

Bubble Observers in Bubbland

Local Observables in a Landscape of Infrared Gauge Modes



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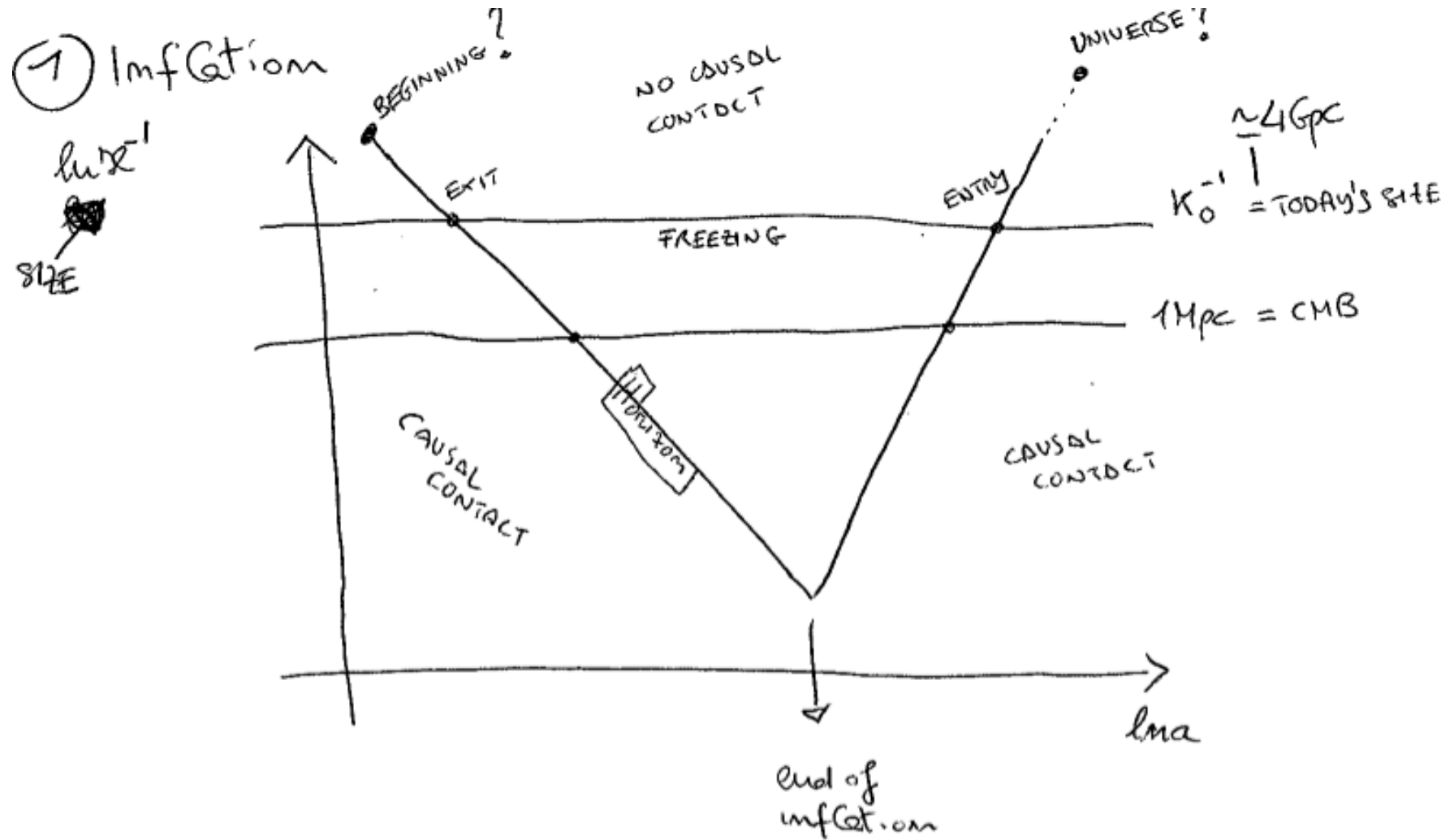
Bubble Zero

- i Inflation, AKA Bubbland
- ii Vectors & Anisotropies
- iii IR Fluctuations & Bias
- iv Background Precession
- v Results

D Mota, M Thursrud, FU Phys. Lett. B **733C** (2014) 140 [arXiv:1311.3302]

D Mota, M Thursrud, FU JCAP **1404** (2014) 010 [arXiv:1312.7491]

Bubble One





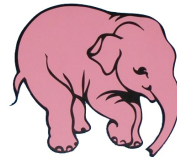
Bubble Two

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



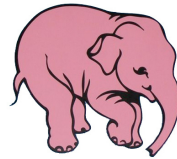
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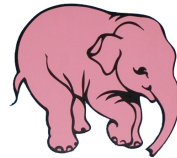
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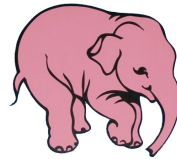
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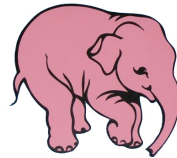
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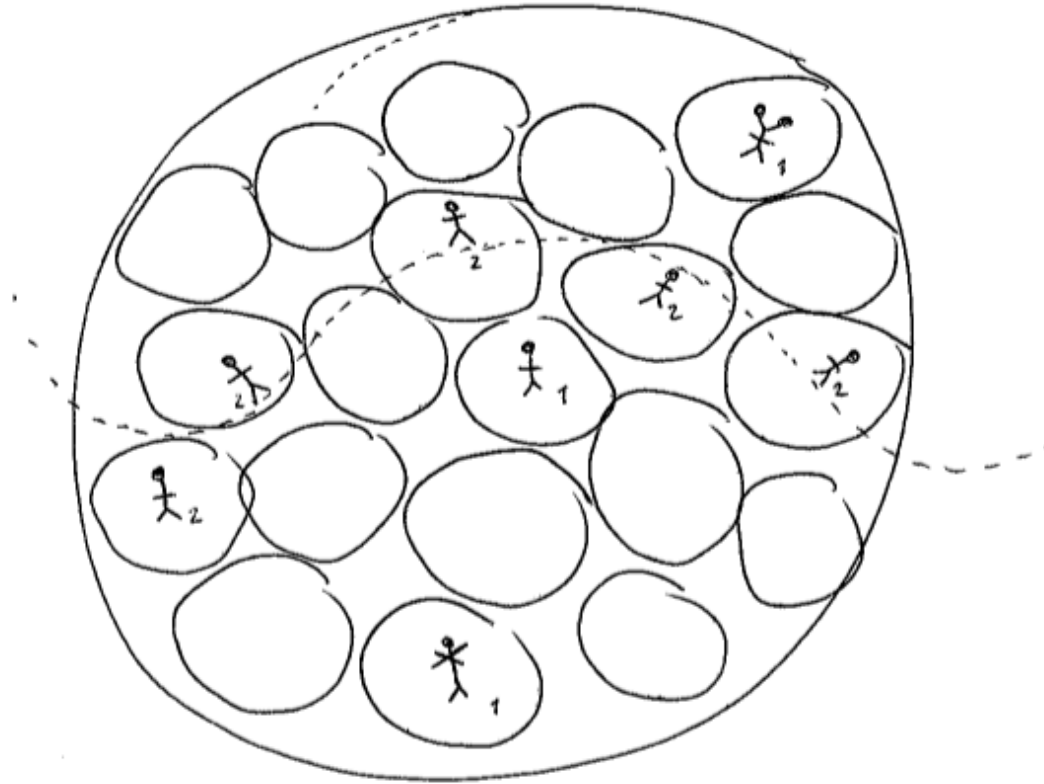
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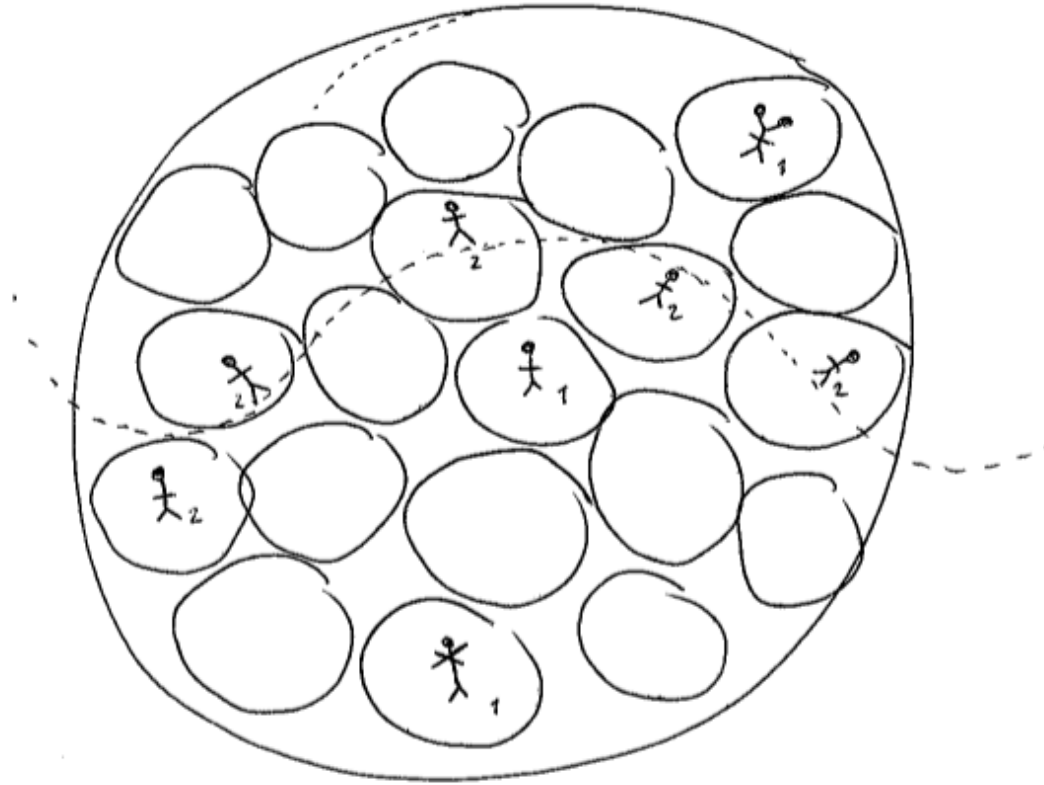


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- Now: quantum fluctuations are a statistical object...

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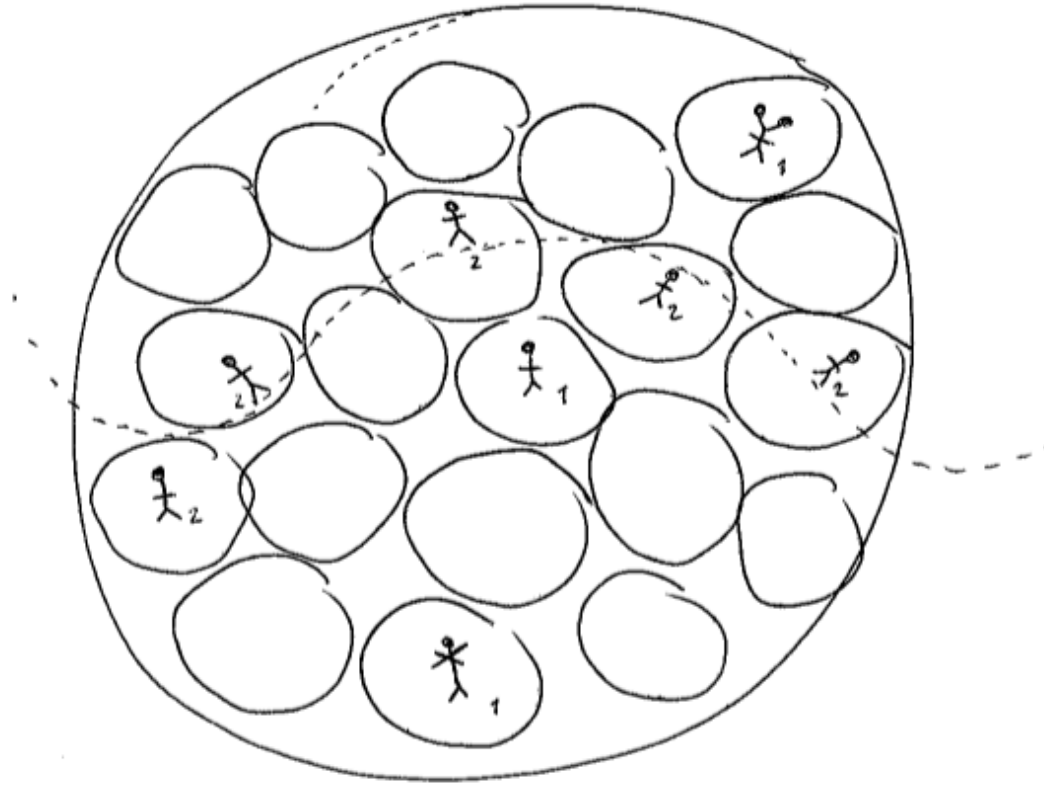


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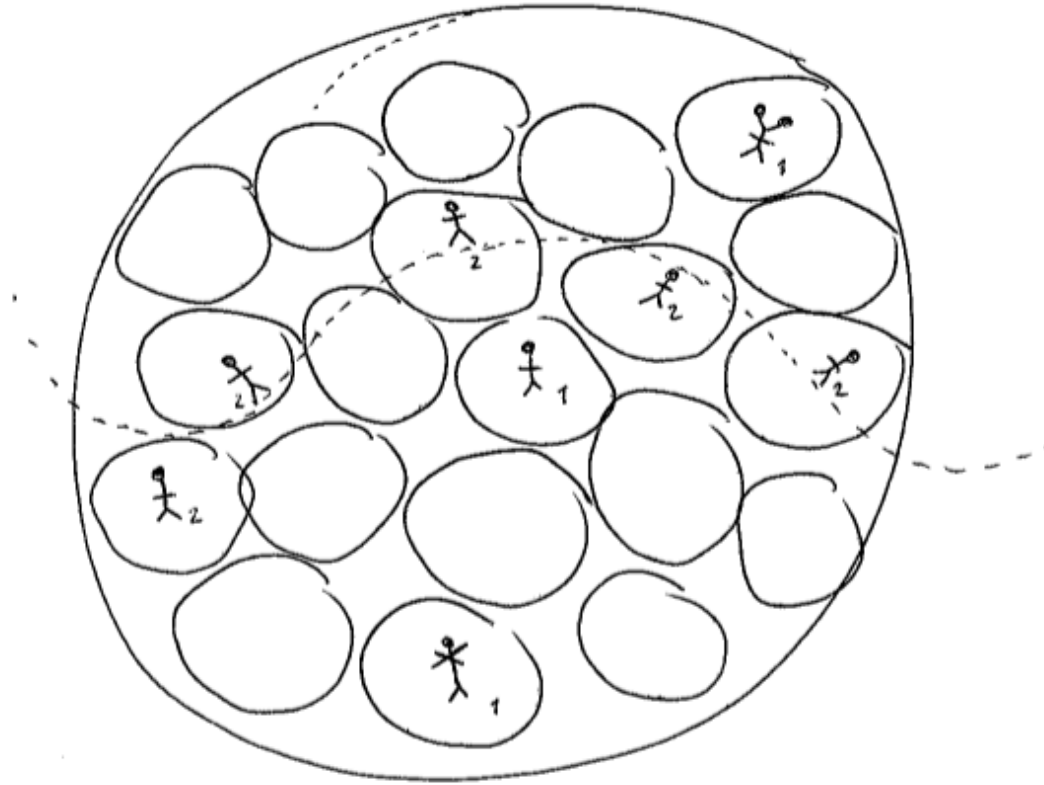
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$$\implies \vec{\mathcal{E}}_{\text{IR}}(\eta) = \int_{\text{dawn of time}}^{\mathcal{H}} d^3k \, e^{-i\vec{k}\vec{x}} \, \delta\vec{\mathcal{E}}(\vec{k})$$

Infrared Statistics – Single Vector

- We are limited UV observers, so we do not directly probe $\vec{\mathcal{E}}_{\text{IR}}$
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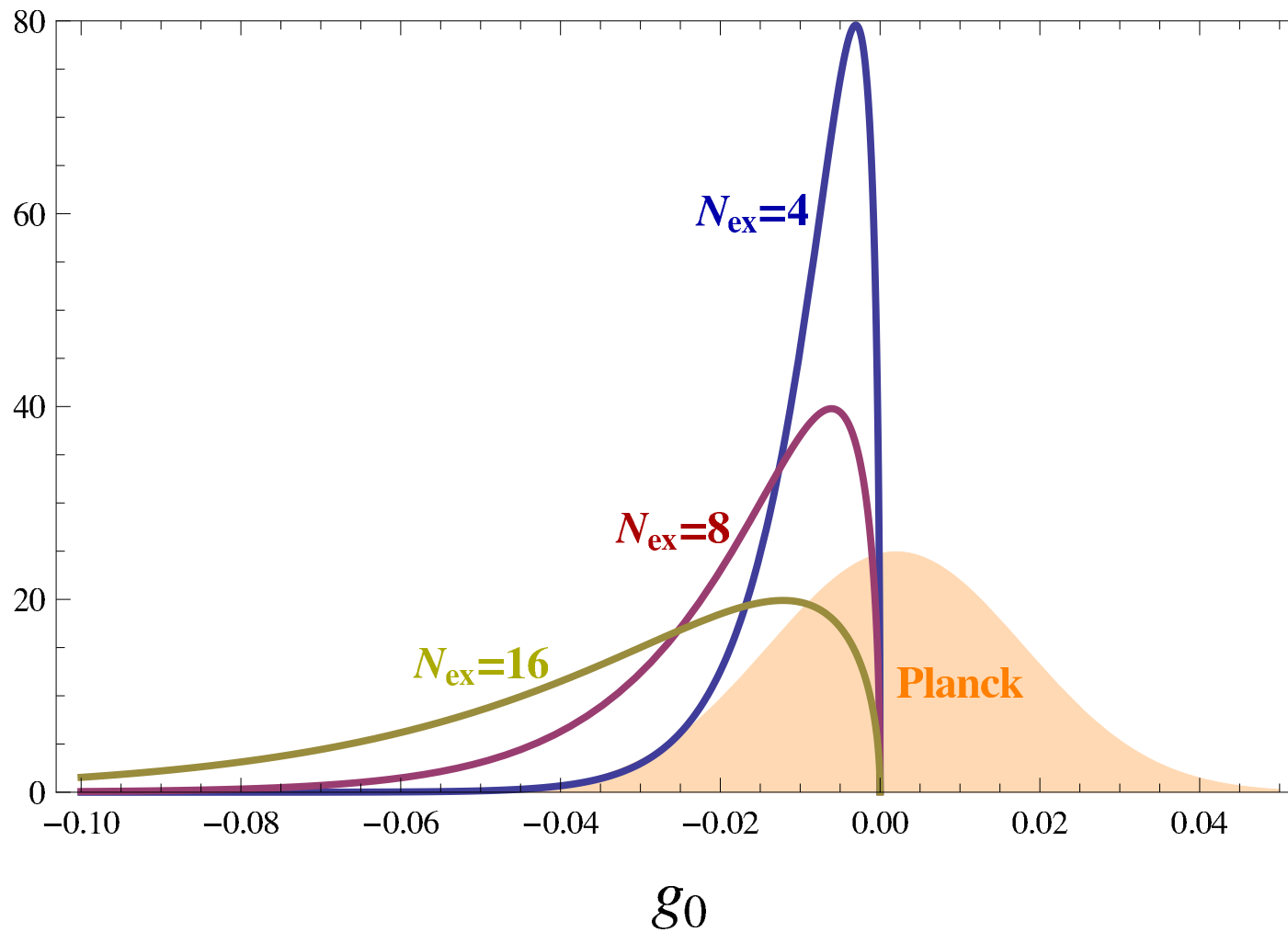
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One parameter: Amplitude $g(k) \sim -|\mathcal{E}_{\text{IR}}(\eta_0)|^2 \mathcal{N}_k^2$

Probability Distributions





Precession

Tweedledum (k_1) and Tweedledee (k_2)

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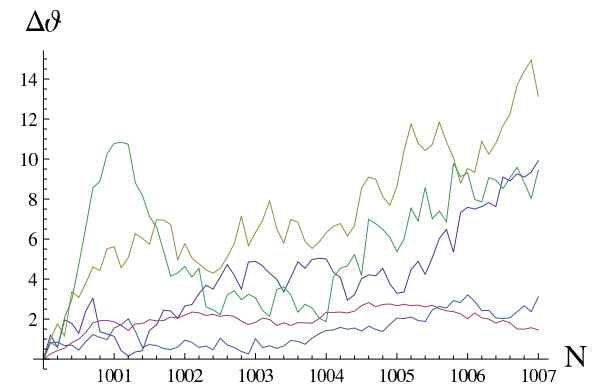
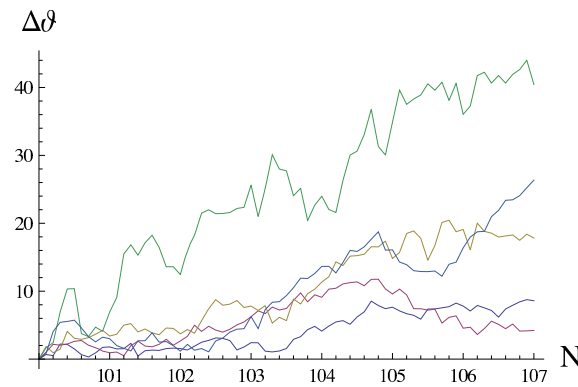
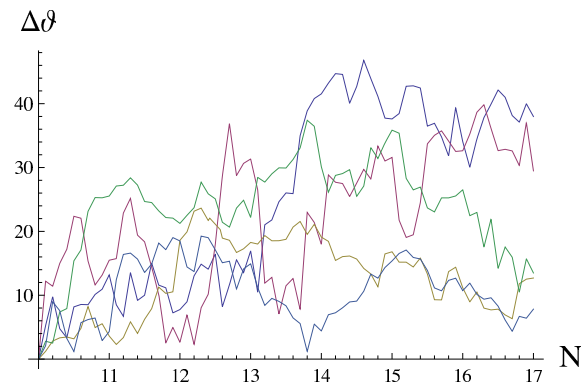
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- $\Rightarrow \vec{\mathcal{E}}_{\text{IR}}$ will be pointing in a different direction

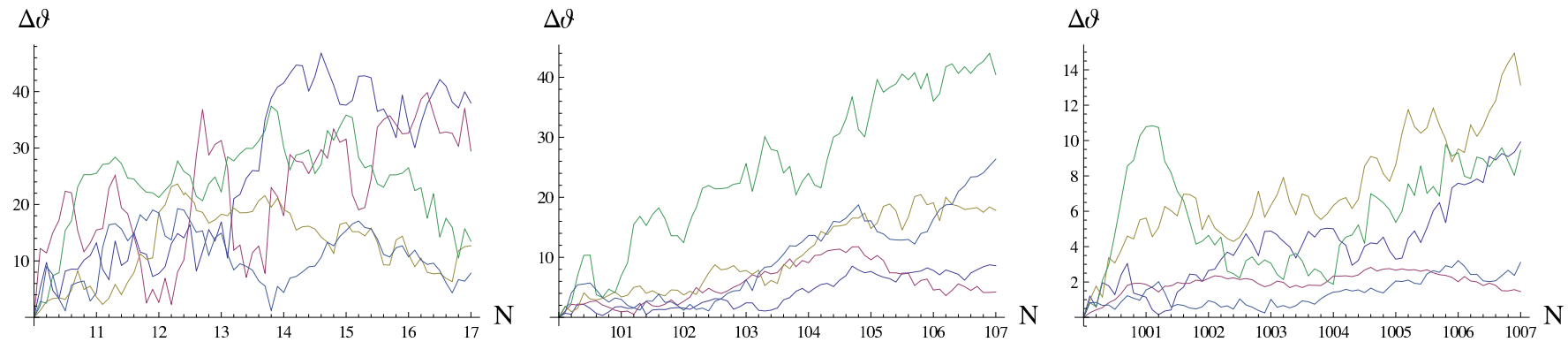
Random Walk

The background vector makes a random walk in direction space



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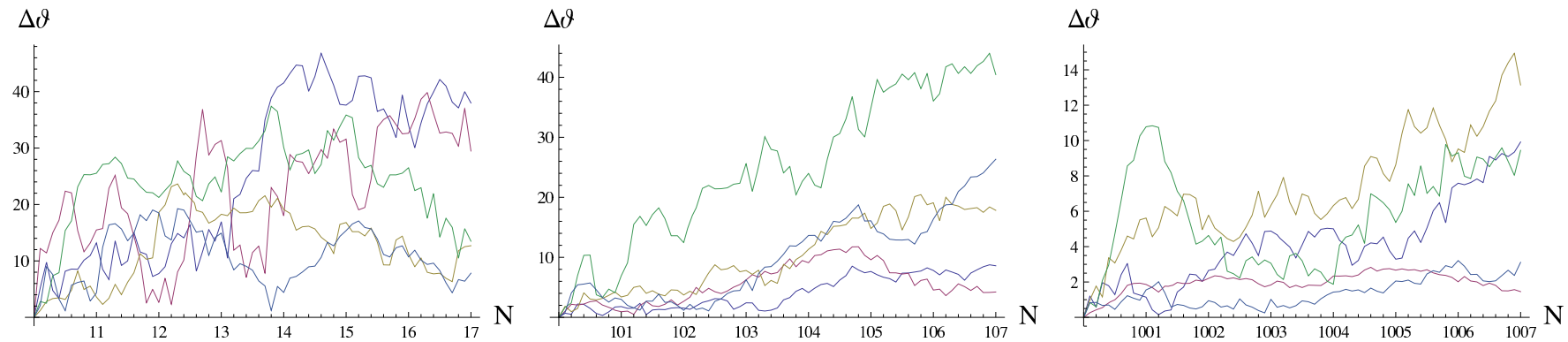
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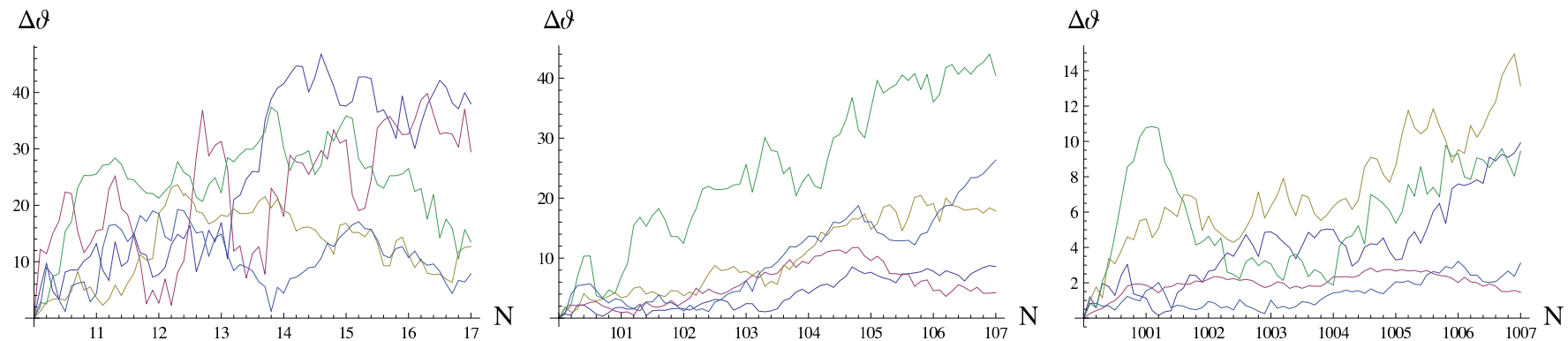
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Seven e-folds make a hundred thousand millions Bubbles

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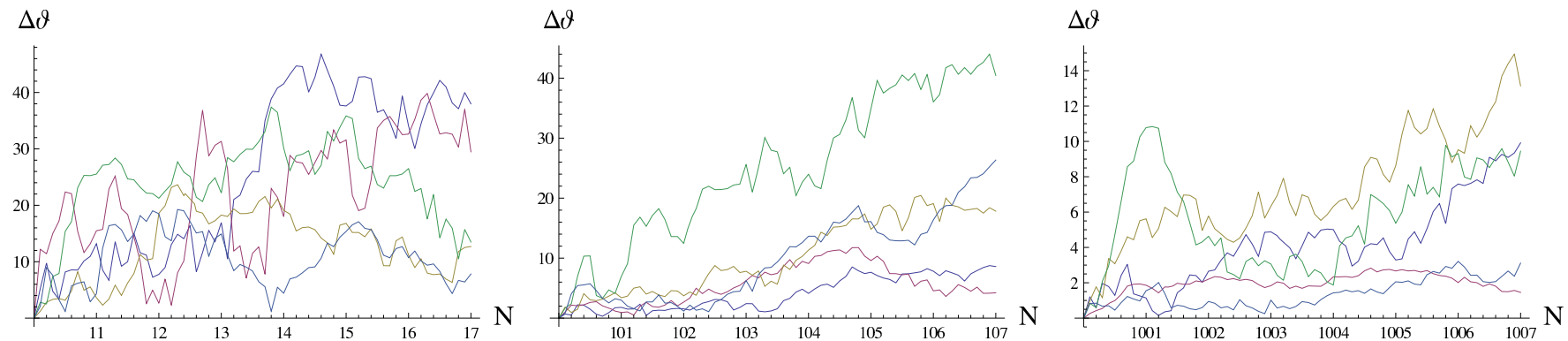
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Poor little thing...

Infrared Statistics – Multiple Vector

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

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

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

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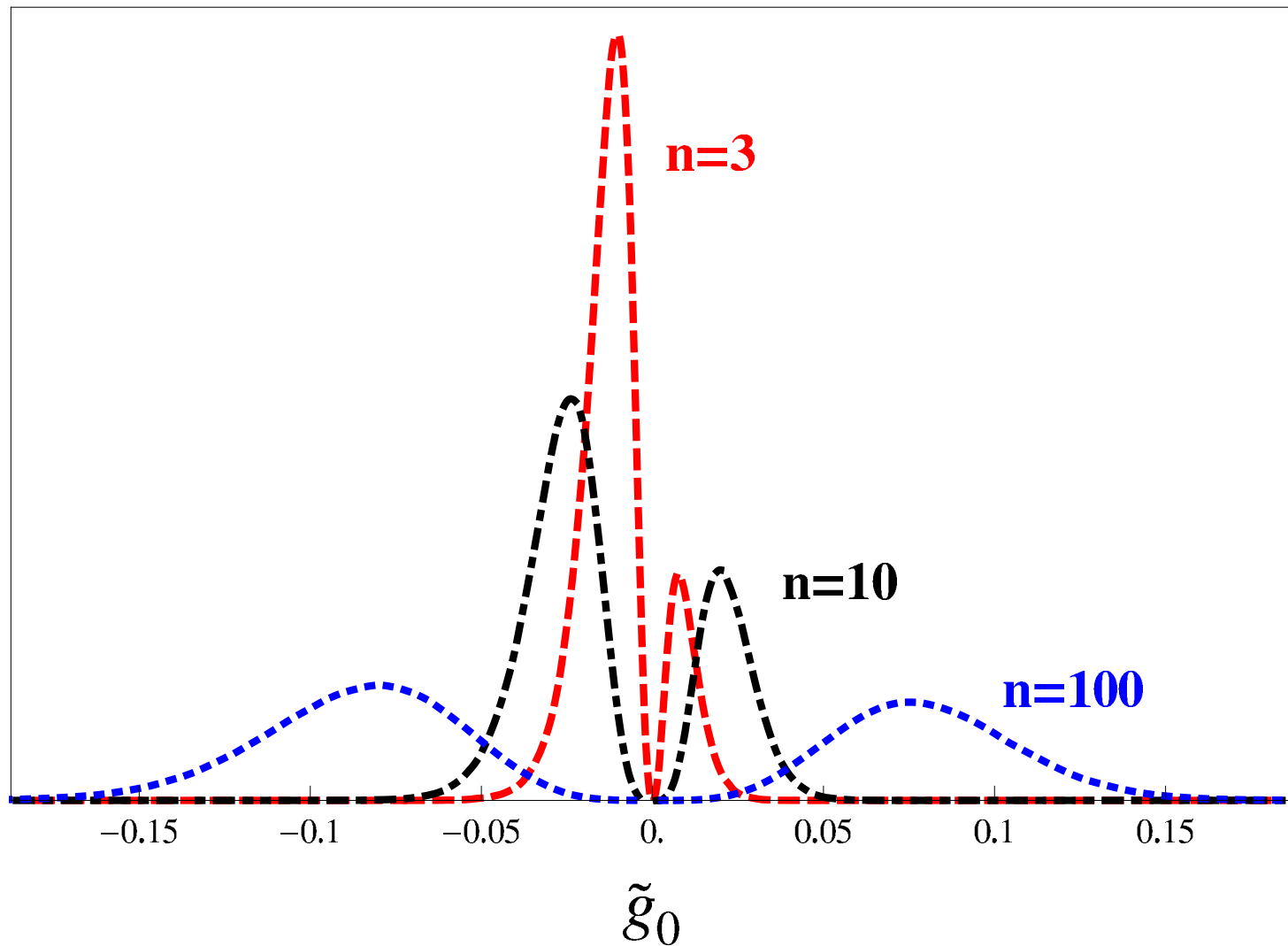
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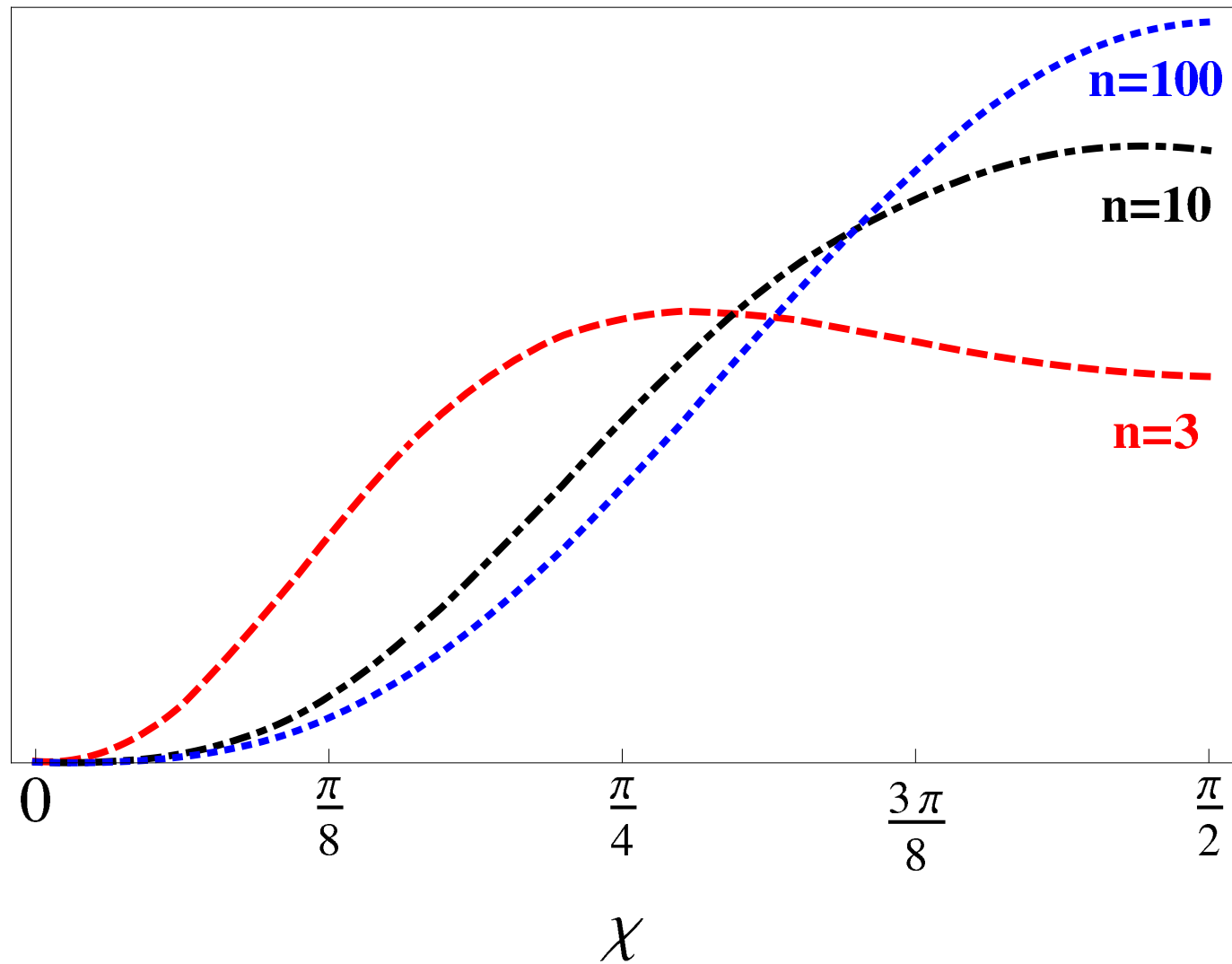
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Two parameters: Amplitude $g(k)$, Shape χ

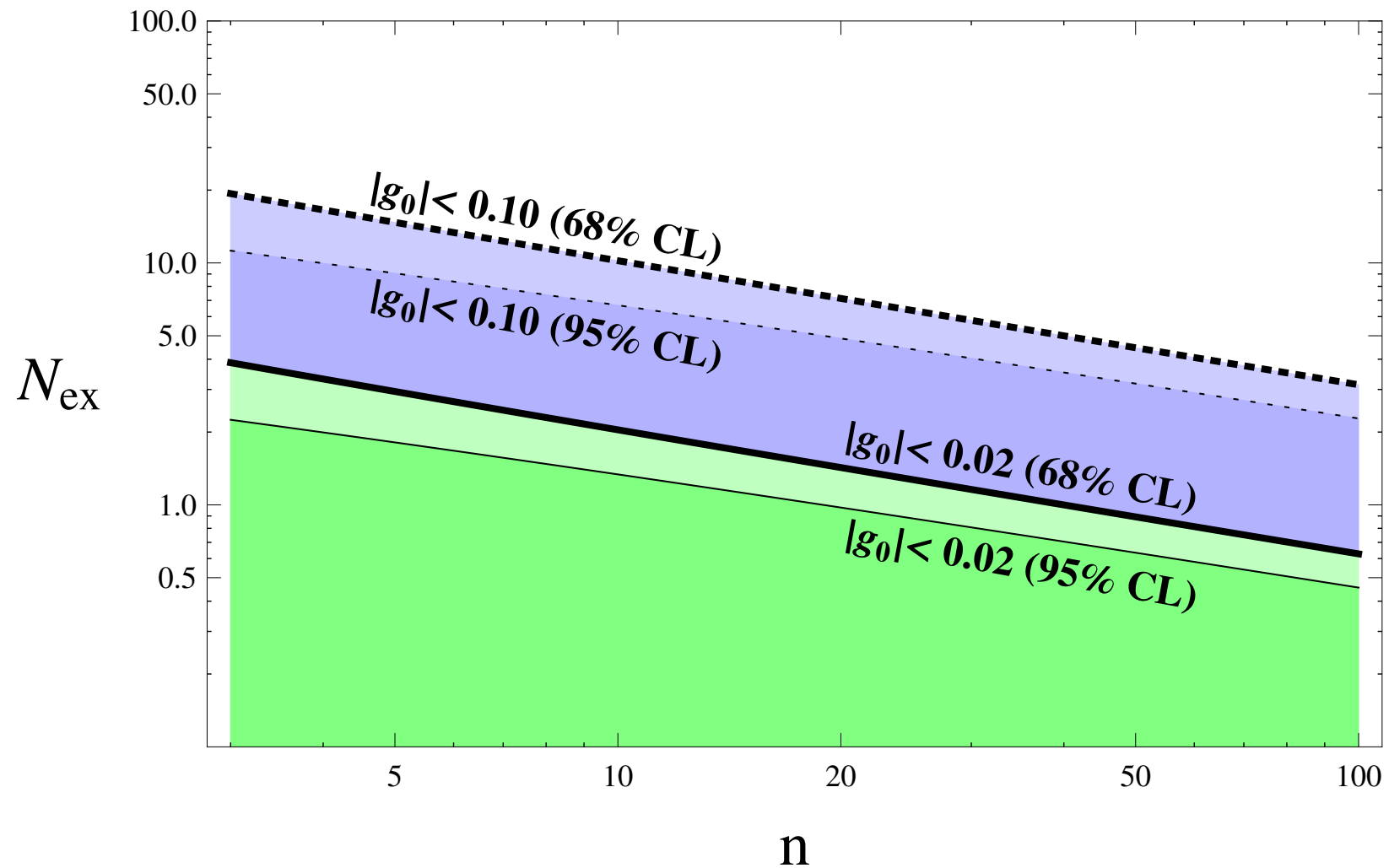
Probability Distributions I



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 biased
- Vectors generate anisotropies
 - Spectator gauge fields can develop into a classical vector background
 - Curvature perturbations are quadrupole-modulated: $\mathcal{P}_\zeta^0(k) [1 + g(k) \cos^2 \vartheta]$
 - (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:

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

⇒ All in all, living in the Bubble can be quite deceiving ← bottom line