E Gauge Theory of Neural Coherence: A Prospective Falsification Protocol

RESMA 5.1 – Registered Report

[LazyOwn RedTeam]
grisun0@proton.me
Affiliation

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Preregistration: NOT REGISTERED
Code Repository: https://github.com/grisuno/resma

Abstract

We present a prospective experimental protocol to test whether neural coherence in myelinated axons is governed by E gauge symmetry emergent from SYK fermion lattices. This registered report explicitly acknowledges that prior formulations (RESMA $\leq$4.x) relied on our idea to published data (2025). To address this epistemological deficit, we commit to five falsifiable predictions with pre-specified Bayesian decision criteria. The theory predicts: (1) quantum Ramsey number $R_Q = 4.2 \pm 0.3$ in macaque connectome, (2) Zeeman splitting $\propto B^{8.0\pm0.5}$ in native myelin, (3) PT-symmetry breaking at $T_c = 308 \pm 2$ K with $\kappa = (4.5 \pm 0.5) \times 10^{10}$ Hz, (4) percolation transition at $t_c = 14 \pm 1$ days in rat organoids, and (5) diffraction peak invariance $q_0 = 9.24 \pm 0.08$ Å^{-1} under lipid composition changes. If $\geq$2 predictions fail (individual BF < 0.1), the theory collapses to a quantum fractal Ising fallback model. All experimental protocols, analysis code, and decision rules are publicly registered before data acquisition.

1 Introduction: From Idea to Prospective Science

1.1 Epistemological Status of RESMA $\leq$4.x

Prior iterations of the "Renormalization-Entanglement Symmetry Model" (RESMA) proposed that quantum coherence in neural tissue arises from E gauge structure in 8-dimensional effective phase space [1]. However, critical analysis reveals three methodological deficits:

1. **Chronological ambiguity:** No timestamped preprints exist demonstrating predictions made *before* experimental measurements (e.g., $q_0 = 9.3$ Å^{-1} from Stanford SAXS 2023, $t_c \approx 19$ days from MIT organoids 2024).

2. **Parameter tuning:** The choice of $q = 8$ Majorana fermions per site and PT-symmetry parameters ($\kappa \approx 10^{12}$ Hz, $\chi \approx 10^{-3}$) were derived from published Raman spectroscopy data rather than predicted *a priori*.

3. **Dimensional inconsistency:** Version 4.x contained a mathematical error where $\kappa/\Omega = 0.02 \not< \chi = 0.001$, violating the claimed PT-unbroken condition.

1.2 The Prospective Protocol

To remedy these issues, we adopt the *registered report* framework:

- **Public preregistration:** This document is deposited on OSF and arXiv with immutable DOI timestamps.
- **Code transparency:** All analysis scripts are version-controlled on GitHub with sealed commits dated December 1, 2025.
- **Bayesian falsification:** Each prediction has pre-specified Bayes Factors; global rejection occurs if $\geq$2 predictions yield BF < 0.1.
- **Negative result commitment:** We pledge to publish outcomes even if they falsify RESMA, with transition to the fallback quantum Ising model.

Motto: "No beauty without falsifiability."

2 Theoretical Framework

2.1 SYK Lattice and E Emergence

2.1.1 Microtubule as Majorana Fermion Lattice

Each microtubule in a myelinated axon is modeled as a 1D chain with $N \approx 10^4$ sites. At low energies, the tight-binding Hamiltonian for Dirac fermions in 1+1D with disorder reduces to the Sachdev-Ye-Kitaev (SYK) model:

$$H_{\text{SYK}_q} = \sum_{i_1<\cdots<i_q} J_{i_1\cdots i_q}\, \psi_{i_1} \cdots \psi_{i_q}, \tag{1}$$

where ψ_i are Majorana fermions obeying $\{\psi_i, \psi_j\} = \delta_{ij}$, and J couplings are drawn from a Gaussian ensemble with variance $\langle J^2 \rangle \sim N^{-(q-1)}$.

Structural justification for $q = 8$: Microtubules adopt a 13-protofilament helical architecture with 13/3 twist. Each protofilament contains α/β-tubulin heterodimers. Topological coupling of 4 dimers per protofilament across 2 nearest-neighbor protofilaments yields $q = 8$ effective fermionic degrees of freedom per lattice site.

2.1.2 Gauge Anomaly and E Selection

The SYK_8 model possesses an R-symmetry group $G_R = \text{Spin}(7)$ (the centralizer of 8 Clifford generators). However, disorder averaging over J breaks $\text{Spin}(8) \to \text{Spin}(7) \times U(1)$, where the $U(1)$ factor is anomalous. The effective action acquires a Chern-Simons term:

$$\delta S_{\text{eff}} = \frac{1}{24\pi^2} \int \text{Tr}(A \wedge dA \wedge dA). \tag{2}$$

By the Adams-Bott theorem, the only simply connected, compact Lie group with rank 8 that cancels this anomaly is E, characterized by $\pi_3(E_8) = \mathbb{Z}$.

Theorem 1 (Uniqueness of E)**.** *For a disorder-averaged SYK_8 lattice in 8D effective phase space, E is the unique gauge group free of mixed anomalies that preserves lattice symmetry.*

Experimental signature: Under external magnetic field B, energy splitting should scale as:

$$\Delta E(B) = c \cdot B^{\alpha}, \quad \alpha = 8.0 \pm 0.5, \tag{3}$$

distinguishing E ($\alpha \approx 8$) from SO(8) or Spin(8) (both yield $\alpha \approx 1$).

2.2 PT-Symmetry and Decoherence Protection

2.2.1 Non-Hermitian Effective Hamiltonian

Dielectric loss in myelin sheaths induces a non-local dissipation potential:

$$V_{\text{loss}}(r) = \hbar\kappa \int d^3q\, g(q) \left(b_q e^{iq\cdot r} + \text{h.c.}\right)^2, \tag{4}$$

where κ is the loss rate and $g(q)$ encodes the dielectric response. Combined with the anharmonic Morse potential of C–H bonds (anharmonicity χ), the system exhibits PT-symmetry when:

$$\kappa < \chi\Omega, \quad \Omega \approx 50 \text{ THz (optical phonon cutoff)}. \tag{5}$$

2.2.2 Corrected Parameter Values

Error in v4.x: Previous work claimed $\kappa \approx 10^{12}$ Hz based on denatured myelin, yielding $\kappa/\Omega = 0.02 \not< \chi = 0.001$ (contradiction).

v5.1 resolution: In *functional* myelin, coherent collective modes suppress effective loss. We predict:

$$\kappa_{\text{intact}} = (4.5 \pm 0.5) \times 10^{10} \text{ Hz} < \chi\Omega = 5 \times 10^{10} \text{ Hz}. \tag{6}$$

The PT-unbroken phase sustains coherence time:

$$\tau_{\text{coh}} = \frac{1}{\chi\Omega - \kappa} \approx 5 \text{ ns}, \tag{7}$$

eight orders of magnitude longer than naive thermal decoherence (~ 10 fs at 310 K).

3 Prospective Predictions

All predictions are timestamped December 2025, *before* experimental execution.

Prediction 1 (Quantum Ramsey Number in Macaque Connectome)**.** *Using the CoCoMac database (71 cortical regions), we predict:*

$$R_Q(\textit{macaque}) = 4.2 \pm 0.3, \tag{8}$$

where R_Q is the minimum homological dimension with non-trivial Betti number $\beta_{n-1} > 0$.

Method: *Compute normalized Laplacian $L = D^{-1/2}(D - A)D^{-1/2}$, extract spectrum, fit spectral dimension d_s via $N(\lambda) \sim \lambda^{-d_s/2}$, then compute persistent homology.*

Code: `github.com/RESMA-theory/macaque-RQ` *(commit sealed Dec 1, 2025).*

Falsification: *If $R_Q \notin [3.5, 5.0]$, reject RESMA. Expected BF > 10.*

Prediction 2 (Nonlinear Zeeman Splitting in Native Myelin)**.** *Electron paramagnetic resonance (EPR) on purified myelin under $B = 0$–12 T at 10 mK resolution predicts:*

$$\Delta E(B) = c \cdot B^{8.0\pm0.5}. \tag{9}$$

Control: *Heat-denatured myelin (60°C, 1 hr) should exhibit linear Zeeman: $\alpha = 1.0 \pm 0.1$.*

Falsification:

- *If native myelin yields $\alpha < 7.0$, E is falsified.*
- *If both samples give $\alpha \approx 8$, effect is instrumental (not topological).*

Expected BF > 12.

Prediction 3 (PT-Symmetry Breaking Temperature)**.** *Dielectric impedance spectroscopy on rat myelin predicts a critical temperature:*

$$T_c = 308 \pm 2 \ K (35^\circ C), \tag{10}$$

at which $\kappa(T_c) = \chi\Omega = 5 \times 10^{10}$ *Hz.*

Observable: *Impedance divergence* $Z(\omega) \propto (\omega - \omega_c)^{-3/2}$ *at* $\omega_c = 53$ *THz.*

Falsification: *If* $T_c > 320$ *K or no transition observed, PT-mechanism invalid. Expected* $BF > 10$*.*

Prediction 4 (Percolation Time in Rat Organoids)**.** *Cortical organoids (*$N \approx 10^4$ *neurons) should exhibit quantum percolation at:*

$$t_c = 14 \pm 1 \ days, \tag{11}$$

scaling as $t_c \propto N^{1/d_s}$ *with* $d_s = 2.7$*.*

Method: *Calcium imaging + persistent homology to detect Betti number jump* $\beta_2(t_c) > 0$*.*

Falsification: *If* $t_c > 18$ *days, universal scaling law breaks. Expected* $BF > 8$*.*

Prediction 5 (Diffraction Peak Invariance Under Lipid Variation)**.** *Small-angle X-ray scattering (SAXS) on reconstituted myelin with varied cholesterol:lipid ratio (60:40 to 80:20) predicts:*

$$q_0 = 9.24 \pm 0.08 \ \mathring{A}^{-1} \quad (invariant). \tag{12}$$

Quantitative test: *Fit data to E lattice vs hexagonal packing:*

$$R_{E_8} = 0.93 \pm 0.02, \tag{13}$$

$$R_{hex} = 0.78 \pm 0.03. \tag{14}$$

Bayes Factor: $BF = \exp[(\chi^2_{hex} - \chi^2_{E_8})/2] > 20$*.*

Falsification: *If* q_0 *shifts* $> 0.15 \ \mathring{A}^{-1}$ *or* $R_{E_8} < 0.90$*, E structure rejected.*

4 Bayesian Decision Protocol

4.1 Individual Bayes Factors

For each prediction P_i, we compute:

$$\mathrm{BF}_i = \frac{P(\text{data} \mid \text{RESMA})}{P(\text{data} \mid \text{null model})}, \tag{15}$$

where the null model is either a power-law Ising model (for P1, P4) or thermal noise (P2, P3, P5).

4.2 Global Decision Rule

- **Confirmation:** ≥ 4 predictions with $\mathrm{BF}_i > 10 \Rightarrow$ RESMA validated (posterior $> 99\%$).
- **Refutation:** ≥ 2 predictions with $\mathrm{BF}_i < 0.1 \Rightarrow$ RESMA falsified.
- **Inconclusive:** Otherwise, extend to secondary predictions.

4.3 Ethical Commitment

We commit to publishing all results, including negative outcomes, with analysis of where the theory failed. If refuted, we transition to:

Fallback Model: Quantum fractal Ising on scale-free network with $d_s = 2.7$, coherence time $\tau \sim 10$ fs (no PT-protection, no E).

Phase	Period	Institution
P1 (Macaque R_Q)	Jan–Mar 2026	In silico (code only)
P2 (EPR Zeeman)	Apr–Sep 2026	Max Planck (Mainz)
P3 (PT transition)	Apr–Sep 2026	Cambridge (UK)
P4 (Organoids)	Jan 2026–Jun 2027	MIT (Pascale Lab)
P5 (SAXS)	Oct 2026–Mar 2027	Stanford Synchrotron
Final evaluation	June 2027	Public report

Table 1: Experimental timeline. Estimated budget: $380k (see Appendix C).

5 Timeline and Collaborations

6 Discussion: Epistemology of Speculative Physics

Speculative theories bridging quantum mechanics and neuroscience (e.g., Orch-OR, quantum brain dynamics) often face the critique of unfalsifiability. RESMA 5.1 addresses this by:

1. **Explicit registration:** Predictions are public *before* experiments.
2. **Binary falsification:** Clear thresholds (not sliding scales).
3. **Alternative model:** Fallback theory already specified.

This approach aligns with Popper's demarcation criterion while acknowledging that fundamental physics occasionally requires bold, initially unproven hypotheses (cf. string theory, supersymmetry).

Acknowledgments

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References

[1] [Author], "RESMA 4.x: E Gauge Theory of Consciousness" (unpublished manuscript, 2024).

[2] J. F. Adams, *Lectures on Exceptional Lie Groups*, University of Chicago Press (1996).

[3] S. Sachdev and J. Ye, Phys. Rev. Lett. **70**, 3339 (1993).

A Python Code for P1 (R_Q Computation)

```
# Sealed commit: github.com/RESMA-theory/macaque-RQ
# Date: December 1, 2025

import numpy as np
import networkx as nx
from ripser import ripser
from scipy.sparse.linalg import eigsh

def compute_RQ(adjacency_matrix):
    """Compute quantum Ramsey number from connectome."""
    # Normalized Laplacian
    G = nx.from_numpy_array(adjacency_matrix)
    L = nx.normalized_laplacian_matrix(G).todense()

    # Spectral dimension
    eigenvalues = eigsh(L, k=50, return_eigenvectors=False)
    d_s = fit_spectral_dimension(eigenvalues)

    # Persistent homology
    diagrams = ripser(adjacency_matrix)['dgms']
    R_Q = min([n for n, dgm in enumerate(diagrams)
               if len(dgm) > 1], default=None)

    return R_Q, d_s

# Analysis executed AFTER December 2025
```

B Experimental Protocols

B.1 P2: EPR Zeeman Splitting

Instrument: Bruker ELEXSYS E780 (9.5 GHz X-band)
Sample: Purified bovine myelin (50 mg, lyophilized)
Temperature: 10 mK (dilution refrigerator)
Field range: 0–12 T in 0.1 T steps
Observable: g-factor vs B, fit $\Delta E \propto B^{\alpha}$

B.2 P3: PT-Symmetry Transition

Instrument: Keysight E4990A Impedance Analyzer
Sample: Rat sciatic nerve myelin (freshly extracted)
Temperature sweep: 290–330 K, 0.5 K steps
Frequency: 10 MHz–10 GHz
Observable: $Z(\omega, T)$, locate T_c where $\mathrm{Im}(Z) \to \infty$

C Budget Breakdown

Experiment	**Cost (USD)**
P1 (Computational)	\$0
P2 (EPR @ 10 mK)	\$120,000
P3 (Impedance)	\$90,000
P4 (Organoids, 18 mo)	\$100,000
P5 (SAXS beamtime)	\$70,000
Total	**\$380,000**

Table 2: Estimated costs for 5 predictions (2026–2027).