N-FLATION IN SUPERGRAVITY

(SAHA THEORY WORKSHOP)
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KUMAR DAS
(THEORY DIVISION)
SAHA INSTITUTE OF NUCLEAR PHYSICS
KOLKATA

BASED ON

Kumar Das & Koushik Dutta **Phys.Lett. B738 (2014) 457-463**
arxiv:1408.6376 [hep-ph]

Introduction

- Inflation ⇒ accelerated expansion
  Early universe filled with a scalar field ϕ (inflaton) whose P.E >> K.E.
- The energy scale for inflation is GUT scale
- By Lyth bound $\Delta\phi \geq \left(\frac{r}{0.01}\right)^{1/2} M_{pl}$, r=tensor to scalar ratio

  for large r , $\Delta\phi > M_{pl}$ *i.e.* super-Planckian
- *Problem* ⇒ Difficulty to realize $\Delta\phi > M_{pl}$ in EFT
- Motivation ⇒To construct a large field model of inflation in SUGRA

Effective Field Theory point of view

To achieve $\Delta\phi > M_{Pl}$ with a single ϕ

$$V_{eff}(\phi) = V(\phi) + \sum_n c_n V(\phi)\frac{\phi^{2n}}{M_{Pl}^{2n}} \text{ (by EFT)}$$

does not make sense as $\Delta\phi > M_{Pl}$

Distribute the job of a single ϕ amongst many ϕ_i`s with each

$$\Delta\phi_i < M_{Pl}$$

also $\phi_i \to \phi_i + iC$

$$\Delta\phi_{Total} = \Delta\phi_1 + \Delta\phi_2 + \Delta\phi_3 \ldots\ldots + \Delta\phi_N >> M_{Pl}$$

So dynamics is governed by N no. of fields

SUGRA Construction

A model in supergravity corresponds to specifying

Kähler potential $K(\Phi, \bar{\Phi})$ and superpotential $W(\Phi)$

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

where $D_{\Phi}W = \partial_{\Phi}W + W\partial_{\Phi}K$

K is a real function of Φ

The simplest choice : $K = \Phi\bar{\Phi}$.

However, at large value of Φ this potential blows up making the slow roll inflation impossible.

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

Too steep to have inflation

Solution:Shift Symmetry

Take the Kähler potential to be

$$K = X\bar{X} - \frac{1}{2}(\Phi - \bar{\Phi})^2, X \Rightarrow \text{auxiliary field}$$

and super potential

$$W = m\,X\,\Phi$$

Shift Symmetry: $\Phi \rightarrow \Phi + iC$ $(C\ \text{real})$; K is invariant

(Kawasaki, Yamaguchi, Yanagida Phys. Rev. Lett. 85 2000; arxiv:hep-ph/0004243)

Now the potential is curved with respect to X and $Im\ \Phi$ and these fields vanish. Also K does not depend upon $\phi = \sqrt{2}\ Re\ \Phi = (\Phi + \bar{\Phi})/\sqrt{2}$.

Identify ϕ to be inflaton

The potential for this field has the simplest form

$$V(\phi) = \frac{1}{2}m^2\phi^2$$

Two field case

We proposed

$$W = m\,X\,(\Phi_1 + \Phi_2)$$ (arxiv: 1408.6376 [hep-ph] Das & Dutta)

The form of Kähler potential is taken to be

$$K = X\bar{X} - \zeta(X\bar{X})^2 - \frac{1}{2}(\Phi_1 - \overline{\Phi_1})^2 - \frac{1}{2}(\Phi_2 - \overline{\Phi_2})^2$$

added for stabilization **($\boldsymbol{m_X > H}$)**

(*precisely* ,$m_X^2 = 12\zeta H^2 + 2m^2$)

The scalar potential is then

$$V(\phi,\chi) = \frac{1}{2}m^2\phi^2 + \frac{1}{2}m^2\chi^2 + m^2\phi\chi$$

where $\phi = \sqrt{2}\,Re\,\Phi_1$ and $\chi = \sqrt{2}\,Re\,\Phi_2$

Here inflaton is a collection of two fields.

The Lagrangian is

$$\mathcal{L}=(\partial_\mu\phi)(\partial^\mu\phi) + (\partial_\mu\chi)(\partial^\mu\chi) - V(\phi,\chi)$$

Define: $\psi_1 = \frac{1}{\sqrt{2}}(\phi + \chi)$ and $\psi_2 = \frac{1}{\sqrt{2}}(\phi - \chi)$

With this field redefinition

$$\mathcal{L}= (\partial\psi_1)^2 + (\partial\psi_2)^2 - \frac{1}{2}\left(\sqrt{2}m\right)^2\psi_1^2$$

So $\psi_2 \Rightarrow$ massless. The eqn. of state parameter for ψ_2 is $w=1$.

The energy density for ψ_2 dilutes very quickly to play any non-trivial contribution in background dynamics.

So, effectively, $\mathcal{L}\approx (\partial\psi_1)^2 - \frac{1}{2}\left(\sqrt{2}m\right)^2\psi_1^2$ ***i.e. a single field*** $\mathcal{L}$

FIELD DYNAMICS PLOTS

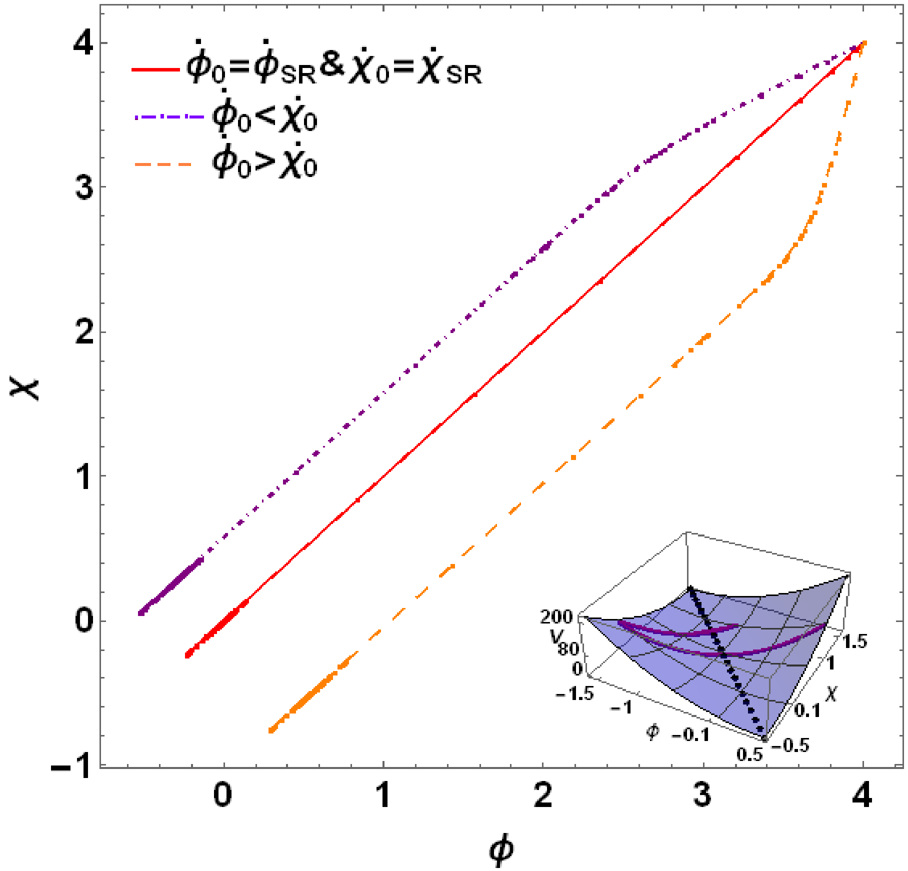

Fig. 1 Field space plots for different boundary conditions

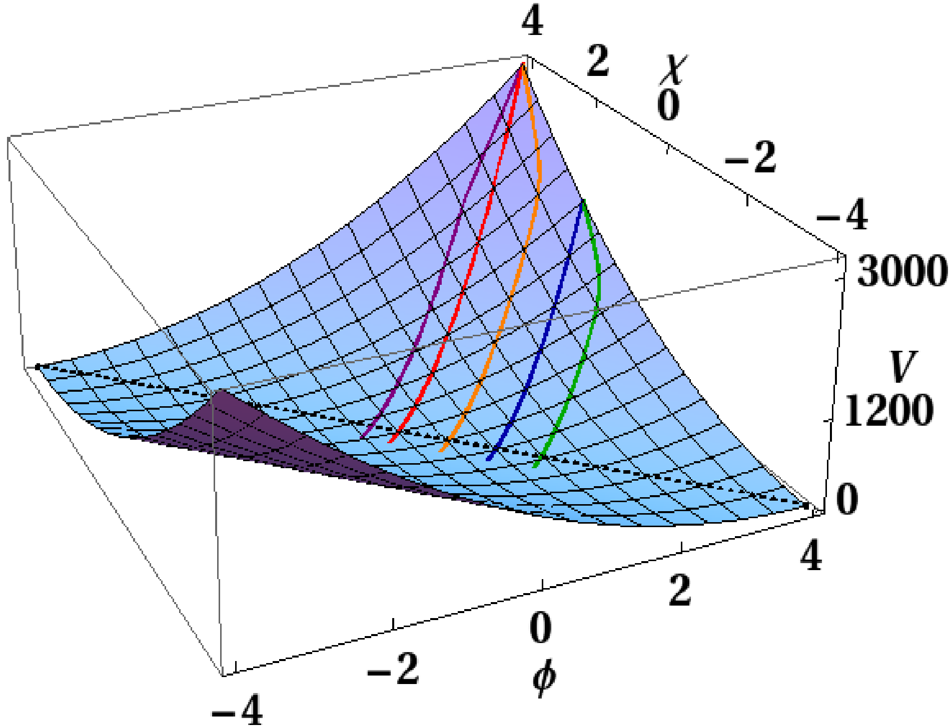

Fig. 2 Effective potential with the joint evolution of both fields

N-FIELD EXTENSION

We propose the following super potential

$$W = m\,X\,(\Phi_1 + \Phi_2 + \ldots\ldots \Phi_N) = m\,X\,\sum_{i=1}^{N} \Phi_i$$

& the Kähler potential

$$K = X\bar{X} - \zeta(X\bar{X})^2 - \frac{1}{2}\sum_{i=1}^{N}(\Phi_i - \overline{\Phi_i})^2$$

So the scalar potential

$$V(\phi_1, \ldots, \phi_N) = \frac{1}{2}m^2\left(\sum_{i=1}^{N}\phi_i\right)^2 + \text{two-field interaction}$$

The Lagrangian

$$\mathcal{L} = \sum_{i=1}^{N}(\partial\phi_i)^2 - \frac{1}{2}m^2\left(\sum_{i=1}^{N}\phi_i\right)^2$$

- Define a column vector $\Phi = \begin{pmatrix} \phi_1 \\ \vdots \\ \phi_N \end{pmatrix}$

  the basis vectors $\{\mathbf{e_i}\}$`s are $\{\mathrm{e}_1 = (1,0,\ldots,0), \mathrm{e}_2 = (0,1,\ldots,0), \ldots, \mathrm{e}_N = (0,0,\ldots,1)\}$

- Move to new set of basis $\{\mathbf{e_i}'\}$ such that

$$\Phi = \phi_i |e_i\rangle = \psi_j |e_j{}'\rangle$$

- Use Gram-Schmidt to find $|e_j{}'\rangle$
- In this new basis Lagrangian becomes

$$\mathcal{L} = \sum_{i=1}^{N} (\partial \psi_i)^2 - \frac{1}{2} (\sqrt{N} m)^2 \psi_1^2$$

Like two field case here all fields except ψ_1 will be diluted out of the background dynamics.

- So the effective Lagrangian is

$$\mathcal{L} \approx (\partial \psi_1)^2 - \frac{1}{2} \left(\sqrt{N} m\right)^2 \psi_1^2$$ ***i.e. again a single field*** $\mathcal{L}$

Conclusion

- We have proposed a simple realization of N-flation in supergravity
- This model is the generalization of single field chaotic inflation in SUGRA
- Even though the Effective potential has field interactions background dynamics is described by one single field.
- Observable parameters will have similar predictions to chaotic inflation.

THANK YOU