# The Cypher Universe – Decoding Quantum Mechanics in the 4-Sphere

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This paper presents a deterministic, geometric reformulation of quantum mechanics within the 4-sphere cosmological framework introduced in *The Matryoshka Universe*. We propose that quantum wavefunctions are best understood not as probabilistic fields evolving in time, but as fixed four-dimensional wavecones propagating inward through a closed, curved spacetime geometry. Decoherence is reinterpreted as a geometric intersection: a slice through a 4D wavecone made by an observer's worldline, governed not by stochastic collapse but by an informational boundary condition we term the *decoherence sphere*. This sphere encodes the quantized degrees of freedom available at any point in spacetime and is anchored by the global entropy structure of the universe, as imprinted in the cosmic microwave background (CMB). Within this framework, quantum randomness emerges from partial access to a deterministic geometry, and quantum measurement is reframed as cryptographic decryption: the wavecone is the plaintext, the CMB is the key, and the observed outcome (in the form of the decoherence sphere) is the ciphertext. We explore entanglement, interference, and measurement as local manifestations of a globally consistent 4D structure and propose that gravity itself may be understood as a constraint on decoherence geometry – a quantum curvature that limits future informational pathways. By unifying quantum theory and general relativity through the informational geometry of the 4-sphere, this model offers a local, deterministic alternative to standard interpretations of quantum mechanics, with testable experimental consequences.

This paper extends the framework introduced in *The Matryoshka Universe*, where we proposed a novel spacetime metric to address growing tensions within the ΛCDM cosmological model. There, we described a non-Euclidean topology: a 4-sphere expanding inward from a finite outer shell at recombination, with time flowing radially along a proper-time axis. Within this geometry, we defined *true inertial frames* (TIFs) as those comoving with the cosmic microwave background (CMB), and suggested that such frames may experience physically distinct behavior from conventional inertial observers. We also reframed *c* not as the speed of light, but as the speed of time – a universal tempo driving observers inward through a fixed spacetime crystal. This reorientation allowed us to visualize quantum entanglement geometrically, but it left a deeper question unresolved: could the entire structure of quantum mechanics be reinterpreted within the 4-sphere? In this paper, we argue that it can, and that doing so reveals a deterministic and geometrically grounded model of quantum theory. Central to this reformulation is the *wavecone*, a four-dimensional generalization of the wavefunction that propagates inward through the nested 3-spheres of the 4-sphere. At each spatial 'now,' the wavecone intersects a 3-sphere to produce a spherical cross-section of quantum potential. We call this the *decoherence sphere* – an informational boundary surface that encodes the set of quantized measurement outcomes available to an observer at that point in spacetime. The shape and structure of this sphere are governed by the entropy field encoded in the CMB, which acts as a universal cipher key: a high-entropy baseline that constrains how wavecones can resolve into classical outcomes.

In this formulation, the act of measurement is not a collapse, but a slice – a deterministic intersection between an observer's worldline and a pre-existing 4D structure. The wavecone is the plaintext, the CMB is the key, and the decoherence sphere is the cipher surface through which outcomes are read. Randomness arises not from indeterminacy, but from partial access to a fixed geometric order, since we are seeing but a 3-dimensional reflection of 4-dimensional objects. By reframing quantum behavior as a cryptographic interaction between wavecones, observers, and an entropy-encoded background, we propose a natural unification with general relativity; one that eliminates stochastic collapse, preserves locality, and redefines quantum measurement as a geometric decoding process embedded in the structure of the cosmos.

Matryoshka dealt with the very large; this essay now turns to the very small. To explore how quantum mechanics arises within the 4-sphere, we must zoom in on the geometry of the miniature and examine how time and space behave at the scale of particles and photons. But before we do so, a reminder: in our framework, $c$ is not the speed of light, but the speed of time – a universal tempo that pushes observers radially inward through spacetime. Let us imagine a park at night, viewed from above, with a single lamp at the center and a scattering of trees. At first the lamp is off. Then, at $t_0$, the lamp turns on. From our 3D perspective, photons begin propagating outward from the lamp in every direction, illuminating the trees one by one as the sphere of light grows. But from the 4D perspective of the 4-sphere, something more interesting is happening. If we stack every moment of this scene as it unfolds in time, we find that the expanding sphere of light becomes a cone – a hollow structure growing inward through spacetime, its base anchored in the present and its tip reaching back to the moment the lamp turned on. In this framing, the trees are not merely locations in space, but are elongated filaments stretching through time, intersected by the advancing light cone. Matter, in our model, is extended radially along the time axis, and what we perceive as an object 'at rest' is simply a worldline that progresses smoothly through time. This temporal extension is what gives matter its persistence, and what we interpret as mass – a notion not unlike the role of the Higgs field, but framed instead as a geometric property of duration. Meanwhile, light traces conical surfaces, not because it travels, but because time pushes us into its frozen, crystal-like geometry. We do not watch light move – we move into light.

Investigations into photons and other fundamental particles reveal that they are not point-like events, but structured objects, carriers of information such as spin, polarization, phase, and momentum. These properties are not separate from the particle's motion, but must be embedded in the geometry of its propagation. To capture this idea, we introduce a new structure: the wavecone. In relativity, light propagates along a null cone – expanding outward at $c$ as time progresses. In our 4-sphere model, quantum waveforms instead propagate inward through time, forming conical probability fields embedded within the nested 3-spheres of the 4-sphere. At every radius, the wavecone intersects a 3-sphere (a spatial 'now'), producing a spherical cross-section whose internal structure is shaped by both quantum interference and global spacetime curvature. These structures are four-dimensional and difficult to visualize intuitively, so we aim for clarity in description. Think of the wavecone as a 4D conical object: when it intersects a 3-sphere (a 2D shell), its projection into 3D space is a spherical region: we call this region the *decoherence sphere*. This sphere represents the set of quantized degrees of freedom available to the particle at that moment in spacetime – a map of possible futures constrained by geometry. The photon, for example, cannot propagate arbitrarily; its future paths are discretized.

All of a particle's identity (its spin, polarization, momentum) is encoded in the evolving geometry of this inward-propagating wavecone. To preserve that identity over time, a fundamental condition must be met: entropy per unit volume must remain conserved. We will return to this principle later, as it underlies the informational consistency of the 4-sphere. Where classical quantum mechanics describes wavefunctions as probabilistic fields vibrating through space over time, the wavecone model embeds these oscillations directly into the fixed geometry of spacetime. Since we only experience 3D slices of this 4D structure, our perception is inherently partial. As time pushes us radially inward through the 4-sphere, we encounter successive cross-sections of the wavecone – like a Platonic observer watching shadows cast by four-dimensional objects projected onto the tilted wall of three-dimensional space. In this metaphor, the unfolding shadows correspond to the bounded measurement outcomes available on each decoherence sphere, shaped not by intrinsic randomness, but by the geometry of projection. Just as in Plato's cave, we do not perceive the object itself, but only its angled trace. The angle of the wall (our orientation through spacetime) acts like a Lorentz transformation, altering the slice we perceive. As we shall later explore, angular deformations of the decoherence sphere under the influence of mass provide a natural explanation for gravity as a curvature not of space, but of informational freedom.

In the 4-sphere model, a decoherence event is not the collapse of a wavefunction in the traditional sense, but a geometric interaction between an observer's worldline and a specific region of a four-dimensional wavecone. The observed outcome (what appears as a discrete measurement result) emerges from the particular way the observer's trajectory intersects the wavecone's volume at a given moment in proper time. The wavecone itself is not destroyed or altered; it remains a fixed, four-dimensional structure encoding the full quantum amplitude of the system. Measurement is understood as a slicing operation: the observer's path through spacetime intersects the wavecone, revealing a lower-dimensional cross-section that corresponds to the decohered outcome. Different orientations or positions of the observer produce different slices, leading to distinct but deterministic results. In this framework, decoherence is not a process of collapse, but one of geometric selection; and because it is deterministic, we may be able to reverse engineer it the way we solve a cypher.

In our first paper, we described entangled particles as diverging along a shared worldline within the 4-sphere – a simple V-shaped structure. We now refine this model using the language of wavecones. Each entangled particle is embedded in its own inward-propagating wavecone, shaped by shared initial conditions and constrained by the curvature of the 4-sphere. These are not lines but four-dimensional, conical-volumetric 4D structures, preserving quantities like spin or polarization across their entire extent. From a 3D perspective, it appears as if the particles are moving apart in space; in reality, observers are progressing inward through a single, unified 4D structure, and are being pushed into that 4D divergent structure at $c$. When one photon is measured, the detector slices its wavecone, revealing a single decohered outcome. But because the two wavecones are globally linked, that slice extends to the other entangled wavecone as well, and simultaneously slices the structure of the partner cone. What emerges is a 3D snapshot of the propagation of both waves at corresponding places in their 4D geometry and periodic wave oscillation. No signal passes between the two wavecones – the correlation is built into the geometry from the start. What appears as nonlocality is, in our model, a symmetry embedded in spacetime, and the deterministic unfolding of a single 4D object projected onto a 3D surface.

In the 4-sphere model, the classic double-slit experiment acquires a precise geometric meaning. Each photon fired toward the slits carries an inward-propagating wavecone – a four-dimensional structure encoding its phase, momentum, and orientation within the curvature of the 4-sphere. As this wavecone intersects successive 3-spheres (spatial 'nows'), it diffracts across both slits simultaneously. The resulting interference pattern is not probabilistic, but a fixed feature of the wavecone's geometry, already encoded in spacetime before measurement occurs. When a detector is introduced to determine which slit the photon passes through, the worldline of the measurement apparatus intersects the wavecone differently. This interaction acts as a geometric filter, slicing through the wavecone in a way that suppresses interference. What appears as the 'collapse' of the wavefunction is, in this view, simply the exposure of one deterministic outcome based on how the observer intersects the 4D structure from a 3D perspective.

This geometry becomes even more apparent in a true inertial frame (TIF) – a frame at rest relative to the CMB and progressing purely through time. In a TIF, the photon, detector, and apparatus share a stable alignment through spacetime. Their only motion is radial, inward through the 4-sphere. When all variables (phase, orientation to the CMB frame, and 3D rotation) are held constant, decoherence should become highly reproducible, and the photons should strike the same point on the detector in trial after trial. There should be no randomness, only a consistent slicing through the same wavecone structure. It is only when the observer's frame drifts from a TIF, due to Earth's rotation, orbital motion, or experimental misalignment, that the angle of intersection changes, introducing the variability we normally interpret as quantum uncertainty. From this perspective, decoherence is not a probabilistic collapse but a geometric event dependent on frame stability.

To visualize this, imagine placing a double-slit experiment in a perfectly aligned TIF. Fire a photon: it lands at a specific point. Rotate the apparatus slightly and fire again: a new, but consistent point. Repeat this process through a full range of spherical orientations, and it traces out a structured interference pattern across a spherical surface, representing possible outcomes – this is the *decoherence sphere*. The decoherence sphere is not a physical object, but an informational one. It serves as a geometric constraint – a kind of boundary condition that governs how a wavecone resolves into a specific 3D decohered outcome. Just as a light cone is not made of matter, but still imposes strict causal limits, or a geodesic isn't visible but still dictates the path of falling objects in curved space, the decoherence sphere defines the allowable outcomes of quantum measurement without being directly observable. It represents the quantized degrees of freedom available to a particle at a particular point in spacetime, a frozen map of possibility determined by its wavecone's intersection with the global entropy field, as defined by the CMB. While not material, it is deeply real in that it constrains outcomes, shapes interactions, and provides a structured framework for how quantum systems unfold through time.

In the 4-sphere model, each quantum particle frozen in time defines a unique decoherence sphere – a structured 3D surface representing the set of measurement outcomes available at a specific point in spacetime. From the perspective of a 3D observer, this sphere arises from the intersection of the particle's inward-propagating 4D wavecone with the entropy field defined by the CMB, at a given 3-sphere radius. Crucially, the decoherence sphere is not a statistical artifact, but a deterministic boundary condition: a geometric encoding of all permissible futures, shaped by both local properties and global curvature. When a measurement occurs, the observer's worldline intersects this boundary, selecting one allowable outcome from the full set – not by collapse, but by geometric alignment. The result appears 'random' only because we experience it as a 3D slice of a hidden 4D order. In truth, the decohered value is no more arbitrary than a letter appearing at the intersection of a cipher grid: fixed, recoverable, and constrained. Different particles yield different decoherence spheres based on their spin, momentum, and orientation within the 4-sphere, while variations in the observer's frame (angular shifts, relative motion, or displacement from a true inertial frame) alter the geometry of the intersection. In this way, the model explains both the statistical consistency of quantum predictions and the variability seen in individual trials: not as indeterminacy, but as differing projections through a fixed, higher-dimensional structure.

In this sense, quantum mechanics functions as a cryptographic system. The 4D wavecone is the plaintext – a full, coherent field of information. The CMB acts as the global key – a high-entropy constraint that shapes how wavecones can resolve into outcomes, like a one-time pad. The decoherence sphere is the ciphertext – the observed signature projected into 3D space. The randomness we perceive is not a lack of structure, but the shadow of an inaccessible whole, and with the correct frame, we might one day decrypt it.

What has often been overlooked in quantum mechanics is that observers on the 3-sphere are bound to measure quantum phenomena from a proper frame, using inherently coordinate-based methods. Each time we make a quantum observation, we intersect a particle's worldline, and our measurement and the particle intersect at a point in the 4-sphere, with their worldlines crossing at both their proper times. However, the quantum models physicists construct are not built from single events, but from the aggregate of many measurements made across different times and locations. Each of these measurements occurs at a slightly different angle to the CMB – a different orientation in the 4-sphere – and so each 'cut' through the wavecone presents a different perspective of the same underlying 4D wavecone. This is mostly due to the fact that the constant rotation of the earth takes us in and out of alignment with the CMB rest frame, influencing all earthbound measurements. Taken on their own, these measurements appear statistically random, but taken together they begin to form a structured pattern. We posit that the randomness we measure in quantum mechanics arises not from indeterminacy, but from the compiling of many differently angled slices through a structure we cannot fully access. In assembling these statistical models, we're not observing the 4D waveform directly; we are reconstructing it from a series of partial, decohered cross-sections. The resulting mismatch between what we predict through coordinate measurement (the wavefunction) and what we observe properly (a single decohered event) leads to familiar paradoxes (like the so-called "spooky action at a distance") and has fueled a century of interpretive confusion. But the map is not the landscape. Decoherence does not collapse the waveform: the wavecone continues to propagate through spacetime, unaffected by our local intrusion. Our observation is simply a cut: one phase, one position, one angle. The quantum waveform is not destroyed by measurement – only sampled from one of infinitely many possible worldline perspectives.

Entropy is a slippery concept, defined in different ways depending on the context. In high school physics, it's often introduced as a measure of disorder or the tendency of systems to evolve toward thermodynamic equilibrium – usually in terms of heat and expansion. In our model, however, entropy is geometric and informational. To clarify this shift in thinking, it may be helpful to borrow a metaphor from cryptography. A codebreaker, when handed a ciphertext, is presented with a message that appears as a random sequence of characters. But randomness in this case is a disguise – the entropy is not meaningless, but structured, hiding a latent order beneath the surface. The codebreaker doesn't initially know the key, but they can still apply statistical tools like bigram frequency analysis to determine whether a pattern is present – a telltale signature that the text carries meaning. Once the proper key is discovered, the apparent randomness dissolves, and the message becomes clear. Quantum mechanics presents us with a similar problem. Decohering waveforms appear to fire photons at detectors unpredictably, as if governed by pure chance. Yet the patterns they produce are regular, stable, and statistically precise – just like ciphertext obeying the rules of an unknown latent plaintext. In our model, the underlying structure is not probabilistic but geometric: what we call a 'waveform' is actually a 4D wavecone, a frozen object whose information is preserved through its volume by conserving entropy per unit of space.

This relationship between randomness and structure is precisely what makes Bell's inequality violations so illuminating. In quantum mechanics, Bell-type experiments test whether measurement outcomes conform to what we would expect from true randomness (as in a classical hidden-variable theory), or whether they exhibit correlations too strong to be explained without invoking nonlocal (spooky action) structure. These stronger-than-random correlations are the quantum equivalent of finding meaningful bigram distributions in a cipher text – a sign that what appears to be noise may in fact be an encoded signal. In our 4-sphere model, these 'signals' are not mysterious; they arise naturally from the deterministic geometry of inward-propagating wavecones and their '3-sphere intersectional' decoherence spheres. Bell's inequality violations thus serve as statistical footprints of a deeper 4D order, hinting that the randomness we observe in quantum mechanics is not fundamental, but rather the shadow of a higher-dimensional structure: a cryptographic system in which every outcome is lawful, encoded, and recoverable in principle.

In order to expand our understanding of entropic geometry, let's consider a thought experiment that imagines a person learning archery. At first, this person is not good at archery, they make many mistakes, and their arrows fly off in many directions, only sometimes hitting the target. But as the archer gets better, all the arrows they fire now hit the target, and they form a pattern. If this archer is teaching themselves, they can start diagnosing their own archery technique based on patterns that emerge from their groupings. If the archer is doing something technically or physically wrong, they will see that error of origin manifesting itself in the grouping on the target. If, for instance, all their arrows land on the left side of the target, they can assume that the emergent pattern represents a physical 'something' the archer is doing that causes the arrows to fly in that direction. But this presents an interesting question – how does the archer know that a particular grouping indicates a technical or physical shortcoming? Certainly, any archer could make the conceptual leap that if all your arrows are landing, say, to the left of where you're aiming, that some sort of preferential rotation is involved – this is how archers get better at archery. But from a philosophical standpoint, how do they know this? It seems as if our archer intuitively knows what pattern they should see if there were no external influences, and define their left biased distribution as evidence that they are deviating from that distribution. But what distribution were they expecting, and does such a distribution represent true randomness, independent of influence?

In our previous paper, we encountered a similar conceptual challenge in defining rotation – a motion that, in the absence of a fixed background, appears to lack a reference point. The 4-sphere model resolves this by grounding all motion relative to the cosmic microwave background (CMB), which functions as an invariant geometric anchor within an otherwise shifting spacetime. Just as rotation becomes meaningful only in relation to this stable backdrop, so too does randomness. In both cases, the phenomenon in question is not defined in absolute terms, but relative to an underlying structure – a pillar against which deviation is measured. In Newtonian physics, motion is defined with respect to an implicit lattice of absolute space; in general relativity, this reference disappears, and the speed of light, $c$, takes its place, not as a velocity per se, but as a ruler for causality and simultaneity. The 4-sphere model refines this further: all motion proceeds relative to the CMB, and all statistical distributions – whether deemed ordered, noisy, or truly random – are evaluated with respect to the high-entropy interference pattern encoded in that primordial radiation. Just as rotation is a deviation from radial alignment, emergent signals are recognized as deviating from the baseline entropy structure etched into the geometry of the universe. The CMB is not an object – it is the ground against which all objects are compared. In our cryptography metaphor, the CMB is a one-time pad for the universal cipher that allows the 4D plaintext of wavecones to resolve into 3D decohered outcomes.

From an informational perspective, objects (like particles, planets, or even people) aren't fundamental building blocks of reality at all. Instead, they emerge out of patterns in entropy: the measure of how spread out or disordered energy is. At the outer edge of the 4-sphere, we find recombination; a state of low entropy and low volume. As we move inward through time, the universe increases in volume, and with it, more space for energy and matter to distribute. Yet intriguingly, the amount of entropy grows in proportion to the volume it occupies within the concentric rings of the 4-sphere. This means that even as disorder increases in absolute terms, the density of entropy (the amount per unit volume) remains constant. The photons reaching us from the recombination surface now form the Cosmic Microwave Background, a smooth, high-entropy field that represents the most random distribution observable from within our 3-sphere. Against this uniform backdrop, localized structures – what we call 'objects' – stand out as coherent deviations from statistical equilibrium. And since these objects appear stable across time, we must assume that entropy is somehow conserved.

It might sound overly poetic to say that objects 'emerge out of entropy,' but this is precisely what occurs when our archer detects a pattern in his arrows. If all the arrows land to the left of center, that deviation from randomness reveals a latent structure: a rotational bias in his technique. The pattern doesn't arise from the arrows themselves, but from their difference relative to an expected random distribution. In this way, physical systems, whether archery patterns or galaxy clusters, reveal themselves through deviation from a known entropic baseline. We quantify this deviation through statistical tools, often setting significance thresholds like 5σ to distinguish signal from noise. In our cosmological model, that entropic baseline is the CMB. What we interpret as structure (an object, an event, a choice) is a statistically significant contrast against that universal randomness. The arrow groupings form a shape in the noise, and the same is true of us. In this way, we can describe the structure of the universe using a simple relationship: the change in entropy with respect to volume stays constant, and that constant is the speed of time.

$$\frac{dS}{dV} = c$$

where $S$ is the total entropy within a 3-sphere of radius $r$, $V$ is the proper volume of that 3-sphere embedded in the 4-sphere spacetime, and $c$ is the speed of time as defined in our 4-sphere model, representing the rate at which spacetime geometry is traversed by observers.

In the 4-sphere framework, mass is not a static point in space, but a radial extension through time – an object's persistence across successive 3-spheres. This persistence shapes the curvature of the 4D spacetime crystal, not through distortions in space, but through warping along the radial axis: mass curves time. In 'Slaughterhouse 5' Kurt Vonnegut imagines a race of four-dimensional entities called the 'Trafalmagorians' who perceived human beings as a kind of millipede; with baby legs at the back, grown up legs in the middle, and elderly legs at the front. If we orient this strange creature such that the elderly legs point towards the center of the 4-sphere and the baby legs towards recombination, we have effectively created a metaphor for how massive objects can be expressed within the geometry of the 4-sphere (in this case, in a TIF). All spacetime objects, massive or not, are encountered at $c$, since $c$ is the speed of time in our model. Therefore, temporally persistent objects must be radially 'long' through time in the 4-sphere. In keeping with General Relativity, we posit that this radial extension introduces local curvature. This curvature does not simply bend the motion of matter; it reshapes the informational landscape in which quantum events occur. Specifically, it distorts the decoherence spheres of particles – the quantized constraint surfaces where 4D wavecones are sliced into classical 3D outcomes. Near a massive object, the geometry of 4D wavecones (and as a result their 3D decoherence spheres) become directionally biased. Instead of being isotropic (as in a true inertial frame), decoherence spheres near mass exhibit asymmetries that favor specific angular trajectories. In this model, gravity is not a force, but a restriction on future informational freedom. A photon passing near a star doesn't 'fall' – rather, its wavecone is intersected along a different path because both the wavecone and its corresponding decoherence sphere have been warped by the star's mass. The geometry of time has curved, and with it, the available slices through which the wavecone can resolve. Mass, then, is not just resistance to acceleration, but also resistance to decoherence branching. Mass narrows the fan of possible outcomes and shapes which cuts are available to observers in nearby frames. In this sense, gravity and quantum measurement become two sides of the same geometric process: one curves the structure of spacetime, the other reveals it. This duality mirrors Einstein's field equations, where mass and energy curve spacetime; here, mass and acceleration bend probability – reshaping the decoherence landscape through which measurement outcomes emerge. From this perspective, planetary orbits, gravitational lensing, and even the experience of weight all emerge from the same source: a distortion of the decoherence landscape. The Earth does not orbit the Sun because it is pulled, but because the Sun's mass biases the geometry of every decoherence spheres of every particle on earth such that the direction of orbit defines the most probable path. Thus, in the 4-sphere, gravity is not a field overlaid on quantum mechanics. It *is* quantum mechanics – expressed as the global modulation of informational geometry. Put succinctly: mass and acceleration bend probability.

We propose two experiments that may confirm or falsify key aspects of our 4-sphere model. The first seeks to detect asymmetrical redshifts in entangled particles based on their motion relative to a true inertial frame (TIF). The second attempts to reproduce specific quantum outcomes by carefully controlling the variables tied to cryptographic decoherence. Let us return to our earlier model of two entangled photons produced within a TIF. Let us imagine that one of the entangled wavecones propagates purely through time; that is, its motion is entirely radial, with no spatial component. The other photon, however, travels through space and thus exhibits motion relative to the CMB rest frame. According to the 4-sphere model, this difference should result in a measurable redshift: the photon moving through space should appear redshifted relative to the one traveling only through time. Crucially, this redshift is expected to be asymmetric: a marked departure from standard relativity, where no single frame is preferred and both particles would be redshifted symmetrically relative to one another. If a systematic redshift difference could be observed between entangled particles at the moment of decoherence, it could indicate differing velocities relative to the CMB rest frame, potentially validating the presence of a preferred cosmic reference frame, as posited by our model.

The second experiment focuses on the reproducibility of decoherence events by treating measurement not as a collapse, but as a geometric slice through a 4D wavecone. If the observer's frame of reference, the quantum system, and the measurement apparatus are all carefully stabilized relative to the CMB (with controlled CMB delta-v orientation, phase, and timing) the results should become reproducible. The angle at which a worldline intersects a wavecone during decoherence should determine the observed outcome. By maintaining consistent experimental geometry, it should be possible to observe specific, repeated results and not statistical distributions. These experiments may already have indirect support from long-term entanglement studies, especially those conducted with high spatial and temporal precision. But if interpreted through the lens of cryptographic decoherence, the full structure of their results might yield far more than previously recognized.

The authors must admit a kind of defeat: we are no closer to resolving what an observer is, or what constitutes a measurement. But the 4-sphere model offers a new geometric language in which such questions might finally be posed with precision. In this framework, the observer is not outside the system, but a worldline; a structured trajectory sweeping inward through the frozen 4D spacetime crystal at the speed of time, intersecting quantum structures as a geometric cut. Measurement, in this context, is not a collapse but an intersection. And consciousness, if it plays a role, is not metaphysical but geometric – another embedded structure within the same lattice. We do not claim to have solved the measurement problem, but we offer a new shape for it, and perhaps a new way to measure it. To support this, we have proposed a specific mathematical form for the underlying metric of our system:

$$ds^2 = -c^2 dr^2 + \left(S_0 \cdot r \cdot e^{\lambda r/2}\right)^2 d\Omega_3^2$$

where $c$ is the speed of time, $r$ is the radial proper time of a true inertial observer, and $S_0$ reflects both the matter-energy configuration and entropy structure present at recombination. We present these ideas not as declarations, but as directions – sketches toward a possible unification of quantum mechanics and general relativity within a shared geometric frame.

We ended *The Matryoshka Universe* by grappling with one of the 4-sphere model's most troubling implications: that it appears to eliminate the possibility of free will. If a conscious observer is merely being pushed through time at $c$ into oncoming spacetime geometry, what claim can they make to authorship over their own destiny? But perhaps it helps to step back and view this assertion not just as a physical theory, but as one moment in the history of theory itself. The Ptolemaic model placed humankind at the center of the cosmos. Kepler displaced us into orbit, Einstein stretched us across a fabric of space and time – and now, in a strange twist, the 4-sphere places us back at the center, once again. Theories are cyclical, yes: but they are also deeply reflective of the eras that produce them. Relativity emerged in a time of clashing global ideologies and shifting human self-conceptions. Gödel's incompleteness theorems followed soon after, arriving precisely when the supremacy of logic and formal systems was being reevaluated. A cryptographic theory of the universe, framed in terms of information, keys, and hidden structure, feels unmistakably like a theory of *our* time. So even if this formulation feels coldly deterministic, I take some comfort in knowing that it, too, will pass. Even if the 4-sphere model is partially or even entirely correct, it will one day serve as scaffolding for something new; some reformulation that restores agency, or reframes structure, or shifts the perspective yet again. All scientific 'truths' are mortal. Every scientific theory is a Gödel sentence: valid within its system, yet pointing beyond it.

Gödel showed that any formal system powerful enough to describe arithmetic mathematics will contain truths it cannot prove. This isn't just a mathematical curiosity, but marks the boundary of what any structure can say about itself. Science, too, is such a structure. The laws of physics must be consistent across the large and small, the near and far, and yet Gödel still reminds us: consistency forbids completeness. Perhaps no causally coherent system can ever be complete from within its own perspective, and the 4-sphere offers a fitting analogy. Since every observer makes a single 'cut' through the spacetime crystal, they only see a partial slice of the whole; no one sees the full structure. Taken this way, Gödel sentences are like superpositions: ambiguous from a local view, yet fully embedded in the global form. When we adopt frameworks (Newtonian mechanics, relativity, free will, determinism) we're choosing projections through a higher dimensional bulk where every projection is incomplete. Gödel's theorem isn't just a boundary on logic, it's a reminder that every theory, no matter how elegant, reveals only part of a deeper whole. Physics must be consistent: and for that very reason, it can never be complete.