Sneutrino Inflation with Asymmetric Dark Matter

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“Sneutrino Inflation with Asymmetric Dark Matter”
Introduction

What is the origin of the baryon asymmetry in the Universe?

What is the origin of the dark matter?

Why the amount of the baryon and the dark matter is closed?
Asymmetric Dark Matter

[Kaplan, Luty and Zurek (2009)]

\[ \mathcal{L} = \mathcal{L}_{\text{SM}} + \mathcal{L}_{\text{DM}} + \mathcal{L}_{\text{int}}. \]

\( \mathcal{L}_{\text{int}} \) enforces the (anti-)dark matter have non-zero \( B-L \) charge.

The \textbf{dark matter} number is generated by non-zero \( B-L \) number.
Asymmetric Dark Matter

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As the temperature of the universe become low, the dark matter number is fixed.
Sneutrino Inflation

[Murayama, Suzuki, Yanagida and Yokoyama (1993)]

MSSM + Right-handed neutrino & sneutrino

\[ W = W_{\text{MSSM}} + y_{ij} N_i L_j H_u + \frac{1}{2} M_i N_i^2 \]

Right-handed sneutrino with small Yukawa couplings acts as the inflaton!

The see-saw mechanism leads to neutrino mass and mixing.

\[ \langle H_u \rangle \quad \langle H_u \rangle \]

\[ M \]
Decay of Right-handed Sneutrino

\[ \tilde{N}_1 \rightarrow \ell^+ \tilde{H}_u^+ \]

\[ \tilde{N}_1 \rightarrow \tilde{\ell} \tilde{H}_u \]

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\[ \tilde{N}_1 \rightarrow \tilde{N}_1 \]

\[ \tilde{N}_1 \rightarrow \ell \tilde{H}_u \]

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Can we combine "Asymmetric Dark Matter" and "Sneutrino Inflation" successfully?

- Asymmetric Dark Matter transmits...
- Sneutrino inflation leads to...
- $B-L$ to dark matter

Inflation
Neutrino mass & mixing
$B-L$ number asymmetry

\[ n_B/s = 8.3 \times 10^{-11} \]
\[ \Omega_{DM}/\Omega_B = 5 \]
Our setup

NMSSM (MSSM+singlet)
+ right-handed neutrino & sneutrino
+ dark matter & anti-dark matter

\[ W = W_{\text{NMSSM}} + \lambda S H_u H_d + \kappa' S X \bar{X} \]

\[ + \frac{M}{2} N_i^2 + y_{ij} N_i L_j H_u + \frac{\kappa_i}{2} N_i \bar{X}^2 \]
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Dark Matter annihilation

Dark matter production

\[ \frac{y_{ij} \kappa_i}{2M} (L_j H_u) \bar{X}^2 \]

<table>
<thead>
<tr>
<th>(Z_{4R})</th>
<th>(X)</th>
<th>(\bar{X})</th>
<th>(S)</th>
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<tbody>
<tr>
<td>(-i)</td>
<td>(i)</td>
<td>(1)</td>
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\(U(1)_L\) | \(-1/2\) | \(1/2\) | \(0\)
Thermal history of the Universe in our model

Right-handed sneutrino

\[ \ddot{\tilde{N}} + 3H \dot{\tilde{N}} + \Gamma \dot{\tilde{N}} + M^2 \tilde{N} = 0 \]

\[ H^2 = \frac{8\pi}{3M_{Pl}^2}(M^2|\tilde{N}|^2 + |\dot{\tilde{N}}|^2) \]
Thermal history of the Universe in our model

Right-handed sneutrino

$yNLH$

$B-L$

Dark Matter

Radiation (thermal bath)
Thermal history of the Universe in our model

Right-handed sneutrino

$y_{NLH}$

$\frac{y\kappa}{M} LH \bar{X}^2$

$B-L$

Dark Matter

Radiation (thermal bath)
Thermal history of the Universe in our model

Right-handed sneutrino

$B-L$

$\frac{n_B}{s} \simeq 8.3 \times 10^{-11}$

Dark Matter

$\Omega_{DM}/\Omega_b \simeq 5$

Radiation (thermal bath)
Thermal history of the Universe in our model

Right-handed sneutrino

\[ \frac{n_B}{s} \approx 8.3 \times 10^{-11} \]

Dark Matter

\[ \frac{\Omega_{DM}}{\Omega_b} \approx 5 \]
Thermal history of the Universe in our model

\[
\begin{align*}
M &= 10^{13} \text{ GeV} \\
T_{RH} &= 2 \times 10^{10} \text{ GeV} \\
\epsilon_{BL} &= 10^{-7} \\
\epsilon_{DM} &= 0 \\
y_{33} &= 0.14 \\
\kappa_3 &= 0.70 \\
m_X &= 550 \text{ GeV}
\end{align*}
\]

\[\Omega_{DM}/\Omega_B = 5\]

Conclusion

The dark matter density today is close to the baryon density. This fact suggests they have a common origin.

We have constructed the model which can realize inflation and appropriate relic abundance of baryon and dark matter simultaneously.
Backup
What determines the abundance of Baryon and Dark Matter?

\[ \dot{n}_{BL} + 3Hn_{BL} \sim \epsilon_{BL} \Gamma \frac{\rho_N}{M} \]

\[ n_{BL} \sim \epsilon_{BL} \Gamma \frac{T_{RH}^4}{M} \times \Gamma^{-1} \]

\[ s \sim T_{RH}^3 \]

\[ n_{BL}/s \sim \epsilon_{BL} \frac{T_{RH}}{M} \]
What determines the abundance of Baryon and Dark Matter?

\[ \dot{n}_{DM} + 3Hn_{DM} \sim y^2\kappa^2 \frac{T^3n_{BL}}{M^2} - \kappa^4 \frac{T^3n_{DM}}{M^2} \]

Wash-out effect of dark matter is **WEAK**.

\[ \Gamma n_{DM} \sim y^2\kappa^2 \frac{T_{RH}^3n_{BL}}{M^2} \]

\[ \frac{n_{DM}}{n_{BL}} \sim y^2\kappa^2 \frac{T_{RH}M_{Pl}}{M^2} \]

(\( \Gamma \sim T_{RH}^2/M_{Pl} \))

Wash-out effect of dark matter is **STRONG**.

\[ y^2\kappa^2n_{BL} \sim \kappa^4n_{DM} \]

\[ \frac{n_{DM}}{n_{BL}} \sim \frac{y^2}{\kappa^2} \]