

Resonant Landau-Zener Conversion in Multi-Axion systems

In collaboration with D. Dunsky, C. Manzari, P. Quilez, and M. Ramos
Presented at Invisibles25

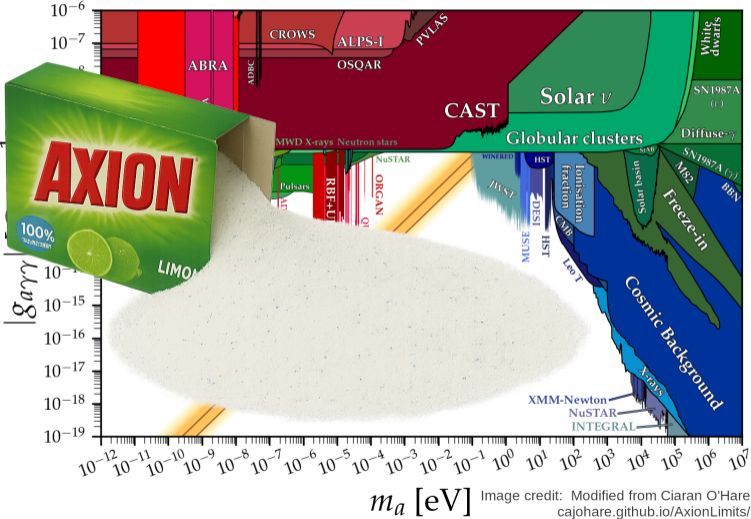
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The axion parameter space (in plural)



QCD axion - ALP mixing

Two axion example:

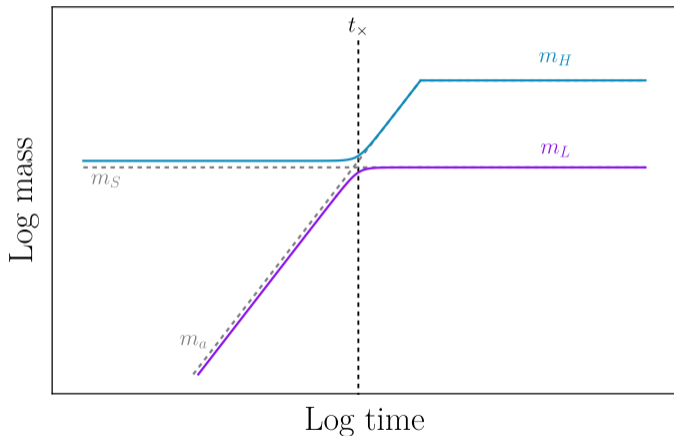
$$\mathcal{L} = \frac{\alpha_s}{8\pi} \left(\frac{a_1}{f} + \frac{a_2}{f} \right) G\tilde{G} - \frac{1}{2} m_s^2 a_2^2$$

- > Both states couple to $G\tilde{G}$
- > PQ symmetry carried by $a_1 \rightarrow a_1 + \delta\theta f$

General case studied in [*Gavala, Quilez, Rasmus*, 2305.15465]:

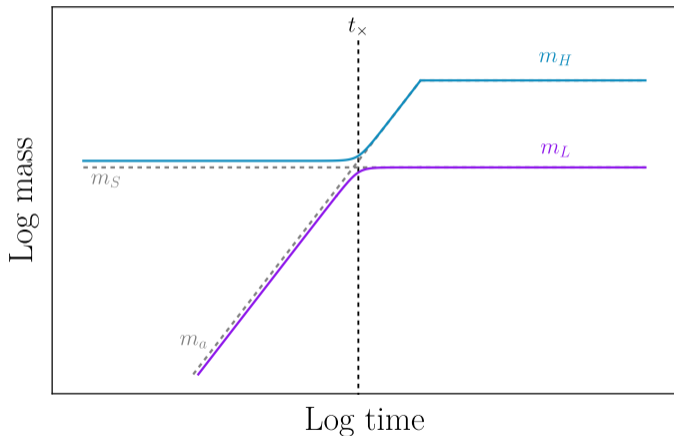
- > QCD axion can mix with N-1 states if mix-potential preserves $U(1)_{PQ}$
- > In general, all states couple to QCD, and all mass eigenstates have $m_i > m_a$
- > The QCD axion is not a mass eigenstate

Cosmology: T-dependent masses and avoided crossing



- > Rich phenomenology
- > A full analytic solution was missing
- > A lot like the neutrino mixing seen on Monday!

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 - We recycle LZ formalism to calculate DM relics

Analytic solution

- 1 Calculate misalignment production with standard WKB solution $\implies n_H^{\text{WKB}}, n_L^{\text{WKB}}$
- 2 Conversion probability calculated from mass mixing matrix parameters:

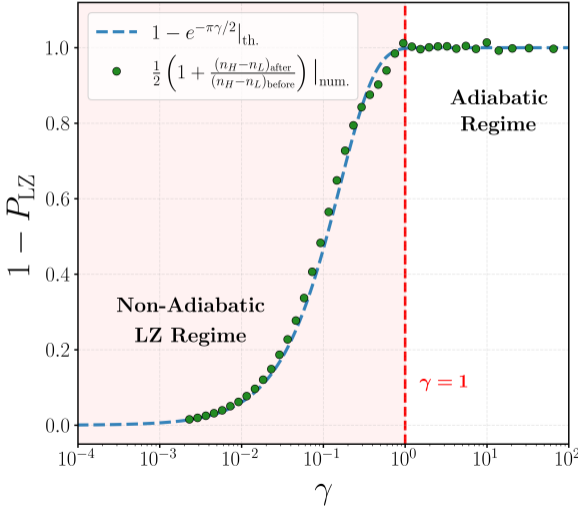
$$P_{\text{LZ}} = \exp(-\pi\gamma/2) \quad \text{where} \quad \gamma = \left| \frac{4(m_{as}^2)^2}{\frac{d m_{aa}^2}{dt} - \frac{d m_{ss}^2}{dt}} \frac{1}{m_H + m_L} \right|_{t=t_x}$$

Mix number densities with Landau-Zener conversion probability:

$$n_H^{\text{Today}} = (1 - P_{\text{LZ}})n_H^{\text{WKB}} + P_{\text{LZ}}n_L^{\text{WKB}}$$
$$n_L^{\text{Today}} = (1 - P_{\text{LZ}})n_L^{\text{WKB}} + P_{\text{LZ}}n_H^{\text{WKB}}$$

- 3 Enjoy DM prediction!

Numerical validation



Haloscope predictions

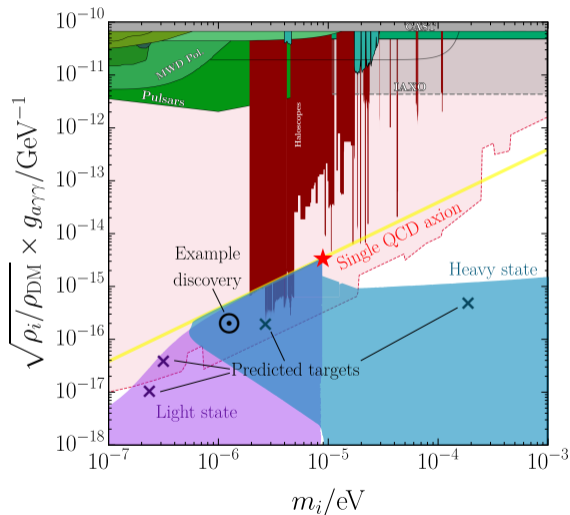
We now know DM relic of each state.
How may these show up in haloscopes?

> Haloscope signal power $\propto g_{a\gamma\gamma}^2 \rho_a$

$$g_{a\gamma\gamma}^{\text{rescaled}} = \sqrt{\frac{\rho}{\rho_{\text{DM}}}} g_{a\gamma\gamma}^{\text{reported}}$$

> If a_i couple only through $G\tilde{G}$, then the $a_i\gamma\gamma$ coupling is fixed by the mixing angle

> Assuming a mixing pattern + total DM then becomes predictive




Thank you!

Questions?

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