Chaotic inflation in Supergravity

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Problems with inflation in supergravity

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Main problem:

$$V(\phi) = e^K \left(K^{-1}_{\Phi\bar{\Phi}} \, |D_\Phi W|^2 - 3|W|^2 \right)$$

Canonical Kahler potential is $K = \Phi\bar{\Phi}$

Therefore the potential blows up at large |φ|, and slow-roll inflation is impossible:

$$V \sim e^{|\Phi|^2}$$

Too steep, no inflation…

Chaotic inflation in supergravity

Kallosh, A.L. 1008.3375, Kallosh, A.L., Rube,1011.5945

$$W = S\, f(\Phi)$$

The Kahler potential is any function of the type

$$\mathcal{K}((\Phi - \bar{\Phi})^2,\, S\bar{S})$$

The potential as a function of the real part of Φ at S = 0 is

$$V = |f(\Phi)|^2$$

FUNCTIONAL FREEDOM in choosing inflationary potential

Example:

$$W = S\, f(\Phi) \qquad\qquad V = |f(\Phi)|^2$$

The Kahler potential is

$$\mathcal{K} = S\bar{S} - \frac{1}{2}(\Phi - \bar{\Phi})^2 - \zeta(S\bar{S})^2 + \frac{\gamma}{2} S\bar{S}(\Phi - \bar{\Phi})^2$$

Curvature of the potential of Im Φ: $$m_\beta^2 \approx 6H^2\,(1+\gamma)\ ,$$

Curvature of the potential of S: $$m_s^2 = m_\alpha^2 \approx 12\zeta H^2\ .$$

The field S with a small mass may play the role of the curvaton

Demozzi, A.L., Mukhanov, 1012.0549

$$\frac{\delta\rho_\sigma}{\rho} \sim \frac{2r\delta\sigma}{\sigma} \qquad r = \rho_\sigma/\rho$$

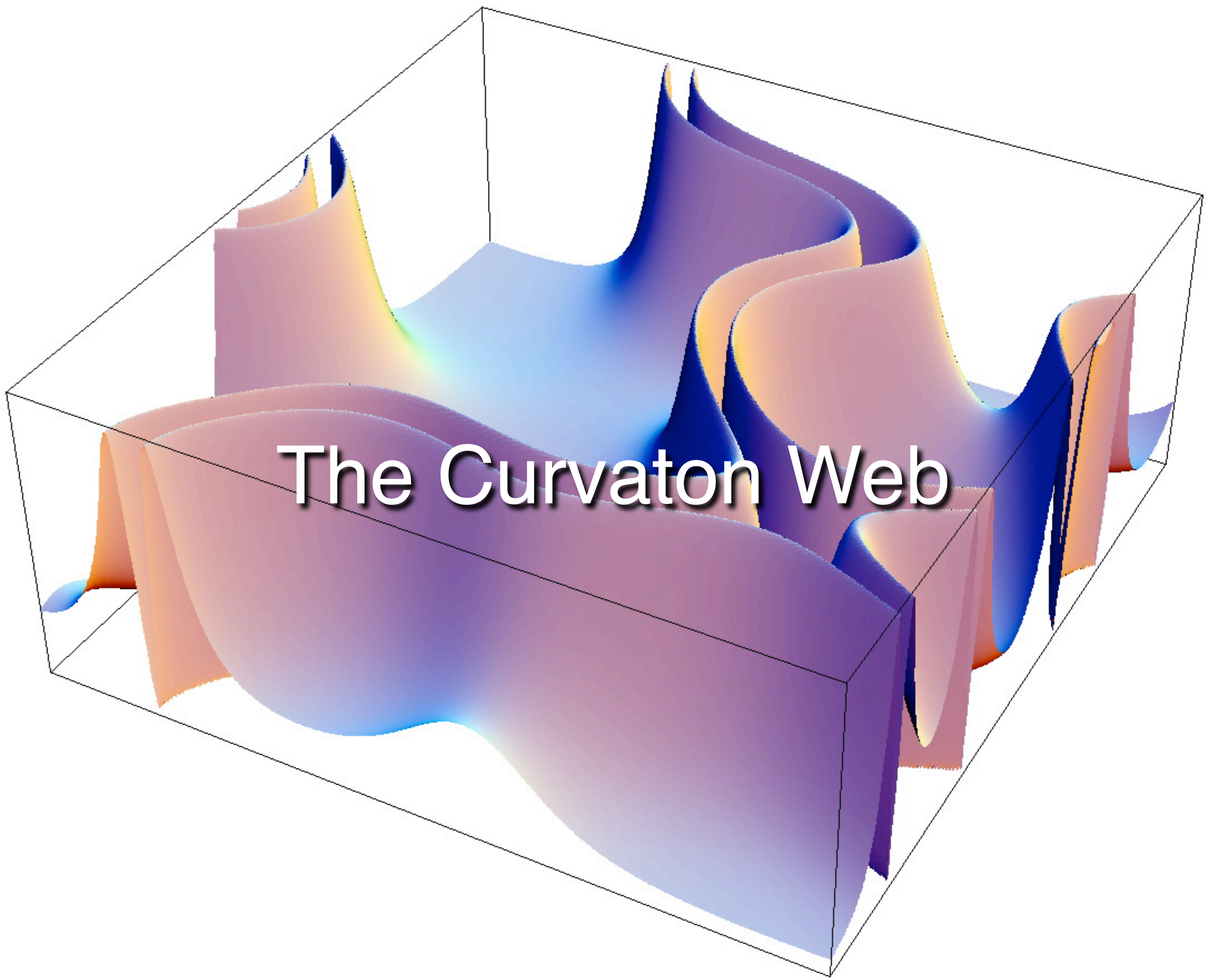
$$f_{\mathrm{NL}} = \frac{5}{4r}$$

If the curvaton classical field survive and start overweighting other fields long after inflation (until they decay), then THE CURVATON PARTICLES produced during reheating can be expected to survive and overweight other particles at the moment of their decay. In this case

$$r = \frac{\rho_\sigma}{\rho_\sigma + \rho_{\sigma-\mathrm{particles}}}$$

The curvaton field and the curvaton particles have the same equation of state and decay simultaneously, no isocurvature perturbations are produced.

$$\frac{\delta\rho_\sigma}{\rho} \sim \frac{2r\delta\sigma}{\sigma}$$



Nongaussianity has topology-related features

For the real curvaton field S, one finds domain walls corresponding to the maxima of the amplitude of perturbations of metric. **These are not the walls of energy density, but walls of the amplitude of perturbations.** If we live near the wall, amplitude of perturbations in the direction towards the wall and away from it will be different (!!!) Hard to make realistic but fun to think about it.

For a complex field, we will have string-like configurations

For a field with O(3) symmetry we may have separate localized regions with high/small amplitude of density perturbations.

"The curvaton web" A.L. Mukhanov 2006

Adding vectors *(Barnaby & Peloso 2010-2011)*

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

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

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

$$A \sim e^{\pi\xi/2}, \qquad \xi \equiv -\frac{\dot{\chi}\alpha}{2H}$$

$$\delta A + \delta A \to \delta\chi$$

Can be implemented in supergravity models of the type described above, and produce equilateral non-gaussianity.

A.L., Mooij, Pajer 2012

However, small black holes are overproduced at the end of inflation.

Add D-term describing a charged field $Q = \frac{h}{\sqrt{2}} e^{i\theta}$ with a minimal Kahler $Q\bar{Q}$ with vanishing superpotential but with the D-term contribution

$$V_D = \frac{g^2}{2} \left(\bar{Q}Q - \xi\right)^2$$

Two cases:

1) $\xi = 0$ A.L., Mooij, Pajer 2012

In this case one can produce local non-Gaussianity by exciting the field h, just as in the curvaton scenario. Unlike the curvaton model, the field h controls duration of inflation and directly contributes to adiabatic perturbations, independently of reheating.

One can do it without overproducing small black holes.

2) $\xi \neq 0$ A.L. 1303.4435

During inflation in this class of theories

$$m_h^2 = V_F(\phi) - \frac{g^2}{2} h_0^2$$

During inflation, the mass squared of the field h becomes → spontaneous symmetry breaking → cosmic strings produced DURING inflation. As a result, only very longest are present, no pulsar bound on string tension (see also Yokoyama 1989, Yokoyama et al 1204.3237)

A note aside: Can we have a reasonable theory with 1 MeV scale domain walls, just one per horizon? Would it account for anomalies, or make life even more complicated?

In this new class of supergravity inflation models, one can have **arbitrary potential for the inflaton field**.

Thus one can have **ANY desirable values of n_s and r.** Moreover, one can generalize this scenario to describe production of non-gaussian perturbations and cosmic strings.