Non thermal CP violation in Soft Leptogenesis

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  2. At larger scales, if matter galaxies and anti-matter galaxies existed at same cluster then there would be huge amount of γ-ray emission from nucleon-anti nucleon annihilations.
- The observed baryon asymmetry must have been generated dynamically, a scenario that is known by the name of *Baryogenesis*.

The baryon asymmetry of the Universe can be defined in the following way.

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  2. It must either provide a departure from thermal equilibrium in addition to the electroweak phase transition (EWPT) or modify the EWPT itself.

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4. Leptogenesis

It generates the baryon asymmetry in the out-of-equilibrium decays of heavy bosons in GUT. The GUT baryogenesis has difficulties with the non-observation of proton decay, which puts a lower bound on the mass of the decaying boson, and therefore on the reheat temperature after inflation.

Its a class of models where the departure from thermal equilibrium is provided by the electroweak phase transitions. In principle, Standard Model belongs to this class, but the phase transition is not strongly first order and the CP violation is too small. Thus, viable models of electroweak baryogenesis need a modification of the scalar potential such that the nature of the EWPT changes, and new sources of CP violation.

The asymmetry arises in classical scalar field, which later decays to particles. In a SUSY model, this field could be some combination of squark, Higgs and slepton field. This field starts from a large expectation value then starts to roll down to the origin. While starting from large initial value and rolling down to origin, there can be contribution from baryons and leptons violating interactions. These impart a net asymmetry from the rolling field.

- After the discovery of neutrino oscillation, Leptogenesis gained much attention as one can explain the neutrino mass with matter anti-matter asymmetry in one single framework.

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- After the discovery of neutrino oscillation, Leptogenesis gained much attention as one can explain the neutrino mass with matter anti-matter asymmetry in one single framework.
- It was first proposed by Fukugita and Yanagida [1]. New particles-singlet neutrinos- are introduced via the see saw mechanism. Their couplings provide the necessary new source of CP violation. The rate of these Yukawa interactions can be slow enough that departure from thermal equilibrium occurs. Lepton number violation comes from the Majorana masses of these new particles.

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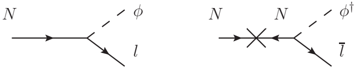

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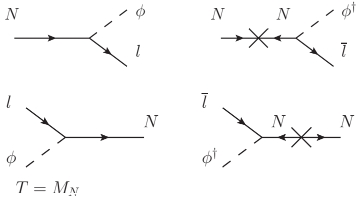
- Washout of lepton asymmetry



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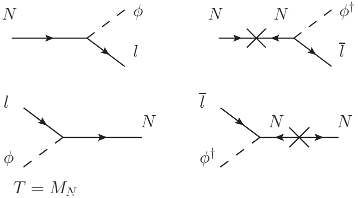

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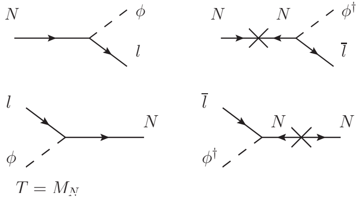

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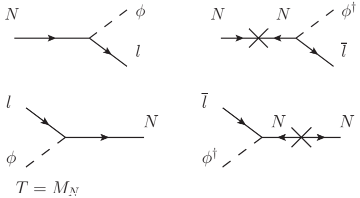

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- Lepton asymmetry is generated !!

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  - Transitions from one vacuum structure to another with a change of B and L by 3 units.
  - Energy barrier between two vacuum structures which is overcome through thermal excitations - **spheleron**

Boltzmann Equations

$$\frac{d\eta_\alpha^N}{dz} = -\left(\frac{\eta_\alpha^N}{\eta_{eq}^N} - 1\right)(D_\alpha + S_\alpha), \quad \frac{d\eta_l^{\Delta L}}{dz} = \sum_\alpha \epsilon_{l\alpha}\left(\frac{\eta_\alpha^N}{\eta_{eq}^N} - 1\right)\tilde{D}_\alpha - \frac{2}{3}\eta_l^{\Delta L} W_l$$

$$\eta_\alpha^N = n_\alpha^N/\eta_\gamma, \qquad \eta^{\Delta L} = n_l^{\Delta L}/n_\gamma, \qquad z = M_N/T, H_N = H(z=1)$$

$$\tilde{D}_\alpha = \frac{z}{\eta^\gamma H_N}\sum_k \tilde{\gamma}_{k\alpha}^D, \quad D_\alpha = \frac{z}{\eta^\gamma H_N}\sum_k \gamma_{k\alpha}^D, \quad S_\alpha = \frac{z}{\eta^\gamma H_N}\sum_k \gamma_{k\alpha}^S,$$

$$W_l = \frac{z}{\eta^\gamma H_N}\left[\sum_\alpha\left(B_{l\alpha}\sum_k \gamma_{k\alpha}^D + \tilde{\gamma}_{l\alpha}^S\right) + \sum_k\left(\gamma_{lk}^{(\Delta L=2)} + \gamma_{lk}^{(\Delta L=0)}\right)\right]$$

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- But a potential drawback of leptogenesis is the lower bound on M_N (mass of heavy Right handed neutrino), which gives a lower bound on reheat temperature which is $T_{reh} > 10^9$ GeV.
- This bound might be in conflict with an upper bound on the reheat that applies in supersymmetric models with a "gravitino problem".
- After inflation, the universe thermalizes to a reheat temperature T_{reheat}. Gravitinos are produced by thermal scattering in that bath, and the rate is higher at higher temperatures. The gravitinos are long-lived; if there are lighter SUSY particles (the gravitino is not the LSP), the decay rate can be estimated to be

$$\Gamma \sim \frac{m_{grav}^3}{m_{pl}^2} \simeq \left(\frac{m_{grav}}{20\text{TeV}}\right)^3 s^{-1}$$

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- One of the plausible solution is to have small reheating temperature $T_{reh} < 10^6 - 10^{10}$ GeV so that the gravitino density is small. Which is provided by "Soft Leptogenesis".

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- In the framework of the supersymmetric standard model extended to include singlet neutrinos (SSM+N), there are, in addition to the soft supersymmetry breaking terms of the SSM, terms that involve the singlet sneutrinos $\widetilde{N}$, in particular biliniear (B) and the trilinear (A) scalar couplings.

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The supersymmetric see-saw model is described by the superpotential

$$W = Y_{ij} N_i L_j H + \frac{1}{2} M_{ij} N_i N_j$$

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The supersymmetry-breaking terms involving the right handed sneutrino $\widetilde{N}_i$ are

$$-\mathcal{L}_{soft} = \widetilde{m}^2_{ij} \widetilde{N}^\dagger_i \widetilde{N}_j + \left(A_{ij} Y_{ij} \widetilde{N}_i \widetilde{l}_j H + \frac{1}{2} B_{ij} M_{ij} \widetilde{N}_i \widetilde{N}_j + \text{h.c} \right)$$

The right handed neutrino N has mass, while sneutrino and anti-sneutrino states mix in the mass matrix. Their mass eiganvectors

$$\widetilde{N}_+ = \frac{1}{\sqrt{2}}\left(e^{i\phi/2}\widetilde{N} + e^{-i\phi/2}\widetilde{N}^\dagger\right), \quad \widetilde{N}_- = -\frac{i}{\sqrt{2}}\left(e^{i\phi/2}\widetilde{N} - e^{-i\phi/2}\widetilde{N}^\dagger\right)$$

with $\phi = arg[BM]$, have mass eigenstate

$$M_\pm^2 = M^2 + \widetilde{M}^2 \pm |BM|$$

The sneutrino interaction Lagrangian in the basis of flavour $(\widetilde{N}, \widetilde{N}^\dagger)$ and the mass $(\widetilde{N}_+, \widetilde{N}_-)$ eigenstate is respectively

$$\begin{aligned} -\mathcal{L}_{int} &= \widetilde{N}\left(Y_{1i}\overline{\widetilde{H}}l_L^i + mY_{1i}^*\widetilde{l}_i^* H^* + AY_{1i}\widetilde{l}_i H\right) + \text{h.c} \\ &= \frac{Y_{1i}}{\sqrt{2}}\widetilde{N}_+\left(\overline{\widetilde{H}}l_L^i + (A+M)\widetilde{l}_i H\right) + i\frac{Y_{1i}}{\sqrt{2}}\left[\overline{\widetilde{H}}l_L^i + (A-M)\widetilde{l}_i H\right] \end{aligned}$$

The CP asymmetry is given as

$$\epsilon = \frac{4\Gamma B}{4B^2+\Gamma^2}\frac{\mathrm{Im}(A)}{M}\Delta_{BF} \qquad ;\Delta_{BF} = \frac{c_B - c_F}{c_B + c_F}$$

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The thermal parts c_B and c_F are due to the bose stimulation and pauli blocking respectively.
But the interesting part is that the diagrams which are considered while doing these calculation do not consider one condition due to which they missed out the non-thermal part...!!

It has been argued earlier[2] that to create a baryon asymmetry there should be net $\Delta B \neq 0$ violation to the right of the "cut" in the loop diagram.

[2] Rathin Adhikari and Raghavan Rangarajan. "Baryon number violation in particle decays". In: *Phys.Rev.* D65 (2002), p. 083504. DOI: 10.1103/PhysRevD.65.083504. arXiv: hep-ph/0110387 [hep-ph].

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$$\sum_{\overline{f}_{B_F}} |_{out}\langle \overline{f}|\overline{X}\rangle|^2 = \sum_{f_{B_F}} \sum_{g} \langle X|g\rangle_{out\ out}\langle g|f\rangle_{in} \langle X|f\rangle_{in}^*$$

$$\sum_{\overline{f}_{B_F}} |_{out}\langle \overline{f}|\overline{X}\rangle|^2 - \sum_{f_{B_F}} |_{out}\langle f|X\rangle|^2$$

$$= \sum_{f_{B_F}} \sum_{g \neq B_F} \left[\langle X|g\rangle_{out\ out}\langle g|f\rangle - \langle X|f\rangle_{out\ out}\langle f|g\rangle\langle g|X\rangle\right]$$

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$$\sum_{\overline{f}_{B_F}} |_{out}\langle \overline{f}|\overline{X}\rangle|^2 - \sum_{f_{B_F}} |_{out}\langle f|X\rangle|^2$$
$$= \sum_{f_{B_F}} \sum_{g \neq B_F} [A^*(X \to g)A(f \to g)A^*(f \to X)$$
$$- A^*(X \to f)A(g \to f)A^*(X \to g)]$$

For 2-body decay scenario, the difference term, i.e, the term on the right-hand side is 0 to $\mathcal{O}(\lambda^2)$, where λ is any coupling in the theory.

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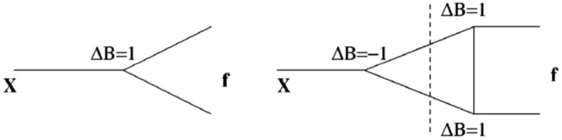
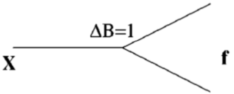
The requirement for an asymmetry is that there must exist diagrams such that the process to the right of the ”cut” should violate baryon number and the net asymmetry is then proportional to the amplitude associated with *these* diagrams.


X
ΔB=1
f
X
ΔB=−1
ΔB=1
ΔB=1
f


ΔB=1
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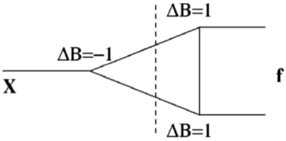
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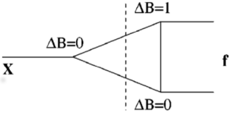
ΔB=1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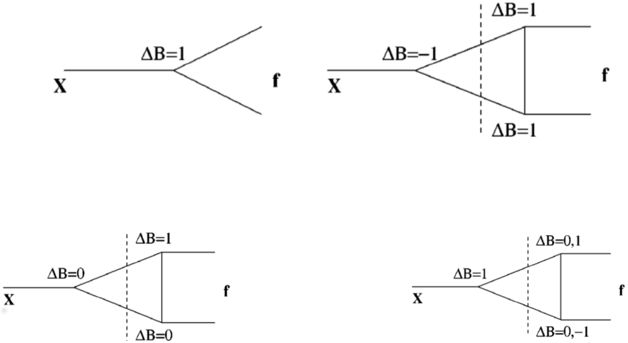
ΔB=1
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ΔB=0
X
f
ΔB=0
ΔB=0,1
ΔB=1
X
f
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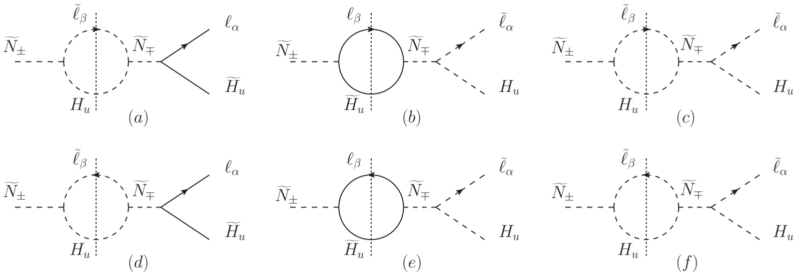
CP violation

To quantify the CP violation, we define the CP asymmetry for the decays $\widetilde{N}_\pm \to a_\alpha$ with $a_\alpha = \{\widetilde{\ell}_\alpha H_u, \ell_\alpha \widetilde{H}_u\}$ as

$$\epsilon^{S,V}_{\pm\alpha} \equiv \frac{\gamma(\widetilde{N}_\pm \to a_\alpha) - \gamma(\widetilde{N}_\pm \to \overline{a_\alpha})}{\sum_{a_\beta;\beta}\left[\gamma(\widetilde{N}_\pm \to a_\beta) + \gamma(\widetilde{N}_\pm \to \overline{a_\beta})\right]}, \qquad (1)$$

where the superscripts S and V indicate the CP violation coming from Self-energy (S) and Vertex (V) corrections respectively

We showed that the diagrams which can be achieved while incorporating the above condition in the context of Soft leptogenesis are



$$\epsilon^{S,(a)}_{\pm\alpha} = \frac{1}{4\pi G_{\pm}(T)} Y_\alpha^2 \sum_\beta Y_\beta \frac{\mathrm{Im}(A_\beta)}{M}\left(1+\frac{\widetilde{M}^2}{M^2}\pm\frac{B}{M}\right)\frac{2BM}{4B^2+\Gamma_{\mp}^2} r_B(T) c_F(T),$$

$$\epsilon^{S,(b)}_{\pm\alpha} = -\frac{1}{4\pi G_{\pm}(T)} Y^2 Y_\alpha \frac{\mathrm{Im}(A_\alpha)}{M}\left(1+\frac{\widetilde{M}^2}{M^2}\pm\frac{B}{M}\right)\frac{2BM}{4B^2+\Gamma_{\mp}^2} r_F(T) c_B(T),$$

$$\epsilon^{S,(c)}_{\pm\alpha} = \frac{1}{4\pi G_{\pm}(T)}\left[\left(Y^2-\sum_\beta\frac{|A_\beta|^2}{M^2}\right)Y_\alpha\frac{\mathrm{Im}(A_\alpha)}{M}-\left(Y_\alpha^2-\frac{|A_\alpha|^2}{M^2}\right)\sum_\beta Y_\beta\frac{\mathrm{Im}(A_\beta)}{M}\right] \times\frac{2BM}{4B^2+\Gamma_{\mp}^2} r_B(T) c_B(T),$$

where we define $Y^2 \equiv \sum_\alpha Y_\alpha^2$ and

$$G_{\pm}(T) \equiv \left[Y^2+\sum_\alpha\left(\frac{|A_\alpha|^2}{M^2}\pm\frac{2Y_\alpha \mathrm{Re}(A_\alpha)}{M}\right)\right]c_B(T)+Y^2\left(1+\frac{\widetilde{M}^2}{M^2}\pm\frac{B}{M}\right)c_F(T). \quad (2)$$

In the above $r_{B,F}(T)$ and $c_{B,F}(T)$ are temperature dependent terms associated with intermediate on-shell and final states respectively

If we sum over the lepton flavor α and use $r_F(T)c_B(T) = r_B(T)c_F(T)$, we obtain $\sum_\alpha \left(\epsilon_{\pm\alpha}^{S,(a)} + \epsilon_{\pm\alpha}^{S,(b)}\right) = \sum_\alpha \epsilon_{\pm\alpha}^{S,(c)} = 0$ in agreement with the $T = 0$ result of Adhikari *et. al.*[3]

[3] Rathin Adhikari and Raghavan Rangarajan. "Baryon number violation in particle decays". In: *Phys.Rev.* D65 (2002), p. 083504. DOI: 10.1103/PhysRevD.65.083504. arXiv: hep-ph/0110387 [hep-ph]

The total CP asymmetry from mixing $\epsilon^S_{\pm\alpha} \equiv \sum_{n=\{a,b,c,d,e,f\}} \epsilon^{S,(n)}_{\pm\alpha}$ is given by

$$\begin{aligned}\epsilon^S_{\pm\alpha} &= \frac{1}{4\pi G_\pm(T)} Y_\alpha^2 \sum_\beta Y_\beta \frac{\mathrm{Im}(A_\beta)}{M} \frac{4BM}{4B^2+\Gamma_\mp^2} \left[c_F(T) - c_B(T)\right] r_B(T) \\ &+ \frac{1}{4\pi G_\pm(T)} \frac{|A_\alpha|^2}{M^2} \sum_\beta Y_\beta \frac{\mathrm{Im}(A_\beta)}{M} \frac{4BM}{4B^2+\Gamma_\mp^2} r_B(T) c_B(T) \\ &+ \frac{1}{4\pi G_\pm(T)} Y_\alpha^2 \sum_\beta Y_\beta \frac{\mathrm{Im}(A_\beta)}{M} \left(\frac{\widetilde{M}^2}{M^2} \pm \frac{B}{M}\right) \frac{4BM}{4B^2+\Gamma_\mp^2} r_B(T) c_F(T).\end{aligned}$$

In the above, the first term vanishes in the zero temperature limit $T \to 0$ when $c_{B,F}(T) \to 1$ and $r_{B,F}(T) \to 1$ while the terms higher order in m_{SUSY}/M survive

Thermal limit

In the limit $Y_\alpha \gg A_\alpha/M$, we have

$$\epsilon^S_{\pm\alpha} \simeq \frac{1}{4\pi} P_\alpha \sum_\beta Y_\beta \frac{\mathrm{Im}(A_\beta)}{M} \frac{4BM}{4B^2+\Gamma_Y^2} \frac{c_F(T)-c_B(T)}{c_F(T)+c_B(T)} r_B(T),$$

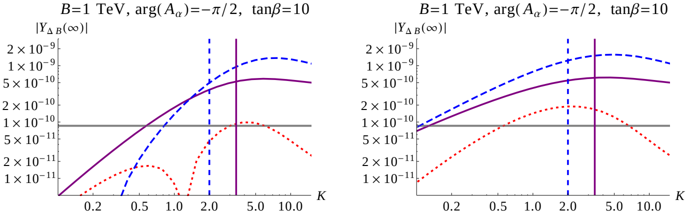
where we define the flavor projector $P_\alpha \equiv Y_\alpha^2/Y^2$ with $\sum_\alpha P_\alpha = 1$ and $\Gamma_Y \equiv \frac{Y^2 M}{4\pi}$ and we have dropped the terms higher order in m_{SUSY}/M. In this case, the CP asymmetry in the above equation is proportional to $c_F(T) - c_B(T)$ which goes to zero as $T \to 0$ and hence the contribution to the CP violation is the thermal one.

Non-Thermal limit

In the other limit $Y_\alpha \ll A_\alpha/M$, we have

$$\epsilon^S_{\pm\alpha} \quad \simeq \quad \frac{1}{4\pi}\frac{|A_\alpha|^2}{\sum_\delta |A_\delta|^2}\sum_\beta Y_\beta \frac{\mathrm{Im}(A_\beta)}{M}\frac{4BM}{4B^2+\Gamma_A^2} r_B(T),$$

where $\Gamma_A \equiv \sum_\alpha \frac{|A_\alpha|^2}{8\pi M}$. The CP asymmetries in the above equation clearly do not vanish at $T=0$ and this represents a *nonthermal* CP violation. Of course thermal effects are always there but the fact that the CP violation is nonvanishing at $T=0$ implies that it is less suppressed compared to the case thermal case.



In the above plot

Non Thermal Dominated (blue dashed) : In this scenario we choose $\mathbf{A}/M = (10^{-4}, 10^{-2}, 1)w$ and $\mathbf{Y} = (10^{-5}, 10^{-3}, 10^{-1})w$.

Thermal Dominated (red dashed) : In this scenario we choose $\mathbf{A}/M = (10^{-5}, 10^{-3}, 10^{-1})w$ and $\mathbf{Y} = (10^{-4}, 10^{-2}, 1)w$.

Mixed (purple solid) : In this scenario we choose $\mathbf{A}/M = (10^{-4}, 10^{-2}, 1)w$ and $\mathbf{Y} = (10^{-4}, 10^{-2}, 1)w$.

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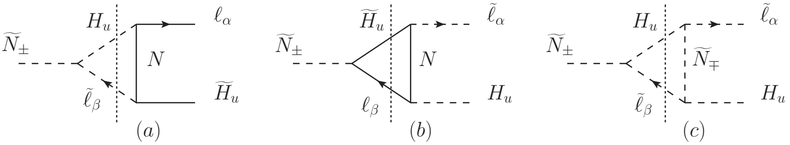
- That the generation of sufficient baryon asymmetry is possible for TeV scale A_α and $B \gg \Gamma_\pm$ i.e far away from resonant regime
- We also see that nonthermal CP violation can significantly enhance the efficiency of soft leptogenesis.


$\widetilde{N}_\pm$
H_u
$\tilde{\ell}_\beta$
N
ℓ_α
$\widetilde{H}_u$
(a)
$\widetilde{N}_\pm$
$\widetilde{H}_u$
ℓ_β
N
$\tilde{\ell}_\alpha$
H_u
(b)
$\widetilde{N}_\pm$
H_u
$\tilde{\ell}_\beta$
$\widetilde{N}_\mp$
$\tilde{\ell}_\alpha$
H_u
(c)

$$\begin{aligned}
\epsilon^{V}_{\pm\alpha} \quad = \quad & \mp\frac{\ln 2}{8\pi G_{\pm}(T)}\left[Y^2 Y_\alpha \frac{\mathrm{Im}(A_\alpha)}{M} + Y_\alpha^2 \sum_\beta Y_\beta \frac{\mathrm{Im}(A_\beta)}{M}\right]\left[c_F(T) - c_B(T)\right] r_B(T) \\
& - \frac{1}{8\pi G_{\pm}(T)}\left[Y^2 Y_\alpha \frac{\mathrm{Im}(A_\alpha)}{M} + Y_\alpha^2 \sum_\beta Y_\beta \frac{\mathrm{Im}(A_\beta)}{M}\right]\frac{B}{M}\left[\frac{c_F(T)}{2} + (\ln 2 - 1)c_B(T)\right] r_B(T) \\
& \mp \frac{\ln 2}{8\pi G_{\pm}(T)}\left[\sum_\beta \frac{|A_\beta|^2}{M^2} Y_\alpha \frac{\mathrm{Im}(A_\alpha)}{M} + \frac{|A_\alpha|^2}{M^2}\sum_\beta Y_\beta \frac{\mathrm{Im}(A_\beta)}{M}\right] r_B(T) c_B(T) \\
& + \frac{1}{8\pi G_{\pm}(T)}\left[\sum_\beta \frac{|A_\beta|^2}{M^2} Y_\alpha \frac{\mathrm{Im}(A_\alpha)}{M} + \frac{|A_\alpha|^2}{M^2}\sum_\beta Y_\beta \frac{\mathrm{Im}(A_\beta)}{M}\right]\frac{B}{M}(\ln 2 - 1) r_B(T) c_B(T).
\end{aligned}$$

We are primarily interested in the mass range $M > 10^7$ GeV.

We are primarily interested in the mass range $M > 10^7$ GeV. But even in $M_\pm \sim$ TeV, the bound on the Yukawa couplings from the requirement of out-of-equilibrium decays of $\widetilde{N}_\pm$

$$\Gamma_\pm \lesssim H(T = M)$$

$$\sqrt{\left[\sum_\alpha Y_\alpha^2 + \frac{|A_\alpha|^2}{2M^2} \pm \frac{Y_\alpha \mathrm{Re} A_\alpha}{M}\right]} \lesssim 1.6 \times 10^{-5} \left(\frac{M}{10^7 \mathrm{GeV}}\right)^{1/2}$$

which make $\widetilde{N}_\pm$ impossible to be produced at colliders.

Electric Dipole Moment

Assuming $\mathcal{O}(1)$ contributing of the phases and mixing angles in the chargino sectors

$$|d_e| \approx \frac{e m_e \tan\beta}{16\pi m_{\tilde{\nu}}^2} \left| \frac{m_\chi Y_\alpha}{M^2} \right| (|A_\alpha + BY_\alpha|)$$

Taking $m_{\tilde{\nu}} = m_\chi = m_{\mathrm{SUSY}}$ and making use of the out-of-equilibrium condition

$$|d_e| \lesssim 5 \times 10^{-38} \left(\frac{\tan\beta}{10} \right) \left(\frac{10^7 \mathrm{GeV}}{M} \right) \left(\frac{1\mathrm{TeV}}{m_{\mathrm{SUSY}}} \right) \mathrm{e-cm}$$

which is much stronger than the current experimental bound

$$|d_e|_{\mathrm{exp}} < 8.7 \times 10^{-29} \mathrm{e-cm}$$

For μ and τ EDM, m_e can be replaced by m_μ and m_τ but the current experimental bounds on them are a lot weaker

$$|d_\mu|_{\exp} < 1.9 \times 10^{-19}\mathrm{e-cm}$$
$$|d_\tau|_{\exp} < 5.1 \times 10^{-17}\mathrm{e-cm}$$

Charged Lepton Flavor Violation

The branching ratio due to non-vanishing off diagonal elements of the soft mass matrix of doublet slpeton $m^2_{\tilde{l}}$

$$\mathrm{BR}(l_\alpha \to l_\beta \gamma) \approx \frac{\alpha^3}{G_F^2} \frac{|(m^2_{\tilde{l}})_{\alpha\beta}|}{m^8_{\mathrm{SUSY}}} \tan^2\beta$$

$$(m^2_{\tilde{l}})_{\alpha\beta} \approx -\frac{1}{8\pi^2} A^*_\alpha A_\beta \ln\left(\frac{M_{GUT}}{M}\right)$$

for $\alpha \neq \beta$

The MEG experiment gives most stringent bound

$$\mathrm{BR}(\mu \to e\gamma)_{exp} < 5.7 \times 10^{-13}$$

$$|A_\mu^* A_e| \lesssim 5 \times 10^3 \mathrm{GeV}^2 \left(\frac{m_{\mathrm{SUSY}}}{1\mathrm{TeV}}\right)^4 \left(\frac{10}{\tan\beta}\right)$$

where $M_{\mathrm{GUT}} = 10^6$ GeV and $M = 10^7$ GeV.

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where $M_{\mathrm{GUT}} = 10^6$ GeV and $M = 10^7$ GeV.
Similarly using the experimental bounds on τ decays
$\mathrm{BR}(\tau \to e\gamma)_{\mathrm{exp}} < 3.3 \times 10^{-18}$ and $\mathrm{BR}(\tau \to \mu\gamma)_{\mathrm{exp}} < 4.4 \times 10^{-8}$

$$|A_\tau^* A_e| \approx |A_\tau^* A_\mu| \lesssim 1 \times 10^6 \mathrm{GeV}^2 \left(\frac{m_{\mathrm{SUSY}}}{1\mathrm{TeV}}\right)^4 \left(\frac{10}{\tan\beta}\right)$$

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Soft Leptogenesis is an interesting scenario in the framework of the supersymmetric seesaw for several reasons

1. The relevant new sources of CP violation and lepton number violation appear generically in this framework. In this sense, soft leptogenesis is qualitatively unavoidable in SSM+N framework, and the question of its relevance is a quantitative one.
2. If $M < 10^9$ GeV (in the supersymmetric framework, this range is preferred by the gravitino problem), then standard leptogenesis encounters problems, while softleptogenesis can be significant.

Now after considering the $\Delta L \neq 0$ to the right of the "cut", we showed that with generic soft trilinear A couplings there are two interesting consequences

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3. One can realize non thermal CP violation where the CP asymmetries in the decays of heavy sneutrinos to lepton and sleptons do not cancel at zero temperature resulting in an enhanced efficiency in generating baryon asymmetry.

Now after considering the $\Delta L \neq 0$ to the right of the "cut", we showed that with generic soft trilinear A couplings there are two interesting consequences

3. One can realize non thermal CP violation where the CP asymmetries in the decays of heavy sneutrinos to lepton and sleptons do not cancel at zero temperature resulting in an enhanced efficiency in generating baryon asymmetry.
4. The dominant CP violation from self-energy corrections is sufficent even far away from the resonant regime and the relevent soft parameters can assume natural values at around the TeV scale.

THANK YOU!