Ab Initio Evidence for the Fine Structure Constant from Density Field Dynamics (Timestamp Preprint)

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Abstract

We report numerical evidence that the electromagnetic fine structure constant $\alpha \approx 1/137$ emerges from a specific gauge-emergence microsector within Density Field Dynamics (DFD). In the DFD gauge-emergence extension, gauge connections are modeled as Berry connections on internal mode subspaces associated with the scalar refractive field ψ. The effective gauge couplings are determined by stiffness coefficients κ through canonical normalization, schematically $g \propto \kappa^{-1/2}$. We perform lattice Monte Carlo simulations for compact U(1) and SU(2) sectors at a locked parameter point and extract an electromagnetic coupling via electroweak mixing with Wilson normalization.

At the locked point $(\beta_{U(1)}, \beta_{SU(2)}) = (3.8, 23.0)$, completed runs committed in the public repository yield Wilson-normalized values clustering within $\sim 1\%$ of the physical value $\alpha_{\text{phys}} = 0.0072973525693\ldots$:

- $L = 4$: $\alpha_W = 0.007265$ (-0.44%)
- $L = 6$: $\alpha_W = 0.007300$ (seed 701, $+0.04\%$) and $\alpha_W = 0.007186$ (seed 702, -1.52%), giving a current mean $\alpha_W = 0.007243$ (-0.74%) over these two seeds
- $L = 8$: $\alpha_W = 0.007365$ ($+0.93\%$; single completed seed in this timestamp set)

Scope of this timestamp. This version is posted to establish a priority timestamp for (i) the locked dictionary mapping measured stiffness outputs to α_W, (ii) the locked parameter point, and (iii) the completed-run outputs present in the repository at the time of posting. Multi-seed verification at larger L and a full systematic error budget are ongoing.

Priority timestamp: December 23, 2025.

Repository: https://github.com/galcock/densityfielddynamics

CONTENTS

I. TIMESTAMP STATEMENT (WHAT THIS VERSION CLAIMS)

This is a **timestamp preprint**. Its job is to lock (a) the precise map from measured lattice outputs to α, (b) the locked numerical point used for the reported runs, and (c) the already-completed outputs stored as machine-readable artifacts in the public repository.

This version **does not** claim that verification is complete. It claims that, under the locked dictionary and locked parameter point stated below, the completed runs already yield α_W near $1/137$.

II. INTRODUCTION

A. Why α matters

The fine structure constant,

$$\alpha \equiv \frac{e^2}{4\pi\epsilon_0\hbar c} \approx 0.0072973525693\ldots \approx \frac{1}{137.036}, \tag{1}$$

sets the strength of electromagnetic interactions and controls atomic structure, chemistry, and the scale separation between classical and quantum phenomena. Within the Standard Model, α is an experimentally measured input parameter. A first-principles mechanism that fixes α (even approximately) is therefore a high-value target.

B. DFD route: coupling from stiffness

In the DFD gauge-emergence extension used here, gauge fields arise as connections on internal mode spaces and the couplings are set by stiffness parameters κ that quantify the energetic cost of twisting those internal frames. The empirical question this paper addresses is:

Does a locked DFD stiffness-to-coupling dictionary, evaluated by lattice simulation at a locked point, produce α near $1/137$ without post-hoc normalization changes?

III. THEORETICAL FRAMEWORK (AS USED HERE)

A. DFD postulates used in this paper

DFD is formulated on flat $\mathbb{R}^3$ with a scalar field $\psi(\mathbf{x}, t)$ and refractive index

$$n(\mathbf{x}, t) = e^{\psi(\mathbf{x},t)}. \tag{2}$$

The one-way light speed is taken as

$$c_1(\mathbf{x},t) = c\, e^{-\psi(\mathbf{x},t)}, \tag{3}$$

and the DFD kinematic acceleration relation used throughout the DFD program is

$$\mathbf{a} = \frac{c^2}{2}\nabla\psi. \tag{4}$$

In this preprint, these postulates primarily serve as the organizing basis for the microsector whose lattice implementation generates stiffness observables.

B. Gauge emergence as a connection on internal frames

We model the gauge sector as arising from local basis changes on an internal mode subspace V_r at each point, indexed by sector $r \in \{U(1), SU(2)\}$. A local orthonormal frame $\Xi_r(\mathbf{x})$ defines a connection (Berry connection)

$$A_i^{(r)} = i\,\Xi_r^\dagger \partial_i \Xi_r, \tag{5}$$

with field strength $F_{ij}^{(r)}$.

C. Stiffness functional and coupling extraction

The stiffness functional is written as

$$\mathcal{L}_{\text{stiff}}^{(r)} = -\frac{\kappa_r}{2}\,\mathrm{Tr}\, F_{ij}^{(r)} F_{ij}^{(r)}. \tag{6}$$

Canonical normalization implies that the effective coupling scales with stiffness as $g_r \propto \kappa_r^{-1/2}$. The lattice implementation in this project is constructed such that the measured lattice stiffness outputs $\kappa_{U(1)}$ and $\kappa_{SU(2)}$ feed into the electroweak mixing dictionary below.

D. Electroweak mixing and the locked Wilson dictionary

Electromagnetism emerges from mixing of the U(1) and neutral SU(2) components. The electromagnetic coupling satisfies

$$\frac{1}{e^2} = \frac{1}{g_1^2} + \frac{1}{g_2^2}. \tag{7}$$

We adopt the **Wilson-normalized** mapping consistent with standard lattice conventions used in this codebase:

$$g_1^2 = \frac{1}{\kappa_{U(1)}}, \qquad g_2^2 = \frac{4}{\kappa_{SU(2)}}. \tag{8}$$

Then

$$e^2 = \frac{g_1^2 g_2^2}{g_1^2 + g_2^2}, \qquad \alpha_W \equiv \frac{e^2}{4\pi} = \frac{(1/\kappa_{U(1)})(4/\kappa_{SU(2)})}{(1/\kappa_{U(1)}) + (4/\kappa_{SU(2)})} \cdot \frac{1}{4\pi}. \tag{9}$$

Lock statement. For timestamp purposes, Eqs. (8)–(9) are treated as locked. Any future change to this normalization constitutes a different claim and must be separately timestamped.

IV. NUMERICAL METHOD

A. Lattice formulation (high-level)

We simulate compact U(1) and SU(2) sectors on an L^4 Euclidean hypercubic lattice with periodic boundary conditions. The run driver writes JSON artifacts containing measured stiffness outputs (reported as `kappa_u1` and `kappa_su2`) and derived quantities.

B. Monte Carlo algorithm (high-level)

The simulation uses Metropolis updates for link variables and auxiliary fields. Each run includes:

- a thermalization phase (discarded),
- a measurement phase,
- measurements recorded at a fixed stride.

C. Locked parameter point for verification runs

The timestamp set reported in this paper uses the locked point

$$(\beta_{U(1)}, \beta_{SU(2)}) = (3.8, 23.0), \tag{10}$$

with typical run controls (as executed in the terminal logs) such as:

- sweeps: 60,000,
- thermalization: 6,000,
- measurement stride: 10.

D. About proposal step sizes (`eps`, `link_step`)

Parameters such as `eps` (SU(2) proposal size) and `link_step` (U(1) proposal size) are numerical tuning parameters that affect acceptance rate and autocorrelation. They do not change the equilibrium distribution when Metropolis is implemented correctly. For exact bitwise reproducibility they matter; for physical comparability they should not, provided equilibration and sampling are adequate.

V. RESULTS (TIMESTAMP SET)

A. Headline results

The physical target is $\alpha_{\text{phys}} = 0.0072973525693\ldots$. At the locked point $(3.8, 23.0)$, the completed runs in this timestamp set yield:

Lattice size	Seeds (completed)	α_W	$\Delta\alpha/\alpha$	Note
$L = 4$	baseline (committed artifacts)	0.007265	-0.44%	locked-point baseline
$L = 6$	seed 701	**0.007300**	**$+0.04\%$**	**near-bullseye**
$L = 6$	seed 702	0.007186	-1.52%	same locked point
$L = 6$	mean over seeds 701,702	0.007243	-0.74%	current timestamp mean
$L = 8$	single seed (timestamp set)	0.007365	$+0.93\%$	needs multi-seed

TABLE I. Wilson-normalized α_W at the locked point $(\beta_{U(1)}, \beta_{SU(2)}) = (3.8, 23.0)$ for the completed runs present in this timestamp set.

B. Auto-generated table from committed JSON artifacts

To reduce transcription risk, the repo can generate `tables_generated.tex` directly from the committed JSON artifacts. If present at compile time, it is included below.

Note: `tables_generated.tex` not found at compile time. (Optional) Generate it from the committed JSON artifacts using the repository script, then recompile.

C. Finite-size scaling (status)

A standard diagnostic is a fit of $\alpha_W(L)$ versus $1/L^2$. In the timestamp set, $L = 4, 6, 8$ are present but $L = 8$ has only one seed and $L = 6$ currently has two. Therefore any continuum extrapolation at this timestamp is qualitative; a controlled extrapolation requires multi-seed statistics at $L \in \{6, 8, 10\}$ (or feasible substitutes) plus autocorrelation diagnostics.

VI. REPRODUCIBILITY

A. Public repository

Code and artifacts are hosted at:

https://github.com/galcock/densityfielddynamics

B. Definition of α_W used in analysis code

The Wilson-normalized extraction used in the analysis matches Eq. (9). In the terminal analysis code used to summarize runs, this is implemented equivalently as:

$$g_1 = \frac{1}{\kappa_{U(1)}}, \qquad g_2 = \frac{4}{\kappa_{SU(2)}}, \qquad \alpha_W = \frac{g_1 g_2}{g_1 + g_2} \cdot \frac{1}{4\pi}. \tag{11}$$

C. Representative run command

A representative verification run (as executed in the logs) is:

```
python3 run_kappa_alpha.py \
```

```
--outdir artifacts/verify_alpha --tag "VERIFY_alpha_L6_u3.8_s23.0
   _eps0.35_u701_s1701" \
--progress_every 5000 --checkpoint_every 10000 \
--u1_L 6 --u1_sweeps 60000 --u1_therm 6000 --u1_meas 10 --u1_beta
   3.8 --u1_seed 701 \
--su2_L 6 --su2_sweeps 60000 --su2_therm 6000 --su2_meas 10 --
   su2_beta 23.0 --su2_eps 0.35 --su2_seed 1701
```

VII. CAVEATS (EXPLICIT)

This timestamp set has limited completed statistics at larger L:

- $L = 6$ has two completed seeds in the timestamp set.
- $L = 8$ has one completed seed in the timestamp set.
- $L = 10$ is not yet included in the timestamp set.

Accordingly, this paper presents **evidence and a locked dictionary**, not a finalized continuum-limit determination with a complete systematic error budget.

VIII. CONCLUSION (TIMESTAMP CLAIM ONLY)

Under a locked Wilson-normalized stiffness-to-coupling dictionary and a locked parameter point $(3.8, 23.0)$, the completed lattice runs present in the repository at the time of posting yield α_W values within $\sim 1\%$ of $1/137$, including one $L = 6$ run at $+0.04\%$. This timestamp preprint is intended to preserve priority for the dictionary, the locked point, and the completed-run outputs already committed in machine-readable form.

Appendix A: Appendix: Minimal analysis snippet (matches terminal logic)

```
import math, json
```

```
def alpha_w_from_json(path):
    d = json.load(open(path))
    r = d.get("results", d)
    ku = float(r["kappa_u1"])
    ks = float(r["kappa_su2"])
    g1 = 1.0/ku
    g2 = 4.0/ks
    alphaW = (g1*g2)/(g1+g2)/(4.0*math.pi)
    return alphaW
```

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[5] M. Creutz, *Quarks, Gluons and Lattices* (Cambridge University Press, 1983).

[6] G. Alcock, *Density Field Dynamics repository*, https://github.com/galcock/densityfielddynamics (December 23, 2025 timestamp).