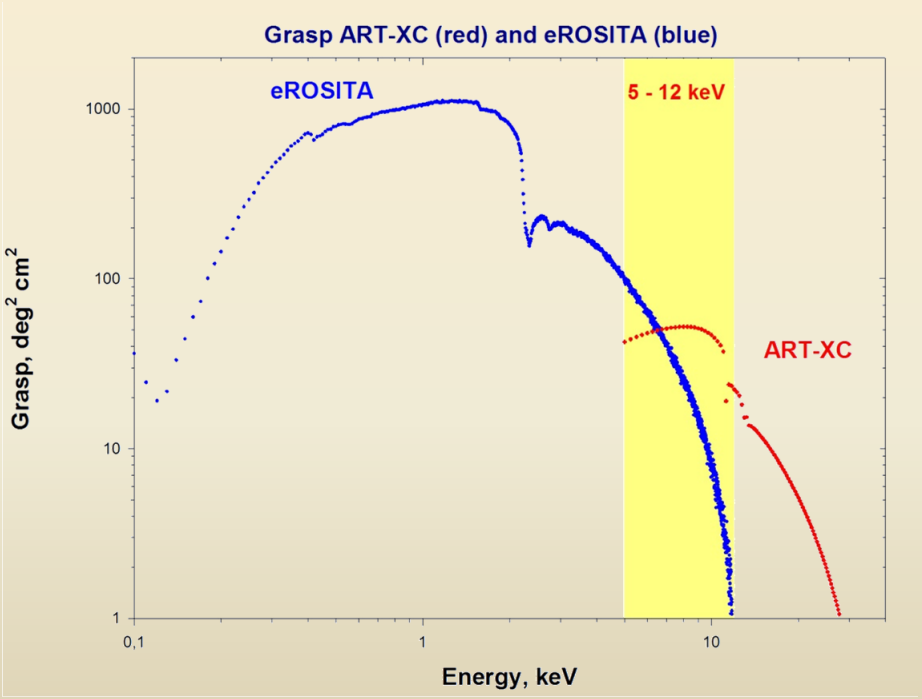
ART-XC & eROSITA

On-axis Effective Area & Grasp



2500 см^2 @ 1.4 keV

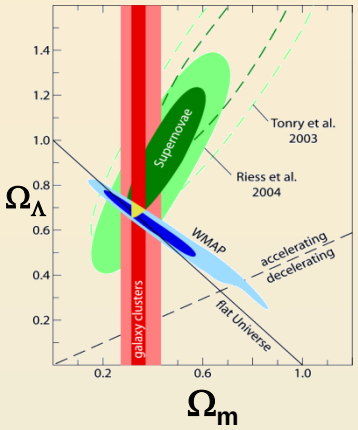
450 см^2 @ 8 keV



1100 см^2 deg^2 @ 1.4 keV

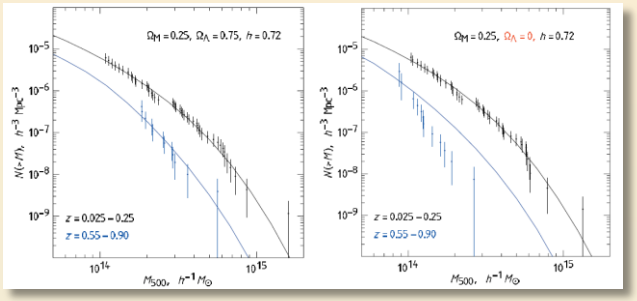
45 см^2 deg^2 @ 8 keV

Cluster Cosmology Design Driving Science



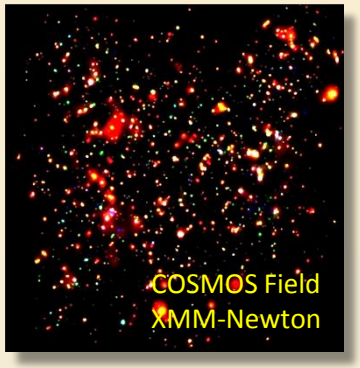
WMAP: Spergel et al. 2003
ROSAT: Schuecker et al. 2003

+



Vikhlinin et al., 2009

+



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

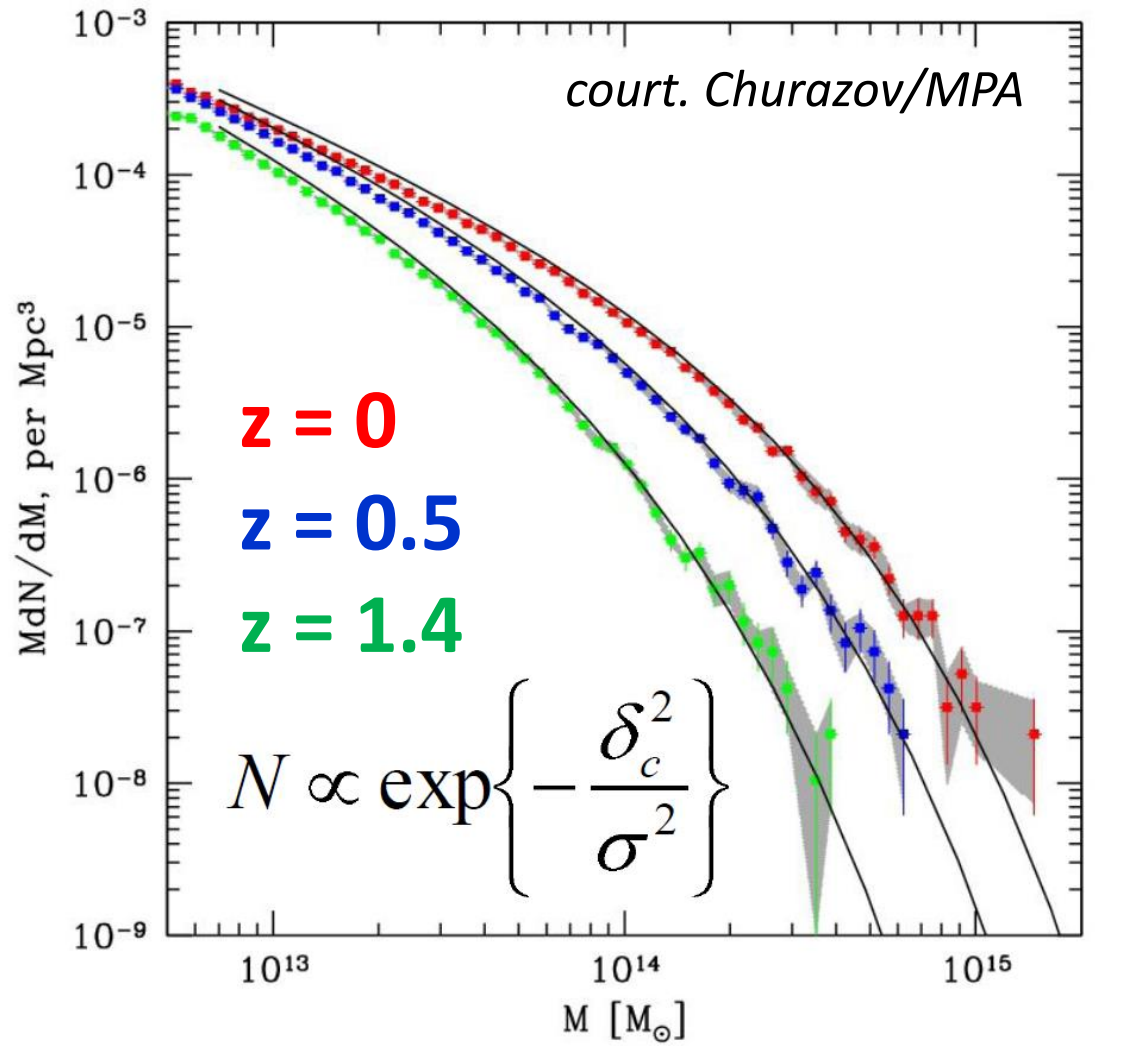
In X-rays we see clusters as one continuous entity.

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

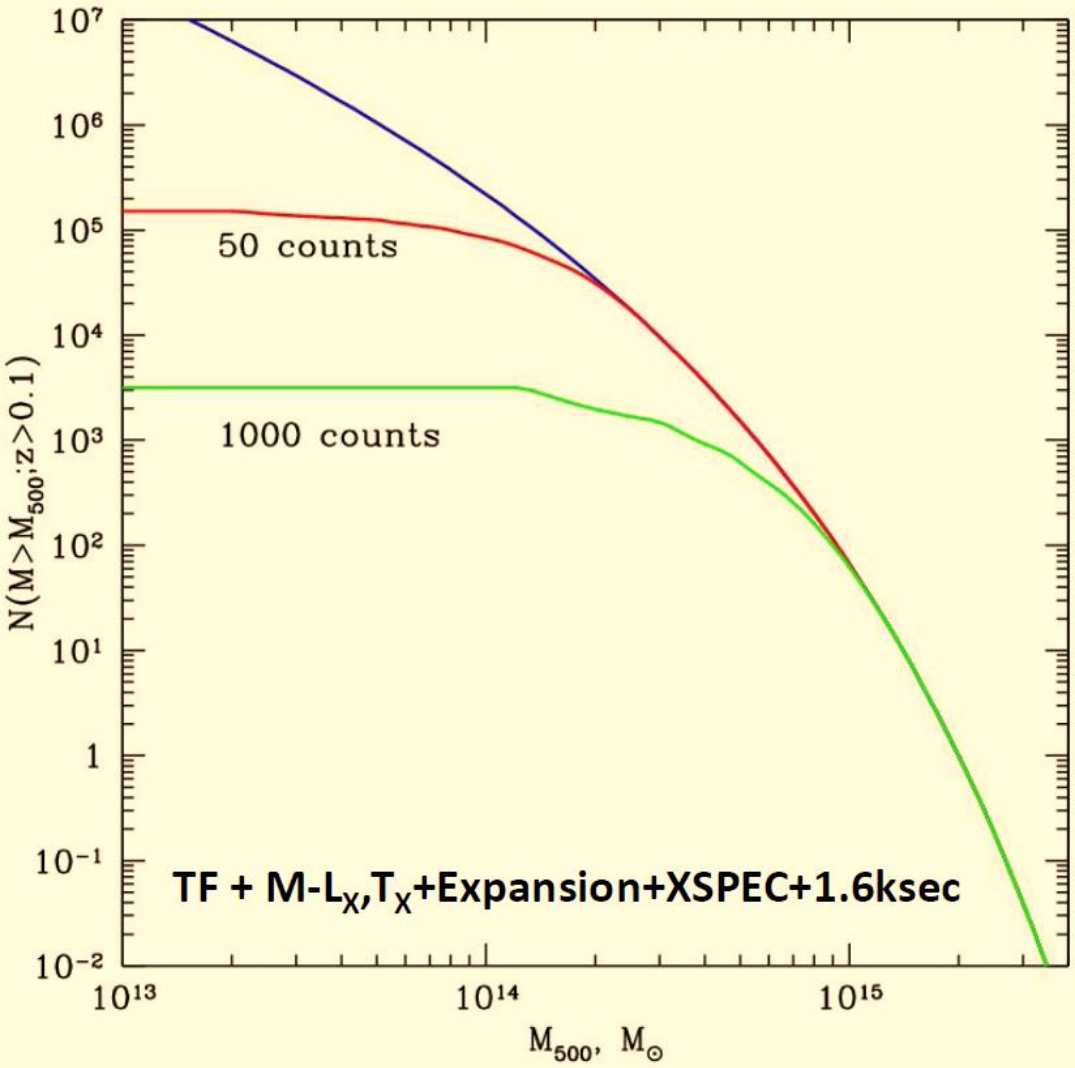
- Moderate angular resolution (< 28 arcsec, aver. over FoV)
- Large collecting area (> 2000 cm^2 @ 1keV)
- Large FoV (1° Ø)
- Long duration (survey 4 years ← → 1/2 year (ROSAT)

Evolution of Cluster Mass Function



Number of most massive clusters is extremely sensitive to cosmology

Will eROSITA detect all Clusters?



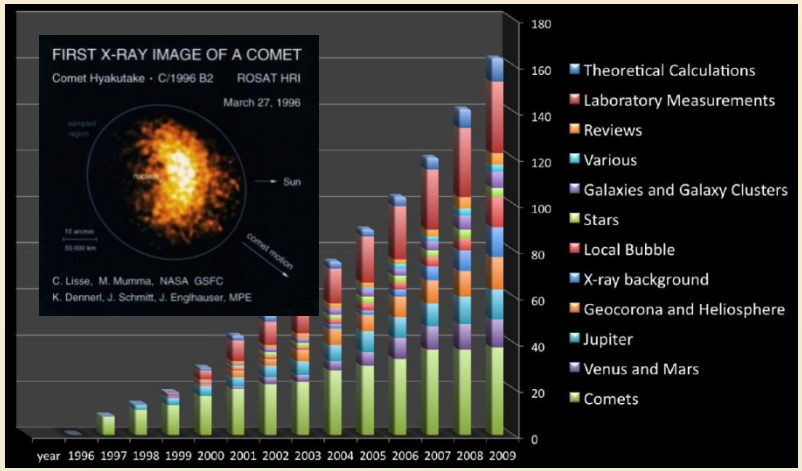
M	z	N	eRosita
10^{14}	~3	$8\ 10^4$	40%
$3\ 10^{14}$	~2	$8\ 10^3$	100%
10^{15}	~1	50	100%

Churazov/MPA: Yes!

Z_{max}~2, M~$3\ 10^{14}\ M_{Sun}$

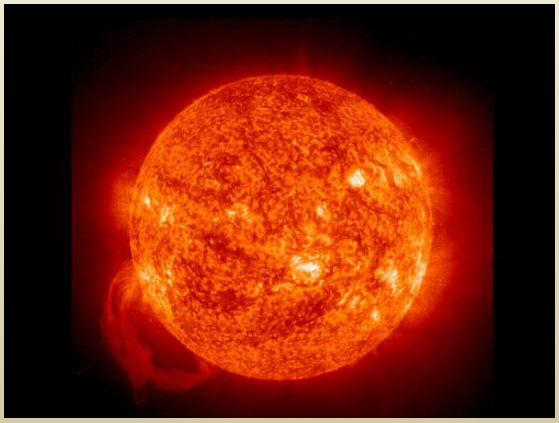
Other Science: Cold Universe

Charge Exchange



court. K. Dennerl

Schmitt et al. 1990

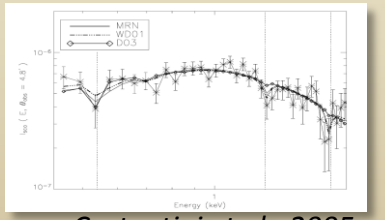


Cool Stars

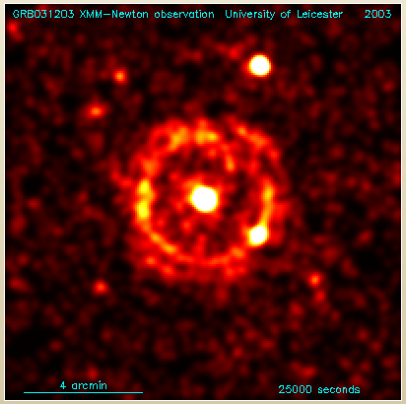
magnetic activity
coronae

Interstellar Dust

scattering
spectroscopy
chemistry



Costantini et al., 2005



Vaughan et al., 2003

Stars

~0.7 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)

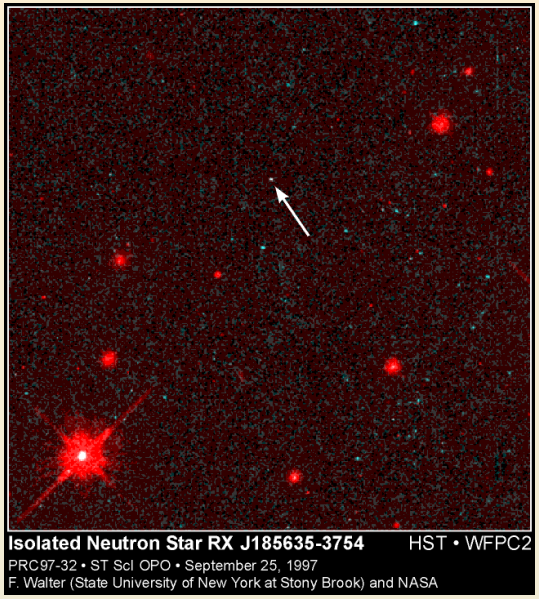
  → Strong shocks, T, densitities, ionization stages, chem. abund., NE effects

  ← 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 line features**
  - **Heavily obscured binary systems**
- Thermonuclear
  - Novae, Bursts
- Cooling, remnant heat
  - WDs, NSs
- Magnetic Fields
  - AXPs, Magnetars
- Spin-down
  - Pulsars
- Other

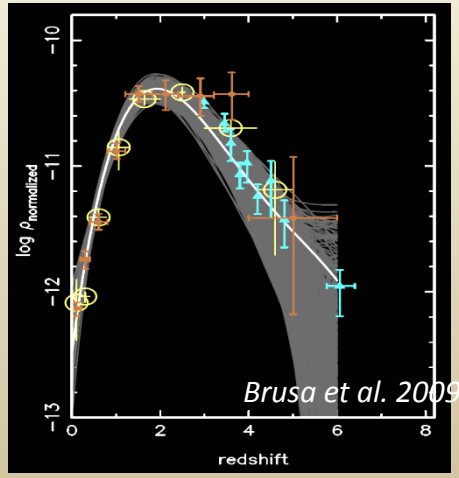


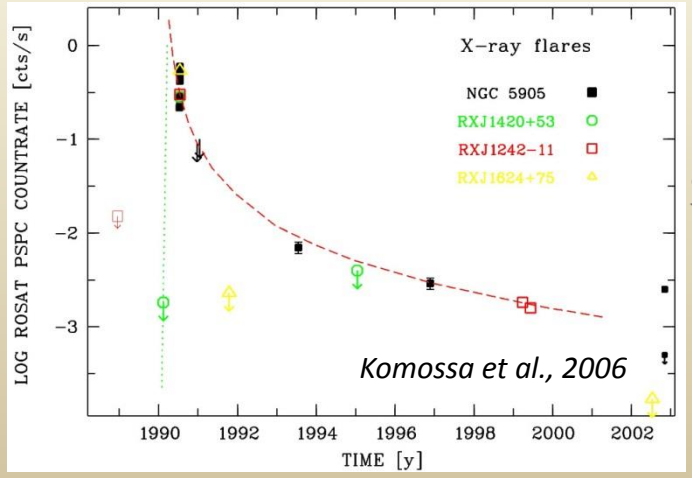
>100 INS?

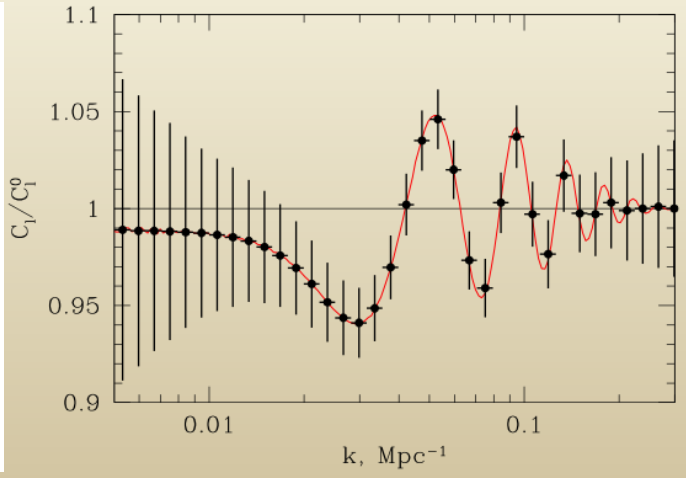
AGN

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
- BAOs: 10σ detection, but precise redshifts needed.



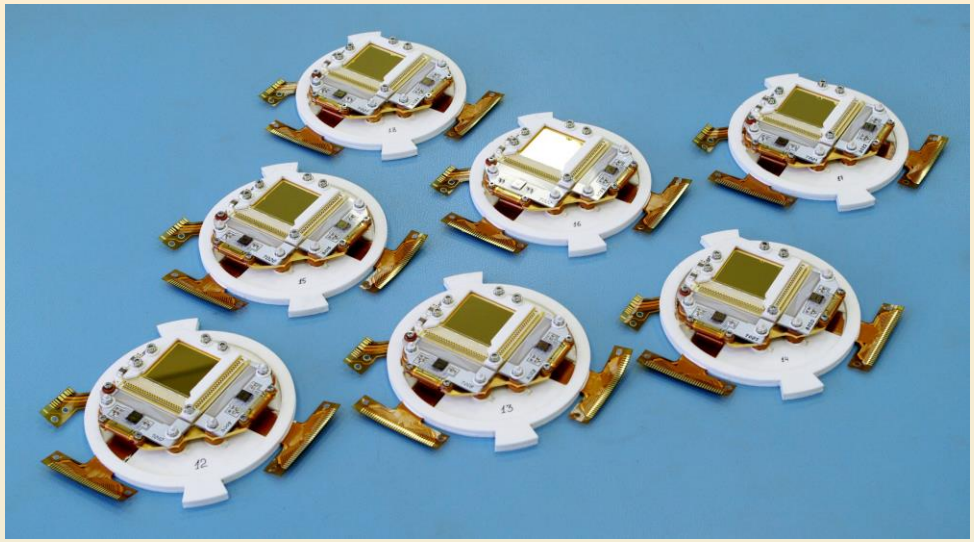




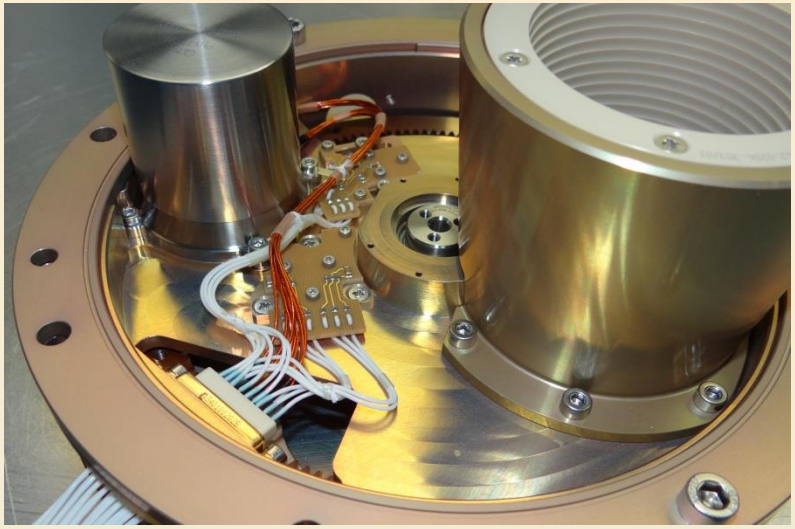
ART-XC Science Targets

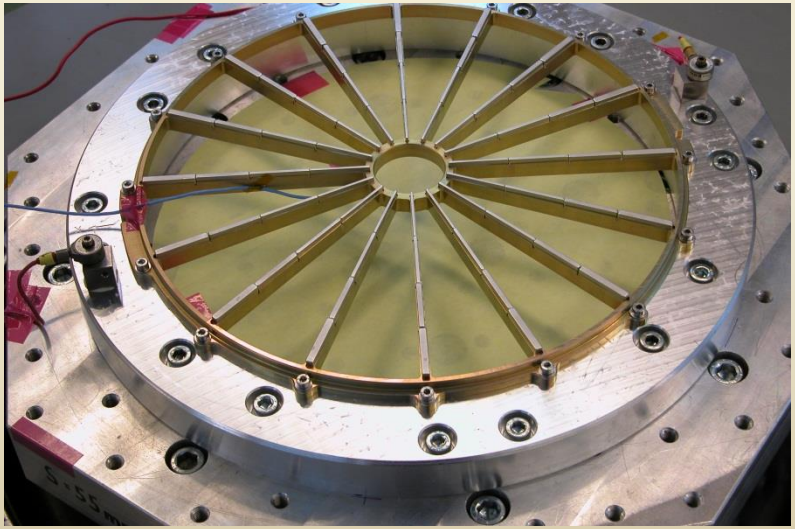
- All-sky survey (5 – 12 keV) $\Rightarrow$ several thousands new AGNs
- Study of massive nearby galaxies clusters with $T \geq 5$ keV in the pointing observation mode
- Study of intrinsically heavily absorbed/Compton thick AGNs ($N_H \geq 3 \times 10^{23}$ см$^{-2}$)
- Survey of galactic black holes and neutron stars with low luminosity
- Study heavily obscured galactic X-ray binary systems
- Study broad band spectra of Galactic objects (including binary systems, anomalous pulsars, SNRs) up to 30 keV, spectroscopy and timing of point sources
- Study of cyclotron lines features of X-ray pulsars with energy resolution 1.5 keV up to 30 keV

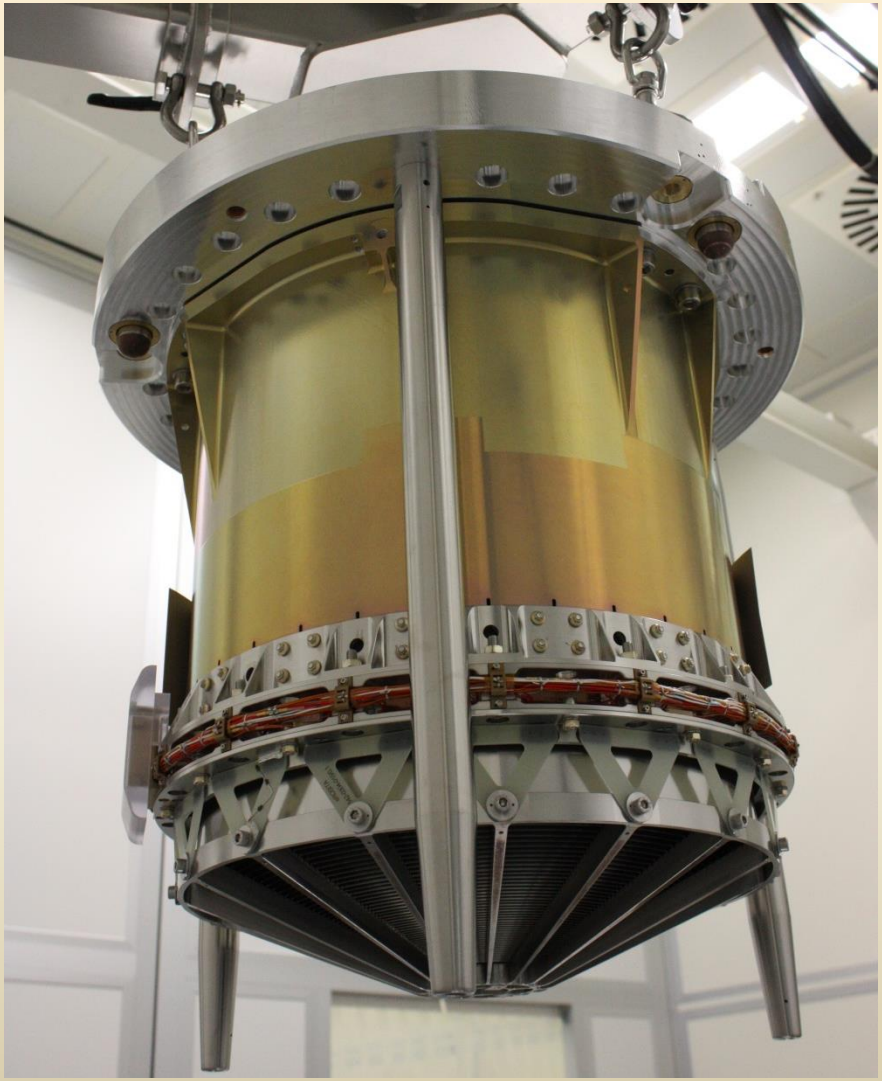
ART-XC Hardware



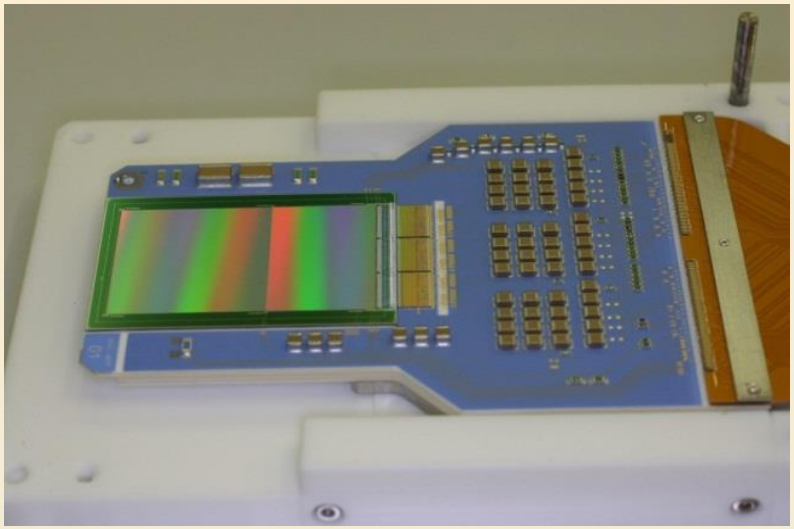
eROSITA Hardware

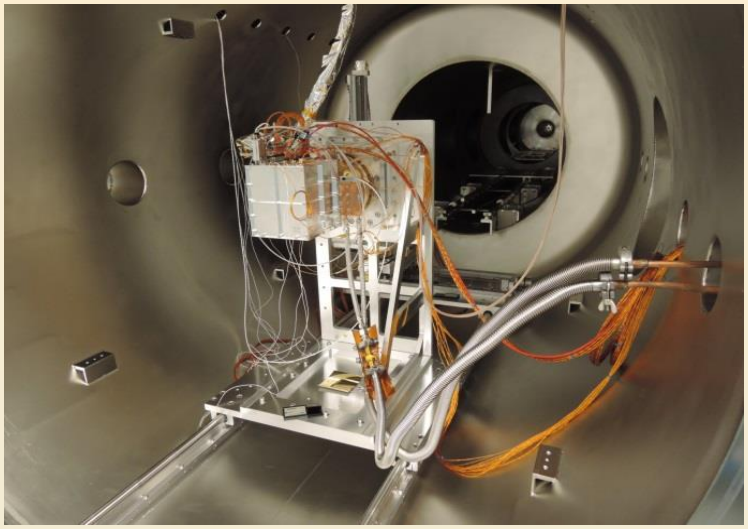


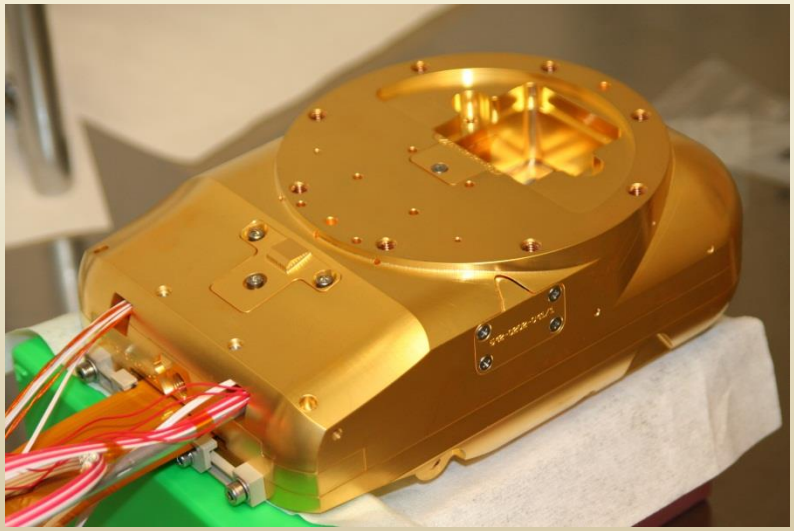


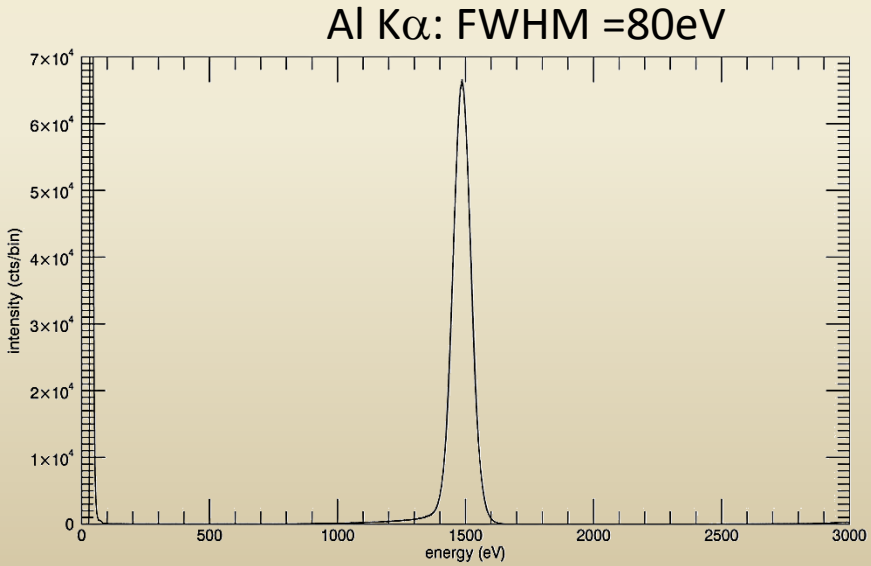


eROSITA Cameras

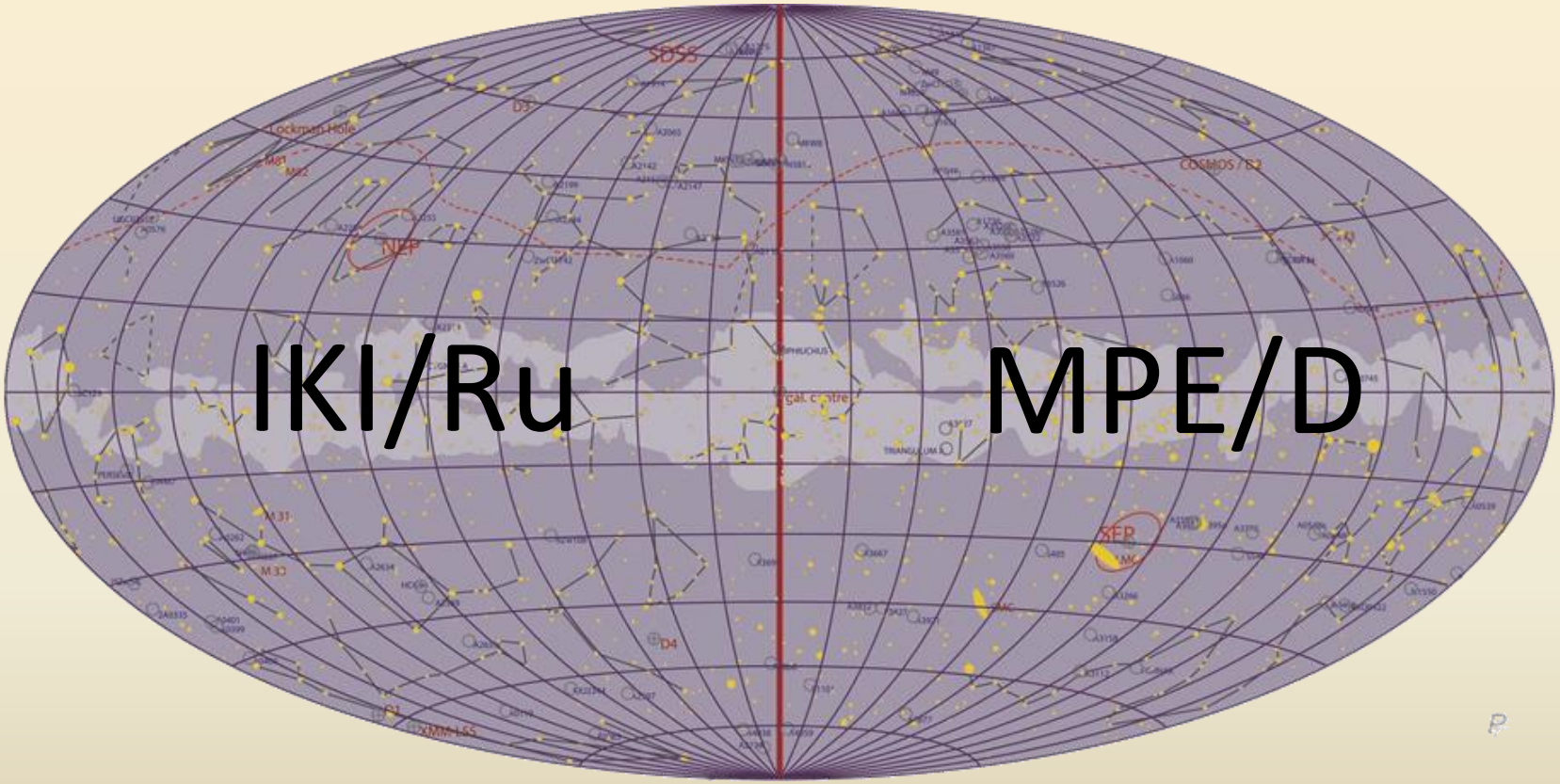




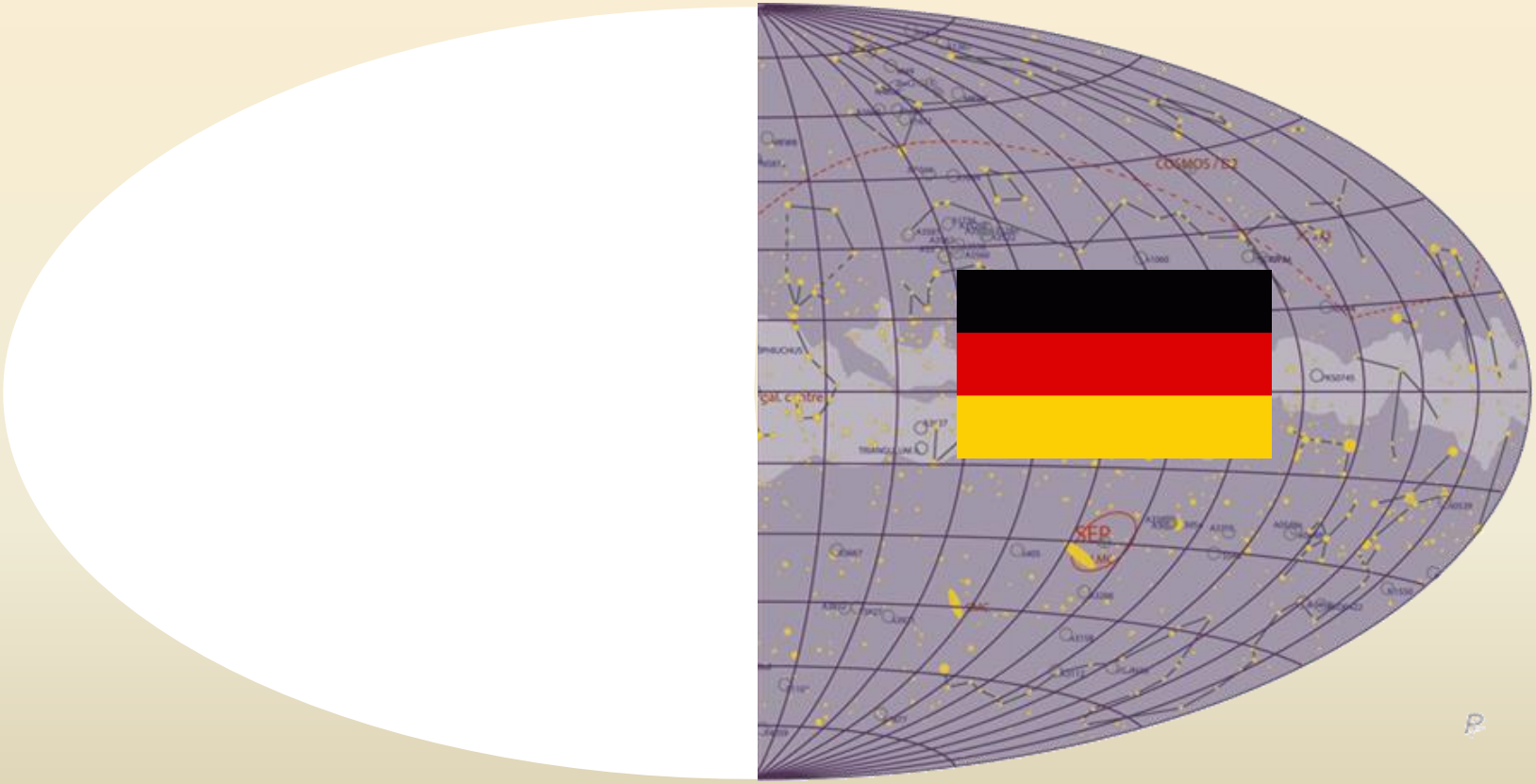




Data Share



Data Share



Data releases after 2 years, incrementally 6, 18, 48 months.
Pointed Phase: Open to world wide community

Data Rights and Policies (MPE)

- German eROSITA data made public after 2 yr proprietary period
- Periodic data releases envisaged (e.g. 6, 24, 48 months)
- Proprietary data via eROSITA_DE collaboration (consortium)
- Projects/Papers regulated by Working Groups
- Individual External Collaborations
- Group External Collaborations

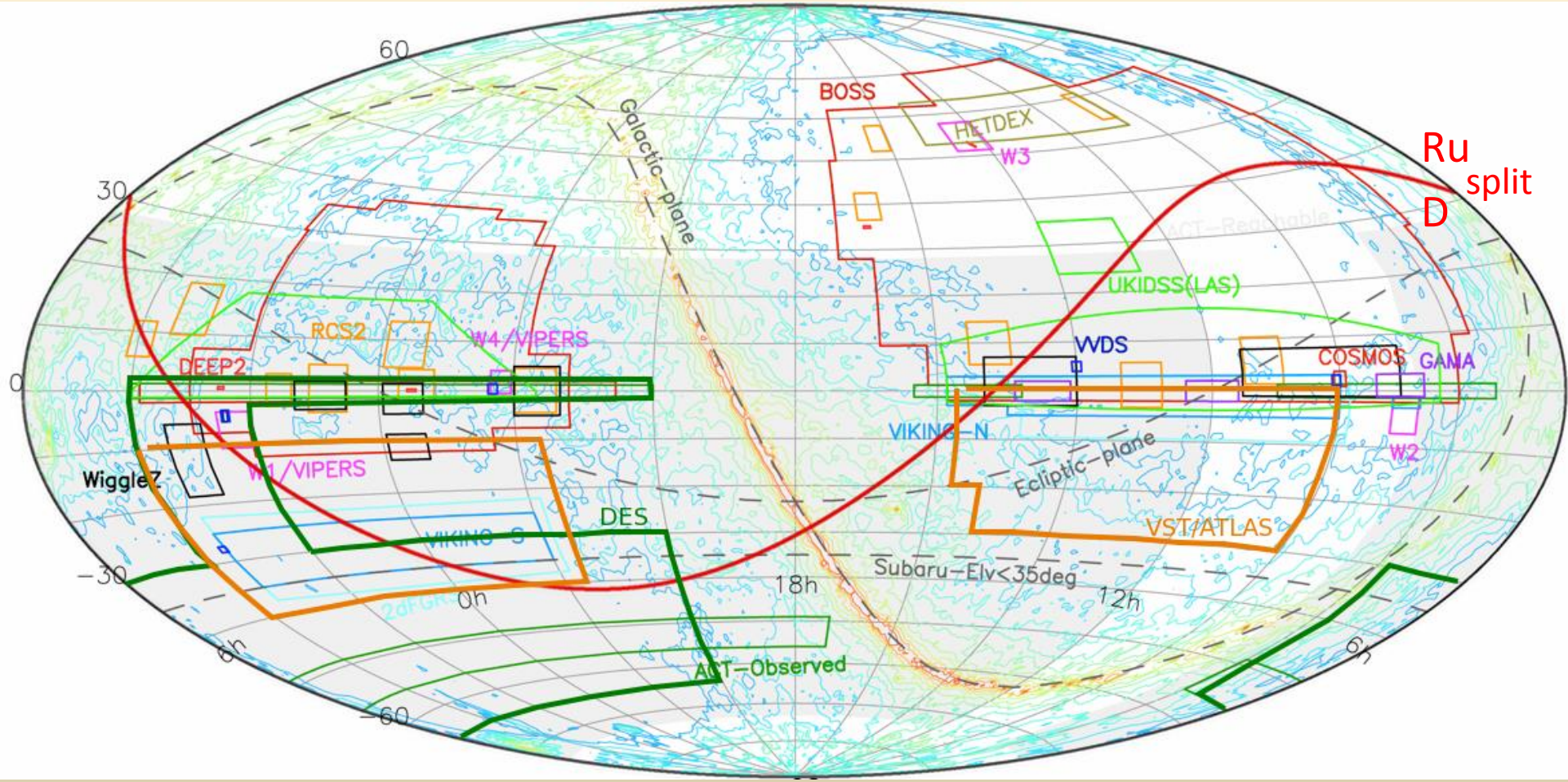
Science Working Groups:

Clusters and Cosmology
AGN, Blazars
Normal Galaxies
Compact objects
Diffuse emission, SNR
Stars, Solar System

Infrastructure Working Groups:

Time Domain Astrophysics
Data analysis, source extraction, catalogs
Multi-wavelength follow-up
Calibration
Background

Redshifts


60
30
0
−30
−60
0h
6h
12h
18h
Galactic−plane
Ecliptic−plane
Subaru−Elv<35deg
BOSS
HETDEX
W3
UKIDSS(LAS)
WDS
COSMOS
GAMA
W2
VIKING−N
VST/ATLAS
RCS2
W4/VIPERS
DEEP2
W1/VIPERS
Wiggle7
VIKING−S
DES
2dFGRS
ACT−Observed
Ru
split
D

eROSITA FM Hardware Readiness

Telescope Structure, Front Cover incl. Mechanism	ready
MLI	ready
Mirror System	ready
FM-1	calibrated
FM-2-8	waiting for calibration (till 9/14)
X-ray Baffles (7+1)	ready
Electron Deflector FM 1-8	ready
E-Box Radiators (2)	ready
Camera Radiators (2)	ready
Camera Heatpipe System	ready
Electronics Heatpipes	ready
Cameras	qualified
CCDs	ready for integration
Detector	QM tested in X-rays, FMs in integration
Electronics	EM tested, QM ready for test
Interface & Thermal Control Electronics	EM tested
Harnesses	ready

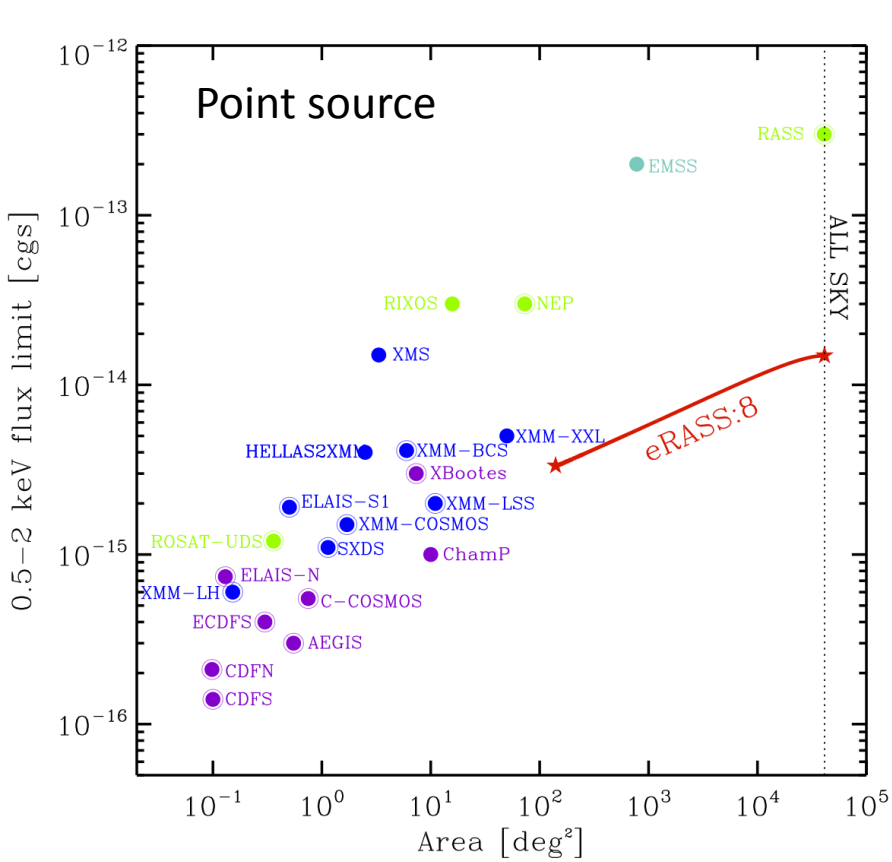
Shipping to Russia planned for June 2015

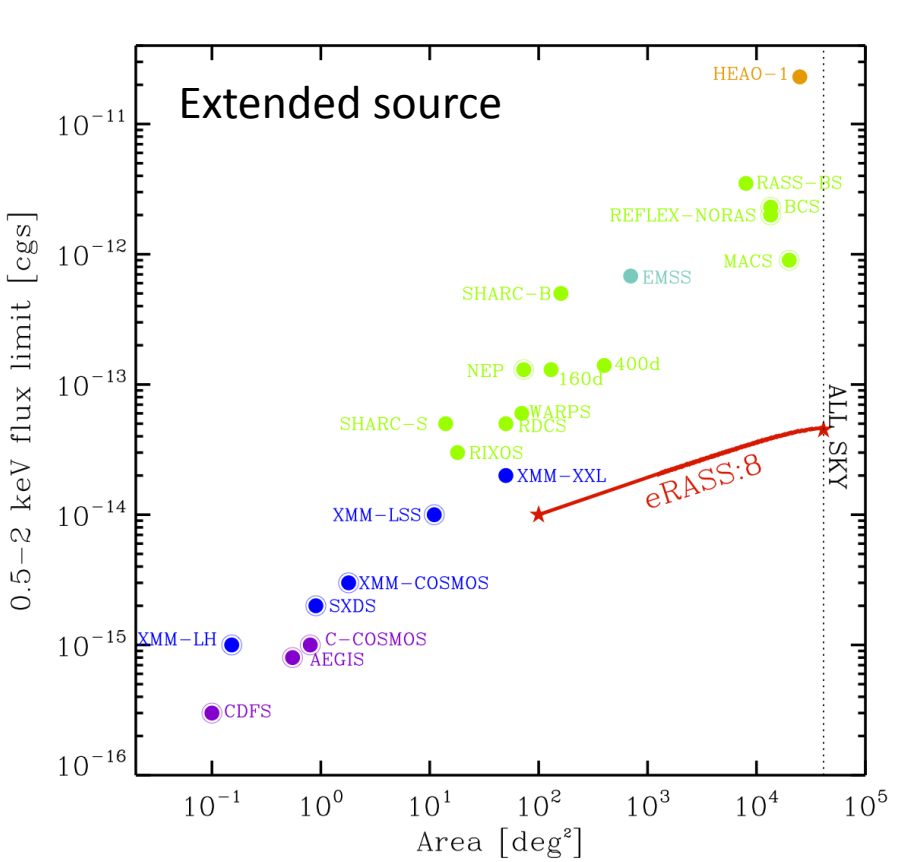
eROSITA FM Mirror Modules

	Goal	FM1	FM2	FM3	FM4	FM5	FM6	FM7	FM8
HEW Al-K @ 1.49 keV	15”	16.1	16.8	15.7	16.0	16.2	16.3	15.6	17.1
HEW Cu-K @ 8.04 keV	20”	15.2	15.4	16.7	16.4	16.2	16.2	16.6	18.4
Eff. Area @ Al-K	364 cm^2	391	391	393	369	388	378	392	390
Eff. Area @ Cu-K	21 cm^2	24.8	24.8	25.1	23.8	24.1	25.1	25.0	24.2
Scattering @ Cu-K	15.5%	10.8	11.2	10.7	12.0	13.3	11.3	11.7	11.4

eROSITA Science Book
Merloni et al.
arXiv:1209.3114

eROSITA Performance





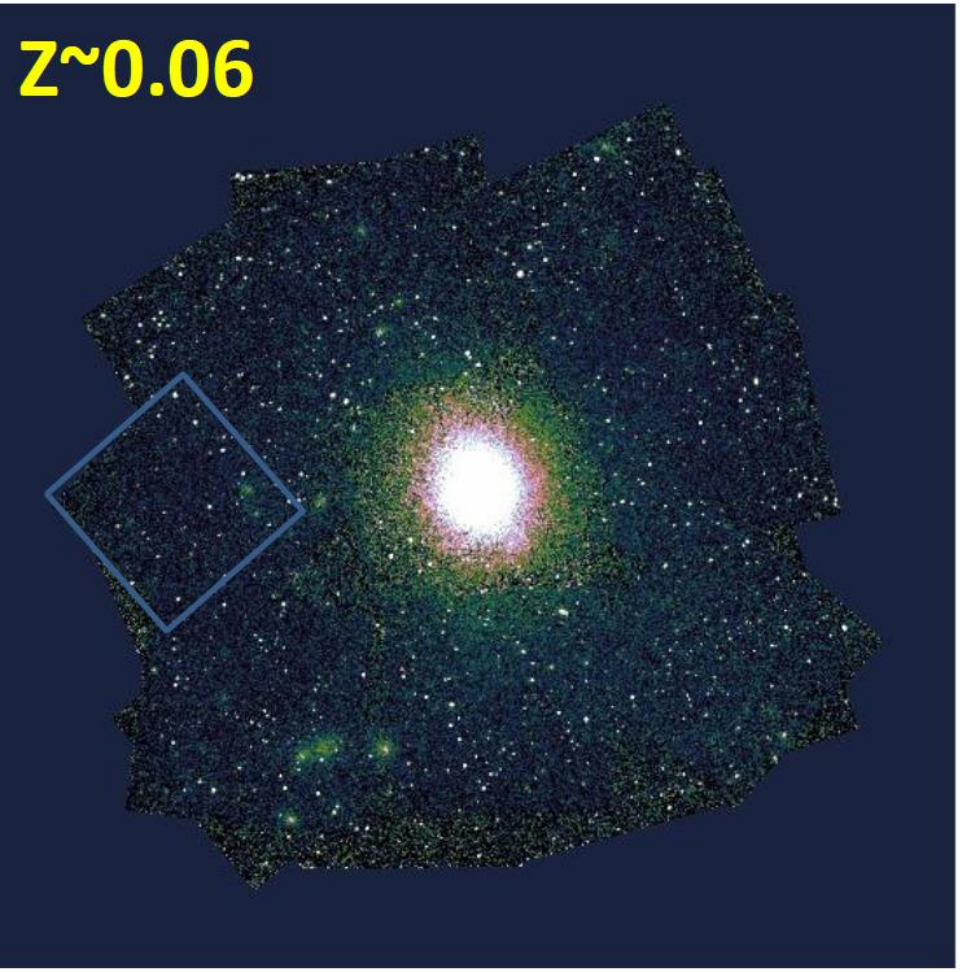
Point source sensitivity:

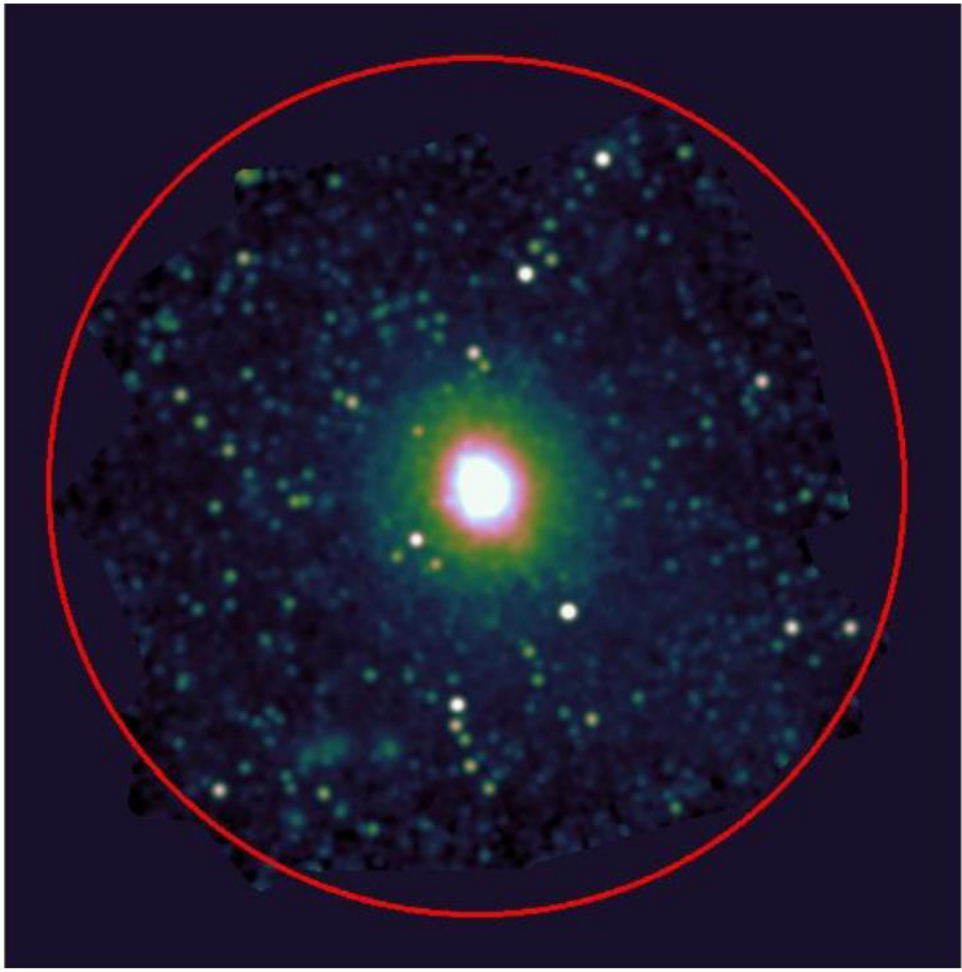
~30 times better than ROSAT (soft band 0.5-2 keV)

~100 times better than HEAO/RXTE (hard band 2-10 keV)

Chandra

eRosita





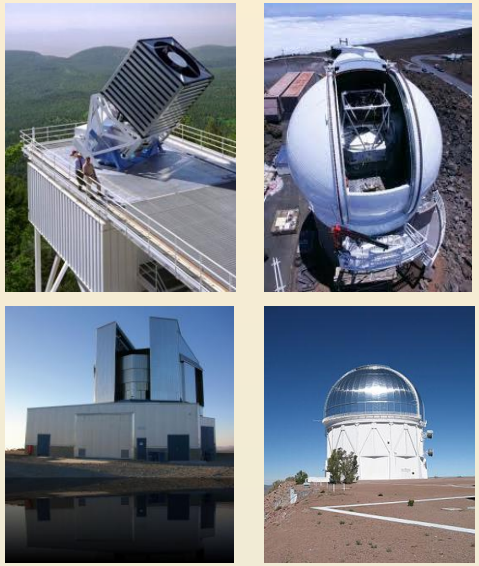
~30 pointings
~2 Msec

~1 pointing
~80 ksec

Churazov, IKI, MPA

Follow-up Observations

1. Needs for followup:
   - Enabling studies of cosmology and cluster physics:
     Redshifts (phot-z + spec-z), Masses: weak lens. + vel. dispersions,
   - Evolution of AGN Population
     Redshifts, host galaxies, BH masses, obscuration, jets
   - Galactic Sources



2. Follow up Context for eROSITA
   (List not complete!)
   - Shallow Multiband OIR Surveys — 2MASS, **PanSTARRS**, UKIDSS, SDSS
   - Deep Multiband OIR Surveys — VISTA, **DES**
   - Optical Spectroscopic Surveys — SDSS, BOSS
   - Proposed Optical Spectroscopic Surveys — **SPIDERS (AS3), 4MOST**, BigBOSS, WEAVE
   - Future OIR Imaging Surveys — **LSST, Euclid**
   - Radio: LOFAR, ASKAP, SKA etc.