# Accidentally Light Scalars from Large Representations

**Giacomo Ferrante**

based on
arXiv:2307.10092
with
F. Brümmer, M. Frigerio and T. Hambye

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# Outline

1. Light Scalars in QFT
2. The Simplest Model: SU(2) five-plet
3. One-loop Effective Potential
4. Possible Applications
5. Conclusions

# Light Scalars in QFT

## Glossary

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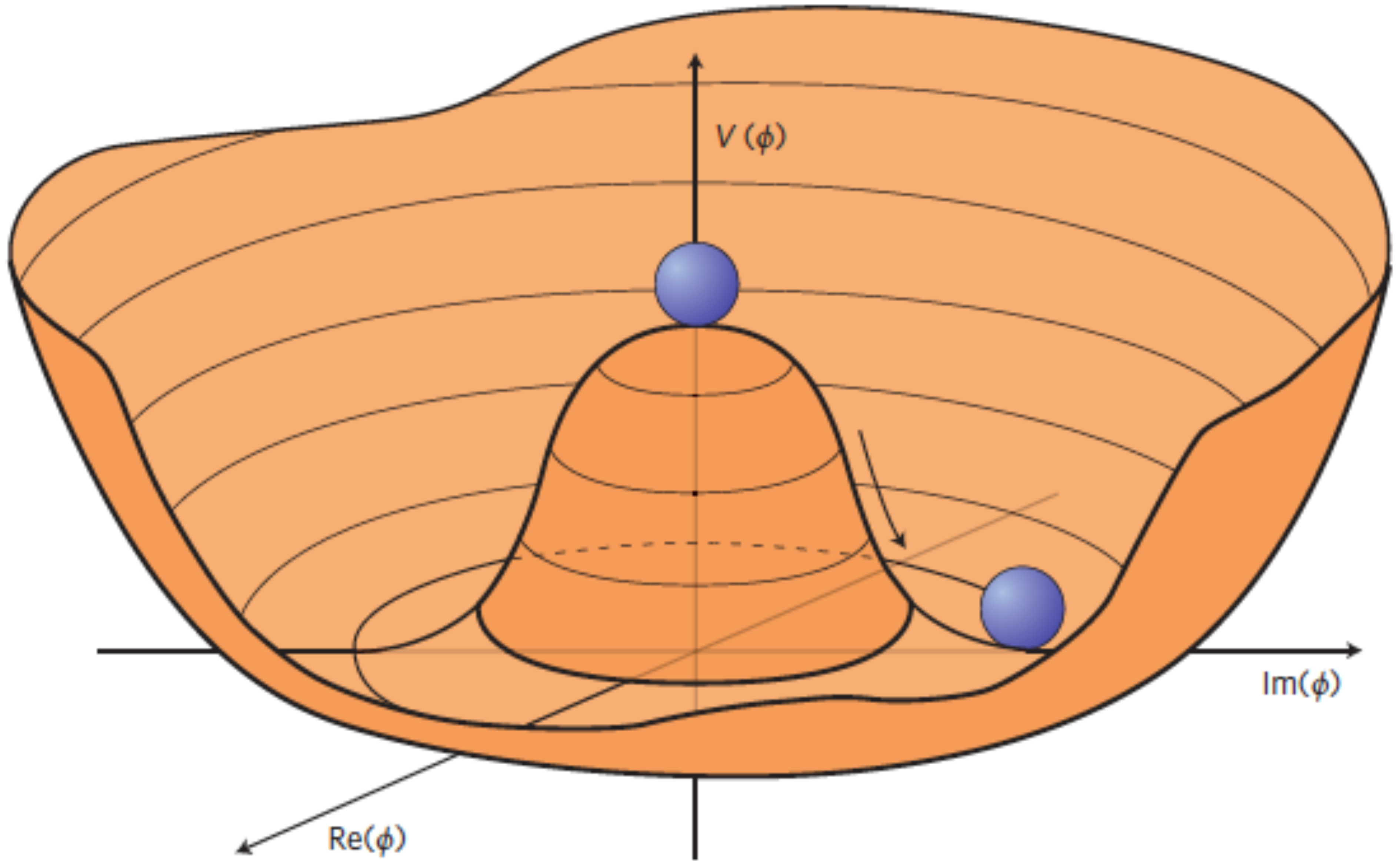
   - SSB: $G = \mathrm{U}(1) \to \emptyset$
   - Massless at all orders




Credit: CERN

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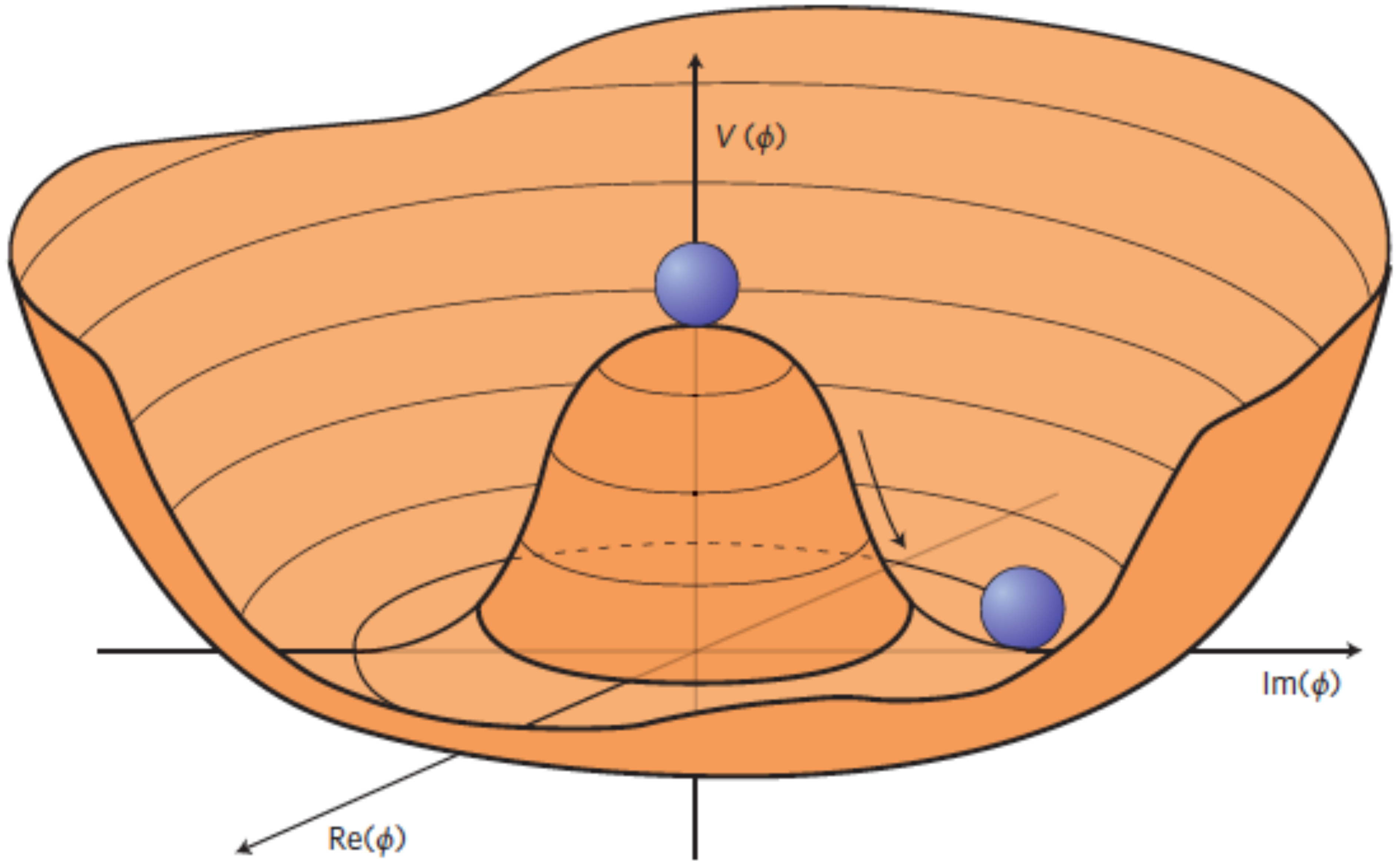
    - SSB + explicit symmetry breaking terms

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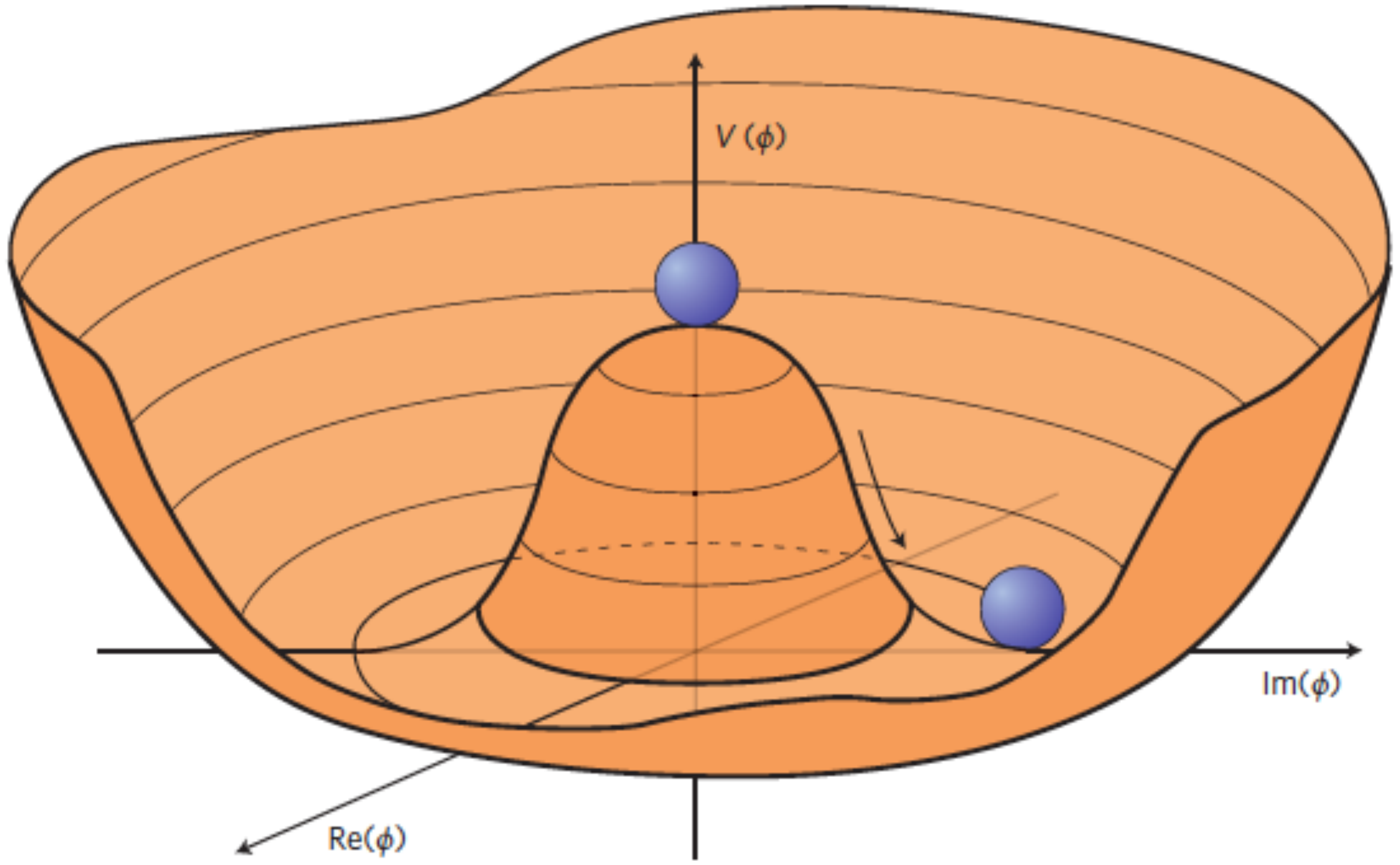
**3. Accidents**

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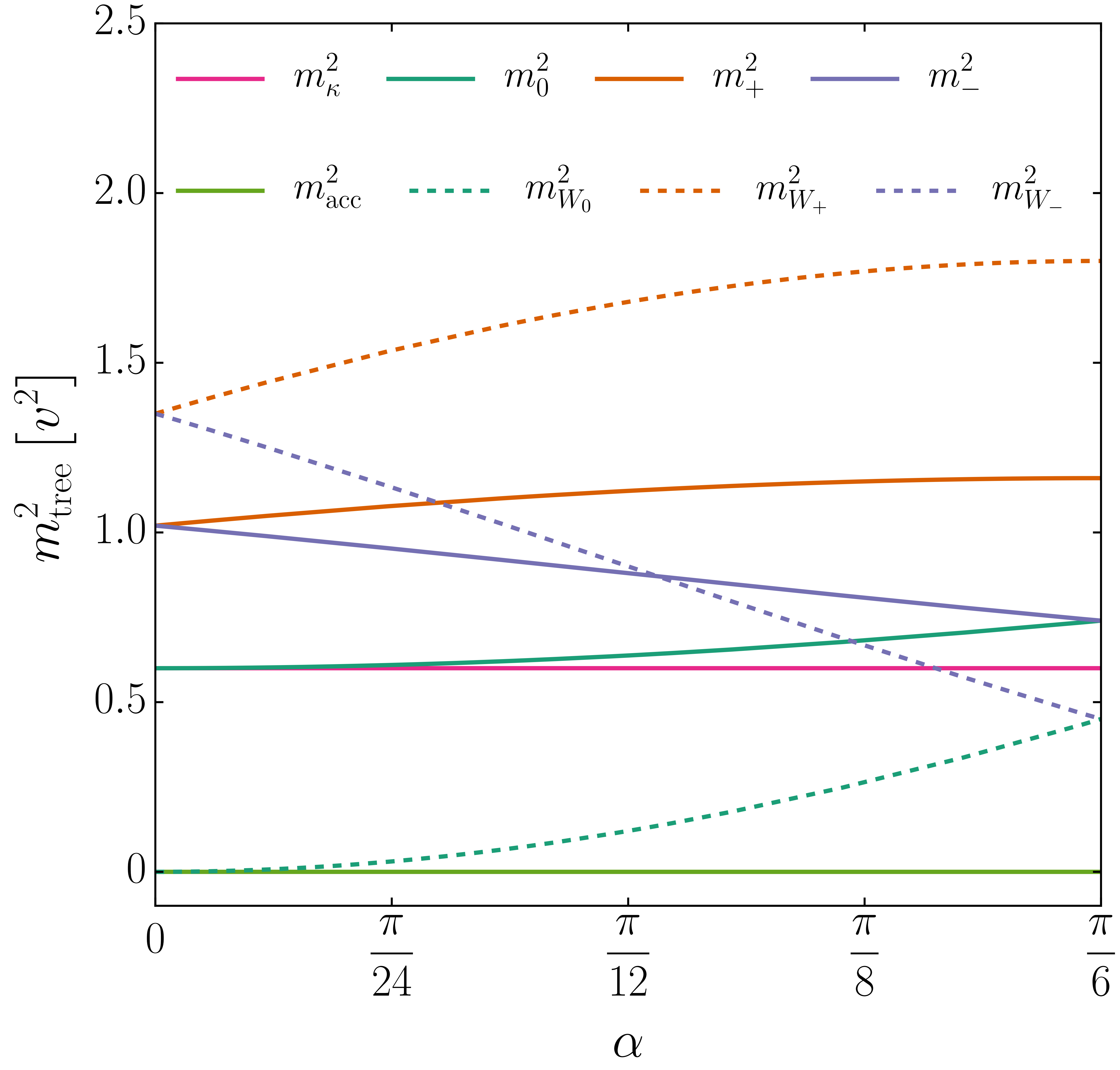

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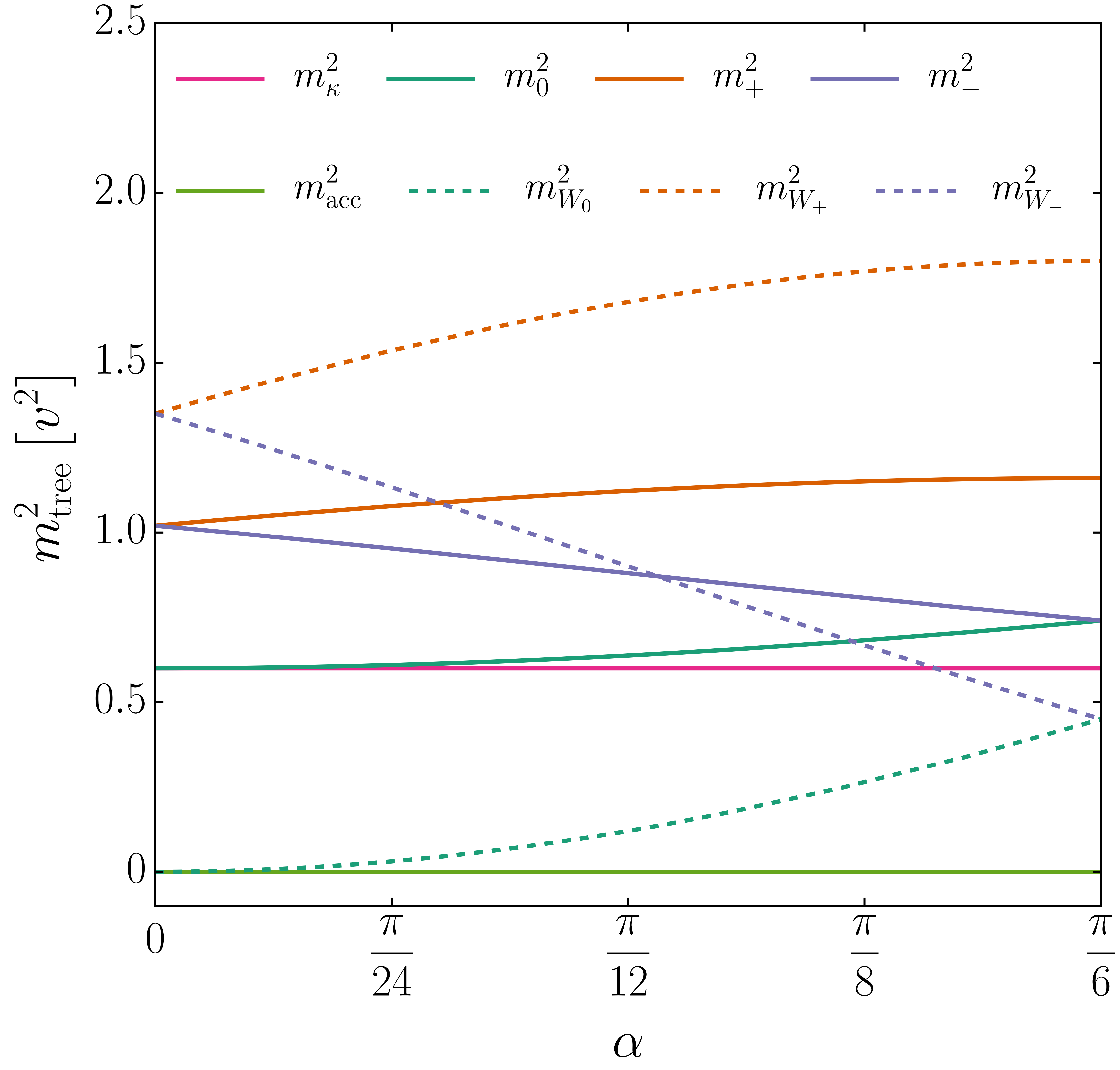

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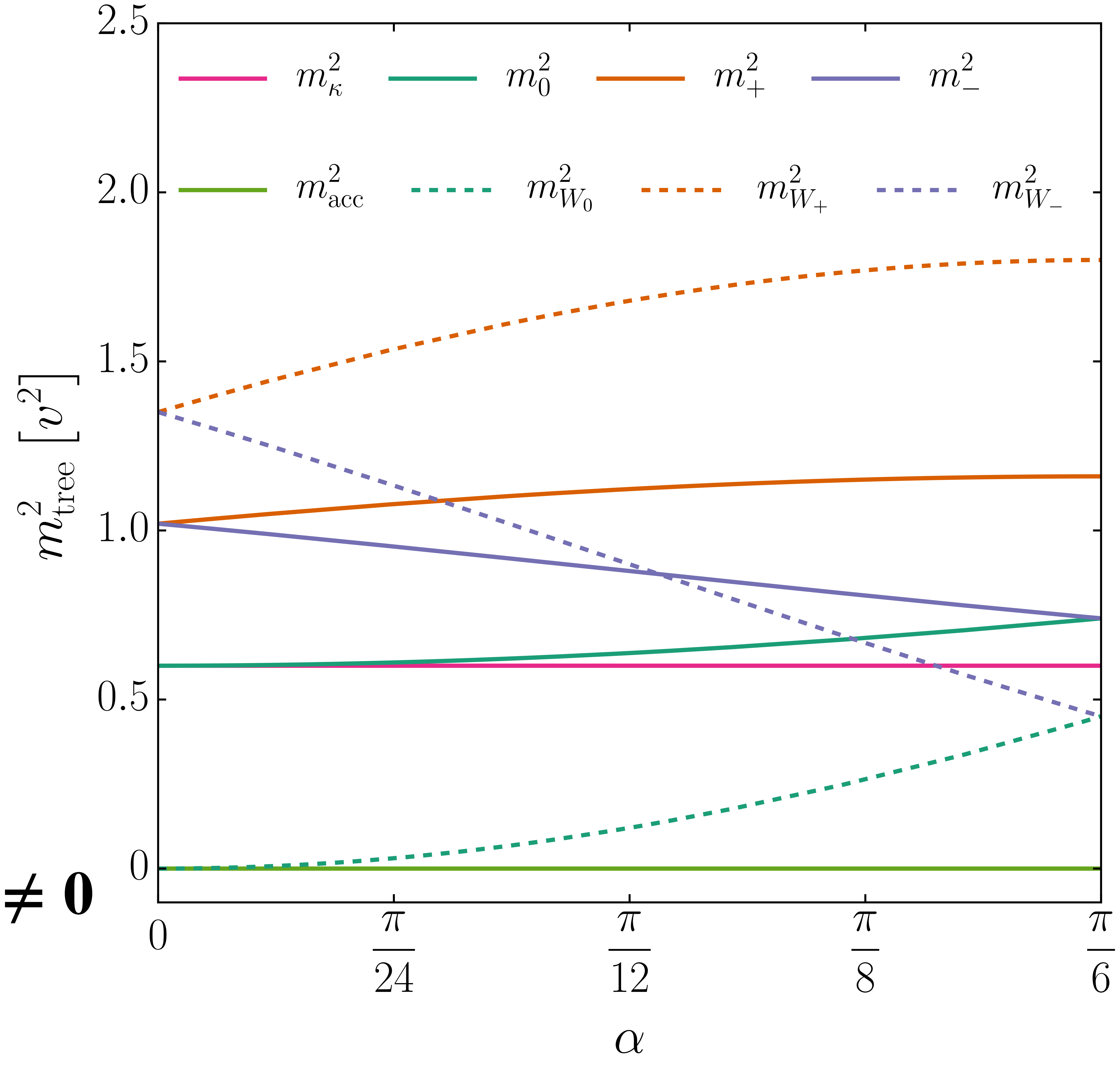

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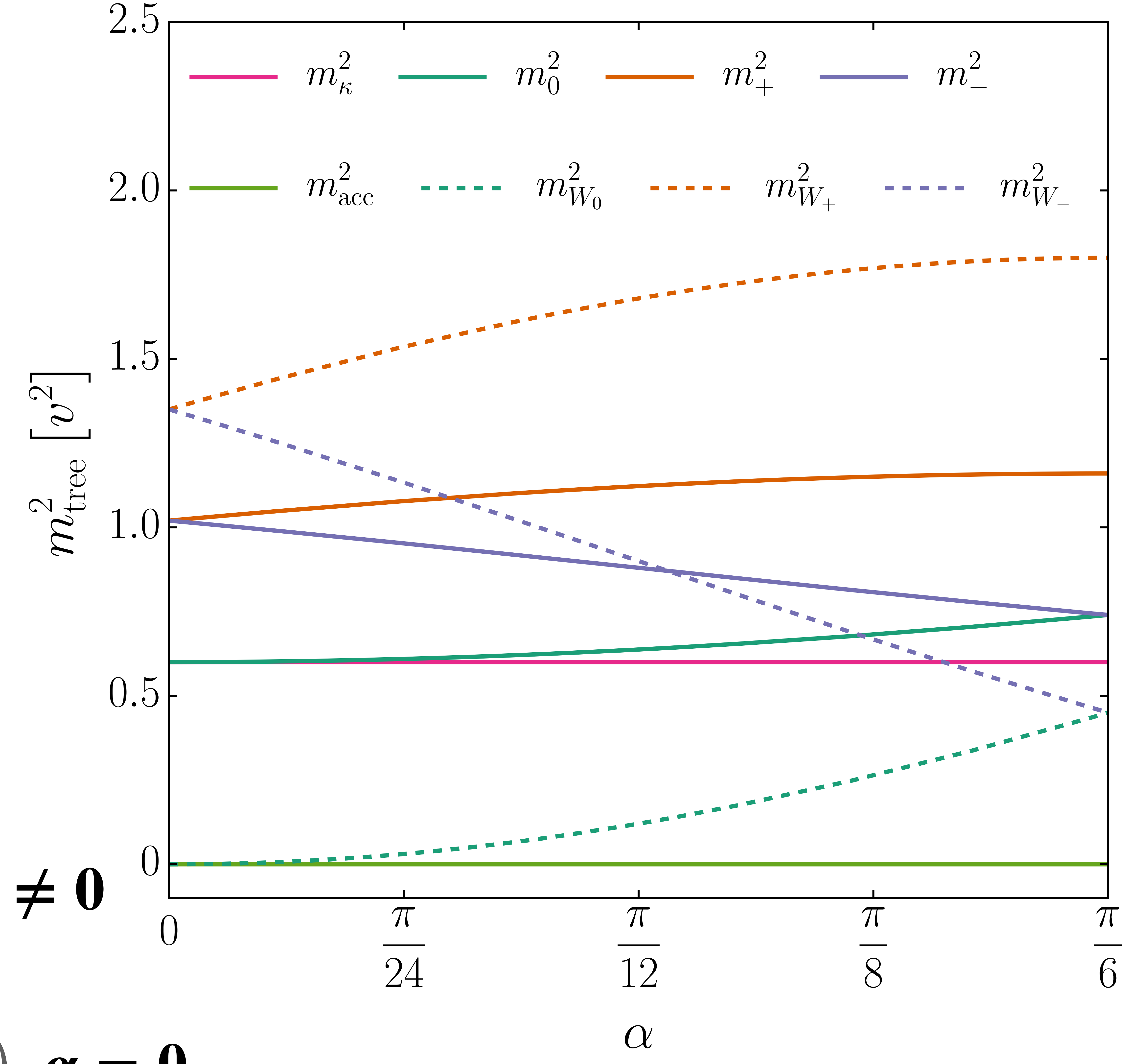


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## Bosonic contribution

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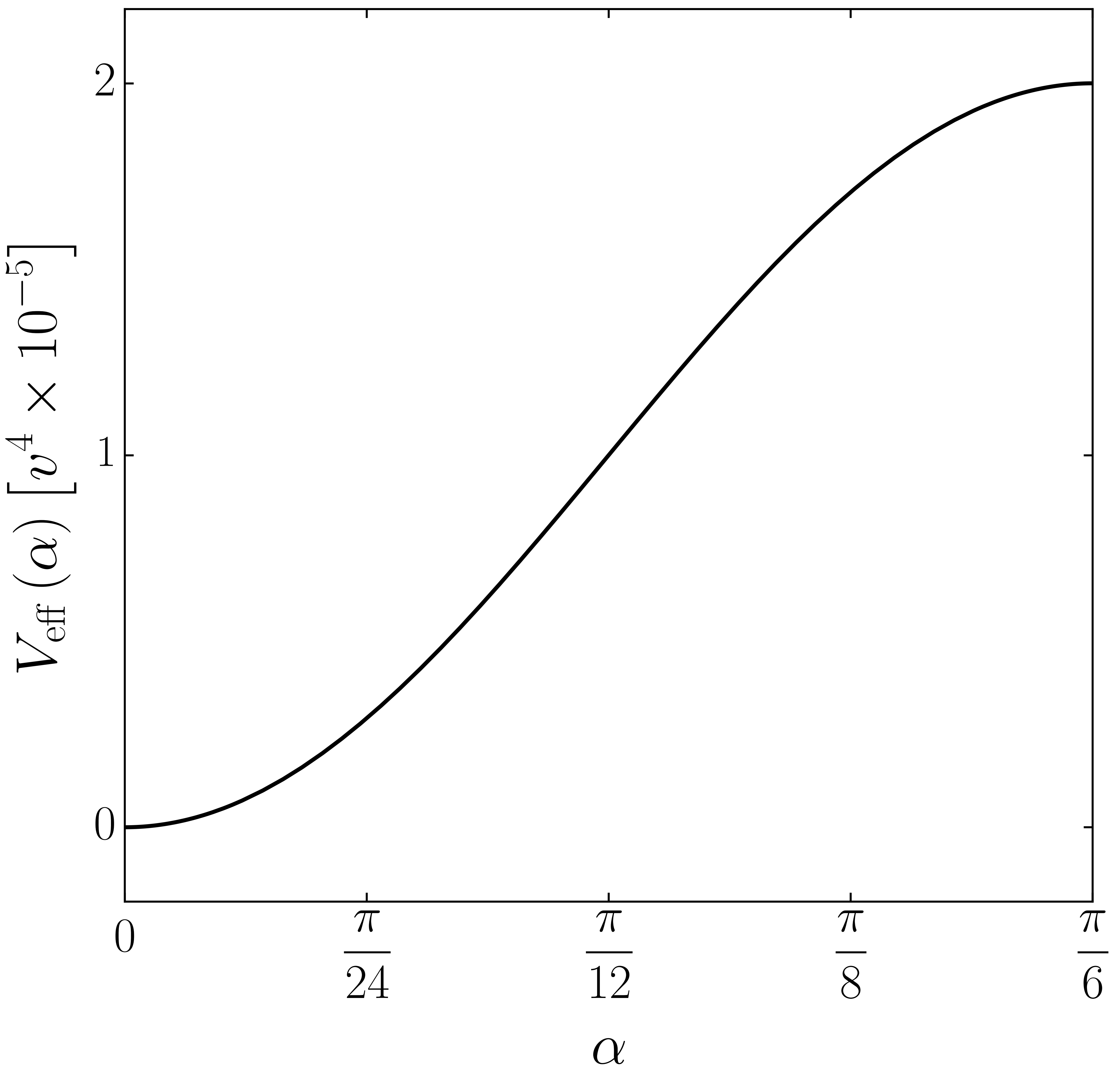

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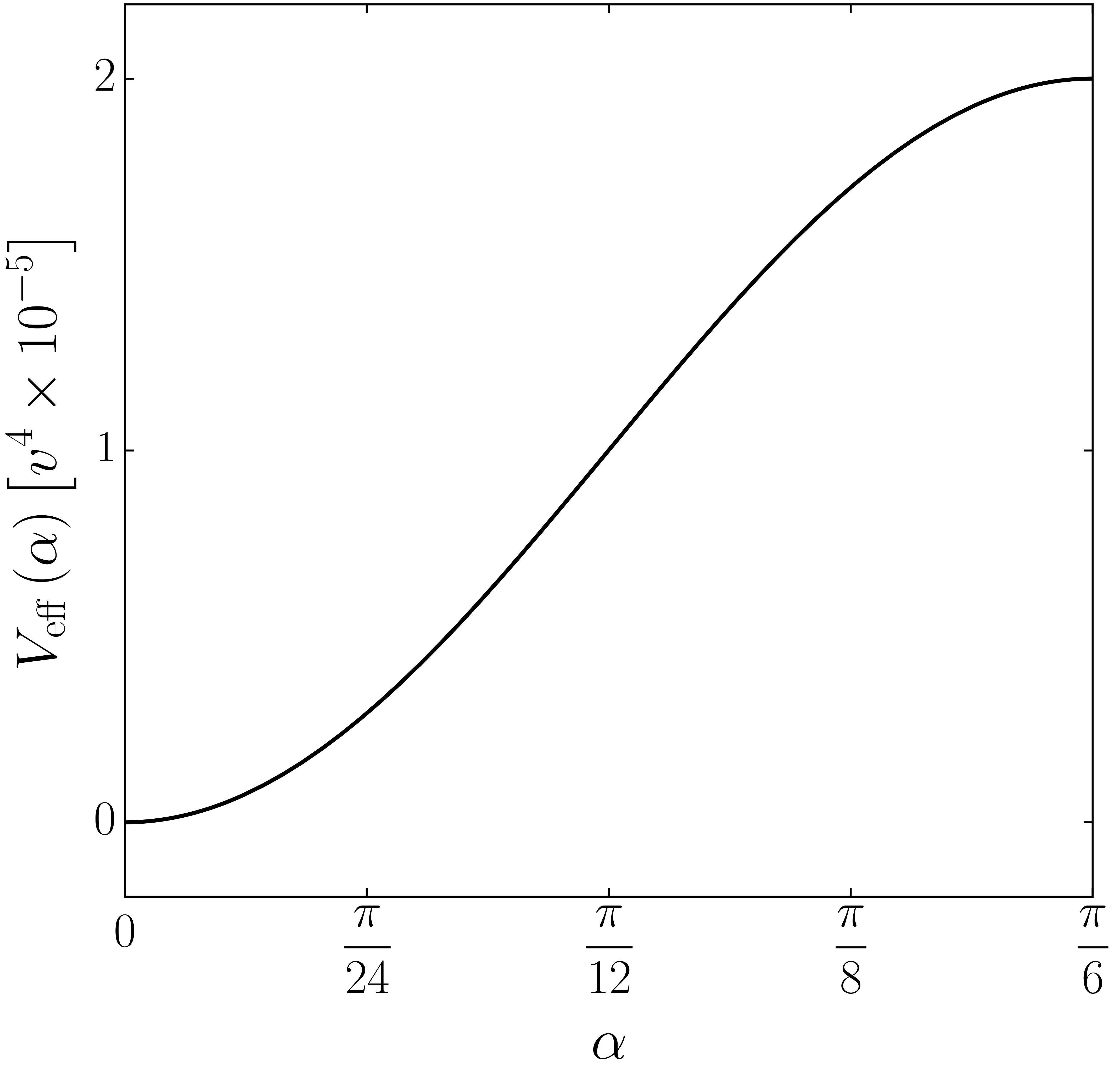

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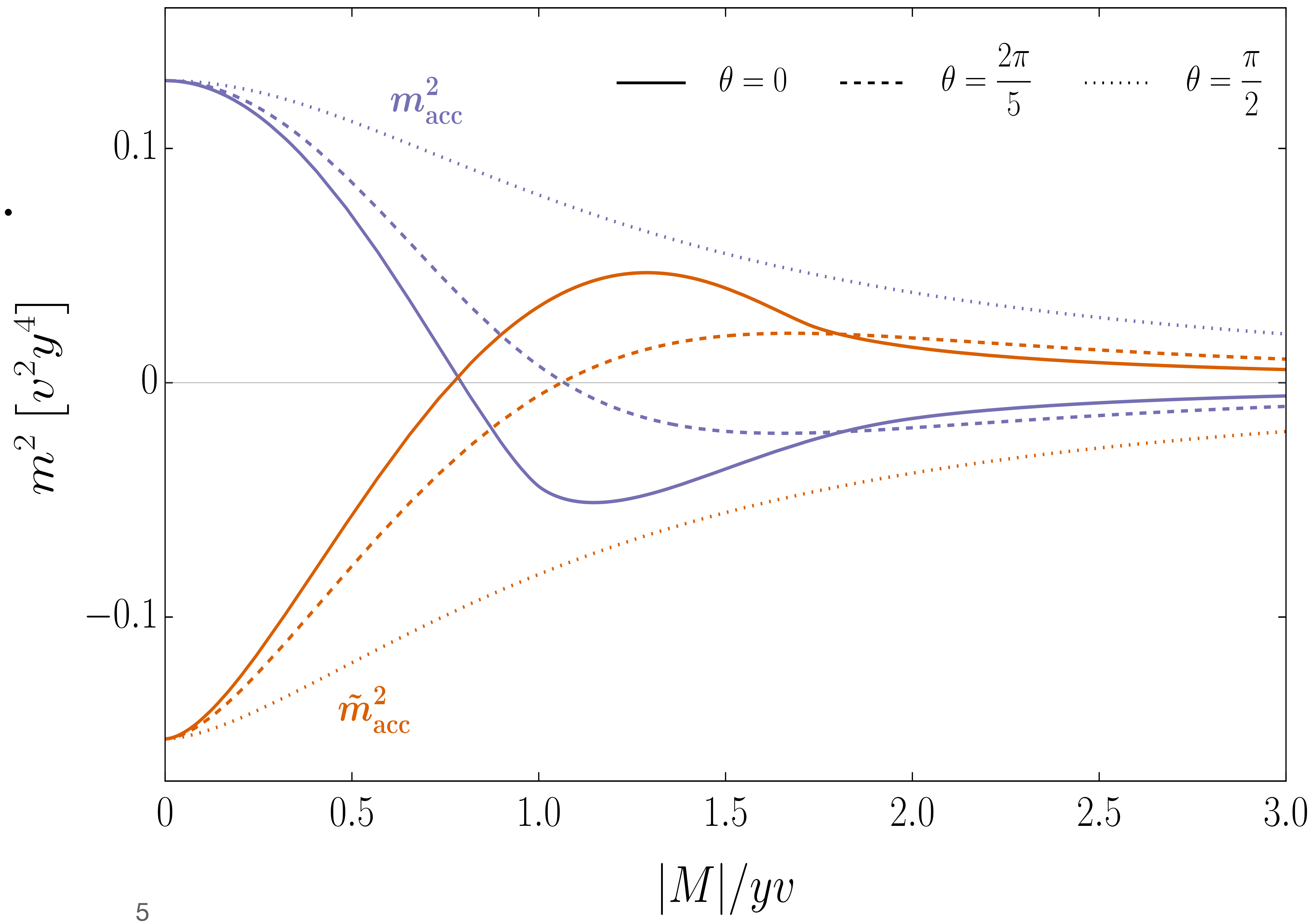

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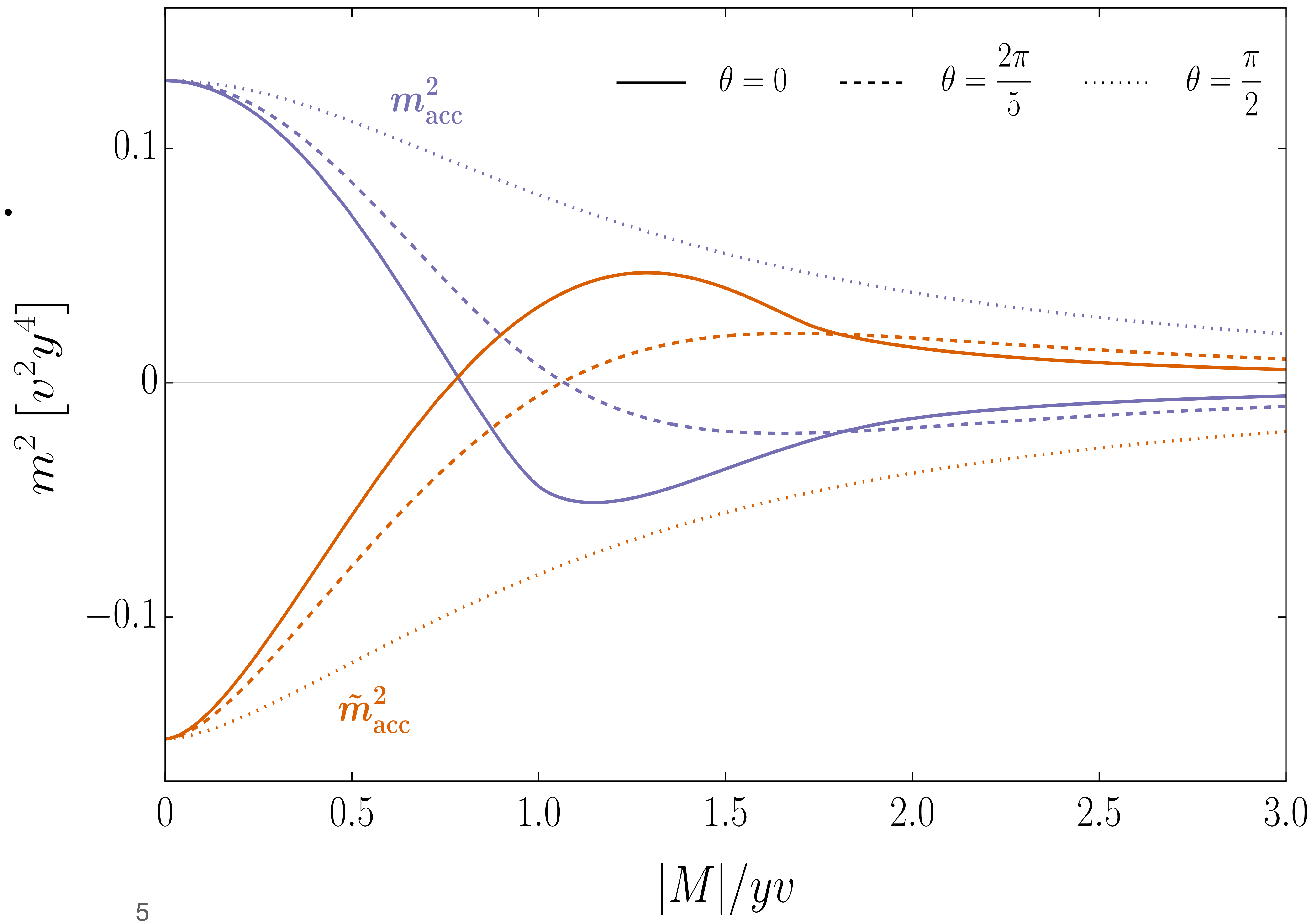

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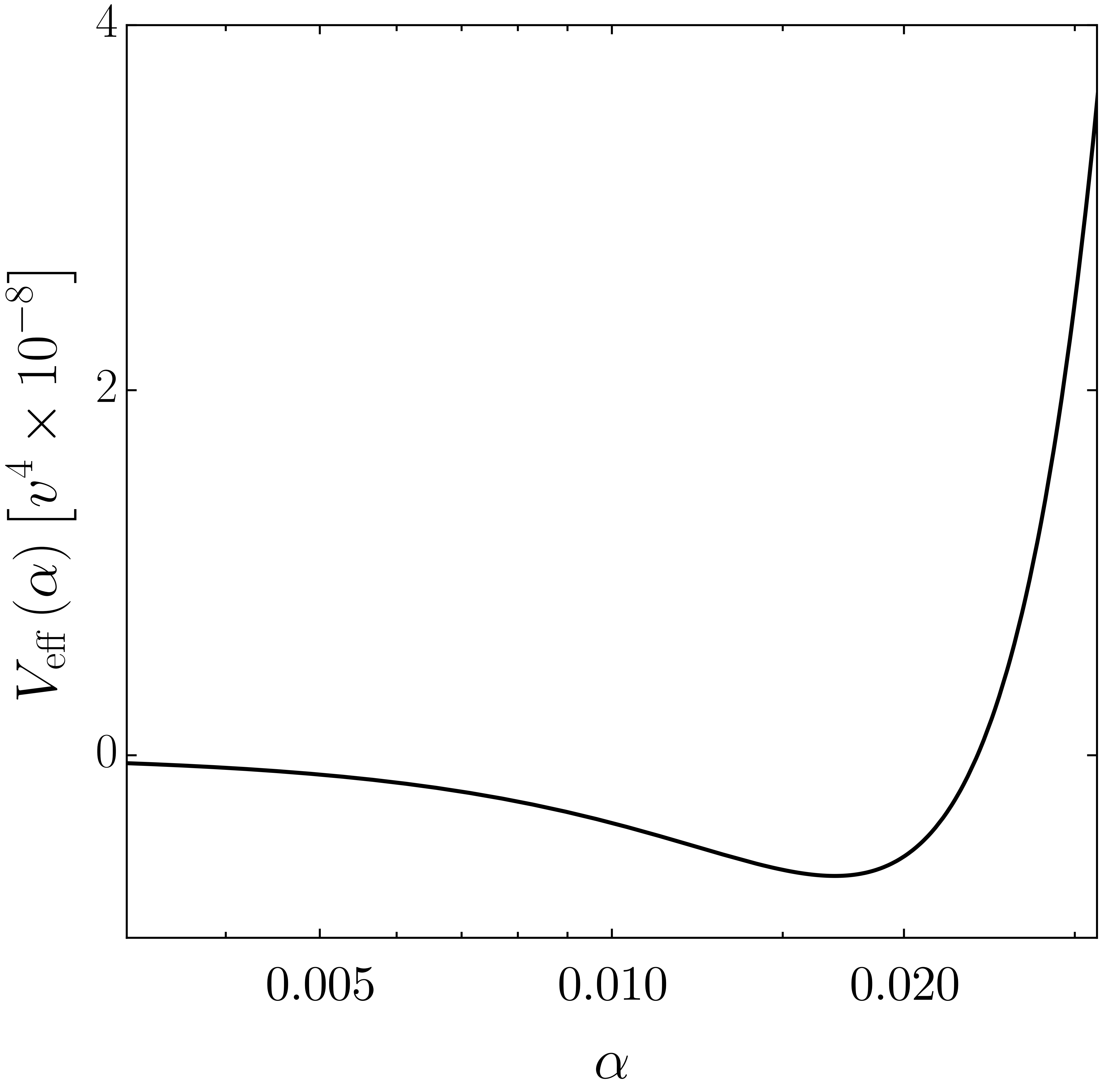


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Tuning $c_1$ against $c_2$:

breaking of $\mathrm{U}(1)'$ at a scale $v' \ll v$

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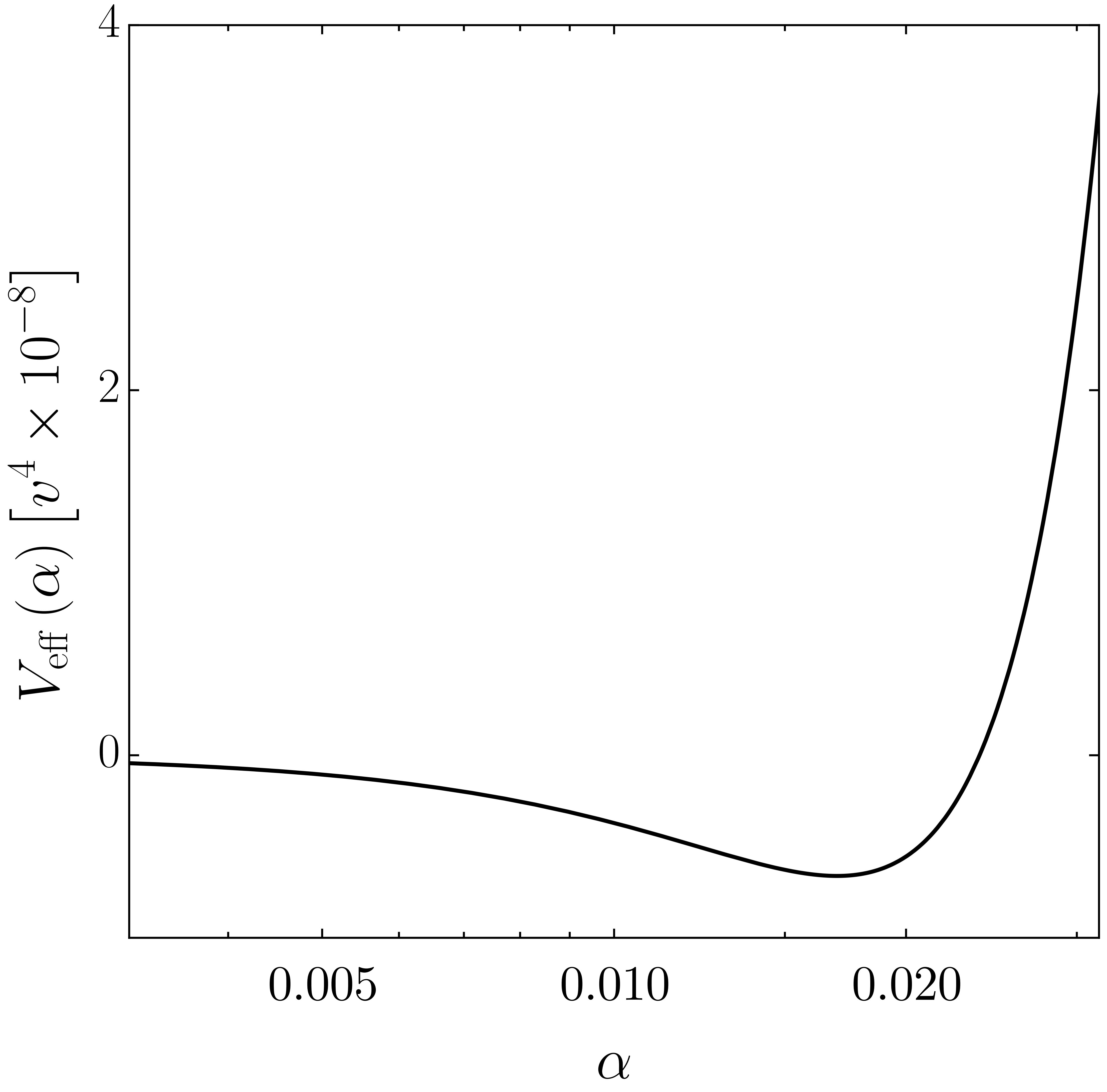


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**We can identify the accident with the Abelian Higgs**

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**DM candidate**:

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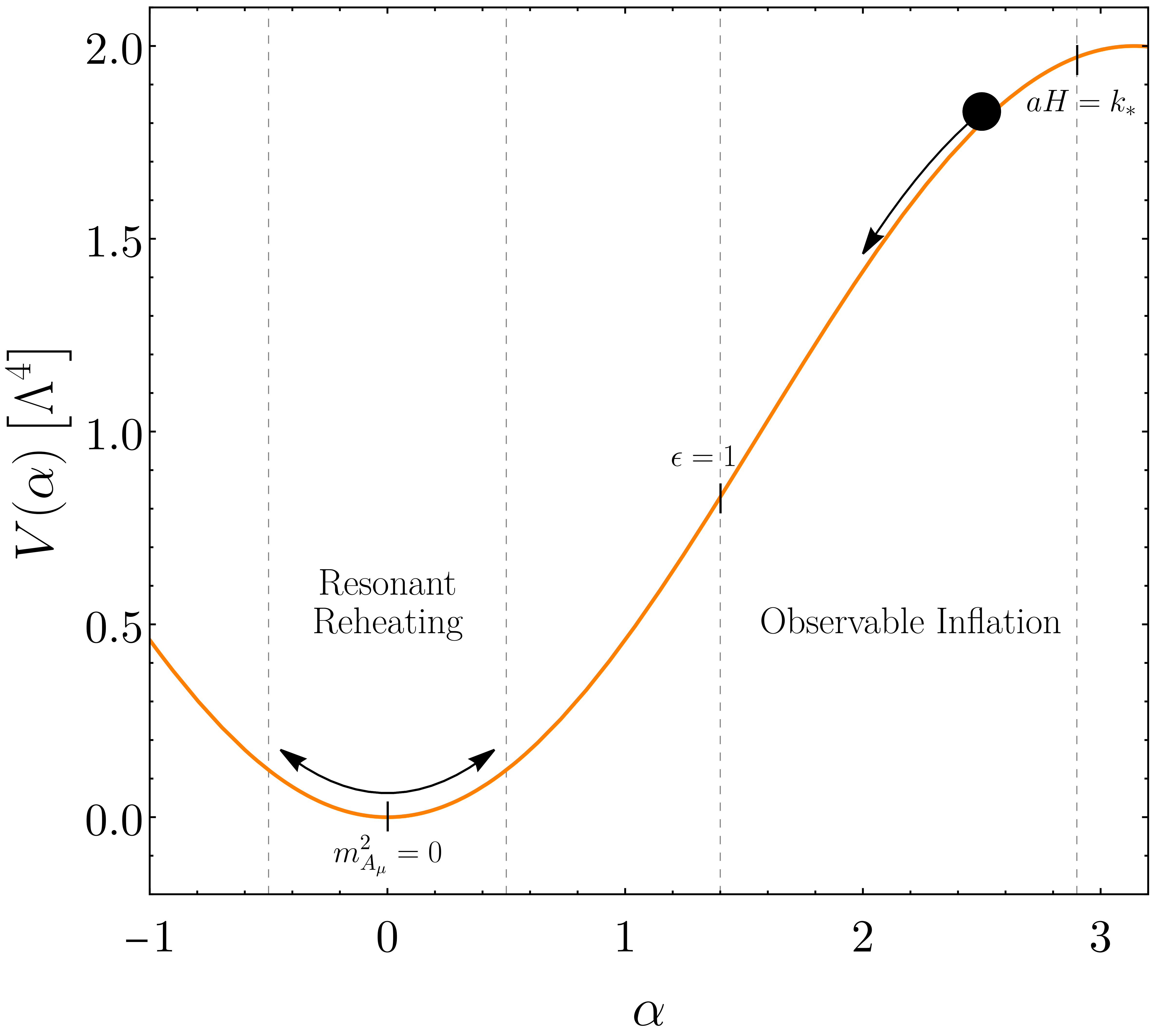
- Possible **reheating mechanism** built in



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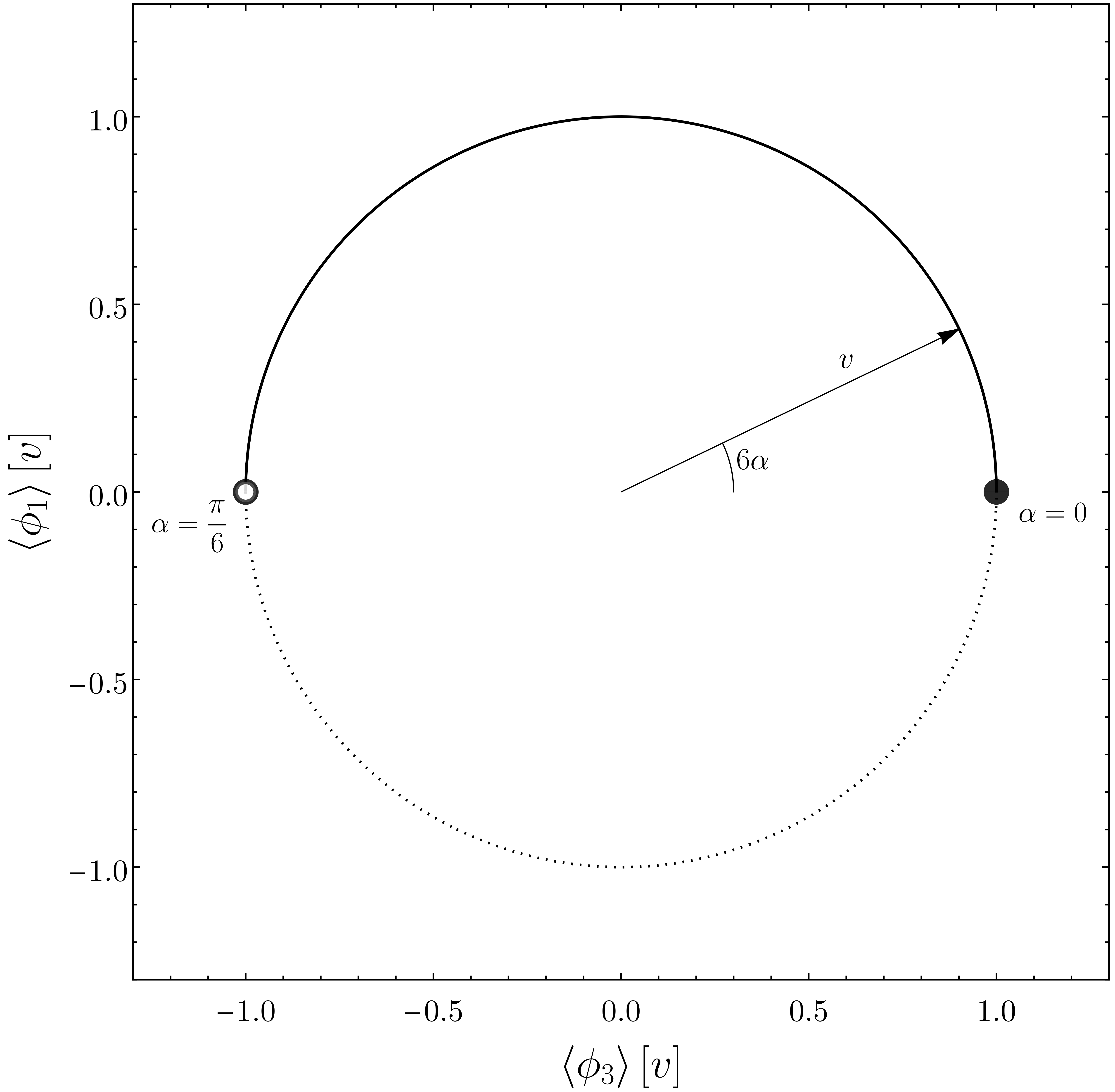
- Large representations $\Longrightarrow$ tree-level **massless scalars**
- No accidental symmetries at work: **accidents $\neq$ pNGBs**
- **Loop corrections** give accidents a mass
- Many different **possible applications**:
    - (Abelian) Higgs model: little hierarchy problem
    - Dark Matter candidate
    - Inflation
    - Reheating

# Thank you for your attention!

# Backup Slides

# Vacuum Manifold



# The SU(3) ten-plet

$$V = -\mu^2 S + \frac{1}{2}(\lambda S^2 + \delta A^a A^a) \longrightarrow$$ Invariant ONLY under $\mathrm{SU}(3) \times \mathrm{U}(1)$

- ESP: $\mathrm{SU}(3) \times \mathrm{U}(1) \longrightarrow \mathrm{U}(1)_3 \times \mathrm{U}(1)_8$ & 6 accidents
- Generic point: $\mathrm{SU}(3) \times \mathrm{U}(1) \longrightarrow \emptyset$ & 2 accidents

Scalar one-loop corrections $\longrightarrow$ The ESP is stabilised

# Accident Dark Matter

## the SU(2) model

Higgs-portal annihilation

Direct detection constraints

↓

$$m_{\rm DM} \gtrsim 2 - 3 \text{ TeV}$$

or

$$m_{\rm DM} \simeq m_h/2$$

Dark photon annihilation

Ellipticity constraint

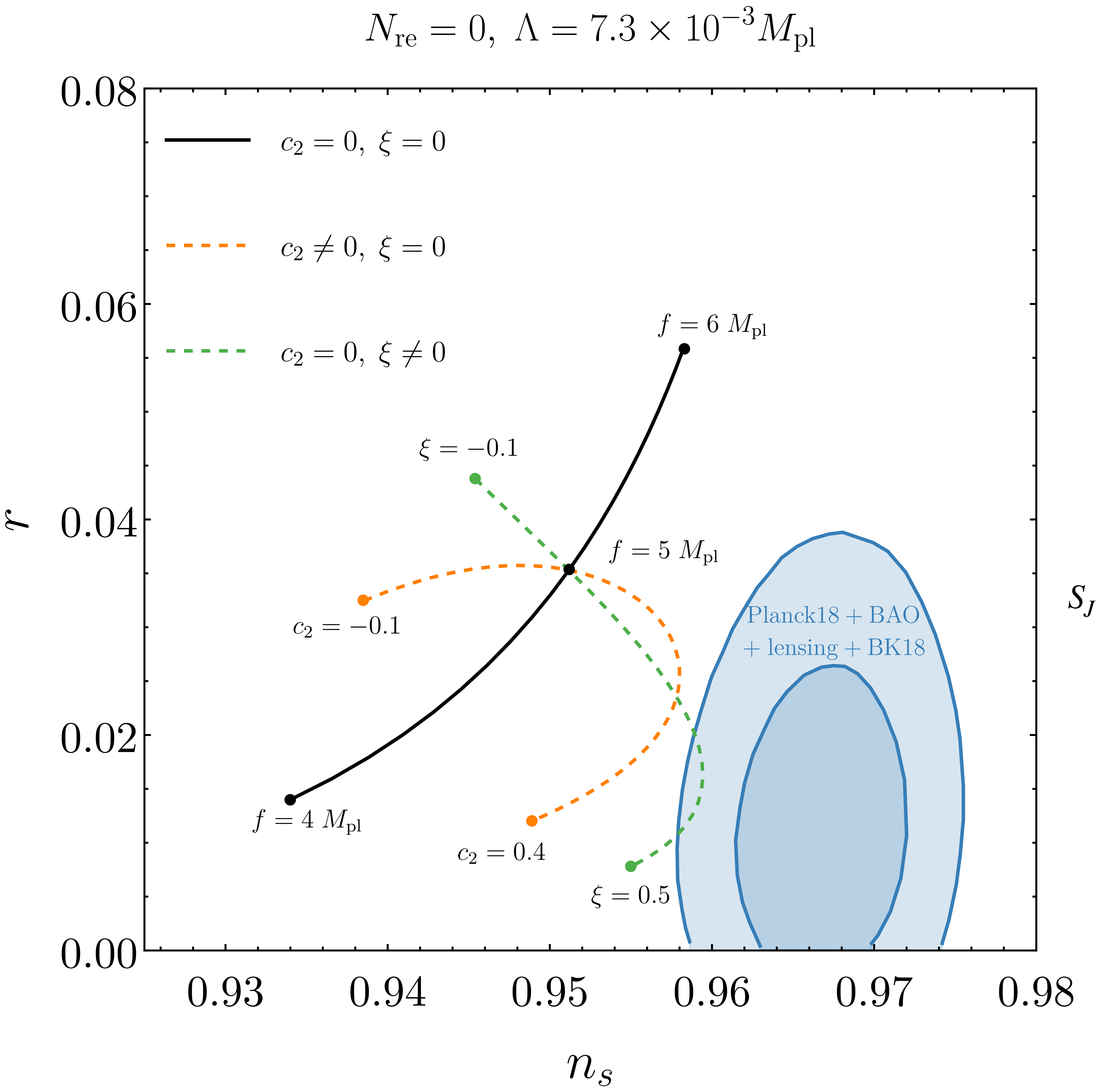
↓

$$Q_D^4 \alpha_D^2 \simeq 2.2 \times 10^{-10} \, (m_{\rm DM}/\text{GeV})^2$$

and

$$m_{\rm DM} \gtrsim 100 \text{ GeV}$$

# Inflation




Second harmonic

$$V(\phi) = \Lambda^4 \left[ 1 - \cos\frac{\phi}{f} + c_2 \left( 1 - \cos 2\frac{\phi}{f} \right) \right]$$

Non-minimal coupling to $R$:

$$S_J = \int d^4x \sqrt{-g} \left\{ \frac{1}{2} M_{\rm pl}^2 R \left[ 1 + \xi \left( 1 - \cos\frac{\phi}{f} \right) \right] - \frac{1}{2} g^{\mu\nu} \partial_\mu \phi \partial_\nu \phi - \Lambda^4 \left( 1 - \cos\frac{\phi}{f} \right) \right\}$$