Galaxy Clusters in the Roman High-Latitude Survey

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Cluster sample from Roman HLS

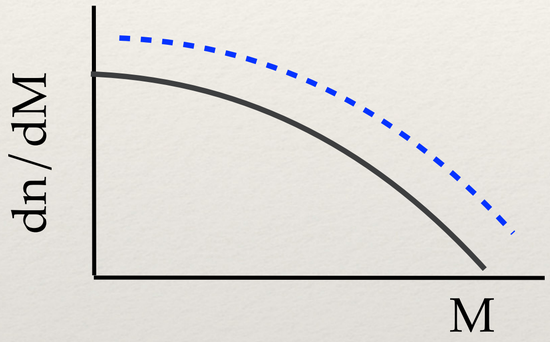
2000 square degree, ~20,000 clusters above 10^{14} $M_\odot$ for $z < 1$

Precise weak lensing cluster mass calibration:

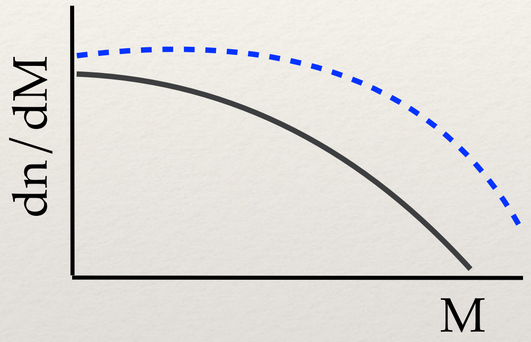
- Low lensing noise
- Cross-correlation with spectroscopic galaxies
- Efficient targeted observations

Cluster number counts vs. mass

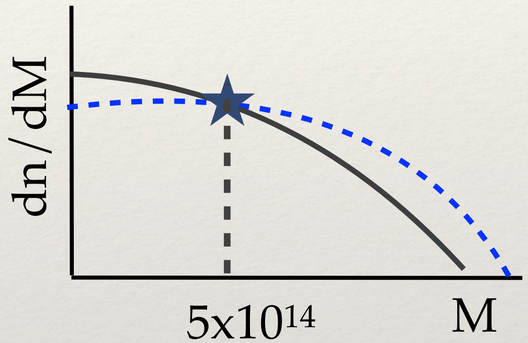
increase Ω_m



increase σ_8

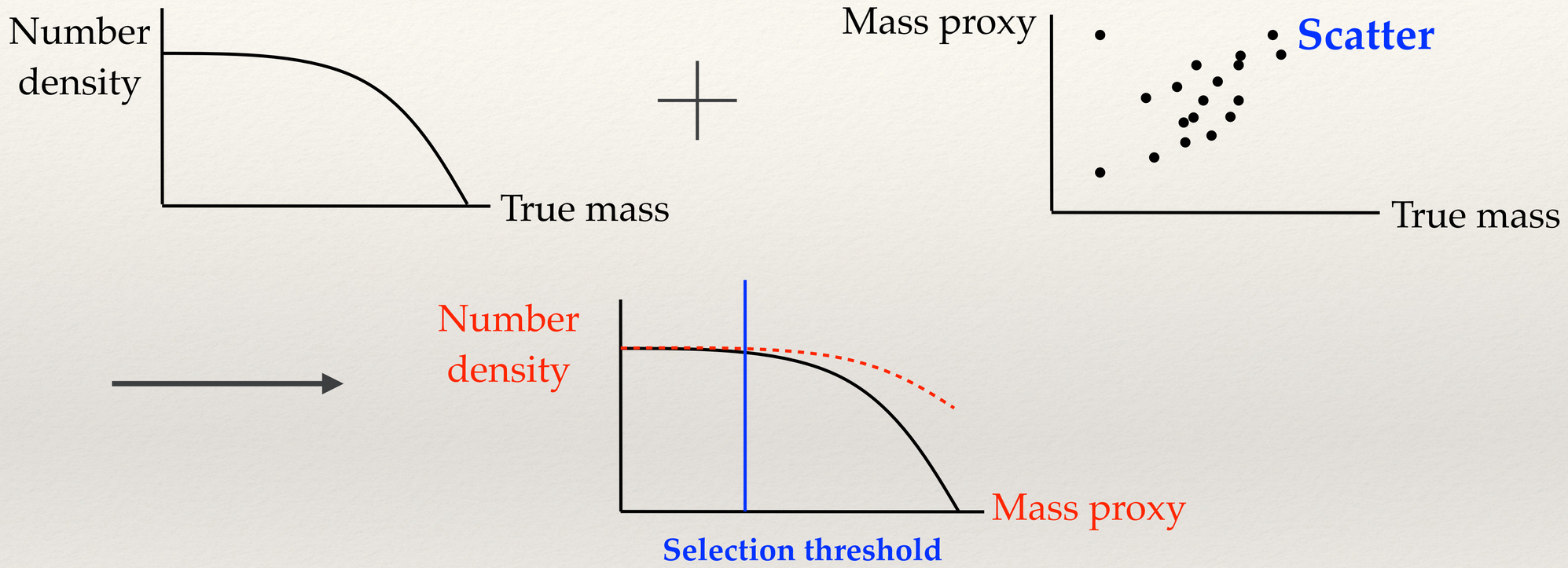


increase σ_8
but fix $\sigma_8\ \Omega_m^{0.5}$



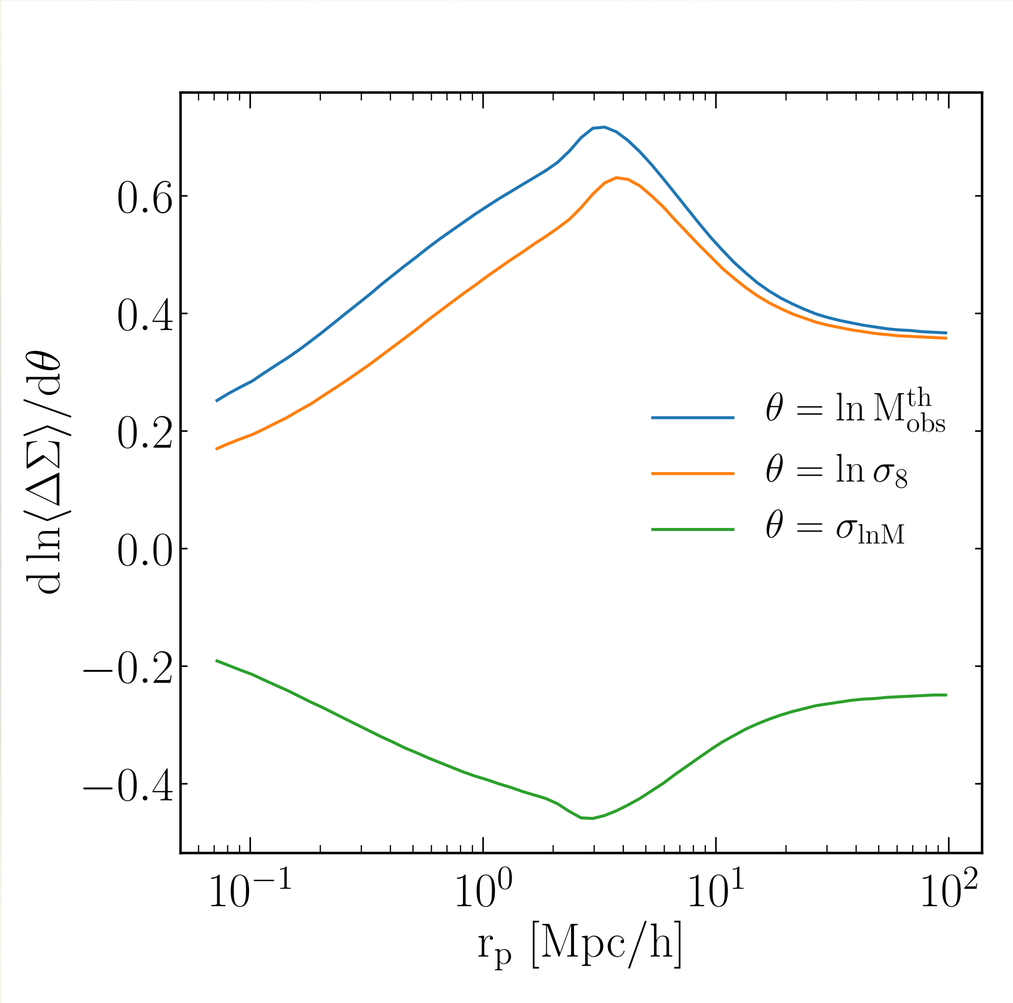
- Increasing Ω_m is equivalent to increasing all cluster masses
- Increasing σ_8 increases the number of clusters at all masses
- Increasing σ_8 with fixed $\sigma_8\ \Omega_m^{0.5}$ fixes the number at ~$5x10^{14}$ but still changes the high-mass end (see Zheng et al. 2002)
- Cluster counts can breaking the degeneracy and constrain growth of structure

Cluster number counts vs. mass



- At a given cosmology, the observed counts depend on (1) scatter and (2) mass scale at the threshold.
- The mass scale comes from lensing, and the scatter relies on external calibration.

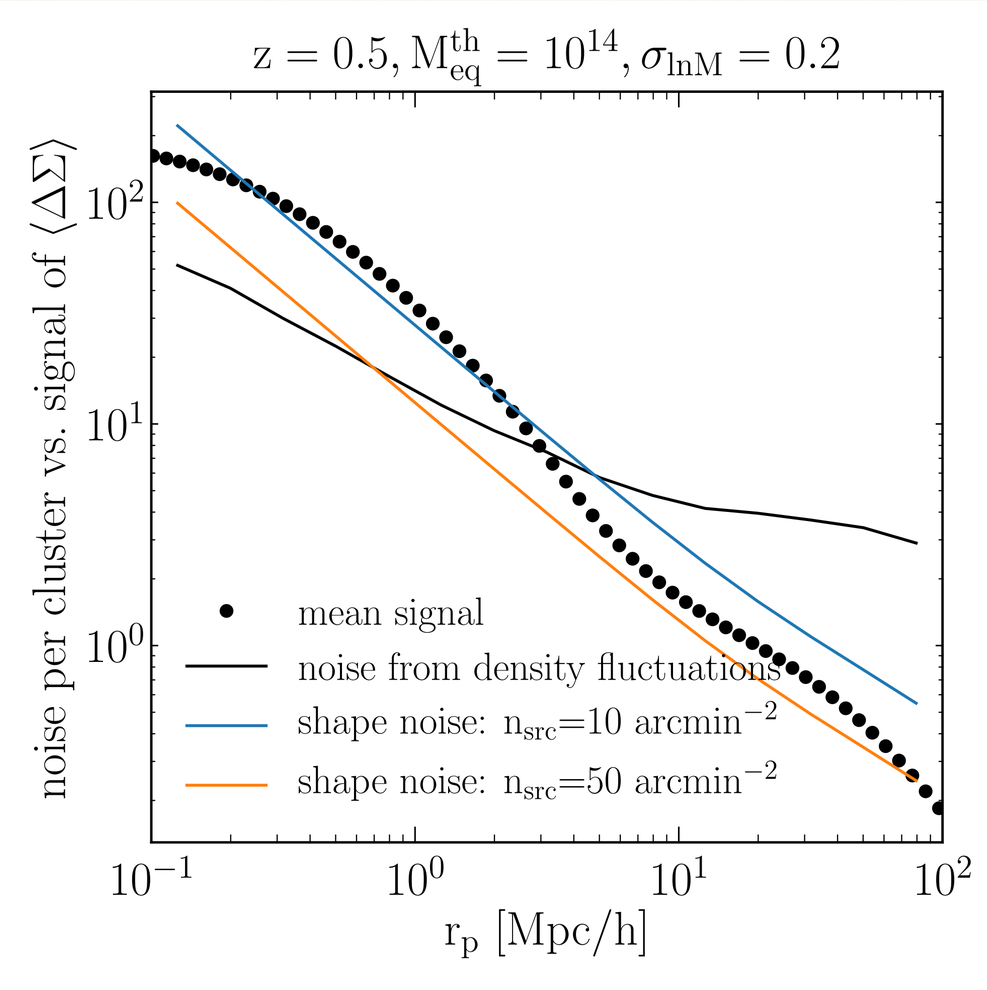
Cluster lensing: parameter sensitivity



- Mass scale, scatter, and σ_8 are degenerate with each other.
- To break the degeneracy, we need to combine cluster lensing, number counts, and prior on scatter.

Wu et al. 2021

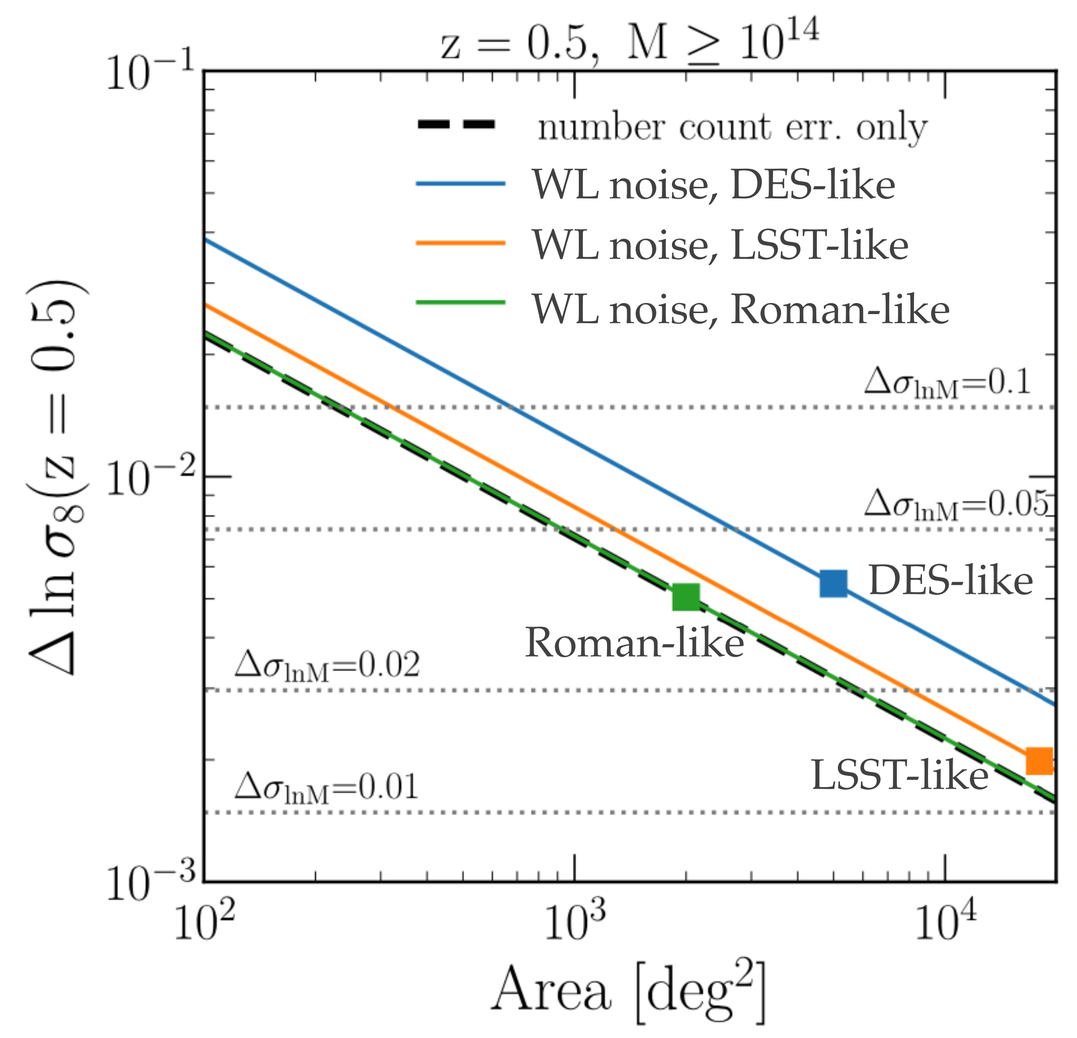
Cluster lensing: signal vs. noise



- Noise is contributed by
  - density fluctuations
  - shape noise ($\propto 1/$number of source galaxies)
- Overall noise $\propto 1/$area
- Even with Roman's source density, signal to noise is not high enough for each cluster. Stacking is needed.

Wu et al. 2019 & 2021

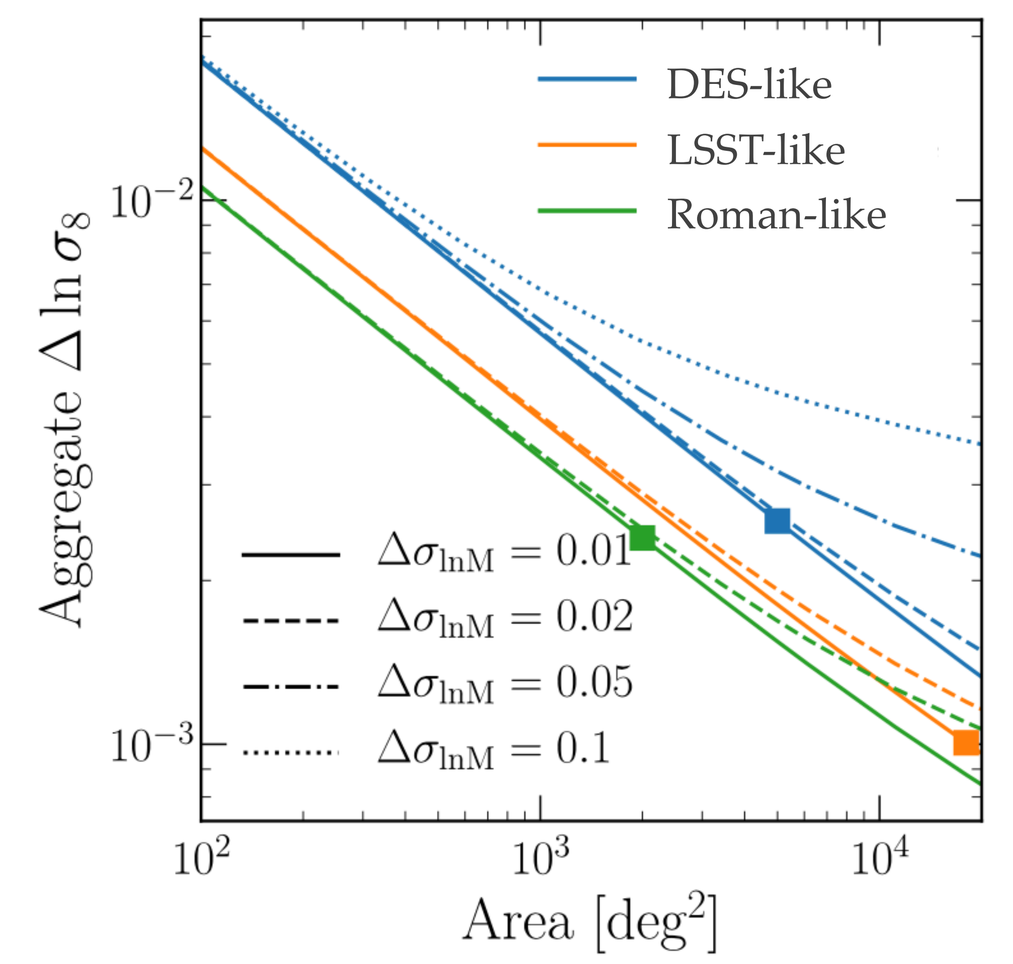
Low lensing noise for Roman clusters



- In number counts + lensing analysis, lensing noise is approaching the number counts noise
- The constraining power scales with area

Wu et al. 2021

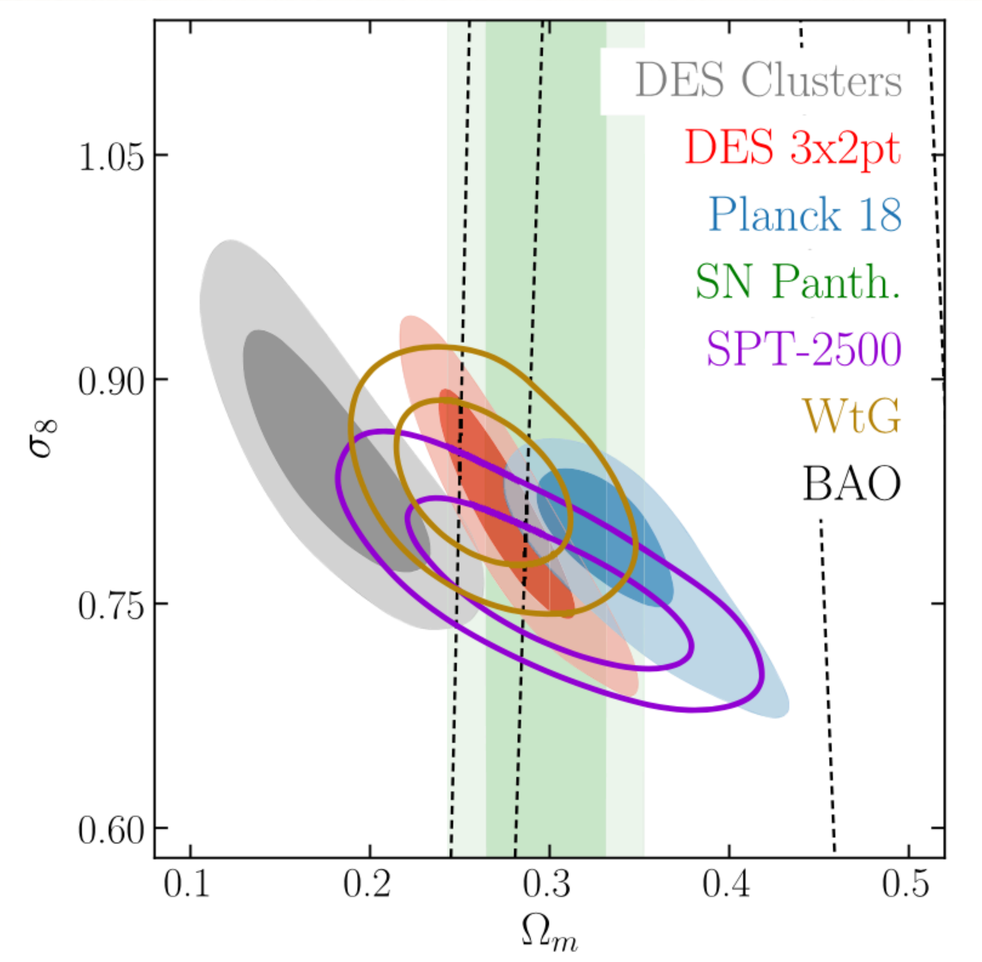
Constraining the scatter is the key



- The prior on scatter determines the constraining power for the survey.
- It's more important than the area.

Wu et al. 2021

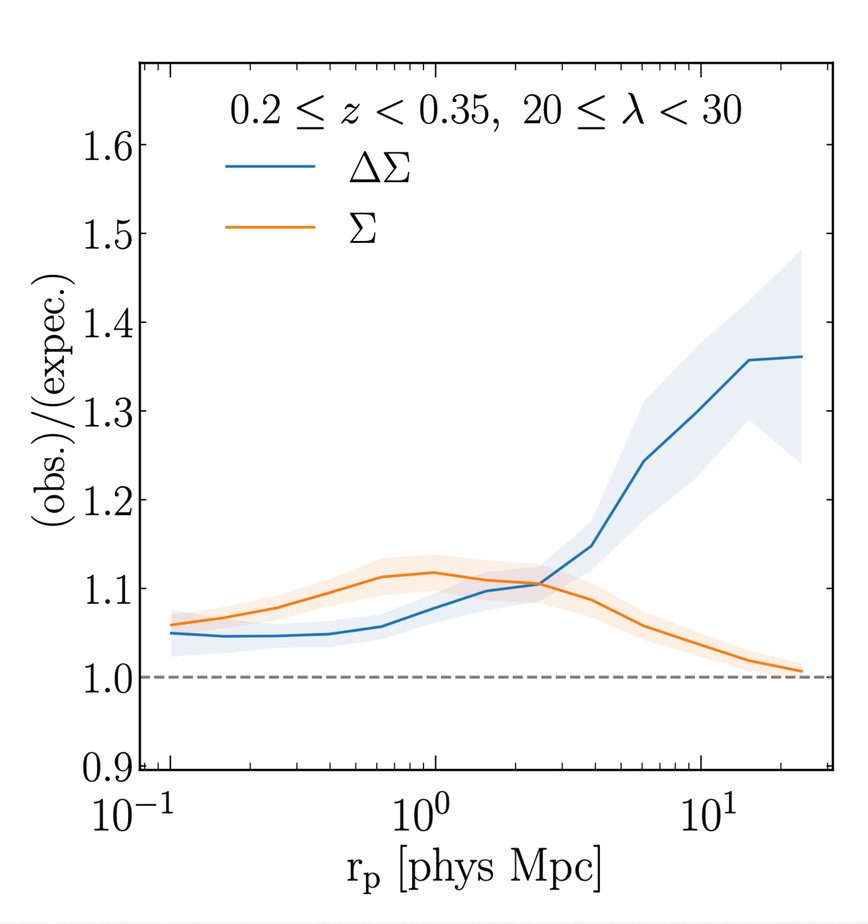
Where does cluster cosmology stand?



- The DES Year-1 cluster cosmology results indicate strong systematic errors
- High-richness clusters: the lensing signal is biased high due to optical selection
- Low-richness clusters: the lensing signal is surprisingly low

Abbott et al. 2020 (DES cluster cosmology results)

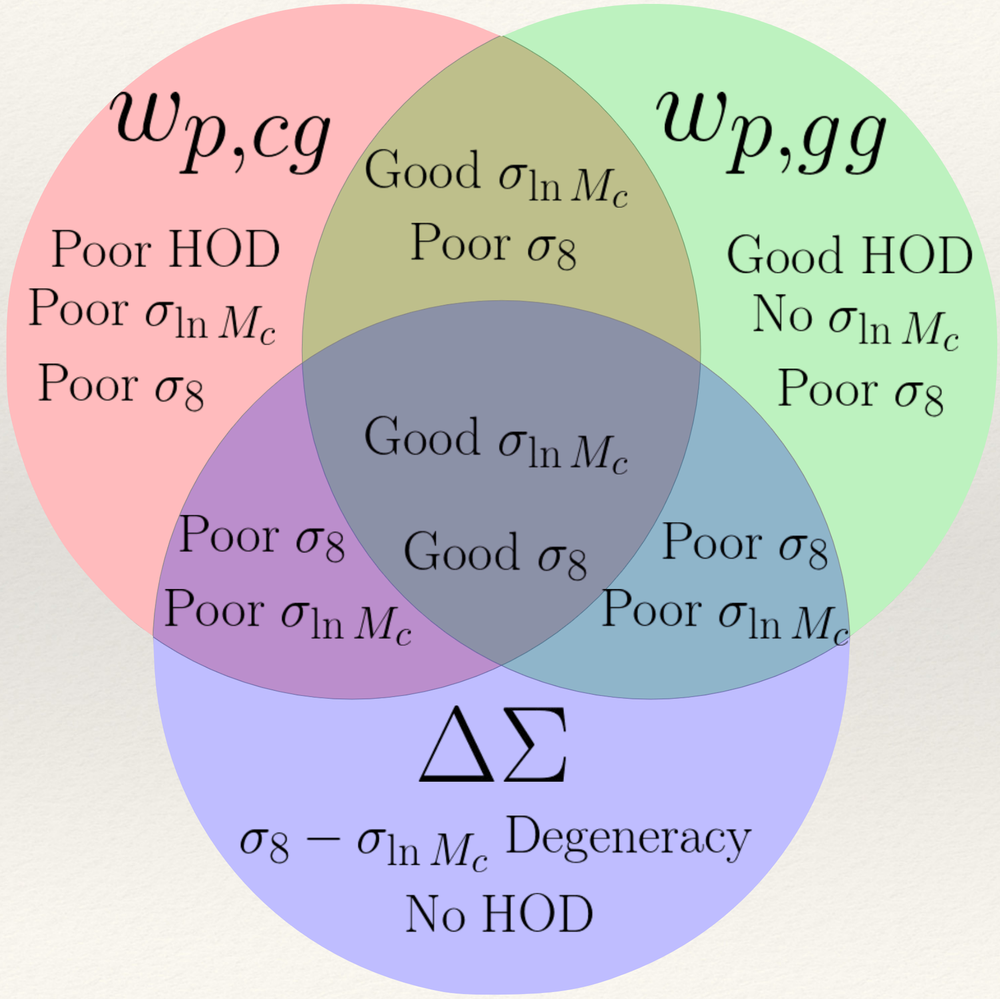
Cluster lensing bias associated with richness selection



- At a given halo mass, richness and lensing are correlated.
- Lensing of the a richness-selected sample is higher than we would expect from their masses.

Wu et al. (to be submitted); also see Sunayama et al. (2020)

Mitigating strategies: cross-correlations



- Using these 3 correlation functions, we can self-calibrate scatter
- We can also self-calibrate the cluster selection bias

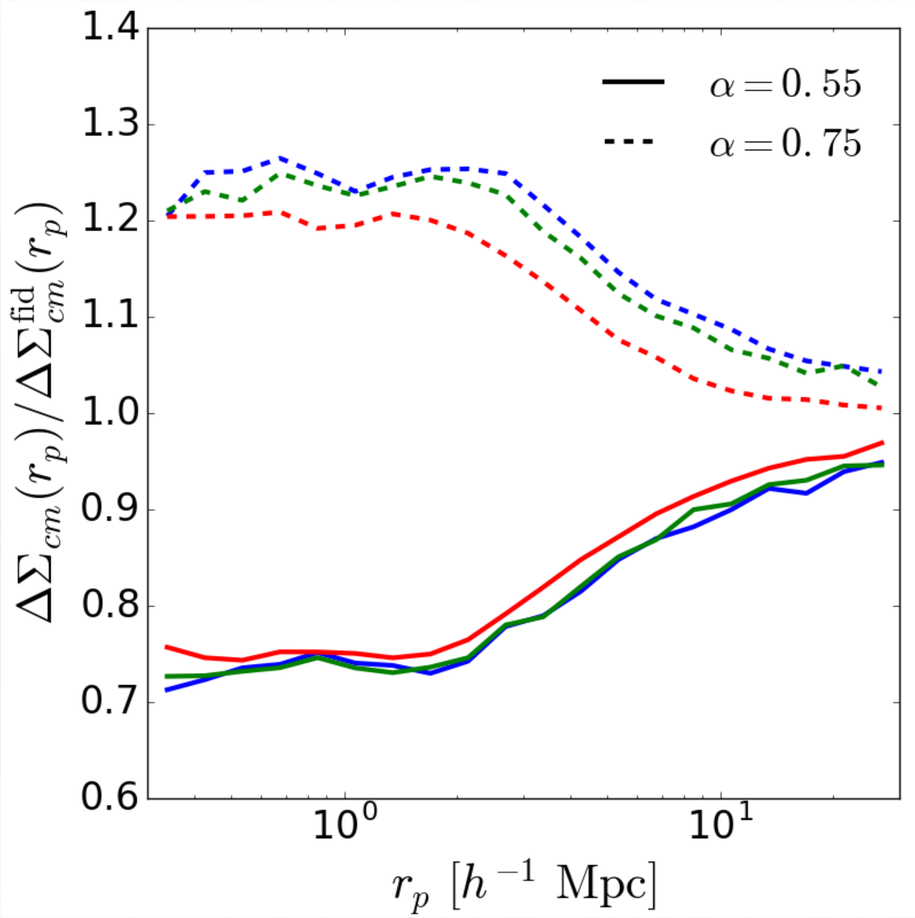
$$\Delta\Sigma \propto b_c \sigma_8^2$$

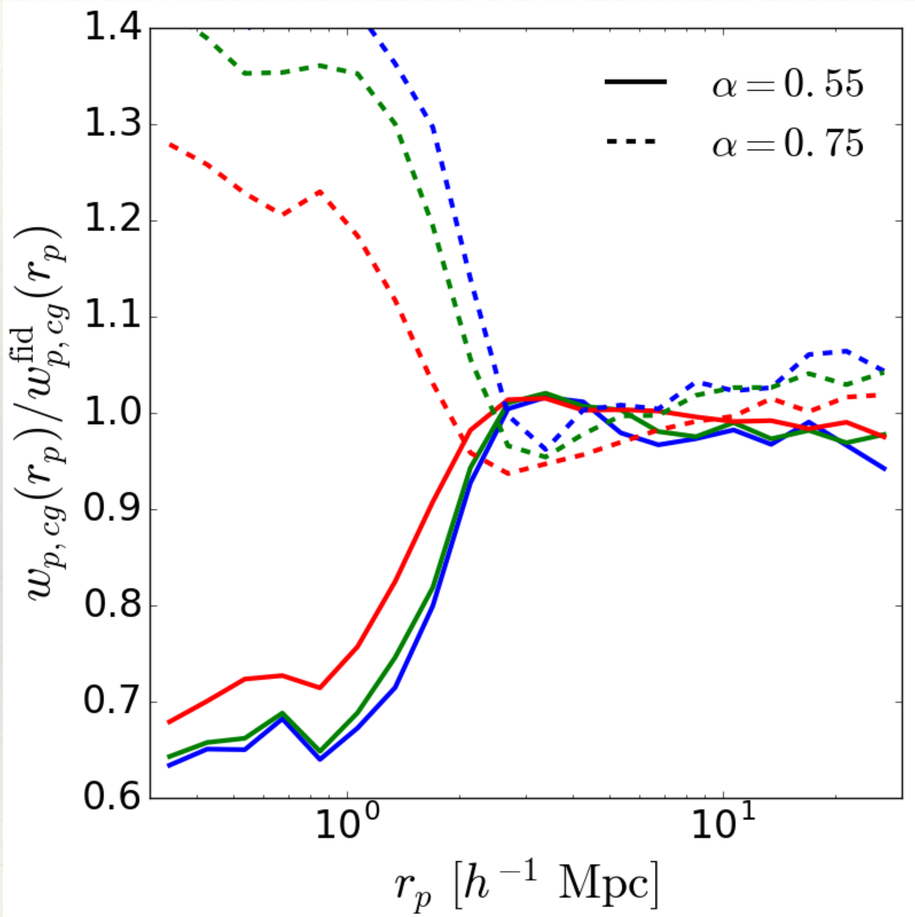
$$w_{p,cg} \propto b_c b_g \sigma_8^2$$

$$w_{p,gg} \propto b_g^2 \sigma_8^2$$

Salcedo et al. (2020), Zeng and Salcedo et al. (in prep)

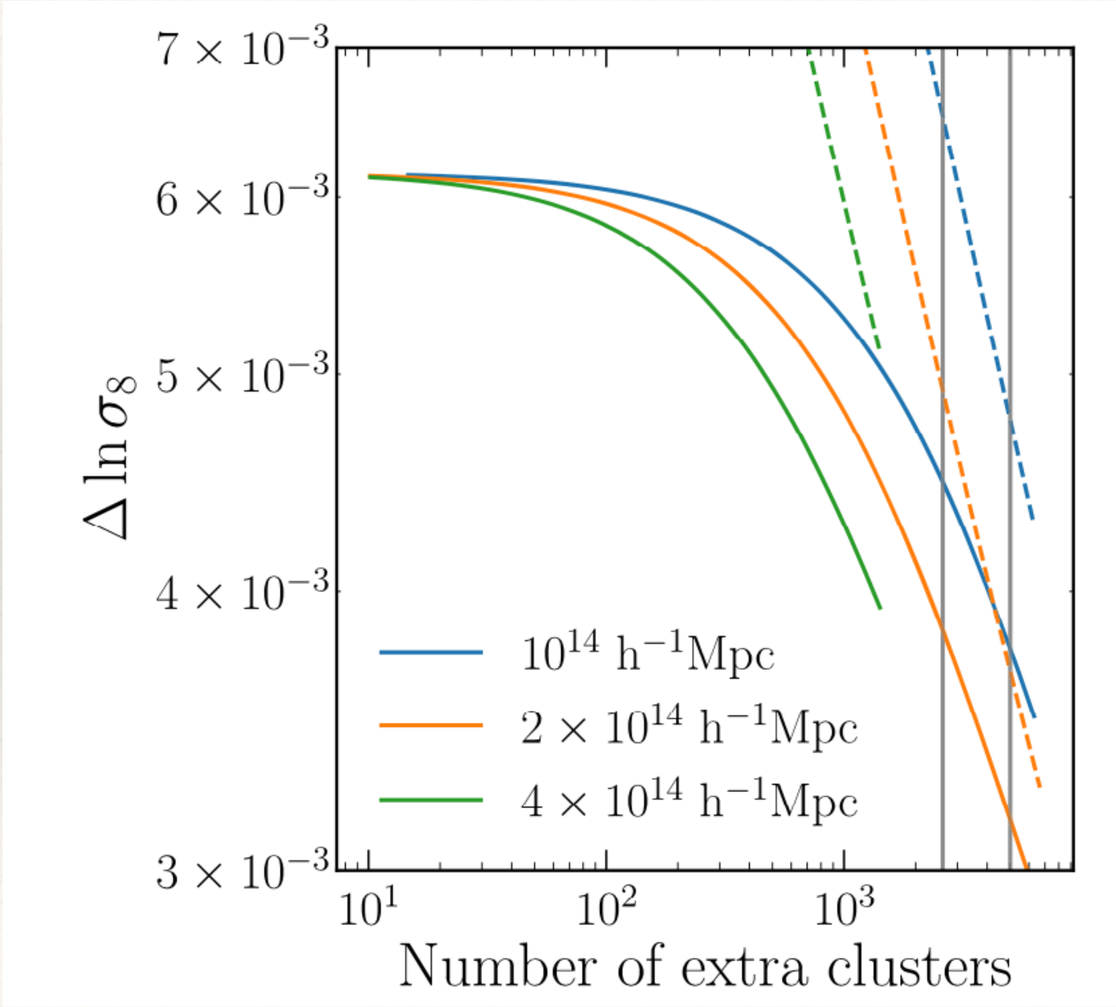
Cluster lensing and clustering vs. HOD parameters





Salcedo et al. in prep

Beyond the baseline HLS



- Roman can observe 1 cluster in 1 ks (or 2600 clusters in a month)
- Extra targeted cluster sample can greatly enhance the baseline HLS's cosmological constraints

Wu et al. 2021

Summary: clusters in Roman HLS

Statistical uncertainties:

- unprecedentedly low lensing noise
- requiring external calibration on scatter
- efficient single-cluster followups

Systematic uncertainties:

- mitigating selection bias using cross-correlation
- simulating a wide range of galaxy models using HOD