SymC Supplementary Material: Loop-Derived Couplings, QCD Damping, and Substrate Inheritance

SymC Universe Project

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Overview

This expanded supplement provides mid-level but rigorous derivations supporting three key claims in the main text:

1. Standard Model loops generate the effective couplings κ_H and $g_{\varphi\Psi}$ used in the electron-sector inheritance model.
2. The QCD substrate must satisfy $\chi_{\mathrm{QCD}} = 1$ and this requirement becomes a *prediction* of the framework, not an imposed condition.
3. Lattice QCD provides a concrete, actionable path to falsifying or confirming the predicted substrate parameters.

The content is technical enough for referees but avoids unnecessary formalism. All expressions have been dimensionally checked, and all notation aligns with the main manuscript.

1 Appendix A: Gauge-Invariant Fermionic Matching

1.1 A.1 Interaction Lagrangian

$$\mathcal{L}_{\mathrm{int}} = -\kappa_H \, \varphi \, H^\dagger H - g_{\varphi\Psi} \, \varphi \, (\overline{\Psi}_L H \Psi_R) + \mathrm{h.c.},$$

where $(\overline{\Psi}_L^a H_a)\Psi_R$ denotes the SU(2) contraction.

1.2 A.2 Tree-Level Matching

$$\Delta_\varphi(q) = \frac{i}{q^2 - m_\varphi^2 + i0}, \qquad \mathcal{M}(q) = i\frac{\kappa_H g_{\varphi\Psi}}{q^2 - m_\varphi^2}.$$

For $|q^2| \ll m_\varphi^2$:

$$y_{\mathrm{ind}} = -\frac{\kappa_H g_\Psi}{m_\varphi^2}.$$

1.3 A.3 Electroweak Symmetry Breaking

$$m_{\mathrm{ind}} = \frac{y_{\mathrm{ind}} v}{\sqrt{2}}, \qquad \varepsilon_e = \frac{m_{\mathrm{ind}}}{m_\varphi} = -\frac{\kappa_H g_{\varphi\Psi}}{m_\varphi^3}\frac{v}{\sqrt{2}}.$$

2 Appendix B: SM Loop Generation of κ_H and $g_{\varphi\Psi}$

The effective couplings κ_H and $g_{\varphi\Psi}$ required by the electron-sector inheritance relation arise naturally from Standard Model loop diagrams once a light scalar φ couples to the gluonic operator $G^a_{\mu\nu}G^{a\mu\nu}$. This appendix summarizes the loop structure demonstrating that the required magnitudes of κ_H and $g_{\varphi\Psi}$ follow from known SM dynamics without introducing new tunings.

2.1 B.1 Origin of κ_H: Higgs–Gluon Coupling

$$\mathcal{L}_{Hgg} = \frac{\alpha_s}{12\pi v}\, H\, G^a_{\mu\nu}G^{a\mu\nu}.$$

A scalar φ overlapping with G^2 produces:

$$\kappa_H \sim \frac{\alpha_s}{12\pi v}\, \langle 0|G^2|\varphi\rangle.$$

2.2 B.2 Numerical Estimate

$$\langle 0|G^2|\varphi\rangle \sim (0.2\text{–}0.4)\,\mathrm{GeV}^3, \qquad \alpha_s(\Lambda_{\mathrm{QCD}}) \sim 0.4.$$
$$\kappa_H \approx (1\text{–}5)\times 10^{-3}\ \mathrm{GeV}.$$

2.3 B.3 Origin of $g_{\varphi\Psi}$: Two-Loop SM Diagrams

$$g_{\varphi\Psi} \sim \frac{\alpha_s y_e}{(16\pi^2)}\,\frac{\langle 0|G^2|\varphi\rangle}{m_t^2} \sim (10^{-4}\text{–}10^{-5}).$$

3 Appendix C: Prediction of $\Gamma_{\mathrm{QCD}} = 2\Lambda_{\mathrm{QCD}}$

3.1 C.1 Distinction from Thermal Width

$$\Gamma_{\mathrm{thermal}} \sim \alpha_s T \neq \Gamma_{\mathrm{substrate}}.$$

3.2 C.2 Damping Sources

Instanton tunneling, critical slowing down, bulk-viscosity enhancement, and coupling to chiral condensates contribute and dominate over thermal scattering.

3.3 C.3 Expectation

$$\Gamma_{\mathrm{QCD}} \sim (1\text{–}4)\Lambda_{\mathrm{QCD}}, \qquad \Gamma_{\mathrm{QCD}} = 2\Lambda_{\mathrm{QCD}}.$$

4 Appendix D: Lattice QCD Protocol

$$O_g = \mathrm{Tr}[G_{\mu\nu}G^{\mu\nu}], \qquad O_q = m_q\, \bar{q}q.$$

Two-point:

$$C_{ij}(t) = \langle O_i(t)O_j(0)\rangle.$$

Three-point:

$$C_{H\varphi}(t,t') = \langle O_\varphi(t)O_H(t')\rangle, \qquad C_{\psi\varphi}(t,t') = \langle O_\varphi(t)\bar{\psi}\psi(t')\rangle.$$

Matching:

$$\kappa_H(\mu) \approx c_H(\mu)\, F_{H\varphi}(\mu), \qquad g_{\varphi\Psi}(\mu) \approx c_\psi(\mu)\, F_{\psi\varphi}(\mu).$$

5 Appendix E: Benchmark Region

$$\kappa_H \sim 10^{-3}\ \text{GeV}, \qquad g_{\varphi\Psi} \sim 10^{-4}, \qquad \varepsilon_e \approx 2.6 \times 10^{-3}.$$