

Preparing for eROSITA Cosmology Simulations as a Guiding Framework

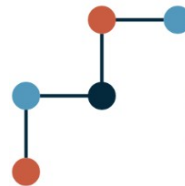
Seppi Riccardo

Ecogia Science Meeting

Ecogia, 02/06/2025



**UNIVERSITÉ
DE GENÈVE**

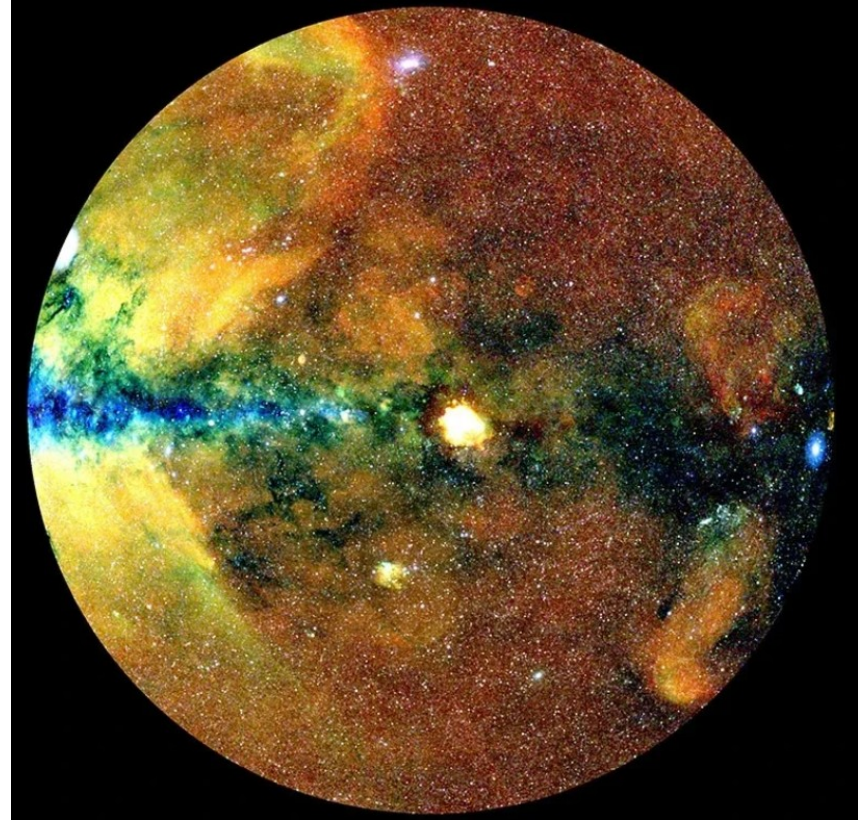


**Swiss National
Science Foundation**

Comparat, **Seppi**, Clerc, Malavasi
and the eROSITA cosmology taskforce

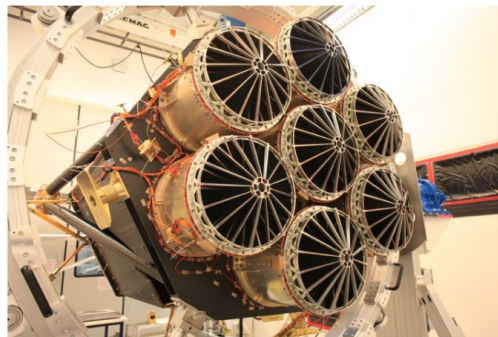
Outline

- *What is eROSITA?*
- *What is Cluster cosmology?*
- *New models and simulations*
 - *Preliminary results*
 - *A perspective to Mass-Observable scaling relations*

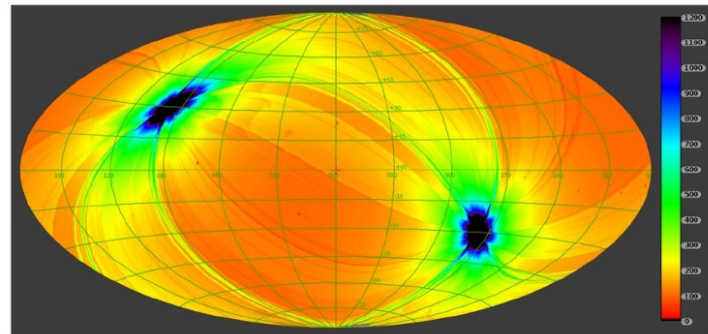
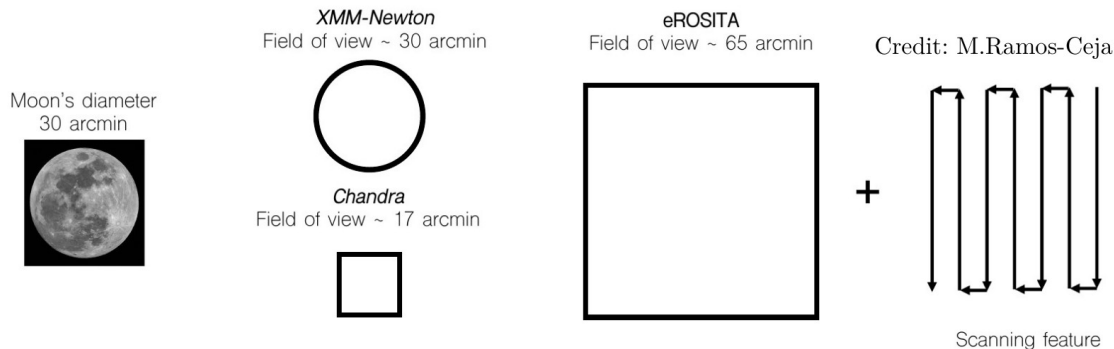
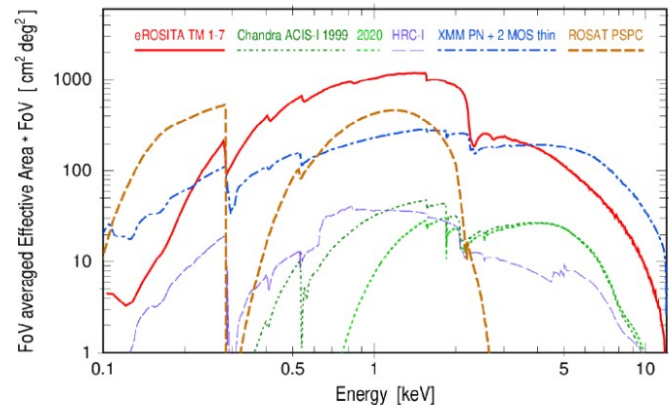


What is eROSITA?

- Soft X-ray telescope onboard SRG
- German – Russian collaboration
 - Launched 13/07/2019
- CalPV phase (eFEDS) + all-sky scans (eRASS1 is public)



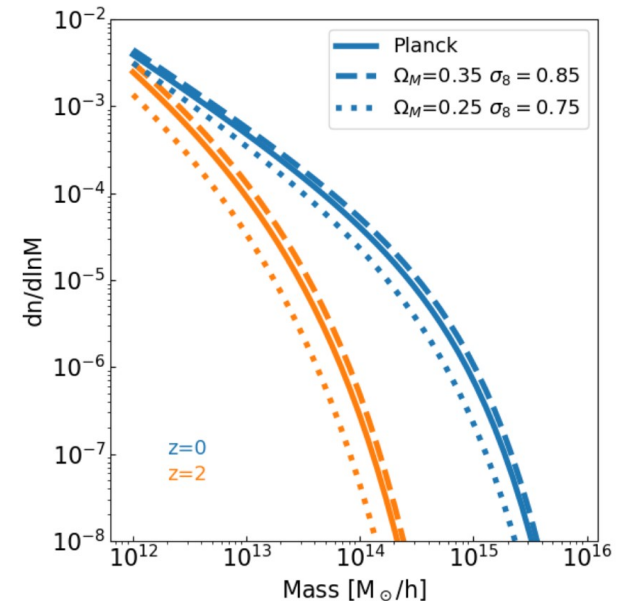
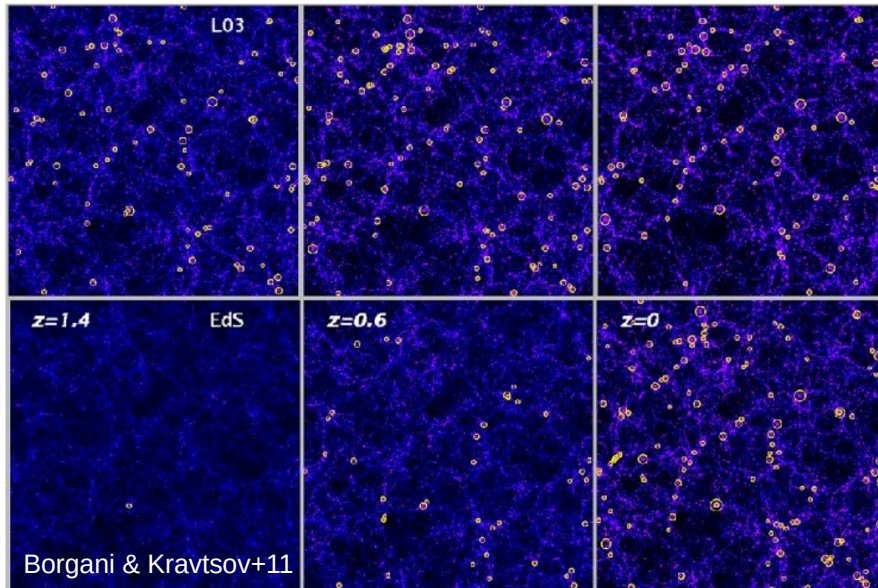
Predehl+21



Cosmology with galaxy clusters

- Clusters trace the nodes of the Large Scale Structure of the Universe
 - Count clusters as a function of mass and redshift

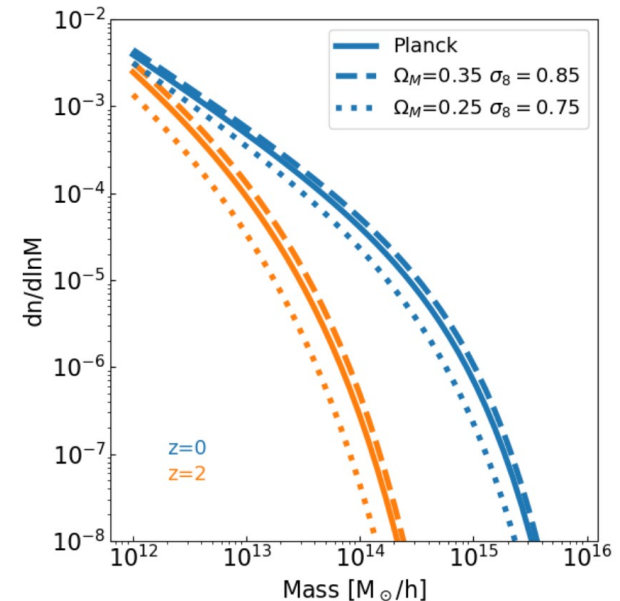
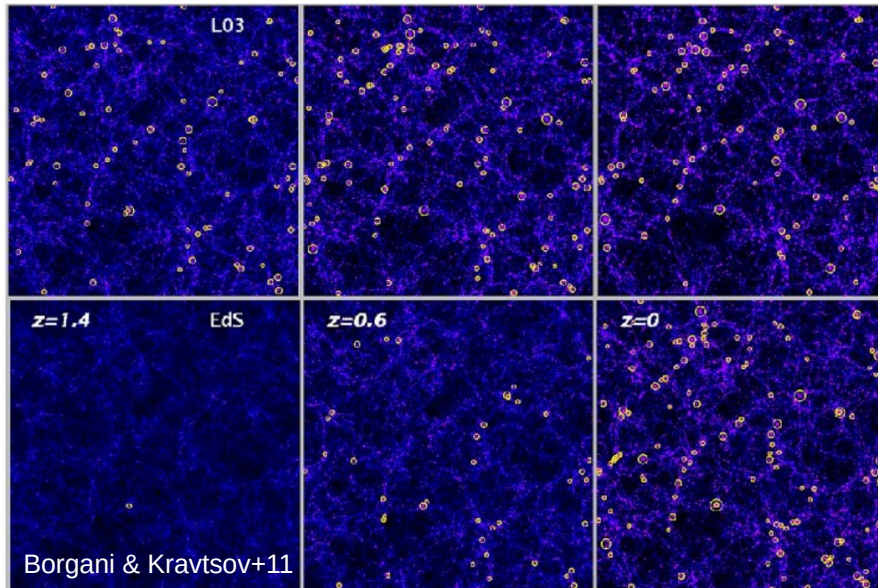
$$\frac{dn}{d\ln M} = \frac{\rho_m}{M} \left| \frac{d\ln \sigma}{d\ln M} \right| f(\sigma)$$



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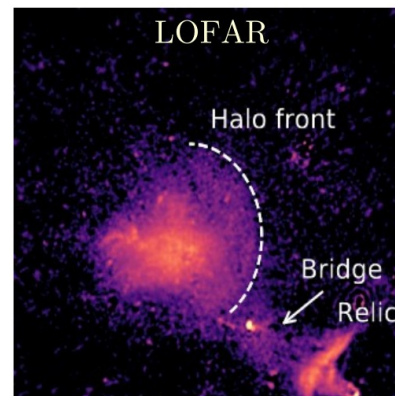
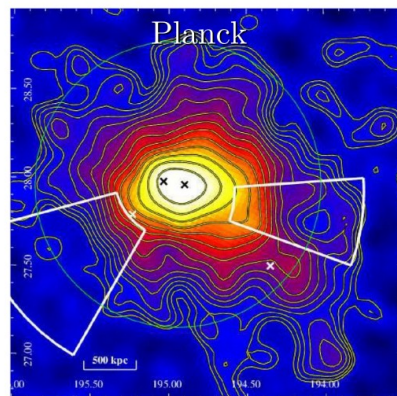
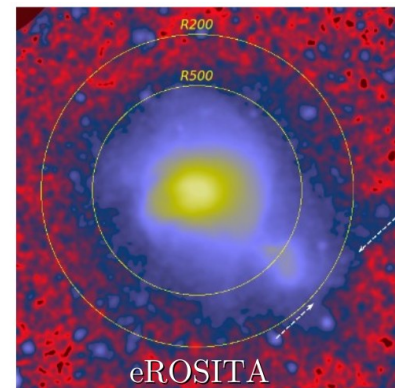
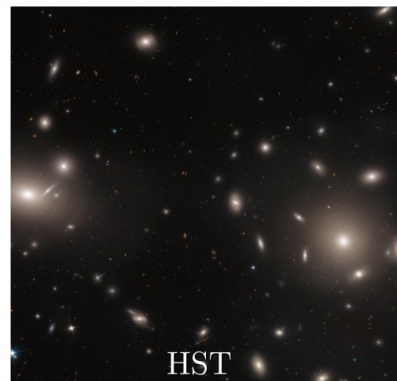
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Cluster cosmology in practice

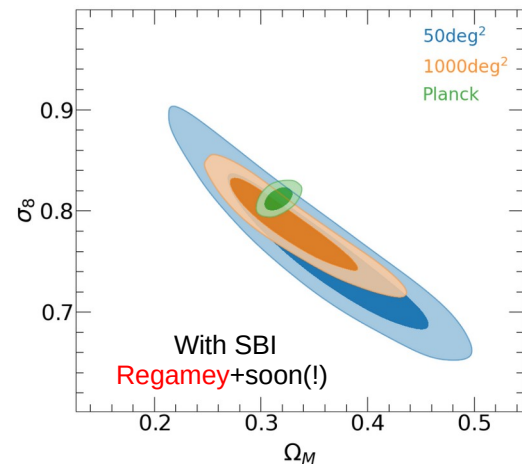
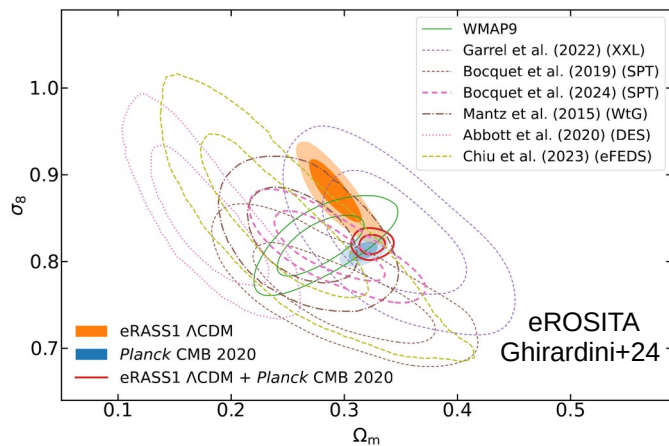
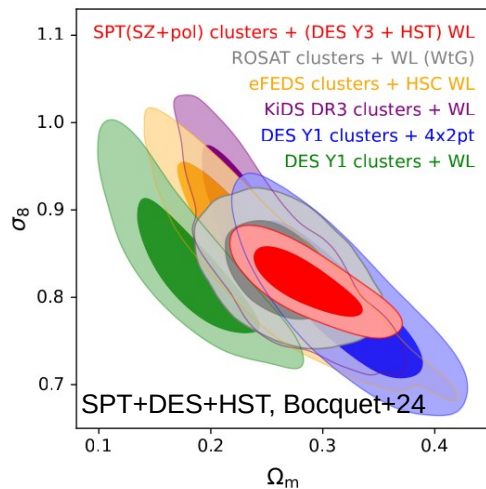
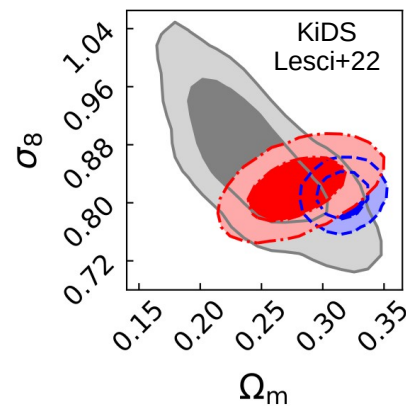
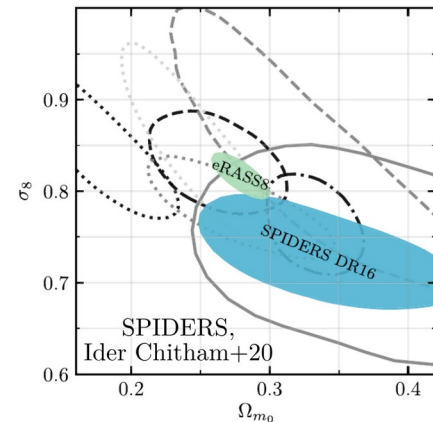
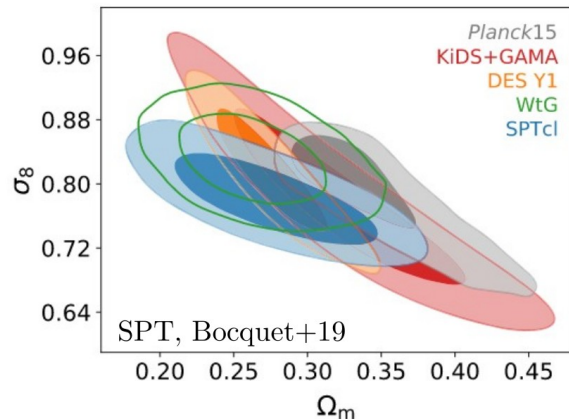
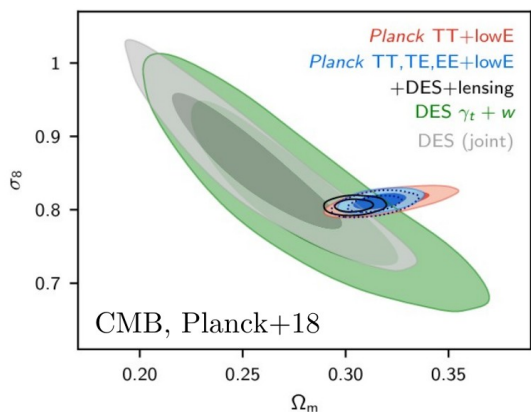
- Mass-observable scaling relation
- ***Selection function***
- Uncertainty on the models, including baryons

(Press-Schechter+74, Sheth+99, Tormen+01, Tinker+08, Angulo+12, Despali+16, Bocquet+16, Comparat+17, Seppi+21, Castro+21, Euclid+24)



$$\frac{dN(O, z)}{dO dz} = \int f(O, z) \frac{dP(O|M, z)}{dO} \frac{dn(M, z)}{dM} \frac{dV}{dz} dM$$

Cluster cosmology Experiments

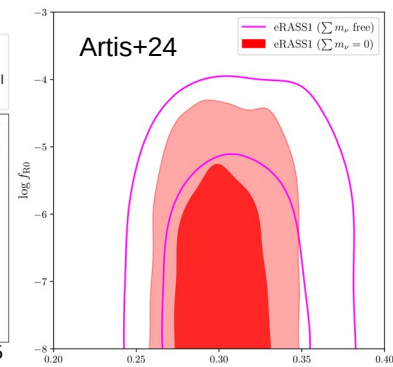
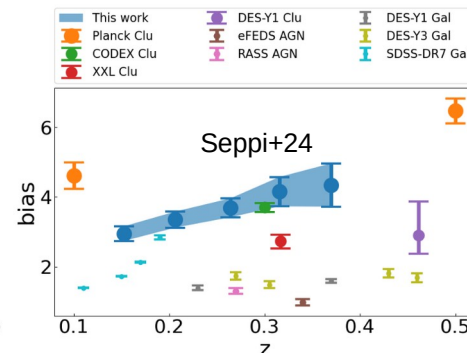
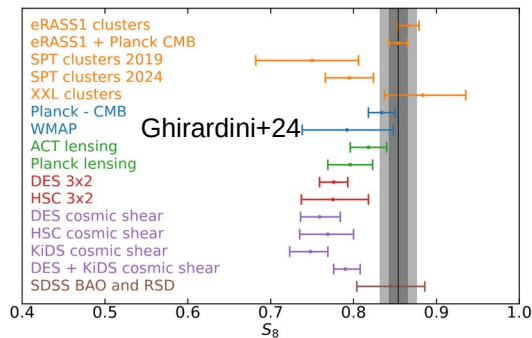
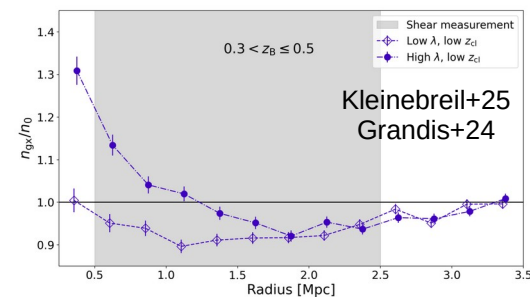
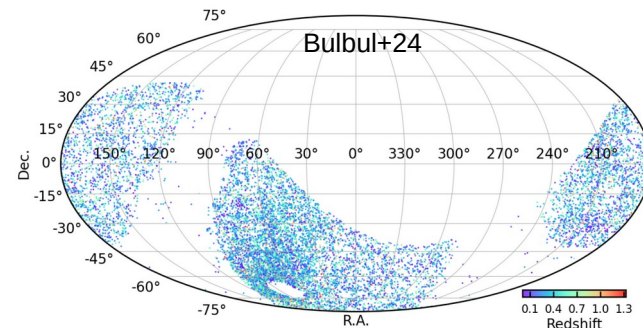
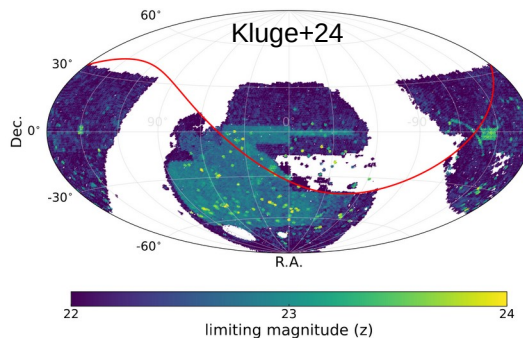
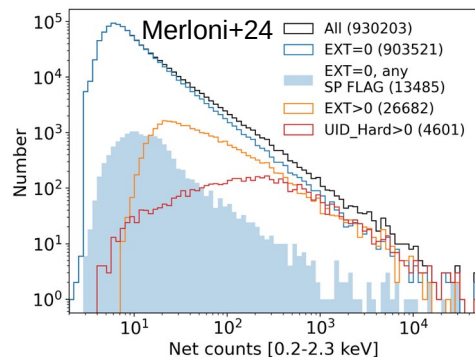


eRASS1

- Data collection:
12/12/2019 – 11/06/2020
- DR1: 31/01/2024
- Almost 1 million sources
- 12k clusters

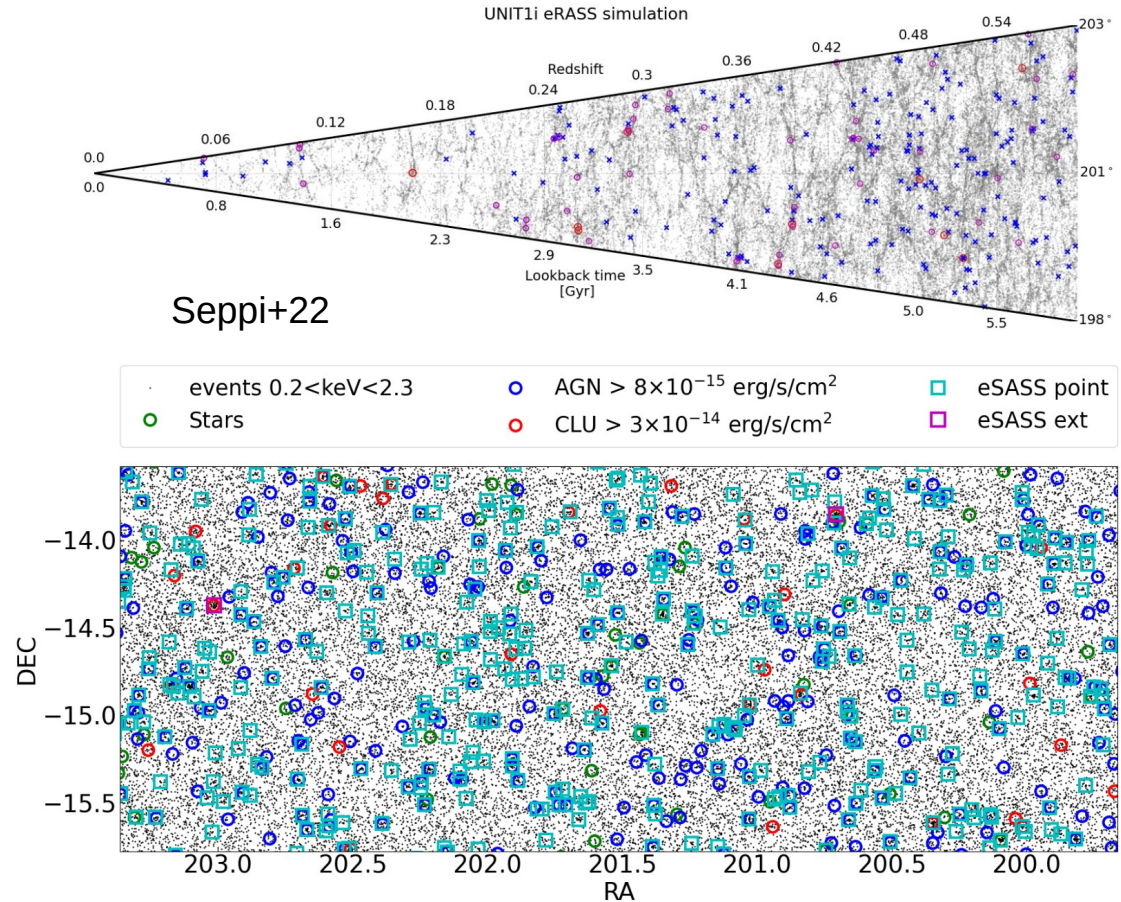


Mapping Cosmic X-rays and Interpreting eRASS1 Data Release 控制宇宙X射线地图，解读eRASS1数据



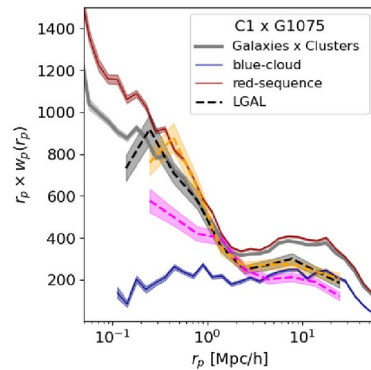
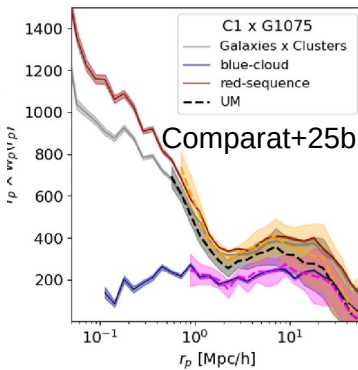
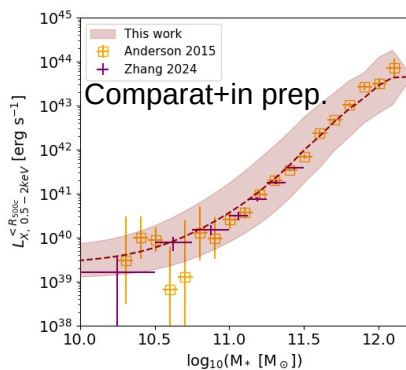
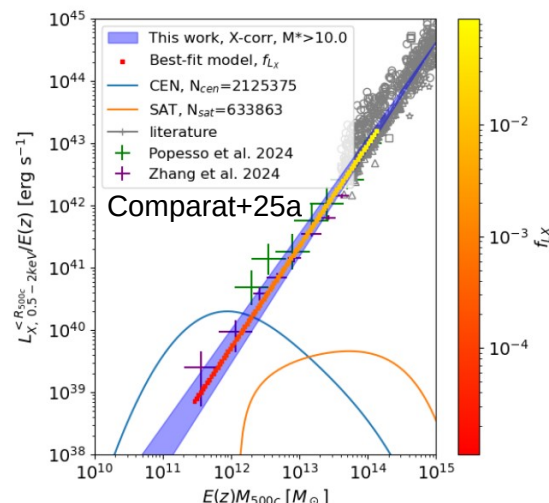
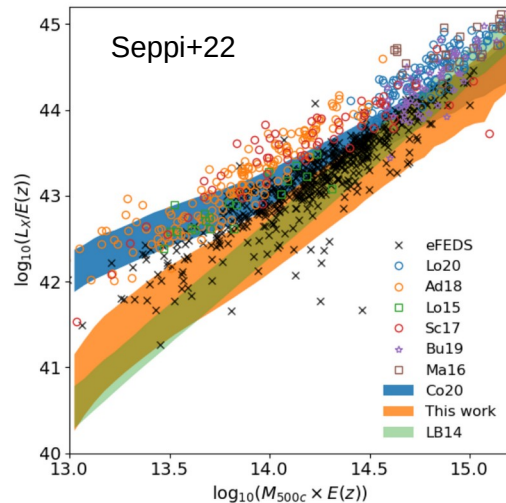
The need for new simulations

- Reach new and improved goals with eRASS:5
- Understand source catalogues
 - Quantify measurement uncertainties
- Calibrate a Selection Function for Cluster Cosmology
- Forward model the eROSITA sky (Comparat+19, Comparat+20, Seppi+22, Clerc+24)



Models upgrade

- Cross correlations:
galaxies + Xray events
galaxies + clusters
- Consistent modeling of
AGN+hot gas (clusters, CGM)
+galaxies with DM cosmo
sims + Xray painting + SHAM
models
- Natural Extension of L-M, T-M
down to $1e11$ Msun (!)

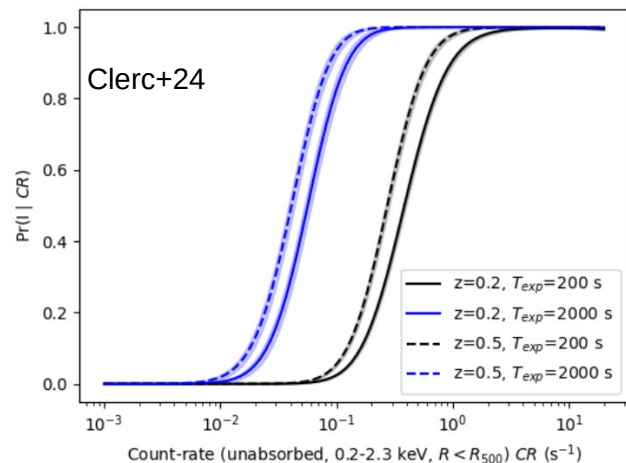
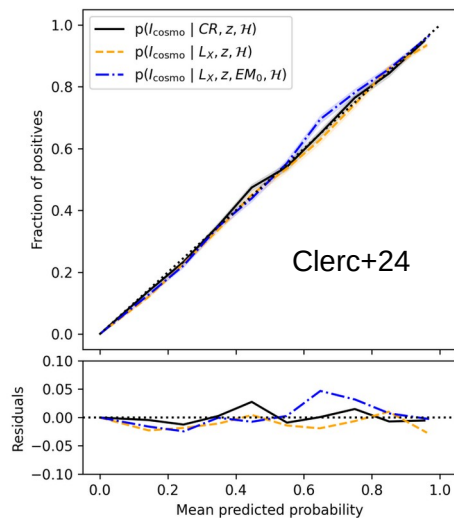
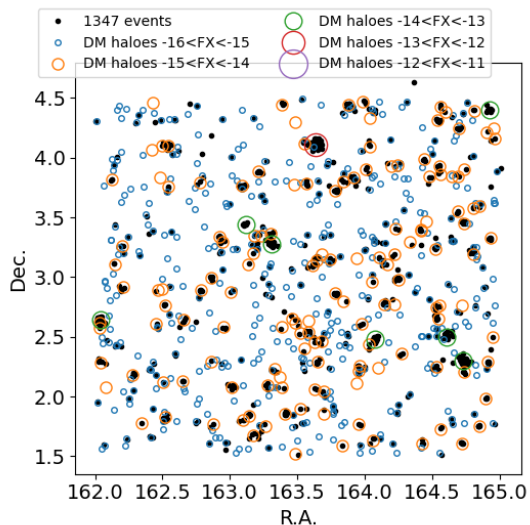


Devising new mocks

FOUR flavors to study completeness/purity

- 1) BKG only (study fluctuations)
- 2) AGN + BKG (for contamination)
- 3) BKG + HOTGAS (ideal completeness)
- 4) AGN + HOTGAS + BKG (full run)

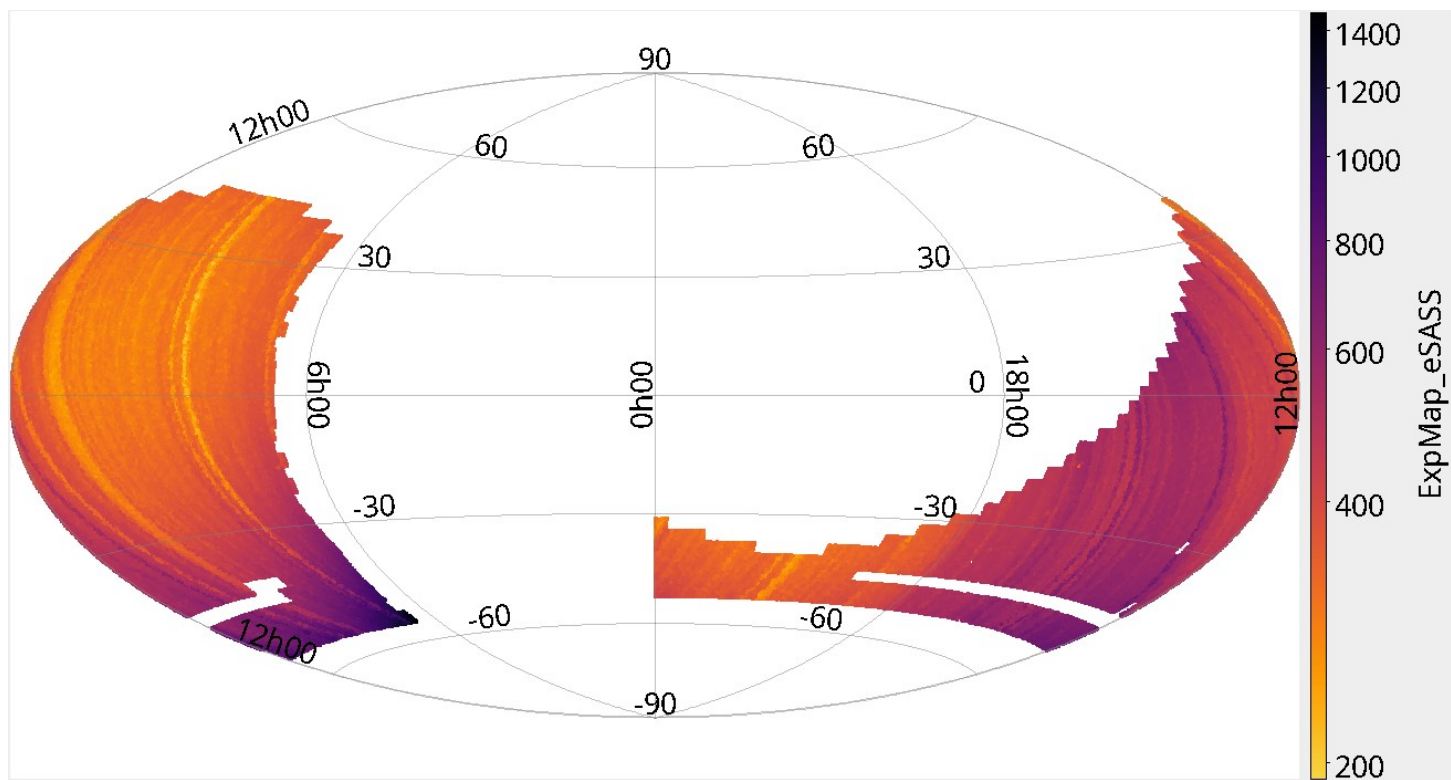
- 8 seeds for 2-4 → 25 half-sky twins to train Selection Function



Preliminary eRASS:5 sims results

Comparat, Seppi, Clerc, Malavasi

Experiment with AGN, CLU, BKG: GE_e4_merge_AGNseed001_SimBKG_CLUseed001
1349/2439 erosita tiles (~55%)



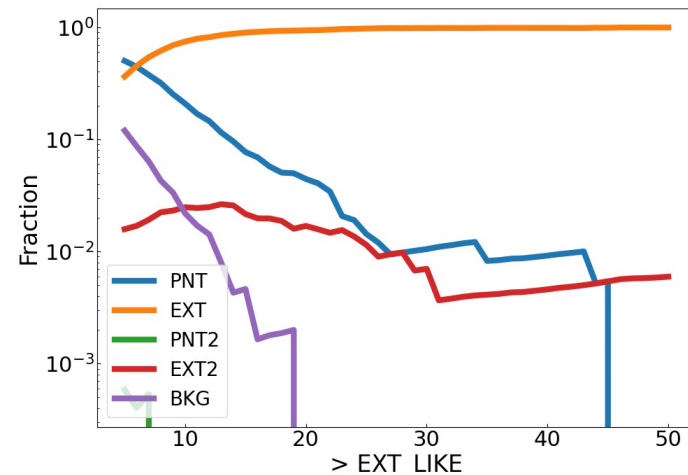
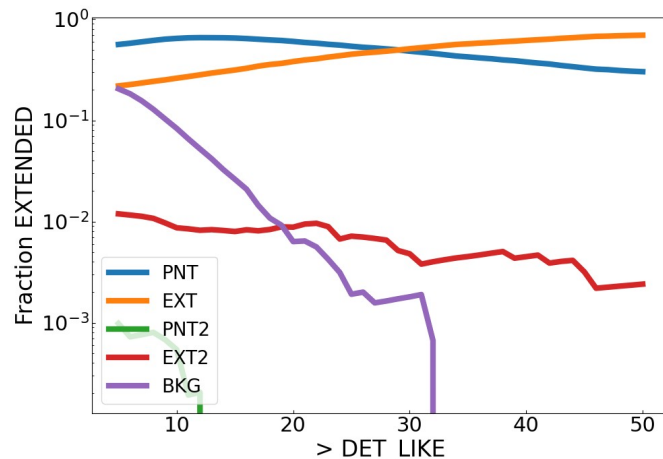
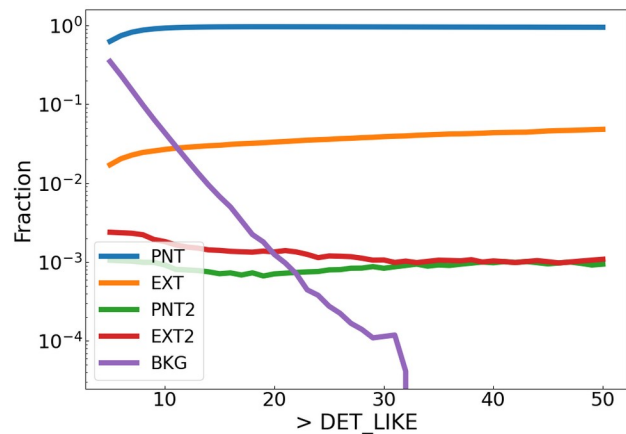
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ESASS catalogue

- real agn (PNT), real cluster (EXT), wings (PNT2 EXT2), fake source (BKG)
- Results align with Seppi+22: 1% spurious at $L_{\text{det}} > \sim 10$
- In extended catalogue: 50% PNT contamination at $\text{DET_LIKE} > \sim 30$
- In extended catalogue: 10% PNT contamination at $\text{EXT_LIKE} > \sim 10$



Preliminary eRASS:5 sims results

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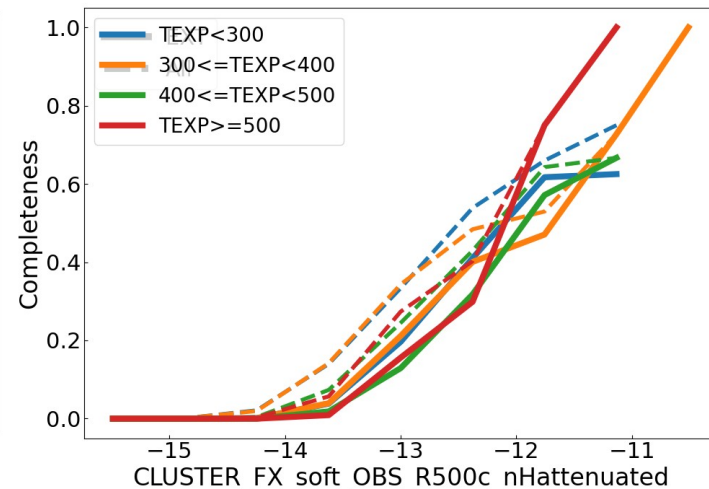
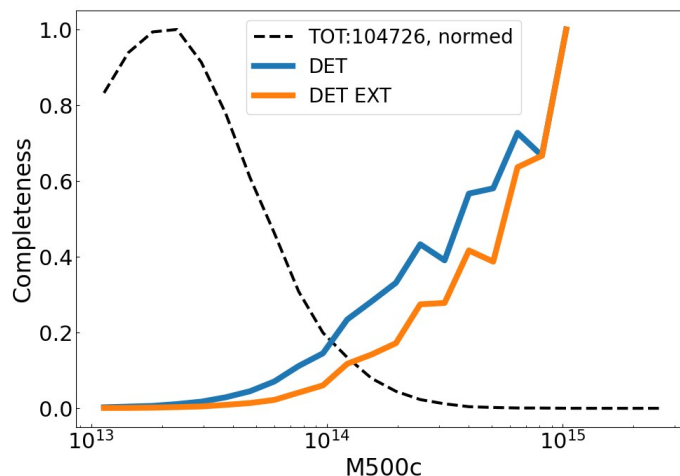
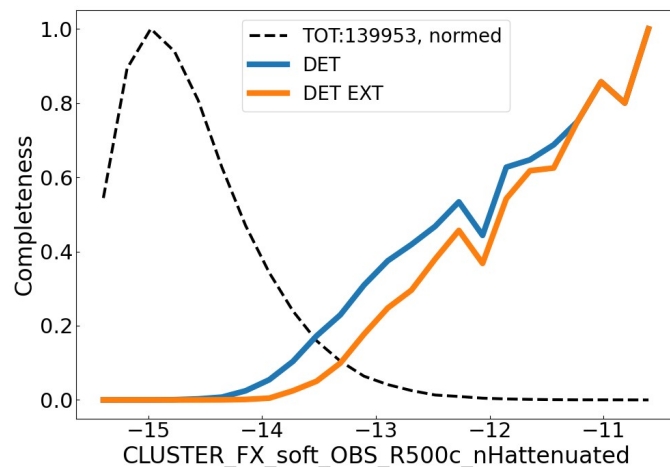
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Cluster completeness

-50% completeness at about -12.5, agrees with Marini+24

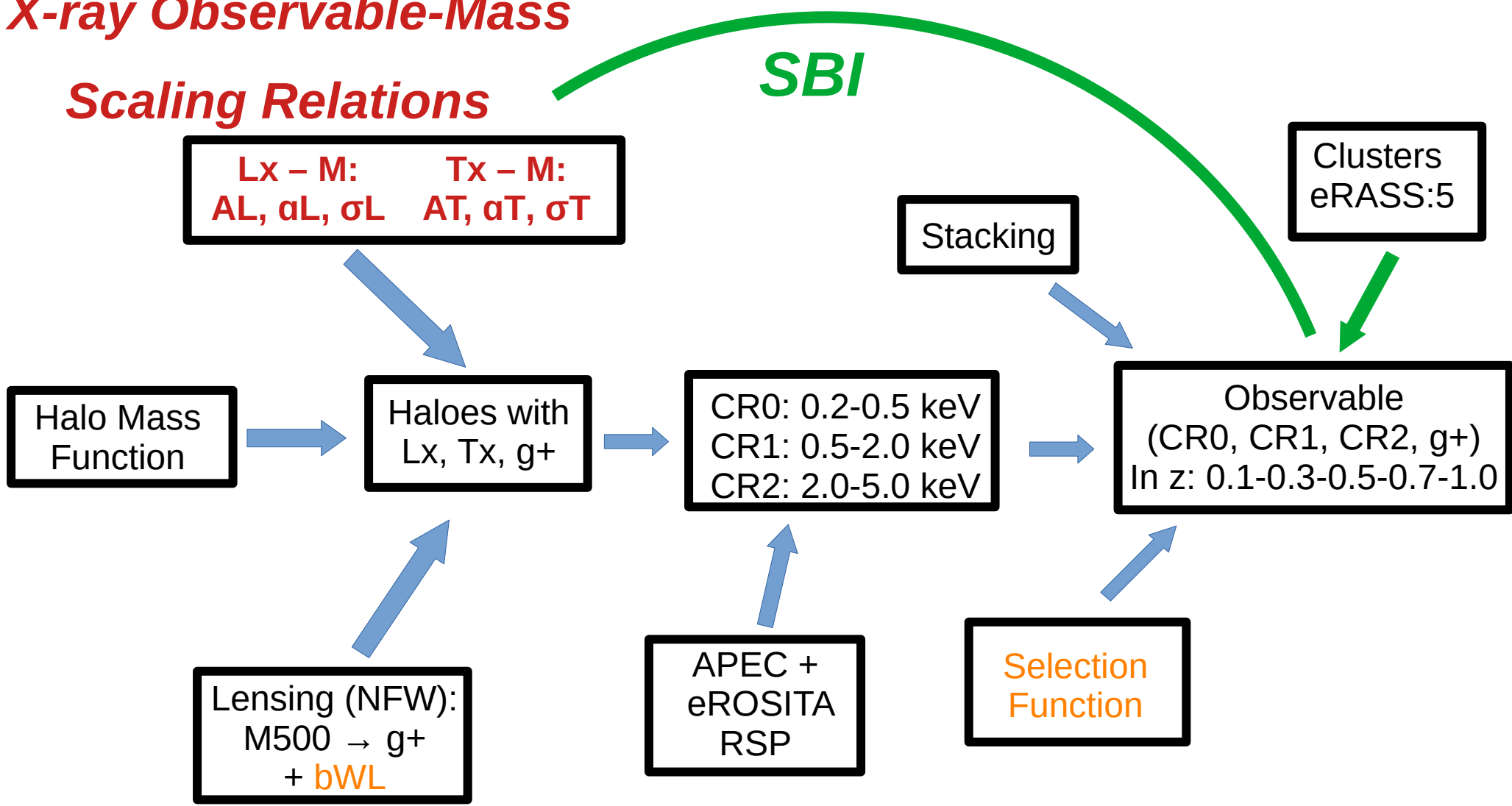
-50% completeness at $\sim 4e14$ Msun

- Next: split Pdet vs Texp (more area available soon)



X-ray Observable-Mass

Scaling Relations



Observable-Mass eRASS:5

the framework

$$O = A_O \left(\frac{M_{500c}}{M_{\text{piv}}} \right)^{\alpha + \delta \log\left(\frac{1+z}{1+z_{\text{piv}}}\right)} \left(\frac{E(z)}{E(z_{\text{piv}})} \right)^{\beta} \left(\frac{1+z}{1+z_{\text{piv}}} \right)^{\gamma}$$

$$\sigma_{\log O} = \sigma_0 + \sigma_M \log \frac{M_{500c}}{M_{\text{piv}}} + \sigma_z \log \frac{1+z}{1+z_{\text{piv}}},$$

$$\Sigma_{\text{crit}} = \frac{c^2}{4\pi G} \frac{D_s}{D_l \max[0, D_{ls}]}$$

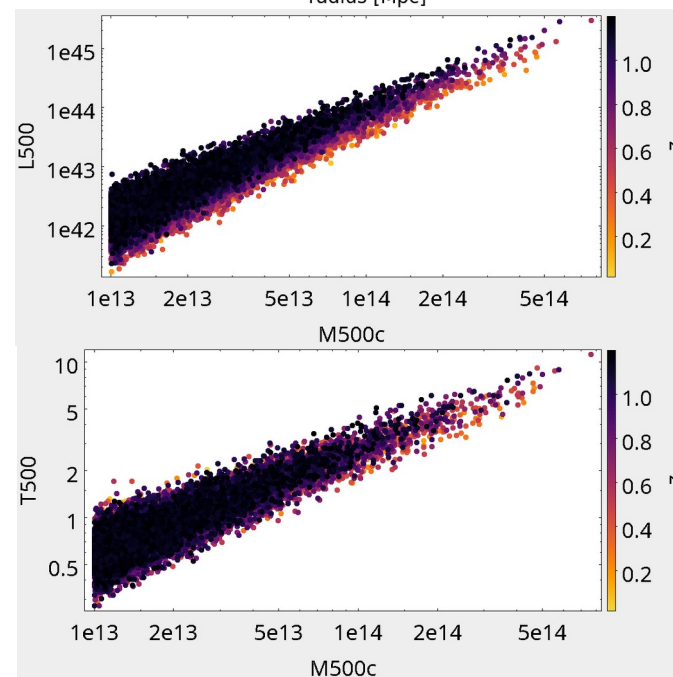
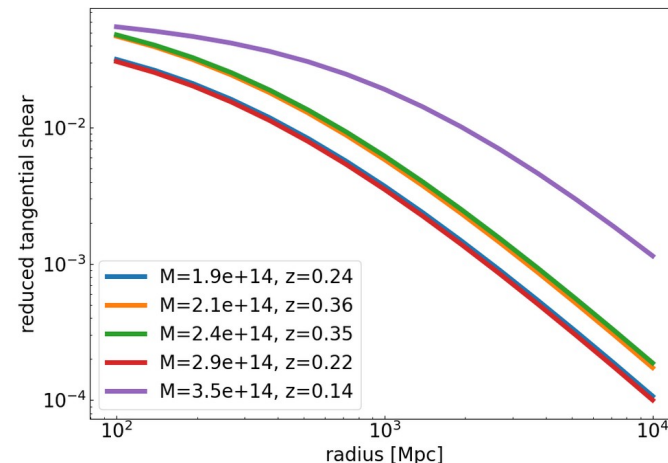
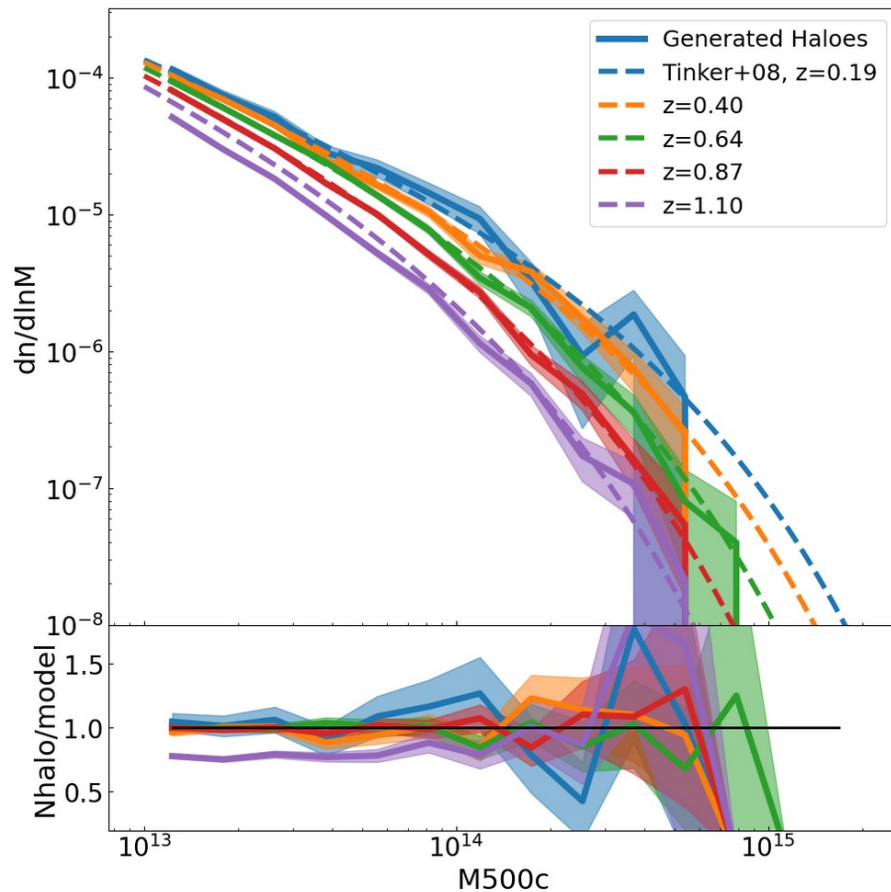
$$\kappa(\mathbf{x}) = \frac{\Sigma(\mathbf{x})}{\Sigma_{\text{crit}}}$$

$$g_t(\mathbf{x}) = \frac{\gamma_t(\mathbf{x})}{1 - \kappa(\mathbf{x})},$$

$$\gamma_t(R) = \frac{\overline{\Sigma(< R)} - \Sigma(R)}{\Sigma_{\text{crit}}},$$

- 8 base parameters
- Latest results (Zhang+24, Popesso+24) show no evidence for break in Lx-M
- M-z evolution of the intrinsic scatter
- Reduced tangential shear prediction from NFW profile
 - Needs bWL and Miscenter (Zenteno+25)
- Preliminary timeline eRASS:5 cosmo: Summer 2026

Observable-Mass eRASS:5: a first realization



Summary

- *Cluster cosmology with eRASS:5 can probe cosmological tensions*
- *New simulations to calibrate its selection function (key step!)*
- *Key step for our work on L-M, T-M scaling relations (stay tuned...)*

THANK YOU!

