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Cogenesis of baryon and dark matter with PBH and QCD axion

Based on : 2403.02401

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Introduction and The Framework

Motivation

- Apart from solving DM and neutrino mass problem, we aim to bring solution of strong CP problem and matter anti-matter asymmetry within same framework.
- We aim give cosmological observations of high-scale leptogenesis.
- We consider a type-I seesaw framework extended by Peccei-Quinn symmetry.
  1. Complex PQ scalar field : $\sigma \equiv \frac{v_{\rm PQ}+\rho}{\sqrt{2}}\, e^{ia/f_a}$ ($\sigma \sim (1,1,0)$).
  2. A heavy quark : $Q \sim (3,1,0)$.
  3. 3 right-handed neutrinos : $N_R \sim (1,1,0)$.

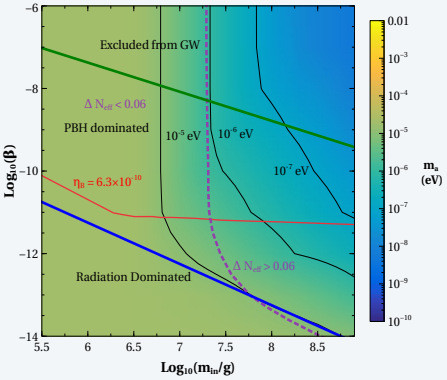
Lagrangian

$$\mathcal{L}_{\mathcal{Y}} = -\left[y\overline{Q}_L \sigma Q_R + G_{ij}\overline{L}_i H l_{jR} + F_{ij}\overline{L}_i \tilde{H} N_{jR} + \frac{1}{2} y_{ij}\, \overline{N}^c_{iR} \sigma N_{jR} \right] + \text{h.c.}$$

- We take : $v_{PQ} = f_a \sim M_i$.

Interplay between Leptogenesis and Axion with PBH

- PBH open up new parameter space to probe.
- Form $m_{\rm in} = \frac{4\pi}{3}\gamma\frac{\rho_R(T_{in})}{H^3(T_{in})}$ with initial fraction $\beta = \frac{\rho_{\rm BH}(T_{\rm in})}{\rho_{\rm R}(T_{\rm in})}$.
- Presence of PBH
  1. Changes $T_{\rm osc}$ as $3M_{\rm p}\mathcal{H}^2 = \rho_r + \rho_{\rm BH}$.
  2. Dilutes existing axions abundance. (2209.14307).
- Baryon-to-photon ratio $\eta_B \approx 10^{-2}\kappa_1\frac{\epsilon}{\xi}$.



Hierarchical; axion 100% DM

DM : Either Axion or RHN

For axion : Vacuum Misalignment.

For RHN : i) PBH evaporation; ✗ ii) Axion portal; ✗ iii) Decay of $W^{\pm}, Z, h$; ✓.

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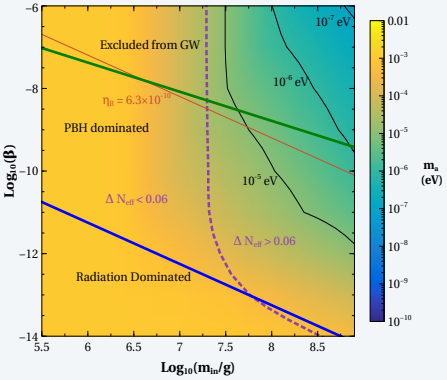

Resonant; axion DM 1%

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Probes from Gravitational Waves

- PBH $\Longrightarrow$ GWs. (2012.08151)

Imposing Leptogenesis

- $f^{\rm peak} \simeq 1.7 \times 10^3\,{\rm Hz}\left(\frac{m_{\rm in}}{10^4{\rm g}}\right)^{-5/6}$.
- Hierarchical : $\Omega_{\rm gw}^{\rm peak} \simeq 6.29 \times 10^{-22}\left(\frac{f_a}{10^{12}{\rm GeV}}\right)^{16/3}\left(\frac{10^7{\rm g}}{m_{\rm in}}\right)^{14/9}$.
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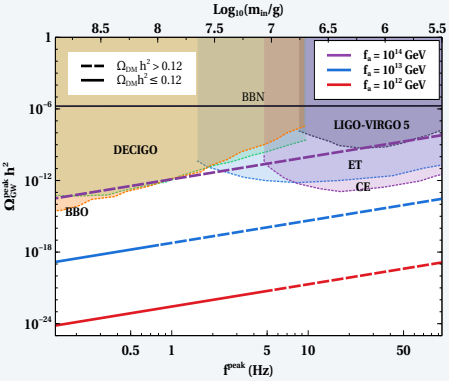

Hierarchical

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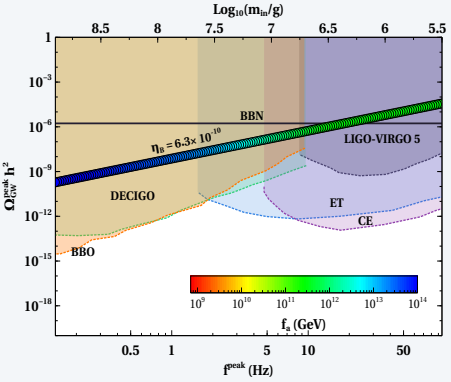
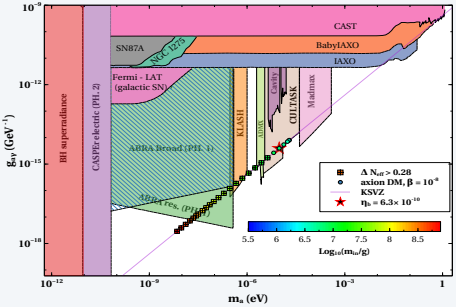


Resonant

Probes from Axion detection

- Axion-photon coupling is $g_{a\gamma} = -\frac{\alpha}{2\pi f_a}\left(\frac{2}{3}\frac{4m_d+m_u}{m_u+m_d}\right) = -1.92\frac{\alpha}{2\pi f_a}$.
- ★ indicates correct observed baryon asymmetry.



Conclusion

- This unified set up address strong CP problem, neutrino mass, DM and baryon asymmetry.
- Resonant enhancement of CP parameter may help in probing high-scale leptogenesis via future GWs experiments.
- Axion detection experiment can also be connected to high-scale leptogenesis.
- Hot axions from PBH ($\Delta N_{\rm eff}$) can get detected in future CMB S4, CMB-HD.

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Thank you for your attention
See you during the poster session.

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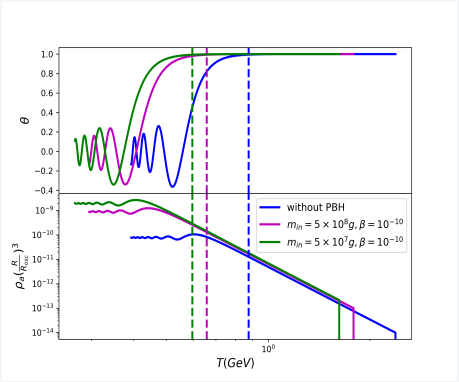
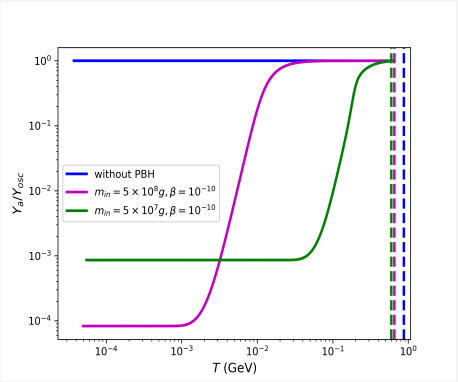
Backup Slide : Axion evolution in presence of PBH



Effect on $T_{\rm osc}$



Entropy Dilution