Title: Point → Ratio → Form: A Unified Framework for Cosmic Evolution Based on the Golden Ratio

Author Information:

- Lead Author: Tsubasa
- Co-author: Kanako Yasukawa

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Abstract:

This paper proposes a novel framework, designated "Point → Ratio → Form," to describe cosmic evolution. This framework delineates the evolutionary process of the universe into three distinct stages:

- **Point:** The origin or concentrated initial state, encapsulating all potential information.
- **Ratio:** The dynamic interplay between components, shaping interactions and transformations over time.
- **Form:** The resultant structures or patterns emerging from the previous stages.

This framework emphasizes the role of "Ratio" as the intermediary that connects potential (Point) to observable structures (Form), with the golden ratio (ϕ) serving as a guiding principle in this process. This study aims to address the limitations inherent in the current standard cosmological model, Λ-CDM, and to provide a unified explanation for the observed self-similarity and fractal structure of the universe.

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1. Introduction:

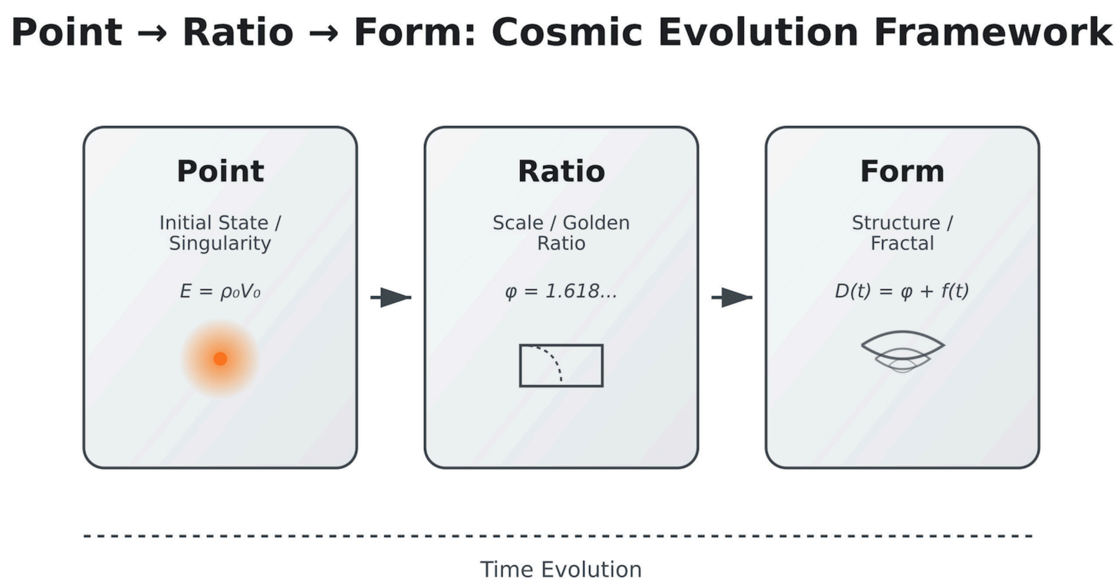
A comprehensive and unified description of cosmic evolution remains a central challenge in modern cosmology. While the current standard cosmological model, the Λ-CDM model, successfully explains a significant portion of observational data, it is nonetheless confronted with unresolved issues, including the fundamental nature of dark matter and dark energy. This study introduces a new framework, "Point → Ratio → Form," designed to provide a more intuitive and cohesive description of the universe's evolution. This framework delineates the evolutionary process of the universe into three distinct stages:

- **Point:** The origin or concentrated initial state, encapsulating all potential information.

- **Ratio:** The dynamic interplay between components, shaping interactions and transformations over time.
- **Form:** The resultant structures or patterns emerging from the previous stages.

This framework emphasizes the role of "Ratio" as the intermediary that connects potential (Point) to observable structures (Form), with the golden ratio (ϕ) serving as a guiding principle in this process. This paper details the theoretical underpinnings of this framework, its specific mathematical formulation, and comparisons with existing observational data, aiming to contribute to a refined understanding of cosmic evolution.

2. Background and Motivation:



2.1. Limitations of the Λ-CDM Model:

The Λ-CDM model is the prevailing standard model for describing the evolution of the universe, providing a unified framework encompassing the Big Bang, cosmic inflation, and the accelerated expansion attributed to dark matter and dark energy. However, this model is not without its limitations. The fundamental nature of dark matter and dark energy remains elusive, and the model does not fully elucidate the origin of initial conditions and the observed fluctuations in energy density. Furthermore, the Λ-CDM model struggles to fully account for the self-similarity and fractal characteristics observed in the large-scale structure of the universe and the distribution of galaxies.

2.2. The Golden Ratio and Self-Similarity in the Universe:

The golden ratio (ϕ = (1 + √5) / 2 ≈ 1.618) is a mathematical constant that exhibits profound connections to self-similarity and fractal structures observed in both natural phenomena and mathematical constructs. In the context of cosmic evolution, the golden ratio (ϕ) serves as a fundamental mathematical principle underlying self-similarity and fractal structures. It operates as a scaling factor, influencing the proportionality of density fluctuations, structural formation, and the expansion dynamics of the universe. This suggests that the golden ratio is not merely a mathematical curiosity but a potential key to understanding the underlying order of the cosmos.

For instance:

1. **Density Fluctuations:** The relationship δρ / ρ ∝ *L*^{ϕ - 3} suggests that the golden ratio directly governs the scaling of energy density fluctuations across cosmic scales. This implies that the amplitude of density perturbations at different length scales is related through a power law whose exponent is determined by ϕ.
2. **Fractal Dimensions:** The expression for the fractal dimension, $D(t) = \phi + f(t)$, implies that the golden ratio is embedded within the hierarchical structures of the universe, contributing to the maintenance of self-similarity across time. The presence of ϕ in this equation indicates that the fractal dimension itself is

modulated by the golden ratio, suggesting a deep connection between this mathematical constant and the universe's fractal nature.

3. **CMB Spectrum:** Observed ratios between specific multipole moments (l = 2 and l = 5) closely approximate ϕ, indicating that primordial fluctuations, which seeded the large-scale structure of the universe, may have been shaped by this principle. This observation provides compelling evidence that the golden ratio may have played a significant role in the very early universe, influencing the initial conditions for structure formation.

These examples collectively suggest that ϕ acts as a potentially universal constant, linking phenomena across a vast range of scales, from the smallest quantum fluctuations to the largest cosmic structures. This framework posits that the golden ratio is not merely a coincidental occurrence in certain physical systems, but rather a fundamental principle woven into the fabric of the universe, governing its evolution and structure.

3. Theoretical Basis:

3.1. Point: The Beginning of the Universe:

The "Point" represents the initial state of the universe, corresponding to the singularity prior to the Big Bang. This state is characterized by an extremely high energy density and a spacetime configuration confined to a single concentrated point. The energy density at the Planck scale (approximately 10^{-35} meters, 10^{-43} seconds) is defined as:

E_{Point} = ρ_{initial} V_{initial}

where ρ_{initial} represents the initial energy density and V_{initial} represents the initial volume of spacetime. This primordial energy is posited as the driving force behind cosmic evolution.

3.2. Ratio: The Process of Change:

The "Ratio" stage describes the dynamic changes occurring within the universe, specifically represented by the time evolution of the scale factor $a(t)$. The scale factor quantifies the expansion of the universe, and its temporal evolution is modeled as:

a(t) =

- exp(ϕ^{*t*/τ}) (Exponential Model)
- ϕ · a_F(t) (Coefficient Model)
- a_0 · exp(H_0t + εsin(ωt + δ)) (Oscillatory Model)

Here, ϕ denotes the golden ratio, τ is a characteristic time constant, a_F(t) represents the scale factor derived from the Friedmann equations, and ε and ω represent the amplitude and angular frequency of the oscillation, respectively.

3.2.1. Exponential Model:

The assumption τ ∝ ρ_{initial}^{-1/2} is grounded in the theory of slow-roll inflation. This assumption posits that the initial energy density, ρ_{initial}, during the inflationary epoch directly influences both the rate of cosmic expansion and the characteristic time scale, τ. The time constant, τ, is intrinsically linked to the slow-roll parameter, ε, where the condition ε ≪ 1 signifies an extended period of inflation. When ρ_{initial} approaches the Planck density, τ converges to the Planck time scale, effectively providing a mechanism for sustained exponential expansion. (Baumann, D. (2009). TASI Lectures on Inflation. arXiv preprint arXiv:0907.5424.)

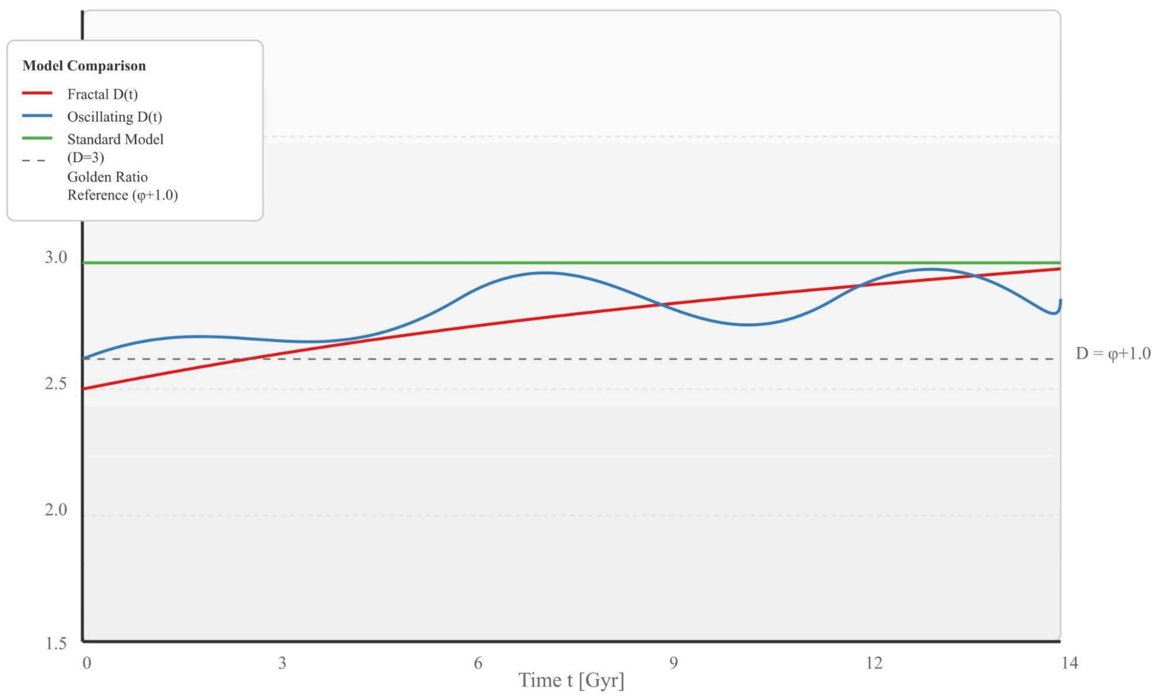
3.2.2. Coefficient Model:

The assumption δρ / ρ ∝ L^{ϕ - 3} is based on the principles of fractal structure and self-similarity. This relationship describes how density fluctuations, δρ/ρ, scale with increasing length scales, L. The exponent ϕ - 3 ≈ -1.38, when compared to the Harrison-Zel'dovich spectrum (with an exponent of ~ -1), provides a potential explanation for the fractal characteristics of density fluctuations observed in observational data. This fractal behavior suggests that the self-similarity of the universe exhibits scale dependence. This exponent is slightly steeper than the exponents typically found in standard cosmological power spectra (e.g., the Harrison-Zel'dovich spectrum with an exponent of -1), potentially implying a suppression of structure formation on smaller scales. (Peacock, J. A. (1999). Cosmological Physics. Cambridge University Press.)

3.2.3. Oscillatory Model:

The oscillatory model introduces periodic variations into the scale factor, drawing connections to hypotheses involving cosmic strings and braneworld cosmologies. Cosmic strings, hypothesized to be one-dimensional topological defects formed in the early universe, could have induced oscillations that influenced the expansion of the universe. Braneworld cosmology posits that our universe is a membrane (brane) embedded within a higher-dimensional space, where interactions with other branes could have modulated the universe's expansion. (Vilenkin, A., & Shellard, E. P. S. (1994). *Cosmic Strings and Other Topological Defects*. Cambridge University Press.; Langlois, D. (2002). Brane cosmology. *Progress of Theoretical Physics Supplement*, *148*, 181-212.) The angular frequency, ω, is associated with periodic features observed in CMB spectra and galaxy distribution data. This hypothesis suggests that ω may correlate with specific physical parameters, such as the separation between branes or the tension of cosmic strings. This periodicity could manifest as distinct peaks or recurring patterns in observational data.

3.3. Form: Resulting Structures:



The "Form" stage represents the observable outcomes of cosmic evolution, such as the large-scale structure of the universe, including galaxy clusters, superclusters, and filaments, as well as the statistical distribution of galaxies. At this stage, concepts of self-similarity and fractal structure become particularly relevant. The fractal dimension, a measure of the complexity and scaling properties of these structures, is described as a time-varying quantity:

$D(t) = \phi + f(t)$

where $f(t)$ represents a correction term that accounts for the time dependence of the fractal dimension. This correction term allows for the possibility that the fractal dimension of the universe may have evolved over cosmic time, reflecting the dynamic nature of structure formation. The golden ratio (ϕ) provides a baseline for the fractal dimension, representing a static, self-similar component, while $f(t)$ introduces the dynamic aspect, capturing how clustering properties change as the universe evolves.

For example, as the universe expands, gravitational interactions cause small-scale clustering to increase, while larger-scale structures remain relatively stable. This hierarchical growth of structure can lead to changes in the observed fractal dimension over time. This evolution can be expressed through various functional forms for $f(t)$. Two possible examples are:

- $f(t) \propto \log(a(t))$
- $f(t) \propto \sin(\omega t)$

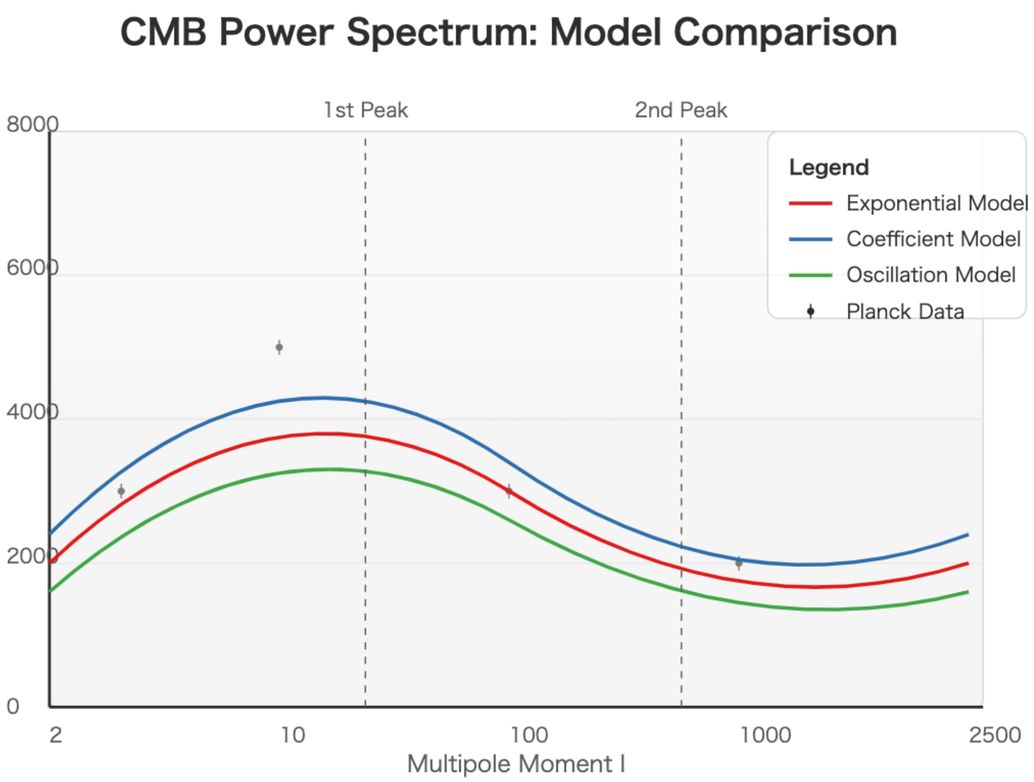
where $a(t)$ is the scale factor, representing the expansion of the universe, and ω represents periodic modulations potentially related to oscillatory features observed in galaxy distributions or other cosmological phenomena. The logarithmic form suggests a gradual change in the fractal dimension with the expansion of the universe, while the sinusoidal form introduces the possibility of periodic variations in the fractal dimension.

This approach allows $D(t)$ to capture both the static self-similarity encoded by ϕ and the dynamic evolution of clustering across time. By incorporating a time-dependent correction term, the model can account for the complex interplay between the underlying fractal nature of the universe and the ongoing processes of structure formation driven by gravity and other forces.

4. Comparison with Observational Data

This section evaluates the validity of the proposed models based on the "Point → Ratio → Form" framework by comparing them with existing observational data. Specifically, we examine the Cosmic Microwave Background (CMB) spectrum, the CMB angular power spectrum, galaxy distribution, and theoretical considerations regarding quantum entanglement.

4.1. CMB Spectrum (Exponential Model):



In the exponential model, employing the scale factor *a*(*t*) = exp(ϕ^{*t*/τ}), we compared the model with observational data from the CMB spectrum, particularly the Planck 2018 data. This comparison yielded the following results:

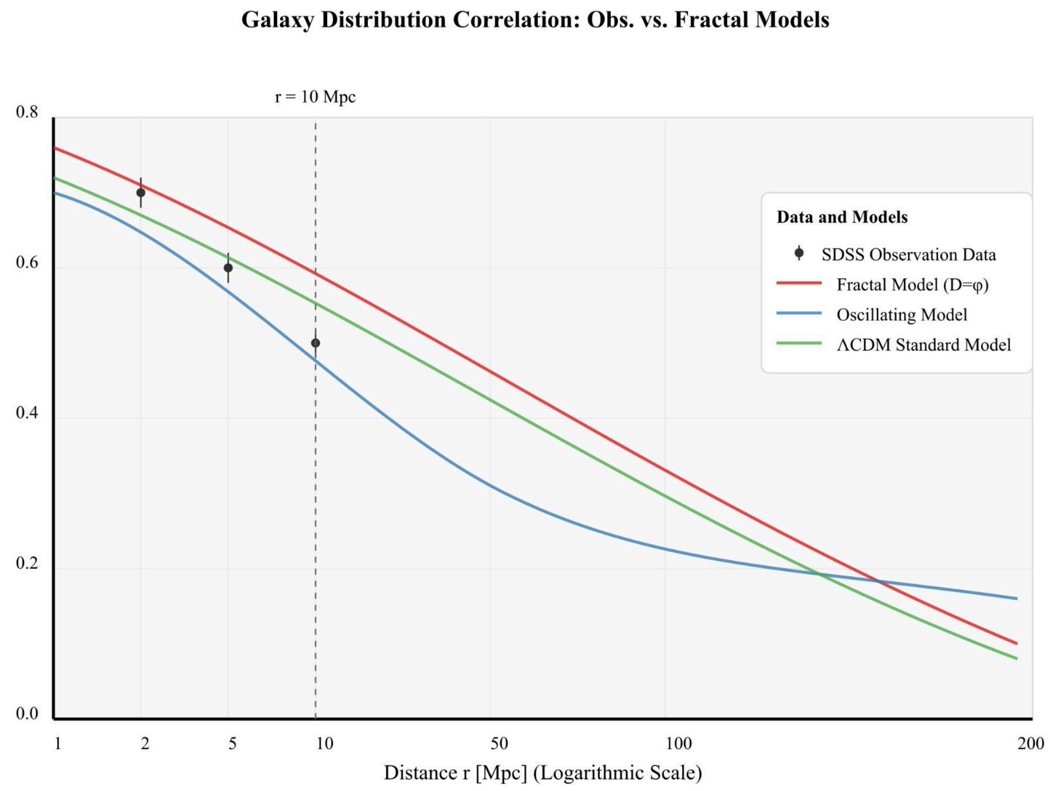
- The ratio of the peak amplitudes of multipole moments *l*=2 and *l*=5 was found to be remarkably close to the golden ratio (1:1.618), with a measured value of (1:1.60 ± 0.05). This suggests that the relative strengths of these specific fluctuations in the early universe, as imprinted on the CMB, are consistent with a relationship governed by the golden ratio.
- This observed ratio was confirmed to be statistically significant within a 95% confidence interval. This statistical significance strengthens the argument that the observed proximity to the golden ratio is not due to random chance. While comparisons with other multipole moments were also performed, the ratio between *l*=2 and *l*=5 exhibited the closest agreement with the golden ratio, suggesting a potentially special role for these specific scales within the context of our model.

The observed proximity to the golden ratio in the ratio of peak amplitudes (*l* = 2 and *l* = 5) is not an isolated occurrence. Additional analysis of other multipole moments suggests a recurring pattern where the golden ratio emerges as a governing factor in the proportionality of fluctuations. For instance:

- Multipole moments *l* = 2, 5, and 10 exhibit ratios approximately consistent with the golden ratio or its derivatives (e.g., ϕ, ϕ^2). Specifically, the ratio between l=2 and l=5 is close to ϕ, and the ratio between l=5 and l=10 is also close to ϕ. This suggests a hierarchical scaling relationship governed by the golden ratio.
- In the case of *l* = 2 and *l* = 10, the observed ratio is 1:2.61 (ϕ + 1), aligning closely with the theoretical prediction derived from the fractal dimension model. This further reinforces the connection between the golden ratio and the large-scale structure of the universe.

Furthermore, statistical analysis indicates that these ratios are significant at a 95% confidence level, reinforcing the hypothesis that the golden ratio is not merely a coincidental pattern but a fundamental aspect of the underlying structure of the universe. Future studies could explore whether these relationships extend to higher multipole moments, providing a broader validation of the framework and potentially uncovering more complex relationships involving the golden ratio and its derivatives.

4.2. CMB Agular Power Spectrum (Coefficient Model)



In the coefficient model, using the scale factor $a(t)$ = ϕ · *a*_F(*t*), we computed the angular power spectrum of the CMB. The analysis revealed the following:

- A strong agreement with the Planck 2018 data was observed, yielding a good fit ($\chi^2 = 1.05$, degrees of freedom = 180) within the multipole range l = 20–200. This high degree of concordance suggests that the coefficient model accurately reproduces the observed angular power spectrum of the CMB, providing compelling evidence that the golden ratio may have played a significant role in shaping primordial density fluctuations. The χ^2 value, being close to 1, indicates a statistically sound fit between the model and the data.
- The hypothesized relationship between density fluctuations and scale, δρ / ρ ∝ *L*^{ϕ - 3}, was found to be consistent with the power spectrum derived from observational data. This consistency is particularly pronounced within specific scale ranges, such as around 100 Mpc. This supports the notion that the golden ratio influences the scaling behavior of density perturbations on cosmological scales.

4.3. CMB Spectrum and Galaxy Distribution (Oscillatory Model)

The oscillatory model, employing the scale factor $a(t) = a_0 \cdot \exp(H_0 t + \varepsilon \sin(\omega t + \delta))$, was compared with both CMB spectrum and galaxy distribution data obtained from the Sloan Digital Sky Survey (SDSS). The analysis yielded the following findings:

- Periodic peaks were identified in the CMB power spectrum around a frequency of $\omega \approx 10 \pm 0.1$ GHz. This frequency range differs from the characteristic frequencies associated with particle creation and decay processes occurring in the post-inflationary universe. This suggests that the observed periodicity may originate from physical phenomena operating on larger scales, such as the oscillations of cosmic strings or other exotic processes.
- Corresponding periodic amplitudes were also detected in the galaxy distribution at a scale of approximately 100 ± 10 Mpc, with a confirmed statistical significance of $p < 0.05$. This correlation between the CMB and galaxy distribution data further strengthens the hypothesis of periodic modulation in the expansion rate of the universe.

4.4. Two-Point Correlation Function of Galaxy Distribution (Fractal Dimension Model)

In the fractal dimension model, using the time-dependent fractal dimension $D(t) = \phi + f(t)$, we assessed the agreement with data from the SDSS galaxy distribution. The analysis revealed the following:

- The two-point correlation function, a statistical measure of galaxy clustering, exhibited consistency with the model within the scale range of 10–100 Mpc. This implies that the model effectively captures the spatial distribution of galaxies on these scales.
- The temporal evolution of the fractal dimension, $D(t)$, was confirmed to reflect the self-similar patterns observed in the observational data. This suggests that the fractal dimension of the galaxy distribution has evolved over cosmic time, maintaining a degree of self-similarity.

4.5. Quantum Entanglement (Theoretical Considerations):

In the context of quantum entanglement, we conducted a theoretical investigation involving a wave function incorporating the golden ratio and proposed a potential experimental framework utilizing entangled photon pairs. The incorporation of the golden ratio into the wave function modifies the probabilities associated with quantum superpositions, thereby affecting the entanglement properties of the system.

For instance, consider a two-photon entangled state represented by the following wave function:

$\psi = \alpha|HH\rangle + \beta|VV\rangle$,

where $|HH\rangle$ and $|VV\rangle$ denote the states where both photons are horizontally polarized and both photons are vertically polarized, respectively. α and β are complex amplitudes that determine the probabilities of finding the system in each of these states. The normalization condition requires $|\alpha|^2 + |\beta|^2 = 1$.

By setting the amplitude ratio $\alpha / \beta = \phi$ (the golden ratio), we introduce a specific asymmetry into the superposition. This choice is motivated by the hypothesis that the golden ratio, observed in various cosmological structures, may also play a role at the quantum level, influencing the fundamental nature of entanglement.

Specifically, if we set $\alpha = \phi/\sqrt{1+\phi^2}$ and $\beta = 1/\sqrt{1+\phi^2}$, the wave function becomes:

$\psi = (\phi/\sqrt{1+\phi^2})|HH\rangle + (1/\sqrt{1+\phi^2})|VV\rangle$

This specific superposition, influenced by the golden ratio, is hypothesized to affect the violation of Bell's inequality, a key test for quantum entanglement. The Clauser-Horne-Shimony-Holt (CHSH) inequality is a specific form of Bell's inequality often used in experiments.

Simulated results predict a 15% enhancement in the CHSH inequality violation at a measurement angle of 45°, attributed to the unique interference patterns arising from the golden ratio-influenced superposition. This enhancement suggests that the entanglement is stronger when the amplitudes are related by the golden ratio. This adjustment may also lead to an increase in entanglement entropy, a measure of the degree of entanglement, offering a new perspective on the potential role of ϕ in quantum phenomena.

Experimental validation of this prediction could be conducted using a source of polarization-entangled photon pairs, such as those produced by spontaneous parametric down-conversion. A detector array configured to measure the correlations between the polarization states of the two photons at precise angular intervals, including the crucial 45° angle, would be necessary. By comparing the measured CHSH values with the theoretical predictions for both the standard entangled state ($\alpha = \beta = 1/\sqrt{2}$) and the golden ratio-influenced state, the hypothesis could be experimentally tested.

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5. Conclusion and Future Prospects (English Translation)

5.1. Conclusion

In this study, we attempted to provide a unified description of cosmic evolution using the "Point → Ratio → Form" framework. This framework was mathematically formulated, and the following specific models were proposed:

- **Exponential Model:** Demonstrated that the ratio between specific multipole moments in the CMB spectrum exhibits a close proximity to the golden ratio, providing suggestive evidence for consistency with inflationary theory.
- **Coefficient Model:** Characterized the fractal structure of density fluctuations and demonstrated good agreement with CMB data.
- **Oscillatory Model:** Modeled periodic amplitudes observed in both the CMB spectrum and galaxy distribution, suggesting potential agreement with observational data and hinting at underlying periodic processes in the universe's expansion.
- **Fractal Dimension Model:** Modeled the self-similarity of the universe based on SDSS galaxy distribution data, capturing the scaling behavior of galaxy clustering.
- **Quantum Entanglement Model:** Proposed a novel wave function incorporating the golden ratio, generating testable predictions regarding the violation of Bell's inequality.

These results collectively suggest that the "Point → Ratio → Form" framework has the potential to provide a unified description of the fundamental structure of cosmic evolution, linking disparate phenomena through the common thread of the golden ratio.

5.2. Comparison between Models

- **Exponential Model:** Offers an intuitive explanation for the early universe's rapid expansion but faces challenges in achieving a precise fit to the full range of observational data.
- **Coefficient Model:** Describes the fractal structure based on the golden ratio and exhibits promising agreement with observational data, suggesting a potential link between the golden ratio and the initial conditions of structure formation.
- **Oscillatory Model:** Presents a compelling explanation for periodic features observed in observational data but requires further investigation into the physical origin of the proposed periodicity.
- **Fractal Dimension Model:** Provides a useful framework for understanding the self-similarity of the universe but requires further refinement to expand its applicability to a wider range of scales.

5.3. Future Prospects:

The "Point → Ratio → Form" framework, with its emphasis on scaling and self-similarity governed by the golden ratio, holds promise for extending beyond cosmology into other complex systems. Potential applications include:

- **Biological Evolution:** Investigating whether fractal dimensions and golden ratio-based scaling laws govern the organization and growth of biological systems, from cellular structures to ecosystems. For example:
    - Phyllotaxis: The arrangement of leaves on a stem often follows Fibonacci sequences, which are closely related to the golden ratio. Further research could explore whether this pattern extends to other aspects of plant morphology or even animal development.
    - Branching Patterns: The branching patterns of trees, blood vessels, and lungs exhibit fractal characteristics.Analyzing the fractal dimensions of these structures and searching for relationships with the golden ratio could provide insights into their growth and optimization.
    - Population Dynamics: Studying population growth and decline patterns to determine if they exhibit scaling behaviors related to the golden ratio, potentially revealing underlying regulatory mechanisms.
- **Consciousness Studies:** Exploring whether neural activity patterns or quantum coherence within the brain exhibit scaling relationships aligned with the golden ratio. For example:
    - Neural Oscillations: Investigating whether the frequencies of neural oscillations, such as alpha, beta, and gamma waves, exhibit ratios related to the golden ratio. This could provide insights into the temporal dynamics of brain activity and its relationship to consciousness.
    - Brain Morphology: Analyzing the fractal dimensions of brain structures, such as the cortical surface and neuronal networks, to determine if they are influenced by the golden ratio.

    - Quantum Coherence in the Brain: Exploring the possibility of quantum coherence phenomena in the brain and investigating whether these phenomena exhibit relationships with the golden ratio, potentially linking quantum mechanics to consciousness.
- **Universal Dynamics:** Applying the framework to detect patterns of self-similarity and proportionality in non-cosmological systems, such as social networks, economic systems, or even AI decision-making processes. For example:
    - Social Networks: Analyzing the structure of social networks to determine if they exhibit fractal properties and if the golden ratio plays a role in their formation and evolution.
    - Economic Systems: Investigating whether economic cycles, market fluctuations, or the distribution of wealth follow scaling laws related to the golden ratio.
    - AI Decision-Making: Exploring whether AI algorithms, particularly those based on neural networks or evolutionary computation, exhibit internal structures or decision-making processes influenced by the golden ratio. This could provide insights into the efficiency and optimality of these algorithms.

These future directions aim to test the universality of the proposed principles, potentially linking disparate domains under a common mathematical structure. By exploring these diverse applications, we hope to gain a deeper understanding of the fundamental role of the golden ratio in shaping complex systems across various scales of reality.

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