First Results in Galaxy Cluster Weak Lensing

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Overview

- Galaxy clusters and Dark Energy
- How to measure cluster mass
- Scaling relations between cluster mass and other observables
- DES projects
  - Four massive clusters
  - Mass calibration of optically-selected clusters
  - Mass calibration of SZ-selected clusters
  - Mass calibration of X-ray selected clusters
Galaxy Clusters and Dark Energy

- Number of high-mass clusters grows over time
- Negative pressure of dark energy hinders rate of cluster growth
- Evolution of cluster mass function over time $\rightarrow$ constraints on evolution of dark energy
Mass Function – Vikhlinin et al, 2009

$\Omega_M = 0.25, \Omega_\Lambda = 0, \, h = 0.72$

$N(> M), \, h^{-3} \text{Mpc}^{-3}$

$z = 0.025 - 0.25$

$z = 0.55 - 0.90$

$M_{500}, \, h^{-1} M_\odot$
Measuring Cluster Mass

- **Direct measures of cluster mass**: weak lensing, dynamical mass, X-Ray hydrostatic mass
  - susceptible to systematic bias → **hard to measure** both data and errors
- **Proxies for cluster mass** – easier to measure
- **Possible proxies**: richness, SZ, X-ray temperature, etc.
- **Need to understand**:
  - Proxy → mass relation
  - Relationship between masses measured by different methods
Measuring Cluster Mass

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- **Scaling Relations**
Scaling Relations

M-T relation
Kettula et al, 2013

M-L relation
Mantz et al, 2010

M-SZ relation
Planck, 2011b

M-N relation
Saro et al, 2015
Simultaneous Measurement of Scaling Relations and Cosmological Parameters – Rozo et al., 2010

cosmological parameters

scaling relation parameters
Measuring Cluster Mass

- Direct measure of mass – weak gravitational lensing
- Light from background galaxies distorted when passing by cluster
- High cluster mass → high distortion of background galaxies

figure credit: Michael Sachs (University of California, Davis), via Wikipedia
Weak Gravitational Lensing

Unlensed

Lensed

figure credit: Wikipedia
DES Cluster Weak Lensing Projects

Melchior et al., 2015
Richness
Image: Melchior et al. 2015

SZ Effect

X-Ray
Image: Philip Rooney and Chris Miller

WL Mass Map
Cluster RXJ2238, $z=0.35$
Optically Selected Clusters

- RedMaPPer cluster-finding algorithm
- thousands of clusters found
- Expecting to find tens of thousands by end of survey
- Binned over richness to get mass-richness scaling relation
Optically Selected Clusters
Preliminary Measurements

\[ \lambda \in [5.0, 7.6] \]
\[ \lambda \in [7.6, 12.7] \]
\[ \lambda \in [12.7, 23.2] \]
\[ \lambda > 23.2 \]

figure credit: DES RedMaPPer Mass Calibration group
Optically Selected Clusters
Preliminary Measurements

\[ \lambda \in [5.0, 7.6] \]

\[ \lambda > 23.2 \]

figure credit: DES RedMaPPer Mass Calibration group
SZ-Selected Clusters

- Found by SPT
- 96 clusters in the SPT sample
- 39 clusters used
- Binned over SZ detection significance to get mass-SZ scaling relation

Gangkofner et al.; in prep
SZ Selected Clusters
Preliminary Measurements

Gangkofner et al.; in prep
X-Ray Selected Clusters

- Found by XCS
- ~175 clusters in the XCS sample
- ~120 clusters used
- Binned over X-ray temperature to get mass-temperature scaling relation

figure credit: Chris Miller
X-Ray Selected Clusters

X-Ray Temperature Distribution

Photo-z Distribution
X-Ray Selected Clusters
Preliminary Measurements

Shear Around 47 Clusters, 3keV<T<6keV

Shear

radius
X-Ray Selected Clusters
Preliminary Measurements

Shear Around Stacks of Clusters Binned by $T_x$

- $3\text{keV} < T_x < 6\text{keV}$
- $T_x > 6\text{keV}$
X-Ray Selected Clusters – Next Steps

- Measure mass-temperature scaling relation within Planck cosmology

\[ P(\mu_s, WL | S_{o,i}, \theta, \psi) = \int d\mu_s \ P(\mu_s, WL | \mu_s) P(\mu_s | S_{o,i}, \theta) P(\mu_s | \psi) \]

Scaling relation parameters (variables)

Probability of measuring a certain stacked WL mass, given observables (temperature), scaling relation variables, and cosmology

observables

cosmology
In Conclusion...

- Characterizing cluster mass function → constraints on cosmological parameters
- Measuring mass proxies is easier than directly measuring cluster mass → scaling laws
- DES is characterizing scaling relations between cluster mass and richness, SZ, and X-ray observables
- Preliminary results look promising
- Lots of wonderful science coming up!
References

- Gangkofner et al. In prep.
- Saro, A. et al. Submitted to MNRAS.
Thank you!