Modeling Ha emission line galaxies: local PNG bias

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Technion

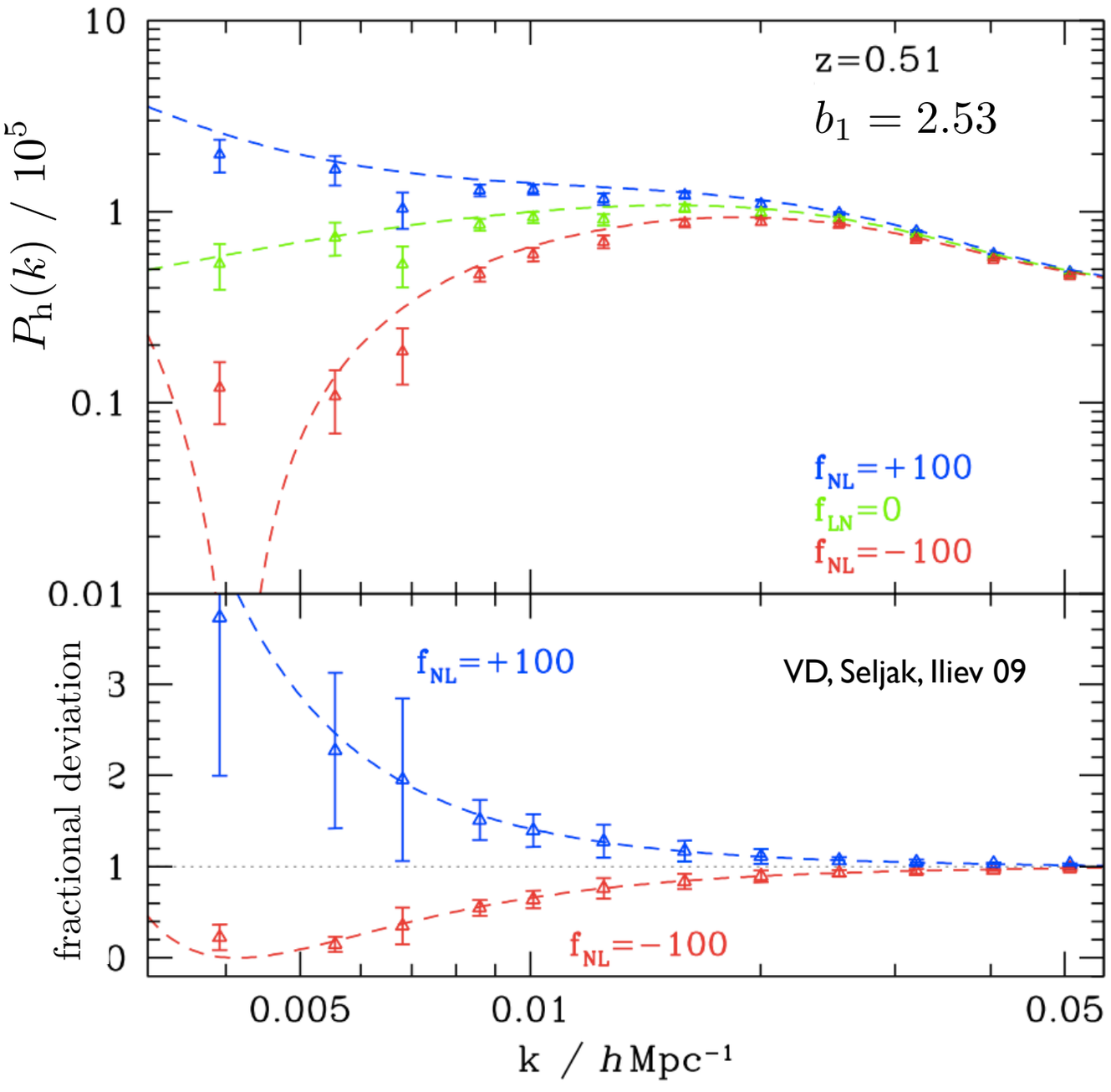
Theoretical modeling of the LSS of the Universe, Edinburgh, June 3-6, 2024

PNG and halo bias

Dalal+ 08; Matarrese & Verde 08; Slosar+ 08

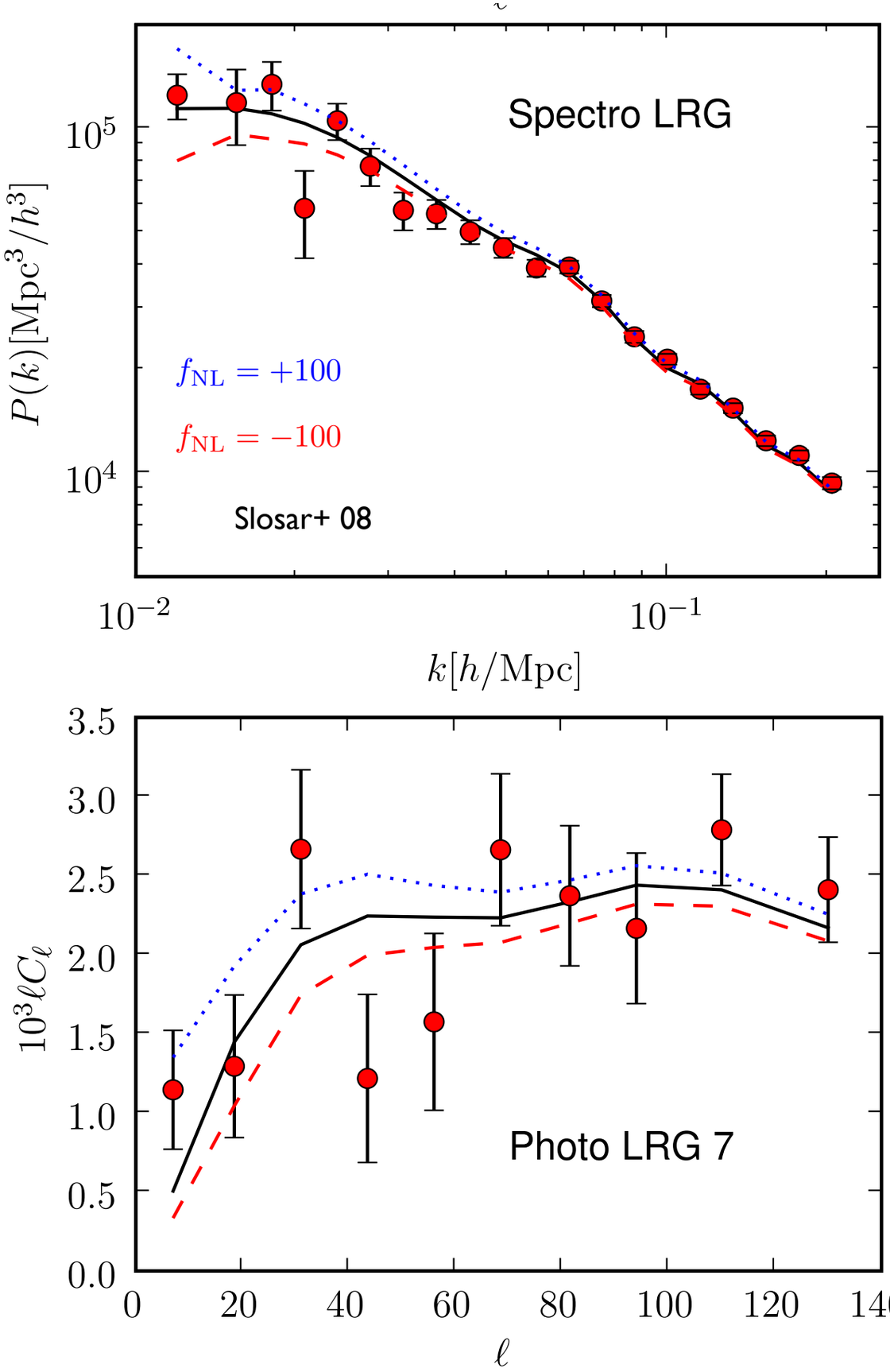
$$\text{Local primordial NG}: \quad \Phi(\mathbf{x}) = \phi(\mathbf{x}) + f_{\rm NL}\phi^2(\mathbf{x}), \quad |\phi| \sim 10^{-5}$$

$$b_{\rm NG} = 2\delta_c\left(b_1 - 1\right)$$



(U. Michigan, 2011)

Limits on PNG from Large Scale Structure



$$\Phi = \phi + f_{\rm NL}\phi^2 :$$

$$-29 < f_{\rm NL} < 69$$

Slosar+ 08

$$\Phi = \phi + g_{\rm NL}\phi^3 :$$

$$-3.5 \times 10^5 < g_{\rm NL} < 8.2 \times 10^5$$

VD & Seljak 10

Caveat: need to know b_{NG} accurately

(U. Michigan, 2011)

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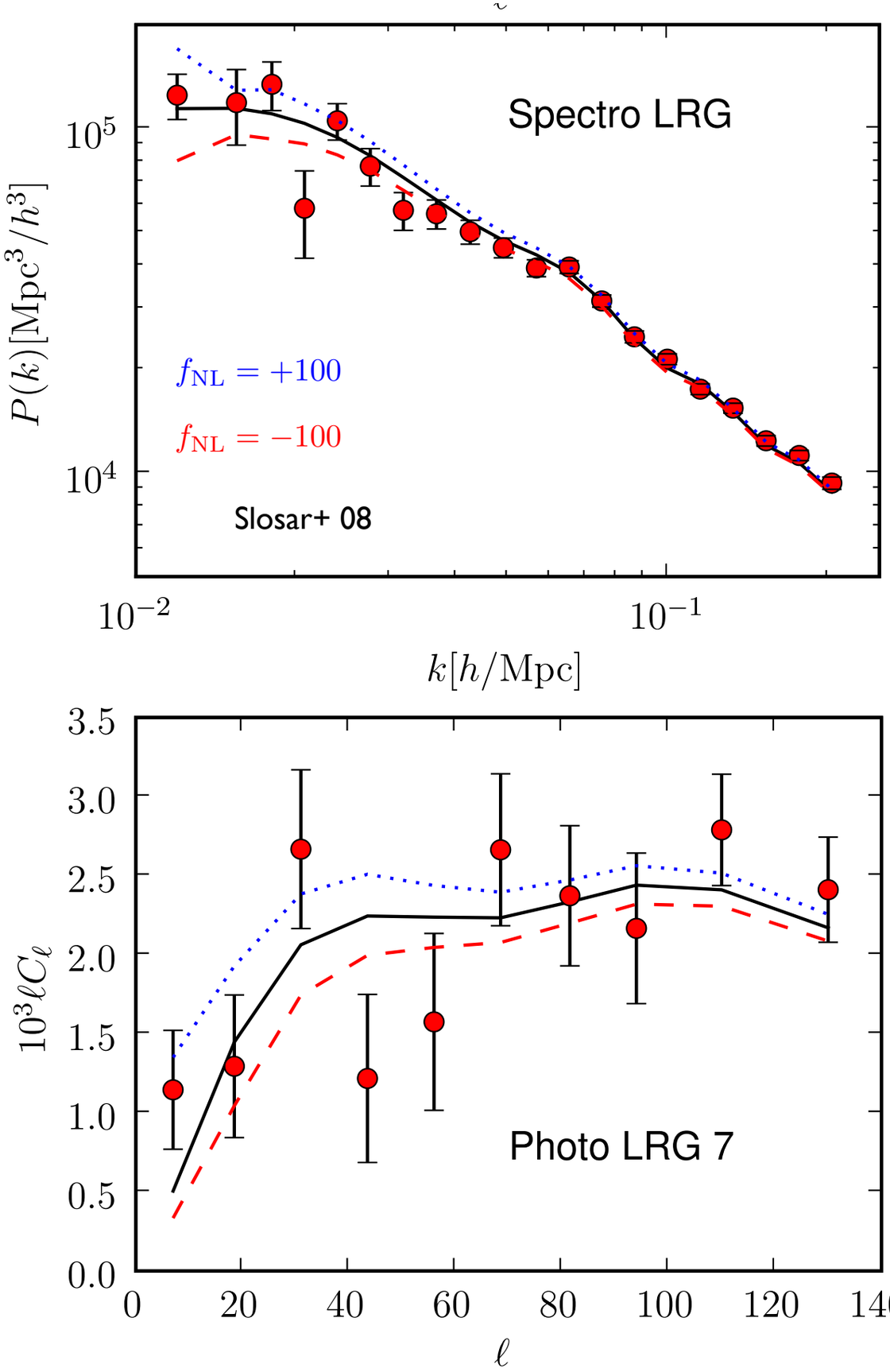

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Caveat: need to know ~~b_{NG}~~ accurately

$$b_\phi = 2\frac{\partial \ln n}{\partial \ln \sigma_8}$$

(U. Michigan, 2011)

Assembly bias with PNG

$$n(M,X) = \bar{n}(M) \times P(X|M)$$

Slosar+ 08: X=recent merger

$$b_\phi = \frac{2}{\left(\bar{n}P_{\rm merg}\right)} \frac{\partial}{\partial \ln \sigma_8} \left(\bar{n}P_{\rm merg}\right) = \bar{b}_\phi + \Delta b_\phi$$

$$\Delta b_\phi = 2 \frac{\partial \ln P_{\rm merg}}{\partial \ln \sigma_8}$$

$$-2 < \Delta b_\phi < 0$$

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Reid+ 10: X=formation redshift

$$b_\phi = \frac{2}{\left(\bar{n}P_{z_f}\right)} \frac{\partial}{\partial \ln \sigma_8} \left(\bar{n}P_{z_f}\right) = \bar{b}_\phi + \Delta b_\phi$$

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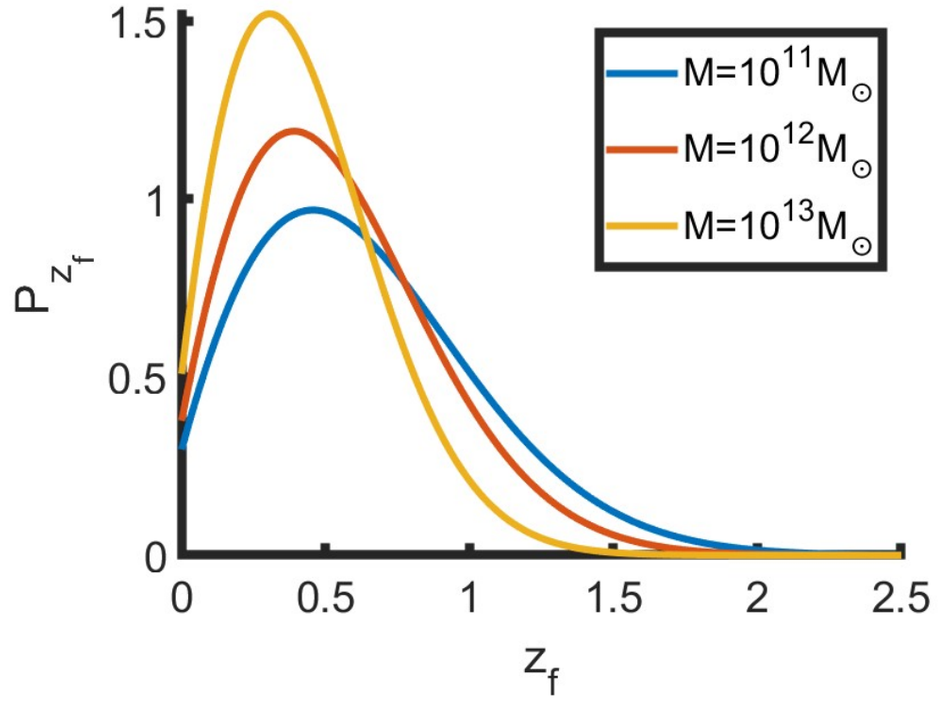

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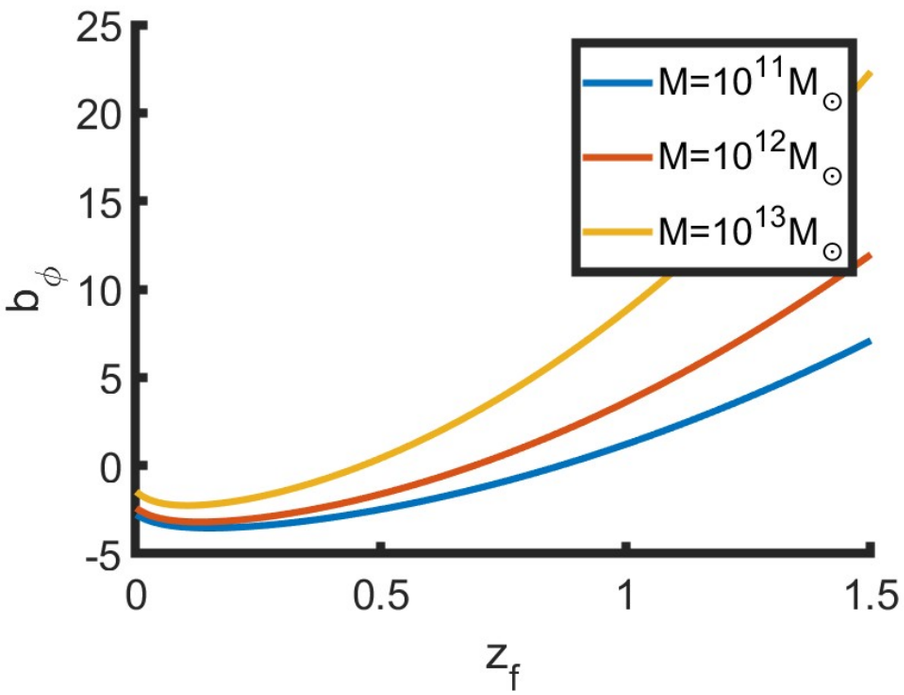
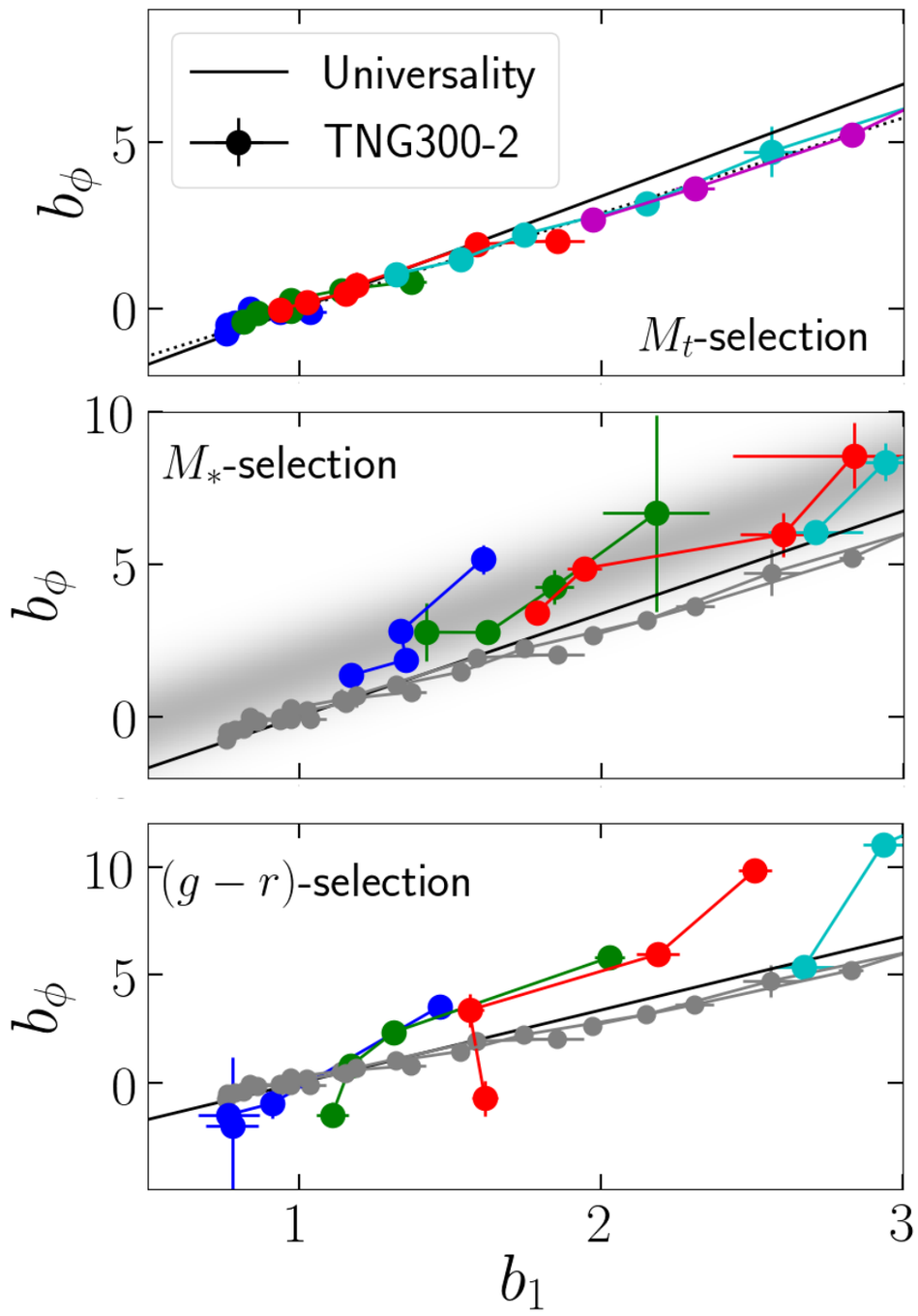


Assembly bias with PNG

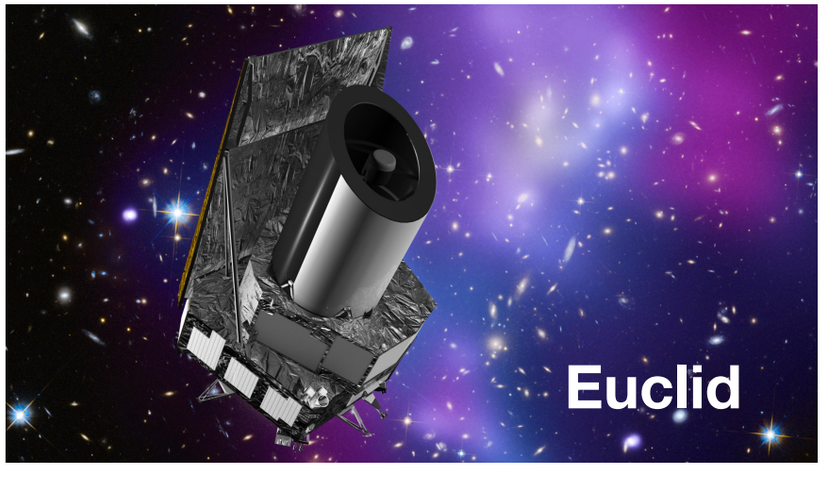
Barreira, Barreira+ 20, 21, 22, 23

$b_\phi(b_1)$ can be messy



$z = 1$

Ha emission line



Transition 3->2:

$$\lambda_{\mathrm{H}\alpha} = 656 \text{ nm}$$

$$E_{\mathrm{H}\alpha} = 1.89 \text{ eV}$$

In HII regions:

$$L_{\mathrm{H}\alpha} \propto \mathrm{SFR}$$

NISP instrument:

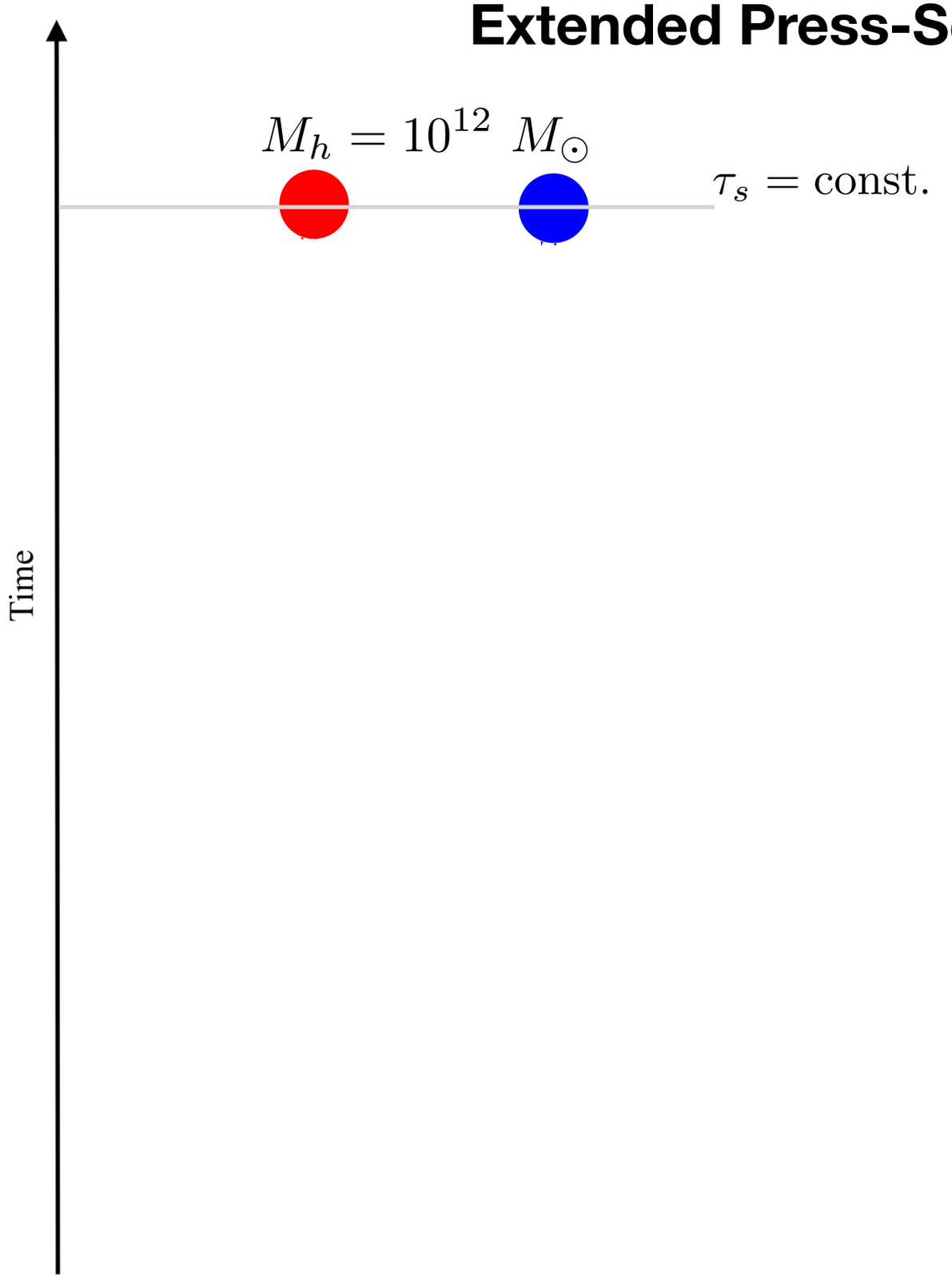
$$0.92 - 1.85 \ \mu\mathrm{m}$$

$$\lambda/\Delta\lambda \sim 400$$

How large is Δb_ϕ for galaxies selected by Hα luminosity?

w/ M. Marinucci and A. Benson (2303.10337)

Extended Press-Schechter approach



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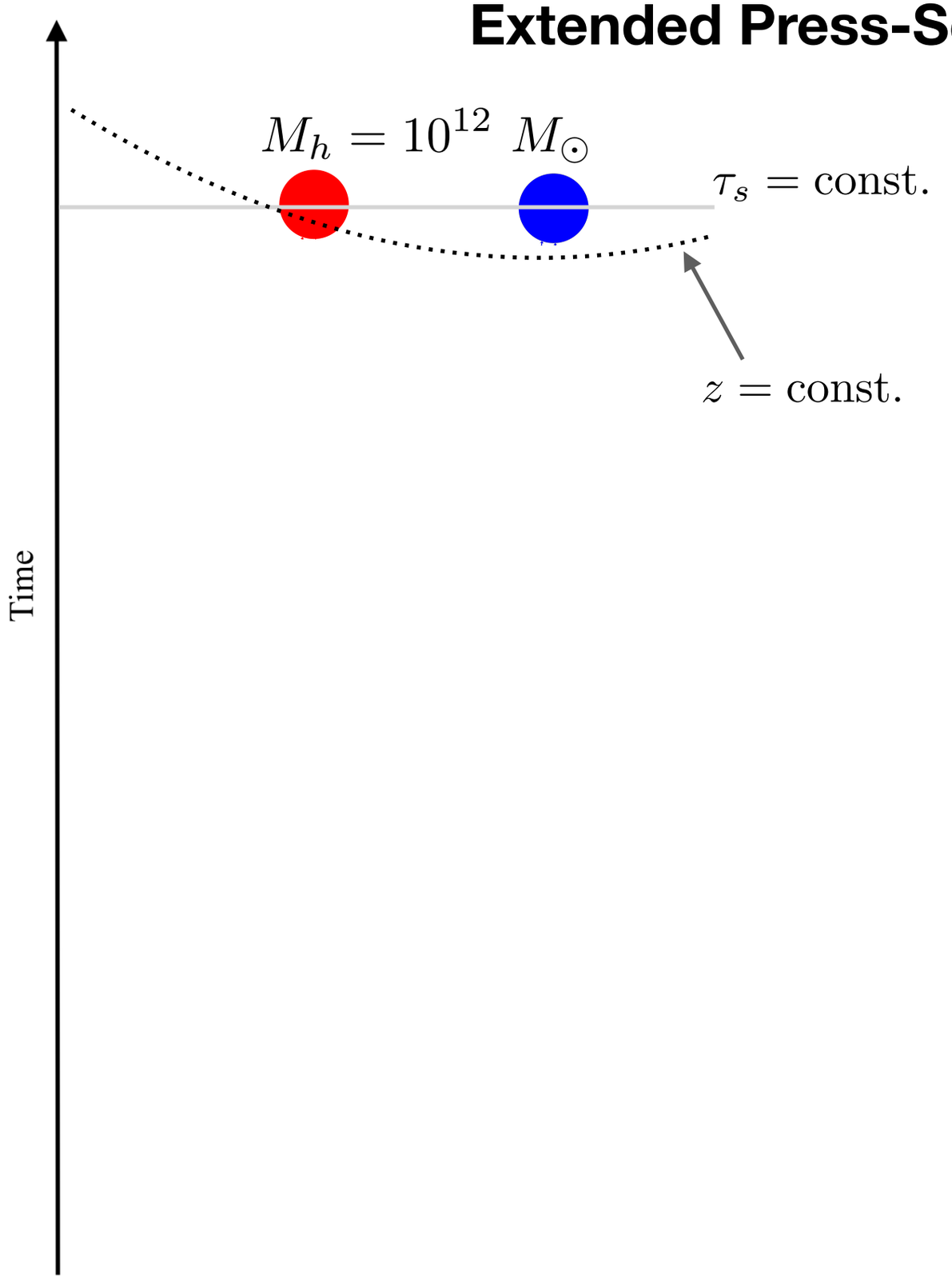

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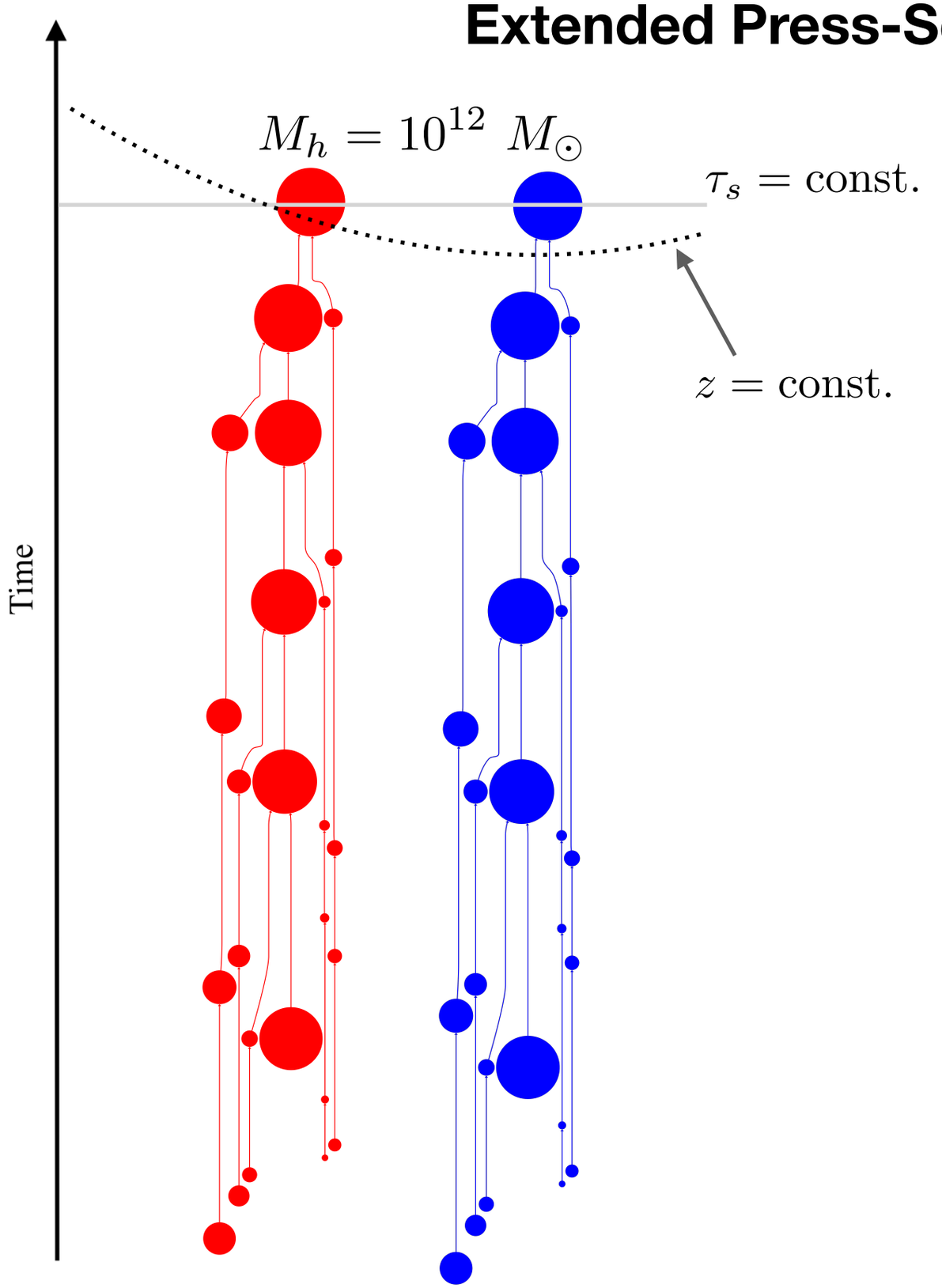

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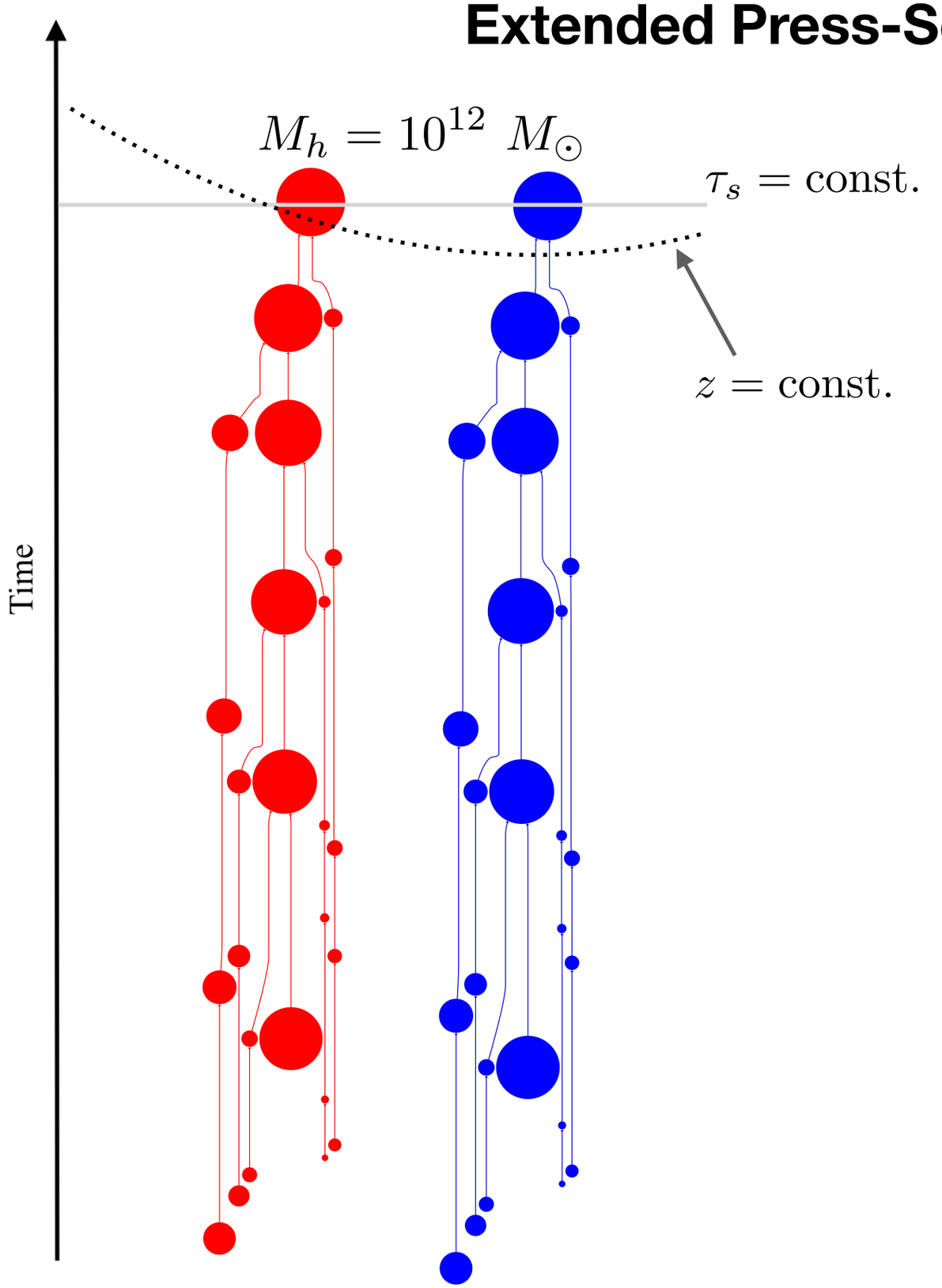
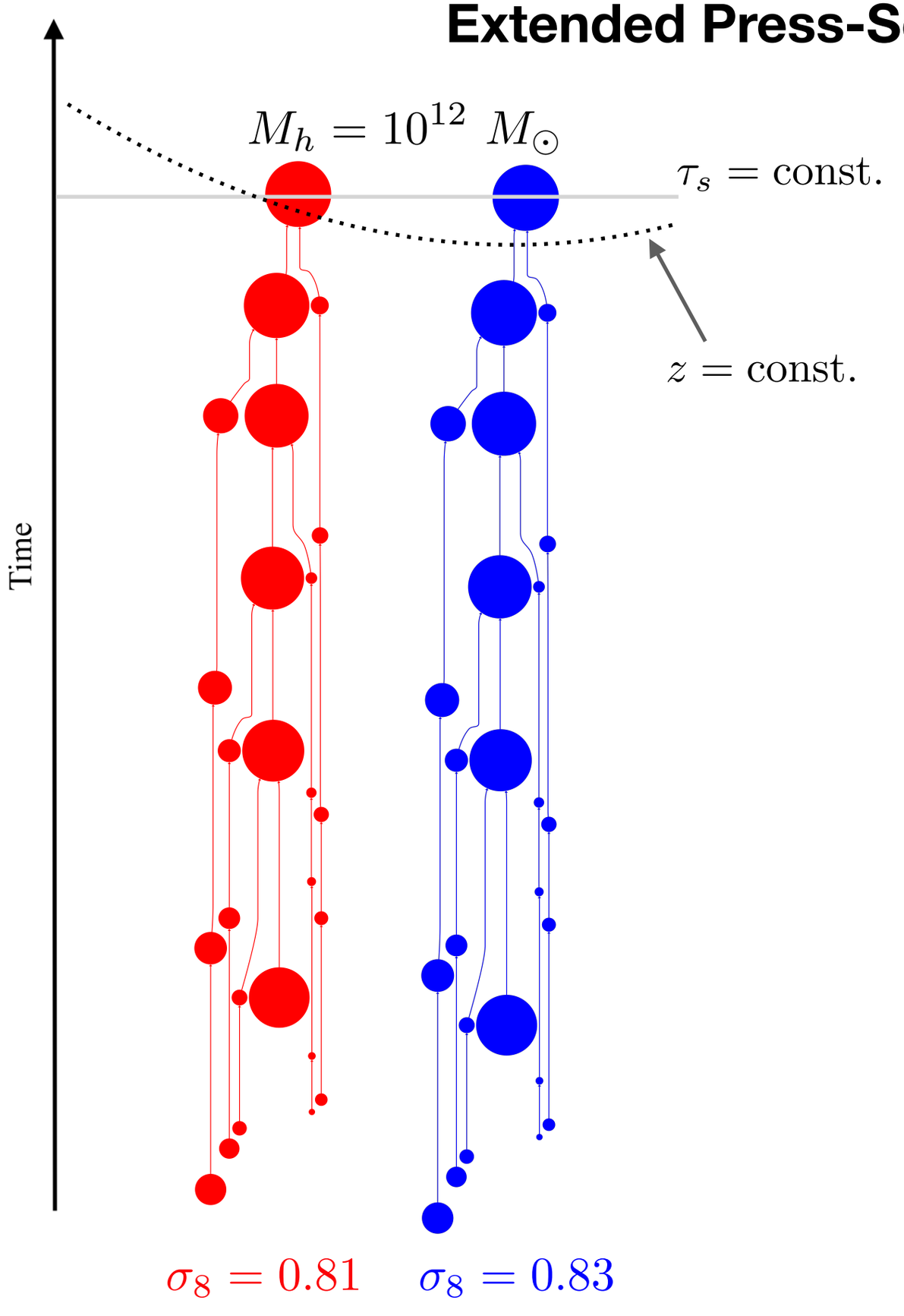


Populate EPS merger trees with a semi-analytical model ("SAM") of galaxy formation

Extended Press-Schechter approach



Populate EPS merger trees with a semi-analytical model ("SAM") of galaxy formation

We use GALACTICUS (A. Benson, 2012)

NG bias: halo density response

Comoving galaxy number density:

$$n_g(X,z) = \int dM_h\, \bar{n}_h(M_h,z)\left[N_c(X|M_h,z) + N_s(X|M_h,z)\right]$$

$$N_{c,s}(X|M_h,z) = \bar{N}_{c,s}(M_h,z)\, P_{c,s}(X|M_h,z)$$

NG bias:

$$b_\phi(X,z) = 2\frac{\partial \ln n_g}{\partial \ln \sigma_8}(X,z)$$
$$= \bar{b}_\phi(X,z) + \Delta b_\phi(X,z)\ ,$$

Halo density response:

$$\bar{b}_\phi(X,z) = \frac{1}{\bar{n}_g}\int dM_h\, b^h_\phi(M_h,z)\,\bar{n}_h(M_h,z)$$
$$\times\left[N_c(X|M_h,z) + N_s(X|M_h,z)\right]$$

NG bias: HOD response

HOD response:

$$\Delta b_\phi(X,z) = \frac{1}{\bar{n}_g}\int dM_h \left[f_c \Delta b_\phi^c(X|M_h,z) + f_s \Delta b_\phi^s(X|M_h,z)\right] \times \bar{n}_h(M_h,z)\left[N_c(X|M_h,z) + N_s(X|M_h,z)\right]$$

Central vs. satellite:

$$\Delta b_\phi^{c,s}(X|M_h,z) = 2\frac{\partial \ln N_{c,s}}{\partial \ln \sigma_8}(X|M_h,z) = 2\frac{\partial \ln \bar{N}_{c,s}}{\partial \ln \sigma_8}(M_h,z) + 2\frac{\partial \ln P_{c,s}}{\partial \ln \sigma_8}(X|M_h,z)$$

In practice:

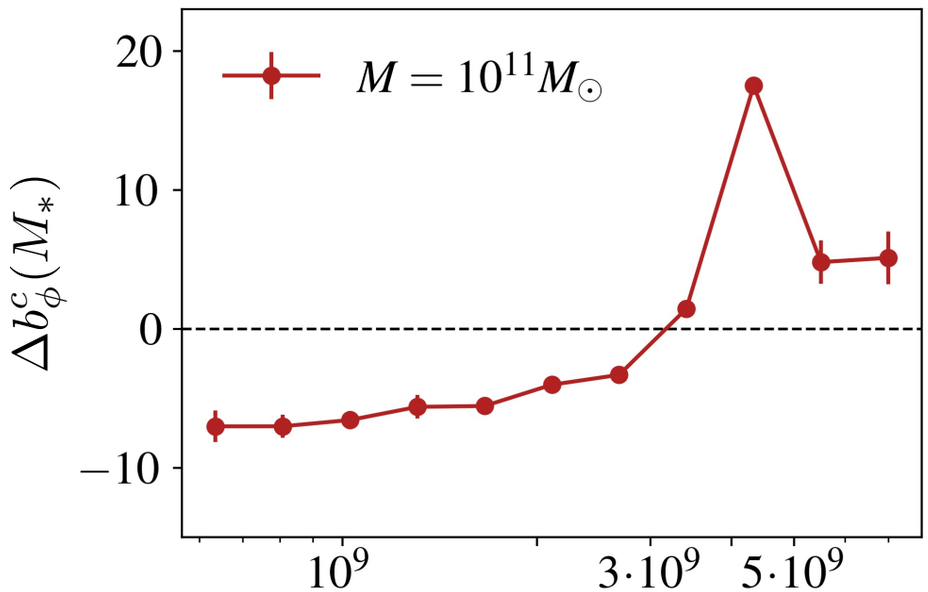
$$\Delta b_\phi^{c,s}(X|M_h,z) = \frac{1}{|\delta_{\sigma_8}|}\left[\frac{N_{c,s}^{\rm high}(X|M_h,z) - N_{c,s}^{\rm low}(X|M_h,z)}{N_{c,s}^{\rm fid}(X|M_h,z)}\right]$$

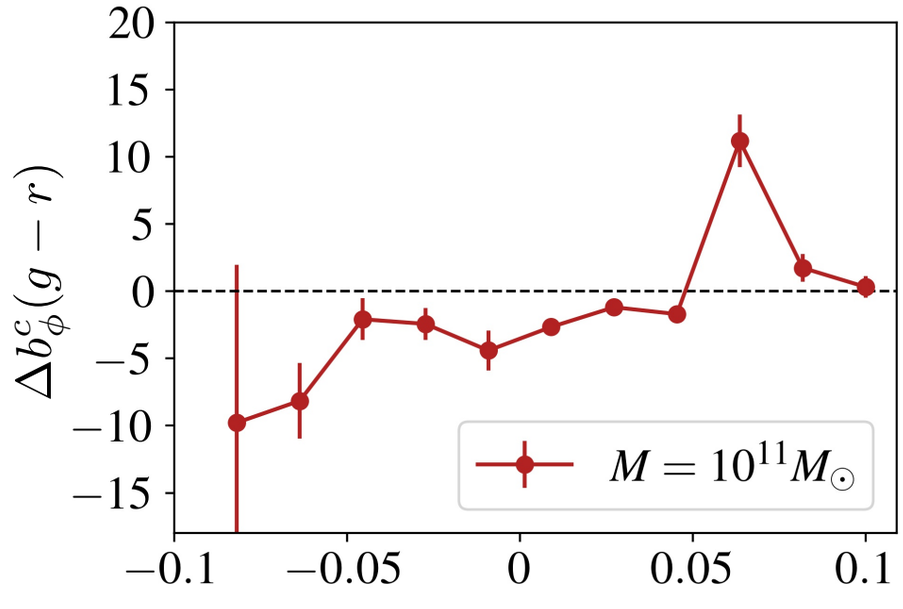
Relation to Voivodic & Barreira 21:

$$R_\phi^g(X|M_h,z) = \left(\bar{N}_c\,\Delta b_\phi^c + \bar{N}_s\,\Delta b_\phi^s\right)(X|M_h,z)$$

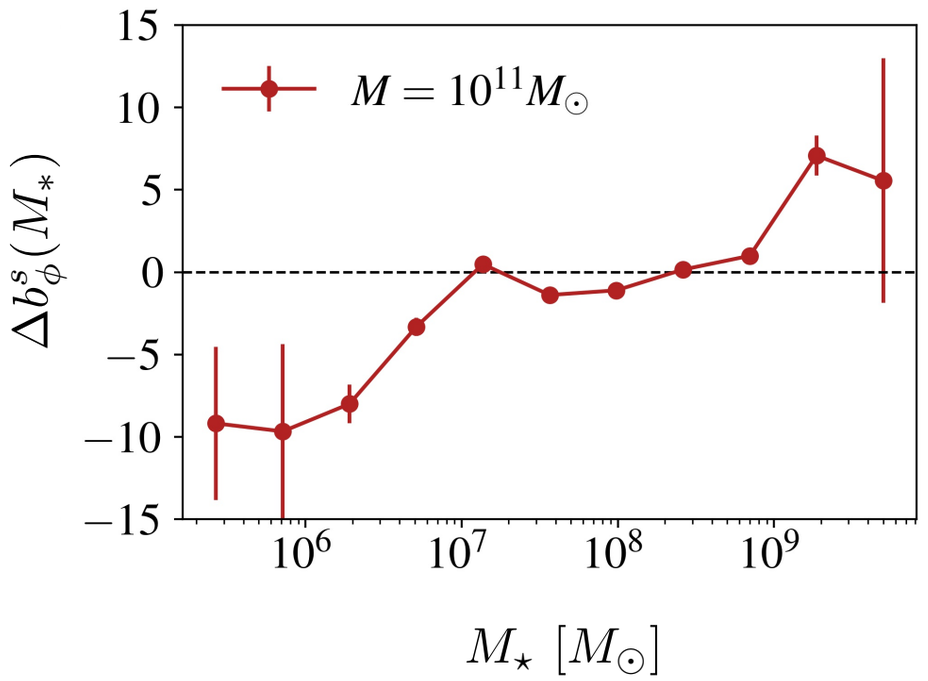
HOD response for stellar mass + color (z=1)

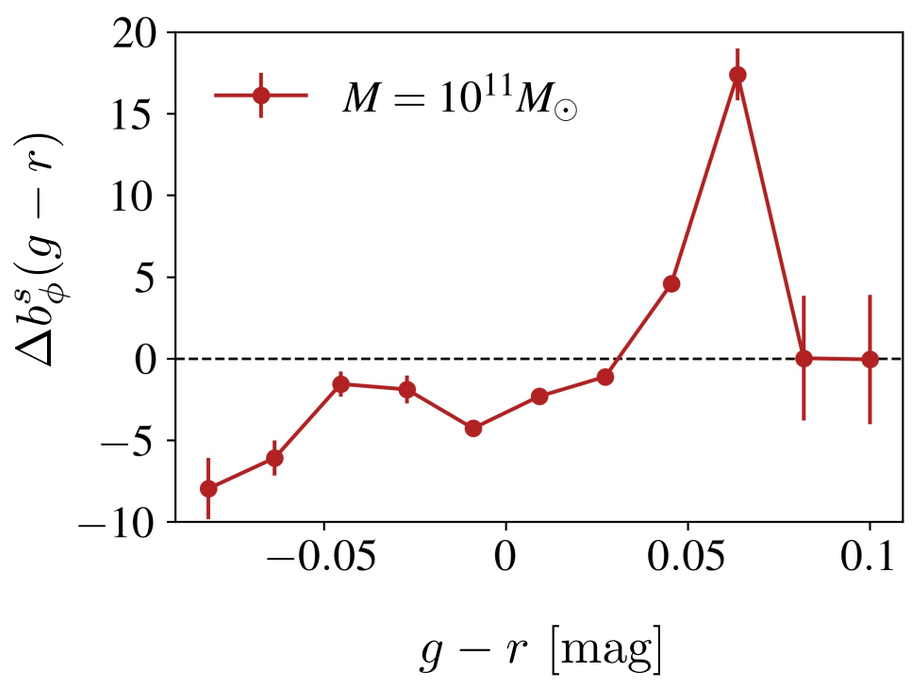
central:





satellite:

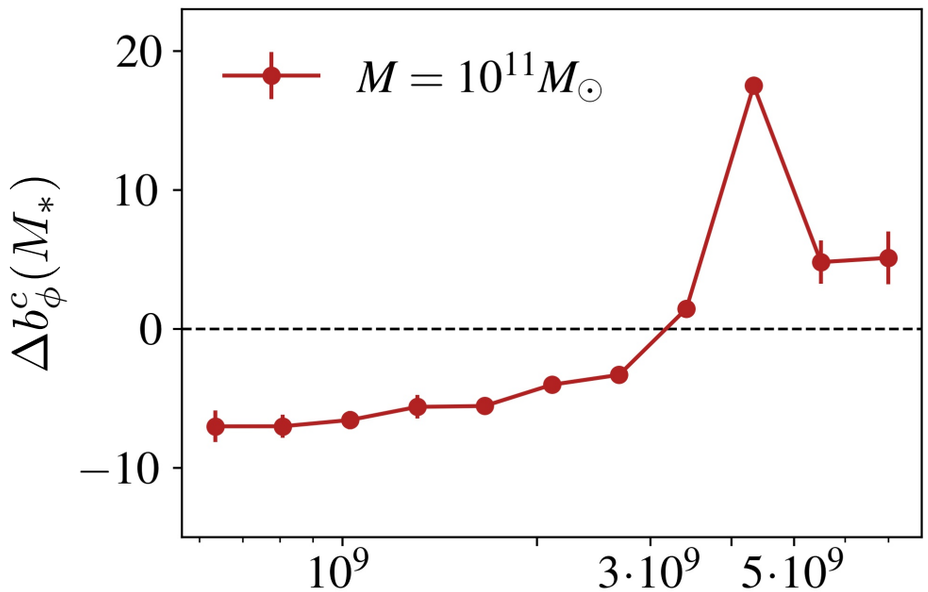


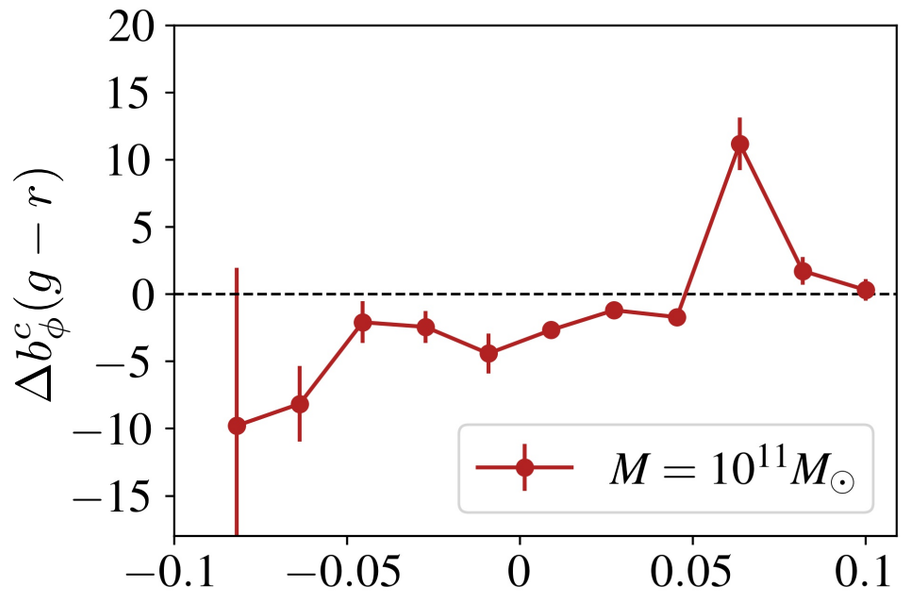


HOD response for stellar mass + color (z=1)

central:

Tinker+ '10 and universality relation: $\bar{b}_\phi \approx -0.24$





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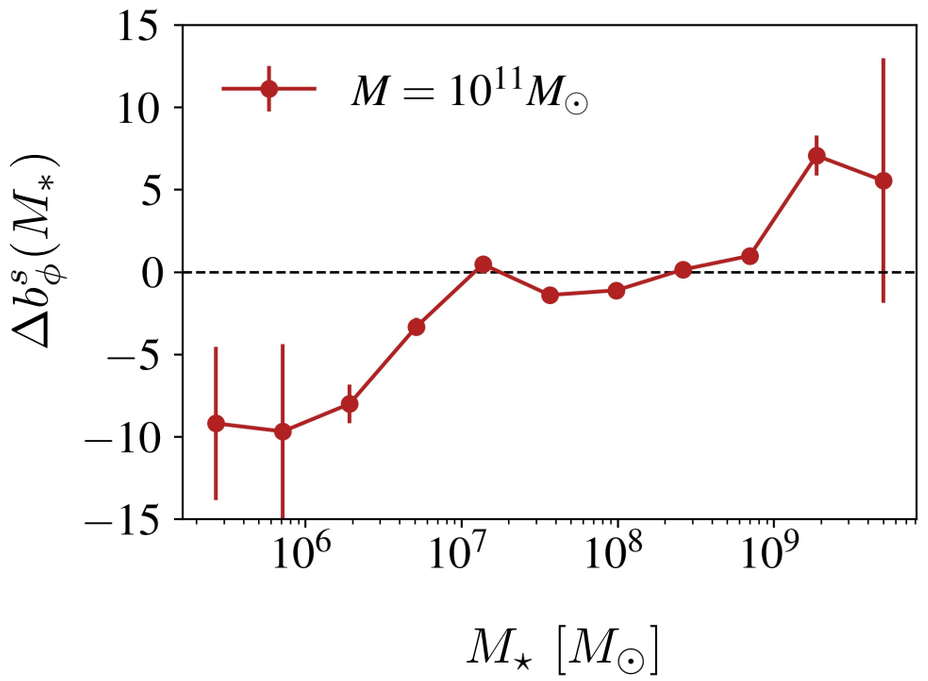
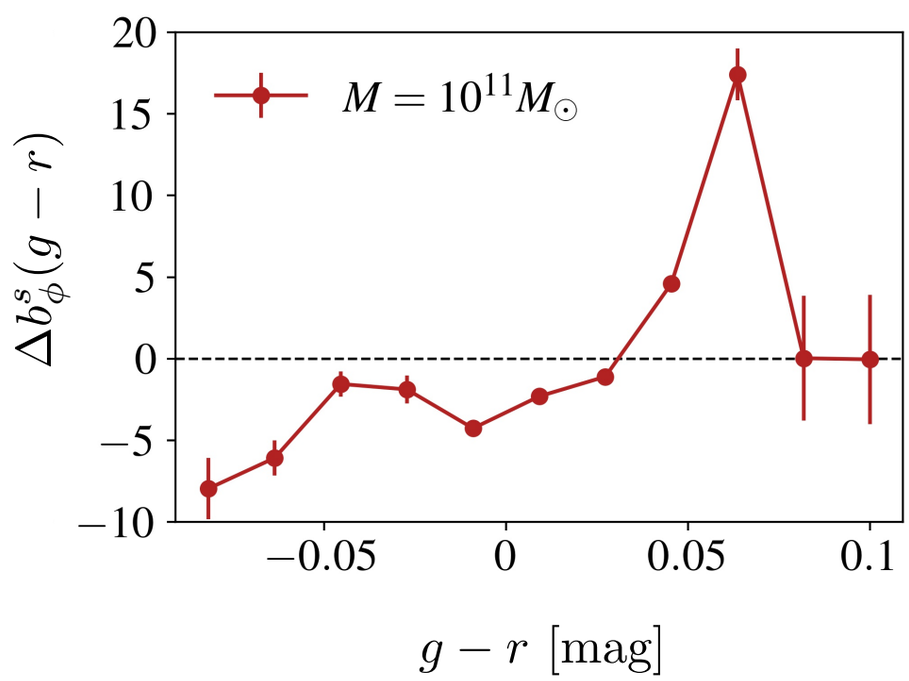
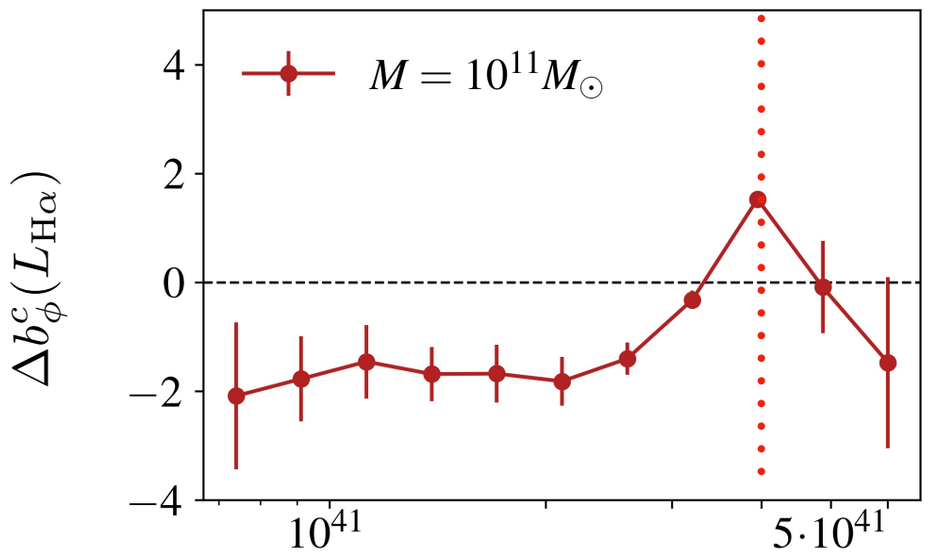


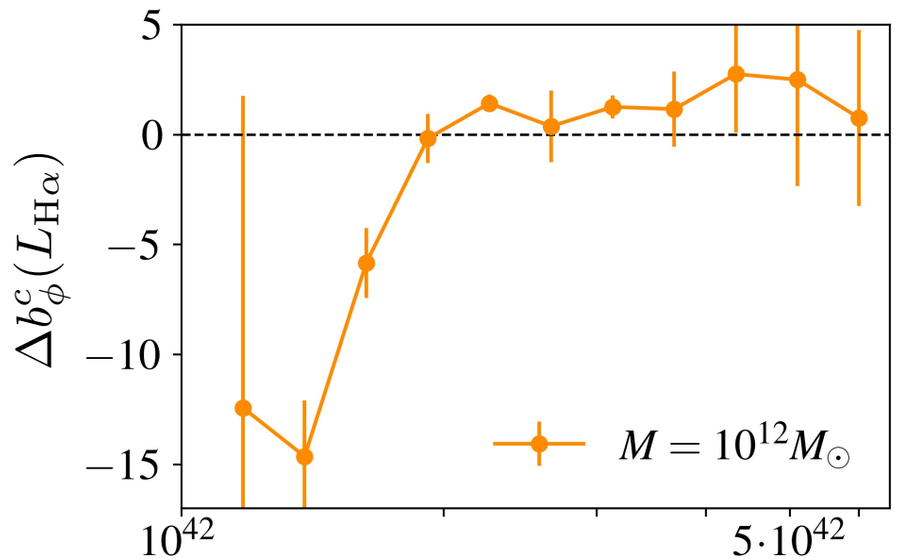


HOD response for Ha luminosity (z=1)

Assuming $L_{\mathrm{H}\alpha} \propto \mathrm{SFR}$

central:





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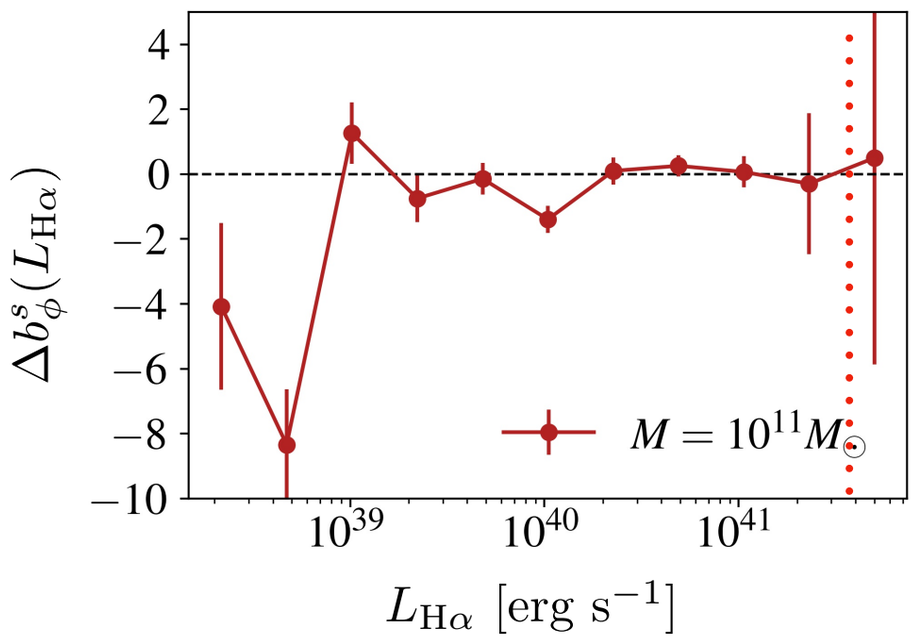
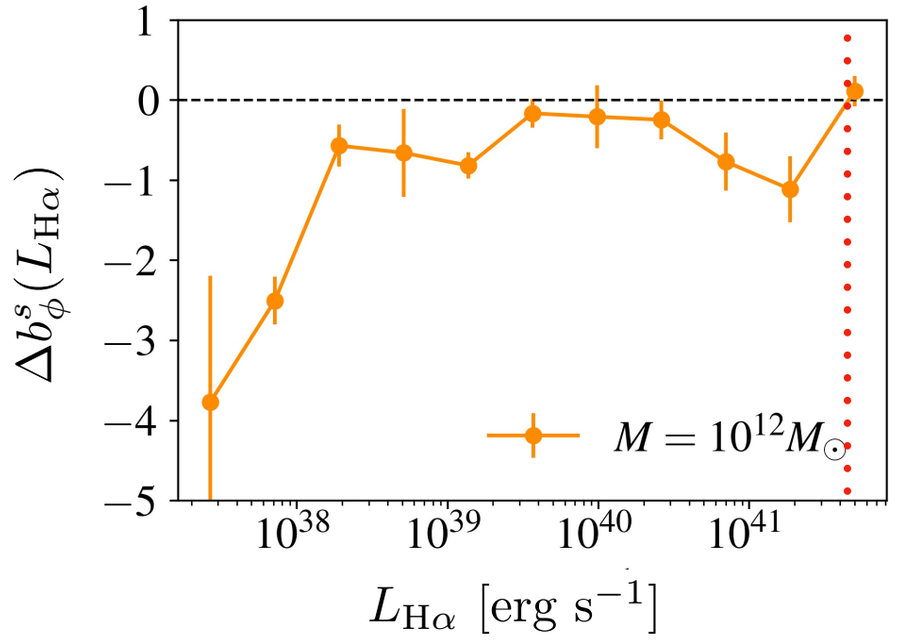
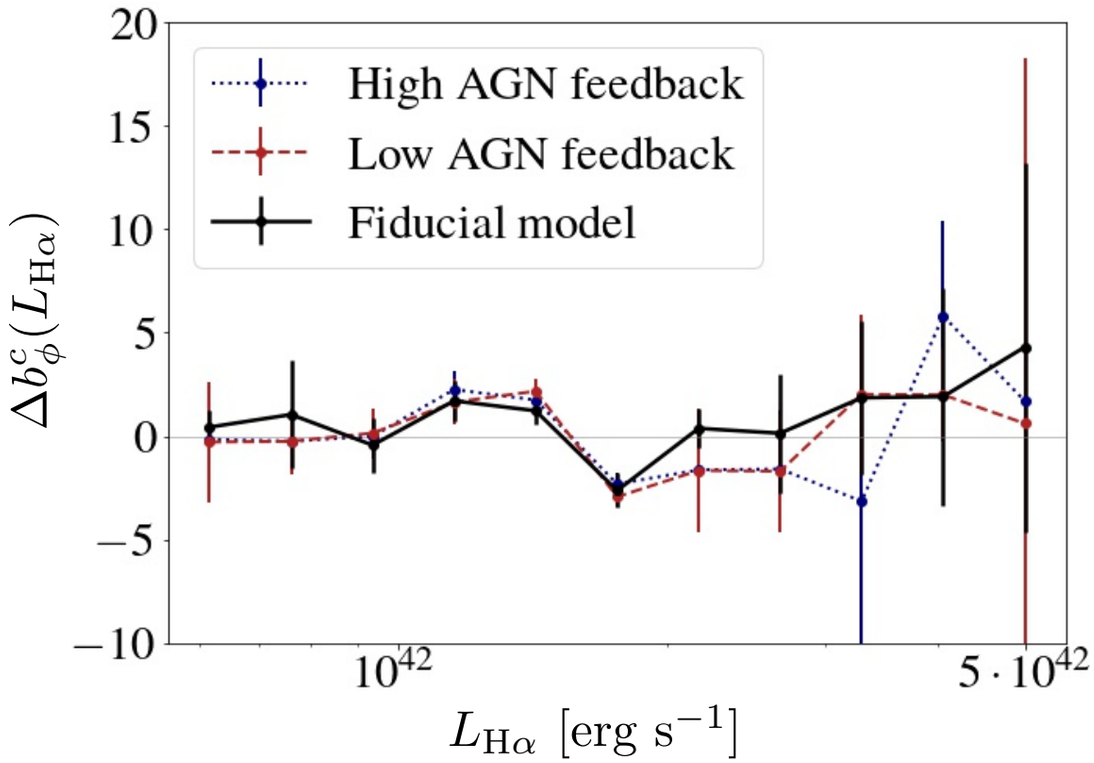
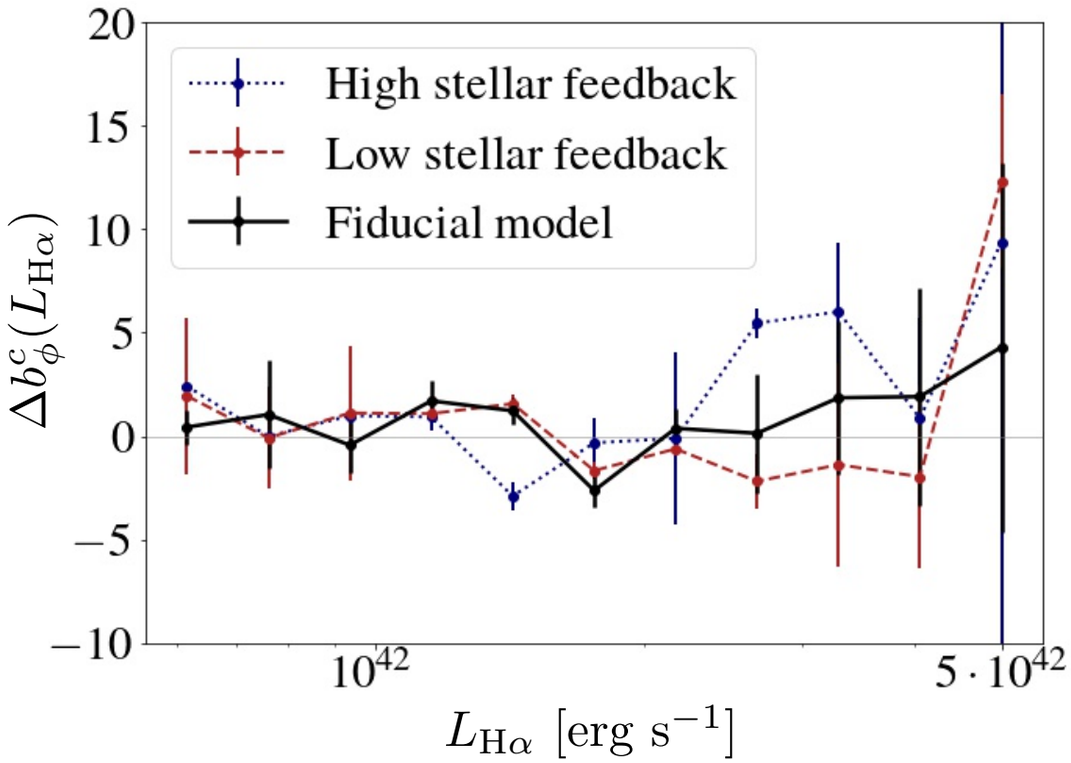
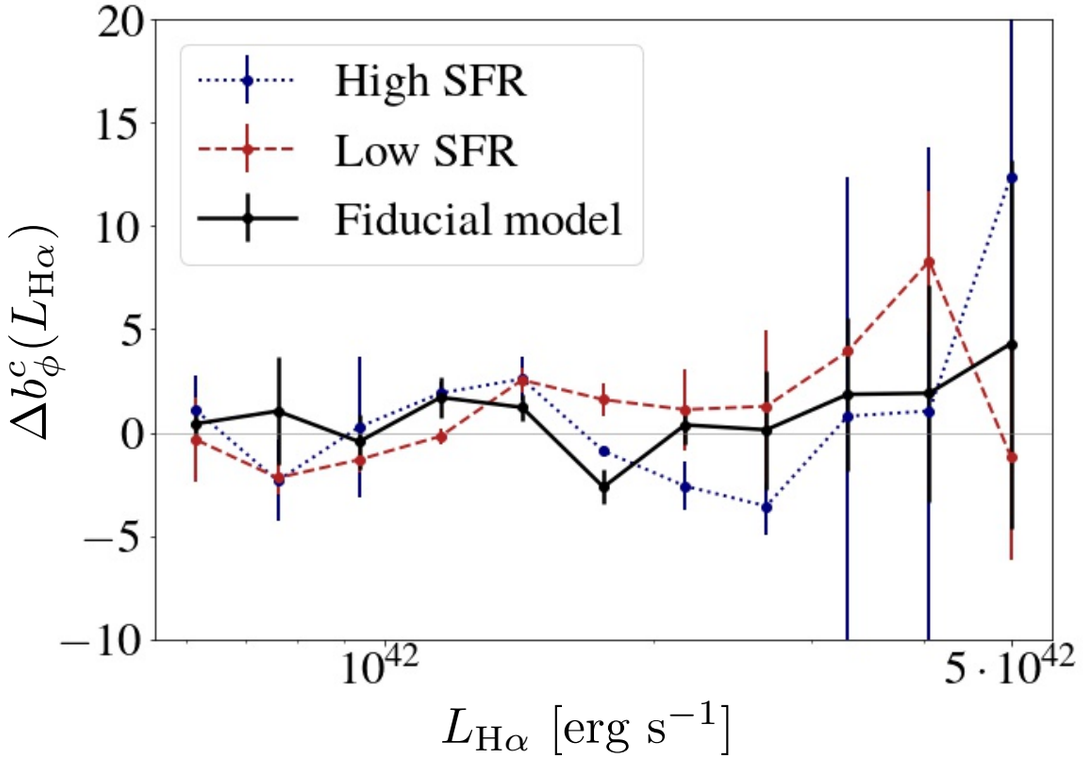




SAM variations







Improved Ha line model

w/ Ehud Behar, Ivan Rapoport

$$E_3 - E_1 \simeq 12.1 \text{ eV}$$

$$T_{\rm vir} \approx 2.9 \times 10^4 \ \Omega_m^{1/3} \left(\frac{M_{\rm vir}}{10^{10} \ M_\odot} \right)^{2/3} (1 + z_{\rm vir}) \ {\rm K}$$

In addition to HII regions, include Ha emission from the hot, diffuse ISM phase

- Collisional-excitations
- Photo-excitations
- Recombinations
- Radiation from stars + AGN

Summary

Large assembly bias for galaxies selected by color or stellar mass because a larger s8 produces faster mass assembly histories with more, and older stars

Smaller assembly bias for L_{Ha} - selected galaxies due to lack of correlation between instantaneous SFR and s8