

The lack of PNG response of zero-bias tracers

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Abstract: Constraining Primordial Non-Gaussianities (PNG) is one of the main goals of new generation large-scale galaxy surveys. It had been proposed that unclustered tracers (with bias $b_1 = 0$) selected in bins of local overdensity could be optimal for PNG studies. Our goal is to test this hypothesis in realistic PNG N -body simulations. For that, we used state-of-the-art simulations from the PNG-UNITsim suite with local $f_{\text{NL}} = 100$. We classify halos by their local density (δ_R) and measure the linear bias (b_1) and PNG-response (b_ϕ). This allows to identify bias-zero, as well as negative and highly positive bias tracers. However, all of them show a PNG-response compatible with $b_\phi = 0$, making them inviable tracers to constrain PNG.

Introduction

- Halos are biased tracers, as they form in overdense DM regions. The relationship between δ and $P(k)$ for halos and DM is given by:

$$\begin{aligned} \delta_g &= b \delta_m \\ P_{gg} &= b^2 P_{mm} \\ P_{gm} &= b P_{mm} \end{aligned} \quad (1)$$

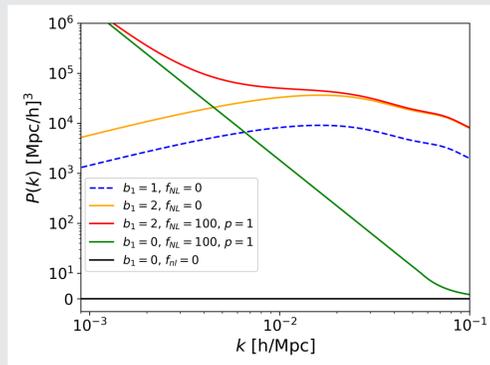


Fig. 1: Theoretical power spectra for DM (blue), a biased tracer in a Gaussian Universe (yellow), a biased universal tracer in a non-Gaussian Universe (red), an unclustered but universal tracer (green) and an unclustered and non-PNG responsive tracer (black).

- Contributions to the bias [1][2]:

$$\begin{aligned} b(k) &= b_1 + b_\phi f_{\text{NL}} \mathcal{M}^{-1}(k) \\ b_\phi &= 2\delta_c(b_1 - p) \end{aligned}$$

Universality Relationship when $p=1$

- f_{NL} encodes the presence of Primordial non-Gaussianities (PNGs).

- Zero-bias tracers have been proposed to have minimal variance of f_{NL} [3]:

$$\sigma_{f_{\text{NL}}}^{-2} \propto \frac{b_1^2(b_1 - p)\mathcal{M}^{-2}(k)P^2(k, z)}{(b_1^2 P(k) + \frac{1}{n})^2} \quad (3)$$

- Local overdensity classification has proven to be able to obtain such zero-bias tracers in simulations with Gaussian ICs [3]. The goal of this study is to test the viability of these tracers to constraint PNG. For that, we use state-of-the-art PNG simulations from the PNG-UNITsim suite, including a $f_{\text{NL}} = 0$ and a $f_{\text{NL}} = 100$ simulation [4].

Discussion

- We have found that the local halo overdensity classification is not capable of detecting a PNG signal, as we obtain values compatible with $b_\phi = 0$. This also rules out this classification method as optimal (as was suggested by Castorina *et al.* [1]), since the Universality Relationship is not satisfied.
- An alternative analysis based on a mixed classification (first binning in mass and then subdividing by overdensity) has been carried out, which exhibits some PNG-response for high masses, but still lower than universal tracers ($p = 1$).
- A strong deviation ($\times \mathcal{O}(10)$) from Poissonian shotnoise has been found. Treating the shotnoise as a free parameter (A_{sn}) in our fits greatly improves the consistency between auto- and cross-correlation.
- The fit parameters for halos with $b_1 \sim 0$ in autocorrelation are degenerate. We find some residual clustering, probably due to higher-order terms, which is absorbed in the bias, making it difficult to find bias zero in the auto-correlation.
- For HODs, the results still appear consistent with $b_\phi = 0$.

Final conclusions

We have proven that local halo density classification is not optimal for the detection of PNGs, as the Universality Relationship is not met, and therefore the proposal made by Castorina *et al.* (see equation 3) is not valid.

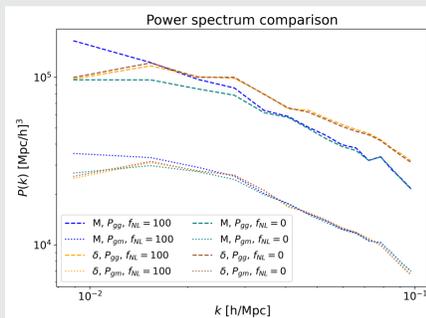


Fig. 5: Comparison of P_{gg} and P_{gm} between mass and δ_R classification, for simulations with $f_{\text{NL}} = 0$ and $f_{\text{NL}} = 100$. Bins of mass and δ_R with similar value of b_1 have been chosen for the comparison. The difference between $f_{\text{NL}} = 0$ and $f_{\text{NL}} = 100$ is clear in the mass classification, but it does not appear when classifying halos by δ_R .

Methods and Results

- Halos are classified according to their local overdensity, defined as $\delta_R = \frac{n_R}{\bar{n}} - 1$, with $R = 8 \text{ Mpc h}^{-1}$. Local overdensity classification allows to obtain zero-bias tracers: less dense zones \rightarrow negative bias, more dense zones \rightarrow positive bias (see figure 2).
- Power spectra are computed for each δ_R bin, and bias is determined through a fit to the expressions given in equations 1 and 2.
- Plotting b_1 as a function of δ_R , we recover zero-bias halos (see figure 3).
- Plotting b_ϕ as a function of b_1 , we obtain our main result. That is, local density classification is not able to detect PNG, as for all halos we obtain values compatible with $b_\phi = 0$.

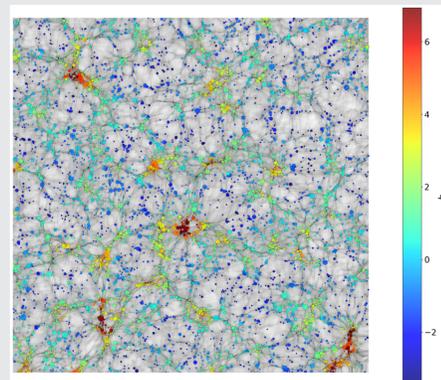


Fig. 2: Distribution of halos over DM density, with dot size proportional to halo mass, for UNIT simulation with $f_{\text{NL}} = 0$. In color, their respective value of b_1 obtained through the fit in δ_R bins.

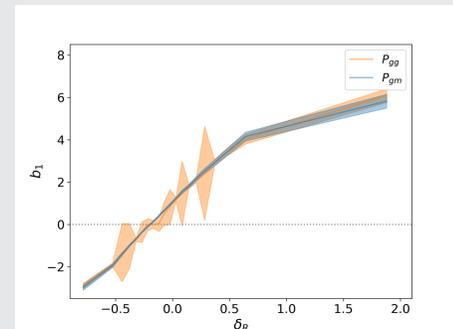


Fig. 3: b_1 as a function of δ_R for the PNG-UNIT simulation with $f_{\text{NL}} = 100$. We recover the presence of zero-bias halos.

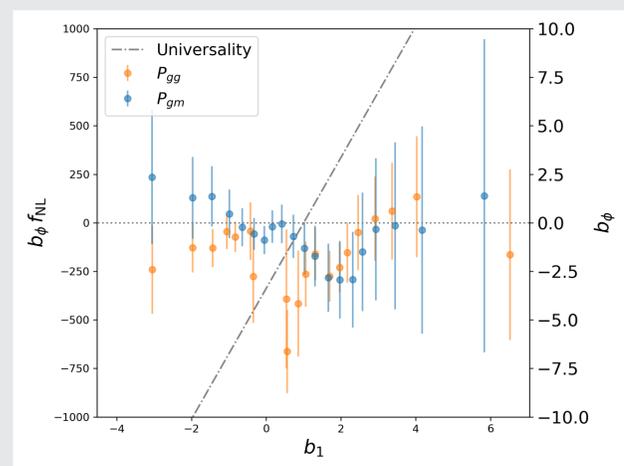


Fig. 4: b_ϕ as a function of b_1 for the PNG-UNIT simulation with $f_{\text{NL}} = 100$. The obtained results are compatible with a value of $b_\phi = 0$, i.e., no PNG signal is detected with the local overdensity classification. For autocorrelation, the region $b_1 \sim 0$ presents a discontinuity, caused by a degeneration in fit parameters.

References

- [1] Slosar, et al. *Journal of Cosmology and Astroarticle Physics* **2008** (08), 031
- [2] Dalal, et al. *Physical Review D* **77** (2008)
- [3] Castorina, et al. *Physical Review Letters*. **121** (2018)
- [4] Adame, et al. *A & A* **689**, A69 (2024)