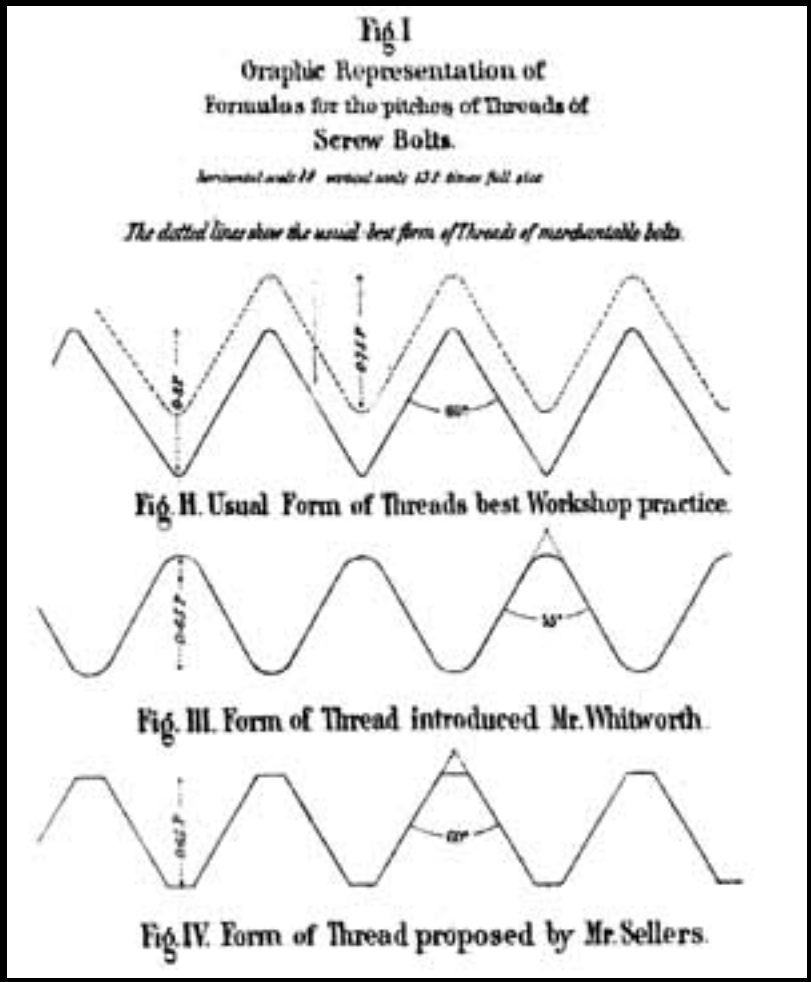
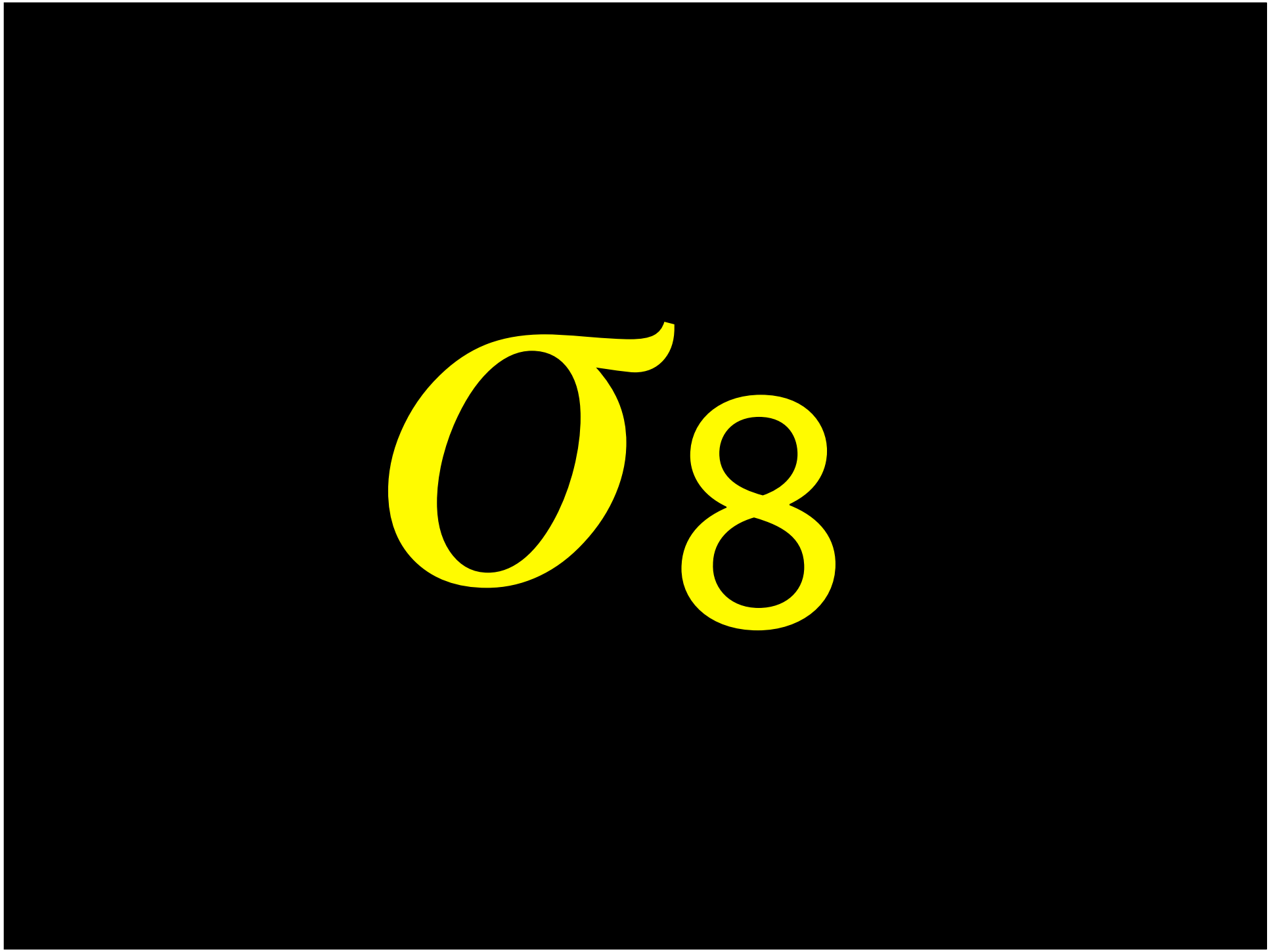
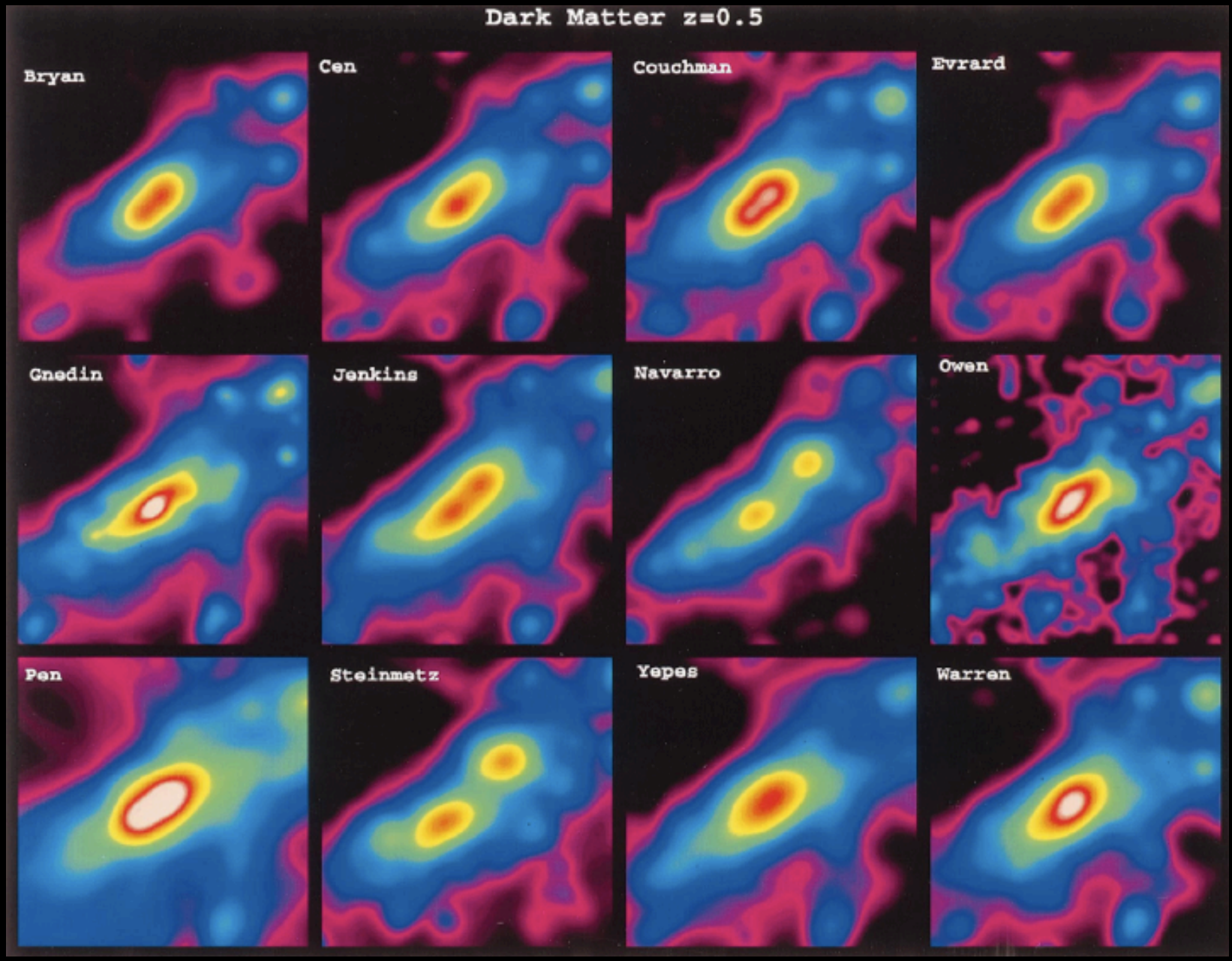
Santa Barbara Cluster
Standards Project

William Sellers



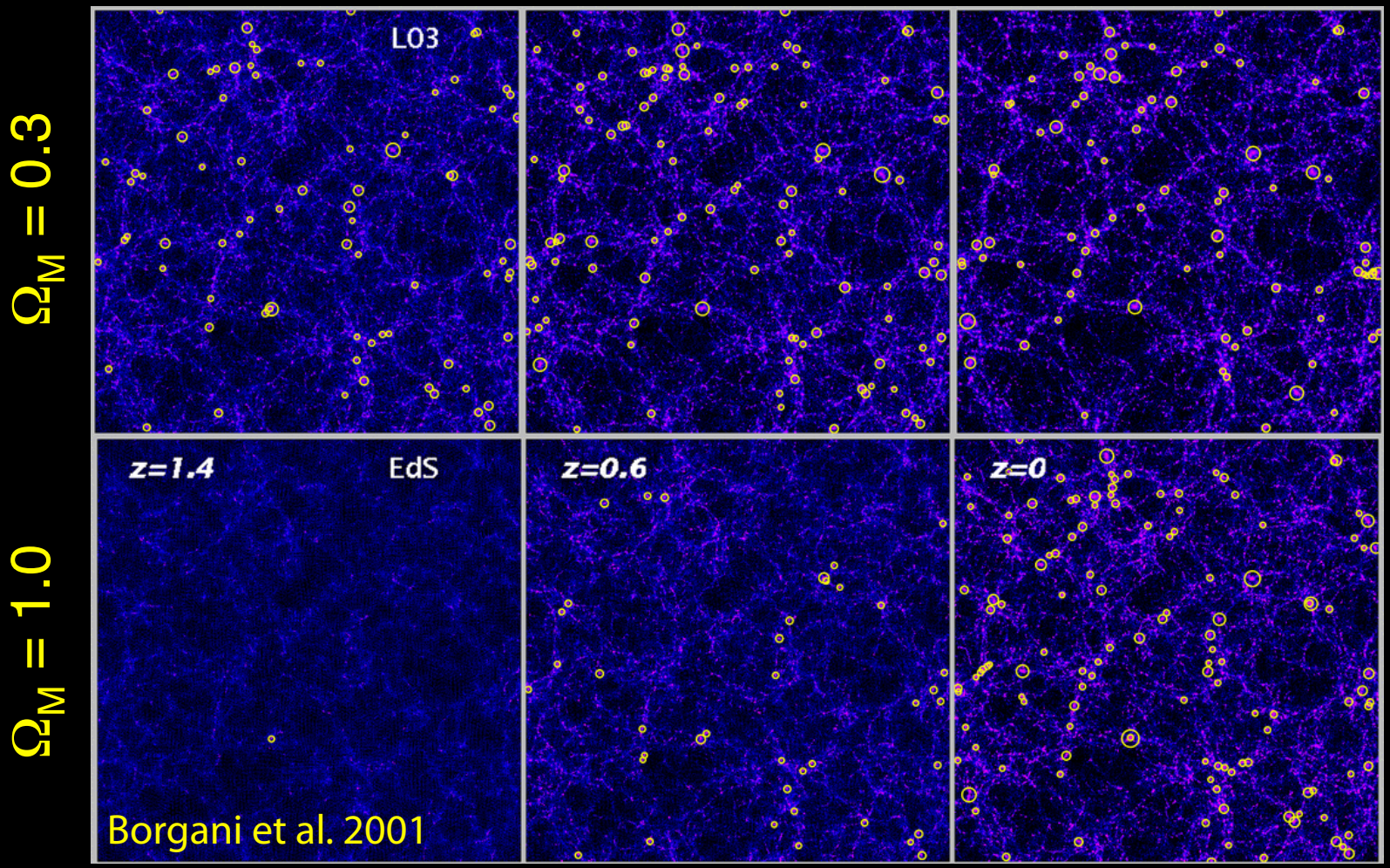

σ_8


Dark Matter z=0.5
Bryan
Cen
Couchman
Evrard
Gnedin
Jenkins
Navarro
Owen
Pen
Steinmetz
Yepes
Warren

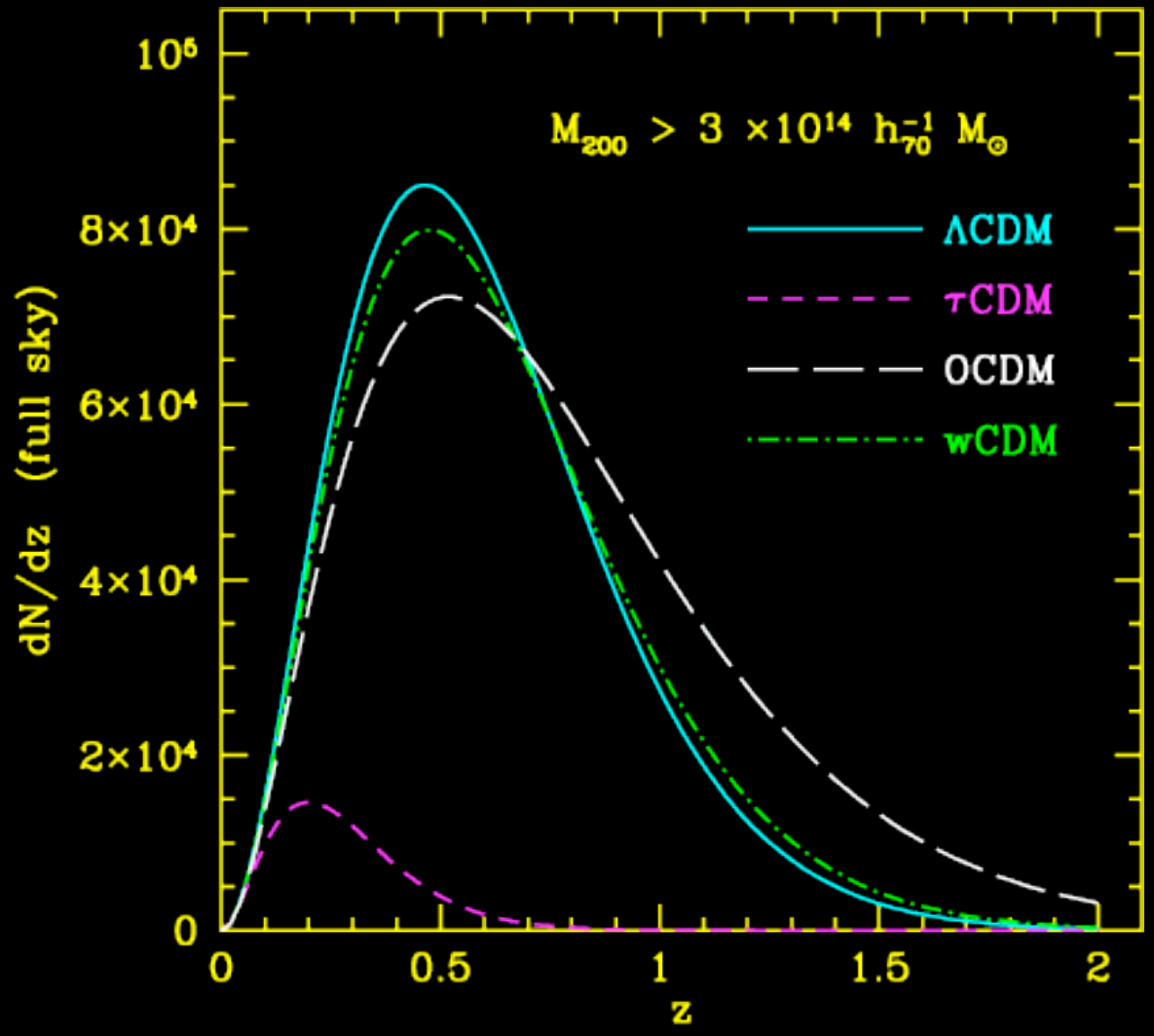
Frenk+ 1999

Galaxy Clusters & Cosmology

Clusters & Structure Growth



Clusters & Dark Energy



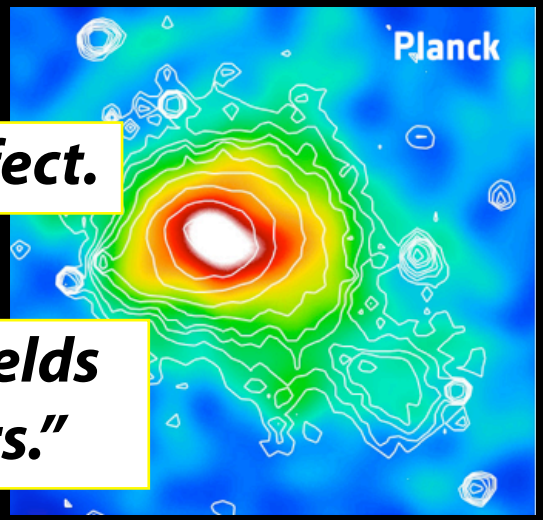
A large cluster survey with 10^4–10^5 clusters can in principle place percent-level constraints on cosmological models

Halo Model & Mass Calibration

Mass-Observable Relation

$$\frac{d^2N}{dX\,dz}(X,z) = \frac{dV_{\rm co}}{dz}\int \frac{dn}{dM}(M,z)\,f(X|M)\,dM$$

Surveying Massive Halos

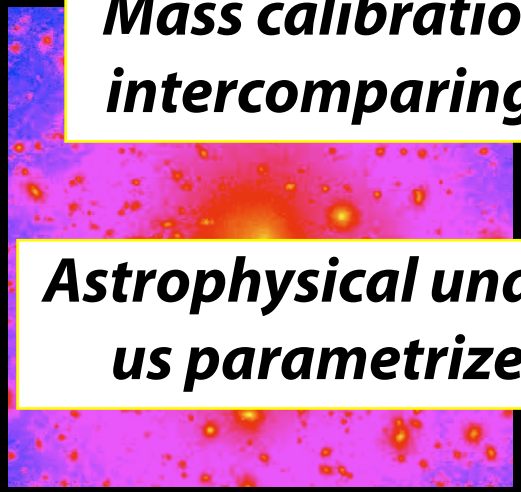


All our mass proxies are imperfect.

Selecting on different proxies yields different populations of "clusters."

σ_{1D} N_{200} κ_{lens} L_X T_X M_g Y_X Y_{SZ}

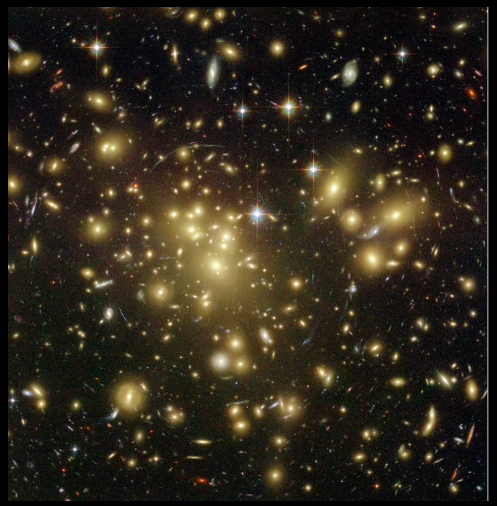
Mass calibration must proceed by intercomparing different proxies.

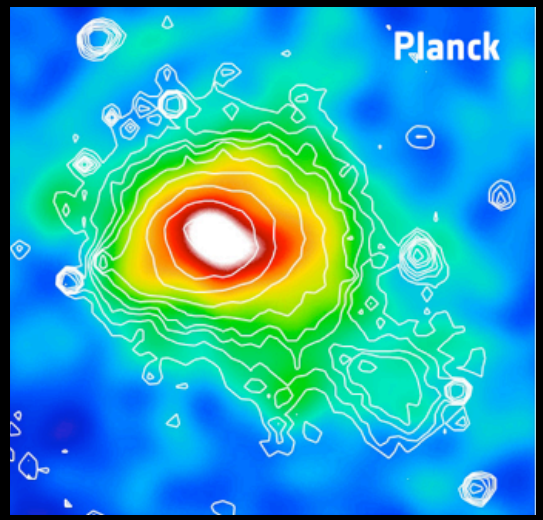


Astrophysical understanding can help us parametrize our comparisons.

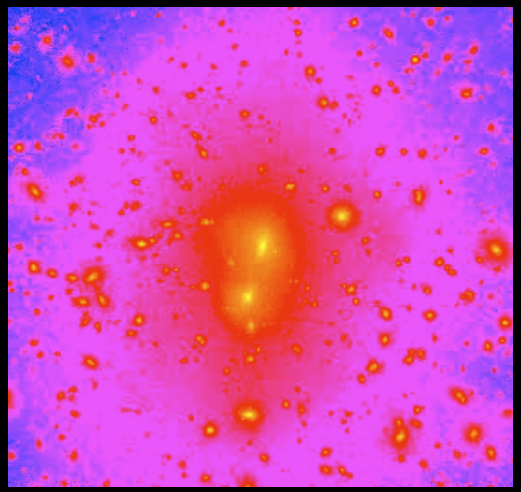
M_{500c} M_{200c} M_{200m} ...

Surveying Massive Halos



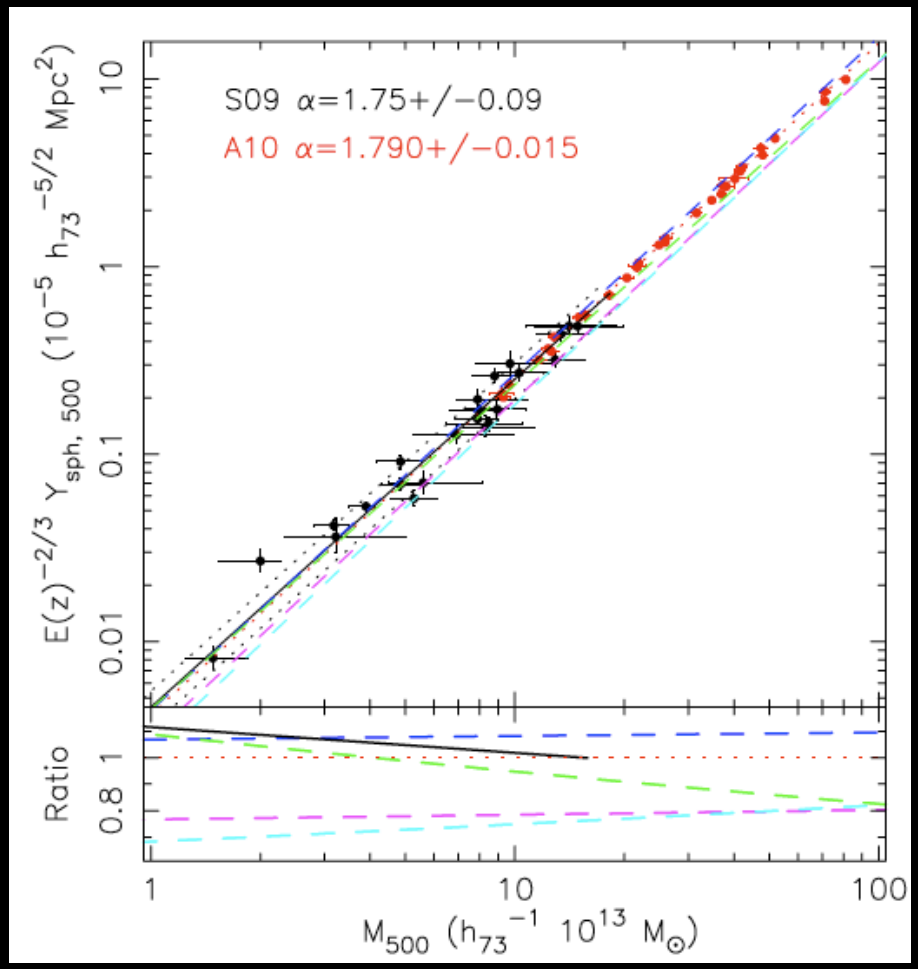


σ_{1D} N_{200} κ_{lens} L_X T_X M_g Y_X Y_{SZ}



M_{500c} M_{200c} M_{200m} ...

Reasons for Optimism

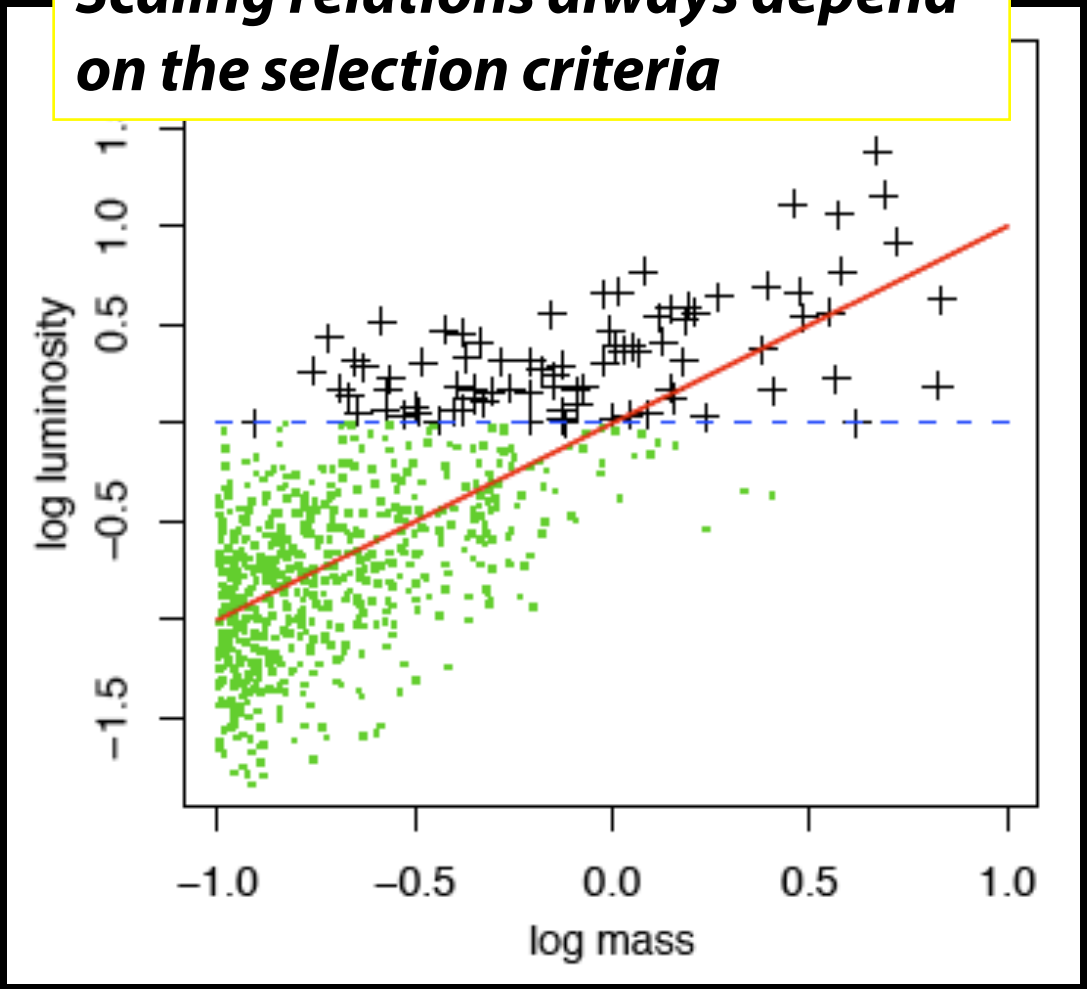


Sun+ 2011

Relationship between $Y_X = M_g T_X$ and mass estimated from hydrostatic equilibrium looks well-behaved over two orders of magnitude in mass

Reasons for Concern

Scaling relations always depend on the selection criteria



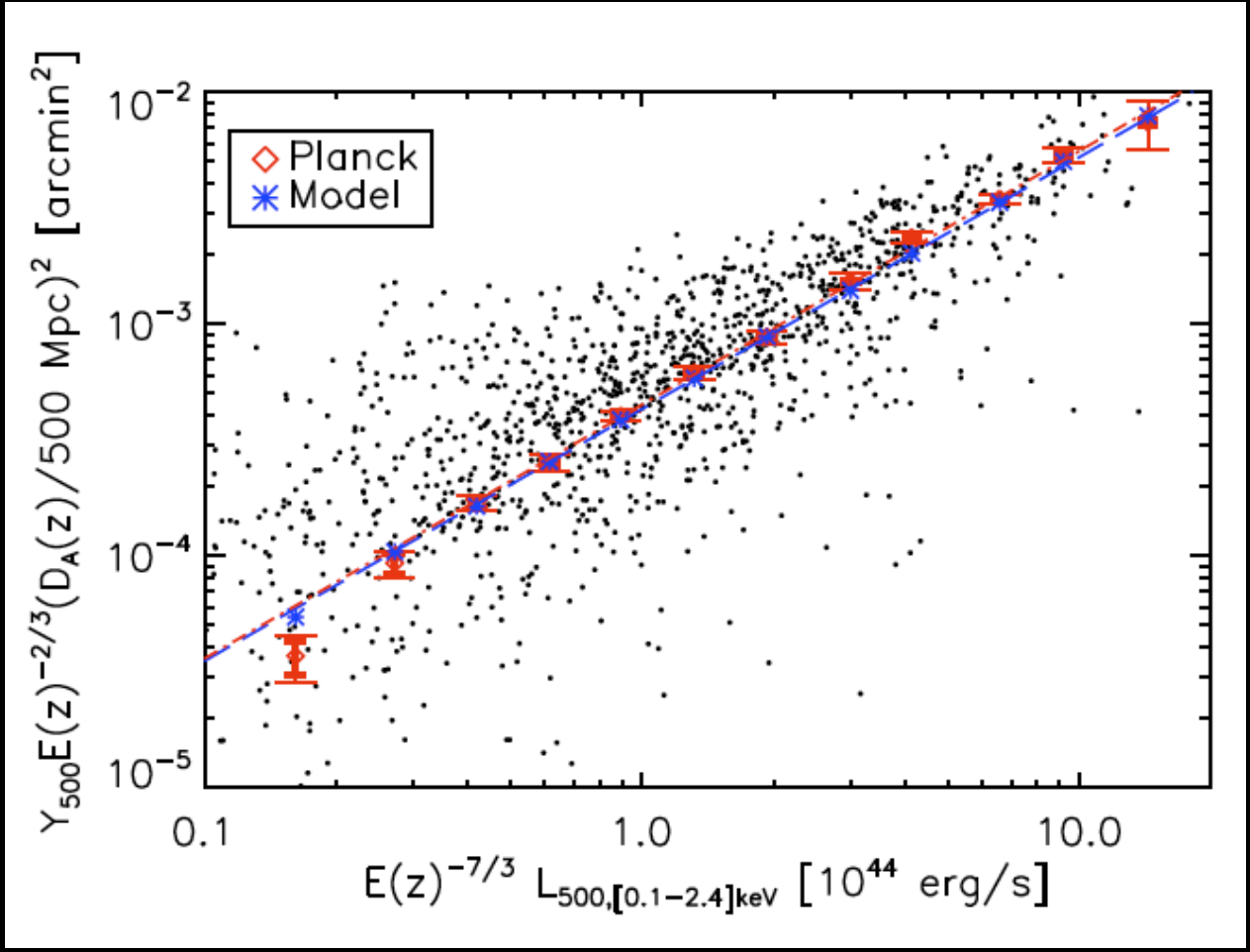
Allen, Evrard, & Mantz (2011)

Best-fit scaling law to a relation with significant scatter depends on the criteria used to select the data used in the fitting procedure

$$f(L_X, T_X, Y_X, Y_{SZ}, N_{200}, \kappa_{\rm lens} \ldots | M)$$

- Comparing surveys relying on different observables can reveal previously unknown systematics
- Cross-calibration is necessary to establish variances and covariances in master mass-observable relation

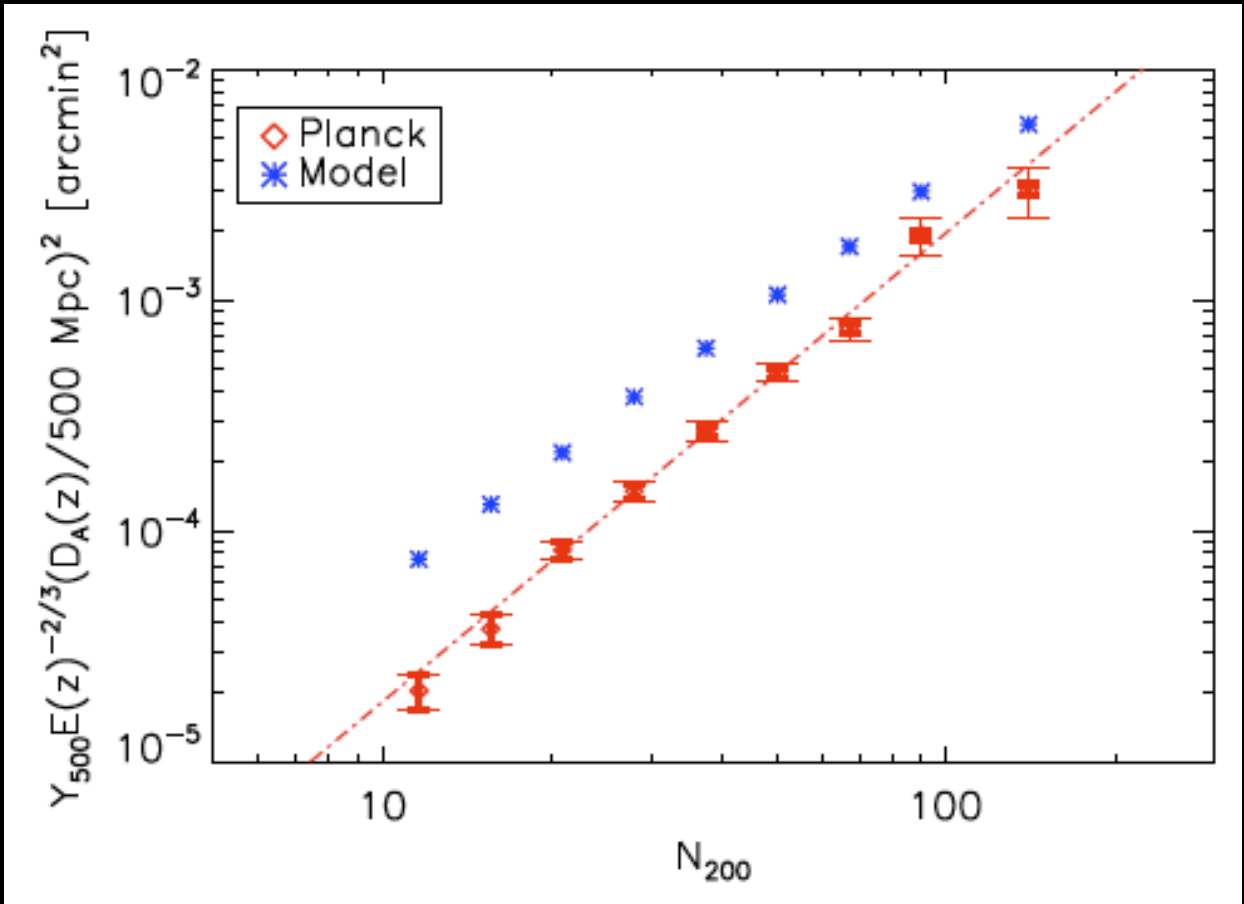
Reasons for Optimism



PLANCK Collaboration 2011

Model predicts SZ signal Y_{500} based on X-ray characteristics

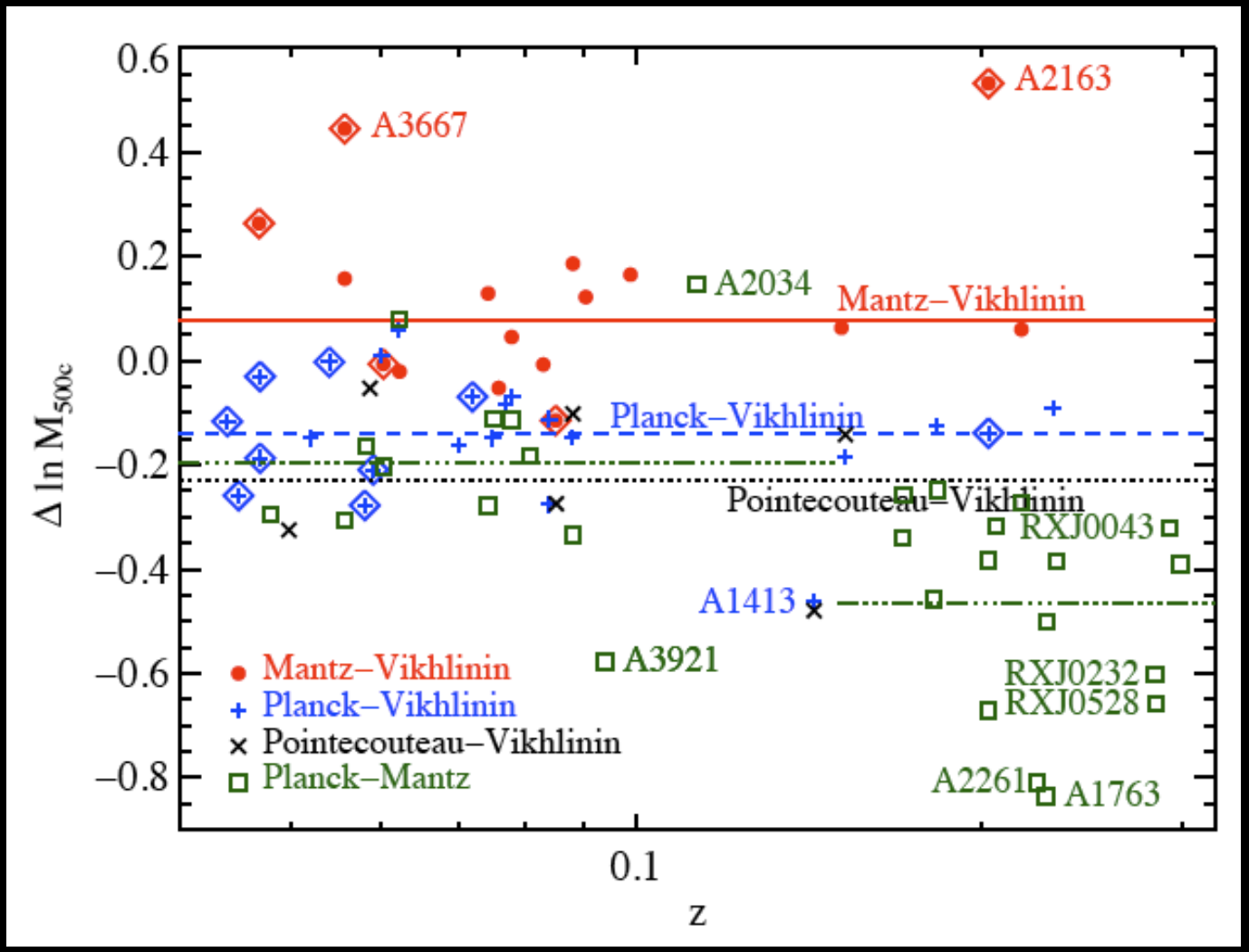
Reasons for Concern



PLANCK Collaboration 2011

Average SZ signal of optically selected clusters is substantially smaller than model prediction

Reasons for Concern

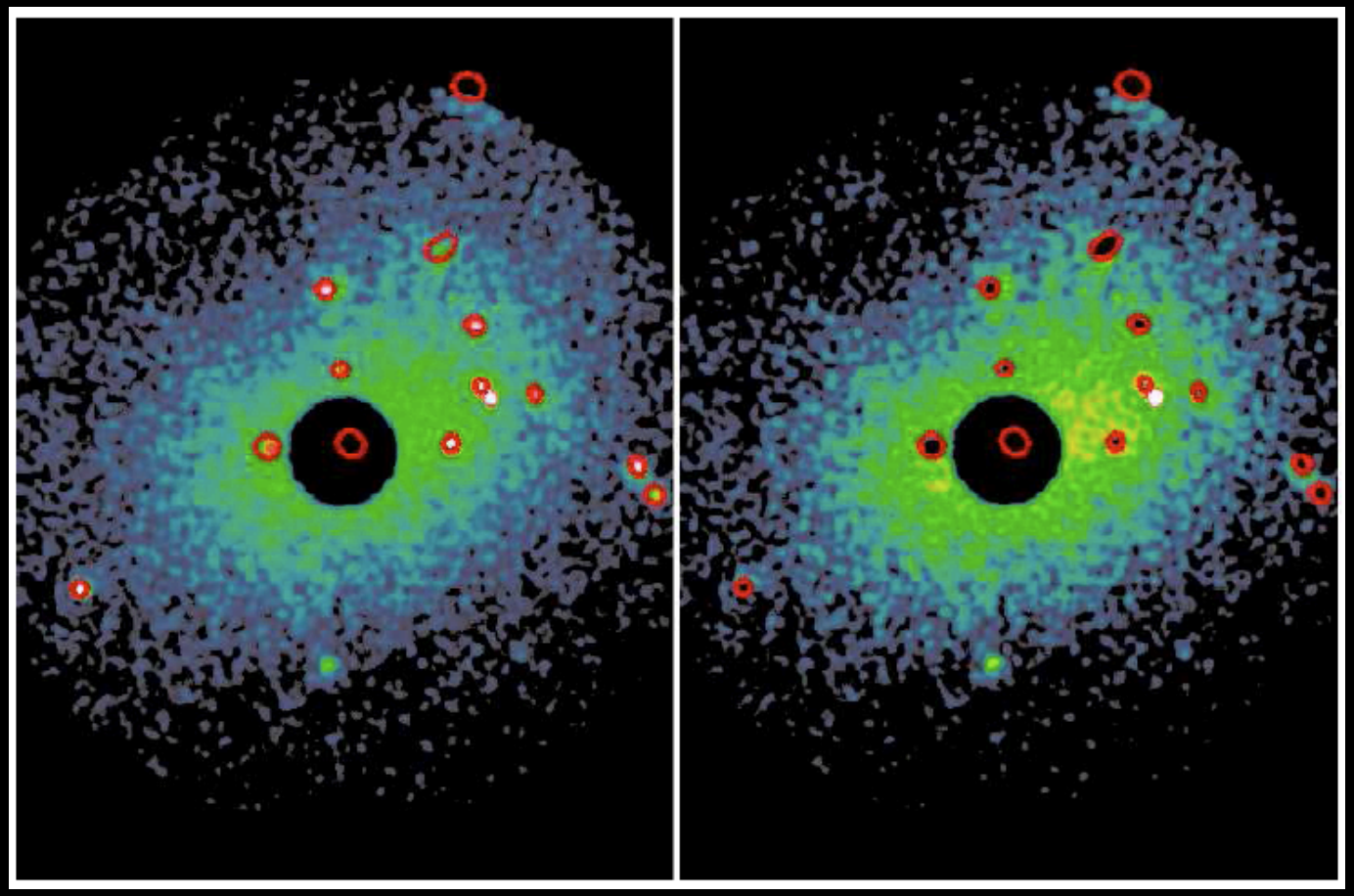


Rozo+ (2011, in prep)

Masses measured for identical clusters by different investigators systematically differ

Mantz: $M(M_g)$
Vikhlinin: $M(Y_X)$
Planck: $M(Y_X)$

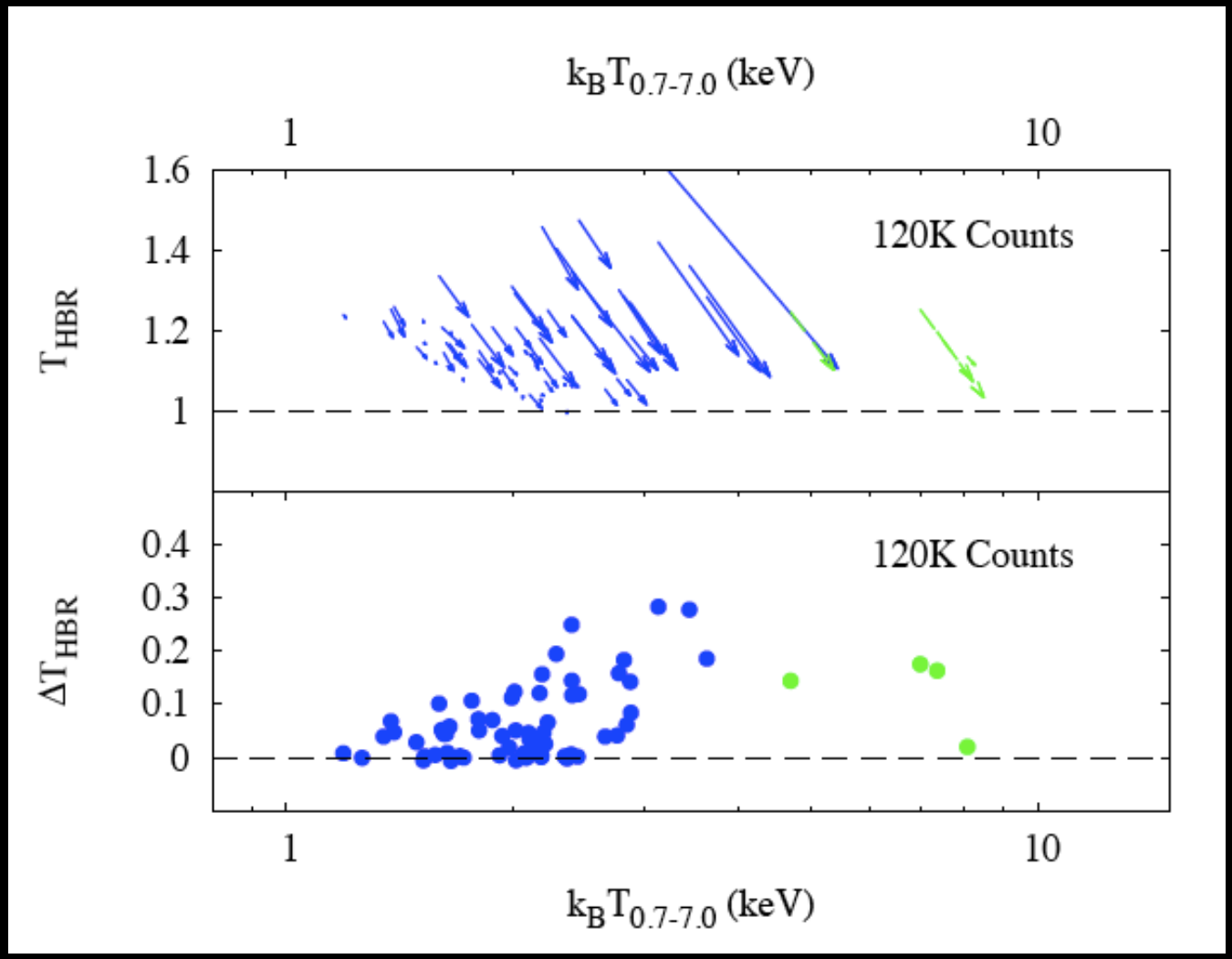
Reasons for Concern



Best-fit spectroscopic temperature can depend on masking of "cool blobs" even after the main cool core is excluded

Ventimiglia+ (2011, submitted)

Reasons for Concern



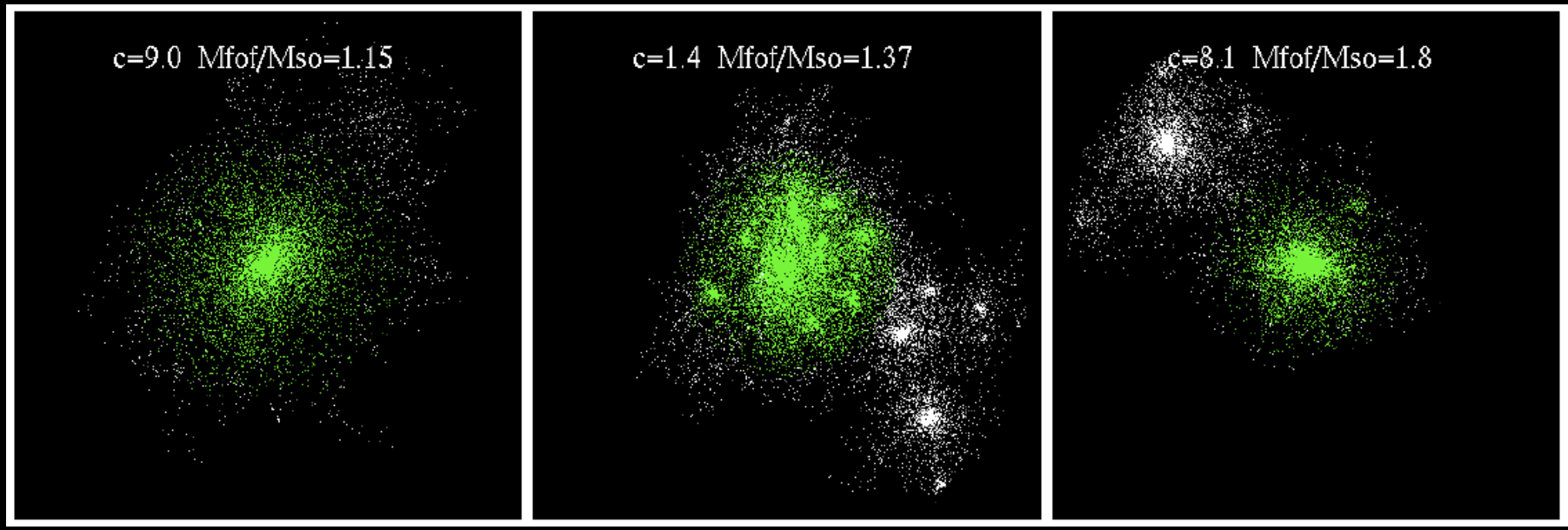
Ventimiglia+ (2011, submitted)

Best-fit spectroscopic temperature can depend on masking of "cool blobs" even after the main cool core is excluded

$$\frac{d^2N}{dX\,dz}(X,z) = \frac{dV_{\rm co}}{dz}\int \boxed{\frac{dn}{dM}(M,z)}\, f(X|M)\,dM$$

Halo Model

Halo Definitions

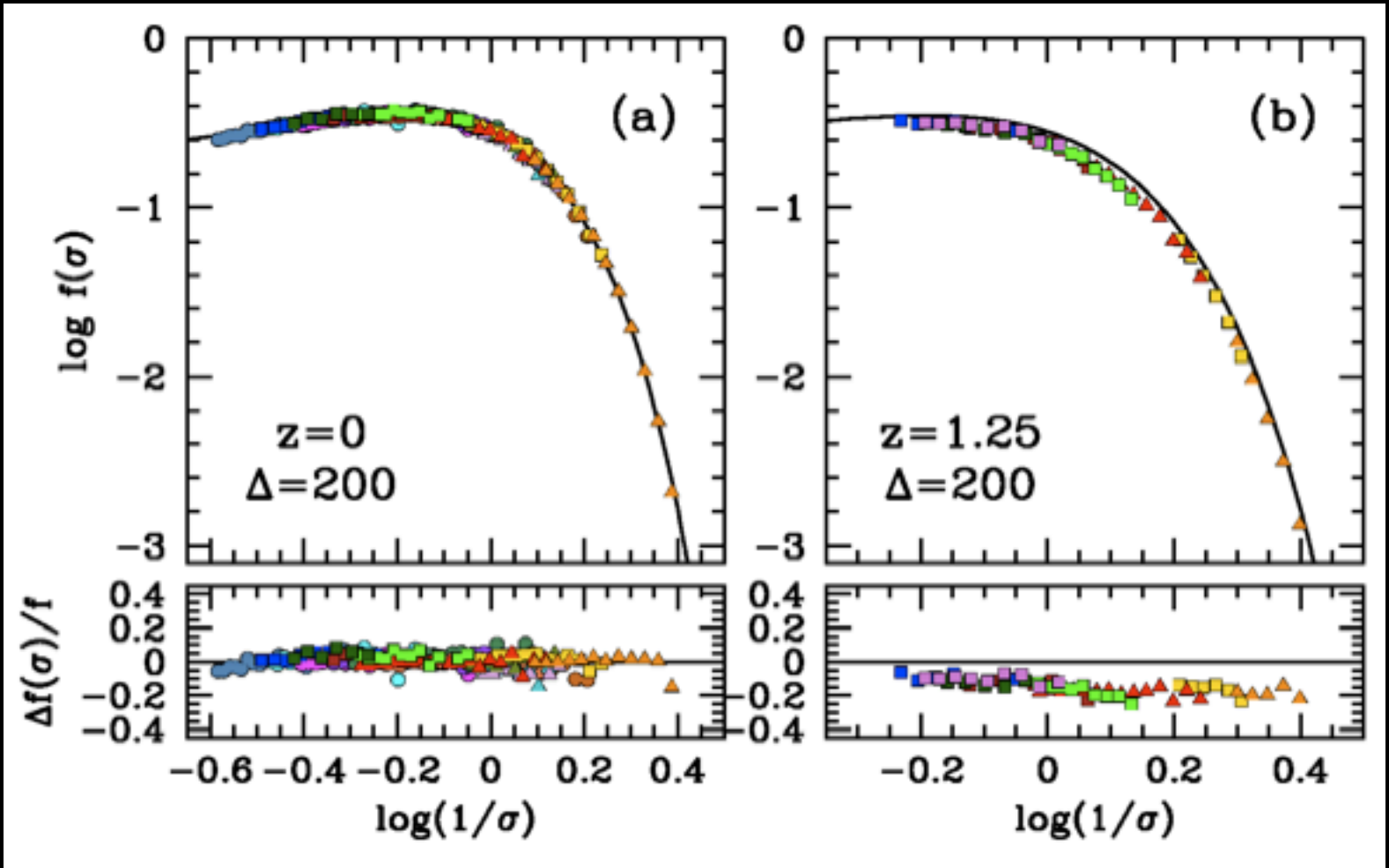


Green: SO halos
Green+White: FOF Halos

Allen, Evrard, & Mantz (2011)

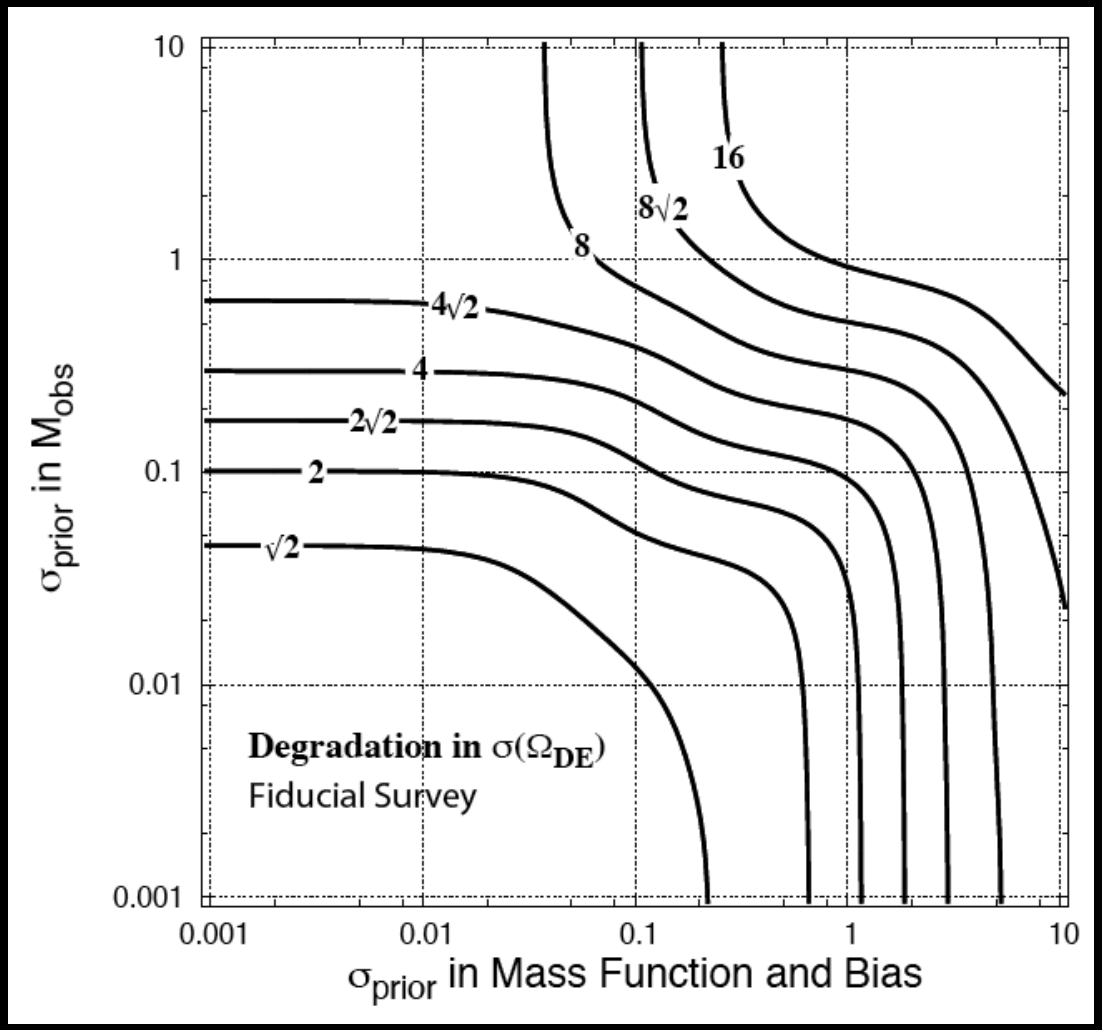
- Different halo-finding methods yield different mass functions
- SO halo catalog depends on centering and counting algorithms

Mass-Function Fitting Formulae



Tinker+ (2011)

Effects of Theoretical Uncertainties



Current uncertainties in halo model are significant and must be accounted for in precision cluster cosmology

Cunha & Evrard (2010)

Mock Catalogs from Simulations

Simulations & Mock Catalogs

Direct computation of distribution functions for all cluster observables as functions of cosmology will eventually be possible

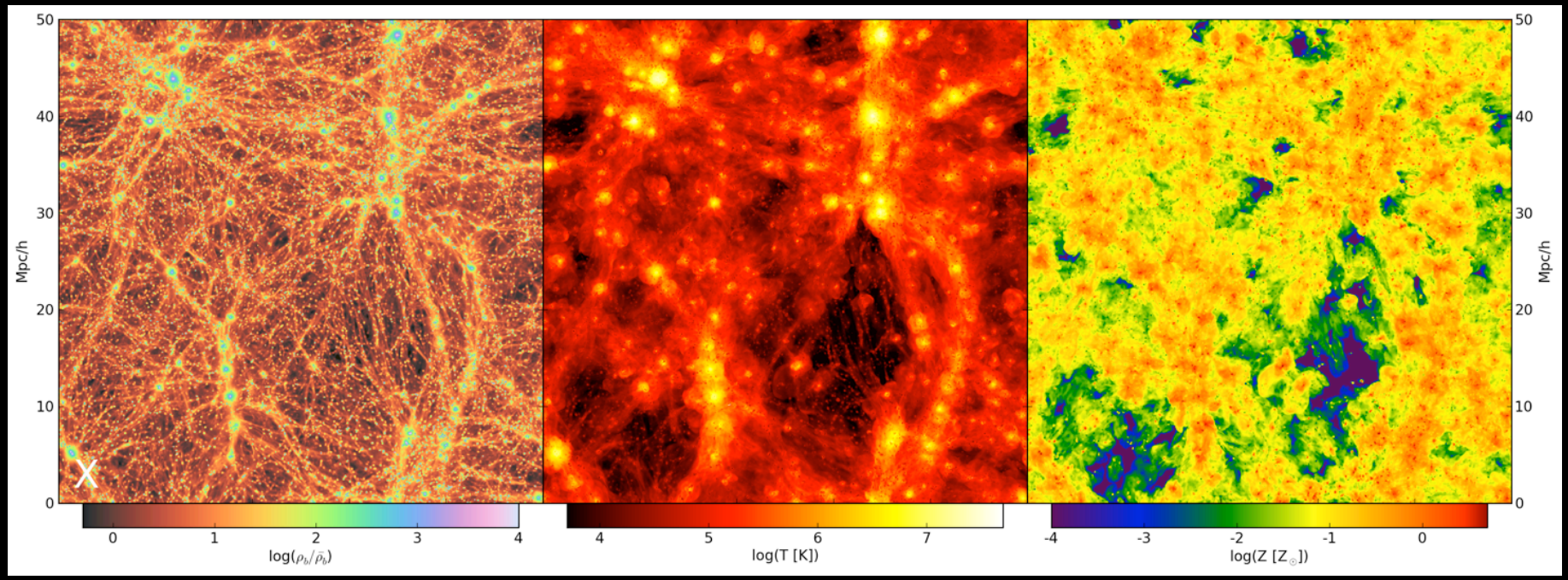


Image: B. Smith

Reasons for Standards

- Algorithmic definitions of observable quantities are needed so that we all can measure the same thing.
  - Publicly available software would be ideal.
- Community will make faster progress with cross-calibration if we can converge on a small number of key observables.
- Having a limited set of standards makes mock catalogs more useful.

Cluster Standards Wiki

★ Santa Barbara Cluster Standards

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Santa Barbara Cluster Standards Project

Talks & Discussion Schedule
Online talks
Reference Material
Big Questions in Cluster Research
Program Wrap Up Discussion
Topical Discussion Groups

- Nonthermal
- Stellar Content
- Planck SZ-Optical scaling relations
- Observer Bias
- Scaling Relations

Santa Barbara Cluster Standards Project

Rationale

Instructions

Contributors

Dick Bond, Megan Donahue, Gus Evrard, Andrey Kravtsov, Surhud More, Eduardo Rozo, Mark Voit

1. Mass Definition Standards

1.1 Friends-of-Friends Masses

1.2 Spherical-Overdensity Masses

1.3 Algorithms for Centering and Mass Assignment of Spherical Halos

1.4 Mass-Definition References

2. X-ray Property Standards

2.1 X-ray Luminosity

2.2 X-ray Temperature

2.3 X-ray Gas Mass

Wiki Item Outline

- Introduction
- Algorithmic Definition
- Links to Software
- Strengths
- Weaknesses
- Discussion

Current Contributions

- Friends-of-Friends Masses: More, Kravtsov
- Spherical Overdensity Masses: Evrard, Kravtsov
- Halo-Defining Algorithms: Kravtsov, Tinker
- Optical Galaxy Richness: Rozo
- Weak-lensing Mass (Spherical Template): Hoekstra
- SZ Thermal Energy (SPT): Marrone (in prep)

Please Participate

- Broad-based community involvement is encouraged and required for the project to be a success.
- We intend to publish an ApJ Supplement article in ~1-2 years listing all contributors as authors.
- http://gclusters11.wikispaces.com
- http://gclusters11.wikispaces.com/Santa+Barbara+Cluster+Standards