



eROSITA



Project overview and status Timelines and catalogs

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EROSITA.DE

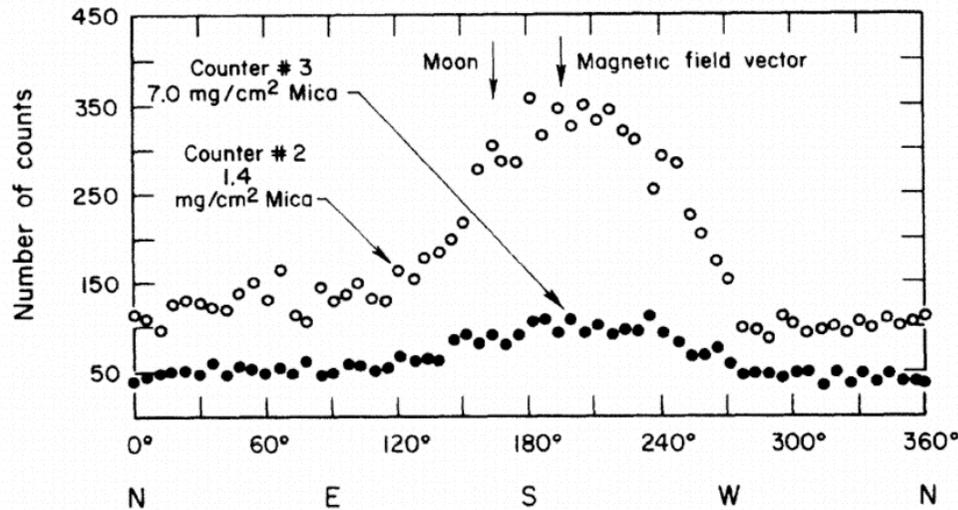


Sco X-1



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1962
Detection



1966
Position

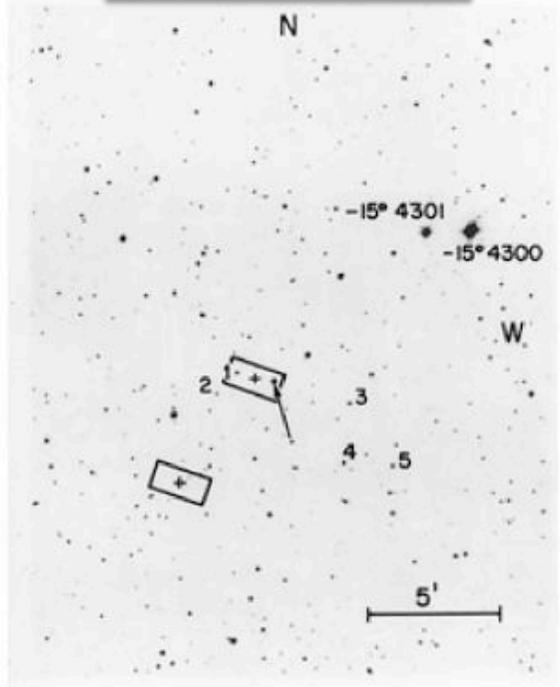
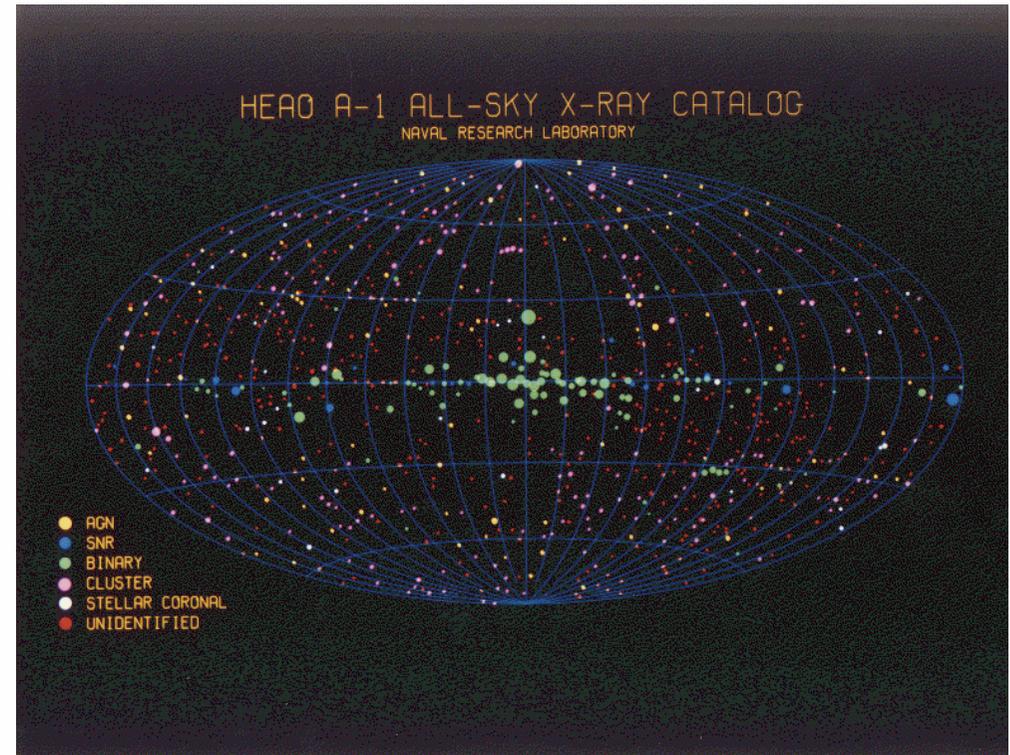


FIG. 5.8. Sky survey showing the first successful optical identification of a pointlike celestial x-ray source. The boxes show the probable locations of Sco X-1, as determined by calculations based on the results of the AS&E-MIT observations of March 1966; the arrow marks the actual position.



HEAO-1

- Survey 1977/78
- Catalog 1984
- 842 sources
- 50% identified



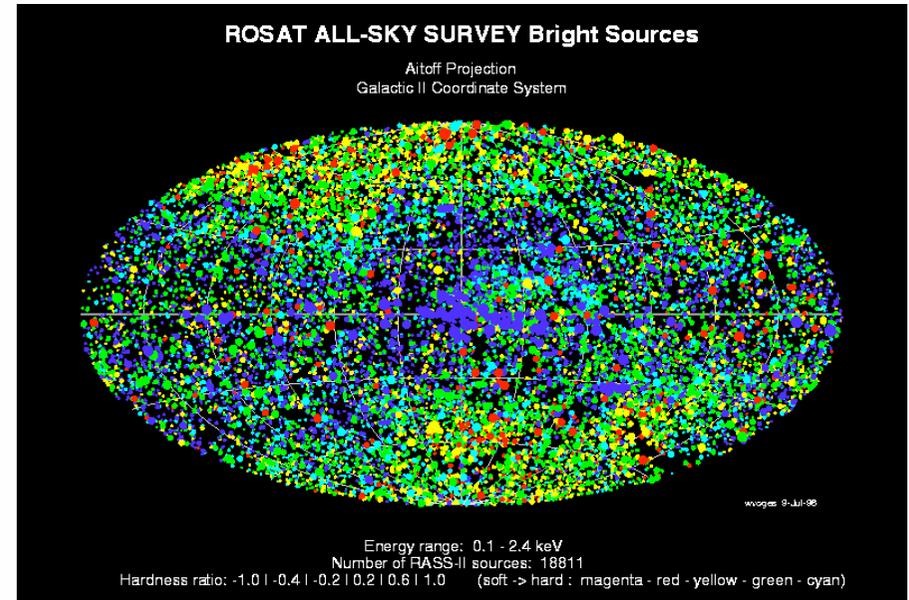
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ROSAT



- Survey 1990
- Catalogs
 - Bright (1999) #18806
 - Faint (2000) #105924
- Identifications:
 - RBS (bright, high latitude): #2012
 - Total: < #10000
 - Fraction: ~5% (incl. sources from pointed obs.)

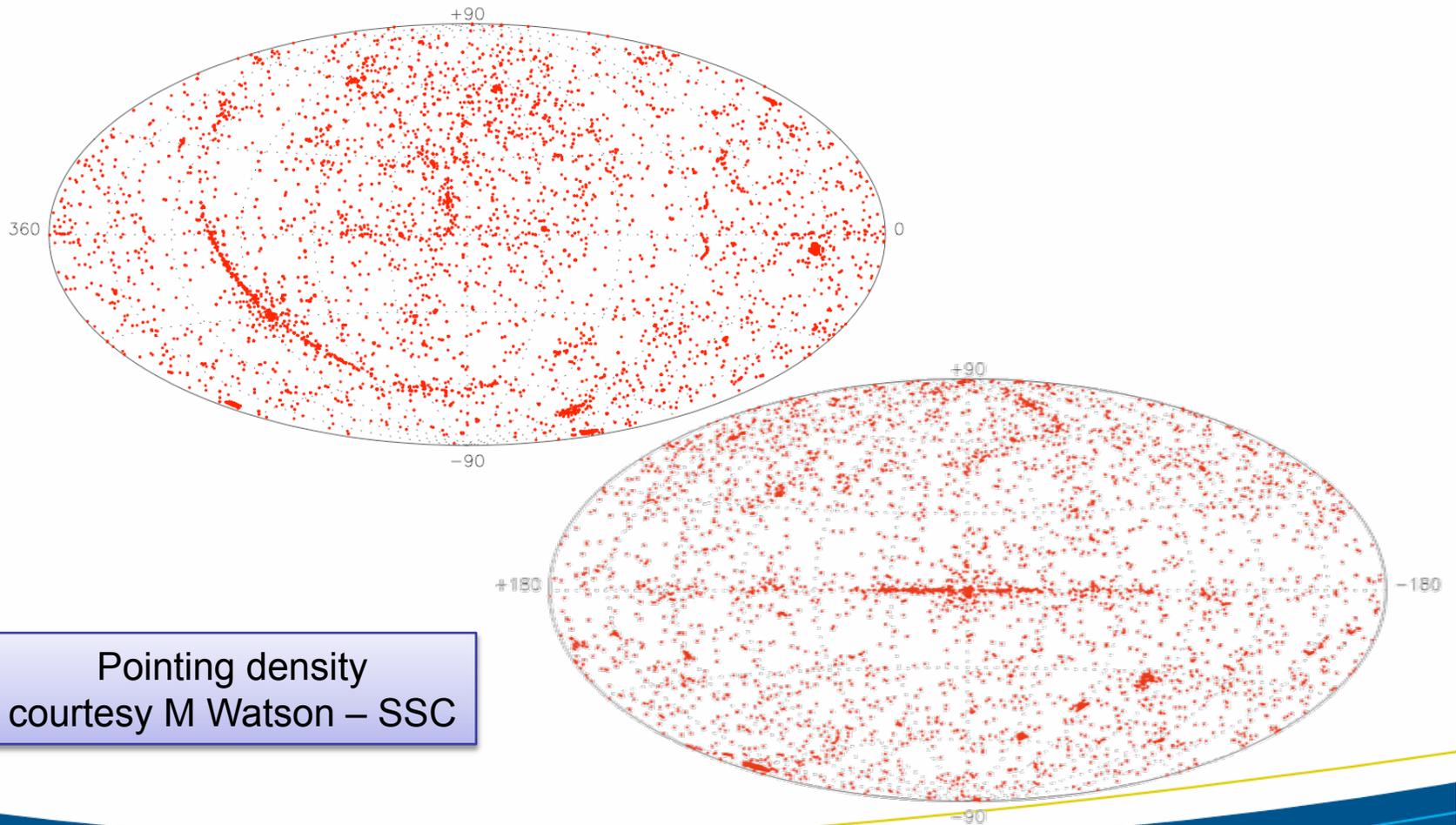


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XMM-Newton

- Launch 1999, pointed observations only

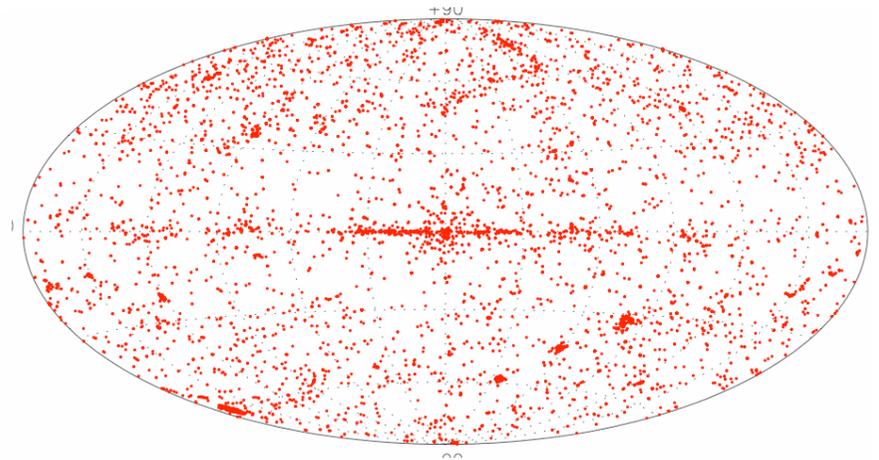


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Pointing density
courtesy M Watson – SSC



XMM-Newton



- Releases



Release	Year	#detect	#source	#fields
1XMM – EDR	2003	33k	28k	585
2XMMp – DR0	2006	153k	123k	2400
2XMM – DR1	2007	246k	192k	3491
2XMMi – DR2	2008	289k	221k	4117
2XMMi – DR3	2010	353k	263k	4953
3XMM	2012	~460k	~330k	~6500

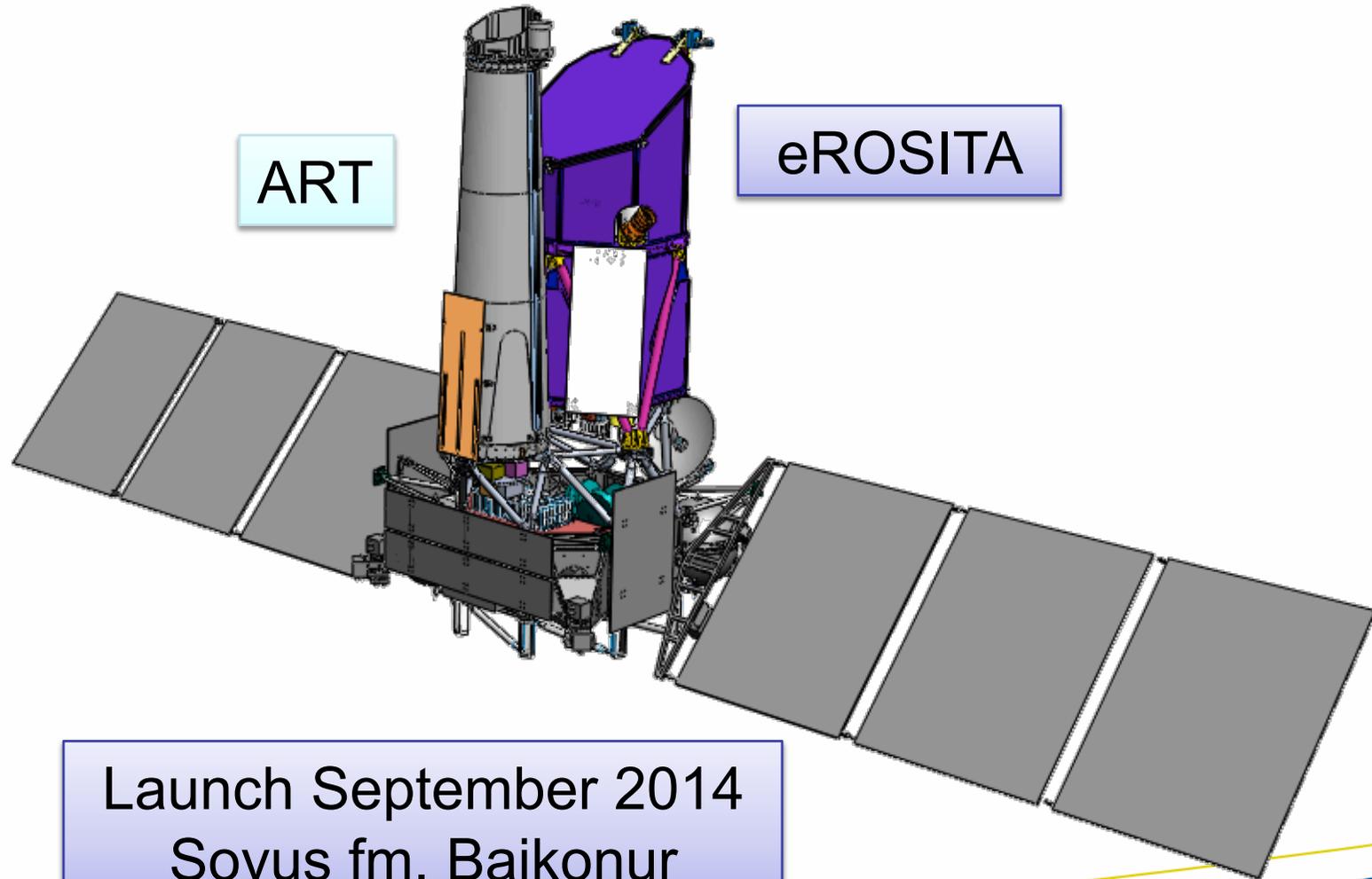


- Identifications:

- community ~5000
- SDSS: ~2700, BOSS 2nd year: 1600



Spektrum-Roentgen-Gamma SRG



Launch September 2014
Soyus fm. Baikonur



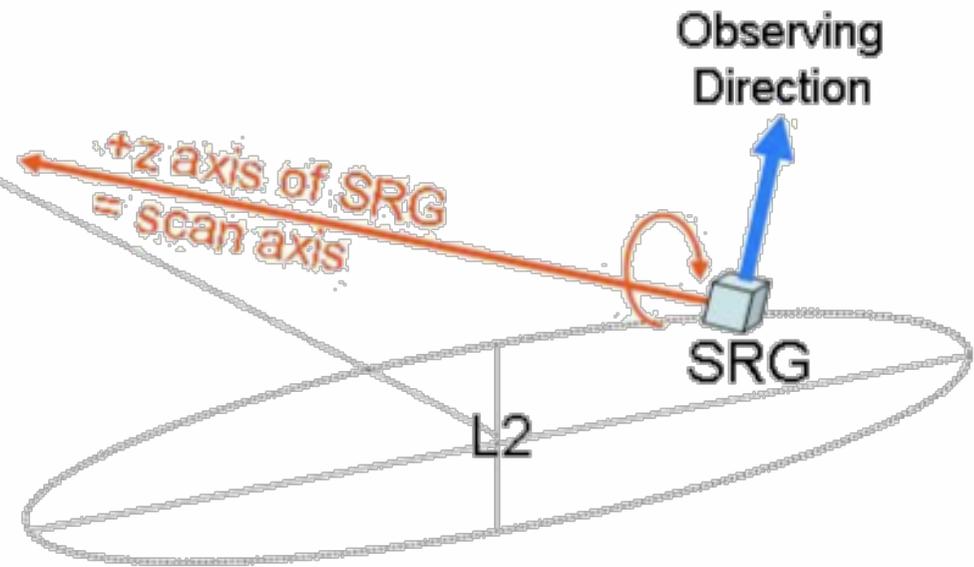
Mission scenario



sun



earth



7 yrs
8x0.5yrs survey
3yrs pointings



Sun-Earth angle max 13°
Scan-Axis always pointing towards Earth (antenna!)
Scanspeed less than in LEO, ~ 4h/revolution



The eROSITA mission goal

Dark Matter and Energy, growth of structure



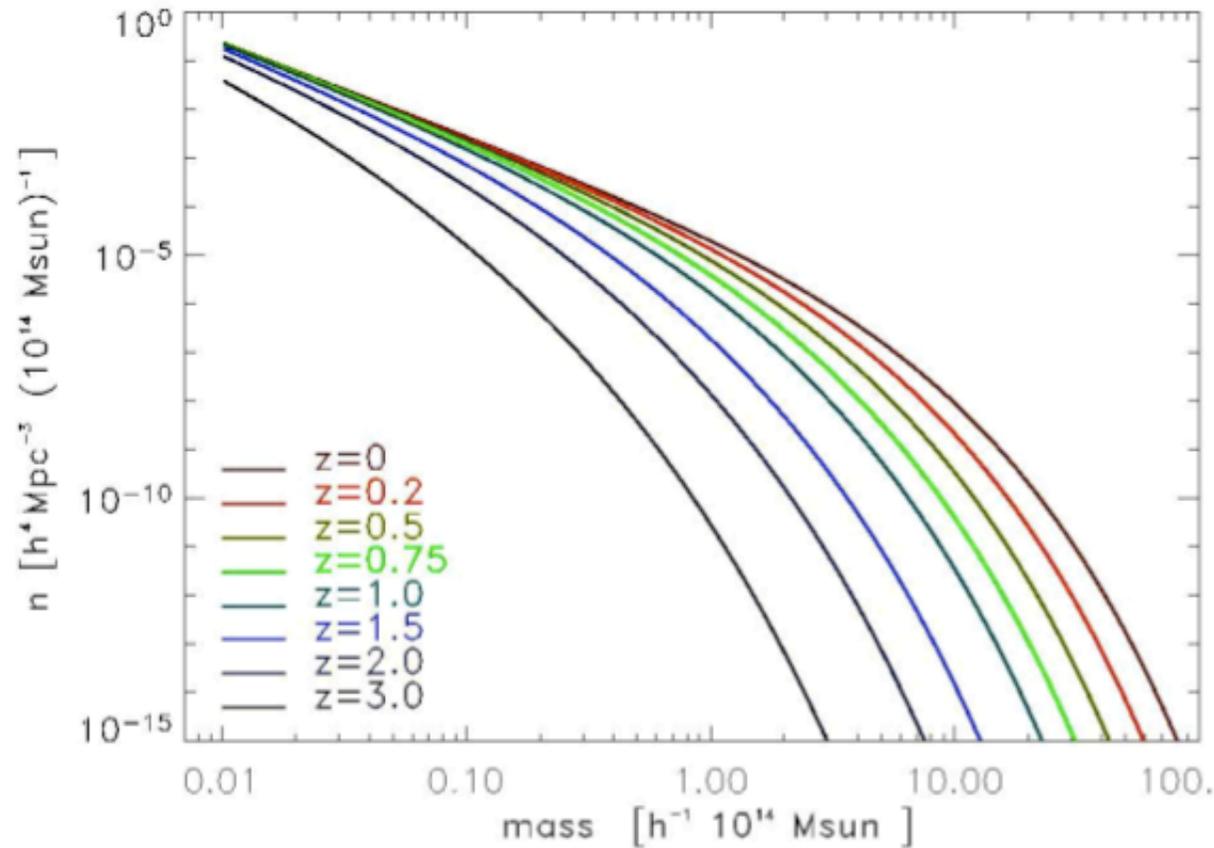
X-ray detection of 100000 galaxy clusters
4MOST-SWG eROSITA clusters (Böhringer)

X-ray detection of about 3 Mio AGN
4MOST-SWG eROSITA AGN (Merloni)





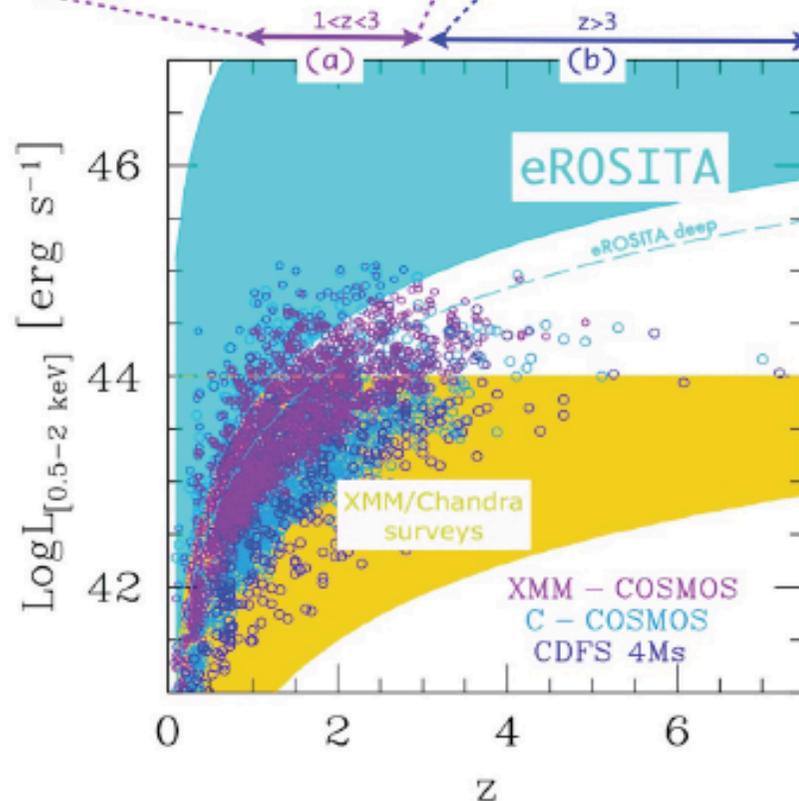
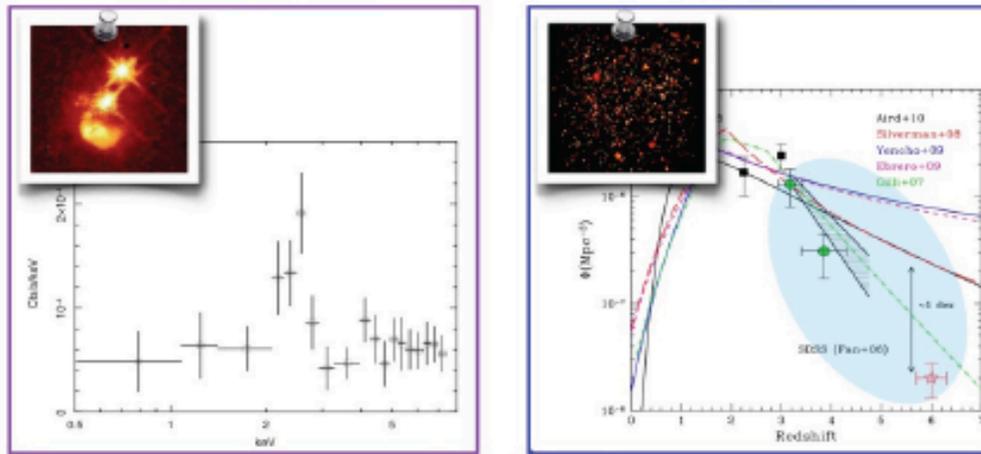
Evolution of the cluster mass function dept. on cosmology



Strong change of the mass function at the high mass end !

eROSITA

2 main AGN topics



1) first sizable sample of X-ray selected $z > 6$ AGN, i.e. first accreting BHs

2) bright hard X-ray selected QSO2 samples at $z = 1-3$, i.e. signposts of major events in galaxy-AGN coevolution

rare objects!

eROSITA key feature: **AREA**

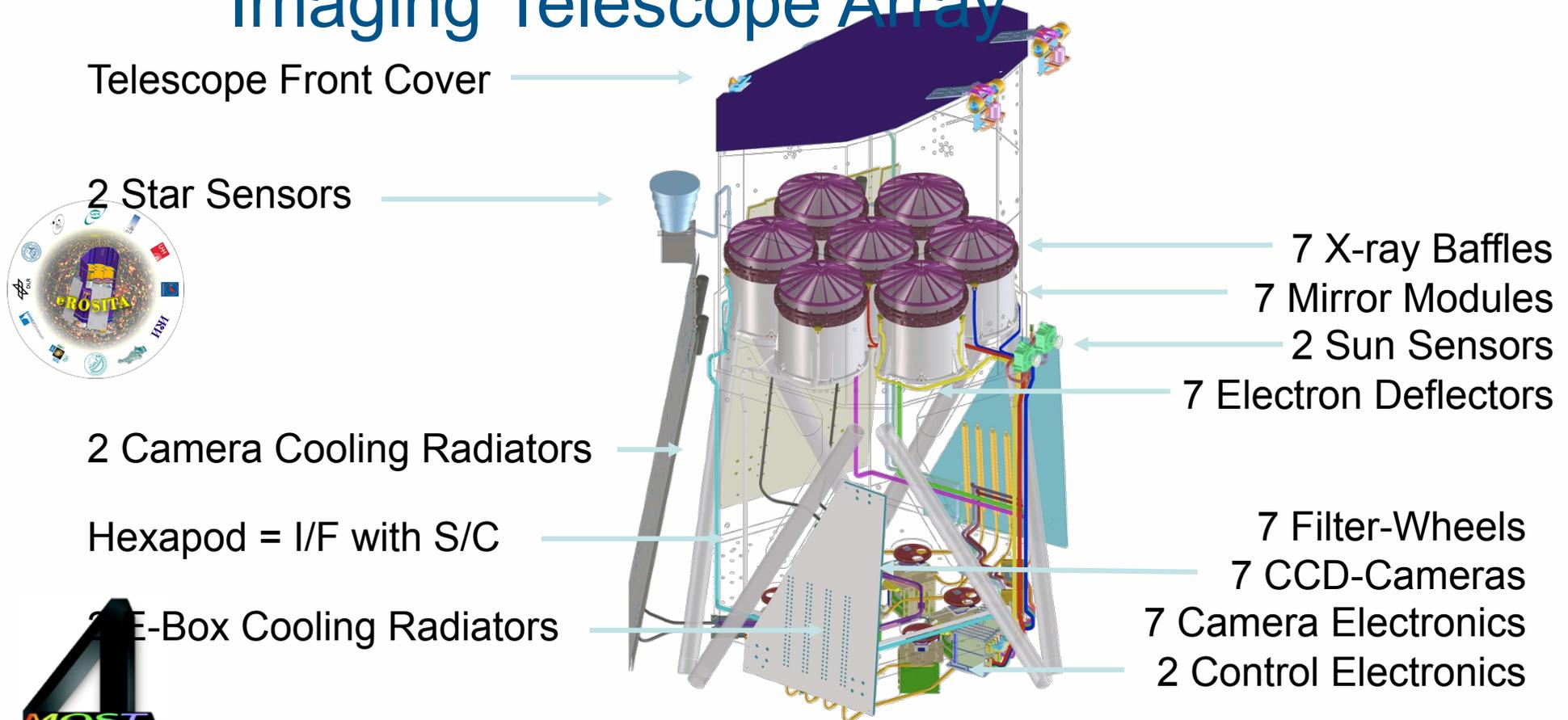
4MOST requirement:

COMPLETENESS



eROSITA

extended ROentgen Survey with an Imaging Telescope Array



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



eROSITA collaboration = eROSITA_DE



Core Institutes (DLR funding):

MPE, Garching/D
Universität Erlangen-Nürnberg/D
IAAT (Universität Tübingen)/D
SB (Universität Hamburg)/D
AIP/D

Associated Institutes:

MPA, Garching/D
IKI, Moscow/Ru
USM (Universität München)/D
AlfA (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.

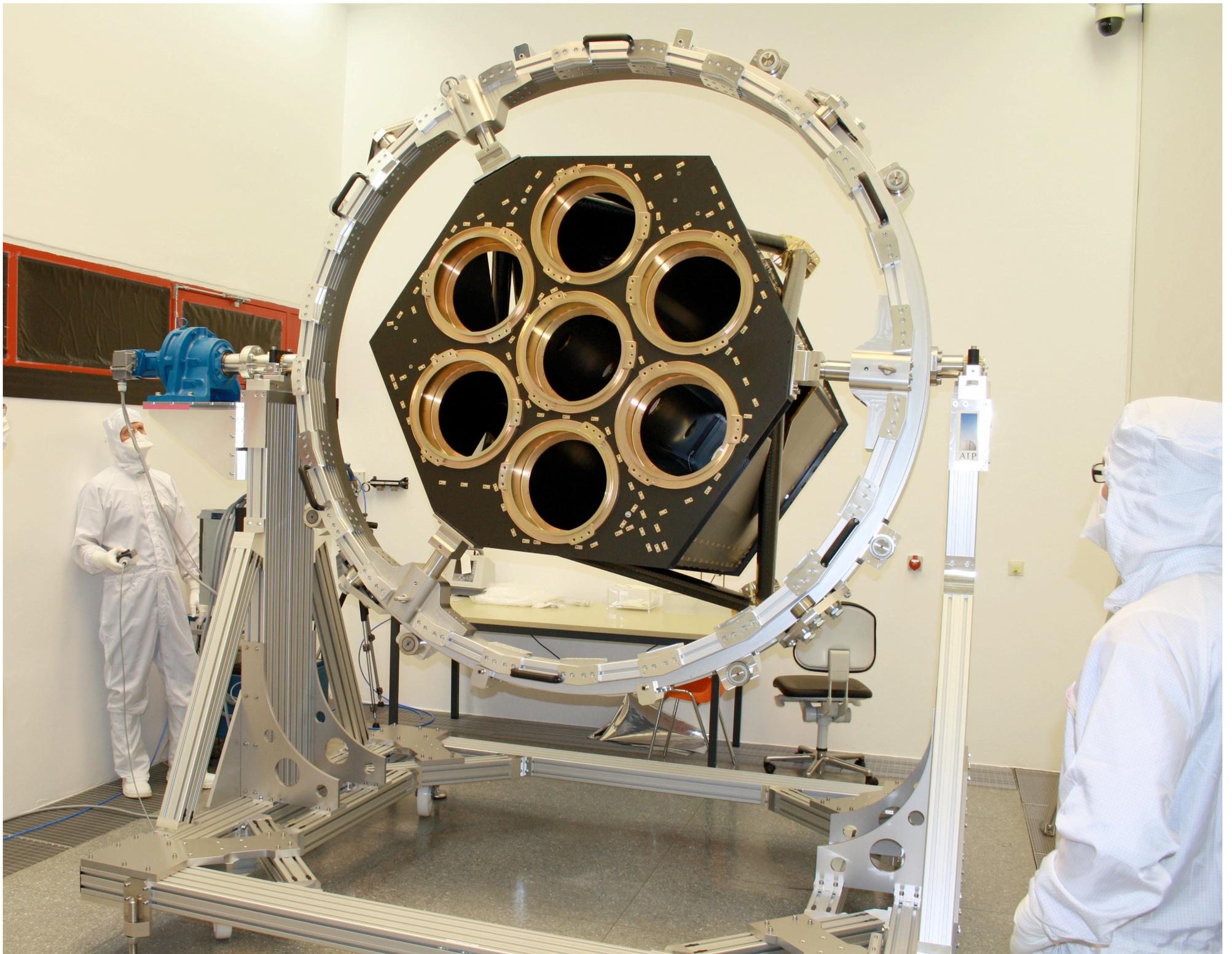


Full technical and scientific description

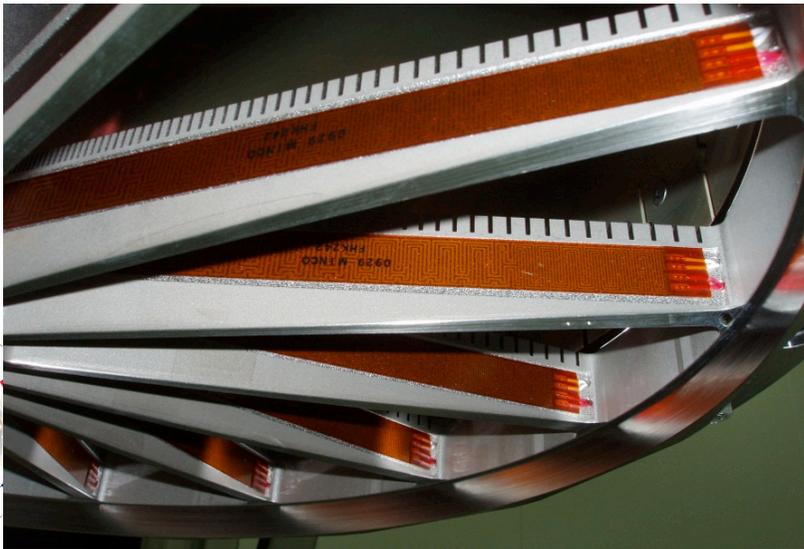


- eROSITA Science Book:
Mapping the Structure of the Energetic Universe
[astro-ph/1209.3114](https://arxiv.org/abs/astro-ph/1209.3114)
Merloni, A.; et al., 2012
- Living document → Online publication only

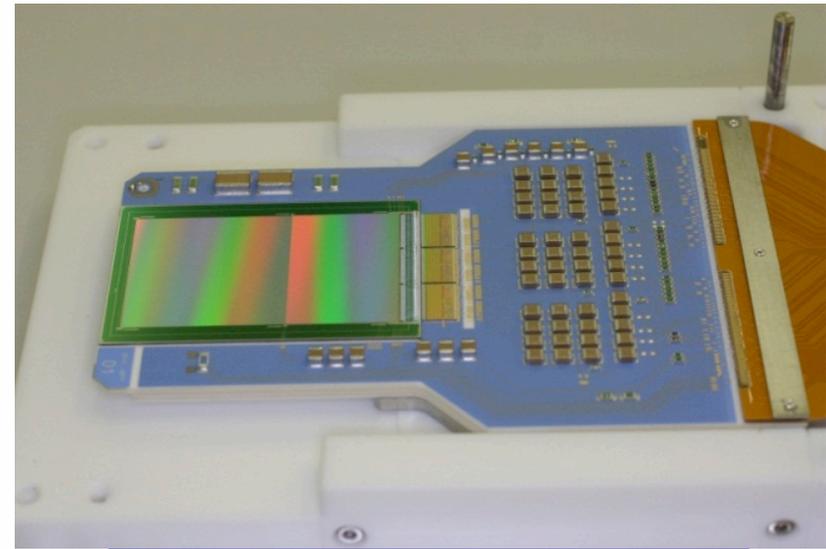




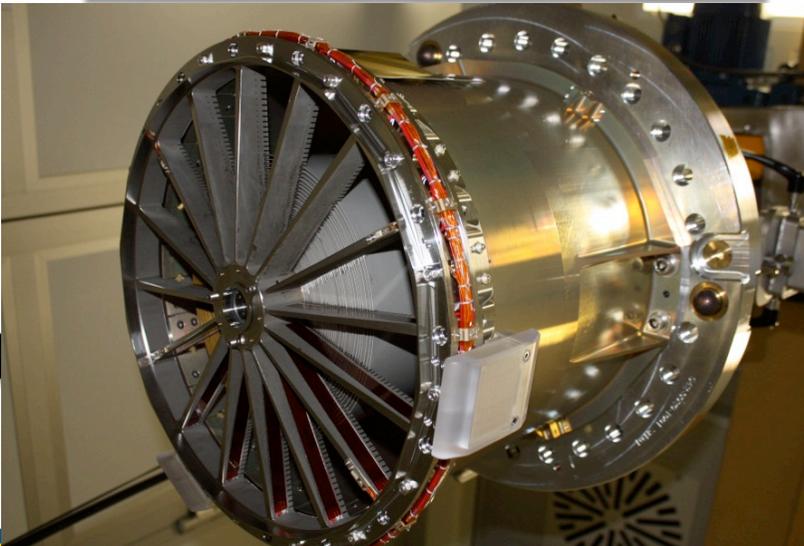
Mirror & camera system



Spider Wheel with heaters integrated



Heart of the Camera: CCD-Module



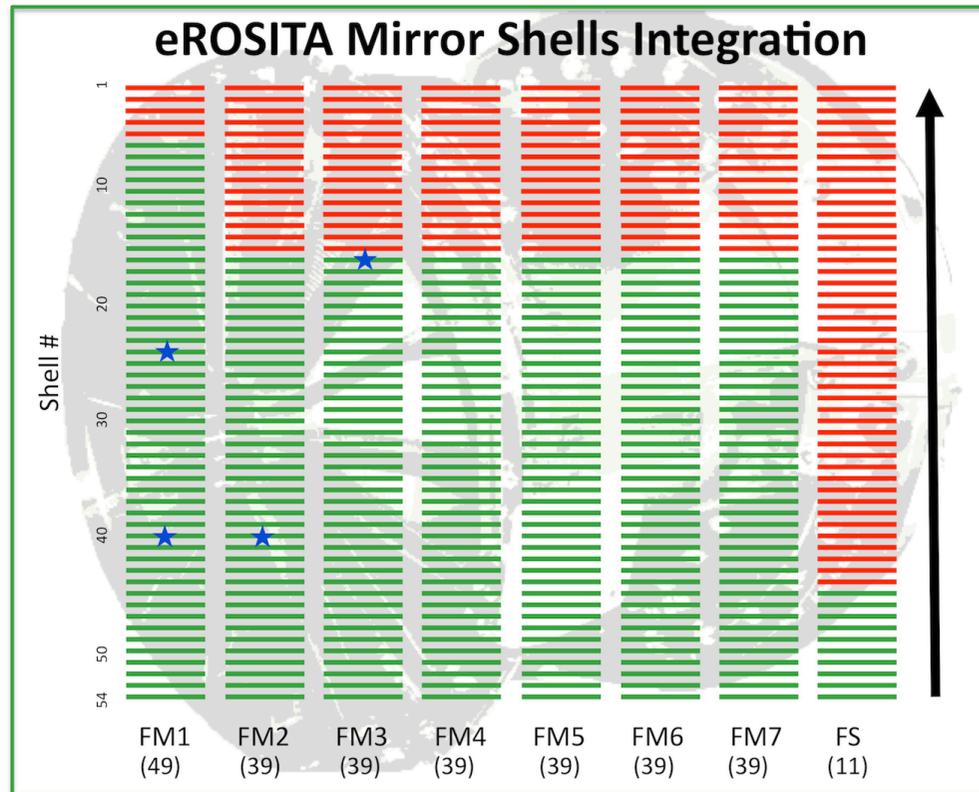
FM-3 Mirror Module with 39/54 shells



Integrated Camera (with massive Copper Housing)



Mirror shell integration



Schematic view of Mirror Modules integration progress, as of November 2012. Green tick marks represent integrated shells, their totals being reported at the bottom. Blue stars mark the tested modules. All tests of partially integrated mirrors so far are within specification (on-axis HEW<15").

All integrated shells within specs!





Status – Hardware tests



eROSITA at the space testing facility IABG during mass measurement.

Mass & Center of gravity & moments of inertia (Oct 12)

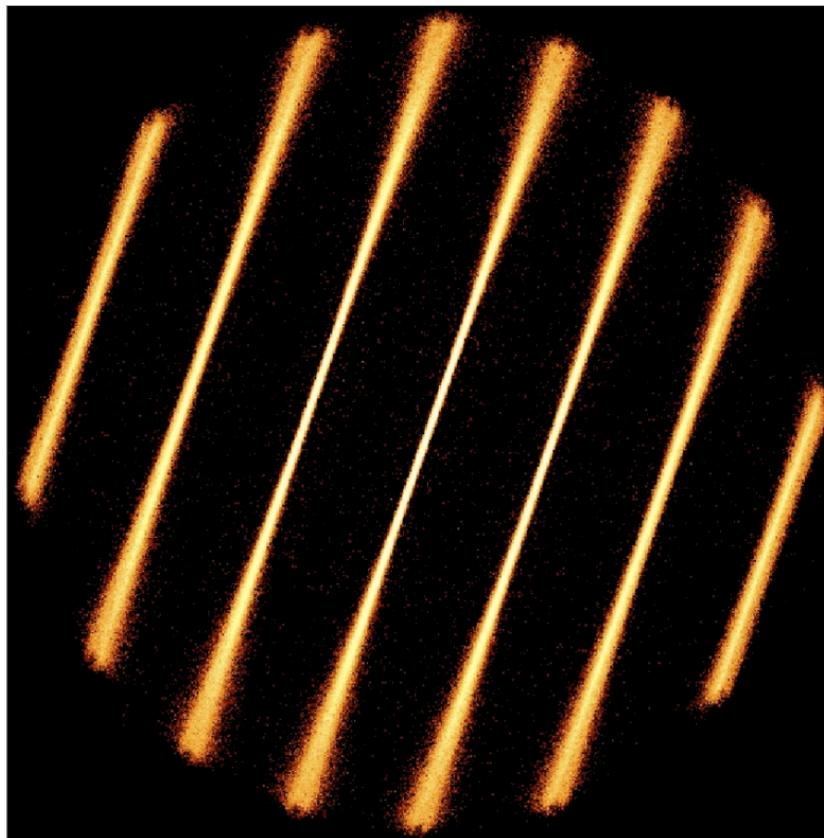
Acoustic noise (Nov 12)

Vibration (Nov 12)

Space simulation (vacuum, Dec 12)



Performance & simulations



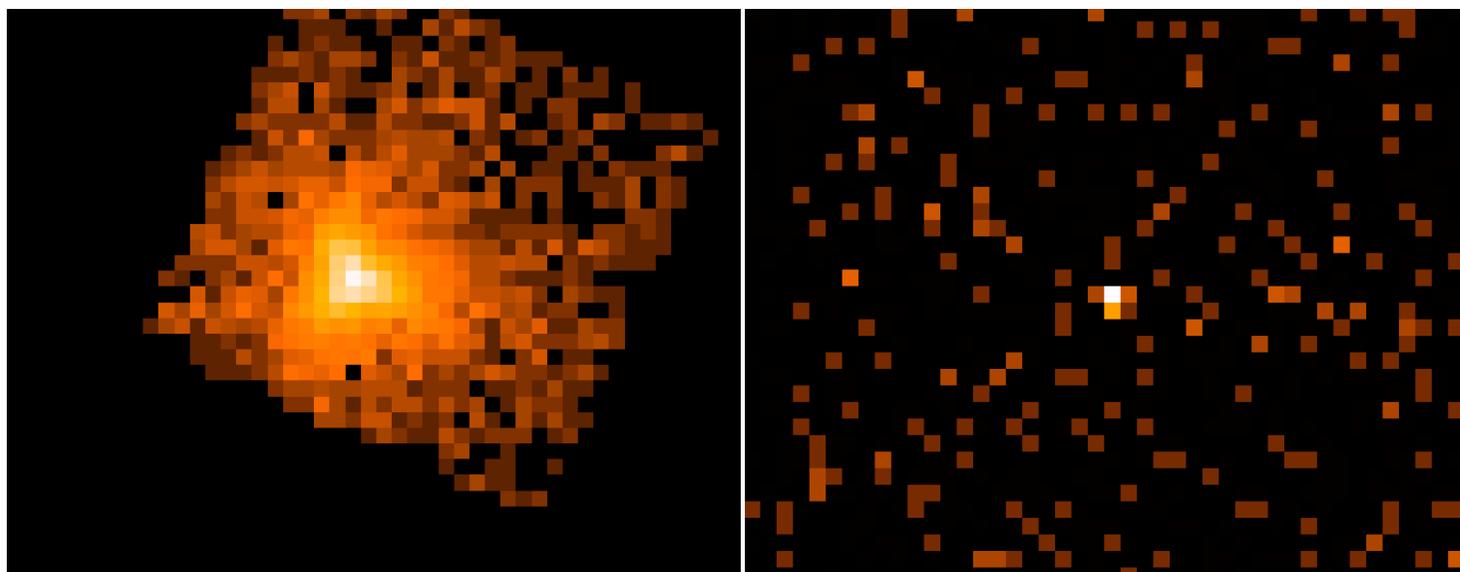
court. Chr. Schmid



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

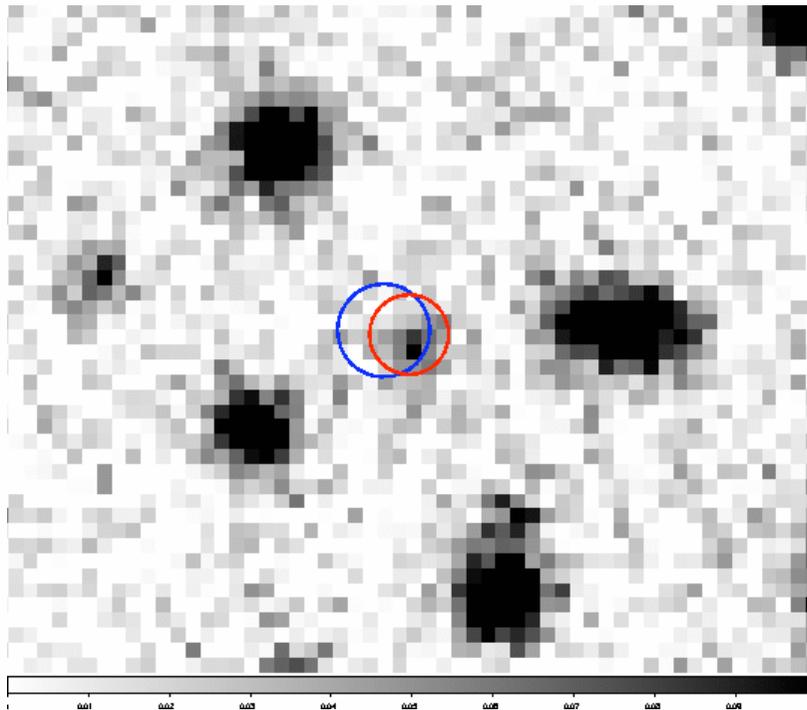


PSF-blurring: XMM-Newton vs Chandra





X-ray positional accuracy



- Chandra (red): 0.6"
- XMM-Newton: 0.7" (eROSITA-like)
- Positional rectification by many associated X-ray/optical sources

- deep optical/NIR reference catalogues
- Exp. accuracy ~2-5"



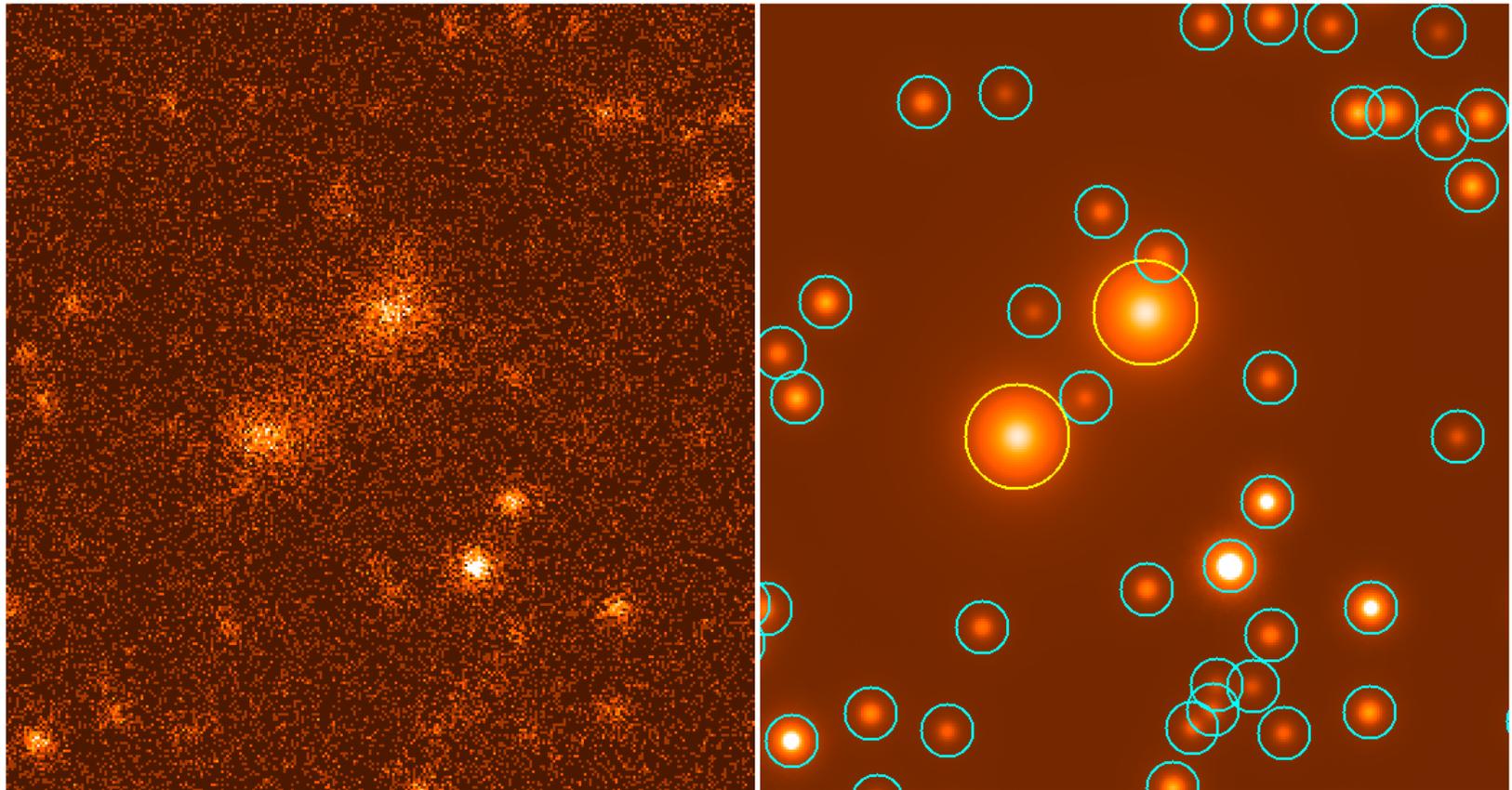


Source detection efficiency

Extended vs pointlike source



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Photon image
AGN logN-logS
Clusters: Hydro

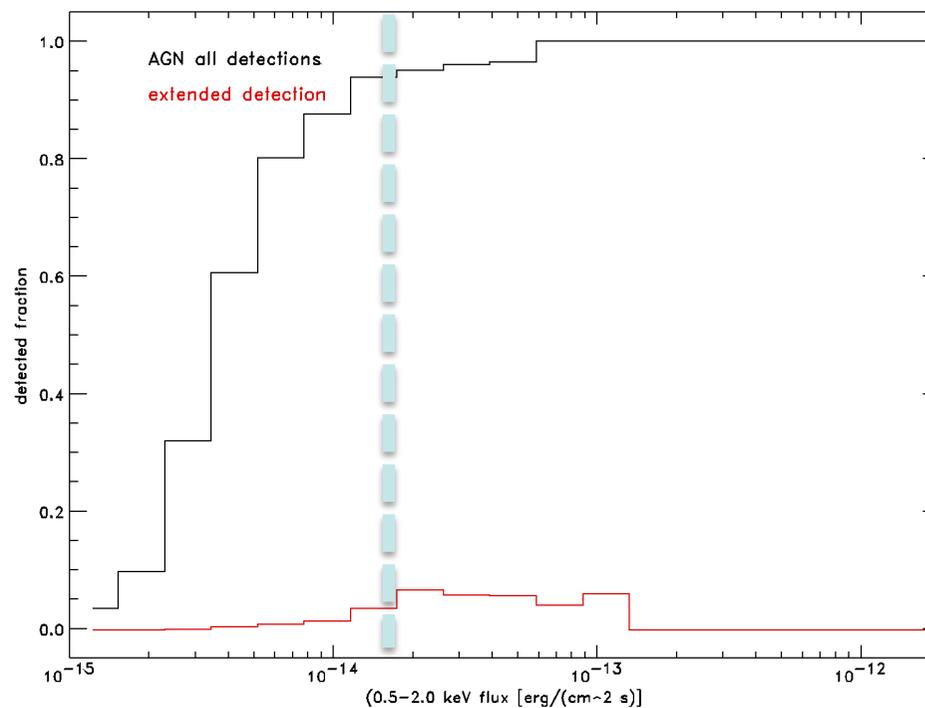
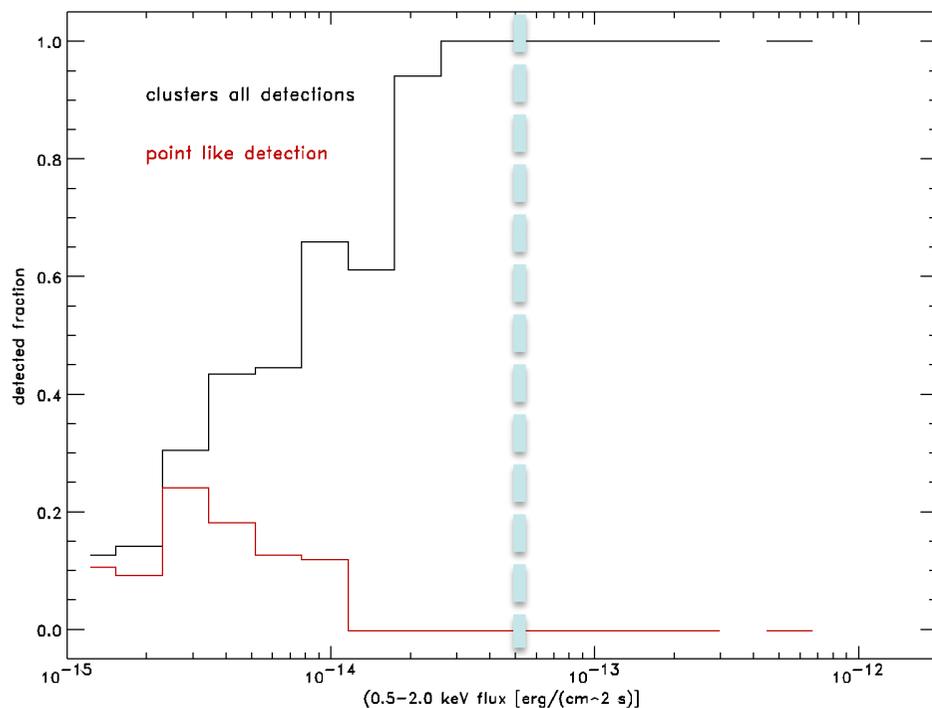
Source detect. image
Extended = cluster
Pointlike = AGN, stars, ...



Detections & recovered fractions

Clusters

AGN

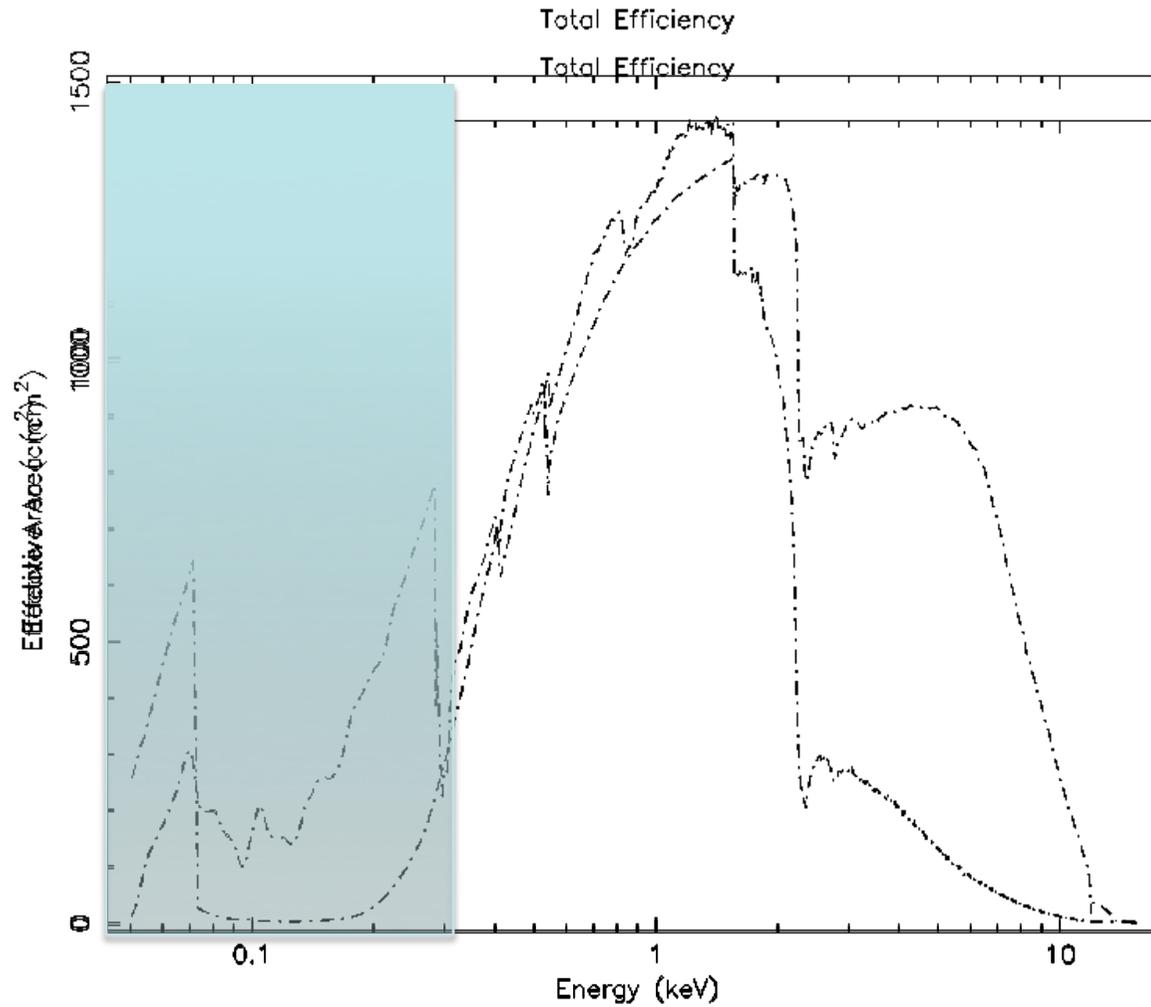


Flagged as point-like

Flagged as extended



Eff Area: eROSITA vs XMM-Newton



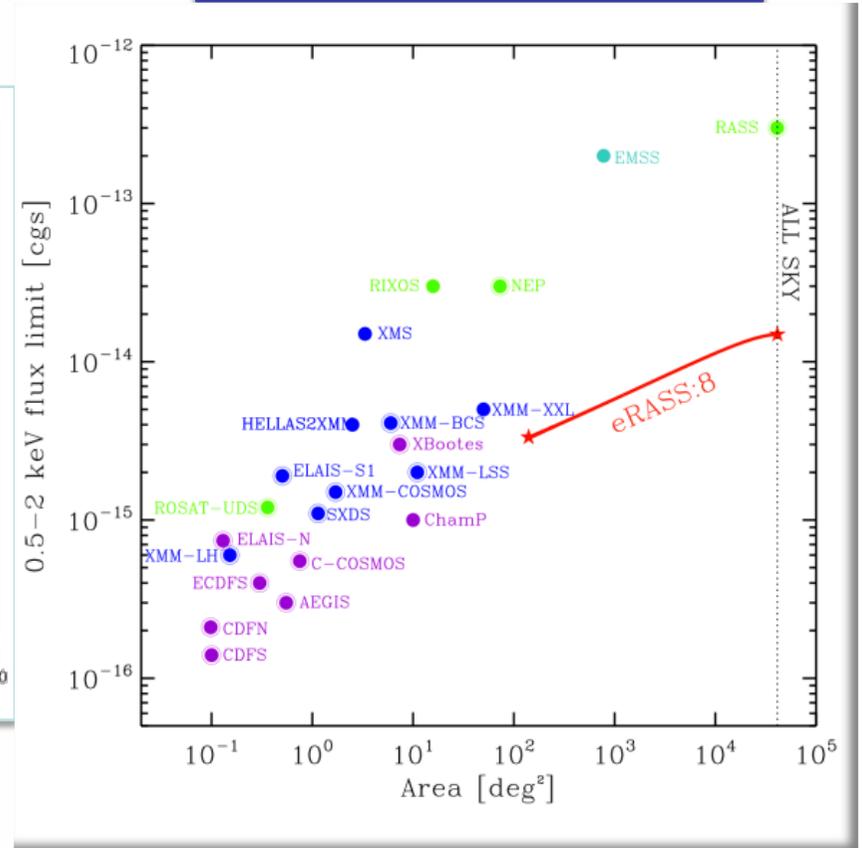
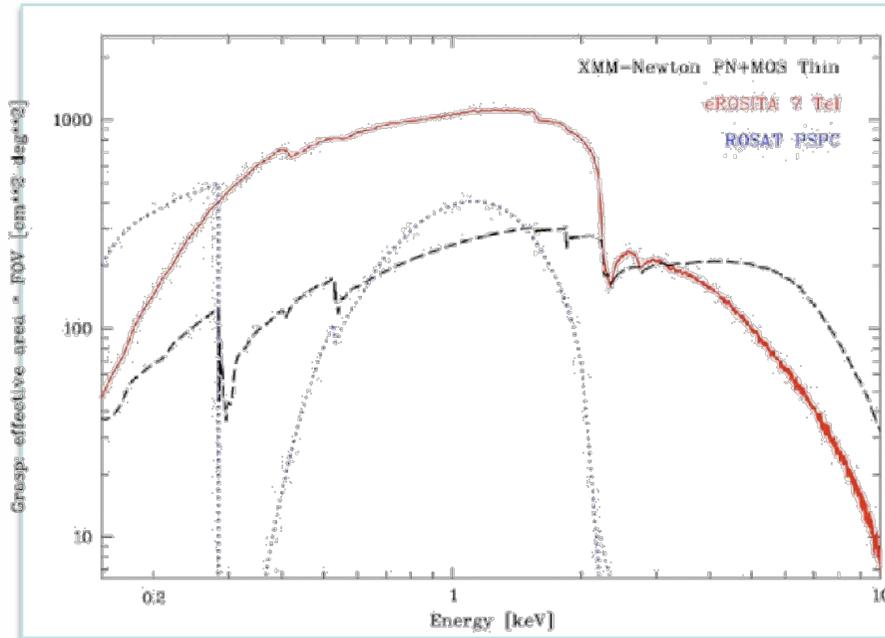
axelschwpe 25-Sep-2012 19:45



eROSITA performance

Grasp = eff area x FOV
 → Survey power

Point Source Sensitivity



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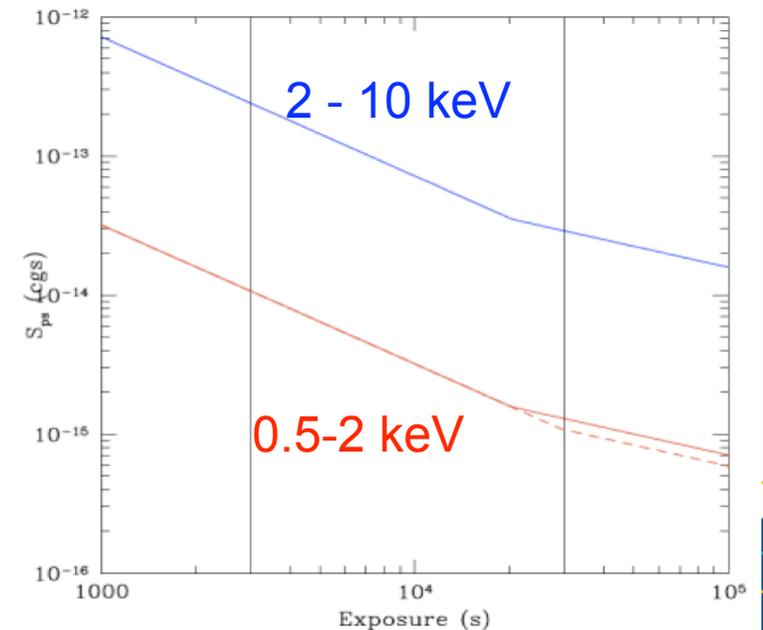
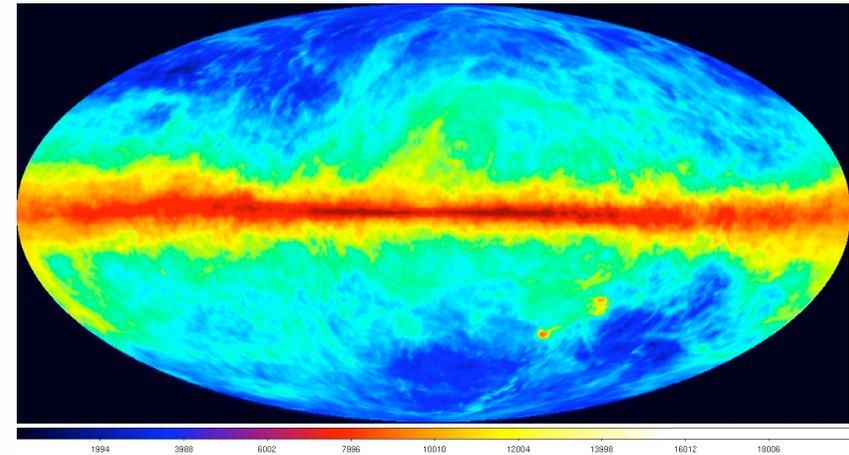
Source content



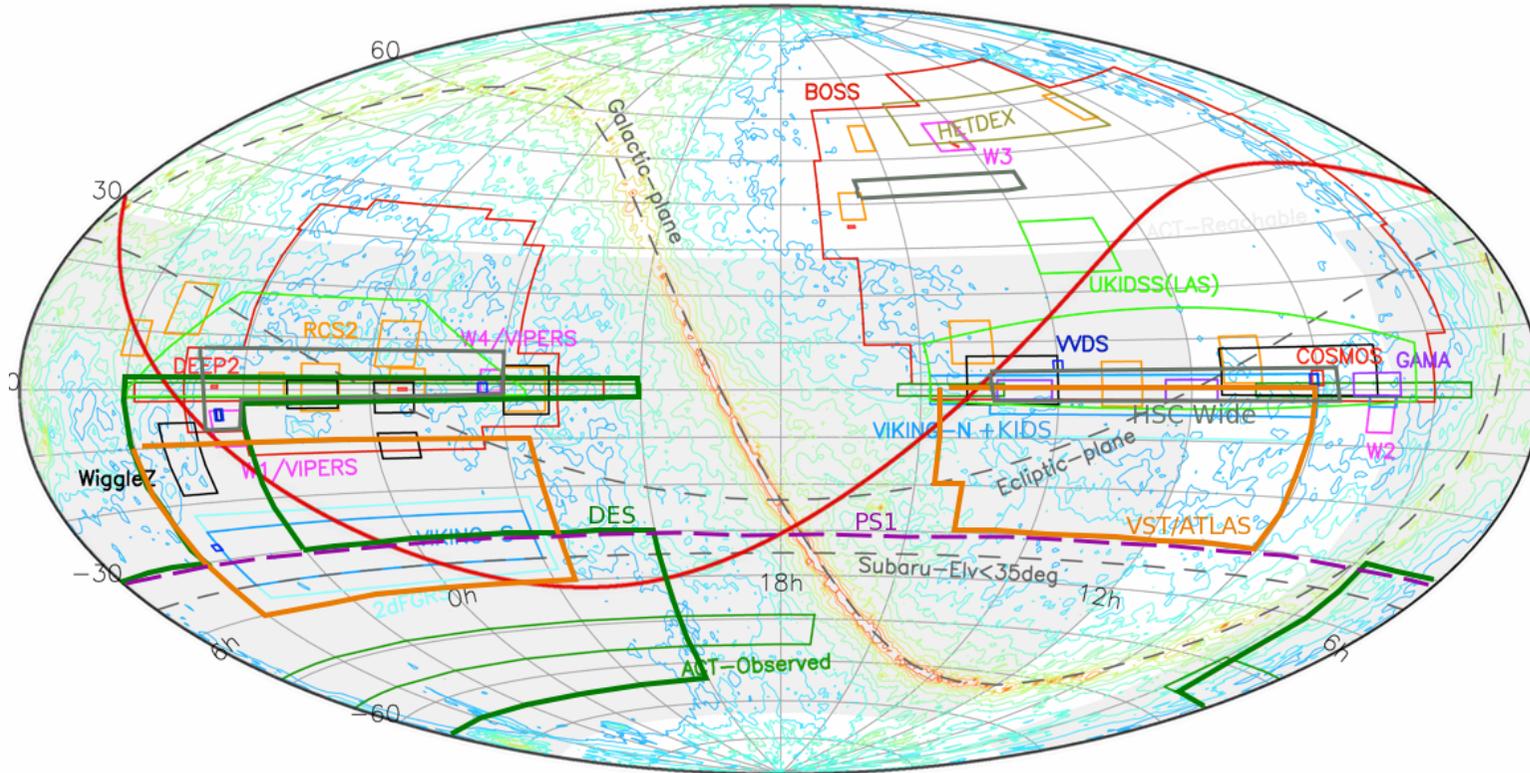
- Sensitivity + Exposure map + Extinction map
→ $F_{x,lim} @ E$
- $\log N - \log S \rightarrow \# / \text{deg}^2$
- FoV \rightarrow #sources

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AGN: 3×10^6
Clusters: 10^5
Stars: 4×10^5
Compact: 2×10^4



Survey of surveys (eROSITA science book)

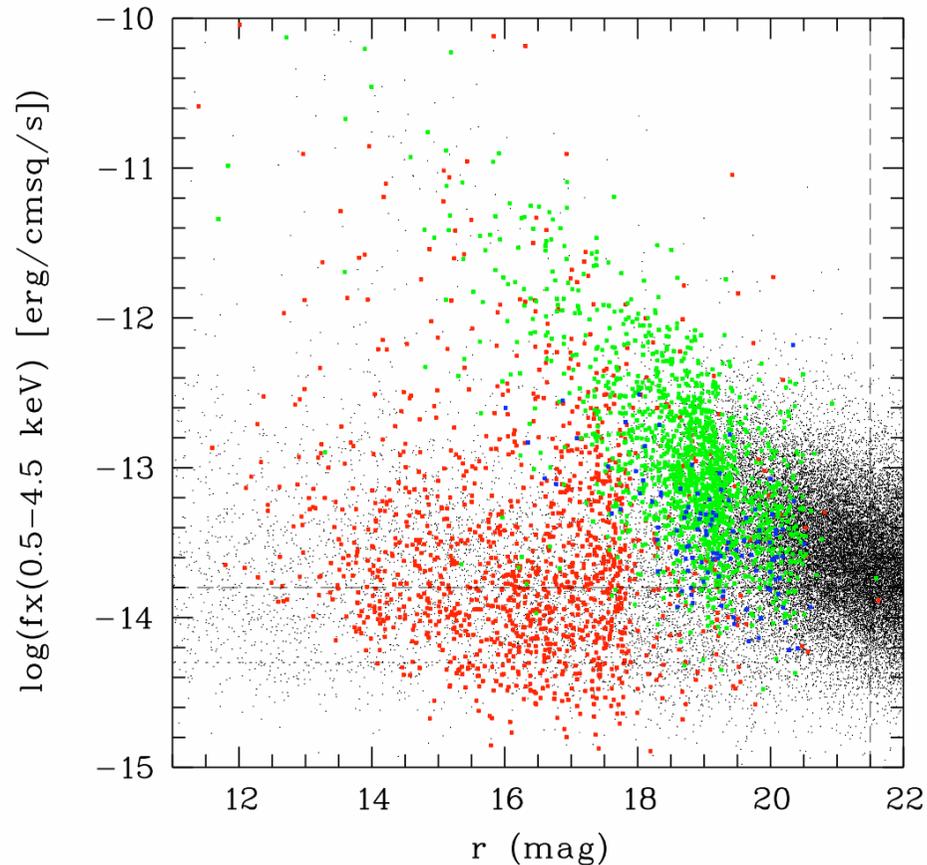


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Figure 6.1.1: Multi-band wide area optical imaging surveys (figure courtesy A. Nishizawa, IPMU) are displayed in equatorial coordinates. The thick red line mark the separation between the German and the Russian eROSITA sky, with the former being the southernmost one. Existing and planned optical/NIR surveys are outlined with colored boxes. Pan-STARRS (PS1) survey will cover all area above the dashed magenta line ($\delta > -30^\circ$). Together, DES and PS1 provide the multi-band photometric data needed for cluster and AGN confirmation in the extragalactic German eROSITA sky, as well as the cluster photometric redshift estimation and weak lensing mass constraints.



XMM/SDSS correlation → 4MOST discovery space



,Galaxies'

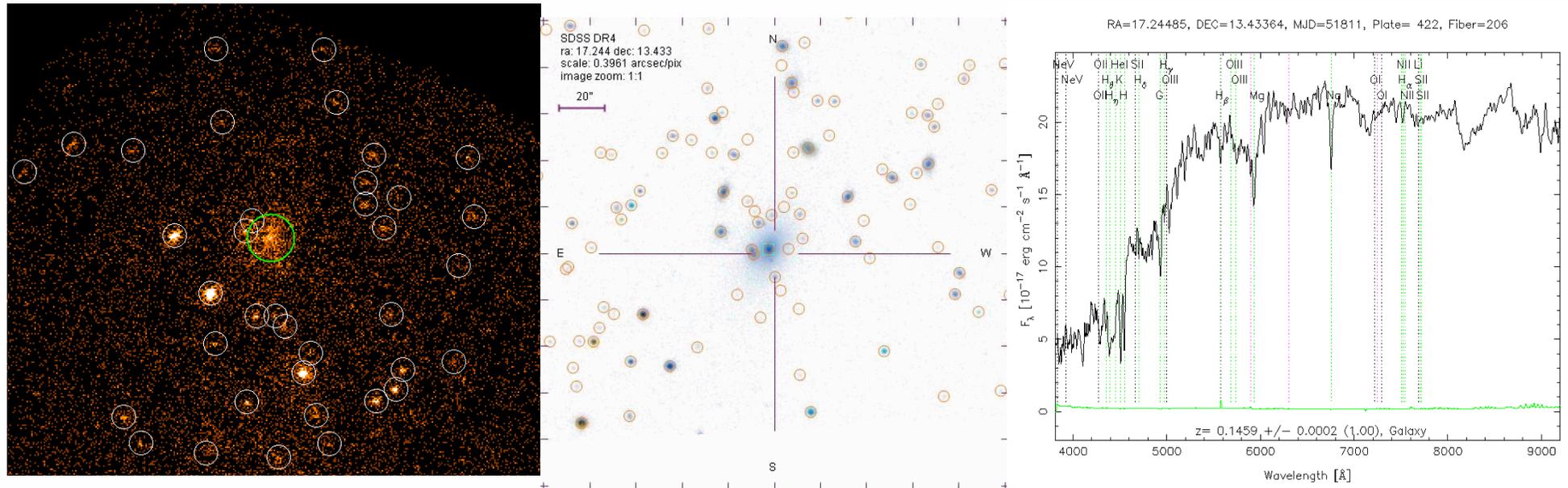
QSOs

Hi-z QSOs

unid

~300 #/sq.deg. → all kinds of AGN

Learning base: XMM-Newton clusters in the SDSS



Targeting strategy:

- Highest priority for Brightest Cluster Galaxy
- Member galaxies with same priority
- Optimize number of spectra

Requirements:

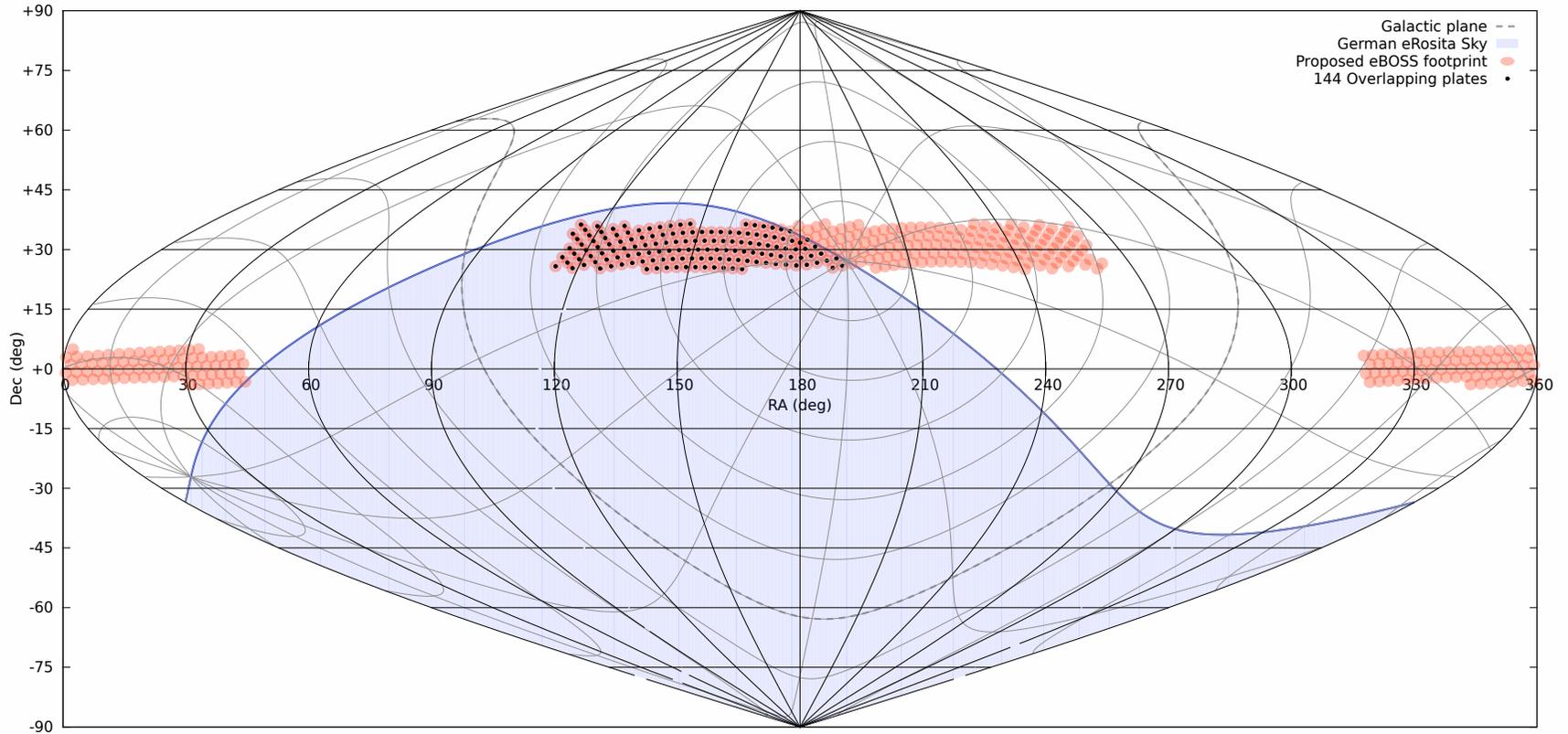
- $r(\text{AB}) < 22$ (incl fibre losses)
- Sampling 5-10 arcmin⁻²
- Wavelength range 400-1000nm
- Resolution > 500
- S/N ~ 5



Precursor to 4MOST in AS3: SPIDERS

SPECTROSCOPIC IDENTIFICATION OF ERosITA SOURCES

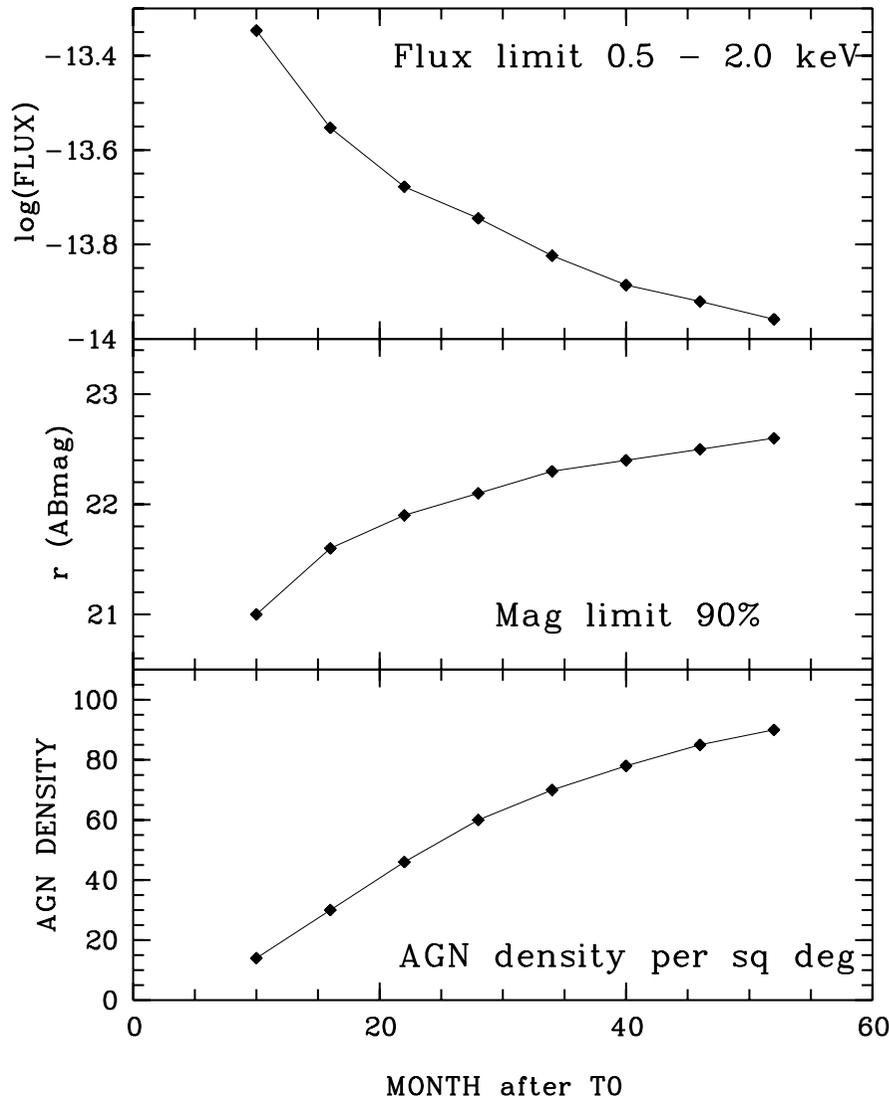
Overlapping sky coverage between eBOSS 'scube' and German eROSITA sky



Tiny fraction of eROSITA X-ray sky



Catalog creation and data releases (tbc)



- T0 = 2014.67
- Time axis = catalog readiness
Month 52 (eRASS:8)
Jan 1, 2019
- Full public release
Tcat + 2 yrs
- Catalog: List of detections with all attributes (pos, cr, flux, color, detml, morph, var.)



eROSITA & 4MOST



- eROSITA hardware on track for launch in 2014
- Catalog development and release plan
- eROSITA collaboration: correlations with opt/NIR catalogs to select targets for 4MOST
- DRS science cases developed for 4MOST
- Follow-up in the Galaxy, synergies with Gaia follow-up



→ expect eROSITA+4MOST = XIDfrac(75% at high galactic latitude)



Why performing eROSITA follow-up with an ESO facility?



- The eROSITA/4MOST survey is not private
- Large X-ray (survey) community European and world-wide
- Large fraction of XMM-time is spent for survey work
 - Need for ‚all-sky‘ data
 - Need for well-calibrated data (both at X-ray and optical wavelength)
 - Need for well-described exposure map





Survey of surveys (eROSITA science book)



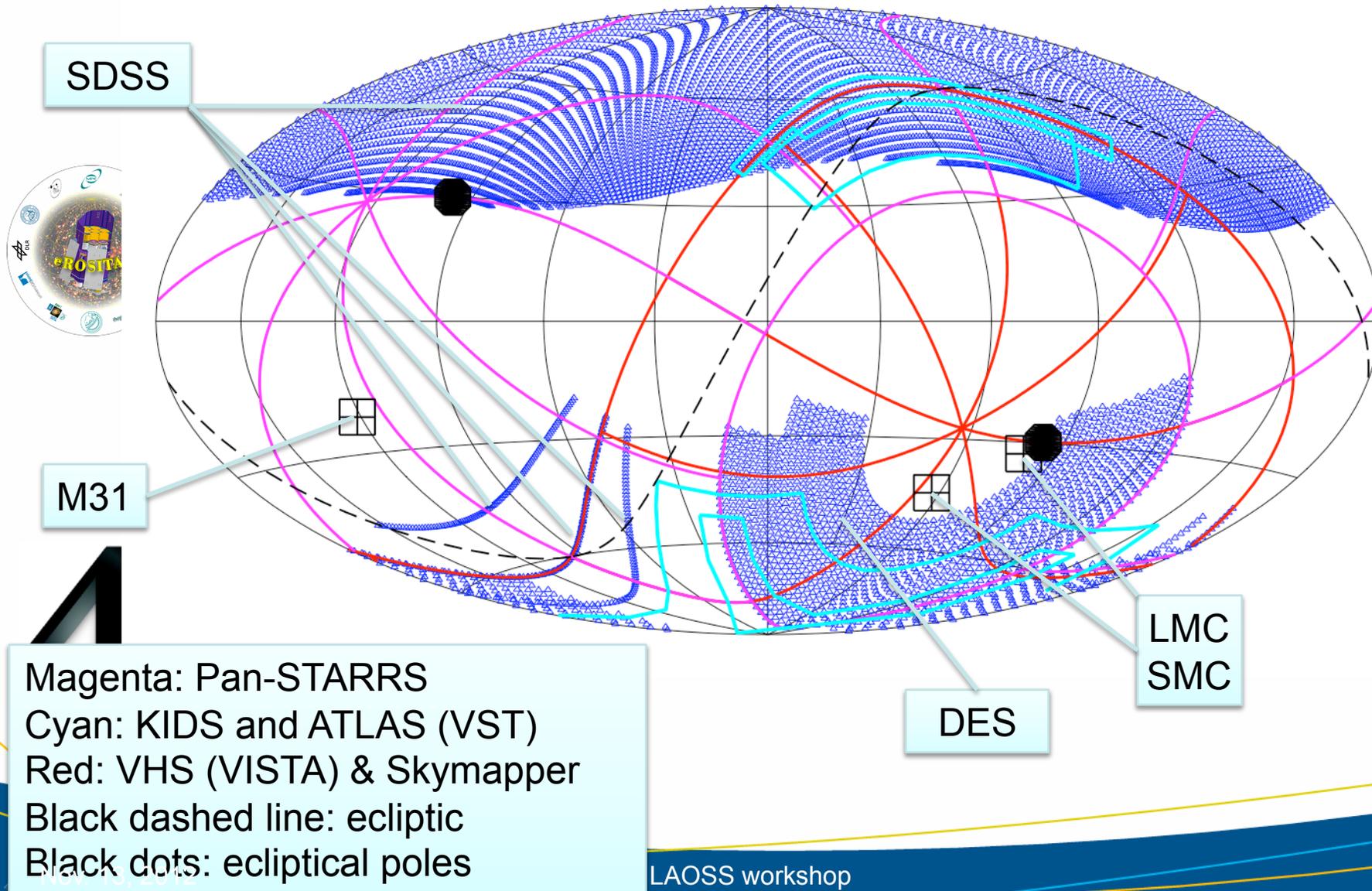
Survey	Lat	Date	Ω	u	g	r	i	z	Y	J	H	K
SDSS	+30	'10	10000	21.6	22.6	22.4	21.6	20.1	-	-	-	-
PS1	+20	'10-'12	30000	-	22.6	22.4	22.1	21.1	-	-	-	-
SkyMapper	-30	11-	30000	-	22.5	22.0	20.9	20.6	-	-	-	-
KIDS+VIKING	-20	11-	1500	24.8	25.4	25.2	24.2	22.4	21.6	21.4	20.8	20.5
DES+VHS	-30	'12-'16	5000	-	24.6	24.1	24.3	23.8	21.5	20.2	20.1	19.5
ATLAS+VHS	-20	11-	4500	22.0	22.2	22.2	21.3	23.8	21.5	20.5	19.9	19.3
HSC	+20	'12-'16	1500	-	25.5	25.2	25.5	24.3	23.3	-	-	-
PS2	+20	14-	10000	-	24.5	24.5	24.5	24.5	-	-	-	-
GAIA	-	'13-	41253				20					
Euclid	-	'19-'24	15000			24.5			24.0	24.0	24.0	-
LSST	-30	'20-'30	18000	24.0	26.0	26.0	26.0	26.0	26.0	-	-	-

Table 6.1.1 Overview of key optical/NIR wide area imaging surveys. Surveys include Sloan Digital Sky Survey (SDSS), Pan-STARRS1 (PS1), Kilo-degree Survey (KIDS), VISTA Kilo-degree Infrared Galaxy Survey (VIKING), Dark Energy Survey (DES), Vista Hemisphere Survey (VHS), VST Atlas Survey (ATLAS), Hyper-Suprime-Cam Survey (HSC), Pan-STARRS 2 (PS2), Euclid Space Mission (Euclid) and the Large Synoptical Survey Telescope (LSST). 'Lat' encodes the latitude of the observatory, 'Date' encodes the range of years over which the survey takes place, and Ω encodes the solid angle of the survey.





XID2: Imaging surveys in galactic coordinates





Competing projects

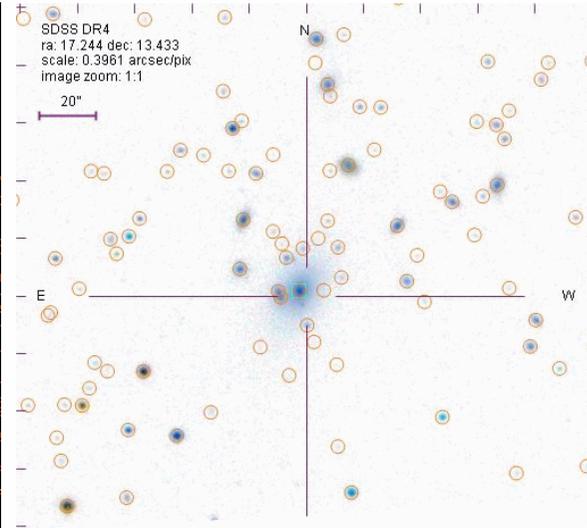
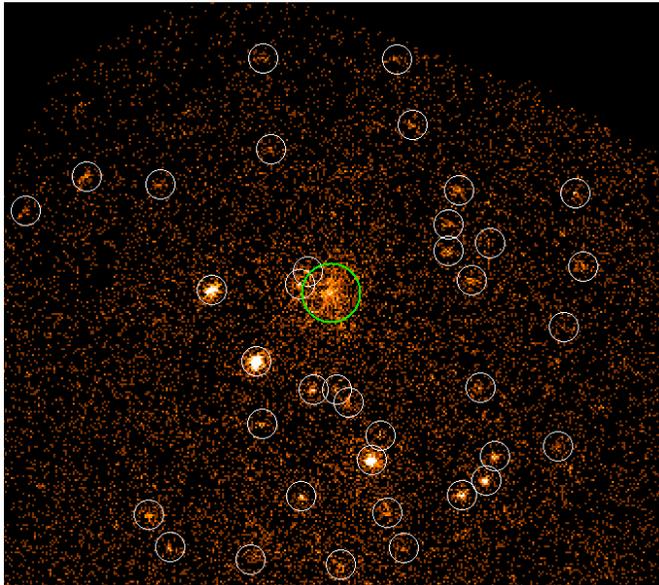


- SDSS: huge optical cluster catalogues compiled based on optical imaging,
- misses $\sim 2/3$ of X-ray selected clusters
- AGN: $< 10\%$ ID rate
- Northern sky
- Good training sample

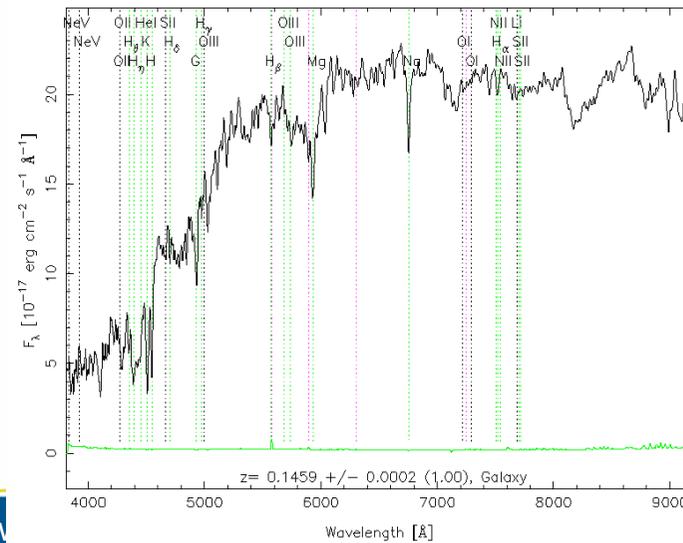




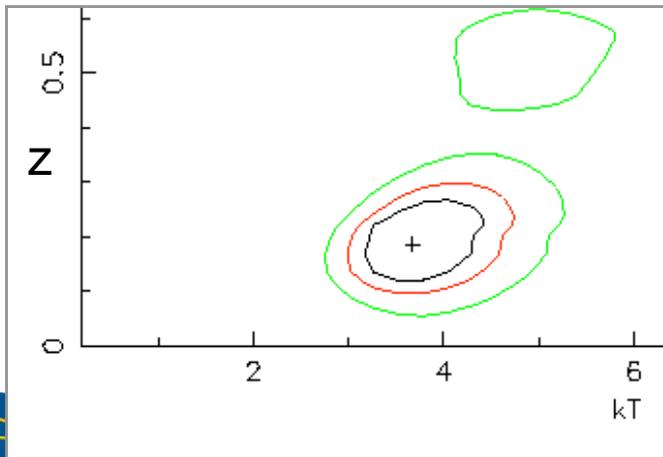
Learning base: XMM-Newton clusters in the SDSS



RA=17.24485, DEC=13.43364, MJD=51811, Plate= 422, Fiber=206

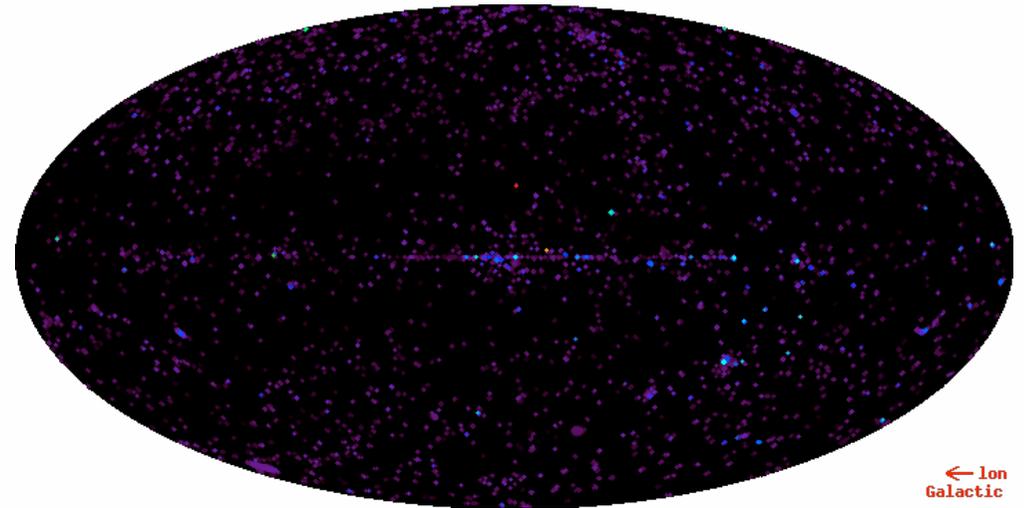


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XMM-Newton



← lon Galactic

- Launch 1999
- Pointed observations only



Release	Year	#detect	#source	#fields
1XMM – EDR	2003	33026	28279	585
2XMMp – DR0	2006	153105	123170	2400
2XMM – DR1	2007	246897	191870	3491
2XMMi – DR2	2008	289083	221012	4117
2XMMi – DR3	2010	353191	262902	4953
3XMM	2012	~460	~330000	~6500



- Identifications:
 - community ~5000, BOSS 2nd year: 1600



Competing/Complementing projects



- BOSS: 2nd year – 2XMMi (~1500 objects)
 - 15% serendipitous AGN identification
 - No X-ray selection, AGN demography?
 - Northern sky
-
- BOSS SPIDERS

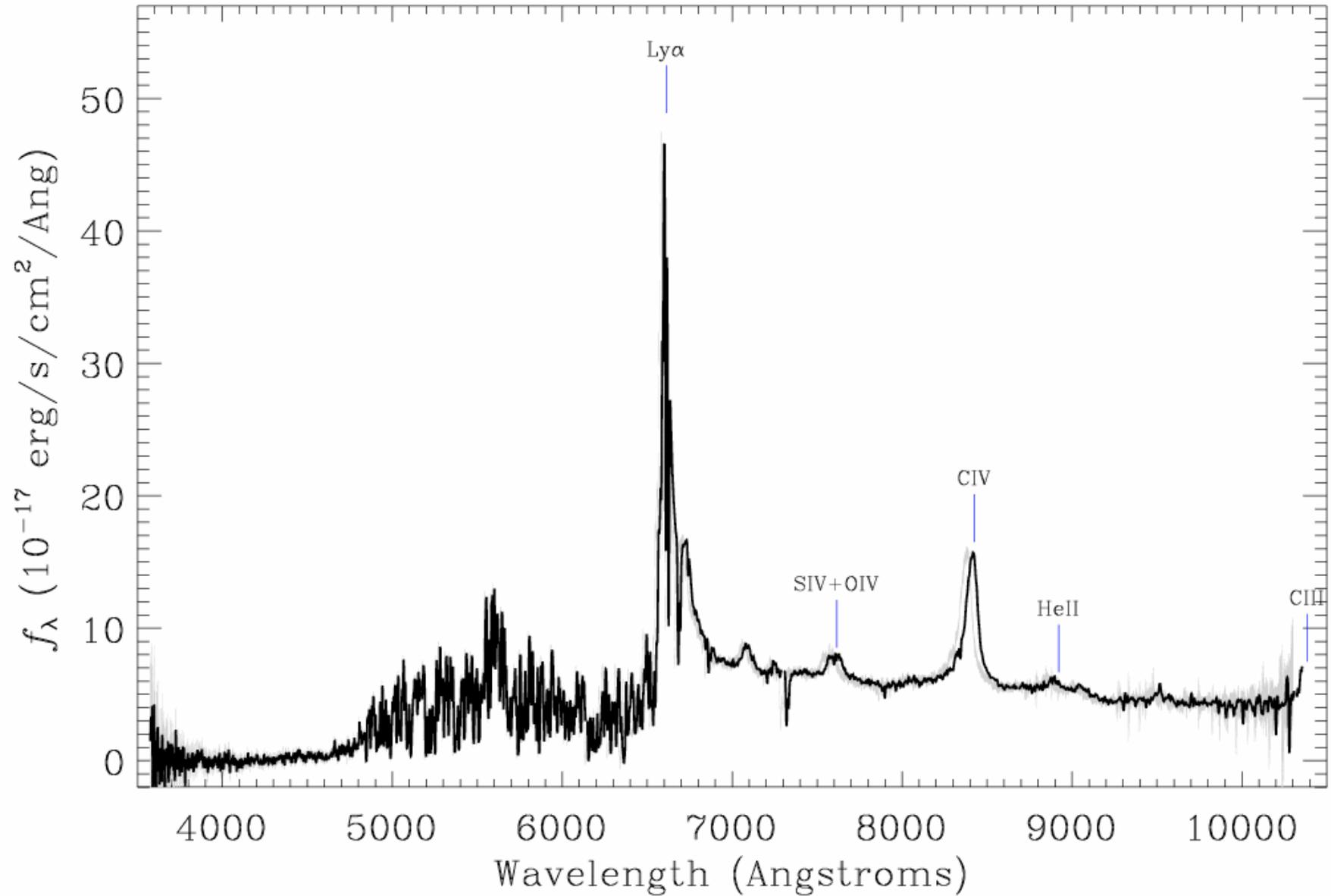


Survey: *boss* Program: *boss* Target: *QSO_LIKE*

RA=16.58019, Dec=0.80648, Plate=3735, Fiber=834, MJD=55209

$z=4.43947 \pm 0.00170$ Class=QSO BROADLINE

No warnings.





Variability, observation time scales



- Individual Scan < 40 sec (1.5deg/min) (*mCrab sensitivity*)
- Revolution ~ 4 hours
- Visibility 1 Day (1 deg/day along equator, 6 passes)
- Sky Coverage 0.5 year
- Survey Duration 4 years

t(min) = 1600 s (200 s per survey)

t(median) ~ 2000 s

t(pole) ~ 20000 s

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MOST



eROSITA output and implications



- eROSITA catalogues: detections, sources, source parameters
- Estimated 5% identification rate from X-rays alone
- A deep X-ray all-sky survey without an optical follow-up program is almost pointless
- An X-ray all-sky survey needs to be complemented by an all-sky follow-up program



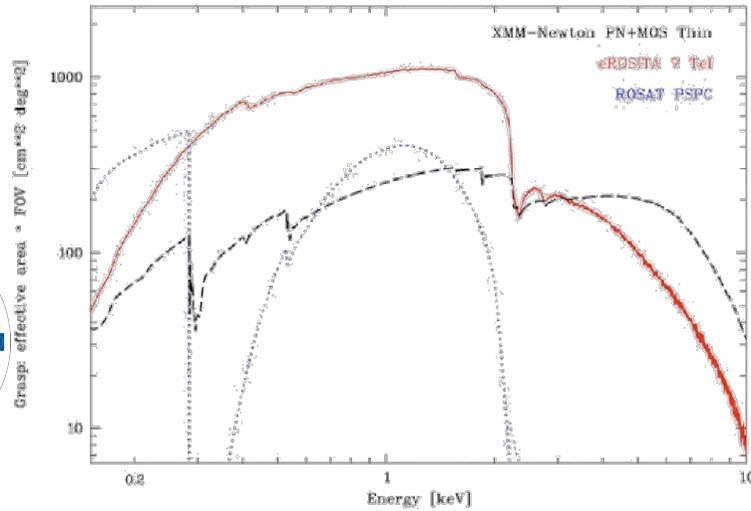
eROSITA + MOST – VDFree (75%)



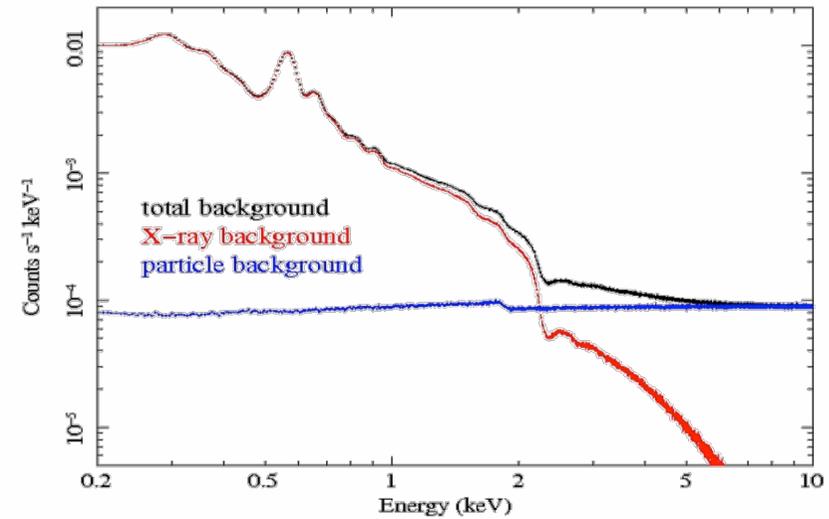
eROSITA performance



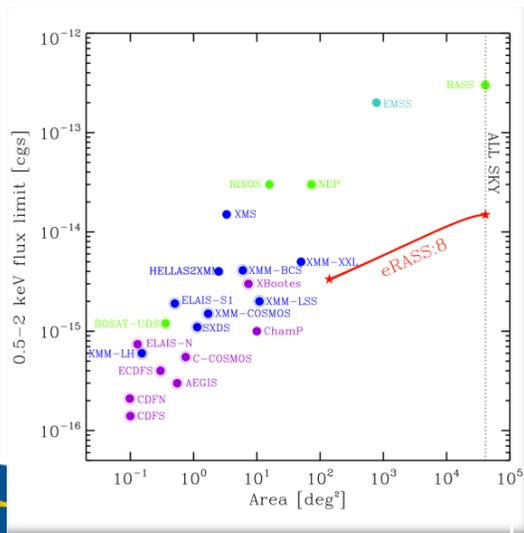
Grasp



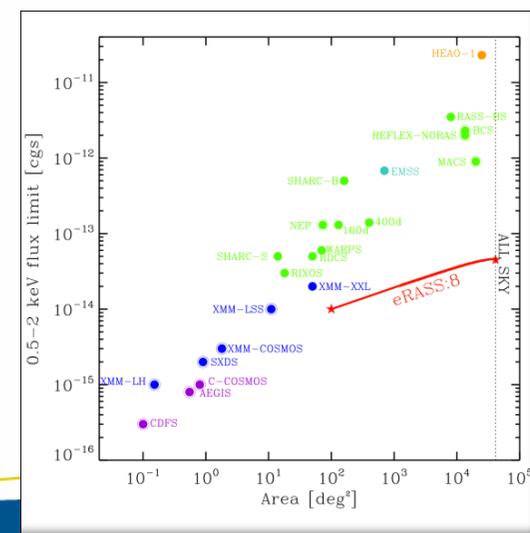
Background



Point Source Sensitivity



Cluster Sensitivity



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X-ray hardness ratios (colors)

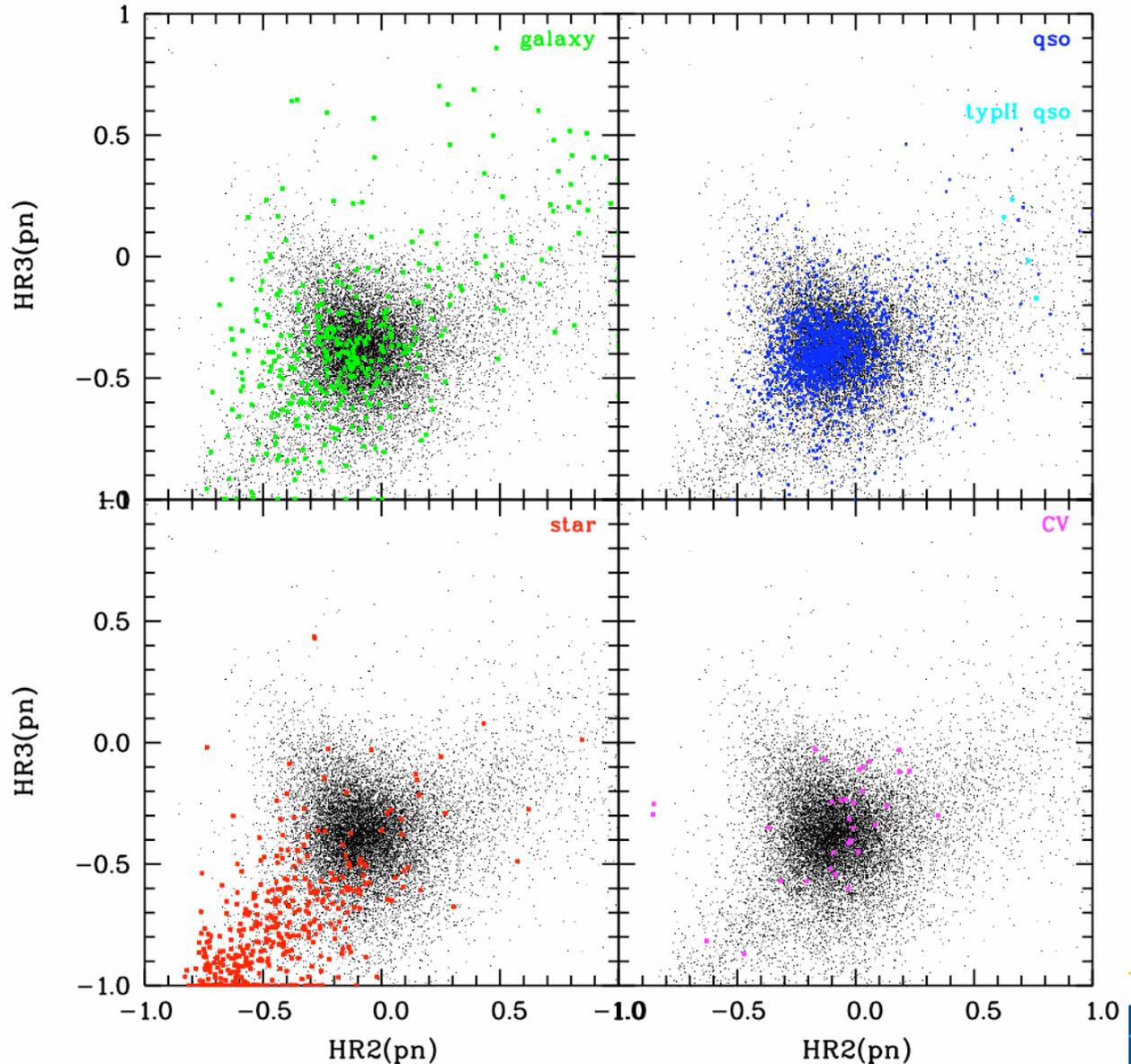
background:
XMM/SDSS
correlated sources
without SDSS
spectrum



Galaxies (hidden
AGN) overlapping
with all other
classes

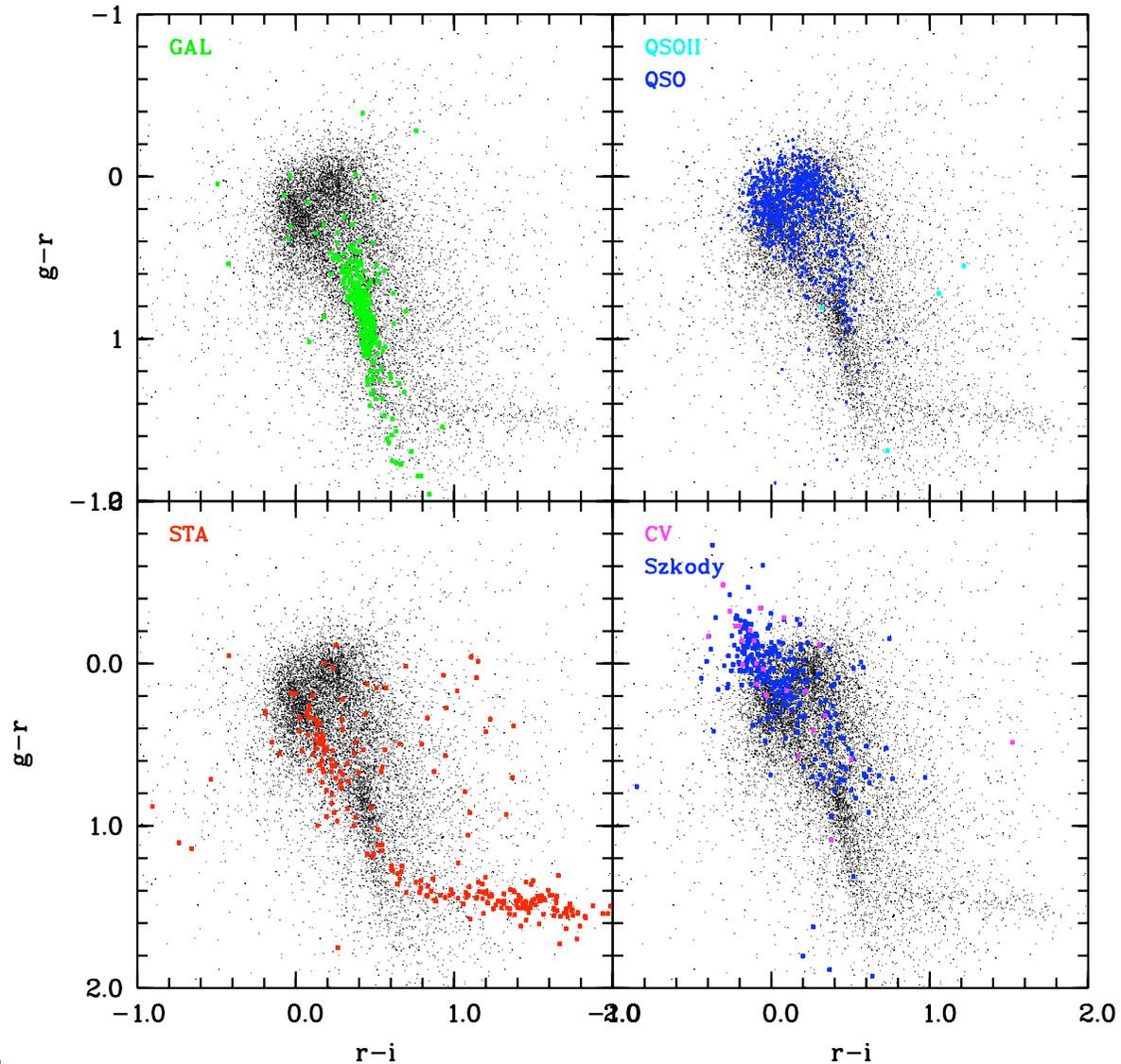
CVs and AGN
similar

Stars rather well
separated





CCDs of XMM/SDSS objects





X-ray/optical vs X-ray color

