# Dark Energy from Clusters

Volume element $V(z)$

Growth factor $D(z)$

Sky counts $$\frac{dN(M,z)}{dz} = n(M,z)\frac{dV(z)}{dz}$$

Spatial clustering $\xi_{hh}(r) = b^2(M,z)\xi_{\rho\rho}(r)$

## model framework

- halo characterization from simulations

  space density : $dn(M,z)/d\ln M$ (±10% in number)

  clustering : $\xi(r|M,z)$ (±20% in large-scale bias)

  internal structure: $\rho_x(r|M,z)$, $T_{gas}(r|M,z)$, $\sigma_{gal}(r|M,z)$ (?)

  form of scaling relations : $p(y_{SZ}, N_{gal}, \ldots | M,z)$ (?)

- predictions for specific world model require

  – observable–mass relation

$$g(\boldsymbol{O}_{\rm int} | M, z) \quad ; \quad \boldsymbol{O}_{\rm int} = [\, y_{SZ}, N_{gal}, L_X, T_X, \ldots \,]$$

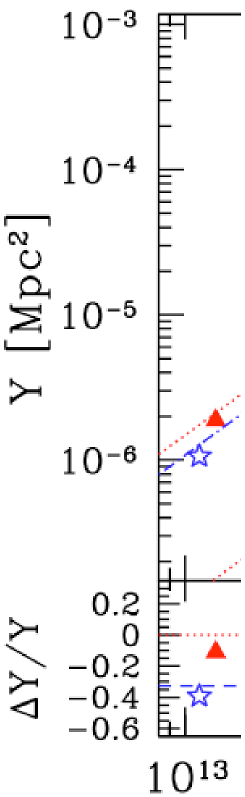
  – effects of sky projection

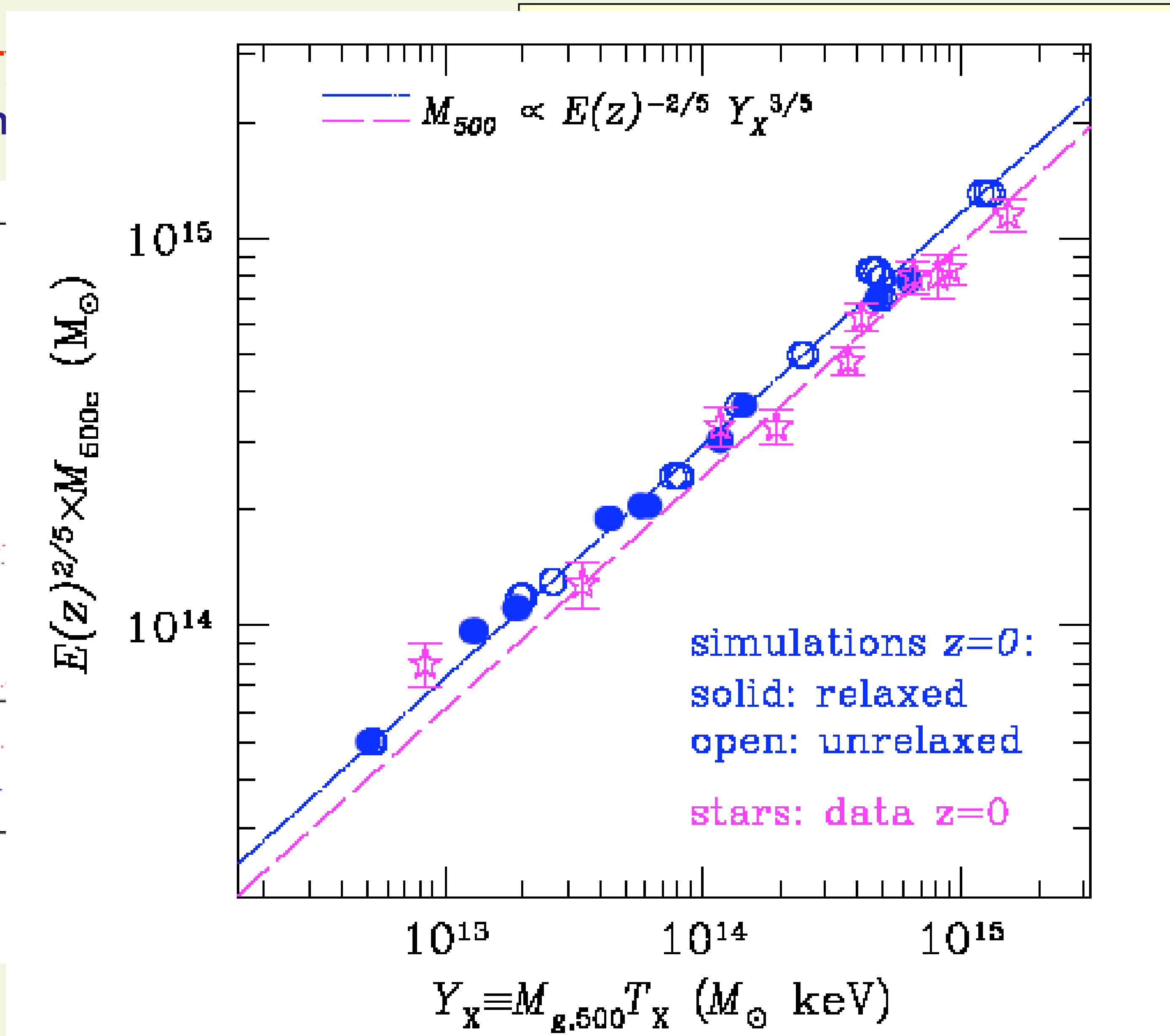
$$p(\boldsymbol{O}_{\rm obs} \,|\, \boldsymbol{O}_{\rm int})$$

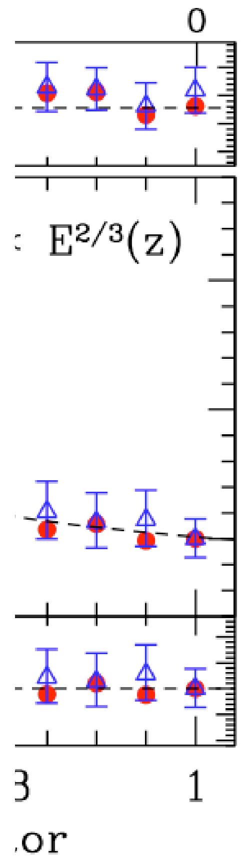
# ART simulations of integration thermal SZ effect

gravit
coolin

s (±12%)




Kravtsov,

# expected counts in thermal SZ

$$\frac{d^2N(z)}{dz\,d\Omega} = \frac{c}{H(z)} D_A^2 (1+z)^2 \int_{O_{min}}^{\infty} f(O,z)\,dO \int_0^{\infty} g(O|M,z) \frac{dn(z)}{dM} dM$$

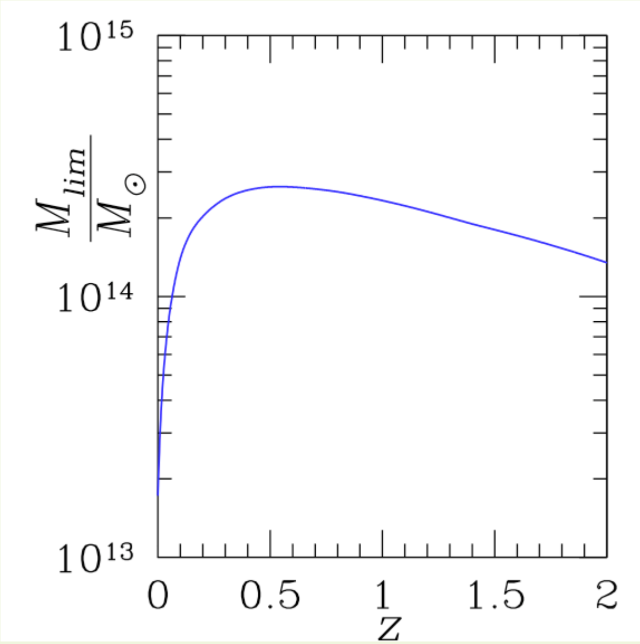
Assumptions:

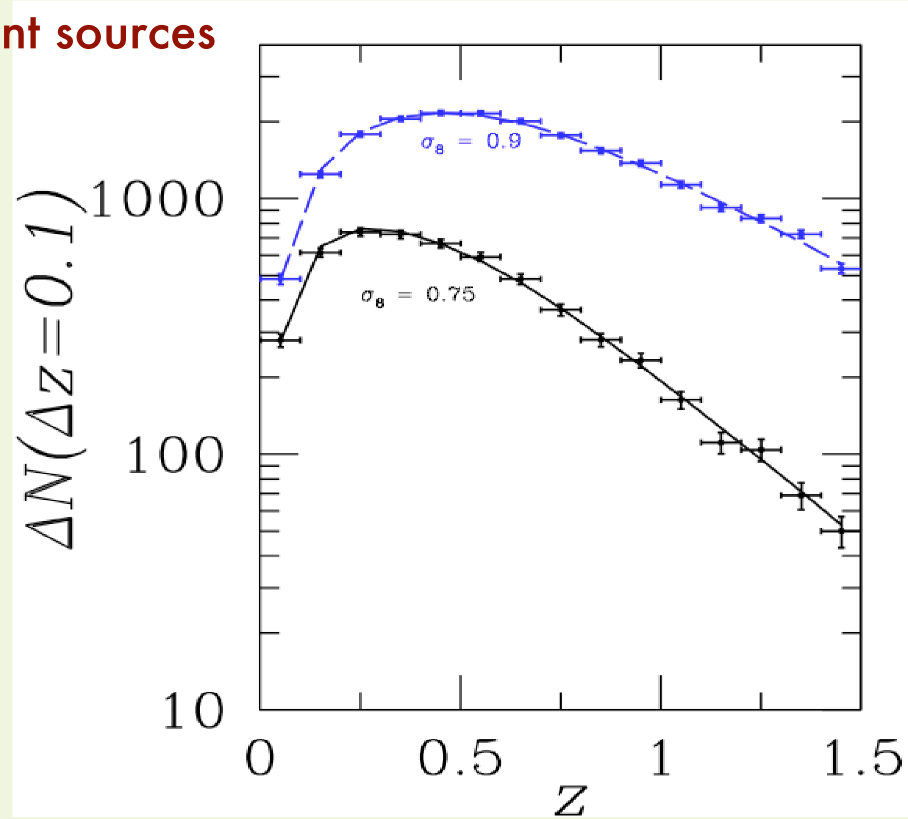
- virial temperature-mass relation zero scatter

  lensing calibration: $\Delta\xi$=0.05, $\Delta\varepsilon$=0.07

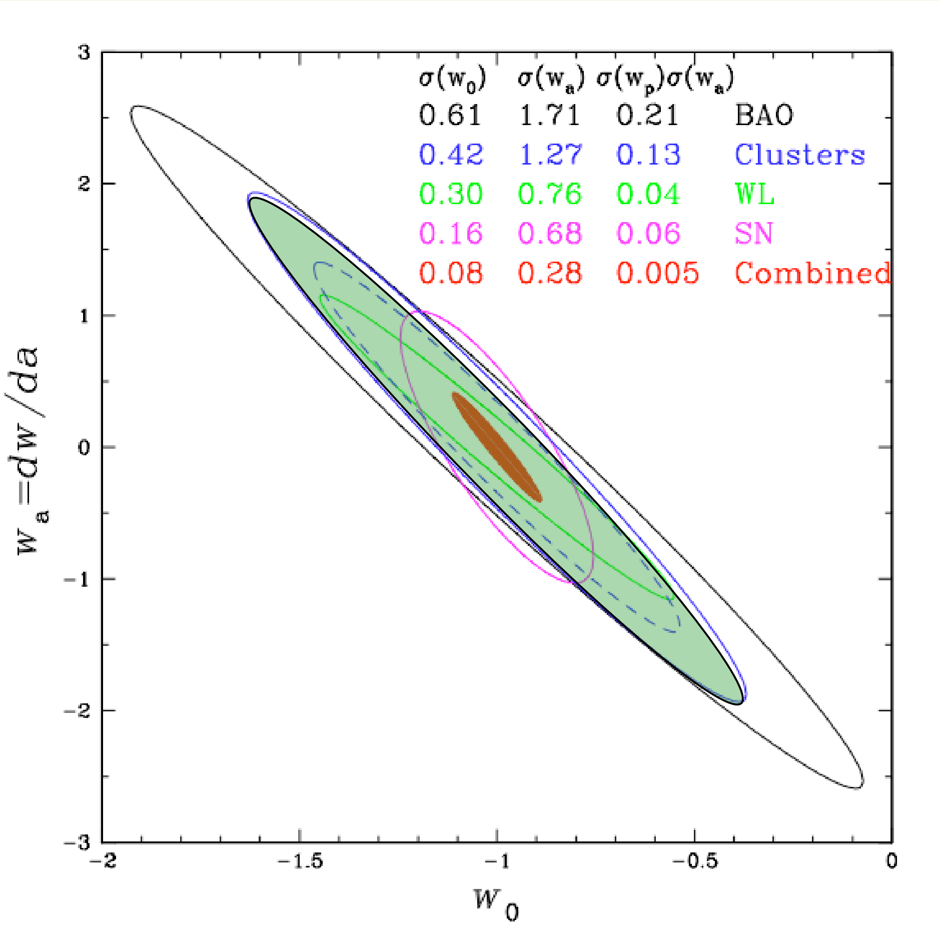
$$\langle T_e \rangle_n \propto T_* \, (1+z)^{\varepsilon-1} \, M_{\rm vir}^{1/\xi} \, .$$

- no baryon loss $M_{ICM} = (\Omega_b / \Omega_m)\, M_{tot}$
- no source confusion from CMB or point sources



# fiducial cluster constraints




## Too aggressive?

- no scatter in g(y|M,z)
- selection function perfectly known
- 100% completeness (no missed halos)
- 100% purity (no false positives)

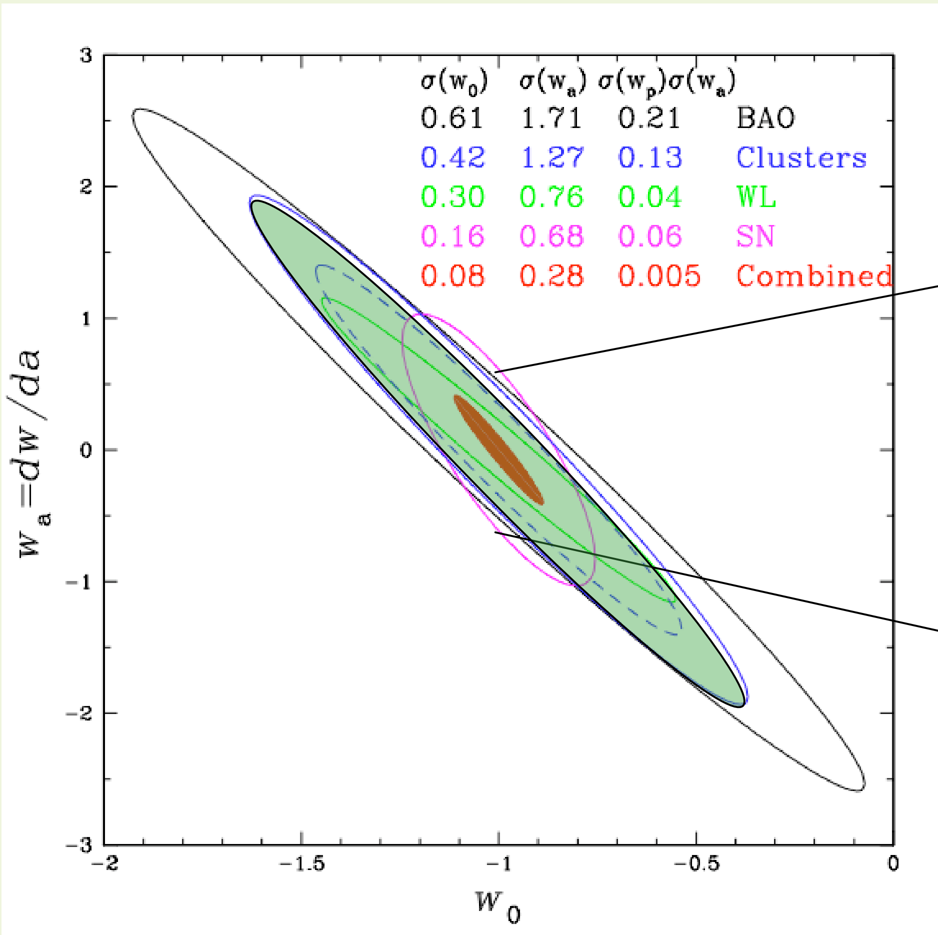
## Too conservative?

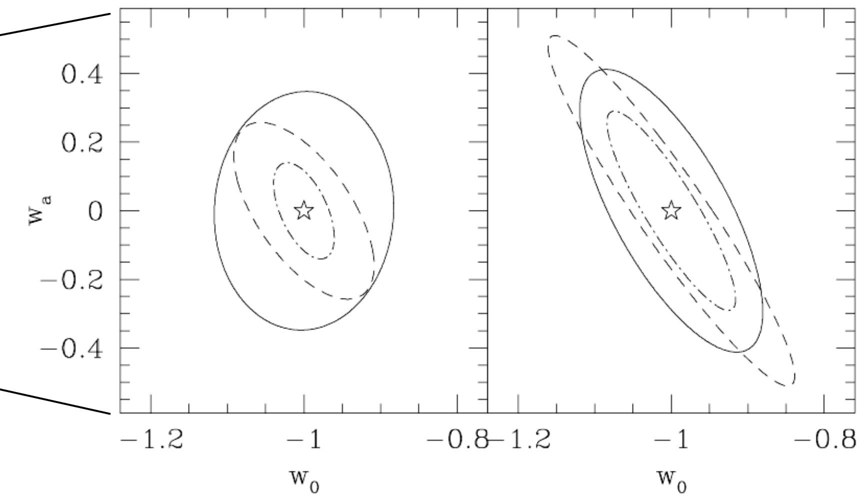
- no `self-calibration'
  - shape of counts, dn(y|z), ignored
  - clustering of sources ignored
- no joint SZ+optical information
- no strong external constraints

# forecasts for SPT + DES + (fictitious) X-ray mission

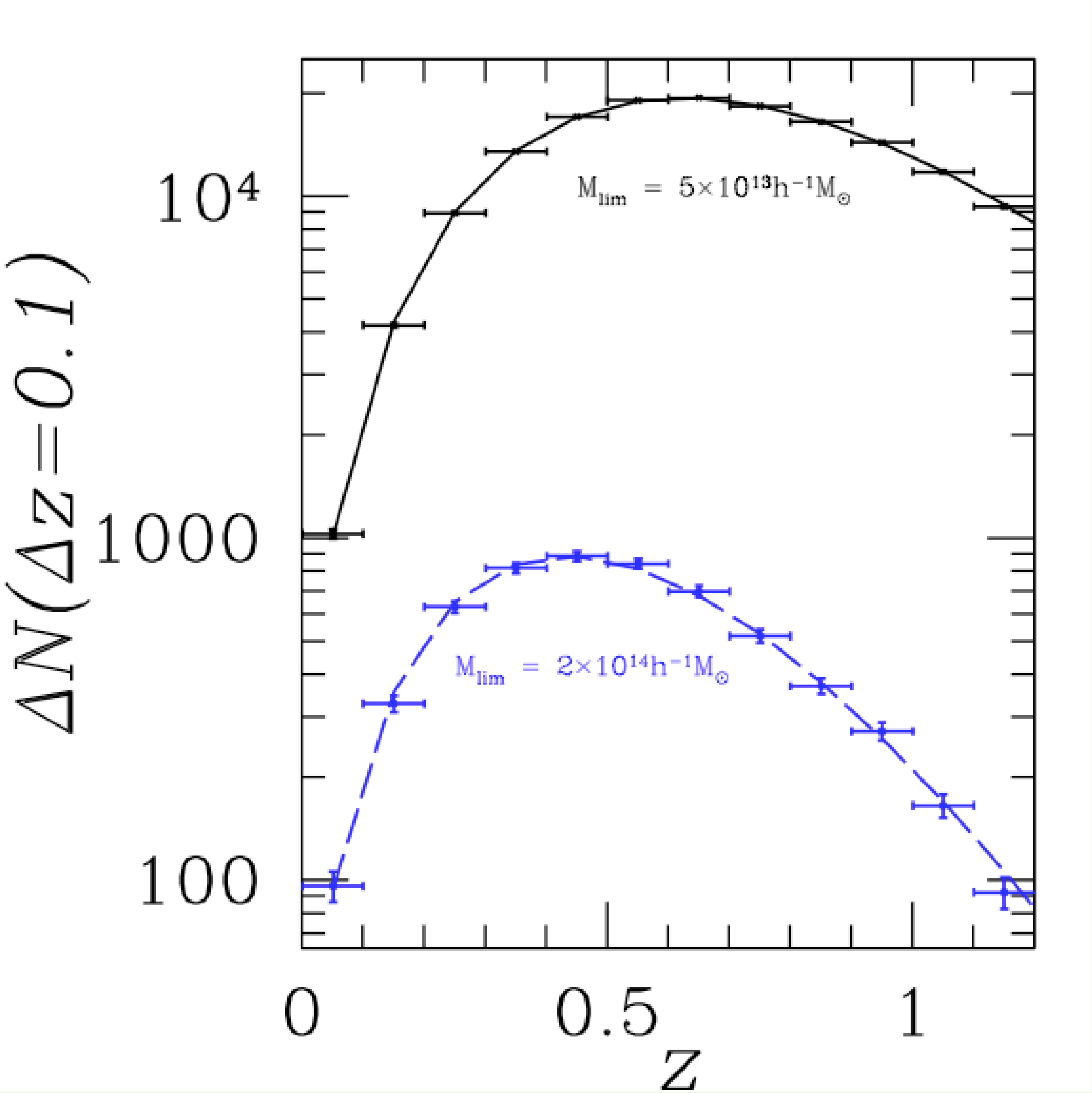
$F_x(0.5 - 2.0\ \mathrm{keV}) > 3 \times 10^{-14}$

physical model (core entropy) links X–ray and SZ observations



# more statistical power available in optical sample




challenge will be to understand selection function (completeness and blending)

# Cosmological Constraints from the maxBCG Cluster Sample

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December 13, 2006

*In collaboration with*: Risa Wechsler, Benjamin Koester, Timothy McKay, August Evrard, Erin Sheldon, David Johnston, James Annis, and Joshua Frieman.

# The Cluster Selection Function

We consider the detection of a cluster of richness $R_{obs}$ as a 2-step process:

1. There is some probability $P(R_{true}|m)$ that a halo hosts $R_{true}$ galaxies *(HOD)*.

$$\langle R_{true} \rangle = 1 + (M / M_1)^{\alpha}$$

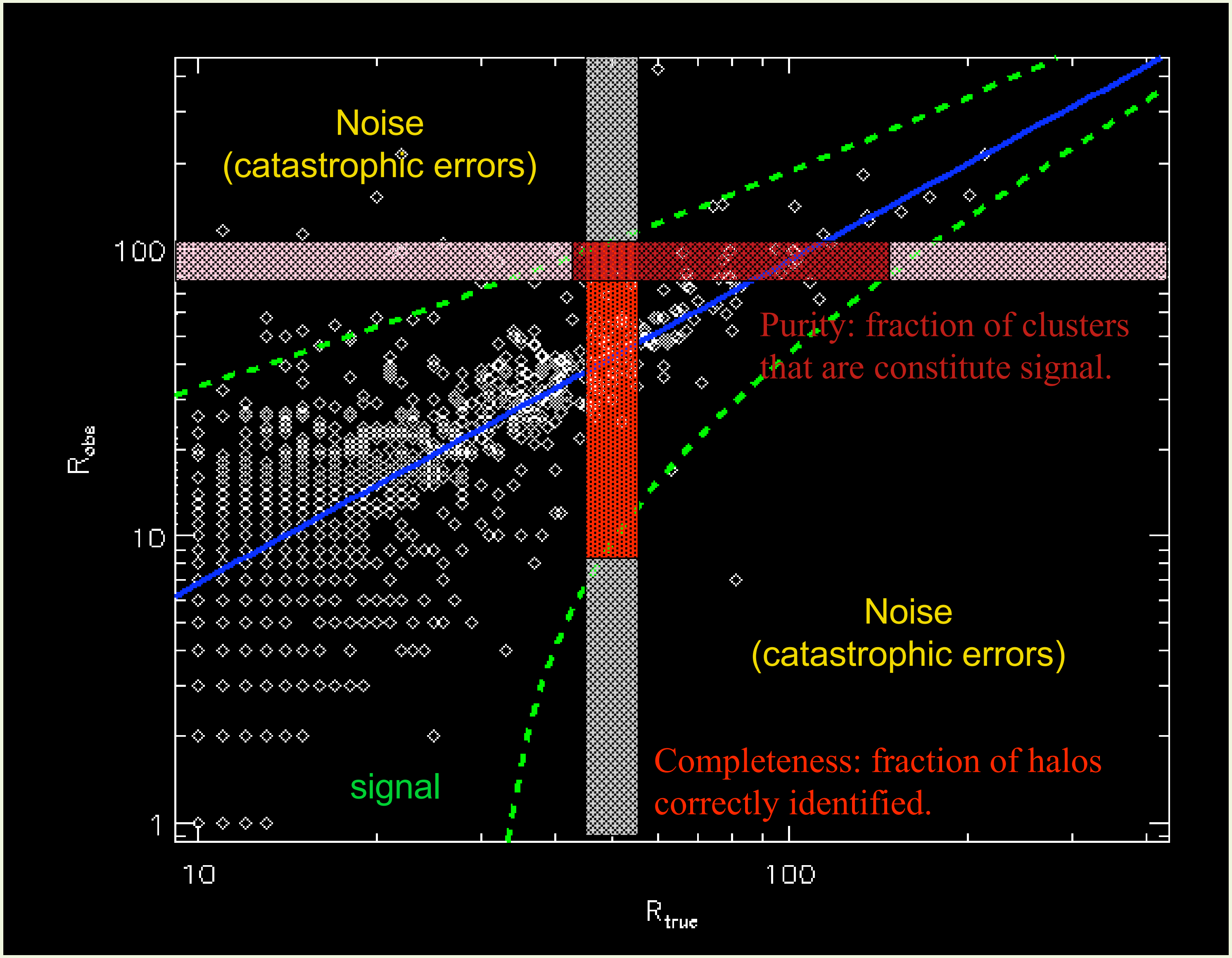
2. Given that a halo hosts $R_{true}$ galaxies, there is a probability $P(R_{obs}|R_{true})$ that the halo is detected as a cluster with $R_{obs}$ galaxies *(selection function)*.

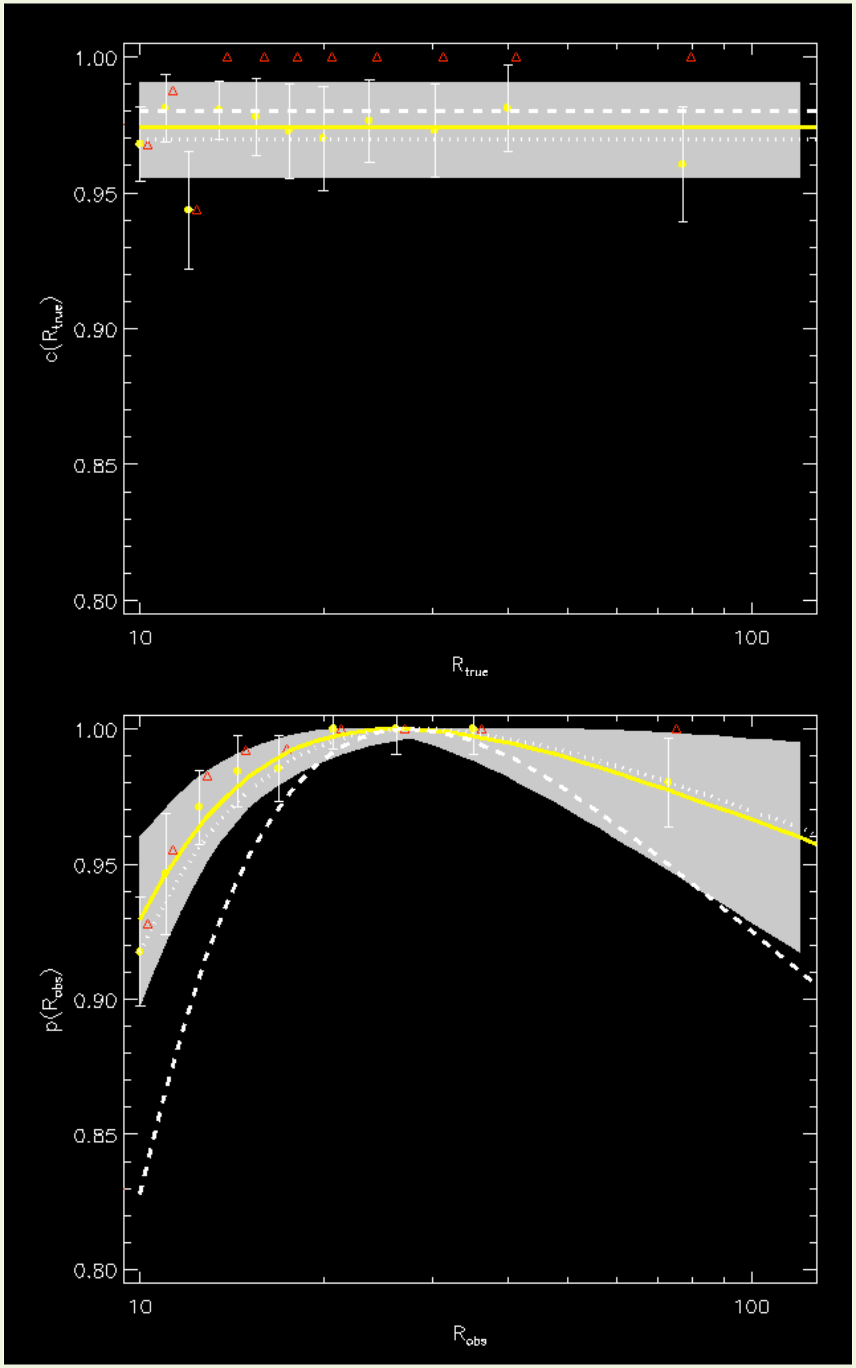
$$\langle R_{obs} \rangle = B_0 \langle R_{true} \rangle^{\beta}$$

The selection function and the HOD fully specify the mass-richness relation for the observed cluster sample.

The hope is that the selection function $P(R_{obs}|R_{true})$ can be shown to be a property of the cluster finding algorithm when richness (galaxy membership) is suitably defined.

# An Example From Simulations






# Results from the Calibration of the Selection Function in Simulations

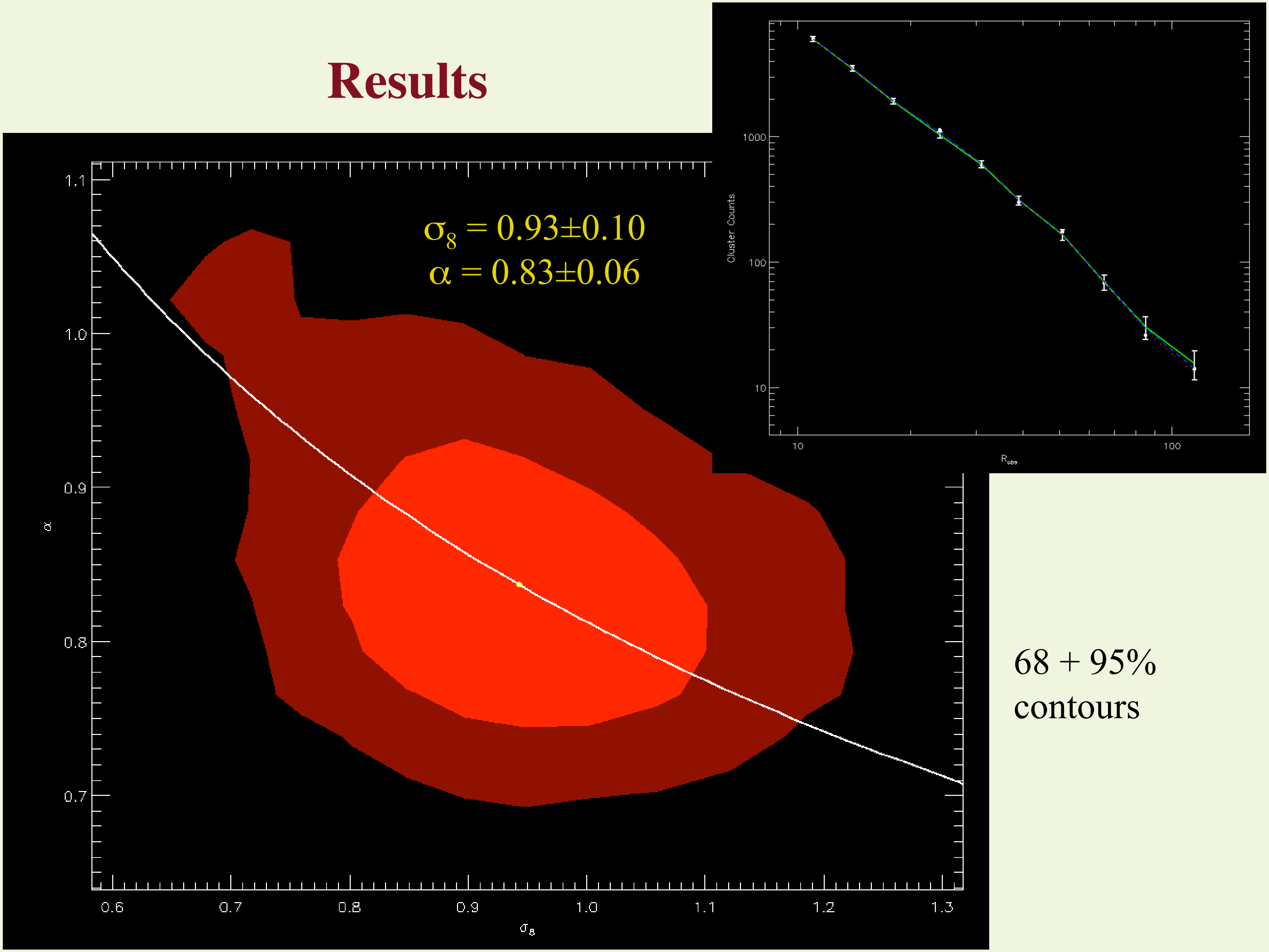
- The maxBCG sample is both highly pure and complete.
- The selection function $P(R_{obs}|R_{true})$ varied as simulation methods were refined.

Main difficulty for analyzing real data: we must use very generous priors.

Forces us to use cosmology/HOD priors

*$\Omega_m h^2=0.128\pm0.010$, $h=0.73\pm0.05$, and $\alpha=1.0\pm0.15$*

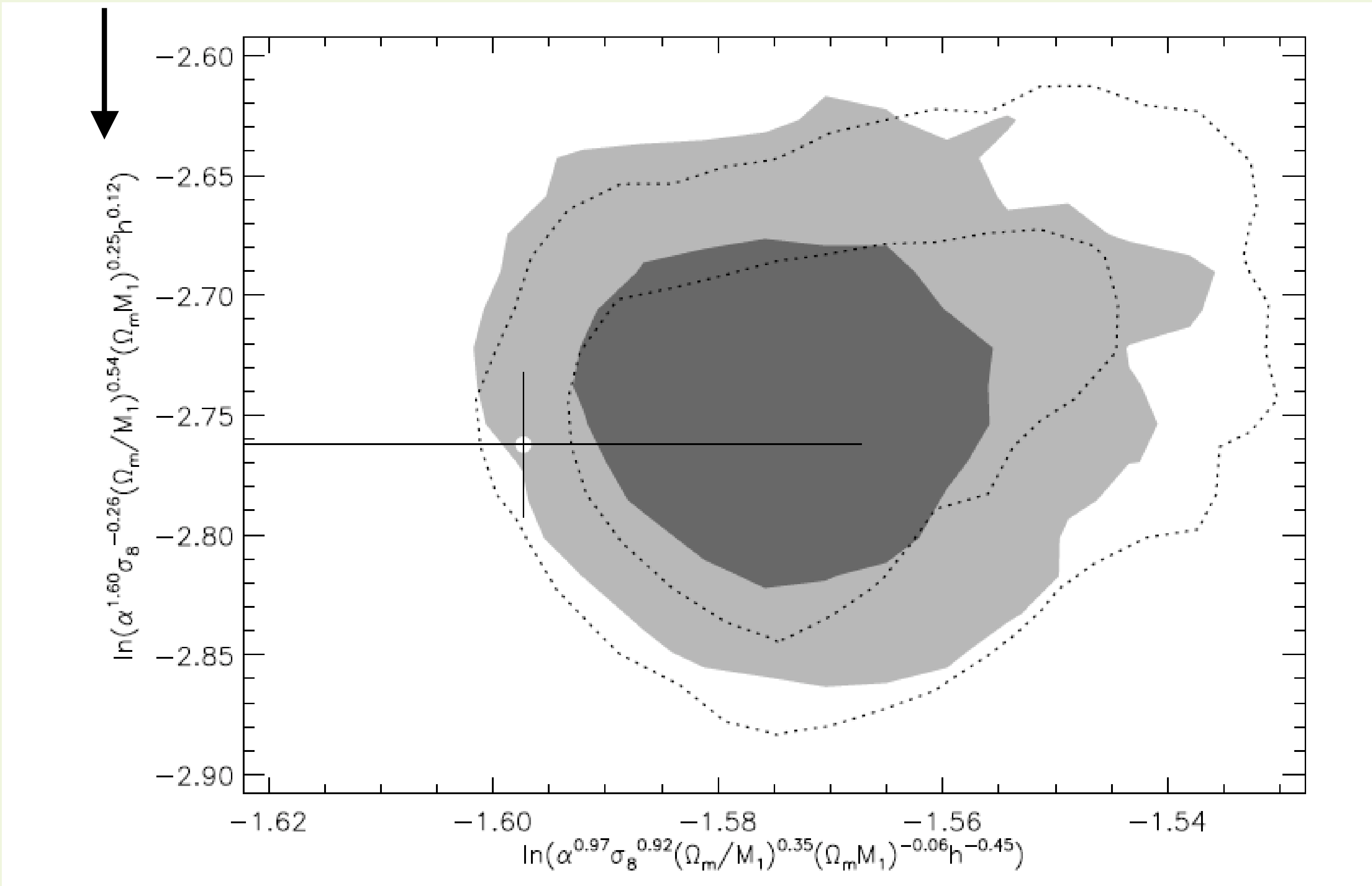
# Results




68 + 95%
contours

# Statistical power of 1% on principle component

$$\ln(\alpha^{1.60}\sigma_8^{-0.26}(\Omega_m/M_1)^{0.54}(\Omega_m M_1)^{0.25}h^{0.12})$$




$$\ln(\alpha^{0.97}\sigma_8^{0.92}(\Omega_m/M_1)^{0.35}(\Omega_m M_1)^{-0.06}h^{-0.45})$$

# Conclusions

• central values: $\sigma_8$ is higher, $\alpha$ is lower than previous studies.

• Error bars are generous. Values are consistent with most existing studies.

• Error bars represent an improvement relative to most previous analyses, as they are marginalized over $\Omega_m$ and $h$.

• We need to improve the robustness of the selection function: this involves improving the simulations and refining the criteria for cluster membership.

• Even in the absence of detailed knowledge of the selection function, the data is strong enough to derive some cosmological constraints.

• These constraints are going to improve as we include additional data (e.g. weak lensing).