The (not so) squeezed limit of the primordial bispectrum

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based on:
P. Creminelli, G. D'A., J. Noreña, M. Musso, *to appear*

Consistency relation

Maldacena 2002
Creminelli, Zaldarriaga 2004
Cheung, Fitzpatrick, Kaplan, Senatore 2007

Squeezed limit in single-field models: one of the modes is already a classical bkg when the other two exit the horizon

$$\langle \zeta_B(\vec{k}_1)\zeta(\vec{k}_2)\zeta(\vec{k}_3)\rangle \simeq \langle \zeta_B(\vec{k}_1)\langle\zeta(\vec{k}_2)\zeta(\vec{k}_3)\rangle_B\rangle \qquad k_1 \ll k_S$$

The long mode acts just as a rescaling of the coordinates

$$\langle\zeta(\vec{x}_2)\zeta(\vec{x}_3)\rangle_B = \xi(\tilde{\vec{x}}_2 - \tilde{\vec{x}}_3) \simeq \xi(\vec{x}_3 - \vec{x}_2) + \zeta_B(\vec{x}_+)(\vec{x}_3 - \vec{x}_2)\cdot\nabla\xi(\vec{x}_3 - \vec{x}_2)$$

Going back to Fourier space we get the consistency relation

$$\langle\zeta(\vec{k}_1)\zeta(\vec{k}_2)\zeta(\vec{k}_3)\rangle \simeq -(2\pi)^3\delta(\vec{k}_1+\vec{k}_2+\vec{k}_3)P(k_1)P(k_S)\frac{\mathrm{d}\ln(k_S^3 P(k_S))}{\mathrm{d}\ln k_S}$$

The not-so-squeezed limit

Creminelli, G D'A, Noreña, Musso, *to appear*

At lowest order in derivatives

$$S_2 + S_3 = M_{\rm Pl}^2 \int d^4x \, \epsilon a^3 \left[(1+3\zeta_B)\dot{\zeta}^2 - (1+\zeta_B)\frac{(\partial_i \zeta)^2}{a^2} \right]$$

Long mode reabsorbed by coordinate rescaling $\vec{x} \to e^{\zeta_B}\vec{x}$

Corrections:

- Corrections from expansion of ζ_B are of order k^2
- Time evolution of ζ_B is of order k^2
- Spatial derivatives will be symmetrized with the short modes, giving k^2
- Constraint contributions give order k^2 corrections

Final result: in the not-so-squeezed limit we have

$$\langle \zeta(\vec{k}_1)\zeta(\vec{k}_2)\zeta(\vec{k}_3)\rangle \simeq -(2\pi)^3 \delta(\vec{k}_1+\vec{k}_2+\vec{k}_3) P(k_1) P(k_S) \left[\frac{\mathrm{d}\ln(k_S^3 P(k_S))}{\mathrm{d}\ln k_S} + \mathcal{O}\left(\frac{k_L^2}{k_S^2}\right) \right]$$

Why is this important?

Bias on large scales goes to a constant.
Corrections induced by NG (Dalal et al. 2007, Matarrese & Verde 2008, Slosar et al. 2008):

$$\frac{\Delta b_h}{b_h} \sim \frac{f_{\rm NL}}{k^2}$$

for local NG

The large scale bias is very sensitive to the squeezed limit behaviour of the bispectrum.

A detection of bias going as k^{-1}, and more generally, any scale dependence of the large scale bias would rule out all single field models!

A correct template

Senatore, Smith, Zaldarriaga 2009
Creminelli, G.D'A, Musso, Noreña, Trincherini 2010

Analysis of CMB is performed by using a sum of factorizable monomials in k's.
We choose the ones with a cosine close to unity w.r.t. the physical shape.

The orthogonal and enfolded template have unphysical behaviour in the squeezed limit: wrong large scale bias!

Solution: we can introduce k^{-4} monomials to cancel divergences in the squeezed limit!
(LSS applications: G. D'A. Manera, Scoccimarro, *in preparation)*

$$F_1(k_1,k_2,k_3) = \frac{16}{9\,k_1k_2k_3^4} + \frac{k_1^2}{9\,k_2^4k_3^4} - \frac{1}{k_1^2k_3^4} - \frac{1}{k_2^2k_3^4} + \text{cycl.}$$

$$F_2(k_1,k_2,k_3) = \frac{1}{k_1^3k_2^3} - \frac{1}{k_1k_2^2k_3^3} - \frac{1}{k_2k_1^2k_3^3} + \text{cycl.}$$

$$F_3(k_1,k_2,k_3) = \frac{1}{k_1^2k_2^2k_3^2}$$

Model	α	|cos|
M_3	0.71	0.95
orth.	0.55	0.98
enf.	0.60	0.98
eq.	0	1

$$F_\alpha(k_1,k_2,k_3) = N f_{\rm NL}\Delta_\Phi^2\left[\alpha F_1 + F_2 + 2(1+\alpha)F_3\right]$$

Thank you!