Leptogenesis of Supersymmetric B-L gauge theory

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K. Babu, YM, U. Sarkar & Z. Tavartkiladze, *upcomming.*

Motivation

- B-L gauge theory naturally introduce right handed neutrinos and their masses
- Maintain R-parity in SUSY
- Allows new ways of leptogenesis
- No gravitino problem

Outline

- Introduction
  - Baryon asymmetry in the universe
  - Sakharov conditions in leptogenesis scenario
- New ways of leptogenesis with Gauged B-L symmetry through Higgs field decay $\Delta \longrightarrow \tilde{N}\tilde{N}$.
  - Soft leptogenesis
  - Leptogenesis in SUSY limit
- Conclusion

Introduction of baryon asymmetry

WMAP result of primordial abundance of Deuterium.

$$\frac{n_B - n_{\bar{B}}}{n_\gamma} \simeq (6.1 \pm 0.3) \cdot 10^{-10}$$

Assuming matter anti-matter symmetry at temperature to $\mathcal{O}(1\ \mathrm{GeV})$:

$$\frac{n_B}{n_\gamma} = \frac{n_{\bar{B}}}{n_\gamma} \simeq 10^{-18}$$

→ Dynamic baryon generation

Sakharov Conditions in leptogenesis scenario

- Baryon number violation:

  Electroweak sphalerons

- Out of equilibrium

  Universe expansion.

- C and CP violation

  Decays of right handed neutrinos or new fields

Leptogenesis with Gauged B-L symmetry

(K. S. Babu, Y M & Z. Tavartkiladze, *Phys. Lett. B681:37-43,2009*)

1. Naturally introducing RH neutrinos for each family
2. In SUSY, breaking (B-L) by even number, conserves R-parity: $R = (-1)^{3(B-L)+2S}$

Fields	e^c	L	(u^c, d^c)	Q	N	Δ_i	$\overline{\Delta}_i$	S
B-L charges	1	-1	-1/3	1/3	1	-2	2	0

All new fields are SM singlet. $\overline{\Delta}$, Δ are Higgs fields breaking B-L symmetry. Their decays generate lepton number asymmetry.

Only soft leptogenesis works with one pair Higgs fields, no leptogenesis in SUSY limit.

Leptogenesis in SUSY limit

Need at least two pairs of Δ $\overline{\Delta}$ fields coupling to N,

$$W_{(B-L)} = M_{ij}\bar{\Delta}_i\Delta_j + \lambda_{ij}\bar{\Delta}_i\Delta_j S + \frac{1}{2}\mu_S S^2 + \frac{1}{3}\kappa S^3 + \frac{1}{2}f^i_{\alpha\beta}\Delta_i N_\alpha N_\beta$$

B-L breaking condition in the SUSY limit

$$\begin{aligned} F_S &= \lambda_{ij}\bar{v}_i v_j + \mu_S s + \kappa s^2 = 0, \\ F_{\Delta_i} &= M_{ji}\bar{v}_j + \lambda_{ji}\bar{v}_j s = 0, \\ F_{\bar{\Delta}_i} &= M_{ij} v_j + \lambda_{ij} v_j s = 0, \end{aligned}$$

Effective superpotential

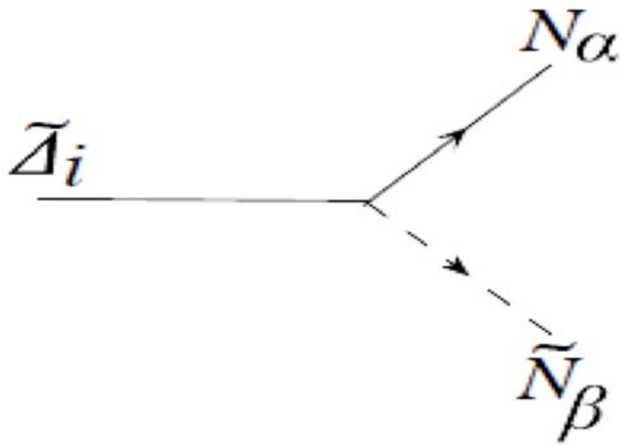
$$W_{\text{eff}}(\Delta_i, N_\alpha) = \frac{1}{2}\mu_i\Delta_i\Delta_i + \frac{1}{2}F^i_{\alpha\beta}\Delta_i N_\alpha N_\beta + \frac{1}{2}M_\alpha N_\alpha N_\alpha$$

New ways of leptogenesis

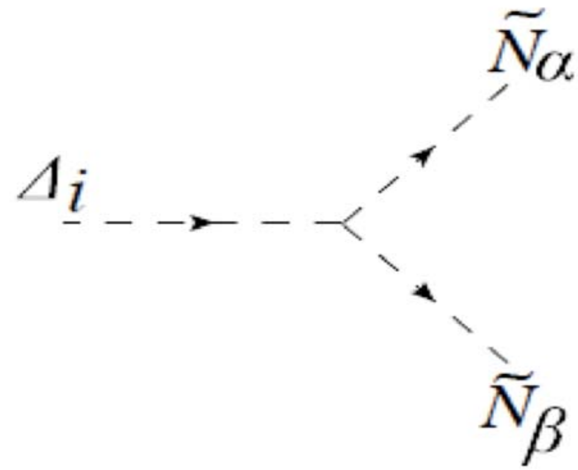
- CP violating decays of new Higgs particles to sneutrinos and antisneutrinos
- Sneutrinos decay into leptons and Higgs, generating lepton number asymmetry
- Electroweak sphalerons convert lepton asymmetry to baryon asymmetry

Decay modes of Higgs(inos)

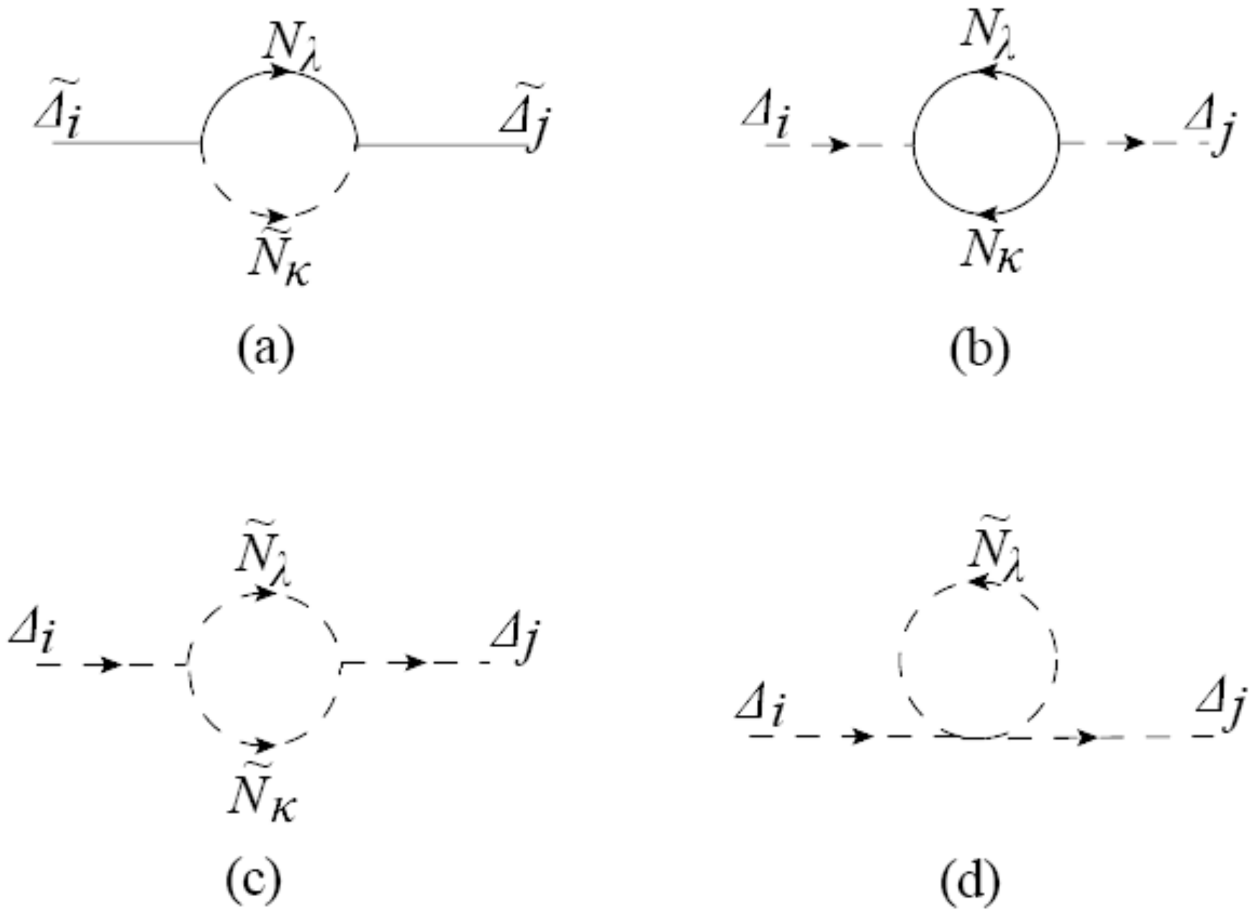
Fermionic decays



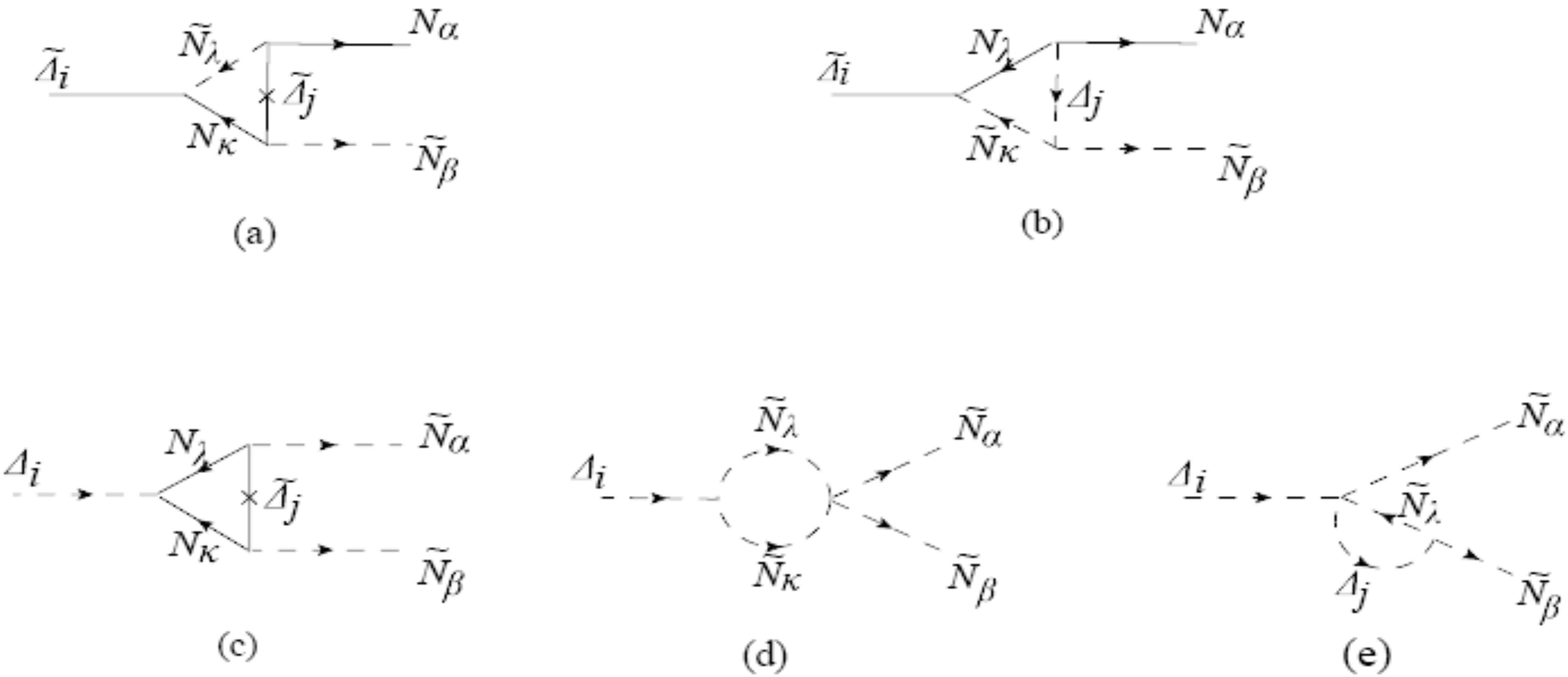
Bosonic decays



Self-energy corrections



Vertex corrections



Quadratic and log divergences cancel.

CP asymmetries

$$\epsilon_{\rm F}^{1} = \sum_{\alpha,\beta} \frac{|T^{\alpha\beta}_{\tilde{\Delta}_1}| - |\bar{T}^{\alpha\beta}_{\tilde{\Delta}_1}|}{|T^{\alpha\beta}_{\tilde{\Delta}_1}| + |\bar{T}^{\alpha\beta}_{\tilde{\Delta}_1}|} = -\sum_{j\neq 1} \frac{{\rm Im}\left({\rm tr}(F^{1\dagger}F^{j})^2\right)}{32\pi \cdot {\rm tr}(F^{1\dagger}F^{1})} \frac{\mu_1\mu_j}{\mu_1^2 - \mu_j^2}$$

$$\epsilon_{\rm B}^{1} = \sum_{\alpha,\beta} \frac{|T^{\alpha\beta}_{\Delta_1}| - |\bar{T}^{\alpha\beta}_{\Delta_1}|}{|T^{\alpha\beta}_{\Delta_1}| + |\bar{T}^{\alpha\beta}_{\Delta_1}|} = \sum_{j\neq 1} \frac{{\rm Im}\left({\rm tr}(F^{1\dagger}F^{j})^2\right)}{32\pi \cdot {\rm tr}(F^{1\dagger}F^{1})} \frac{\mu_1\mu_j}{\mu_1^2 - \mu_j^2}$$

$$\epsilon'^{1}_{\rm F} = \sum_{\alpha\beta} \frac{|T'^{\alpha\beta}_{\tilde{\Delta}_1}|^2 - |\bar{T}'^{\alpha\beta}_{\tilde{\Delta}_1}|^2}{|T'^{\alpha\beta}_{\tilde{\Delta}_1}|^2 + |\bar{T}'^{\alpha\beta}_{\tilde{\Delta}_1}|^2} = \sum_{i\neq 1} \frac{{\rm Im}\left({\rm tr}(F^{1\dagger}F^{j})^2\right)}{32\pi \cdot {\rm tr}(F^{1\dagger}F^{1})} \left[2 - \left(1 + 2\frac{\mu_j^2}{\mu_1^2}\right) \ln\left(1 + \frac{\mu_1^2}{\mu_j^2}\right)\right] \frac{\mu_j}{\mu_1}$$

$$\epsilon'^{1}_{\rm B} = \sum_{\alpha\beta} \frac{|T'^{\alpha\beta}_{\Delta_1}|^2 - |\bar{T}'^{\alpha\beta}_{\Delta_1}|^2}{|T'^{\alpha\beta}_{\Delta_1}|^2 + |\bar{T}'^{\alpha\beta}_{\Delta_1}|^2} = -\sum_{j\neq 1} \frac{{\rm Im}\left({\rm tr}(F^{1\dagger}F^{j})^2\right)}{32\pi \cdot {\rm tr}(F^{1\dagger}F^{1})} \ln\left(1 + \frac{\mu_1^2}{\mu_j^2}\right) \frac{\mu_j}{\mu_1}$$

Sample fit

$$\epsilon^1 = \epsilon^1_{\rm F} + 2\epsilon^1_{\rm B} + \epsilon'^1_{\rm F} + 2\epsilon'^1_{\rm B}$$

Choose

$$\lambda_{11} \sim \lambda_{22} \sim 10^{-3}, \; \lambda_{12} \sim \lambda_{21} \sim 10^{-1},$$
$$\kappa \sim 10^{-2} - 10^{-3}, \; M_1 \sim 10^4 \text{ GeV},$$
$$M_2 \sim 10^8 \text{ GeV}, \; \mu_s \sim 10^5 - 10^6 \text{ GeV}$$

Numerical result

We have

$$F^1_{\alpha\beta} \sim 10^{-4}, \;\; F^2_{\alpha\beta} \sim F^3_{\alpha\beta} \sim 10^{-1}$$

$$\mu_1 \sim 10^5 - 10^6 \text{ GeV}, \;\; \mu_2 \sim \mu_3 \sim 10^8 \text{ GeV}$$

$$\epsilon^1 \sim 10^{-5} - 10^{-6} \text{ for optimal Yukawa phases.}$$

With $\eta \sim 10^{-1} - 10^{-2}$,

$$\frac{n_B - n_{\bar{B}}}{s} \simeq -8.05 \cdot 10^{-4} \epsilon^1_{\tilde{N}} \eta$$

$\mu_1 < 10^8$ GeV. There is no gravitino problem.

Conclusion

- We outlined a new idea of leptogenesis.
- Leptogenesis works through CP violating decays of new Higgs fields to sneutrinos.
- Observed baryon asymmetry of the universe is realized in SUSY limit without inducing gravitino problem.