Mapping the star formation histories of the Universe

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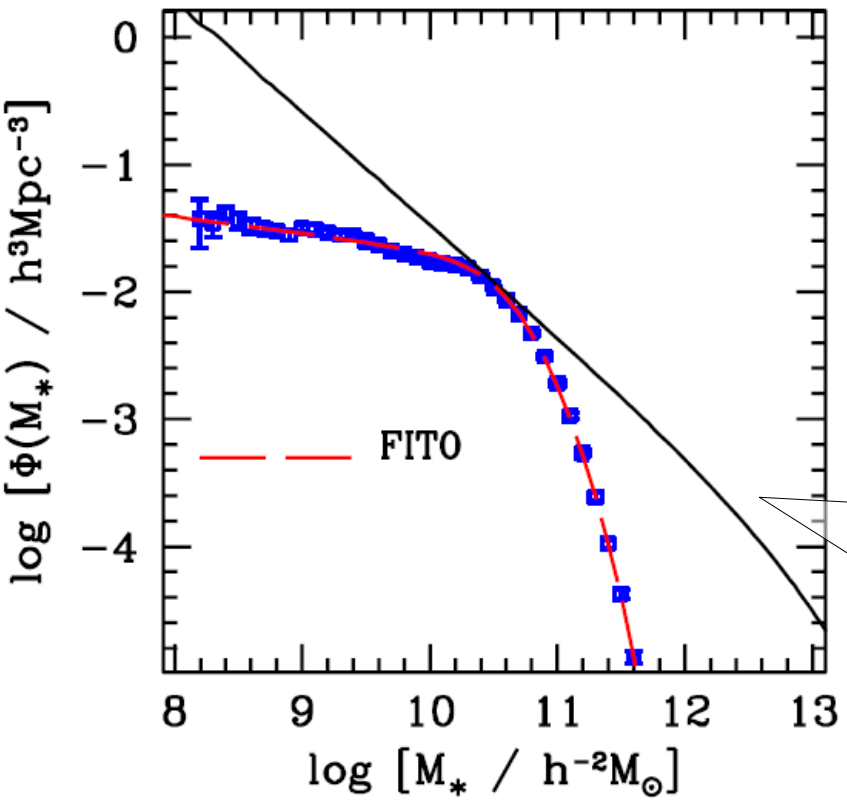
KIAS 30/10/2012

Outline:

- Linking galaxies with dark matter halos using SHAM
  - The reliable link is important for our understanding of galaxy formation
  - It is also important for the precision cosmology
- The Evolving Conditional Stellar Mass Function model with subhalo accretion component (ECSMF)
- The assembly of galaxies
- The star formation histories of the central galaxies
- Some related predictions

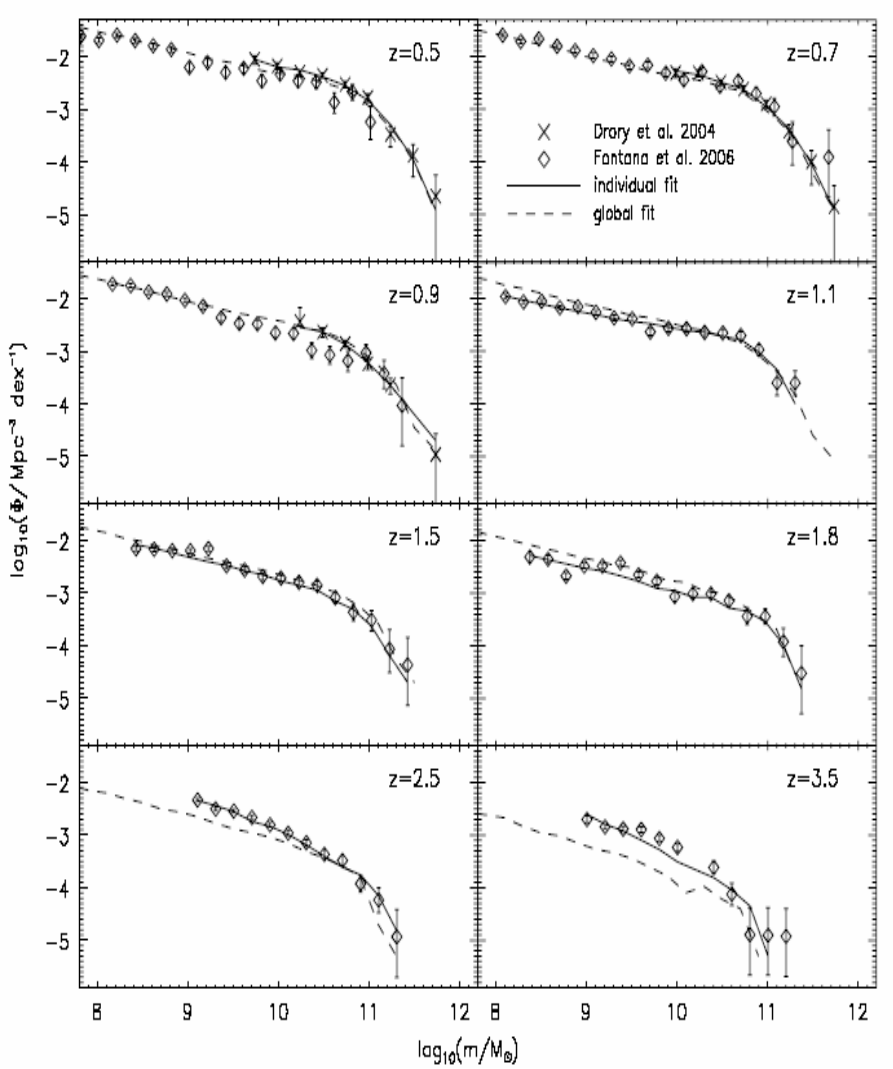
SHAM: Sub-Halo Abundance Matching



SHAM:

Assume central and satellite galaxies are associated with the dark matter host and sub halos according to e.g. their masses.

Reasonable constraints of the central-host relation using SHAM



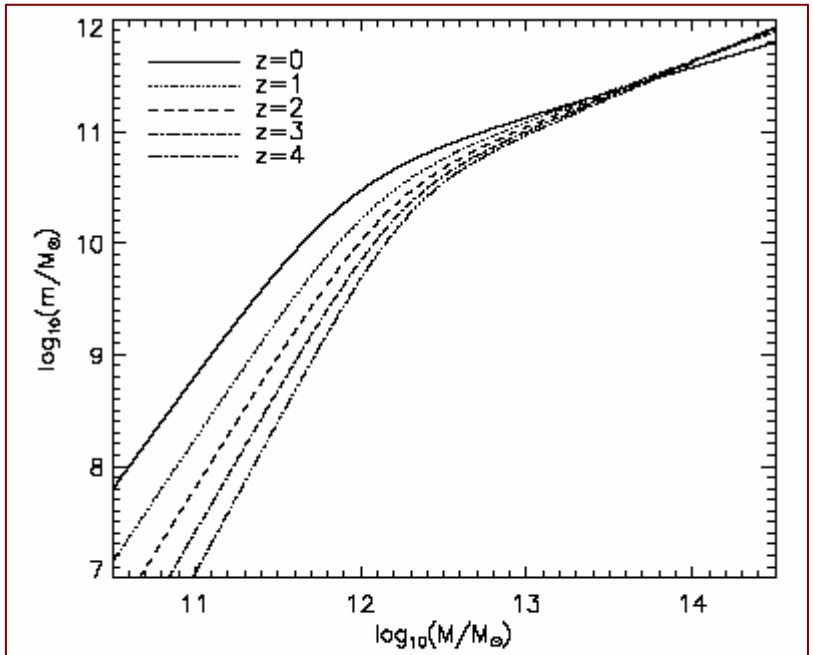


FIG. 14.— Stellar mass as a function of halo mass for different redshifts. The solid lines show different redshifts, which are indicated at the top of the panels.

Moster et al. 2010

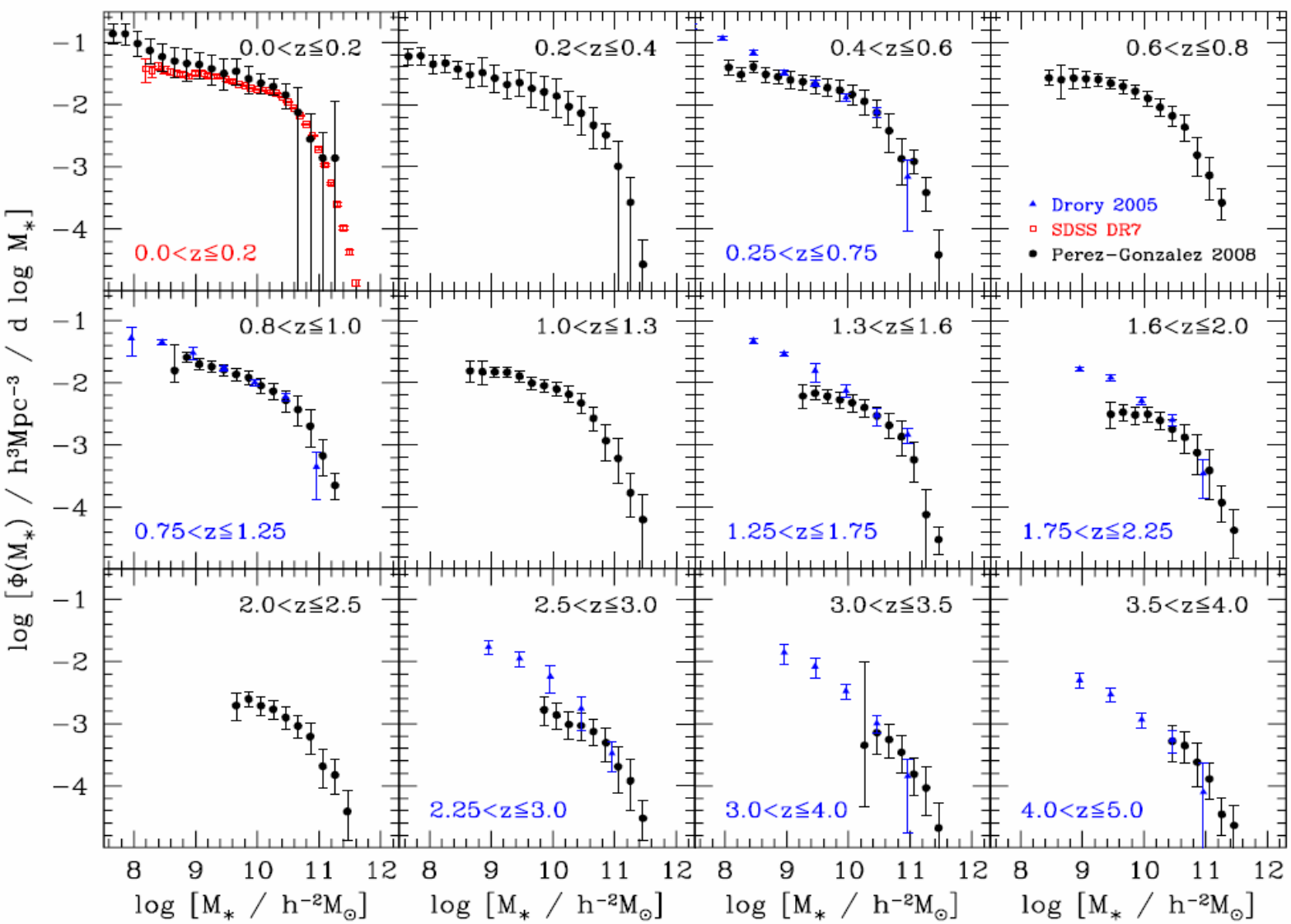
Success and inconsistency of SHAM

- **Success:** SHAM provides reasonably good predictions of the central galaxy population even if only the LF/SMF is used!

- **Inconsistency:**
  - Hidden Assumption: (I) M-L relation doesn't evolve, while SHAM itself shows that M-L relation does evolve!
  - Hidden Assumption:(II) The subhalo and satellite have same dynamical disruption rate: No orphan satellite galaxies!
  - It is based on given N-body simulations, resolution dependent!

- All about the satellites: make the corrections with the help of analytical subhalo accretion models.

Stellar mass functions at high redshift



Model the SMFs using the CSMFs

- **The stellar mass functions as a function of redshift:**

$$\Phi(M_*, z) = \int_0^\infty \Phi(M_*|M, z)\, n_{\rm h}(M, z)\, {\rm d}M\ ,$$

- **Separating the central and satellite contributions:**

$$\Phi(M_*|M, z) = \Phi_{\rm c}(M_*|M, z) + \Phi_{\rm s}(m_*|M, z)\ .$$

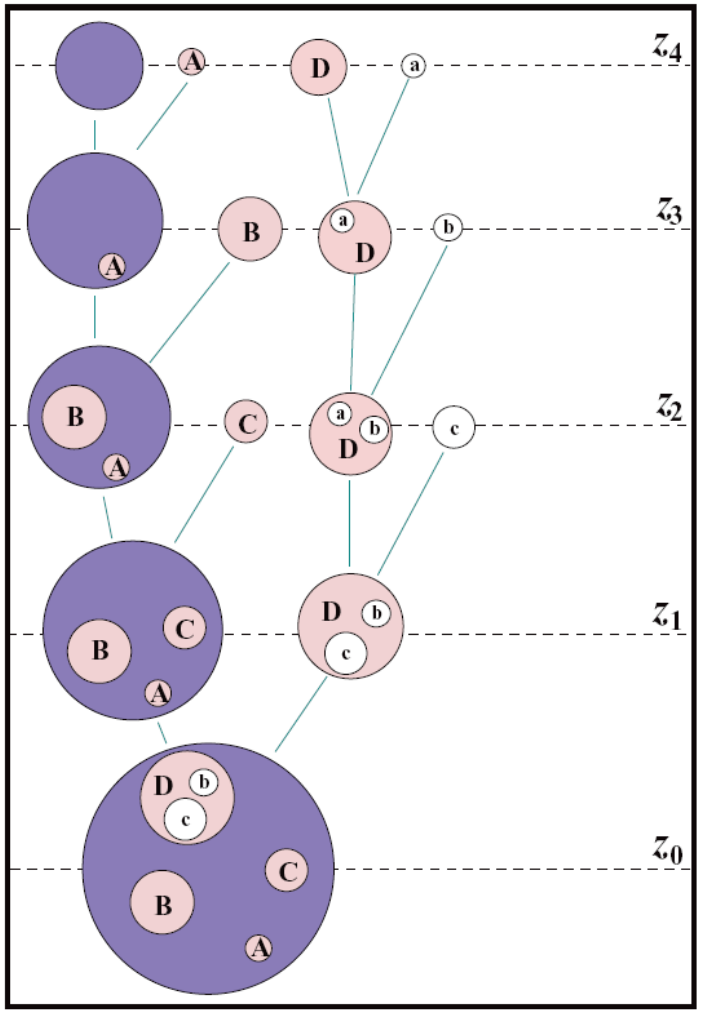
- **Well established central-host halo relations:**

$$\Phi_{\rm c}(M_*|M, z) = \frac{1}{\sqrt{2\pi}\sigma_c} \exp\left[-\frac{(\log M_*/M_{*,c})^2}{2\sigma_c^2}\right]\ ,$$

- **Update the satellite contributions that are selfconsistent:**

$$\Phi_{\rm s}(m_*|M, z) = \int_0^M {\rm d}m_a \int_z^\infty \frac{{\rm d}z_a}{1+z_a} \int_0^M {\rm d}M_a \int_0^1 {\rm d}\eta$$
$$\Phi_{\rm e}(m_*|m_a, z_a, z)\, n_{\rm sub}(m_a, z_a|M, z)$$
$$P(M_a, z_a|M, z)\, P(\eta)\, \Theta(p_t\, t_{\rm df} - \Delta t)\ ,$$

Evolving Conditional Stellar Mass Functions (ECSMF):



$$\Phi_{\rm s}(m_*|M,z) = \int_0^M {\rm d}m_a \int_z^\infty \frac{{\rm d}z_a}{1+z_a} \int_0^M {\rm d}M_a \int_0^1 {\rm d}\eta$$

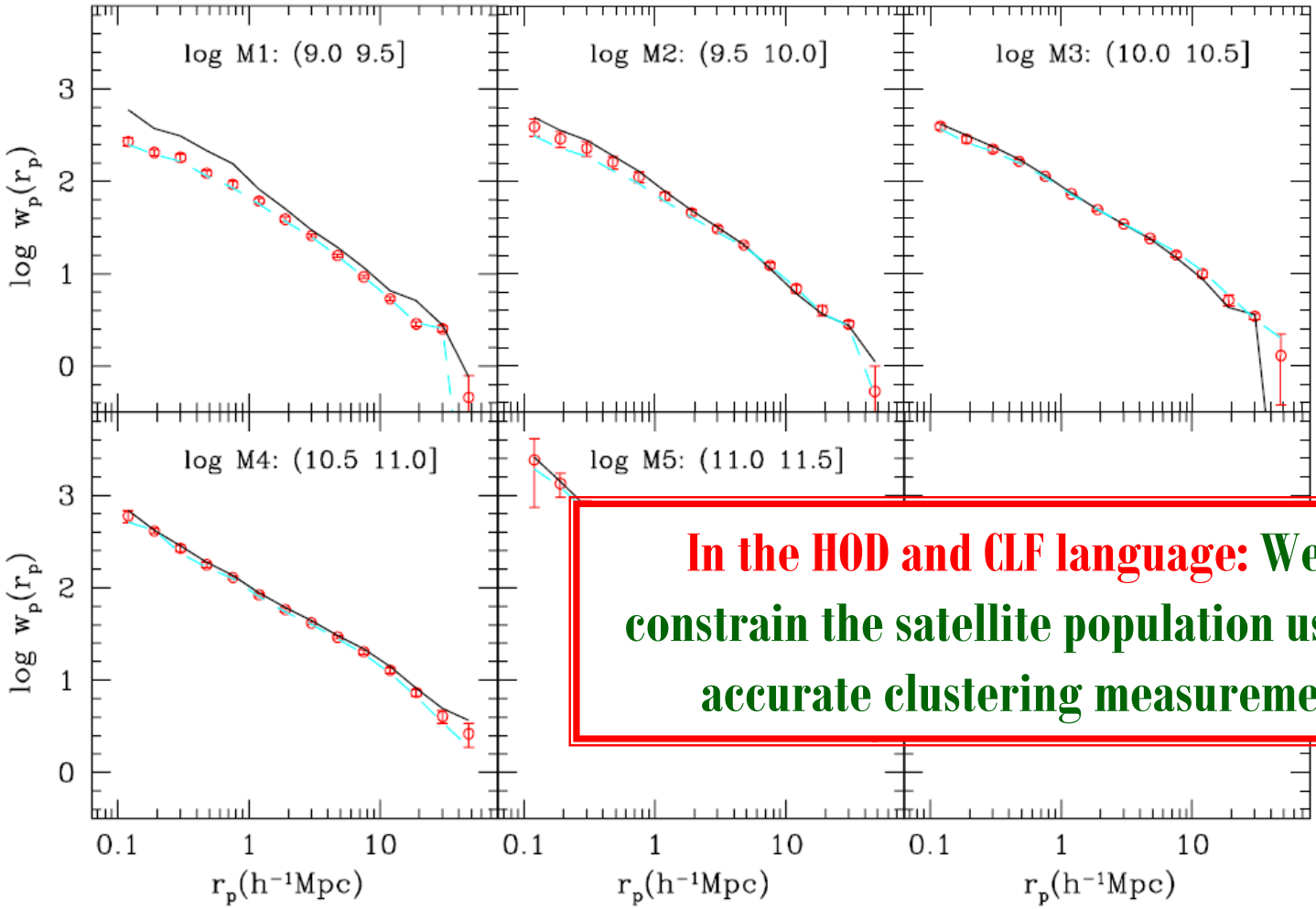
$$\Phi_{\rm e}(m_*|m_a,z_a,z)\, n_{\rm sub}(m_a,z_a|M,z)$$

$$P(M_a|M,z)\, P(\eta)\, \Theta(\quad_t\, t_{\rm df} - \Delta t)\,,$$

In total: We only have two free parameters regarding the satellite population in the whole subhalo accretion framework: '**c**' – the stellar mass evolution; '**p_t**' -- the disruption of satellite galaxies.

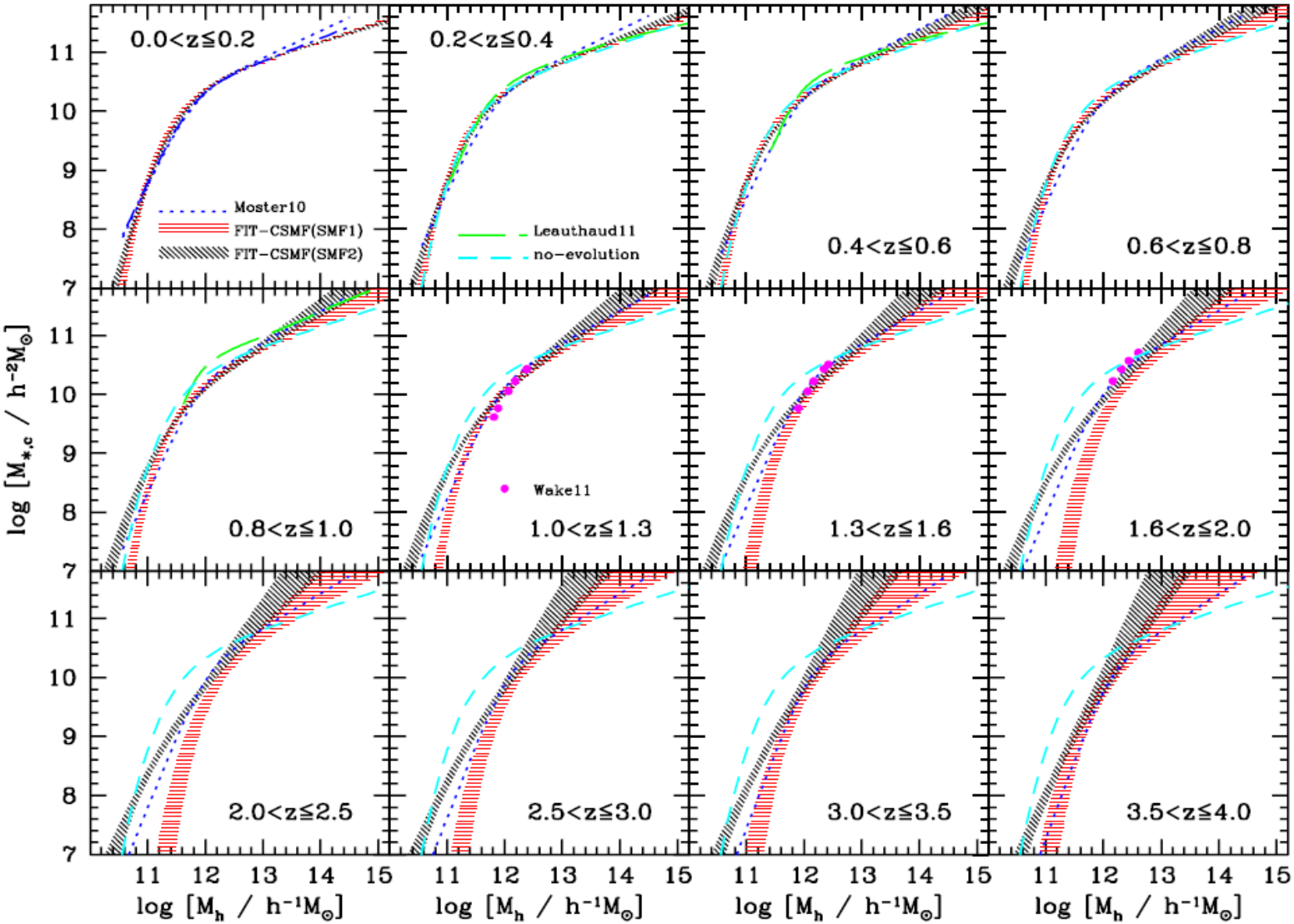
Yang et al. 2012

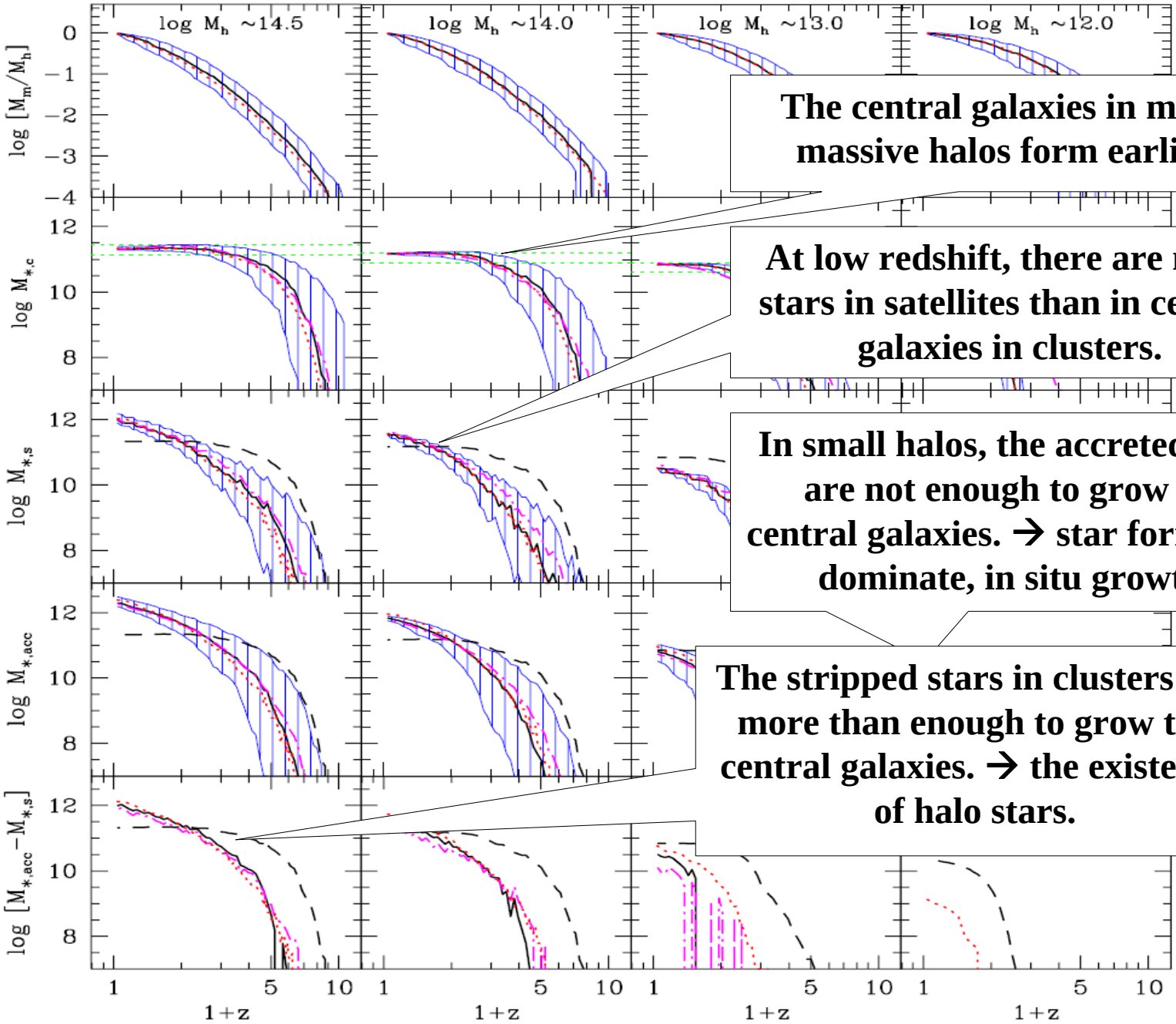
The 2PCFs at low redshift



In the HOD and CLF language: We can constrain the satellite population using the accurate clustering measurements.

Comparisons with other similar constraints




log M_h ~14.5
log M_h ~14.0
log M_h ~13.0
log M_h ~12.0
log [M_m/M_h]
log M_*,c
log M_*,s
log M_*,acc
log [M_*,acc − M_*,s]
1+z
The central galaxies in more massive halos form earlier
At low redshift, there are more stars in satellites than in central galaxies in clusters.
In small halos, the accreted stars are not enough to grow the central galaxies. → star formation dominate, in situ growth.
The stripped stars in clusters are more than enough to grow the central galaxies. → the existence of halo stars.

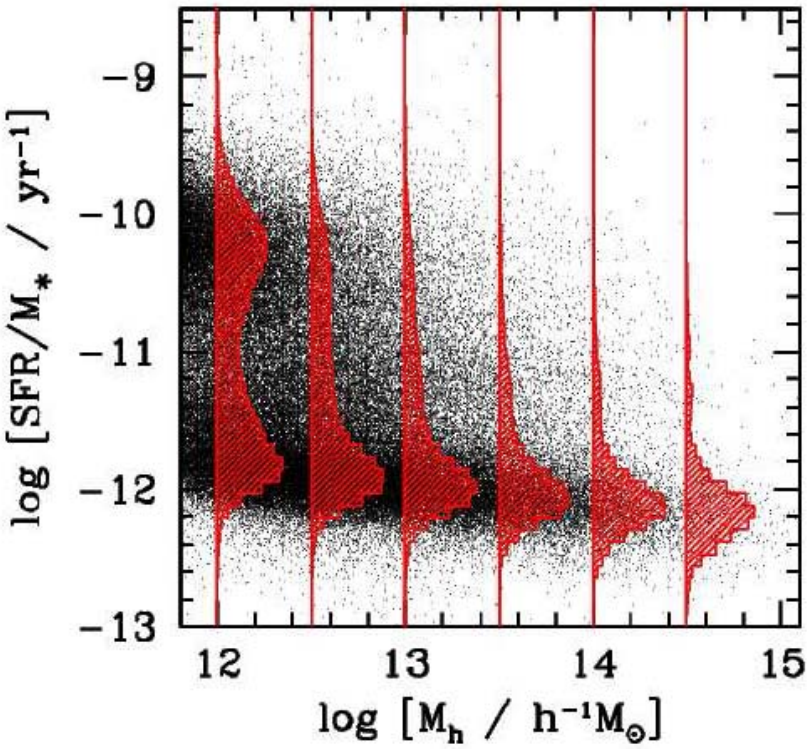
Extract the Star Formation Histories of the central galaxies

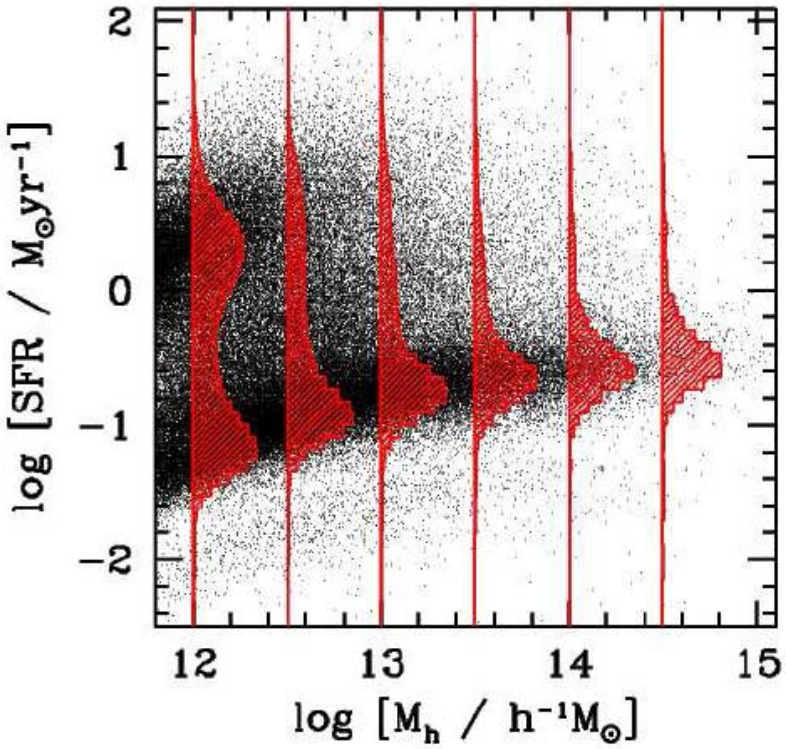
- **The growth of central galaxies:**
  - **The in situ star formation**
  - **The accretion of satellite stars**
  - **The passive evolution of existing stars** (provided by Stephane Charlot)

- **Assumptions about the contribution of satellite stars:**
  - **None (max SFR)**
  - **Max (min SFR)**
  - **→ using local observation to constrain (obs SFR)**

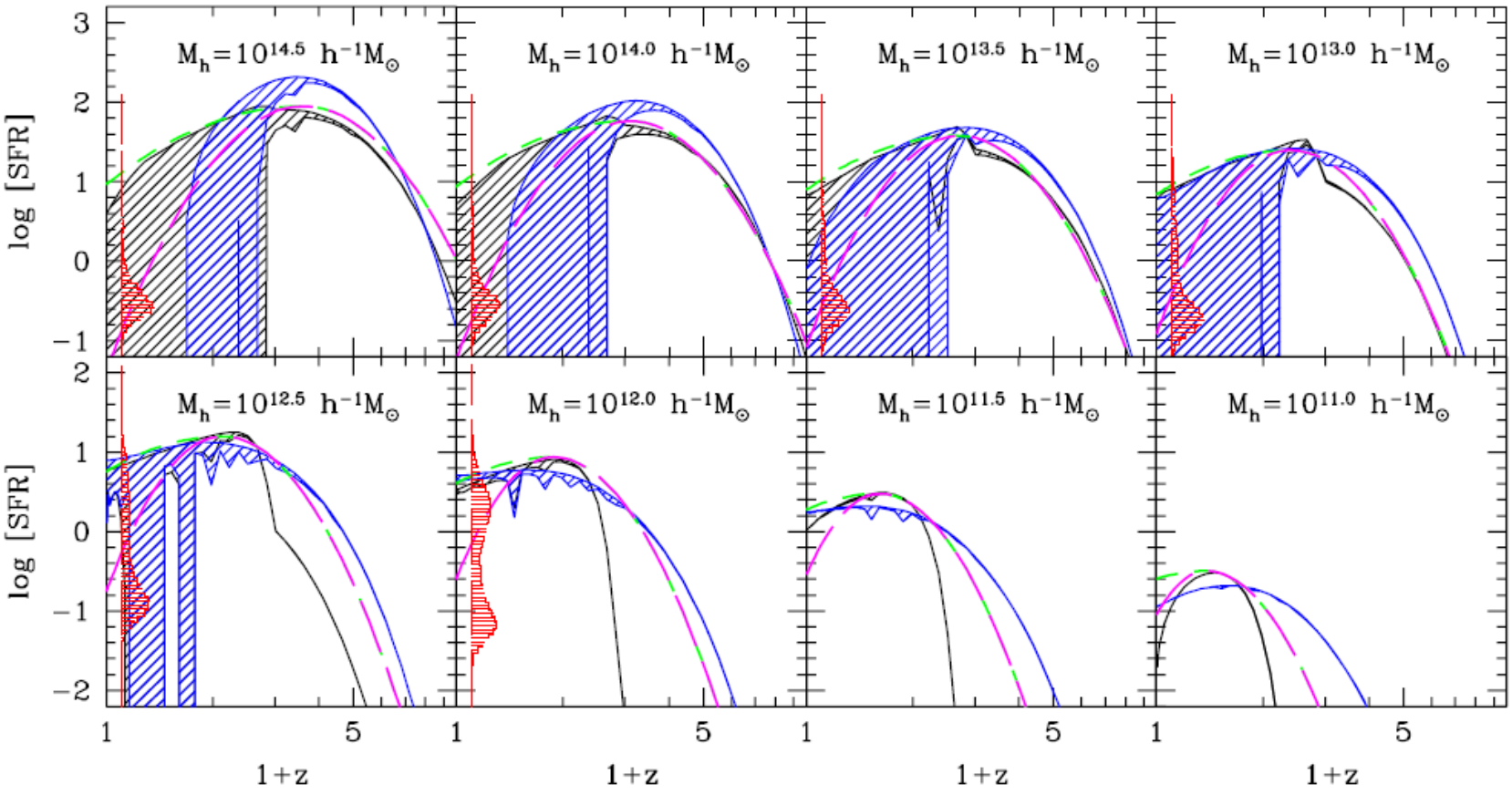
Yang et al. 2012, in preparation

The star formation rate of the central galaxies (local)

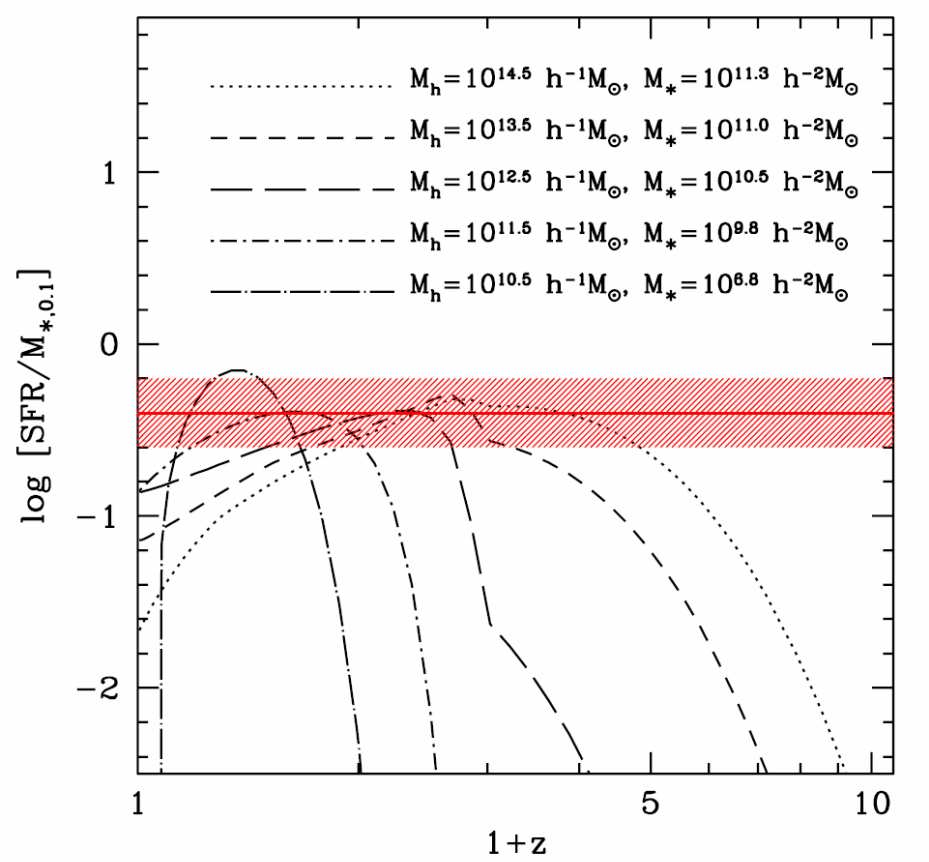




The SFH of the central galaxies

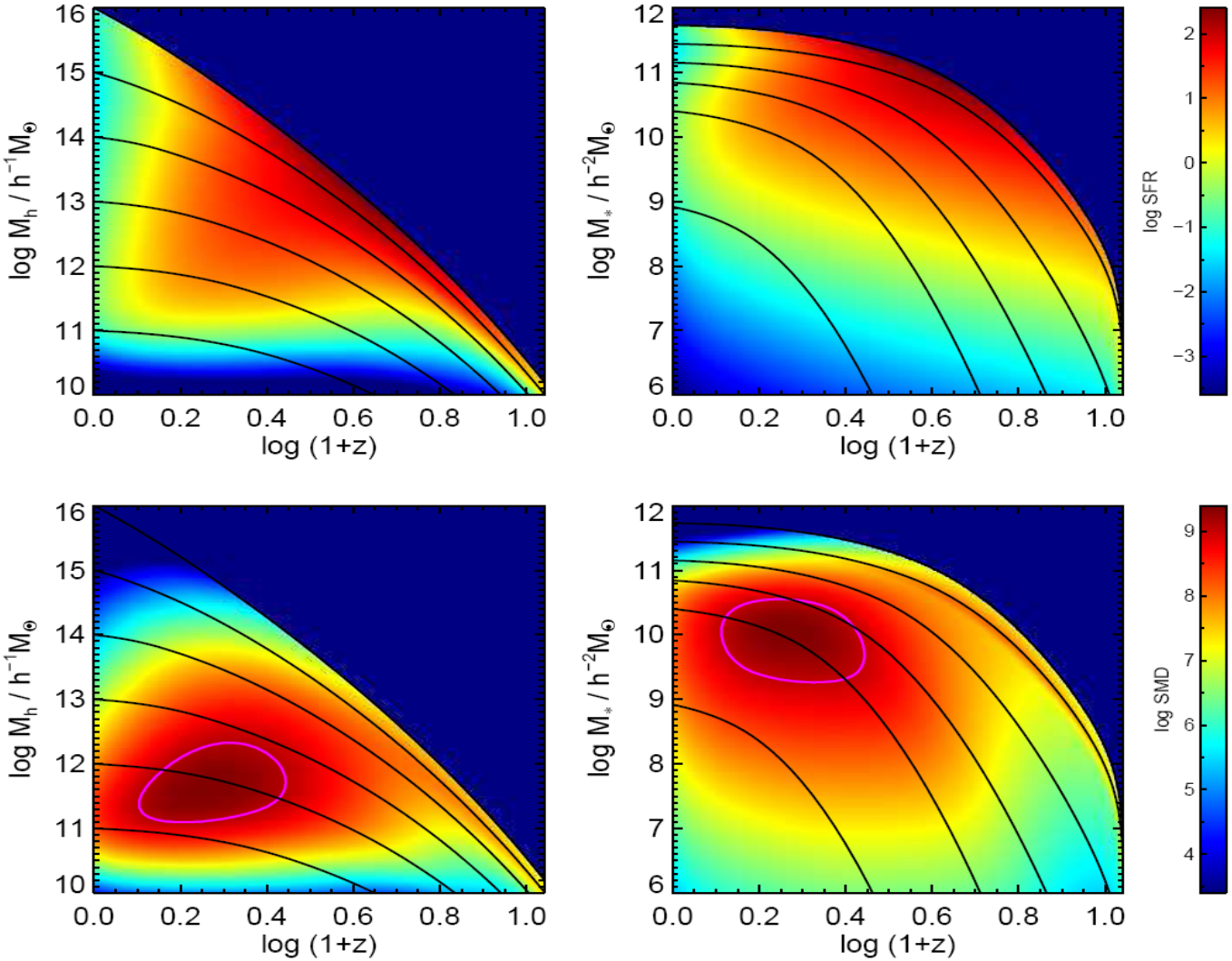


The universal SFR peak

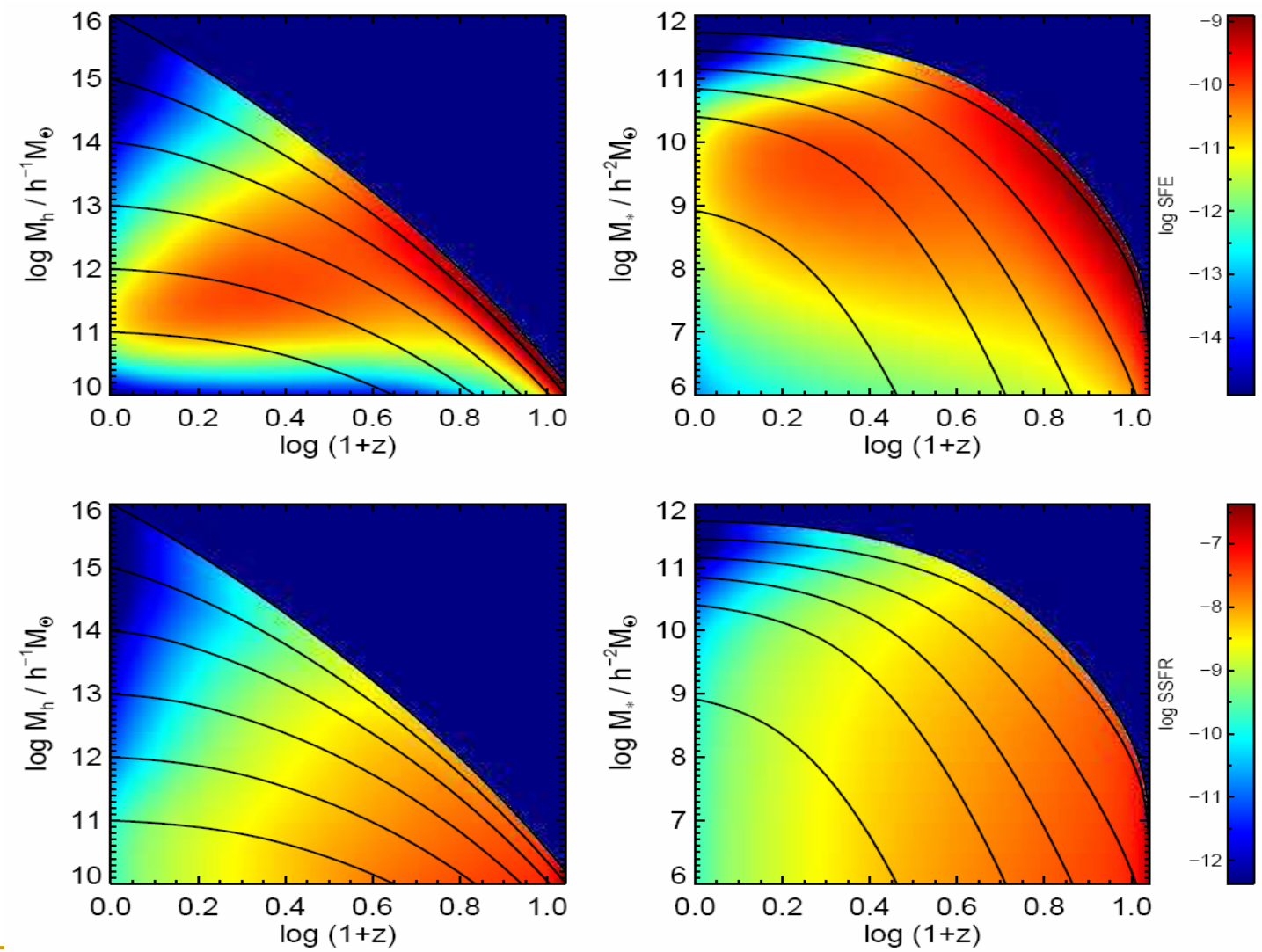


$$\mathrm{SFR}(M_h, z) = \mathrm{SFR}_{\mathrm{pk}} \times \exp\left\{-\frac{\log^2[(1+z)/(1+z_{\mathrm{pk}})]}{2\sigma^2(z_{\mathrm{pk}})}\right\}$$

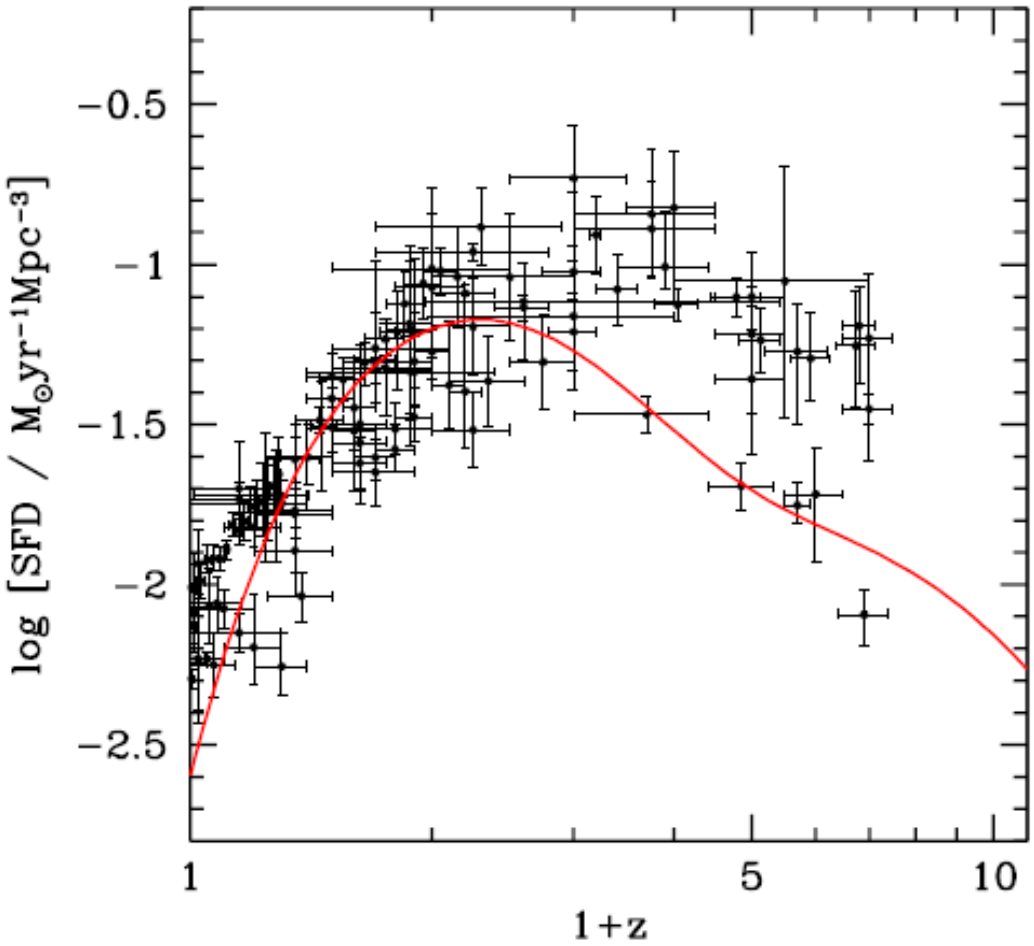
The SFR map of the galaxies



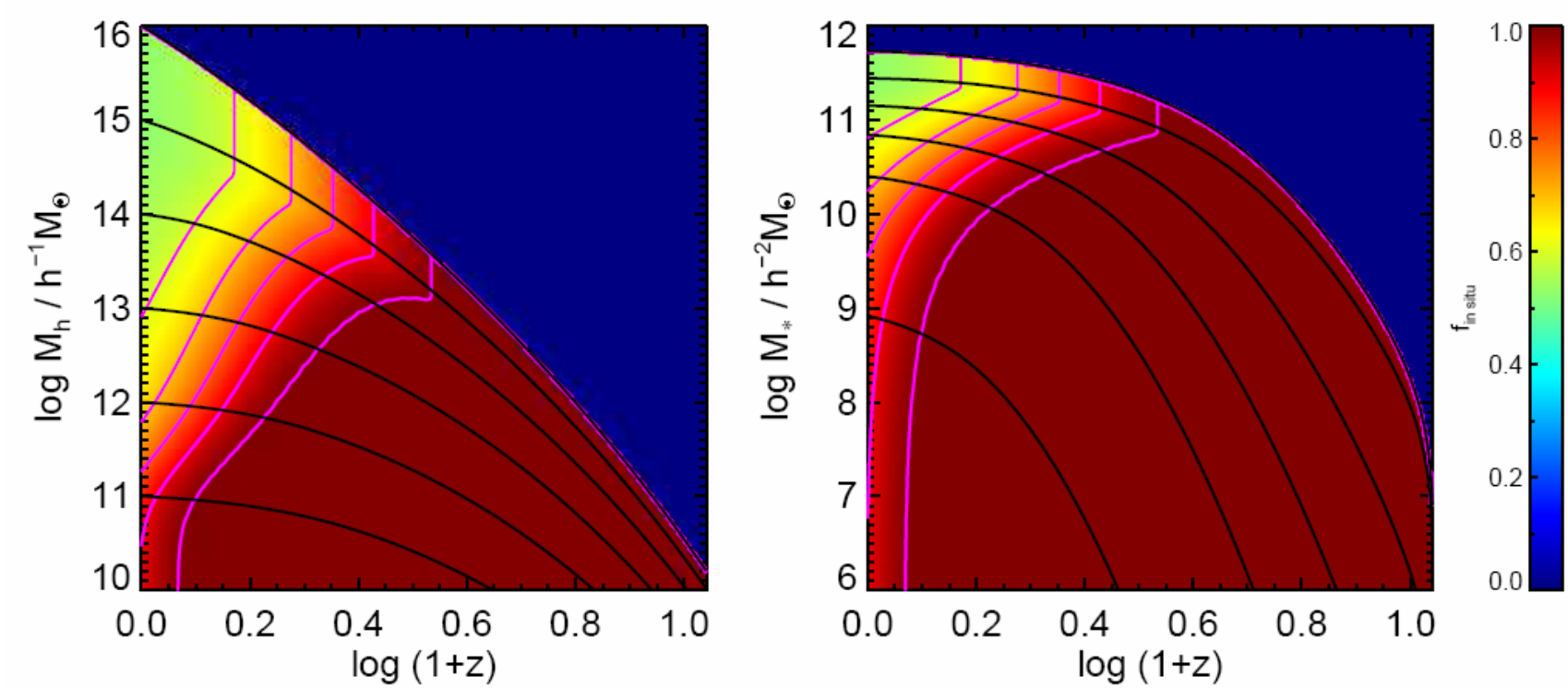
The SFE and SSFR map of the galaxies



The SFD of the Universe



The fraction of the in situ formed stars



Summary

- SHAM is a useful tool to link galaxies and dark matter halos.
- However, it suffers from a number of intrinsic issues.
- If combined with subhalo accretion models, by constructing a selfconsistent population of satellite galaxies, it can be used to probe the evolution of galaxies using the current observational data at high redshift already!
- The SFHs of central (and satellite) galaxies can be constrained from these models……

Thank you!