Sneutrino Inflation with Asymmetric Dark Matter

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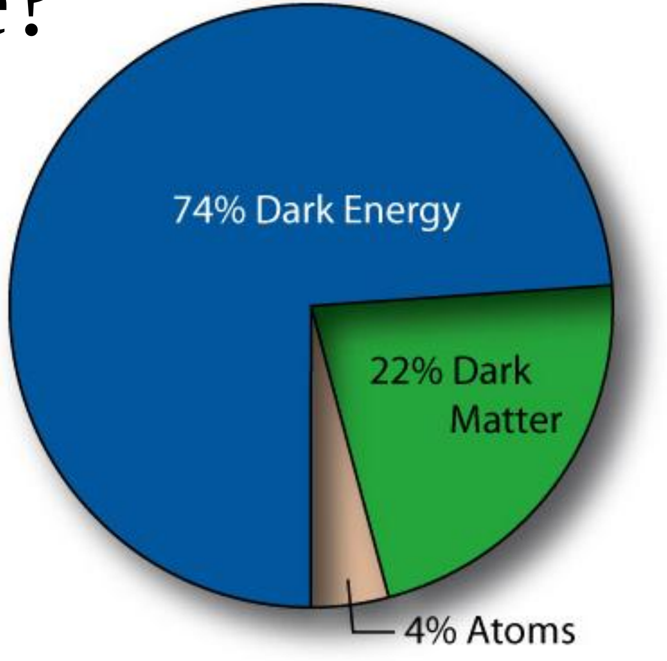
"Sneutrino Inflation with Asymmetric Dark Matter"
N. Haba, S. Matsumoto and RS [arXiv : hep-ph/1101.5679]

Introduction

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

What is the origin of the dark matter?



[NASA/WMAP Science Team]

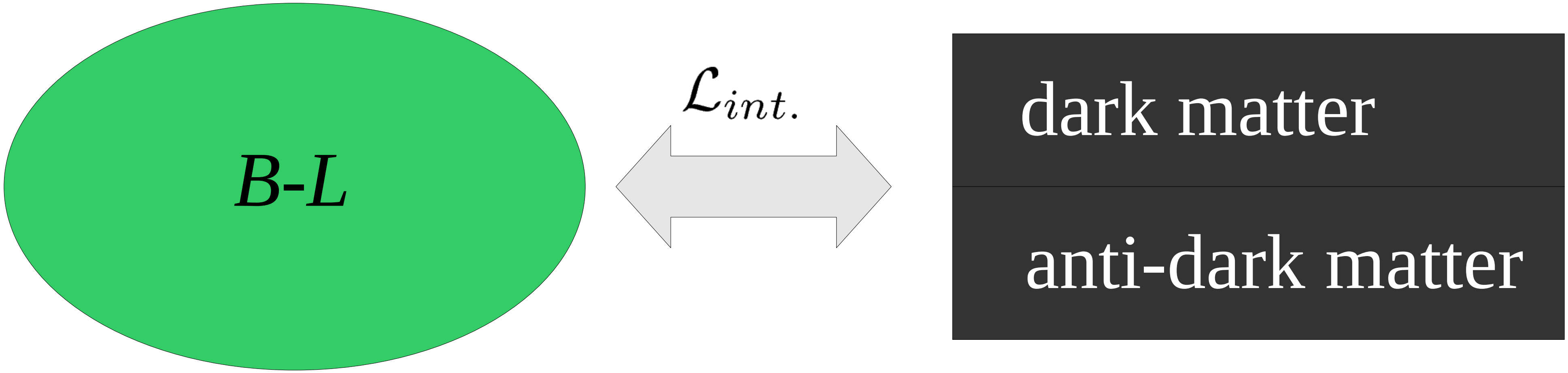
Why the amount of the baryon and the dark matter is closed?

Asymmetric Dark Matter

[Kaplan, Luty and Zurek (2009)]

$$\mathcal{L} = \mathcal{L}_{\rm SM} + \mathcal{L}_{\rm DM} + \mathcal{L}_{int.}$$

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



The **dark matter** number is generated by non-zero ***B-L*** number.

Asymmetric Dark Matter

[Kaplan, Luty and Zurek (2009)]

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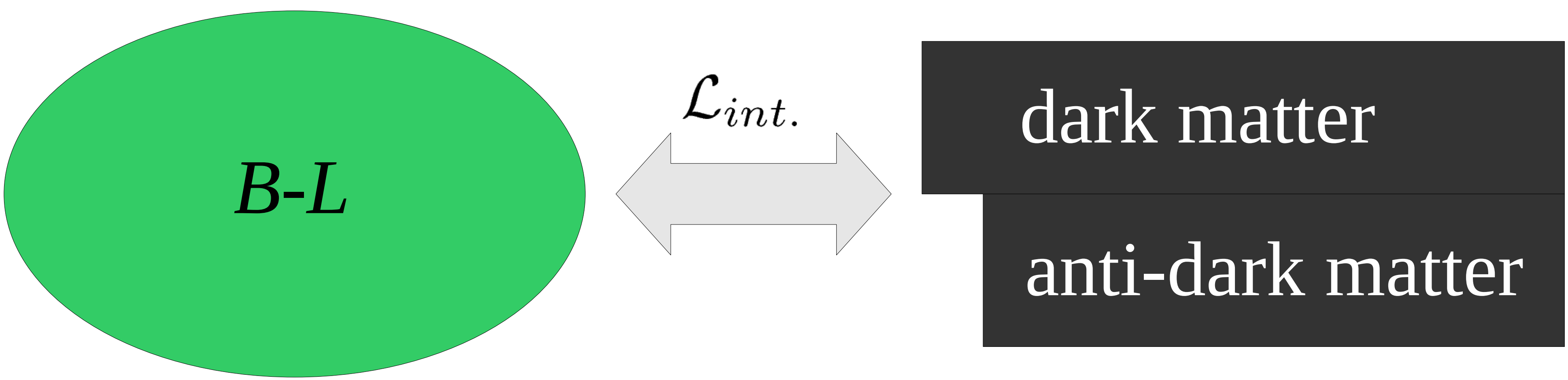

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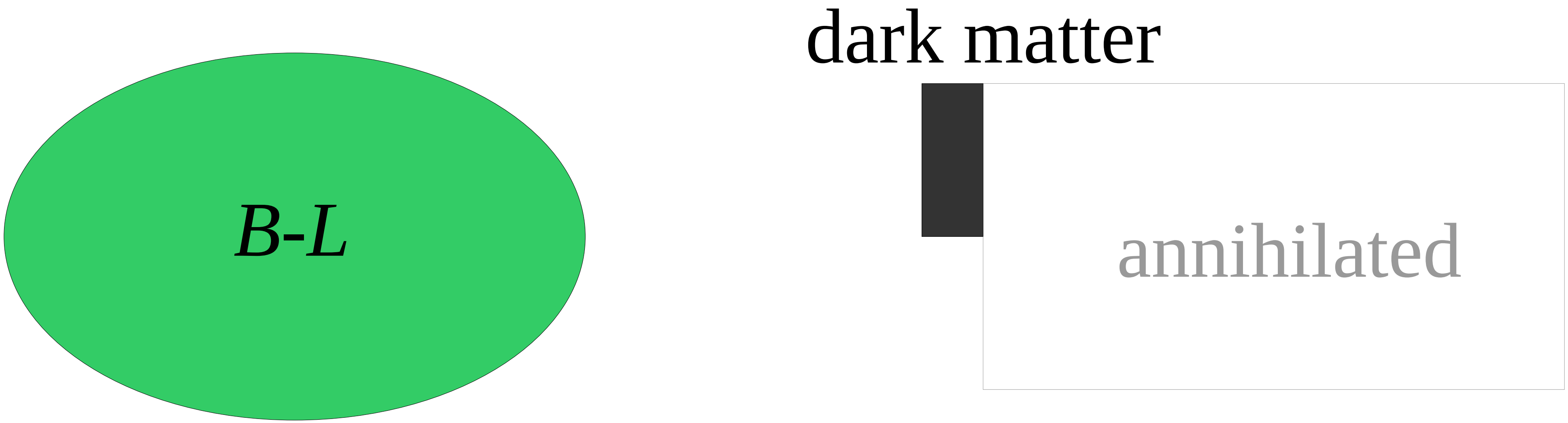


As the temperature of the universe become low,
the dark matter number is fixed.

Sneutrino Inflation

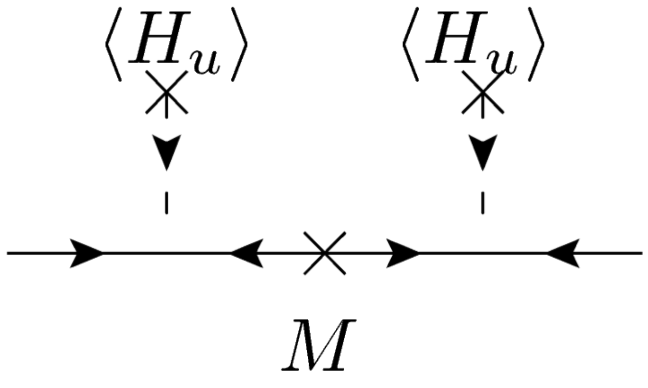
[Murayama, Suzuki, Yanagida and Yokoyama (1993)]

MSSM + Right-handed neutrino & sneutrino

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

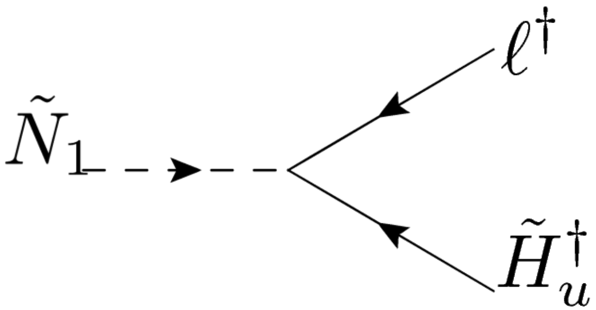
Right-handed sneutrino with small Yukawa couplings acts as **the inflaton**!

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



Decay of Right-handed Sneutrino

$$\tilde{N}_1 \to \ell^\dagger \tilde{H}_u^\dagger$$



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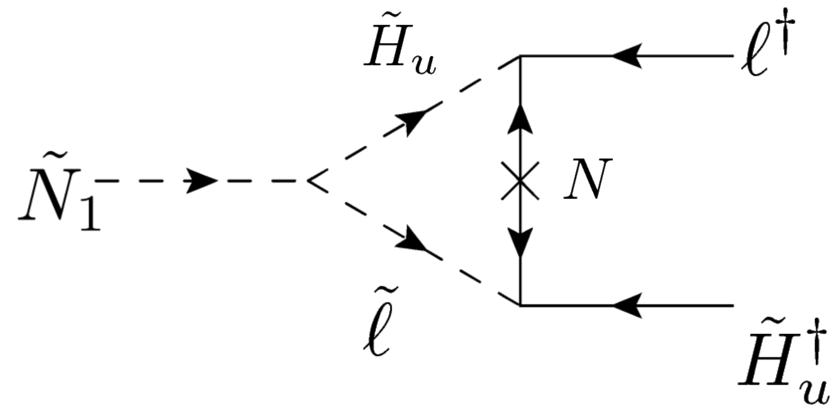

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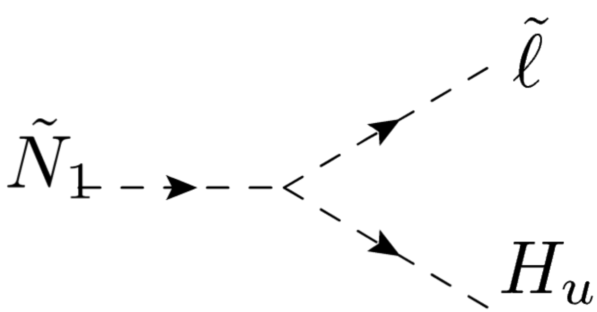

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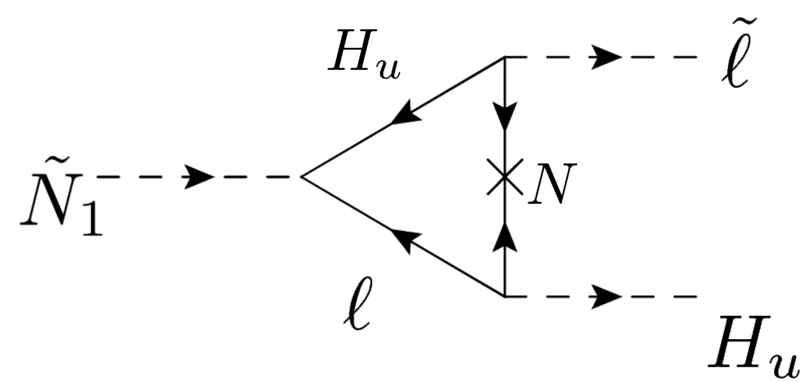

Asymmetric Dark Matter
transmits...

B-L to **<u>dark matter</u>**

Sneutrino inflation
leads to....

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

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

$$\begin{cases} n_B/s = 8.3 \times 10^{-11} \\ \Omega_{DM}/\Omega_B = 5 \end{cases}$$

Our setup

NMSSM (MSSM+singlet)

+ right-handed neutrino & sneutrino

+ dark matter & anti-dark matter

$X, \bar{X}$: (anti-) Dark matter

S : Singlet in NMSSM

$$W = W_{\mathrm{NMSSM}} + \lambda S H_u H_d + \kappa' S X \bar{X}$$

$$+ \frac{M}{2} N_i^2 + y_{ij} N_i L_j H_u + \frac{\kappa_i}{2} N_i \bar{X}^2$$

Our setup

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$X, \bar{X}$: (anti-) Dark matter

S : Singlet in NMSSM

$$W = W_{\rm NMSSM} + \boxed{\lambda S H_u H_d + \kappa' S X \bar{X}}$$

Dark Matter annihilation

$$+\frac{M}{2}N_i^2 + \underline{y_{ij} N_i L_j H_u + \frac{\kappa_i}{2} N_i \bar{X}^2}$$

Dark matter production

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

	X	$\bar{X}$	S
Z_{4R}	$-i$	i	1
$U(1)_L$	$-1/2$	$1/2$	0

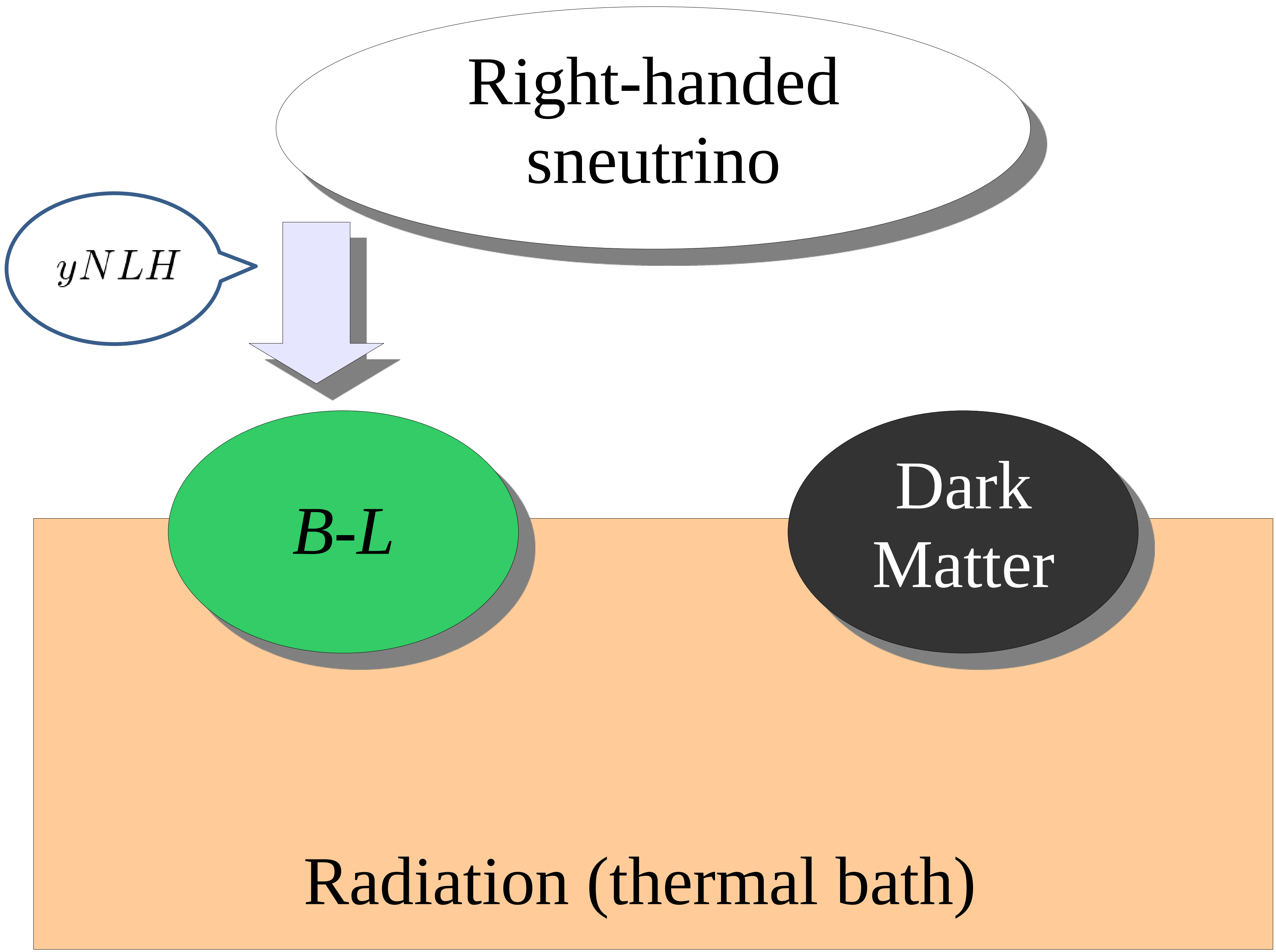
Thermal history of the Universe in our model

Right-handed
sneutrino

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

$$H^2 = \frac{8\pi}{3M_{\rm Pl}^2}(M^2|\tilde{N}|^2 + |\dot{\tilde{N}}|^2)$$

Thermal history of the Universe in our model



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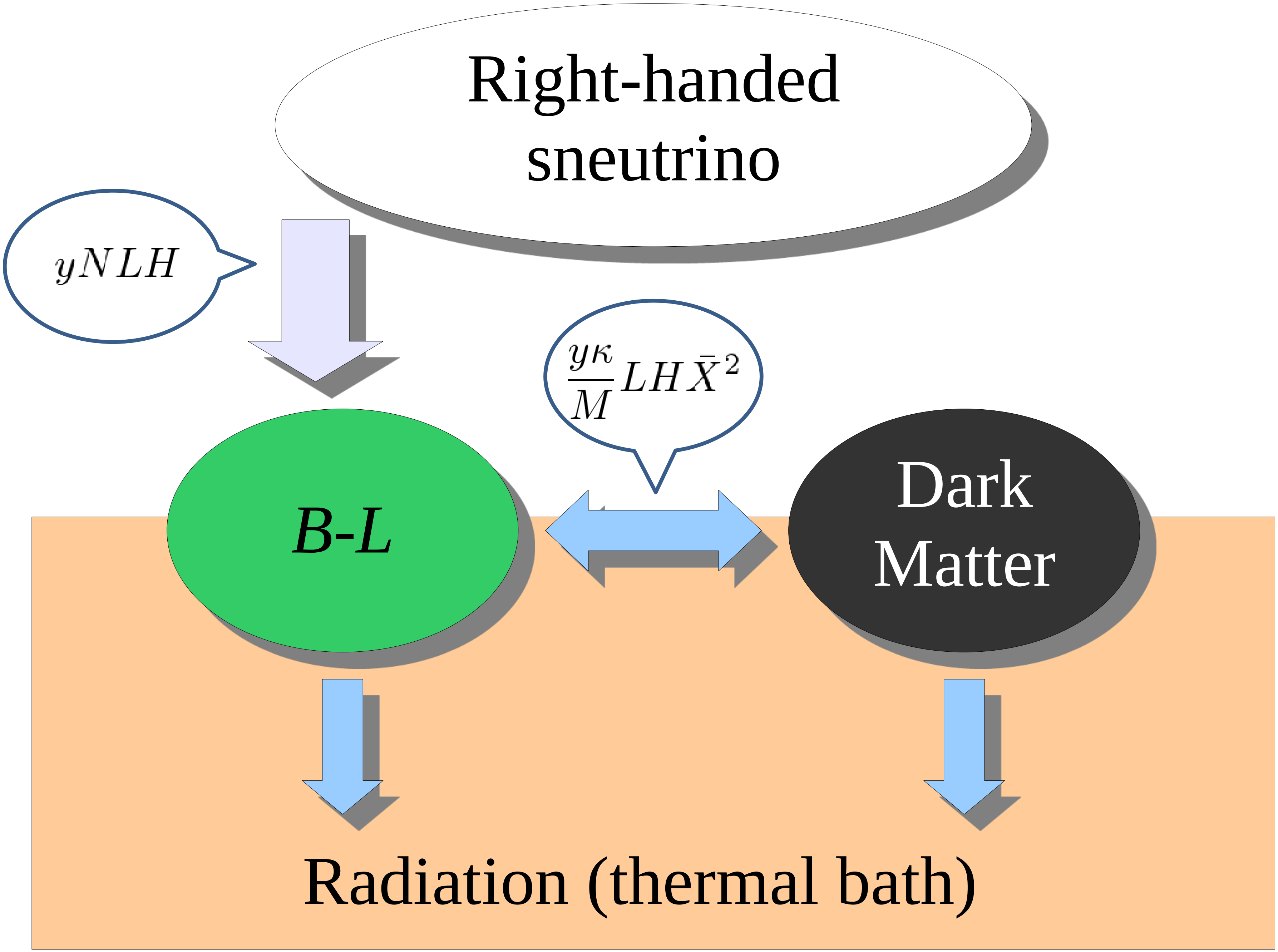

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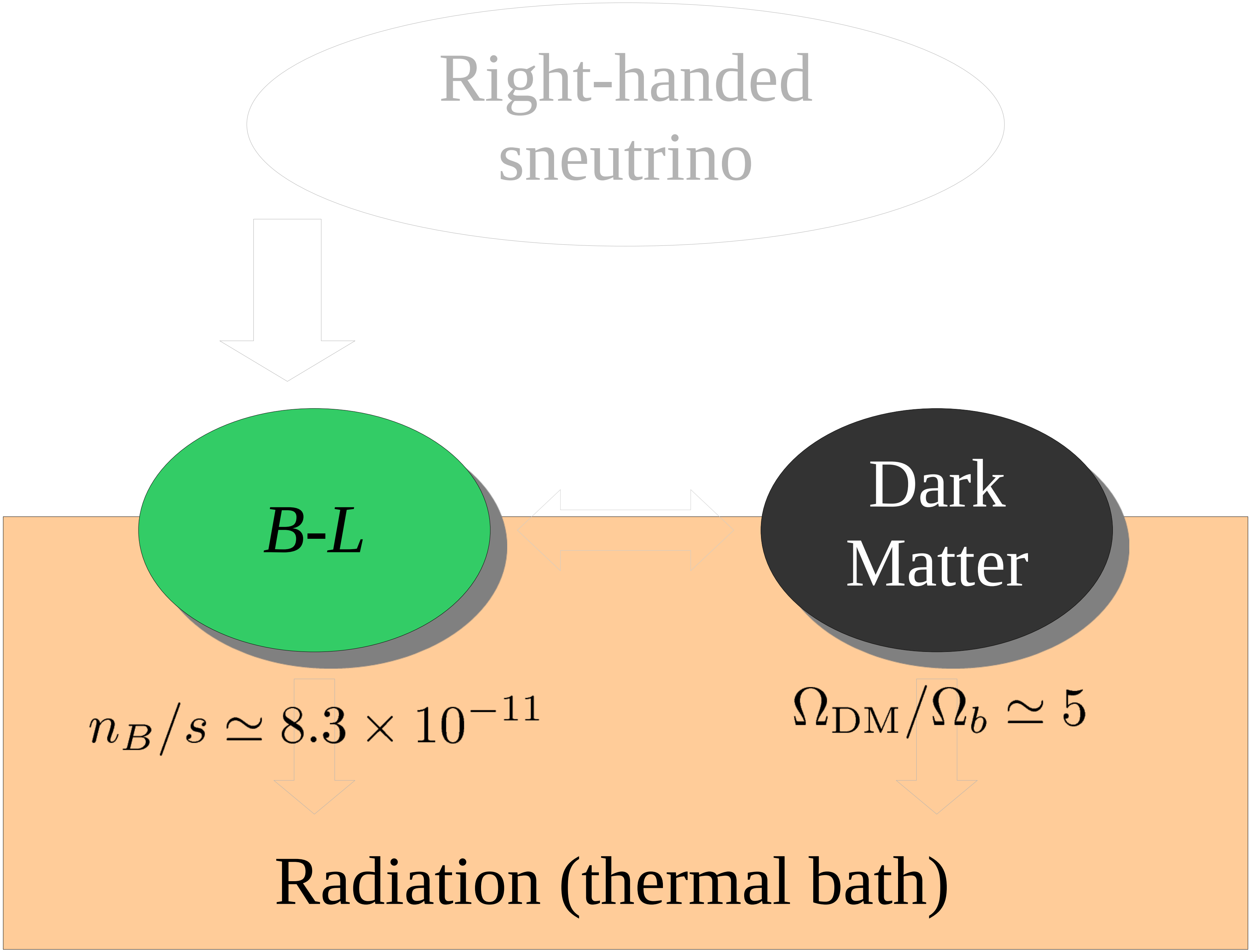
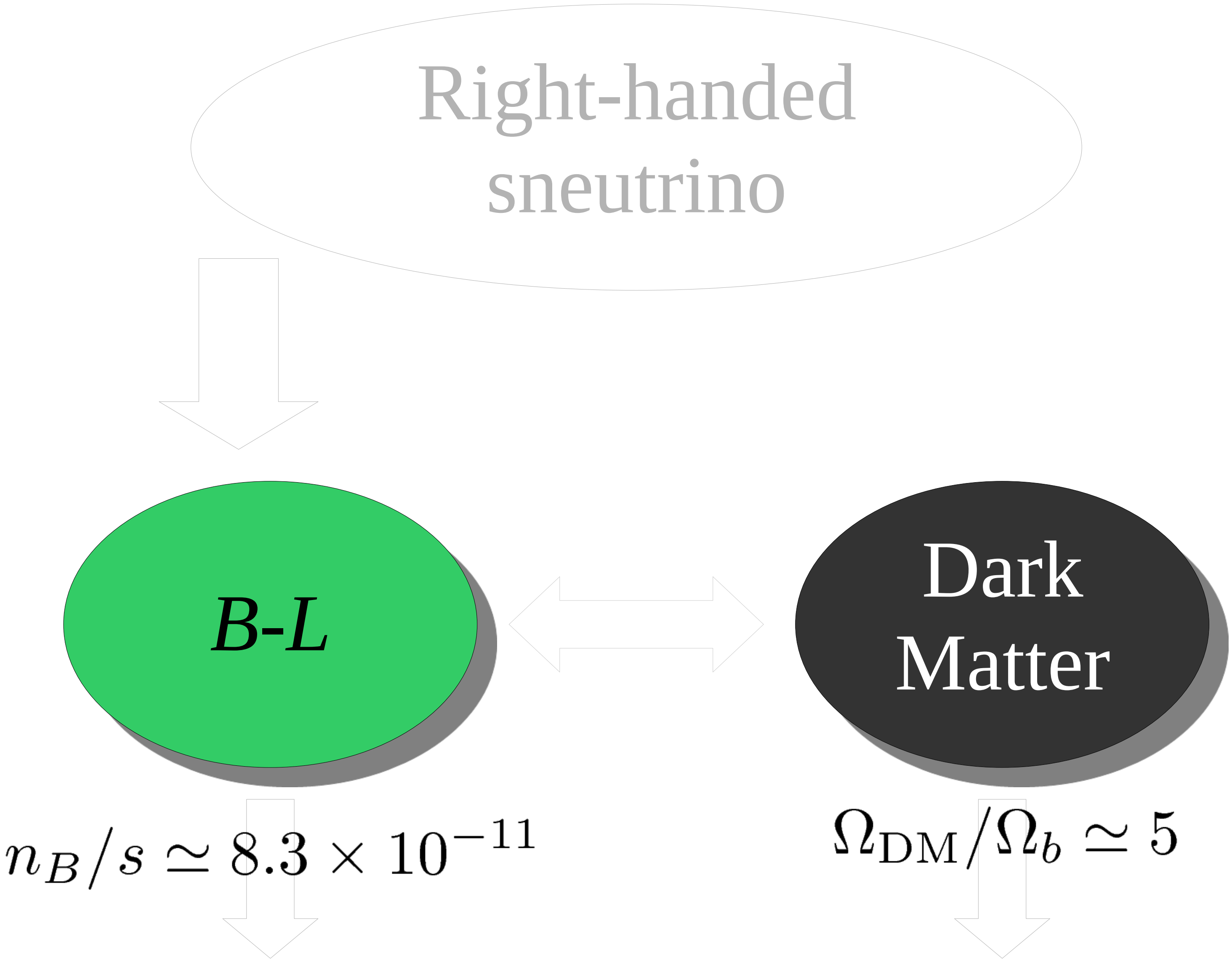
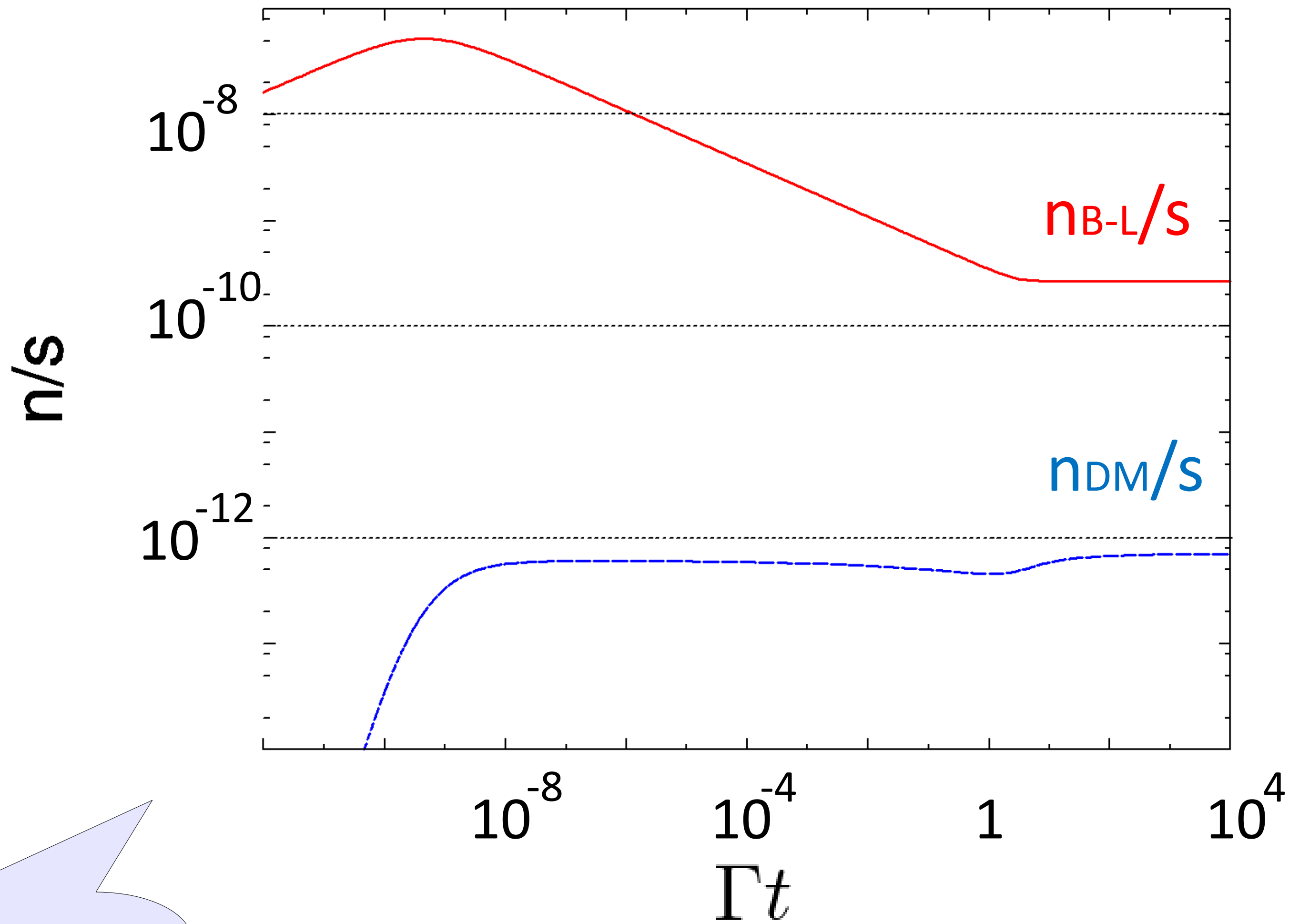


Thermal history of the Universe in our model



Thermal history of the Universe in our model

$$
\begin{aligned}
M &= 10^{13}\ \mathrm{GeV} \\
T_{RH} &= 2\times 10^{10}\ \mathrm{GeV} \\
\epsilon_{BL} &= 10^{-7} \\
\epsilon_{DM} &= 0 \\
y_{33} &= 0.14 \\
\kappa_3 &= 0.70 \\
m_X &= 550\ \mathrm{GeV}
\end{aligned}
$$



$$\Omega_{DM}/\Omega_B = 5$$

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<u>Conclusion</u>

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 **<u>baryon</u>** and **<u>dark matter</u>** simultaneously.

Backup

What determines the abundance of Baryon and Dark Matter?

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

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

$$s \sim T_{RH}^3$$

$$\Rightarrow$$

$$n_{BL}/s \sim \epsilon_{BL}\frac{T_{RH}}{M}$$

What determines the abundance of Baryon and Dark Matter?

$$yNLH_u + \frac{1}{2}\kappa N\bar{X}^2$$

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

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

$$\Gamma n_{DM} \sim y^2\kappa^2 \frac{T_{RH}^3 n_{BL}}{M^2} \Rightarrow n_{DM}/n_{BL} \sim y^2\kappa^2 \frac{T_{\rm RH} M_{\rm Pl}}{M^2}$$

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

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

$$y^2\kappa^2 n_{BL} \sim \kappa^4 n_{DM} \Rightarrow n_{DM}/n_{BL} \sim y^2/\kappa^2$$