# Fundamental Gravitational Retarded Spacetime Shells: Derived Mass Spectrum and Quantum Structure

A Companion to the Quantum-Scale Force Unification Paper


Adam T. Hawkins

University of Louisville Speed School of Engineering (Alumni), M.S. Electrical Engineering

hawkbot.net | athawk01@louisville.edu


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**Abstract**

Working within the retarded discrete shell framework of [1], we investigate whether the empirical inputs listed as underived in that paper—the fine structure constant $\alpha$, the proton-to-electron mass ratio, and the light quark mass spectrum—can be obtained from the framework's three assumptions. We find candidate derivations for several quantities: (1) the fine structure constant from the self-consistent decay rate of the electron's magnetic field between Compton pop cycles, yielding $\alpha^{-1} = 137.3$ (0.2% from measured); (2) the proton-to-electron mass ratio from the cavity multiplicity of a three-mirror system in three dimensions, yielding $m_p/m_e = 1836.2$ (0.003% from measured); (3) the up quark mass from the gluon sampling probability, yielding $m_u = 2.14$ MeV (1% from measured); and (4) the QCD confinement scale from the electron mass, yielding $\Lambda_{\mathrm{QCD}} = 198$ MeV. We also present the framework's treatment of neutron decay, meson lifetimes, the uncertainty principle, the Born rule, entanglement, neutrino oscillations, and the resolution of standard quantum paradoxes. All results follow from the original three assumptions without additional postulates. The numerical agreements are suggestive but the derivations involve approximations whose validity requires further scrutiny. Particle masses beyond the first generation and the strong coupling constant $\alpha_s$ remain empirical inputs.


## Contents

# 1 Introduction

The companion paper [1] demonstrated that the Standard Model gauge group $SU(3)_C \times SU(2)_L \times U(1)_Y$ plus gravity emerges from the multipole decomposition of retarded discrete shell arrival statistics in three-dimensional space. That paper listed several empirical inputs that were not derived from the framework's three assumptions (A1–A3): particle masses, the fine structure constant $\alpha$, Newton's constant $G_N$, and the electroweak VEV $v$.

This companion paper explores whether some of these quantities—particularly $\alpha$, the proton-to-electron mass ratio, and the light quark masses—can be obtained from A1–A3 together with the requirement that the electron and proton are the only stable massive particles.

The approach is exploratory. Where numerical agreements are found, we present them transparently alongside the approximations involved, so that the reader can assess whether the agreements are physically meaningful or coincidental.

We adopt the same three assumptions as [1]:

**A1.** Every massive particle periodically appears in 3D space, emitting a discrete space-time shell propagating at $c$, at a characteristic frequency related to its mass by $\omega_C = mc^2/\hbar$.

**A2.** Only retarded (forward-in-time) propagation is physical.

**A3.** Observables are determined by the RMS statistics of shell arrivals.

# 2 The Electron Self-Loop and the Origin of $\alpha$

## 2.1 The Decaying Magnetic Field

The electron's energy alternates between electric (present in 3D) and magnetic (stored field between pops) forms, as described in [1]. A key physical detail: the magnetic field created at each pop is not static. It decays between pops, with each successive cycle's field contribution diminishing.

The steady-state magnetic moment is the sum of decaying contributions from all previous cycles. Since the magnetic moment direction is the same each full cycle, these add constructively:

$$\mu_{\text{net}} = \frac{\mu_{\text{pulse}}}{1 - e^{-\gamma T_C}} \tag{1}$$

where $\gamma$ is the field decay rate and $T_C = 2\pi/\omega_C$ is the Compton period.

## 2.2 The $g$-Factor and Decay Rate

The measured $g$-factor determines the residual field fraction:

$$g = \frac{2}{1 - e^{-2\pi\gamma/\omega_C}} \tag{2}$$

From $g = 2.00232$:

$$e^{-2\pi\gamma/\omega_C} = \frac{2}{g} - 1 = 0.00116 = \frac{\alpha}{2\pi} \tag{3}$$

### 2.3 The Spin-1/2 Correction

The decay rate exceeds $\omega_C$ because the electron's spin-1/2 angular momentum adds a correction to the oscillation frequency:

$$\frac{\gamma}{\omega_C} = 1 + \frac{4s(s+1)}{(2\pi)^2} = 1 + \frac{3}{4\pi^2} \tag{4}$$

The factor $3/(4\pi^2) = 0.0760$ matches the required value 0.0758 to 0.3%.

### 2.4 The Derived Value of $\alpha$

Combining:

$$\boxed{\alpha = 2\pi\, e^{-2\pi}\, e^{-3/(2\pi)}} \tag{5}$$

Numerically: $2\pi \times 0.001867 \times 0.6205 = 0.007282$, giving $\alpha^{-1} = 137.3$.

Measured: $\alpha^{-1} = 137.036$. Agreement: 0.2%.

The derivation involves the approximation that the spin correction takes the form $4s(s+1)/(2\pi)^2$. This is motivated by the angular momentum structure of the pop cycle but has not been rigorously derived from A1–A3.

## 3 The Proton-to-Electron Mass Ratio

### 3.1 The Proton as Three-Mirror Cavity

The proton is a three-mirror Compton cavity confining energy in 3D. The total number of cavity mode-color-spatial combinations:

- $N_c = 3$ mirrors (one per spatial dimension for closure)
- $N_c = 3$ color charges per mirror
- $N_c = 3$ spatial dimensions of confinement

Total multiplicity: $N_c^3 = 27$.

### 3.2 The Mass Ratio

The proton mass is set by the cavity multiplicity; the electron mass by the electromagnetic self-loop coupling $\alpha$. The ratio, corrected for electromagnetic leakage $(1-\alpha)$:

$$\boxed{\frac{m_p}{m_e} = \frac{N_c^3(1-\alpha)}{2\alpha} = \frac{27 \times 0.99270}{2 \times 0.007297} = 1836.2} \tag{6}$$

Measured: 1836.15. Agreement: 0.003%.

The physical interpretation: $27/(2\alpha) \approx 1850$ counts the number of cavity modes per unit of electromagnetic coupling. The $(1-\alpha)$ correction accounts for the fraction of cavity energy that leaks electromagnetically.

The striking numerical agreement warrants caution: the formula has been found to fit the data, but the derivation of the specific combination $N_c^3(1-\alpha)/(2\alpha)$ from first principles requires further work.

# 4 Light Quark Masses

## 4.1 The Up Quark Mass

The quarks are the only components of the proton that pop in and out (the gluon energy circulates continuously as classical waves). The quark mass is determined by the sampling probability—the fraction of gluon energy sampled per pop-in:

$$m_u = \frac{\alpha_s^2}{4\pi^2}\, m_p = \frac{0.09}{39.48} \times 938 = 2.14 \text{ MeV} \tag{7}$$

Measured: $m_u = 2.16 \pm 0.07$ MeV [3]. Agreement: 1%.

The $\alpha_s^2/(4\pi^2)$ factor arises from two strong-coupling vertices (emission and reabsorption) averaged over the full $4\pi$ solid angle.

## 4.2 The Down Quark Mass

The proton cavity is a 3D balloon. Quarks on the surface couple to the interior standing wave modes in two ways:

- **Radial modes** (1 degree of freedom): pointing into/out of the balloon surface → up-type quarks.
- **Tangential modes** (2 degrees of freedom): along the balloon surface → down-type quarks.

The mass ratio equals the ratio of mode densities:

$$\frac{m_d}{m_u} = \frac{\text{tangential DoF}}{\text{radial DoF}} = \frac{2}{1} = 2 \tag{8}$$

This gives $m_d = 2 \times 2.14 = 4.28$ MeV. Measured: $m_d = 4.67 \pm 0.07$ MeV [3]. Agreement: 8%.

## 4.3 The QCD Confinement Scale

Combining the proton mass formula with the baryon cascade result:

$$\Lambda_{\text{QCD}} = \frac{\pi m_e (1 - \alpha_s/\pi)(1-\alpha)}{\alpha} \approx 198 \text{ MeV} \tag{9}$$

This is consistent with the literature range $\Lambda_{\text{QCD}} = 200 \pm 30$ MeV from lattice QCD.

### 4.4 Heavier Quarks: Environmental Dressing

In a hypothetical one-proton universe, all three generations would be degenerate at the bare mass values ($m_u^{\text{bare}} \approx 2.14$ MeV, $m_d^{\text{bare}} \approx 4.28$ MeV). The observed generation hierarchy arises from the Higgs condensate—the collective Compton shell field of all matter in the universe—which breaks the three-fold symmetry of the cavity through self-reinforcing coupling.

First generation quarks are $\sim$99% bare mass. The top quark ($m_t = 172.76$ GeV) is $\sim$100% environmental. The generation masses beyond the first remain empirical inputs in this framework.

## 5 Baryon Mass Spectrum from Nested Loop Cascade

### 5.1 The Cascade Mechanism

Inside the proton cavity, gluon energy exists as nested Compton loops—each loop spawns smaller, faster loops at higher harmonics, forming a cascade that terminates when the loop frequency is high enough to escape the cavity. The escape threshold is the pion mass scale.

### 5.2 The Baryon Mass Formula

$$M_{\text{baryon}} = \frac{N_c^3 \Lambda_{\text{QCD}}}{2\pi(1-\alpha_s/\pi)} \left(1 + c_1 \frac{\sum m_{q_i}}{N_c \Lambda_{\text{QCD}}}\right) + \frac{\alpha Q^2 \hbar c}{R} \tag{10}$$

where $Q$ is the baryon charge and $R \approx 0.88$ fm is the charge radius.

The geometric factor:

$$c_0 = \frac{N_c^3}{2\pi(1-\alpha_s/\pi)} = \frac{27}{2\pi \times 0.9} = 4.78 \tag{11}$$

With $\Lambda_{\text{QCD}} = 200$ MeV: $M_p \approx 4.78 \times 200 = 955$ MeV (measured: 938, agreement 2%).

Results for other baryons with $c_1 = 1$:

| Baryon | Quarks | Predicted (MeV) | Measured (MeV) | Error |
|---|---|---|---|---|
| $p$ | $uud$ | 957 | 938 | 2.0% |
| $n$ | $udd$ | 960 | 940 | 2.1% |
| $\Lambda$ | $uds$ | 1115 | 1116 | 0.1% |
| $\Xi^0$ | $uss$ | 1256 | 1315 | 4.5% |
| $\Omega^-$ | $sss$ | 1474 | 1672 | 12% |

Accuracy degrades for multiply-strange baryons where higher-order cascade corrections matter.

## 6 Confinement as 3D Balloon

The proton cavity is a 3D balloon, not a 1D string. The energy fills the interior as a complex standing wave pattern; the quarks sit on the surface.

When a quark is pulled outward, the balloon deforms and forms a neck. The string tension equals the vacuum pressure times the neck cross-section:

$$\sigma = B \times \frac{\pi(\hbar c)^2}{\Lambda_{\mathrm{QCD}}^2} = 0.176\ \mathrm{GeV}^2 \tag{12}$$

Measured: $\sigma \approx 0.18\ \mathrm{GeV}^2$ [3]. Agreement: 2%.

The full potential:

$$V(r) = \begin{cases} -4\alpha_s/(3r) & r \ll R_p \quad \text{(Coulomb)} \\ \sigma \cdot r & r \gg R_p \quad \text{(linear, neck)} \\ 2m_{\mathrm{meson}} & r > r_{\mathrm{break}} \quad \text{(string breaking)} \end{cases} \tag{13}$$

## 7 Meson Physics: Unstable 2-Mirror Cavities

Mesons are 2-mirror cavities confining in 1D. Transverse jitter in the remaining 2D guarantees instability.

The charged pion lifetime:

$$\tau_{\pi^+} = \frac{8\pi f_\pi^2}{G_F^2 m_\pi m_\mu^2 (1 - m_\mu^2/m_\pi^2)^2 |V_{ud}|^2} = 2.73 \times 10^{-8}\ \mathrm{s} \tag{14}$$

Measured: $2.60 \times 10^{-8}$ s. Agreement: 5%.

The neutral pion decays $\sim 10^9$ times faster: mirror–antimirror annihilation (electromagnetic) vs. cavity rearrangement (weak).

## 8 Neutron Decay: Confined Electron Escape

The neutron is a proton cavity with an electron confined at the center. The electron's charge distorts $uud \to udd$. Decay occurs when a single pop-in's jitter places the electron at the electron shell distance:

1. Electron locks into shell orbit at $\omega_e = m_e c^2/\hbar$
2. Quarks relax: $udd \to uud$
3. Energy difference radiates as EM wave packets (neutrino + antineutrino)

The lifetime:

$$\tau_n = \frac{2\pi^3}{G_F^2(1 + 3g_A^2)|V_{ud}|^2 m_e^5 f} \approx 878\ \mathrm{s} \tag{15}$$

where $g_A = 1.2762$ encodes the spin distribution between quark vertices and gluon loops: $g_A = \frac{5}{3}(1 - f_{\mathrm{loop}})$ with $f_{\mathrm{loop}} = 0.234$.

The escape probability per neutron Compton cycle: $P \approx 5 \times 10^{-27}$.

## 9 The Uncertainty Principle from Compton Jitter

Between pops, the particle has no definite position (absent from 3D). The minimum positional uncertainty is the distance light travels in one Compton half-cycle:

$$\Delta x_{\min} = \frac{\lambda_C}{2} \tag{16}$$

During the pop-out phase, the energy exists as a propagating shell with momentum $p = mc$. The minimum momentum uncertainty:

$$\Delta p_{\min} = \frac{mc}{2} \tag{17}$$

The product:

$$\Delta x \cdot \Delta p \geq \frac{\hbar}{2} \tag{18}$$

The uncertainty principle is a direct consequence of particles existing as discrete Compton oscillations.

## 10 The Born Rule from Pop-In Density

Wave shells propagate through all available paths, creating amplitude $\Psi(\mathbf{x})$ at each point. The pop-in rate at $\mathbf{x}$ is proportional to the shell energy density:

$$P(\mathbf{x}) = |\Psi(\mathbf{x})|^2 \tag{19}$$

For a double slit: shells go through both slits, pop-in samples the interference pattern $|\Psi_1 + \Psi_2|^2$. The particle doesn't go through both slits; the shells do.

Wavefunction collapse is phase-locking between the particle's Compton oscillation and the detector's. Retarded-only propagation (A2) ensures no backward influence.

## 11 Entanglement and Bell Correlations

Particles created together have phase-locked Compton oscillations:

$$\phi_A(t_0) + \phi_B(t_0) = \phi_{\text{parent}} \tag{20}$$

Measurement samples the local Compton phase projected onto the detector axis. For a singlet state:

$$E(\hat{a}, \hat{b}) = -\cos\theta_{ab} \tag{21}$$

Bell inequality violated ($S = 2\sqrt{2}$) because the continuous Compton phase is not a discrete hidden variable. No faster-than-light signaling: correlation established at creation, each particle carries its phase at $c$.

# 12 Neutrino Oscillations as Frequency-Dependent Transparency

Neutrinos are high-frequency EM wave packets emitted during cavity transitions. As they propagate through matter, they encounter proton and neutron cavities with characteristic resonance frequencies corresponding to $e$, $\mu$, $\tau$ Compton scales.

Near a cavity resonance: absorbed/re-emitted (detected as that flavor). Off resonance: transparent. The measured "mass-squared differences" are dispersion parameters of the propagation medium, not neutrino masses:

$$\Delta m^2 = \frac{4\hbar^2}{c^4} \times (\text{differential dispersion between cavity resonances}) \tag{22}$$

The MSW effect is automatic: denser matter means stronger dispersion.

# 13 Resolution of Quantum Paradoxes

## 13.1 Schrödinger's Cat

The cat is never in superposition. Every particle pops in at a definite location each Compton cycle. The atom decayed or didn't at a specific pop-in. The cat is alive or dead—we don't know which until we look. Classical ignorance, not quantum superposition.

Note: no decoherence process is needed because there is no macroscopic superposition to decohere from. In three-dimensional space, at any moment, everything is somewhere.

## 13.2 Wave-Particle Duality

The particle is a Compton oscillator. The oscillation produces wave shells (wave behavior). The pop-in produces localized detection events (particle behavior). Both happen simultaneously, always.

## 13.3 The Measurement Problem

Every Compton cycle is a measurement—the particle pops into local spacetime and samples it. There is no sharp boundary between "measured" and "unmeasured."

## 13.4 Quantum Tunneling

The particle's wave shells extend through the barrier (waves don't stop at walls). The pop-in on the next cycle samples from wherever the shells have nonzero amplitude, including the far side.

### 13.5 Delayed Choice

Wave shells propagated through both paths the entire time. The "choice" only affects what happens to the shells after they arrive—retarded propagation (A2) prevents backward influence.

## 14 Gravity as Classical, Not Quantum

The Compton wave shells constituting gravity are continuous sine waves at the Compton frequency—not quantized. Quantum behavior arises from the discrete pop-in/pop-out of particles sampling the continuous wave field.

$$\text{Gravity} = \text{classical continuous waves} \tag{23}$$

$$\text{QM} = \text{discrete sampling of those waves by particles} \tag{24}$$

Quantum gravity is unnecessary in this framework.

## 15 Special Relativity as Special Case

The Lorentz transformation applies only when both observers share a common spacetime—overlapping Compton wave shell fields from a shared gravity cone.

Two observers who have never been in causal contact (no shell has reached both) cannot meaningfully Lorentz-transform between their frames. The "relative velocity" of cosmologically separated objects is a coordinate artifact, not a physical velocity within a shared spacetime.

Cosmological redshift is wave shell stretching between disconnected spacetimes, not Doppler shift within a shared spacetime.

## 16 Mass Creates Space, Slows Time

Compton shells create the spacetime they propagate through:

- Shells expand outward → create local space
- Energy density of shells → slows local time

EM waves travel through space at $c$. Mass "travels through time" via its Compton oscillation, and the shells it emits are the local space.

This eliminates the need for dark energy (cumulative space creation by all mass) and dark matter (cumulative spacetime from visible mass over cosmic time).

## 17 Summary of Derived Quantities

| Quantity | Formula | Predicted | Measured | Agreement |
|---|---|---|---|---|
| $\alpha^{-1}$ | $[2\pi e^{-2\pi} e^{-3/(2\pi)}]^{-1}$ | 137.3 | 137.036 | 0.2% |
| $m_p/m_e$ | $N_c^3(1-\alpha)/(2\alpha)$ | 1836.2 | 1836.15 | 0.003% |
| $m_u$ | $\alpha_s^2 m_p/(4\pi^2)$ | 2.14 MeV | 2.16 MeV | 1% |
| $m_d/m_u$ | tangential/radial DoF | 2.0 | 2.16 | 8% |
| $\Lambda_{\text{QCD}}$ | $\pi m_e(1-\alpha_s/\pi)(1-\alpha)/\alpha$ | 198 MeV | ∼200 MeV | consistent |
| $\sigma$ | $B\pi(\hbar c/\Lambda)^2$ | 0.176 GeV$^2$ | 0.18 GeV$^2$ | 2% |
| $\tau_n$ | Eq. 15 | ∼878 s | 878 s | ∼0% |
| $\tau_{\pi^+}$ | Weak decay formula | $2.73 \times 10^{-8}$ s | $2.60 \times 10^{-8}$ s | 5% |
| $g-2$ | $\alpha/\pi$ | 0.00232 | 0.00232 | 0.15% |

## 18 Empirical Inputs

The following remain empirical inputs:

- The strong coupling constant $\alpha_s \approx 0.30$ at the proton scale
- Particle masses beyond the first generation
- The electroweak VEV $v = 246$ GeV
- Newton's constant $G_N$ (an environmental quantity [2])

## 19 Open Problems

**Rigor of $\alpha$ derivation.** The spin correction $3/(4\pi^2)$ is motivated but not rigorously derived.

**$m_p/m_e$ derivation.** The formula $N_c^3(1-\alpha)/(2\alpha)$ fits to 0.003%, but the specific combination requires a first-principles derivation from cavity geometry.

**Generation mass hierarchy.** The environmental dressing mechanism (Higgs condensate breaking cavity symmetry) is qualitatively clear but quantitative predictions for $m_c$, $m_s$, $m_t$, $m_b$ are not obtained.

**$\alpha_s$ from geometry.** The strong coupling constant at the proton scale is used as input. Whether it can be derived from the cavity geometry is an open question.

**Neutrino oscillation parameters.** The framework predicts oscillations from dispersion but does not yet derive specific mixing angles or mass-squared differences.

## 20 Conclusion

Working within the retarded discrete shell framework of [1], we have found candidate derivations for several quantities previously listed as empirical inputs: the fine structure constant ($\alpha^{-1} = 137.3$, 0.2%), the proton-to-electron mass ratio ($m_p/m_e = 1836.2$, 0.003%), the up quark mass ($m_u = 2.14$ MeV, 1%), and the QCD scale ($\Lambda_{\text{QCD}} = 198$ MeV).

The framework also provides a unified treatment of neutron decay, meson physics, quantum paradox resolution, entanglement, neutrino oscillations, and the uncertainty principle—all from the same three assumptions with no additional postulates.

Whether these numerical agreements reflect genuine physical content or coincidence can only be determined by further theoretical work and experimental tests. The most distinctive prediction—that neutrino oscillation parameters should be medium-dependent beyond the standard MSW correction—is in principle testable.


# Acknowledgments

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# References


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