Majoron for cogenesis of BAU & DM

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19TH PATRAS WORKSHOP ON AXIONS, WIMPS AND WISPS

15-20 SEPTEMBER 2024
UNIVERSITY OF PATRAS
PATRAS, GREECE

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30 JUNE 2024

AXION-
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SCIENTIFIC PROGRAMME

THE PHYSICS CASE FOR WIMPS, AXIONS
AND WISPS // DIRECT AND INDIRECT
SEARCHES FOR DARK MATTER AND

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Baryogenesis & DM from the same origin?

Majoron $\theta \equiv \frac{a}{f_a}$ in Seesaw Model with $U(1)_{B-L}$

Connection to neutrino mass

$$\mathcal{L}_N = y_\nu lHN + \frac{1}{2}\Phi NN + \text{h.c.} \Leftarrow \Phi = \frac{f_a}{\sqrt{2}}e^{i\theta}$$

$$V_n = \frac{1}{n^2}m_a^2 f_a^2 (1 - \cos(n\theta))$$

$$\mathcal{L}_\theta = \sum x_\psi \partial_\mu \theta \, \bar{\psi}\gamma^\mu \psi$$

DM from classical oscillation of $\theta, \dot{\theta}$

Spontaneous Baryogenesis in the background of $\dot{\theta} \neq 0$

Cohen-Kaplan, '87, '88

$$\frac{\rho_{\text{DM}}}{s} = m_a \frac{n_a}{s} = m_a Y_\theta \approx 0.44\text{eV}$$

$$Y_B = \frac{\mu_B T^2}{s} \sim \left(\frac{\dot{\theta}}{T}\right)_{T_B} \sim 10^{-10}$$

Axiogenesis

Majorogenesis

Co-Harigaya, 1910.02080

- pNGB of $U(1)_{PQ}$ $\qquad \mathcal{L} = \frac{a}{f_a} F\tilde{F}$

- B+L is generated when WS/SS is in equilibrium:

$$\text{WS}: N_g(3\mu_q + \mu_l) = c_W \dot{\theta}$$

$$\text{SS}: N_g(2\mu_q + \mu_{u^c} + \mu_{d^c}) = c_S \dot{\theta}$$

- $Y_{B,B+L}$ frozen at $T_B = T_{EW}$

$$Y_B = c_B Y_\theta \left(\frac{T_{EW}}{f_a}\right)^2 \qquad Y_\theta = \frac{n_\theta}{s} = \frac{\dot{\theta} f_a^2}{s}$$

$$\Rightarrow m_a = \frac{0.44\text{eV}}{Y_\theta} \approx 10^{-9}\,\text{eV}\left(\frac{10^{11}\text{GeV}}{f_a}\right)^2 \Longleftrightarrow m_a \sim \frac{m_\pi f_\pi}{f_a}$$

- pNGB of $U(1)_{B-L}$

$$\mathcal{L} = y_\nu LHN + \frac{1}{2}M_N NN + \frac{\dot{a}}{f_a}\sum_\psi x_\psi \,\bar{\psi}\gamma^0\psi$$

- B-L is generated when LNV is in equilibrium
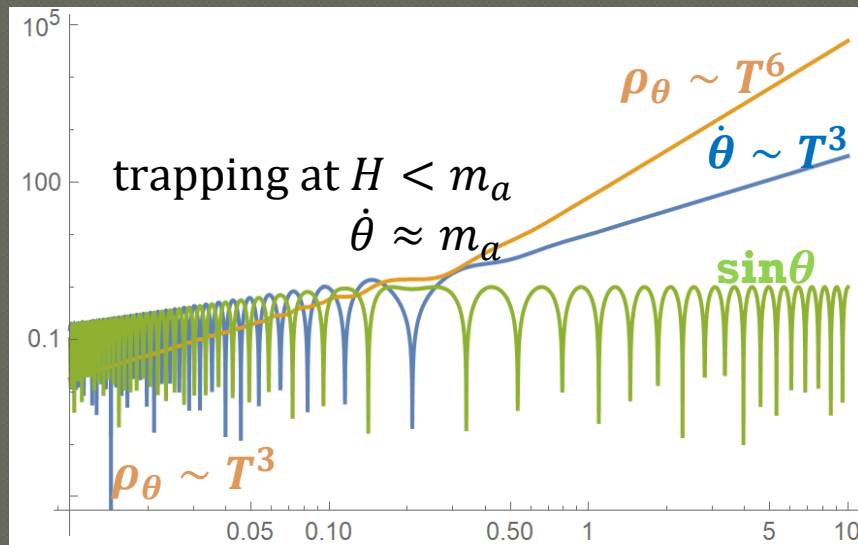
$$\text{LNV}: \mu_l + \mu_H = x_l \dot{\theta}$$

- $Y_{B,B-L}$ frozen at $T_B \sim \text{Max}(M_N, T_{EW})$

$$Y_B = c_B Y_\theta \left(\frac{T_B}{f_a}\right)^2$$

$$\Rightarrow m_a = \frac{0.44\text{eV}}{Y_\theta} = 0.44\text{eV}\frac{c_B}{Y_B}\left(\frac{T_B}{f_a}\right)^2$$
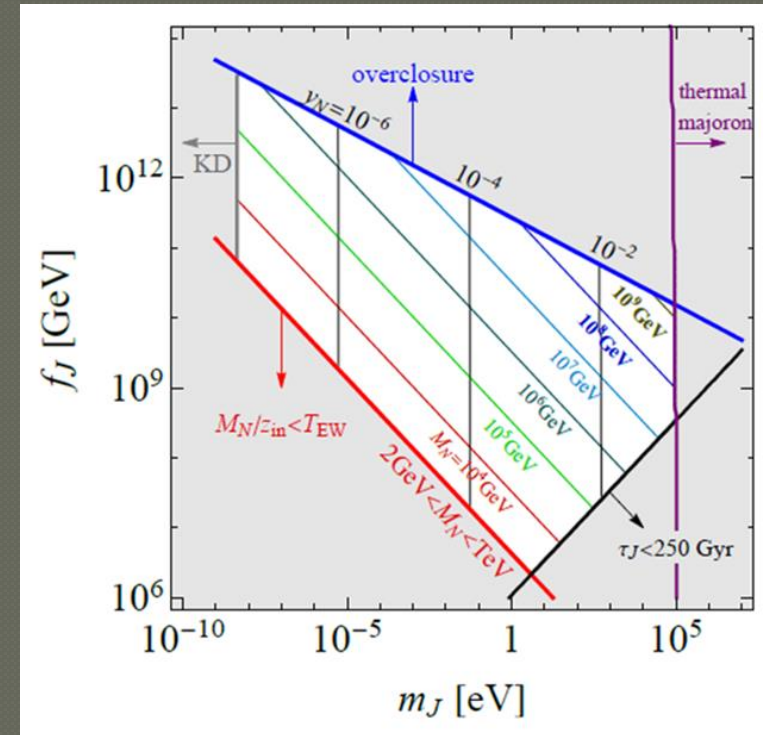
Cogenesis from kinetic motion

- $\ddot{\theta} + 3H\dot{\theta} + m_a^2 \sin\theta = 0$

$$\rho_\theta = f_a^2 \left(\frac{1}{2}\dot{\theta}^2 + m_a^2(1 - \cos\theta) \right)$$
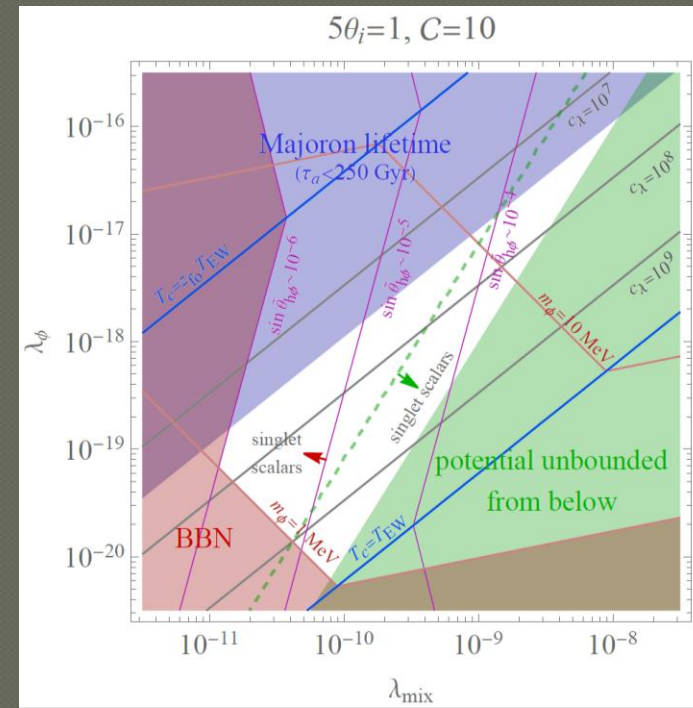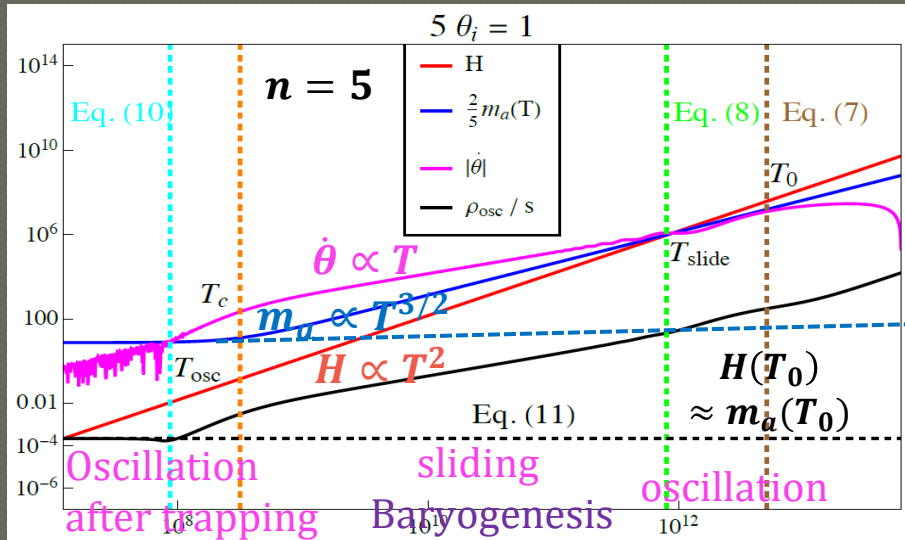
Co, Hall, Harigaya, 1910.14152

Cogenesis from misalignment: symmetry non-restoration

$$\ddot{\theta} + H\dot{\theta} + m_a^2(T)\sin\theta = 0$$

$$V(\Phi, S) = \lambda_\phi |\Phi|^4 - 2\lambda_{\text{mix}}|\Phi|^2|H|^2 + \cdots$$

$$f_a(T) = f_{a0}\sqrt{1 + \frac{T^2}{T_c^2}} \qquad m_a^2(T) = m_{a0}^2 \left(\frac{f_a(T)}{f_{a0}}\right)^{n-2}$$

$$m_{a0} \approx \frac{5\text{eV}}{C^{\frac{1}{9}}(5\theta_i)^{\frac{4}{9}}}\left(\frac{10^8}{\lambda_{\text{mix}}/6\lambda_\phi}\right)^{\frac{5}{9}}$$

$$f_{a0} \approx 3\cdot10^6\text{GeV}\, C^{\frac{1}{18}}(5\theta_i)^{\frac{2}{9}}\left(\frac{\lambda_{\text{mix}}/6\lambda_\phi}{10^8}\right)^{\frac{5}{18}}$$

- Type-I seesaw model with majoron provides an affordable framework for the simultaneous generation of baryon asymmetry and dark matter enjoying freedom with the parameters (m_a, f_a, M_N).

- Trivial extension to any seesaw models?

- PQ Symmetry non-restoration for cogenesis?