Leptogenesis and Dark Matter From a Sneutrino Condensate

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DESY Theory Workshop

September 30, 2004

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Precise determination of Cosmological parameters from CMB:

$\Omega_b h^2 = 0.024 \pm 0.001$ ← good agreement with BBN determination

$\Omega_m h^2 = 0.14 \pm 0.002$

$\frac{\delta\rho}{\rho} = \text{few} \times 10^{-5}$

Baryogenesis: GUT, electroweak, Affleck-Dine, leptogenesis, gravitational, ...

Dark matter: neutralino, gravitino, axion, axino, Q-ball, QCD-ball, ...

Density perturbations: inflaton, curvaton, modulated fluctuations, ...

Typically, different sectors of the theory probed.

Example: leptogenesis (neutrino sector) +
neutralino (MSSM sector) +
inflaton (inflation sector)

Thermal scenarios well explored, not depend on physics before reheating, BUT constrained:

Thermal leptogenesis: $T_R > 10^8$ GeV (unless fine-tuning).

$T_R < (10^5 - 10^9)$ GeV from gravitino production.

The same origin for leptogenesis, dark matter and perturbations?

Must rely on a non-thermal scenario.

Requirements:

- Perturbations: a late decaying field with its own fluctuations.
- Leptogenesis: $T_R > 100$ GeV, for conversion by sphalerons.
- Dark matter: $T_R < T_f \Rightarrow$ gravitino DM.

$\Rightarrow$ Out-of-equilibrium decay of a right-handed sneutrino condensate.

$$\frac{n_B}{s} \simeq \frac{1}{3} \, \varepsilon_L \, \frac{3 T_R}{m_N}$$ ← dilution factor

$$\frac{n_{3/2}}{s} = Br(\tilde{N} \to N + \tilde{G}) \, \frac{3 T_R}{m_N}$$

$$\frac{\delta \rho}{\rho} \sim \frac{H_I}{N_0}$$

H_I ← expansion rate during inflation

N_0 ← VEV of $\tilde{N}$ condensate

$$W \supset \frac{1}{2} m_N N N + h N H_u L$$

$$V_{soft} \supset m_0^2 |\tilde{N}|^2 + (B m_N \tilde{N} \tilde{N} + A h \tilde{N} H_u \tilde{L} + h.c.)$$

$$m_{\tilde{N}_R} = m_N + B \qquad m_{\tilde{N}_I} = m_N - B$$

$B \gg m_{3/2}$:

$$\frac{n_{3/2}}{s} \simeq 10^{-2} \frac{B^4}{m_{3/2}^2 T_R M_P}$$

$$1 \text{ TeV} < B < 10 \text{ TeV} \Rightarrow T_R < 3 \times 10^5 \text{ GeV}$$

$$\frac{n_B}{s} \simeq 10^{-10} \left(\frac{T_R}{10^6 \text{ GeV}} \right)$$ Standard leptogenesis

$$\propto \frac{A M_2 T_R}{m_N^3}$$ Soft leptogenesis

Standard leptogenesis generates insufficient asymmetry unless fine-tuning introduced.

$$\frac{N_0}{M_P} \gtrsim 10^{-2} \left(\frac{M_3}{1\,\mathrm{TeV}}\right)\left(\frac{T_R}{200\,\mathrm{GeV}}\right)\left(\frac{1\,\mathrm{TeV}}{B}\right)^2$$

↑ $\tilde{N}$-dominance + dilution of thermal gravitinos

Example: $B = 5\,\mathrm{TeV}$, $A = M_2 = 300\,\mathrm{GeV}$, $T_R = 1\,\mathrm{TeV}$ ⇒

Dark matter: $m_{3/2} \simeq 10\,\mathrm{GeV}$.

Baryon asymmetry: $m_N \simeq 3\times 10^5\,\mathrm{GeV}$.

Density perturbations: $N_0 \simeq 2\times 10^{15}\,\mathrm{GeV}$, $H_I \simeq 2\times 10^{10}\,\mathrm{GeV}$.

$N_0 \lesssim M_{GUT}$ is interesting, natural if (s)neutrinos are charged under GUT (e.g. SO(10) model).

Model works for $1\,\mathrm{MeV} < m_{3/2} < 1\,\mathrm{TeV}$, $M_N \simeq (10^5 - 10^6)\,\mathrm{GeV}$, $T_R < 10^6\,\mathrm{GeV}$.

Summary:

- Right-handed sneutrino condensate may be the origin of baryon asymmetry, dark matter and density perturbations.

- Model works for very low reheat temperatures. Soft leptogenesis is the preferred mechanism.

- Baryon and DM abundance both depend on the neutrino and ~~SUSY~~ parameters.

- Sneutrino VEV $\lesssim M_{GUT}$ is sufficient for its domination. Thermal gravitinos are diluted.

- Model works for a narrow range of m_N, but rather wide range of $m_{3/2}$ and T_R. Narrow down the latter through collider signatures of gravitino?