Neutrino mass & proton decay in an R-symmetric model

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1. Motivation

☆Why SUSY NOT discovered yet?

Heavy SUSY ? Or Extension of MSSM ?

We focus on $U(1)_R$ symmetric extension from MSSM,

- Dirac gaugino
  - → Suppressed production rate. (Kribs & Martin, 2012)
- Extended Higgs sector (with vis. SUSY br.)

2. Model

$$\mathcal{L} = \left(\int d^2\theta \, [W_{\rm Higgs} \cdots]\right) + m_{3/2} G_{\rm R\text{-}bre.} - V_{\rm soft\ SUSY\text{-}bre.}$$

R-symmetric higgs sector

$$W_{\rm Higgs} = X_0 \left(f + \lambda H_u H_d\right) + \mu_1 X_u H_u + \mu_2 X_d H_d$$

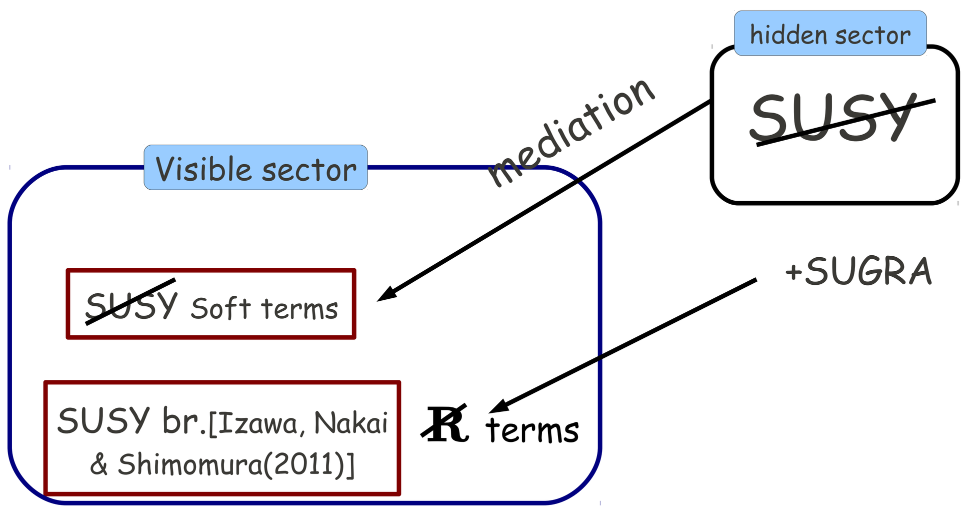
$$m_{3/2} G_{\rm Rbre.} = m_{3/2} \left(2 f X_0 + \mu_1 X_u H_u + \mu_2 X_d H_d\right)$$

R-breaking term

f : visible SUSY br. scale
μ_1, μ_2 : Higgsino mass

	$SU(2)_L$	$U(1)_Y$	$U(1)_R$
X_0	1	0	2
X_u	2	$-1/2$	2
X_d	2	$1/2$	2
H_u	2	$1/2$	0
H_d	2	$-1/2$	0

- SUSY is broken in visible sector and hidden sector
- LSP is the pseudo Goldstino
- SUSY breaking in visible sector is the origin of EW breaking
- R symmetry need to be broken after tuning cosmological const.



In this work, we discuss R breaking effects;

1) Neutrino mass,
2) Proton decay constraint.

4. Neutrino mass

	$SU(2)_L$	$U(1)_Y$	$U(1)_R$
X_d	2	$1/2$	2
L	2	$-1/2$	1
N	1	1	-1

$$\mathcal{L} = \left(\int d^2\theta y_\nu N X_d L\right)$$

$$+\{\mu_2 m_{3/2} \langle H_d \rangle\} X_d - \{\mu_2^2 + m_{X_d}^2\} |X_d|^2$$

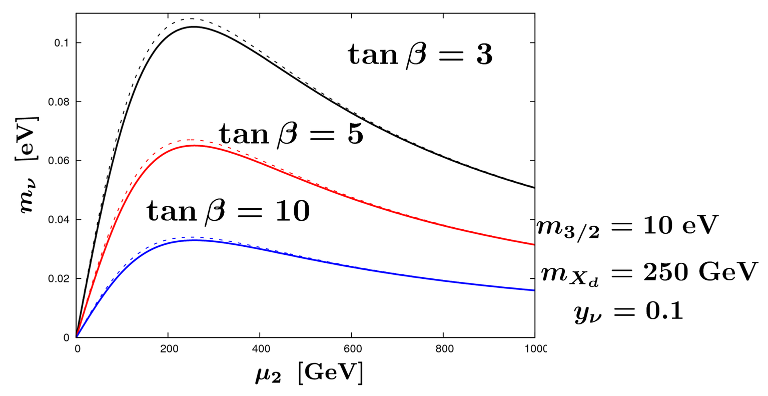
N : R-handed neutrino
L : Lepton doublet
X_d : R-charged Higgs

Neutrino is massless in R symmetric limit → (Minimal R br.) → R-charged higgs gets VEV from R br. term → Neutrino mass Generation !

If gravitino mass is small,
Neutrino mass with large Yukawa is generated !

$$m_\nu = y_\nu m_{3/2} \left(\frac{v \mu_d \cos\beta}{\mu_2^2 + m_{X_d}^2}\right)$$

$$= 0.1\ eV \times \left(\frac{m_{3/2}}{10\ {\rm eV}}\right)\left(\frac{y_\nu}{0.1}\right)\left(\frac{\mu_2^2 + m_{X_d}^2}{(320\ {\rm GeV})^2}\right)$$



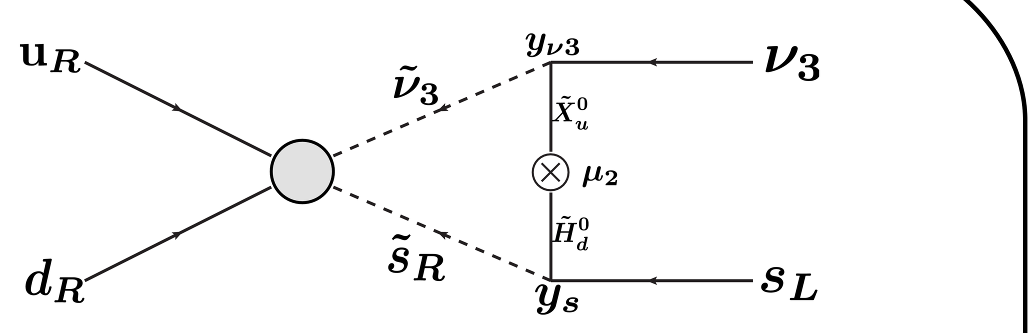
5. Proton decay

R-symmetry prohibits:

$$\frac{(QQ)(QL)}{\Lambda_{\rm cut\text{-}off}} \qquad \frac{U^c U^c D^c E^c}{\Lambda_{\rm cut\text{-}off}}$$

Our R-symmetry allows:

$$\frac{U^c D^c D^c N}{\Lambda_{\rm cut\text{-}off}}$$

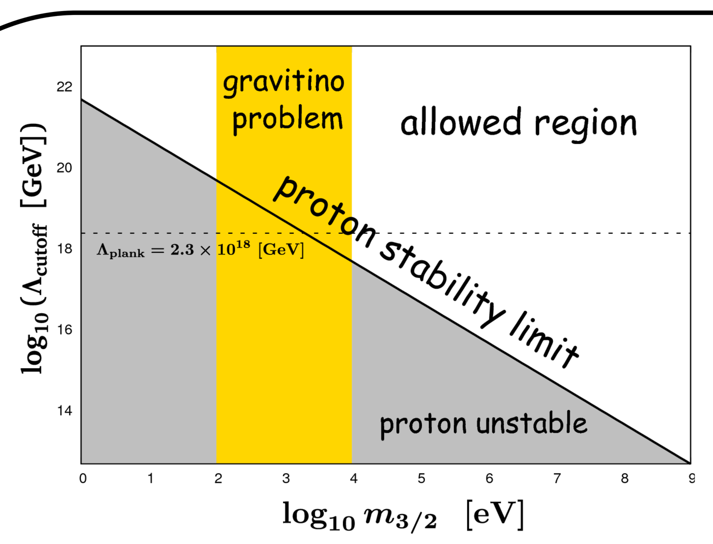


$$\tau \approx \frac{2^{13}\pi^5 \Lambda_{\rm cut\text{-}off}^2 v^2 m_{2/3}^2}{y_{D32}^2 m_p m_\nu^2} \left(\frac{f_\pi}{\alpha_p}\right)^2 \left(\frac{m_p^2}{m_p^2 - m_{K+}^2}\right)^2 \geq 2.3 \times 10^{33} {\rm yr.}$$

→ $m_{3/2} > 1$ keV

- R(N)=-1 allows Lepton, baryon number violating operator.
- Constraint is milder than MSSM
- Large yukawa, or light gravitino may induce proton decay for $m_{3/2} < 1$ keV

5. proton decay & cosmological constraint



- Naively, gravitino of order KeV or smaller is excluded by proton decay constraint
- Cosmology disfavors gravitino in the range: $100\ {\rm eV} < m_{3/2} < 10\ {\rm keV}$

Gravitino mass should be $m_{3/2} < 100$ eV
or $10\ {\rm keV} < m_{3/2} < 100\ {\rm MeV}$

If we have $m_{3/2} < 100$ eV

- Neutrino with order 1 yukawa
- Proton unstable → Flavor symmetry ?
- Gravitino is a warm dark matter ?

If we have $10\ {\rm keV} < m_{3/2}$

- Neutrino yukawa comparable to electron yukawa for $m_{2/3} \approx {\rm MeV}$
- Proton is stable enough
- Gravitino dark matter

6. Summary & Discussion

Summary

We discussed SUGRA R-breaking effect of R-symmetric model with visible SUSY breaking;

- Dirac neutrino mass with large yukawa can be generated if gravitino is light
- Proton decay may occur through R-handed neutrino if gravitino is lighter than 1 keV

Discussion

- Higgs mass (125 GeV ?)
- Constraint from diffused gamma ?
- Light gravitino with flavor symmetry ?
- Dark matter ?