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Prospects for constraining the shape of non-Gaussianity with the scale-dependent bias

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Prospects for Constraining non-Gaussianity with the Scale Dependent Bias

Jorge Noreña
ICC, University of Barcelona

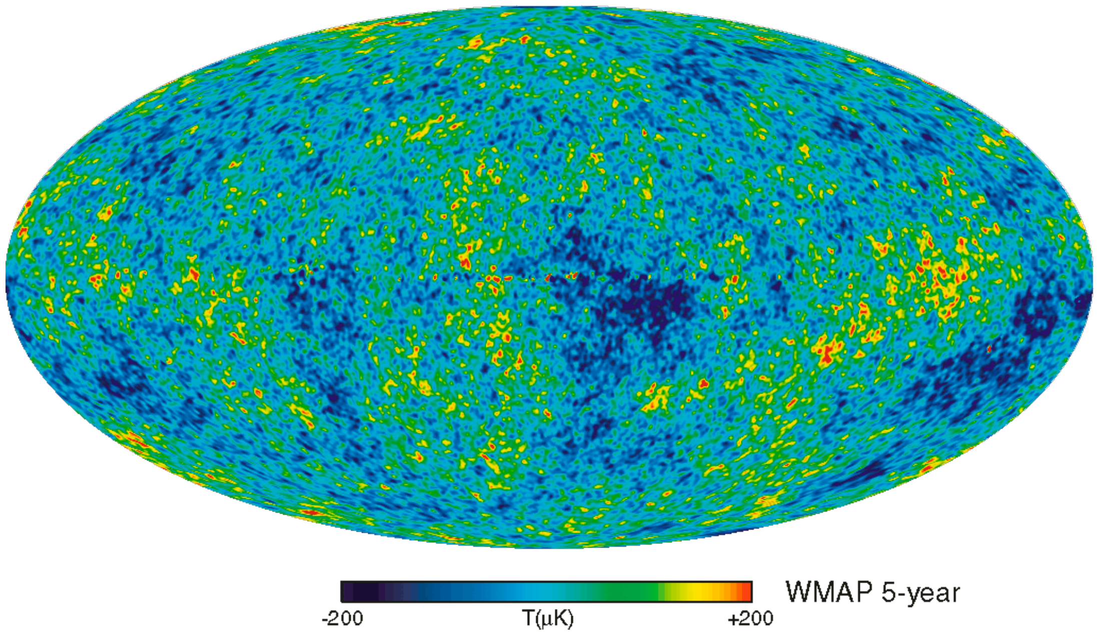
Based on:

J. Noreña, L. Verde, G. Barenboim and C. Bosch, arXiv:1204.6324 [astro-ph.CO]

See also: Sefusatti et. al. [arXiv:1204.6318]

Introduction

The most successful feature of inflation is that it provides us with a dynamical mechanism to generate the observed perturbations



G. Hinshaw, et al., 2009

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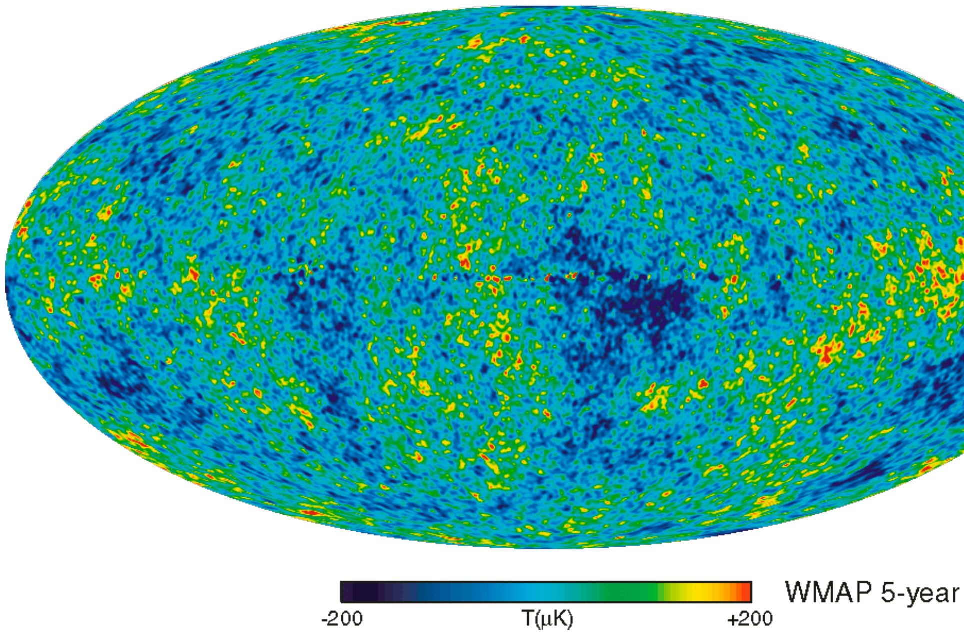
$$\langle \zeta_{\mathbf{k}_1} \zeta_{\mathbf{k}_2} \rangle = (2\pi)^2 \delta(\mathbf{k}_1 + \mathbf{k}_2) \frac{A}{k^3} \left(\frac{k}{k_*} \right)^{n_s - 1}$$



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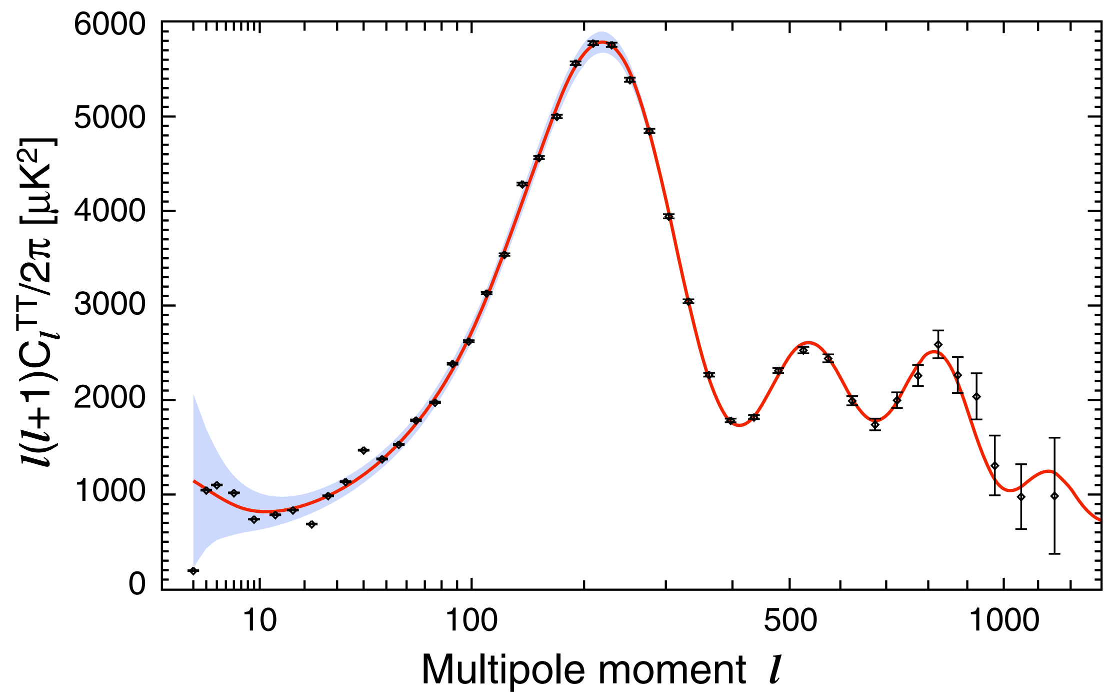

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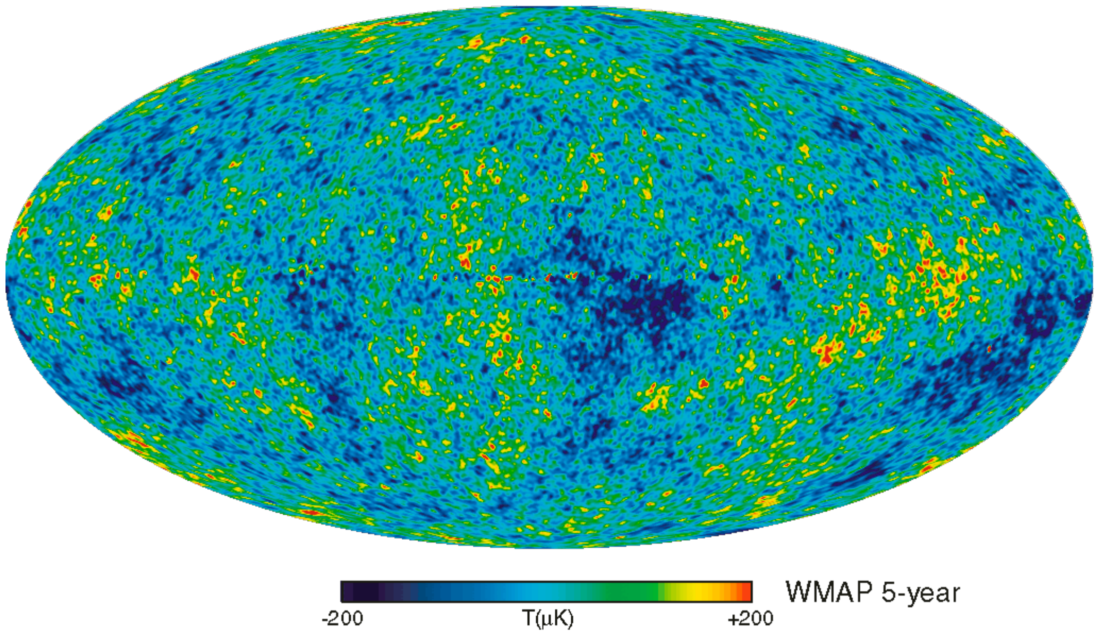

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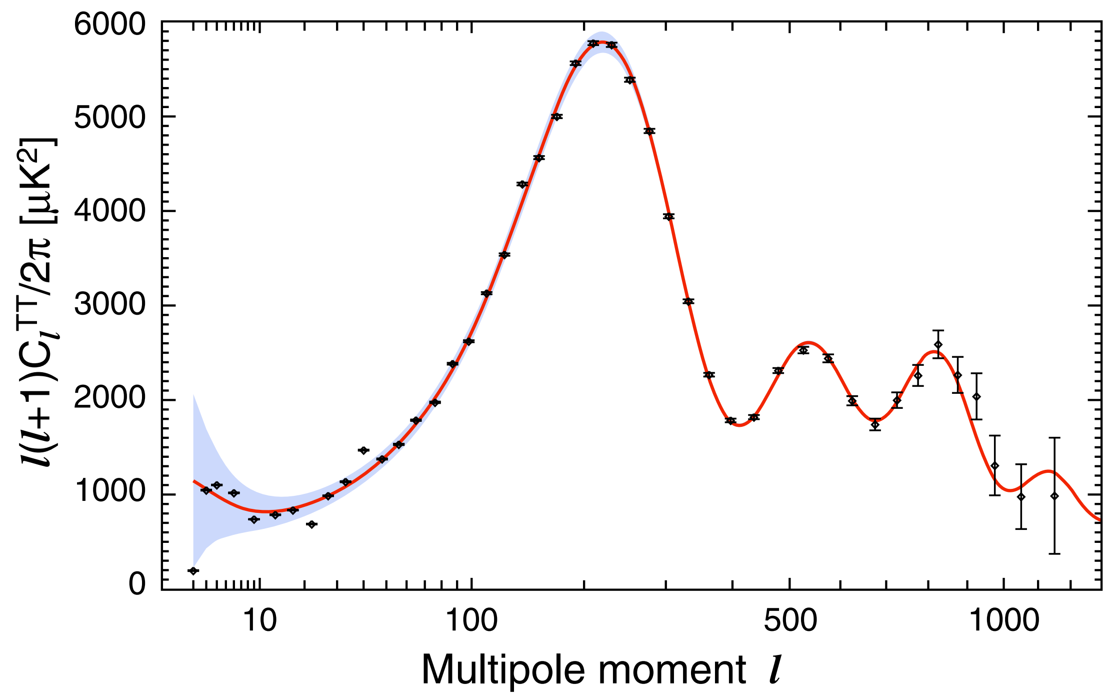

But if we wish to learn which is the correct model of inflation we need to go beyond the power spectrum.

Outline

- Introduction
- Non-Gaussianity and the squeezed limit
- The Scale Dependent Bias (SDB)
- Quasi-single field model
- Forecast

Message: The scale dependent halo bias observations and CMB observations are complementary probes of non-Gaussianity.

Non-Gaussianity

Since perturbations are small, the correlation function which is the easiest to observe beyond the power spectrum is the three point function:

$$\langle \zeta_{\mathbf{k}_1} \zeta_{\mathbf{k}_2} \zeta_{\mathbf{k}_3} \rangle = (2\pi)^3 \delta(\mathbf{k}_1 + \mathbf{k}_2 + \mathbf{k}_3) B(k_1, k_2, k_3)$$

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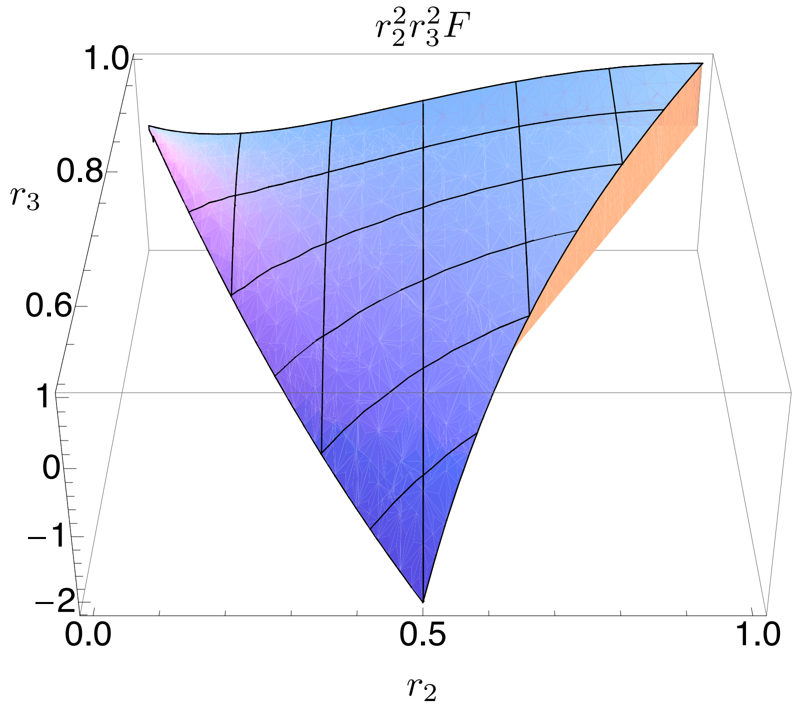
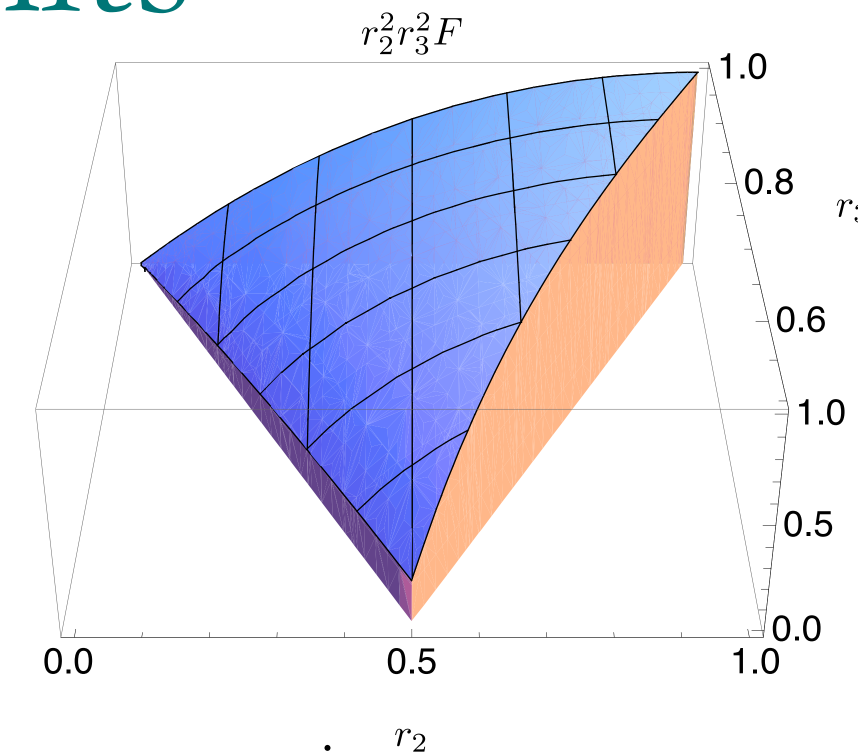
Squeezed limit $k_2 \ll k_1, k_3$:

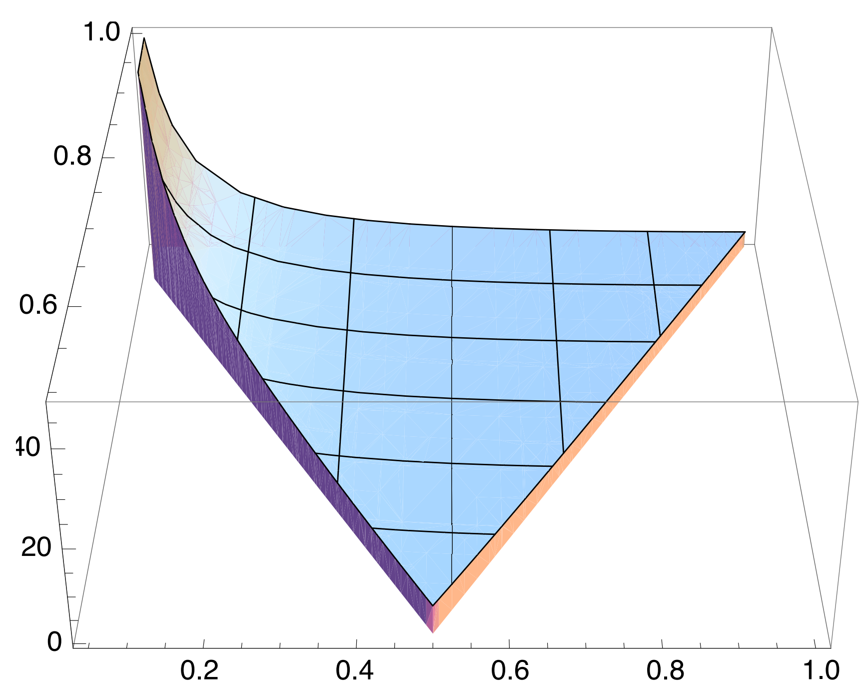
CMB limits



$$f_{NL}^{\mathrm{orth}} = -202 \pm 104$$



$$f_{NL}^{\mathrm{equi}} = 26 \pm 140$$

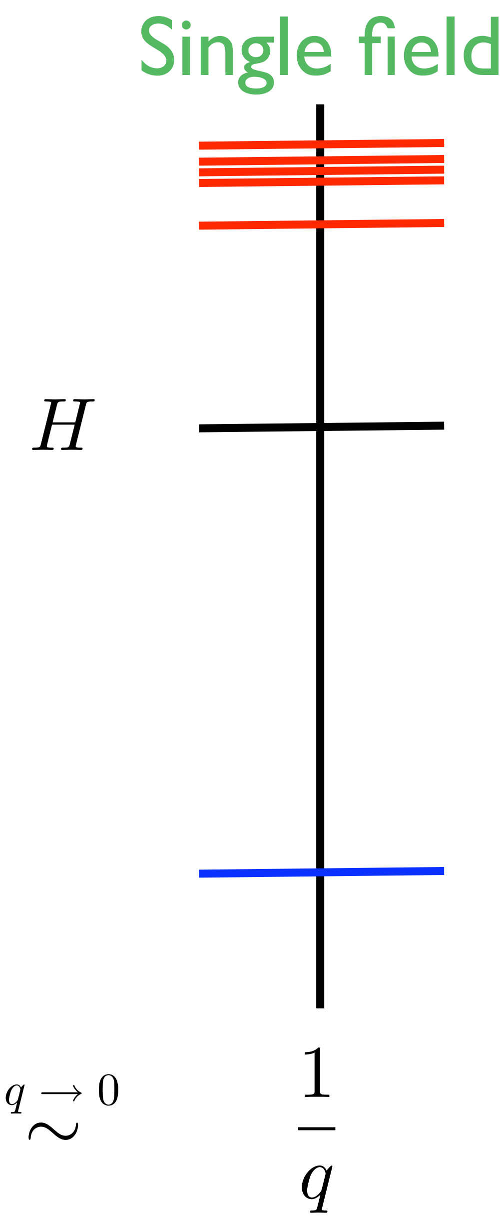


$$f_{NL}^{local} = 32 \pm 21$$

Komatsu et. al. [arXiv:1001.4538]

The squeezed limit

The squeezed limit contains (model independent) information about the physics during inflation



$$B(q,k,k) \overset{q \to 0}{\sim}$$

J. Maldacena, 2003
P. Creminelli, M. Zaldarriaga, 2004
P. Creminelli, G. D'Amico, M. Musso, JN, 2011
P. Creminelli, JN, M. Simonovic, 2012

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Single field | Multi-field

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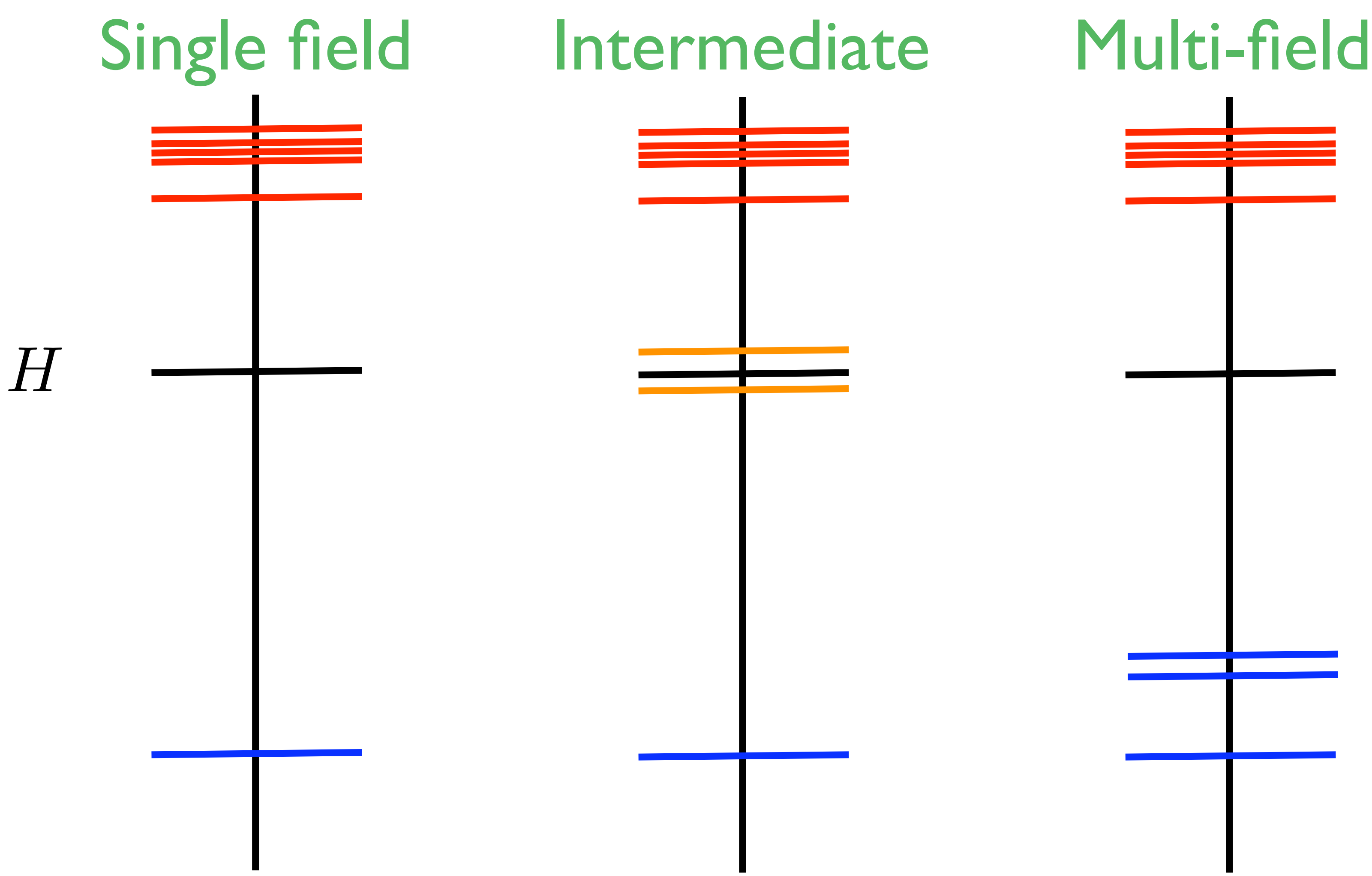

$B(q,k,k) \overset{q \to 0}{\sim}$ $\quad \frac{1}{q} \quad \frac{1}{q^\alpha} \quad 1 < \alpha < 3 \quad \frac{1}{q^3}$

X. Chen, J. Wang, 2009 P. Creminelli, G. D'Amico, M. Musso, JN, 2011 P. Creminelli, JN, M. Simonovíc, 2012

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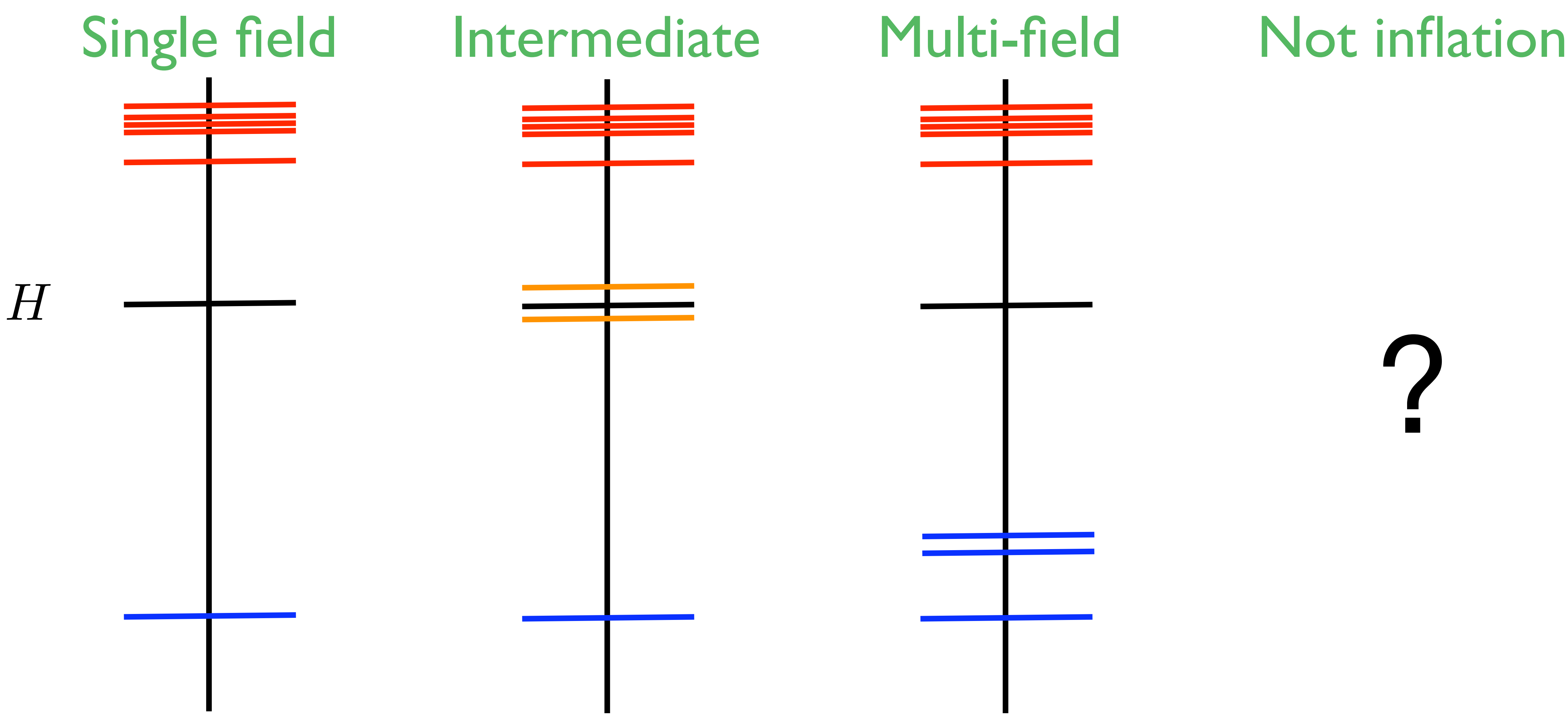

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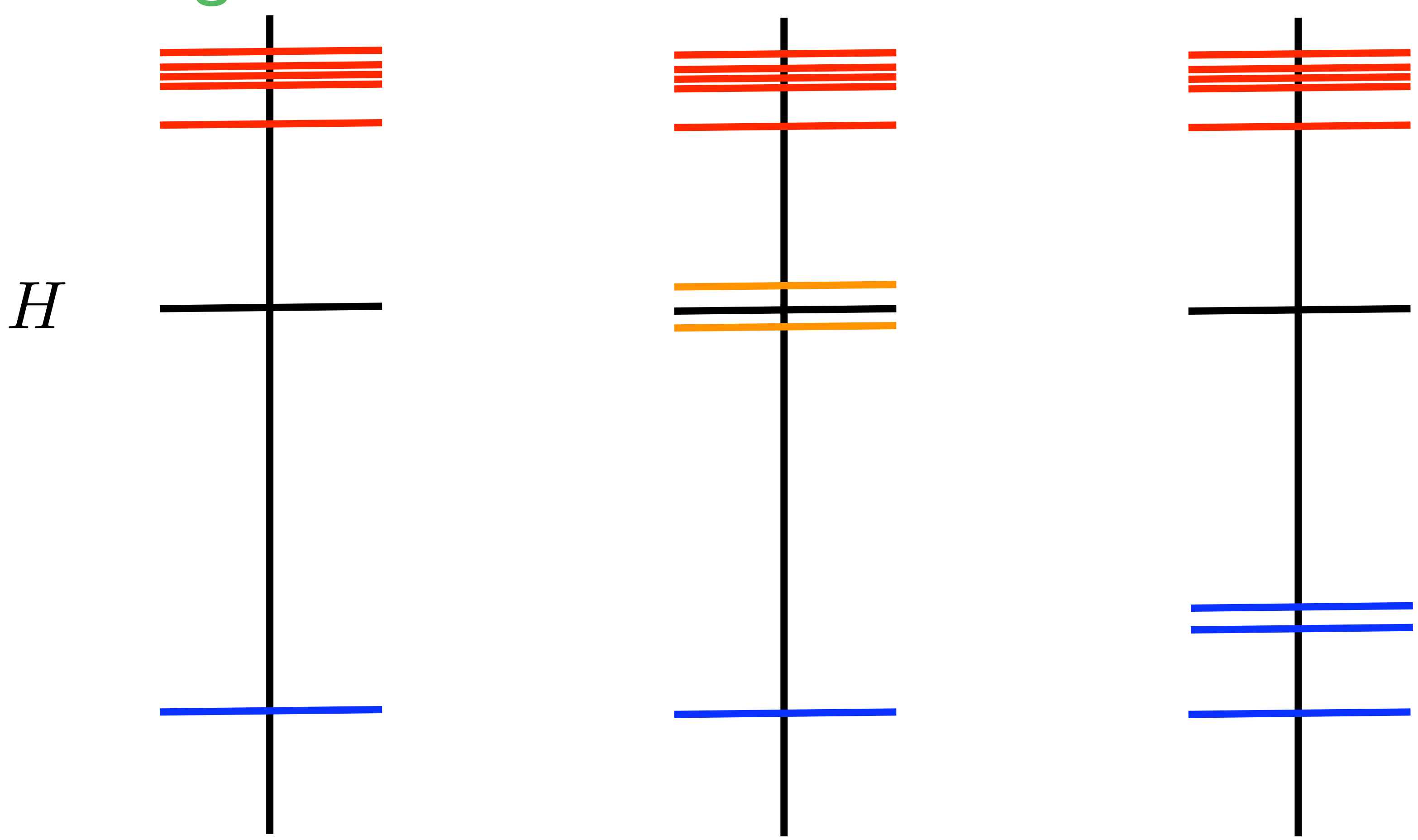
V. Assassi, D. Baumann, D. Green, 2012

The squeezed limit

The squeezed limit contains (model independent) information about the physics during inflation

Single field | Intermediate | Multi-field | Not inflation ?



Strange features

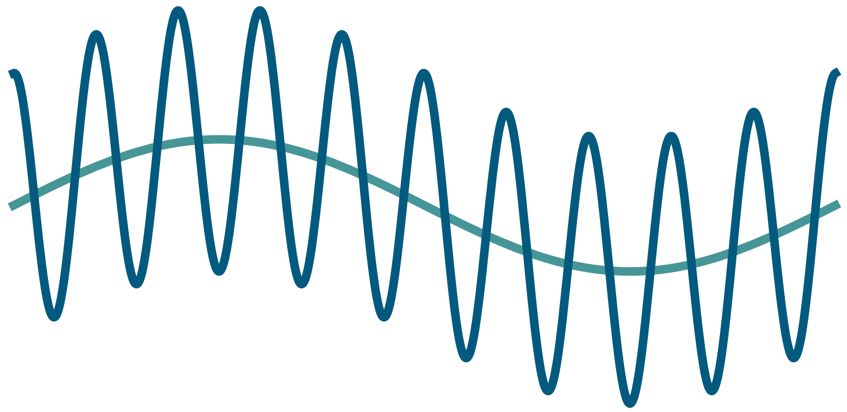
?

Modified Initial State

$B(q,k,k) \overset{q\to 0}{\sim}$ $\frac{1}{q}$ | $\frac{1}{q^{\alpha}}$ $1 < \alpha < 3$ | $\frac{1}{q^3}$ | $\frac{1}{q^{\alpha}}$ $\alpha > 3$

The Scale Dependent Bias

For the local model: $\zeta = \zeta_g + \frac{3}{5} f_{NL}^{local} \zeta_g^2$



$f_{\rm NL} = 0$

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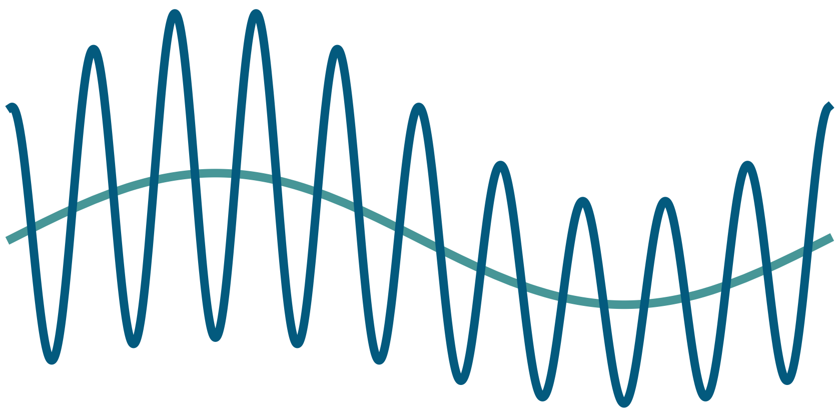
Dalal, et. al., 2008

Matarrese, Verde, et. al., 2008

Slosar, et. al., 2008



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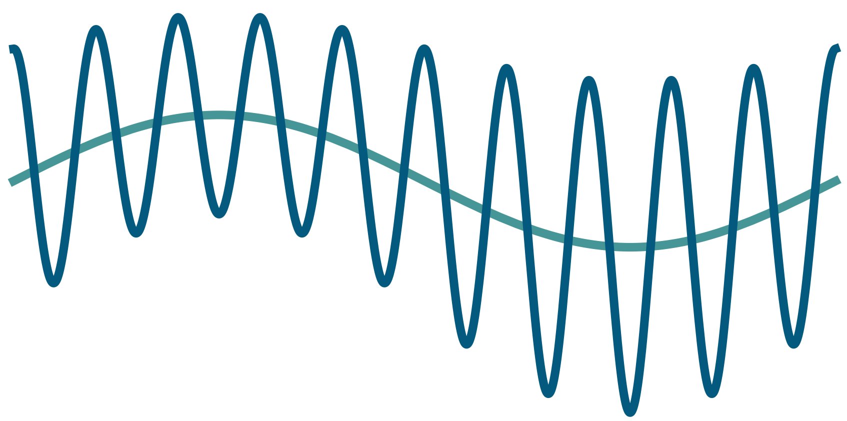

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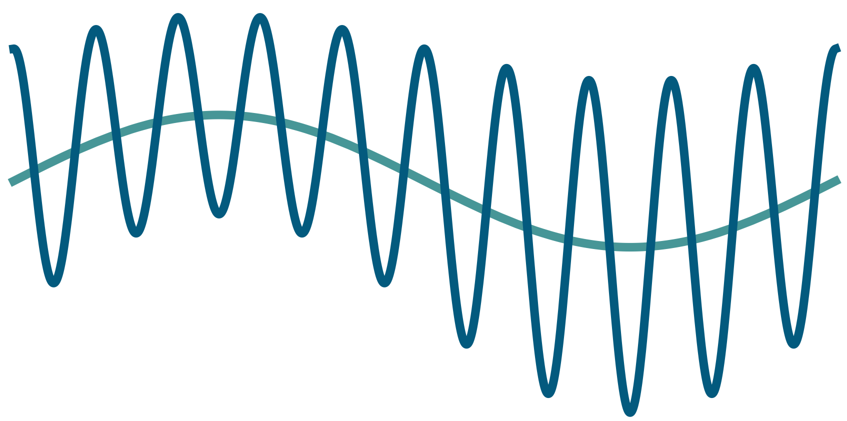

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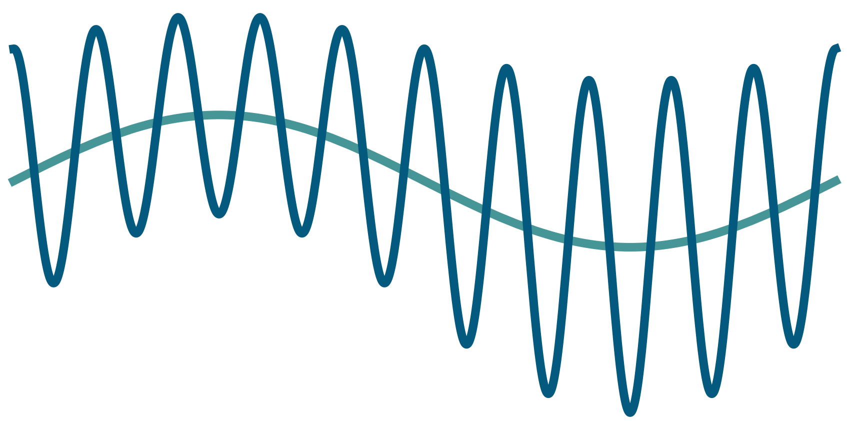

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More quantitatively:

$$\Delta b(k, M) = \frac{1}{\mathcal{M}_M(k)} \left(\frac{(b_E^{(g)} - 1)\delta_c}{D(z)} \mathcal{F}(k, M) + \frac{\mathrm{d}\mathcal{F}(k, M)}{\mathrm{d} \ln \sigma_M} \right)$$

Desjacques, et. al., 2011

The SDB is sensitive to the squeezed limit.

$$\mathcal{F}(k,M) = \frac{1}{8\pi^2\sigma_M^2 P_\zeta(k)} \int \mathrm{d}k_1\, k_1^2 \mathcal{M}_M(k_1) \int_{-1}^{1} \mathrm{d}\mu\, \mathcal{M}_M\left(\sqrt{k^2+k_1^2+2k_1 k\mu}\right) B_\zeta\left(k, k_1, \sqrt{\ldots}\right)$$

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Scale of observation: $0.003\, h\,\mathrm{Mpc}^{-1} \lesssim k \lesssim 0.1\, h\,\mathrm{Mpc}^{-1}$

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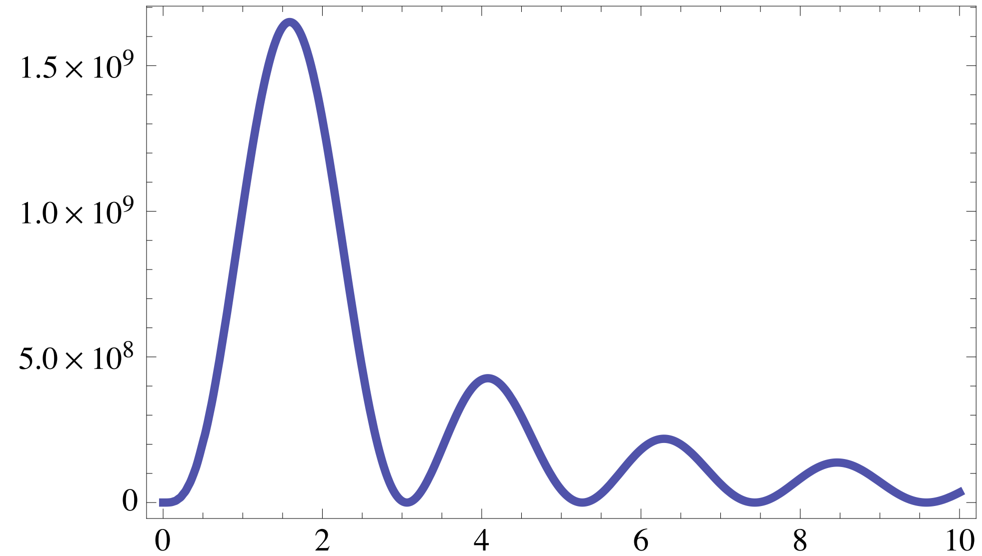

$\longrightarrow k_1 \sim \mathcal{O}(1)\,\mathrm{Mpc}^{-1}\,h$

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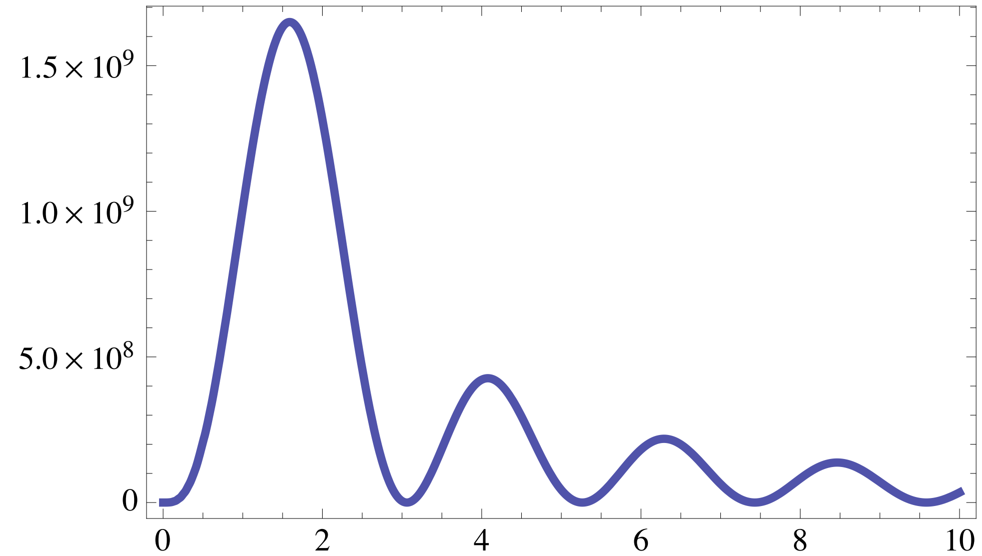


$\rightarrow k_1 \sim \mathcal{O}(1)\,\mathrm{Mpc}^{-1}\,h$

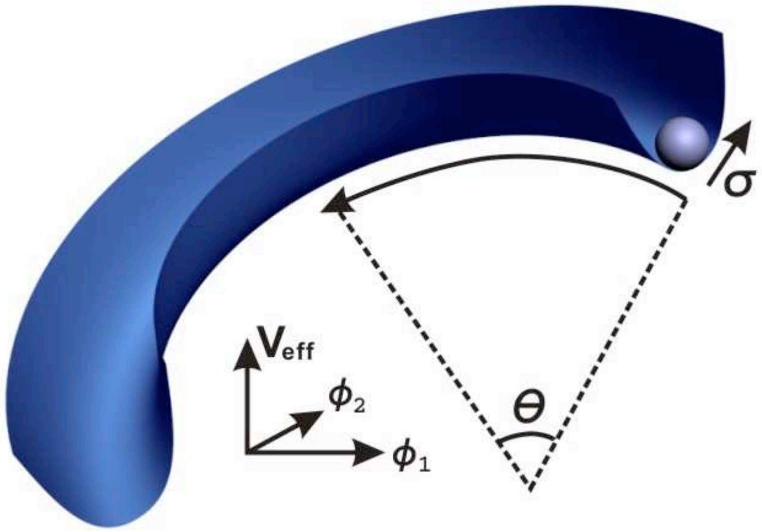
The scale dependent bias is sensitive to a configuration for which:

$$\frac{k_L}{k_s} \simeq \mathcal{O}(0.1) \text{ to } \mathcal{O}(0.001)\,\mathrm{Mpc}\,h^{-1}$$

Quasi-single field inflation

Two fields, one light inflaton + a curvaton with a mass of order H

Chen, Wang, 2009, [arXiv:0911.3380]



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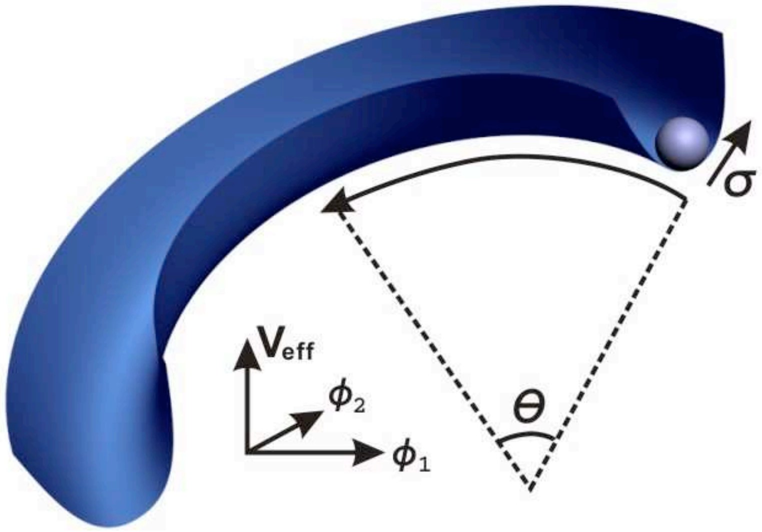

Template:

$$B_\zeta(k_1,k_2,k_3) = (2\pi)^4 \Delta_\zeta^4 k_p^{2(1-n_s)} \frac{3^{7/2}}{10N_\nu(\alpha/27)} \frac{f_{\rm NL}}{(k_1k_2k_3)^{3/2}(k_1+k_2+k_3)^{3/2}}$$

$$\times N_\nu\left(\frac{\alpha k_1k_2k_3}{(k_1+k_2+k_3)^3}\right)$$

$$\nu \equiv \sqrt{9/4 - m^2/H^2}$$

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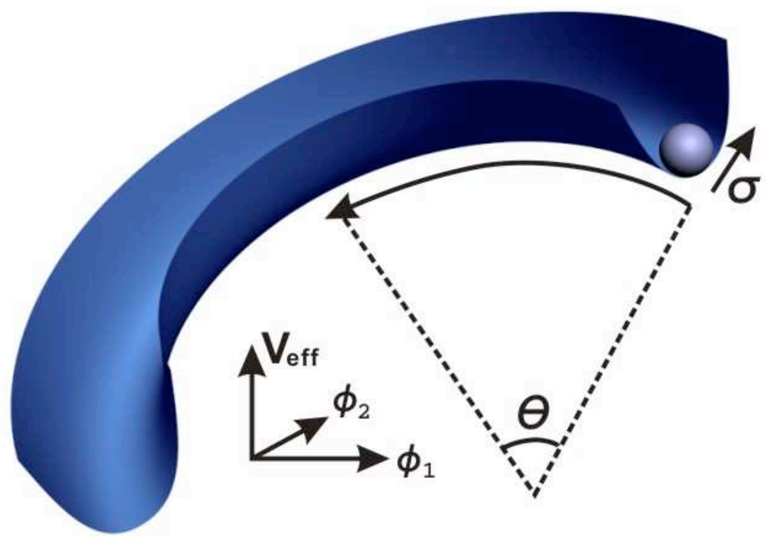

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$$\nu \equiv \sqrt{9/4 - m^2/H^2}$$

In the squeezed limit: $\langle\zeta(\vec{k}_1)\zeta(\vec{k}_2)\zeta(\vec{q})\rangle \overset{q\to 0}{\sim} 1/q^{3/2+\nu}$

CMB and LSS are complementary

shape "Overlap"

$$F_1 \cdot F_2 \equiv \sum_{k_1,k_2,k_3} \frac{F_1(k_1,k_2,k_3)F_2(k_1,k_2,k_3)}{\sigma^2(k_1)\sigma^2(k_2)\sigma^2(k_3)}$$

$$\cos(F_1,F_2) \equiv \frac{F_1 \cdot F_2}{\sqrt{(F_1 \cdot F_1)(F_2 \cdot F_2)}}$$

⟵ Two shapes are "similar" for the CMB if they have a cosine of order one.

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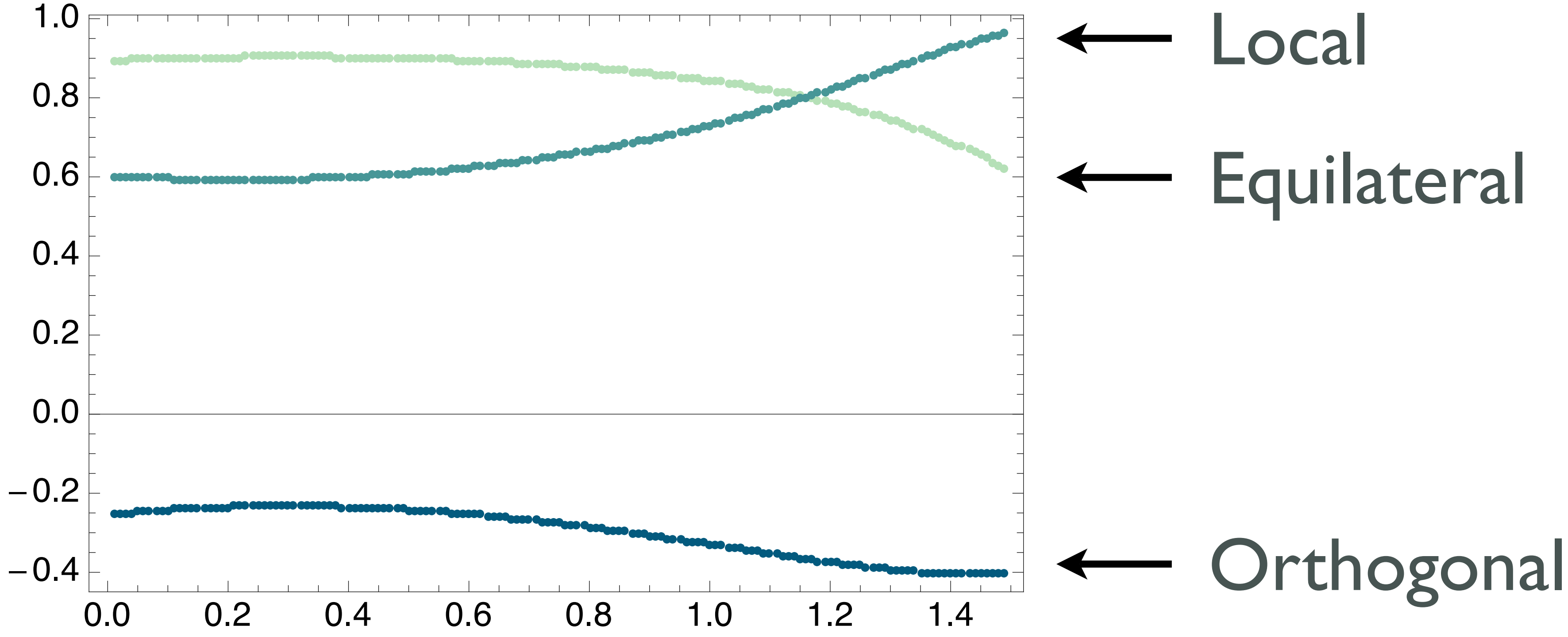


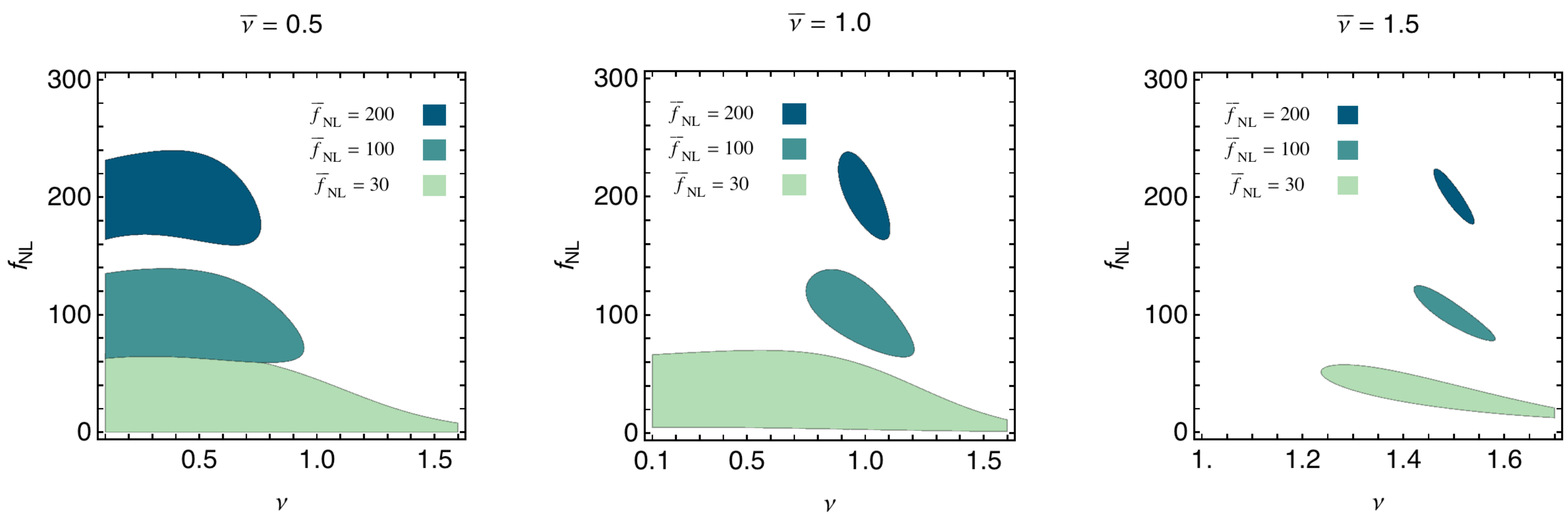
Forecast

$$\Delta\chi^2 = \sum_i \frac{V(z_i)}{(2\pi)^2} \int_{k_{min}}^{k_{max}} \mathrm{d}k\, k^2 \left(1 - \frac{1}{n_g(z_i)P(k)}\right)^2 \left(\frac{\Delta P(k, z_i)}{P(k, z_i)}\right)^2$$

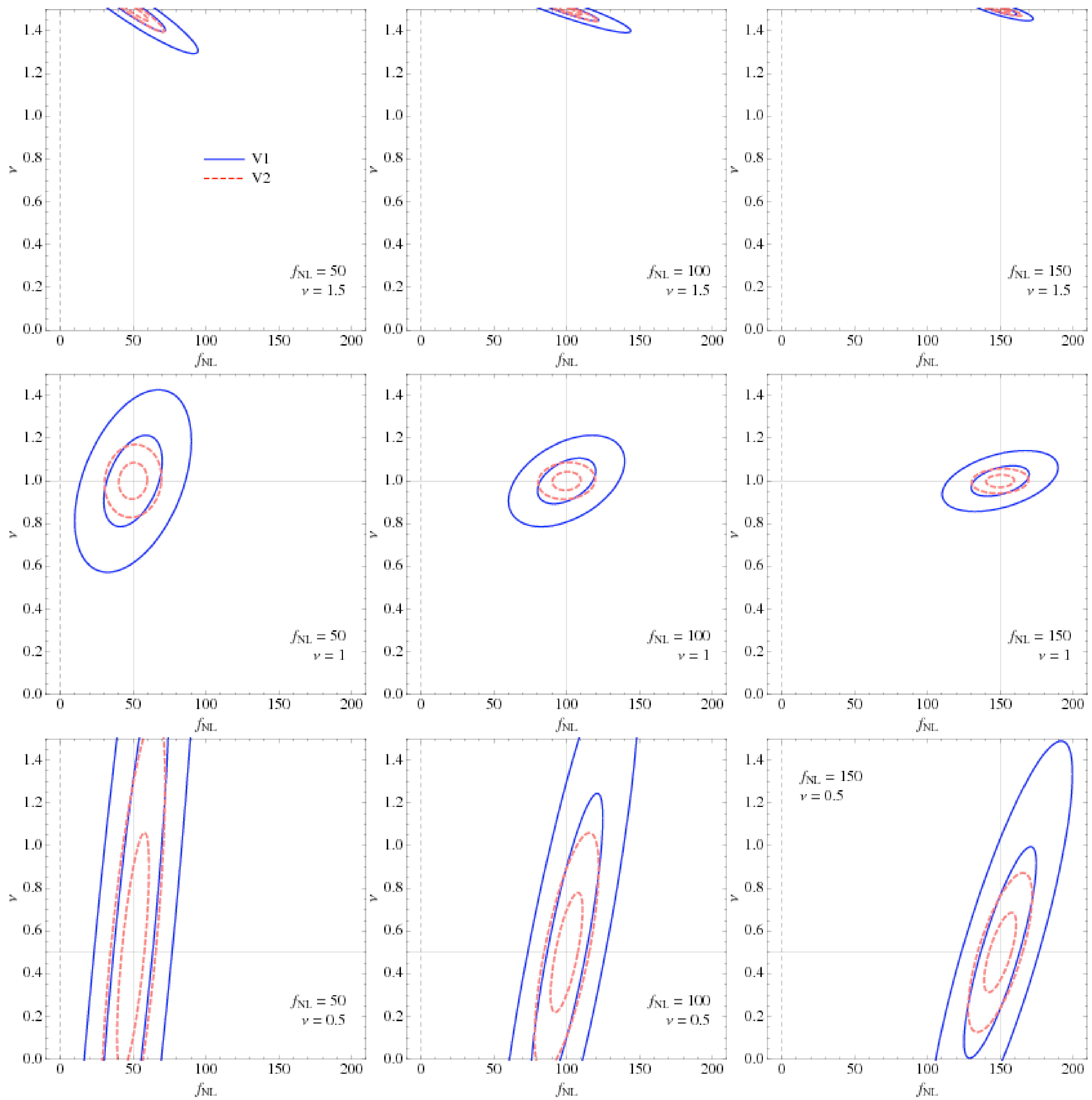
Dark Energy Task Force stage IV:

$\langle \zeta^3 \rangle \sim 1/q^{3/2+\nu}$

Sky coverage	2×10^4 square degrees
Minimum redshift	0.5
Maximum redshift	2.1
Typical galaxy halo mass	$10^{12}\ M_\odot h^{-1}$
k_{max}	$0.1\, h/\mathrm{Mpc}$



Results of other groups

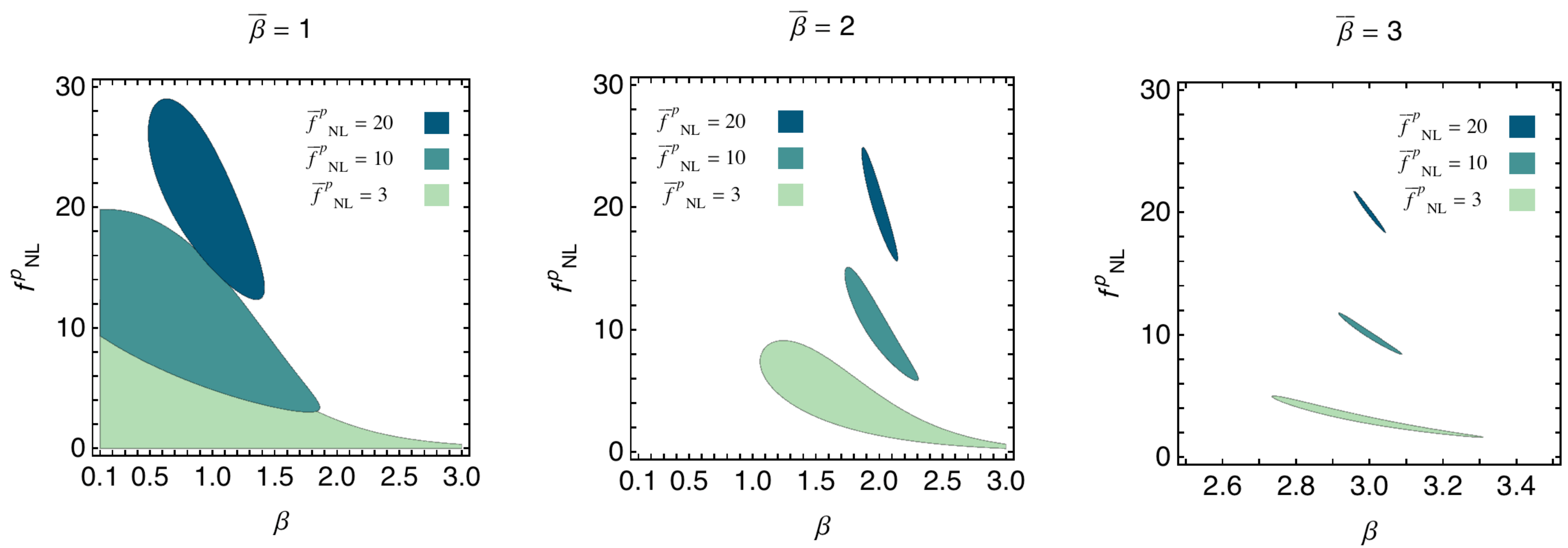


Sefusatti et. al. [arXiv:1204.6318]

A parametrization

One can roughly approximate Δb with a power law

$$\Delta b(k, M) = f^{p}_{\rm NL} \frac{A(M)}{k^{\beta}}$$



See also: Agullo, Shandera [arXiv:1204.4409]

Gank, Komatsu [arXiv:1204.4241]

Conclusions

- Recent developments tell us that the squeezed limit of the bispectrum contains a wealth of model independent information.
- The scale dependent halo bias is a good probe of the squeezed limit (while the CMB might not be).
- The CMB and scale dependent halo bias observations are complementary probes of non-Gaussianity.
- If Planck observes a large local and equilateral non-Gaussianity, the scale-dependent halo bias will be needed to tell whether it is due to a model like the quasi-single field.

THE END