EDCA Gravitation and Curved Geometry: Newtonian and Tensorial GR Analogs from Energy-Spot-Driven Cellular Automaton Dynamics

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***Abstract*—Energy-Driven Cellular Automata (EDCA) are cellular automata whose local transitions are explicitly gated by mobile discrete energy quanta ("spots"). A site may satisfy a readiness predicate but does not transition unless it is covered by an energy spot. Spots propagate as expanding wavefronts, collapse onto ready sites, trigger births/deaths depending on polarity, and flip polarity after successful collapse before beginning a new expansion cycle. EDCA also supports dynamic space instantiation: cell sites are allocated/instantiated only when needed for readiness evaluation, spot coverage, or state updates. This motivates a coarse-grained allocation density field $\rho(x,t)$, which encodes cumulative spot-driven activity and becomes a proxy for mass-energy distribution. Because already-instantiated sites require fewer resources, EDCA's collapse incidence criterion explicitly prioritizes higher allocation density. We derive an emergent potential $\Phi = -\gamma \ln \rho$ and a drift field $\mathrm{g} = -\nabla\Phi$, show that its weak-field steady-state limit yields a Poisson-like equation and the classical Newtonian inverse-square law, and then define an effective conformal metric $g^{\mathrm{eff}}_{\mu\nu}(\rho)$ that enables a General Relativity (GR)-like geometric interpretation. Finally, we introduce a full tensor field equation $G_{\mu\nu}[g(\rho)] = \kappa_{\mathrm{EDCA}} T^{\mathrm{EDCA}}_{\mu\nu}$, where the EDCA stress-energy tensor is explicitly constructed from measurable spot wavefront flux, collapse events, and transition activity. A conservation analysis connects EDCA's invariant $2\sigma_t + E_t$ to the interpretation of T^{EDCA}_{00} as a conserved curvature source.**

***Index Terms*—EDCA, energy-driven cellular automata, spots, allocation density, emergent gravity, Newtonian limit, General Relativity analog, conformal geometry, stress-energy tensor**

I. Introduction

Classical cellular automata update all sites synchronously at each tick. EDCA introduces a key structural difference: *local readiness does not force a transition*. Instead, EDCA transitions occur only when energy arrives in the form of discrete mobile quanta called *spots* [1]. This introduces an explicit separation between:

1) **Readiness** — a local predicate computed from neighborhood configuration, and
2) **Energy availability** — whether an energy spot reaches and covers the site.

A second major EDCA departure is that the lattice is not necessarily fully instantiated. Cell sites may be *allocated/instantiated on demand* to support readiness evaluation, spot wavefront propagation, and transition execution [1]. This motivates the allocation density field $\rho(x,t)$ as a coarse-grained measure of the density of allocated sites.

The aim of this paper is to show that these EDCA principles imply a self-consistent analog of gravity and curved geometry. The physical intuition is:

> *spots drive activity; activity allocates and reinforces space; reinforced space becomes preferred for future collapses; this feedback induces drift and emergent geometry.*

II. EDCA Ontology and Notation

Let space be a discrete lattice $\mathbb{Z}^d$ (typically $d=3$). EDCA consists of:

- A matter field $M_t(x) \in \{0,1\}$ indicating whether site x is occupied by a living cell at time t.
- A set of $K(t)$ mobile energy spots indexed by $a \in \{1,\dots,K(t)\}$, each with polarity $p_a(t) \in \{+1,-1\}$ and wavefront expansion dynamics [1].

Matter does not propagate; spots do. Spots are the mechanism by which energy is delivered to enable local transitions.

A. Terminology: allocated site vs. living cell

Allocation density concerns *whether the computational substrate contains instantiated sites* in a region. This must not be confused with the *living* state. A region may have high allocation density even if few sites are living, because allocation is driven by the history of spot wavefront traversal and readiness evaluation.

III. Readiness Predicates and Energy-Gated Transitions

EDCA defines readiness predicates for transitions:

$$R_t^+(x) = 1 \quad \text{if } x \text{ is empty and birth-ready,} \tag{1}$$

$$R_t^-(x) = 1 \quad \text{if } x \text{ is occupied and death-ready.} \tag{2}$$

A foundational EDCA rule is:

> *A ready-for-transition site performs its transition only if it is covered by an energy spot.*

Thus, readiness is necessary but not sufficient for state change [1]. This is essential because it makes the EDCA evolution explicitly energy-mediated rather than purely synchronous.

IV. Spot Dynamics: Expansion, Collapse, Conditioning, and Flip

Spots propagate as wavefronts and collapse when encountering ready sites [1]. This section summarizes the spot cycle, which is the dynamical core of EDCA.

A. Wavefront expansion

Each spot expands approximately isotropically with radius

$$r_a(t) \approx c\,(t - t_{a,0}), \tag{3}$$

where $t_{a,0}$ is the spot start time and $c > 0$ is an effective propagation speed.

B. Candidate set

Define the set of ready sites encountered by spot a at time t:

$$C_{a,t} = \{x : x \text{ lies on the wavefront of spot } a \text{ at time } t,\ R_t^+(x) = 1 \text{ or } R_t^-(x) = 1\}. \tag{4}$$

If $C_{a,t} = \emptyset$, the spot continues expanding. If $C_{a,t} \neq \emptyset$, the wavefront collapses onto one selected site using an incidence criterion [1].

C. Polarity-conditioned transition

Let $X_a(t) \in C_{a,t}$ denote the collapse site. If polarity matches readiness, a transition occurs:

$$p_a(t) = +1 \ \wedge\ R_t^+(X_a(t)) = 1 \Rightarrow M_{t+1}(X_a(t)) = 1, \tag{5}$$

$$p_a(t) = -1 \ \wedge\ R_t^-(X_a(t)) = 1 \Rightarrow M_{t+1}(X_a(t)) = 0. \tag{6}$$

If polarity does not match, the collapse does not induce transition and the wavefront continues [1].

D. Polarity flip and new expansion cycle

After a successful transition, polarity flips:

$$p_a(t^+) = -p_a(t), \tag{7}$$

and the spot proceeds into the next wavefront expansion cycle with updated polarity. This feedback couples birth/death to energetic accounting and is the reason a global matter-energy invariant exists [1].

V. Dynamic Space Instantiation and Allocation Density

EDCA supports dynamic instantiation: the lattice does not need to exist fully at initialization. Instead, sites are allocated when needed to evaluate readiness, support wavefront propagation, and execute transitions [1]. Let $A_t \subset \mathbb{Z}^d$ be the allocated site set.

A. Allocation density

Define the coarse-grained allocation density field

$$\rho(x,t) \in [0,1]. \tag{8}$$

Intuitively, ρ is large in regions where EDCA repeatedly needed to allocate and maintain sites (e.g., frequently traversed by wavefronts or frequently evaluated for readiness).

B. Priority of already-allocated space

A central computational principle is: already-instantiated space has priority. In practical terms, it is cheaper to reuse allocated sites than to allocate new ones; therefore collapse and readiness selection incorporate explicit bias toward high ρ [1].

VI. Incidence Criterion and Emergent Potential

When a wavefront intersects multiple candidates, EDCA uses a multiplicative incidence criterion:

$$W_t(a,x) = w_d(a,x)\, w_s(a,x)\, w_\rho(x,t), \tag{9}$$

where the allocation-density factor is

$$w_\rho(x,t) = \rho(x,t)^\gamma, \tag{10}$$

with $\gamma > 0$ [1].

A. Potential from allocation-density preference

Because the preference is multiplicative, negative log turns it into an additive "cost" contribution. Define:

$$\Phi(x,t) \equiv -\gamma \ln \rho(x,t). \tag{11}$$

This potential is *not assumed*; it is directly induced by the EDCA collapse weighting in Eq. (10).

B. Emergent drift/acceleration field

In a continuum approximation, biased selection produces drift toward decreasing potential:

$$\mathbf{g}(x,t) = -\nabla\Phi(x,t) = \gamma\nabla \ln \rho(x,t). \tag{12}$$

This is the EDCA gravity analog: spots and transitions are statistically attracted toward regions with higher allocation density.

VII. Allocation Density as Cumulative Spot Activity

Allocation density is driven primarily by spot-related operations:

- wavefront reachability computations,
- collapse selection among candidates,
- transition execution and neighborhood updates.

Thus it is natural to define a coarse-grained activity/energy density $\varepsilon(x,t)$ and propose:

$$\frac{\partial \rho}{\partial t} = \alpha\, \varepsilon(x,t) - \beta\,(\rho - \rho_0) + D\nabla^2\rho. \tag{13}$$

In equilibrium $\partial_t \rho \approx 0$,

$$\nabla^2\rho - \mu^2\rho = -k\,\varepsilon(x), \quad \mu^2 = \beta/D, \quad k = \alpha/D. \tag{14}$$

Equation (14) is the EDCA analog of a "field equation": activity sources allocation density.

VIII. Newtonian Limit: Poisson Equation and Inverse-Square Law

Assume small deviations around background:

$$\rho(x) = \rho_0 \left(1 + \psi(x)\right), \quad |\psi| \ll 1. \tag{15}$$

Then $\Phi = -\gamma \ln \rho \approx -\gamma\psi + \text{const}$ and one obtains

$$\nabla^2 \Phi = \gamma \frac{k}{\rho_0} \varepsilon(x). \tag{16}$$

Define

$$4\pi G_{\text{EDCA}} \equiv \gamma \frac{k}{\rho_0}, \tag{17}$$

giving the Newton-like Poisson equation

$$\nabla^2 \Phi = 4\pi G_{\text{EDCA}} \, \varepsilon(x). \tag{18}$$

For a point source $\varepsilon(x) = M\delta^{(3)}(x)$ in $d = 3$:

$$\Phi(r) = -\frac{G_{\text{EDCA}} M}{r}, \tag{19}$$

$$\mathbf{g}(r) = -\nabla\Phi(r) = -\frac{G_{\text{EDCA}} M}{r^2}\hat{\mathbf{r}}, \tag{20}$$

$$\mathbf{F}(r) = m\mathbf{g}(r) = -G_{\text{EDCA}} \frac{Mm}{r^2}\hat{\mathbf{r}}. \tag{21}$$

This recovers the full classical Newtonian picture as an EDCA weak-field limit.

IX. Weak-Field GR Analog: Geometry from Allocation Density

To reinterpret the attraction geometrically, define an effective spatial metric:

$$g_{ij}^{\text{eff}}(x,t) = \rho(x,t)^{-2\beta}\delta_{ij}, \tag{22}$$

so the effective line element is

$$ds^2_{\text{eff}} = \rho(x,t)^{-2\beta} ds^2_{\text{flat}}. \tag{23}$$

Since $\rho = e^{-\Phi/\gamma}$,

$$g_{ij}^{\text{eff}} = \exp\left(\frac{2\beta}{\gamma}\Phi\right)\delta_{ij} \approx \left(1 + \frac{2\beta}{\gamma}\Phi\right)\delta_{ij}. \tag{24}$$

Equation (24) matches the structural form of weak-field GR, where potential appears as a small perturbation of the metric.

X. Full Tensor EDCA–GR Analog

This section clarifies the tensor mapping and the physical meaning of each component.

A. Effective spacetime metric

Define

$$g_{\mu\nu}^{\text{eff}}(x,t) = \rho(x,t)^{-2\beta}\eta_{\mu\nu}, \tag{25}$$

where $\eta_{\mu\nu}$ is Minkowski. This says: the "amount of instantiated space" (allocation density) rescales local spacetime intervals. Higher ρ corresponds to more available infrastructure and therefore reduced effective "cost" of spatial-temporal progression.

B. Einstein tensor and curvature

Using $g_{\mu\nu}^{\text{eff}}$, standard differential geometry constructs the Einstein tensor

$$G_{\mu\nu}[g] = R_{\mu\nu}(g) - \frac{1}{2}g_{\mu\nu}R(g). \tag{26}$$

Because $g = g(\rho)$, curvature becomes a functional of allocation density. Thus, in the EDCA analogy, curvature is ultimately driven by gradients and second derivatives of $\rho(x,t)$.

C. Why a stress–energy tensor is needed in EDCA

In GR, the stress–energy tensor $T_{\mu\nu}$ encodes:

- T_{00}: energy density (source of Newtonian gravity),
- T_{0i}: energy/momentum flux (produces frame-dragging analogs),
- T_{ij}: stress/pressure/shear (produces anisotropic curvature).

EDCA possesses analogous measurable quantities because spots propagate, deposit energy, and create directional flux patterns. Therefore, to fully generalize beyond the scalar Newtonian limit, we construct a tensor $T_{\mu\nu}^{\text{EDCA}}$ from spot events.

D. Formal event indicators

Define collapse indicator $\chi_a(x,t)$:

$$\chi_a(x,t) = \begin{cases} 1, & \text{if spot } a \text{ collapses at site } x \text{ at time } t, \\ 0, & \text{otherwise.} \end{cases} \tag{27}$$

Define transition indicator $\tau_a(x,t)$ (collapse + correct polarity + matching readiness):

$$\tau_a(x,t) = \begin{cases} 1, & \text{if } \chi_a(x,t) = 1,\ p_a(t) = +1,\ R_t^+(x) = 1, \\ 1, & \text{if } \chi_a(x,t) = 1,\ p_a(t) = -1,\ R_t^-(x) = 1, \\ 0, & \text{otherwise.} \end{cases} \tag{28}$$

Define wavefront reachability term $\omega_a(x,t)$ (a shell of thickness Δr):

$$\omega_a(x,t) = \begin{cases} 1, & \text{if } \big||x - x_a(t)| - r_a(t)\big| \le \Delta r, \\ 0, & \text{otherwise.} \end{cases} \tag{29}$$

E. Constructing EDCA energy density $\varepsilon(x,t)$

We define EDCA energy/activity density as the local rate of energetic spot work:

$$\varepsilon(x,t) = \sum_{a=1}^{K(t)} \left(\alpha_{\text{col}}\chi_a(x,t) + \alpha_{\text{tr}}\tau_a(x,t) + \alpha_{\text{wf}}\omega_a(x,t)\right). \tag{30}$$

Interpretation:

- The χ_a term counts collapse selection/evaluation work.
- The τ_a term counts actual state transitions (true energy deposition).
- The ω_a term counts wavefront coverage/maintenance work even when no collapse occurs.

Thus $\varepsilon(x,t)$ can be estimated empirically by counting events in simulation logs.

F. Constructing EDCA flux/momentum density $J_i(x,t)$

Let

$$n_{a,i}(x,t) = \frac{(x - x_a(t))_i}{|x - x_a(t)|} \tag{31}$$

be the unit outward direction from spot center to x. Define the EDCA flux:

$$W_a(x,t) = \beta_{\mathrm{col}}\chi_a(x,t) + \beta_{\mathrm{tr}}\tau_a(x,t) + \beta_{\mathrm{wf}}\omega_a(x,t). \tag{32}$$

$$J_i(x,t) = \sum_{a=1}^{K(t)} W_a(x,t)\, n_{a,i}(x,t). \tag{33}$$

Interpretation: J_i measures the net directional flow of spot influence. In GR analogy, $T_{0i} = J_i$ acts like momentum density or energy flux and can generate "gravitomagnetic"-type effects (e.g., preferred rotational drift).

G. Constructing EDCA stress tensor $\Pi_{ij}(x,t)$

Define the stress tensor:

$$V_a(x,t) = \gamma_{\mathrm{col}}\chi_a(x,t) + \gamma_{\mathrm{tr}}\tau_a(x,t) + \gamma_{\mathrm{wf}}\omega_a(x,t). \tag{34}$$

$$\Pi_{ij}(x,t) = \sum_{a=1}^{K(t)} V_a(x,t)\, n_{a,i}(x,t)\, n_{a,j}(x,t) + \Sigma_{ij}(x,t). \tag{35}$$

where $\Sigma_{ij}(x,t)$ aggregates additional anisotropic stresses induced by spin-based incidence weighting and directional collapse biases [1].

Interpretation: Π_{ij} captures how spot propagation distributes activity across directions:

- If propagation is isotropic, $\Pi_{ij} \propto \delta_{ij}$ (pressure-like).
- If propagation is anisotropic, off-diagonal terms appear (shear-like).
- Spin preference contributes to Σ_{ij}, encoding directional torsion analogs.

H. EDCA stress–energy tensor

Assemble:

$$T^{\mathrm{EDCA}}_{\mu\nu}(x,t) = \begin{pmatrix} \varepsilon(x,t) & J_j(x,t) \\ J_i(x,t) & \Pi_{ij}(x,t) \end{pmatrix}. \tag{36}$$

This makes explicit how each component corresponds to measurable quantities in the EDCA evolution.

I. EDCA–Einstein coupling

We propose the tensor field equation:

$$G_{\mu\nu}[g(\rho)] = \kappa_{\mathrm{EDCA}}\, T^{\mathrm{EDCA}}_{\mu\nu}. \tag{37}$$

Interpretation: Eq. (37) states that the curvature of the effective geometry induced by allocation density is sourced by spot-driven activity. In the weak-field limit, the 00-component reduces to the scalar Poisson equation in Eq. (18).

XI. Conservation and Source Interpretation: The Invariant $2\sigma_t + E_t$

The foundational EDCA framework identifies a conserved matter-energy quantity [1]:

$$2\sigma_t + E_t = \mathrm{constant}, \tag{38}$$

where σ_t is the total number of living cells and E_t is the algebraic energy accounting (associated with spot polarity and energy bookkeeping). The invariance is a direct consequence of polarity-conditioned transitions and the polarity flip rule in Eq. (7).

A. Why the invariant matters for the GR analogy

In GR, the dominant Newtonian source is T_{00}, and the theory is grounded in conservation. In EDCA, Eq. (38) identifies what is globally conserved. Therefore the *correct* EDCA analog of energy density must be built from the same event mechanisms responsible for this conservation: wavefront expansion, collapse, and successful transitions (which flip polarity). This motivates the definition $\varepsilon(x,t)$ in Eq. (30).

B. Mapping global conservation to local source

A consistency condition for the EDCA gravity analogy is that the spatial integral of ε tracks the conserved total:

$$\int \varepsilon(x,t)\, d^d x \;\propto\; 2\sigma_t + E_t, \tag{39}$$

up to coarse-graining constants. This provides a conservation-based grounding for the interpretation

$$T^{\mathrm{EDCA}}_{00}(x,t) = \varepsilon(x,t) \tag{40}$$

as the curvature source in Eq. (37).

XII. Conclusion

EDCA's gravity/geometry analogy follows from its foundational spot-driven rules: ready sites transition only under spot coverage; polarity conditions birth/death; polarity flips after successful transitions; and dynamic site allocation supports spot propagation and readiness evaluation [1]. These mechanisms produce allocation density $\rho(x,t)$ as a record of cumulative energetic activity. Because already-instantiated space is preferred, allocation density enters the collapse incidence criterion and yields an emergent potential $\Phi = -\gamma \ln \rho$ and drift field $\mathbf{g} = -\nabla\Phi$. A weak-field steady-state limit recovers the Newtonian Poisson equation and inverse-square force law. Finally, a conformal metric $g^{\mathrm{eff}}_{\mu\nu}(\rho)$ and an explicitly spot-derived tensor $T^{\mathrm{EDCA}}_{\mu\nu}$ enable a full tensorial EDCA–GR analog. EDCA's invariant $2\sigma_t + E_t$ provides the conservation grounding that justifies interpreting T^{EDCA}_{00} as the curvature source.

References

[1] R. Sanchez Perez, "Energy Driven Cellular Automaton (EDCA): Fundaments / Foundational Paper," EDCAWorld, PDF document, Jan. 2026. Available: https://edcaworld.com/wp-content/uploads/2026/01/fundaments.pdf