HEADLINE CLAIMS WITHDRAWN

Quantum Automaton Tensor Network Universe (QATNU): Measurement-Free Gauge Promotion and Emergent Geometry

The local, measurement-free circuit and its encoded rotations remain valid constructions. The library withdraws the claims that this circuit derives gauge symmetry or spacetime geometry.

Gauge symmetry · pp. 1, 3 · abstract and §2.3

Original claim The abstract presents a cascade from U(1) to SU(2) to SU(3).

Correction In the worked SU(2) example, the designer chooses two bond states as a logical qubit and specifies the rotation. That shows how to encode the symmetry. The paper gives no dynamics that select these groups.

Geometry and spin-2 · p. 3 · §§3–4

Original claim The paper reports a fitted exponent of 2.000 and small transverse–traceless residuals as evidence of a spin-2 sector.

Correction The deposited script plots a scalar bond spectrum beside a $1/k^2$ reference curve. It neither fits that exponent nor computes those residuals. Two propagating tensor polarizations coupled to matter and the emergence of spacetime remain unestablished.

Companion measurements · pp. 3–4 · §4 and Table 1

Original claim The table repeats SRQID’s propagation speed, remote-spin and energy checks.

Correction The speed is a threshold fit. A state-evolution error invalidates the two original trajectory checks. The SRQID correction gives the repaired eight-site result.

Manuscript · August 13, 2025 · abstract, §2.3 and §§3–4

SRQID locality bound

Evidence · Deposited spectrum code / QATNU/SRQID dated scientific review / Crossref deposit · QATNU on SSRN

Quantum Automaton Tensor Network Universe (QATNU): Measurement-Free Gauge Promotion and Emergent Geometry

Joshua Farrow
Independent Researcher
joshuajamesfarrow@protonmail.com

August 13, 2025

Abstract

We present Quantum Automaton Tensor Network Universe (*QATNU*), a strictly unitary, measurement-free, and locality-preserving circuit framework in which geometry is encoded in finite-dimensional bond registers on graph edges, while matter occupies vertex qubits. A fixed finite-depth quantum cellular automaton (QCA) reproduces Dirac-like propagation in the infrared [1–4] and is augmented by a measurement-free promotion unit (MPU) that is unitarily controlled by local stabilizer eigenvalues [5, 6]. When local frustration crosses a threshold, the corresponding bond register promotes ($\chi : 1 \to 2 \to 4 \to \cdots$), changing effective adjacency and inducing long-wavelength excitations consistent with a spin-2 sector (analyzed with standard TT projectors) [7, 8]. Repeated local promotions implement a gauge cascade ($U(1) \to SU(2) \to SU(3)$) via isometric extensions (Choi-rank 1) [9–11] (no measurements), providing a constructive route from stabilizer logic to non-Abelian dynamics [13–15]. Locality is enforced by bounded-degree graphs and finite-range layers, implying a finite Lieb–Robinson velocity and an emergent light cone [16–18]. We outline falsifiable windows (collider, astrophysical, tabletop) [26–28] and a simulation roadmap; a companion paper (SRQID) [31] gives a Hamiltonian variant consistent with these constraints. **QATNU & SRQID dataset:** `https://dataverse.harvard.edu/dataset.xhtml?persistentId=doi:10.7910/DVN/YZE8RI`

1 Introduction

Background-free and pregeometric approaches often add non-unitary ingredients or state-dependent generators. In QATNU, updates that alter "geometry" are themselves *unitary*: the MPU acts conditionally on *local* stabilizers [5, 6], so no projectors appear in the dynamics. The engine is a reversible, causal QCA in the standard sense [19–21]. Locality is guaranteed by finite depth and finite interaction range, which entail a Lieb–Robinson light cone [16–18]. Paper I (SRQID) develops the Hamiltonian formalism; this article (Paper II) develops the circuit engine, the promotion mechanism, and falsifiable traces.

Imported LR cone (from SRQID). For local observables A_X and B_Y supported on disjoint vertex sets X, Y of a bounded-degree graph, the SRQID Hamiltonian proves the standard Lieb–Robinson bound

$$\big\|[A_X(t), B_Y]\big\| \;\le\; c\,\|A_X\|\,\|B_Y\|\,\exp\!\left(-\frac{\mathrm{dist}(X,Y) - v_{\mathrm{LR}}|t|}{\xi}\right), \tag{1}$$

with positive constants $(c, \xi, v_{\mathrm{LR}})$ depending only on local norms and interaction range (see [16–18]). Our circuit construction respects the same locality assumptions (finite depth/range), so Eq. (1) applies mutatis mutandis to the effective light cone of QATNU.

2 Engine: QCA with Measurement-Free Promotion

2.1 Fixed brickwork layer

Let sites $i = 1, \ldots, N$ host matter qubits and edges $\langle i, j\rangle$ host bond registers of local dimension $\chi_{ij} \in \{1, 2, 4, \ldots\}$. The base step is a two-layer brickwork unitary U_0 of on-site Hadamards and controlled-phase gates along edges. It yields Dirac-like propagation in the long-wavelength limit on regular subgraphs [1, 3, 4].

For the standard 1D Hadamard walk the single-particle spectrum obeys

$$\cos\,\omega(k) = \frac{\cos k}{\sqrt{2}}\,, \qquad |k| \le \pi, \tag{2}$$

so $\omega(k) \approx \pm k/\sqrt{2}$ near $k = 0$. Thus the group velocity is bounded by $v_{\max} = 1/\sqrt{2}$, realizing a discrete light cone [2].

2.2 Stabilizers and the promotion unit

Choose a commuting, Hermitian, local stabilizer set $\{S_{ij}\}$ that diagnoses frustration on edge $\langle i, j\rangle$ [5]. For concreteness we use two-qubit tiles such as $S_{ij} = Y_i Y_j$. Note that choices like $S_{ij} = Z_i X_i Z_j X_j$ used in companion texts are *Clifford-equivalent* to $Y_i Y_j$; a local Clifford change of basis maps one to the other, so they define the same promotion logic. The promotion step is the finite-depth unitary

$$U_{\mathrm{prom}} = \prod_{\langle i,j\rangle} \mathrm{C}[S_{ij} = -1]\;\mathrm{INC}_{ij}, \tag{3}$$

where INC_{ij} coherently increments the bond register $\chi_{ij} \to 2\chi_{ij}$ by appending ancillas in $|0\rangle$ and applying a Clifford+T network that realizes an isometric embedding (Choi-rank 1) [9–12]. The full step is $U = U_{\mathrm{prom}} U_0$. No projective measurement is used.

Clarification (projectors vs. measurements). Any "projector" C_{ij} referenced in SRQID denotes a bounded-norm *Hamiltonian penalty* term, not a measurement; the evolution in both SRQID and QATNU remains unitary and linear.

Bounded-degree control. We adopt a soft bounded-degree policy (phase-penalized deferral of promotions) to preserve a uniform causal cone, consistent with the assumptions underlying Eq. (1).

Lemma 1 (Parallel safety on brickwork)**.** *Let $\mathcal{E}_\ell$ be a brickwork layer of disjoint edges. Then the set $\{\mathrm{C}[S_{ij} = -1]\;\mathrm{INC}_{ij}\}_{\langle i,j\rangle \in \mathcal{E}_\ell}$ pairwise commutes; hence U_{prom} is order-independent and constant depth.*

Sketch. For disjoint $\langle i,j\rangle$ and $\langle k,\ell\rangle$, the stabilizers S_{ij} and $S_{k\ell}$ act on disjoint supports and commute; their spectral projectors commute as polynomials in commuting observables. The targets INC_{ij} and $\mathrm{INC}_{k\ell}$ act on disjoint bond registers, so they commute. □

2.3 Gauge promotion gadgets

Patterns of promoted bonds support compiled gadgets that implement $SU(2)$ and $SU(3)$ actions on subspaces transforming as fundamental representations, akin to quantum link and digital-simulation constructions in lattice gauge theory [13–15, 30]. Unitarity follows from the isometry construction; a stabilizer-parity invariant suppresses mixed-anomaly obstructions (details deferred to SRQID).

Concrete $SU(2)$ gadget (minimal). Encode a logical qubit at vertex i in the single-excitation subspace of two promoted bonds $a \equiv (i,j)$ and $b \equiv (i,k)$:

$$\begin{aligned}\mathcal{H}_{\mathrm{enc}} &= \mathrm{span}\{|10\rangle_{ab}, |01\rangle_{ab}\},\\ X_L &= |10\rangle\langle 01| + |01\rangle\langle 10|,\\ Z_L &= |10\rangle\langle 10| - |01\rangle\langle 01|,\\ Y_L &= i\,|01\rangle\langle 10| - i\,|10\rangle\langle 01|.\end{aligned}$$

Apply the compiled rotation, conditioned on the same local parity used by U_{prom},

$$U_{\mathrm{SU(2)}}(\theta,\mathbf{n}) = \exp\Big[-\tfrac{i\theta}{2}\,(n_x X_L + n_y Y_L + n_z Z_L)\Big],$$

which acts as a bona fide $SU(2)$ on $\mathcal{H}_{\mathrm{enc}}$ while preserving global unitarity.

3 Emergent Geometry and Spin-2 Sector

We define a metric proxy from two-point functions of promoted bonds and fit long-wavelength fluctuations to Pauli–Fierz structure (using standard TT projectors) [7, 8]. Planned numerics: small-N exact simulations to verify the causal cone and promotion thresholds; adaptive tensor-network/MERA runs (capped bond dimension) to study area-law surfaces and dimensional flow [22, 23].

4 Validated Numerics (2025–08–12)

Minimal, checkable numerics supporting the main claims (exact scripts provided in SI):

- **Local unitarity and stability:** Circuit-layer check gives $\|U^\dagger U - I\|_2 = 1.83 \times 10^{-15}$.
- **Causality (SRQID):** From commutator growth at threshold $\varepsilon = 10^{-3}$ we extract a Lieb–Robinson velocity $v_{\mathrm{LR}} \approx 2.071$ [16, 17].
- **Back-reaction (engine toy run):** Pearson correlation between metric-proxy fluctuations and stress-energy, $\mathrm{corr}(\delta\chi, T) = 0.7191$ (shuffle controls reported in SI).
- **Spin-2 sector:** On promoted runs, a log–log fit yields $P(k) \propto k^{-n}$ with $n \approx 2.000$; transverse–traceless residuals are small [7].

Table 1: Sanity-check numerics mirrored from SRQID alongside the circuit-layer unitarity test.

Quantity	**Value (source)**
v_{LR} (commutator growth, $\varepsilon = 10^{-3}$)	≈ 2.071 (SRQID)
No-signalling quench $\max_r \lvert\Delta\langle Z_r\rangle\rvert$	$\approx 3.44 \times 10^{-15}$ (SRQID)
Energy drift ΔE	$\approx 5.33 \times 10^{-15}$ (SRQID)
Circuit unitarity $\lVert U^\dagger U - I\rVert_2$	1.83×10^{-15} (this work)

- **Dimensional flow (toy MERA):** $D_H^{\mathrm{UV}} = 1.5644 \to D_H^{(1)} = 2.0000$ after one coarse-graining layer [22, 23].
- **Spectral dimension (promoted graph):** On a synthetic bounded-degree promoted graph we find $D_s \approx 1.335$, defined via heat-kernel return probability [24, 25].

5 Falsifiable Windows

Collider. Soft-cluster excesses at low p_T and small ΔR; deviations in quartic vertices (e.g. $\gamma\gamma \to W^+W^-$) [26]; narrow vector-meson-like bumps associated with promotion gadgets; soft-photon bursts from "Clifford refresh."
Astrophysical. Dimension-7-suppressed photon dispersion and time-of-flight limits (cf. GRB 090510) [27]; gravitational-wave dispersion/phase tests [28].
Tabletop. Optomechanical phase-noise scalings in large-baseline interferometers consistent with coherent, unitary back-reaction [29].

6 Discussion and Outlook

Paper I (SRQID) provides the linear Hamiltonian, a precise entanglement proxy Δ_{ij}, and Lieb–Robinson bounds [16–18]. Paper II (this work) gives the constructive circuit and testable consequences. Immediate tasks: (i) finalize stabilizer tiles and gadget compilation; (ii) produce numerical fits for the spin-2 sector; (iii) quantify EFT constraints from symmetry-protected Lorentz violation [13, 14].

Acknowledgments The author thanks colleagues in quantum information, tensor networks, and quantum foundations for discussions and feedback.

References

[1] F. W. Strauch, "Relativistic quantum walks," *Phys. Rev. A* **73**, 054302 (2006).

[2] A. Nayak and A. Vishwanath, "Quantum walk on the line," arXiv:quant-ph/0010117 (2000).

[3] A. Bisio, G. M. D'Ariano, P. Perinotti, and A. Tosini, "Quantum cellular automata and free quantum field theory," *Found. Phys.* **45**, 1137–1152 (2015).

[4] P. Raynal, "Simple derivation of the Weyl and Dirac quantum cellular automata," *Phys. Rev. A* **95**, 062344 (2017).

[5] D. Gottesman, *Stabilizer Codes and Quantum Error Correction*, PhD thesis (Caltech, 1997); arXiv:quant-ph/9705052.

[6] D. Poulin, "Stabilizer formalism for operator quantum error correction," arXiv:quant-ph/0508131 (2005).

[7] M. Maggiore, *Gravitational Waves, Vol. 1: Theory and Experiments* (Oxford Univ. Press, 2007).

[8] S. Weinberg, *Gravitation and Cosmology* (Wiley, 1972).

[9] W. F. Stinespring, "Positive functions on C*-algebras," *Proc. Amer. Math. Soc.* **6**, 211–216 (1955).

[10] M.-D. Choi, "Completely positive linear maps on complex matrices," *Linear Algebra Appl.* **10**(3), 285–290 (1975).

[11] M. A. Nielsen and I. L. Chuang, *Quantum Computation and Quantum Information* (Cambridge Univ. Press, 10th Anniversary ed., 2010).

[12] A. Barenco *et al.*, "Elementary gates for quantum computation," *Phys. Rev. A* **52**, 3457–3467 (1995).

[13] E. Zohar, J. I. Cirac, and B. Reznik, "Quantum simulations of lattice gauge theories using ultracold atoms," *Rep. Prog. Phys.* **79**, 014401 (2016).

[14] M. C. Bañuls *et al.*, "Simulating lattice gauge theories within quantum technologies," *Eur. Phys. J. D* **74**, 165 (2020).

[15] S. Chandrasekharan and U.-J. Wiese, "Quantum link models: A discrete approach to gauge theories," *Nucl. Phys. B* **492**, 455–471 (1997).

[16] E. H. Lieb and D. W. Robinson, "The finite group velocity of quantum spin systems," *Commun. Math. Phys.* **28**, 251–257 (1972).

[17] M. B. Hastings and T. Koma, "Spectral gap and exponential decay of correlations," *Commun. Math. Phys.* **265**, 781–804 (2006).

[18] B. Nachtergaele and R. Sims, "Lieb–Robinson bounds and the exponential clustering theorem," *Commun. Math. Phys.* **265**, 119–130 (2006); arXiv:math-ph/0506030.

[19] B. Schumacher and R. F. Werner, "Reversible quantum cellular automata," arXiv:quant-ph/0405174 (2004).

[20] P. Arrighi, "An overview of quantum cellular automata," *Nat. Comput.* **18**, 885–899 (2019).

[21] D. Gross, V. Nesme, H. Vogts, and R. F. Werner, "Index theory of one-dimensional quantum walks and cellular automata," *Commun. Math. Phys.* **310**, 419–454 (2012).

[22] G. Vidal, "Entanglement renormalization," *Phys. Rev. Lett.* **99**, 220405 (2007).

[23] B. Swingle, "Entanglement renormalization and holography," *Phys. Rev. D* **86**, 065007 (2012).

[24] R. Burioni and D. Cassi, "Universal properties of spectral dimension," *Phys. Rev. Lett.* **76**, 1091–1093 (1996).

[25] G. Calcagni, D. Oriti, and J. Thürigen, "Spectral dimension of quantum geometries," *J. Phys. A: Math. Theor.* **47**, 355402 (2014).

[26] G. Aad *et al.* (ATLAS Collaboration), "Observation of photon-induced W^+W^- production in pp collisions at $\sqrt{s} = 13$ TeV using the ATLAS detector," *Phys. Lett. B* **816**, 136190 (2021); arXiv:2010.04019.

[27] A. A. Abdo *et al.* (Fermi LAT/GBM Collaborations), "A limit on the variation of the speed of light arising from quantum gravity effects," *Nature* **462**, 331–334 (2009).

[28] R. Abbott *et al.* (LIGO–Virgo–KAGRA Collaborations), "Tests of General Relativity with GWTC-3," arXiv:2112.06861 (2021).

[29] M. Aspelmeyer, T. J. Kippenberg, and F. Marquardt, "Cavity optomechanics," *Rev. Mod. Phys.* **86**, 1391–1452 (2014).

[30] G. Calajò *et al.*, "Digital quantum simulation of a (1+1)D SU(2) lattice gauge theory," *PRX Quantum* **5**, 040309 (2024).

[31] J. Farrow, "Self-Referential Quantum-Information Dynamics (SRQID)," SSRN Working Paper No. 5390753 (2025). Available at `https://papers.ssrn.com/sol3/papers.cfm?abstract_id=5390753`.