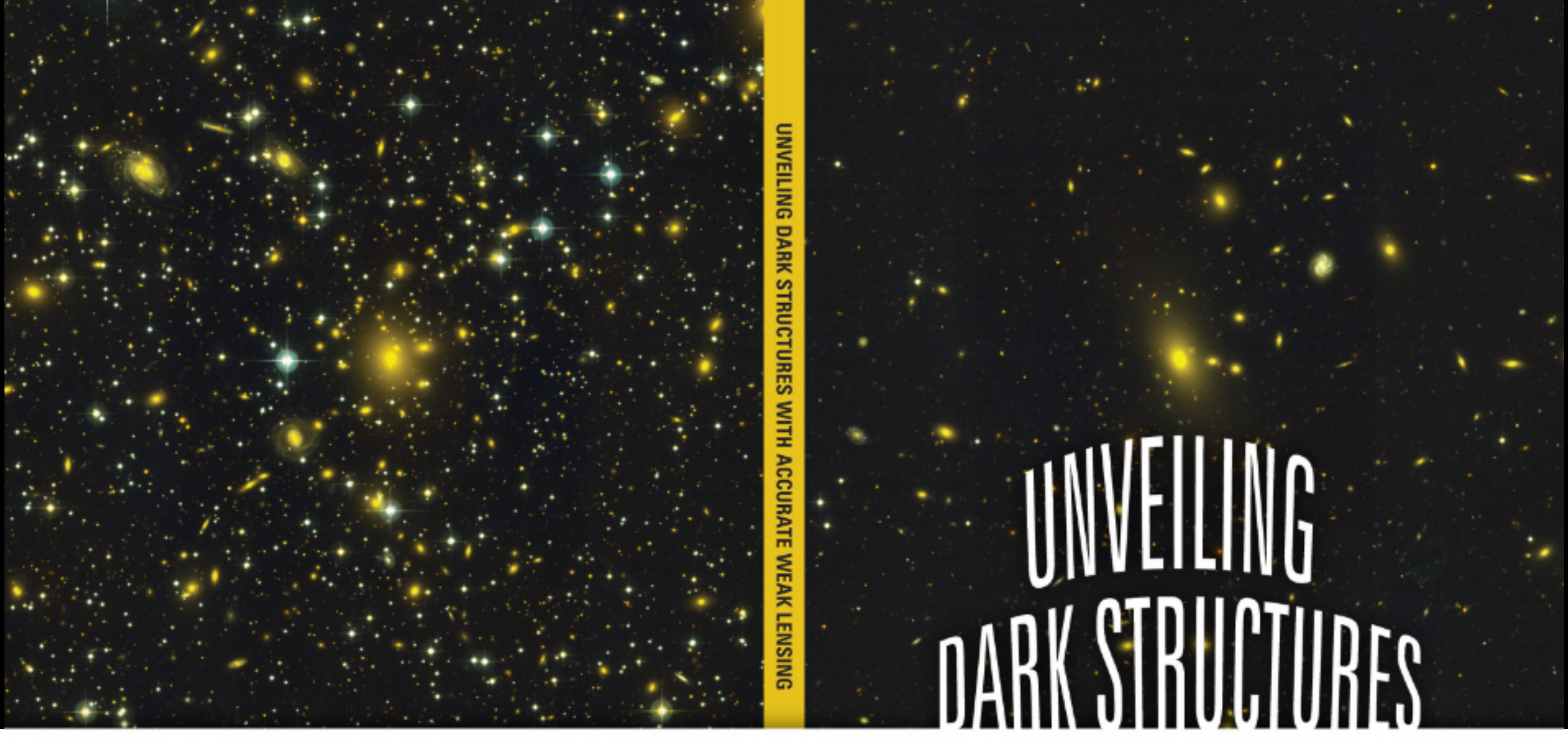


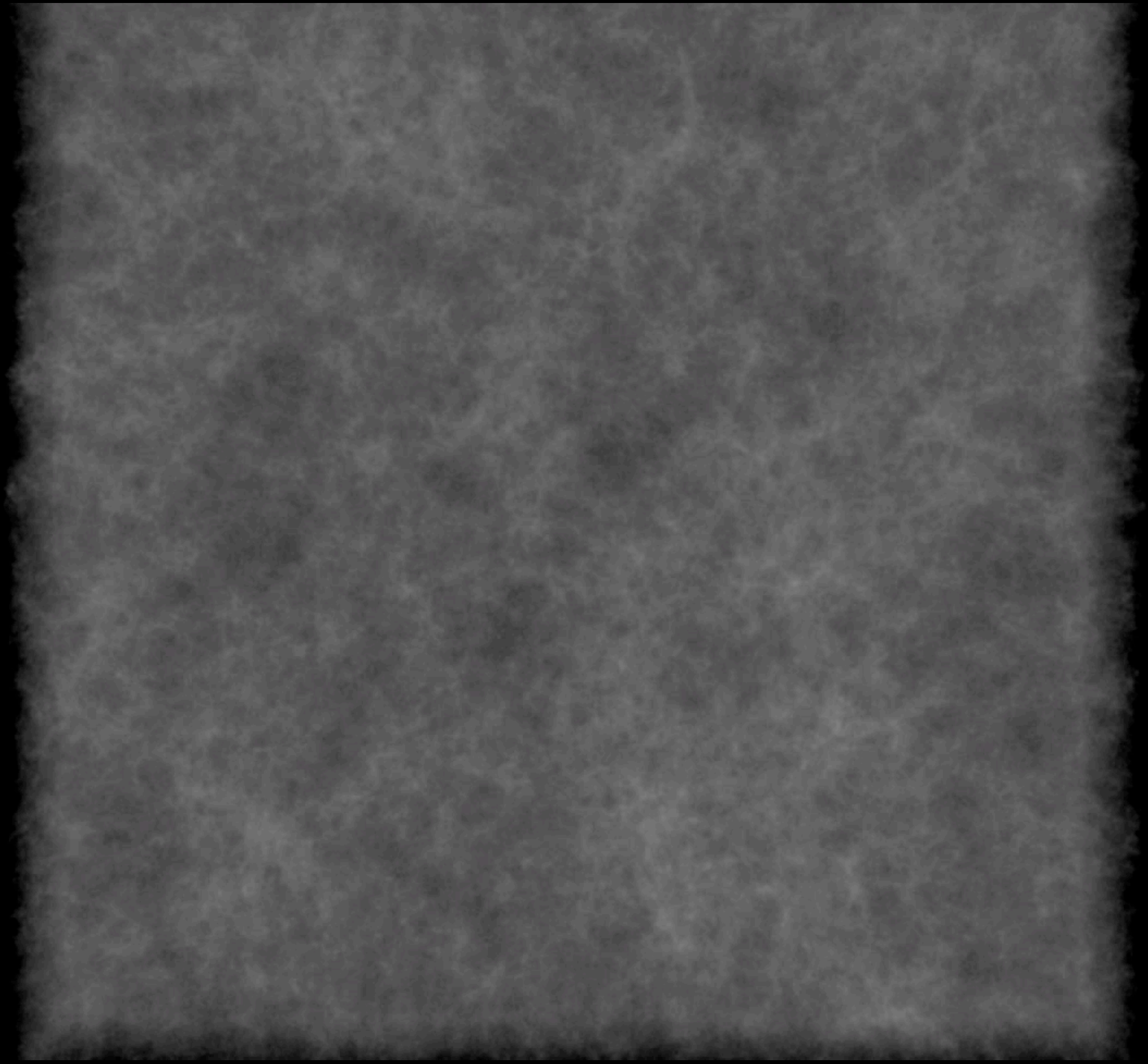
Weak lensing masses and scaling relations for 100 clusters

Stony Brook University

Sesto

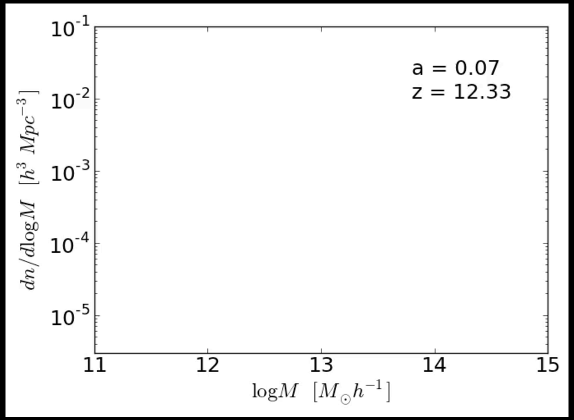
July 8 2019

Counting Halos



Matt Becker, Ralf Kaehler, Yao-Yuan Mao, Rachel Reddick, Anja von der Linden, Risa Wechsler (Stanford/SLAC)

halo mass function



- number of gravitationally bound halos sensitive to cosmological model
- both *geometry* (volume) and *growth of structure* (evolution of mass function)

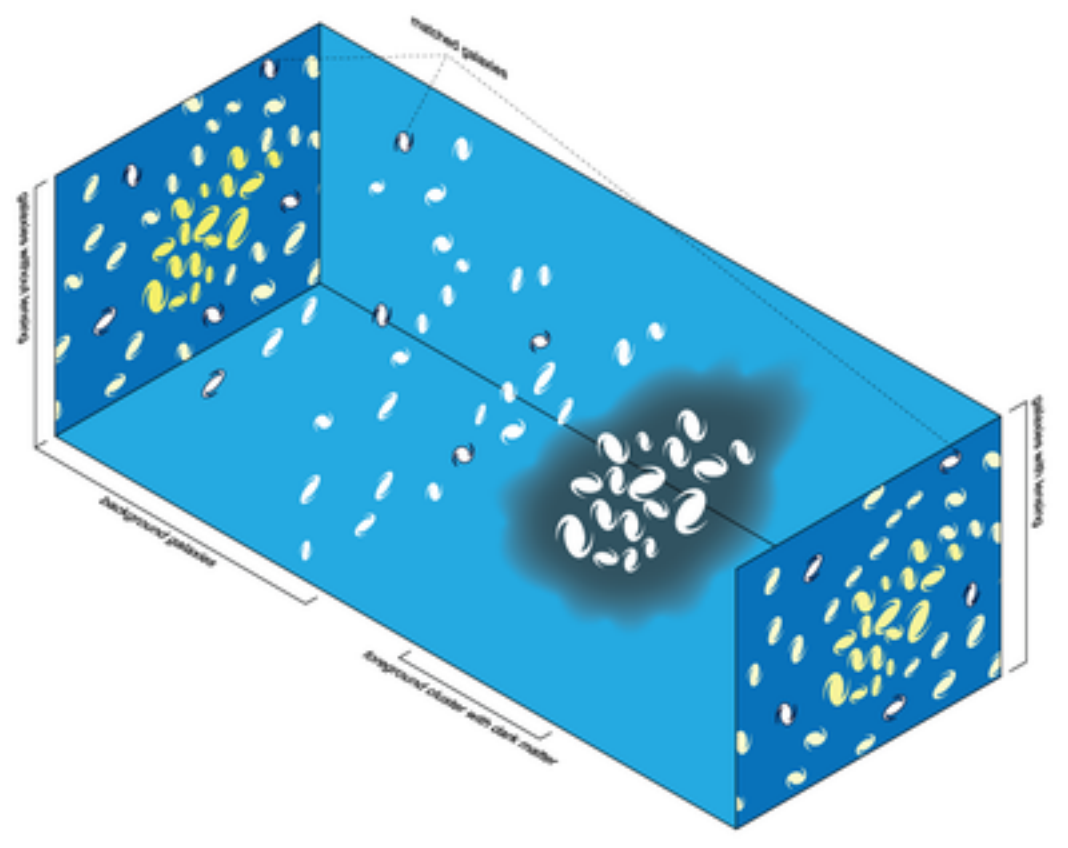
Halo masses from cluster weak lensing

- Shear measurement
- Photometric redshift distribution
- Source galaxy selection
- Mass determination

Scaling relation

Weak lensing measures total mass, but measurements are noisy for individual clusters

Calibrate more precise observables with ensembles of clusters



Weak lensing cluster sample

MENeaCS

Multi Epoch Nearby Cluster Survey

Most X-ray luminous clusters in the local Universe

~50 galaxy clusters
$0.05 < z < 0.15$ $M_{200} > 10^{14}\ M_{\odot}$

deep *r* band CFHT observations
seeing < 0.8" $20 < m_r < 24.5$

CCCP

Canadian Cluster Comparison Project

Hoekstra et al. 2012
Hoekstra, Herbonnet et al. 2015

~50 galaxy clusters
$0.15 < z < 0.55$ $M_{200} > 3\times10^{14}\ M_{\odot}$

deep *r* band CFHT observations
seeing < 0.9" $22 < m_r < 25$

Steps in cluster weak lensing

Source redshift distribution

Observations lack colour information to estimate reliable redshifts.
We use COSMOS as a reference field.
~5% uncertainty

Shear calibration

Calibration with image simulations mimicking our own observations.
~2% uncertainty
(Hoekstra, Herbonnet et al. 2015)

Source sample selection

Boost correction
Statistically correct for unsheared galaxies in the source sample.
~2% uncertainty

Mass modelling

Hydrodynamical cluster simulations
Run our mass estimation on HYDRANGEA (Bahé et al. 2017).
~3% uncertainty

Cluster cosmology

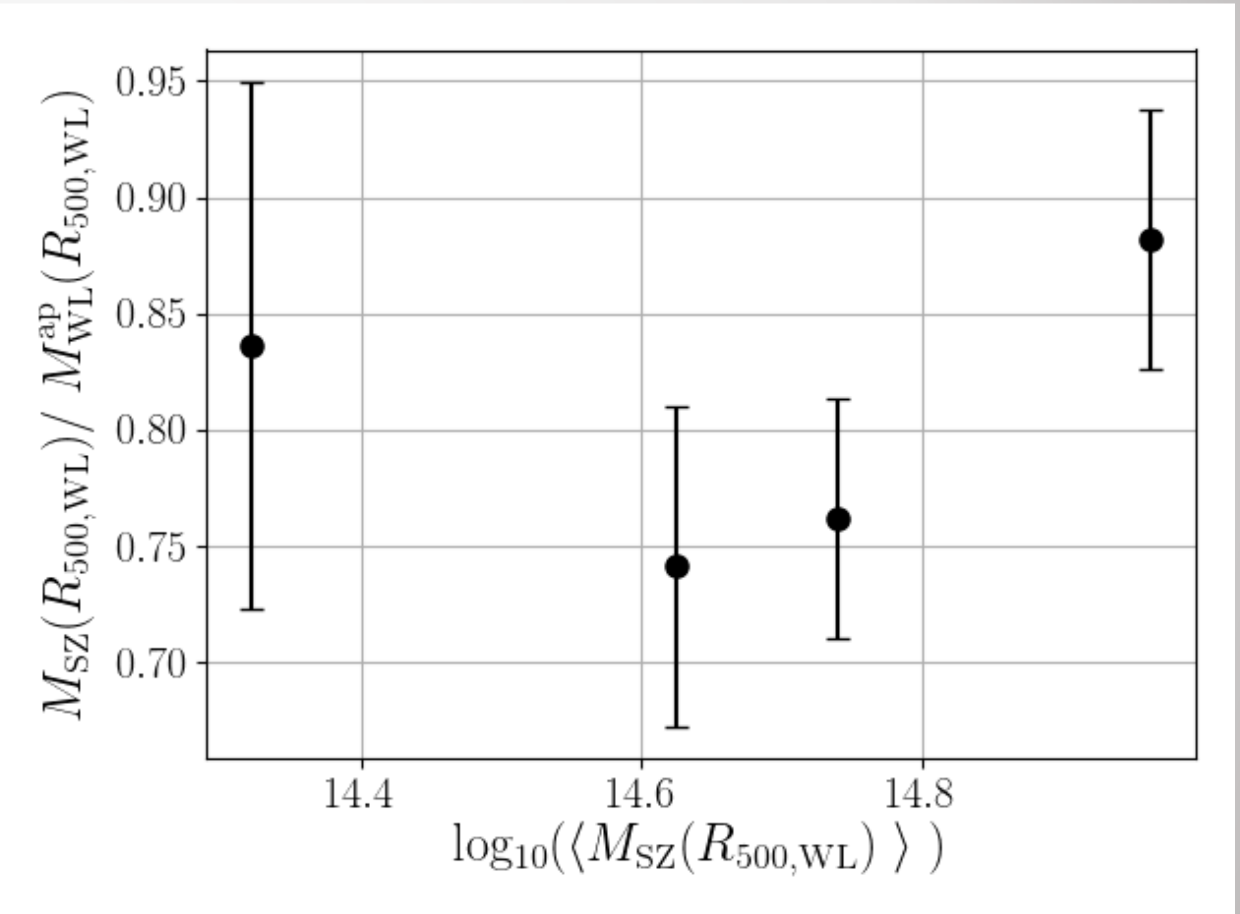
Planck has measured SZ masses for hundreds of clusters

- SZ masses are biased estimates of true cluster mass
- WL masses are imprecise estimates of true cluster mass
- Use WL to calibrate SZ masses

Consistent with 0.8, used for the 2015 *Planck* cosmological analysis

Higher than 0.71+/-0.10 of the reanalysis by Zubeldia & Challinor (2019)

No significant trend with mass



Preliminary result

Cluster cosmology

Mantz et al. have measured the mass of the gas content in clusters

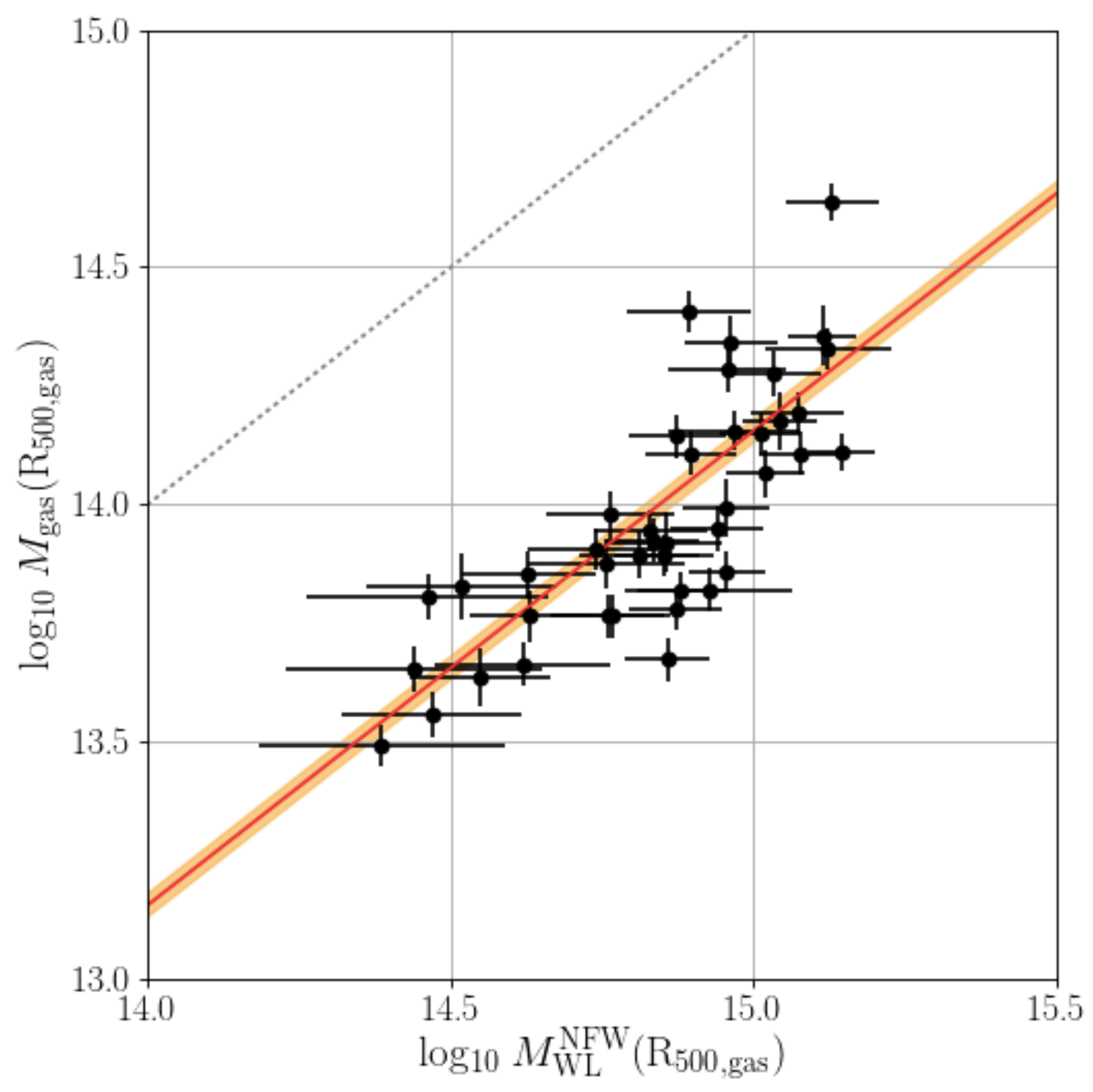
~40 are in our weak lensing sample

Slope = 0.133 +/- 0.008

12 clusters are relaxed

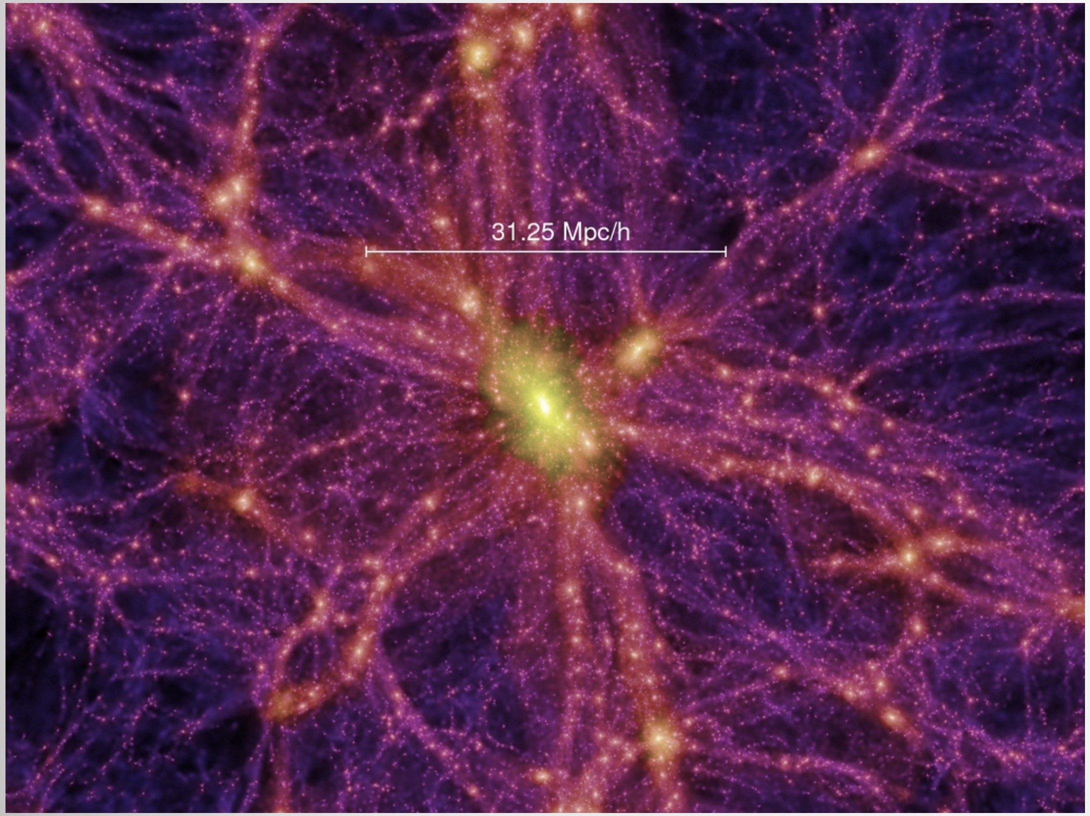
Gas fraction in relaxed clusters can be related to total amount of mass in the Universe Ω_m (poster by Lucie Baumont)

Large scatter in weak lensing mass



Preliminary result

Halo orientation and WL cluster masses



Springel et al. (2005) Millennium Simulation

Non-spherical haloes

Lensing measures projected mass density and usually assumes spherical symmetry

Halo orientation introduces scatter in the mass estimate of a cluster, which is usually assumed to average out for large samples

Selection bias if selection criterium depends on halo orientation
e.g. optical, SZ cluster finders

Halo orientation and WL cluster masses

Weighing the Giants

Von der Linden et al. 2014, Kelly et al. 2014, Applegate et al. 2014, Mantz et al. 2015, 2016

~50 galaxy clusters
selected on X-ray luminosity

deep SUBARU observations
Chandra X-ray observations

Weak lensing masses and gas masses

Quantifying WL mass scatter

The residual of the weak lensing mass to the total mass is dominated by the orientation of the DM halo

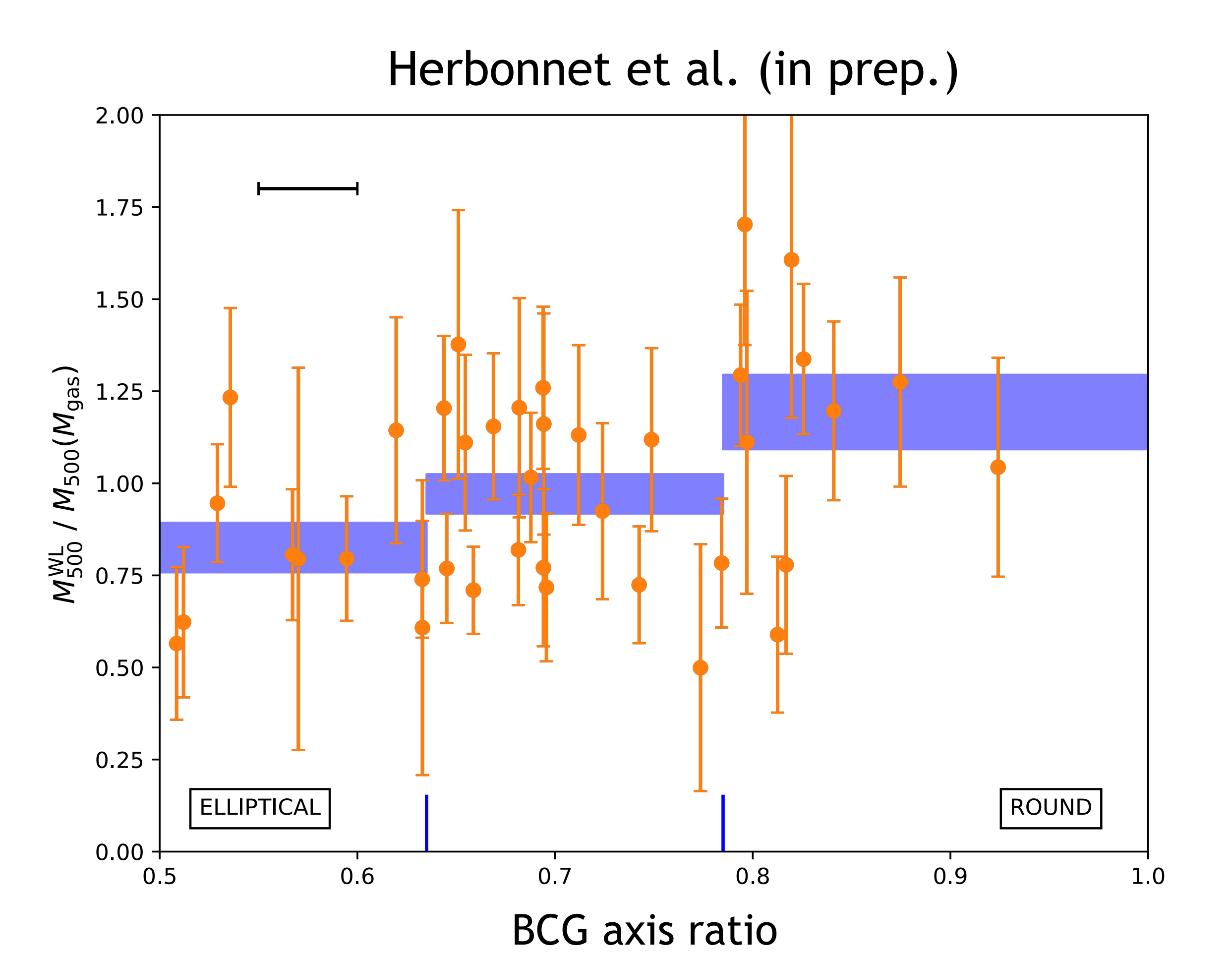
Gas mass as low scatter proxy for total mass

Weak lensing provides the overall scaling between gas mass and true mass:

$f_{gas} = 0.125$ (Mantz et al. 2016)

Total cluster mass $M_{500} = 0.125\ M_{gas}$

Halo orientation and WL cluster masses



Proxy for halo orientation

Baryonic material follows dark matter distribution
Brightest cluster galaxy (BCG) should be aligned with the halo

In projection the ellipticity of the BCG is a proxy for halo orientation and should correlate with weak lensing scatter

Round BCG: halo oriented along line-of-sight
high weak lensing mass

Elliptical BCG: halo in plane of the sky
low weak lensing mass

We indeed see the expected trend of the weak lensing mass with BCG ellipticity

Meeting challenges for upcoming surveys

Source redshift distribution
Source sample selection

More reliable deep redshift catalogues are necessary for deep optical surveys

Permutations of COSMOS might not be realistic for cluster fields

Building redshift catalogue for MACS0454 with PRIMUS-like data down to 25 mag LSST-like filters and good HST coverage

Shear calibration

Validate *MetaCalibration* in cluster fields, where blending of galaxy light is a major source of systematic uncertainty when attempting to measure galaxy shapes

Triaxiality

BCG ellipticity as proxy for halo orientation to reduce weak lensing mass scatter and to mitigate selection biases