Quantitatively defining consistent relaxed galaxy cluster samples for precision cosmology with impending surveys

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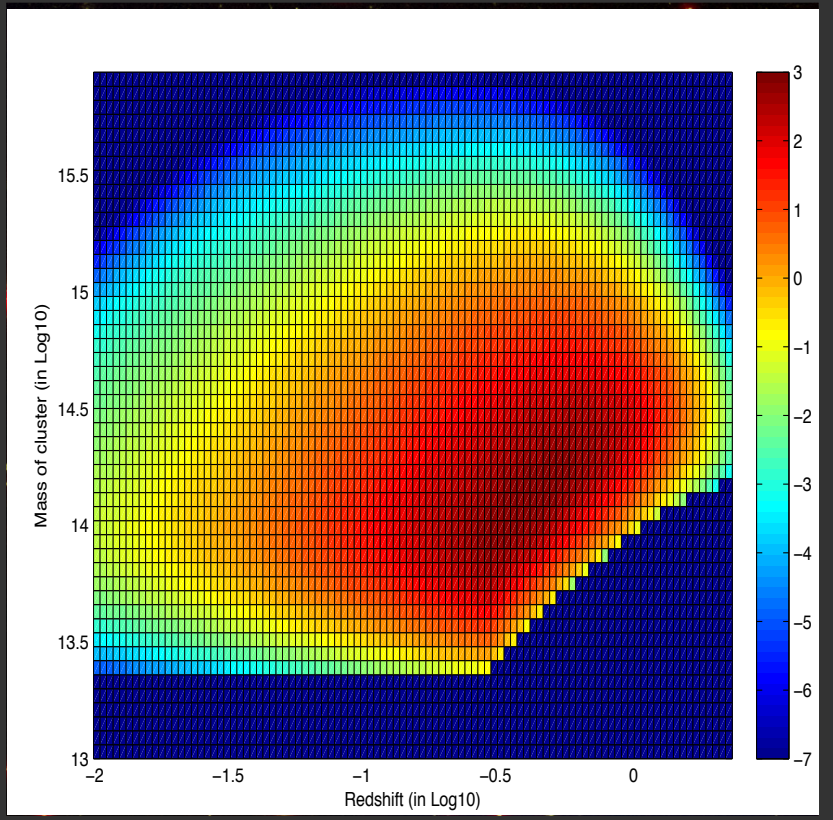
KICC 10th Anniversary – 09/10/19

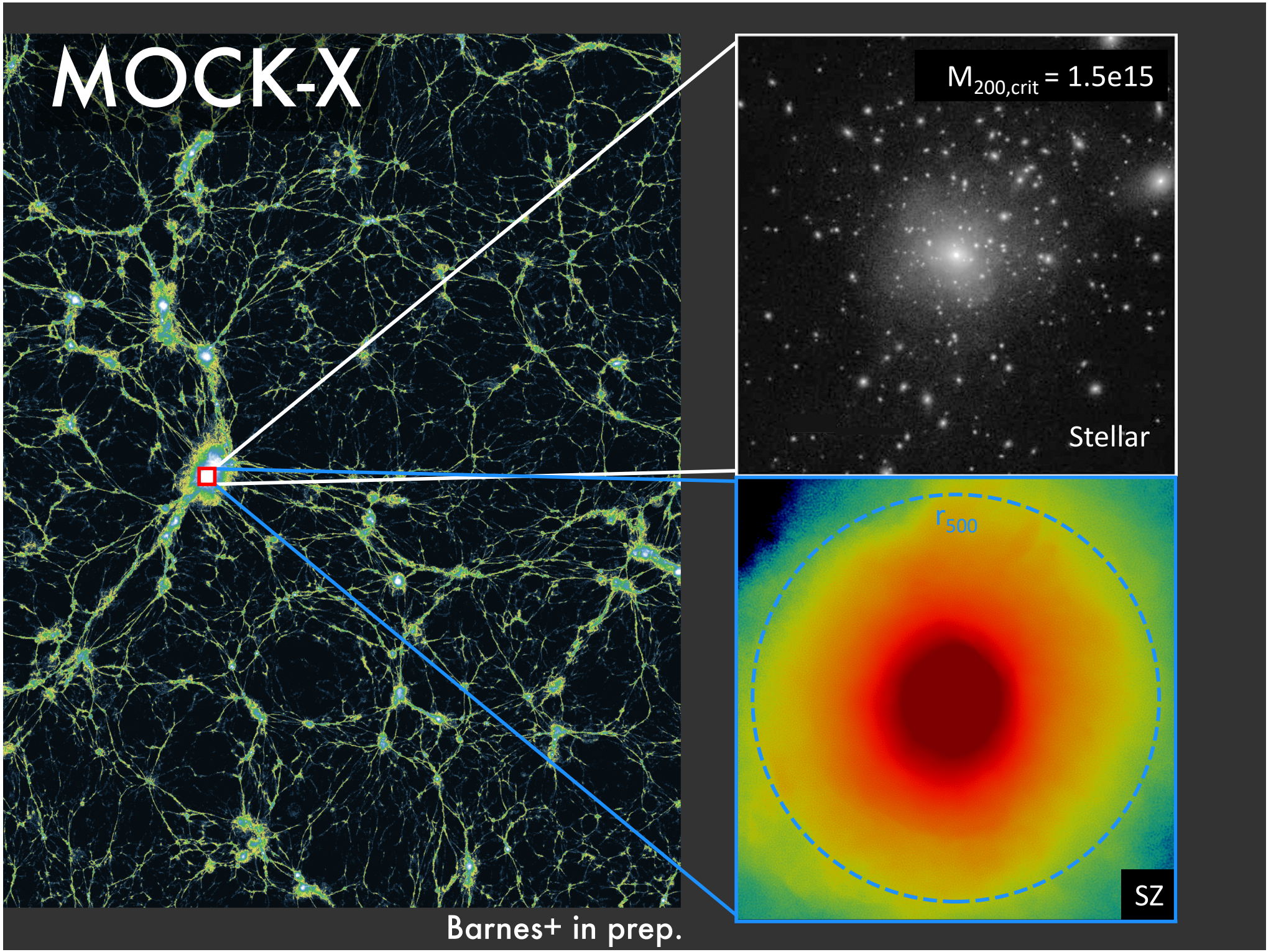
Motivation

- Distribution of galaxy clusters is very sensitive to cosmology
- Facilities like eRosita, LSST and Simons Observatory increase the number of known clusters by two orders of magnitude
- Systematics limited with new surveys

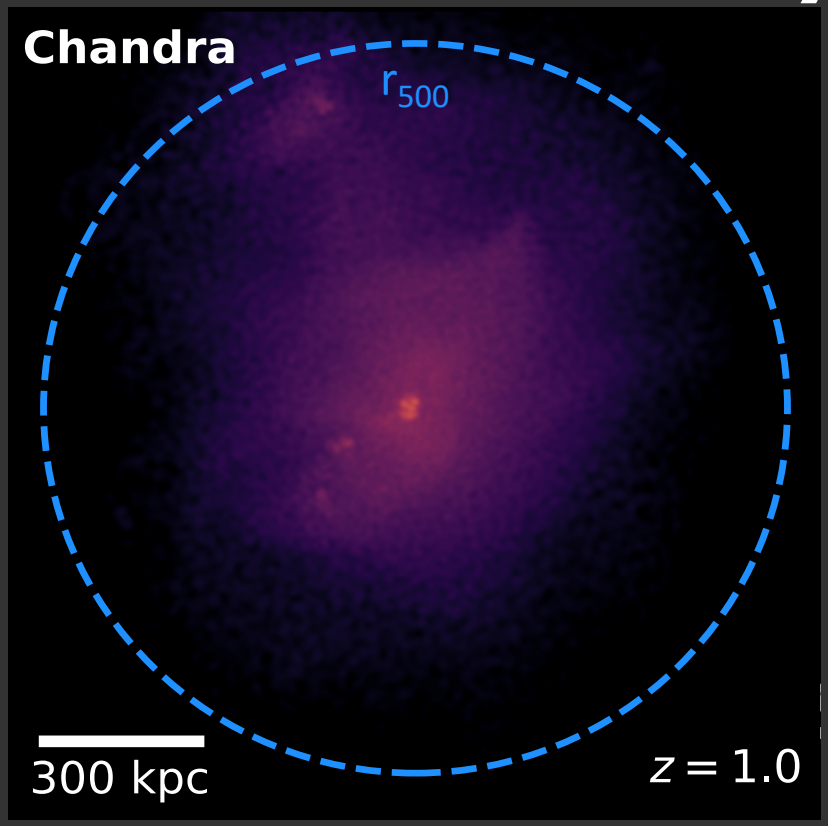


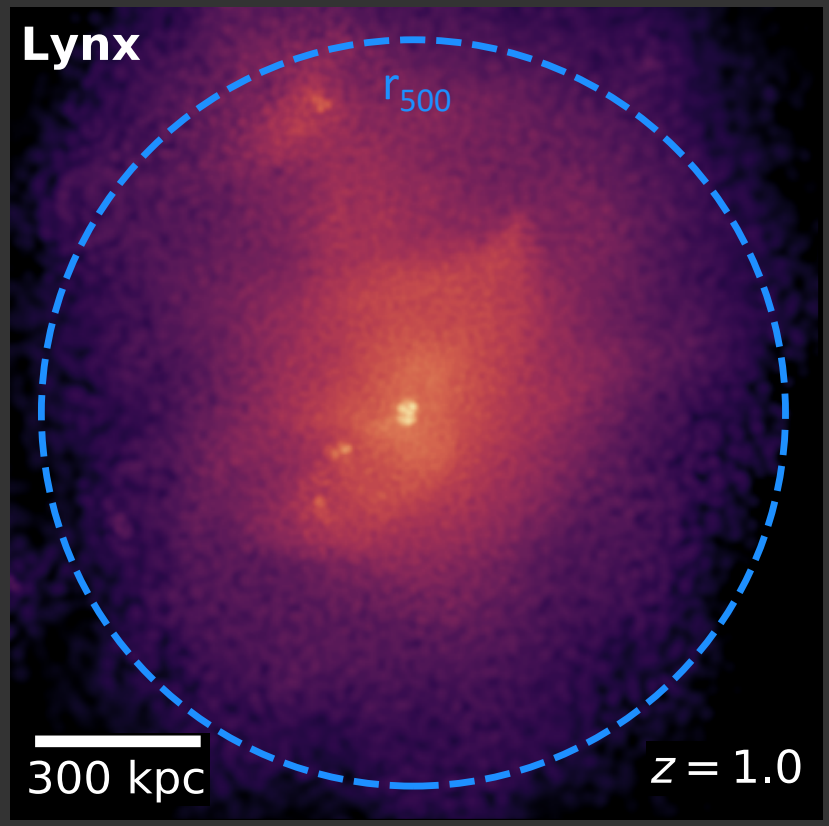
Borm+ 14

- Numerical simulations provide a “truth”, allowing us to explore potential systematics
- Goal: Explore systematics


MOCK-X
$M_{200,crit}$ = 1.5e15
Stellar
r_{500}
SZ
Barnes+ in prep.

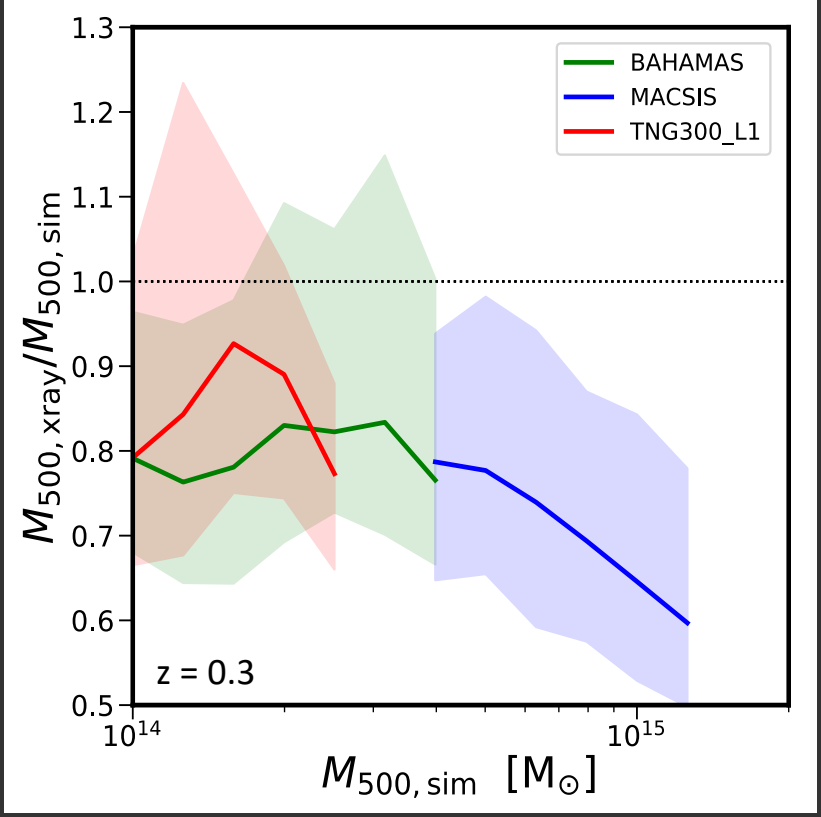
MOCK-X – X-rays

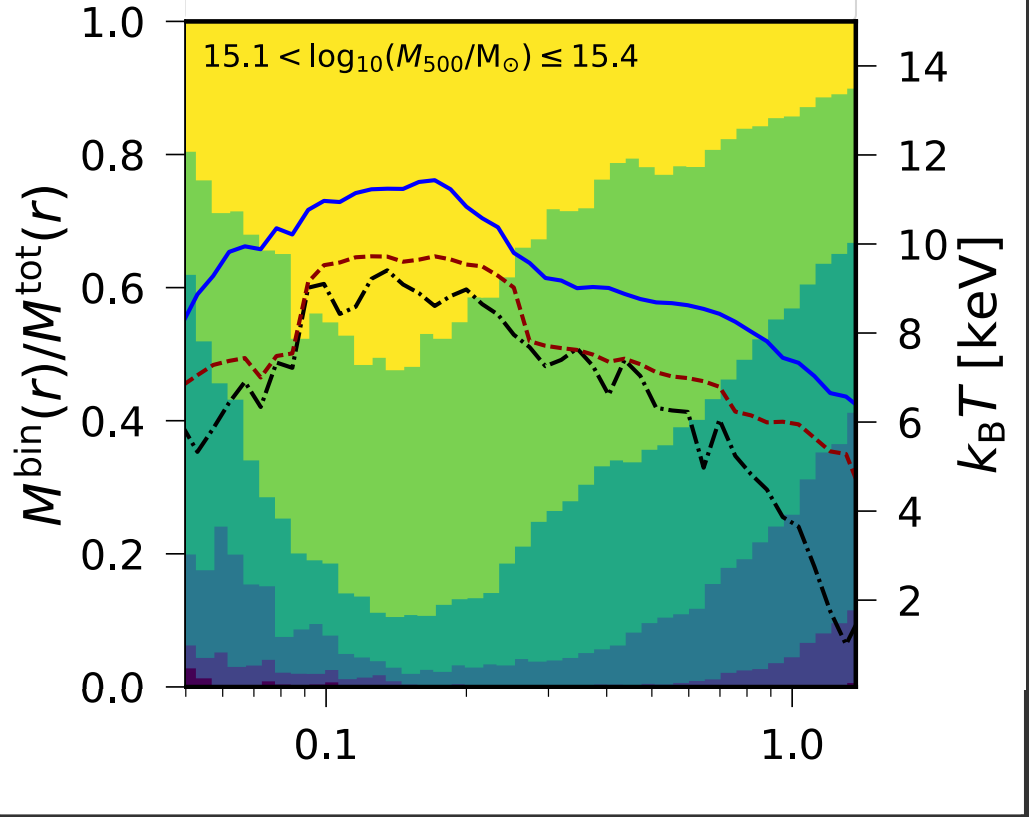




- Synthetic datacubes: IllustrisTNG, BAHAMAS, MACSIS
- $M_{500} > 10^{14}\ M_{\odot}$, 6 Chandra-*like* projections
- 11,000+ at z = 0, properties via observational techniques

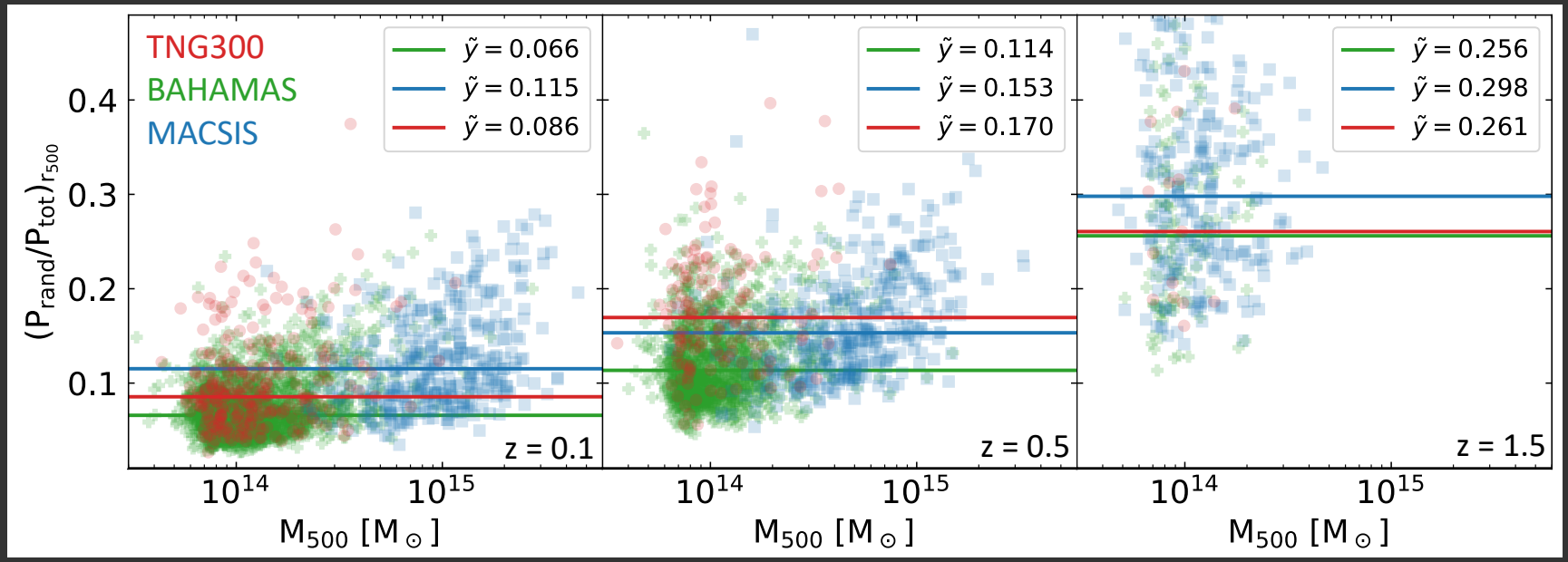
Mass bias – X-ray

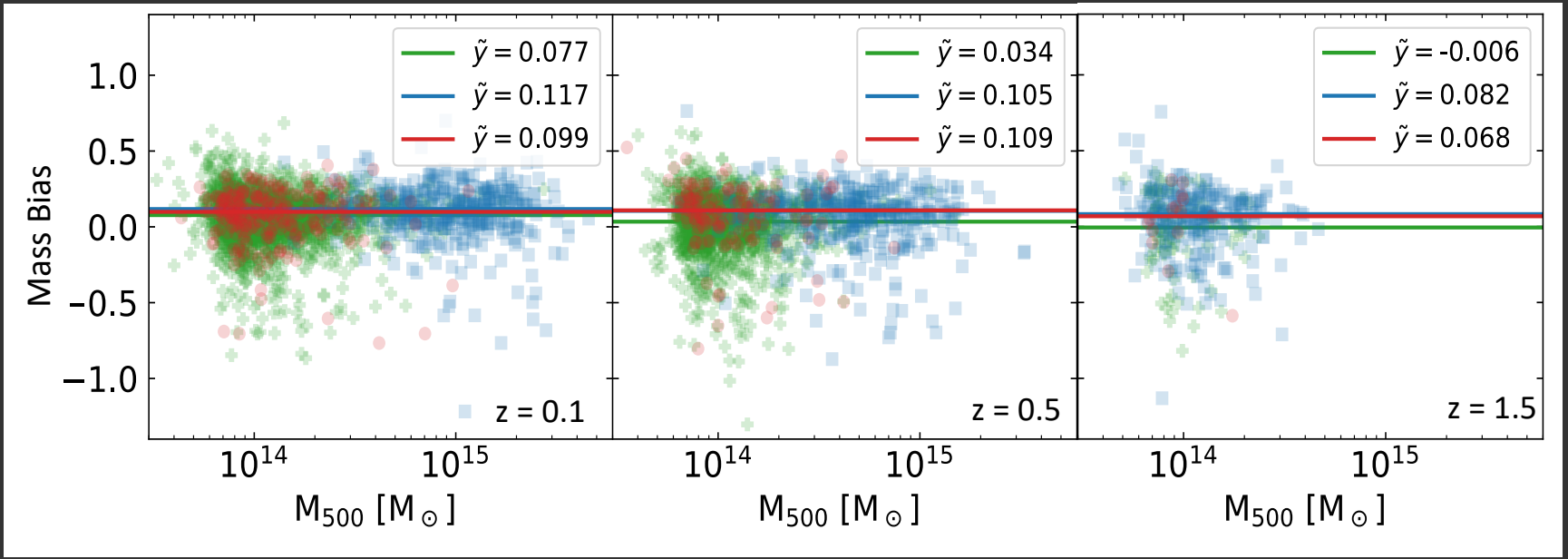




- Find typical mass bias of b = 0.2, however bias increases for largest clusters
- Result of fitting a single temperature model to diverse temperature distribution

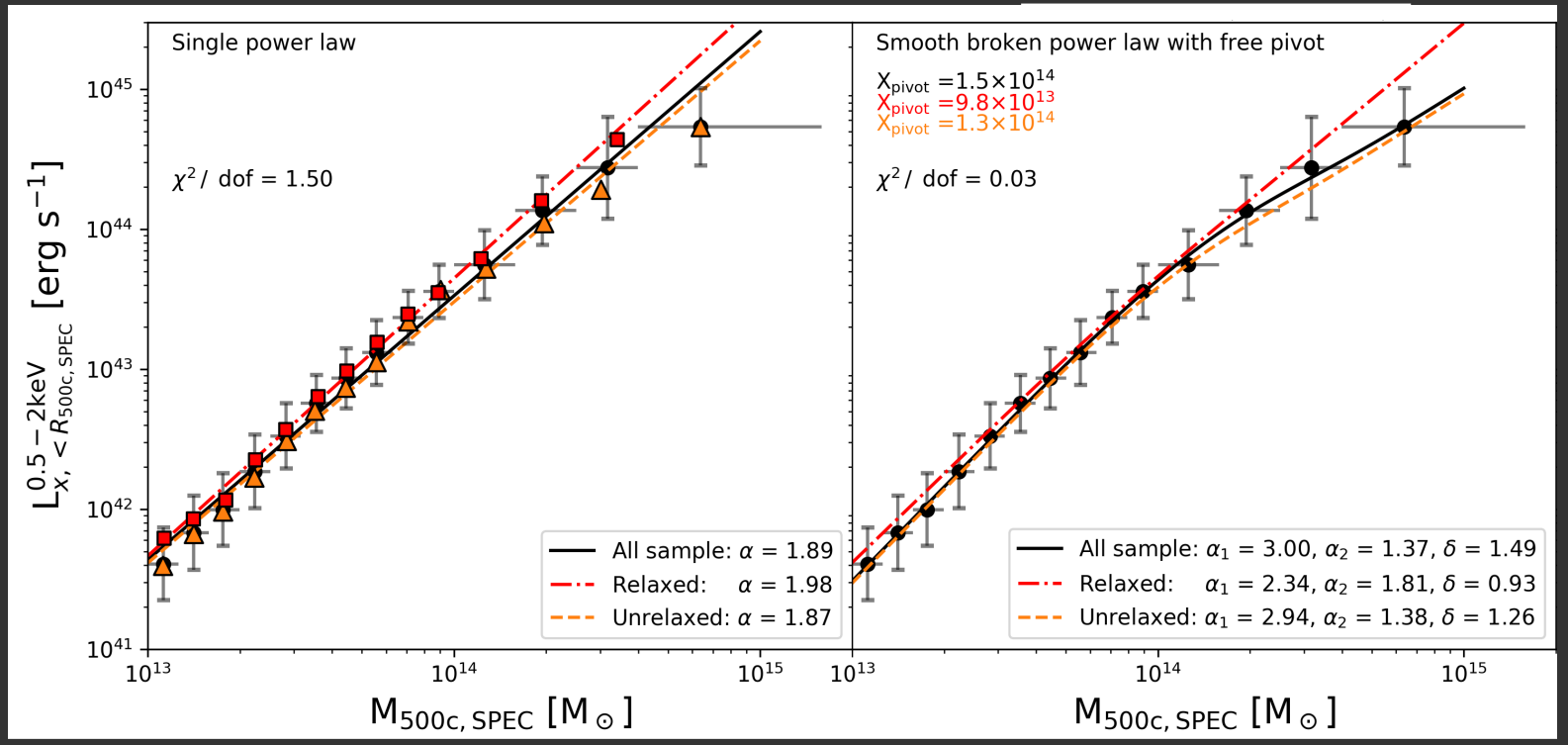
Mass bias – X-ray + SZ





Kannan, DJB+ in prep.

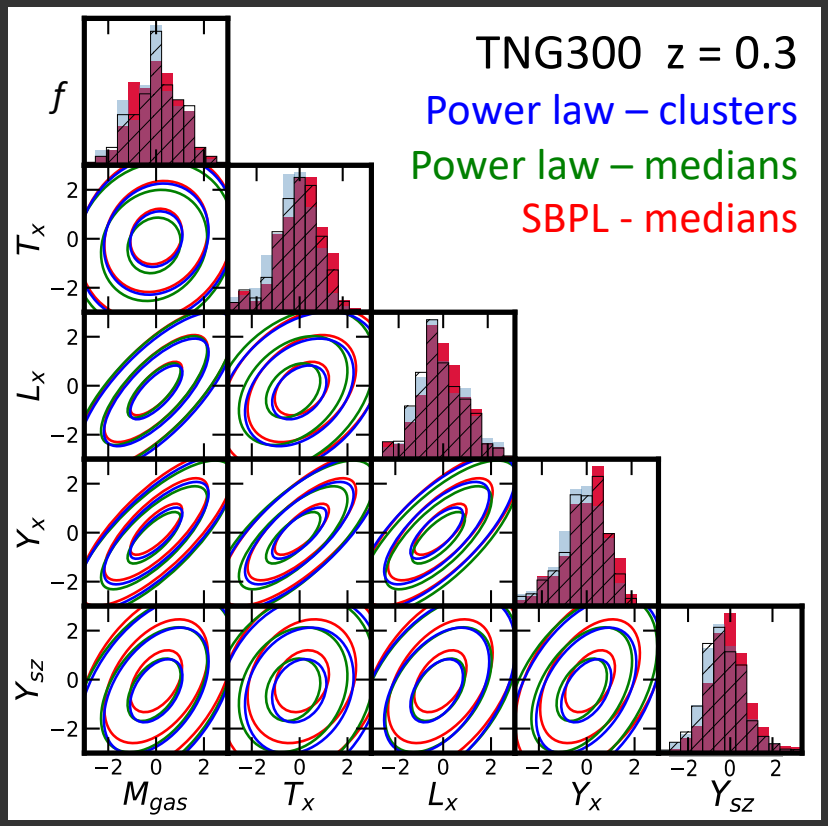
Scaling relations

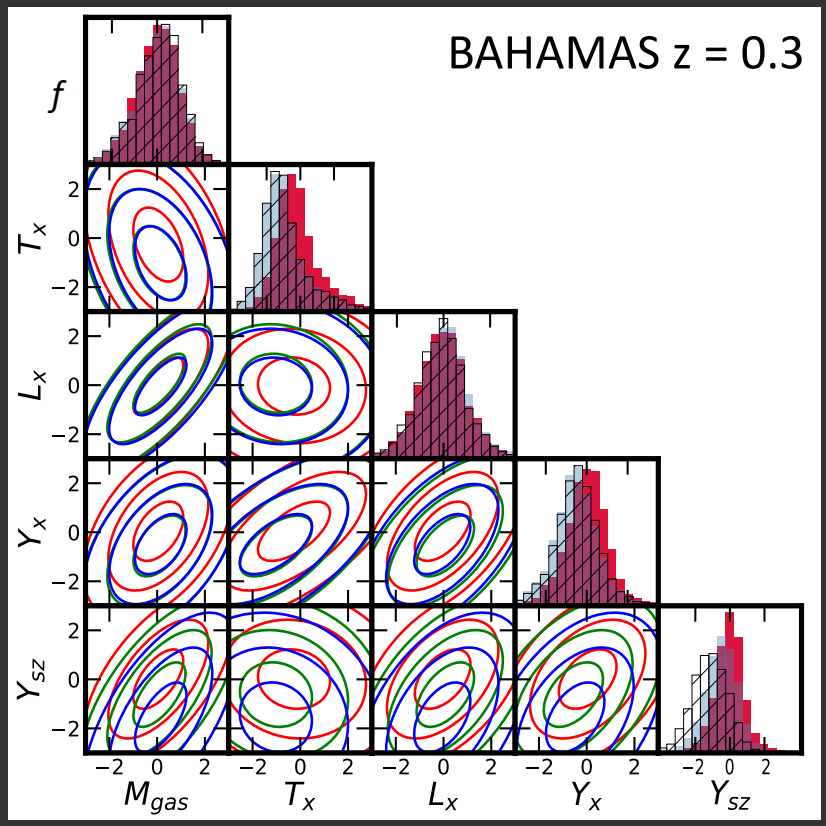


Pop, DJB+ in prep.

- High-mass slope depends on fitting method
- Relative mass calibration potentially depends on method

Observational covariance

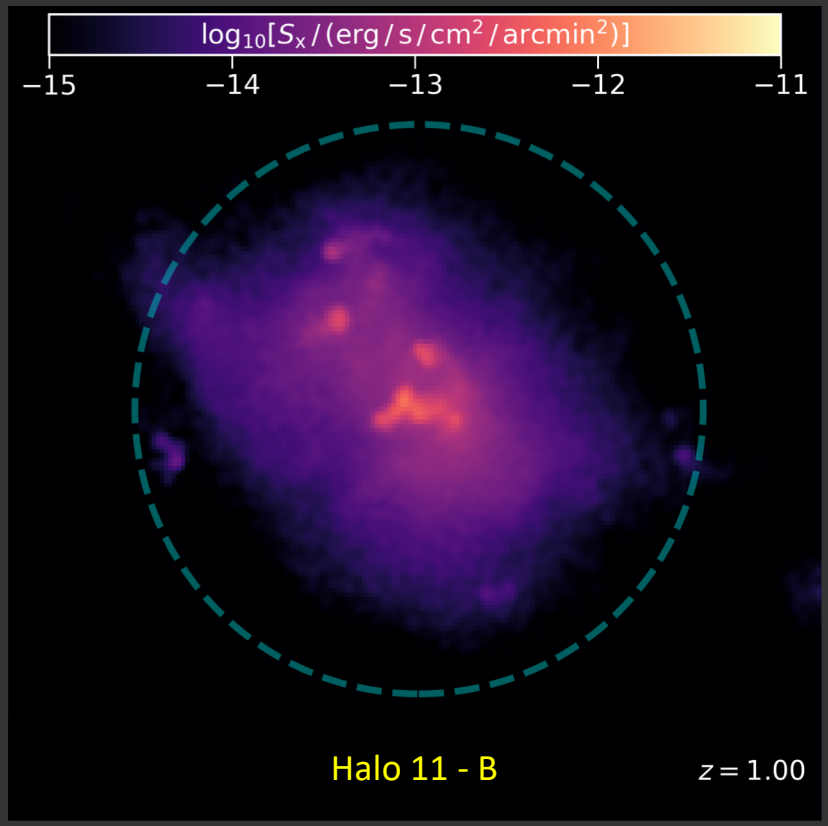


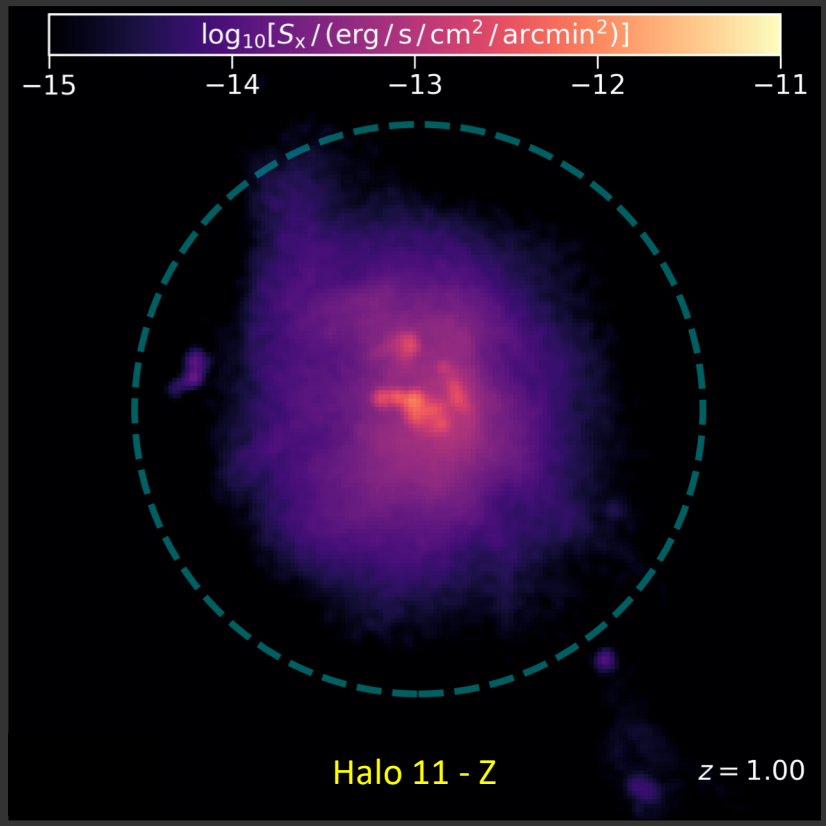


Jorgenson, DJB+ in prep.

- For small samples fit has a negligible impact, but becomes important for large samples of objects
- Must characterize scatter and covariance for survey

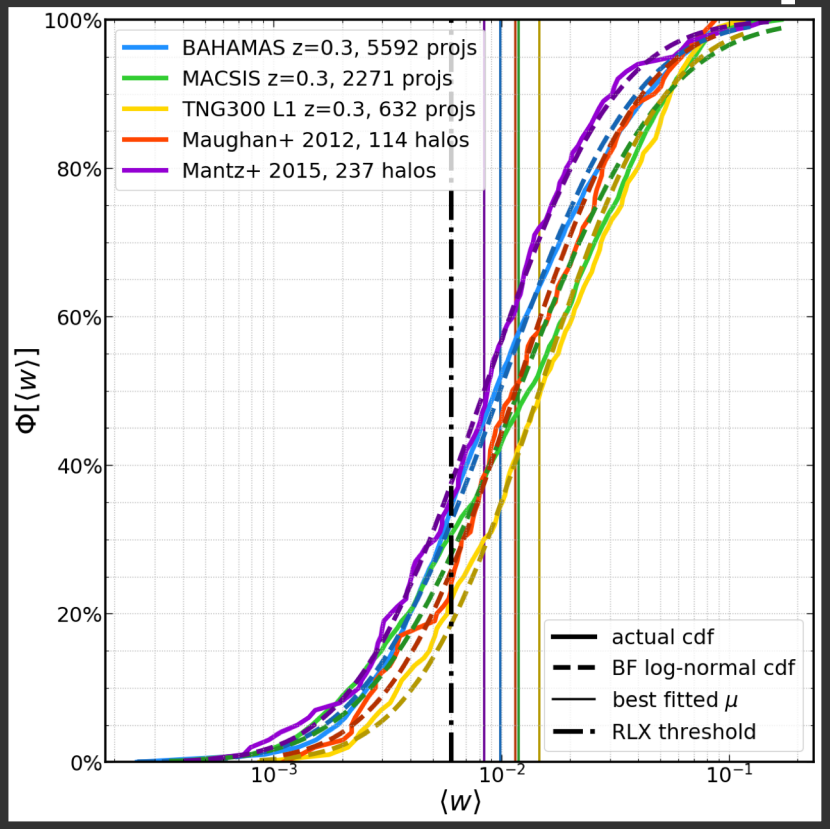
Relaxed clusters?

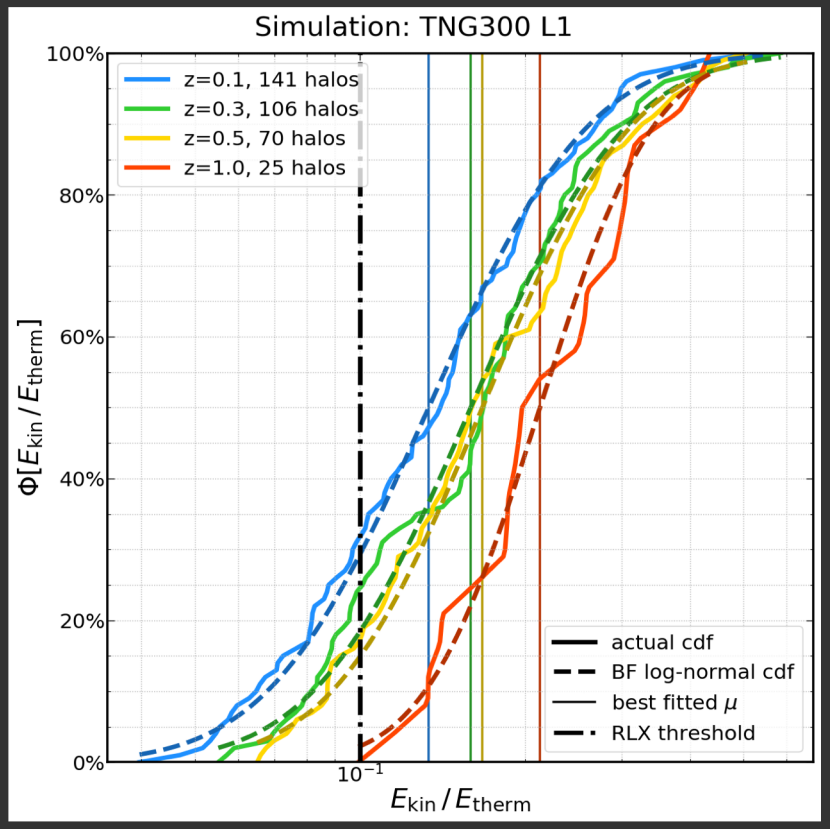




- Visual classification impractical in the future, but how do image features perform?
- Explore a range of observational and theoretical criteria for classifying clusters as relaxed

Relaxation comparison

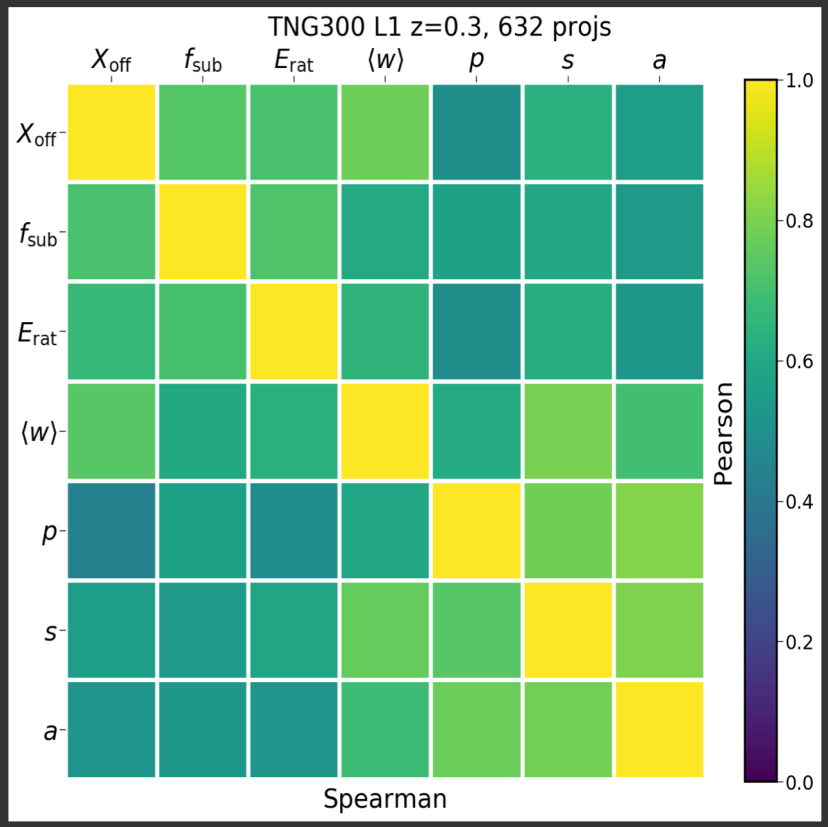


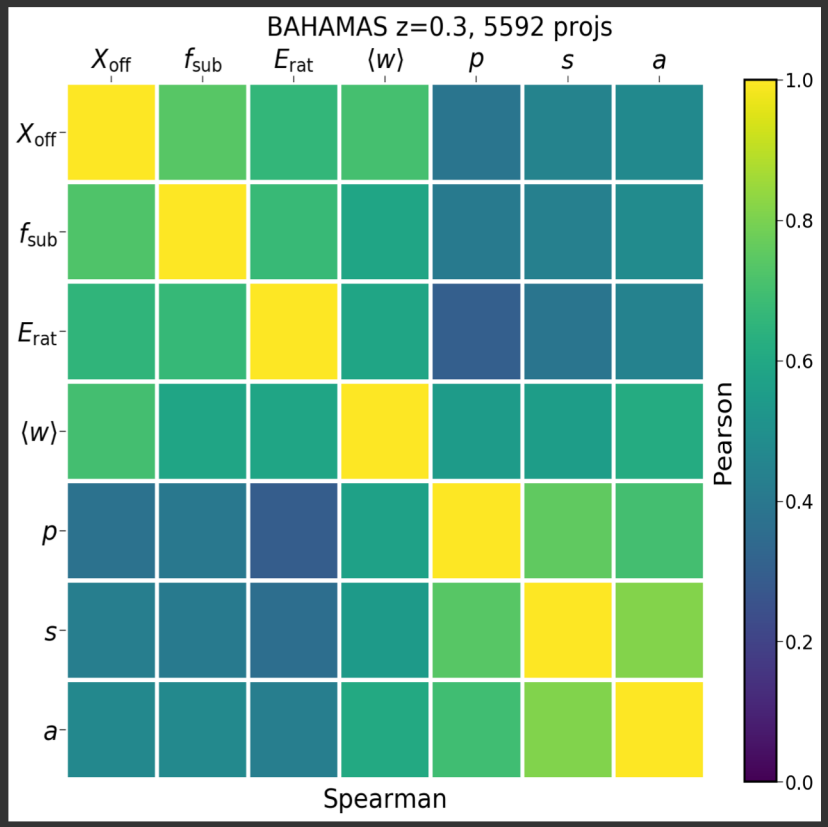


Cao, DJB+ in prep.

- Simulated and observed distributions agree
- All criteria evolve with both redshift and numerical choices

Parameter correlation





Cao, DJB+ in prep.

- All criteria are generally correlated with each other, though it weakens for theory-observation comparison
- Currently exploring the "best" combination via machine learning techniques

Conclusions

- Will be systematics limited in 5 years time
- Simulations have matured to the point that they can be used to explore systematics
- Mass bias does not evolve with redshift, but non-thermal pressure fraction increases. Haloes at high redshift appear over-pressured due to accretion
- Scaling relation slopes, scatter and observable covariance are sensitive to method
- Relaxation parameters evolve with redshift and numerical choices, but are well matched to low-redshift observations