Bubble Observers in Bubbland

Local Observables in a Landscape of Infrared Gauge Modes

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Bubble Zero

i Inflation, AKA Bubbland

ii Vectors & Anisotropies

iii IR Fluctuations & Bias

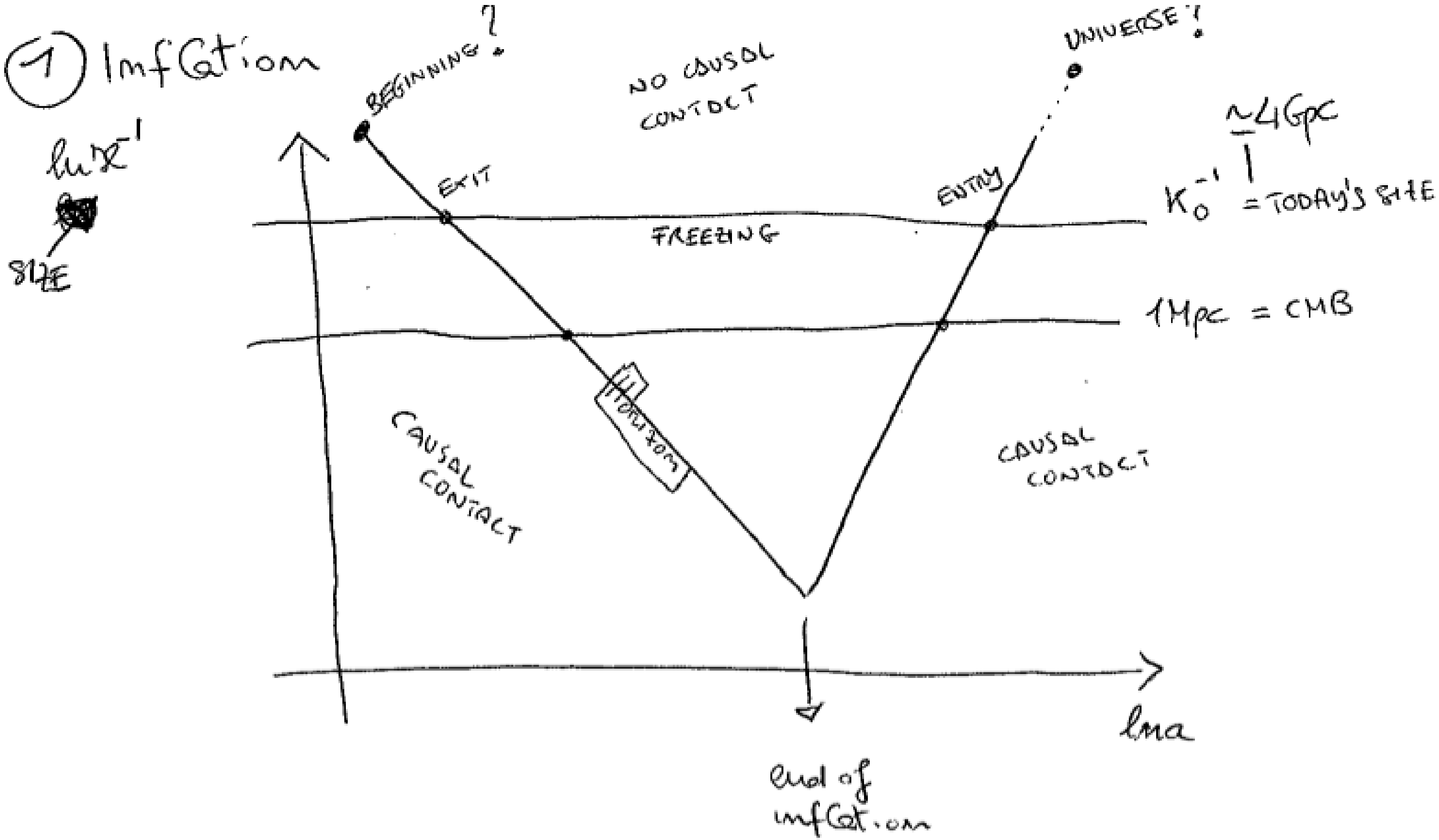
iv Background Precession

v Results

M Thursrud, D Mota, F Urban, arXiv:1311.3302

M Thursrud, F Urban, D Mota, arXiv:1312.7491

Bubble One



1 Inflation
BEGINNING ?
NO CAUSAL CONTACT
UNIVERSE ?
~4Gpc
EXIT
ENTRY
FREEZING
= TODAY'S SIZE
SIZE
1Mpc = CMB
HORIZON
CAUSAL CONTACT
CAUSAL CONTACT
ln a
end of inflation

Bubble Two

All Bubbles are equal, but some Bubbles are more equal than others

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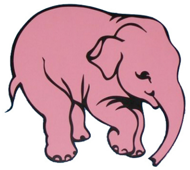

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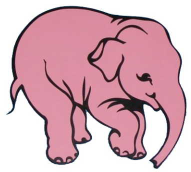

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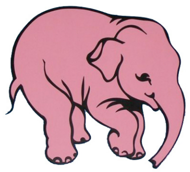

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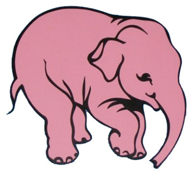

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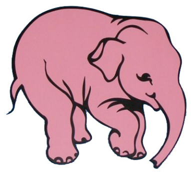

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- Now: quantum fluctuations are a statistical object...

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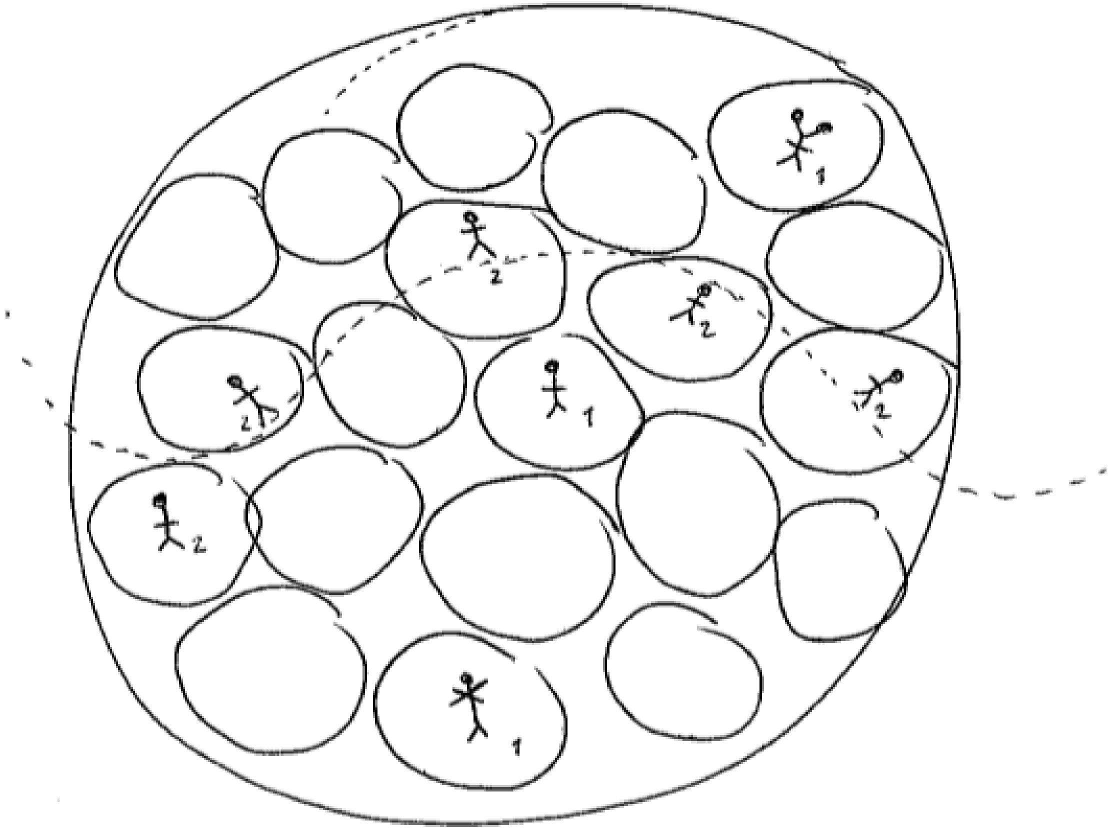

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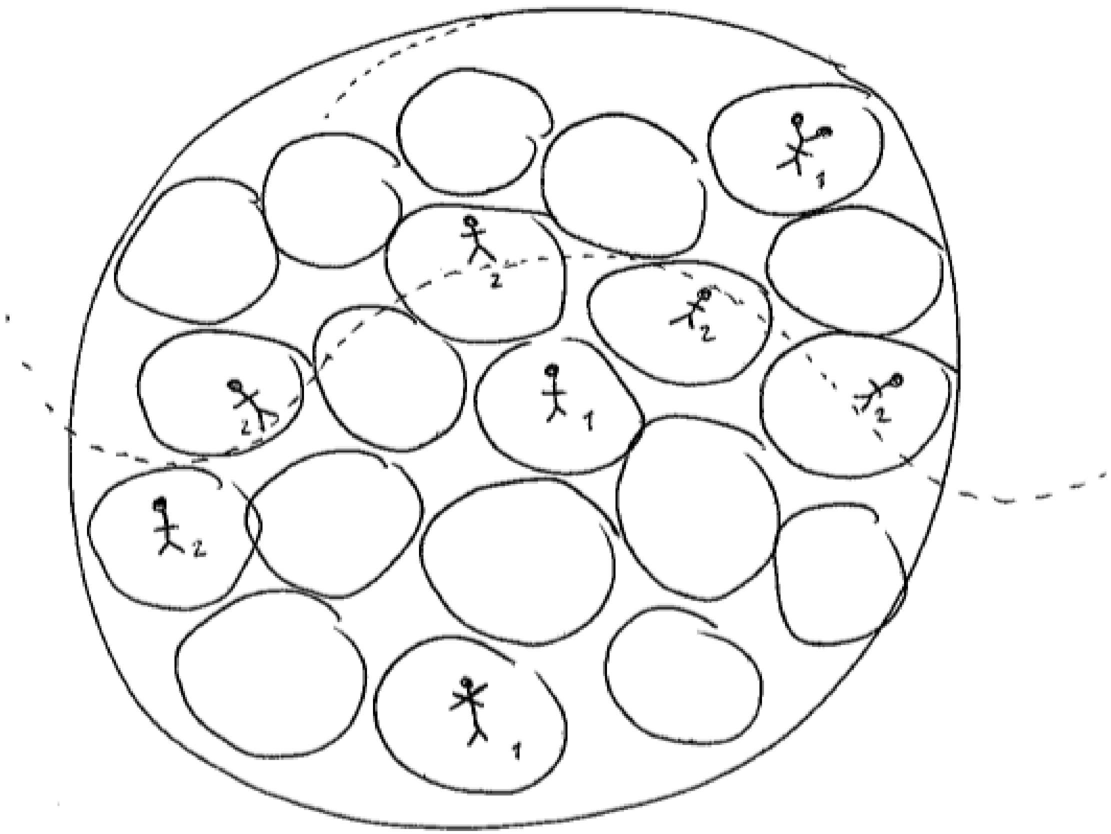

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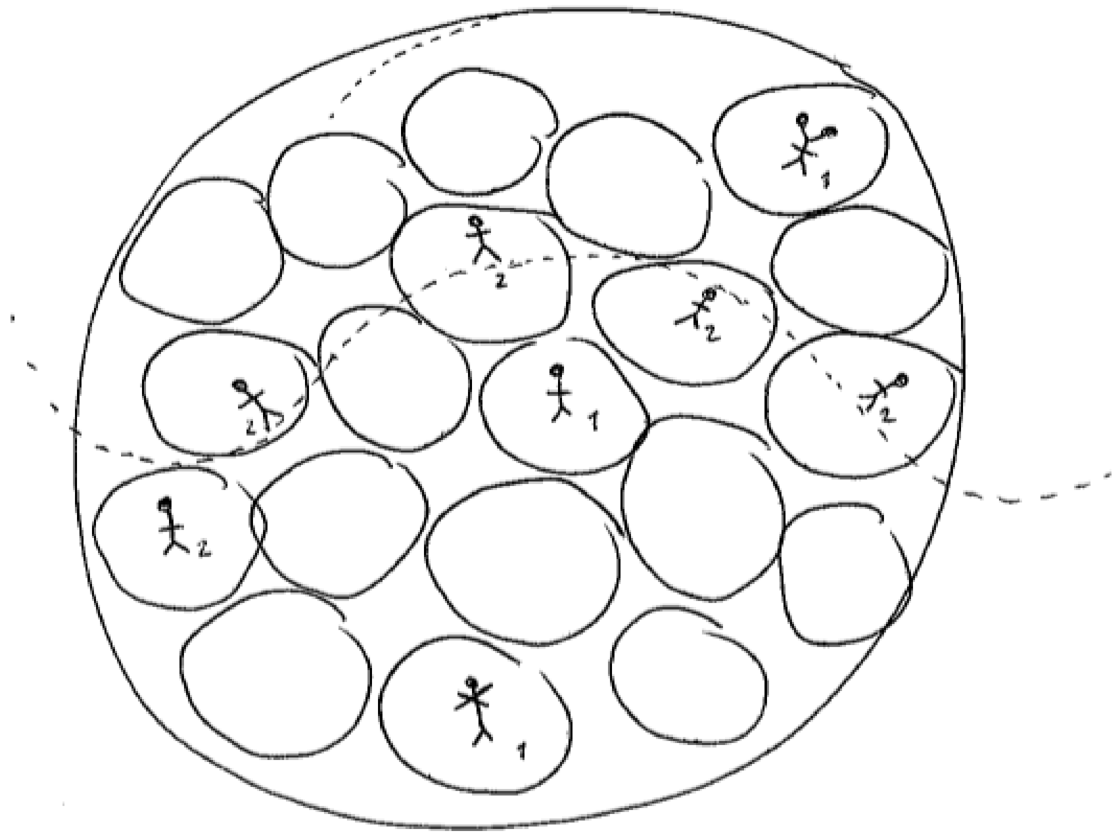

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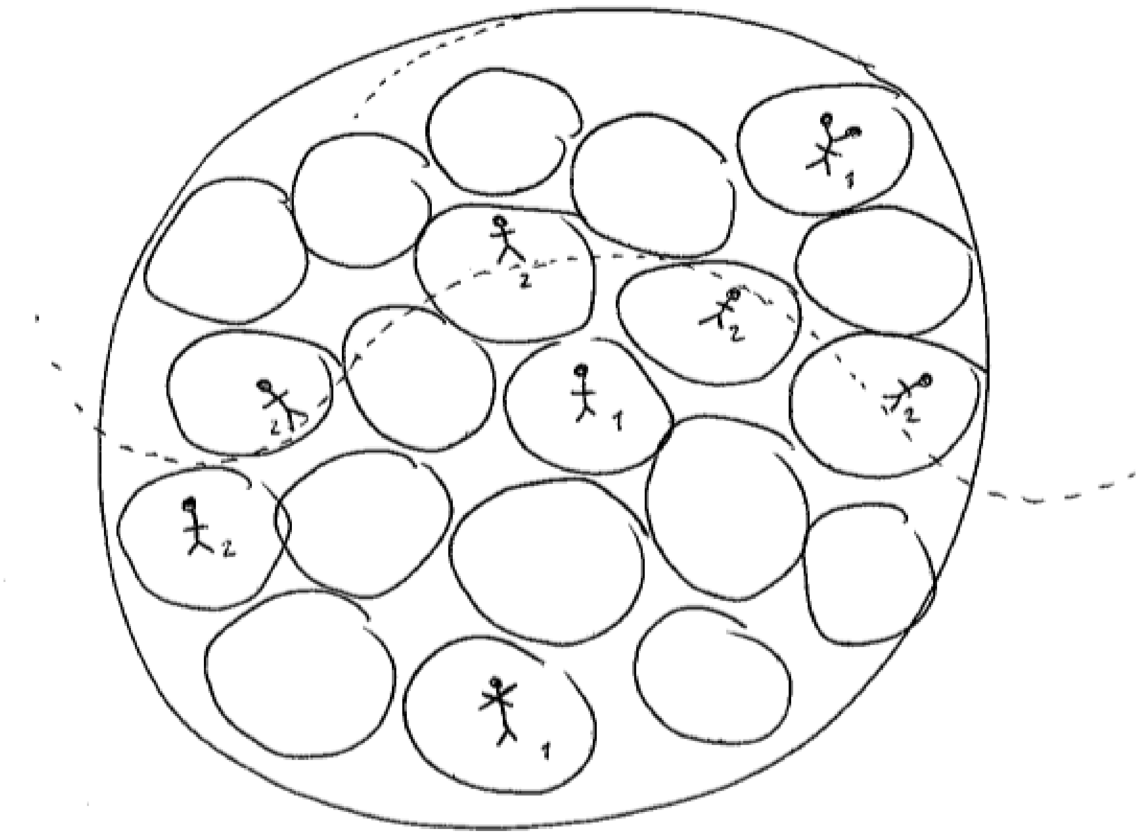

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-  Q: Is this bias observable? A: Perhaps... 

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$$\Longrightarrow \quad \vec{\mathcal{E}}_{\mathrm{IR}}(\eta) = \int_{\text{dawn of time}}^{\mathcal{H}} \mathrm{d}^3 k \; e^{-i\vec{k}\vec{x}} \, \delta\vec{\mathcal{E}}(\vec{k})$$

Infrared Statistics – Single Vector

- We are limited UV observers, so we do not directly probe $\vec{\mathcal{E}}_{\text{IR}}$
- This becomes a statistical object which inherits Gaussianity

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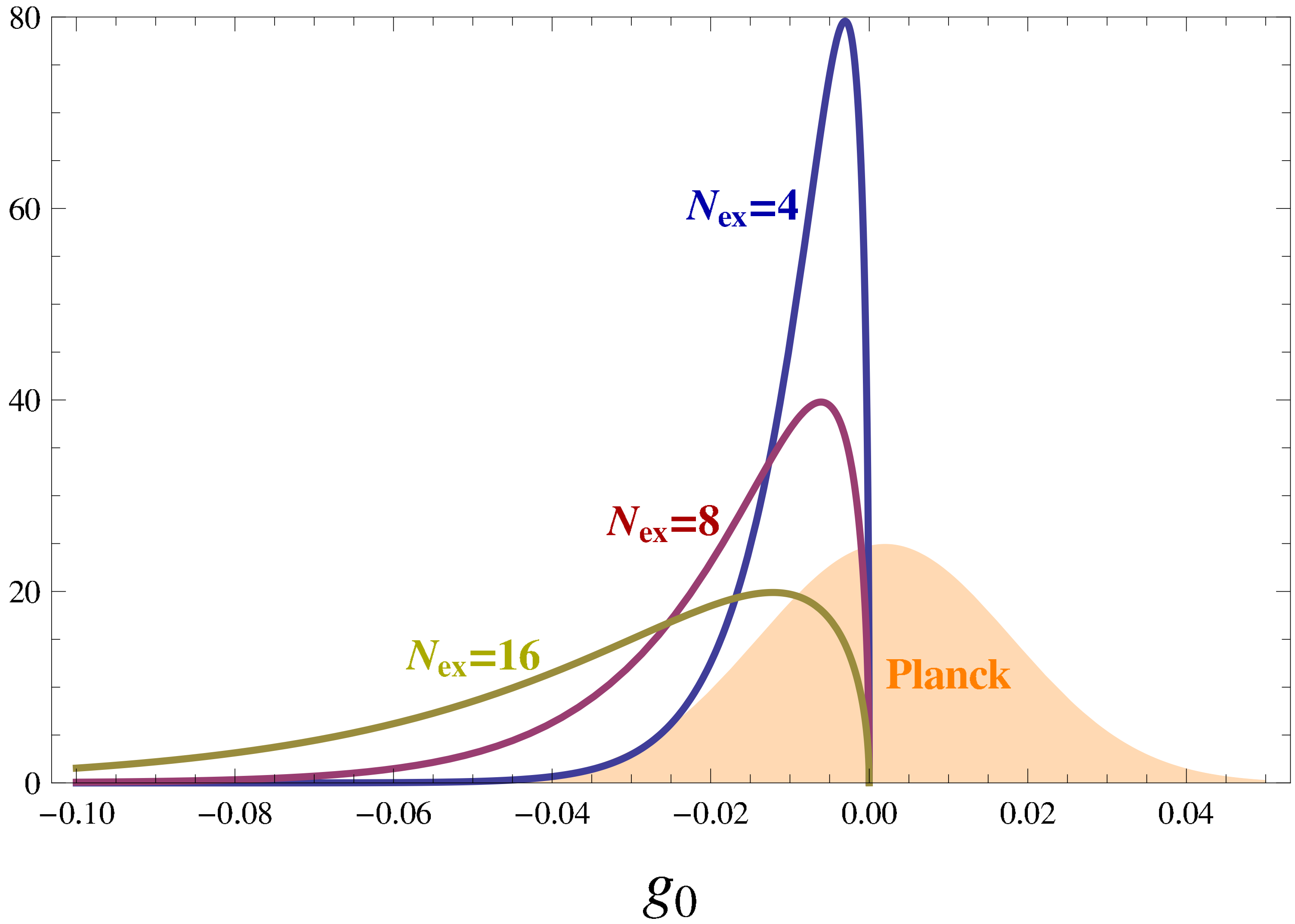
One parameter: Amplitude $g(k) \sim -|\mathcal{E}_{\text{IR}}(\eta_0)|^2 \mathcal{N}_k^2$

Probability Distributions



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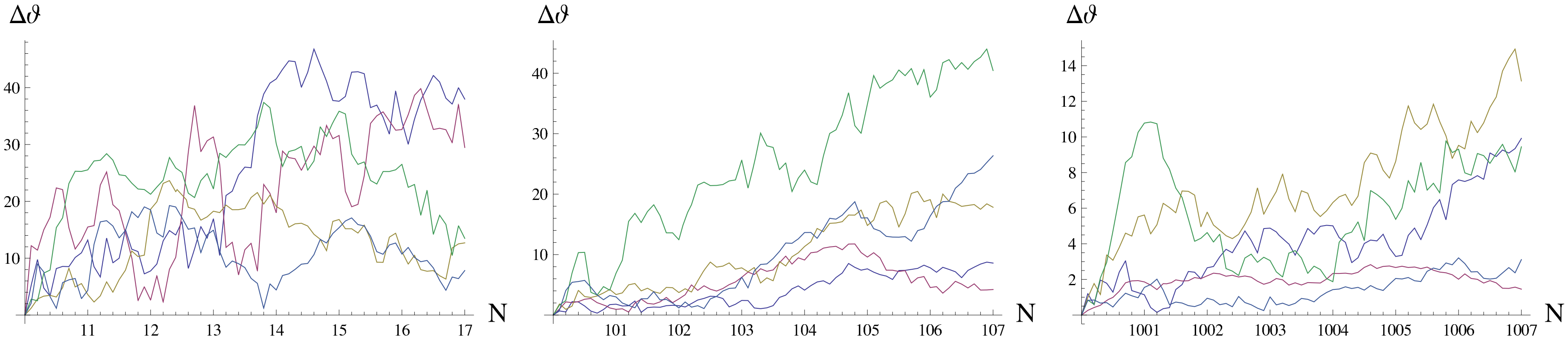
$\Rightarrow \quad \vec{\mathcal{E}}_{\rm IR}$ will be pointing in a different direction

Random Walk

The background vector makes a random walk in direction space



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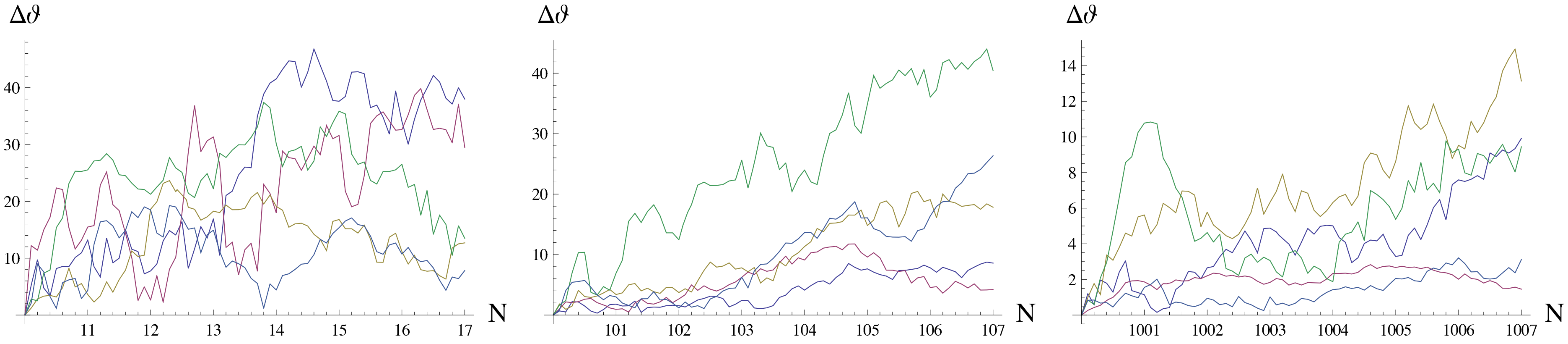

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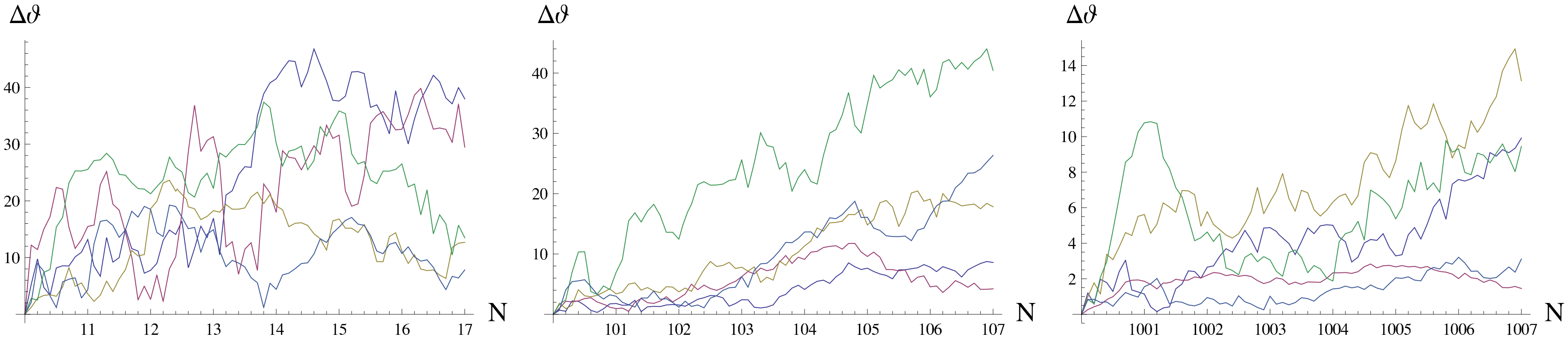

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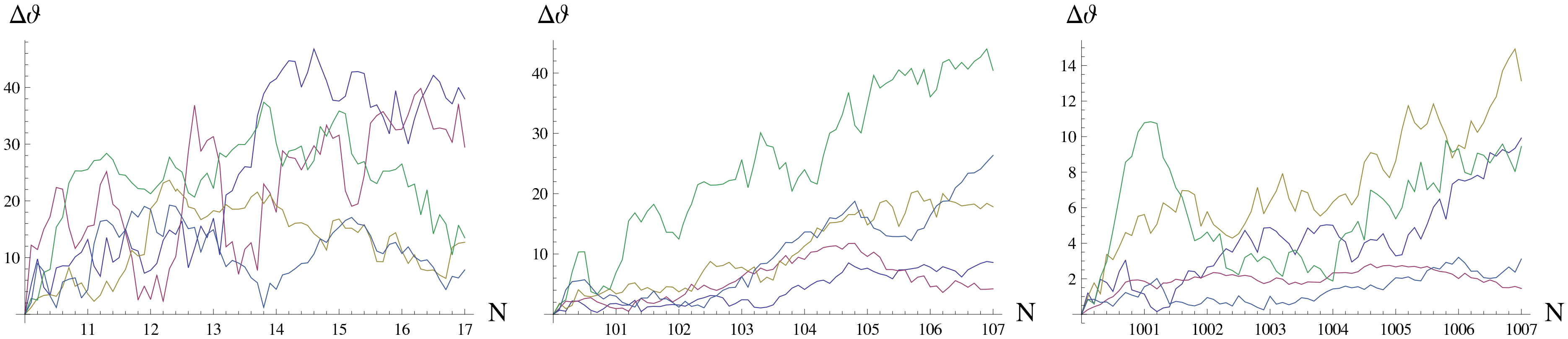

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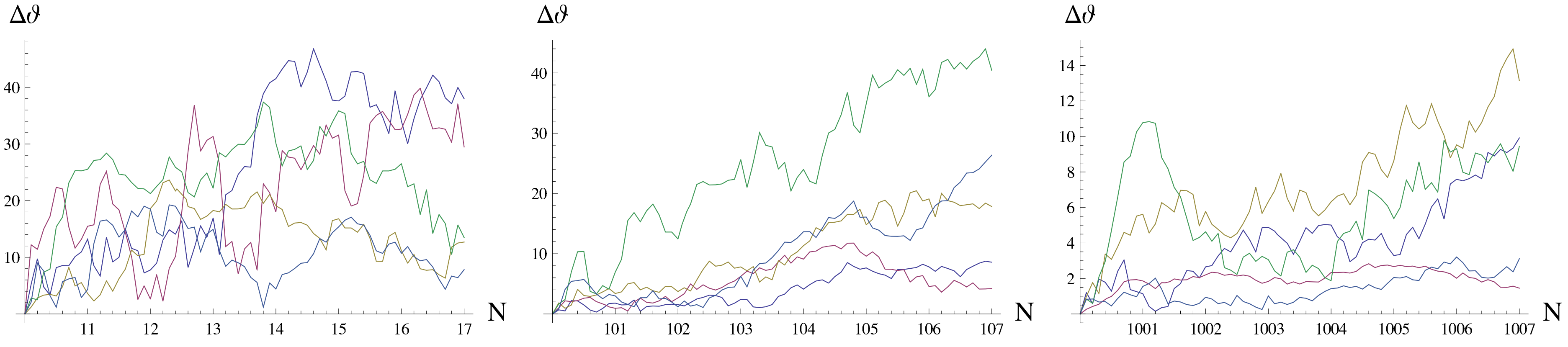

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Poor little thing...

Infrared Statistics – Multiple Vector

Multiple vector case – identical coupling: $\mathcal{L} = \sum_a f^2(\varphi) F^a_{\mu\nu} F_a^{\mu\nu}$

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$\mathcal{A}_{\hat{k}} \sim 3\cos^2\vartheta - 1$, $\quad \mathcal{B}_{\hat{k}} \sim \sin 2\vartheta \cos\varphi$

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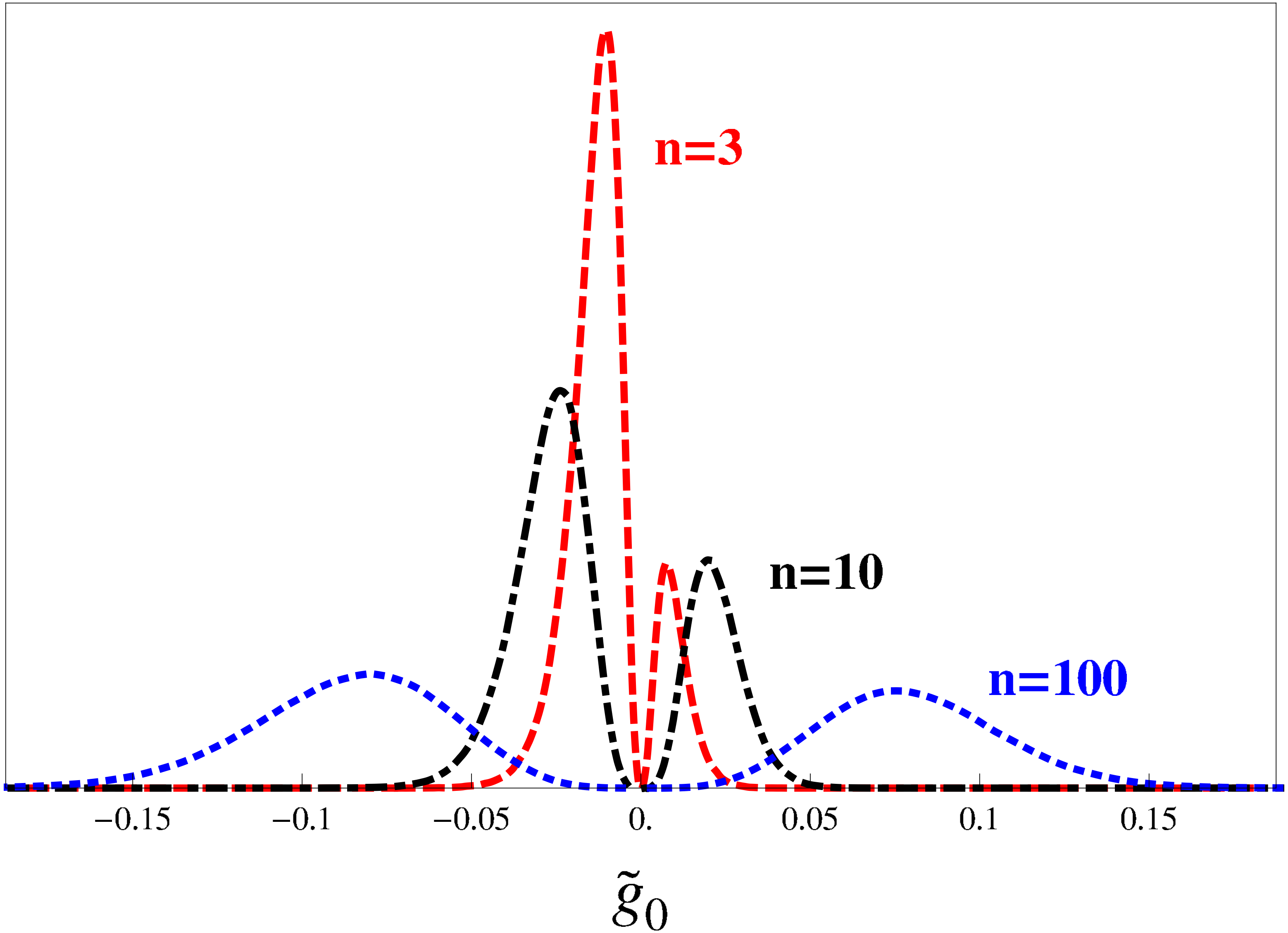
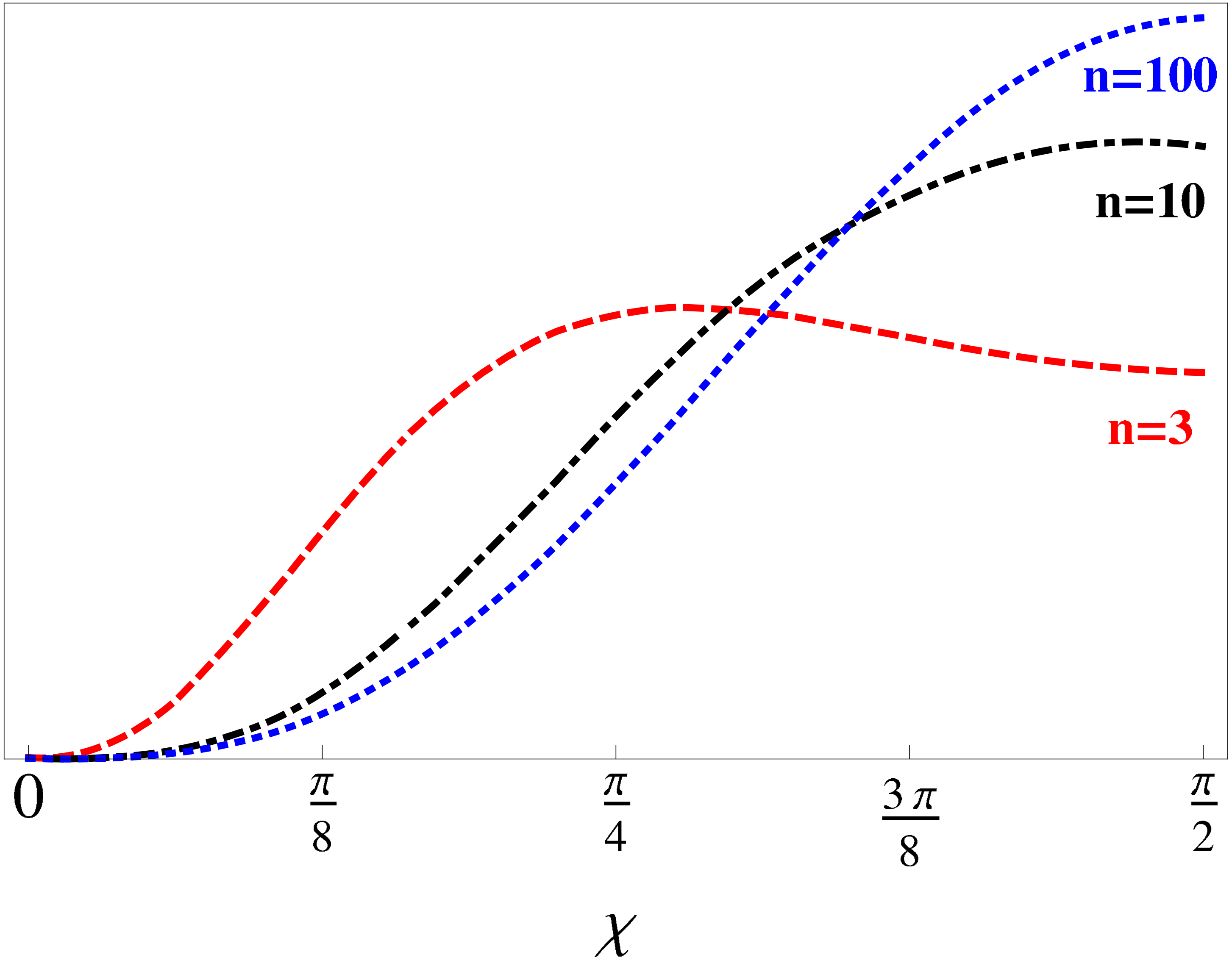
Two parameters: Amplitude $g(k)$, Shape χ

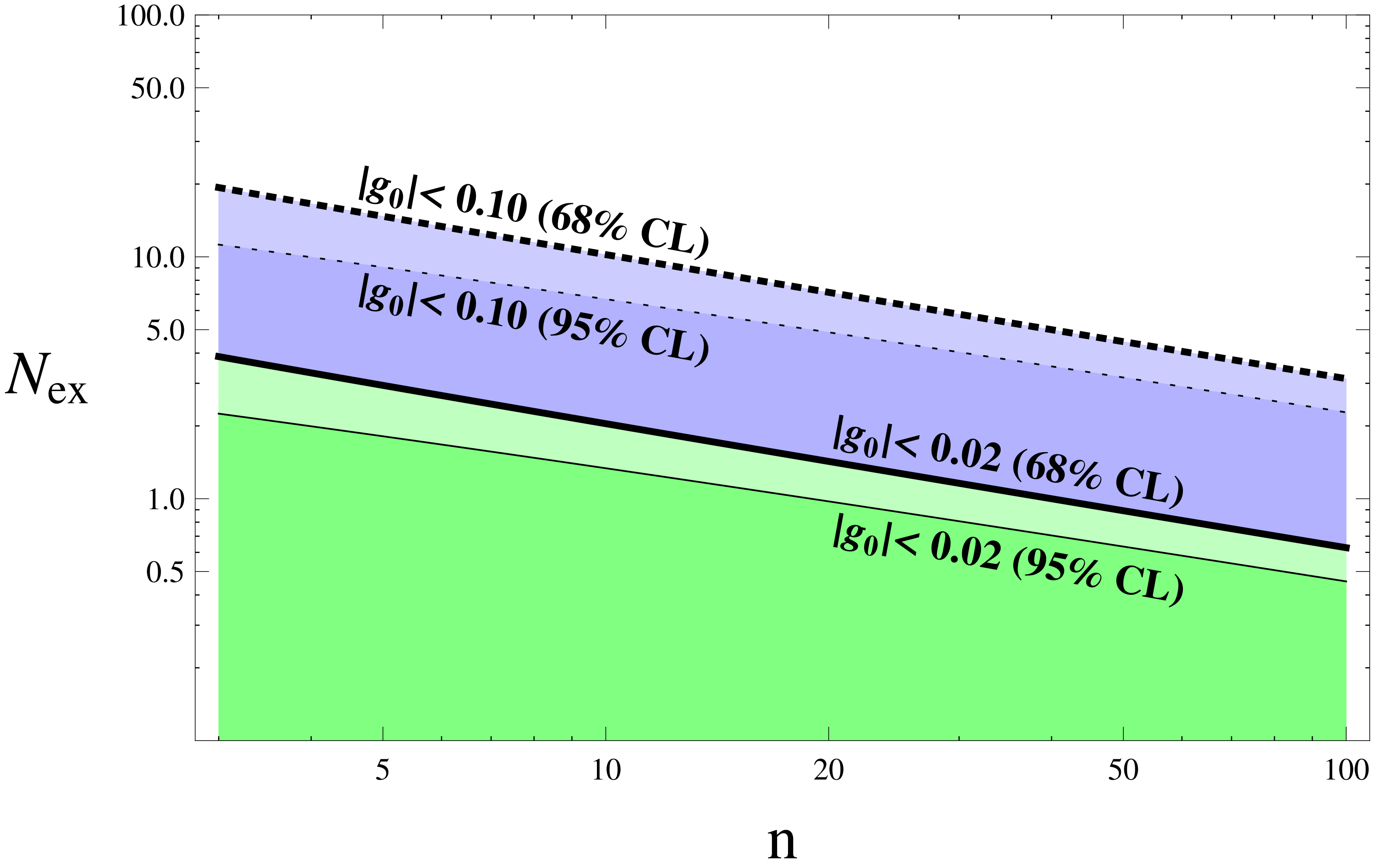
Probability Distributions I



Probability Distributions II



How Likely Are We?



Summary

- Inflation generates Bubbland
  - Bubbland is comprised of a multitude of Bubbles
  - As observers, we have access to only one Bubble
  - Our link with "The Theory" is statistical – observations are biassed
- Vectors generate anisotropies
  - Spectator gauge fields can develop into a classical vector background
  - Curvature perturbations are quadrupole-modulated: $\mathcal{P}_\zeta^0(k)\left[1+g(k)\cos^2\vartheta\right]$
  - (Non-)Observations of $g(k)$ put *statistical* constraints on $\mathcal{N}$
- The precession effect
  - The background vector is not a constant, but precesses with time
  - In the multi-vector case this produces two important features:
    a. The quadrupole amplitude $g(k)$ can be *positive*
    b. We need one further shape parameter χ to describe the correction:

$$\mathcal{P}_\zeta^0(k)\left[1+g(k)\left(\mathcal{A}_{\hat{k}}\cos\chi+\mathcal{B}_{\hat{k}}\sin\chi\right)\right]$$

$\Rightarrow$ All in all, living in the Bubble can be quite deceiving $\leftarrow$ bottom line