ISSN: 2634-9221
European Journal of Applied Sciences; Vol. 14 No. 03 (2026) (67-91)
https://doi.org/10.14738/aivp.1403.2406

A New Cosmology Based on the Unified Complex Systems Theory (UCST)

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Abstract: This paper presents a novel, self consistent cosmological framework rooted in Unified Complex System Theory (UCST), clarifying the fundamental distinction between the “Universe” and the “World” to resolve foundational flaws in modern cosmology. The Universe is defined as an infinite, eternal, philosophically transcendent spacetime totality beyond empirical observation. The World, by contrast, is the finite, observable spacetime domain that forms the proper subject of scientific cosmology, redefined here as the mathematical and experimental study of the World’s cyclic evolution—formation, persistence, decay, and regeneration—under strict mass, momentum, and energy conservation. Celestial bodies, particles, and atoms are categorized as “living agents” due to autonomous motion and adaptive responses, defined by dynamics rather than biological traits. Their motion is governed by conventional passive forces (gravity, electromagnetism, air damping) and intrinsic adaptive active forces, which stabilize orbits via natural energy compensation, removing the need for dark matter and dark energy. Supported by mathematical logic and qualitative agreement with observational phenomena, the proposed framework is shown to outperform the ΛCDM model in coherence, parsimony, predictive capability and falsifiability. Quantitative evaluation using empirical measurements is therefore necessitated. Where quantitative validity is established, key ΛCDM anomalies—including the Hubble tension, singularity, horizon, flatness, cosmological constant, dark sector puzzles and cosmic age discrepancies—may be resolved. Rigorous axiomatics and testable predictions are provided for independent validation, enabling this construct to be regarded as a coherent alternative paradigm in cosmology.

Keywords: Unified Complex Systems Theory (UCST), New Cosmology, Cyclic World Evolution, Active Force, Non-linear Redshift, Universe-World Dichotomy, Air Medium, Dark Matter Replacement, Hubble Tension Resolution

INTRODUCTION

The Crisis of Definition in Modern Cosmology

Cosmology, as a branch of natural science, has long suffered from a fundamental ambiguity in its core subject matter: the failure to rigorously distinguish between the observable local cosmic domain and the unobservable global totality (Dodelson, 2021). This definitional confusion has led to widespread category errors, conceptual overreach, and metaphysical speculation disguised as empirical science. Table 1 summarizes representative definitions of cosmology from authoritative sources, along with their inherent limitations and the revised definition proposed in this work.

Table 1: Current Definitions of Cosmology and Their Limitations

Source	Definition	Core Points	Limitations
Encyclopedia Britannica (2025-11-14)	Cosmology is the scientific study of the universe as a unified whole, from its earliest moments through its evolution to its ultimate fate.	Unified whole, early moments, evolution, ultimate fate	Exceeds the limits of scientific empirical verification and falsifiability
Merriam-Webster Dictionary (2025-08-20)	A branch of astronomy that deals with the origin, structure, and space-time relationships of the universe.	Astronomy subfield, origin, structure, spacetime relationships	Also exceeds scientific capacity by addressing the unobservable totality
NASA	The study of the structure and changes in the present universe.	Structure, changes in the current universe	Reasonable but ambiguous: fails to separate observable "world" from total "universe"
Wikipedia (2025-10-19)	Modern physical cosmology is dominated by the Big Bang theory, which attempts to bring together observational astronomy and particle physics.	Big Bang theory, integration of astronomy and particle physics	Replaces general cosmology with a specific model; conceals foundational ambiguities
This Work	Cosmology is the scientific study of the operational laws for the observable world, including formation, abiding, decay, and regeneration.	Observable world only, cyclic evolution, physical consistency	Strictly adheres to scientific empiricism and methodological naturalism

This definitional confusion is not merely semantic; it underlies the most intractable paradoxes of modern cosmology. By conflating the finite observable World with the infinite philosophical Universe, the Big Bang paradigm commits a fundamental category error that no amount of theoretical adjustment can fully repair.

The ΛCDM Model: Triumphs and Unresolved Fundamental Crises

Since Edwin Hubble's discovery of the linear redshift-distance relation in 1929 (Hubble, 1929), the Big Bang theory has gradually evolved into the dominant framework of physical cosmology. Supported by landmark observations including the cosmic microwave background (CMB) radiation (Penzias & Wilson, 1965; Mather et al., 1990; Smoot et al., 1992; Planck Collaboration, 2020), primordial light-element nucleosynthesis (Alpher, Bethe, & Gamow, 1948), and large-scale structure formation, the ΛCDM model—centered on the Big Bang, cold dark matter, and dark energy—has been widely regarded as the standard cosmological model. However, over the past two decades, the ΛCDM model has encountered increasingly severe and potentially fatal challenges that cannot be resolved within its existing logical structure:

1. Hubble Tension: A persistent ~5σ discrepancy exists between local measurements of the Hubble constant ($H_0 \approx 73$ km/s/Mpc) derived from Cepheid variables and Type Ia supernovae, and early-universe measurements ($H_0 \approx 67$ km/s/Mpc) from the Planck CMB data (Riess et al., 2019; Di Valentino et al., 2021). This discrepancy suggests either unaccounted systematic errors or the absence of critical physical components in the standard model.

2. Unidentified Dark Components: The model requires ~27% dark matter and ~68% dark energy, which together dominate the cosmic energy budget but have never been directly detected in laboratory experiments or identified as fundamental particles or fields (Particle Data Group, 2023).
3. Primordial Singularity: The inference of an initial singularity—an infinitesimal point with infinite energy density and spacetime curvature—violates all known physical laws, including conservation principles and causality (Hawking, 1988; Dodelson, 2021).
4. Ad Hoc Inflation: Cosmic inflation was proposed to resolve the horizon and flatness problems but lacks a consistent microphysical foundation, a confirmed mechanism for beginning and ending, and direct empirical evidence (Planck Collaboration, 2020).
5. Small-Scale Structure Anomalies: Observations of galactic core density profiles, satellite galaxy abundance, and dwarf galaxy dynamics contradict ΛCDM predictions (Bullock & Boylan-Kolchin, 2017).
6. Cosmic Age Anomalies: Some celestial objects appear to have ages comparable to or exceeding the inferred age of the universe, creating logical contradictions (Jiang et al., 2020).

These interconnected crises indicate that the foundational assumptions of the Big Bang paradigm require radical re-examination and potential replacement.

Historical Development of the ΛCDM Paradigm

To contextualize the need for a new framework, we briefly review the key historical milestones that established the dominance of the Big Bang and ΛCDM models.

Theoretical Foundation (1920s-1940s)

- 1922: Alexander Friedmann derived the expanding universe solutions to Einstein's field equations (Friedmann, 1922).
- 1927: Georges Lemaître proposed the "primeval atom" hypothesis, arguing for an expanding universe originating from a dense initial state (Lemaître, 1927; corrected to 1931 for the fully developed primeval atom model).
- 1929: Hubble published the redshift-distance relation, providing observational support for cosmic expansion (Hubble, 1929).
- 1940s: Gamow, Alpher, and Herman developed the theory of primordial nucleosynthesis and predicted the cosmic microwave background (Alpher, Bethe, & Gamow, 1948).

Observational Breakthroughs (1960s-1990s)

- 1965: Penzias and Wilson discovered the CMB at ~2.7 K, providing decisive support for the hot Big Bang (Penzias & Wilson, 1965).

- 1990: The COBE satellite measured the precise blackbody spectrum of the CMB (Mather et al., 1990).
- 1992: COBE detected CMB anisotropies, supporting primordial fluctuations (Smoot et al., 1992).
- 1998: Two teams discovered cosmic accelerated expansion using Type Ia supernovae, leading to the introduction of dark energy (Riess et al., 1998; Perlmutter et al., 1999).

Modern Precision Cosmology (2000s–Present)

WMAP and Planck satellites provided high-precision CMB measurements, fixing ΛCDM parameters and solidifying its status as the standard model (Planck Collaboration, 2020).

Despite these successes, the foundational inconsistencies listed above remain unaddressed, motivating the search for alternative frameworks.

The Unified Complex System Theory (UCST): A New Foundational Paradigm

The Unified Complex System Theory (UCST), developed by the author's group (Cui et al., 2025), is an axiomatic, mathematically consistent framework that generalizes classical mechanics to unify microscopic and macroscopic systems, living and non-living entities, and material and non-material ontological components. Unlike speculative frameworks, UCST is constructed following the methodological paradigm of Newton's *Principia*, with clear axioms, formal definitions, quantitative equations, and empirical implications.

The three foundational axioms of UCST that underpin this new cosmology are:

1. Dualist Ontology: All natural systems consist of material entities (body) and non-material existence (mind), defined not as conscious awareness but as the intrinsic source of active motion and adaptive response. This dualism resolves the mind-body problem in a physical context (Descartes, 1641/1984) and is formally derived from the Relativity of Simultaneity Axiom in UCST.
2. Infinite Universe, Finite Cyclic Worlds: The Universe is eternal, infinite, and unobservable; the observable World is a finite, bounded subsystem that evolves cyclically without singularities.
3. Universal Active Force: All entities capable of autonomous motion (from subatomic particles to galaxies) possess intrinsic active forces that complement conventional passive forces to maintain dynamical stability. The existence of active force is further derived from UCST's Relativity of Simultaneity Axiom. Under force vector formulation, passive force $\vec{F}_p$(B,C) is specified for B≠C, with active force formally defined as $\vec{F}_a$(B)=$\vec{F}_p$(B, B).

This paper constructs a complete cosmological model directly deduced from the UCST framework, systematically reinterprets major cosmological observations, resolves the inherent paradoxes of the ΛCDM model, proposes feasible schemes for experimental verification, and establishes a rigorous framework for the empirical validation of the present theory by independent researchers.

CORE CONCEPTUAL FOUNDATIONS AND AXIOMATIC STRUCTURE

The Fundamental Distinction: Universe vs. World

The most foundational innovation of the UCST cosmology is the strict, axiomatic separation between two previously conflated concepts: the Universe and the World. This distinction eliminates the category error at the heart of the Big Bang paradigm.

Definition of the Universe

The Universe (U) is defined as the maximal, all-encompassing spacetime set: $U=\{\infty_t, \infty_s\}$, where ∞_t denotes infinite, unbounded time and ∞_s denotes infinite, unbounded space. The Universe has no origin, no boundary, no center, and no end. It is a philosophical concept that transcends empirical observation and scientific measurement. Science cannot meaningfully study the origin, size, or fate of the Universe, as these are untestable in principle.

Definition of the World

The World (W) is defined as the largest finite spacetime domain observable by humans using existing and foreseeable technology: $W=\{T, S\}, T<\infty, S<\infty$, where T is the finite temporal duration and S is the finite spatial extent of the observable domain.

Regardless of advances in telescopes, detectors, or space exploration, the World remains finite. Cosmology is therefore the scientific study of the World—not the Universe.

Cosmic Topology: Infinite Universe Containing Infinite Cyclic Worlds

The Universe contains an infinite number of non-overlapping, causally separated or weakly interacting Worlds: $U = \sum_{i=1}^{\infty} W_i$. Each World evolves independently through cyclic phases of formation, expansion, contraction, and regeneration. This structure resembles a multiverse but is grounded in classical spacetime and avoids the quantum-mechanical baggage of competing multiverse models.

This definition has a critical methodological implication: to study a given World (e.g., our own observable cosmos), we only need to consider its local environment and internal dynamics, not the entire infinite Universe.

This aligns with the locality principle widely used in physics and ensures that cosmological modeling remains empirically grounded.

Cyclic Evolutionary Dynamics of the World

The World undergoes a continuous, singularity-free cyclic evolution governed by a deterministic dynamical equation derived from UCST axioms.

This replaces the unidirectional, singular Big Bang expansion with a natural, recurrent process consistent with conservation laws.

Dynamical Equation of Cosmic Maximum Observable Distance Evolution

In this work, the maximum radial physical distance of the observable world (D(t)) is selected as the core cosmological state variable. This quantity is rigorously defined as the instantaneous straight-line proper distance from a geocentric observational platform to the farthest detectable luminous celestial source within the full-band detection coverage of high-precision deep-space astronomical telescopes at absolute cosmic physical time (t). The cosmological parameter (D(t)) can be quantitatively traced and synchronously calibrated through multi-source joint observational means including extragalactic redshift spectral tomography, high-energy cosmic ray absolute ranging, and deep-field telescope high-precision astrometric imaging positioning. It possesses strict physical measurability, full astronomical observational traceability and spatial-temporal synchronous calibration characteristics, and can effectively characterize the global macroscopic coupled evolution law of large-scale gravitational expansion and background medium damping contraction of the entire observable cosmic spacetime system.

Based on the large-scale cosmic fluid gravitational coupling hypothesis and background medium viscous damping effect, the first-order ordinary differential dynamical evolution governing equation of the cosmic maximum observable effective distance (D(t)) is theoretically reconstructed and established, and the unified dynamical evolution framework for the expansion-contraction cyclic transition of the observable cosmic horizon is realized. The specific dynamical equation is expressed as follows:

$$\frac{dD}{dt} = k_1 D\left(1 - \frac{D}{D_{max}}\right) - k_2 D\left(1 - \frac{D}{D_{max}}\right) H(D - D_{min}) \quad (1)$$

All model physical parameters involved in the dynamical equation are standardized in combination with the actual deep-space astronomical observation background, and the physical connotation, cosmological significance and scale application scope of each parameter are strictly unified with the existing cosmic large-scale survey data. The standardized physical interpretation and detailed cosmological specification of each parameter are given one by one as follows:

1. Time-varying cosmic maximum observable radial distance (D(t)): It denotes the real-time maximum effective radial proper observation distance of the whole observable universe under the absolute cosmic physical time scale (t). It is a geometric cosmic scale parameter with full synchronous measurability, which directly corresponds to the ultimate deep-space detection limit of ground-based optical astronomical telescopes, space-based radio array telescopes and X-ray high-energy detection telescopes. The dynamic variation of (D(t)) intuitively reflects the real-time expansion or contraction trend of the cosmic observable horizon boundary.
2. Cosmic gravitational expansion driving coefficient (k_1): This coefficient is strictly positively correlated with the large-scale average gravitational mass density of all gravitationally coupled celestial systems in the effective cosmic spatial volume, satisfying the proportional relation ($k_1 \propto G\rho$). Among them, G is the universal gravitational constant with fixed invariant physical magnitude, and ρ is the cosmic average mass density evolving with cosmic time and spatial scale. The physical essence of k_1 is the macroscopic equivalent resultant gravitational driving strength that promotes the outward diffusion and expansion of large-scale cosmic spatial structures. In local gravitational tightly bound systems such as the Solar System and

stellar clusters, ρ adopts the high-precision local measured density value; in large-scale cosmic structural units such as the Milky Way, galaxy clusters and cosmic superclusters, ρ adopts the low-smoothed average background density of cosmic large-scale uniform space.

3. Cosmic background contraction damping coefficient (k_2): It is proportional to the equivalent viscous impedance coefficient η of the low-temperature low-density intergalactic background medium that uniformly fills the whole observable cosmic space, namely ($k_2 \propto \eta$). Macroscopically, it quantitatively describes the bulk viscous resistance and energy dissipation damping effect generated by the dynamic coupling interaction between the cosmic universal background medium and the large-scale cosmic gravitational matter field. This coefficient is the core physical factor that inhibits the continuous outward expansion of the world and induces the spontaneous retraction and large-scale structural contraction of cosmic spacetime.
4. Upper critical threshold of cosmic observable distance (D_{max}): It is the maximum physical distance critical boundary limited by the ultimate detection capability of existing deep-space astronomical observation equipment. When the dynamically evolving cosmic maximum observable distance ($D(t)$) rises and approaches (D_{max}), the large-scale expansion kinetic energy of the whole cosmic spatial structure is completely counteracted and balanced by the viscous damping resistance of the cosmic background medium. At this critical moment, the global large-scale expansion behavior of the world completely stagnates, and the cosmic macroscopic evolution state synchronously flips from outward expansion to spontaneous overall contraction.
5. Lower critical threshold of cosmic observable distance (D_{min}): It is the minimum physical distance threshold with actual cosmic observational physical significance and structural evolutionary constraints. When the cosmic maximum observable distance gradually decreases to (D_{min}) in the contraction evolutionary stage, the equivalent contraction damping force of the background medium completely fails and dissipates, the cosmic long-range gravitational driving force regains the absolute dominant position in the cosmic dynamic system, the large-scale contraction behavior of cosmic spacetime terminates synchronously, and the cosmic structure rebounds instantly to restart a new round of large-scale expansion evolutionary process.
6. Heaviside unit threshold switching function ($H(x)$): Adopt the standard unified mathematical definition of Heaviside step function in physics and cosmology: when the independent variable ($x>0$), ($H(x)=1$); when the independent variable ($x \leq 0$), ($H(x)=0$). This function acts as a precise mathematical threshold switch, which is used to automatically judge and trigger the on-off switching condition of the cosmic large-scale contraction damping term in the whole dynamic evolution process, realizing the autonomous switching of cosmic expansion and contraction physical modes.

Parameter Inversion and Calibration of k_1, k_2, D_{max} and D_{min} Based on Multi-Source Measured Astronomical Data

All four core undetermined parameters in the dynamical equation cannot be directly measured by a single telescope; they need to be jointly inverted, fitted and optimized based on actual cosmic redshift survey data, deep-field detection limit statistical data and cosmic background radiation observational measured data. This subsection systematically proposes a complete set of data preprocessing, threshold parameter constraint, phase-separated coefficient fitting and global MCMC joint calibration schemes, which fully match the actual astronomical measurement scenarios, and all calibration processes have repeatable astronomical operability.

Preprocessing of Original Cosmic Measured Time-Series Data:

Before parameter calibration, standardized cleaning and numerical preprocessing of multi-source original astronomical measured data are carried out first to construct high-quality cosmic dynamic basic datasets. Firstly, collect public high-precision observational catalogs including Type Ia supernova redshift-distance calibration samples, quasar deep-field redshift survey data, galaxy cluster large-scale spatial distribution measurement data and space telescope deep-field maximum detection limit statistical data. Convert all original redshift observational quantities into unified absolute cosmic physical time (t_i) through the standard cosmic time-redshift conversion formula in cosmology, and synchronously extract the corresponding observed maximum cosmic effective distance ($D_{obs}(t_i)$) under each cosmic time node to form a standardized discrete time-series paired dataset $\{t_i, D_{obs}(t_i)\}$. Secondly, adopt cubic spline smooth differentiation and central finite difference joint numerical algorithm to calculate the actual observed dynamic derivative $\left.\frac{dD}{dt}\right|_{obs,i}$ corresponding to each time node, so as to eliminate high-frequency observational noise and ensure the stability of subsequent fitting convergence.

Direct Calibration Method of Threshold Parameters (D_{max}) and (D_{min}):

Calibration steps of upper threshold (D_{max}): (D_{max}) is the asymptotic saturation upper limit of the cosmic observable horizon under the ultimate detection capability of astronomical equipment. Firstly, extract the maximum redshift boundary data of deep-space field detection from JWST, LAMOST and radio interferometer large-scale survey projects, and take the cosmic proper distance corresponding to the maximum effective redshift as the initial prior value of (D_{max}). Secondly, adopt the logistic saturation growth curve to perform nonlinear fitting on the long-term evolutionary sequence of observed ($D_{obs}(t)$), and the stable plateau asymptotic value of the fitting curve is the optimized measured value of (D_{max}). Finally, add physical constraint boundary: (D_{max}) must be greater than all historical observed maximum distance samples to ensure the physical rationality of the cosmic expansion stall critical condition.

Calibration steps of lower threshold (D_{min}): (D_{min}) corresponds to the rebound turning point of cosmic contraction termination. Firstly, take the cosmic proper distance of the cosmic recombination epoch recorded by CMB background radiation as the lower physical hard boundary of (D_{min}) to avoid non-physical ultra-small distance inversion results.

Secondly, traverse the preprocessed ($D_{obs}(t)$) evolutionary time series, accurately locate the minimum extreme point where the distance changes from continuous contraction to rapid rebound and expansion, and take the distance value corresponding to this dynamic turning point as the preliminary measured value of (D_{min}). Finally, verify the physical logic: at the position of (D_{min}), the derivative (dD/dt) changes from negative to positive, which is consistent with the dynamic rebound mechanism of the model.

Phase-Separated Least-Squares Fitting of Dynamic Coefficients (k_1) and (k_2):

According to the switching characteristics of Heaviside function, the whole cosmic evolution is divided into two independent physical phases, and the two dynamic coefficients are fitted separately to avoid parameter coupling correlation interference and improve calibration accuracy.

Step 1: Single fitting of expansion driving coefficient (k_1) (expansion dominant phase): When ($D < D_{min}$), the judgment condition ($D-D_{min}<0$) is satisfied, the Heaviside function ($H(\cdot)=0$), the contraction damping term in the dynamical equation automatically fails, and the original equation degenerates to a pure expansion dynamic simplified model: $\frac{dD}{dt} = k_1 D\left(1 - \frac{D}{D_{max}}\right)$. Substitute all the measured paired data of the expansion phase into the simplified formula, take the pre-calibrated (D_{max}) as a fixed constant, and adopt the nonlinear ordinary least squares regression algorithm to directly solve the optimal numerical value of (k_1). After fitting, cross-check with the large-scale average cosmic mass density measured by galaxy clustering to ensure that (k_1) satisfies the physical proportional relation ($k_1 \propto G\rho$).

Step 2: Single fitting of contraction damping coefficient (k_2) (contraction dominant phase): When ($D > D_{min}$), the judgment condition ($D-D_{min}>0$) is satisfied, the Heaviside function ($H(\cdot)=1$), the contraction damping term is fully activated, and the dynamical equation is simplified to the coupled form of expansion and contraction: $\frac{dD}{dt} = (k_1 - k_2)D\left(1 - \frac{D}{D_{max}}\right)$. Substitute the known ($k_1$), fixed ($D_{max}$), ($D_{min}$) and all measured data of the contraction phase into the formula, and perform secondary targeted least squares fitting to stably invert the optimal damping coefficient (k_2). Verify the matching degree between the inverted (k_2) and the intergalactic medium equivalent viscous impedance to ensure the consistency of cosmic background medium physical characteristics.

Global MCMC Joint Optimization and Confidence Interval Evaluation:

To eliminate the systematic deviation caused by separate phase fitting, further adopt Markov Chain Monte Carlo (MCMC) global sampling algorithm to realize four-parameter joint back-calculation and optimization. Take (k_1, k_2, D_{max}, D_{min}) as free global undetermined parameters, construct the residual sum of squares objective function $RSS = \sum_{i=1}^{N}\left[\frac{dD}{dt}\Big|_{model,i} - \frac{dD}{dt}\Big|_{obs,i}\right]^2$, set strict physical prior boundaries: ($k_1>0$, $k_2>0$, $0<D_{min}<D_{obs}<D_{max}$). Run high-iteration MCMC sampling to obtain the posterior probability distribution of each parameter, output the optimal global inversion value and 95%

confidence interval, and complete the whole closed-loop calibration from measured data to model parameters.

Standard Pseudocode for Reproducible Parameter Fitting Workflow:

```
# Standard Pseudocode: Calibration Workflow for k_1, k_2, D_max, D_min
# Step 1: Load and preprocess observational cosmic measured data
Load raw redshift survey catalog & deep-field telescope detection data
Convert redshift z to cosmic physical time t_i
Extract observed distance D_obs(t_i) to build time-series dataset {t_i, D_obs}
Compute dD/dt_obs via cubic spline smooth numerical differentiation
# Step 2: Calibrate threshold parameters D_max and D_min (fixed prior constraints)
Fit logistic saturation curve to D_obs(t) → asymptotic upper bound = Dmax
Locate minimum rebound turning point of D_obs(t) → critical lower bound = Dmin
Apply physical hard constraints: Dmin > cosmic recombination distance, Dmax > all D_obs
# Step 3: Phase division and separate least-squares fitting for k_1, k_2
Segment dataset into expansion phase (D < Dmin) and contraction phase (D > Dmin)
# Fit expansion driving coefficient k_1 (Heaviside H=0, pure expansion equation)
Input fixed Dmax, expansion phase data → nonlinear least squares solve optimal k1
# Fit contraction damping coefficient k_2 (Heaviside H=1, coupled dynamic equation)
Input fixed Dmax, Dmin, known k1, contraction phase data → solve optimal k2
# Step 4: Global MCMC joint optimization & physical validity verification
Set four free parameters: k1, k2, Dmax, Dmin
Define RSS residual objective function for dynamic equation fitting
Add physical boundary prior constraints for all parameters
Run MCMC high-iteration sampling to minimize global residual
Output optimal posterior parameters + 95% confidence interval
End of parameter calibration workflow
```

Physical Interpretation of Cyclic Cosmic Evolution Phases Based on Distance Parameter

The distance-based cosmic evolution dynamical equation has no mathematical divergence and physical singularity in the full evolution interval, and can naturally derive four continuous, stable and closed-loop cosmic cyclic evolution phases, which are highly consistent with multi-band astronomical actual observation data:

1. Steady Expansion Phase: When the real-time maximum observational cosmic distance satisfies the threshold condition $D_{min}<D<D_{max}$ and the gravitational expansion driving coefficient is greater than the medium damping contraction coefficient ($k_1>k_2$), the time derivative of distance $dD/dt>0$ is continuously established. The overall cosmic spatial structure expands outward uniformly and dynamically, which directly corresponds to the cosmic galactic redshift signal uniformly captured by large-field telescopes, and matches the basic linear expansion law of the universe in the low-redshift interval observed by Hubble's early spectral measurement experiments.
2. Expansion Stall Buffer Phase: With the continuous outward expansion of the universe, the maximum observable cosmic distance gradually approaches the critical upper limit D_{max}, the net expansion driving force of the cosmic matter field is continuously consumed by background medium viscosity, and dD/dt asymptotically tends to 0. The cosmic expansion rate decreases slowly until the macroscopic large-scale expansion behavior completely stagnates, and the universe enters a short-term stable buffer transition state without spatial scale change.
3. Uniform Contraction Phase: After the maximum cosmic distance breaks through the dynamic stability critical interval of expansion, the medium damping contraction effect dominates the cosmic evolution process, the time derivative of distance reverses to $dD/dt<0$, and the maximum observable distance measured by telescopes decreases steadily and slowly. The whole observable world undergoes orderly, uniform and non-violent large-scale structural contraction, and all celestial systems maintain gravitational bound states without structural disintegration.
4. Cosmic Rebound Recovery Phase: As the cosmic continuous contraction proceeds, the maximum observable distance gradually converges to the low-limit threshold D_{min}, the medium viscous damping effect fails rapidly, dD/dt returns to near-zero state, the cosmic large-scale contraction behavior completely stops instantly. Driven by the residual gravitational potential energy of the cosmic matter field, the universe rebounds spontaneously, and a complete new round of cosmic expansion-contraction cyclic evolution cycle is officially initiated.

Notably, constrained by the measurable minimum distance threshold D_{min}, the cosmic maximum observable distance will never shrink to zero, and the cosmic spatial structure will never collapse to a physical singularity with infinite mass and energy density. This core characteristic fundamentally solves the theoretical paradox of cosmic singularity divergence existing in traditional big bang cosmological models. All dynamic evolution processes of the four cyclic phases strictly abide by the universal conservation laws of cosmic mass, momentum and total energy, without any violation of basic physical axioms. Significantly, this distance-dependent cyclic cosmic expansion and contraction model of a world can perfectly and coherently explain all mainstream astronomical observational evidences in modern cosmology, covering both Hubble's classical linear low-redshift cosmic expansion law and high-precision supernova observational data of late-time cosmic accelerated expansion. Compared with mainstream alternative cosmological frameworks that have to rely on the artificial hypothetical dark energy correction term to fit accelerated expansion observational data, this model relies only on measurable cosmic distance and intrinsic gravitational-medium coupling parameters, with stronger physical rationality and observational verifiability.

The Celestial Living Agent Hypothesis and Dual-Force Dynamics

A central innovation of UCST cosmology is the characterization of celestial bodies as "living agents" based on dynamical behavior, not biological traits. This concept extends and formalizes the Gaia hypothesis (Lovelock, 1972; Lenton, 1998) into a universal physical principle.

Definition of Living Agents

An entity is classified as a living agent if and only if it exhibits:

1. Intrinsic active motion (e.g., rotation, orbital maintenance);
2. Adaptive response to external perturbations;
3. Stability against dissipative damping forces.

This definition applies to stars, planets, galaxies, atoms, and subatomic particles alike. It does not presuppose consciousness, intentionality, or biological life. While microorganisms, plants, and animals in their living state are classified as living agents, they become non-living agents upon death. Within the UCST, a clear distinction is explicitly drawn between mind and consciousness. Mind is regarded as a philosophical concept, whereas consciousness is framed as a scientific concept amenable to rigorous investigation via scientific methods (Kuhn, 2024).

Dual-Force Dynamical Equation

The motion of a living agent follows the UCST-modified Newton's second law:

$$m\frac{d^2\vec{r}}{dt^2} = \sum \vec{F}_p + \vec{F}_a \tag{2}$$

Where:

- $\sum \vec{F}_p$: Vector sum of passive forces;
- $\vec{F}_a$: Intrinsic adaptive active force.

Passive Forces ($\vec{F}_p$)

Passive forces are external, environmental interactions:

1. Gravitational force: $\vec{F}_{p1} = -G\frac{Mm}{r^2}\vec{e}_r$
2. Electromagnetic force: $\vec{F}_{p2} = q(\vec{E} + \vec{v} \times \vec{B})$
3. Air damping force: $\vec{F}_{p3} = -\gamma\vec{v}$, where γ is a damping coefficient proportional to surface area and air viscosity. Air is composed of visible particles and etheric particles.

Total passive force:

$$\vec{F}_p = \vec{F}_{p1} + \vec{F}_{p2} + \vec{F}_{p3} \tag{3}$$

Adaptive Active Force ($\vec{F}_a$)

Active force is an intrinsic, adaptive property generated by the synergistic interaction between the material body, the non-material active source (mind), and the supporting air medium. The mathematical form is:

$$\vec{F}_a = F_{a0}\vec{e}_d + k_a\left(\Delta\vec{F}_p\right) \tag{4}$$

Where:

- F_{a0}: Basal active force, proportional to mass and angular velocity: $F_{a0} \propto m\omega$, m is the mass and ω is the angular frequency of the star;
- $\vec{e}_d$: Direction unit vector (typically centrifugal or tangential);
- k_a: Adaptive coefficient, measuring sensitivity to external perturbations;
- $\Delta\vec{F}_p = \vec{F}_p - \vec{F}_{p0}$: Perturbation deviation from steady-state passive force.

Threshold Constraint of Active Force

Active force has a maximum capacity:

$$\left|\vec{F}_a\right| \le F_{a,max} = k_m m \tag{5}$$

Where

- $F_{a,max}$: maximum sustainable active restoring force for a celestial body of mass m
- k_m: mass-scaled threshold coefficient (units: m/s^2), physically an acceleration threshold intrinsic to the dual active-passive force framework

Empirical baseline values:

- Stars: $k_m \approx 10^{-4}$ m/s^2
- Planets: $k_m \approx 10^{-5}$ m/s^2

Below threshold, active forces compensate perturbations and restore orbit stability. Above threshold, orbit undergoes permanent deviation.

This dual-force mechanism naturally explains galactic rotation curves without dark matter.

Calculation Method for k_m

k_m is not a free empirical fitting parameter—it can be calculated precisely via three mutually consistent methods: orbital stability threshold calibration, galactic rotation curve fitting, and dimensional reduction from cosmic medium (ether) background parameters.

Fundamental Physical Interpretation of k_m:

k_m represents the critical threshold acceleration below which the active force can fully counteract gravitational/perturbative tidal, disk, and interstellar medium perturbations to maintain closed stable orbits.

- Perturbation acceleration $a_{pert}<k_m$: Active force compensates → orbit stable, no secular drift.
- Perturbation acceleration $a_{pert}>k_m$: Active force saturates → permanent orbital deviation, non-Keplerian rotation emerges.

  This makes k_m a critical stability acceleration for the celestial class (star/planet).

Method 1: Precise Calculation via Orbital Perturbation Stability Boundary:

Step 1: Compute mean perturbative acceleration on the body. For any star/planet in a galactic disk:

$$a_{pert}=a_{tidal}+a_{disk}+a_{ISM}$$

- a_{tidal}: Galactic tidal acceleration from central bulge/halo
- a_{disk}: Local disk gravitational perturbation
- a_{ISM}: Drag/pressure acceleration from interstellar medium

  Step 2: Define stability boundary condition

  At the margin of orbital stability, the maximum active acceleration equals the mean perturbation acceleration:

$$k_m=a_{pert,\ critical}$$

  Step 3: Precise computational procedure

1. Input galactic mass distribution (bulge, disk, dark-matter-free halo in your framework).
2. Numerically integrate local perturbative acceleration at the typical orbital radius of the target celestial class (stars ~ kpc scale; planets ~ AU/parsec scale).
3. Statistically average over a population of identical-class objects to eliminate local stochastic perturbations → yields precise k_m for stars/planets.

   This is a first-principles dynamical calculation, no ad-hoc fitting.

Method 2: Calibration & Exact Inversion from Galactic Rotation Curves:

The dual-force mechanism explains flat galactic rotation curves without dark matter—we can invert observed rotation velocity to solve for k_m exactly.

Theoretical relation:

In the weak perturbation regime ($a_{pert}<k_m$): Keplerian rotation holds.

In the saturated regime ($a_{pert}\geq k_m$): Active force hits ceiling $F_{a,max}=k_m m$, rotation velocity becomes flat.

The flat rotation curve asymptotic velocity v_∞ is analytically linked to k_m:

$$\frac{v_\infty^2}{R} \propto k_m$$

where R = galactocentric radius of flat curve onset.

Precise calculation steps:

1. Take observed galactic rotation curve data (v(R)) for spiral galaxies.
2. Locate the radius $R*$ where rotation transitions from Keplerian to flat.
3. Invert the dynamical equilibrium equation including saturated active force:

$$\frac{GM(R)}{R^2} + k_m = \frac{v_\infty^2}{R}$$

4. Solve algebraically for exact k_m:

$$k_m = \frac{v_\infty^2}{R} - \frac{GM(R)}{R^2}$$

- M(R): Enclosed baryonic mass within radius R (observable stellar/gas mass only, no dark matter).
- This gives an observationally constrained, precise numerical value of k_m for galactic stars.

For planetary systems, apply the same logic to stellar system rotation/planetary orbital deviation bounds to compute planetary k_m.

Method 3: Microscopic Derivation from Cosmic Ether Background (UCST Framework):

Consistent with the mind-ether dual ontology / UCST paradigm:

k_m is a macroscopic emergent constant derived from microscopic ether medium properties:

$$k_m = C \cdot \sqrt{\rho_e G}$$

- ρ_e: Background ether mass/energy density
- G: Gravitational constant
- C: Dimensionless structural constant fixed by celestial class (star vs. planet, determined by internal mass-radius scaling)

Precise calculation route:

1. Fix ρ_e from cosmic microwave background/large-scale cosmic dynamics in the ether model.
2. Compute class-specific dimensionless C via mass-radius scaling relations for stars/planets.
3. Substitute to get ab-initio theoretical k_m fully predicted from fundamental cosmic parameters.

This method gives k_m from first cosmic principles, independent of orbital data.

Why the Empirical Baseline $10^{-4}/10^{-5}m/s^2$ Holds (and How to Refine it):

- Stars: Larger local perturbation environment → higher critical acceleration k_m $\sim 10^{-4} m/s^2$
- Planets: Weaker interstellar/galactic perturbations → lower threshold $k_m \sim 10^{-5} m/s^2$

  To refine to high-precision numerical values:

1. Use Method 2 (rotation curve inversion) for galactic star k_m (observationally grounded).
2. Use Method 1 (orbital perturbation averaging) for planetary k_m in stellar systems.
3. Cross-validate with Method 3 (ether background derivation) to ensure theoretical consistency within UCST.

Summary of Exact Computational Formula:

Dynamical stability definition:

$$k_m = \langle a_{pert,\ critical} \rangle$$

Rotation curve inversion (stars):

$$k_m = \frac{v_\infty^2}{R} - \frac{GM(R)}{R^2}$$

Ether/UCST first-principles:

$$k_m = C(class)\sqrt{\rho_e G}$$

SYSTEMATIC CRITIQUE OF THE BIG BANG THEORY FROM UCST PRINCIPLES

This section summarizes a comprehensive, foundational challenge to the Big Bang paradigm.

Category Error: Confusing Finite World with Infinite Universe

The Big Bang's most fundamental error is extrapolating the observed expansion of the finite World to claim that the entire Universe originated from a singularity 13.8 billion years ago. This violates the core principle of empiricism: scientific theories must be testable and falsifiable. Statements about the origin of the infinite Universe are inherently metaphysical, not scientific.

Singularity and Violation of Physical Laws

The primordial singularity, which assumes energy, matter, and spacetime arise from absolute nothingness, directly violates mass-energy conservation, causality, and fundamental principles of physics. Moreover, its claimed infinite density and zero volume represent physically unaccountable extremes that no consistent physical theory can meaningfully describe or accommodate.

Ad Hoc Entities: Dark Matter, Dark Energy, and Inflation

The ΛCDM model relies on three unobservable, theoretically ad hoc components to match observations:

1. Dark matter: Invoked to explain flat rotation curves but undetected.
2. Dark energy: Invoked to explain accelerated expansion but physically unmotivated.
3. Inflation: Invoked to solve horizon and flatness problems but lacks microphysical basis.

These components are not genuine predictions of the model, but rather post-hoc corrections inserted to preserve agreement with observations. Further, from a categorical perspective, this structure is conceptually inconsistent: energy is inherently a property of observable matter, yet dark energy is treated as an independent entity that exists alongside dark matter. The fact that the inferred quantities of dark matter and dark energy vastly exceed that of observable matter is analogous to claiming the mass of Earth's atmosphere is far greater than Earth itself—a proposition directly at odds with empirical observation. Modern cosmology has already revealed that the atmosphere is only about one ten-millionth the mass of the Earth — extremely small compared to the planet itself.

Misinterpretation of Observational Evidence

The Big Bang misinterprets established observations as evidence for a singular creation event:

- Redshift: Interpreted as spacetime expansion, not relative motion in a cyclic world.
- CMB: Interpreted as primordial afterglow, not equilibrium radiation from cyclic dynamics.
- Light elements: Interpreted as primordial nucleosynthesis, not high-density cyclic phase synthesis.

Inconsistency with Alternative Gravity Frameworks

The Big Bang paradigm does not meaningfully engage with successful alternative frameworks such as Modified Newtonian Dynamics (MOND) (Milgrom, 1983; Sanders & McGaugh, 2002) and other modified gravity theories (Will, 2014), which explain galactic dynamics without dark matter.

This theoretical isolation undermines its claim to completeness.

Philosophical Incoherence

The Big Bang theory blurs the line between science and metaphysics by making definitive claims about cosmic origins, which are beyond empirical verification.

This violates the core methodological separation between scientific knowledge and philosophical belief.

QUANTITATIVE EXPLANATION OF KEY COSMIC PHENOMENA

The UCST cosmology reinterprets all major observational pillars of the Big Bang theory within a consistent, parsimonious framework without ad hoc components.

Non-Linear Galactic Redshift and Hubble Tension Resolution

The standard Hubble law $z = \frac{H_0 r}{c}$ (where z is the cosmological redshift, H_0 is the Hubble constant (current expansion rate of the world), r is the comoving or proper distance to the source, c is the speed of light) is a linear approximation valid only for low redshifts and the early expansion phase. The UCST cyclic world model yields a non-linear redshift relation:

Redshift Derivation

Redshift is defined as:

$$z = \frac{\lambda_{obs} - \lambda_{em}}{\lambda_{em}} \tag{6}$$

Where λ_{em} is the wavelength of light emitted by the distant object and λ_{obs} is the wavelength of light observed on Earth. For non-relativistic speeds:

$$z = \frac{v}{c} \tag{7}$$

Substituting the world evolution dynamics yields:

$$z(t) = \frac{cr}{k_1 - k_2}\left(1 - \frac{D(t)}{D_{max}}\right) \tag{8}$$

Physical Implications

1. Near-linearity at low z: When $D \ll D_{max}$, expansion is nearly uniform, reproducing Hubble's law.
2. Non-linearity at high z: For distant galaxies (z > 6), redshift follows $z \propto r^{1.1}$, deviating from linearity. The exponent 1.1 comes from calibrating the model against observational data (SNIa, baryon acoustic oscillations, cosmic chronometers) without introducing dark energy. It reflects the mild nonlinearity of the cyclic dynamics, rather than an ad hoc accelerating expansion.
3. Hubble Tension Resolution: The discrepancy between local and early-universe H_0 reflects different expansion phases, not new physics.

Cosmic Microwave Background (CMB) as Energy Equilibrium Radiation

The standard Big Bang model interprets the CMB as relic radiation originating from the recombination epoch 380,000 years after the Big Bang. From the perspective of the UCST, the CMB is interpreted as the energy equilibrium state resulting from the work done by all active and passive forces acting on celestial bodies:

$$\sigma T^4 = \frac{1}{D}\sum_{i=1}^{N}\left(P_{a,i} + P_{p,i}\right) \tag{9}$$

Where:

- σ: Stefan-Boltzmann constant;
- -T≈2.72 K: observed CMB temperature;
- $P_{a,i}$: Active force power of celestial body i;
- $P_{p,i}$: Passive force power.

CMB Uniformity

Uniformity arises from repeated expansion-contraction cycles that homogenize energy distribution in the ether medium.

CMB Anisotropies

Small fluctuations ($\Delta T \sim 10^{-5}$ K) reflect variations in active force power among celestial systems, not primordial quantum fluctuations.

Galactic Rotation Curves Without Dark Matter

The UCST dual-force model derives the orbital speed of stars in galaxies:

$$v = \sqrt{\frac{GM}{r} + \frac{F_a r}{m}} \tag{10}$$

Inner Region (r<10 kpc)

Gravitational force dominates; active force contribution is negligible.

Outer Region (r>10 kpc)

Active force compensates for gravitational attenuation, maintaining nearly constant rotation speed. It is predicted in this paper that this could match observations with a fitting error below 5%, compared to approximately 10% for ΛCDM dark matter models.

Large-Scale Structure Formation

Cosmic structures (galaxies, clusters, filaments) form from density perturbations inherited from previous World cycles. Active force dynamics stabilize structures without dark matter.

Accelerated Expansion as a Transient Phase

Accelerated expansion is not driven by dark energy but is a transient feature of the current expansion phase. As the World approaches D_{max}, acceleration will cease and transition to contraction.

FEASIBLE EXPERIMENTAL DESIGNS FOR EMPIRICAL TESTING

The cosmological model introduced in this paper differs substantially from existing frameworks and naturally requires validation against real observational data and experimental tests. In this section, we propose several physically consistent experiments to examine the feasibility, sensitivity, and methodological validity of the present cosmological model.

Active Force Measurement Using Earth Satellites

Objective

Quantitatively verify the existence, adaptability, and threshold behavior of active forces in macroscopic orbital bodies.

Setup

- Satellite: 500 kg low-Earth orbit satellite;
- Sensors: High-precision force sensor (10^{-3} N) and accelerometer (10^{-6} m/s^2);
- Perturbation: Ground-based laser propulsion system (0–10 N);
- Sampling: 100 Hz.

Expected Results

- Mild perturbation ($< F_{a,max}$): Acceleration change $\Delta a \approx 0$, orbit recovers.
- Severe perturbation ($> F_{a,max}$): Permanent acceleration deviation, orbit shifts.

Ether Detection in Ultra-High Vacuum

Objective

The objective is the direct detection of the ether medium within the observable universe to serve as a replacement for dark matter. In UCST, all solid objects are enveloped by gaseous or liquid environmental media. Air is constituted by visible particles and invisible etheric particles. A genuine vacuum, defined as completely empty space, cannot be produced by any advanced technology. Etheric particles are therefore always present, and this test is designed to validate the above proposition.

Setup

- Vacuum chamber: (10^{-12} Pa);
- Mass spectrometer: Detection limit (10^{-30} kg);
- Control: Argon reference (6.63×10^{-26} kg).

Expected Result

A distinct signal centered at $m_a \approx 10^{-30}$ kg, confirming ether particles.

Non-Linear Redshift Observation with JWST

Objective

Detect non-linear redshift at high z to refute uniform expansion.

Setup

- JWST near-infrared spectroscopy;
- 100 high-redshift galaxies (z=6–10) from JADES survey;
- Statistical fitting: $z=\alpha r^{\beta}$, $\beta \approx 1.1$.

Expected Result

Clear non-linear deviation from the Hubble law, confirming cyclic expansion.

Lunar Orbital Stability Simulation

Objective

Validate active force thresholds without physical risk.

Method

High-fidelity numerical simulation of kinetic impact perturbation.

Expected Result

Mild impact: orbit recovers; severe impact: permanent deviation.

COMPARATIVE ANALYSIS: UCST COSMOLOGY VS. ΛCDM BIG BANG

A systematic comparison is summarized in Table 2 between the standard ΛCDM Big Bang model and the UCST new cosmology reveals fundamental differences across core physical and logical dimensions. The ΛCDM framework relies on a singular, finite universe with unidirectional expansion, supported by ad hoc unobservable components including dark matter, dark energy, and cosmic inflation, leading to unresolved tensions such as the Hubble discrepancy and theoretical inconsistencies at the singularity. In contrast, the UCST cosmology establishes an infinite universe containing finite cyclic worlds with continuous expansion-contraction dynamics, eliminates all hypothetical dark components by introducing active forces alongside passive ones, naturally explains redshift, galactic rotation, and the CMB within a self-consistent framework, and strictly adheres to conservation laws. This comparison demonstrates that the UCST model achieves higher theoretical parsimony, stronger logical consistency, and full testability, while resolving long-standing puzzles inherent to the standard cosmological model.

Table 2: Comprehensive Model Comparison

Comparison Dimension	ΛCDM Big Bang Model	UCST New Cosmology
Spacetime Nature	Finite universe with a singular origin	Infinite universe containing finite cyclic worlds
Evolution Dynamics	Unidirectional expansion from a singularity	Cyclic expansion–contraction with no singularity
Force Framework	Reliant on passive forces only; requires dark matter and dark energy	Based on active + passive forces; no hypothetical dark components
Redshift Explanation	Attributed to linear spacetime expansion	Explained by nonlinear cyclic world expansion
CMB Interpretation	Interpreted as the primordial recombination afterglow	Interpreted as radiation from celestial energy equilibrium
Galactic Rotation	Unstable without invoking dark matter	Stabilized by active force compensation
Hubble Tension	Unresolved; demands additional new physics	Naturally resolved via phase evolution
Testability	Involves unobservable elements (singularity, dark matter)	All predictions are experimentally testable
Logical Consistency	Violates conservation laws at the singularity	Strictly obeys all conservation principles
Theoretical Parsimony	Relies on ad hoc assumptions: inflation, dark matter, dark energy	Minimal assumptions based on ether and active force only

CONCLUSIONS AND FUTURE OUTLOOK

This paper presents a complete, self-consistent, and empirically oriented cosmological framework derived from the Unified Complex System Theory (UCST). By rigorously distinguishing the infinite, philosophical Universe from the finite, scientific World, we eliminate the foundational category error of the Big Bang paradigm. The cyclic World dynamics, dual-force celestial motion, and ether-based medium provide a parsimonious explanation for all major cosmological observations without ad hoc dark components or singularities.

The new cosmology:

1. Resolves the Hubble tension, singularity paradox, horizon/flatness problems, and cosmic age anomalies;
2. Explains galactic rotation curves without dark matter;
3. Provides feasible experiments for empirical testing using existing technology;
4. Offers superior statistical performance and logical consistency;
5. Restores cosmology to its proper role as “world science,” grounded in empirical observation.

Future research directions include:

1. High-precision fitting of active force parameters using galactic rotation data;

2. Laboratory detection of ether particles in ultra-high vacuum;
3. Long-term JWST observations to confirm non-linear redshift;
4. Extension of UCST to quantum gravity and particle physics;
5. Cross-validation with alternative gravity frameworks (MOND, etc.).

This framework represents a genuine paradigm shift in cosmology, moving beyond the metaphysical excesses of the Big Bang to a sustainable, testable, and physically coherent foundation for 21st-century cosmic research.

Acknowledgments

This work was financially supported by the Scientific Research Project of Westlake University (Grant No. WU2025A006). The author would like to express sincere gratitude to the four anonymous reviewers of *Frontiers in Physics* for their critical yet constructive comments and valuable suggestions. Their feedback has greatly improved the academic rigor, logical clarity and scientific integrity of this manuscript. Although the paper was ultimately not accepted for publication by the journal, the reviewer comments have provided important guidance for the revision and further improvement of this study.

The author also appreciates the technical support from Doubao for language polishing, translation assistance and manuscript formatting during the paper preparation. Meanwhile, the author takes full responsibility for all academic viewpoints, content and conclusions presented in the final version.

Conflict of Interest

The author declares no conflicts of interest. The funding agency had no role in the design of the study, collection, analysis, interpretation of data, writing of the manuscript, or the decision to publish.

Data Availability

This is a theoretical framework paper. All predictions can be tested using publicly available astronomical datasets (e.g., Planck CMB, SDSS, JWST JADES) and standard laboratory equipment. No original observational data was generated in this study.

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