Lifting primordial non-Gaussianity above the noise

Based on [YW, van der Woude, Pajer, arXiv:1605.06426]

Motivation

Are we able to constrain primordial non-Gaussianity with LSS surveys
at the level $\sigma\left(f_{NL}\right)\sim 1$?

Our focus: how much does the EFT of LSS help us to improve the constraints?
More accurate description bispectrum, but new free parameters.

We focus exclusively on the matter bispectrum.

(i.e. no galaxy bias, redshift space distortions)

Matter bispectrum

In short, the parametrization for the matter bispectrum is given by:

– Gaussian + non-Gaussian terms

– SPT + EFT contributions (we go to 1-loop order)

$$\boxed{B^{th} = B^{G}_{SPT} + B^{G}_{EFT} + f_{NL}\left(B^{NG}_{SPT} + B^{NG}_{EFT}\right)}$$

Matter bispectrum

Free parameters in the matter bispectrum

The parameter we
are interested in:
Amplitude of PNG

$$B^{th} = B^{G}_{SPT} + B^{G}_{EFT} + f_{NL}\left(B^{NG}_{SPT} + B^{NG}_{EFT}\right)$$

$$\xi B^{G}_{\xi} + \Sigma_i \epsilon_i B^{G}_{\epsilon_i}$$

$$\xi B^{NG}_{\xi} + \Sigma_i \gamma_i B^{NG}_{\gamma_i}$$

The EFT provides a more accurate
description of the bispectrum,
but introduces nuisance parameters

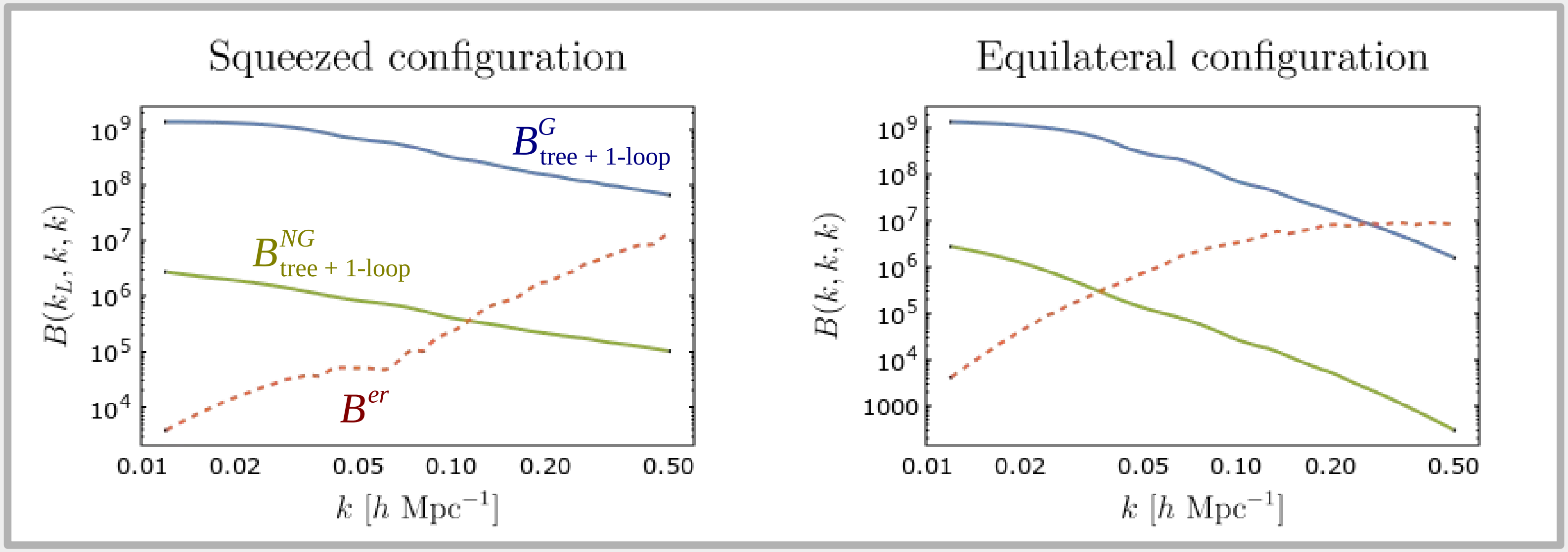
[Baldauf, Mercolli, Mirbabayi, Pajer 2014
Angulo, Foreman, Schmitfull, Senatore, 2014
Assassi, Baumann, Pajer, YW, van der Woude, 2015]

Theoretical error

There is always an *intrinsic error* in perturbation theory: $\boxed{B^{true} = B^{th} + B^{er}}$

Its estimated size $B^{er} = B_{332}$ (estimate for $B^{G}_{\text{2-loop}}$) tells us at what scale k_{max} it becomes comparable to the NG-bispectrum and where we should stop.

However, k_{max} is *configuration dependent* (ánd f_{NL} *– dependent*)



Theoretical error

There is always an *intrinsic error* in perturbation theory: $\boxed{B^{true} = B^{th} + B^{er}}$

Its estimated size $B^{er} = B_{332}$ (estimate for $B^{G}_{2\text{-loop}}$) tells us at what scale k_{max} it becomes comparable to the NG-bispectrum and where we should stop.

However, k_{max} is *configuration dependent* (ánd f_{NL}– *dependent*)

We do not want to stop at a fixed k_{max} for each fiducial value of f_{NL}!

To parametrize the higher order corrections, we introduce nuisance parameters in the bispectrum. These should allow for any smoothly varying function of similar size as B^{er}. Marginalizing over them leads to converging errorbars.

$$\boxed{B^{true}(\bar{k}) = B^{th}(\bar{k}) + n(\bar{k})\, B^{er}(\bar{k})}$$

[Baldauf, Mirbabayi, Simonovic, Zaldarriaga, arXiv:1602.00674]

Take care: shape of ansatz

Effects of integrating out theoretical error on chi-squared test for f_{NL}

Setup

We generate fake data without PNG, and with some higher order corrections:

$$B^{\text{data}} = B^{G}_{\text{tree}} + E_b + \text{cosmic noise}$$

Theoretical model bispectrum + ansätze theoretical error (different shape!)

$$B^{\text{theory}} = f_{NL} B^{NG}_{\text{tree}} + B^{G}_{\text{tree}} \quad + \quad B^{\text{er}} = \alpha\, B_{332} \neq E_b$$

Fit to data

Equals 0, 1 and 10

Some configurations more pessimistic, others more optimistic

Method

We fit the theory to data with a chi-squared analysis.

For each choice of α we determine k_{max} by the p-value:

If $\text{p-value} > 0.99$ or $\text{p-value} < 0.01$ we stop.

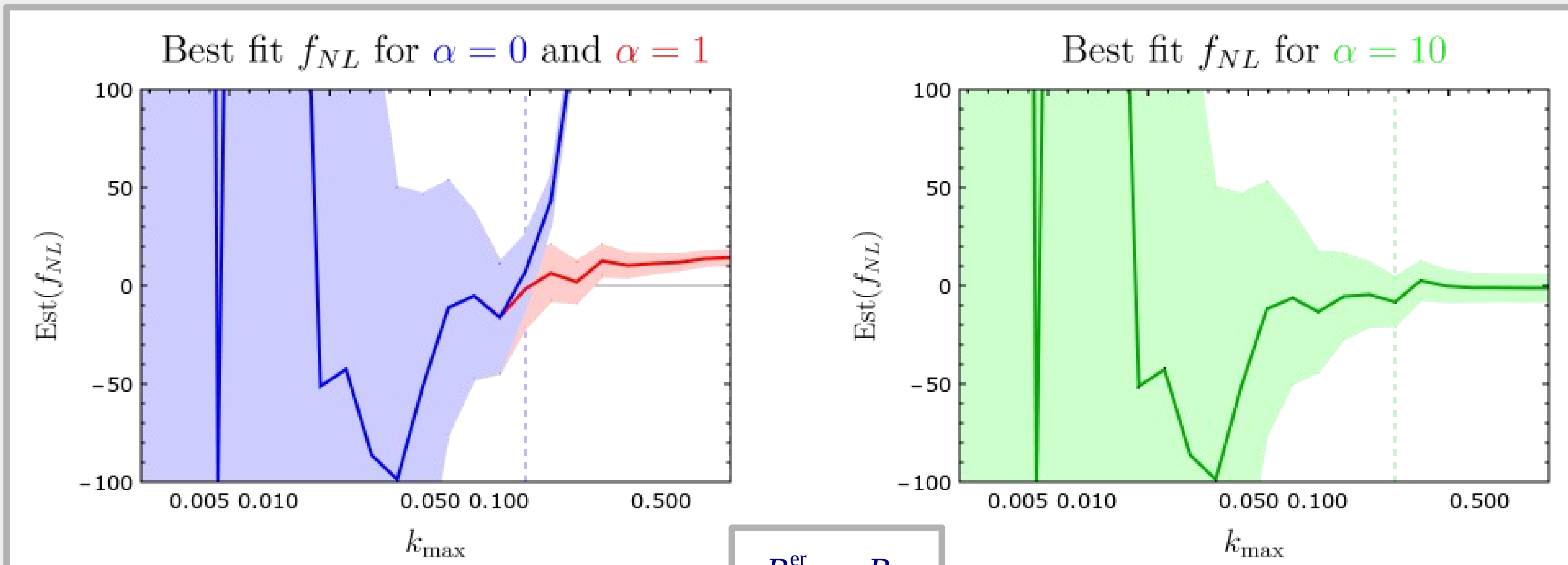
Take care: shape of ansatz

Effects of integrating out theoretical error on chi-squared test for f_{NL}

Conclusion

Integrating out the theoretical error gives sharper errorbars

BUT: assuming the *wrong shape* for the theoretical error might lead to a *false detection* of primordial non-Gaussianity



$$B^{er} = \alpha\, B_{332}$$

Main results

EFT *improves* constraints

Fisher analyis

Specs Euclid (redshift range and shotnoise) + priors $\sigma(\xi)=1$ and $\sigma(\gamma_i,\epsilon_i)=10$

To study how much the EFT helps us constraining PNG

$$B^{th} \subseteq B^{G}_{SPT} + B^{G}_{EFT} + f_{NL}\left(B^{NG}_{SPT} + B^{NG}_{EFT}\right)$$

$$B^{er} = B_{332} + \text{all neglected terms}$$

(subset full 1-loop matter bispectrum)

.

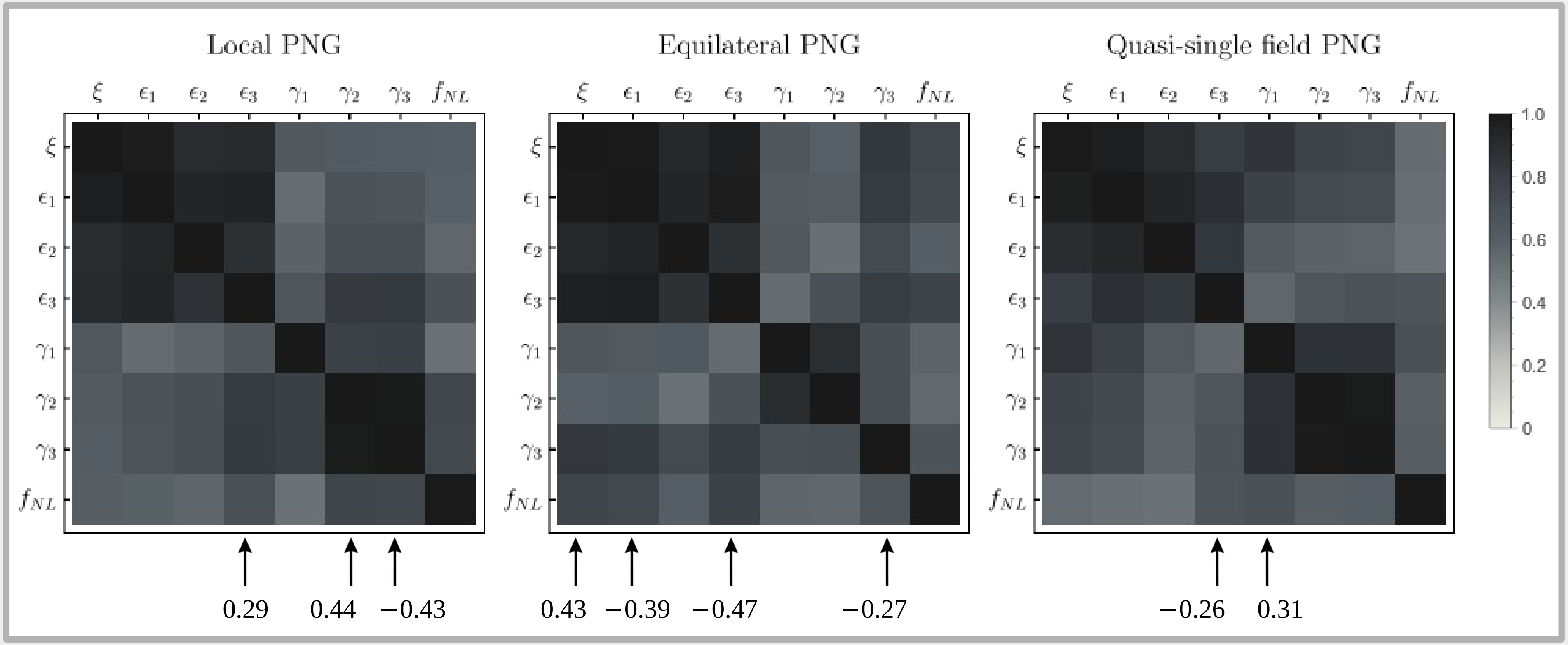
Results

Approach	$\sigma(f_{NL}^{\rm loc})$	$\sigma(f_{NL}^{\rm eq})$	$\sigma(f_{NL}^{\rm qsf})$
EFT (G+NG)	1.77	11.37	8.92
EFT G+SPT NG	1.78	11.37	8.92
SPT (G+NG)	6.11	27.61	21.76
SPT (G+NG tree)	7.17	30.58	24.23

- EFT *improves* constraints with a factor of about 3
- The NG counterterms do not help (unfortunately)
- The SPT 1-loop contribution should be included

Why? Shapes are sufficiently *distinct*

Plot correlation coefficients $r_{ij} = \frac{\sigma_{ij}^2}{\sigma_i \sigma_j}$ without priors on EFT parameters



The EFT contributions to the bispectrum are *sufficiently distinct* from the PNG contributions

Discussion

Interpretation errorbars (galaxy bias and redshift space distortions)
– Lower bound for equilateral (and quasi-single field?)
– Modeling matter bispectrum for local PNG is already at level of sigma~1

Possible improvements..?
– Include cross-correlations between redshift bins (work in progress)
– Compute two loop matter bispectrum
– Joint analysis of:
    multiple LSS surveys
    multiple observables
– Join forces with N-body simulations
– Optimized survey to reduce shot noise

Thanks!

[YW, van der Woude, Pajer, arXiv:1605.06426]