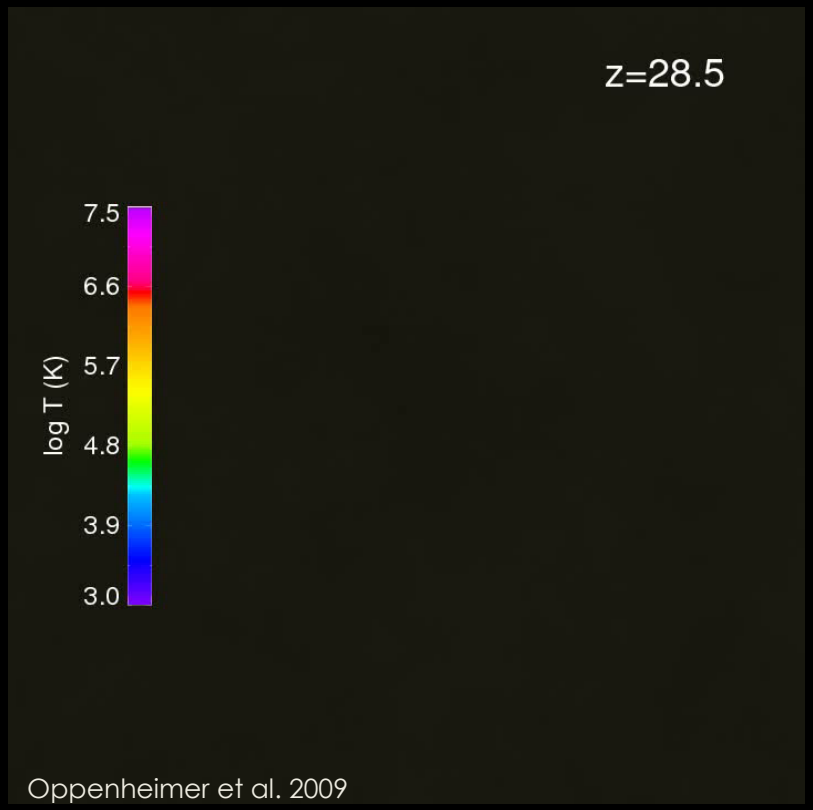
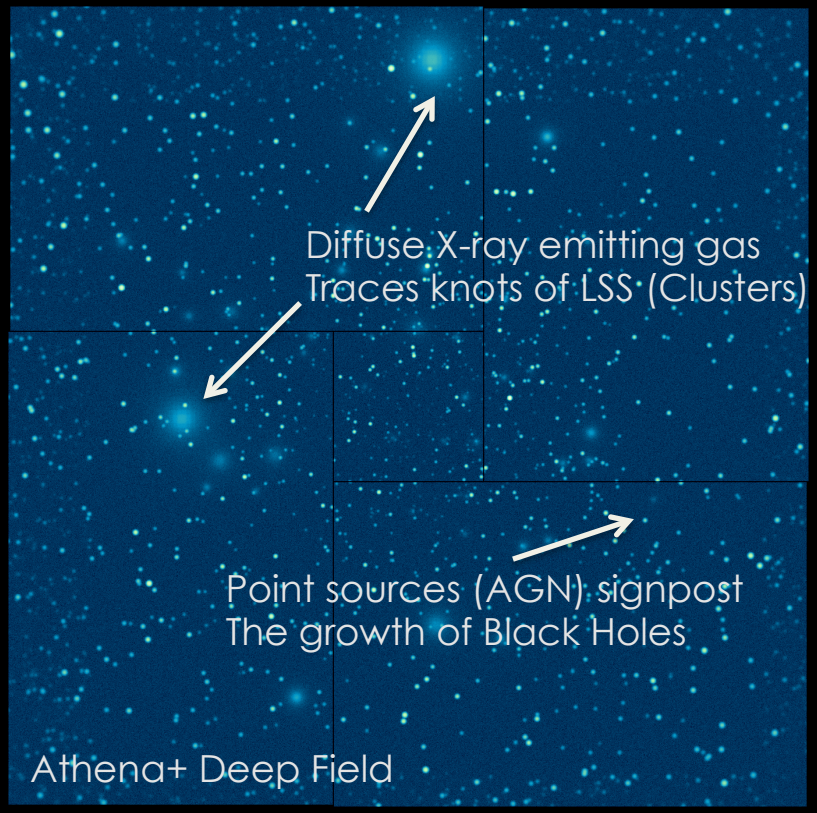
The SRG/eROSITA all-sky survey

A. Merloni (MPE)

X-ray map "hot spots" in LSS

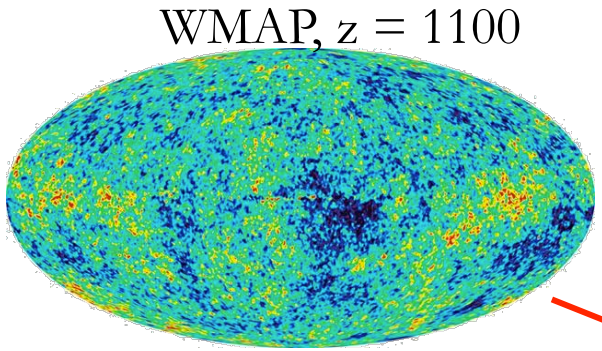
- 1. How does ordinary matter assemble into the large scale structures we see today?

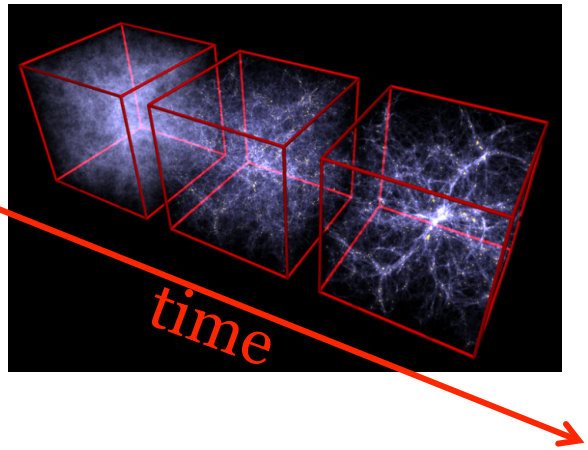


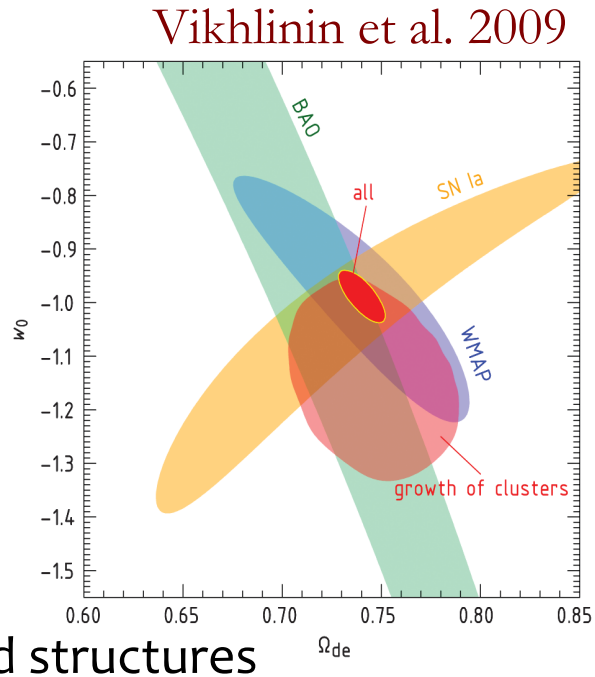


Pointecouteau, Reiprich et al., 2013 arXiv1306.2319

Main science driver: Cluster Cosmology and LSS







- Clusters of galaxies are the largest gravitational bound structures
- They are exponentially sensitive tracers of LSS
- A signature of clusters is the existence of hot, X-ray emitting baryons
- Cosmological constraints with (well calibrated) ROSAT samples of <100 obj.
- Designed to **detect ALL clusters more massive than ~3x10^{14} M$_\odot$**

eROSITA Collaboration

PI: Peter Predehl; PS: A. Merloni (MPE)

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

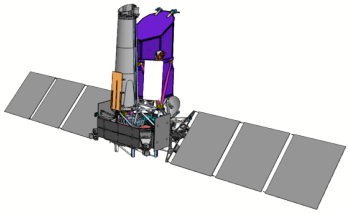
+ many small companies

MPE: Scientific Lead Institute, Project Managment

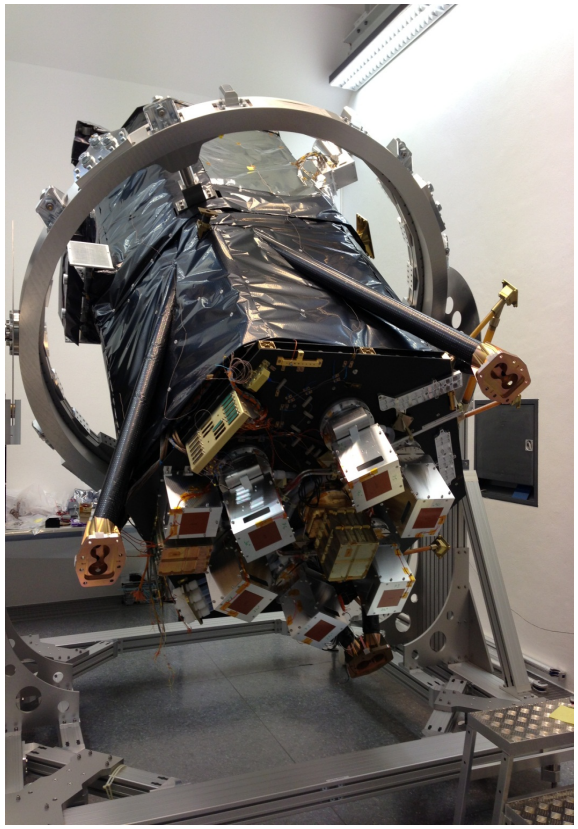
Instrument Design, Manufacturing, Integration & Test

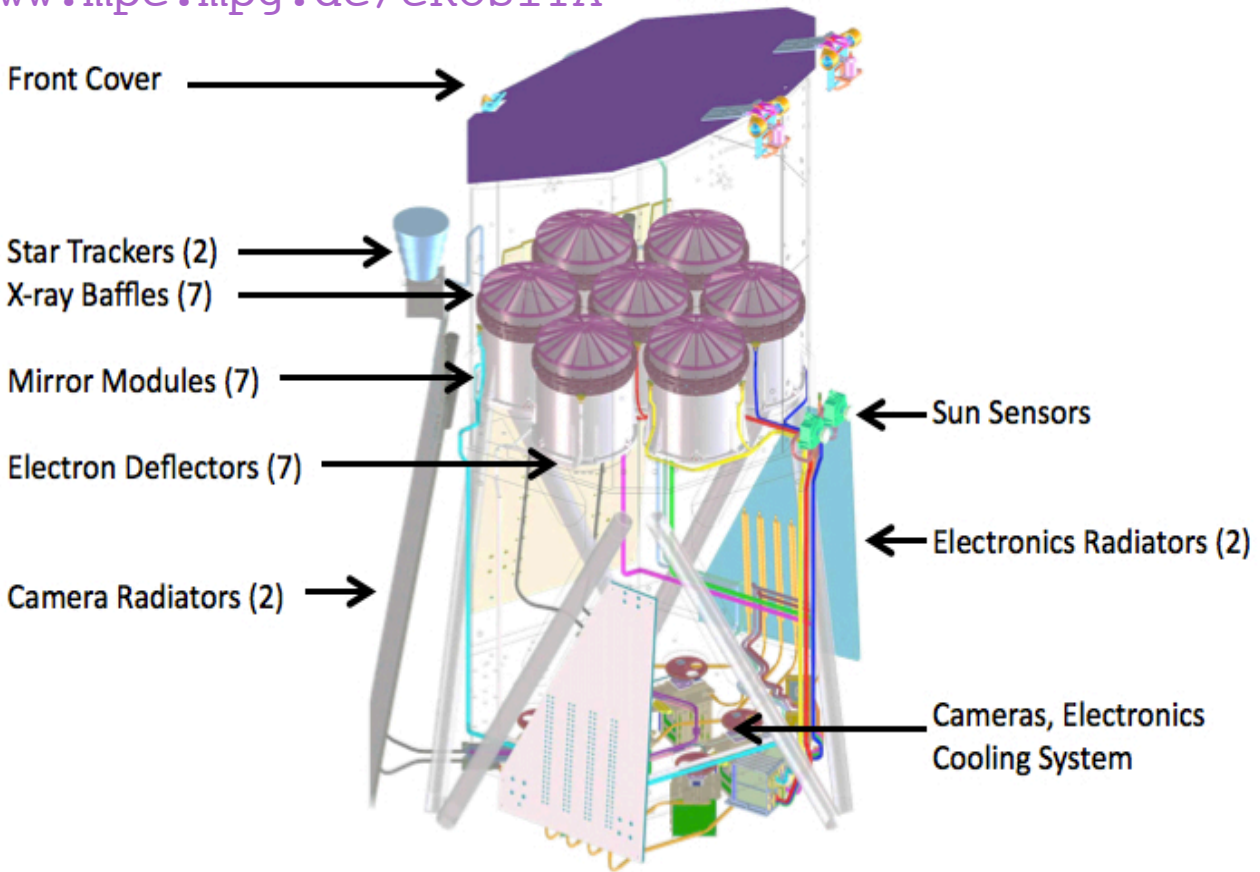
Data Handling & Processing, Archive etc.

The eROSITA telescope



www.mpe.mpg.de/eROSITA

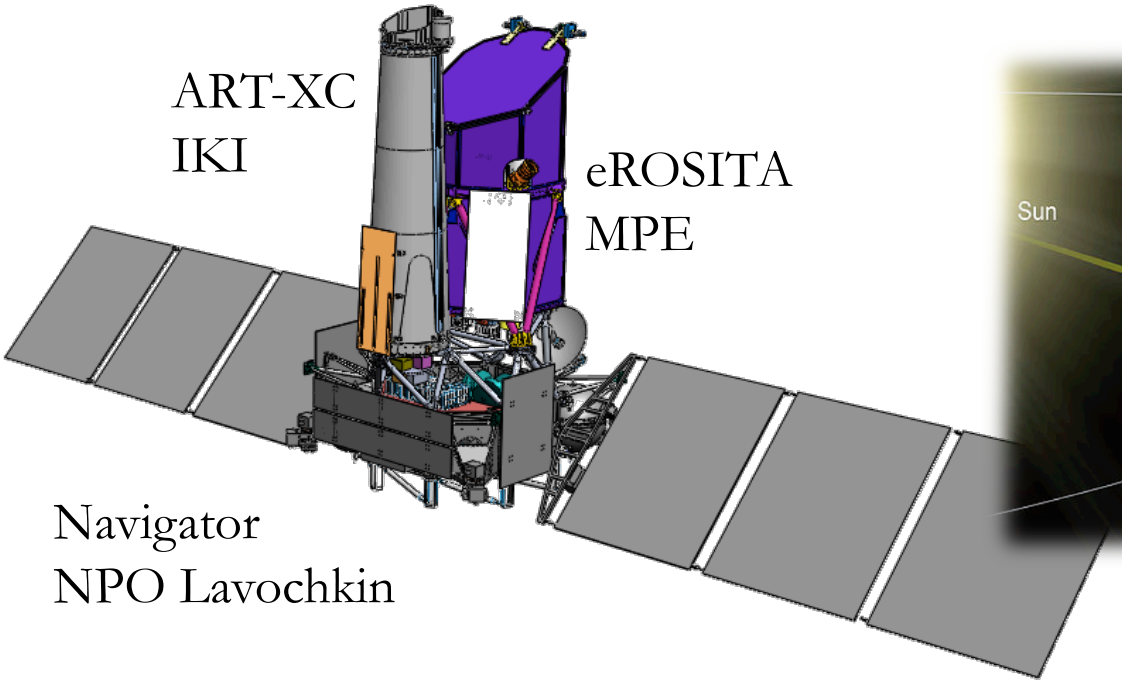


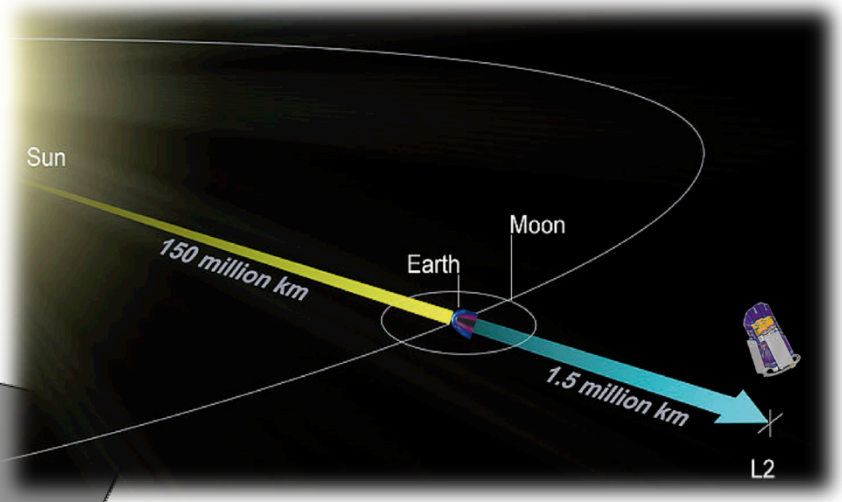


Focal length 1.6 m
F.o.V. = 0.81 sqdeg
54 nested mirror shells
Total weight ~800 kg

7 identical telescopes (Wolter-I/ pnCCD-cameras)
Energy range: 0.3-8 keV
Energy resolution: 138 eV @ 6 keV
Effective Area: ~1400 cm2 (@1keV)

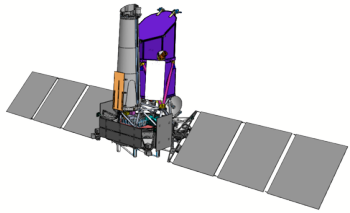
SRG: the Mission

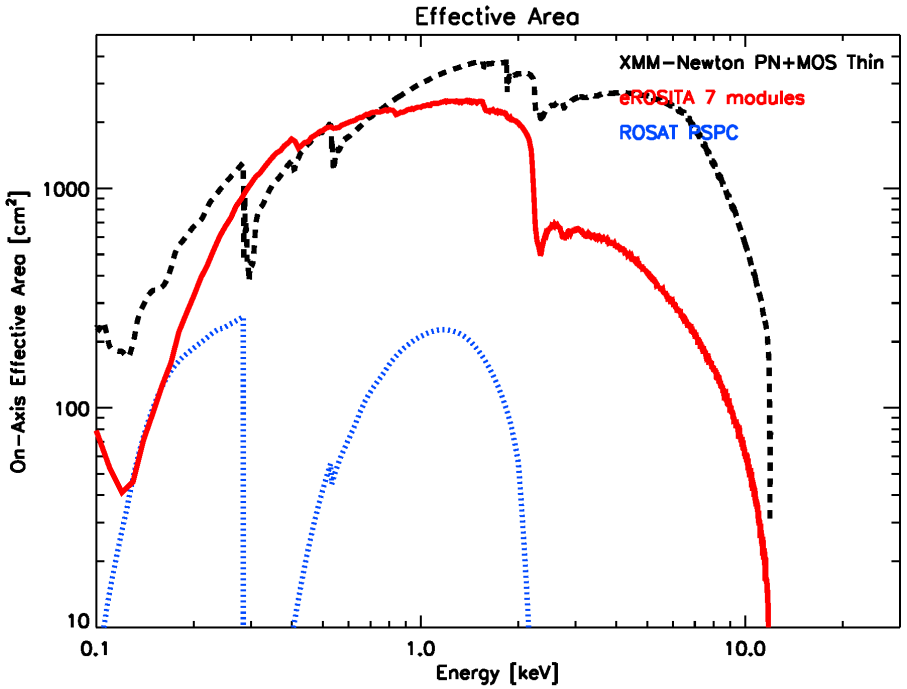


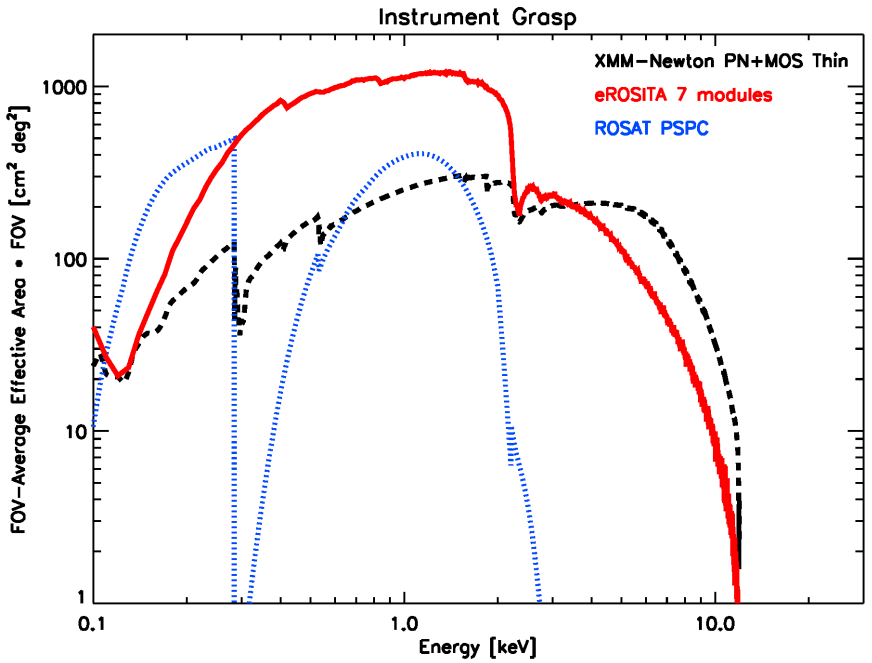


- **Launch:** Dec. 2015/Jan. 2016 from Baykonour on Zenit/Fregat
- **3 Months:** flight to L2, verification and calibration phase
- **4 years**: 8 all sky surveys eRASS:1-8 (scanning mode: 6 rotations/day)
- **3.5 years**: pointed observation phase, including ~20% of GTO. 1 AO per year

A fast survey machine



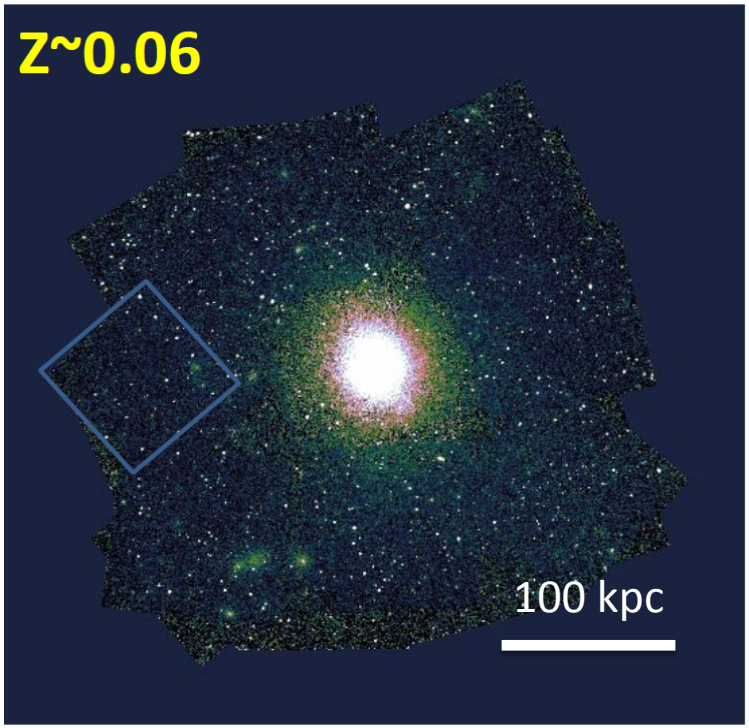




- Effective area at 1keV comparable with XMM/Newton
- Factor ~7-8 larger surveying speed
- 4 years dedicated to all sky survey (with estimated 70-80% efficiency)

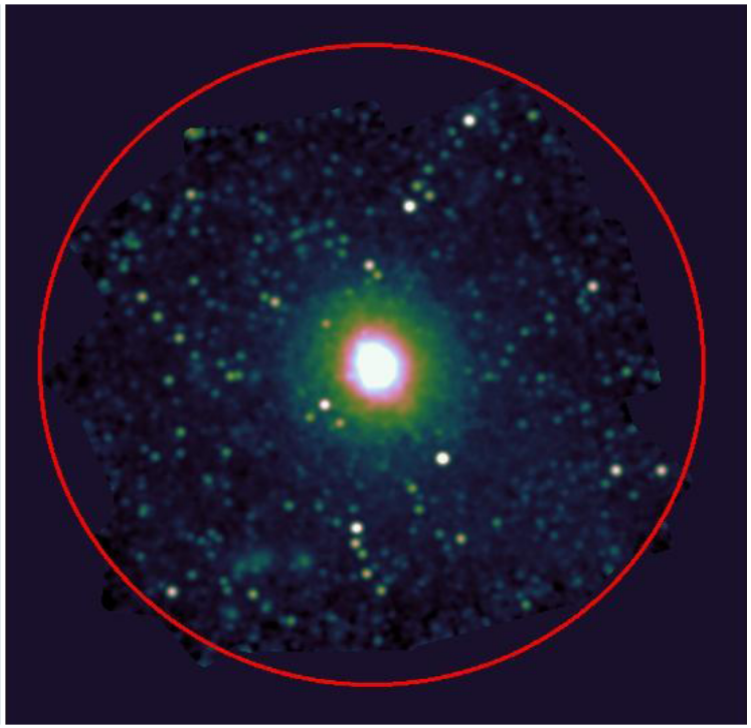
A fast survey machine

Chandra



~30 pointings
~2 Msec
[0.5” HEW]

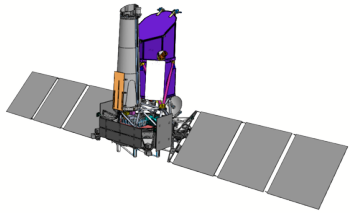
eRosita



~1 pointing
~80 ksec
[28” HEW (FoV avg)]

Churazov, IKI, MPA

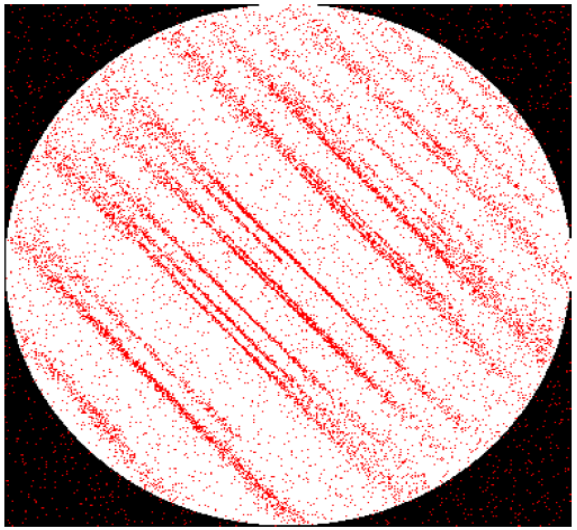
eRosita PSF

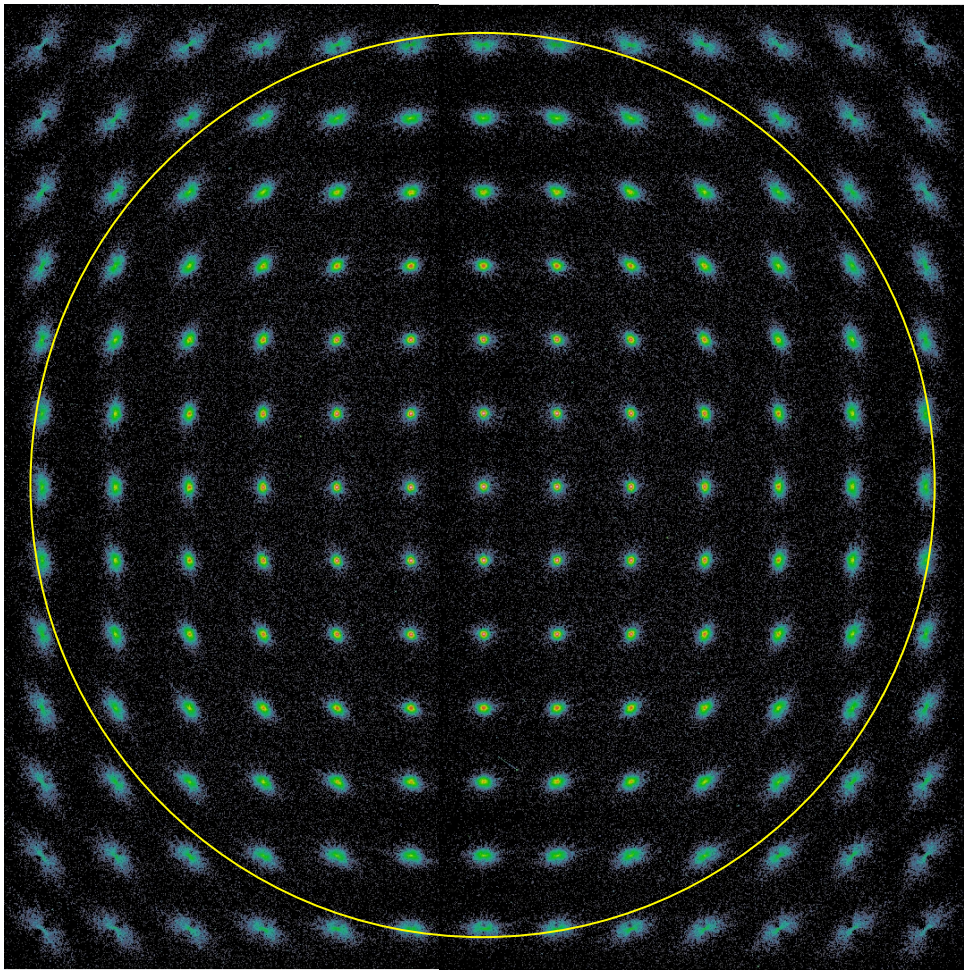


- 16”/**18”** on-axis HEW (@ 1.5 keV)

➔ 29”/**26”** survey-averaged

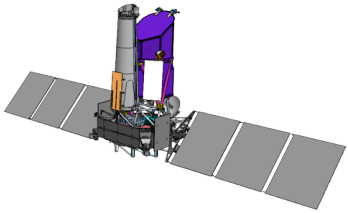
➔ 4”-6” Localization accuracy

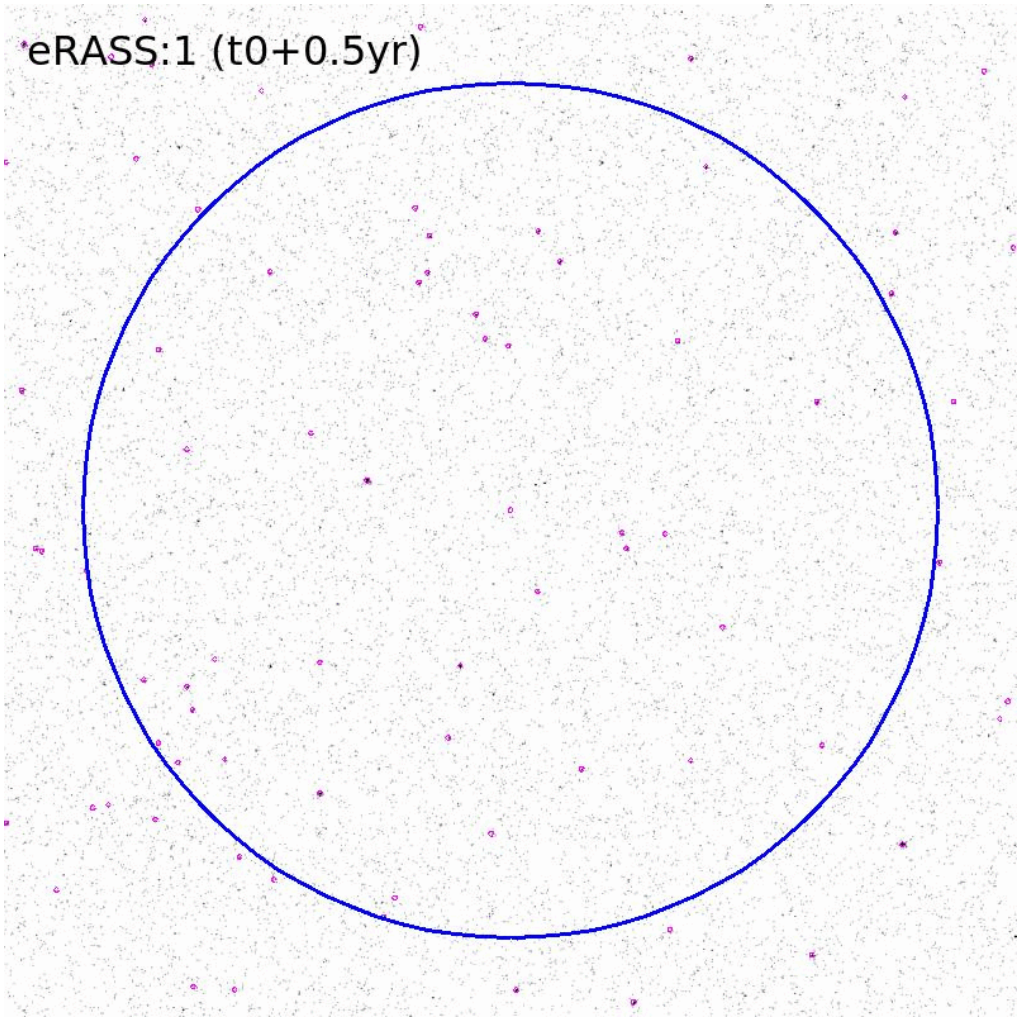




PANTER FM2 focal plane measurements @ 1.49 keV (*image NC, Panter-MPE*)

eRASS:1-8

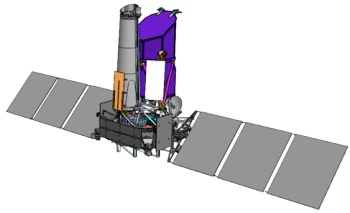


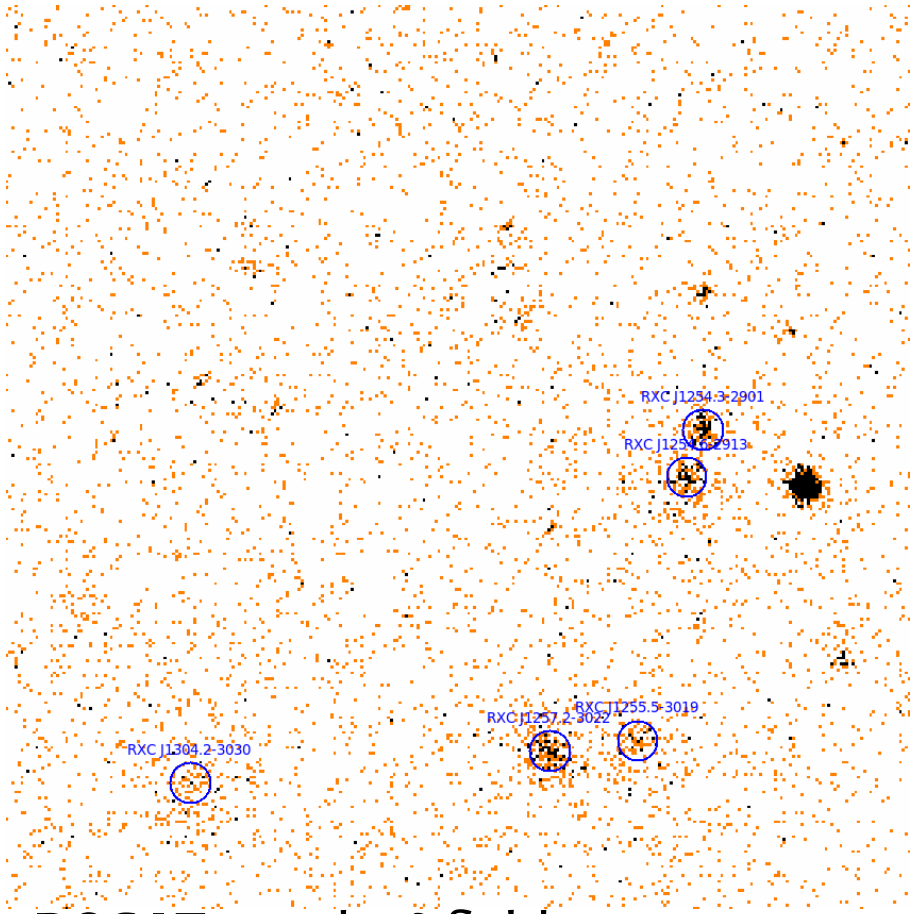


Simulated eROSITA field point-sources (no cluster)
Animation: 1 frame=6 months
N. Clerc, C.Schmid, H.Brunner…

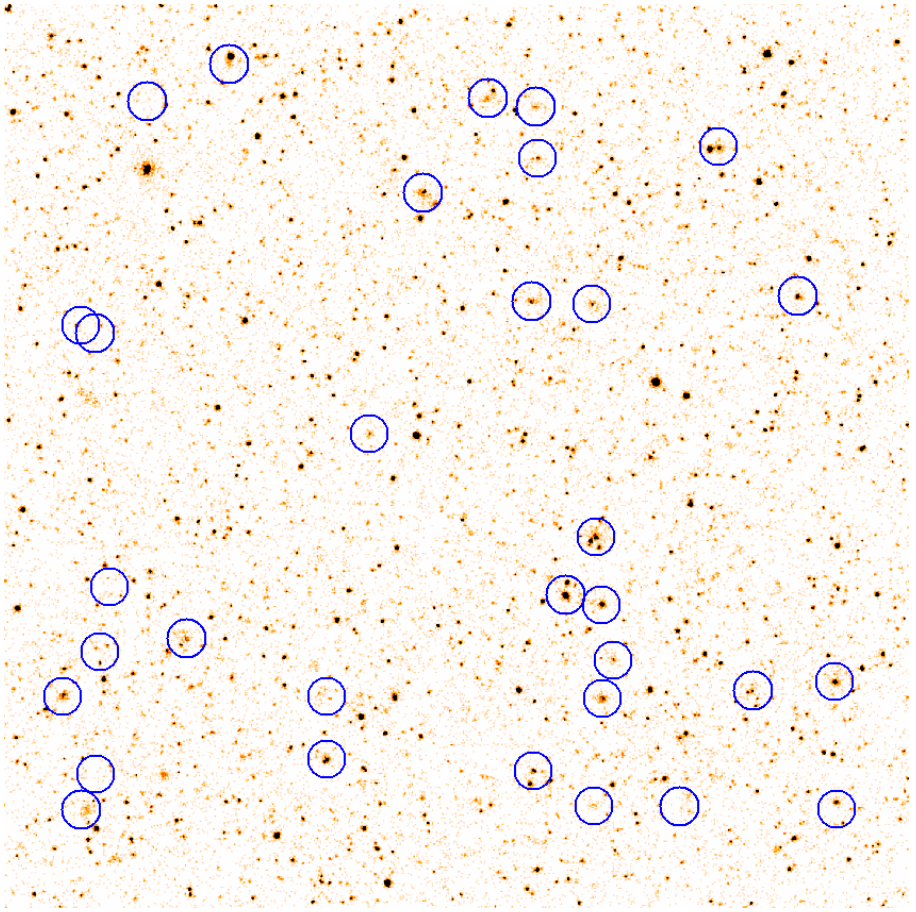
(circle ∅=3 deg)

eRASS:1-8



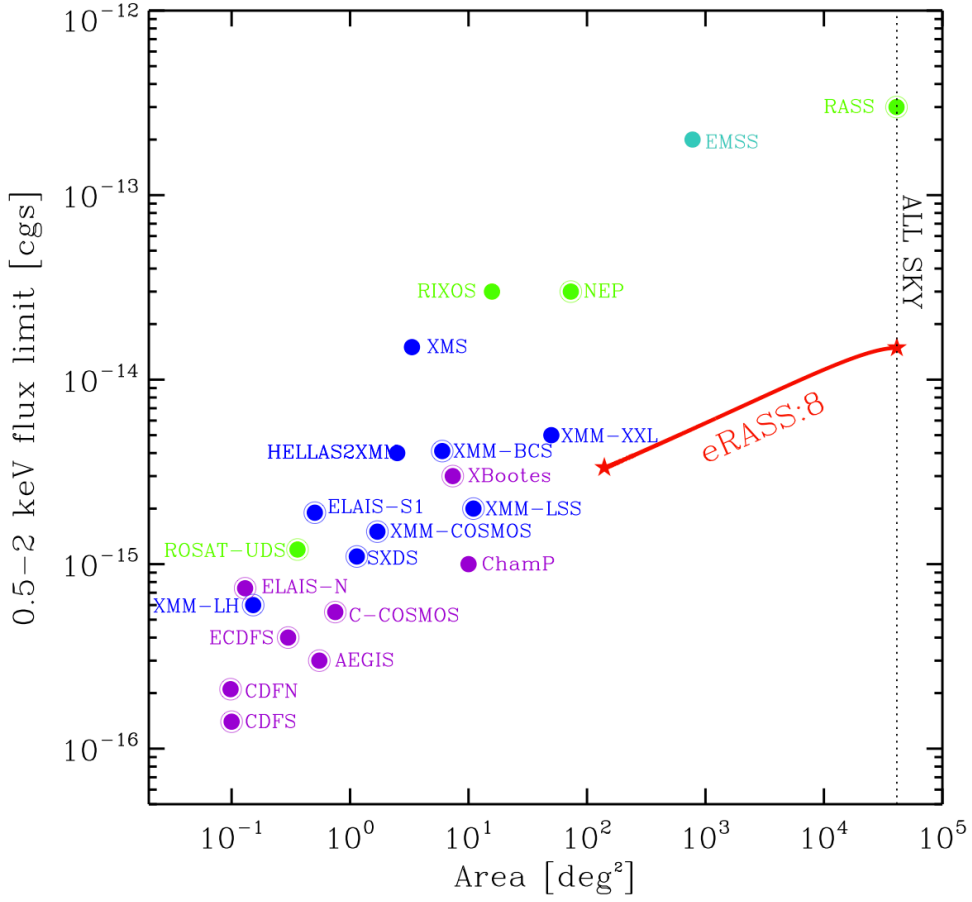


ROSAT 3x3 deg² field with REFLEX detections (Böhringer 2005)

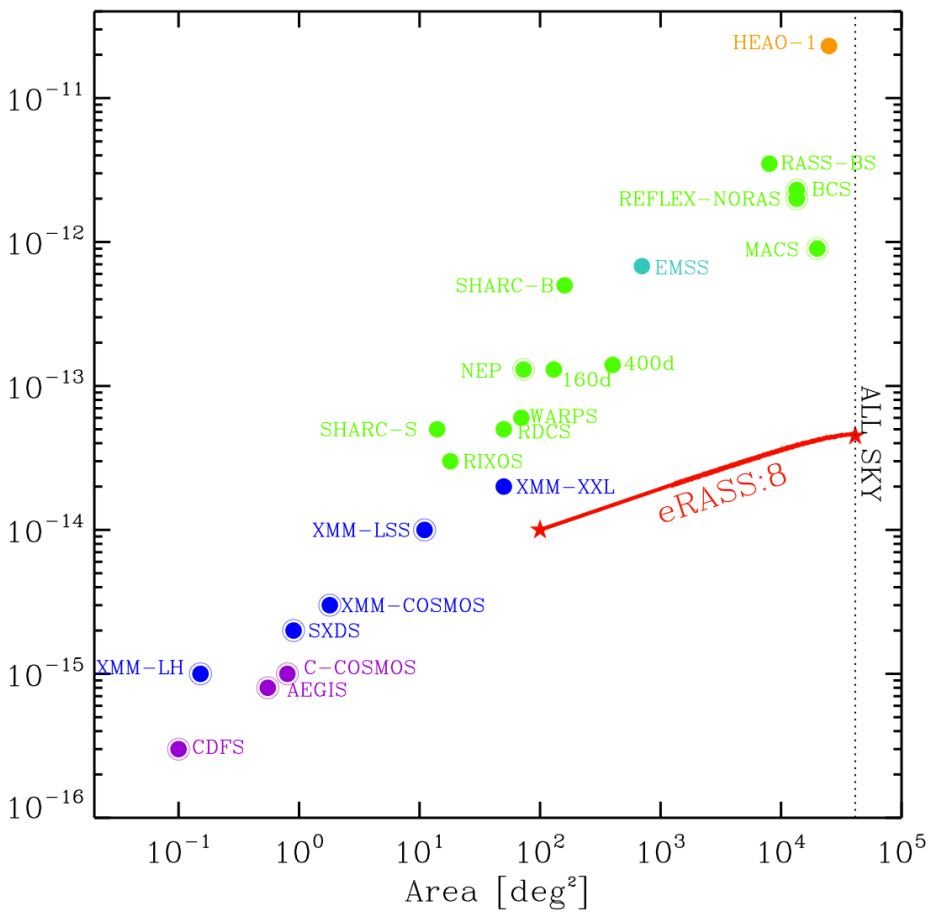


eROSITA all-sky survey 3x3 deg² simulation(N. Clerc, C.Schmid, F.Pace, M.Roncarelli)

eROSITA surveys in context



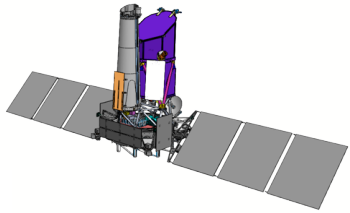
All sky: 10^{-14} (0.5-2 keV)
2×10^{-13} (2-10 keV) [erg/cm^2/s]



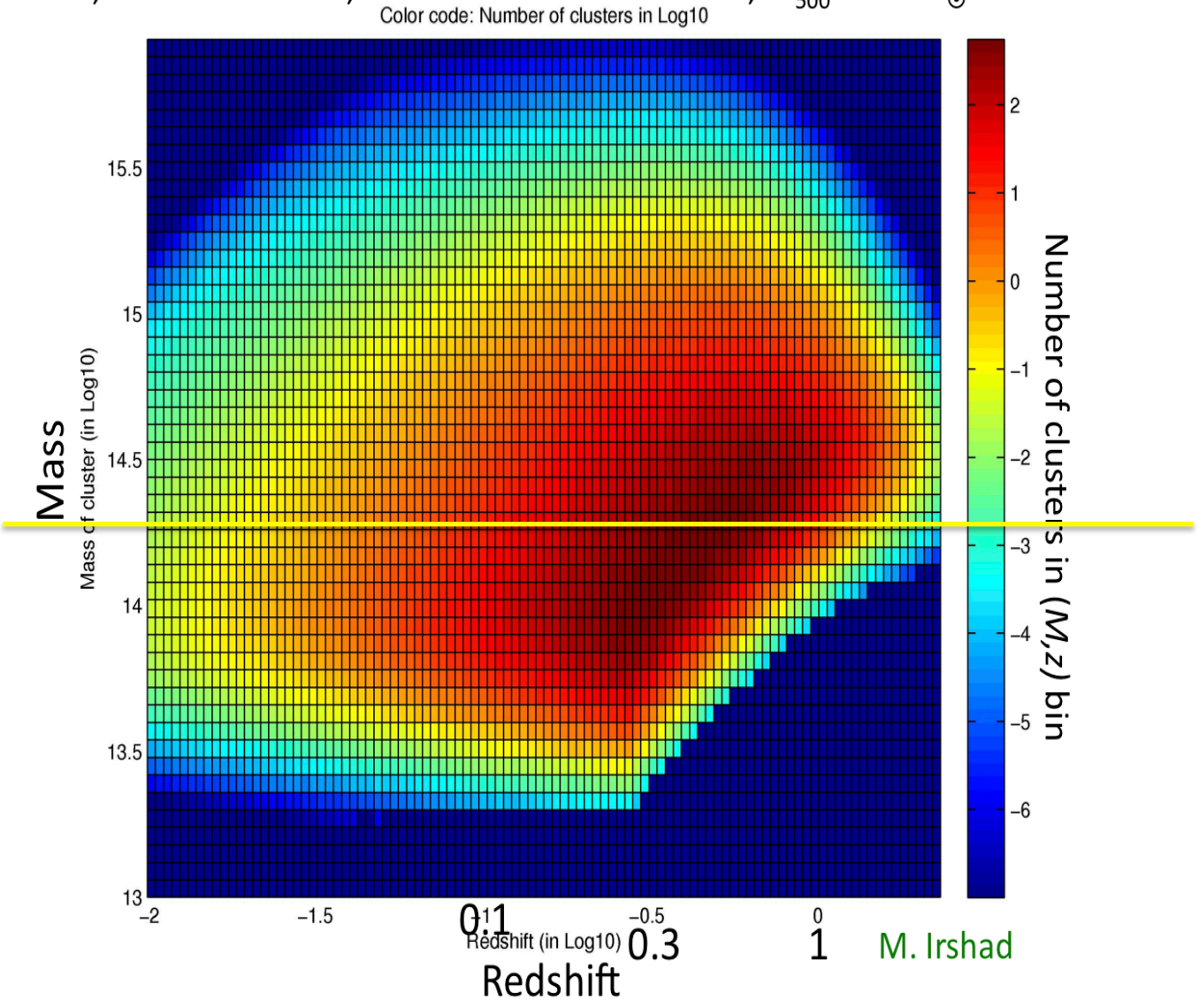
All sky: 3.4 x 10^{-14} (0.5-2 keV)

Merloni et al. 2012

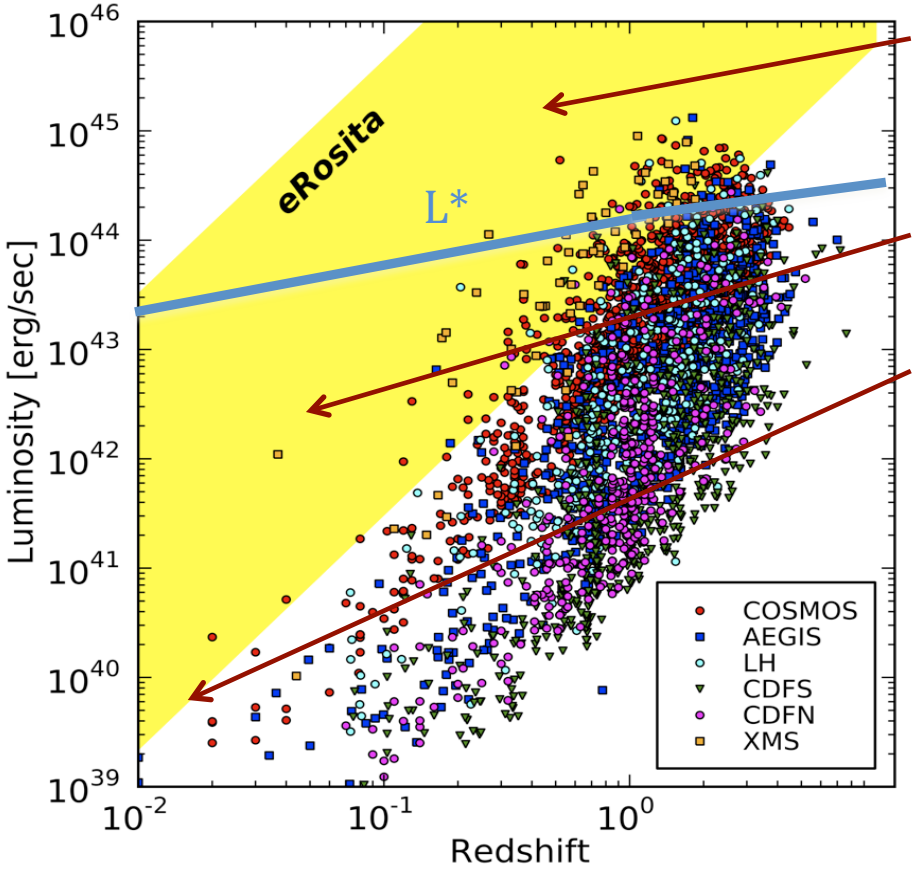
Detect ALL massive clusters



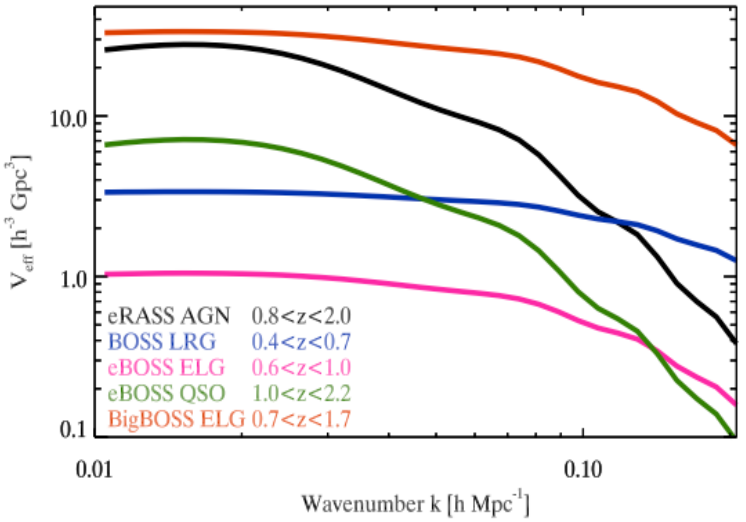
~100,000 clusters total, most clusters around z~0.3, M_{500}~10^{14} $M_{\odot}$.



3 Million eROSITA AGN: Physics and Cosmology

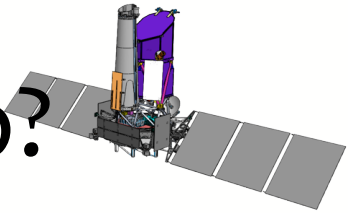


1. The most luminous AGN, tracers of large scale structure: the "quasar" mode of AGN feedback
2. Nearby LLAGN: the "kinetic (radio)" mode of AGN feedback
3. "Quiescent" Black holes revealed by tidal disruption of nearby stars

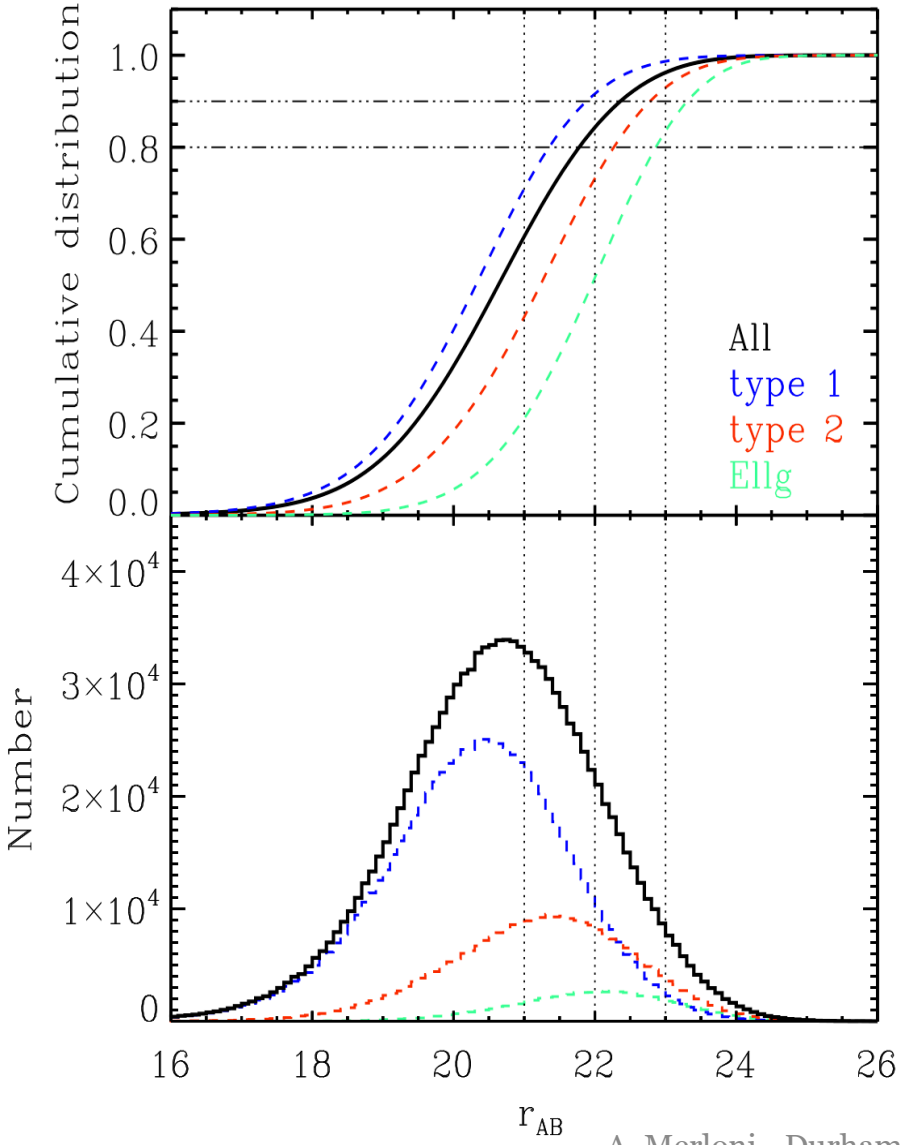


Survey effective Volume

AGN: Can we follow them up?



CALIBRATED ON XMM-COSMOS



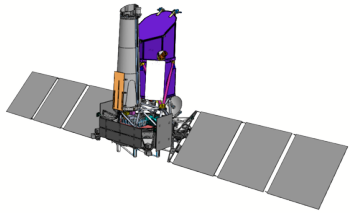
- Expected r_{AB} magnitude distribution of 0.5-2 keV selected AGN in eROSITA surveys
- 90% IDs at r~22.5 (22 for type1, 22.8 for type2

Merloni et al. 2012

And More…

- Provide a detailed view of the **compact objects** (NS, BH, CV) population of the Milky Way
- Enable population synthesis studies of magnetically active stars in our Galaxy with **~1/2 Million X-ray active stars**
- Map the diffuse X-ray emission and the **hot ISM in the Milky W**ay and in the Solar neighborhood
- Study **nearby star-forming galaxies** and galaxy groups
- Provide a dynamical view of the X-ray sky and identify transients and variable sources (expect ~1000s of **Tidal Disruption Events** up to z~0.8)
- Serendipity…

The landscape of O/IR wide area surveys



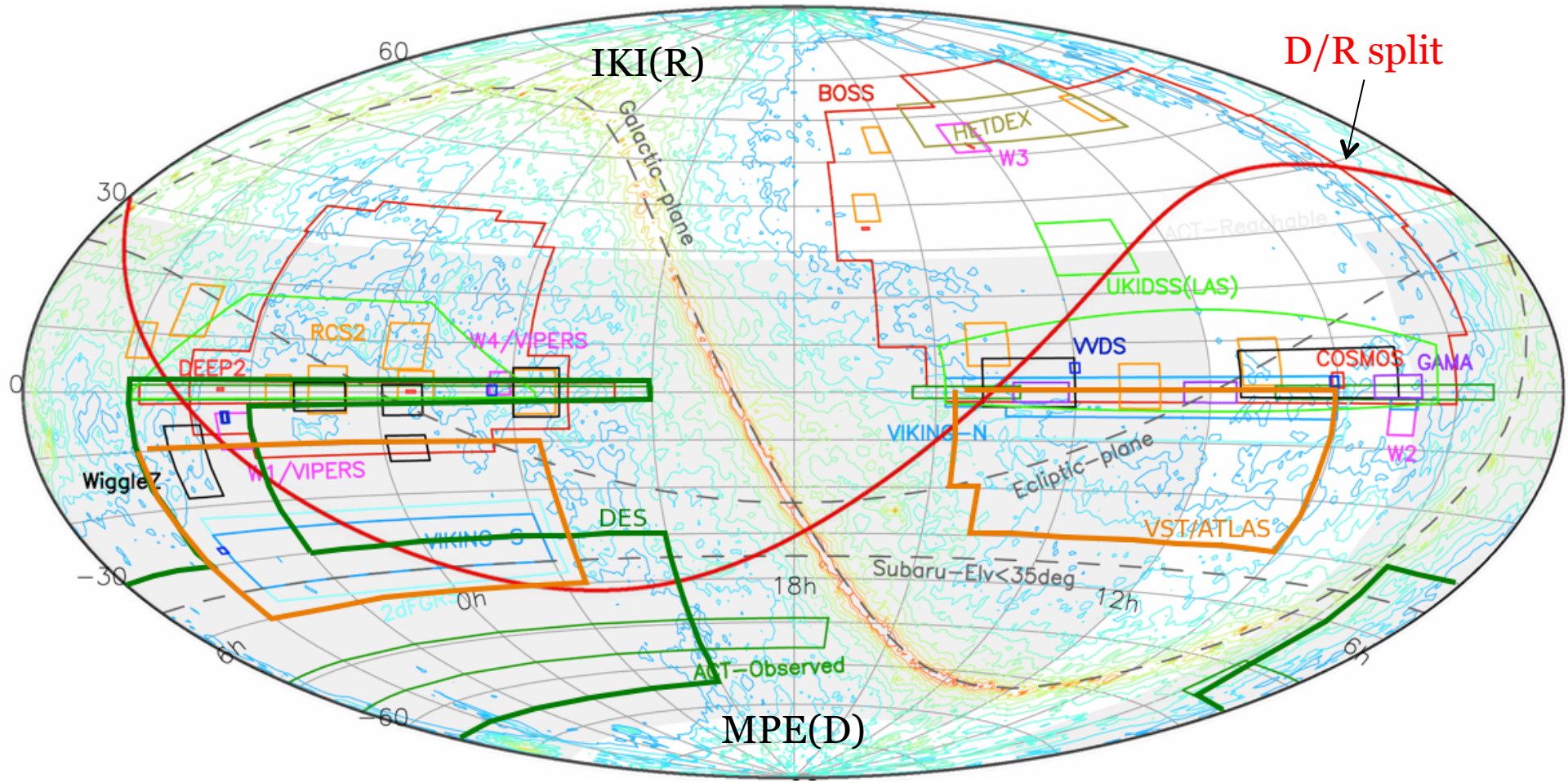
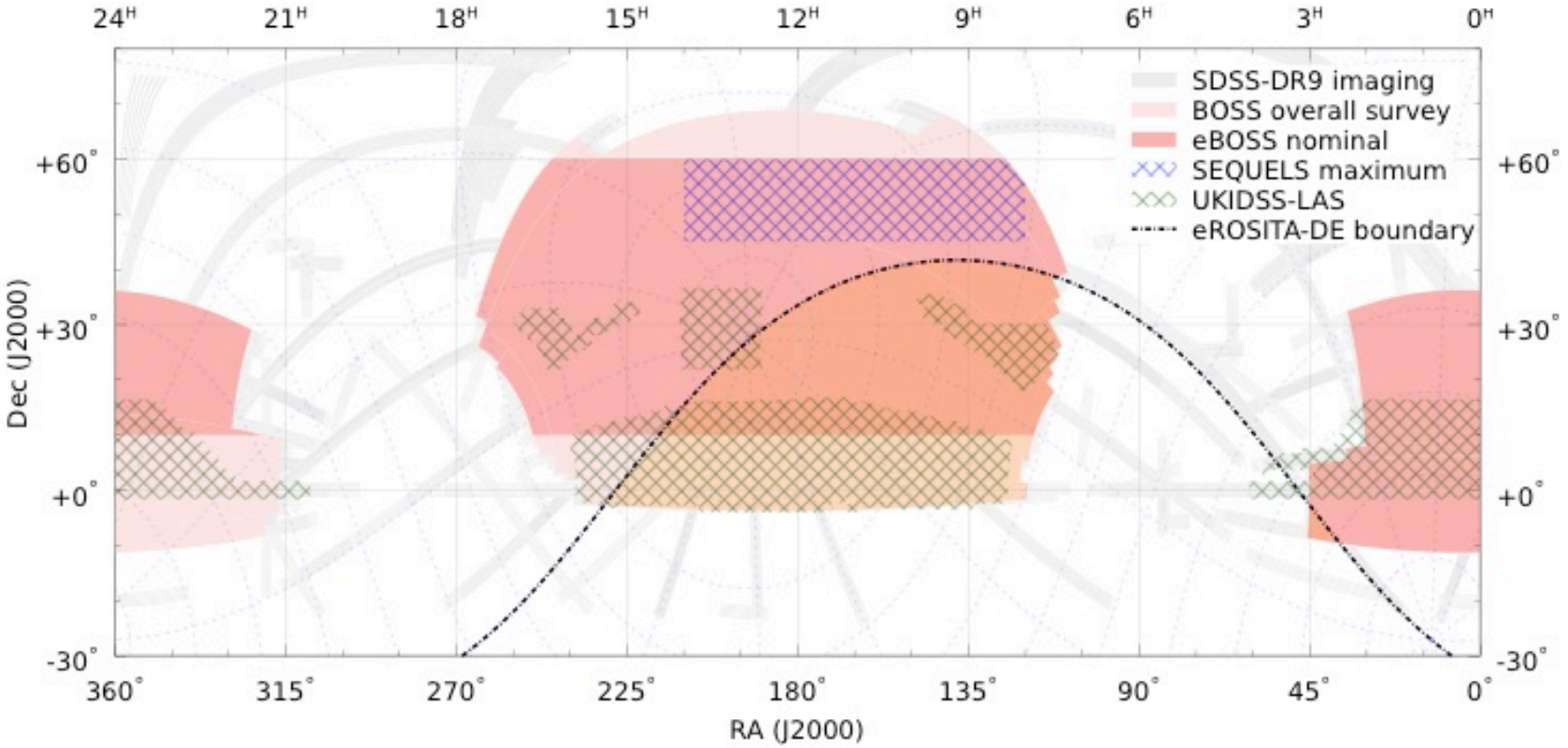


Image A. Nishizawa (IPMU), AM

eROSITA_DE
Spectroscopic follow-up plans

- **North: SDSS IV/SPIDERS (2014-2020)**
  - Early follow-up over a ~2000 deg^2 area in the NGC: reach >80% completeness for eRASS:4, up to ~60,000 X-ray selected spectra
- **South: VISTA/4MOST (2020-2025)**
  - Complete, systematic follow-up of both Clusters and AGN from eROSITA: reach >80% completeness for eRASS:8
  - ~700k AGN spectra 0<z<6
  - 1.4M galaxies in ~70k X-ray selected clusters (Clusters clustering, RSD, velocity dispersion, gravitational redshift)

SPIDERS



Early (eRASS:1-4) spectroscopic follow-up over most of the eROSITA_DE/eBOSS overlap region (~2000 deg^2)
+ complete follow-up of RASS AGN and clusters
(PI: Merloni & Nandra)

SPIDERS/eBOSS
A legacy survey

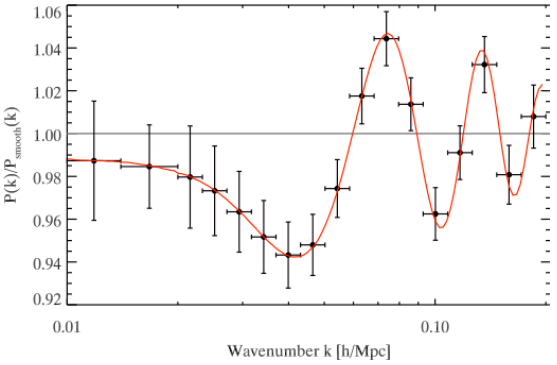
- Tier 0: complete RASS FSC follow-up:
  - ~6000 new X-ray selected AGN (and stars) identified thanks to WISE priors (adding in ~10k SDSSI,II,III sources, almost complete follow-up of r<17 RASS sources)
  - ~5000 RASS clusters matched to RedMapper (SDSS), goal get 10 redshift/cluster for more massive objects (30k spectra); 0.1<z<0.6
- Deeper Tiers: eRASS:1-4 follow-up
  - AGN (52k X-ray selected spectra); z<1
  - ~3000 Clusters (12k spectra); 0<z<0.8

SPIDERS/4MOST pilot in XMM-XXL

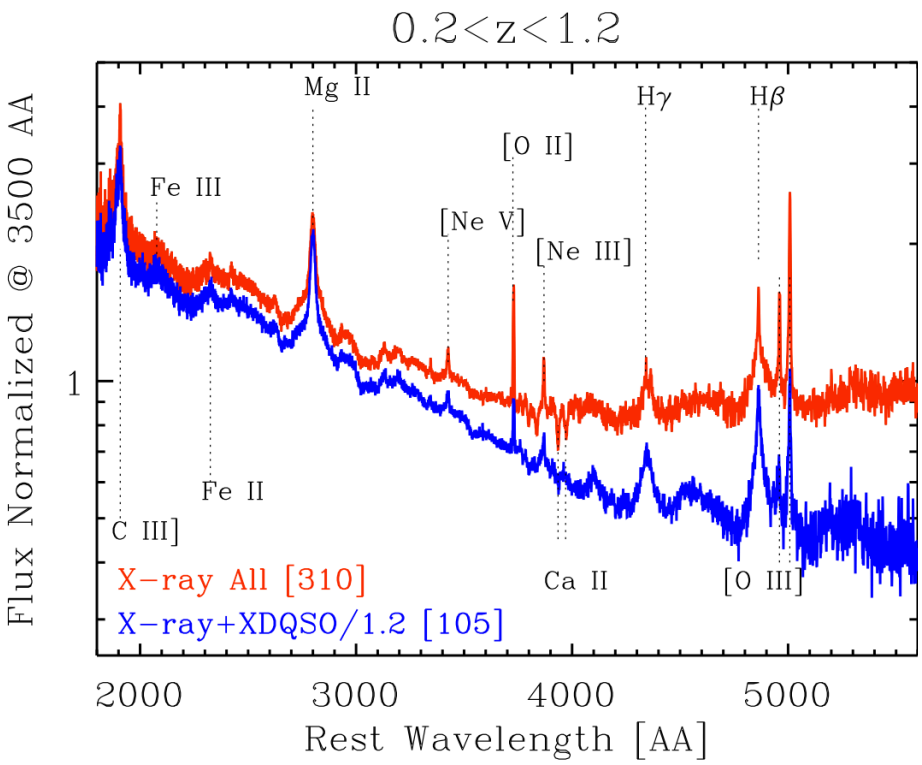
PIs: Merloni, Georgakakis (MPE)

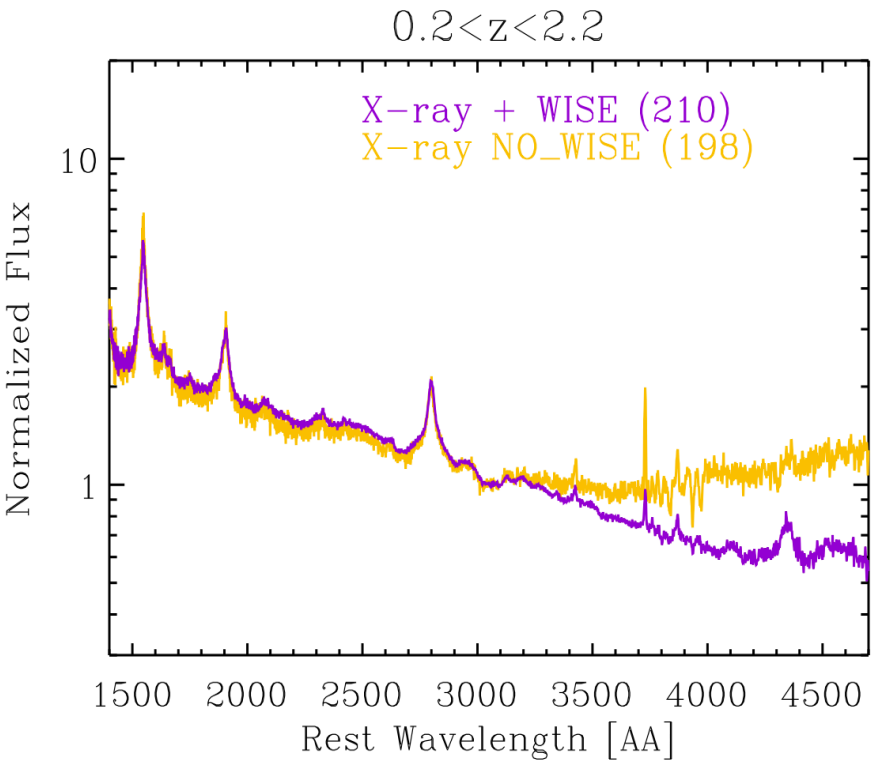
- BOSS ancillary program (1hr integration): The largest contigous X-ray selected spectroscopic surveys of AGN
- ~2700 X-ray selected AGN ($f_{X,0.5\text{-}10\ keV}>10^{-14}$) over ~20 deg^2; $17<r_{AB}<22.5$
- AGN/QSO densities [deg^{-2}]
  - eRASS:8 only: **48** (**26** in 0<z<0.8; **22** in 0.8<z<2.5)
  - eRASS:8+XDQSO: **24** (0.8<z<2.2)
  - XDQSO only: **50** (0.8<z<2.2)
- Reach **~100/deg^2** in 0.8<z<2.5

12σ BAO detection in 0.1<z<3 (8σ in 0.8<z<2) eROSITA+4MOST; Kolodzig et al. 2013



Uniqueness of X-ray selected AGN



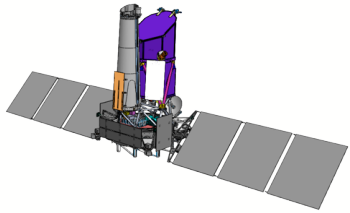


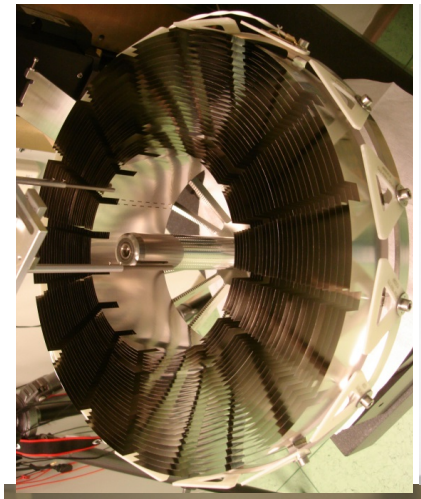
Optical (XDQSO) and WISE QSO selection are very similar (nuclear light must dominate); (soft) X-ray selection helps with 'galaxy-diluted' AGN. Ideal for studies of AGN-galaxy co-evolution, scaling relations, etc.

Menzel et al. in prep.

SRG/eROSITA Mission status

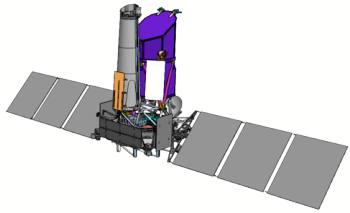
7 Mirror Modules





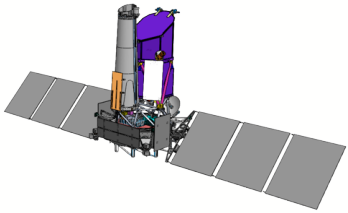
- Mirror assembly competed in November 2013
- Testing of all 8 telescopes at PANTER until end-2014
- All measures in spec!

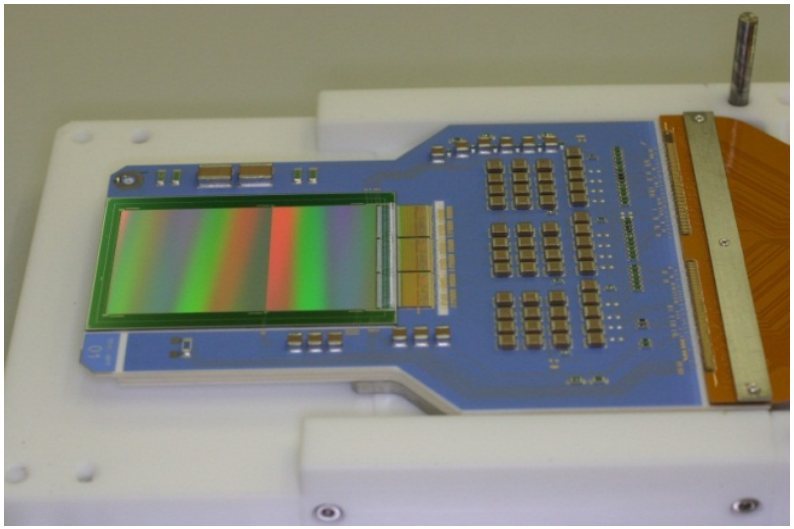
7 Mirror Modules

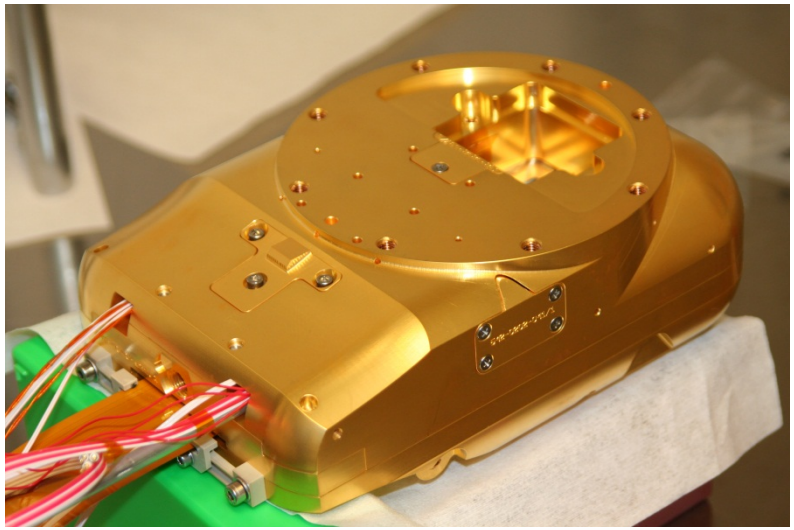


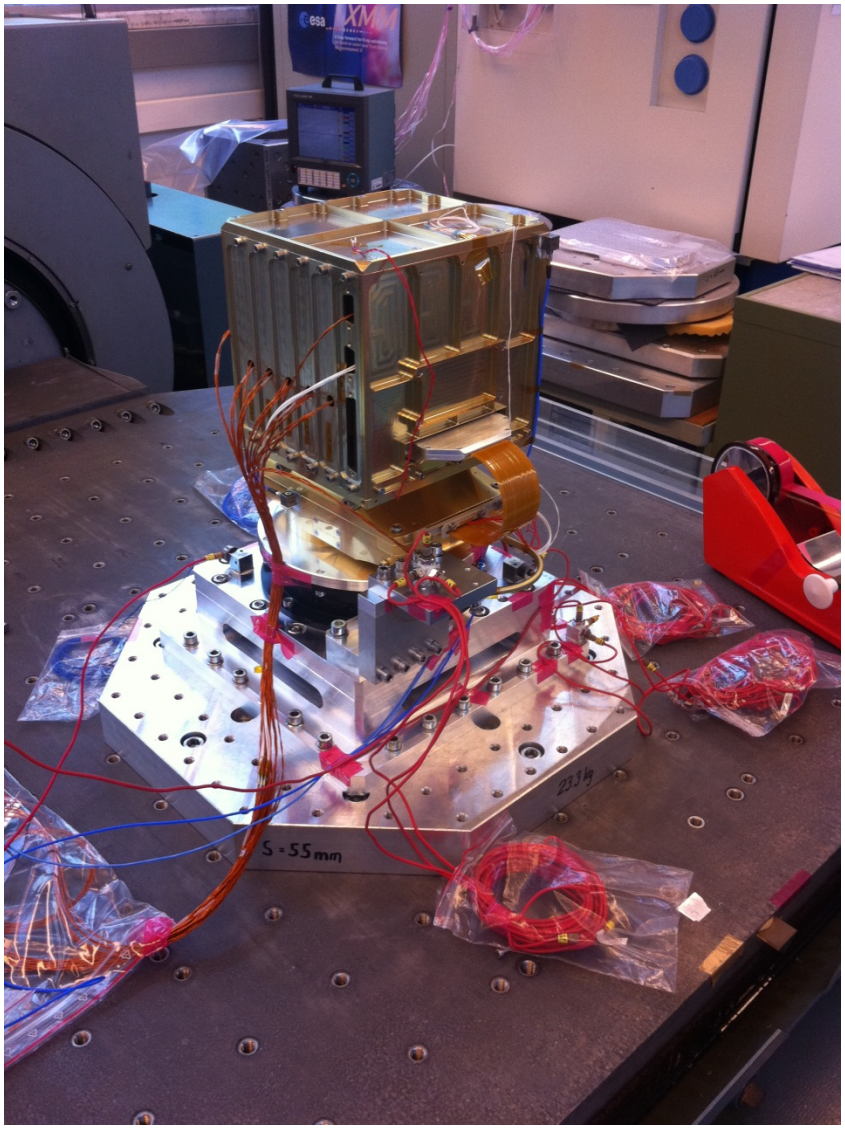
	Specification		Acceptance Test							
	Orbit	Derived for PANTER	FM 1	FM 2	FM 3	FM 4	FM 5	FM 6	FM 7	FM 8
			Dec 2012 / Jan 2013	Mar 2013	May 2013	Sep 2013 / Oct 2013	Sep 2013	Dec 2013	Dec 2013	Jun 2013
HEW Al-K (1.49 keV)	< 15''	< 15''	16.1''±0.2''	16.8''±0.3''	15.7''±0.3''	16.0''±0.3''	16.2''±0.2''	16.3''±0.3''	15.6''±0.3''	17.1''±0.3''
HEW Cu-K (8.04 keV)	< 20''	< 20''	15.2''±0.1''	15.4''±0.3''	16.7''±0.4''	16.4''±0.3''	16.2''±0.3''	16.2''±0.3''	16.6''±0.3''	18.4''±0.4''
W90 C-K (0.28 keV)	< 90''	< 90''	~89.8''	~106.5''	~107.9''	~106.7''	~119.6''	~127.3''	~107.9''	~123.6''
Eff. Area[1] Al-K	> 350 cm^2	> 363.6 cm^2	391.9 cm^2 ± 16.1 cm^2	391.1 cm^2 ± 20.6 cm^2	392.6 cm^2 ± 15.5 cm^2	369.4 cm^2 ± 24.8 cm^2	387.9 cm^2 ± 19.2 cm^2	378.4 cm^2 ± 19.2 cm^2	391.6 cm^2 ± 24.8 cm^2	389.6 cm^2 ± 20.5 cm^2
Eff. Area[1] Cu-K	> 20 cm^2	> 21.0 cm^2	24.8 cm^2 ± 0.8 cm^2	24.8 cm^2 ± 1.1 cm^2	25.1 cm^2 ± 1.2 cm^2	23.8 cm^2 ± 0.9 cm^2	24.1 cm^2 ± 0.6 cm^2	25.1 cm^2 ± 1.1 cm^2	25.0 cm^2 ± 0.9 cm^2	24.2 cm^2 ± 1.0 cm^2
Micro-roughness	< 0.5 nm	Scattering Cu-K < 15.7%	Scattering Cu-K 10.8%	Scattering Cu-K 11.2%	Scattering Cu-K 10.7%	Scattering Cu-K 12.0%	Scattering Cu-K 13.3%	Scattering Cu-K 11.3%	Scattering Cu-K 11.7%	Scattering Cu-K 11.4%
Focal length	1600±10 mm	1600±10 mm (with lens equation)	1600.94 ±0.5 mm	1600.90 ±0.5 mm	1600.77 ±0.5 mm	1600.93 ±0.5 mm	1601.14 ±0.5 mm	1601.80 ±0.5 mm	1600.93 ±0.5 mm	1601.21 ±0.5 mm
Optical axis alignment	< 30''	< 30''	0''±21''	30''±14''	110''±14''	47''±14''	72''±14''	61''±14''	38''±14''	105''±14''

7 cameras

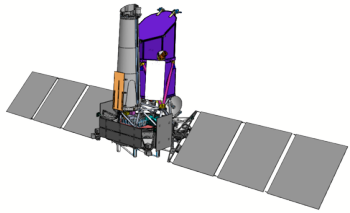


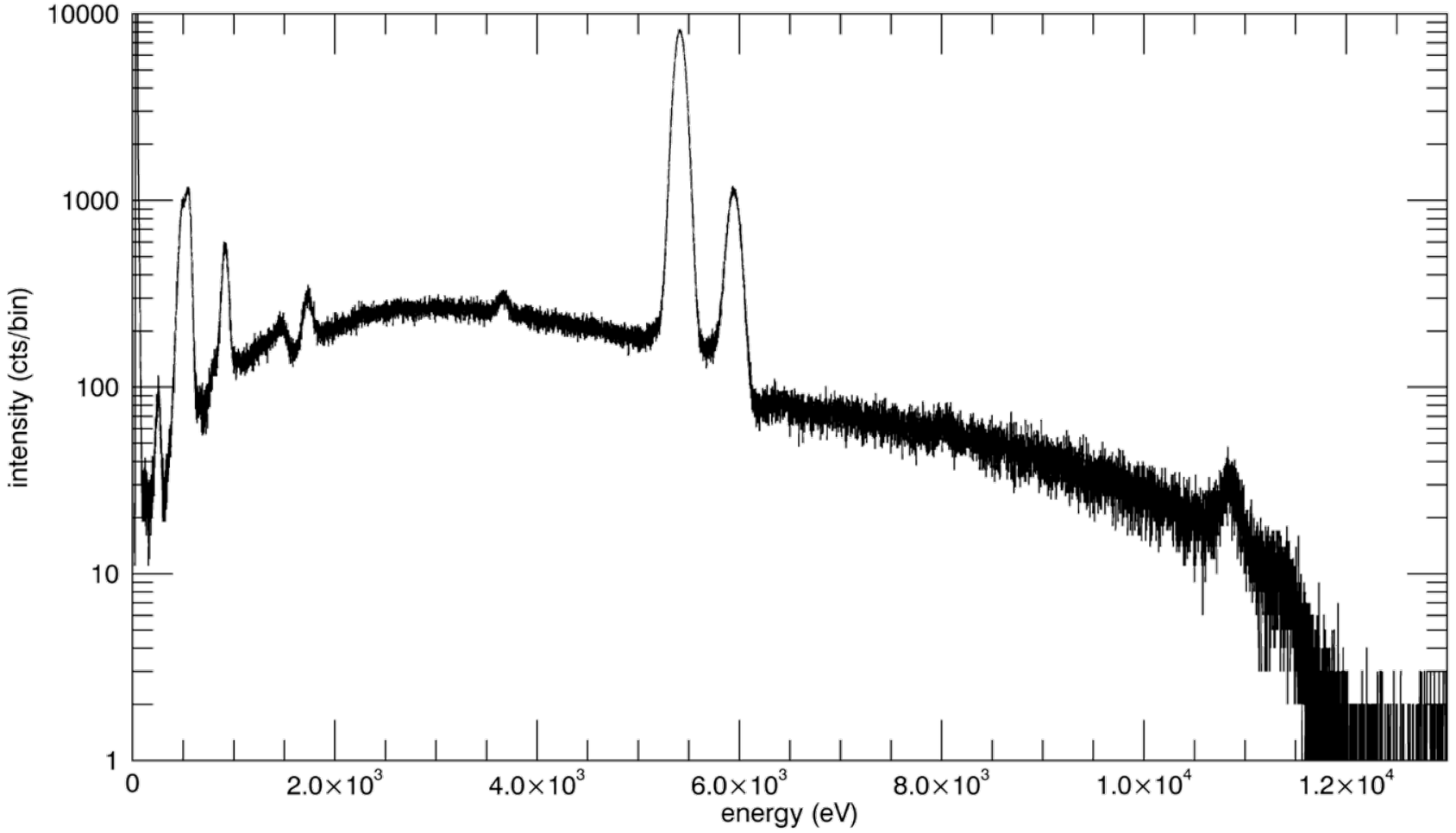




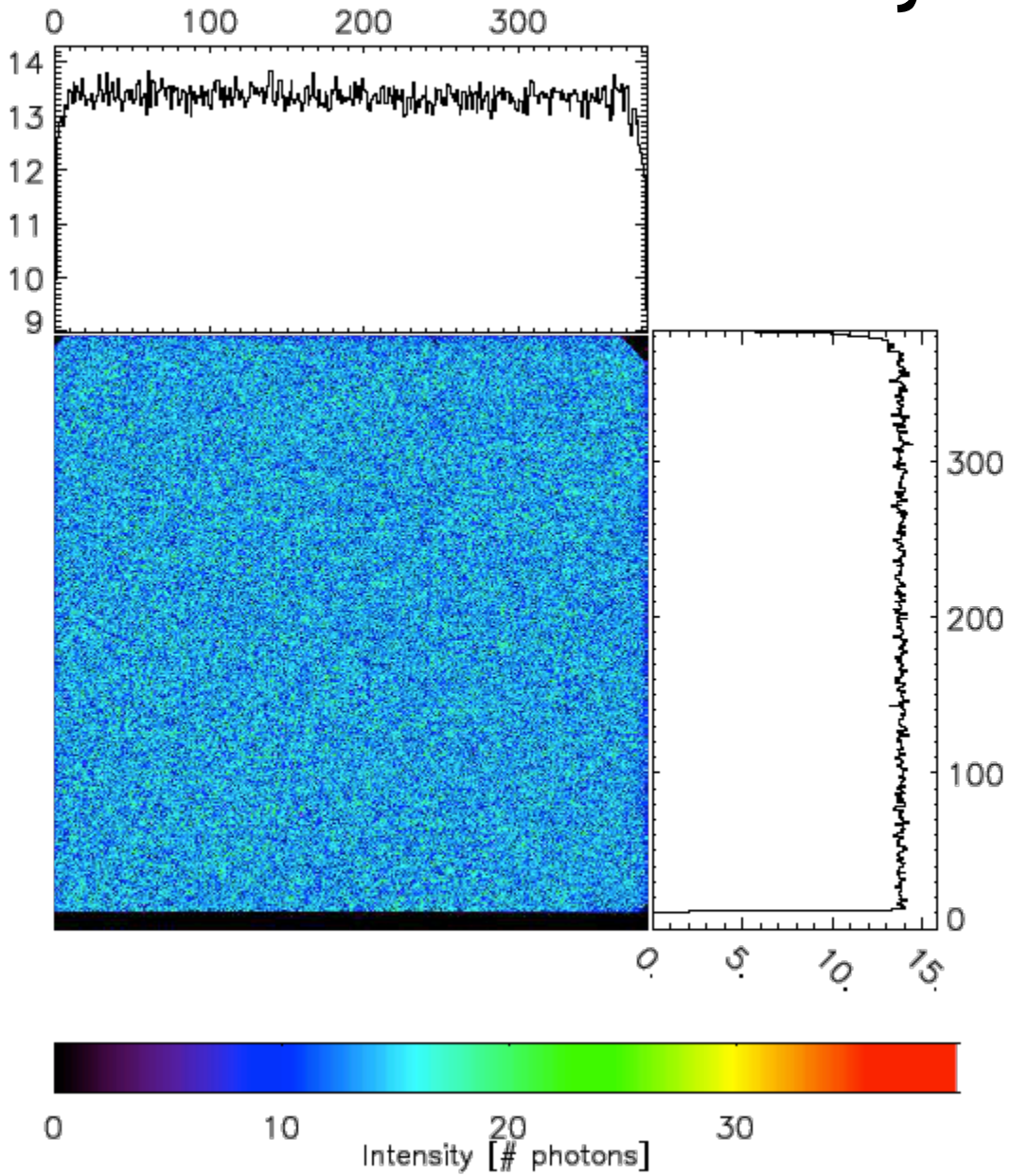


Cr-Kα 136eV FWHM
Cu-L 70eV FWHM

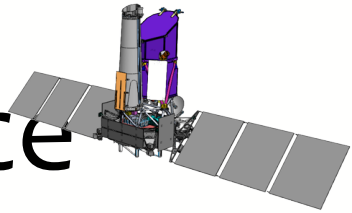




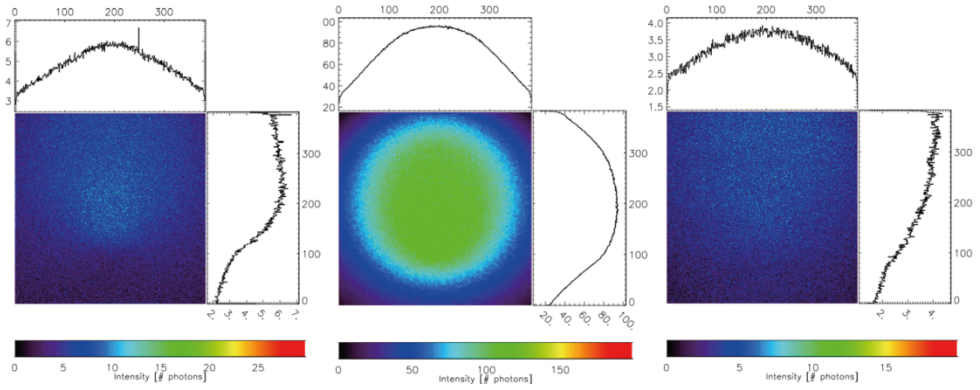
Perfect Uniformity

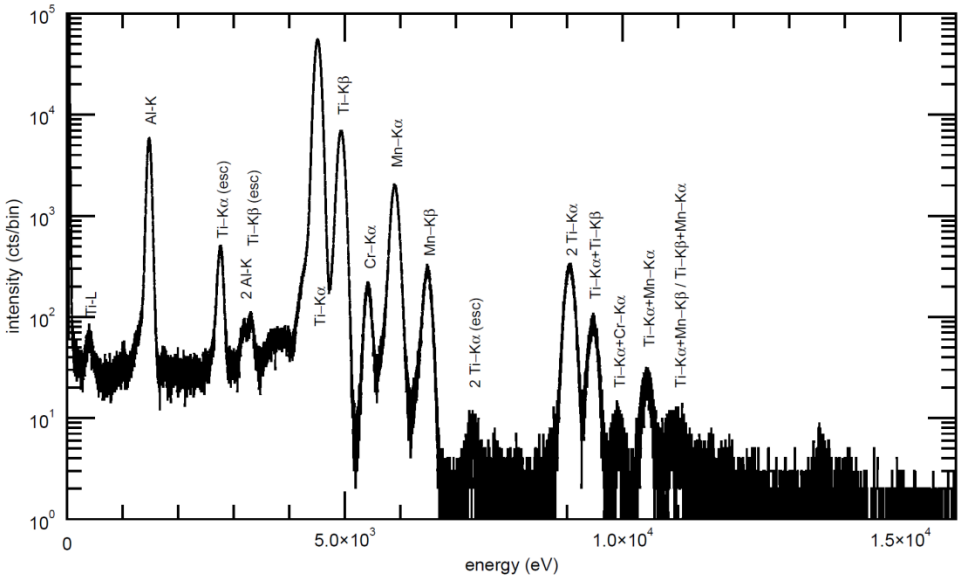


Onboard Calibration Source

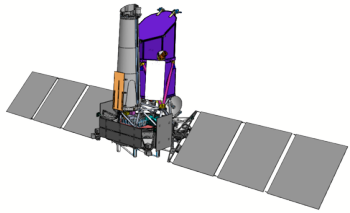


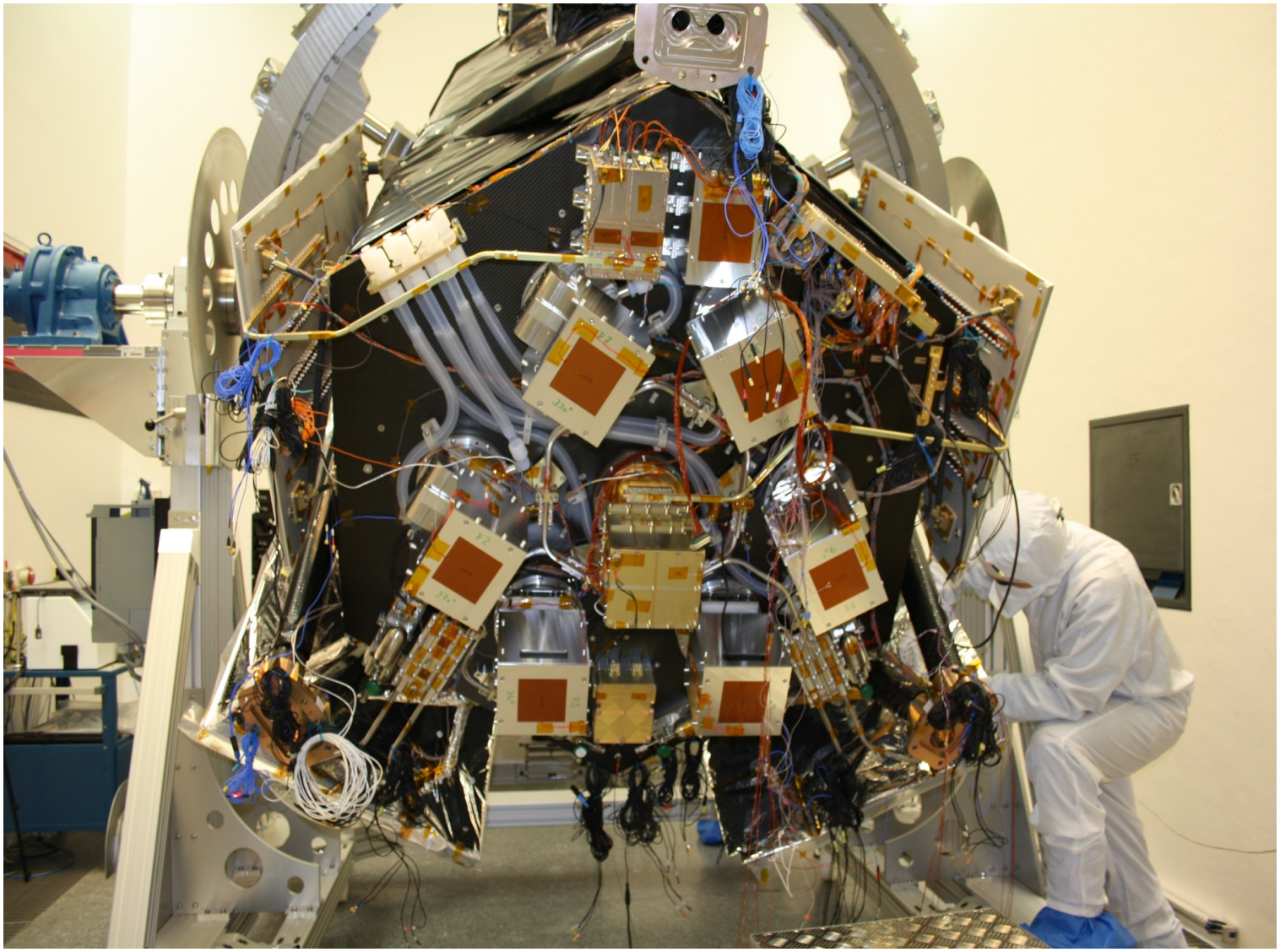
Al Kα Ti Kα Mn Kα



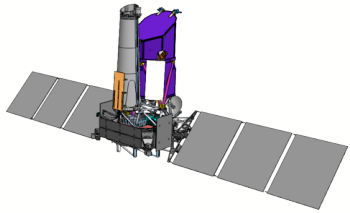


Focal plane



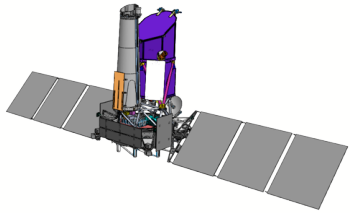


Timeline



- Mirror Modules characterization → Dec 2014
- FM cameras & electronics production and calibration → Jan 2015
- Delivery to Lavochkin (Moscow) → June 2015
- **SRG Launch window → Dec 2015 - Jan 2016**
- First survey data → ~ Summer 2016

Working with eROSITA



- **eROSITA is a PI instrument**
  - Data split 50% MPE and 50% IKI West/East
  - German data public after **2 years**, 2 or 3 Public Releases of DE-sky data (2018/2019-**2022**)
  - Proprietary access via eROSITA_DE consortium
  - Projects/papers regulated by working groups
- **Working Groups:**
  - Science: Clusters/Cosmology, AGN, Normal galaxies, Compact objects, Diffuse emission/SNR, Stars, Solar System
  - Infrastructure: Time Domain, Data analysis and catalogues, Multiwavelength follow-up, Calibration, Background
- **Collaboration policy:**
  - Individual External Collaborations (proposal to WGs)
  - Group External Collaborations (team-to-team MoUs)

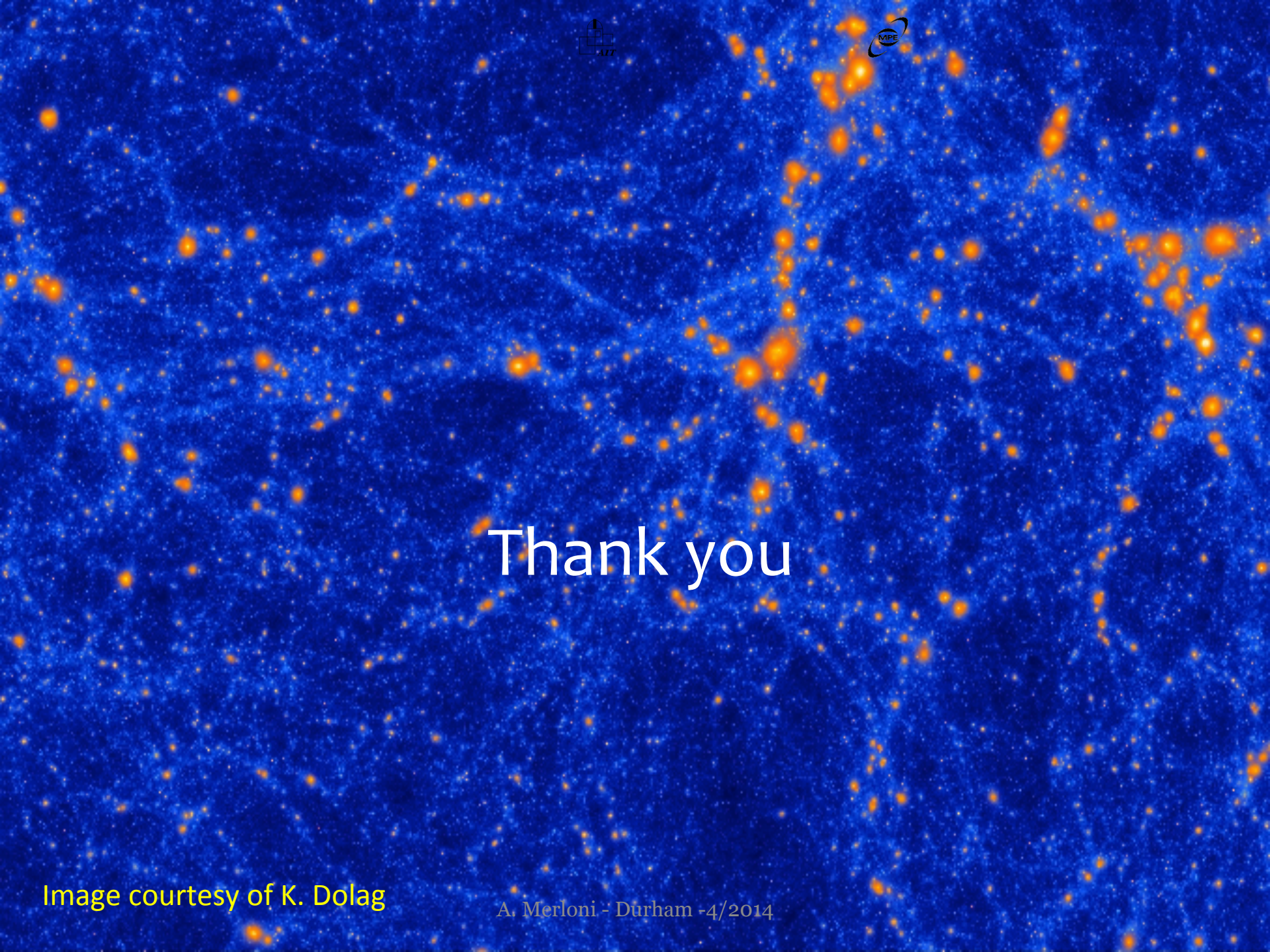
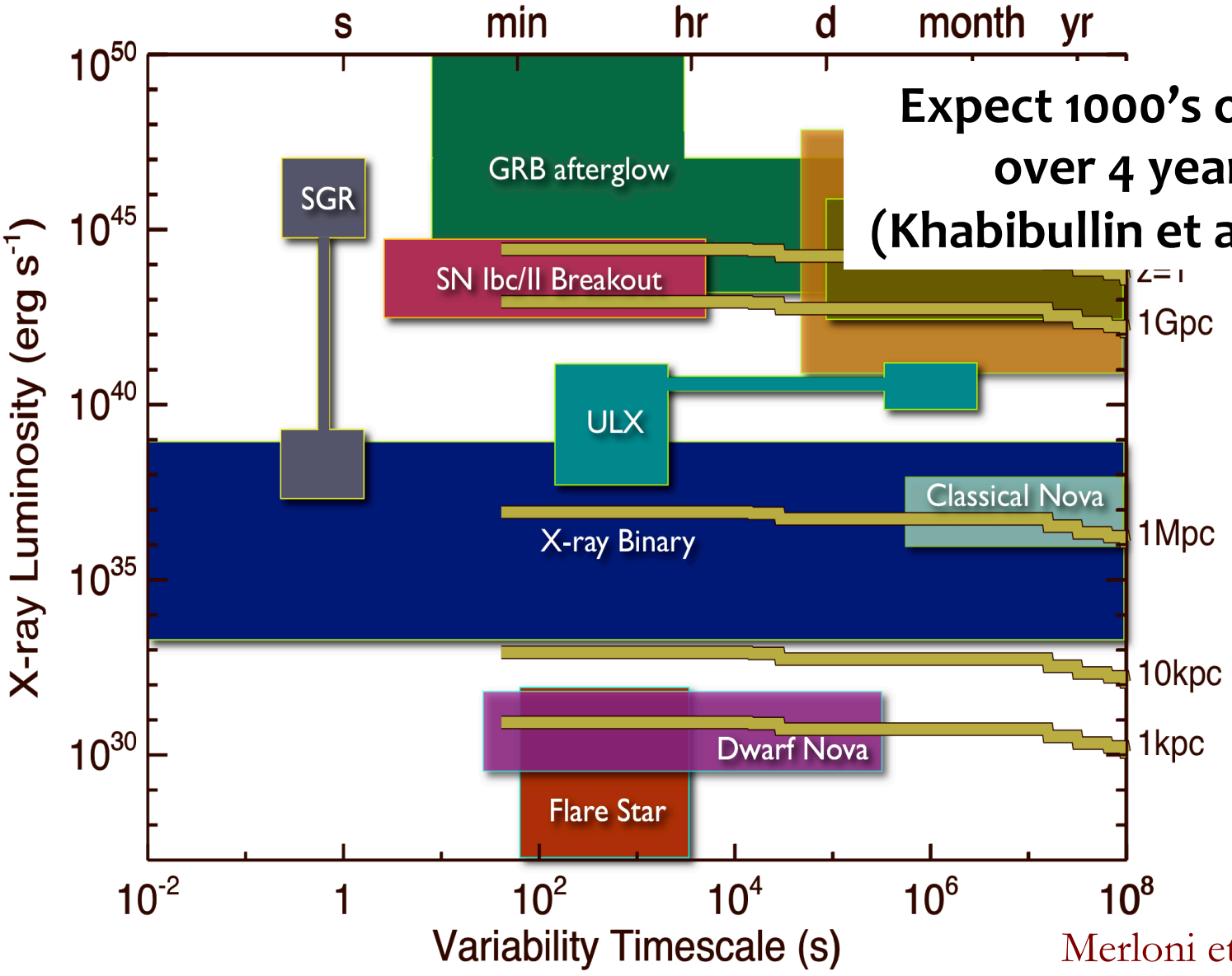


Image courtesy of K. Dolag

eROSITA sensitivity to variables



Expect 1000's of TDE over 4 years (Khabibullin et al. 2013)

Merloni et al. 2012