Majoron Dark Matter, High-Scale Seesaw, and Leptogenesis

PIKIMO 21, November 7th, 2026

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Department of Physics and Astronomy



University of Pittsburgh®

Elevator Pitch

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- Lepton number breaking in singlet majoron model
- Vanilla leptogenesis influences symmetry breaking scale, reheating temperature
- Influences cosmological Majoron production
- Different cosmological constraints on Majoron

Model

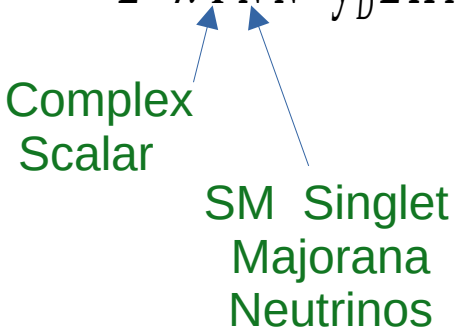
Model

$$L \supset \lambda \Phi N N + y_D L H N + h.c. + V(\Phi)$$

Complex Scalar

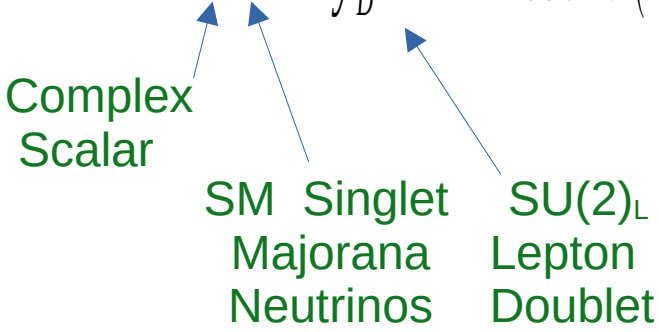
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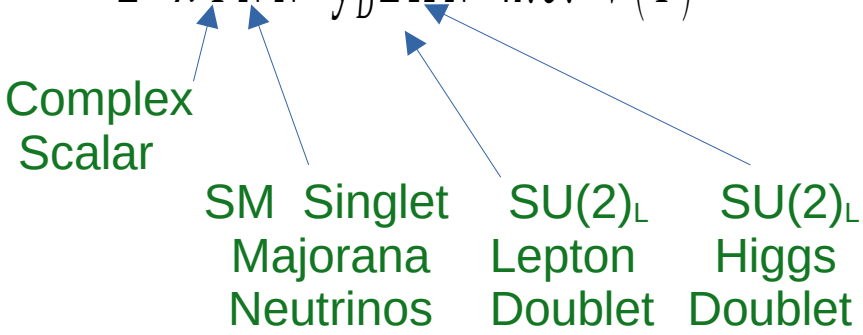
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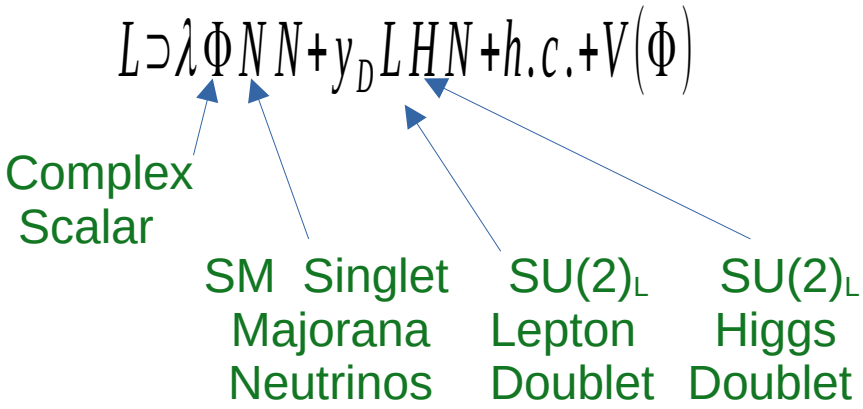
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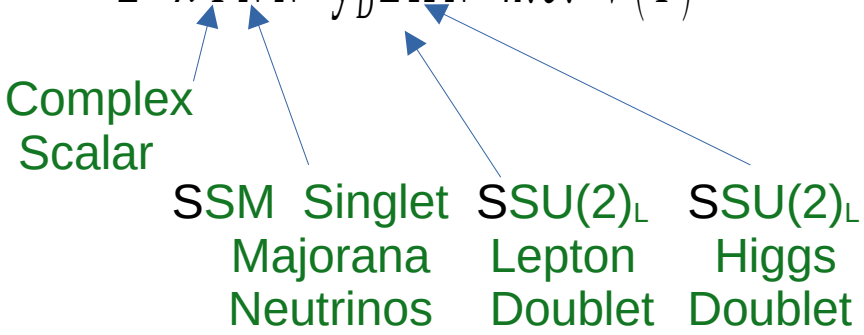
- Scalar Potential

$$V(\Phi) = \kappa\left(\Phi^2 - f^2\right)^2$$

Model

- $U(1)_L$ Global Symmetry

$$L \supset \lambda \Phi N N + y_D L H N + h.c. + V(\Phi)$$



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Complex Scalar

SSM Singlet Majorana Neutrinos

SSU(2)$_L$ Lepton Doublet

SSU(2)$_L$ Higgs Doublet

- U(1)$_L$ Global Symmetry

Spontaneously Broken

$\langle \Phi \rangle = \frac{f}{\sqrt{2}}$ → Symmetry Breaking Scale

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Spontaneously Broken

$$\langle \Phi \rangle = \frac{f}{\sqrt{2}}$$

Symmetry Breaking Scale

$$\Phi N N \rightarrow \frac{f}{\sqrt{2}} N N$$

- Lepton number violation
- Majorana mass for N

Model

$$\Phi = \frac{(f+S)}{\sqrt{2}} e^{i\frac{a}{f}}$$

Majoron

$$\theta = \frac{a}{f}$$

Model

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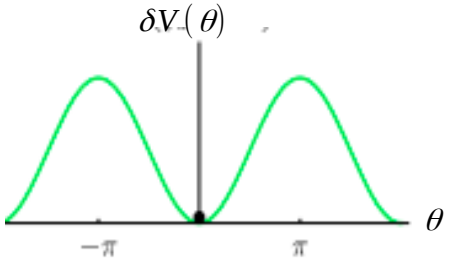
Majoron

$$\theta = \frac{a}{f}$$

- Explicit $U(1)_L$ breaking

$$\delta V = m_a^2 f^2 \left(1 - \cos\left(\theta\right)\right)$$

Majoron Mass



Phenomenology

- Leptogenesis

  $N \to LH, \bar{L}\bar{H}$

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- Seesaw I

  $\frac{f \lambda}{\sqrt{2}} N N + y_D L H N \to m_\nu \simeq y_D^T m_N^{-1} y_D$

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Tree Level

$a \to \nu\nu$

$\Gamma(a \to \nu\nu) \simeq \frac{m_a}{16\pi f^2} \sum_{i=1}^{3} {m_{\nu i}}^2$

[C. Garcia-Cely, J. Heeck, 2017]

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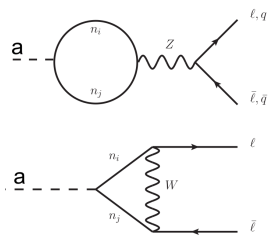
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One Loop

$a \to \bar{f} f$



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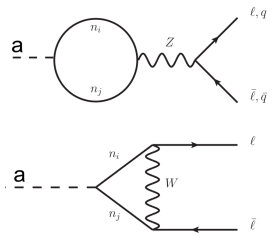
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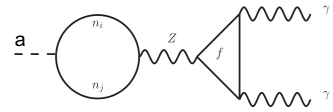
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[J. Heeck, H. Patel, 2019]

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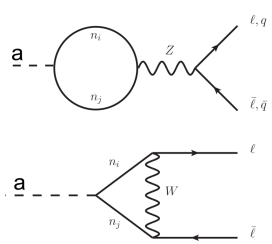
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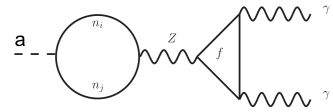
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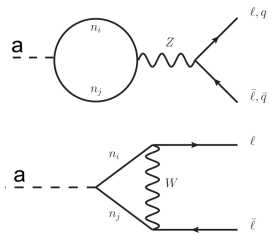
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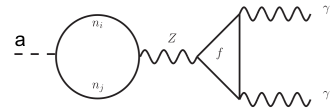
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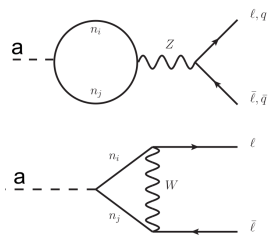
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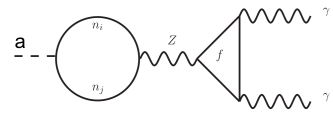
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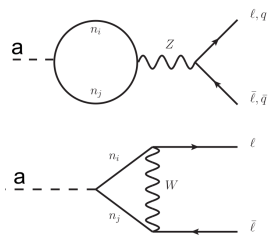
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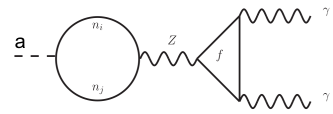
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- Natural separation between sub and super MeV

C[**[C. Garcia-Cely, J. Heeck, 2017]**

Results

Pre-Inflationary

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Short Inflation

Pre-Inflationary

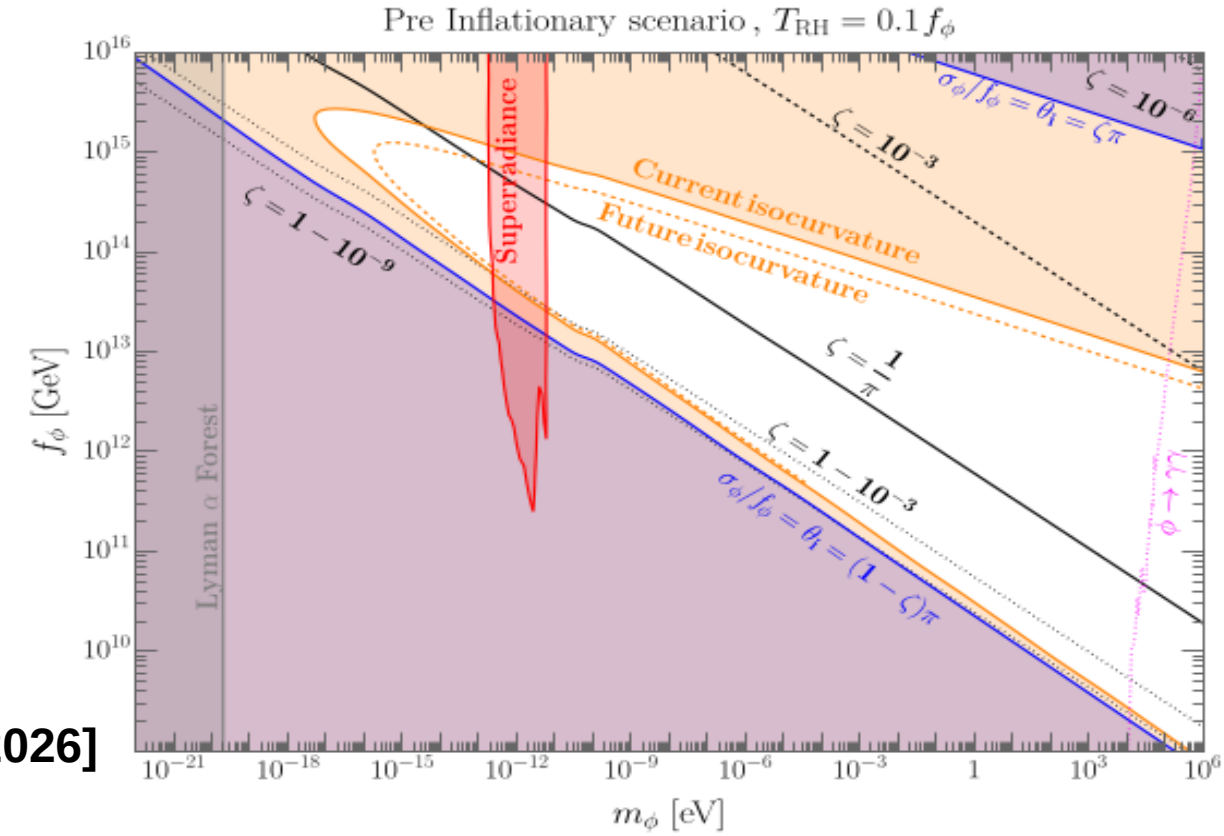
Short Inflation

- Maximal Reheating Temperature

Pre-Inflationary

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[Batell, Dasgupta, SD, Ghalsasi, 2026]

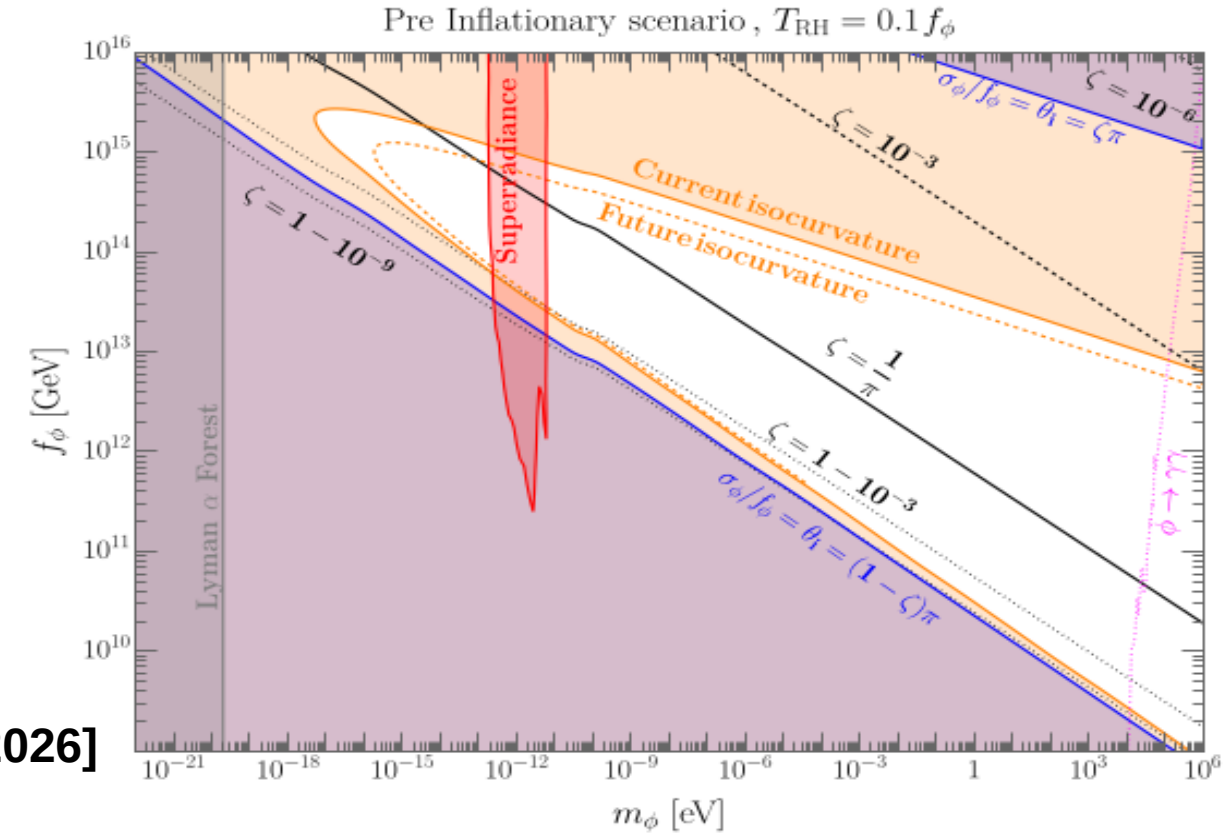
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$$\zeta = \frac{\theta_i}{\pi}$$

[Batell, Dasgupta, SD, Ghalsasi, 2026]



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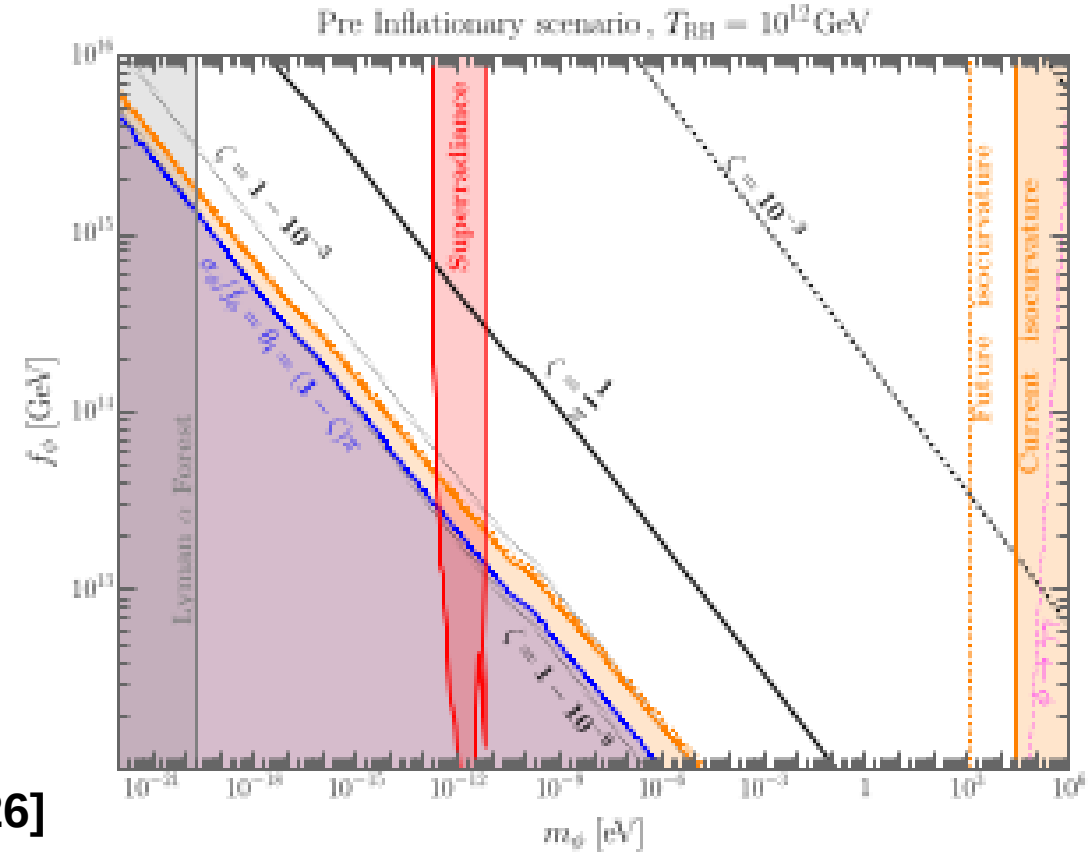
- Intermediate Reheating Temperature

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Short Inflation

- Intermediate Reheating Temperature

$T_{RH} = 10^{12}$ GeV



[Batell, Dasgupta, SD, Ghalsasi, 2026]

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Short Inflation

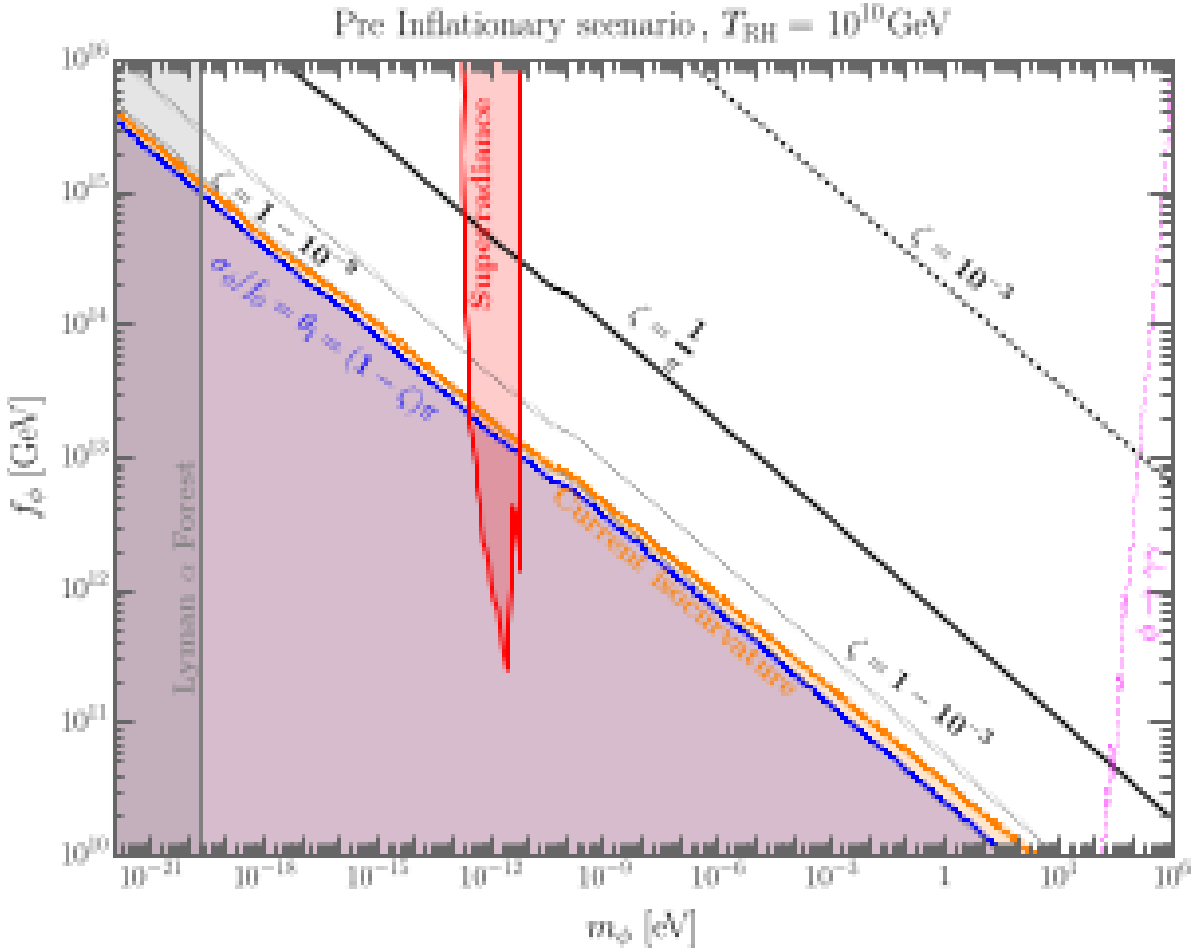
- Minimal Reheating Temperature

Pre-Inflationary

Short Inflation

- Minimal Reheating Temperature
  $T_{RH} = 10^{10}$ GeV

[Batell, Dasgupta, SD, Ghalsasi,2026]

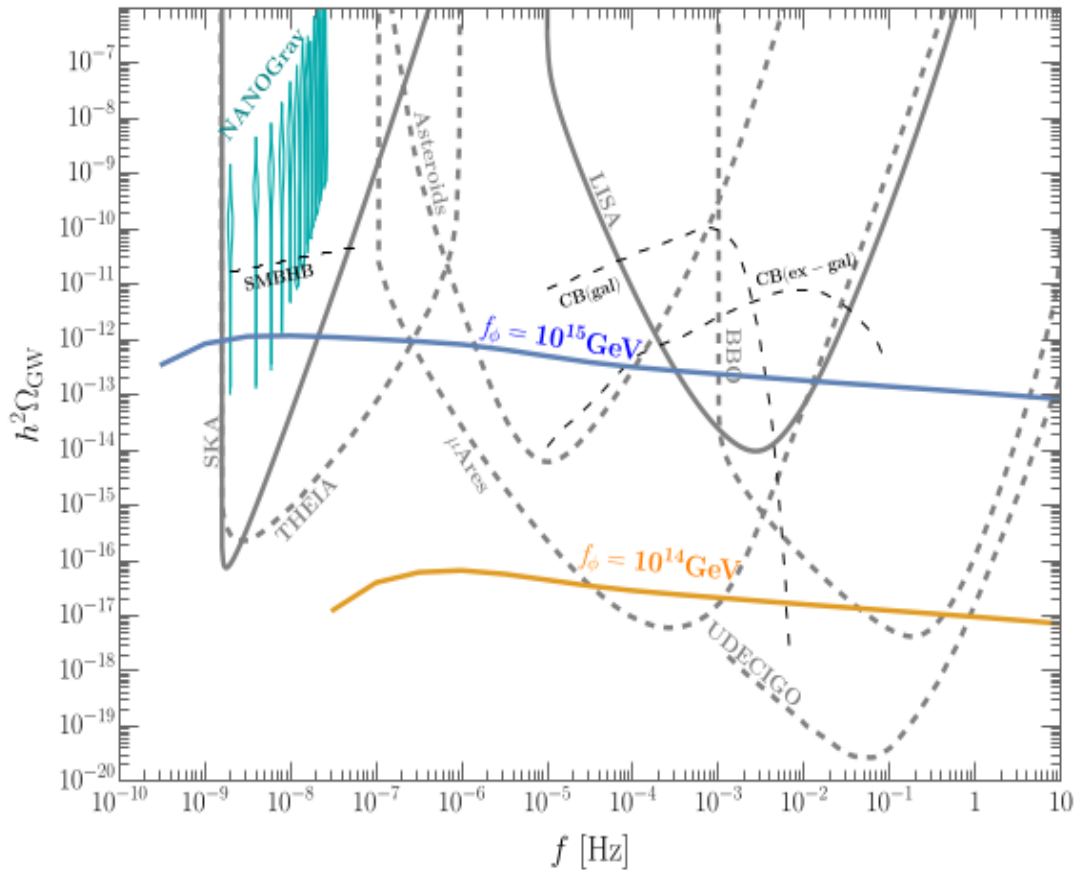


Post Inflationary

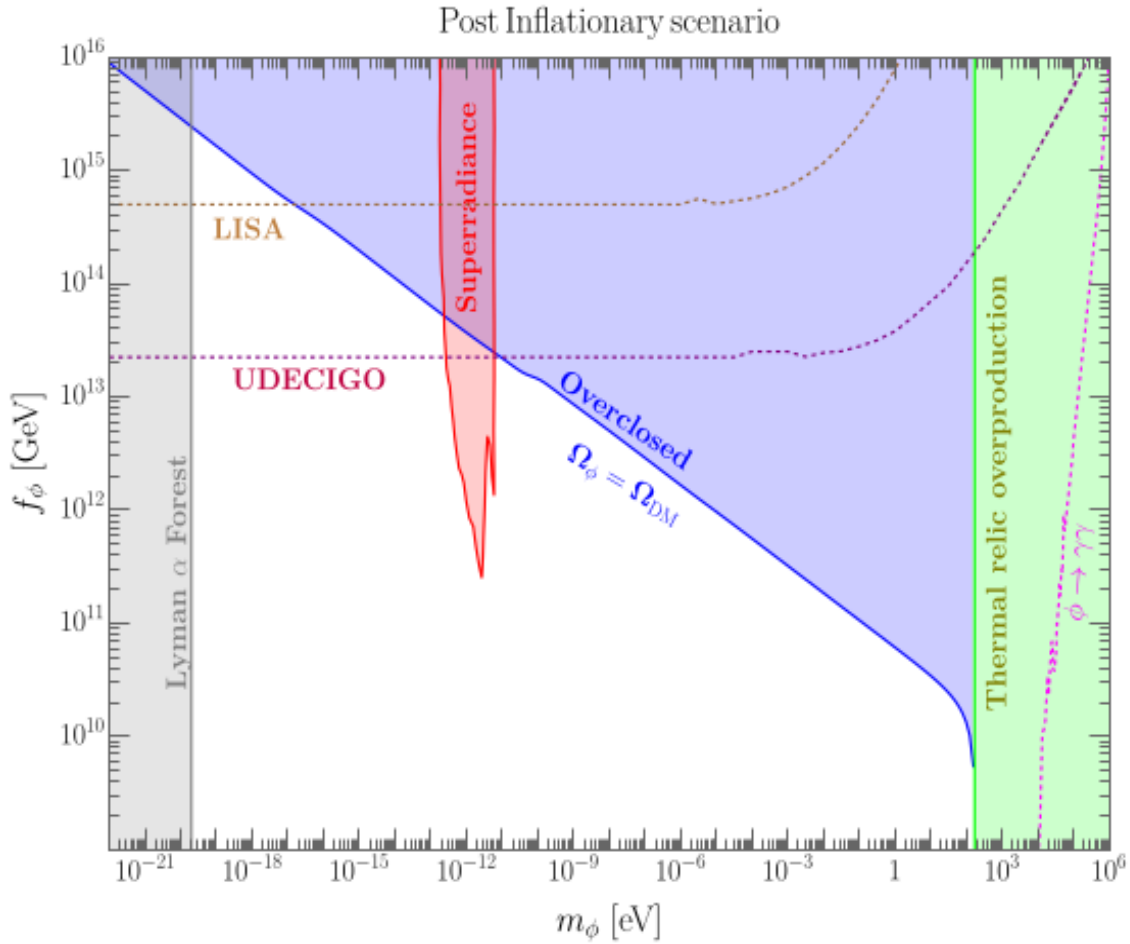
Post Inflationary

- Stochastic Gravitational Wave Background

[Batell, Dasgupta, SD, Ghalsasi, 2026]



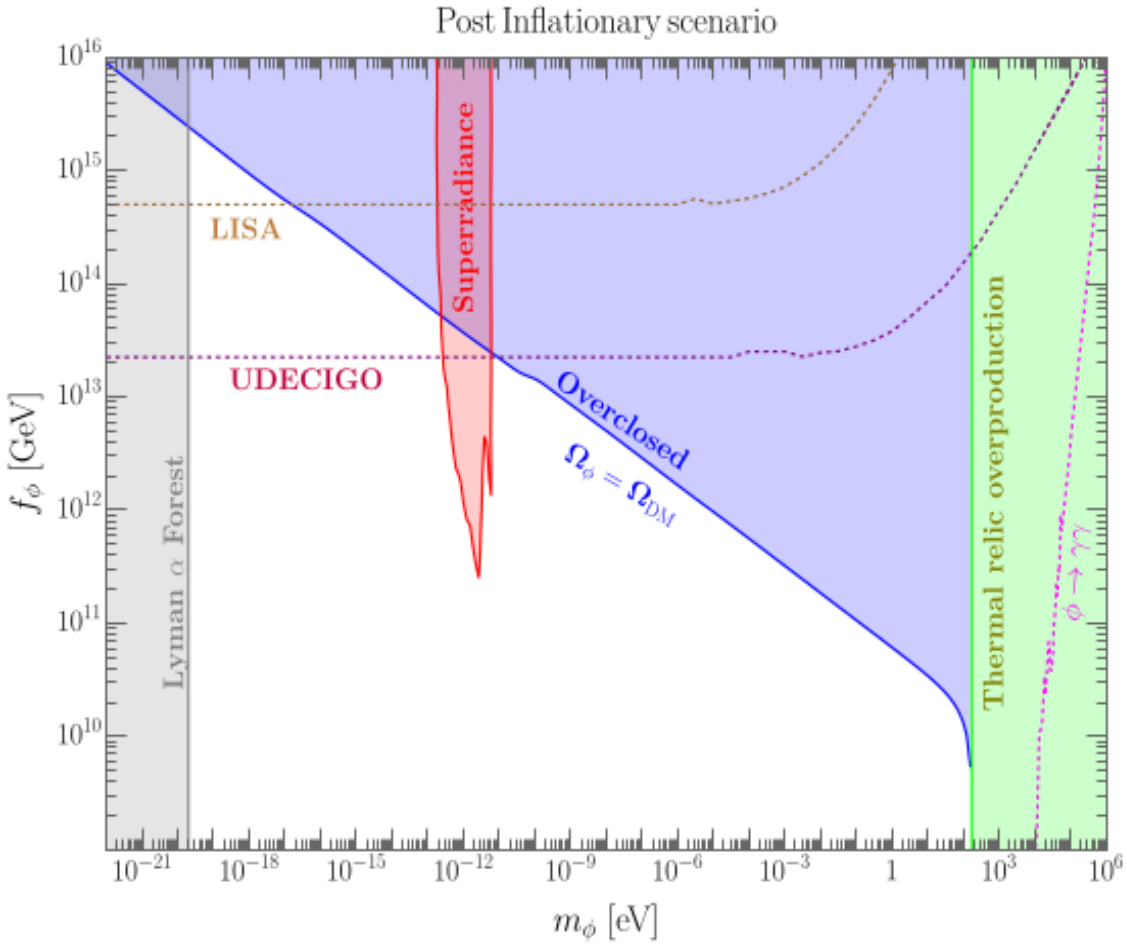
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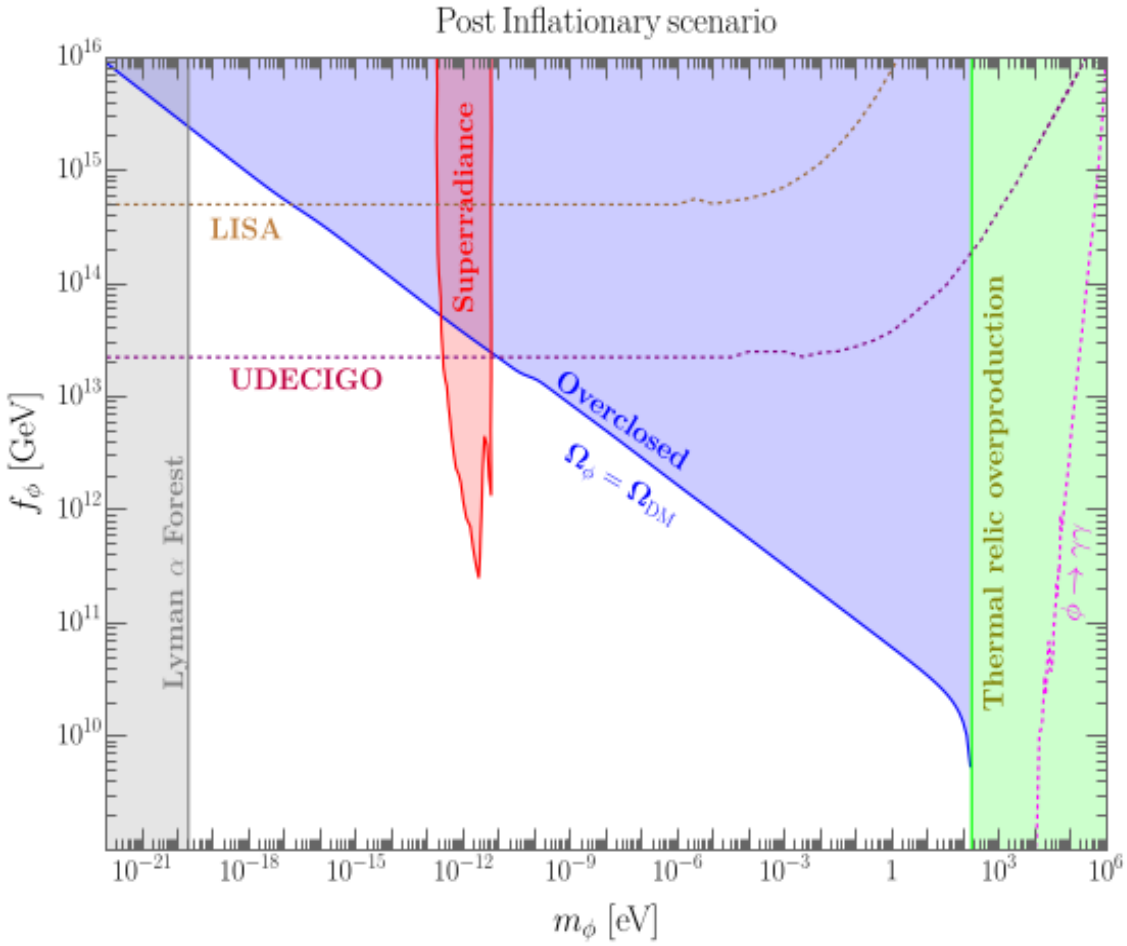
- $m_\phi \geq 170$ eV ruled out from Thermal overproduction



[Batell, Dasgupta, SD, Ghalsasi, 2026]

Post Inflationary

- $m_\phi \geq 170$ eV ruled out from Thermal overproduction
- Constraints from current and future GW experiments



[Batell, Dasgupta, SD, Ghalsasi, 2026]

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- Constrains the parameter space


Thank You