Cluster Cosmology

Cosmology → halo abundance (dn/dMdz).

To relate to observations one must convolve with mass-observable relation $P(X|M,z)$.

Main difficulty for all cluster cosmology experiments: what is $P(X|M,z)$?

Determine using simulations or empirical mass calibration.

See Hans Boehringer’s and Neelima Sehgal’s talk.
Optical Cluster Cosmology

Optical clusters:
Clusters are found as galaxy associations.
mass tracer $X = \text{galaxy content (richness)}$.

Finding clusters in optical is not hard: galaxy clusters are high contrast systems!
See Michael Gladder’s talk.
Clusters are High Contrast Systems
Optical Cluster Cosmology

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Projection effects in optical are rare (~5%), but when they occur, they are severe.
Lines-of-sight that intersect significant overdensities are rare.

Projection out to $R=250 \, h^{-1} \, Mpc$. 

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Not the dominant systematic at present.
Mass Calibration

Main difficulty for all cluster cosmology experiments: what is $P(X|M,z)$?

Most natural solution for optical: stacked weak lensing.
Also see Hank Hoekstra and Alexie Leauthaud’s talk.

Main drawback: only constrains the mean.

Can rely on other observables for scatter.
See Rozo et al. 2009.
Application to SDSS Clusters
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Clusters selected with \textit{maxBCG algorithm}. Koester et al. 2007.

red-sequence cluster finder
13,000 clusters in 8,000 deg$^2$, $0.1 < z < 0.3$
Results

Model is a *good fit* to the data.

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Thursday, July 1, 2010
Results

\[ \sigma_8(\Omega_m/0.25)^{0.41} = 0.832 \pm 0.033 \]

Application to SDSS Clusters

Clusters selected with \textit{maxBCG algorithm}. Koester et al. 2007.

red-sequence cluster finder
13,000 clusters in 8,000 deg$^2$, 0.1 < z < 0.3

Main systematic uncertainties:
- Photometric redshift uncertainties of source galaxies used for weak lensing analysis.
- Cluster miscentering.
Comparison with X-rays

Mantz et al. 2008
Henry et al. 2008
Vikhlinin et al. 2009
maxBCG

All include WMAP5 prior
Comparison with X-rays

Agreement demonstrates cosmological constraints from vend constraints are robust and systematics are well understood.

All include WMAP5 prior
DES Forecasts

5,000 deg$^2$
g,r,i,z,Y ~ 24
M$>$10$^{13.7}$ M$_{\text{sun}}$
0$<$z$<$1
DES Stacked WL Forecast

1. Forecast precision of $<M|X>$. 

2. Add this information to standard self-calibration (i.e. abundance+clustering) Fisher matrix analysis.

Observed mass bins: $\Delta \log_{10} M_{\text{obs}} = 0.2$, $\Delta z=0.1$.

$$n_{\text{gal}} = 20 \text{ gal/deg}^2$$

($\sim 15$ sources/deg$^2$ for $z_{\text{lens}}=0.5$).
DES Stacked WL Forecast

Mass detection threshold

w/ Fabian Schmidt, Hao-Yi Wu.
The Impact of Stacked WL on the DES Figure of Merit

w/ Fabian Schmidt, Hao-Yi Wu.

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The Impact of Stacked WL on the DES Figure of Merit

Comparable precision to that achievable with a realistic optimal X-ray Follow-up Program.

(Wu, Rozo, and Wechsler 2010)

w/ Fabian Schmidt, Hao-Yi Wu.
The Upshot

Stacked weak lensing will remain an effective mass calibration tool.

Comparable precision to X-ray mass calibration results in a highly non-trivial test of systematics.

Similar conclusions hold for optical + SZ data.

Cunha 2009.
Conclusions

• Optical cluster selection is robust.
• Projection effects are rare, but when they occur, they are severe.
• Stacked weak lensing is an effective tool for mass calibration.

Mass calibration is the dominant systematic in cluster cosmology.

Agreement of multiple mass proxies is a powerful systematics check.
The Future of Cluster Cosmology

The statistical precision of near future data sets such as DES is phenomenal.

Experiments will almost certainly be systematics limited (we already are!).

We need a systematic approach for identifying systematic uncertainties in our experiments.
The role of simulations is to test data analysis rather than to calibrate.

The DES Solution: Use Simulations!

1. Simulate entire data set using input cosmology.
2. Analyze simulations as though they were real data to test whether input cosmology is recovered.

The role of simulations is to test data analysis rather than to calibrate.
The DES Blind Cosmology Challenge

1. Start with a dark matter simulation.
2. Populate simulation with galaxies.
3. Ray trace through entire survey volume to properly lens all galaxies.
4. Run cluster finders on synthetic sky.
5. Do mass calibration on synthetic sky.
6. Do analysis to recover cosmology.

Explicit test of systematics in a controlled environment.
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Great Richness Comparison Project

**Goal:** determine an optimal richness measure for use in future surveys.

optimal = most tightly correlated with mass.

Use scatter in $L_X$-richness relation as proxy.

| Richness       | $\sigma_{\ln L|N}$ |
|----------------|---------------------|
| $\lambda$      | 0.62                |
| $N_{200}$      | 0.86                |
| $\Lambda_{\text{Postman}}$ | 0.92              |
| Abell          | 1.15                |
| red $B_{gc}$   | 0.71                |
| $N_{\text{WHL}}$ | 0.88              |

If interested, please come see me!
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