

The chiral Lagrangian for CP-violating axion-like particles

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work with Luca Di Luzio and Paride Paradisi, ArXiv 2311.12158

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Probing the CPV ALP - Setup

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CP-violating observables with (basically) **no SM background**

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Our idea: **probe CP-violating ALPs** at low energies. We started from the most general $SU(3)_c \times U(1)_{em}$ invariant

EFT for a CP-violating ALP ϕ at the EW scale ($\Lambda \gg M_W$)

$$\begin{aligned} \mathcal{L}_{\text{ALP}}^{\text{dim-5}} \supset & +e^2 \frac{C_\gamma}{\Lambda} \phi F^{\mu\nu} F_{\mu\nu} + e^2 \frac{\tilde{C}_\gamma}{\Lambda} \phi F^{\mu\nu} \tilde{F}_{\mu\nu} + g_s^2 \frac{C_g}{\Lambda} \phi G_a^{\mu\nu} G_{\mu\nu}^a \\ & + g_s^2 \frac{\tilde{C}_g}{\Lambda} \phi G_a^{\mu\nu} \tilde{G}_{\mu\nu}^a + \frac{v}{\Lambda} y_S^{ij} \phi \bar{f}_i f_j + i \frac{v}{\Lambda} y_P^{ij} \phi \bar{f}_i \gamma_5 f_j + \mathcal{O}\left(\frac{1}{\Lambda^2}\right) \end{aligned}$$

[Di Luzio, Gröber, Paradisi, '20]

Jarlskog invariants: $C_a \tilde{C}_b, y_S^{ii} \tilde{C}_a, y_P^{ii} C_a, y_S^{ii} y_P^{jj}, y_S^{ik} y_{SM}^{kk} y_P^{ki}$

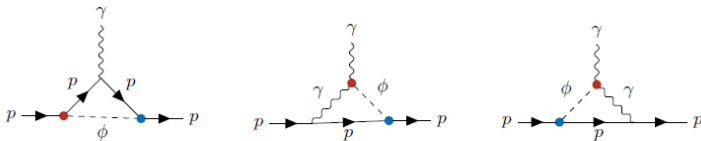
[Bonnefoy, Grojean, Kley, '22]

Probing the CPV ALP - What have we done?

- Provided the **RGEs** for the CPV ALP Lagrangian from the EW to the QCD scale [Chala, Guedes, Ramos, Santiago,'20],[Bakshi, Machado-Rodríguez, Ramos,'23],[Bauer, Neubert, Renner, Schnubel, Tamm,'20],[Bonilla, Brivio, Gavela, Sanz,'20]
- Constructed the most general **Chiral Lagrangian** for a **CPV ALP** both in a **2-flavors** and in a **3-flavors** setting
- Provided the **matching dictionary** relating the IR couplings in the chiral Lagrangian to the UV couplings at the EW scale
- Classified the **low-energy Jarlskog invariants** of the theory.
- Written a FeynRules **model** for both the 2- and the 3-flavors setting → extensive, automatized pheno analyses

Probing the CPV ALP - What can be done?

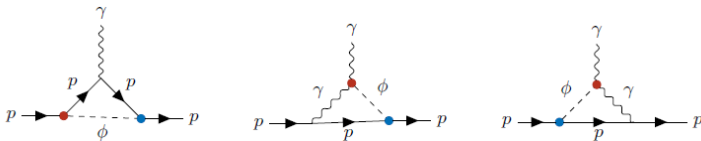
EDMs of protons, neutrons, atoms, molecules ...



$$d_p \longrightarrow |C_g \tilde{C}_g| < 4.4 \times 10^{-8}$$

Probing the CPV ALP - What can be done?

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In the future ...

- **UV completion** and hierarchy of couplings
- **Extensive phenomenological analysis**
- **Baryogenesis?** Dark Matter?

Thanks for your attention!

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