South Pole Telescope and Atacama Cosmology Telescope: Prospects for Inflation ***with Gaussianity Tests***

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Center for Cosmology, The University of Texas Austin

- The new Center for Cosmology, founded in January 2009, at the University of Texas at Austin!

Research Unit, Center for Cosmology

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Gary Hill	Willy Fischler
Eiichiro Komatsu(Director)	Vadim Kaplunovsky
Milos Milosavljevic	Sonia Paban
Paul Shapiro	Steven Weinberg

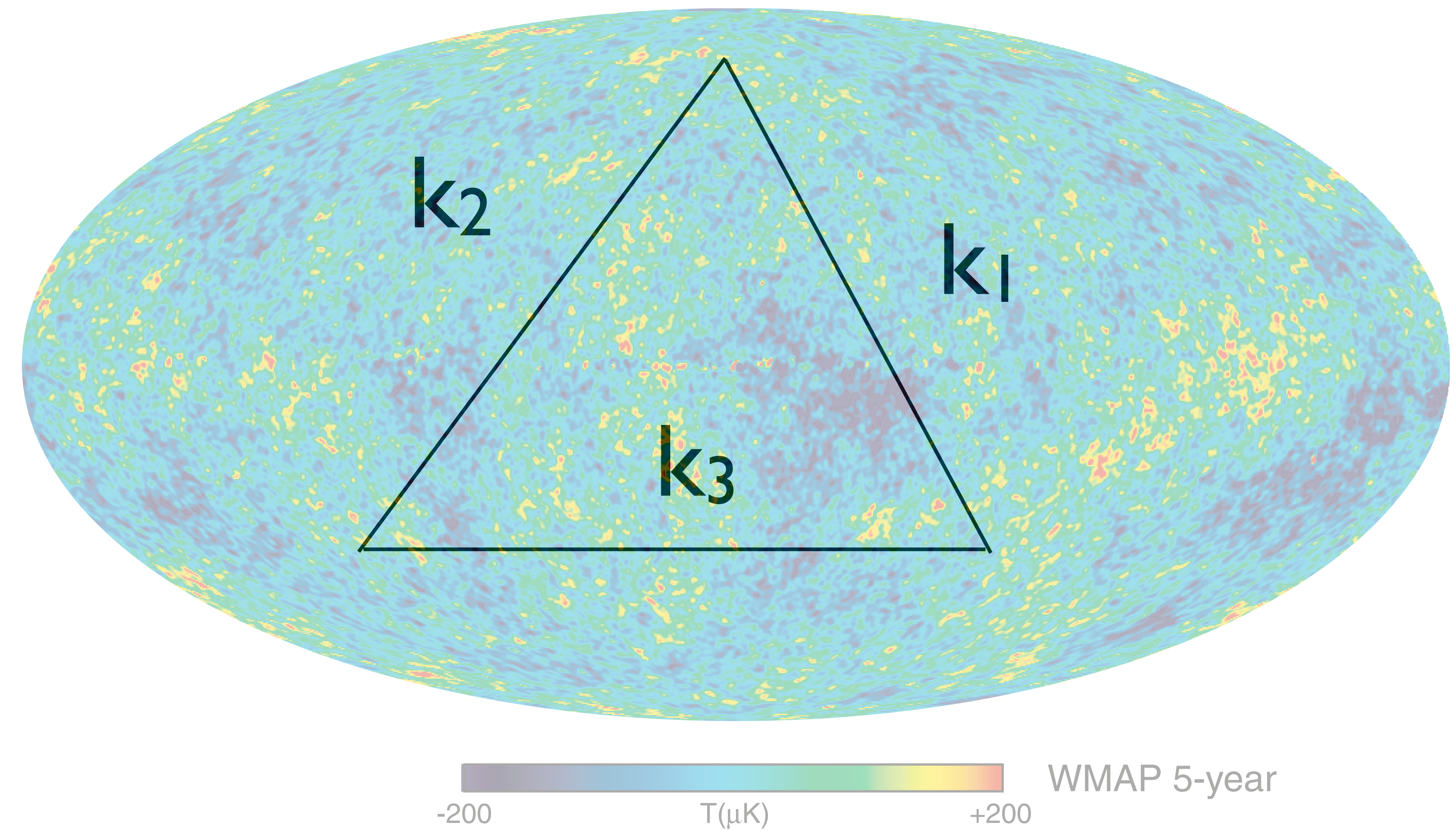
Why Study Non-Gaussianity?

- Because a detection of f_{NL} has a best chance of **ruling out the largest class of inflation models**.
- Namely, it will rule out inflation models based upon
    - a single scalar field <u>with</u>
    - the canonical kinetic term <u>that</u>
    - rolled down a smooth scalar potential slowly, <u>and</u>
    - was initially in the Bunch-Davies vacuum.
- ***Detection of non-Gaussianity would be a major breakthrough in cosmology.***

Tool: Bispectrum

- **Bispectrum = Fourier Trans. of 3-pt Function**
- **The bispectrum <u>vanishes</u>** for Gaussian fluctuations with random phases.
- Any non-zero detection of the bispectrum indicates the presence of (some kind of) non-Gaussianity.
- A sensitive tool for finding non-Gaussianity.

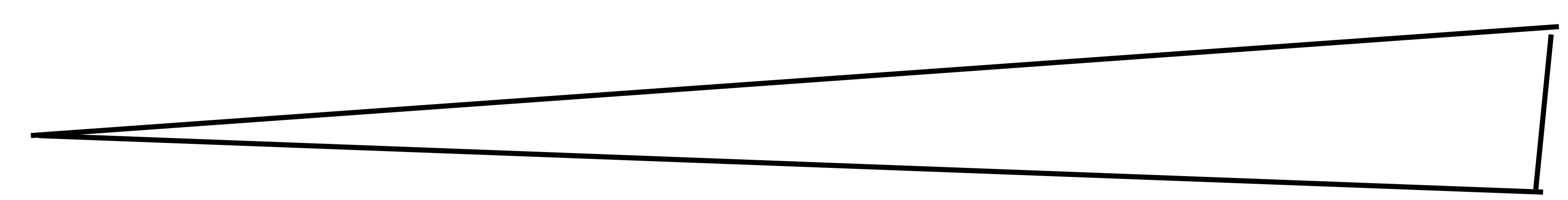
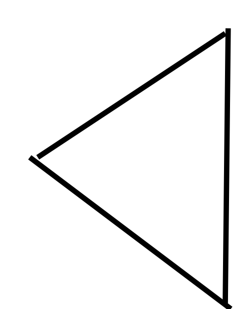
f_{NL} Generalized



- **f_{NL} = the amplitude of bispectrum**, which is
  - $=\langle\Phi(k_1)\Phi(k_2)\Phi(k_3)\rangle = f_{NL}(2\pi)^3\delta^3(k_1+k_2+k_3)b(k_1,k_2,k_3)$
  - where $\Phi(k)$ is the Fourier transform of the curvature perturbation, and $b(k_1,k_2,k_3)$ is a model-dependent function that defines the shape of triangles predicted by various models.

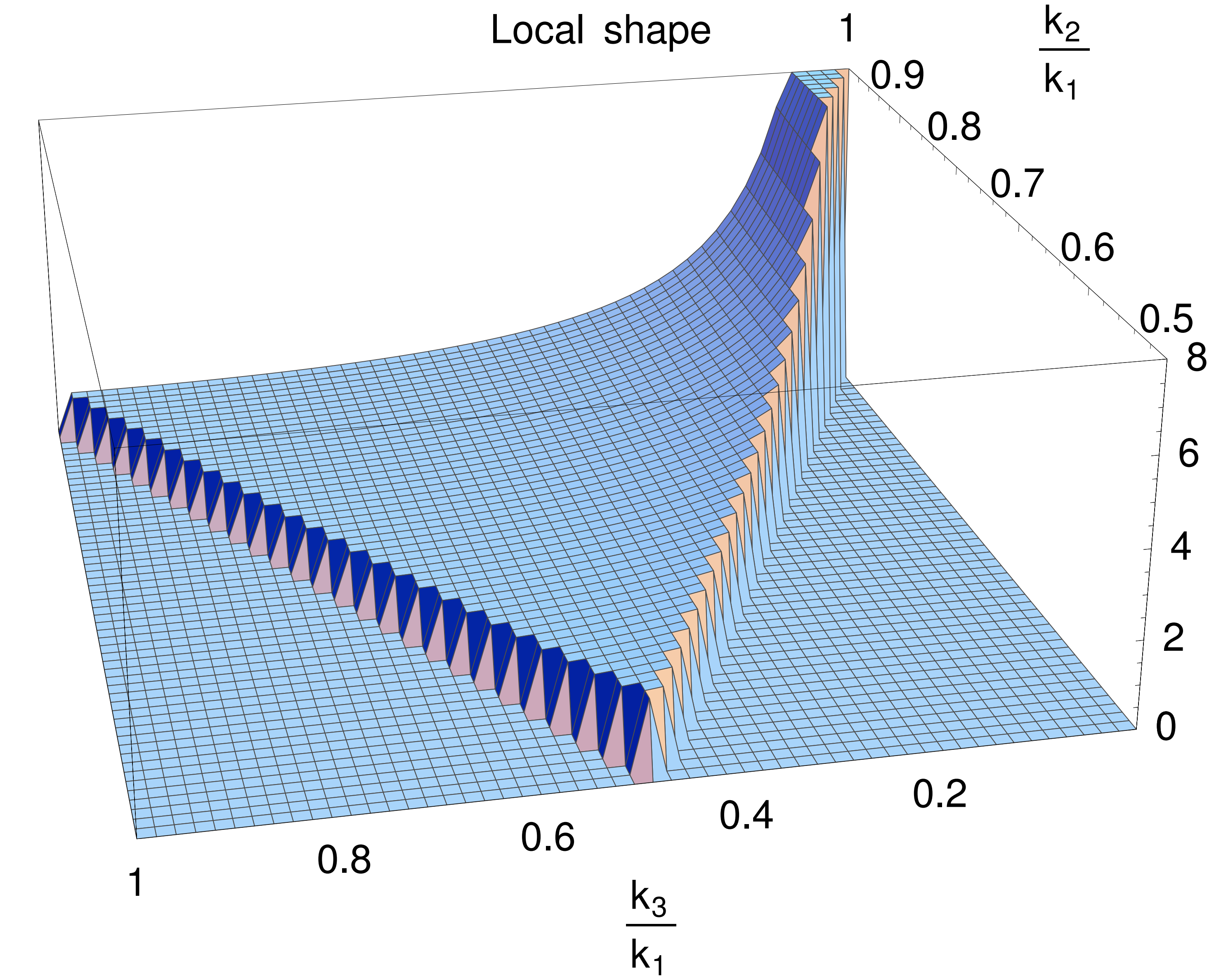
Two f_{NL}'s

There are more than two; I will come back to that later.

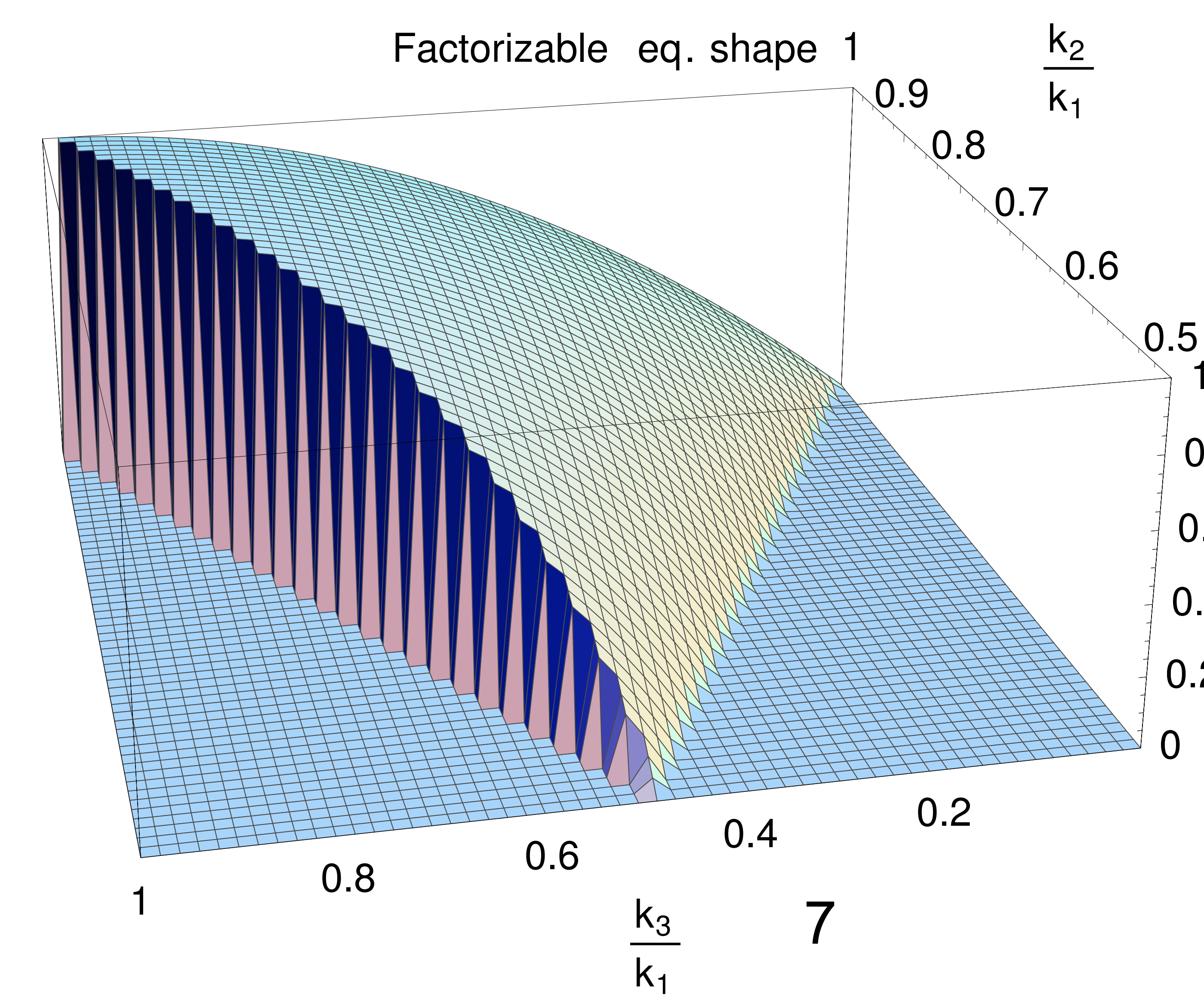
- Depending upon the shape of triangles, one can define various f_{NL}'s:
- "Local" form 
  - which generates non-Gaussianity locally in position space via $\Phi(x)=\Phi_{gaus}(x)+f_{NL}^{local}[\Phi_{gaus}(x)]^2$
- "Equilateral" form 
  - which generates non-Gaussianity locally in momentum space (e.g., k-inflation, DBI inflation)

Forms of $b(k_1,k_2,k_3)$

- Local form (*Komatsu & Spergel 2001*)
  - $b^{local}(k_1,k_2,k_3) = 2[P(k_1)P(k_2)+cyc.]$



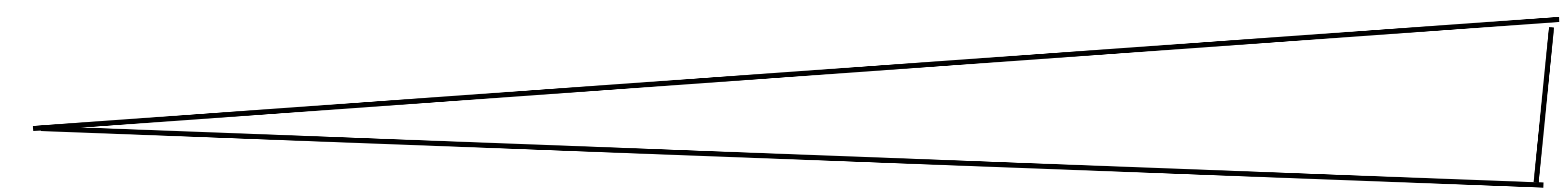
- Equilateral form (*Babich, Creminelli & Zaldarriaga 2004*)
  - $b^{equilateral}(k_1,k_2,k_3) = 6\{-[P(k_1)P(k_2)+cyc.] - 2[P(k_1)P(k_2)P(k_3)]^{2/3} + [P(k_1)^{1/3}P(k_2)^{2/3}P(k_3)+cyc.]\}$



What if f_{NL} is detected?

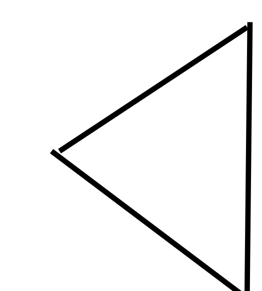
- A single field, canonical kinetic term, slow-roll, and/or Banch-Davies vacuum, must be modified.

Local • Multi-field (curvaton);



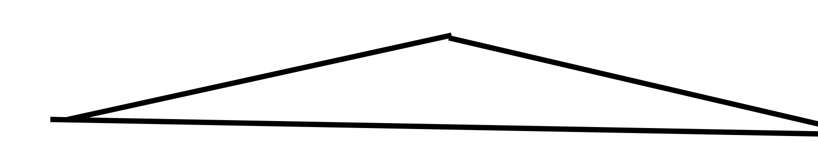
Preheating (e.g., *Chambers & Rajantie 2008*)

Equil. • Non-canonical kinetic term (k-inflation, DBI)



Bump +Osci. • Temporary fast roll (features in potential)

Folded • Departures from the Bunch-Davies vacuum



- *It will give us a lot of clues as to what the correct early universe models should look like.*

...or, simply not inflation?

- It has been pointed out recently that New Ekpyrotic scenario generates f_{NL}^{local} ~100 generically
  - *Creminelli & Senatore; Koyama et al.; Buchbinder et al.; Lehners & Steinhardt*

Measurement

- Use everybody's favorite: χ^2 minimization.
  - Minimize:

$$\chi^2 \equiv \sum_{2 \leq l_1 \leq l_2 \leq l_3} \frac{\left(B^{obs}_{l_1 l_2 l_3} - \sum_i A_i B^{(i)}_{l_1 l_2 l_3}\right)^2}{\sigma^2_{l_1 l_2 l_3}}$$

  - with respect to $A_i=(f_{NL}^{local}, f_{NL}^{equilateral}, b_{src})$
  - B^{obs} is the observed bispectrum
  - $B^{(i)}$ is the theoretical template from various predictions

Journal on f_{NL}

- Local
  - $-3500 < f_{NL}^{local} < 2000$ [COBE 4yr, $l_{max}=20$] Komatsu et al. (2002)
  - $-58 < f_{NL}^{local} < 134$ [WMAP 1yr, $l_{max}=265$] Komatsu et al. (2003)
  - $-54 < f_{NL}^{local} < 114$ [WMAP 3yr, $l_{max}=350$] Spergel et al. (2007)
  - **$-9 < f_{NL}^{local} < 111$ [WMAP 5yr, $l_{max}=500$]** Komatsu et al. (2008)
- Equilateral
  - $-366 < f_{NL}^{equil} < 238$ [WMAP 1yr, $l_{max}=405$] Creminelli et al. (2006)
  - $-256 < f_{NL}^{equil} < 332$ [WMAP 3yr, $l_{max}=475$] Creminelli et al. (2007)
  - **$-151 < f_{NL}^{equil} < 253$ [WMAP 5yr, $l_{max}=700$]** Komatsu et al. (2008)

Future Prospects

- Planck satellite (to be launched in April 2009)
  - 1-σ error: Δf_{NL}^{local} =4; $\Delta f_{NL}^{equilateral}$=26
  - C.f., WMAP5: Δf_{NL}^{local} =30; $\Delta f_{NL}^{equilateral}$=100
- Small-scale CMB (temperature) experiments
  - Vary f_{sky} & l_{max} (cosmic-variance-limited out to l_{max})
    - Δf_{NL}^{local} ~ 15*sqrt(0.1/f_{sky})*(2000/l_{max})
    - $\Delta f_{NL}^{equilateral}$ ~ 120*sqrt(0.1/f_{sky})*(2000/l_{max})
- ACT: f_{sky}~0.025 (1000 deg^2); SPT: f_{sky}~0.1 (4000 deg^2)

Summary

- ACT, SPT would yield limits on f_{NL}^{local} & $f_{NL}^{equilateral}$ that are **comparable to WMAP5 (and WMAP9).**
- A choice of l_{max}=2000 is reasonable, considering the foreground sources such as SZ effects and point sources.
- The definite limit is l_{max}=3000 because of lensing (Komatsu & Spergel 2001).
- Planck would yield much better limits.

Non-Gaussianity Has Not Been Discovered Yet, but...

- At 68% CL, we have $\mathbf{f_{NL}=51\pm30}$ (positive 1.7σ)
  - Shift from Yadav & Wandelt's 2.8σ "hint" (f_{NL}~80) from the 3-year data can be explained largely by adding more years of data, i.e., statistical fluctuation, and a new 5-year Galaxy mask that is 10% larger than the 3-year mask
- There is a room for improvement
  - More years of data (WMAP 9-year survey funded!)
  - Better statistical analysis (*Smith & Zaldarriaga 2006*)
  - IF (big if) f_{NL}=50, we would see it at **3σ** in the 9-year data