Affleck-Dine leptogenesis

and its backreaction to inflaton dynamics

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Tohoku University

Based on: M. Y., Phys.Lett. B754 (2016) 208-213 (arXiv:1510.08514 [hep-ph])

Revealing the history of the Universe
with underground particle and nuclear research 2016
May 11th

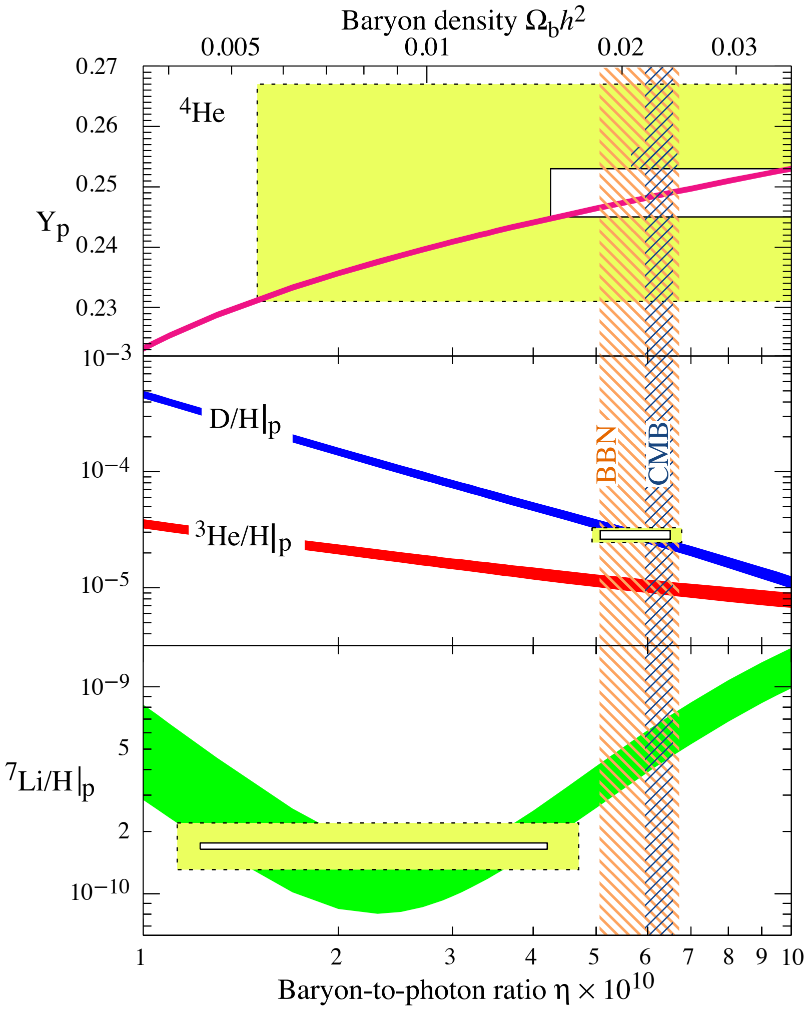
1. Introduction: baryon asymmetry

What is the origin of visible matter?

Visible matter = Baryons (and leptons)

$$Y_b^{(\mathrm{obs})} \equiv \frac{n_b}{s} = 8.6 \times 10^{-11}$$

How can we generate baryon asymmetry?



Pargicle Data Group (2014)

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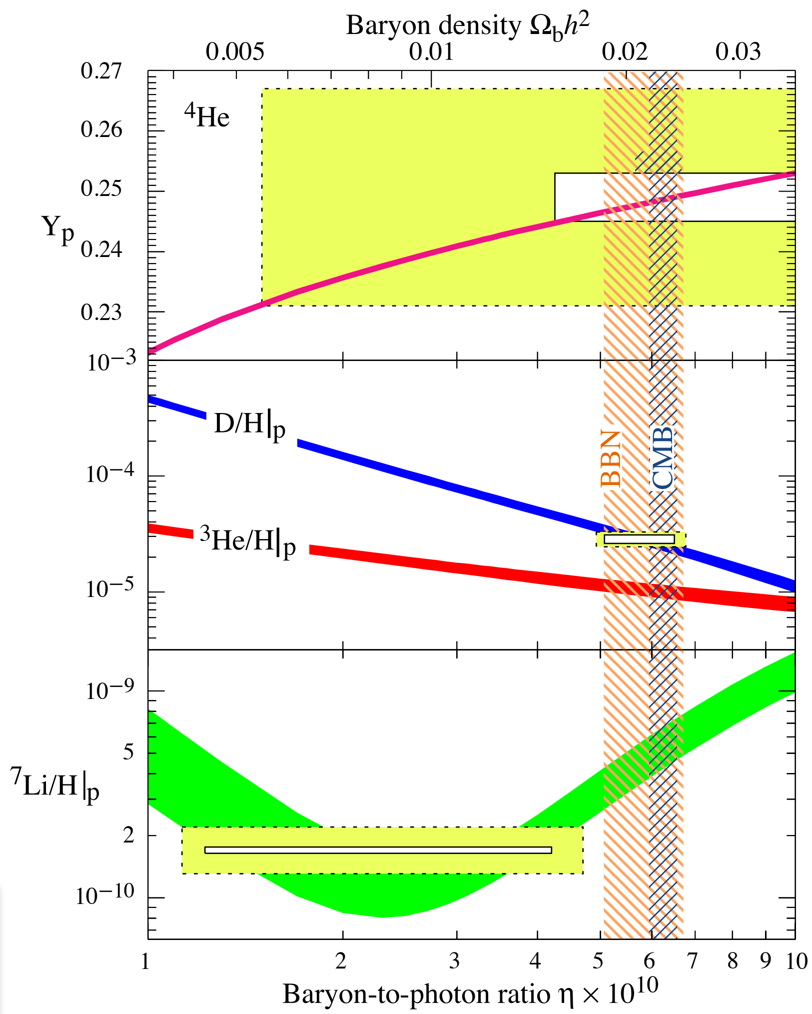
It is impossible to generate sufficient baryon asymmetry in the Standard Model.

Baryon asymmetry is a clue to find a physics beyond the Standard Model.



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1. Introduction: thermal leptogenesis

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Neutrino oscillation requires a new physics, too.

$$\Delta m^2_{31} = (7.53 \pm 0.18) \times 10^{-5}\ \mathrm{eV}^2$$
$$\Delta m^2_{32} = (2.44 \pm 0.06) \times 10^{-3}\ \mathrm{eV}^2$$

(Normal hierarchy)

Forero, Tortola, Valle '14
Gonzalez-Garcia, Maltoni, Schwetz '14

⇒ **Seesaw mechanism:**

$$\mathcal{L} = -yLH^* N_R - \frac{1}{2} M_R N_R N_R + h.c.$$

Yanagida '79,
Gell-Mann, Ramond, Slansky '79,
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Thermal leptogenesis:

Fukugita and Yanagida '86

Decay of N_R can generate lepton asymmetry!

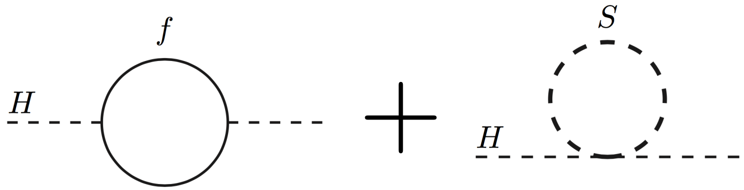
$$Y_b \simeq 8.6 \times 10^{-11} \Longleftrightarrow 10^9\ \mathrm{GeV} \lesssim M_R \lesssim T_{\mathrm{RH}}$$

1. Introduction: SUSY

Baryon asymmetry is a clue
to find a physics beyond the Standard Model.

Supersymmetry is a symmetry that relates fermions and bosons.
It is also motivated as a new physics because it can

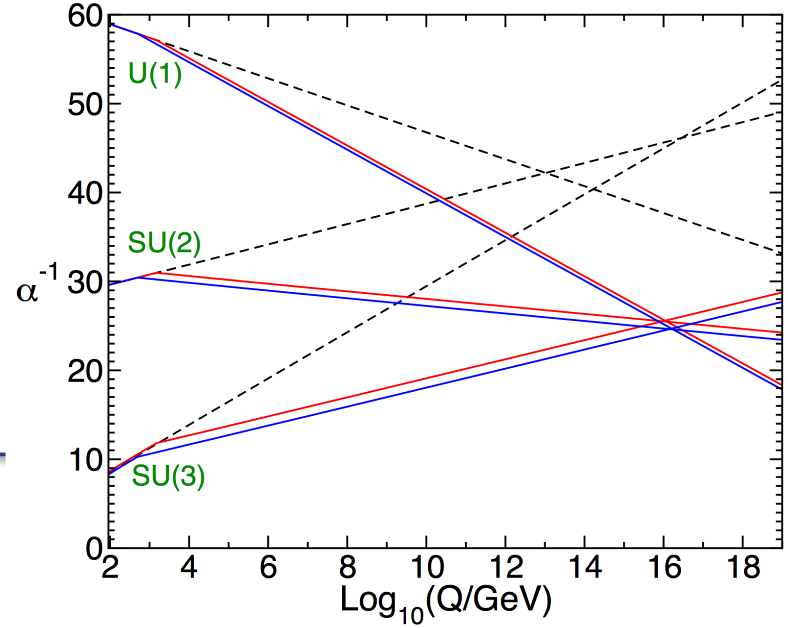
- solve the hierarchy problem



$$\Delta m_H^2 = -\frac{1}{8\pi^2}\left(|\lambda_f|^2 - \lambda_s\right)\Lambda_{\rm UV}^2 + \mathcal{O}(m_S^2)$$

$= 0$

- achieve gauge coupling unification



- predicts dark matter
(lightest SUSY particle)

1. Introduction: gravitino problem

Baryon asymmetry is a clue
to find a physics beyond the Standard Model.

N_R + SUSY

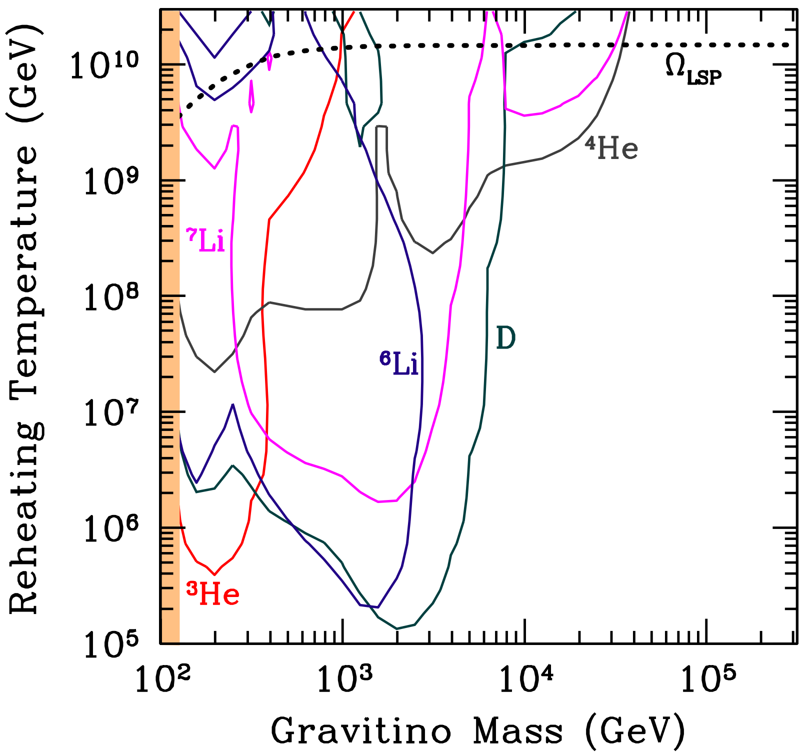
Can we realize thermal leptogenesis in SUSY theories?

Yes, if $10^9\ \mathrm{GeV} \lesssim M_R \lesssim T_{\mathrm{RH}}$

However, there is gravitino problem,
which puts an upper bound on T_{RH}.

We may need another mechanism
to generate baryon asymmetry in SUSY.

⇒ **Affleck-Dine mechanism**



Kawasaki, Kohri, Moroi, Yotsuyanagi '08

2. Affleck–Dine mechanism

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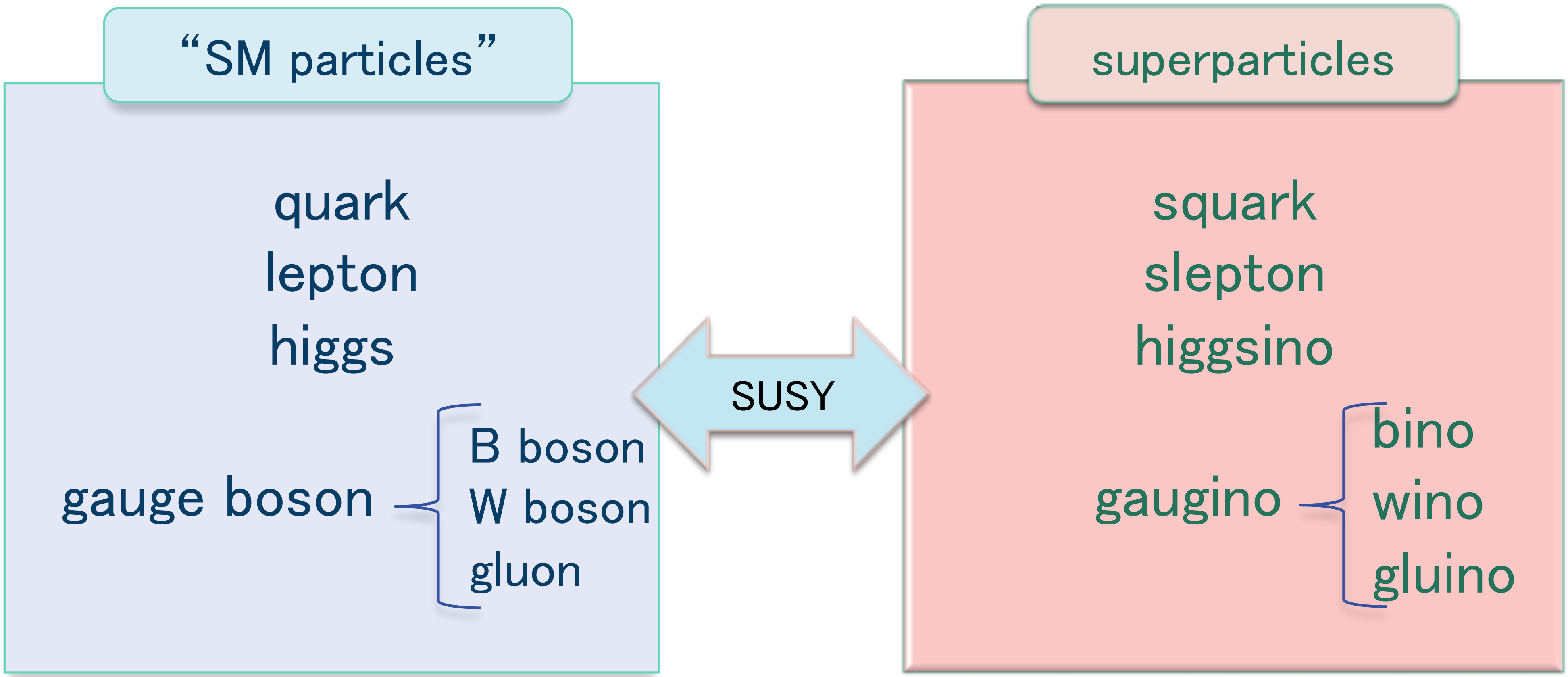

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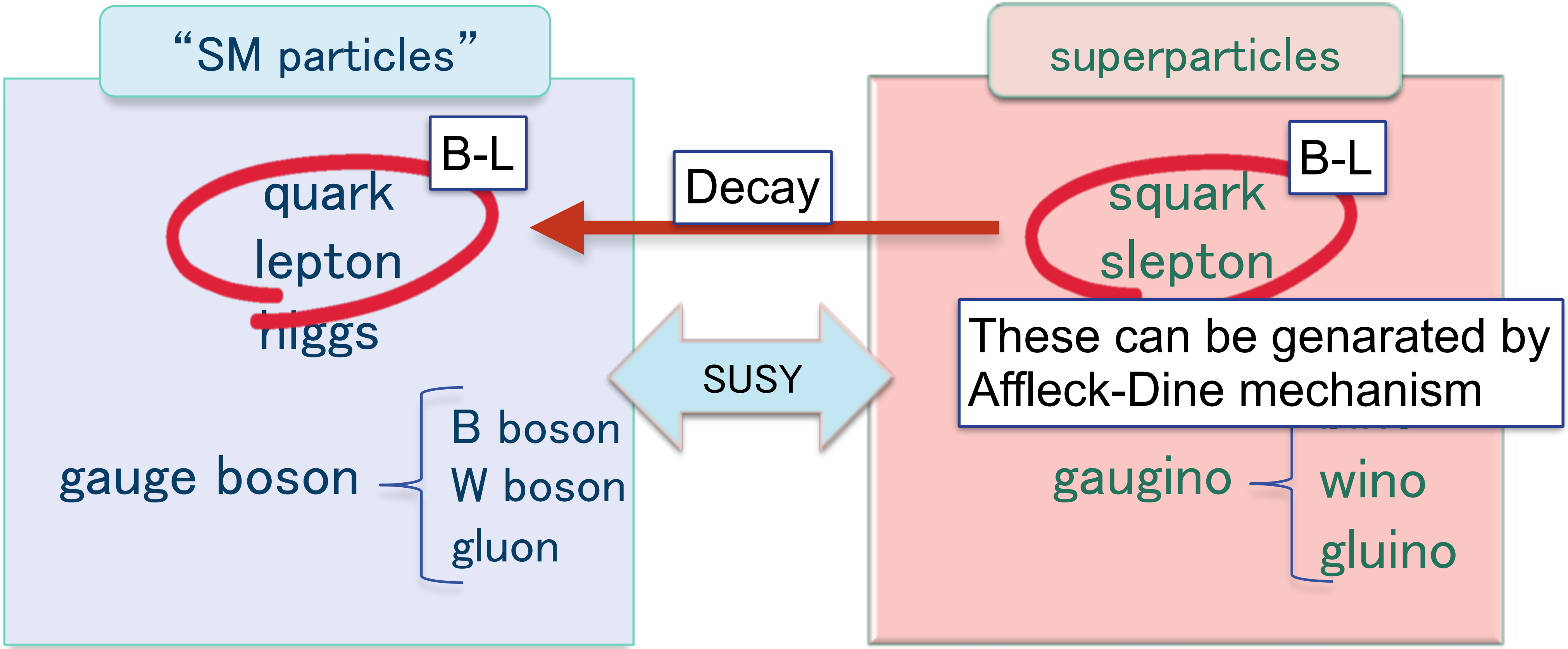

2. Affleck–Dine mechanism

Affleck, Dine, 85
Murayama, Yanagida, 94
Dine, Randall, Thomas, 96

The following term gives Majorana mass term for left-handed neutrinos:

$$W = \frac{y^2}{4M_R}(LH_u)^2$$

$$\Rightarrow \quad m_\nu \simeq 10^{-5}\ \mathrm{eV} \times y^2 \left(\frac{M_R}{M_{\mathrm{Pl}}}\right)^{-1}$$

It also gives a scalar potential for
a linear combination of slepton and higgs field ϕ :

$$V(\phi) = m_\phi^2 |\phi|^2 + y^4 \frac{|\phi|^6}{M_R^2} + a m_{3/2} y^2 \frac{\phi^4}{M_R} + c.c.$$

Let us consider the dynamics of ϕ.

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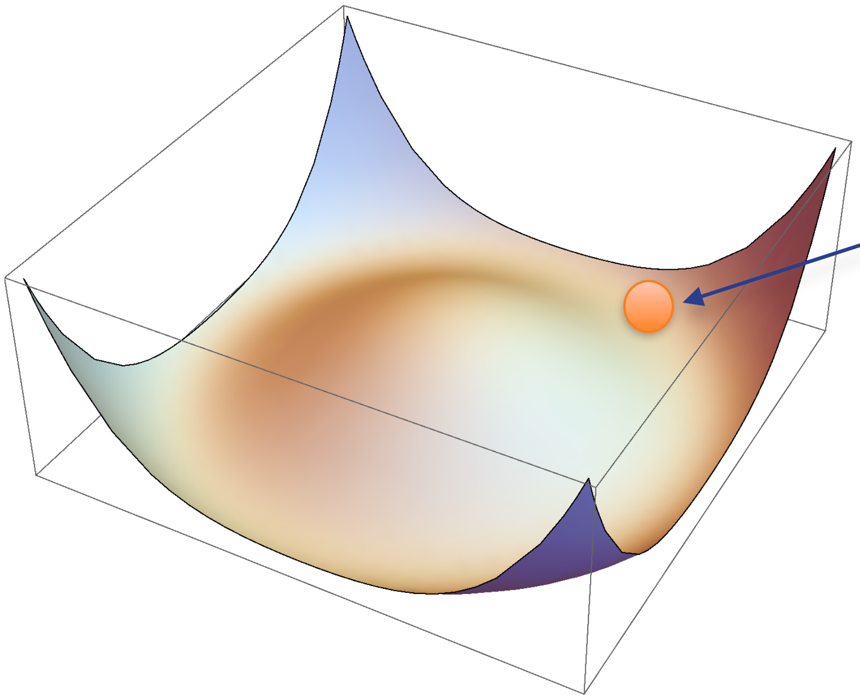
$$- cH^2(t) |\phi|^2 + c_T T^4 \log\left(\frac{|\phi|^2}{T^2}\right)$$



ϕ has a large vacuum expectation value in the very early Universe, when the energy scale of the Universe is larger than its mass.

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Fujii, Hamaguchi, Yanagida, '01

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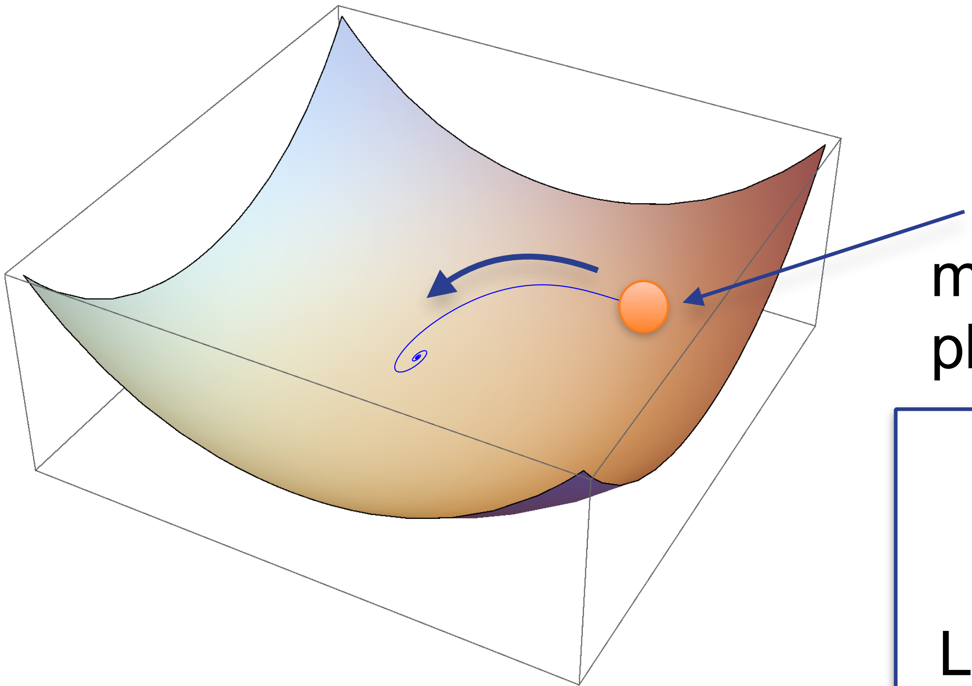


ϕ starts to oscillate around the minimum and rotate in the complex plane at some time.

$$B - L = \int \mathrm{d}V \mathrm{Im}\left(\phi \partial_0 \phi^*\right)$$

Larger initial amplitude leads to larger B-L asymmetry.

2. Affleck–Dine mechanism and $0\nu\beta\beta$

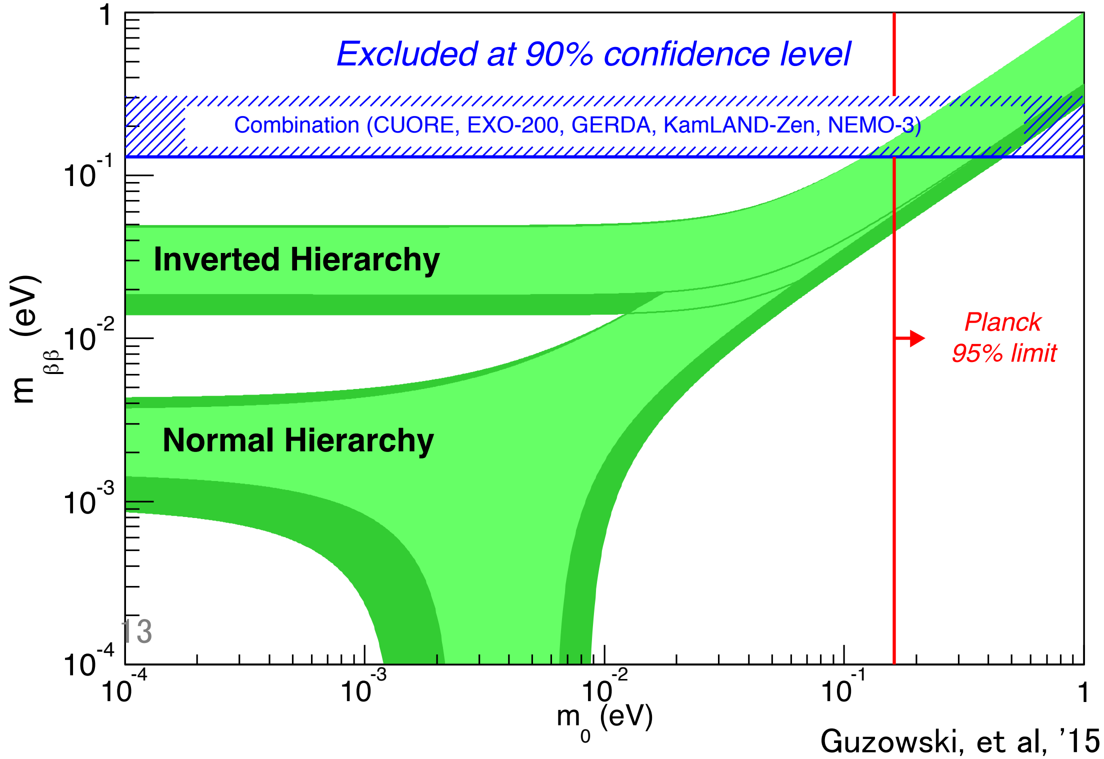
Fujii, Hamaguchi, Yanagida, '01

The resulting baryon asymmetry is given as

$$Y_b \simeq 3.7 \times 10^{-10} \left(\frac{m_{\nu_1}}{10^{-9}\ \mathrm{eV}} \right)^{-3/2} \left(\frac{m_{3/2}}{1\ \mathrm{TeV}} \right) \qquad \text{for} \quad T_R \gtrsim \frac{m_\phi}{y \alpha_s}$$

- T_R indep. ⇨ Free from gravitino problem
- Lightest left-handed neutrino mass $\approx 10^{-9}$ eV

⇨ measurement for $0\nu\beta\beta$



Guzowski, et al, '15

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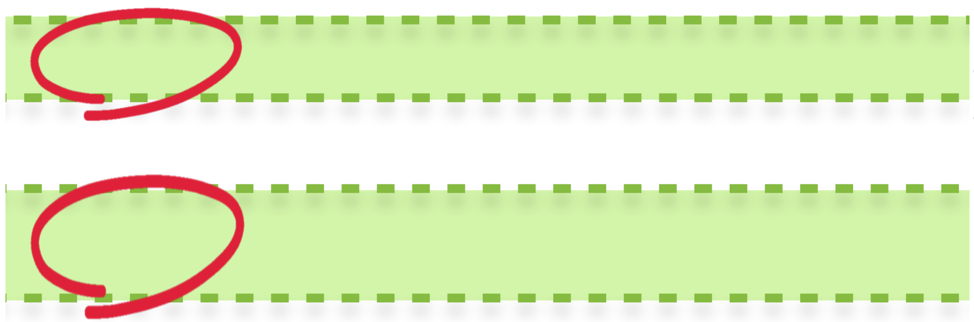
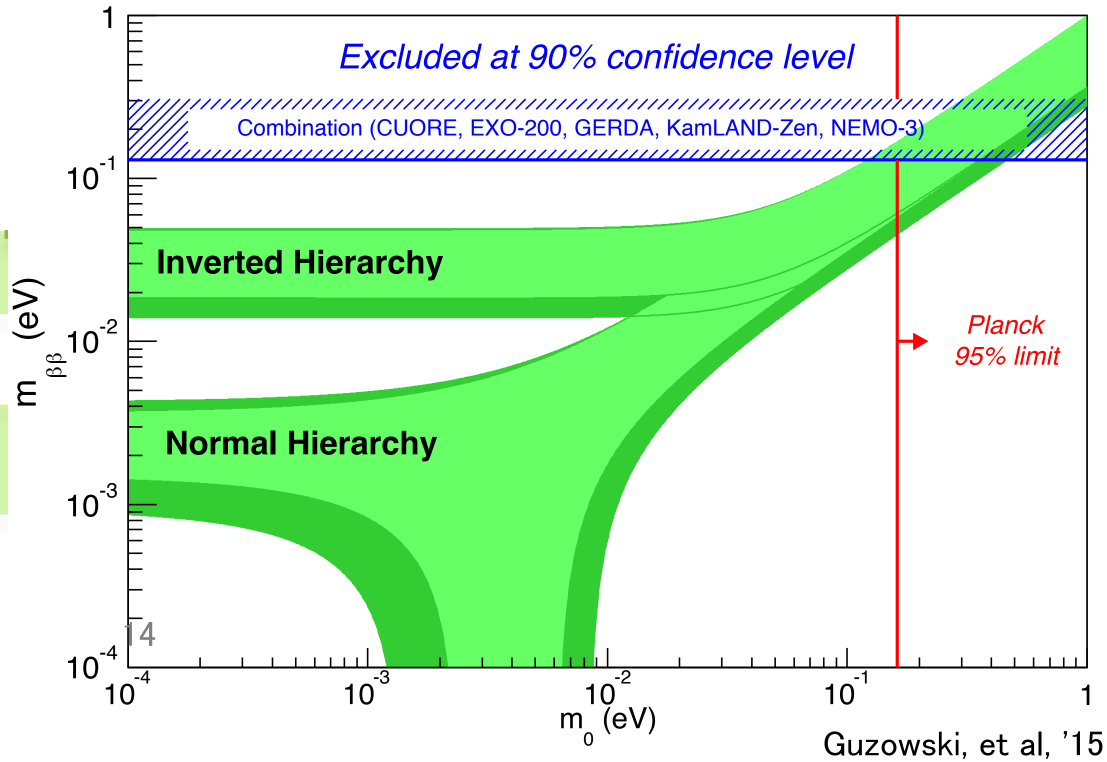


$10^{-9}\ \mathrm{eV}$



Guzowski, et al, '15

3. Backreaction to inflaton dynamics

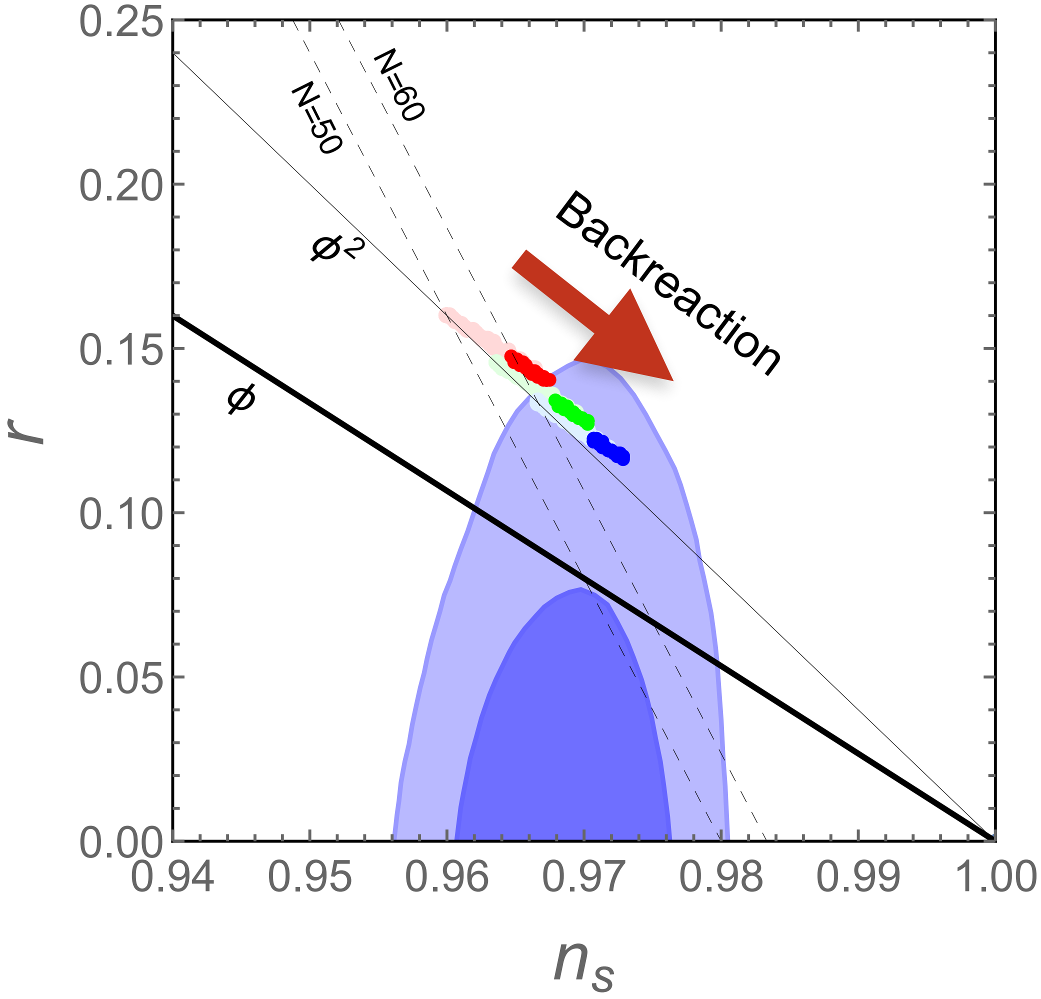
Harigaya, Ibe, Kawasaki, Yanagida '15
M.Y., '15

Chaotic inflation in SUSY

$$m_{\mu_1} \approx 10^{-9}\ \mathrm{eV}$$

$$\Leftrightarrow \langle \phi \rangle_{\rm inf} \approx M_{\rm Pl}$$

Affleck-Dine leptogenesis affects some predictions of chaotic inflation model.



Blue region: Planck 2015 (astro-ph.CO/1502.01589)

4. Summary

Thermal leptogenesis requires

$$10^9 \text{ GeV} \lesssim M_R \lesssim T_{\rm RH}$$

but, such a high reheating temperature may be inconsistent with gravitino problem.

We have another mechanism to generate baryon (lepton) asymmetry in SUSY: Affleck-Dine mechanism.

$$Y_b \simeq 3.7 \times 10^{-10} \left(\frac{m_{\nu_1}}{10^{-9} \text{ eV}} \right)^{-3/2} \left(\frac{m_{3/2}}{1 \text{ TeV}} \right)$$

Fujii, Hamaguchi, Yanagida, '01

Large Y_b ⟺ Large amplitude of ϕ ⟺ Small Yukawa ⟺ Small m_{μ_1}

ϕ may affect some predictions of inflation models.