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Axion paradigm with "coloured" neutrino masses

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Motivation

The Standard Model cannot explain:

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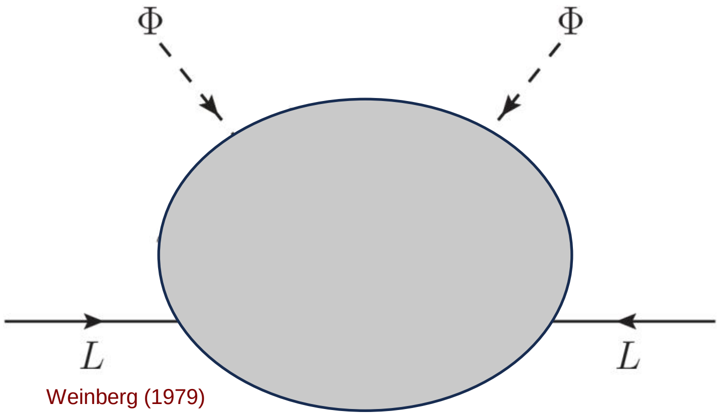

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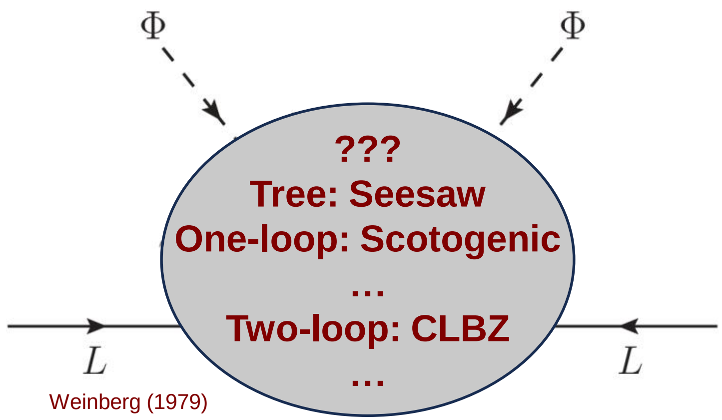

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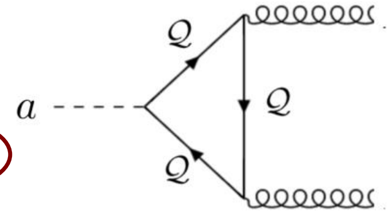

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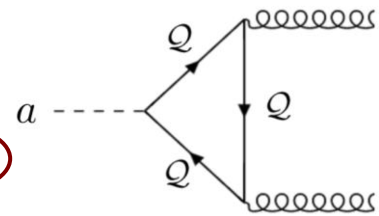

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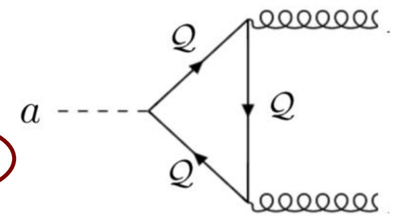

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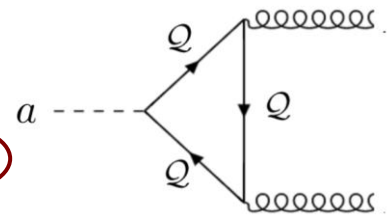

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Our approach:

New class of models where **neutrino masses** are **radiatively generated by coloured particles** which **simultaneously** solve through the PQ mechanism the **strong CP problem.** The predicted **axion** particle accounts for **dark matter**.

Axion paradigm with colour-mediated neutrino masses

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Scalar Potential

$$V \supset \mu_{ijk} \chi_i \chi_j \chi_k + \kappa_{ij} \eta_i^\dagger \Phi \chi_j + \lambda_{ijk} \Phi^\dagger \eta_i \chi_j \chi_k + \text{H.c.}$$

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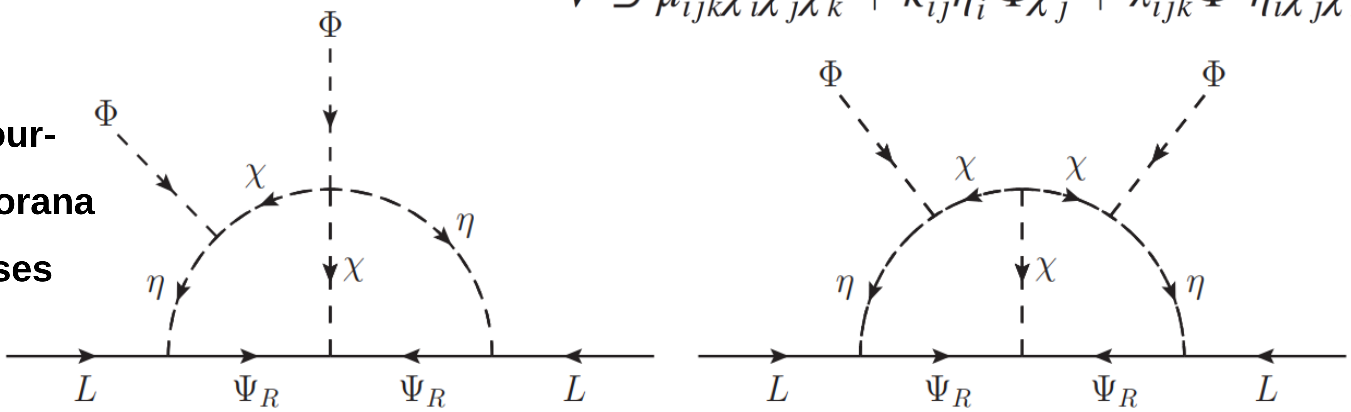
Two-loop colour-mediated Majorana neutrino masses



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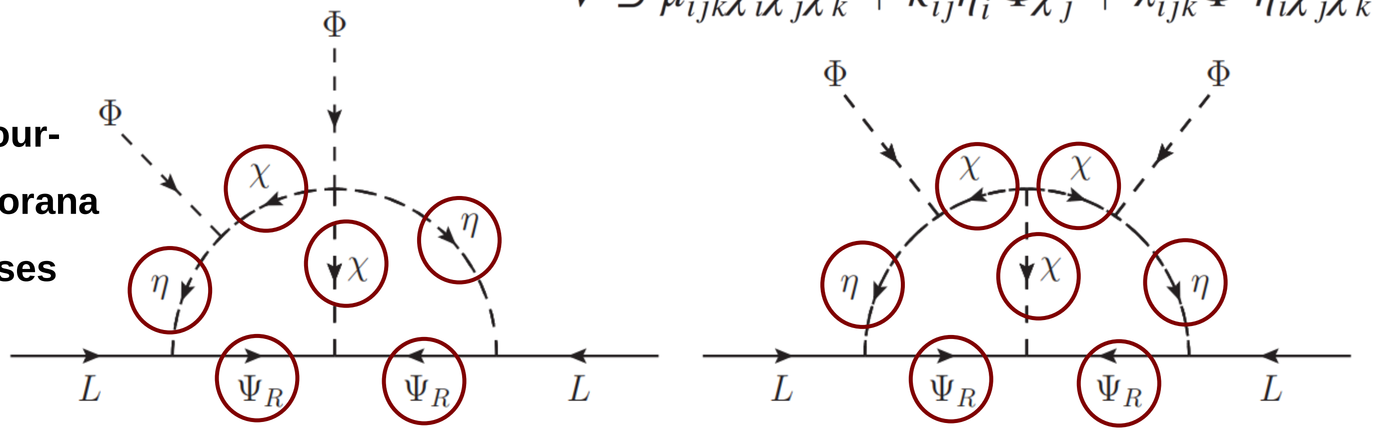

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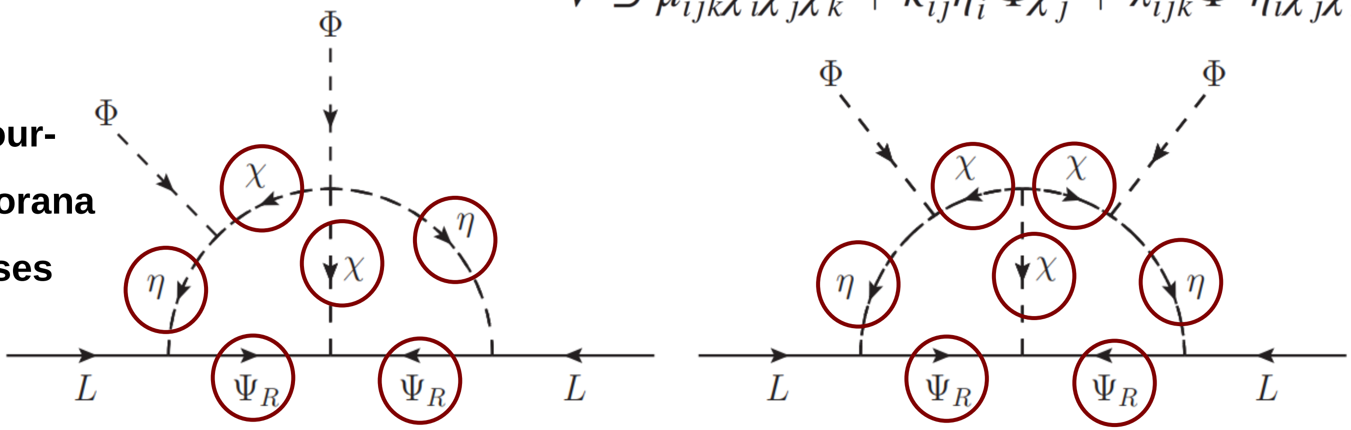

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$$(m_\nu)_{\alpha\beta} \sim 0.1 \text{ eV}\left(\frac{\tilde{Y}^j_{a\alpha}(\tilde{Y}_\chi)^k_{ab}\tilde{Y}^l_{b\beta}}{10^{-3}}\right)\left(\frac{\tilde{\mu}_{jkl}}{10^8 \text{ GeV}}\right)\left(\frac{v}{246\text{ GeV}}\right)^2\left(\frac{10^8\text{ GeV}}{m_\zeta}\right)^2$$

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Colour-anomaly factor

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Probing the axion-to-photon coupling

Axion-to-photon coupling

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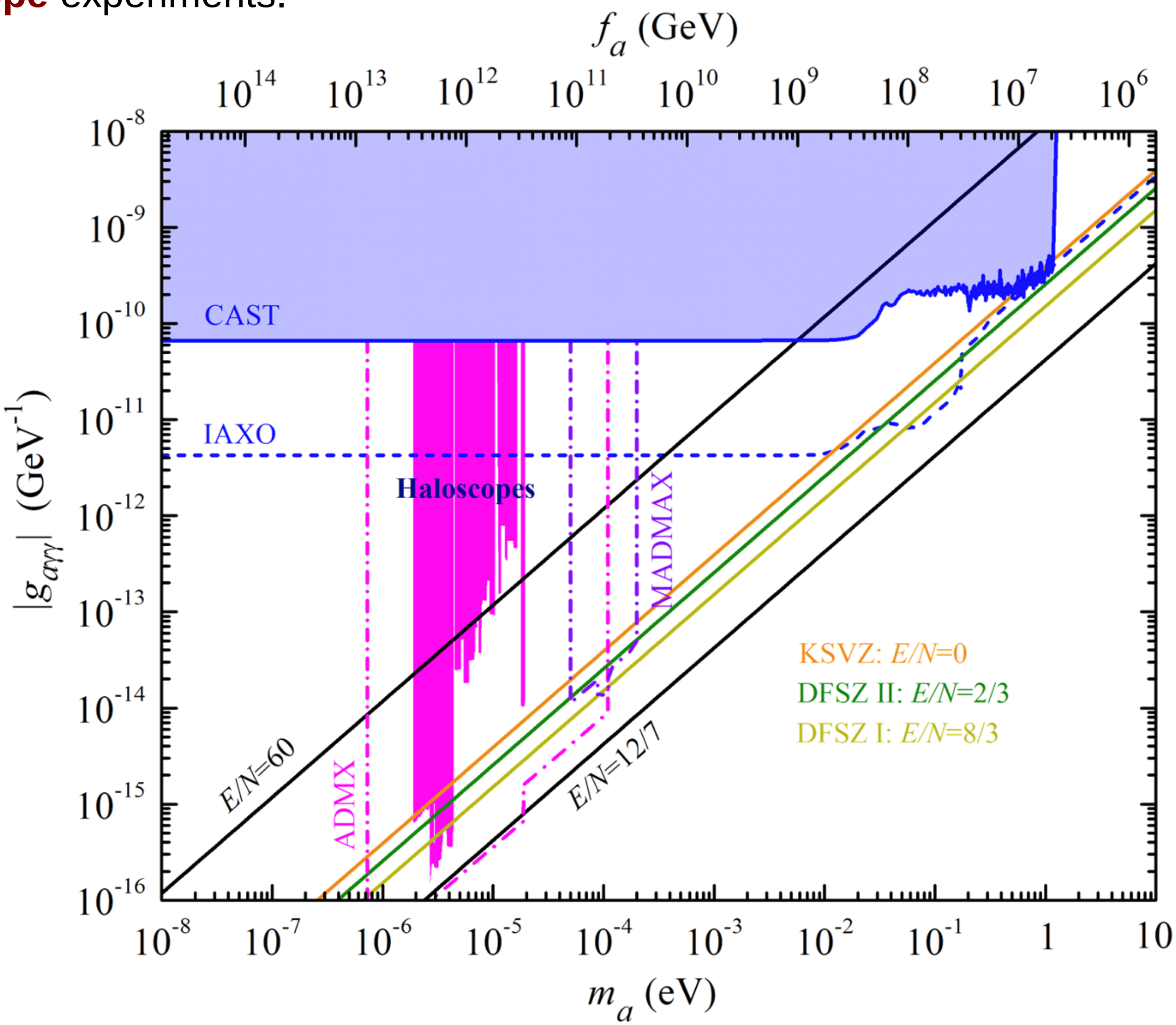
E/N		$SU(2)_L$				
		3	**5**	**7**	**9**	**11**
$SU(3)_c$	**3**	4	12	24	40	60
	6	8/5	24/5	48/5	16	24
	10	8/9	8/3	16/3	80/9	40/3
	15	1	3	6	10	15
	15′	4/7	12/7	24/7	40/7	60/7

Probing the axion-to-photon coupling

The different models can be probed through the **axion-to-photon coupling** at **helioscope** and **haloscope** experiments.



Axion dark matter and cosmology

Axions are naturally light, weakly coupled with ordinary matter, cosmologically stable, and can be nonthermally produced in the early Universe being an excellent DM candidate.

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Axion dark matter via the misalignment mechanism in the pre-inflationary scenario

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$$\Omega_a h^2 \simeq \Omega_{\rm CDM} h^2 \frac{\theta_0^2}{2.15^2} \left(\frac{f_a}{2 \times 10^{11}\ \mathrm{GeV}} \right)^{\frac{7}{6}}$$

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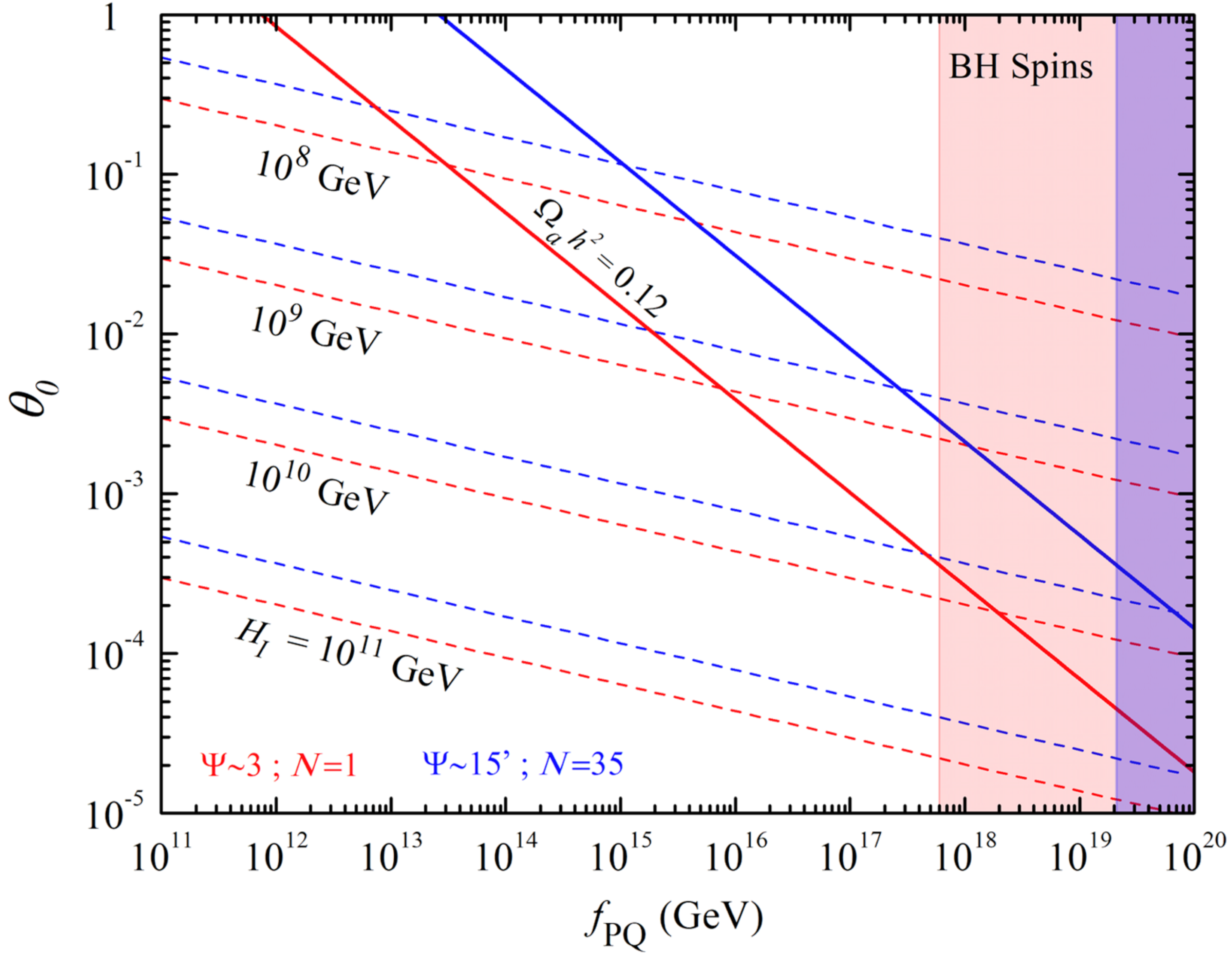

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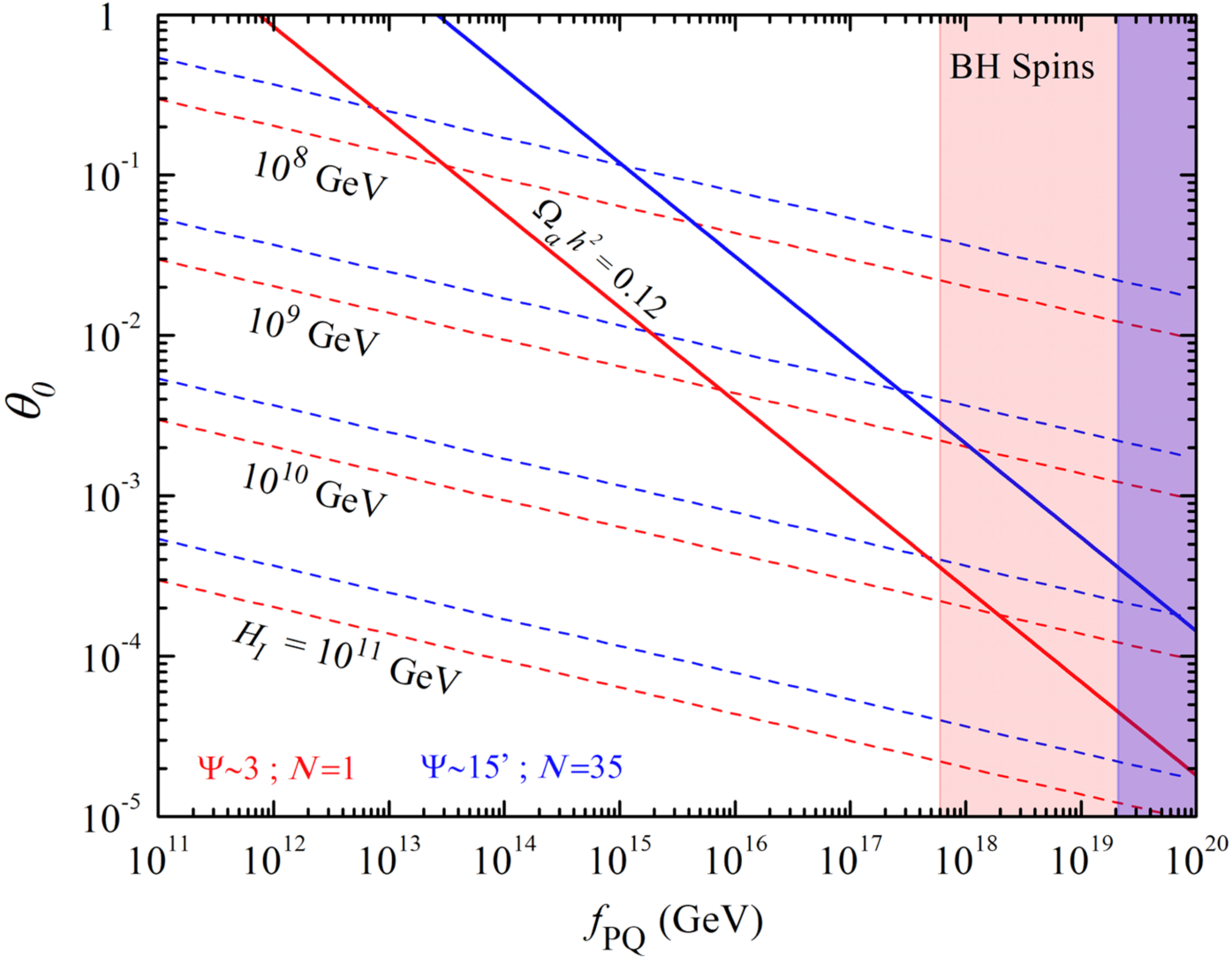

For $\theta_0 \sim \mathcal{O}(1)$ axions can account for the **full CDM budget**, provided $\mathbf{f_a \sim 5 \times 10^{11}}$ GeV, a region currently under scrutiny at **haloscopes.**

Conclusion

- We proposed a **connection between** two seemingly unrelated facts: **small neutrino masses and the strong CP problem**. This was achieved within a **novel class** of KSVZ axion schemes, containing **exotic coloured fermions and scalars** that act as **Majorana neutrino mass mediators** at the two-loop level.

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Thank you!

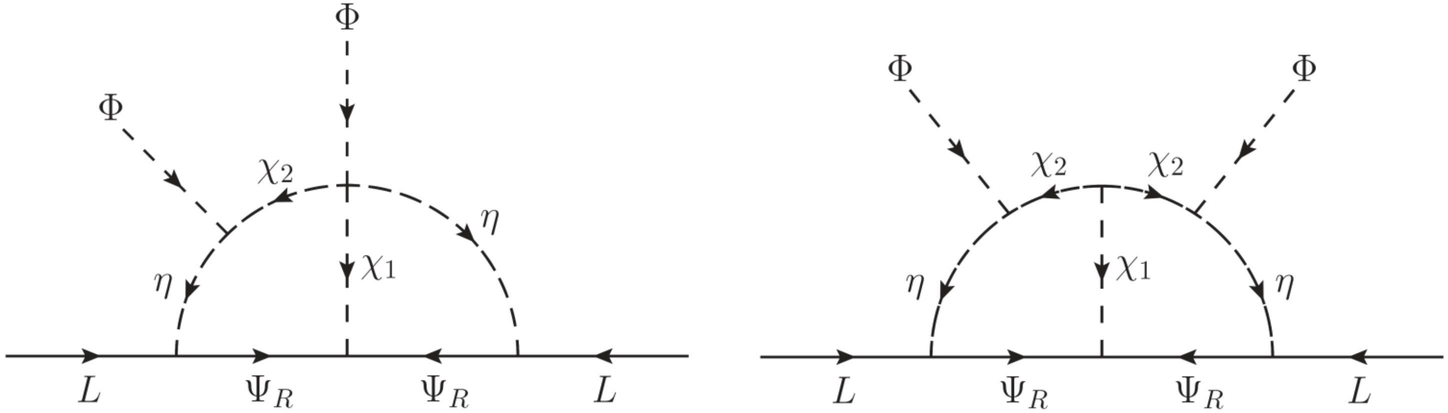
Backup

Post-inflationary scenario

	Fields	$SU(3)_c \otimes SU(2)_L \otimes U(1)_Y$	$U(1)_{PQ}$	Multiplicity
Fermions	Ψ_L	$(\mathbf{3}, \mathbf{1}, -1/3\ (2/3))$	0	n_Ψ
	Ψ_R	$(\mathbf{3}, \mathbf{1}, -1/3\ (2/3))$	$-1/n_\Psi$	n_Ψ
Scalars	σ	$(\mathbf{1}, \mathbf{1}, 0)$	$1/n_\Psi$	1
	η	$(\mathbf{3}, \mathbf{2}, 1/6\ (7/6))$	$-1/n_\Psi$	n_η
	χ_1	$(\mathbf{6}, \mathbf{1}, 2/3\ (-4/3))$	$2/n_\Psi$	n_{χ_1}
	χ_2	$(\mathbf{3}, \mathbf{1}, -1/3\ (2/3))$	$-1/n_\Psi$	n_{χ_2}

$$-\mathcal{L}_{\text{Yuk.}} \supset \mathbf{Y}_\Psi \overline{\Psi_L} \Psi_R \sigma + \frac{1}{2} \mathbf{Y}_{\chi_{1j}} \Psi_R^T\, C\, \chi_{1j} \Psi_R + \mathbf{Y}_i \overline{L}\, \eta_i^* \Psi_R + \mathbf{m}\, \overline{\Psi_L} d_R\ (+\mathbf{m}\, \overline{\Psi_L} u_R) + \text{H.c.}\,,$$

$$V \supset \mu_{ijk} \chi_{1i} \chi_{2j} \chi_{2k} + \kappa_{ij} \eta_i^\dagger \Phi \chi_{2j} + \lambda_{ijk} \Phi^\dagger \eta_i \chi_{1j} \chi_{2k} + \text{H.c.}\,.$$



$$\left\langle \theta_0^2 \right\rangle \simeq 2.15^2 \;\rightarrow\; f_a \lesssim 2 \times 10^{11}\ \text{GeV}$$