The efficiency of galaxy formation in different environments

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Ingredients from COSMOS+zCOSMOS

- zCOSMOS 20k redshifts
- density field from nearest neighbour reconstruction
- galaxy stellar masses and photometric classification from SED fitting

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Aim:

Estimate as a function of redshift and environment:

- the fraction of baryons of a halo falling in a galaxy
- the fraction of baryons of a halo forming stars in a galaxy

↪ understand how the different environments affect the formation of galaxies and their evolution

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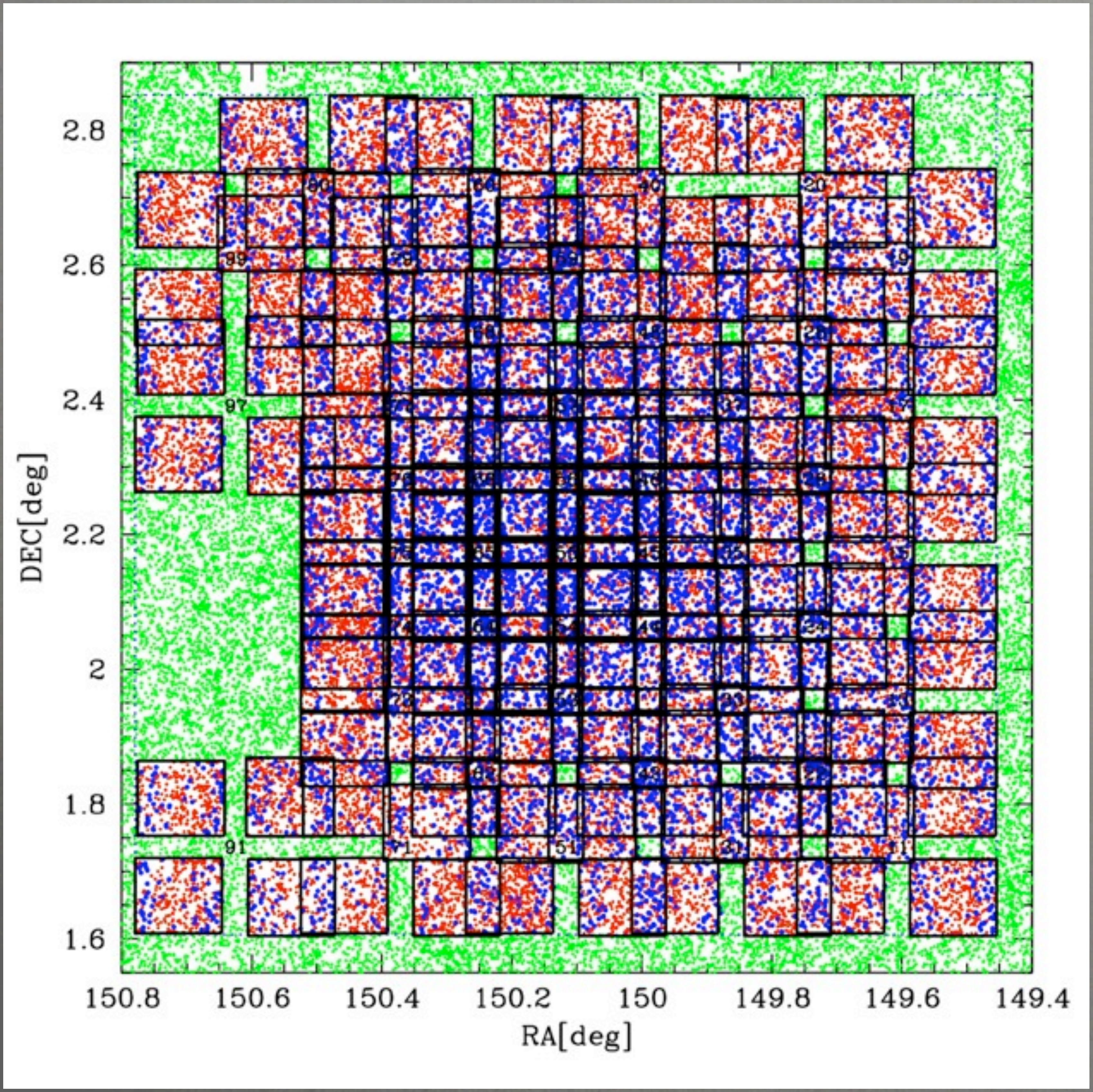

green: objects with COSMOS photometry

red: possible targets inside masks

blue: observed targets

zCOSMOS 10k

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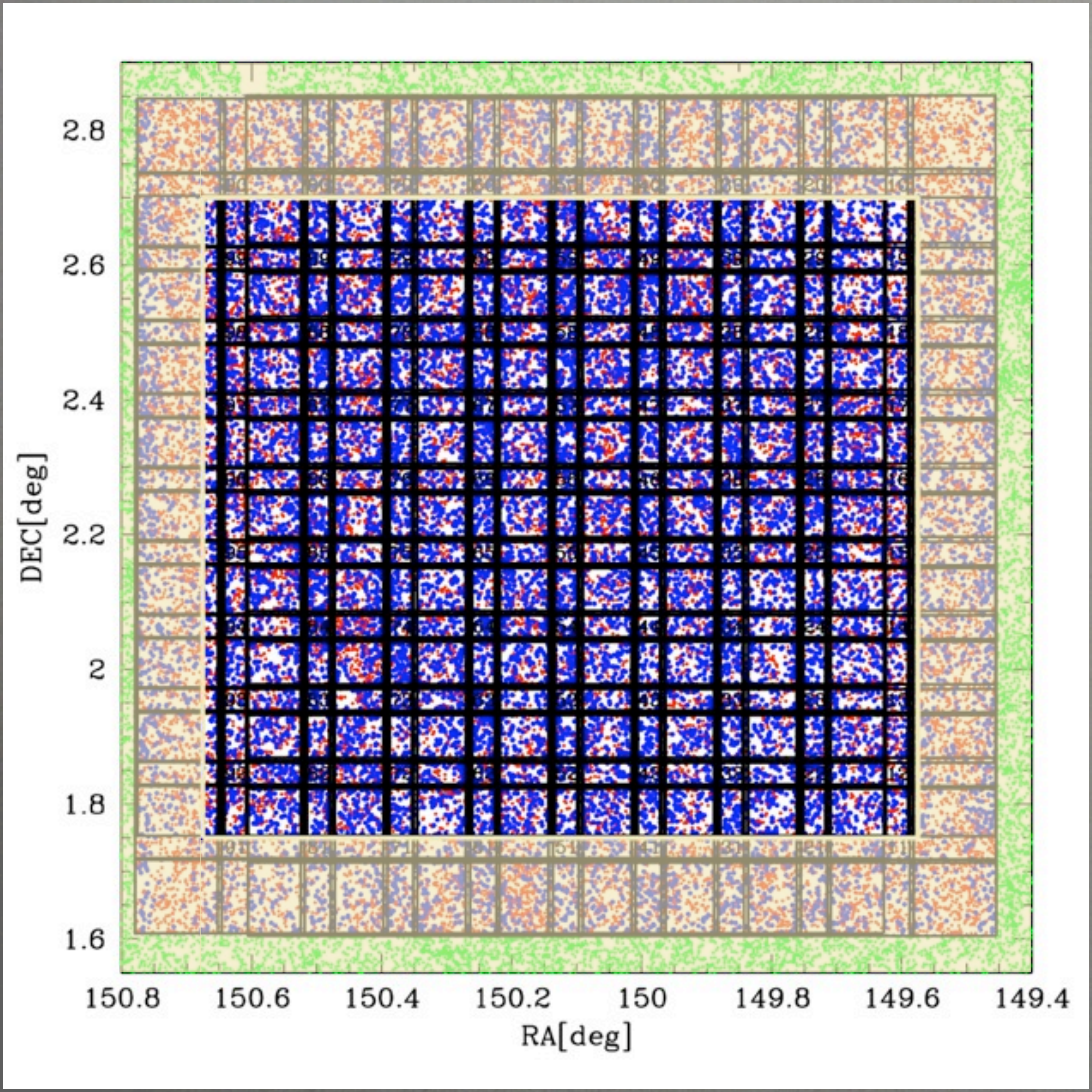

green: objects with COSMOS photometry
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zCOSMOS 20k
~1sq. deg. with high sampling rate (~ 67% on average) and high success rate (83 to 98% from faint to bright galaxies)

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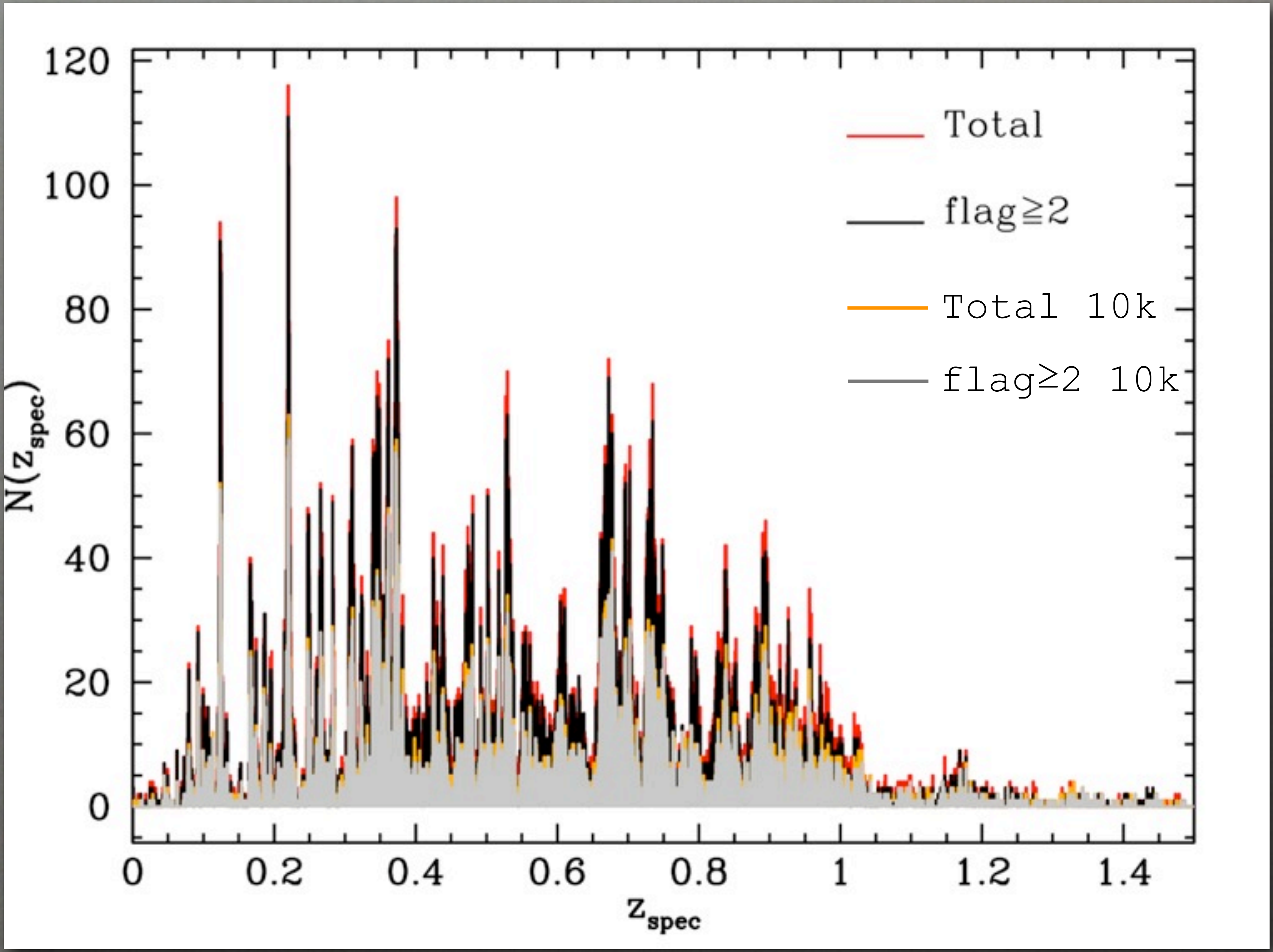
zCOSMOS BRIGHT ($I_{AB} \leq 22.5$) - 20k (final) sample



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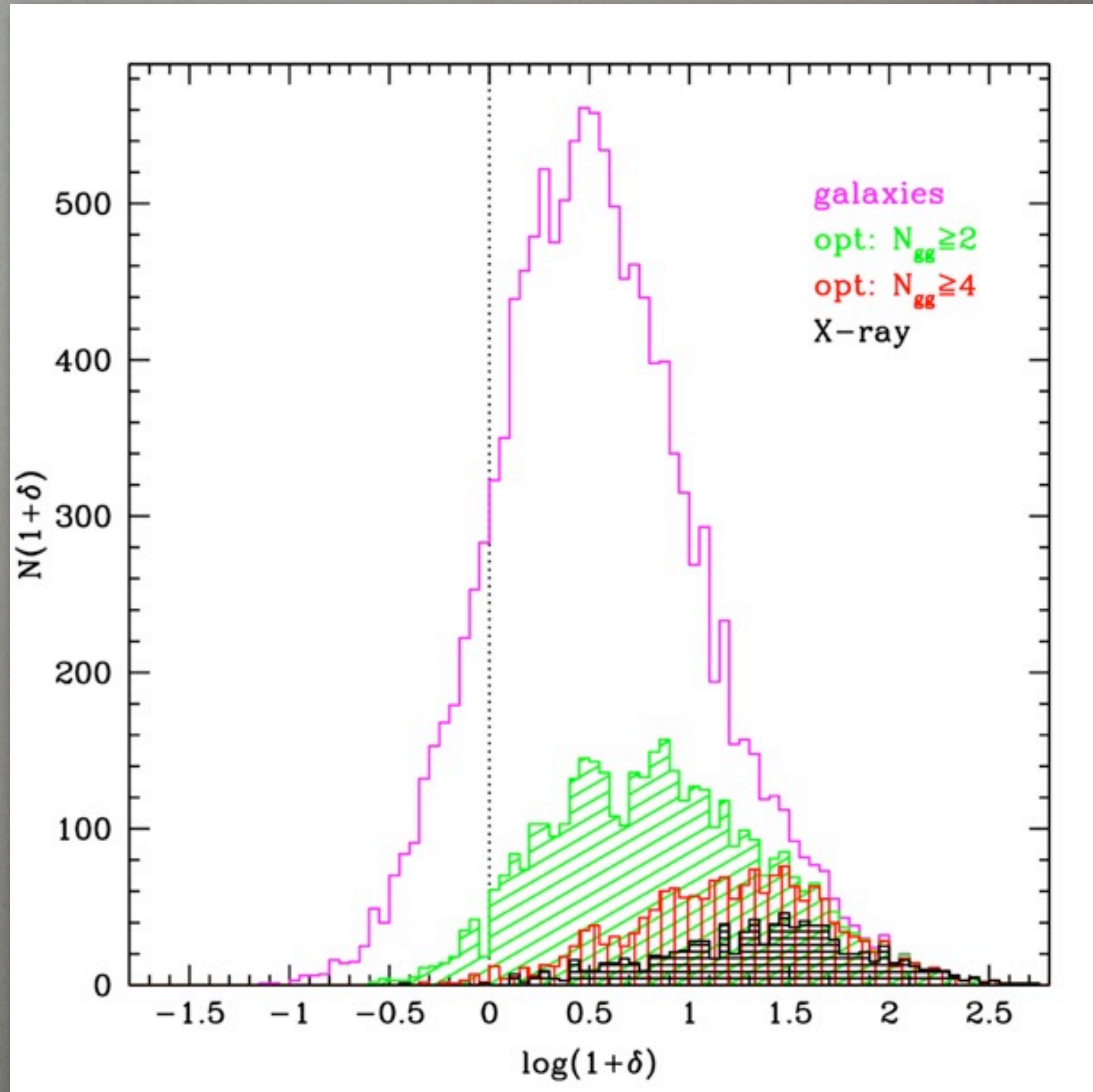
Comparison of 5th nearest neighbour local density estimate with other environment definitions:

optical groups and X-ray groups

(20k sample)



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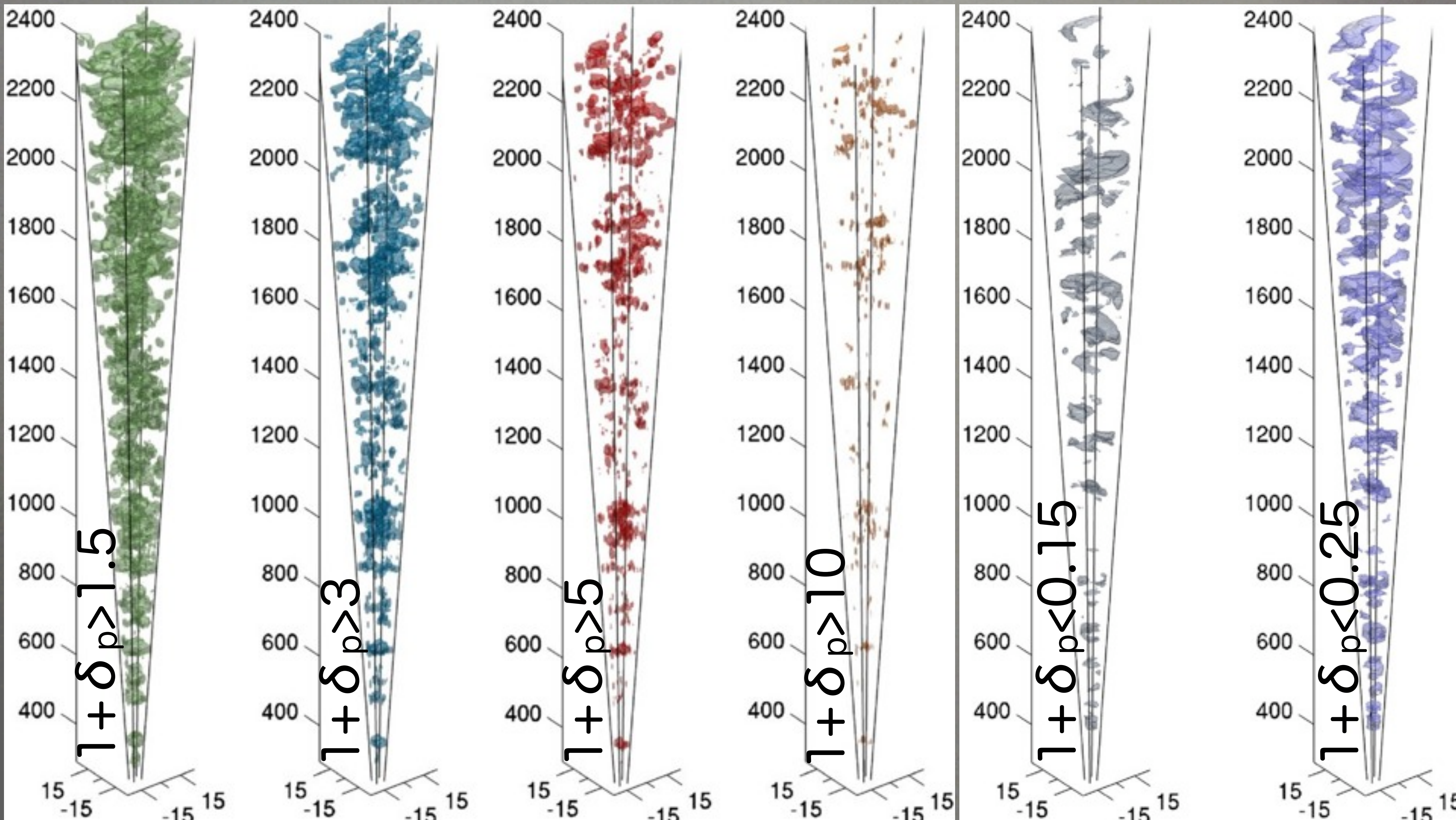
zCOSMOS density field (Kovač et al. 2010)

Distribution of over-dense and under-dense structures



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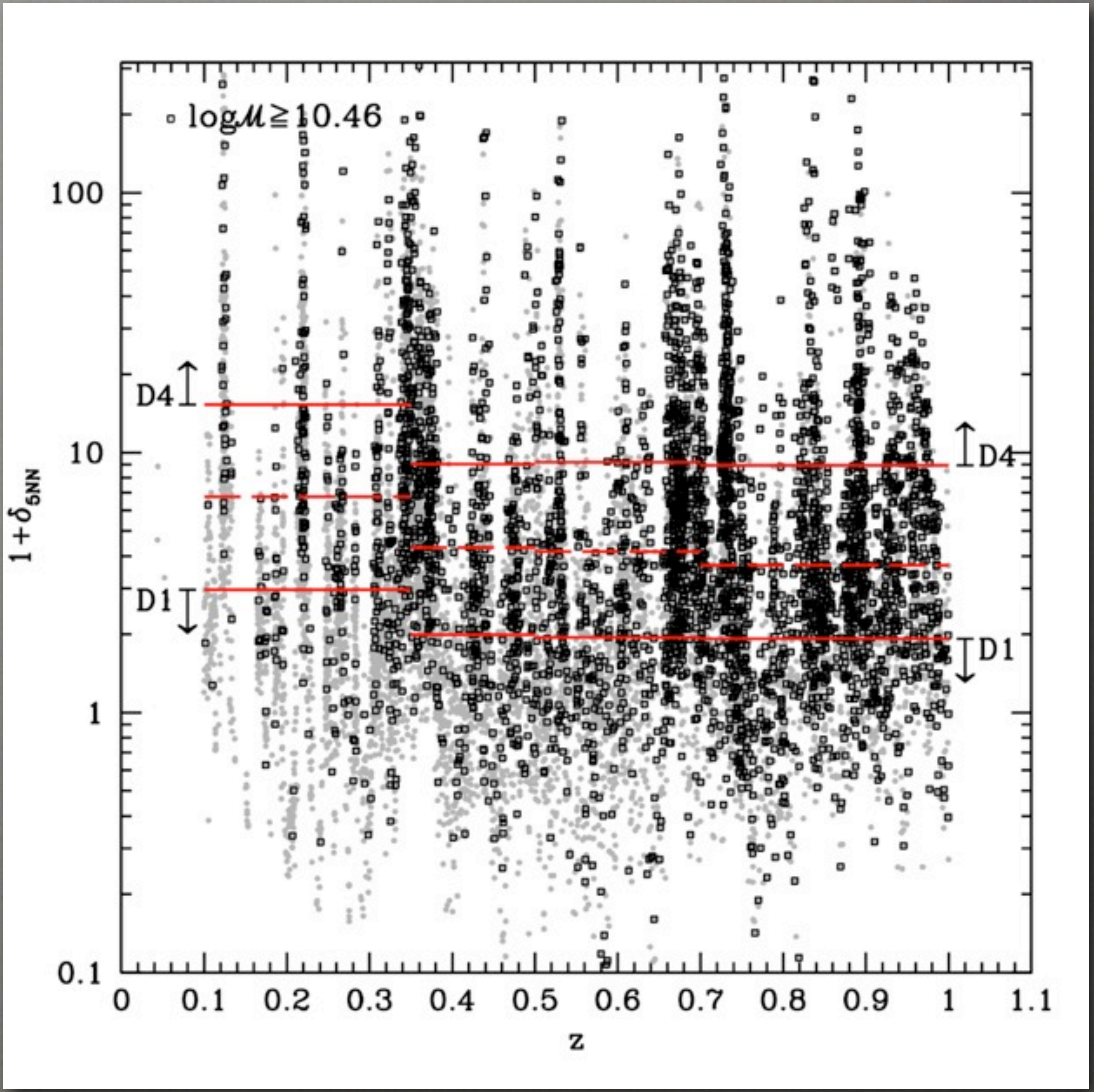
Selection of two environments in the common mass range

D1: under-dense regions (lowest quartile)

D4: over-dense regions (highest quartile)



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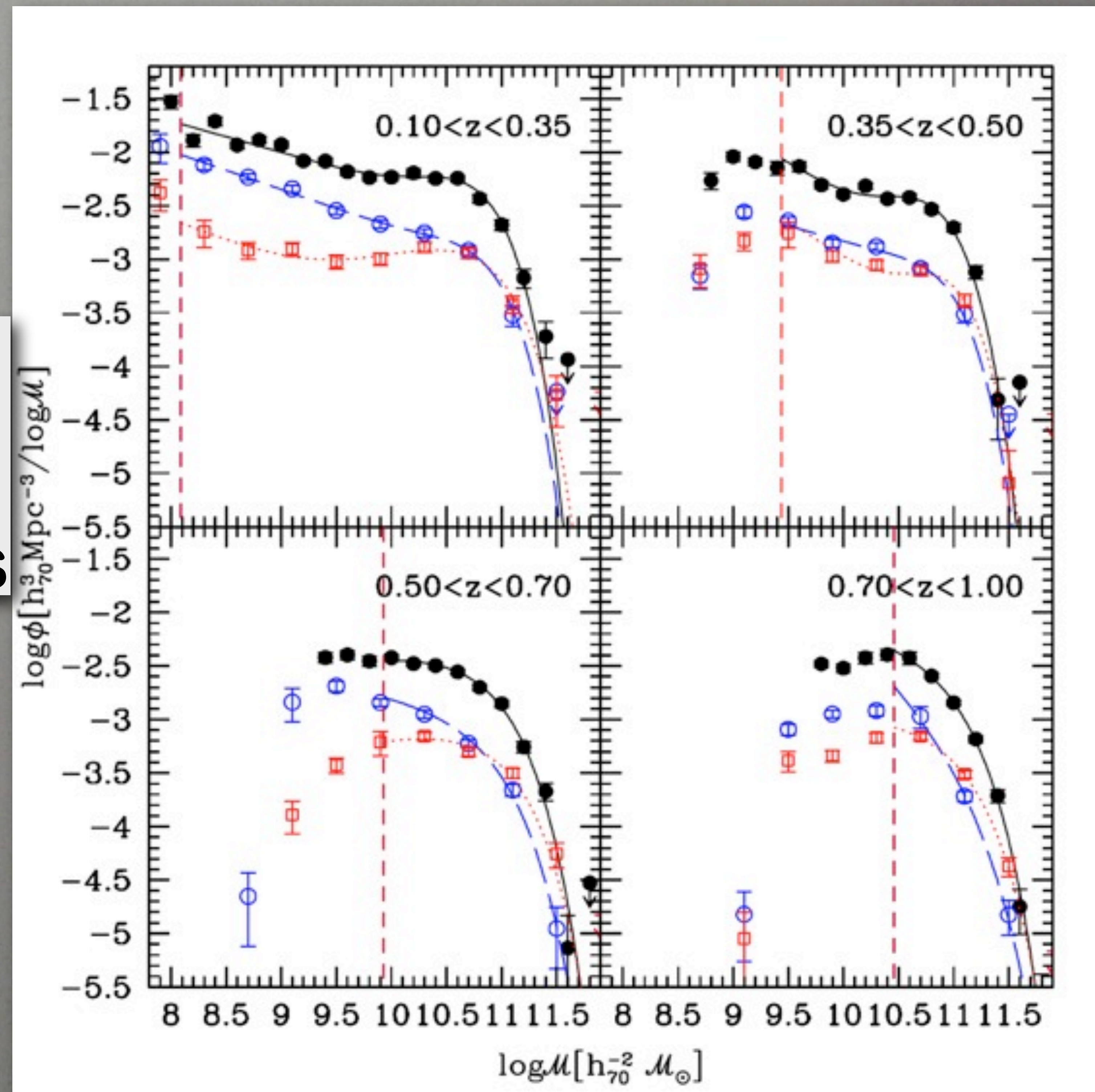
Recap of results on GSMF/environment:

(Bolzonella et al. 2010 for 10k, here 20k data have been used)



Bimodality of the GSMF, more evident in high density regions

Black: total

Blue: D1 (under-dense)

Red: D4 (over-dense)

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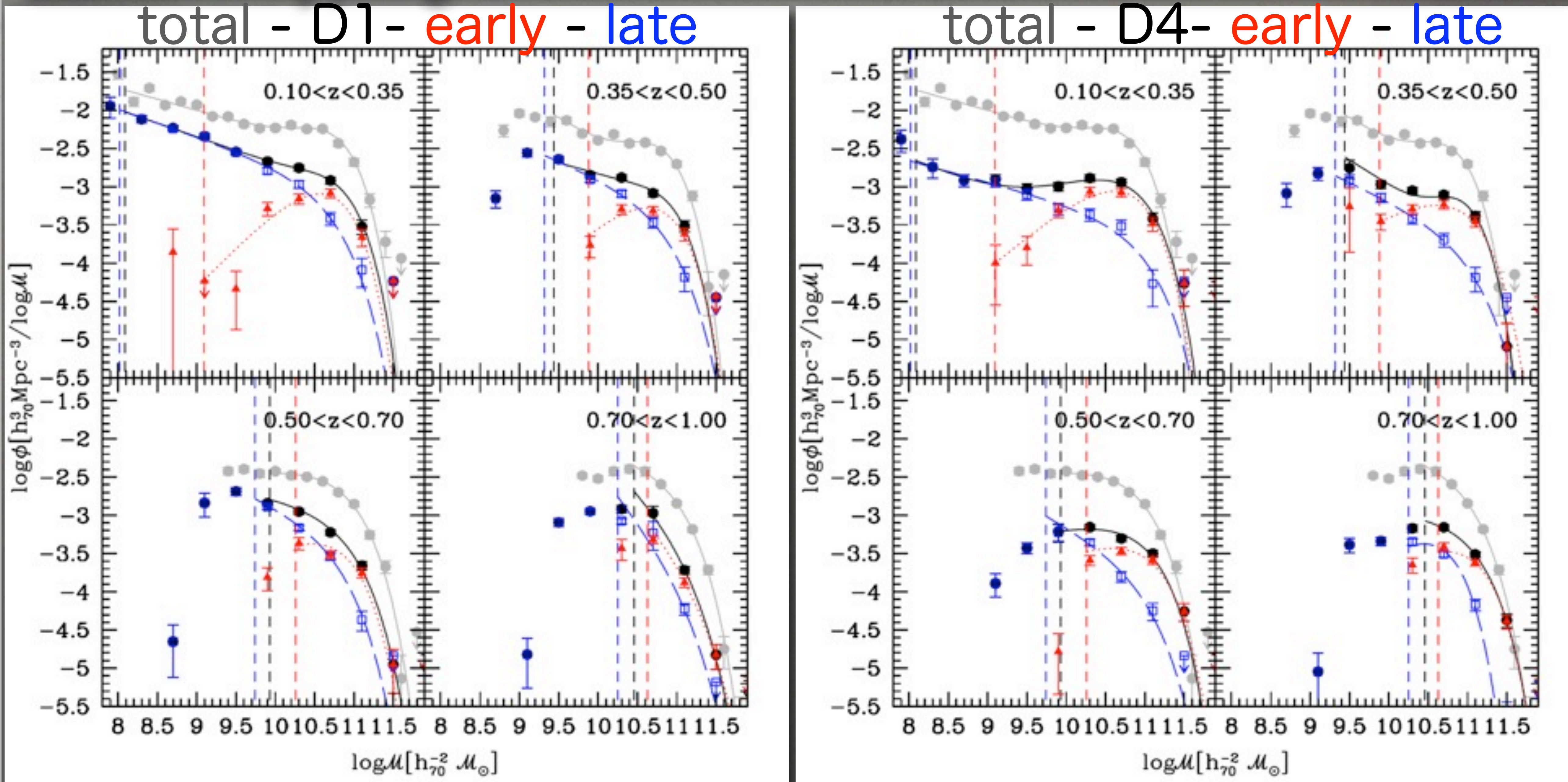
Recap of results on GSMF/environment:

Bimodality is due to the different contribution of early and late type galaxies as a function of environment



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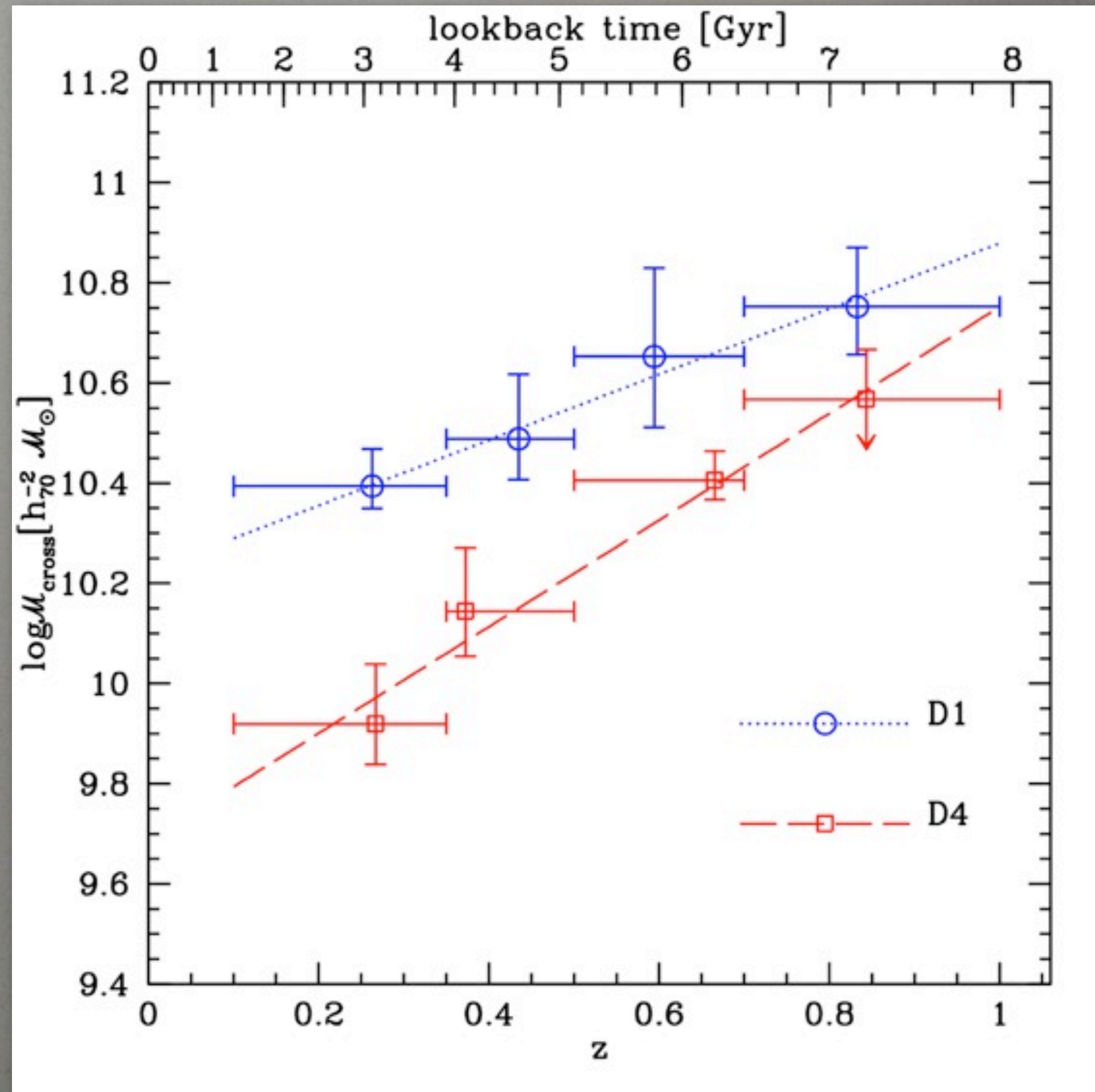
Recap of results on GSMF/environment:

M_{cross} of early/late photometric types evolves faster in high density environments, reaching similar values at z≳1 in under- and over-dense regions



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The Questions:

- The mass of a galaxy is considered to be the main driver of its evolution, but the probability of a given galaxy stellar mass depends on the environment in which the galaxy resides. What shapes the GSMF?
- The stellar mass is a proxy of the corresponding halo mass, is the halo mass the main driver of the galaxy evolution?
- How the environmental properties of GSMFs are connected to the mass of the haloes?
- Are there differences in the efficiency of galaxy formation in different environments?

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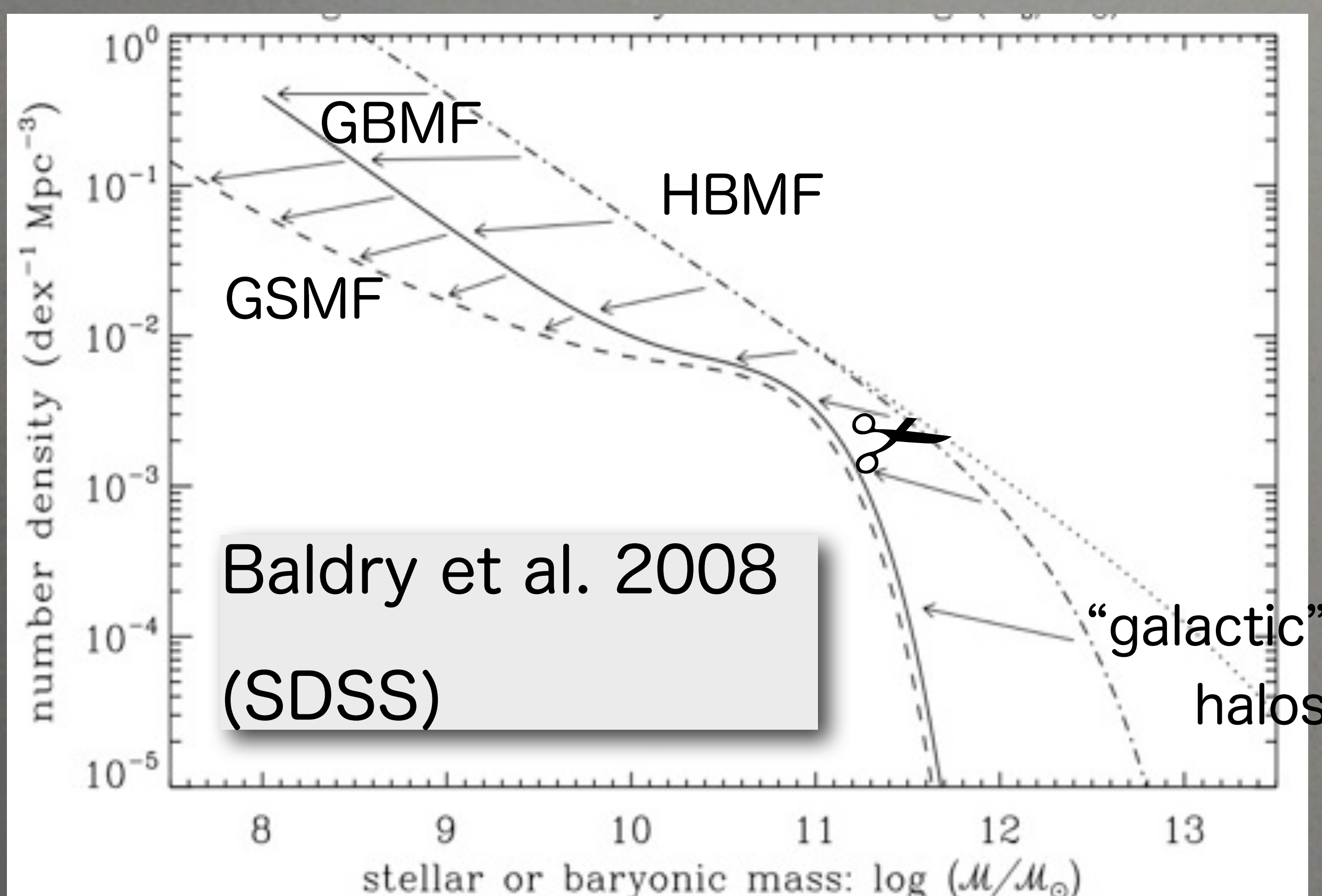
GSMF: galaxy Stellar mass Function — GBMF: Galaxy Baryonic mass function

HMF: Halo Mass Function — HBMF: Halo Baryonic Mass Function=HMF×Ω_b/Ω_m

GHBMF: Galactic Halo Baryonic Mass Function = HBMF- groups&cluster haloes

η_1 = fraction of halo baryons falling in a galaxy ➟ efficiency of galaxy formation

η_2 = fraction of baryons forming stars in a galaxy ➟ efficiency of star formation



To compute η_1 and η_2 we assume a one to one and monotonic relation between M_{halo} and M_{star}

☛Abundance matching ☚

$$N(>\mathcal{M}_{\rm halo}) = N(>\mathcal{M}_{\rm star})$$

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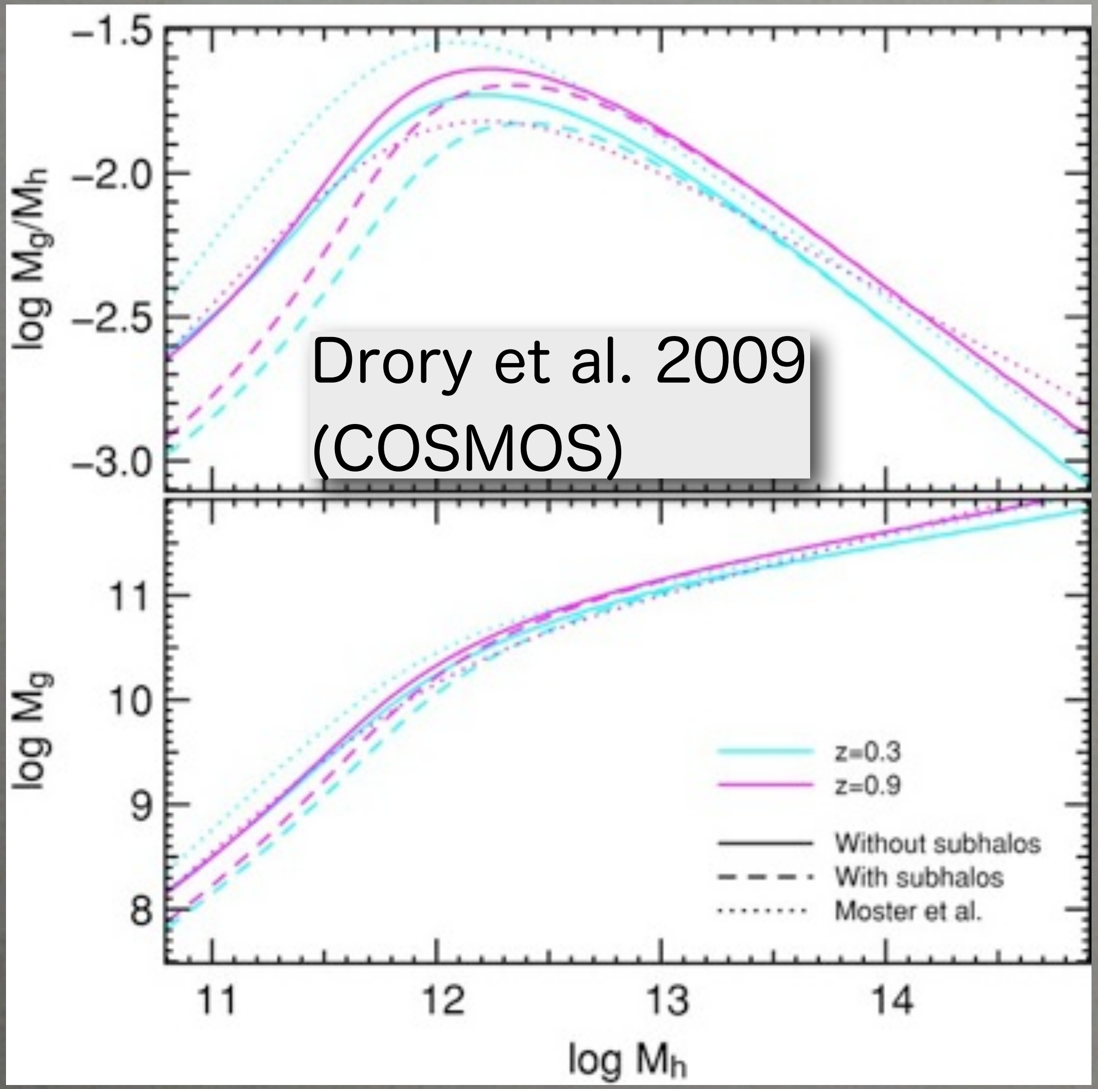
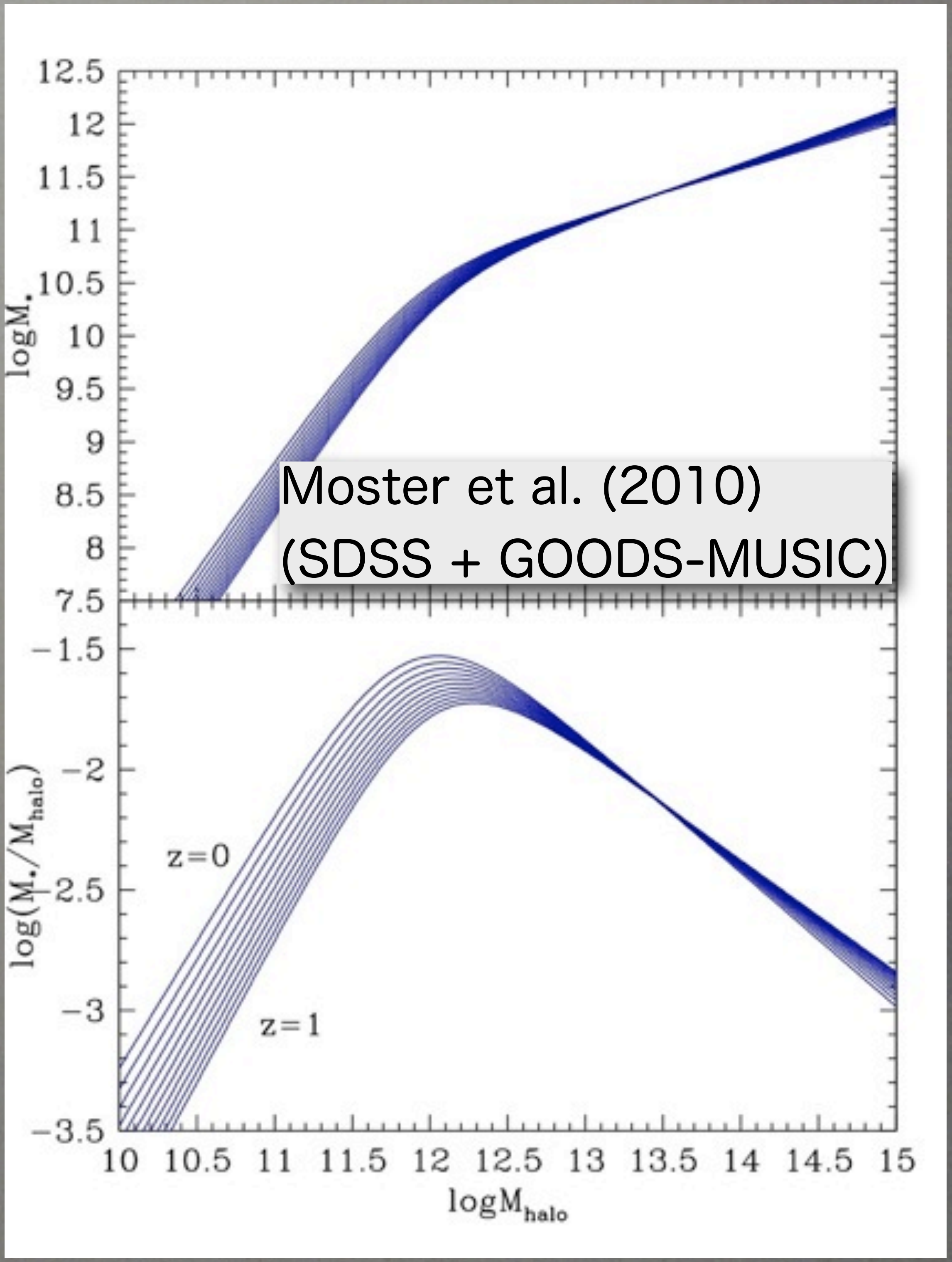
Previous studies computed the evolution of the stellar to halo mass relation:





(and many others: Conroy, Behroozi, Guo, Lehautaud, Stewart, ...)

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The Halo Mass Function:

- the dark matter HMF and its evolution can be easily computed theoretically given the cosmological parameters set (P.-S. formalism)
- the HMF evolves a little in the range z=[0,1] and mostly at the highest masses (not at the galactic haloes scales)

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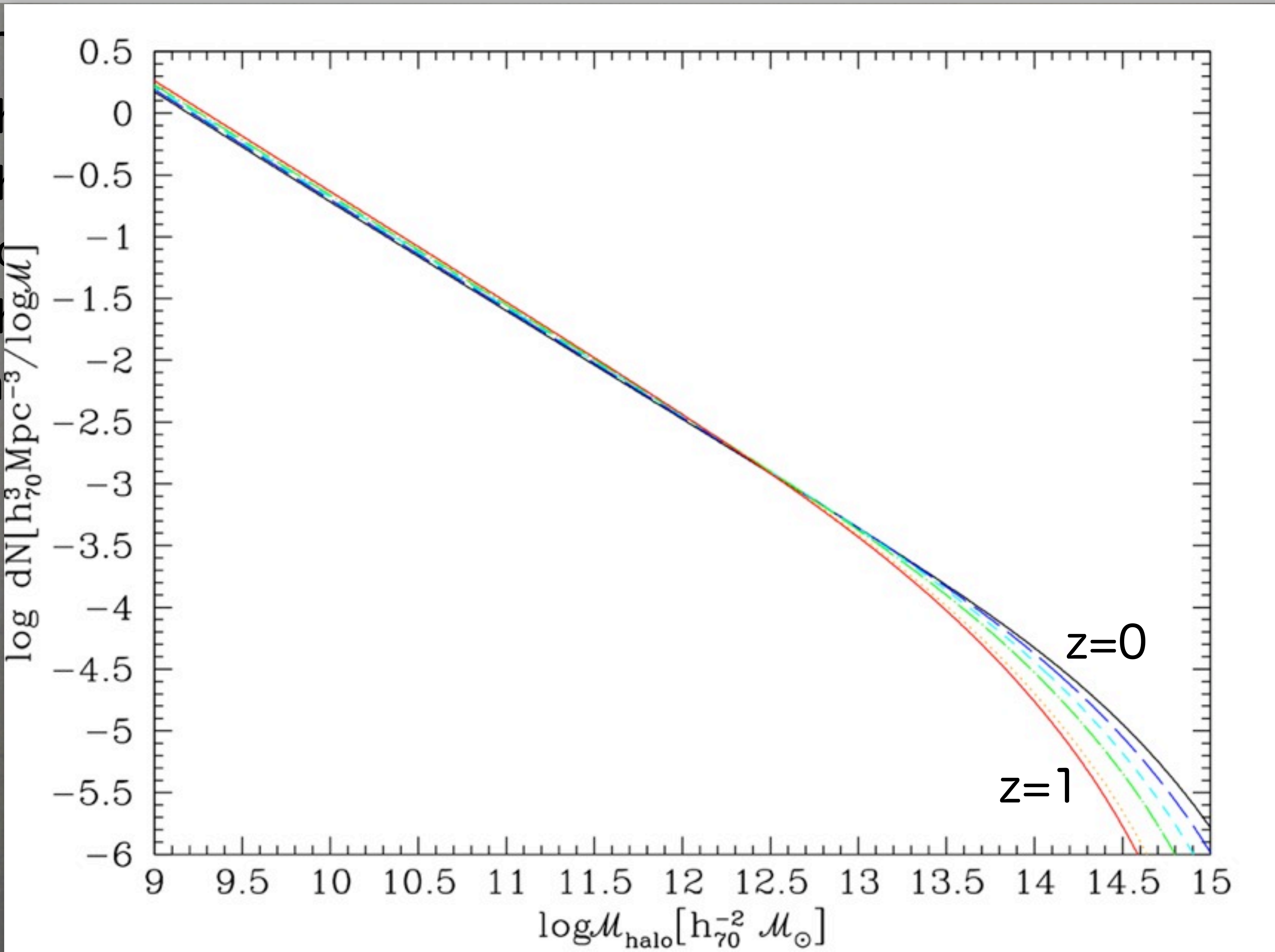

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- to obtain the galactic halo mass function (1 galaxy/1 halo) the groups/clusters haloes must be removed: Shankar et al. 2006

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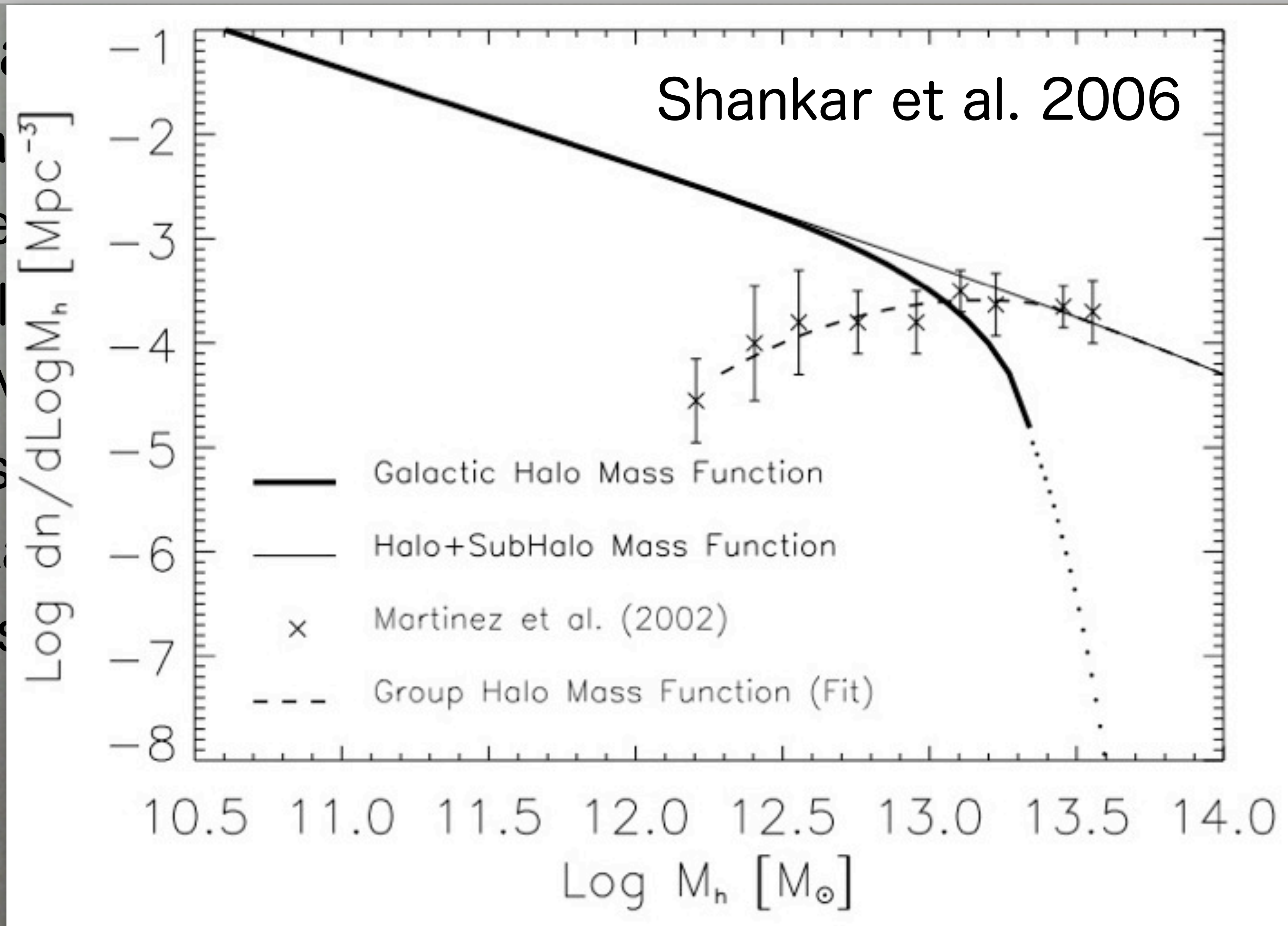

$$\mathrm{GHMF}(M_h)\,dM_h = \frac{\theta}{\tilde{M}}\left(\frac{M_h}{\tilde{M}}\right)^{\alpha} e^{-(M_h/\tilde{M})}\,dM_h, \qquad (9)$$

with $\alpha = -1.84$, $\tilde{M} = 1.12\times10^{13}\,M_\odot$, and $\theta = 3.1\times10^{-4}$ Mpc^{-3}.

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The Halo Mass Function:

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- the HMF evolves a little in the range z=[0,1] and mostly at the highest masses (not at the galactic haloes scales)
- to obtain the galactic halo mass function we must remove the groups/clusters haloes (sub-haloes should be introduced back): see Shankar et al. 2006
- the galactic baryonic HMF is finally obtained by rescaling it to the Ω_b cosmological value ($f_b=\Omega_b/\Omega_m=0.045/0.27$)

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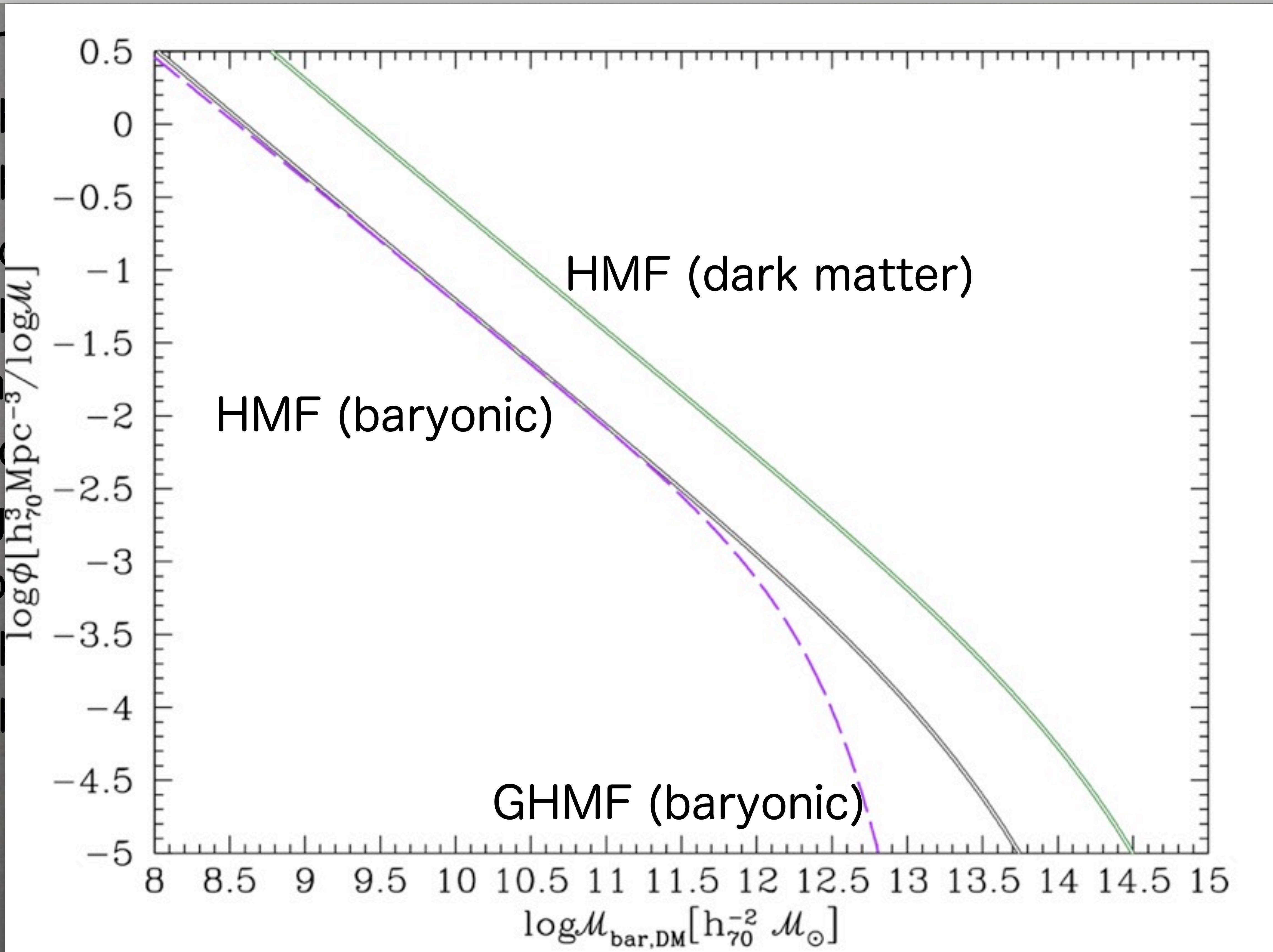

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Problems I know:

- the HMF depends on environment too (e.g. Faltenbacher et al. 2010)
- the mass function of groups also evolves as a function of redshift (the cutoff in the HMF must change with z)
- sub-haloes must be added to the standard HMF considering their mass at the infall time into a bigger halo (e.g. Drory et al. 2009: $N_{halo}=N_{distinct}+N_{sub}$). Moreover, the number of sub-haloes should be different in the high- and low-density environments.
- the baryon fraction may also depend on environment
- the best way to do this work is probably using the Millennium simulations

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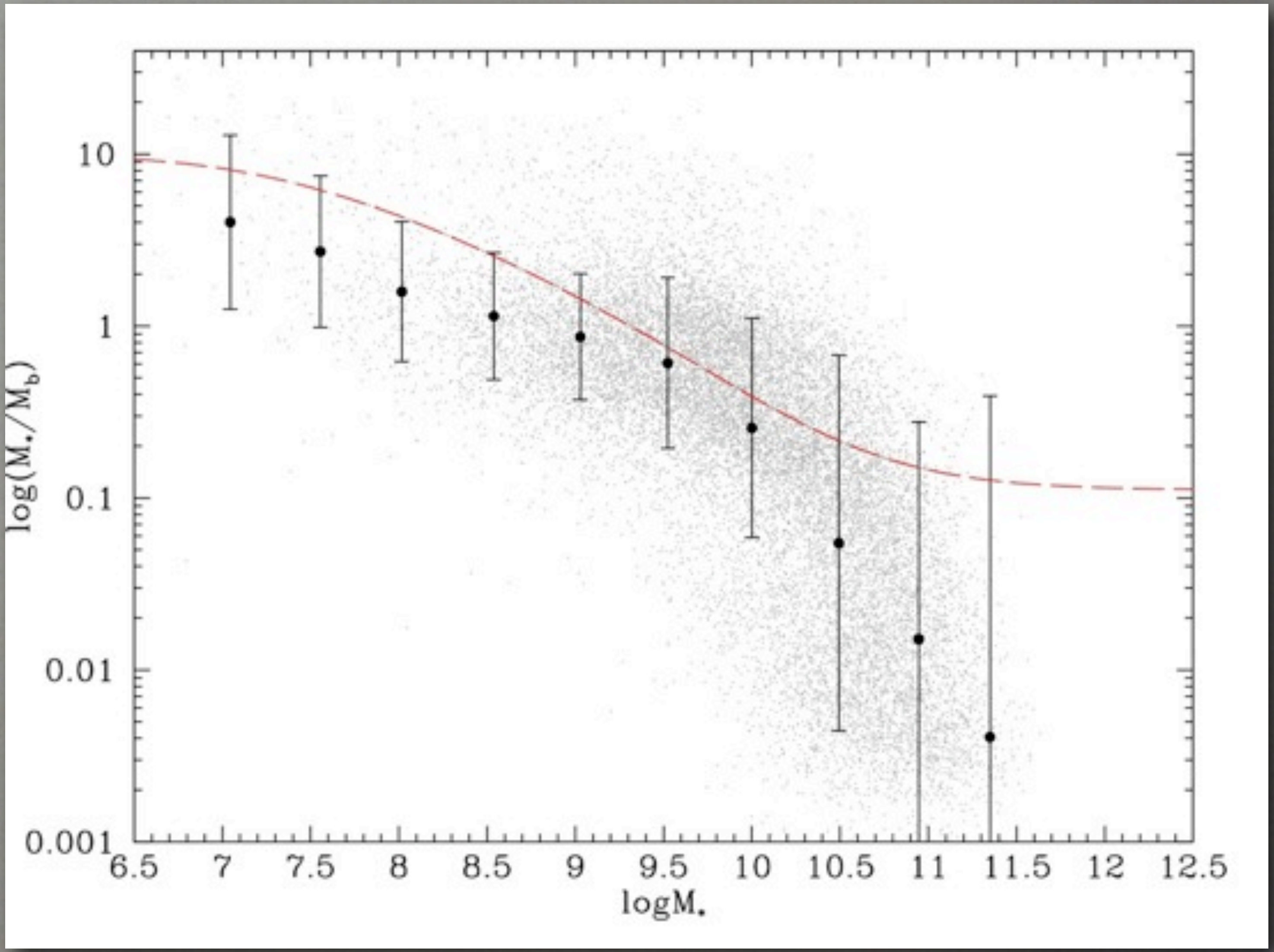
The baryonic mass content of galaxies:

gas fraction is computed from the SFR using the Kennicutt-Schmidt relation (Kennicutt 1998):

$\Sigma_{SFR} = 2.5 \cdot 10^{-4}\, \Sigma_{gas}^{1.4}$
$\Sigma_{SFR} = SFR[M_\odot/yr]/area[kpc^2]$
$\Sigma_{gas} = M_{gas}[M_\odot]/area[pc^2]$

(area estimated from Petrosian semi-major axis and ellipticity)
$M_b = M_* + M_{gas}$



For galaxies without SFR or without estimate of the size I used the analytical relation between stellar and baryonic mass of a galaxy by Baldry et al. 2008 (red dashed line)

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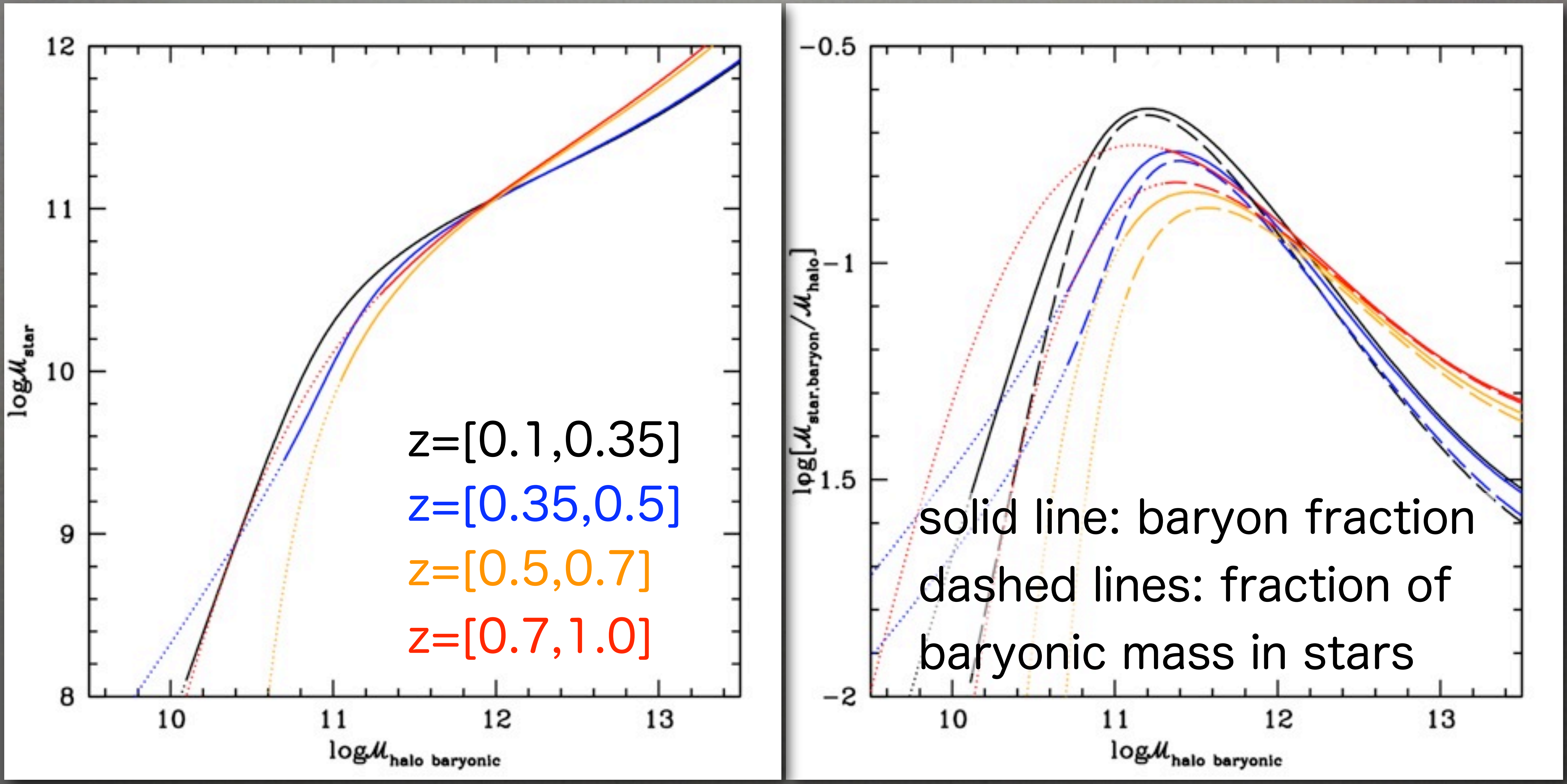
The stellar to halo mass relation and the fraction of halo baryons fallen into a galaxy and locked in stars:



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The stellar to halo mass relation and the fraction of halo baryons fallen into a galaxy and locked in stars in D1 and D4:

Coming soon

Conclusions:

- galaxy stellar mass functions depend on the large scale environment through the different evolution of early and late type galaxies, with a faster growth of the number of early type galaxies in dense regions
- the estimate of the efficiency of galaxy formation in dark matter haloes through the abundance matching can allow to understand the origin of the shape of the GSMF
- computing the efficiency as a function of environment is more tricky than I thought (it may take more than two days of meeting...)

⇛ must wait for GEE3! ⇚

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