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# Maxwell's Equations with a Measurement-Dependent Collapsible Field

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# Maxwell's Equations with a Measurement-Dependent Collapsible Field

**Abstract**

Classical electrodynamics presumes that all physically relevant field degrees of freedom are directly accessible to measurement. We examine whether coherence-dependent dynamics can nevertheless influence observable behaviour while remaining operationally hidden. We introduce a minimal extension of Maxwell's equations incorporating a hidden field whose influence is transient and suppressed by measurement-like collapse. The field neither sources space-time curvature nor introduces new interactions, but modifies electromagnetic propagation and energy redistribution in a coherence-limited regime. Analytical derivations and numerical simulations demonstrate transient phase accumulation, energy-density gradients, and short-lived force-like responses that vanish smoothly as the collapse rate increases, recovering standard electrodynamics. The resulting dynamics exhibit a source–mediator–sink structure governed by collapse control. We identify experimentally accessible signatures based on dispersive, phase-sensitive measurements, establishing a controlled framework for probing hidden coherence effects within classical field theory.

# 1 Introduction

Maxwell's equations for electromagnetism and Einstein's General Relativity for gravity have been experimentally validated to extraordinary precision in their respective domains but, taken together, they are yet disunited with each other or with quantum mechanics, indicating a clear gap in our understanding of fundamental physical laws.

This lacuna has motivated fervent explorations, not least through approaches reliant on hidden or collapsed fields. In current physics, gravity and electromagnetism are fundamentally different forces, with gravity acting on mass-energy and always attractive, whereas electromagnetism acts on electric charge and can be attractive or repulsive. Historically, several attempts have been made to link them, such as in Kaluza-Klein theory, string theory, or emergent gravity models [1–3]. The absence of strong experimental bases for these theories hinders their advancement. For example, no "real world" configuration of electromagnetic fields can neutralize or reverse gravity to produce true gravitational repulsion. There have been exotic ideas such as gravitomagnetic [4], negative mass [5], and electrogravitics. Gravitomagnetism is a weak analogy of magnetism in General Relativity theory, while the concept of negative mass is highly hypothetical in mainstream physics. Fringe science, which is considered by many to be hardly worth mentioning, has popularized certain interesting concepts, such as electrogravitics [6].

Classical field theories are built on the fundamental assumption that all field components are fully observable and measurable. However, recent advances in quantum information theory and gravitational physics suggest that certain physical phenomena may be governed by hidden or collapsible variables [7]. These terms could evade direct measurement and yet influence observable dynamics. The fundamental question is then: can a hidden term exist within the electromagnetic field equations that collapses or vanishes upon measurement in a manner akin to the collapse of a qubit state? Could this term help explain phenomena currently attributed to gravity or enable

the manipulation of gravitational effects through electromagnetic interactions? Such a hidden electromagnetic field $G$ would be unobservable under classical measurement, manifesting only in coherent quantum systems.

We propose a novel extension of Maxwell's equations by introducing a measurement-sensitive non-observable term that collapses upon observation, analogous to quantum state collapse. We explore whether $G$ could reconcile classical electrodynamics with quantum-like behavior, particularly in regimes where gravitational and electromagnetic interactions converge. This approach challenges the conventional assumption of complete observability in classical fields and potentially opens a pathway toward a unified framework where measurement itself becomes a dynamic operator, revealing new physics at the intersection of electromagnetism, quantum theory, and gravity.

## 2 Theoretical Framework

To introduce a measurement-sensitive term, we define a field or operator $\mathcal{M}$, denoting measurement, that contributes to the dynamics of $E$ and $B$, but becomes unobservable under classical measurement, i.e., $\mathcal{M} \to 0$. This construction may require a nonlinear, nonlocal, or non-Hermitian extension of the field equations. Such abstractions exist in quantum field theory [8], collapse models such as GRW or Penrose [9], or hidden variable theories [10]. Because measurement invariance is not a feature of classical field theories, introducing $\mathcal{M}$ could violate Lorentz invariance [11], gauge symmetry, or energy conservation unless carefully formulated. Currently, no direct experimental data support the existence of $\mathcal{M}$. However, the absence of evidence does not constitute evidence of absence. Consequently, we shall assume that its status is untested rather than disproved. Albeit speculative, this idea aligns with mainstream theoretical bases

for extending classical field theories, such as Erik Verlinde's emergent theory of gravity, hidden sector fields such as dark electromagnetism, quantum gravity including noncommutative geometry, and collapse models in quantum foundations [12–16].

## 2.1 Standard Maxwell's Equations

Maxwell's equations in vacuum are:

$$\nabla \cdot \mathbf{E} = \frac{\rho}{\varepsilon_0} \tag{1}$$

$$\nabla \cdot \mathbf{B} = 0 \tag{2}$$

$$\nabla \wedge \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t} \tag{3}$$

$$\nabla \wedge \mathbf{B} = \mu_0 \mathbf{J} + \mu_0 \varepsilon_0 \frac{\partial \mathbf{E}}{\partial t} \tag{4}$$

The hidden field can be written as a complex field $G$ i.e., $\mathbf{F}_{\text{total}} = \mathbf{E} + i\mathbf{G}_E, \quad \mathbf{B}_{\text{total}} = \mathbf{B} + i\mathbf{G}_B$ giving the complex modified Maxwell's equations:

$$\nabla \cdot (\mathbf{E} + i\mathbf{G}_E) = \frac{\rho}{\varepsilon_0} + \alpha \Phi_G \tag{5}$$

$$\nabla \cdot (\mathbf{B} + i\mathbf{G}_B) = 0 \tag{6}$$

$$\nabla \wedge (\mathbf{E} + i\mathbf{G}_E) = -\frac{\partial (\mathbf{B} + i\mathbf{G}_B)}{\partial t} \tag{7}$$

$$\nabla \wedge (\mathbf{B} + i\mathbf{G}_B) = \mu_0 \mathbf{J} + \mu_0 \varepsilon_0 \frac{\partial (\mathbf{E} + i\mathbf{G}_E)}{\partial t} + \alpha \mathbf{R} \tag{8}$$

The additional terms $\alpha\mathbf{R}$ and $\alpha\Phi_G$ represent phenomenological coherence-dependent contributions that encode the indirect influence of the collapsible hidden sector on the observable electromagnetic dynamics. They act respectively as effective response-current–like and polarization- or bound-charge–like terms, parametrizing transient redistribution of energy, phase, and field divergence mediated by hidden

electromagnetic structure that remains inaccessible to direct measurement. Importantly, neither term corresponds to new free charges or currents, nor implies additional observable degrees of freedom beyond standard electrodynamics. Consistency with charge conservation and Maxwell's equations is ensured by requiring that both $\mathbf{R}$ and $\Phi_G$ vanish under strong measurement, such that the classical Gauss and Ampère–Maxwell laws are recovered exactly in all operationally classical regimes. Fig. 1 illustrates the interaction of $G$ and classical fields $E$ and $B$, and the measurement boundary. Alternatively, the hidden, measurement collapsible non-classical field can

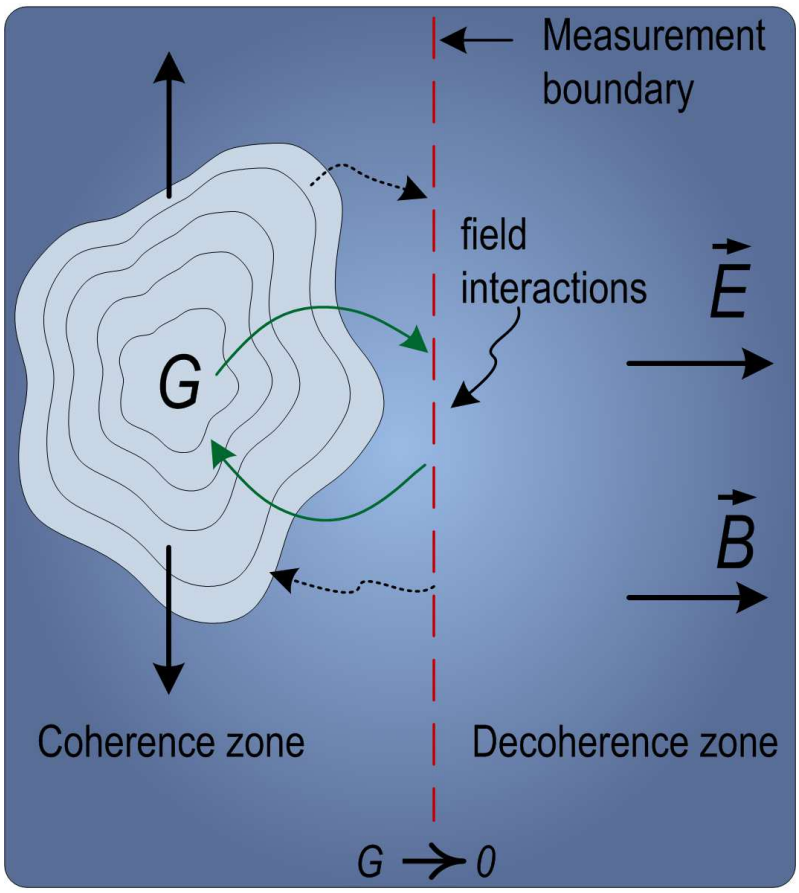



**Fig. 1** Conceptual diagram of hidden field $G$ interacting with classical fields, showing the boundary of measurement collapse.

be defined as $C(t)$. Assuming that $C(t)$ decays exponentially with a measurement-like parameter $M$ denoting the strength of observation, i.e. $C(t) = C_0 e^{Mt}$. The parameter $M$ sets the exponential collapse of $C(x,t)$ through both its time dependence and the quadratic potential: $V(C) = \frac{1}{2}M^2C^2$, then Maxwell's equations can be modified according to:

$$\nabla \cdot \mathbf{E} = \frac{\rho}{\varepsilon_0} + \chi_1 \cdot \nabla \cdot \mathbf{C} \tag{9}$$

$$\nabla \cdot \mathbf{B} = \chi_2 \cdot \nabla \cdot \mathbf{C} \tag{10}$$

$$\nabla \wedge \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t} + \chi_3 \cdot \nabla \wedge \mathbf{C} \tag{11}$$

$$\nabla \wedge \mathbf{B} = \mu_0 \mathbf{J} + \mu_0 \varepsilon_0 \frac{\partial \mathbf{E}}{\partial t} + \chi_4 \cdot \frac{\partial \mathbf{C}}{\partial t}, \tag{12}$$

where $\chi_1 \cdots \chi_4$ are phenomenological coupling constants. We assume a quadratic potential to render the vanishing field configuration $C = 0$ the unique energetically stable state. That is, because $\mathbf{F} = -\nabla V$, the restoring force $\mathbf{F}$ always points toward the equilibrium state $C$=0. A higher value of $M$ means stronger measurement effect. For amplitude-normalized base electromagnetic fields $E_0(t) = \sin(t)$ and $B_0(t) = \cos(t)$, the modified fields become:

$$E_{\mathrm{mod}}(x,t) = E_0(x,t) + \lambda C(x,t), \qquad B_{\mathrm{mod}}(x,t) = B_0(x,t) + \lambda C(x,t). \tag{13}$$

The parameter $\lambda$ is a weighting factor that specifies the strength of the coupling between the classical electromagnetic field and the hidden collapsible field $C(x,t)$. Smaller $\lambda$ means weaker effect of the hidden field, keeping the modified field close to the classical counterparts. Considering only the 1D formulation for simplicity and clarity, $\lambda$ directly controls how strongly the hidden field contributes to the classical fields. Deviations induced by $C(x,t)$ are perturbative and transient, with the observable dynamics dominated by the background fields $E_0$ and $B_0$. Conversely, larger

values of $\lambda$ amplify the influence of the hidden field, allowing $C(x,t)$ to produce substantial departures from classical behavior during the period in which it persists. The magnitude of these departures scales linearly with $\lambda$, making it a direct measure of the system's sensitivity to hidden dynamics. Importantly, $\lambda$ does not control the lifetime or decay rate of the hidden field but determines the visibility of the hidden field's influence on observable quantities. Even when $C(x,t)$ collapses rapidly, a sufficiently large $\lambda$ can produce noticeable but short–lived modifications to the electromagnetic fields. In a physical sense, $\lambda$ defines an effective interaction strength between the electromagnetic sector and an underlying hidden degree of freedom. In this sense, it is analogous to a coupling constant in field theory, regulating the degree of information transfer between otherwise independent dynamics. Within the measurement–induced collapse analogy, $\lambda$ controls how strongly the hidden state manifests in observable behavior before being suppressed by collapse or decoherence effects [17]. Overall, it provides a tunable parameter that interpolates smoothly between a purely classical regime, in which hidden dynamics are effectively invisible, and a regime in which transient, non-classical behavior becomes appreciable, without altering the intrinsic collapse mechanism of the hidden field itself. Fig. 2 shows the simulated effects of measurements with $\lambda = 0.3$ for $M \in \{0.1, 0.5, 1.0, 2.0\}$. Fig. 2 illustrates how the hidden field $C(t)$ modulates the classical electromagnetic fields $E$ and $B$ through its coupling strength and collapse rate. For low values of the control parameter $M$, such as $M = 0.1$, the hidden field decays slowly and persists over an extended time interval. In this regime, $C(t)$ contributes significantly to the modified fields $E_{\mathrm{mod}}$ and $B_{\mathrm{mod}}$, producing pronounced deviations from their classical sinusoidal behavior and indicating a strong hidden-field influence. As $M$ increases, the decay of $C(t)$ becomes progressively faster. For sufficiently large values, such as $M = 2.0$, the hidden field collapses rapidly, and its contribution becomes negligible, causing the modified fields

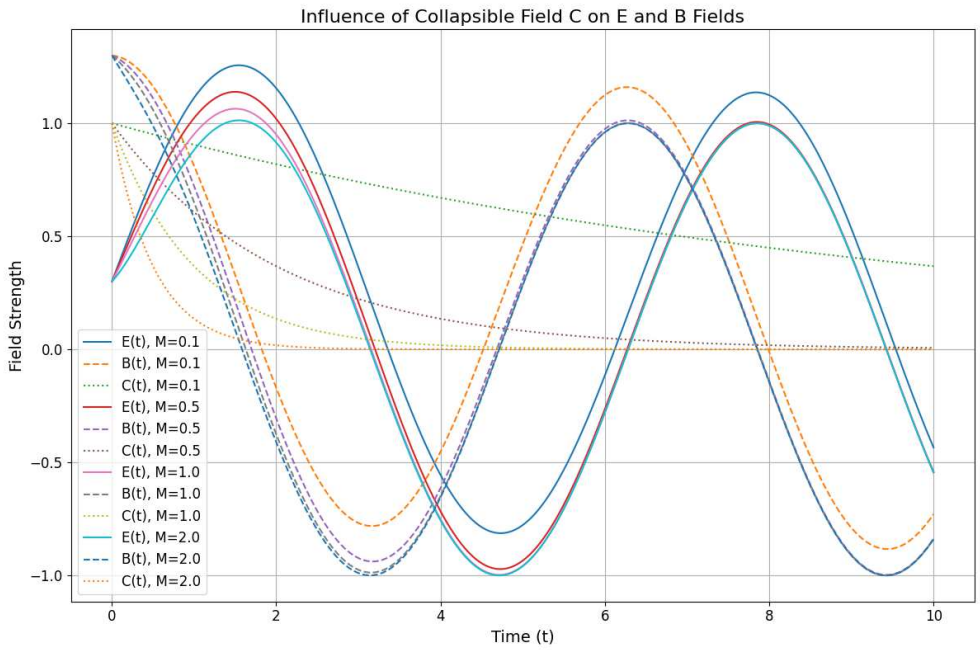



**Fig. 2** Simulated responses of the effect of different measurement strengths of collapsible field on classical EM fields.

to converge smoothly to the classical solutions $E_0(t)$ and $B_0(t)$. This behavior is consistent with a measurement-induced collapse picture in which increasing interaction or observational strength suppresses hidden dynamics and restores the familiar classical electromagnetic response.

## 2.2 Measurement-modified Lagrangian density

We restrict the system to one spatial dimension (1D), denoted by $x$, to simplify interpretation and isolate the essential dynamics of the coupling mechanism. This provides a minimal, analytically tractable framework for exploring transient deviations from classical electrodynamics driven by hidden dynamics. Both the EM and hidden collapsible fields are treated as effectively scalar fields $E(x,t)$ and $C(x,t)$, respectively. This 1D formulation preserves the qualitative behavior of the model while clarifying the influence of the hidden field. The background field is chosen as a simple standing

wave solution,

$$E_0(x,t) = \sin(x)\sin(t), \tag{14}$$

while the hidden field is a collapsible mode of the form

$$C(x,t) = e^{-Mt}\sin(x)\cos(t). \tag{15}$$

The dynamics of the system are described by the 1D Lagrangian density

$$\mathcal{L}(x,t) = \frac{1}{2}\left(\frac{\partial E_{\text{mod}}}{\partial t}\right)^2 - \frac{1}{2}\left(\frac{\partial E_{\text{mod}}}{\partial x}\right)^2 - V(C), \tag{16}$$

where the potential energy associated with the hidden field is given by the quadratic potential, $V(C)$. Specifically, when $C > 0$, the resulting force is negative, while for $C < 0$, the force is positive. Therefore, deviations from equilibrium are dynamically suppressed, ensuring that the hidden field cannot remain nonzero and must collapse over time. The $C$ modifies the observable EM response only through its contribution to $E_{\text{mod}}$, while its own collapse is enforced by the quadratic potential. Fig. 3 plots the 1D Lagrangian densities for varying coupling strengths of the collapsible field on the classical EM fields. It is evident that as $M$ increases, the features in the Lagrangian density plots tend to decay more rapidly along the time axis ($t$). This is consistent with $M$ representing a measurement-like parameter, as defined above. The spatial variations (along $x$) are still evident, but their temporal persistence is significantly reduced with higher $M$. The darker regions in the plots correspond to locations where the Lagrangian density attains its lowest values. These regions arise primarily from a strong negative contribution of the potential term, indicating that the hidden field $C(x,t)$ is locally most pronounced. The nontrivial dynamics of the system are not confined to a single color scale but are instead revealed through pronounced spatial and temporal variations in the color patterns. Such regions signify active evolution

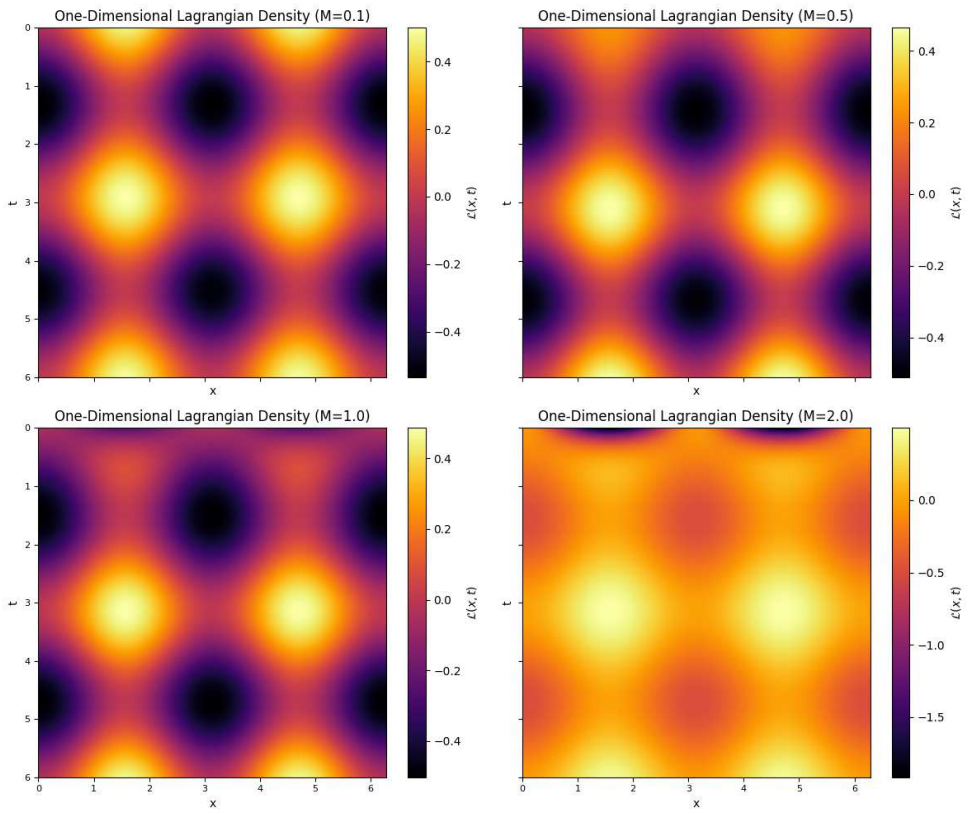



**Fig. 3** Simulated one-dimensional Lagrangian densities illustrating the influence of a collapsible hidden field on classical electromagnetic dynamics for measurement strengths $M \in \{0.1, 0.5, 1.0, 2.0\}$. Darker regions correspond to lower Lagrangian density, arising predominantly from strong negative contributions of the quadratic potential, where the hidden field $C(x,t)$ is most pronounced. Pronounced spatial and temporal variations in the color patterns indicate regions of nontrivial dynamics, where rapid evolution of the modified electric field enhances the kinetic and gradient contributions $(\partial_t E)^2$ and $(\partial_x E)^2$. As $M$ increases, the hidden field collapses more rapidly, suppressing these variations and driving the system toward the classical electromagnetic regime.

of the fields $E(x,t)$ and $C(x,t)$, where the kinetic and gradient terms, $(\partial_t E)^2$ and $(\partial_x E)^2$, contribute significantly. Together with the local strength of $C(x,t)$, these variations highlight the interplay between field dynamics and the collapse mechanism encoded in the Lagrangian density.

## 2.3 Analogy with gravitational influence

Although the present framework does not constitute a theory of quantum gravity, the nontrivial dynamics of the collapsible field $C(x,t)$ suggest a useful analogy with gravitational influence in General Relativity. In the Lagrangian formulation, the quadratic expression of $V(C)$ locally modified the dynamical landscape of the electromagnetic field without introducing a direct force. Regions where $C(x,t)$ is large correspond to pronounced distortions of this effective background, evident as strong negative contributions to the Lagrangian density, and conceptually reminiscent of curvature generated by mass–energy in spacetime. Crucially, the source of this modification is itself transient: as $C(x,t)$ collapses, its influence weakens and the electromagnetic dynamics relax smoothly toward their classical form. In this sense, the hidden field may be viewed as a temporary, dynamically evolving mediator that reshapes the environment in which electromagnetic propagation occurs before dissipating, evoking the emergence and subsequent flattening of an effective curvature without invoking geometric gravity directly.

## 2.4 Euler-Lagrange field dynamics and variational result

The dynamics of the modified electromagnetic field are governed by the 1D Lagrangian density in Eq. 16, and the observable field is defined through linear coupling to a collapsible hidden field define in Eq. 13. The variation of the action with respect to $E_{\text{mod}}$ yields the Euler–Lagrange equation

$$\left(\partial_t^2 - \partial_x^2\right) E_{\text{mod}}(x,t) = 0, \qquad E_{\text{mod}} = E_0 + \lambda C, \tag{17}$$

showing that hidden–field dynamics enter the electromagnetic sector as an effective, transient modification of wave propagation. As the hidden field collapses, its contribution vanishes and the classical electromagnetic behavior is smoothly recovered.

The full derivation of this result is provided in the Supplementary Information. Fig. 4 shows numerical solutions of the modified electric field using the Euler-Lagrange equations using the above values of $\lambda$ and $M$. The plots demonstrate that the mod-

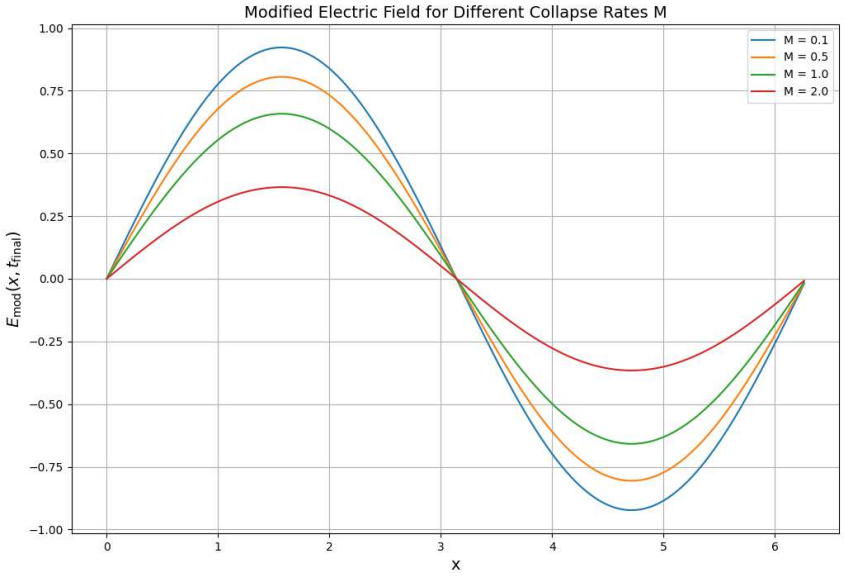



**Fig. 4** Dependence of the modified electric field $E_{\text{mod}}$ on the collapse rate $M$ of the hidden field $C(x,t)$. Small values of $M$ correspond to slow decay of $C$, producing sustained deviations from the unperturbed field, while larger $M$ values rapidly suppress the hidden field and restore classical electromagnetic behavior. This progression provides a direct analogue of measurement-induced collapse, with increasing $M$ representing stronger effective measurement and faster relaxation to the classical regime.

ification of the electric field is controlled by the decay of the collapsible field $C(x,t)$, whose exponential dependence $e^{-Mt}$ makes the parameter $M$ the primary determinant of how long hidden dynamics persist. For small $M$, the collapse is slow and $C$ retains significant amplitude at late times, leading to pronounced deviations of $E_{\text{mod}}$ from the unperturbed field. As $M$ increases, the decay of $C$ accelerates and its contribution rapidly vanishes, causing $E_{\text{mod}}$ to relax toward the classical baseline. This systematic behavior provides a clear analogue of measurement-induced collapse, with

larger $M$ corresponding to stronger effective measurement that suppresses hidden dynamics and restores classical electromagnetic behavior.

## 2.5 Effective energy density

The present framework also invites exploration of whether the hidden field $C(x,t)$ could influence the effective gravitational potential or mass distribution within a localized region, without constituting gravity itself. In this perspective, the role of $C$ is not to source spacetime curvature directly, but to modify how energy and inertia are distributed and perceived locally. Such an approach is consistent with analogue gravity and emergent geometry paradigms, where gravitational-like effects arise as effective descriptions of underlying field dynamics rather than as fundamental interactions [18]. Plausibly, the hidden field can be associated with a local, time-dependent contribution to an effective mass density. Defining an effective energy density for $C$,

$$\mathcal{E}_C(x,t) = \frac{1}{2}\left[(\partial_t C)^2 + (\partial_x C)^2 + M^2 C^2\right],$$

one may write an effective mass distribution in a form that maintains correspondence with the Hamiltonian energy:

$$\rho_{\text{eff}}(x,t) = \rho_0(x) + \alpha\, \mathcal{E}_C(x,t),$$

where $\rho_0(x)$ denotes the ordinary matter density and $\alpha$ parametrizes the strength of coupling. The effective energy density is positive definite (due to $C^2$) comprises kinetic, gradient, and potential contributions that together capture the essential dynamics of the hidden field. The kinetic term accounts for temporal evolution, ensuring that time-dependent configurations carry energy, while the gradient term encodes spatial

variation and localization necessary for generating effective forces or mass clustering. The potential term penalizes sustained nonzero field amplitudes and is directly responsible for collapse, with larger $M$ increasing the energetic cost and accelerating decay. This minimal decomposition provides a physically grounded measure of the transient influence exerted by the hidden field. This form of effective energy density is used because it is the canonical local energy density of a massive scalar field [19]. It is the lowest-order, positive-definite quantity that measures how much "physical substance" the field carries at each point in space and time. Using it ensures that any gravity-like interpretation is grounded in standard field theory rather than ad-hoc construction. In regions where $C(x,t)$ is appreciable, the system behaves as though excess inertial mass is temporarily present. As the hidden field collapses, this contribution fades, restoring the baseline mass distribution. In this way, mass becomes a context-dependent quantity that tracks the coherence and persistence of hidden dynamics. At a phenomenological level, such modifications may be mapped onto a Newtonian-like effective gravitational potential through a Poisson equation,

$$\nabla^2 \Phi_{\text{eff}}(x,t) = 4\pi G\, \rho_{\text{eff}}(x,t),$$

used here as a diagnostic tool rather than as a fundamental gravitational law ($G$ is the universal gravitational constant). Localized enhancements of $C$ would then correspond to transient deepening of the effective potential, while collapse of $C$ would flatten the potential profile. Even in this simplified description, gravity-like effects are intrinsically time-dependent and coherence-limited, sharply distinguishing them from conventional gravitation. From the viewpoint of matter dynamics, one may further define an effective, environment-dependent mass,

$$m_{\text{eff}}(x,t) = m_0 \left[1 + \beta C(x,t)\right],$$

implying that inertia itself depends on the local state of hidden coherence. The parameter $\beta$ quantifies the sensitivity of a test particle's effective inertial mass to the local amplitude of the hidden field. It is a phenomenological coupling that controls how strongly hidden-field coherence modulates dynamical response, without implying a fundamental change to rest mass. Any mass variation induced by $\beta$ is transient and collapses with the hidden field, ensuring that inertial properties relax smoothly back to their classical values. This interpretation places $\beta$ in direct analogy with effective mass parameters in condensed-matter and open-system contexts, reflecting environmental influence rather than intrinsic particle attributes. Such dependence could manifest as time-dependent phase shifts, altered oscillation frequencies, or modified responses to external forces, particularly in interferometric or coherent quantum systems. Importantly, all such effects remain transient, collapsing together with $C(x,t)$ and leaving no residual modification once coherence is lost. Taken together, these considerations suggest that the hidden field may act as a temporary mediator of gravity-like behavior, reshaping effective mass distributions and potentials without invoking fundamental spacetime curvature. While highly speculative, this viewpoint positions the present model as a minimal testbed for studying emergent and transient gravitational analogues, where mass and inertia arise dynamically from hidden degrees of freedom rather than being imposed as fixed inputs.

## 2.6 Effective potential due to the hidden-field

We define an effective gravitational-like potential that is proportional to the hidden-field energy density,

$$\Phi_{\text{eff}}(x,t) = \alpha\, \mathcal{E}_C(x,t), \tag{18}$$

where $\alpha$ is the coupling strength between the hidden-field energy and matter. A test particle of mass $m$ placed in this background experiences an effective force given by

$$F(x,t) = -m\,\partial_x \Phi_{\text{eff}}(x,t) = -m\alpha\,\partial_x \mathcal{E}_C(x,t). \tag{19}$$

Changes in the sign of $C$ modify the spatial variation and effective direction of the force. The resulting equation of motion for the particle trajectory $x(t)$ is then

$$\ddot{x}(t) = -\alpha\,\partial_x \mathcal{E}_C(x,t). \tag{20}$$

Since $C(x,t)$ decays as $e^{-Mt}$, the force is intrinsically time-dependent and vanishes as the hidden field collapses. Fig. 5 shows the simulated trajectories of the test mass. In this model, a localized configuration of the hidden field stores energy that varies in space and time, giving rise to an effective force on matter through the gradient of the hidden-field energy density. The test mass accelerate toward regions where $\mathcal{E}_C$ is largest, in direct analogy with motion toward regions of higher gravitational potential, although no fundamental spacetime curvature is invoked. The force is transient: as the hidden field collapses under the control of $M$, its energy density dissipates and the induced acceleration diminishes, ensuring that no permanent modification of motion remains. In this way, the hidden field acts as a temporary mediator of gravity-like behavior, with mass responding dynamically to coherent energy stored in hidden degrees of freedom rather than to a fixed gravitational source.

## 2.7 Effective conformal metric induced by the hidden field

Although thus far we have not invoked dynamical spacetime curvature or Einstein's field equations, the influence of the collapsible field $C(x,t)$ on electromagnetic propagation admits a natural interpretation in terms of an effective background geometry.

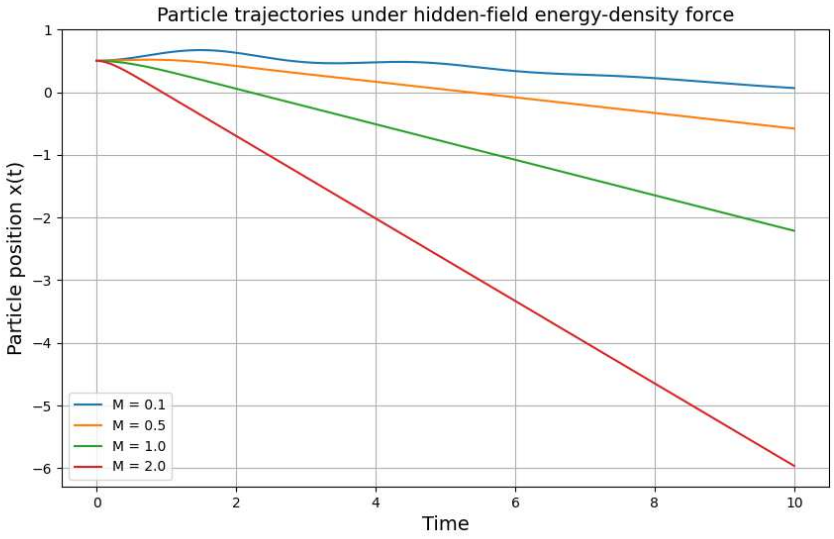



**Fig. 5** Particle trajectories under the influence of a dynamic hidden-field energy density. Shown is the one-dimensional motion $x(t)$ of a test particle ($m = 1.0$) subject to a force proportional to the spatial gradient of the energy density associated with a collapsing scalar field $C(x, t, M)$, with coupling $\alpha = 1.0$. Each curve corresponds to a different decay parameter $M \in \{0.1, 0.5, 1.0, 2.0\}$, while initial conditions ($x_0 = 0.5$, $v_0 = 0.0$) are held fixed. Smaller values of $M$ lead to slower collapse of $C$ and sustained forces that produce larger deviations from the initial position, whereas larger $M$ values rapidly suppress the hidden field and yield only transient perturbations [20]. The results illustrate a measurement-induced dissipation analogue, in which stronger collapse reduces the dynamical impact of hidden-field coherence on particle motion.

In particular, the linear coupling between the observable field and the hidden field allows the dynamics to be re-expressed in a form formally analogous to wave propagation on a conformally rescaled spacetime. A complementary geometric interpretation follows from the conformal metric induced by $C$ if we introduce an effective metric of the form

$$g_{\mu\nu}(x,t) = \Omega^2(x,t)\,\eta_{\mu\nu}, \tag{21}$$

where $\eta_{\mu\nu}$ is the Minkowski metric [21] and the conformal factor is defined by

$$\Omega^2(x,t) = 1 + \lambda\, C(x,t). \tag{22}$$

In the weak-field, non-relativistic limit, such a conformal rescaling implies an effective potential

$$\Phi_{\text{eff}} \sim \tfrac{1}{2} \ln \Omega^2(C) \approx \tfrac{\lambda}{2} C,$$

so that test particles and fields experience accelerations toward regions where $C(x,t)$ is large. As the hidden field decays, this effective geometry relaxes toward flat spacetime, and the induced accelerations vanish. Within this interpretation, gravity-like attraction arises not from curvature dynamics but from the transient deformation of an effective background. Regions in which $C(x,t)$ attain significant amplitude correspond to local rescalings of the effective geometry experienced by the electromagnetic field. The collapse of $C(x,t)$ therefore induces a dynamical relaxation of this geometry back toward the flat Minkowski limit. Propagation of the electromagnetic field in this effective background may be formally described by the curved-space wave equation

$$\frac{1}{\sqrt{-g}} \partial_\mu \left( \sqrt{-g}\, g^{\mu\nu} \partial_\nu E_0 \right) = 0, \tag{23}$$

which reduces to the standard wave equation as $\Omega(x,t) \to 1$. No assumption is made that $g_{\mu\nu}$ satisfies Einstein's equations, nor that $C(x,t)$ constitutes a source of genuine spacetime curvature. Thus, this effective metric construction is intended purely as a phenomenological and interpretive tool and should not be construed as implying genuine spacetime curvature or replacing General Relativity. Rather, the conformal metric should be viewed as an effective description that captures how hidden dynamics reshape the local propagation environment of the electromagnetic field. This formulation places the model within the broader class of analogue and emergent gravity frameworks, in which interaction terms or background fields are reinterpreted as inducing effective geometrical structures. In the present case, the transient existence of $C(x,t)$ gives rise to a time-dependent conformal deformation of the background, while

its collapse ensures the eventual restoration of classical electromagnetic propagation in flat spacetime.

## 2.8 Hidden field as coherent source or sink

Within the present framework, the hidden field can operate either as a coherent source or as a coherent sink of energy and dynamical influence, depending on the competition between its coupling to observable degrees of freedom and its intrinsic collapse dynamics (Fig. 6). The decisive factor is whether coherence and energy flow predominantly out of the hidden sector into observable dynamics or are instead absorbed and dissipated within it. When the collapse parameter $M$ is small, the hidden field is long lived, and its spatial and temporal structure enables coherent storage and subsequent release of energy into the electromagnetic field and coupled matter. In this source-like regime, gradients of hidden-field energy density generate effective forces, while sustained coupling produces amplification, phase accumulation, and delayed response effects in the observable sector. As $M$ increases, collapse accelerates and the hidden field transitions into a sink-like role. Strong collapse rapidly damps the field amplitude, suppressing coherent redistribution and instead absorbing energy and smoothing spatial structure, thereby driving relaxation toward classical electromagnetic behavior in a manner analogous to measurement-induced dissipation. Between these limits lies an intermediate regime in which the hidden field acts transiently as both source and sink: initially injecting coherence and effective forces, before collapse converts it into a dissipative channel that erases its own influence. This hybrid behavior supports rich but self-terminating dynamics, ensuring that all departures from classical behavior remain finite in duration and consistent with established electromagnetic phenomenology. Crucially, the hidden field does not function as an unlimited or external reservoir. Its role as source or sink is self-limiting, controlled by the collapse dynamics encoded in the parameter $M$. As collapse completes, both sourcing and sinking cease, and the

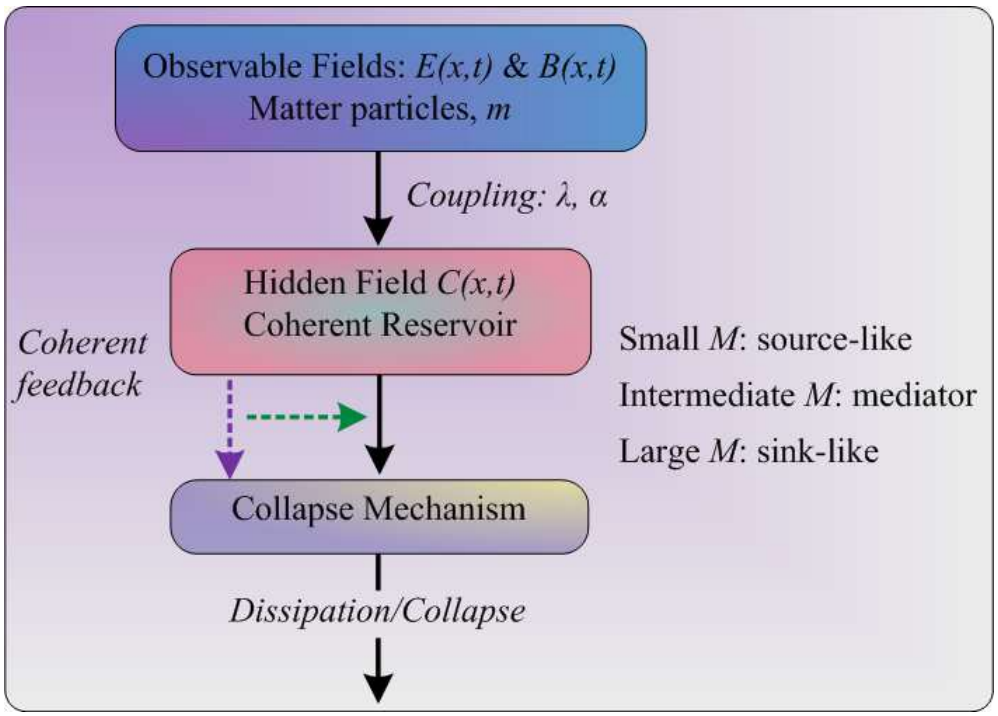



**Fig. 6** Schematic block diagram illustrating the role of the hidden field $C(x,t)$ as a coherent source, sink, or mediator. Coupling to observable fields allows $C$ to store and redistribute energy and coherence, while the collapse parameter $M$ controls the rate at which this influence dissipates.

system relaxes to its baseline electromagnetic and inertial state. This self-terminating behavior ensures consistency with conservation principles and reinforces the interpretation of the hidden field as a transient mediator of coherence rather than a permanent dynamical agent. Fig. 7 shows the effective potential, hidden-field induced forces and trajectories using the foregoing parameter values. Fig. 8 shows the correlation between the force induced by the hidden field and the parameter $M$.

## 2.9 Potential contributions to effective mass

An intriguing direction emerging from the present framework concerns the role of the hidden antisymmetric field $G^{\mu\nu}$ in shaping effective mass and inertia through its coupling to electromagnetic dynamics and background geometry. Although no

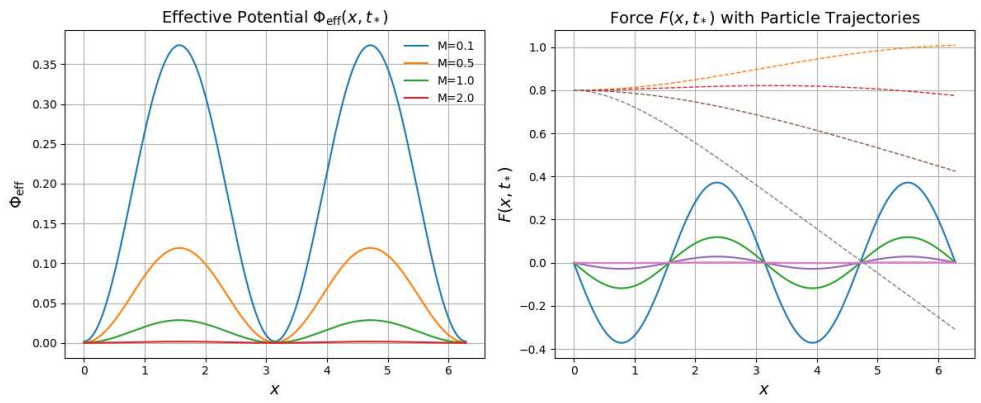



**Fig. 7** Hidden-field–induced effective forces and particle dynamics. The hidden field acts as a transient energy reservoir, generating spatially varying potential wells that drive test masses toward regions of higher hidden-field energy density. The persistence of this influence is controlled by the collapse parameter $M$: for small $M$, particle trajectories curve strongly toward force maxima, reflecting source-like behavior, whereas for large $M$ the hidden field collapses rapidly, suppressing both force magnitude and trajectory deflection and leaving motion close to the inertial limit. Upon collapse, the induced potential and force vanish, restoring classical dynamics.

fundamental mass generation mechanism is proposed, interaction with a structured or transient configuration of $G^{\mu\nu}$ could lead to state-dependent mass shifts, symmetry-broken spectra in coherent systems, or time-dependent phase accumulation analogous to mass oscillations. When embedded in an effective curved or conformally rescaled spacetime, such couplings may further renormalize inertial properties through geometry-dependent propagation, evoking parallels with emergent or induced gravity scenarios. These effects would be intrinsically transient, collapsing as the hidden field dissipates, and thus offer a pathway toward understanding mass as an environmental and dynamical attribute rather than an immutable parameter. While highly speculative, this perspective motivates future exploration of hidden-field extensions of electrodynamics as a minimal testbed for probing emergent mass phenomena, interferometric signatures, and coherence-dependent inertia beyond conventional field-theoretic descriptions.

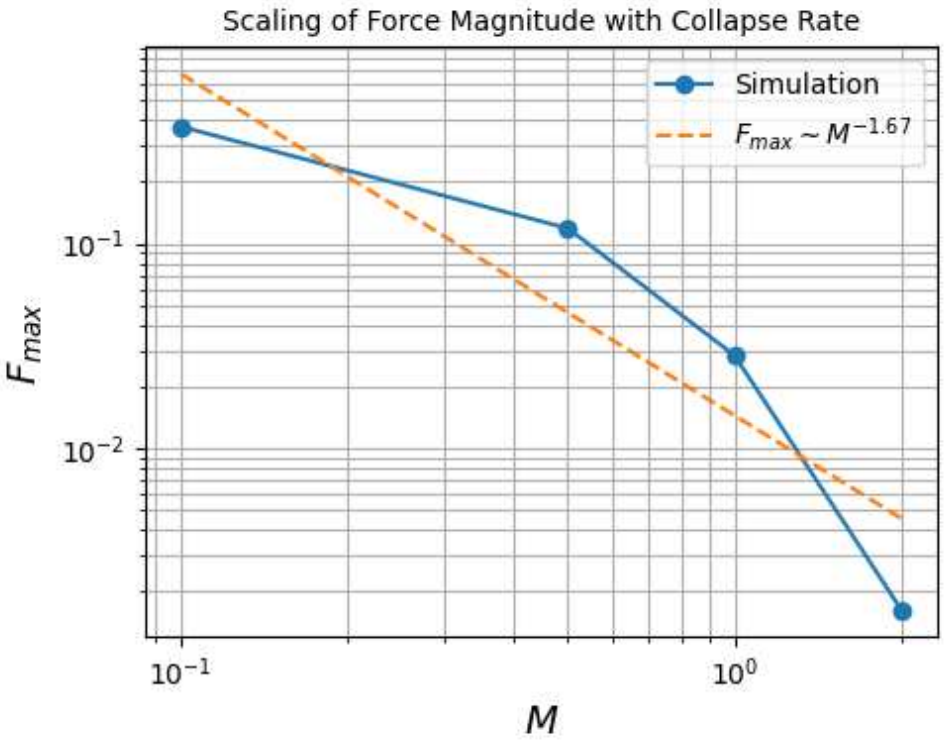



**Fig. 8** Scaling of the hidden-field–induced force with the collapse parameter $M$. Numerical simulations show that the maximum force on a test mass decreases rapidly as $M$ increases, reflecting exponential suppression of hidden-field coherence and the resulting transition from source-like to sink-like behavior.

## 2.10 Possible experimental verification pathways

Experimental verification of the proposed hidden-field framework requires probes sensitive to energy redistribution, phase accumulation, or inertial response, while avoiding strong, projective measurements that would suppress hidden-field coherence. This condition is naturally met by existing high-coherence platforms, including superconducting microwave cavities, optical and microwave interferometers, optomechanical resonators, levitated nanoparticles, and atomic interferometers [20, 22]. These systems operate in weak-measurement or dispersive regimes, allowing detection of transient, coherence-dependent effects through phase shifts, dispersion, inertial response, or

noise signatures, consistent with the analogue and non-fundamental nature of the proposed mechanism [23]. Table 1 lists some suggested experimental approaches of probing possible hidden-field effects in EM/mass systems.

**Table 1** Summary of experimentally feasible platforms for probing hidden-field effects using coherence-preserving, non-projective measurement strategies.

| **Experimental Platform** | **Measurement Observable** | **Rationale** | **Expected Sensitivity** |
|---|---|---|---|
| Superconducting microwave cavity | Resonant frequency shifts, phase drift | Dispersive readout avoids photon absorption | High |
| Optical/ microwave interferometer | Phase accumulation, fringe drift | Phase-only measurement preserves coherence | High |
| Optomechanical resonator | Resonance frequency, Q-factor changes | Back-action-evading readout | Medium-High |
| Levitated nanoparticle trap | Trap frequency shift, anomalous drift | Statistical position inference only | High |
| Atom interferometer/ clocks | Phase shifts, frequency offsets | Sensitive to integrated potentials | High |
| Noise spectroscopy | Excess low-frequency correlated noise | Indirect fluctuation-based probe | Medium |

## Conclusion

We have introduced a minimal extension of Maxwell's equations in which a hidden, coherence-dependent field transiently mediates observable electromagnetic and inertial effects before collapsing under measurement-like suppression. By construction, the hidden field influences dynamics only temporarily and self-erases, ensuring recovery of classical electrodynamics without invoking permanent new degrees of freedom or spacetime curvature. The resulting framework is neither a theory of modified gravity nor unification, but a controlled testbed for exploring how structured, collapsing coherence may mediate short-lived physical effects.

Numerical simulations reveal a clear source–mediator–sink paradigm governed by the collapse parameter, with weak collapse allowing coherent energy redistribution and effective forces, and strong collapse rapidly suppressing all deviations from classical

behavior. These effects are causal, finite in duration, and robust against specific functional choices, depending primarily on the interplay between coupling strength and collapse dynamics. Gravitational language is employed strictly as analogy: effective potentials, force gradients, and geometry-like interpretations emerge without sourcing curvature or modifying Einstein's equations.

Importantly, the framework admits experimentally feasible tests using existing high-coherence platforms operated in weak-measurement or dispersive regimes, including superconducting cavities, interferometric probes, optomechanical systems, and inertial sensors. Detection of the predicted collapse-controlled scaling behavior would support the presence of transient coherence-mediated effects, while null results would tightly constrain the model. More broadly, the work demonstrates how hidden coherence, when required to self-erase, may leave subtle but testable imprints on observable dynamics before vanishing from direct observation.

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## Declarations

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- Conflict of interest/Competing interests - The authors declare no competing interests.
- Ethics approval and consent to participate - The work did not require ethical approval and no human or animal subjects were used in the study.
- Consent for publication - All authors have read and have given their consent for publication of this work.
- Data availability - Any data generated will be made available upon written request.
- Materials availability - no materials were used in this work, except those publicly accessible in the media.

- Code availability - the code is hosted on Google Colaboratory and will be free to run and modify with attribution.
- Author contribution - Both authors contributed equally to this work.

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