Quantum Recursive Relativity: A Phenomenological Unification of Curvature and Quantum Feedback via Voxel Based Dynamics

Aaron McKee[1]

[1]Theoretical Physics, Independent Research Initiative,
arttechnologiesllc@gmail.com

May 21, 2025

Abstract

This paper introduces a novel simulation and theoretical framework named *Quantum Recursive Relativity (QRR)*, which unifies spacetime curvature, quantum feedback, and emergent particle dynamics within a recursive voxel-based lattice. By embedding nonlinear curvature propagation and quantum pressure fields into a discrete recursive tensor structure, QRR demonstrates a feasible phenomenological bridge between general relativity and quantum field behavior. The framework includes energy-threshold nucleation, layered feedback dynamics, and multi-resolution voxel modeling, offering new insights into recursive field evolution, emergence, and high-resolution simulation environments.

Contents

1 Introduction

The relationship between quantum mechanics and general relativity remains one of the greatest unresolved frontiers in physics. Each theory independently provides remarkably accurate predictions within its domain—quantum mechanics at microscopic scales and general relativity at cosmological ones. Yet efforts to unify them often result in singularities, infinities, or breakdowns in mathematical consistency.

This paper introduces **Quantum Recursive Relativity (QRR)**: a voxel-based simulation and theoretical model that proposes a phenomenological pathway to reconcile these frameworks. The model does so through recursive feedback structures, localized curvature dynamics, and emergent quantum behavior—encoded within a voxel lattice governed by nonlinear update rules.

2 Motivation

2.1 Why Voxel-Based Curvature?

Voxels offer spatially localized yet scalable discretizations of spacetime fields. They preserve locality at every scale and enable highly parallelizable computation. Recursive update rules naturally embody causality and memory effects, both essential for modeling feedback in coupled curvature-quantum systems.

2.2 Why Choose Voxels?

Many might question the decision to use voxels over other discretization strategies. The answer lies in their structure: voxels allow for a structured, volumetric decomposition of space, enabling complex field behaviors to emerge locally and recursively, without relying on pre-defined particle or string-based assumptions.

2.3 Voxel Recursion

By choosing a voxel-based (volumetric pixel) approach, we discretize spacetime into a 3D tensor structure. This enables the evolution of curvature, quantum feedback, and matter emergence via physically motivated update laws.

Recursion introduces nonlinear self-interaction in a stable, iterative format. The recursive logic in QRR models not just forward evolution, but also history-sensitive memory—critical for simulating quantum uncertainty and gravitational entanglement without analytic divergence.

3 Theoretical Foundation

3.1 Does It Align With Physics?

Traditional field-theoretic simulations rely on grid-based differential equations or continuous manifolds. These break down under nonlinear relativistic feedback or quantum uncertainty. Voxels, by contrast, offer:

- Spatially localized computation
- Finite-resolution regularization of divergence
- Physically causal neighbor interactions

Each voxel in QRR contains:

- Curvature: C
- Energy Density: D
- Quantum Feedback Field: Q
- Gradient Energy: G

This format allows for recursive equations where each voxel evolves with its neighbors through a localized memory loop.

3.2 Traditional Methods vs QRR

It's been famously difficult—nearly impossible—to simultaneously satisfy the mathematical conditions of both general relativity and quantum mechanics without introducing nonlinear infinities. General relativity relies on smooth spacetime curvature, while quantum field theory handles discretized energy packets. Their assumptions about locality, causality, and time evolution fundamentally differ.

QRR sidesteps direct unification by embedding both field behaviors in a recursive, voxel-based substrate. Quantum pressure gradients influence curvature, and curvature in turn modifies local energy and quantum dynamics. This avoids:

- Infinite self-energy problems
- Operator-valued curvature tensors
- Need for perturbative renormalization

3.3 Recursive Update Equation

$$C_{t+1}(x, y, z) = f\left(C_t, \nabla C_t, Q_t, D_t\right)$$

Where:

- C_t: curvature at time t
- ∇C_t: local curvature gradient
- Q_t: quantum feedback
- D_t: energy density
- f: nonlinear sculpting function with built-in memory and symmetry

3.4 Quantum-Inspired Pressure Feedback

$$Q_t(x, y, z) = \alpha \cdot (\nabla \cdot \nabla C_t) - \beta \cdot \left(\frac{\partial^2 C_t}{\partial t^2}\right)$$

Where α and β are tunable constants controlling:

- Spatial sensitivity
- Feedback response time

3.5 Energy-Threshold Nucleation

$$\text{EmitParticle}(x, y, z) \iff E(x, y, z) > E_{\text{crit}} \wedge \nabla C > C_{\min}$$

This mimics phase transitions in QFT without requiring string-scale physics.

4 Simulation Framework

4.1 Voxel Grid Structure

A 3D tensor of size $N \times N \times N$, each voxel contains:

- Curvature C
- Quantum Field Pressure Q
- Density D
- Gradient Energy G
- Emergence Potential P

4.2 Recursive Tensor Logic

Each voxel updates via neighboring states:

$$C_{t+1}(i,j,k) = \frac{1}{Z} \sum_{n \in \text{neighbors}} [w_n \cdot C_t(n) + g(C_t(n), Q_t(n), D_t(n))]$$

Where g is the local interaction function, and Z normalizes the update.

5 Simulation Code (Illustrative)

```python
import numpy as np
from scipy.ndimage import laplace

# Parameters
N = 64  # grid size
alpha = 0.1
beta = 0.05
E_crit = 0.25
C_min = 0.15

# Initialize voxel arrays
C = np.zeros((N, N, N))
Q = np.zeros_like(C)
D = np.zeros_like(C)

# Recursive update function (simplified)
def update_voxels(C, Q, D, C_prev):
    lap_C = laplace(C)
    Q_new = alpha * lap_C - beta * (C - C_prev)  # temporal term
    D_new = np.abs(Q_new) * 0.5 + 0.5 * D
    C_new = (np.roll(C, 1, axis=0) + np.roll(C, -1, axis=0) +
             np.roll(C, 1, axis=1) + np.roll(C, -1, axis=1) +
             np.roll(C, 1, axis=2) + np.roll(C, -1, axis=2)) / 6.0
    C_new += Q_new * 0.1  # feedback term
    return C_new, Q_new, D_new

# Main loop example
for t in range(100):
    C_prev = C.copy()
    C, Q, D = update_voxels(C, Q, D, C_prev)
    emit_particles = (D > E_crit) & (np.gradient(C)[0] > C_min)
    # Particle emission logic (not shown)
```

Listing 1: Illustrative Python snippet for voxel recursive curvature updates

This example illustrates the recursive, neighbor-based updates modeling curvature and quantum feedback interaction without detailing full proprietary components.

6 Results and Visualizations

Below are key visualizations from simulations demonstrating recursive curvature evolution and emergent particle nucleation.

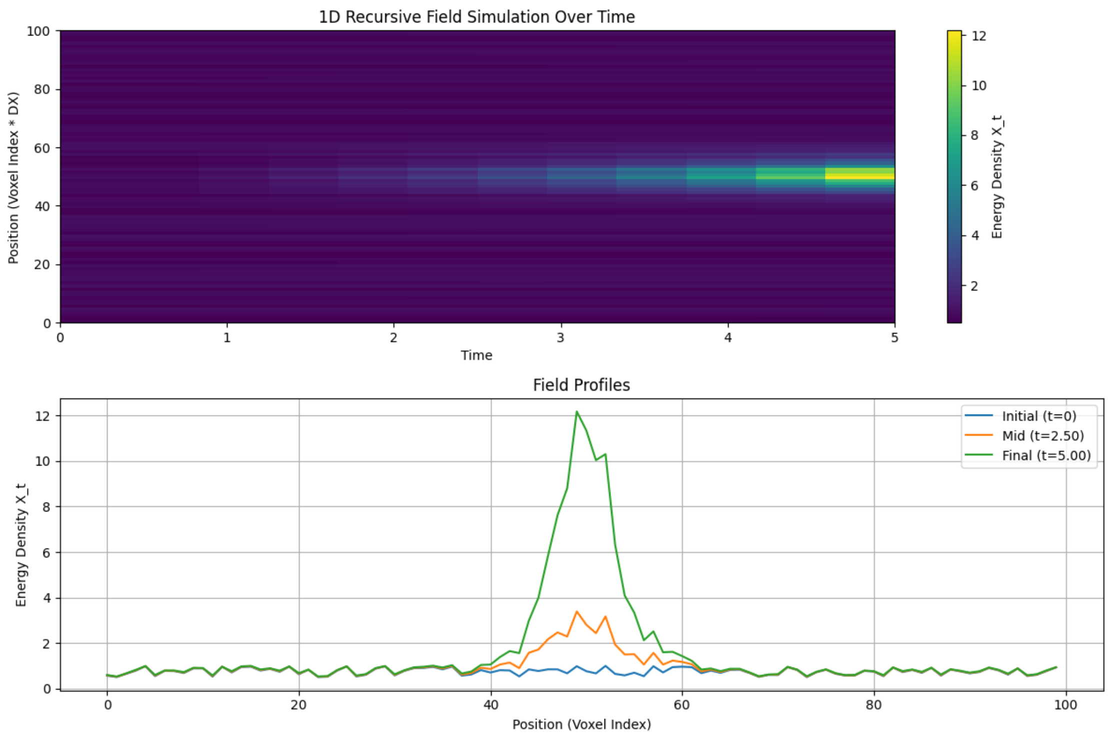

Figure 1: Recursive voxel curvature propagation over time. Peaks in curvature indicate strong nonlinear feedback, modeling gravitational-like field concentration. The spatial patterns highlight local recursion effects leading to emergent structure formation.

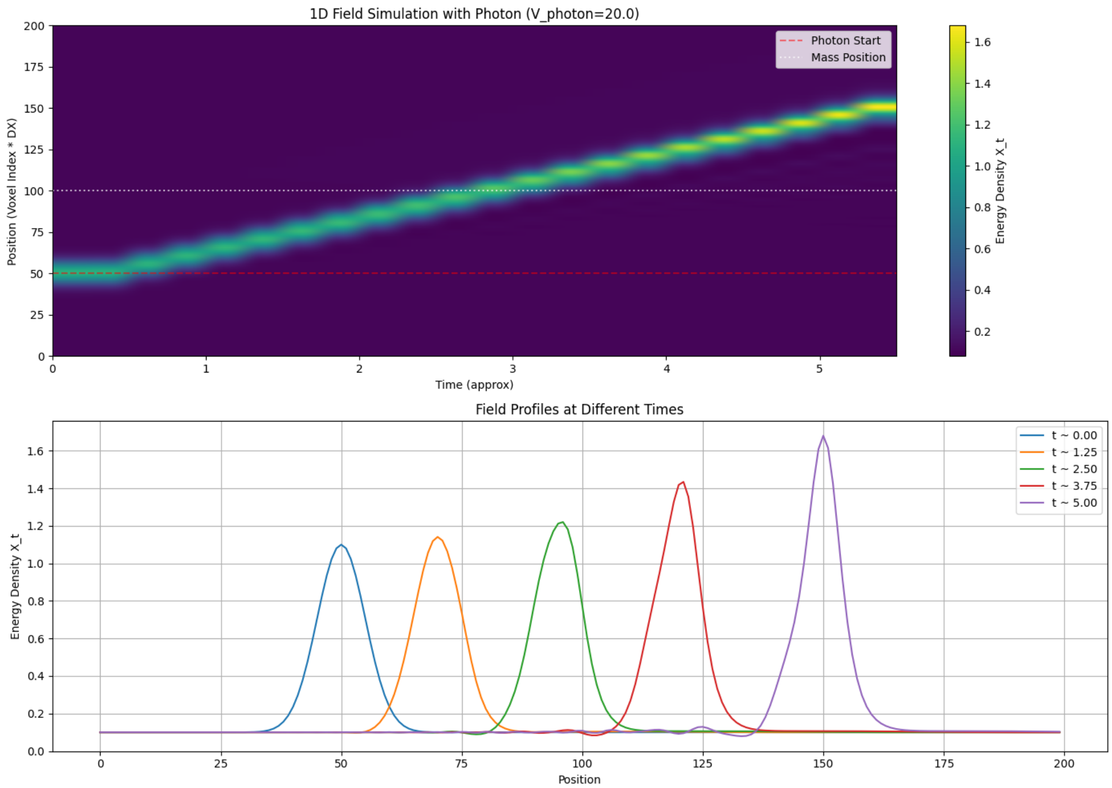

Figure 2: Emergent particle nucleation regions visualized via energy density thresholding. The bright regions correspond to locations where the energy exceeds the nucleation threshold E_{crit}, triggering localized quantum excitations reminiscent of particle formation in quantum fields.

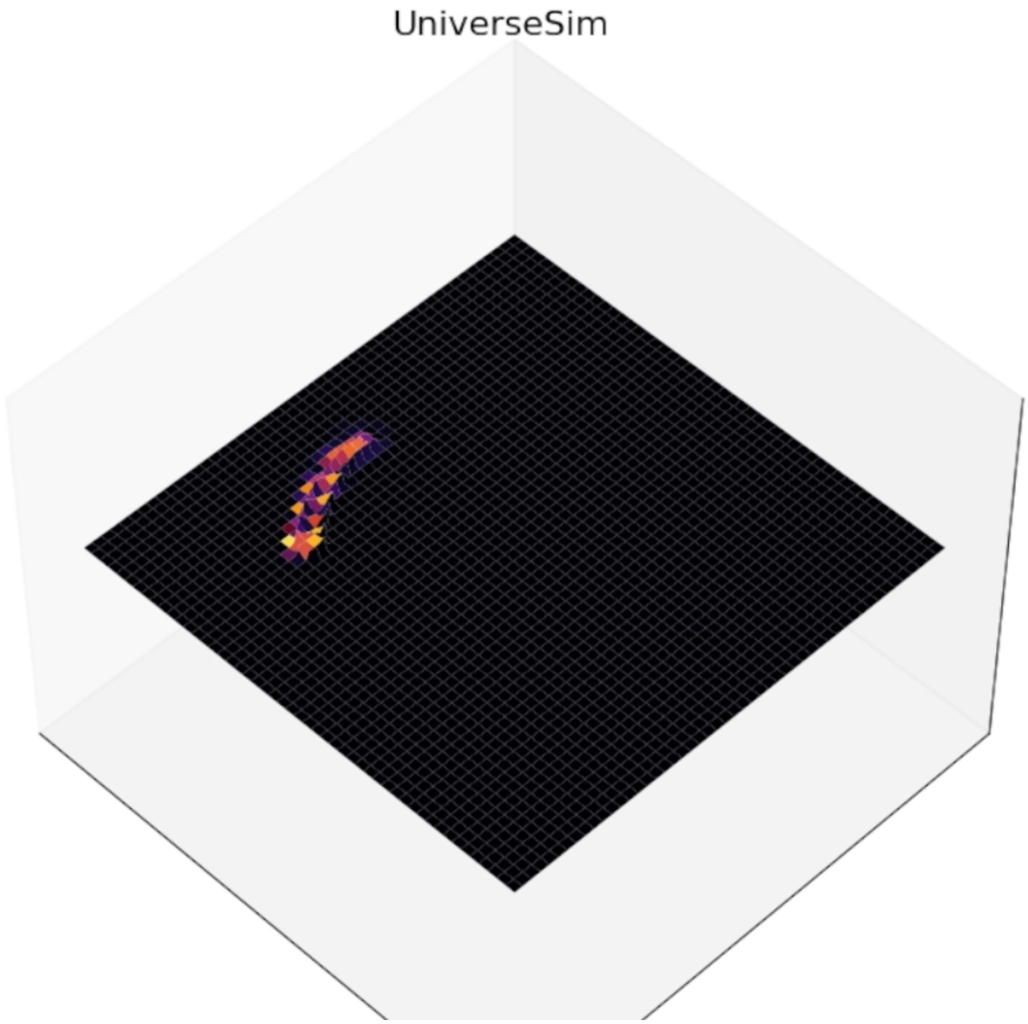

Figure 3: 3D gradient energy mapping within the voxel lattice. This visualization reveals spatially varying feedback dynamics, illustrating how gradient energy G mediates local recursive interactions and stabilizes emergent quantum structures.

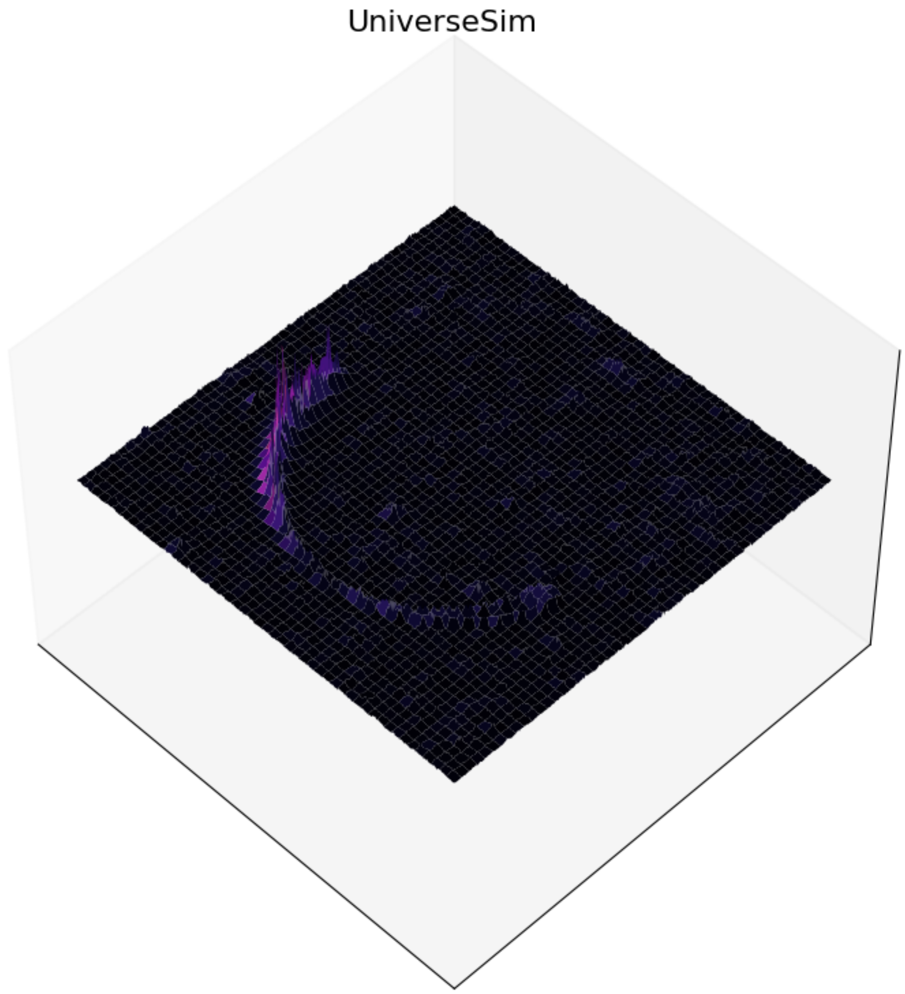

Figure 4: Recursive curvature field simulation rendered with `matplotlib` LightSource shading. This enhanced 3D rendering emphasizes the topological complexity of curvature evolution and the spatial heterogeneity introduced by quantum feedback loops.

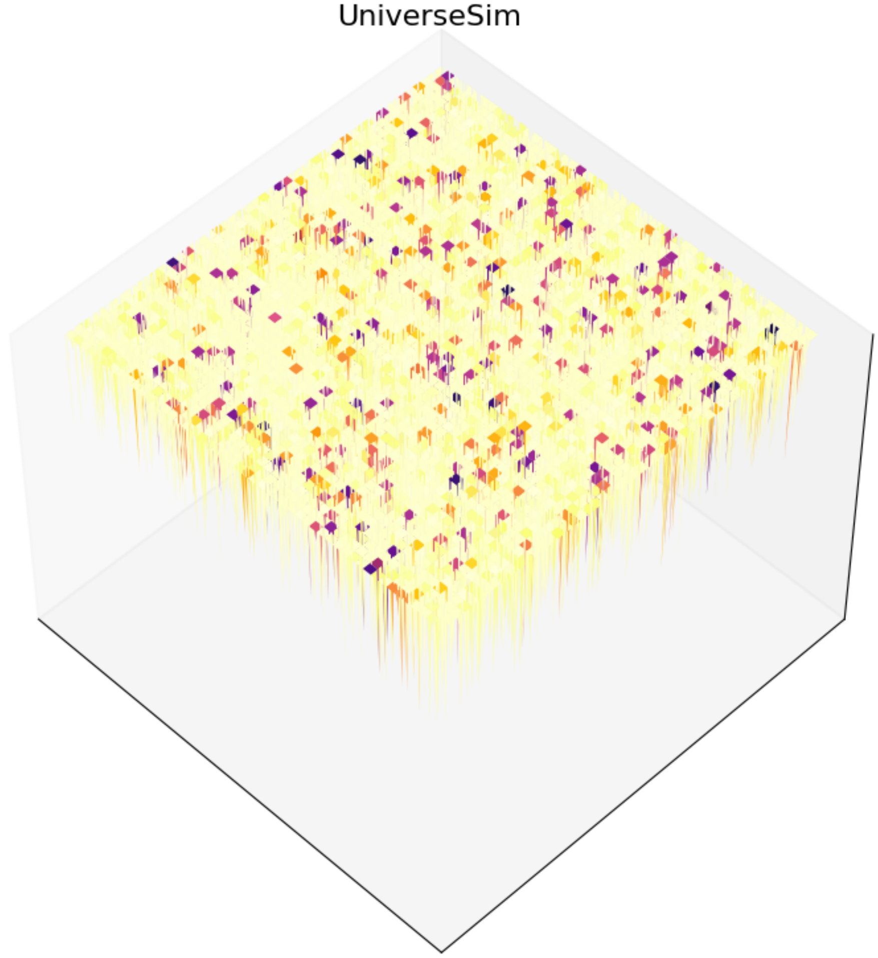

Figure 5: Final high-resolution voxel lattice showing complex recursive quantum feedback and nucleation patterns. The intricate spatial interplay highlights the stability and self-organization achievable through the QRR recursive update rules.

7 Discussion

Quantum Recursive Relativity provides a discrete computational model for emergent interactions balancing nonlinear feedback between curvature and quantum pressure fields:

- Recursive feedback mimics nonlocal vacuum responses and entanglement-like correlations.
- Curvature feedback reproduces gravitational behavior consistent with finite energy concentrations.
- Energy threshold nucleation resembles wave-particle duality without singularities or infinite self-energy.

The recursive tensor framework enables:

- Scalable parallel simulation for high-resolution grids.
- Memory retention simulating quantum uncertainty effects.

- Natural regularization avoiding the infinities plaguing continuous analytic models.

Balancing energy thresholds carefully is crucial — set too low, and noise dominates; too high, and emergence is suppressed. QRR's parameter space suggests a physically meaningful "sweet spot" supporting stable emergent particle-like phenomena.

8 Conclusion and Future Work

QRR demonstrates a modular, voxel-based recursive system unifying curvature and quantum feedback with a physically grounded discrete model. This work opens new pathways toward discrete quantum gravity and emergent particle simulation using feasible physics principles.

Future expansions include:

- Multi-resolution adaptive grids for better scale bridging and computational efficiency.
- Incorporation of spin-like vector fields and torsion terms capturing fermionic behavior.
- Hybrid AI-driven rule learning for adaptive, data-driven curvature synthesis.
- Exploration of holographic dualities via boundary recursion conditions.

These directions aim to extend QRR beyond phenomenology into predictive frameworks connecting quantum field theory and general relativity.

Acknowledgments

This work was built with theoretical support, sleepless calculation, and philosophical insight. Much love to those chasing unified physics.

References

- Einstein, A. (1916). The Foundation of the General Theory of Relativity.
- Misner, C.W., Thorne, K.S., Wheeler, J.A. (1973). Gravitation.
- Peskin, M.E., Schroeder, D.V. (1995). An Introduction to Quantum Field Theory.
- Numerical Recipes in C: The Art of Scientific Computing (3rd Edition).
- SciPy Documentation: `https://docs.scipy.org/doc/scipy/reference/generated/scipy.ndimage.laplace.html`

Appendix: Deep Physical Interpretation

The recursive update function,

$$C_{t+1}(x, y, z) = f\left(C_t, \nabla C_t, Q_t, D_t\right),$$

acts as a discrete analog to Einstein's field equations, replacing smooth manifolds with voxelized tensors incorporating quantum feedback fields.

The quantum feedback term,

$$Q_t = \alpha \nabla^2 C_t - \beta \frac{\partial^2 C_t}{\partial t^2},$$

represents spatial diffusion and temporal inertia of vacuum fluctuations responding dynamically to curvature evolution.

Particle nucleation via energy thresholds mimics spontaneous field condensations and soliton formations:

$$\text{EmitParticle}(x, y, z) \iff E(x, y, z) > E_{\text{crit}} \land \nabla C > C_{\min},$$

enabling stable excitations without singularities or renormalization divergence.

Quantum popcorn: heat and pressure must align perfectly for particles to pop. This humorous metaphor underscores the delicate energy and curvature conditions required for particle emergence in the recursive voxel lattice.