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Constructive Resonance and the Emergent Universe: A New Systemic Interpretation of Einstein Field Equations for Cyclical Cosmology

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ABSTRACT

This study presents a novel theoretical framework unifying classical physics, quantum mechanics, and general relativity through the paradigm of energy transformation. It introduces the concept of constructive resonance coherent energy interactions that underlie the emergence of mass, matter, space, and time. Positioning time as an emergent property of energetic interactions, the paper proposes a modified interpretation of the Einstein Field Equations (EFE), incorporating the total cosmic energy density E, the speed of light to the fourth power c^4, and the cosmological constant Λ. Central to this approach is the idea that photons initiate structural formation in the early universe, contributing to spacetime curvature and the cosmic microwave background. The model further explores a cyclical cosmology, in which the universe alternates between phases of expansion and contraction. Even in a seemingly static or "heat death" state, hidden quantum activity may sustain dynamic evolution. The framework suggests a Complexified Curvature Tensor to account for both observable and "hidden" energy contributions in spacetime geometry. Observational phenomena such as gravitational lensing, Mercury's orbital precession, and gravitational waves are revisited to emphasize the foundational role of c^4 in spacetime dynamics. This reinterpretation offers fresh insight into unresolved mysteries like dark energy, cosmic evolution, and the possible rebirth of the universe. Ultimately, the paper proposes that constructive energy interactions are the engine of cosmic structure, potentially reshaping our understanding of gravity, time, and the destiny of the universe.

Keywords: Constructive Resonance, Energy Transformation, Cyclical Cosmology, Einstein Field Equations

INTRODUCTION

There is growing recognition within the modern scientific community that cosmic reality is far more complex, multidimensional, and fundamentally interconnected than what current models typically suggest. By exploring these deeper dimensions through a systems-based approach and developing novel theoretical tools, we may achieve a more holistic understanding of the universe and our place within it. This research seeks to unify classical physics, quantum mechanics, and general relativity under the overarching paradigm of energy transformation, offering a new lens through which to examine the formation and evolution of the universe.

CONSTRUCTIVE RESONANCE, ENERGY TRANSFORMATION AND THE EMERGENCE OF SPACE-TIME

Constructive resonant energy is a ubiquitous phenomenon found in macroscopic and microscopic environments. In a recent discovery of field particle energy transfer during chorus emissions in space by (Liu et al., 2025), it has been found that the waves are associated with resonant currents antiparallel to the wave magnetic field, as predicted by nonlinear wave theory. It has also estimated the nonlinear field–particle energy transfer inside the waves, finding that the waves extract energy from local thermal electrons, in line with the positive growth rate of the waves derived from an instability analysis. New scientific investigations have revealed that the electron energy spectrum is modulated to produce different energy sidebands when specific resonance circumstances are met. Tsarev, Thurner, and Baum (2023) documented these sidebands displaying well-defined interference maxima, which can be mathematically expressed as ΔE representing discrete energy sidebands and characterizing the modulation and interference patterns governing the electron energy spectrum under specified resonant conditions.

$$\Delta E = f(E, n) \tag{1}$$

It can be postulated that the constructive resonance through the mechanism of wave interaction leads to particle pairing or the formation of complex entities when one incident particle approaches the resonant frequency of another particle. In the post-interaction phase, the combined frequency becomes the sum of the interacting wave frequencies, resulting in a higher energy state E_{high}. Projecting at macroscopic level, this higher energy state equates to the creation of 'regions' characterized by pronounced 'space-time curvature,' which can be mathematically described in terms of Einstein's field equations or other relevant equations from general relativity theory. The intricate process of matter creation is contingent upon the precise frequency f and corresponding wavelength λ that photons γ and fermions (e.g., electrons, e^-) exhibit. The relationship between energy E frequency f, and wavelength λ can be shown by the photon energy equations:

$$E = hf \quad \text{or} \quad E = hc/\lambda \tag{2}$$

In the above, E is energy of a photon or fermion, h is Planck constant, f is frequency of the photon or fermion, c is speed of light and λ is wavelength of the photon or fermion. Matter creation occurs when the energy E of the photons or/and fermions meet or exceed the minimum energy required E_{min} for the matter creation process to manifest under specific frequency and wavelength conditions:

$$E \geq E_{min} \tag{3}$$

This phenomenon establishes a 'center of mass frame' for all newly formed matter entities in which the total momentum comes to be zero. Adam et al. (2021) suggested that the concept of mass-driven gravity, as originally postulated by Newton, can be attributed to the presence of mass m and its associated energy mc^2 in the vicinity, leading to gravitational effects. So, the elevated energy state of resonant Constructive Resonance Waves $|Y^2\Psi^2|^2$ enhances the probability density ρ of locating particles (e^- and e^+) in a collapsed state with mass attributes m at specific space-time coordinates (x, y, z, t). This can be represented as:

$$\rho(x, y, z, t) \propto |Y^2\Psi^2|^2 \tag{4}$$

Conversely, the reversal of this mechanism, referred to as 'out-form' interference, may give rise to regions characterized by destructive wave resonance across a spectrum of frequencies. Such domains could exhibit negative permittivity ε and permeability μ, which are theoretically associated with phenomena resembling anti-gravity and dark energy. Various modifications to Einstein's general relativity such as the inclusion of scalar fields or higher-order curvature terms have been proposed to account for these exotic spacetime properties (Sotiriou & Faraoni, 2010).

Building on the findings of Brodsky, Zerwas, Methods in Physics Research Section A: Accelerators, and Equipment (1995), which show that photons can couple directly to all fundamental fields carrying electromagnetic currents including leptons, quarks, W bosons, and supersymmetric particles it is posited that constructive couplings between electrons and photons, or between photons themselves, may generate resonant attractive forces similar to gravity at the subatomic level. This process conserves energy within the system by redistributing or absorbing destructive interference through constructive modes, or by returning energy to a source-reservoir attributed to a dark energy component that counteracts gravity (Peebles & Ratra, 2003).

Constructive interference, therefore, plays a crucial role in the emergence of dimensions and the organization of vector space within the fabric of spacetime. This mechanism provides a foundational template for the formation of complex cosmic symmetries and large-scale structures. According to the Standard Model of particle physics(GLOSSARY, 2007), matter can be generated either directly through pair creation ($\gamma + \gamma \rightarrow e^+ + e^-$) or indirectly via the decay of intermediary particles such as the W^- boson ($\gamma + W^- \rightarrow e^- + \nu_e$), resulting in the formation of an electron and an electron-antineutrino.

The probability and rate of these processes are described using quantum field theory and the corresponding resonance coupling constants. The interaction between photons γ and charged particles such as electrons (e^-) is captured by the electromagnetic Lagrangian term:

$$\mathcal{L}_{\text{EM}} = -\frac{1}{4} F^{\mu\nu} F_{\mu\nu} \tag{5}$$

Here, $F_{\mu\nu}$ denotes the electromagnetic field tensor, and the corresponding Lagrangian term describes the interaction between the electromagnetic field and charged fermions. Photon-mediated interactions play a crucial role in the early universe, contributing to the emergence of fundamental particles that form the building blocks of matter.

$$\mathcal{L}_{\text{Higgs}} = -y_F\, \overline{\psi}_F\, H\, \psi_F + h.c \tag{6}$$

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Here, $\mathcal{L}_{\text{Higgs}}$ represents the Yukawa interaction term that couples the Higgs field H to fermion fields $\overline{\psi}_F$. This term is essential in the Higgs mechanism and is responsible for the generation of fermion masses after spontaneous symmetry breaking (C. Collaboration, 2014).

This holistic perspective integrates our understanding of the cosmos across all scales, from the minutiae of quantum events to the vast structure of the universe, by emphasizing the foundational role of energy transformation. Furthermore, the spontaneous creation of a fermion pair (i.e., matter particles) from a single photon is forbidden by conservation laws. Matter generation becomes possible only when an additional particle, either a boson or a fermion, participates in the interaction, sharing the photon's momentum and thereby ensuring compliance with momentum conservation principles.

Role of Photonic Observation

In quantum field theory, particles and fields are regarded as excitations of underlying energy fields distributed throughout space-time. The interactions and transformations of these fields are governed by the principles of quantum mechanics. Struyve (2017) emphasized that various quantum gravity theories propose that space-time may itself emerge from more fundamental quantum processes, such as those described in string theory and loop quantum gravity. Accordingly, the creation of the universe involved not only physical interactions but also the act of observation, which played a critical role in the emergence of space-time and matter. Photons, being the first particles to decouple from matter, contributed to this process by filling the universe with the cosmic microwave background. The collective interaction energy of photons can be interpreted as a form of primordial "observation" that influenced the universe's initial structure, expressed as:

$$E = h\nu \tag{7}$$

Furthermore, gravity, as described in both Newtonian and Einsteinian frameworks, may originate from the dynamics of constructive resonance and wave interference among interacting fields. Primordial perturbations, as discussed by Mukhanov, Feldman, and Brandenberger (1992), arise from quantum fluctuations at Planck-scale dimensions, which later evolve into galactic-scale density variations where gravity manifests as a clustering of mass particles. The interaction between photon bosons and electron fermions initiates the emergence of time and space, intertwined with matter. Photons acquire temporal attributes through their interaction with fermions, resulting in the realization of spatial structure.

The presence of a scalar field breaks the symmetry of the system, leading to the generation of mass in originally massless particles, as observed in the Higgs mechanism (Wilczek, 2005). Even in the late evolutionary stages of the universe, such as near the heat death phase, singularities may be avoided due to quantum gravitational effects associated with matter distribution. In such regimes, matter creation and its dynamics may be better described by quantum field theory rather than classical gravitational models (Candelas, 1974).

It can thus be inferred that within the four-dimensional framework, comprising one dimension of time and three dimensions of space, the total mass and energy of interacting particles exert resonant quantum gravitational influences on one another.

These interactions operate at the quantum level in a manner conceptually analogous to the gravitational effects observed between celestial bodies within the large-scale fabric of spacetime. Importantly, exchange interactions differ fundamentally between bosons and fermions, primarily due to the Pauli Exclusion Principle. For fermions, this principle prohibits identical particles from occupying the same quantum state, leading to an effective repulsion that increases inter-particle distances. In contrast, bosons are not subject to this restriction and tend to cluster into the same quantum state, resulting in an effective attraction.

This phenomenon is exemplified by Bose–Einstein condensation (Einstein, 1924), where overlapping wave functions cause a significant decrease in the average separation between particles. As demonstrated in early quantum theory (Dirac & Character, 1926), the expectation values of inter-particle distances vary based on particle type. They increase for indistinguishable fermions and decrease for bosons, in contrast to the behavior observed with distinguishable particles. These distinctions have profound implications for understanding particle interactions, quantum field behavior, and the emergent properties of matter under extreme conditions.

COSMIC INFORMATION AND THE RESONANCE-INDUCED INFORMATION FORCE FIELD (RIIFF)

Building on the preceding concepts, space-time can be conceptualized as an interconnected fabric that encodes both linear and non-linear patterns within an underlying Information Field. This field governs interactions between fundamental particles through what may be described as Constructive Resonance Waves, which collectively give rise to the material universe. These quantum forces manifest within the dynamic framework of constructive wave interactions occurring at the microscopic level (Liu et al., 2025).

This synthesis of quantum forces and wave-based interactions serves to bridge the domains of quantum gravity and classical gravity across the unified framework of time, space, and observation, functioning collectively as an information vector. However, the numerous functional dependencies inherent in wave interference across diverse physical contexts present significant challenges to the formulation of a unifying general theory.

To address this, we propose a distinct and linear force field: the Resonance-Induced Information Force Field (RIIFF), conceptualized as a force field of cosmic information generated by resonance. Physical fields often exhibit structured correlations and follow well-established physical laws. To reconcile the mismatch between the degrees of freedom in physical fields and the limited set of measurement points, it is necessary to integrate information directly into field inference.

This need is met by Information Field Theory (Enßlin, 2019), which is further supported by Quantum Field Theory (Peskin,

2018) as a robust framework that unifies field theory, the principles of relativity, and quantum mechanics.

Within this context, we introduce the notion of Cosmic Information (CI) as a fundamental basis vector that spans the dimensions of space and time, thereby extending the model to a five-dimensional universe. In the realm of quantum information processing, Srivastava, Sahni, and Satsangi (2011) introduced Graph-Theoretic Quantum System Modelling (GTQSM), a framework that employs the quantum bit, or qubit, as the fundamental building block. Within this model, unit directional vectors, such as 'ket 0' and 'ket 1', represent orthonormal basis vectors in Hilbert space, specifying the direction of information propagation. Complementary quantum flow variables specify probability amplitudes, serving as scalar surrogates for quantum information measures such as von Neumann entropy.

The mathematical representation of this proposed force field framework, which extends the conceptual foundation of the universe into five dimensions by integrating space, time, and information-consciousness, is given as follows:

$$F_{5D(x,y,z,t,I)} = -\nabla U_{5D} \quad (8)$$

This mathematical construct defines a force field that integrates the conventional three spatial dimensions, the temporal dimension, and an additional dimension associated with information consciousness. It captures the quantum-level interactions of particles and extends the conceptual framework of the cosmos into a five-dimensional (5-D) model.

To establish a general theoretical basis for the Resonance-Induced Information Force Field (RIIFF) (Bhushan, 2023), which evolves over time, we begin with a foundational formulation that describes how forces vary across space and time due to resonant interactions. This general framework can then be adapted to model specific force interactions as required. Let us denote the force as $\boldsymbol{F}$, and proceed as follows:

$$\frac{\partial F}{\partial t} = \nabla . R_f \quad (9)$$

Where $\partial F/\partial t$ represents the rate of change of force over time, ∇ denotes the gradient operator, which captures spatial derivatives such as divergence, and R_f refers to the Resonance-Induced Information Force Field (RIIFF). This expression suggests that the time evolution of force fields is governed by the spatial variation of RIIFF.

The specific formulation of RIIFF and how it influences interactions like gravity and electromagnetism would require further development, with detailed models tailored to each type of force. Wang and Yang (2008) highlighted notable similarities between such approaches and several leading theoretical models that adopt a dynamic, time-dependent view of the cosmological constant Λ to address the expansion contraction behavior of the universe.

In contemporary cosmology, the concept that space may possess intrinsic energy gravitationally equivalent to Einstein's cosmological constant is widely accepted. This form of energy, referred to as dark energy or quintessence, may not be static.

A dynamic dark energy model allows for the possibility that the energy density evolves over time, gradually approaching zero, which aligns with the idea that the current universe is relatively old and slowly expanding. This perspective could also resolve the issue of the unusually small energy scale (on the order of millielectron volts) associated with a constant Λ (Peebles & Ratra, 2003).

Moreover, a time-varying dark energy component may help reconcile discrepancies between local and early-universe (primordial) measurements of cosmological parameters, challenging the traditional notion of a constant Λ (Di Valentino, 2017). In practical terms, the exact mathematical formulation that describes how RIIFF affects various forces would depend on the specific physical mechanisms underlying resonant particle interactions throughout the universe. This paper attempts to outline the theoretical basis for such interactions, while acknowledging that further equations must be derived within the framework of applicable physical theories and observational evidence.

Ultimately, the Resonance-Induced Information Force Field (RIIFF) framework introduces a dynamic perspective on fundamental interactions, offering a unified approach to phenomena such as gravity and electromagnetism. By incorporating time-dependent fluctuations in the resonance constant, RIIFF has the potential to inspire new theoretical developments and may contribute to a broader paradigm shift in our understanding of the evolving universe.

Time is regarded as an integral component of the four-dimensional spacetime continuum, as described in both special and general relativity. Within this framework, time is treated as one of the fundamental basis vectors of the spacetime manifold. Beyond its scientific interpretation, time also holds deep philosophical and spiritual significance, as emphasized in the scriptures and verses of the Indian religion of Saints (Sant Mat, Dayalbagh: Ra-Dha-Sva-Aa-Mi) (Prem Saran Satsangi, Horatschek, & Srivastav, 2024).

This view suggests that time is not a fixed, independent entity but rather emerges from energetic interactions at the fundamental level. As a result, the passage of time and the evolution of cosmic structures are consequences of dynamic physical processes (Rovelli, 2012). This interpretation aligns with quantum field theory, which posits that space is saturated with potential fields, and the interactions among particles transform these fields into observable matter and forces. Accordingly, the initial constructive resonance among fundamental particles including hypothetical carriers such as gravitons may signify the origin of time and the formation of cosmic structure. This links the emergence of fundamental forces with the genesis of the observable universe.

CYCLICAL COSMOLOGY, ENERGY AND CURVATURE OF SPACE-TIME

According to general relativity, mass and energy directly influence the curvature of spacetime (Einstein, 1905). Higher energy densities correspond to greater curvature, a relationship formalized by the Einstein Field Equations (EFE), which relate the distribution of energy and momentum to the geometry of spacetime:

$$G_{\mu\nu} + \Lambda\, g_{\mu\nu} = \left(\frac{8\pi G}{c^4}\right) T_{\mu\nu} \tag{10}$$

In exploring this relationship from the perspective of energy transformation, we propose a novel framework known as Complexified Curvature, denoted by the symbol $\tilde{R}\ S$. This symbol is partially inspired by the phonetic stream "Ra-Dha-Sva-Aa-Mi," an element central to the Indian Sant Mat tradition, which regards this sound current as a subtle force that facilitates the progressive awakening of human consciousness. Within this spiritual framework, the resonance between the microcosm (the individual) and the macrocosm (the universe) is established through this vibrational current originating in higher cosmic realms.
To provide a mathematical formulation for these interactions, we adopt an abstract representation rooted in topological graph theory, offering a structured and minimalistic approach to model the interfaces between energy, space, and consciousness (Prem Saran Satsangi, 2006; Prem Saran Satsangi et al., 2024).
The "R" in $\tilde{R}$ S acknowledges the Ricci tensor, named after Gregorio Ricci-Curbastro, and reflects the curvature due to observable matter-energy distributions. The proposed Complexified Curvature is expressed as:

$$\tilde{R}\ S_{\mu\nu} = R_{\mu\nu} + iS_{\mu\nu} \tag{11}$$

Here, $R_{\mu\nu}$ is the standard Ricci curvature tensor-a symmetric second-order tensor fundamental to general relativity, representing the gravitational field resulting from mass-energy content and producing the observable curvature of spacetime. In contrast, $S_{\mu\nu}$ is introduced as a new, hypothetical tensor capturing the "hidden" or transformative aspects of energy. This imaginary component is associated with pre-geometric quantum states and energy transformations occurring prior to spacetime becoming manifest-concepts supported by quantum gravity models and the notion of external observation (Struyve, 2017).
In this formulation, $\tilde{R}$ represents the observable (real) curvature of spacetime, while $S_{\mu\nu}$ corresponds to its concealed (imaginary) counterpart. The introduction of this dual structure enables the exploration of both visible and hidden aspects of cosmic evolution, offering a richer understanding of energy dynamics. This interpretation is analogous to the role of complex numbers in quantum mechanics, where the imaginary part carries phase information essential to describing quantum states. As elaborated in Equations 14 and 15, these components are crucial to quantum formalism and provide an elegant representation of the underlying quantum nature of the cosmos (Renou et al., 2021).

Pre-Big Bang Scenario

In the pre-Big Bang scenario, which is characterized by high symmetry, homogeneity, and isotropy, energy density becomes the dominant component. In this regime, we propose that a simplified approximation of the EFE, may provide a more reasonable description of the integrative cosmic dynamics.

Here, postulating gravity itself as a quantum emergent phenomena, in which 8πG on the right side of EFE (as a measure of the 'elasticity' or as an entropy density of the underlying quantum fabric), can be considered equivalent to a form of energy density of the quantum system that creates space-time akin to 'gravitons' as a fundamental primordial quantum particle estimated to carry energy and momentum in gravitational waves, just as similar particles are known to carry the other three fundamental forces of nature (Merali, 2013). Tobar (Tobar, Manikandan, Beitel, & Pikovski, 2024) analyzed the feasibility of observing the exchange of single energy quanta between matter and gravitational waves. Their results show that single graviton signatures are within reach of experiments.
In analogy to the discovery of the photo-electric effect for photons, such signatures can provide the first experimental clue of the quantization of gravity. Hence, the energy of a graviton could be expressed in a similar form to photon energy as $E = \hbar\omega$, where $\hbar$ is the reduced Planck's constant and ω is the angular frequency of the gravitational wave. This construct may lead to a better understanding of the relationship between gravity and other types of energy in the universe. Secondly, $T_{\mu\nu}$ in the EFE would also include the energy and momentum density of gravitons and the contributions from quantum fluctuations of the gravitational field. Therefore, our novel interpretation suggests that both the Complexified Curvature energy tensor- $\tilde{R}\ S_{\mu\nu}$ related to energy and scaled by c^4 and the cosmological constant Λ contribute to spacetime curvature after the big bang.
The factor of c^4 can be seen as an operator that transforms the 'hidden' energy into the 'manifest' energy that we observe as spacetime curvature and energy density. Building and extending upon the General Relativity principle that mass and energy influence spacetime curvature, we propose a final approximation of the EFE to incorporate the intertwined components as follows:

$$\tilde{R}\ S_{\mu\nu} \sim \Lambda \left(\frac{E}{c^4}\right) g_{\mu\nu} \tag{12}$$

Where E is the total energy density derived from the total energy of the universe in the sum of all forms of energy, including mass-energy, relativistic kinetic energy, energy of photons and the energy of gravitons.

$$E_{Total} = \sum i(mc^2 + (\gamma - 1)mc^2 + h\nu + \hbar\omega) \tag{13}$$

This approximation highlights the dominant role of energy transformations in shaping spacetime curvature during the early universe. Kaczmarek and Szczęśniak (2021) recommended that we can always reconstruct a model; unifying both matter dominated and accelerated phases, where ordinary matter is neglected and using inverted reconstruction scheme, we recover specific function which gives rise to the de-Sitter evolution. Similarly, we can write down the equations using tensor notation under a modification to the standard Ricci tensor $R_{\mu\nu}$ to ensure consistency and to be able to explore their consequences.

$$\tilde{R}\, S_{\mu\nu} = R_{\mu\nu} + i \left(\frac{G}{c^4}\right) T_{\mu\nu} \tag{14}$$

The left-hand side represents the energy associated with spacetime curvature, with the imaginary part representing the energy involved in transforming between curvature and matter/fields. The right-hand side represents the energy associated with matter and fields. The equation describes the transformation of energy between these two forms. We can further elaborate and define $\tilde{R}\, S_{\mu\nu}$ (akin to a set of complex number), in order to capture quantum gravitational effect as:

$$\tilde{R}\, S_{\mu\nu} = R_{\mu\nu} + i\,\beta \left(\frac{Lp}{L}\right)^4 \langle h_{\mu\nu} \rangle \tag{15}$$

where $R_{\mu\nu}$ is a real-valued tensor while i is the imaginary unit $\sqrt{-1}$ representing $S_{\mu\nu}$, β is a dimensionless constant, Lp is the Planck length, $\langle h_{\mu\nu} \rangle$ represents the expectation value (average) of quantum fluctuations of the metric tensor $h_{\mu\nu}$, and $(Lp/L)^4$ indicates that the quantum gravitational effects become significant when the characteristic length scale L approaches the Planck length Lp.

So, it is clear that the imaginary part of $\tilde{R}\, S_{\mu\nu}$ i.e. $S_{\mu\nu}$ is proportional to the non-zero vacuum expectation value of quantum metric fluctuations which is actually the energy associated with the quantum nature of spacetime when it breaks the symmetry of the system, resulting in particles acquiring mass through the Higgs mechanism (A. Collaboration, 2012; Wilczek, 2005).

In the pre-Big Bang scenario, where these fluctuations are expected to be dominant, this term becomes crucial, potentially leading to describe specific pre-Big Bang dynamics, such as singularity avoidance or a bounce in which the restoration of symmetry at grand unification in a closed contracting 'Robertson–Walker' universe could slow down and halt the contraction, causing the universe to bounce and avoid the singular state or the ultimate 'big crunch' (Petrosian, 1982).

So, in the limit of low energies and curvatures, the quantum fluctuations become negligible, and our equations should reduce to the standard EFE plus small quantum corrections, which is crucial for maintaining consistency with well-established observations and experimental results.

The above description is further supported by visualizing the four-dimensional spacetime as a four-dimensional space in itself, with each point representing an event in spacetime under complex Mankowski Spacetime framework (Penrose, 2005). However, near the pre-Big Bang scenario, where energy densities are extremely high, the c^4 factor scaling in the EFE becomes essential to maintain dimensional consistency.

Here, c as speed of light, acting from the 'four sides' as a conversion factor between space and time originating into four-dimensional universe (3-D Space and 1-D Time), reflects their intertwined nature in the realm of relativity.

Additionally, in relativistic contexts, especially concerning spacetime curvature, varied powers of c may also impart dimensional consistency. Furthermore, in the very early phase, the resonant interplay between these elements most likely played a crucial role in determining the cosmic evolution.

Unlike ordinary matter and energy, which cause spacetime to curve inwards resulting in gravity, a positive Λ will cause spacetime to curve outwards, leading to the observed accelerating expansion of the universe (Zehavi & Dekel, 1999).

Therefore, the presence of c^4 and Λ, along with total energy density E, in our simplified Einstein field equations is not arbitrary. It arises directly from the fundamental relationship between spacetime geometry and the distribution of energy and momentum described by general relativity. Additionally, the coupling of time and space with matter (via photons and fermions) implies that spacetime curvature is fundamentally tied to the energy content in the universe.

When we abstractly consider the decoupling of photons and their interaction energy as an initial 'observation, the energy density E becomes a central quantity that influence the dynamics of curvature.

This ensures that the modified equations are consistent and they accurately reflect the interplay between the fundamental aspects of the dynamically evolving cosmos. The recommended framework thus serves as a valuable heuristic for understanding the deep connection between energy and spacetime curvature, especially under extreme conditions. In this, because both sides now represent energy in different forms with an appropriate conversion factor of c^4 ensuring dimensional consistency and the equation maintains its tensorial structure, as both sides are rank-2 tensors.

The imaginary part of the curvature now has a clearer physical interpretation as representing the 'transformative' aspect of energy. Our fundamental axiom therefore, suggests that everything is governed by a two-way process of energy transformation where the curvature itself is treated as a form of energy, and the energy can be transformed into curvature.

Post Big Bang: Power-Law Distribution

In the post big bang scenario, the expansion of the universe with observable large-scale structures displaying fractal-like characteristics can as well be captured in the following equation explaining the time evolution of the scale factor a (Mandal, Pradhan, Sahoo, & Harko, 2023).

$$a = a_0 + \left(\frac{t}{t_o}\right) \beta \tag{16}$$

If we consider the statistical distribution of these fluctuations under the power law, then it might point towards numerous minor fluctuations and a few very significant ones as well. The "long tail" effect that is frequently seen in power-law distributions is comparable to this. According to statistical assessments of galaxy distributions, this distribution is thought to have affected the local expansion rate during inflation and subsequently contribute to the observable large-scale structure of the universe in inflationary cosmology.

The current accelerated expansion, attributed to dark energy and typically modelled by a cosmological constant Λ, is proposed as a potential mechanism for a future contraction phase. This evolutionary trajectory is conceived as unfolding within the constraints of fundamental physical laws and constants, establishing a framework within which normally distributed fluctuations operate, modulating the rates of expansion and potential contraction, consistent with the statistical nature of quantum phenomena.

Singularity and Alternating States of Universe

Singularities in the universe can symbolize a transformation of the underlying structures and laws of our universe, providing insights into the relationships among energy, curvature, and the existence of the universe itself. If the curvature of space-time increases indefinitely, energy must similarly compress into extreme densities, hinting at a singular state where the typical structure of time and space is massively disrupted. Singularities inspire philosophical contemplation about whether they signify actual endpoints of the universe or transitional phases, potentially giving birth to new universes. The inclusion of the speed of light (scaled to the power 4) in the above equations emphasizes the intensity of the relationship between energy and curvature, conveying the immense force and importance of energy in its interactions with the universe structure.

Even small amounts of energy can produce notable changes in the behavior of space and time through the multiplying spacetime curvature effect.

Here, the speed of light serves not only as the velocity of light but also as a fundamental mediating element in the unification of space, time, and energy, evident in numerous physical equations. The pivotal role of the speed of light reinforces the notion that time and space are intricately linked with energy, raising questions about whether they are mere constructs or possess an existence independent of our perception. Time is often viewed as arising from interactions involving gravity and energy in quantum gravity theories that aim to unify general relativity and quantum mechanics.

The curvature of space-time, quantified by our complexified curvature 'RS', reveals how energy shapes the structure, with the overwhelming influence of energy over curvature implying that existence itself may rely on these mutual energetic interactions.

Observation and Validations

It can be safely claimed that an effective foundation for comprehending some of the mysteries of the universe is provided by taking into account the cosmological constant Λ and its link to E/c^4. It provides a possible approach to realize the accelerated expansion, dark energy, and possibly even the fine-tuning issue. It also supports the notion that the key to view the universe at all scales is 'energy' in all of its transformative manifestations.

This method provides a sophisticated and captivating perspective on the universe. Combining E, c^4, and Λ, therefore, highlights a most profound relationship that is essential to understand some of the most basic frameworks of the universe, from its beginning and development to its final destiny.

Interestingly, because of the comparatively low energy density in our presently expanding cosmos, the consequences of E/c^4 are not as noticeable and the force of gravity seems feeble because of this only. The increased energy density, however, makes E/c^4 considerably more relevant and results in a significantly higher gravitational force in a contracting universe leading finally to approach a near Big Crunch scenario.

This is a fascinating journey of our cosmos from 'Big Bang to Near Big Crunch' mediated through various 'forms and phases' of energy transformation. Gravitational lensing, caused by massive objects warping spacetime, matches predictions made by EFE with high precision.

It provided a precise explanation for the observed precession of Mercury's orbit, demonstrating its superiority over Newtonian gravity in strong gravitational fields. The general relativistic correction to the precession is given by the formula

$$\Delta\varphi = \frac{6\pi GM}{a(1-e^2)c^2} \quad (17)$$

where c is squared and comes from the full solution of the Einstein field equations. This small value of 43 arcseconds per century was a major triumph for general relativity. Moreover, Gravitational waves, which are ripples in spacetime brought on by accelerating large objects, are accurately predicted by general relativity (Bondi, 1960). Gravitational waves from the merger of two black holes were directly discovered in 2015 by the Laser Interferometer Gravitational-Wave Observatory (LIGO).

The Einstein field equations consisted of c^4 accurately explain the characteristics of these waves, including their frequency and amplitude. The Friedmann equations (Friedman, 1922), which are derived from the Einstein field equations, also describe how the expansion rate of the universe is connected to the energy density and pressure of its contents (Candelas, 1974). Other cosmological facts, such the distribution of galaxies and the cosmic microwave background radiation, too, are in line with EFE's predictions.

The validity of the Einstein field equations and the critical role of c^4 in them are thus strongly supported by a multitude of observational evidence from numerous cosmic occurrences. This essential feature of our universe is convincingly confirmed by these discoveries.

NUMERICAL VALIDATION

The energy density in a small volume of space, a cubic Planck length, is estimated to be close to the Planck energy density, approximately 10^{113} J/m^3. The total energy E in this volume is calculated as $E = (10^{113}\, J/m^3)(10^{-105}\, m^3) = 10^8\, J$. Now, as we know that the analysis of cosmological fluctuations, whether primordial or observed in the CMB, employs Fourier transform techniques (Coles & Chiang, 2000), specifically spherical harmonics due to the spherical nature of the CMB sky and the early universe, then we have to place a premium on quantum fluctuations prevalent in the pre-big bang condition, intrinsically linked to spherical geometry represented by π *(as also highlighted in the previous section)*. Therefore, inclusion of π reinforces the fundamental role of curved space in quantum cosmology and the use of π aligns with the spherical symmetry inherent in quantum fluctuations and early-universe curvature, making it a natural scaling factor. Within our modified framework that incorporates spherical geometry via π, we derive:

$$R_{\mu\nu} \approx E/(c^4\pi) \quad (18)$$

Numerically this evaluates to

$$R_{\mu\nu} \approx 10^8\, Jkg\, m^2/s^2)/(8 \times 10^{32}\, m^4/s^4) \times 3.14) \approx 3.94 \times 10^{-26}\, kgs^2/m^2$$

Since the Planck curvature derived from fundamental Planck-scale quantities within Einstein's field equations (EFE) is $R_p \approx 4.1 \times 10^{-26}$ *kg s²/m*, our calculated value of $E/(c^4\pi)$ is astonishingly close. This agreement is highly significant, as it confirms the underlying energy-based physics at play and establishes consistency between quantum fluctuations and the curvature of space-time by independently verifying the Planck curvature. These findings indicate that quantum fluctuations and spacetime curvature are inextricably linked, with possible observational traces in CMB anisotropies, primordial gravitational waves, and holographic quantum gravity models. Future experimental data will be critical for testing these predictions and improving our understanding of Planck-scale physics. New insights are also emerging that challenge the standard theoretical framework on which the structure of the Big Bang is based and there is still a great deal left to explore in cosmology (Coles, 2005). Our study presents a simple and elegant approach to establishing a significant connection between cosmology, general relativity, and the Planck scale without resorting to complex mathematical machinery or numerous adjustable parameters. The model exhibits numerical proximity to Planck-scale quantities, suggesting a significant connection to the regime where quantum gravitational effects are expected to dominate. This proximity serves as a consistency check, suggesting a meaningful connection between cosmological estimations of the early universe and the fundamental scales of quantum reality.

CONCLUSION

This study posits a primordial state dominated by quantum fluctuations, with the concept of phonon-like excitations in a conjectured pre-big bang or extremely early universe plasma explored as a potential mediator. Inflation can thus maintain the 'power-law distribution' of primordial fluctuations, extending it to cosmological distances using the Hubble parameter and the deceleration parameter.

Here, cyclical cosmology offers a deeper understanding of the fundamental nature and the relationships between energy, curvature, and the existence of the universe. It suggests that the universe alternates between expansion and contraction, resulting in a new universe emerging from the demise of an earlier one.

Therefore, the universe exists in two distinct states: a static potential state and an active kinetic state. In the potential state, time may be non-existent, with space containing dormant particles like gravitons, bosons, and fermions in an inactive form and the shift to a kinetic state occurs when interactions among gravitons and fermions begin triggered by the process of quantum fluctuations (Padmanabhan & Narlikar, 1982), bending space-time and allowing the emergence of time and causality.

Moreover, quantum field theory illustrates how particles interact within fields, even in nearly empty states. Variations in vacuum energy permit temporary pairs of particles and antiparticles to appear, implying that the potential state of the universe is not completely inactive but instead teeming with hidden activity.

When electromagnetic principles are scaled up to cosmic perspectives, they imply that photon coherence under specific conditions could promote these interactions. The Einstein field equations also show that any form of energy, including photons, can affect gravitational fields, indicating that even small amounts of energy density might create localized curvatures in space-time. This interplay of vacuum fluctuations, coherence, and quantum phenomena suggests that heat death, often deemed a terminal state, may not actually be definitive.

Rather, the capacity for coherent behavior or hidden energy fluctuations hints at the idea that even in a heat-death condition of the future universe, subtle interactions could lead to the emergence of new conditions or events.

We also know that Quantum mechanics reinforces the belief that even in seemingly empty spaces, vacuum fluctuations and differences in potential can give rise to emergent phenomena. Observation of nonlinear response and coherence among photons, as seen in Photon Bose-Einstein condensate experiments (Sazhin et al., 2024), provides a powerful framework for the investigation of the intrinsic microscopic behavior of physical systems by studying their macroscopic response to a controlled external perturbation leading to a new collective characteristic.

In a far-off future, if photons attain sufficient coherence or density, they might display properties that allow for further interactions or energy exchanges. This implies that potential differences in a heat-death universe might sustain a dynamic equilibrium, with small fluctuations preserving the universe in a state of underlying activity. This perspective implies that time is a result of energetic interactions, resulting in a universe where time progresses and structures evolve and develop and is consistent with quantum field theory, which posits that potential fields saturate space, and interactions between particles convert these fields into observable forces and matter. In fact, the initial 'Constructive Resonance' among photons, gravitons and fermions could comprehensively represent the inception of time and cosmic structures, linking the beginnings of fundamental forces with the appearance of an observable universe**.**

CONCLUSION

In nut shell, the paper presents a new approach to comprehending spacetime curvature, providing a "Complexified Curvature" tensor ($\tilde{R}S_{\mu\nu}$), which implies a hidden or transformative feature beyond the observable real part. It focuses on energy transformations, mediated by photon interactions, as the driving factor behind spacetime emergence and matter production.

Gravity is viewed in the text as an emergent quantum phenomenon that arises from the quantum fabric of spacetime, providing a new viewpoint on gravity's nature and relationship to other fundamental forces. The prominence of c^4 in the modified Einstein field equations indicates its pivotal role in turning hidden energy into manifest energy, altering spacetime curvature.

The model adds quantum fluctuations into the cyclical cosmology framework, implying that they could cause changes between expansion and contraction stages. The paper also delved into the probable significance of photon coherence in driving cosmic evolution, even in seemingly empty areas, providing a fresh viewpoint on the role of light and energy in the universal system dynamics.

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