

Accidentally Light Scalars from Large Representations

Giacomo Ferrante

based on

arXiv:2307.10092 (JHEP)

with

F. Brümmer, M. Frigerio and T. Hambye



The $SU(2)$ five-plet

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$SU(2) \times U(1)$ and $\phi = (\phi_1, \phi_2, \phi_3, \phi_4, \phi_5)$

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$$\text{vev:} \quad \begin{cases} \langle \phi_1 \rangle = v \sin \alpha \\ \langle \phi_3 \rangle = v \cos \alpha \end{cases} \quad \alpha = \text{“accident”}$$

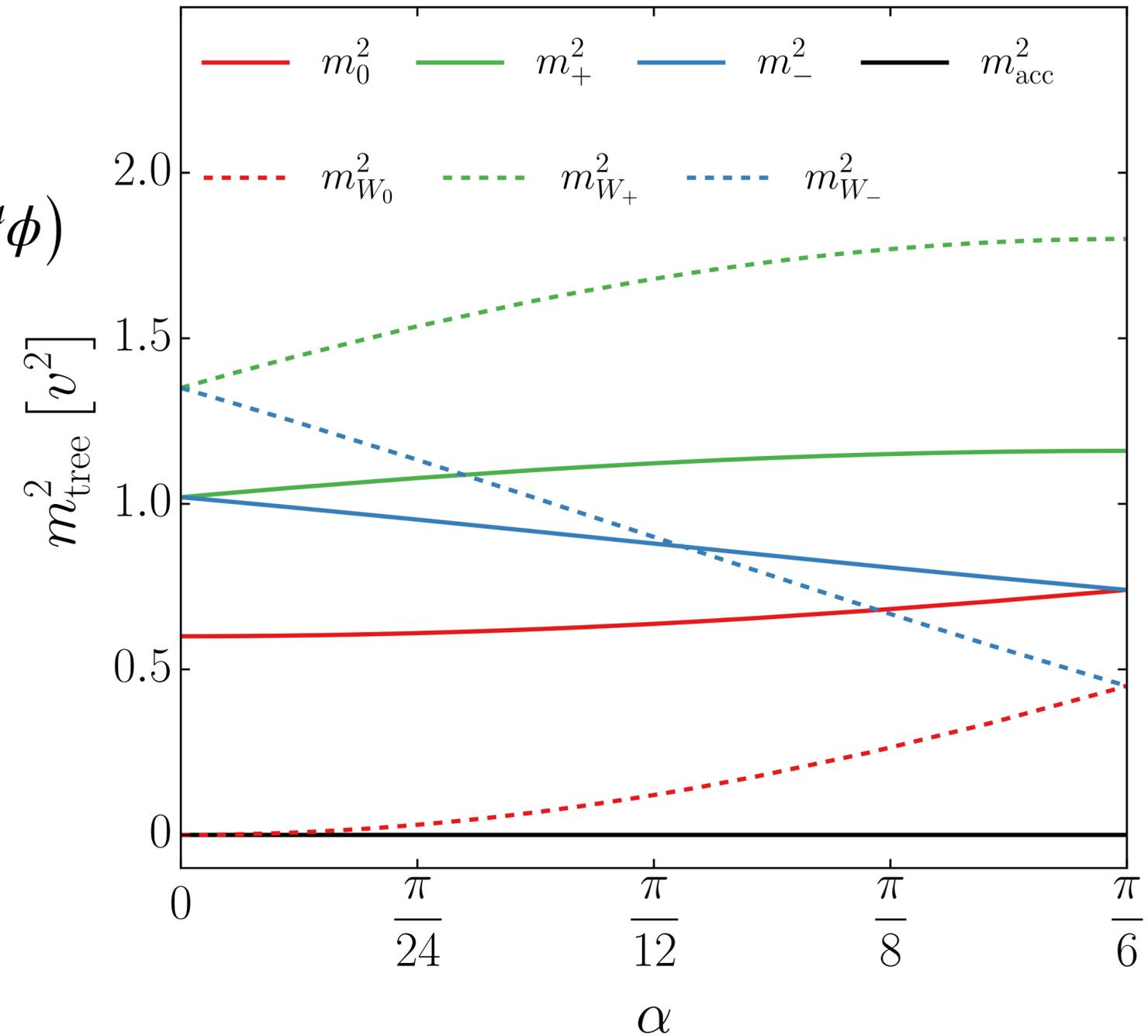
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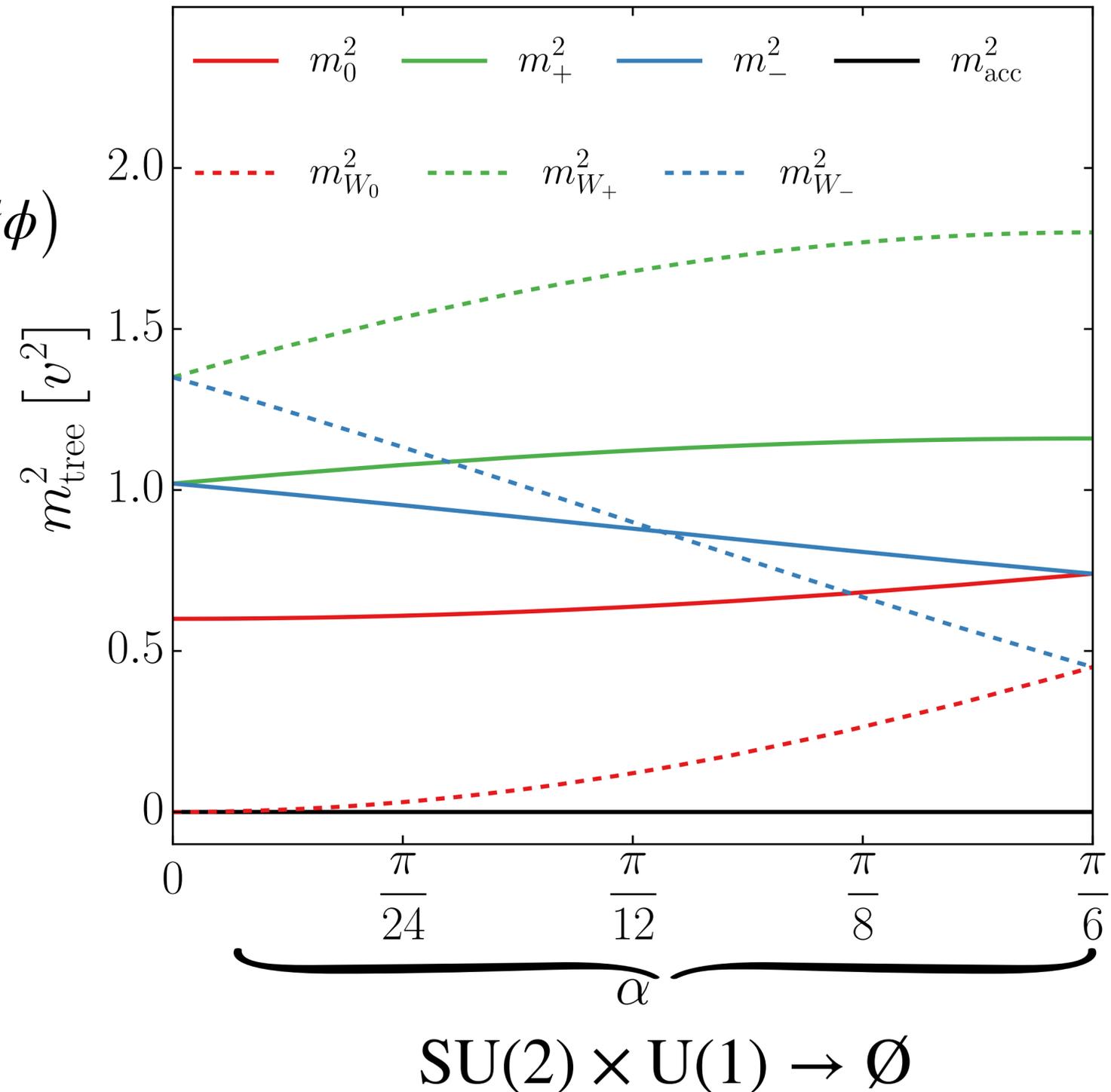
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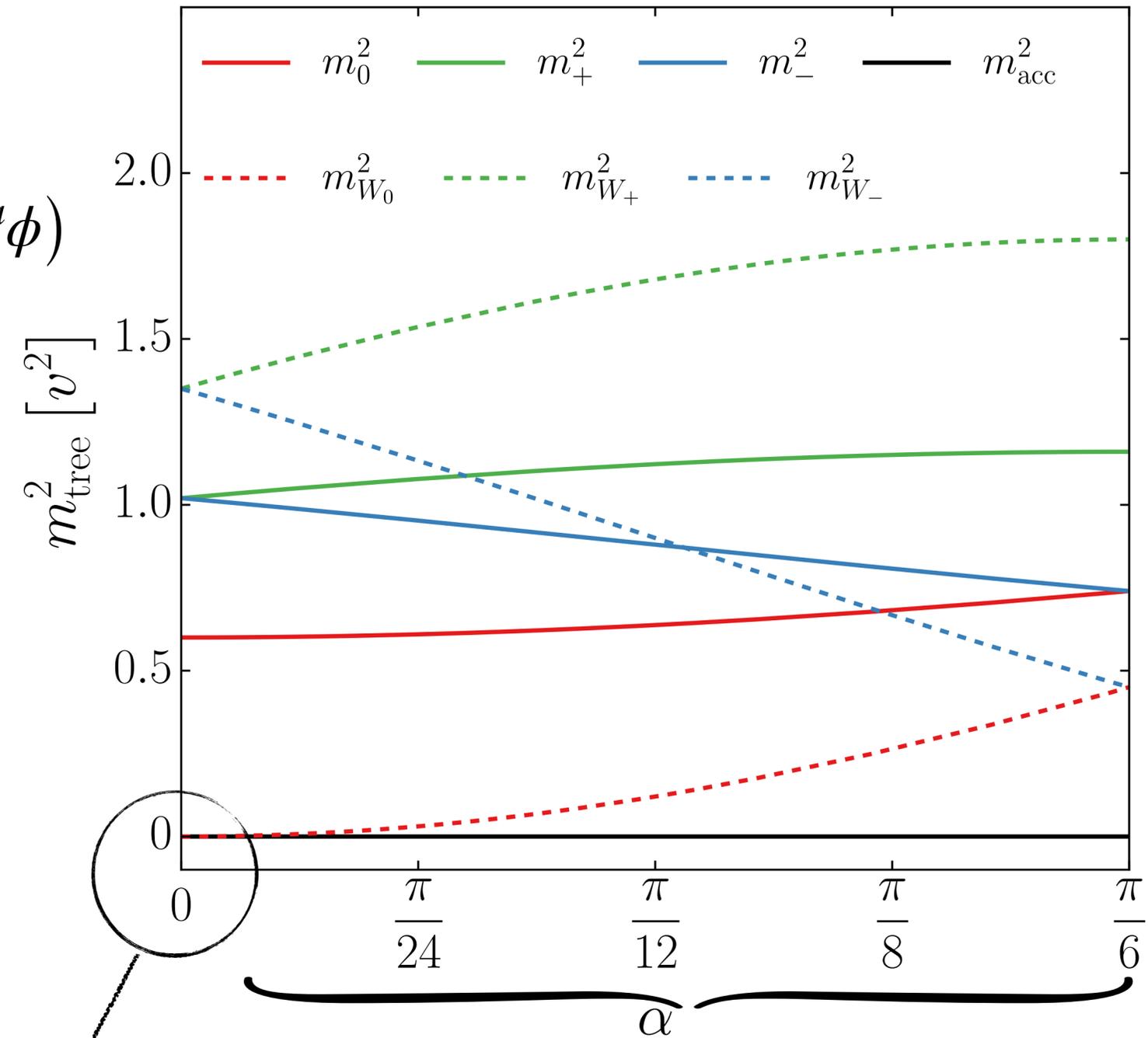
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U(1)' restoration

SU(2) \times U(1) $\rightarrow \emptyset$

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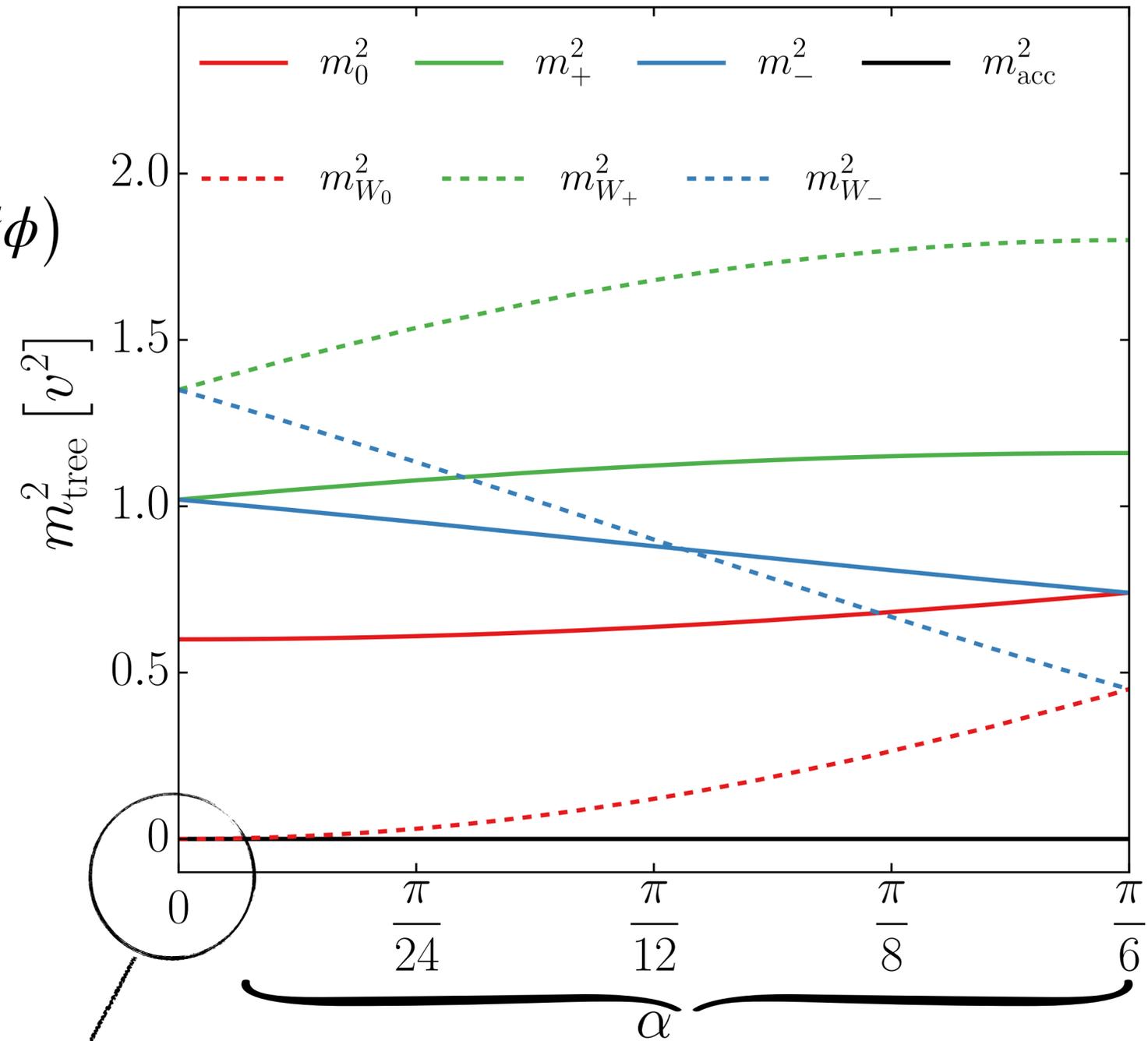
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No symmetry protection



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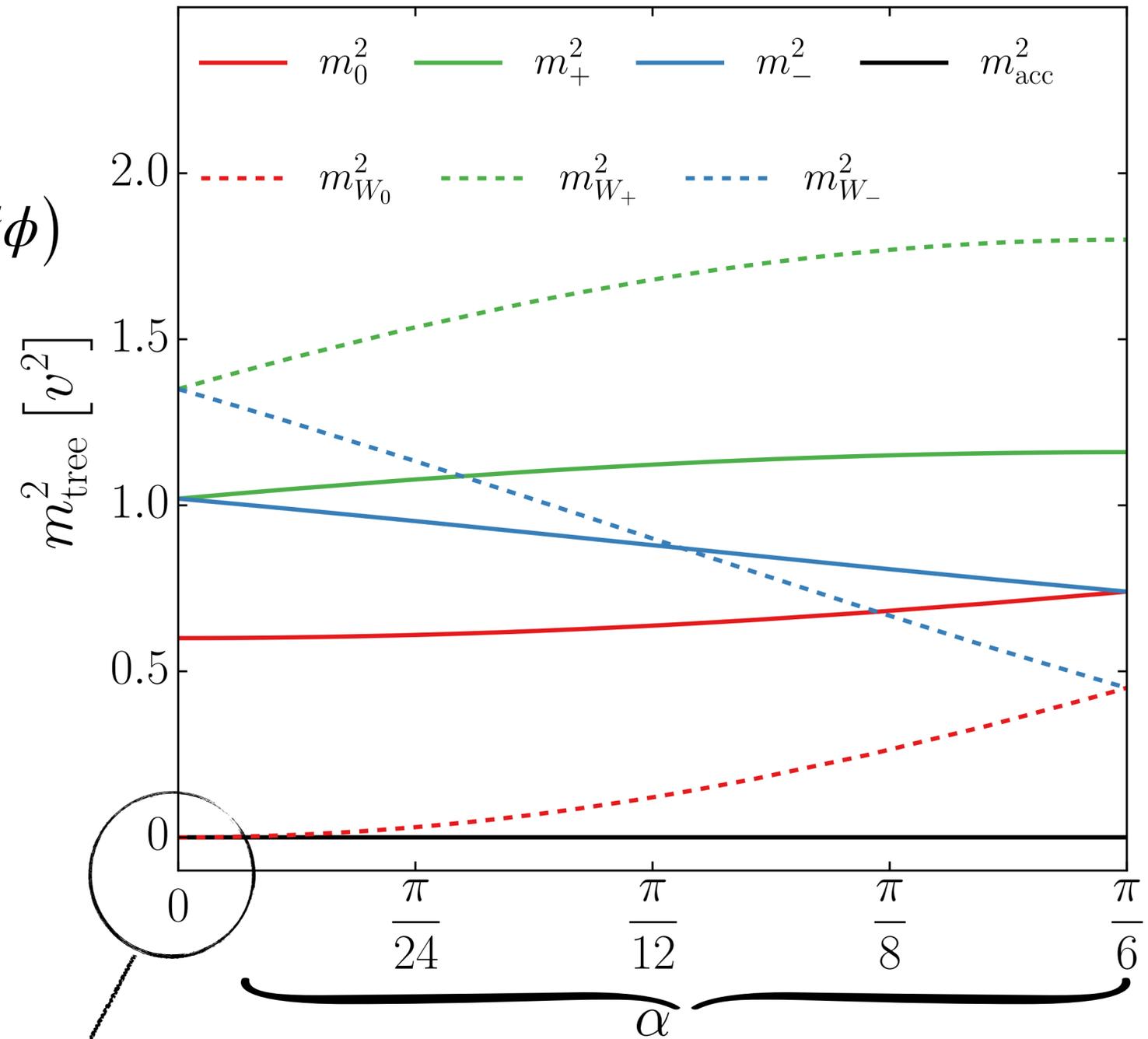
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α gets a **one-loop suppressed mass**

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3. **Inflation:** Accident potential naturally flat [ArXiv:2405.xxxxx, F. Brümmer, **GF**, M. Frigerio]

Poster #10

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F. Brümmer, G. Ferrante*, M. Frigerio and T. Hambye arXiv:2307.10092



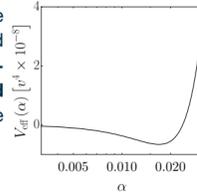
Accidents do not receive a tree-level mass although they are not (pseudo) Nambu-Goldstone bosons.

Applications

Little hierarchies

Radiative corrections give a small VEV to the accident, breaking a U(1) symmetry.

The accident is the **abelian Higgs** and its **mass is one-loop suppressed** with respect to the UV scale.



Dark matter

The accident is the **lightest particle** and it is **charged** under a U(1).

Higgs portal annihilation:

$$m_{\text{DM}} \gtrsim 2 - 3 \text{ TeV} \text{ or } m_{\text{DM}} \simeq m_h/2$$

Dark photon annihilation:

$$m_{\text{DM}} \gtrsim 100 \text{ GeV}, \quad g_D^2 \simeq 4.6 \times 10^{-5} \frac{m_{\text{DM}}}{\text{GeV}}$$

Inflation¹

The **flatness** of the inflationary potential

$$V(\alpha) \simeq M^4 \cos 6\alpha$$

is **protected** by the inflaton being an accident.

We construct a model of **hybrid natural inflation** by introducing a second scalar field χ .

¹ In preparation [arXiv:2405.xxxxx].

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$$V = -\mu^2 \phi^\dagger \phi + \lambda (\phi^\dagger \phi)^2 + \kappa \left((\phi^\dagger \phi)^2 - |\phi^T \phi|^2 \right) + \delta (\phi^\dagger T^a \phi)$$

V is **not invariant** under any **symmetry larger than G** (accidents \neq pNGBs).

The vacuum manifold is parametrised by one **non-Goldstone flat direction**

$$\text{VEV} : \quad \langle \phi_1 \rangle = v \sin \alpha, \quad \langle \phi_3 \rangle = v \cos \alpha.$$

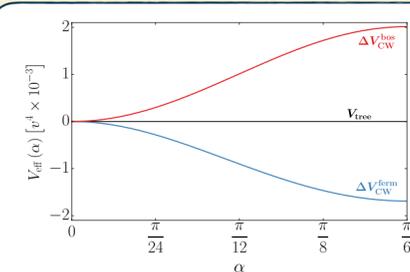
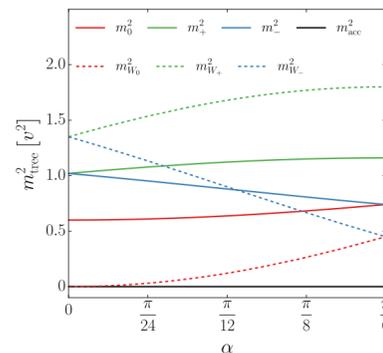
α is the accidentally flat direction, which is associated with an **accidentally tree-level massless scalar**.

Points along the α -direction are **not physically equivalent**:

$$\alpha \neq 0 : \quad \text{SU}(2) \times \text{U}(1) \rightarrow \emptyset,$$

$$\alpha = 0 : \quad \text{SU}(2) \times \text{U}(1) \rightarrow \text{U}(1)'$$

The mass spectrum of the model changes moving along the accident direction α .



One-loop effective potential

No symmetry associated with the accidentally flat direction: the accident gets a potential at the one-loop level

$$\Delta V_{\text{CW}}(\alpha) = \frac{1}{64\pi^2} \text{Str} \left(\mathcal{M}(\alpha)^4 \log \frac{\mathcal{M}(\alpha)^2}{\Lambda^2} \right).$$

- **Boson loops** stabilize $\alpha = 0$;
- **Fermion loops** stabilize $\alpha = \pi/6$.

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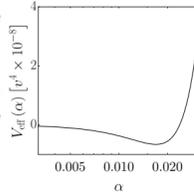
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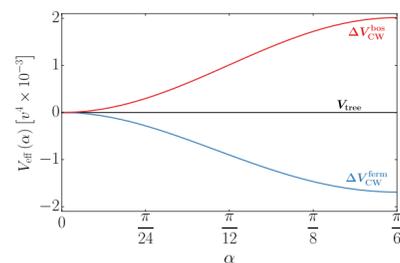
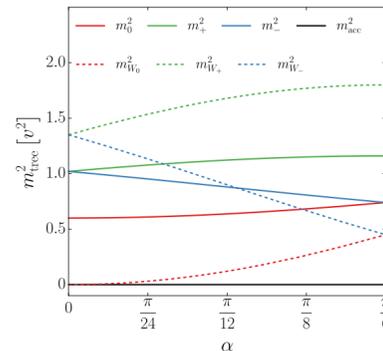
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Thank you for your (lightning) attention!