DARK ENERGY
SURVEY

Galaxy cluster mass calibration with the Dark Energy Survey

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THE UNIVERSITY OF ARIZONA
COLLEGE OF SCIENCE
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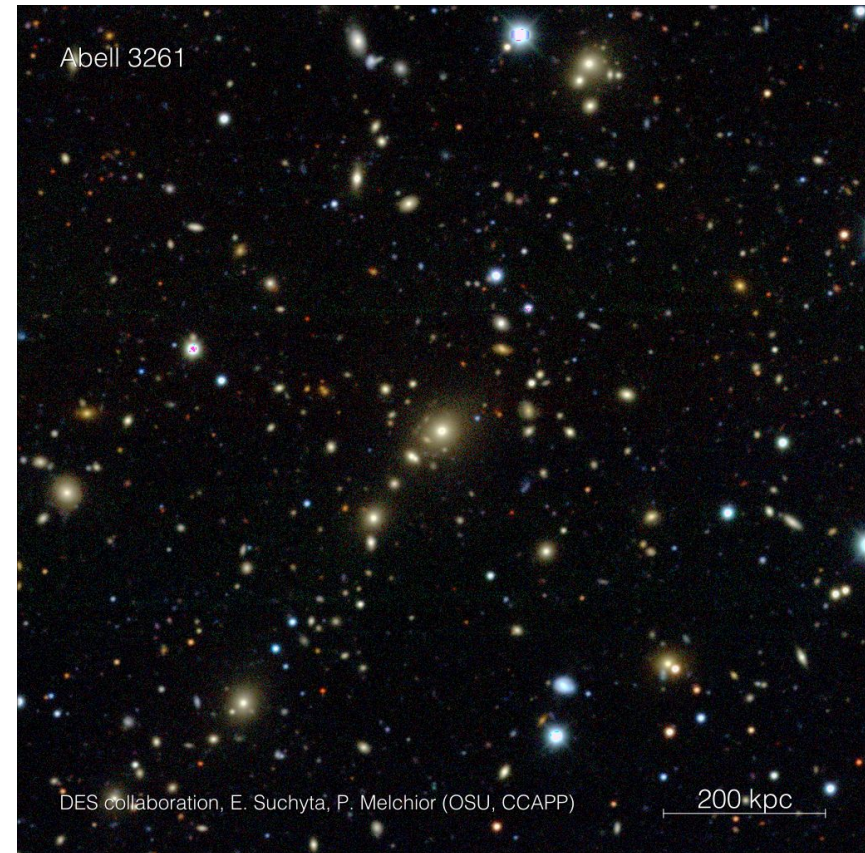# DES - Cerro Tololo Inter-American Observatory

Dark Energy Survey:
- 5000 sq. deg.
- Project lifetime of 5.5 years
- Goal is to measure dark energy
- Optically selected galaxy clusters with **redMaPPer** algorithm
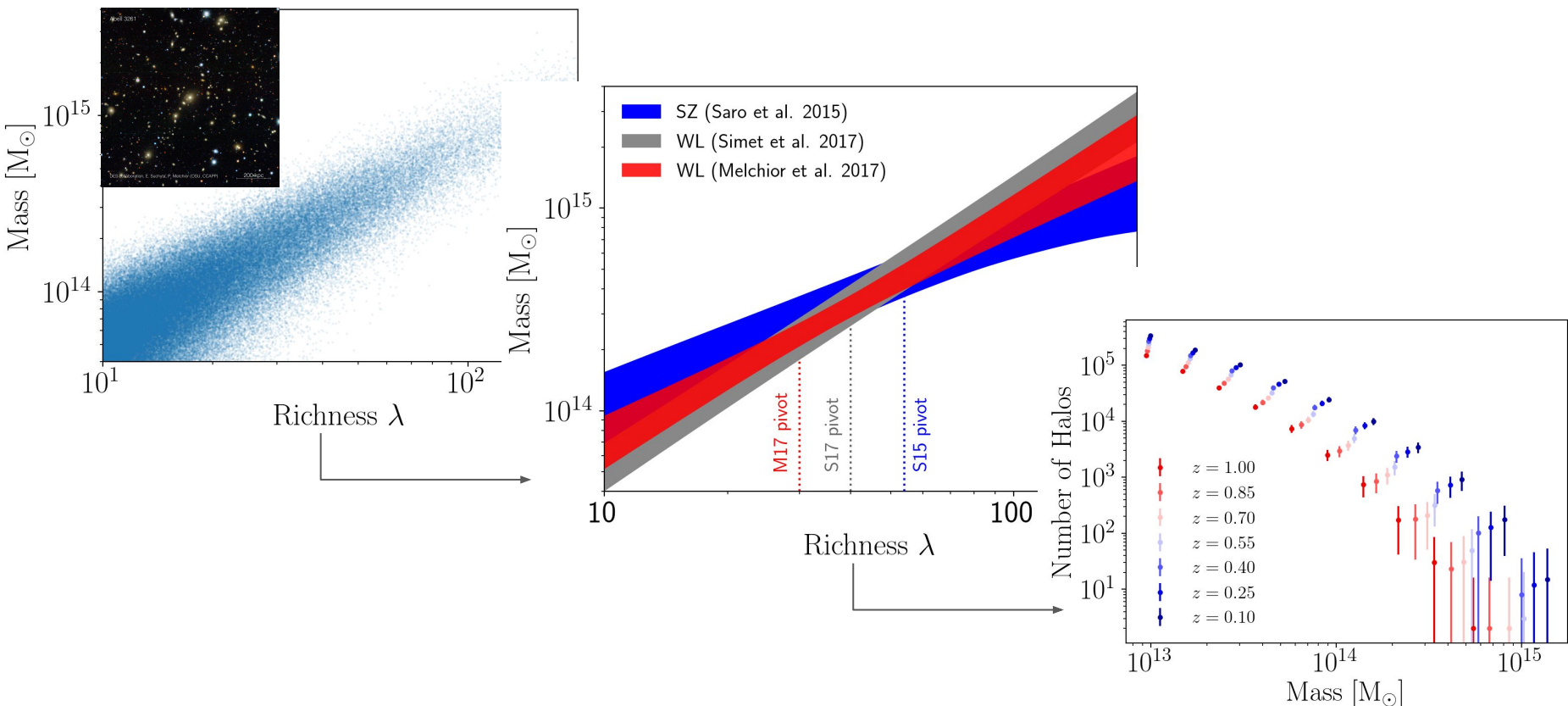
Galaxy clusters & cosmology

Cosmic Visions Report:

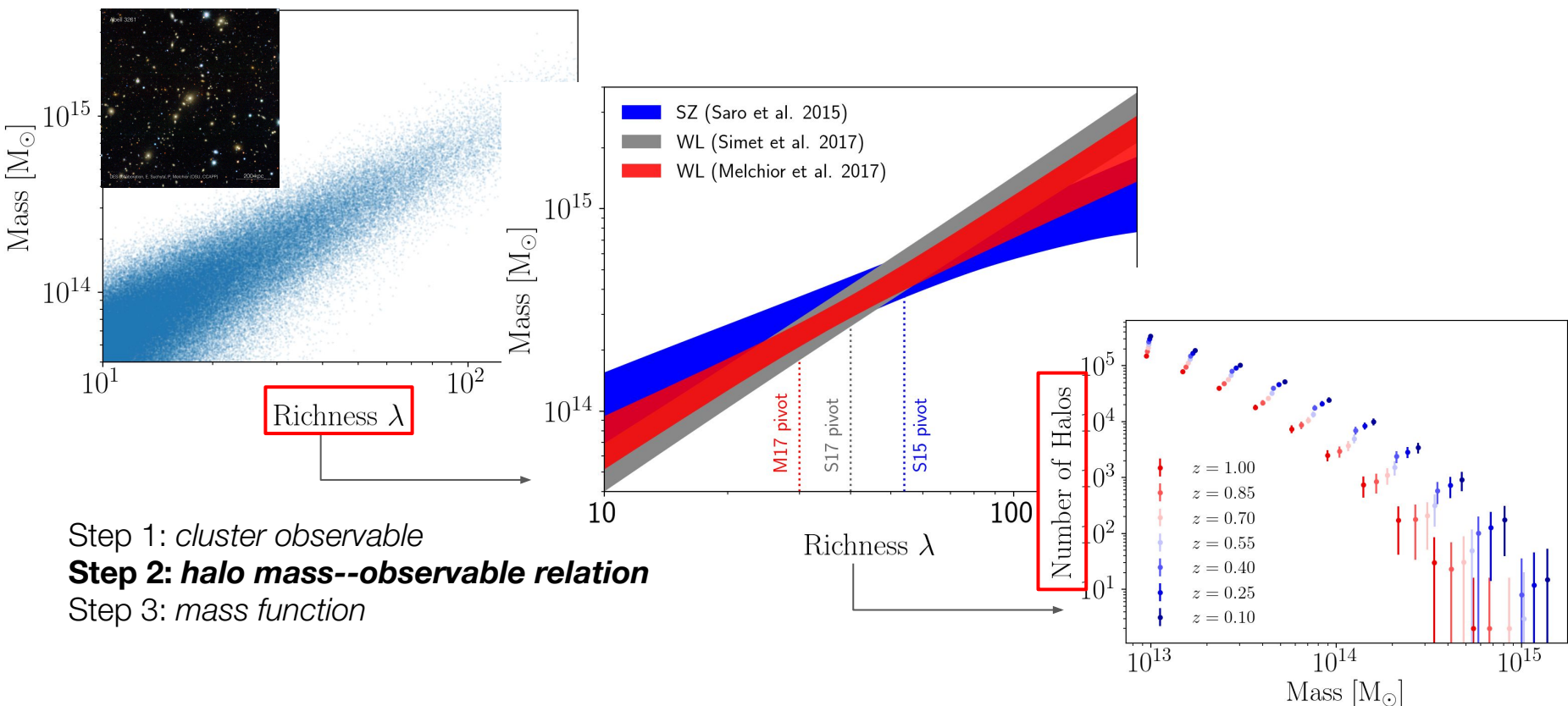"galaxy clusters could emerge as the most powerful cosmological probe"

$$\sigma_{\ln \sigma_8 \Omega_m^{0.5}} \approx \frac{1}{2} \sigma_{\ln M}$$

Abell 3261

DES collaboration, E. Suchyta, P. Melchior (OSU, CCAPP)   200 kpc

Cluster cosmology 101

Cluster cosmology 101

Step 1: *cluster observable*
Step 2: *halo mass--observable relation*
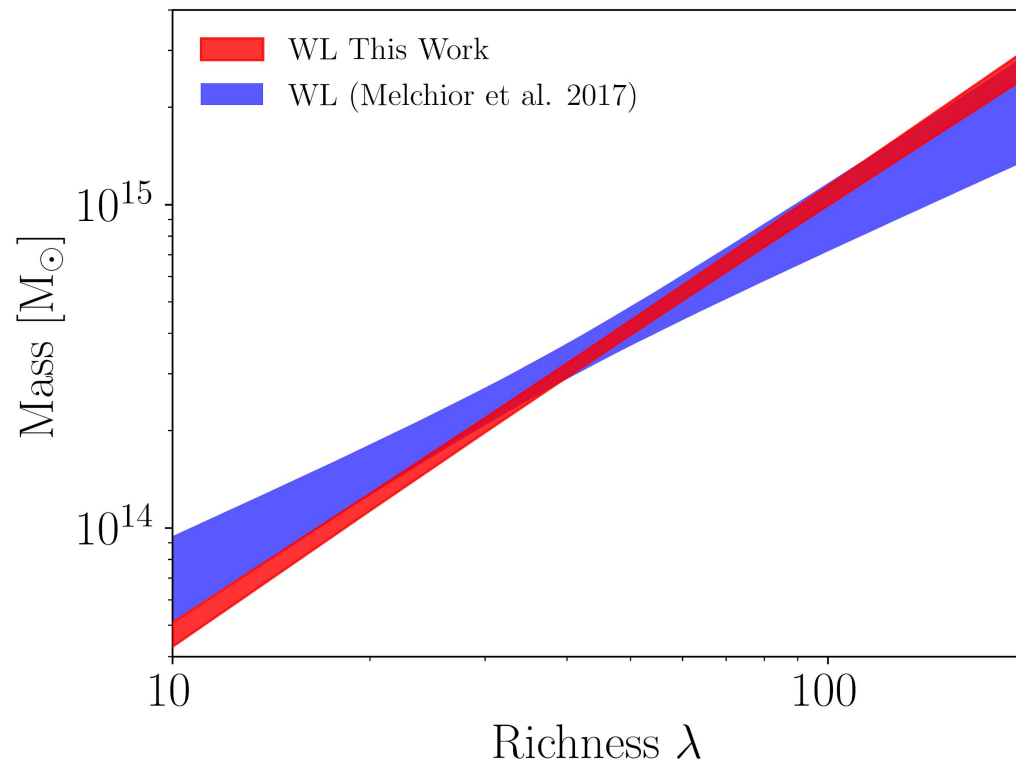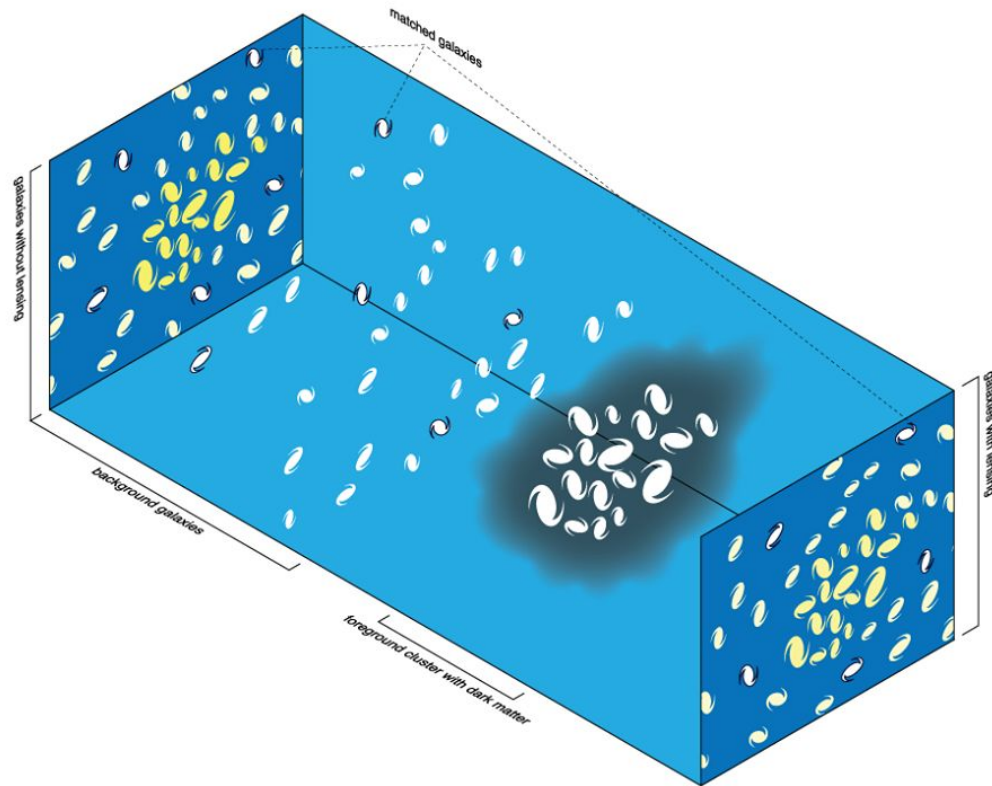Step 3: *mass function*
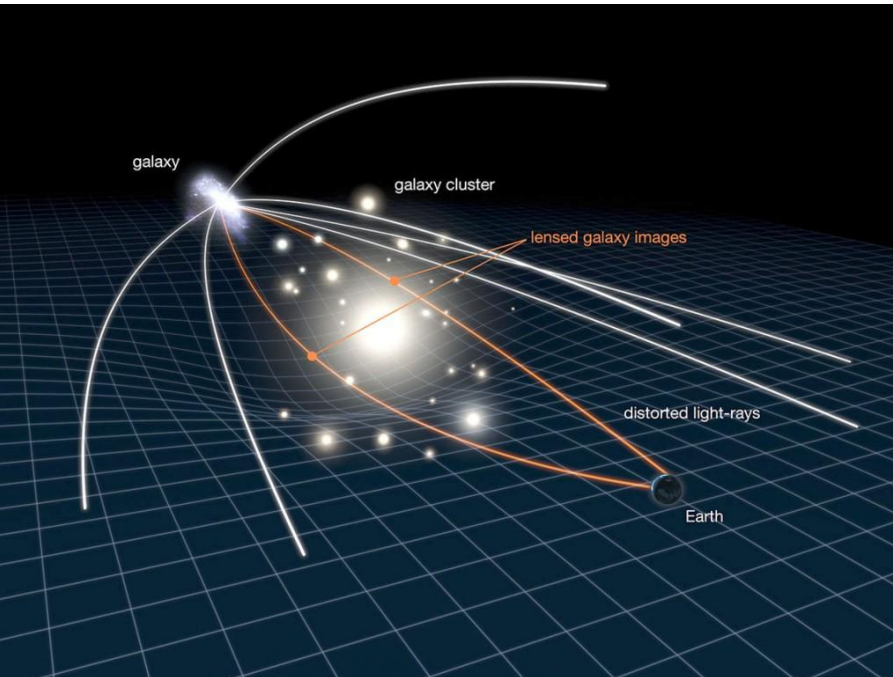
Upgrades compared to SV (Melchior+)

1. Many clusters

2. Semi-analytic covariance matrix

3. Calibration of modeling systematics

Results:

- Tight mass calibration

- Well understood error budget

Cluster masses from gravitational lensing

galaxy

galaxy cluster

lensed galaxy images

distorted light-rays

Earth

matched galaxies

galaxies without lensing

galaxies with lensing

background galaxies

foreground cluster with dark matter
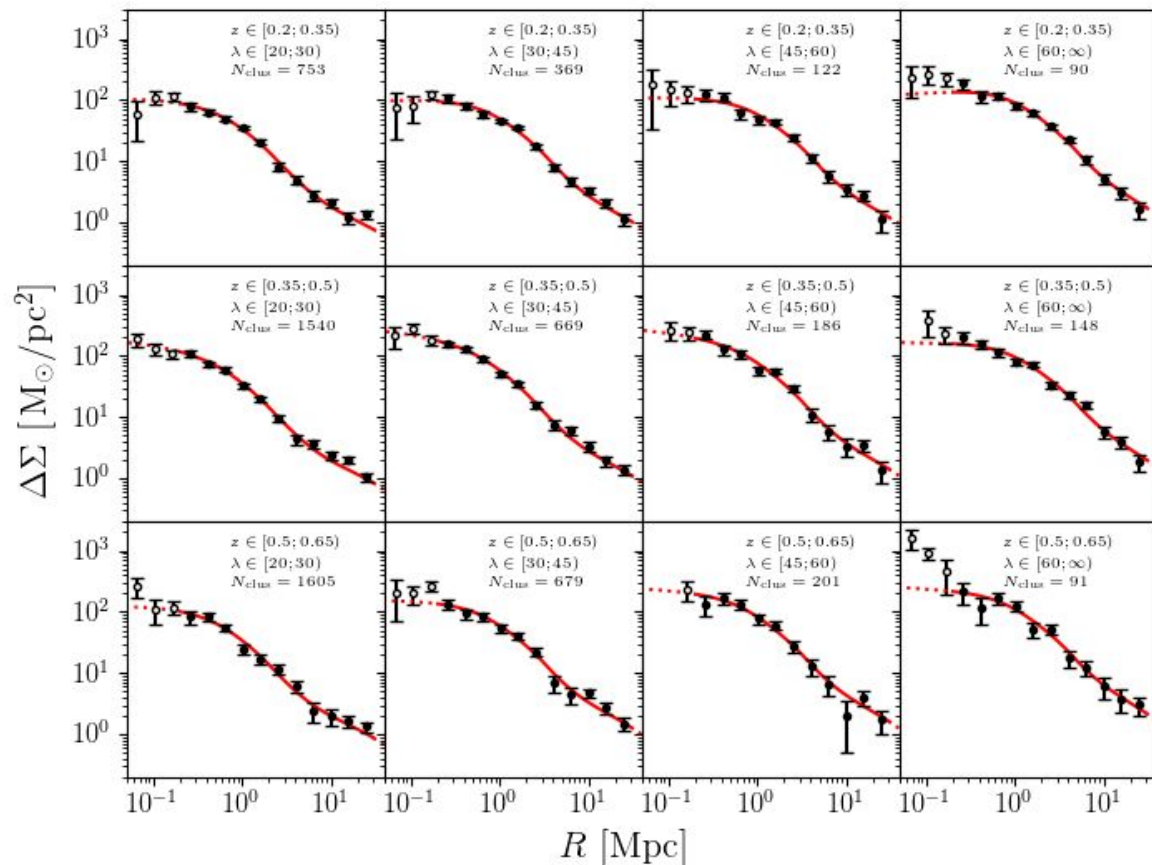
Cluster weak lensing profiles

Differential surface density
- Proportional to galaxy tangential shear
- 1-halo + 2-halo profile

Black points - used in fit

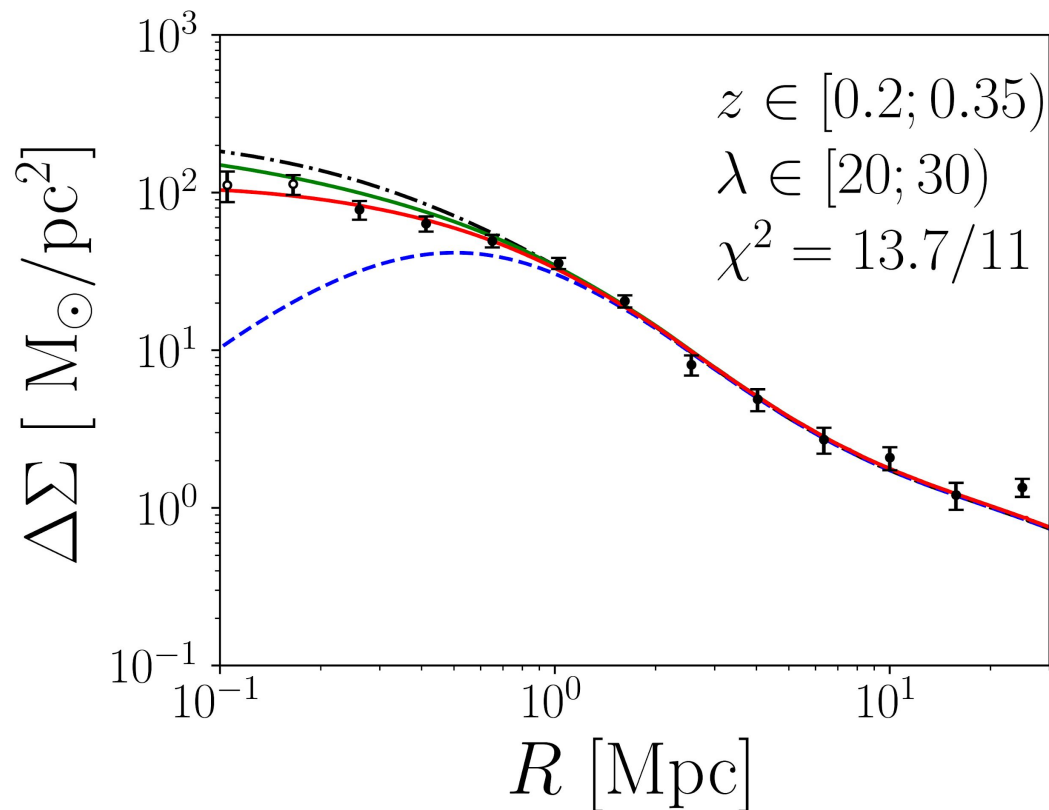Unfilled points - not fit

Red line - best fit model

Lensing model:
- centered (black .-)
- miscentered (blue -)
- boost factor, shear+pz (red)
- triaxiality+proj. (not shown)

Boost factor model (not shown):
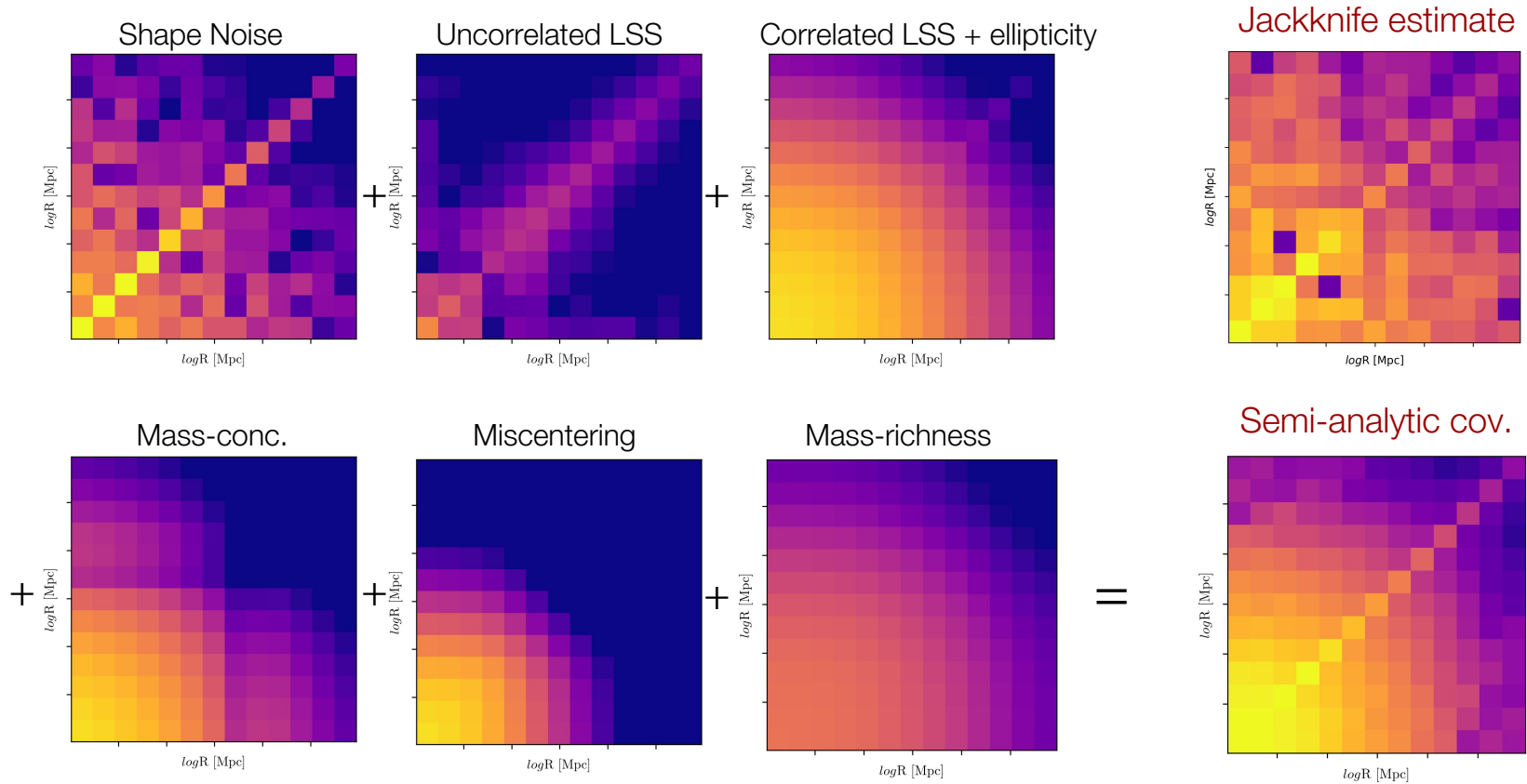- NFW 2-parameter model

De-boosted the lensing profile to match the data points

$z \in [0.2; 0.35)$
$\lambda \in [20; 30)$
$\chi^2 = 13.7/11$

Semi-analytic covariance matrix

Shape Noise

Uncorrelated LSS

Correlated LSS + ellipticity

Jackknife estimate

Mass-conc.

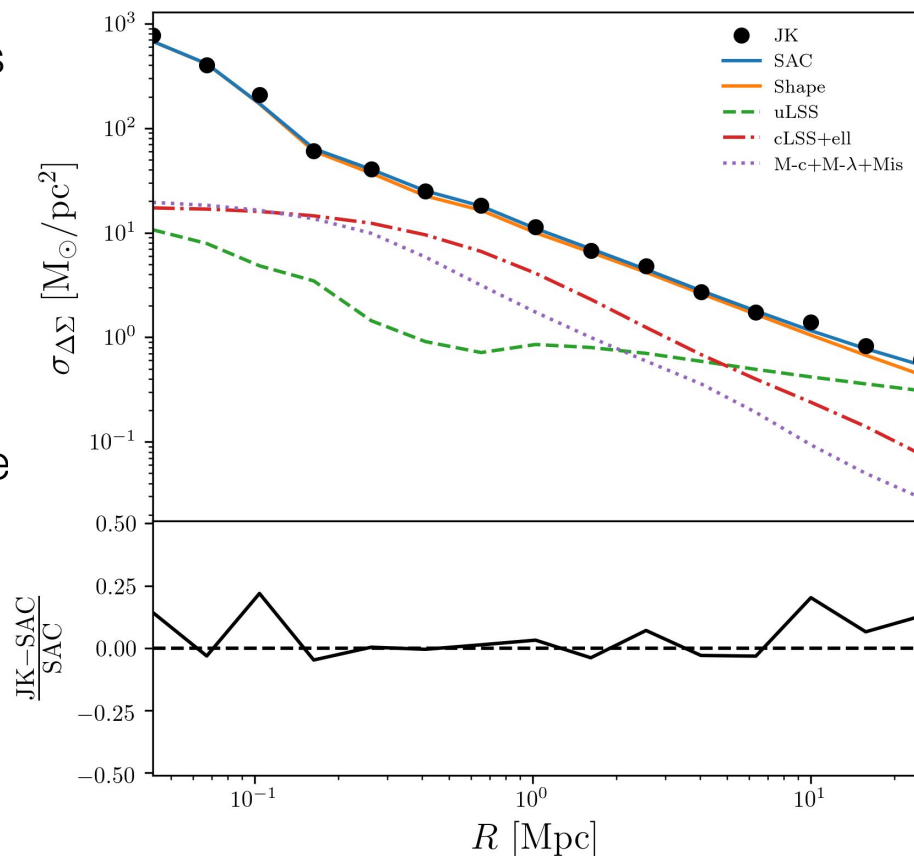Miscentering

Mass-richness

Semi-analytic cov.
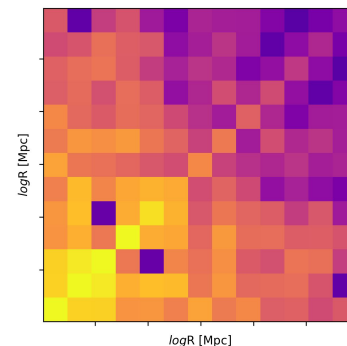
Semi-analytic covariance matrix

Dominant component is **shape noise**.

Largest scales limited by **uncorrelated large scale structure**.
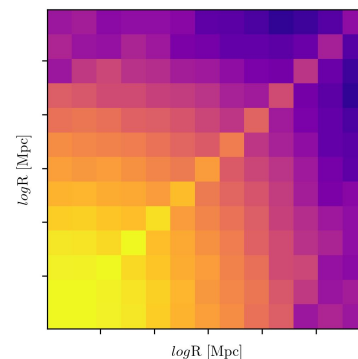
Covariance matrices are **consistent** but **noise is reduced**.

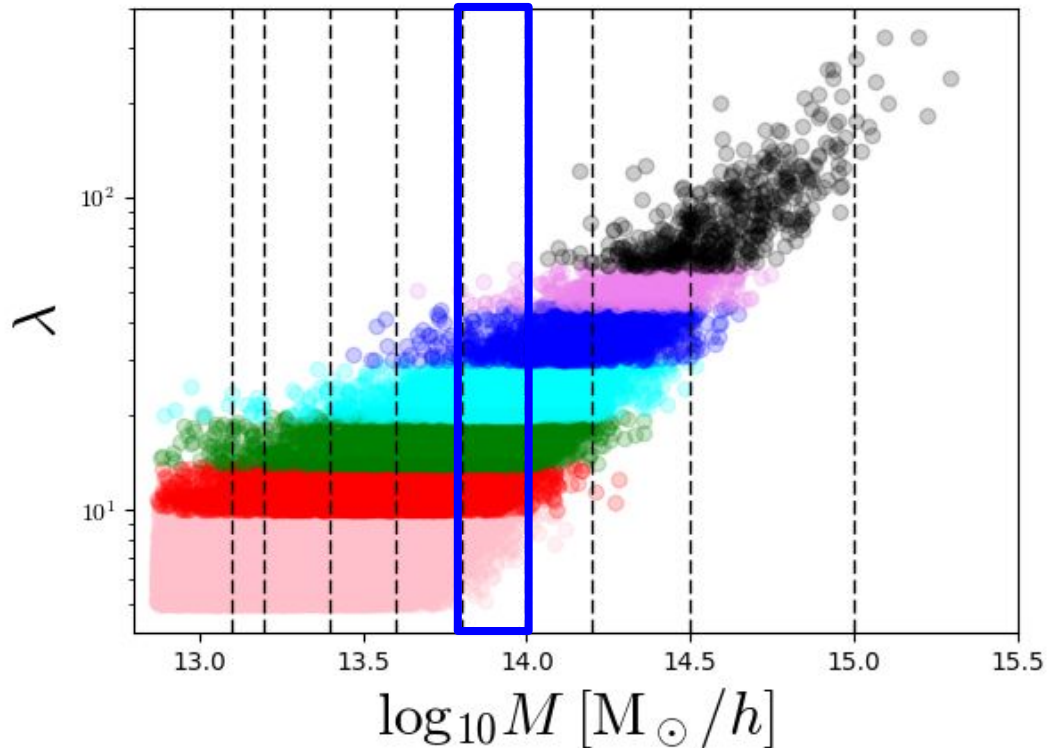Jackknife estimate

Semi-analytic cov.

Modeling systematics calibration

Modeling systematic - mass correction based on simulations.

$$\mathcal{C} = \frac{M_{\text{true}}}{M_{\text{obs}}}$$

Blue box and blue points have the same average (i.e. "true") mass, but their clustering properties are very different.

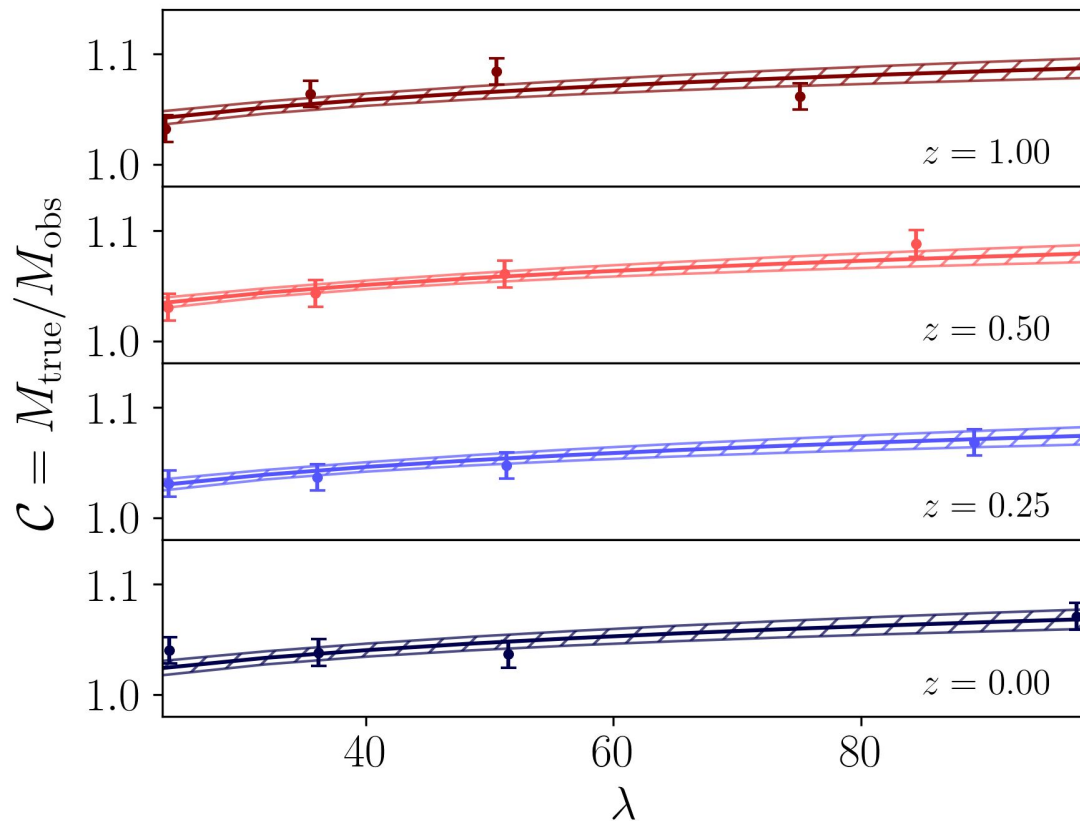Difference in clustering results in a change of ~4% in the mass bias.

Typical calibration was ~4%.

Up from <1% in Melchior+ (2017).

Not a significant contributor to the error budget, but is motivation for a **lensing emulator**.
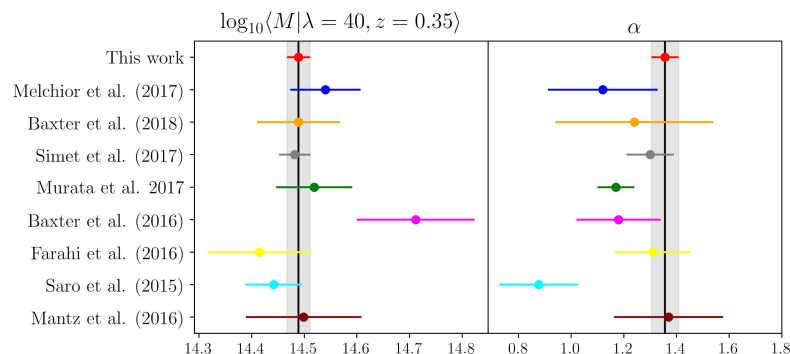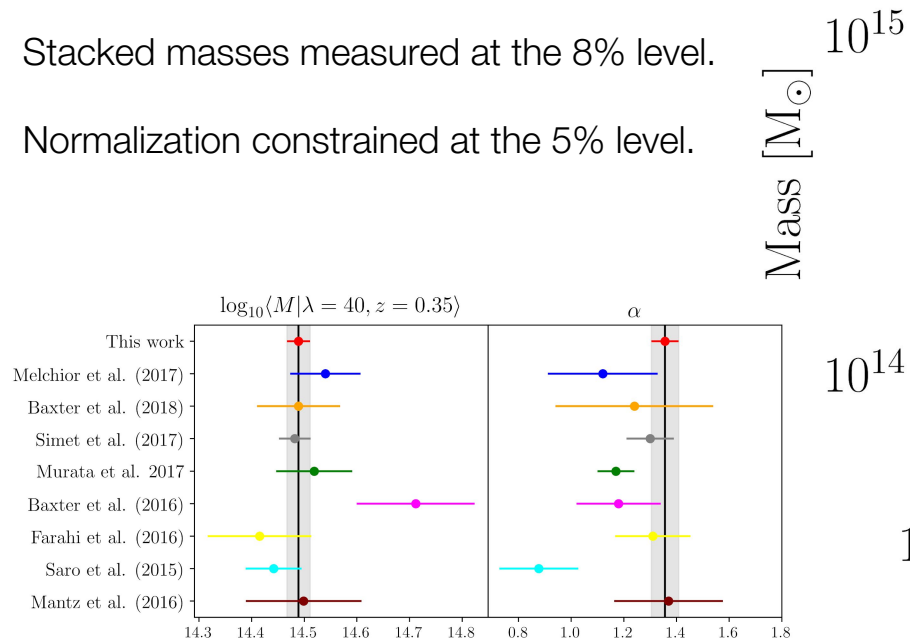
$$\langle M | \lambda, z \rangle = M_0 \left(\frac{\lambda}{\lambda_0} \right)^\alpha \left(\frac{1+z}{1+z_0} \right)^\beta$$

Stacked masses measured at the 8% level.

Normalization constrained at the 5% level.

Error budget & looking forward

Source of systematic	SV Amplitude uncertainty	Y1 Amplitude Uncertainty
Shear measurement	4%	1.7%
Photometric redshifts	3%	2.6%
Modeling systematics	2%	0.73%
Cluster triaxiality	2%	2.0%
Line-of-sight projections	2%	2.0%
Membership dilution + miscentering	$\leqslant 1\%$	0.78%
Total Systematics	6.1%	4.3%
Total Statistical	9.4%	2.4%
Total	11.2%	5.0%

Future plans:
- prioritize improving photometric redshifts
- model triaxiality and projection effects
- emulate lensing signal to reduce mass calibration
- covariance between the sources of systematic uncertainty

Enabling galaxy cluster cosmology in DES
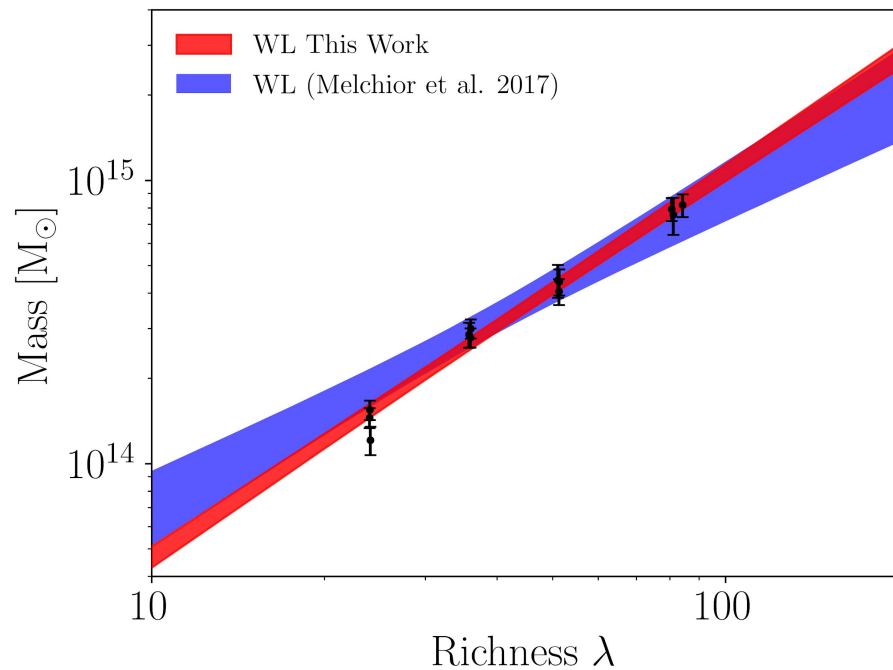
Cluster cosmology is competitive with DES Key Project
Arxiv: 1805.00039