Inflation in Gauge Mediation

Manabu Sakai
(Particle Physics Group)

Y. Nakai and M. S, Prog. Theor. Phys. 125 (2011) 395.
K. Kamada, Y. Nakai and M. S, arXiv:1103. 5097 [hep-ph].

YITP lunch seminar 7/13/2011

Cosmological Inflation

is now considered as a part of “standard” cosmology.

can solve many cosmological ploblems.
(the horizon, flatness, monopole problems)

accounts for the origin of the primordial fluctuations.

requires a scalar field with very flat potential.

How inflation is embedded in a particle physics model?

⇨ Supersymmetry

Supersymmetry

suppresses the radiative corrections for a scalar field.

⇨ Inflaton potential can be naturally flattened.

However…

Supersymmetry must be broken!

SUSY breaking

Hidden sector → SSM sector

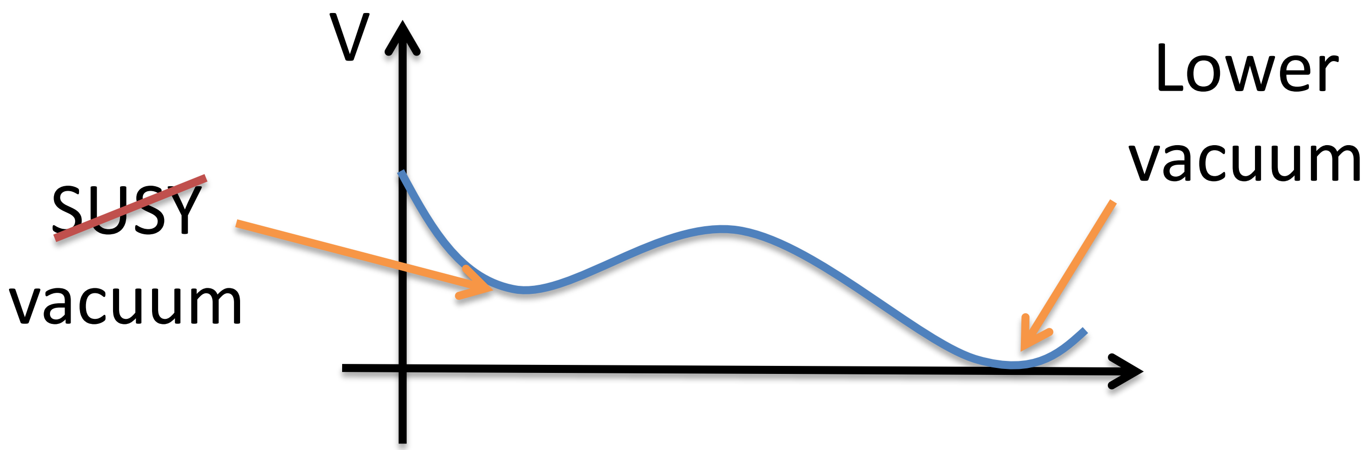
Direct gauge mediation

Flavor symmetry → SM gauge symmetries

Dark matter candidate is gravitino.

To obtain same order gaugino and soft scalar masses,
lower energy vacuum is required.

Vacuum structure



Vacuum stability

⇨ Two hierarchical mass scales

$$m \gg \mu$$

The inflationary scale (→ m)

The SUSY breaking scale (→ μ)

Model

	$SU(N)$	$U(1)_1$	$U(1)_2$	$U(1)_R$
χ	$\mathbf{1}$	1	0	0
$\bar{\chi}$	$\mathbf{1}$	-1	0	0
ρ	$\Box$	0	1	0
$\bar{\rho}$	$\bar{\Box}$	0	-1	0
Z	$\Box$	-1	1	2
$\bar{Z}$	$\bar{\Box}$	1	-1	2
Y	$\mathbf{1}$	0	0	2
Φ	$\mathbf{1}$	0	0	2

$$W = m^2 Y + \mu^2 \Phi - h_{\rm Y} \chi Y \bar{\chi} - h_{\Phi} \rho \Phi \bar{\rho} - h_{\rm Z}(\chi Z \bar{\rho} + \rho \bar{Z} \bar{\chi}) - m_{\rm Z} Z \bar{Z}$$

$$m \gg \mu$$

Inflaton

Moduli field

$SU(N)$ Flavor symmetry → SM gauge symmetry

Cosmic history

Inflation

Hybrid inflation occur in the SUSY breaking sector.

↓

Reheating

Inflaton and waterfall fields decay into gaugino pair.

$$T_{\rm R} \simeq 10^{10}\,{\rm GeV}$$

Gravitino is over produced in the thermal bath!

$$\frac{\rho_{3/2}^{\rm (th)}}{s} \simeq 9.5 \times 10^{-8}\,{\rm GeV}$$

Cosmic history

Moduli oscillation

Moduli oscillates and dominates the energy density!

The lifetime is rather long

It decays before the BBN.

⇒ Gravitino is diluted by the entropy production!

Gravitino is also produced by moduli decay.

Summary

Inflation in the SUSY breaking sector

Gravitino is over produced in the thermal bath.

diluted by moduli field

⇒ consistent dark matter abundance

The model parameters are severely constrained.

Our model is testable in the near future.

Cosmological perturbation

COBE/WMAP normalization, $\mathcal{P}_{\mathcal{R}}^{1/2} \simeq 4.9 \times 10^{-5}$

$$\Rightarrow \quad \frac{m}{h_{\rm Y}^{1/2}} \simeq 5.9 \times 10^{15}{\rm GeV} \times \begin{cases} \left(\dfrac{h_Y}{3\times 10^{-3}}\right)^{1/3} & \text{for} \quad h_Y < 3\times 10^{-3} \\ \left(\dfrac{\mathcal{N}_{\rm COBE}}{51}\right)^{-1/4} & \text{for} \quad h_Y > 3\times 10^{-3} \end{cases}$$

Spectral tilt :

$$n_s = 1 - 6\epsilon + 2\eta \simeq \begin{cases} 1 - \dfrac{h_Y^3 M_{\rm pl}^2}{2\pi^2 m^2} \simeq 1 & \text{for} \quad h_Y < 3\times 10^{-3} \\ 1 - \dfrac{1}{\mathcal{N}_{\rm COBE}} \simeq 0.98, & \text{for} \quad h_Y > 3\times 10^{-3} \end{cases}$$

Scalar-to-tensor ratio :

$$r = 16\epsilon \simeq \begin{cases} \dfrac{h_{\rm Y}^{10/3}}{16\pi^4}\left(\dfrac{h_{\rm Y}^{5/6} M_{\rm pl}}{m}\right)^2 & \text{for} \quad h_Y < 3\times 10^{-3} \\ \dfrac{h_{\rm Y}^2}{2\pi^2}\dfrac{1}{\mathcal{N}_{\rm COBE}} & \text{for} \quad h_Y > 3\times 10^{-3} \end{cases}$$

Model parameters

$$h_\Phi \simeq 0.036 \times \frac{1}{\sqrt{N}} \left(\frac{r_{\rm g}}{3.5}\right) \left(\frac{m_\Phi}{300\,{\rm GeV}}\right) \left(\frac{m_{\tilde g}}{1.5\,{\rm TeV}}\right)^{-1}$$

$$h_{\rm Z} \simeq 1.8 \times 10^{-3} \times \frac{1}{\sqrt{N}} \left(\frac{r_{\rm g}}{3.5}\right)^2 \left(\frac{m_{3/2}}{15\,{\rm GeV}}\right) \left(\frac{m_\Phi}{300\,{\rm GeV}}\right) \left(\frac{m_{\tilde g}}{1.5\,{\rm TeV}}\right)^{-2} \left(\frac{h_Y}{3 \times 10^{-3}}\right)^{-1/3}$$

$$h_{\rm Y} \simeq 2.2 \times 10^{-3} \times \frac{1}{N^{21/34}} \times \left(\frac{r_{\rm g}}{3.5}\right)^{18/17} \left(\frac{m_{3/2}}{15\,{\rm GeV}}\right)^{9/17} \left(\frac{m_\Phi}{300\,{\rm GeV}}\right)^{21/34} \left(\frac{m_{\tilde g}}{1.5\,{\rm TeV}}\right)^{-18/17}$$

$$\mu \simeq 7.9 \times 10^9\,{\rm GeV} \times \left(\frac{m_{3/2}}{15\,{\rm GeV}}\right)^{1/2}$$

$$\frac{m}{h_{\rm Y}^{1/2}} \simeq 5.9 \times 10^{15}{\rm GeV} \times \begin{cases} \left(\frac{h_Y}{3 \times 10^{-3}}\right)^{1/3} & \text{for} \quad h_Y < 3 \times 10^{-3} \\ \left(\frac{\mathcal{N}_{\rm COBE}}{51}\right)^{-1/4} & \text{for} \quad h_Y > 3 \times 10^{-3} \end{cases}$$

$$m_{\rm Z} \simeq 8.2 \times 10^{12}\,{\rm GeV} \times \frac{1}{\sqrt{N}} \left(\frac{r_{\rm g}}{3.5}\right)^3 \left(\frac{m_{3/2}}{15\,{\rm GeV}}\right) \left(\frac{m_\Phi}{300\,{\rm GeV}}\right) \left(\frac{m_{\tilde g}}{1.5\,{\rm TeV}}\right)^{-2}$$