The Matryoshka Universe: An Investigation Into 4-Sphere Cosmology

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We propose a cosmological model in which the universe is described as a 4-sphere: a non-Euclidean, inwardly expanding spacetime geometry. In this framework, past states of the universe are represented by concentric shells surrounding the central present, like nested Matryoshka dolls with increasing internal volume. Time flows radially inward from the Cosmic Microwave Background (CMB) toward the present, resolving the horizon problem geometrically and reframing redshift as a consequence of progressive curvature rather than accelerating expansion. The model suggests that entanglement arises from global geometric constraints, not nonlocal signaling, and that inertial frames comoving with the CMB may be physically privileged. While the model is presented conceptually, it invites further mathematical development and may offer insights into dark energy, the Hubble tension, and the structure of spacetime itself.

Our investigation begins with a curious observational fact: no matter which direction we look in the sky, we see light from earlier stages of the universe's evolution. The farther we look, the younger the universe appears to be – yet curiously, this younger universe surrounds us on all sides, as though we were nested within it. Propositions such as the photon horizon and early inflationary expansion have been introduced to account for this observation and to reconcile it with the standard ΛCDM model. In ΛCDM cosmology, the early universe was hot, dense, and small, and expanded outward as space itself grew. It explains that distant galaxies are therefore receding away from us, and that the light we observe from them was emitted when the universe was physically smaller. But this standard framing raises a subtle puzzle. If the early universe were simply a scaled-down version of the present, expanding uniformly in all directions, why does it appear to wrap around us, with the past lying outward in every spatial direction? How can the smaller early universe completely surround the larger, later universe? To resolve this paradox, we propose a new geometric interpretation: a universe with non-Euclidean topology in which time itself curves inward, and earlier states are not distant slices of an outwardly expanding volume, but instead nested layers of a collapsing spacetime structure. In this model, recombination forms the outermost shell of the universe, representing the earliest visible state, while more recent epochs unfold toward the center. Like a set of Russian Matryoshka dolls with their volumes inverted, the inner layers are larger than the outer ones. The universe, rather than expanding outward from a point, unfolds inward from a boundary.

The spacetime metric we are proposing is non-Euclidean, four dimensional, and involves progressive curvature. As such, it is extremely difficult to model intuitively. We believe that a slightly simpler version of our model may help the reader better visualize the exotic universe we wish to describe. As in the concept of Brian Greene's 'spacetime-loaf,' we have elected to collapse the three special dimensions down to two, and instead of modeling our universe formally as a 4-dimensional hypersphere, we instead imagine the entirety of our universe, space and time, as a 3-dimensional sphere. We will call this the 4-sphere, since while it is (in our model) 3-dimensional, it nonetheless represents all four dimensions of spacetime. Within this 4-sphere are an infinite number of concentric 2-dimensional spheres that gradually increase in volume as we move from the surface of the 4-sphere into the center. We will call these 3-spheres. Each of these 3-spheres represents a 3-dimensional picture of our universe at a certain point in proper time, according to an observer comoving with the CMB. In this model, the arrow of time points inwards from the surface of the 4-sphere, such that the present state of the universe occupies the center of the 4-sphere. A sphere with finite surface area and infinite volume is clearly not a shape which can exist in Euclidean space, but such an exotic topology is permitted within general relativity. The outer surface of the 4-sphere represents the source of the earliest photonic information that we on earth have received, namely, the Cosmic Microwave Background; the outermost shell of our model therefore represents a 3-dimensional picture of the universe as it was at recombination. The surface area of our universe is not changing, but its volume is gradually increasing, and matter and radiation are therefore able to exploit new degrees of freedom as the internal volume of the 4-sphere metrically expands. This causes the distances between objects in the universe to increase, and results in the kinematic expansion we observe in the modern universe. While we may perceive the older universe as moving away from us, it is in fact we who are receding away from it, always at the center of an ever-increasing volume.

One helpful reason for modeling the universe this way is that it geometrically resolves the horizon problem without the need for an early expansionary epoch. Since the past completely surrounds the present, matter and radiation propagate naturally and homogenously inwards from all points on the outer surface of the 4-sphere. In the 4-sphere framework, any given 3-sphere surface is contiguous with the 3-spheres immediately internal and external to it. Since these 3-spheres represent 3-dimensional states of the universe at different points in proper time, each successive 3-sphere 'snapshot' of the universe follows causally from the last. We could therefore hypothetically trace the path of a photon emitted at recombination all the way through the inwardly expanding universe and into one of our detectors. This built-in causal continuity eliminates the need for a rapid early inflationary phase to explain the homogeneity and isotropy of the universe. In this model, the horizon problem resolves itself as a natural consequence of the universe's underlying geometry.

In our model, time progresses inwards from the surface to the center of our 4-sphere, from the small outer past towards the larger inner present. The radius of the 4-sphere represents the proper time of an inertial observer comoving with the cosmic microwave background. In the FLRW metric, the universe expands outwards into an unbounded space, and there is no apparent directional element or discernable point of origin for the CMB. This can be explained by the fact that the ΛCDM model hypothesizes an early expansionary period that acts as a homogenizer of matter and radiation in the universe. Therefore, in ΛCDM cosmology, it is not particularly interesting that, for instance, the earth moves at roughly 370 km/s relative to the CMB; within relativity theory, a frame at rest to the CMB is a frame like any other. However, in our model, an inertial frame's speed relative to the CMB takes on a deeper meaning. Since recombination in our model is represented by the 2-dimensional shell that completely surrounds our 4-sphere (which is 3D in our model), it acts as both the origin of matter and radiation in the universe, and as a geometrically stable surface against which we can orient movement through the universe. If we go up one dimension and apply this concept to our actual universe, recombination would appear less intuitively as a finite 3D shell wrapped around the inwardly expanding 4-dimensional hypersphere that is our universe. As such, an inertial frame at rest to the CMB should be considered to be in a different class than other inertial frames. All inertial frames are at rest, but some are more at rest than others, and we propose referring to inertial frames at rest with respect to the CMB using the terms 'true inertial frame' and 'true inertial observer' (TIF and TIO), for brevity. Given the structure of our inwardly expanding topology, we select true inertial frames as the fastest proper clocks in our model, and they are represented by all radial lines in the 4-sphere. We are also suggesting that the difference between an inertial frame and a true inertial frame is not semantic but physical, and it may be measurable.

Our model offers a fully geometric representation of spacetime, encompassing both the earliest signals of the universe and its present state. Everything that ever was, and is, along with all causal connections between events, can be understood as frozen information embedded within the 4-sphere. Therefore, if we imagine moving inward along the radius of the 4-sphere at a constant rate, away from the outer shell and toward the center, we would theoretically witness all of time replaying in a continuous unfolding of history (from the perspective of a TIF) until we arrive at the present. Taken seriously, this framing implies that light does not actually 'travel' in our model. Since light experiences no passage of time, all of its 'c-energy' is directed into spatial motion. Light, then, becomes a kind of atemporal crystalized structure, encoded along the null geodesics of each 3-sphere; we might think of it as a permanent feature of the spacetime 4-sphere. To experience this structure as 'moving at c,' an observer must themselves be in motion, pushed through the 4-sphere by time. In our model, this corresponds to traveling along the radial (or close to radial) direction of the 4-sphere at speed c. Thus, in our theory, c is not the speed of light per se, but the speed of time itself – a kind of universal tempo by which all observers encounter the frozen geometry of spacetime. Einstein's assertion that all light travels at c regardless of the speed of the emitter or receiver holds true because any path we take through the 4-sphere at the speed of time will encounter light at c. We might also consider the temporal inversion of our model as a new form of the equivalence principle: no observer can distinguish between light reaching them at speed c, and time pushing them into light at speed c. The sign asymmetry in the spacetime interval, with time contributing negatively, may hint at a deeper physical truth: that time, unlike space, is the only dimension in active motion.

Let us imagine two true inertial observers (TIOs) initially moving side by side, both at rest relative to the CMB shell. If one of them begins to move relative to the CMB, the moving frame's new worldline on the 4-sphere will no longer follow the radial path, which in our model represents pure progression through proper time. Instead, it will deviate at an angle, incorporating spatial displacement along the 3-sphere at that radius. This deviation creates a measurable difference in how much of the moving frame's total 'c-energy' is used for time versus space, and as such, their motion can be geometrically described as a tilt away from the radius. This change of propagation angle relative to the radius is analogous to the rotation of a Minkowski spacetime diagram. In Minkowski diagrams, we rotate coordinate axes relative to a four-dimensionally invariant spacetime event as a way to visualize the Lorenz transformations. Depending on the direction and degree of this rotation, an event may appear to involve more spatial displacement and less elapsed time, or vice versa. These changes represent coordinate calculations made by a proper observer. In our 4-sphere, angular momentum away from the radius grants movement through space, but these 4D angularly moving frames must correspondingly give up some of their pure radial momentum through time from the perspective of the TIO. The angle of the worldlines of moving frames with respect to the radius corresponds directly to relativistic effects such as time dilation and redshift, analogous to predictions made by general relativity.

While a full treatment of quantum mechanics is beyond the scope of this paper, our model offers a promising geometric intuition for bridging general relativity and quantum theory. In the 4-sphere framework, entangled particles are not 'spookily' connected across space, but are instead topologically linked within the static, curved geometry of spacetime itself. In our model, entangled particles do not 'move away from each other' through space; rather, observers are pushed into their paths by the stable progression of time, represented by the constant *c*. Imagine two massive particles entangled along the radius of the 4-sphere. These particles begin at the same spatial location along a radial line and then diverge. Within the 4-sphere, their motion is described by straight paths that angle outward from the radius, forming a V shape in four-dimensional space. The origin point of this V lies in the past, and the two rays extend toward the inner present. However, to an observer confined to a single 3-sphere (a picture of space at a 'slice' of time), this V-shaped structure appears simply as two objects moving away from each other. If one of these entangled particles is measured and collapses into an eigenstate, the waveform collapse does not involve faster-than-light communication or 'spooky action at a distance.' Instead, the correlated outcomes are embedded as global constraints on the 4-sphere; a kind of geometric entanglement that exists prior to and independent of observation. This interpretation preserves the nonlocal correlations observed in quantum mechanics while remaining fully compatible with the causal structure of general relativity. Rather than violating relativistic causality, entanglement in our model might emerge naturally from the topology of spacetime, made possible by our reformatting of *c* as the speed of time. Unfortunately, formulating the universe in this manner carries with it a troubling implication: it appears to eliminate the need for free will. We will return to this philosophical problem at the end of the essay.

Our investigation into the structure of the 4-sphere began by noticing the potentially paradoxical manner in which the universe presents itself to earth-bound observers; namely, the large and expanding modern universe seems to be surrounded on all sides by a smaller, older universe. In order to explain this apparent contradiction, we suggested a spacetime structure that expands metrically inwards like a set of Matryoshka dolls where the inner dolls have larger volume than the outer dolls. However, we have yet to define precisely what mechanism causes our spacetime model to fold in on itself in this way, and we shall address this issue now. In the FLRW metric time expands outwards, and as such it requires only minimal curvature to explain the motion of matter and radiation in the universe. However, our model describes a non-Euclidean inward expansion, and thereby necessitates some type of curvature to explain the exotic topology of our model. Therefore, in our 4-sphere model of the universe, we posit that the space within the 4-sphere is intrinsically curved, with a progressive curvature that begins steeply at recombination and smooths out as time progresses inwards towards the present. Our reasons for selecting progressive curvature for our model are twofold. Firstly, as discussed, we select a curvature that justifies our inwardly expanding model, and causes spacetime to 'fold in on itself.' Secondly, defining our model with a curved time axis may allow us to analyze early universe redshift in a manner that, if defined properly, might reduce or even eliminate the need for kinematic expansion in the present universe, and perhaps offer new insights into the twin phenomena of the Hubble tension and dark energy.

As observers in the present universe, we find ourselves at the center of the 4-sphere. As we look out towards the outer shell of the CMB, photons reaching us from deep space seem to be redshifted, and the further away we observe photons, the more redshifted they appear. In the classical FLRW model, redshift in the early universe suggests kinematic expansion in the present, and so classical cosmology assumes that the expansion of the universe must be accelerating. However, to justify this expansion, FLRW relies on an unexplained vacuum energy exerting negative pressure on all matter and radiation in a mostly flat topology. Unmotivated as this interpretation may appear, it nonetheless explains the phenomenological evidence as it reaches us at earth. By contrast, expansion in our 4-sphere model proceeds geometrically inwards in an expanding volume and away from an invariant outer surface area. As we look outward toward recombination from the center of the 4-sphere, and if we accept that the intrinsic curvature of space decreases from the outer surface toward the center, then we should expect that photons emitted in the early universe had to escape a deep temporal curvature – a kind of gravitational well – which would naturally stretch their wavelengths as they traveled inward through time. The equivalence principle (which we shall examine in depth later) theoretically makes no distinction between redshift due to kinematic expansion and redshift due to spacetime curvature. We are implying that type 1a supernovae at high redshift may appear more redshifted not because the universe's expansion is accelerating, but because they originated deeper in the temporal curvature of the 4-sphere, and thus should appear more redshifted than their kinematic movement would suggest. This offers a kind of 'differential diagnosis' that may help us explain away at least some of the redshift of the early universe as resulting from the structure of spacetime, as opposed to accelerating kinematic motion.

Several cosmological models have explored the idea of large-scale dynamic curvature to address the Hubble tension and dark energy. Some approaches modify the FLRW metric by introducing time-dependent curvature terms, often in the form of evolving Ricci or Weyl curvature. For instance, certain inhomogeneous models, such as Lemaître–Tolman–Bondi (LTB) cosmologies, allow for a varying spatial curvature to account for discrepancies in the local and global Hubble rates. In contrast, our 4-sphere model does not introduce curvature as a phenomenological correction, but derives it from the geometry itself. The model's topology requires intrinsic, time-dependent curvature in order for spacetime to close in upon itself; progressive curvature is not an auxiliary feature but a structural necessity. Rather than postulating a mysterious vacuum energy with no known origin, our approach offers a geometrically motivated account of redshift and cosmic evolution, one in which curvature plays a central and essential role.

The author of this paper was not formally trained in physics, and so we approach mathematical descriptions with caution. Where possible, we prefer to express the structure of spacetime in conceptual rather than formal terms. Nonetheless, we have assembled a provisional 'toy' metric intended to capture the essential geometry of the 4-sphere model we've proposed.

$$ds^2 = -c^2\, d\tau^2 + S_0^2 \tau^2 \left(\frac{d\chi^2}{1 - e^{-\lambda\tau}\chi^2} + \chi^2 d\Omega_2^2 \right)$$

This 4-sphere metric bears a close resemblance to the Friedmann–Lemaître–Robertson–Walker (FLRW) metric, which has served as the standard cosmological framework since its development in the 1920s and '30s. The FLRW metric remains one of the most successful tools in theoretical physics, underpinning our understanding of cosmic expansion, the cosmic microwave background (CMB), and the large-scale structure of the universe. Since we'll be comparing our model to FLRW throughout this section, we begin by presenting it in its classical form.

$$ds^2 = -c^2dt^2 + a(t)^2\left(\frac{dr^2}{1-kr^2} + r^2 d\Omega_2^2\right)$$

While the overall structure of the 4-sphere metric is similar to FLRW, we've introduced several key changes. Two of the symbolic conventions have been adjusted, but more importantly, we've modified the scale factor and the curvature term. These revisions are subtle but significant, and we now turn to explain the reasoning behind each. In relativity theory, time is treated as being on 'equal footing' with the three spatial dimensions – a central idea of Minkowski spacetime. But because time and space are measured in different units (seconds and meters, for example), the mathematics of relativity introduces the conversion *ct*, allowing time to be expressed as a distance for use in spacetime intervals. In the 4-sphere model, however, τ represents a proper distance along the time axis and requires no such conversion; it is already geometrically compatible with the spatial coordinates. Our framework can therefore be understood as describing a 'block' or 'eternalist' geometry in which time is a spatially extended dimension. That said, we still express the spacetime interval in the 4-sphere as $s^2 = -c^2\tau^2 + x^2 + y^2 + z^2$, retaining the constant *c* not as the speed of light per se, but as the speed of time – a universal tempo by which all frames progress inward through spacetime. In this interpretation, *c* governs the rate of causal unfolding, and applies equally to all observers. Since the radius of our model corresponds to proper time, we adopt τ in place of the conventional *t*. Conveniently, τ also resembles the radial coordinate *r*, reinforcing the model's geometric intuition. However, to avoid confusion (especially given the resemblance between *r* and τ) we depart from the FLRW convention and use χ to denote the radius of the 3D spatial slices (the 3-spheres).

In any spacetime metric, the scale factor governs the rate at which the universe expands. In the FLRW model, this factor – typically denoted $a(t)$ – is not a simple function, but a dynamic quantity that emerges from solving the Friedmann equations. It depends not only on time, but also on the distribution of matter, radiation, spatial curvature, and dark energy. Technically, $a(t)$ is not closed-form in the way a function like $E(m) = mc^2$ is; rather, $a(t)$ arises from the differential equations that describe cosmic evolution. In contrast, the 4-sphere model introduces a much simpler scale factor, composed of just two terms, neither of which is itself a function. Because our model expands inward from a boundary, we must first establish a fixed size and structure for that initial boundary (the outermost 3-sphere) which we denote S_0. This boundary represents the epoch of recombination: the earliest state from which we receive photonic information, and the outer shell of our inwardly expanding universe. All subsequent 3-spheres are nested within this surface, making S_0 a natural geometric reference and a foundational scale for every inner layer – a kind of cosmic ruler for measuring successive spatial snapshots. To this we add τ, the radial time coordinate, ensuring that frames of reference can proceed unimpeded into the center of the 4-sphere (the present). A true inertial observer is pushed into the crystalized light of the 4-sphere at *c*, and if that internal space were not itself growing at *c*, that observer would encounter a kind of geometric bottleneck, and be unable to continue. Including τ in the scale factor guarantees this forward propagation: as time flows inward at *c*, space expands at the same radial tempo, maintaining consistency between the geometry and the 'motion' of light. In this sense, adding τ to the scale factor aligns the expansion of the universe with the fundamental speed of time itself.

Another key departure from the FLRW metric lies in the curvature term, which in a spacetime metric describes the intrinsic curvature of space. In FLRW, this curvature is constant and denoted by k, taking values of +1, 0, or −1 to represent closed, flat, or open geometries, respectively. By contrast, the 4-sphere model introduces a dynamically evolving curvature, expressed as an exponential decay: $e^{-\lambda\tau}$. At recombination, where $\tau = 0$, this term evaluates to 1, representing maximal positive curvature. As τ increases (that is, as time flows inward) the curvature decays smoothly toward zero, implying that the early universe was highly curved, while the modern universe appears nearly flat. As we mentioned earlier, this curvature profile takes inspiration from several alternative cosmological models that attempt to explain dark energy and the Hubble tension using large-scale geometric effects, such as Lemaître–Tolman–Bondi (LTB) cosmologies. Our model, however, builds this curvature directly into the topology: the 4-sphere's non-Euclidean structure requires progressive curvature to maintain its inwardly folding geometry. This curvature must leave imprints on photons propagating through it – distortions that may appear observationally as excess redshift. If the spatial curvature of the universe decreases over time (as encoded by the exponential term) then photons emitted from more distant (and thus earlier) regions must climb out of a deeper curvature well. This would naturally stretch their wavelengths beyond what kinematic expansion alone would predict. Indeed, by examining the curvature expression more closely, we find that the denominator $(1 - e^{-\lambda\tau}\chi^2)$ produces a mathematical singularity when $\chi = e^{\lambda\tau/2}$. For every value of τ, there exists a radial boundary in 3D space that matter and radiation cannot reach – a kind of moving limit surface. In a traditional FLRW context, this might resemble an expanding universe bounded by a mysteriously warped horizon. But in the 4-sphere framework, this singularity is not a paradox but a feature – the stable outer boundary of our inwardly growing geometry. It represents recombination: the fixed 3-sphere shell from which observers like us continuously recede, as the volume of the universe expands inward at a rate governed by $S_0\tau$.

Our 4-sphere model offers a fresh perspective on one of the oldest and most persistent questions in the philosophy of science: the nature of rotation. For centuries, physicists from Newton to Bohr to Einstein have debated how to define rotational motion in the absence of an absolute frame. The classic thought experiment asks us to imagine spinning a mop in deep interstellar space; the bristles flare outward, indicating rotation – but relative to what? Newton attributed this motion to rotation with respect to absolute space, but the Michelson–Morley experiment undermined that idea. Niels Bohr, drawing on Mach's principle, suggested that rotation must be defined relative to the mass-energy of the entire universe, though it's unclear how a mop could 'feel' the mass of distant stars. Our 4-sphere model offers an alternative. In this framework, the recombination surface (the outer shell of the 4-sphere) acts as a stable, all-encompassing geometric boundary. It provides a physically grounded reference surface against which angular motion can be meaningfully defined. Objects rotate not with respect to emptiness, but with respect to the 4-sphere itself, a closed manifold that encodes the full mass-energy content of the universe. Just as early 20th-century physics imagined a luminous ether to define a universal frame, our model invokes the CMB and the recombination shell as a modern counterpart: a real, observable boundary embedded in the geometry of spacetime. This geometric reference may help resolve two different, yet possibly related, astrophysical puzzles.

First, modern observations suggest that galaxies may exhibit a preferred rotational handedness, a potential asymmetry between clockwise and counterclockwise spin directions across large cosmological volumes. Such a bias is difficult to explain within the standard FLRW framework, which assumes no global directionality. But in the 4-sphere model, global rotation is not only permitted, but naturally accommodated. By introducing a frame-dragging cross term into the metric, the entire 4-sphere can be endowed with a slow, causally consistent rotation. This global spin could imprint a subtle bias onto the angular momentum of forming structures, explaining the observed handedness not through unseen forces, but through the quiet influence of the universe's geometry. A second challenge is the problem of galactic rotation curves: the observation that stars at the outer edges of galaxies orbit faster than expected based on visible matter. This discrepancy is typically explained by invoking dark matter halos as hypothetical sources of unseen mass. However, in the context of the 4-sphere model, this phenomenon may too instead reflect geometric effects. If the 4-sphere exhibits not just evolving spatial curvature but also slow global rotation, it could produce frame-dragging or inertial distortions that influence large-scale orbital velocities. These curvature-induced effects might mimic the gravitational pull attributed to dark matter, without requiring any additional mass. From this perspective, the observed dynamics of galaxies may not indicate missing matter, but rather reflect the underlying geometry of spacetime within a closed, rotating universe.

Finally, our model has intriguing implications for the equivalence principle. By defining 'true inertial observers' as those at rest relative to the CMB, and using them as our proper clocks, we have effectively distinguished them from other inertial frames. This raises the question of whether further distinctions within our current understanding of the equivalence principle might also be possible. One could argue that the principle has always rested on an ambiguous notion of what constitutes a 'local' region. While the equivalence principle likely holds at truly microscopic scales, the fact that physicists can already detect anisotropies over human-scale distances suggests it may begin to break down at larger scales. In our model, c is not framed as the speed of light, but rather the speed of time, and so in a sense we are defining a new form of the equivalence principle: no observer can distinguish between light reaching them at speed c and time pushing them into light at speed c. In order for our 4-sphere model of an inwardly expanding universe to be compatible with general relativity, this equivalency of moving light and moving time must hold true; we might call this a 'time-light symmetry.' It is not in the interest of the author to fully break the equivalency principle; after all, our model also uses the equivalence of kinematic redshift and gravitational redshift to suggest a 'differential diagnosis' for the twin phenomena of dark matter and the Hubble tension. Rather, we propose an extension of the principle, one that incorporates the geometric directionality of time and recognizes the subtle influence of global curvature on local measurements. In this context, the equivalence principle does not fail, but evolves, gaining new structure when viewed through the lens of a curved, frozen, inwardly expanding spacetime.

Every physical theory (with perhaps no exceptions) must deal with motion. While motion seems intuitively obvious, in formal physics it is surprisingly mathematically treacherous. To define something as moving, we must also define what is not moving – and it is this latter component that proves difficult. Newton defined motion relative to absolute space, which most physicists no longer believe exists. Einstein's relativity instead defines motion through the invariant speed of light, which regulates causality and information flow. Our model retains Einstein's speed, but adds a direction; we might say that Einstein's *c* is a scalar, while ours is a vector. Aligning with stability in the universe, then, requires moving in a specific direction – radially inward through the 4-sphere and at rest to the CMB. A rotating observer, by contrast, would periodically drift in and out of alignment with this stable direction, as its angular momentum carries it through orientations offset from the true inertial frame (TIF). To test the existence of TIFs as predicted by the 4-sphere model, we propose a ground-based interferometry experiment that uses Earth's rotation as a natural deviation from radial motion. All observers on Earth experience a tangential velocity due to planetary rotation – a small but constant angular deviation from TIF alignment. According to our model, this deviation should produce a measurable asymmetry in light propagation: a residual redshift or phase shift in an interferometer aligned in different directions. Unlike the known Sagnac effect, which is symmetric and fully accounted for in relativity, the predicted shift here would be non-reciprocal, and would modulate with Earth's sidereal rotation as the interferometer's orientation relative to the CMB changes. We propose placing a precision laser or fiber interferometer in an east–west / north-south configuration to maximize sensitivity to Earth's rotational velocity (465 m/s at the equator). The key signature would be a small, cyclical variation in phase or frequency correlated with Earth's rotation relative to the CMB frame. If observed, such an effect would offer direct evidence for the physical distinctiveness of TIFs and support the 4-sphere model's prediction that motion relative to the CMB alters light propagation through a global geometric structure. What we propose is, in essence, a large-scale resurrection of Michelson and Morley's experiment – perhaps one better suited to the structure of the universe they sought to glimpse.

The geometric model presented here describes a universe where all events, including decisions, thoughts, and experiences, are encoded within a fixed 4-dimensional structure. From this view, causality is complete, and the passage of time that seems to carry our lives forward is reinterpreted as an inevitable traversal through already waiting frozen light. In such a model, there is quite clearly no use for free will, since all that was, all that is, and all that will be is already encoded within the 4-sphere. But before the reader stops going to work or paying their taxes, it might be helpful to recall the concept of wave-particle duality. We are perfectly comfortable thinking of waves and particles coexisting in an interwoven dance that is neither nor, and we accept that the more clearly we see one side of the duality, the more the other recedes from view. I like to think that free will and determinism exist in just such a superposition. It's not that one is right and the other wrong, but rather that our human perspective can't hold both fully at once. I do not believe that the 4-sphere model offered in this essay precludes free will. Rather, I suspect that our evolved ape brains are simply not up to the task of thinking past the paradoxes nestled within these cosmic Gödel sentences. Perhaps free will and determinism are complementary descriptions, not opposing truths. Perhaps the deepest mysteries of the universe are not ours to understand. They may be simply ours to ponder, to measure, and to marvel at.