Resolving the Black Hole Information Paradox, Dark Energy, and Dark Matter by Sourcing Entanglement Entropy in GR

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This paper explores a new reinterpretation of gravity: the idea that mass-energy is not the direct source of gravitational effects. Instead, gravity emerges from a deep quantum mechanism rooted in boundary entanglement entropy. In this view, not only spacetime curvature, but spacetime itself arises from an infinite network of non-local, lower-dimensional quantum boundaries—each representing entangled surfaces that encode information about gravitational energy. These boundaries are not passive features of the universe; they are active, dynamic structures that generate the very connectivity of spacetime in the bulk. Gravity, in this model, is the observable bulk consequence of quantized temporal entanglement entropy across this infinite, hidden network of lower-dimensional boundaries. This paper introduces this concept as the *Quantum Boundaries Gravitational Energy Entanglement Entropy Theory*, or **QBGE³ Theory**, which we will refer to simply as **GE³ Theory**.

A previous publication by Daniel James Stoker introduces the concept of Eide Spheres: 2S+T quantized surfaces of gravitational energy that travel at the speed of light in entangled pairs—one sphere propagating forward in time, and its partner moving backward. These bidirectionally entangled, lower-dimensional quantum boundaries emerge from mass-energy and radiate outward, forming a temporally symmetric web that encodes gravitational interactions across spacetime. Crucially, the model proposes that **lower-dimensional boundary entanglement entropy and quantized gravitational energy are not separate concepts, but rather two expressions of the same physical phenomenon**—two faces of a unified, underlying structure.

This perspective challenges the classical framework of Einstein's General Relativity, where spacetime curvature is sourced by the local stress-energy tensor. Instead, it aligns with emerging insights from holography and quantum gravity—particularly the idea that gravity originates from quantum entanglement, though a precise mechanism remains elusive. This view resonates with the concept of quantum extremal surfaces and the role of entropy in defining the geometry of spacetime, as illustrated in the AdS/CFT correspondence and black hole thermodynamics.

By reframing gravity as a bulk effect of our universe resulting from lower-dimensional boundaries of quantized gravitational energy and entanglement entropy, this model offers a novel path toward resolving long-standing paradoxes, such as the black hole information problem. Because Eide Spheres propagate information in both temporal directions, they provide a natural mechanism for preserving—and eventually recovering—information that would otherwise be lost behind an event horizon, as discussed below. Furthermore, this bidirectional propagation suggests a symmetric foundation for time and causality itself, from which an arrow of time emerges through entropic processes. Sourcing entanglement entropy in the equations of General Relativity also offers potential explanations for dark energy and dark matter, as we will explore in this paper. First, however, we will review relevant background and related works, followed by a mathematical investigation into modifying Einstein's GR equations to source gravitational effects in the bulk from boundary entanglement entropy of 2S+T quantized gravitational energy, rather than from mass-energy directly.

BACKGROUND AND RELATED WORK

Black Hole Thermodynamics (Bekenstein & Hawking, 1973-1975)

The foundation of black hole thermodynamics was laid in the 1970s through the pioneering work of Jacob Bekenstein and Stephen Hawking. Bekenstein proposed that the entropy of a black hole is proportional to the area of its event horizon, not its volume—an insight that fundamentally shifted our understanding of information and gravity. Shortly after, Hawking discovered that black holes emit thermal radiation due to quantum effects near the event horizon, a phenomenon now known as Hawking radiation. These discoveries suggested a deep connection between gravity, quantum mechanics, and thermodynamics, but they also introduced a serious puzzle: if black holes radiate thermally and eventually evaporate, where does the information go?

This conundrum became known as the black hole information paradox. In classical General Relativity, any information that falls into a black hole is lost beyond the event horizon. But in quantum mechanics, the evolution of information is unitary—meaning it cannot be destroyed. Reconciling these two views remains one of the most important challenges in theoretical physics.

QBGE³ Interpretation:

The GE³ Theory offers a compelling resolution to this paradox by reframing the nature of black hole entropy itself. In this model, black hole entropy is not merely a measure of information stored on the horizon, but a manifestation of deeper quantum boundary structures—Eide Spheres—that encode gravitational energy as entanglement entropy. These lower-dimensional, temporally entangled quantum boundaries propagate at the speed of light, forming a bidirectional network across spacetime.

In this model, when matter collapses to form a black hole, it generates a dense lattice of forward- and backward-time Eide Spheres. These boundaries preserve information in a unitary manner, with the backward-propagating Eide Spheres encoding the infalling data. From the perspective of an external observer, this information appears lost—but it is, in fact, stored within the boundary entanglement entropy. As the black hole evaporates and the event horizon recedes, the entangled backward-time Eide Spheres reemerge in the past, during the period preceding the formation of the event horizon. And because Eide Spheres carry temporal entanglement, the backward-time Eide Spheres preserve their stored information through their entangled forward-time counterparts—completing the cycle and preserving unitarity.

This reinterpretation transforms the role of the event horizon from a one-way boundary into a dynamically entangled surface, with entropy representing the degree of entanglement in the surrounding Eide Sphere field. The classical area-law entropy becomes a geometric projection of the quantum information encoded within the entangled Eide Sphere structure. In this way, GE³ Theory not only preserves the insights of Bekenstein and Hawking but extends them into a quantum framework that unifies entropy, geometry, and information through a common physical mechanism.

Quantum Eraser Experiment (Scully, M. O., & Drühl, K., 1982)

In the quantum eraser setup, entangled photon pairs are generated. One photon (the signal) travels toward a screen where an interference pattern may appear, while the other (the idler) carries which-path information. If the which-path information is preserved, the interference pattern disappears. However, if this information is “erased” after the signal photon has already been detected, the interference pattern re-emerges—but only in coincidence counts with the idler. This suggests that the future manipulation of entangled information can influence a previously recorded outcome.

QBGE³ Interpretation:

In the QBGE³ interpretation, both the signal and idler photons are entangled not only with each other, but also with gravitational Eide Spheres that encode quantum boundary information in both temporal directions. The idler’s delayed which-path erasure influences the entangled configuration of these Eide Spheres, thereby modifying the boundary conditions that define the bulk geometry into which the signal photon’s behavior is resolved. Even though the signal photon has already been detected, the emergent geometry associated with its event was never fully classical until the entire boundary configuration—including the idler’s outcome—was resolved.

Wheeler's Delayed Choice Experiment (Wheeler, J. A., 1984)

In Wheeler’s delayed choice experiment, a photon passes through a double-slit apparatus where it could exhibit either wave-like interference or particle-like which-path behavior. The twist is that the decision to insert or remove the which-path detector — determining whether the photon’s behavior is recorded as wave or particle — is made *after* the photon has passed the slits. Astonishingly, the photon seems to behave *as though it “knew” the future* — displaying interference when no which-path detector is present, or particle-like behavior when it is.

QBGE³ Interpretation:

In GE³ Theory, a photon's trajectory is not predetermined. Prior to detection, the photon remains entangled with a pair of Eide Spheres—bidirectionally time-entangled quantum boundaries that encode both past and potential future conditions. The act of measurement triggers a boundary-to-bulk transition, collapsing the entangled boundary configuration into a localized geometric event within emergent bulk spacetime. Because Eide Spheres are entangled across time, the future measurement choice (such as whether to insert or remove the which-path detector) is already embedded in the entangled gravitational structure. Thus, the photon does not retroactively alter its past; rather, the emergent event reflects a coherent geometry derived from a boundary that already encompassed both past and future configurations.

The Holographic Principle (’t Hooft, 1993; Susskind, 1995)

The Holographic Principle, originally proposed by Gerard ’t Hooft and later developed by Leonard Susskind, suggests that all of the information contained within a volume of space can be described by degrees of freedom encoded on its boundary. This principle was inspired by the thermodynamic properties of black holes—particularly the discovery that black hole entropy is proportional not to volume, but to the area of the event horizon.

Susskind's formulation of the Holographic Principle generalized this idea beyond black holes, proposing that the entire universe may be a hologram, with its fundamental physics encoded on a two-dimensional surface at the boundary of spacetime. This insight laid the conceptual foundation for later developments such as the AdS/CFT correspondence and quantum gravity dualities.

QBGE³ Interpretation:

GE³ Theory builds directly on the logic of the Holographic Principle but extends it in a bold new direction. Rather than treating boundary-encoded information as a dual description of bulk physics, GE³ Theory proposes that the quantum boundaries themselves are the source of gravitational effects in the bulk. In this framework, the lower-dimensional quantum boundaries are not mathematical abstractions or idealized limits, but physically real, quantized surfaces of entanglement entropy—Eide Spheres—that generate spacetime, including its curvature and connectivity, through their interactions. The infinite boundary of spacetime in the Holographic Principle is replaced in GE³ Theory by an infinite network of quantum boundaries, entangled and giving rise to spacetime itself.

By identifying quantized gravitational energy with boundary entanglement entropy, GE³ Theory transforms the holographic surface from a descriptor of information into a dynamic engine that constructs the bulk geometry. This reframes the relationship between boundary and bulk as causal rather than merely dual: spacetime curvature is not just encoded on boundaries—it is created by them.

In this sense, GE³ Theory offers a constructive realization of the Holographic Principle: the Eide Spheres are quantum, time-entangled, null-propagating structures that encode, transmit, and shape the informational and geometric content of the universe. Their structure naturally obeys area laws and satisfies holographic entropy bounds, reinforcing the idea that the true degrees of freedom of gravity reside not in the bulk, but on the surfaces that bound it.

Entropic Gravity (Jacobson, 1995)

In 1995, Ted Jacobson made a groundbreaking contribution to theoretical physics by demonstrating that Einstein's field equations could be derived from thermodynamic principles. Rather than assuming gravity as a fundamental force, Jacobson proposed that it could instead be understood as an emergent phenomenon—a kind of entropic force that arises from the coarse-grained behavior of underlying microscopic degrees of freedom. By associating the energy flow across local Rindler horizons with changes in entropy, Jacobson showed that the geometry of spacetime and the dynamics of gravity could be interpreted as thermodynamic responses to entropic gradients.

This work opened the door to a radically new interpretation of General Relativity—one where gravity is not a primary interaction, but a macroscopic expression of microscopic statistical physics. However, while Jacobson's derivation revealed the thermodynamic character of Einstein's equations, it did not identify the microscopic carriers of entropy responsible for gravitational phenomena. The identity and behavior of these fundamental degrees of freedom remained unspecified.

QBGE³ Interpretation:

GE³ Theory builds upon Jacobson's entropic framework by proposing a specific physical origin for the entropy that drives gravitational dynamics. In this model, quantized gravitational energy is entanglement entropy, encoded in the structure of bidirectionally entangled quantum boundaries—Eide Spheres—that propagate at the speed of light. These 2S+T quantized surfaces move in opposite temporal directions, forming a dynamic lattice of entropic flux that gives rise to bulk spacetime and governs its curvature.

The entropy gradients that appear in Jacobson's thermodynamic derivation correspond, in GE³ Theory, to variations in the density and structure of Eide Spheres across spacetime. These variations reflect localized differences in entanglement between forward- and backward-time quantum boundaries. As Eide Spheres radiate from matter and entangle across null-like surfaces, their interactions give rise to the curvature effects we interpret as gravity in the bulk.

This gives Jacobson's insight a concrete physical mechanism: the entropic force of gravity arises from the statistical behavior of Eide Spheres as they propagate, entangle, and influence the emergent geometry of spacetime. Rather than treating entropy as an abstract statistical quantity, it becomes a measurable, quantized energy field encoded in the geometry of entangled surfaces. GE³ Theory thus provides a natural extension of entropic gravity by supplying the missing link between microscopic degrees of freedom and macroscopic gravitational behavior—a link rooted in quantum boundary entanglement.

Holographic Entanglement Entropy (Ryu & Takayanagi, 2006)

In 2006, Shinsei Ryu and Tadashi Takayanagi introduced a groundbreaking result that helped crystallize the deep relationship between quantum information and spacetime geometry. Known as the Ryu-Takayanagi (RT) formula, this result equates the entanglement entropy of a region in a conformal field theory (CFT) with the area of a minimal surface in the corresponding anti-de Sitter (AdS) bulk spacetime. The RT formula not only provided a powerful computational tool for holographic theories, but also strengthened the idea that spacetime geometry is fundamentally emergent from patterns of quantum entanglement.

This insight suggested that the structure of spacetime itself—its shape, curvature, and even causal relationships—might be encoded in the entanglement properties of a lower-dimensional boundary theory. The area law for entanglement entropy, long known from black hole thermodynamics, was thus generalized into a broader principle that linked gravitational geometry directly to quantum information theory.

QBGE³ Interpretation:

GE³ Theory naturally incorporates and extends the logic of the Ryu-Takayanagi framework by proposing that entanglement entropy is not merely a geometric boundary condition—it is the physical source of gravitational effects in the bulk. In this model, Eide Spheres are quantized 2S+T surfaces of entangled gravitational energy that propagate at the speed of light in both forward- and backward-time directions. These quantum boundaries encode entanglement entropy not as an abstract quantity, but as a physical, measurable, and dynamic energy field.

If quantized gravitational energy is the same phenomenon as lower-dimensional boundary entanglement entropy, as GE³ Theory proposes, then the RT formula acquires a new interpretation: the area of the minimal surface is not merely a measure of entropy—it is a projection of the energy content encoded in Eide Spheres. These quantized surfaces naturally obey area laws and function as entropic boundaries that dynamically generate and shape the bulk geometry of spacetime. In this light, Ryu-Takayanagi surfaces are not simply tools for calculating entropy—they directly correspond to configurations of Eide Spheres that define the gravitational structure of spacetime.

GE³ Theory therefore reframes the RT formula not merely as a reflection of emergent geometry, but as a window into the underlying quantum architecture of gravity itself. Rather than treating spacetime as a smooth manifold shaped by classical fields, GE³ envisions it as the collective behavior of entangled quantum boundaries—surfaces whose area reflects not a statistical measure, but a real energy density in the form of quantized entanglement. This places the RT formula at the heart of quantum gravity—not as a boundary condition, but as an operational law describing how gravitational energy emerges from entanglement geometry.

Gravity from Entanglement (Van Raamsdonk, 2010)

In 2010, Mark Van Raamsdonk offered a bold and elegant insight that significantly shaped the modern understanding of spacetime in the context of quantum gravity. His work proposed that the geometric structure of spacetime itself is built from patterns of quantum entanglement. Through thought experiments involving quantum fields and the AdS/CFT correspondence, Van Raamsdonk demonstrated that increasing entanglement between regions in a boundary field theory causes the bulk spacetime to become more connected, while reducing entanglement leads to disconnection and, eventually, the disintegration of the bulk.

This revolutionary idea suggested that spacetime is not fundamental, but emergent—an emergent geometry woven from the entangled states of an underlying quantum system. Van Raamsdonk's argument helped establish the growing consensus that quantum entanglement is not merely a feature of quantum systems, but the very fabric from which space and time arise.

QBGE³ Interpretation:

GE³ Theory fully embraces and extends this principle by proposing that entanglement is not merely responsible for the emergence of spacetime—it is the same phenomenon as quantized gravitational energy. In this model, Eide Spheres represent the fundamental units of this substance: quantized, temporally entangled boundaries that propagate at the speed of light and define the structure and geometry of the bulk. These boundaries are not emergent from a deeper layer of reality; they are the quantized gravitational energy itself, transmitting the information of mass-energy throughout the universe and giving rise to spacetime and its geometry.

Where Van Raamsdonk demonstrated that entanglement governs the connectivity of spacetime, GE³ Theory offers a concrete mechanism: the entangled Eide Spheres are the fundamental building blocks that construct and connect spacetime from the bottom up. Their bidirectional temporal motion encodes both the geometry and causal structure of the universe, while their density and configuration determine curvature and gravitational interaction. As Eide Spheres radiate outward from mass-energy in time-symmetric pairs, they weave a non-local, entropic network whose topology gives rise to spacetime and its geometry we observe.

This reinterpretation advances Van Raamsdonk's idea from a geometric heuristic to a physical model: quantized gravitational energy is the same phenomenon as boundary entanglement entropy, and the lower-dimensional quantum boundaries that carry this entropy—Eide Spheres—are the entities that create spacetime and its geometry. Rather than merely mapping entanglement onto geometry, GE³ Theory identifies entanglement as the source of gravitational dynamics, offering a fully quantized picture of how the universe's structure emerges from quantum information.

ER=EPR Conjecture (Maldacena & Susskind, 2013)

In 2013, Juan Maldacena and Leonard Susskind proposed a profound unifying principle in theoretical physics: the ER=EPR conjecture, which posits that Einstein-Rosen bridges (wormholes) and Einstein-Podolsky-Rosen entanglement are fundamentally the same phenomenon. In this view, every pair of entangled particles is connected by a non-traversable wormhole, implying that the geometry of spacetime and the structure of quantum entanglement are two sides of the same coin.

This conjecture draws a remarkable connection between two areas previously thought to be distinct—General Relativity and quantum mechanics—by suggesting that the fabric of spacetime is threaded together by a vast network of microscopic wormholes, each corresponding to an entangled pair. This reimagines the entanglement of particles not as a feature of an underlying geometry, but as the generator of geometry itself. The ER=EPR idea provides a framework for understanding how information might be preserved in black holes and how spacetime may emerge from the entanglement structure of quantum fields.

QBGE^3 Interpretation:

GE^3 Theory naturally integrates and elaborates upon the ER=EPR conjecture by identifying a physical mechanism that makes this equivalence operational. In GE^3, Eide Spheres are the fundamental units of quantized gravitational energy—lower-dimensional, entangled surfaces that propagate at the speed of light in temporally symmetric pairs. Each pair of Eide Spheres forms a non-traversable, temporally extended bridge of entanglement, reminiscent of an Einstein-Rosen wormhole—bridging not only different regions of space, but also different directions in time.

The bidirectional entanglement of Eide Spheres suggests that information is not merely preserved in spatially extended wormhole structures, but is encoded and transported through quantum-entangled boundary pairs that stretch between the past and future. These pairs link events and regions in spacetime via entropic correlations, ensuring unitary evolution even in scenarios of apparent information loss, such as black holes. In this sense, GE^3 Theory offers a temporal realization of ER=EPR, where each entangled Eide Sphere pair functions as an information-preserving conduit.

Moreover, if every quantum of gravitational energy is an entangled Eide Sphere pair, then the entire structure of spacetime can be understood as a vast entanglement network composed of microscopic ER-like links, each preserving causal structure and geometric connectivity. In this framework, spacetime emerges from the global entanglement of gravitational energy, and what we perceive as curvature or topology arises from the distribution, linkage, and temporal orientation of these Eide Sphere bridges.

Thus, GE³ Theory not only supports the ER=EPR conjecture—it expands its scope by offering a concrete, quantized model of the entanglement-geometry duality, grounding it in a framework where entangled surfaces of gravitational energy serve as the fundamental building blocks of space, time, and information flow.

Quantum Extremal Surfaces and the Island Formula (Engelhardt & Wall, 2019; Almheiri et al., 2020)

Netta Engelhardt, in collaboration with Aron Wall and others, introduced the concept of Quantum Extremal Surfaces (QES)—surfaces that extremize the generalized entropy, which includes both the area term and bulk entanglement entropy. These surfaces are crucial in recent formulations of the Island Rule, which proposes that in certain gravitational systems—such as evaporating black holes—the entanglement wedge contributing to the von Neumann entropy of Hawking radiation includes not just the exterior but also *islands* inside the black hole.

This framework led to a breakthrough in resolving the black hole information paradox. Rather than assuming information is lost, the island prescription shows how entanglement entropy initially grows but eventually plateaus, producing a Page curve consistent with unitary quantum evolution. The inclusion of islands in the entanglement wedge indicates that information inside black holes can, in principle, be recovered from their radiation.

QBGE³ Interpretation:

GE³ Theory shares deep conceptual parallels with Engelhardt's QES and Island framework. In both models, entanglement entropy is not merely an auxiliary quantity, but the central force shaping the gravitational and informational structure of spacetime. In Engelhardt's formulation, quantum extremal surfaces determine the entropy and evolution of information, while in GE³ Theory, Eide Spheres are the quantum boundaries that *are* the gravitational energy—their entangled structure across time gives rise to emergent geometry and governs the flow of information.

The bidirectional temporal propagation of Eide Spheres suggests that the Islands described in the QES formalism may correspond to regions enclosed by temporally entangled Eide Sphere pairs. These spheres naturally define extremal surfaces as they radiate at light speed and encode gravitational energy through entropic tension. In this interpretation, Islands are not ad hoc insertions into entropy calculations, but emergent regions shaped and bounded by the entanglement structure of Eide Spheres.

Moreover, GE³ Theory provides a concrete physical mechanism for the flow of information through time. While the island formula demonstrates that information is accessible via entanglement, Eide Spheres explain how that information is preserved: forward- and backward-time spheres remain in unitary correlation, allowing data that falls into a black hole to be encoded in backward-time quantum boundaries and later recovered as the horizon evaporates.

This connection offers a novel interpretation of Engelhardt's insights: that QES and Islands may not merely describe entropy surfaces, but reveal the underlying architecture of quantum gravity itself—an architecture composed of discrete, bidirectionally entangled gravitational boundaries whose interactions define curvature, causality, and the flow of entropy in the bulk.

The Basis Problem in Quantum Measurement (von Neumann, 1932; Everett, 1957; Zurek, 1981–1984)

The basis problem, or preferred basis problem, lies at the heart of the quantum measurement conundrum. It addresses a fundamental question: Why do measurements in quantum mechanics yield definite outcomes in specific bases (such as position or spin-z), even though the formalism allows a quantum state to be described in any basis? This challenge was first implicitly raised by John von Neumann in his *Mathematical Foundations of Quantum Mechanics* (1932), where he introduced a dual-process framework for measurement. According to von Neumann, the evolution of a quantum system proceeds via the deterministic Schrödinger equation (Process 1), until a measurement occurs, invoking the projection postulate (Process 2)—an instantaneous, probabilistic "collapse" into a specific eigenstate. But what selects the measurement basis? Von Neumann left this question open.

Later, Hugh Everett (1957) advanced the Many-Worlds Interpretation, positing that the wavefunction never collapses but instead branches into distinct worlds for each possible outcome. While this avoided non-unitary collapse, it introduced a new puzzle: in a universe with infinite branching, why do observers perceive definite outcomes in a stable, classical basis? This brought the basis problem to the forefront in interpretations of quantum mechanics.

A major breakthrough came with the advent of decoherence theory, especially in the work of Wojciech Zurek (1981, 1982, 1984). Zurek introduced the concept of *environment-induced superselection* (or "einselection"), showing how interactions with the environment dynamically select a "pointer basis"—a stable set of states that are robust to decoherence. In this view, classicality and basis selection emerge from the entanglement between quantum systems and their environments, offering a physical mechanism for why certain outcomes manifest in specific bases. Decoherence does not solve the measurement problem in full—collapse still lacks a precise mechanism—but it crucially narrows the question: what determines the observable basis in which measurements occur.

QBGE³ Interpretation:

GE³ Theory offers a radical reinterpretation of the basis problem through the lens of gravitational entanglement. In GE³, all quantum systems are entangled with lower-dimensional boundaries known as Eide Spheres—discrete 2S+T quantum surfaces that propagate in both forward and backward time directions. Quantum measurement is reframed not as wavefunction collapse, but as a boundary-to-bulk transition: a transfer of entanglement from the lower-dimensional boundaries into the higher-dimensional bulk, where geometry and locality emerge.

In this interpretation, the preferred basis emerges from the geometry of the entangled Eide Spheres. Each Eide Sphere defines a natural observational frame, corresponding to specific eigenbases—such as position, spin, or energy—determined by the curvature and directionality of the entropic flow across the boundaries. Measurement occurs when a quantum system's superposed entanglement with multiple Eide Spheres collapses into a single frame, selecting a unique outcome in the basis defined by that sphere's geometry. Thus, basis selection is neither arbitrary nor observer-dependent, but a manifestation of the physical entanglement structure embedded in the fabric and geometry of spacetime.

Moreover, GE³ aligns with and extends decoherence-based approaches: the role of the environment is played by the vast network of temporally entangled Eide Spheres, which collectively induce einselection through geometric constraint. Unlike standard decoherence, however, GE³ Theory introduces a gravitational mechanism—namely, the bidirectional propagation and geometric overlap of quantized gravitational energy Eide Spheres—as the source of observable classicality.

By embedding basis selection in the gravitational-entropic geometry of quantum boundaries, GE³ offers a unified solution to the basis problem: measurements yield outcomes in a specific basis because that basis is geometrically encoded in the quantum gravitational structure of the universe. What Zurek attributes to the environment, and Everett attributes to branching, GE³ attributes to the emergent geometry of entangled gravitational boundaries—revealing the basis problem not as a flaw in quantum mechanics, but as a window into the quantum nature of spacetime itself.

The key innovation is that the measurement basis is determined by the gravitational entanglement geometry of the Eide Spheres entangled with the system and the measuring apparatus. Formally, if the total entangled state of the system, measurement device, and Eide Spheres is:

$$|\Psi_{\text{total}}\rangle = \sum_i c_i |a_i\rangle \otimes |M_i\rangle \otimes |\varepsilon_i\rangle ,$$

then the GE³ transition collapses this superposition into a single outcome:

$$|\Psi_{\text{total}}\rangle \xrightarrow{\text{GE}^3} |a_k\rangle \otimes |M_k\rangle \otimes |\varepsilon_k\rangle ,$$

Here, $\{ |a_i\rangle \}$ forms the preferred measurement basis, selected by the eigenmodes of the Eide Spheres' entanglement operator $\widehat{H}_{\text{Eide}}$, such that:

$$\widehat{H}_{\mathrm{Eide}}|a_i\rangle=\lambda_i|a_i\rangle$$

This makes the measurement basis an emergent gravitational feature—not an arbitrary or observer-defined choice. It is the structure and symmetry of the boundary entanglement geometry that imposes a natural collapse direction.

This approach seamlessly integrates with ideas from holography, quantum extremal surfaces, and the Page curve. The Eide Spheres act like quantized holographic screens encoding information about both the system and the measurement apparatus. Their temporal entanglement structure selects a stable and causally consistent set of bulk outcomes.

GE³ therefore resolves the basis problem by rooting basis selection in the physics of boundary entanglement geometry. The preferred basis is not an ad hoc choice, but the natural outcome of quantized gravitational interactions governing the boundary-to-bulk transition of measurement.

REFORMULATING THE STRESS-ENERGY TENSOR WITH ENTANGLEMENT ENTROPY

In classical General Relativity, Einstein's equations relate spacetime curvature to the stress-energy tensor

$$R_{\mu\nu}-\frac{1}{2}Rg_{\mu\nu}=\frac{8\pi G}{c^4}T_{\mu\nu}$$

where

$T_{\mu\nu}$ represents the classical energy-momentum distribution. Since GE³ Theory replaces mass-energy with entanglement entropy, we replace this distribution with the quantum entanglement-energy tensor,

$S_{\mu\nu}$

which encodes quantized gravitational energy as quantum entanglement entropy, now giving the equation as,

$$R_{\mu\nu}-\frac{1}{2}Rg_{\mu\nu}=\alpha S_{\mu\nu}$$

Next we define the quantum entanglement-energy tensor to model 2S+T bidirectional temporal propagation. Given that gravitational energy in this theory is quantized across a surface area boundary, we define:

$$S_{\mu\nu}=\frac{\hbar}{G}\left(\mathscr{E}_{\mu\nu}^{\ +}+\mathscr{E}_{\mu\nu}^{\ -}\right)$$

where,

$\mathscr{E}_{\mu\nu}{}^{+}$ represents the forward-time entanglement entropy

$\mathscr{E}_{\mu\nu}{}^{-}$ represents the backward-time entanglement entropy

Because the entangled quantum boundaries move at the speed of light, we require that,

$$g^{\mu\nu}\mathscr{E}_{\mu\nu}{}^{\pm} = 0$$

This ensures that the entangled quantized gravitational energy propagates as null-like wavefronts.

Next we represent quantized gravitational energy as entangled energy flow. The usual energy-momentum conservation equation:

$$\nabla^{\mu}T_{\mu\nu} = 0$$

is modified to account for bidirectional temporal entanglement flow:

$$\nabla^{\mu}S_{\mu\nu} = \frac{1}{c}\left(\mathfrak{I}_{\nu}{}^{+} - \mathfrak{I}_{\nu}{}^{+}\right)$$

where,

$\mathfrak{I}_{\nu}{}^{+}$ is the entanglement energy flux propagating forward in time

$\mathfrak{I}_{\nu}{}^{-}$ is the entanglement energy flux propagating backward in time

Since these components are always entangled, they obey the unitary propagation condition:

$$\mathfrak{I}_{\nu}{}^{+}\,\mathfrak{I}_{-}{}^{\nu} = \frac{c^{4}}{G}S_{ee}$$

The equation states that quantized gravitational energy propagates as entanglement entropy pairs, maintaining unitary information conservation.

Next we modify the Ricci tensor to account for quantum boundaries. In classical GR, the Ricci tensor describes spacetime curvature due to energy-momentum:

$$R_{\mu\nu} = \frac{8\pi G}{c^{4}}\left(T_{\mu\nu} - \frac{1}{2}g_{\mu\nu}T\right)$$

Because in GE³ Theory, spacetime is emergent from entanglement entropy, we define a quantum entanglement curvature tensor,

$$\mathfrak{K}_{\mu\nu}$$

that replaces the classical GR curvature tensor.

$$\mathfrak{K}_{\mu\nu} = \frac{8\pi G}{c^4}\left(S_{\mu\nu} - \frac{1}{2}g_{\mu\nu}S_{ee}\right)$$

where:

$\mathfrak{K}_{\mu\nu}$ represents curvature arising from the quantum entanglement structure rather than classical mass-energy.

S_{ee} is the local entanglement entropy density

This equation states that curvature is not directly caused by stress-energy, but by temporally entangled quantum boundary interactions propagating at the speed of light.

Next we derive the modified Einstein equations. Substituting $\mathfrak{K}_{\mu\nu}$ into the Einstein equation:

$$R_{\mu\nu} - \frac{1}{2}Rg_{\mu\nu} = \alpha S_{\mu\nu}$$

Since entanglement entropy is the source of gravity, we use:

$$S_{\mu\nu} = \frac{\hbar}{G}\left(\mathcal{E}_{\mu\nu}{}^{+} + \mathcal{E}_{\mu\nu}{}^{-}\right)$$

Thus, the final modified Einstein equations in GE³ Theory become:

$$R_{\mu\nu} - \frac{1}{2}Rg_{\mu\nu} = \frac{\hbar}{G}\left(\mathcal{E}_{\mu\nu}{}^{+} + \mathcal{E}_{\mu\nu}{}^{-}\right)$$

This expresses the effects of gravity in the bulk as occurring from quantized gravitational energy propagating at the speed of light in temporally entangled bidirectional boundary pairs.

Next we find the Schwarzschild-like metric in GE³ Theory with 2S+T quantum entangled propagation. We start with the modified field equations and because quantized gravitational energy propagates at the speed of light, the effective stress-energy structure must be null-like:

$$g^{\mu\nu}\mathcal{E}_{\mu\nu}{}^{\pm} = 0$$

A static, spherically symmetric metric in the presence of entanglement-modified gravity must take the general form:

$$ds^2 = -f(r)\,dt^2 + g(r)^{-1}dr^2 + r^2 d\Omega^2$$

where f(r) and g(r) are metric functions we need to determine.

In classical Schwarzschild solutions, the function f(r) satisfies:

$$f(r) = 1 - \frac{2GM}{c^2 r}$$

However, in GE³ Theory, the mass terms is replaced by the entanglement entropy derived energy:

$$M_{ee}(r) = \frac{S_{ee}(r)}{Gr}$$

where:

$$S_{ee}(r) = S_o\left(1 - e^{\left(-r^2/l^2_p\right)}\right)$$

Thus, the effective gravitational potential function is:

$$f(r) = 1 - \frac{c^2}{2GS_o} r\left(1 - e^{\left(-r^2/l^2_p\right)}\right)$$

For gauge consistency, we take:

$$g(r) = f(r)$$

The final form of the metric is then found as,

$$ds^2 = -\left(1 - \frac{c^2}{2GS_o} r\left(1 - e^{\left(-r^2/l^2_p\right)}\right)\right)dt^2 + \left(1 - \frac{c^2}{2GS_o} r\left(1 - e^{\left(-r^2/l^2_p\right)}\right)\right)^{-1} dr^2 + r^2 d\Omega^2$$

In this form, we find that for

$r >> l_p$

we have

$$e^{\left(-r^2/l^2_p\right)} \rightarrow 0$$

Thus, the metric reduces to:

$$ds^2 \approx -\left(1 - \frac{c^2 r}{2GS_o}\right)dt^2 + \left(1 - \frac{c^2 r}{2GS_o}\right)^{-1} dr^2 + r^2 d\Omega^2$$

Identifying that,

$$S_o = \frac{GM}{r}$$

this recovers the classical Schwarzschild metric:

$$f(r) = 1 - \frac{2GM}{c^2 r}$$

For,

$$r << l_p$$

we have

$$e^{\left(-r^2/l^2_p\right)} \approx 1 - \frac{r^2}{l^2_p} \Rightarrow f(r) \to 1 - \frac{c^2 r^3}{2GS_o l^2_p}$$

The metric is regular near r = 0, this **avoids a singularity inside the black hole**.

We find that the equation for the event horizon in the GE³ Theory modified metric is,

$$f(r) = 1 - \frac{c^2}{2GS_o} r\left(1 - e^{\left(-r^2/l^2_p\right)}\right)$$

This defines the location of the event horizon implicitly but we can interpret this where,

as

$$r \to \infty \;:\; 1 - e^{\left(-r^2/l^2_p\right)} \to 1$$

so the left-hand side approaches

$$\frac{c^2}{2GS_o} r$$

and the horizon becomes approximately

$$r_h \approx \frac{2GS_o}{c^2} \; (\textit{classical Schwarzschild radius})$$

as

$$r \to 0 : 1 - e^{\left(-r^2/l^2{}_p\right)} \to 0, \; so\, f(r) \to 1$$

and the metric becomes flat, regularized at the center, avoiding a singularity.

EXPLORING THE IMPACT OF GE³ MODELING ON DARK MATTER

In Newtonian gravity, the orbital velocity of a star orbiting at radius r from the center of a galaxy is:

$$\nu_{Newton}(r) = \sqrt{\frac{GM(r)}{r}}$$

where the total mass is enclosed with radius r, implying that,

$$v(r) \propto \frac{1}{\sqrt{r}}$$

outside the visible galaxy (where mass is assumed to be constant).

Predicting that rotation curves should decline at large r, however, observations show that,

$$v_{observation}(r) \approx constant \; as \; r \to \infty$$

To match this, dark matter halos are added with a density profile such as the Navarro-Frenk-White (NFW) profile:

$$\rho_{DM}(r) = \frac{\rho_0}{\frac{r}{r_s}\left(1 + \frac{r}{r_s}\right)^2}$$

This leads to:

$$v^2(r)_{DM} \propto \frac{M(r)_{DM}}{r} \to constant \; at \; large \; r$$

In GE³ Theory, gravity effects in the bulk are not sourced directly from mass but directly from entanglement entropy, which as we have seen, modifies the metric function,

$$f(r) = 1 - \frac{c^2}{2GS_o} r\left(1 - e^{\left(-r^2/l^2_p\right)}\right)$$

Using the modified effective potential:

$$V^{GE^3}{}_{eff}(r) = f(r)\left(1 + \frac{L^2}{r^2}\right)$$

The circular orbital velocity is found from:

$$v_{GE^3}(r) = \sqrt{\frac{d\Phi_{eff}}{dr}} = \sqrt{r \cdot \frac{d}{dr}\left(-\frac{1}{2}f(r)\right)}$$

Computing this:

$$v_{GE^3}(r) = \sqrt{\frac{c^2}{2GS_0}\left(1 - e^{\left(-r^2/l^2_p\right)} + \frac{2r^2}{l^2_p} e^{\left(-r^2/l^2_p\right)}\right)}$$

From the behavior of GE³ orbital velocity, we find that:

Regime	Behavior of GE³ orbital velocity
$r << l_p$	$v(r) \propto r$ (*harmonic oscillator* − *like core*, *regularized center*)
Intermediate	$v(r)$ *increases slowly*
$r >> l_p$	$v(r) \rightarrow constant$ (*matching observed rotation curves*)

This shows that by modifying GR tensor equations to source the gravity in the bulk directly from boundary entanglement entropy, instead of mass energy, we can reproduce the flat rotation curves of galaxies without dark matter. The observed rotation curves can be understood purely as a result of quantum entanglement-modified spacetime geometry.

EXPLORING THE IMPACT OF GE³ MODELING ON DARK ENERGY

In the standard ΛCDM model, the Friedmann equation governs the expansion of the Universe:

$$H^2 = \left(\frac{\dot{a}}{a}\right)^2 = \frac{8\pi G}{3}\rho + \frac{\Lambda}{3}$$

where

H : *Hubble parameter*

ρ : *total energy density of matter and radiation*

Λ : cosmological constant

$a(t)$; *scale factor*

The dark energy interpretation in ΛCDM model finds,

$$\rho_\Lambda = \frac{\Lambda}{8\pi G} \qquad P_\Lambda = -\rho_\Lambda \qquad w = \frac{P}{\rho} = -1$$

In GE³ Theory, quantized gravitational energy is the same phenomenon as boundary entanglement entropy, and backward-time Eide Spheres expand from our forward-time perspective, appearing as negative pressure.

The energy density contributed by entangled backward-moving Eide Sphere is:

$$\rho_{backward\ Eide}(r) = \frac{S_0}{Gr^2} e^{\left(-r^2/\Lambda^2{}_{eff}\right)}$$

Backward-moving spheres contract in their own time, so from our frame, their energy expansion appears as negative pressure:

$$P_{backward\ Eide} = -\rho_{forward\ Eide}$$

In cosmology, dark energy is characterized by the equation of state,

$$w_{Eide} = \frac{P}{\rho} = -1$$

The GE³ Theory derives the Eide Spheres equation of state that exactly matches the equation of state of the cosmological constant.

So from Einstein's equations, the cosmological term can be replaced with the entanglement-driven energy:

$$\Lambda^{GE^3}{}_{eff} = \frac{8\pi G}{c^4}\rho_{backward\ Eide} = \frac{8\pi S_0}{c^4 r^2} e^{\left(-r^2/\Lambda^2{}_{eff}\right)}$$

This is dynamical, as it depends on r, i.e., the scale of the Universe. As r goes to infinity, this contribution stabilizes, resembling a constant.

Substituting the energy density contributed by entangled backward-moving Eide Spheres into the Friedmann equation:

$$H^2 = \frac{8\pi G}{3}\left(\rho_{matter} + \rho_{backward\ Eide}\right)$$

where:

$$\rho_{backward\ Eide}(r) = \frac{S_0}{Gr^2} e^{\left(-r^2/\Lambda^2{}_{eff}\right)}$$

and the pressure remains:

$$P = -\rho_{Eide} \Rightarrow accelerated\ expansion\ of\ the\ Universe$$

Showing that late-time acceleration comes naturally from entangled backward motion of quantized gravitational energy.

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