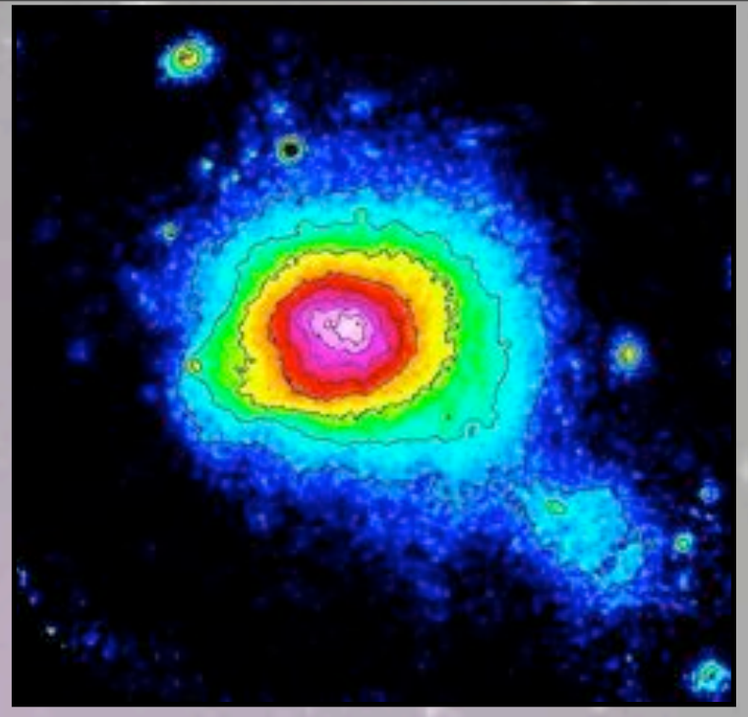

Cluster concentration-mass relation and baryonic cooling

MNRAS 424, 1244 (2012)

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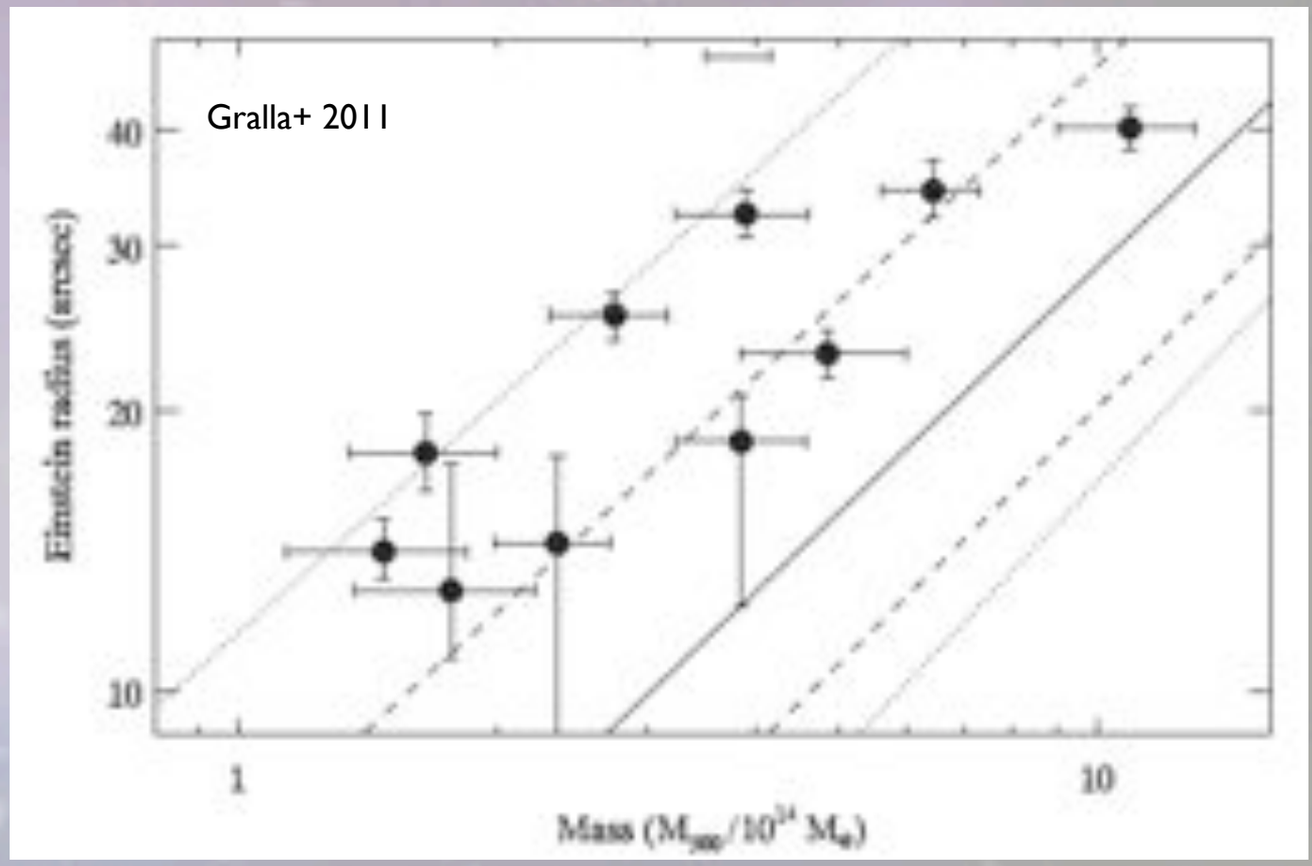
University of Florida

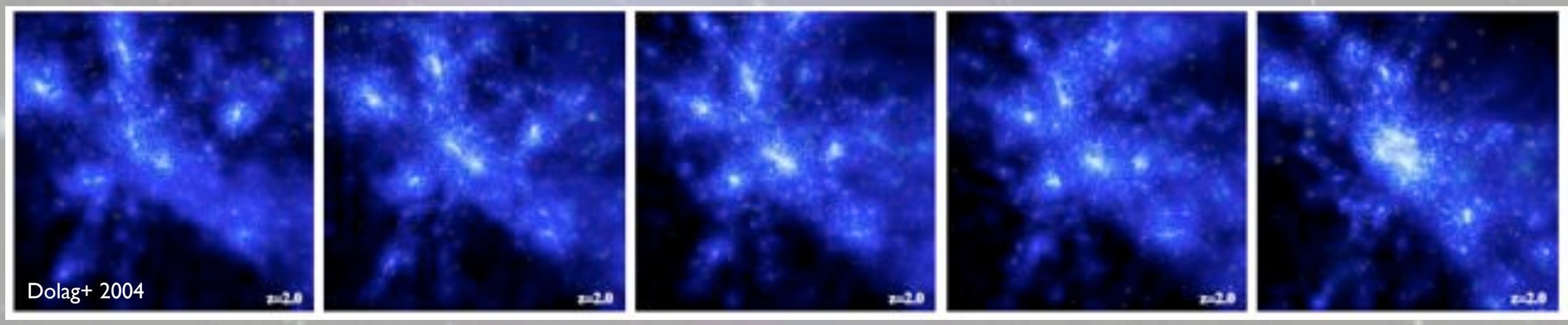
Madrid 09/10/2012

The structure of galaxy clusters

Main properties

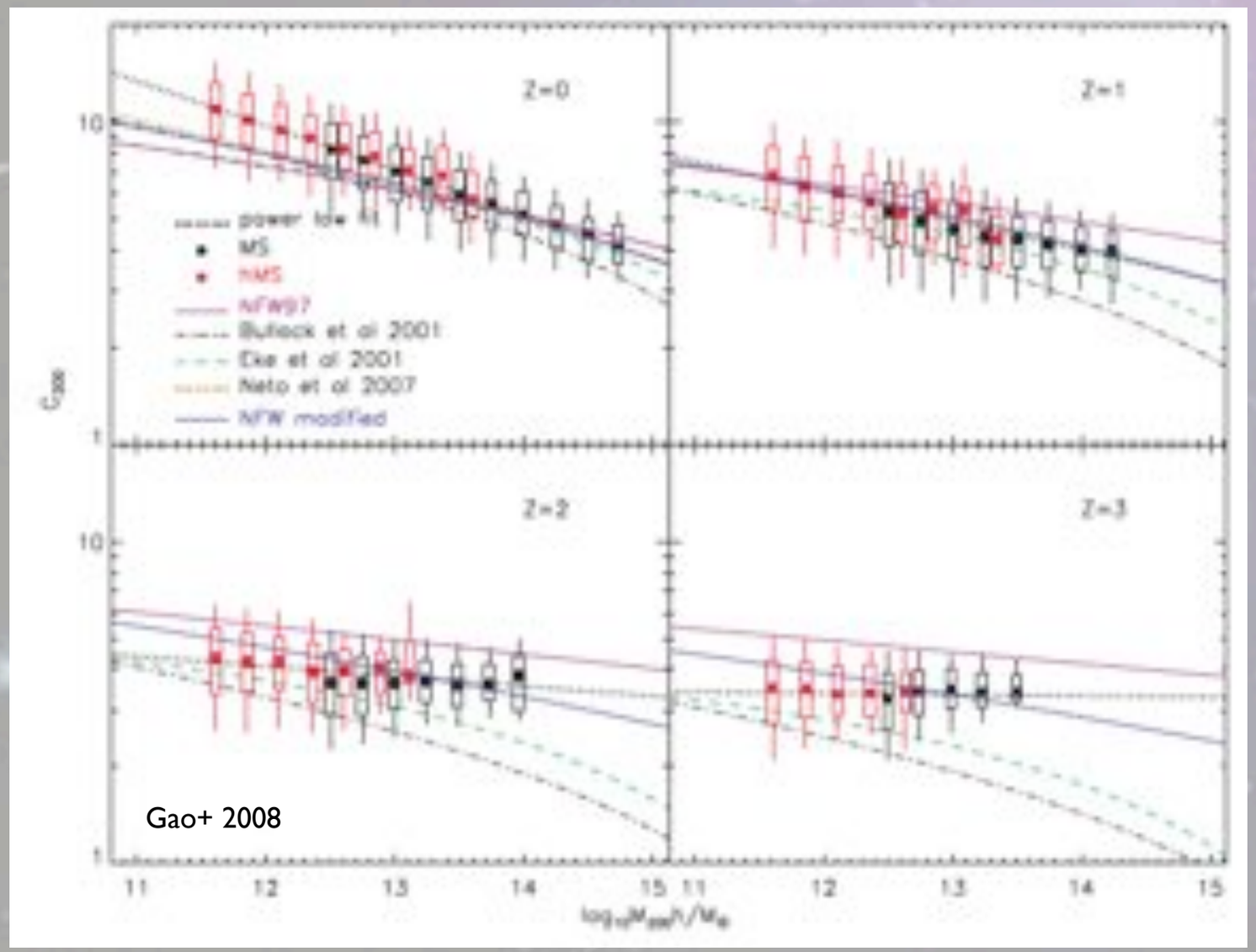
- Dark matter follows a **universal density profile** (NFW)
- It depends on the underlying cosmology
- It is influenced by the properties of dark matter particles
- It is affected by the **abundance and distribution of gas and stars** within dark matter halos
- More in general, it depends on the assembly history of clusters and cluster galaxies

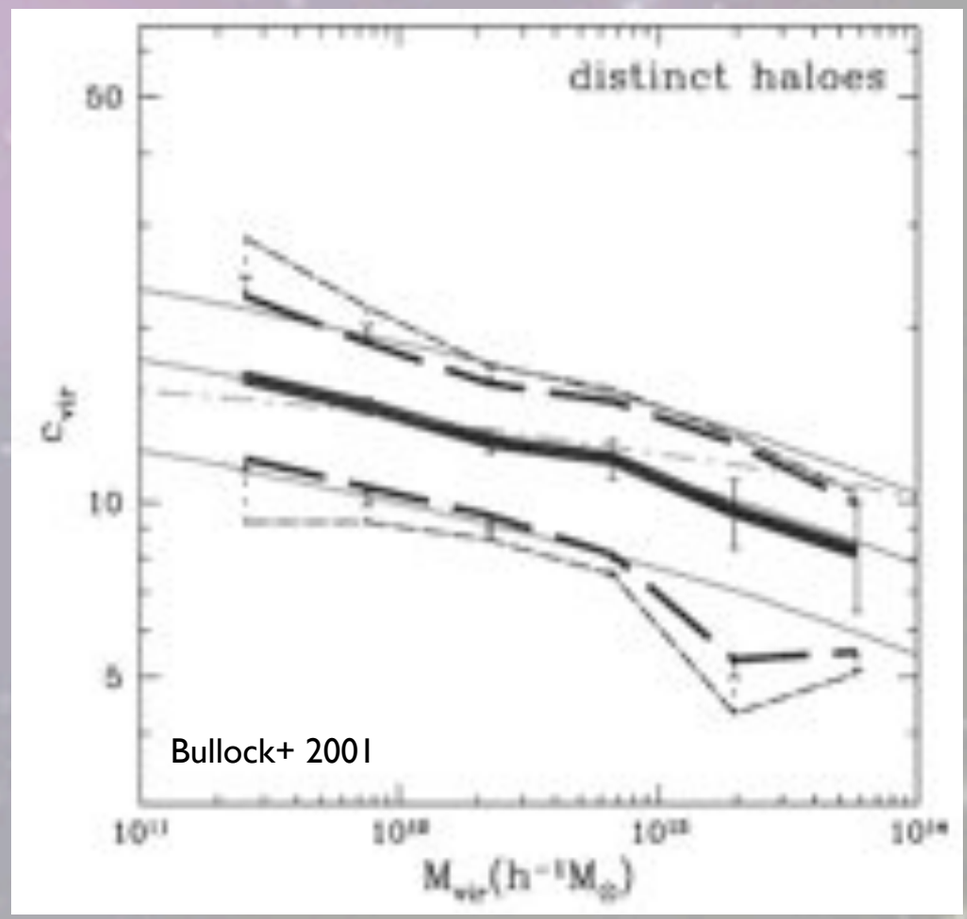


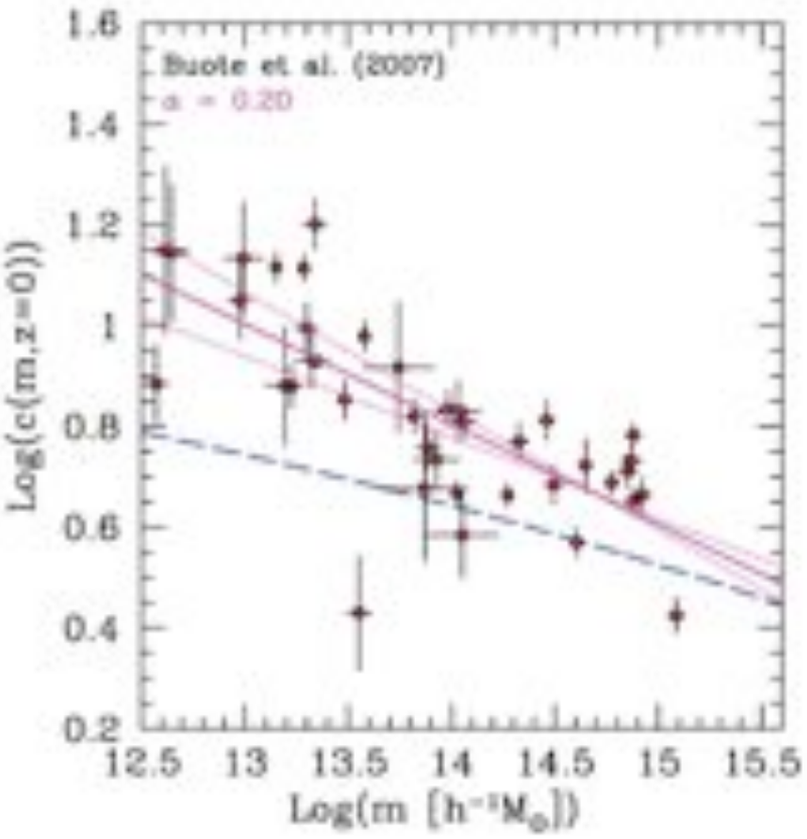


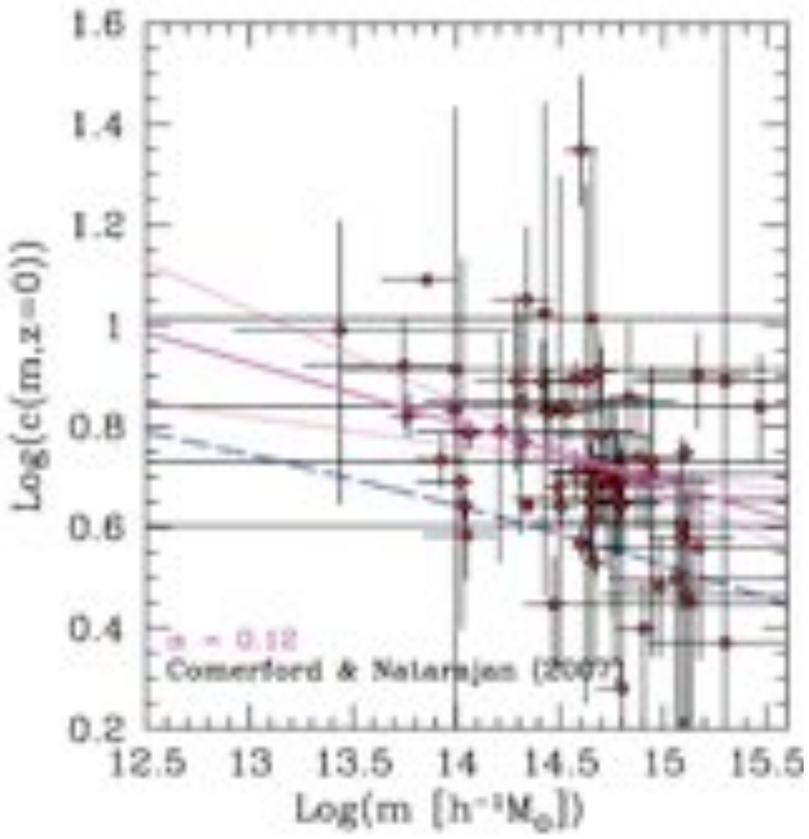
Concentration-mass: theoretical predictions

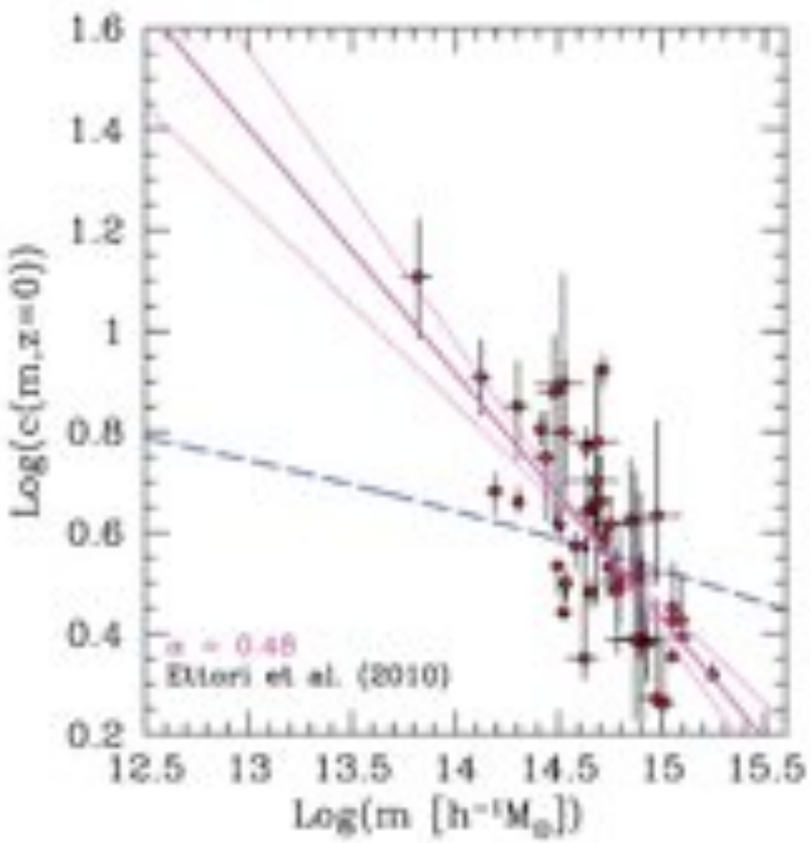
- The concentration is a measure of a halo compactness
- It mildly depends on mass
- Power-law with slope α ~ -0.1, seemingly independent on redshift and cosmology
- Normalization depends on cosmology, most notably σ_8
- Lognormal distribution with scatter ~ 0.25
- Redshift dependence is still unclear

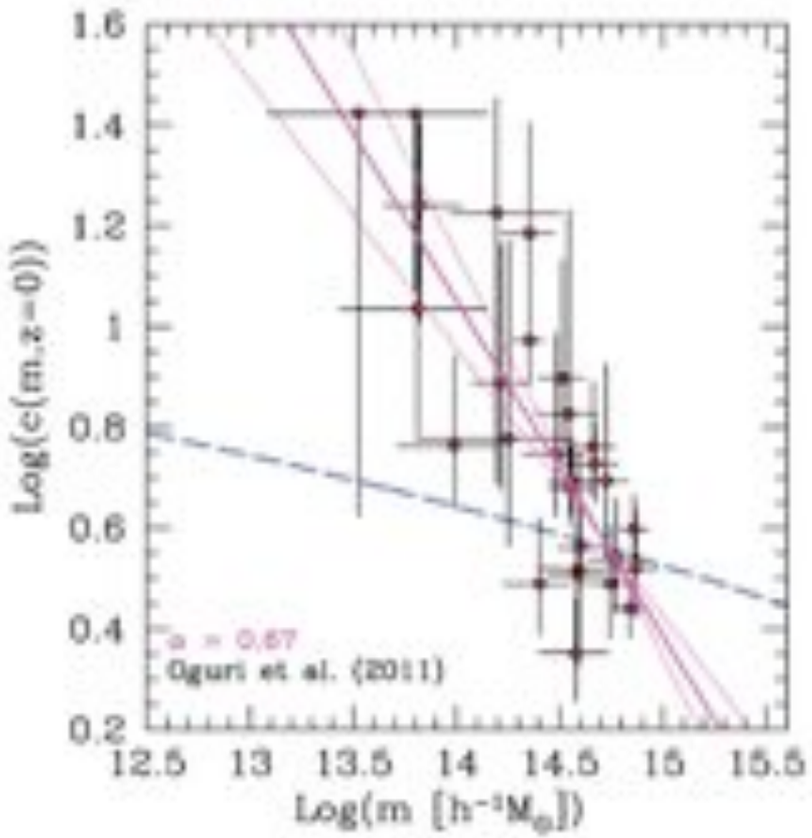


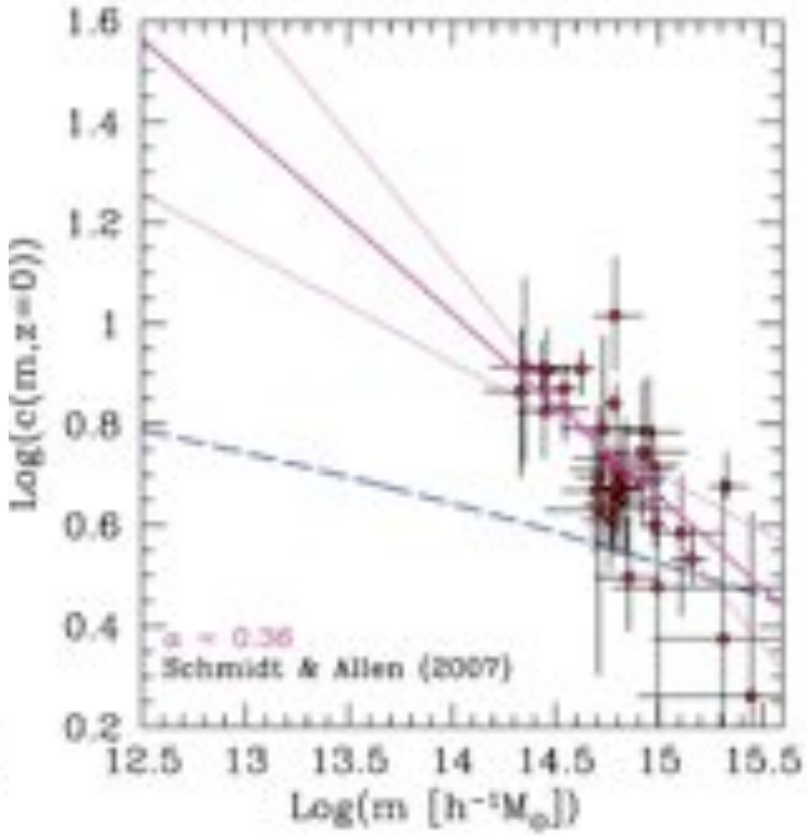


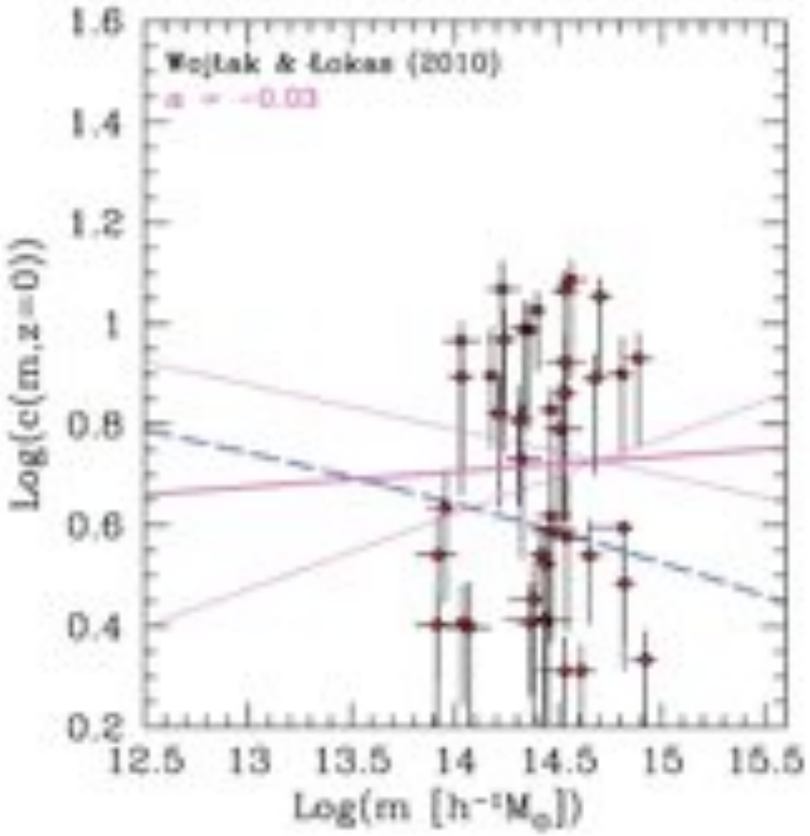

Buote et al. (2007)
α = 0.20
Log(c(m,z=0))
Log(m [h⁻¹M⊙])


α = 0.12
Comerford & Natarajan (2007)
Log(c(m,z=0))
Log(m [h⁻¹M⊙])


α = 0.46
Ettori et al. (2010)
Log(c(m,z=0))
Log(m [h⁻¹M⊙])


α = 0.67
Oguri et al. (2011)
Log(c(m,z=0))
Log(m [h⁻¹M⊙])


α = 0.36
Schmidt & Allen (2007)
Log(c(m,z=0))
Log(m [h⁻¹M⊙])

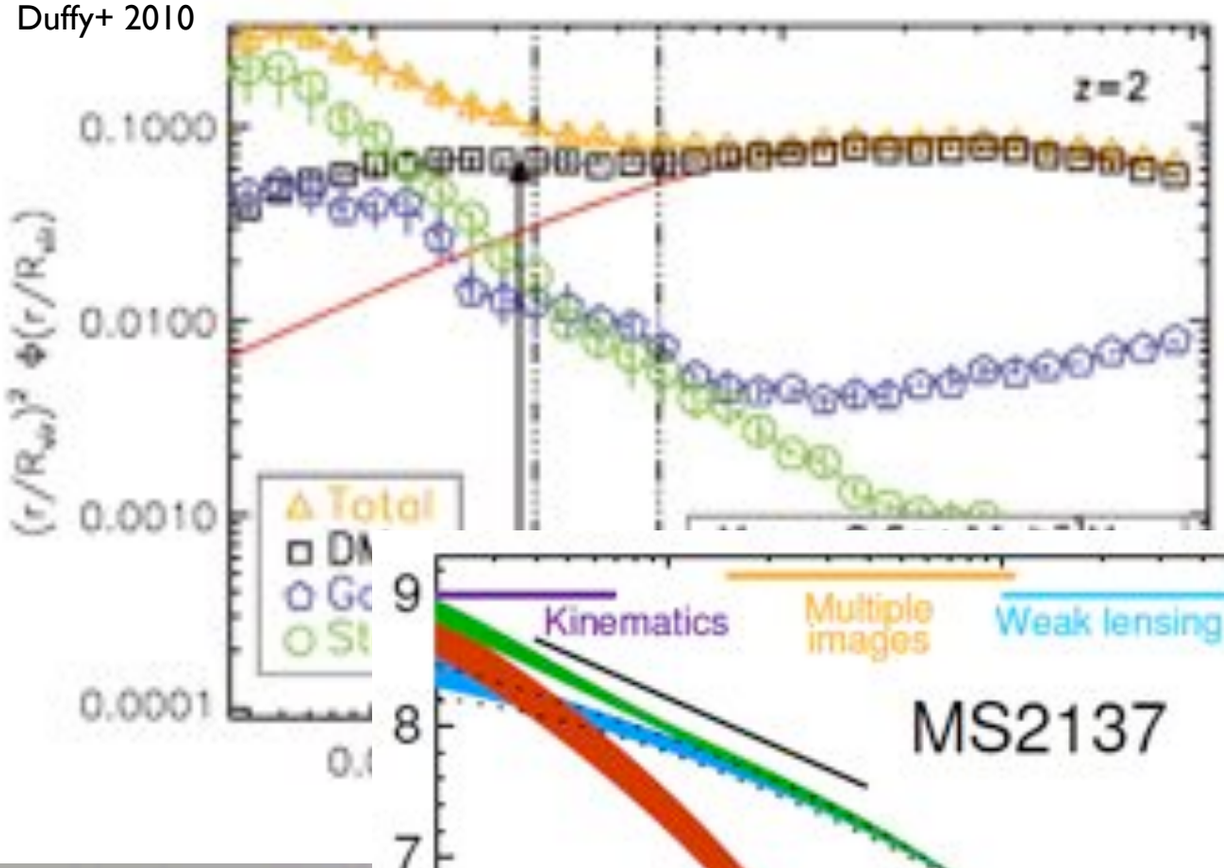

Wojtak & Lokas (2010)
α = -0.03
Log(c(m,z=0))
Log(m [h⁻¹M⊙])

Concentration-mass: observations

- Large sample-to-sample variance
- Observed slope can be as steep as α ~ -0.6
- Lensing selection bias does not account for the discrepancy
- Disagreement is more severe at low mass

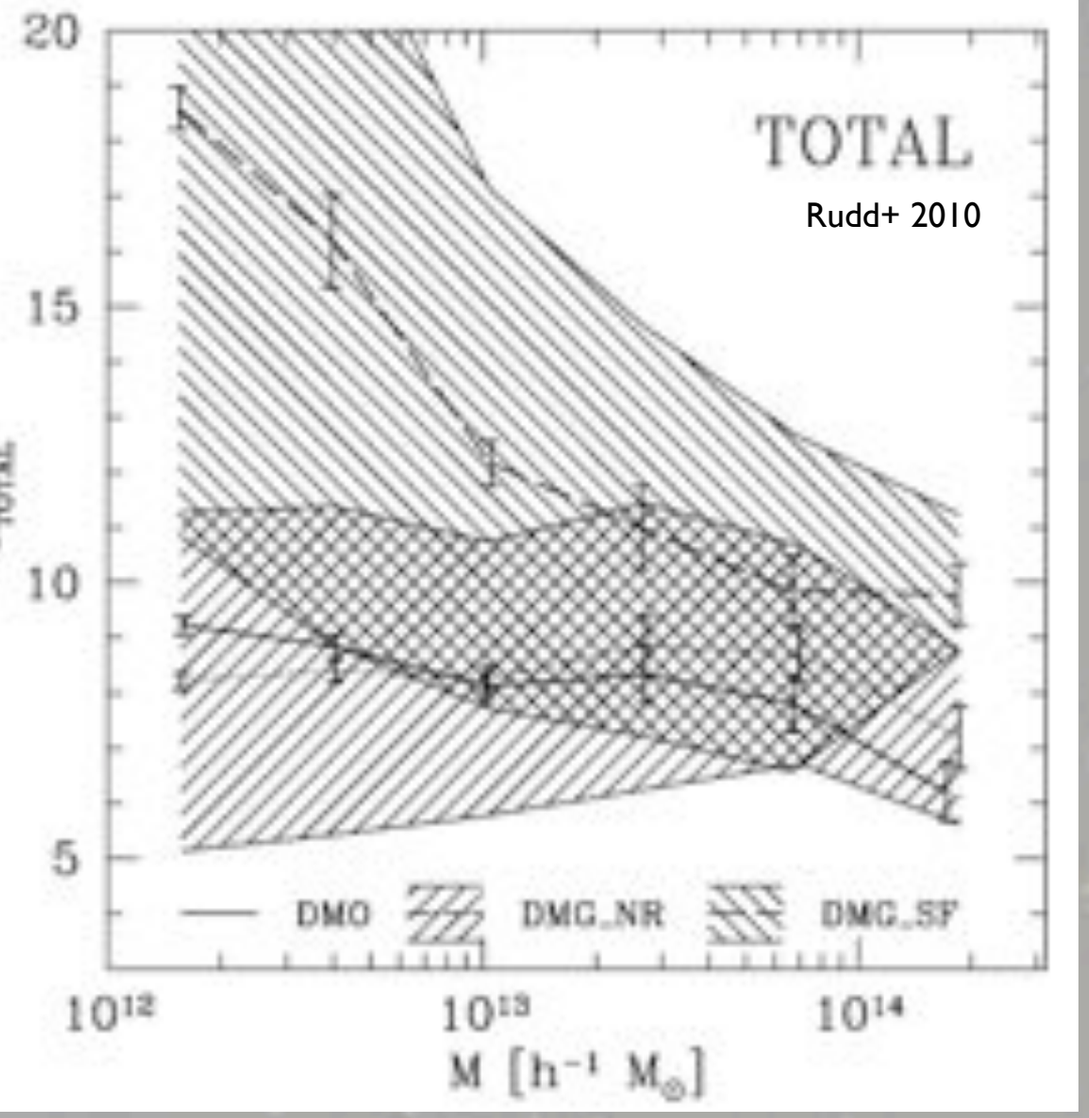
Gas cooling and star formation are important

Duffy+ 2010



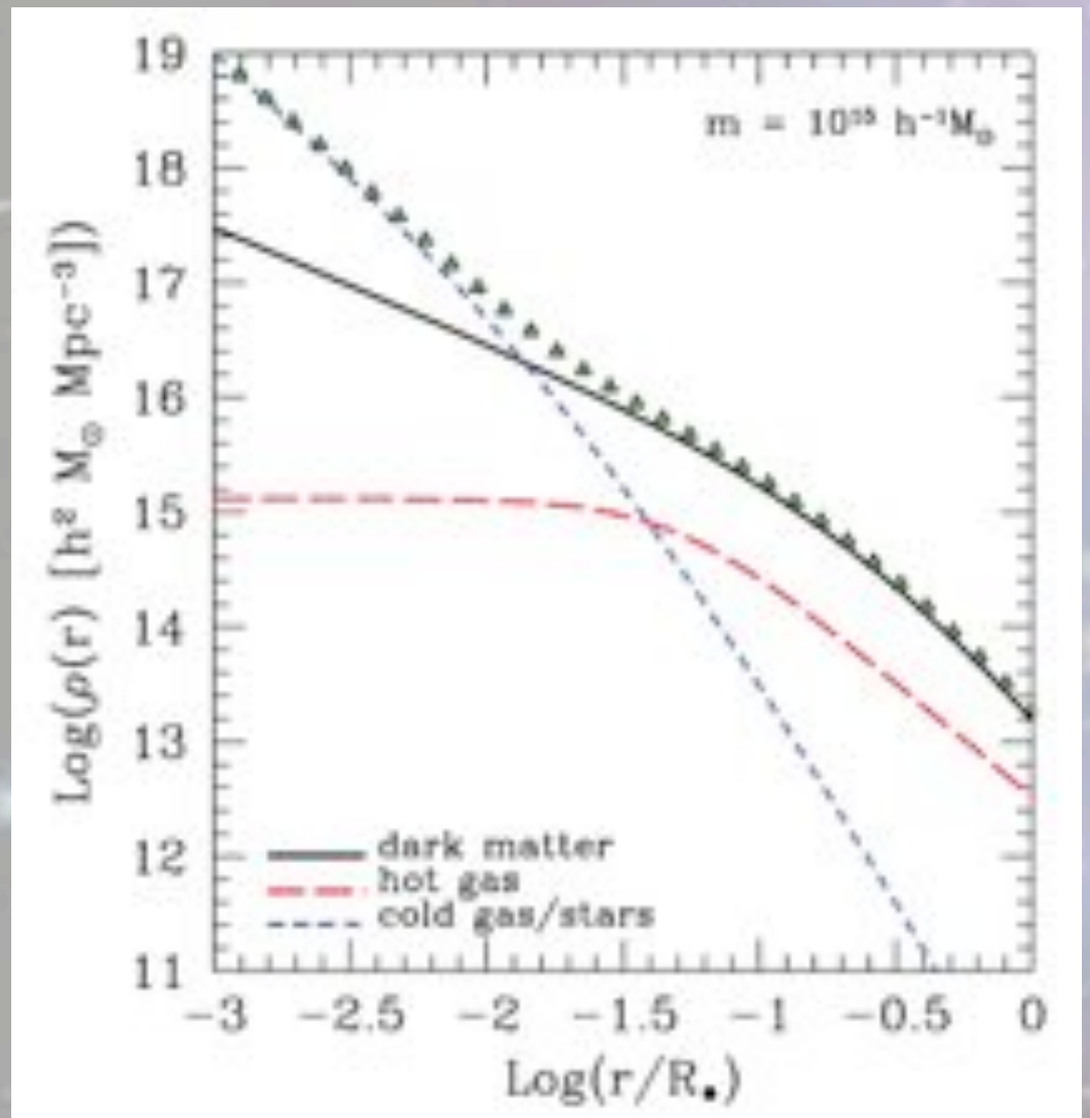
Newman+ 2012

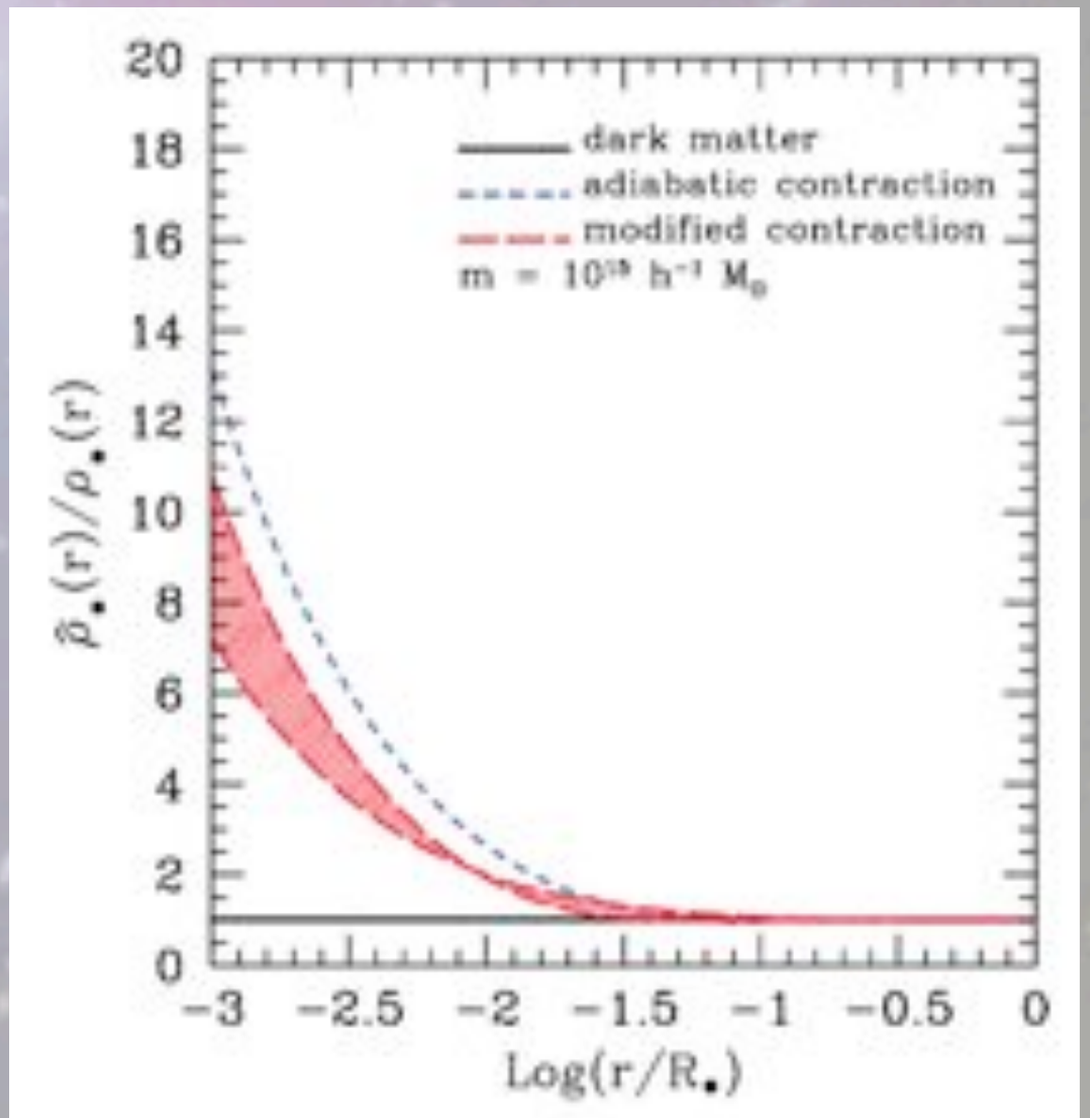
Rudd+ 2010



A simple toy model

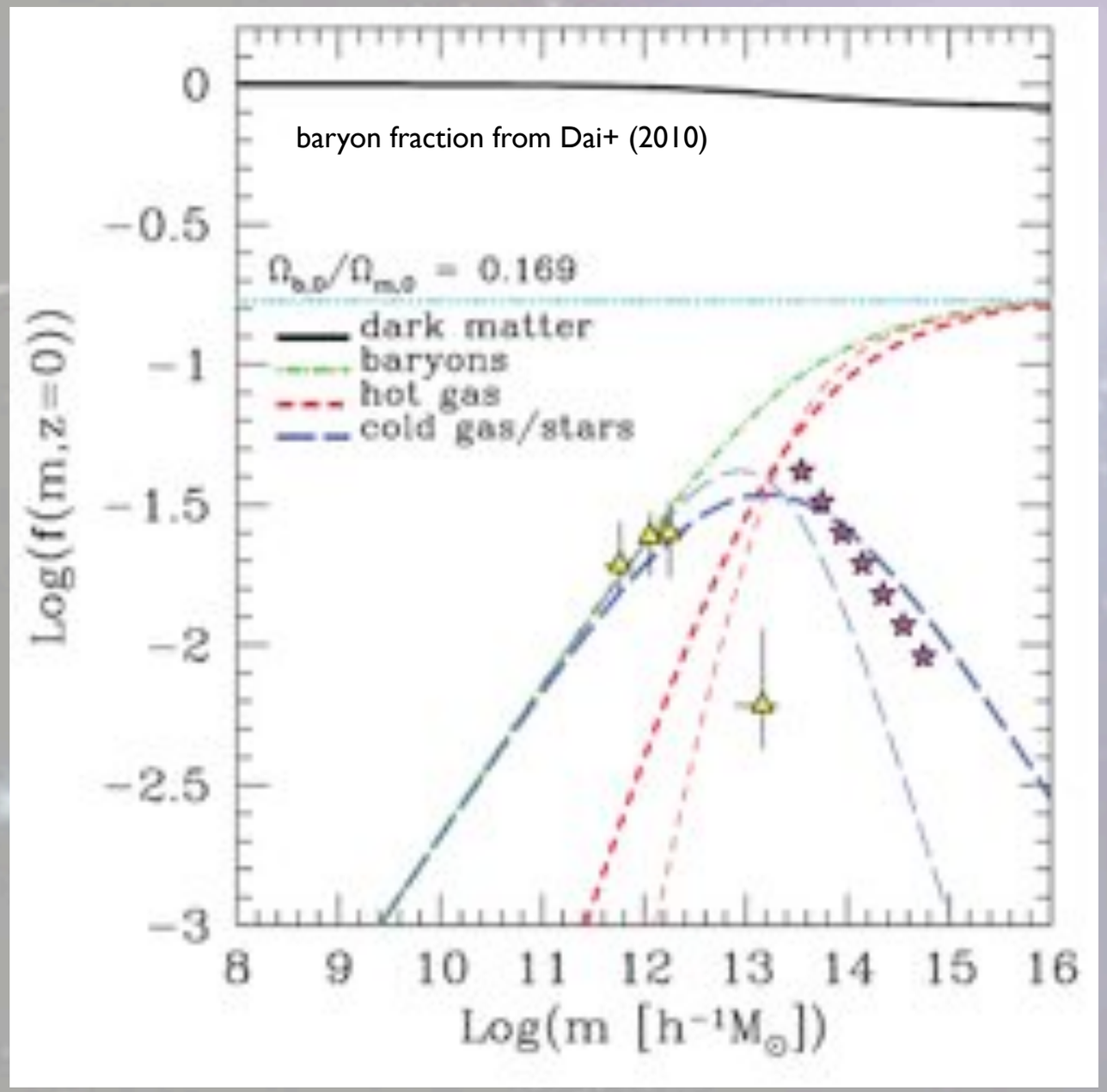
- Spherical halo model containing dark matter, gas, and stars
- Gas is distributed with a β-profile
- Stars are allocated according to a Jaffe profile
- Gas has little influence, while stars are dominating near the center
- Contraction of dark matter has to be taken into account





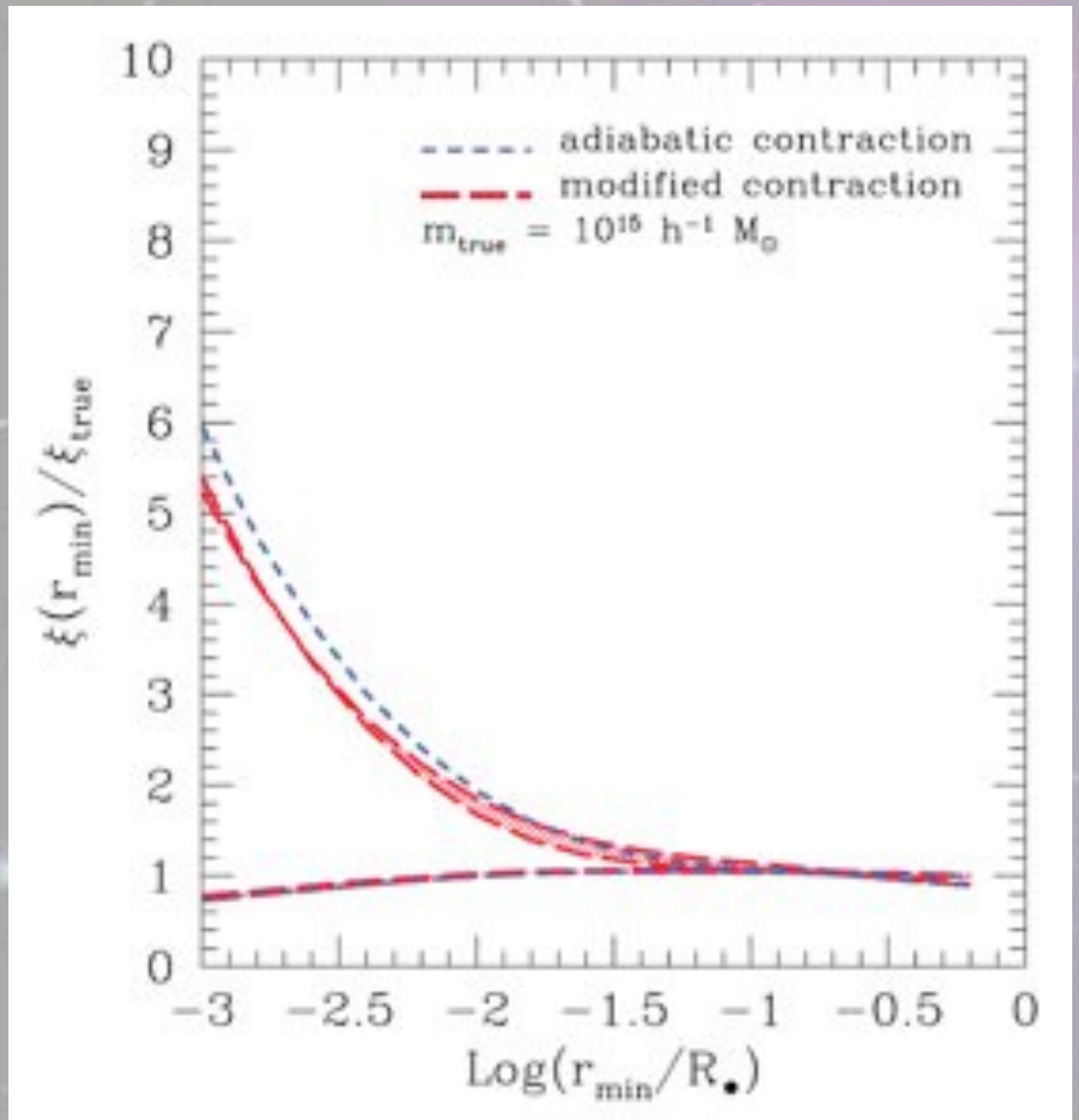
A simple toy model

One important ingredient: the baryon fraction



- Gas content grows steadily with mass
- Stellar fraction peaks at Log(m/M$_\odot$) ~ 12-13
- Total baryon fraction is constant at high mass
- The baryon fraction is still highly uncertain
- Several models bracket realistic alternatives

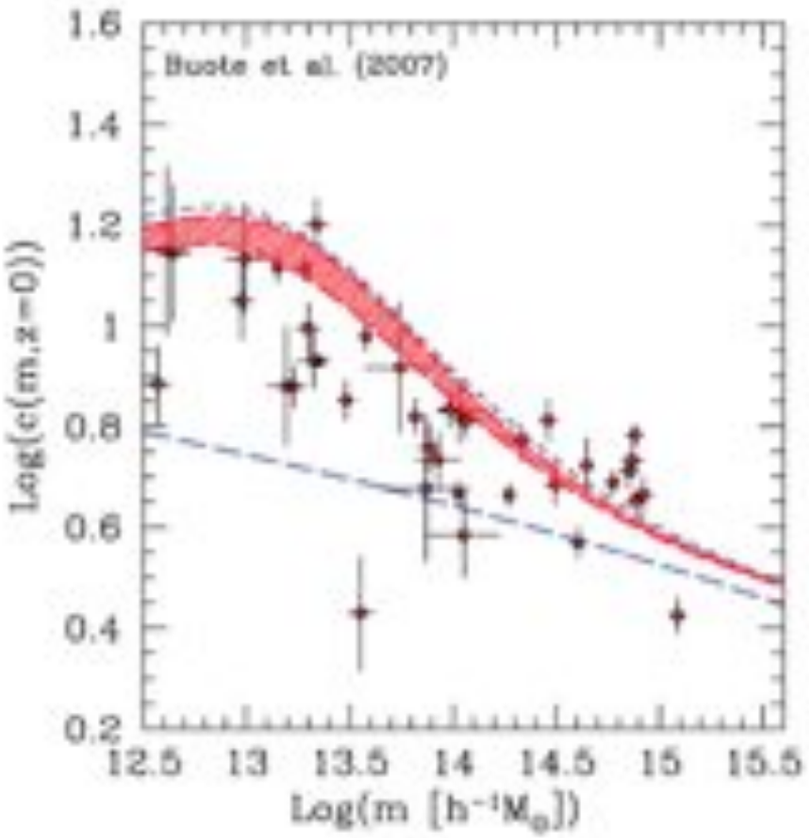
Main results

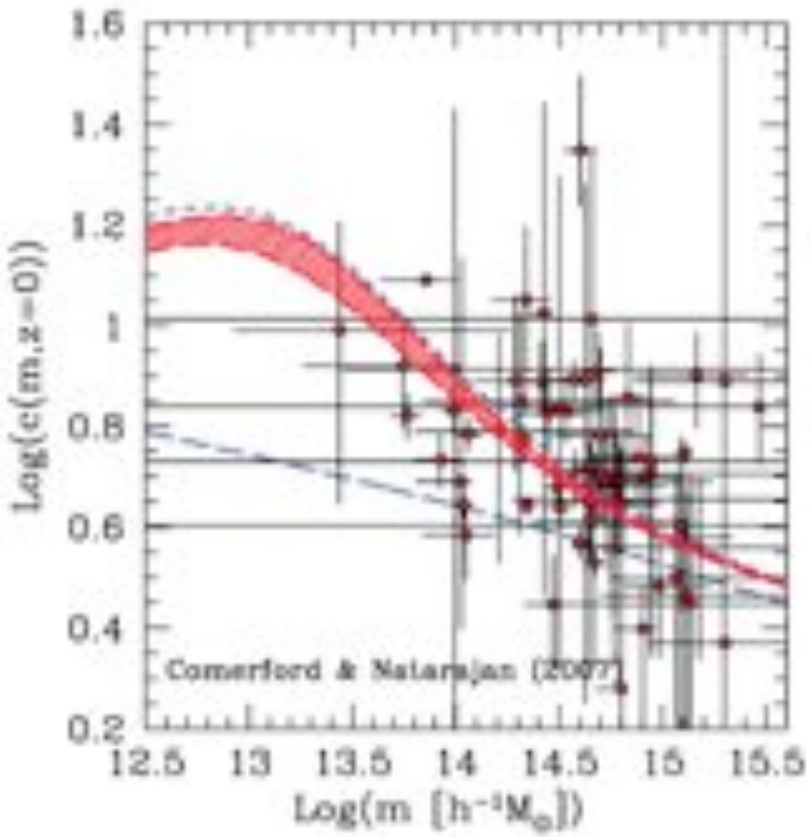


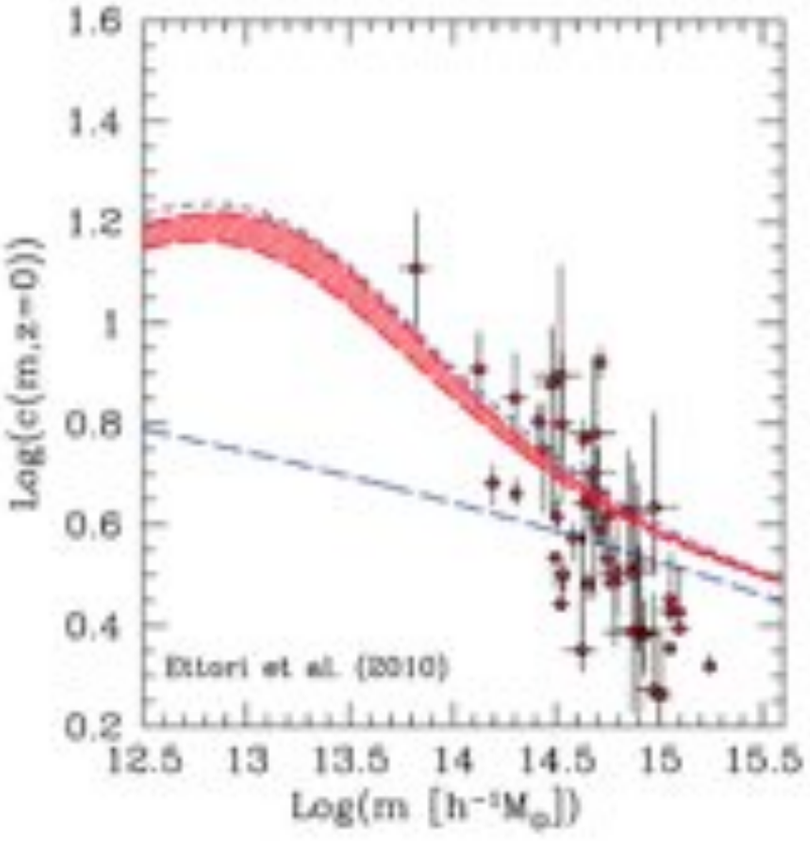
Halo mass estimate is almost unbiased by the effect of baryonic cooling

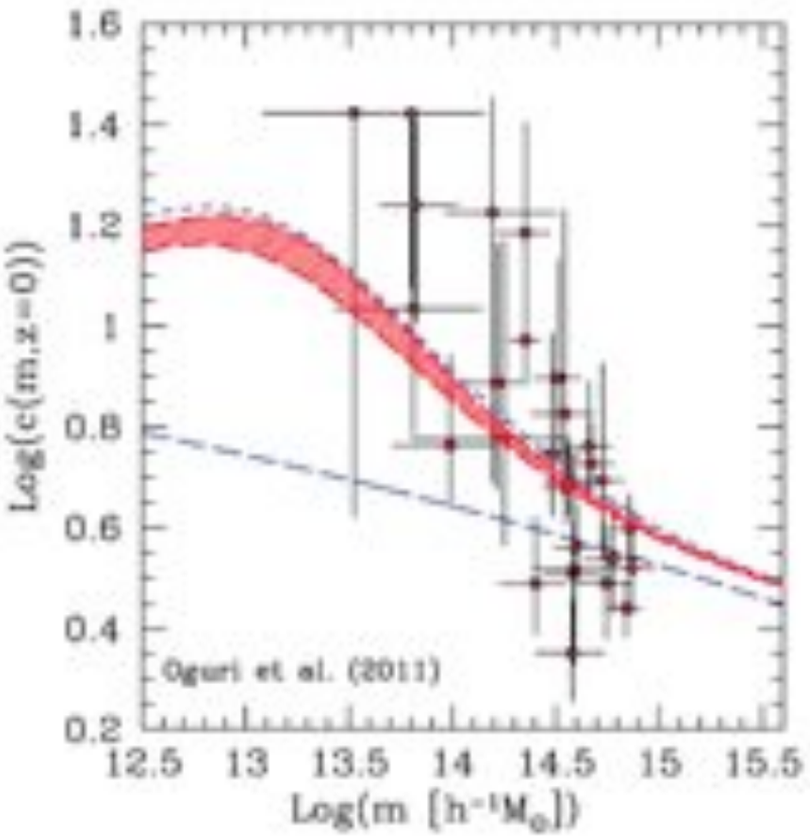
Dark matter halo concentration gets systematically overestimated, more so at low mass

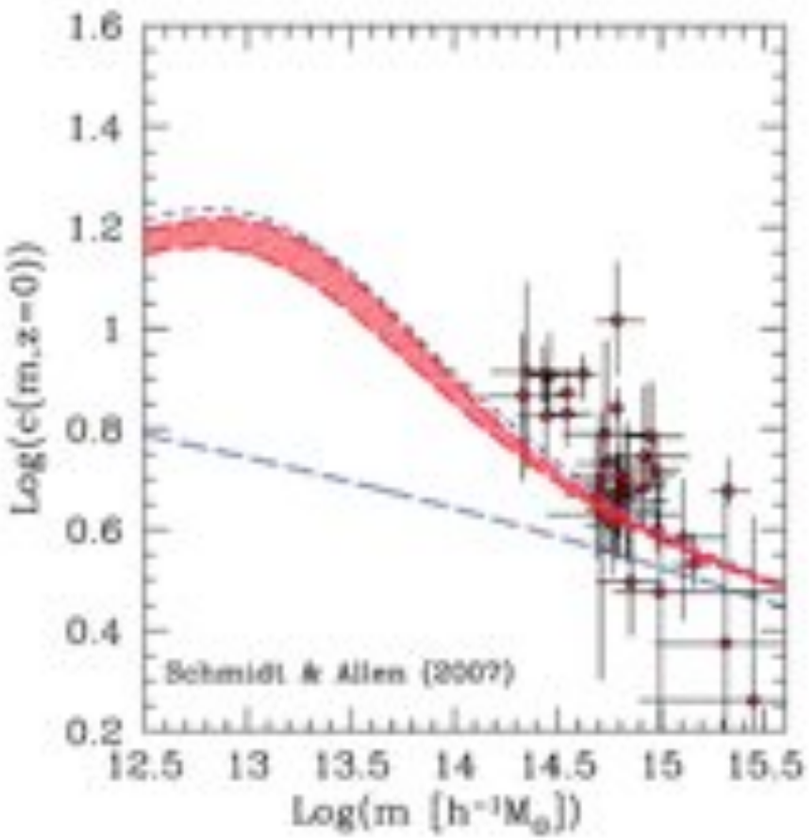
The level of overestimation depends on the radial range that is adopted for the fitting

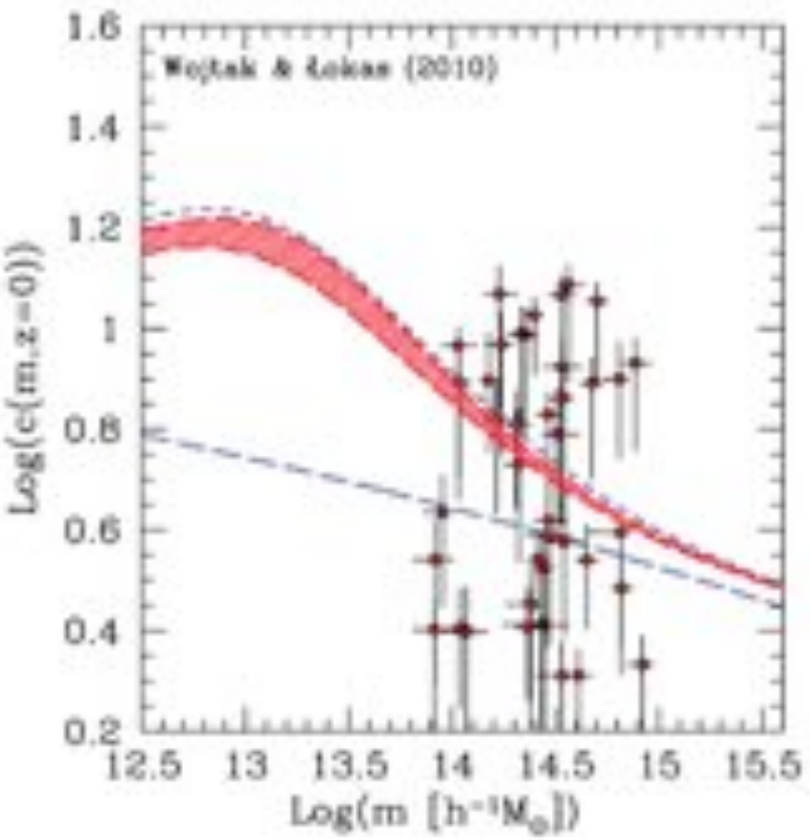

Buote et al. (2007)
Log(c(m,z=0))
Log(m [h⁻¹M⊙])


Comerford & Natarajan (2007)
Log(c(m,z=0))
Log(m [h⁻¹M⊙])


Ettori et al. (2010)
Log(c(m,z=0))
Log(m [h⁻¹M⊙])

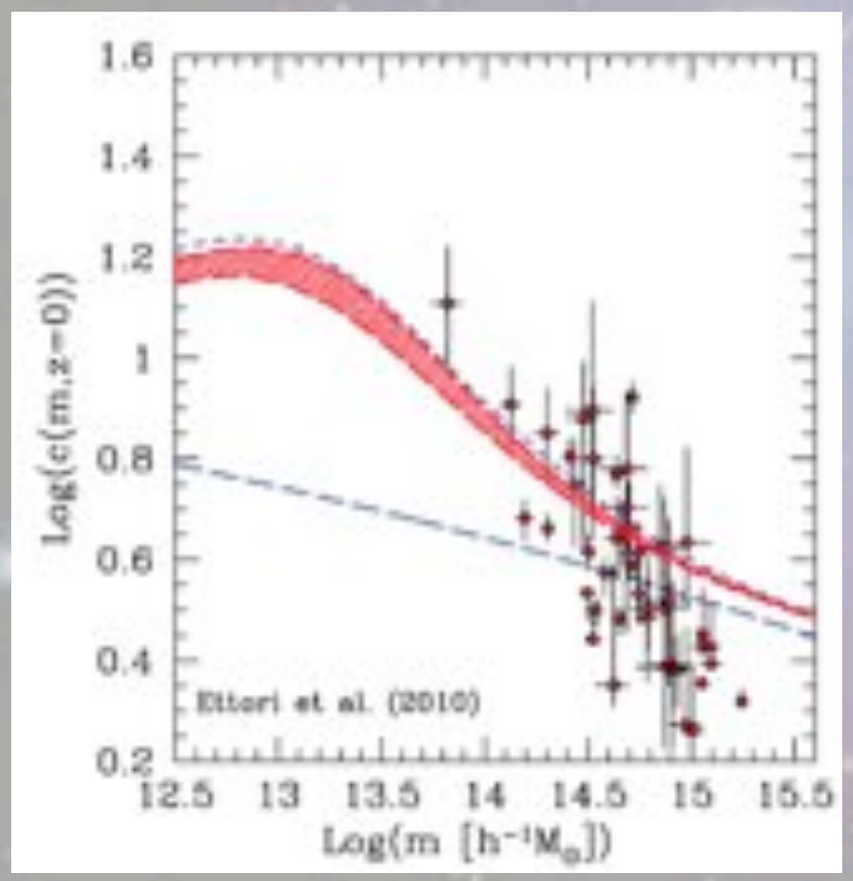

Oguri et al. (2011)
Log(c(m,z=0))
Log(m [h⁻¹M⊙])

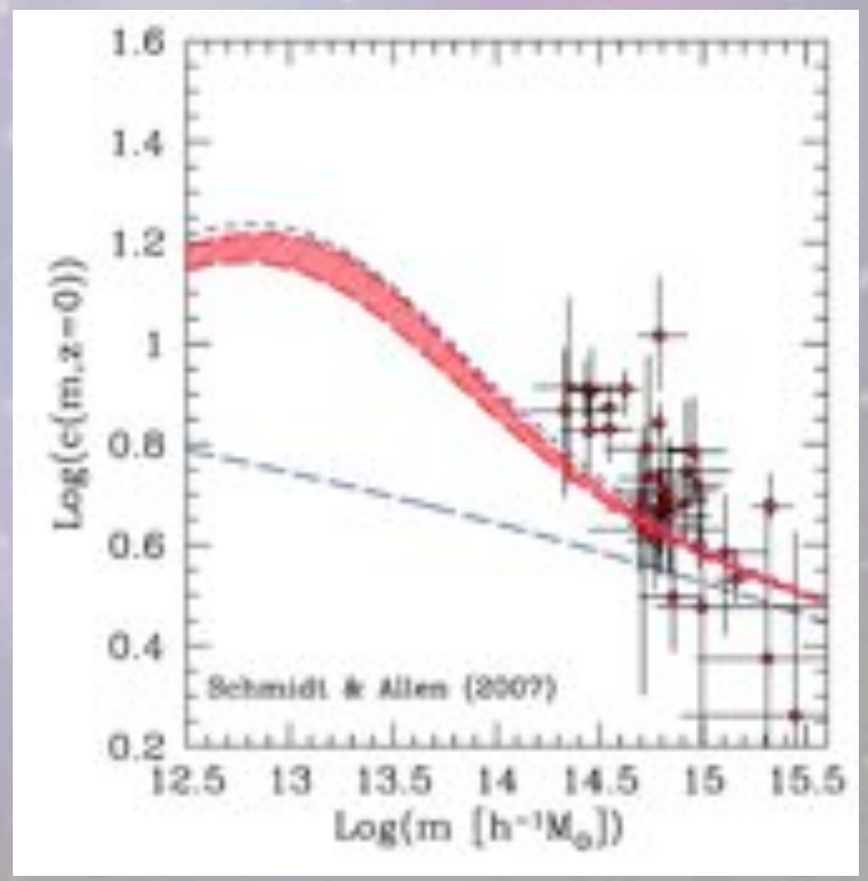

Schmidt & Allen (2007)
Log(c(m,z=0))
Log(m [h⁻¹M⊙])


Wojtak & Lokas (2010)
Log(c(m,z=0))
Log(m [h⁻¹M⊙])

Main results

- Almost all samples are **better represented** by the simple toy model
- Fitting of the Schmidt & Allen (2007) sample (X-ray) has the best improvement (χ^2 is halved)
- Fitting of the Ettori+ (2010) sample (X-ray) is basically unchanged
- Low-concentration clusters **cannot be accounted** for by this model
- AGN energy injection might be responsible for underconcentrated objects (but need further study)





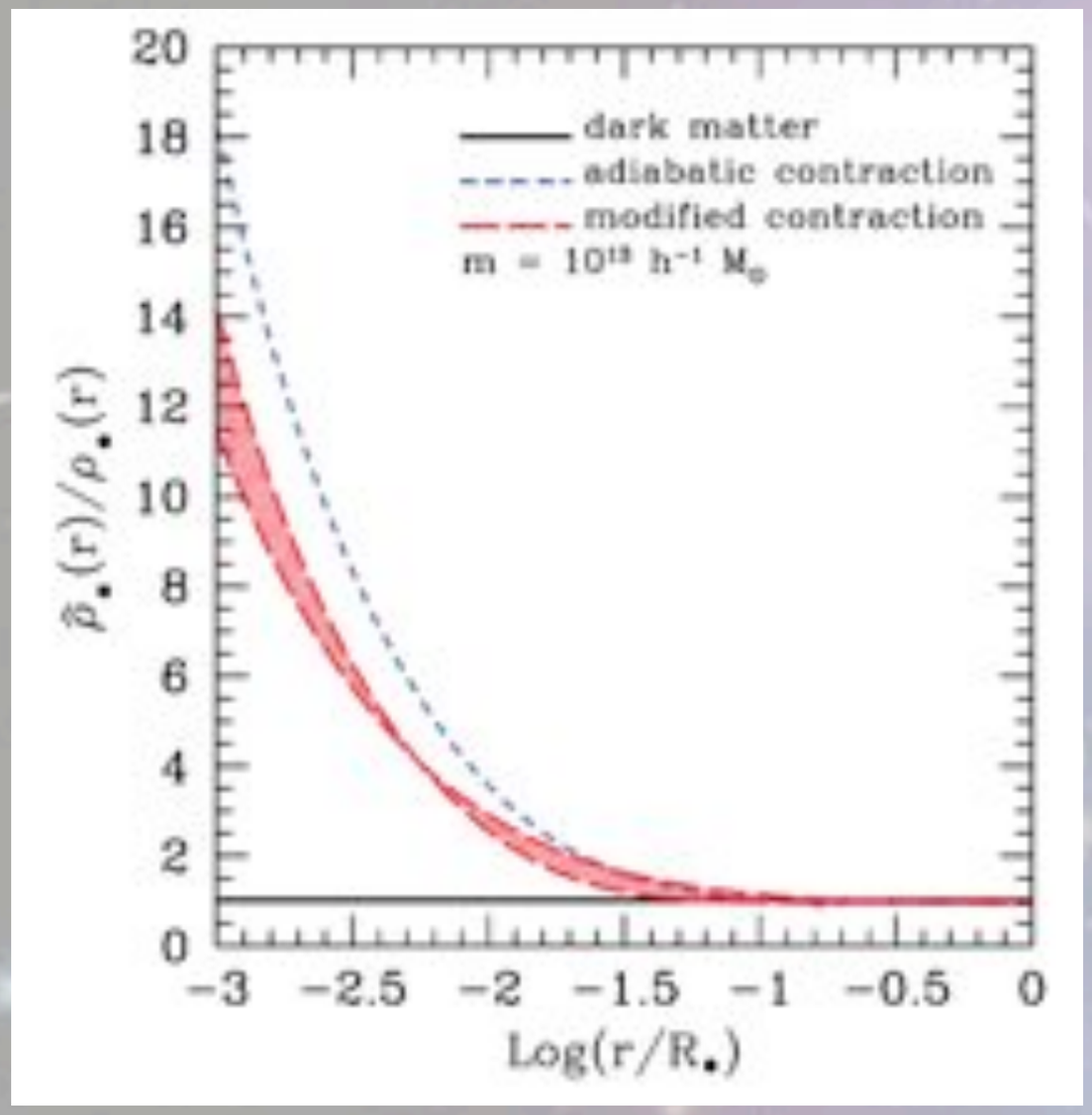
Summary

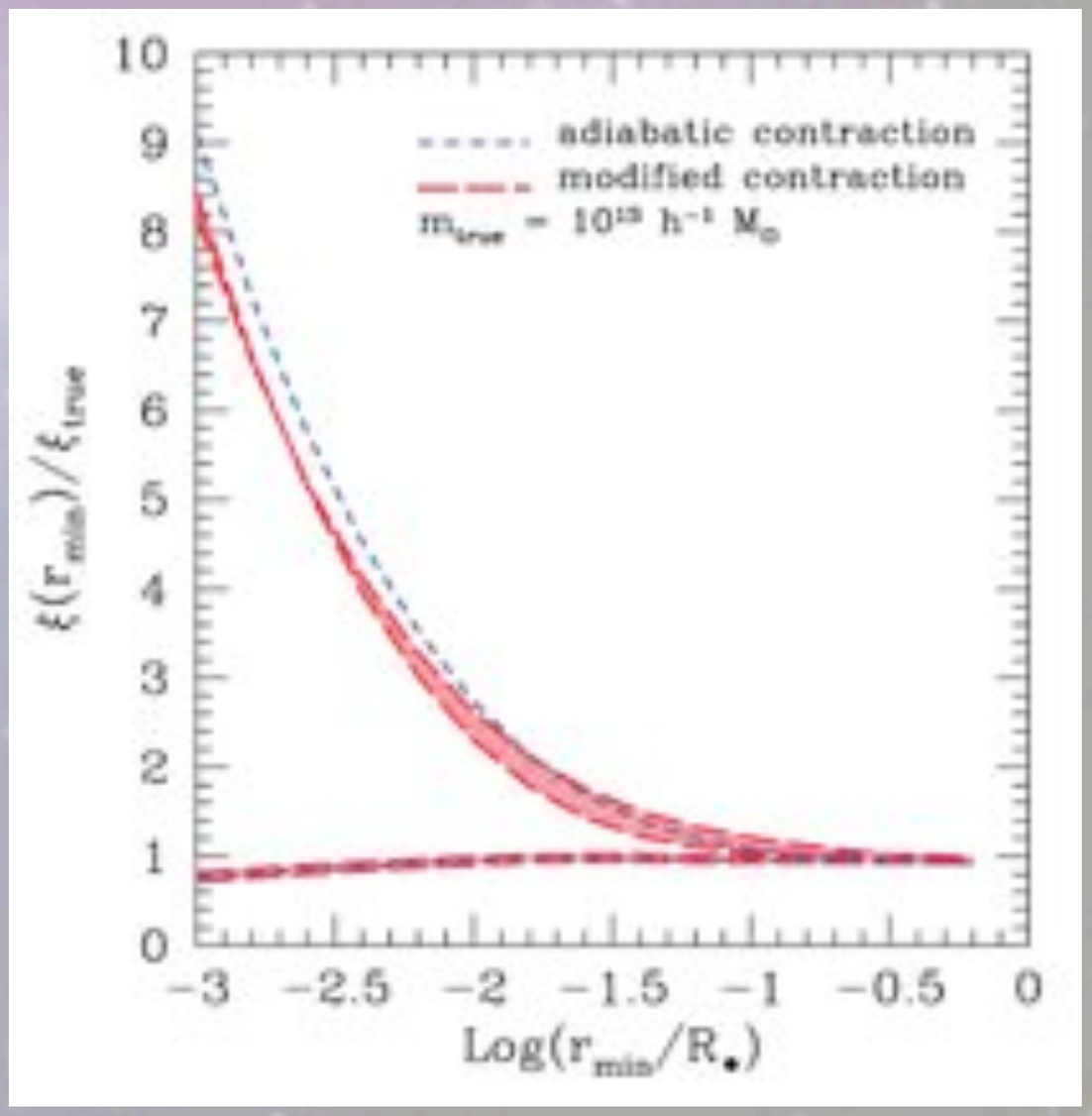
- Numerical simulations predict a mildly declining c-m relation, with slope α ~ -0.1
- Observed concentrations of galaxy groups are substantially larger than expected
- As a result, the observed c-m slope can be as steep as α ~ -0.6
- Gas cooling and star formation partially mends this, affecting more low-mass objects
- Almost all samples are better fit by a toy model with baryonic physics

Open Issues

- Reduce the sample-to-sample variance: larger homogeneous catalogs
- Define the concentration redshift dependence: deeper catalogs
- Understand the impact of AGN: numerical simulations/semi-analytic models
- Reconsider the use of concentrations: ellipticity and substructures?

THANK YOU!


dark matter
adiabatic contraction
modified contraction
m = 10^13 h^-1 M_⊙
ρ̂_•(r)/ρ_•(r)
Log(r/R_•)


adiabatic contraction
modified contraction
m_true = 10^13 h^-1 M_⊙
ξ(r_min)/ξ_true
Log(r_min/R_•)