

DETECTABILITY OF THE EFFECT OF INFLATIONARY NON-GAUSSIANITY ON HALO BIAS

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ABSTRACT

We consider the description of the clustering of halos for physically motivated types of non-Gaussian initial conditions. In particular, we include non-Gaussianity of the type arising from single-field slow roll, multifields, curvaton (local type), higher-order derivative type (equilateral), vacuum-state modifications (enfolding type), and horizon-scale GR corrections type. We show that large-scale halo bias is a very sensitive tool for probing non-Gaussianity, potentially leading, for some planned surveys, to a detection of non-Gaussianity arising from horizon-scale GR corrections. In tandem with cosmic microwave background constraints, the halo bias approach can help enormously to discriminate among different shapes of non-Gaussianity and thus among models for the origin of cosmological perturbations.

Key words: galaxies: clusters: general – galaxies: halos – large-scale structure of universe

1. INTRODUCTION

A powerful test of the generation mechanism for cosmological perturbations in the early universe is offered by constraining non-Gaussianity of the primordial fluctuations. The leading theory for the origin of primordial perturbations is inflation: non-Gaussianity is a sensitive probe of aspects of inflation that are difficult to probe otherwise, namely the interactions of the field(s) driving inflation. While standard single-field models of slow-roll inflation lead to small departures from Gaussianity, non-standard scenarios allow for a larger level of non-Gaussianity (Bartolo et al. 2004 and references therein). In particular, large non-Gaussianity can be produced if any of the following conditions is violated: (1) single field, (2) canonical kinetic energy, (3) slow-roll and, (4) adiabatic (Bunch–Davies) initial vacuum state. The standard observables to constrain non-Gaussianity are the cosmic microwave background (CMB) and large-scale structure and in particular their bispectrum (or three-point correlation function), although halo abundance and clustering can offer complementary constraints. It has recently been shown (Linde & Mukhanov 1997; Lyth et al. 2003; Babich et al. 2004; Chen et al. 2007a, 2007b; Holman & Tolley 2008; Langlois et al. 2008; Meerburg et al. 2009) that violation of each of the conditions above produces its own signature in the bispectrum shape (i.e., the dependence on the form of the triangle made by its three wave vectors).

The type of non-Gaussianity arising in standard inflation is of the type (Salopek & Bond 1990; Gangui et al. 1994; Verde et al. 2000; Komatsu & Spergel 2001)

$$\Phi = \phi + f_{\text{NL}}(\phi^2 - \langle \phi^2 \rangle), \quad (1)$$

where Φ denotes Bardeen’s gauge-invariant potential, which, on sub-Hubble scales reduces to the usual Newtonian peculiar gravitational potential, up to a minus sign and ϕ denotes a Gaussian random field. The non-Gaussianity parameter f_{NL} is often considered to be constant, in which case this is called local non-Gaussianity and its bispectrum is maximized for squeezed configurations (where one wave vector is much smaller than

the other two). Non-Gaussianity of the local type is generated in standard inflation (in this case f_{NL} is expected to be of the same order as the slow-roll parameters) and for multi-field models. Note, however, that an expression like Equation (1) is not general and there are many inflationary models that predict different types of deviations from Gaussianity. In general, their non-Gaussianity is specified by their bispectrum. There are some cases where the trispectrum may be important (when, for example, the bispectrum is zero) but in general one expects the trispectrum contribution to be sub-dominant compared to the bispectrum one.

While CMB and large-scale structure can measure the bispectrum shape dependence and thus can in principle discriminate the shape of non-Gaussianity (e.g., Fergusson & Shellard 2008 and references therein) there are also other powerful probes. One technique is based on the abundance (Robinson & Baker 2000; Robinson et al. 2000; Matarrese et al. 2000; Verde et al. 2001; LoVerde et al. 2007; Kamionkowski et al. 2009; Jimenez & Verde 2009) of rare events such as dark matter density peaks as they trace the tail of the underlying distribution. This probe is sensitive to the primordial skewness: the skewness being an integral over all bispectrum shapes, this probe cannot easily discriminate among different shapes of non-Gaussianity.

Recently, Dalal et al. (2008) and Matarrese & Verde (2008) (hereafter MV08) have shown that primordial non-Gaussianity affects the clustering of dark matter halos inducing (in the case of local non-Gaussianity) a scale-dependent bias on large scales. This effect, which goes under the name of non-Gaussian halo bias, is particularly promising, yielding already stringent constraints from existing data (Slosar et al. 2008; Afshordi & Tolley 2008) and, with forthcoming data, offers the potential to rival the constraints achievable from an ideal CMB survey (Carbone et al. 2008). Despite being so promising, this effect has not been extensively considered for non-Gaussianity which is not of the local type. In fact, the derivation of Dalal et al. (2008) and Slosar et al. (2008) can only deal with local non-Gaussianity. Taruya et al. (2008) use a perturbation theory approach and obtain expressions for the local and equilateral type of non-Gaussianity.

On the other hand, the approach of MV08 is general enough to yield an expression for the large-scale non-Gaussian halo bias for any type of non-Gaussianity specified by its bispectrum. Here we explore the effect on the clustering of halos of physically motivated primordial non-Gaussianity different from the local case. We briefly review the local case, and examine equilateral and enfolded types. We then concentrate on a type of non-Gaussianity sourced by inflation and affecting large-scale structures, only arising when considering general-relativistic (GR) corrections to the standard Newtonian treatment. The paper is organized as follows: in Section 2 we briefly review the Matarrese & Verde (2008) description of the non-Gaussian halo bias. In Section 3, we consider physically motivated primordial non-Gaussianity different from the local case and introduce the non-Gaussianity arising from GR corrections. In Section 4, we consider the constraints that planned experiments can place on these non-Gaussianities and present our conclusions.

2. NON-GAUSSIAN HALO BIAS FOR A GIVEN PRIMORDIAL BISPECTRUM

Halo clustering can be modeled by assuming that halos correspond to regions where the (smoothed) linear dark matter density field exceeds a suitable threshold. For massive halos, the threshold is high compared to the field rms. The MV08 approach to non-Gaussian halo bias relies on the fact that the two-point correlation function of regions above a high threshold for a general non-Gaussian field has an analytical expression (Matarrese et al. 1986) that depends on all higher-order (connected) correlations. For most inflationary models the expression can be truncated so that it includes only terms up to the three-point correlation function. With the additional assumptions of small non-Gaussianity and separations that are much larger than the Lagrangian halo radius, MV08 conclude that the halo power spectrum $P_h(k, z)$ is related to the dark matter density field $P(k, z)$ by

$$P_h(k, z) = \frac{\delta_c^2(z)P(k, z)}{\sigma_M^2 D^2(z)} [1 + 2\delta_c(z)\beta(k)]. \quad (2)$$

Here, δ_c is the critical collapse threshold: $\delta_c(z) = \Delta_c(z)/D(z)$, where $\Delta_c(z)$ is the linearly extrapolated overdensity for spherical collapse; it is 1.686 in the Einstein-de Sitter case, while it slightly depends on redshift for more general cosmologies. $D(z)$ is the linear growth factor, which depends on the background cosmology; $\sigma_M \equiv \sigma_R$ is the rms value of the underlying (linear) dark matter fluctuation field at $z = 0$, smoothed on a scale R related to M by $M = \Omega_{m,0}3H_0^2/(8\pi G)(4/3)\pi R^3$, with $\Omega_{m,0}$ denoting the present-day matter density parameter; H_0 is the present-day Hubble parameter, and G is Newton's constant. The effect of non-Gaussianity is enclosed in the function $\beta(k)$ which in this approach is

$$\beta(k) = \frac{\mathcal{G}}{8\pi^2\sigma_R^2\mathcal{M}_R(k)} \int dk_1 k_1^2 \mathcal{M}_R(k_1) \times \int_{-1}^1 d\mu \mathcal{M}_R(\sqrt{\alpha}) \frac{B_\Phi(k_1, \sqrt{\alpha}, k)}{P_\Phi(k)}. \quad (3)$$

Here B_Φ denotes the expression for the primordial bispectrum of the Bardeen potential Φ , and P_Φ its power spectrum. Since in Equation (1) Φ is the primordial potential deep in the matter dominated era, $\mathcal{G} \sim 1.3$ accounts for the fact that the potential evolves in redshift in a non-Einstein-deSitter universe; $\mathcal{M}_R(k)$

is related to the Poisson equation via

$$\delta_R(\mathbf{k}) = \frac{2}{3} \frac{T(k)k^2}{H_0^2\Omega_{m,0}} W_R(k)\Phi(\mathbf{k}) \equiv \mathcal{M}_R(k)\Phi(\mathbf{k}), \quad (4)$$

with $W_R(k)$ being the Fourier transform of the top-hat window function of radius R .

Thus the correction to the standard halo bias due to the presence of primordial non-Gaussianity is

$$\frac{\Delta b_h}{b_h} = \frac{\Delta_c}{D(z)}\beta(k). \quad (5)$$

It is clear that a scale-dependent $\beta(k)$ could in principle give a distinctive detectable signature on the observed power spectrum.

The above expressions were derived under the assumption that non-Gaussianity is a “small” correction to the dominant Gaussian component of the primordial perturbations. An extensive discussion of the limits of this approximation and possible improvement is reported in Carbone et al. (2008); here it will suffice to say that, looking for example at Equation (1), $f_{\text{NL}}\phi^2 \ll \phi$ and since $\phi = \mathcal{O}(10^{-5})$, even for f_{NL} of an order 10^3 (a value that is already observationally excluded anyway) can be considered “small.”

3. INFLATIONARY NON-GAUSSIANITIES

In the local non-Gaussian case, the bispectrum of the potential is given by

$$B_\Phi(k_1, k_2, k_3) = 2f_{\text{NL}}^{\text{loc}}F^{\text{loc}}(k_1, k_2, k_3), \quad (6)$$

where

$$F^{\text{eq}}(k_1, k_2, k_3) = P_\Phi(k_1)P_\Phi(k_2) + 2cyc. \quad (7)$$

Looking at Equation (3), it is easy to write analytically the form for $\beta(k)$, and to compute it for the local non-Gaussian case:

$$\beta^{\text{loc}}(k) = \frac{2f_{\text{NL}}^{\text{loc}}}{\mathcal{M}_R(k)} \frac{\mathcal{G}}{8\pi^2\sigma_R^2} \int dk_1 k_1^2 \mathcal{M}_R(k_1) P_\Phi(k_1) \times \int_{-1}^1 d\mu \mathcal{M}_R(\sqrt{\alpha}) \left[\frac{P_\Phi(\sqrt{\alpha})}{P_\Phi(k)} + 2 \right]. \quad (8)$$

However, in the standard slow-roll inflation, $f_{\text{NL}}^{\text{loc}}$ is expected to be immeasurably small. Inflationary models that can produce larger non-Gaussianity of the local form are those where the fluctuations of an additional light field, different from the inflaton, contribute to the curvature perturbations we observe (see, e.g., Babich et al. 2004), for example, curvaton models (e.g., Sasaki et al. 2006; Assadullahi et al. 2007 and references therein) and multi-field models (e.g., Bartolo et al. 2002; Bernardeau & Uzan 2002).

On the other hand, inflationary models with higher-derivative operators of the inflaton, such as, for example, the DBI model have a different type of non-Gaussianity, whose bispectrum is maximized for k modes of similar scales (equilateral type; Seery & Lidsey 2005; Chen et al. 2007b). The equilateral type of non-Gaussianity can be well described by the following template (Creminelli et al. 2006):

$$B_\Phi(k_1, k_2, k_3) = 6f_{\text{NL}}^{\text{eq}}F^{\text{eq}}(k_1, k_2, k_3), \quad (9)$$

where

$$F^{\text{eq}}(k_1, k_2, k_3) = -P_\Phi(k_1)P_\Phi(k_2) + 2cyc \\ - 2[P_\Phi(k_1)P_\Phi(k_2)P_\Phi(k_3)]^{2/3} \\ + (P_\Phi^{1/3}(k_1)P_\Phi^{2/3}(k_2)P_\Phi(k_3) + 5cyc.). \quad (10)$$

General deviations from the simplest slow-roll inflationary models are likely to have bispectra that are not well described by the two cases above (e.g., Fergusson & Shellard 2008).

Predictions for the primordial bispectrum evaluated in the regular Bunch–Davies vacuum state are of local or equilateral type, depending on whether higher-derivative corrections play a significant role in the inflationary evolution. Non-Gaussianity generated by dropping the assumption that the vacuum is Bunch–Davies (modified initial state non-Gaussianity) is instead maximal for “enfolding” (or “squashed”) configurations (Chen et al. 2007b; Holman & Tolley 2008; Meerburg et al. 2009). The associated bispectrum is a complicated function of the k s that is not easily factorizable, but Meerburg et al. (2009) proposed a factorized enfolding template that captures very well the features of the modified initial-state bispectrum. This enfolding factorizable template is given by

$$B_\Phi(k_1, k_2, k_3) = 6f_{\text{NL}}^{\text{enf}}F^{\text{enf}}(k_1, k_2, k_3), \quad (11)$$

where

$$F^{\text{enf}}(k_1, k_2, k_3) = P_\Phi(k_1)P_\Phi(k_2) + 2cyc \\ + 3[P_\Phi(k_1)P_\Phi(k_2)P_\Phi(k_3)]^{2/3} \\ - (P_\Phi^{1/3}(k_1)P_\Phi^{2/3}(k_2)P_\Phi(k_3) + 5cyc.). \quad (12)$$

While so far we have concentrated on non-Gaussianity generated during or right at the end of inflation, there are other non-Gaussian signals generated after the end of inflation and still before matter domination. One source of non-Gaussianity that has received renewed attention is the second-order evolution of perturbations from inflation to matter domination (Bartolo et al. 2005, 2007; Pillepich et al. 2007; Fitzpatrick et al. 2009). The large-scale structure probes clustering on scales that entered the horizon when radiation was important; for large-scale modes that enter the horizon deep in matter dominated era, no perturbation growth is expected before matter domination so their entire growth history can be modeled in the standard way assuming matter domination. Non-Gaussianity induced by the nonlinear growth of perturbations during radiation dominance, as discussed in Bartolo et al. (2007) and Fitzpatrick et al. (2009), does not affect the non-Gaussian halo bias, as the relevant scales are different ($> 100 \text{ Mpc}/h$ for the halo bias).

On such large scales, there is, however, an additional source of non-Gaussianity, arising from GR corrections on scales comparable to the Hubble radius. This effect was first pointed out by Bartolo et al. (2005), who performed the calculation both in the comoving and Poisson gauges. Fitzpatrick et al. (2009) then extended the calculation to scales that entered the horizon during radiation dominance and recovered the Bartolo et al. (2005) expressions on large scales (those of interest here). A relevant discussion on the issue can be found in Wands & Slosar (2009) and Yoo et al. (2009). In particular, Wands & Slosar (2009) argue that computing the density fluctuation field in the comoving time-orthogonal gauge yields the physical expression needed to compute the large-scale halo bias.

Using the comoving density perturbation at second order in the usual Poisson equation allows us to obtain the GR correction

to the primordial f_{NL} . Indeed, one can easily check (Bartolo et al. 2005) that the resulting expression is unaffected by the presence of constant gauge modes, both at the linear and second-order levels.

With this assumption, we obtain the following expression for the large-scale structure linear-regime bispectrum including GR corrections:

$$B_\Phi(k_1, k_2, k_3) = 2 \left[\frac{5}{3}(a_{\text{NL}} - 1) + f_{\text{NL}}^{\text{infl,GR}}(k_1, k_2, k_3) \right] \\ \times P(k_1)P(k_2) + cyc., \quad (13)$$

where $cyc.$ denotes terms with $\{k_2, k_3, k_1\}$ and $\{k_1, k_3, k_2\}$ and

$$f_{\text{NL}}^{\text{infl,GR}}(k_i, k_j, k_k) = -\frac{5}{3} \left[1 - \frac{5}{2} \frac{k_i k_j \cos \theta_{ij}}{k_k^2} \right] \quad (14)$$

with θ_{ij} denoting the angle between the vectors k_i and k_j . Equation (14) is obtained from Equation (7) of Bartolo et al. (2005) considering the terms that multiply the linear growth factor (thus dropping the Newtonian, gravitational instability terms), setting $a_{\text{nl}} = 1$, and translating to the gravitational potential as usual.

The first term on the right-hand side of Equation (13) is the primordial contribution from standard slow-roll inflation: $|a_{\text{NL}} - 1| \ll 1$, being of the order of the order of the slow-roll parameters (Gangui et al. 1994; Acquaviva et al. 2003; Maldacena 2003). All that follows is the additional effect of interest here. Let us reflect on the meaning of this contribution, which, as Equation (13) shows and because it is a second-order term like the $|a_{\text{NL}} - 1|$ one, adds up to the “intrinsic” non-Gaussianity:

1. The right-hand side of Equation (13) is non-zero even if (strictly speaking) the primordial contribution is zero. Inflationary models different from the standard slow roll would yield a different expression for the first term on the right-hand side as briefly discussed above.
2. The shape of $f_{\text{NL}}^{\text{infl,GR}}$ is peculiar to the inflationary initial conditions in two respects. (i) Perturbations on super-Hubble scales are needed in order to initially feed the GR correction terms. In this respect, the significance of this term is analogous to the well-known large-scale anti-correlation between CMB temperature and E-mode polarization: it is a consequence of the properties of the inflationary mechanism to lay down the primordial perturbations. (ii) Initial conditions arising from standard slow-roll single-field inflation imply that the second-order comoving curvature perturbation, defined as in Salopek & Bond (1990), $\zeta^{(2)} \approx 0$, or equivalently $a_{\text{NL}} - 1 \approx 0$: it is this very fact that leads to the dominance of the GR corrections.

We note that in Equation (31) of Pillepich et al. (2007)⁴ one can find the same quantity calculated in the Poisson gauge. We have numerically verified that using the Poisson-gauge expression the results for the non-Gaussian halo bias are practically unchanged (once the constant, pure gauge, modes appearing in the Poisson-gauge expression are ignored). This is indeed encouraging, as we recover that measurable quantities are gauge independent.

Equation (3) enables us to compute immediately the effect of these four different types of non-Gaussianity on the large-scale

⁴ Note that the Pillepich et al. paper is about the bispectrum of the redshifted 21 cm fluctuations from the dark ages: this bispectrum is present in different large-scale structure tracers.

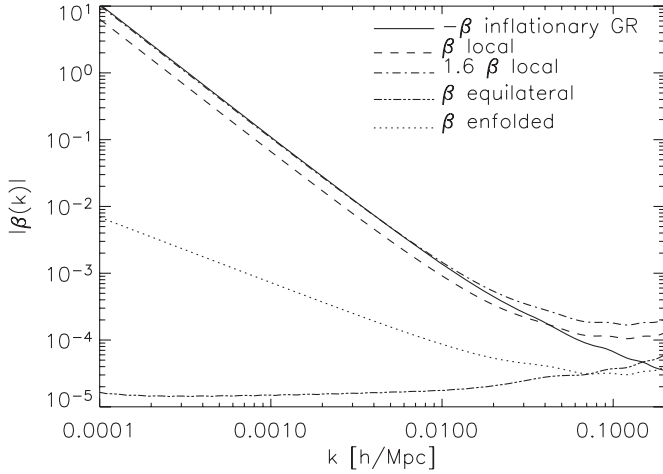


Figure 1. Scale dependence of the large-scale halo bias induced by a non-zero bispectrum, indicated by the β function of Equation (3) for the four types of non-Gaussianity discussed in the text. The solid line shows the absolute value of β for the inflationary, GR correction large-scale structure bispectrum. Note that the quantity is actually negative. The dashed line shows β for the local type of primordial non-Gaussianity for $f_{\text{NL}}^{\text{loc}} = 1$ (the quantity is positive). It is clear that the scale-dependent bias effect due to the inflationary bispectrum mimics a local primordial non-Gaussianity with effective $f_{\text{NL}} \sim -1$ at $k > 0.02h/\text{Mpc}$ and ~ -1.6 for $k < 0.01h/\text{Mpc}$. The dot-dot-dot-dashed line shows the effect of equilateral non-Gaussianity for $f_{\text{NL}}^{\text{eq}} = 1$ and the dotted line shows the enfolded type with $f_{\text{NL}}^{\text{enf}} = 1$.

clustering of halos.⁵ This is the necessary step to be able to quantify their detectability for this observable.

In Figure 1, we show the scale dependence of the halo bias (i.e., the $\beta(k)$ of Equation (5)) generated by the “inflationary,” GR-correction, large-scale structure bispectrum and we compare it with the one for the local-type primordial non-Gaussianity with $f_{\text{NL}}^{\text{loc}} = 1$. On the scales of interest, $\beta(k)^{\text{infl}} \propto \beta(k)^{\text{local}}$ where the proportionality is a factor between -1 and -1.6 . In other words, the scale-dependent bias effect of the inflationary, GR-correction, non-Gaussianity is that of a local non-Gaussianity with $f_{\text{NL}} \simeq -1.6$.

The dot-dot-dot-dashed line shows the effect of equilateral type of non-Gaussianity for $f_{\text{NL}}^{\text{eq}} = 1$, in agreement with the findings of Taruya et al. (2008). The effect for the $f_{\text{NL}}^{\text{enf}} = 1$ enfolded type (which closely describes the effects of a modified initial state) is shown by the dotted line.

4. FORECASTS AND CONCLUSIONS

It is clear from Figure 1 that while local and inflationary non-Gaussianity leave a strongly scale-dependent signature on the halo clustering, equilateral and enfolded types have a much smaller effect. This is not unsurprising: local and inflationary-type primordial non-Gaussianity have strong mode correlations between small and large-scale Fourier modes. For this reason, biasing, a small-scale phenomenon, can affect the power spectrum on very large scales. Equilateral and enfolded types of non-Gaussianity have correlations for modes that are of comparable scales.

Following the calculations presented in Carbone et al. (2008)⁶ (taking into account the calibration on N -body simulations

⁵ Up to small, sub-dominant corrections involving details of the transformation between Lagrangian and Eulerian bias factors.

⁶ Carbone et al. (2008) used the large-scale structure f_{NL} normalization, while here we use the CMB normalization. See Table 1 of Grossi et al. (2009) for the CMB-normalized forecasts.

Table 1
Forecasted Non-Gaussianity Constraints

Type NG	CMB Bispectrum		Halo Bias	
	Planck	(CM)BPoI	Euclid	LSST
1σ errors				
Local	3 ^(A)	2 ^(A)	1.5 ^(B)	0.7 ^(B)
Equilateral	25 ^(C)	14 ^(C)
Enfolded	$\mathcal{O}10$	$\mathcal{O}10$	39 ^(E)	18 ^(E)
$\#\sigma$ Detection				
GR	N/A	N/A	1 ^(E)	2 ^(E)
Secondaries	3 ^(F)	5 ^(F)	N/A	N/A

References. (1) Yadav et al. 2007, (2) Carbone et al. 2008, (3) Baumann et al. 2009; Sefusatti et al. 2009, (4) this work, (5) e.g., Mangilli & Verde 2009.

presented in Grossi et al. 2009) we can forecast what constraints could be achieved from future surveys.

Equilateral type of non-Gaussianity cannot effectively be constrained using the scale-dependent halo-bias effect: the bispectrum of the CMB temperature fluctuations or of the galaxy distribution will be a much more powerful tool in this case. On the other hand, large-scale halo-bias is extremely promising for local and GR types. Forecasts for the local type were presented in Carbone et al. (2008); here we report that a survey of the type of Euclid⁷ can constrain GR corrections type of non-Gaussianity at the 1σ level, while a survey like LSST⁸ could detect this signal at the 2.2σ level. For the enfolded type we obtain that a survey of the type of Euclid can yield a 1σ error of $\Delta f_{\text{NL}}^{\text{enf}} = 39$ while $\Delta f_{\text{NL}}^{\text{enf}} = 18$ for LSST.

These error bars are dominated by cosmic variance and could thus, in principle, be reduced further by a factor of \sim few using the approach proposed by Seljak (2009). This opens up the possibility of detecting the signal from inflationary non-Gaussianity. Should a non-Gaussianity of the GR-correction type (and predicted amplitude) be detected it would mean that (1) initial conditions are of inflationary type and (2) strictly primordial non-Gaussianity is sub-dominant to this contribution (e.g., $f_{\text{NL}}^{\text{loc}} < 1.6$).

Moreover, the big difference in the scale-dependent biasing factor between the classes (equilateral, local, and enfolded) of non-Gaussian models implies that the large-scale halo bias is a very sensitive tool to probe the shape of non-Gaussianity, highly complementary to other approaches.

In Table 1, we show a comparison of the forecasted constraints on different types of non-Gaussianity for a selection of planned experiments for CMB bispectrum and large-scale halo bias.

This table highlights the complementarity of the two approaches. While forecasted constraints for enfolded non-Gaussianity from CMB data are not available, we can estimate that the errors would be in between the equilateral and the local cases. One could thus envision different scenarios.

If non-Gaussianity is local with negative f_{NL} and CMB obtains a detection, then the halo bias approach should also give a high-significance detection (GR correction and primordial contributions add-up), while if it is local but with positive f_{NL} , the halo-bias approach could give a lower statistical significance for small f_{NL} as the GR correction contribution has the opposite sign.

⁷ <http://sci.esa.int/science-e/www/area/index.cfm?fareaid=102>

⁸ <http://www.lsst.org>

If the CMB detects f_{NL} at the level of ~ 10 and of a form that is close to local, but halo bias does not detect it, then the CMB bispectrum is given by secondary effects.

If the CMB detects non-Gaussianity but is not of the local type, then halo bias can help discriminate between equilateral and enfolded shapes: if halo bias sees a signal it indicates the enfolded type, and if halo bias does not see a signal it indicates the equilateral type. Thus even a non-detection of the halo-bias effect, in combination with CMB constraints, can have an important discriminative power.

In any case, if the simplest inflationary scenario holds, for surveys like Euclid and LSST, the halo-bias approach is expected to detect a non-Gaussian signal very similar to the local-type signal with an amplitude of $f_{\text{NL}} \sim -1.5$ which is due to large-scale GR corrections to the Poisson equation. This effect should leave no imprint in the CMB: once again the combination of the two observable can help enormously to discriminate among models for the origin of cosmological structures.

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