Vacuum Gravity – Effective Scalar Framework

Foundations of vacuum-based gravitation within the Vacuum Gravity Model.

— **Vacuum Gravity Model (CE001)**—

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Abstract

Could gravitation be nothing more than the inertial balance of a structured vacuum? This essay establishes the foundational framework of the *Vacuum Gravity Model* (VGM), in which gravitational phenomena arise from spatial gradients of a scalar cadence field that encodes the vacuum's intrinsic rhythm. The vacuum is described by the complex scalar

$$\Phi(x,t) = A(x,t)e^{i\theta(x,t)},$$

where the amplitude $A(x,t)$ represents the directly measurable cadence shift,

$$z(x,t) \equiv \frac{\delta\omega}{\omega}.$$

Hence, A is not an internal variable but a dimensionless observable calibrated by clocks and frequency standards.

In this scalar–inertial framework, gravity and inertia emerge from the same underlying mechanism: mass–energy locally drains the cadence of the vacuum, creating a gradient that accelerates matter, while the surrounding field elastically redistributes its cadence to preserve global balance. The apparent "curvature" of motion thus results from this dynamic equilibrium between drainage and redistribution rather than from spacetime geometry.

Abandoning the geometric paradigm of General Relativity, the VGM formulates gravity as a conservative response of the vacuum's cadence field. The universal acceleration law $\vec{a} = -c^2\nabla z$ and the cadence–Poisson equation $\nabla^2 z = F_\Phi\,\rho$ reproduce all first post–Newtonian tests of GR—redshift, deflection, and Shapiro delay—while defining a measurable and falsifiable scalar foundation for future extensions of inertial and cosmological dynamics.

Contents

Note to the Reader.

This paper belongs to the exploratory development of the *Vacuum Gravity Model (VGM)*, a scalar–inertial framework that investigates whether inertia, gravitation, and cosmic evolution can emerge from the dynamics of a structured vacuum field rather than from spacetime curvature.

The philosophical stance of this work follows the tradition of open theoretical inquiry pursued by the broader scientific community—ranging from scalar–tensor gravitation (Brans–Dicke), to emergent and superfluid vacuum analogies (Volovik, Afshordi, Verlinde), and to Born–Infeld and Machian approaches to inertia. In this spirit, the VGM does not aim to replace General Relativity, the Standard Model, or Quantum Field Theory, but to offer a complementary perspective that may highlight alternative pathways toward their unification.

The goal is not reiteration, but exploration: to examine whether the same observed phenomena might be understood through a different conceptual lens—one grounded in metrology, scalar dynamics, and the measurable cadence of the vacuum itself.

This manuscript is therefore presented in a constructive and collaborative spirit. All results are intended for open discussion, critical review, and possible replication by any interested researchers. All numerical values are illustrative or derived from publicly available data. The author encourages dialogue and welcomes both analytical and experimental scrutiny.

The Author.

Introduction

Gravitation has long been framed through the geometry of spacetime. *General Relativity* (GR) remains one of the greatest theoretical achievements of physics, describing the dynamics of curvature generated by energy–momentum and verified by innumerable experiments, from planetary precession to gravitational waves. Yet this geometric paradigm leaves open a fundamental question: *why* should inertia and gravitation be equivalent, and what physical medium transmits this coupling? In GR, geometry itself acts as the carrier of gravitation, but geometry has no measurable substance—it is a relational description, not a physical field.

The *Vacuum Gravity Model* (VGM) proposes a scalar–inertial alternative. Rather than curving spacetime, the vacuum is treated as a structured oscillatory medium described by the complex cadence field

$$\Phi(x,t) = A(x,t)e^{i\theta(x,t)},$$

where the amplitude $A(x,t)$ encodes the local inertial cadence of the vacuum. By definition,

$$z(x,t) \equiv A(x,t) = \frac{\delta\omega}{\omega},$$

so that z is a directly measurable, dimensionless observable calibrated by clocks. Gradients of this cadence field produce accelerations,

$$\vec{a} = -c^2\nabla z,$$

while its Laplacian couples to mass–energy through

$$\nabla^2 z = F_\Phi\,\rho.$$

These relations reproduce the Newtonian and first post–Newtonian limits of GR without invoking curvature, thereby reformulating gravity as the inertial response of a structured vacuum.

Inertial balance and the emergence of curvature. Within this scalar framework, gravitation originates from a dynamic equilibrium of the vacuum itself. Localized mass–energy drains cadence, creating an inward gradient that drives the acceleration of matter. The surrounding field responds elastically, redistributing cadence so that the global inertial flux remains conserved. The apparent curvature of motion thus emerges from this balance between drainage and redistribution, not from geometric deformation. This principle of *inertial balance* defines the physical origin of gravitational attraction and will serve as the foundation for subsequent developments of the VGM.

Position in the theoretical landscape. The VGM belongs to the broader lineage of emergent and scalar gravities, from Sakharov's induced vacuum elasticity to Verlinde's entropic gravity and Afshordi's superfluid vacuum approaches. While these frameworks suggest that spacetime may be an emergent phenomenon, none provide a single measurable scalar linking inertia and gravity. The VGM fills this gap by introducing z as a metrologically defined field, bridging classical gravitation, quantum coherence, and cosmological evolution within one falsifiable, observable–first formulation.

The Vacuum Phase Field

In the *Vacuum Gravity Model* (VGM), the vacuum is not an empty background but a structured oscillatory medium whose state carries both inertial and gravitational information. At each spacetime point, this state is represented by the complex cadence field

$$\Phi(x,t) = A(x,t)\,e^{i\theta(x,t)},$$

where the amplitude $A(x,t)$ quantifies the local *inertial tension* of the vacuum and the phase $\theta(x,t)$ defines its temporal rhythm.

Observable identification. By construction,

$$z(x,t) \equiv A(x,t) = \frac{\delta\omega}{\omega},$$

so that z is a directly measurable, dimensionless quantity describing the relative cadence shift between two reference clocks. Unlike potential functions in geometric gravitation, A is not an abstract degree of freedom—it is an operational observable, defined through metrological comparison and reproducible anywhere in the Universe.

Inertial reference and homogeneity. A homogeneous vacuum with constant $A = A_0$ establishes the universal reference cadence Ω_0 and defines local inertial frames. Gradients in A correspond to spatial variations of this cadence and produce accelerations through

$$\vec{a} = -\, c^2 \nabla A.$$

The weak–field limit identifies the observable cadence shift with the Newtonian potential:

$$z(x,t) = \frac{\Phi_N(x)}{c^2}, \qquad n = 1 - 2z,$$

ensuring dimensional closure with standard post–Newtonian quantities.

Physical interpretation. The field Φ provides a unified carrier for proper time, light propagation, and inertial stability. Where GR attributes gravitational effects to geometric curvature, the VGM attributes them to spatial variations of A, interpreted as the elastic response of the vacuum cadence to matter–energy. A local decrease in A corresponds to drained cadence—massive presence—while the surrounding field redistributes cadence to preserve global equilibrium. Thus, the vacuum phase field replaces metric curvature with a physically measurable, scalar architecture of inertia.

Inertia and Gravitation

The central postulate of the *Vacuum Gravity Model* (VGM) is that inertia and gravitation are two expressions of the same underlying process—the dynamic structuring of the vacuum cadence field Φ. Both effects emerge from local variations of the dimensionless cadence shift

$$z(x,t) \equiv \frac{\delta\omega}{\omega} = A(x,t),$$

which quantifies the relative change of the vacuum's oscillatory rhythm. Spatial gradients of z create accelerations,

$$\vec{a}(x,t) = -\, c^2 \nabla z(x,t),$$

while the Laplacian of z couples to the mass–energy density through the cadence–Poisson relation

$$\nabla^2 z(x,t) = F_\Phi\, \rho(x,t).$$

These equations define inertia and gravity within a single scalar framework, recovering all first post–Newtonian results of GR in the weak–field limit.

Inertial motion

A freely moving body follows a trajectory determined by the local distribution of z. In a region where $\nabla z = 0$, the cadence of the vacuum is uniform and the motion remains uniform and rectilinear. Where a gradient exists, the imbalance of cadence produces a finite acceleration according to $\vec{a} = -c^2 \nabla z$. The motion of matter thus reflects the effort of the vacuum to restore cadence equilibrium, not the traversal of curved geometry.

Equivalence principle as a scalar identity

All clocks and matter fields interact with the same cadence field A, so their response to a gradient in z is universally identical. This intrinsic coupling ensures

$$\kappa = 1, \qquad \sigma = 1,$$

where κ encodes the universality of clock redshifts and σ that of free fall. The equivalence of inertial and gravitational mass is therefore not an independent postulate but a scalar identity arising from the common dependence of all systems on z. At first post–Newtonian order, the predictions of GR are exactly recovered.

Physical interpretation

Inertia appears as the vacuum's resistance to changes in cadence, while gravitation corresponds to the spatial redistribution of this cadence around localized sources. A concentration of energy drains cadence locally ($\delta\omega < 0$), producing an inward gradient; the surrounding field compensates elastically, maintaining global conservation of the inertial flux. This feedback—the balance between drainage and redistribution—is the physical origin of gravitational attraction. Hence, the equality of inertial and gravitational mass expresses a deeper principle: both are manifestations of the same scalar architecture of the vacuum, encoded in A.

Mathematical Framework

To establish the formal structure of the *Vacuum Gravity Model* (VGM), we begin from the measurable cadence shift

$$z(x,t) \equiv \frac{\delta\omega}{\omega} = A(x,t),$$

which, in the weak and static regime, coincides with the Newtonian potential scaled by c^2:

$$z(x,t) = \frac{\Phi_N(x)}{c^2}.$$

Variational origin. The field equations of the VGM follow from a conservative Lagrangian density expressed in terms of the cadence amplitude A:

$$\mathcal{L}_\Phi = \frac{1}{2}(\partial_\mu A)(\partial^\mu A) - F_\Phi\, \rho\, A,$$

where $F_\Phi = 4\pi G/c^2$ is the inertial coupling constant. Variation of $\mathcal{L}_\Phi$ with respect to A yields

$$\nabla^2 A = F_\Phi\, \rho,$$

which constitutes the *cadence–Poisson equation.* Thus, Newtonian gravity appears as the stationary condition of the vacuum's scalar cadence field rather than of geometric curvature.

Acceleration law and potential. A test particle experiences the inertial response of the field through

$$\vec{a} = -\,c^2 \nabla A = -\,\nabla \Phi_{\text{eff}}, \qquad \Phi_{\text{eff}} = c^2 A = c^2 z.$$

In the weak–field limit, Φ_{eff} reduces exactly to the Newtonian potential Φ_N, ensuring full continuity with classical mechanics.

Exterior solution and source parameter. For an isolated spherical source of barycentric mass M, integration of the cadence–Poisson equation gives

$$z(r) = -\,\frac{K}{r}, \qquad K \equiv \frac{GM}{c^2}.$$

All measurable observables—clock shifts, accelerations, Shapiro delays, and light deflections—can be expressed solely in terms of K, without introducing G or M separately. This guarantees metrological closure: the field amplitude, its gradient, and its source parameter are all dimensionless or directly measurable.

Compact form of the inertial field. The entire weak–field structure of the VGM can therefore be written as

$$\vec{a} = -\,c^2 \nabla z, \tag{1}$$

$$\nabla^2 z = F_\Phi\, \rho, \tag{2}$$

$$z(r) = -\,\frac{K}{r}. \tag{3}$$

Eqs. (1)–(3) reproduce Newtonian gravity in the appropriate limit and define a scalar, cadence-first formulation of gravitation that dispenses entirely with metric curvature.

Observable Consequences

The *Vacuum Gravity Model* (VGM) reproduces all verified weak–field predictions of *General Relativity* (GR) while expressing them in purely observable form through the cadence shift z. Every classical gravitational effect—clock redshift, free fall, Shapiro delay, and light deflection—appears as a direct manifestation of spatial gradients of z, without invoking metric curvature.

Clock redshift. Two clocks located at r_1 and r_2 in the cadence field of a spherical source compare as

$$\Delta z = z(r_2) - z(r_1) = K\left(\frac{1}{r_1} - \frac{1}{r_2}\right),$$

yielding the observed gravitational redshift $\Delta\nu/\nu = \Delta z$. This relation coincides exactly with GR predictions at first post–Newtonian (1PN) order but is expressed solely in terms of the measurable, dimensionless field z.

Free fall. A test body released at rest in the field of a spherical source experiences an acceleration

$$a_r(r) = -\,c^2 \frac{\partial z}{\partial r} = -\,\frac{c^2 K}{r^2}.$$

This reproduces Newton's inverse–square law with the identification $K = GM/c^2$, ensuring empirical equivalence with classical dynamics and 1PN GR.

Light propagation. Light propagates through the cadence field with an effective refractive index

$$n(x) = e^{-2A(x)} \simeq 1 - 2z(x),$$

so that null trajectories follow the same deflection and delay relations as metric geodesics at 1PN order:

$$\delta\theta = \frac{4\,K}{b}, \tag{4}$$

$$\Delta t_{\text{Shapiro}} = \frac{2\,K}{c}\ln\!\left(\frac{4r_1 r_2}{b^2}\right), \tag{5}$$

where b is the impact parameter. These expressions coincide with GR results for solar–system tests and radio interferometry, confirming the optical equivalence of the two frameworks.

Gauss law in cadence form. The flux of ∇z through a closed surface defines the enclosed mass:

$$\oint \nabla z \cdot d\vec{S} = 4\pi K = F_\Phi\, M, \qquad M = \frac{4\pi}{F_\Phi}\,K.$$

This provides a purely metrological definition of mass and energy through field measurements, closing the dynamical and observable hierarchy.

Summary table

Observable	GR Expression	VGM Equivalent	Status (1PN)
Clock redshift	$\Delta\nu/\nu = \Delta\Phi_N/c^2$	$\Delta\nu/\nu = \Delta z$	Identical
Free fall	$a = -\nabla\Phi_N$	$a = -c^2\nabla z$	Identical
Light deflection	$\delta\theta = 4GM/(c^2 b)$	$\delta\theta = 4K/b$	Identical
Shapiro delay	$\Delta t = 2GM/c^3 \ln(...)$	$\Delta t = 2K/c \ln(...)$	Identical
Gauss flux	$\oint \nabla\Phi_N \cdot dS = 4\pi GM$	$\oint \nabla z \cdot dS = 4\pi K$	Identical

Table 1: Comparison between GR and VGM predictions in the weak–field regime. All observables are numerically identical at 1PN order; the difference lies in ontology—geometry versus cadence field.

Interpretation. In the VGM, each of these classical effects measures the same physical quantity: the variation of the vacuum's intrinsic cadence z. Where GR employs metric coefficients $g_{\mu\nu}$, the VGM expresses the same observables through directly measurable frequency ratios and time delays. Hence, gravitation appears not as curvature of an abstract manifold but as the inertial response of a real, structured vacuum.

Discussion

The *Vacuum Gravity Model* (VGM) reproduces every tested weak–field result of *General Relativity* (GR) yet rests on a different physical ontology. Where GR attributes gravitation to the curvature of spacetime, the VGM attributes it to the inertial response of a structured vacuum whose cadence field z governs both matter and radiation. This section highlights the conceptual implications and experimental reach of this scalar–inertial framework.

Equivalence principle revisited

In GR, the equality of inertial and gravitational mass is postulated and then verified experimentally. In the VGM, it follows necessarily from the scalar nature of the vacuum field: all systems couple identically to z, so that

$$\kappa = 1, \qquad \sigma = 1.$$

The universality of free fall and of clock redshift is therefore not assumed but derived. In this sense, the equivalence principle becomes a consequence of the vacuum's uniform cadence rather than an external axiom.

Observable primacy and metrological closure

The cadence field provides a direct bridge between theory and measurement. Where GR introduces the potential Φ_N or the metric $g_{\mu\nu}$ as intermediate constructs, the VGM works entirely with measurable quantities: frequency ratios, time delays, and acceleration gradients. Every observable depends only on the dimensionless field z and on the empirically calibrated source parameter K. This *metrological closure* eliminates unobservable intermediates, making the framework intrinsically falsifiable.

Continuity with General Relativity

At first post–Newtonian order, Eqs. (1)–(3) recover the same predictions as GR. The correspondence holds because both theories share the same weak–field expansion of proper time:

$$\frac{d\tau}{dt} \simeq 1 + z = 1 + \frac{\Phi_N}{c^2}.$$

Thus, GR appears as the geometric limit of an underlying scalar equilibrium. In the limit of infinite vacuum rigidity—when cadence redistribution is instantaneous—the VGM reduces exactly to GR.

Implications for extensions

Because z is a scalar field rather than a metric potential, its evolution can be extended consistently beyond 1PN without modifying spacetime geometry. Higher–order (2PN) or effective–field corrections can be represented as small nonlinear terms in $\mathcal{L}_\Phi$, preserving metrological interpretability. Such refinements would be testable through modern precision experiments: optical–clock comparisons, VLBI astrometry, and long–baseline time–transfer measurements sensitive to cadence gradients at the 10^{-18} level.

Falsifiability and physical interpretation

The VGM is falsifiable in a strictly operational sense. Independent determinations of z—from gravitational redshift, free–fall acceleration, and Shapiro delay—must coincide within experimental uncertainty. Any inconsistency would immediately refute the scalar hypothesis. Conversely, continued agreement would support the view that gravitation is not curvature but the macroscopic signature of the vacuum's cadence equilibrium.

Discussion Addendum — Significance for **Emergent Gravity.**

Scalar and emergent gravities have a long intellectual lineage, from Brans–Dicke scalar–tensor theories and Sakharov's induced gravity to Verlinde's entropic approach and Volovik's superfluid analogies. Each of these frameworks recognizes that gravitation may arise from the microstructure of the vacuum, yet none provides a closed, measurable field replacing spacetime geometry itself.

The present formulation advances this lineage by introducing a *metric–free scalar field* directly tied to observation. The dimensionless cadence shift

$$z = \frac{\delta\omega}{\omega}$$

serves simultaneously as the gravitational potential, the inertial amplitude, and the metrological observable accessible to precision clocks and interferometers. No geometric tensor is required: the full content of weak–field gravitation is carried by z and its source parameter K.

This shift in ontology—from geometry to vacuum cadence—constitutes the principal innovation of CE001. Where previous scalar or emergent models offered conceptual analogies, the VGM offers a *falsifiable closure*: its equations are dimensionally complete, empirically normalized, and directly testable through clock networks, VLBI, and time–transfer measurements. In this sense, the VGM transforms emergent gravity from an interpretive framework into an experimental discipline.

For researchers exploring emergent or superfluid vacua, the inertial–equilibrium mechanism proposed here offers a new bridge: it translates the idea of "vacuum elasticity" into a scalar conservation law governing cadence drainage and redistribution. The curvature of motion becomes the macroscopic signature of this balance, not an intrinsic property of spacetime.

By grounding emergent gravity in measurable cadence dynamics, the VGM invites a new generation of tests and theoretical refinements—a continuation of the program initiated by Brans, Sakharov, Verlinde, Volovik, and Afshordi, but completed here at the level of a single, observable scalar field.

Conclusion

The *Vacuum Gravity Model* (VGM) provides a cadence–first reformulation of gravitation and inertia. Instead of interpreting gravitational phenomena as the manifestation of curved spacetime geometry, the VGM describes them as the inertial response of a structured vacuum field whose intrinsic rhythm varies with mass–energy. The dimensionless observable

$$z(x,t) = \frac{\delta\omega}{\omega} = A(x,t)$$

acts as the universal potential governing both clock rates and accelerations.

From this single scalar field arise the standard weak–field effects:

- gravitational redshift and clock dilation through Δz,

- free–fall acceleration $\vec{a} = -c^2\nabla z$,
- light propagation delays and deflections via $n \simeq 1 - 2z$,
- the source relation $z = -K/r$ ensuring metrological closure.

All are numerically identical to GR predictions at first post–Newtonian order, but differ in interpretation: curvature is replaced by the elastic equilibrium of the vacuum's cadence.

Physical essence. Mass–energy locally drains the cadence of the vacuum, while the surrounding field redistributes it to restore balance. This dynamic equilibrium—the *inertial balance* of the vacuum—is the physical origin of gravitation. In this view, geometry is an emergent description of a deeper scalar process, and the equality of inertial and gravitational mass reflects the vacuum's universal cadence coupling.

Empirical closure and falsifiability. Because every observable derives from z and the source parameter K, the framework is fully metrological and falsifiable. Independent determinations of z from clocks, accelerometers, and optical time–transfer must agree within measurement precision. Any discrepancy would refute the model; consistency would strengthen the hypothesis that gravitation is the macroscopic signature of a self–balancing vacuum.

Outlook. The foundations established here define a complete and testable scalar theory of gravitation at 1PN accuracy. Future work will extend this inertial equilibrium to dynamic regimes, quantum coherence, and cosmological evolution, exploring whether the same cadence field underlies the full hierarchy of physical phenomena.

Inertial Equilibrium Principle. Gravitation is the observable imprint of the vacuum's effort to preserve its own cadence balance. The curvature of motion reflects not geometry but the elastic redistribution of cadence within the structured vacuum field.

BIBLIOGRAPHY

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Online Library

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Foundations and Theoretical Framework

CE000 — Emergent Gravity and the Vacuum Rhythm of Spacetime **(PDF)**
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