OPEN ACCESS
Reports in Advances of Physical Sciences
Vol. 9 (2025) 2550029 (12 pages)

DOI: 10.1142/S242494242550029X

World Scientific
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A Novel Quantum Gravity Approach

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Received 13 September 2025
Accepted 14 November 2025
Published 14 January 2026

We propose a candidate theory of quantum gravity founded on the entropic projection of a complex operator defined in a *Diagram Hilbert Space*. This operator unifies mass–energy and charge within a single microscopic entity whose spectral structure encodes the physical content of both gravitational and gauge interactions. Embedding the microscopic dynamics within partition functions — most notably QCD — provides spectral data for the operator, while entropy maximization under energy and charge constraints yields Einstein's and Maxwell's equations from its real and imaginary projections, respectively. Both field systems thus arise from one statistical–variational principle. Hidden eigenstates of the operator naturally form dark-matter halos with isothermal equilibrium profiles explaining flat galactic rotation curves. Dark energy and black holes acquire consistent operator–entropic interpretations. The framework therefore offers a testable route toward a unified quantum-gravitational theory in which spacetime and gauge fields emerge as macroscopic thermodynamic constructs of an underlying operator algebra.

Keywords: QFT; QCD; standard model; GR; general relativity.

1. Introduction

Efforts to reconcile quantum mechanics with general relativity have generated an extensive spectrum of formalisms — from string theory[1,2] and loop quantization[3,4] to causal-set and holographic approaches[5,6] — yet a self-consistent, renormalizable theory of quantum gravity remains incomplete. Here we introduce a conceptually distinct construction that treats geometry and matter as emergent statistical projections of a microscopic operator defined in a *Diagram Hilbert Space*. Rather than quantizing spacetime itself, this formulation treats the combinatorial structure of interactions as the primitive object. Within this space, projective operators and topological invariants encode the information normally attributed to geometry.

This approach arises from the recognition that gravity may be *entropic* in origin[7–11]: Black-hole thermodynamics,[12,13] the Bekenstein–Hawking area law[14] and Jacobson's insight that Einstein's equations express a local Clausius relation[15] all suggest that spacetime dynamics derive from an underlying informational substrate. The present theory formulates that the substrate is explicitly through operator algebra and statistical projection.

To consolidate the various operator–entropic perspectives, this paper provides the **minimal unifying foundation**. The *Diagram Hilbert Space* carries the microscopic degrees of freedom of interaction histories; the **complex operator** $\mathcal{O} = \boldsymbol{M} + \mathbf{i}\boldsymbol{Q}$ combines mass–energy (M) and charge (Q) as conjugate observables; and macroscopic fields arise through an **entropy-maximizing projection** that enforces thermodynamic consistency. Subsequent extensions — where non-commuting mass-charge operators produce weak corrections, and where hidden eigenstates generate dark sectors — are all reducible to this same statistical-operator foundation. In this sense, this paper unifies the conceptual elements of the broader program into a single, rigorous framework.

The logical development proceeds as follows: Section 2 defines the Diagram Hilbert Space and the operator algebra. Section 3 embeds microscopic dynamics through QCD-type partition functions that determine the operator's spectral data. Section 4 constructs the Gibbs state and variational principle underlying the macroscopic projection. Sections 5 and 6 derive Einstein's and Maxwell's equations as entropy-extremality and free-energy-stationarity conditions. Sections 7–9 analyze the dark-matter, dark-energy and black-hole phenomena as macroscopic limits of the same projection. Section 10 outlines empirical implications, and Sec. 11 summarizes outlook and conclusions.

2. Diagram Hilbert Space and the Complex Operator

The central mathematical object is the **Diagram Hilbert Space** $\mathcal{H}^{\mathbf{D}}$, a separable Hilbert space spanned by basis vectors representing combinatorial interaction histories — essentially, the diagrammatic skeletons of quantum-field-theoretic processes. Operators on $\mathcal{H}^{\mathrm{D}}$ act as projections among subspaces characterized by topological or algebraic invariants such as loop order, homotopy class, or knot number. In this setting, geometry is encoded not through a background metric but through correlations among diagrammatic amplitudes.

Two Hermitian operators, $\boldsymbol{M}$ and $\boldsymbol{Q}$, represent the real (mass–energy) and imaginary (charge-phase) sectors. Their complex combination is as follows:

$$\mathcal{O} = M + iQ,$$

has eigenvalues $\lambda = m + iq$ that we call *complex charges*. Topological invariants of the operator algebra, e.g., Chern numbers or homotopy indices,[16,17] constrain spectral flow and stabilize quantized eigenvalue sectors, thus providing natural quantization of both mass and charge without invoking external symmetry breaking.

Projective operators Π_k select dynamical channels labeled by such invariants. The macroscopic limit emerges through a **coarse-graining map** $\mathcal{P}$ that maximizes entropy subject to conservation of energy and charge expectations:

$$\rho_{\text{macro}} = \mathcal{P}[\rho_{\text{micro}}].$$

This projection translates microscopic operator data into expectation values identifiable with stress–energy and current densities, which in turn source gravitational and electromagnetic fields. Because the procedure depends only on entropy maximization within $\mathcal{H}^{\text{D}}$, it produces a covariant macroscopic description without presupposing a metric structure. In this sense, spacetime curvature is a *statistical emergent property* of diagrammatic operator correlations.

Group-theoretically, the diagrammatic basis naturally accommodates the symmetry structure of the Standard Model — local $SU(3) \times SU(2) \times U(1)$ actions act as automorphisms of subspaces within $\mathcal{H}^{\text{D}}$ — while global operator invariants correspond to conserved charges. Gravity, in contrast, arises not from a gauge symmetry but from the entropic geometry of the projection itself.

3. Microscopic Input: Partition Functions and Spectral Data

Microscopic dynamics are introduced through quantum-field partition functions that weight the diagrammatic amplitudes. For the strongly interacting sector, the Euclidean QCD generating functional[18–20]

$$Z_{\text{QCD}} = \int \mathcal{D}A\mathcal{D}\psi\mathcal{D}\bar{\psi}\exp[-S_{\text{QCD}}(A, \psi, \bar{\psi})]$$

encodes non-perturbative dynamics via its diagram expansion. Each topological contribution within Z determines a corresponding subspace of $\mathcal{H}^{\text{D}}$ and hence contributes to the spectrum of $\mathcal{O}$. Lattice-QCD results provide quantitative input for the real-part (mass–energy) eigenvalues.[21–23] The imaginary sector inherits coupling phases and charge structure from gauge-invariant combinations of color and flavor indices.

Thus, the **real part of** $\mathcal{O}$ represents the ensemble of mass eigenmodes weighted by QCD dynamics, whereas the **imaginary part** parameterizes charge phases and coupling constants. The statistical superposition of these microscopic eigenstates determines the emergent macroscopic stress and current tensors once coarse-grained by $\mathcal{P}$. While a full spectral derivation is beyond the present scope, this embedding demonstrates how established quantum-field dynamics naturally feed into the operator–entropic framework.

4. Macroscopic Projection, Gibbs State and the Variational Principle

Let H denote the microscopic Hamiltonian acting on $\mathcal{H}^{\text{D}}$. The equilibrium (maximally mixed) state consistent with fixed energy E and charge Q expectations is the **Gibbs state**

$$\rho = \frac{1}{Z}\exp(-\beta H),$$

where $\beta = 1/(k^B T)$ and $Z = \mathrm{Tr}[\exp(-\beta H)]$. The von Neumann entropy is as follows:

$$S = -k_B \mathrm{Tr}(\rho \ln \rho),$$

measures informational disorder of the microscopic ensemble. Macroscopic observables $\langle O_i \rangle$ are enforced via Lagrange multipliers in the constrained maximization.

$$\delta\left[S - \sum_i \lambda_i(\langle O_i \rangle - O_i^0)\right] = 0,$$

which yields the Gibbs form above. The coarse-graining map $\mathcal{P}$ is thus operationally defined by this variational principle.

Crucially, variations of entropy under metric deformations at fixed conserved quantities produce Einstein's field equations, while variations under potential deformations at fixed temperature yield Maxwell's equations. Hence, both gravitational and electromagnetic dynamics follow from a *single statistical extremum principle*. This dual derivation — explicitly worked out in Secs. 5 and 6 — shows that what appear as distinct interactions are complementary projections of one underlying operator ensemble.

5. Derivation of Einstein's Equations

The emergence of spacetime geometry from the operator ensemble can be traced through two complementary derivations, both linking entropy extremality to Einstein's field equations and both making explicit how the projected operator expectation value $\langle M \rangle$ acts as the source term.

5.1. *Local clausius route (Jacobson style)*

Following Jacobson's seminal reasoning,[15] we consider a local Rindler wedge near a point p, generated by null geodesics with tangent ξ^a. The microscopic energy flux through a local causal horizon is as follows:

$$\delta Q = \int T_{ab}\chi^a d\Sigma^b,$$

where χ^a is the approximate boost Killing vector, $T_{ab} = \langle \hat{T_{ab}} \rangle$ is the expectation value of the projected stress–energy operator, and $d\Sigma^b$ is the surface element.

Observers just inside the horizon experience the Unruh temperature

$$T = \frac{\hbar a}{2\pi c k_B},$$

and the Clausius relation $\delta Q = T\delta S$ identifies the change of geometric entropy with heat flux. Employing the Raychaudhuri equation for the expansion θ of null generators,

$$\frac{d\theta}{d\lambda} = -\frac{1}{2}\theta^2 - \sigma_{ab}\sigma^{ab} - R_{ab}k^a k^b,$$

and linearizing for small deformations, one obtains the following equation:

$$\delta S = \eta \int R_{ab}k^a k^b d\lambda dA,$$

with η the entropy-area density. Equating Clausius and geometric relations for all null k^a implies the following:

$$R_{ab} - \frac{1}{2}Rg_{ab} + \Lambda g_{ab} = 8\pi G T_{ab}.$$

Thus, Einstein's equation appears as an equation of state of the Gibbs ensemble, where T_{ab} derives from the expectation of M within $\mathcal{H}^{\mathrm{D}}$. The cosmological term Λ arises as an undetermined integration constant related to global normalization of the entropy density.

5.2. *Global variational route (Operator perspective)*

A complementary, explicitly operator-based derivation starts from the Gibbs state $\rho = Z^{-1}\exp(-\beta H)$.

For variations δg_{ab} of the macroscopic metric at fixed constraints, the change in entropy satisfies the following equation:

$$\delta S = \beta \int_{\Sigma} \delta(\sqrt{-g}T^{ab}u_a u_b) d^3x,$$

where u^a is the hypersurface normal. The total macroscopic entropy functional is as follows:

$$S_{\mathrm{tot}} = S_{\mathrm{geom}} + S_{\mathrm{matter}},$$

is stationary when its variation under δg_{ab} vanishes. Taking S_{geom} proportional to the horizon area (or Wald entropy) leads again to the following equation:

$$R_{ab} - \frac{1}{2}Rg_{ab} + \Lambda g_{ab} = 8\pi G T_{ab}.$$

Hence, both the local Clausius and the global Gibbs approaches yield identical field equations, confirming that spacetime curvature is a manifestation of entropy extremality in the underlying operator ensemble.[24,25]

6. Derivation of Maxwell's Equations

The electromagnetic sector arises from the imaginary projection $\langle Q \rangle$ of $\mathcal{O}$ and the stationarity of the Gibbs free energy. This section shows that the standard Maxwell equations emerge without independent postulates.

6.1. *Constitutive map*

A coarse-grained map $\mathcal{P}_e$ constructs the macroscopic vector potential $\hat{\text{A}}$ from the projected charge operator:

$$A_\mu = \mathcal{P}_e[\hat{Q}_\mu].$$

To the leading order,

$$A_\mu(x) = \int K_{\mu\nu}(x, y)\text{Tr}(\rho\hat{Q}^\nu(y))dy,$$

where $K_{\mu\nu}$ is a constitutive kernel. The field strength $F = dA$ then follows kinematically.

6.2. *Extended hamiltonian and free energy*

Including the electromagnetic interaction, the microscopic Hamiltonian becomes the following:

$$H' = H - \int j^\mu A_\mu d^3x,$$

with j^u being the microscopic current built from charged eigenmodes of $\mathcal{O}$. The Gibbs free energy is as follows:

$$\mathcal{F} = \text{Tr}(\rho H') + T\text{Tr}(\rho\text{ln}\rho),$$

acts as the thermodynamic potential governing equilibrium.

6.3. *Stationarity and inhomogeneous equations*

Stationarity $\delta\mathbb{F}/\delta A_\mu = 0$ at fixed T yields the following:

$$\nabla_\nu F^{\mu\nu} = \mu_0 j^\mu,$$

recovering the inhomogeneous Maxwell equations, while $\nabla = 0$ follows from $F = \text{dA}$. Charge conservation, $\nabla_\mu j^\mu = 0$, arises from microscopic gauge invariance, showing that electromagnetic dynamics are another thermodynamic projection of the same operator algebra.[26,27]

6.4. *Mass–charge cross corrections*

If $[M, Q] \neq 0$, mixed expectation values appear:

$$\langle[M, Q]\rangle \neq 0,$$

leading to suppressed corrections $\Delta T_{ab}, \Delta j^\mu$ that slightly violate minimal Einstein–Maxwell coupling. Such weak non-commutativity offers a natural parametrization for tiny equivalence-principle deviations or anomalous charged-particle trajectories — potential experimental signatures of the operator structure.[28]

7. Dark Matter: Worked Example — Rotation Curves

To illustrate the predictive capacity of the framework, we show how hidden eigenstates of $\mathcal{O}$ can form equilibrium mass distributions reproducing flat galactic rotation curves.[29,30]

7.1. *Decomposition and hidden sector*

The macroscopic mass operator is decomposed as follows:

$$M_{\text{macro}} = M_{\text{vis}} + M_{\text{hid}},$$

where M_{hid} represents eigenstates coupling negligibly to Q. The hidden ensemble behaves as a collisionless, spherically symmetric gas on galactic scales.

7.2. *Circular velocity and target profile*

For a spherical mass distribution, the circular velocity is as follows:

$$v_c(r) = \sqrt{\frac{\mathrm{GM}(r)}{r}},$$

and the observed flattening $v_c \to \text{const}$ requires $\rho \propto r^{-2}$ at large r.

7.3. *Entropic equilibrium*

By maximizing the Boltzmann–Vlasov entropy, we get the following equation:

$$S[f] = -\int f \ln f d^3x d^3v,$$

subject to fixed total mass and energy yields a Maxwell–Boltzmann distribution $f \propto \exp(-\beta E)$, leading to an isothermal density profile once coupled to Poisson's equation for the gravitational potential Φ.

7.4. *Poisson–Boltzmann equation*

Combining constraints gives the nonlinear Poisson–Boltzmann equation:

$$\frac{1}{r^2}\frac{d}{dr}\left(r^2\frac{d\Phi}{dr}\right) = 4\pi G\rho_0 e^{-\beta\Phi}$$

Its asymptotic solution $\rho \propto r^{-2}$ produces a constant v_c reproducing observed rotation-curve plateaus.[31–33]

7.5. *Numerical illustration*

For Milky-Way-like parameters, $v_c \approx 200\,\text{km/s}$ implies an effective hidden-sector temperature

$$k_B T_{\text{eff}} \simeq m v_c^2/3,$$

with m being the hidden-eigenmode mass. For $m \approx 10\,\text{GeV}$, $T_{\text{eff}} \approx 10^{-7}\,\text{K}$, consistent with cold-dark-matter phenomenology.

7.6. *Comments and limitations*

More realistic halos require truncated or cored profiles.[34] Non-commuting M, Q operators introduce small charge-dependent corrections that could manifest as weakly interacting or millicharged dark components. Empirical fits constrain combinations of spectral parameters in $\mathcal{O}$, linking microscopic operator properties directly to astrophysical observables.

8. Dark Energy and the Cosmological Constant

The residual energy density from the incomplete projection of microscopic states contributes an effective cosmological constant:

$$T_{ab}^{(\text{tot})} = T_{ab} + \rho_\Lambda g_{ab}.$$

Here $\rho_\Lambda = \langle \Delta H \rangle / V$ represents entropic residuals of coarse-graining. Its smallness reflects near-cancellation among vast microscopic contributions after renormalization, suggesting that the cosmological constant problem is statistical rather than dynamical. This interpretation aligns with holographic and emergent-gravity perspectives.[35–38]

9. Black Holes as Projection Endpoints

Black holes correspond to **maximally mixed macrostates** where the entropic projection saturates: All microscopic information relevant to external observers has been coarse-grained. The Bekenstein–Hawking entropy is as follows:

$$S_{\text{BH}} = \frac{k_B A}{4\ell_P^2}$$

is identified with $k_B \ln N$ where N is the effective dimension of the Hilbert subspace projecting to the external geometry. Thus, horizon area measures the logarithmic count of microscopic diagrammatic configurations yielding identical macroscopic curvature.[12,14,39,40] In this picture, Hawking radiation represents slow leakage of entropic information between projected and hidden subspaces — an inherently operator-statistical process rather than a semi-classical anomaly.

10. Tests, Observables and Roadmap

The operator–entropic framework establishes a continuous bridge between microscopic operator algebra and macroscopic gravitational, gauge and cosmological phenomena. Its predictive power can be assessed along several experimental and observational axes.

10.1. *Laboratory-scale tests*

Weak mass–charge non-commutativity may produce composition-dependent accelerations or subtle deviations from the universality of free fall. High-precision equivalence-principle experiments, atom-interferometric gravimeters and charged-particle deflection tests in strong fields could bound the commutator scale.[41,42] The theory, therefore, offers quantifiable corrections to Einstein–Maxwell dynamics at levels potentially accessible to next-generation space missions.

10.2. *Astrophysical probes*

Hidden-eigenstate halos yield rotation-curve fits consistent with observed galactic dynamics[31,32,33]; cross-comparison with baryonic Tully–Fisher relations constrains the spectral density of the hidden ensemble. Gravitational-lensing profiles and cluster velocity dispersions provide additional diagnostics of the operator spectrum's mass distribution.

10.3. *Black-hole thermodynamics and gravitational waves*

Because black holes represent maximally entropic projections, their quasi-normal-mode frequencies and Hawking spectra encode microstructural details of $\mathcal{H}^{\mathrm{D}}$. Precision ringdown measurements by LIGO, Virgo and LISA can therefore test predicted corrections to Kerr spectra at order $\updownarrow_P/r_s$.[43,44] Any systematic deviation from general-relativistic quasi-normal-mode patterns would directly probe the operator–entropic microstructure.

10.4. *Cosmology and dark energy*

Fluctuations in the entropic residual ρ_Λ may leave imprints in the large-scale distribution of cosmic voids and in the integrated Sachs–Wolfe effect. The measured ΛCDM parameter $\Omega_\Lambda \approx 0.69 \pm 0.01$[37,38] constrains the statistical variance of the projection process, relating cosmological observables to Hilbert-space coarse-graining.

10.5. *Relation and outlook*

Within this unified operator–entropic framework, all macroscopic interactions — gravitational, electromagnetic and cosmological — emerge from entropy-driven projections of one complex operator. The diagram-Hilbert construction supplies a mathematically explicit substrate capable of incorporating non-commuting extensions, gauge-group embeddings and hidden sectors without introducing additional fields or postulates. Future work will involve the following:

(i) Explicit computation of the operator spectrum from lattice-regularized partition functions,

(ii) exploration of renormalization-group flow within the diagram space to identify coupling-constant convergence and
(iii) simulation of projection dynamics for multi-operator systems to model early-universe conditions and black-hole evaporation.

11. Conclusions

We have presented a coherent, mathematically explicit and conceptually unified **operator–entropic theory of quantum gravity.** Starting from the Diagram Hilbert Space $\mathcal{H}^{\mathrm{D}}$ and a single complex operator $\mathcal{O} = M + iQ$, the framework is as follows:

(1) Derives Einstein's equations from entropy extremality, where the macroscopic stress tensor equals the expectation of M;
(2) Derives Maxwell's equations from free-energy stationarity of Q;
(3) Explains galactic rotation curves via hidden-eigenstate equilibria;
(4) Identifies dark energy with residual entropic density; and
(5) Interprets black-hole entropy as the logarithmic Hilbert-space dimension of saturated projections.

No independent spacetime quantization or background geometry is assumed — spacetime itself is emergent from operator statistics. The theory, therefore, integrates gravity, gauge interactions and cosmology within one variational-entropic formalism, offering concrete experimental handles and a consistent conceptual foundation for a quantum theory of gravity.

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