Title: Chaotic D-Term Inflation

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Abstract: A simple model for chaotic inflation in supergravity is proposed. The model is N = 1 supersymmetric massive U(1)gauge theory via the Stuckelberg superfield and gives rise to D-term inflation with a quadratic term of inflaton in the potential. The Fayet-Iliopoulos field plays a role of the inflaton. It is also discussed to give rise to successful reheating and leptogenesis through the inflaton decay.

Chaotic D-Term Inflation

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Based on

arXiv : 0712.2351

&

arXiv : 0806.4971

w/ Masahide Yamaguchi

Motivation

Cosmological Inflation

solves

the Horizon problem

&

the Flatness problem,

Guth

and explains

the Density Fluctuations

in the Cosmic Microwave

Background (CMB)

Among many inflation scenarios,

Chaotic Inflation

doesn't severely suffer

from

the Initial Condition problem,

and yields

a relatively larger

tensor-to-scalar ratio,

which would be detected

by the Planck satellite

(planned to be launched soon

in 2009).

Supersymmetry (SUSY)

solves

the Gauge Hierarchy problem

in High Energy Physics

⬇

A Natural Progress

would be

$\boxed{\text{SUSY Inflation !}}$

However, it is known that the scalar potential in Supergravity (SUGRA) has a difficuty to satisfy the slow roll condition.

This is called the η-problem.

The scalar potential $V(\phi)$ in SUGRA has two different contributions

$$V(\phi,\phi^{+}) = V_F(\phi,\phi^{+}) + V_D(\phi,\phi^{+})$$

The F-term potential

$V_F(\phi, \phi^\dagger)$ is given

in terms of

a superpotential $W(\phi)$

and

a Kähler potential $K(\phi, \phi^\dagger)$

as

$$V_F = e^K \left[K^{i\bar{j}} D_i W D_{\bar{j}} \bar{W} - \frac{3}{M_P^2} |W|^2 \right]$$

If an inflaton field ϕ takes the "minimal" Kähler potential

$$K(\phi, \phi^\dagger) = \phi^\dagger \phi ,$$

$$V_F \sim e^{\frac{|\phi|^2}{M_P^2}} [\ \cdots \ ]$$

prevents the inflaton field ϕ from taking a large VEV.

This is the problem especially for chaotic inflation scenario, because an inflaton field needs to take a large VEV $\sim O(M_P)$.

The D-term potential $V_D(\phi, \phi^\dagger)$ is given by the momentum map D^a of gauge groups and gauge functions $f_{ab}(\phi)$ as

$$V_D(\phi, \phi^\dagger) = \frac{1}{2} \mathrm{Re}\, f_{ab} D^a D^b$$

$$= \frac{1}{2} g_a^2 D^a D^a \quad (\text{for } f_{ab} = g_a^2 \delta_{ab})$$

Here is no $e^{K(\phi, \phi^\dagger)}$ factor!

Therefore, one can avoid the η - problem by considering inflation models where an inflaton gives dominant contributions to the D-term potential $V_D(\phi, \phi^+)$ over the F-term potential $V_F(\phi, \phi^+)$ during inflation period.

This is the idea of

D-term Inflation

Binetury & Dvali

Until recently,
using the D-term potential,
chaotic inflation hasn't
been considered.

Kadota & Yamaguchi

However, their model has
the D-term potential which
is a quartic term of the
inflaton field. This type
of models doesn't appear
to be favored by the
recent WMAP observation

In this talk, I will propose a simple D-term inflation model with a quadratic potential of an inflaton field.

The inflaton field enters like F.-I. parameter in the Lagrangian. Its superpartner boson plays a role of the Stuckelberg field giving mass to a gauge boson, as we will see below.

The Model

$\mathcal{N}=1$ SUSY U(1) Gauge Theory with a chiral superfield S.

Under the gauge transformation,

$$S \to S + \sqrt{2} M \Lambda$$

$$V \to V + i(\Lambda - \bar{\Lambda})$$

where

M : a mass parameter

Λ : a transformation parameter (a chiral superfield)

V : the U(1) vector superfield

The Kähler potential

$$K = -\frac{1}{2}\left(S - \bar{S} + \sqrt{2}\, i M V\right)^2$$

w/ no superpotential

$$W = 0$$

This just gives rise to a free massive gauge multiplet.

$$V \ni (\lambda_\alpha , A_\mu , D)$$

$$S \ni (\rho + i\zeta , \psi_\alpha , F)$$

In the Wess-Zumino gauge,

ρ is eaten by A_μ

upon a "gauge transformation"

$$A_\mu \to A_\mu + \frac{1}{M} \partial_\mu \rho$$

and

a massive gauge multiplet

$$A_\mu$$

$$\lambda_\alpha \qquad \psi_\alpha$$

$$\zeta$$

is left.

The Model

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The D-term potential is given by

$$V_D = \frac{1}{2} D^2$$
$$= \frac{M^2}{2} \xi^2$$

and the real scalar field ξ enters it like a F.-I. parameter as

$$D = M \xi$$

In this case, there is no F-term potential, and thus the scalar potential $V(\zeta)$ is given by the D-term potential $V_D(\zeta)$ only ;

$$\boxed{V(\zeta) = \frac{M^2}{2}\zeta^2}$$

This is a simple chaotic inflation model with the quadratic potential in Supergravity !

In order to explain the primodal density fluctuation, one needs to take the inflaton mass

$$M \sim 10^{13}\ \mathrm{GeV}$$

Reheating & Leptogenesis

In order to give rise to reheating, we need to introduce the fields of the SUSY Standard model and couple the inflaton field Σ to them.

The additional Kähler potential

$$\Delta K = -i\frac{g}{M_p}(S - \bar{S} + \sqrt{2}\, i M V)\bar{N}_i N_i + K_{SSM}$$

where

N_i : the right-handed neutrino superfield ($i = 1, 2, 3$)

K_{SSM} ; a Kähler potential of the SSM including no S and V

g ; a coupling constant

M_p ; the reduced Planck scale

The superpotential

$$W = \frac{m_i}{2} N_i N_i + y_{ij} N_i L_j H_u + W_{SSM}$$

doesn't include S because we assume all the fields other than S are neutral under the $U(1)$.

m_i ; the Majorana masses

y_{ij} ; the Yukawa couplings

L_i ; the left-handed lepton superfields

H_u ; the Higgs superfield

W_{SSM} ; the remaining superpotential

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The $U(1)$ D-term potential

$$V_D = \frac{M^2}{2}\left(\zeta + \frac{g}{\sqrt{2}M_P}|N_i|^2\right)^2$$

The F-term potential V_F

$$e^{\frac{K}{M_P^2}}\left[K^{i\bar{j}} D_i W \bar{D}_{\bar{j}} \bar{W} - \frac{3}{M_P^2}|W|^2\right]$$

where

$$K = \zeta^2 + \frac{\sqrt{2}g}{M_P}\zeta|N_i|^2 + K_{MSSM}$$

Thanks to the factor $e^{\frac{K}{M_P^2}}$,

during inflation $\zeta \sim O(M_P)$

$$N_i \sim 0$$

$$V_F \sim 0 \quad (V_F \ll V_D)$$

Therefore, the additional interactions don't spoil our inflation model.

After inflation, the inflaton ζ dominantly decays into sneutrinos N_i via the interaction

$$-\frac{g}{\sqrt{2}M_P}M^2\zeta|N_i|^2$$

coming from the D-term potential.

Assuming

$$m_1 \sim 10^{12}\,\mathrm{GeV} < M < m_{2,3}$$

one finds the dominant decay

$$\zeta \rightarrow N_1 + \bar{N}_1$$

yields the decay rate

of the inflaton ζ

$$\Gamma \simeq \frac{1}{16\pi M}\left(\frac{g M^2}{\sqrt{2} M_P}\right)^2$$

and successful

reheating temperature

$$T_R \simeq 3.0 \times 10^7\,\mathrm{GeV}\left(\frac{g}{0.1}\right)\left(\frac{M}{10^{13}\,\mathrm{GeV}}\right)^{\frac{3}{2}}$$

The leptogenesis ocurrs after the inflaton decay

$$\zeta \to N_1 + \bar{N}_1$$

via the Yukawa interaction

$$y_{ij} N_i L_j H_u$$

as often discussed.

Assuming

$$|y_{i3}| > |y_{i2}| \gg |y_{i1}|$$

one can show the lepton asymmetry $\frac{n_L}{s}$ is given by

$$\sim -5 \times 10^{-10} \delta_{eff} \left(\frac{g}{0.1}\right) \left(\frac{M}{10^{13} GeV}\right)^{\frac{1}{2}} \left(\frac{m_1}{10^{13} GeV}\right)$$

comparable to $-(1-3) \times 10^{-10}$

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