www.mpe.mpg.de/eROSITA

The eROSITA X-ray all-sky survey

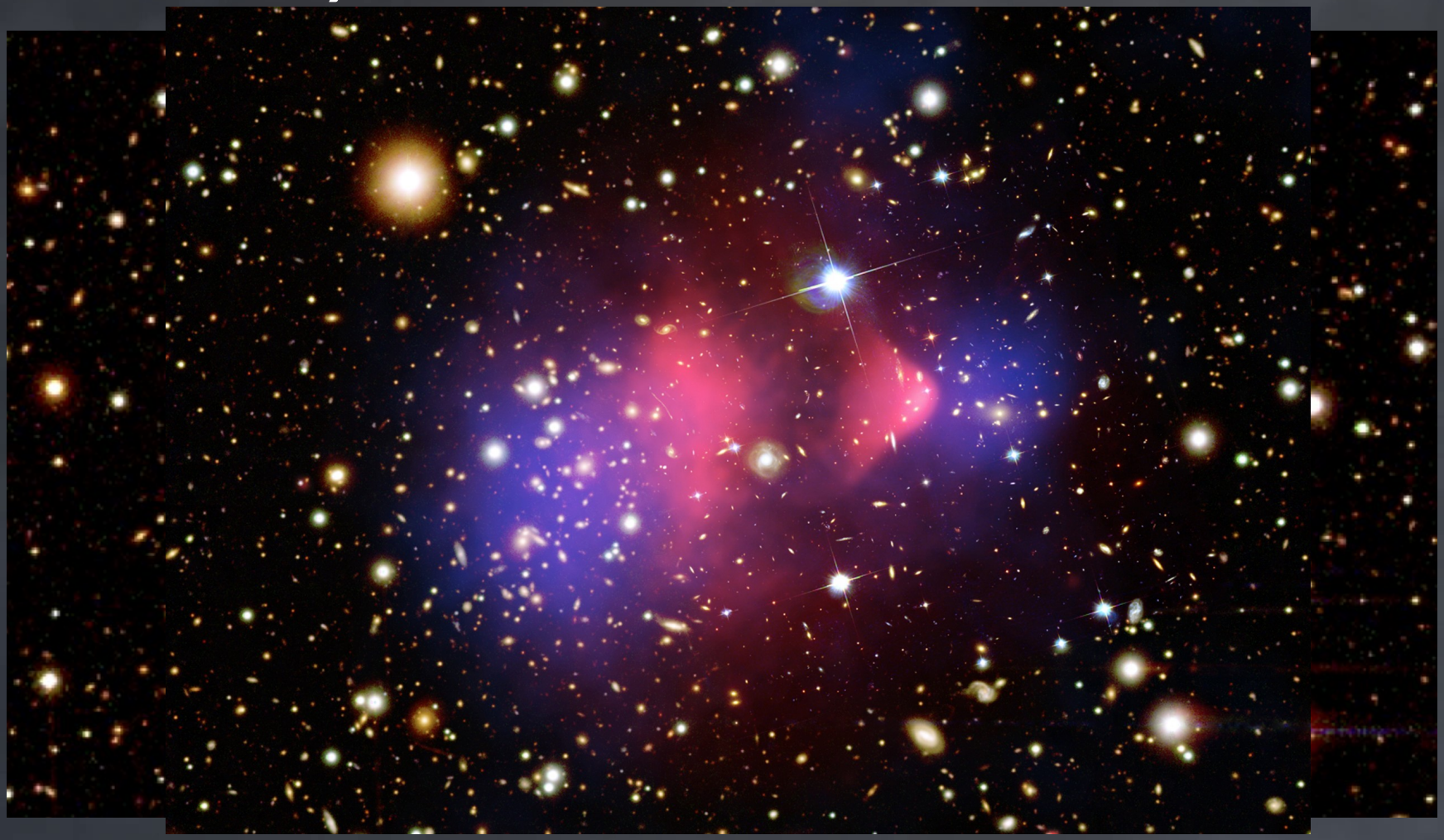
Dominique Eckert
University of Geneva
MPE, Garching

On behalf of Mara Salvato and the eROSITA team

Outline

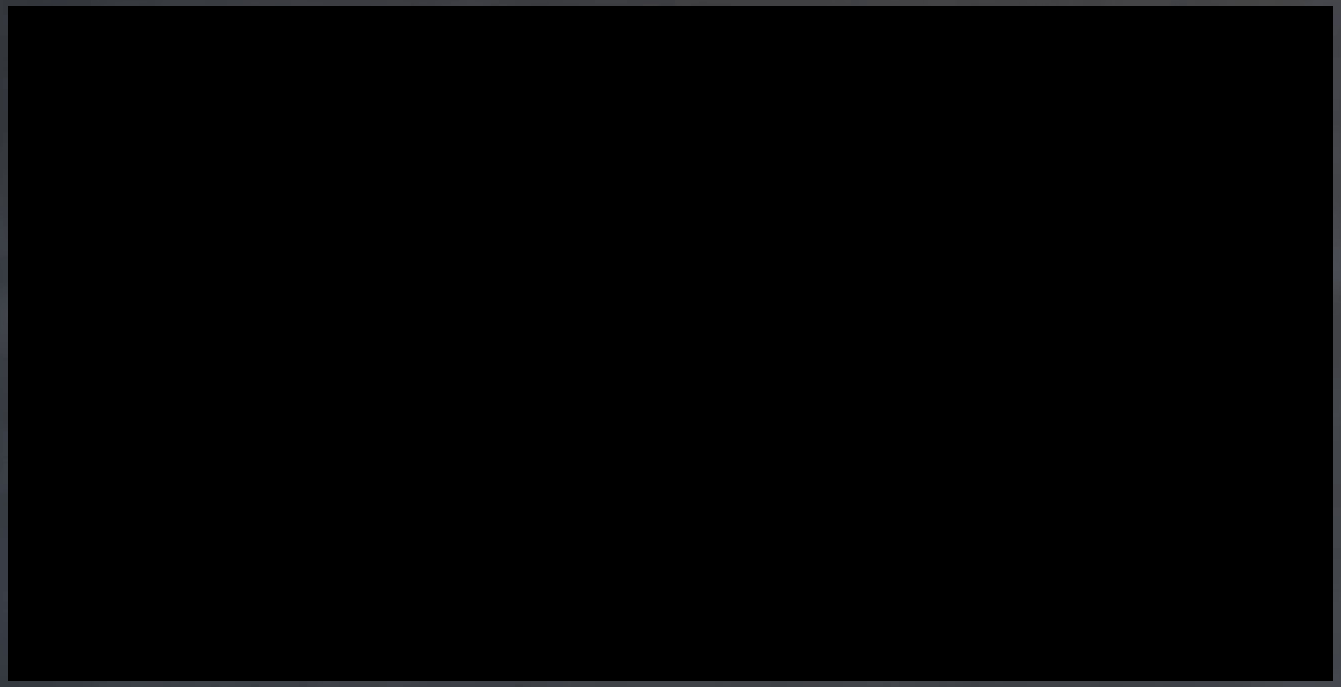
- Galaxy clusters: an introduction
- The eROSITA instrument on SRG
- Survey design
- Constraining dark energy with eROSITA
- Additional science (AGN, TDEs, …)

Galaxy clusters: an introduction

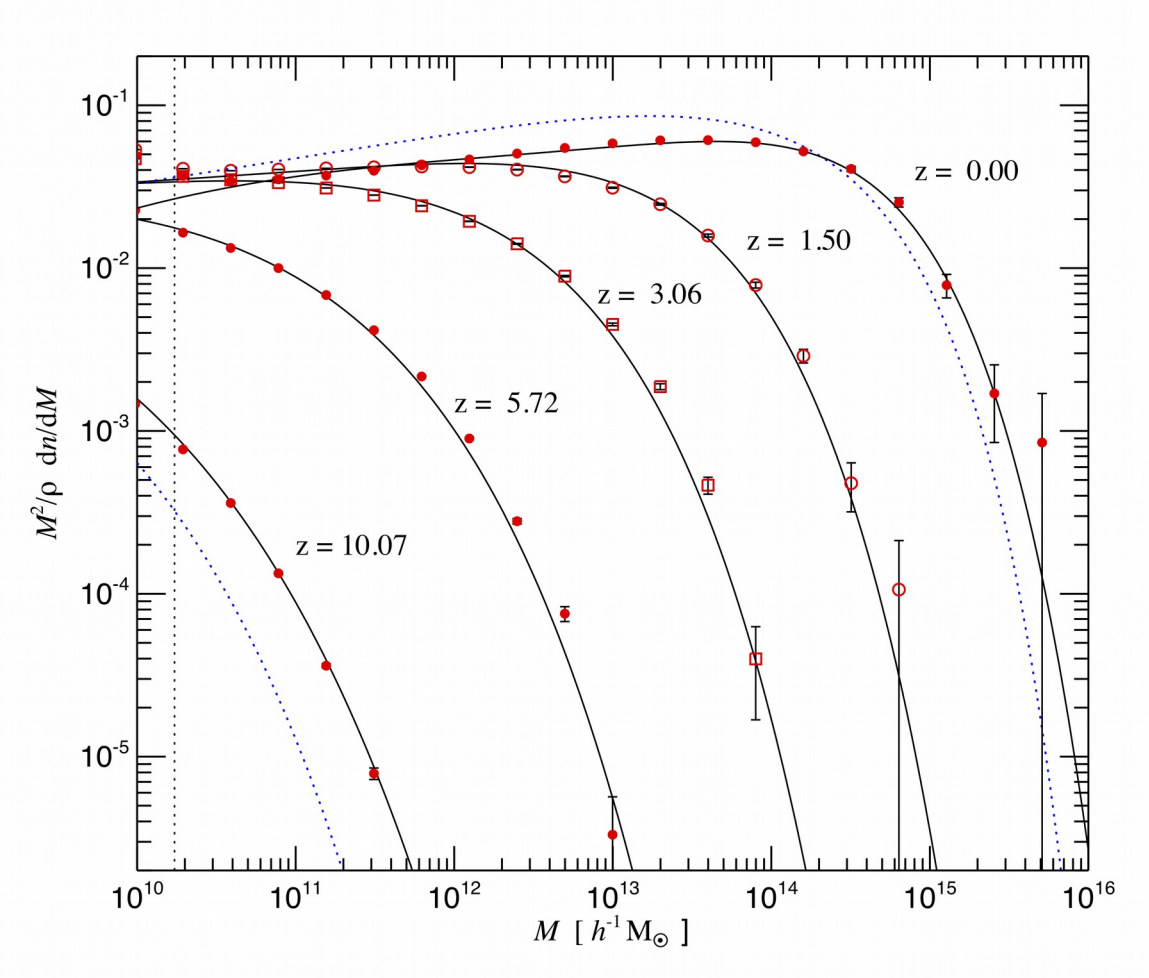


The gravitational lensing effect (Mathiesen & Simonsen 1999) can be used to map the mass

Formation and evolution of a galaxy cluster



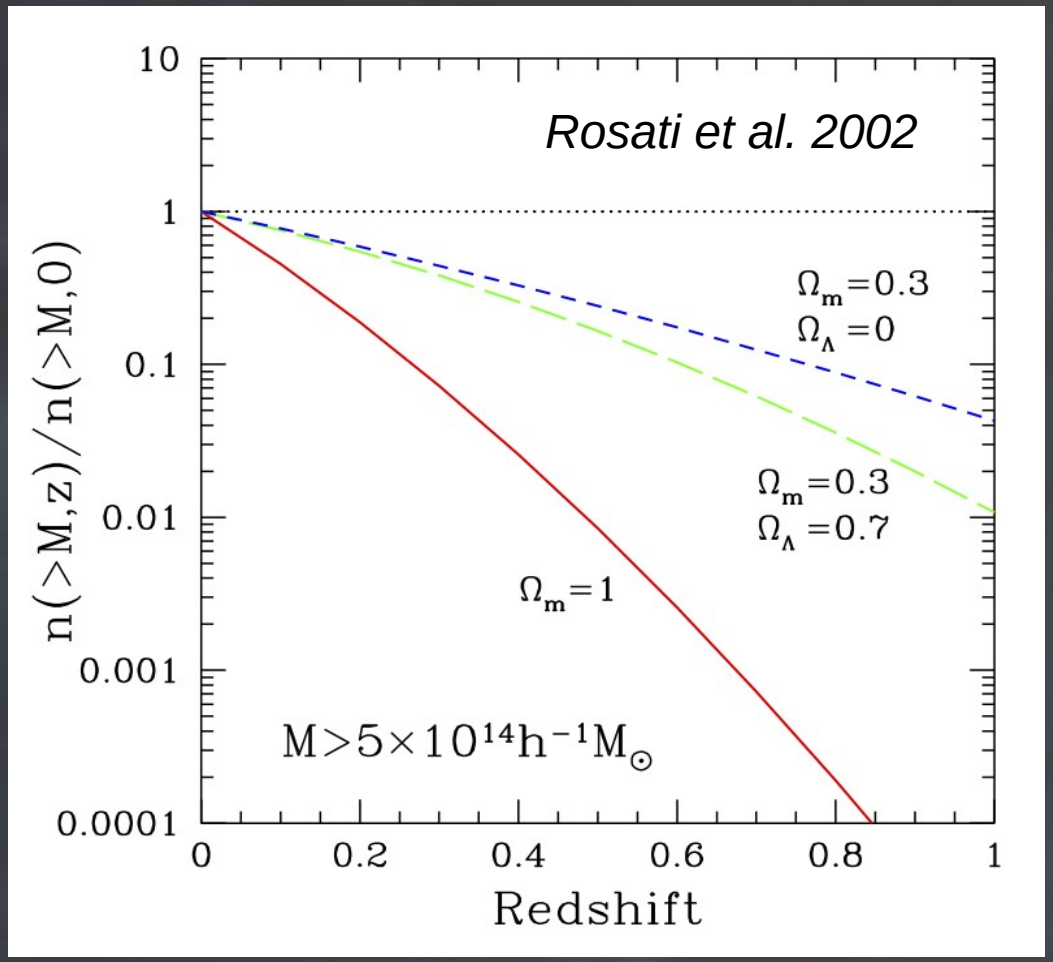
The halo mass function and its cosmological dependence



Springel et al. 2006

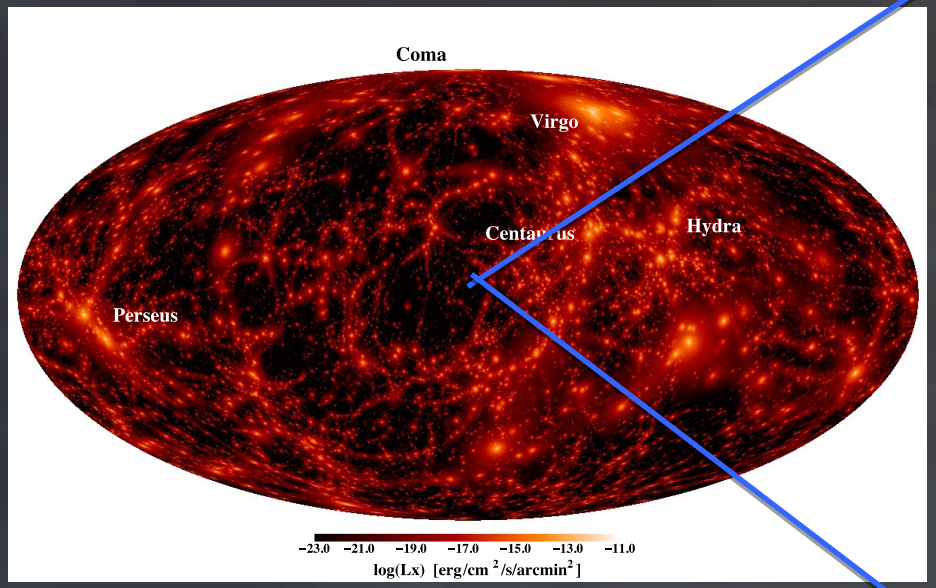
Dark energy with a galaxy cluster survey

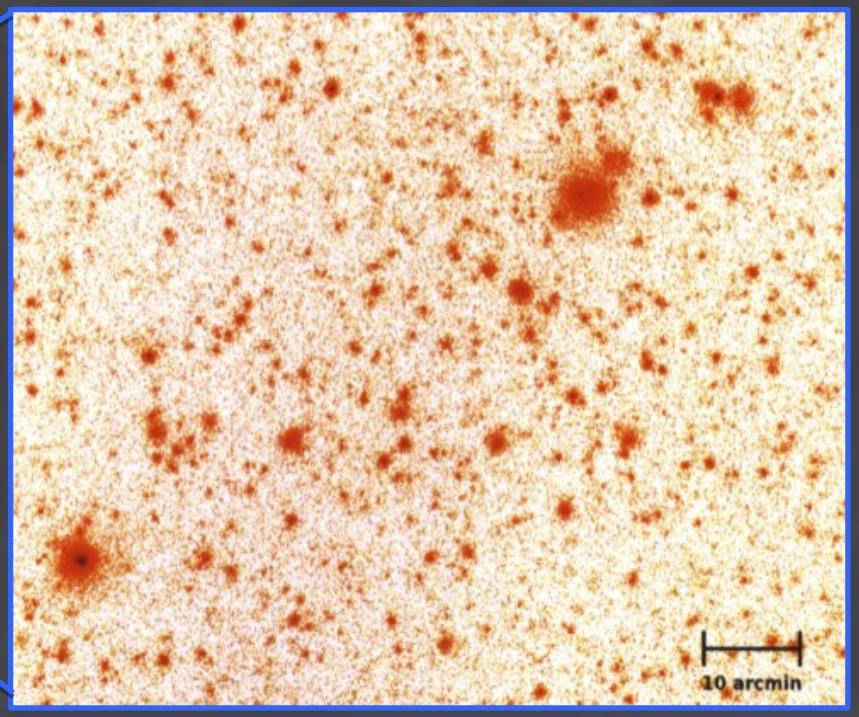
- The growth rate of galaxy clusters depends on the expansion rate, hence on dark energy



Mapping the structure of the hot Universe

Simulation of an eROSITA field



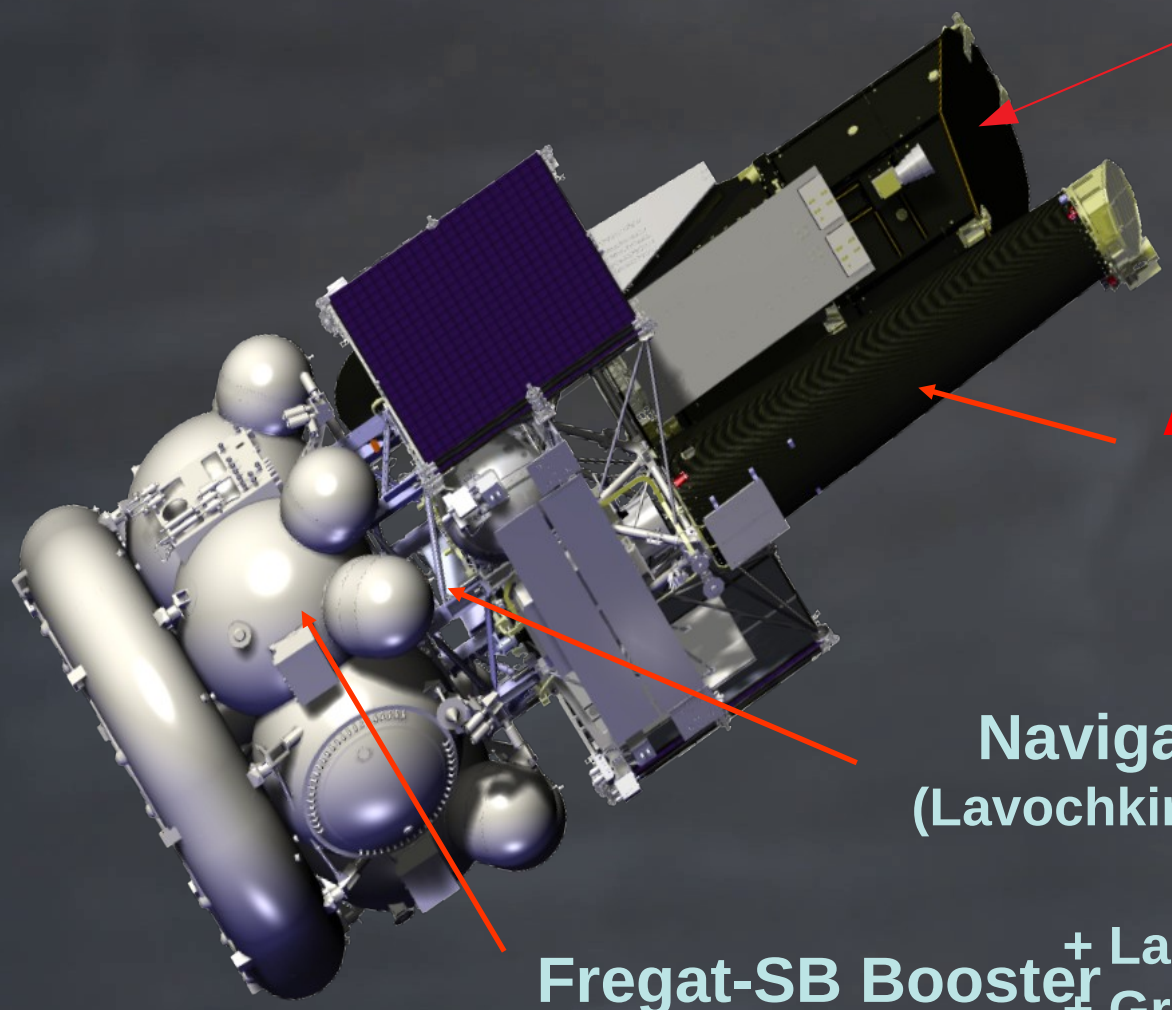


Diffuse X-ray emitting gas traces the massive knots of the cosmic web (Clusters)

Point sources (Quasars) signpost the growth of black holes

Images coutesy of K. Dolag (LMU), M. Mühlegger (MPE), O. Hahn (ETH)

Spectrum-Roentgen-Gamma



eROSITA: the Project

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:

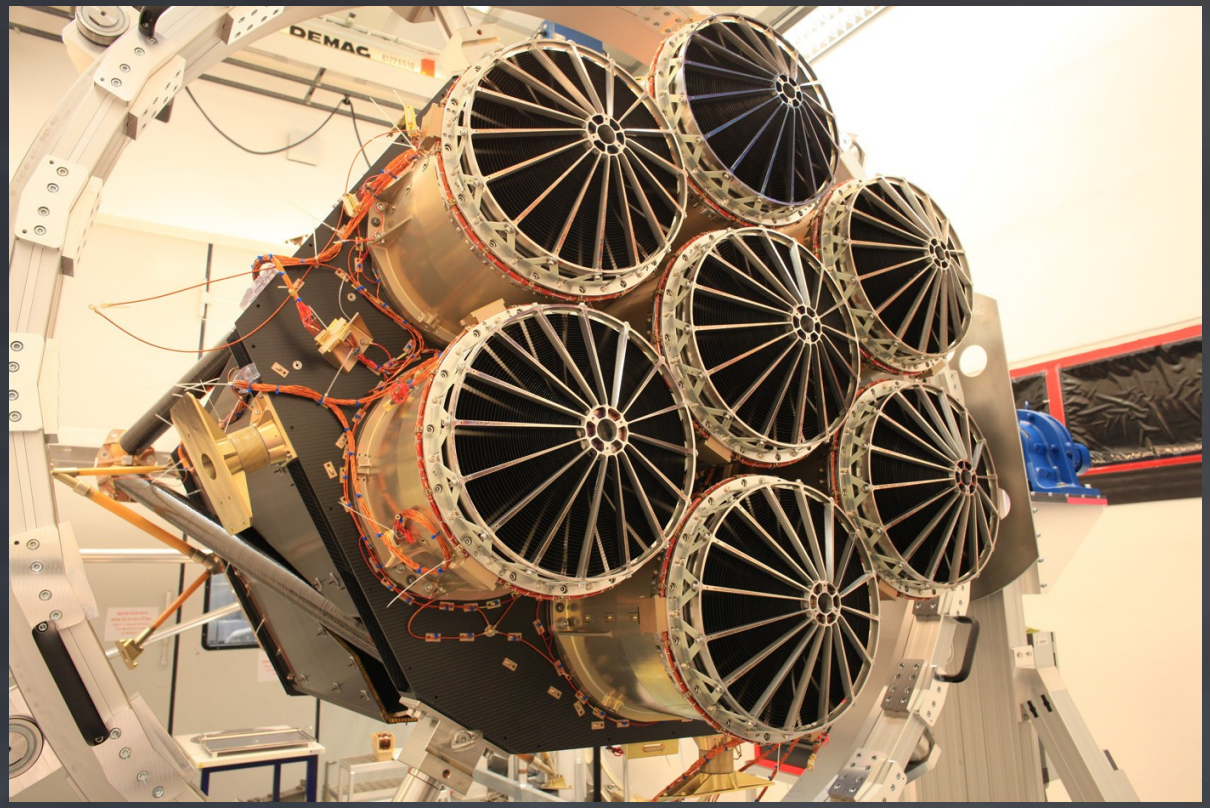
Media Lario/I	Mirrors, Mandrels
Kayser-Threde/D	Mirror Structures
Carl Zeiss/D	ABRIXAS-Mandrels
Invent/D	Telescope Structure
pnSensor/D	CCDs
IberEspacio/E	Heatpipes
RUAG/A	Mechanisms
HPS/D,P	MLI

+ many small companies

COSTS: ~80-90 M€ (eROSITA)
~250-300 M€ (SRG)

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

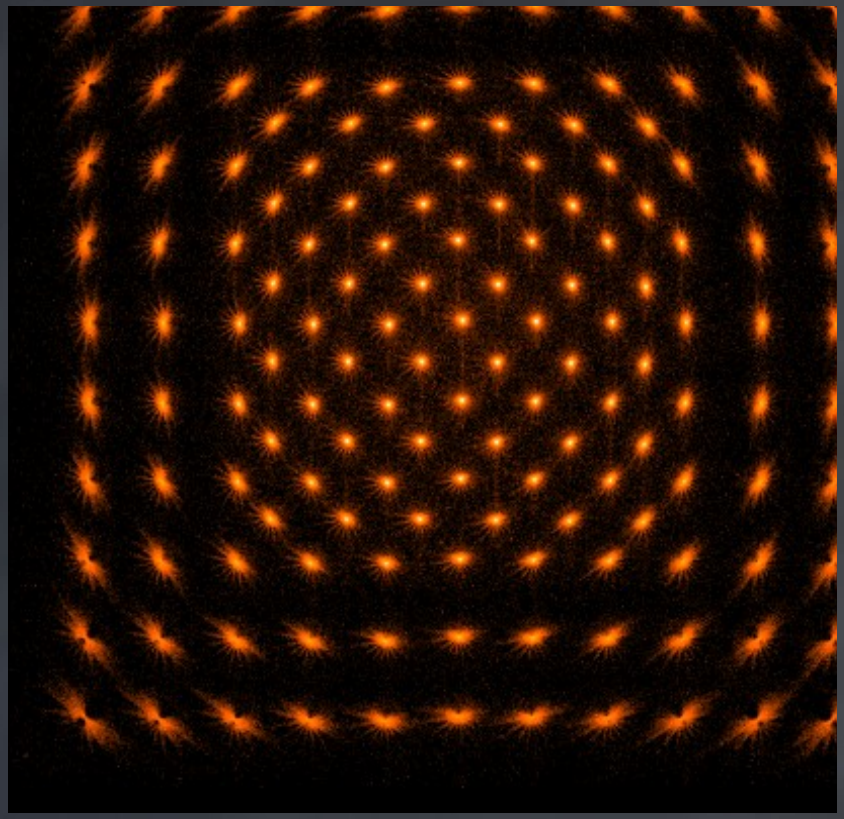
7+1 Mirror assemblies

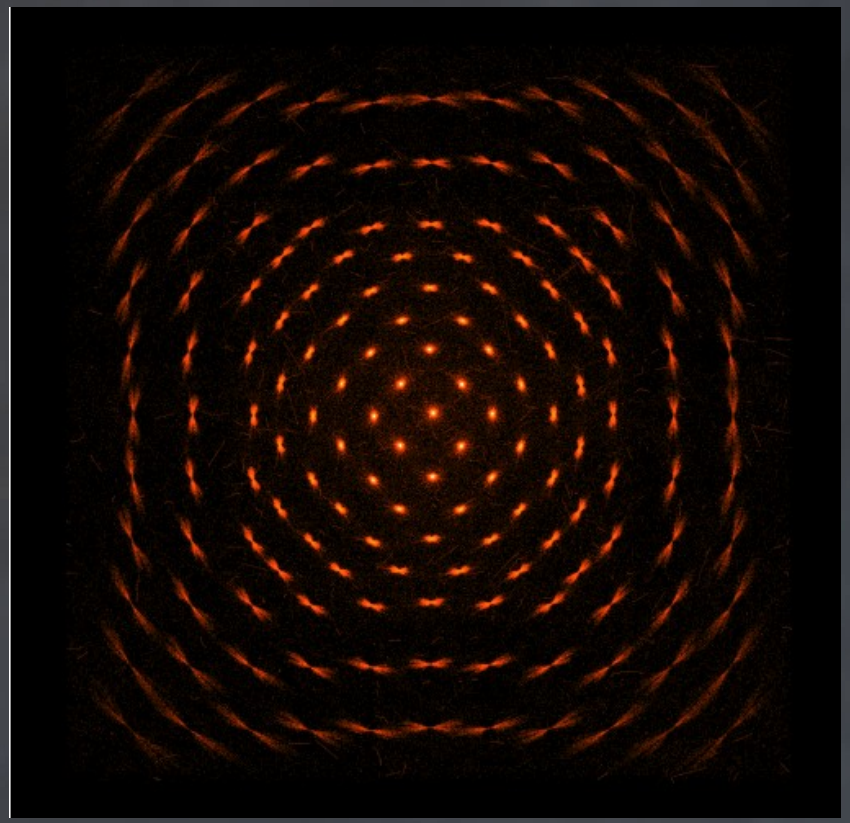


X-ray Baffle [MPE]

- 54 nested gold-coated nickel mirror shells
- Focal length: 1.6 m, Field of view: 1 degree (diameter)
- On-axis Half-Energy width (HEW) ~16.1” (nominal)
- X-ray baffle (10µm precision alignment): 92% stray light reduction
- Calibration of all 8 telescopes at PANTER completed in June

Point Spread Function





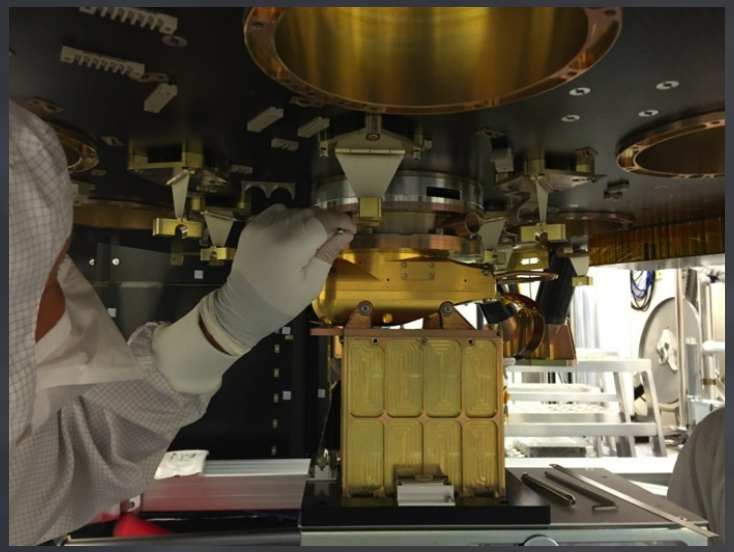
Al Kα (1.49 keV)

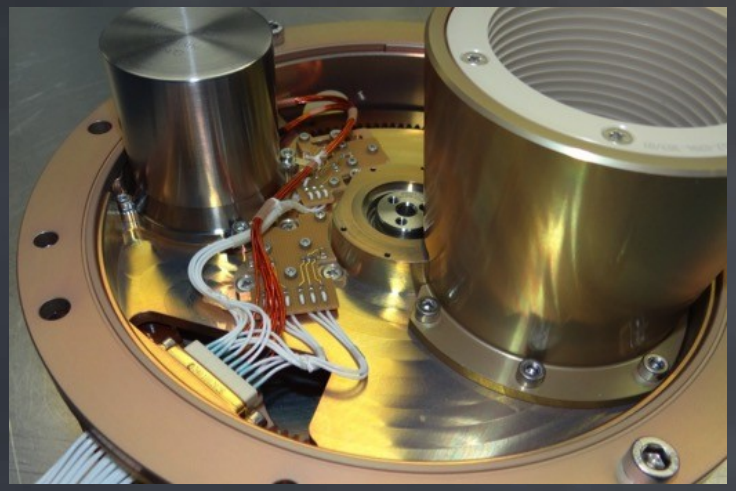
HEW = 18.1“ (on axis)
~ 24.8“ (FoV avg.)

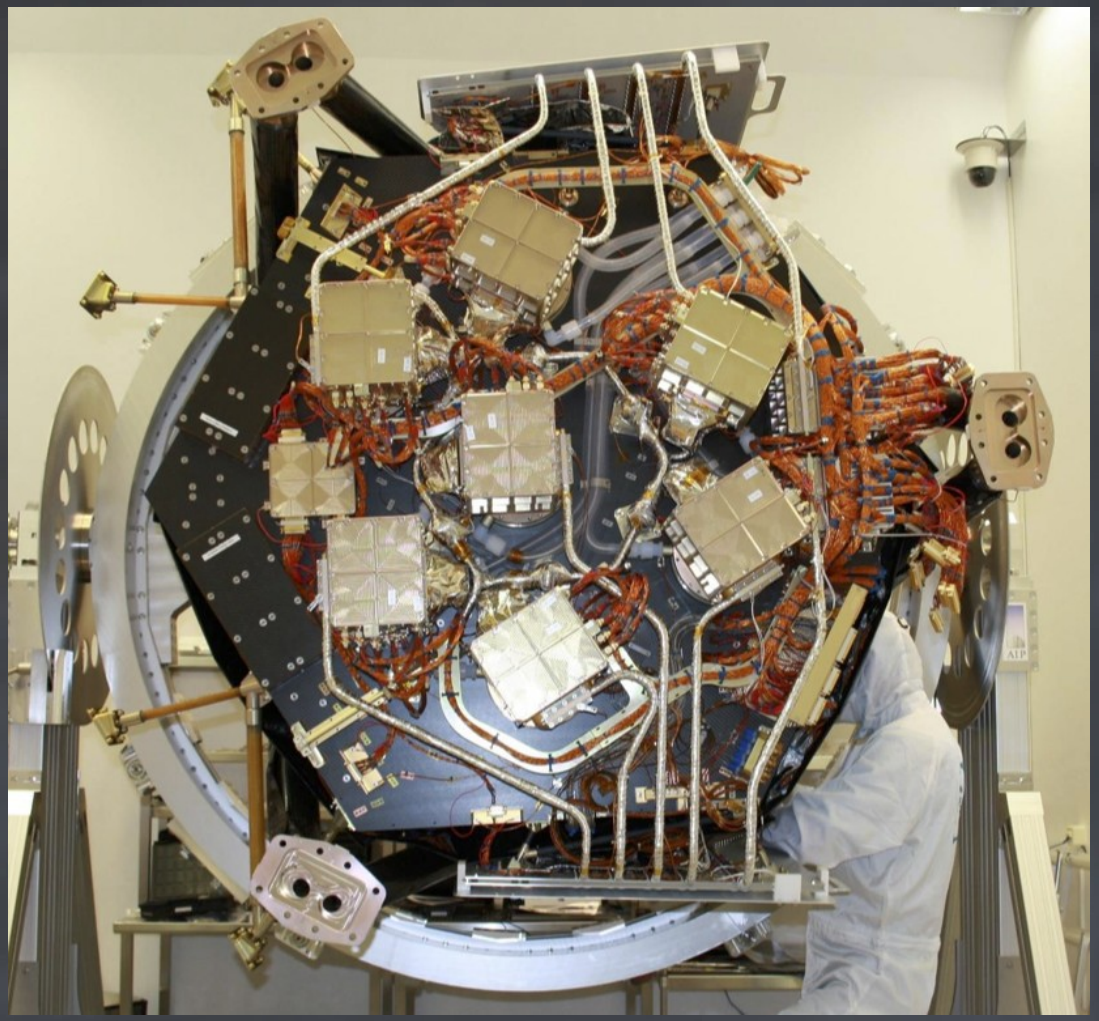
Cu Kα (8 keV)

HEW = 15.4“ (on axis)
~42“ (FoV avg.)

7+1 Framestore pnCCD



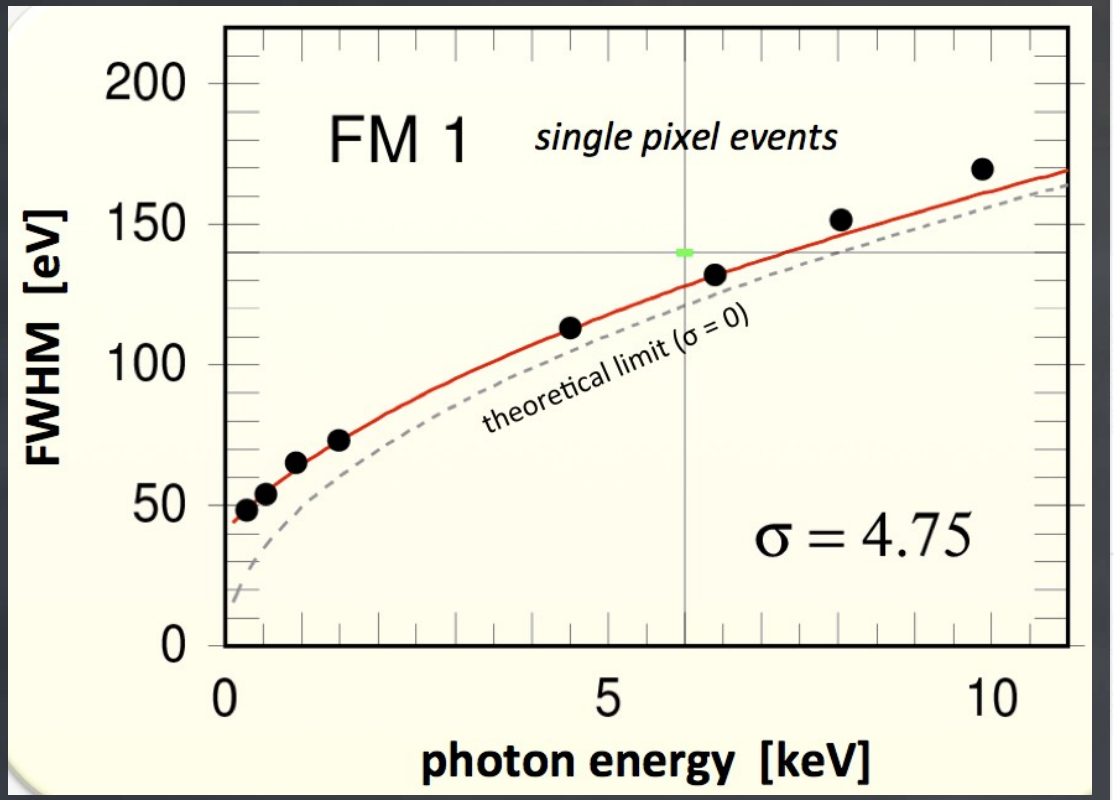


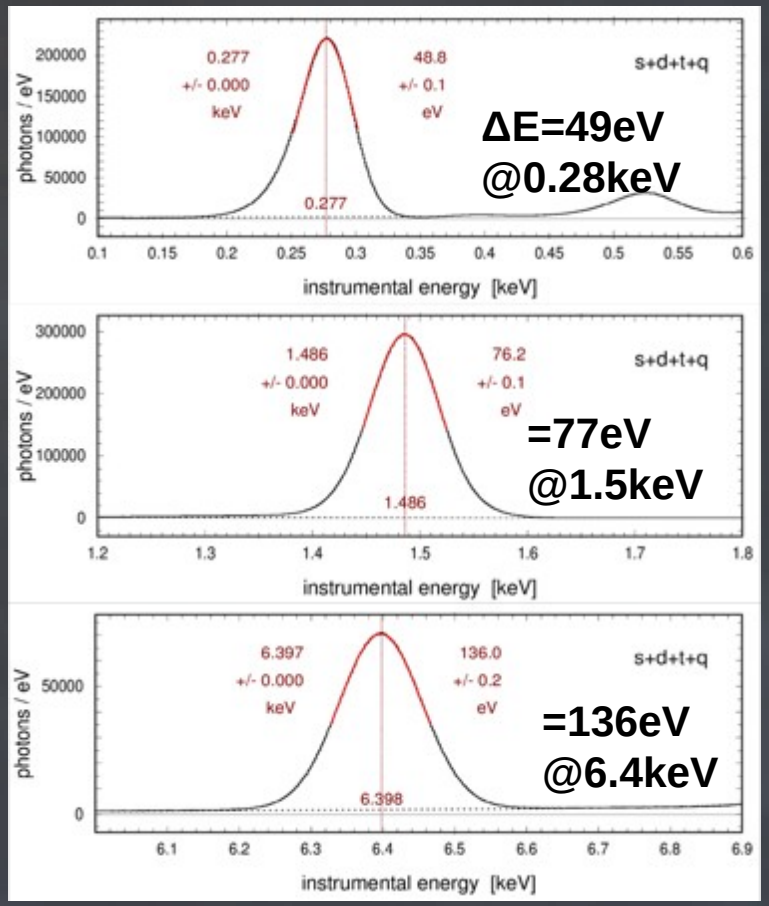


Meidinger et al, 9144E..1WM

Cameras Calibration

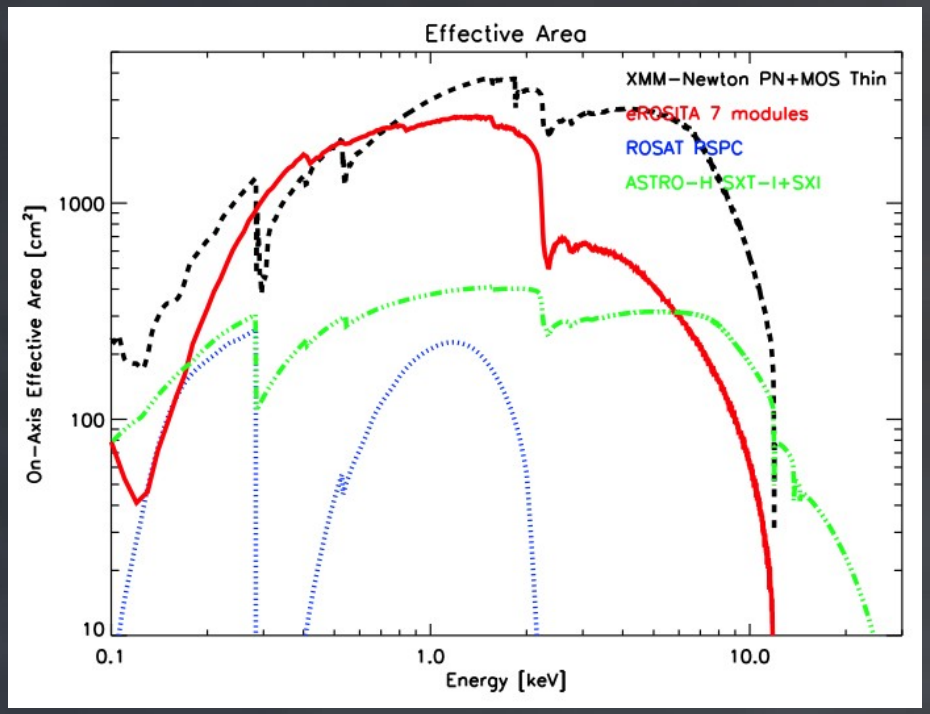
- **3.3 Billion** calibrated events! (K. Dennerl, N. Meidinger)
- **Spectral resolution** at all measured energies within specification (R~20 @1.5keV)
- Extremely good **uniformity**
- Only weak dependence on CCD and electronics temperature (unlike XMM)
- Very accurate absolute energy reconstruction (<0.06%)

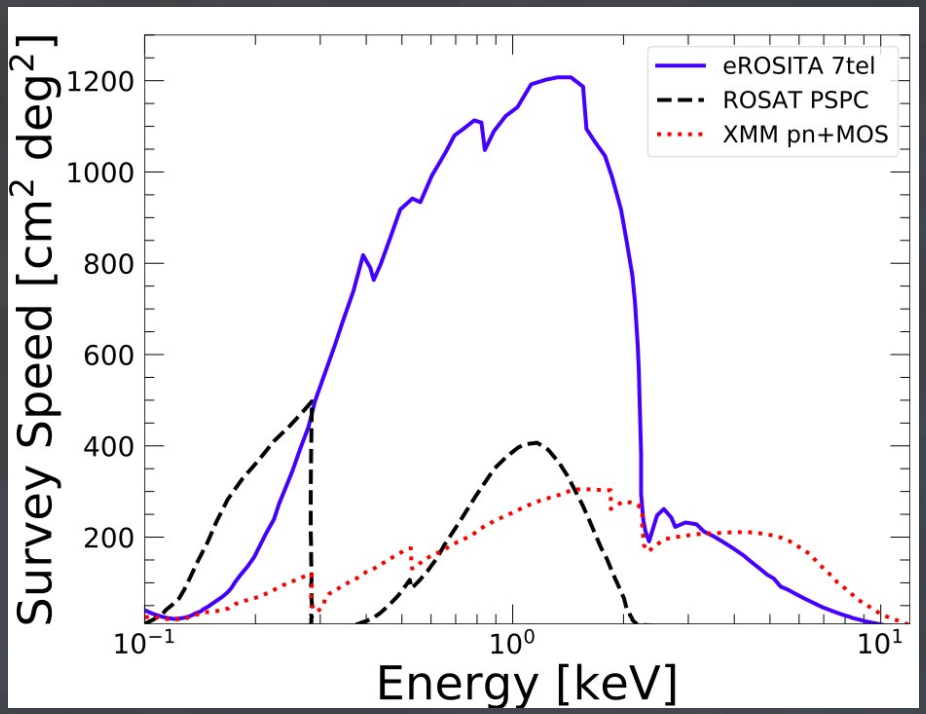




Effective Area and Grasp

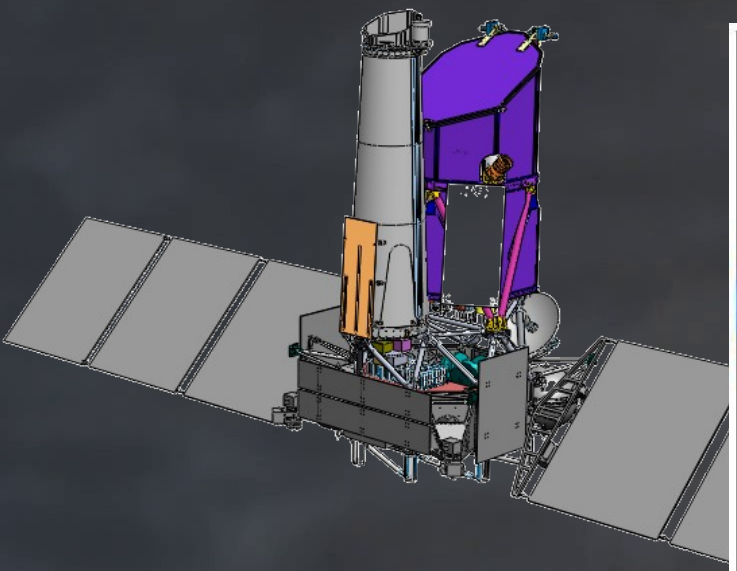
Effective Area: ~1700 cm² (FoV avg. @1keV)

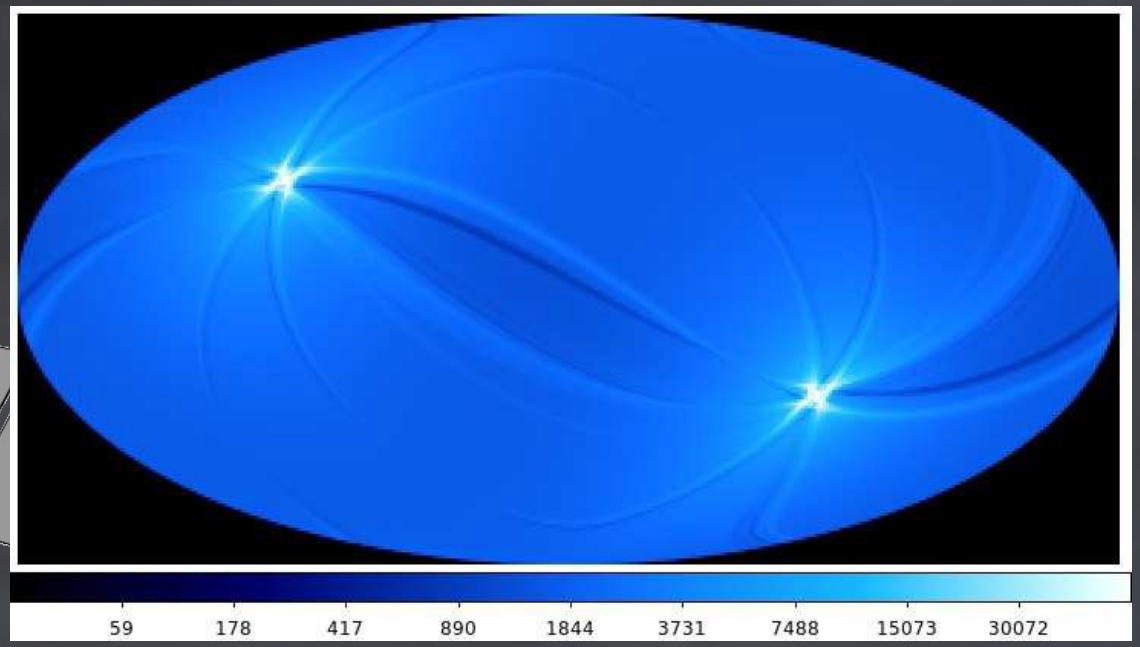




- Effective area at 1keV comparable with XMM-Newton
- Factor ~7-8 larger surveying speed
- 4 years dedicated to all sky survey (with estimated 70-80% efficiency)
- **XMM-quality data over the whole sky !**

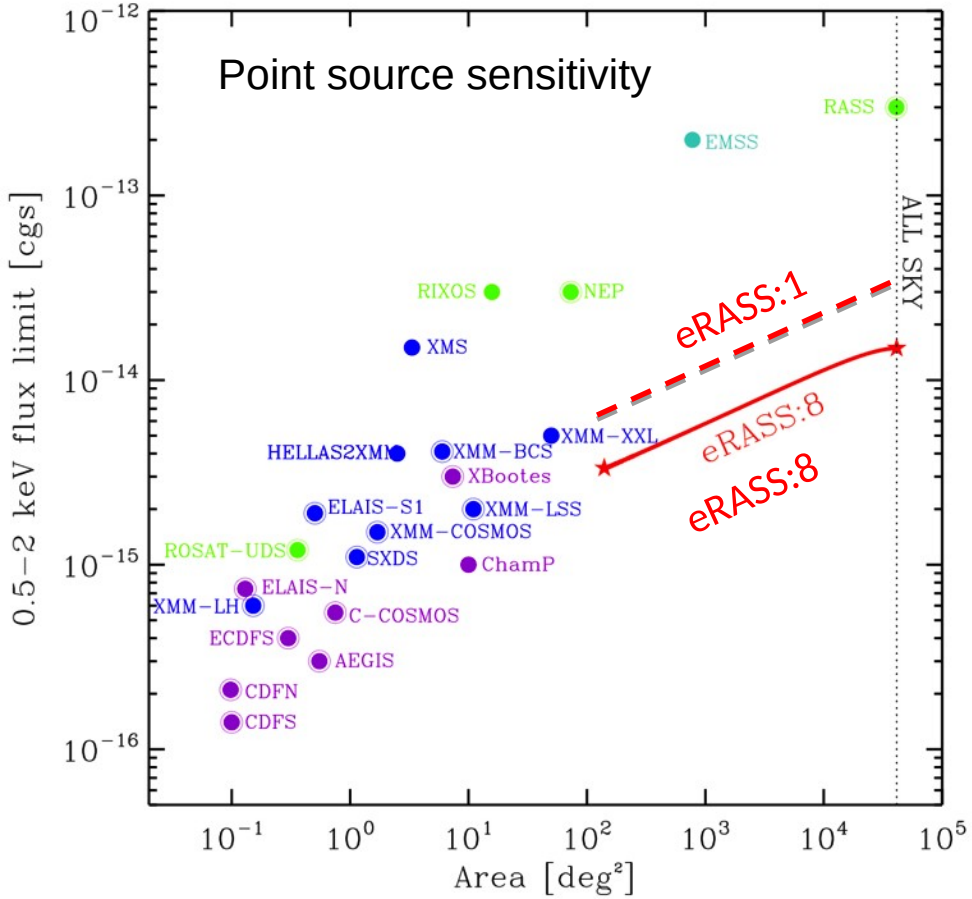
SRG: Mission timeline

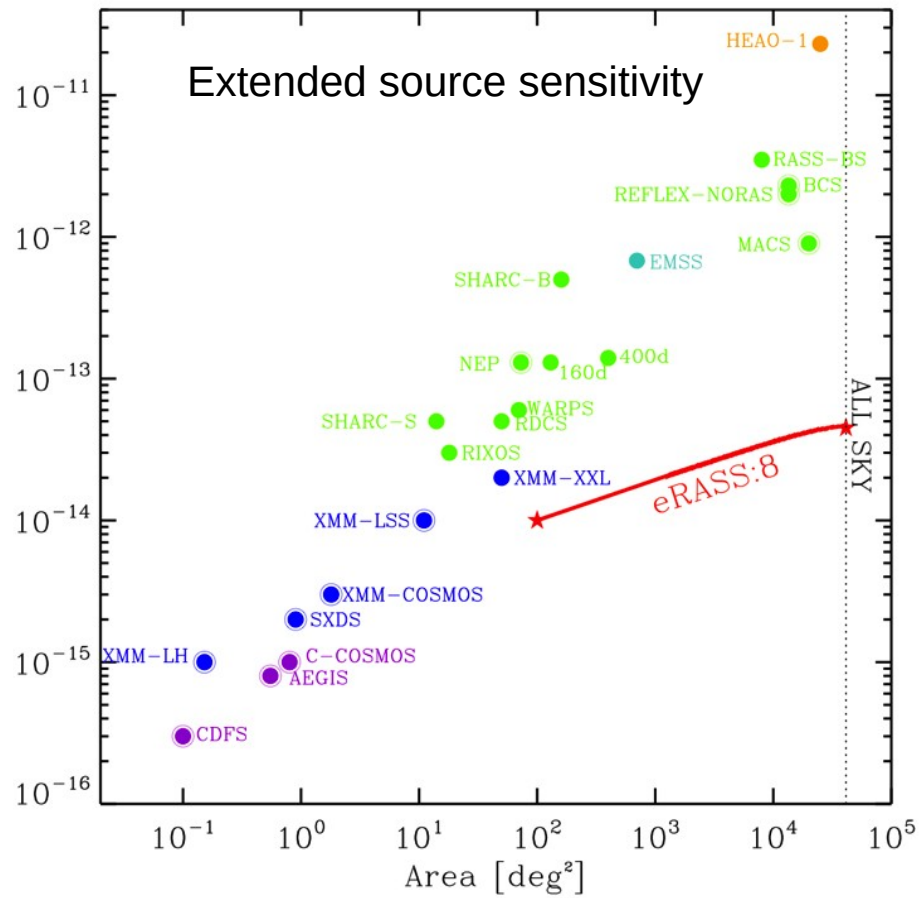




- **eROSITA delivery to Russia**: January, 2017
- **Launch:** June-August 2019 from Baykonour
- **3 Months:** flight to L2, PV and calibration phase
- **4 years**: 8 all sky surveys eRASS:1-8 (scanning mode: 6 rotations/day). Re-visit LMC & SMC every ~month (down to $L_{0.5\text{-}2\ keV}$ ~10^{34} erg/s)
- **3.5 years**: pointed observation phase, including ~20% GTO. 1 AO per year

eROSITA surveys in context



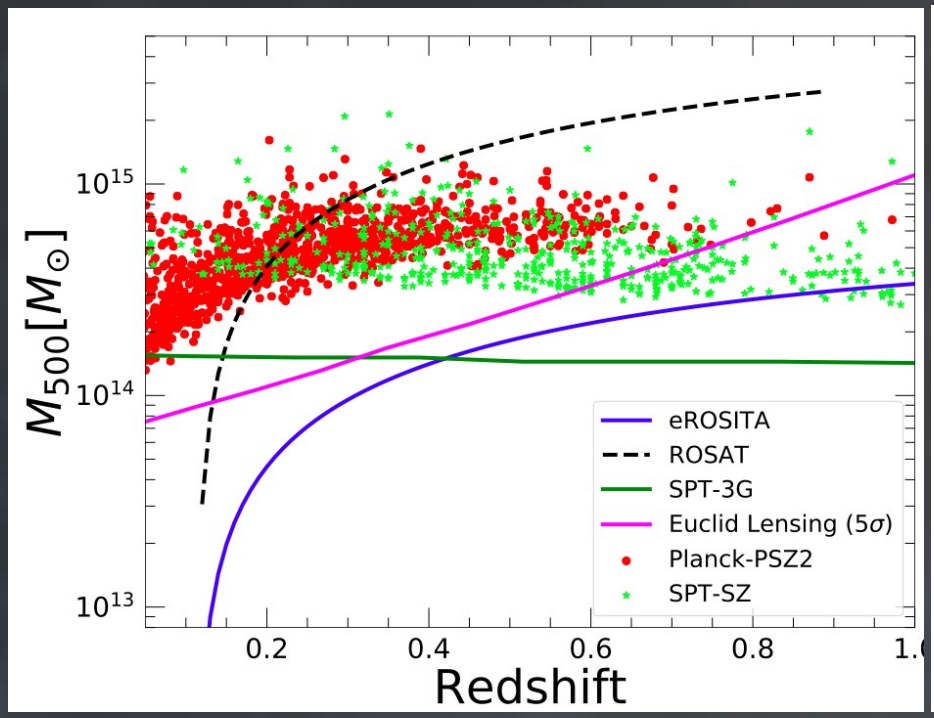


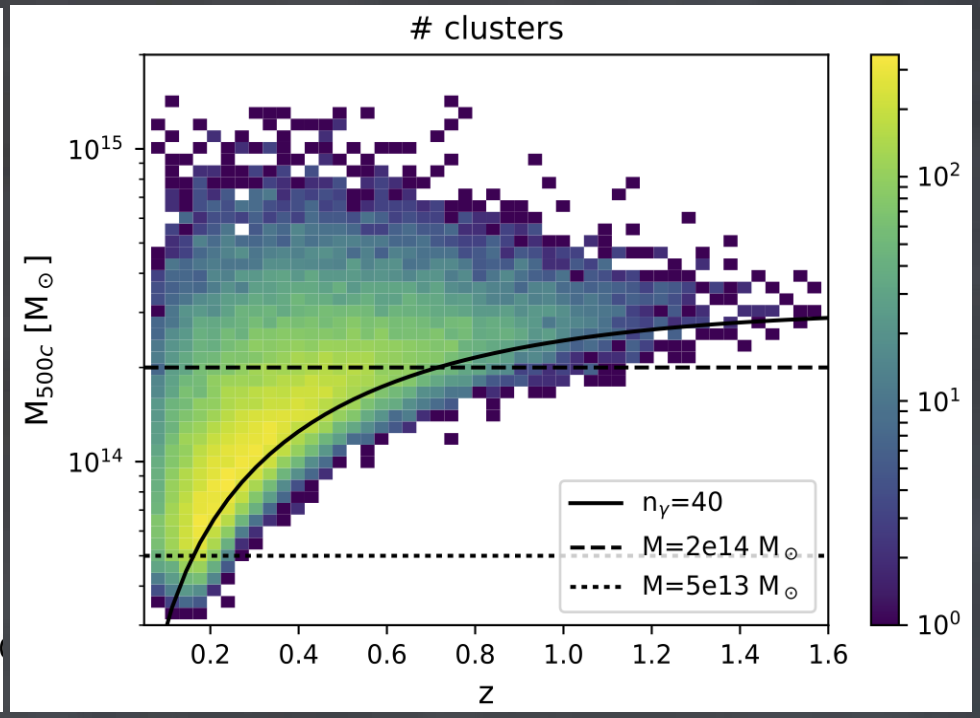
All sky: 10^{-14} (0.5-2 keV)
2×10^{-13} (2-10 keV) [erg/cm²/s]

All sky: 3.4×10^{-14} (0.5-2 keV)

Merloni et al. 2012

All massive clusters

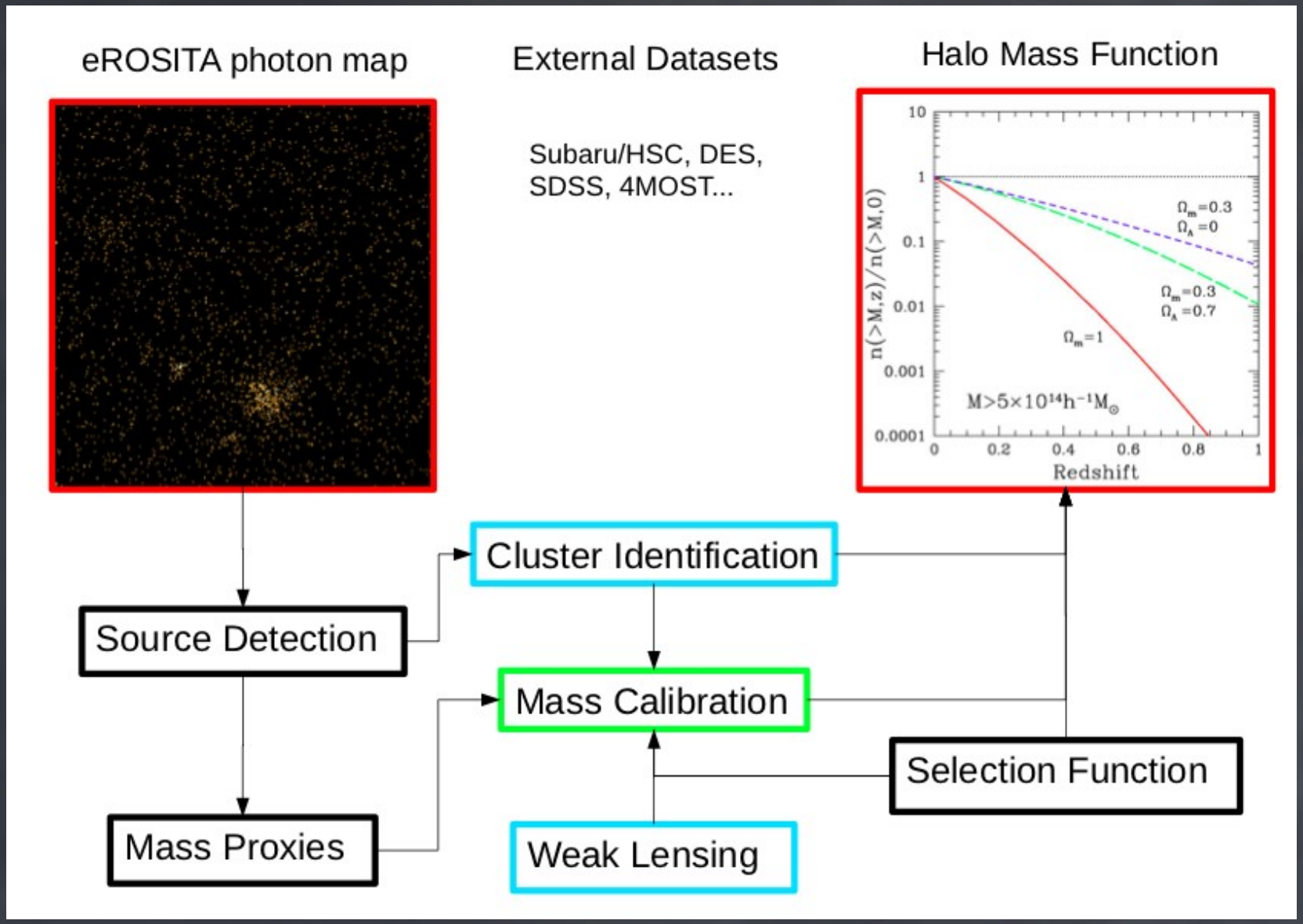




Grandis et al. 2018

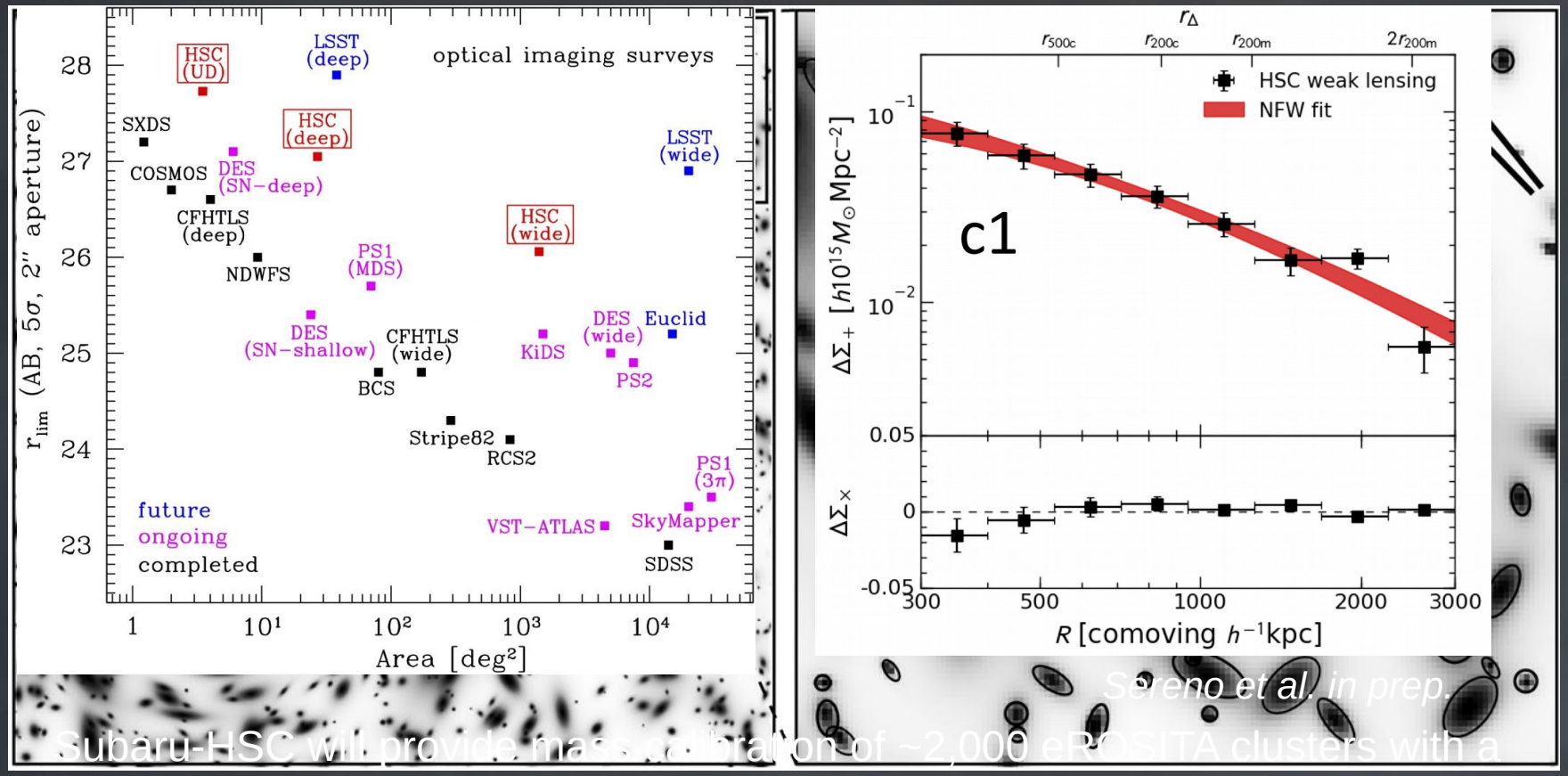
- 110k clusters with >50 net counts (“secure” detections, Pillepich et al. 2018)
- 23k clusters with accurate redshift determination from X-ray alone
- ~2k clusters with accurate temperature determination from X-ray spectra

From X-ray photons to cosmology



Weak lensing mass calibration

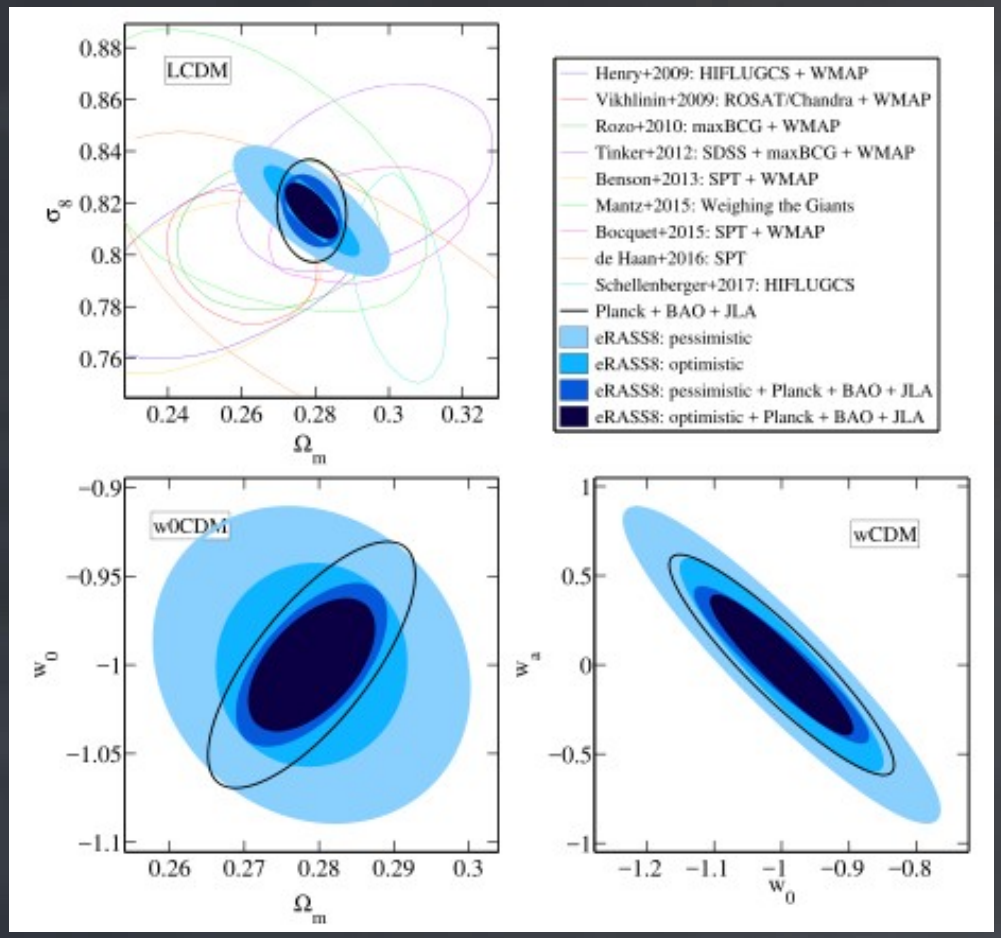
- Weak gravitational lensing is the best way of calibrating the mass scale of eROSITA clusters



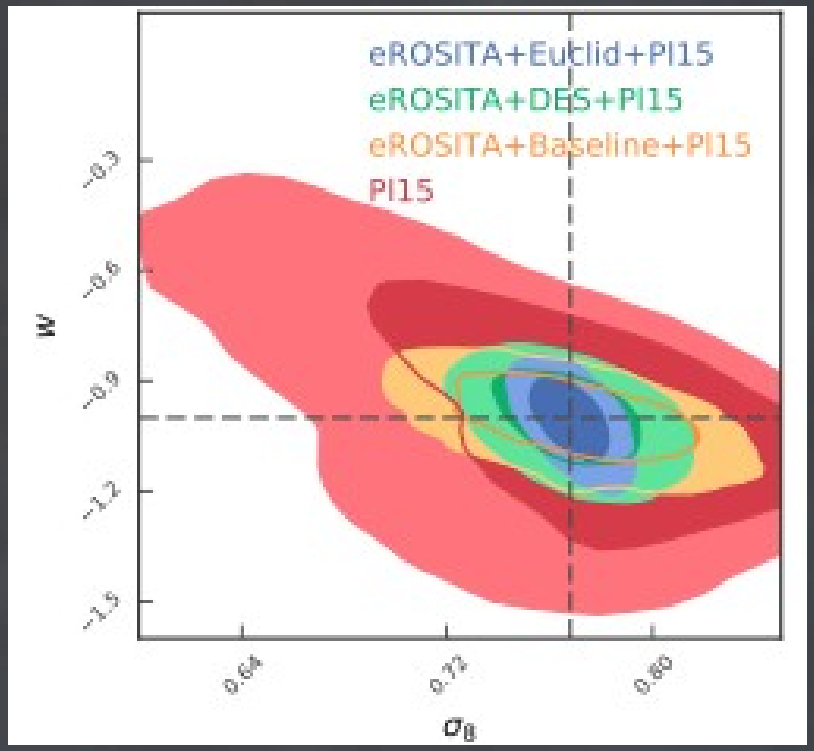
Sereno et al. in prep.

Subaru-HSC will provide mass calibration of ~2,000 eROSITA clusters with a precision of 2 %

Dark energy forecasts



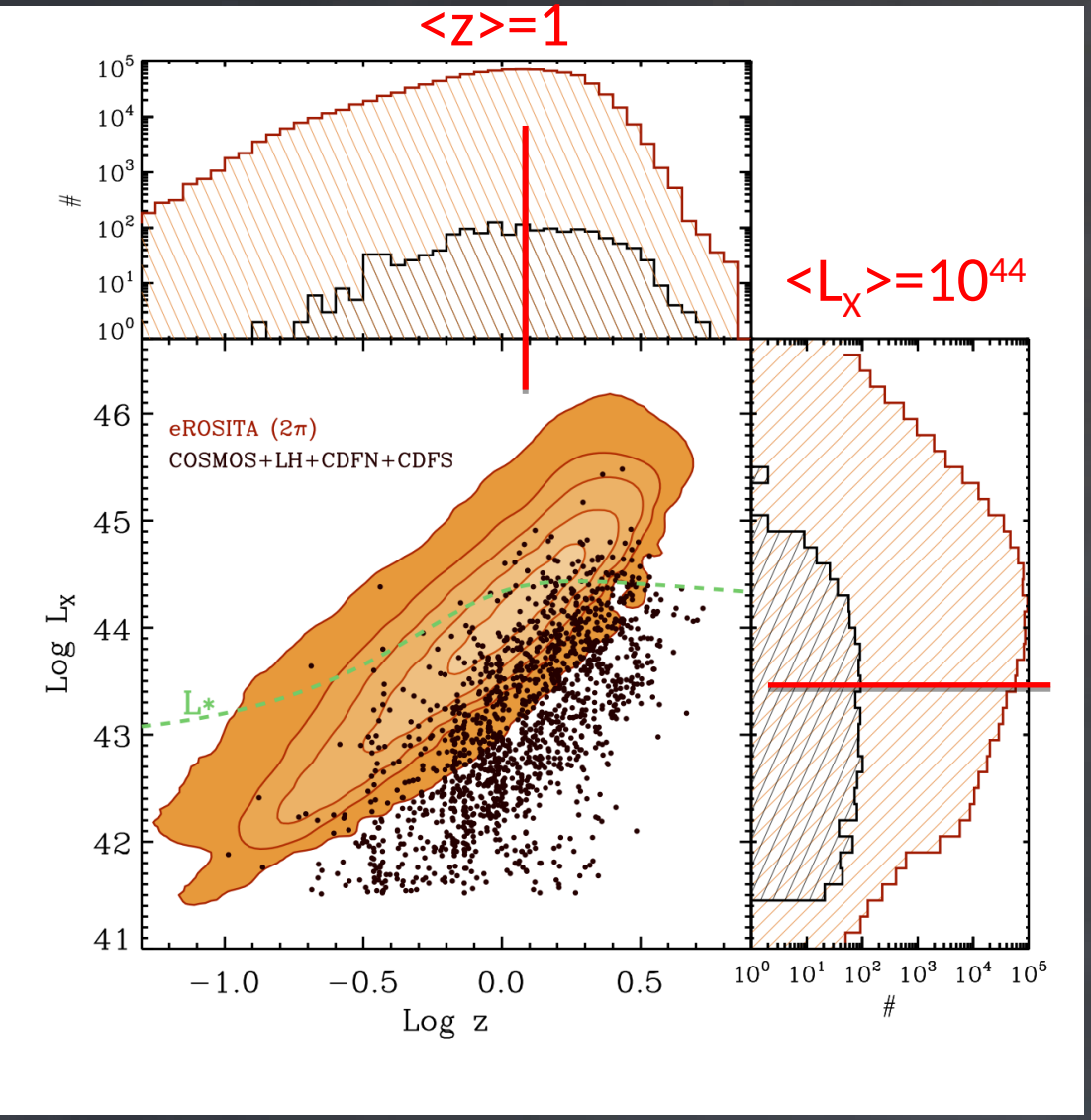
Pillepich et al. 2018



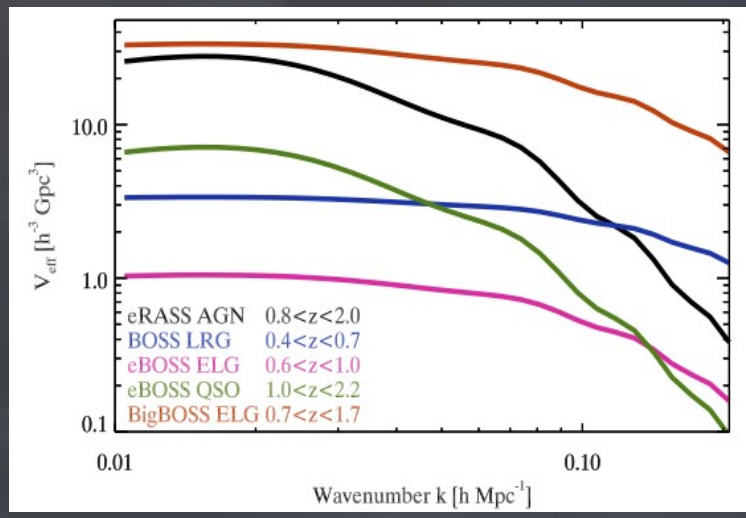
Grandis et al. 2018

eROSITA will bring the first constraints on time evolution of the dark energy equation of state

3 Million AGN: Physics and Cosmology



- Population studies
- The most luminous AGN, tracers of large scale structure: the "quasar" mode of AGN feedback
- (Obscured) accretion history
- High-z AGN
- Huge effective volume, BAO signal with biased tracers
- SED vs. L, L/L_{EDD}

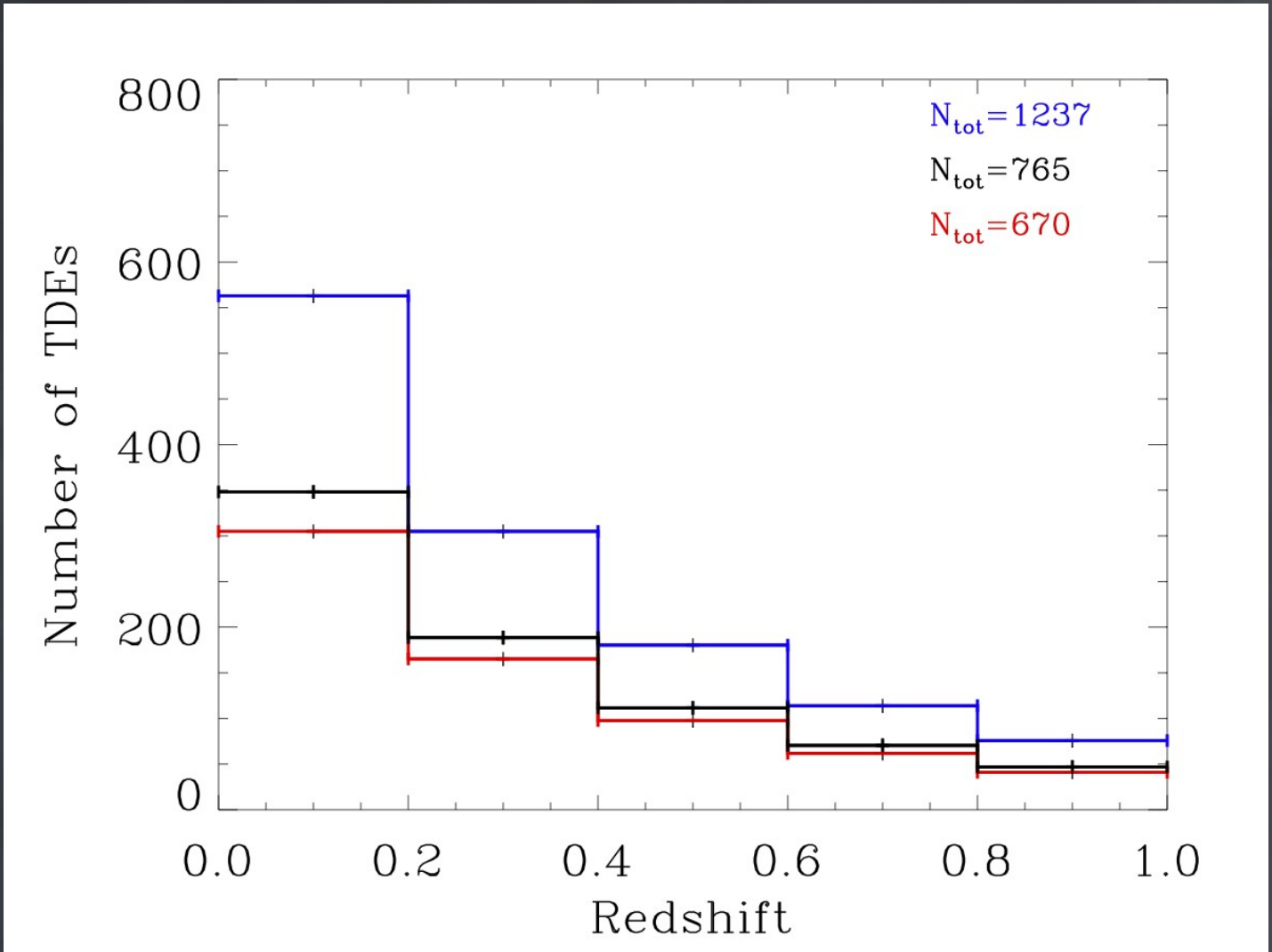


Effective Volume

Spectroscopic follow-up

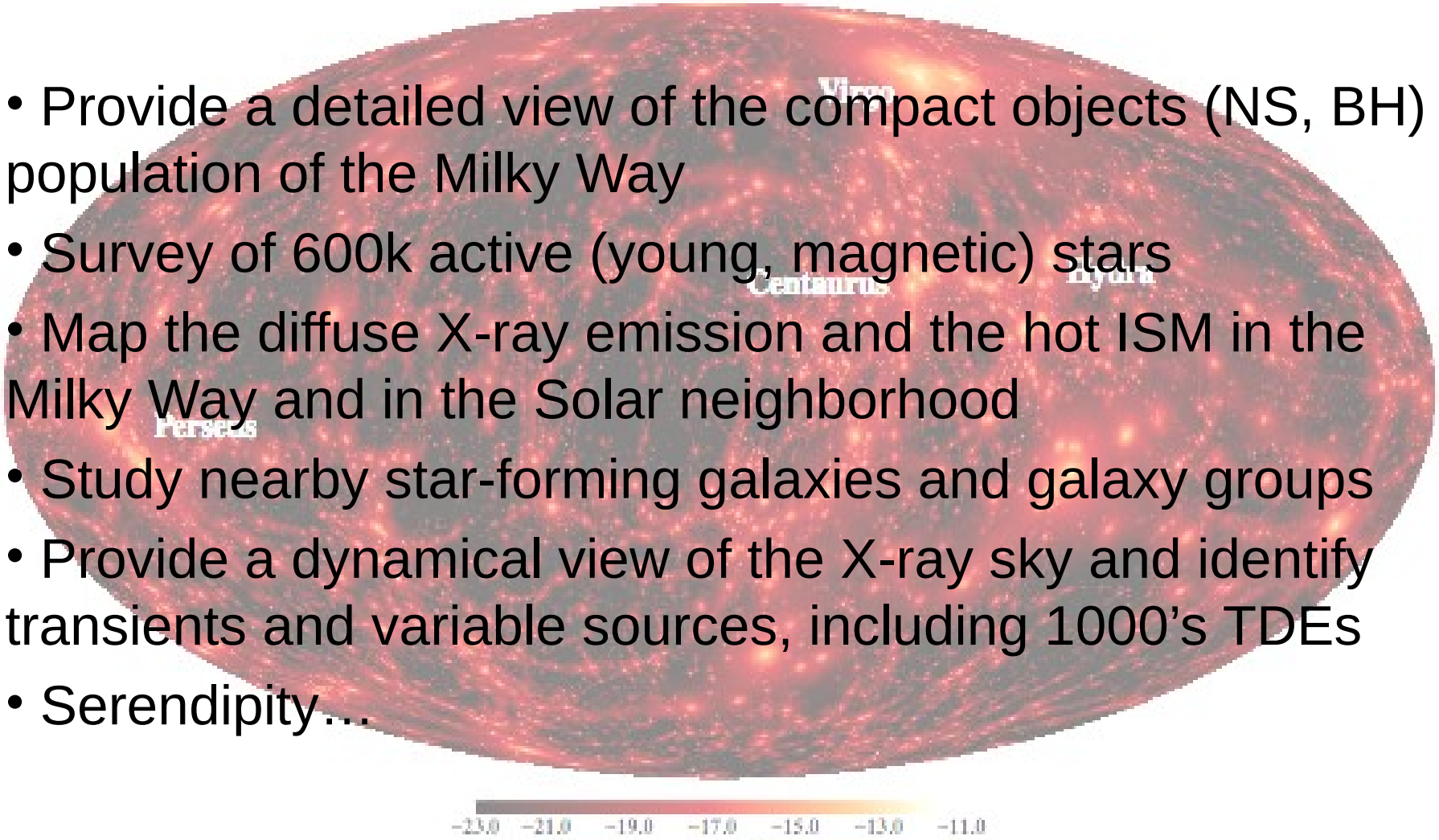
- **SDSS-V (2020-2024)** www.sdss.org/future/
  - 'Black Hole Mapper' (BHM): SDSS + LCO full-sky coverage complete follow-up of eRASS:3:
    - over ~10,000 deg^2 (250k AGN spectra to r=21.5, 80k galaxies in 10k clusters)
- **VISTA/4MOST (2023-2027)** www.4most.eu
  - Complete, systematic follow-up of both Clusters and AGN from eROSITA: reach >80% completeness for eRASS:8 (down to r~22.8)
  - ~700k AGN spectra 0<z<6
  - ~1M galaxies in ~50k X-ray selected clusters (Clusters clustering, RSD, velocity dispersion, gravitational redshift)

>100 TDEs per month…



# of TDEs in ONE eROSITA all-sky survey (6 months)

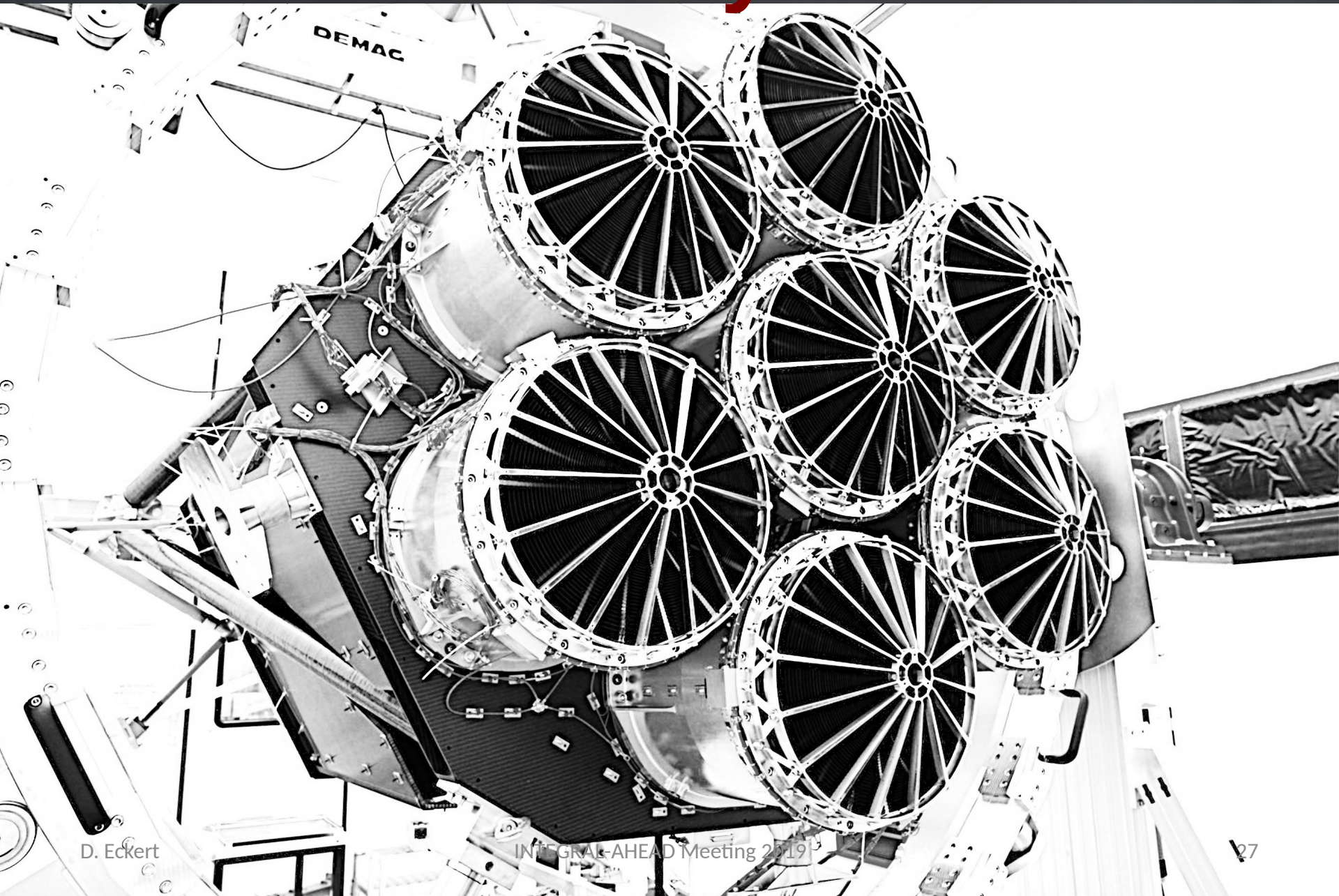
And More…



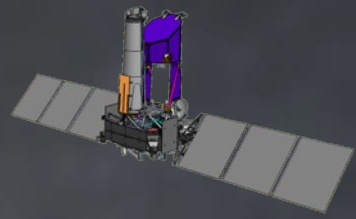
- Provide a detailed view of the compact objects (NS, BH) population of the Milky Way
- Survey of 600k active (young, magnetic) stars
- Map the diffuse X-ray emission and the hot ISM in the Milky Way and in the Solar neighborhood
- Study nearby star-forming galaxies and galaxy groups
- Provide a dynamical view of the X-ray sky and identify transients and variable sources, including 1000's TDEs
- Serendipity…

[eROSITA Science Book: Merloni et al. 2012, arXiv:1209.3114]

Thank you!



Working with eROSITA



- **eROSITA is a PI instrument**
  - Scientific exploitation of data shared between the partners: 50% MPE and 50% IKI, West/East (gal. coord.)
  - German data public after 2 years, 3 releases (‘20, ‘22, ‘24; TBC)
  - Proprietary access via eROSITA_DE (/RU) consortium
  - Projects/papers regulated by working groups
- **Working Groups:**
  - Science: Clusters/Cosmology, AGN, Normal galaxies, Compact objects, Diffuse emission/SNR, Stars, Solar System, Time Domain Astrophysics
  - Infrastructure: Data analysis and catalogues, Multiwavelength follow-up, Calibration, Background
- **Collaboration policy:**
  - Individual External Collaborations (proposal to WGs)
  - Group External Collaborations (team-to-team MoUs)

RASS (ROSAT) vs. eROSITA vs. XMM

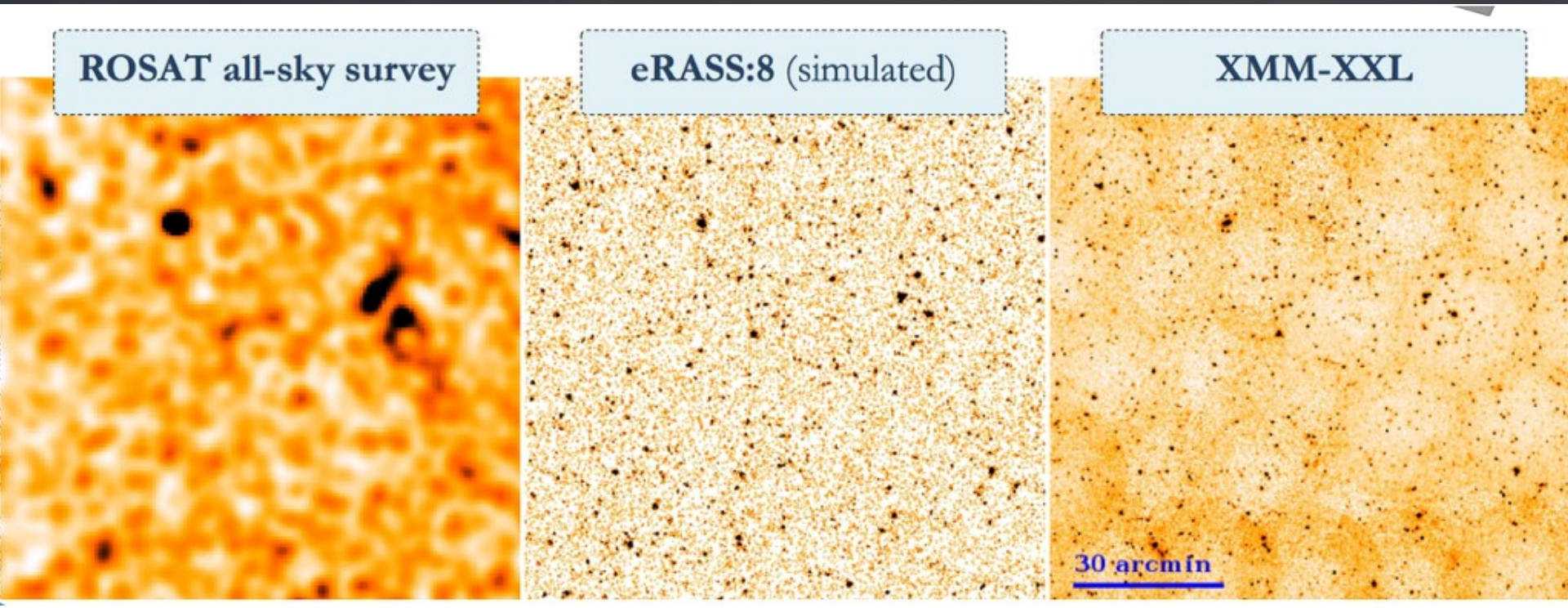
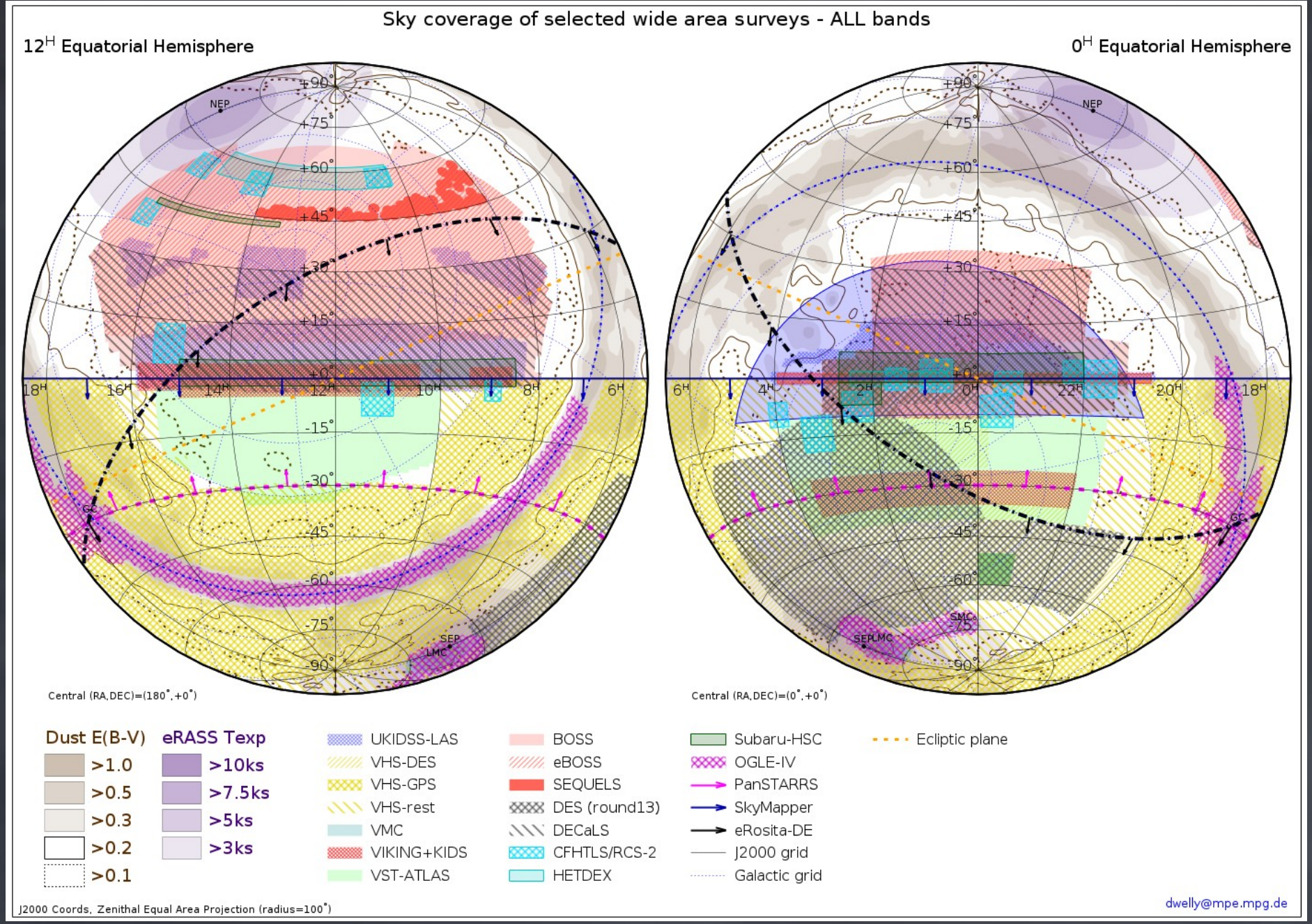


Image credits: MPE, eRosita_DE consortium, XMM-XXL


Sky coverage of selected wide area surveys - ALL bands
12H Equatorial Hemisphere
0H Equatorial Hemisphere
NEP
SEP
LMC
SMC
GC
Central (RA,DEC)=(180°,+0°)
Central (RA,DEC)=(0°,+0°)
Dust E(B-V)
>1.0
>0.5
>0.3
>0.2
>0.1
eRASS Texp
>10ks
>7.5ks
>5ks
>3ks
UKIDSS-LAS
VHS-DES
VHS-GPS
VHS-rest
VMC
VIKING+KIDS
VST-ATLAS
BOSS
eBOSS
SEQUELS
DES (round13)
DECaLS
CFHTLS/RCS-2
HETDEX
Subaru-HSC
OGLE-IV
PanSTARRS
SkyMapper
eRosita-DE
J2000 grid
Galactic grid
Ecliptic plane
J2000 Coords, Zenithal Equal Area Projection (radius=100°)
dwelly@mpe.mpg.de