Gauge field production during inflation

1212.1693, in collaboration with Andrei Linde and Enrico Pajer

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Quantum Universe 3
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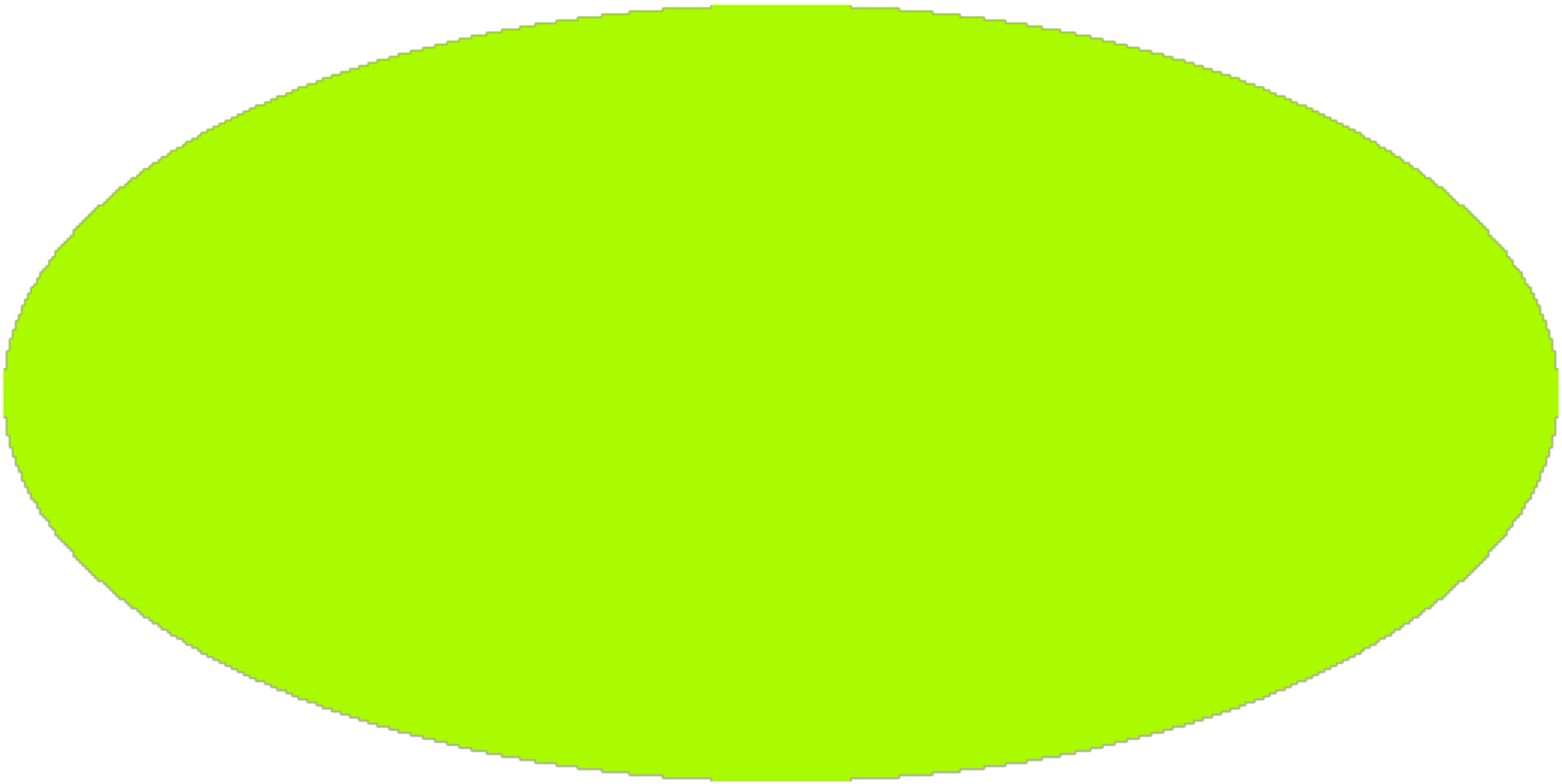
Plan of talk

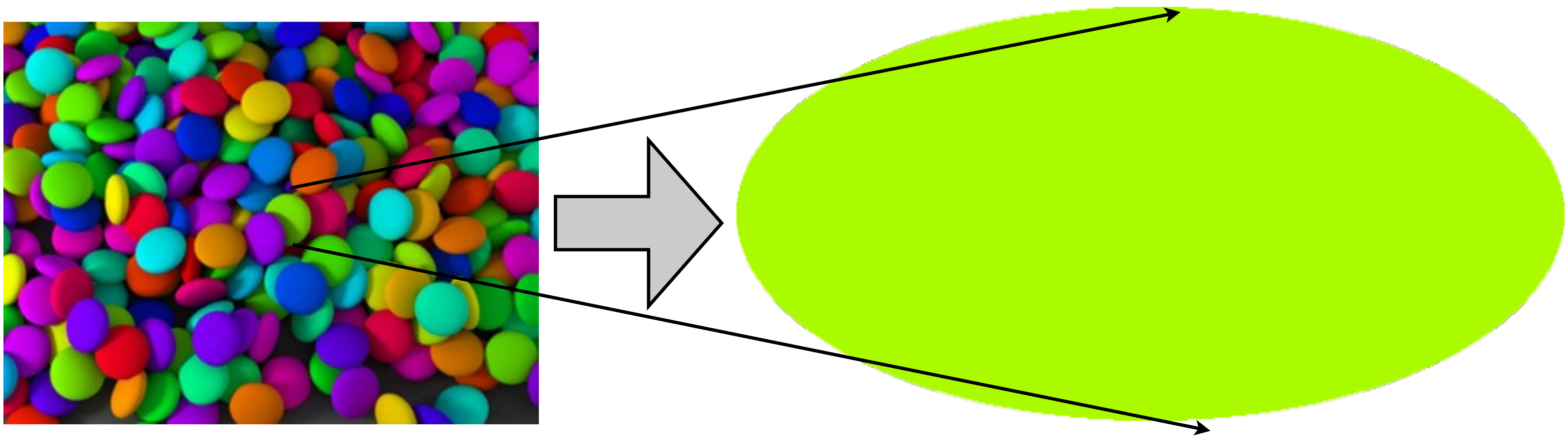
- **Introduction: inflation**
- Model
- Observational constraints
- Implementation in SUGRA
- Massive gauge fields

Looking at the CMB we would expect...

... but we observe

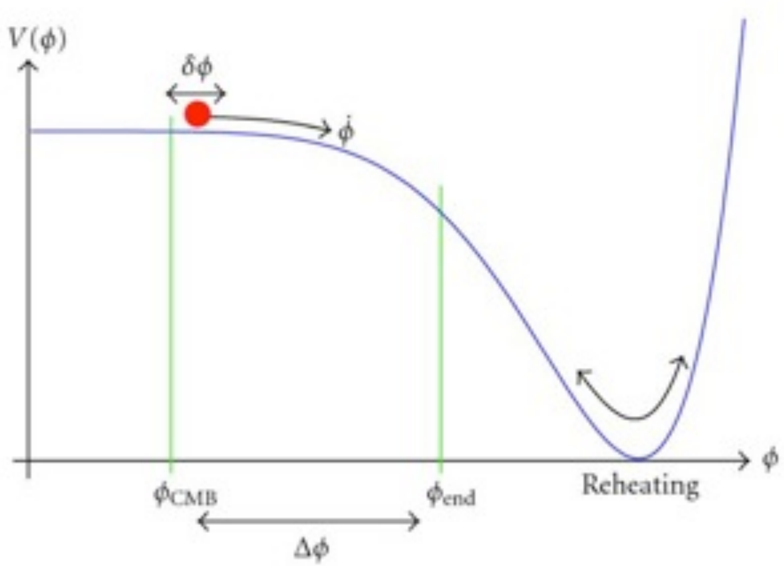


Inflation!



$$\frac{a(t_{\rm end})}{a(t_{\rm begin})} \geq e^{60}$$

Structure formation



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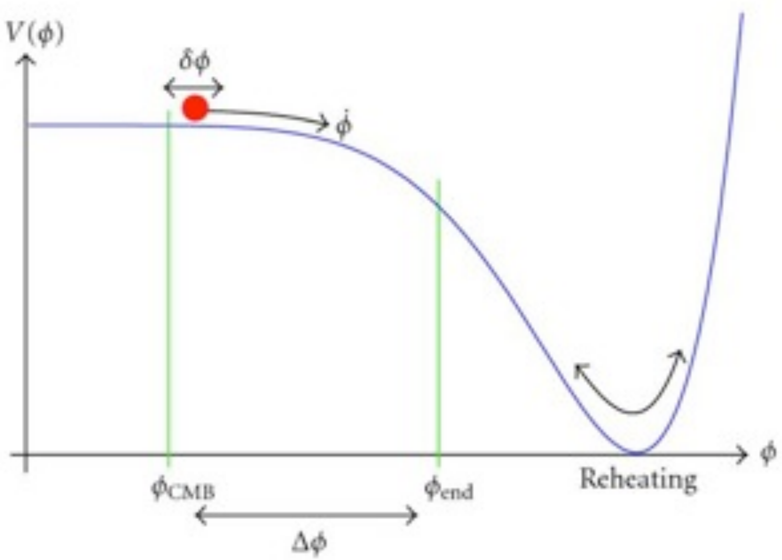

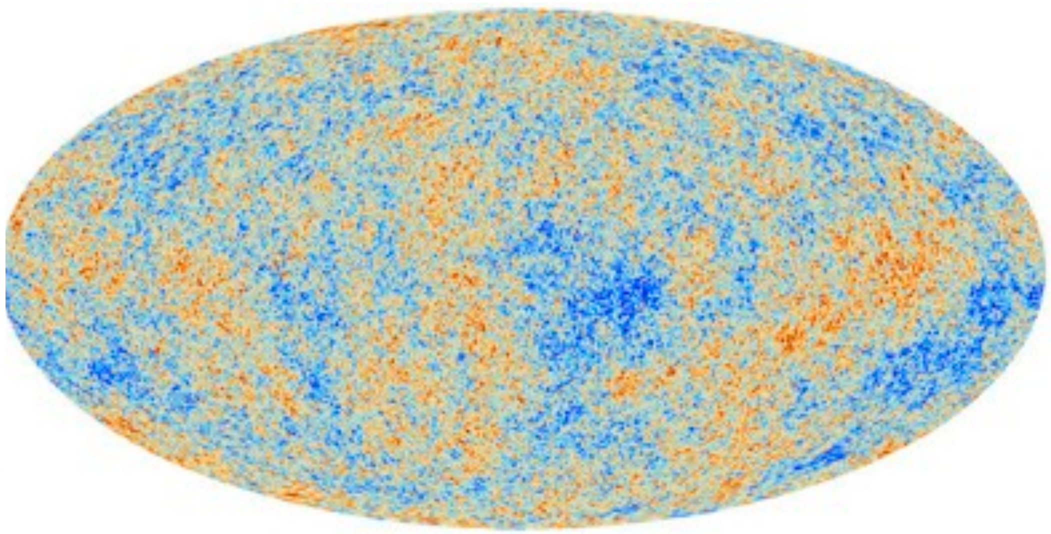

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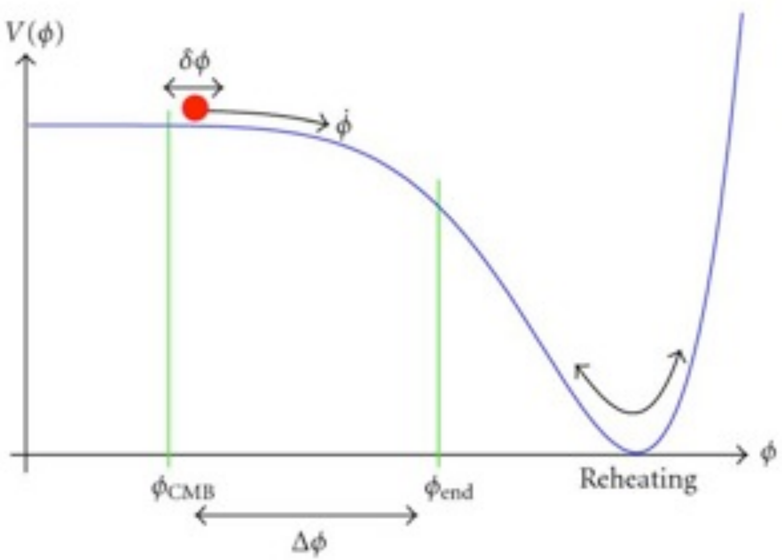

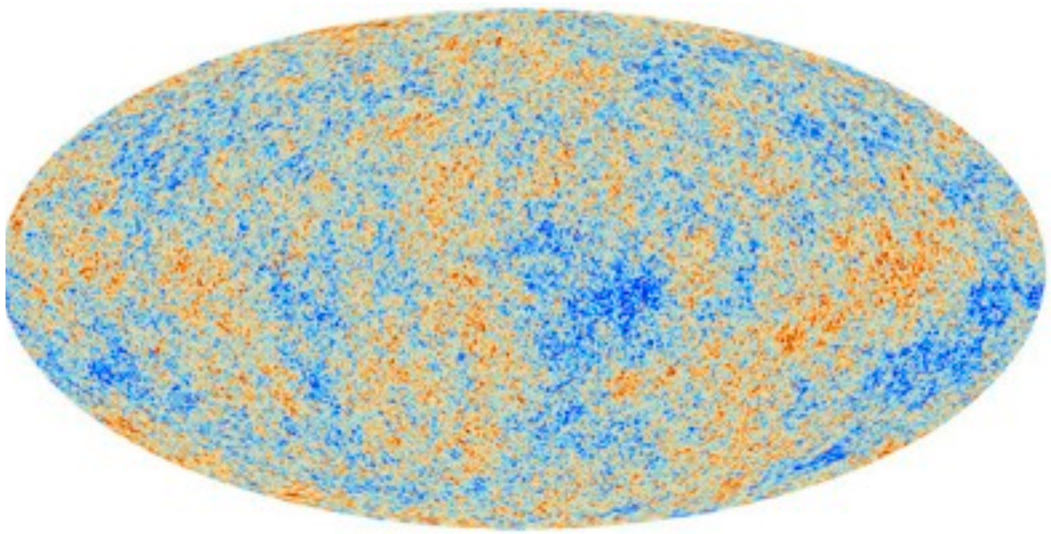

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Model *(Barnaby & Peloso 2010-2011)*

- Pseudoscalar inflaton χ coupled to gauge field A:

$$S = -\int d^4x\sqrt{-g}\left[\frac{1}{2}\partial_\mu\chi\partial^\mu\chi + \frac{1}{4}F_{\mu\nu}F^{\mu\nu} + V(\chi) + \frac{\alpha}{4}F_{\mu\nu}\tilde{F}^{\mu\nu}\right]$$

$$F_{\mu\nu} \equiv \partial_\mu A_\nu - \partial_\nu A_\mu$$

$$\tilde{F}_{\mu\nu} \equiv \frac{1}{2}\frac{\epsilon^{\mu\nu\rho\sigma}}{\sqrt{-g}}F_{\rho\sigma}$$

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- Equilateral non-Gaussianity from inverse decay:

$$\delta A + \delta A \rightarrow \delta\chi$$

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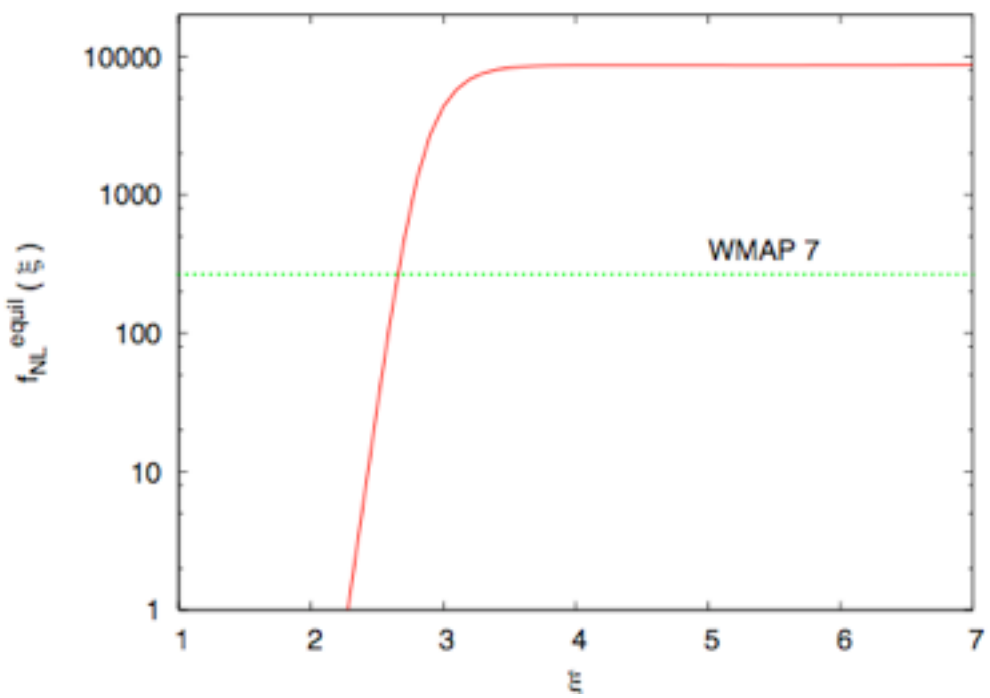
Equilateral non-Gaussianity

- WMAP7:

$$-214 < f_{\rm NL}^{\rm eq} < 266, \qquad (2\sigma) \qquad \Rightarrow \qquad \xi < 2.65$$



(1102.4333)

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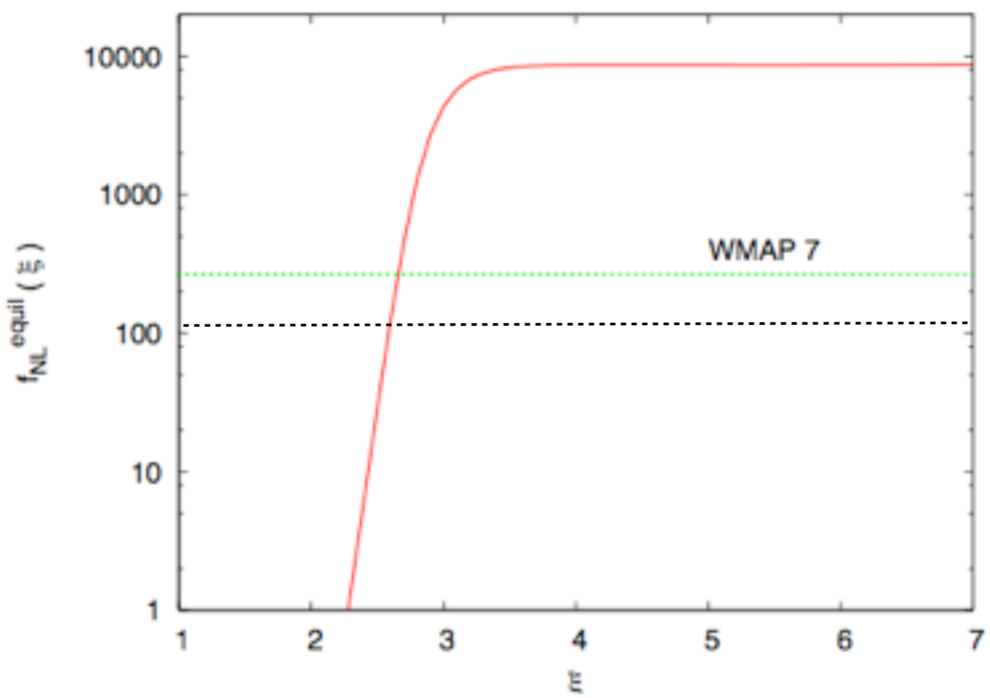


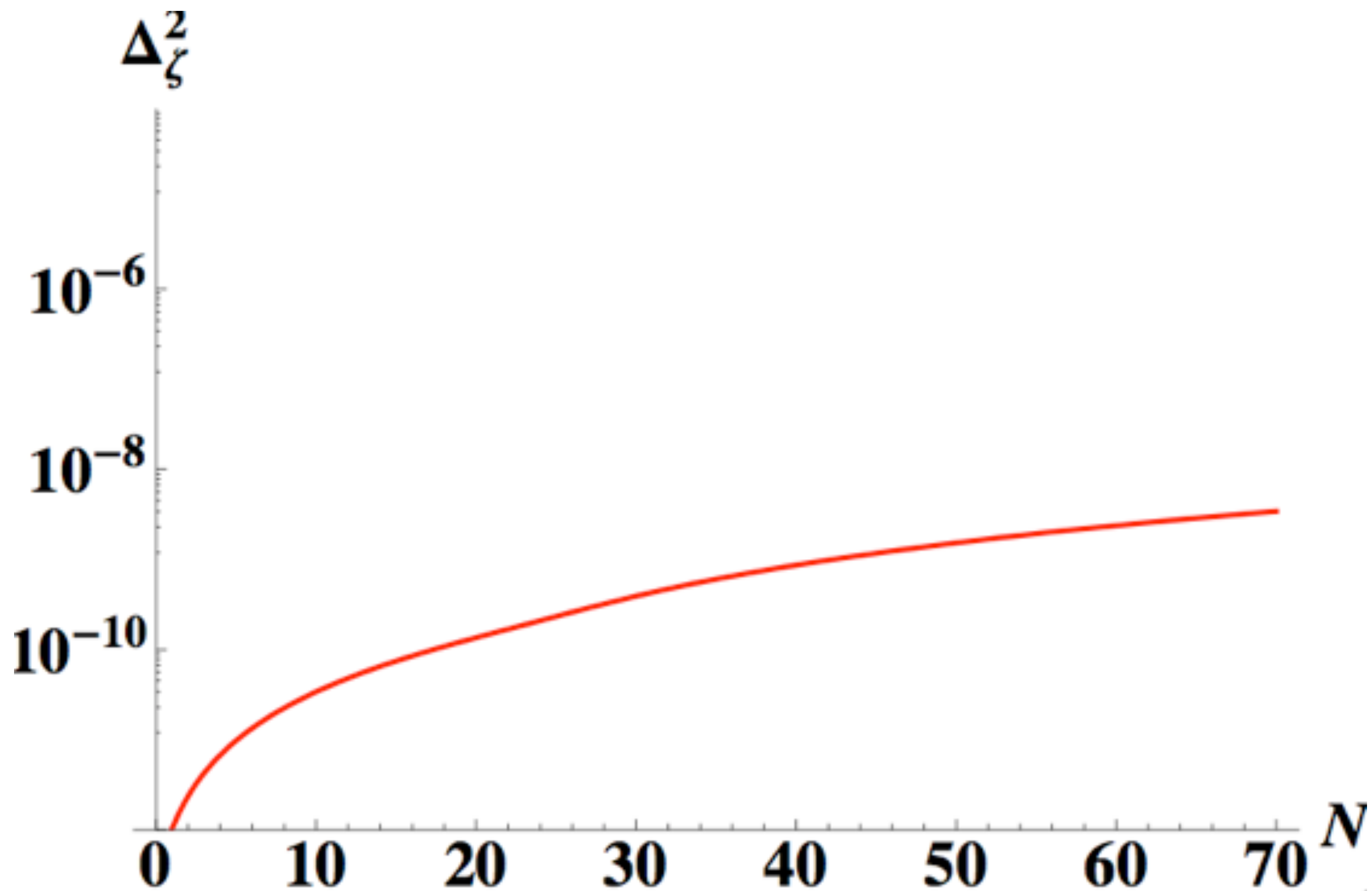
(1102.4333)

- Planck:

$$-192 < f_{\rm NL}^{\rm eq} < 108, \qquad (2\sigma) \qquad \Rightarrow \qquad \xi < 2.5$$

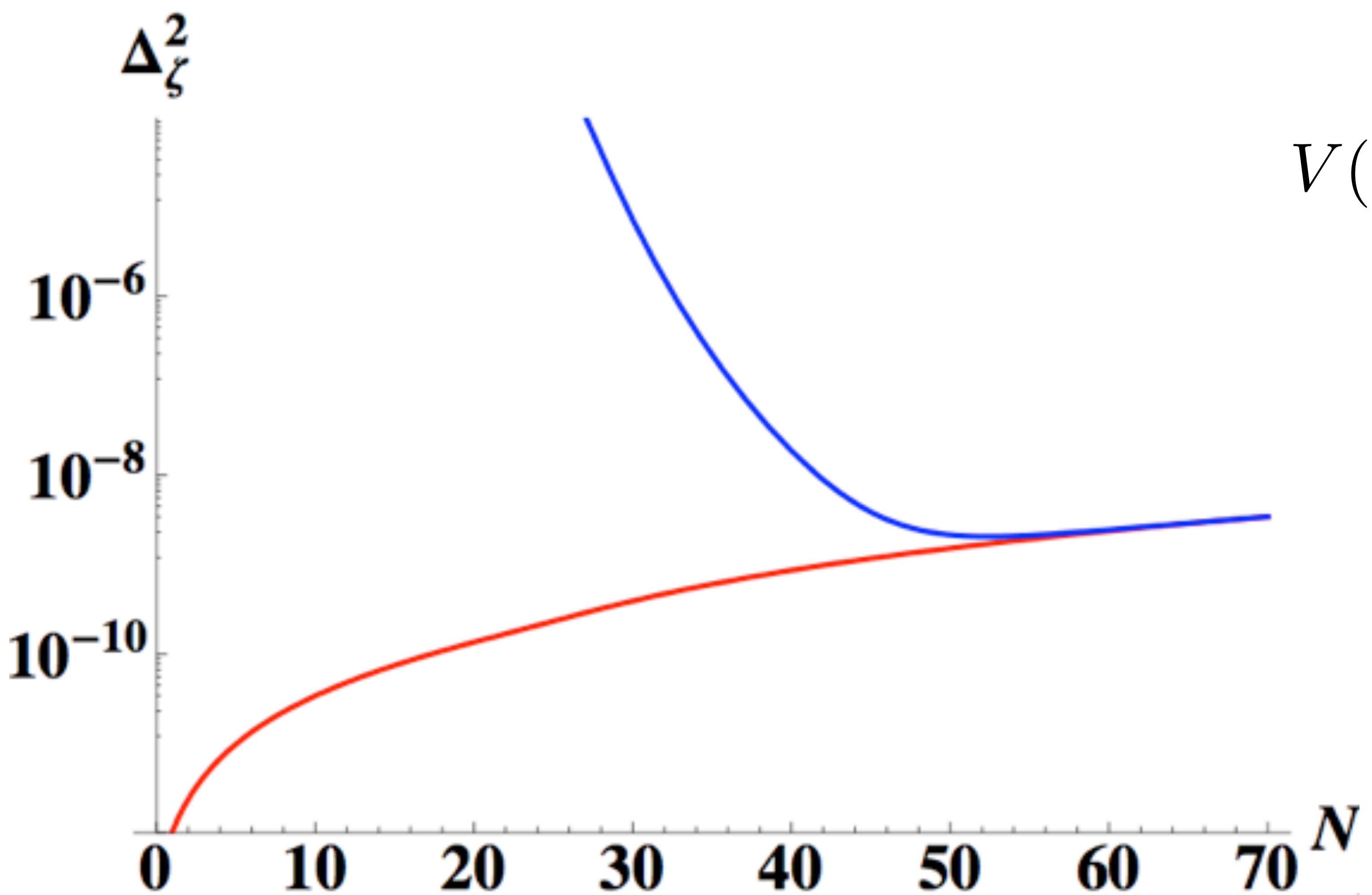
Power spectrum constraints *(Meerburg & Pajer 2012)*

- Standard slow-roll power spectrum



Power spectrum constraints *(Meerburg & Pajer 2012)*

- WMAP 7 + ACT



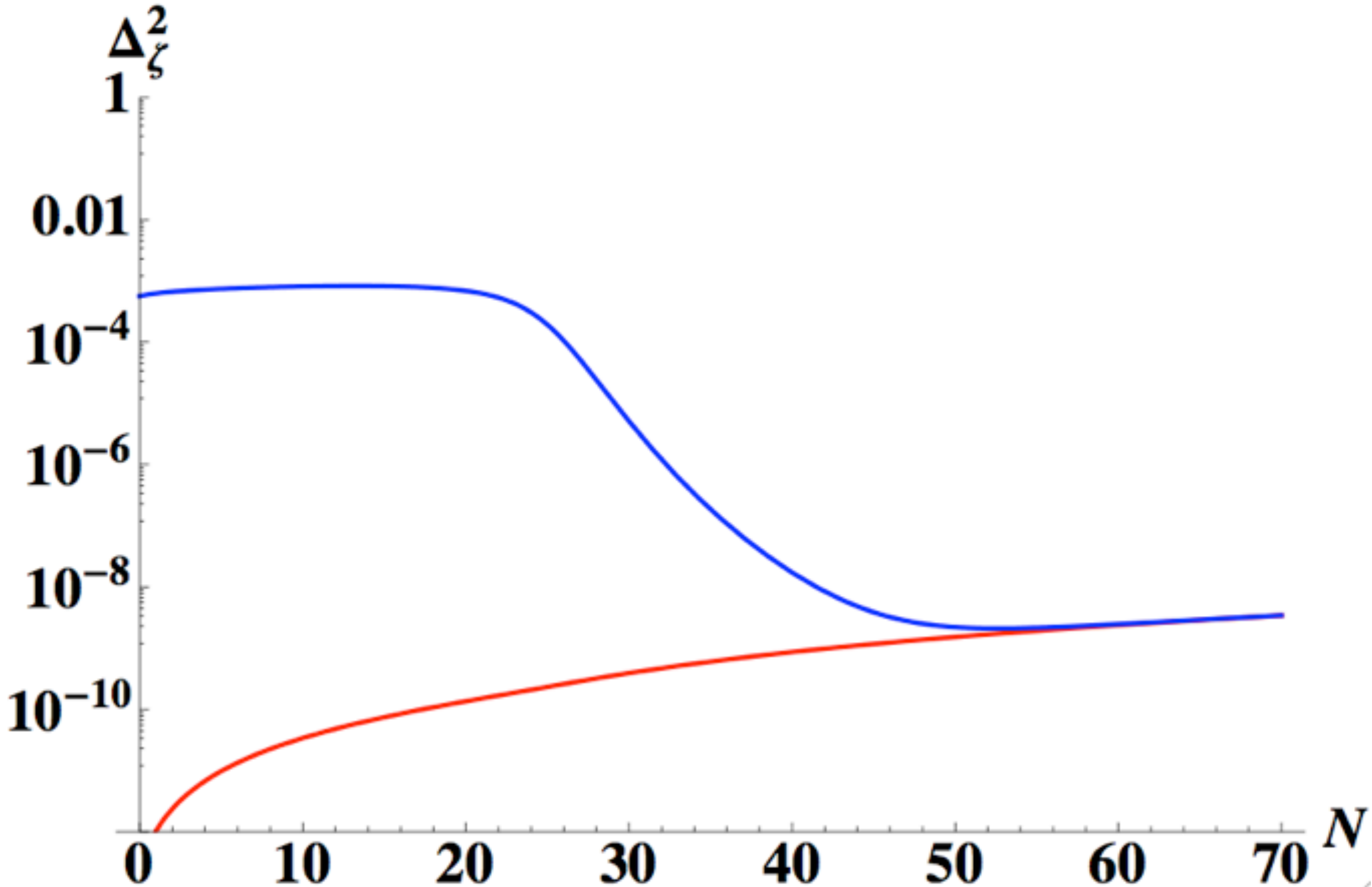
$$\xi = 2.5$$
$$V(\chi) = \frac{1}{2}m^2\chi^2$$

$$\Rrightarrow \quad \xi < 2.2 \quad (2\sigma)$$

Late time power spectrum

- Backreaction from produced gauge fields

- Estimate:



Black hole constraints

- Power spectrum follows from fraction of space b that can collapse to a black hole

Byrnes, Copeland, Green 2012
Lyth 2012

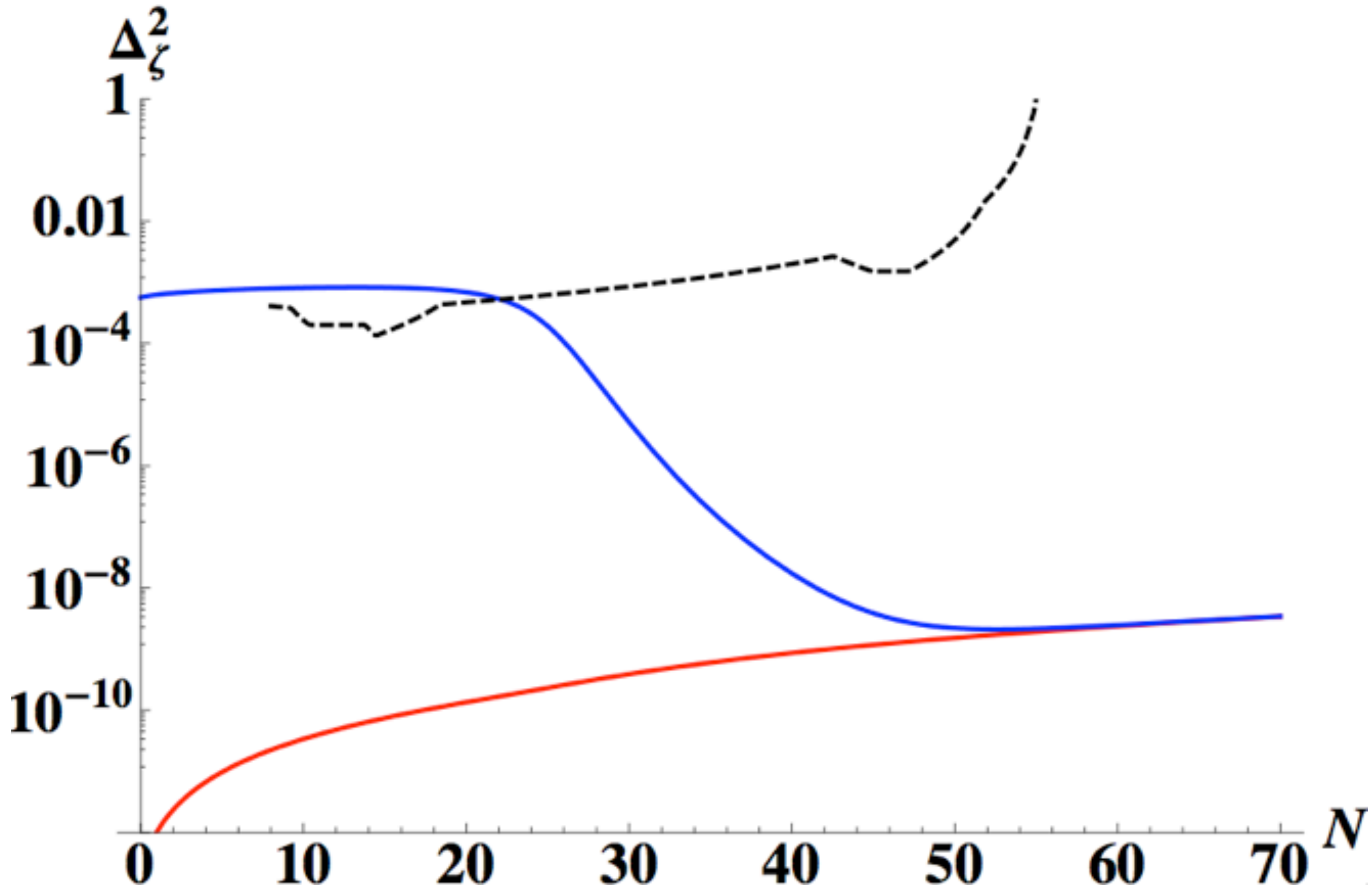
$$b = \int_{\zeta_c}^{\infty} P(\zeta) d\zeta, \qquad P(\zeta) = \frac{1}{\sqrt{2\pi(\zeta+\sigma^2)}\sigma} e^{-\frac{\zeta+\sigma^2}{2}\sigma^2}$$

- Space fraction b as function of M_{BH} (Hawking evaporation, grav. effects)

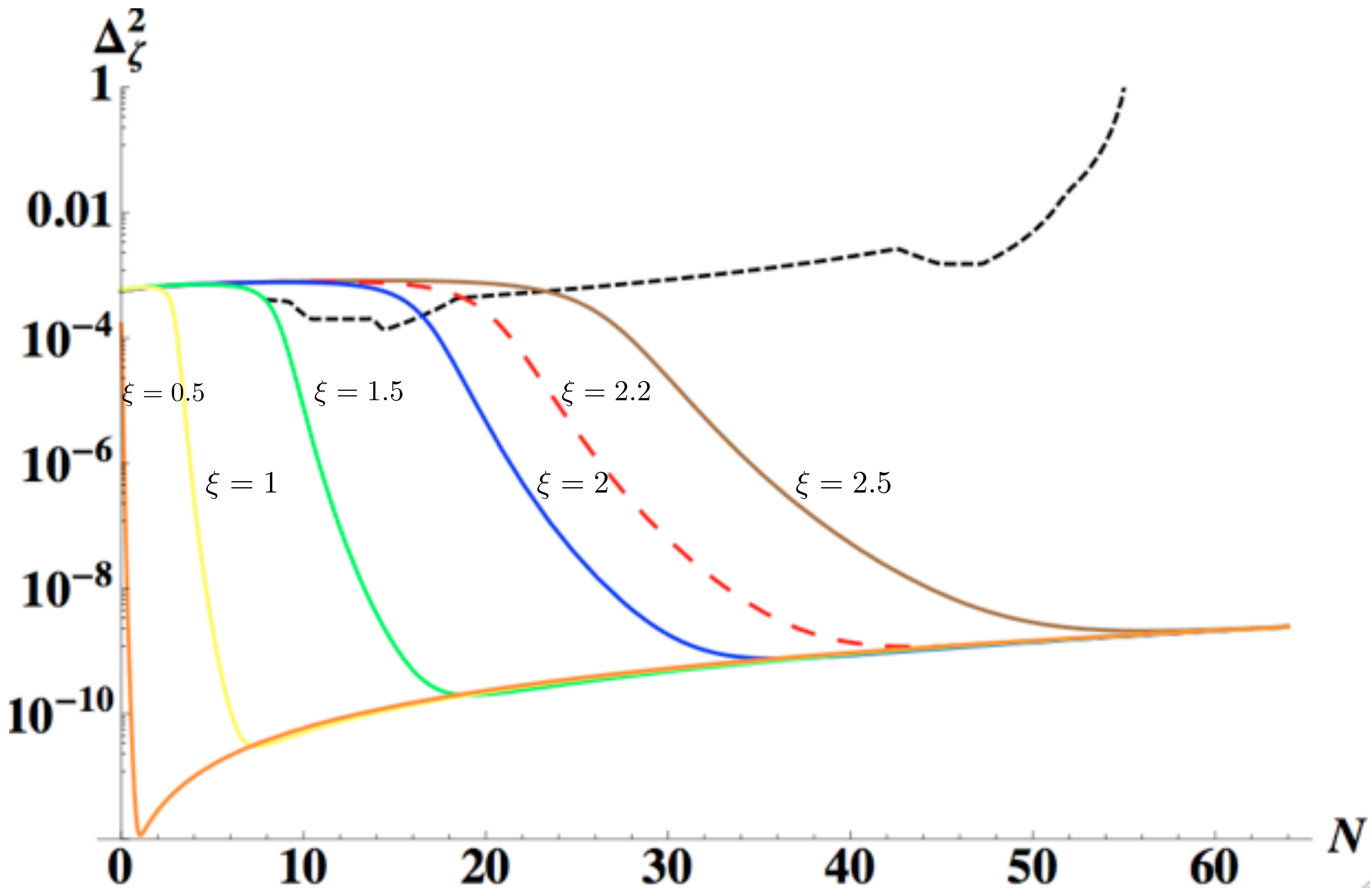
Josan, Green, Malik 2009,
Carr, Kohri, Sendouda, Yokoyama 2010

- Black hole mass M_{BH} as function of N

Black hole constraints (II)



Black hole constraints (III)



$$\Rrightarrow \qquad \xi < 1.5$$

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Functional freedom in SUGRA *(Kallosh, Linde, Olive & Rube 2011)*

- ``flexible” F-term potential

$$K = K(\Phi + \bar{\Phi}, S\bar{S})$$
$$W = S f(\Phi)$$

$$\Rightarrow \quad V(\chi) = |f(\chi/\sqrt{2})|^2$$
$$(\chi = \sqrt{2}\mathrm{Im}\Phi)$$

- can get any n_s and r

- Reheating via additional gauge coupling: $\chi F \tilde{F}$

SUGRA model

- Reheating at

$$T_R \approx \frac{2\xi}{\sqrt{\epsilon}} \times 10^9 \mathrm{GeV}$$

- Energy in vector field: rapid thermalization

- OK for

$$m_{3/2} \gtrsim 10^2 \mathrm{TeV}$$

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Massive scenario

- Mass via Higgs mechanism
- Interesting features for $\xi < 1$ as well
- No black hole trouble
- Local NG from fluctuations in Higgs field H (Brownian motion)
- Implementation in SUGRA via

$$\begin{aligned} K &= K(\Phi + \bar{\Phi}, S\bar{S}) + H\bar{H} + \kappa H\bar{H}S\bar{S} \\ W &= mS\Phi \end{aligned}$$

Conclusions

- study (χ F Fdual) coupling

- original model: gauge production, equilateral NG, black hole troubles

- implementation in sugra

- massive scenario: no BH problem, local non-Gaussianity