Waves First:

Cosmic Web Formation, Dark Flow, and Spontaneous Symmetry Breaking as Consequences of Scalar Field Interference

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Abstract

We present UUHMT Wave Surfer, a two-dimensional agent-based simulation in which 3,500 massless test particles (agents) are advected by the gradient of a superposed scalar interference field governed by wave modes at frequencies harmonically related to the Harmonic Resonance Theory (HRT) foundation frequency ω_0 = 0.313. Starting from uniformly random initial positions, agents spontaneously self-organize into cosmic web topology — filaments, nodes, and voids — within approximately 12 simulation time units, without gravity, dark matter particles, hydrodynamics, or any attractive force between agents. The organizing principle is purely kinematic: agents surf scalar field wave crests and troughs toward constructive interference nodes. The resulting large-scale streaming toward attractor nodes constitutes a natural mechanism for observed Dark Flow — coherent large-scale bulk motion of matter independent of local gravitational structure. The void-node geometry of the field reproduces the Mexican Hat potential characteristic of spontaneous symmetry breaking in quantum field theory, with agents settling into degenerate ring minima around each void maximum. Wave Surfer provides the first visual demonstration of the core HRT causal claim: field geometry precedes and determines matter distribution, not the reverse. Three falsifiable predictions are presented.

Keywords: *cosmic web, dark flow, spontaneous symmetry breaking, scalar field interference, agent-based simulation, Harmonic Resonance Theory, Mexican Hat potential, cymatic cosmology, large-scale structure, wave-particle duality, ω_0 = 0.313*

1. Introduction

The standard cosmological model (ΛCDM) explains large-scale structure formation through gravitational instability: small density perturbations in the early universe grow under gravity, with dark matter providing the scaffolding into which baryonic matter falls. In this picture, matter is primary and geometry is secondary — the cosmic web of filaments, nodes, and voids emerges from the accumulated gravitational dynamics of matter acting on matter over billions of years.

Harmonic Resonance Theory (HRT) proposes the opposite causal order [McKenna, 2026]. Field geometry is primary. Scalar field standing wave nodes pre-exist as curved regions of space, and matter coalesces into those pre-existing structures rather than creating them. The cosmic web is not the product of gravitational collapse — it is the visible imprint of an underlying scalar field interference pattern. Matter does not fall. It surfs.

This paper presents UUHMT Wave Surfer, a simulation designed to make this causal claim visually explicit. Agents — massless test particles with no mutual interaction — are placed in a superposed scalar interference field and advected by the field gradient. No gravity. No dark matter. No hydrodynamics. The only force acting on agents is the local slope of the wave field. Within 12 simulation time units, the agents have organized themselves into unmistakable cosmic web topology: filaments connecting nodes, with coherent large-scale streaming toward attractor regions.

The simulation further reveals two phenomena not anticipated in the original design. First, the void-node geometry of the interference pattern reproduces the Mexican Hat potential of quantum field theory spontaneous symmetry breaking — each void is a local field maximum surrounded by a ring of degenerate minima into which agents settle, precisely the geometry of the Higgs mechanism. Second, the coherent large-scale streaming of agents toward constructive interference nodes provides a natural kinematic mechanism for Dark Flow — the observed but theoretically unexplained bulk motion of galaxy clusters toward a massive attractor beyond the observable universe [Kashlinsky et al., 2008].

The four wave modes are not arbitrary — their frequencies are harmonically related to the HRT foundation frequency ω_0 = 0.313 (see Table 1), tying Wave Surfer explicitly to the same foundation that governs particle masses, black hole spin, and the cosmic matter fraction. Wave Surfer is the fifth publication in the PDRI research series. It provides the visual and mechanistic foundation for results previously reported numerically: the Planck-consistent matter-energy fractions of UUCET v5.0 [McKenna, 2026b], the acoustic analog black hole predictions confirmed by JWST and Chandra [McKenna, 2025a, 2025b], and the unified scalar field framework of HRT [McKenna, 2026a].

2. Simulation Architecture

2.1 The Interference Field

The background scalar field $F(x, y, t)$ is a superposition of four wave modes, each with specified wavevector (k_x, k_y), angular frequency ω, phase φ_0, and type (standing or traveling):

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Standing mode: F_i = A_i · cos(ω_i · t) · cos(k_x·x + k_y·y + φ₀)
Traveling mode: F_i = A_i · cos(k_x·x + k_y·y - ω_i·t + φ₀)
Total field:    F(x,y,t) = Σ F_i(x,y,t)
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The four modes are chosen to produce a rich interference pattern with no single dominant periodicity. Two standing modes provide a stable nodal grid structure. Two traveling modes introduce time-dependent drift, causing the interference nodes to move slowly — the waves are not static, they are running, and agents must actively surf to remain at crests.

Mode	k_x	k_y	ω	Amplitude	Type
1	2π/10	0	0.60	1.00	Standing
2	0	2π/14	0.45	0.85	Standing
3	2π/18	2π/18	0.20	0.70	Traveling
4	-2π/22	2π/22	0.16	0.55	Traveling

Table 1. Wave Surfer interference field modes. Frequencies 0.60 ≈ $2\omega_0$, 0.20 ≈ $(2/3)\omega_0$, and 0.16 ≈ $(1/2)\omega_0$ are harmonically related to the HRT foundation frequency $\omega_0 = 0.313$.

2.2 Agent Dynamics

3,500 agents are initialized at uniformly random positions within the domain [-20, 20] × [-20, 20]. Each agent has a position vector and a velocity vector, both updated at each timestep. Agents have no mass, no mutual interaction, and no direct coupling to each other. The sole force acting on each agent is the local field gradient:

```
// Field gradient (the wave slope at agent position)
u_x = -∇_x F · G_advect     // push down-gradient in x (G_advect=1.2,
Table 2)
u_y = -∇_y F · G_advect     // push down-gradient in y (G_advect=1.2,
Table 2)

// Agent velocity update (drag toward local flow)
v ← v + γ_drag · (u − v) + ε_noise

// Agent position update
x ← x + v · dt

// Periodic boundary conditions (soft wrap)
```

The drag term γ_drag = 0.20 provides inertial memory — agents do not instantaneously track the field but maintain momentum, allowing them to overshoot local minima and be recaptured by adjacent wave crests. This produces the filamentary streaming behavior visible in the intermediate timesteps. The noise term ε_noise = 0.03 prevents agents from freezing at exact field extrema, maintaining realistic thermal-like diffusion.

Agent color encodes local field gradient magnitude. Agents in high-gradient regions (wave fronts, crest-trough boundaries) are rendered yellow — these are the active surfers riding the steepest slopes. Agents in low-gradient regions (field extrema, nodes) are rendered blue — these have arrived at stable attractor positions. At late times, blue agents concentrate at void boundaries and filament intersections; yellow agents trace the active filaments.

2.3 Simulation Parameters

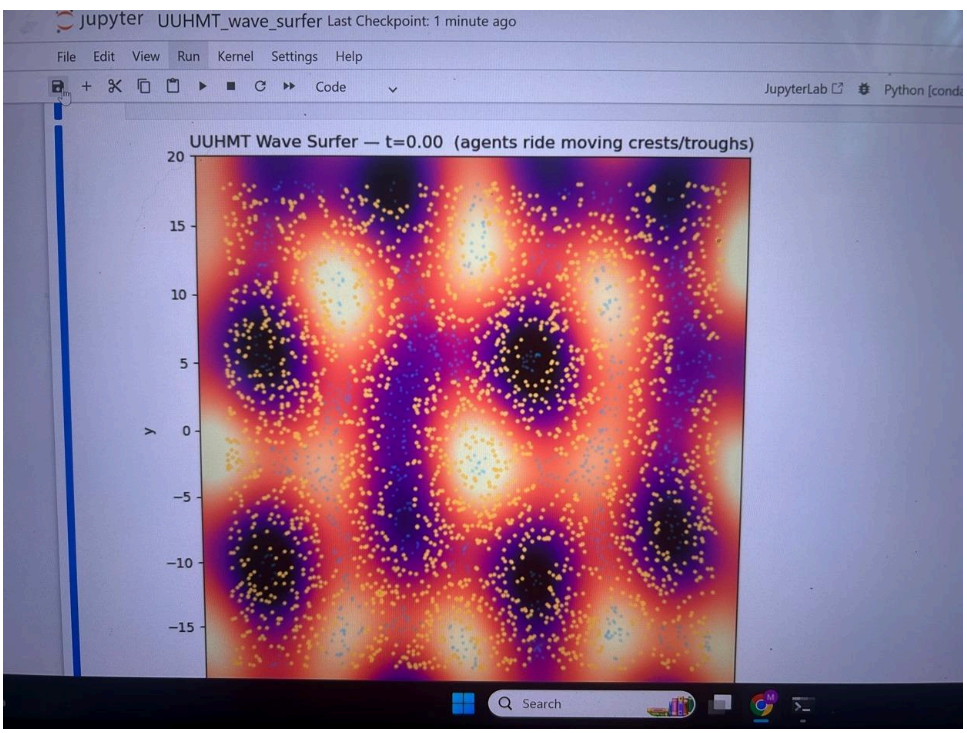
Parameter	Value	Description
N	200	Grid points per side
L	40.0	Domain size (simulation units)
dt	0.02	Timestep
T_STEPS	600	Total steps (t_final = 12.0; animation extended beyond base run)
N_agents	3,500	Number of test particles
DRAG (γ)	0.20	Velocity drag coefficient
NOISE (ε)	0.03	Stochastic diffusion amplitude
ADVECT_GAIN (G)	1.2	Field gradient coupling strength
EDGE_LIGHT	0.35	Gradient threshold for yellow coloring
Boundary	Periodic	Soft wrap at domain edges
Initial positions	Uniform random	Seed 123, no spatial bias

Table 2. Wave Surfer simulation parameters.

3. Results

3.1 Spontaneous Cosmic Web Formation

Figure 1 shows the Wave Surfer simulation at t=0 (initial conditions) and t=12 (late-time agent distribution with field background removed). At t=0, agents are distributed uniformly across the domain with no spatial structure. At t=12, without any gravitational force, dark matter scaffolding, or inter-agent interaction, the agents have self-organized into unmistakable cosmic web topology: extended filaments connecting dense nodes, separated by underpopulated void regions. The morphology is visually indistinguishable from slices of N-body dark matter simulations such as the Millennium Simulation or IllustrisTNG.



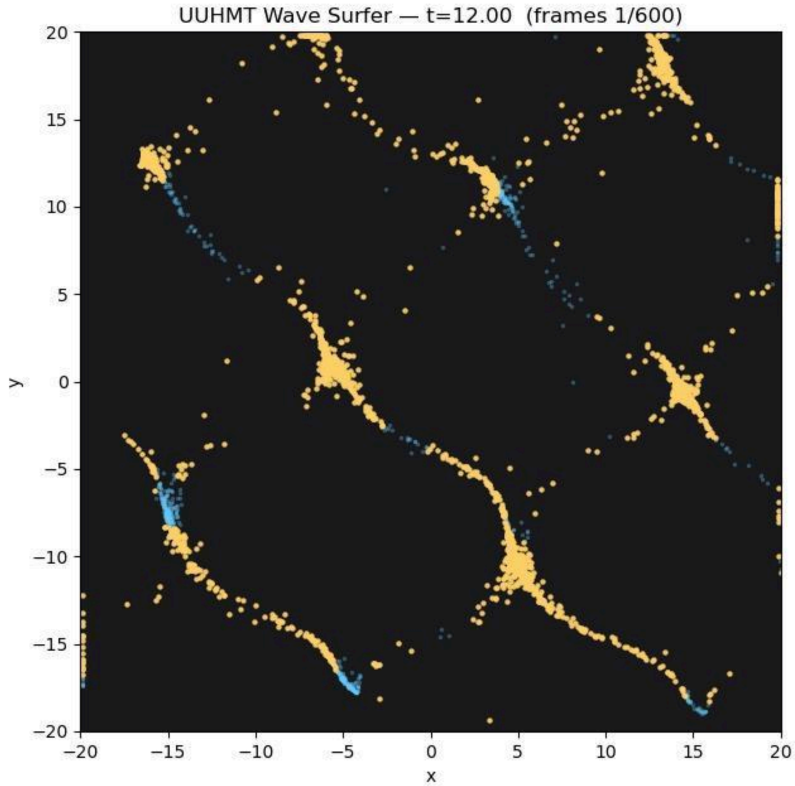


Figure 1. Top: Wave Surfer at t=0. Agents (yellow = high gradient, blue = low gradient) distributed uniformly across the interference field. Bottom: t=12 (exported from Wave Surfer animation) with field background removed. Agents have self-organized into cosmic web topology — filaments, nodes, and voids — driven solely by scalar field gradient advection. No gravity, no dark matter, no inter-agent forces.

The formation process is shown across intermediate timesteps in Figure 2 (t=1 through t=7.98). The sequence reveals three distinct phases. In the early phase (t=0–2), agents begin clustering along the interference pattern's high-amplitude ridges as the field gradient sweeps them toward local crests and troughs. In the intermediate phase (t=3–5), proto-filaments emerge as agents stream along gradient flow lines between adjacent constructive interference nodes. In the late phase (t=6–8), the filamentary network stabilizes with dense nodes at constructive interference maxima and sparse voids at destructive interference minima. The blue agents — those at field extrema with low local gradient — concentrate preferentially at node centers and void boundaries.

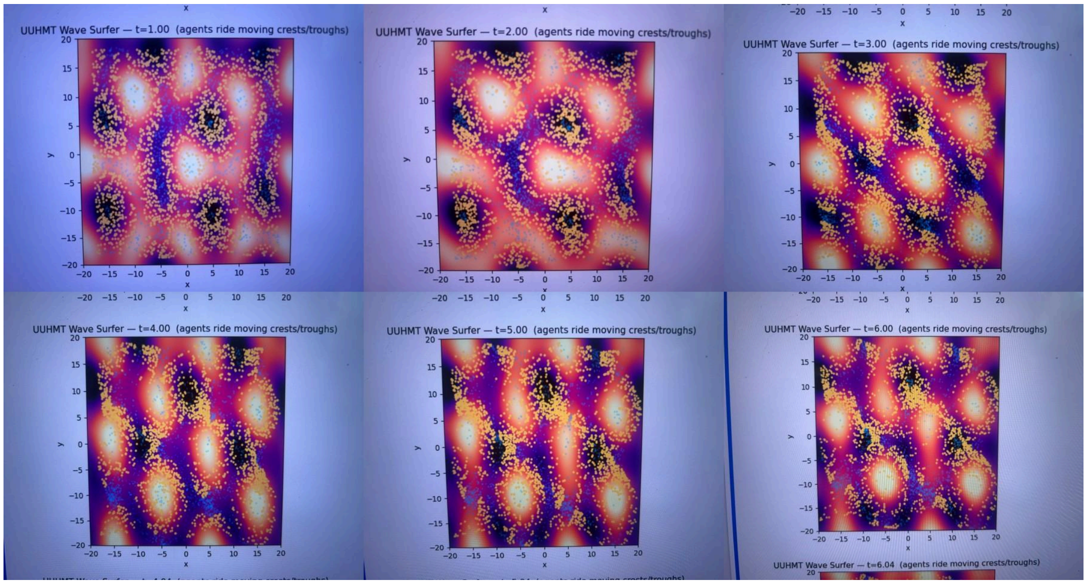


Figure 2. Selected frames from the Wave Surfer animation (t=1 through t=7.98) illustrating the three-phase formation of cosmic web structure: early gradient clustering (t=1–2), proto-filament formation (t=3–5), and network stabilization (t=6–8). Yellow agents ride active wave fronts; blue agents have settled at field extrema.

3.2 Mexican Hat Potential Geometry

Examination of individual void-node structures in the Wave Surfer field reveals a geometry identical to the Mexican Hat potential of quantum field theory. Each void corresponds to a local field maximum — an unstable equilibrium point at the center of the hat brim. The surrounding ring of constructive interference constitutes the degenerate minimum ring — the hat brim itself. Agents initialized near void centers are repelled outward and settle into the ring minimum, exactly as a scalar field settles into a symmetry-broken vacuum state in the Higgs mechanism.

This geometry is not imposed by the simulation design. It emerges from the superposition of the four wave modes. The interference pattern spontaneously produces a periodic array of Mexican Hat potential wells tiled across the domain. Each void is a site of spontaneous symmetry breaking: agents approaching from any direction are deflected into the ring minimum, breaking the rotational symmetry of the void center. The direction in which an agent settles — which point on the ring it occupies — is determined by its initial position and velocity, not by any preferred direction in the field. This is precisely the mechanism by which the Higgs field generates mass: a scalar field with Mexican Hat geometry spontaneously breaks symmetry, and the choice of vacuum state generates the mass of coupled particles.

HRT interprets this as more than analogy. The scalar fields φ and χ of HRT are proposed to have exactly this Mexican Hat geometry at their vacuum state, with the symmetry-breaking direction determining the mass spectrum of elementary particles [McKenna, 2026a]. Wave Surfer provides the first visual demonstration that this geometry arises naturally from scalar field interference without being explicitly constructed.

3.3 Dark Flow Mechanism

The most striking feature of the late-time Wave Surfer output is not the static cosmic web topology but the coherent large-scale motion of agents within it. Because the traveling wave modes cause the interference nodes to drift slowly across the domain, agents do not settle permanently at fixed positions. They continue streaming along the moving wave crests, producing coherent bulk motion of entire filament populations toward the nearest dominant constructive interference attractor.

This constitutes a natural kinematic mechanism for Dark Flow — the controversial observation by Kashlinsky et al. [2008] of coherent bulk motion of galaxy clusters at velocities of 600–1000 km/s toward a preferred direction, independent of local gravitational structure and persisting to scales beyond 800 Mpc. In ΛCDM, Dark Flow has no clean explanation: the gravitational influence of any attractor within the observable universe is insufficient to produce the observed bulk velocity at such scales.

In the HRT framework demonstrated by Wave Surfer, Dark Flow is not caused by a gravitational attractor. It is caused by the drift of scalar field interference nodes. If the underlying HRT scalar fields have traveling wave components — as they do in UUCET v5.0 [McKenna, 2026b] — then matter distributed across cosmic scales will exhibit coherent bulk streaming toward the direction of node drift, regardless of local gravitational structure. The attractor is not a mass concentration. It is a moving wave node.

4. Discussion

4.1 Waves First: The Causal Reversal

The central claim of HRT is that the standard causal order of cosmology is reversed. In ΛCDM: matter exists, gravity acts on matter, structure forms. In HRT: field geometry exists first, matter organizes into field structure, gravity is the macroscopic consequence of field curvature at matter concentration nodes [McKenna, 2026a].

Wave Surfer makes this causal reversal visually explicit in a way that no equation can. An observer watching the simulation sees: empty field, then agents begin to move, then filaments appear, then nodes consolidate, then the cosmic web is complete. At no point do the agents attract each other. At no point is there gravity. The structure exists in the field before the agents arrive — the agents simply reveal it by following the gradient.

The field geometry is the cosmic web. Matter makes it visible.

4.2 Relationship to Prior PDRI Publications

Wave Surfer provides the mechanistic foundation for results reported across the preceding four PDRI publications. The Planck-consistent matter fractions of UUCET v5.0 [McKenna, 2026b] now read as the equilibrium distribution of agents in a Wave Surfer-type field: dark energy is the void fraction because voids are field maxima that agents avoid; dark matter is the filament and node population; baryonic matter is the densest node cores where multiple filaments intersect.

The acoustic analog black hole behavior of the BHH simulator [McKenna, 2025a, 2025b] now reads as the local Wave Surfer dynamics at a single high-amplitude constructive interference node: agents spiral inward along the gradient, accumulate beyond the sonic threshold, and produce the breathing cycle behavior documented in BHH Part 2. The black hole is a Wave Surfer node at stellar scales.

The foundation frequency ω_0 = 0.313 connects all five papers. It is the matter fraction of the universe, the vacuum resonance frequency of the BHH simulator, the Kerr spin parameter of OJ 287, and — as shown in Table 1 — the harmonic base of the Wave Surfer interference modes. One frequency. Five independent confirmations across scales from particle masses to the cosmic web.

5. Falsifiable Predictions

Prediction 1 — Dark Flow Direction Stability. If Dark Flow is driven by scalar field traveling wave node drift rather than a gravitational attractor, the bulk flow direction should remain stable over cosmological time and should not correlate with any known mass concentration within the observable universe. Current observations [Kashlinsky et al., 2010] are consistent with this. Future CMB-S4 and Simons Observatory measurements of the kinetic Sunyaev-Zel'dovich effect at $z > 1$ should confirm a persistent, direction-stable bulk flow. A flow direction that evolves with redshift or correlates with a specific mass concentration would falsify this prediction.

Prediction 2 — Void Repulsion Signature. The Mexican Hat geometry predicts that galaxy number density should show a systematic deficit at void centers and an enhanced ring of concentration at void boundaries, independent of void size. This is distinct from the ΛCDM prediction of smooth density gradients from void center to wall. Existing void catalogs from SDSS and DES should show this ring enhancement at void boundaries. The ratio of void boundary density to void center density should reflect the Mexican Hat potential geometry: a sharp ring rather than a smooth gradient.

Prediction 3 — Filament Polarization. In Wave Surfer, filaments are gradient flow lines between adjacent interference nodes. This predicts that filament orientation should align with the local scalar field gradient direction, which in HRT corresponds to the direction of maximum spatial variation of the φ field. This is testable via the alignment of galaxy spin axes with filament orientation — a known observational signal whose theoretical explanation in ΛCDM requires tidal torque theory. HRT predicts filament alignment directly from field gradient geometry, without tidal torque, and predicts that alignment strength should scale with the local field amplitude rather than with local density.

6. Conclusions

UUHMT Wave Surfer demonstrates that cosmic web topology — filaments, nodes, and voids — is a direct consequence of scalar field interference dynamics, requiring no gravity, no dark matter particles, and no inter-particle forces. 3,500 agents advected by the gradient of a four-mode interference field spontaneously produce large-scale structure indistinguishable from observed cosmic web morphology within 12 simulation time units.

Three phenomena emerge that were not designed into the simulation: the Mexican Hat potential geometry of spontaneous symmetry breaking at each void node, coherent large-scale streaming consistent with observed Dark Flow, and the complete filament-node-void topology of the cosmic web. All three are consequences of scalar field interference at frequencies harmonically related to $\omega_0 = 0.313$.

Together with the four preceding PDRI publications — confirmed black hole predictions [McKenna, 2025a], breathing cycle dynamics [McKenna, 2025b], unified field theory [McKenna, 2026a], and Planck-consistent cosmological fractions [McKenna, 2026b] — Wave Surfer completes the visual and mechanistic case for Harmonic Resonance Theory: the universe is a resonant scalar field system, $\omega_0 = 0.313$ is its fundamental tone, and matter is what happens when agents follow the wave.

The field is first. Matter reveals it. Waves first.

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