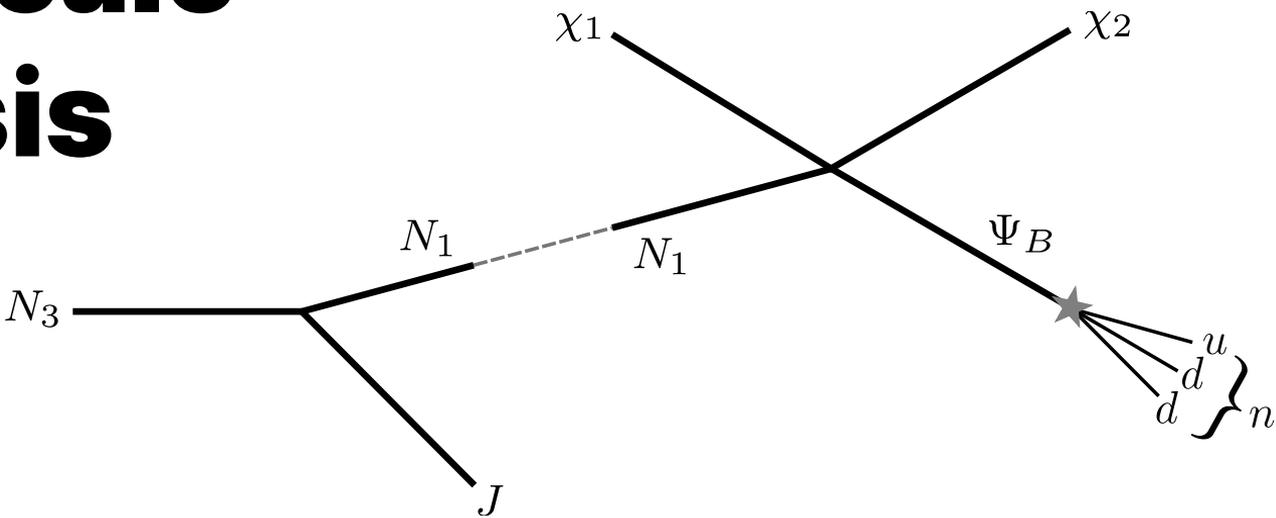


Dark Low-Scale Leptogenesis

PIKIMO @ tOSU

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In collaboration with Julia Gehrlein and Jure Zupan (23xx.xxxx)

Matter-matter asymmetry

$$\eta \equiv \frac{n_B - n_{\bar{B}}}{n_\gamma} \sim \text{constant after BBN}$$

Measured value: $\eta = (6.12 \pm 0.04) \times 10^{-10}$

Naive estimate: Consider $\eta = 0$ and compute ratio at freeze out ($T_{\text{FO}} \sim 20$ MeV).

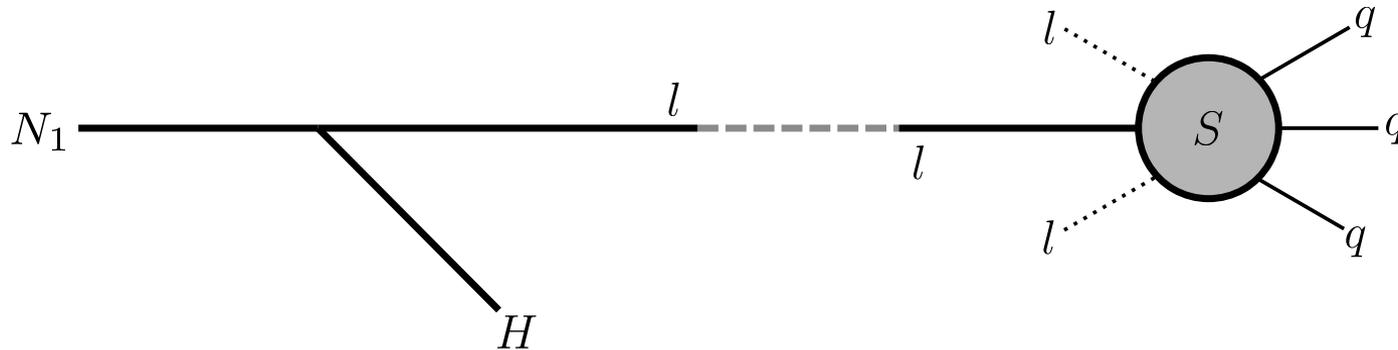
$$\frac{n_B}{n_\gamma} \simeq \frac{n_{\bar{B}}}{n_\gamma} \simeq \left(\frac{m_p}{T}\right)^{3/2} e^{-m_p/T} \simeq 10^{-18}$$

Matter-matter asymmetry

What about electroweak baryogenesis with SM ingredients?
Requires strong 1st order phase transition bubbles i.e. $m_H < 72$ GeV.

BSM required!

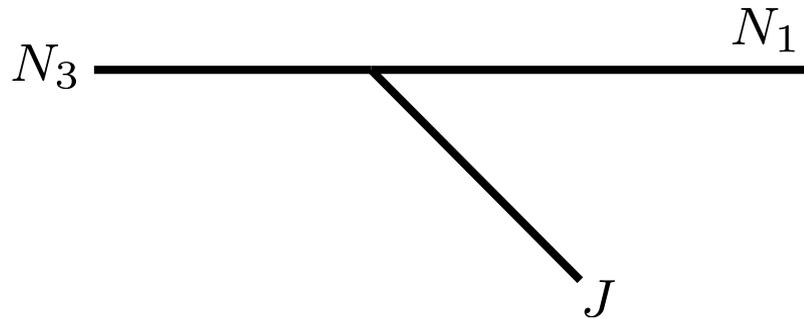
Many models... for example high scale (> 100 GeV) leptogenesis + sphalerons



The mechanism - overview

Our mechanism: low-scale (< 100 GeV) leptogenesis + DM scattering

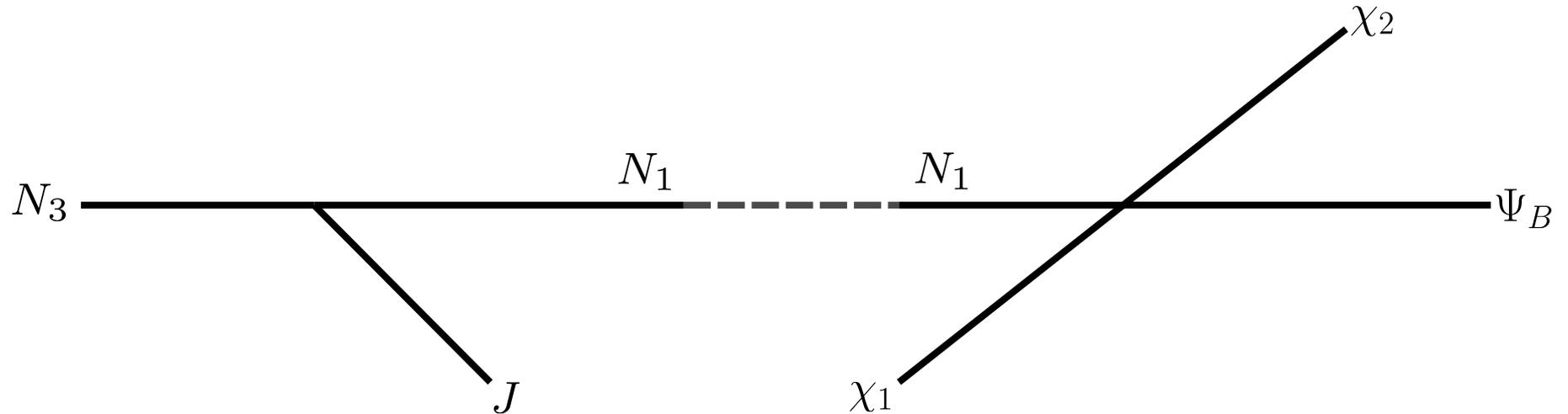
1. Production of lepton asymmetry



The mechanism - overview

Our mechanism: low-scale (< 100 GeV) leptogenesis + DM scattering

1. Production of lepton asymmetry
2. Transfer to baryon asymmetry

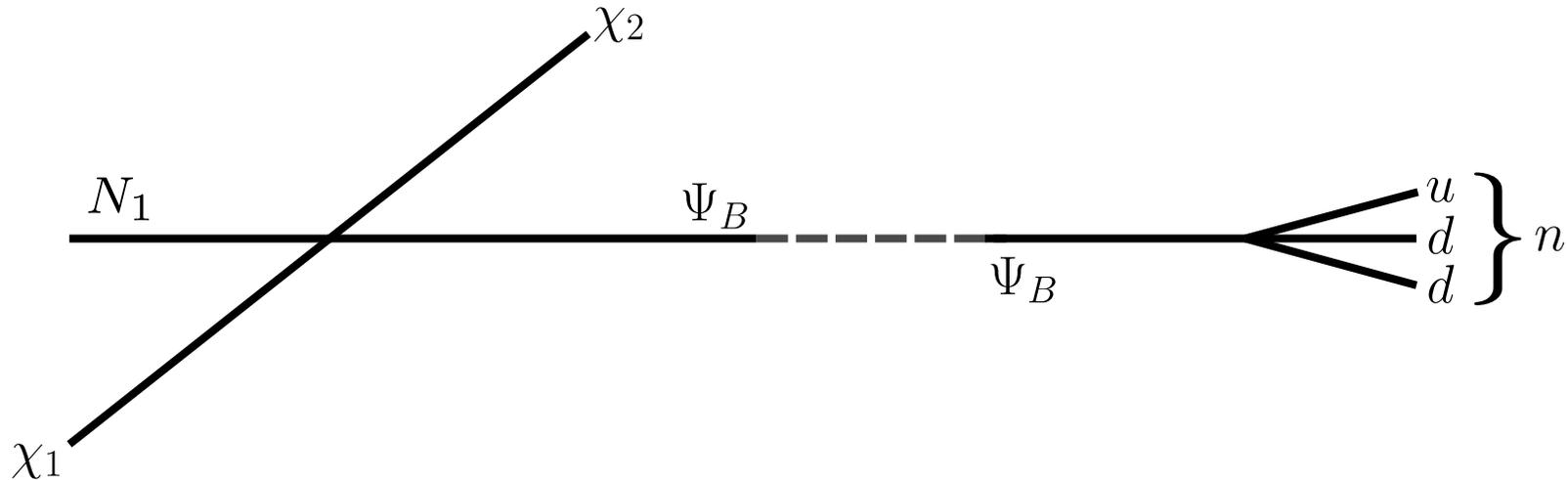


The mechanism - overview

Our mechanism: low-scale (< 100 GeV) leptogenesis + DM scattering

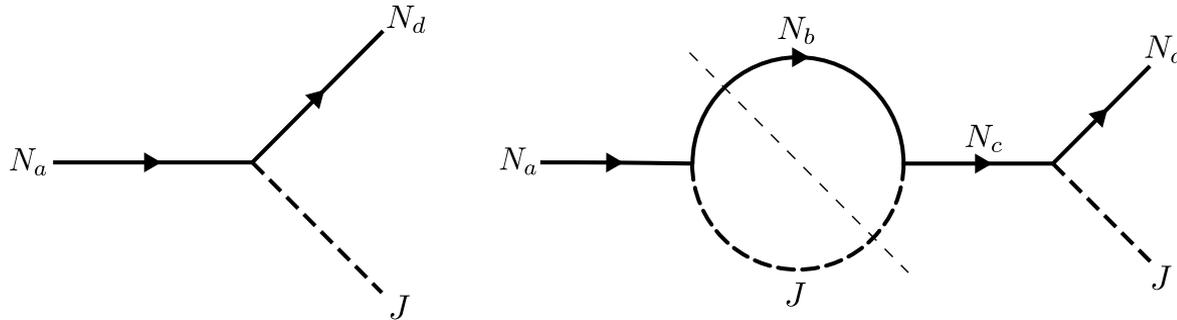
2. Transfer to baryon asymmetry

3. Heavy dark baryon decay



The mechanism - details

1. Lepton asymmetry



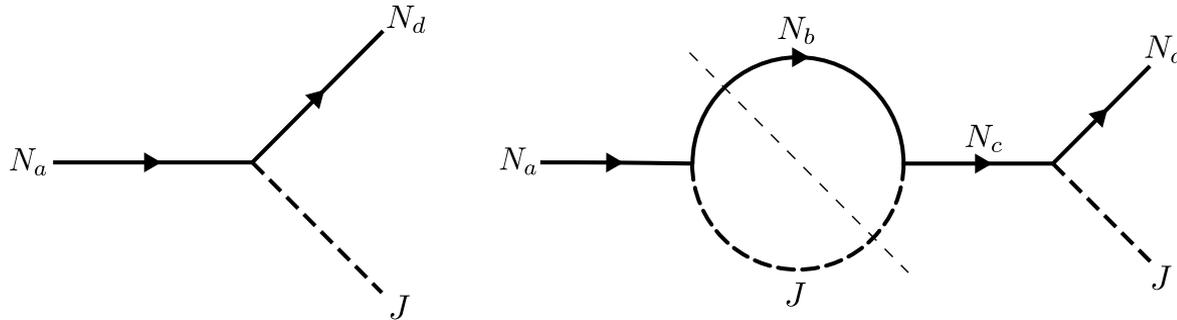
A) Dirac mass

B) Majorana mass

$$\epsilon = \frac{\Delta\Gamma}{\Gamma} \propto \frac{\text{Im}[y_{cb}y_{ba}^*y_{dc}^*y_{da}]}{|y_{da}|^2}$$

The mechanism - details

1. Lepton asymmetry



A) Dirac mass

B) Majorana mass

$$\epsilon = \frac{\Delta\Gamma}{\Gamma} \propto \frac{\text{Im}[y_{cb}y_{ba}^*y_{dc}^*y_{da}]}{|y_{da}|^2}$$

The mechanism - details

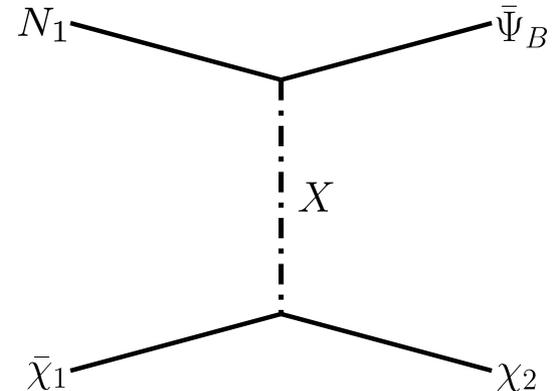
2. Baryon asymmetry

Introduce a dark sector:

	N_1	X	Ψ_B	χ_1	χ_2
L	1	1	0	2	1
B	0	-1	1	1	2
spin	1/2	0	1/2	1/2	1/2

With interactions:

$$\mathcal{L} \supset \lambda \bar{N}_1 X \Psi_B + \lambda' \bar{\chi}_1 X \chi_2 + \text{h.c.}$$



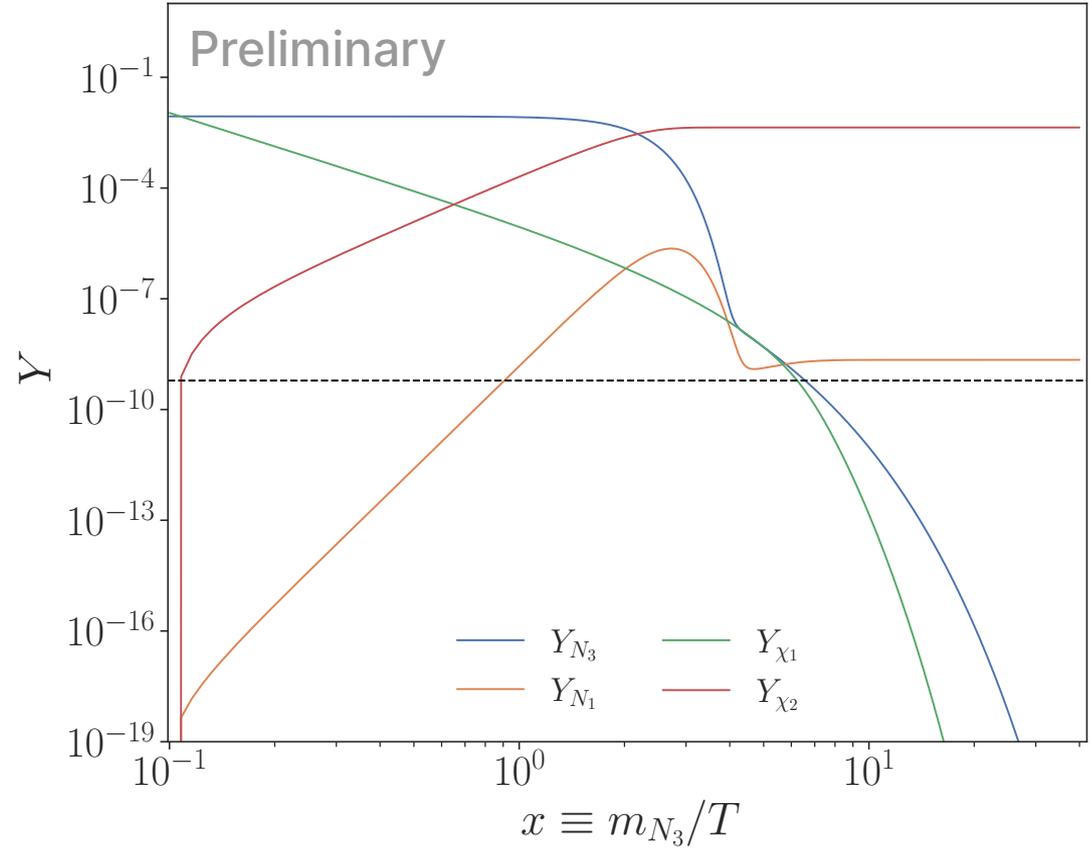
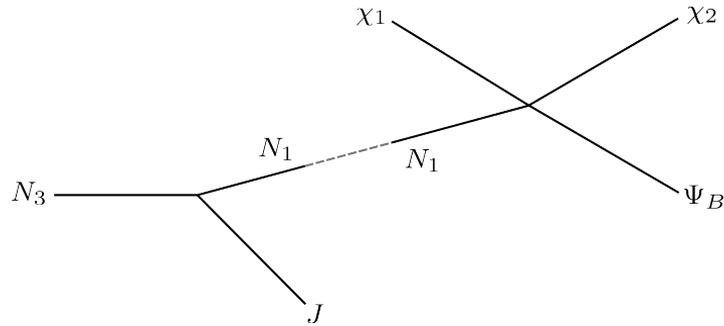
Evolution

$$m_{N_3} = 20 \text{ GeV}$$

$$m_{\chi_1} = 0.5 \text{ GeV}$$

$$m_{\chi_2} = 0.3 \text{ GeV}$$

$$m_{\psi_B} = 1.2 \text{ GeV}$$



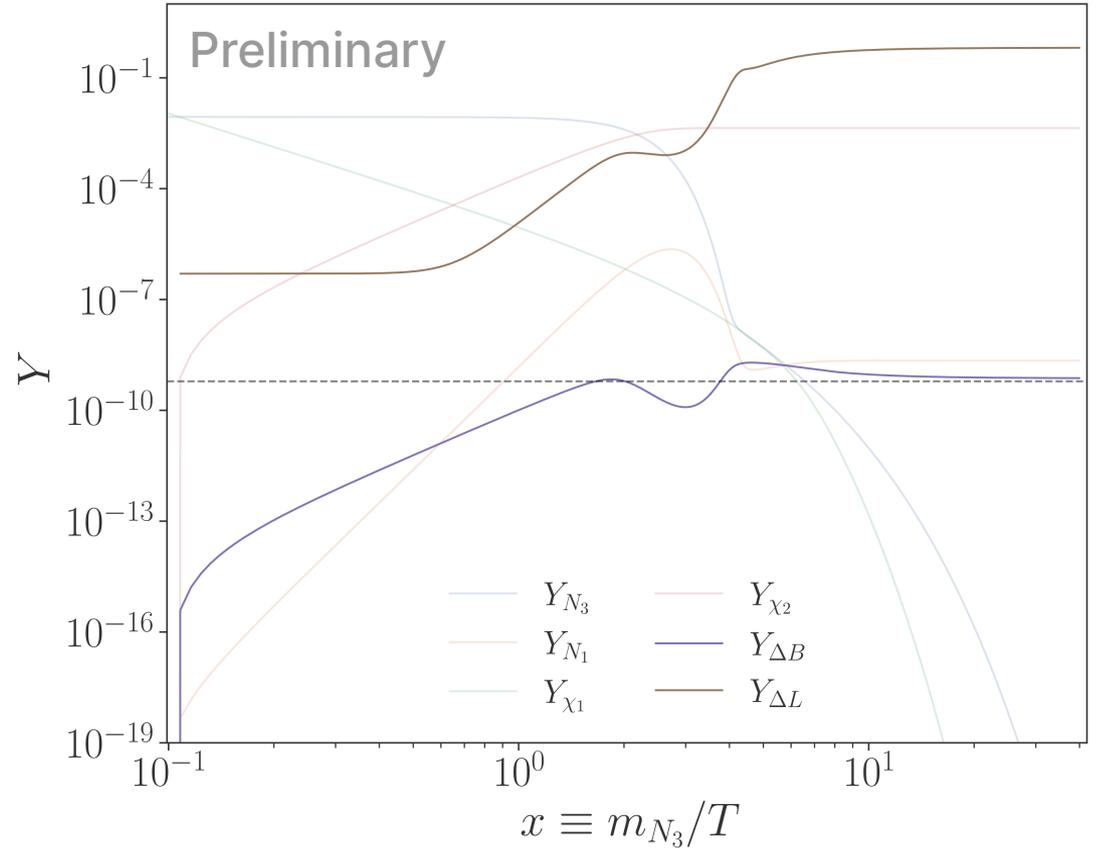
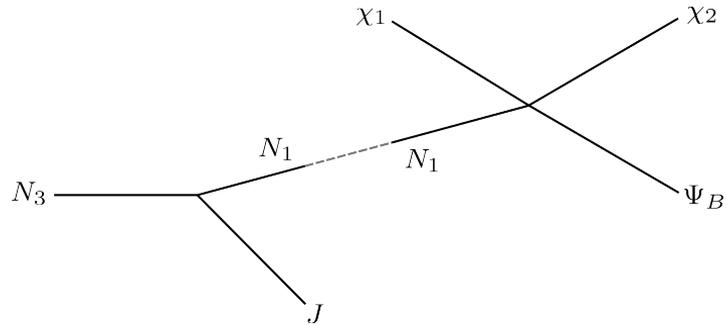
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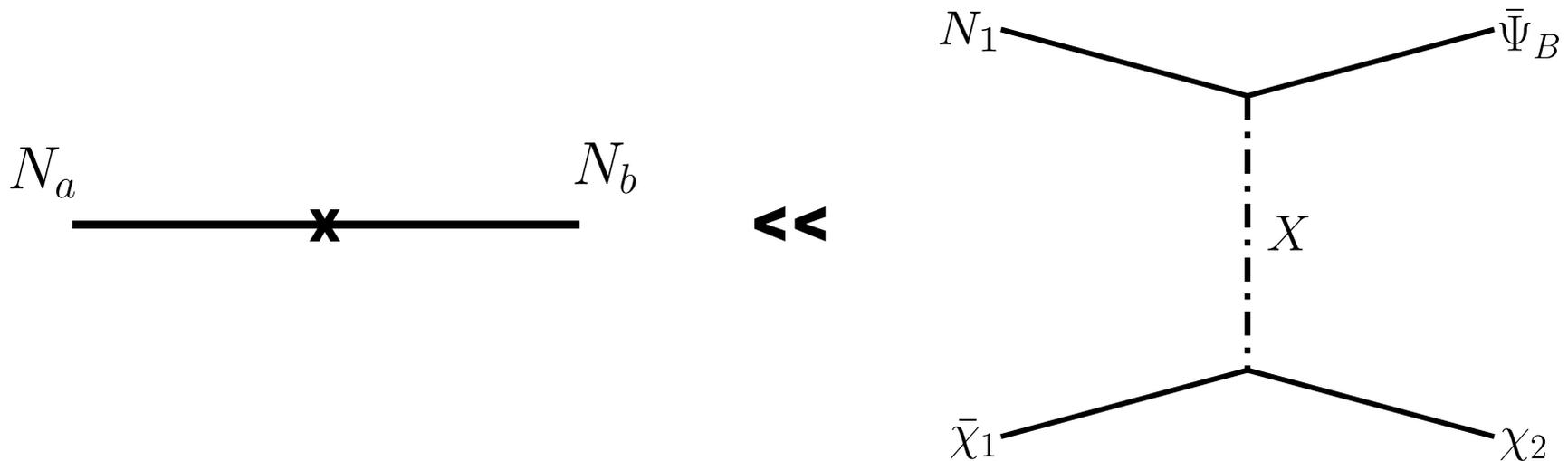
$$m_{\psi_B} = 1.2 \text{ GeV}$$



Majorana neutrinos

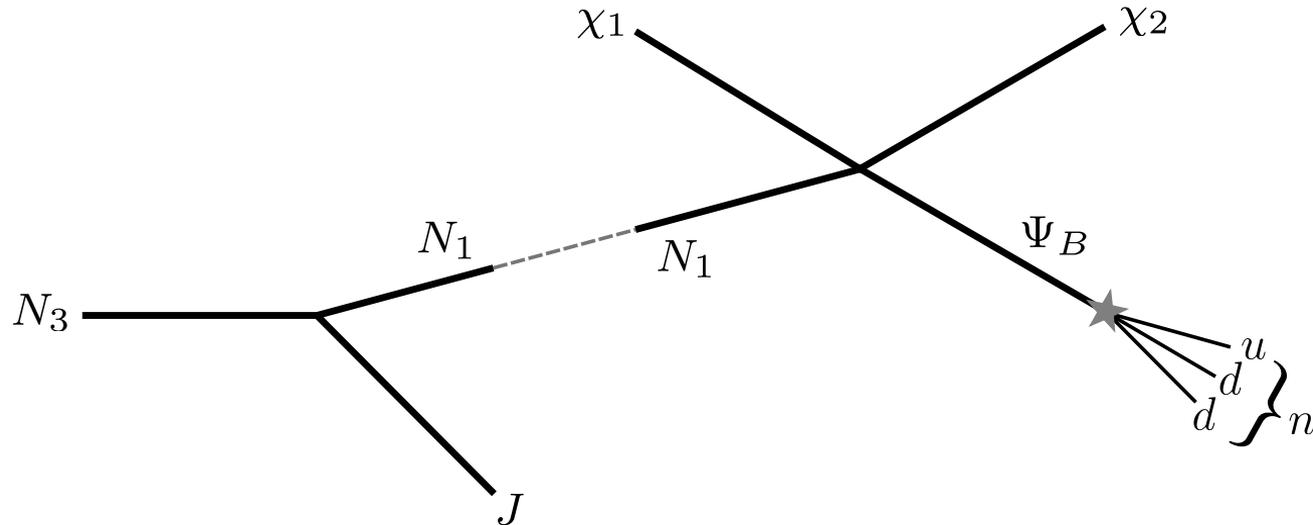
Connect lepton asymmetry to smallness of neutrino masses

$J \rightarrow \text{Majoron}$



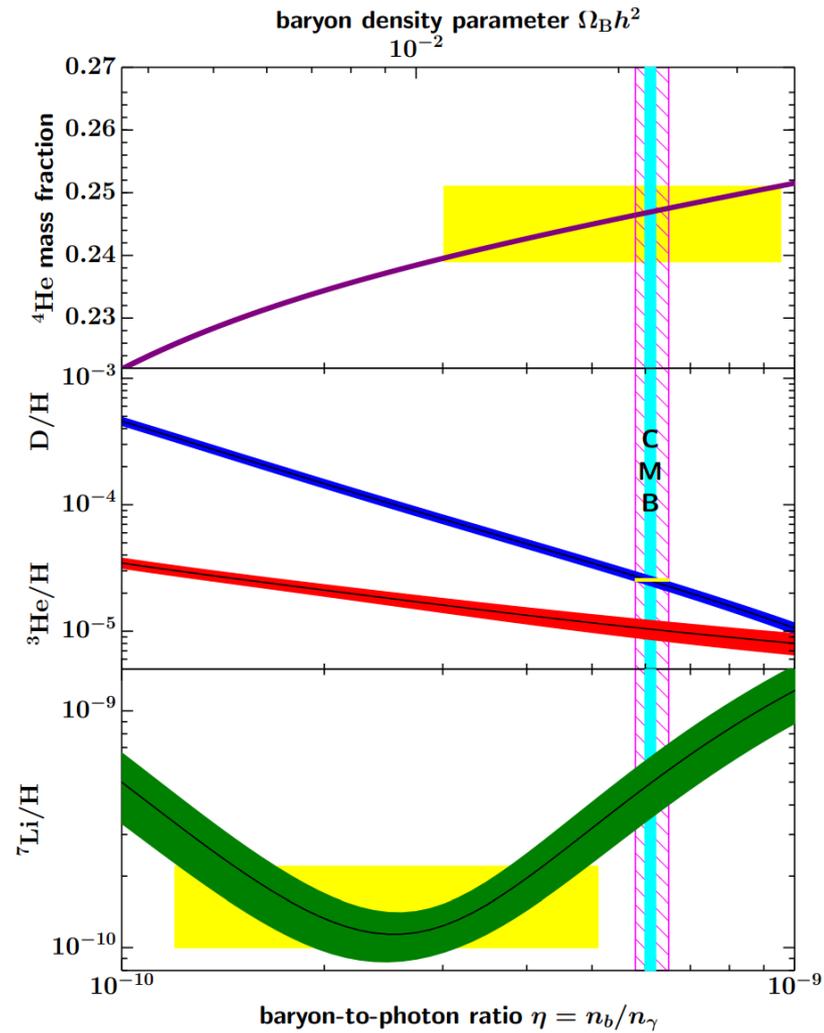
Conclusion

Phenomenologically promising model of low-scale leptogenesis.



BACK-UPS

Primordial abundances as predicted by the standard model of BBN (1912.01132)



The mechanism - details

1. Lepton asymmetry

Spontaneous symmetry breaking of $U(1)_L$ at the scale f

$$\sigma \rightarrow \frac{1}{\sqrt{2}}(f + \sigma_0 + iJ)$$

Neutrinos acquire hierarchical masses: $\mu' \ll m_D \ll m$, $m_\nu \simeq \frac{\mu m_D^2}{m^2}$, $m_{N_1, N_2} \simeq m \mp \frac{\mu}{2}$

$$\mathcal{L}_J = -\frac{iJ}{2f} \bar{\mathbf{N}}_R^a \begin{pmatrix} \frac{\mu' m_D^2}{m^2} & -\frac{i\mu' m_D}{\sqrt{2}m} & -\frac{\mu' m_D}{\sqrt{2}m} \\ -\frac{i\mu' m_D}{\sqrt{2}m} & -\frac{\mu'}{2} & \frac{i\mu'}{2} \\ -\frac{\mu' m_D}{\sqrt{2}m} & \frac{i\mu'}{2} & \frac{\mu'}{2} \end{pmatrix}_{ab} \mathbf{N}_L^b + \text{h.c.} \equiv -J \bar{\mathbf{N}}_R^a y_{ab} \mathbf{N}_L^b + \text{h.c.}$$

The mechanism - details

1. Lepton asymmetry

Introduce SM singlets:

	\mathcal{N}_i	\mathcal{N}'_i	σ
L	1	-1	2
spin	1/2	1/2	0

Neutrino sector (extended inverse seesaw):

$$\mathcal{L}_M = -\frac{1}{2} \begin{pmatrix} \overline{\nu_R^C} & \overline{\mathcal{N}_R} & \overline{\mathcal{N}'_R} \end{pmatrix} \begin{pmatrix} 0 & m_D^\top & 0 \\ m_D & \lambda\sigma^* & m^\top \\ 0 & m & \lambda'\sigma \end{pmatrix} \begin{pmatrix} \nu_L \\ \mathcal{N}_L^C \\ \mathcal{N}'_L^C \end{pmatrix} + \text{h.c.}$$