Right-Handed Sneutrino Modification of D-term Hybrid Inflation in Non-mininal Supergravity

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Topics

- Inflation

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- SUSY Inflation

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- What is D-term inflation?

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- What is D-term inflation?
- What are the problems with D-term Inflation?
- Provide a solution.

Inflation

Once upon a time, the Universe was dominated by some mysterious vacuum energy:

$$V(\phi) = 3H^2 M_{Pl}^2 \approx \rho_\phi \approx const.$$

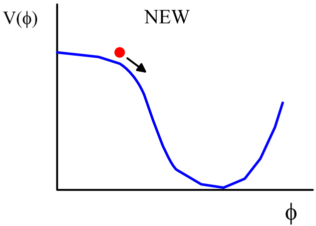
$$\therefore \dot{\rho} \approx 0 \Rightarrow H \equiv \frac{\dot{a}}{a} \approx const.$$

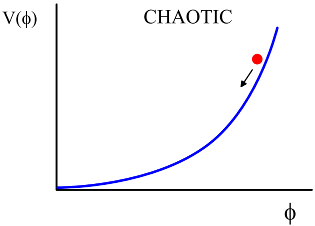
$$\frac{da}{a} = Hdt \Rightarrow a \propto e^{Ht}$$

People named this dramatic expansion "Inflation". The problem is, what in the world is $V(\phi)$ after all?!

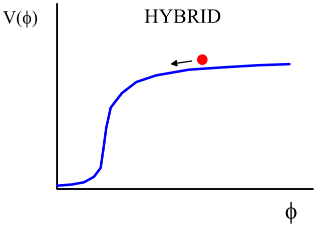
Inflation

So people start to play the game of Inflation by inventing all kinds of potentials...





Inflation



Inflation

Slow-roll inflation:
A scalar potential of the field(s) $V(\phi, ...)$ tells you almost everything! $\eta = M^2 V''/V$ and $\epsilon = (M^2/2)(V'/V)^2$ Spectral index:

$$n = 1 + 2\eta - 6\epsilon$$

Curvature perturbation:

$$P_\zeta = \frac{1}{12\pi^2 M^6} \frac{V^3}{V'^2}$$

etc.

Supersymmetry (Boson$\leftrightarrow$Fermion)

Every particle corresponds to its superpartner, which must be HEAVY due to SUSY breaking.

Supersymmetry

Reasons for implanting SUSY into Inflation:

- Have scalar fields

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- etc.

Supersymmetry

Scalar potential

$$V = V_F + V_D$$

SUSY:

$$V_F = |F|^2 \equiv |W_m|^2$$

$$V_D = \frac{1}{2}(\frac{g}{2}\sum_n q_n|\phi_n|^2 + \xi)^2$$

SUGRA:

$$V_F = e^{K/M^2}\left[(W_m + \frac{WK_m}{M^2})K^{m^\dagger n}(W_n + \frac{WK_n}{M^2}) - \frac{3|W|^2}{M^2}\right]$$

$$V_D = \frac{1}{2}(\mathrm{Re}f)^{-1}g^2(q_n K_n \phi^n + \xi)^2$$

Conventional D-term Inflation

The superpotential of D-term hybrid inflation is given by

$$W_D = \lambda S \Phi_+ \Phi_-$$

One-loop potential:

$$V(S) = V_0 + \frac{g^4 \xi^2}{16\pi^2} \ln\left(\frac{|S|^2}{\Lambda^2}\right)$$

Problems of conventional D-term Inflation

From WMAP

$$n = 0.958 \pm 0.016$$

However,

$$n = 0.983$$

From cosmic string study (for example astro-ph:0702223):

$$\xi^{1/2} < 3.9 \times 10^{15} \text{GeV}$$

(assume an upper limit of 10%) However,

$$\xi^{1/2} = 7.9 \times 10^{15} \text{GeV}$$

Non-minimal Supergravity

We consider the Kähler potential of the form:

$$K = |S|^2 + |\Phi_+|^2 + |\Phi_-|^2 + f_+(\frac{|S|^2}{M_P^2})|\Phi_+|^2 + f_-(\frac{|S|^2}{M_P^2})|\Phi_-|^2 + b\frac{|S|^4}{M_P^2}$$

where

$$f_\pm(\frac{|S|^2}{M_P^2}) = c_\pm \frac{|S|^2}{M_P^2} = \frac{c_\pm s^2}{2}.$$

D-term Inflation

The effective scalar potential for the D-term inflationary model reads

$$V_{eff}(|S|) = \frac{g^2\xi^2}{2}\left\{1 + \frac{g^2}{16\pi^2}\left[2\ln(z\frac{g^2\xi}{\Lambda^2}) + f_V(z)\right]\right\}.$$

where

$$f_V(z) = (z+1)^2\ln(1+\frac{1}{z}) + (z-1)^2\ln(1-\frac{1}{z})$$

and

$$z \equiv \frac{\lambda^2 s^2}{2g^2\xi} exp(\frac{s^2}{2} + b\frac{s^4}{4})\frac{1}{(1+f_+)(1+f_-)}$$

right-handed sneutrino correction

$$W_\nu = \lambda_\nu \Phi H_u L + \frac{m_\Phi}{2}\Phi^2$$

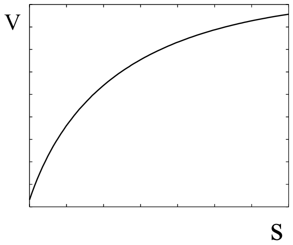
$$K = S^\dagger S + \Phi^\dagger \Phi + \frac{c S^\dagger S \Phi^\dagger \Phi}{M^2}$$

$$\Delta V = -\frac{\kappa |S|^2}{2} + \frac{M_\phi^2 \phi^2}{2},$$

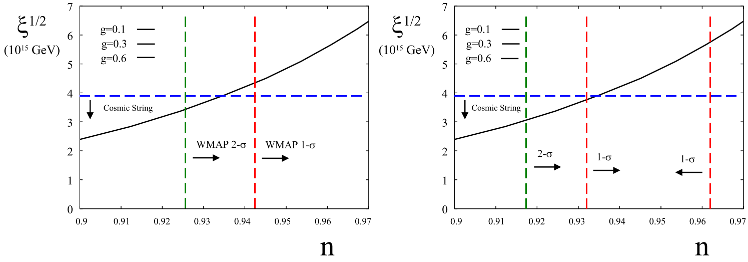
where we have defined κ by

$$\kappa \equiv \frac{(c-1)M_\phi^2 |\phi|^2}{M^2}.$$

results

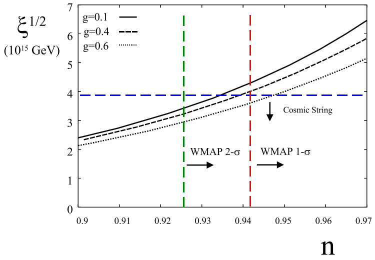


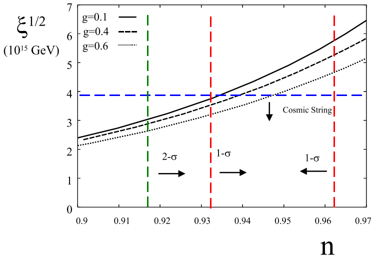
results


$\xi^{1/2}$
(10^{15} GeV)
g=0.1
g=0.3
g=0.6
Cosmic String
WMAP 2-σ
WMAP 1-σ
n
$\xi^{1/2}$
(10^{15} GeV)
g=0.1
g=0.3
g=0.6
Cosmic String
2-σ
1-σ
1-σ
n

results

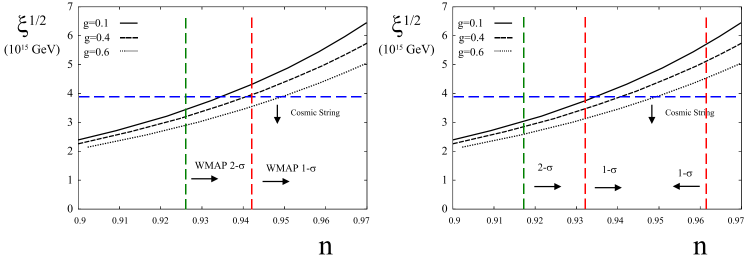
$$c_+ = c_- = 3.0$$





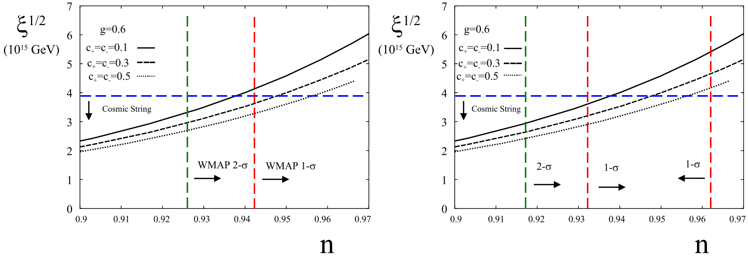
results

$c_+ = 2.0,\ c_- = 5.0$

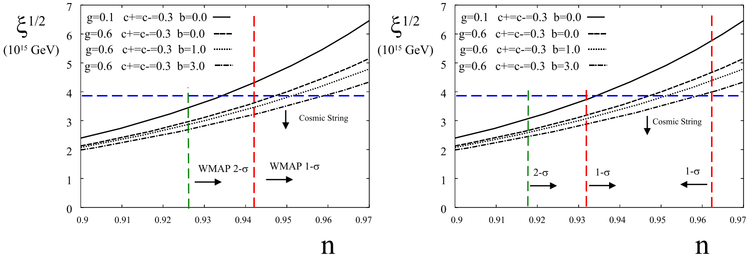


results

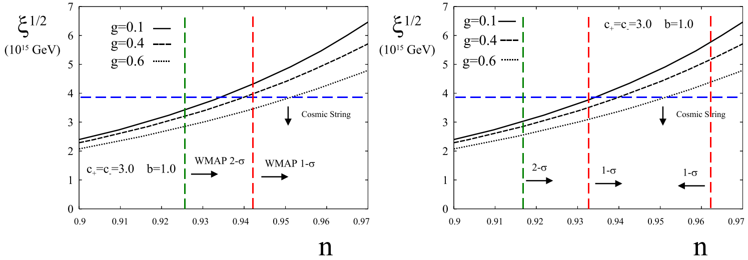
$g = 0.6$


ξ1/2
(10^15 GeV)
g=0.6
c+=c-=0.1
c+=c-=0.3
c+=c-=0.5
Cosmic String
WMAP 2-σ
WMAP 1-σ
n
ξ1/2
(10^15 GeV)
g=0.6
c+=c-=0.1
c+=c-=0.3
c+=c-=0.5
Cosmic String
2-σ
1-σ
1-σ
n

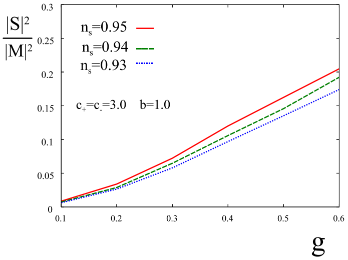
results

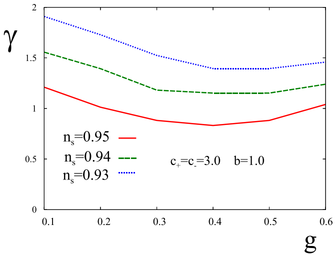

ξ 1/2
(10¹⁵ GeV)
g=0.1 c+=c-=0.3 b=0.0
g=0.6 c+=c-=0.3 b=0.0
g=0.6 c+=c-=0.3 b=1.0
g=0.6 c+=c-=0.3 b=3.0
Cosmic String
WMAP 2-σ
WMAP 1-σ
n
ξ 1/2
(10¹⁵ GeV)
g=0.1 c+=c-=0.3 b=0.0
g=0.6 c+=c-=0.3 b=0.0
g=0.6 c+=c-=0.3 b=1.0
g=0.6 c+=c-=0.3 b=3.0
Cosmic String
2-σ
1-σ
1-σ
n

results

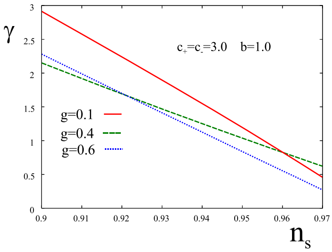

$\xi^{1/2}$
(10^{15} GeV)
g=0.1
g=0.4
g=0.6
WMAP 2-σ
WMAP 1-σ
Cosmic String
$c_+ = c_- = 3.0$ b=1.0
2-σ
1-σ
1-σ
n

results


|S|²
|M|²
0.3
0.25
0.2
0.15
0.1
0.05
0
0.1
0.2
0.3
0.4
0.5
0.6
g
n_s=0.95
n_s=0.94
n_s=0.93
c_+=c_-=3.0 b=1.0


γ
2
1.5
1
0.5
0
0.1
0.2
0.3
0.4
0.5
0.6
g
n_s=0.95
n_s=0.94
n_s=0.93
c_+=c_-=3.0 b=1.0

results


γ
c+=c-=3.0 b=1.0
g=0.1
g=0.4
g=0.6
0
0.5
1
1.5
2
2.5
3
0.9
0.91
0.92
0.93
0.94
0.95
0.96
0.97
ns