Looking for the nALPs photon coupling

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ALPs

- ALPs are pseudo Goldstone bosons of an approximate chiral symmetry.
- some soft symmetry breaking gives the ALP a small mass
- They are a dark matter candidate

ALP coupling to fermions

The fermion couplings are related to how the fermions transform under the global symmetry. For fermions that transform like $\psi_f \to e^{-iq_f \phi \gamma_5 / 2} \psi_f$, the coupling to the ALP is

$$\mathcal{L} \supset i q_f \frac{m_f}{f_a} a \bar{\psi}_f \gamma_5 \psi_f + \text{h.c.}$$

ALP coupling to photons

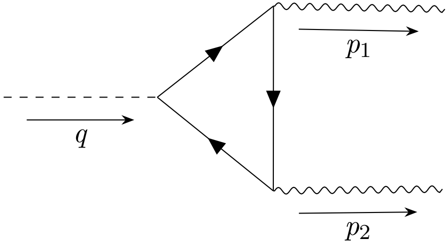

Figure 1: The diagram plus the diagram switching p_1 and p_2 contribute to the photon coupling.

For $m_a << m_f$ integrating out a fermion gives an effective coupling to the photon $\mathcal{L} \supset -q_f Q_f^2 \frac{\alpha}{4\pi}\frac{a}{f_a}(1-\frac{m_a^2}{12m_f^2})F_{\mu\nu}\tilde{F}^{\mu\nu}$ for on shell processes. The term that is independent of the fermion mass is the anomaly contribution

nALP coupling to photons

- An nALP is an ALP where this anomaly contribution cancels among the fermions
- The dominant contribution the comes from the lightest fermion as

$$g_{a\gamma_{\text{eff}}} = q_f\, Q_f^2\, \frac{\alpha}{48\pi} \frac{a}{f_a} \frac{m_a^2}{m_f^2}$$

- The question that I attempt to answer what is the significance of this coupling, could an nALP be found at experiments looking currently looking for ALPs

ALP mixing with light mesons

If the ALP couples has a color anomaly or if it couples to quarks the ALP can mix with light pseudoscalar mesons. This can lead to large coupling to photons. So we don't consider models where the ALP couples to colored particles

CAST

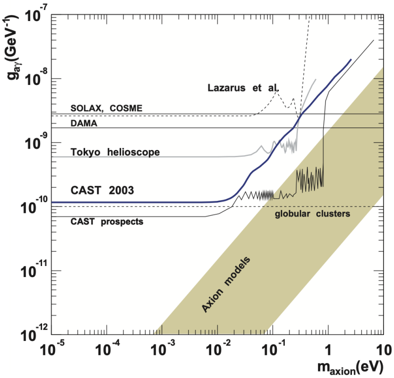

Figure 2: CAST constrains on the coupling of ALPs to photons from arXiv:hep-ex/0507007

CAST is an experiment looking for ALPs lighter than an eV emitted from the Sun It is sensitive to ALPs with a photon coupling greater than about 10^{-7}TeV^{-1}

Electron Muon model

- Consider a model with the only particles charged under the global symmetry to the the electron and the muon with opposite charges
- the size of the proton coupling is contained by constraints on the electron and muon coupling.
- One interesting constraint is that the f_a scale can't be much less than the mass of the heaviest fermion charged under the global symmetry.

Electron Muon model

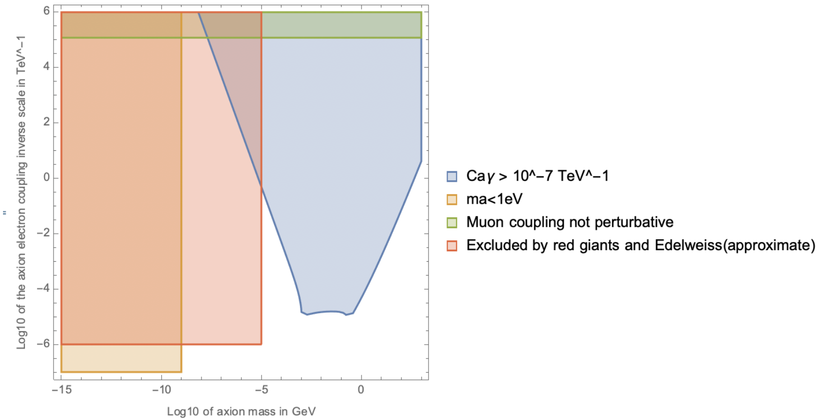

Figure 3: The blue area has an photon axion coupling large enough to be found at CAST. The orange area is light enough to be detected at CAST. Note that these do not overlap in a viable region of parameter space

BSM charged particles

- Could the charged fermions be BSM particles?
- BSM charged particles with unit charge must be quit heavy more that 75GeV. So they could not generate an observable photon coupling in a non-anomalous theory at CAST.
- We also considered theories with fermions of fractional charge.

BSM charged particles

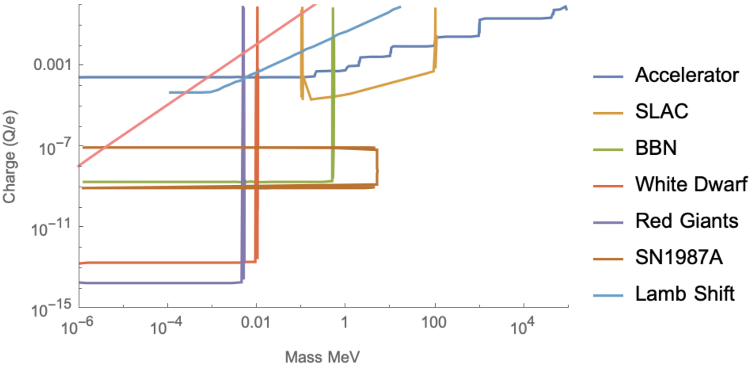

Figure 4: The area below the pink line can't generate a non anomalous photon coupling large enough to generate a signal at CAST. The only assumption made was that the couplings to axions are perturbative. The millicharged partical constraints come from arXiv:hep-ph/0001179

So these can't generate an observable signal at CAST either.

Conclusion

- The photon coupling of a nALP could not be detected at CAST nor a near term experiment look in this mass range.
- Perhaps a different way to phase this is that there are fairly natural ALP models that are invisible to most ALP searches presently being done.