Non-Gaussianity as a Probe of the Physics of the Primordial Universe

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Cook's Branch, April 15, 2010

Motivation

- Non-Gaussianity (3- and 4-point functions of fluctuations) can be used to rule out **(almost) all** inflation models!
  - That's the slide#42. Please stay awake...

How Do We Test Inflation?

- How can we answer a simple question like this:
  - "*How were primordial fluctuations generated?*"

Power Spectrum

- A very successful explanation (Mukhanov & Chibisov; Guth & Pi; Hawking; Starobinsky; Bardeen, Steinhardt & Turner) is:
  - *Primordial fluctuations were generated by quantum fluctuations of the scalar field that drove inflation.*
  - The prediction: a nearly scale-invariant power spectrum in the curvature perturbation, ζ:
    - **$P_\zeta(k) = A/k^{4-n_s} \sim A/k^3$**
    - where $n_s \sim 1$ and A is a normalization.

Komatsu et al. (2010)

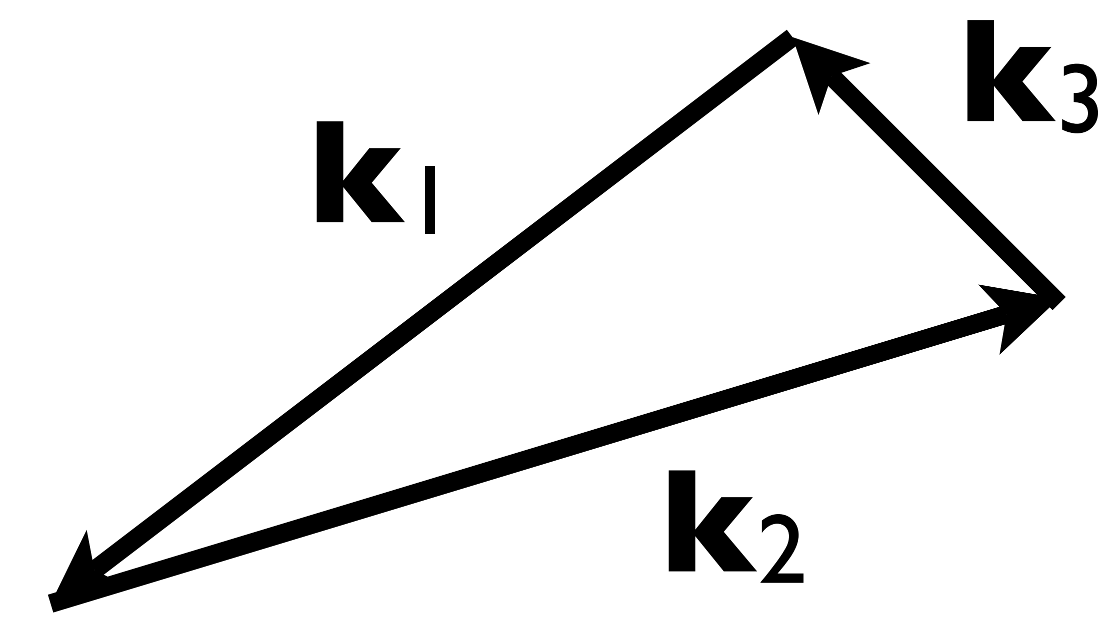
n_s<1 Observed (at >3σ)

- The latest results from the WMAP 7-year data:
  - **n_s=0.963 ± 0.012** (68%CL; for tensor modes = zero)
- $n_s \neq 1$: another line of evidence for inflation
- Detection of non-zero tensor modes is a next important step

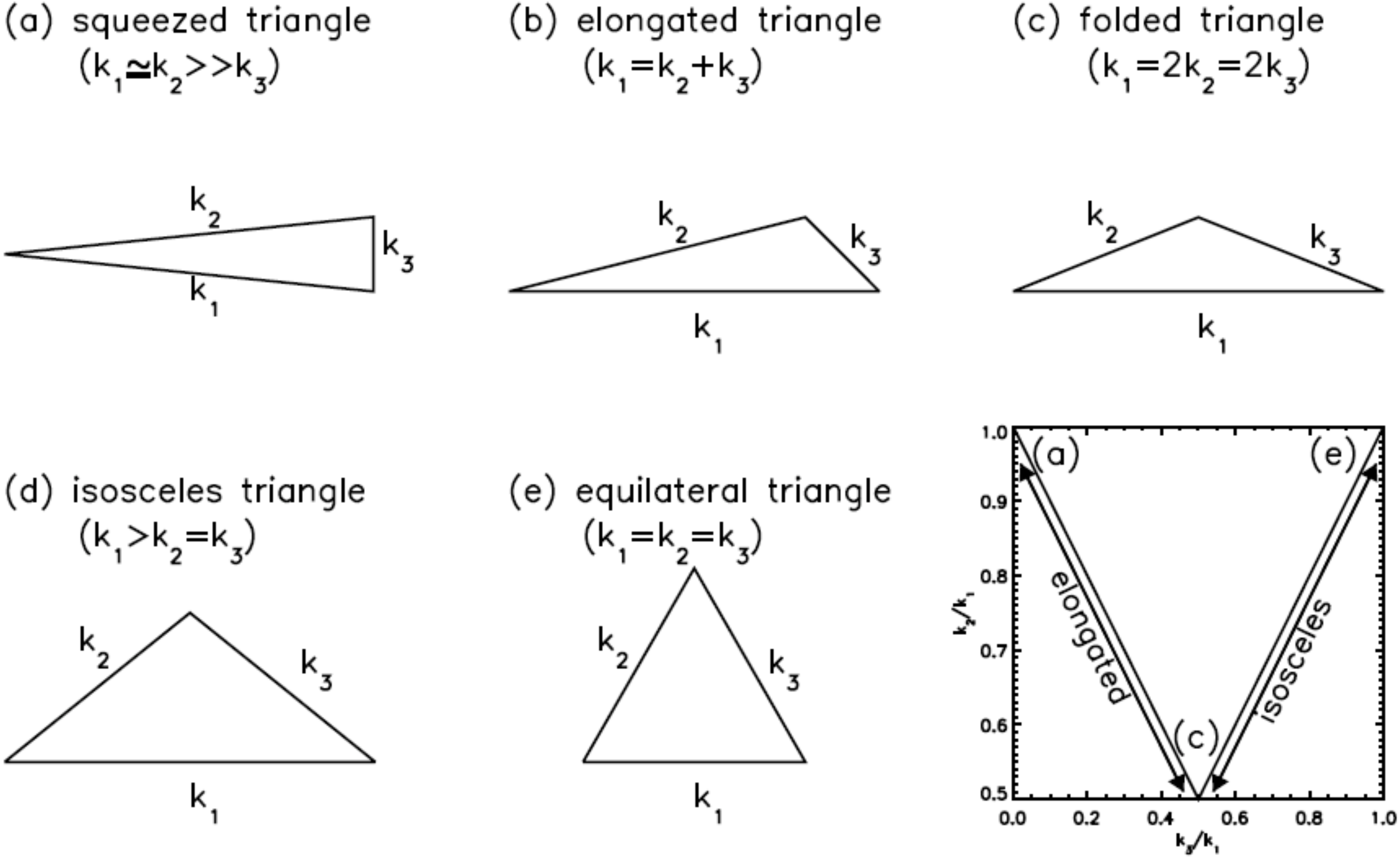
Beyond Power Spectrum

- These are based upon fitting the observed power spectrum (of scalar and tensor perturbations).
- Is there any more information one can obtain, beyond the power spectrum?

Bispectrum



- Three-point function!
- $B_\zeta(\mathbf{k}_1,\mathbf{k}_2,\mathbf{k}_3)$
  $= \langle\zeta_{\mathbf{k}1}\zeta_{\mathbf{k}2}\zeta_{\mathbf{k}3}\rangle$ = (amplitude) x $(2\pi)^3\delta(\mathbf{k}_1+\mathbf{k}_2+\mathbf{k}_3)F(k_1,k_2,k_3)$
  model-dependent function



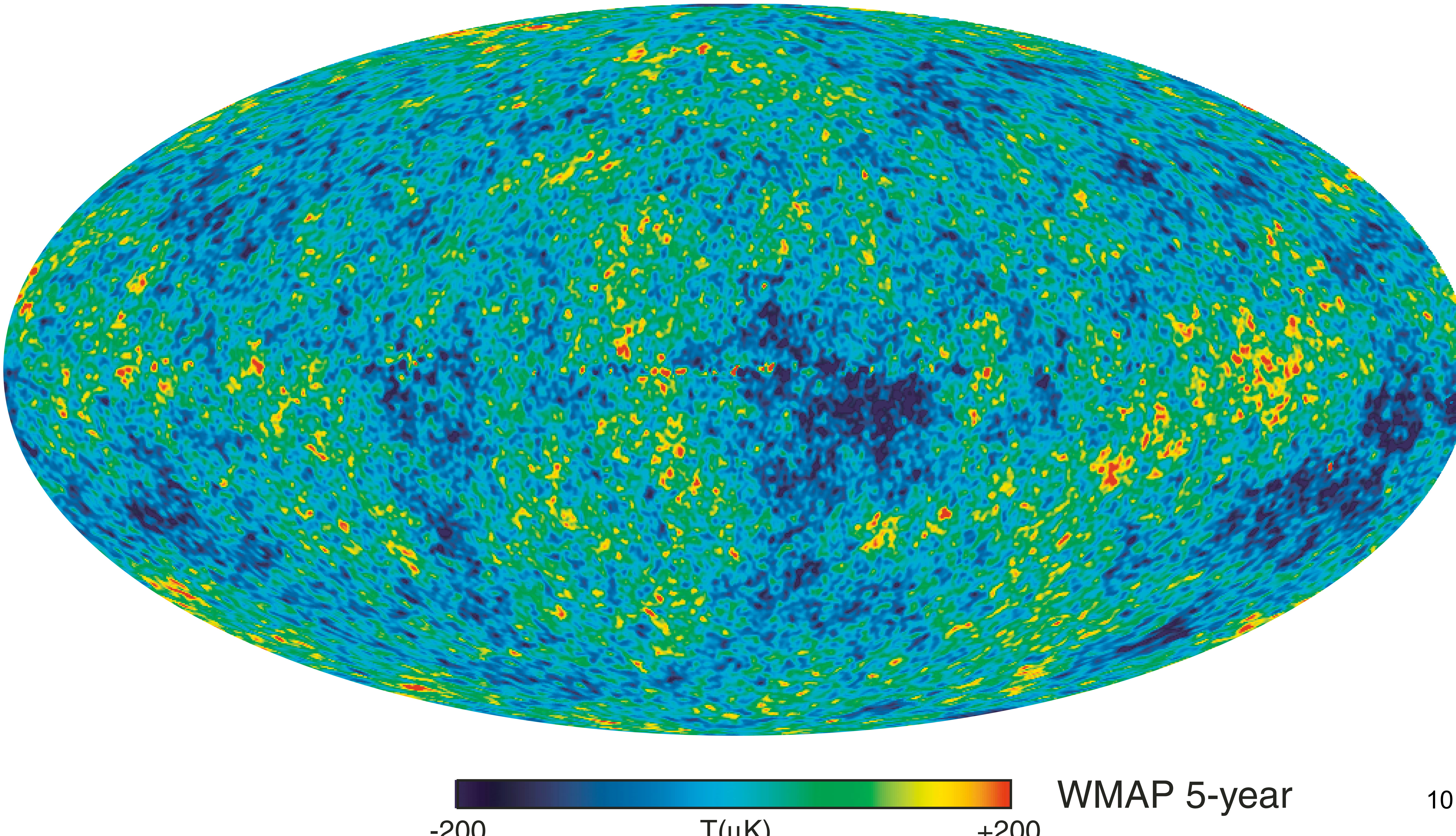
(a) squeezed triangle
(k1≃k2>>k3)
(b) elongated triangle
(k1=k2+k3)
(c) folded triangle
(k1=2k2=2k3)
(d) isosceles triangle
(k1>k2=k3)
(e) equilateral triangle
(k1=k2=k3)
k1
k2
k3
elongated
isosceles
(a)
(c)
(e)
k2/k1
k3/k1
1.0
0.9
0.8
0.7
0.6
0.5
0.0
0.2
0.4
0.6
0.8
1.0

Why Study Bispectrum?

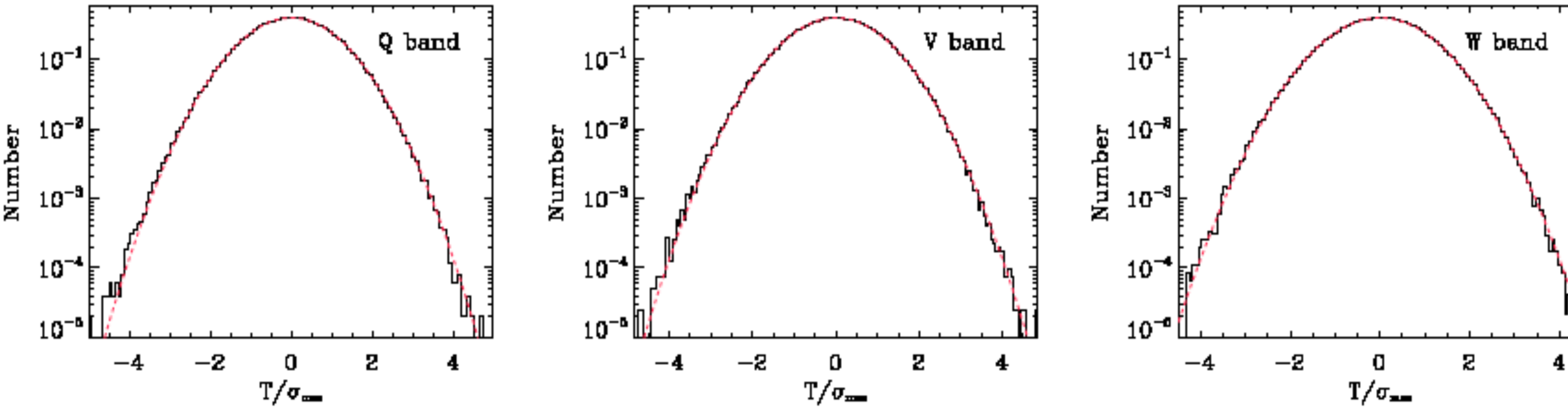
- It probes the interactions of fields - new piece of information that cannot be probed by the power spectrum
- But, above all, it provides us with a **critical test** of the simplest models of inflation: "***are primordial fluctuations Gaussian, or non-Gaussian?***"
- Bispectrum vanishes for Gaussian fluctuations.
- Detection of the bispectrum = detection of non-Gaussian fluctuations

Gaussian?

WMAP5



Take One-point Distribution Function



- The one-point distribution of WMAP map looks pretty Gaussian.
  - –Left to right: Q (41GHz), V (61GHz), W (94GHz).
- Deviation from Gaussianity is small, if any.

Inflation Likes This Result

- According to inflation (Mukhanov & Chibisov; Guth & Yi; Hawking; Starobinsky; Bardeen, Steinhardt & Turner), CMB anisotropy was created from **quantum fluctuations of a scalar field in Bunch-Davies vacuum** during inflation
- Successful inflation (with the expansion factor more than e^{60}) *demands* the scalar field be almost interaction-free
- The wave function of free fields in the ground state is a Gaussian!

But, Not Exactly Gaussian

- Of course, there are always corrections to the simplest statement like this.
- For one, inflaton field **does** have interactions. They are simply weak – they are suppressed by the so-called slow-roll parameter, $\varepsilon \sim O(0.01)$, relative to the free-field action.

A Non-linear Correction to Temperature Anisotropy

- The CMB temperature anisotropy, $\Delta T/T$, is given by the curvature perturbation in the matter-dominated era, Φ.
  - One large scales (the Sachs-Wolfe limit), $\Delta T/T = -\Phi/3$.
- Add a non-linear correction to Φ:

  For the Schwarzschild metric, $\Phi = +GM/R$.

  - $\Phi(\mathbf{x}) = \Phi_g(\mathbf{x}) + f_{NL}[\Phi_g(\mathbf{x})]^2$ (Komatsu & Spergel 2001)
  - f_{NL} was predicted to be small (~0.01) for slow-roll models (Salopek & Bond 1990; Gangui et al. 1994)

f_{NL}: Form of B_ζ

- Φ is related to the primordial curvature perturbation, ζ, as $\Phi=(3/5)\zeta$.

↓

- $\zeta(\mathbf{x}) = \zeta_g(\mathbf{x}) + (3/5)f_{NL}[\zeta_g(\mathbf{x})]^2$

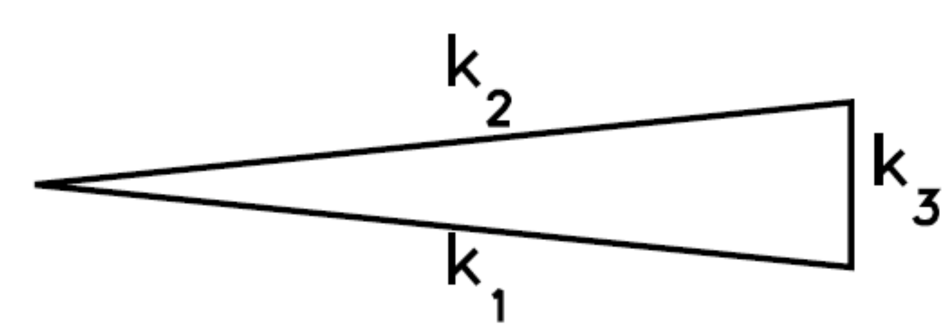
↓

- $B_\zeta(\mathbf{k}_1,\mathbf{k}_2,\mathbf{k}_3)=(6/5)f_{NL} \times (2\pi)^3\delta(\mathbf{k}_1+\mathbf{k}_2+\mathbf{k}_3) \times [P_\zeta(k_1)P_\zeta(k_2) + P_\zeta(k_2)P_\zeta(k_3) + P_\zeta(k_3)P_\zeta(k_1)]$

f_{NL}: Shape of Triangle

- For a scale-invariant spectrum, $P_\zeta(k)=A/k^3$,
  - $B_\zeta(\mathbf{k}_1,\mathbf{k}_2,\mathbf{k}_3)=(6A^2/5)f_{NL} \times (2\pi)^3\delta(\mathbf{k}_1+\mathbf{k}_2+\mathbf{k}_3) \times [1/(k_1k_2)^3 + 1/(k_2k_3)^3 + 1/(k_3k_1)^3]$
- Let's order k_i such that $k_3 \le k_2 \le k_1$. For a given k_1, one finds the largest bispectrum when the smallest k, i.e., k_3, is very small.
  - $B_\zeta(\mathbf{k}_1,\mathbf{k}_2,\mathbf{k}_3)$ peaks when $k_3 << k_2 \sim k_1$
  - Therefore, the shape of f_{NL} bispectrum is the squeezed triangle!

(Babich et al. 2004)



B_ζ in the Squeezed Limit

- In the squeezed limit, the f_{NL} bispectrum becomes:
$B_\zeta(\mathbf{k}_1,\mathbf{k}_2,\mathbf{k}_3) \approx (12/5)f_{NL} \times (2\pi)^3\delta(\mathbf{k}_1+\mathbf{k}_2+\mathbf{k}_3) \times P_\zeta(k_1)P_\zeta(k_3)$

Maldacena (2003); Seery & Lidsey (2005); Creminelli & Zaldarriaga (2004)

Single-field Theorem (Consistency Relation)

- For **ANY** single-field models*, the bispectrum in the squeezed limit is given by
  - $B_\zeta(\mathbf{k}_1,\mathbf{k}_2,\mathbf{k}_3) \approx (1-n_s) \times (2\pi)^3\delta(\mathbf{k}_1+\mathbf{k}_2+\mathbf{k}_3) \times P_\zeta(k_1)P_\zeta(k_3)$
  - Therefore, all single-field models predict $f_{NL} \approx (5/12)(1-n_s)$.
  - With the current limit $n_s=0.963$, f_{NL} is predicted to be 0.015.

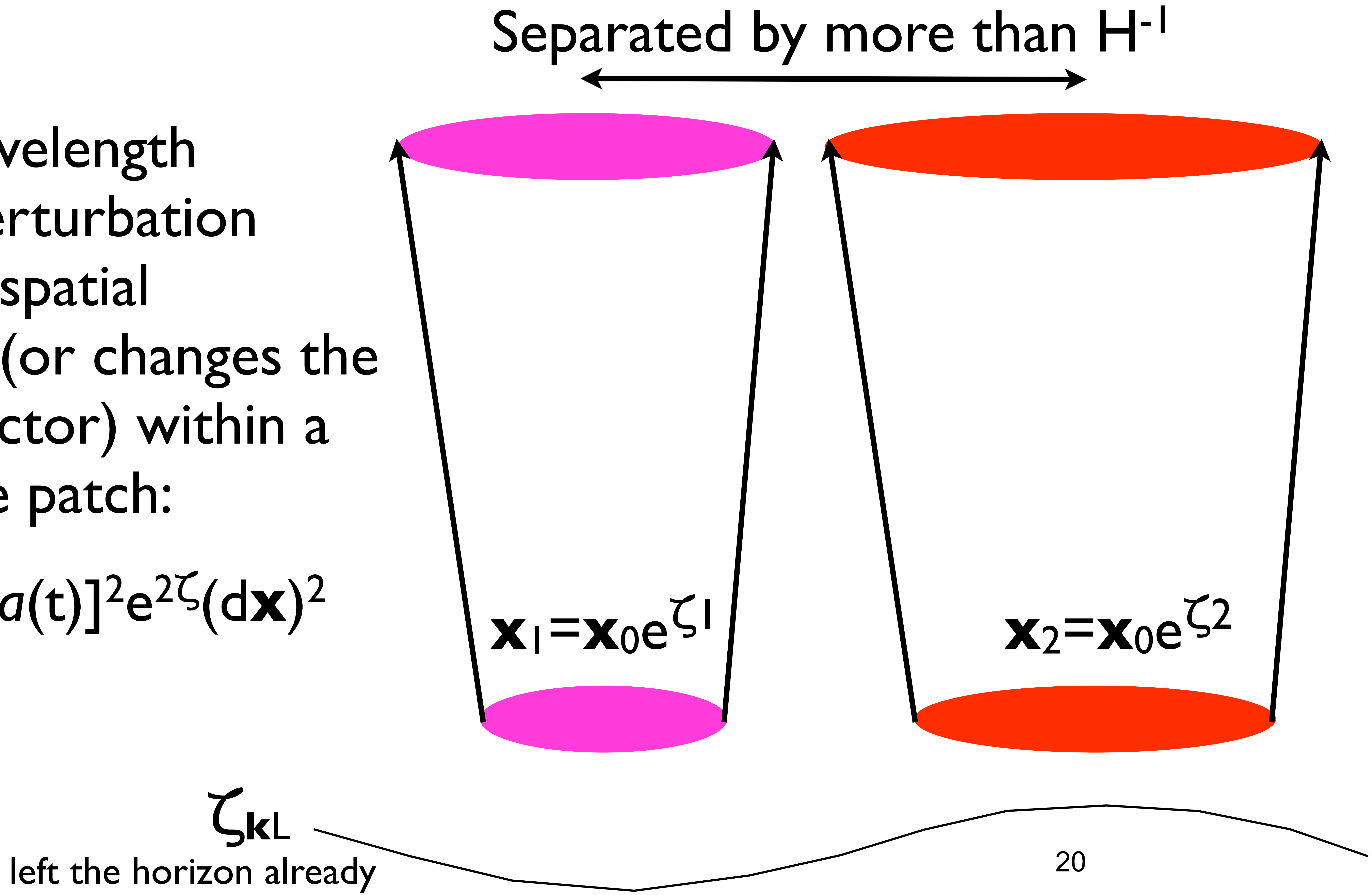
* for which the single field is solely responsible for driving inflation and generating observed fluctuations.

Understanding the Theorem

- First, the squeezed triangle correlates one very long-wavelength mode, k_L (=k_3), to two shorter wavelength modes, k_S (=$k_1 \approx k_2$):
  - $\langle\zeta_{\mathbf{k}1}\zeta_{\mathbf{k}2}\zeta_{\mathbf{k}3}\rangle \approx \langle(\zeta_{\mathbf{k}S})^2\zeta_{\mathbf{k}L}\rangle$
- Then, the question is: "why should $(\zeta_{\mathbf{k}S})^2$ ever care about $\zeta_{\mathbf{k}L}$?"
  - The theorem says, "it doesn't care, if $\zeta_{\mathbf{k}}$ is exactly scale invariant."

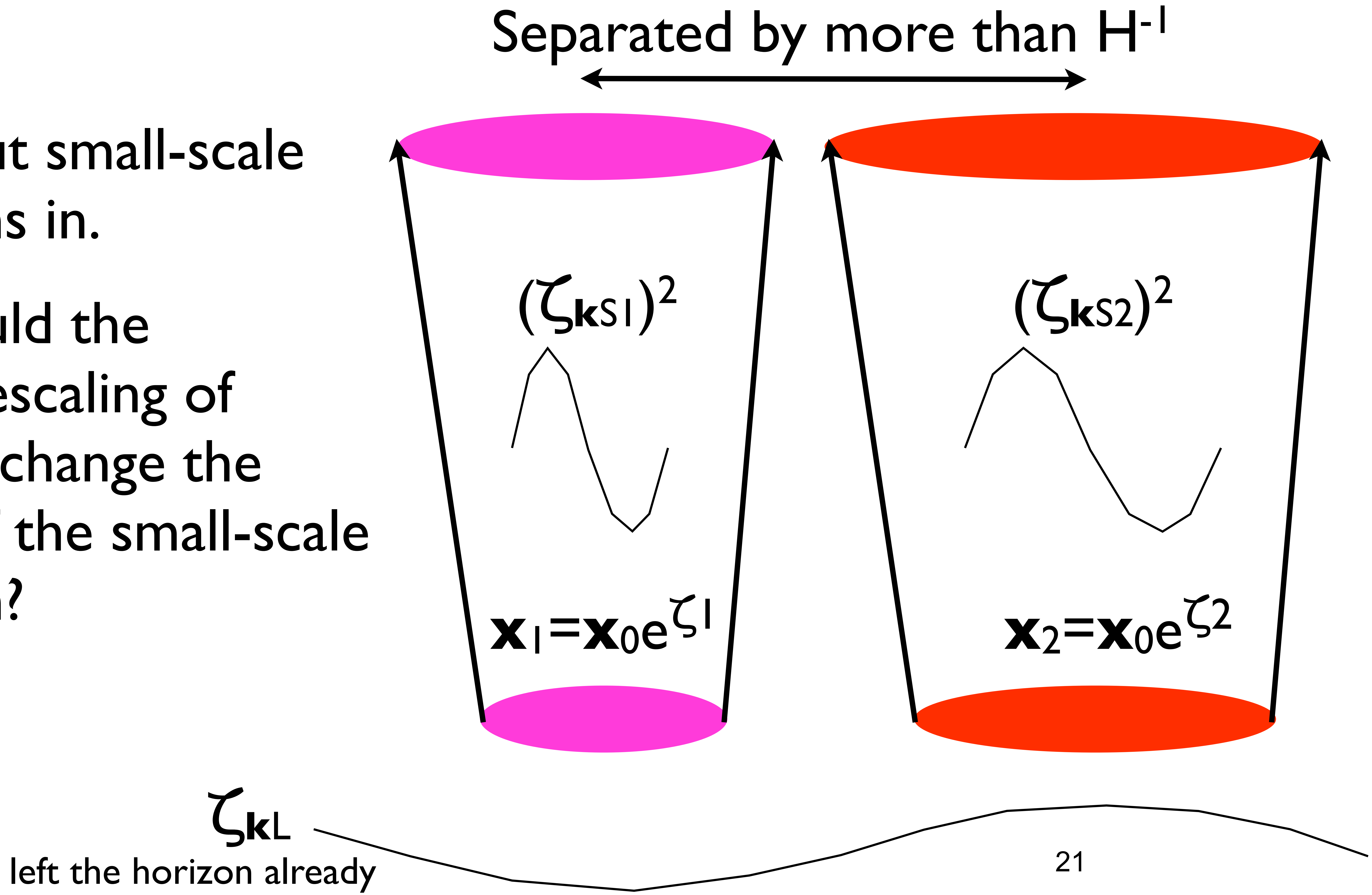
$\zeta_{\mathbf{k}L}$ rescales coordinates

- The long-wavelength curvature perturbation rescales the spatial coordinates (or changes the expansion factor) within a given Hubble patch:
  - $ds^2 = -dt^2 + [a(t)]^2 e^{2\zeta} (d\mathbf{x})^2$



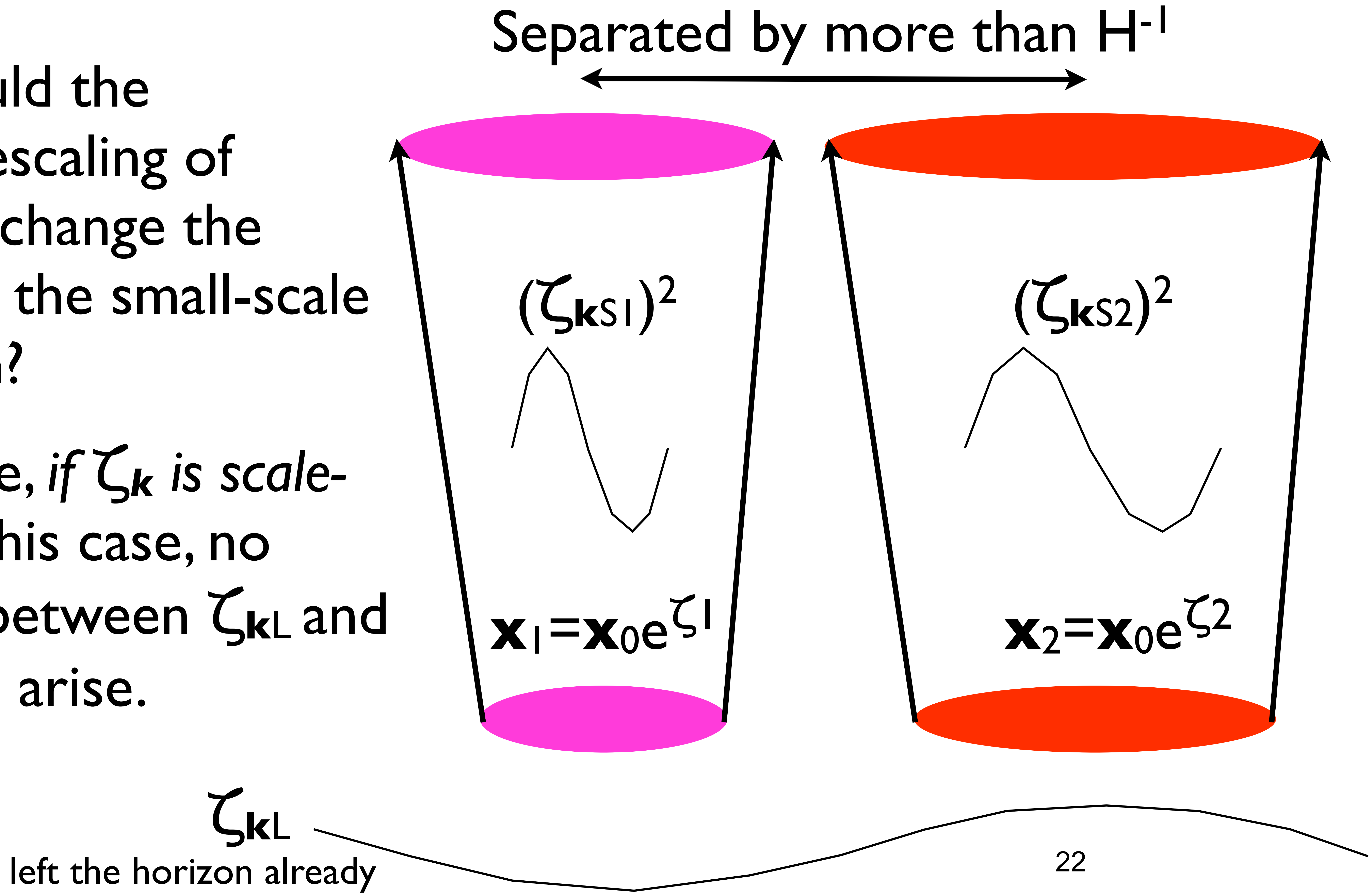
$\zeta_{\mathbf{k}L}$ rescales coordinates

- Now, let's put small-scale perturbations in.
- Q. How would the conformal rescaling of coordinates change the amplitude of the small-scale perturbation?



$\zeta_{\mathbf{k}L}$ rescales coordinates

- Q. How would the conformal rescaling of coordinates change the amplitude of the small-scale perturbation?
- A. No change, *if $\zeta_{\mathbf{k}}$ is scale-invariant*. In this case, no correlation between $\zeta_{\mathbf{k}L}$ and $(\zeta_{\mathbf{k}S})^2$ would arise.



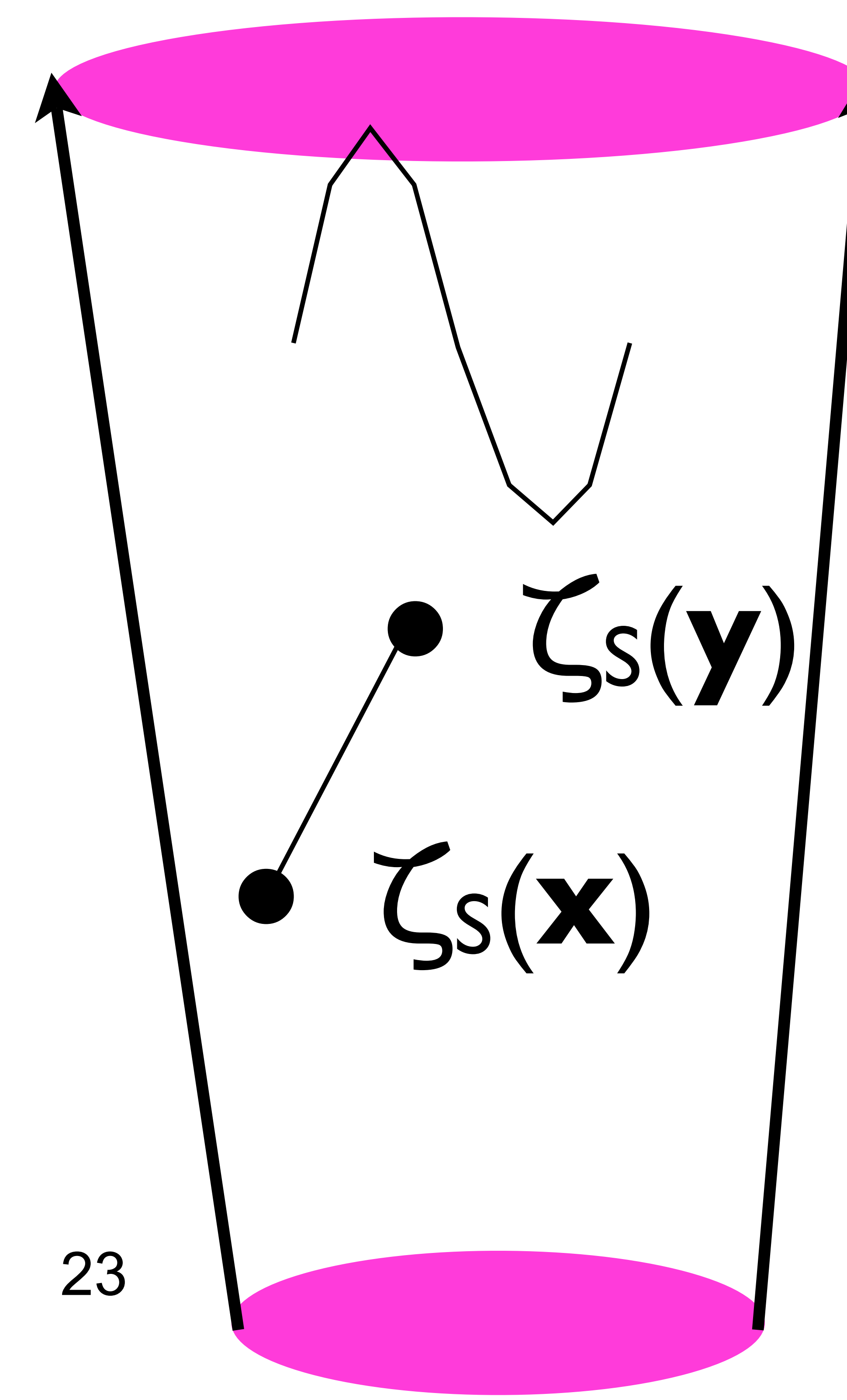
Creminelli & Zaldarriaga (2004); Cheung et al. (2008)

Real-space Proof

- The 2-point correlation function of short-wavelength modes, $\xi = \langle \zeta_S(\mathbf{x}) \zeta_S(\mathbf{y}) \rangle$, within a given Hubble patch can be written in terms of its vacuum expectation value (in the absence of ζ_L), ξ_0, as:

  - $\xi_{\zeta_L} \approx \xi_0(|\mathbf{x}-\mathbf{y}|) + \zeta_L\, [d\xi_0(|\mathbf{x}-\mathbf{y}|)/d\zeta_L]$
  - $\xi_{\zeta_L} \approx \xi_0(|\mathbf{x}-\mathbf{y}|) + \zeta_L\, [d\xi_0(|\mathbf{x}-\mathbf{y}|)/d\ln|\mathbf{x}-\mathbf{y}|]$
  - $\xi_{\zeta_L} \approx \xi_0(|\mathbf{x}-\mathbf{y}|) + \zeta_L\, (1-n_s)\xi_0(|\mathbf{x}-\mathbf{y}|)$

$$\text{3-pt func.} = \langle (\zeta_S)^2 \zeta_L \rangle = \langle \xi_{\zeta_L} \zeta_L \rangle$$
$$= (1-n_s)\xi_0(|\mathbf{x}-\mathbf{y}|)\langle \zeta_L^2 \rangle$$



Where was "Single-field"?

- Where did we assume "single-field" in the proof?
- For this proof to work, it is crucial that there is only one dynamical degree of freedom, i.e., it is only ζ_L that modifies the amplitude of short-wavelength modes, and nothing else can modify it.
- Also, ζ must be constant outside of the horizon (otherwise anything can happen afterwards). This is also the case for single-field inflation models.

Therefore...

- A convincing detection of $f_{NL} > 1$ would rule out ***all*** of the single-field inflation models, regardless of:
  - the form of potential
  - the form of kinetic term (or sound speed)
  - the initial vacuum state
- A convincing detection of f_{NL} would be a breakthrough.

Side Note:

Large Non-Gaussianity from Single-field Inflation

But not in the squeezed limit

- $S=(1/2)\int d^4x \sqrt{-g}\,[R-(\partial_\mu\varphi)^2-2V(\varphi)]$
- 2nd-order (which gives P_ζ)
  - $S_2=\int d^4x\, \varepsilon\, [a^3(\partial_t\zeta)^2-a(\partial_i\zeta)^2]$
- 3rd-order (which gives B_ζ)
  - $S_3=\int d^4x\, \boldsymbol{\varepsilon^2}\, [\ldots a^3(\partial_t\zeta)^2\zeta+\ldots a(\partial_i\zeta)^2\zeta+\ldots a^3(\partial_t\zeta)^3] + O(\varepsilon^3)$

Cubic-order interactions are suppressed by an additional factor of ε.
(Maldacena 2003)

Side Note:

Large Non-Gaussianity from Single-field Inflation

But not in the squeezed limit

- $S=(1/2)\int d^4x\,\sqrt{-g}\,\{R-2P[(\partial_\mu\varphi)^2,\varphi]\}$ [general kinetic term]
- 2nd-order
  - $S_2=\int d^4x\,\varepsilon\,[a^3(\partial_t\zeta)^2/c_s^2-a(\partial_i\zeta)^2]$

“Speed of sound”
$c_s^2=P_{,X}/(P_{,X}+2XP_{,XX})$

- 3rd-order
  - $S_3=\int d^4x\,\boldsymbol{\varepsilon^2}\,[\ldots a^3(\partial_t\zeta)^2\zeta/\boldsymbol{c_s^2}+\ldots a(\partial_i\zeta)^2\zeta+\ldots a^3(\partial_t\zeta)^3/\boldsymbol{c_s^2}]+O(\varepsilon^3)$

Some interactions are enhanced for $c_s^2<1$.

(Seery & Lidsey 2005; Chen et al. 2007)

Side Note:

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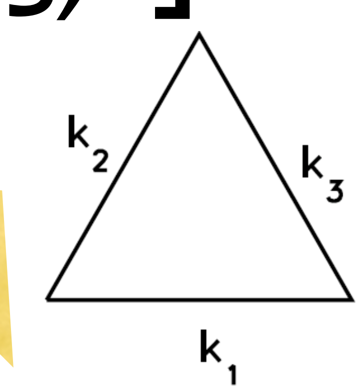
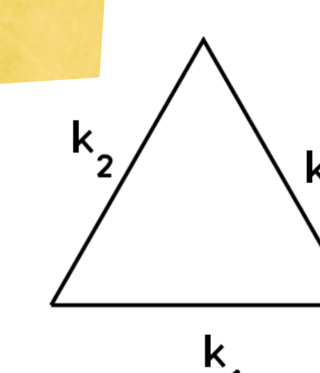
"Speed of sound"
$c_s^2=P_{,X}/(P_{,X}+2XP_{,XX})$



- 3rd-order
  - $S_3=\int d^4x\, \boldsymbol{\varepsilon^2}\, [\ldots a^3(\partial_t\zeta)^2\zeta/\boldsymbol{c_s^2}+\ldots a(\partial_i\zeta)^2\zeta+\ldots a^3(\partial_t\zeta)^3/\boldsymbol{c_s^2}]+O(\varepsilon^3)$

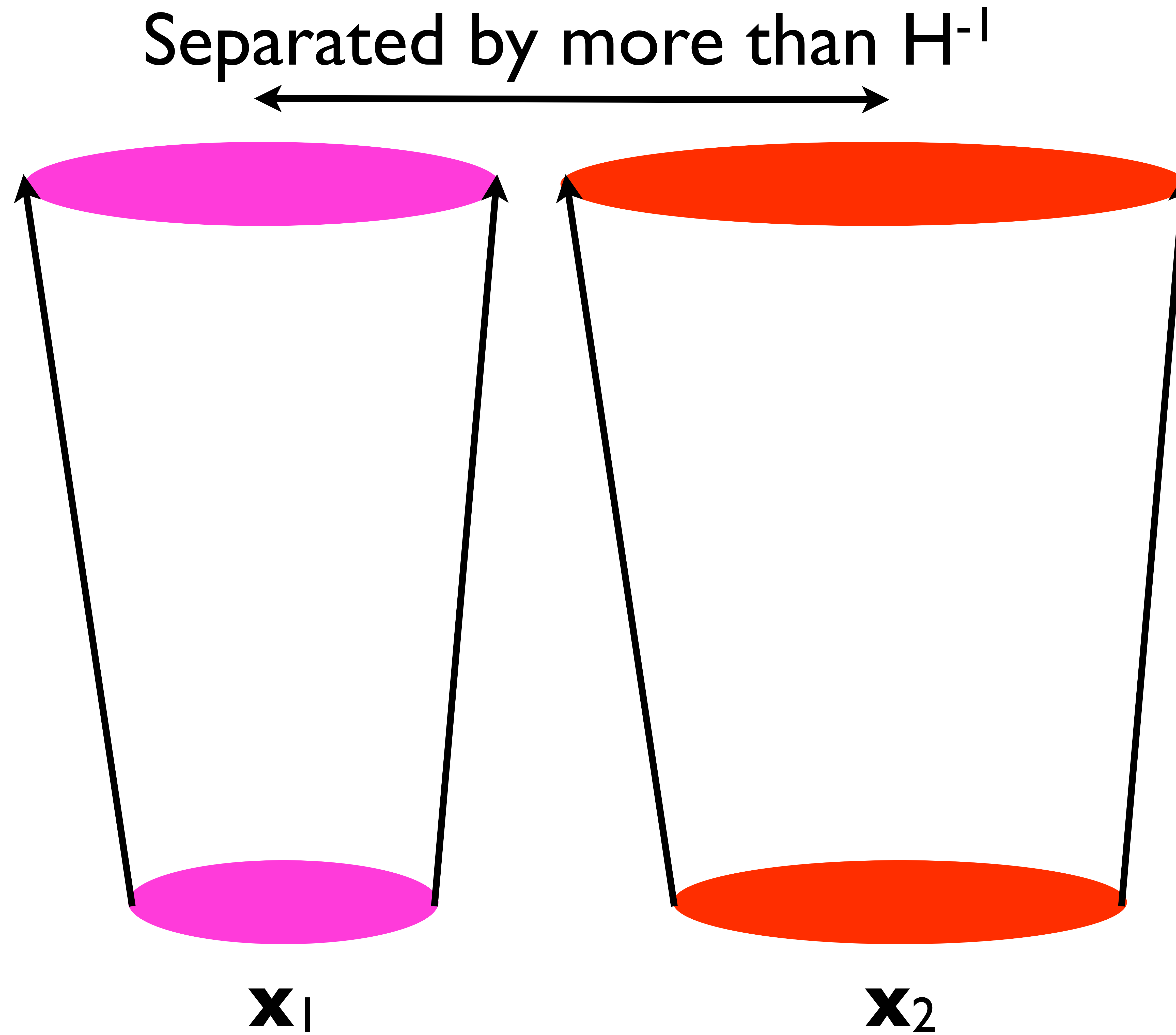


Some interactions are enhanced for $c_s^2<1$.

(Seery & Lidsey 2005; Chen et al. 2007)

Another Motivation For f_{NL}

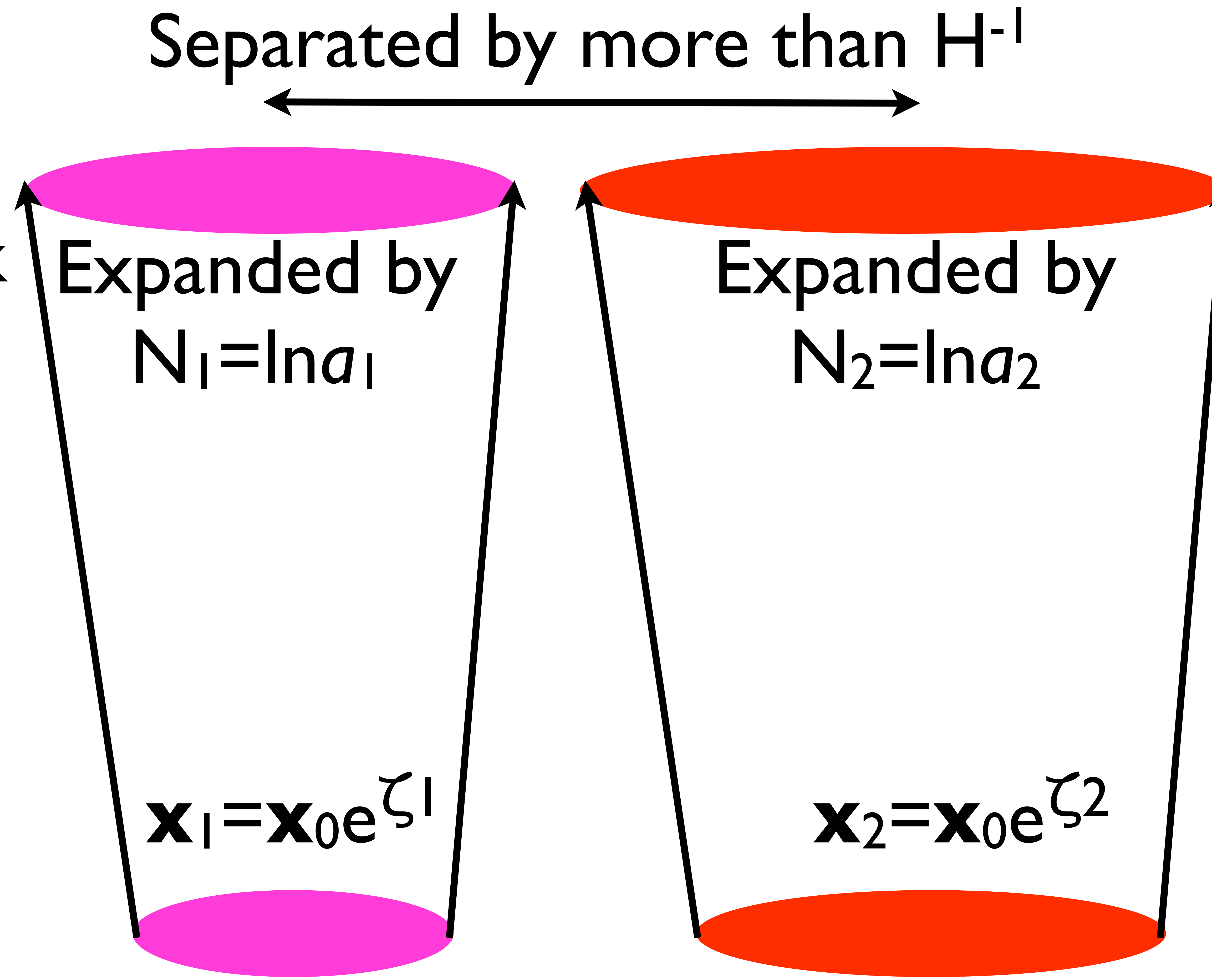
- In multi-field inflation models, $\zeta_{\boldsymbol{k}}$ can evolve outside the horizon.
- This evolution can give rise to non-Gaussianity; however, causality demands that the form of non-Gaussianity must be local!



$$\zeta(\mathbf{x})=\zeta_g(\mathbf{x})+(3/5)f_{NL}[\zeta_g(\mathbf{x})]^2+A\chi_g(\mathbf{x})+B[\chi_g(\mathbf{x})]^2+\ldots$$

The δN Formalism

- The δN formalism (Starobinsky 1982; Salopek & Bond 1990; Sasaki & Stewart 1996) states that the curvature perturbation is equal to the difference in $N=\ln a$.
  - $\zeta=\delta N=N_2-N_1$
  - where $N=\int H dt$



Getting the familiar result

- Single-field example at the linear order:
  - $\zeta = \delta\{\int H dt\} = \delta\{\int (H/\varphi')d\varphi\} \approx (H/\varphi')\delta\varphi$
  - Mukhanov & Chibisov; Guth & Pi; Hawking; Starobinsky; Bardeen, Steinhardt & Turner

Extending to non-linear, multi-field cases

$$\zeta = \sum_I \frac{\partial N}{\partial \phi_I}\delta\phi_I + \frac{1}{2}\sum_{IJ}\frac{\partial^2 N}{\partial \phi_I \partial \phi_J}\delta\phi_I\delta\phi_J + \ldots$$

(Lyth & Rodriguez 2005)

- Calculating the bispectrum is then straightforward. Schematically:
  - $<\zeta^3> = <(1st)x(1st)x(2nd)> \sim <\delta\varphi^4> \neq 0$
  - $f_{NL} \sim <\zeta^3>/<\zeta^2>^2$

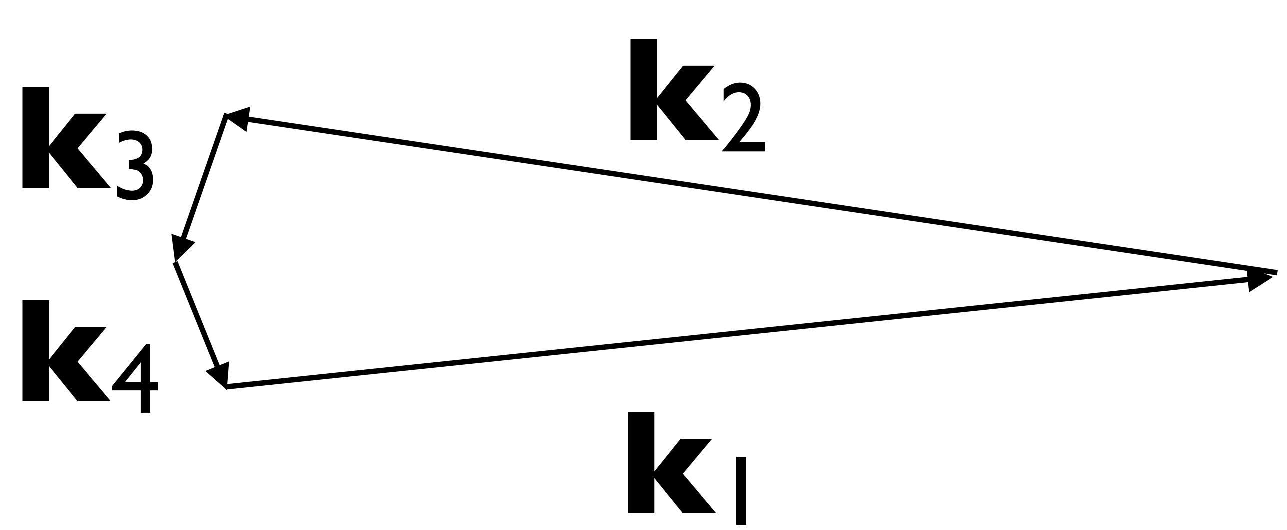
$$\frac{6}{5} f_{\rm NL}^{\rm local} = \frac{\sum_{IJ} N_{,IJ} N_{,I} N_{,J}}{[\sum_I (N_{,I})^2]^2}$$

Trispectrum: Next Frontier

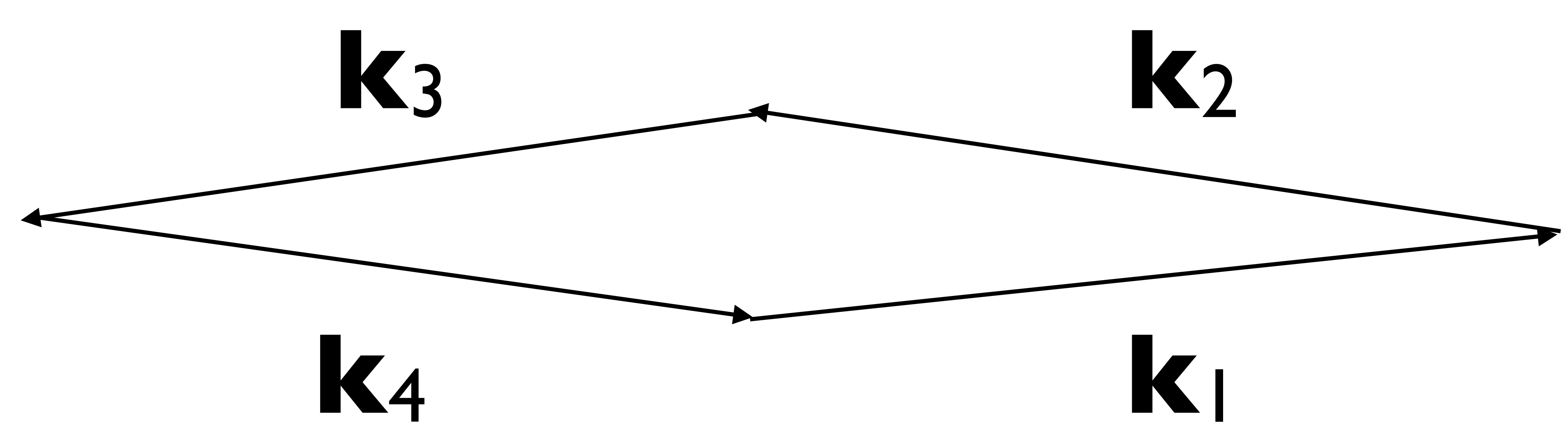
- The local form bispectrum, $B_\zeta(\mathbf{k}_1,\mathbf{k}_2,\mathbf{k}_3)=(2\pi)^3\delta(\mathbf{k}_1+\mathbf{k}_2+\mathbf{k}_3)f_{NL}[(6/5)P_\zeta(k_1)P_\zeta(k_2)+\text{cyc.}]$
- is equivalent to having the curvature perturbation in position space, in the form of:
  - $\zeta(\mathbf{x})=\zeta_g(\mathbf{x}) + (3/5)f_{NL}[\zeta_g(\mathbf{x})]^2$
- This can be extended to higher-order:
  - $\zeta(\mathbf{x})=\zeta_g(\mathbf{x}) + (3/5)f_{NL}[\zeta_g(\mathbf{x})]^2 + (9/25)g_{NL}[\zeta_g(\mathbf{x})]^3$

Local Form Trispectrum

- For $\zeta(\mathbf{x})=\zeta_g(\mathbf{x}) + (3/5)f_{NL}[\zeta_g(\mathbf{x})]^2 + (9/25)g_{NL}[\zeta_g(\mathbf{x})]^3$, we obtain the trispectrum:
  - $T_\zeta(\mathbf{k}_1,\mathbf{k}_2,\mathbf{k}_3,\mathbf{k}_4)=(2\pi)^3\delta(\mathbf{k}_1+\mathbf{k}_2+\mathbf{k}_3+\mathbf{k}_4)$
    $\{\boldsymbol{g_{NL}}[(54/25)P_\zeta(k_1)P_\zeta(k_2)P_\zeta(k_3)+\text{cyc.}] +$
    $\boldsymbol{(f_{NL})^2}[(18/25)P_\zeta(k_1)P_\zeta(k_2)(P_\zeta(|\mathbf{k}_1+\mathbf{k}_3|)+P_\zeta(|\mathbf{k}_1+\mathbf{k}_4|))+\text{cyc.}]\}$



g_{NL}

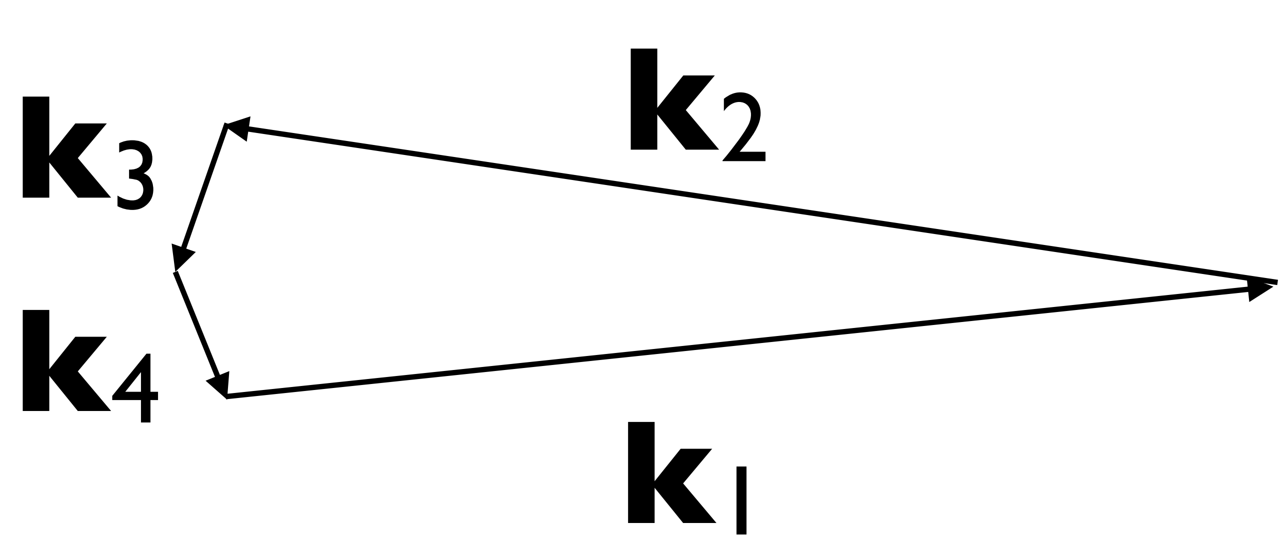


f_{NL}^2

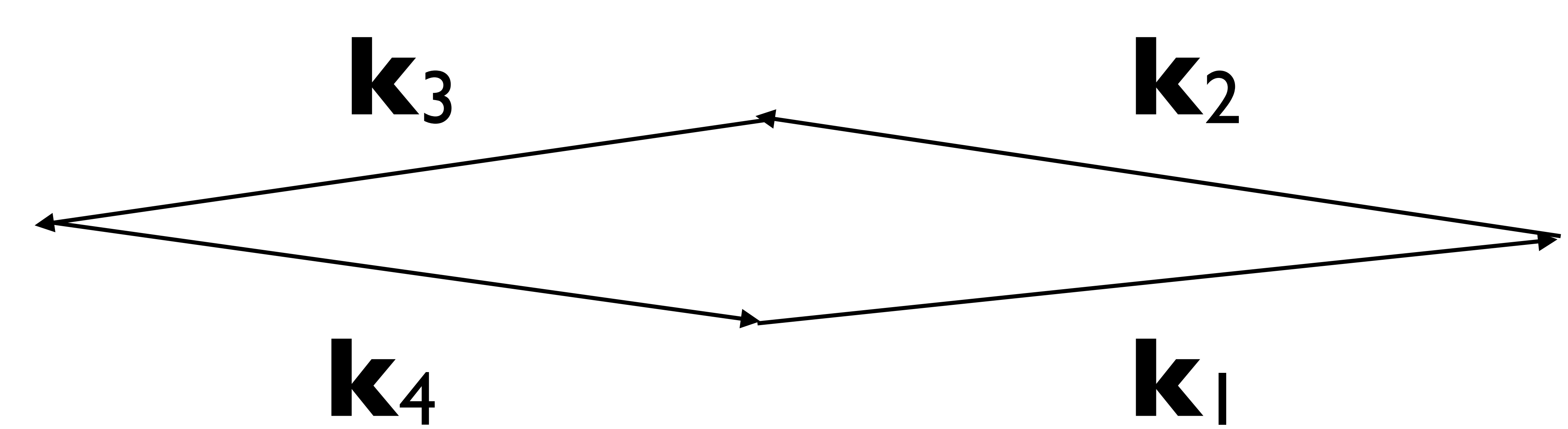
(Slightly) Generalized Trispectrum

- $T_\zeta(\mathbf{k}_1,\mathbf{k}_2,\mathbf{k}_3,\mathbf{k}_4)=(2\pi)^3\delta(\mathbf{k}_1+\mathbf{k}_2+\mathbf{k}_3+\mathbf{k}_4)$
  $\{g_{NL}[(54/25)P_\zeta(k_1)P_\zeta(k_2)P_\zeta(k_3)+\text{cyc.}]$
  $+\tau_{NL}[P_\zeta(k_1)P_\zeta(k_2)(P_\zeta(|\mathbf{k}_1+\mathbf{k}_3|)+P_\zeta(|\mathbf{k}_1+\mathbf{k}_4|))+\text{cyc.}]\}$

The local form consistency relation, $\tau_{NL}=(6/5)(f_{NL})^2$, may not be respected – additional test of multi-field inflation!



g_{NL}



τ_{NL}

Coming back to δN...

$$\zeta = \sum_I \frac{\partial N}{\partial \phi_I}\delta\phi_I + \frac{1}{2}\sum_{IJ}\frac{\partial^2 N}{\partial\phi_I\partial\phi_J}\delta\phi_I\delta\phi_J + \dots$$

(Lyth & Rodriguez 2005)

- Calculating the trispectrum is also straightforward. Schematically:
  - $<\zeta^4> = <(1st)^2(2nd)^2> \sim <\delta\varphi^6> \neq 0$
  - $f_{NL} \sim <\zeta^4>/<\zeta^2>^3$

$$\tau_{\rm NL} = \frac{\sum_{IJK} N_{,IJ}N_{,J}N_{,IK}N_{,K}}{[\sum_I (N_{,I})^2]^3} = \frac{\sum_I(\sum_J N_{,IJ}N_{,J})^2}{[\sum_I (N_{,I})^2]^3}$$

Now, stare at these.

$$\frac{6}{5} f_{\rm NL}^{\rm local} = \frac{\sum_{IJ} N_{,IJ} N_{,I} N_{,J}}{[\sum_I (N_{,I})^2]^2},$$

$$\tau_{\rm NL} = \frac{\sum_{IJK} N_{,IJ} N_{,J} N_{,IK} N_{,K}}{[\sum_I (N_{,I})^2]^3} = \frac{\sum_I (\sum_J N_{,IJ} N_{,J})^2}{[\sum_I (N_{,I})^2]^3}$$

Change the variable...

$$\frac{6}{5} f_{\rm NL}^{\rm local} = \frac{\sum_{IJ} N_{,IJ} N_{,I} N_{,J}}{[\sum_I (N_{,I})^2]^2},$$

$$\tau_{\rm NL} = \frac{\sum_{IJK} N_{,IJ} N_{,J} N_{,IK} N_{,K}}{[\sum_I (N_{,I})^2]^3} = \frac{\sum_I (\sum_J N_{,IJ} N_{,J})^2}{[\sum_I (N_{,I})^2]^3}$$

$$a_I = \frac{\sum_J N_{,IJ} N_{,J}}{[\sum_J (N_{,J})^2]^{3/2}}$$

$$b_I = \frac{N_{,I}}{[\sum_J (N_{,J})^2]^{1/2}}$$

$(6/5)f_{NL}=\sum_I a_I b_I$

$\tau_{NL}=(\sum_I a_I)^2(\sum_I b_I)^2$

Then apply the Cauchy-Schwarz Inequality

$$\left(\sum_I a_I^2\right)\left(\sum_J b_J^2\right) \geq \left(\sum_I a_I b_I\right)^2$$

- Implies (Suyama & Yamaguchi 2008)

$$\tau_{\rm NL} \geq \left(\frac{6\, f_{\rm NL}^{\rm local}}{5}\right)^2$$

This holds for almost all (if not **all** - left unproven) for multi-field models!

Be careful when 0=0

- The Suyama-Yamaguchi inequality does not always hold because the Cauchy-Schwarz inequality can be 0=0. For example:

$$\zeta = \frac{\partial N}{\partial \phi_1}\delta\phi_1 + \frac{1}{2}\frac{\partial^2 N}{\partial \phi_2^2}\delta\phi_2^2$$

In this harmless two-field case, the Cauchy-Schwarz inequality becomes 0=0 (both f_{NL} and τ_{NL} result from the second term). In this case,

$$\tau_{\rm NL} \sim 10^3 (f_{\rm NL}^{\rm local})^{4/3}$$

(Suyama & Takahashi 2008)

But, even in this case...

$$\tau_{\rm NL} \sim 10^3 (f_{\rm NL}^{\rm local})^{4/3}$$

still satisfies

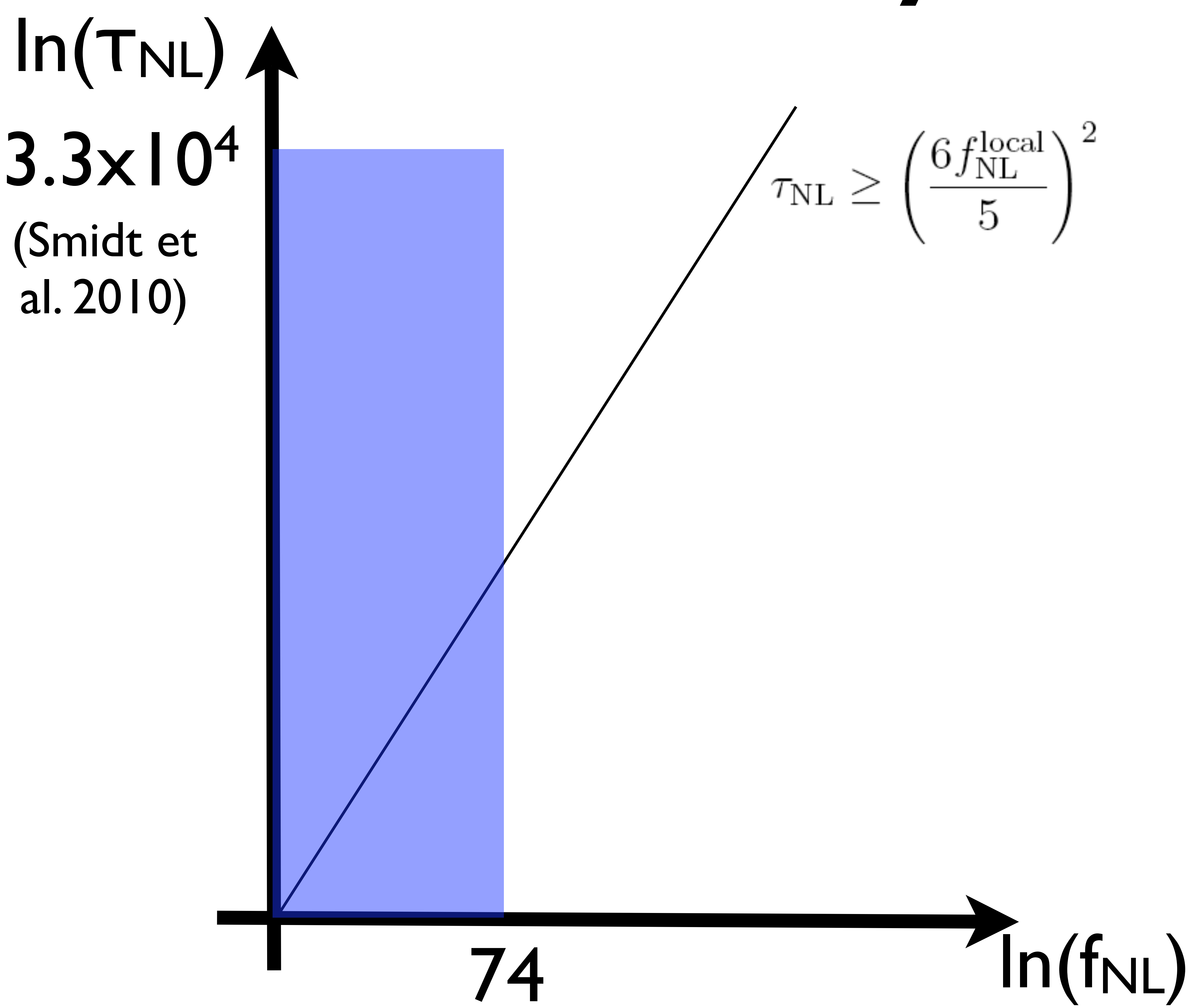
$$\tau_{\rm NL} \geq \left(\frac{6 f_{\rm NL}^{\rm local}}{5}\right)^2$$

as long as f_{NL}<18000. Current limit?

$$f_{\rm NL}^{\rm local} = 32 \pm 21 \ (68\% \ {\rm CL})$$

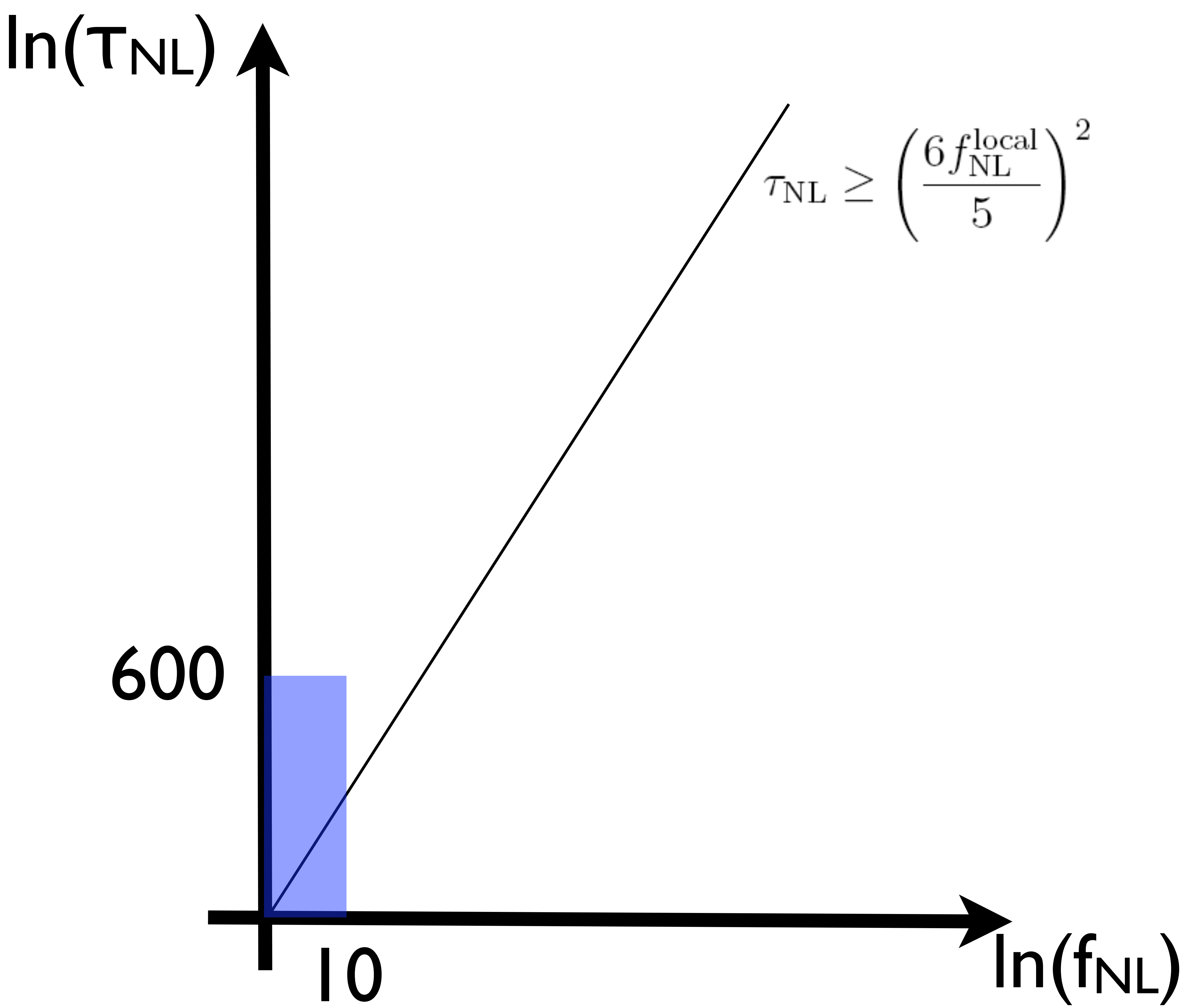
(Komatsu et al. 2010)

The diagram that you should take away from this talk.



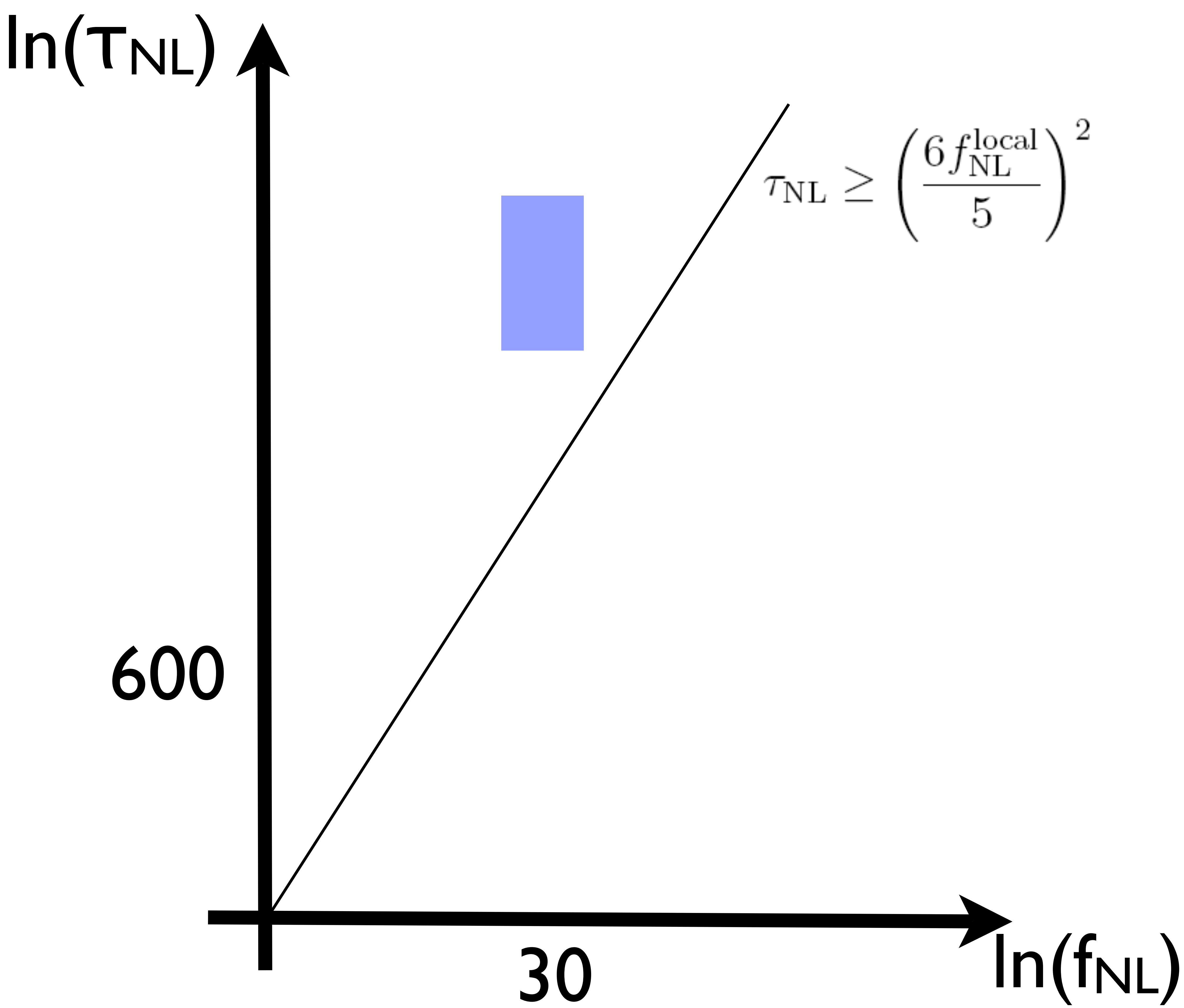
- The current limits from WMAP 7-year are consistent with single-field or multi-field models.
- So, let's play around with the future.

Case A: Single-field Happiness



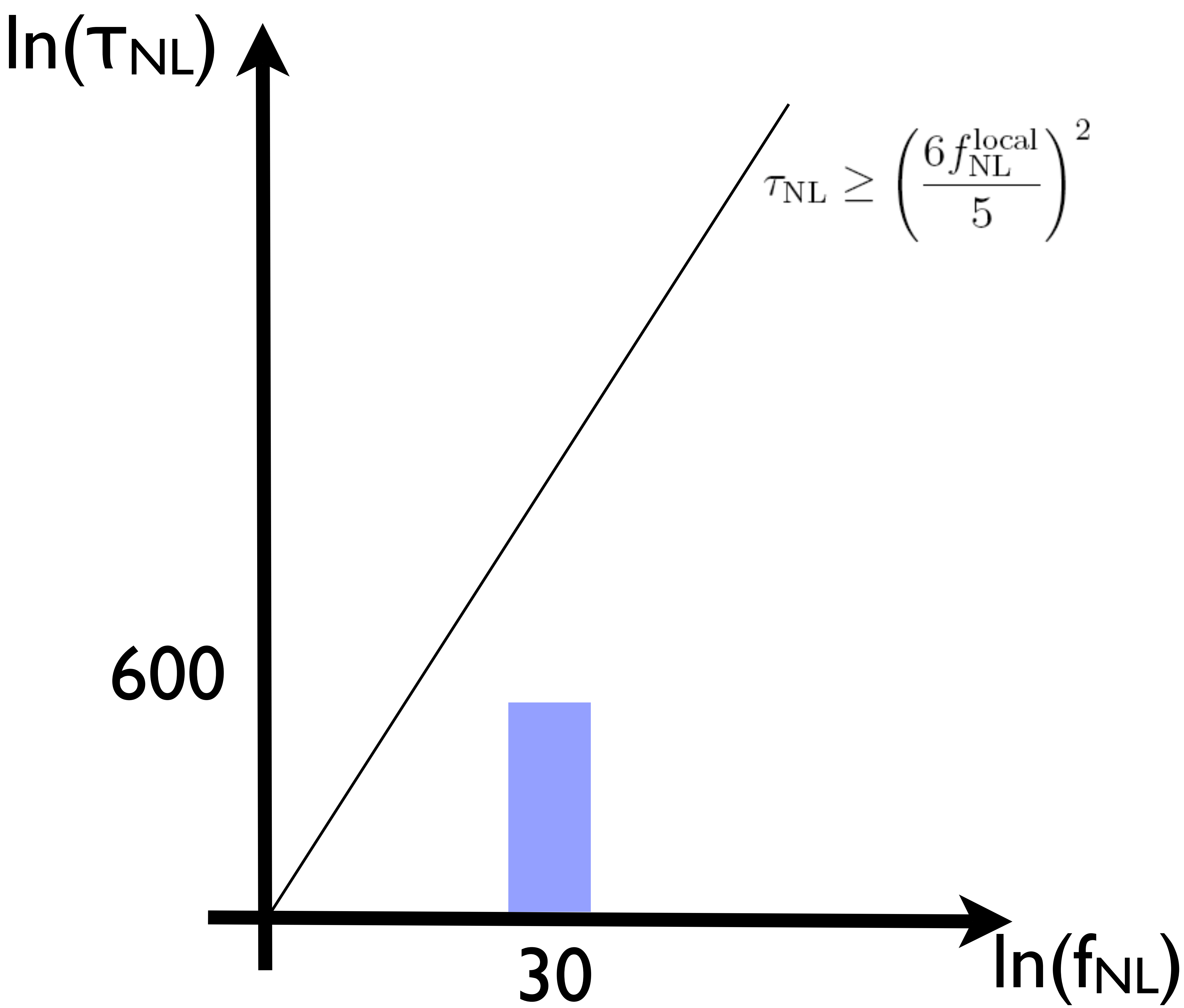
- No detection of anything after Planck. Single-field survived the test (for the moment: the future galaxy surveys can improve the limits by a factor of ten).

Case B: Multi-field Happiness



- f_{NL} is detected. Single-field is dead.
- But, τ_{NL} is also detected, in accordance with the Suyama-Yamaguchi inequality, as expected from most (if not all - left unproven) of multi-field models.

Case C: Madness



- f_{NL} is detected. Single-field is dead.
- But, τ_{NL} is **not** detected, inconsistent with the Suyama-Yamaguchi inequality.
- (With the caveat that this may not be completely general) BOTH the single-field and multi-field are gone.

An exciting field

Non-Gaussianity as a Probe of the Physics of the Primordial Universe and the Astrophysics of the Low Redshift Universe

E.Komatsu, N.Afshordi, N.Bartolo, D.Baumann, J.R.Bond, E.I.Buchbinder, C.T.Byrnes, X.Chen, D.J.H.Chung, A.Cooray, P.Creminelli, N.Dalal, O.Dore, R.Easther, A.V.Frolov, K.M.Gorski, M.G. Jackson, J.Khoury, W.H.Kinney, L.Kofman, K.Koyama, L.Leblond, J.-L.Lehners, J.E.Lidsey, M.Liguori, E.A.Lim, A.Linde, D.H.Lyth, J.Maldacena, S.Matarrese, L.McAllister, P.McDonald, S.Mukohyama, B.Ovrut, H.V.Peiris, C.Raeth, A.Riotto, Y.Rodriguez, M.Sasaki, R.Scoccimarro, D.Seery, E.Sefusatti, U.Seljak, L.Senatore, S.Shandera, E.P.S.Shellard, E.Silverstein, A.Slosar, K.M.Smith, A.A.Starobinsky, P.J.Steinhardt, F.Takahashi, M.Tegmark, A.J.Tolley, L.Verde, B.D.Wandelt, D.Wands, S.Weinberg, M.Wyman, A.P.S.Yadav, M.Zaldarriaga

Science White Paper submitted to the Cosmology and Fundamental Physics (CFP) Science Frontier Panel of the Astro 2010 Decadal Survey

See Komatsu, arXiv:1003.6097 for a recent review

Summary

- Non-Gaussianity provides the only means (so far) to rule out single-field inflation models altogether.
- Non-Gaussianity provides the only, possible means (because it has not been proven completely yet) to rule out multi-field inflation models altogether.
- As a result, non-Gaussianity can be used to rule out inflation models altogether - something that was not conceived to be possible before.

See Komatsu, arXiv:1003.6097 for a recent review

Summary

- *Planck* is well-position to achieve this.
- If not, inflation still needs to pass more stringent tests from (near; ~5 years) future data, reaching f_{NL}~1 and τ_{NL}~10.