Originally written: April 2026

Theory of Spheres ('Quantum Gravity')

or

Empty Spheres in 'Dimensionless Space' – The 'Fundamental Force' Behind Everything

(Quantum–Gravitational Force, 'Dark Matter' / 'Dark Energy', etc.)

Paper III: The Quantum–Gravitational Force as Derived from the Spheres

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ABSTRACT

The Geometric Origin of Mass and Gravity: Bridging the Quantum-Newtonian Gap through the 0-D Harmonic Oscillator.

This paper presents a fundamental derivation of mass and gravitational force within the framework of the **Theory of Spheres (ToS)**. We demonstrate that Newton's Law of Universal Gravitation **($1/R^2$)** is not an independent postulate but an emergent geometric result of spherical normalized pressure distribution **(P=1)** within a zero-dimensional (0-D) harmonic oscillator.

A side effect of this work is the resolution of the **Vacuum Catastrophe** through the distinction between two types of mass and energy:

1. **Scalar Material Mass ($E = m^{l}{}_{D0} \times c^2$):** A cumulative energy manifestation capable of performing work, acting identically for both matter and antimatter.
2. **Vectorial Vacuum Mass:** Energy associated with the internal static pressure of the 0-D oscillator, which undergoes near-perfect **Vectorial Cancellation** (Destructive Interference).

By deriving the coupling constant **$\alpha \approx 7 \times 10^{-244}$**, we provide a mathematical mechanism explaining how the immense energy of the quantum vacuum is suppressed to the observed residual 'noise' of reality. This framework successfully establishes the long-sought direct link between sub-quantum interference and classical Newtonian mechanics, offering a unified, purely geometric description of the fundamental forces.

Part A: Introduction

This paper is a direct continuation of the previous one, which primarily focused on the interior expansion from the center toward the surface of the sphere. However, as established in the principles of the **Theory of Spheres (ToS)**, a second expansion exists: outward from the surface of the **'Equilibrium Sphere'.** Correspondingly, there are also two modes of contraction: reduction from the outside onto the surface of the **'Equilibrium Sphere'** and from the surface back into the interior. This symmetry is not merely mathematical but represents the fundamental nature of cosmic pressure and stability, consistent with the **'Twin Universe Theory'** and the **'entanglement Quartet'** (Part E First paper in the series).

In this work, we distinguish between two fundamental types of energy within the ToS framework:

1. **Mass-based Energy (Scalar Material Mass of the 0-D Oscillator):** This is the energy defined by Einstein's **E=**$\boldsymbol{m^{l}_{D0}}$ $\times$**c**$^{\mathbf{2}}$ equation. Unlike cosmic pressure, this energy is **non-canceling**; It functions as a cumulative scalar property that adds up $\sum_{i=1}^{n} \mathbf{Ei}$ for both matter and antimatter alike.
2. **Velocity-based Energy (Vectorial Vacuum Mass of the speed of light variation over time/Uncertainty):** This energy relates to the dynamics of speed of light **(**$\mathbf{C_{(t)}}$**)** and the Uncertainty Principle. It functions as a vectorial cosmic pressure that reaches equilibrium and cancels out through the system's geometric symmetry.

We will demonstrate how these geometric dynamics lead to the emergence of '**Newtonian Gravity'**, and show that while cosmic pressure reaches equilibrium through symmetry, mass-energy remains cumulative, allowing Newton's equations to emerge directly from the **'ToS'** framework.

Chapter 1: The Four Entangled Sides of the Sphere

To define the **'Four Entangled Sides'**, we categorize the velocity distribution into distinct quadrants of the harmonic cycle.

The First Quadrant (our universe state)**:** Represents the expansion phase starting from the boundary. In this framework, at **t=0**, the velocity $\mathbf{C_{(t)}}$ is 0, satisfying the boundary condition at the origin. As the system evolves, $\mathbf{C_{(t)}}$ transitions to its maximal value at the equilibrium point, as represented by Eq. 1 of Papers 'A' and 'B', laying the groundwork for the structural entanglement of subsequent quadrants.

. Eq 1) $C_{(t)} = e^{K_{(D0)}t} - 1$

The Second Quadrant: represents the continuation of expansion from the system's equilibrium point to the outside boundary.

In this phase, the speed of light $\mathbf{C_{(t)}}$ transitions from its maximal value at the equilibrium point back to zero at the opposite boundary. This behavior is governed by the same family of Eq 1 but as exponential decay:

. Eq 2) $C_{(t)} = e^{-K_{(D0)}t}$

The Third and Fourth Quadrants: While the first and second quadrants represent the expansion phases of the system, **Quadrants 3 and 4** represent the phases of contraction.

The Third Quadrant: marks the transition from the boundary point—where the speed of light is zero ($\mathbf{C_{(t)} = 0}$)—back toward the equilibrium point, where it reaches its maximal value. This inward acceleration mirrors the dynamics of the first quadrant and is therefore governed by the same functional form as **Equation 1**:

The Fourth Quadrant: completes the harmonic cycle. It represents the contraction from the equilibrium point back to the original boundary, where the velocity returns to zero **($\mathbf{C_{(t)}=0}$)**. This phase is governed by the decay characteristics of **Equation 2**:

By defining these four quadrants, we establish a complete, symmetrical oscillation within the sphere. This geometric enclosure demonstrates how the speed of light fluctuates harmonically, forming the **'Four Entangled Sides'** of the **'ToS'** framework.

As derived in Paper II chapters 1 & 2 (Eq. 2 & 14), and according to the Hubble Law **($v = \pm H_0D$)**, the fundamental constants $\mathbf{H_0 \approx \underline{\pm 48.41}_{(km/s/Mpc)}}$ and $\mathbf{\Lambda \approx \underline{\pm 0.54194 \times 10^{-52}}_{(m^{-2})} \approx \underline{\pm 1.44 \times 10^{-122}}}$, represent the equilibrium state of the oscillator. In the current framework, these values remain consistent but fluctuate in sign across the quadrants to maintain the harmonic symmetry of the sphere.

universe number / constant	1	2	3	4
$H_{0(km/s/Mpc)}$	48.41	48.41	-48.41	-48.41
$\Lambda_{(m^{-2})}$ vacuum catastrophe	0.54194×10^{-52}	-0.54194×10^{-52}	0.54194×10^{-52}	-0.54194×10^{-52}
$\Lambda_{(p)}$ – Planck units	1.44×10^{-122}	-1.44×10^{-122}	1.44×10^{-122}	-1.44×10^{-122}

Concluding Note: The transition into quadrants 3 and 4 represents states of contraction characterized by **inverse Entropy (Negentropy)**. The reversal of the velocity vector $\mathbf{C}_{(t)}$ necessitates a corresponding shift in the thermodynamic and temporal arrows, where the system transitions from expansion to contraction. This ensures the conservation of the 0-D harmonic state, allowing the sphere to complete its cycle without energy loss.

Chapter 2: Newton Gravity

Proving the Inverse-Square Law, Assuming a central force, ($1/R^2$) within the 'ToS' Framework
To establish that the emergent geometric force is proportional to **$1/R^2$**, we present three distinct analytical paths

Method 1: Volumetric-Pressure Equilibrium
This path derives the **$1/R^2$** law from the physical requirement of pressure normalization. In the **ToS framework**, the internal energy of the 0-D oscillator is a volumetric property **($V = 4/3\pi \times R^3$) → ($V \propto R^3$).** For the system to maintain a stable equilibrium **(P=1)**, this internal pressure must be distributed across the sphere's bounding surface **($A \propto R^2$)**. The resulting force interaction is therefore governed by the ratio of these geometric constraints, naturally emerging as an inverse-square relationship to ensure structural stability.

Method 2: Classical Potential Gradient
We begin by defining the central force as a derivative of the energy potential within the sphere's volume.

- **Sphere Volume: $V = 4/3 \times \pi R^3$**.
- **Internal Energy:** Proportional to the volume: **$E \approx - P \times V \approx - P \times R^3$**.
- **Potential (Φ):** Assuming the potential is distributed across the radius **R** as a harmonic oscillator, we define: **$\Phi_{(r)} \approx - E/r$**.
- **Force Derivation:** The force is the negative gradient of the potential:
  $F_{(r)} = -d\Phi/dr \approx E/r^2$

  This confirms that the energy density and geometric constraints naturally yield the **$1/R^2$** relationship.

Method 3: Spherical Surface Distribution (Flux)
In a three-dimensional framework, any property radiating or exerting pressure from a center must distribute itself over the surface area of a sphere.

- **Surface Area: $A = 4\pi R^2$**
- **Force as Pressure (Δp):** If the force is viewed as an external pressure applied by the spheres, it is spread across the spherical shell: **$F = \Delta p \times 4\pi R^2$**
- **Effective Result:** Therefore, the intensity of the force at any given point on the surface must be inversely proportional to the area it covers, leading to: **$F_{eff} \propto 1/R^2$**

The Principle of Pressure Invariance and Energy-Volume Duality
The foundational framework of the **Theory of Spheres (TOS)** rests upon the equilibrium between internal and external spherical pressures. In paper 1 chapter 1, we established the total pressure acting upon the system as a continuous integral of all surrounding infinitesimal components. This relationship is governed by the **Principle of Pressure Invariance**, where the total external pressure **(P_{test})** is normalized to a constant value of unity **('1')**.

. Eq 3) $P_{test} = \sum_i \mathrm{P}\,(i) = \int_{i=1}^{\infty} P(i)\,di = 1$

This invariance ensures that physical laws remain consistent across all scales—from discrete sub-quantum elements to continuous macro-systems.

Energy Derivation from Pressure Dynamics
In a spherical geometry, energy is not an abstract property but a direct consequence of the pressure acting upon a volume. Following the classical definition where Energy is the product of Pressure and Volume **(E = P x V)**, and given that **P_{test}=1** from outside within our normalized framework, the energy density of the sphere is intrinsically linked to its geometric boundaries.
Within this framework, we define the energy of a **'Mass point'** (or a zero-dimension light-mass of the localized 0-D Oscillator) as: **E = $m^l{}_{D0}$ x $C^2{}_{(t)}$.**

This definition aligns with the foundational proposition established in **Paper 1, Chapter 24**, where Mass is described not as a static quantity, but as the net curvature of space resulting from the aggregate of instantaneous wavefunctions in superposition.

Here, **$C_{(t)}$** represents the time-dependent expansion velocity of the sphere's boundaries. By anchoring the energy **E** to the invariant pressure **P**, we establish that any change in the observed mass or gravity is not a loss of fundamental energy, but a result of the **interplay between the internal frequency of the mass and the external pressure of the vacuum**.

In the **'TOS'** framework, the relationship **E$m^l{}_{D0}$ ×=C^2** undergoes a critical phase-shift. While classical physics assumes energy scales linearly with mass, our model demonstrates that as mass increases toward the macroscopic limit, its **'Effective mass'** actually decreases and so it's **'Effective Energy'** actually decreases too. This is due to the Destructive Interference between the mass's intrinsic wavelength and the invariant pressure of the vacuum **(P=1).**

This mechanism is analogous to the double-slit experiment (dark fringes, for example): just as destructive interference creates zones of zero observed energy, the TOS framework shows that at macroscopic scales, the vast majority of universal energy cancels itself out vectorially. This **'cancelled'** energy isn't lost; it transitions from observable kinetic form to static spherical pressure, maintaining the universal equilibrium **(P=1).**

The Mechanism of Effective Mass Decay
From the integral in Equation 3 above, we obtain the external pressure toward **'1'** based on the fact that mass — as stated in the previous paragraph — is a superposition of the internal and external pressure acting on the components that constitute space, and is therefore not a fundamental property but an emergent result of sub-quantum interference.
For an infinitesimal or minimal mass, the attenuation is almost negligible, and therefore the effective mass is nearly identical to the actual mass, as the NAVP wavefunctions exhibit minimal overlap and thus minimal destructive interference.
As the mass increases, the attenuation becomes more significant, due to increasing destructive interference between densely packed NAVP's, causing the effective mass to decrease relative to the true mass.
Therefore, we can express the effective mass — in an approximate form, assuming an exponential decay distribution — as follows (see a more detailed explanation in Chapter 24 of Article 1):

. Eq 4) $M_{(eff)} = K_M \times M^l{}_{D0} \times (1 - e^{\alpha \times M^l{}_{D0}})$

Where:

- **M_{eff}** is the decayed mass of the sum of the zero-dimension light-mass of the oscillator - $\boldsymbol{M^{l}}_{\boldsymbol{D0}}$ (as defined in Paper II, chapter 3 very important note) which constitute the space **'M'**, forming a process that maintains the cosmic pressure equilibrium.
- **K_M** is the mass-normalization constant, representing the geometric scaling factor that aligns the zero-dimension light-mass with the observed effective gravitational mass.
- The coupling constant **'α'** represents the geometric interaction strength between scalar material mass and the vectorial vacuum mass of the 0-D oscillator. Its extremely small value ensures that only a minute fraction of scalar energy couples into the vacuum interference field, stabilizing the universe and suppressing the vacuum energy

The Mechanism of Effective Energy Decay

Having defined the effective mass, the effective energy follows directly from substituting into the generalized energy expression. Since energy scales linearly with mass, the decay in mass induces an identical exponential decay in the effective energy. Therefore, the effective energy can be written as:

. Eq 5) $\mathrm{E_{eff}} = K_M \times \mathrm{C}^2_{(t)} \times M_{eff} = K_M \times \mathrm{C}^2_{(t)} \times (1 - e^{-\alpha M^{l}{}_{D0}\mathrm{C}^2_{(t)}}) \times M^{l}{}_{D0}$

This formulation shows that the energy inherits the same attenuation mechanism as the mass, preserving consistency across the model.

Note: As established in the ToS framework, the exponential attenuation affects only the vectorial vacuum component through geometric interference, while the scalar backbone (Material Mass) remains cumulative and invariant (see Conclusion for the complete physical mechanism).

***Deriving the Effective Mass and the Coupling Constant* 'α' *in* Planck Units and the Effective Energy Relation**

Substituting the known values, we take the accepted Planck mass: **M_p = 2.176 x 10^{-8} kg** and the baryonic mass of the observable universe: ***$M_{universe}$ = 10^{53} kg***

From this, the mass of the universe expressed in Planck units becomes approximately:
$M_{universe}$ = 10^{53} kg / (2.176x10^{-8}) ≈ **4.6x10^{60} p.**

Substituting into the Effective Energy Expression

We now *define* ***K_{M-m} = G_0*** and substitute values into Equation (5), using Planck units where the speed of light and the *modulation constants are defined as:* ***C = 1*** *and* ***G_0 = 1***
In these units, the effective energy becomes:

. Eq 6) $\mathrm{E_{eff}} = (1 - e^{-\alpha M^{l}{}_{D0}}) \times M^{l}{}_{D0}$

Now we impose the condition: $\mathbf{E_{eff}} = \boldsymbol{\Lambda}$

which yields:

. Eq 7) $\Lambda = (1 - e^{-\alpha M^{l}{}_{D0}}) \times M^{l}{}_{D0}$

Rearranging:

. Eq 8) $\alpha = -\frac{1}{M^l{}_{D0}} ln\left(1 - \frac{\Lambda}{M^l{}_{D0}}\right)$

We substitute the value of obtained in Article 2, Chapter 4, Equation 22, namely: **Λ = 1.44x10^{-122}$_{p}$**, and the baryonic mass of the universe found earlier: ***$M_{universe}$*≈ 4.6x10^{60}$_{p}$** into Equation (8), yielding the value of **α**.

Then, using the first-order Taylor expansion of for small, we obtain:

. Eq 9) $\alpha \approx \frac{\Lambda}{M^2_{universe}} \approx \frac{1.44\times 10^{-122}}{(4.6\times 10^{60})^2} \approx 0.07 \times 10^{-242} \approx 7 \times 10^{-244}$

Interpretation and Physical Meaning

This decay of mass/energy with increasing total mass provides a natural explanation for the vacuum catastrophe discussed in Article 4, Chapter 2.
The exponential attenuation suppresses the effective contribution of large-scale mass-*energy densities, preventing the divergence predicted by naïve quantum field estimates*.

The Effective Force

After determining **α**, we return to Equation (4) for the decay of the mass and substitute it into the expression for the effective force, using the inverse-square proportionality established at the beginning of the chapter: **F_{eff}** ∝ **1/R^2**.

More explicitly, we can write:

. Eq 10) $F_{eff} \approx \frac{M_{eff}\times m_{eff}}{R^2} = K_{M-m} \times C^2_{(t)} \frac{M_{eff}\times m_{eff}}{R^2}$

We now substitute the effective masses from Equation 4:

. Eq10a) $M_{(\boldsymbol{eff})} = K_M \times M^l{}_{D0} \times (1 - M^l{}_{D0}C^2_{(t)}e^{-\alpha M^l{}_{D0}C^2_{(t)}})$

&

. Eq10b) $m_{(\boldsymbol{eff})} = K_m \times m^l{}_{D0} \times (1 - m^l{}_{D0}C^2_{(t)}e^{-\alpha m^l{}_{D0}C^2_{(t)}})$

*Defining **K_{M-m} = G_0** (as done for equation 6) and collecting terms, we obtain:*

.Eq 11) $F_{eff} = G_0 \times \left[(1 - M^l{}_{D0}C^2_{(t)}e^{-\alpha M^l{}_{D0}C^2_{(t)}}) \times (1 - m^l{}_{D0}C^2_{(t)}e^{-\alpha m^l{}_{D0}C^2_{(t)}})\right] \times \frac{M^l{}_{D0}\times m^l{}_{D0}}{R^2}$

In Planck units, where: **C(t) =1**, **G_0 =1**

the expression simplifies to:

. Eq 12) $F_{eff} = \left[(1 - M^l{}_{D0} \times e^{-\alpha M^l{}_{D0}}) \times (1 - m^l{}_{D0} \times e^{-\alpha m^l{}_{D0}})\right] \times \frac{M^l{}_{D0}\times m^l{}_{D0}}{R^2}$

Substituting the Value of α = 7X10^-244 (Equation 9)
we obtain:

. Eq 13) $F_{eff} = \left[(1 - M^l{}_{D0} e^{-7\times10^{-244} M^l{}_{D0}}) \times (1 - m^l{}_{D0} e^{-7\times10^{-244} m^l{}_{D0}}) \right] \times \frac{M^l{}_{D0} \times m^l{}_{D0}}{R^2}$

To substitute specific masses, we expand the expression to first order using a Taylor series, yielding:

For clarity, we expand the term $\mathbf{(1 - e^{-\alpha M^l{}_{D0}})}$ in a Taylor series: $\mathbf{(1 - e^{-\alpha M^l{}_{D0}} = 1 - (1 - \alpha M^l{}_{D0} + (\alpha M^l{}_{D0}{}^2)/2 - (\alpha M^l{}_{D0}{}^3)/6 + ...) = \alpha M^l{}_{D0} - (\alpha M^l{}_{D0}{}^2)/2 + (\alpha M^l{}_{D0}{}^3)/6 + \ldots)}$ Thus, the constant **'1'** term is not part of the decaying contribution at all; only the exponential tail – corresponding to the vectorial vacuum mass (the higher-order terms in $\boldsymbol{\alpha M^l{}_{D0}}$) - is subject to cancellation, while the underlying 0-D light mass remains as the static geometric scalar mass $\mathbf{(M^l{}_{D0})}$ of the system.

. Eq14) $\Delta F_{eff} = (7 \times 10^{-244})^2 \times M^l{}_{D0} \times m^l{}_{D0} \times \frac{M^l{}_{D0} \times m^l{}_{D0}}{R^2} = 49 \times 10^{-488} \times \frac{M^l{}_{D0} \times m^l{}_{D0}}{R^2}$

Therefore, the total effective force can be written as:

. Eq 15) $F_{eff} = G_0 \times \frac{M^l{}_{D0} \times m^l{}_{D0}}{R^2} + \Delta F_{eff} = (G_0 + 49 \times 10^{-488}) \times \frac{M^l{}_{D0} \times m^l{}_{D0}}{R^2}$

It is important to emphasize that the cancellation mechanism applies only to the exponential tail of the expression.

The leading constant term '1' corresponds to the static 0-D light mass of the oscillator, which does not participate in destructive interference and therefore does not decay.

The cancellation affects only the vectorial vacuum component represented by the exponential term.

To isolate the leading deviation from Newtonian gravity, we expand the term $\mathbf{1 - e^{-\alpha M^l{}_{D0}}}$ in a Taylor series and keep only the first-order term. Since $\boldsymbol{\alpha M^l{}_{D0} \ll 1}$ for any physically relevant mass — from the electron mass up to even **100 times the mass of the observable universe** — higher-order terms are completely negligible. Consequently, the first-order term provides the dominant correction, which remains vanishingly small in all cases, so the effective force reduces to Newtonian gravity throughout the entire physical mass range.

Chapter 2 Summary

Having shown that the term **1 –** $e^{-\alpha M^{l}{}_{D0}}$ yields an extremely small first-order correction for any physically relevant mass — **from the electron mass up to even 100 times the mass of the observable universe**. And that established in Article 2, Chapter 4, the gravitational constant is also time-dependent $\mathbf{G_{0(t)}}$ — it follows that the effective gravitational force converges to the Newtonian form with excellent accuracy.

Therefore, when **reintroducing** the gravitational time-dependent $\mathbf{G_{0(t)}}$ (or $\mathbf{G_0}$ as constant used before) which was set to unity in Planck units in Eq. 12, substituting into the limit of equation 15, we obtain the time-dependent effective Newtonian gravitational force as follows:

$$\textbf{Eq 16)}\ F_{eff_{(t)}} = G_{0_{(t)}} \times \frac{M^{l}{}_{D0} \times m^{l}{}_{D0}}{R^2} \begin{pmatrix} \textit{The time-dependent} \\ \text{Q.E.D}-\textit{Newton law} \end{pmatrix}$$

Conclusion:

In this paper, we have successfully closed the conceptual and mathematical loop regarding the fundamental nature of mass and force within the **Theory of Spheres (ToS)**.

The Geometric Foundation
We began by establishing the four dynamic possibilities of the sphere: two stages of expansion (from the center to the equilibrium point—the universe we inhabit—and beyond) and two stages of contraction (from the exterior toward equilibrium and back to the center). This **Entangled Quadruplet** provides the necessary symmetric framework for a stable, self-sustaining 0-D harmonic oscillator.

Bridging the 100-Year Gap: From Quantum to Newton
The most critical achievement of this work is the formal derivation of **Newton's Law of Universal Gravitation** directly from the quantum-mechanical properties of the 0-D oscillator. We have demonstrated that gravity is not an independent fundamental force, but an emergent geometric result of spherical pressure distribution. This resolves the century-old conflict between quantum mechanics and classical gravitation.

The Duality of Mass and the Solution to the Vacuum Catastrophe.
Our derivation reveals that mass-energy manifests in two distinct response modes originating from the same 0-D oscillator source associated with the external pressure discussed at the beginning of Chapter 2 of this paper, and in Part B, Chapter 1 of Article 1: the local modulation of light speed. This fundamental separation arises because the 0-D oscillator source lacks internal spatial degrees of freedom, forcing its energy to couple through a dimension-independent scalar mode.
That led to the discovery of two distinct manifestations of mass:

- **Scalar Material Mass:** This *zero-dimensional,* non-interfering mode *cannot undergo directional cancellation and therefore* remains cumulative, forming the *effective Newtonian* mass capable of performing work (**E=$M^{l}{}_{D0}$c²**). It is a scalar quantity that aggregates simply, explaining why both matter and antimatter contribute to the total Newtonian attraction. This scalar nature, for example, is evidenced in laboratory settings, where antimatter must be suspended by immense magnetic fields (Penning trap) to prevent its gravitational attraction to the material walls of the container.
- **Vectorial Vacuum Mass (0-D Light):** In contrast this is the mass, associated with the vector mode distributes over the three spatial dimensions available to the observer. Unlike material mass This spatial embedding subjects the energy to massive destructive interference (Destructive Interference), leaving only the vanish small residual remnant observed as the Cosmological Constant **(Λ)**, which *depends explicitly on the number of spatial dimensions available to the observer*.

*Thus, the scalar and vector terms do not represent two different physical pressures, but two different spatial response modes of the same underlying modulation of the speed of light***.**

Universal Stability and the Cosmological Constant
By proving that this energy cancels out as mass increases, we provide a definitive solution to the **Vacuum Catastrophe**. This mechanism allows for a stable universe with a measured Cosmological Constant **'Λ'** of approximately **1.44×10^{-122}** in Planck units. What

remains is only the **'minimal noise of reality'**—the residual effective mass defined by our derived coupling constant $\boldsymbol{\alpha \approx 7 \times 10^{-244}}$.

Final Summary:
The Theory of Spheres provides a unified framework where the speed of light, the gravitational force, and the cosmological constant are all reconciled. Gravity is revealed to be the macroscopic manifestation of sub-quantum interference, finally offering the 'direct link' that physics has sought for decades.

To the beginning of the paper