Are the halo occupation predictions consistent with large scale clustering of galaxies in simulations?

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arXiv:1306.5761

ICTP, Trieste, October 9th, 2013

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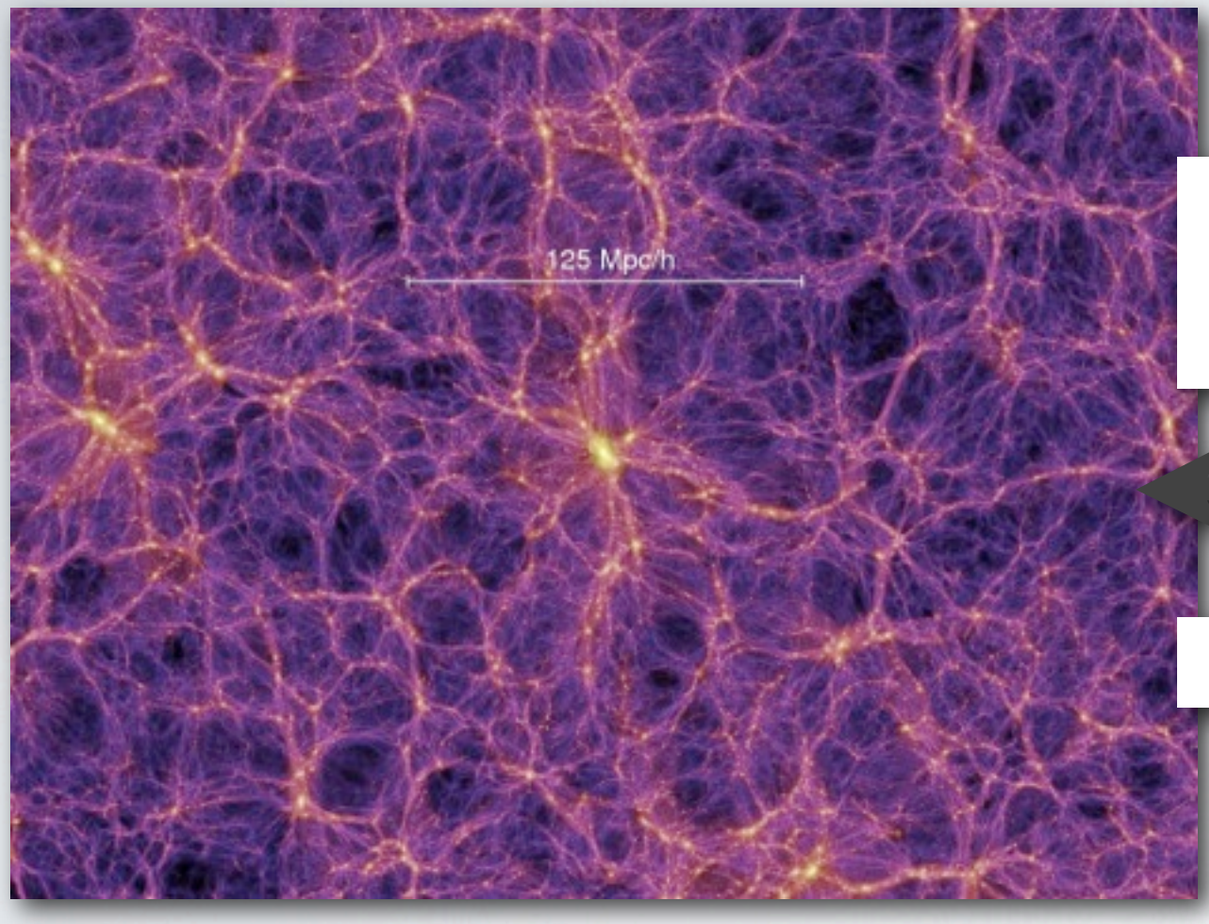
Outline

- Introduction and goals
- Millennium Simulation
- Bias and HOD
- Reconstructions of galaxy bias
- Halo vs galaxy bias
- Subhalo occupation
- Conclusions

Introduction

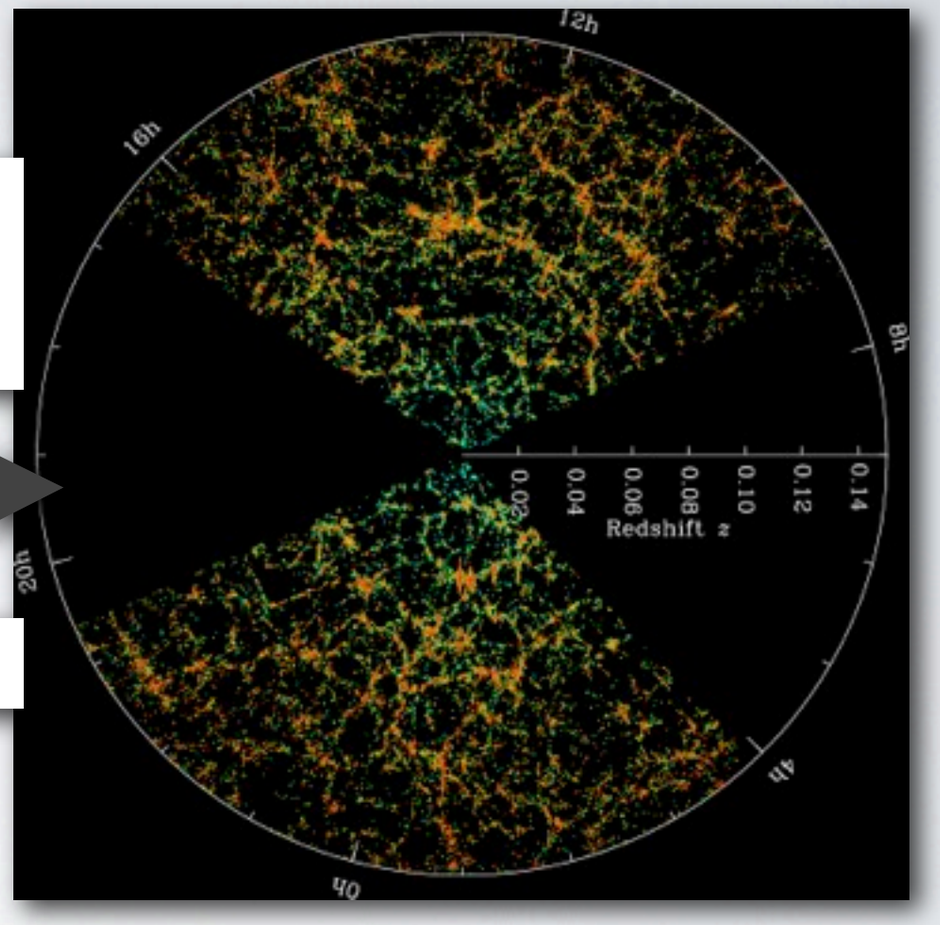
Millennium Simulation



galaxy formation models

HOD

SDSS



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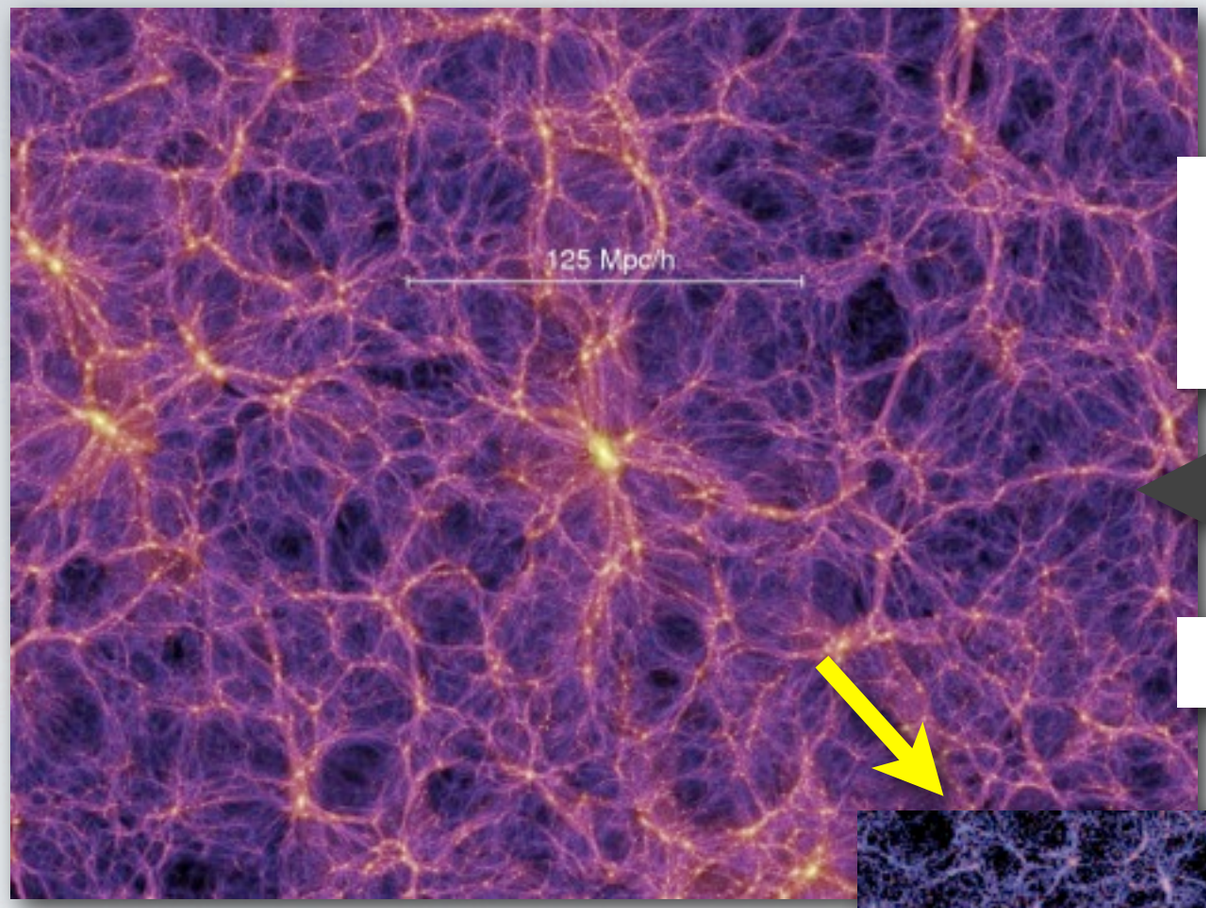
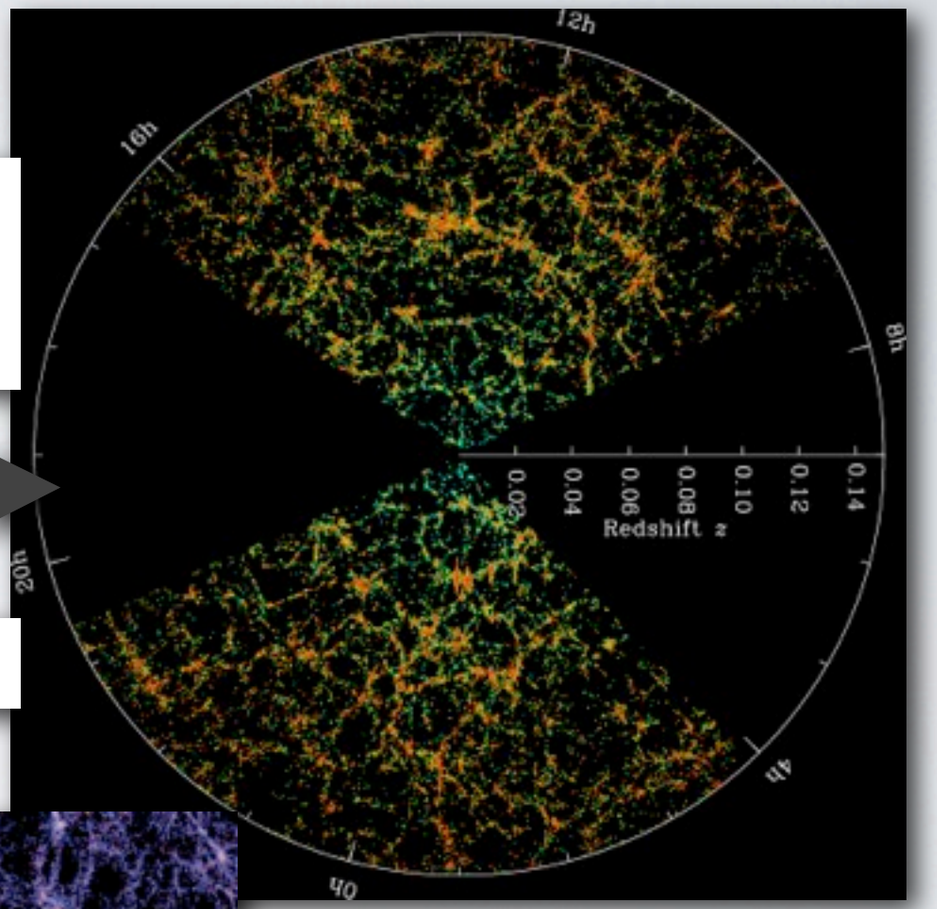
Millennium Simulation

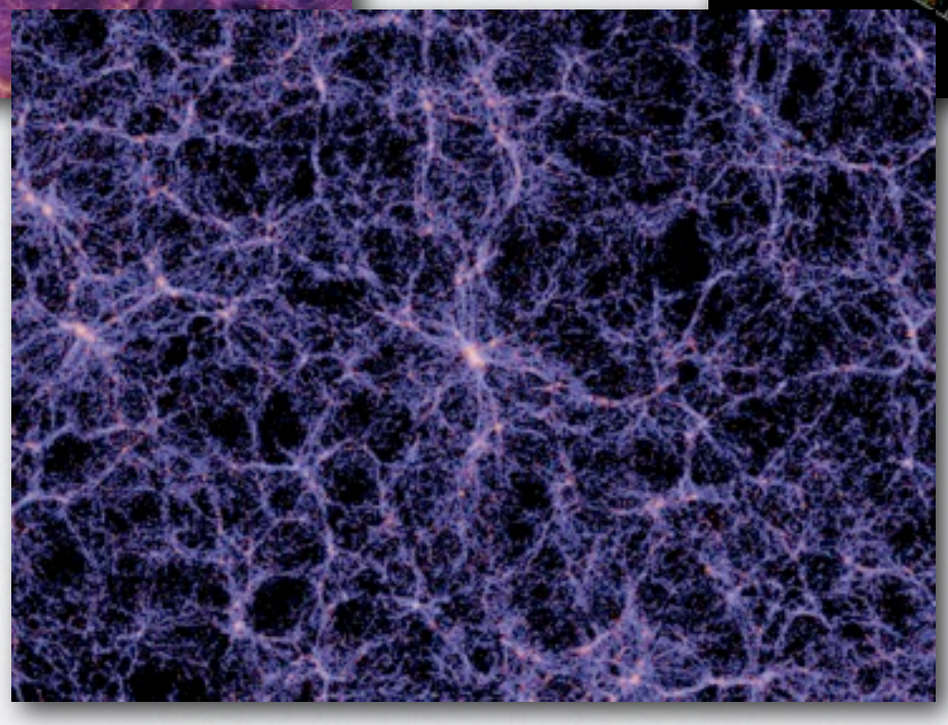
SDSS



galaxy formation models



HOD



galaxy catalog

Introduction

HOD model

$$N(M) = N_c(M) + N_s(M)$$

$$N_c(M) = \frac{1}{2}\left[1 + erf\left(\frac{\log M - \log M_{min}}{\sigma_{\log M}}\right)\right]$$

$$N_s = N_c(M) \times \left(\frac{M - M_0}{M_1}\right)^{\alpha}$$

Zheng et al. 2005

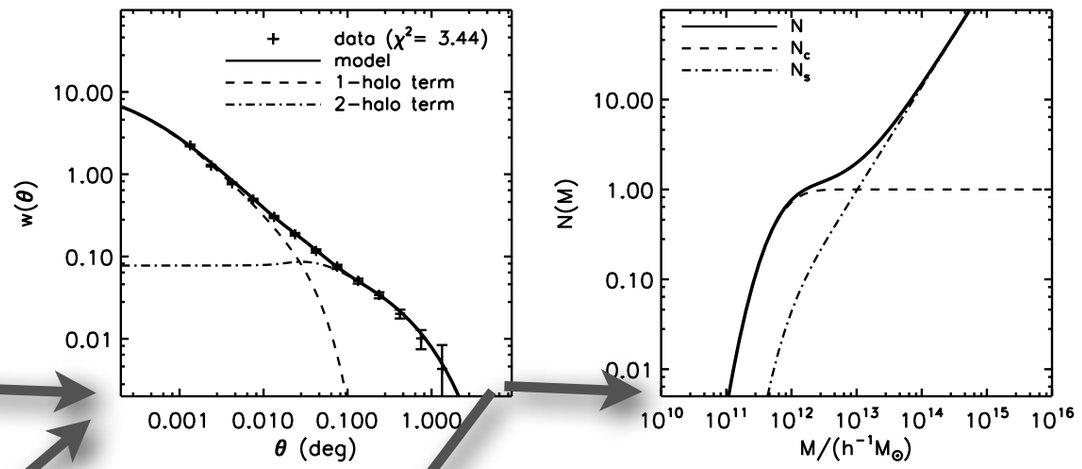
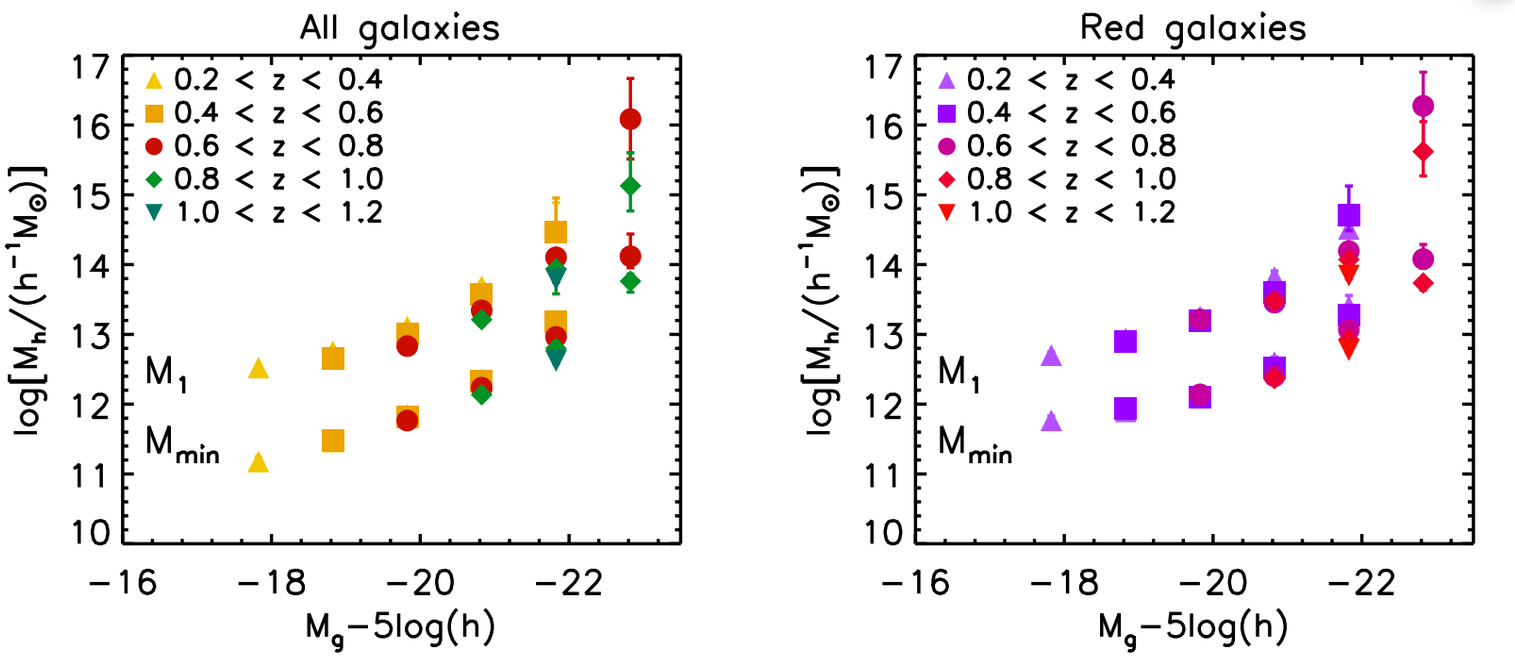


Fig. 7. Example of a measured $w(\theta)$ (all galaxies in the redshift range $0.4 < z < 0.6$ and for $Mg - 5\log h < -19.8$), as well as the best-fitting model, as described in sec. 4. Left: $w(\theta)$ measurement and model. Right: $N(M)$, showing the central term N_{cent} and the satellite term N_s.

$$\xi_{gal}(r) = \xi^{1\mathrm{halo}}_{gal}(r) + b^2_{gal}\xi^{\mathrm{Lin}}_{dm}(r)$$

Coupon et al. 2012

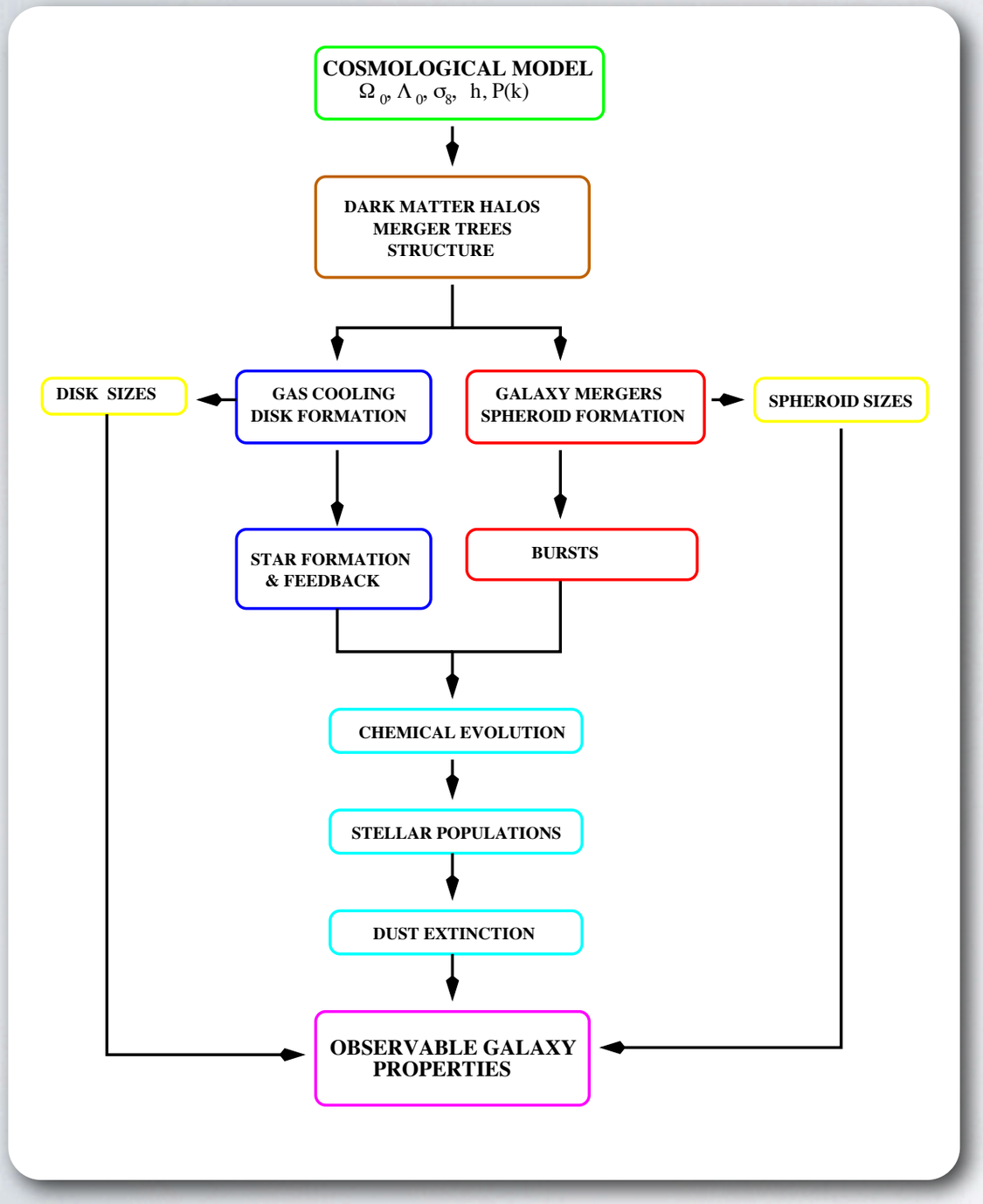


M_1 and M_{min} vs galaxy luminosity thresholds for all (left) and red (right) galaxies.

Coupon et al. 2012

Introduction

Semi-Analytical models



Cole et al. 2000

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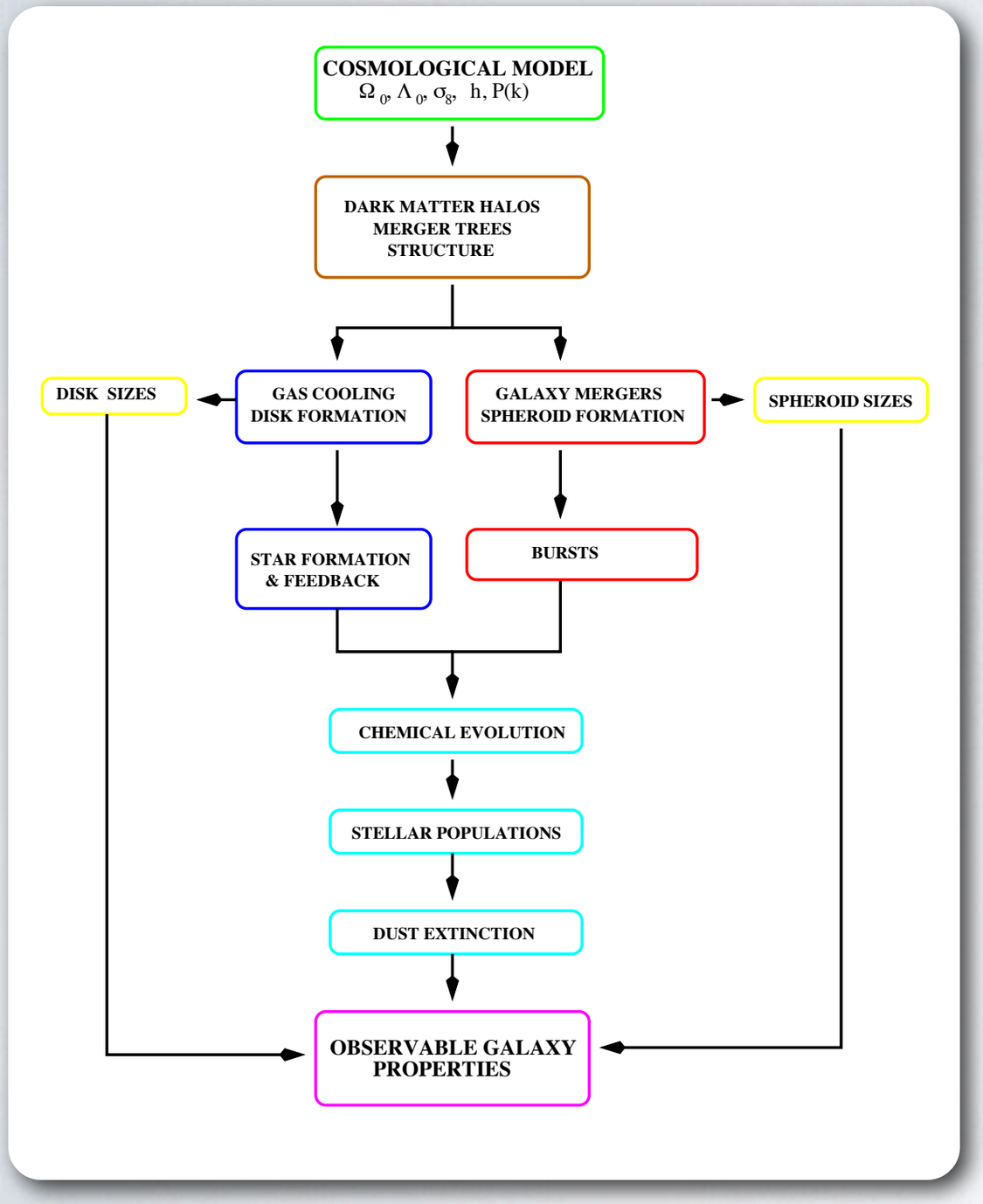
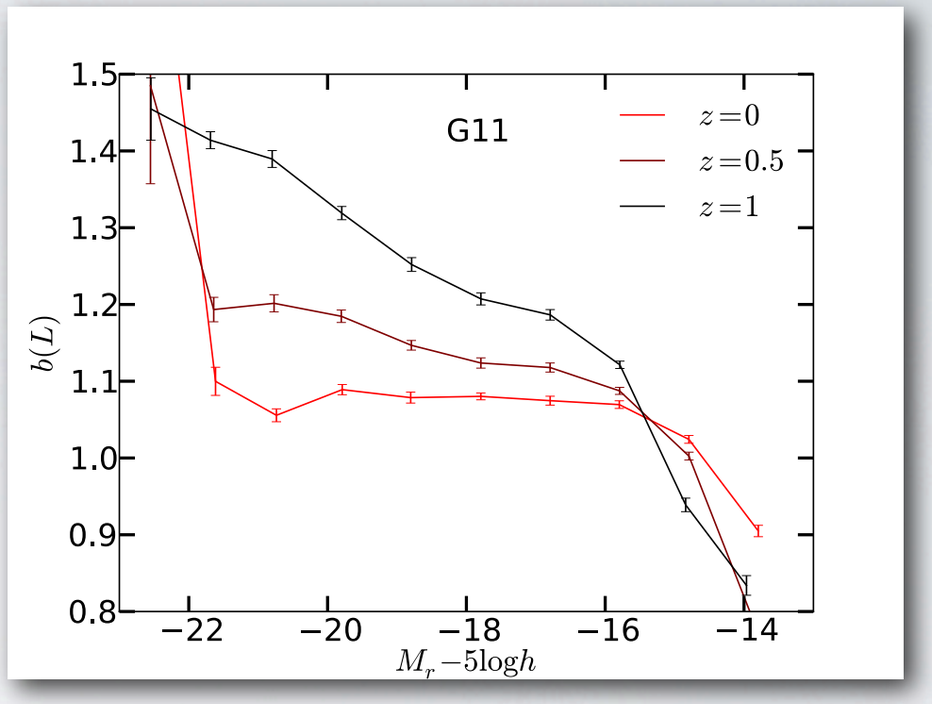


Cole et al. 2000

galaxy bias Guo et al. 2011 model



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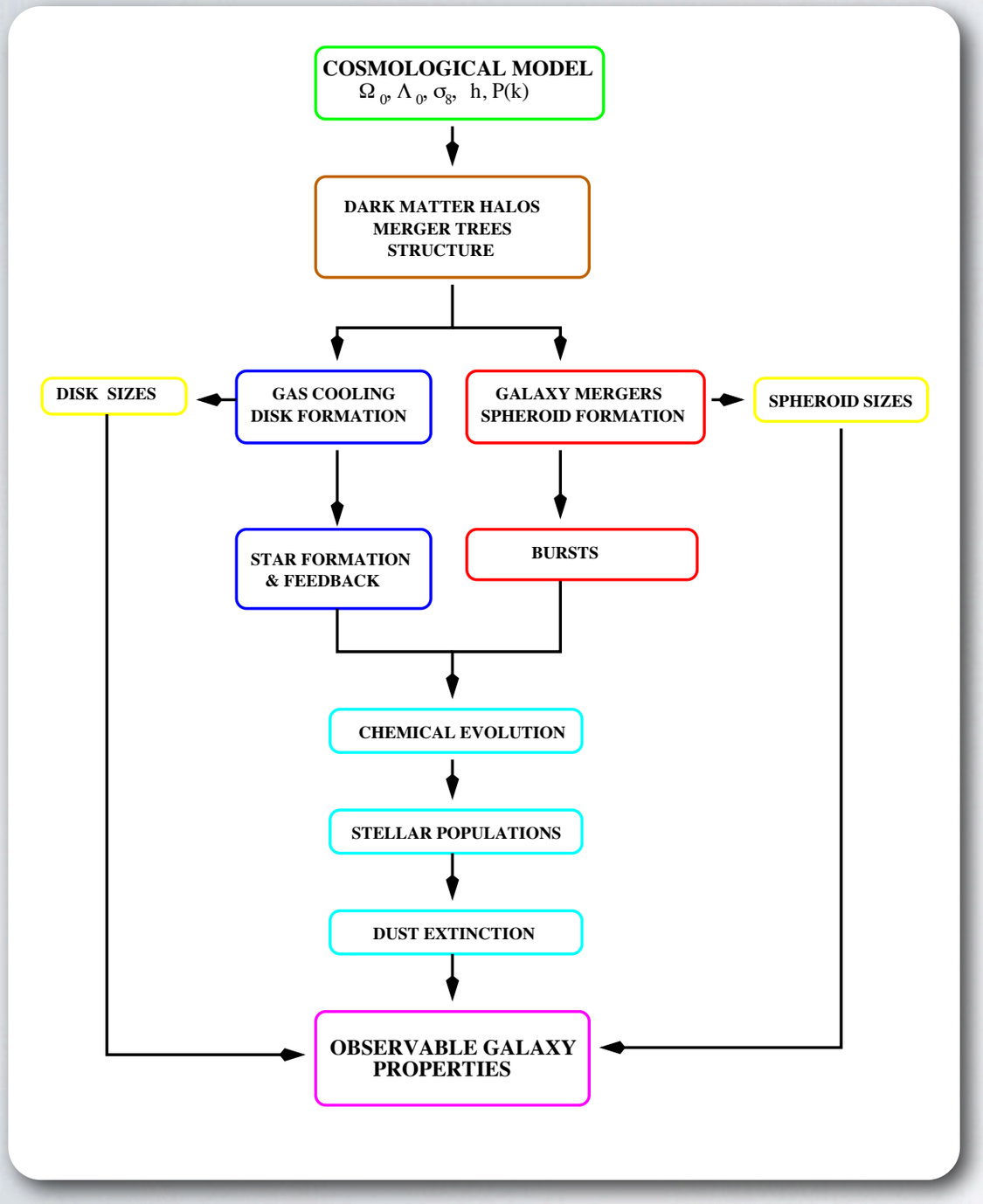

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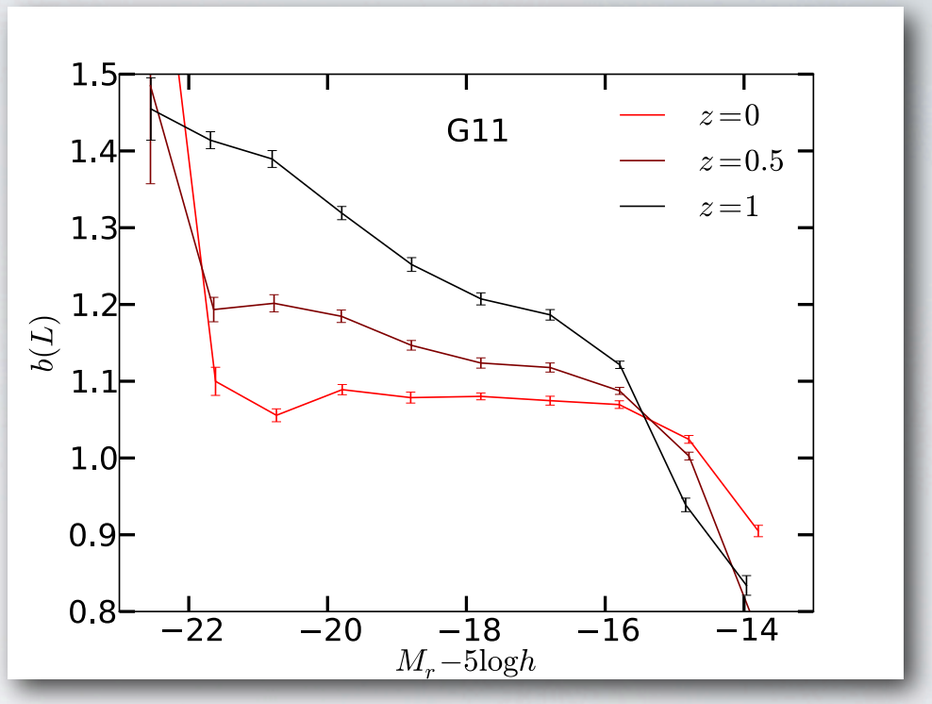


HOD ?

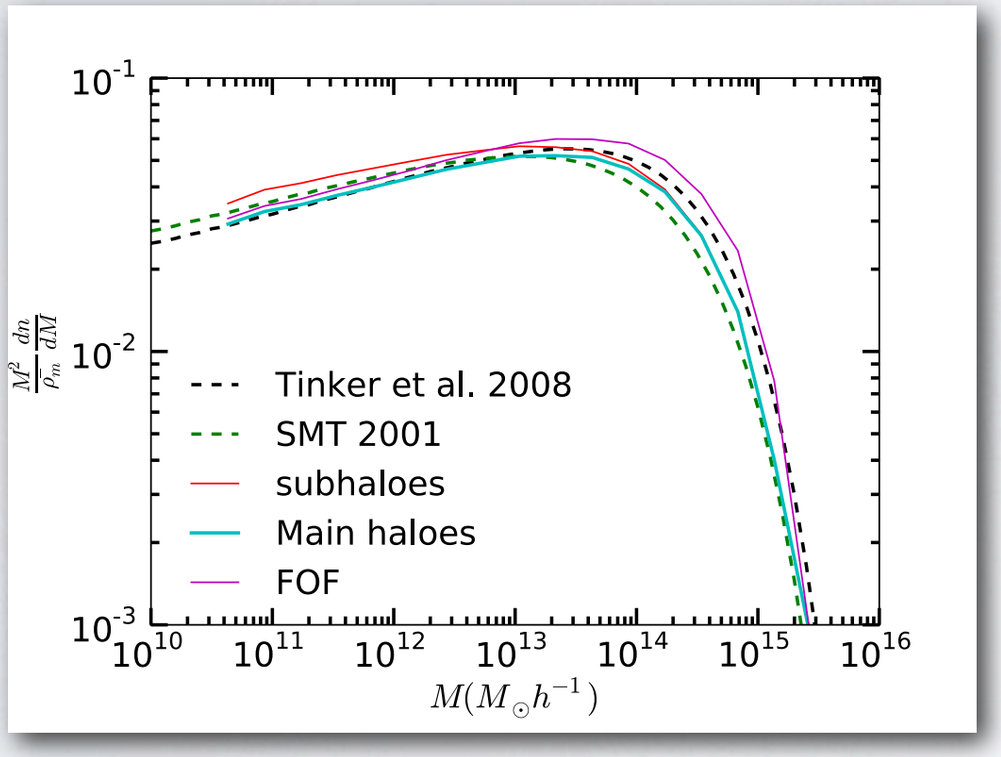
Millennium Simulation

(Springel et al. 2005)

ΛCDM with:

$$\Omega_m = 0.25 \quad n = 1$$
$$\Omega_\Lambda = 0.75 \quad \sigma_8 = 0.9$$
$$h = 0.73$$

$$V = (500 h^{-1} Mpc)^3$$
$$m_p = 8.6 \times 10^8 M_\odot$$



Normalized mass function of haloes, main haloes and subhaloes

- haloes: FOF with linking lenth b=0.2
- subhaloes: SUBFIND algorithm (Springel et al. 2001)
- main haloes: largest SUBFIND object in FOF

Millennium Simulation

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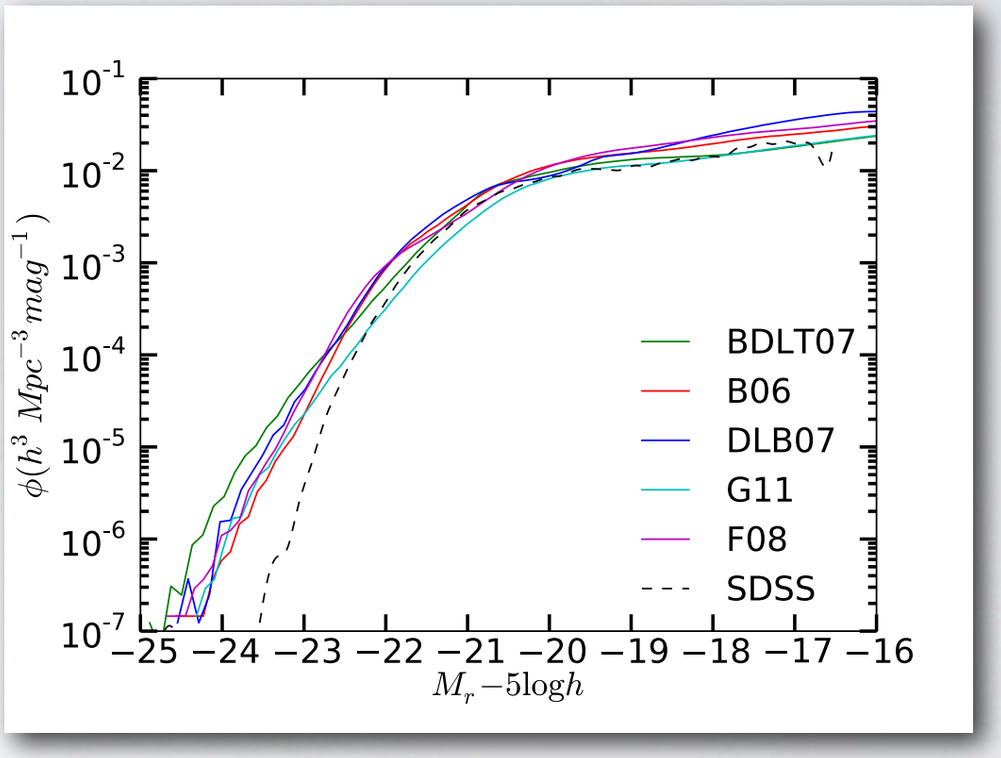
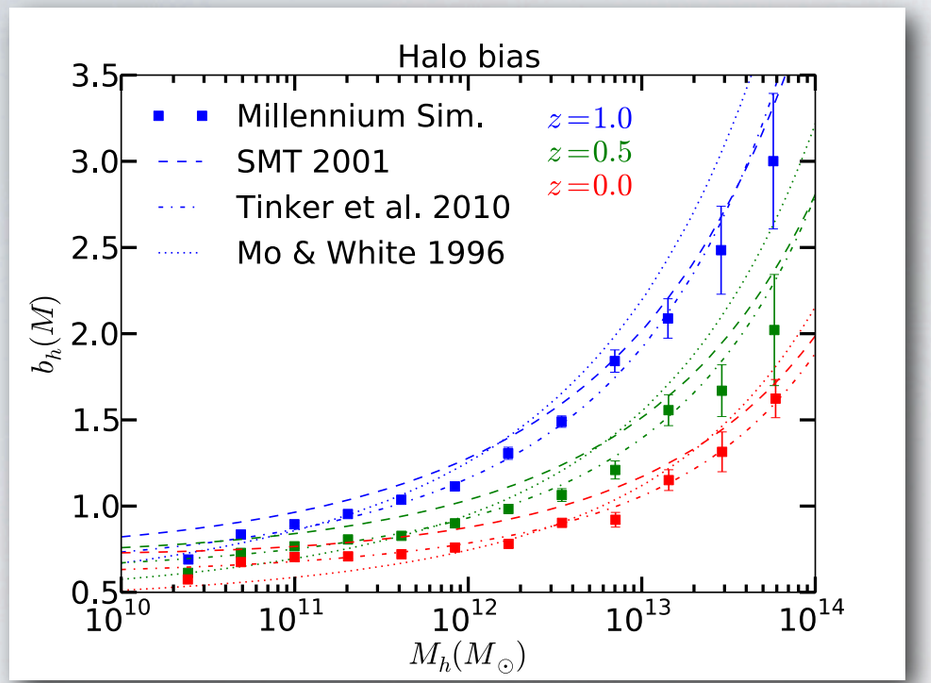
- BDLT07: Bertone et al. 2007 (MPA)
- B06: Bower et al. 2006 (Durham)
- DLB07: De Lucia & Blaizot 2007 (MPA)
- G11: Guo et al. 2011 (MPA)
- F08: Font et al. 2008 (Durham)

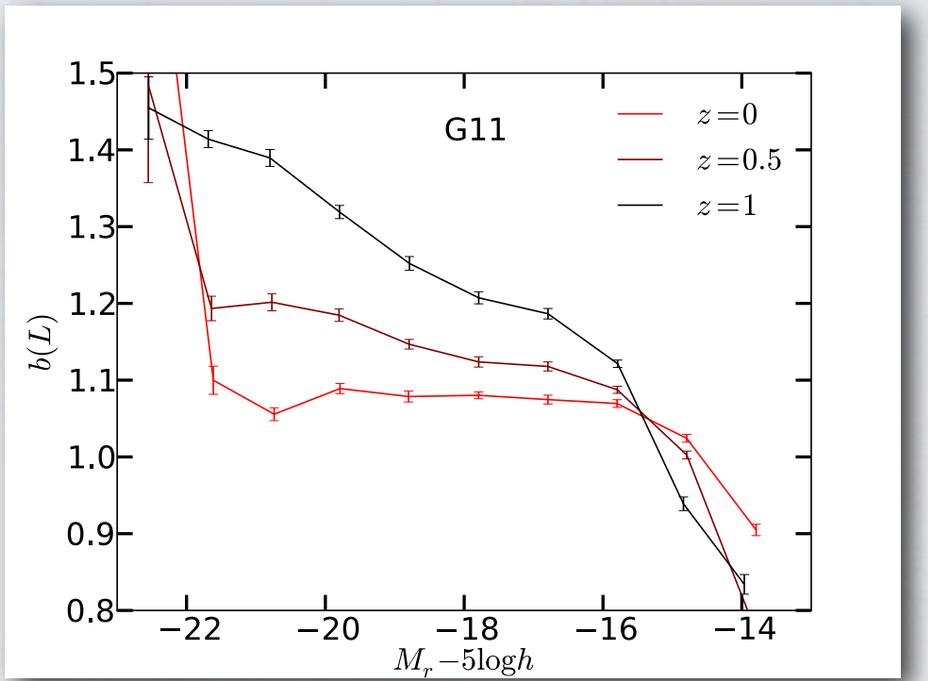


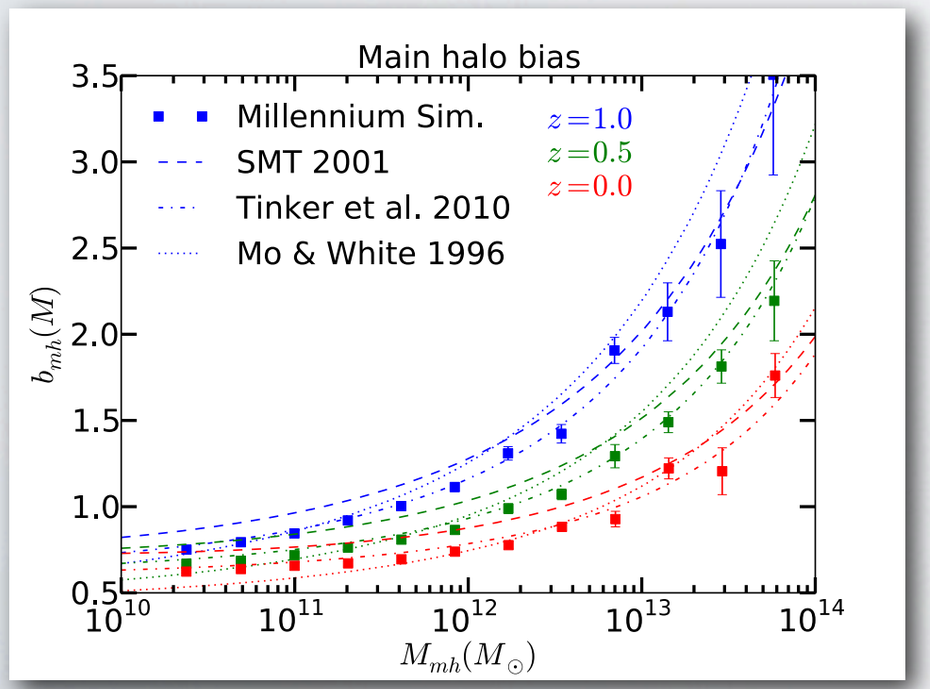
Luminosity function of SAMs

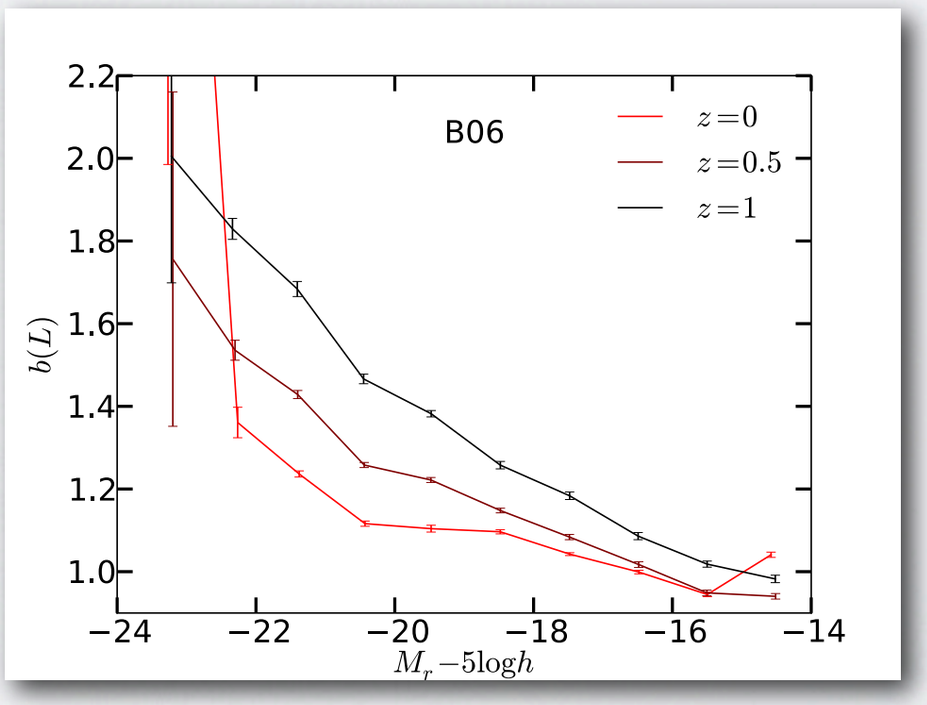
Bias and HOD

Halo and galaxy bias









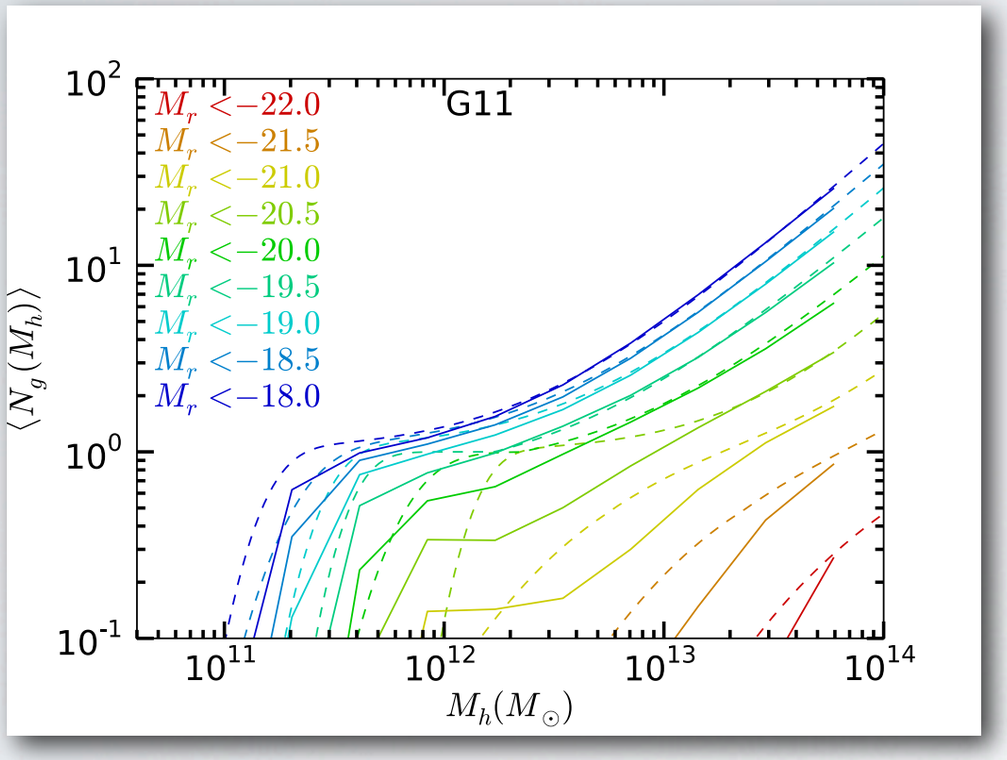
$$b_{g,h}(r) = \sqrt{\frac{\xi_{g,h}(r)}{\xi_m(r)}}$$

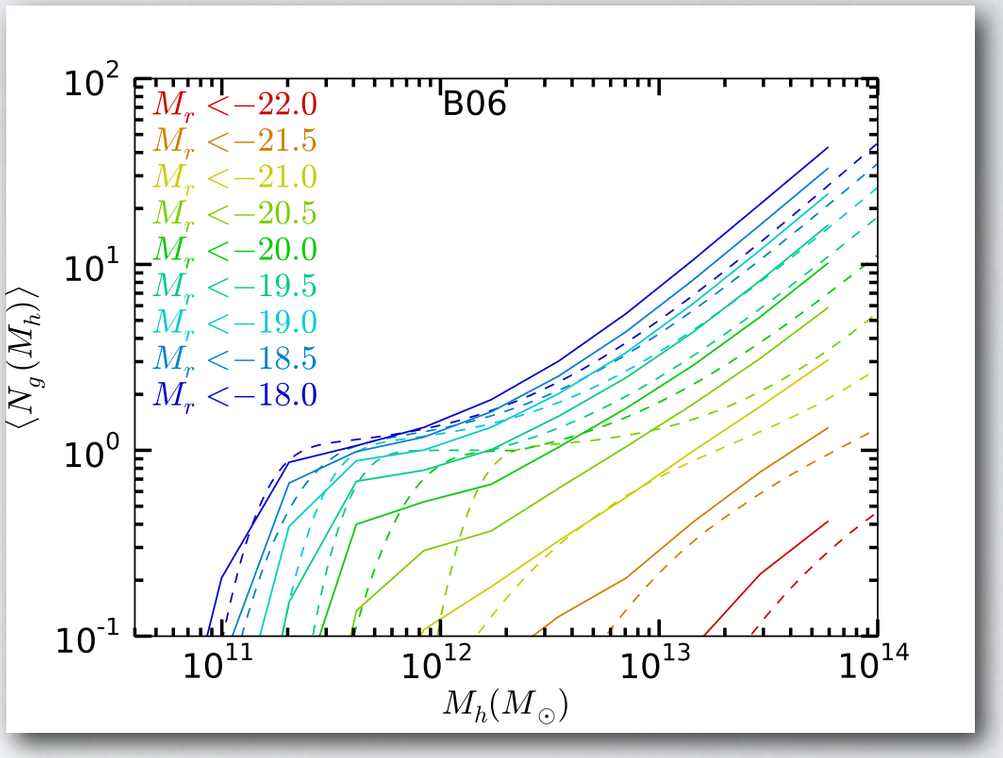
fitted as constant at

$r = [20-30]h^{-1}Mpc$

Bias and HOD

HOD



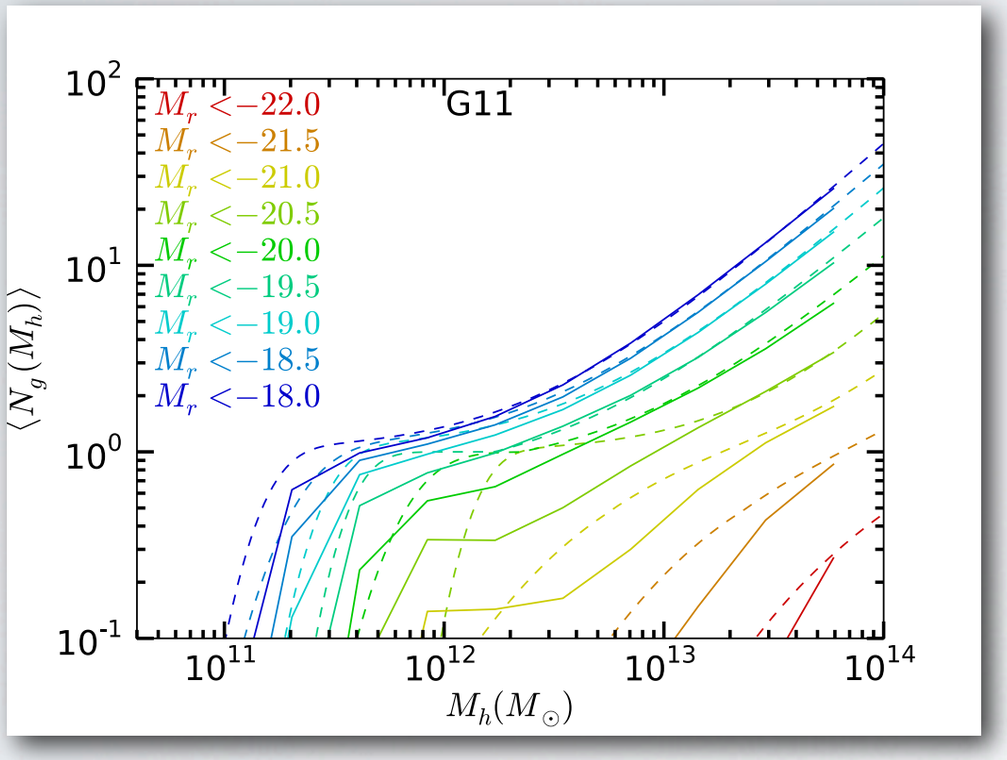


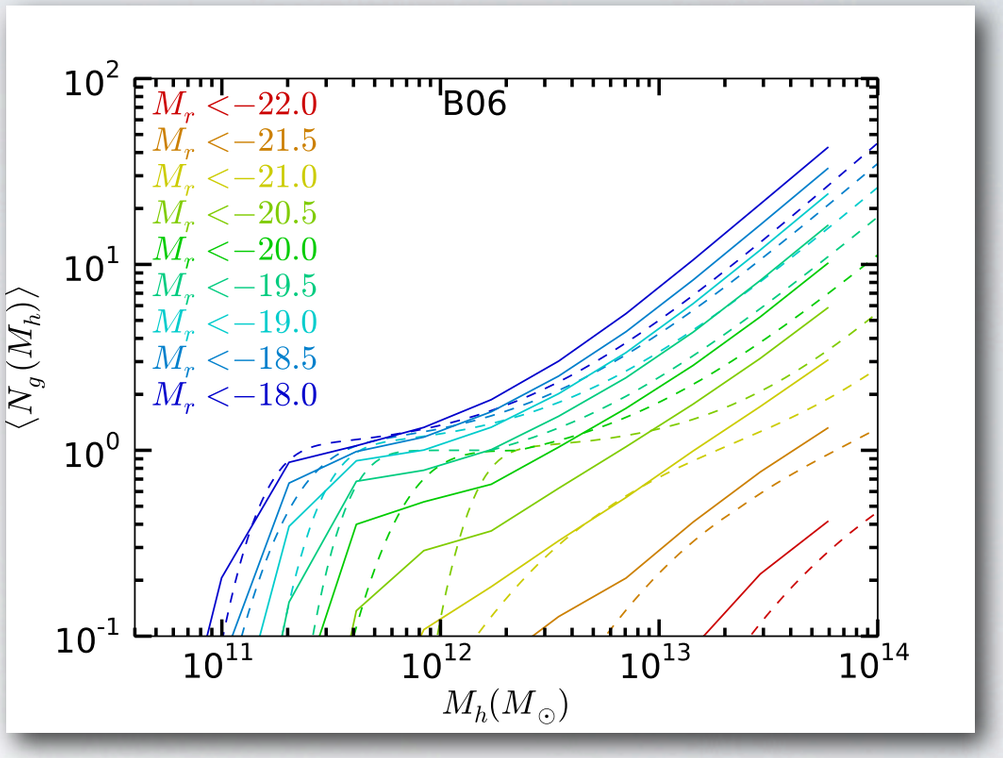
Number of galaxies per halo of mass M_h at different M_r thresholds (solid) vs SDSS DR-7 (dashed)

$$b_g(L) = \int dM b_h(M) n(M) \frac{N_g(L,M)}{n_g(L)}$$

Bias and HOD

HOD





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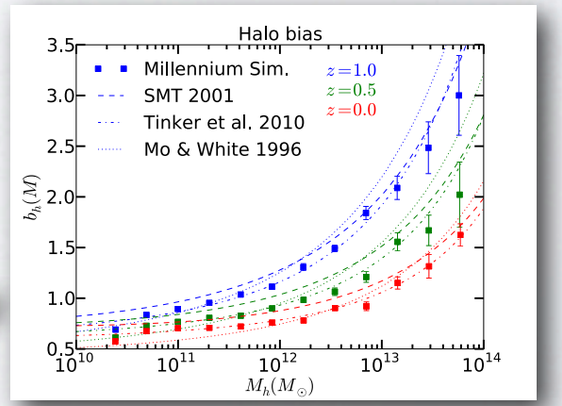
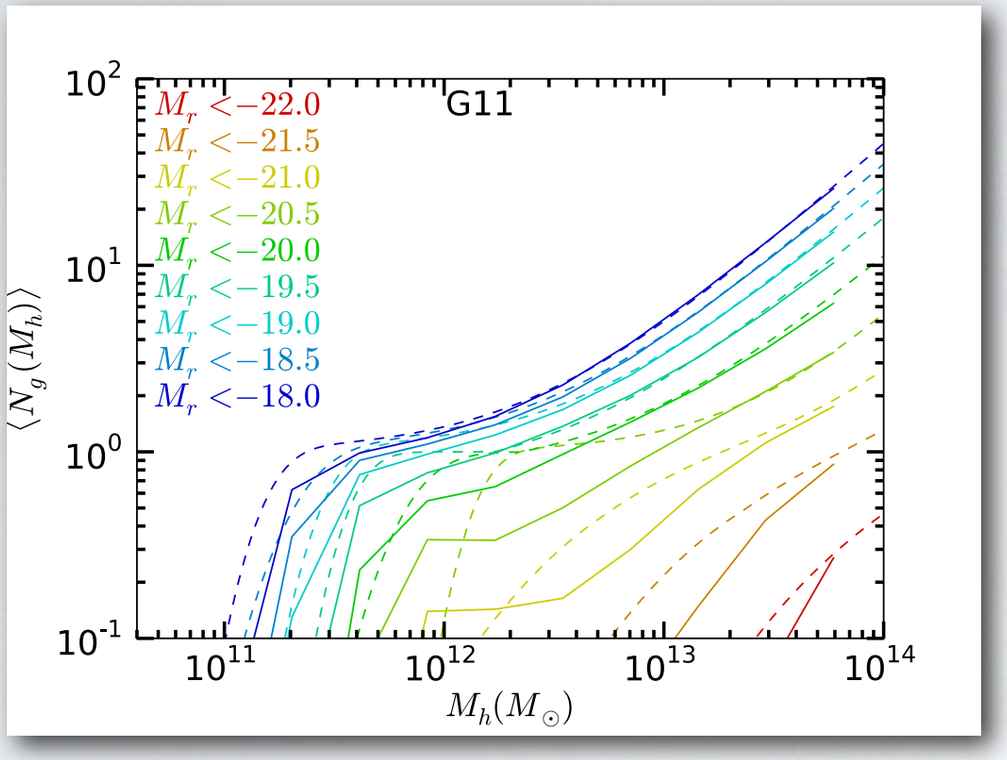
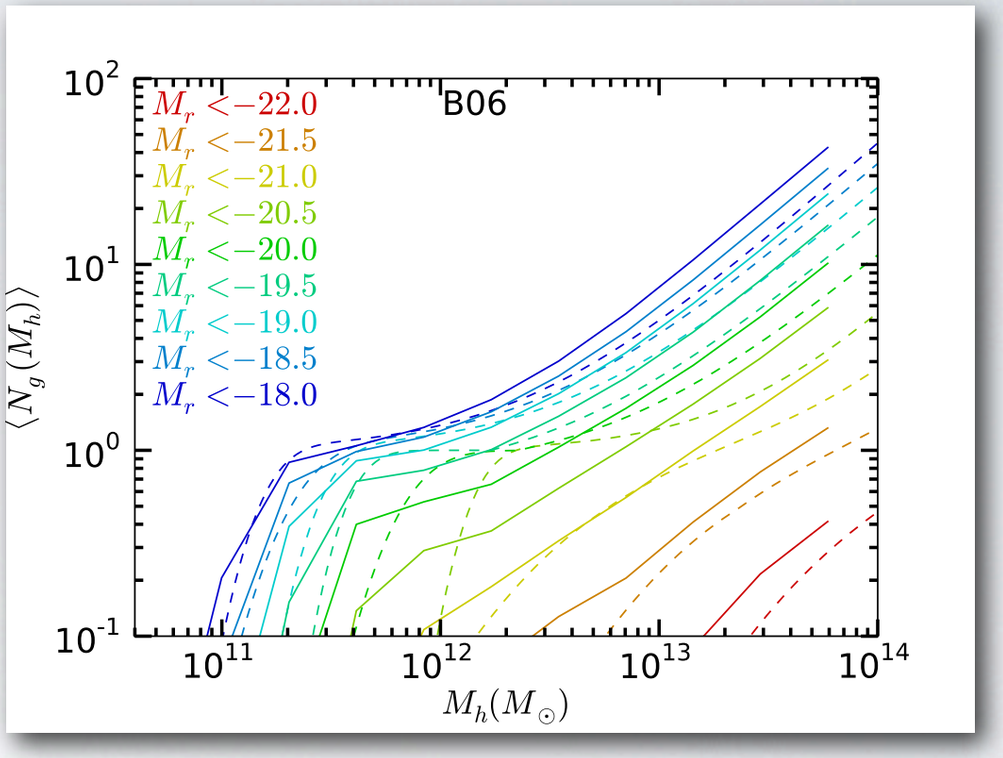


Bias and HOD

HOD





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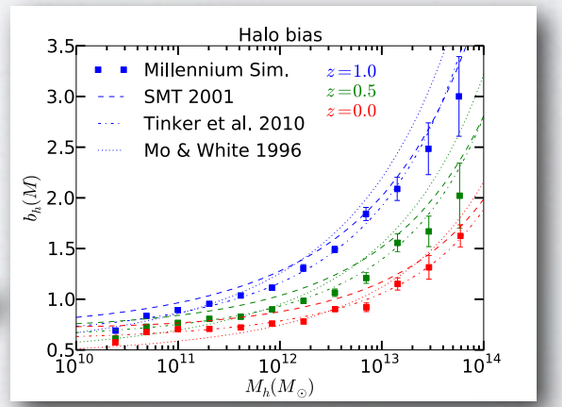
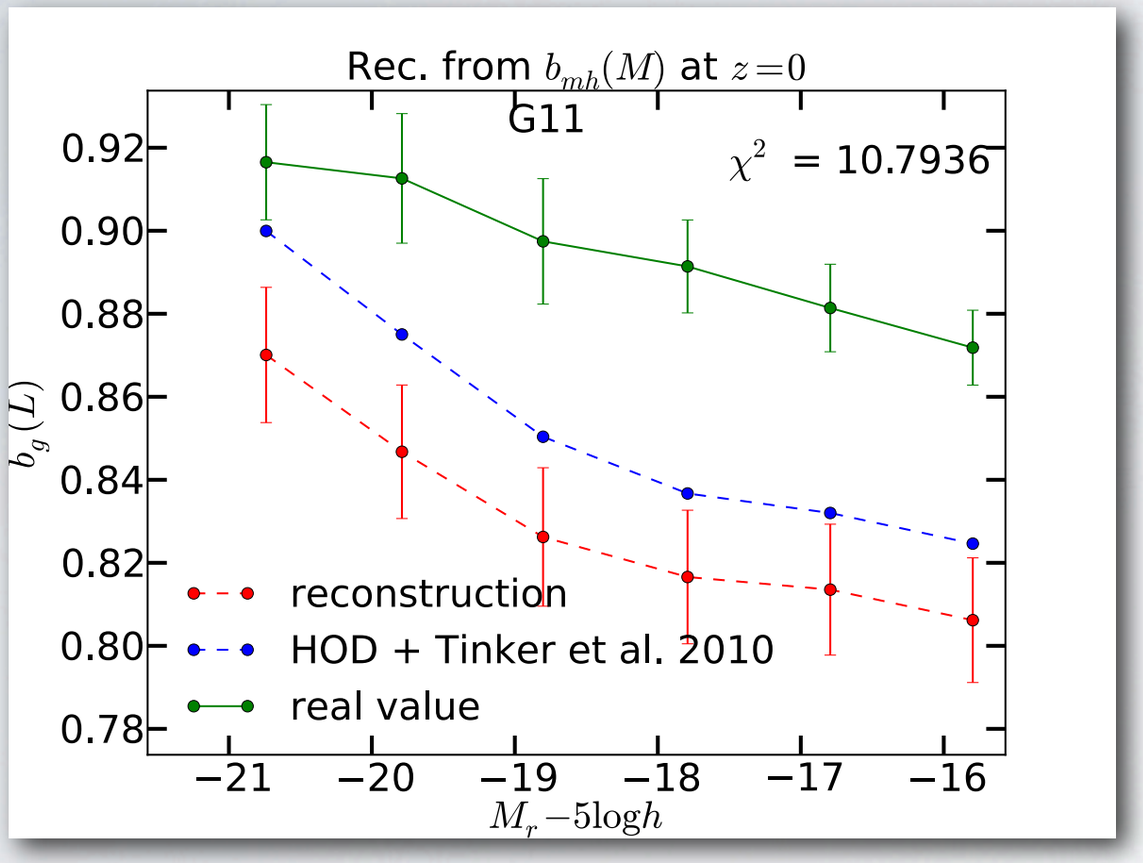
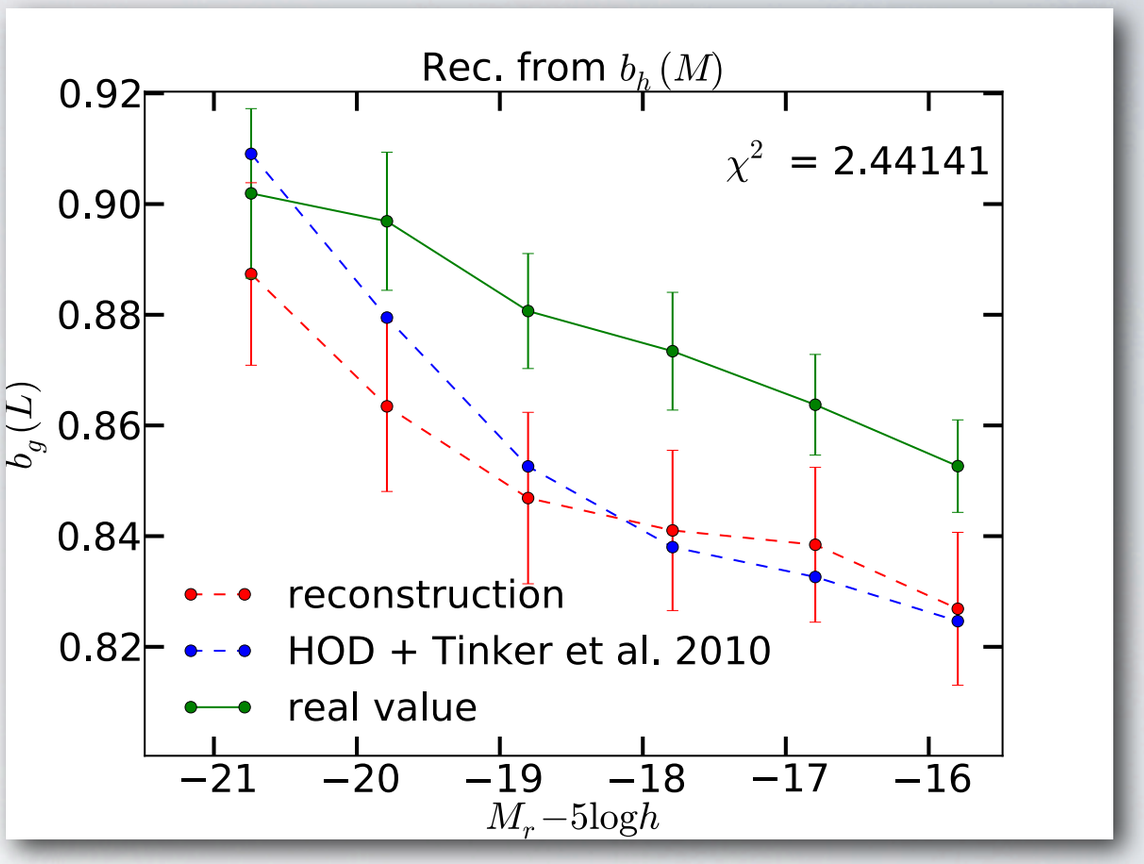


Reconstructions of galaxy bias



Rec. from main haloes



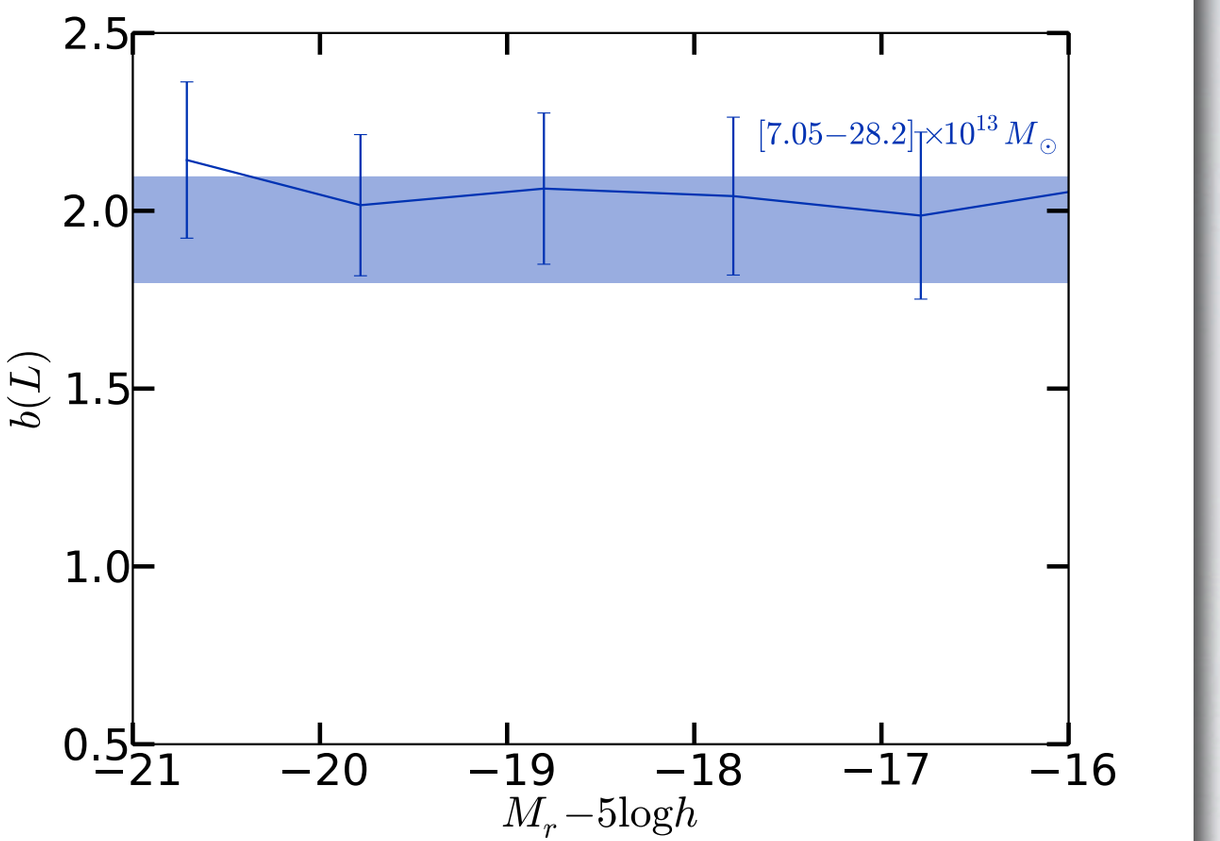
Rec. from haloes

$$b_g(L) = \int dM b_h(M) n(M) \frac{N_g(L,M)}{n_g(L)}$$

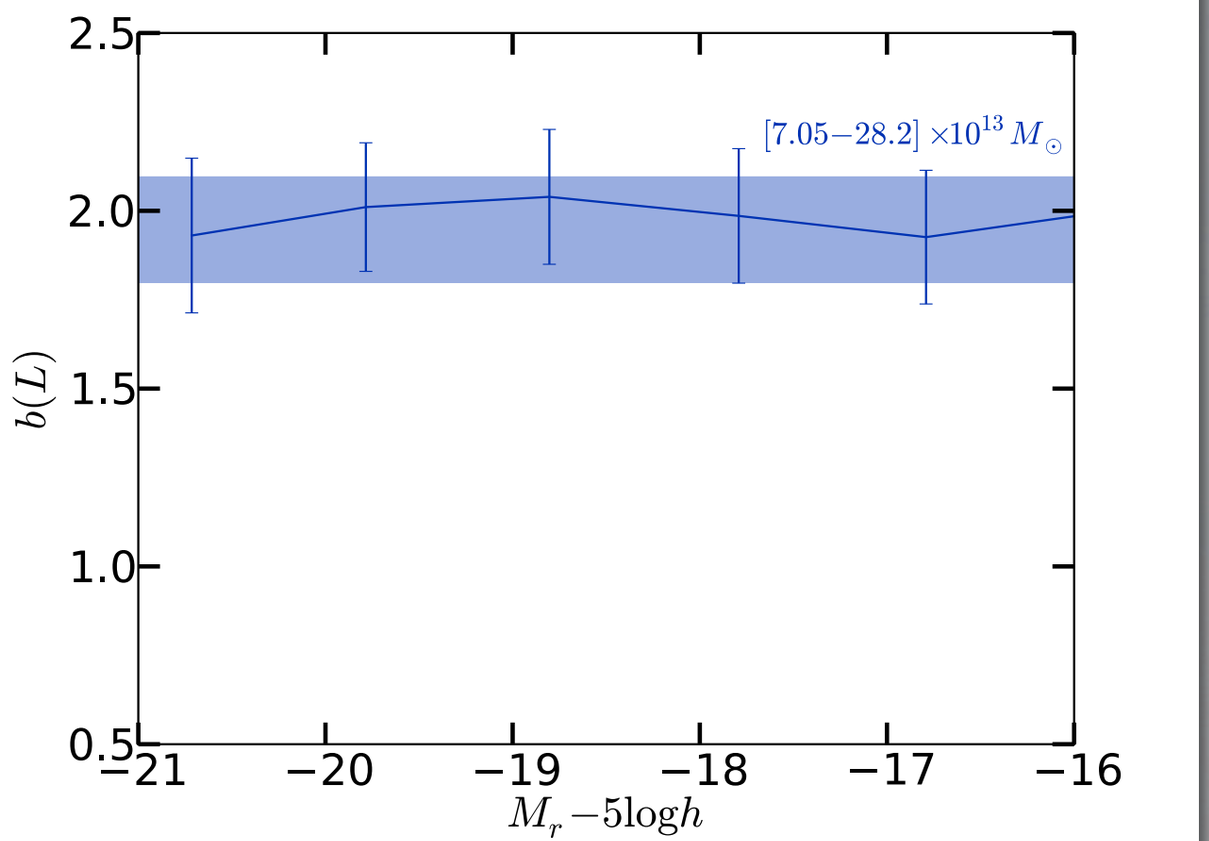
- Underprediction of galaxy bias
- haloes (FOFs) make better reconstructions than main haloes (gravitationally bound haloes).

halo vs galaxy bias

Galaxy bias in main halo mass bins



Galaxy bias in halo mass bins



Galaxy bias for different halo (right) and main halo (left) mass bins. Solid lines represent galaxy bias of those galaxies in the haloes (right) or main haloes (left) of the corresponding range in mass. The horizontal coloured zones refer to the ranges of halo or main halo bias $\pm1\sigma$

halo vs galaxy bias

$b_g(L)$

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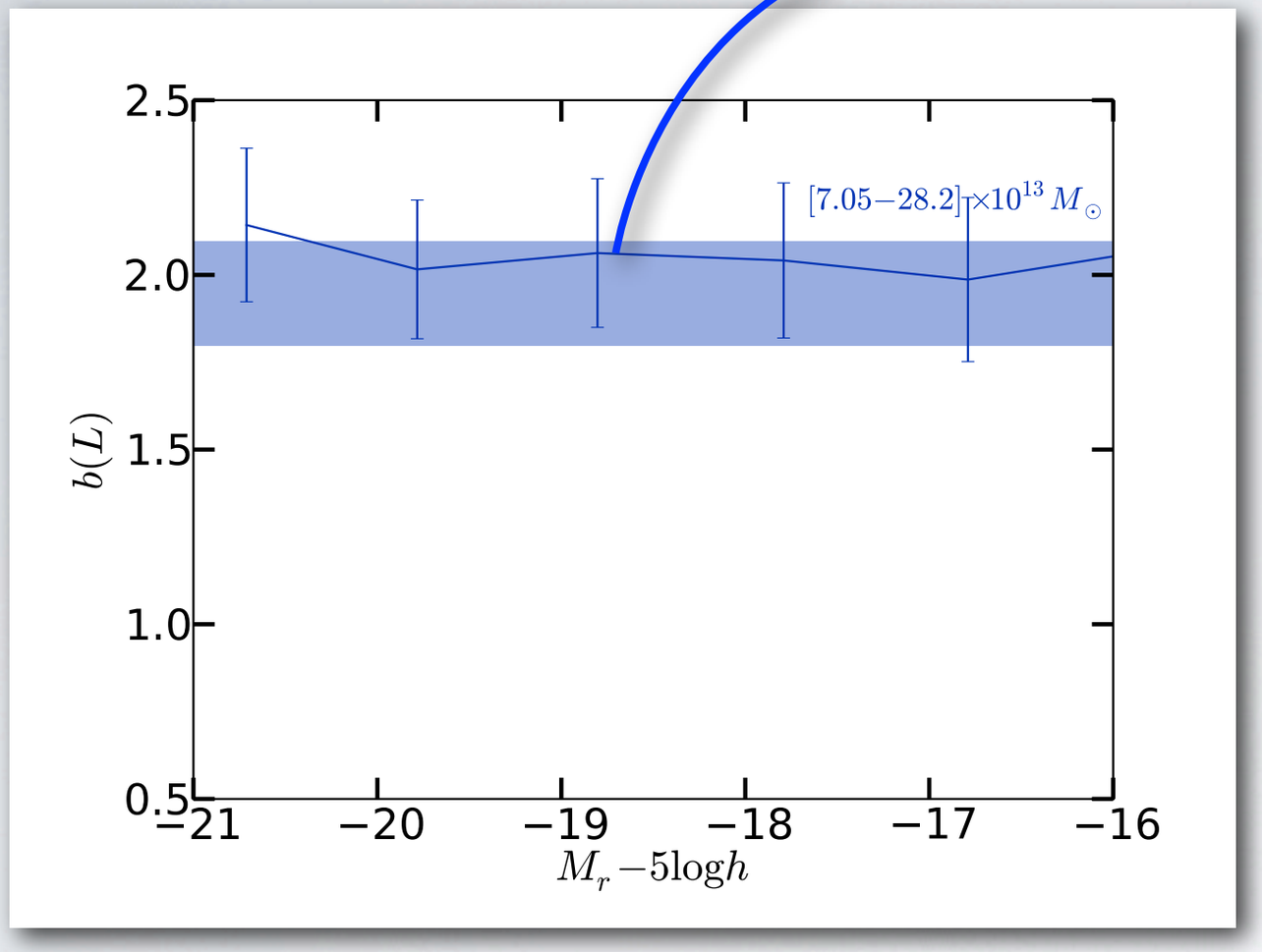

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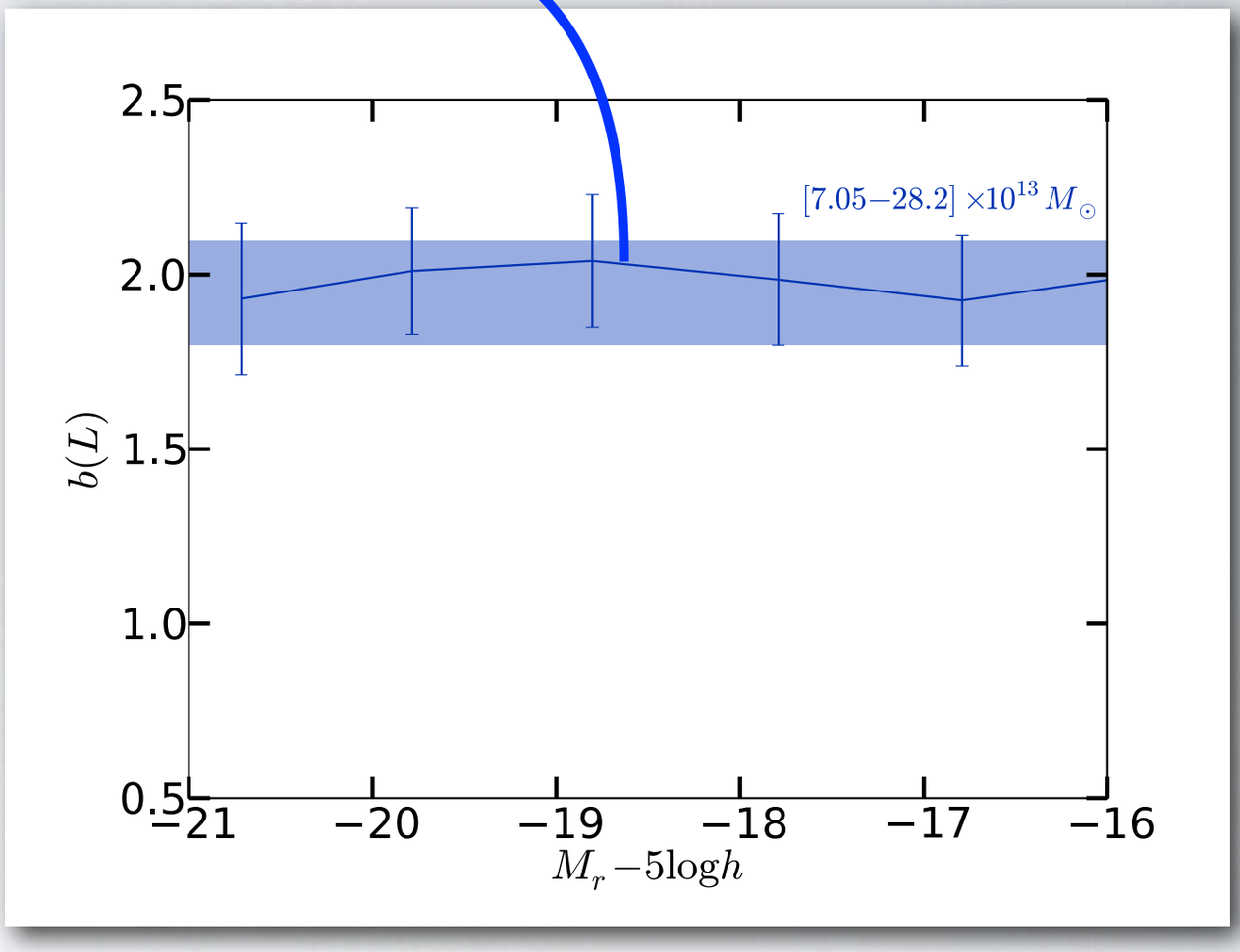

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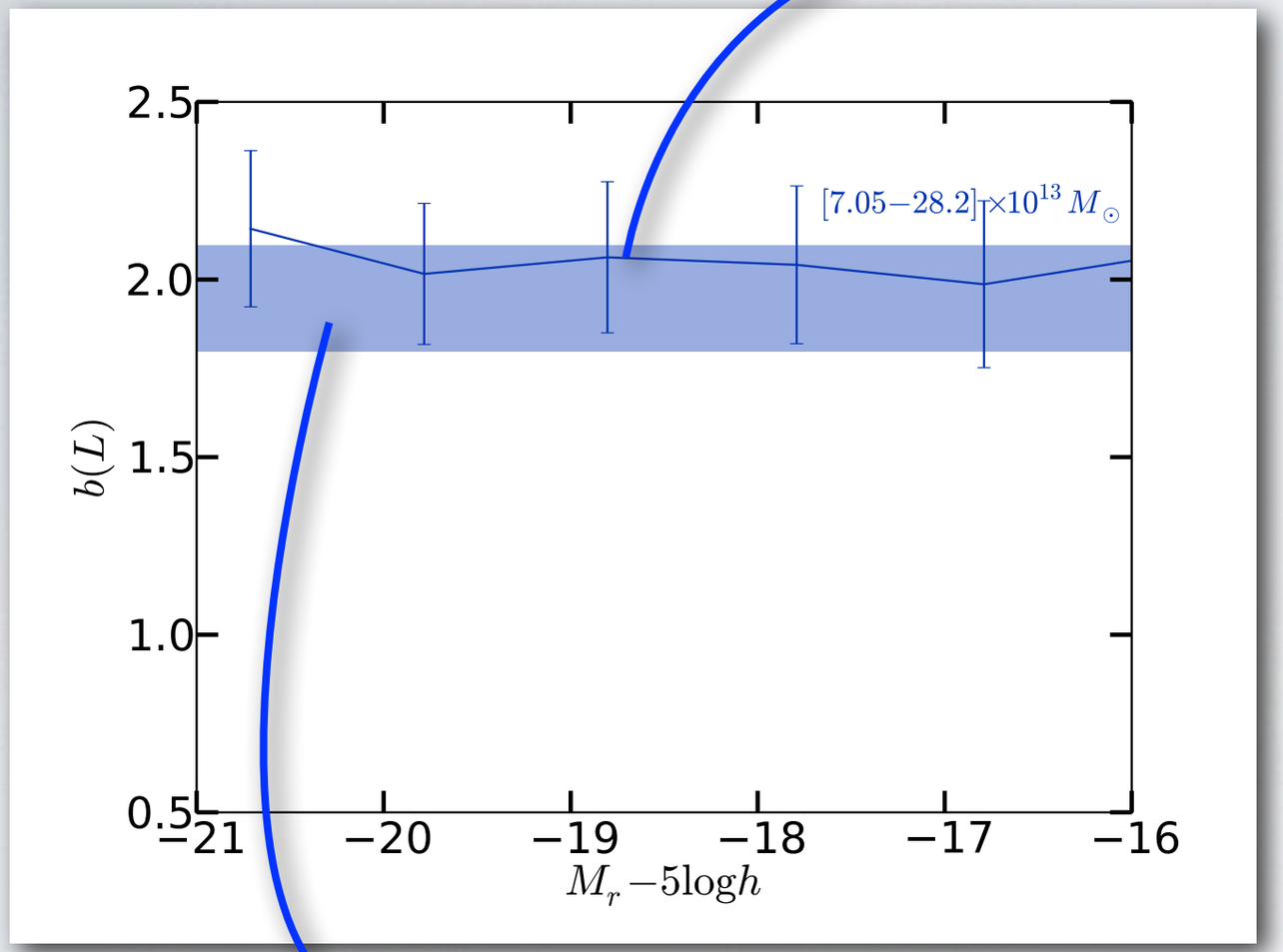

$b_{mh}(M)\pm1\sigma$

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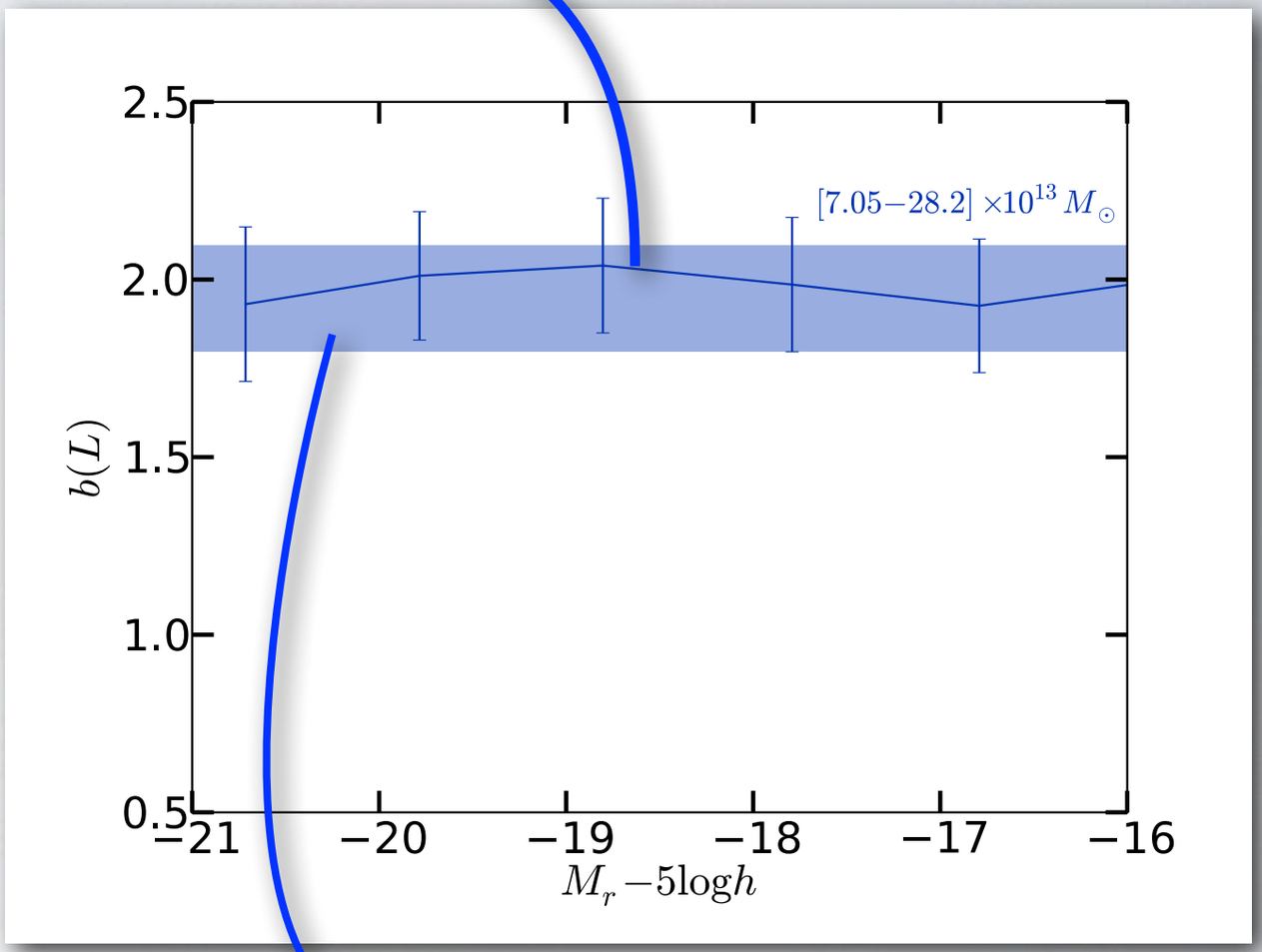

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halo vs galaxy bias

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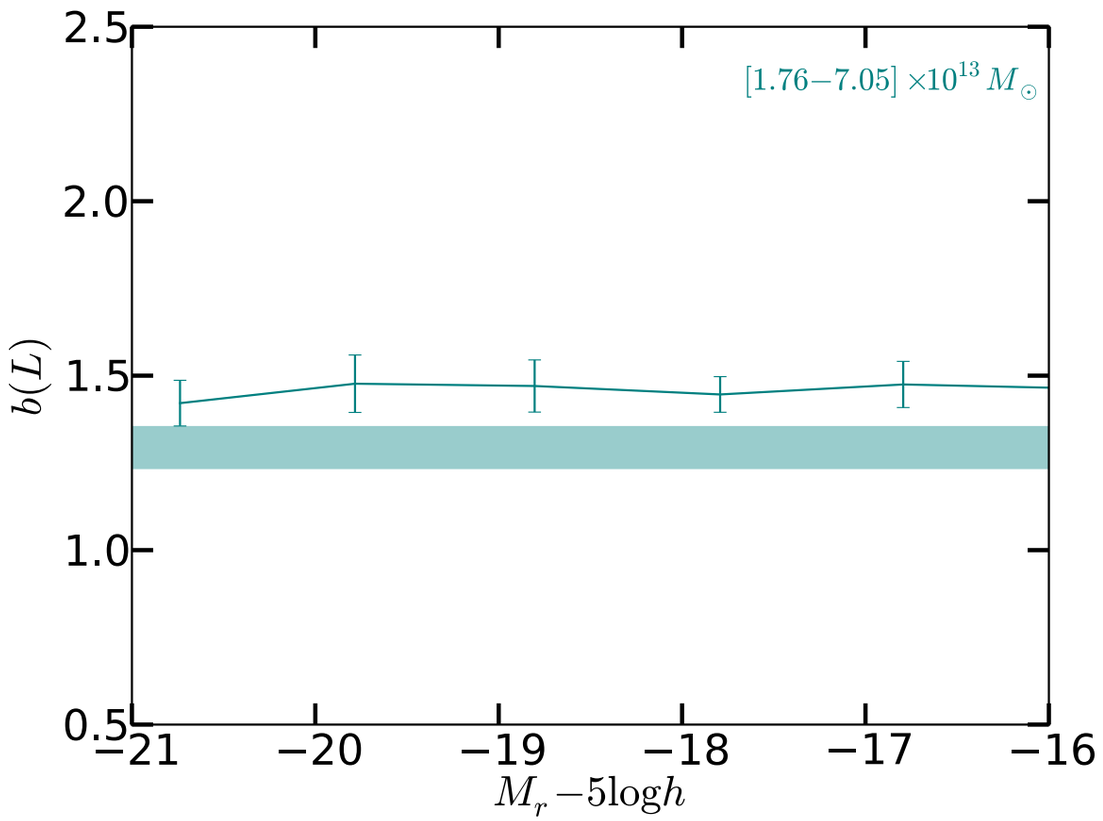

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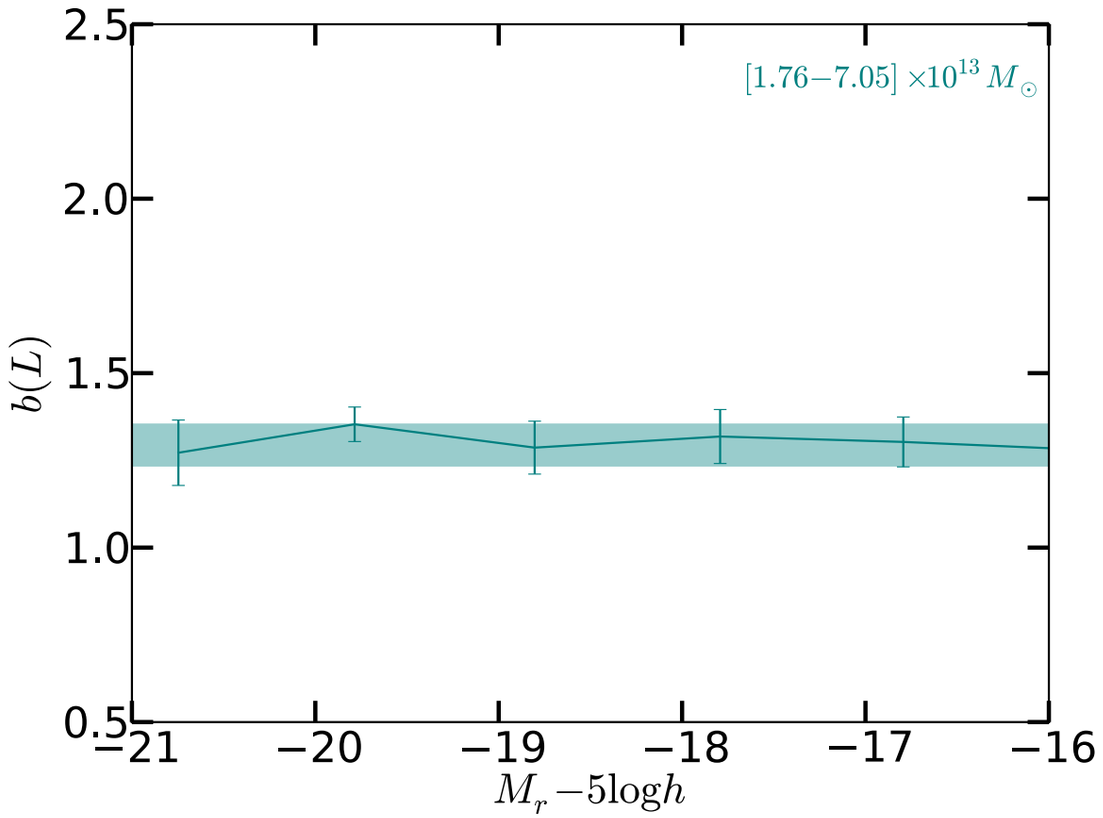

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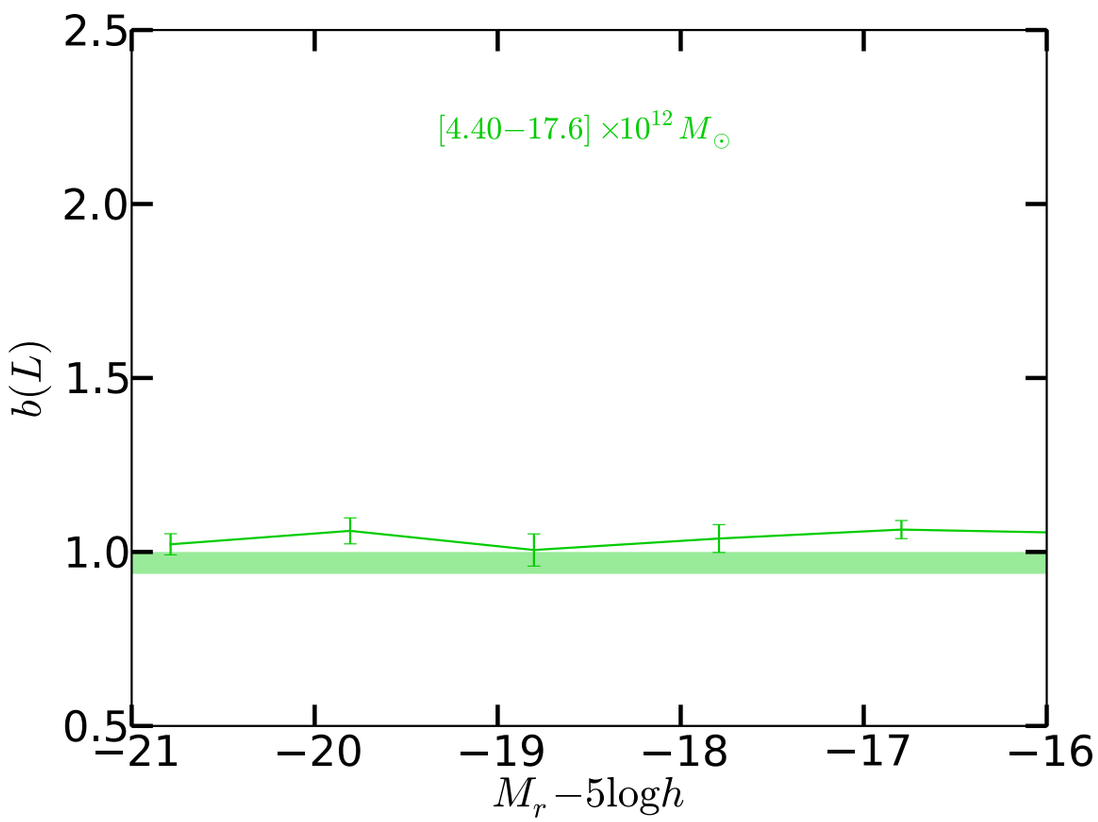

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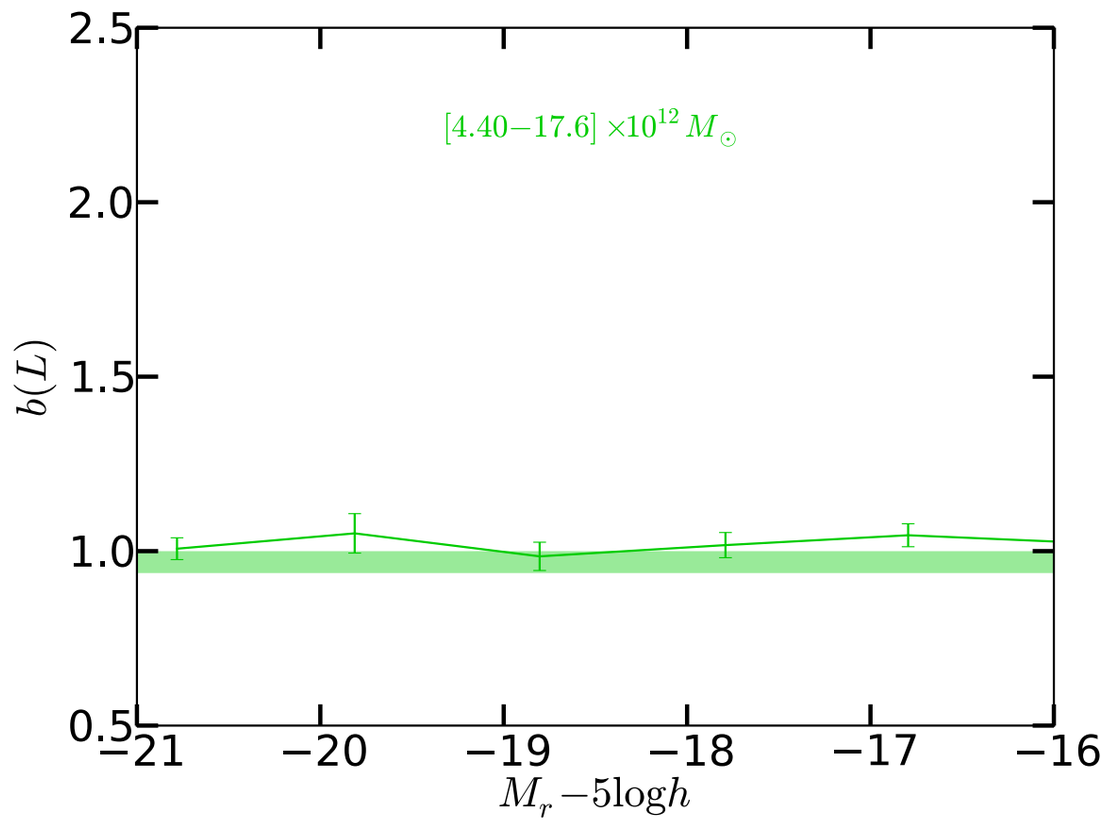

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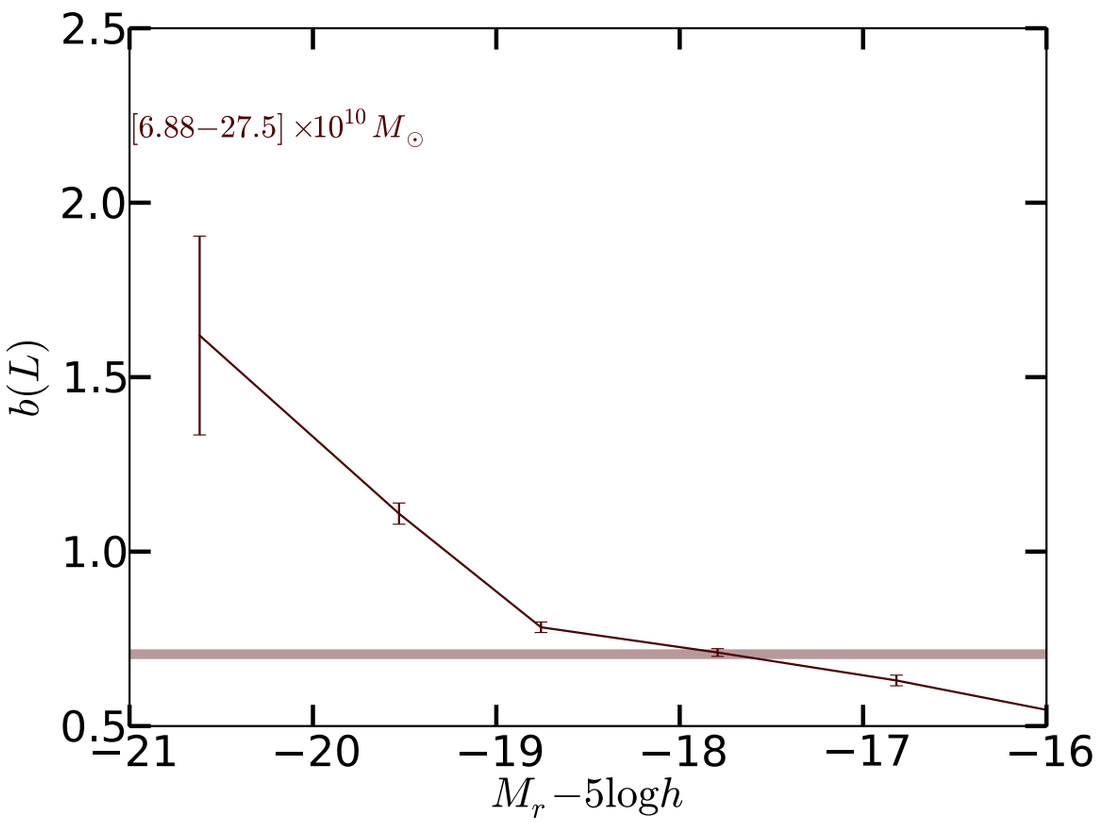

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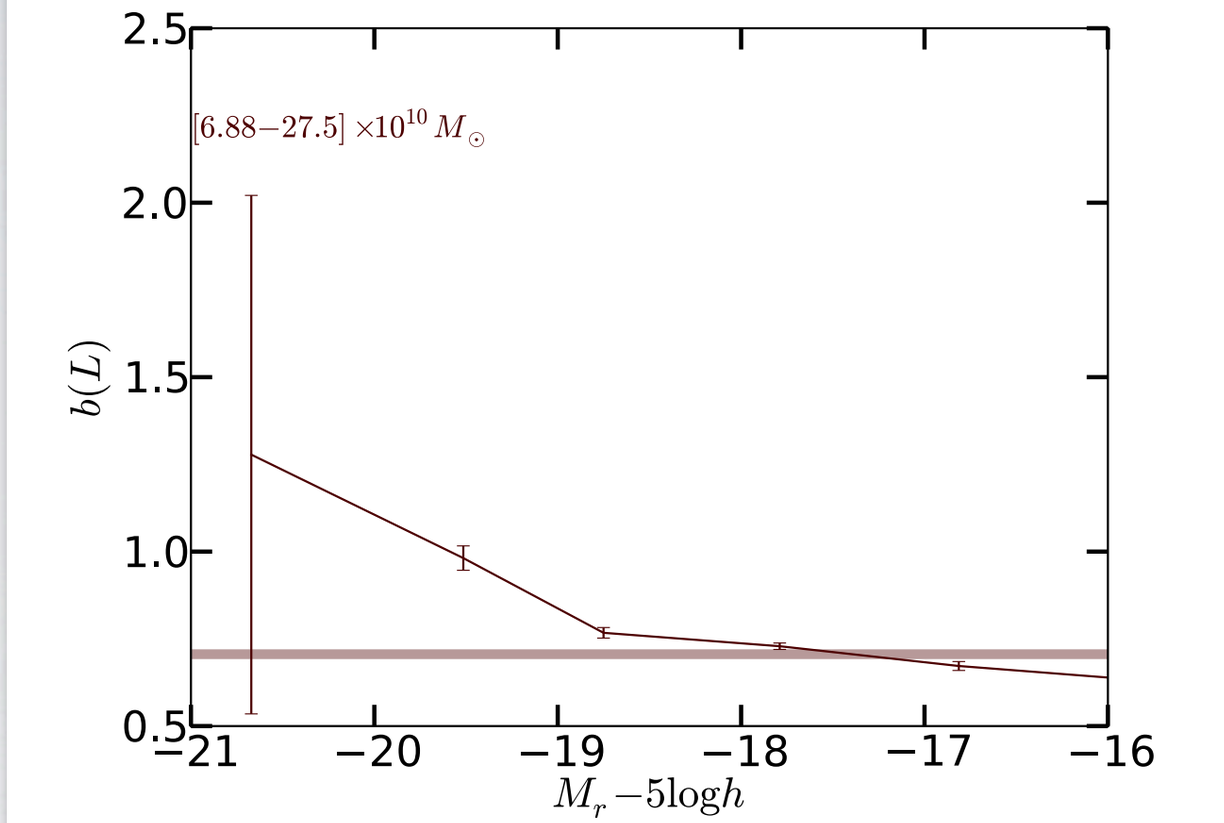

Galaxy bias in low mass bins is higher than halo and main halo bias of the same mass bin. This is an indication of assembly bias, since these galaxies (solid lines) are distributed in these haloes. (coloured regions). HOD predictions not compatible with SAMs at $M \lesssim 10^{11} M_\odot$

halo vs galaxy bias

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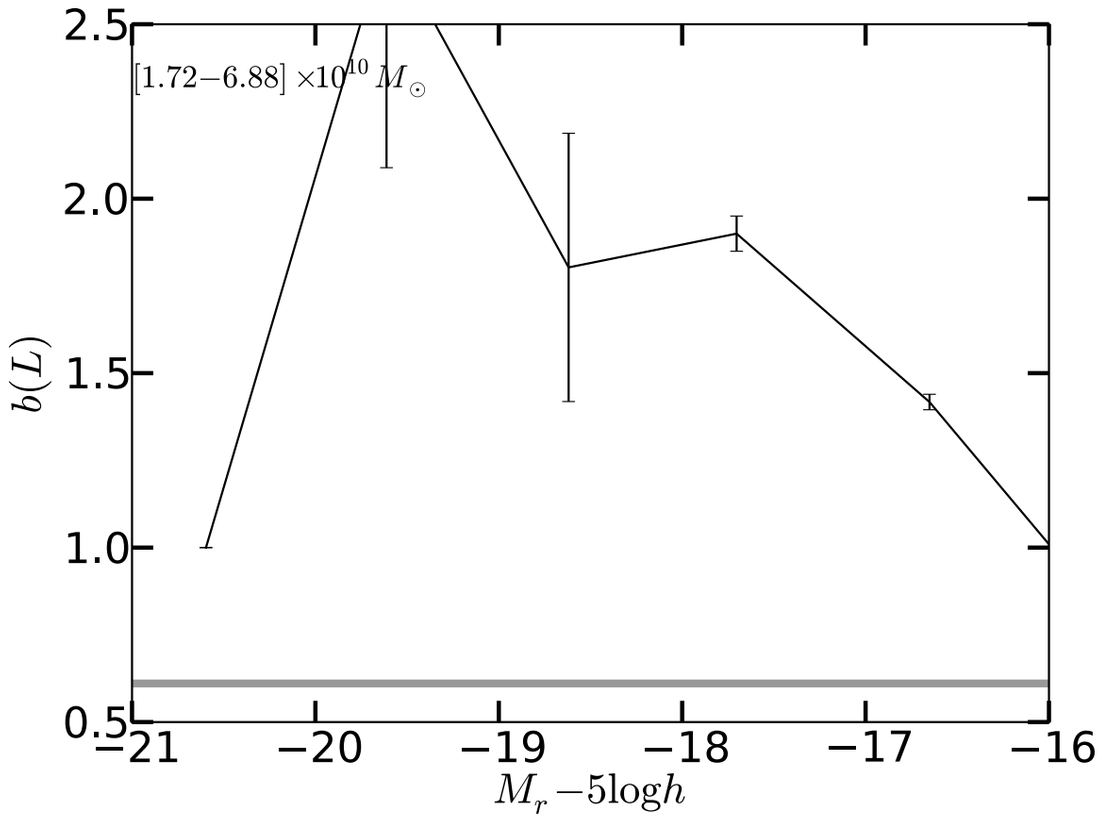

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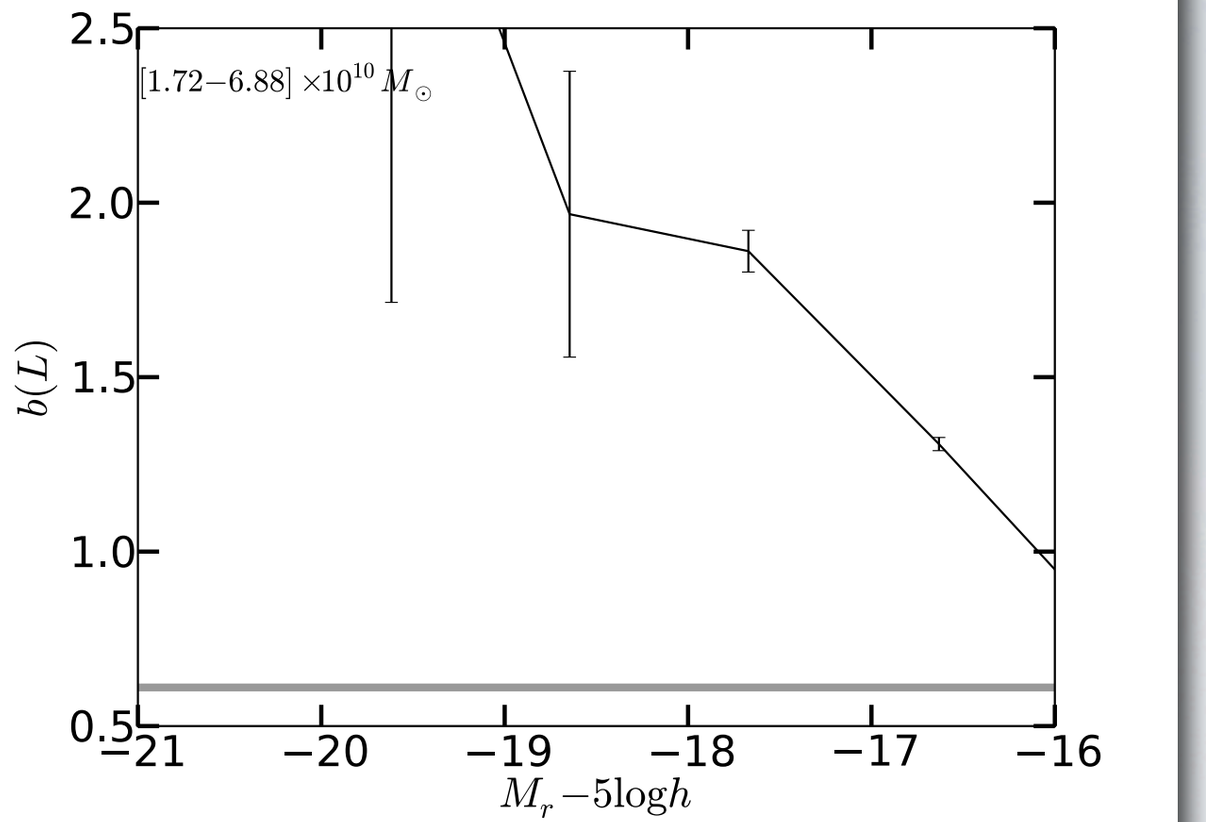

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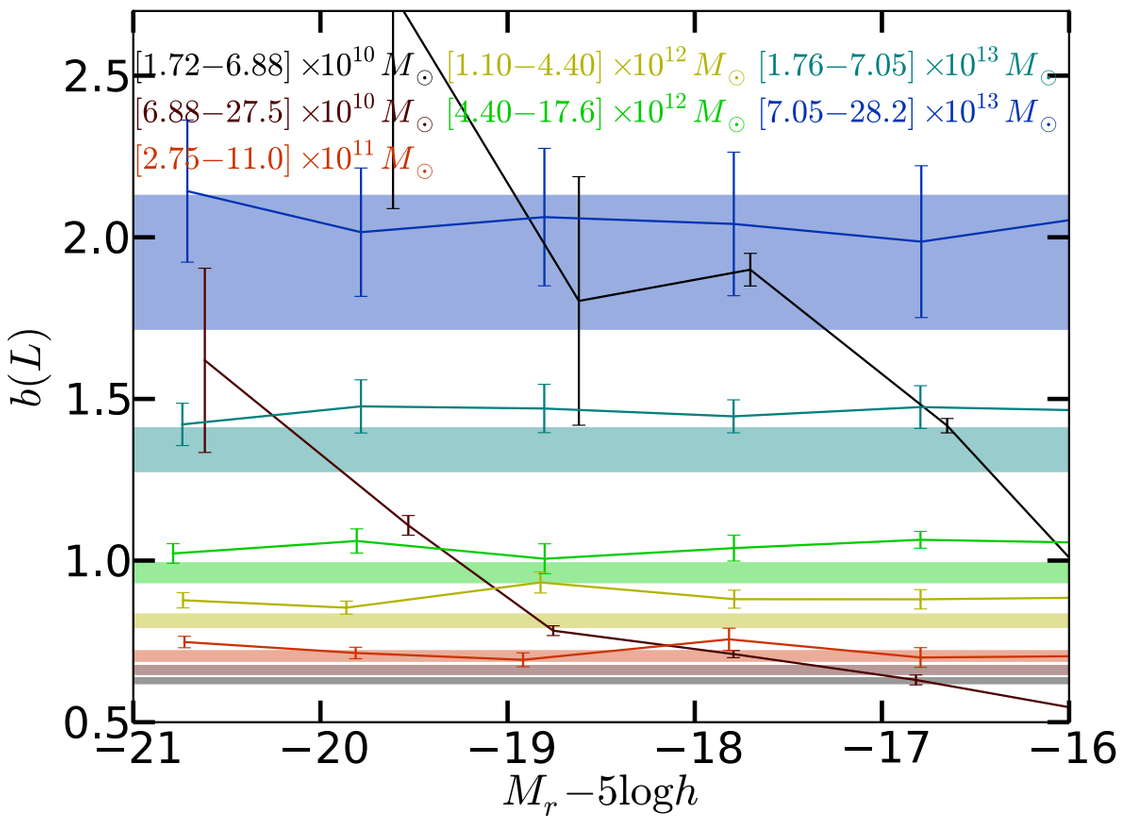

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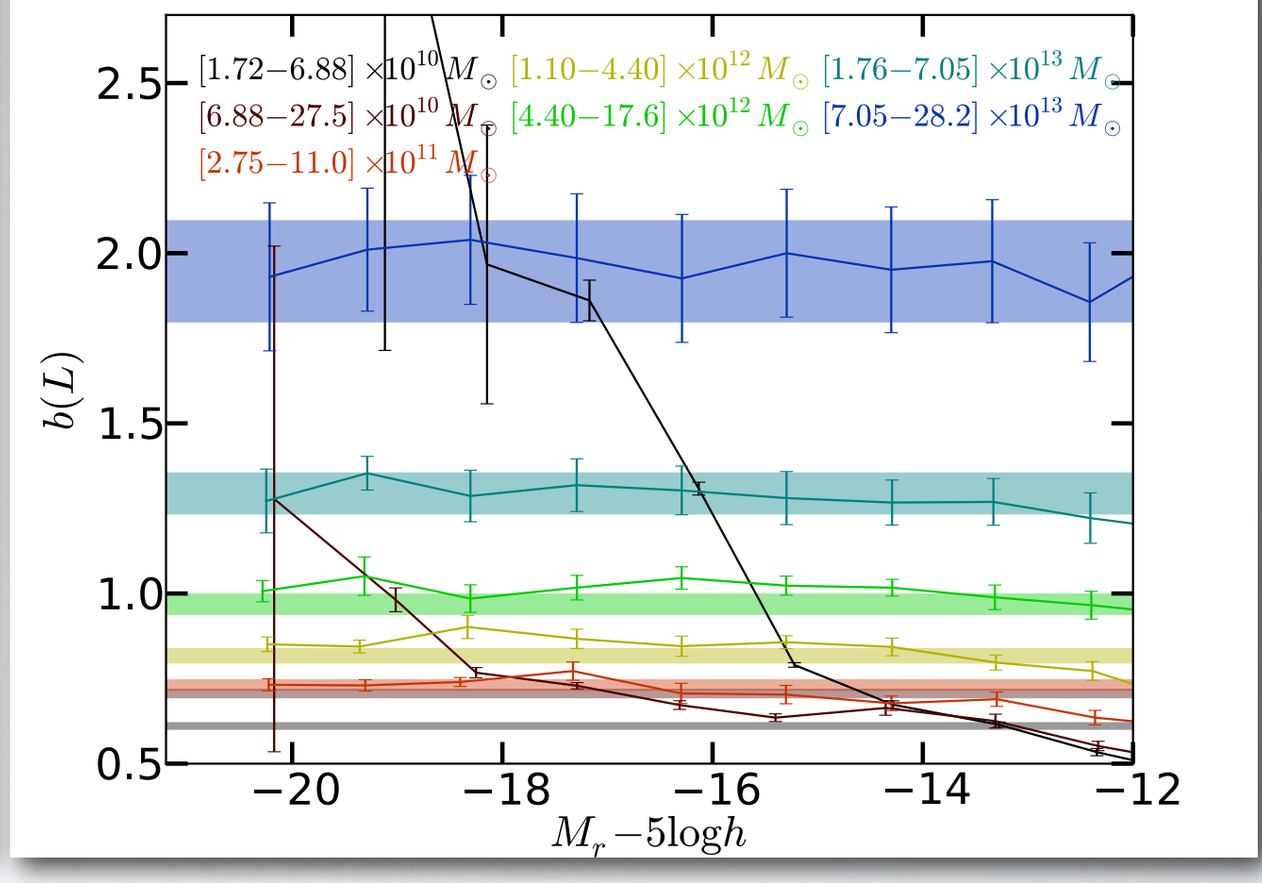

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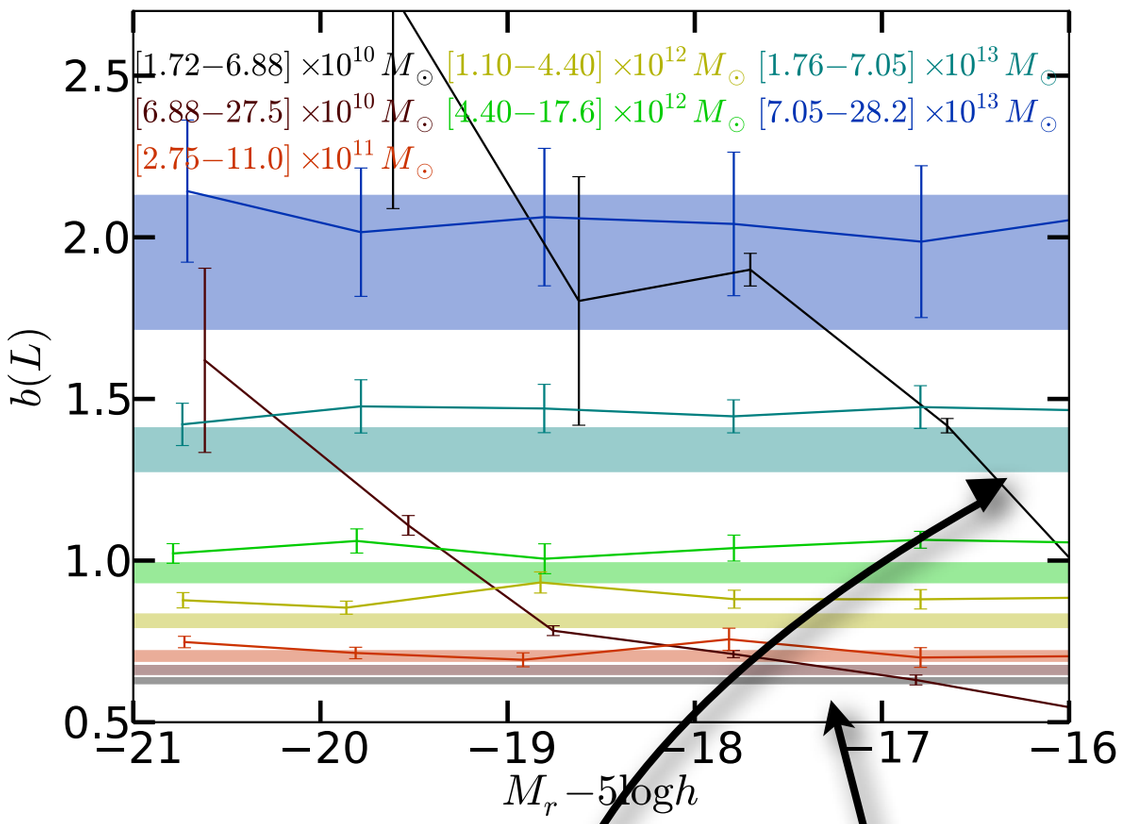
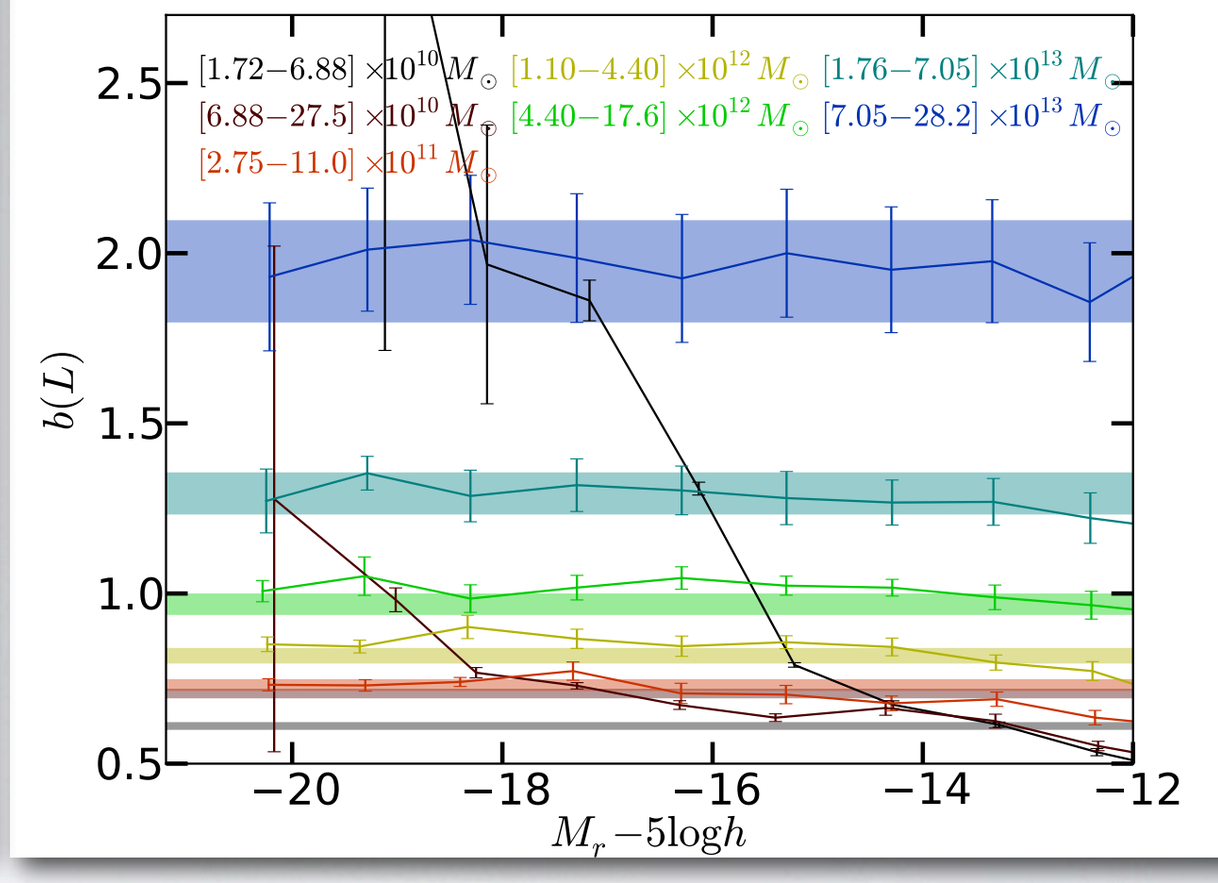


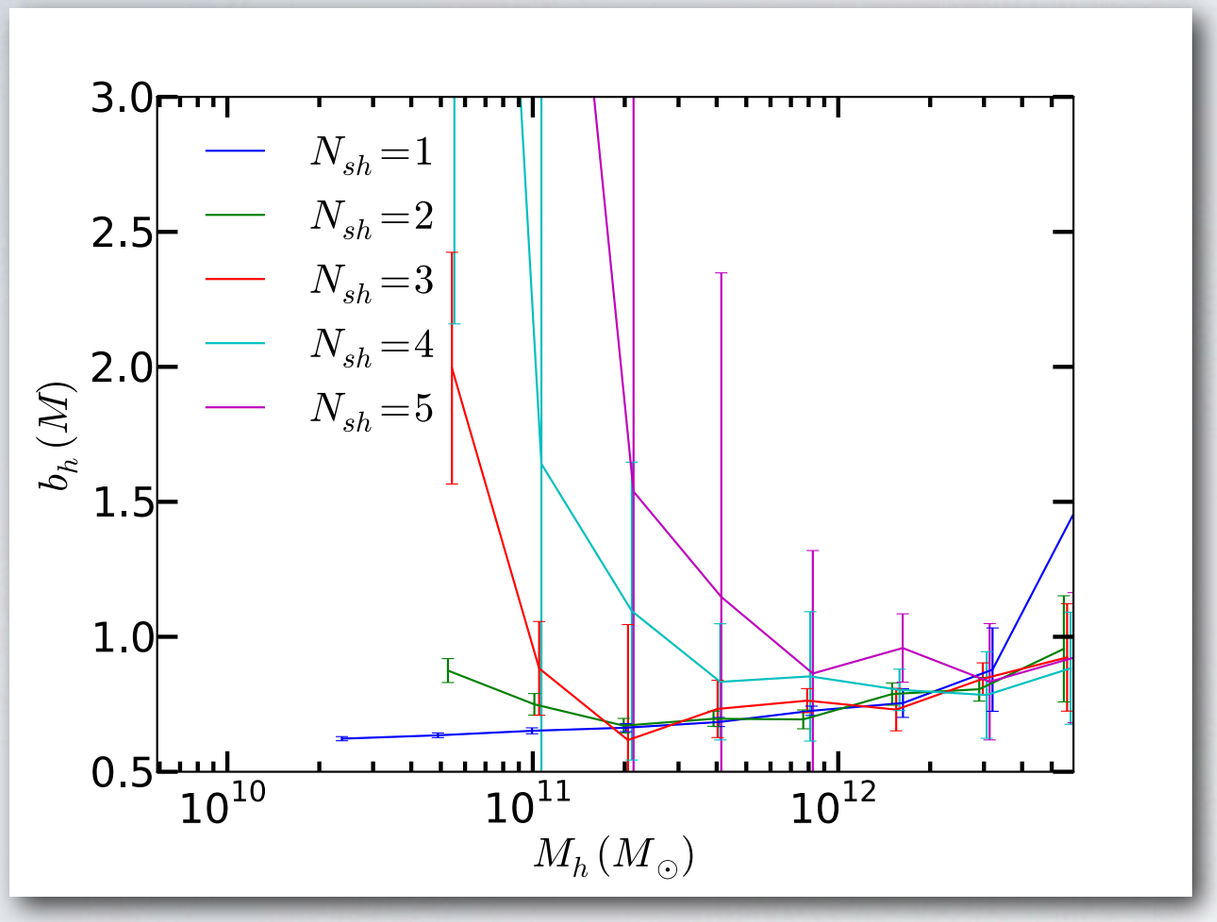
Galaxy bias in halo mass bins



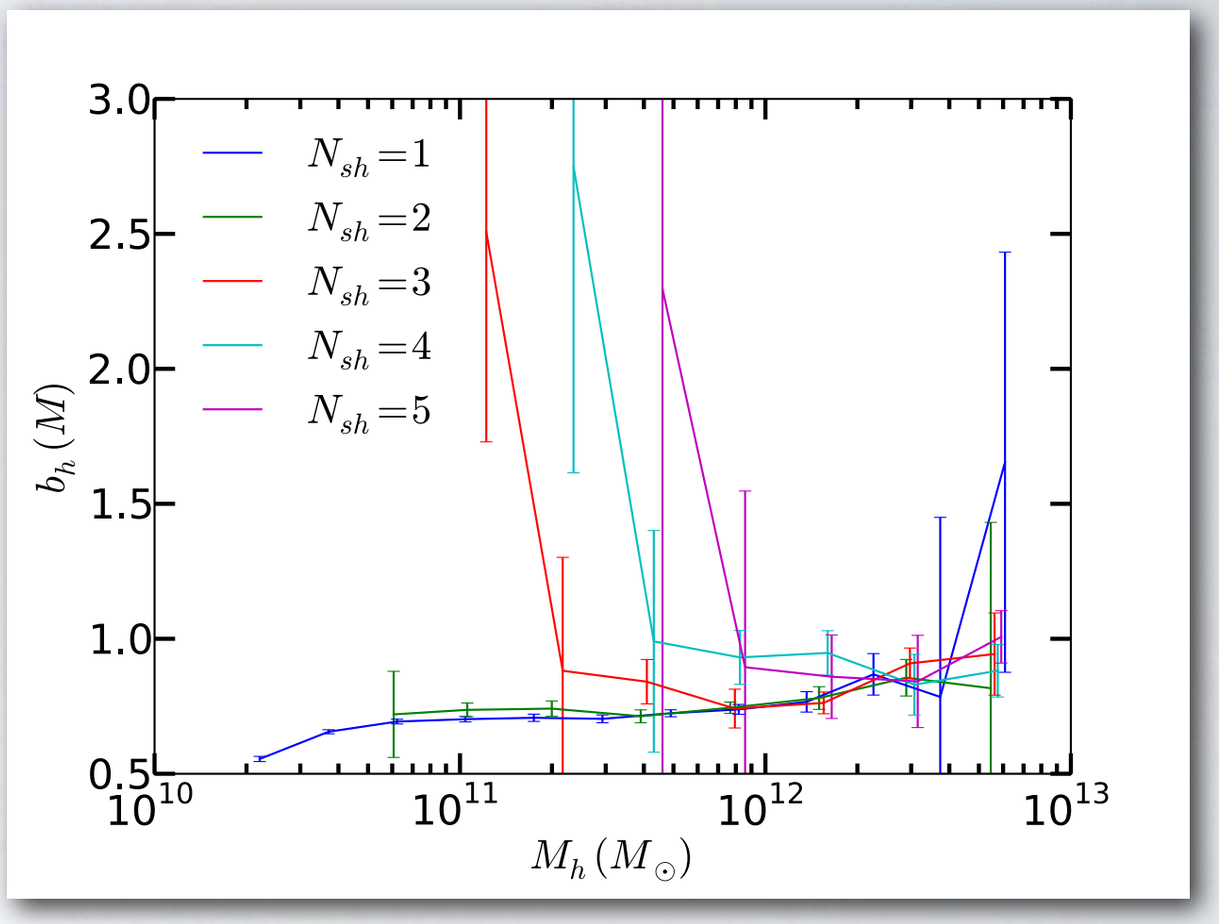
$$b_g(L) = \int dM\, b_h(M)\, n(M)\, \frac{N_g(L,M)}{n_g(L)}$$

Galaxy bias in low mass bins is higher than halo and main halo bias of the same mass bin. This is an indication of assembly bias, since these galaxies (solid lines) are distributed in these haloes. (coloured regions). HOD predictions not compatible with SAMs at $M \lesssim 10^{11}\,M_\odot$

Subhalo occupation



main halo bias for different subhalo occupations



halo bias for different subhalo occupations

Strong subhalo abundance dependence of halo bias for fixed mass. For a fixed mass bin, haloes (or main haloes) with more subhaloes (and more galaxies) have more clustering. Correlation between halo occupation and halo bias for fixed mass.

Conclusions

- HOD underestimates the bias of galaxies. This results in a systematic error for bias or for mass estimation.
- haloes (FOFs) make better reconstructions than main haloes (gravitationally bound haloes).
- Strong subhalo abundance dependence of halo bias for fixed mass. For a fixed mass bin, haloes (or main haloes) with more subhaloes (and more galaxies) have more clustering. Correlation between halo occupation and halo bias for fixed mass.
- HOD predictions not compatible with SAMs at $M \lesssim 10^{11} M_{\odot}$
- Care must be taken when inferring dark matter halo information from galaxy clustering in observations using HOD

Pujol & Gaztañaga 2013, arXiv:1306.5761