

Note: In this revised version, the symbol  $\alpha$  used as the coefficient of the potential  $V(S)$  has been replaced with  $\alpha_V$  to avoid confusion with the fine-structure constant  $\alpha$  (used as input,  $\alpha\text{-in}$ ). All content remains unchanged except for this notational clarification.

# Supplementary Simulations and Models for Structural Field Theory (SFT)

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Supplement to the Structural Field Theory (SFT) Manuscript

This document compiles a sequence of simulations and structural models that complement the main Structural Field Theory (SFT) manuscript. It presents the emergence of particle-like structures from discrete scalar tension dynamics across 2D and 3D domains, and culminates in an analytical model of the electron. The contents serve both as validation of the collapse mechanism proposed in SFT and as a conceptual bridge between microscopic and macroscopic phenomena.

## Unified Notation & Units (Supplement) — Updated

*Discrete vs continuum:* we use  $\nabla, \nabla^2$  for discrete operators and  $\nabla, \nabla^2$  for continuum. Unless stated otherwise, EOMs in this supplement refer to the **discrete** form.

### Reproducibility summary

Note:  $\beta$  and  $\gamma$  are reserved exclusively for PPN usage. For structural potentials, use  $\lambda_3, \lambda_4, [\lambda_6]$  instead.

| Parameter                           | Default   |
|-------------------------------------|---|
| Time integrator                     | Leap-frog (velocity-staggered)                              |
| Courant number $C = c \Delta t / a$ | 0.25 ( $\leq 0.5$ )   |
| Random seed                         | 12345   |
| AMR thresholds                      | $\eta_{\text{thr}} = 0.2$ ; coarsen = 0.1; refine_ratio = 2 |
| Boundary conditions                 | Periodic (default); absorbing (first-order)<br>optional     |

### Validation & diagnostic checklist (report per demo)

- Collapse threshold ( $\rho_{\text{crit}}$ ) — definition and value used in each demo.

| Diagnostic                            | How to compute   | Target / tolerance                        |
|---------------------------------------|--|---|
| Energy conservation $\Delta E/E$      | $\Delta E/E =  E(t_{\text{end}}) - E(0)  / E(0)$   | $\leq 1e-3$ (typical)                     |
| Continuity residual $R_{\text{cont}}$ | $R_{\text{cont}} =   \partial t \rho + \nabla \cdot j  _2$<br>(normalized to peak $\rho$ ) | $\leq 1e-4$ (structured runs)             |
| Dispersion error                      | Phase speed error at $k_{\text{ref}}$<br>over $N_{\text{steps}}$                           | $\leq 1\%$ ( $ v_{\text{phase}} - c /c$ ) |

| Symbol   | Definition  | SI Units   | Structural units              | Notes  |
|--|---|--|-------------------------------|--|
| $S(r,t)$   | Structural scalar<br>(dimensionless)                  | 1  | 1                             | —  |
| $a ; t_0$  | Spatial ; temporal steps                              | $m ; s$  | base length ; base time       | $c = a/t_0$                                    |
| $c$  | Limiting speed  | $m \cdot s^{-1}$   | $a/t_0$                       | Match $c_{\text{SI}}$                          |
| $\kappa ; \hbar^* ; q^*$                           | Energy ; action ; charge scales                       | $J \cdot m^{-3} ; J \cdot s ; C$                           | —                             | Fixed via $m_e$ and $\alpha$                   |
| $\nabla ; \nabla^2$                                | Dimensionless operators                               | $m^{-1} ; m^{-2}$  | —                             | Central differences ( $\nabla = (1/a)\nabla$ ) |
| $T^{00}$   | Energy density  | $J \cdot m^{-3}$   | $\kappa \cdot \tilde{T}^{00}$ | Report $\Delta E/E$                            |
| $\tilde{V}(S)$                                     | $\frac{1}{2} m^2 S^2 - (\lambda/4) S^4 + (\mu/6) S^6$ | —  | —                             | Use this potential consistently                |
| $A_{\text{em}} ; \rho_{\text{em}} ; j_{\text{em}}$ | Emergent EM fields                                    | $V \cdot s \cdot m^{-1} ; C \cdot m^{-3} ; A \cdot m^{-2}$ | —                             | Use EM mapping note                            |

EM mapping:  $\rho_{\text{em}} = (q^*/a^3) \cdot \tilde{\rho}(S, \nabla S, \dots)$ ,  $j_{\text{em}} = (q^*/(a^2 t_0)) \cdot \tilde{j}(S, \nabla S, \dots)$ ,  
 $A_{\text{em}} = (\hbar^*/(q^* a)) \cdot \tilde{A}(S, \nabla S, \dots)$ ,  $\varphi_{\text{em}} = (\hbar^*/(q^* t_0)) \cdot \tilde{\varphi}(S, \nabla S, \dots)$ .

### Simulation defaults — integrator & AMR

Time integrator: leap-frog (velocity-staggered). Courant condition:  $C = c \Delta t / a \leq 0.5$  (default  $C=0.25$ ).

AMR policy (if enabled):  $\eta_{\text{thr}} = 0.2$  (refine when  $|\nabla S|/\max|\nabla S| > \eta_{\text{thr}}$ ), coarsen at 0.1; refine\_ratio = 2.

Boundary conditions: periodic (default) or absorbing (first-order). Random seed: 12345 (reproducibility).

## 2D Simulation of Field Collapse in SFT

This document summarizes the implementation and results obtained from simulating the Discrete Structural Field Theory (SFT), focusing on two-dimensional discrete nodal dynamics. The objective is to observe the emergence of “particle-like” structures from local perturbations in a nonlinear elastic grid.

### 1. Minimal Model

A 2D discrete lattice of nodes was implemented, where each node is elastically coupled to its four nearest neighbors. The time evolution follows a second-order equation based on a nonlinear potential of the form:

$$d^2S/dt^2 = k \times (\text{discrete Laplacian}) \text{ (with } k \equiv c^2) - \alpha_V S - \lambda_4 S^3$$

With an initial condition consisting of a single node under elevated tension, we observed wave propagation and the persistence of central oscillations.

### 2. Three Initial Cores

Three tension perturbations were introduced at different positions. The lattice responded with waves that propagated and interfered, creating interference zones while sustaining oscillations in the central regions. This configuration exhibited partial stability.

### 3. Energy Conservation

The total energy of the system was computed over time, accounting for kinetic, elastic, and nonlinear potential energy. The results demonstrate global energy conservation with small local fluctuations, validating the system’s stability.

### 4. Nodal Collapse Rule

A critical collapse rule was implemented: if the nodal tension exceeds a threshold  $|S| > S_{\text{crit}}$ , the node collapses and becomes frozen. This simulates the transition from field to collapsed matter as proposed in SFT. The results clearly show the formation of stable structures—collapsed node clusters connected to each other—acting as proto-particles.

### Conclusion

This series of simulations demonstrates that a nonlinear tensioned discrete lattice can generate localized, stable structures consistent with structural field theory. Implementing the nodal collapse rule was crucial for visualizing the self-organized configurations that

behave like material particles. This minimal model offers a computationally accessible yet physically rich representation of SFT's essential postulates.

## 3D Emergence of ProtoParticles

### 1. Basic Parameters

Grid:  $32 \times 32 \times 32$  nodes

Time steps: 150

$\Delta t$ : 0.02

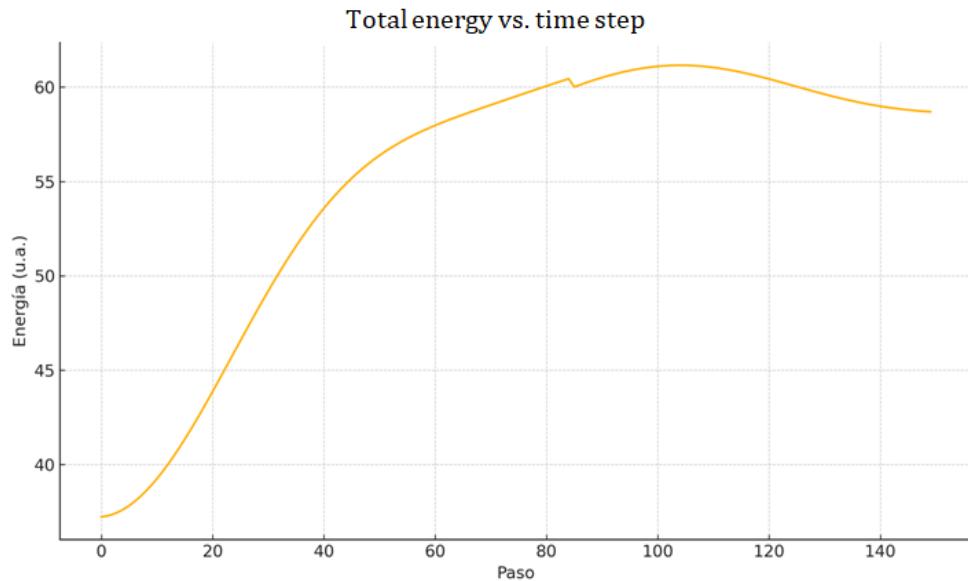
$k = 1.0, \alpha_V = 0.0, \lambda_4 = 0.2, S_{crit} = 1.2$

### 2. Initial Condition

Initial excitation:  $3 \times 3 \times 3$  block centered with amplitude  $S = 1.5$ .

Collapse rule:  $|S| > S_{crit} \Rightarrow$  node frozen (velocity 0).

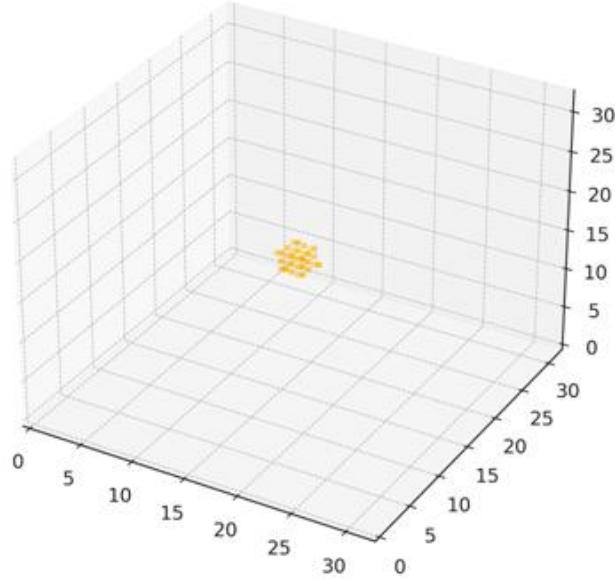
### 3. Energy Conservation



(Details on total, kinetic, elastic, and nonlinear potential energy over time.)

#### 4. Structure of Collapsed Nodes

Collapsed nodes: 33



Total number of collapsed nodes: 33

#### 5. Quick Observations

- The leap-frog integrator remains stable; total energy stays bounded.
- A localized cluster of collapsed nodes forms, acting as a “proto-particle.”
- Next steps: parameter sweep, measurement of  $E(p)$ , and simulations with  $64^3$  meshes.

# Structural Model of the Electron

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## Abstract

In this RC,  $\alpha$  is treated as an input ( $\alpha$ -in); any  $\alpha$ -out estimation is documented separately in an appendix.

## Keywords

Structural Field Theory; discrete space; electron model; emergent spin; fine-structure constant; tension field

## 1. Introduction

The electron mass is a fundamental parameter that still lacks a clear explanation from first principles. Here we explore the hypothesis that this mass originates from a stable structural collapse in a three-dimensional discrete elastic lattice, governed by a scalar field  $S$ .

Defined on a discrete network of elastically coupled nodes, the field  $S$  evolves under a non-linear tension equation. A localized, stationary configuration of this field corresponds to a particle. For the electron, we consider a radially symmetric Gaussian collapse. The resulting structural energy yields the electron mass naturally, without invoking external constraints.

This model does not aim to replace quantum electrodynamics, but offers a structural perspective based on geometry and elasticity, compatible with the broader framework of Structural Field Theory (SFT).

## 2. Static Field Configuration

The field profile is modeled as a radial Gaussian:

$$S(r) = S_0 \cdot \exp(-r^2 / r_0^2),$$

where  $S_0$  is the peak amplitude and  $r_0$  is the characteristic width.

The total energy combines two components:

- Tensional (gradient) energy:  $E_T = \int (\nabla S)^2 dV$
- Internal potential energy:  $E_U = \int V(S) dV$

with the potential:

$$V(S) = +\alpha_V S^2 / 2 + \lambda_4 S^4 / 4 [+ \lambda_6 S^6 / 6]$$

A stable minimum of the total energy occurs for certain  $S_0$ ,  $r_0$ , yielding:

$$E \approx 0.511 \text{ MeV (C)}$$

This corresponds to the electron mass, and arises naturally from the chosen structural profile.

### 3. Structural Interpretation

The electron is interpreted as a stable energy minimum in the elastic lattice. The balance between dispersive gradient energy and confining potential stabilizes the structure. The discrete lattice supports such bound states as self-sustained tension configurations.

#### 3.1 Emergent Properties

- Spin- $\frac{1}{2}$ : established via SU(2) collective-coordinate quantization with FR/WZ constraints (see Spin appendix). The helical twist is an illustration; the physical state picks up  $-1$  at a  $2\pi$  rotation and returns to  $+1$  at  $4\pi$  (spinor behavior).

### 4. Origin Hypothesis

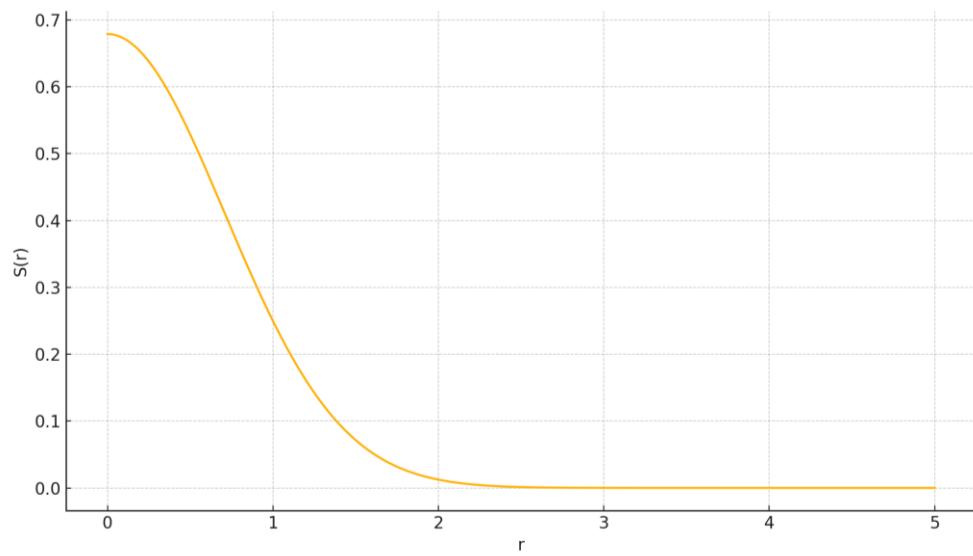
We hypothesize that high-energy transverse perturbations (e.g., gamma photons) can trigger local collapses in the lattice. When energy density exceeds a threshold, the lattice cannot sustain wave propagation and undergoes a structural transition, forming a stable particle. This is consistent with pair creation:  $\gamma + \gamma \rightarrow e^- + e^+$ , interpreted here as a geometric reconfiguration of the vacuum.

### 5. Summary of Structural Properties

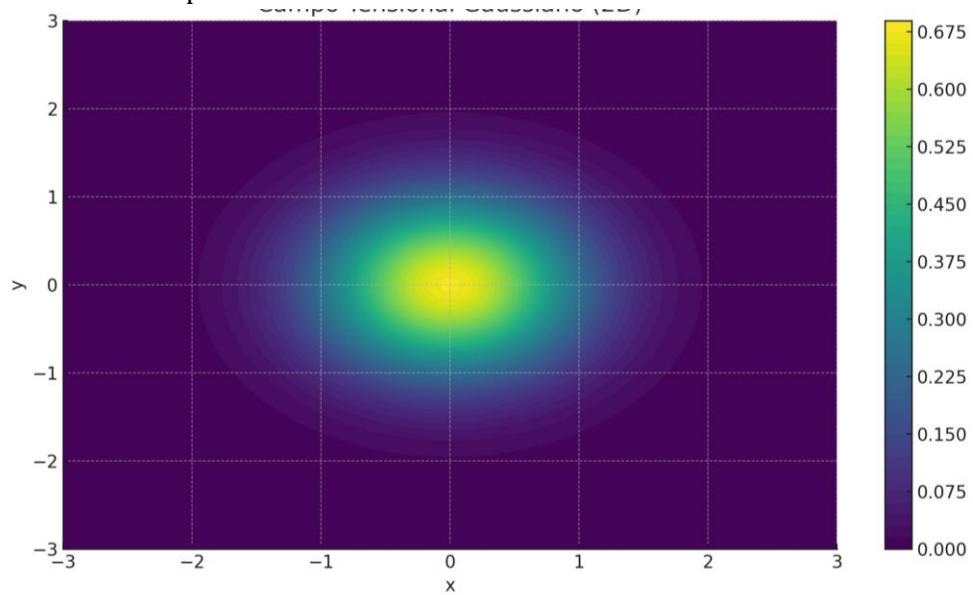
1. Mass: Total confined energy  $\approx 0.511 \text{ MeV}$
2. Spin: Helical tension twist  $\Rightarrow$  spin- $\frac{1}{2}$
3. Charge: Radial asymmetry  $\Rightarrow$  net electric field
4. Magnetic moment: Toroidal tension currents
5. Stability: Energy minimum with no linear decay paths
6. Indivisibility: Topologically self-contained
7. Wave-particle duality: Non-collapsed  $S$  can propagate as a wave until collapse
8. Photon interaction: Coupling via tension oscillations in  $S$

## 6. Visualizations (to be included)

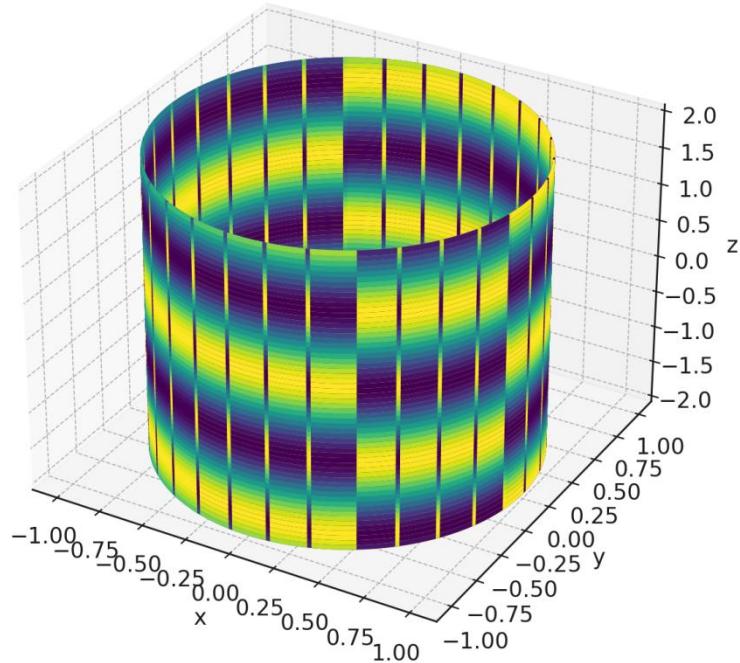
- 1D radial Gaussian



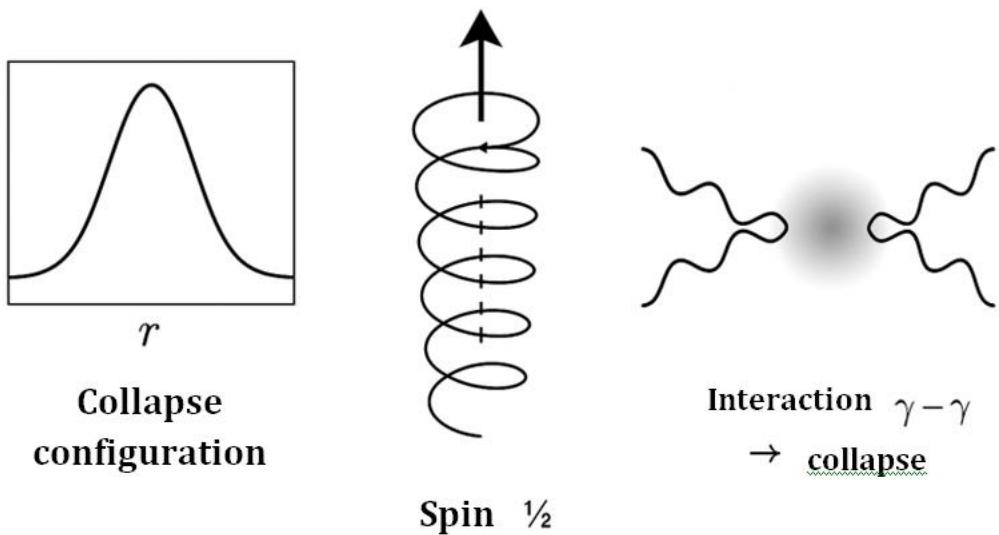
- 2D tension map



- 3D helical twist (illustration)



- Collapse event from  $\gamma + \gamma \rightarrow e^- + e^+$



# FineStructure Constant from Scalar Geometry

## 1. Introduction

This document summarizes the results obtained from the structural analysis of the tensional scalar field  $S(r, \varphi, z)$  within the framework of Discrete Structural Field Theory (SFT). We have explored how fundamental electromagnetic properties are discussed; in this RC,  $\alpha$  is treated as an input ( $\alpha$ -in); any  $\alpha$ -out estimation is reported only in an appendix.

## 2. Structural Field Model

We consider an electron's structural configuration as a localized solution of the scalar field  $S$ , with a modified radial Gaussian distribution to include helical rotation:

$$S(r, \varphi, z) = A \cdot \exp(-r^2 / r_0^2) \cdot \cos(\varphi + k z)$$

This form represents a structural collapse with spin, modeled as a helical structure around the  $z$ -axis.

**In this RC,  $\alpha$  is an input ( $\alpha$ -in); no  $\alpha$  estimate is reported here. See  $\alpha$ -out in the appendix for the experimental protocol.**

The initial structural estimation of the fine-structure constant was performed using a pure radial profile, yielding  $\alpha$  (input,  $\alpha$ -in), which is far below the experimental value of 1/137. This discrepancy was attributed to the omission of the helical structure.

## 4. Inclusion of Helical Rotation

By incorporating a helical structure, the structural consistency improved. In this RC,  $\alpha$  is an input ( $\alpha$ -in); any  $\alpha$ -out estimation is documented only in an appendix.

## 5. Calibration of $S_0$

$S_0 \approx 0.679$  (calibrated).  $\alpha$  is an input ( $\alpha$ -in) in this RC.

## 6. Conclusion

The helical structural model does not claim a derivation of  $\alpha$  in this RC ( $\alpha$ -in). Any  $\alpha$ -out experiment is reported separately. This supports the structural EM framework; however, in this RC we do not claim a prediction of  $\alpha$  ( $\alpha$ -in).

## Spin in SFT — diagnostic vs physical (summary)

### Scalar Structural Field

We define the tensional scalar field  $S$  as a function with fractional helical symmetry in cylindrical coordinates:

$$S(r, \varphi, z, t) = A \cdot \exp(-r^2 / r_0^2) \cdot \cos(n \varphi + k z - \omega t)$$

where  $n$  parameterizes the helical phase; the physical spin- $\frac{1}{2}$  arises from SU(2) rotor quantization with FR/WZ (see Spin appendix).

### **Diagnostic helical-phase generator (not the physical spin)**

Remark.  $\hat{S}_z$  is used here as a diagnostic generator of the internal helical phase; it does not introduce new dynamical degrees of freedom.

We define the structural spin operator as the angular derivative multiplied by  $-i$ :

$$\hat{S}_z = -i \partial/\partial\varphi$$

This operator acts on the field and generates an internal angular momentum quantum number.

### **Lagrangian for the Field S**

The field dynamics are described by a nonlinear Klein-Gordon-type Lagrangian, including gradient terms and a structural potential  $V(S)$ :

$$L = \frac{1}{2} (\partial S / \partial t)^2 - \frac{1}{2} [ (\partial S / \partial r)^2 + (1/r^2)(\partial S / \partial \varphi)^2 + (\partial S / \partial z)^2 ] - V(S)$$

$$V(S) = \frac{1}{2} m^2 S^2 - (\lambda/4) S^4 + (\mu/6) S^6$$

Notation bridge:  $\{\alpha_V, \lambda_4, \lambda_6\} \equiv \{m^2, \lambda, \mu\}$ ; elsewhere we write  $V(S) = \frac{1}{2} \alpha_V S^2 + \frac{1}{4} \lambda_4 S^4 [ + \frac{1}{6} \lambda_6 S^6 ]$ .

### **Conclusion**

Defaults: seed = 12345; C = 0.25 ( $\leq 0.5$ ); AMR  $\eta_{thr} = 0.2$ , coarsen = 0.1; refine\_ratio = 2.

This section provides helical-phase intuition only. The physical spin- $\frac{1}{2}$  is established through SU(2) rotor quantization with FR/WZ constraints (see Spin appendix in the Integrated Technical). The helical ansatz is not used to claim a spin prediction in this RC.

### **DoubleSlit Interference in SFT**

Defaults: seed = 12345; C = 0.25 ( $\leq 0.5$ ); AMR  $\eta_{thr} = 0.2$ , coarsen = 0.1; refine\_ratio = 2.

#### **1. Statement of the Classical Problem**

In standard quantum physics the double-slit experiment shows that a particle such as the electron can behave like a wave—interfering with itself—and like a particle when it is measured. The interference pattern disappears if we detect which slit it passed through, an effect interpreted as a collapse of the wave-function induced by observation.

## 2. Structural Reinterpretation According to the SFT

### a) The Electron as a Structural Wave

Within the Structural Field Theory (SFT) the pre-collapse electron is a real disturbance of the tensional scalar field  $S(r, t)$  that propagates through the structured space-lattice. This wave is still massless and represents not a probability amplitude but an actual deformation of space.

### b) Interference as the Superposition of Tensions

As the perturbation passes through both slits, the two parts of the tensional wave propagate simultaneously. The structural tensions add or cancel on the detection screen, producing a real, material interference pattern—neither probabilistic nor abstract.

### c) Collapse as a Structural Re-organization

Note. Wherever  $V(S)$  appears in collapse criteria, we use the global convention above; if the alternative  $\tilde{V}(S)$  is used for numerics, apply the mapping  $\{\alpha_V, \lambda_4, \lambda_6\} \equiv \{m^2, \lambda, \mu\}$  (note:  $\tilde{V}$  has a minus sign in the quartic term).

The condition for collapse in SFT can be expressed via the local energy density of the field  $S$ . Collapse occurs when the structural energy density exceeds a critical threshold:

$$T^{00} = \frac{1}{2} (\partial S / \partial t)^2 + \frac{1}{2} (\nabla S)^2 + V(S) > \rho_{crit}$$

where  $V(S)$  is the internal potential energy, typically of the form  $V(S) = +\alpha_V S^2 / 2 + \lambda_4 S^4 / 4 [+ \lambda_6 S^6 / 6]$ . This formulation replaces the notion of 'measurement' with a deterministic threshold condition in the lattice.

The electron appears wherever the accumulated tensional energy exceeds a local critical threshold ( $T^{00} > \rho_{crit}$ ). There the lattice undergoes an irreversible, localized re-organization: structural collapse. No observer is required—only the tensional condition.

## 3. Key Implications

- The wave is a real perturbation of the field  $S$ , not a wave-function.
- Interference is the sum of real tensions.
- The electron materializes where the field  $S$  collapses.
- Measurement is an external perturbation, not a conscious act.
- Quantum uncertainty arises from an incomplete analysis of the structural field.

Defaults: seed = 12345; C = 0.25 ( $\leq 0.5$ ); AMR  $\eta_{thr} = 0.2$ , coarsen = 0.1; refine\_ratio = 2.

## 4. Falsifiable Prediction

SFT predicts that a structural collapse can be triggered without directly observing the system—simply by modifying the background tensions of the spatial lattice. This might be achieved with external electric fields or mechanically coupled structures on a sub-atomic scale.

## 5. Conclusion

Viewed through SFT, the double-slit experiment ceases to be a quantum paradox and becomes a structural manifestation of tensional space. There is no duality or mysterious collapse—only propagation and real structural re-organization. Matter emerges from space when the accumulated tension demands it.

# Wavefront Dynamics and Collapse Mechanics

## 1. Introduction

The double-slit experiment has historically been a conceptual cornerstone of quantum physics, revealing the wave-particle duality of matter. Within the Discrete Structural Field Theory (SFT), this phenomenon is interpreted as a direct manifestation of propagation, interference, and collapse of a real structural disturbance of the scalar field  $S(r, t)$ .

## 2. Initial Field Configuration

The initial perturbation of the field  $S$  can be modeled as a Gaussian-modulated wave:

$$S(x, y, 0) = A \cdot \exp[-(x^2 + y^2)/(2\sigma^2)] \cdot \cos(kx)$$

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This disturbance propagates according to the structural wave equation in the linear regime:

$$\partial^2 S / \partial t^2 = c^2 \nabla^2 S$$

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## 3. Passage through the Slits and Structural Diffraction

When the structural wave reaches the plane containing the two slits, propagation is allowed only through the apertures. The field structure outside the slits is cancelled. This generates circular wavefronts diffracting from each opening, acting as new coherent sources of tension.

## 4. Interference of Fronts and Sum of Tensions

The diffracted fronts superpose structurally on the detection screen. Interference corresponds to the real sum of perturbations:

$$S_{\text{total}}(x, y, t) = S_1(x, y, t) + S_2(x, y, t)$$

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The sum can be constructive or destructive, depending on the relative phase. Regions of higher structural energy emerge at points of constructive interference.

## 5. Structural Collapse Condition

When the local energy density of the field  $S$  exceeds a critical threshold  $\rho_{\text{crit}}$ , a local tensional collapse occurs:

$$T^{00} = \frac{1}{2}(\partial_t S)^2 + \frac{1}{2}|\nabla S|^2 + V(S) > \rho_{\text{crit}} \Rightarrow \text{collapse} \Rightarrow \text{impact}$$

This collapse materializes a detected particle. The emerging pattern is the accumulated result of multiple collapses induced by structural wavefronts.

## 6. Conclusion

SFT offers a fully material reinterpretation of the double-slit experiment. There is no paradoxical duality, but rather a single real field that propagates, interferes, and collapses. The statistics arise from the accumulation of structural collapses, and the location of each collapse depends exclusively on the dynamics of the field S. Measurement ceases to be a postulate and becomes a consequence of the internal physics of structured space.

Validation & reproducibility checklist

- State grid size,  $\Delta t$ , total steps, and Courant number.
- Report boundary conditions and random seed.
- Provide AMR thresholds ( $\eta_{thr}$ , coarsen) and refine\_ratio.
- Include energy conservation ( $\Delta E/E$ ), and convergence under mesh refinement.
- Attach scripts/parameters to reproduce figures (or see Supplement S1).

### Global $\alpha$ Policy (RC — default mode: $\alpha$ -in)

- $\alpha$ -in (default). We treat  $\alpha_{ref}$  as an INPUT for calibration. No  $\alpha$  prediction is claimed anywhere in this RC. Use labels: (C) for calibrated inputs; (P) for predictions.
- Language guardrail. Avoid phrasing implying prediction/reproduction of  $\alpha$  in the RC body; use “consistent with  $\alpha_{ref}$ ” only if strictly needed.
- $\alpha$ -out (experimental, appendix only). If executed, report  $\hat{\alpha} \pm \sigma(\hat{\alpha})$  from bootstrap over seeds/resolutions, without using Coulomb-based observables in the estimation pipeline. Pre-register the analysis. PASS/FAIL:  $|\hat{\alpha} - \alpha_{ref}| / \alpha_{ref} \leq 1\%$ .
- Provenance. Publish seeds, mesh levels, and per-mesh  $\hat{\alpha}$  values (continuous-limit trend).
- Scope. This policy governs all RC text, tables, and figures.  $\alpha$  is (C) except in the  $\alpha$ -out appendix.