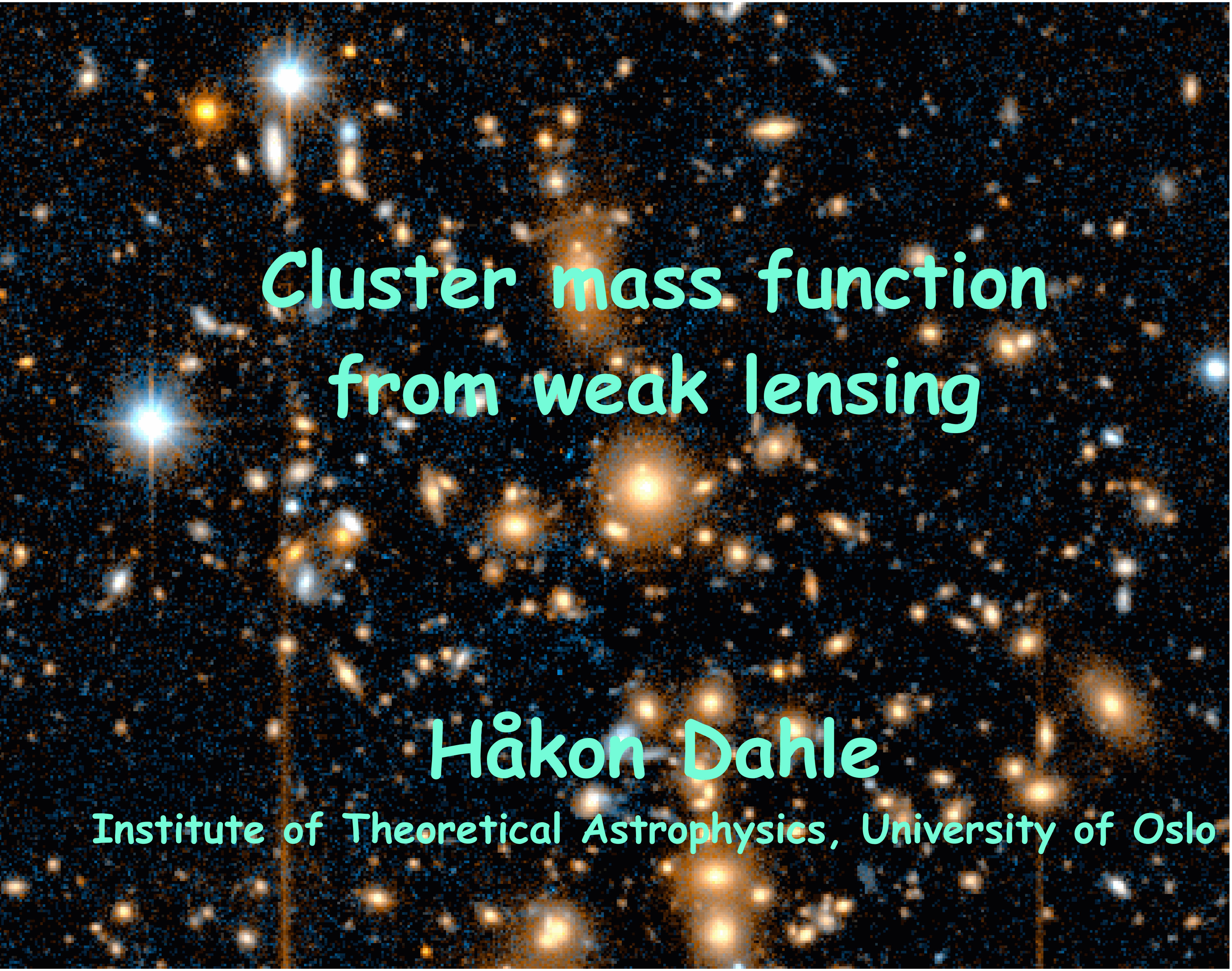

Cluster mass function from weak lensing

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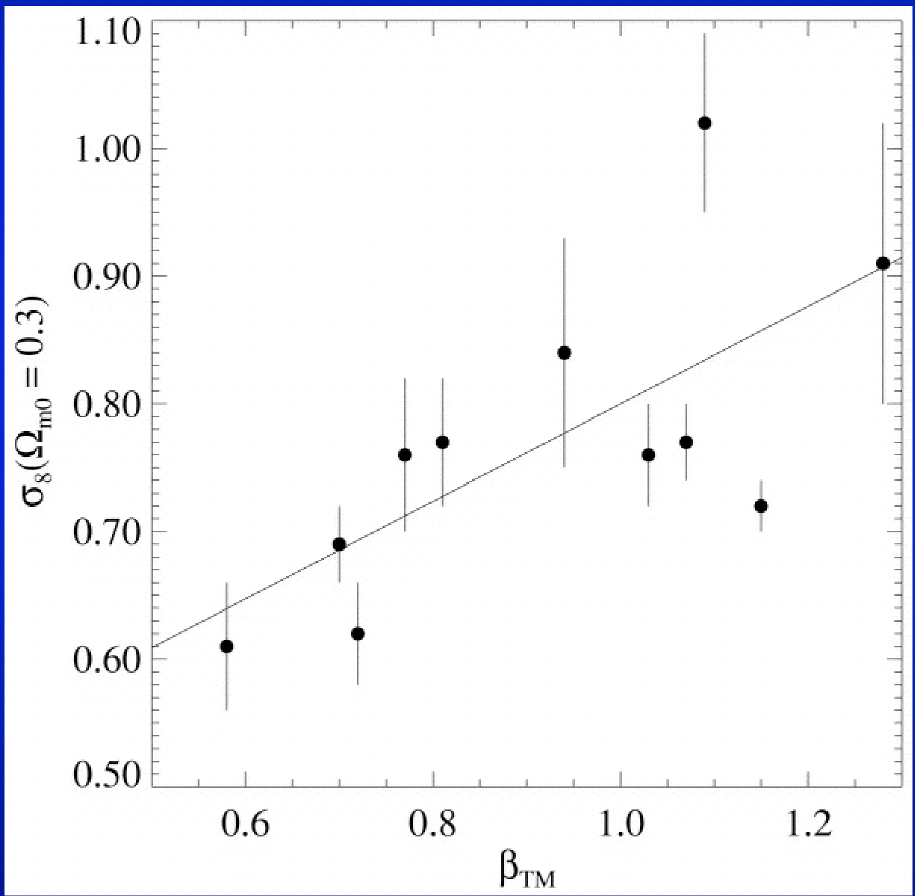
Motivation

- Current studies commonly use the X-ray temperature function (XTF) or the X-ray Luminosity function (XLF) to constrain MF
- Normalization (and scatter!) of M-T_x or M-L_x relation should be determined
- Recent efforts to calibrate M-T_x via lensing (G. Smith et al. 2003, 2004)
- Here (for the first time!) we derive MF from lensing directly (i.e., not via XLF or XTF)
- X-ray data only enter through the cluster sample selection. "Bigger is better" (H. Ebeling)

Constraints from XTF: Dependency on the normalization of the mass-temperature relation.



$$kT = \frac{7.98\text{keV}}{\beta_{TM}} \left[\frac{\Omega_{m0}\Delta(\Omega_{m0}, \Omega_{\Lambda 0}, w, z_{\text{vir}})}{18\pi^2}\right] (hM_{15})^{2/3}(1+z_{\text{vir}})$$

$\beta_{TM} = 1.03 \pm 0.04$ (from simulations)
$\beta_{TM} = 0.72 \pm 0.04$ (from observations)
Δ is ratio of average density of the cluster to the background density

Determinations of σ_8 from cluster abundances in the recent literature (assuming $\Omega_{m0} = 0.3$ concordance model)

(Henry 2004, ApJ, 609, 603).

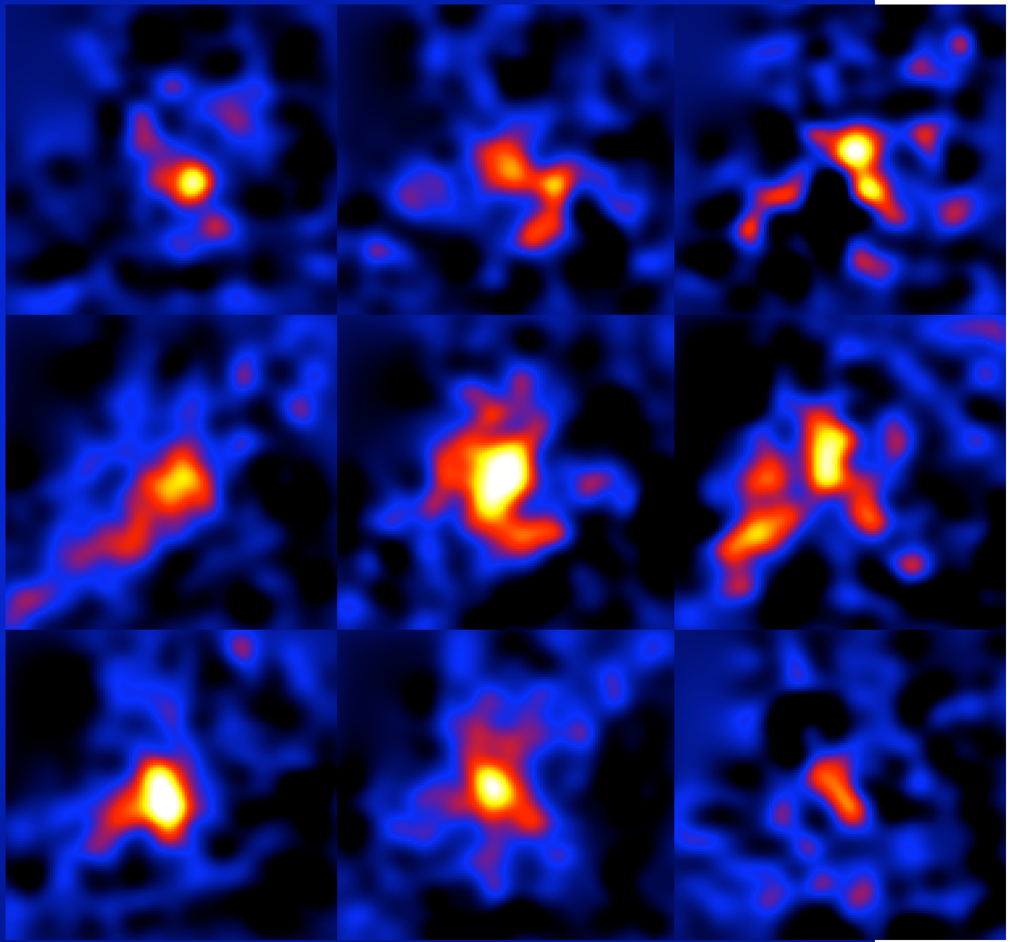
Weak lensing survey of X-ray luminous clusters

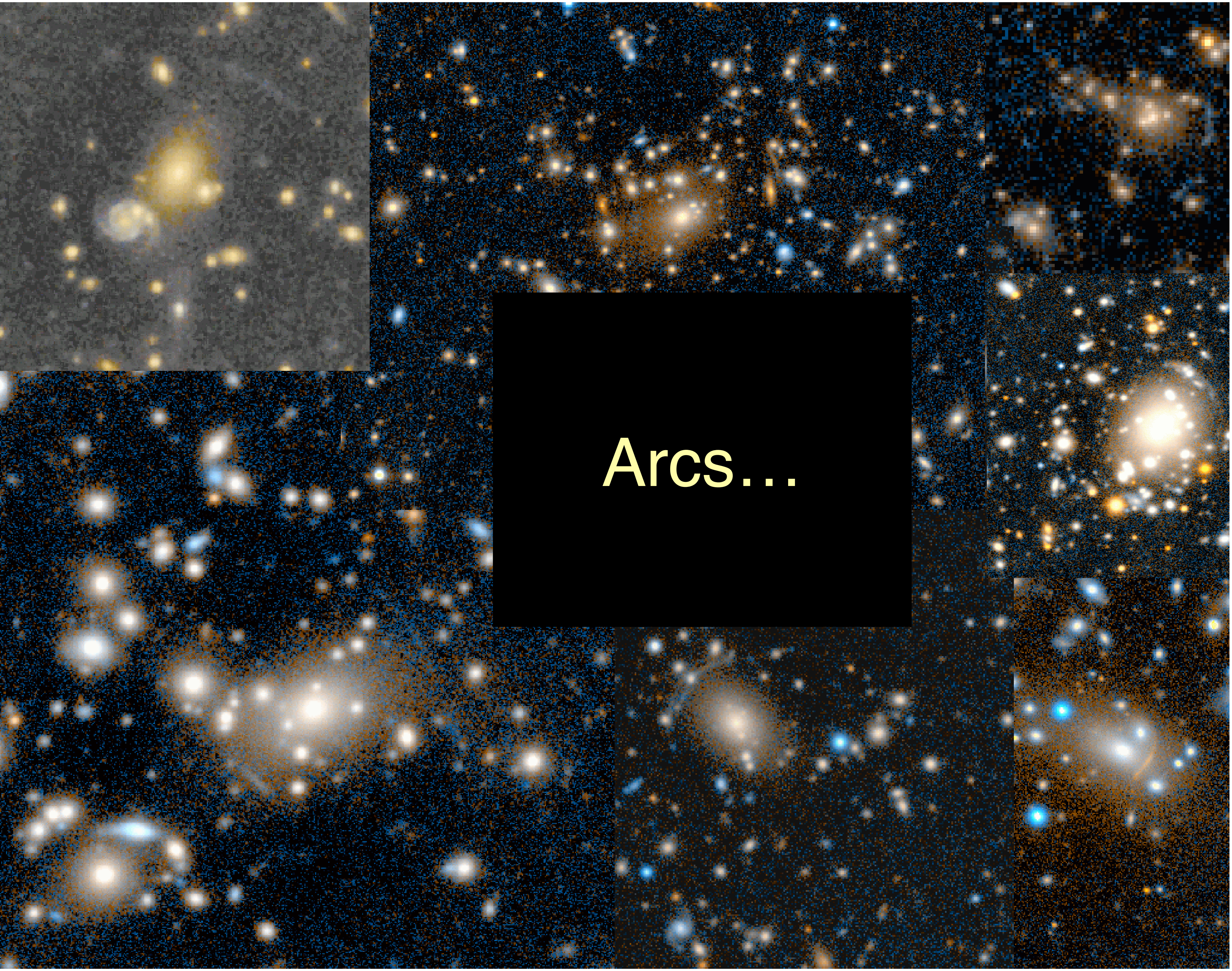
- Initial data set: 38 clusters Dahle et al. 2002
- Current data set: 53 clusters
- From RASS-based samples of X-ray luminous clusters ($L_X > 1.2\times10^{45}\ h_{50}^{-2}$ erg/s)
  Ebeling et al. 1996,1998,2000; Boehringer et al. 2000; Briel & Henry 1993
- Volume-limited sub-sample of 35 (e)BCS clusters ($0.1<z<0.3$, $\delta > 0^o$, $|b| > 20^o$)
- NOT and UH 2.24m V+I-band imaging:

2k CCDs (f.o.v.~1 h^{-1} Mpc) or UH8K mosaic (f.o.v.~3 h^{-1} Mpc)

Weak lensing cluster survey UH2.2m + 2.56m NOT

(Initial sample: Dahle et al.2002 ApJS,139,313)




Arcs…

M_{180} estimate from lensing

Observable: reduced shear

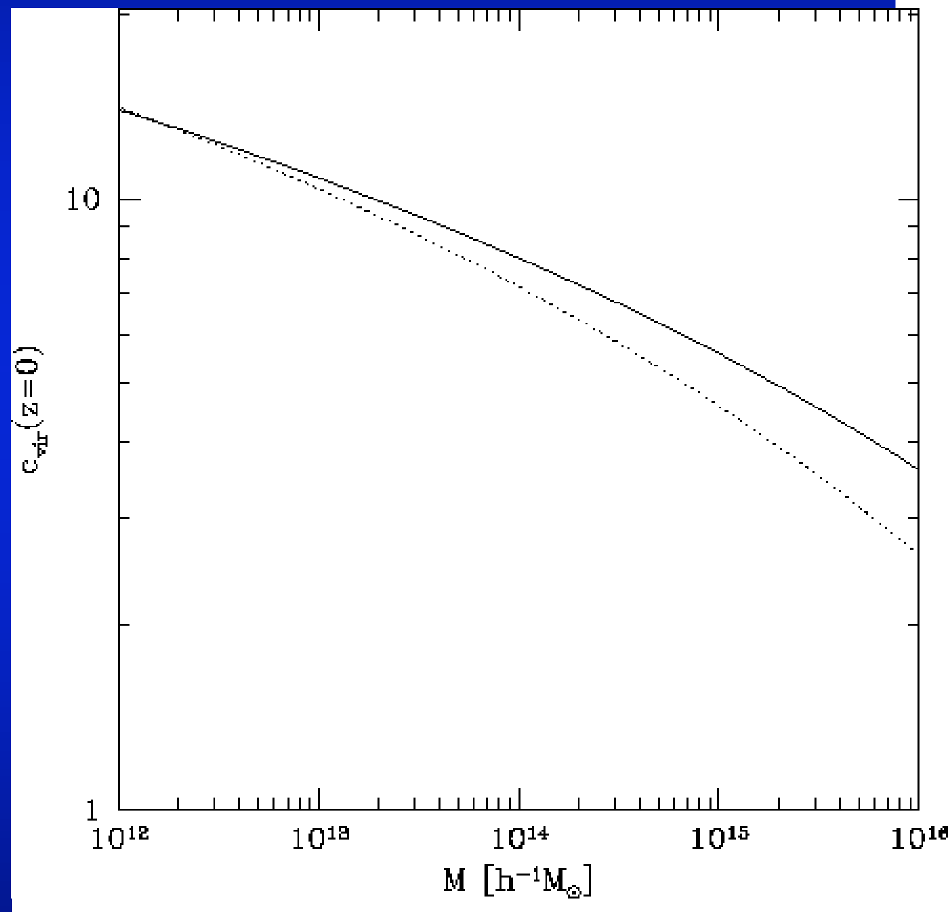
$$g_T = \gamma_T/(1-\kappa),$$

averaged in radial bins

Fit to NFW profile with concentration parameter predicted by Bullock et al. (2001)

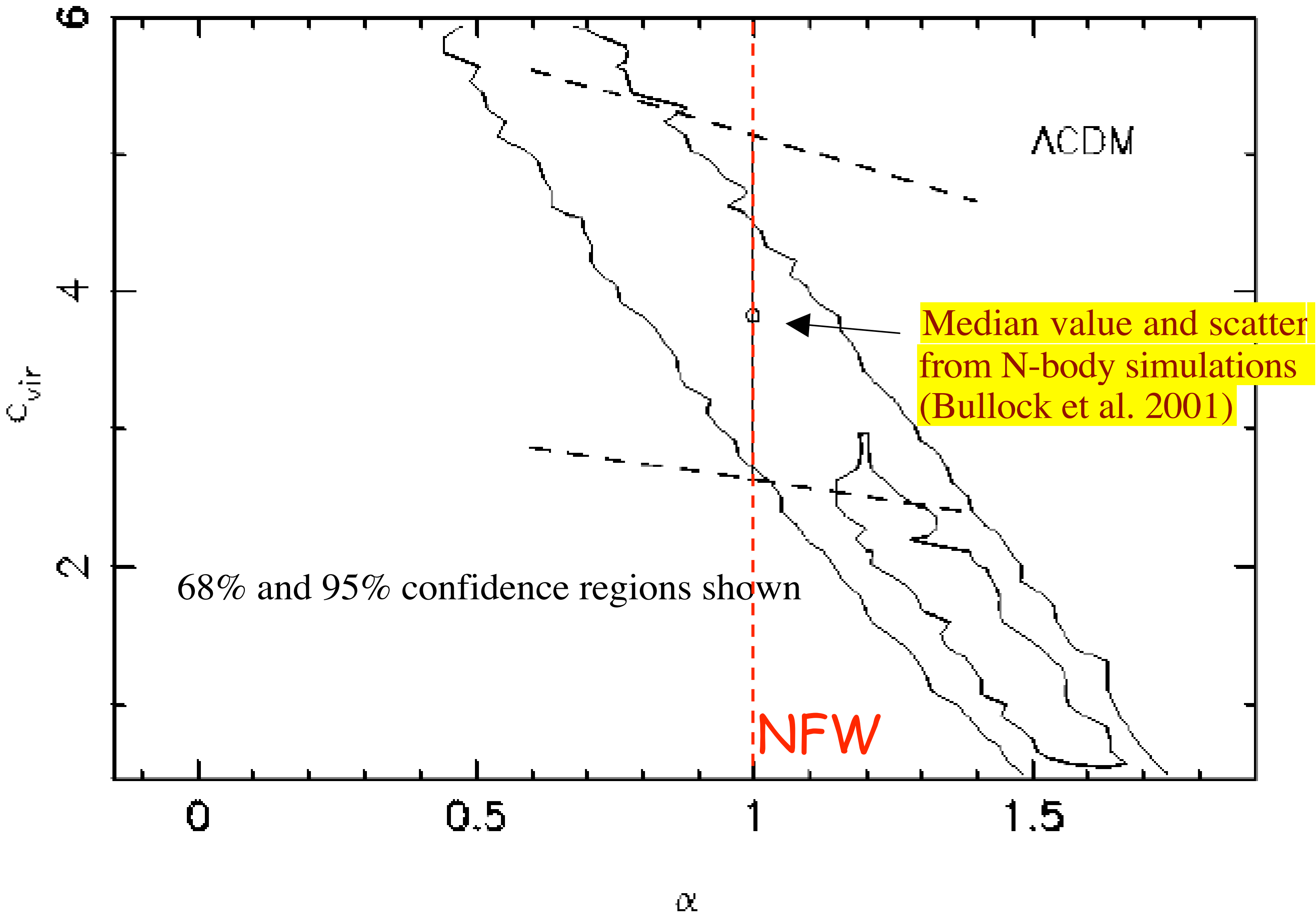
$\rightarrow M_{180c}$

Significant extrapolation is required for ~2/3 of the clusters (those not observed with UH8k camera)



Observed mass profile

(average of 6 z~0.3 clusters with wide-field UH8K data)



Dahle, Hannestad & Sommer-Larsen (2003)

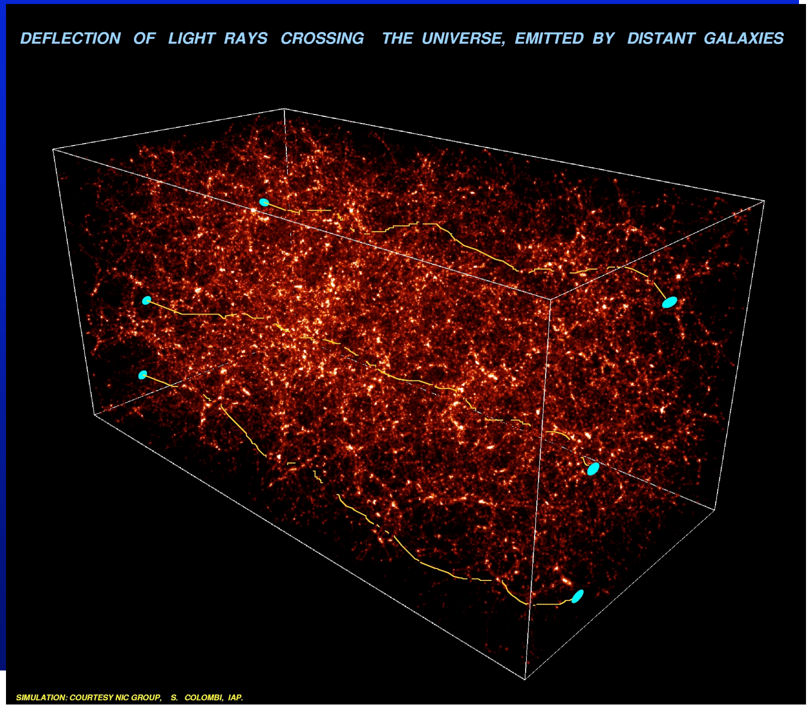
Projection effects

Effect of correlated structures

Metzler, White & Loken (2001) estimate M_{obs}/M_{true} =1.33 for projected mass, dispersion of 0.26 about the mean, tail towards high M_{obs}/M_{true}

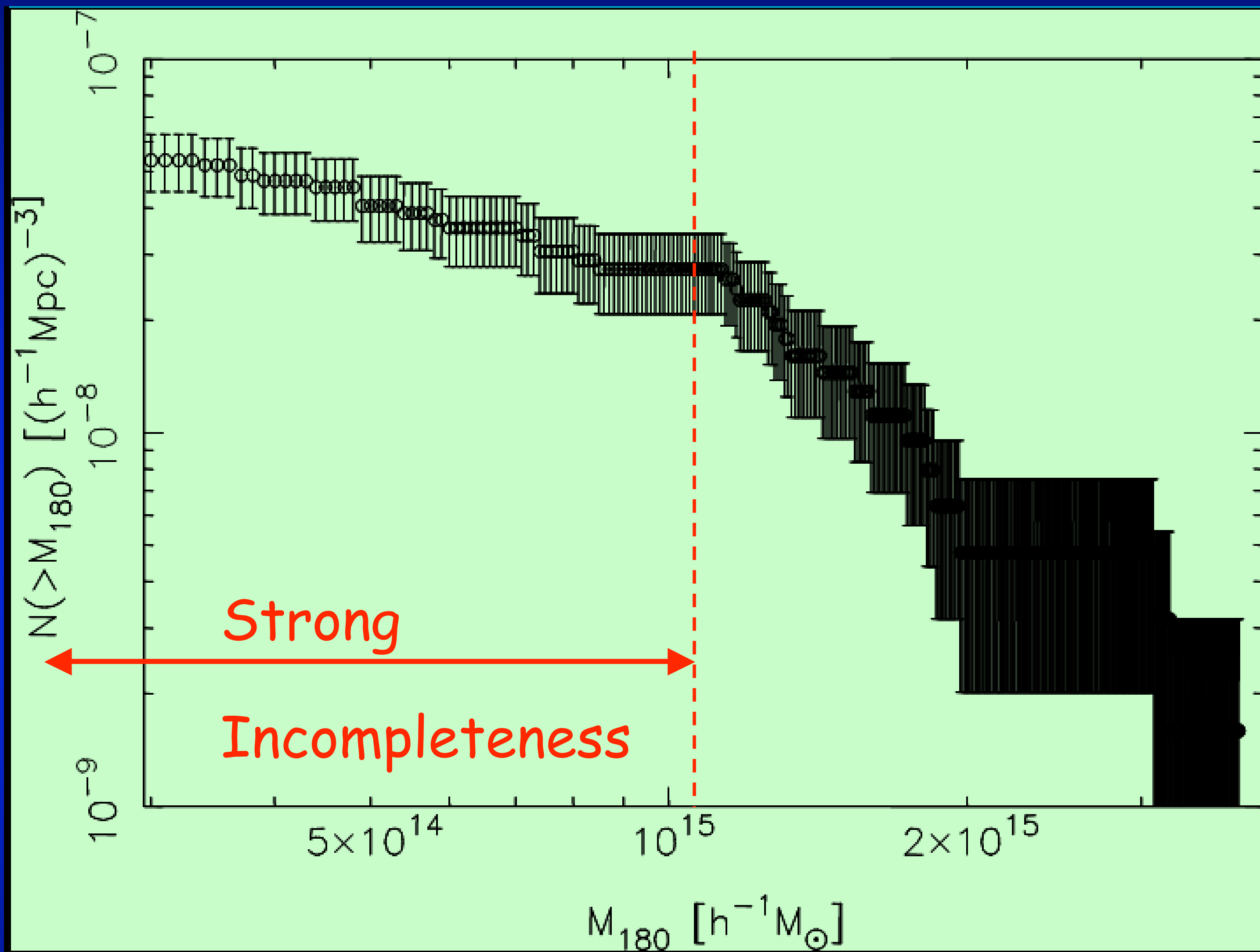
Clowe, De Lucia & King (2004) find no bias when fitting the radial shear profile out to the virial radius

Effect of uncorrelated structures



Foreground and background structures do not produce a net bias, but add $\sim 1.0\times10^{14}\ h^{-1}\ M_{sun}$ to the mass uncertainty

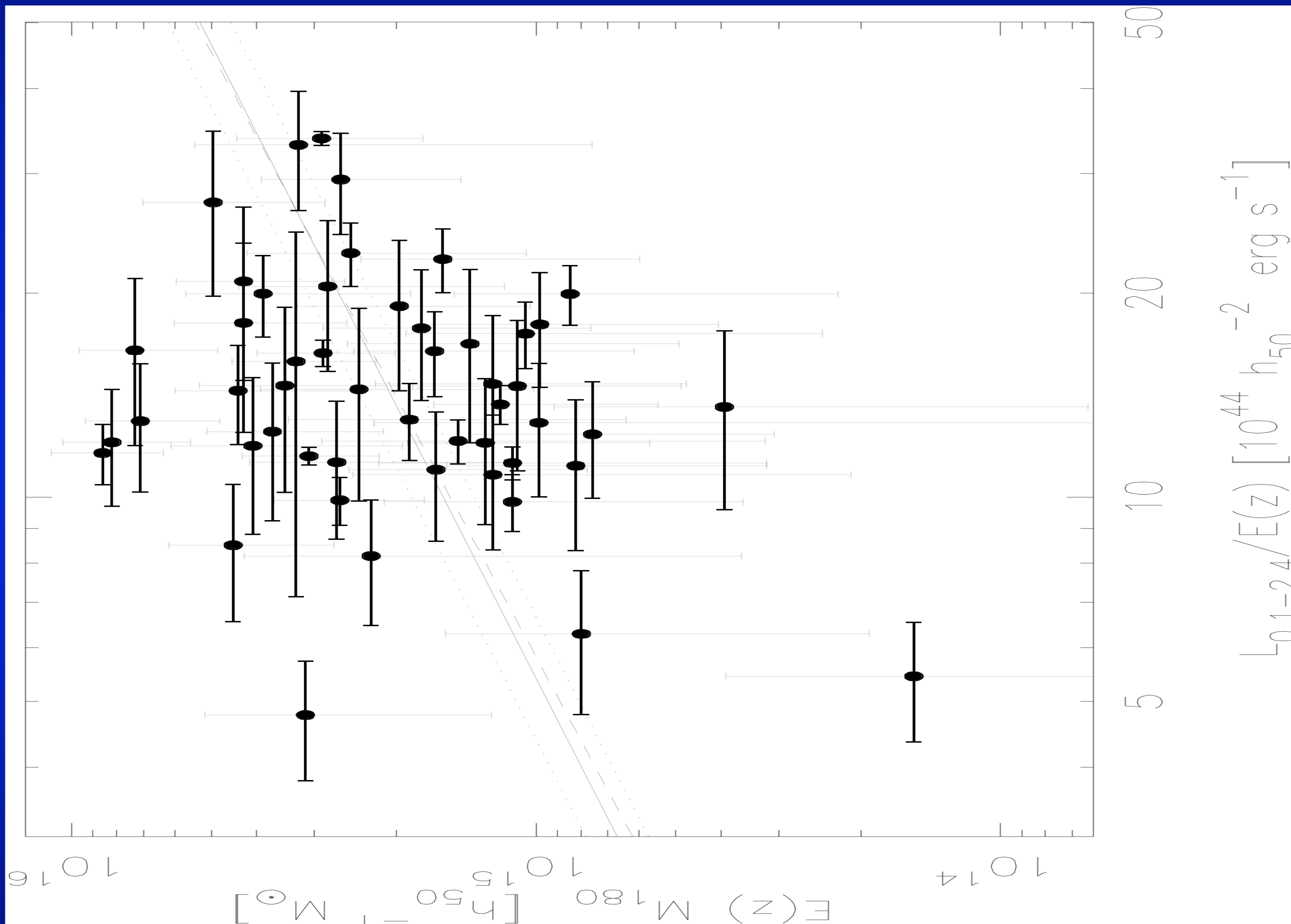
Observed cumulative mass function



L_x cutoff + scatter → soft mass cutoff.

Probablility of including cluster of mass M_{180c} ?

M-L_x normalization and scatter



Weak lensing masses for 50 clusters; L_x values from ROSAT

(Solid: fixed slope; dashed: arbitrary slope)

The mass-luminosity relationship

$$E(z)M_{180} = M_0 \left[\frac{L_X}{E(z)}\right]^\alpha$$

evolution parameter

$$E(z) = (1+z)\sqrt{(1 + z\Omega_m + \Omega_\Lambda/(1+z)^2 - \Omega_\Lambda)}$$

Best fit slope and normalization from 50 clusters with weak lensing masses:

Best fit normalization when fixing slope to theoretical value (α=0.75):

Luminosity cutoff limit $L_X > 1.2\times10^{45}\ h_{50}^{-2}$ erg/s corresponds to mass cutoff

$$M_{180} > 7.45 \times 10^{14} h^{-1} M_\odot$$

Procedure:

Account for selection effects:

- BCS or eBCS completeness estimate
- Probability of including a cluster of intrinsic mass M_{180c}

Only used clusters well above mass cutoff $M_{180c} > 10^{15}\ h^{-1}\ M_{sun}$

Account for observed uncertainties:

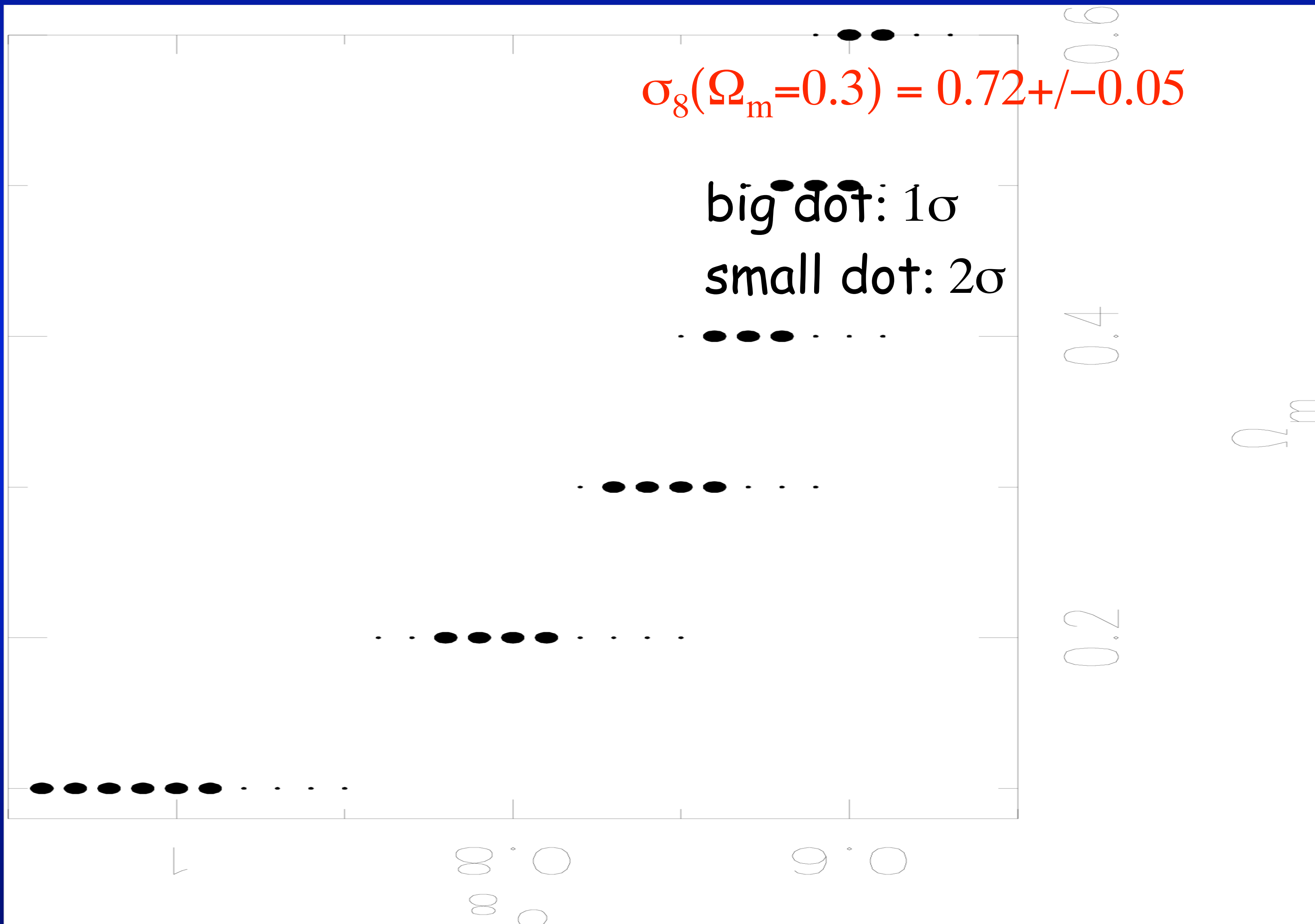
- Convolve theoretical mass function with set of observed uncertaintie
M_{180c}

Contribution to these from 2D projection effects should be better understood w.r.t. bias and scatter

Include errors from cosmic variance

Fit to theoretical mass function

Joint constraints on Ω_m and σ_8



$\sigma_8(\Omega_m\!=\!0.3) = 0.72+/-0.05$

big dot: 1σ

small dot: 2σ

Summary

- First cluster mass function directly from weak lensing

- Avoids the problem with M-T_x calibration

-There are still some systematics to consider,
e.g. projection of structure outside r_{180}.

- We find $\sigma_8(\Omega_m=0.3) = (0.72+/-0.05)$

Future:

Combination with similar cluster sample at higher z
(e.g. from MACS, Donovan/Ebeling/Kaiser) → evolution