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

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Abstract

Four-Dimensional Kinetic Cosmology is founded on the postulate that the observable three-dimensional universe is a hypersurface progressing through a flat four-dimensional Euclidean manifold.

The progression of this hypersurface is governed by a single scalar flow field, while every physical system satisfies a constant four-dimensional speed constraint that partitions its total kinematic motion between the observable three-dimensional hypersurface and the fourth spatial dimension. Increasing motion within the observable three-dimensional hypersurface necessarily reduces progression through the fourth spatial dimension while preserving the total kinematic speed.

Time is the observable measure of physical progression through the fourth spatial dimension, not a fundamental dimension.

Interaction between the scalar flow field and the electromagnetic field associated with the $\boldsymbol{L}$ direction transfers energy from the background hypersurface progression into electromagnetic binding and stable bound matter. This energy transfer produces local reductions in the equilibrium progression rate and an accumulated flow-deficit wake, which together constitute the origin of the observed gravitational interaction.

Newtonian gravity, the weak-field limit of General Relativity, gravitational time dilation, gravitational redshift, inertia, and the equivalence principle emerge as macroscopic consequences of the scalar flow dynamics.

The theory reproduces the local predictions of Special Relativity, with the Lorentz transformations emerging as geometric consequences of the constant four-dimensional speed constraint.

The resulting framework provides a unified continuum-mechanical description of gravity, relativity, and cosmological evolution while maintaining a globally flat geometry and explicit energy accounting. General Relativity is recovered as an effective weak-field approximation, while galactic and cosmological phenomena are long-range consequences of the evolving scalar flow field and its persistent wake.

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 other repeatable physical processes therefore depend upon 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)

Thus, a clock measures physical progression rather than an independent temporal dimension.

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 is the master kinematic relation of the theory. It 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 therefore emerges as a direct consequence of Euclidean geometry rather than as a separate postulate.

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.

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

The constant $c^2/2$ is chosen so that the potential approaches zero in the asymptotically undisturbed region,

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

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 causes the acceleration to point 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,

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

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

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

Therefore, in the Newtonian limit,

$$\mathit{\Psi}_{\mathrm{inst}} \to \varphi_N \tag{25}$$

Applying $-\nabla\mathit{\Psi}_{\mathrm{inst}}$ then gives

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

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),

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

$-\frac{GM}{r^2}\hat{\mathbf{r}}$ 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

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

Then

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

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 this work 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.

Continuous 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 therefore be written schematically as

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

where the total wake energy is

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

Here 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.

Within this interpretation, 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 therefore 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 written as

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

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

There is no fundamental distinction between 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 postulate, 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.

0.2.5 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). Let capital Latin indices denote the four coordinates,

$$A, B, C, D \in \{1, 2, 3, L\}, \tag{54}$$

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

$$i, j, k \in \{1, 2, 3\}. \tag{55}$$

The fundamental electromagnetic field is an antisymmetric tensor

$$F_{AB} = -F_{BA}. \tag{56}$$

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

$$F_{ij} = \epsilon_{ijk} B_k, \qquad F_{iL} = \frac{E_i}{c}, \tag{57}$$

where ϵ_{ijk} is the three-dimensional Levi–Civita symbol. Thus, 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 may therefore be written as

$$F_{AB} = \begin{pmatrix} 0 & B_z & -B_y & E_x/c \\ -B_z & 0 & B_x & E_y/c \\ B_y & -B_x & 0 & E_z/c \\ -E_x/c & -E_y/c & -E_z/c & 0 \end{pmatrix}. \tag{58}$$

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

$$\partial_{[A} F_{BC]} = 0, \tag{59}$$

while the second is the inhomogeneous field equation

$$\partial_A F^{BA} = \mu_0 \mathcal{J}^B, \tag{60}$$

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

$$\mathcal{J}^A = (J_x, J_y, J_z, -c\rho). \tag{61}$$

The appearance of the fourth spatial direction in Eqs. (59) and (60) allows the four Maxwell equations to be obtained as different components of the same four-dimensional field equations.

Magnetic Gauss Law

First consider Eq. (59) with all three indices in the ordinary spatial hypersurface:

$$\partial_{[i}F_{jk]} = 0. \tag{62}$$

Expanding the antisymmetrization gives

$$\partial_i F_{jk} + \partial_j F_{ki} + \partial_k F_{ij} = 0. \tag{63}$$

Using

$$F_{ij} = \epsilon_{ijk} B_k, \tag{64}$$

the preceding expression reduces to

$$\nabla \cdot \mathbf{B} = 0. \tag{65}$$

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,

$$\partial_{[i}F_{jL]} = 0. \tag{66}$$

Expanding gives

$$\partial_i F_{jL} + \partial_j F_{Li} + \partial_L F_{ij} = 0. \tag{67}$$

Using

$$F_{iL} = \frac{E_i}{c}, \qquad F_{Li} = -\frac{E_i}{c}, \qquad F_{ij} = \epsilon_{ijk} B_k, \tag{68}$$

yields

$$\frac{1}{c}\left(\partial_i E_j - \partial_j E_i\right) + \epsilon_{ijk}\partial_L B_k = 0. \tag{69}$$

This is equivalent to

$$\nabla \times \mathbf{E} + c\frac{\partial \mathbf{B}}{\partial L} = 0. \tag{70}$$

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

$$dL = c\,dt, \tag{71}$$

and therefore

$$\frac{\partial}{\partial L} = \frac{1}{c}\frac{\partial}{\partial t}. \tag{72}$$

Equation (70) consequently becomes

$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}, \tag{73}$$

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. (60) is

$$\partial_A F^{LA} = \mu_0 \mathcal{J}^L. \tag{74}$$

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

$$\partial_i F^{Li} = \mu_0 \mathcal{J}^L. \tag{75}$$

Using

$$F^{Li} = -\frac{E_i}{c}, \qquad \mathcal{J}^L = -c\rho, \tag{76}$$

gives

$$-\frac{1}{c}\nabla \cdot \mathbf{E} = -\mu_0 c\rho. \tag{77}$$

Therefore,

$$\nabla \cdot \mathbf{E} = \mu_0 c^2 \rho. \tag{78}$$

Since

$$\mu_0 c^2 = \frac{1}{\epsilon_0}, \tag{79}$$

we obtain

$$\nabla \cdot \mathbf{E} = \frac{\rho}{\epsilon_0}, \tag{80}$$

which is Gauss's law.

Ampère–Maxwell Law

Finally, consider the spatial component $B = i$ of Eq. (60):

$$\partial_A F^{iA} = \mu_0 \mathcal{J}^i. \tag{81}$$

Expanding the derivative gives

$$\partial_j F^{ij} + \partial_L F^{iL} = \mu_0 J_i. \tag{82}$$

Using

$$F^{ij} = \epsilon_{ijk} B_k, \qquad F^{iL} = \frac{E_i}{c}, \tag{83}$$

we obtain

$$(\nabla \times \mathbf{B})_i + \frac{1}{c}\frac{\partial E_i}{\partial L} = \mu_0 J_i. \tag{84}$$

Consequently,

$$\nabla \times \mathbf{B} + \frac{1}{c}\frac{\partial \mathbf{E}}{\partial L} = \mu_0 \mathbf{J}. \tag{85}$$

Applying the identification of Eq. (72) gives

$$\nabla \times \mathbf{B} + \frac{1}{c^2}\frac{\partial \mathbf{E}}{\partial t} = \mu_0 \mathbf{J}. \tag{86}$$

Using

$$\frac{1}{c^2} = \mu_0 \epsilon_0, \tag{87}$$

the result becomes

$$\nabla \times \mathbf{B} = \mu_0 \mathbf{J} + \mu_0 \epsilon_0 \frac{\partial \mathbf{E}}{\partial t}, \tag{88}$$

which is the Ampère–Maxwell law.

The four Maxwell equations are therefore obtained from the two four-dimensional equations Eqs. (59) and (60) by decomposing the four-dimensional electromagnetic tensor relative to the progressing three-dimensional hypersurface:

$$\begin{aligned}
\partial_{[A}F_{BC]} = 0 \quad &\Longrightarrow \quad \begin{cases} \nabla \cdot \mathbf{B} = 0, \\ \nabla \times \mathbf{E} = -\dfrac{\partial \mathbf{B}}{\partial t}, \end{cases} \\
\partial_A F^{BA} = \mu_0 \mathcal{J}^B \quad &\Longrightarrow \quad \begin{cases} \nabla \cdot \mathbf{E} = \dfrac{\rho}{\epsilon_0}, \\ \nabla \times \mathbf{B} = \mu_0 \mathbf{J} + \mu_0 \epsilon_0 \dfrac{\partial \mathbf{E}}{\partial t}. \end{cases}
\end{aligned} \tag{89}$$

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. Thus 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 now 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.

0.2.6 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. The scalar flow field v_0 governs the kinematic progression of the observable hypersurface through L, while the electromagnetic field describes the interaction between physical structure carried by the hypersurface and the electromagnetic character of the fourth dimension.

Stable electromagnetic configurations provide the mechanism through which energy can be transferred between the background hypersurface progression and bound structure. In particular, electromagnetic binding permits kinetic energy associated with the local progression through L to become stored in stable matter. This process constitutes the continuous electromagnetic extraction that modifies the local equilibrium state of the scalar flow field.

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,

$$v_{\mathrm{eq}} = c - \mathit{\Delta} v(\rho_b), \tag{90}$$

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

The quantity $\mathit{\Delta} v(\rho_b)$ 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 $v_{\mathrm{eq}} = c - \mathit{\Delta} v_b(\rho_b) - \mathit{\Delta} v_{\mathrm{EM}}(u_{\mathrm{EM}}, C)$ 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

$$F_{AB} \longleftrightarrow \text{electromagnetic coupling} \longrightarrow \mathit{\Delta} v(\rho_b) \longrightarrow v_0(\mathbf{r}, \lambda) \longrightarrow \mathit{\Psi} \longrightarrow \mathbf{g}. \tag{91}$$

So, 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.

0.2.7 Matter Creation

Matter creation is a second macroscopic consequence of the same electromagnetic coupling that produces gravitational deceleration. Electromagnetism provides the physical interaction through which energy associated with the L-directed progression of the hypersurface can be transferred into localized electromagnetic structure.

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. This process is the microscopic origin of the reduction in equilibrium progression rate expressed in Eq. (19), which in turn produces the gravitational deceleration described by Eq. (16).

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.

The two regimes may therefore be represented schematically as

$$\text{background progression} \longrightarrow \begin{cases} \text{binding} \longrightarrow \text{bound matter} \longrightarrow \text{reduction in } v_0 \longrightarrow \text{deceleration,} \\ \\ \text{EM excitation} \longrightarrow \text{stable field configuration} \longrightarrow \text{new bound matter.} \end{cases} \tag{92}$$

Thus, gravitational extraction and matter creation are interpreted as two branches of the same underlying interaction between the electromagnetic field and the kinetic energy of the hypersurface progression. The distinction is not the direction of energy transfer, but the local electromagnetic environment and whether stable bound structure is already present.

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

$$u_{\text{EM}} = \frac{\epsilon_0}{2}|\mathbf{E}|^2 + \frac{1}{2\mu_0}|\mathbf{B}|^2. \tag{93}$$

The dimensionless bound-structure fraction is then defined as

$$\eta_b = \frac{\rho_b c^2}{\rho_{\text{flow}}}, \tag{94}$$

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

$$\eta_{\text{EM}} = \frac{u_{\text{EM}}}{\rho_{\text{flow}}}. \tag{95}$$

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. We therefore introduce a dimensionless electromagnetic coherence scalar $\mathcal{C}$, with

$$0 \leq \mathcal{C} \leq 1, \tag{96}$$

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

$$\mathcal{C} = C[F_{AB}] \tag{97}$$

.

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

$$\rho_b < \rho_{b,\text{crit}}, \qquad u_{\text{EM}} > u_{\text{crit}}, \qquad \mathcal{C} > \mathcal{C}_{\text{crit}}, \tag{98}$$

where $\rho_{b,\text{crit}}$, u_{crit}, and $\mathcal{C}_{\text{crit}}$ 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 a dimensionless creation indicator,

$$\chi = \frac{u_{\text{EM}}}{u_{\text{crit}}} \left(1 - \frac{\rho_b}{\rho_{b,\text{crit}}}\right) \mathcal{C}, \tag{99}$$

with matter creation permitted only when

$$\chi > 1. \tag{100}$$

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 introducing 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. (98), 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 can be represented phenomenologically by

$$\Gamma_{\text{create}} = \Gamma_0 \left[\frac{u_{\text{EM}}}{u_{\text{crit}}} - 1\right]_+ \left[1 - \frac{\rho_b}{\rho_{b,\text{crit}}}\right]_+ \mathcal{C}, \tag{101}$$

where

$$[x]_+ \equiv \max(x, 0) \tag{102}$$

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.

This formulation makes clear that matter creation is not an additional source term imposed independently upon the scalar-flow theory. Rather, 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

$$\frac{\partial}{\partial \lambda}\left(\rho_{\text{flow}} + \rho_{\text{EM}} + \rho_b\right) + \nabla \cdot \mathbf{J}_E = 0, \tag{103}$$

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

$$\frac{\partial \mathbf{P}}{\partial \lambda} + \nabla \cdot \boldsymbol{\Pi} = \mathbf{f}_{\text{EM}}, \tag{104}$$

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 likewise satisfies

$$\frac{\partial \rho_q}{\partial \lambda} + \nabla \cdot \mathbf{J}_q = 0, \tag{105}$$

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.

0.3 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 therefore experimentally distinguishable and, in principle, falsifiable through multiple independent lines of evidence.

0.3.1 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.

0.4 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.

0.4.1 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.

0.4.2 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.

0.4.3 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
$F_u v$	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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