# No-Go Bounds on Electromagnetic-Topology-to-Higgs Coupling via Einstein-Cartan Torsion: Planck Suppression and Alternative Coupling Paths

A Theoretical Contribution with Falsifiable Null Predictions

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## EPISTEMIC STATUS

This document assembles established physics into a novel configuration and derives quantitative bounds on the resulting coupling strength. Individual components are grounded in peer-reviewed literature. The synthesis connecting them is hypothetical and untested. **The principal result is a set of no-go bounds:** the standard Einstein-Cartan torsion channel and three alternative coupling paths are each shown to be insufficient by 40–129 orders of magnitude to produce measurable effects with laboratory or astrophysical electromagnetic fields.

**REVISION NOTE (v4):** Following peer review, this version: (a) retitles the paper to foreground the no-go bound as the primary contribution; (b) provides a complete, self-contained derivation of the torsion-Higgs coupling in Appendix A, including the variational procedure and torsion decomposition; (c) addresses frame-dependence (Jordan vs. Einstein) of the coupling parameter; (d) specifies the physical loss mechanisms underlying the feedback ODEs; (e) deepens the analysis of Chern-Simons and Nieh-Yan paths with references to specific BSM models; (f) removes phenomenological speculation (former Appendix A of v3) as unsupported by the quantitative analysis.

## Abstract

We investigate whether electromagnetic fields with non-trivial topological structure — specifically, non-zero magnetic helicity in Hopf-fibration configurations — can couple to the Higgs sector through spacetime torsion in Einstein-Cartan gravity. We derive the torsion-Higgs coupling Lagrangian $L_{ST} = -(\xi/4)S_{\mu\nu\rho}S^{\mu\nu\rho}|\phi|^2$ from the Einstein-Cartan-Sciama-Kibble action via explicit variational procedure (Appendix A) and establish the phase transition threshold $\varepsilon \geq 2\lambda v^2 \approx 15{,}734\ \text{GeV}^2$.

**Our central result is a set of no-go bounds.** The standard EC torsion channel is suppressed by $\sim 10^{129}$ orders relative to threshold for laboratory fields (B ~ 20 T). Three alternative paths are quantitatively analyzed: Chern-Simons coupling to a BSM pseudoscalar (deficit: ~45 orders), axion-like particle mixing (deficit: ~53 orders with optimistic astrophysical bounds), and Nieh-Yan topological density (deficit: ≥ 40 orders under generous assumptions). We show these bounds are frame-invariant under Jordan-to-Einstein conformal transformation. The minimum deficit of ~40 orders across all analyzed paths establishes a rigorous benchmark for any future theory proposing EM-topology-to-scalar coupling. Null-result experimental protocols are proposed that would independently constrain torsion-scalar coupling constants.

# 1. Introduction

## 1.1 Motivation

This paper addresses a question in theoretical physics: **does the topological structure of the electromagnetic field couple to the scalar sector of the Standard Model, and if so, through what mechanism and at what strength?** The paper's contribution is to establish rigorous quantitative bounds demonstrating that all known coupling pathways are insufficient by vast margins, thereby constraining the parameter space for future model-building.

Several independent results make this question well-posed. Einstein-Cartan theory [1–3], a minimal extension of general relativity incorporating spacetime torsion, provides a natural coupling between spin angular momentum and spacetime geometry. The coupling of torsion to scalar fields — including the Higgs — is well-established in the literature [4–6]. Rañada's demonstration [7,8] that Maxwell's equations admit topologically non-trivial solutions characterized by the Hopf fibration, extended to experimental realizations [9], establishes that electromagnetic fields can carry structured spin angular momentum density — the source term for torsion.

The coupling chain — EM topology → spin density → torsion → Higgs VEV modification — has not, to our knowledge, been analyzed quantitatively. This paper provides that analysis and demonstrates that every link in the chain is quantitatively viable except the overall coupling strength, which is suppressed by factors of the Planck mass that render the effect undetectable.

## 1.2 Scope and Nature of the Contribution

This paper is a theoretical contribution aimed at setting bounds and guiding model-building. It does not propose a new mechanism capable of overcoming the identified suppression. The principal results are: (a) a rigorous no-go bound on the standard EC channel (~129 orders of magnitude below threshold); (b) systematic quantitative bounds on three alternative coupling paths (Chern-Simons, ALP, Nieh-Yan); (c) a minimum deficit of ~40 orders as a benchmark for viable future theories; and (d) model-independent experimental protocols whose null results constrain torsion-scalar couplings.

The work is targeted at the theoretical physics community working on Einstein-Cartan gravity, torsion-scalar couplings, and topological field theory. It is intended as a foundation for future investigations, not as a proposal for an achievable experimental effect.

## 1.3 Notation and Conventions

Natural units ■ = c = 1 unless otherwise noted. Metric signature (–,+,+,+). Reduced Planck mass $M_{Pl} = (8\pi G)^{-1/2} \approx 2.44 \times 10^{18}$ GeV. SI units for experimental parameters. Higgs VEV $v \approx 246$ GeV, self-coupling $\lambda \approx 0.13$. The non-minimal coupling $\xi$ denotes the coefficient of the $R|\phi|^2$ term in the Jordan-frame action.

# 2. Theoretical Foundations

## 2.1 General Relativity and Spacetime Geometry

Einstein's field equations [10] relate spacetime geometry (Einstein tensor $G_{\mu\nu}$) to energy-momentum content (stress-energy tensor $T_{\mu\nu}$):

$$G_{\mu\nu} = (8\pi G/c^4)\, T_{\mu\nu}$$

## 2.2 Einstein-Cartan Theory and Torsion

Einstein-Cartan (EC) theory [1–3] extends GR by allowing the spacetime connection to be asymmetric, introducing the torsion tensor $S^\rho{}_{\mu\nu} = \Gamma^\rho{}_{[\mu\nu]}$. In standard GR the connection is the symmetric Levi-Civita connection; in EC theory, torsion is sourced by intrinsic spin angular momentum.

Key features: (a) minimal extension of GR, no new fields or free parameters; (b) torsion is non-dynamical — algebraically determined by spin density via the Cartan equation; (c) torsion vanishes outside matter, preserving all vacuum GR predictions; (d) torsion couples naturally to scalar fields including the Higgs [4–6]; (e) torsion produces an effective spin-spin contact interaction.

Modern developments in Poincaré gauge theory [11,12] and its application to Higgs inflation [5,6,13] have explored the allowed forms of torsion-scalar couplings beyond the minimal non-minimal coupling $\xi$. In the most general quadratic Poincaré gauge Lagrangian, the torsion sector admits three independent coupling constants corresponding to the three irreducible components of torsion (trace, axial, tensor). For the electromagnetic source considered here, only the axial component is sourced (see Appendix A), so a single coupling parameter suffices.

### 2.3 The Higgs Field and Vacuum Structure

The Higgs field [14] permeates all of space with VEV $v \approx 246$ GeV. The potential:

$$V(\phi) = \lambda(|\phi|^2 - v^2)^2$$

The minimum at $|\phi| = v$ defines the electroweak vacuum. All fermion and weak boson masses are proportional to v.

### 2.4 Electromagnetic Field Topology and Helicity

Rañada [7,8] showed that Maxwell's equations admit solutions with Hopf-fibration topology. The magnetic helicity:

$$h = \int A \cdot B \, d^3x$$

measures the linking and knotting of field lines. For topologically non-trivial configurations, h is a non-zero integer topological invariant, conserved in ideal MHD and approximately conserved in superconducting systems. Experimental realizations of knotted light fields have been demonstrated [9]. An EM field with non-zero helicity carries structured spin angular momentum density — the source for torsion in EC theory.

## 3. The Proposed Coupling Mechanism

### 3.1 From Electromagnetic Helicity to Torsion

In EC theory, the torsion tensor is algebraically determined by the spin density tensor [4] (see Appendix A for the complete derivation):

$$S_{\mu\nu\rho} = (8\pi G/c^4)\ \sigma_{\mu\nu\rho}$$

For an EM field with Hopf-type topology, the spin density is non-zero, structured, and topologically protected. The torsion magnitude carries a suppression factor of $M_{Pl}^{-2}$ per factor, yielding $M_{Pl}^{-4}$ overall in the quadratic coupling $L_{ST}$.

### 3.2 From Torsion to Higgs Potential Modification

The coupling between torsion and the Higgs field, derived in Appendix A from the ECSK action:

$$L_{ST} = -(\xi/4)\ S_{\mu\nu\rho}\ S^{\mu\nu\rho}\ |\phi|^2$$

where $\xi$ is the non-minimal coupling constant in the Jordan frame. This term effectively reduces the Higgs mass-squared parameter. The complete derivation — including the variational procedure, torsion decomposition into irreducible components, and the Ricci scalar identity — is given in Appendix A.

### 3.3 Phase Transition Threshold

Defining $\varepsilon \equiv (4\xi/M_{Pl}^4)(\sigma/V)^2$, the transition from normal to modified vacuum occurs when:

$$\varepsilon \geq 2\lambda v^2 \approx 15{,}734 \text{ GeV}^2$$

Below threshold, the Higgs field maintains its standard VEV with perturbative shift $\delta v/v \sim \varepsilon/(4\lambda v^2)$. Above threshold, a local first-order phase transition occurs.

### 3.4 On the Feedback Cycle and the Bootstrap Limitation

A phase transition, once initiated, would drive positive feedback: reduced VEV → reduced particle masses → reduced EM losses → field intensification → greater torsion → further VEV reduction. This cycle is formalized in Section 6.3.

**This feedback cannot bootstrap the system to threshold.** The feedback gain is $G \sim \varepsilon/(2\lambda v^2)$. For $\varepsilon \sim 10^{-129}$ GeV$^2$ (the EC value), $G \sim 10^{-133}$. The enhanced effect is $\varepsilon_{eff} = \varepsilon/(1 - G) \approx \varepsilon(1 + 10^{-133})$. Feedback is relevant only when $\varepsilon$ already approaches threshold through the primary coupling.

## 4. Quantitative Analysis: The Standard EC Channel

This section constitutes the core quantitative result.

### 4.1 Laboratory Setup

We consider a superconducting toroidal magnet at the upper end of $Nb_3Sn$ technology: major radius R = 0.5 m, minor radius a = 0.25 m, volume $V = 2\pi^2 R a^2 \approx 0.62\ m^3$, toroidal and poloidal fields $B_T = B_P = 20$ T. The field strength is $4.5 \times 10^{-9}\ B_{Schwinger}$.

### 4.2 Spin Density and Torsion Estimate

Converting to natural units: $B = 20\ T \approx 3.9 \times 10^{-15}\ GeV^2$. The vector potential at the minor radius scale: $A \sim B_P \times a = 20\ T \times 0.25$ m. Using 1 T·m = e■/($m_e{}^2c^3$) × ... ≈ $4.8 \times 10^{-15}$ GeV (via ■c = 0.197 GeV·fm), we obtain $A \approx 2.4 \times 10^{-14}$ GeV.

The electromagnetic spin density (helicity density):

$$\sigma \sim A \cdot B \approx 9.4 \times 10^{-29}\ GeV^3$$

Torsion from the EC algebraic equation (Appendix A, Eq. A.12):

$$|S| = (4/M_{Pl}{}^2)\sigma \approx 6.3 \times 10^{-65}\ GeV$$

$$|S|^2 \approx 4.0 \times 10^{-129}\ GeV^2$$

### 4.3 The Planck Wall

With $\xi = 10^4$ (Higgs inflation, Jordan frame), $\eta = \xi/4 = 2500$:

$$|\eta|S^2 \approx 10^{-125}\ GeV^2$$

**The ratio to threshold ($2\lambda v^2 \approx 15{,}734\ GeV^2$) is ~$10^{-129}$.** The $M_{Pl}{}^{-4}$ suppression makes any EM contribution negligible. For context: the electroweak hierarchy problem concerns a gap of ~$10^{17}$; the gap here is approximately eight times larger in logarithmic scale.

### 4.4 Frame Invariance of the Bound

A crucial question raised in peer review [Section 9.4 discusses this further]: the large value $\xi \sim 10^4$ from Higgs inflation models is typically associated with the Jordan frame. Under the Weyl rescaling $g_{\mu\nu} \to \Omega^2 g_{\mu\nu}$ with $\Omega^2 = 1 + 2\xi|\phi|^2/M_{Pl}{}^2$, the action transforms to the Einstein frame where the non-minimal coupling is absorbed into the scalar field kinetic term.

However, the physical observable — the torsion-induced shift δv/v — must be frame-invariant [6,13]. In the Einstein frame, ξ is replaced by a field-dependent function in the kinetic sector, but the effective four-fermion contact interaction mediated by torsion retains the same $M_{Pl}{}^{-4}$ suppression [5]. Explicitly: in the Einstein frame, the torsion equation becomes $S^{\mu\nu\rho} = -(4/M_{Pl}{}^2)\sigma^{\mu\nu\rho}$ (unchanged, since torsion is algebraically determined and the Weyl rescaling does not alter the antisymmetric part of the connection [15]). The coupling to the Higgs kinetic term modifies the effective η but cannot compensate for 129 orders of magnitude. Following Karananas et al. [13], the Einstein-frame coupling generates corrections of order $\xi^2|\phi|^2/M_{Pl}{}^2 \sim 10^{-24}$ to the effective η, which is negligible. **The no-go bound is frame-invariant.**

### 4.5 Scaling to Extreme Fields

| Scenario | B (T) | log(ε/ε_thr) | Status |
|---|---|---|---|
| Standard EC, ξ = 1 | 20 | –133 | Inaccessible |
| EC with ξ = 10■ (Jordan) | 20 | –129 | Inaccessible |
| EC with ξ = 10■ (Einstein) | 20 | –129 | Inaccessible |

| | | | |
|---|---|---|---|
| At Schwinger limit | 4.4 × 10■ | –92 | Inaccessible |
| Magnetar surface | $10^{11}$ | –85 | Inaccessible |
| Phase transition threshold | — | 0 | Required |

Even at the Schwinger limit, the deficit remains ~92 orders. The bound is independent of frame choice.

### 4.6 Summary

**The standard EC torsion channel cannot produce detectable EM-topology-to-Higgs coupling at any achievable field strength.** This is a fundamental consequence of the weakness of gravity ($M_{Pl}^{-4}$ suppression), not a technical limitation.

## 5. Quantitative Analysis: Alternative Coupling Paths

The Planck wall motivates a systematic search for coupling mechanisms that bypass gravitational suppression. We analyze three candidates with full quantitative estimates and references to specific BSM models.

### 5.1 Chern-Simons Coupling

In gauge theory, the Chern-Simons term couples a pseudoscalar field to the EM topology:

$$L_{CS} = (g_{CS}/4)\ \phi_{ps}\ F_{\mu\nu}\ F\blacksquare^{\mu\nu}$$

where $F\blacksquare^{\mu\nu} = (1/2)\varepsilon^{\mu\nu\rho\sigma}F_{\rho\sigma}$ and $F_{\mu\nu}F\blacksquare^{\mu\nu} = -4\mathbf{E}\cdot\mathbf{B}$. This couples directly to helicity without gravitational constants.

**Why this does not exist for the SM Higgs.** The Standard Model Higgs doublet is a scalar under CP. The coupling $\phi F\ F\blacksquare$ requires a pseudoscalar. In the SM, no such coupling exists at tree level; it arises only through loop-induced effects suppressed by $(\alpha/4\pi)^2 \sim 10^{-6}$. A direct Chern-Simons coupling to the scalar sector requires BSM physics: either (i) a two-Higgs-doublet model (2HDM) with a CP-odd scalar $A^0$ [16], (ii) a scalar-pseudoscalar mixing mechanism [17], or (iii) an extended Higgs sector with explicit CP violation.

**Quantitative estimate.** In a Type-II 2HDM, the coupling of $A^0$ to photons is $g_{CS} \sim \alpha/(4\pi v) \times \cot\beta$, where $\tan\beta = v_u/v_d$. For $\tan\beta \sim 1$: $g_{CS} \sim 10^{-5}$ GeV$^{-1}$. With $E\cdot B \sim 10^{-34}$ GeV$^4$ (from 20 T fields at 1 GHz modulation) and requiring Higgs-$A^0$ mixing angle $\alpha_{mix}$ (constrained by LHC Run 2 to $\alpha_{mix} < 0.1$ [18]):

$$\delta\mu^2 \sim \alpha_{mix} \times g_{CS} \times E\cdot B \approx 10^{-1} \times 10^{-5} \times 10^{-34} \approx 10^{-40}\ \mathrm{GeV}^2$$

Threshold: $2\lambda v^2 \approx 1.6 \times 10^4$ GeV$^2$. **Deficit: ~44 orders of magnitude.** This recovers ~85 orders relative to EC but remains vastly insufficient. The deficit scales linearly with $E\cdot B$: even at the Schwinger limit (~$10^{17}$ enhancement in $E\cdot B$), ~27 orders remain.

### 5.2 Axion-Like Particle (ALP) Coupling

$$L_{ALP} = (g_{a\gamma\gamma}/4)\ a\ F_{\mu\nu}\ F\blacksquare^{\mu\nu}$$

Astrophysical bounds from stellar cooling and SN 1987A [19] require the axion decay constant $f_a > 10^8$ GeV. The CAST experiment [20] constrains $g_{a\gamma\gamma} < 6.6 \times 10^{-11}$ GeV$^{-1}$ for $m_a < 0.02$ eV. Future experiments (IAXO [21]) will probe $g_{a\gamma\gamma} \sim 10^{-12}$ GeV$^{-1}$.

For ALP-Higgs mixing: the most general scalar potential coupling a to the Higgs doublet $\Phi$ gives a mixing angle $\theta_{aH} \sim \mu_{aH} v/m_H^2$, where $\mu_{aH}$ is the portal coupling. LHC constraints on exotic Higgs decays require $\theta_{aH} < 10^{-2}$ for $m_a \sim 1$ GeV [22].

**Quantitative estimate:** $\delta V \sim \theta_{aH} \times g_{a\gamma\gamma} \times E\cdot B \times v \approx 10^{-2} \times 6.6 \times 10^{-11} \times 10^{-34} \times 246 \approx 10^{-44}$ GeV$^4$. Threshold: $\lambda v^4 \approx 4.8 \times 10^8$ GeV$^4$. **Deficit: ~53 orders.** Future ALP experiments cannot improve this by more than ~1 order.

### 5.3 Nieh-Yan Topological Density

The Nieh-Yan four-form [23] is a topological invariant in Riemann-Cartan geometry:

$$N = d(e^a \wedge T_a) = T^a \wedge T_a - R_{ab} \wedge e^a \wedge e^b$$

Coupling to pseudoscalar fields through $L_{NY} = (1/f_{NY})\ \phi \int N$ has been studied in the context of pseudoscalar inflation in EC-Palatini formulations [24,25]. The Nieh-Yan coupling is attractive because it is topological — potentially bypassing perturbative suppression.

**Models in the literature.** Karananas, Shaposhnikov, and Zell [13,25] have shown that in Palatini gravity with a pseudoscalar inflaton, the Nieh-Yan term generates an effective coupling with $f_{NY} \sim M_{Pl}$. Castillo-Felisola et al. [26] considered torsion-induced couplings in the context of dark matter portals with $f_{NY} \sim 10^{16}$ GeV. In all studied models, $f_{NY} \geq 10^{16}$ GeV.

**Perturbative regime.** For EM-sourced torsion with $|S| \sim 10^{-65}$ GeV, the Nieh-Yan density evaluates to $N \sim |S|^2$ + curvature corrections $\sim |S|^2$ (the curvature corrections are higher-order). The effective coupling $\delta L \sim (v/f_{NY}) \times N \sim (246/10^{16}) \times 4 \times 10^{-129} \approx 10^{-142}$ $GeV^2$. This is *worse* than the direct EC channel.

**Non-perturbative (topological winding) scenario.** If the EM field configuration produces torsion with non-trivial topological winding number $n_T$, the Nieh-Yan integral could yield a contribution proportional to $n_T$ rather than $|S|^2$. This is analogous to instanton contributions in QCD proportional to $e^{-8\pi^2/g^2}$ rather than any power of g. However: (a) no known mechanism generates topological winding from EM-sourced torsion; (b) the analogy to QCD instantons is incomplete because torsion in EC theory is non-dynamical and does not support tunneling solutions; (c) even with an optimistic $n_T \sim 10^{20}$, the deficit remains ≥ 40 orders.

**Deficit: ≥ 40 orders (optimistic); ≥ 129 orders (perturbative). The Nieh-Yan path does not improve on the EC channel in the perturbative regime.**

### 5.4 Combined and Resonant Effects

Independent coupling channels add linearly; combining three paths each deficient by 40–130 orders provides no improvement. Resonant enhancement ($Q \sim 10^{10}$ for superconducting cavities) enters linearly in effective field energy, improving by at most ~10 orders — negligible.

### 5.5 Summary of All Coupling Paths

| Path | Suppression | Deficit | Status |
|---|---|---|---|
| Standard EC | M_Pl■■ | ~129 | Robustly excluded; frame-invariant |
| Chern-Simons (2HDM) | α/(4πv) | ~44 | Requires BSM scalar sector; LHC-constrained |
| ALP mixing | g_aγγ × θ_aH | ~53 | Constrained by CAST + LHC |
| Nieh-Yan (pert.) | v/f_NY × $S^2$ | ≥129 | No improvement over EC |
| Nieh-Yan (optimistic) | Topological | ≥40 | Unphysical assumptions required |

**No known coupling mechanism can bridge the gap.** The minimum deficit is ~40 orders under assumptions far exceeding theoretical support. This establishes the benchmark: any viable future theory must produce an enhancement factor $\geq 10^{40}$ over the best known path.

# 6. Complete Lagrangian, Field Equations, and Dynamics

## 6.1 The Full Effective Lagrangian

After substituting the algebraic torsion solution (derived in full in Appendix A) into the ECSK action:

$$L = (M_{Pl}^2/2)R - (1/4)F_{\mu\nu}F^{\mu\nu} + |D_\mu\phi|^2 - \lambda(|\phi|^2 - v^2)^2 - (4\xi/M_{Pl}^4)\sigma_{\mu\nu\rho}\sigma^{\mu\nu\rho}|\phi|^2$$

## 6.2 Derived Field Equations

**Modified Maxwell equations:**

$$\nabla_\mu F^{\mu\nu} = J^\nu + J^\nu_{torsion}$$

The torsion-induced current is suppressed by $M_{Pl}^{-4}$ (~$10^{-152}$ relative to normal EM currents for laboratory fields).

**Modified Einstein equations:** the coupling stress-energy tensor has the $g_{\mu\nu}$ component acting as an effective local cosmological constant with magnitude ~$10^{-125}$ GeV$^4$ — 76 orders below cosmological vacuum energy.

## 6.3 Feedback Dynamics: Derivation and Physical Mechanisms

The feedback cycle is formalized as coupled ODEs for the spatially-averaged Higgs VEV $\phi(t)$ and magnetic field B(t). The derivation proceeds from the Higgs equation of motion and the energy balance for the EM field (see Appendix B for details).

**Equation 1** (Higgs field, overdamped regime):

$$\Gamma_\phi\, d\phi/dt = -4\lambda\phi(\phi^2 - v^2 + \varepsilon/2\lambda)$$

where $\Gamma_\phi \sim m_H \approx 125$ GeV is the Higgs dissipation rate from decay into SM particles.

**Equation 2** (EM field, energy balance):

$$dB/dt = P_{input}/(VB) - B/\tau(\phi)$$

**Physical origin of $\tau(\phi)$.** The dominant energy loss mechanism for a 20 T superconducting field is synchrotron radiation from residual charged particles in the toroidal volume. The synchrotron power scales as $P_{sync} \propto m_e^{-2}B^2\gamma^2$, where $m_e = y_e\phi/\sqrt{2}$ is the electron mass (proportional to the Higgs VEV). Therefore:

$$\tau(\phi) = \tau_0(\phi/v)^2$$

with exponent $\alpha = 2$ arising from the $m_e^{-2}$ dependence of synchrotron losses. Here $\tau_0$ is the loss timescale at the standard VEV. Secondary loss channels (pair production, curvature radiation) contribute at higher field strengths but maintain the same qualitative $\phi$-dependence since all lepton masses scale linearly with VEV.

**Bootstrap limitation (quantified):** the feedback gain $G = (2\varepsilon)/(4\lambda v^2 - 2\varepsilon)$. For $\varepsilon \sim 10^{-125}$ GeV$^2$, $G \sim 10^{-129}$. The effective $\varepsilon$ is enhanced by factor $(1 - G)^{-1} \approx 1 + 10^{-129}$. No feedback amplification.

# 7. Constraints from Standard Model Physics

## 7.1 Particle Masses and Gauge Couplings

Fermion masses scale linearly: $m_f' = m_f(v'/v)$. W and Z masses scale identically. The fine structure constant $\alpha$ and strong coupling $\alpha_s$ are independent of v at leading order ($\alpha_s$ acquires logarithmic corrections through $\Lambda_{QCD}$ threshold effects).

## 7.2 Nuclear Stability

Nucleon mass $m_N \approx 938$ MeV is ~95% QCD binding energy. A 10% VEV reduction changes $m_N$ by ~0.5%. Pion mass $m_\pi \sim \sqrt{(m_q \Lambda_{QCD})}$ scales as $\sqrt{v}$; reduced v strengthens nuclear force [27]. For $v' \to 0$, hadronic physics changes qualitatively.

### 7.3 Electroweak Vacuum Stability

The SM EW vacuum is metastable (potential turns negative at $|\phi| \sim 10^{10}$ GeV). VEV reduction does not trigger this: we lower $|\phi|$ toward zero, not toward the instability region. A modified region collapses to normal vacuum when the driving field is removed.

| Scenario | VEV | Status | Effect |
|---|---|---|---|
| 10% reduction | 0.9v | Safe | Nuclear binding slightly increases |
| 50% reduction | 0.5v | Prob. safe | Chemistry disrupted; masses halved |
| 90% reduction | 0.1v | Dangerous | Atomic structure qualitatively different |
| Full restoration | 0 | Catastrophic | All fermion masses vanish |

## 8. Experimental Predictions and Null-Result Constraints

The EC channel predicts undetectable signals. The protocols below are model-independent tests of *any* EM-topology-to-scalar coupling. The key discriminant is **helicity-dependence**: all predicted effects depend on the topological invariant h, not on field magnitude alone.

### 8.1 Gravimetric Test

**Protocol:** Superconducting toroidal magnet with variable magnetic helicity h; atomic gravimeter (sensitivity $\sim 10^{-11}$ g) at geometric center; h = 0 control. **EC prediction:** $\delta g/g \sim 10^{-129}$. **Null-result constraint:** excludes non-standard couplings at $> 10^{118} \times$ EC. **Discovery scenario:** any helicity-dependent anomaly above $10^{-11}$ g is new physics.

### 8.2 Interferometric Test

**Protocol:** High-precision interferometer within helical superconducting field. EC prediction: $\delta n \sim 10^{-129}$. Null result excludes coupling at $> 10^{118} \times$ EC.

### 8.3 Spectroscopic Test

**Protocol:** Spectroscopy of plasma in topologically non-trivial B-fields. VEV reduction shifts $m_e$ and hence spectral lines [28,29] with signature depending on h, not $|B|$. This helicity-dependence discriminates from Doppler, Stark, and Zeeman effects.

### 8.4 Gyroscopic Test

**Protocol:** Precision gyroscope in superconducting field with controlled helicity. Precession rate depends on h. Previous rotating-superconductor experiments [30,31] reported debated anomalies; this protocol specifically isolates helicity dependence.

## 9. Discussion

### 9.1 Nature of the Result

This paper establishes a comprehensive set of no-go bounds. The standard EC channel is excluded by ~129 orders. Three alternative paths are each insufficient (44–53 orders for BSM-dependent paths, ≥ 40 for speculative topological amplification). The bounds are frame-invariant (Section 4.4). The minimum deficit of ~40 orders under any analyzed mechanism establishes a rigorous benchmark.

### 9.2 What Would Be Required

A viable coupling must produce an enhancement factor $\geq 10^{40}$ over the best known path. This would require: (a) a non-perturbative amplification analogous to QCD instantons but in the EM-scalar sector — no such mechanism is known, and the non-dynamical nature of EC torsion makes tunneling solutions impossible in this framework; (b) a new topological coupling in gauge theory not yet identified; or (c) BSM physics with new light mediators unconstrained by current bounds. Each possibility is speculative. The value of the present work lies in quantifying the target.

### 9.3 Relation to Contemporary Torsion Literature

Our analysis assumes the simplest non-minimal coupling $\xi R|\phi|^2$. In the most general quadratic Poincaré gauge Lagrangian [11,12], the torsion sector admits six independent coupling constants. For axial torsion (the only component sourced by EM fields), the general coupling reduces to a single effective parameter that our $\xi$ captures. Extended models with propagating torsion [32] could in principle modify the algebraic relation $S \propto \sigma$, but introduce new mass scales $m_T$ for the torsion field. For $m_T \sim M_{Pl}$ (as expected from naturalness), the suppression is unchanged. For $m_T \sim$ TeV (as in some extra-dimension models), the suppression is reduced but replaced by the propagator $1/m_T^2$, yielding a deficit of ~40 orders at best — consistent with our Nieh-Yan optimistic bound.

### 9.4 On Frame Dependence

The question of physical equivalence between Jordan and Einstein frames in scalar-tensor theories remains debated [33,34]. For our purposes, the key point is narrower: the observable $\delta v/v$ is frame-invariant because it is defined as a ratio of physical masses (which are measurable) at two spacetime points. Both frames agree on this ratio to leading order [6]. The difference appears only at higher orders in $\xi|\phi|^2/M_{Pl}^2 \sim 10^{-28}$, which is negligible compared to the 129-order deficit.

### 9.5 Broader Implications

The existence of topological terms in gauge theory ($\theta$-term in QCD, Chern-Simons terms in condensed matter) that produce physical effects suggests that EM topology may play unexplored roles. The present work identifies the Higgs sector as a candidate endpoint and establishes that all known coupling pathways are quantitatively excluded. This constrains the space of viable theories and guides future model-building toward mechanisms requiring enhancement factors $\geq 10^{40}$.

## 10. Attribution

### 10.1 Established Physics

EC theory [1–3]; Higgs mechanism [14]; EM topology and helicity [7,8]; Hopf fibrations [9]; Alcubierre metric [35]; torsion-scalar coupling [4–6]; Poincaré gauge theory [11,12]; dynamical Casimir effect [36].

### 10.2 Novel Contributions

(a) Identification of EC-mediated EM-topology-to-Higgs coupling chain; (b) complete self-contained derivation of $L_{ST}$ (Appendix A); (c) phase transition threshold condition; (d) **no-go bound: EC channel insufficient by ~129 orders (frame-invariant)**; (e) **systematic bounds: CS (~44), ALP (~53), Nieh-Yan ($\geq$40) with BSM model analysis**; (f) minimum deficit benchmark (~40 orders); (g) feedback ODEs with explicit loss mechanism (synchrotron, $\alpha$ = 2) and bootstrap limitation; (h) SM constraints on VEV modification; (i) model-independent null-result experimental protocols.

## 11. Conclusion

We have systematically analyzed whether electromagnetic field topology can couple to the Higgs sector through Einstein-Cartan torsion or alternative mechanisms. The principal results are negative bounds: the standard EC channel is excluded by ~129 orders of magnitude; Chern-Simons coupling in a 2HDM by ~44 orders; ALP mixing by ~53 orders; and the Nieh-Yan topological density by ≥ 40 orders under generous assumptions. These bounds are frame-invariant and robust against variations in the coupling parameter $\xi$ within the range allowed by Higgs inflation models.

The minimum required enhancement factor of ~$10^{40}$ over the best known coupling path provides a precise target for future theoretical investigation. The experimental protocols proposed in Section 8, while expected to yield null results through any known mechanism, constitute model-independent searches for helicity-dependent anomalies with no conventional explanation. These can independently constrain torsion-scalar coupling constants.

The question of whether EM topology couples to vacuum structure remains open. Through all analyzed channels, the answer is quantitatively negative. Whether this reflects fundamental impossibility or the inadequacy of known coupling mechanisms is a question for future investigation. This paper provides the quantitative framework within which that question can be precisely posed.

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## Appendix A: Complete Derivation of the Torsion-Higgs Coupling

This appendix provides the self-contained derivation requested in peer review, showing all steps from the ECSK action to the effective coupling Lagrangian.

### A.1 The Einstein-Cartan-Sciama-Kibble Action

We begin with the action for gravity non-minimally coupled to a scalar field [4–6]:

$$S = \int d^4x \sqrt{(-g)} \; [ \; f(\phi)R\blacksquare + |D_\mu\phi|^2 - V(\phi) - (1/4)F_{\mu\nu}F^{\mu\nu} \; ] \quad (A.1)$$

where $f(\phi) = M_{Pl}^2/2 + \xi|\phi|^2$ and $R\blacksquare$ is the Ricci scalar constructed from the full Cartan connection $\Gamma\blacksquare^\rho_{\mu\nu}$, which includes torsion.

### A.2 Decomposition of the Connection

The full connection decomposes as:

$$\Gamma\blacksquare^\rho_{\mu\nu} = \{^\rho_{\mu\nu}\} + K^\rho_{\mu\nu} \quad (A.2)$$

where $\{^\rho_{\mu\nu}\}$ is the Levi-Civita connection (symmetric, torsion-free) and $K^\rho_{\mu\nu}$ is the contorsion tensor, related to torsion by:

$$K^\rho_{\mu\nu} = S^\rho_{\mu\nu} + S_\mu{}^\rho{}_\nu + S_\nu{}^\rho{}_\mu \quad (A.3)$$

where the torsion tensor is defined as the antisymmetric part of the connection:

$$S^\rho_{\mu\nu} = \Gamma\blacksquare^\rho_{[\mu\nu]} = (1/2)(\Gamma\blacksquare^\rho_{\mu\nu} - \Gamma\blacksquare^\rho_{\nu\mu}) \quad (A.4)$$

### A.3 Irreducible Decomposition of Torsion

Under the Lorentz group, the torsion tensor (24 independent components) decomposes into three irreducible representations [4,11]:

(i) **Trace vector:** $T_\mu = S^\nu_{\nu\mu}$ (4 components)

(ii) **Axial vector:** $A^\sigma = \varepsilon^{\sigma\mu\nu\rho}S_{\mu\nu\rho}$ (4 components)

(iii) **Tensor part:** $q^\rho_{\mu\nu}$ (16 components, traceless)

For the electromagnetic field, the canonical spin tensor is totally antisymmetric in its three lower indices [4,15]. A totally antisymmetric rank-3 tensor in 4D is dual to a vector, so only the axial component (ii) is sourced:

$$S_{\mu\nu\rho} = (1/6)\varepsilon_{\mu\nu\rho\sigma}A^\sigma \quad (A.5)$$

This is the key simplification: EM fields source only axial torsion.

### A.4 Ricci Scalar Decomposition

The Ricci scalar of the full Cartan connection relates to the torsion-free Ricci scalar as [4]:

$$R\blacksquare = R + \nabla_\mu(T^\mu - T\blacksquare^\mu) + K_{\mu\nu\rho}K^{\nu\mu\rho} - K_{\mu\nu\rho}K^{\mu\nu\rho} \quad (A.6)$$

For purely axial torsion ($T_\mu = 0$, $q^\rho_{\mu\nu} = 0$), the contorsion tensor simplifies and the quadratic contorsion terms evaluate to:

$$K_{\mu\nu\rho}K^{\nu\mu\rho} - K_{\mu\nu\rho}K^{\mu\nu\rho} = -(1/4)S_{\mu\nu\rho}S^{\mu\nu\rho} \quad (A.7)$$

The total derivative term vanishes for axial torsion. Therefore:

$$\mathbf{R\blacksquare = R - (1/4)S_{\mu\nu\rho}S^{\mu\nu\rho}} \quad (A.8)$$

This is the identity used in the main text (Section 3.2).

### A.5 Expanding the Action

Substituting (A.8) into (A.1):

$$S = \int d^4x \sqrt{(-g)}\ [\ f(\phi)(R - (1/4)S_{\mu\nu\rho}S^{\mu\nu\rho}) + \ldots\ ]\ \text{(A.9)}$$

Expanding $f(\phi) = M_{Pl}^2/2 + \xi|\phi|^2$:

$$= \int d^4x \sqrt{(-g)}\ [\ (M_{Pl}^2/2)R + \xi|\phi|^2 R - (M_{Pl}^2/8)S_{\mu\nu\rho}S^{\mu\nu\rho}$$
$$- (\xi/4)S_{\mu\nu\rho}S^{\mu\nu\rho}|\phi|^2 + |D_\mu\phi|^2 - V(\phi) - (1/4)F_{\mu\nu}F^{\mu\nu}\ ]\ \text{(A.10)}$$

The cross term is the torsion-Higgs coupling:

$$\mathbf{L_{ST} = -(\xi/4)S_{\mu\nu\rho}S^{\mu\nu\rho}|\phi|^2}\ \text{(A.11)}$$

with $\eta \equiv -\xi/4$. For conformal coupling $\xi = 1/6$: $\eta \approx -0.042$. For Higgs inflation $\xi \sim 10^4$: $|\eta| \sim 2500$.

### A.6 The Algebraic Torsion Equation

Varying (A.10) with respect to $S^\rho{}_{\mu\nu}$ (treating torsion as an independent variable):

$$\partial L/\partial S^\rho{}_{\mu\nu} = 0 \rightarrow (M_{Pl}^2/4 + \xi|\phi|^2/2)\ S^{\mu\nu\rho} = -\sigma^{\mu\nu\rho}{}_{EM}\ \text{(A.12)}$$

Since $M_{Pl}^2/4 \approx 1.5 \times 10^{36}$ GeV$^2$ >> $\xi v^2/2 \approx 3 \times 10^9$ GeV$^2$ (even for $\xi = 10^4$):

$$\mathbf{S^{\mu\nu\rho} \approx -(4/M_{Pl}^2)}\ \sigma^{\mu\nu\rho}{}_{\mathbf{EM}}\ \text{(A.13)}$$

This is the algebraic (non-dynamical) torsion equation. Each factor of torsion carries $M_{Pl}^{-2}$; $L_{ST}$ involves $S^2$, giving overall $M_{Pl}^{-4}$ suppression. QED.

## Appendix B: Derivation of Feedback ODEs

This appendix derives the coupled ODEs of Section 6.3 and specifies the physical loss mechanisms.

### B.1 Higgs Field Equation in the Overdamped Limit

The full Higgs equation of motion in the presence of torsion coupling (from Section 3.3) is:

$$\Box\phi + 2\lambda(|\phi|^2 - v^2)\phi + (\xi/4)S_{\mu\nu\rho}S^{\mu\nu\rho}\phi = 0 \quad (B.1)$$

For a spatially homogeneous, slowly varying field in the overdamped regime ($d^2\phi/dt^2 << \Gamma_\phi d\phi/dt$), the d'Alembertian reduces to $\Box\phi \approx -\Gamma_\phi d\phi/dt$, where $\Gamma_\phi$ is the effective dissipation rate from Higgs decay channels ($H \to b\bar{b}$, WW*, ZZ*, etc.). At tree level, $\Gamma_\phi \sim m_H \approx 125$ GeV [14]. Writing $\varepsilon = (\xi/4)S_{\mu\nu\rho}S^{\mu\nu\rho} = (4\xi/M_{Pl}^4)(h/V)^2$:

$$\Gamma_\phi\, d\phi/dt = -2\lambda\phi(\phi^2 - v^2) - \varepsilon\phi = -2\lambda\phi(\phi^2 - v^2 + \varepsilon/2\lambda) \quad (B.2)$$

*Note: the factor of 4 vs. 2 in $\lambda$ depends on whether one uses the real or complex field normalization. Here we follow the convention $|\phi|^2 = \phi^\dagger\phi$ with $V = \lambda(|\phi|^2 - v^2)^2$.*

### B.2 EM Field Energy Balance

The magnetic energy density is $u_B = B^2/(2\mu_0)$. The total stored energy is $U = u_B V$. The energy balance:

$$dU/dt = P_{input} - P_{loss}(\phi) \quad (B.3)$$

Since $U \propto B^2$, we have $dU/dt = VBdB/dt$ (in appropriate units):

$$dB/dt = P_{input}/(VB) - B/\tau(\phi) \quad (B.4)$$

### B.3 Physical Origin of $\tau(\phi)$

The dominant energy loss mechanism in a high-field superconducting toroid is **synchrotron radiation** from residual charged particles (electrons, positrons from pair production near the field). The synchrotron power per particle is:

$$P_{sync} = (q^2c)/(6\pi\varepsilon_0) \times (\gamma^4/R^2) \propto 1/m_e^2 \quad (B.5)$$

for ultra-relativistic particles, where $\gamma = E/(m_e c^2)$. Since $m_e = y_e v/\sqrt{2}$, the electron mass is proportional to the Higgs VEV. The field decay time $\tau$ is inversely proportional to the loss power: $\tau \propto m_e^2 \propto \phi^2$. Therefore:

$$\boldsymbol{\tau(\phi) = \tau_0(\phi/v)^2} \quad (B.6)$$

with $\alpha = 2$. Here $\tau_0$ is the dissipation timescale at the standard VEV, determined by the residual particle density and field geometry. For a well-shielded superconducting system, $\tau_0 >> 1$ s.

Secondary loss channels: **curvature radiation** ($P \propto \gamma^4/R^2$, same $m_e$ dependence); **Schwinger pair production** (rate $\propto \exp(-\pi m_e^2/eB)$, exponentially sensitive to $m_e$ and hence $\phi$ — this actually provides a stronger positive feedback than synchrotron, but is negligible at $B = 20$ T which is far below $B_{Schwinger}$). All channels maintain the qualitative result that losses decrease as $\phi$ decreases.

### B.4 Equilibrium and Stability

Setting $d\phi/dt = 0$ and $dB/dt = 0$:

$$\phi^* = \sqrt{(v^2 - \varepsilon/(2\lambda))} \text{ for } \varepsilon < 2\lambda v^2 \quad (B.7)$$

The Jacobian of the system at equilibrium has eigenvalues:

$$\lambda_1 = -(4\lambda/\Gamma_\phi)(3\phi^{*2} - v^2 + \varepsilon/2\lambda) < 0 \quad (B.8)$$

$$\lambda_2 = -1/\tau(\phi^*) + (\text{feedback correction}) \approx -1/\tau(\phi^*) \quad (B.9)$$

Both eigenvalues are negative for $\varepsilon << 2\lambda v^2$: the equilibrium is stable. As $\varepsilon \to 2\lambda v^2$, $\phi^* \to 0$ and $\lambda_1 \to 0$ (critical slowing down). For $\varepsilon > 2\lambda v^2$, the standard vacuum is unstable.