Statistics of the Largest Structures

Ben Koester
University of Chicago

Chicago: Sarah Hansen, Matt Becker, Josh Frieman
Caltech/JPL: Dave Johnston
NYU: Erin Sheldon
Michigan: Tim McKay, Gus Evrard
FNAL: Jim Annis
UCSB: Eli Rykoff
Ohio State: Eduardo Rozo
Stanford: Risa Wechsler
Pittsburgh: Ryan Scranton
Outline

• Clusters: Signposts of Large Scale Structure
  – Sensitivie to cosmology
  – Galaxy formation, evolution
• MaxBCG-SDSS
• Cosmology and Mass Calibration
• Information from Galaxy Populations
Clusters and Cosmology

- High S/N peaks in LSS map
- Exponentially sensitive to cosmology
  - Number density above some mass
  - Growth rate of structure
  - Mass functions
- Requires clusters with redshifts and mass proxies

\[ n(M, z) = \frac{d \ln \sigma^{-1}(M, z)}{d \ln M} f(M, z) \]

Jenkins et al., 2001

Evrard et al., 2002
MaxBCG-SDSS

Fields of 2 rich maxBCG clusters ($r<1.5$ Mpc)

$z = 0.10, N_{\text{gals}} = 95$

$z = 0.24, N_{\text{gals}} = 95$
MaxBCG-SDSS
(Koester et al., ApJ: 660, 1, 221 & 239)

- Run on 8000 sq. SDSS data
- Distill \( \sim 23 \times 10^6 \) galaxies down to \( \sim 150,000 \) clusters
  - Redshift error < 0.02
  - Richness, \( N_{200} \), number of red galaxies > 0.4L* (public: \( N_{200} > 9 \))
  - >90% pure and complete (Koester et al., 2007; Rozo et al., 2007)
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Cosmology Proof of Concept

(Rozo et al., astro-ph/0703574, 0703571)

- Constrain cosmology with abundances
- Calibrate MaxBCG on mock catalogs
  - Calibrate \( \sim \) mass dependent purity and completeness

1) Can recover \( \sigma_8 \) from sims
2) Data gives \( \sigma_8 = 0.92 \pm 0.1 \)

*Redshifts are as good as they’ll get, but we’ve done very little about the masses.*
Mass Calibration

• Cosmology:
  – Redshifts: $\sigma_z < 0.02$
  – Masses: need work to move beyond abundances

• Use other methods to inform cluster mass
  – Weak lensing (SDSS imaging)
  – Dynamics (SDSS Spectroscopy)
  – X-ray luminosities (RASS)
Weak Lensing

*(Sheldon et al., arXiv:0709.1153)*

- Mass induces coherent distortions in shapes of background galaxies (G. Bernstein on Monday, and A. Zentner this morning)

- Stacking clusters enhances low signal => high S/N

Systematics:

1) Photoz measurements

2) Shear calibration: actual distortion vs. measured distortion

Exquisite control of these required to turn signal into meaningful statement about mass
Weak Lensing

(Johnston et al., arXiv:0709.1159)

- Now invert 2D mass map into 3D average halo profile
  - Lensing signal: NFW + 2-halo + BCG point mass + miscentering
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Cosmology with Mass Calibration


Rozo et al., 2007

Rozo et al., 2007+Sheldon/Johnston

...updated cosmological constraints in progress...
Optical Properties

• Measuring serves a few purposes
  – Understand cluster evolution and galaxy formation
  – Improved richesses (mass proxy), cluster finding

• Hansen et al. (2007, arXiv:0710.3780): cluster galaxies at z=0.25
  – K-correction to z=0.25, global background subtraction

• First, basic luminosity functions (just a sample – red and blue populations)
Optical Properties

- Great statistics allow various sub-bins

Among many conclusions:
1) Various scaling relations
2) Increasing red fraction with $z$
3) BCG luminosity increases with mass
Mass-to-Light

- MaxBCG-SDSS applied to M/L
- Sheldon et al., 2007: Combine WL+Hansen et al. luminosity measurements

\[
\langle M/L \rangle b^{-2} M/L = \begin{cases} 
362 \pm 54h & \text{within } 22h^{-1}\text{Mpc} \\
357 \pm 9h & \text{asymptotic fit} 
\end{cases} \quad (20)
\]

\[
\Omega_m b^{-2} M/L = \begin{cases} 
0.20 \pm 0.03 & \text{within } 22h^{-1}\text{Mpc} \\
0.194 \pm 0.008 & \text{asymptotic fit} 
\end{cases} \quad (21)
\]
Where We Stand

• Cosmology:
  – Laying groundwork for future optical surveys, or for cross-calibration of non-optical (SPT+DES)
  – Lensing greatly improves mass calibration & cosmology
    • Scatter in mass at fixed observable and covariance of mass proxies non-trivial
  – Galaxy population work is improving richness measurements, understanding of cluster selection
  – Working on “centering”, maxBCG calibration
  – What else can we pull in?
    • WMAP → stacked SZ masses?

• Cluster astrophysics
  – What do optical clusters look like in X-ray, IR, radio, etc.