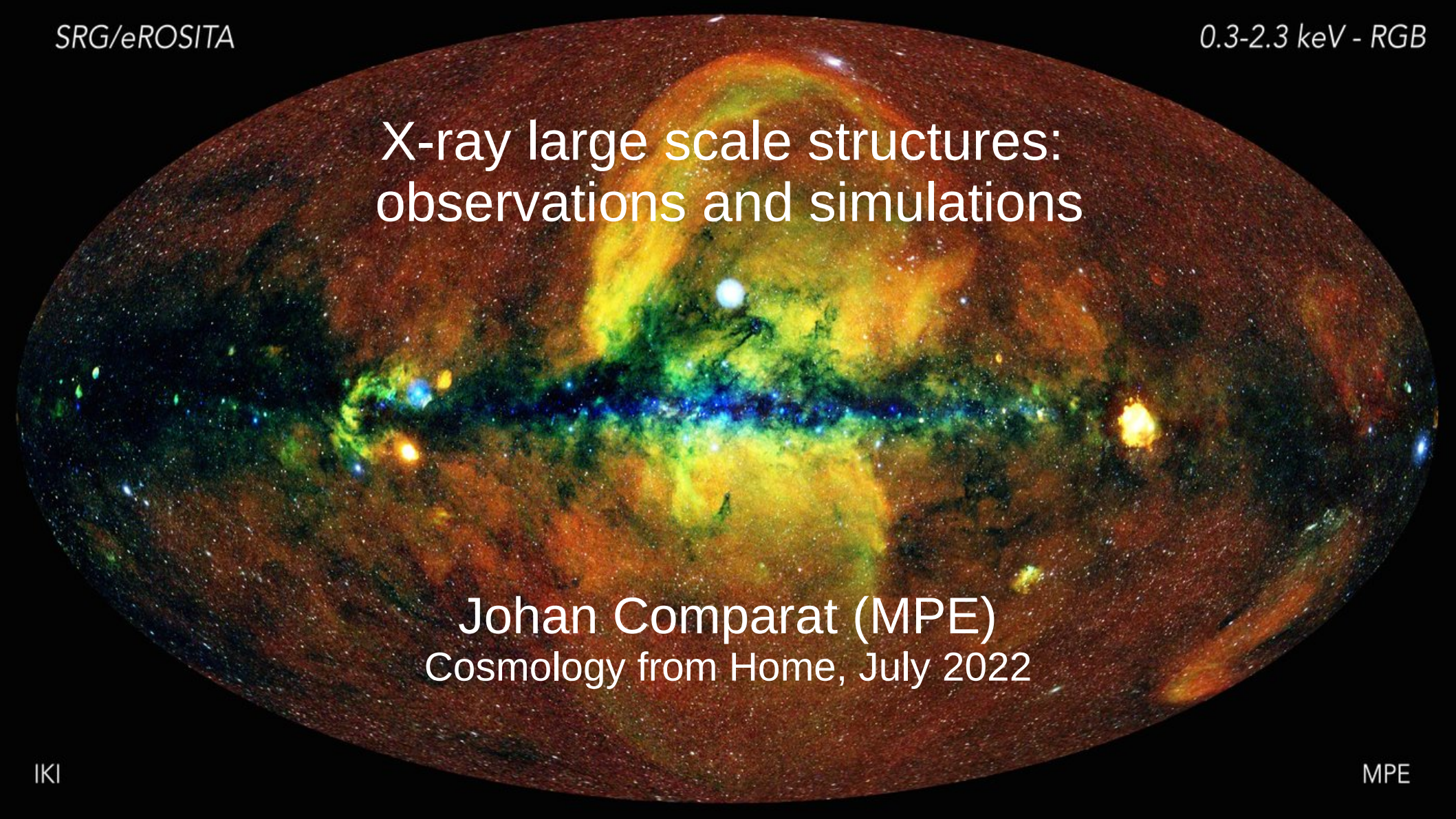


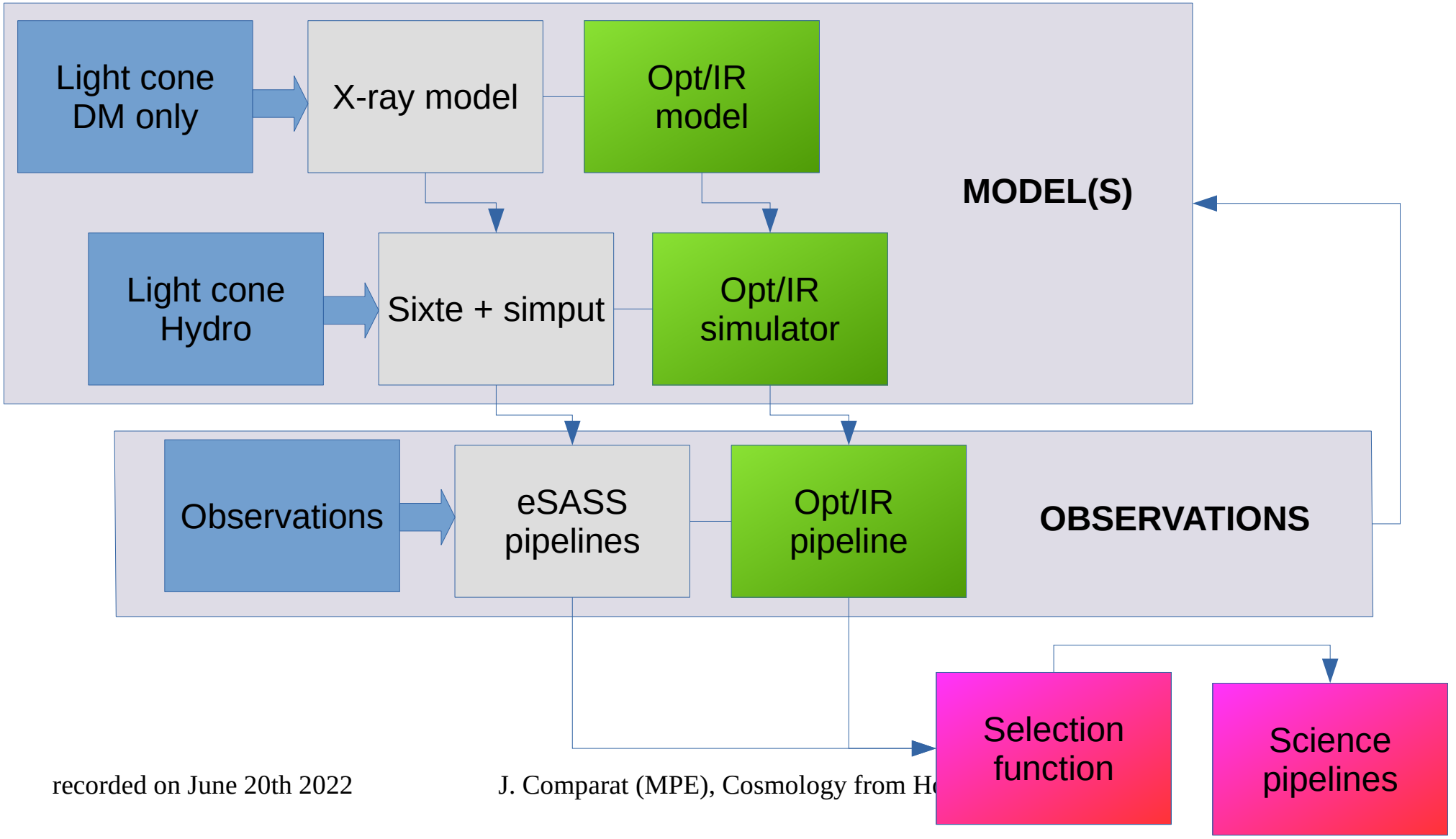
X-ray large scale structures: observations and simulations

Johan Comparat (MPE)

Cosmology from Home, July 2022

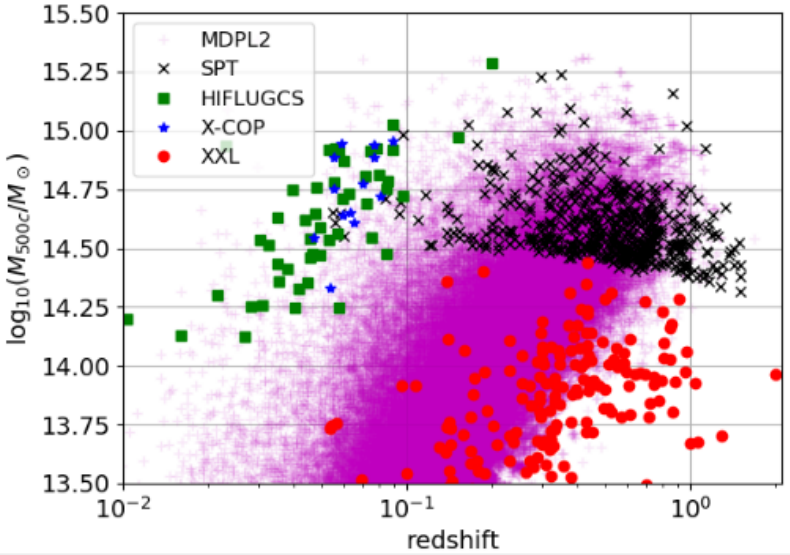
Outline

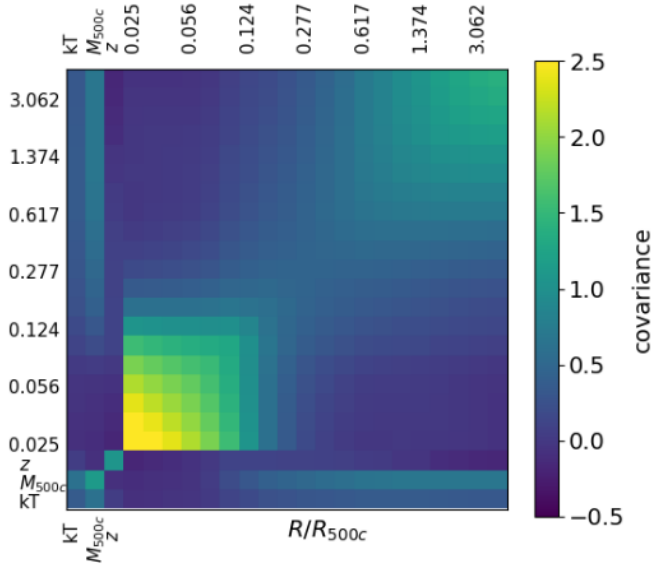
- Models of X-ray LSS
  - Galaxy clusters
  - Active galactic nuclei
  - Milky Way foreground
- Results
  - Stellar mass – X-ray luminosity relation
  - Characterization of sample (completeness, purity, spurious)

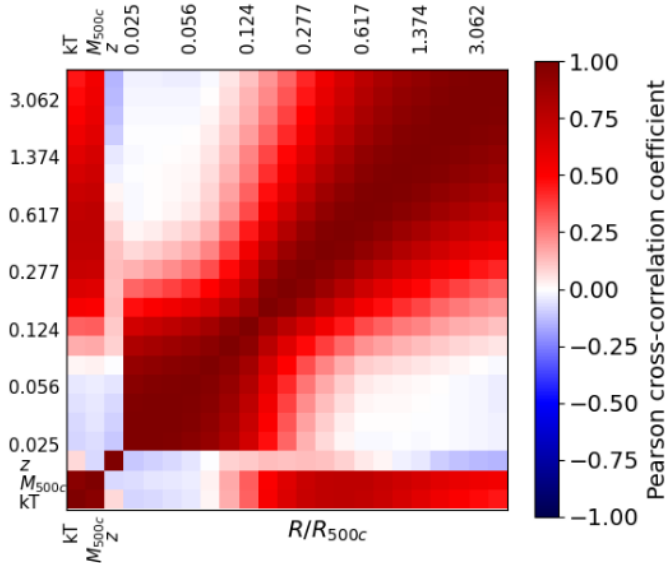

Light cone
DM only
X-ray model
Opt/IR
model
MODEL(S)
Light cone
Hydro
Sixte + simput
Opt/IR
simulator
Observations
eSASS
pipelines
Opt/IR
pipeline
OBSERVATIONS
Selection
function
Science
pipelines

Cluster model

- Clusters froms XXL, X-COP, HIFLUGCS, SPT
- Generate covariance matrix
  - M_{500c}, kT, z, EM profile



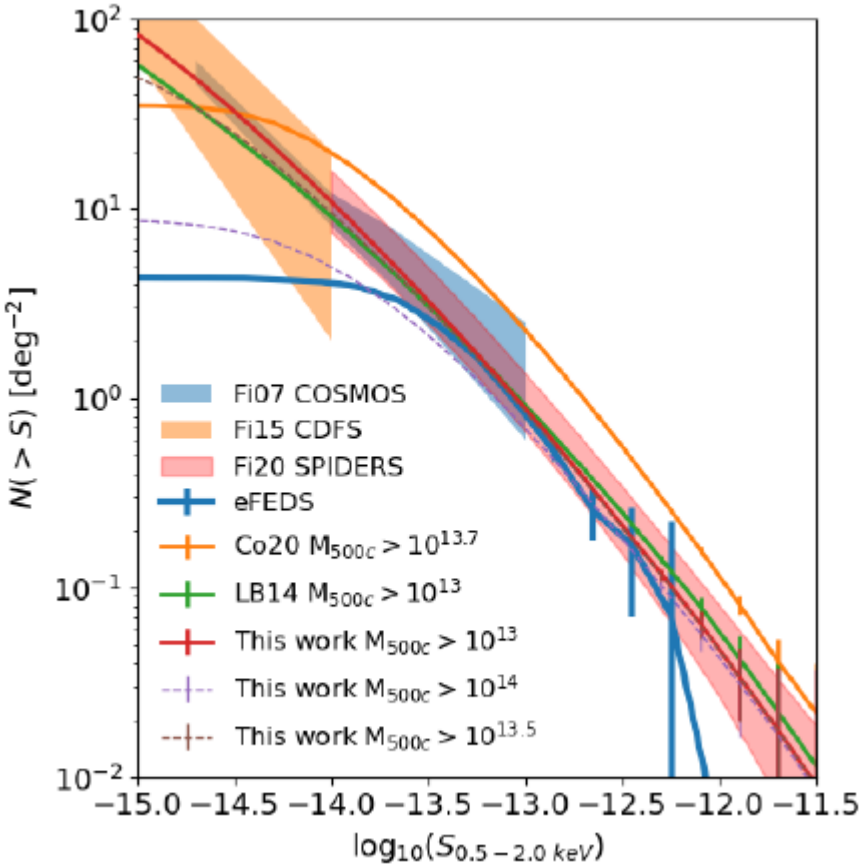




Comparat, Eckert, et al. 2020. Arxiv: 2008.08404

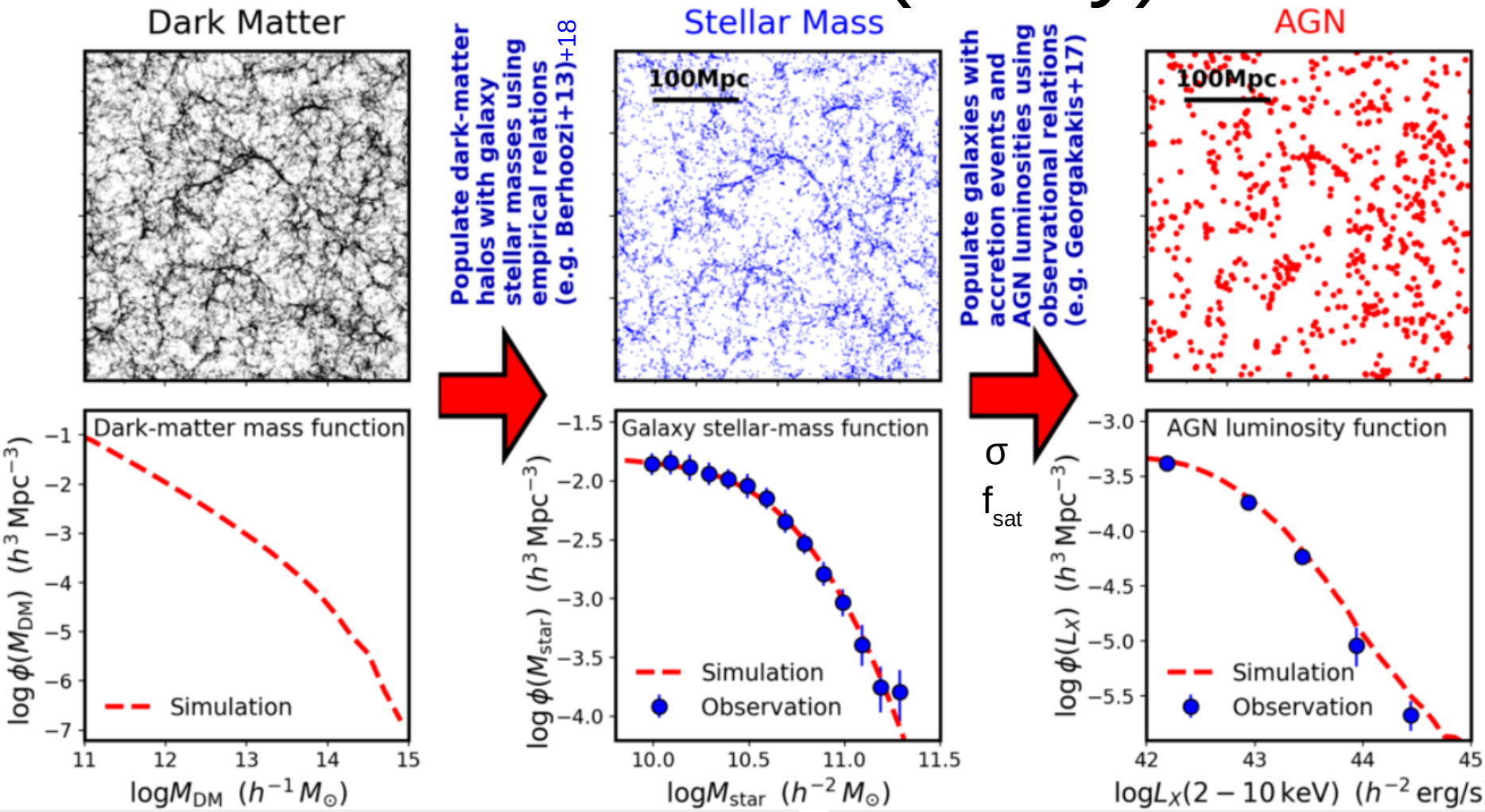
Predicted logN-logS

- In good agreement with existing data
  - M500c – LX
  - M500c – kT
  - KT – LX
- Predicted scatter in agreement with data
- Input cluster set dominated by high mass clusters => extrapolation to groups problematic => too bright
- Empirical correction using stellar mass – luminosity scaling relation Anderson et al. 2015, Comparat et al. 2022
- Benchmark eROSITA eFEDS (Liu, Ang, et al. 2021): logNlogS, XLF.
- Extension to 1e13 !
- Profiles will likely need adjustments



Seppi, Comparat et al. submitted

AGN model (X-ray)

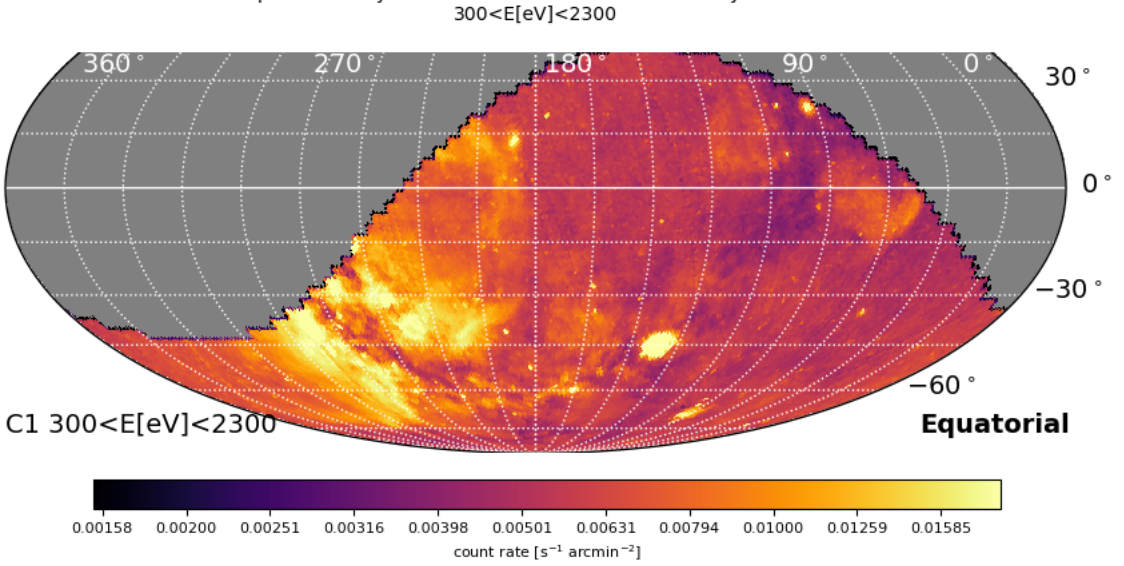


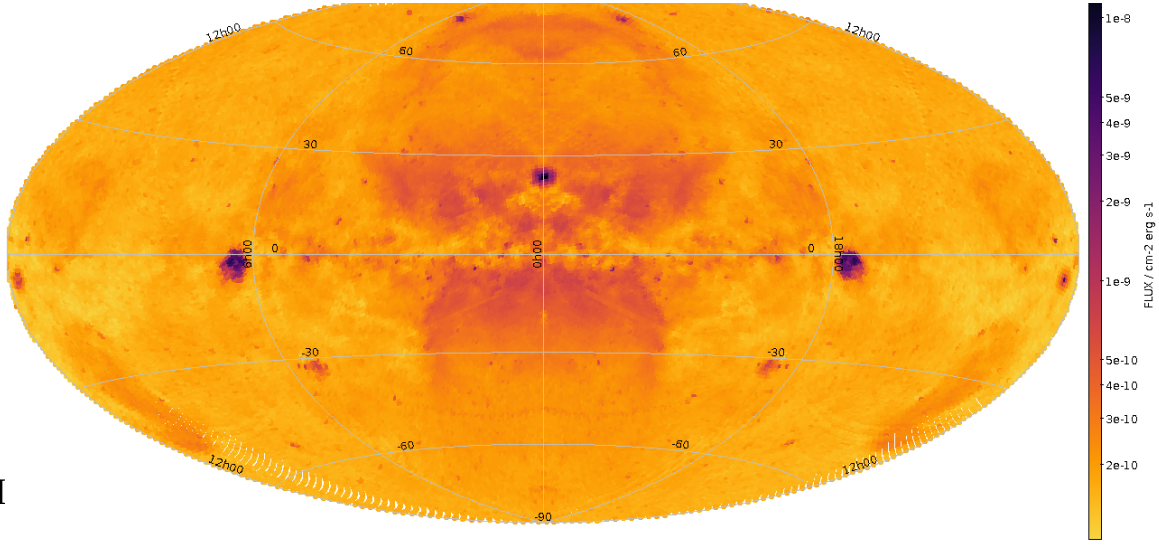
Georgakakis, Comparat et al. MNRAS 2018. ArXiv: 1812.04025

Comparat, Merloni et al. MNRAS 2019. ArXiv: 1901.10866

Diffuse emission

- Resample observations (photons away from sources) 0.2-2.3 keV + symmetry
- Diffuse emission with large scale patterns
- Single all-sky average spectrum



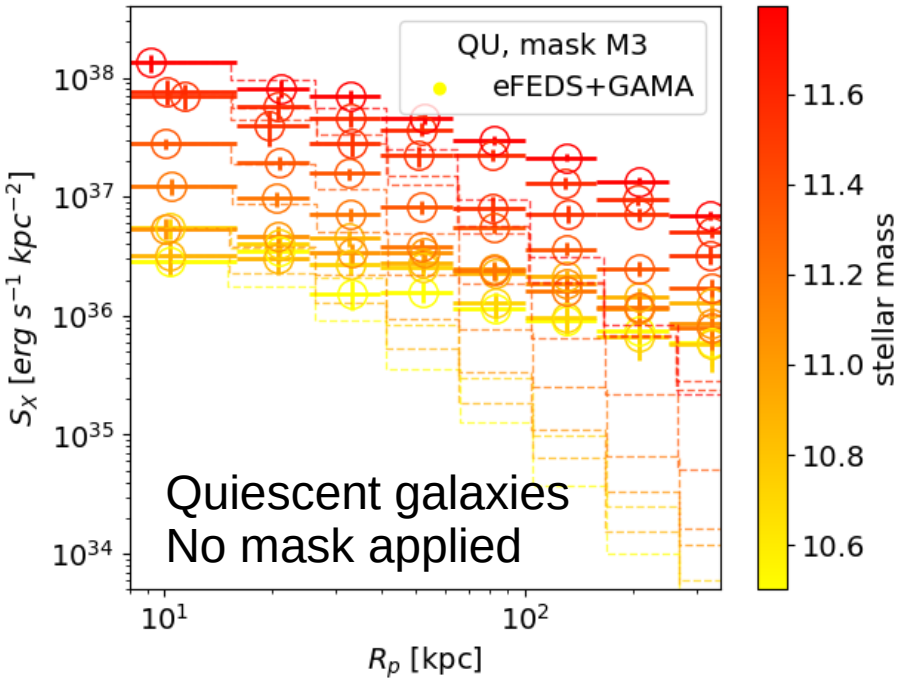


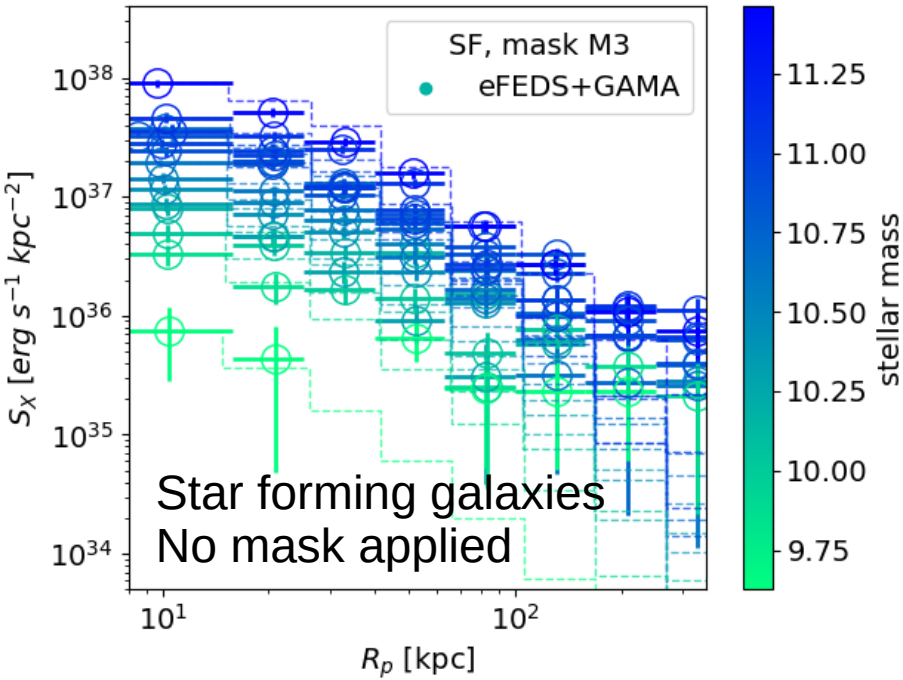
Outline

- Results
  - Stellar mass – X-ray luminosity relation
  - Characterization of samples (completeness, purity, spurious)

- GAMA 9h galaxies (Driver et aL. 2022)
  - 60 deg^2, 98% **complete**
  - 35,521 central galaxies ranked with M^* split in star-forming / quiescent (Bellstedt et al. 2020, 2021, Robotham et al. 2020)
- X-ray event list (~10^7) and sources (~$3x10^4$) eROSITA eFEDS (Brunner et al. 2022)
  - Measure X-ray (0.5-2 keV) profiles via stacking
  - different masking schemes

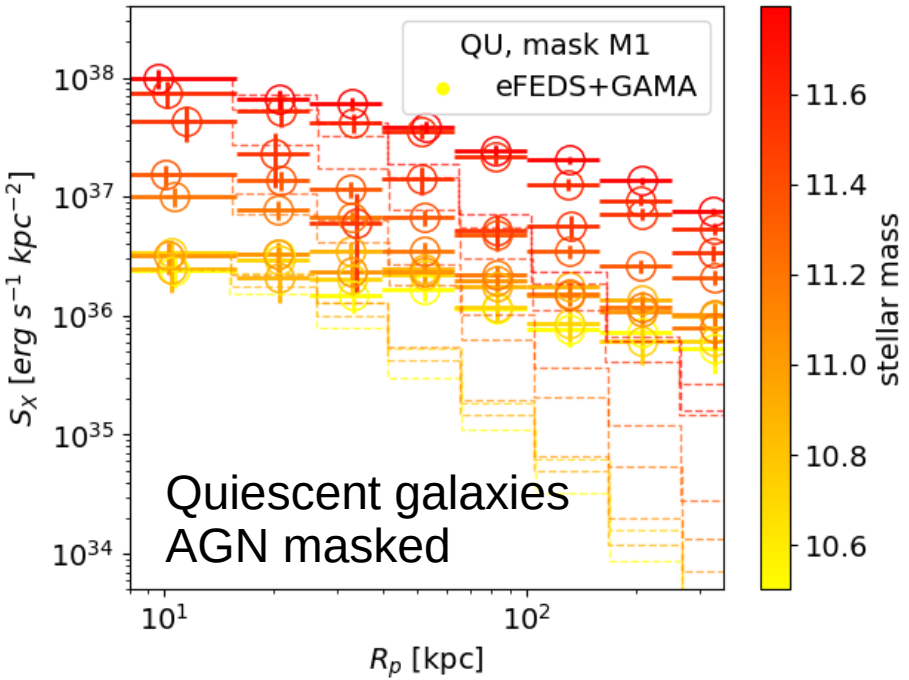
Measured projected X-ray profiles around SF and QU galaxies

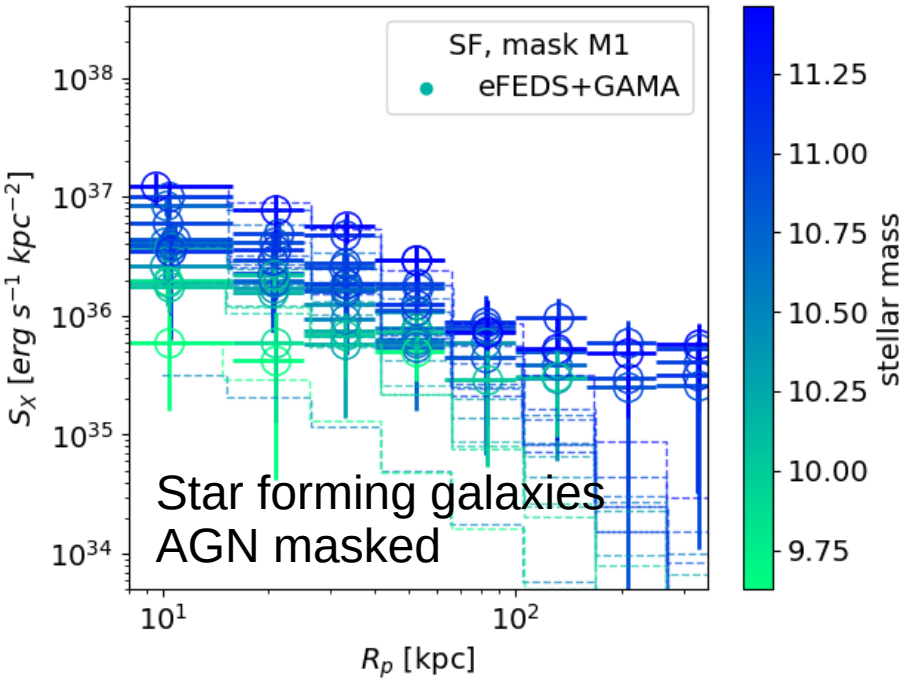




Arxiv 2201.05169

Measured projected X-ray profiles around SF and QU galaxies

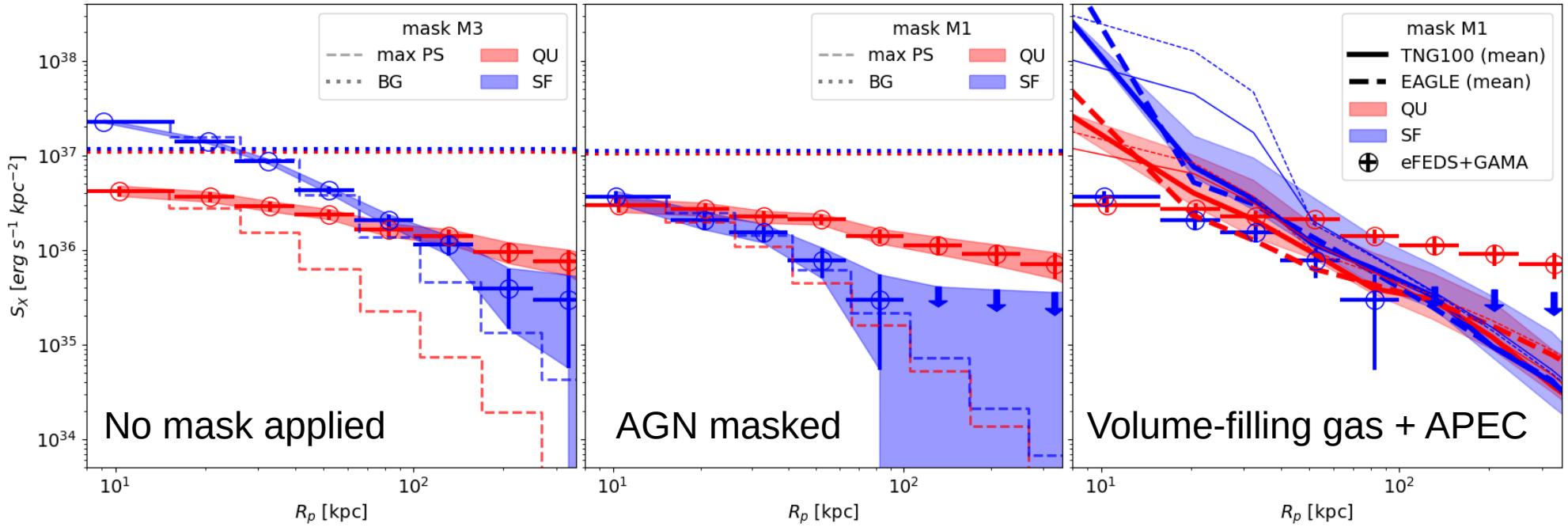




Arxiv 2201.05169

Focus at $M^* \sim 5 \times 10^{10} M_{sun}$ (halo $2.7 \times 10^{12} M_{sun}$)

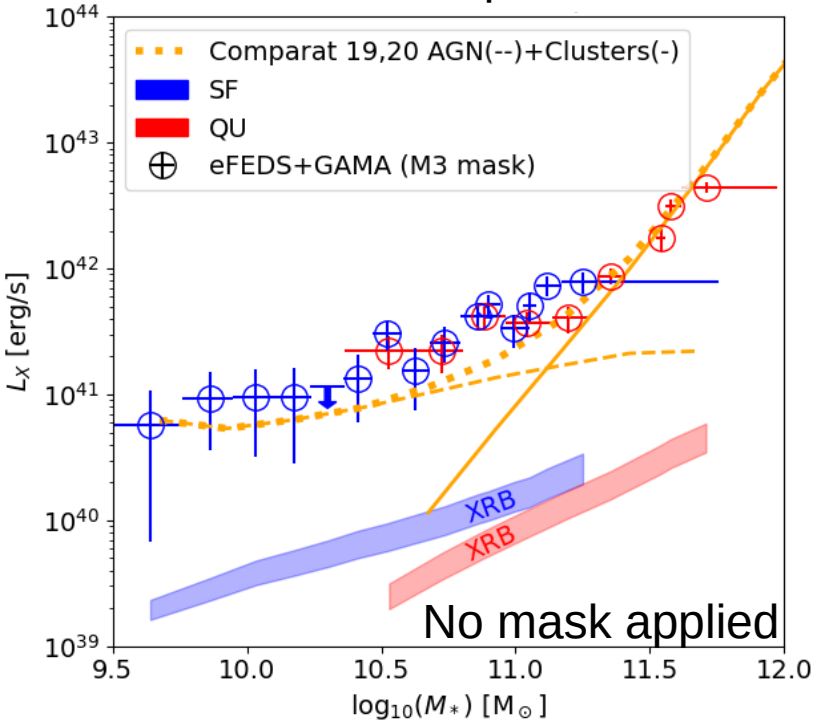
- Milky-Way analog: discrepancy in AGN population and on large scale X-ray emission
- SF compatible with PS. QU shows extended emission.
- Illustris & EAGLE: such difference not predicted. Large discrepancy on small scales.



Arxiv 2201.05169

The L_X – stellar mass relation

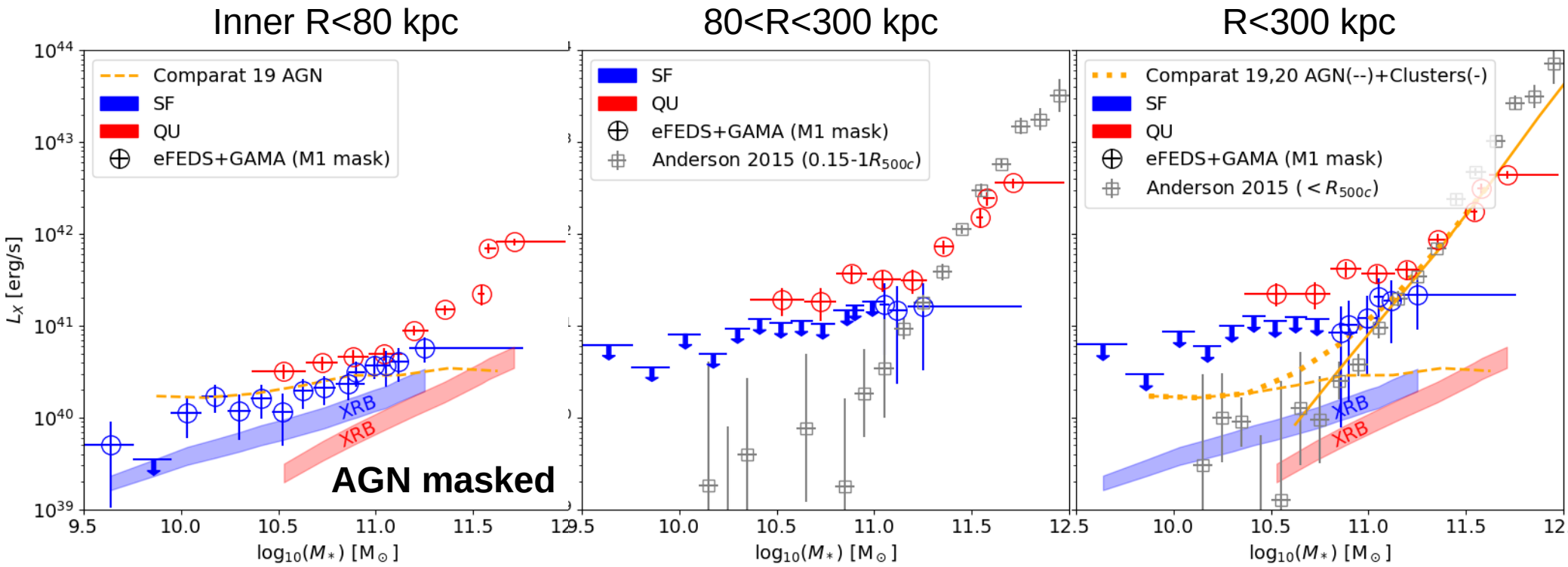
R<300kpc



- New perspective on this relation (XRB+AGN+ICM+CGM)
- Predictions from AGN and cluster models (Comparat et al. 2019, 2020, Liu et al. 2022, Seppi et al. subm.) that accurately reproduce statistics of X-ray detected sources (eFEDS and eRASS:1)
- Extra signal
  - Projection effects ? Could constitute 20 (40)% of the signal at 130 (860) kpc.
  - CGM emission ?

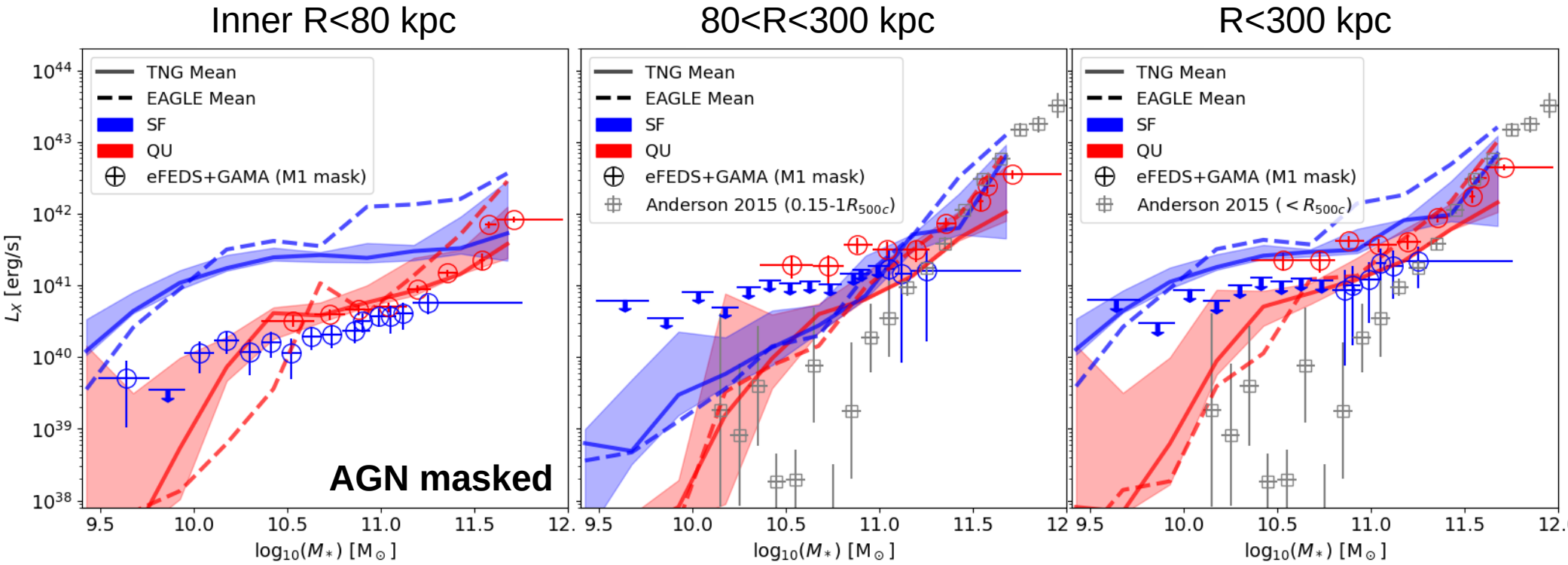
Arxiv 2201.05169

Decomposing L_X – stellar mass



Arxiv 2201.05169

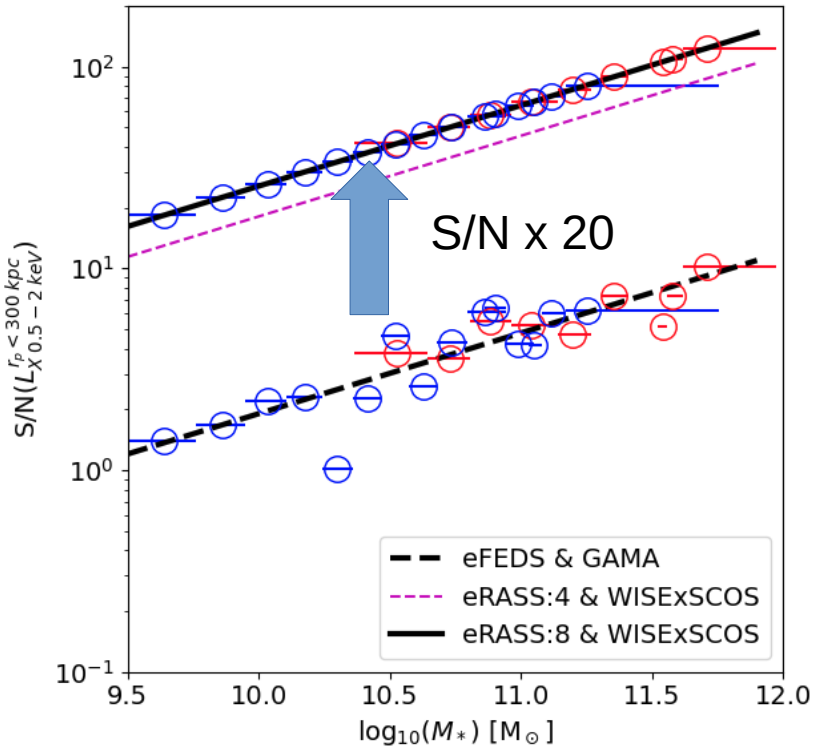
Comparison with simulations

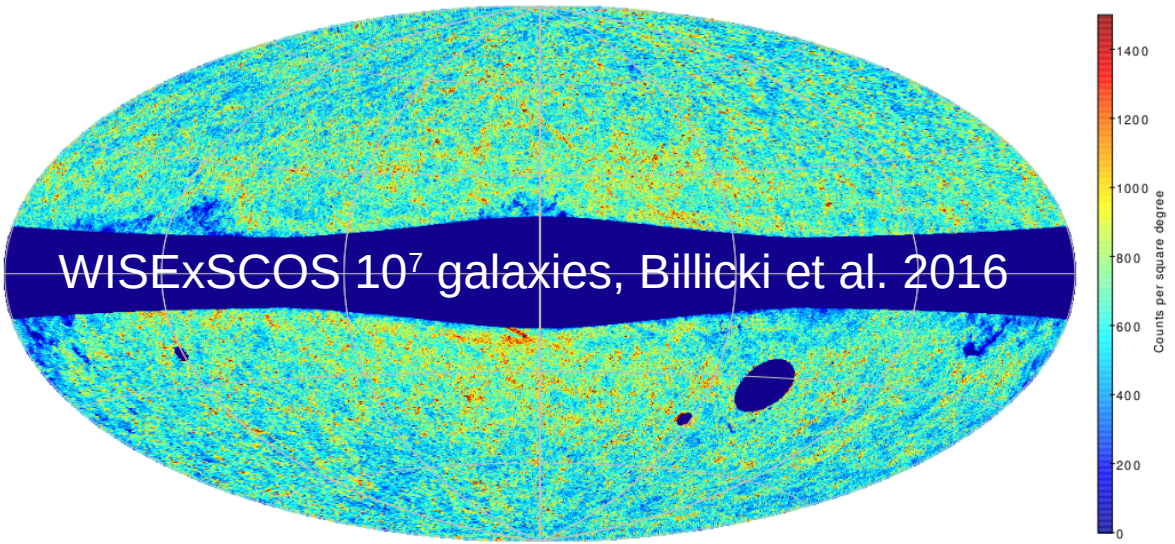


Arxiv 2201.05169

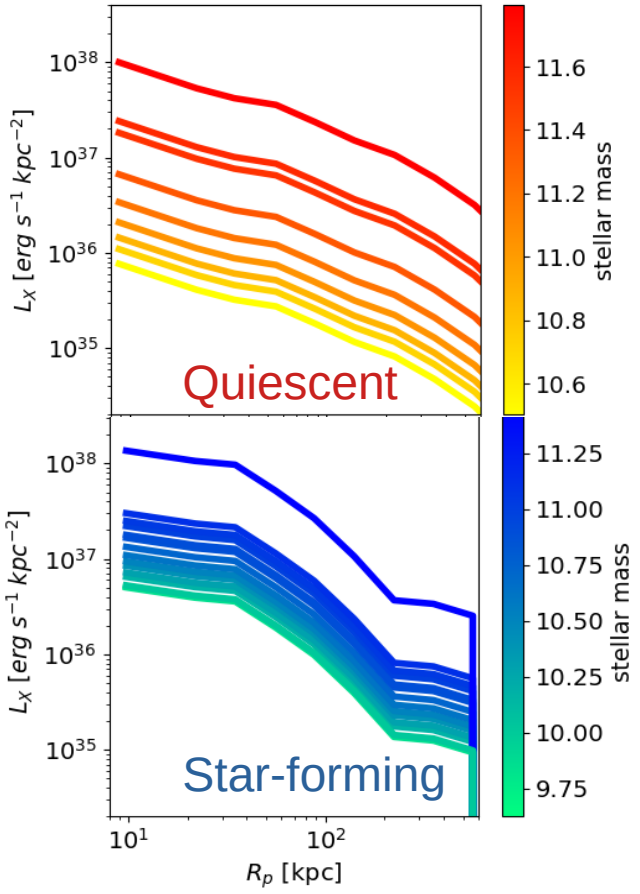
Outlook

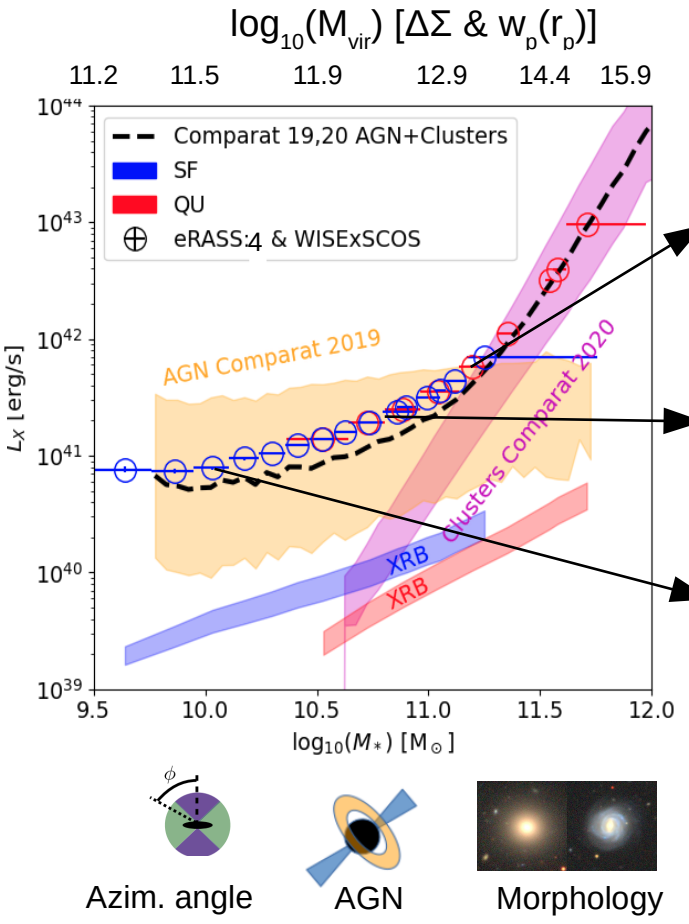
- ½ sky eRASS:4-8. 2-4x10^9 events
- 10^7 galaxies WISExSCOS + LS DR10
- LSST+Euclid weak lensing & clustering products

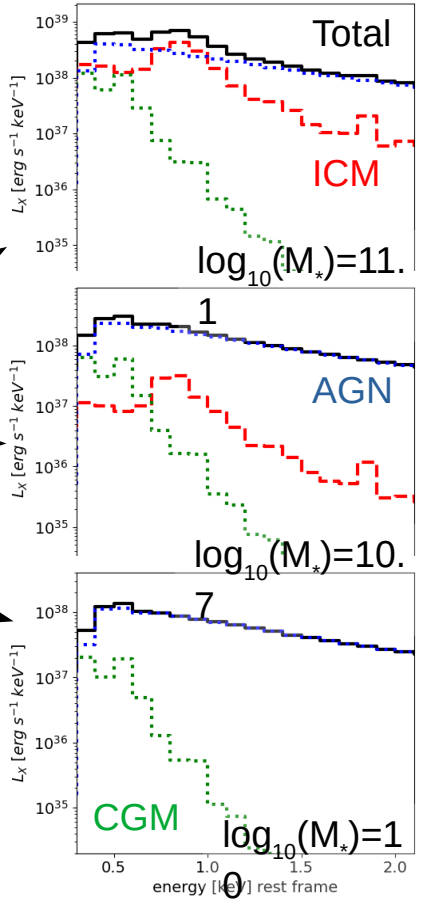




Outlook


Quiescent
Star-forming
L_X [erg s^{-1} kpc^{-2}]
R_p [kpc]
stellar mass
stellar mass

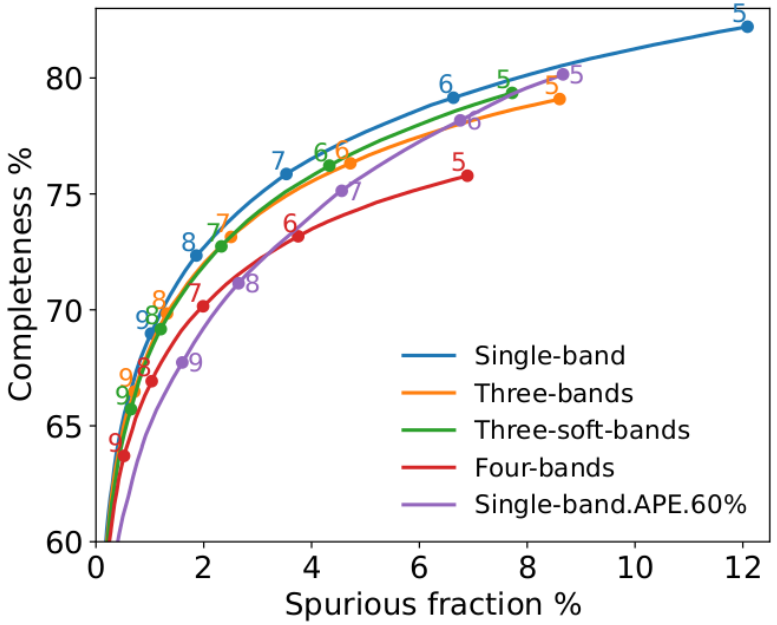

log$_{10}$(M$_{vir}$) [ΔΣ & w$_p$(r$_p$)]
Comparat 19,20 AGN+Clusters
SF
QU
eRASS:4 & WISExSCOS
AGN Comparat 2019
Clusters Comparat 2020
XRB
XRB
L_X [erg/s]
log$_{10}$(M_*) [M$_\odot$]
Azim. angle
AGN
Morphology


Total
ICM
log$_{10}$(M$_*$)=11.
AGN
log$_{10}$(M$_*$)=10.
CGM
log$_{10}$(M$_*$)=10
L_X [erg s^{-1} keV^{-1}]
energy [keV] rest frame

Outline

- Results
  - Stellar mass – X-ray luminosity relation
  - Characterization of samples (completeness, purity, spurious)
- Simulations
  - 18xeFEDs simulations
    - Texp~1,400 s
    - Area~140 deg^2
    - Liu, Merloni, Comparat et al. 2021, arxiv: 2106.14528
  - 1xeRASS:1 simulation
    - Texp~200 s
    - Area~17,700 deg^2
    - Seppi, Comparat et al. submitted

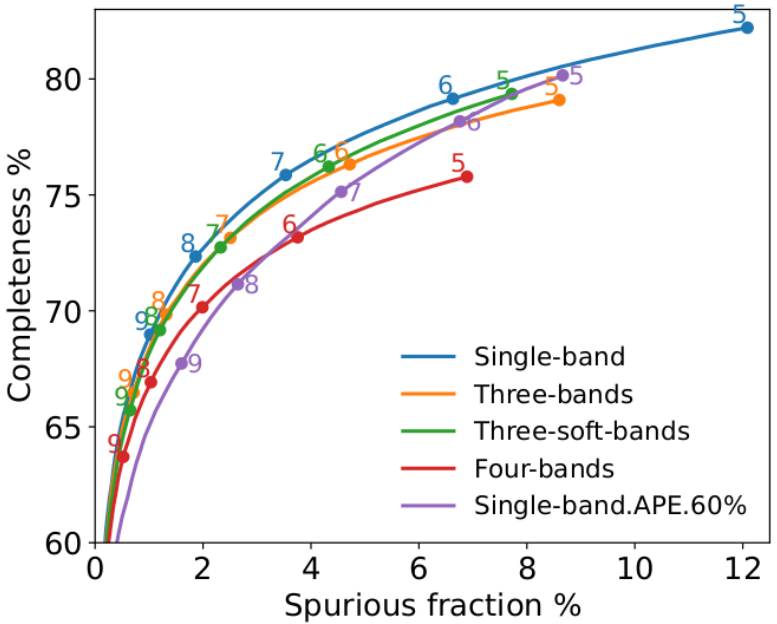
Sample characterization (eFEDs)

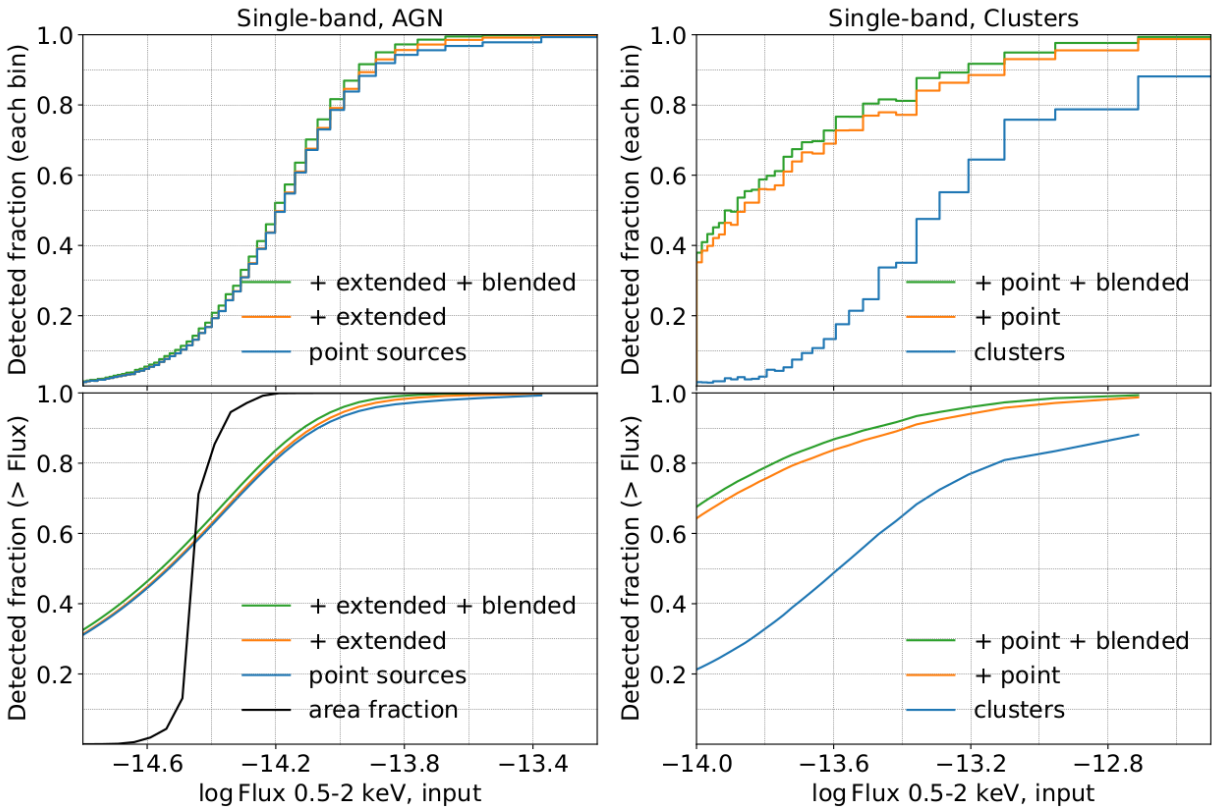


DET_LIKE	Clusters			AGN		
	N events <0.5×R_{500c}			N events <30″		
	ALL	CLU	BG	ALL	AGN	BG
5	21.3	8.7	10.1	5.1	3.7	1.3
8	25.8	11.4	11.4	6.6	5.0	1.5
10	30.4	13.8	13.0	7.7	6.0	1.6
15	42.6	21.3	16.9	10.1	8.4	1.7
20	48.8	25.4	17.9	12.5	10.6	1.7
25	74.4	36.6	23.6	14.6	12.7	1.8
50	100.8	62.3	29.8	25.2	22.6	2.4
75	152.4	96.3	42.5	35.6	32.3	3.0
100	209.0	127.2	61.5	46.5	42.1	3.7

Sample characterization (eFEDs)

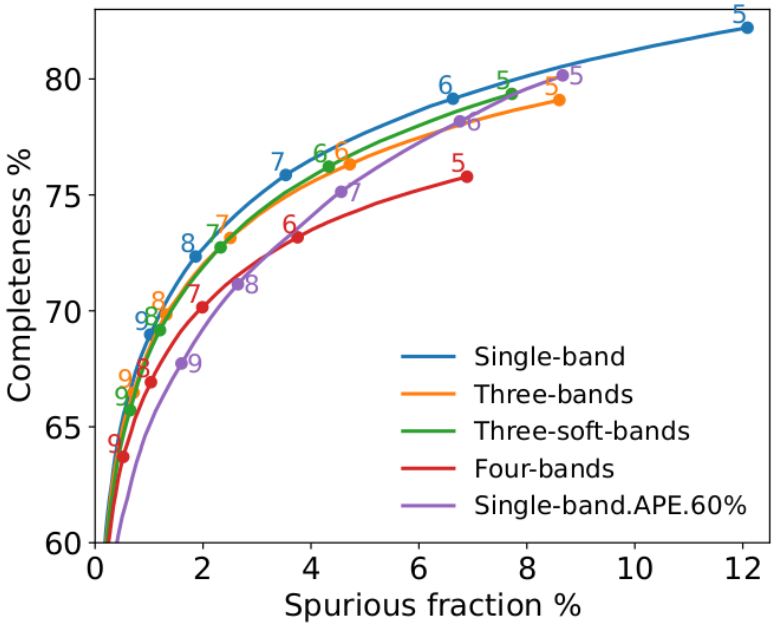
Gradient as a function of input flux
Completeness at $F_X=10^{-14.2}$ erg cm^{-2} s^{-1}

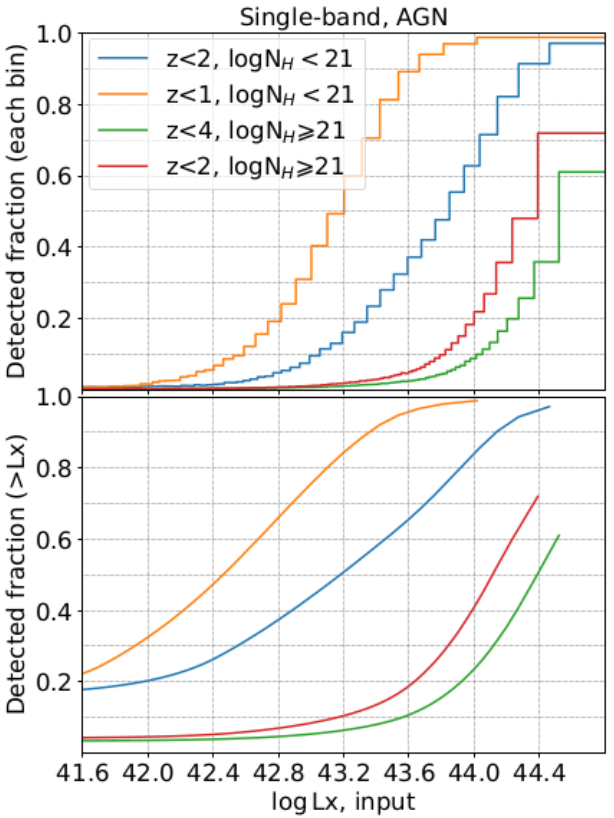


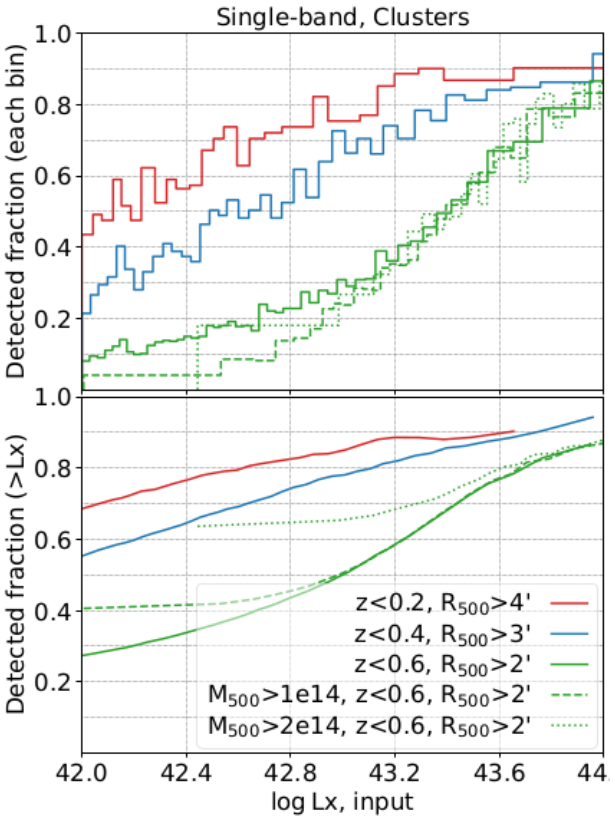


Sample characterization (eFEDs)

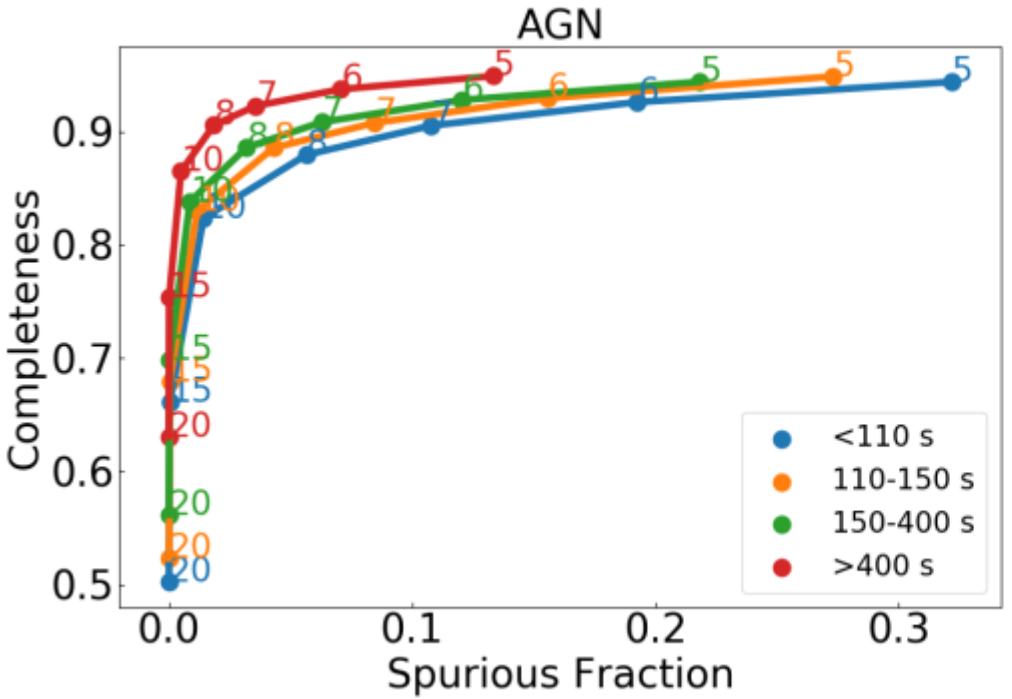
Gradient as a function of properties
Completeness at $F_X=10^{-14.2}$ erg cm^{-2} s^{-1}

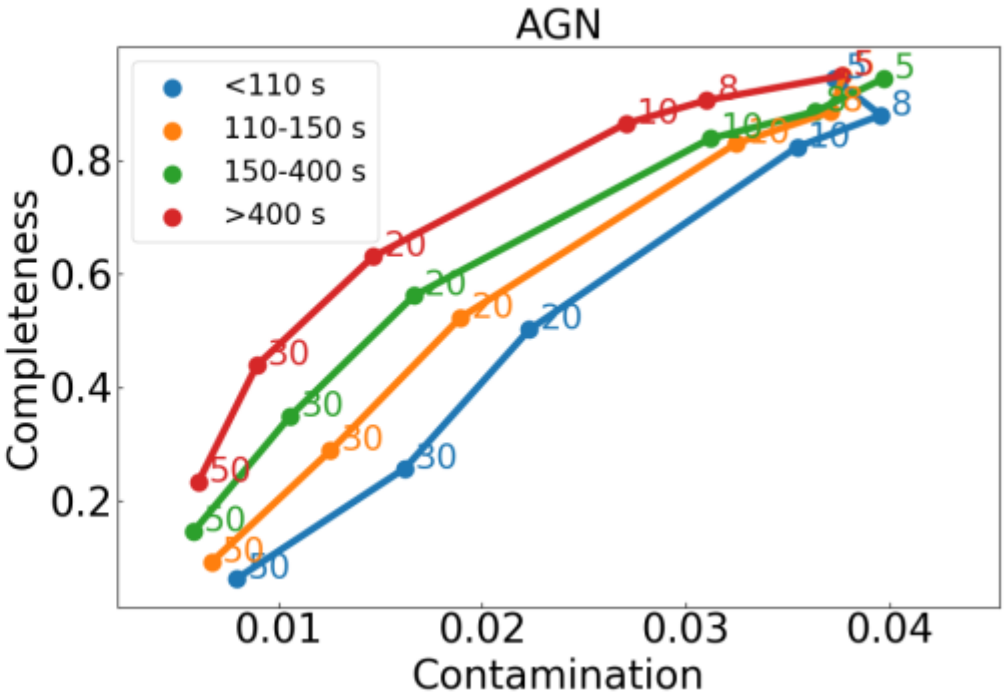






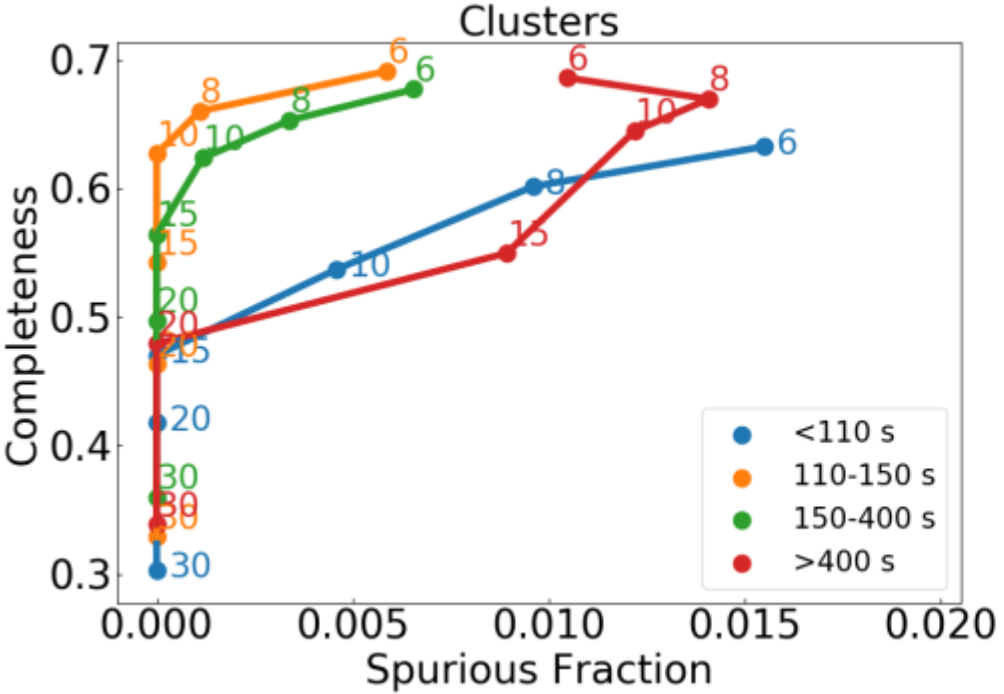
Sample characterization (eRASS:1)

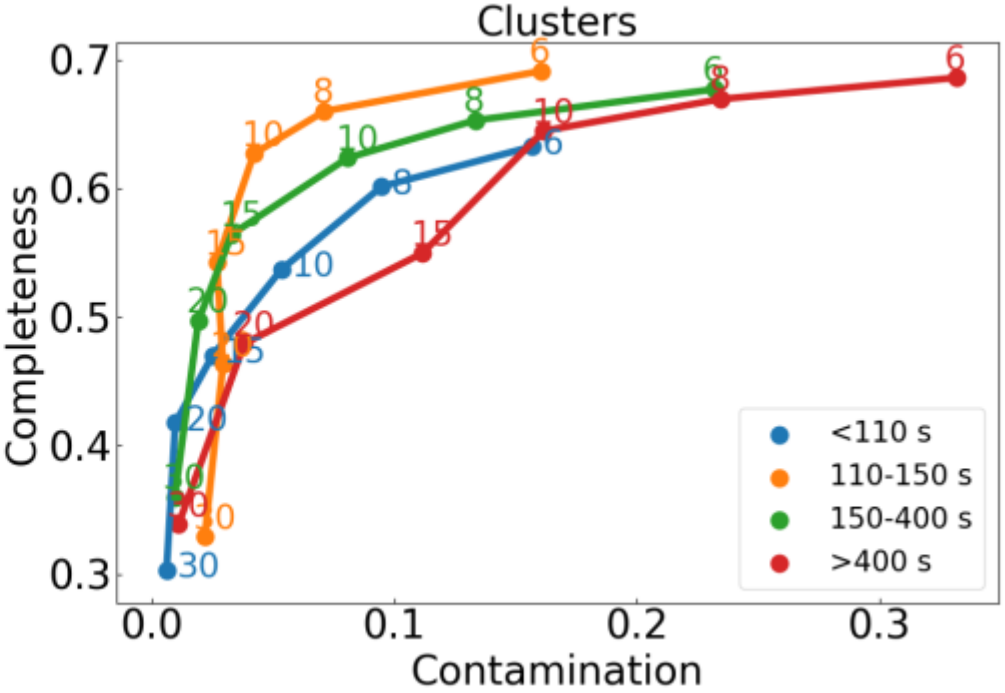




	eRASS1						
Exposure	Area [deg^2]	N_{CLU}/deg^2	Flux CLU 50%	Flux CLU 80%	N_{AGN}/deg^2	Flux AGN 50%	Flux AGN 80%
< 110 s	6710	0.13	7.13×10^{-13}	3.39×10^{-12}	21.78	3.76×10^{-14}	7.02×10^{-14}
110 s – 150 s	4543	0.22	4.67×10^{-13}	1.2×10^{-12}	29.41	3.01×10^{-14}	5.31×10^{-14}
150 s – 400 s	6073	0.34	3.28×10^{-13}	9.72×10^{-13}	42.94	2.22×10^{-14}	3.98×10^{-14}
> 400 s	377	1.05	1.12×10^{-13}	4.75×10^{-13}	93.71	1.10×10^{-14}	1.93×10^{-14}

Sample characterization (eRASS:1)





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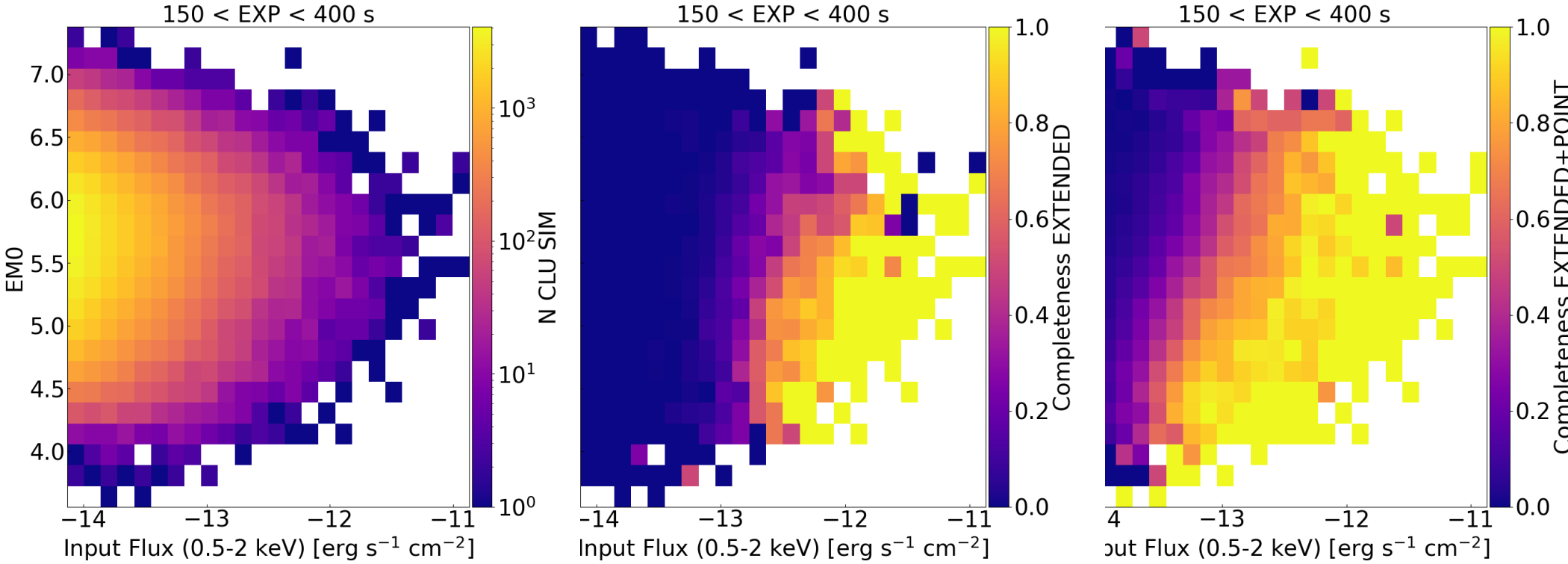
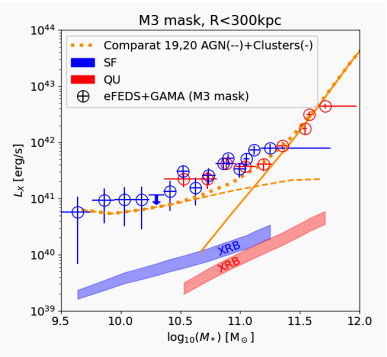
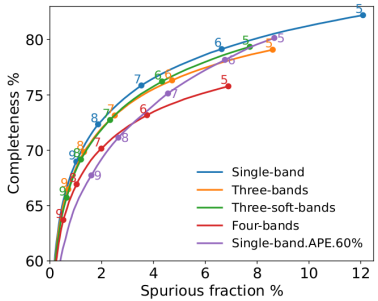
Sample characterization (eRASS:1)



Summary



- **Result 1: L_x-M^* relation**
  - XRB+AGN+ICM+CGM
  - Hints of CGM around MW analog. Strong for QU. Weak for SF
  - Differences in profiles



- **Result 2: simulated sample characteristics**
  - Completeness-contamination-spurious
  - Trends with properties

- **X-ray LSS Models**
  - AGN + clusters are accurate
  - Ongoing: AGN clustering
  - Future: galaxy models
- **Outlook**
  - eRASS selection functions
  - Large scale clustering studies

References

- Models :
  - Comparat, Merloni et al. 2019. Active galactic nuclei and their large-scale structure: an eROSITA mock catalogue.
  - Comparat, Eckert et al. 2020. Full-sky photon simulation of clusters and active galactic nuclei in the soft X-rays for eROSITA.
- Results :
  - Liu Teng, Merloni, Comparat et al. 2021. Establishing the X-ray Source Detection Strategy for eROSITA with Simulations.
  - Seppi R. et al. submitted, eRASS1 simulation. Detecting clusters of galaxies and active galactic nuclei in an eROSITA all-sky survey digital twin.
  - Comparat et al. 2022. X-ray emission around star-forming and quiescent galaxies at $0.05<z<0.3$