Galaxy size as a zero-bias tracer for local PNG

How I learned to stop worrying about non-universality and b_ϕ

Nguyễn Nhật Minh (KIPMU & ICISE) - Croucher AIS Primordial Non-Gaussianities (CityUHK) - 2026 June 16

Local Primordial non-Gaussianity

Local PNG detection would rule out standard inflation

For local PNG of the form $\phi(\mathbf{x}) = \phi_G(\mathbf{x}) + f_{\rm NL}\left[\phi_G(\mathbf{x})^2 - \left\langle \phi_G^2(\mathbf{x})\right\rangle\right]$,

Komatsu & Spergel, PRD (2001)

the local PNG amplitude is expected to be $f_{\rm NL} \sim \frac{5}{12}\left(n_s - 1\right)$

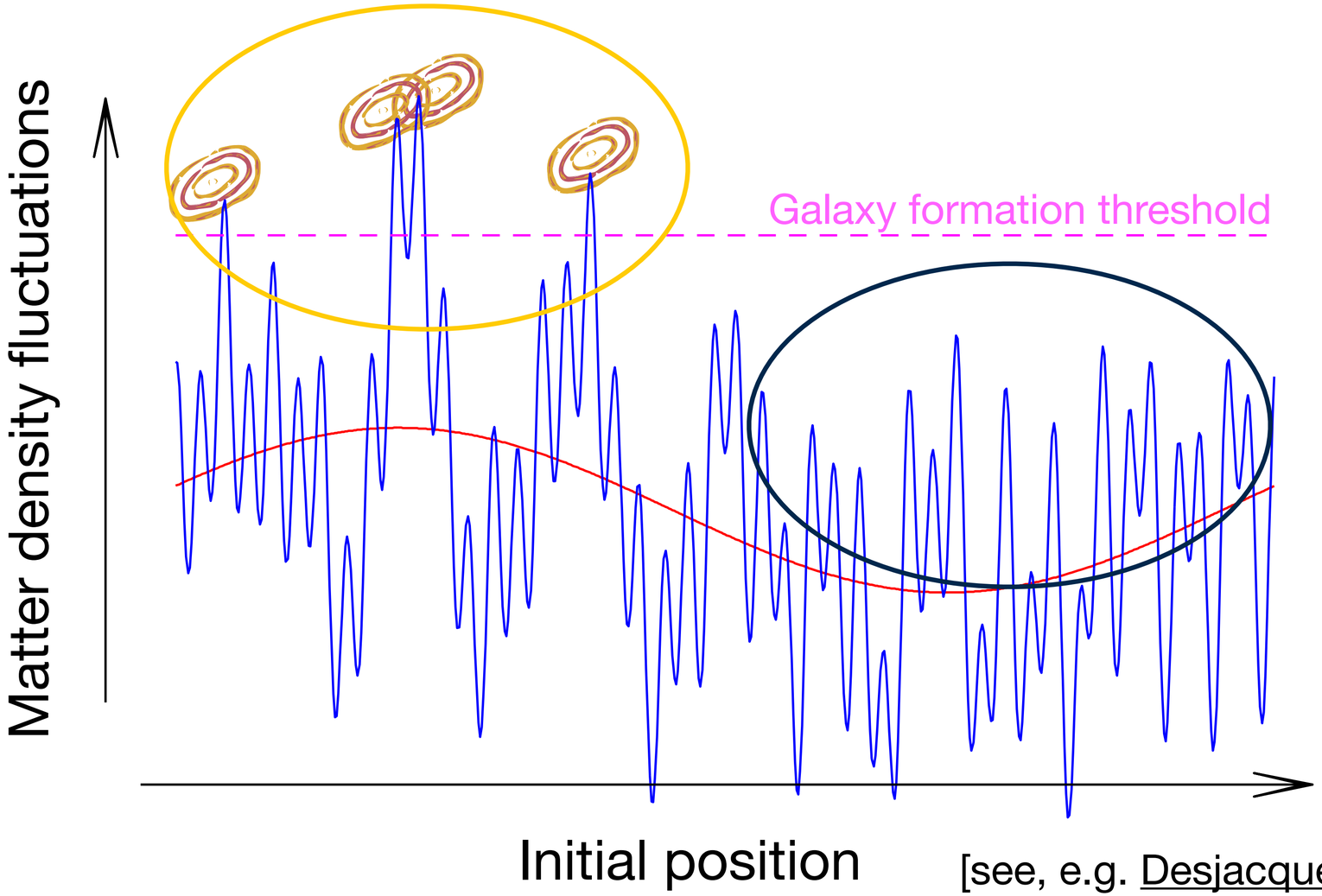
Maldacena, JHEP (2003)

for slow-roll, single-field inflation.

$\mathcal{O}\left(f_{\rm NL}\right) \sim 1 - 10$ is the target to falsify slow-roll, single-field inflation.

Galaxies as LSS tracers

Galaxies respond to the presence of long density modes



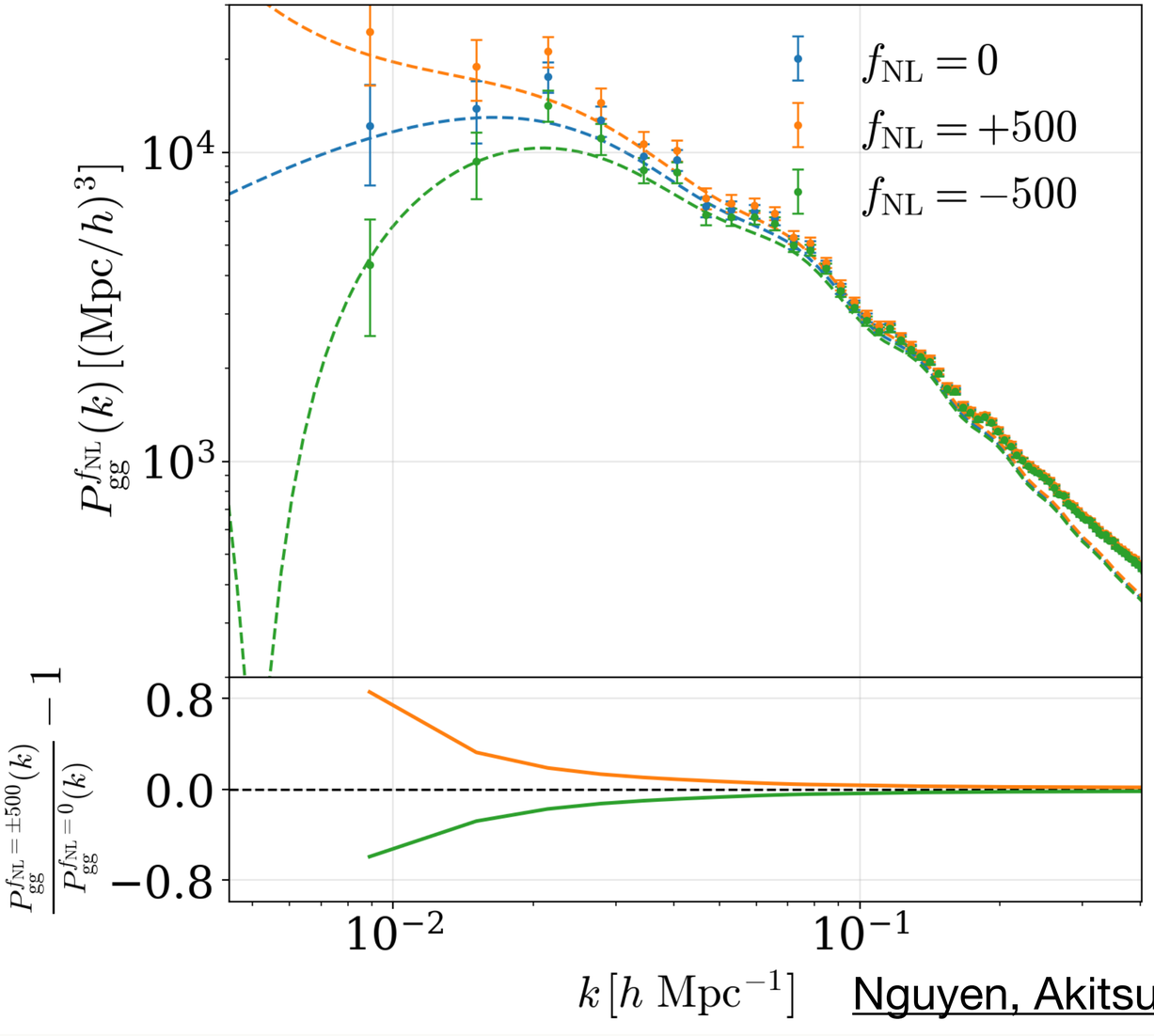
$$\delta_g = b_g \delta_m$$

$$P_{gg} = b_g^2 P_{mm} + P_{\rm shot}$$

[see, e.g. Desjacques, Jeong, and Schmidt, Phys Rep (2017)]

Galaxy scale-dependent bias and local PNG

Galaxies respond to long-short mode coupling in local PNG



$$b_g^{f_{\rm NL}}(k) = b_g^{f_{\rm NL}=0} + \frac{b_\phi f_{\rm NL}}{\mathscr{M}(k)},\ \mathscr{M}(k) \propto k^2$$

[Dalal, Doré, Huterer, and Shirokov, PRD (2008)]

Nguyen, Akitsu, Taruya, PRD (2026)

The universality relation and $f_{\rm NL}$ constraints

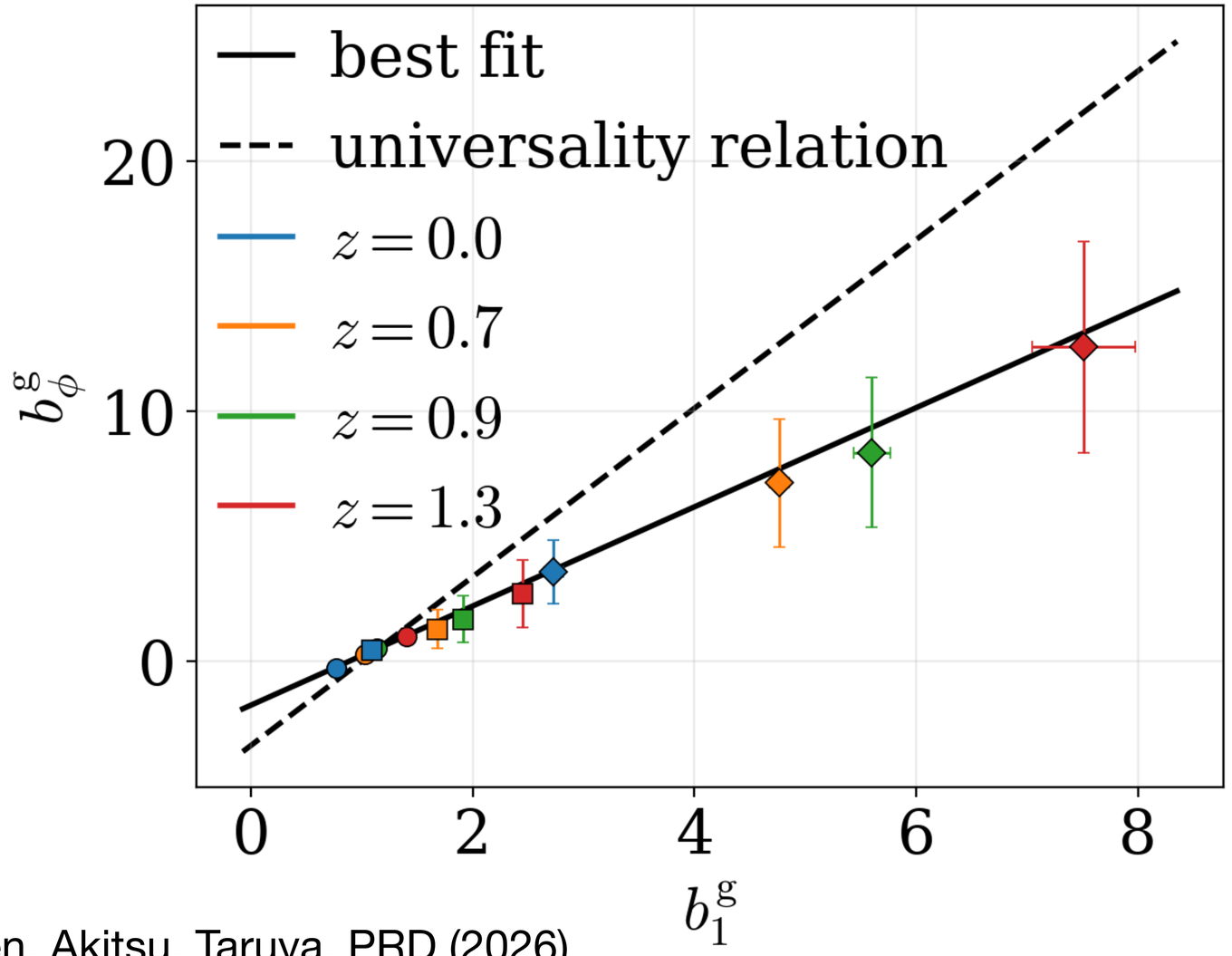
Pinning down $f_{\rm NL}$ requires additional assumption or prior information

$$b_1(M,z) = \frac{d\ln n(M,z)}{d\ln \bar{\rho}_m(z)}$$

$$b_\phi(z) = 2\frac{d\ln n(M,z)}{d\ln \sigma_8(z)}$$

From universal mass function and tracer conservation:

$$b_\phi(M,z) = 2\delta_{\rm cr}\left[b_1(M,z) - 1\right]$$



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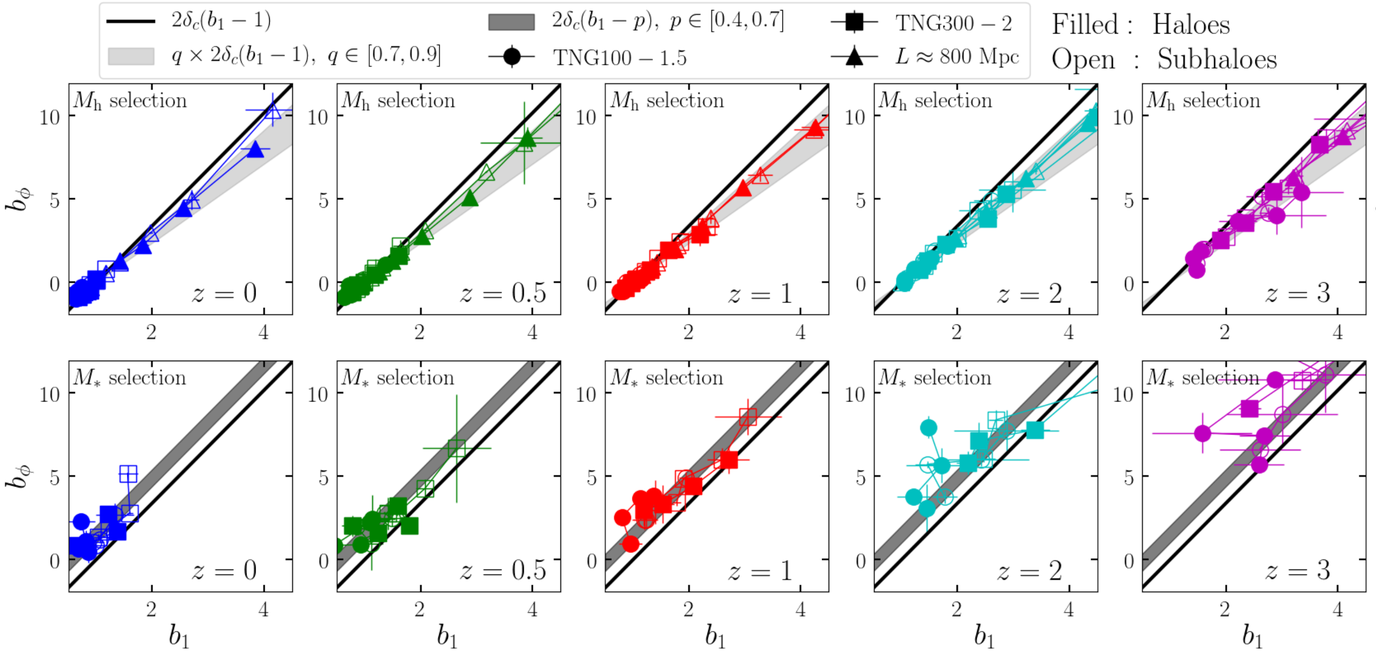
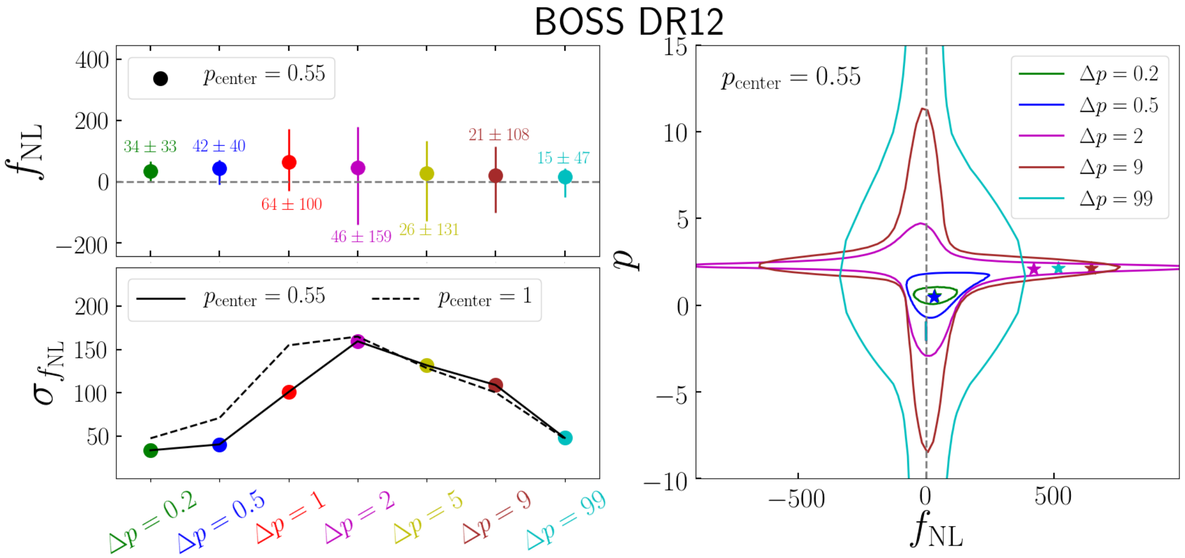
Can we actually constrain $f_{\rm NL}$ this way?

Why we might want to worry





Barreira, Cabass, Schmidt, Pillepich and Nelson, JCAP (2020)

Barreira, JCAP (2020)

Barreira, JCAP (2022)

Barreira, JCAP (2022)

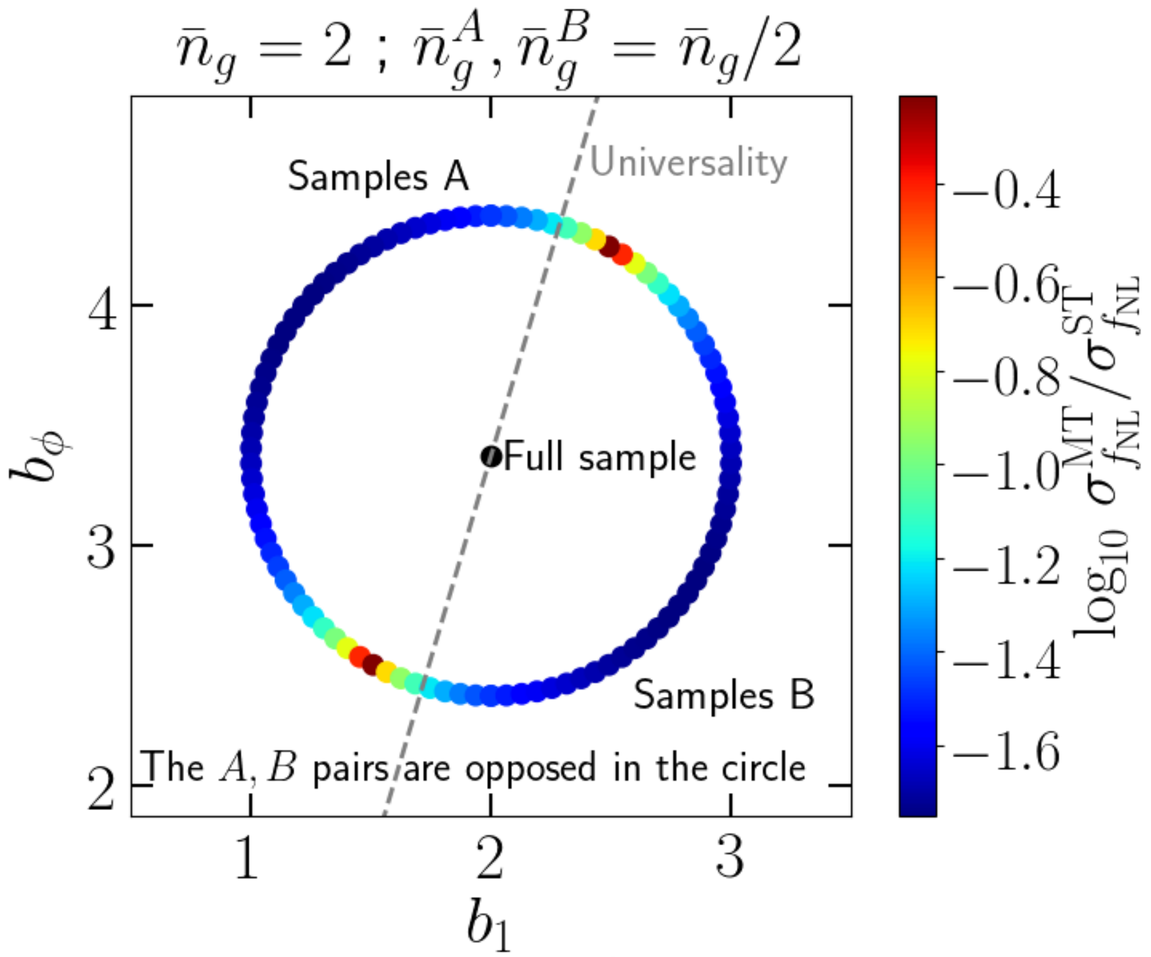
$$b_\phi(M,z) = 2\delta_{\rm cr}\left[b_1(M,z) - p\right]$$

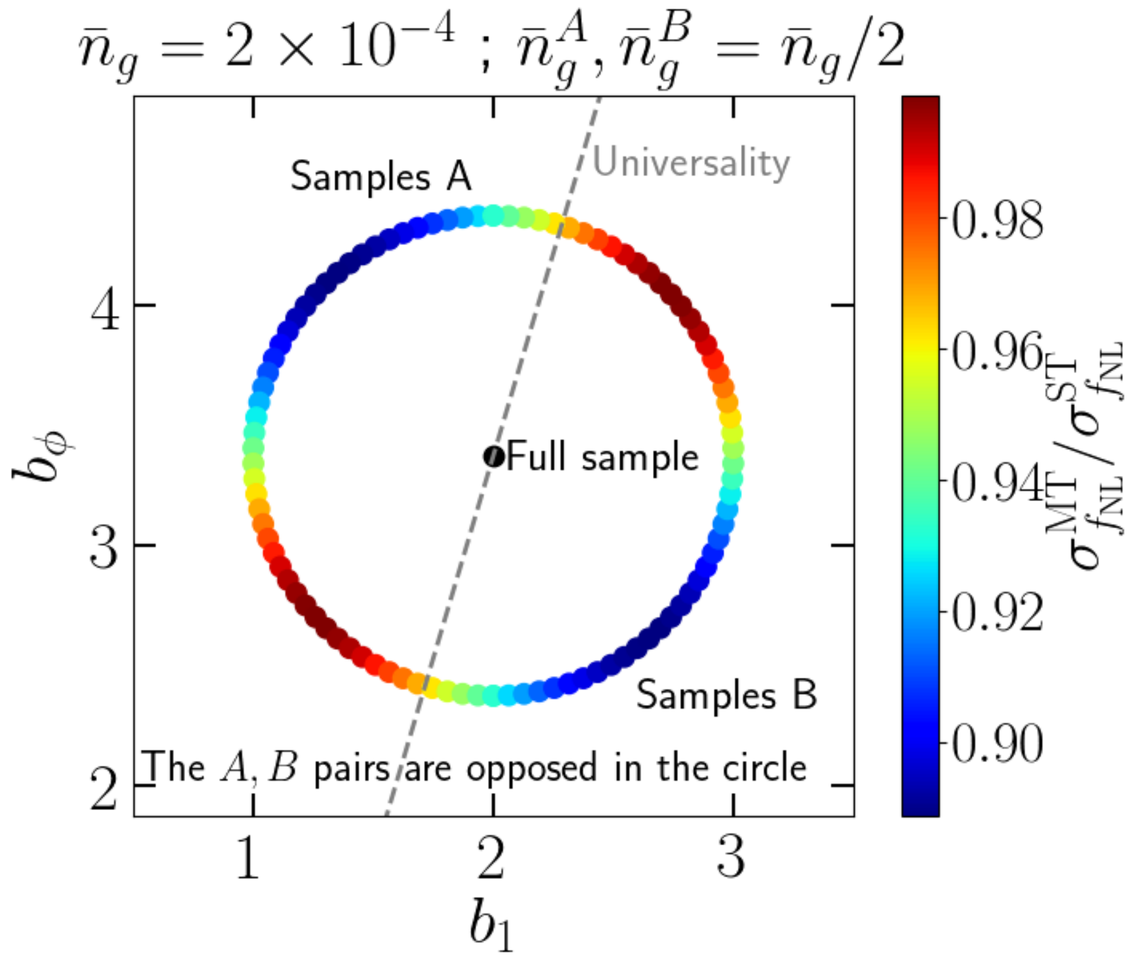
marginalizing over p

Embrace the nonuniversality

Why I stopped worrying—and you should, too

Barreira & Krause, JCAP (2023)



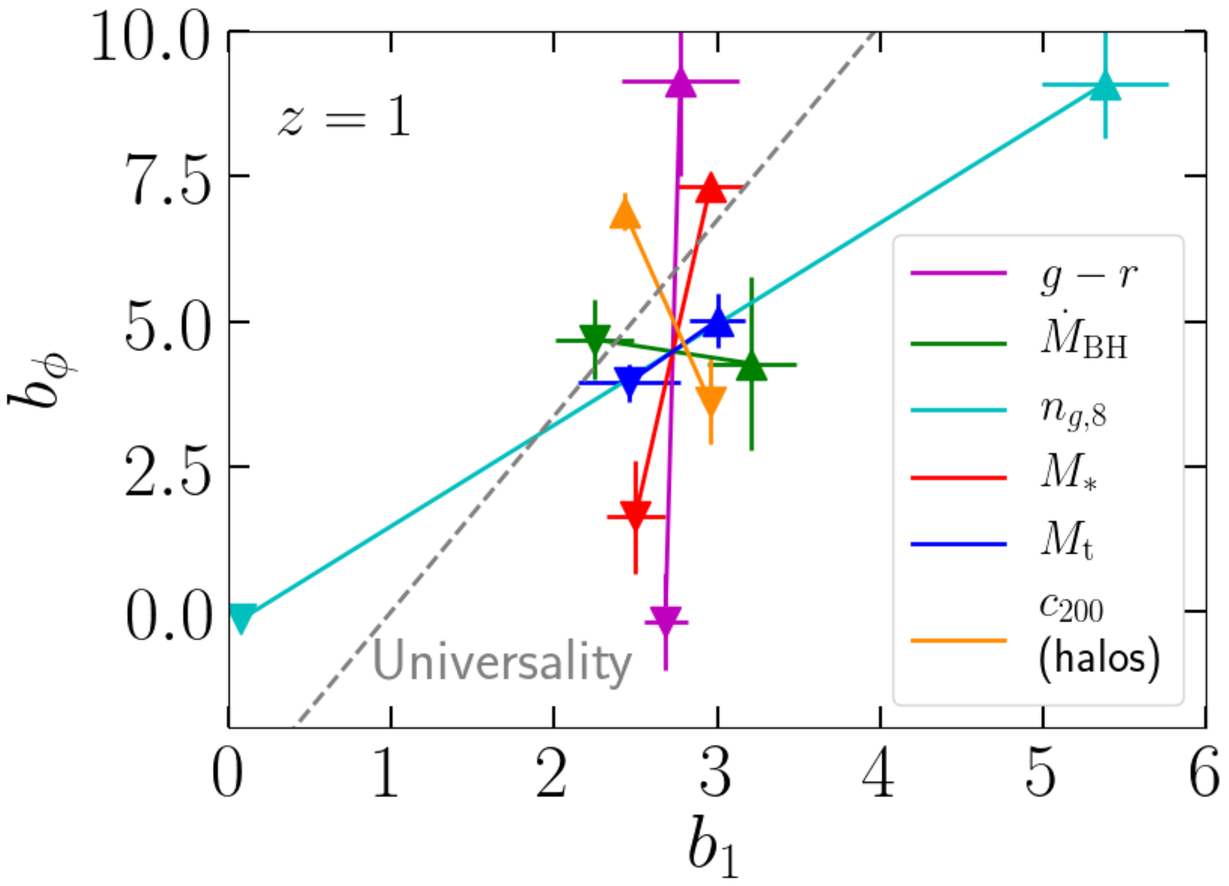


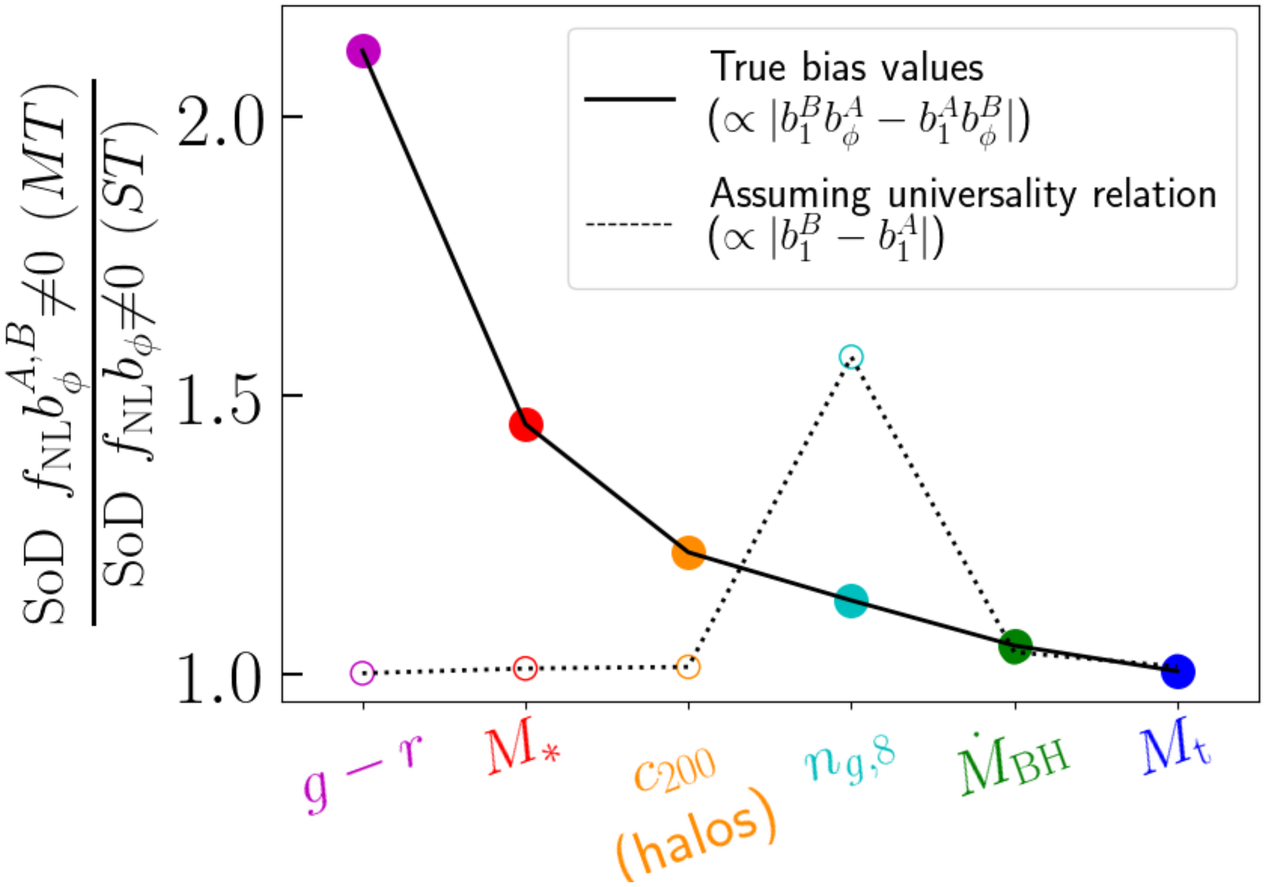
Improvement of local $f_{\rm NL}$ detection w/ multitracer as a function of sample split strategy

Embrace the nonuniversality

Why I stopped worrying—and you should, too

Barreira & Krause, JCAP (2023)

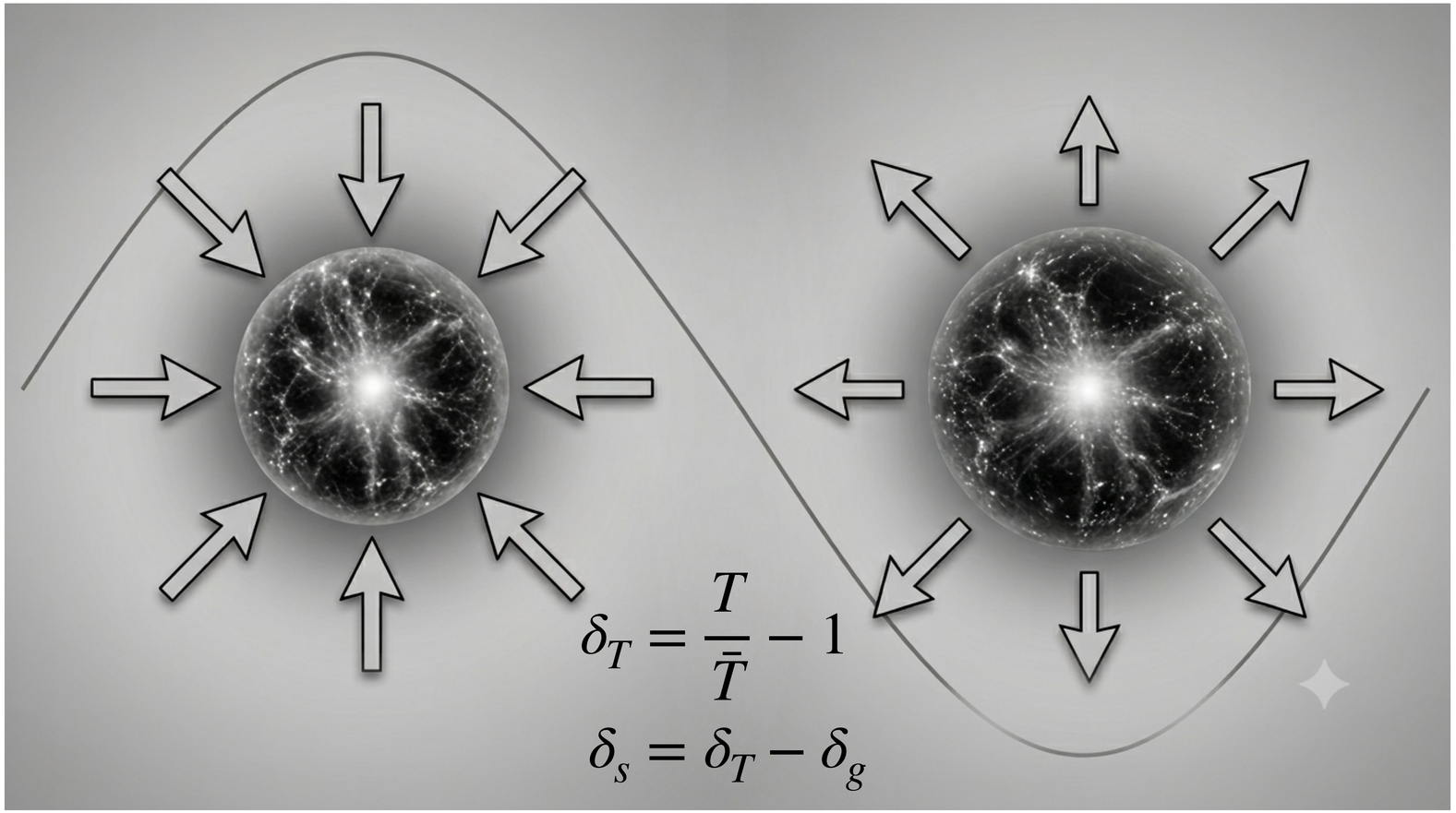




Improvement of local $f_{\rm NL}$ detection w/ multitracer as a function of sample split strategy

Galaxy sizes as LSS tracers

Information already available, formalism is exactly the same

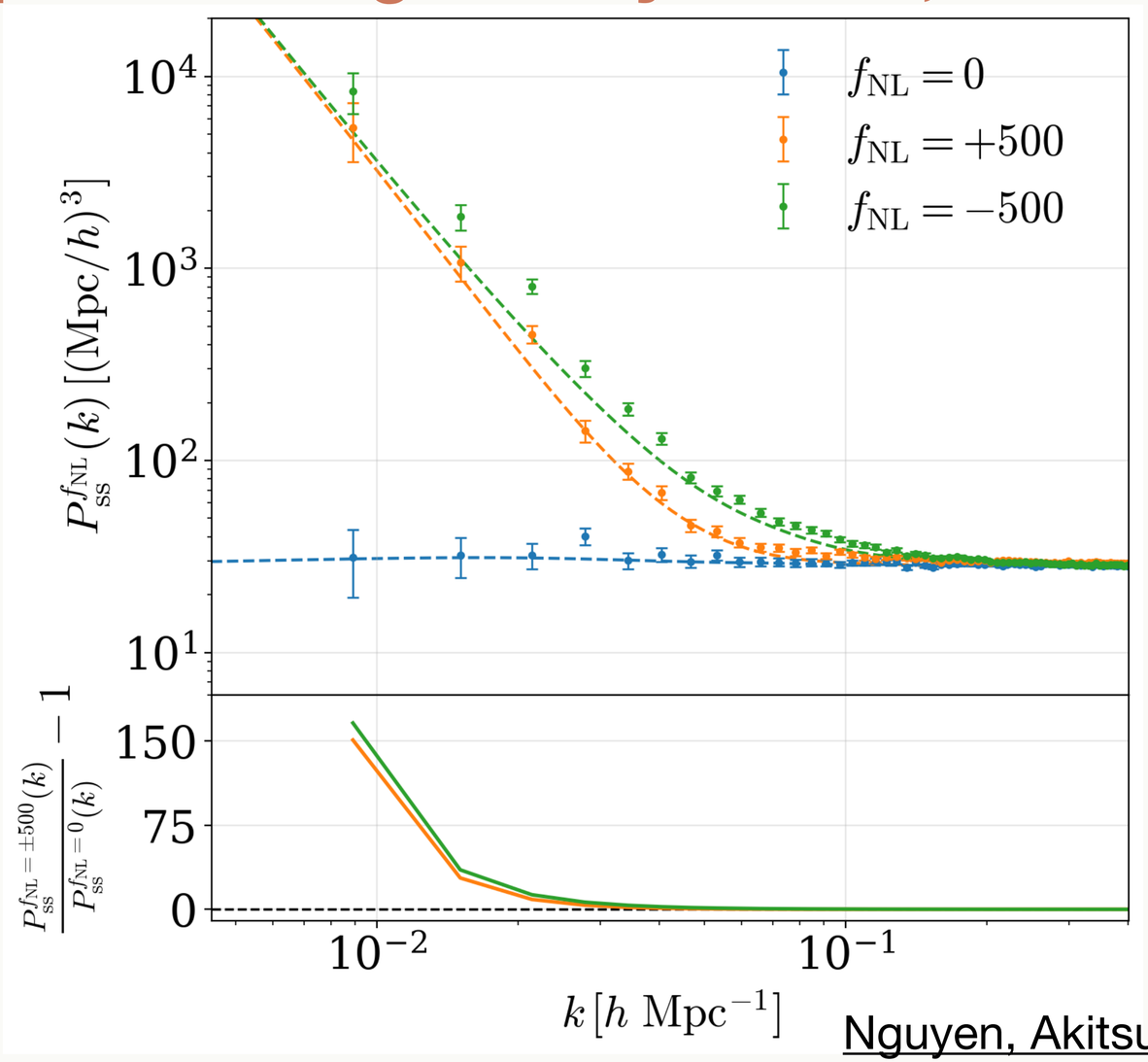


$$\delta_s = b_s \delta_m$$

$$P_{ss} = b_s^2 P_{mm} + P^s_{\text{shot}}$$

Galaxy sizes as LSS zero-bias tracers

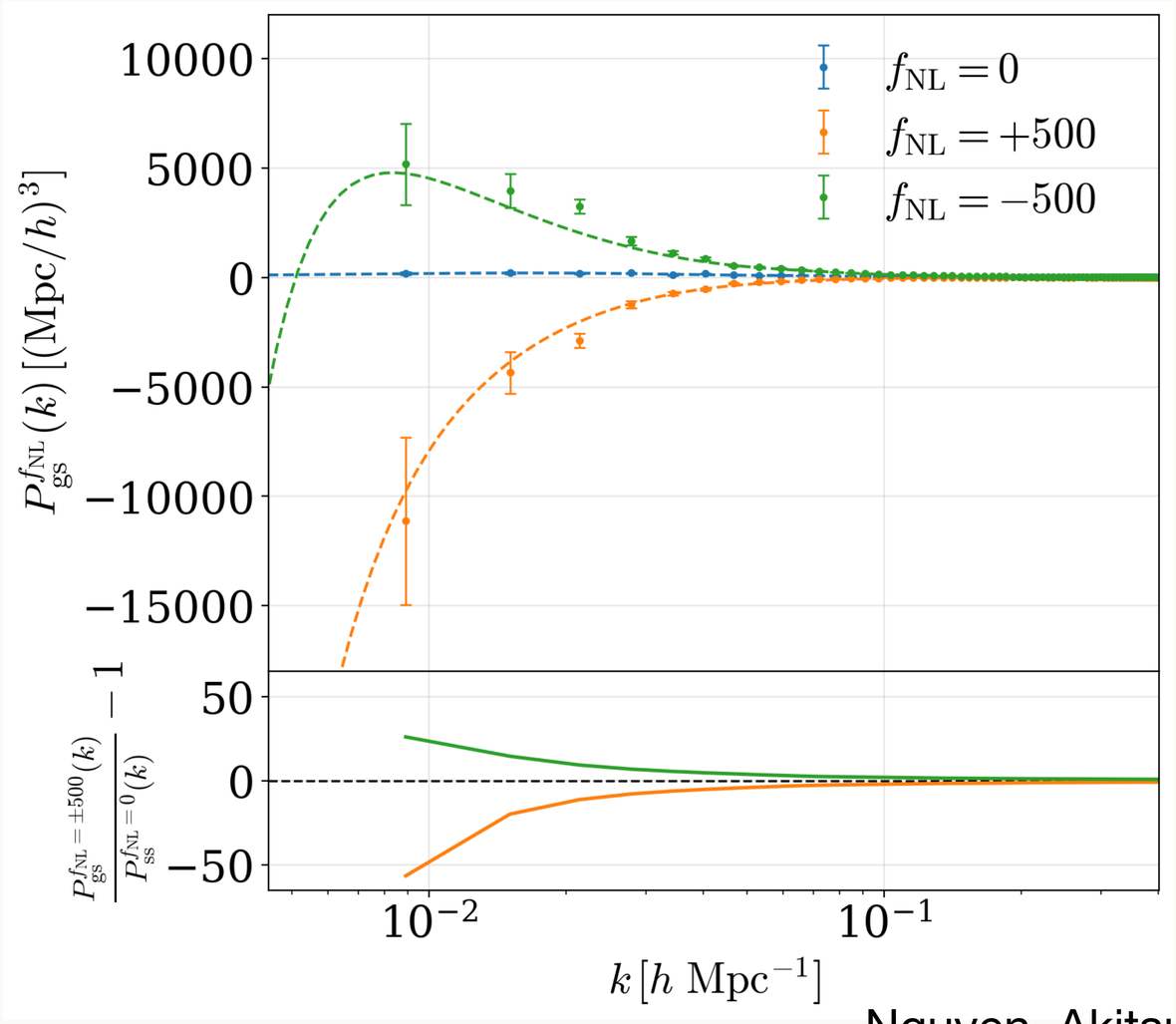
Galaxy sizes respond to long density modes, but weakly



Nguyen, Akitsu, Taruya, PRD (2026)

Galaxy size scale-dependent bias

Galaxy sizes respond to long-short mode coupling, but opposite

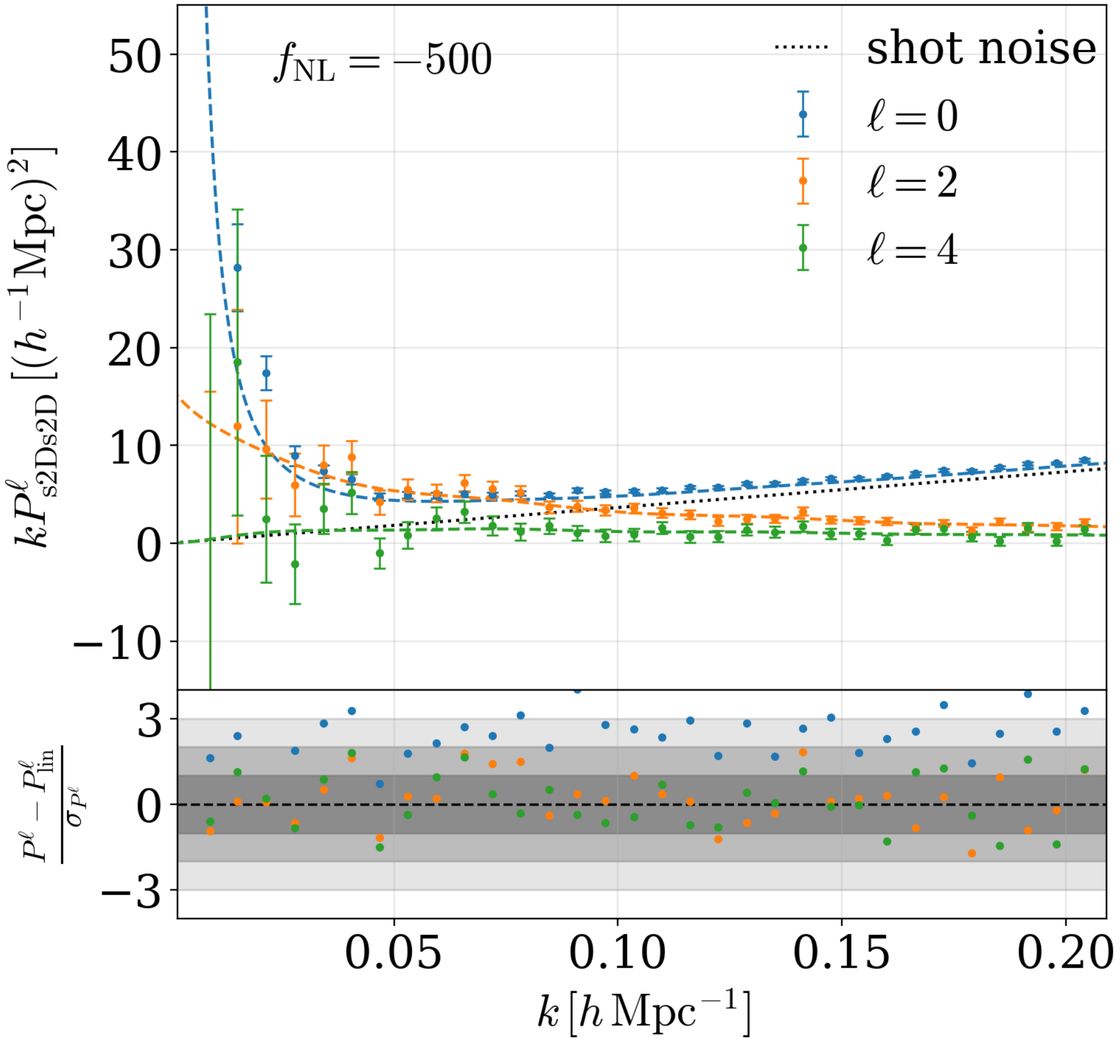


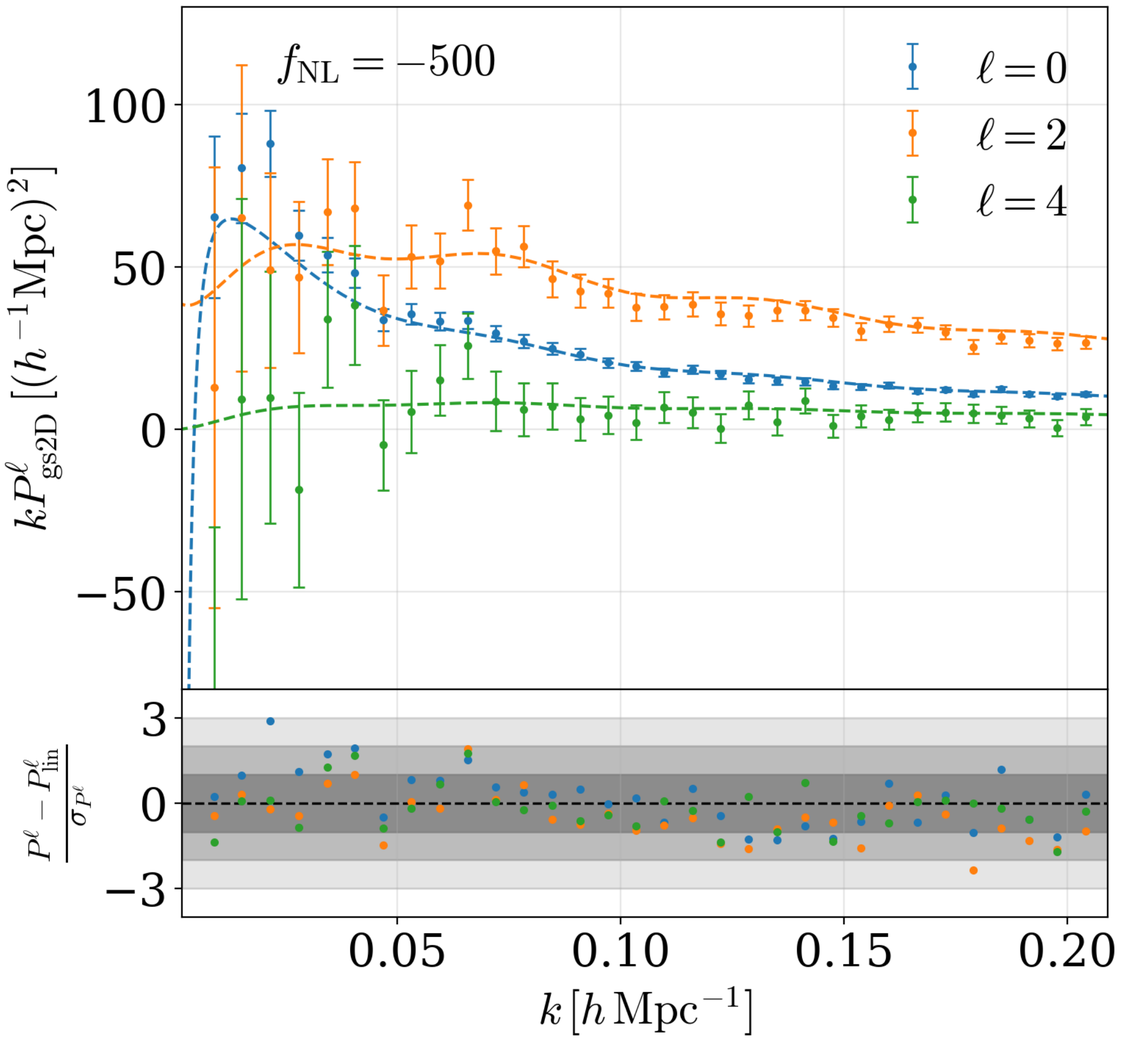
Nguyen, Akitsu, Taruya, PRD (2026)

Observational effects

Line-of-sight projection and redshift-space distortion

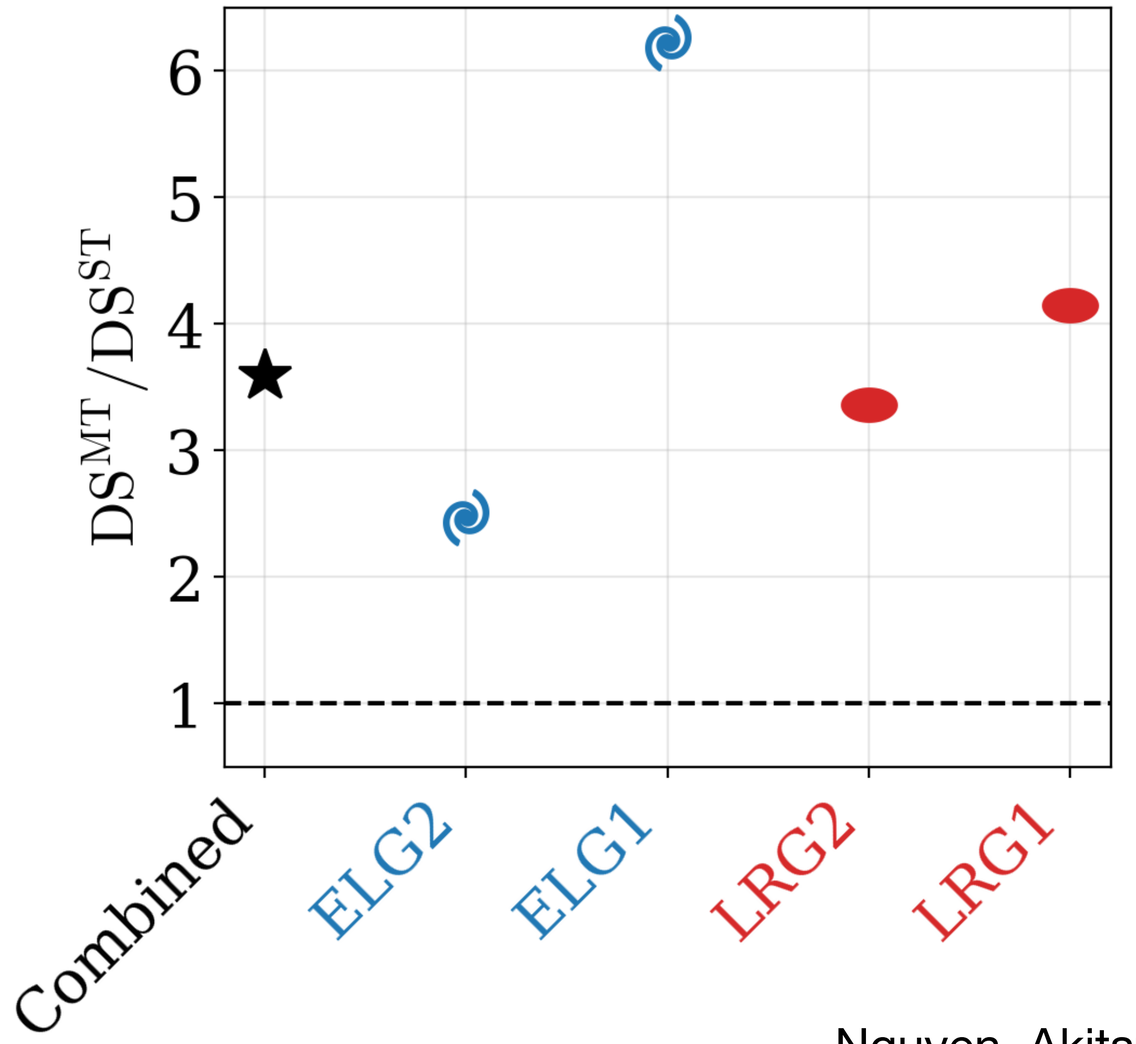
Nguyen, Akitsu, Taruya, PRD (2026)





Multitracer forecast for DESI

Galaxy sizes and counts together form a natural multitracer setup



Nguyen, Akitsu, Taruya, PRD (2026)

Observational systematics

What I still worry about (and try to work out)

- Halo-galaxy size correlation - galaxy formation and evolution physics
- Baryonic feedback and star formation - gas physics
- Size measurement systematics - PSF, blending, etc.

Summary and Outlook

Stop worrying about galaxy non-universality and b_ϕ

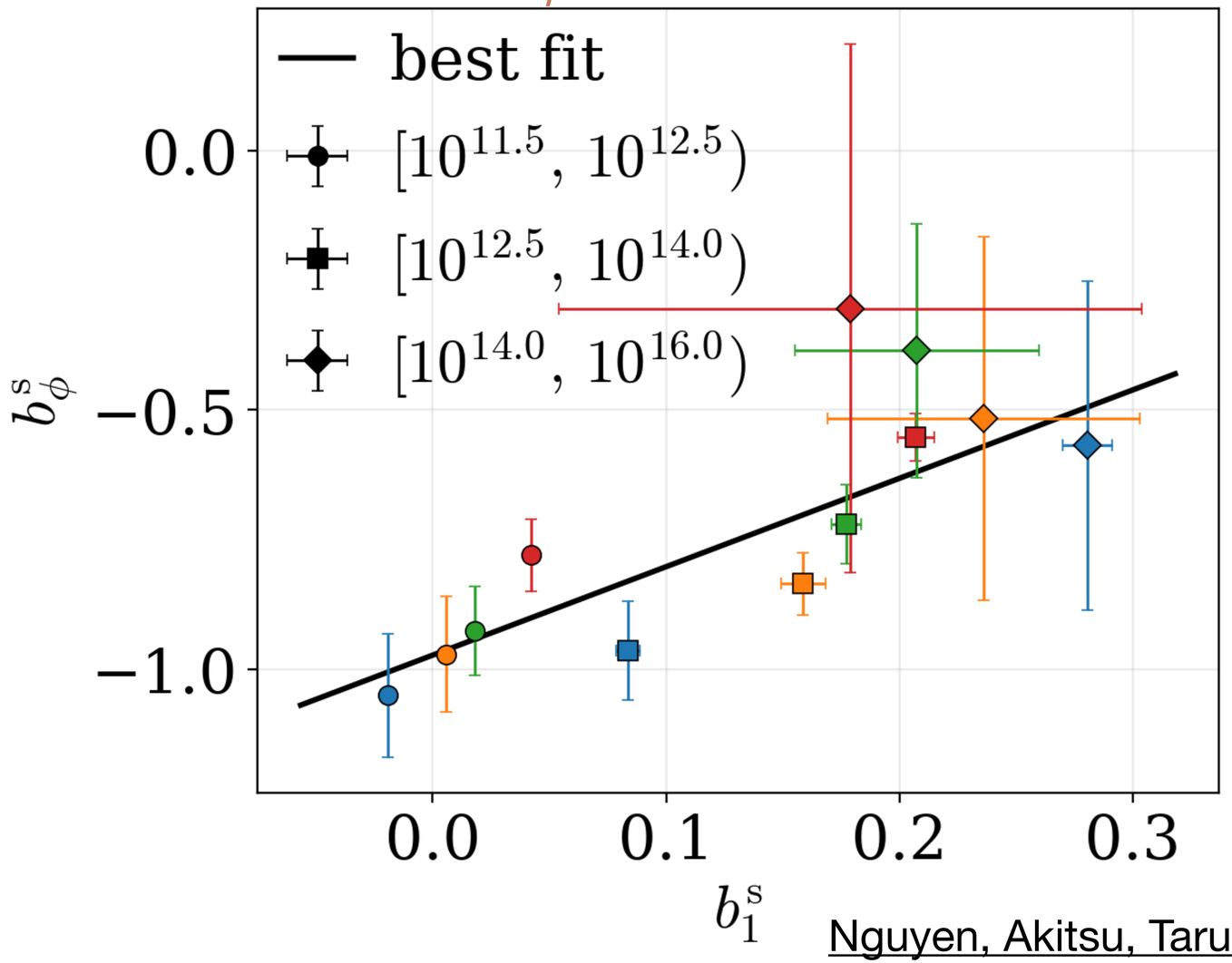
- Galaxy sizes naturally augment the LSS observable data vector
- Galaxy sizes respond to long-wavelength density modes (Gaussian response) and potential modes (non-Gaussian response) different from galaxy count
- Galaxy sizes therefore complement galaxy count (and galaxy shapes) in multitracer constraint of isotropic (and anisotropic) local PNG
- Measurements aren't trivial but data already available and will only improve
- Worth to think about other galaxy properties as LSS biased tracers?

Questions? Comments welcome! nhat.minh.nguyen@ipmu.jp

Supplementary Materials

Galaxy size (non)universality

Empirical relation between b_1^s and b_ϕ^s



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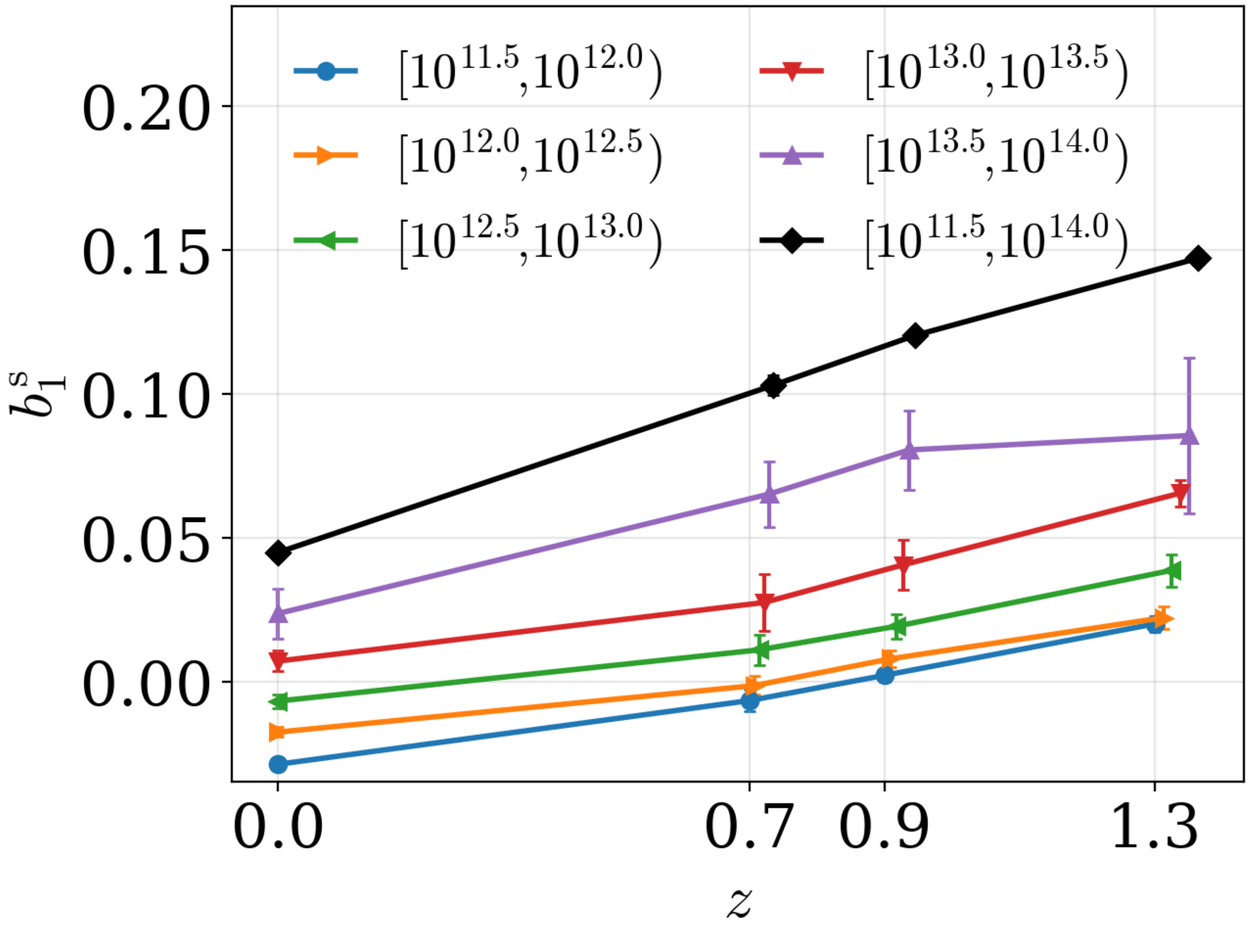
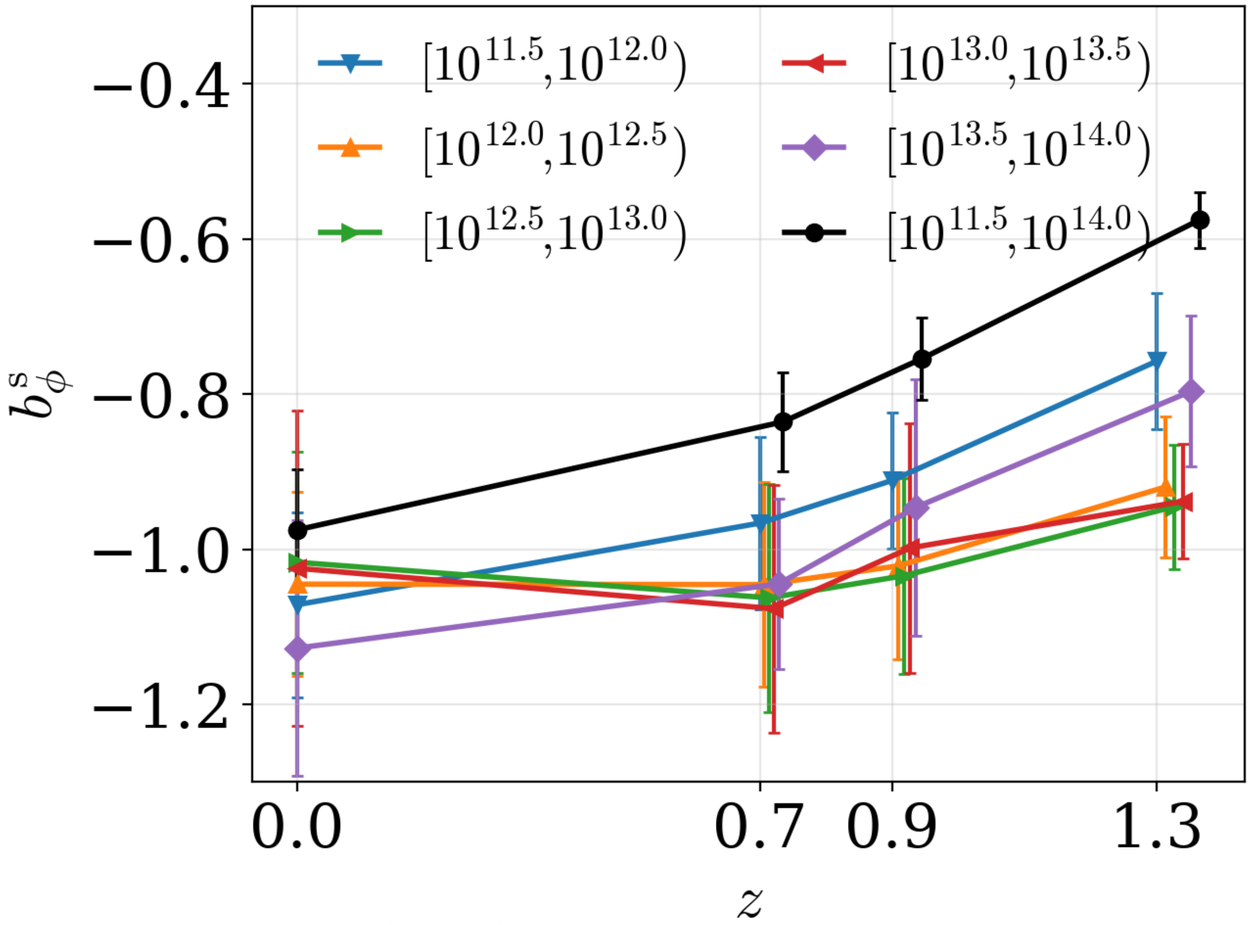
Redshift and mass bin trends





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