Detecting and weighing galaxy clusters with weak lensing

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and

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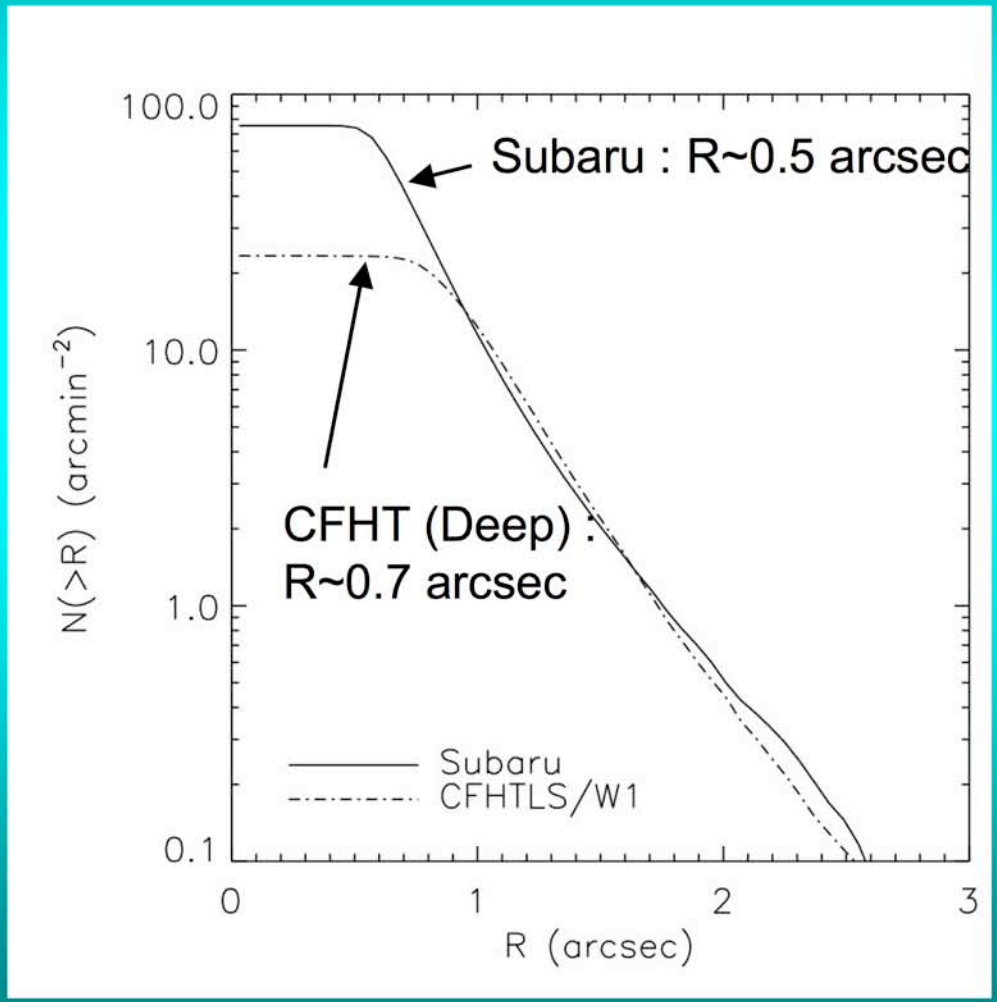
XXL workshop, Paris, April 15, 2008

Weak lensing and mass estimation

- Weak lensing directly probes the mass distribution
- It allows a direct estimation of the mass of galaxy clusters
- Selection function is well defined if systematics are controlled.

Effect of seeing

The bigger the seeing, the smaller the number of useable galaxies

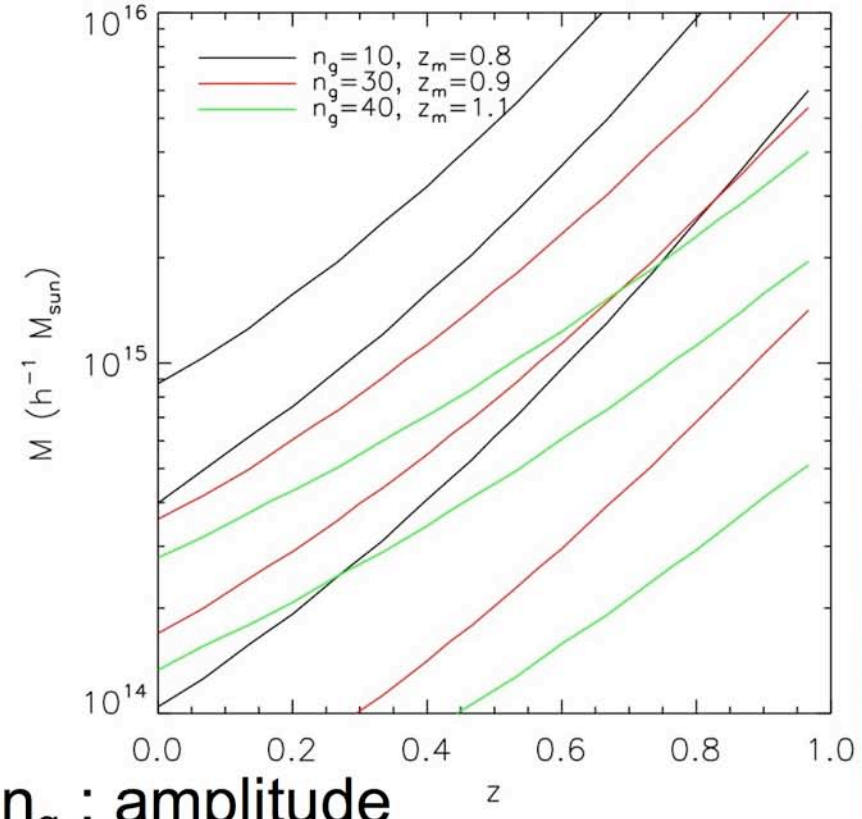


Selection function & halo counts

Berge, Amara & Refregier in prep

Maturi et al 2005

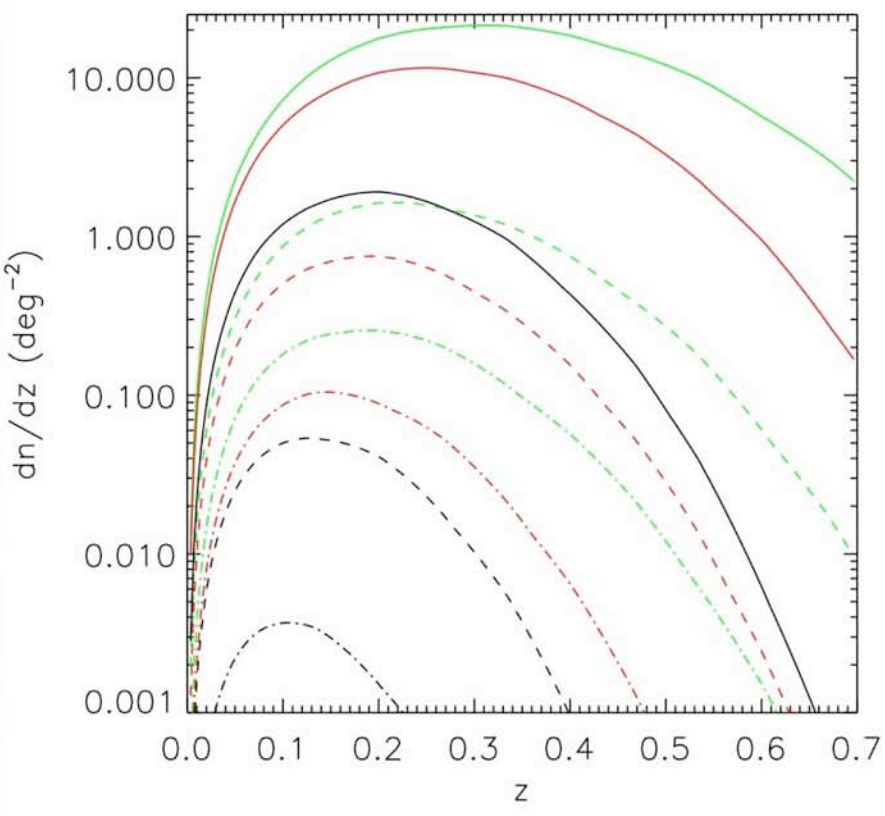
$$\nu = \frac{\sqrt{n_g}}{\sigma_\gamma} \sqrt{\int \mathrm{d}^2x\, \kappa^2(x)}$$



n_g : amplitude

z_m : slope

$$\frac{\mathrm{d}^2N(z,w)}{\mathrm{d}\Omega\, \mathrm{d}z} = \frac{\mathrm{d}^2V_c}{\mathrm{d}\Omega\, \mathrm{d}z} \int_{M_{\mathrm{lim}}(z)}^{\infty} n(M,z,w)\, \mathrm{d}M$$



Combined weak lensing and X-ray in CFHTLS / XMM-LSS

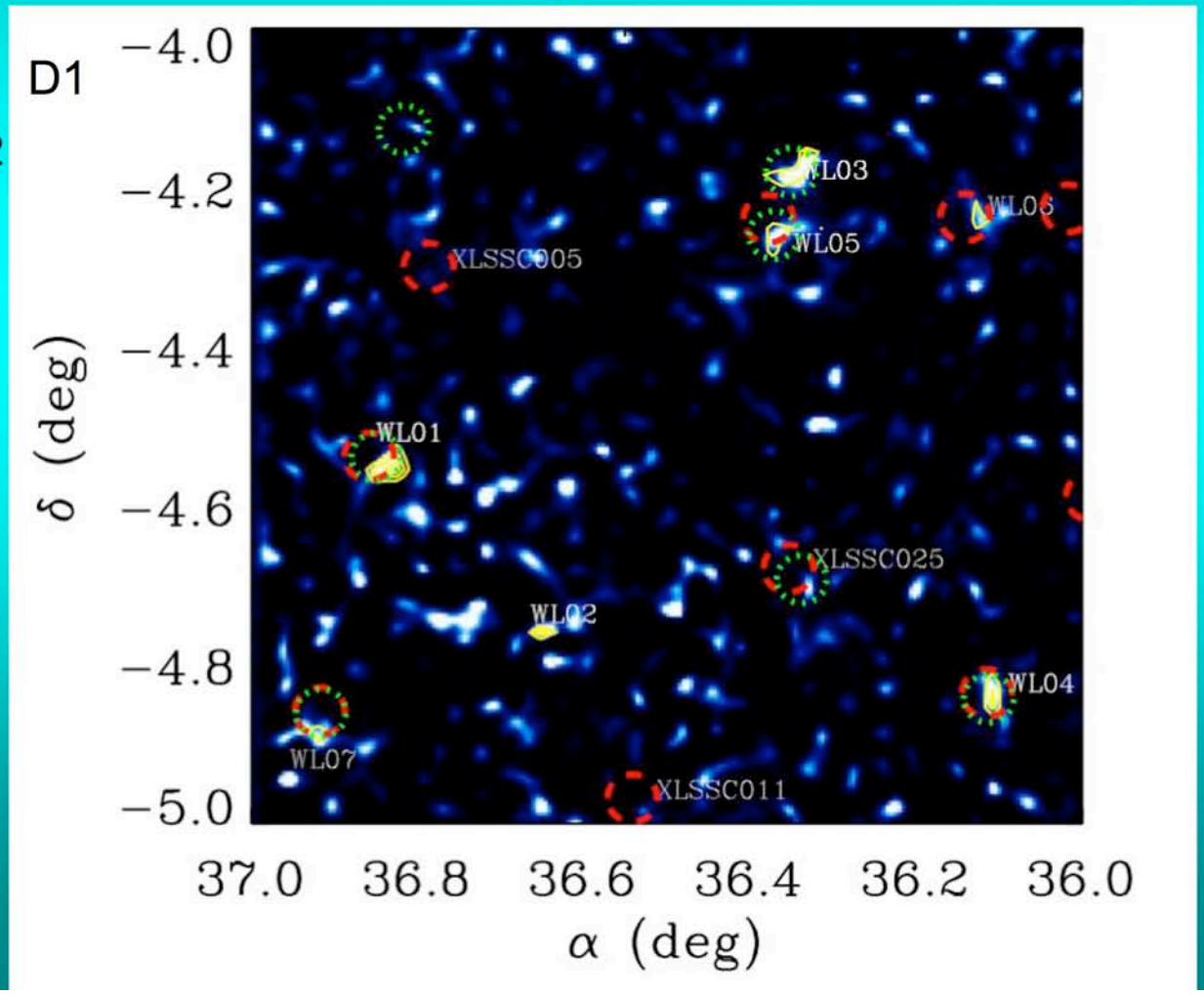
Shapelets detections

X-ray clusters

Gavazzi & Soucail 2007 (KSB)

Bergé et al 2008

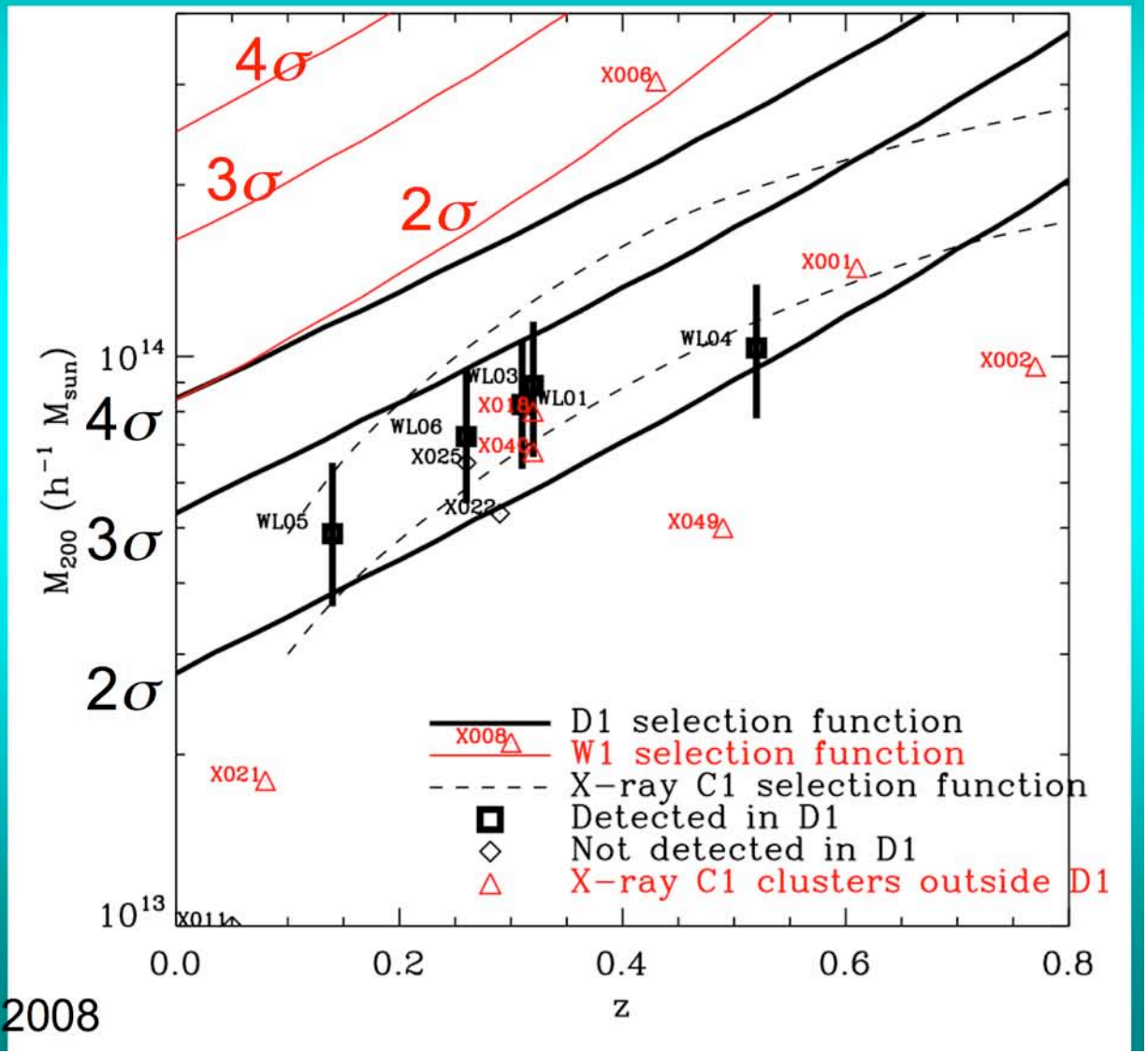
1 deg^2



CFHTLS : selection function

Weak lensing selected clusters : gravitational mass

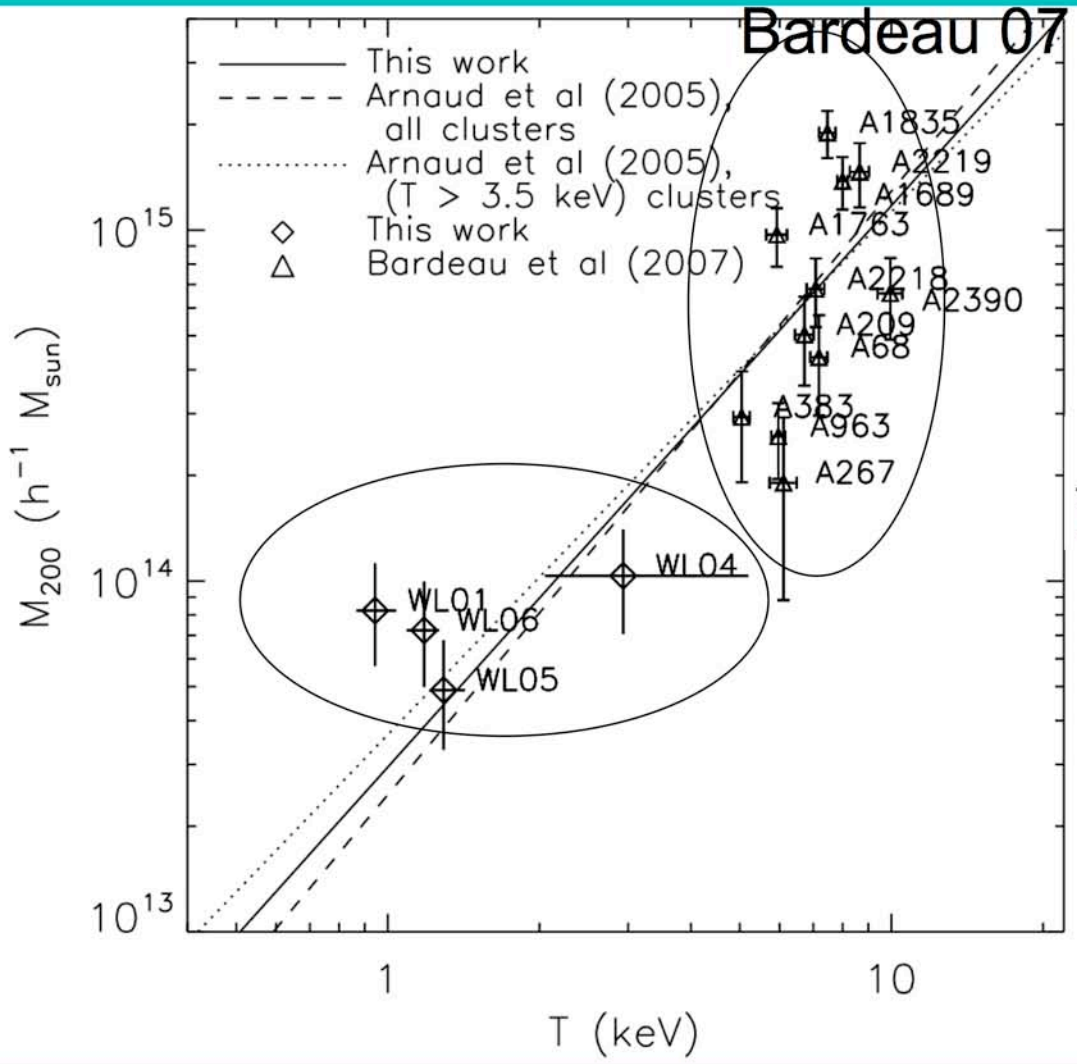
Others : X-ray mass



Bergé et al 2008

Mass-temperature relation

Bergé et al 2008



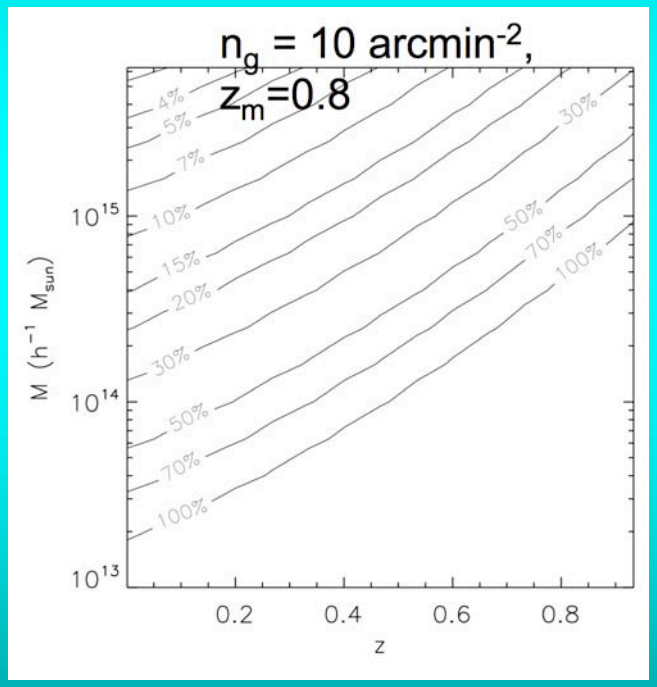
2-parameter fit : slope and normalization

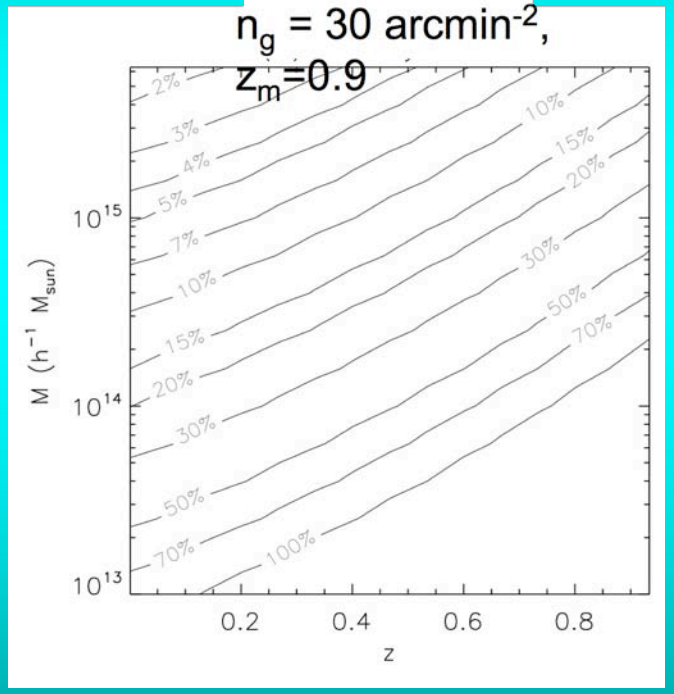
$$\frac{M_{200}}{10^{14}h^{-1}M_{\odot}} = 2{,}71^{+0{,}79}_{-0{,}61}\left(\frac{T}{4\ \mathrm{keV}}\right)^{1{,}60\pm0{,}4}$$

Weighing galaxy clusters

Mass measurement error

$$\Delta M/M = 1/\nu$$





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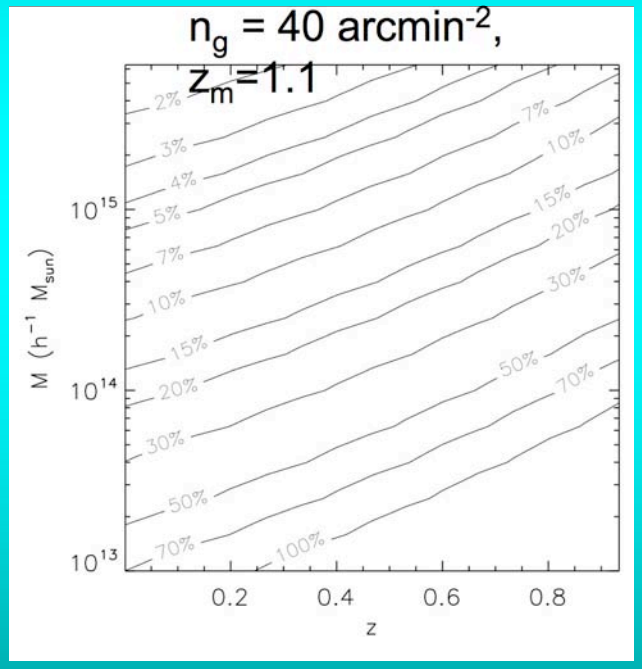

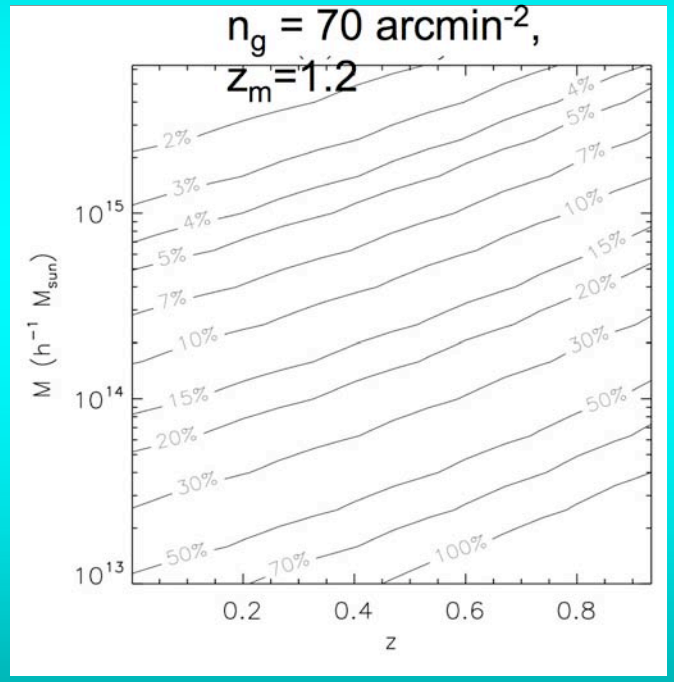

Weighing galaxy clusters

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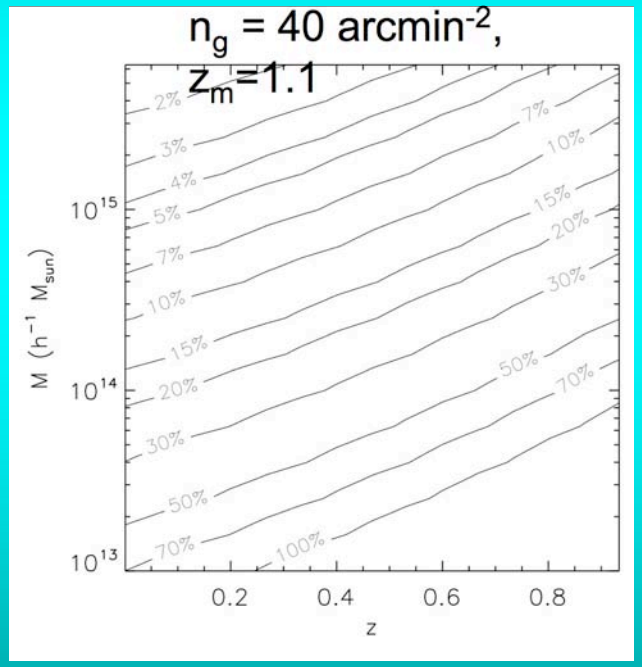
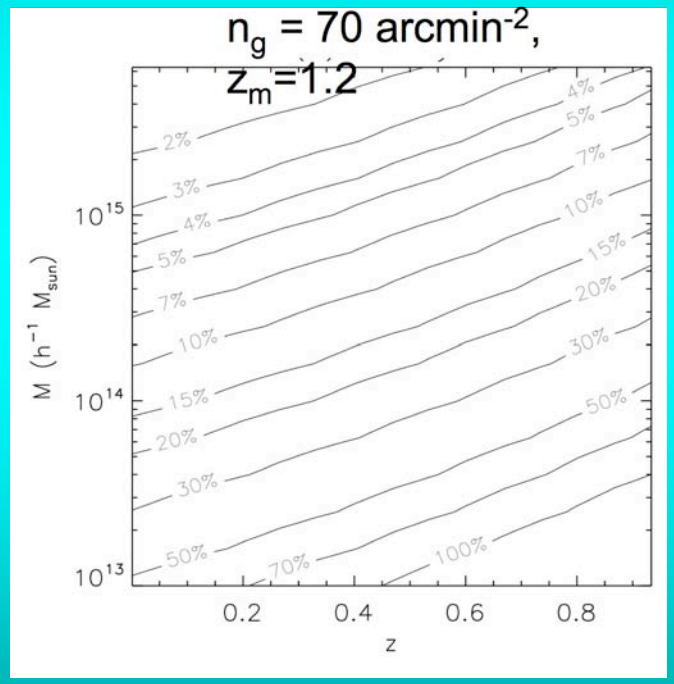


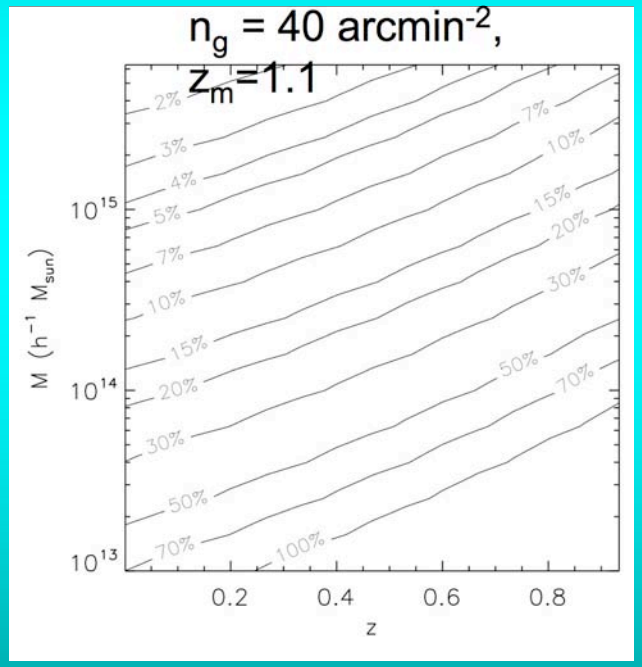


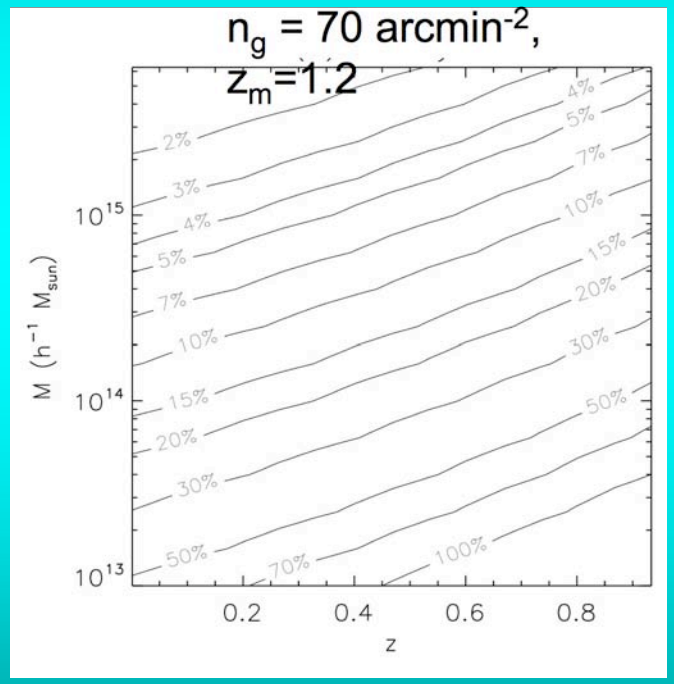
$\Delta M/M$ ~> 25% for best surveys (M~5 10^{14} h^{-1} M_{sun})

Weighing galaxy clusters

Mass measurement error

$\Delta M/M = 1/\nu$





$\Delta M/M$ ~> 25% for best surveys (M~5 10^{14} h^{-1} M_{sun}) →

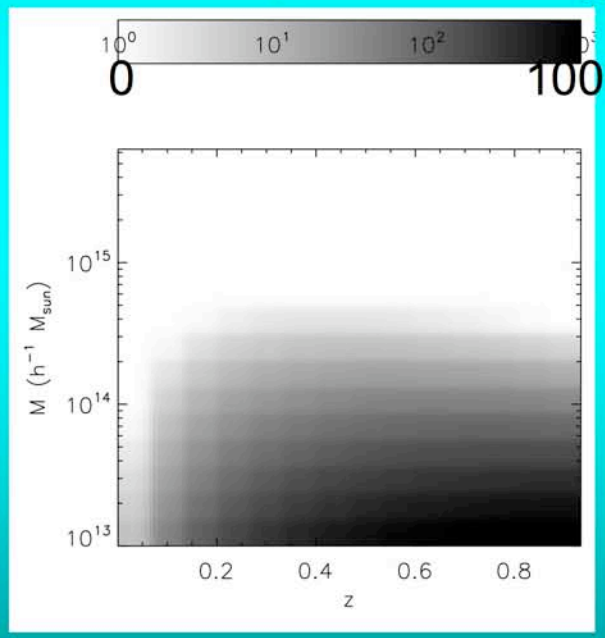
Stack similar clusters

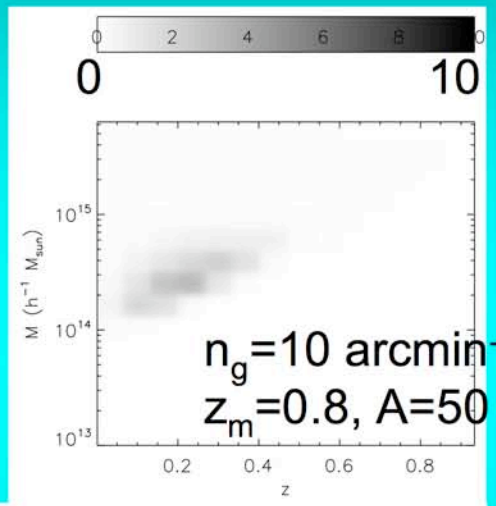
$\Delta M/M_{stack}$ ~ 1/sqrt(N) $\Delta M/M_{ind}$

Stacking clusters (I)

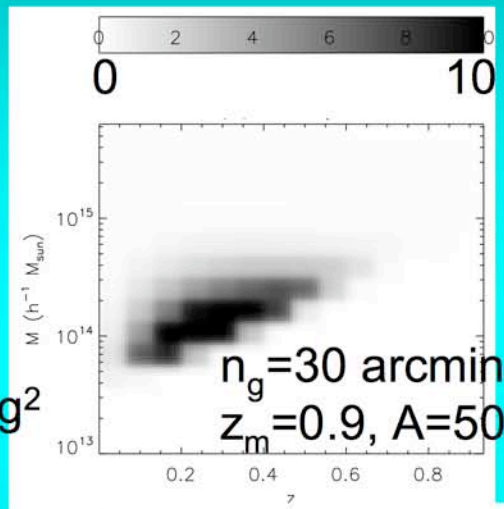
Absolute number of clusters that can be detected

All clusters, $M>10^{13}\ h^{-1}\ M_{sun}$

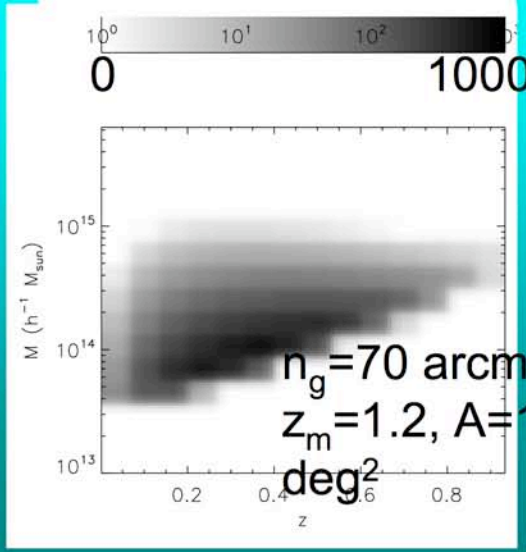




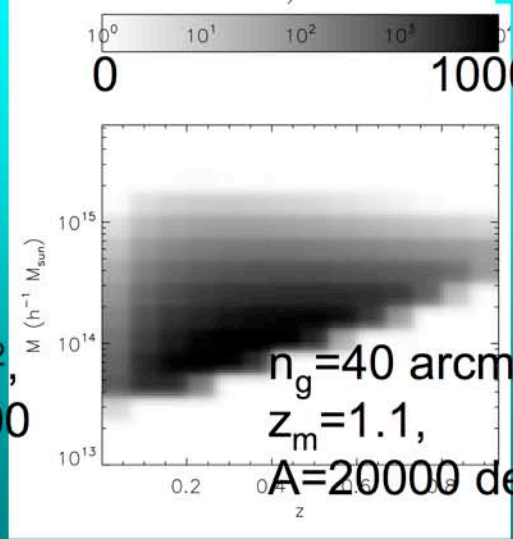
$n_g=10$ arcmin^{-2}, $z_m=0.8$, A=50 deg^2



$n_g=30$ arcmin^{-2}, $z_m=0.9$, A=50 deg^2



$n_g=70$ arcmin^{-2}, $z_m=1.2$, A=1000 deg^2

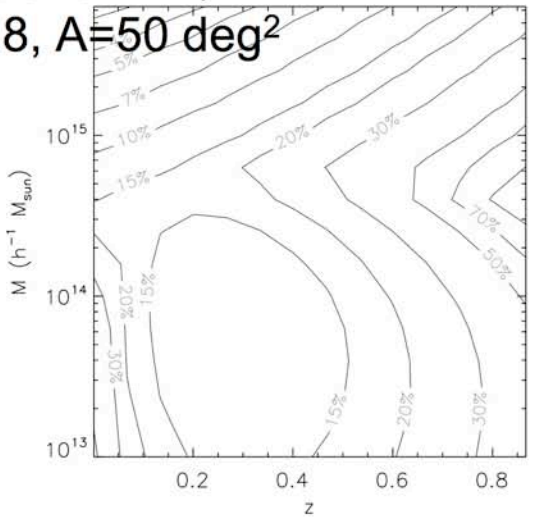


$n_g=40$ arcmin^{-2}, $z_m=1.1$, A=20000 deg^2

Stacking clusters (II)

Mass measurement errors

n_g=10 arcmin^{-2},
z_m=0.8, A=50 deg^2



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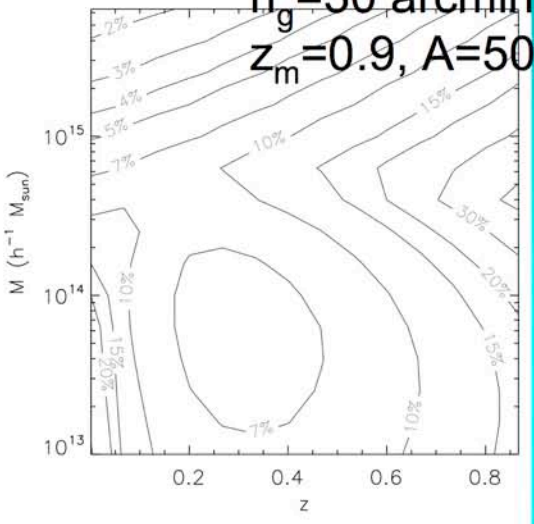

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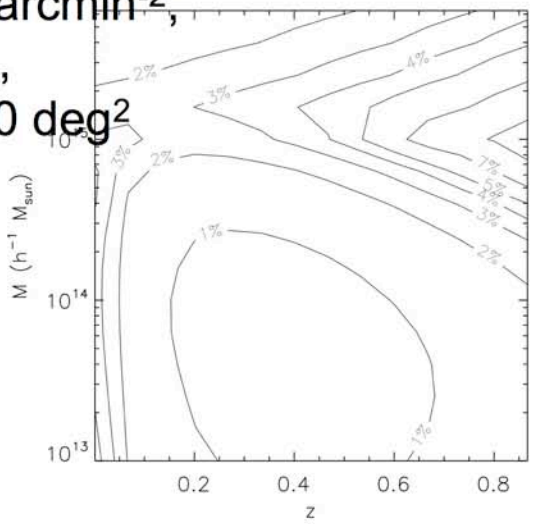

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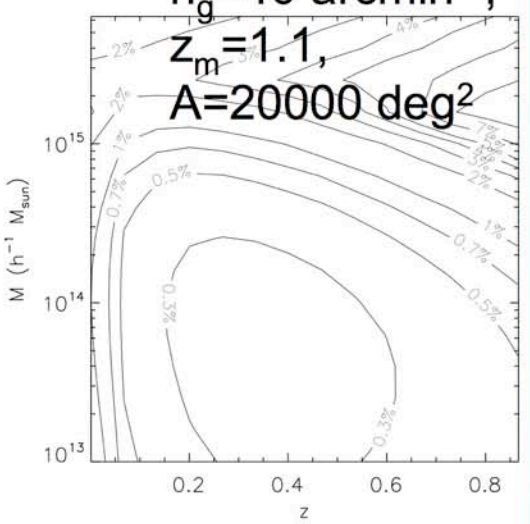


Galaxy clusters can be weighed at the 1% level

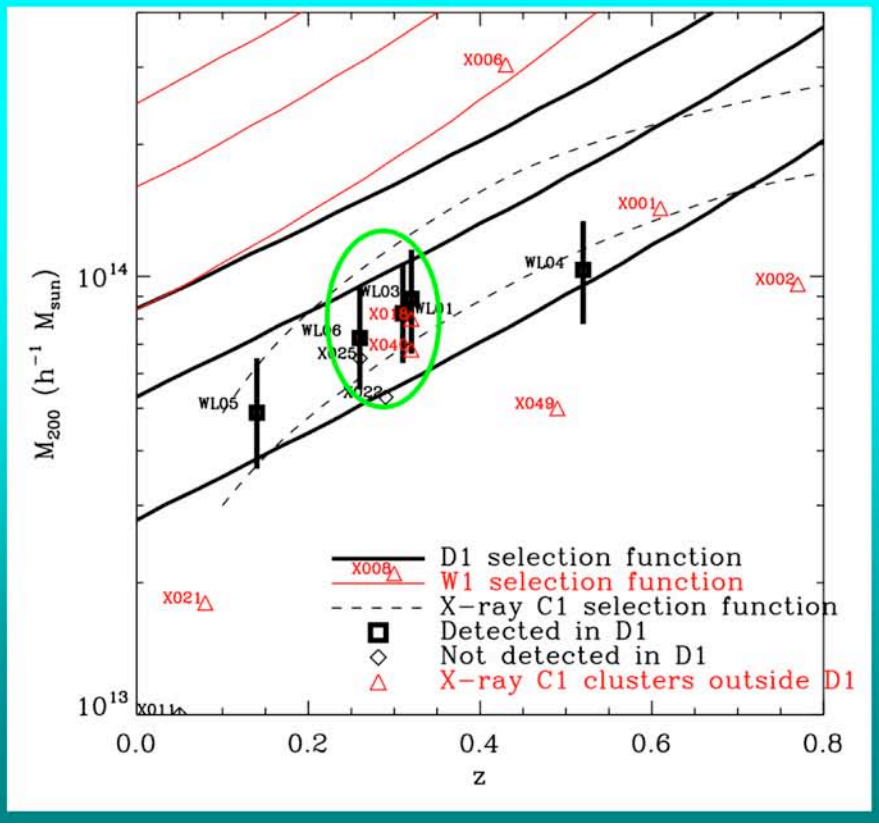
Need large surveys (some 1000 deg^2)

XXL-like survey (100 deg^2) : $\Delta M/M$~4-5%

Stack of galaxy clusters in CFTHLS Wide / XMM-LSS fields

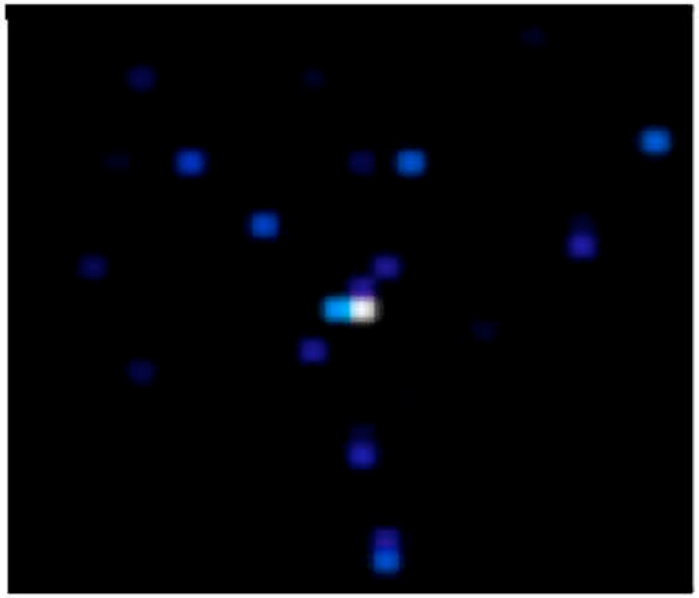
Berge et al in prep

Stack WL signal of 6 X-ray clusters, none of them detectable by itself with WL, all in a narrow (z,T) bin, 0.2<z<0.4, 0.5 keV<T<2 kev, in 4 deg^2

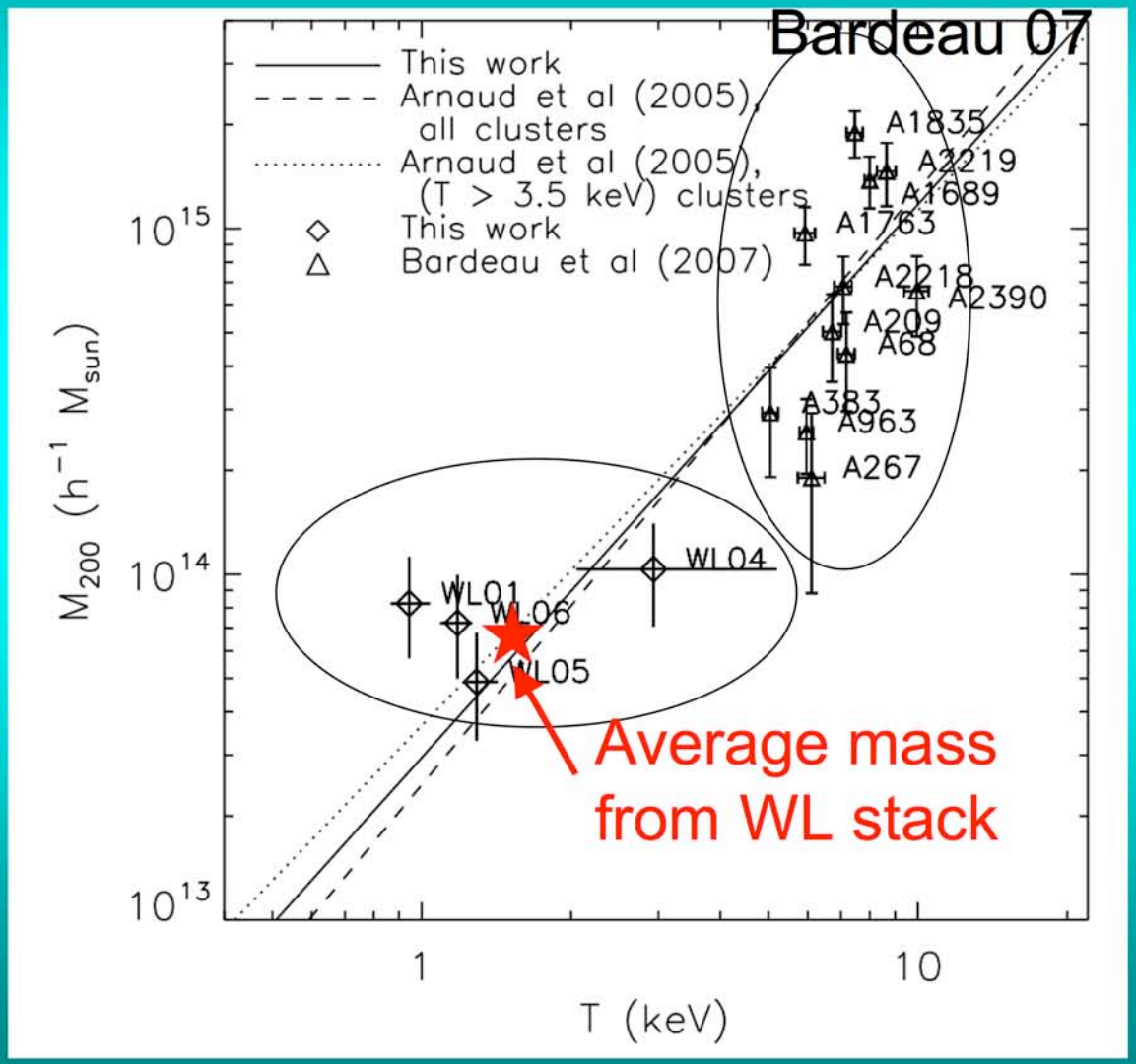


Preliminary

Stack: S/N map (0.2x0.2 deg^2)



Mass-temperature relation



Conclusions

- Importance of seeing to optimize number of useable galaxies : should be ~< 0.5 arcsec
- Weak lensing allows us to weigh individual clusters at a mass precision about 10% (but only most massive)
- Stack :
  - lowers mass measurement errors by sqrt(N)
  - provide accurate characterization of halo profile (SDSS: Johnston et al 2008)
  - stack CFHTLS weak lensing signal of XMM-LSS clusters, allows us to probe more distant clusters than SDSS
- Future space based surveys (A>1000 deg^2): $\Delta M/M$ ~1%

Stack of galaxy clusters in CFTHLS Wide / XMM-LSS fields

Preliminary

Berge et al in prep

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