# Galaxy Clusters in the Dark Energy Survey

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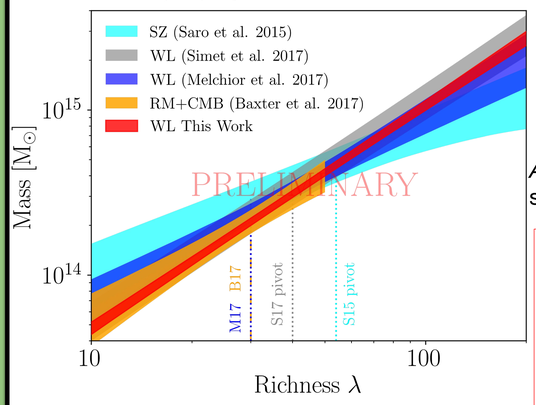
## 30 Second Summary

- We constrain the **mean cluster mass--optical richness** scaling relation at the **5%** (2.4% statistical, 4.3% systematic) level using weak lensing measurements around redMaPPer clusters in DES Year 1 data.
- Our analysis accounts for multiplicative shear bias, photometric redshift calibrations, miscentering, membership dilution, projection effects, halo triaxiality, and mass bias.
- We construct a **halo mass function emulator** trained on simulations satisfying DES Y5 & LSST Y1 requirements.

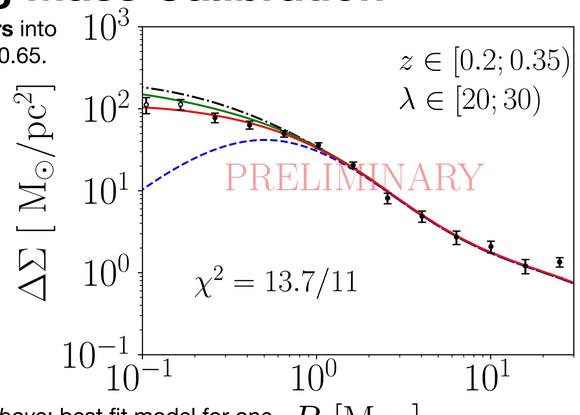
## 1. Weak Lensing Mass Calibration

Stacked the weak lensing signal of **~6400 clusters** into 4 richness and 3 redshift bins spanning 0.2 < z < 0.65.

Model included:
- Shear+photo-z calibration
- Miscentering
- Boost factors
- Mass bias
- Triaxiality & projection effects



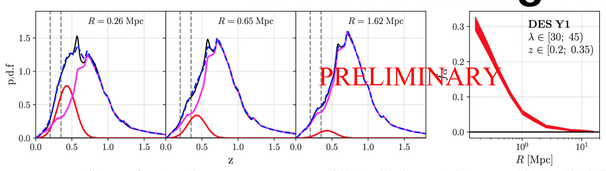

*Above*: Mass--richness relation calibrated to **5%**




*Above*: best fit model for one stacked lensing profile

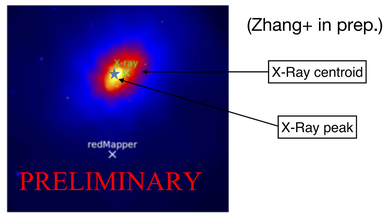
Takeaway:
- Used a **semi-analytic** approach to estimate the **covariance** of the lensing profiles.
- Entire analysis was performed **blind**.
- Calibrated the **mean cluster mass as a function of richness and redshift** at the **5% level**.
- Our scaling relation is **systematics limited**.

## 2. Accounting for Systematics




*Left*: Comparing photo-z distributions of galaxies in radial bins around the cluster to that of the background accurately yields the boost factor. Verified this in simulations (Varga+ in prep.)

*Bottom right*: Incorporated miscentering priors from archival Chandra data (Zhang+ in prep.)



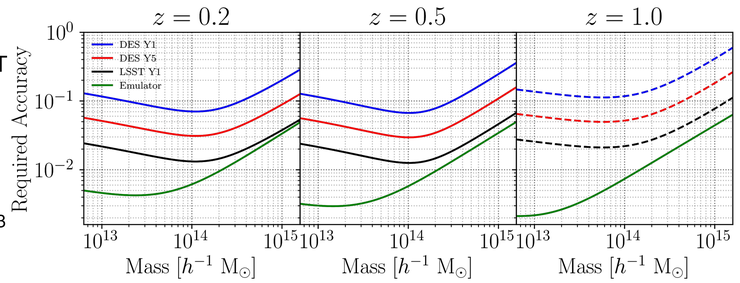

| Source of systematic | SV Amplitude uncertainty | Y1 Amplitude Uncertainty |
|---|---|---|
| Shear measurement | 4% | 1.7% |
| Photometric redshifts | 3% | 2.6% |
| Modeling systematics | 2% | 0.66% |
| Cluster triaxiality | 2% | 2% |
| Line-of-sight projections | 2% | 2% |
| Membership dilution + miscentering | ⩽ 1% | 0.9% |
| **Total Systematics** | 6.1% | 4.3% |
| **Total Statistical** | 9.4% | 2.6% |
| **Total** | 10.7% | 5.0% |

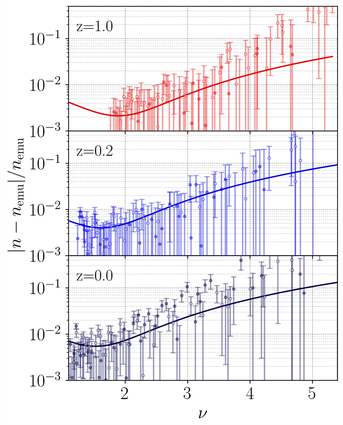
## 3. Halo Mass Function Emulator

Cluster abundance analyses must account for **modeling uncertainty**. We construct a high accuracy halo mass function predictor using a **cosmic emulator** trained on N-body simulations called ***Aemulus*** (DeRose+ in prep).

*Right*: accuracy required for systematic uncertainties to not exceed 10% of the statistical error for DES Y1/Y5 and LSST Y1. Green line is emulator accuracy

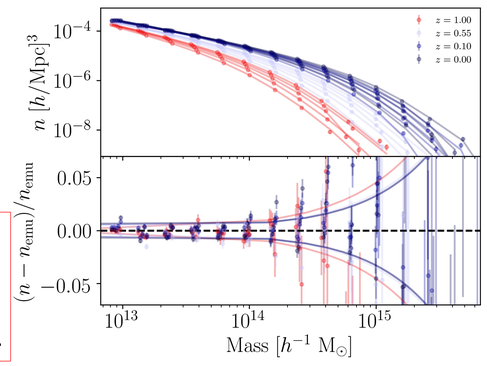
- Trained on **40 simulations**
- Tested with **35 simulations**
- 1.05 Gpc/h per side
- 1400^3 particles
- Extra 0.4 and 3 Gpc/h simulations with 2048^3 particles for comparison tests




*Bottom right*: emulated mass function compared to measurements (top) and the residuals (bottom)

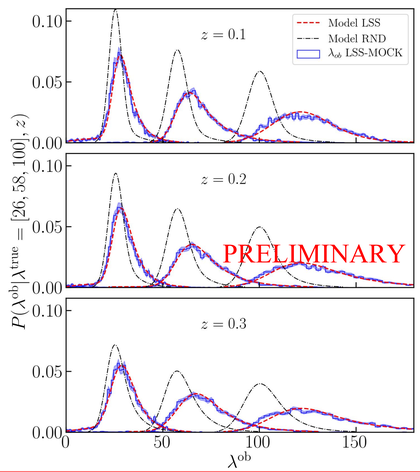
*Left*: Modeled the scale and epoch dependent emulator uncertainty.

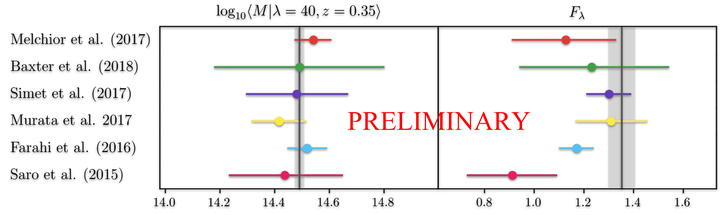



Takeaway:
- Constructed a **halo mass function emulator**.
- Trained on a suite of **40 wCDM+ N-body simulations.**

## 4. Cluster Cosmology in DES

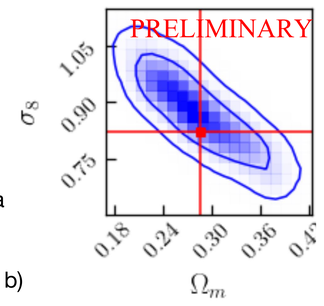
Cluster cosmology in DES seeks to mitigate two primary systematic sources of error in order to make competitive constraints on parameters: **mass calibration** and **projection effects**.




*Above*: comparison of the mean cluster mass and richness scaling index from the DES Y1 result (McClintock+ in prep.) to other results

*Left*: projection effects require modeling the relation between observed richness and true richness (Costanzi+ in prep.; a)




*Right*: constraints on mock SDSS-like data vector using only cluster abundances (Constanzi+ in prep.; b)

Takeaway:
- Developed a **quantitative model for projection effects** and demonstrate its need in the DES era.
- Performed a **blind analysis on SDSS and DES RM clusters**. Results for the former will unblind in ~1 month.

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Aemulus collaborators: Joe DeRose, Sean McLaughlin, Zhongxu Zhai, Risa Wechsler, Jeremy Tinker

LSST DESC Dark Energy Science Collaboration
DARK ENERGY SURVEY