Research Statement

I highlight below two areas of survey cosmology I would like to pursue over the next three to five years of my research career. I already have the skills to handle large datasets from the SDSS and other surveys, and I am comfortable working within large collaborations like the XMM Cluster Survey and SDSS.

Testing theories of modified gravity using the cluster mass function.

The cluster mass function measures the density of clusters as a function of both mass and redshift, and is strongly dependent on the cosmological parameters (Press and Schechter [1974], Sheth et al. [2001]). Furthermore, it has been shown recently to be strong test of the strength of gravity on small–to–intermediate scales and thus provides a unique test of theories of modified gravity (see Schaefer and Koyama [2008], Song and Koyama [2008]). To utilize clusters for such analyses, one needs large datasets of clusters, which span a wide range of redshifts and masses. Moreover, one requires precise measurements of the cluster masses with a well-understood completeness. In my PhD thesis, I have tackled the latter of these problems using large samples of clusters to measure the mass of clusters using a number of optical proxies (richness, luminosity, weak lensing magnification) and X-ray astrophysics (Hoyle et al. [2009a,b]).

In the near future, the size of cluster catalogs available will increase substantially. First, the Sloan Digital Sky Survey (Adelman-McCarthy et al. [2008]) Date Release 7 (SDSS DR7) will provide a large sample of photometrically selected clusters (via maxBCG) with an increased completeness of both photometric (LRG) and spectroscopic redshifts. In the short-term, this will remain the largest cluster catalog available for cosmology and I would like to use this catalog to constrain theories of modified gravity. On the horizon, the Dark Energy Survey (Eisenstein et al. [2005a]) will provide a joint deep optical and infra-red imaging survey of the southern hemisphere (5000 deg^2 of sky imaged in grizYJHK). From this data, we expected to detect ∽12,000 cluster above $10^{14} M_{sun}$ out to a redshift of one (assuming the concordance ΛCDM cosmology). One can also improve the mass estimates using both the infra-red colors (Lin and Mohr [2004]) and the Sunyaev-Zeldovich data from the overlap with the South Pole Telescope (SPT). DES should decrease the error on a constant equation of state of dark energy (w) to approximately 2% when combined with Planck.

By extending cluster finding routines similar to the SDSS MaxBCG (Koester et al. [2007]) to the full SDSS DR7 will enable the creation of a large cluster catalogue. Applying my optical based mass proxies to both currently available SDSS and the future full 5000 sq-degree DES survey will allow me to assign mass estimates to a unprecedented number of clusters. Additionally, I could look at the SZ - optical mass scaling relations to further improve the mass measurements. These robust mass measurements will place strong constraints on cosmological parameters and test alternative theories of gravity.

Luminous red galaxies as tracers of the dark matter.

How light traces the underlying dark matter remains a key problem in cosmology. In recent years, Luminous Red Galaxies (LRGs; Eisenstein et al. [2001]) have become important and efficient tracers of the large-scale structure in the universe and have been used to detect and measure the Baryon Acoustic Oscillations (see Eisenstein et al. [2005b], Percival et al. [2007]). Therefore, it is imperative that we have a detailed understanding of how LRGs are biased compared to the dark matter and how this potentially changes with scale and/or redshift.

I plan to study LRG biasing using a combination of both new data and new modeling techniques. First, during my PhD, I have constructed the largest LRG photometric catalog from the SDSS; over 2 million LRGs, out to a redshift of z$\sim$ 0.7, of which 11% have a known spectroscopic redshift. Using this catalog, in-conjunction with distant quasar catalogs, I can directly probe the LRG bias using a combination of the LRG auto-correlation and the LRG-quasar cross-correlation, which measures the underlying mass of LRGs via weak lensing magnification (see Scranton et al. [2005]). Beyond these direct measurements, the halo masses of LRGs can be inferred using the Halo model of clustering, namely the determination of the Halo Occupation Distribution (HOD). I will do this directly by counting LRGs with known X-ray (XMM, ROSAT) and optical clusters (see Ho et al. [2007], Rozo et al. [2007]) as well as modeling the spatial clustering of these LRGs on small–to–intermediate scales (see Blake et al. [2007]).

Beyond exploiting the existing SDSS data, new surveys by DES and SDSS-III BOSS will greatly improve our knowledge of high redshift LRGs and provide millions of spectroscopic LRGs. I would plan to look at the marriage of these two surveys (which overlap by over 2000 deg^2 around the South Galactic Pole) further improving our detailed understanding of the biasing of LRGs, e.g., using the lensing map from DES to trace the large-scale structure, as well as deep UV, optical and infra-red data from the ESO VST and VISTA surveys.

Ben Hoyle, August 2008

References

Jennifer K. Adelman-McCarthy et al. The Sixth Data Release of the Sloan Digital Sky Survey. *Astrophys. J. Suppl.*, 175:297–313, 2008.

Chris Blake, Adrian Collister, and Ofer Lahav. Halo-model signatures from 380,000 SDSS Luminous Red Galaxies with photometric redshifts. 2007.

Daniel Eisenstein et al. 2005a.

Daniel J. Eisenstein et al. Spectroscopic Target Selection for the Sloan Digital Sky Survey: The Luminous Red Galaxy Sample. *Astron. J.*, 122:2267, 2001.

Daniel J. Eisenstein et al. Detection of the Baryon Acoustic Peak in the Large-Scale Correlation Function of SDSS Luminous Red Galaxies. *Astrophys. J.*, 633:560–574, 2005b.

Shirley Ho, Yen-Ting Lin, David Spergel, and Christopher M. Hirata. Luminous Red Galaxy Population in Clusters at $0.2 \leq z \leq 0.6$. 2007.

Ben Hoyle, David Bacon, and Nichol Robert. The Magnification Bias around Optically Selected Clusters. 2009a.

Ben Hoyle et al. The X-ray Propertries of Optically Selected Clusters. 2009b.

Benjamin Koester et al. A MaxBCG Catalog of 13,823 Galaxy Clusters from the Sloan Digital Sky Survey. *Astrophys. J.*, 660:239–255, 2007.

Yen-Ting Lin and Joseph J Mohr. K-band Properties of Galaxy Clusters and Groups: Brightest Cluster Galaxies and Intracluster Light. *Astrophys. J.*, 617:879, 2004.

Will J. Percival et al. Measuring the matter density using baryon oscillations in the SDSS. *Astrophys. J.*, 657:51–55, 2007.

W.H. Press and P. Schechter. *ApJ.*, 185:716, 1974.

Eduardo Rozo et al. Cosmological Constraints from SDSS maxBCG Cluster Abundances. 2007.

Bjoern Malte Schaefer and Kazuya Koyama. Spherical collapse in modified gravity with the Birkhoff- theorem. *Mon. Not. Roy. Astron. Soc.*, 385:411–422, 2008.

Ryan Scranton et al. Detection of Cosmic Magnification with the Sloan Digital Sky Survey. *Astrophys. J.*, 633:589–602, 2005.

Ravi K. Sheth, H. J. Mo, and Giuseppe Tormen. Ellipsoidal collapse and an improved model for the number and spatial distribution of dark matter haloes. *Mon. Not. Roy. Astron. Soc.*, 323:1, 2001.

Yong-Seon Song and Kazuya Koyama. Consistency test of general relativity from large scale structure of the Universe. 2008.