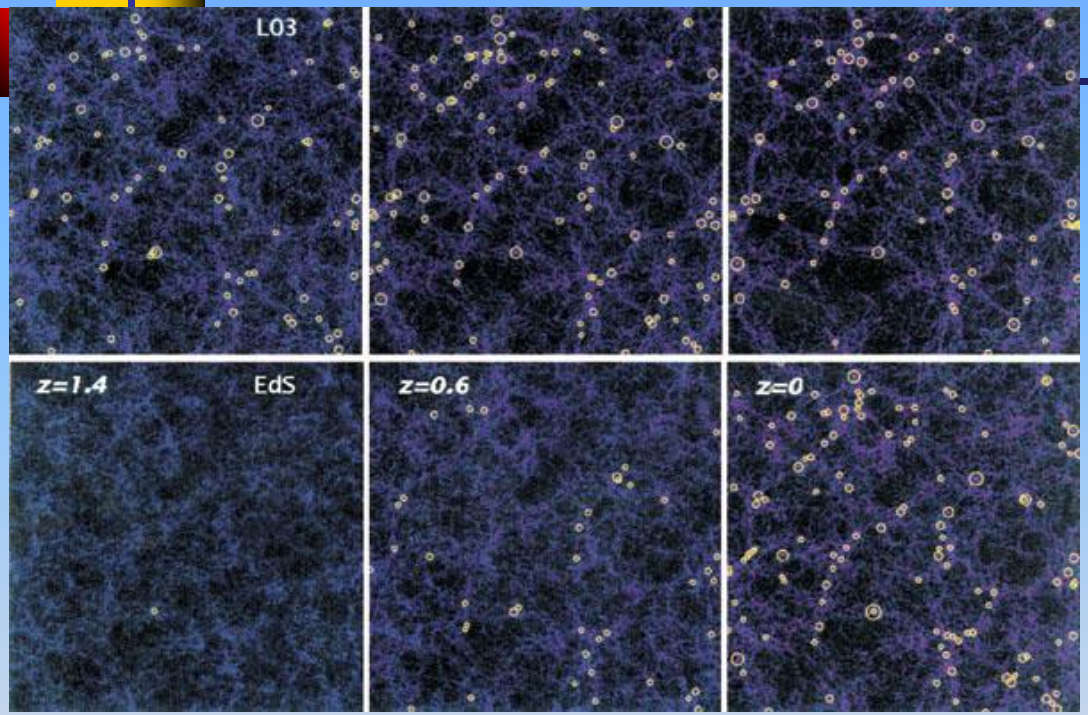
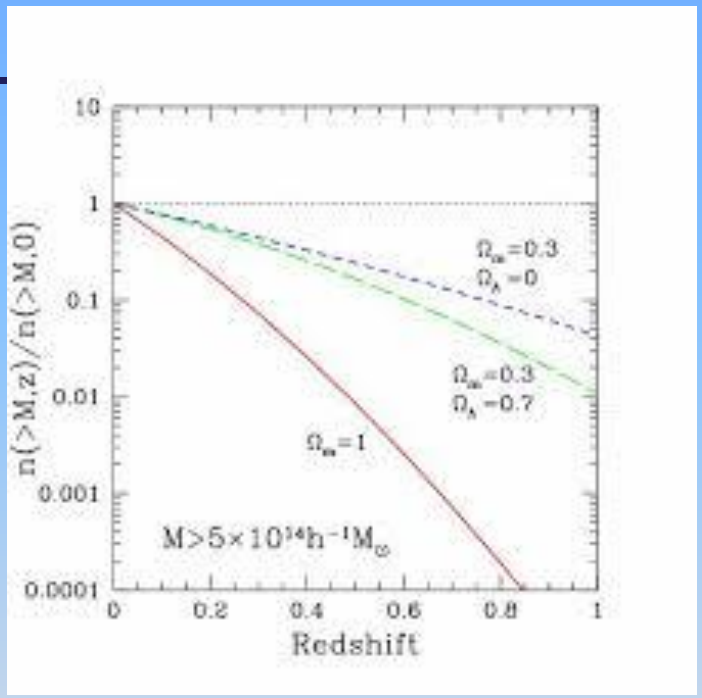
Future LSS surveys with eROSITA and 4MOST





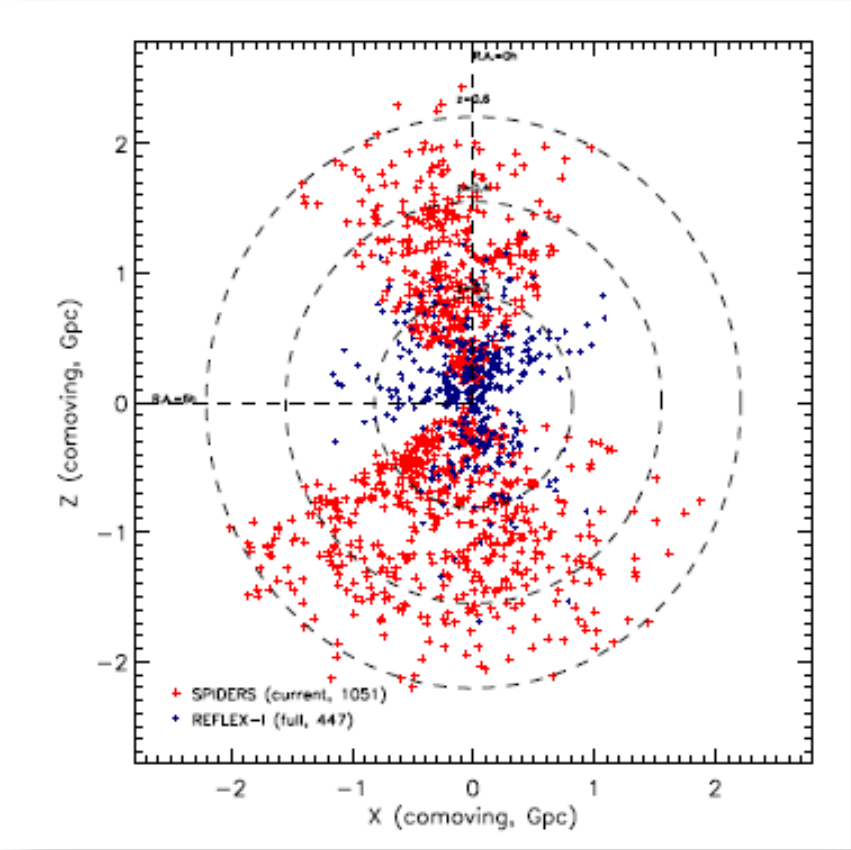
Rosati, Norman, Borgani 2002

Alexis Finoguenov

X-ray cluster identification

Point source+by eye **BCS, REFLEX, NORAS, MACS**	**Point source+optical survey** **CODEX, RASSinDES**
Extended source+by eye RDCS, 400 sq.deg., SPT	Extended source+optical survey COSMOS, CDFS, AEGIS, SXDF, XMM-XXL

Galaxy clusters: status (1 yr ¾)



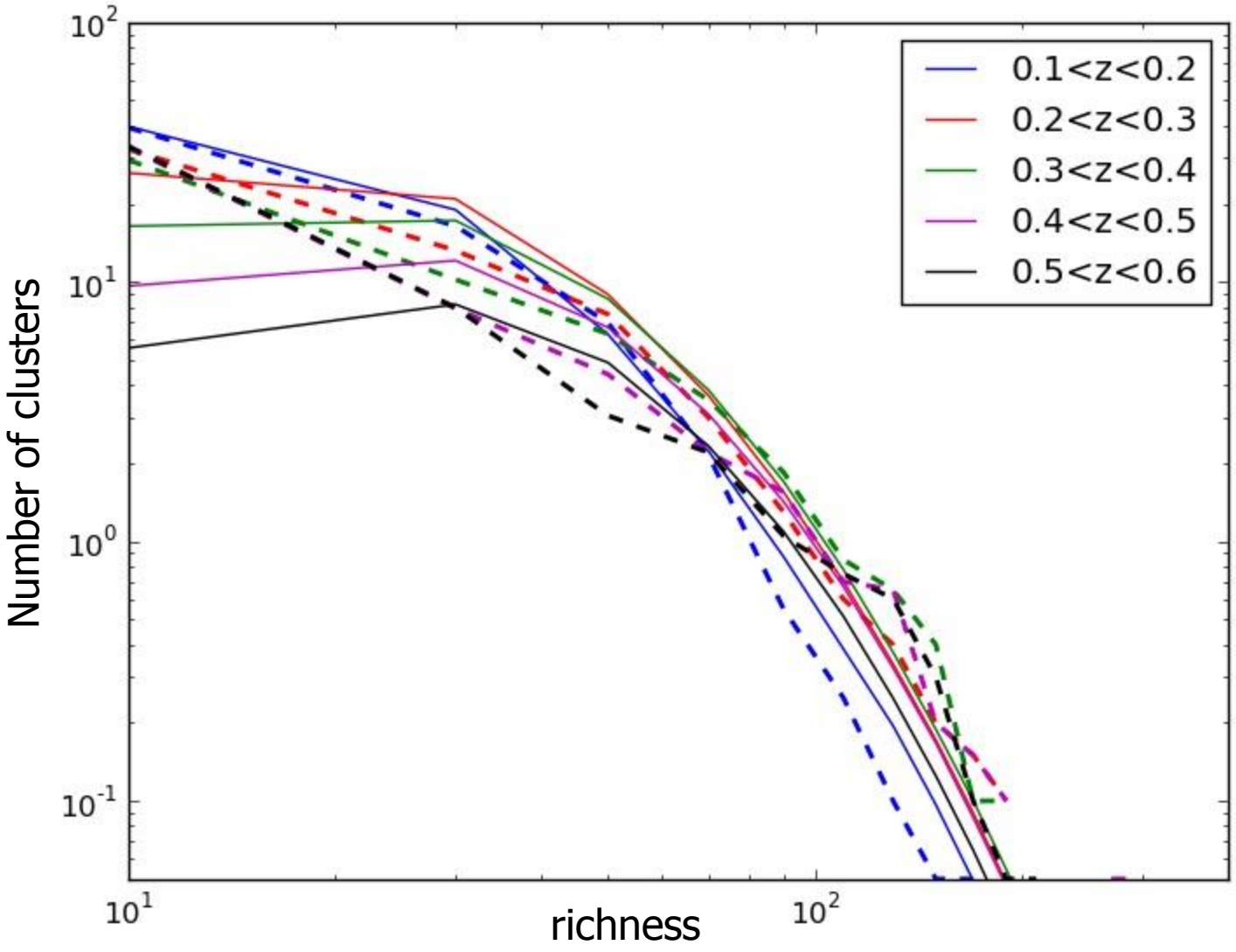
Status 2016-03-29 (CODEX)

1942 candidates richness > 10

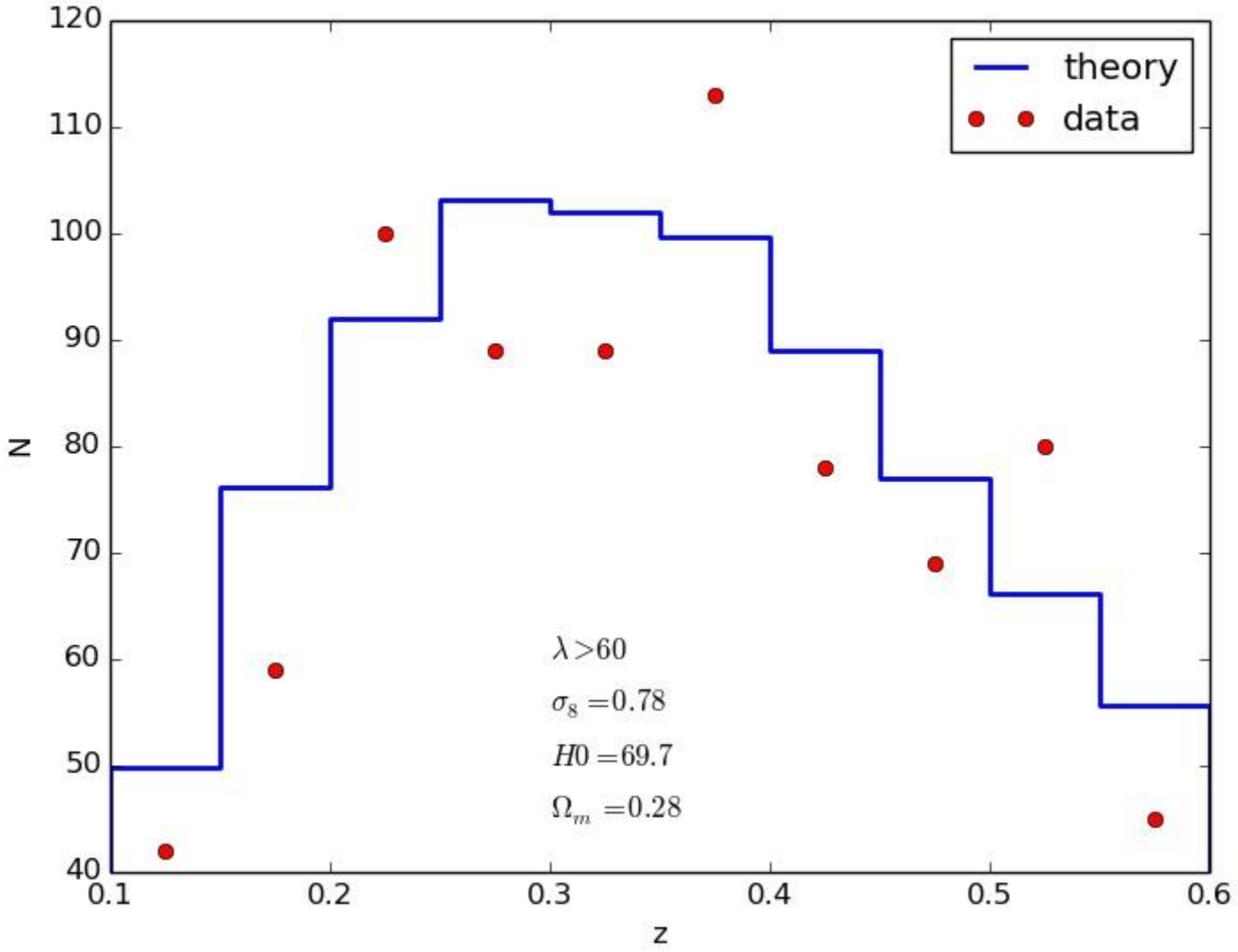
- 1307 *Nspec >3*
- 754 *Nspec >10*
- 427 *Nspec >15*

Of them: **1600/1942** completed

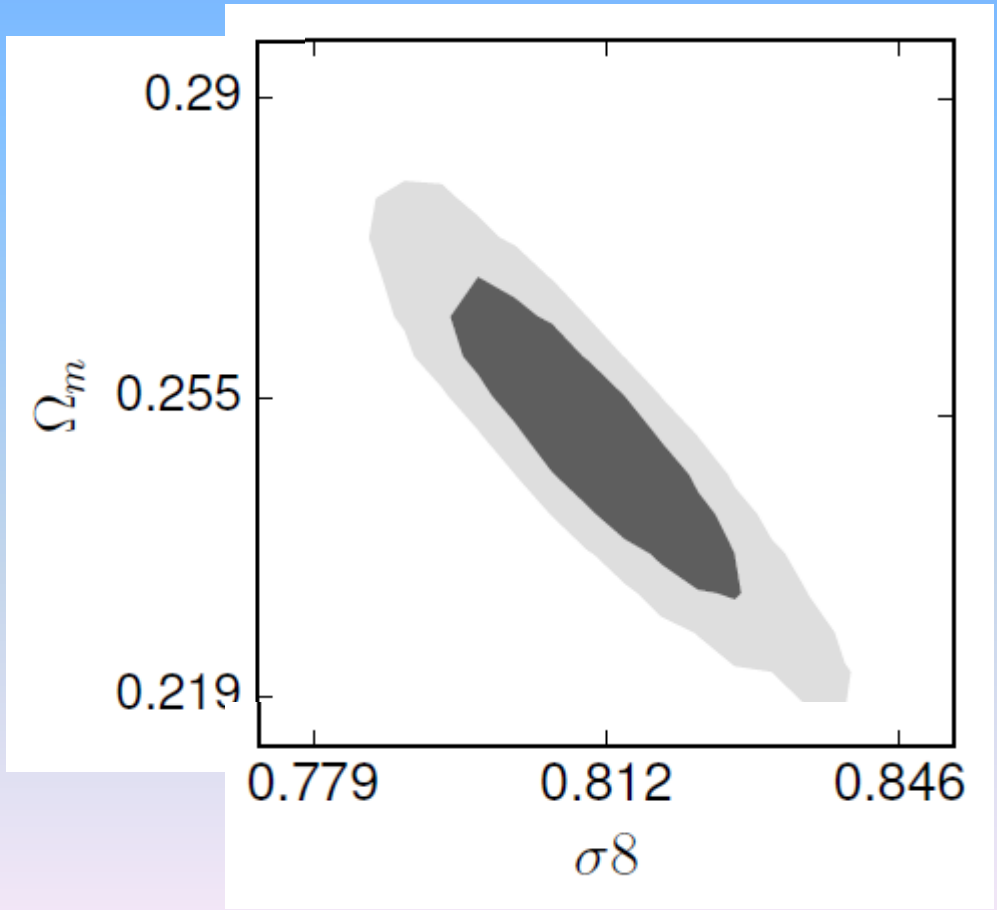
- 1051 *Nspec >3*
- 630 *Nspec >10*
- 369 *Nspec >15*


Number of clusters
richness
10^2
10^1
10^0
10^{-1}
10^1
10^2
0.1<z<0.2
0.2<z<0.3
0.3<z<0.4
0.4<z<0.5
0.5<z<0.6

Rich clusters seems fine

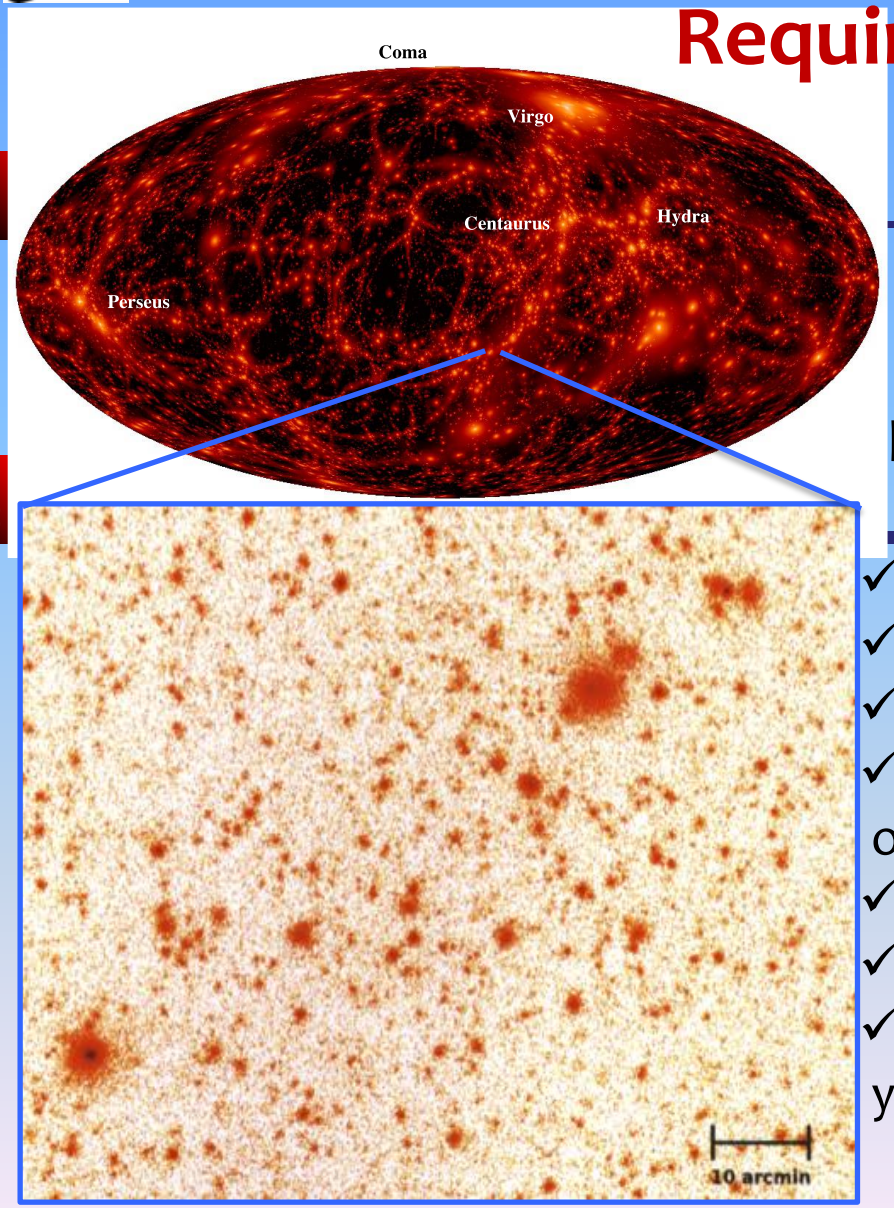


Cosmology from richness function



This is intermediate results, used to produce covariance matrix

Mapping the structure of the hot Universe: Requirements



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

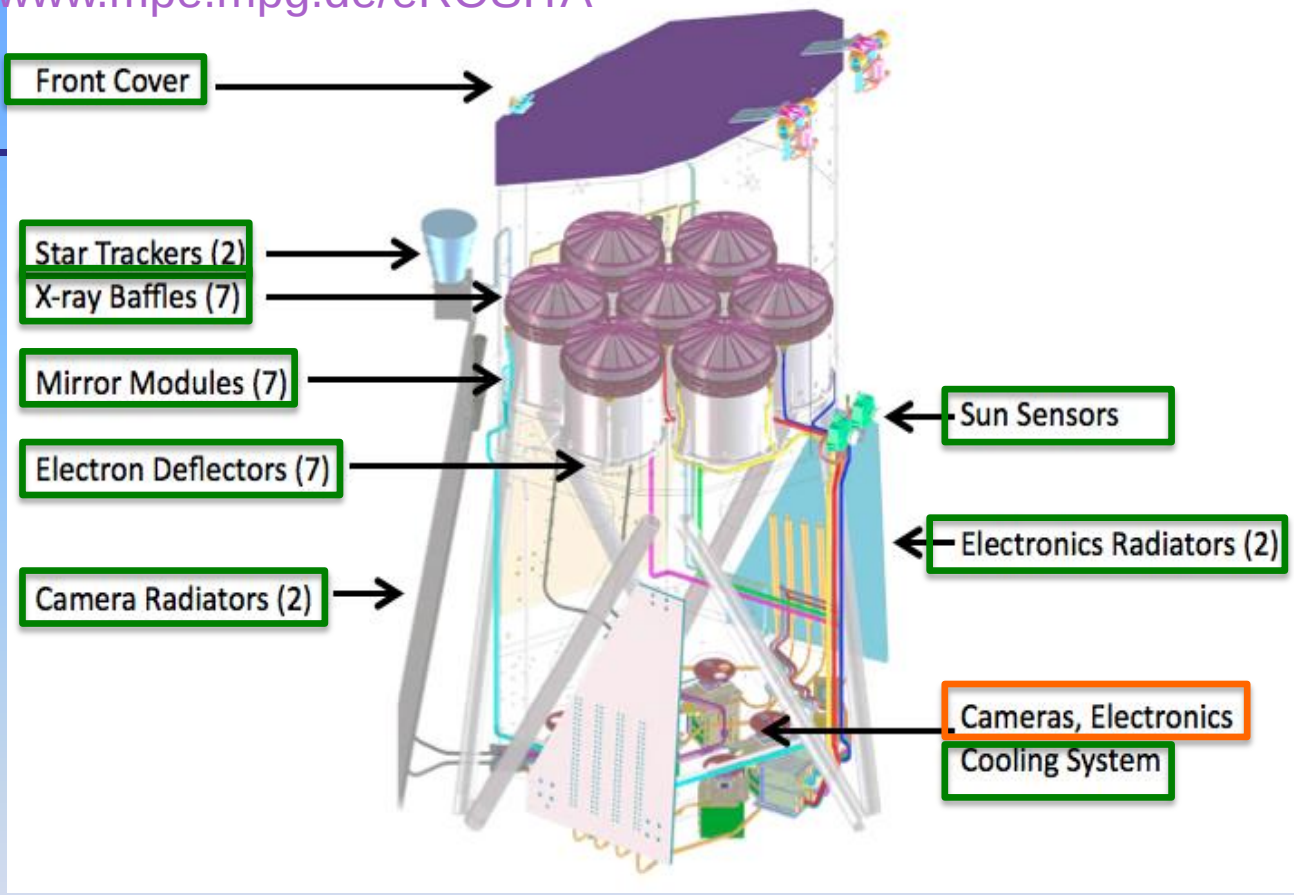
Detect 100.000 Clusters of Galaxies

- ✓ All-sky survey sensitivity 6×10^{-14} erg/cm^2/s
- ✓ Deep survey field(s) (~100 deg^2) to 1×10^{-14}
- ✓ Individual pointed observations
- ✓ Moderate angular resolution (<30“ aver. over FoV)
- ✓ Large collecting area (> 2000 cm^2 @1keV)
- ✓ Large FoV (1° Ø)
- ✓ Long duration survey: 4 years ← → 1/2 year (ROSAT)

The eROSITA telescope

Telescope structure

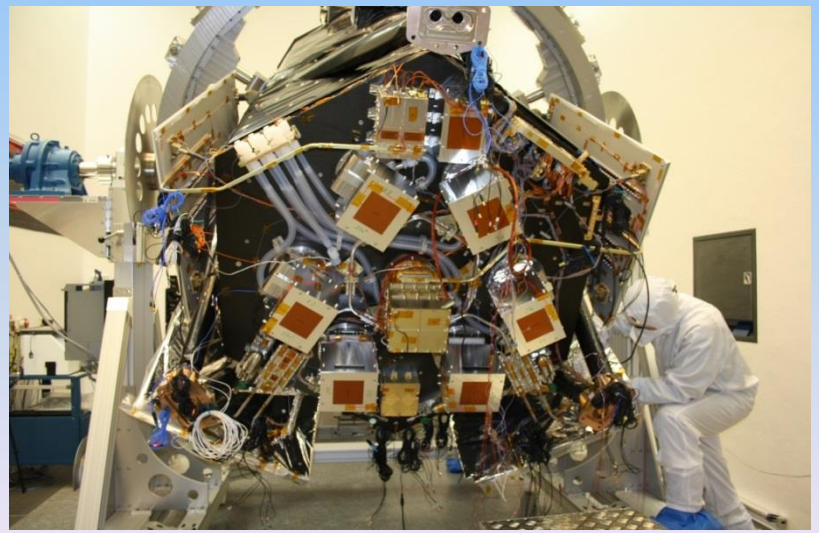
www.mpe.mpg.de/eROSITA



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

7 identical telescopes (Wolter-I/ pnCCD-cameras)
Energy range: 0.3-8 keV
Energy resolution: ~136 eV @ 6 keV
Effective Area: ~1400 cm² (@1keV)
PSF: 15“ onaxis

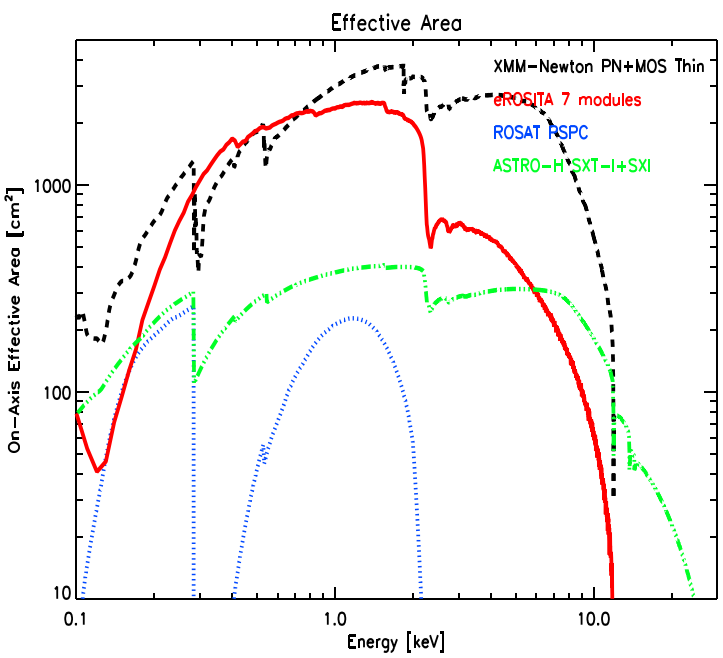
eROSITA Hardware

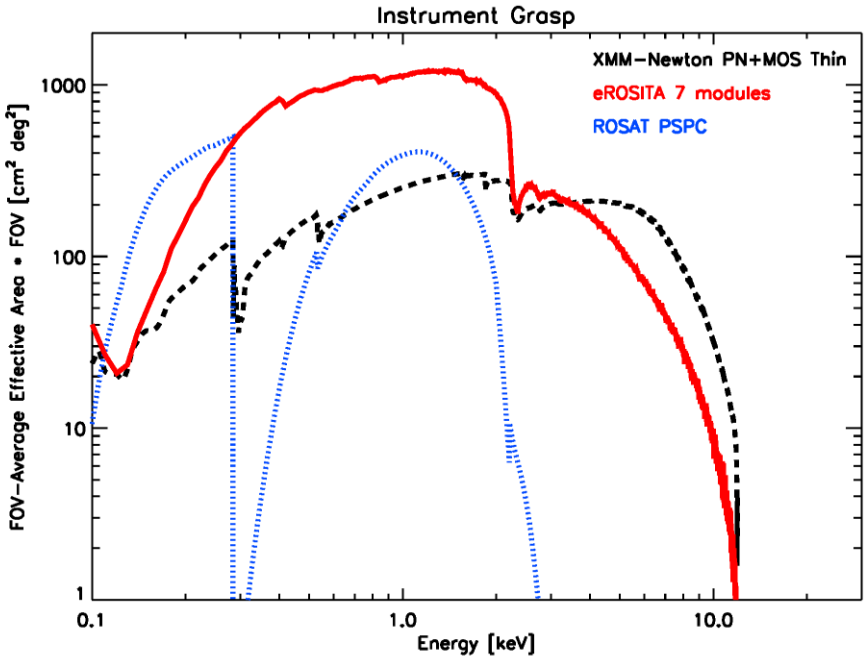


Friedrich et al, 9144-185

Fürmetz et al, 9144-192

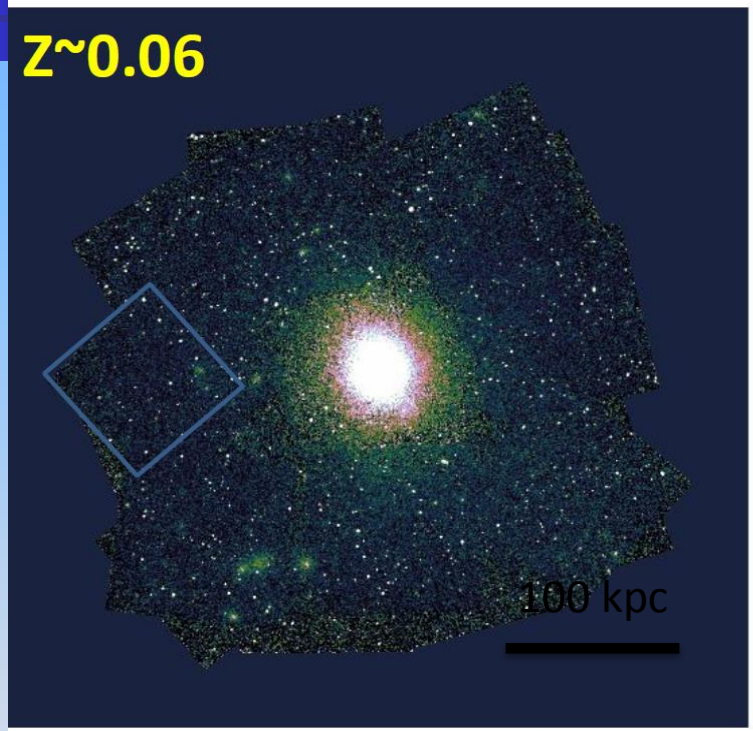
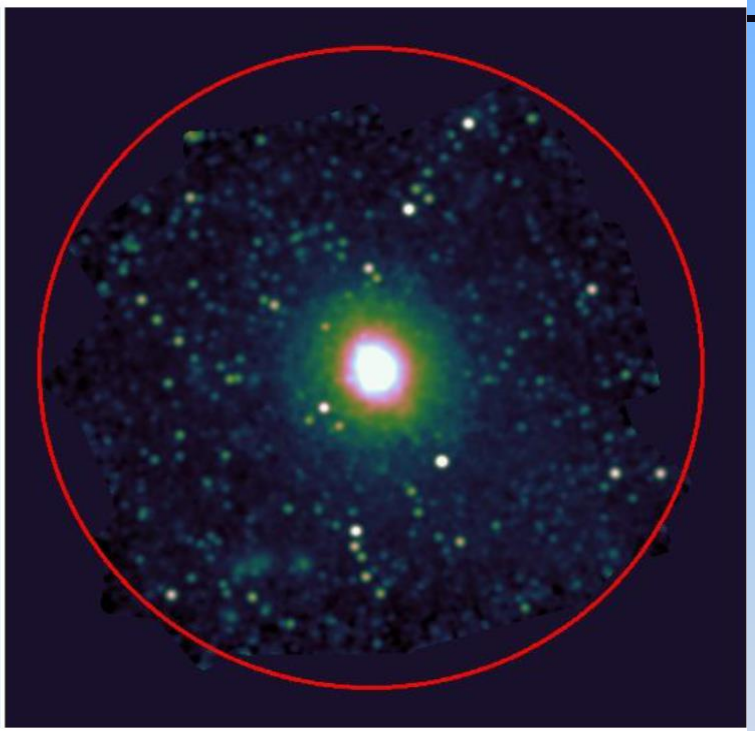
Effective Area and Grasp





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

A fast survey machine

Chandra	eRosita
	
~30 pointings ~2 Msec [0.5” HEW]	~1 pointing, ~80 ksec [26” HEW (FoV avg)]

Churazov, IKI, MPA

eROSITA extragalactic sky

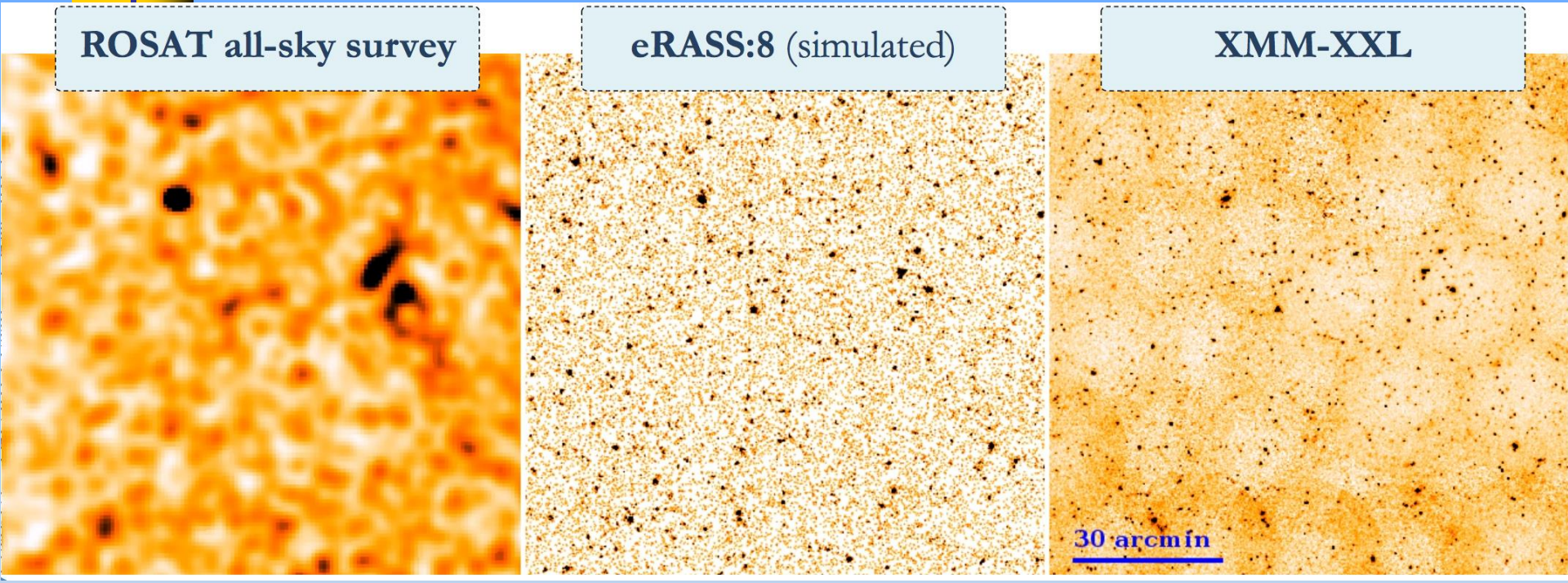
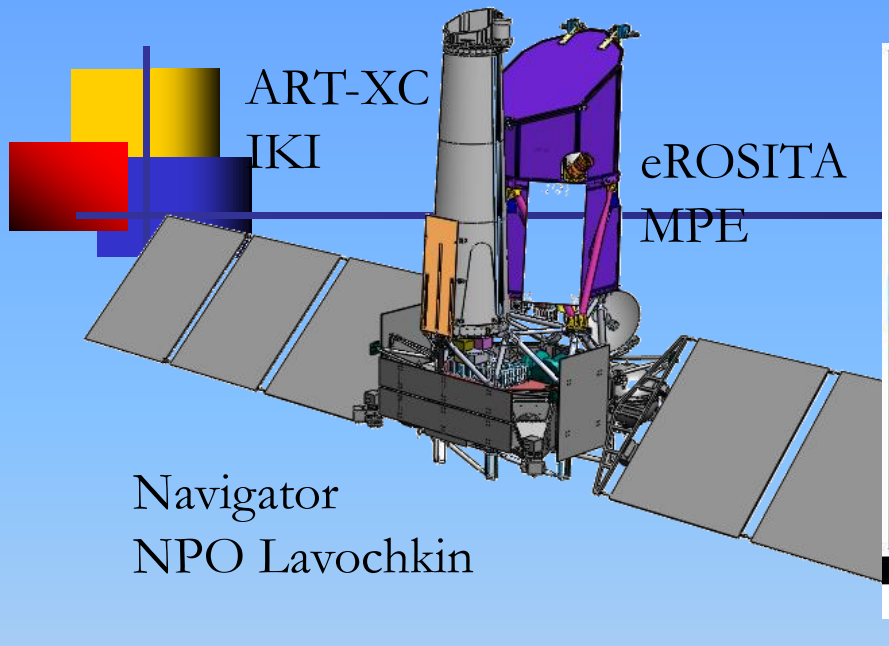
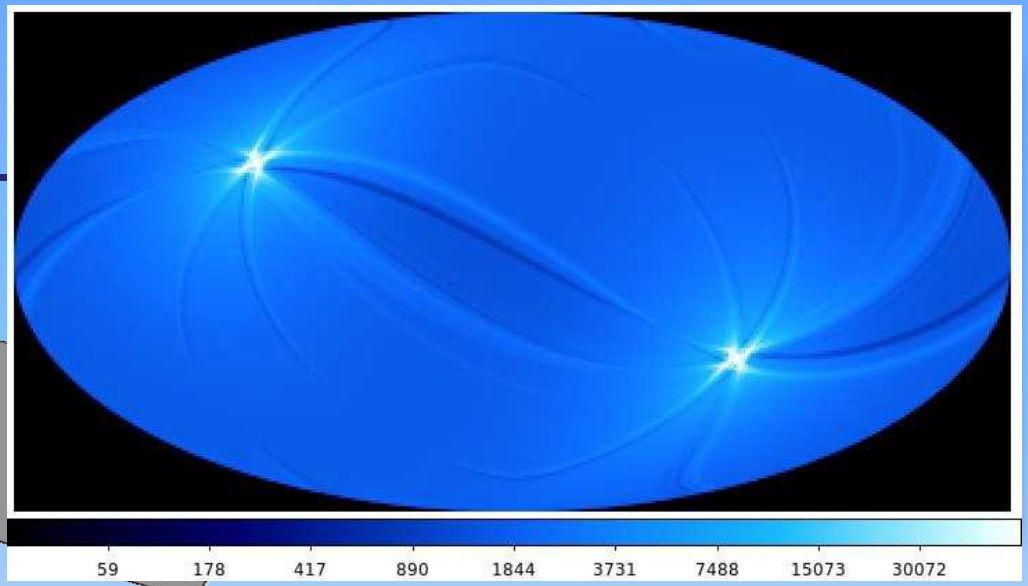


Image credits: MPE, eRosita_DE consortium, XMM-XXL

Wide-area census of galaxy clusters (10^5) and active galactic nuclei (10^6)

RG: Mission timeline

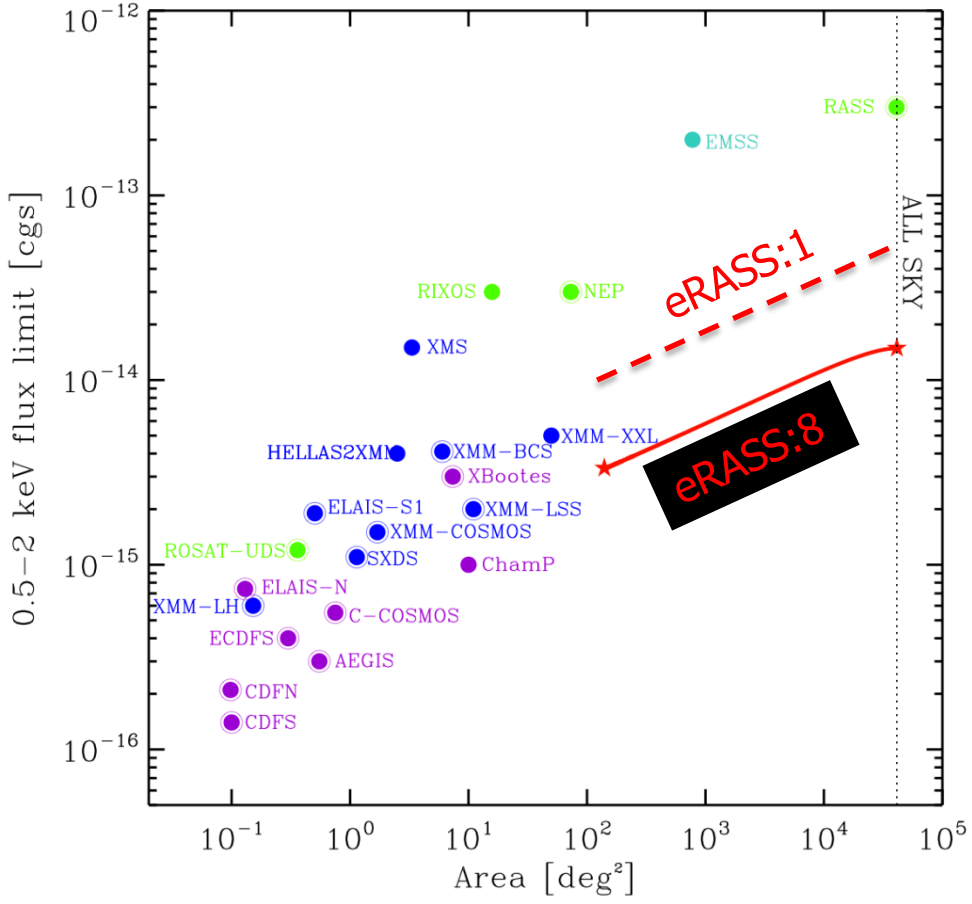




- **eROSITA delivery to Russia**: Q4 2016
- **Launch readiness:** December 2017 from Baykonour (Zenit+Fregat
- **3 Months:** flight to L2, PV and calibration phase
- **4 years**: 8 all sky surveys eRASS:1-8 (scanning mode: 6 rotations/day)
- **3.5 years**: pointed observation phase, including ~20% GTO. 1 AO per year

eROSITA surveys in context

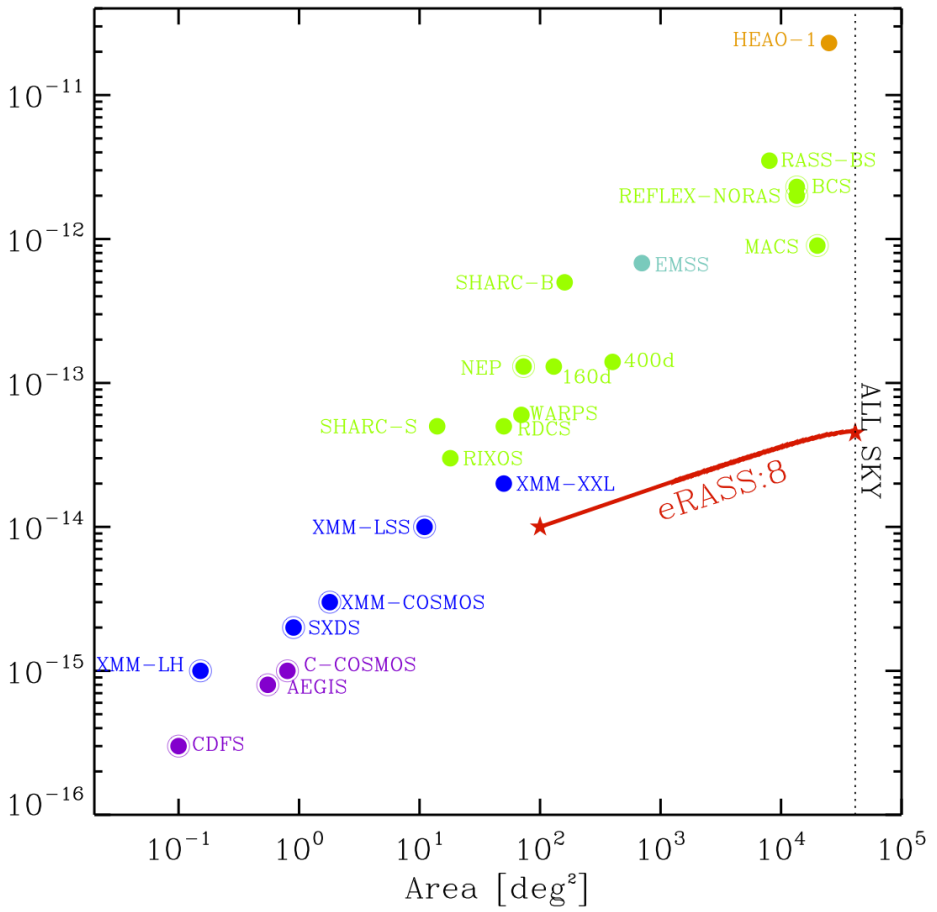
Point sources sensitivity



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

2×10^{-13} (2-10 keV) [erg/cm²/s]

Extended sources sensitivity



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

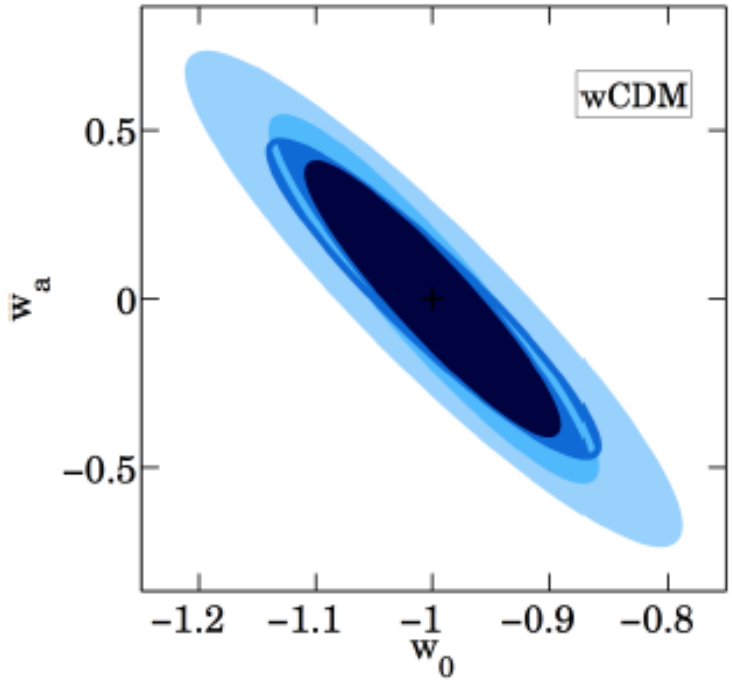
Merloni et al. 2012

eROSITA cosmology forecast

Pillepich, Borm, Reiprich, Porcianni

Results for

- cluster abundance + clustering
- optimistic cases
- wCDM-cosmology



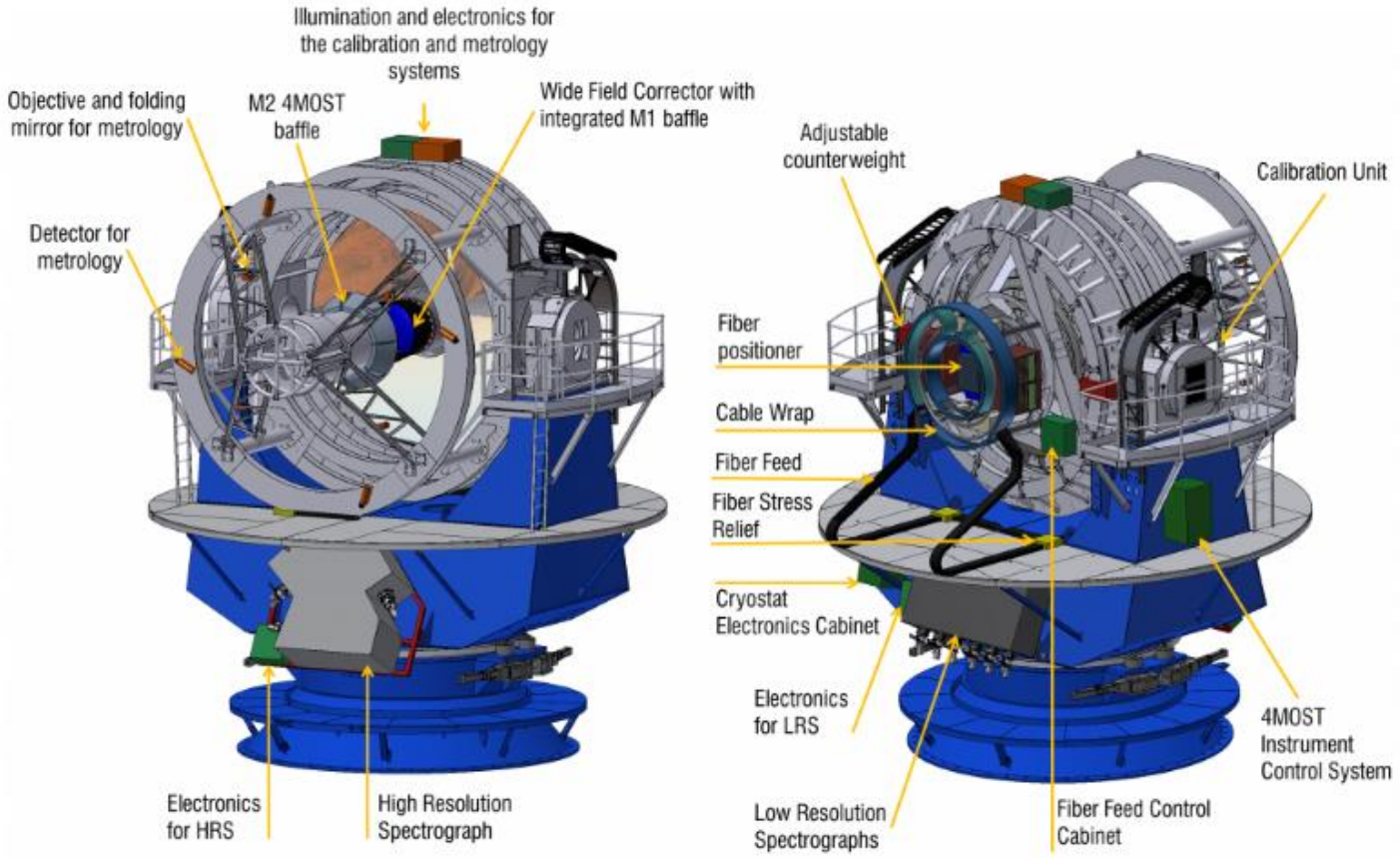
Data	$\Delta\sigma_8$	$\Delta\Omega_m$	Δw_0	Δw_a
eRASS:8	0.011	0.008	0.091	0.36
eRASS:8+Planck	0.007	0.006	0.071	0.27

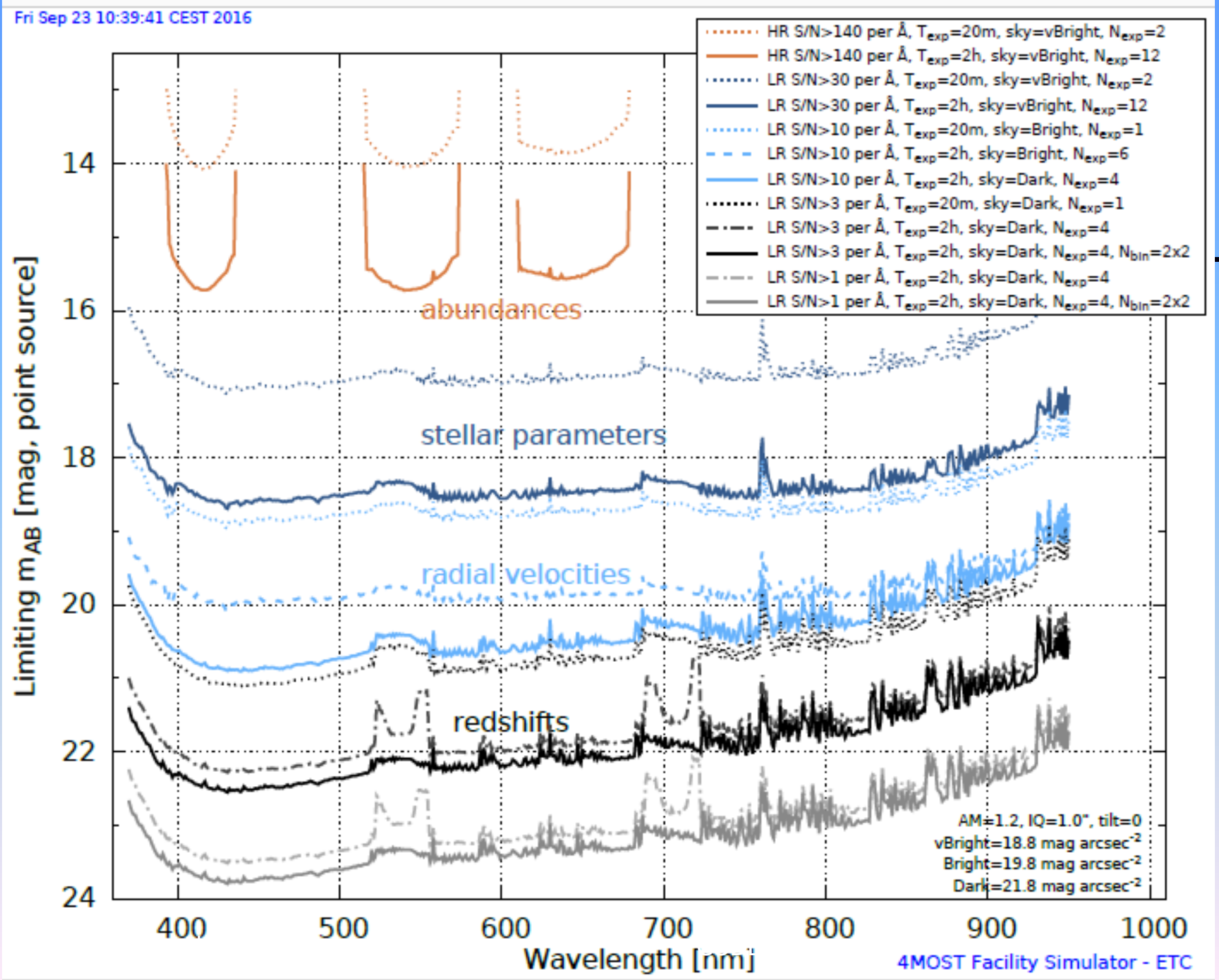
Spectroscopic follow-up

- **North: SDSS IV/SPIDERS (2014-2020), SDSS V proposal**
  - ~8,000 redshifts of RASS & XMMSL AGN (adding in ~10k SDSSI,II,III, almost complete follow-up of r<17 RASS sources) + 4,000 Clusters
  - eROSITA follow-up over a ~1500 deg^2 area in the NGC: reach >80% completeness for eRASS:4 (~35,000 spectra)
- **South: VISTA/4MOST (2021-2026)**
  - Complete, systematic follow-up of both Clusters and AGN from eROSITA: reach >80% completeness for eRASS:8
  - ~1M galaxies in ~50k X-ray selected clusters (Cluster clustering, RSD, velocity dispersion)

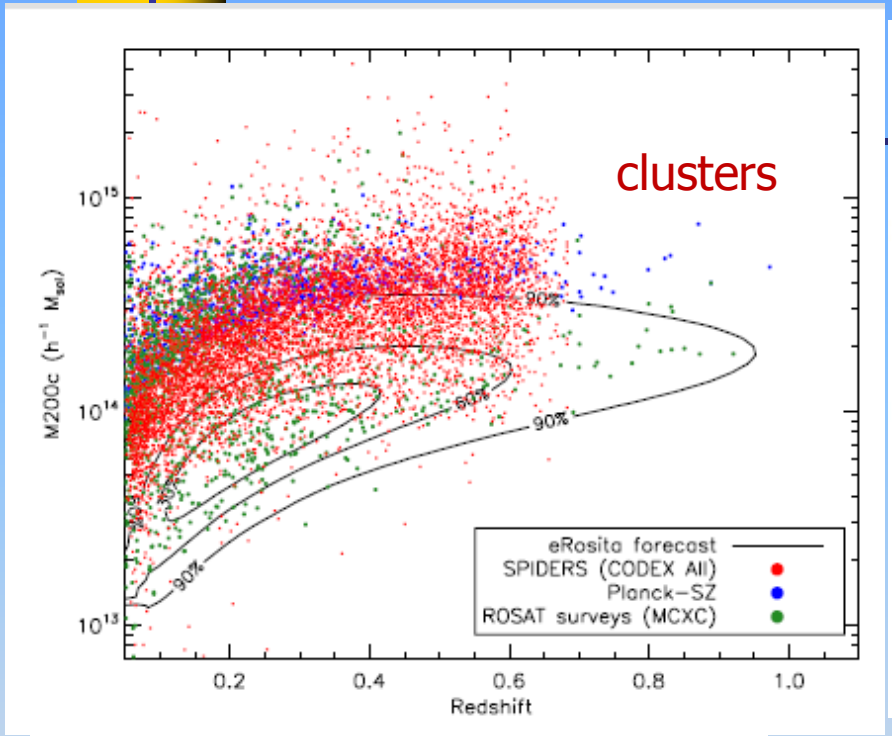
WWW.4MOST.EU

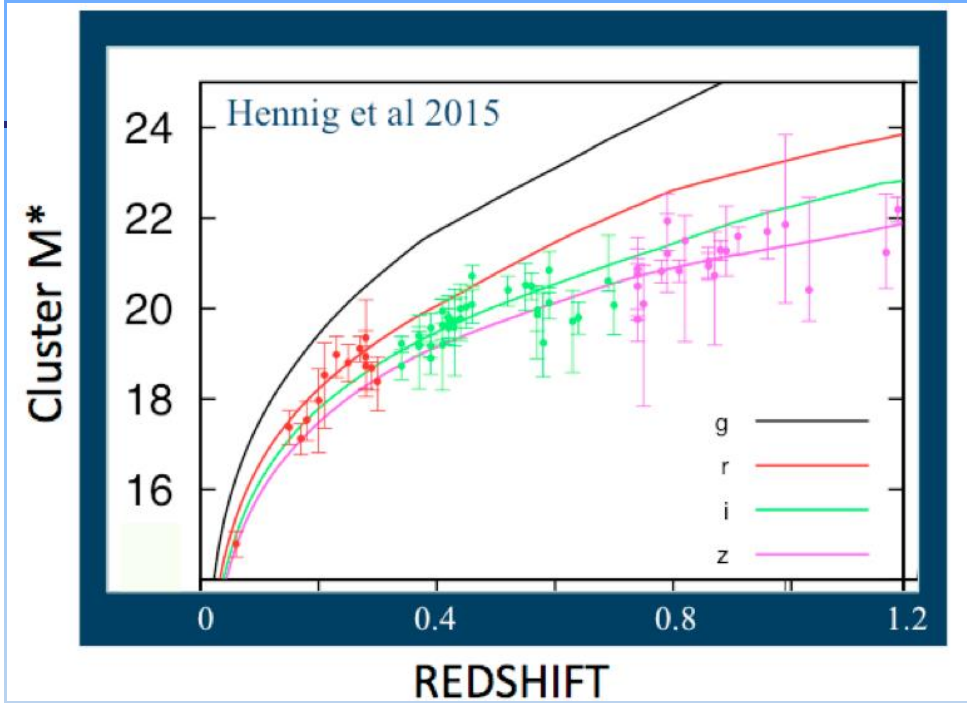
Facility

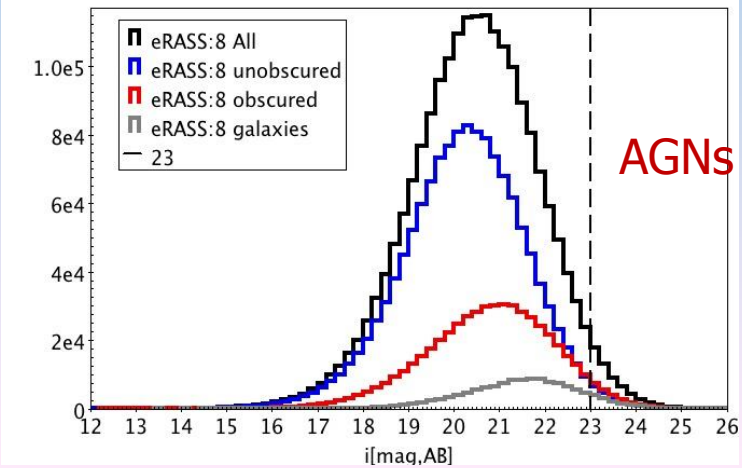



Fri Sep 23 10:39:41 CEST 2016
HR S/N>140 per Å, T_exp=20m, sky=vBright, N_exp=2
HR S/N>140 per Å, T_exp=2h, sky=vBright, N_exp=12
LR S/N>30 per Å, T_exp=20m, sky=vBright, N_exp=2
LR S/N>30 per Å, T_exp=2h, sky=vBright, N_exp=12
LR S/N>10 per Å, T_exp=20m, sky=Bright, N_exp=1
LR S/N>10 per Å, T_exp=2h, sky=Bright, N_exp=6
LR S/N>10 per Å, T_exp=2h, sky=Dark, N_exp=4
LR S/N>3 per Å, T_exp=20m, sky=Dark, N_exp=1
LR S/N>3 per Å, T_exp=2h, sky=Dark, N_exp=4
LR S/N>3 per Å, T_exp=2h, sky=Dark, N_exp=4, N_bin=2x2
LR S/N>1 per Å, T_exp=2h, sky=Dark, N_exp=4
LR S/N>1 per Å, T_exp=2h, sky=Dark, N_exp=4, N_bin=2x2
abundances
stellar parameters
radial velocities
redshifts
Limiting m_AB [mag, point source]
14
16
18
20
22
24
400
500
600
700
800
900
1000
Wavelength [nm]
AM=1.2, IQ=1.0", tilt=0
vBright=18.8 mag arcsec^-2
Bright=19.8 mag arcsec^-2
Dark=21.8 mag arcsec^-2
4MOST Facility Simulator - ETC

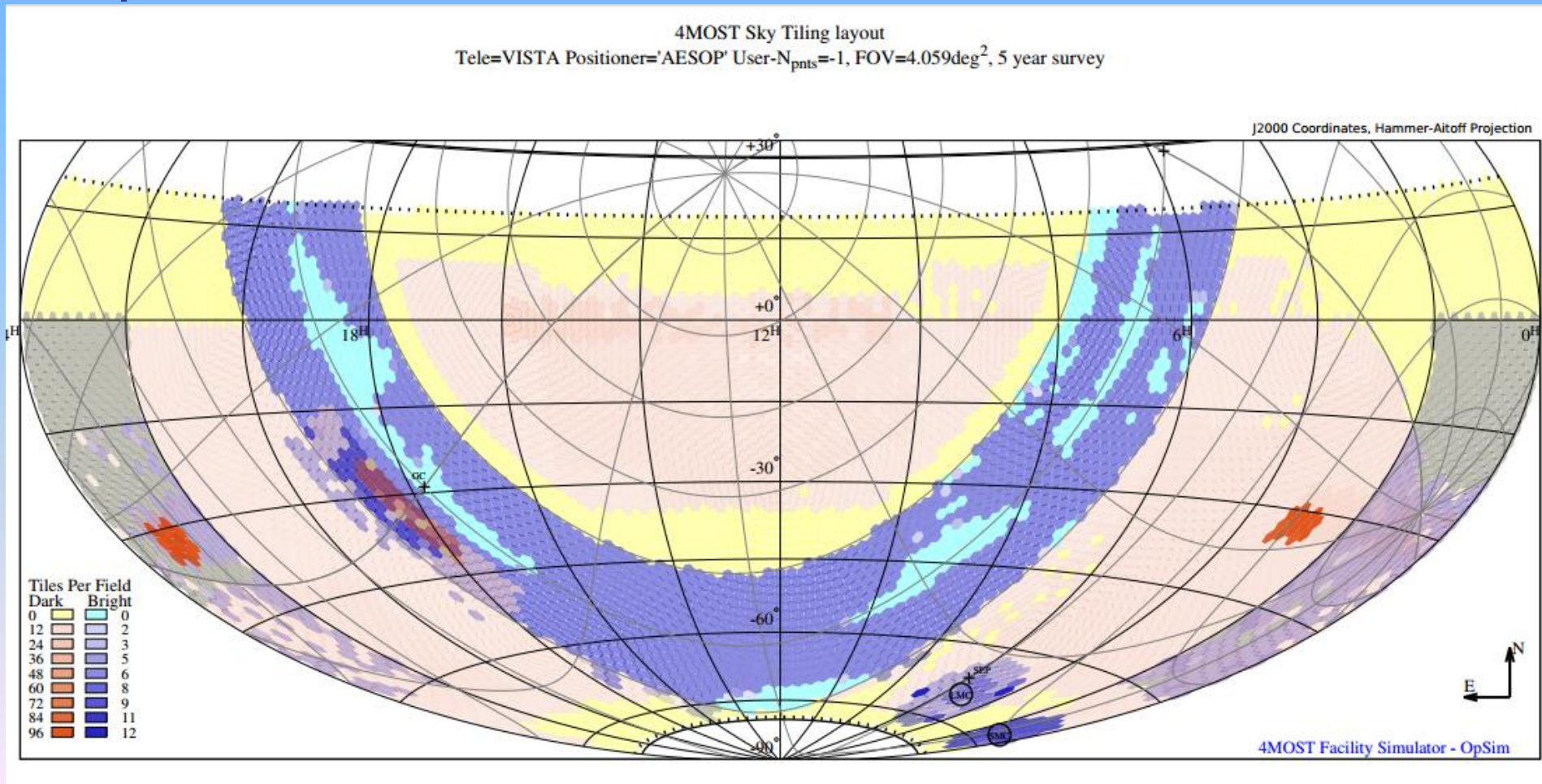
eROSITA targets







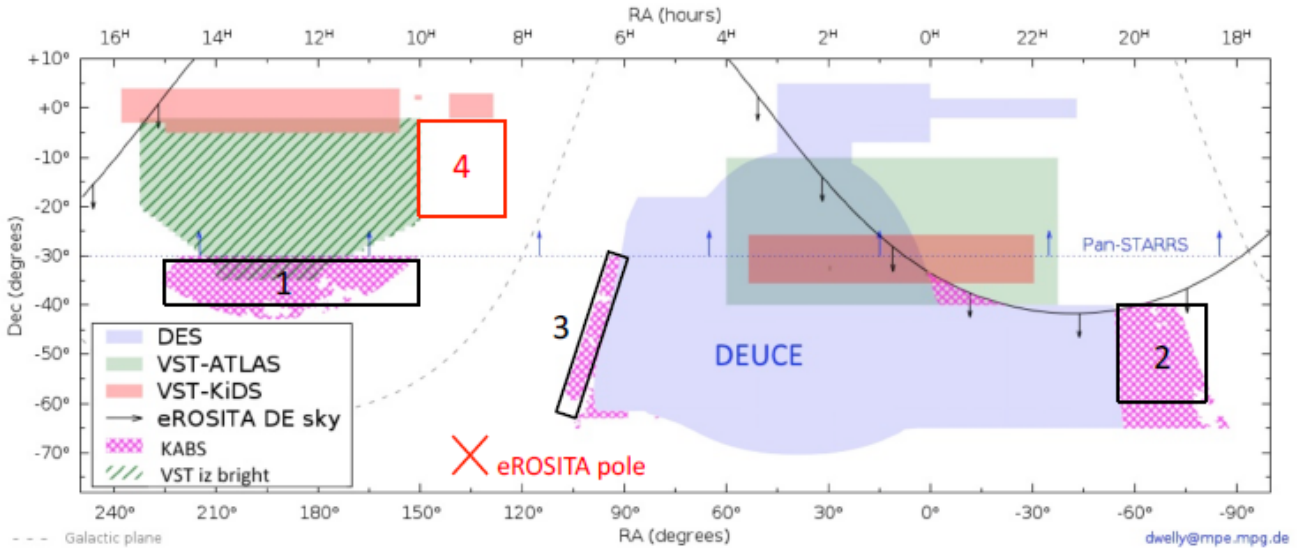
4MOST footprint

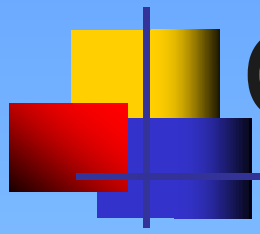


KABS

FINAL KABS areas

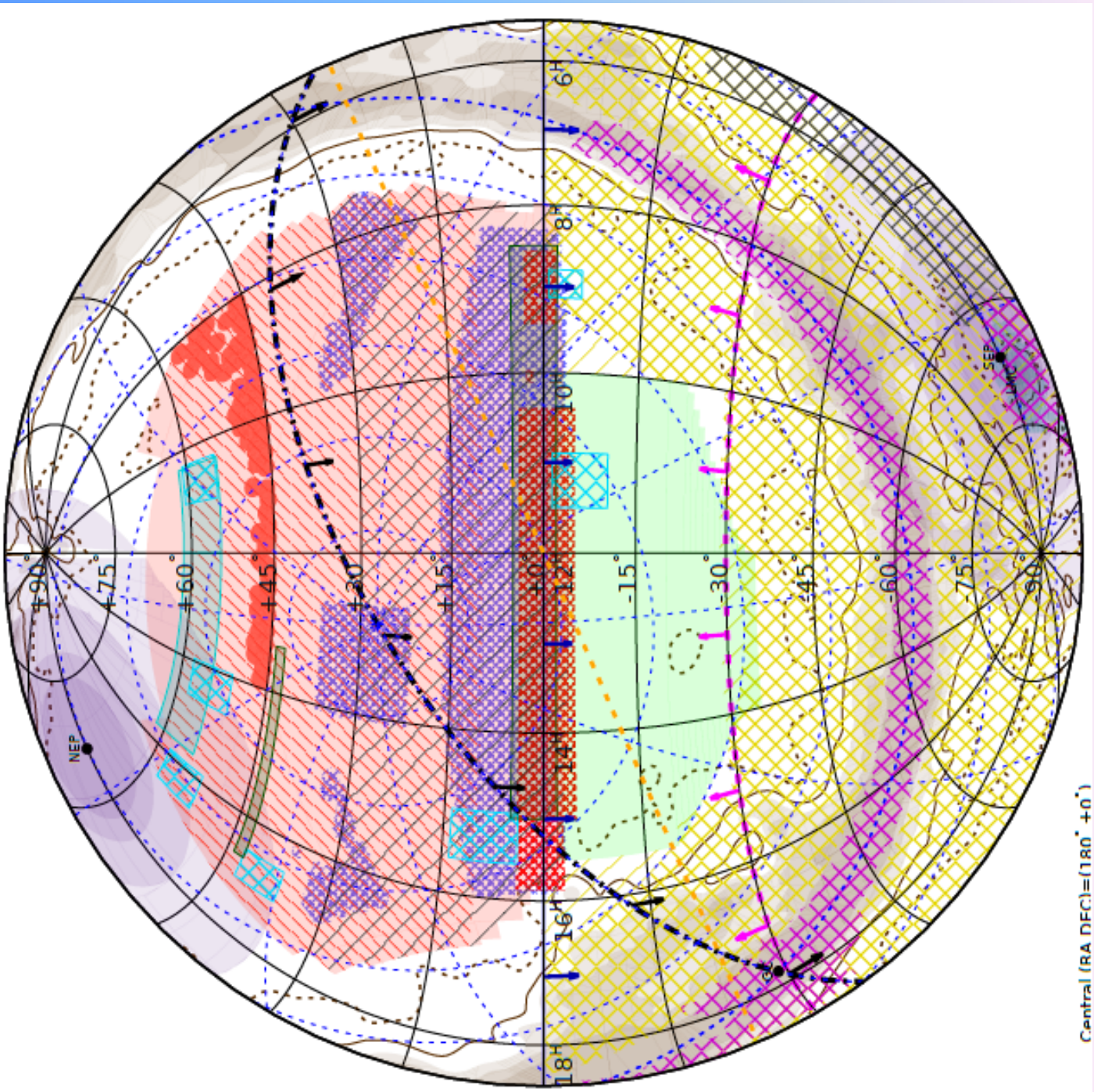
F1 10.5h<RA<15.0h -30<DEC<-42 (~450deg2) DECCam
F2 18.5h<RA<20.4h -42<DEC<-60 (~450deg2)
F3 6.0h<RA< 7.5h -30<DEC<-60 (~200deg2)
----------> ~1100deg2
F4 8.0h<RA<10.0h -20<DEC< 0 (~600deg2) DECCam





Conclusions

- X-ray cluster catalogs have long history, achieving impressive depths and redshift
- SDSS allowed us to complete the cluster cosmology of RASS
- Extended source selection is most promising for robust cosmology
- Huge improvement is expected from eROSITA in 2020s.



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

J2000 Coords, Zenithal Equal Area Projection (radius=100°)

Central (RA,DEC)=(180°,+0°)

Alexis Finoguenov