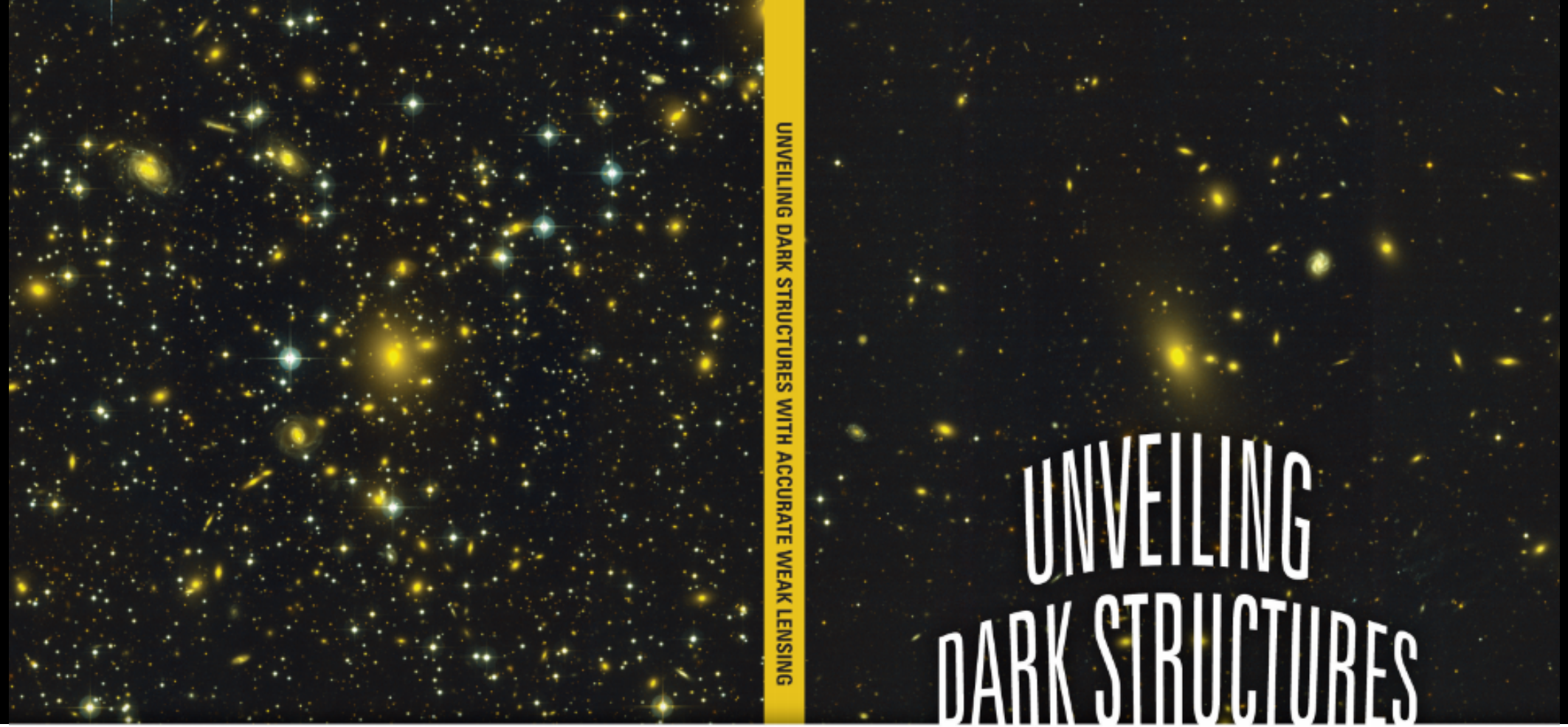
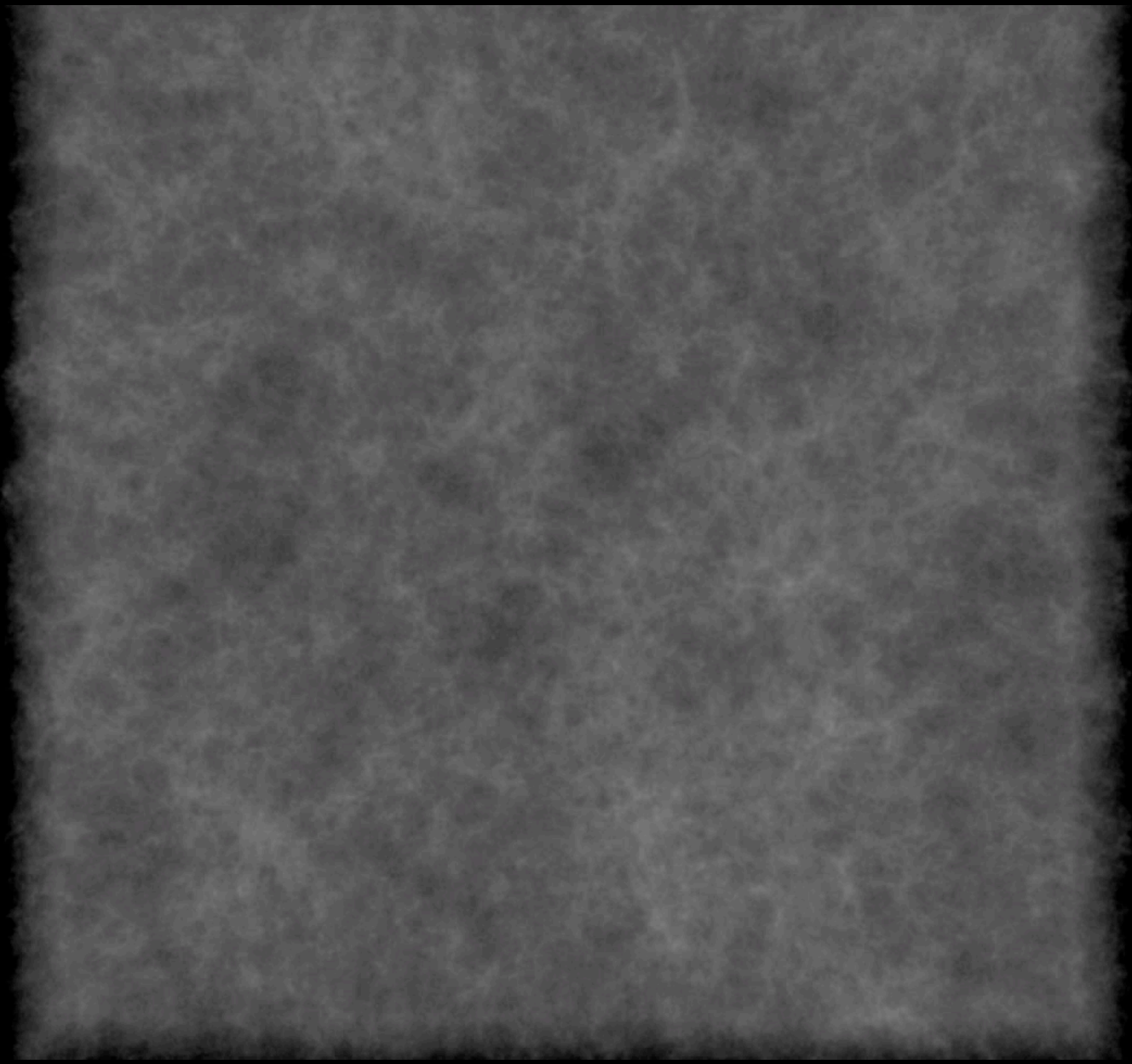


Weak lensing - SZ scaling relation

SnowCluster

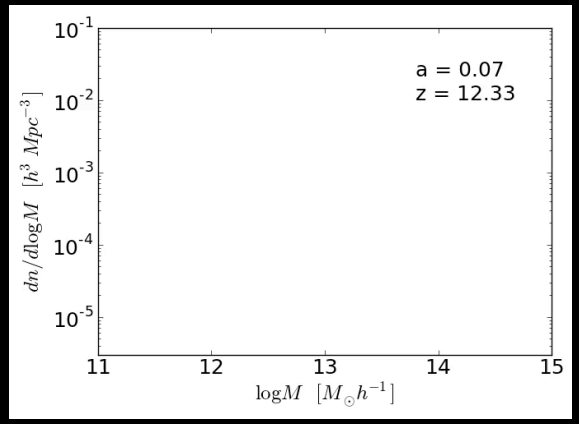
March 22 2018

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)

Weak lensing cluster sample

MENeaCS

Multi Epoch Nearby Cluster Survey

Most X-ray luminous clusters in the local Universe

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

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
$0.15 < z < 0.55$ $M_{200} > 3\times10^{14}\ M_o$

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

Systematics in cluster weak lensing

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

Systematics in cluster weak lensing

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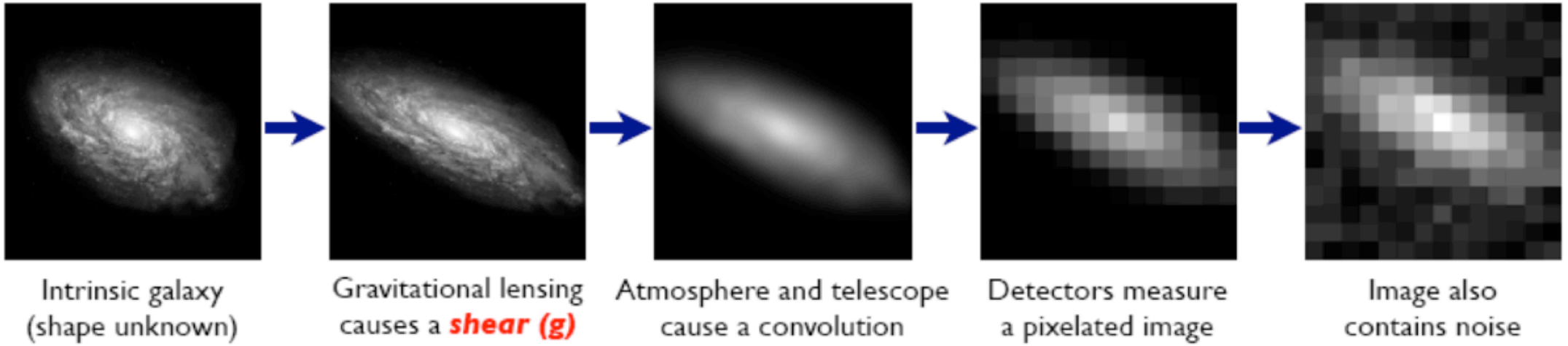
$$g^{est} \approx \Sigma_{gal}(\epsilon^{int} + g^{true})/N_{gal}$$

$$g^{meas} = (1+m)g^{est} + c$$



Bridle et al. 2008

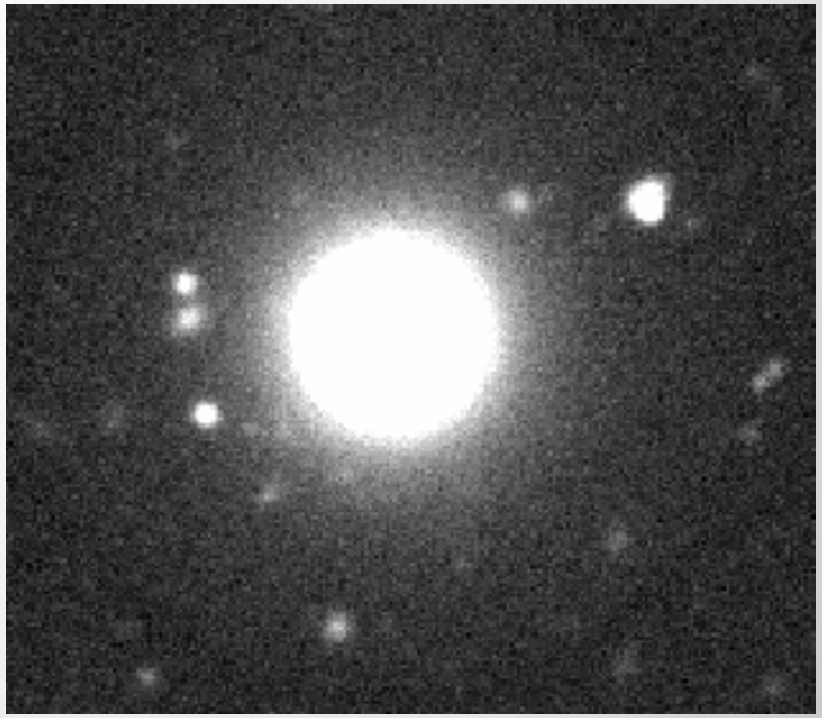
Shear measurement

Calibrated KSB method with large suite of simulated telescope images for CCCP:
~2% remaining uncertainty (Hoekstra, Herbonnet et al. 2015)

Cluster image simulations consisting of a background population and foreground cluster members

Simulated cluster galaxies based on the light profile of MENeaCS galaxies (Sifon et al. 2015)

Corrected for the effect of cluster galaxies
Sifon, Herbonnet et al. 2017



Systematics in cluster weak lensing

- Shear measurement
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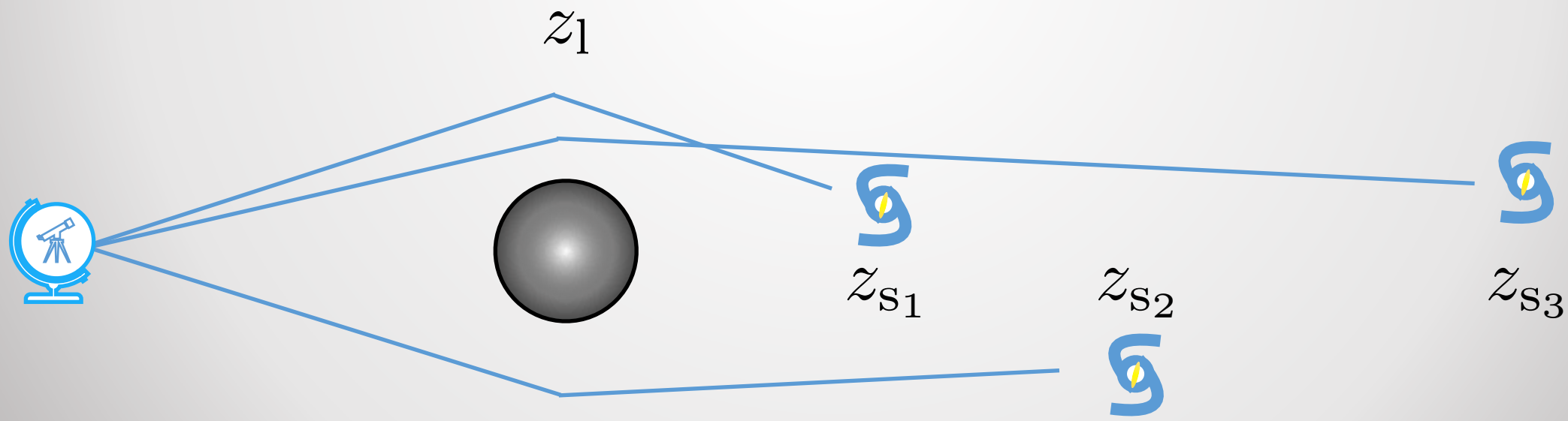
$$\Sigma_{\rm crit} = \frac{c^2}{4\pi G}\frac{D(0,z_{\rm s})}{D(z_{\rm l},z_{\rm s})D(0,z_{\rm l})}$$



Systematics in cluster weak lensing

- Shear measurement
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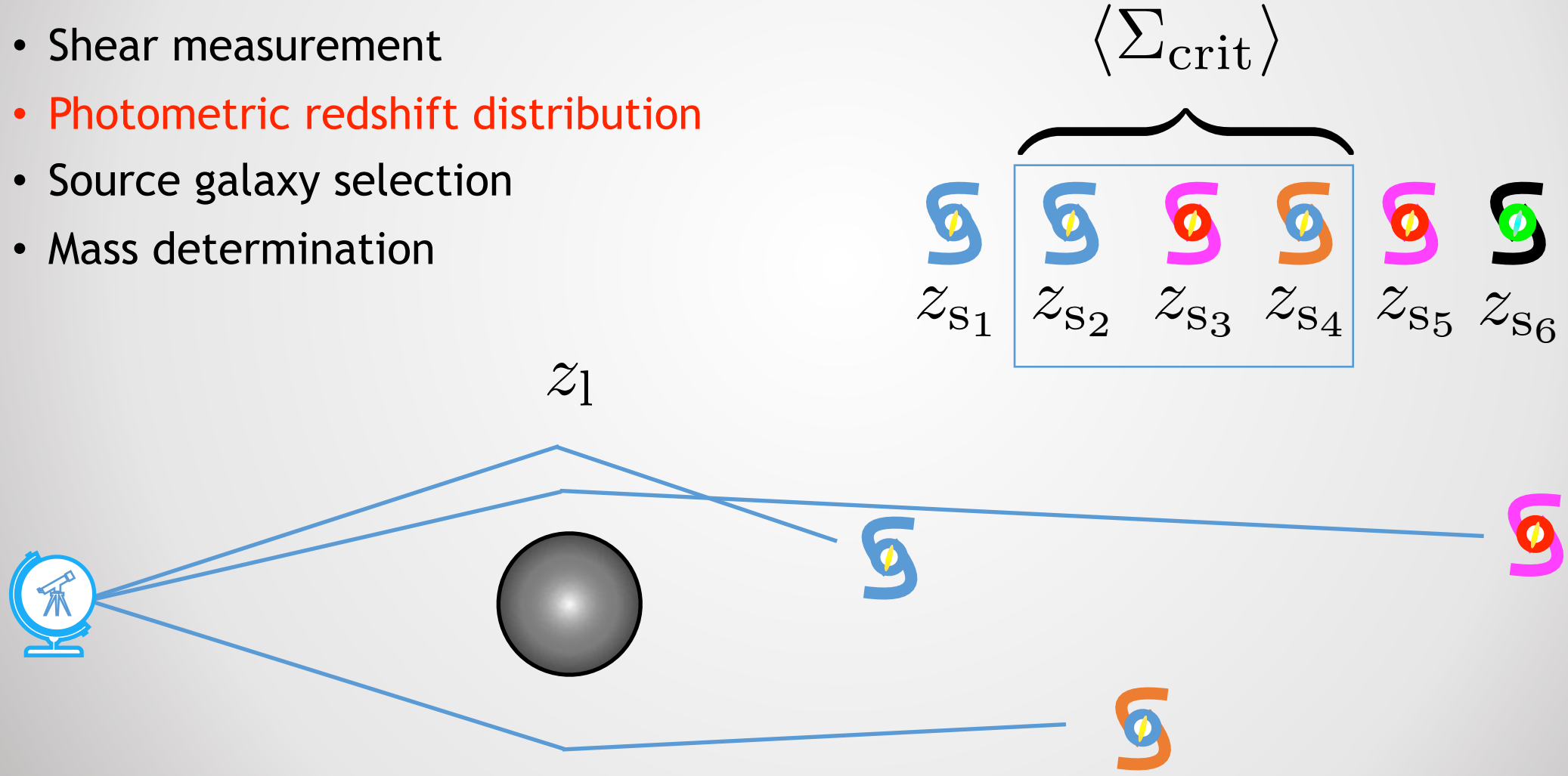

Photometric redshift distribution

COSMOS2015 Laigle et al. 2016
2 sq. deg. 30+ filter photometry

1 sq. deg. lensing measurements
Matched COSMOS catalogue to lensing catalogue to mimic each cluster observation

1 sq. deg. for $\langle \Sigma_{\rm crit} \rangle$ measurement

1 sq. deg. for Poisson errors <1%

CFHT Deep fields Ilbert et al. 2006
~4 sq. deg. 5 filter photometry

Cosmic variance <1%

UltraVista DR3 Muzzin in prep.
~0.73 sq. deg. 50+ filter photometry

Comparison of different photo-z codes <1%

Systematics in cluster weak lensing

- Shear measurement
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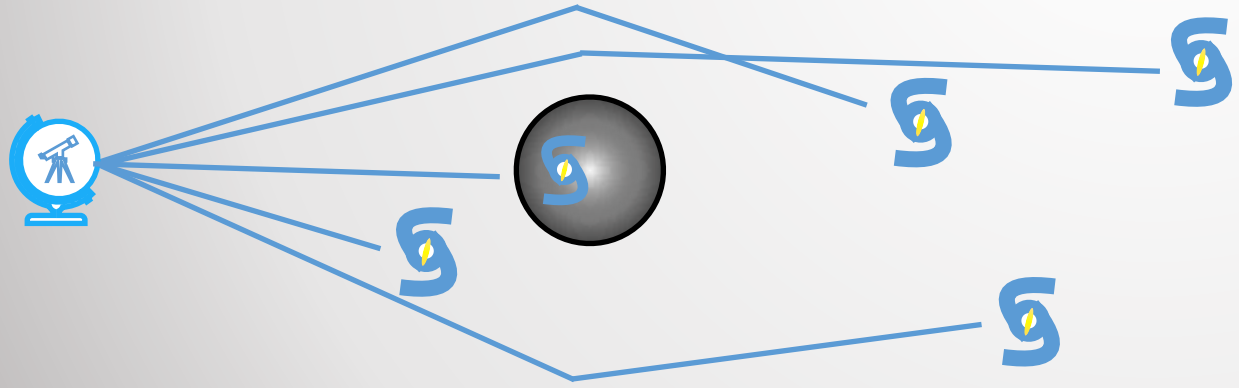


Which galaxies are behind the cluster?

Source galaxy selection

Contamination reduces the shear signal

$$g_{\rm meas} = \frac{\Sigma_{\rm bg}(\epsilon_{\rm int}+g_{\rm true})+\Sigma_{\rm cl}(\epsilon_{\rm int})}{N_{\rm bg}+N_{\rm cl}}$$

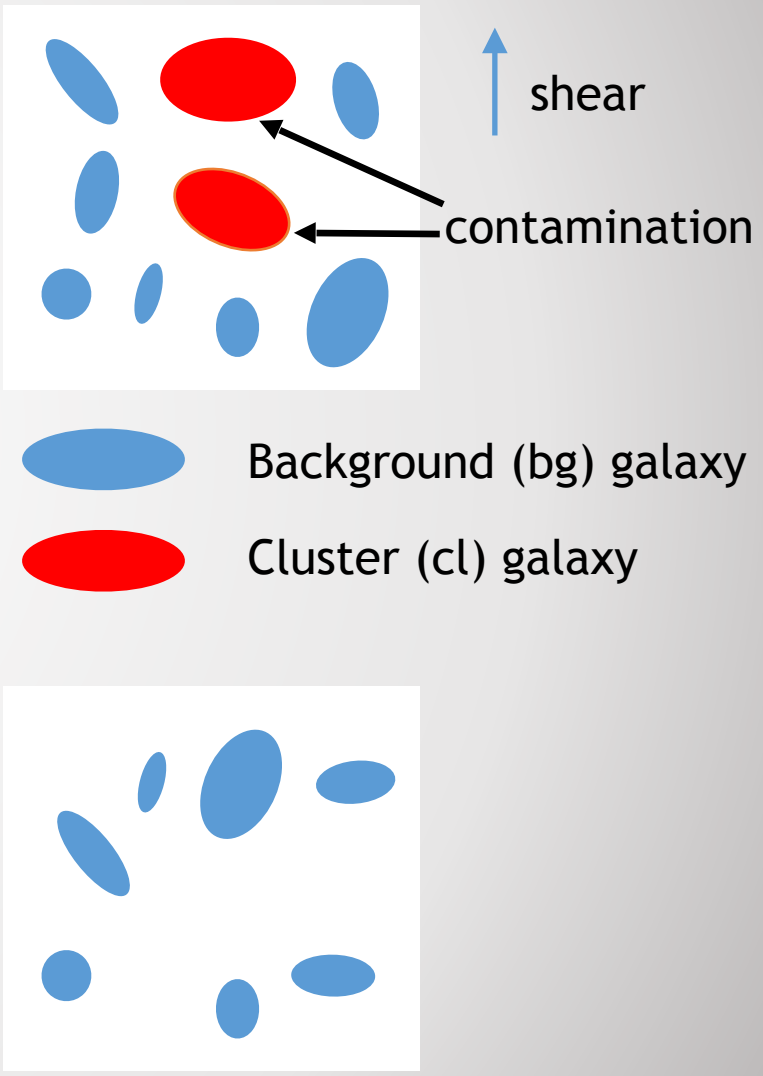
$$g_{\rm meas} = \frac{N_{\rm bg} g_{\rm true}}{N_{\rm bg}+N_{\rm cl}} < g_{\rm true} \qquad (\Sigma(\epsilon_{\rm int}) = 0)$$

Statistical correction to boost shear signal

$$g_{\rm meas} \frac{N_{\rm bg}+N_{\rm cl}}{N_{\rm bg}} = g_{\rm true}$$

Measure $N_{\rm bg} + N_{\rm cl}$ from a cluster region

Measure $N_{\rm bg}$ from a region without cluster galaxies



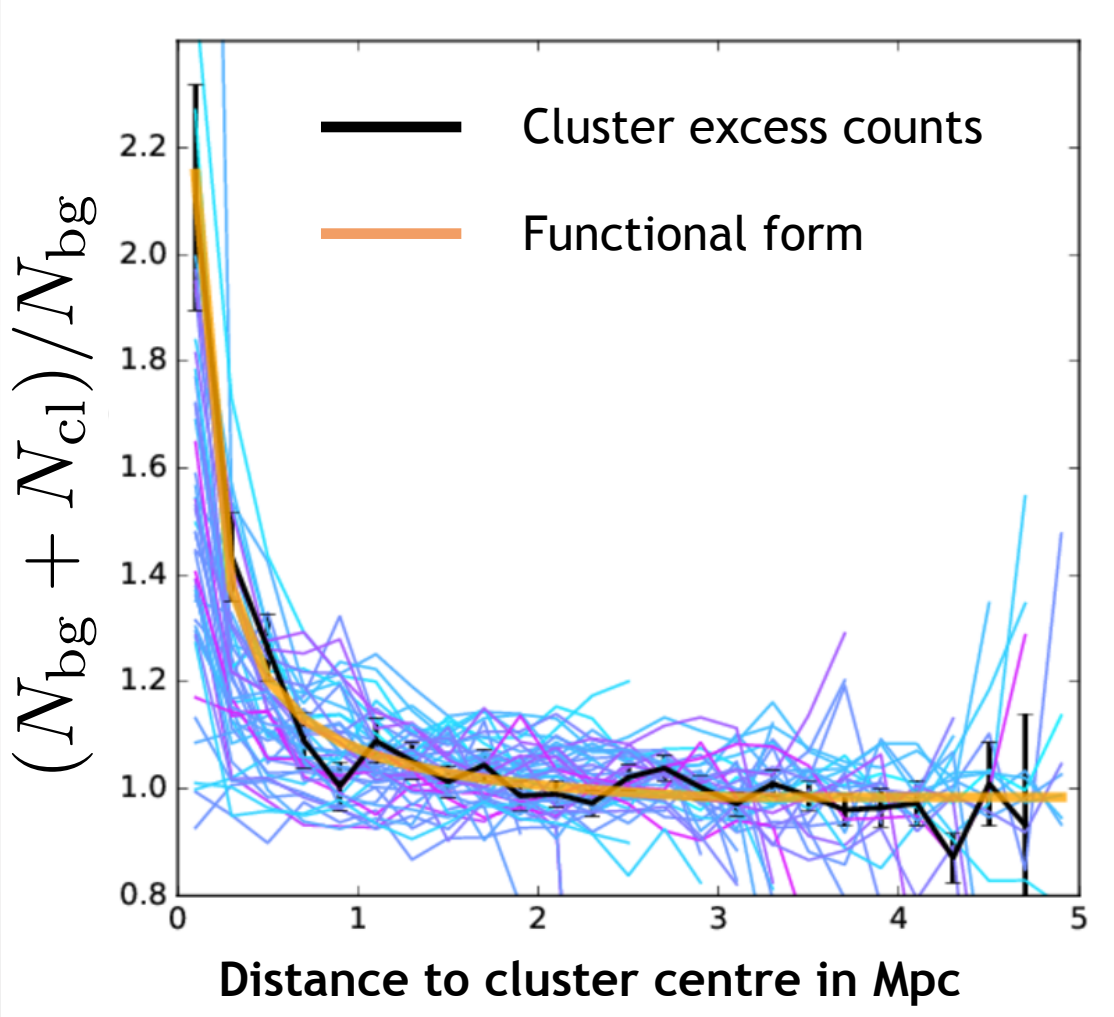
Contamination by cluster members

Image simulations to account for obscuration of background galaxies by cluster members

~40 sq. deg. of deep CFHT observations of blank sky to predict the background galaxy counts $N_{\rm bg}$

Fit a functional form to the excess counts of individual clusters with which to boost the shear signal

Remaining uncertainty from contamination ~2%



Systematics in cluster weak lensing

- Shear measurement
- Photometric redshift distribution
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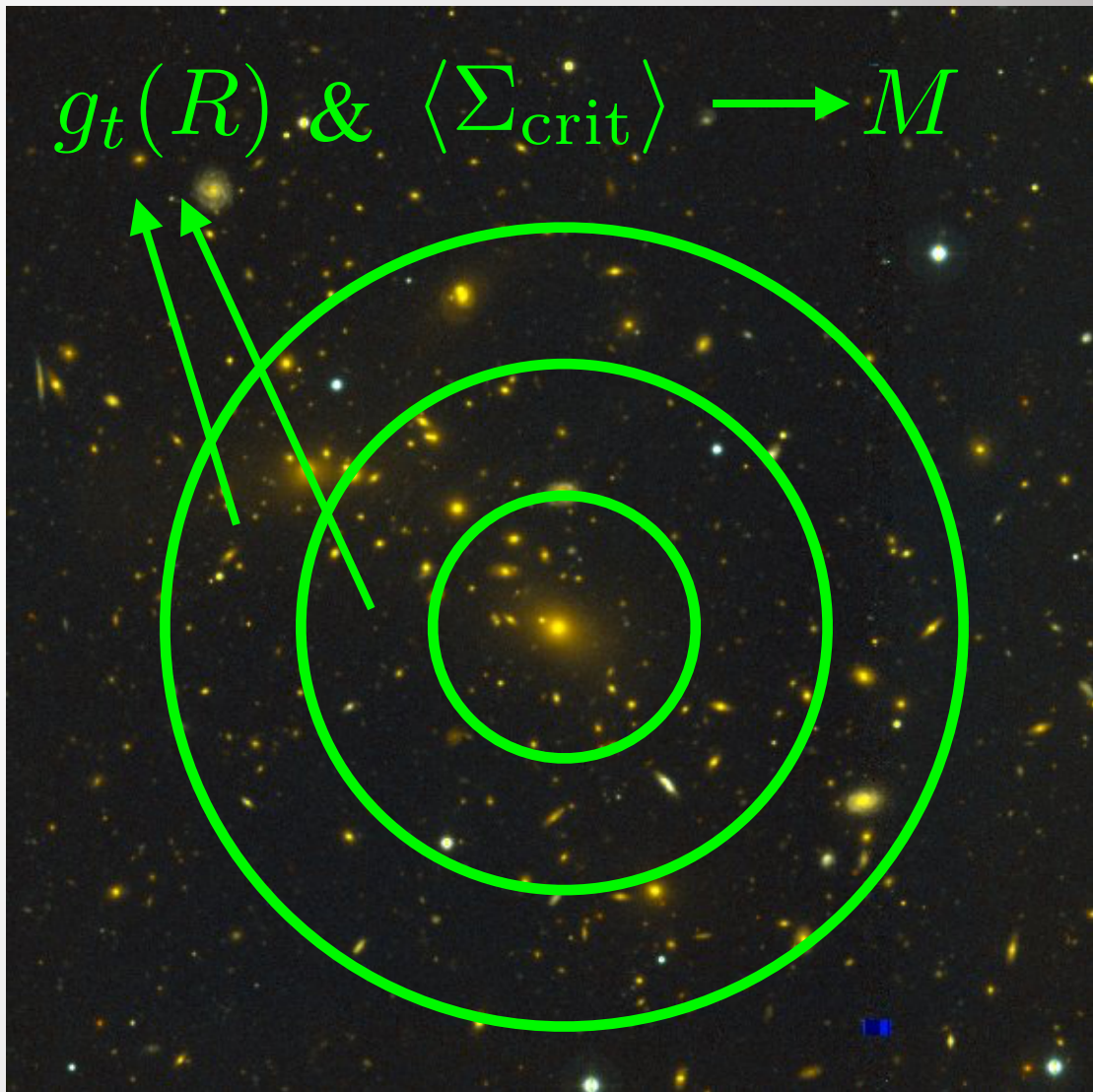
Cluster centre: brightest cluster galaxy and X-ray profile agree on centre

Fit a circular density profile

Deprojected aperture mass



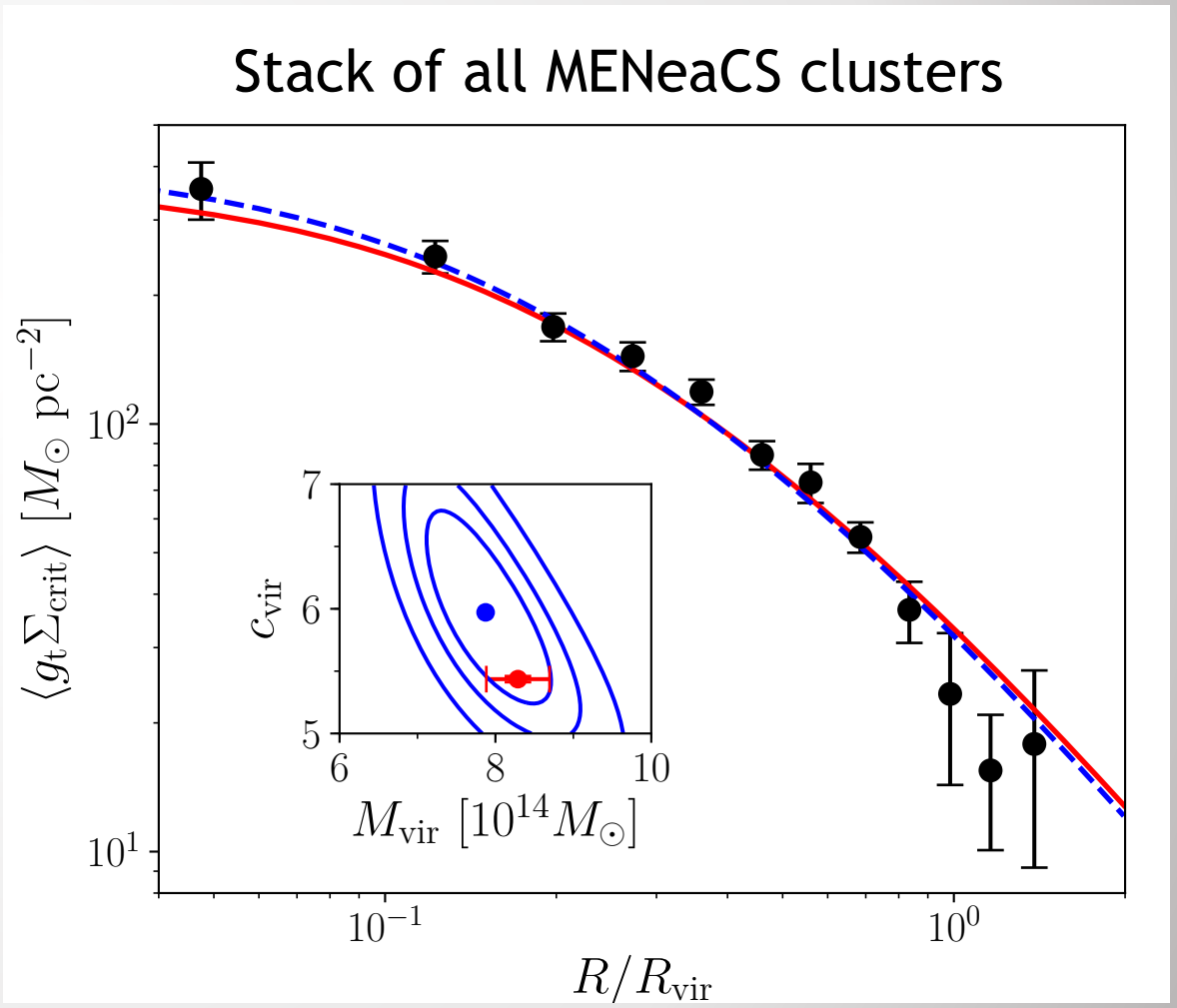
Mass determination

Navarro Frenk White profile fit

Density profile based on simulations and good fit to average cluster profile

Decent agreement with dynamical estimates of cluster masses

Underestimates mass in simulations
Restricted fit range 0.5 - 2 Mpc



Mass determination

Aperture mass

Projected average surface density

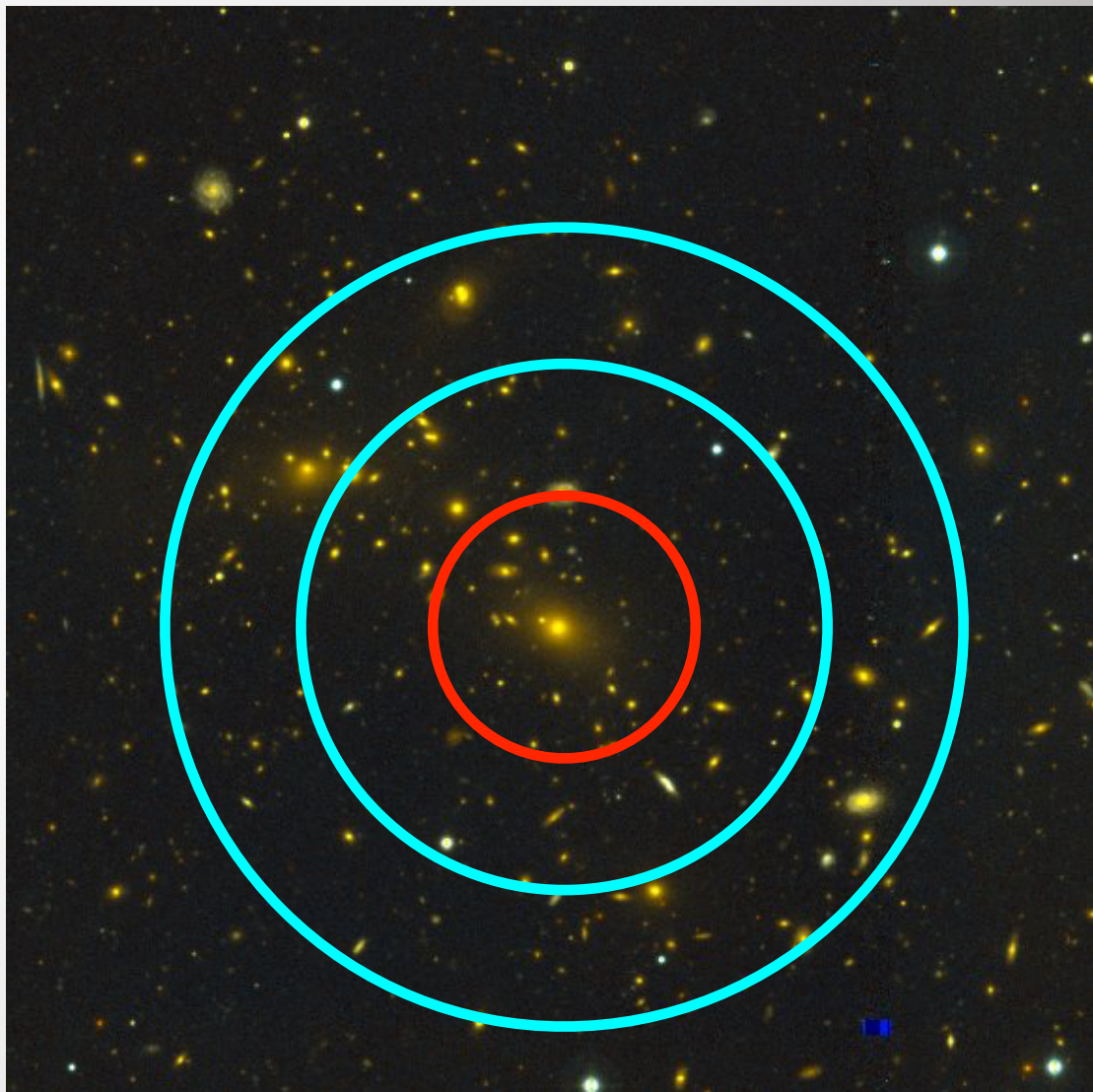
Projected average density in annulus

$$\overline{\kappa}(r \leq r_1) - \overline{\kappa}(r_2 < r \leq r_{\rm max}) =$$

$$2\int_{r_1}^{r_2} \langle \gamma_t \rangle d\ln r + 2(1 - r_2^2/r_{\rm max}^2)^{-1} \int_{r_2}^{r_{\rm max}} \langle \gamma_t \rangle d\ln r$$

Compute from shear measurements

Deproject assuming NFW along the line of sight



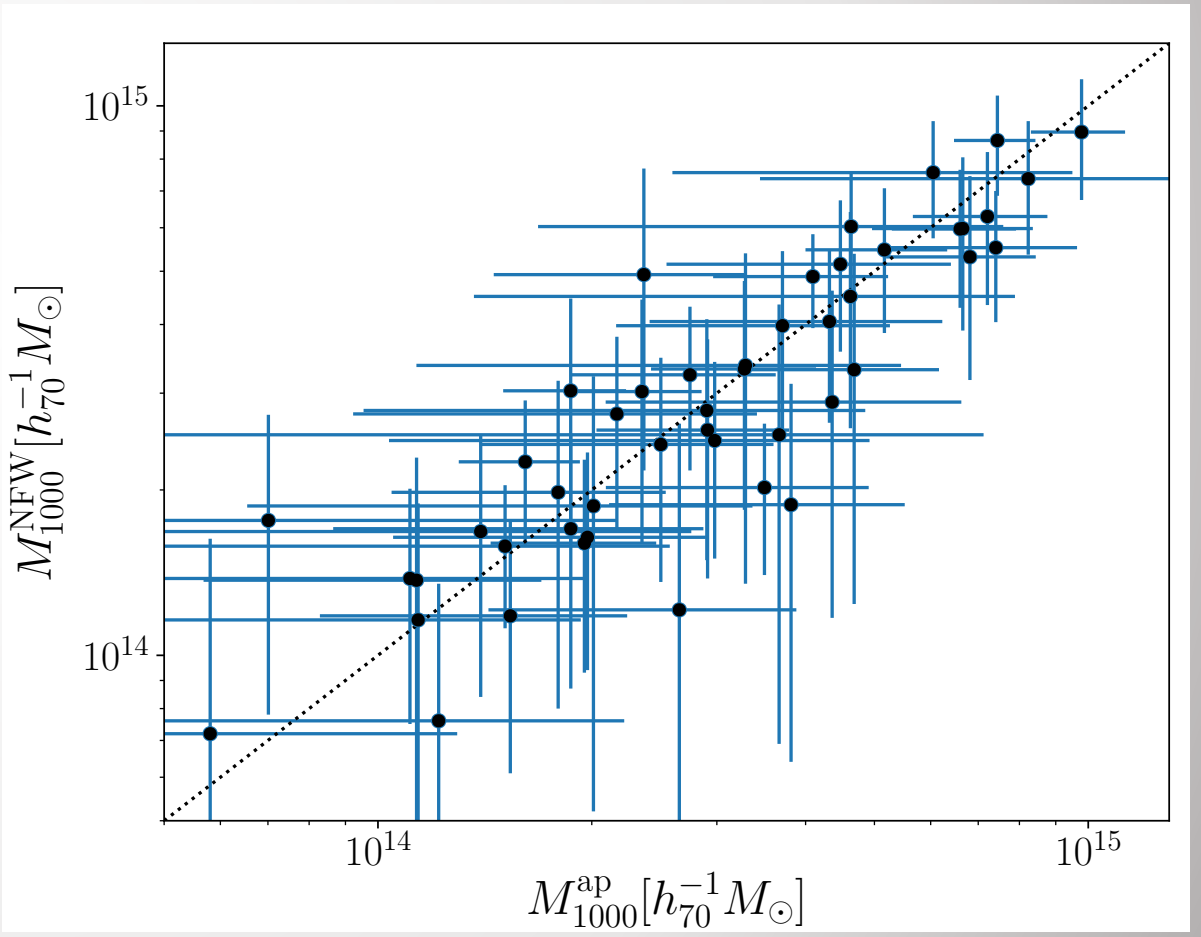
Mass determination

Aperture mass

Good agreement between aperture masses and NFW masses at M_{1000}

Further out there are issues, because the clusters are large compared to the FOV at z~0.1 FOV ~3 Mpc

Check mass estimators on HYDRANGEA cluster simulations (Bahé et al. 2017) and quantify the error in mass determination



Scaling relation

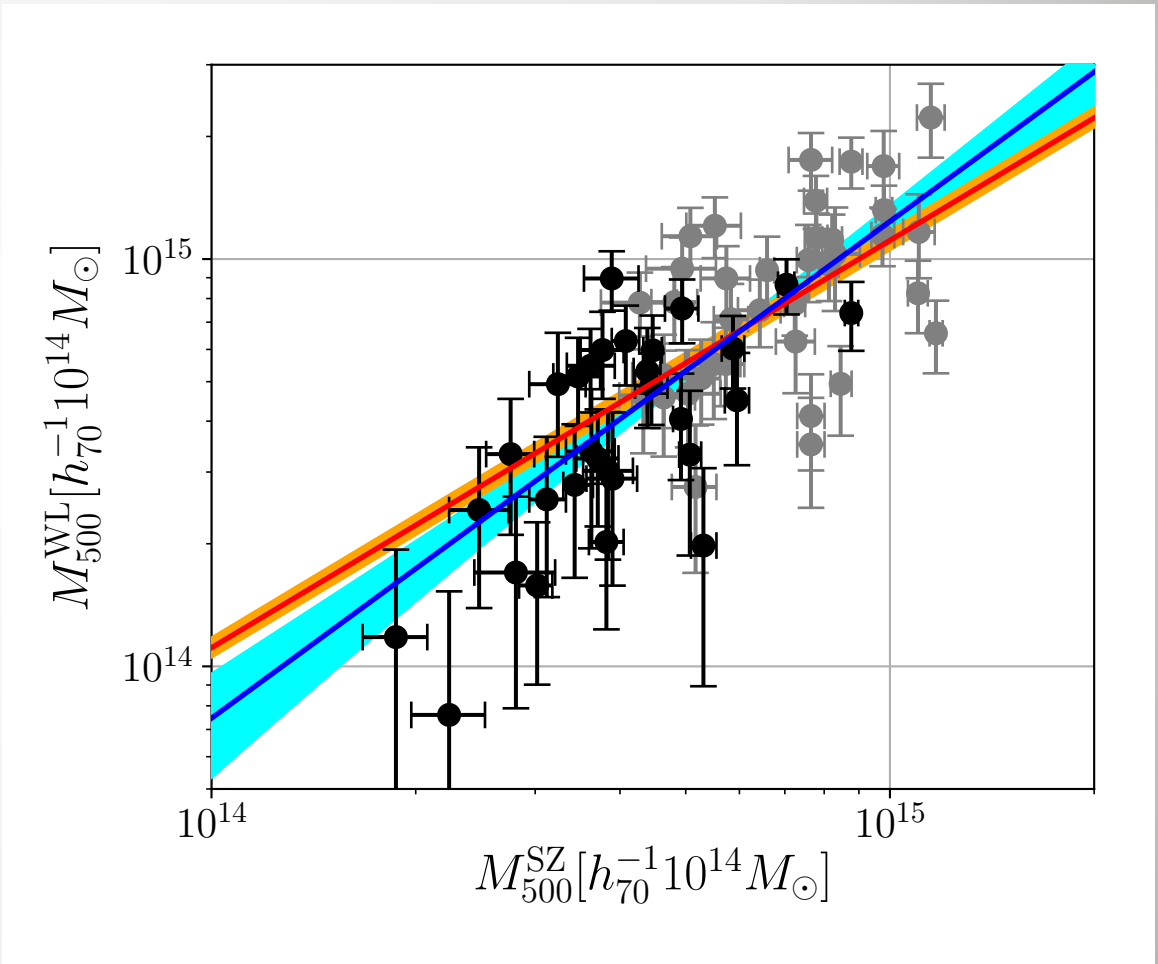
Scaling relation between total mass and *Planck* mass proxy

- **MENeaCS NFW mass**
- **CCCP NFW mass**
- $M_{SZ} = (0.90 \pm 0.05) M_{WL}$
- $M_{SZ} = (0.84 \pm 0.07)(M_{WL})^{(0.82 \pm 0.08)}$

Some clusters have no *Planck* value

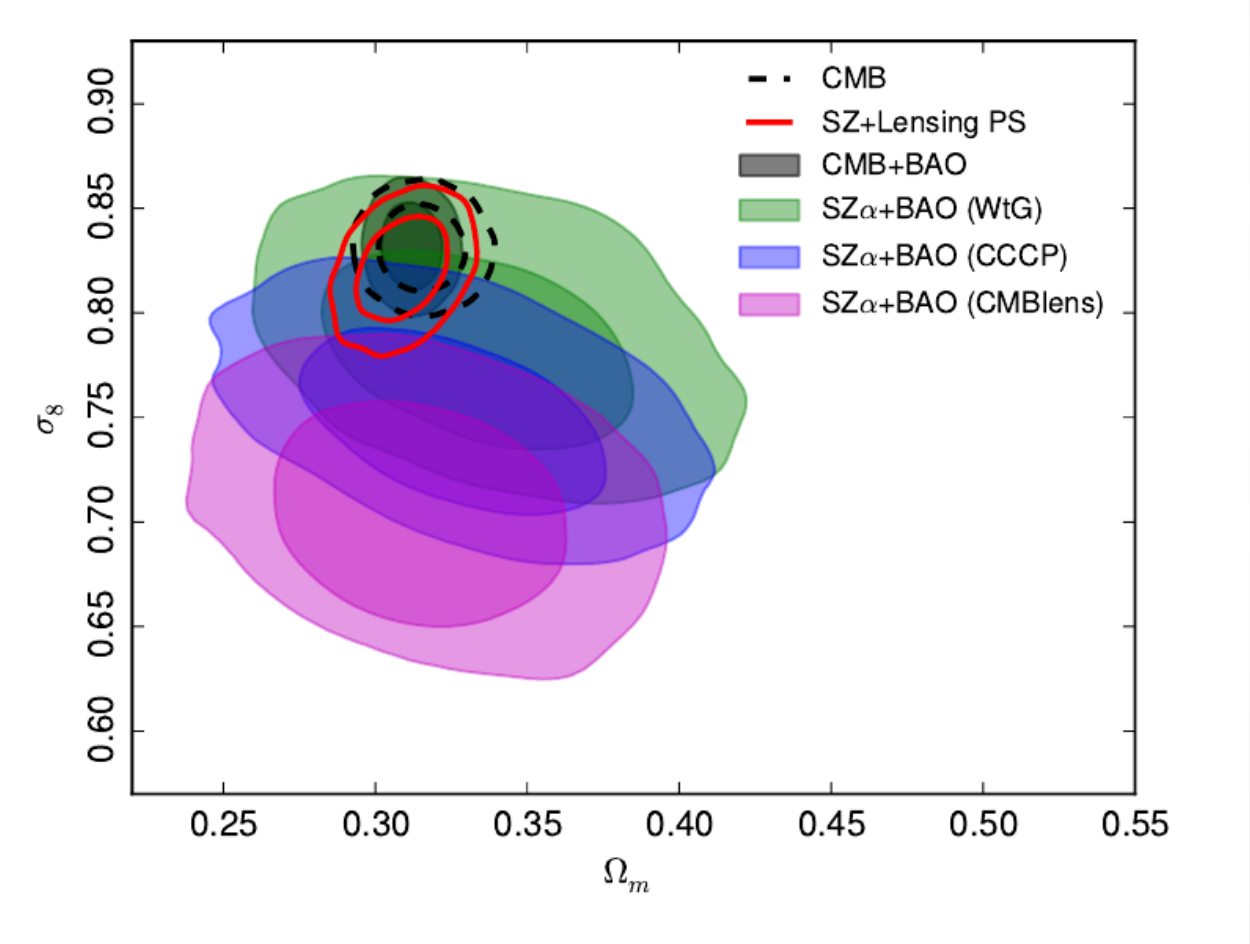
To avoid selection bias Jean-Baptiste Melin will measure the SZ signal for these clusters

Use same radius for both measurements



PRELIMINARY

Cluster count cosmology



Planck collaboration XXIV 2016

MENeaCS + CCCP provides large mass range to test mass dependence of scaling relation

Mass dependent scaling relation may explain the offsets of the CCCP and WtG contours

Von der Linden et al. 2014

Hoekstra, Herbonnet et al. 2015

Weak gravitational lensing of galaxy clusters

Challenges

- Shear measurement
  ~2% uncertainty
- Redshift distribution
  ~2% uncertainty
- Contamination
  ~2% uncertainty
- Mass determination
  …

MENeaCS + CCCP

Great sample to constrain scaling relations

Lensing analyses with single filter observations are possible

Mass dependent scaling relation may provide concordance with Planck???