

A Visible QCD Axion Portal to GeV-Scale Dark Matter

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17th Patras Workshop on Axions, WIMPs and WISPs

11 August 2022

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- Strong-CP problem (and Peccei-Quinn quality problem)
- Interesting region of the parameter space
- Visible QCD axions at the MeV scale have recently been reconsidered as viable candidates
- $(g - 2)_\mu$
- XENON1T excess could be fit by GeV Dark Matter (DM) with pseudoscalar mediator in the MeV range
[\[Buttazzo et al., 2021, arXiv:2011.08919\]](#)

- Write down a general Lagrangian for an ALP field a that couples to Standard Model (SM) fermions f_i

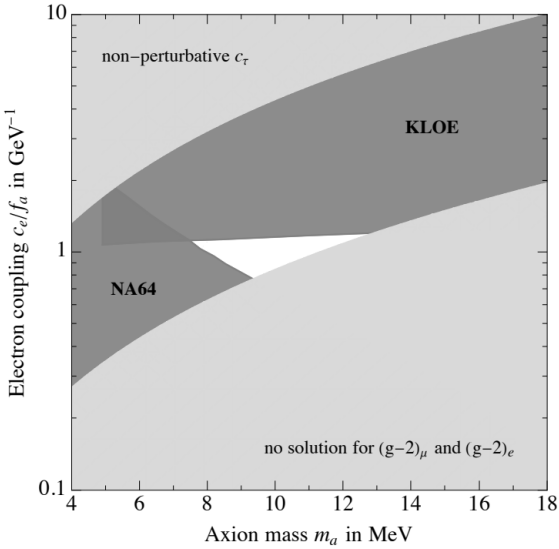
$$\mathcal{L} \supset \frac{\partial_\mu a}{2f_a} \sum_i c_i \bar{f}_i \gamma^\mu \gamma_5 f_i + c_\gamma \frac{\alpha}{8\pi f_a} \epsilon^{\mu\nu\rho\sigma} a F_{\mu\nu} F_{\rho\sigma}$$

- $m_a \sim \text{MeV}$ implies constraints from collider and beam dump experiments

- Constrain couplings to leptons using $(g-2)_e$ and $(g-2)_\mu$

$$\rightarrow c_e/f_a \sim 1 \text{ GeV}^{-1}, c_\mu/f_a \sim 0.01 \text{ GeV}^{-1}, c_\tau/f_a \sim 0.3 \text{ GeV}^{-1}$$





- The QCD axion is an immediate choice

$$m_a \simeq 5.7 \text{ MeV} \left(\frac{\text{GeV}}{f_a} \right)$$

$f_a \sim \text{GeV}$ yields the desired axion mass

- Solves the Strong-CP problem
- $f_a \sim \text{GeV}$ yields an immediate solution to the PQ quality problem



A QCD axion at the MeV scale

- Recently shown that a QCD axion with $m_a \sim \text{MeV}$ is viable despite strong experimental constraints [[Alves and Weiner, 2017, arXiv:1710.03764](#)]
- Must promptly decay into electrons (beam-dump constraints)
→ Naturally fulfilled in our scenario
- Must have suppressed couplings to heavy quarks (quarkonia decays)
→ Small PQ charges of heavy quark generations
- Must be “pion-phobic”, i.e. have suppressed mixing with the neutral pion

$$\rightarrow c_u \approx 2/3, \quad c_d \approx 1/3$$



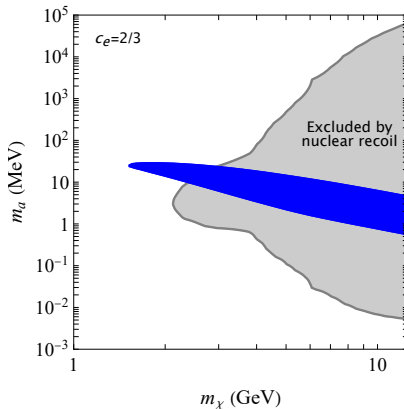
- Let the axion couple also to a DM fermion χ

$$\mathcal{L} = -i \frac{a}{f_a} \sum_{i=\chi, u, d, e, \mu, \tau} c_i m_i \bar{f}_i \gamma_5 f_i - m_\chi \bar{\chi} \chi$$

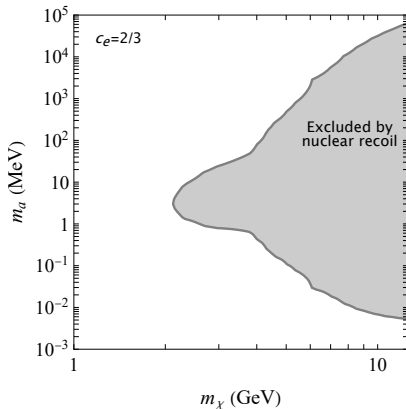
- Coupling to quarks will induce nuclear recoils, but suppressed due to pion-phobia
- Coupling a -DM fixed to the value given by perturbative unitarity:
 $c_\chi = \sqrt{8\pi/3}$
- $\chi\chi \rightarrow e^+e^-$ cross-section would imply $\Omega_\chi \sim 10^{-4} \Omega_{\text{DM}}^{\text{obs}}$, so need asymmetric DM



- Constraints by direct detection experiments with nuclear recoils



- Constraints by direct detection experiments with nuclear recoils



- No more XENON1T excess \rightarrow Thermal WIMP instead?

- A QCD axion with $m_a \sim \text{MeV}$ is viable and appealing to solve $(g - 2)_\mu$ and the PQ quality problem
- Constrain couplings to SM leptons using $(g - 2)_e$ and $(g - 2)_\mu$, and to quarks from quarkonia decay (heavy) and pion-phobia (light)
- XENON1T excess explained by coupling the axion to a DM fermion, with asymmetric DM
- With XENON1T excess gone, consider a thermal relic WIMP instead
- UV model under construction to obtain the right couplings in the IR

