Galaxy Clusters in the Roman High-Latitude Survey

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Cluster sample from Roman HLS

2000 square degree, \( \sim 20,000 \) 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

- Increasing $\Omega_m$ is equivalent to increasing all cluster masses.
- Increasing $\sigma_8$ increases the number of clusters at all masses.
- Increasing $\sigma_8$ with fixed $\sigma_8 \Omega_m^{0.5}$ fixes the number at $\sim 5 \times 10^{14}$ but still changes the high-mass end (see Zheng et al. 2002).
- Cluster counts can break the degeneracy and constrain growth of structure.
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 $\sigma_8$ are degenerate with each other.
- To break the degeneracy, we need to combine cluster lensing, number counts, and prior on scatter.
Cluster lensing: signal vs. noise

- Noise is contributed by:
  - density fluctuations
  - shape noise ($\propto 1/\text{number of source galaxies}$)
- Overall noise $\propto 1/\text{area}$
- 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.
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