Large Scale Systematics in measurement of Local Primordial Non-Gaussianity using SPHEREx

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[1]Work in progress with Marilena Loverde, Matthew McQuinn and Thejs Brinckmann

Local Primordial Non-Gaussianity and Scale dependent bias

Local primordial non-gaussianity makes the galaxy bias scale dependent out to arbitrarily large distance scales:

$$\Delta b_g \propto \frac{f_{NL}}{k^2}$$

Can only have a primordial origin - hence the promise of surveys like SPHEREx ($k_{min} = 0.001$ h/Mpc)

Non-primordial, horizon-scale effects can however impact measurement of f_{NL}^{local} !

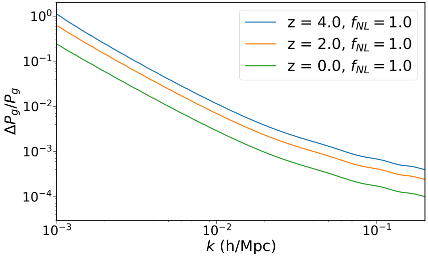

Figure: Fractional change in galaxy power spectrum due to local $f_{NL} = 1$

Effect of free-streaming neutrinos/radiation

Galaxy bias at near-horizon/larger scales is suppressed as compared to galaxy bias at smaller scales (Chiang et al. 2018; Shiveshwarkar, Jamieson, and Loverde 2021)

$$\frac{b_L(k)}{b_L(k_{\max})} \rightarrow \text{constant} < 1.; \;\; k \rightarrow 0$$

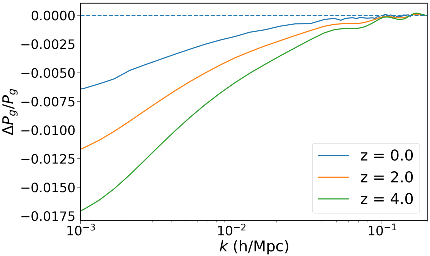

Figure: Fractional change in galaxy power spectrum due to three neutrinos each with mass 0.02 eV.

Although a small effect, the scale dependence in the galaxy bias due to free-streaming neutrinos/radiation becomes more important for intermediate scales $k \geq 0.01$ h/Mpc and at higher redshifts.

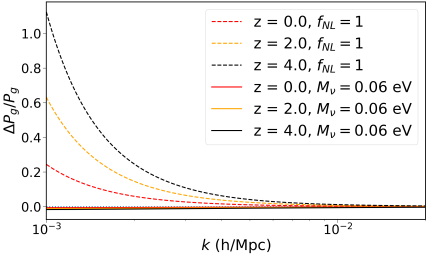

Figure: Effect of neutrinos and $f_{NL} = 1$ on galaxy power spectrum

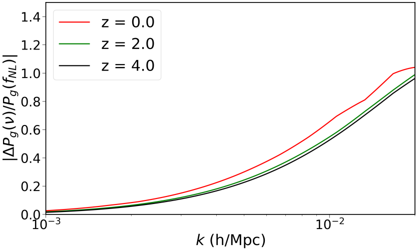

Figure: Relative effect of neutrinos w.r.t effect of $f_{NL} = 1$

Effect of Ionising Radiation Fluctuations

Fluctuations in the ionising radiation background affect galaxy number density fluctuations through their effect on the cooling rate of gas in dark matter halos

$$\delta_g = b_g \delta_m - b_J \delta_J \quad (1)$$

$$P_g = P_{mm} \left(b_g - b_J \frac{P_{mJ}}{P_{mm}} \right)^2 + b_J^2 P_{Jshot} \quad (2)$$

$-b_J$ encodes the response of the cooling rate of gas in dark matter halos to ambient fluctuations in the ionising radiation background δ_J. Any reasonable value for b_J is $\lesssim 0.1$(Sanderbeck et al. 2019)

Effect of ionising radiation fluctuation on the galaxy power spectrum becomes more important at high redshifts and intermediate length scales.

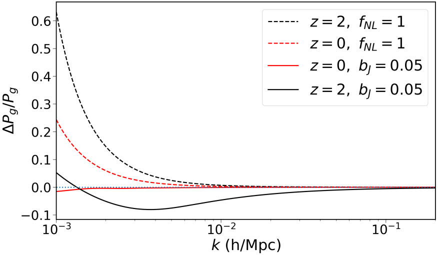

Figure: Effect of ionising radiation fluctuations $b_J = 0.05$ and $f_{NL} = 1$ on P_g

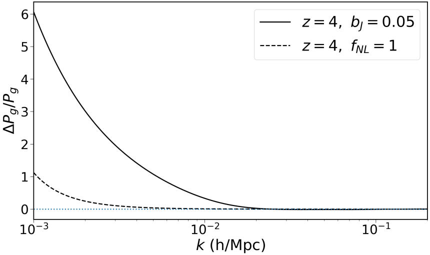

Figure: Effect of ionising radiation fluctuations $b_J = 0.05$ and $f_{NL} = 1$ on P_g

Effect of neutrinos/radiation on measurement of f_{NL}

We construct a SPHEREx likelihood and study how MCMC/Fisher forecasts for f_{NL} obtained using MontePython(Brinckmann and Lesgourgues 2019) are affected by the inclusion/exclusion of the aforementioned large scale effects.

Without neutrino/radiation and ionising radiation effects : $\sigma(f_{NL}) = 0.85$ around $f_{NL} = 1$ (MCMC constraint) which is consistent with Fisher matrix analysis in (Doré et al. 2014).

Marginalising over the effect of scale dependent bias caused by three degenerate neutrinos ($M_\nu = 0.06$ eV) yields $\sigma(f_{NL}) = 0.86$

Not including the effect of neutrinos in modelling the galaxy power spectra may however bias $\langle f_{NL} \rangle$ w.r.t fiducial $f_{NL} = 1$

$$\langle f_{NL} \rangle (\text{unbiased}) = 1.03$$

$$\langle f_{NL} \rangle (\text{biased}) = 0.861$$

$\Delta f_{NL} < 0$ because the free-streaming of neutrinos suppresses the galaxy bias on larger scales compared to the bias at smaller scales.

For three degenerate neutrinos with total mass $M_\nu = 0.06$ eV, $\Delta \langle f_{NL} \rangle = -0.17 \approx -0.2\sigma$

Effect of ionising radiation fluctuations on measurement of f_{NL}

We study how ionising radiation fluctuations affect the forecast of f_{NL} for individual galaxy samples of SPHEREx.
We consider two galaxy samples -

- sample 1 :$\sigma(f_{NL}) = 3.85$ (most constraining)
- sample 2 :$\sigma(f_{NL}) = 1.16$ (least constraining)

Marginalising over b_J increases $\sigma(f_{NL})$ of a single galaxy sample by around 40% - result obtained by Fisher analysis in (Sanderbeck et al. 2019). Imposing a reasonable prior on the intensity bias b_J ($\sigma(b_J) \lesssim 0.1$) however does not significantly worsen the Fisher forecast

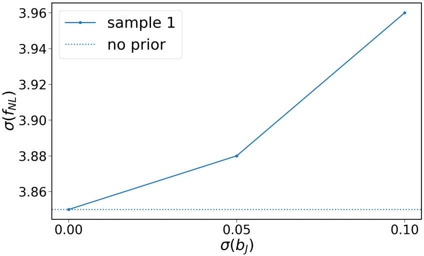

Figure: $\sigma(f_{NL})$ for priors on b_J : $\sigma(b_J) = 0.0, 0.05, 0.1$

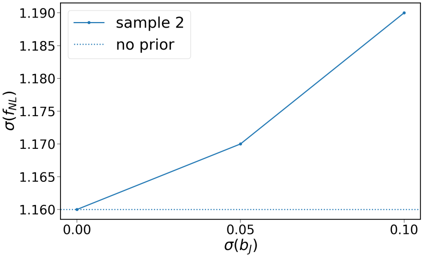

Figure: $\sigma(f_{NL})$ for priors on b_J : $\sigma(b_J) = 0.0, 0.05, 0.1$

Ignoring the effect of ionising radiation fluctuations in modelling the galaxy power spectrum can however lead to a more significant bias in $\langle f_{NL} \rangle$

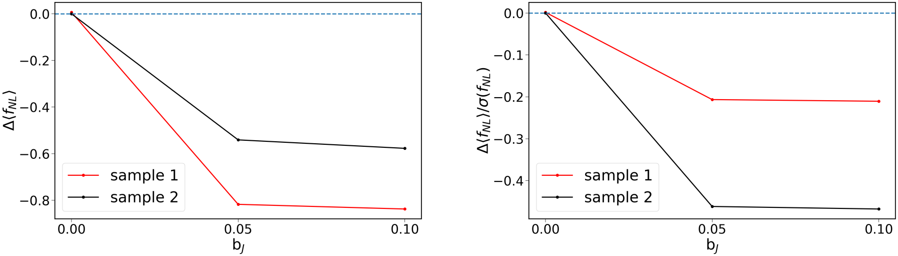

Figure: Bias in $\langle f_{NL} \rangle$ due to ignoring fixed $b_J = 0.05, 0.1$

Figure: Relative bias in $\langle f_{NL} \rangle$ due to ignoring fixed $b_J = 0.05, 0.1$

While $\Delta f_{NL} \sim -0.2\sigma$ for sample 1, it can be as large as $\Delta f_{NL} \sim -0.46\sigma$ for sample 2.

Conclusion

The scale dependent bias caused by neutrinos does not significantly weaken constraints on f_{NL} as long as it is accounted for in modelling the galaxy power spectrum. Otherwise one may obtain a value of f_{NL} biased by -0.2σ (possibly higher for larger M_ν).

Marginalising over b_J may not increase $\sigma(f_{NL})$ if one imposes reasonable priors on b_J.

Not including the effect of ionising radiation fluctuations in modelling the galaxy power spectrum can lead to a bias in measurement of f_{NL} as large as $\Delta f_{NL} \sim -0.46\sigma$.