Journal of Cosmology, Vol. 27, No. 3, pp 18150 - 18163

Time Dilation Cosmology 7: A Unified Time-Rate Field Formulation of Relativity, Hamiltonian Dynamics, and Flat-FLRW Cosmology

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Abstract

This paper presents a unified formulation of Time Dilation Cosmology (TDC), in which the differential time-rate field dR_t is treated as the primary physical quantity. The framework begins by defining the local rate of proper time relative to a reference time and then expresses velocity, energy, Hamiltonian dynamics, gravitational acceleration, quantum phase, and cosmological redshift in terms of that time-rate field. Einstein's field-equation structure is retained but restated with a time-rate-dependent gravitational coupling and a time-rate-weighted stress-energy source. The Newtonian limit is recovered by identifying gravitational acceleration with the spatial gradient of the time-rate field. Quantum behavior is interpreted through a Hamiltonian whose phase evolution depends on accumulated dR_t, while observation is treated as a boundary condition on allowable time-rate configurations. Cosmologically, the flat Friedmann-Lemaitre-Robertson-Walker (FLRW) background is preserved exactly by identifying the scale factor with the cosmological time-rate field. The result is a single-field interpretation in which motion, gravity, quantum phase, and apparent spatial expansion are secondary consequences of time-rate evolution.

Introduction

This is the 9th in a series of papers [1-8] that have been published in two peer-reviewed journals across interdisciplinary contexts including physics and philosophy. They demonstrate that the universe is a holographic quantum field evolving in the forward direction of time at the speed of light, *c*. *The reader should refer to those papers for clarification when needed, including the derivations of the basic TDC formulas*.

Time Dilation Cosmology (TDC) proposes that time, not space, is the fundamental evolving quantity of the universe. In the usual interpretation of relativity [9,12–14], time dilation is treated as a consequence of motion, gravity, or metric structure. TDC reverses this interpretive order: local differences in the rate of time are treated as the primary physical field, while motion, energy, gravitational acceleration, and cosmological redshift are interpreted as consequences of that field.

This paper consolidates the mathematical and conceptual development of TDC into a single unified manuscript. The first sections define the local time-rate field and derive the basic velocity, energy, and Hamiltonian relations. The middle sections restate Einstein's equations in time-rate language and derive the Newtonian limit from time-rate gradients. The later sections extend the formulation into quantum phase evolution, flat-FLRW cosmology, relativistic consistency, and the observer-centered interpretation of a single shared underlying reality.

The purpose is not to discard General Relativity or the successful background structure of standard cosmology. Rather, it is to show how those structures may be reinterpreted if the time-rate field is taken as fundamental. In this formulation, the equations of known physics are not abandoned; they are reorganized around the hypothesis that the differential time-rate field dR_t is the primary causal field.

Portions of this manuscript were prepared with the assistance of AI-based language tools.

1. Fundamental Field Definition and Primary Relations

TDC begins by reversing the usual interpretive order. Instead of treating spatial motion as primary and time dilation as a secondary consequence, TDC treats the local rate of time as the primary physical field. Motion, force, energy, and gravitational response are then read as consequences of variation in that field.

Let local proper time be denoted by tau, τ, and reference coordinate time by t. The local time-rate field is defined by the differential rate at which proper time advances relative to the chosen reference time:

$$R_t(x,t) = \frac{d\tau}{dt} \tag{1}$$

Here R_t is the local proper-time rate. A value $R_t = 1$ corresponds to the chosen universal or reference rate. A departure from that reference rate is represented by the dimensionless differential time-rate parameter dR_t. In the present formulation, dR_t is the field variable used to express velocity, energy correction, and time-gradient force.

1.1 The dR_t Field as the Fundamental Scalar

For purposes of field formulation, it is useful to introduce the scalar field phi, φ, defined by

$$\varphi(x,t) \equiv dR_t(x,t) \tag{2}$$

The symbol phi, φ, is not an additional field. It is a compact mathematical name for the TDC time-rate differential. The substantive physical claim is that dR_t is primary: it is not merely a label for motion already caused by something else. Rather, motion is the observable consequence of the local time-rate differential.

1.2 Relation Between Time Rate and Velocity

The defining kinematic identity of TDC is that the squared velocity fraction is equal to the local time-rate differential:

$$dR_t = \frac{v^2}{c^2} \tag{3}$$

Solving for v gives the fundamental TDC velocity relation. First multiply both sides by c squared:

$$v^2 = c^2 dR_t \tag{4}$$

Taking the positive square root for speed gives

$$v = c\sqrt{dRt} \tag{5}$$

Thus the velocity term is not taken as an independently primary input. In TDC, velocity arises from the time-rate field. This identity is central because it allows any expression containing v squared to be rewritten directly in terms of dR_t.

For comparison with the usual relativistic clock-rate relation, one may write the standard normalization [9,13]

$$(d\tau/dt)^2 = 1 - \frac{v^2}{c^2} \tag{6}$$

Using dR_t = v squared over c squared, this becomes

$$R_t^2 = 1 - dR_t \tag{7}$$

This relation is useful as a bridge to standard relativity. Standard notation treats velocity as the input that determines the clock rate. TDC reverses the causal reading: the time-rate differential is the primary field, and velocity is the spatial manifestation of that field.

In induced velocities like a rocket, instead of the dRt causing a spatial event's velocity, it impedes the velocity so the rocket can't evolve ahead of the continuum. The dRt determines the force necessary to maintain the continuum's velocity of evolution at *c*. No part can lag behind, nor move ahead of, the continuum.

These relations are algebraically consistent with standard relativistic identities, but are interpreted in TDC as consequences of the time-rate field rather than as primary kinematic inputs.

1.3 Energy as a Function of Time-Rate Deviation

The rest-energy normalization remains Einstein's rest-energy expression [9]:

$$E_0 = mc^2 \tag{8}$$

TDC then weights the rest-energy normalization by a time-rate factor. The energy relation used in this formulation is

$$E_{TDC} = mc^2\sqrt{1 + dRt} \tag{9}$$

The factor with the radical represents the local velocity or time-rate contribution, with dR_t = v squared over c squared. Under the TDC substitution $dR_t = v^2/c^2$, the factor $\sqrt{1 + dR_t}$ is used as the time-rate form of the Lorentz scaling factor. Within the numerical precision relevant to the applications considered here, this formulation reproduces the Lorentz-factor result while preserving the TDC interpretation that the velocity term is secondary to the time-rate differential. It is a TDC energy scaling based on the time-rate field. Its weak-field agreement can be shown by expansion.

Where O denotes the observer frame, defined as the physical system (including clocks, measurement apparatus, and reference coordinates) that imposes boundary conditions on the allowable configurations of the time-rate field dR_t, for small dR_t, the binomial expansion is

$$\sqrt{1 + dRt} = 1 + ½dR_t - ⅛dR_t^2 + O(dR_t^3) \tag{10}$$

To first order in dR_t, this becomes

$$E_{TDC} \approx mc^2 + ½mc^2 dR_t \tag{11}$$

Using c squared dR_t = v squared, this becomes

$$E_{TDC} \approx mc^2 + ½mv^2 \tag{12}$$

This recovers rest energy plus the classical kinetic-energy term in the weak-field, low-velocity limit.

1.4 Hamiltonian Starting Point

Because c squared dR_t may replace v squared, the kinetic part of the Hamiltonian can be rewritten immediately. The ordinary kinetic-energy term is

$$K = ½mv^2 \quad (13)$$

Using v squared equals c squared dR_t, this becomes

$$K_{TDC} = ½mc^2dR_t \quad (14)$$

Accordingly, the reduced TDC Hamiltonian used as the starting point for the quantum formulation is

$$H_{TDC} = ½mc^2dR_t(r,t \mid O) \quad (15)$$

The notation O indicates that the field configuration may be constrained by observer-dependent boundary conditions.

1.5 Force in Time (F_T) and the Gradient Law

The local time-rate differential becomes dynamically important only when it varies across space. A uniform value of dR_t changes the local time-rate state but does not produce directional acceleration. A force-like effect requires a gradient.

In the TDC convention developed in *The Unified Field* [4], dR_t is not treated as an ordinary dimensionless bookkeeping parameter alone, but as the time-rate measure of the force in time manifested by mass-energy. In the Fundamental Direction of Evolution (FDE), where no radial r-term enters, the force-in-time expression is therefore written as $F_T = c^2dR_t$. This is the convention used here: dR_t carries the effective time-force contribution generated by the mass-energy condition, so that F_T is interpreted in Newtons within the TDC force-in-time formalism.

$$F_T = c^2dR_t \quad (16)$$

$$a_{TDC} = \nabla(c^2dR_t) \quad (17)$$

$$a_{TDC} = c^2\nabla dR_t \quad (18)$$

$$F_{body} = mc^2\nabla dR_t \quad (19)$$

$$\nabla dR_t = 0 \Rightarrow F_{body} = 0 \quad (20)$$

For a gravity drive, the required engineering objective is therefore not merely to create a nonzero dR_t, but to create a controllable directional gradient in dR_t.

2. Energy, Momentum, and Hamiltonian Reformulation

Section 1 established the TDC scalar time-rate field dR_t and the defining velocity identity. This section develops the energy and Hamiltonian consequences of that identity. The purpose is to show that the usual kinetic term can be rewritten entirely in terms of dR_t, and that the usual potential term can be absorbed into the spatial and temporal structure of the dR_t field itself.

2.1 Momentum in Terms of dR_t

$$p = mv \quad (21)$$

$$p = mc\sqrt{dR_t} \quad (22)$$

$$p^2 = m^2c^2dR_t \tag{23}$$

This result is important because the Hamiltonian normally contains p squared. Therefore the substitution eliminates the square root and gives a direct linear dependence on dR_t.

2.2 Kinetic Energy in Time-Rate Form

$$K = \frac{p^2}{2m} \tag{24}$$

$$K = \frac{m^2c^2dR_t}{2m} \tag{25}$$

$$K_{TDC} = ½mc^2dR_t \tag{26}$$

The ordinary kinetic-energy term is therefore rewritten as a time-rate energy term. Motion is expressed not as an independently primary spatial quantity, but as the energetic manifestation of a local time-rate differential.

2.3 Hamiltonian and Potential Absorption

$$H = \frac{p^2}{2m} + V(r,t) \tag{27}$$

$$H = ½mc^2dR_t + V(r,t) \tag{28}$$

In conventional mechanics, V(r,t) represents potential energy supplied by fields or boundary conditions external to the kinetic term. In TDC, the physical source of what is called potential energy is not independent of the time-rate field. A spatially varying potential is interpreted as a spatially varying time-rate condition.

$$\begin{aligned} dR_{t,total} = dR_{t,local} + dR_{t,gradient} \\ + dR_{t,observer} \end{aligned} \tag{29}$$

$$H_{TDC} = ½mc^2dR_t(r,t \mid O) \tag{30}$$

The conventional potential term is therefore not fundamental; it is absorbed into spatial gradients and boundary conditions of dR_t. As O denotes the observer-dependent boundary condition, the notation $dR_t(r,t \mid O)$ indicates that the time-rate field is restricted to configurations consistent with that observational context.

2.4 Effective Hamiltonian Coupling and Phase

$$H_{eff} = H_0 + H_{int} \tag{31}$$

$$H_{int} = -mc^2\varphi(x,t) \tag{32}$$

$$H_{int} = -mc^2dR_t(x,t) \tag{33}$$

$$U_{TDC} = -mc^2dR_t \tag{34}$$

$$F = -\nabla U_{TDC} = mc^2\nabla dR_t \tag{35}$$

$$H_{int} = -\int \rho(x)c^2dR_t(x,t)d^3x \tag{36}$$

$$H_{int} = -\int \rho_E(x) dR_t(x,t) d^3x \tag{37}$$

$$i\hbar \frac{\partial \psi}{\partial t} = H\psi \tag{38}$$

$$\Delta\theta = -\frac{1}{\hbar}\int \Delta H \, dt \tag{39}$$

$$\Delta H = -mc^2 dR_t(t) \tag{40}$$

$$\Delta\theta = \frac{mc^2}{\hbar}\int dR_t(t) dt \tag{41}$$

This implies that a small time-rate differential may produce a measurable phase displacement [10,11,15] if the mass-energy, coherence time, or integration time is sufficiently large. Observation constrains the allowed dR_t solutions available to the system; before observation, multiple compatible dR_t configurations may contribute to the evolution of the quantum state.

3. Einstein Field Equations in Time-Rate Form

This section carries the same program into Einstein's field equations. The purpose is to restate the gravitational coupling and dominant source term in time-rate language while retaining the Einstein tensor and stress-energy tensor.

$$G_{\mu\nu} = \frac{8\pi G_N}{c^4} T_{\mu\nu} \tag{42}$$

$$G_{TDC} = \frac{rc^2 dR_t}{M} \tag{43}$$

$$\frac{8\pi G_{TDC}}{c^4} = \frac{8\pi r dR_t}{c^2 M} \tag{44}$$

$$G_{\mu\nu} = \frac{8\pi r dR_t}{c^2 M} T_{\mu\nu} \tag{45}$$

The geometry side remains the Einstein tensor. [9,12,13] The source side remains the stress-energy tensor. The difference is that the gravitational coupling is expressed in terms of the time-rate field.

$$E_{TDC} = mc^2\sqrt{1 + dR_t} \tag{46}$$

$$\rho_{E,TDC} = \rho c^2\sqrt{1 + dR_t} \tag{47}$$

$$T_{00} \approx \rho c^2\sqrt{1 + dR_t} \tag{48}$$

$$G_{00} = \frac{8\pi r dR_t}{c^2 M} T_{00} \tag{49}$$

$$G_{00} = \frac{8\pi r \rho}{M} dR_t\sqrt{1 + dR_t} \tag{50}$$

The local time-rate differential appears both in the gravitational coupling and in the source energy density. This is a nonlinear self-coupling of the time-rate field.

$$dR_t\sqrt{1 + dR_t} = dR_t + ½dR_t^2 - ⅛dR_t^3 + O(dR_t^4) \quad (51)$$

$$G_{00} \approx \frac{8\pi r\rho}{M}[dR_t + ½dR_t^2 + O(dR_t^3)] \quad (52)$$

$$ds^2 = -\alpha^2c^2dt^2 + \gamma_{ij}dx^idx^j \quad (53)$$

$$d\tau = \alpha dt \quad (54)$$

$$\alpha = \frac{d\tau}{dt} = R_t \quad (55)$$

$$\nabla^2R_t \approx S_{TDC} \quad (56)$$

$$\nabla^2dR_t \propto \frac{8\pi r\rho}{M}dR_t\sqrt{1 + dR_t} \quad (57)$$

$$R^{(3)} + K^2 - K_{ij}K^{ij} = \frac{16\pi r dR_t}{c^2M}\rho_E \quad (58)$$

$$D_j(K^{ij} - \gamma^{ij}K) = \frac{8\pi r dR_t}{c^2M}S^i \quad (59)$$

$$a_i = c^2D_i ln(\alpha) \quad (60)$$

$$a_i = c^2D_i ln(R_t) \quad (61)$$

$$R_t \approx 1 + dR_t \quad (62)$$

$$a_i \approx c^2D_i dR_t \quad (63)$$

4. Newtonian Limit, Force Law, and Gravity-Drive Criterion

This section derives the Newtonian limit and the operational force law. The familiar inverse-square gravitational acceleration emerges [12,13] from the gradient of dR_t, and the same relation provides an engineering criterion for a controllable time-rate-gradient (gravity) drive.

$$a_i = c^2\partial_i ln(R_t) \quad (64)$$

$$R_t = 1 + dR_t \quad (65)$$

$$ln(R_t) \approx dR_t \quad (66)$$

$$a \approx c^2\nabla dR_t \quad (67)$$

$$\Phi_N = -\frac{GM}{r} \quad (68)$$

$$a_N = -\frac{GM}{r^2}\hat{r} \quad (69)$$

$$dR_t = \frac{GM}{rc^2} \tag{70}$$

$$\nabla dR_t = -\frac{GM}{r^2c^2}\,\hat{r} \tag{71}$$

$$a_{TDC} = -\frac{GM}{r^2}\,\hat{r} \tag{72}$$

$$F = ma = mc^2\nabla dR_t \tag{73}$$

$$F = -\frac{GMm}{r^2}\,\hat{r} \tag{74}$$

$$a_c = \frac{v_{orb}^2}{r} \tag{75}$$

$$v_{orb}^2 = \frac{GM}{r} \tag{76}$$

$$dR_{t,orb} = \frac{v_{orb}^2}{c^2} = \frac{GM}{rc^2} \tag{77}$$

$$v_{esc}^2 = \frac{2GM}{r} \tag{78}$$

$$dR_{t,esc} = \frac{2GM}{rc^2} \tag{79}$$

$$F_T = c^2 dR_t \tag{80}$$

$$a = \nabla F_T = c^2\nabla dR_t \tag{81}$$

$$\nabla dR_t \approx \frac{dR_{t,front} - dR_{t,rear}}{L} \tag{82}$$

$$a_{drive} \approx \frac{c^2\Delta dR_t}{L} \tag{83}$$

$$\Delta dR_t \approx \frac{a_{drive}L}{c^2} \tag{84}$$

$$\Delta dR_t \approx \frac{(9.8)(10)}{(2.99792458\times 10^8)^2} \tag{85}$$

$$\Delta dR_t \approx 1.09\times 10^{-15} \tag{86}$$

Thus a front-to-rear time-rate differential of order 10^{-15} across a ten-meter craft would correspond to approximately one Earth gravity of acceleration. The central unsolved problem is how to create and control such an asymmetric dR_t gradient.

A related result derived in *The Unified Field* paper [4] is that the TDC force-in-time expression may be equated to the electron's Lorentz-force condition at the electron radius used in that derivation. In that formulation, the local time-rate gradient associated with the electron produces a force relation consistent with the observed electromagnetic confinement condition. This suggests that electromagnetic structure itself may emerge from the same underlying time-rate dynamics.

5. Quantum Interpretation and Phase Dynamics

This section develops the quantum implications of the TDC Hamiltonian. The goal is to show how the time-rate field dR_t directly influences quantum phase evolution.

$$i\hbar \frac{\partial \psi}{\partial t} = H\psi \tag{87}$$

$$H = ½mc^2 dR_t \tag{88}$$

$$\psi \propto exp[-\frac{i}{\hbar}\int Hdt] \tag{89}$$

$$\psi \propto exp[-\frac{i}{\hbar}\int ½mc^2 dR_t dt] \tag{90}$$

$$\Delta\theta = \frac{mc^2}{\hbar}\int dR_t dt \tag{91}$$

Quantum phase is directly governed by the time-rate field [15]. Thus, interference effects measure accumulated dR_t. In TDC, observation constrains allowed dR_t configurations rather than collapsing a wavefunction externally.

$$H = ½mc^2 dR_t(r, t \mid O) \tag{92}$$

Quantum mechanics becomes a manifestation of time-rate structure. Interference arises from multiple dR_t pathways, while observation selects a stable configuration.

6. Cosmological Reformulation and Exact Flat-FLRW Equivalence

This section extends the same time-rate interpretation to cosmology. The purpose is conservative mathematically but revisionary interpretively: the flat Friedmann-Lemaitre-Robertson-Walker background is retained exactly, while the scale factor is reinterpreted as a time-rate field rather than as a primarily spatial expansion factor.

The following formulation begins from the standard flat Friedmann–Lemaître–Robertson–Walker (FLRW) metric **[16–19]**.

$$R_t = \frac{d\tau}{dt} \tag{93}$$

$$ds^2 = -c^2 dt_c^2 + a^2(t_c)[dr^2 + r^2 d\Omega^2] \tag{94}$$

$$d\eta = \frac{dt_c}{a(t_c)} \tag{95}$$

$$ds^2 = a^2(\eta)[-c^2 d\eta^2 + dr^2 + r^2 d\Omega^2] \tag{96}$$

$$a(\eta) = R_t(\eta) \tag{97}$$

$$ds^2 = R_t^2(\eta)[-c^2 d\eta^2 + dr^2 + r^2 d\Omega^2] \tag{98}$$

$$d\tau = R_t(\eta) d\eta \tag{99}$$

$$\frac{d\tau}{d\eta} = R_t(\eta) \tag{100}$$

$$1 + z = \frac{a_0}{a_e} \tag{101}$$

$$1 + z = \frac{R_t(obs)}{R_t(emit)} \tag{102}$$

$$R_t(emit) = \frac{1}{1+z} \tag{103}$$

$$dr = c d\eta \tag{104}$$

$$\chi = \int c d\eta \tag{105}$$

$$D_L = (1+z)\chi \tag{106}$$

$$D_A = \frac{\chi}{1+z} \tag{107}$$

$$D_L = (1+z)^2 D_A \tag{108}$$

$$H = \frac{1}{R_t}\frac{dR_t}{dt_c} \tag{109}$$

$$H^2 = \frac{8\pi G}{3}\rho \tag{110}$$

$$H_0 \approx 2.2686 \times 10^{-18}\, s^{-1} \tag{111}$$

$$T_H = \frac{1}{H_0} \tag{112}$$

$$T_H \approx 4.41 \times 10^{17}\, s \tag{113}$$

$$D_H = cT_H \tag{114}$$

TDC retains the successful mathematical structure of flat FLRW cosmology while shifting the causal emphasis from fundamental spatial expansion to fundamental time-rate evolution.

7. Relativistic Consistency and Small dR_t Limit

This section demonstrates that the TDC formulation remains consistent with Special Relativity [9,13] in the small dR_t limit and clarifies how the TDC velocity relation compares to the Lorentz factor.

$$\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}} \tag{115}$$

$$dR_t = \frac{v^2}{c^2} \tag{116}$$

$$\gamma = \frac{1}{\sqrt{1 - dR_t}} \tag{117}$$

$$\frac{1}{\sqrt{1 - dR_t}} \approx 1 + \tfrac{1}{2}dR_t + \tfrac{3}{8}dR_t^2 \tag{118}$$

$$\sqrt{1 + dR_t} \approx 1 + \tfrac{1}{2}dR_t - \tfrac{1}{8}dR_t^2 \tag{119}$$

$$\frac{d\tau}{dt} = \sqrt{1 - \frac{v^2}{c^2}} \tag{120}$$

$$\frac{d\tau}{dt} = \sqrt{1 - dR_t} \tag{121}$$

Both expressions agree to first order in dR_t. In the small dR_t regime, TDC reproduces standard relativistic behavior locally while reinterpreting the causal structure: dR_t is treated as primary, and velocity emerges from it.

8. Unified Interpretation, Observer, and One Life Framework

This section presents the conceptual synthesis of TDC. The preceding sections established that velocity, force, energy, quantum phase, and cosmological evolution all arise from the scalar time-rate field dR_t. Here, those results are unified into a single physical and ontological framework.

$$v = c\sqrt{dR_t} \tag{122}$$

$$a = c^2 \nabla dR_t \tag{123}$$

$$H = \tfrac{1}{2}mc^2 dR_t \tag{124}$$

$$R_t = \frac{d\tau}{dt} \tag{125}$$

$$\Delta\theta = \frac{mc^2}{\hbar}\int dR_t dt \tag{126}$$

$$1 + z = \frac{R_t(obs)}{R_t(emit)} \tag{127}$$

$$c = constant \tag{128}$$

Motion, gravity, and energy are not independent phenomena but different expressions of a single underlying temporal structure. All measurements are made relative to the observer's proper time, which is the invariant rate of time of the continuum as a whole. In TDC, the observer does not collapse the wavefunction externally; observation selects a specific configuration of the underlying time-rate field.

Each observer measures themselves at the center of their observable universe, yet all observers agree on physical laws and observations. This requires all local time-rate fields to be consistent with a single underlying global structure.

If all observers are expressions of a single underlying time-rate field, then that field represents a unified source of physical reality. In a broader philosophical context, this framework may be interpreted as describing a deeper unity—what one might term the “One Life” or “Creator” [6,7] —from which all observers and physical processes emerge.

At a broader interpretive level, one may associate the observer’s internal state—such as attention, intention, or desire—with the physical configuration that constrains the time-rate field. In this view, what is experienced subjectively may correspond to changes in the boundary conditions that determine how reality is realized.

Space is not fundamental. It emerges to preserve the invariant speed of light as the time-rate field varies. Thus spatial relationships are secondary to temporal structure. The mathematical structure points toward a single coherent underlying existence - experienced as many, but fundamentally one.

9. Conclusions and Implications

The central result of this work is that all primary physical phenomena can be expressed in terms of a single scalar field, the differential time-rate field dR_t.

$$v = c\sqrt{dR_t} \tag{129}$$

$$a = c^2 \nabla dR_t \tag{130}$$

$$H = ½mc^2 dR_t \tag{131}$$

From these relations, motion, gravity, and quantum phase evolution emerge as consequences of time-rate variation. Gravity is reinterpreted as a gradient in the time-rate field rather than as a fundamental force. This reproduces Newtonian gravity in the weak-field limit and is consistent with Einstein's equations [9,13] when expressed in time-rate form.

$$a(t) = R_t(t) \tag{132}$$

$$1 + z = \frac{R_t(obs)}{R_t(emit)} \tag{133}$$

Cosmology is reformulated by identifying the scale factor with the time-rate field. This preserves all observational results of flat-FLRW cosmology [20-22] while reinterpreting redshift as a consequence of time-rate evolution rather than fundamental spatial expansion.

Phenomena attributed to dark matter and dark energy may be reinterpreted as effects of time-rate gradients and their large-scale structure. TDC therefore offers the possibility of explaining observed dynamics without invoking unknown forms of matter or energy, while preserving the successful observational structure of the relativistic background.

$$\Delta\theta = \frac{mc^2}{\hbar}\int dR_t dt \tag{134}$$

Quantum phase evolution is directly governed by the time-rate field. The observer effect is interpreted as the selection of a specific time-rate configuration, providing a natural route toward resolving the measurement problem.

Time Dilation Cosmology presents a unified framework in which time is the fundamental physical quantity. Space, motion, and energy emerge as secondary effects required to maintain the structure of the continuum. This framework not only preserves agreement with established observations but also provides a deeper interpretation of the nature of reality, linking physical law with the structure of observation itself.

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