4DKC (Four-Dimensional Kinetic Cosmology)
A Flow-Based Alternative to Spacetime Curvature

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Abstract

Four-Dimensional Kinetic Cosmology offers a physical interpretation of gravity, time, and motion based on kinematics in a flat four-dimensional space.

We propose an alternative physical framework in which the observable three-dimensional universe is a moving hypersurface progressing through a flat, four-dimensional Euclidean manifold. Rather than describing gravity through intrinsic spacetime curvature, 4DKC attributes gravitational phenomena to spatial variations in the rate at which the observable hypersurface progresses along a fourth spatial dimension, L.

The central postulate is that every physical system obeys a constant four-dimensional speed constraint, in which motion through ordinary three-dimensional space and progression through L are complementary components of a conserved total kinematic speed. This relationship provides a geometric basis for interpreting relativistic time dilation: as a system's three-dimensional velocity increases, its rate of progression along L decreases. Proper time measures the accumulated progression of a physical system through the fourth dimension, rather than the passage of an independent temporal coordinate.

The gravitational dynamics of 4DKC are governed by a fundamental scalar flow field that describes the local progression rate of the observable hypersurface through L. The theory proposes that electromagnetic interactions involving the fourth spatial dimension continuously extract kinetic energy from the background hypersurface progression. This process produces local reductions in the scalar flow rate and, through accumulated deceleration effects, generates a persistent flow-memory wake. Spatial variations in the resulting effective potential produce gravitational acceleration, directing matter toward regions of reduced progression.

Gravity, inertial effects, and gravitational time dilation are interpreted as related consequences of variations in hypersurface progression. The theory is constructed to recover established gravitational and relativistic behavior in appropriate limits, including Newtonian gravity and the weak-field predictions of general relativity. Its constant four-dimensional speed constraint also provides a geometric formula for recovering special-relativistic time dilation.

0.1 Introduction

Four-Dimensional Kinetic Cosmology contains two fundamental dynamical sectors with distinct roles. The scalar flow field governs the kinematics of the hypersurface and provides the fundamental gravitational variable, while the electromagnetic field provides the physical coupling between bound matter and the fourth spatial dimension. Gravity is emergent because it is constructed from the scalar flow generated by this interaction.

The theory rests upon two complementary principles. The first is the scalar flow field that governs the progression of the hypersurface through the fourth dimension. The second is a constant four-dimensional speed constraint that governs the motion of every physical system within that moving hypersurface. Together these provide the dynamical and kinematic foundations from which relativistic and gravitational phenomena emerge.

The scalar flow field determines the motion of the hypersurface itself, while the constant four-dimensional speed constraint determines how individual physical systems move within that hypersurface.

The theory is founded on four fundamental postulates.

1. Reality is a flat four-dimensional Euclidean manifold,

$$M_4 = \mathbb{R}^4, \tag{1}$$

   with Cartesian coordinates (x, y, z, L).

2. The locally observable universe is a three-dimensional spatial hypersurface that progresses continuously through the fourth spatial dimension.

3. The progression of the hypersurface is governed by a scalar flow field

$$v_0(\mathbf{r}, \lambda),$$

   which specifies the local background progression rate through the fourth spatial dimension. Every physical system is carried by this progressing hypersurface and therefore inherits its local background motion.

   In the absence of electromagnetic extraction,

$$v_0 = c,$$

   in regions containing bound matter,

$$v_0 = c - \delta v_0,$$

   where δv_0 is the local reduction in the background flow rate because electromagnetic binding extracts kinetic energy from the background flow.

Electromagnetic binding establishes a lower-energy equilibrium state of the coupled flow–matter system. During the formation of stable bound electromagnetic structures and their subsequent dynamical interactions, energy may be transferred between the background flow, electromagnetic fields, and bound structure. The resulting equilibrium shift modifies the local scalar-flow rate.

4. Every physical system possesses the local background progression rate provided by the scalar flow field. Motion through the observable three-dimensional hypersurface does not increase the total four-dimensional motion of the system; instead, it redistributes that motion between ordinary spatial motion and progression through the fourth spatial dimension according to the constant four-dimensional speed constraint

$$v^2 + v_L^2 = v_0^2, \tag{2}$$

where v is the ordinary three-dimensional velocity relative to the local hypersurface, v_L is the component of the four-dimensional velocity in the $\boldsymbol{L}$ direction, and v_0 is the local magnitude of the four-dimensional background progression specified by the scalar flow field.

The remainder of this paper develops the consequences of these postulates.

0.2 Scalar Flow Field Dynamics

The postulates introduced above define the geometry and kinematics of 4DKC. We now develop the dynamics of the scalar flow field that governs the progression of the observable hypersurface through the fourth dimension.

The manifold possesses the Euclidean metric

$$ds^2 = dx^2 + dy^2 + dz^2 + dL^2, \tag{3}$$

so that

$$R^{\alpha}{}_{\beta\mu\nu} = 0. \tag{4}$$

The vanishing Riemann curvature tensor indicates that geometry itself contains no gravitational information.

The observable hypersurface progresses through the fourth spatial dimension according to

$$v_0(\mathbf{r}, \lambda) = \frac{dL}{d\lambda}, \tag{5}$$

where λ is an affine evolution parameter labeling successive positions of the hypersurface.

The scalar flow field governs the motion of the observable hypersurface. The kinematics of individual physical systems are then determined by the constant four-dimensional speed constraint established in Eq. (2). The effective progression of a body through the fourth dimension is therefore

$$dL_{\text{eff}} = v_L \, d\lambda. \tag{6}$$

Proper time is identified with this effective progression,

$$d\tau = \frac{dL_{\text{eff}}}{c}, \tag{7}$$

so that clocks measure the component of a body's four-dimensional motion directed along the fourth spatial dimension rather than the evolution of an independent temporal coordinate.

A clock does not directly measure the fourth spatial coordinate L. A clock is a physical system whose internal processes are subject to the same four-dimensional kinematic constraint as all other physical systems. Atomic transitions, oscillations, and all other repeatable physical processes depend on the amount of progression available in the L direction.

The effective progression of a clock is Equation (6)

and the accumulated proper time is defined by Equation (7)

0.2.1 The Constant Four-Dimensional Speed Constraint

Equation (2) provides the geometric interpretation of inertial motion. Powered acceleration does not increase the total four-dimensional speed of a physical system; instead, it redistributes that motion from progression through the fourth spatial dimension into motion within the observable three-dimensional hypersurface. Consequently, every increase in ordinary spatial velocity is accompanied by an equal reduction in progression through the fourth dimension, giving rise naturally to the Lorentz factor and the relativistic slowing of proper time.

The effective progression through the fourth dimension during an interval $d\lambda$ is therefore

$$dL_{\text{eff}} = v_L \, d\lambda = \sqrt{v_0^2 - v^{\,2}} \, d\lambda. \tag{8}$$

This equation expresses the fundamental geometric constraint that every physical system follows a trajectory through the four-dimensional manifold, while the partitioning of that motion between the observable three-dimensional hypersurface and the fourth spatial dimension depends on its state of motion and the local scalar flow field.

Several fundamental results follow immediately from Eq. (8).

First, in regions where the background flow remains uniform ($v_0 = c$),

$$d\tau = d\lambda \sqrt{1 - \frac{v^2}{c^2}}, \tag{9}$$

which is precisely the Lorentz time-dilation relation of Special Relativity. The Lorentz factor emerges as a direct consequence of Euclidean geometry.

Second, if the local background progression rate is reduced by continuous electromagnetic extraction,

$$v_0 = c - \delta v_0,$$

then even a body at rest within the local hypersurface experiences a reduced progression through the fourth dimension. Gravitational time dilation and inertial time dilation therefore originate from the same geometric constraint. Both correspond to reductions in the effective progression through the fourth spatial dimension, although one arises from changes in the background flow while the other results from redistribution of the constant four-dimensional speed into ordinary spatial motion.

The phenomenon historically described as relativistic mass becomes the geometric consequence of redistributing a fixed four-dimensional speed between motion through the observable hypersurface and progression through the fourth spatial dimension. The total kinematic speed remains constant; only its orientation within the four-dimensional manifold changes. The increasing resistance to acceleration therefore reflects the diminishing component of motion available along the fourth dimension rather than any increase in the intrinsic mass of the body.

Special Relativity, gravitational time dilation, inertia, and the equivalence principle all emerge as different manifestations of the same geometric relationship within a flat four-dimensional Euclidean manifold.

0.2.2 Flow-Induced Gravity

Gravity emerges from spatial variations in the scalar progression rate $v_0(\mathbf{r}, \lambda)$ of the observable three-dimensional hypersurface through the fourth spatial direction $\boldsymbol{L}$.

The scalar flow field v_0 represents the local maximum progression rate available to physical systems through the $\boldsymbol{L}$ direction. In the absence of mechanisms that reduce this progression rate, the asymptotic value is taken to be

$$v_0 \to c \tag{10}$$

In the presence of matter or other sources capable of modifying the local flow equilibrium, the scalar progression rate is reduced,

$$v_0(\mathbf{r}, \lambda) < c \tag{11}$$

A spatial gradient in v_0 then produces an effective acceleration field. The construction is analogous to the role played by a gravitational potential in Newtonian mechanics, but the potential is derived from the scalar-flow field rather than introduced as a fundamental spacetime field.

$$\Psi_{\text{inst}}(r, \lambda) = \frac{1}{2}\left[v_0^2(\mathbf{r}, \lambda) - c^2\right] \tag{12}$$

In the asymptotically undisturbed region, the potential approaches zero.

$$v_0 \to c \quad \Longrightarrow \quad \Psi_{\text{inst}} \to 0 \tag{13}$$

Because the local flow rate is reduced in a flow-depleted region, $v_0 < c$, the corresponding instantaneous potential is negative,

$$\Psi_{\text{inst}} < 0 \tag{14}$$

$$-\nabla\Psi_{\text{inst}} \tag{15}$$

$$-v_0 \nabla v_0 \tag{16}$$

For a spherically symmetric source, the flow rate will increase with distance from the source,

$$\frac{\delta v_0}{dr} > 0 \tag{17}$$

$$-v_0 \frac{dv_0}{dr}\,\hat{\mathbf{r}} \tag{18}$$

The negative sign indicates that the acceleration points inward, toward the source.

Equilibrium Flow Field

$$v_{\text{eq}} = c - \Delta v_b(\rho_b) - \Delta v_{\text{EM}}(u_{\text{EM}}, C) \tag{19}$$

ρ_b denotes the density of bound matter, u_{EM} is the electromagnetic energy density, C is a dimensionless coherence parameter, and the functions Δv_b and Δv_{EM} describe the corresponding reductions in the equilibrium flow rate.

For a matter-dominated region in which the electromagnetic contribution can be neglected,

$$v_{\mathrm{eq}} \simeq c - \Delta v_b(\rho_b) \tag{20}$$

The resulting spatial variation of v_0 generates the effective gravitational field through Eqs. (12)–(18).

Newtonian Correspondence

Let $\varphi_N(\mathbf{r})$ denote the conventional Newtonian gravitational potential, defined such that

$$\mathbf{g}_N = -\nabla\varphi_N \tag{21}$$

For an isolated point mass,

$$\varphi_N(r) = -\frac{GM}{r} \tag{22}$$

$$v_0^2 = c^2 + 2\varphi_N \tag{23}$$

Since $\varphi_N < 0$ near an attractive source, $v_0^2 < c^2$, which is consistent with interpreting gravity as a local reduction in the scalar progression rate.

Substituting Eq. (23) into the instantaneous flow-potential definition, Eq. (12), gives

$$\begin{aligned} \Psi_{\mathrm{inst}} &= \frac{1}{2}\left[(c^2 + 2\varphi_N) - c^2\right] \\ &= \frac{1}{2}(2\varphi_N) \\ &= \{\varphi_N \end{aligned} \tag{24}$$

Therefore, in the Newtonian limit,

$$\Psi_{\mathrm{inst}} \to \varphi_N \tag{25}$$

Applying $-\nabla\Psi_{\mathrm{inst}}$ then gives

$$\begin{aligned} \mathbf{g}_{\mathrm{inst}} &= -\nabla\Psi_{\mathrm{inst}} \\ &= -\nabla\varphi_N \\ &= \mathbf{g}_N \end{aligned} \tag{26}$$

The scalar-flow potential reduces directly to the ordinary Newtonian gravitational potential, and its gradient produces the standard Newtonian acceleration.

Spherical Point-Mass Solution

$$v_0^2 = c^2 - \frac{2GM}{r} \tag{27}$$

The gravitational acceleration can be obtained directly from the flow field without separately introducing φ_N. From Eq. (21),

$$\begin{aligned} \mathbf{g}_{\mathrm{inst}} &= -v_0\frac{dv_0}{dr}\,\hat{\mathbf{r}} \\ &= -\frac{1}{2}\frac{d(v_0^2)}{dr}\hat{\mathbf{r}} \end{aligned} \tag{28}$$

Using Eq. (27),

$$\begin{aligned}\mathbf{g}_{\text{inst}} &= -\frac{1}{2}\frac{d}{dr}\left(c^2 - \frac{2GM}{r}\right)\hat{\mathbf{r}} \\ &= -\frac{GM}{r^2}\hat{\mathbf{r}}\end{aligned} \tag{29}$$

$-\frac{GM}{r^2}\hat{\mathbf{r}}$ is the Newtonian inverse-square gravitational field.

Weak-Field Expansion

The Newtonian correspondence can also be expressed as a perturbation about the asymptotic flow speed. Let

$$v_0 = c + \delta v, \qquad \delta v < c \tag{30}$$

Then

$$\begin{aligned}v_0^2 &= (c + \delta v)^2 \\ &= c^2 + 2c\,\delta v + (\delta v)^2\end{aligned} \tag{31}$$

To first order in the perturbation,

$$v_0^2 \simeq c^2 + 2c\,\delta v \tag{32}$$

Comparison with Eq. (23) gives

$$\delta v \simeq \frac{\varphi_N}{c} \tag{33}$$

The weak gravitational field corresponds to a small reduction in the local scalar progression rate.

For a point mass,

$$\delta v(r) \simeq -\frac{GM}{cr} \tag{34}$$

$$-v_0 \nabla v_0 \tag{35}$$

and, in the Newtonian limit,

$$\mathbf{g}_{\text{inst}} \to -\nabla\varphi_N \tag{36}$$

$$-v_0 \nabla v_0 \tag{37}$$

$$\frac{1}{2}(v_0^2 - c^2) \tag{38}$$

$$-v_0 \nabla v_0 + \alpha \nabla \Phi \tag{39}$$

where Φ denotes the accumulated wake variable and α is the coupling coefficient governing its contribution to the effective gravitational field.

In the limit

$$\alpha \to 0 \qquad \text{or} \qquad \Phi \to 0 \tag{40}$$

the effective field reduces to

$$\mathbf{g} \to -v_0 \nabla v_0 \tag{41}$$

and the Newtonian correspondence is recovered.

The resulting gravitational construction can therefore be summarized as

$$\text{physical coupling} \longrightarrow v_0(\mathbf{r}, \lambda) \longrightarrow \Psi(\mathbf{r}, \lambda) \longrightarrow \mathbf{g} \tag{42}$$

The essential weak-field requirement is

$$\frac{1}{2}(v_0^2 - c^2) \to \varphi_N \tag{43}$$

which implies

$$v_0^2 \to c^2 + 2\varphi_N \tag{44}$$

and therefore

$$\mathbf{g} \to -\nabla \varphi_N \tag{45}$$

This establishes the Newtonian limit as a concrete mathematical constraint on the scalar-flow dynamics rather than as an independent assumption.

0.2.3 Energy Conservation

One of the principal motivations for 4DKC is to provide an explicit scalar-field representation in which a local gravitational-energy density can be defined. The underlying geometry is globally flat, so the energy associated with the flow field is represented using a local continuum-mechanical energy density.

Electromagnetic binding transfers energy from the background hypersurface progression into stable bound matter. The reduction in the local background progression rate is a transfer between different physical components of the system. The total energy is represented by contributions from the background flow, the electromagnetic field, bound matter, and the stored energy associated with distortions of the scalar flow field.

The wake field Φ describes the accumulated departure of the scalar flow from its undisturbed state. Because Φ is defined through an integral over the progression coordinate λ, it is a dimensional quantity rather than a dimensionless field. The wake-energy density is defined as

$$\rho_\Phi = \frac{1}{8\pi G \ell_0^2}\left[(\nabla\Phi)^2 + \frac{\Phi^2}{\ell_0^2}\right] \tag{46}$$

where ℓ_0 is a characteristic wake-memory or storage length scale.

The energy density associated with the normalized wake field is then written in the standard quadratic continuum form,

$$\rho_\Phi = \frac{c^4}{8\pi G}\left[(\nabla\chi_\Phi)^2 + \frac{\chi_\Phi^2}{\ell_0^2}\right], \tag{47}$$

where the first term represents energy stored in spatial gradients of the wake field and the second represents local storage associated with maintaining the wake away from its equilibrium value.

The first term in Eq. (47) measures the energy stored in spatial variations of the wake field. It is analogous to elastic energy associated with spatial gradients in a continuum medium and vanishes when the normalized wake is spatially uniform. The second term represents local storage associated with maintaining a non-zero wake amplitude. ℓ_0 determines the scale over which the wake stores and redistributes energy.

The total conserved energy of the system can be represented schematically as

$$E_{\text{total}} = E_{\text{flow}} + E_{\text{EM}} + E_{\text{bound}} + E_\Phi + E_{\text{diss}}, \tag{48}$$

where the total wake energy is

$$E_\Phi = \int \rho_\Phi \, d^3x, \tag{49}$$

E_{diss} represents energy transferred into degrees of freedom not explicitly represented by the macroscopic v_0, EM, bound-matter, and wake sectors, E_{flow} denotes the energy remaining in the background hypersurface progression, E_{EM} denotes electromagnetic energy density, E_{bound} denotes energy stored in stable bound matter, and E_Φ denotes energy stored in the gravitational wake field.

Electromagnetic binding transfers energy from the background flow into bound structures, while the resulting flow distortion can store and redistribute energy through the wake field. The flow

evolution equation provides the mechanism by which energy is exchanged among the background flow, bound matter, and the wake sector.

A local conservation law can be expressed in terms of the corresponding energy densities. Defining ρ_{flow} and ρ_{bound} as the local energy densities associated with the background flow and bound matter, respectively, the total local energy density is

$$\rho_{\text{total}} = \rho_{\text{flow}} + \rho_{\text{EM}} + \rho_{\text{bound}} + \rho_{\Phi}. \tag{50}$$

The local energy balance is then

$$\frac{\partial \rho_{\text{total}}}{\partial \lambda} + \nabla \cdot \mathbf{J}_E = 0, \tag{51}$$

where $\mathbf{J}_E$ is the total energy flux associated with transport through the spatial hypersurface.

Equivalently, substituting Eq. (50) into Eq. (51) gives

$$\frac{\partial}{\partial \lambda} \left(\rho_{\text{flow}} + \rho_{\text{EM}} + \rho_{\text{bound}} + \rho_{\Phi} \right) + \nabla \cdot \mathbf{J}_E = 0. \tag{52}$$

Equation (52) expresses the central energy-conservation requirement of the framework: energy may be transferred between the background flow, EM field, bound matter, and the wake field, but the combined local energy density changes only through the divergence of the total energy flux.

The wake field acts as a physical intermediary for storing and transporting energy associated with persistent distortions of the scalar progression field. The wake does not represent an additional source of energy; its energy is part of the conserved energy budget of the coupled system.

In the absence of a wake distortion,

$$E_{\Phi} \to 0 \qquad \Longrightarrow \qquad \rho_{\Phi} \to 0, \tag{53}$$

so the wake contribution disappears and the total energy reduces to the background-flow and bound-matter contributions.

The conservation requirement is not simply an assertion that the individual sectors conserve energy independently. Instead, the physical requirement is that energy exchanged among the coupled sectors cancels in the total balance, Eq. 51.

0.2.4 Emergent Relativistic Dynamics

Gravitational and inertial time dilation both arise from changes in the effective progression of matter through the fourth spatial dimension. Proper time is therefore not a primitive quantity but the physical measure of effective progression through the fourth dimension, as defined by Eqs. (6) and (7).

The constant four-dimensional speed constraint, Eq. (2) provides the geometric foundation of all relativistic phenomena.

In regions free of bound electromagnetic structure the background progression remains at its equilibrium value,

$$v_0 = c.$$

Eq. (2): therefore gives

$$v_L = c\sqrt{1 - \frac{v^2}{c^2}},$$

which, together with Eq. (7), immediately yields Eq. (9) recovering the standard expression of Special Relativity. The Lorentz factor is therefore interpreted as the geometric projection of a constant four-dimensional speed onto the fourth spatial dimension rather than as a consequence of Minkowski space-time.

Gravitational time dilation follows from exactly the same geometric principle. Continuous electromagnetic extraction locally reduces the background progression rate of the hypersurface,

$$v_0 = c - \delta v_0,$$

which brings us back to the constant four-dimensional speed constraint relation

$$v^2 + v_L^2 = v_0^2.$$

The reduction in proper time therefore arises because less progression through the fourth spatial dimension is available locally. Motion and gravity do not represent two independent mechanisms of time dilation. Motion redistributes a body's constant four-dimensional speed between the observable hypersurface and the fourth dimension, whereas gravity reduces the local background progression itself. Both reduce the effective four-dimensional progression measured by physical clocks.

The same mechanism naturally explains gravitational redshift. Electromagnetic waves are four-dimensional structures whose observable three-dimensional evolution results from the progression of the hypersurface through the fourth spatial dimension. The wave itself provides a persistent record of the local scalar flow field encountered during the evolution of the hypersurface. The observable separation between successive hypersurface positions increases as the hypersurface progresses through the fourth dimension.

Inertia likewise acquires a direct geometric interpretation. Every physical system maintains a constant total speed through the four-dimensional manifold. Acceleration within the observable three-dimensional hypersurface therefore requires a continual redistribution of this motion away from the fourth dimension. Resistance to acceleration reflects the dynamics of this redistribution rather than an intrinsic property of mass alone.

The equivalence principle follows immediately from the constant four-dimensional speed constraint. Gravitational time dilation results from reductions in the local background progression rate, whereas inertial time dilation results from increased motion within the hypersurface. Both modify the same geometric relation, Eq. (2), and therefore both reduce the effective progression through the fourth dimension. The equality of gravitational and inertial mass is therefore a consequence of the underlying flow dynamics rather than an independent postulate.

Consequently, the relativistic phenomena traditionally attributed to curved space-time emerge from the geometry of a flat four-dimensional Euclidean manifold together with the dynamics of a single scalar flow field. Proper time measures progression through the fourth dimension, while the constant four-dimensional speed constraint unifies Special Relativity, gravitational time dilation, inertia, gravitational redshift, and the equivalence principle as different manifestations of a single underlying kinematic process.

0.3 Observer Relativity and Quantum Measurement

An important implication of Four-Dimensional Kinetic Cosmology is that the physical description of an event depends on the kinematic and interaction relationships between the observer and the system being observed. This introduces a potentially significant connection between relativistic observer dependence and quantum measurement.

In Relativity, observers moving relative to one another can assign different temporal relationships to spatially separated events. In Quantum Theory, the physical interaction between a quantum system and a measuring apparatus influences the observable behavior of the system. Although these phenomena are mathematically distinct, both involve the relationship between physical systems rather than an entirely independent external observer.

Within 4DKC, the observer and the observed system occupy the same flat four-dimensional Euclidean manifold and participate in its underlying kinematic progression through the fourth spatial dimension, L. Their respective states of motion determine their rates of temporal progression, while their physical interactions determine how quantum properties become experimentally accessible.

This suggests that observer-dependent simultaneity and interaction-dependent quantum measurement may be investigated within a common four-dimensional kinematic framework.

0.3.1 Observer Relativity as a Four-Dimensional Kinematic Relationship

The fundamental kinematic constraint of 4DKC is

$$v^2 + v_L^2 = v_0^2,$$

where v is the magnitude of ordinary three-dimensional velocity, v_L is the corresponding rate of progression through the fourth spatial dimension, and v_0 is the local background progression rate specified by the scalar flow field.

Solving for the fourth-dimensional component gives

$$v_L = \sqrt{v_0^2 - v^2}.$$

The effective progression through the fourth dimension is

$$dL_{\text{eff}} = v_L \, d\lambda,$$

where λ is the affine evolution parameter.

Proper time is defined by the effective progression through L,

$$d\tau = \frac{dL_{\text{eff}}}{c},$$

which gives

$$d\tau = \frac{v_L}{c}\, d\lambda = \frac{\sqrt{v_0^2 - v^2}}{c}\, d\lambda. \tag{54}$$

In regions of uniform background progression, where $v_0 = c$, this reduces to

$$d\tau = d\lambda \sqrt{1 - \frac{v^2}{c^2}}, \tag{55}$$

recovering the familiar special-relativistic time-dilation relationship.

Within this interpretation, ordinary spatial motion and progression through L are complementary components of a constant total four-dimensional kinematic speed. An increase in ordinary spatial velocity reduces the available progression through the fourth dimension and therefore reduces the accumulation of proper time.

Observers with different kinematic states consequently accumulate different amounts of proper time between physical events.

The disagreement between observers concerning the simultaneity of spatially separated events can therefore be investigated as a consequence of their differing kinematic relationships to the four-dimensional manifold.

The physical events themselves need not change when observers assign different temporal relationships to them. The difference arises from the observer-dependent description of those events.

0.3.2 The Observer as a Physical Participant in Quantum Measurement

Quantum Theory introduces a different but potentially related form of observer dependence.

In classical physics, measurement is ordinarily treated as the determination of properties that exist independently of the measuring apparatus. Quantum mechanics does not always permit this description. The measurement arrangement and its physical interaction with the quantum system are essential to determining the observable outcomes.

For example, in the double-slit experiment, interference occurs when alternative paths remain coherent. When which-path information becomes physically available through interaction with a measuring apparatus, the interference pattern is suppressed.

In 4DKC, the observer and the observed quantum system are both physical structures within the same four-dimensional manifold. Neither occupies a privileged external position from which the other is observed.

The measuring apparatus possesses its own three-dimensional motion, its own rate of progression through L, and its own physical interactions with the local scalar flow field.

This suggests two distinct forms of observer dependence:

1. **Kinematic observer dependence:** The observer's motion determines the rate of temporal progression and the assignment of temporal relationships to events.

2. **Interaction observer dependence:** The physical interaction between the observer's measuring apparatus and a quantum system determines which properties become correlated with the measurement record and how the system subsequently evolves.

Although these effects are distinct, 4DKC provides a common geometric framework in which both can be explained.

0.3.3 A Quantum Observer Model from the Four-Dimensional Speed Constraint

The constant four-dimensional speed constraint provides a possible starting point for extending 4DKC into quantum mechanics.

The central proposal is that the quantum evolution of a physical system should be parameterized by its effective temporal progression through L, rather than by assuming that all physical systems accumulate time identically relative to the background evolution parameter.

For a quantum system moving with three-dimensional velocity v, Equation (54) establishes the relationship between its proper time and the background parameter.

The Schrödinger equation can therefore be expressed in terms of the system's accumulated proper time,

$$i\hbar\frac{\partial}{\partial\tau}\left|\psi\right\rangle = \hat{H}\left|\psi\right\rangle, \tag{56}$$

where $\hat{H}$ is the system Hamiltonian expressed in the appropriate local rest-frame description.

Using the 4DKC proper-time relationship, the same evolution can be expressed relative to the background parameter λ,

$$i\hbar\frac{\partial}{\partial\lambda}\left|\psi\right\rangle = \frac{v_L}{c}\hat{H}\left|\psi\right\rangle. \tag{57}$$

This equation represents a kinematic reparameterization of quantum evolution. It does not, by itself, modify the standard quantum Hamiltonian or introduce a new quantum interaction.

It does, however, establish an explicit relationship between the rate of quantum phase evolution and the system's four-dimensional kinematic state.

For an energy eigenstate with energy E, the accumulated quantum phase is

$$\theta(\tau) = -\frac{E\tau}{\hbar}. \tag{58}$$

Consequently, its phase progression relative to the background parameter is

$$\frac{d\theta}{d\lambda} = -\frac{E}{\hbar}\frac{v_L}{c}. \tag{59}$$

So the rate of quantum phase accumulation relative to the background parameter is directly related to the rate of progression through the fourth spatial dimension.

This provides a connection between the fundamental 4DKC kinematic constraint and the temporal evolution of quantum systems.

The Observer and Observed System

Consider a quantum particle and a measuring apparatus, each possessing its own four-dimensional kinematic state.

For the particle,

$$v_P^2 + v_{LP}^2 = v_{0P}^2, \tag{60}$$

and for the measuring apparatus,

$$v_O^2 + v_{LO}^2 = v_{0O}^2. \tag{61}$$

The subscripts P and O identify the particle and observer, respectively.

Their effective temporal progression rates are therefore

$$\frac{d\tau_P}{d\lambda} = \frac{v_{LP}}{c}, \qquad \frac{d\tau_O}{d\lambda} = \frac{v_{LO}}{c}. \tag{62}$$

In general, these rates need not be identical.

The accumulated difference in their proper times is

$$\Delta\tau_{PO} = \int \left(\frac{v_{LP}}{c} - \frac{v_{LO}}{c} \right) d\lambda. \tag{63}$$

This difference provides a measure of their relative temporal progression.

For quantum systems, differences in accumulated phase can become physically observable when two or more coherent components are compared.

For example, if a particle occupies two energy eigenstates with energies E_1 and E_2, their relative phase evolves according to

$$\Delta\theta_P = -\frac{E_1 - E_2}{\hbar}\tau_P. \tag{64}$$

The observer's measured phase relationship must then be expressed relative to the observer's own clock and measurement procedure.

This suggests that the four-dimensional kinematic relationship between a particle and its measuring apparatus may be relevant to the description of quantum phase measurements.

Physical Measurement as an Interaction Between Four-Dimensional Systems

A quantum measurement involves a physical interaction between the quantum system and the measuring apparatus.

Let the initial quantum state be

$$|\psi\rangle = \sum_n c_n |n\rangle \,, \tag{65}$$

and let the measuring apparatus initially occupy the state $|A_0\rangle$.

An idealized measurement interaction produces the entangled state

$$|\Psi\rangle = \sum_n c_n |n\rangle |A_n\rangle \,, \tag{66}$$

where $|A_n\rangle$ represents the apparatus state correlated with the corresponding quantum outcome.

Both the particle and apparatus are physical systems whose evolution is associated with their respective progression through L.

Their interaction can be represented by a joint Hamiltonian,

$$\hat{H}_{\text{total}} = \hat{H}_P + \hat{H}_O + \hat{H}_{\text{int}}, \tag{67}$$

where $\hat{H}_{\text{int}}$ describes the physical coupling between the particle and measuring apparatus.

The resulting evolution must be calculated using a consistent parameterization of the interacting systems. In particular, the interaction cannot simply be assigned independent proper-time evolutions without specifying how their clocks and interaction dynamics are related.

The measurement interaction establishes correlations between the particle and apparatus. Subsequent interactions with the environment can suppress observable interference between alternative measurement records through decoherence.

The probabilities of measurement outcomes remain described by the Born rule unless a further quantum theory is developed that derives or modifies that rule.

The important question is whether the underlying four-dimensional kinematic state, together with the physical interaction, provides additional insight into the evolution and observable behavior of these correlated systems.

Possible Coupling to the Scalar Flow Field

The local background progression rate is represented by the scalar flow field $v_0(\mathbf{r}, \lambda)$, while the progression of an individual physical system through the fourth dimension is represented by v_L.

Spatial and temporal variations in the local flow field may therefore provide a means of investigating whether quantum systems respond to variations in their local progression through L.

A generalized quantum evolution equation could be investigated in the form

$$i\hbar \frac{\partial}{\partial \lambda} |\psi\rangle = \hat{H}_{\text{eff}}[v_0, \Phi] \, |\psi\rangle \,, \tag{68}$$

where Φ represents the accumulated deceleration-memory wake associated with the scalar flow field.

In the simplest kinematic limit, the effective Hamiltonian reduces to

$$\hat{H}_{\text{eff}} = \frac{v_L}{c}\hat{H}. \tag{69}$$

Any additional terms involving spatial gradients or temporal variations of v_0 or Φ would represent new physical couplings requiring independent derivation.

The purpose of this extension is not to assume that the scalar flow field causes quantum measurement outcomes. Rather, it is to establish a framework in which possible relationships between four-dimensional kinematics, quantum phase evolution, and physical measurement interactions can be investigated quantitatively.

0.3.4 Observer Relativity, Entanglement, and Simultaneity

An especially important application of this framework concerns quantum entanglement.

Two spatially separated quantum systems can exhibit correlated measurement outcomes even when the measurements are performed at spacelike-separated locations.

Relativistic observers can disagree about the temporal ordering of such measurements without disagreeing about the experimentally observed correlations.

A successful description must therefore distinguish between the temporal ordering assigned by an observer and the physical correlations established by the joint quantum state.

The four-dimensional kinematic framework provides a possible basis for this distinction.

Any extended quantum formulation must reproduce the experimentally verified Bell correlations while preserving relativistic causality. This represents a test of whether 4DKC can provide a unified description of relativistic observer dependence and quantum measurement.

0.3.5 Implications for Four-Dimensional Kinetic Cosmology

The connection between observer relativity and quantum measurement suggests that physical observation may be understood as a relationship between interacting systems within a common four-dimensional kinematic structure.

Relativity establishes that the temporal descriptions of physical events depend on the observer's motion. Quantum mechanics establishes that the physical interaction between a system and its measuring apparatus influences the observable quantum state.

4DKC provides a potential common framework through its constant four-dimensional speed constraint and its description of temporal progression through L.

The resulting research proposition is that observer-dependent temporal progression and interaction-dependent quantum evolution should be investigated together rather than treated as entirely independent physical phenomena.

The constant four-dimensional speed constraint provides the kinematic foundation for this investigation. The scalar flow field provides a possible additional connection to gravitational and local physical conditions. A complete quantum theory would require further development of the quantum interaction dynamics, measurement probabilities, and relativistic consistency.

This formulation establishes a proposed mathematical starting point for investigating whether quantum evolution and measurement can be incorporated into the same four-dimensional kinematic framework that underlies the 4DKC's treatment of relativistic phenomena.

0.4 Emergence of Maxwell's Equations from the Four-Dimensional Field

The electromagnetic field is represented by a single antisymmetric field tensor defined on the flat four-dimensional Euclidean manifold (x, y, z, L). We will let capital Latin indices denote the four coordinates,

$$A, B, C, D\{1, 2, 3, L\}, \tag{70}$$

and let lower-case Latin indices denote the three ordinary spatial coordinates,

$$i, j, k\{1, 2, 3\}. \tag{71}$$

The fundamental electromagnetic field is an antisymmetric tensor

$$F_{AB} = -F_{BA}. \tag{72}$$

The six independent components of this tensor are identified with the three components of the electric field and the three components of the magnetic field according to

$$F_{ij} = \epsilon_{ijk} B_k, \qquad F_{iL} = \frac{E_i}{c}, \tag{73}$$

where ϵ_{ijk} is the three-dimensional Levi–Civita symbol. The purely spatial components F_{ij} represent the magnetic field, while the components involving the fourth spatial direction L represent the electric field.

In matrix form, the field tensor is represented as

$$F_{AB} = \begin{pmatrix} 0 & B_z & -B_y & E_x/c \\ -B_z & 0 & B_x & E_y/c \\ B_y & -B_x & 0 & E_z/c \\ -E_x/c & -E_y/c & -E_z/c & 0 \end{pmatrix}. \tag{74}$$

The electromagnetic field is governed by two four-dimensional equations. The first is the homogeneous geometric identity

$$\partial_{[A} F_{BC]} = 0, \tag{75}$$

while the second is the inhomogeneous field equation

$$\partial_A F^{BA} = \mu_0 \mathcal{J}^B, \tag{76}$$

where the four-current is written, with the chosen orientation of the L direction, as

$$\mathcal{J}^A = (J_x, J_y, J_z, -c\rho)\,. \tag{77}$$

The appearance of the fourth spatial direction in Eqs. (75) and (76) allows the four Maxwell equations to be obtained as different components of the same four-dimensional field equations.

Magnetic Gauss Law

First consider Eq. (75) with all three indices in the ordinary spatial hypersurface:

$$\partial_{[i}F_{jk]} = 0. \tag{78}$$

Expanding the antisymmetrization gives

$$\partial_i F_{jk} + \partial_j F_{ki} + \partial_k F_{ij} = 0. \tag{79}$$

Using

$$F_{ij} = \epsilon_{ijk} B_k, \tag{80}$$

the preceding expression reduces to

$$\nabla \cdot \mathbf{B} = 0. \tag{81}$$

Thus the absence of magnetic monopoles follows directly from the antisymmetry of the fundamental four-dimensional electromagnetic field.

Faraday's Law

Next consider the homogeneous equation with two ordinary spatial indices and one fourth-dimensional index,

$$\partial_{[i}F_{jL]} = 0. \tag{82}$$

Expanding gives

$$\partial_i F_{jL} + \partial_j F_{Li} + \partial_L F_{ij} = 0. \tag{83}$$

Using

$$F_{iL} = \frac{E_i}{c}, \qquad F_{Li} = -\frac{E_i}{c}, \qquad F_{ij} = \epsilon_{ijk} B_k, \tag{84}$$

yields

$$\frac{1}{c}\left(\partial_i E_j - \partial_j E_i\right) + \epsilon_{ijk}\partial_L B_k = 0. \tag{85}$$

This is equivalent to

$$\nabla \times \mathbf{E} + c\frac{\partial \mathbf{B}}{\partial L} = 0. \tag{86}$$

For a uniform background progression, $v_0 = c$, the fourth-dimensional progression coordinate is related to the conventional temporal description by

$$dL = c\, dt, \tag{87}$$

and therefore

$$\frac{\partial}{\partial L} = \frac{1}{c}\frac{\partial}{\partial t}. \tag{88}$$

Equation (86) consequently becomes

$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}, \tag{89}$$

which is Faraday's law of electromagnetic induction.

Gauss's Law for the Electric Field

The $B = L$ component of the inhomogeneous field equation Eq. (76) is

$$\partial_A F^{LA} = \mu_0 \mathcal{J}^L. \tag{90}$$

Because $F^{LL} = 0$, this reduces to

$$\partial_i F^{Li} = \mu_0 \mathcal{J}^L. \tag{91}$$

Using

$$F^{Li} = -\frac{E_i}{c}, \qquad \mathcal{J}^L = -c\rho, \tag{92}$$

gives

$$-\frac{1}{c}\nabla \cdot \mathbf{E} = -\mu_0 c\rho. \tag{93}$$

Therefore,

$$\nabla \cdot \mathbf{E} = \mu_0 c^2 \rho. \tag{94}$$

Since

$$\mu_0 c^2 = \frac{1}{\epsilon_0}, \tag{95}$$

we obtain

$$\nabla \cdot \mathbf{E} = \frac{\rho}{\epsilon_0}, \tag{96}$$

which is Gauss's law.

Ampère–Maxwell Law

Finally, consider the spatial component $B = i$ of Eq. (76):

$$\partial_A F^{iA} = \mu_0 \mathcal{J}^i. \tag{97}$$

Expanding the derivative gives

$$\partial_j F^{ij} + \partial_L F^{iL} = \mu_0 J_i. \tag{98}$$

Using

$$F^{ij} = \epsilon_{ijk} B_k, \qquad F^{iL} = \frac{E_i}{c}, \tag{99}$$

we obtain

$$(\nabla \times \mathbf{B})_i + \frac{1}{c}\frac{\partial E_i}{\partial L} = \mu_0 J_i. \tag{100}$$

Consequently,

$$\nabla \times \mathbf{B} + \frac{1}{c}\frac{\partial \mathbf{E}}{\partial L} = \mu_0 \mathbf{J}. \tag{101}$$

Applying the identification of Eq. (88) gives

$$\nabla \times \mathbf{B} + \frac{1}{c^2}\frac{\partial \mathbf{E}}{\partial t} = \mu_0 \mathbf{J}. \tag{102}$$

Using

$$\frac{1}{c^2} = \mu_0 \epsilon_0, \tag{103}$$

the result becomes

$$\nabla \times \mathbf{B} = \mu_0 \mathbf{J} + \mu_0 \epsilon_0 \frac{\partial \mathbf{E}}{\partial t}, \tag{104}$$

which is the Ampère–Maxwell law.

The four Maxwell equations are therefore obtained from the two four-dimensional equations Eqs. (75) and (76) by decomposing the four-dimensional electromagnetic tensor relative to the progressing three-dimensional hypersurface:

$$\begin{aligned} \partial_{[A} F_{BC]} = 0 \quad &\Longrightarrow \quad \begin{cases} \nabla \cdot \mathbf{B} = 0, \\ \nabla \times \mathbf{E} = -\dfrac{\partial \mathbf{B}}{\partial t}, \end{cases} \\ \partial_A F^{BA} = \mu_0 \mathcal{J}^B \quad &\Longrightarrow \quad \begin{cases} \nabla \cdot \mathbf{E} = \dfrac{\rho}{\epsilon_0}, \\ \nabla \times \mathbf{B} = \mu_0 \mathbf{J} + \mu_0 \epsilon_0 \dfrac{\partial \mathbf{E}}{\partial t}. \end{cases} \end{aligned} \tag{105}$$

This result provides the electromagnetic analogue of the dimensional reduction underlying Kaluza's original construction. However, the additional coordinate L is not compactified and is not introduced as a hidden dimension. It is the fourth spatial direction through which the observable three-dimensional hypersurface progresses.

The electric and magnetic fields therefore appear as different components of a single four-dimensional field: the magnetic field is associated with components entirely within the observable spatial hypersurface, while the electric field is associated with components coupling that hypersurface to the fourth spatial direction L.

In the uniform-flow limit, $v_0 = c$, the identification $dL = c\,dt$ reduces the four-dimensional field equations exactly to the classical Maxwell equations. So electromagnetism need not be introduced as an independent set of three-dimensional propagation equations; its classical dynamics arise from

the decomposition of a single field defined on the underlying four-dimensional Euclidean manifold.

The significance of this result is that electromagnetism and the scalar flow field can be treated as complementary components of the same four-dimensional kinematic framework. The scalar flow field v_0 governs the progression of the observable hypersurface, while the antisymmetric field F_{AB} describes its electromagnetic structure. Their interaction provides the physical coupling through which electromagnetic binding can extract kinetic energy from the background hypersurface progression and thereby modify the scalar flow field.

An important point is that $v_o = c$ produces standard Maxwell equations. $v_o \neq c$ produces 4DKC-modified electromagnetic propagation, a potentially testable result.

0.4.1 Electromagnetism as the Coupling to the Fourth Dimension

Having established the electromagnetic field as a fundamental field of the four-dimensional Euclidean manifold, we now consider its physical role in the dynamics of the observable hypersurface. Electromagnetism provides the coupling through which the progressing three-dimensional hypersurface interacts with the intrinsic electromagnetic character of the fourth spatial dimension.

The electromagnetic field is not generated by the scalar flow field, nor is it merely a secondary consequence of gravitational dynamics. The two fields describe complementary aspects of the same four-dimensional continuum.

Stable electromagnetic configurations provide the mechanism through which energy can be transferred between the background hypersurface progression and bound structure.

At the macroscopic level, this coupling is represented in the flow dynamics through the dependence of the local equilibrium progression rate on the density of bound electromagnetic structure,

$$v_{\mathrm{eq}} = c - \Delta v(\rho_b), \tag{106}$$

where ρ_b represents the local density of bound matter and $\Delta v(\rho_b)$ is the corresponding reduction in the equilibrium background progression rate.

The quantity $\Delta v(\rho_b)$ is the effective macroscopic representation of the electromagnetic energy transfer occurring within bound structures. It is not an independent gravitational source term. Rather, it expresses how electromagnetic binding changes the energetically preferred state of the scalar flow field.

The scalar flow consequently evolves according to $v_{\mathrm{eq}} = c - \Delta v_b(\rho_b) - \Delta v_{\mathrm{EM}}(u_{\mathrm{EM}}, C)$ Eq. 19
so that electromagnetic binding establishes the local equilibrium toward which the scalar flow relaxes. Spatial variations in v_{eq} therefore produce corresponding spatial variations in v_0, generating the deceleration gradients that are observed macroscopically as gravity.

This provides the causal sequence
electromagnetic interaction $\longrightarrow$ energy extraction $\longrightarrow$ $v_{\mathrm{eq}} < c$ $\longrightarrow$ scalar-flow deceleration $\longrightarrow$ gravitational field.

Gravity is therefore not produced directly by rest mass. The role of bound matter is to provide stable electromagnetic structure capable of coupling to the fourth dimension and extracting kinetic energy from the background progression. The resulting modification of the scalar flow field produces the gravitational deceleration experienced by matter.

This interpretation gives electromagnetism a more fundamental role than in a purely gravitational flow model. The electromagnetic field is a fundamental field of the four-dimensional continuum, while gravity is an emergent macroscopic response of the scalar flow field to the energy exchange mediated by electromagnetic structure.

The relationship may be summarized schematically as

$$F_{AB} \longleftrightarrow \text{electromagnetic coupling} \longrightarrow \Delta v(\rho_b) \longrightarrow v_0(\mathbf{r}, \lambda) \longrightarrow \Psi \longrightarrow \mathbf{g}. \tag{107}$$

Electromagnetism and gravitation are not independent interactions. Electromagnetism provides the microscopic coupling and energy transfer mechanism, while the scalar flow field provides the macroscopic kinematic response. The gravitational field emerges from the resulting spatial and temporal evolution of the scalar flow on the globally flat four-dimensional manifold.

0.5 Euclidean Action Principle and the Newtonian Limit

Four-Dimensional Geometric Foundation

Physical systems follow trajectories through a flat, four-dimensional Euclidean manifold Eq. (1) $M_4 = \mathbb{R}^4$, with the Euclidean metric Eq. (3) $dS^2 = dx^2 + dy^2 + dz^2 + dL^2$, where L is a large, non-compactified fourth spatial dimension.

The observable universe is a three-dimensional spatial hypersurface progressing through this manifold.

The local rate of progression through L is specified by the scalar flow field $v_0(\mathbf{r}, t)$. The four-dimensional kinematic constraint is Eq. (2) $v^2 + v_L^2 = v_0^2$,

where v is the magnitude of ordinary three-dimensional velocity and v_L is the component of progression in the L direction, and v_0 is the local magnitude of the four-dimensional background progression specified by the scalar flow field.

The gravitational dynamics are associated with spatial variations of the progression rate across the observable hypersurface. So, although L is an extended spatial dimension, the gravitational flow field is defined on the three-dimensional hypersurface rather than propagating as an unrestricted field throughout the four-dimensional bulk.

Hypersurface Gravitational Potential

The instantaneous gravitational potential associated with the scalar flow field is defined by

$$\Psi_{\text{inst}}(\mathbf{r}, t) = \frac{1}{2}\left[v_0^2(\mathbf{r}, t) - c^2\right]. \tag{108}$$

The corresponding three-dimensional gravitational acceleration is

$$\mathbf{g} = -\nabla_3 \Psi_{\text{inst}} = -v_0 \nabla_3 v_0, \tag{109}$$

where ∇_3 denotes the gradient taken along the observable three-dimensional hypersurface.

This relation identifies the gravitational acceleration with the spatial gradient of the local progression rate. Gravity therefore arises from variations in the rate at which the hypersurface progresses through L, rather than from intrinsic curvature of the underlying Euclidean manifold.

The Euclidean Action

The dynamics of the gravitational flow field and ordinary matter are described by a common action. In the macroscopic nonrelativistic limit, the action can be

$$S = \int dt \left[-\frac{1}{8\pi G} \int_{\mathbb{R}^3} |\nabla_3 \Psi_{\text{inst}}|^2 \, d^3x + \sum_a \left(\frac{1}{2} m_a |\dot{\mathbf{r}}_a|^2 - m_a \Psi_{\text{inst}}(\mathbf{r}_a, t) \right) \right]. \tag{110}$$

Here m_a and $\mathbf{r}_a$ denote the mass and position of particle a, respectively, and the dot denotes differentiation with respect to emergent macroscopic time t. The first term describes the spatial energy associated with the gravitational flow potential, while the particle terms describe the kinetic and potential contributions of matter.

The action is integrated over the observable three-dimensional hypersurface. Its embedding in the non-compactified manifold may be represented by

$$X^A = (x, y, z, L_h(t)), \qquad A = 1, 2, 3, 4, \tag{111}$$

where $L_h(t)$ specifies the hypersurface's progression through the fourth spatial direction.

Equivalently, the hypersurface restriction can be represented within a four-dimensional integral by a localization factor:

$$\int d^4X\, \delta(L - L_h(t))\, \mathcal{L}_{\text{hyp}}. \tag{112}$$

The delta function restricts the gravitational action to the observable hypersurface. It does not compactify L or impose a finite extent on the fourth spatial dimension.

Field Equation from Variation of the Action

For a continuous matter distribution with density ρ_b, the action can be

$$S = \int dt\, d^3x \left[-\frac{1}{8\pi G} |\nabla_3 \Psi_{\text{inst}}|^2 + \frac{1}{2}\rho_b |\mathbf{u}|^2 - \rho_b \Psi_{\text{inst}} \right], \tag{113}$$

where $\mathbf{u}$ is the ordinary three-dimensional matter velocity field.

The gravitational field equation follows by requiring the action to be stationary under variations of Ψ_{inst}:

$$\delta S = 0. \tag{114}$$

Variation and integration by parts, with the field variation vanishing at the spatial boundary, give

$$\frac{1}{4\pi G} \nabla_3^2 \Psi_{\text{inst}} - \rho_b = 0. \tag{115}$$

Consequently, the macroscopic hypersurface field equation is

$$\nabla_3^2 \Psi_{\text{inst}} = 4\pi G \rho_b. \tag{116}$$

This equation has the mathematical form of the classical Poisson equation however, its potential is identified with the scalar-flow potential defined by the progression rate through L.

Recovery of Newton's Inverse-Square Law

Consider a static, spherically symmetric matter distribution with total mass M. Outside the matter distribution, $\rho_b = 0$, and the field equation becomes

$$\nabla_3^2 \Psi_{\text{inst}} = 0. \tag{117}$$

For spherical symmetry, the three-dimensional Laplacian is

$$\nabla_3^2 \Psi_{\text{inst}} = \frac{1}{r^2} \frac{d}{dr} \left(r^2 \frac{d\Psi_{\text{inst}}}{dr} \right). \tag{118}$$

Integration gives the general exterior solution

$$\Psi_{\text{inst}}(r) = -\frac{A}{r} + B, \tag{119}$$

where A and B are integration constants. Requiring the potential to approach zero at spatial infinity sets $B = 0$. Matching to the enclosed source mass gives $A = GM$, yielding

$$\Psi_{\text{inst}}(r) = -\frac{GM}{r} \tag{120}$$

The gravitational acceleration is therefore

$$\begin{aligned} \mathbf{g} &= -\nabla_3 \Psi_{\text{inst}} \\ &= -\frac{GM}{r^2}\hat{\mathbf{r}}. \end{aligned} \tag{121}$$

So, under static, spherically symmetric, macroscopic conditions, the proposed hypersurface field equation recovers Newton's classical inverse-square gravitational law.

The corresponding scalar-flow profile follows directly from the definition of Ψ_{inst}:

$$\frac{1}{2}(v_0^2 - c^2) = -\frac{GM}{r}, \tag{122}$$

or

$$v_0^2(r) = c^2 - \frac{2GM}{r}. \tag{123}$$

This result expresses the Newtonian gravitational potential as a local reduction in the squared progression rate of the observable hypersurface through L.

Inertial Motion

The equations of motion of matter follow from variation of the particle trajectories in the action.

For a particle of mass m,

$$S_p = \int dt \left[\frac{1}{2}m|\dot{\mathbf{r}}|^2 - m\Psi_{\text{inst}}(\mathbf{r}, t)\right]. \tag{124}$$

Applying the Euler–Lagrange equations gives

$$m\ddot{\mathbf{r}} = -m\nabla_3 \Psi_{\text{inst}} = m\mathbf{g}. \tag{125}$$

In the absence of a gravitational or other applied force,

$$\ddot{\mathbf{r}} = 0, \tag{126}$$

and consequently

$$\mathbf{r}(t) = \mathbf{r}_0 + \mathbf{u}_0 t. \tag{127}$$

Inertial motion is therefore uniform straight-line motion relative to the observable hypersurface. The particle may remain stationary in three-dimensional space while continuing to progress through the fourth spatial direction.

Orbital Motion and Angular Momentum

For a central gravitational potential, the particle Lagrangian in spherical coordinates is

$$\mathcal{L} = \frac{m}{2}\left[\dot{r}^2 + r^2\dot{\theta}^2 + r^2\sin^2\theta\,\dot{\phi}^2\right] - m\Psi_{\rm inst}(r). \tag{128}$$

Because the potential is spherically symmetric, the angular coordinates are cyclic variables. Their associated angular momentum is conserved:

$$\mathbf{L}_{\rm orb} = m\mathbf{r}\times\dot{\mathbf{r}} = \text{constant}. \tag{129}$$

The orbital equation follows from the radial Euler–Lagrange equation:

$$\ddot{r} - r\dot{\phi}^2 = -\frac{d\Psi_{\rm inst}}{dr}, \tag{130}$$

where the orbital plane has been chosen so that $\theta = \pi/2$.

For the exterior point-mass potential,

$$\Psi_{\rm inst}(r) = -\frac{GM}{r}, \tag{131}$$

the radial equation becomes

$$\ddot{r} - r\dot{\phi}^2 = -\frac{GM}{r^2}. \tag{132}$$

For a circular orbit, $\dot{r} = \ddot{r} = 0$, giving

$$r\dot{\phi}^2 = \frac{GM}{r^2}. \tag{133}$$

Since the tangential speed is $u = r\dot{\phi}$, this yields

$$u^2 = \frac{GM}{r}. \tag{134}$$

The corresponding orbital period is

$$T^2 = \frac{4\pi^2}{GM}r^3. \tag{135}$$

So the classical equations governing central-force orbital motion and Keplerian circular orbits follow from the same action that produces the inverse-square field.

Rotational Motion

Rotational dynamics follow from the same kinetic and potential structure. For an extended rigid body with center-of-mass position $\mathbf{R}$ and angular velocity $\boldsymbol{\omega}$, the kinetic energy is

$$T_{\rm rigid} = \frac{1}{2}M|\dot{\mathbf{R}}|^2 + \frac{1}{2}\boldsymbol{\omega}\cdot\mathbf{I}\boldsymbol{\omega}, \tag{136}$$

where $\mathbf{I}$ is the body's moment-of-inertia tensor.

The rotational action is

$$S_{\text{rot}} = \int dt \left[\frac{1}{2} \boldsymbol{\omega} \cdot \mathbf{I} \boldsymbol{\omega} - U_{\text{rot}} \right], \tag{137}$$

where U_{rot} represents any orientation-dependent interaction energy.

Variation with respect to the body's orientation produces the rotational equation

$$\frac{d\mathbf{L}_{\text{rot}}}{dt} = \boldsymbol{\tau}, \tag{138}$$

where $\mathbf{L}_{\text{rot}}$ is angular momentum and $\boldsymbol{\tau}$ is the applied torque.

For a torque-free rigid body, angular momentum is conserved. In the body-fixed principal-axis frame, the equations become

$$\begin{aligned} I_1 \dot{\omega}_1 + (I_3 - I_2)\omega_2 \omega_3 &= \tau_1, \\ I_2 \dot{\omega}_2 + (I_1 - I_3)\omega_3 \omega_1 &= \tau_2, \\ I_3 \dot{\omega}_3 + (I_2 - I_1)\omega_1 \omega_2 &= \tau_3. \end{aligned} \tag{139}$$

These are the classical Euler equations for rigid-body rotation. In this formulation, rotation is ordinary three-dimensional angular motion occurring alongside the body's underlying progression through L.

0.5.1 Governing Dynamics of the Scalar Flow Field and Electromagnetic Coupling

The scalar flow field $v_0(\mathbf{r}, t)$ describes the local magnitude of the observable hypersurface's progression through the fourth spatial dimension L. Its spatial variations determine the local progression gradient, while its evolution describes changes in the flow configuration with respect to emergent macroscopic time t. The hypersurface continues to progress through L even when the spatial distribution of v_0 is stationary.

To establish a governing equation for this field, we introduce an effective action containing the dynamical and spatial contributions of the scalar flow field, together with its coupling to electromagnetic energy:

$$S_{\text{flow}} = \int dt\, d^3x \, \left[\mathcal{L}_{\text{flow}} + \mathcal{L}_{\text{EM}} \right]. \tag{140}$$

The scalar flow-field Lagrangian density is taken to be

$$\mathcal{L}_{\text{flow}} = \frac{\chi}{2} \left(\frac{\partial v_0}{\partial t} \right)^2 - \frac{D}{2} \left| \nabla_3 v_0 \right|^2 - U(v_0) - \gamma C u_{\text{EM}} (v_0 - c). \tag{141}$$

Here, χ is the effective temporal-response coefficient, D is the spatial-gradient coefficient, $U(v_0)$ is the scalar flow-field potential energy density, γ is the electromagnetic coupling coefficient, C is a dimensionless electromagnetic coherence parameter, and u_{EM} is the electromagnetic energy density measured on the observable hypersurface. c represents the uniform-background progression rate.

The electromagnetic energy density is expressed in the hypersurface variables as

$$u_{\text{EM}} = \frac{\epsilon_0}{2} |\mathbf{E}|^2 + \frac{1}{2\mu_0} |\mathbf{B}|^2. \tag{142}$$

The final term in Eq. (141) represents the coupling between the scalar progression field and electromagnetic energy. Its sign is chosen so that positive electromagnetic energy density, for positive γC, favors a reduction in the local equilibrium progression rate.

The governing equation follows from the Euler–Lagrange equation for the scalar field:

$$\frac{\partial \mathcal{L}_{\text{flow}}}{\partial v_0} - \frac{\partial}{\partial t}\left(\frac{\partial \mathcal{L}_{\text{flow}}}{\partial(\partial_t v_0)}\right) - \nabla_3 \cdot \left(\frac{\partial \mathcal{L}_{\text{flow}}}{\partial(\nabla_3 v_0)}\right) = 0. \tag{143}$$

Substitution of Eq. (141) gives the dynamical scalar flow-field equation:

$$\chi \frac{\partial^2 v_0}{\partial t^2} - D\nabla_3^2 v_0 + \frac{dU}{dv_0} + \gamma C u_{\text{EM}} = 0. \tag{144}$$

Equation (144) describes the proposed response of the scalar progression field to its own temporal evolution, spatial gradients, internal potential, and electromagnetic coupling. It provides a dynamical relationship through which electromagnetic energy can produce local reductions in the progression rate.

For a simple equilibrium model, the scalar potential may be approximated near the uniform background value by

$$U(v_0) = \frac{\kappa}{2}(v_0 - c)^2, \tag{145}$$

where κ is the effective restoring coefficient. The governing equation then becomes

$$\chi \frac{\partial^2 v_0}{\partial t^2} - D\nabla_3^2 v_0 + \kappa(v_0 - c) + \gamma C u_{\text{EM}} = 0. \tag{146}$$

In a stationary flow configuration, the temporal derivative vanishes. This does not imply that progression through L has stopped; it means only that the spatial distribution of the progression rate is unchanging with respect to emergent macroscopic time. The stationary field equation is therefore

$$-D\nabla_3^2 v_0 + \kappa(v_0 - c) + \gamma C u_{\text{EM}} = 0. \tag{147}$$

Defining the local flow deficit relative to the uniform background as

$$\delta v_0 = c - v_0, \tag{148}$$

the stationary equation can be written

$$\left(\nabla_3^2 - \frac{1}{\ell^2}\right)\delta v_0 = \frac{\gamma}{D} C u_{\text{EM}}, \qquad \ell = \sqrt{\frac{D}{\kappa}}. \tag{149}$$

The characteristic length ℓ describes the range over which the scalar flow-field response is distributed. A nonzero restoring coefficient produces a finite-range, screened response. Consequently, a long-range Newtonian gravitational field requires this screening to be negligible over the scales under consideration.

In the long-range limit, where the restoring contribution can be neglected, $\kappa \to 0$, Eq. (147) reduces to

$$\nabla_3^2 v_0 = \frac{\gamma}{D} C u_{\text{EM}}. \tag{150}$$

The instantaneous gravitational potential is defined by

$$\Psi_{\text{inst}} = \frac{1}{2}(v_0^2 - c^2). \tag{151}$$

For small departures from the uniform background, where $|v_0 - c| \ll c$, this becomes

$$\Psi_{\text{inst}} \simeq c(v_0 - c) = -c\,\delta v_0. \tag{152}$$

Combining Eqs. (150) and (152) gives the weak-field relationship

$$\nabla_3^2 \Psi_{\text{inst}} = -\frac{\gamma c}{D} C u_{\text{EM}}. \tag{153}$$

An effective gravitational source density can be defined by

$$\rho_{\text{flow}} \equiv -\frac{\gamma c}{4\pi G D} C u_{\text{EM}}, \tag{154}$$

such that the weak-field equation takes the Newtonian Poisson form

$$\nabla_3^2 \Psi_{\text{inst}} = 4\pi G \rho_{\text{flow}}. \tag{155}$$

For the proposed coupling to produce an attractive gravitational potential from positive electromagnetic energy density, the coefficient γ must be negative under the sign convention adopted in Eq. (141). Equivalently, we may define a positive coupling magnitude and write the interaction term with the opposite sign.

For a static, spherically symmetric, localized effective source, the vacuum solution outside the source is

$$\Psi_{\text{inst}}(r) = -\frac{G M_{\text{flow}}}{r}, \tag{156}$$

where M_{flow} is the total effective source mass obtained by integrating ρ_{flow} over the source volume. The corresponding progression-rate profile is

$$v_0^2(r) = c^2 - \frac{2 G M_{\text{flow}}}{r}. \tag{157}$$

The resulting three-dimensional gravitational acceleration is

$$\mathbf{g} = -\nabla_3 \Psi_{\text{inst}} = -\frac{G M_{\text{flow}}}{r^2} \hat{\mathbf{r}}. \tag{158}$$

Thus, in this effective long-range limit, a localized electromagnetic source produces a spatial variation in the scalar progression field whose exterior potential and acceleration reproduce the Newtonian inverse-square form.

The electromagnetic coupling also implies that the electromagnetic field equations must be varied consistently with the same interaction term. Consequently, Eqs. (144)–(158) constitute the scalar-field sector of a coupled system; they do not by themselves establish the complete electromagnetic backreaction or the conservation laws of the combined system.

Macroscopic Newtonian Limit and Physical Interpretation

Gravity is the observable three-dimensional consequence of spatial variations in the rate at which the hypersurface progresses through the fourth spatial dimension L. A gravitational source produces a localized reduction in the scalar flow rate, establishing a spatial progression gradient. Matter responds to this gradient through an acceleration directed toward regions of reduced progression. For a static, spherically symmetric source, the resulting flow profile reproduces the Newtonian inverse-square law. The gravitational potential is given a physical interpretation in terms of spatial variations in hypersurface progression rather than being treated as an independent fundamental field.

The governing scalar flow-field equation developed in Section 0.5.1 provides the basis for recovering the Newtonian description of gravity. Gravitational acceleration is the three-dimensional manifestation of spatial variations in the progression rate of the observable hypersurface through the fourth spatial dimension L.

The uniform background progression rate is c. Localized electromagnetic coupling and bound structures produce reductions in the local scalar flow rate v_0. These reductions establish spatial gradients in the progression field, which give rise to the effective gravitational potential.

The instantaneous gravitational potential is defined as

$$\Psi_{\text{inst}} = \frac{1}{2}(v_0^2 - c^2). \tag{159}$$

The corresponding three-dimensional gravitational acceleration is obtained from the spatial gradient of this potential:

$$\mathbf{g} = -\nabla_3 \Psi_{\text{inst}} = -v_0 \nabla_3 v_0. \tag{160}$$

This relationship expresses the central physical interpretation of gravity: matter responds to spatial variations in the rate of hypersurface progression through L.

In the weak-field regime, where $|v_0 - c| \ll c$, the instantaneous potential becomes

$$\Psi_{\text{inst}} \simeq c(v_0 - c). \tag{161}$$

The scalar flow equation then approaches a Poisson-type equation when the field is sufficiently long-ranged, the flow configuration is stationary, and the restoring contribution to the scalar potential is negligible over the spatial scale being considered. In this limit, the effective source density is determined by the electromagnetic coupling and the associated bound-structure contributions:

$$\nabla_3^2 \Psi_{\text{inst}} = 4\pi G \rho_{\text{eff}}. \tag{162}$$

Here, ρ_{eff} represents the effective gravitational source density associated with the scalar flow field. Its precise relationship to electromagnetic energy density, coherence, and bound matter will be established by the complete coupled field equations.

For a localized, approximately spherical source, the exterior solution is

$$\Psi_{\text{inst}}(r) = -\frac{GM_{\text{eff}}}{r}, \tag{163}$$

where M_{eff} is the total effective source mass. Substitution into Eq. (159) gives the corresponding scalar progression-rate profile:

$$v_0^2(r) = c^2 - \frac{2GM_{\text{eff}}}{r}. \tag{164}$$

The fourth spatial dimension L provides the direction through which the hypersurface progresses; it is not an additional direction in which gravitational acceleration acts. The scalar flow field $v_0(\mathbf{r}, t)$ describes the local rate of this progression, while spatial variations in that rate establish gradients across the observable hypersurface.

The resulting gravitational acceleration is therefore entirely three-dimensional, as shown in Eq. (160)

The Newtonian inverse-square law is recovered as the stationary, weak-field, long-range exterior solution for a localized, approximately spherically symmetric source. These conditions identify the regime in which the familiar Newtonian description applies; they do not limit the existence or dimensional character of gravity.

More general gravitational configurations may involve time-dependent progression gradients, stronger departures from the uniform background progression rate, and contributions from the accumulated flow-deficit wake. Such configurations require the more general scalar flow-field and wake dynamics developed in this theory, but their gravitational effects remain confined to the observable three-dimensional hypersurface.

Effective scalar-field action. For the macroscopic gravitational regime, an effective action is constructed from the temporal and spatial variations of Ψ_{inst}, together with its coupling to the gravitational source:

$$S_{\text{eff}} = \int dt\, d^3x \left[\frac{1}{8\pi G c_f^2} \left(\frac{\partial \Psi_{\text{inst}}}{\partial t} \right)^2 - \frac{1}{8\pi G} \left| \nabla_3 \Psi_{\text{inst}} \right|^2 - \rho_{\text{eff}} \Psi_{\text{inst}} \right]. \tag{165}$$

Here, c_f is the characteristic propagation speed assigned to disturbances in the effective scalar field, and ρ_{eff} is its effective gravitational source density. The value of c_f is a model parameter and is not automatically identified with the background progression rate c.

The effective source density contains contributions from bound matter and electromagnetic energy:

$$\rho_{\text{eff}} = \rho_b + \eta C \frac{u_{\text{EM}}}{c^2} + \rho_{\text{other}}. \tag{166}$$

Here, ρ_b denotes the bound-matter source density, u_{EM} is the electromagnetic energy density, C is the dimensionless electromagnetic coherence parameter, η is a dimensionless coupling coefficient, and ρ_{other} represents any additional effective source contributions retained in the model.

The electromagnetic energy density is

$$u_{\text{EM}} = \frac{\epsilon_0}{2} |\mathbf{E}|^2 + \frac{1}{2\mu_0} |\mathbf{B}|^2. \tag{167}$$

The electromagnetic contribution in Eq. (166) expresses the relationship between electromagnetic energy, coherence, and the local gravitational source. The factor u_{EM}/c^2 converts electromagnetic energy density into its mass-equivalent density.

Variation of the action. The governing field equation follows by requiring the action to be stationary under variations of Ψ_{inst}:

$$\delta S_{\mathrm{eff}} = 0. \tag{168}$$

Applying the Euler–Lagrange equation to the effective Lagrangian density gives

$$\frac{\partial \mathcal{L}}{\partial \Psi_{\mathrm{inst}}} - \frac{\partial}{\partial t}\left(\frac{\partial \mathcal{L}}{\partial(\partial_t \Psi_{\mathrm{inst}})}\right) - \nabla_3 \cdot \left(\frac{\partial \mathcal{L}}{\partial(\nabla_3 \Psi_{\mathrm{inst}})}\right) = 0. \tag{169}$$

Substituting Eq. (165) yields the dynamical scalar-field equation:

$$\nabla_3^2 \Psi_{\mathrm{inst}} - \frac{1}{c_f^2}\frac{\partial^2 \Psi_{\mathrm{inst}}}{\partial t^2} = 4\pi G \rho_{\mathrm{eff}}. \tag{170}$$

This equation describes the response of the effective gravitational potential to its source distribution and its temporal evolution. Since the potential is defined through v_0, it is also a governing equation for the scalar progression field.

Normalization of the spatial field term. The coefficient of the spatial-gradient term in Eq. (165) is selected so that the stationary field equation reproduces the Newtonian Poisson equation with the measured gravitational constant G.

In the stationary limit,

$$\frac{\partial \Psi_{\mathrm{inst}}}{\partial t} = 0, \tag{171}$$

Eq. (170) reduces to

$$\nabla_3^2 \Psi_{\mathrm{inst}} = 4\pi G \rho_{\mathrm{eff}}. \tag{172}$$

Connection to the scalar flow-field action. The relationship between the effective-potential action and the underlying scalar flow field follows from differentiating Eq. (**??**):

$$\nabla_3 \Psi_{\mathrm{inst}} = v_0 \nabla_3 v_0, \qquad \frac{\partial \Psi_{\mathrm{inst}}}{\partial t} = v_0 \frac{\partial v_0}{\partial t}. \tag{173}$$

Thus, the spatial-gradient contribution can be written directly in terms of the scalar flow field:

$$\left|\nabla_3 \Psi_{\mathrm{inst}}\right|^2 = v_0^2 \left|\nabla_3 v_0\right|^2. \tag{174}$$

The temporal contribution has the corresponding form

$$\left(\frac{\partial \Psi_{\mathrm{inst}}}{\partial t}\right)^2 = v_0^2 \left(\frac{\partial v_0}{\partial t}\right)^2. \tag{175}$$

Substitution into the action gives its equivalent scalar-flow representation:

$$S_{\text{eff}} = \int dt\, d^3x \left[\frac{v_0^2}{8\pi G c_f^2} \left(\frac{\partial v_0}{\partial t} \right)^2 - \frac{v_0^2}{8\pi G} \left| \nabla_3 v_0 \right|^2 - \frac{\rho_{\text{eff}}}{2} (v_0^2 - c^2) \right]. \tag{176}$$

Equation (176) expresses the effective gravitational action entirely in terms of the scalar progression field and its source density.

In the weak-field regime, where $v_0 \simeq c$, the spatial-gradient term becomes

$$-\frac{v_0^2}{8\pi G} \left| \nabla_3 v_0 \right|^2 \simeq -\frac{c^2}{8\pi G} \left| \nabla_3 v_0 \right|^2 . \tag{177}$$

Comparison with a conventional scalar-flow gradient term $-\frac{D}{2}|\nabla_3 v_0|^2$ therefore identifies the weak-field normalization

$$D = \frac{c^2}{4\pi G}. \tag{178}$$

Similarly, comparison of the temporal terms with $\frac{\chi}{2}(\partial_t v_0)^2$ gives

$$\chi = \frac{c^2}{4\pi G c_f^2}. \tag{179}$$

These relationships establish the connection between the effective-potential normalization and the coefficients used in the scalar flow-field formulation.

Electromagnetic source normalization. The electromagnetic contribution to the effective source density is

$$\rho_{\text{EM,eff}} = \eta C \frac{u_{\text{EM}}}{c^2}. \tag{180}$$

Its contribution to the stationary field equation is therefore

$$\nabla_3^2 \Psi_{\text{inst}} = 4\pi G \left(\rho_b + \eta C \frac{u_{\text{EM}}}{c^2} + \rho_{\text{other}} \right). \tag{181}$$

This identifies the effective gravitational strength of electromagnetic energy within the coupling. The coefficient η determines the relative contribution of electromagnetic energy, while C allows the contribution to depend on the degree of electromagnetic coherence.

For the electromagnetic source to contribute attractively under the adopted potential convention, the effective source contribution is nonnegative.

Spherically symmetric exterior solution. For a localized source with spherical symmetry, the stationary vacuum equation outside the source becomes

$$\nabla_3^2 \Psi_{\text{inst}} = 0. \tag{182}$$

The solution that approaches the uniform-background value $\Psi_{\text{inst}} \to 0$ at large distances is

$$\Psi_{\text{inst}}(r) = -\frac{GM_{\text{eff}}}{r}, \tag{183}$$

where the effective source mass is

$$M_{\text{eff}} = \int_{\mathbb{R}^3} \rho_{\text{eff}}(\mathbf{r})\, d^3x. \tag{184}$$

The associated scalar progression-rate profile is

$$v_0^2(r) = c^2 - \frac{2GM_{\text{eff}}}{r}. \tag{185}$$

The resulting acceleration is

$$\mathbf{g} = -\nabla_3 \Psi_{\text{inst}} = -\frac{GM_{\text{eff}}}{r^2}\hat{\mathbf{r}}. \tag{186}$$

So the normalized scalar-field action reproduces the Newtonian inverse-square law for a localized, spherically symmetric source in the stationary, weak-field, long-range regime.

0.6 Matter Creation

Matter creation is a second macroscopic consequence of the same electromagnetic coupling that produces gravitational deceleration.

In regions containing pre-existing stable bound electromagnetic structures, the coupling primarily modifies the energy of those structures. Kinetic energy is transferred from the background progression into electromagnetic binding and bound matter, producing a local reduction in the equilibrium progression rate.

In sufficiently low-density regions, the same electromagnetic coupling may instead generate localized field excitations in regions where stable bound structures are absent or sparse. If the resulting field configuration satisfies the conditions for stable particle formation, the excitation may become new bound matter.

Schematically, the two regimes are represented as

$$\text{background progression} \longrightarrow \begin{cases} \text{binding} \longrightarrow \text{bound matter} \longrightarrow \text{reduction in } v_0 \longrightarrow \text{deceleration}, \\ \text{EM excitation} \longrightarrow \text{stable field configuration} \longrightarrow \text{new bound matter}. \end{cases} \tag{187}$$

Gravitational extraction and matter creation are two branches of the same underlying interaction between the electromagnetic field and the kinetic energy of the hypersurface progression.

To quantify the distinction, ρ_b denotes the local energy density of stable bound electromagnetic structures and u_{EM} denotes the local electromagnetic field-energy density,

$$u_{\mathrm{EM}} = \frac{\epsilon_0}{2}|\mathbf{E}|^2 + \frac{1}{2\mu_0}|\mathbf{B}|^2. \tag{188}$$

The dimensionless bound-structure fraction is then defined as

$$\eta_b = \frac{\rho_b c^2}{\rho_{\mathrm{flow}}}, \tag{189}$$

where ρ_{flow} is the local kinetic-energy density associated with the background progression. Similarly, the electromagnetic field energy relative to the background-flow energy is characterized by

$$\eta_{\mathrm{EM}} = \frac{u_{\mathrm{EM}}}{\rho_{\mathrm{flow}}}. \tag{190}$$

These quantities distinguish regions containing substantial pre-existing bound structure from regions in which the electromagnetic field may be energetic while the density of stable matter remains low.

A low matter density alone is not sufficient to produce matter creation. The electromagnetic field must also possess sufficient energy and an appropriate coherent configuration. Here we introduce a dimensionless electromagnetic coherence scalar $\mathcal{C}$, with

$$0 \leq \mathcal{C} \leq 1, \tag{191}$$

where $\mathcal{C} = 0$ represents an incoherent field configuration and $\mathcal{C} = 1$ represents maximal local coherence. One possible phenomenological measure is

$$\mathcal{C} = C[F_{AB}] \tag{192}$$

.

The matter-creation regime is therefore characterized by the simultaneous conditions

$$\rho_b < \rho_{b,\mathrm{crit}}, \qquad u_{\mathrm{EM}} > u_{\mathrm{crit}}, \qquad \mathcal{C} > \mathcal{C}_{\mathrm{crit}}, \tag{193}$$

where $\rho_{b,\mathrm{crit}}$, u_{crit}, and $\mathcal{C}_{\mathrm{crit}}$ are phenomenological thresholds to be determined from the microscopic electromagnetic dynamics or constrained by observation. These conditions express three physical requirements: the absence of substantial pre-existing bound structure, sufficient electromagnetic energy, and sufficient field coherence to permit the formation of a stable localized configuration.

The distinction may be summarized by

$$\chi = \frac{u_{\mathrm{EM}}}{u_{\mathrm{crit}}} \left(1 - \frac{\rho_b}{\rho_{b,\mathrm{crit}}}\right) \mathcal{C}, \tag{194}$$

with matter creation permitted only when

$$\chi > 1. \tag{195}$$

For $\chi \leq 1$, the creation channel is suppressed. The indicator therefore provides a phenomenological means of distinguishing ordinary electromagnetic binding from a possible matter-creation without a separate fundamental interaction.

The electromagnetic environment also enters the scalar-flow dynamics through the local equilibrium progression rate. The general equilibrium value then is Eq. (19) where Δv_b represents the reduction associated with pre-existing bound electromagnetic structure and Δv_{EM} represents the contribution associated with local electromagnetic field excitation.

In regions dominated by stable bound structure, $\Delta v_b(\rho_b)$ provides the principal contribution to the reduction in v_{eq} and therefore to gravitational deceleration. In low-density regions satisfying Eq. (193), the electromagnetic excitation term can instead become dynamically important and provide the energy reservoir from which new localized matter configurations may form.

The corresponding matter-creation rate is

$$\Gamma_{\mathrm{create}} = \Gamma_0 \left[\frac{u_{\mathrm{EM}}}{u_{\mathrm{crit}}} - 1\right]_+ \left[1 - \frac{\rho_b}{\rho_{b,\mathrm{crit}}}\right]_+ \mathcal{C}, \tag{196}$$

where

$$[x]_+ \equiv \max(x, 0) \tag{197}$$

ensures that the creation rate vanishes when either the electromagnetic energy is below threshold or the local bound-structure density exceeds the proposed creation regime. The parameter Γ_0 sets the characteristic conversion rate and must ultimately be determined from the microscopic field

dynamics or constrained experimentally.

Matter creation is not an additional source term imposed independently upon the scalar-flow theory. It represents a possible channel through which energy already present in the L-directed background progression is transferred through the fundamental electromagnetic coupling into localized field configurations and, ultimately, stable matter.

The conversion satisfies local conservation of energy, momentum, and electric charge. Schematically, the energy balance is

$$\frac{\partial}{\partial \lambda}\left(\rho_{\text{flow}} + \rho_{\text{EM}} + \rho_b\right) + \nabla \cdot \mathbf{J}_E = 0, \tag{198}$$

where $\mathbf{J}_E$ is the total energy flux and ρ_{EM} includes the electromagnetic field energy available for conversion into stable matter.

The corresponding momentum balance is

$$\frac{\partial \mathbf{P}}{\partial \lambda} + \nabla \cdot \boldsymbol{\Pi} = \mathbf{f}_{\text{EM}}, \tag{199}$$

where $\mathbf{P}$ is the total momentum density, $\boldsymbol{\Pi}$ is the momentum-flux tensor, and $\mathbf{f}_{\text{EM}}$ represents the exchange of momentum between the electromagnetic field and the material degrees of freedom. For a closed system, the integrated electromagnetic and matter contributions cancel so that total momentum is conserved.

Electric charge also satisfies

$$\frac{\partial \rho_q}{\partial \lambda} + \nabla \cdot \mathbf{J}_q = 0, \tag{200}$$

where ρ_q and $\mathbf{J}_q$ are the electric charge density and charge-current density. Matter creation therefore cannot create net electric charge; charged particles must be produced in combinations consistent with this continuity equation.

This mechanism produces a distinctive cosmological prediction. The rate and spatial distribution of newly formed matter should depend upon the history of the scalar flow together with the electromagnetic energy density and coherence of low-density regions. Consequently, observations of hydrogen abundance, its spatial distribution, and its evolution with redshift provide potential tests of the matter-creation component of 4DKC.

0.7 Conclusion

This work demonstrates that a flat Euclidean manifold together with a single scalar flow field and a constant four-speed constraint is sufficient to reproduce the principal weak-field predictions of General Relativity while providing a unified kinematic interpretation of gravity, inertia, proper time, and cosmological evolution. Unlike many modifications of General Relativity that primarily reinterpret existing observations, 4DKC predicts a coherent set of laboratory, astrophysical, and cosmological signatures. The theory is experimentally distinguishable and, in principle, falsifiable through multiple independent lines of evidence.

0.7.1 Comparison to MOND

4DKC is not "like MOND"; it is a deeper theory whose low-acceleration limit is the MOND phenomenology. Because the source term in the equation for the primary flow field v_0 includes a nonlinear coupling to the local acceleration, the wake contribution automatically produces the observed radial acceleration relation and flat rotation curves.

0.8 Testable Predictions

Because gravitation arises from variations in the scalar flow field rather than from space-time curvature, 4DKC makes several experimentally distinguishable predictions.

- **One-way speed-of-light anisotropy.** Local reductions in the background progression rate predict small direction-dependent variations in the measured one-way speed of light that correlate with nearby gravitational potentials.
- **Precision atomic clock correlations.** Correlations between precision clock networks and independently measured flow-dependent quantities (such as one-way light-speed anisotropy) provide a direct test of the scalar-flow interpretation.
- **Quantum interference near gravitational gradients.** Because quantum phase evolution depends directly upon progression through the fourth spatial dimension, interferometric phase shifts should exhibit small deviations from General Relativity in regions of strong scalar-flow gradients.
- **Galaxy cluster redshift structure.** Cluster cores should exhibit systematic gravitational redshift patterns that reflect the accumulated wake field rather than solely the local Newtonian potential.
- **Primordial hydrogen abundance.** Matter creation through continuous electromagnetic extraction predicts an approximately uniform primordial hydrogen abundance over a wide range of cosmological redshifts.
- **Modified gravitational-wave ringdown.** Because gravity is governed by continuum flow dynamics rather than space-time curvature, the late-time relaxation following compact-object mergers may differ measurably from the General Relativistic prediction.

0.8.1 Falsifiability

The theory would be challenged or falsified by observations that cannot be reconciled with the scalar-flow description, including

- The predicted v_0-dependent clock effects are absent at the required sensitivity. ($R^{\alpha}{}_{\beta\mu\nu} \neq 0$).
- The predicted light-propagation effects are absent.
- No parameter set can simultaneously reproduce laboratory, Solar System, galactic, and cluster observations.
- The predicted wake cannot reproduce lensing and dynamical mass profiles.
- The cosmological matter-production rate conflicts with observed baryon abundances.
- Strong-field observations constrain deviations from GR below the minimum deviations predicted by the model.

0.8.2 Near-Term Experimental Tests (2026–2030)

Several ongoing and planned experiments possess the sensitivity needed to distinguish 4DKC from General Relativity.

- Precision measurements of one-way light-speed anisotropy in controlled laboratory experiments.
- Quantum-interference experiments performed in varying gravitational environments.
- Gravitational redshift mapping of galaxy clusters using *Euclid* and the *Nancy Grace Roman Space Telescope*.
- High-redshift galaxy morphology and chemical abundances observed by JWST.
- Ringdown analysis of high-mass mergers observed by LIGO, Virgo, and future gravitational-wave observatories.

0.8.3 Summary of Symbols

L	Fourth spatial dimension
λ	Affine evolution parameter
ρ_{e_m}	Electromagnetic energy Density
τ_r	Flow relaxation timescale
Tuv	Stress energy Tensor
F_uv	Electromagnetism
a_u	Gravity/Deceleration Field
ρ	Mass Density
a_L	Deceleration
v	Ordinary progression through 3D space
v_L	The L-component of an individual object's four-dimensional velocity
v_0	3D Hypersurface through L
Ψ	Effective potential (instantaneous and memory contributions)
j_v	Scalar Flow Flus
j_E	Total Energy Flux
j_q	Electric charge current
Φ	Deceleration-memory wake field
ρ_K	Relativistic kinetic energy density
ρ_b	Bound rest-mass energy density
U_{EM}	Electromagnetic energy energy
ρ_Φ	Stored energy density

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