



## Overview

We present a first combined theory prediction for the distribution of axion-photon couplings for non-minimal DFSZ and KSVZ models. Couplings of DFSZ models with more than one additional Higgs doublet ( $n_D > 2$ ) are comparable to the non-minimal KSVZ literature values. They extend over a large range of parameters, reaching values up to almost three orders of magnitude larger than the ones observed in minimal models. The distributions of both DFSZ- and KSVZ-types of models display similar, very specific patterns. For the subset of DFSZ models with domain wall number of unity ( $N_{DW} = 1$ ) we find significantly enhanced axion-photon couplings. Our findings are relevant for axion searches like haloscopes, helioscopes, or light-shining-through-a-wall experiments.

## **Basics**

- DFSZ-type models have SM fermions that carry PQ charge and require at least one Higgs singlet (to decouple PQ scale from EW scale) and an additional Higgs doublet (to make PQ current anomalous)
- Anomaly in PQ current only depends on difference of PQ charges of right- and left-handed fermions  $\rightarrow$  set charges of left-handed to zero for simplicity

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## Procedure

1) Specify Yukawa sector u c t d s b e $\mu \tau$ $H_1 H_1 H_2 H_3 H_3 H_3 H_4 H_4 H_4$	<ul> <li>Couple exactly one Higgs doublet to each fermion</li> <li>Allow breaking of generation symmetry</li> <li>Don't couple across fermion type</li> <li>n<sub>D</sub> = 4 → 9 options</li> </ul>	<ul> <li>4) Compute E/N</li> <li>✓ E/N = 2/3 + 2 ∑Xu + ∑Xl/∑Xu + ∑Xd</li> <li>Solve all linear systems of equations for the charges</li> <li>Discard underdetermined systems</li> <li>Add potentials of all equal PQ charges</li> <li>5) Counts to Probabilities</li> <li>Model is chosen at random, no</li> </ul>	
2) Expl. sym. breaking potentia $V_{eb,1} = H_1 H_4 S^{\dagger} S^{\dagger} + H_2 H_3 H_1^{\dagger} H_2$ $+ H_3^{\dagger} H_4 H_1^{\dagger} H_2$ $V_{eb,2} =$	<ul> <li>Introduce potential to break down U(1)<sup>n<sub>D</sub>+1</sup> symmetry</li> <li>At least one term containing singlet S</li> <li>n<sub>D</sub> - 2 terms either two S and two doublets H or four H</li> </ul>	<ul> <li>and and a second of the second of t</li></ul>	
3) Fix PQ charges $\chi_i$ $H_1 H_3 S^{\dagger} S^{\dagger}$ $\rightarrow \chi_{H_1} + \chi_{H_3} - 2\chi_S = 0$	<ul> <li>Potential has to be PQ invariant</li> <li>Orthogonality between PQ current and weak hypercharge current</li> <li>Well-definiteness of domain wall number fixes <i>X<sub>S</sub></i></li> </ul>	<ul> <li>No (phenomenological) selection criteria included</li> <li>Different relative probabilities of the models could be considered</li> <li>Right-handed neutrinos could have non-zero PQ charges</li> <li>Too many possible potentials for n<sub>D</sub> &gt; 7 → extrapolation necessary (but difference between limits &lt; 1%)</li> </ul>	
DFSZ-Type Results	inimal DFSZ ( $E/N = 2/3, 8/3$ ) remains im	portant DFSZ and KSVZ look very similar	



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ArXiv: 2302.04667

GitHub: jhbdiehl/DFSZforest

Data: doi.org/10.5281/zenodo.7620202