[arXiv: 2411.15312]

The Seiberg-Witten Axion

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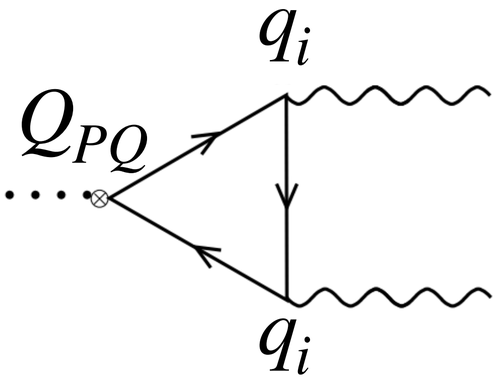
Axion-Photon Coupling

Peccei-Quinn Mechanism

- Quantized anomaly generated coupling

$$\mathscr{L} \supset -\frac{a}{f}\left(\sum_i Q_{PQ} q_i^2\right)\frac{e^2}{16\pi^2}F\tilde{F} \propto \sum_i$$



- **Heuristic:** magnetically charged PQ fermions $\alpha^{-2} \sim 10^4$ enhancement

$$e \to \frac{4\pi}{e}, \qquad \mathscr{L} \sim \frac{1}{e^2}\frac{a}{f}F\widetilde{F}$$

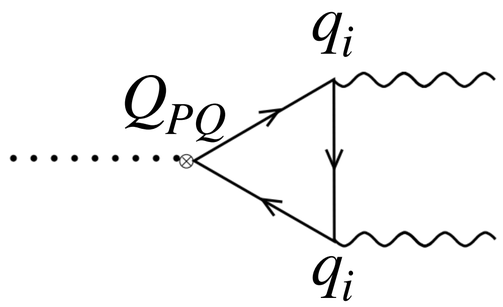
Can the axion coupling be large?

Example: Instantons

$$\mathscr{L} \supset -\frac{e^2}{16\pi^2} F_{\mu\nu}\widetilde{F}^{\mu\nu}\left\{N\frac{a}{f} - \sum_{k=1}^{\infty}\left[b_k \sin\left(\frac{ka}{f}\right) + c_k \cos\left(\frac{ka}{f}\right)\right]\right\}$$

$$\simeq -\frac{e^2}{16\pi^2} F_{\mu\nu}\widetilde{F}^{\mu\nu}\frac{a}{f}\left\{N - \sum_{k} k\, b_k\right\} + O\left(\frac{a^2}{f^2}\right)$$

Usual anomaly



Instanton corrections
Linear coefficient not quantized and can be large!

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Is axion QED duality covariant?

Can we keep Bianchi? (Answer: Yes!)

- Maxwell equations + axion

[Sikivie '83]

[Raffelt & Stodolsky '83]

$$\partial_\mu F^{\mu\nu} = -\, g_{a\gamma}(\partial_\mu a)\,\widetilde{F}^{\mu\nu}\,, \qquad \partial_\mu \widetilde{F}^{\mu\nu} = 0$$

EOM — Bianchi identity

- Seems **inconsistent** w/S-duality ($F^{\mu\nu} \to \widetilde{F}^{\mu\nu}\,, \quad \widetilde{F}^{\mu\nu} \to -\, F^{\mu\nu}$)

- Naive fix

$$\partial_\mu F^{\mu\nu} = -\, g_{a\gamma}(\partial_\mu a)\,\widetilde{F}^{\mu\nu}\,, \qquad \partial_\mu \widetilde{F}^{\mu\nu} = g_{a\gamma}\partial_\mu F^{\mu\nu}$$

[Ringwald & Sokolov '22]

Violates Bianchi identity

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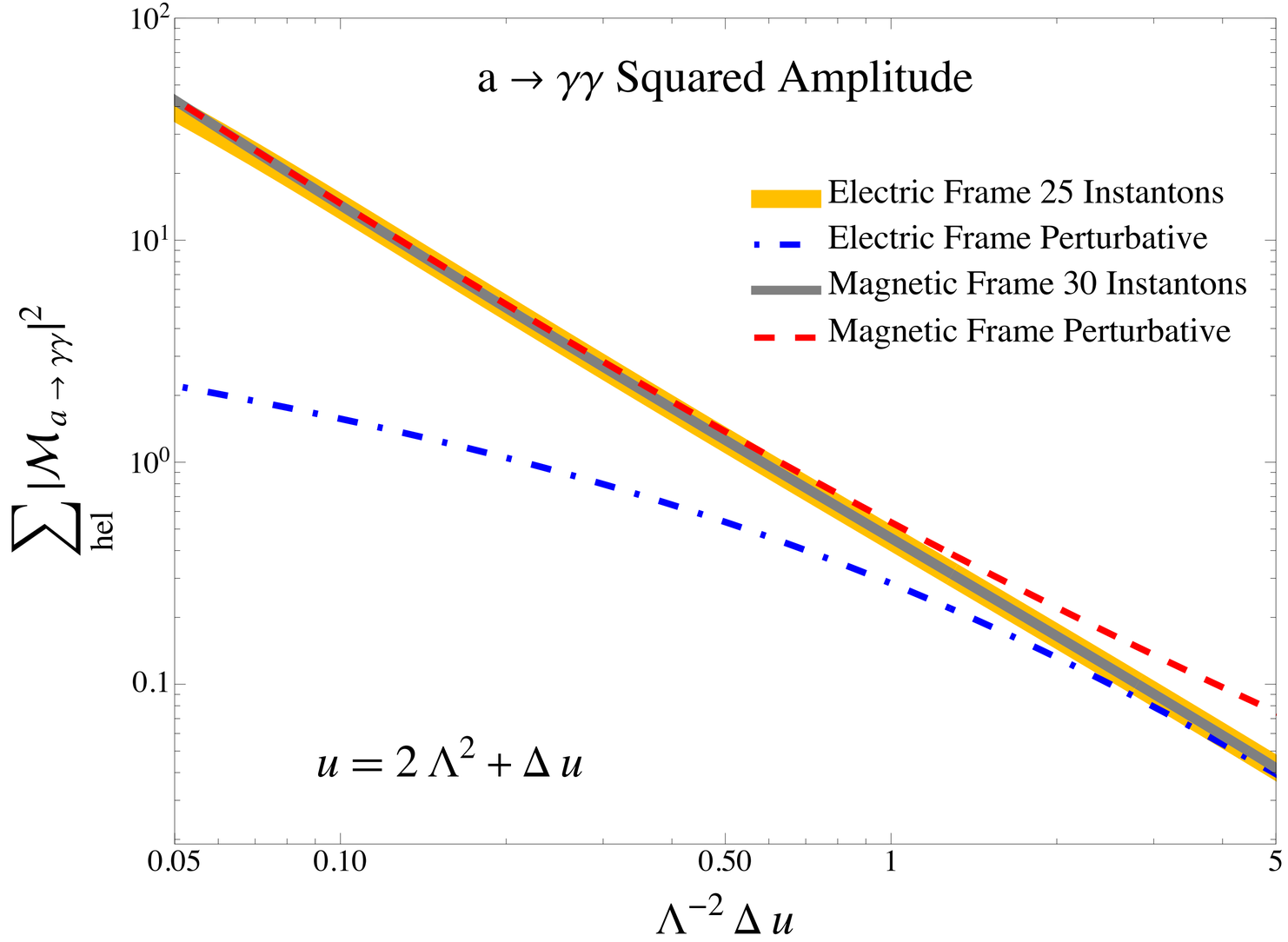
Why Seiberg-Witten theory?

It has all the ingredients.

- We need a toy model that has:
  - IR axion electrodynamics [our contribution]
  - Weak and strongly coupled regimes
  - EM duality
  - Charges and monopoles
  - Analytic control over instantons (SUSY)

$\mathcal{N} = 2$, $SU(2)$ **Super Yang-Mills has them all**

[Seiberg & Witten '94]



- Generalization + string theory axion EFT [arXiv: 2509.XXXXX]

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