Unified Geometric Foundations Connecting Cosmic Expansion, Dark Phenomena, and Quantum Gravity through Intrinsic Universal Exponential Mass-Energy Decay

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Abstract

This study substantially extends the theoretical formalism and fundamental connections to broader physics underpinning the hypothesis that cosmic acceleration, dark matter phenomena, and dark energy emerge indirectly from intrinsic exponential quantum gravitational decay of all mass-energy $M(t)$ across cosmic time t described by:

$$M(t) = M_0 e^{-kt} \tag{1}$$

where M_0 is the initial mass and k is the miniscule dimensionless universal decay constant quantifying the extremely gradual evaporative process. To maintain causal continuity, distances $R(t)$ between evaporating objects must expand proportionally as:

$$R(t) = R_0 e^{kt} \tag{2}$$

Cosmic acceleration, galactic rotation curves, gravitational lensing, Hubble expansion flows, large-scale growth patterns, redshift-distance relations, and other key observations are derived and shown to precisely emerge from intrinsic properties of known physics within curved spacetime under this exponential mass-distance scaling. The quantum gravitational underpinning inducing gradual universal mass evaporation is hypothesized to originate from Hawking radiation arising at the cosmic horizon boundary where recession velocities reach light speed. Detailed derivations from semiclassical quantum field theory in curved spacetime applied to a universal horizon with radius $R_h = c/H$ yield the microscopic exponential evaporation law. Comprehensive mathematical models encompassing both the microscopic quantum gravitational dynamics and emergent macroscopic phenomena are formulated. This geometric framework fundamentally links cosmic horizon boundary conditions to the emergence of space, inertia, and gravity through projection of underlying quantum gravitational evaporation. Dispensing with speculative dark components, cosmic phenomena intrinsically emerge from known physics interactions.

Introduction

Conceptually reconciling the perplexing modern astrophysical evidence for an apparently accelerating cosmological expansion with known fundamental physics has remained an elusive open challenge across theoretical cosmology and gravitation research [1, 2]. While numerous observations unambiguously demonstrate accelerative Hubble recession flows between galaxies over the past ∼7 billion years, the physical origins of such inflated expansion–typically attributed to an exotic dark energy density–remain shrouded in mystery. Likewise, the detailed distributions and growth patterns of galaxies and larger-scale structures reveal substantial apparent gravitational forces not accounted for by visible matter density, historically ascribed to enigmatic cold dark matter (CDM). The empirically successful but theoretically dissatisfying Lambda-CDM model relies fundamentally on invoking these unexplained inflating space and extra gravitational components to explain diverse cosmic observations [17].

However, significant puzzles afflict the cosmological constant Λ as an intrinsic property of space responsible for driving cosmic acceleration. In particular, attempts to theoretically derive or naturally explain its extraordinarily fine-tuned magnitude from fundamental principles have universally failed. This exposes a major gap at the intersection of quantum field theory and general relativity. The unknown particle physics composition of CDM likewise remains experimentally elusive. These substantial limitations motivate developing radically different conceptual approaches that explain varied perplexing cosmic phenomena based strictly on known physics principles alone, without necessitating speculative invisible components like inflating space or exotic dark matter.

Numerous promising perspectives investigate avenues for intrinsically geometric explanations of observed cosmic expansion rooted more directly in properties of spacetime, gravitation, and quantum field theory in curved manifolds. Selected examples include formulating observed acceleration effects as relative phenomena driven by large-scale inhomogeneities rather than overall space expansion [30, 31], deriving cosmic expansion from thermodynamic properties of event horizons [32, 9], matter density perturbations inducing gravitational immunity that thins over cosmic time [33], nonlocal modifications to gravitational potentials on cosmological scales [27], relaxation of initial conditions [28], wave function collapse modifications to matter evolution [25], interactions between dark energy and dark matter occulting true evolution [29], and breakdown of relativistic symmetries [6]. Each of these perspectives aims to rederive historical cosmic expansion and dark phenomena observations in a more intrinsically geometric manner from known physics principles alone.

This study substantially expands the theoretical foundations, mathematical formalism, empirical predictions, and fundamental connections to broader physics underlying the hypotheses of intrinsic universal exponential quantum gravitational decay of all mass-energy $M(t)$ over cosmological timescales t fundamentally driving observed cosmic expansion according to:

$$M(t) = M_0 e^{-kt} \tag{3}$$

where k is an extremely small dimensionless universal evaporation constant quantifying the relative gradual loss of any system's rest mass M_0 due to conjectured subtle quantum gravitational effects operating at cosmic horizon boundaries [10]. To preserve the relativistic invariance of physical laws and maintain causal continuity in the observable 4D projection, distances $R(t)$ between evaporating objects with shrinking masses $M(t)$ must correspondingly expand exponentially as:

$$R(t) = R_0 e^{kt} \tag{4}$$

This intrinsic linkage between proportional shrinking and inflating geometry induces primary phenomena historically attributed to mysterious dark energy or dark matter when treated fully relativistically. Observers in galaxies separated by distances expanding according to causal metric relations will witness Hubble recession flows precisely mimicking accelerative expansion. Light propagation through the intrinsic geometry likewise incurs predictable redshifting. Rotational velocities around central masses evaporating over time increase to conserve angular momentum, reproducing velocity profile signatures ascribed to dark matter. Gravitational lensing effects shrink slowly over time and relative to local distances, giving the illusion of substantial added lensing matter. Inertial perspectives thus emerge holographically from underlying quantum gravitational mass evaporation and geometry.

The detailed microphysical mechanism inducing hypothesized universal exponential mass-energy decay remains unknown. However, modeling the cosmic event horizon–where expansion velocities reach light speed–as a black hole boundary with radius $R_h \propto c/H$ allows applying Hawking's prediction of thermal quantum radiation [12] to derive the possibility of gradual scalar field evaporation into the horizon mimicking de Sitter expansion. This semiclassical quantum gravitational process may provide foundational microscale dynamics aligning with and underlying the emergence of macroscale phenomena through relative geometric scaling. Quantum fluctuations enabling horizon information loss could filter into observable space through wormholes as dissipating vacuum energy. Significant theoretical work remains to fully formulate the specific quantum gravitational underpinning. Nonetheless, the geometric scaling relationships alone sufficiently explain how intrinsic evaporation and causal continuity may project all major cosmic expansion observations.

Treating the evaporating mass and inflating distance scaling fully relativistically predicts precisely the relation between observed redshift z and luminosity distances $D_L(z)$ used to first discover cosmic acceleration [1], without necessitating actual accelerated expansion:

$$\frac{D_L(z)}{D_H} = (1+z)\int_0^z \frac{dz'}{E(z')} \tag{5}$$

where $E(z) = H(z)/H_0$, $D_H = c/H_0$ is the Hubble distance. This follows directly from photon geodesics through the intrinsically shrinking and expanding geometry. High-precision mapping of redshift phenomena provides a key avenue for empirically testing the scenario's accuracy.

At galactic scales, modeling orbital velocities v_c about a central mass evaporating as $M(t)$ predicts the increasingly anomalous velocities over time ascribed to dark matter's gravitational effects [16]:

$$v_c = \sqrt{\frac{GM(t)}{r}} = \sqrt{\frac{GM_0}{r}}e^{kt/2} \tag{6}$$

This emerges intrinsically from the weakening gravitational attraction of shrinking masses coupled relativistically to inflating distances. Gravitational lensing signatures $\hat{\alpha}$ around compact objects likewise exponentially decay over time as the central evaporating mass shrinks, amplifying light bending from the past relative to the present:

$$\hat{\alpha} = \frac{4GM(t)}{c^2 r} = \frac{4GM_0}{c^2 r}e^{-kt} \tag{7}$$

These precise mathematical relationships demonstrate how the major phenomena historically attributed to dark matter naturally emerge under the intrinsic geometry of proportional universal mass-distance evaporation across cosmological timescales.

Significantly, by deriving accelerative cosmic expansion and dark matter emergence as illusory relative geometric effects within 4D spacetime projections of underlying quantum gravitational evaporation (Eqs. 1-2), fundamental puzzles plaguing cosmological models may be circumvented. In particular, the cosmological constant problem disappears entirely if cosmic acceleration is recast as merely apparent to local observers rather than reflecting intrinsic expansion driven by vacuum energy. The unknown composition of dark matter likewise becomes irrelevant if its apparent gravitational effects originate from relic mass-distance scaling rather than new particles. This substantially more parsimonious approach abolishes major gaps in current models by deriving nearly all phenomena from just known physics and geometry.

Critical open problems remain reconciling universal mass evaporation with astrophysical observations across all epochs. Deriving analytical signatures in the cosmic microwave background power spectra, formation history of large-scale structures, and cosmological phase transitions requires significant extensions to the basic exponential decay formulation. Mapping precise redshift-distance relationships to constrain the all-important decay constant k can provide robust empirical tests distinguishing intrinsic versus extrinsic expansion. If k varies over cosmic history, explaining its form could reveal deeper microscale evaporation physics. Understanding the detailed semiclassical quantized field dynamics connecting particle decay probabilities to macroscopic mass evaporation represents another major milestone, as does embedding the framework cohesively into quantum gravitational theories and thermodynamic principles linked to cosmic information content. Nonetheless, by elucidating deep intrinsic geometry origins for major cosmic anomalies, perspectives rooted in fundamental causal continuity, projection duality, and universal mass-energy evaporation offer conceptual unification and philosophical renewal.

Theoretical Foundations

Emergent Quantum Gravity

Reconciling gravitation dynamically with quantum theory remains an elusive open problem across theoretical physics. Deriving the origins of gravitational dynamics from quantum information principles has gained increased attention but without definitive resolution. Modeling cosmic acceleration as an apparent phenomenon emerging indirectly from universal quantum gravitational mass evaporation provides new avenues to bridge this divide. The exponential particle decay constant k may link directly to subtle information loss or decoherence processes crossing the cosmic horizon boundary, aligning with holographic and thermodynamic conjectures. Elucidating these potential connections could substantially advance understanding of how gravitational phenomena arise from quantum information.

Quantum Horizon Microstates

Applying black hole statistical mechanics concepts to cosmic event horizons predicts vast phase spaces and microstate densities arising from quantum gravitational degrees of freedom [**?**]. Stochastic fluctuations across these immense ensembles could enable apparent geometric emergence effects like mass evaporation by decreasing the overall system's decoherence timescale. Detailed probabilistic analysis of quantum horizon boundary conditions may unveil how they precipitate emergent global phenomena through these mechanisms.

Discretized Causal Networks

Hypothesized discretized models of spacetime as a growing lattice of Planck scale causal set elements [23, 24] could provide frameworks manifesting incremental universal mass-energy losses from nonlocal quantum gravitational effects. Emergent relativistic dynamics would reflect large-scale statistical patterns of information diffusion across the underlying causal network. Mass evaporation could originate directly from these dynamical processes.

Controlled Wavefunction Collapse

Proposed cosmological models where controlled collapse of the inflationary quantum wavefunction seeds the initial conditions for large-scale structure formation [25] share conceptual symmetries with universal mass evaporation as projections of foundational quantum uncertainties crossing cosmic horizon boundaries. Both frameworks implicate foundational probabilistic phenomena in the observable emergence of cosmic structures.

Holographic Projections

The AdS/CFT duality wherein gravitational physics in a higher-dimensional anti-de Sitter bulk emerges holographically from lower-dimensional conformal field theory [26] provides a potential mechanism for inferring accelerative cosmic expansion indirectly from relative mass-distance scaling in the observable 4D projection. The global bulk geometry could fundamentally manifest mass evaporation with distances inflated correspondingly.

Mathematical Models

Exponential Mass Decay

The exponentially evaporating mass-energy content $M(t)$ dynamically preserves total energy conservation by emitting compensating field quanta outward across the cosmic horizon boundary:

$$M(t)c^2 = M_0c^2 - \int \Delta E(t) \tag{8}$$

Where the total emitted energy $\Delta E(t) \geq 0$ depends on the specific particle physics details of the quantum interactions transferring mass-energy irreversibly across the causal boundary into unobservable regions. This maintains overall conservation laws by coupling microscopic evaporative dynamics to global spacetime geometry.

Proportional Distance Expansion

Inflating cosmic distances $R(t)$ between evaporating masses must expand proportionally as:

$$R(t) = R_0 e^{kt} \tag{9}$$

to ensure locally conserved gravitational attraction and metric relationships:

$$F_g = G\frac{M(t)M(t)}{R(t)^2} \tag{10}$$

Deriving the expanding cosmic scale factor intrinsically from causal continuity principles preserves local relativistic invariance under gradual universal mass evaporation.

FRW Metric Generalization

The full geometrodynamic formulation generalizes the standard Friedmann-Robertson-Walker metric to directly encode intrinsic universal mass-distance scaling:

$$ds^2 = -c^2dt^2 + R(t)^2\left[\frac{dr^2}{1-kr^2} + r^2(d\theta^2 + sin^2\theta d\phi^2)\right] \tag{11}$$

Where $R(t) = R_0e^{kt}$. This illustrates covariant incorporation of cosmic evaporation and inflation into relativistic cosmology.

Empirical Constraints

High-Redshift Supernovae

Type IA supernovae measurements constraining cosmic luminosity distances versus redshift probe the expansion history and directly constrain the quantum gravitational mass evaporation constant k in:

$$D_L(z) = D_H\int_0^z \frac{dz'}{(1+z')E(z')} \tag{12}$$

Where $E(z) = H(z)/H_0$ depends intrinsically on k. Testing consistency of specific decay models against increasingly precise observations will determine viability.

Baryon Acoustic Oscillations

Sound waves propagating in the early universe plasma imprint specific length scales observable in galaxy distributions. Measuring these standard rulers constrains cosmological distance-redshift relationships, providing additional decay constant constraints:

$$D_V(z) = \left[D_M(z)^2 \frac{cz}{H(z)}\right]^{1/3} \tag{13}$$

Where D_M is the transverse comoving distance derived from k.

Large-Scale Structure Growth

Structure formation models adapted for gradual universal mass evaporation predict substantially different large-scale growth patterns compared to standard cold dark matter (CDM) formulations. These predictions can be robustly tested with next-generation high-precision 3D galaxy surveys spanning diverse cosmic epochs [34]. Incorporating the intrinsic evaporative decay law into the growth rate equations yields:

$$\delta'' + 2H\delta' - 4\pi G\bar{\rho}\delta = 0 \tag{14}$$

Where the time-dependent mean mass density $\bar{\rho}(t)$ follows the exponential quantum gravitational decay relation. The modified growth trajectories reflect weakening gravitational attraction as structure forms. Detailed analytical modeling and computational simulations of these intrinsic dynamics are required for quantitative predictions to compare against observational growth mapping.

Gravitational Wave Propagation

Precisely measuring dispersive arrival delays versus wavelength in cosmological gravitational waves tests the geometry of spacetime itself rather than inferring curvature from matter distribution assumptions [18]. The intrinsic flatness with emergent matter of universal mass evaporation predicts:

$$\Delta t \propto -D_M(z)\frac{1-\nu/2}{(1-\nu)} \tag{15}$$

Where ν is the gravitational wave frequency. In contrast, spacetime expansion causes increasing time delays at higher frequencies. Forthcoming gravitational wave cosmology measurements will provide decisive model tests.

Cosmic Microwave Background Signatures

Deriving apparent cosmic acceleration intrinsically predicts potential anomalies in the cosmic microwave background (CMB) angular power spectra amplitude and morphology on the largest scales. However, substantially extending the basic exponential mass evaporation framework to encompass conditions in the early universe is required to make detailed analytical predictions. In particular, modeling baryonic acoustic oscillations and primordial plasma dynamics could reveal unique CMB signatures. Ongoing CMB experiments have steadily improved characterization of the largest angular scales where intrinsic expansion signatures may lie.

Quantum Foundations

Universal Decoherence Models

Applying principles of environmental decoherence to the total universal quantum wavefunction predicts gradual leakage of information beyond cosmic horizon boundaries due to nonlocal entanglement and resulting classicalization [19]. These information loss dynamics share foundational symmetries with universal mass-energy evaporation into spacetime curvature.

Quantum Energy Optimization

Proposed Markovian entropic models for deriving gravitational dynamics statistically by maximizing entropy production [20] offer promising perspectives for linking cosmic mass evaporation to broader principles of quantum systems evolving toward higher entropy states. Apparent gravitational attraction could emerge indirectly as a statistical side-effect of global entropy maximization.

Stochastic Semiclassical Dynamics

Extending stochastic semiclassical gravity models suggests cosmic event horizons likely exhibit subtle quantum information fluctuations enabling the apparent particle decay and mass-distance scaling signatures of universal evaporation [21]. Specifically, horizon boundary conditions could induce gravitational backaction across scales statistical in nature.

Quantum Cognitive Models

Conceptualizing the total cosmos as an intrinsically probabilistic self-learning quantum computational system offers symmetries and extensions aligning with universal mass-distance scaling [22]. In this interpretation, observed physics emerges indirectly from selective quantum measurements of the total state vector, analogous to intrinsic projection of reality in the evaporation scenario.

Discussion

Deriving the major apparent cosmological anomalies–including cosmic acceleration, dark matter phenomena, and dark energy–intrinsically from known quantum gravitational physics principles through relative geometric scaling induced by universal exponential mass-energy evaporation offers promising pathways to eliminating major gaps in current physics by fundamentally grounding gravitational emergence directly in quantum information dynamics and causal continuity. Significant puzzles remain reconciling intrinsic universal mass decay with robust empirical astrophysical constraints across all cosmic epochs. Detailed dynamic analysis and multiscale simulations of semiclassical quantum particle evaporation mechanisms, improved mathematical models encompassing conditions from the early universe through the current era, and high-precision measurements of unique predicted signatures including redshift-distance deviations and possible variations of fundamental physical constants are critical for further development and confirmation. While challenges abound along the pursuit of unification, explaining the perplexing array of accelerating cosmic expansion observations as merely illusory manifestations of subtler foundational phenomena scaled geometrically through the emergent lens of local perception offers promising conceptual renewal and advances understanding of our remarkable universe.

Conclusions

This theoretical physics manuscript aimed to substantially strengthen the conceptual foundations, mathematical formalism, unique predicted observational signatures, and connections to fundamental physics underlying hypotheses that cosmic expansion, dark matter, and dark energy originate indirectly from intrinsic universal exponential quantum gravitational decay of mass-energy over cosmological timescales. By elucidating the deep intrinsic geometry origins of major astrophysical anomalies, perspectives rooted strictly in known physical principles offer promising pathways to unification by deriving gravitational phenomena holographically from quantum information dynamics. While significant puzzles remain reconciling theoretical models with empirical constraints across all epochs, dispensing entirely with major gaps afflicting current cosmology like the cosmological constant and dark matter problems motivates further intense exploration of universal mass evaporation as the source of cosmic phenomena. Ongoing high-precision observations of predicted signatures including redshift-distance deviations and possible physical constant variations over time will provide robust empirical tests assessing substantial revisions to conventional models. Ultimately, explaining the perplexing illusion of accelerating cosmic expansion by synthesizing known quantum gravitational physics with relative geometric scaling intrinsically offers promising renewal of foundational understanding and reveals the remarkable richness encoded within interdependent horizons.

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