Can Inflation Induce Supersymmetry breaking in a Metastable vacuum?

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Introduction

Metastable Supersymmetry Breaking: ISS Model

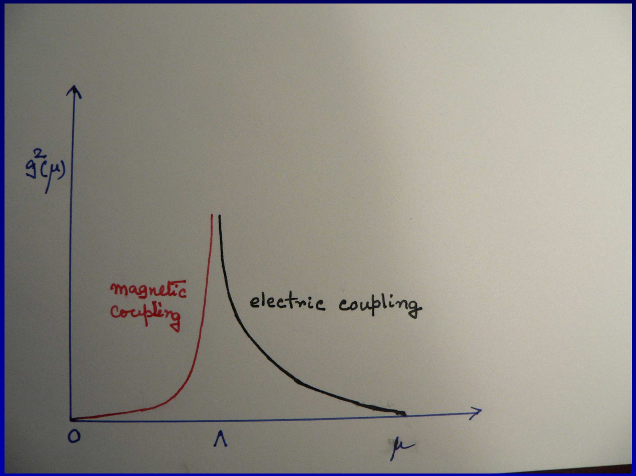
(An Overview)

It permits a SUSY vacuum along with the existence of a long-lived supersymmetry breaking vacuum; we are in this non-SUSY minimum which is the metastable one.

- Start with SU(N_c) SQCD with N_f flavors of massive quarks.

Microscopic (Electric) :

W = m Tr$Q\tilde{Q}$



	$SU(N_c)$
Q	N_c
$\tilde{Q}$	$\bar{N}_c$

For $N_c + 1 \leq N_f \leq \frac{3}{2} N_c$;

Macroscopic (Magnetic):

W = Tr $q \Phi \tilde{q}$ – μ^2 TrΦ + W$_{dyn}$

$q, \tilde{q} \longrightarrow$ magnetic quarks;

$\Phi = \frac{Q\tilde{Q}}{\Lambda} \longrightarrow$

Singlet made of mesons.

(Λ - strong coupling scale of the th.)

	$SU(N); \;\; N = N_f - N_C$
q	N
$\tilde{q}$	$\bar{N}$
Φ	1

- The local Non-SUSY Vacuum:
$\langle\Phi\rangle = 0; \langle q\rangle = \langle\tilde{q}^T\rangle = (\mu \mathrm{I}_{N_f - N_c}, 0)$.

- The SUSY minimum is obtained while incorporating the non-perturbative term,

$$W_{dyn} = N \left(\frac{det\Phi}{\Lambda^{N_f - 3N}} \right)^{\frac{1}{N}},$$

at $\Phi_0 = \langle\Phi\rangle = \mu[\frac{\Lambda}{\mu}]^{\frac{N_f - 3N}{N_c}}, \ \langle q\rangle = \langle\tilde{q}\rangle = 0.$

- By choosing $\mu \ll \Phi_0 < \Lambda$, it is possible to ensure the metastability of the non-susy minimum.

Motivation

- Note two points:

  a) μ is set by hand
  b) why the universe should be in the non-SUSY minimum?

- We want to answer both these questions in a single framework.

Set Up

- Assume two separate sectors:
  (a) Inflationary sector :
  (described by Supersymmetric Hybrid Inflation)

$$W_{\text{Inf}} = kS(\chi^2 - M_{\text{Inf}}^2),$$

  and
  (b) ISS sector with massless electric quarks.
- These two sectors are connected only through gravity,

$$W_{int} = \frac{g}{M_P}\chi^2 \text{Tr} Q\tilde{Q},$$

(Note that the interaction term respects R-symmetry.)

- At the end of inflation, the waterfall field χ gets a vev $\sim M_{\text{Inf}}$, that develops the mass term for quarks, producing

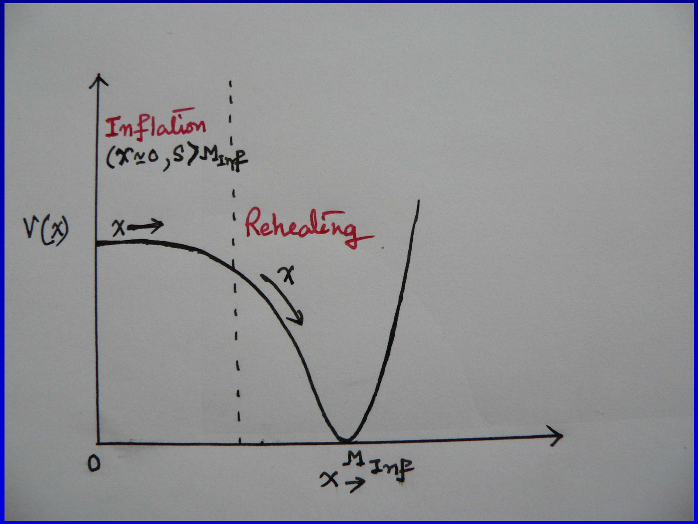
$$\mu^2 = \frac{\Lambda}{M_P} M_{\text{Inf}}^2.$$

- To discuss (b) we need to understand the inflationary dynamics in brief.

Inflation

$$V = k^2|\chi^2 - M_{\rm Inf}^2|^2 + 4|\chi|^2(k^2|S|^2 + |Q\tilde{Q}|^2/M_P^2)$$

- $S > M_{\rm Inf}$, and $\chi = 0 \rightarrow$
  Inflation with Vac. Energy $\sim k^2 M_{\rm Inf}^4$
- SUSY Minimum: $\langle S \rangle = 0;\ \langle \chi \rangle = M_{\rm Inf}$



- Slow roll :
  The inclination over the inflationary valley is provided by the Coleman-Weinberg correction to the scalar potential

- Estimate of $\frac{\delta T}{T} \sim 10^{-5}$, spectral index n_s in the right range:
  set $\sqrt{k} M_{Inf} \simeq (10^{13} - 10^{15})$ GeV

- End of Inflation:
  when $S_c > M_{\mathrm{Inf}}$, the mass term of χ becomes negative, and the system ends up in the supersymmetric minimum.

- Once $\chi \neq 0$,
  W_{int} would generate a dynamical mass term for quarks,
  $m_Q = g\langle\chi\rangle^2/M_P \ll \Lambda$
- Then at this stage the ISS sector can be described by

$$W_{\rm ISS} = \Phi q\tilde{q} - m_Q \Lambda Tr\Phi + W_{dyn},$$

  (in the IR magnetic phase)

- It consists of metastable supersymmetry breaking vacua at
  $\langle q\rangle = \langle\tilde{q}^T\rangle = \mu = \sqrt{m_Q\Lambda}$, and $\langle\Phi\rangle = 0$.
- SUSY minimum:
  $\langle q\rangle = \langle\tilde{q}^T\rangle = 0;\ \langle\Phi\rangle = \mu(\chi)\left(\frac{\mu}{\Lambda}^{\frac{N_f-3N}{N_c}}\right)^{-1}\mathbb{I}_{N_f}$

Why we should be at the metastable vacuum?

- During Inflation:
  $Q, \tilde{Q}$ acquire positive mass square terms $\sim H^2$
  $(H^2 = k^2 M_{\rm Inf}^4 / 3M_P^2)$ from supergravity corrections,
  and thereby they settle at the origin.
  (assuming canonical Kahler potential)
- After Inflation:
  As $Q = \tilde{Q} = 0$ happens to coincide with the location of the false minimum ($\Phi = 0$), it is possible that the field remains stranded there even after inflation is over. Thus provides a natural solution to (b).
- Ensure Metastability:
  $$S_{bounce} = \frac{2\pi^2}{3} \frac{N^3}{N_f^2} \left(\frac{\langle \Phi \rangle}{\mu} \right)^4 \simeq \frac{1}{(\frac{\mu}{\Lambda})^{4(N_f - 3N)/(N_f - N)}} \gg 1,$$
  for $\mu \ll \Lambda$.

- Possible constraints over mass scales μ, Λ:
  (1) metastability condition:
  $\mu \ll \Lambda$ to preserve the ISS vacuum,
  (2) supersymmetry mediation condition:
  $m_{\rm susy} M_P \simeq F_{sugra} \geq F_{ISS} = \mu^2$.
- $k = O(10^{-2}), g = O(10^{-1} - 10^{-2}), \mu = O(10^{12}\ \text{GeV})$ and $\Lambda = O(10^{14}\ \text{GeV})$.
- Reheating:
  After Inflation, inf system falls toward the minimum at $\chi = M_{\rm Inf}$ and performs damped oscillation about it; can decay through a possible term $f_{ij}\chi^2 N_i N_j / M_P$, where N_i are neutrino superfields with $T_{\rm Rh} \sim 10^9$ GeV.

Conclusions

- Natural solution to (a) and (b).
- The susy breaking scale is related to the inflationary scale and for SHI it is in the range of gravity mediation.
- Future Directions: problem with R-symmetry breaking, whether other possible mediation mechanism, e.g. gauge mediation can be adapted to the scenario.