Inheritance in clusters & galaxies

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Overview

(I) Halo and galaxy formation: a review

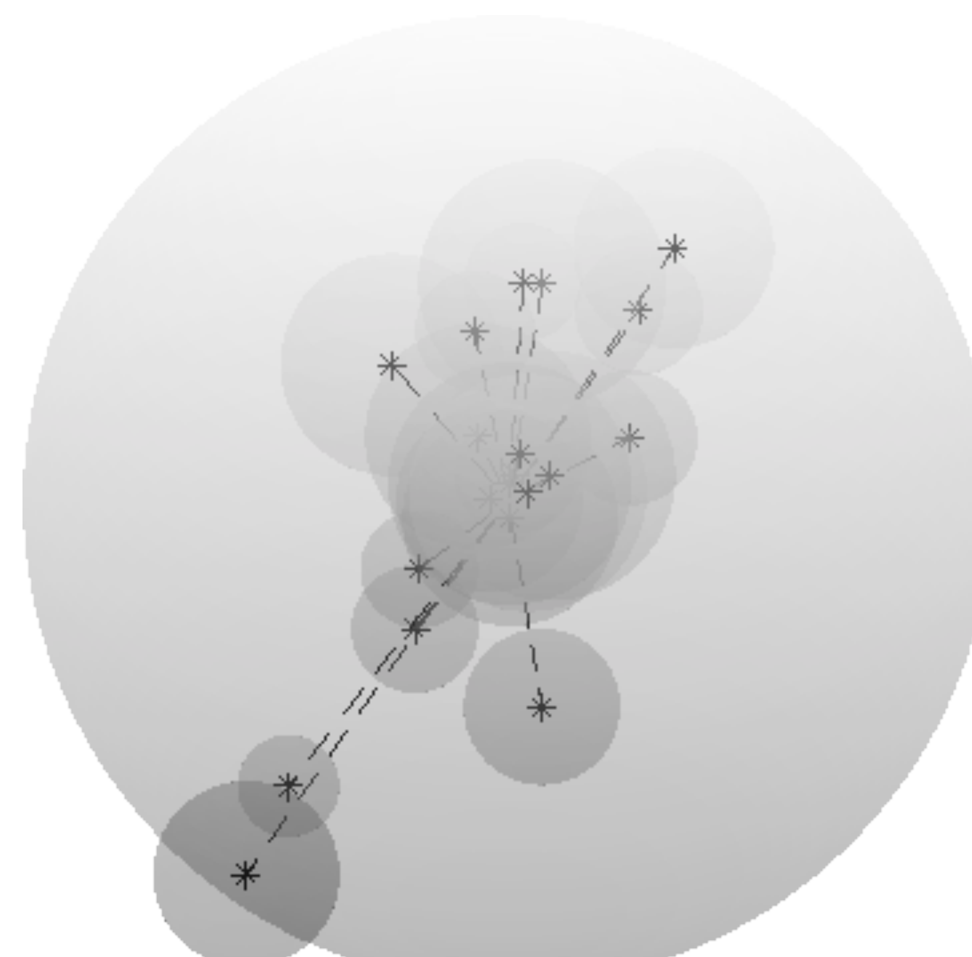
(II) Galaxies, groups and AGN in the Cosmic Evolution Survey

(III) Results on clustering behaviour

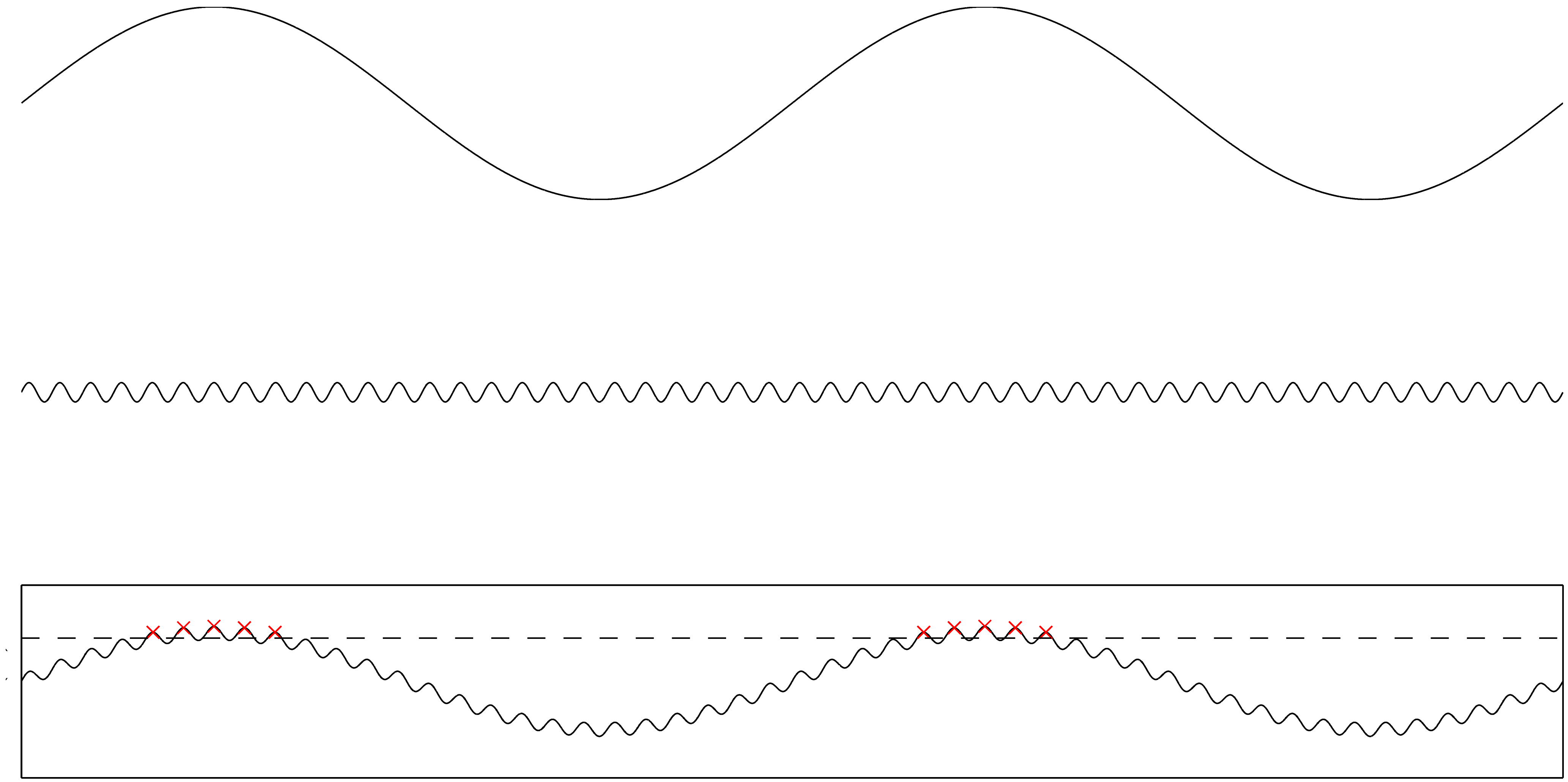
- (i) In the context of galaxy groups
- (ii) In the context of AGN

(IV) Analogies and results for the time-domain: a new era

(V) Endpoints and trajectories



(I) Review of dark matter halo and galaxy modelling



Galactic & cluster scale physics

Decelerative processes

- long cooling time
- tidal dissapation
- exploding supernovae
- AGN jets
- entropy barrier
- accretion shock

Accelerative processes

- $\Delta M/M \sim 1$ (mergers)
- $\Delta M/M \ll 1$ (gas accretion)

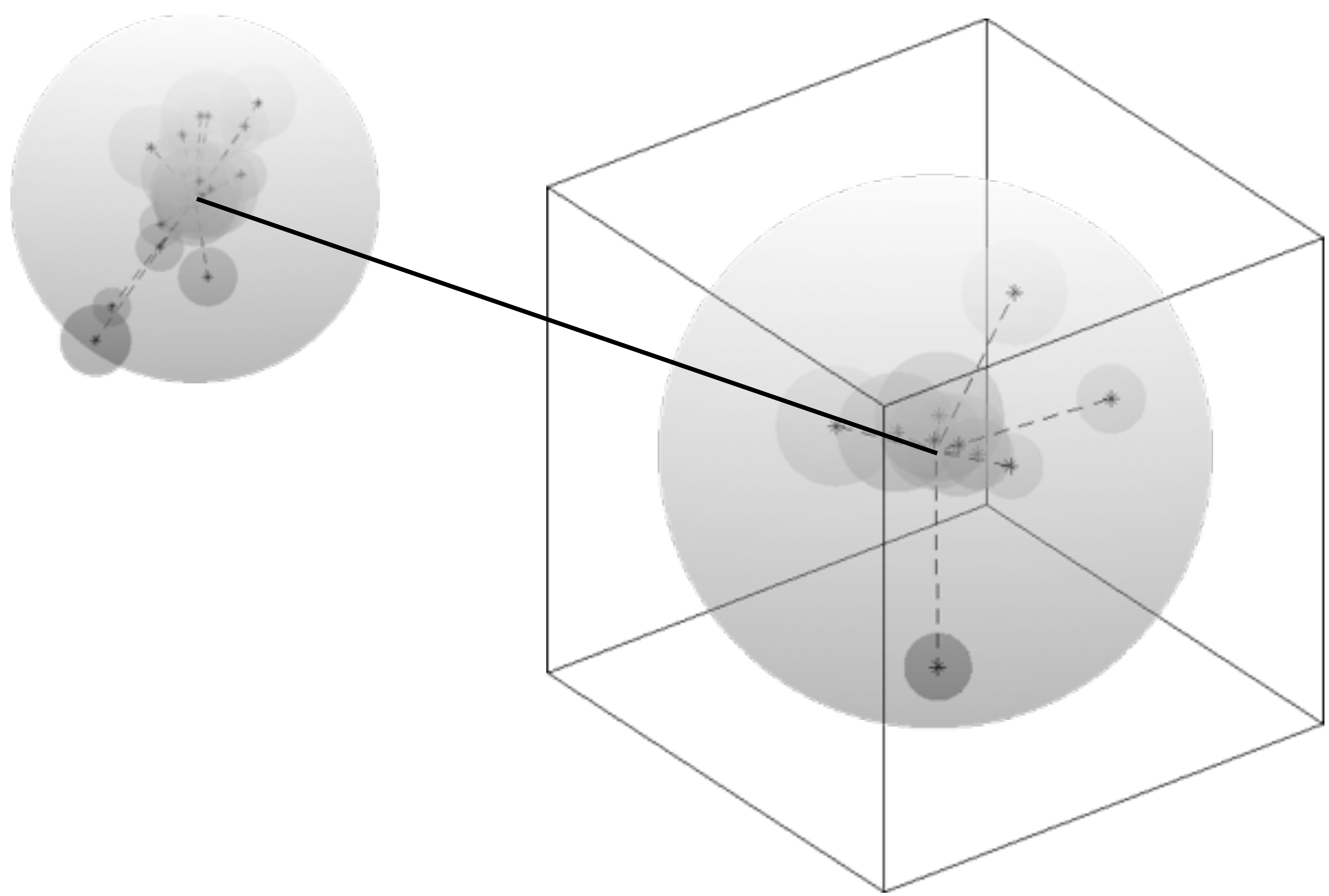
Inheritance and environment

Which properties are inherited?

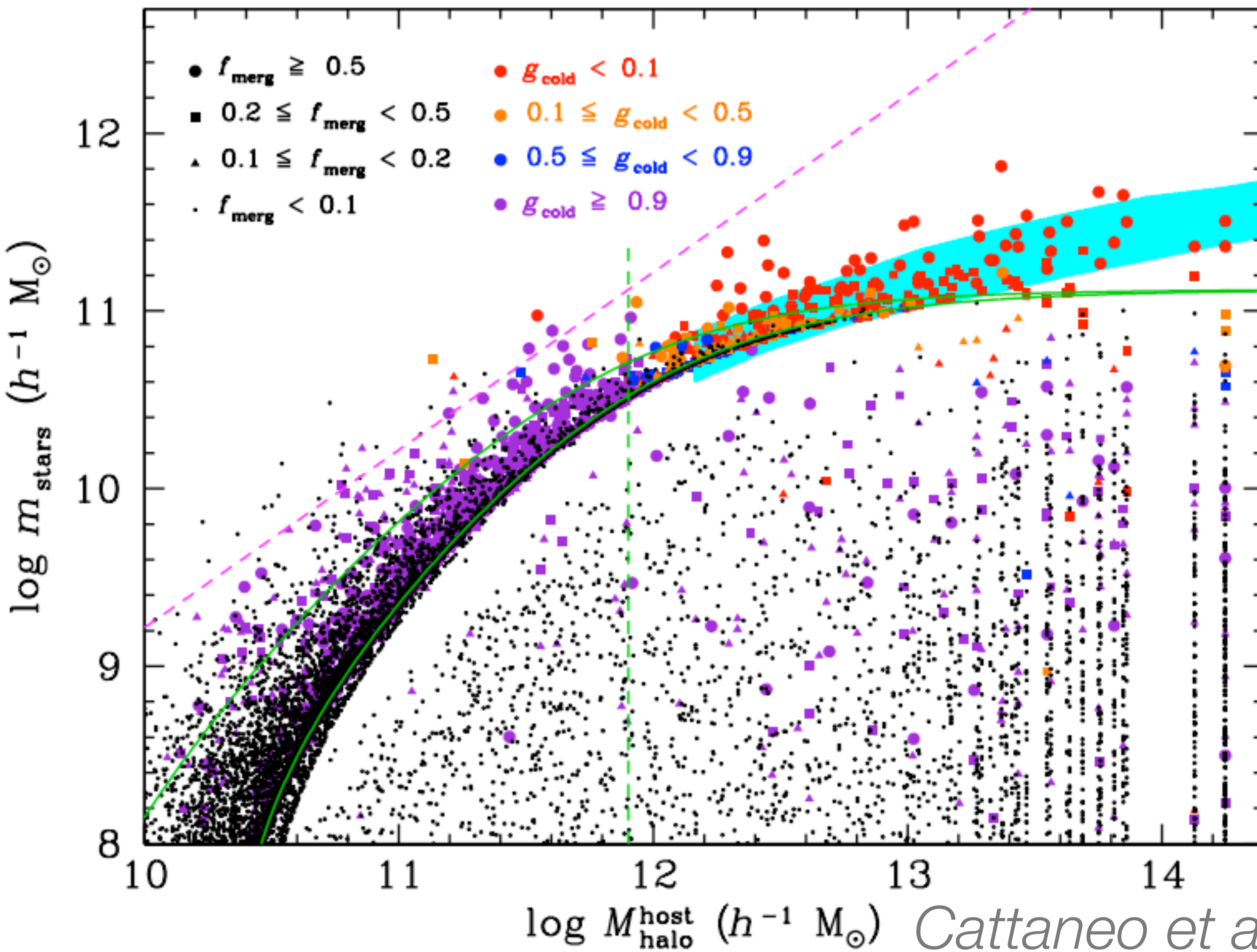
- stellar mass distribution
- luminosity distribution
- colour?

Which are incidental?

- non-distributional properties
- specific formation history

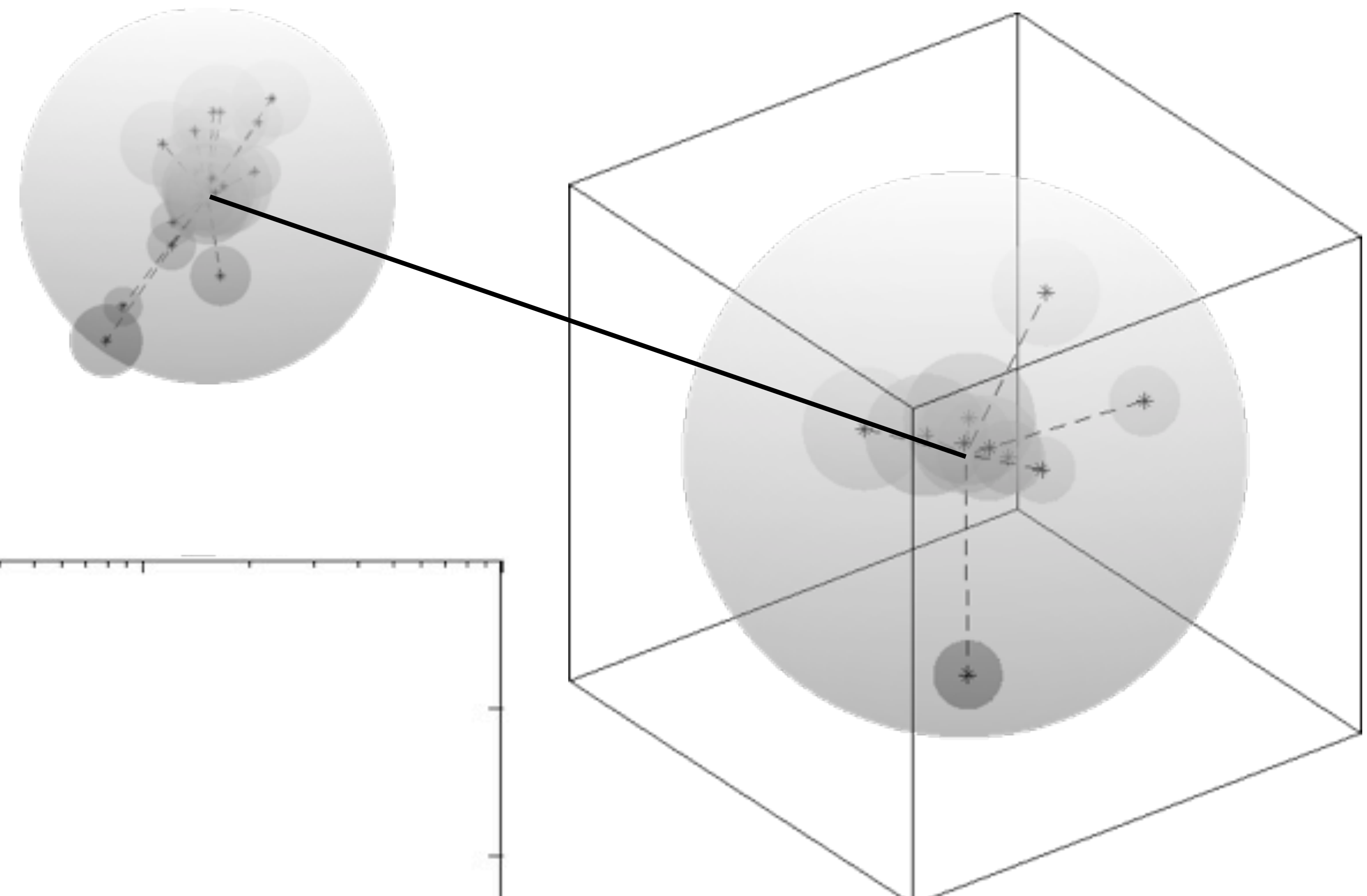


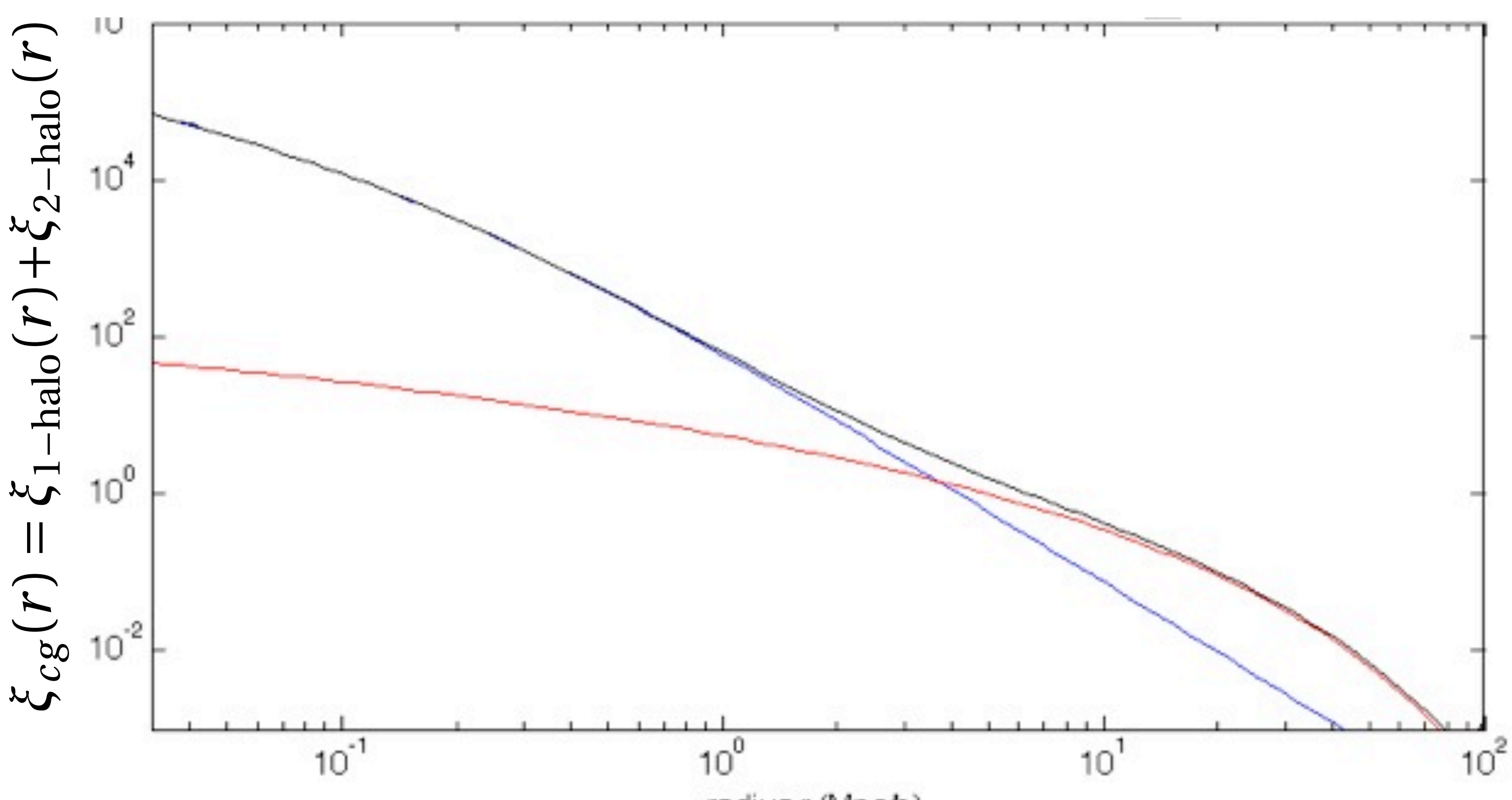
Distributional properties vs. specific properties



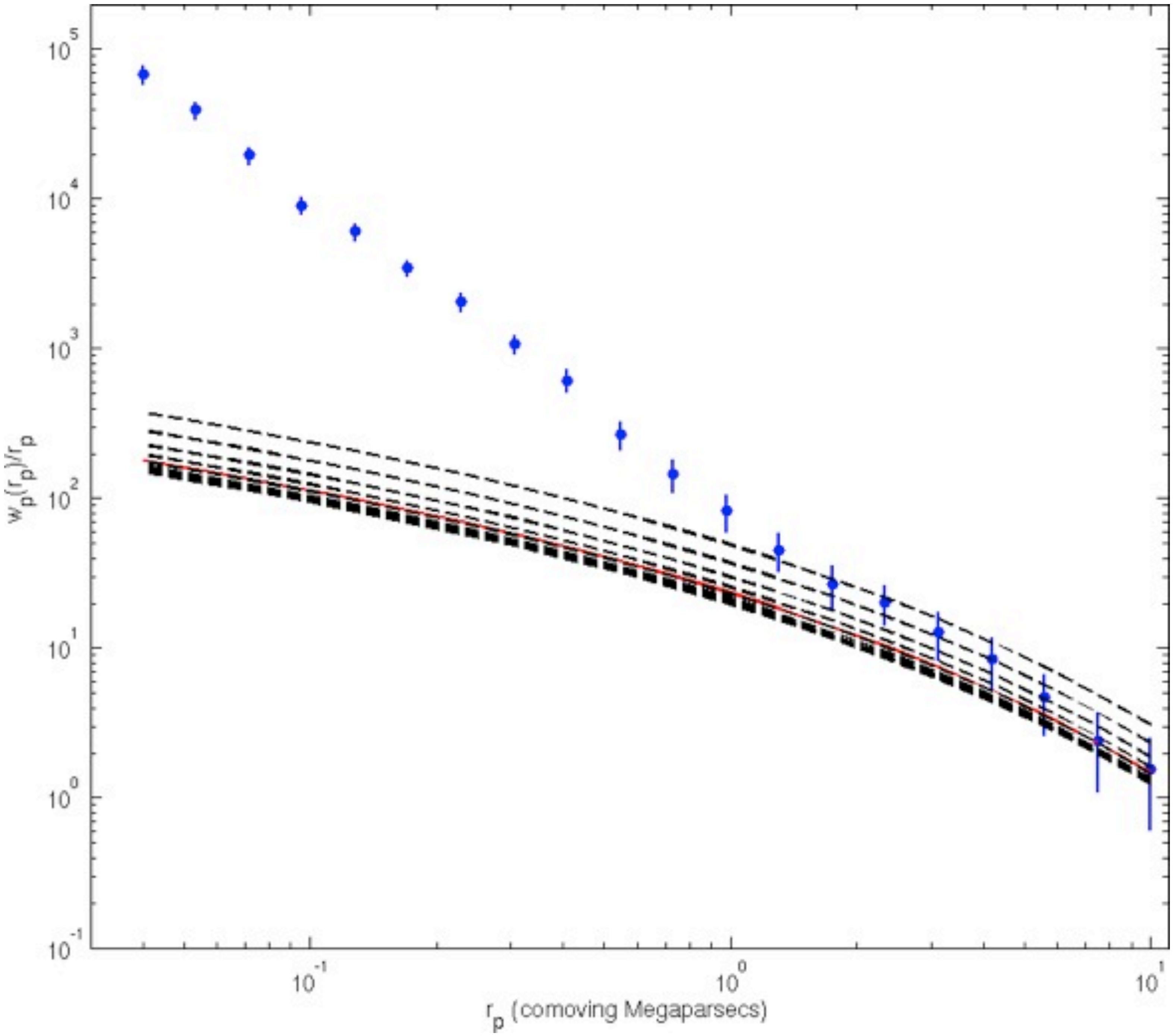
Cattaneo et al. (2010)

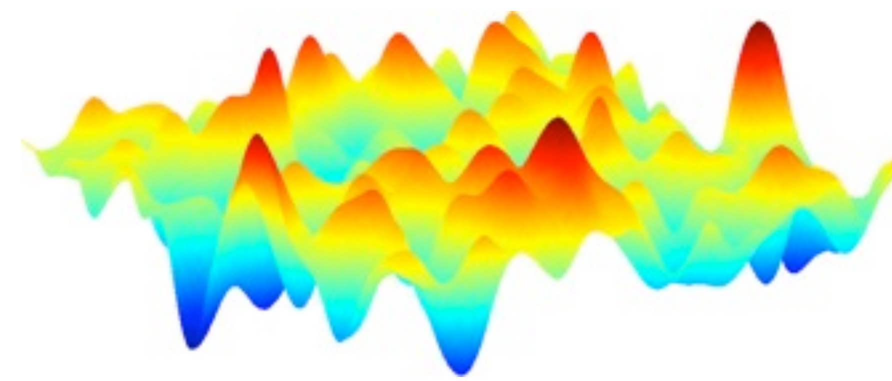
Inheritance leads naturally to the 'halo model'





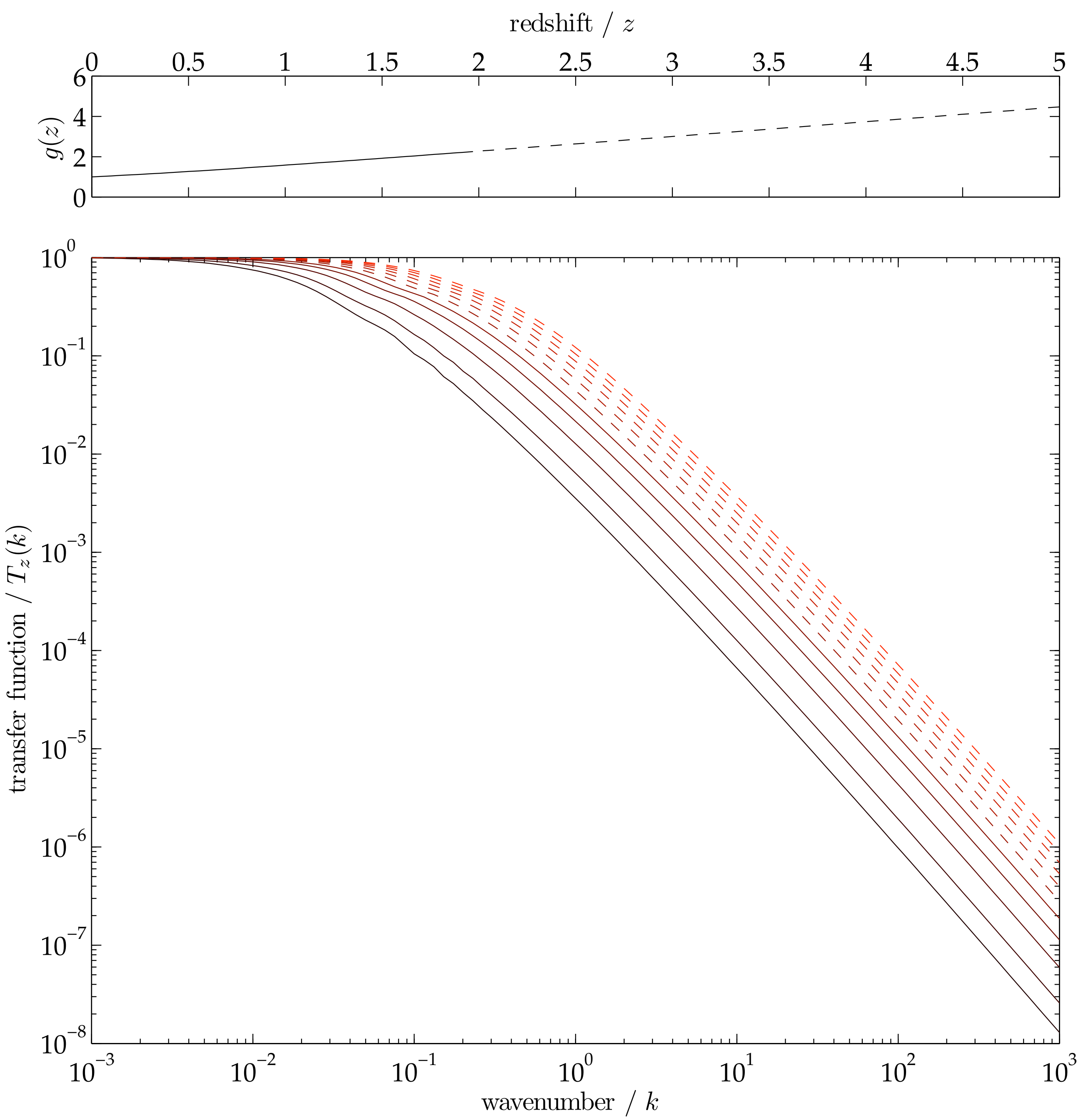
Clustering between haloes

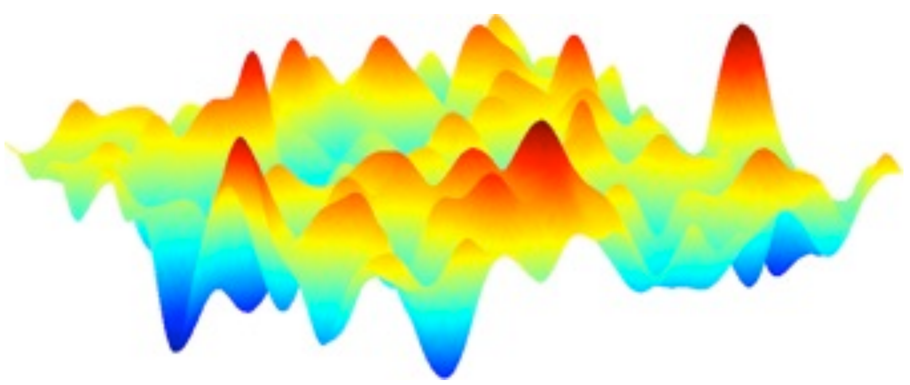




$$\nu \equiv \frac{\delta_c}{\sigma(M,z)}$$

Linear matter power spectrum



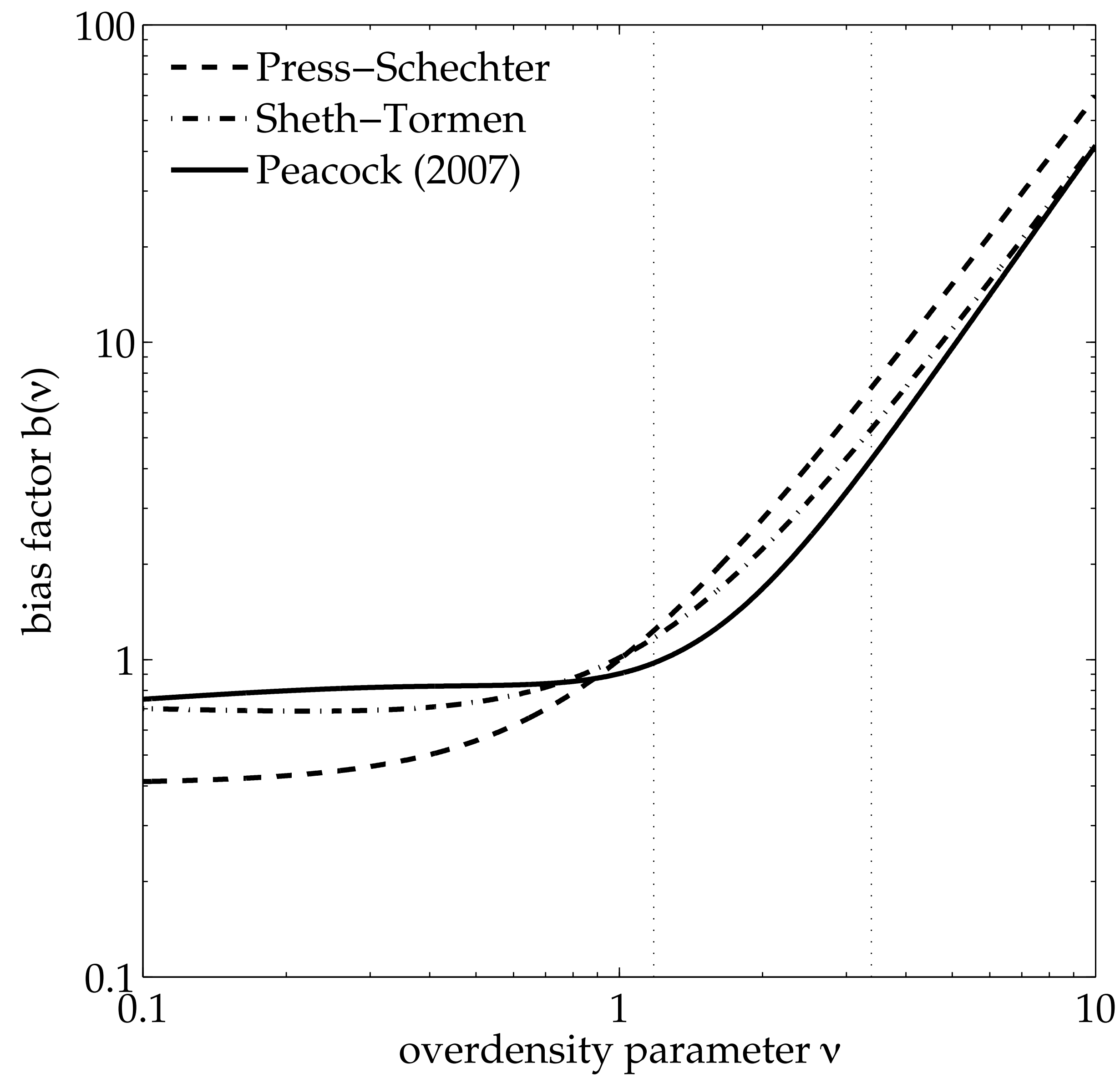


$$\Delta^2(k) = \frac{4}{25}\Delta^2_{\mathcal{R}}(k_0)\left(\frac{k}{k_0}\right)^{n_s-1} \times \left(\frac{ck}{H_0}\right)^4 T^2(k)\left(\frac{D_1(z)}{D_1(0)}\right)^2$$

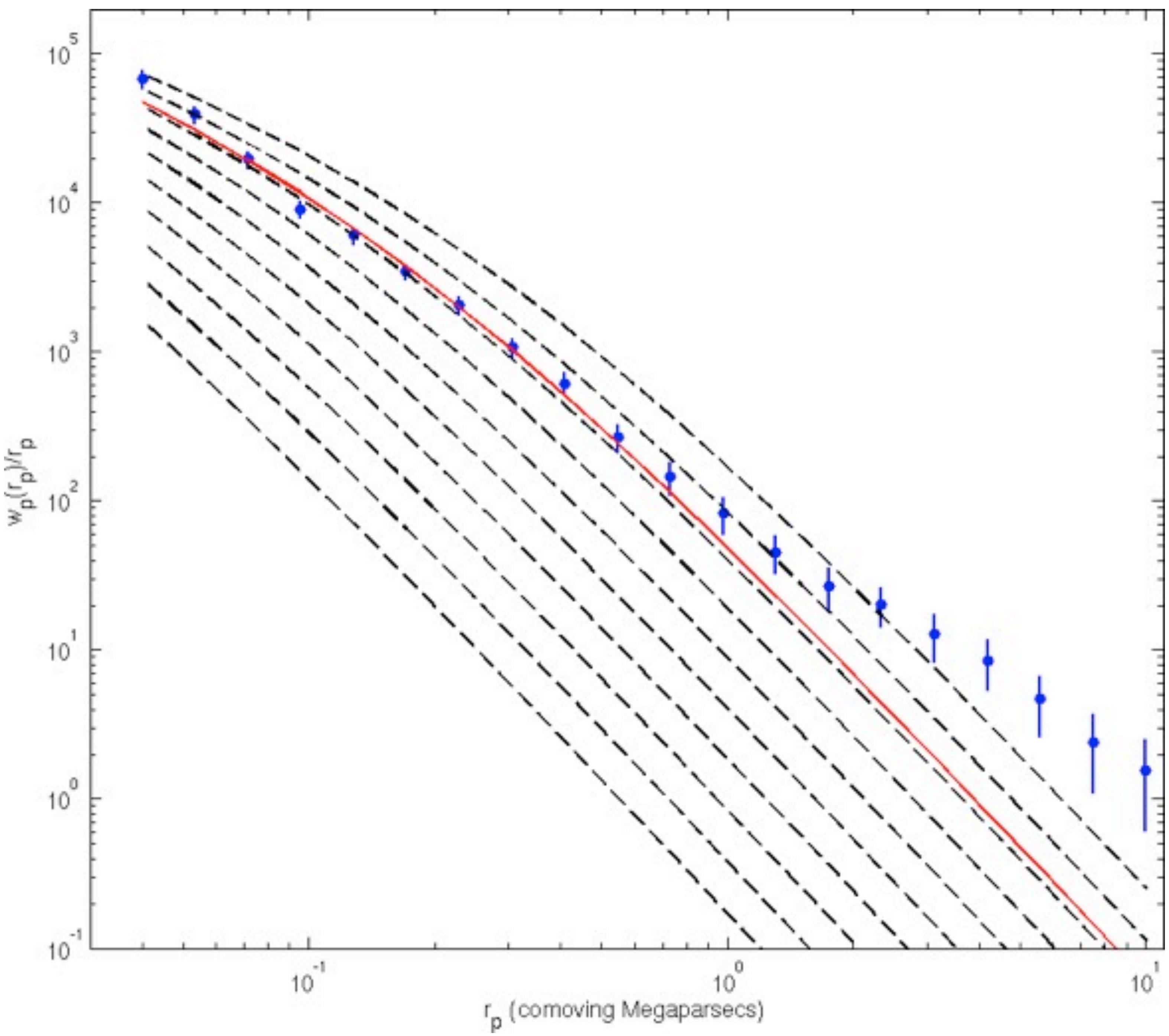
Bias: how clusters and galaxies follow dark matter

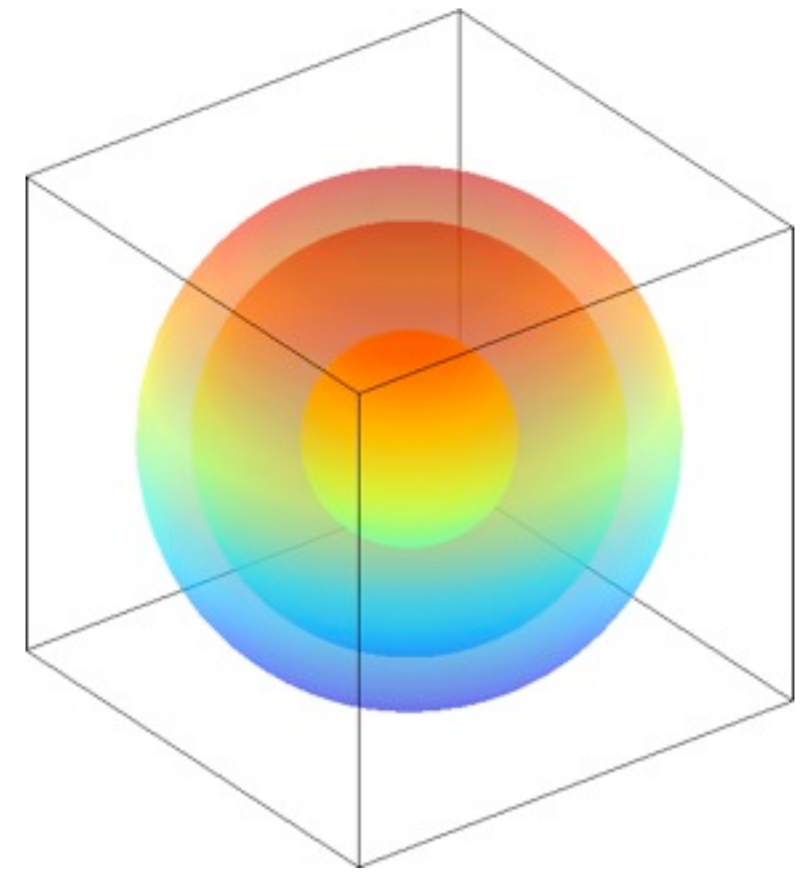
$$b_{\rm Eul} = 1 - \frac{1}{\delta_c}\frac{d}{d\log\nu}\left(\log\frac{df_c}{d\log\nu}\right)$$
$$= 1 - \frac{1}{\sigma}\frac{d}{d\nu}\left(\log\frac{df_c}{d\log\nu}\right)$$

$$\frac{df_c}{d\log\nu} = \frac{2}{\sqrt{2\pi}}\nu\exp\left(-\frac{\nu^2}{2}\right)$$
$$\Rightarrow b^{\rm PS}_{\rm Eul}(\nu) = 1 + \frac{\nu^2-1}{\delta_c}$$



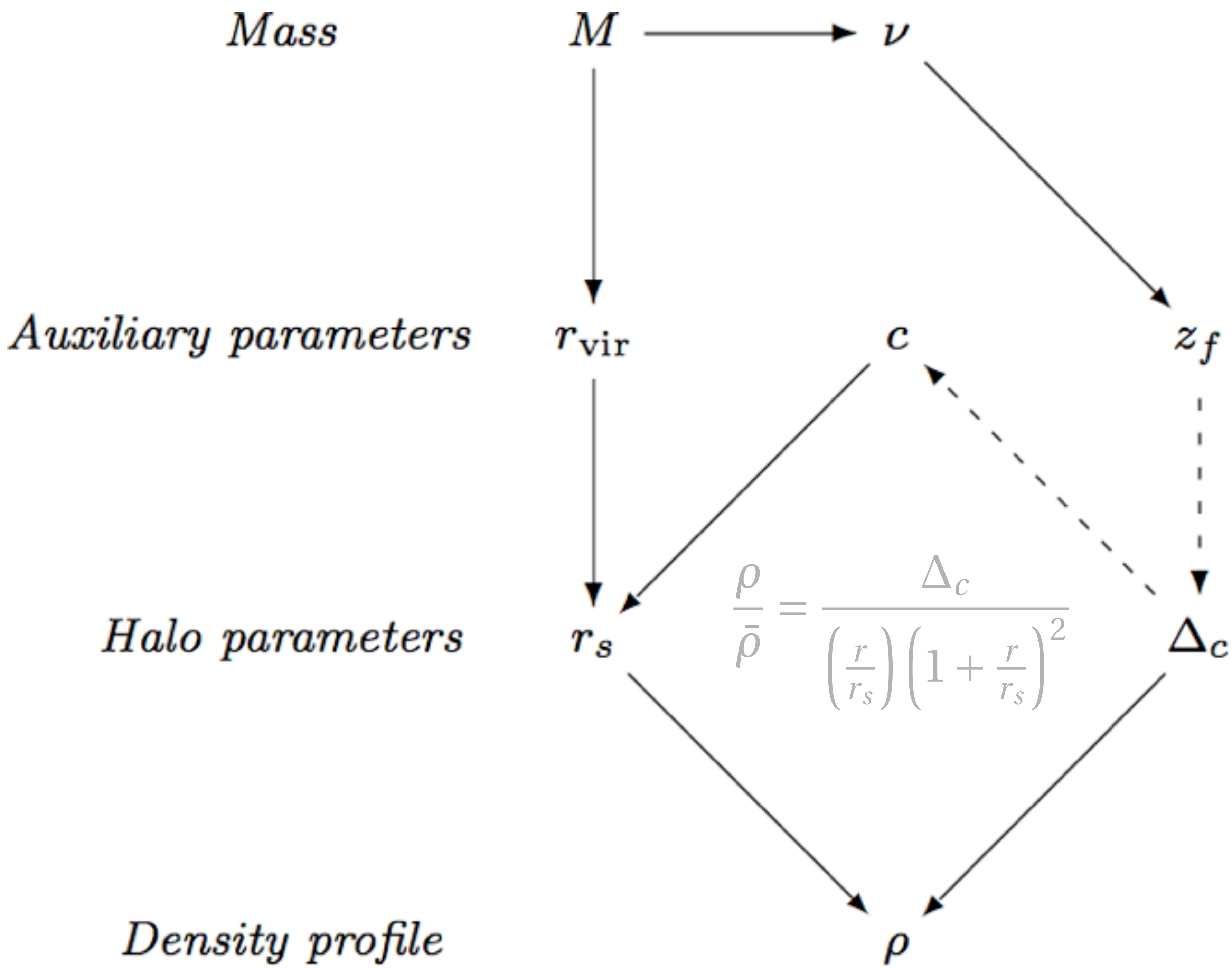
Clustering within haloes



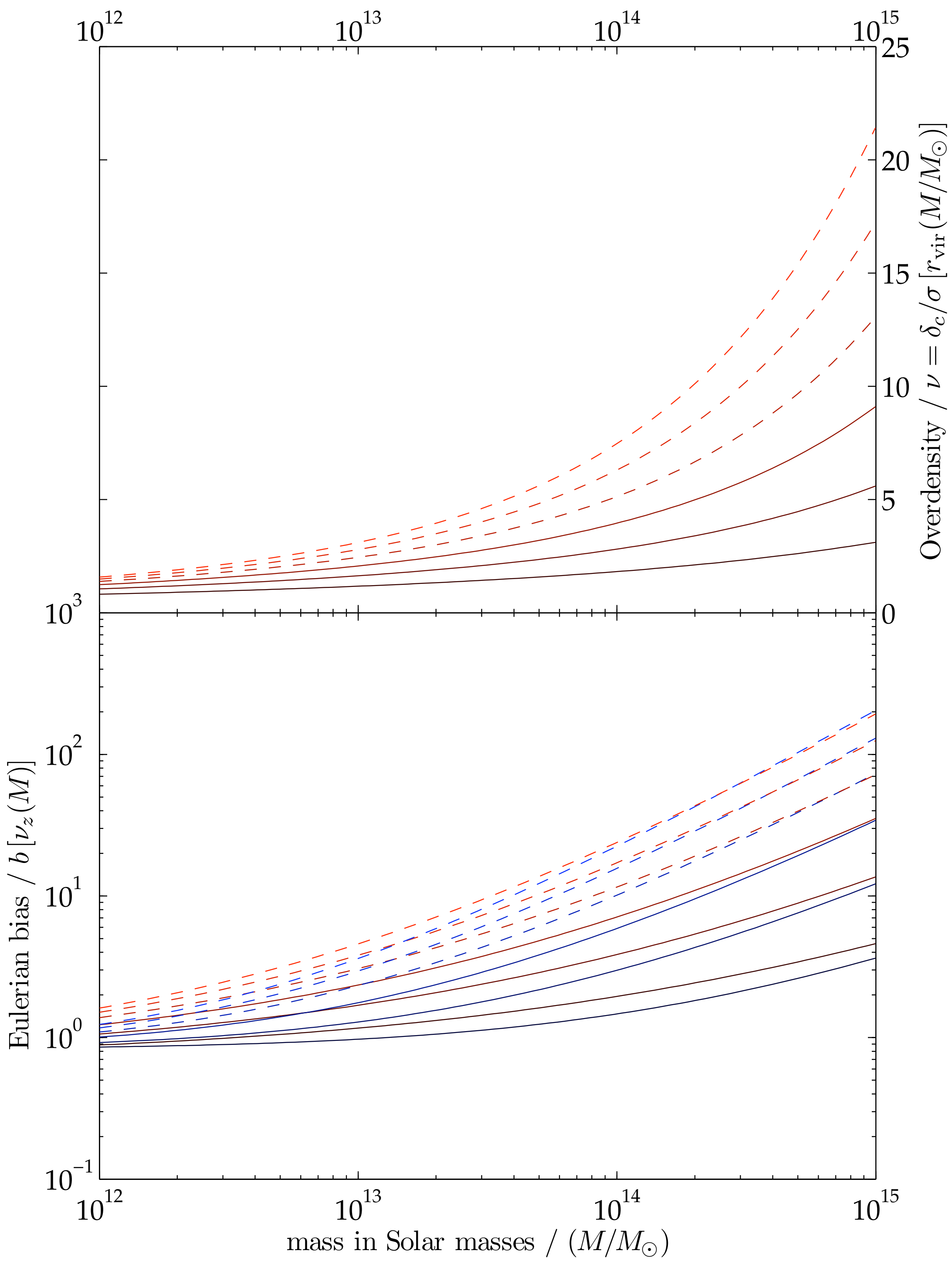


$$\frac{\rho}{\bar{\rho}} = \frac{\Delta_c}{\left(\frac{r}{r_s}\right)\left(1 + \frac{r}{r_s}\right)^2}$$

Density profile of dark matter haloes



Galaxy bias and halo occupation



$$b_{\rm eff} \approx b_c(M) b_g$$

$$b_g = \frac{\int b_c(M)\langle N_g(M)\rangle n(M) dM}{\int \langle N_g(M)\rangle n(M) dM}$$

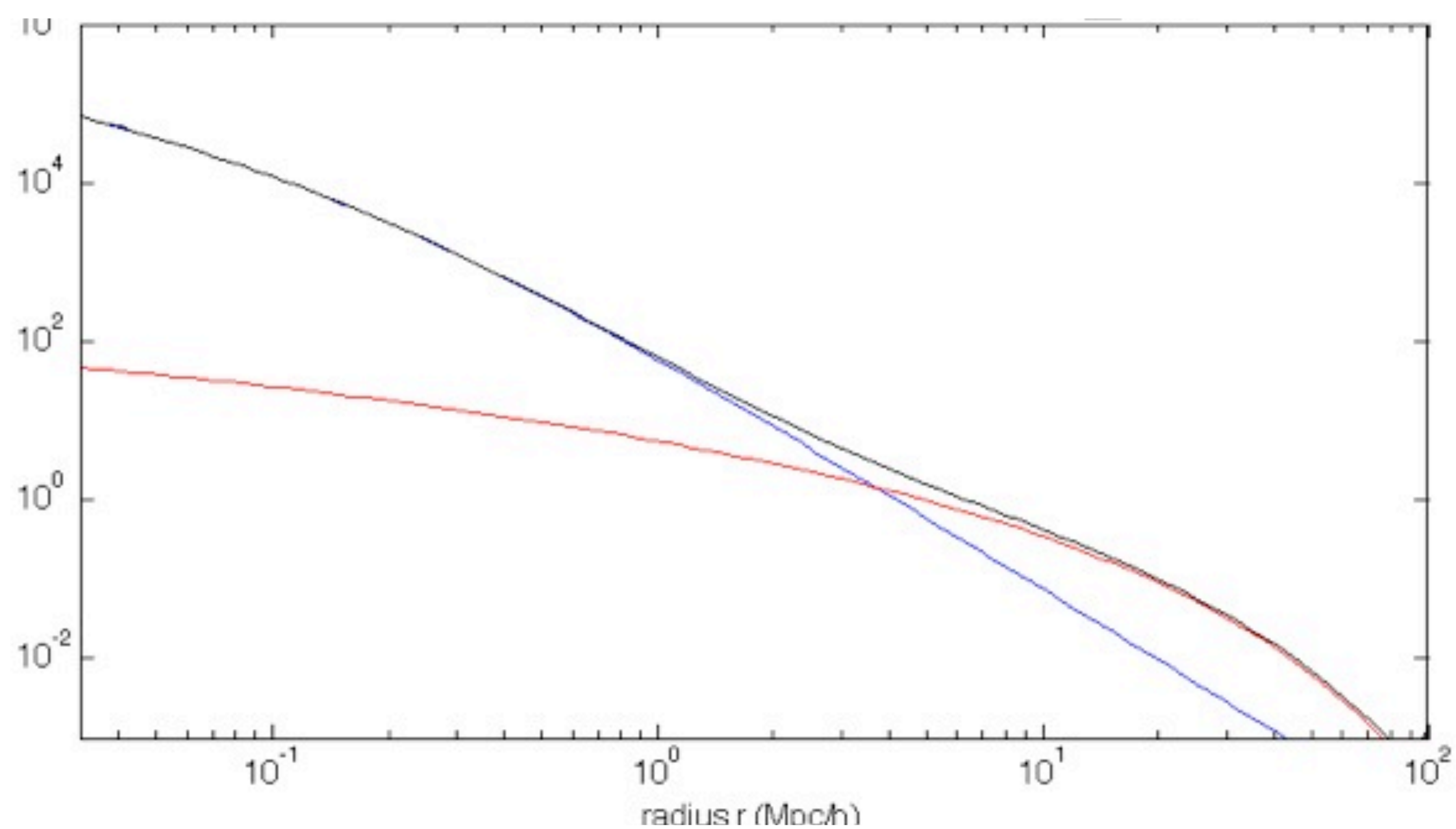
$$b_g \approx \frac{\sum_{i=1}^{n_c} b_c(M_i)\langle N_g(M_i)\rangle}{\sum_{i=1}^{n_c}\langle N_g(M_i)\rangle}$$

Summary (I)

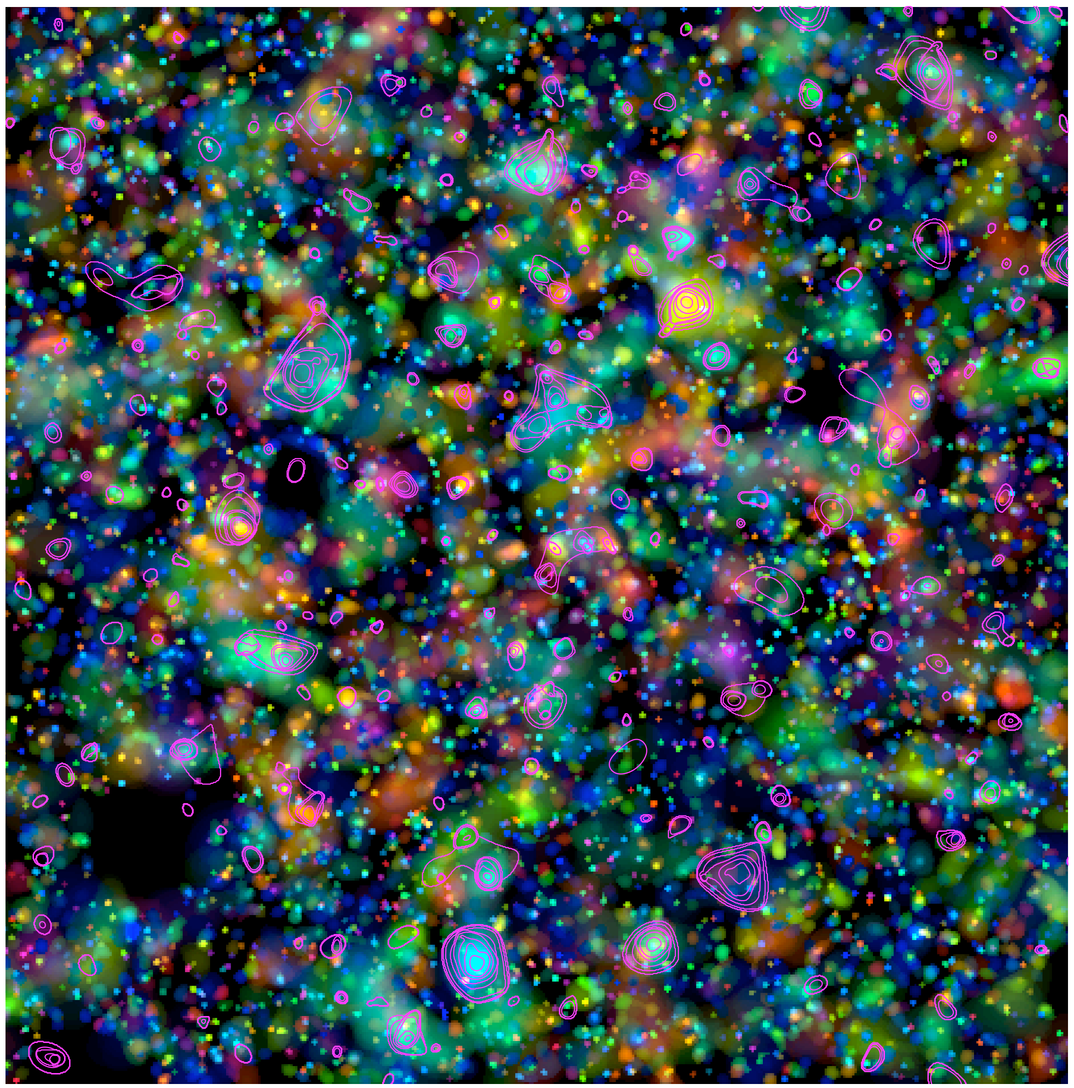
Which properties of galaxies, either individually or in distribution, can be linked to the properties of the larger structures in which they are embedded?

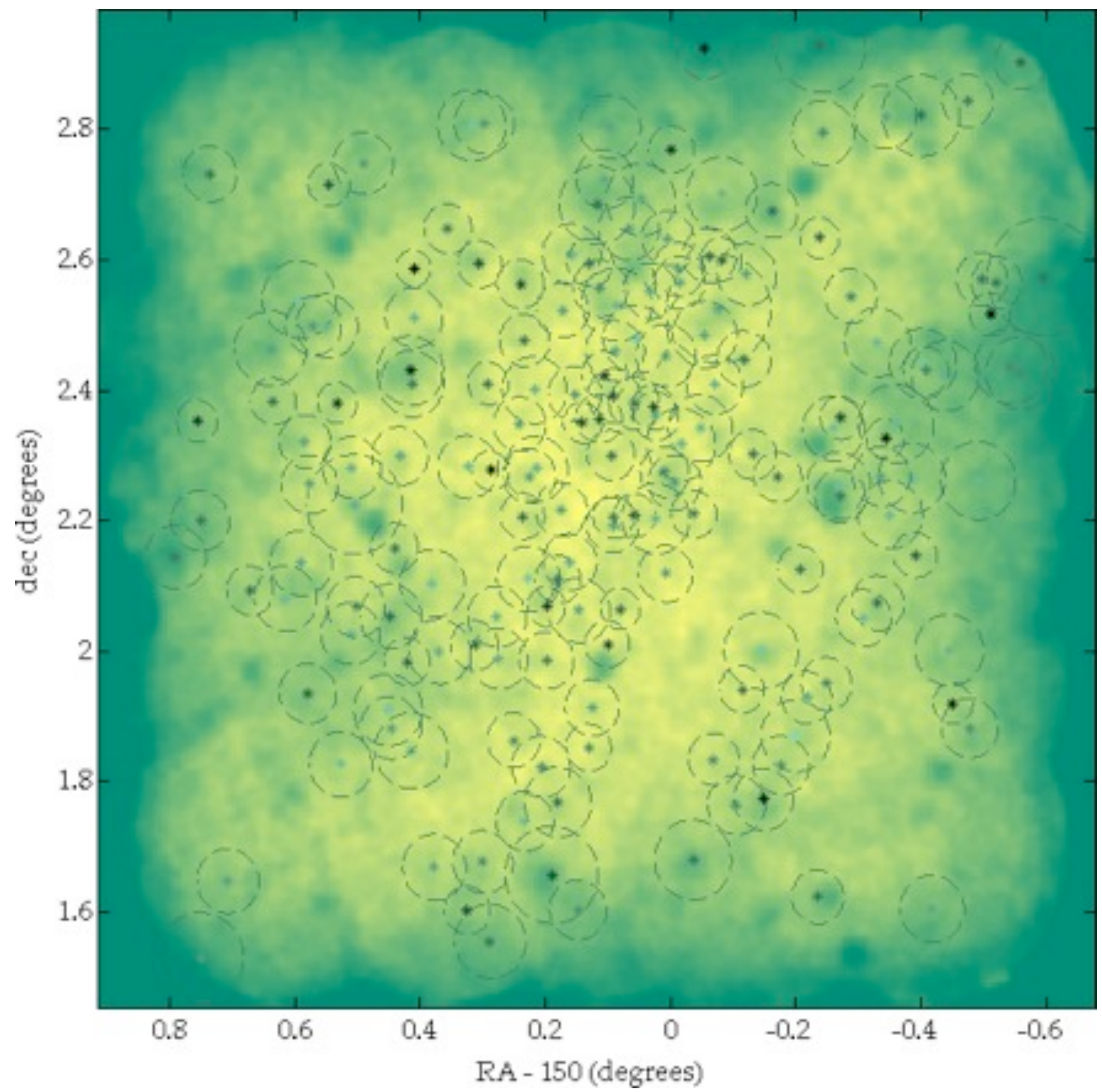
Which properties result from individual formation histories and local environmental states?

$$\xi_{cg}(r) = \xi_{1-\mathrm{halo}}(r) + \xi_{2-\mathrm{halo}}(r)$$

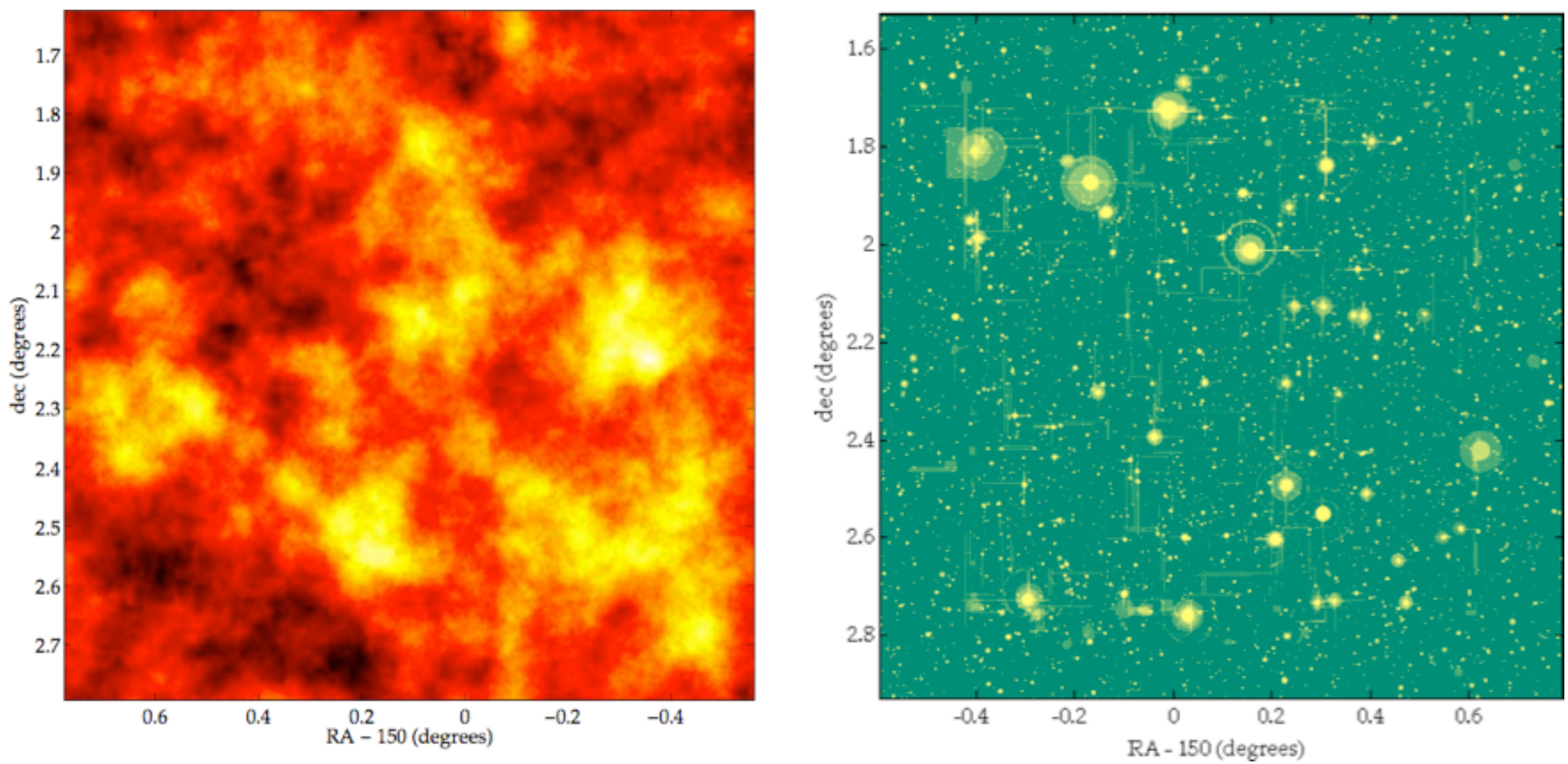


(II) Galaxies, groups & AGN in COSMOS

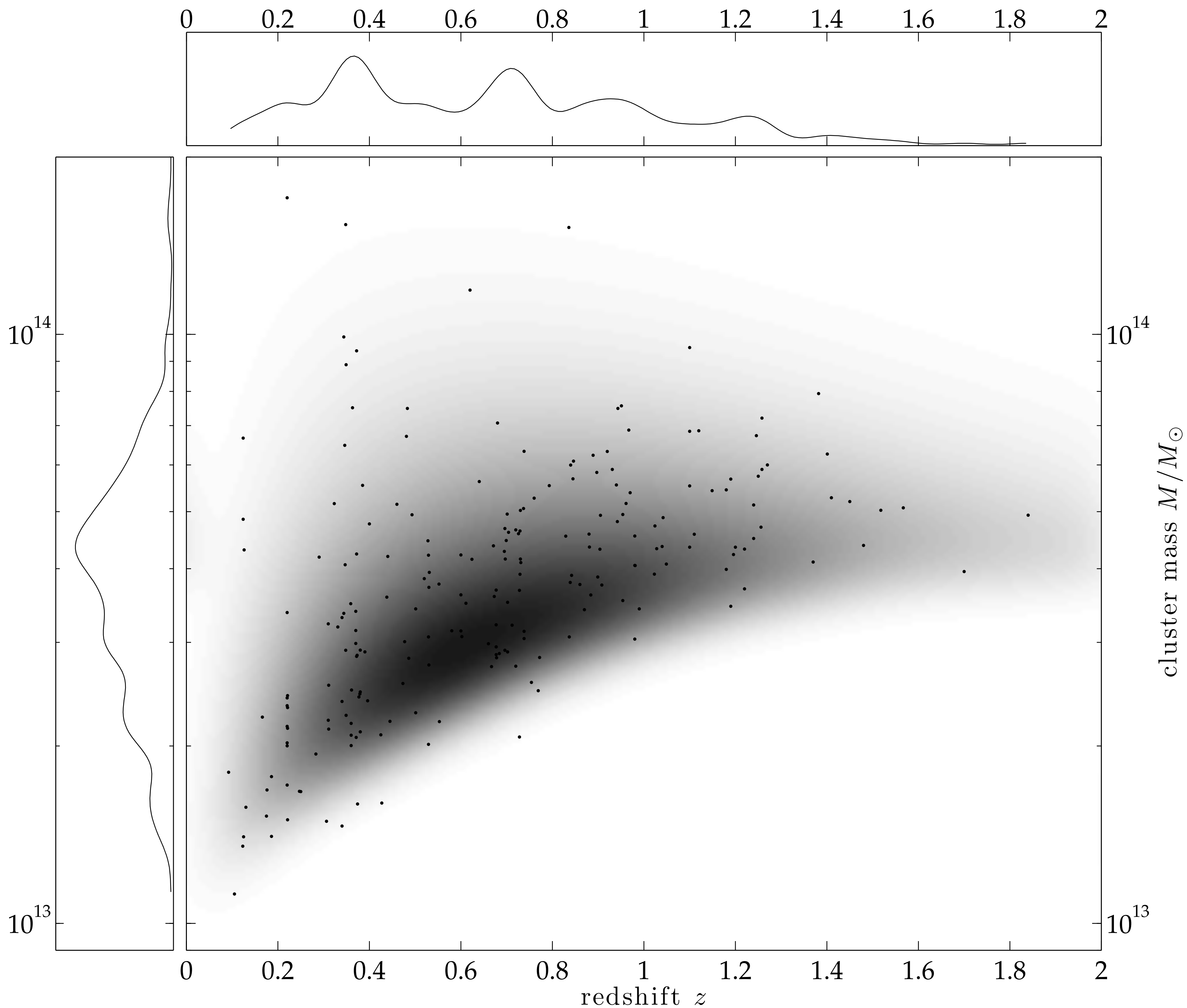




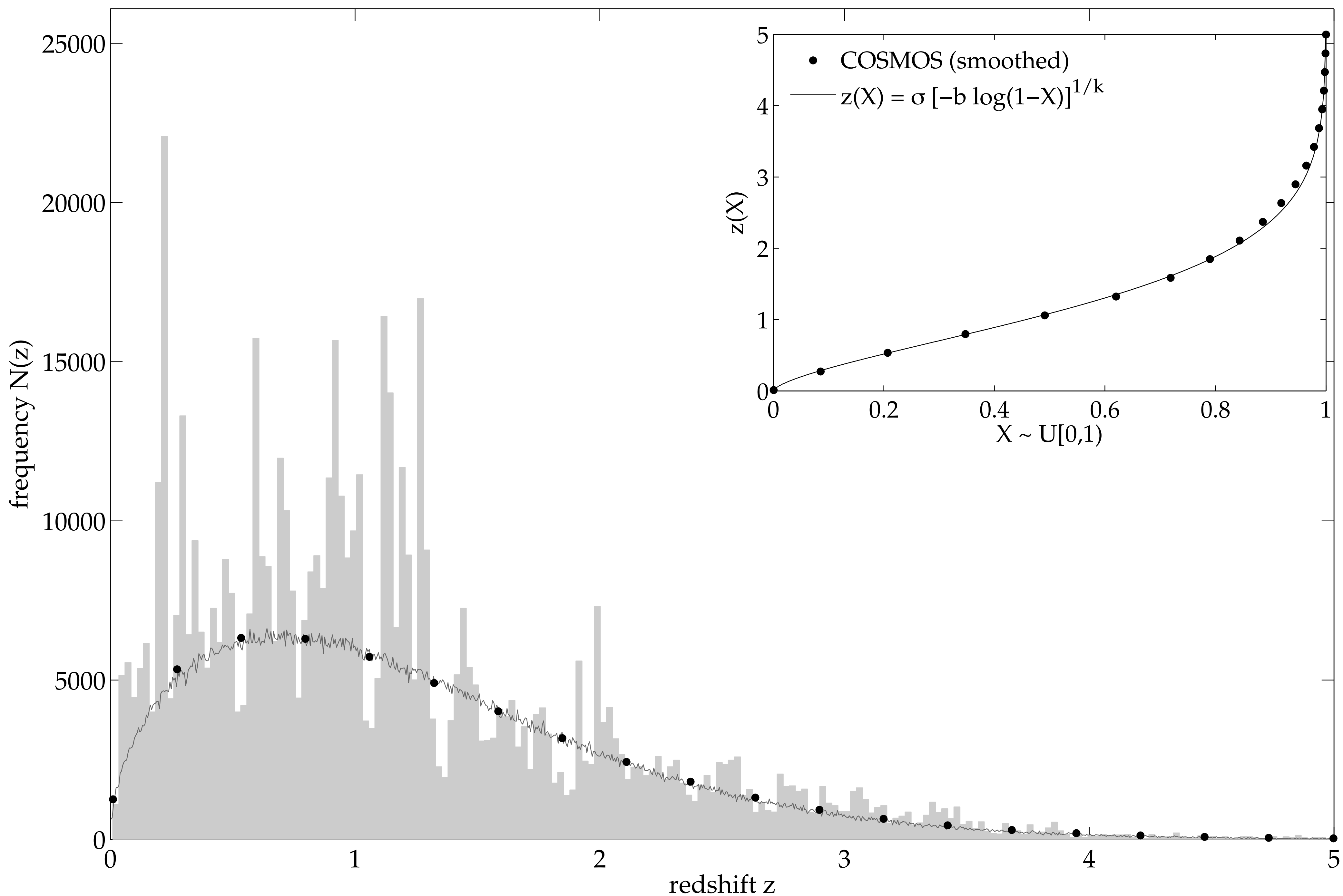
Galaxies in the Cosmic Evolution Survey



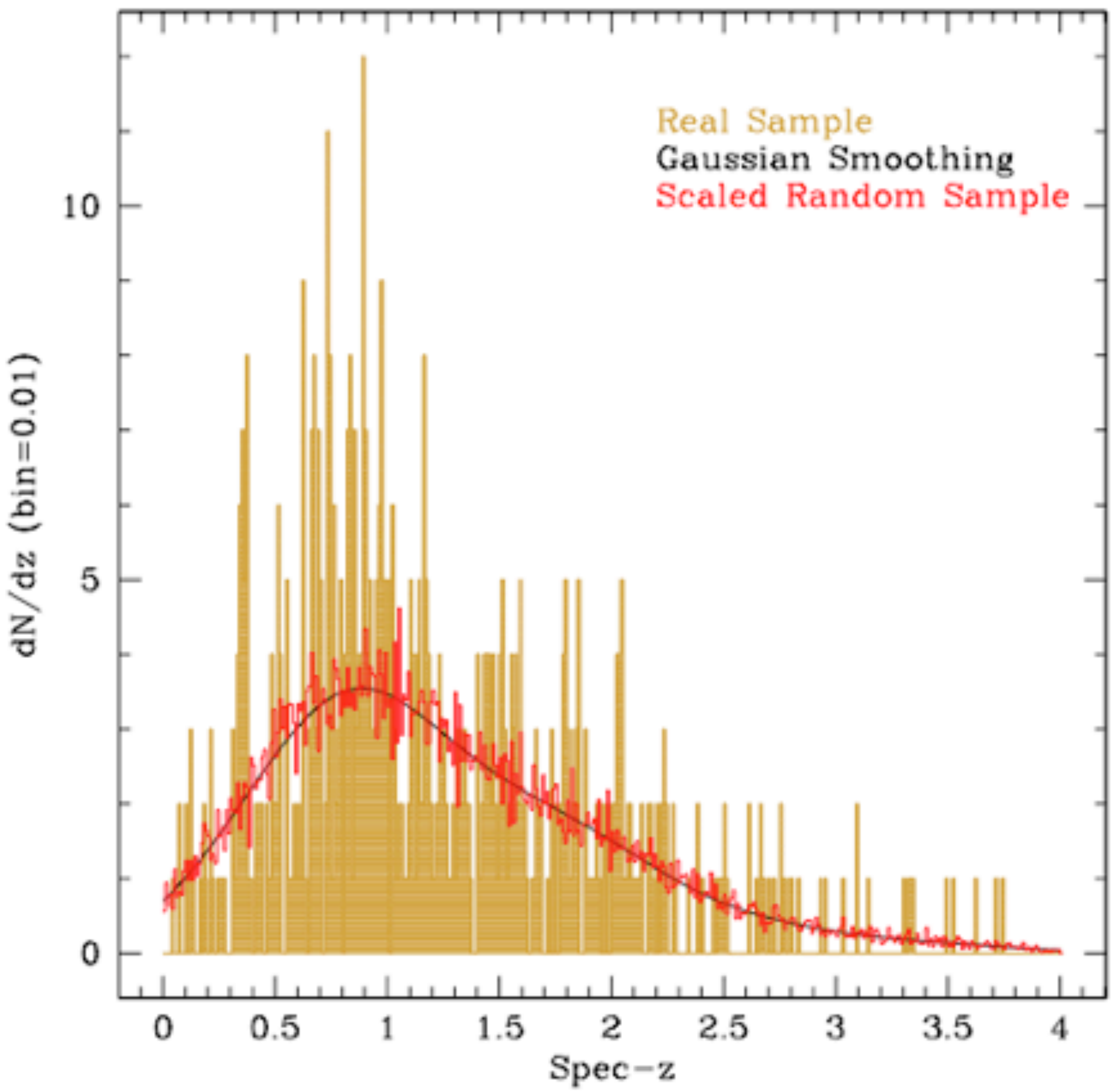
Cluster mass-redshift plane

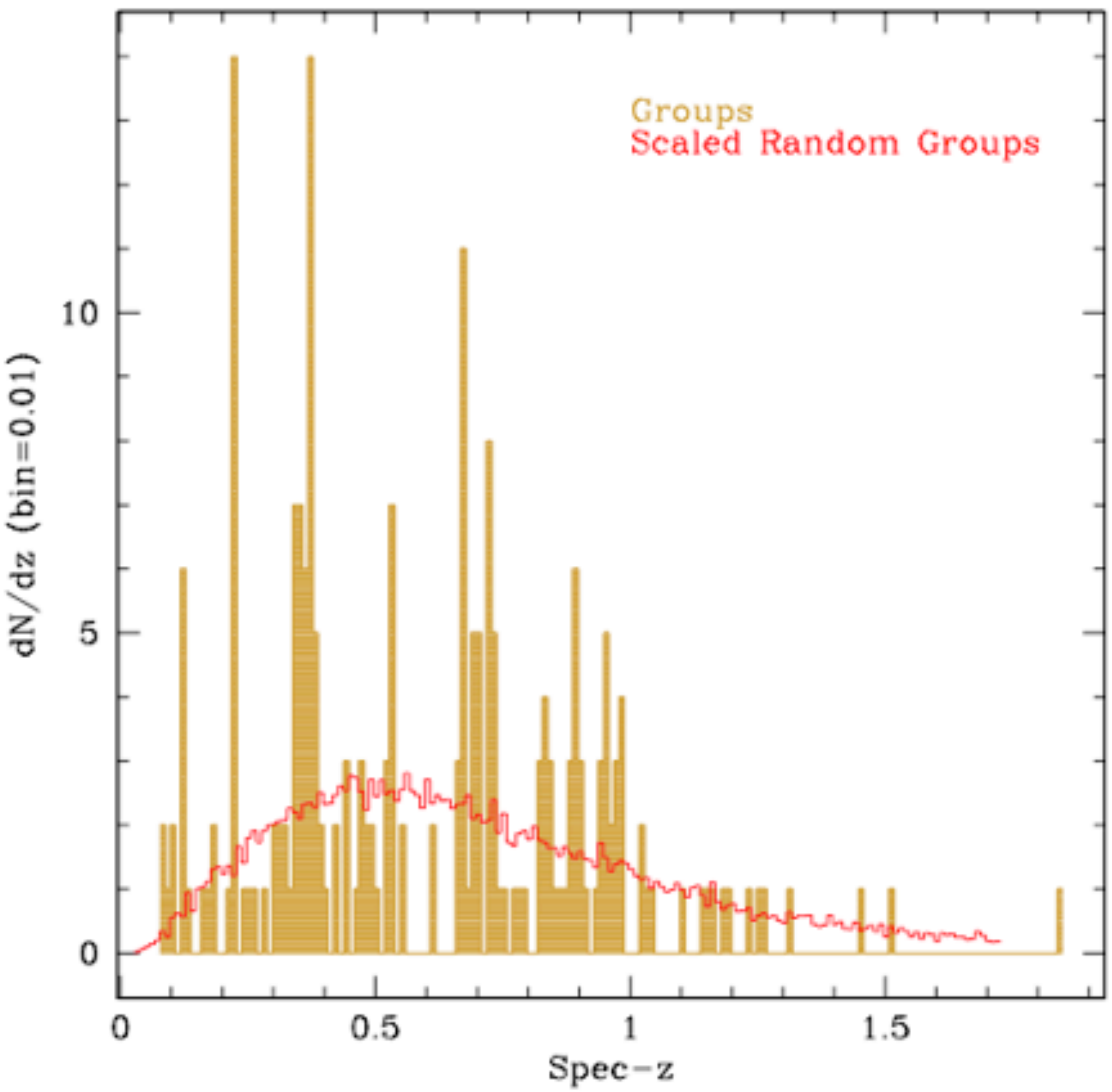


Fitting the redshift distribution of galaxies



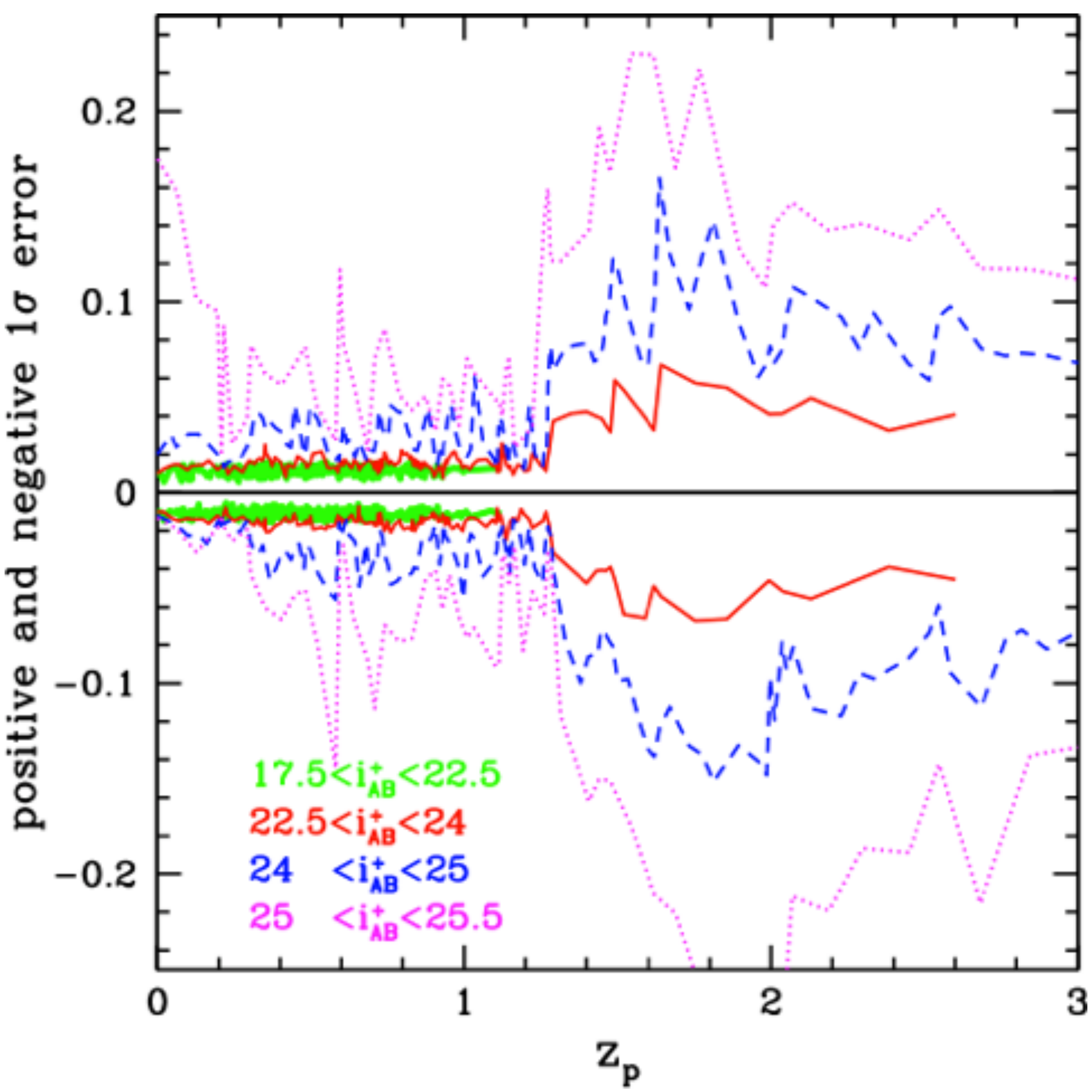
Redshift distribution of AGN in COSMOS



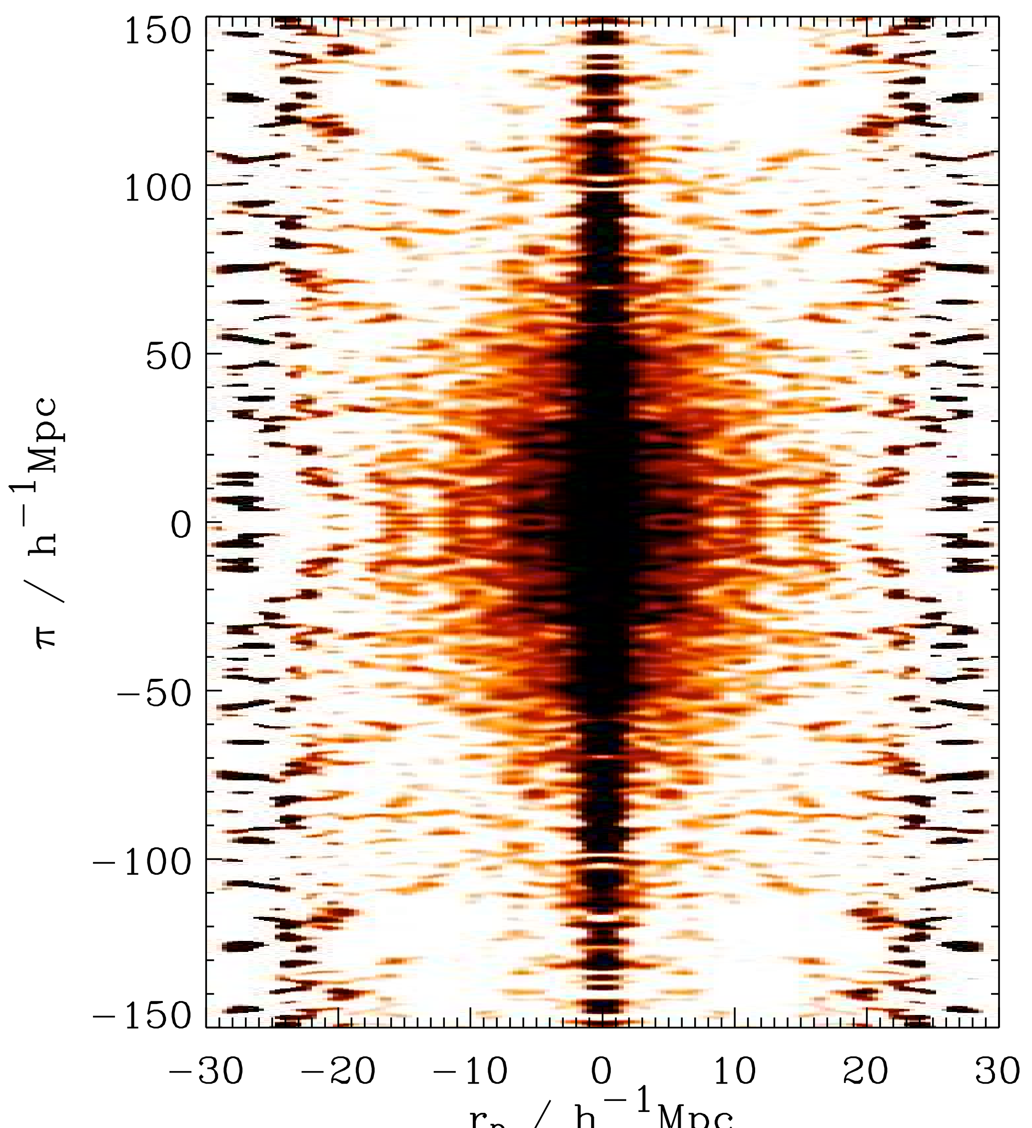


Allevato et al. (in prep)

Use of projected correlation function

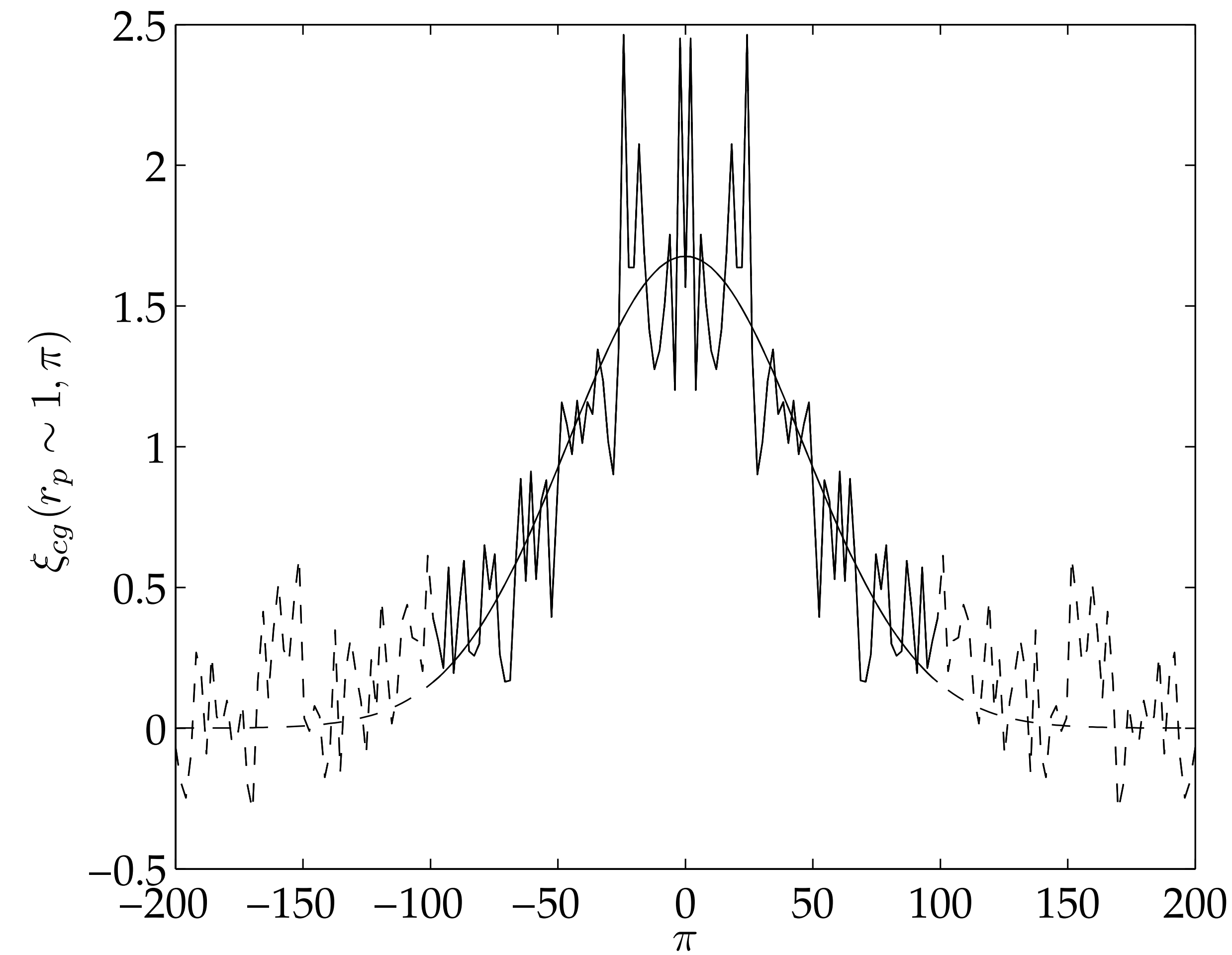


Ilbert et al. (2009) ApJ 690 1239



$$w_p(r_p) = 2\int_0^\infty \xi_{cg}^{LS}(r_p,\pi)\,d\pi;$$

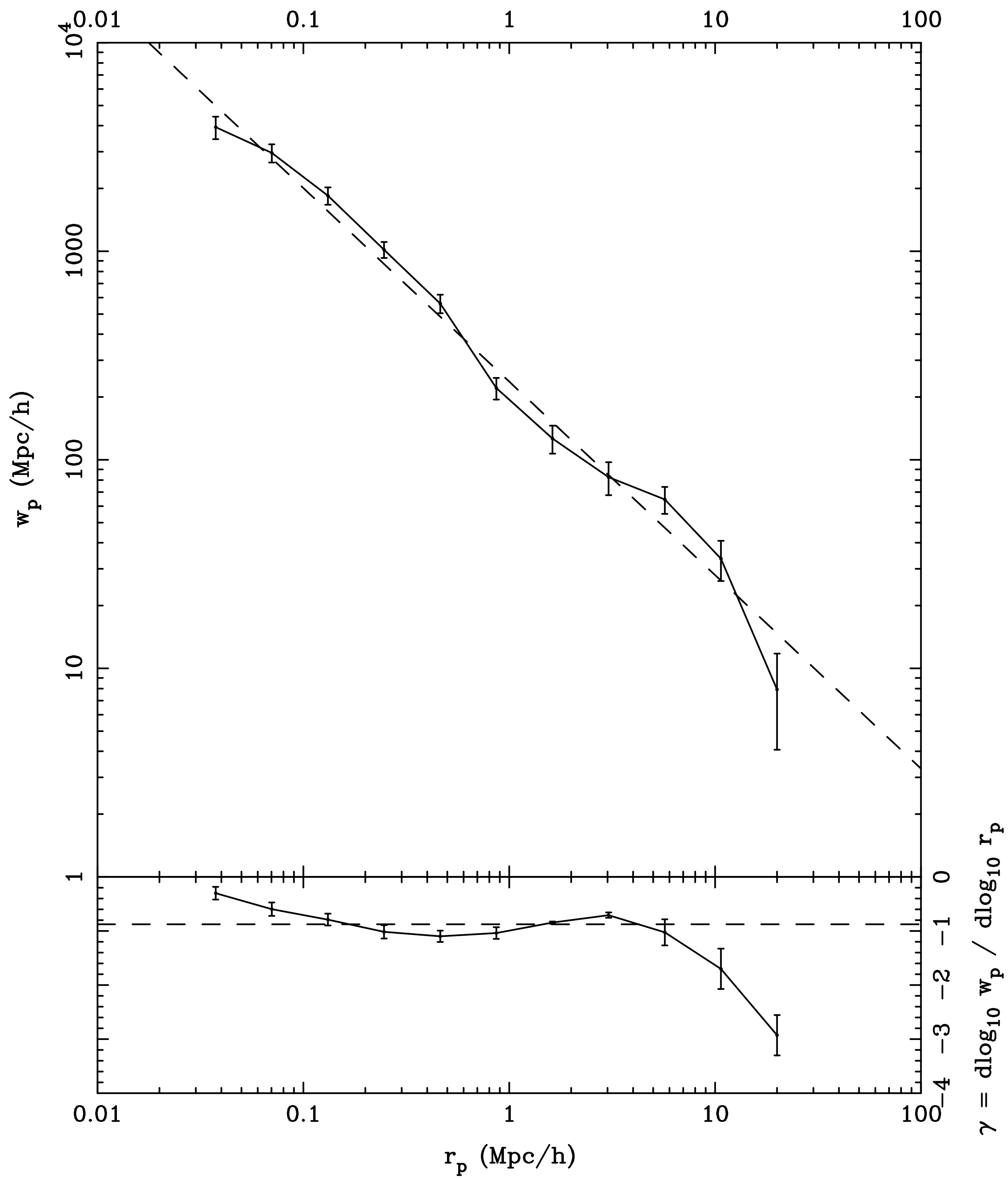
Projection of decomposed distribution



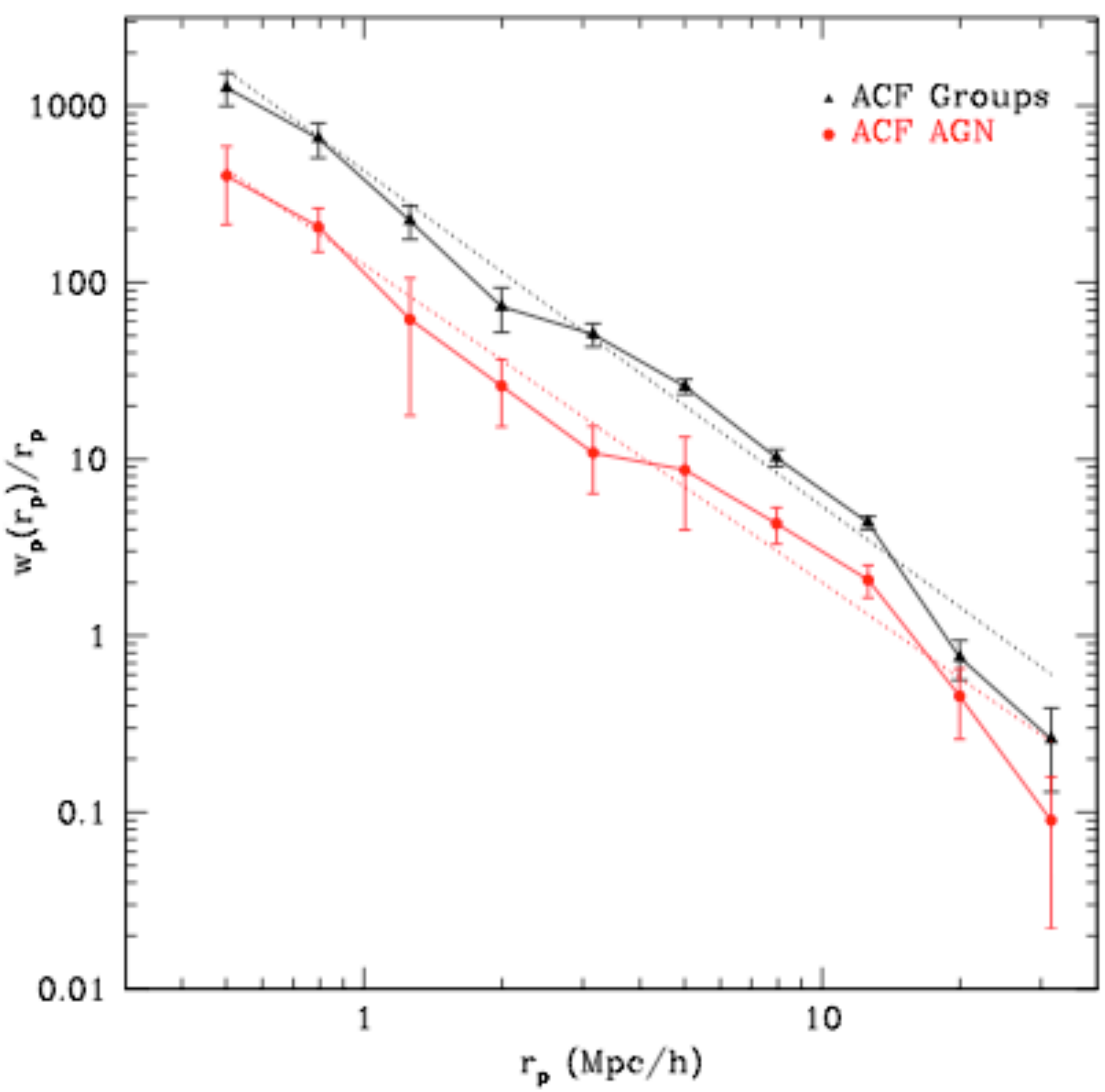
$$
\begin{aligned}
w_p(r_p) &= 2\int_0^{\pi_{\rm cut}} \xi_{cg}^{\rm LS}(r_p,\pi)d\pi + \\
& \quad 2\int_{\pi_{\rm cut}}^{\infty} A_\pi(r_p)\exp\left[-\frac{\pi^2}{2\sigma_\pi(r_p)^2}\right]d\pi \\
&= w_p(r_p)_{\rm cut} + 2A_\pi(r_p){\rm erf}_c\left(\frac{\pi_{\rm cut}}{\sigma_\pi(r_p)\sqrt{2}}\right)
\end{aligned}
$$

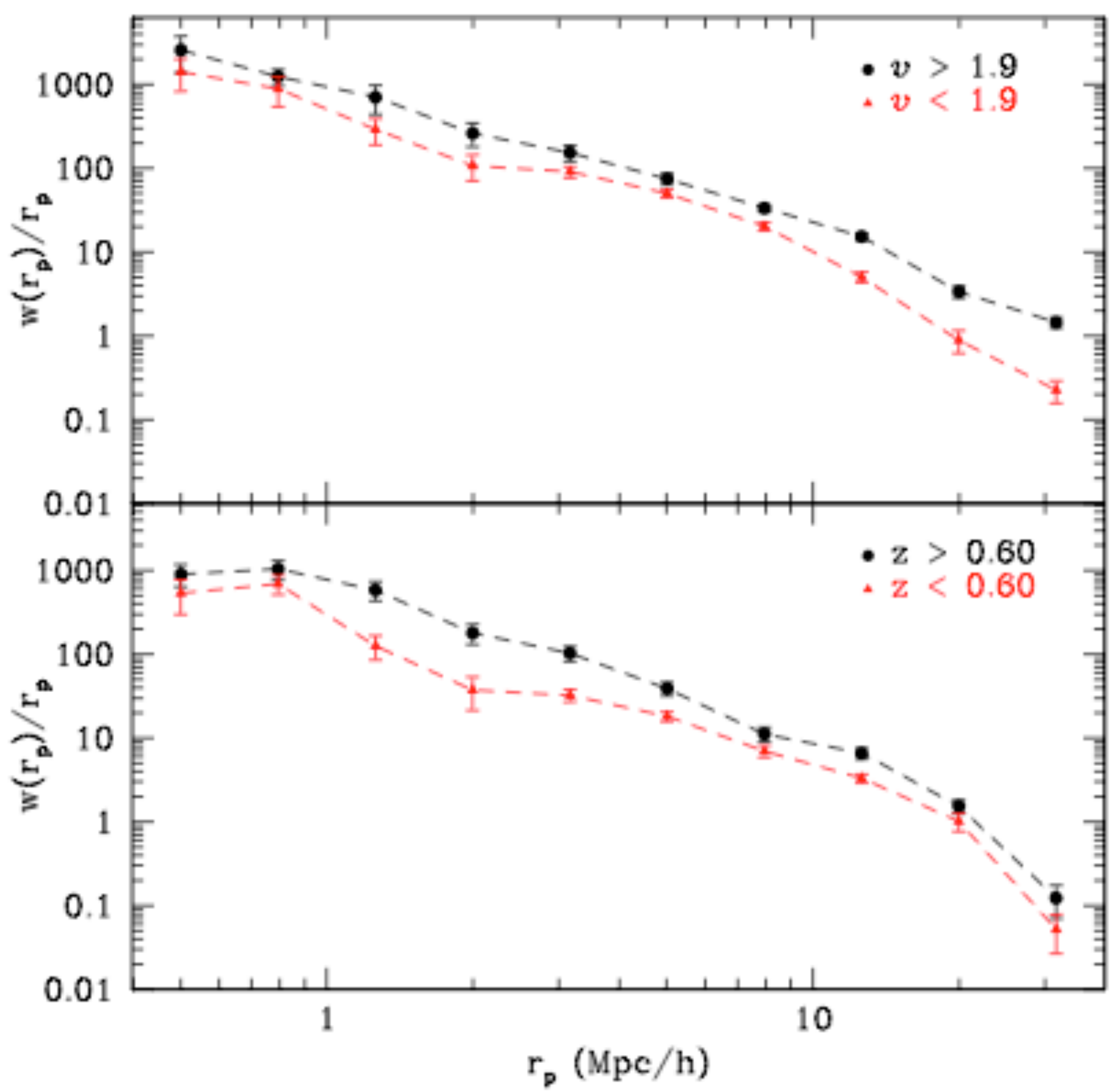
(III) Results on clustering behaviour

- Group auto-correlation
- AGN auto-correlation
- Group-AGN cross correlation
  - NL AGN vs. BL AGN
  - Group mass, redshift
- Group-galaxy cross correlation
  - Group mass, redshift



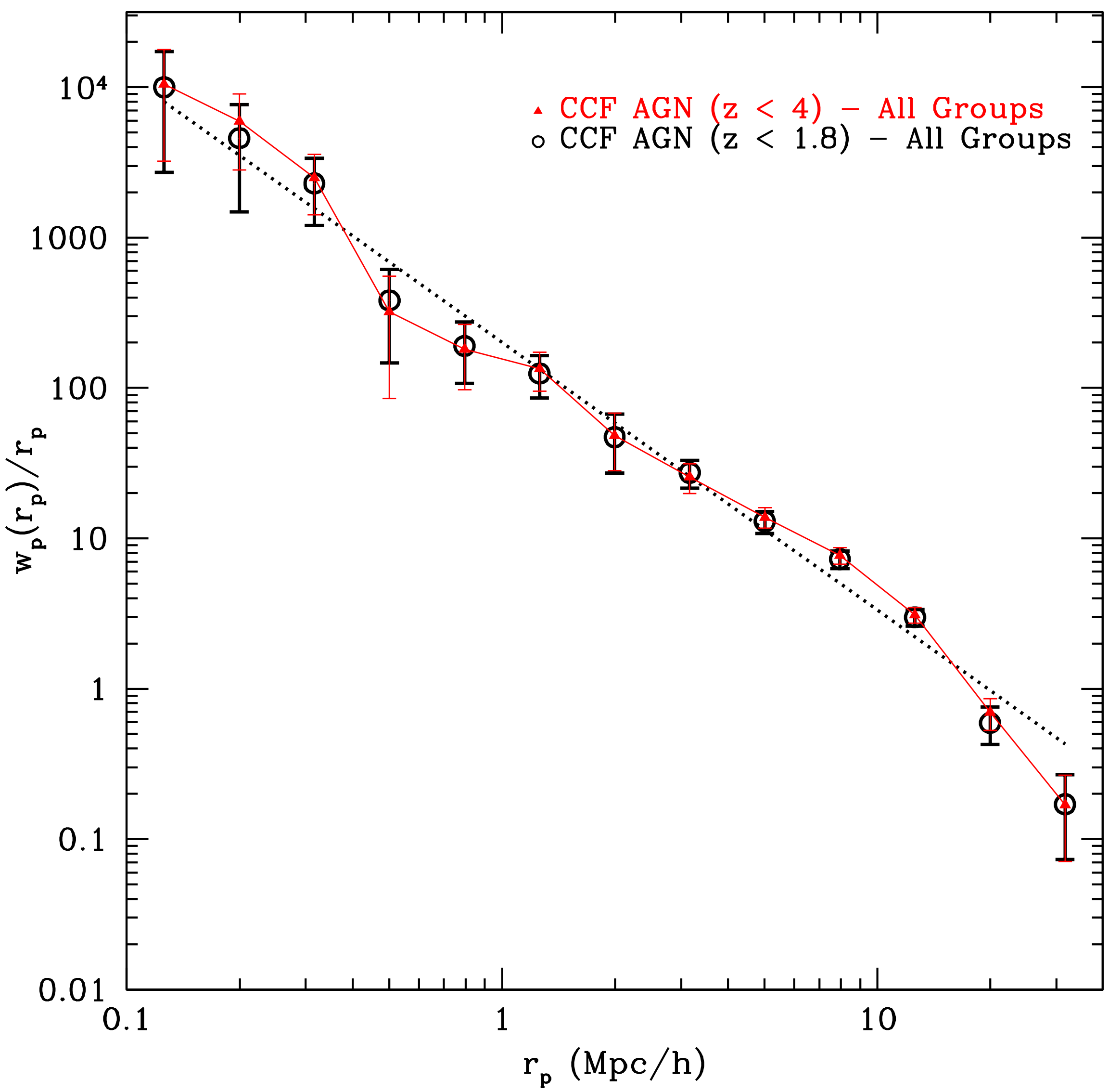
Results: Group and AGN auto-correlation

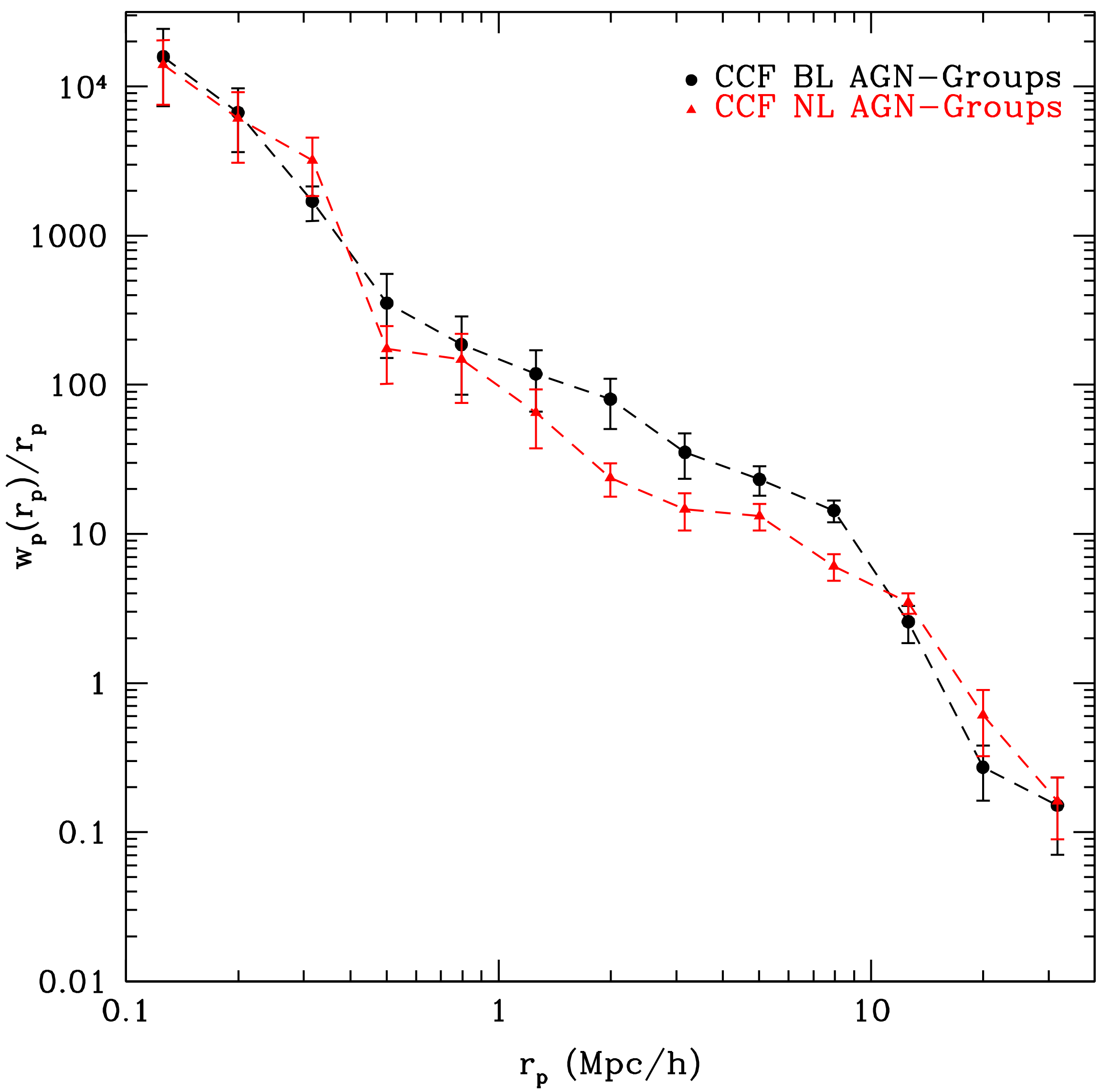




Allevato et al. (in prep)

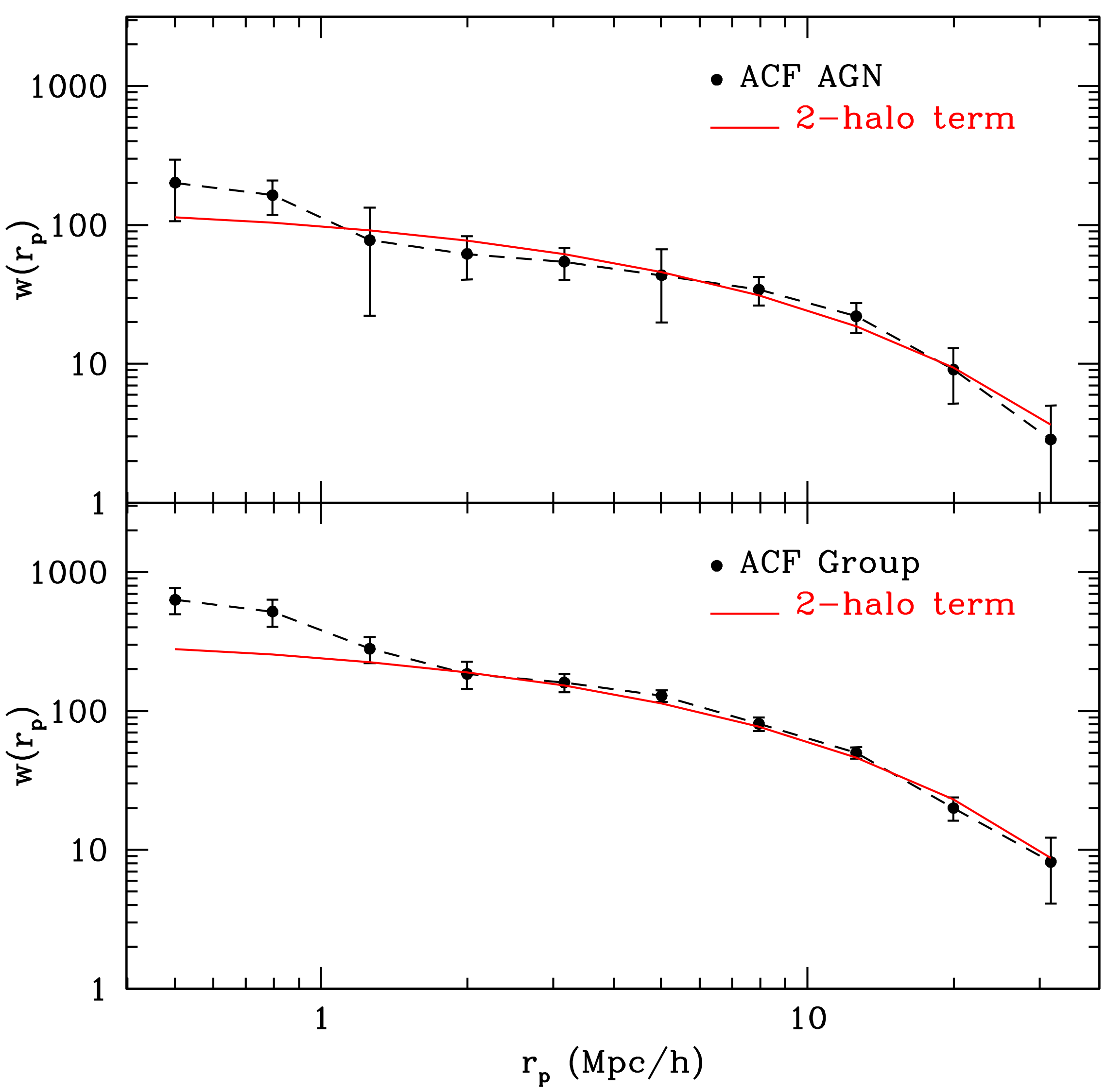
Results: Group--AGN correlation (BL v NL)

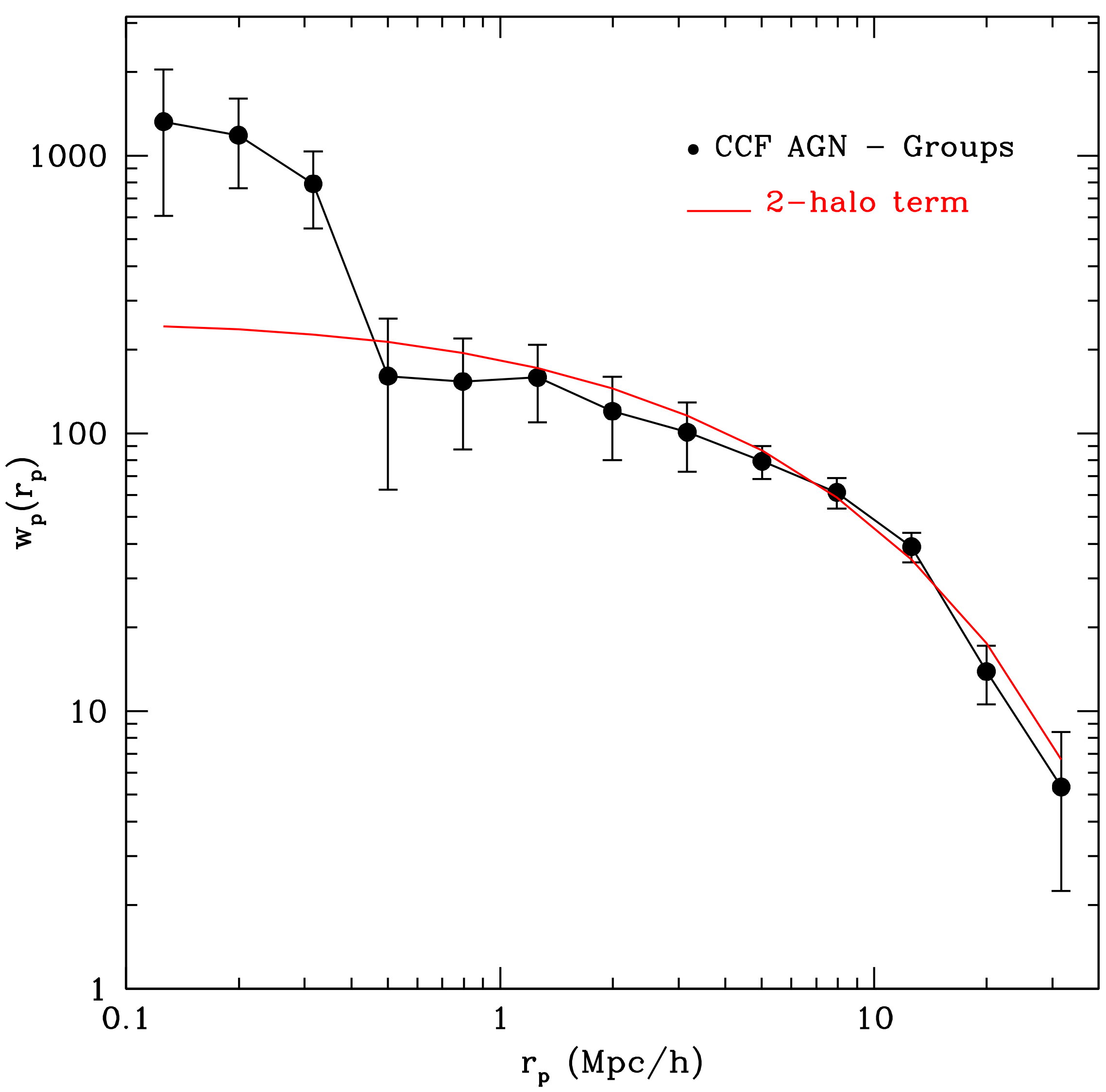




Allevato et al. (in prep)

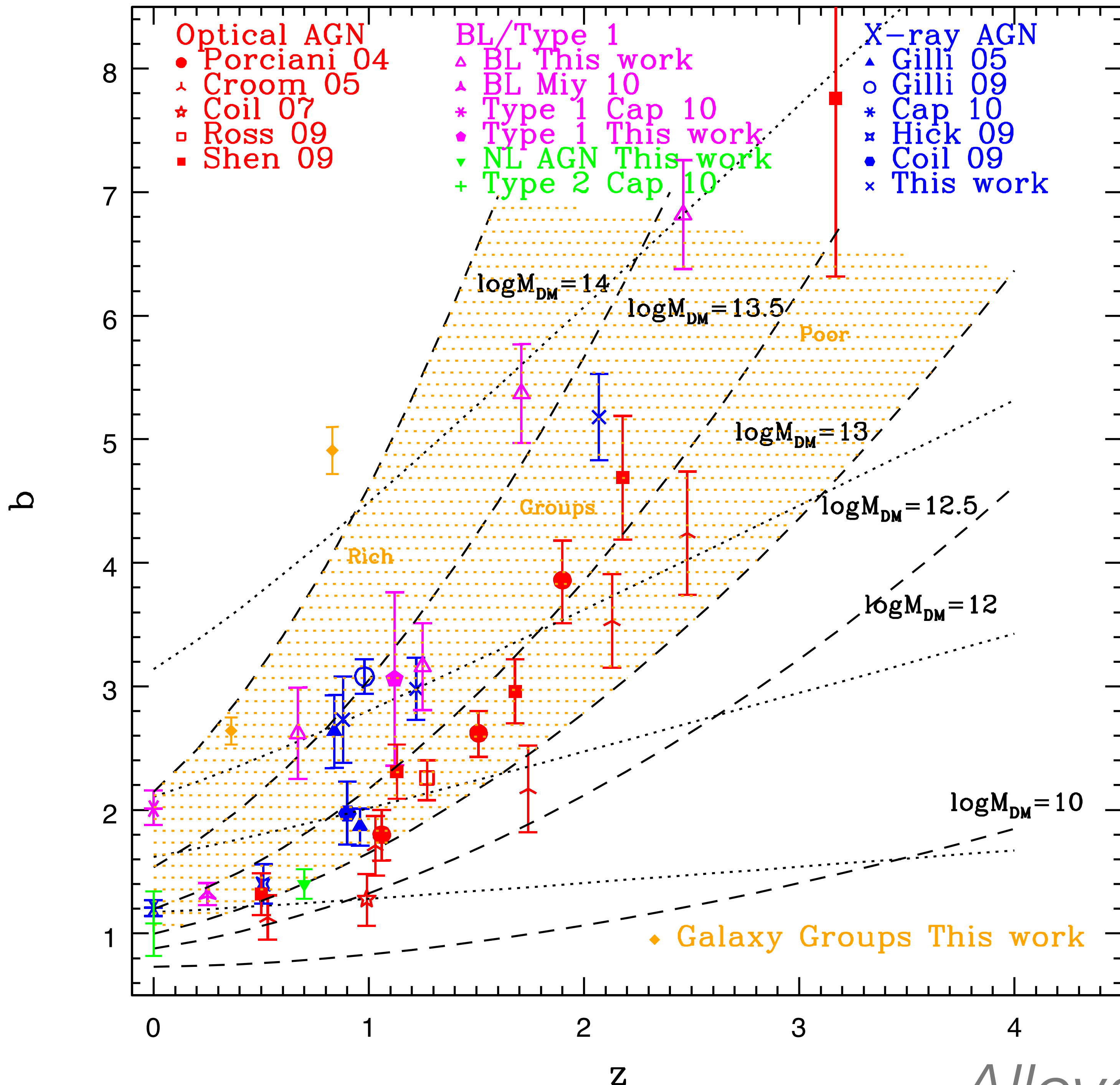
Results: Bias of AGN and groups





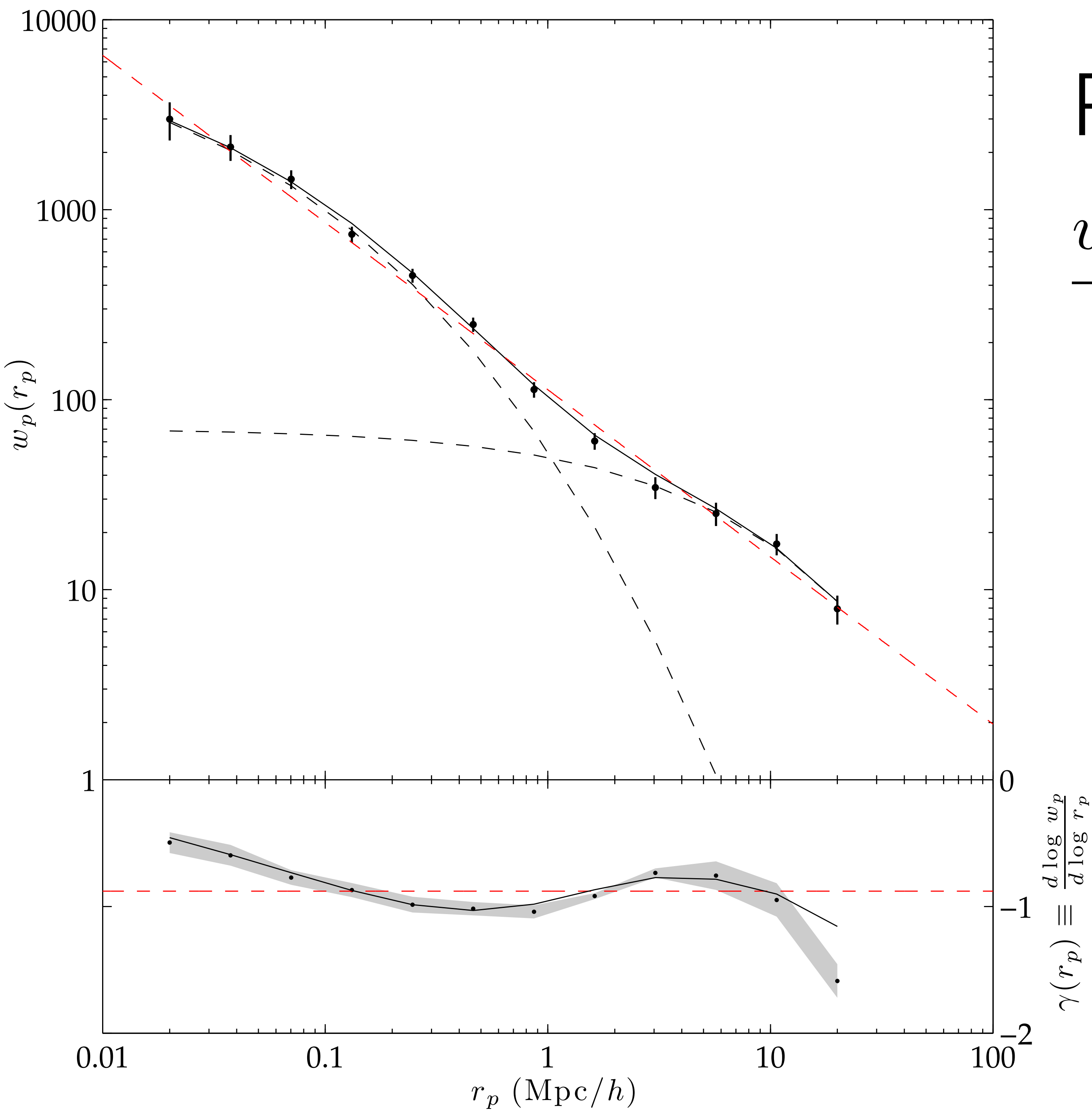
Allevato et al. (in prep)

Bias estimates from clustered objects



Allevato et al. (in prep)

Group--galaxy cross-correlation

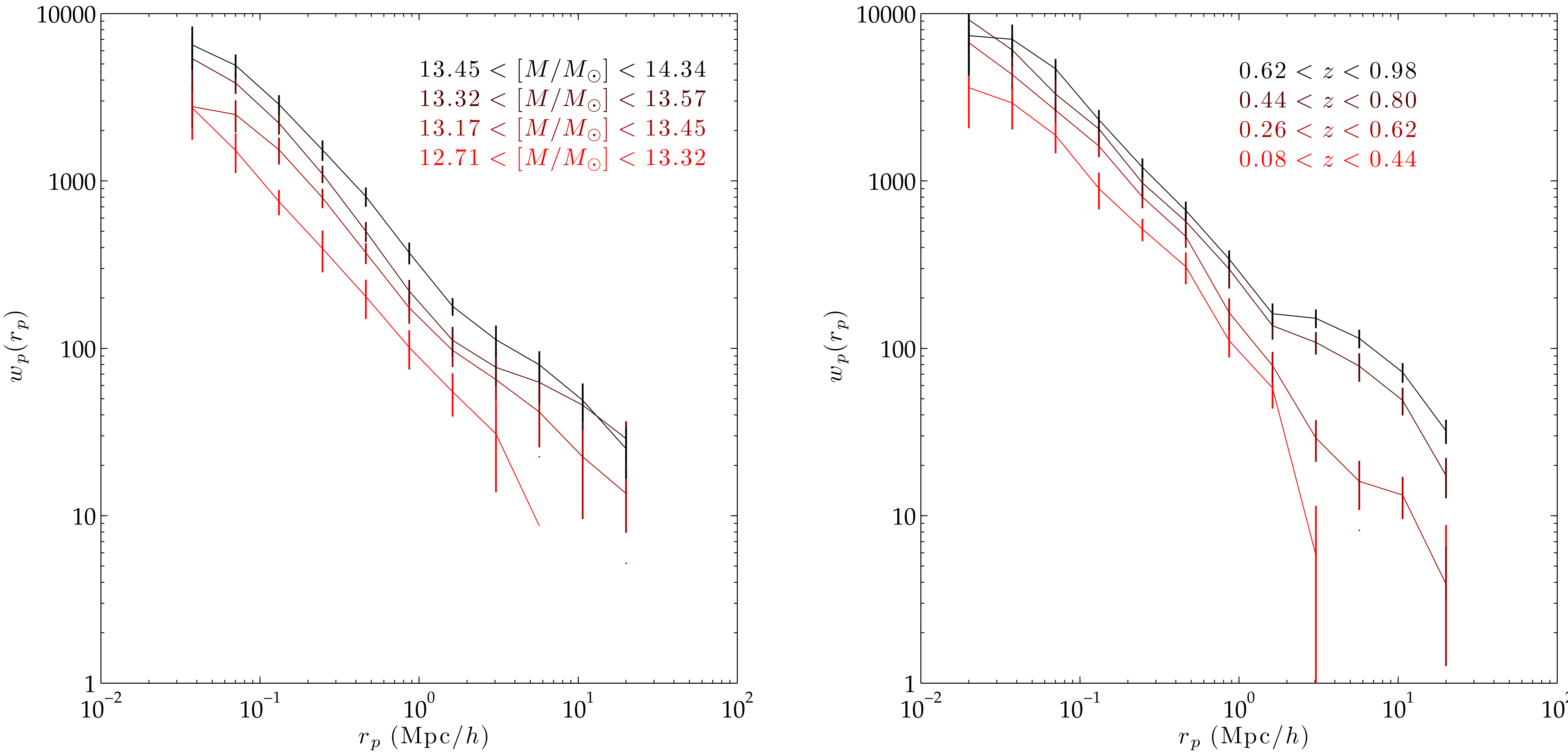


Power law

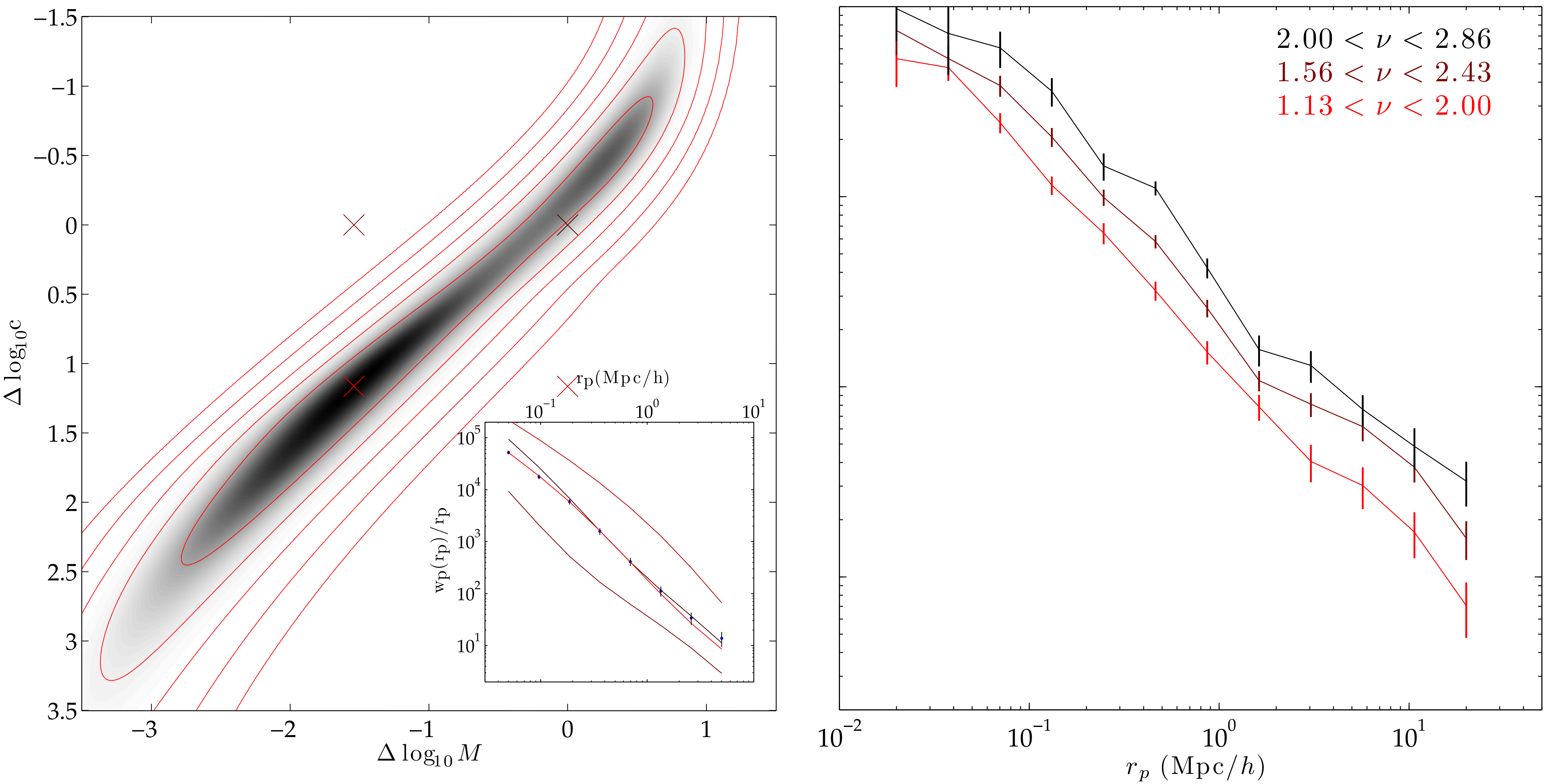
$$\frac{w_p^m}{r_p} = \frac{\Gamma\left(\frac{1}{2}\right)\Gamma\left(\frac{\gamma-1}{2}\right)}{\Gamma\left(\frac{\gamma}{2}\right)}\left(\frac{r_p}{r_0}\right)^{-\gamma}$$

$$\gamma(r_p) \equiv \frac{d \log w_p}{d \log r_p}$$

Group--galaxy correlation (group mass, redshift)



Mass-concentration relation



(V) Conclusions: Endpoints and trajectories

- The distinction between inheritance and ‘environmental’ effects; this distinction can be thought to map onto the dichotomy between studies of distributional properties and direct causal physics

- The types of correlations one can describe from the halo model are evinced in the Cosmic Evolution Survey, and extend to descriptions of galaxy groups (X-ray groups), galaxies & AGN.

- There is a well-motivated push to go beyond two-point statistics in describing the correlations between objects. In the spatial domain, such quantities go beyond the distribution of power across spatial scales, to provide information about the relationship between power at different scales. The same is true in the time domain.