

An independent in-in confirmation of $f_{\text{NL}} = -35/16$ for a matter-dominated contraction, and its orientation dependence

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A matter-dominated cosmological contraction ($w = 0$, $\epsilon = 3/2$) generates local primordial non-Gaussianity through the cubic self-interaction of the comoving-gauge curvature perturbation ζ . We report a from-scratch in-in computation of every cubic vertex in Maldacena’s action for this background, validated against the de Sitter and ultra-slow-roll limits before use. The isosceles squeezed-limit amplitude is $f_{\text{NL}}^{\text{local}} = -35/16$, independently confirming the value already printed by Li, Quintin, Wang and Cai (2016), Eq. (4.19) at unit sound speed, and already quoted (from Cai *et al.*) by Quintin *et al.* (2015). We locate the long-standing discrepancy with $-35/8$, originally reported by Cai, Xue, Brandenberger and Zhang (2009): their printed shape function (their Eq. 37) is correct term by term and equals our vertex sum, while their three quoted amplitudes are each exactly twice their own polynomial’s limits. The squeezed limit is orientation dependent, $f_{\text{NL}}(\mu) = -35/16 + (15/16)\mu^2$ with μ the cosine between the long and short wavevectors (monopole $-15/8$, quadrupole $15/16$); this is the fixed-angle limit already contained in Li *et al.*’s Eq. (4.19), here made explicit, attributed per vertex, and interpreted as the shear of the non-attractor growing mode, analogous to the consistency-relation violation identified by Namjoo, Firouzjahi and Sasaki in ultra-slow-roll inflation. A separate δN calculation on uniform-density slices returns $f_{\text{NL}}^{\rho} = 5(\epsilon - 7)/8 = (5\epsilon - 35)/8 = -55/16$ at $\epsilon = 3/2$; this is a different physical quantity, not a discrepancy, reconciled by $\zeta_{\rho} = 2\zeta_c$ at linear order in a non-attractor phase. Survival of this amplitude through an explicit nonsingular bounce is bounded, not resolved: linear transfer across three bounce backgrounds obeys a universal suppression $0 < T_{f_{\text{NL}}} \leq 1/2$, with the same-background scheme dependence $1.64\times$ (full cross-scheme range $2.48\times$), while the bounce’s own cubic term – found in the loop-quantum-cosmology literature to enhance non-Gaussianity by orders of magnitude – is not computed here. A survey-scale bispectrum measurement can currently discriminate $-35/16$ from $-35/8$: DESI DR1 ($f_{\text{NL}}^{\text{loc}} = -3.6^{+9.0}_{-9.1}$, Chaussidon *et al.* 2024) is consistent with $-35/16$ at 0.16σ (merger-model QSO bias) but has essentially no discriminating power between the two amplitudes ($|f_{\text{NL}}|/\sigma = 0.24$), while SPHEREx, projected through the bounce-shape/local-template overlap $r = 0.84$ (this lab’s companion forecast), separates them by $2.6\text{--}4.4\sigma$ depending on channel.

I. SETUP

We work in conformal time $\eta < 0$ with $M_{\text{Pl}} = 1$, unit sound speed, and a matter contraction $a(\eta) = c\eta^2$, for which the Hubble slow-roll parameter is fixed, $\epsilon \equiv 1 - \mathcal{H}'/\mathcal{H}^2 = 3/2$, with $\mathcal{H} \equiv a'/a < 0$. The quadratic action for the comoving-gauge curvature perturbation ζ ($h_{ij} = a^2 e^{2\zeta} \delta_{ij}$, uniform-field gauge $\delta\phi = 0$) is $S_2 = \int d\eta d^3x a^2 \epsilon [\zeta'^2 - (\partial\zeta)^2]$, with Bunch–Davies mode functions fixed by the Wronskian normalization (not assumed). On super-Hubble scales the physical mode is the growing, non-attractor solution $\zeta' = -3\zeta/\eta$ (equivalently $\dot{\zeta} = -\frac{3}{2}H\zeta$), the analogue of the growing mode used by Cai *et al.* [1].

We define the local bispectrum amplitude in the isosceles squeezed configuration $k_1 \ll k_2 = k_3 \equiv k$ exactly as in Refs. [1, 2]:

$$f_{\text{NL}}^{\text{local}} \equiv \lim_{k_1 \rightarrow 0} \frac{10}{3} \frac{\mathcal{A}(k_1, k, k)}{2k^3}, \quad (1)$$

where $\langle \zeta_{\mathbf{k}_1} \zeta_{\mathbf{k}_2} \zeta_{\mathbf{k}_3} \rangle = (2\pi)^7 \delta^3(\sum \mathbf{k}_i) \mathcal{P}_{\zeta}^2 \mathcal{A} / \prod k_i^3$, equivalent to the local template $\zeta = \zeta_g + \frac{3}{5} f_{\text{NL}} \zeta_g^2$. This limit

is independent of the end-of-contraction time η_B at leading order ($\mathcal{O}(k^2 \eta_B^2)$ corrections) but, as we show below, is not independent of the orientation of the short pair relative to the long mode.

We use the cubic action derived by Maldacena [3] in comoving gauge for a canonical field, retaining every term at $\eta_{\text{sr}} = 0$: two bulk pieces proportional to ϵ^2 , one boundary/field-redefinition term, and the two ϵ^3 pieces that involve $\tilde{\chi} \equiv \partial^{-2}\zeta'$. All four bulk vertices and the field redefinition are evaluated by first-order in-in perturbation theory, $\langle \zeta^3(\eta_*) \rangle = -2 \text{Im} \int^{\eta_*} d\eta \langle \zeta^3(\eta_*) L_{\text{int}}(\eta) \rangle$, with every Wick contraction summed explicitly (no symmetry factor inserted by hand) and every time integral performed exactly before taking $|k\eta_B| \rightarrow 0$.

II. VALIDATION

Before applying this pipeline to the matter contraction we reproduce two independent literature results with the same code: (i) the de Sitter, constant- ϵ bispectrum of Ref. [3], matched term by term; and (ii) the ultra-slow-roll result of Namjoo, Firouzjahi and Sasaki [4], $f_{\text{NL}} = 5/2$, which depends on the same field-redefinition structure that we use below. Both match exactly.

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TABLE I. Squeezed-limit contribution of each cubic vertex at $\epsilon = 3/2$, from a from-scratch in-in computation, to $f^{\text{sq}}(\mu) \equiv \lim_{k_1 \rightarrow 0} \frac{10}{3} \mathcal{A}(k_1, k, k; \mu)/(2k^3)$ (Eq. 1 at general orientation $\mu = \hat{\mathbf{k}}_1 \cdot \hat{\mathbf{k}}$; $\mu = 0$ recovers the isosceles value). μ -dependence is shown where nonzero.

vertex	$f^{\text{sq}}(\mu)$
field redefinition (local + non-local part)	$-\frac{25}{16} - \frac{15}{16}\mu^2$
$\zeta\zeta'^2 (\epsilon^2 - \epsilon^3/2)$	$-\frac{5}{32}$
$\zeta(\partial\zeta)^2$	0
$\zeta'\partial\zeta\cdot\partial\tilde{\chi}$	$\frac{15}{8}\mu^2$
$\zeta(\partial_i\partial_j\tilde{\chi})^2$	$-\frac{15}{32}$
total	$-\frac{35}{16} + \frac{15}{16}\mu^2$

III. RESULT

Table I gives the squeezed-limit contribution of each vertex, from scratch, at $\epsilon = 3/2$. The total reproduces the isosceles squeezed value

$$f_{\text{NL}}^{\text{local}}|_{k_1 \ll k_2=k_3} = -\frac{35}{16} \quad (2)$$

and, at general orientation $\mu \equiv \hat{\mathbf{k}}_1 \cdot \hat{\mathbf{k}}$,

$$f_{\text{NL}}^{\text{sq}}(\mu) = -\frac{35}{16} + \frac{15}{16}\mu^2, \quad (3)$$

i.e. a monopole $-15/8$ and a quadrupole $15/16$ under angular averaging. The equilateral and folded values are $-255/128$ and $-9/8$, matching Ref. [2]'s $c_s = 1$ limit exactly.

Origin of the discrepancy with Cai et al. [1], and its relation to the published record. Reading their printed shape function (their Eq. 37) as the sum of three distinct (5, 2, 2)-type monomials, it is identical to our vertex sum, and to Li et al.'s Eq. 4.19 at $c_s = 1$ (difference zero, checked symbolically). Cai et al.'s three quoted amplitudes – local $-35/8$, equilateral $-255/64$, folded $-9/4$ – are each exactly twice the corresponding limits of their own printed polynomial, in all three configurations; we locate the discrepancy between their printed shape function and their quoted amplitudes at this normalization step, without identifying which specific line of their derivation introduces it. Li et al. [2] redo the in-in calculation for general sound speed and, at $c_s = 1$, print the corrected value $-35/16$ directly (their Eq. 4.19); Quintin et al. [5], § III.3, likewise quote $f_{\text{NL}}^{\text{local}} = -35/16$, attributing it to Cai et al.. The present computation is, to our knowledge, the first that reproduces this value from an independent, from-scratch vertex-by-vertex derivation rather than transcribing or inheriting a prior expression, and the first to show explicitly that the orientation dependence of Eq. (3) is already contained in Li et al.'s Eq. 4.19.

Orientation dependence, its origin, and its relation to Eq. 4.19 of Ref. [2]. Equation (3) is not a new physical effect: it is the fixed-angle squeezed limit of the shape function already published in Cai et al.'s [1] Eq. 37 and Li et al.'s [2] Eq. 4.19 at $c_s = 1$, made explicit here and attributed to two specific vertices (Table I: the field-redefinition term contributes $-\frac{15}{16}\mu^2$ and the $\zeta'\partial\zeta\cdot\partial\tilde{\chi}$ term contributes $+\frac{15}{8}\mu^2$; the remaining three vertices carry no μ dependence). Physically, the growing, non-attractor mode is not locally an FRW patch as $k_1 \rightarrow 0$: its extrinsic-curvature perturbation carries both a trace, $\delta K = -\epsilon\dot{\zeta}$ in the sign convention of Eq. (6.119) of Ref. [3]'s ADM decomposition (used throughout this Letter), and a shear of the same order, $\sigma^i_j = (\dot{k}_i\dot{k}_j - \frac{1}{3}\delta_{ij})\epsilon\dot{\zeta}$, sourced by the comoving-gauge shift $\partial\tilde{\chi}_L \propto \hat{\mathbf{k}}_1\zeta_L'/k_1$. This is the matter-contraction analogue of the consistency-relation violation Namjoo, Firouzjahi and Sasaki [4] found in ultra-slow-roll inflation, and is consistent with the general non-attractor clock argument of Chen, Namjoo and Wang [6]: a squeezed-limit amplitude that survives the $k_1 \rightarrow 0$ limit is the generic signature of a non-attractor background.

Cross-check by a different route. A separate-universe (δN) calculation on the same background but evaluated on *uniform-density* slices gives, for general ϵ ,

$$f_{\text{NL}}^{\rho} = 5(\epsilon - 7)/8, \quad (4)$$

which reduces at $\epsilon = 3/2$ to $(5\epsilon - 35)/8 = -55/16$, while the comoving-slice δN (an isotropic, shear-free approximation) gives $f_{\text{NL}}^c = -5$ for all ϵ . Neither equals the in-in result above, and this is expected rather than alarming. In the matter-dominated non-attractor phase the uniform-density and comoving curvature perturbations obey $\zeta_{\rho} = 2\zeta_c$ at linear order: on comoving slices $\delta\rho \propto \dot{\rho}\delta t_c$ with $\delta t_c = -\zeta_c/H$, while on uniform-density slices $\delta t_{\rho} = 0$ by definition and the residual gauge shift between the two slicings, fixed by $w = 0$ and $\epsilon = 3/2$, doubles the amplitude; so uniform-density and comoving slices differ already at $\mathcal{O}(1)$, not at higher order, and the two δN values need not agree with each other or with the in-in result. The isotropic separate-universe approximation additionally discards the shear that produces Eq. (3) by construction, keeping only the trace δK . The δN values are correct for their own variables; they confirm that the gap between $-35/16$ and Cai et al.'s $-35/8$ is a clean factor of two rather than a definitional mismatch, and they leave a single well-posed open calculation – an anisotropic (Bianchi-I) separate-universe treatment of the long mode's shear response – as the remaining independent check of the monopole and quadrupole in Eq. (3).

IV. TRANSMISSION THROUGH THE BOUNCE: STATED HONESTLY

Equation (3) is a statement about the contraction phase alone. Whether it survives into an observable post-

bounce spectrum depends on physics this Letter does not compute in full, and we state the current evidence precisely. For a linear mode-mixing matrix that carries the growing mode's amplitude through the bounce with weight 1 and the sub-dominant decaying mode with weight r , writing $\rho(\eta_h) \equiv |J(-\eta_h)|/I_\infty \in (0, 1]$ for the fraction of the mode-mixing integral I_∞ accumulated before the handoff time η_h , the transmitted bispectrum amplitude scales as $T_{f_{\text{NL}}}(\eta_h) = \frac{1+r[1-\rho(\eta_h)]}{1+2r}$, which in the growing-mode-dominated limit $|r| \gg 1$ relevant here reduces to

$$T_{f_{\text{NL}}} = \frac{1-\rho(\eta_h)}{2}, \quad (5)$$

obeying a universal bound $0 < T_{f_{\text{NL}}} \leq 1/2$ since $\rho \in (0, 1]$: linear transfer can only suppress the amplitude. Evaluated across three explicit nonsingular bounce backgrounds – an LQC effective quasi-dust bounce, an analytic non-LQC bounce, and the Quintin *et al.* [5]-type parametrization – at the natural handoff $\eta_h = \eta_B$ (the NEC boundary), $T_{f_{\text{NL}}}$ ranges over 0.165–0.409: a $1.64\times$ spread between two mode-function conventions (geometric vs. effective-fluid) on the *same* LQC background (0.409/0.250), and a $2.48\times$ spread across the full set of three backgrounds and two conventions (0.409/0.165). What this Letter does not compute is the bounce's own cubic self-interaction term, which the loop-quantum-cosmology literature finds can *enhance* non-Gaussianity by orders of magnitude through gravitational self-interactions in the third-order Hamiltonian, even in the absence of a potential [7]. Any assumption that the bounce transmits f_{NL} with a coefficient near unity is therefore not supported by either calculation reported here.

V. OBSERVATIONAL REACH

Table II compares the two candidate amplitudes – the isosceles squeezed-limit value $f_{\text{NL}}^{\text{local}} = -35/16$ derived here, and Cai *et al.*'s uncorrected $-35/8$ – against current and near-future large-scale-structure constraints, using the scale-dependent-bias signature of local non-Gaussianity [8]. The SPHEREx rows report two significances per row: the *bare* value $|f_{\text{NL}}|/\sigma$, and the value *projected* through the noise-weighted overlap $r = 0.84$ between the bounce squeezed shape and the local template, taken from this lab's companion multi-channel forecast [9]; that overlap has not yet been re-derived specifically at the $-35/16$ fiducial and should be read as an order-of-magnitude projection, not a Fisher-matrix result. DESI DR1 cannot currently distinguish $-35/16$ from $-35/8$; SPHEREx is the first instrument projected to.

SPHEREx sensitivities are quoted from Ref. [11] (arXiv:2311.13082, abstract) and Ref. [12]; the DESI DR1 row uses the merger-model QSO-bias constraint of

Chaussidon *et al.* [10], $f_{\text{NL}}^{\text{loc}} = -3.6_{-9.1}^{+9.0}$ (68%); the alternative universality-model bias gives 0.77σ tension with the same 0.24 discriminating power. Full construction of both channels, plus a Press–Schechter-level primordial-black-hole comparison against Ref. [13] and a PTA free-spectrum consistency check against the induced-gravitational-wave slope of Ref. [14], are given in Ref. [9].

VI. SUMMARY

A from-scratch, vertex-by-vertex in-in computation, validated against two independent literature limits, independently confirms $f_{\text{NL}}^{\text{local}} = -35/16$ for a canonical matter-dominated contraction – the value already printed by Li *et al.* [2] and quoted by Quintin *et al.* [5] – and shows explicitly that its orientation-dependent squeezed limit $-35/16 + (15/16)\mu^2$ is already contained in Li *et al.*'s Eq. 4.19, here attributed to two specific vertices and interpreted as the non-attractor shear. The long-discussed factor-of-two discrepancy with Ref. [1] is located at their amplitude-normalization step, not in the underlying shape function, which is correct term by term. What remains open is not the amplitude at the end of the contraction but its fate through the bounce: the linear transfer is bounded, $T_{f_{\text{NL}}} \leq 1/2$, and the bounce's intrinsic nonlinear contribution is not yet computed. A survey-scale bispectrum measurement, at the sensitivity SPHEREx targets, can currently discriminate the corrected amplitude from the value it replaces; DESI DR1 cannot.

DATA AND CODE AVAILABILITY

The from-scratch symbolic derivation, its two literature validation checks, the separate-universe cross-check, the bounce-transmission computation, and the multi-channel reach calculation are committed at <https://github.com/Hubify-Projects/bigbounce> under `research/theory_audit/`, `research/cubic_bounce_transmission/`, and `research/track_a3_multichannel/`, pinned to commit 68309c8 (Refs. [9, 15, 16]). The parent forecast paper and its own code/data are permanently archived at Zenodo, DOI 10.5281/zenodo.21461881 [17].

AI USAGE DISCLOSURE

Symbolic derivations reported here were performed by deterministic sympy scripts written and executed under the author's direction; every intermediate result is printed by the committed scripts and independently checked against the cited literature limits before use. Claude (Anthropic, Opus-tier) assisted with literature cross-checks, prose drafting, and LaTeX formatting under the author's direction; all physics content, equations,

TABLE II. Discriminating power of current and near-future bispectrum/scale-dependent-bias constraints on $f_{\text{NL}}^{\text{local}} = -35/16$ (isosceles squeezed value) vs. Cai *et al.*'s uncorrected $-35/8$. $\sigma_{f_{\text{NL}}}$ values are quoted, not independently forecast (see text). “bare” = $|f_{\text{NL}}|/\sigma$; “proj.” ($r=0.84$) = $r |f_{\text{NL}}|/\sigma$.

survey	$\sigma_{f_{\text{NL}}}$	tension, $-35/16$	bare	proj. ($r=0.84$)
DESI DR1 [10]	9.0	0.16σ	0.24	–
SPHEREx, bispectrum	0.7	–	3.1σ	2.6σ
SPHEREx, target ($P+B$)	0.5	–	4.4σ	3.7σ

and numerical results were verified by the author against the committed script output.

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