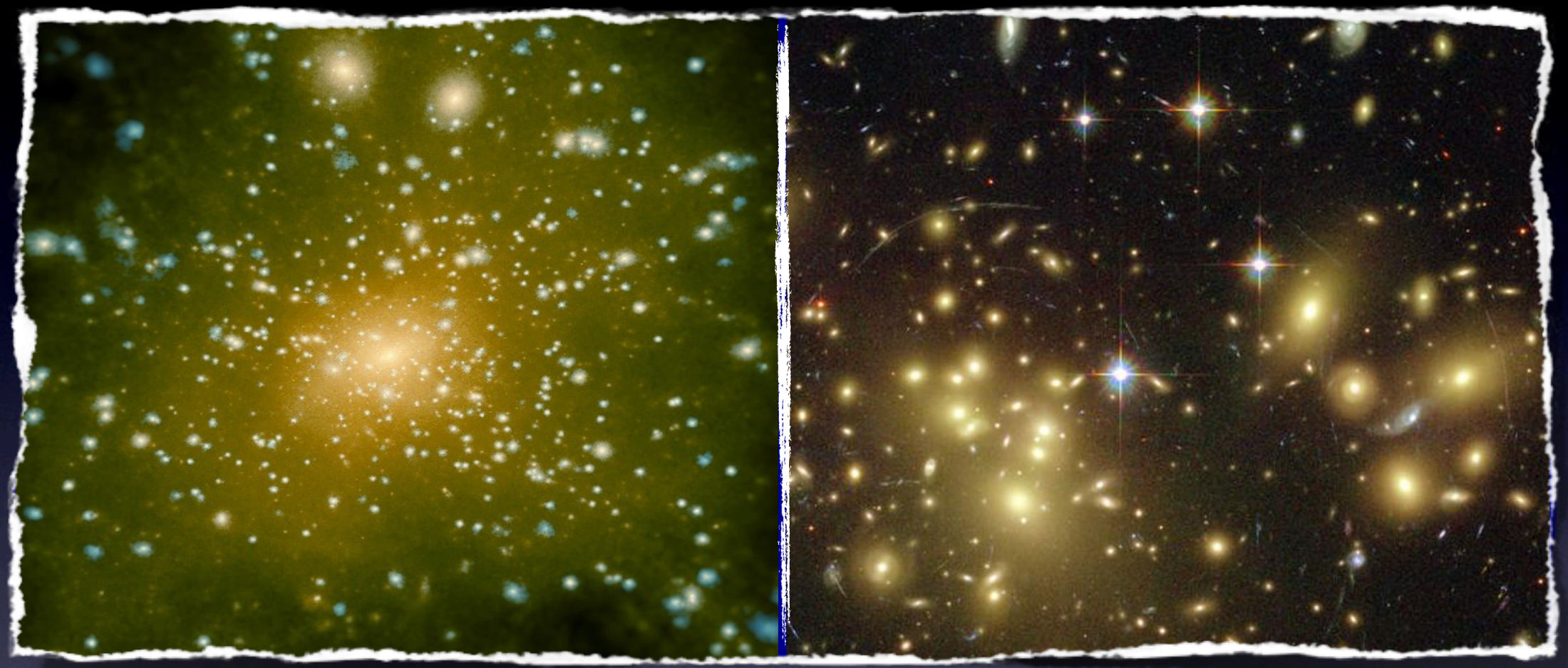
A Self-Consistent, Dynamic Model for the Evolution of the Galaxy-Dark Matter Connection



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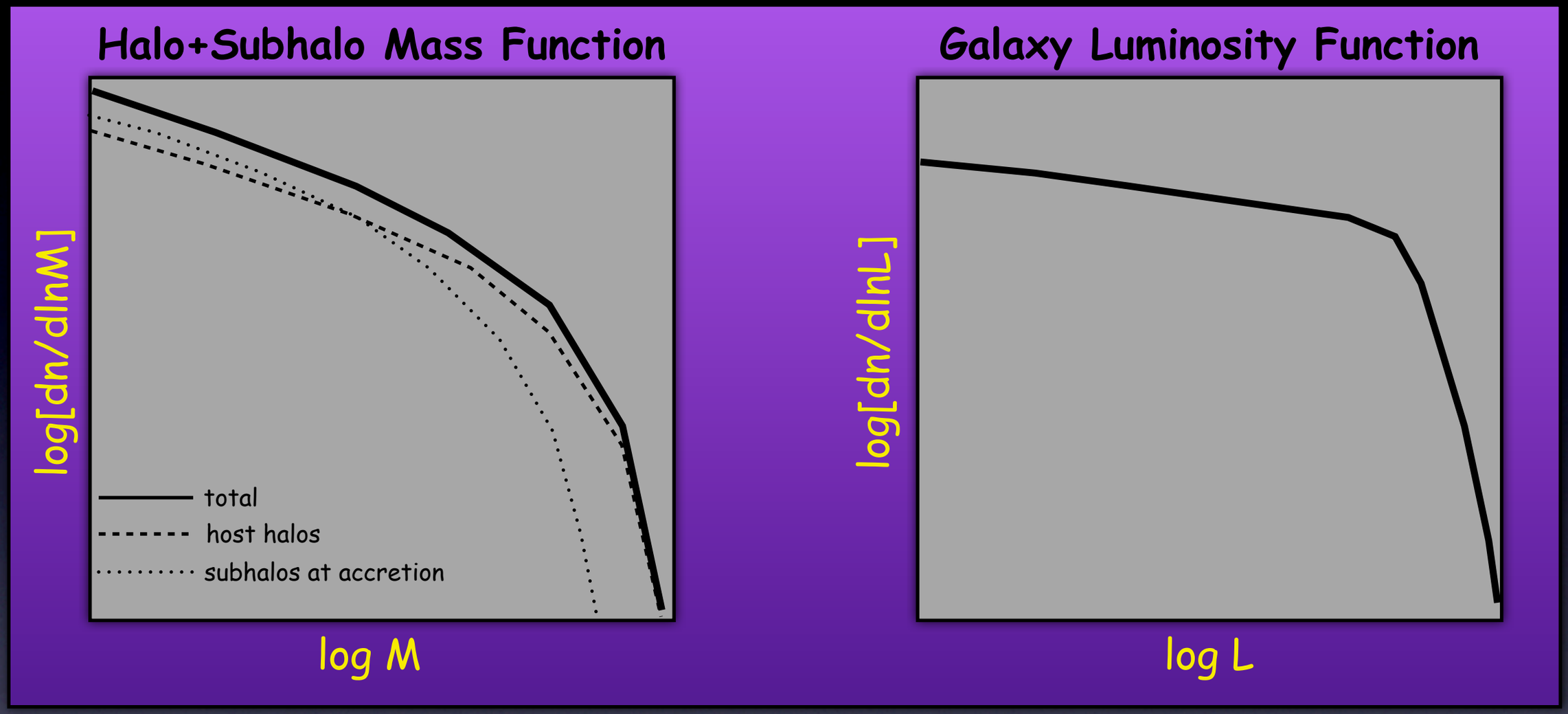
Xiaohu Yang, Houjun Mo, Youcai Zhang, Jiaxin Han

Yang et al. 2011, ApJ, 741, 13

Yang et al. 2011 [arXiv:1110.1420]

SubHalo Abundance Matching (SHAM)



Establish connection between galaxy luminosity and halo mass by matching their abundances:

$$n_{\rm g}(>L) = n_{\rm h}(>M) + n_{\rm sh}(>M)$$

Mo & Fukugita 1996; Mo, Mao & White 1999; Vale & Ostriker 2004, 2006; Conroy et al. 2006; Shankar et al. 2006; Conroy & Wechsler 2009; Moster et al. 2010; Behroozi et al. 2010; Wetzel & White 2010

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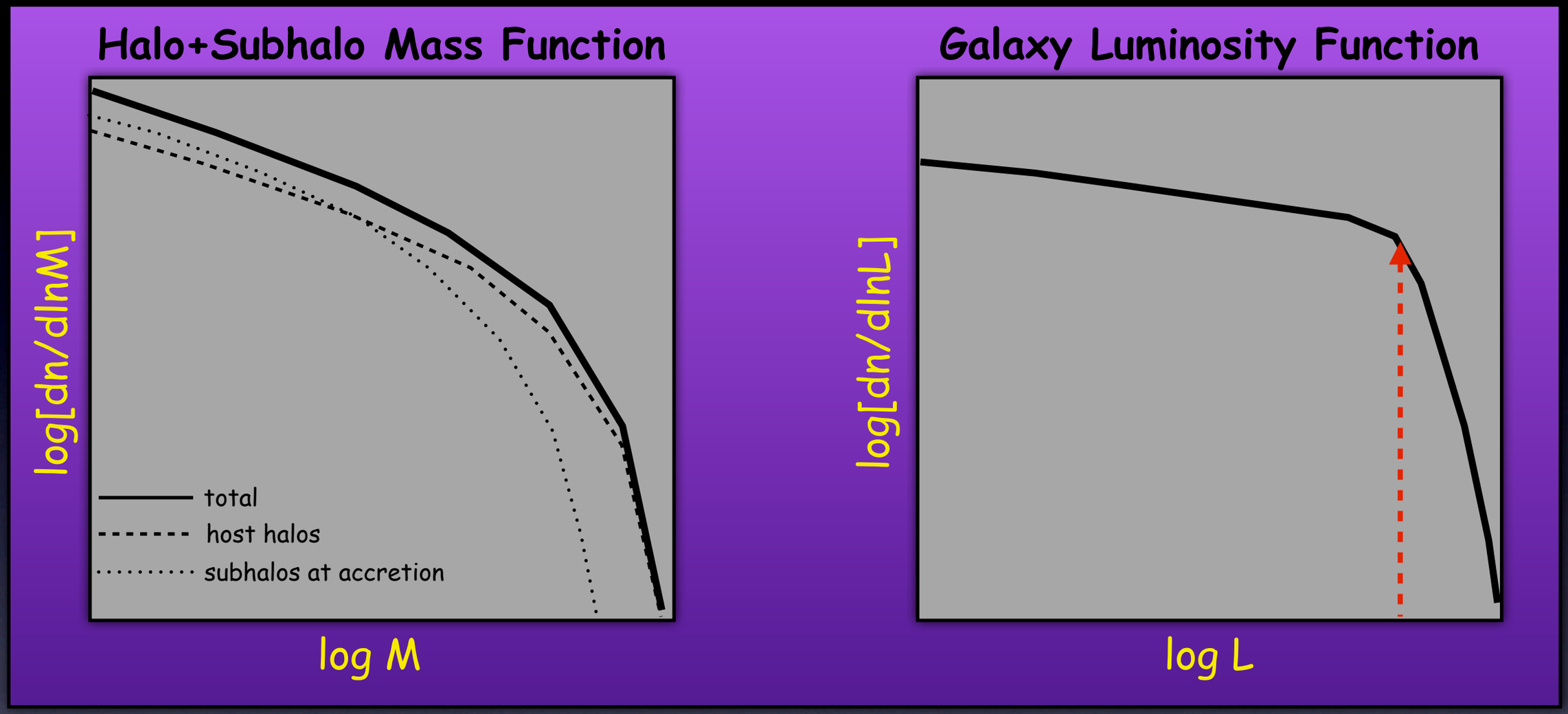

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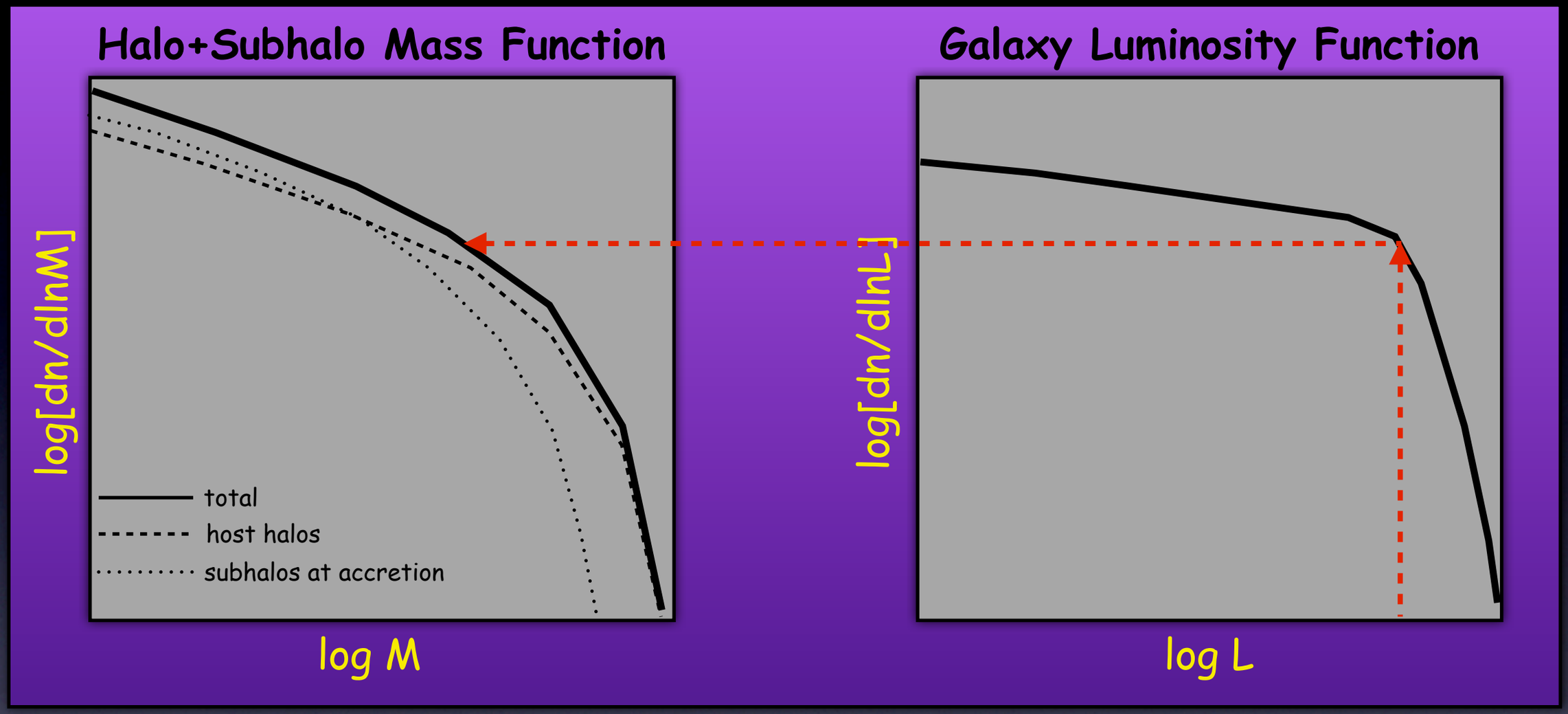

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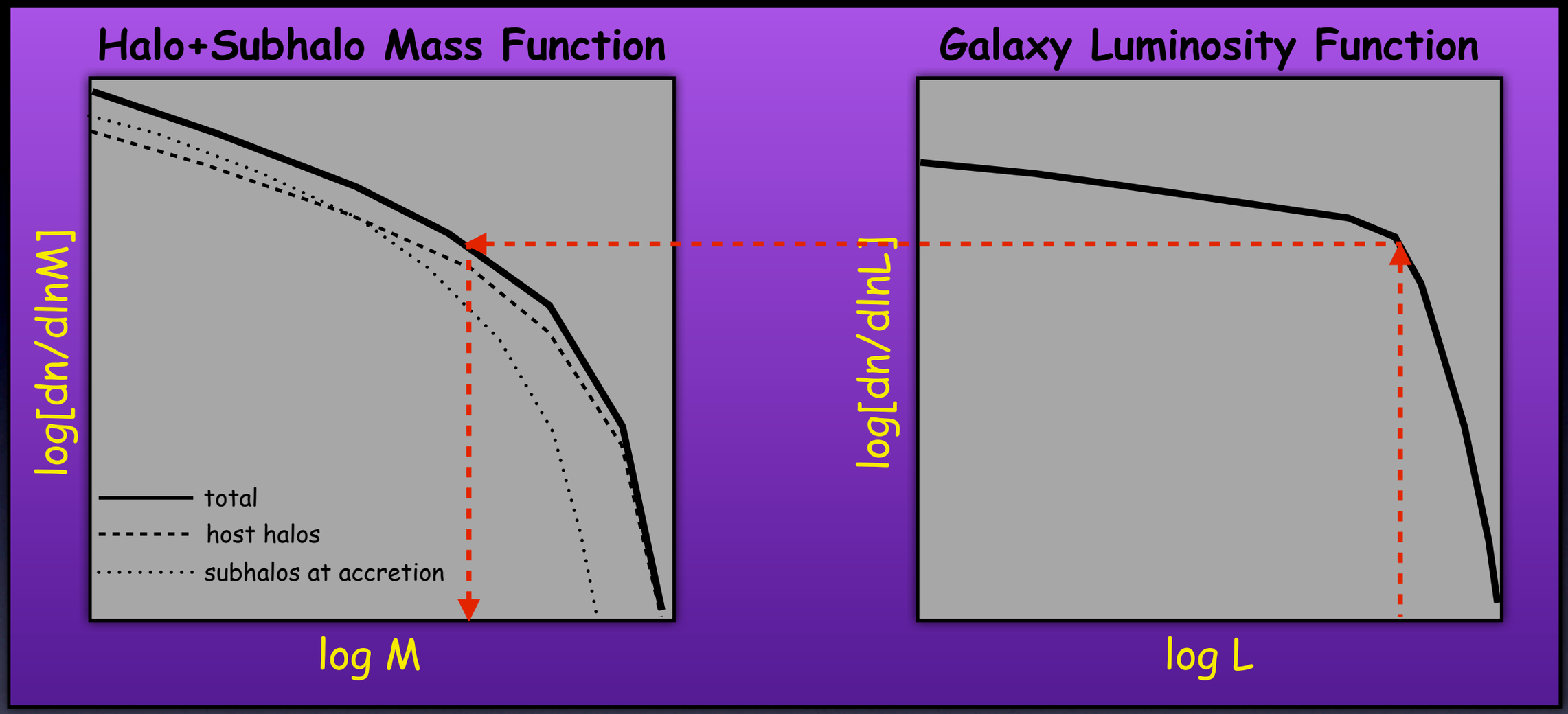

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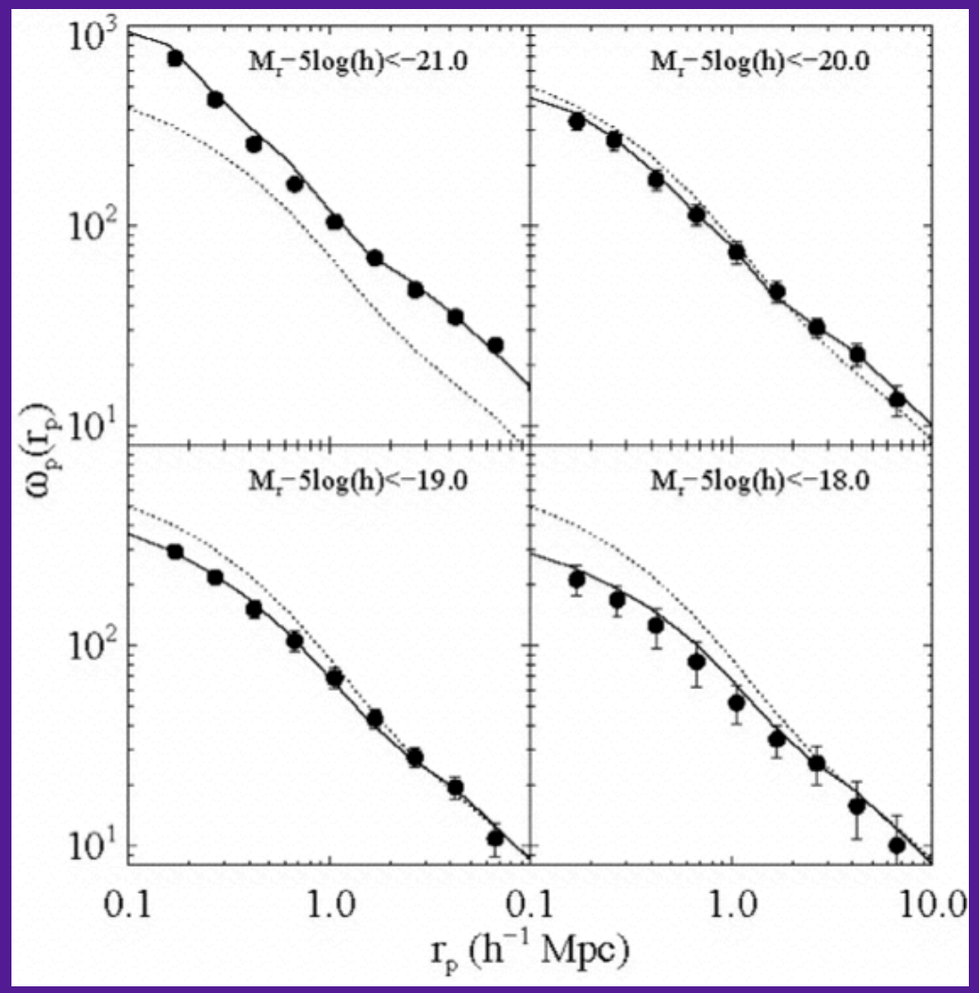
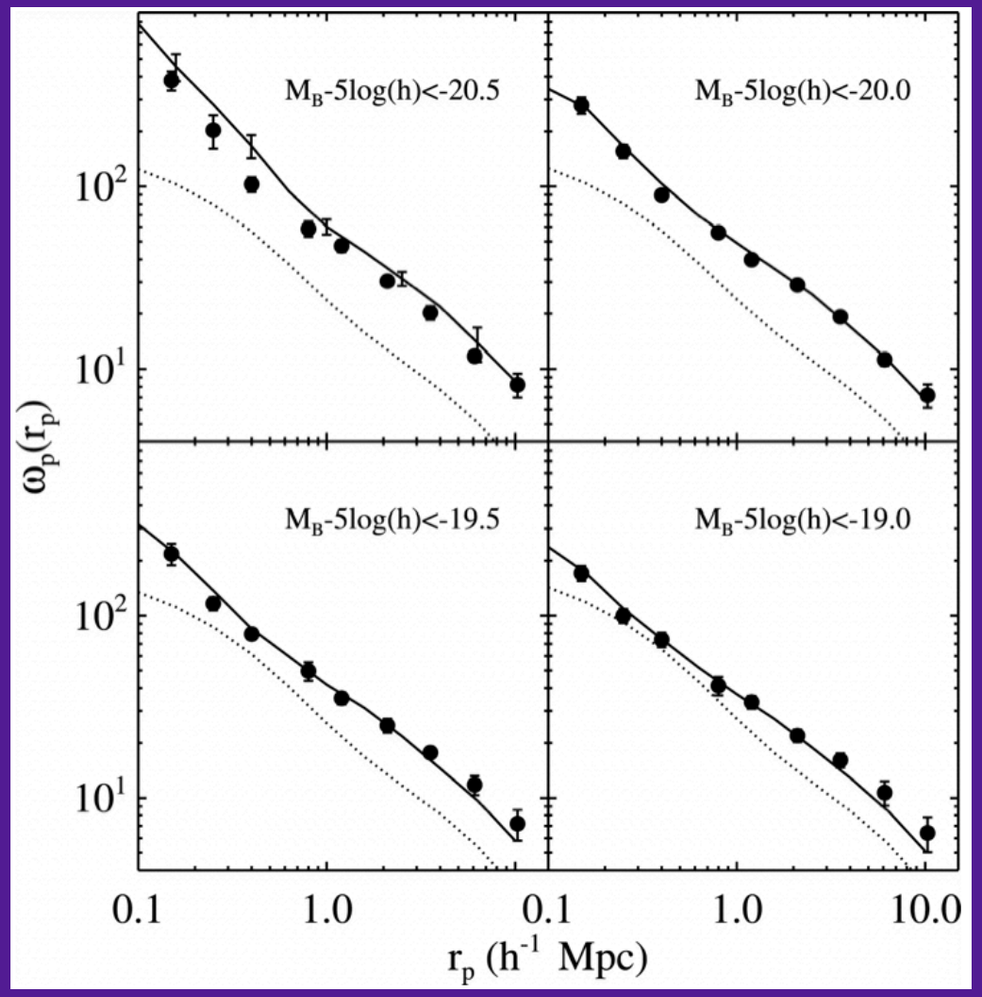
SHAM's Amazing Success

- Has no free parameters (or one; scatter)
- Only requires stellar mass functions: easier than correlation functions.
- Fits the observed correlation functions amazingly well!!!

DATA: SDSS @ z~0.1

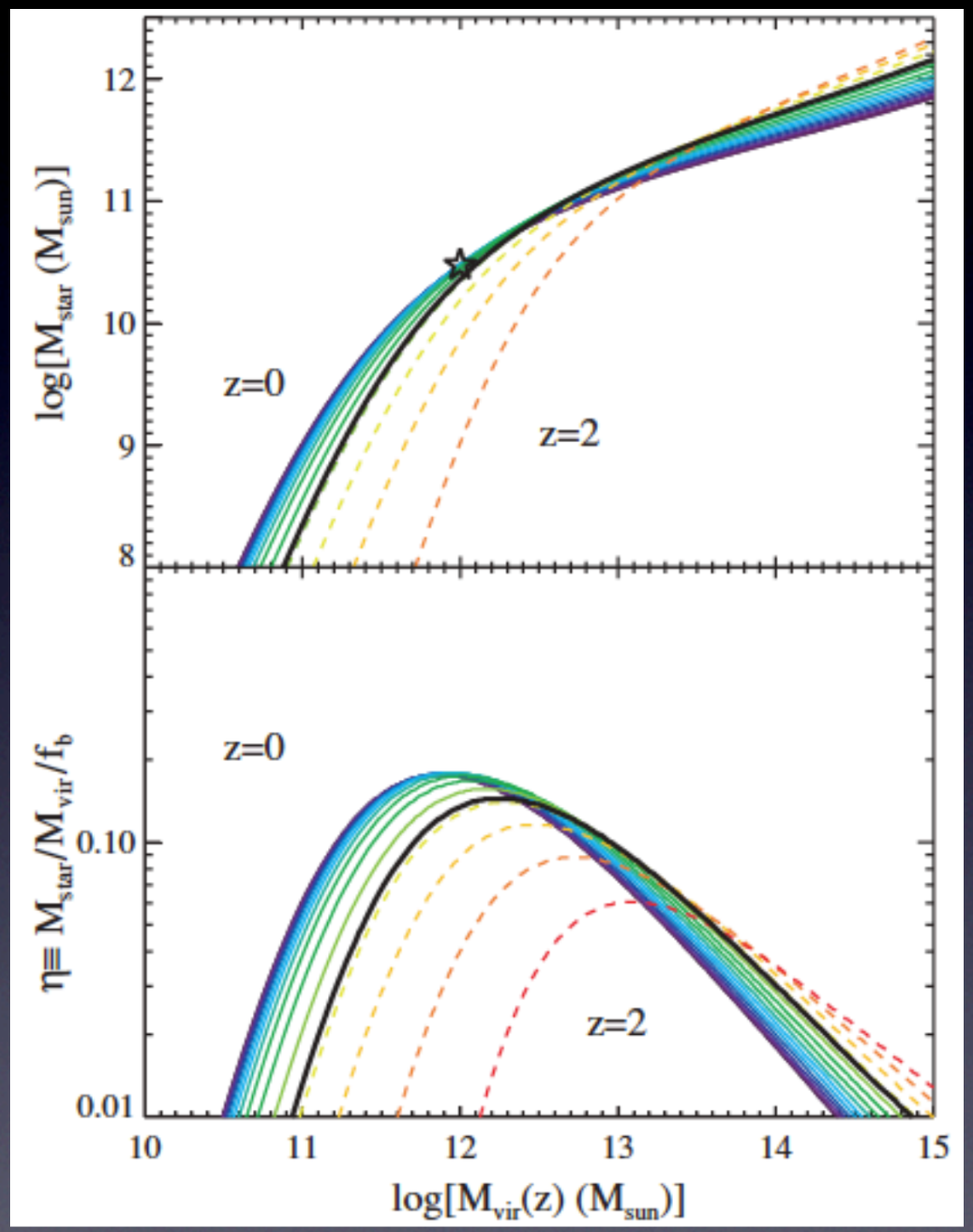


DATA: DEEP-2 @ z~1



Source: Conroy, Wechsler & Kravtsov (2006)

SHAM's inconsistency problem



Source: Conroy & Wechsler (2009)

For satellites, SHAM uses (sub)halo mass at accretion, which is treated similar as a host halo of same mass at z=0.

Hidden Assumption: M-L relation doesn't evolve!

Inconsistency: SHAM itself shows that M-L relation does evolve!

Solution: Use M-L relation at accretion redshift to populate subhalos with satellites.

This is not possible with SHAM without some iterative scheme...

Even when you can establish the galaxy-dark matter connection at different redshifts, this still does not constitute a dynamic model

Galaxy-Dark Matter Connection across Cosmic Time

Yang et al. 2011 [arXiv:1110.1420]

The Model

central galaxies

$$\Phi_{\rm c}(M_*|M,z) = \frac{1}{2\pi\sigma_{\rm c}} {\rm EXP}\left[-\frac{(\log\, M_*/\overline{M}_*)^2}{2\sigma_{\rm c}^2}\right] \qquad \left.\begin{array}{l} \overline{M}_* = \overline{M}_*(M,z) \\ \sigma_{\rm c} = \sigma_{\rm c}(z) \end{array}\right\} \text{9 free parameters}$$

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satellite galaxies are centrals at infall:

$$\Phi_{\rm s}(M_*|M,z) = \int_0^\infty {\rm d}M_{*,a} \int_0^M {\rm d}m_a \int_z^\infty {\rm d}z_a \int_0^M {\rm d}M_a \int_0^1 {\rm d}\eta\; \Phi_{\rm c}(M_{*,a}|m_a,z_a)\, n_{\rm sub}(m_a,z_a|M,z)$$

$$P(M_*,z|M_{*,a},z_a;m_a;M_a,\eta)\, P(M_a,z_a|M,z)\, P(\eta)$$

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$$P(M_*,z|M_{*,a},z_a;m_a;M_a,\eta)\, P(M_a,z_a|M,z)\, P(\eta)$$

a highly simplified model for the dynamical evolution of satellites:

$$P(M_*,z|M_{*,a},z_a;m_a;M_a,\eta) = \begin{cases} \delta^{\rm D}(M_*-M_{*,a}) & \text{if } \Delta t < \alpha\, t_{\rm df}(m,M,z,\eta) \\ 0 & \text{otherwise} \end{cases}$$

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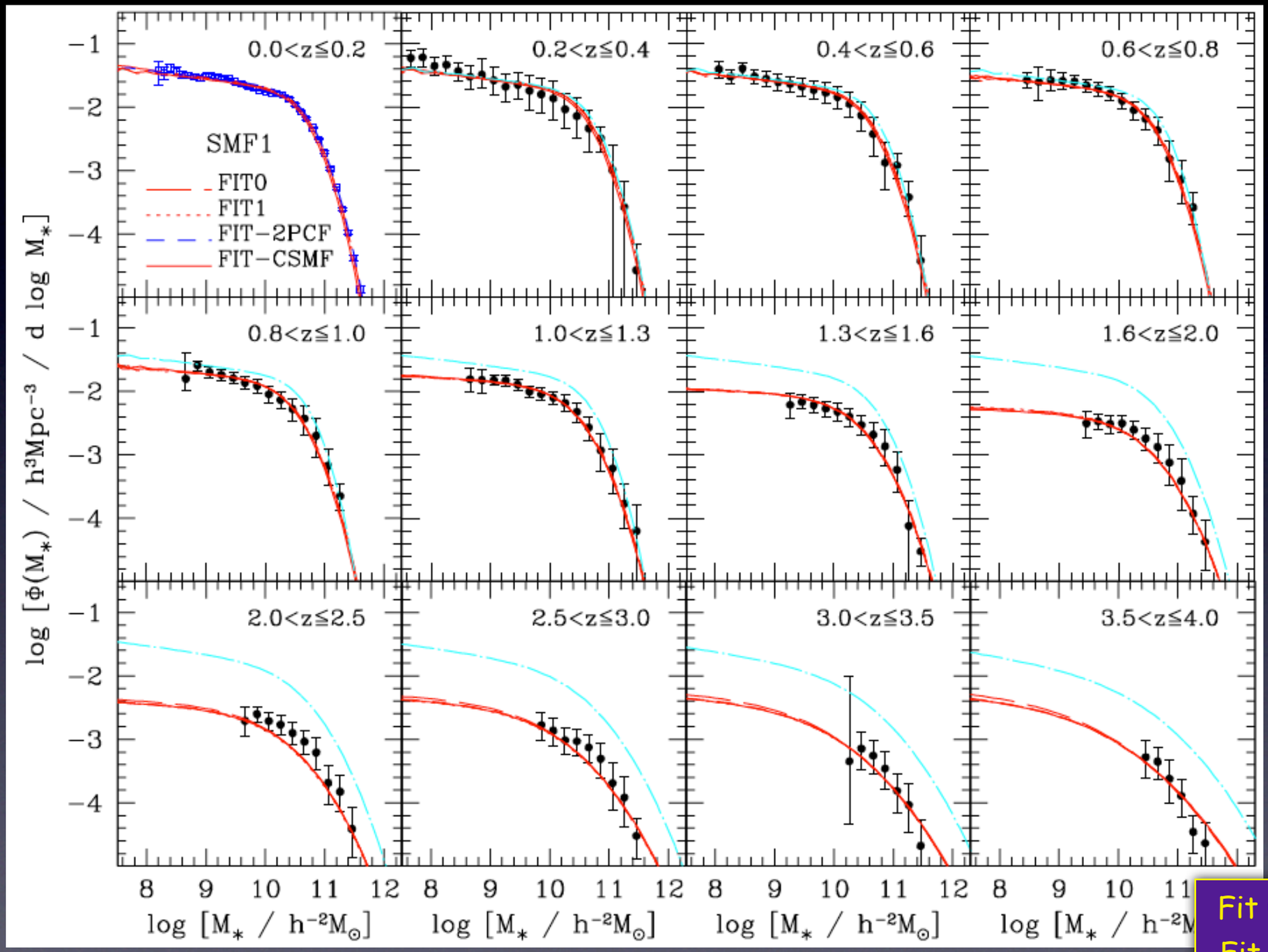
free parameter

Fit to Stellar Mass Functions across Cosmic Time

Data: Yang et al (2009; z~0.1)
Perez-Gonzales et al. (2008)

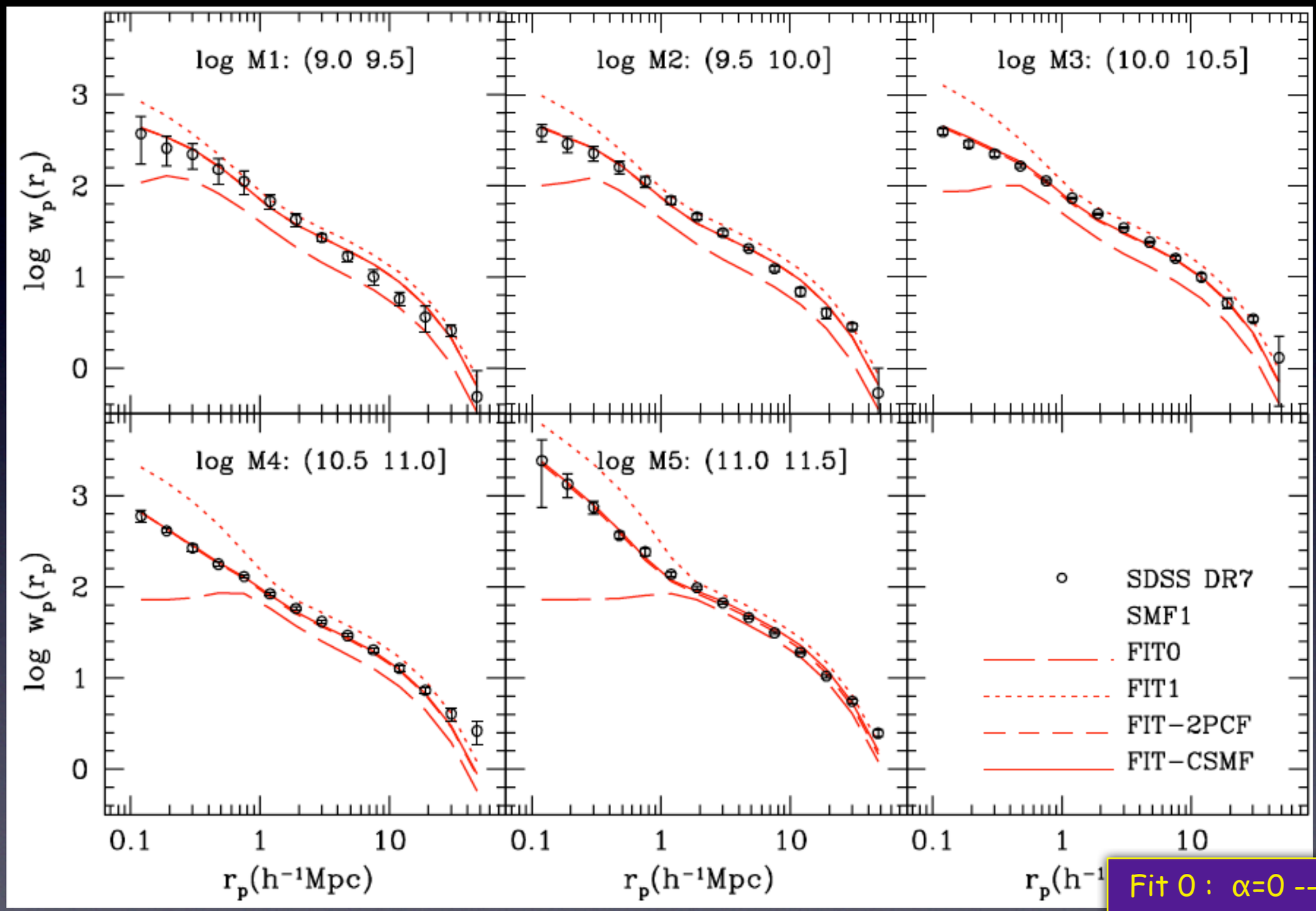


Source: Yang et al. 2011 [arXiv:1110.1420]

Fit 0 : α=0 --> no sats
Fit 1 : α=∞ --> no evolution
2PCF : fit to $\Phi(M_\star)$ + 2PCF
CSMF : fit to $\Phi(M_\star)$ + $\Phi(M_\star|M,z=0)$

Fit to Two-Point Correlation Functions at z=0.1

Data: SDSS DR7 (Yang et al. 2011)



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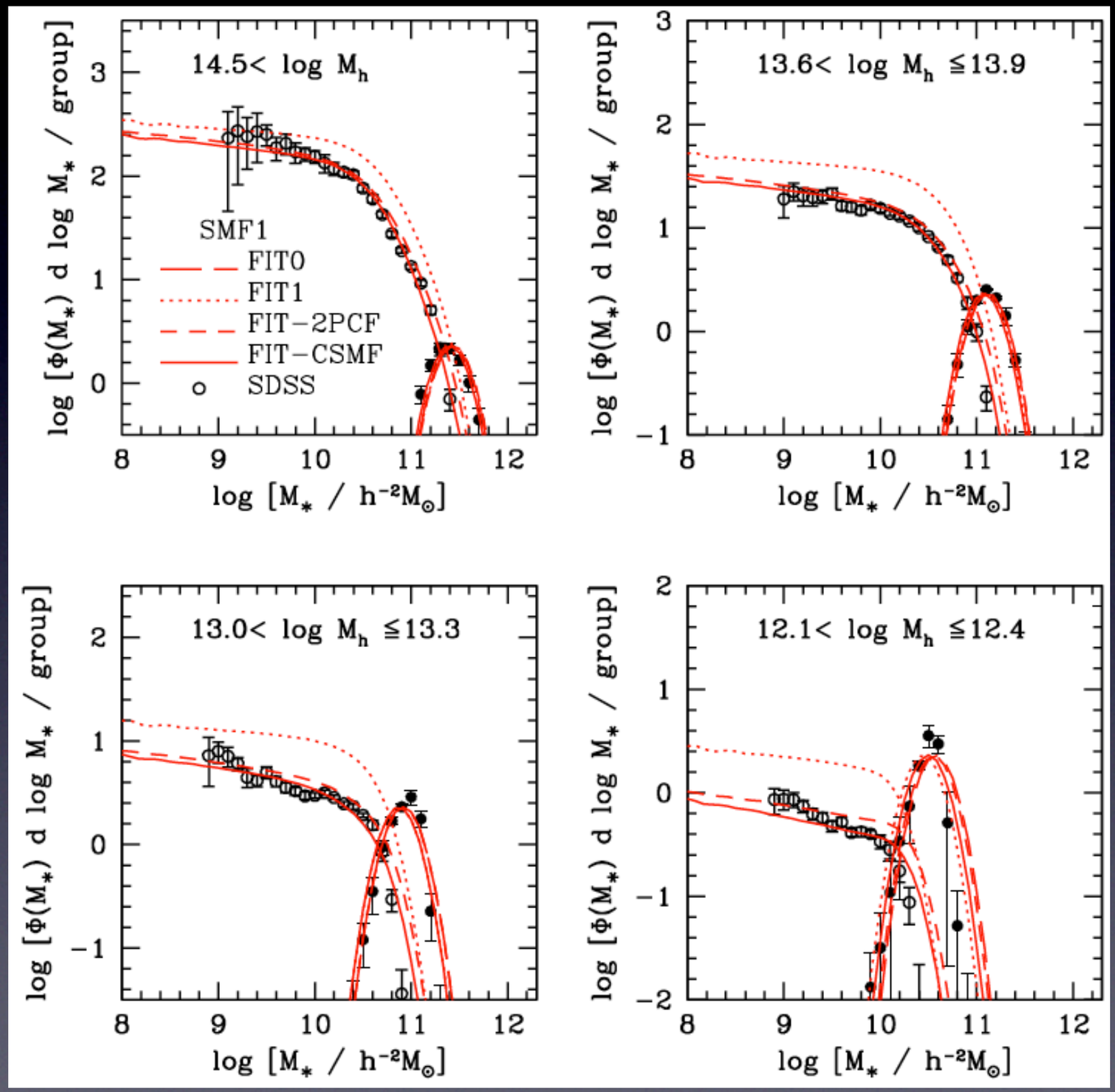
Fit to Conditional Stellar Mass Functions at z=0.1

Data: SDSS Galaxy Group Catalogues (Yang et al. 2009)



Source: Yang et al. 2011 [arXiv:1110.1420]

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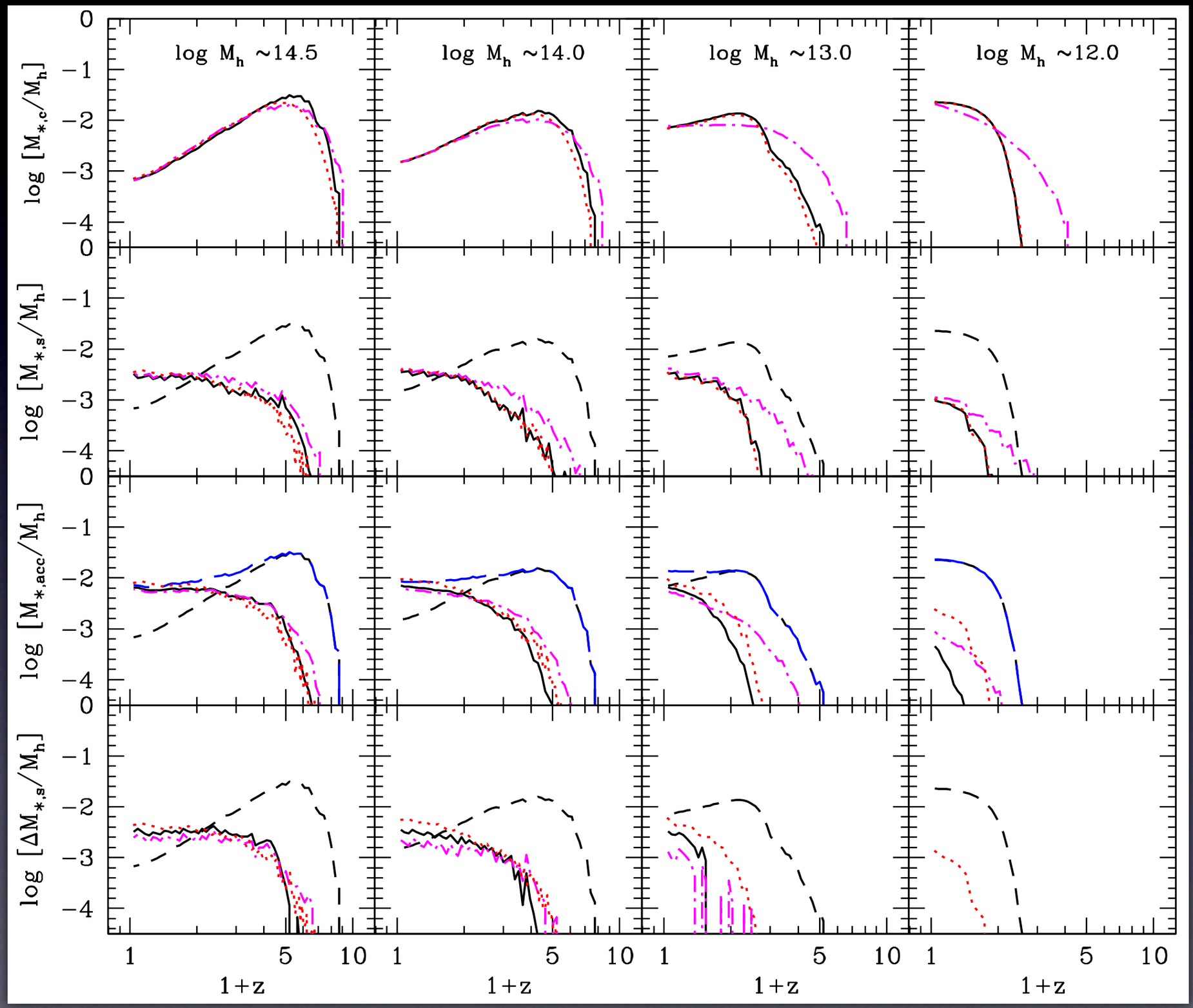
Stellar Assembly Histories of Galaxies



centrals

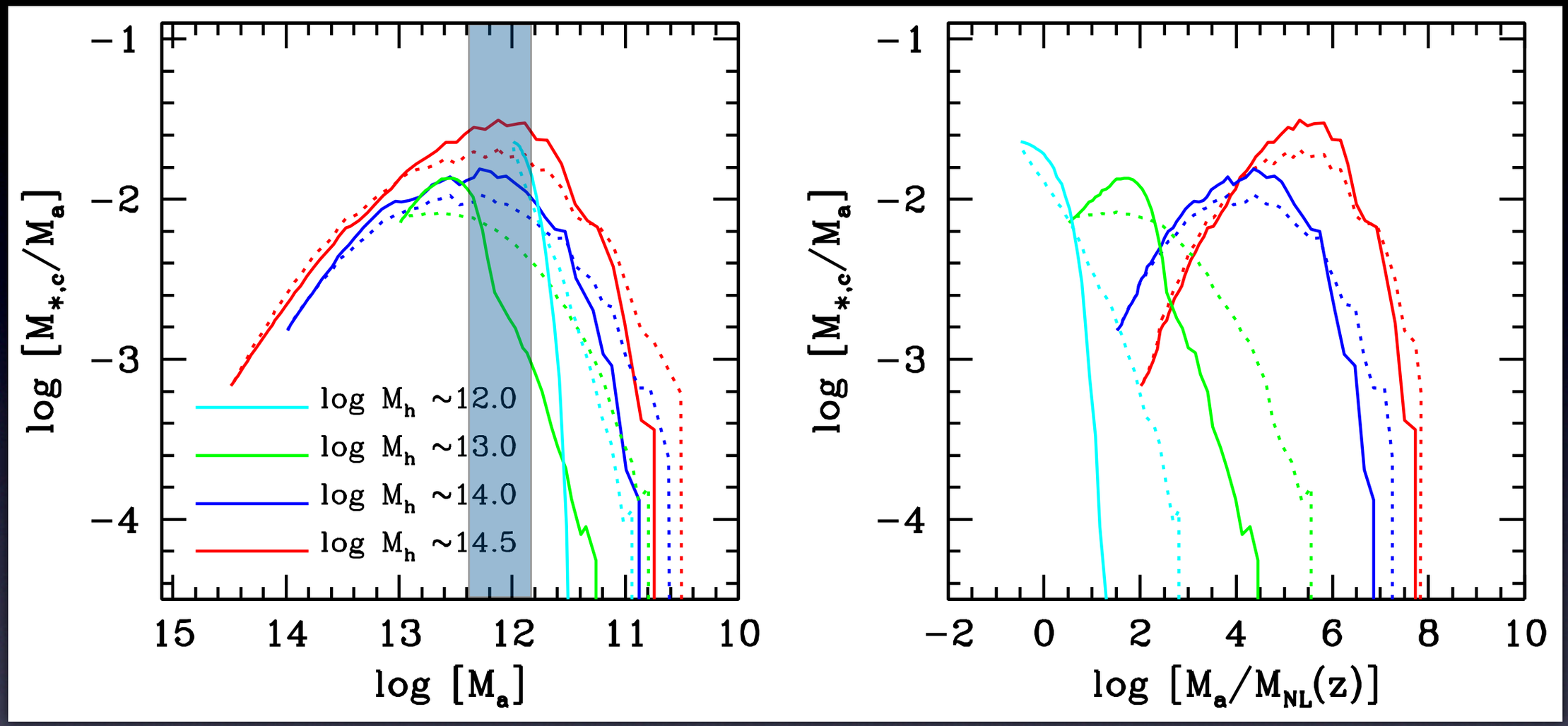
surviving satellites

accreted satellites

stellar halo

Source: Yang et al. 2011 [arXiv:1110.1420]

The Stellar Assembly History of Central Galaxies



Stellar Mass Growth is truncated ones halo mass reaches $\sim 10^{12} h^{-1} M_{\odot}$

CONCLUSIONS

- We presented the first fully self-consistent, dynamic model of the galaxy-dark matter connection across cosmic time.

- The model accurately matches all data (stellar mass functions, correlation functions, conditional stellar mass functions)

- Limiting factor is accuracy of stellar mass functions at high z. Additional limitation is restriction of model (e.g. Neistein et al. 2011)

- Time scale for satellite disruption ~ dynamical friction time.

- Central galaxies `quench' once halo mass reaches ~10^{12}Msun

- Stellar mass growth of centrals is COMPLETELY decoupled from mass growth of its host halo; star formation only happens over roughly one decade in halo mass: 10^{11}- 10^{12}Msun