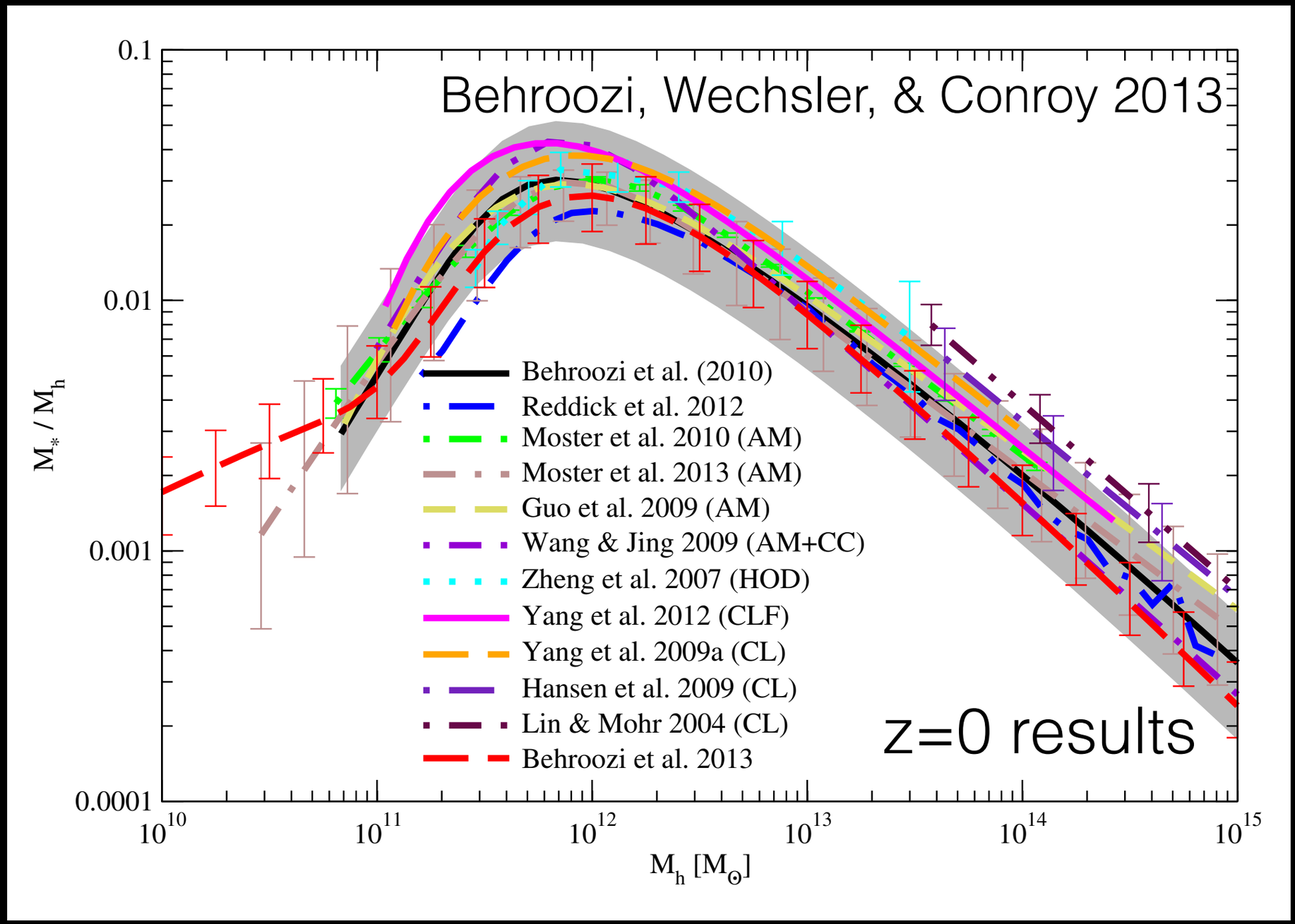
What Can Scatter Do for You?

Jeremy Tinker
Center for Cosmology and Particle Physics
New York University

arXiv:1607.04678
arXiv:1607.05383
arXiv:1607.06099

The Stellar to Halo Mass Relation



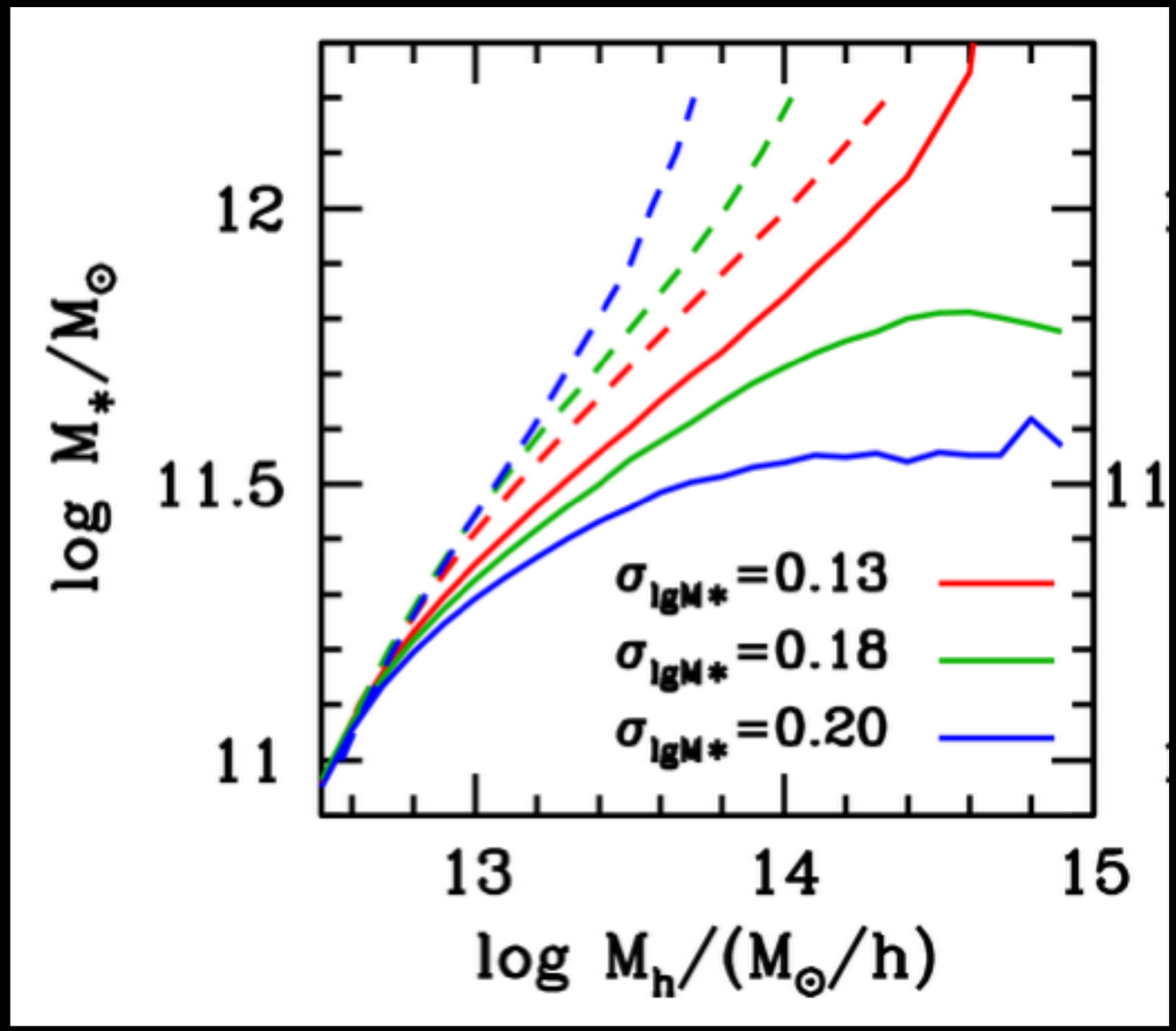
What's the next question?

- Second moment: scatter in stellar mass at fixed halo mass.

$$\sigma_{\log M*}$$

- Assume lognormal in M_{star}. (Not enough data to test this yet… but Occam's razor.)

- **RIGHT**: All these models match the observed SMF of BOSS galaxies.



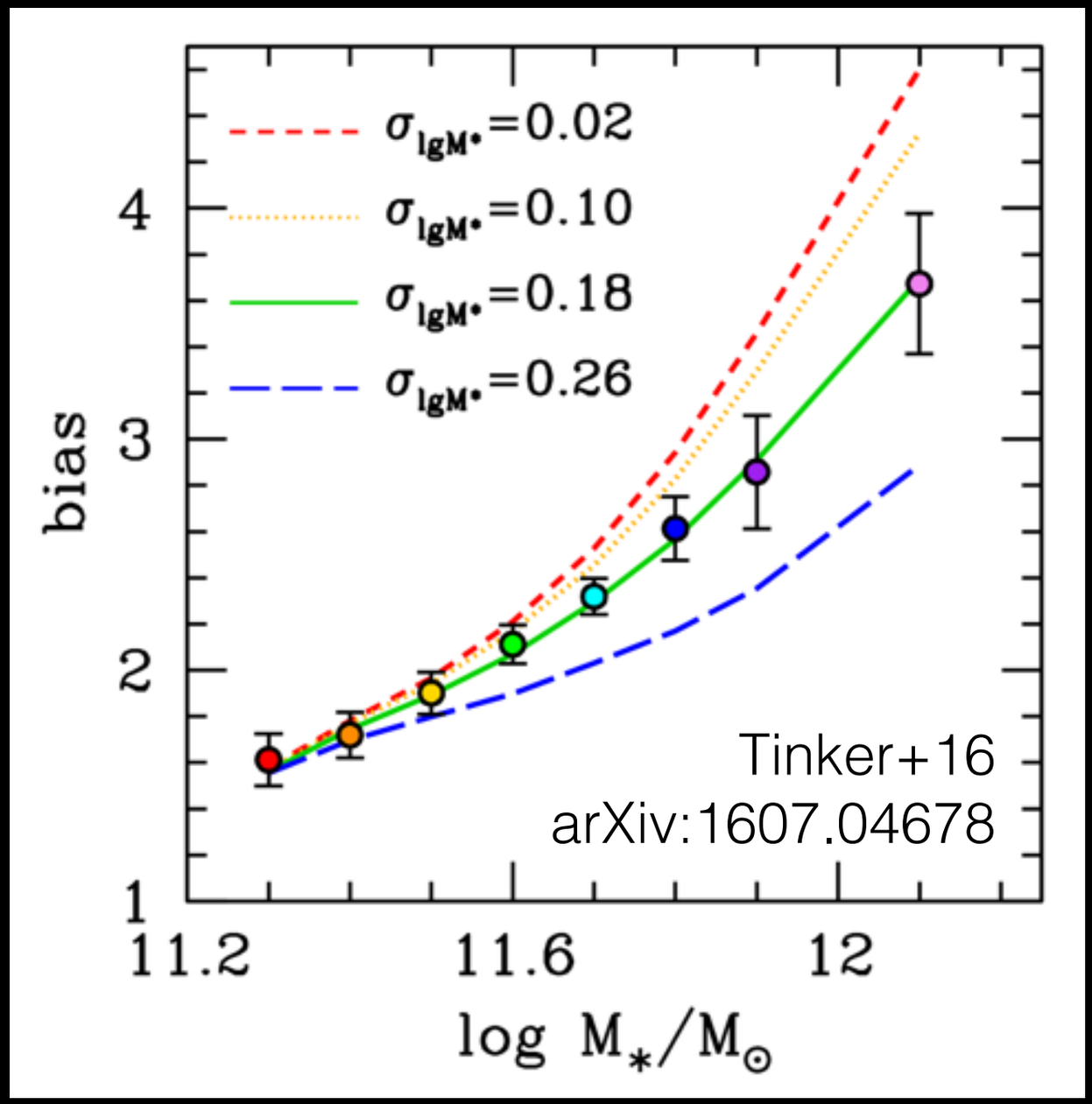
Tinker+16
arXiv:1607.04678

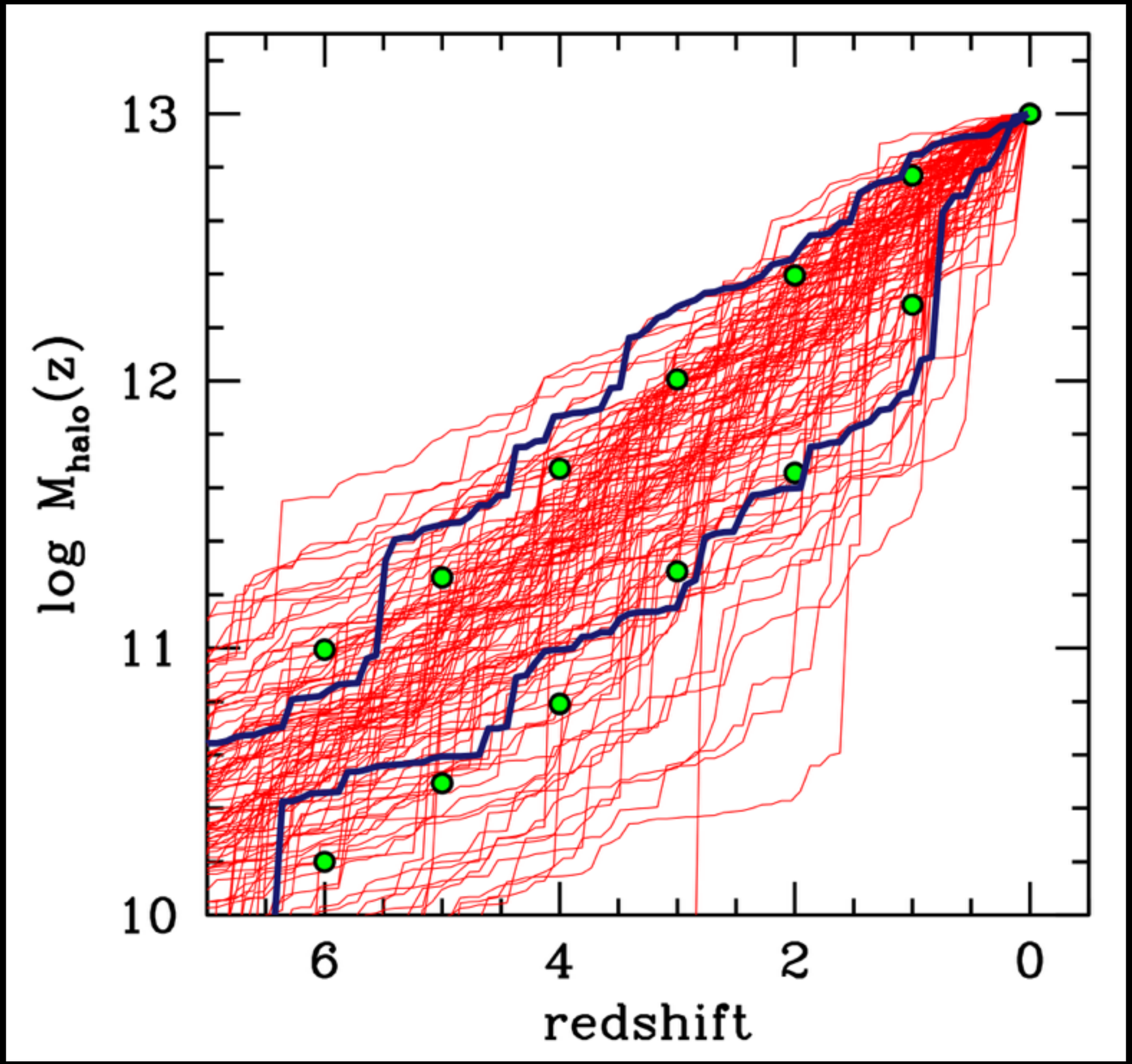
Constraints on the Scatter

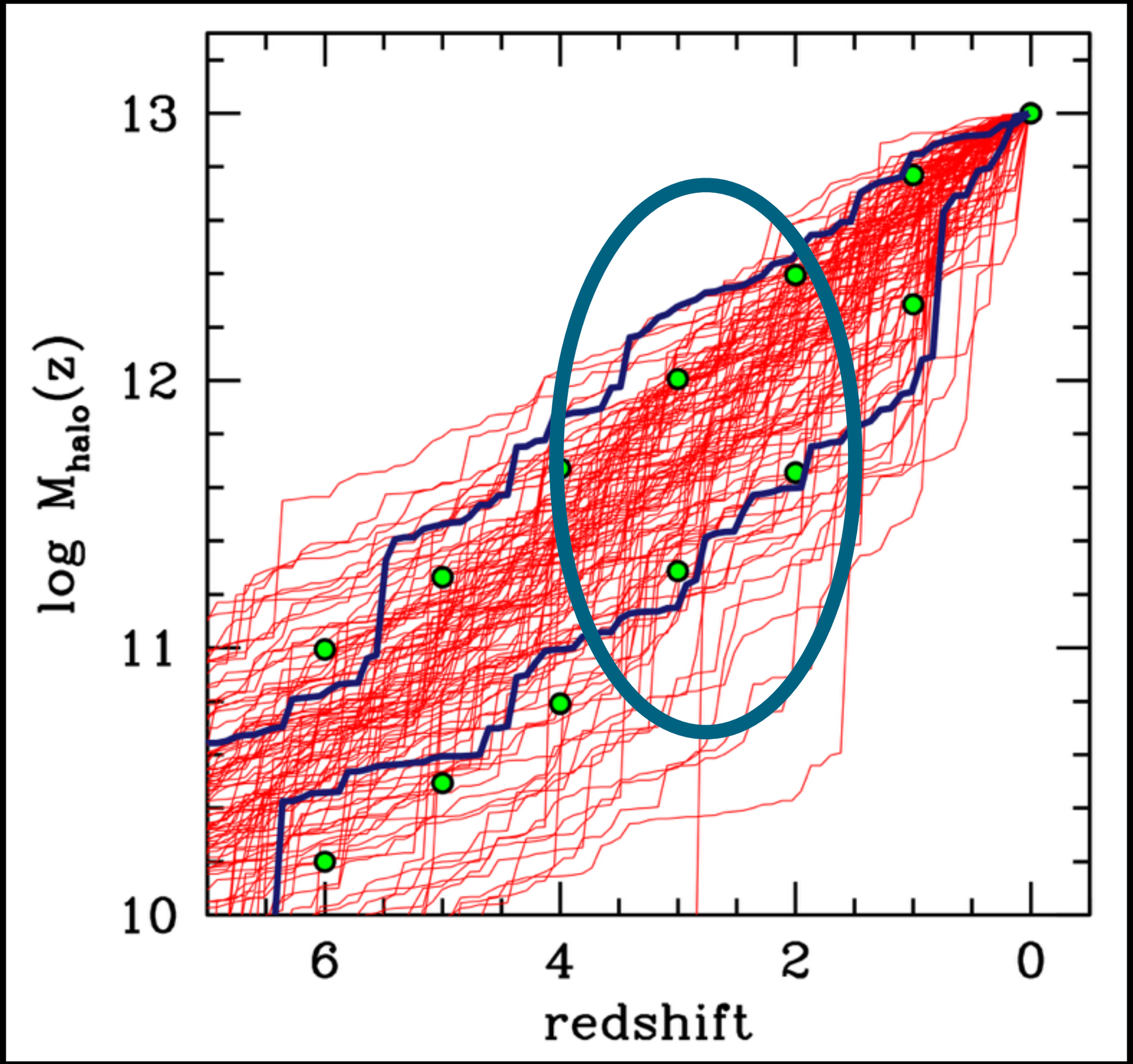
- Strong constraints obtained from the clustering of galaxies.
- Scatter at fixed Mhalo is symmetric, but abundance of halos is not.
- Wider scatter brings in more lower mass halos, driving down the clustering.
- 0.18 dex includes measurement scatter, thus conservative upper limit on the intrinsic scatter is:

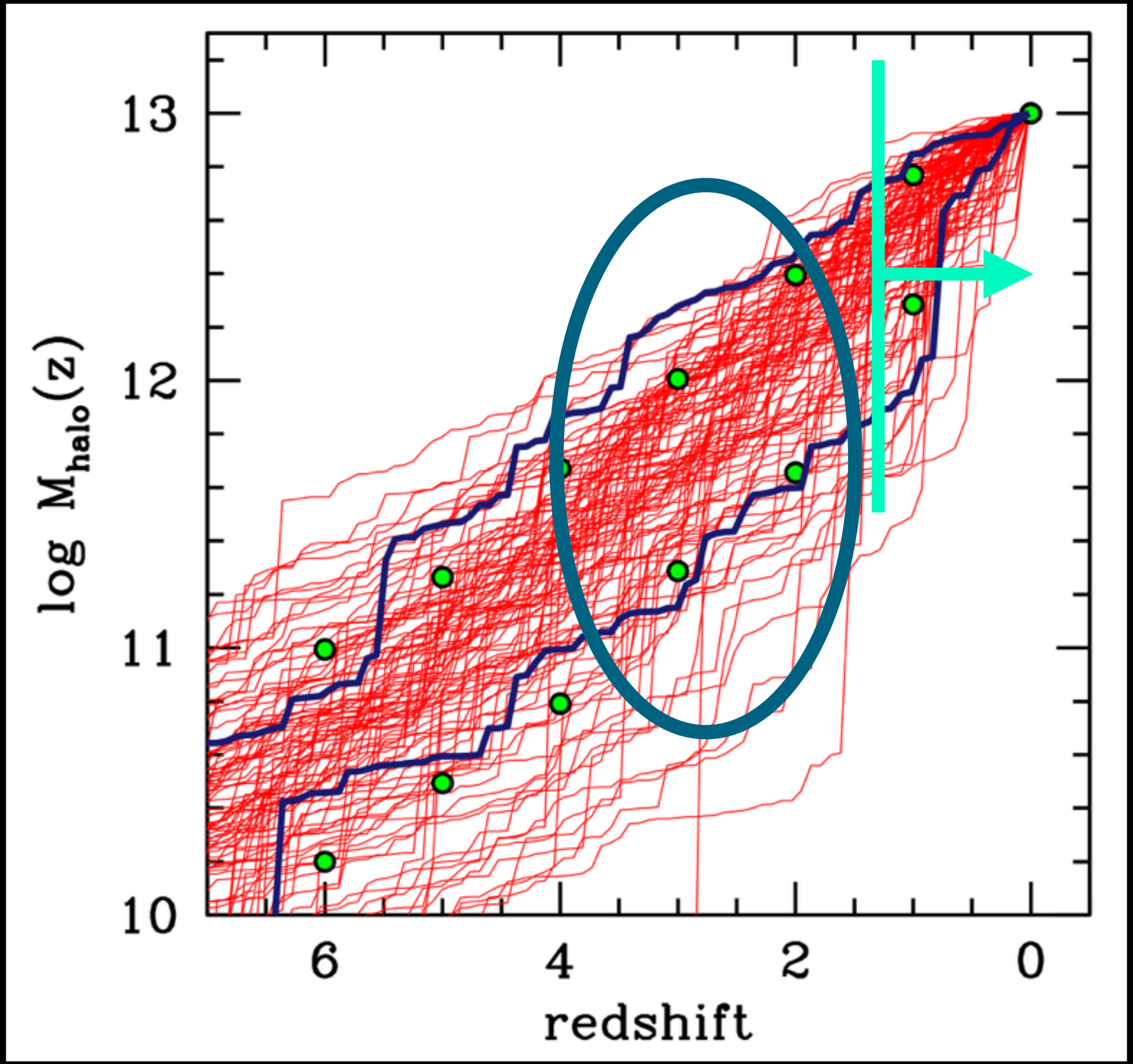
$$\sigma_{\log M*} = 0.16 \text{ dex}$$

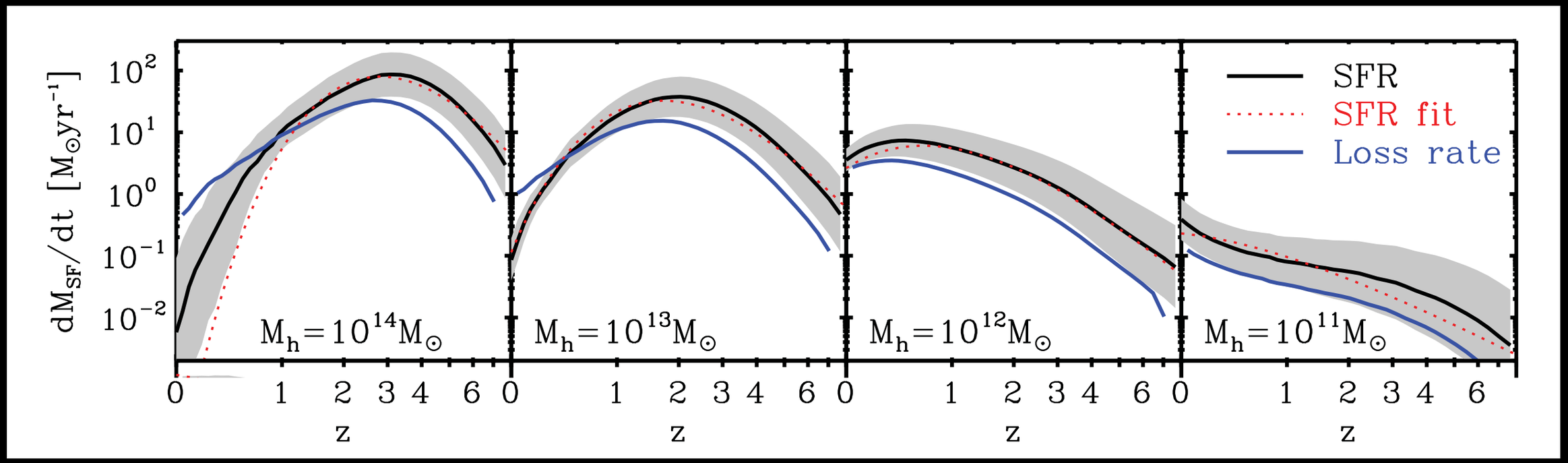
$$\text{bias} = \sqrt{\frac{\xi_{\text{gal}}}{\xi_{\text{matter}}}}$$



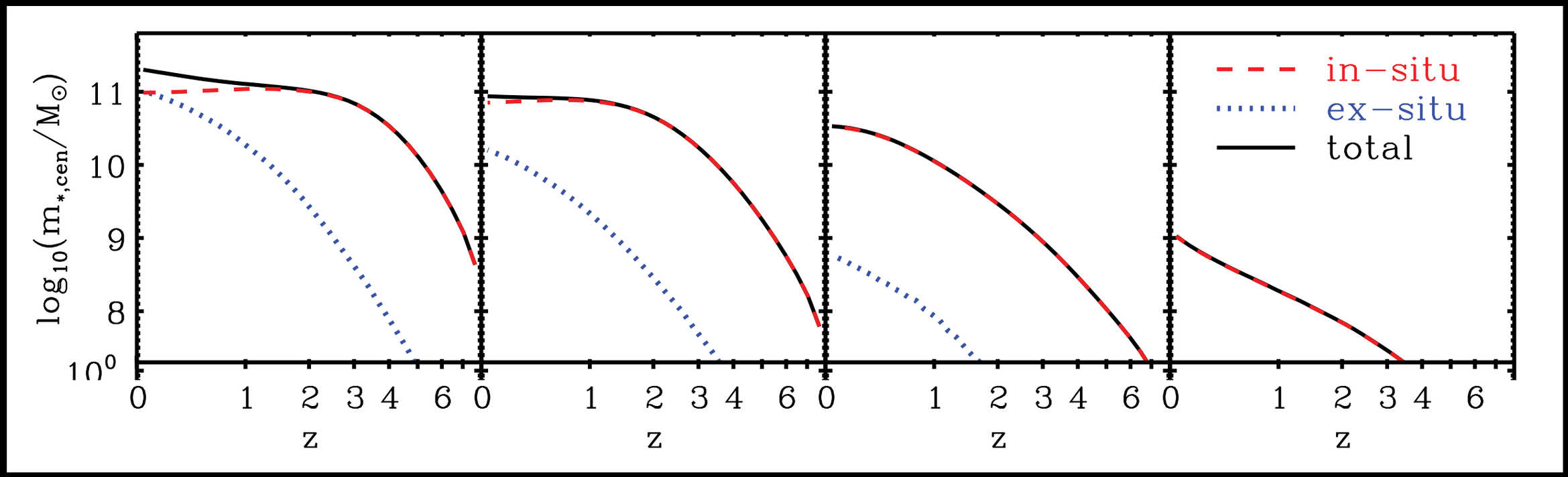

13
12
11
10
log M_halo(z)
6
4
2
0
redshift


13
12
11
10
log M_halo(z)
6
4
2
0
redshift

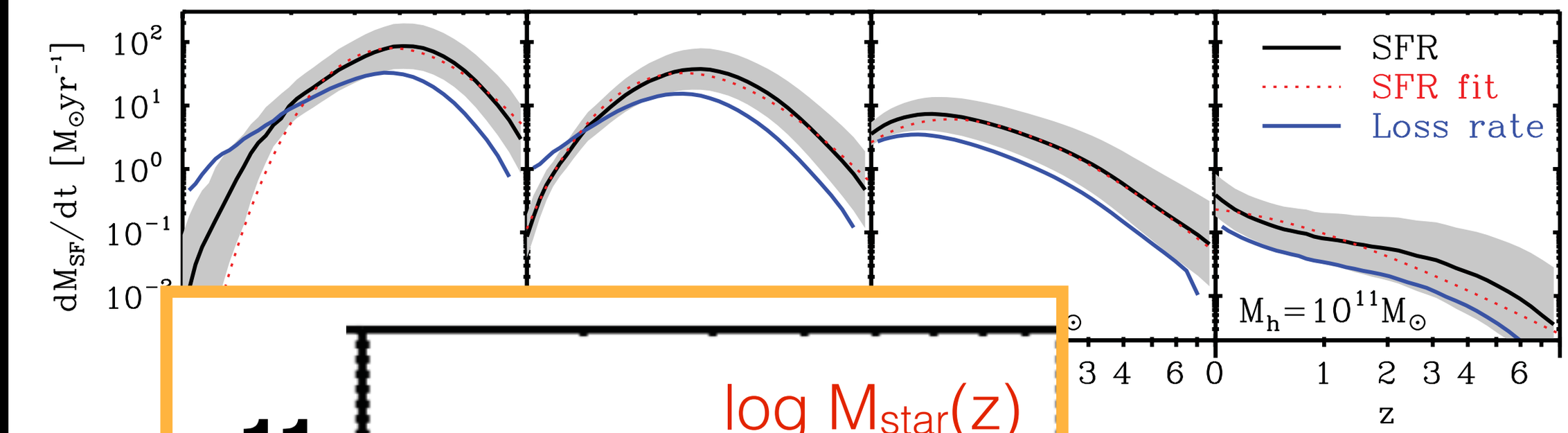

13
12
11
10
log M_halo(z)
6
4
2
0
redshift

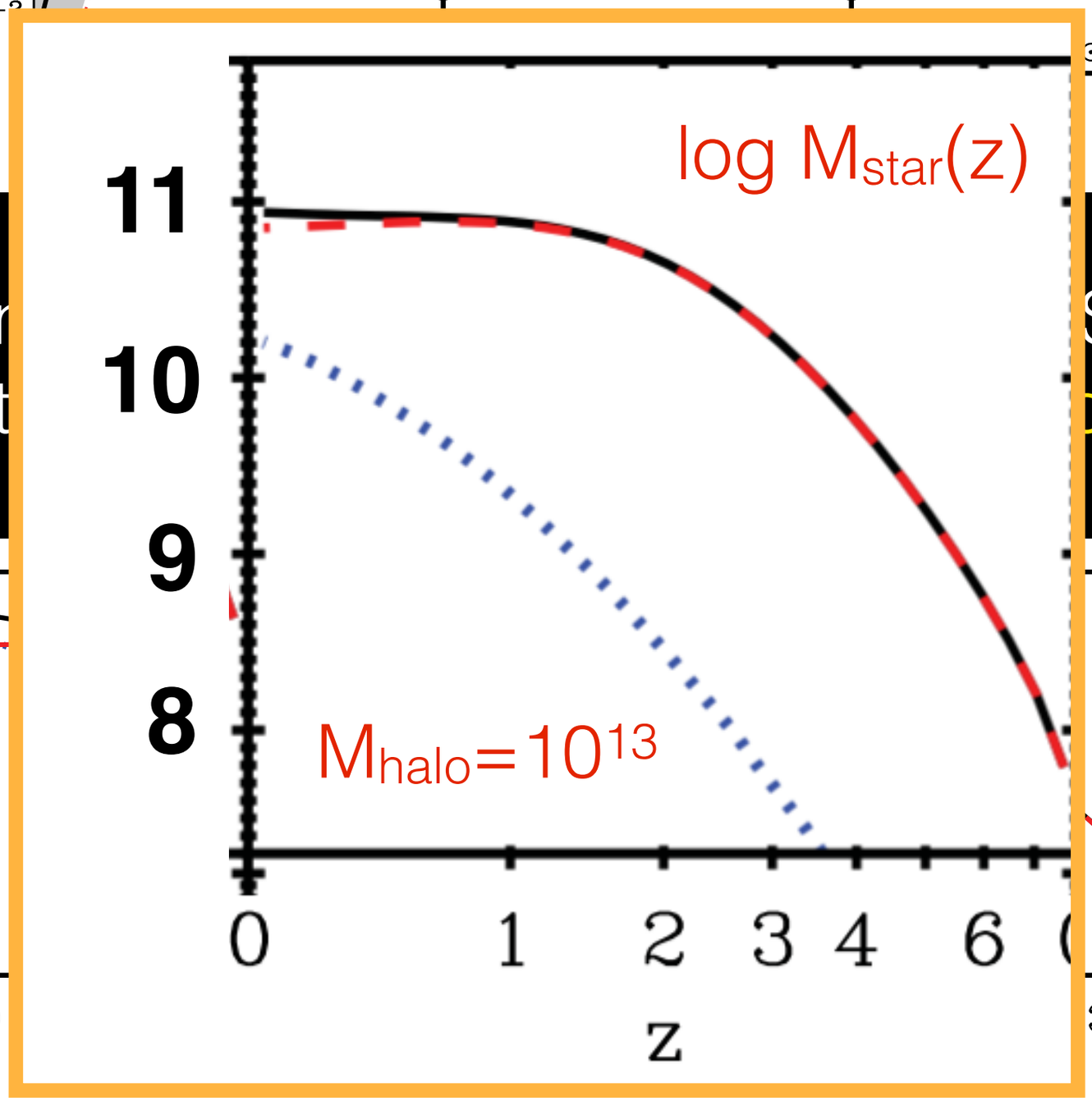


Using abundance matching to infer SFR and growth histories of galaxies within halos. Moster et al 2013.



Usi SFR and growth
hist oster et al 2013.





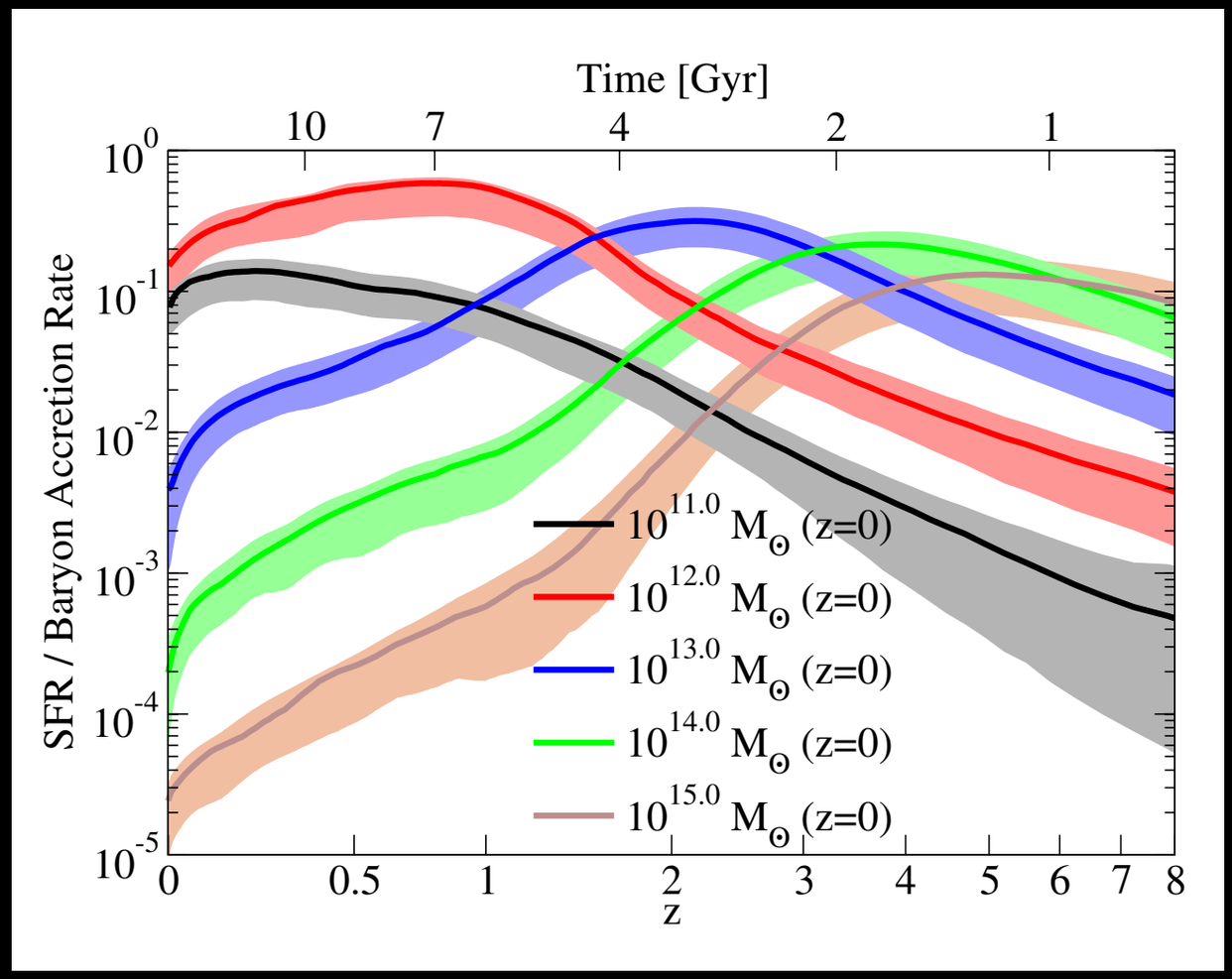
Star Formation Histories in Dark Matter Halos

- Abundance matching results show us <u>mean</u> conversion efficiency of baryons into stars.

$$f_{\rm con} \equiv SFR \times \left[\frac{\Omega_b}{\Omega_m}\dot{M}_h\right]^{-1}$$

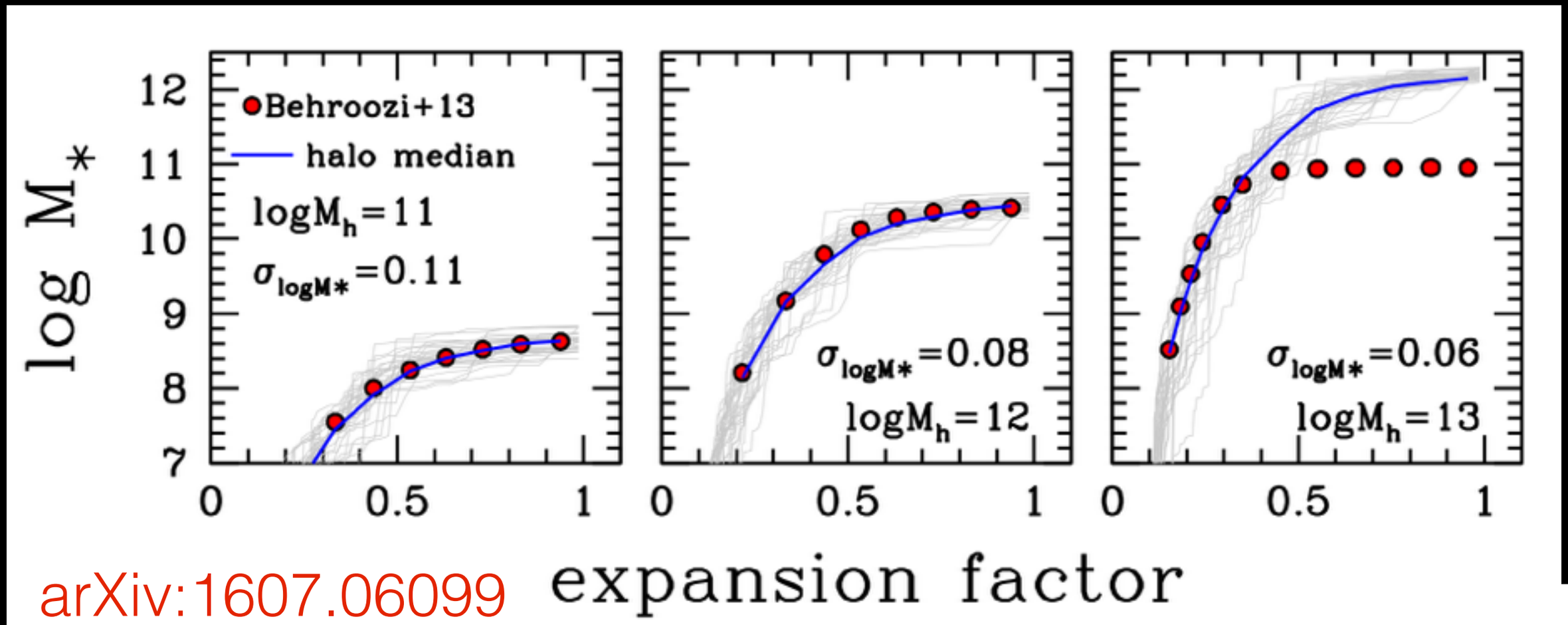
- But not all halos have the same accretion history, even though present-day halo mass is the same.

- Thus, two halos with same z=0 halo mass will have different z=0 stellar mass.



Behroozi, Wechsler, Conroy 2013b

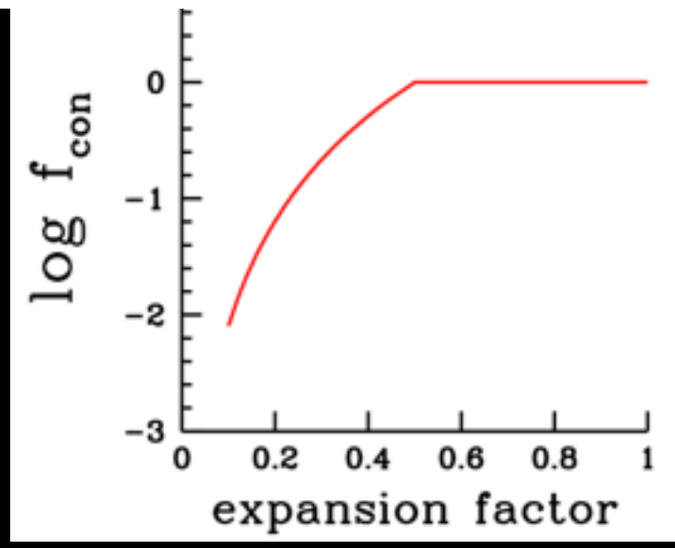
Applying a universal $f_{con}(z)$ to individual halos.



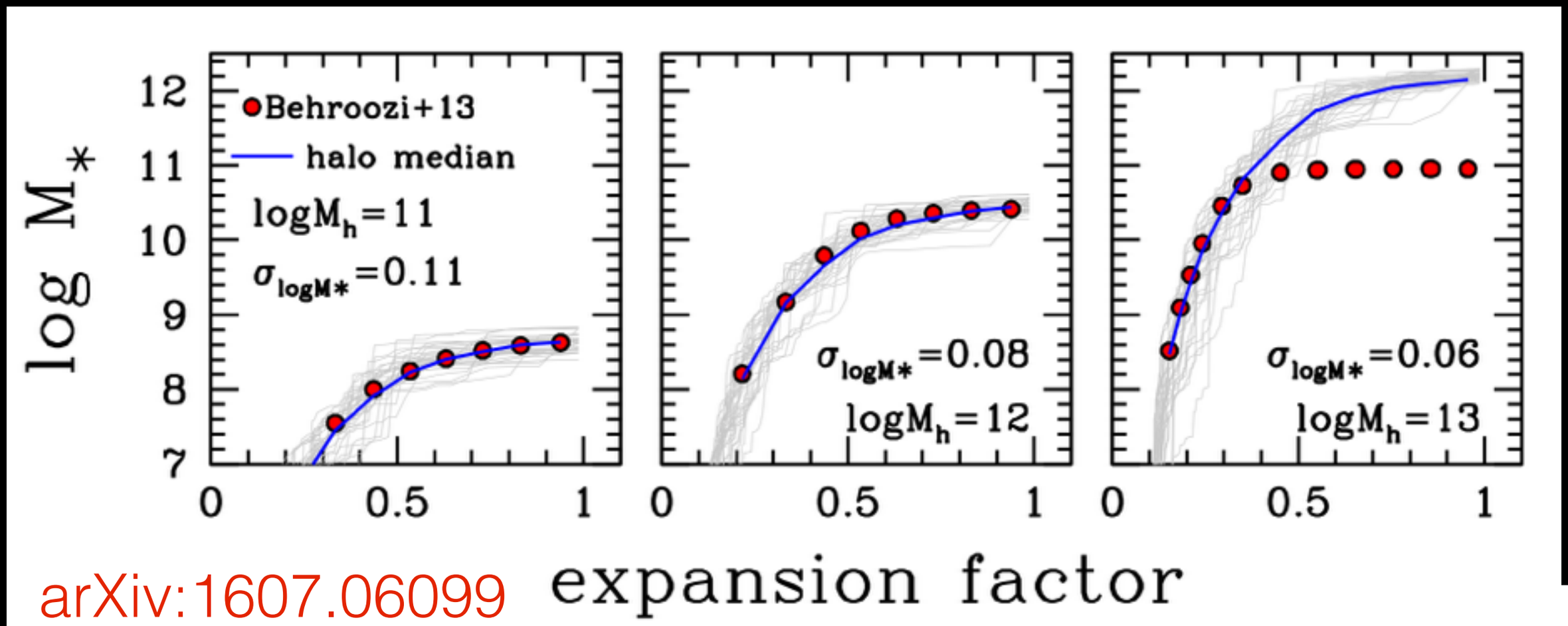
arXiv:1607.06099

Simple Model:

$$M_*(z) = \int_0^{t(z)} SFR(t)\,dt = \int_\infty^z f_{\rm con}(z')\,f_b\dot{M}_h\,\frac{dt}{dz'}\,dz'.$$



Applying a universal $f_{con}(z)$ to individual halos.

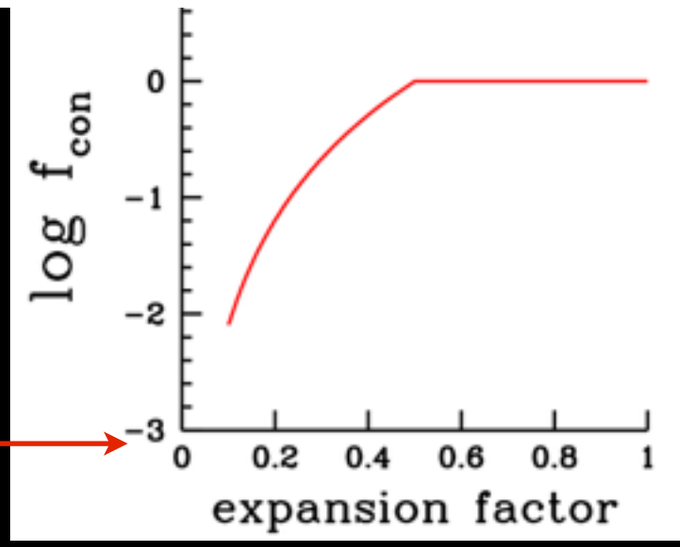


arXiv:1607.06099

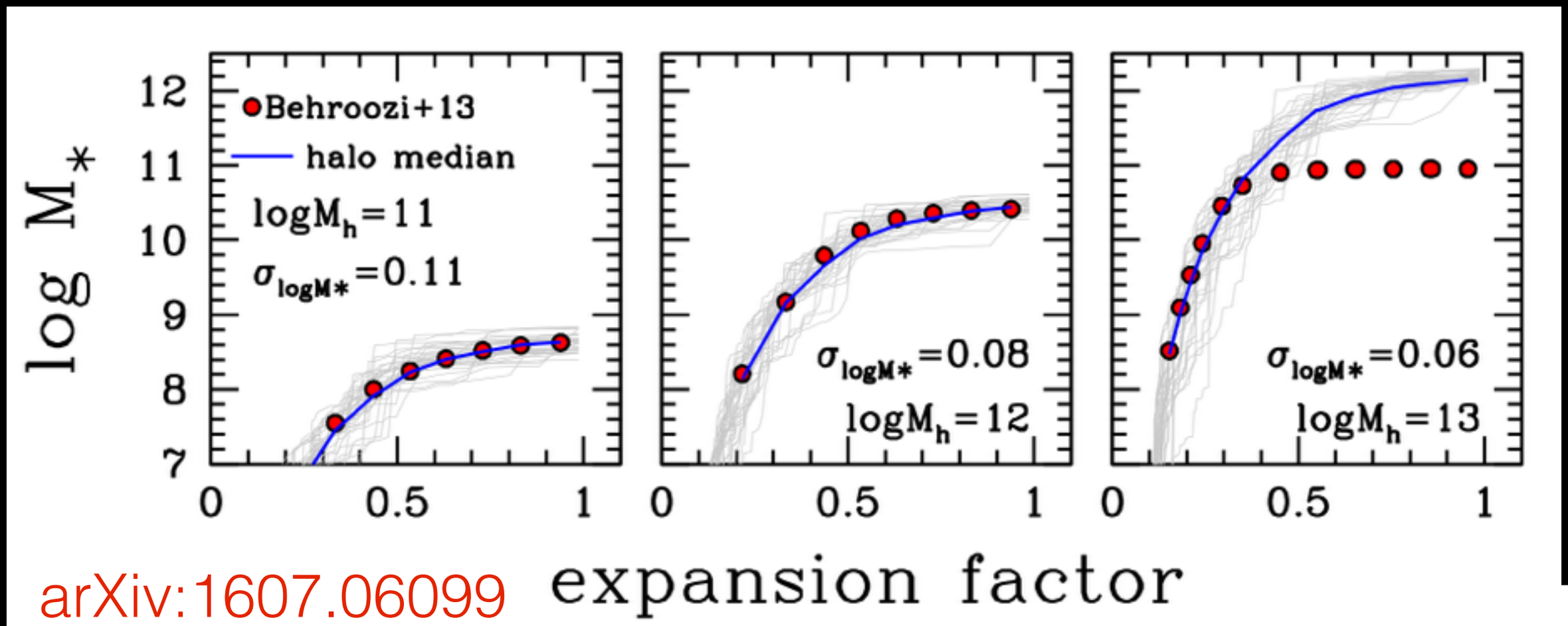
Simple Model:

$$M_*(z) = \int_0^{t(z)} SFR(t)\,dt = \int_\infty^z f_{\rm con}(z')\, f_b \dot{M}_h \frac{dt}{dz'} dz'.$$

Universal shape



Applying a universal $f_{con}(z)$ to individual halos.

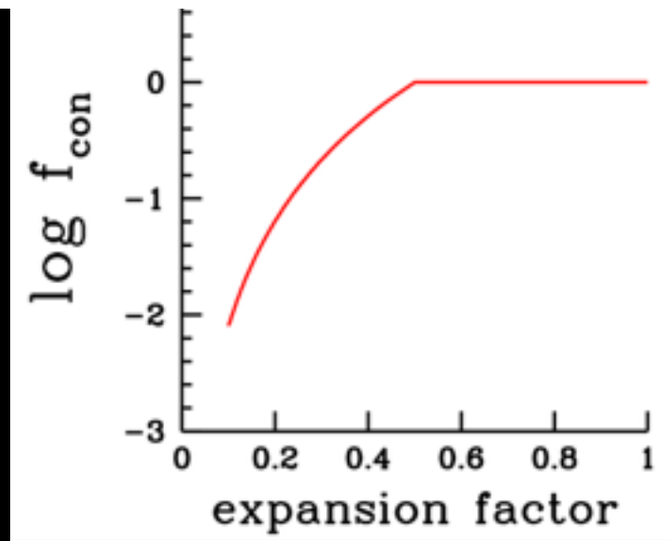


arXiv:1607.06099

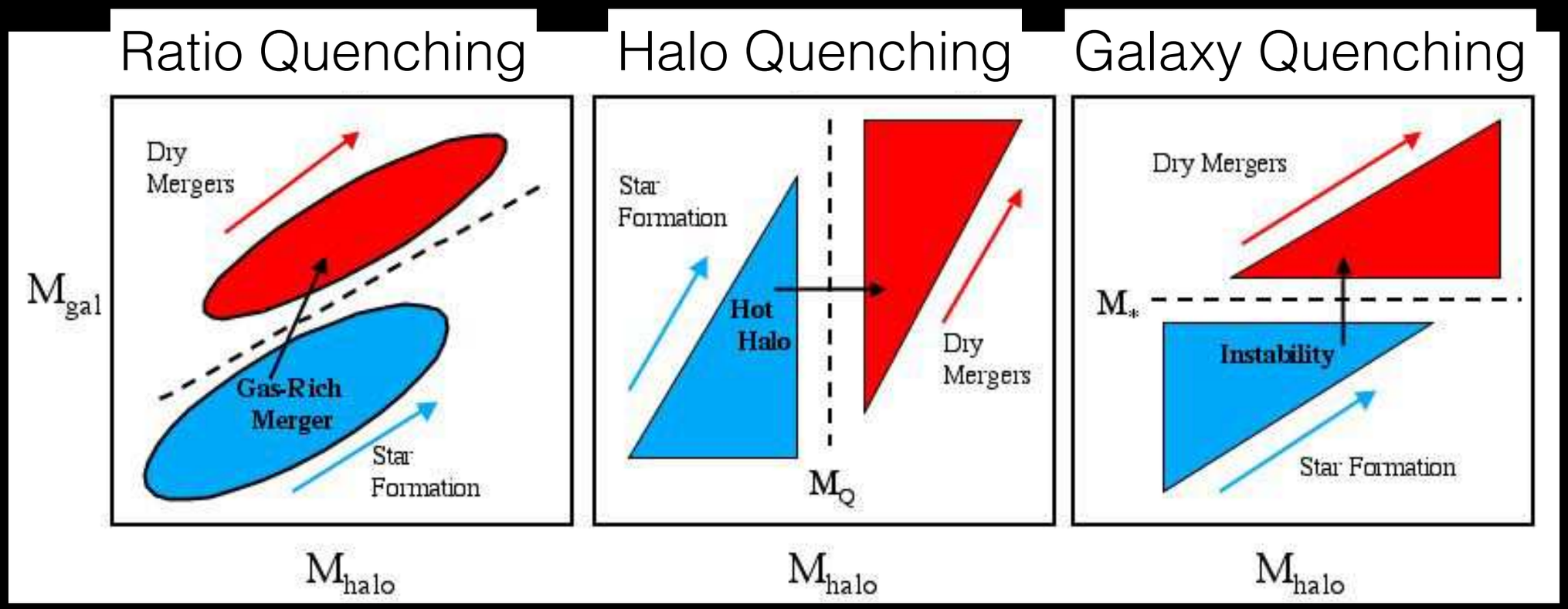
Simple Model:

$$M_*(z) = \int_0^{t(z)} SFR(t)\,dt = \int_\infty^z f_{\rm con}(z') f_b \dot{M}_h \frac{dt}{dz'} dz'.$$

Varies halo-to-halo



Quenching Star Formation



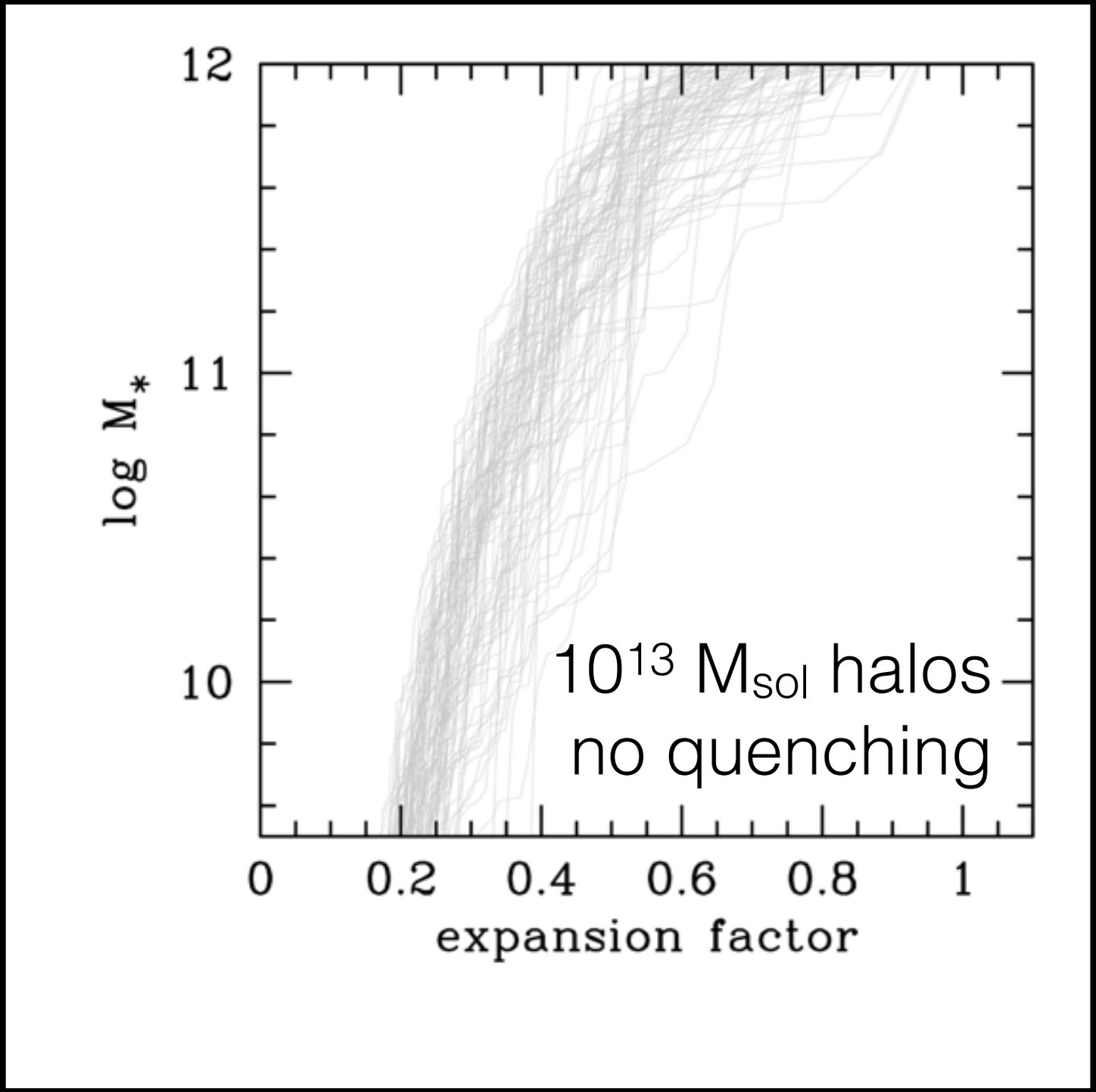
Hopkins et al 2008b

Model: Quenching begins after a halo crosses a threshold in some physical quantity.

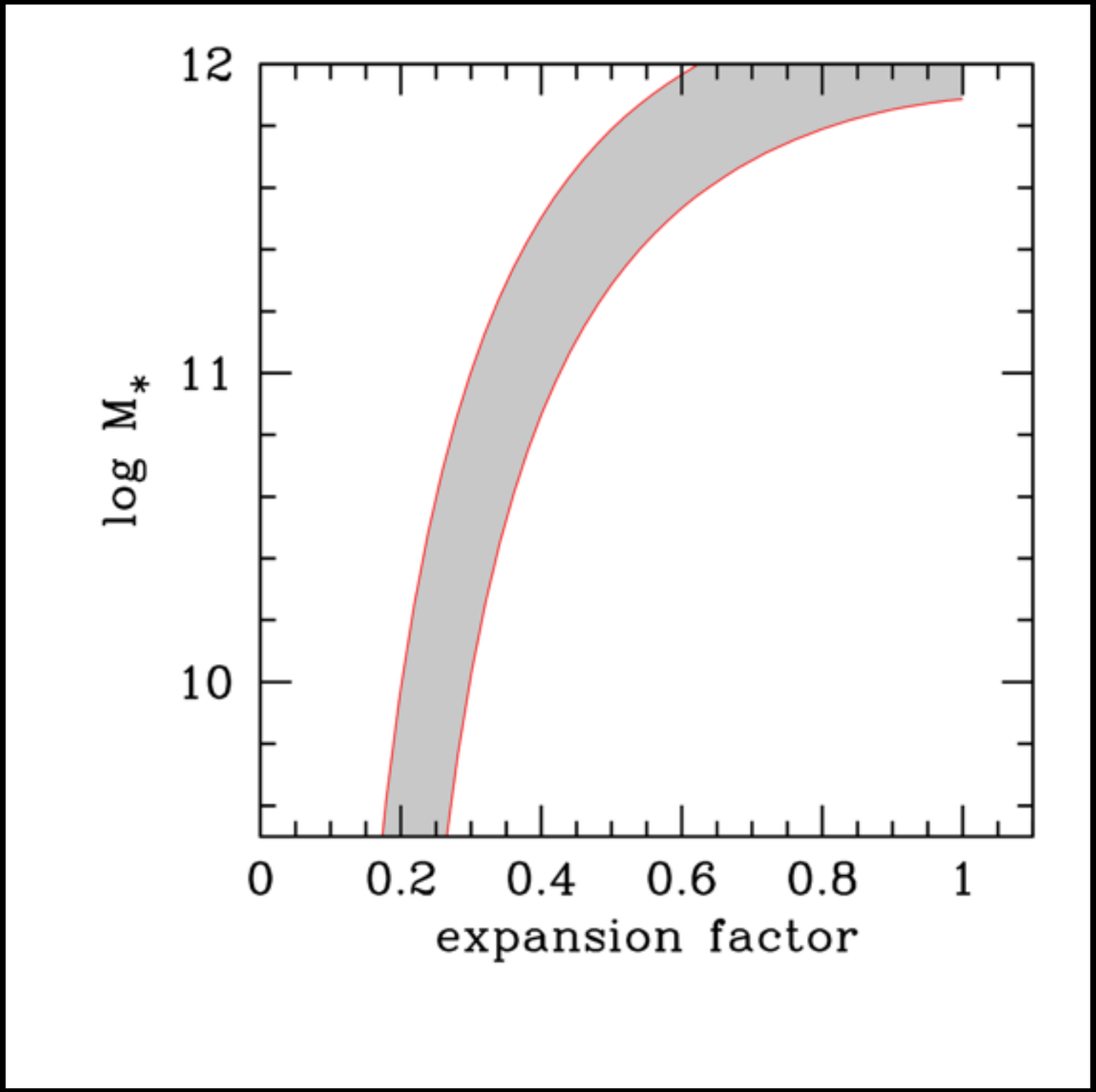
Details: Quenching can be fast or slow, but must match the mean $M_{star}(z)$.

Test: If a model yields a scatter smaller than 0.16 dex, leaving room for other sources.

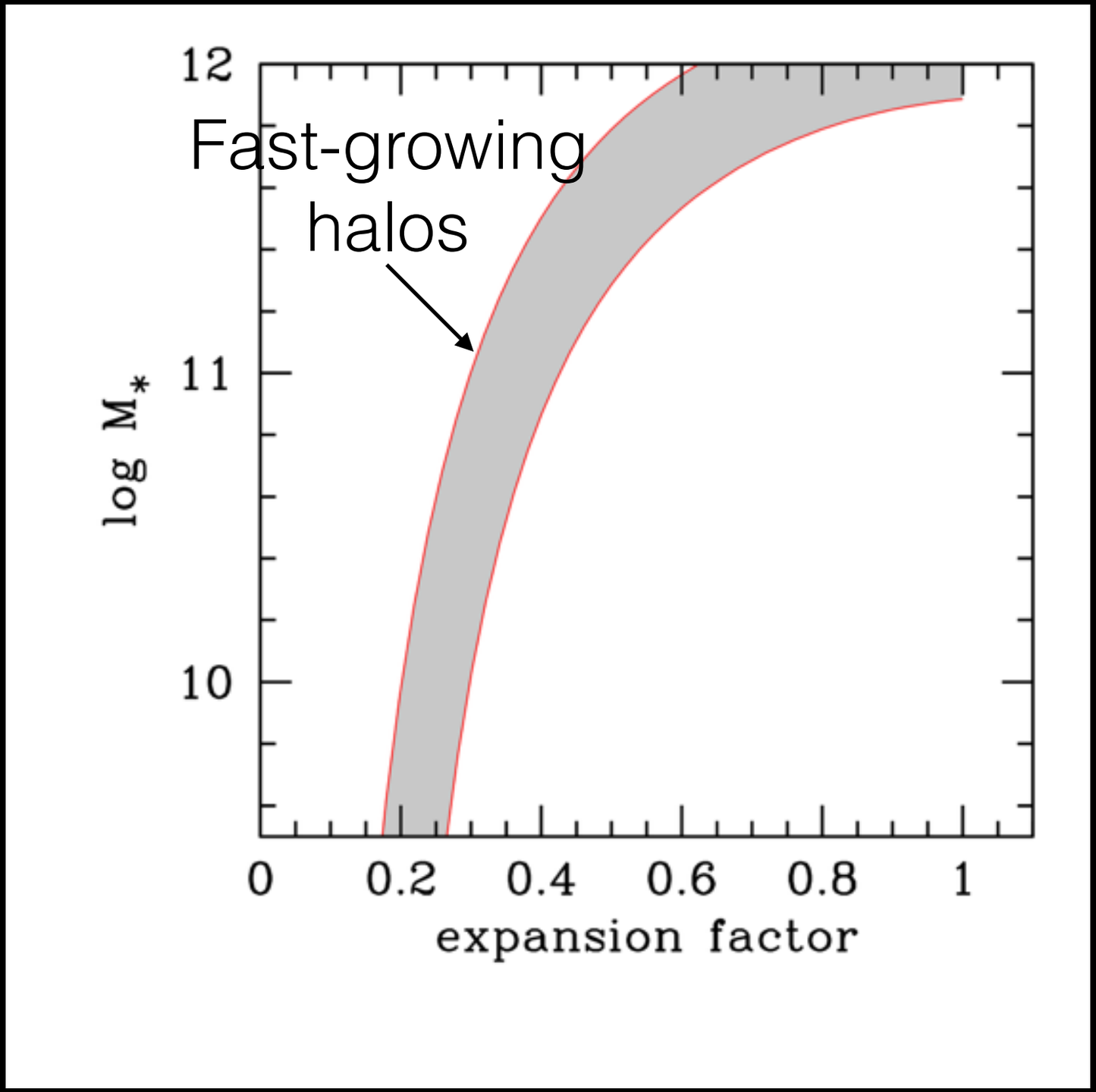
How does quenching affect scatter?



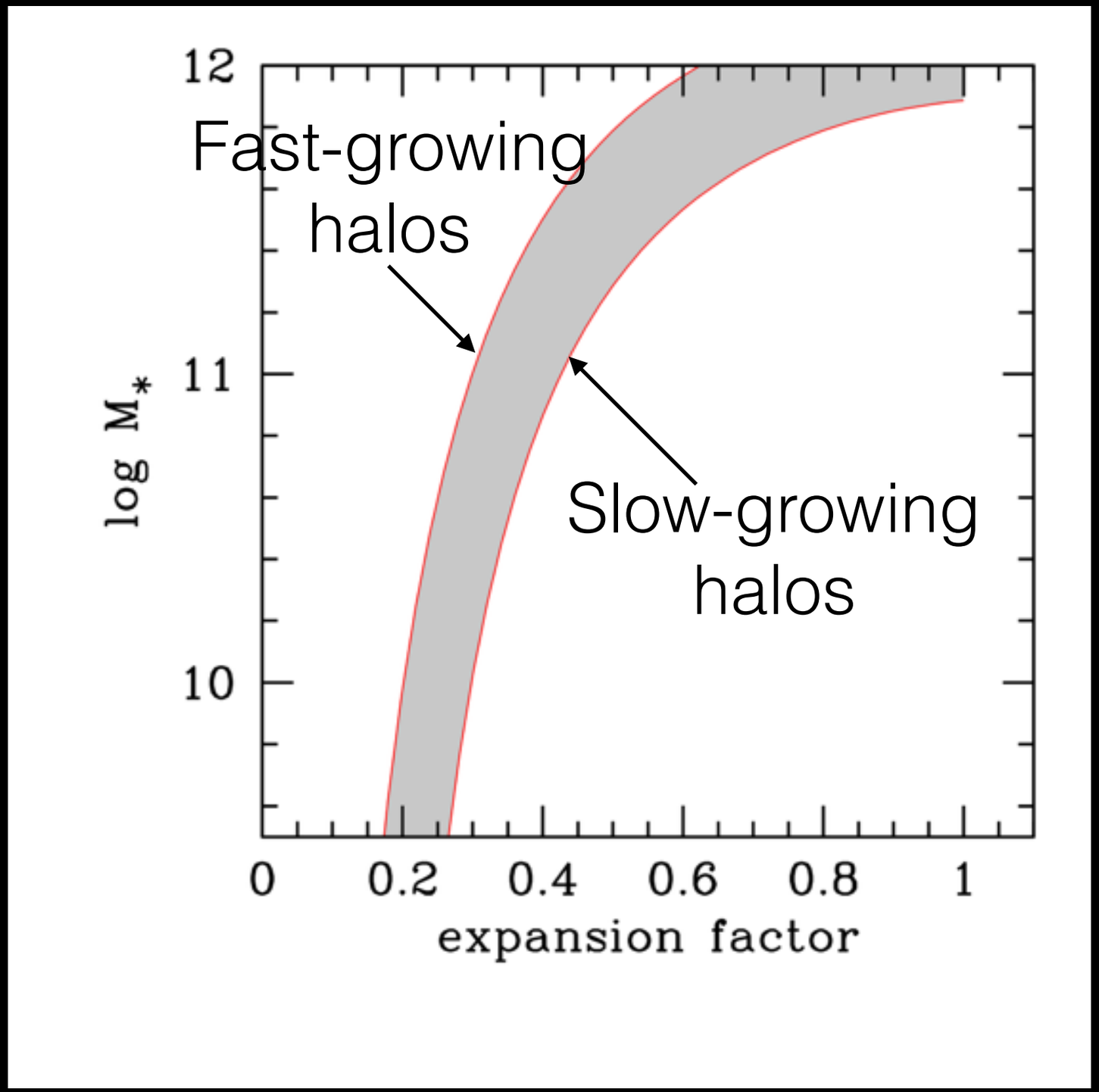
How does quenching affect scatter?



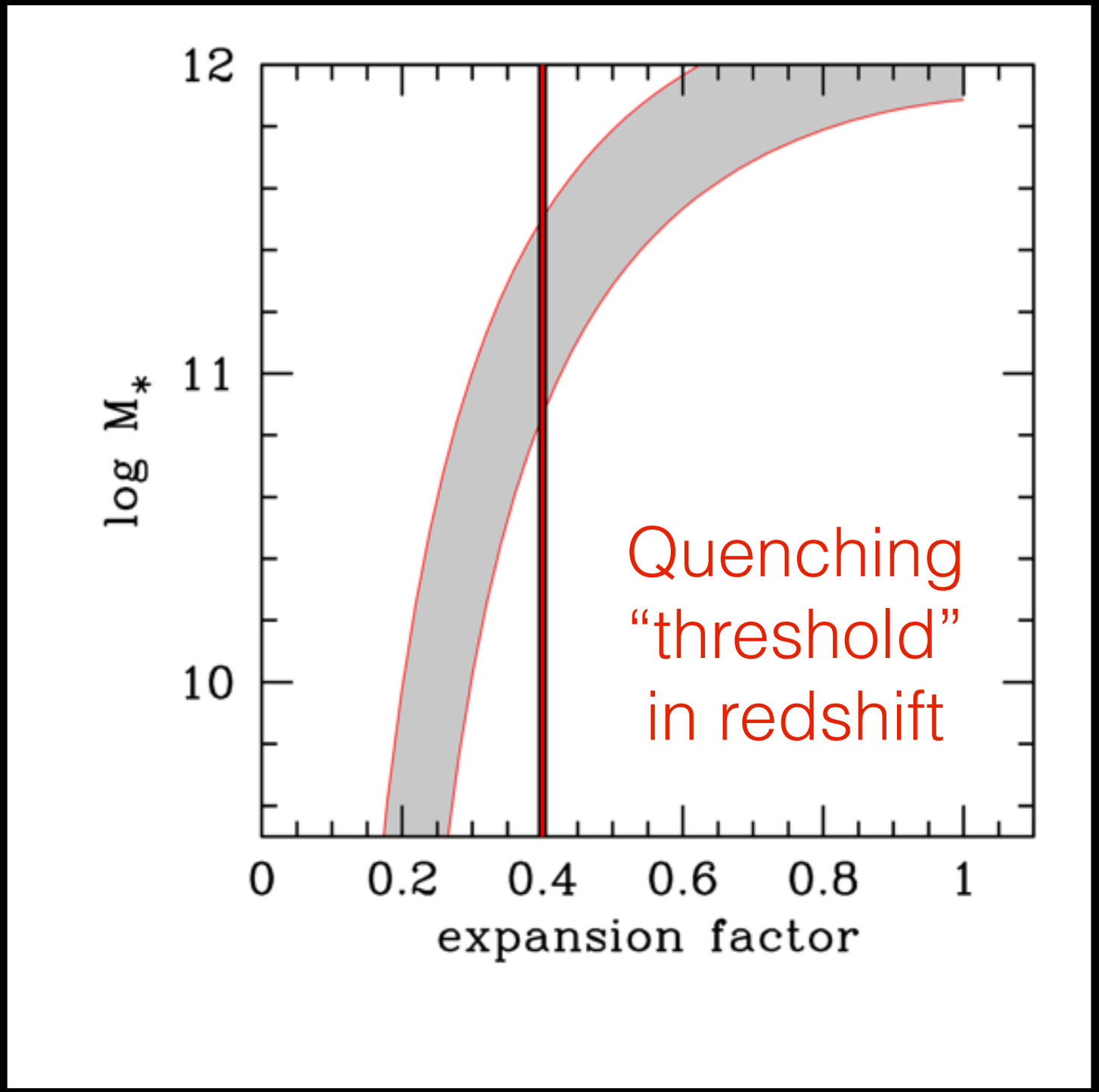
How does quenching affect scatter?



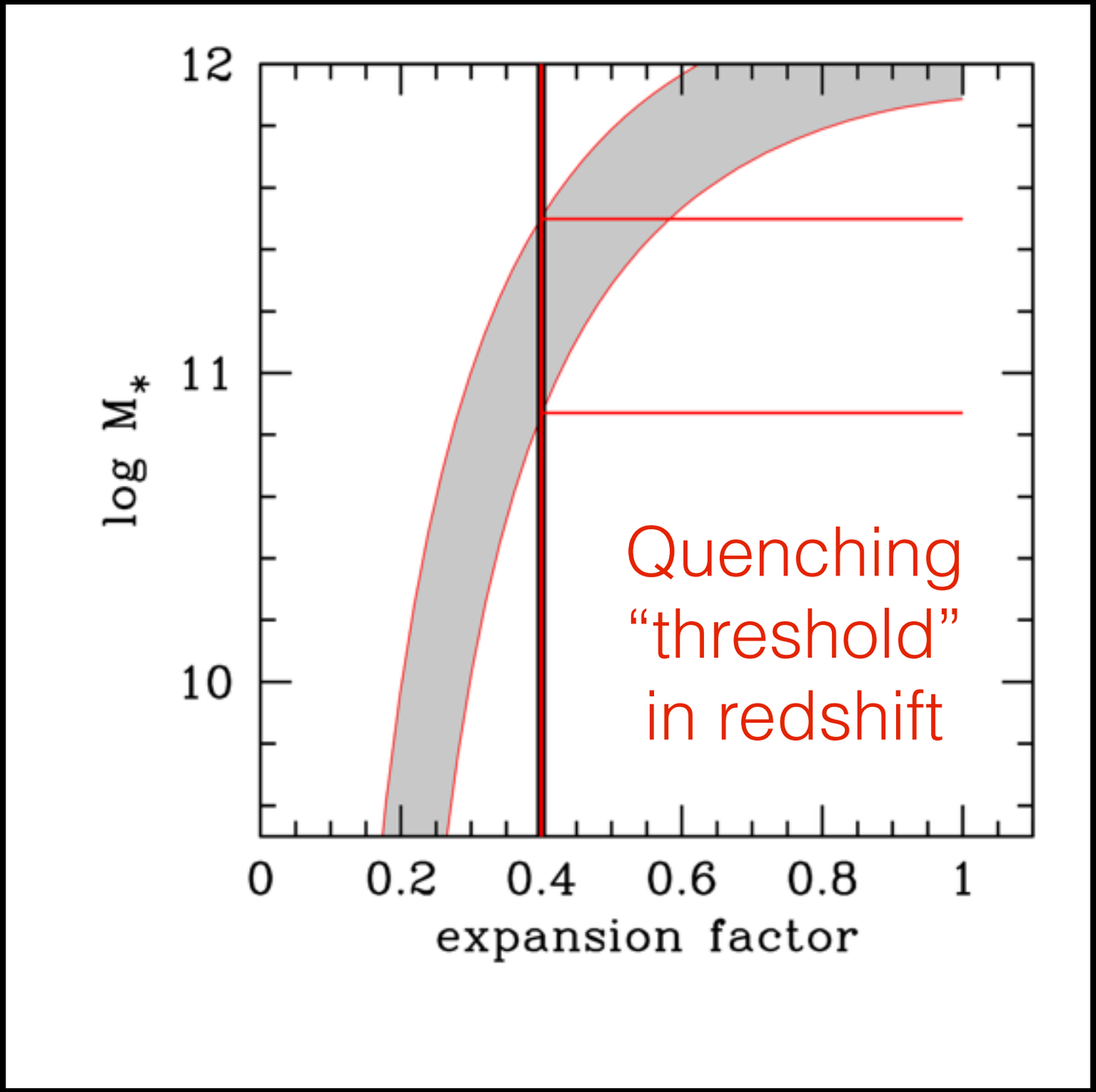
How does quenching affect scatter?



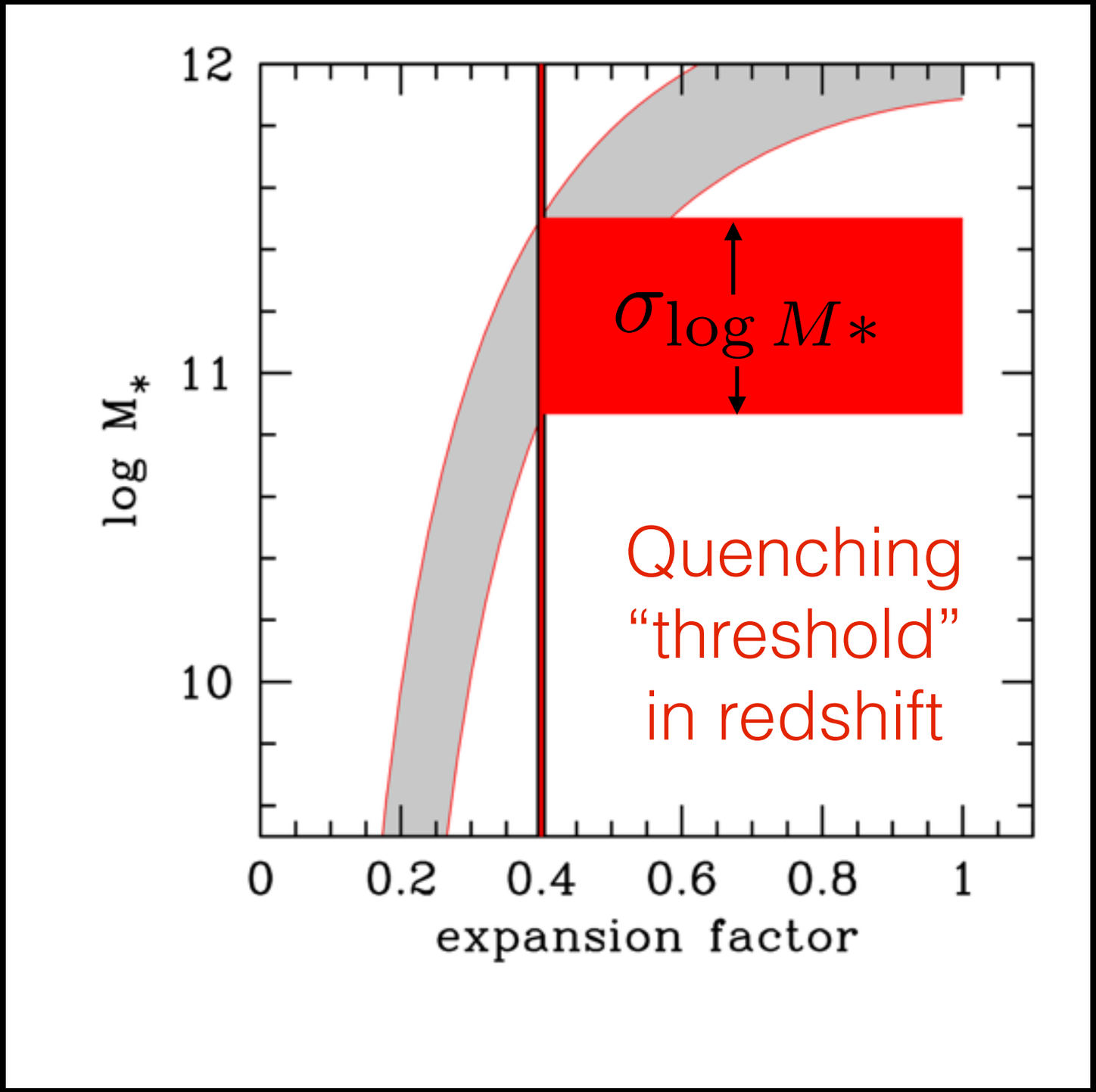
How does quenching affect scatter?



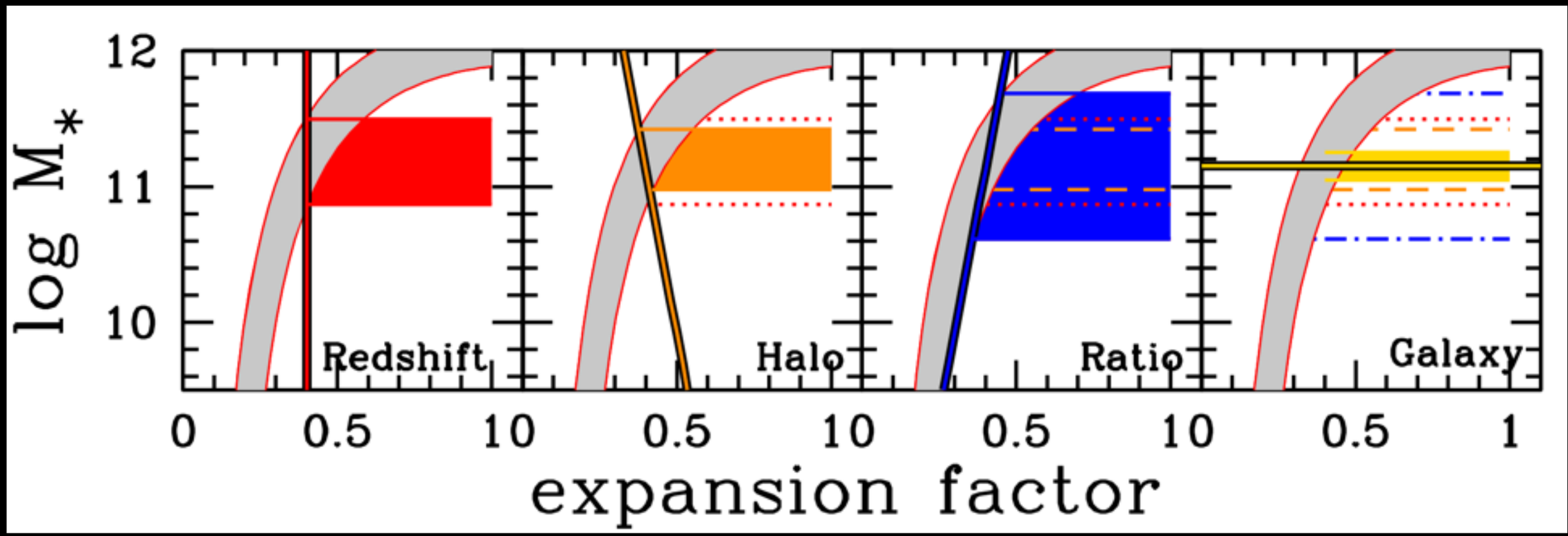
How does quenching affect scatter?



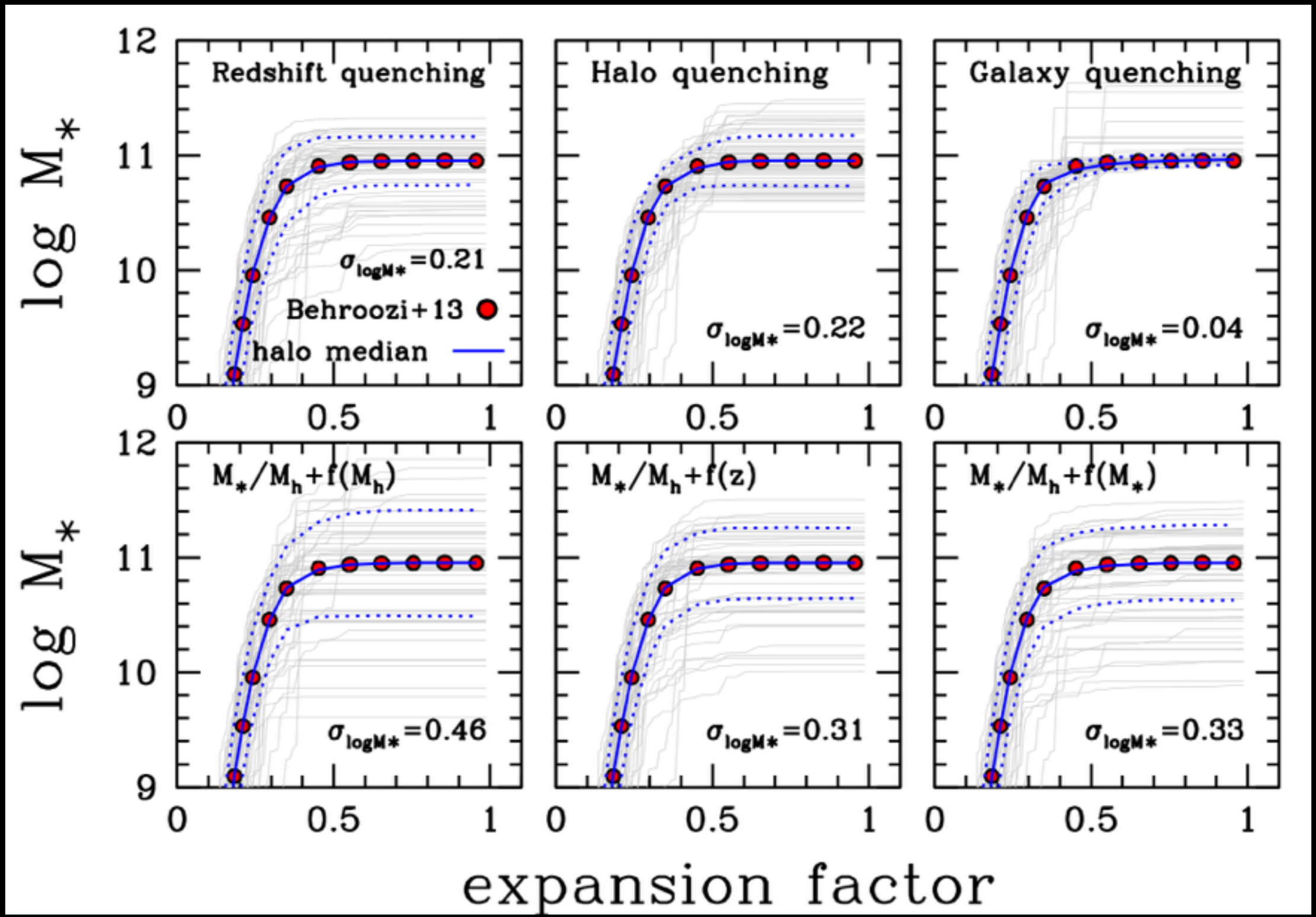
How does quenching affect scatter?



Testing all the models

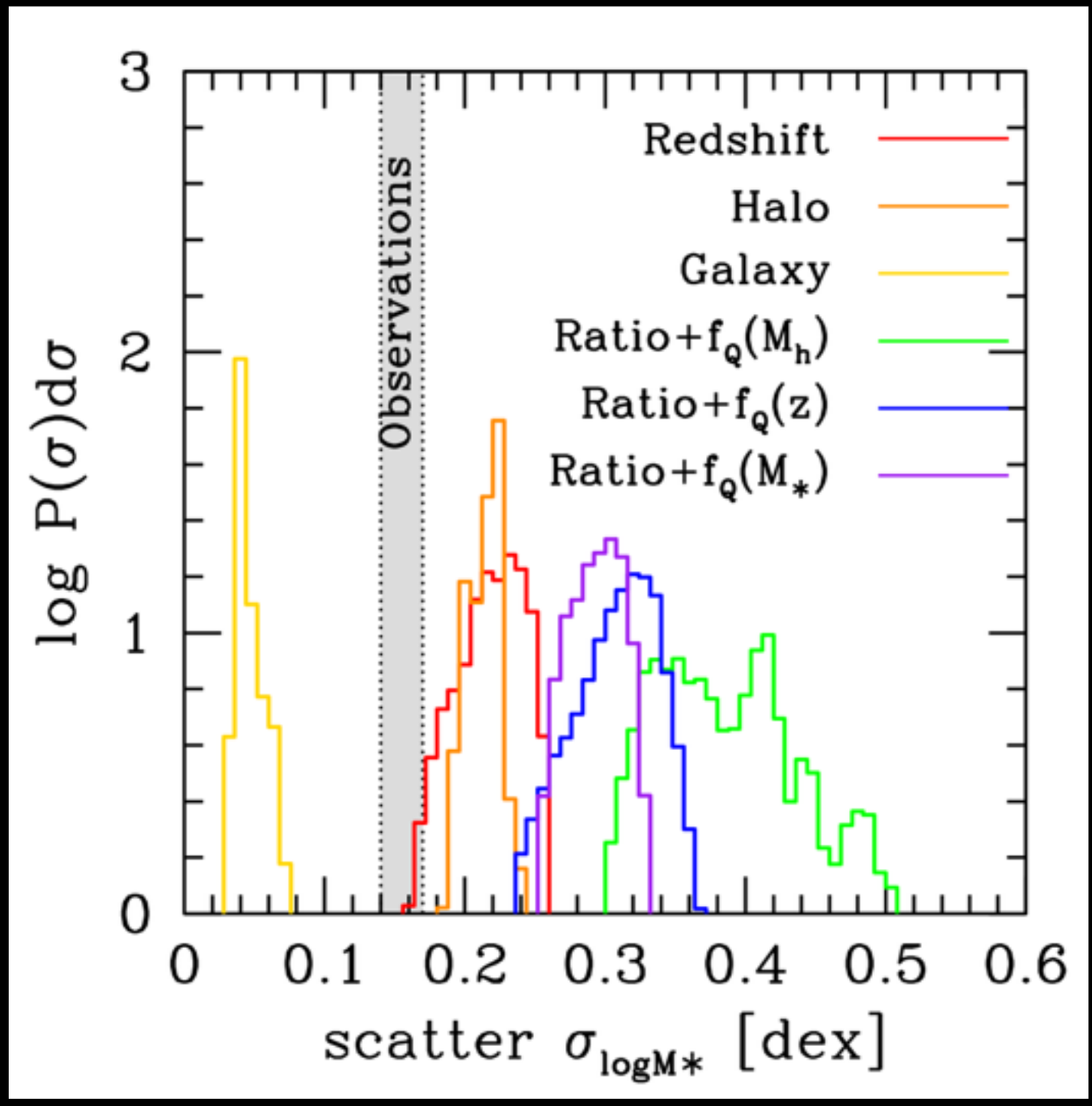


Testing all the models



Comparing to the Data

- Only galaxy quenching yields scatter below the observed levels.
- Halo quenching can achieve lower scatter if the quenching threshold <u>decreases</u> with cosmic time.
- Any stochasticity in the critical halo mass must be less than 0.1 dex.
- Any reduction in σ_{logM*} requires halo formation history correlate with observed properties which is measurable through clustering.



Summary

- Why is the scatter so small?
- Matching observations requires either
  - Quenching tied to galaxy mass
  - Quenching correlates strongly with halo formation history.
- Both make testable predictions for how clustering depends on other properties: luminosity, color, metallicity.
- Wealth of data out there of massive galaxies: 1.6 million BOSS galaxies (finished), 400k eBOSS galaxies (ongoing), 1 million DESI galaxies (starting 2018), probing $0.2<z<1.0$.
- Answering this question may be key to understanding what regulates star formation in galaxies.