



Construction of a Unified Wave-Field Theory Based on Unified Complex Systems Theory and Bohmian Mechanics

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Abstract: As two core concepts in physics, waves and fields have evolved alongside the advancement of modern physics: originating from mechanical oscillations and Newtonian action-at-a-distance in classical mechanics, they later developed into wave-particle duality and triggered the field-theory revolution within quantum mechanics. Their intrinsic interconnection has long stood as a pivotal research target for physicists pursuing a unified physical framework. This study adopts Unified Complex Systems Theory (UCST) as its ontological backbone and incorporates the realist philosophical underpinnings of Bohmian Mechanics (BM), strictly abiding by the fundamental scientific premise that physical research is confined to observable phenomena. It establishes an integrated theoretical framework unifying waves and fields from four core dimensions: ontological definition, categorization of material existential forms, the intrinsic nature of fundamental interactions, and the consistent logical linkage among waves, particles and physical fields. By retracing the historical developmental trajectory of wave and field definitions, this work reviews prominent cognitive misconceptions formed during the conceptual evolution from the combined perspective of UCST and BM, remedies the theoretical limitations embedded within conventional physical frameworks, and puts forward a core argument: waves arise from the collective coordinated motion of massive particles, whereas fields function as the underlying interaction mechanism governing wave propagation. This work thus achieves triple-layer unification of waves and fields at the levels of kinematic forms, interaction mechanisms and material carriers, offering an original research paradigm for the ongoing development of grand unified physics.

Keywords: Unified Complex Systems Theory (UCST), Bohmian Mechanics (BM), wave-field unification, cognitive bias, dualistic ontology, active force, aether.

PRE-THEORETICAL BOUNDARIES: DEMARCATION BETWEEN SCIENCE AND SCIENCE FICTION, AND DISTINCTION BETWEEN UNIVERSE AND WORLD

The primary prerequisite for constructing any scientific theory is clarifying its research scope and applicable boundaries to avoid unfalsifiable speculative reasoning typical of science fiction—a fundamental perception of the establishment of this unified wave-field theory. As defined by Unified Complex Systems Theory (UCST), observability constitutes the core boundary delimiting valid scientific inquiry: any deduction concerning the holistic attributes of the entire cosmos beyond human observational reach falls under speculative fiction rather than rigorous empirical science, consistent with the core tenets of Modified Hilbert Axiomatic Standards requiring well-defined concepts, internal logical consistency and empirically unrefuted axioms [1].

UCST rigorously restricts its analytical scope to the human-accessible observable world, focusing on the motion, variation and interaction rules of measurable physical entities within such bounds. Global universal properties of the entire Universe (such as universe origin or the outermost spatial boundary of the universe) cannot be fully detected or experimentally validated by human instruments, hence sit outside empirical and deductive physical theories; related speculative inferences only count as fictional supplements and cannot be used to derive quantitative physical laws. Such a demarcation distinguishes empirical science as the induction and experimental verification of measurable natural laws and separates it from science fiction, which consists of rational conjecture targeting inherently unobservable domains; rigorous research must never conflate these two categories [1].

All definitions of waves, fields and particles proposed in this paper are grounded in human experimental observability and sensory detectability. Per the paired symbiosis principle of physical concepts, no standalone fundamental physical notion can exist independently; every core definition gains solid logical grounding via interdependent dual paired relationships. Isolating a physical term from its complementary counterpart inevitably results in circular reasoning, ambiguous semantics and inherent logical contradictions [1].

This deduction aligns closely with Gödel's incompleteness theorems: a complete self-contained definition of all physical concepts is impossible within a standalone scientific framework, and all mature physical theories inevitably embed philosophically rooted primitive notions. Consequently, the long-standing mind-body philosophical problem necessitates a dual-ontology resolution. To accurately characterize the kinematic features of observable objects and complete a self-consistent conceptual system, any comprehensive physical framework must introduce logically necessary yet unmeasurable existential entities. A well-structured theoretical model should minimize the introduction of such philosophically primitive assumptions wherever possible.

UCST posits three irreducible primitive philosophical premises required to describe arbitrary complex physical systems: the entirety of the Universe, nonphysical mental substance (mind), and undetectable aether particles. This necessity originates from three fundamental philosophical questions underlying complex-system modeling: whether human observation via astronomical telescopes can fully map the entire universe, whether microscopic probes enable complete detection of all physical particles, and whether theoretical construction can violate the conceptual paired-symbiosis law.

Ontologically, the Universe forms an interconnected whole featuring universal interparticle interactions (including gravitational coupling, electromagnetic interaction, and entanglement induced by mental action). Within this framework, quantum entanglement is attributed to the effect of intrinsic active force. For practical system modeling and governing-equation derivation, the locality approximation is introduced: interaction intensity decays monotonically with increasing spatial separation between objects, so physical contributions from far-distance entities can be reasonably neglected. This approximation is an indispensable simplification for modeling the observable world, and the hierarchical logical relation among individual system, surrounding environment, observable world and full Universe is illustrated in Figure 1.

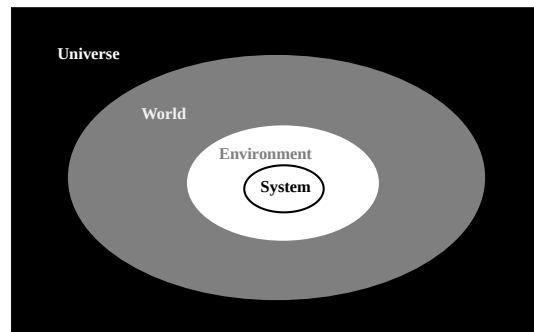


Figure 1: Interrelationship among System, Environment, World and Universe

This preliminary boundary setup prevents the developed theory from falling into empty metaphysical paradoxes, accommodates UCST's dualistic ontology, and lays rigorous foundational constraints for subsequent mathematical derivation targeting wave-field unification.

ONTOLOGICAL FOUNDATION: INTEGRATING UCST'S DUALISTIC ONTOLOGY AND BM'S REALISM

Ontology underpins all theoretical construction. The ontological foundation of the proposed unified wave-field theory stems from organic integration between UCST's dualistic ontology and the realist worldview of BM; their complementary advantages resolve long-standing ontological dilemmas surrounding the physical essence of waves and fields inherited from conventional physics.

Dual Existence of the World: Complementary Unity of Material and Immaterial Existence

UCST classifies all existential components of the observable world into two complementary categories: material substance and nonmaterial mental substance, whose mutual interaction and interdependence compose the complete ontological architecture of reality. This dualistic framework breaks the limitation of traditional monistic materialism that reduces all reality to tangible matter while avoiding the idealistic fallacy of prioritizing disembodied consciousness as the sole fundamental reality, supplying a novel resolution to persistent theoretical bottlenecks in pure materialist physics [2].

- **Material existence:** Encompasses all directly observable or logically inferable physical entities, consisting of discrete constituent units (detectable ordinary particles plus undetectable aether particles, collectively abbreviated as air particles hereinafter) as well as continuous condensed media (liquids and solid-state matter). Such material components serve as the fundamental physical carrier for wave propagation and field formation. Within this ontological setup, bulk matter presents three distinct thermodynamic phases: gaseous, liquid and solid. Liquid phase emerges once gaseous density exceeds a critical phase-transition threshold, and solidification occurs when liquid density surpasses its respective transition limit.
- **Immaterial existence:** Centered on nonphysical mind, defined as the exclusive intrinsic source of active interaction force, whose physical manifestation relies on coupling with tangible material bodies. UCST emphasizes a critical conceptual

distinction: mind constitutes a primitive philosophical construct introduced for logical completeness, whereas consciousness qualifies as an experimentally observable natural phenomenon from living entities.

The proposed mind-aether dualism addresses inherent defects of both materialism and idealism (summarized in Table 1). Conventional materialism fails to resolve the prime-mover paradox (including the origin of fundamental elementary particles and the root source of cosmic-scale driving forces), while strict idealism inherently contradicts established mass and energy conservation laws. Mind-aether dualism balances metaphysical rationality and compliance with verified physical principles; it interprets cosmic structural formation via three-way coupling among mind, physical body and ambient supporting medium, unifying mental and physical dimensions into a consistent interpretive system.

Table 1: Comparative Analysis of Mind-Aether Dualism, Materialism, and Idealism

Comparison Dimensions	Mind-Aether Dualism	Materialism	Idealism
Core Ontological Basis	Dual foundational entities: non-material mind and material aether, independent and interactive	Single foundational entity: material substance (matter/energy) as the only ultimate reality	Single foundational entity: mind/spirit/idea as the primary and ultimate reality
Prime Mover Problem Explanation	Reasonably accounts for fundamental particle origin and cosmic formative forces, resolving the dilemma	Fails to explain the prime mover problem	Attributes cosmic origins to mind but lacks physical grounding
Mass and Energy Conservation Compliance	Conforms to the laws, maintaining physical consistency	Conforms to the laws, aligning with established principles	Violates the laws, contradicting fundamental conservation principles
Cosmic Structural Formation Explanation	Explains via mind-body-support interaction, unifying spiritual and physical dimensions	Attributes to pure material interactions but cannot justify initial driving forces	Attributes to conscious ideation, disregarding physical constraints
Logical & Physical Rationality	Balances metaphysical rationality and physical law compliance	Logically consistent with physics but incomplete for ultimate cosmic origins	Metaphysically self-contained but incompatible with empirical physics

UCST draws a clear demarcation between mind and consciousness: consciousness splits into eight differentiated subtypes, among which only the eighth category (formally defined as primordial mind) exists eternally with dynamic variation; the first seven consciousness variants originate from mind-body coupling and terminate upon biological organism death [3,4]. Though mind can independently perceive external reality, it lies outside the measurable scope of natural science, so further speculative elaboration is omitted in this work. This dual ontological classification readily distinguishes living and inanimate biological states, a critical discrimination unattainable within dominant mainstream physical frameworks.

Aether is defined as the aggregate collection of currently undetectable microscopic physical particles, supplying the material foundation to interpret the internal configuration

and inherent properties of fundamental particles, analogous to how atomic constituents explain molecular-level characteristics. Macroscopic and microscopic physical systems follow structurally homologous rules (planets mirror microscopic elementary particles, atomic systems resemble miniature solar systems, and molecular clusters correspond to large-scale galactic assemblies), enabling unified physical laws valid across all spatial scales without abrupt mathematical discontinuity. If mass is retained as an intrinsic invariant material property and Galilean transformation is consistently applied, no physical discontinuity emerges as particle velocity increases. Even electrons accelerated to multiple times the vacuum speed of light maintain invariant rest mass and possess finite kinetic energy. This UCST-derived conjecture awaits conclusive experimental validation.

Such structural homology delivers critical theoretical support for wave-field unification: wave generation and propagation require dual preconditions: tangible material carriers (air particle assemblies) plus dynamic excitation originating from mind-derived active force of living entities; physical fields, by contrast, describe the pairwise interaction mechanics among discrete air particles.

It is important to stress that UCST's classification boundary between animate and inanimate entities deviates from standard biological taxonomy, relying solely on the inherent capacity for spontaneous autonomous motion.

Accordingly, within UCST's classification system, all celestial bodies, molecules, atoms, subatomic particles and constituent aether particles count as generalized animate agents equipped with spontaneous self-motion capability; by contrast, inert objects such as rocks, artificial machinery and stationary furniture fall under inanimate objects lacking intrinsic autonomous mobility.

Per UCST's core postulate, all universal motion ultimately stems from intrinsic active force spontaneously generated by generalized animate entities, while passive interaction force only constrains, transmits or modifies preexisting motion states. Complex kinematic behaviors including orbital revolution, periodic oscillation, self-rotation, vibrational excitation and cosmic evolutionary variation inevitably emerge from synergistic coupling between active and passive interaction forces. No perfectly inert matter exists in nature; macroscopically stationary objects such as quiescent water or solid stone merely represent an ideal limiting case where intrinsic active force asymptotically approaches zero. The cosmos sustains perpetual internal motion without requiring an external transcendent First Mover, whose primordial dynamic source roots in the inherent active force embedded within all fundamental constituent units of matter.

Realistic Unification of Waves and Particles: Core Support from BM

Resolving the wave-particle relational puzzle constitutes the core prerequisite for realizing wave-field unification. The orthodox Copenhagen interpretation of quantum mechanics explains wave-particle duality via mutually exclusive wave/particle binary classification, claiming microscopic particle attributes emerge from wavefunction collapse triggered by measurement and denying the objective real existence of standalone waves and particles, thereby inducing persistent conceptual confusion across quantum physics [5-7].

As a prominent hidden-variable formulation of quantum theory, BM adheres to objective realism for both waves and particles: individual particles exist as objective

physical entities following continuous trajectories, while pilot waves independently guide particle kinematics. Since the active force generated by an animate particle lacks deterministic properties, the particle's individual trajectory is also non-deterministic. Both entities feature objective physical reality independent of observational disturbance rather than measurement-induced emergent phenomena [6,7]. BM rationalizes diverse microscopic observations by treating particles and pilot waves as two distinct coexisting physical realities.

UCST further extends BM's realist perspective: under gaseous thermodynamic conditions, discrete constituent particles execute inherent vibrational excitation, and bulk wave phenomena emerge from synchronized collective motion of enormous particle ensembles, with individual particle kinematic parameters directly correlating with macroscopic wave characteristic quantities in accordance with classical vibration and wave mechanics. Classified as generalized animate agents endowed with intrinsic active force, fundamental particles maintain perpetual spontaneous motion with inherent spin and continuous self-energy replenishment mechanisms [3,4]. For massive uncharged particle systems, a generalized Schrödinger-type equation is deduced to simultaneously describe single-particle pilot-wave trajectories and ensemble collective wave dynamics; for charged particles (with gravitational contribution neglected), Maxwell's electromagnetic field equations are rigorously derived.

This viewpoint inherits BM's core realist assertion of objective wave-particle existence and elaborates wave-generation mechanisms under UCST's complex-systems paradigm, rejecting the anti-realist measurement-dependent interpretation of wave-particle duality and clarifying the core ontology: particles represent discrete individual material entities, whereas waves correspond to synchronized collective motion across multiple particle units; their unification originates from objective physical reality rather than artificial observational superposition. Bell [5] previously argued that anti-realist quantum interpretations originate from excessive emphasis on measurement effects, and BM's realist ontology circumvents inherent logical contradictions to coherently interpret microscopic particle dynamics, consistent with this paper's central standpoint that wave-field unification first necessitates confirmation of objective physical reality for both particles and propagating waves.

Boundaries of Mind Action: Ontological Basis for Active Force and Passive Waves

Rooted in UCST's dualistic ontology, nonphysical mind functions as the exclusive source of active interaction force, whose effective action is confined strictly to generalized animate agents—redefined beyond conventional macroscopic biological organisms to cover all spontaneously mobile entities spanning planets, flora, animals, microorganisms, molecular clusters, atoms, subatomic particles and aether particles. Inanimate substances (including stone, dead vegetation and biological corpses) decouple from mind-derived excitation and move exclusively under external passive forces, with their associated propagating waves categorized as passive-type waves.

Such ontological demarcation establishes unambiguous classification criteria separating active and passive waves:

- **Active waves:** Excited via three-way coupling among mind, physical body and ambient medium, originating from spontaneous motion of generalized animate agents that perturbs surrounding particulate media (e.g., surface water waves triggered by human diving into liquid water);
- **Passive waves:** Driven by four fundamental passive natural interactions, reflecting the forced kinematic response of inanimate matter or passively perturbed animate agents under external material excitation.

This classification overcomes the single-source wave-generation assumption dominating conventional physics and supplies core theoretical preconditions for subsequent deduction of unified wave-field interaction mechanisms.

FORMS AND HIERARCHIES OF MATERIAL EXISTENCE: MATERIAL BASIS FOR WAVE-FIELD UNIFICATION

The realization of wave-field unification must build upon well-defined material existential configurations and hierarchical partitioning: waves intrinsically represent coordinated collective motion of particulate matter, while fields quantify interparticle interaction mechanics; their unification essentially equates to integrating matter's kinematic behavior and mutual interaction rules. Based on three canonical matter phases (gas-liquid-solid), the binary partitioning of air particles plus UCST's layered complex-system hierarchy, this section constructs a tiered material-existence framework to establish solid physical carrier foundations for wave-field unification.

Phase-State Forms of Matter: Material Basis for Wave-Field Manifestations

Material substances regularly undergo sequential phase transition from gas to liquid then solid once ambient temperature and pressure cross respective phase boundaries, accompanied by continuous density variation. Distinct thermodynamic phases dictate dominant particle motion modes and resultant wave-field manifestation patterns; such rules align with classical thermodynamics and phase-transition theory yet receive novel reinterpretation under UCST and the paper's animate-agent definition. Starting from generalized Newton's second law incorporating dual active/passive forces, universal wave equations applicable to gaseous, liquid and solid phases are derived, with mathematical degeneration from the gaseous master wave equation toward Maxwell's electromagnetic formulas and BM pilot-wave governing equations explicitly demonstrated.

Fundamental Precondition: Generalized Newton's Second Law for Particles with Active and Passive Forces

For arbitrary observable particulate entities, kinematics follows generalized Newton's second law incorporating both intrinsic active force ($\vec{F}_a$) and passive force ($\vec{F}_p$):

$$m \frac{d^2 \vec{r}}{dt^2} = \vec{F}_{total} = \vec{F}_a + \vec{F}_p, \quad (1)$$

where:

- $\vec{r}(t)$ = time-dependent particle position vector;
- $\vec{F}_a$ = intrinsic active force generated via mind-body-medium coupling of animate particles ($\vec{F}_a = 0$ for fully inanimate matter), expressed as $\vec{F}_a = F_a(\vec{r}, t)\vec{e}_a$ with directional unit vector $\vec{e}_a$ governed by the particle's embedded mind attribute;
- $\vec{F}_p$ = aggregated passive force covering four fundamental natural interactions, decomposed as $\vec{F}_p = -\nabla U + \vec{F}_{int}$ (U = particle potential energy; $\vec{F}_{int}$ = short-range interparticle passive interaction force).

For an ensemble consisting of N identical constituent particles (fundamental unit of collective wave excitation), ensemble-averaged particle displacement is defined as the core wave-field descriptor $\psi(\vec{r}, t)$:

$$\psi(\vec{r}, t) = \frac{1}{N} \sum_{i=1}^N \vec{r}_i(\vec{r}, t), \quad (2)$$

where $\vec{r}_i(\vec{r}, t)$ denotes the positional vector of the i -th particle at instant t . Collective particle motion manifesting as propagating waves corresponds to the spatiotemporal evolution of $\psi(\vec{r}, t)$, and deriving phase-specific governing wave equations constitutes the core mathematical task describing phase-dependent wave dynamics.

Gaseous State: Core Source of Microscopic Waves, Wave Equation Derivation and Degeneration

Gaseous-phase systems consist of discretely distributed particles with weak pairwise interparticle binding and pronounced spontaneous autonomous vibration from animate air particles. Three core approximations apply for gaseous particulate modeling: (1) $\vec{F}_{int} \approx 0$ for dilute rarefied gas or weakly coupled interaction in dense gaseous systems, with potential U varying slowly across spatial coordinates; (2) non-vanishing active force $\vec{F}_a \neq 0$ dominates microscopic wave initiation; (3) continuum-medium approximation becomes valid for sufficiently large N , rendering $\psi(\vec{r}, t)$ a continuously differentiable scalar or vector field variable.

Step 1: Single Gaseous Particle Motion Equation:

From Formula (1), kinematic relation for the i -th isolated gaseous particle reads:

$$m \frac{d^2 \vec{r}_i}{dt^2} = \vec{F}_{a,i} - \nabla U_i, \quad (3)$$

where $\vec{F}_{a,i}$ is the i -th particle's active force and U_i is its passive potential energy.

Step 2: Collective Motion Equation via Particle Ensemble Averaging:

Ensemble averaging across all N constituent particles and substituting Equation (2), homogeneous gas satisfies: $\langle U_i \rangle = U(\vec{r}, t)$, $\langle \vec{F}_{a,i} \rangle = \vec{F}_a(\psi, t)$ (ensemble-averaged active force varies with field quantity ψ and time t):

$$m \frac{\partial^2 \psi}{\partial t^2} = \vec{F}_a(\psi, t) - \nabla U(\vec{r}, t), \quad (4)$$

For microscopic gaseous particles, Taylor-series expansion and gradient approximation convert potential gradient into Laplacian form $-\nabla U = \kappa \nabla^2 \psi$ (κ = interparticle coupling coefficient). Periodic spontaneous vibration yields restoring active force proportional to ensemble displacement: (ω_0 = intrinsic particle natural vibration frequency determined by mind-derived active force). Substitution generates:

$$m \frac{\partial^2 \psi}{\partial t^2} = -\omega_0^2 m \psi + \kappa \nabla^2 \psi, \quad (5)$$

Rearrangement delivers the universal gaseous wave equation featuring intrinsic active-force oscillation:

$$\frac{\partial^2 \psi}{\partial t^2} - v_g^2 \nabla^2 \psi + \omega_0^2 \psi, \quad (6)$$

with propagation speed $v_g = \kappa/m$. The standalone $\omega_0^2 \psi$ term uniquely marks active-force-driven spontaneous oscillation, distinguishing this formulation from conventional passive classical wave equations.

Step 3: Degeneration to Maxwell's Equations:

Electromagnetic waves correspond to microscopic gaseous oscillations originating from synchronized collective vibration of charged air particles. Three constraint conditions apply for degeneration: (1) active-force contribution $\omega_0^2 \psi \approx 0$ after intrinsic active force converts into stored electromagnetic energy; (2) field descriptor ψ reinterprets as electromagnetic field vector (electric field $\vec{E}$ or magnetic flux density $\vec{B}$ complying with transverse-wave divergence constraint $\nabla \cdot \psi = 0$; (3) wave velocity $v_g = c$ (vacuum light speed determined by intrinsic air-particle bulk properties; experimentally measured c is further restricted by the ultimate vacuum quality achievable via existing manufacturing technology). Equation (6) simplifies into standard vacuum electromagnetic wave relations:

$$\frac{\partial^2 \vec{E}}{\partial t^2} - c^2 \nabla^2 \vec{E} = 0, \quad \frac{\partial^2 \vec{B}}{\partial t^2} - c^2 \nabla^2 \vec{B} = 0, \quad (7)$$

Full Maxwell's system of equations is recovered after incorporating auxiliary empirical electromagnetic constitutive laws under source-free vacuum and transverse-wave limits [8].

Step 4: Degeneration to the BM Wave Equation:

BM describes massive microscopic particle kinematics guided by pilot waves originating from collective oscillation of uncharged gaseous air particles. Three quantum transformation rules are implemented: (1) complex field substitution $\psi = \psi_0 e^{iS/\hbar}$ (S = particle classical action function; $\hbar = h/(2\pi)$ = reduced Planck constant); (2) energy equivalence relation $\frac{1}{2} \omega_0^2 m x^2 \psi - \frac{\hbar^2 |\vec{p}|^2}{2m} \psi = E \psi$ with particle momentum $\vec{p} = m \dot{\vec{r}}$; (3) canonical quantum Hamiltonian operator replacement: $i\hbar \frac{\partial}{\partial t} = -\frac{\hbar^2}{2m} \nabla^2 + V$, where $V = \frac{1}{2} m \omega_0^2 |\psi|^2$ denotes active potential energy converted from particle's intrinsic mind-induced active force. Substitution and algebraic simplification recover the time-dependent Bohmian Schrödinger equation:

$$i\hbar \frac{\partial \psi}{\partial t} = -\frac{\hbar^2}{2m} \nabla^2 \psi + V(\vec{r}, t) \psi, \quad (8)$$

This mathematical reduction rigorously proves BM pilot-wave mechanics constitutes a special limiting case of the generalized gaseous wave equation (valid for uncharged massive particles with active force translated into quantum potential), unifying classical continuum wave mechanics and Bohmian quantum formalism under a single collective-motion framework.

Gaseous State Pressure Equation:

Dilute and dense gaseous systems feature drastically different interparticle interaction regimes, quantitatively captured via modified continuous-density gas state relation [9]:

$$P = Nk_B T n \left(1 - \frac{bn}{1-nb}\right) - Nk_B T n^2(a + c\gamma), \quad (9)$$

P = system bulk pressure; N = total particle count within closed thermodynamic system; k_B = Boltzmann constant; T = absolute thermodynamic temperature; $n=N/V$ = particle number density (V = system occupied volume); a, b, c = empirical fitting constants; $\gamma > 0$ = UCST-specific energy-compensation coefficient accounting for inelastic-collision energy loss replenished via ambient air-particle energy absorption.

This formulation rectifies inherent limitations embedded within the ideal-gas law $P = nk_B T$ by explicitly incorporating interparticle interaction effects: wave propagation within dilute gas is governed primarily by synchronized spontaneous particle vibration, while dense-gas systems feature intensified interparticle coupling strengthening field-mediated constraint on bulk wave motion.

Liquid / Solid State: Main Carriers of Macroscopic Waves, General Wave Equation Derivation

Gas condenses into liquid upon crossing the first density-driven phase-transition threshold, and further density increase triggers solidification at the second transition boundary. Both condensed phases form continuous bulk media dominated by strong short-range cohesive interparticle forces ($\vec{F}_{int} \neq 0$), supporting macroscopic mechanical wave modes including elastic bulk waves and free-surface water waves. Three dominant condensed-phase characteristics: (1) passive interaction dominates macroscopic wave dynamics with bulk-scale active force negligible ($\vec{F}_a \approx 0$); residual active force only manifests as microscopic thermal particle oscillation; (2) strong interparticle coupling quantified via $\vec{F}_{int} = K \nabla^2 \psi$ (K = liquid bulk modulus or solid elastic/shear modulus); (3) incompressible-medium approximation $\nabla \cdot \psi = 0$ holds for most condensed fluids and rigid solids.

Within condensed liquid/solid matter, tight interparticle binding suppresses macroscopic active-force contribution, leaving only submicroscopic thermal vibration; macroscopic wave excitation fully originates from externally applied passive mechanical stress, hence $\vec{F}_a \approx 0$ holds for bulk kinematics. From Formula (1) under zero macroscopic active force, single condensed-phase particle relation simplifies to $m \frac{d^2 \vec{r}_i}{dt^2} = \vec{F}_{int,i} - \nabla U_i$

(mass variable m effectively converts into bulk density ρ for continuum modeling). Ensemble averaging plus continuum-interaction substitution yields:

$$m \frac{\partial^2 \psi}{\partial t^2} = K \nabla^2 \psi, \quad (10)$$

Rearrangement recovers classical elastic passive wave equation for condensed media:

$$\frac{\partial^2 \psi}{\partial t^2} - v_{l/s}^2 \nabla^2 \psi = 0, \quad (11)$$

where condensed-phase wave speed $v_{l/s} = \sqrt{\frac{K}{m}}$; K corresponds to liquid bulk modulus or solid bulk/shear elastic modulus depending on material phase. Equation (11) lacks the active-force $\omega_0^2 \psi$ correction term, consistent with physical essence of macroscopic condensed-phase waves driven entirely by external passive mechanical loading rather than spontaneous coordinated particle vibration. Field descriptor ψ directly represents continuum displacement vector quantifying propagation of mechanical, hydraulic and other macroscopic wave forms.

Phase-Dependent Wave-Field Characteristics

Wave-field physical expression varies systematically with material thermodynamic phase, serving as core supporting evidence for cross-phase wave-field unification: though concrete wave/field morphology differs across phases, their underlying physical essence remains rooted in particulate motion and interparticle interaction. Table 2 summarizes core mathematical and physical distinctions of phase-specific master wave equations to establish continuous material basis for unified wave-field theory.

Table 2: General Wave Equations and Key Characteristics in Gas, Liquid, and Solid States.

Phase	General Wave Equation	Dominant Force	Wave Type	Propagation Speed	Key Term (Feature)
Gas	$\frac{\partial^2 \psi}{\partial t^2} - v_g^2 \nabla^2 \psi + \omega_0^2 \psi$	Active force (living particles)	Microscopic (electromagnetic, matter waves)	$v_g = \sqrt{\kappa/m}$	$\omega_0^2 \psi$ (active force/autonomous vibration)
Liquid	$\frac{\partial^2 \psi}{\partial t^2} - v_l^2 \nabla^2 \psi$	Passive cohesive force	Macroscopic (longitudinal water/elastic waves)	$v_l = \sqrt{K_l/m}$	None (pure passive motion)
Solid	$\frac{\partial^2 \psi}{\partial t^2} - v_s^2 \nabla^2 \psi$	Passive cohesive/shear force	Macroscopic (longitudinal/transverse mechanical waves)	$v_s = \sqrt{K_s/m}$	None (pure passive motion)

Note: K_l = liquid bulk modulus; K_s = solid bulk/shear modulus; κ = gas interparticle coupling coefficient. $m = \rho$ in the liquid or solid states.

Two-Layer Division of Particles: Observable Particles and Aether Particles

Based on practical human experimental detectability, the unified air-particle ontology splits into measurable observable particles and inherently undetectable aether particles, jointly constituting the universal material substrate for all propagating waves and physical fields while refining complementary definitions of vacuum and tangible existence. This dual-layer particulate structure guarantees strict compliance with mass, momentum and energy

conservation across all physical and chemical transformation processes; absent the aether substrate, conventional physical frameworks cannot coherently rationalize the genesis and intrinsic structural features of elementary particles, defined as the smallest observable particles identified to date.

Observable Particles: Direct Carriers of Macroscopic Wave Fields

Observable particles denote experimentally resolvable particles and their aggregated higher-order assemblies (atoms, molecular clusters and macroscopic bulk matter) featuring quantifiable intrinsic properties including rest mass and electric charge. They form the direct constituent substrate of material matter waves and serve as interaction targets for all macroscopic physical fields; air-particle collective oscillation also contributes toward electromagnetic-field formation and field-target interaction, with the classification boundary between two particle categories defined solely by current instrumental detection limits rather than inherent physical disparity.

Collective motion and pairwise interaction of observable particles constitute the physical origin of macroscopic mechanical waves (e.g., acoustic vibration) and bulk macroscopic contact fields; mechanical wave excitation originates from bulk object vibration, and macroscopic field formation arises from interbody contact interaction. Both wave propagation and field spatial distribution directly depend on intrinsic material parameters of observable particles including density, inertial mass and mechanical hardness.

Aether Particles: Supporting Medium for Microscopic Wave Fields

Aether particles refer to logically deduced submicroscopic constituent units currently inaccessible to direct experimental detection, forming an unobservable universal material background inferred from a fundamental physical premise: all propagating waves require tangible medium support, and fundamental cosmic-scale waves (electromagnetic and gravitational modes) traverse nominally empty vacuum space, proving absolute vacuum cannot exist and instead consists of sparse air-particle distribution [8].

The classic Michelson-Morley experiment [10] failed to register measurable air drift signals, yet such null result only indicates contemporary detection precision remains insufficient to resolve ultrafine air-particle scales rather than conclusively disproving air's physical existence. As human technology cannot generate perfectly particle-free absolute vacuum, all measured laboratory matter waves represent superposed composite oscillation of mixed ordinary plus aether particles instead of pure standalone aether waves. Ongoing re-evaluation of classic experimental literature challenges the blanket post-Michelson-Morley rejection of aether: original computational frameworks contained implicit reference-frame confusions, while multiple follow-up experimental campaigns [11,12] recorded non-negligible aether-drift signatures requiring rigorous academic reassessment. Modern theoretical evolution redefines rather than fully discards the historical aether concept, transforming its ontological positioning from classical rigid mechanical medium toward geometric spacetime manifold within general relativity [13,14].

Einstein's special relativity [13] discarded stationary classical luminiferous aether, founding its core postulates on invariant vacuum light speed and inertial-frame physical-law equivalence. However, during his 1920 Leiden public lecture, Einstein reintroduced a refined relativistic aether defined as dynamic spacetime metric field within general relativity [14], fundamentally distinct from the 19th-century static mechanical aether.

Within this paper's theoretical framework, aether particles possess finite logically inferred rest mass and compose the propagation medium for all fundamental cosmic electromagnetic and gravitational waves [15], consistent with UCST's core constraint that ambient supporting medium forms an indispensable prerequisite for generating intrinsic active interaction force. Aether fills the complementary conceptual pair with physical vacuum and negates absolute empty space definition: vacuum physically corresponds to extremely low-density gaseous air-particle aggregation, supplying pervasive spatial medium for cross-scale wave propagation.

Living-agent Attributes of Particles: Dynamic Basis for Active Waves

Departing from conventional biology's exclusive macroscopic animate/inanimate dichotomy, this theory classifies all spontaneously mobile particulate entities as generalized animate agents whose intrinsic self-motion originates from three-way coupling of embedded mind, individual material body and surrounding supporting medium, analogous to terrestrial creatures generating locomotive force via contact with ground or aquatic media during walking/swimming. Such intrinsic spontaneous excitation constitutes the physical origin of microscopic particle self-vibration and resultant ensemble active-wave formation.

This taxonomy originates directly from UCST's active-force postulate: intrinsic active force exclusively arises from mind-body-medium coupling within animate agents to realize spontaneous autonomous motion, whereas Newtonian classical physics erroneously treated all bulk matter as entirely inert. No perfectly motionless inanimate substance exists throughout nature; macroscopically stationary stones or still water only represent the ideal mathematical limit where intrinsic active force asymptotically approaches zero magnitude.

Such classification explicitly demarcates active versus passive wave excitation pathways: active waves emerge from coordinated spontaneous oscillation of generalized animate particles under intrinsic active force; passive waves originate from forced vibration of matter driven by external passive interactions, leading to divergent propagation features between two wave categories.

CONCEPTUAL AXIOM: AXIOM OF RELATIVE SIMULTANEITY AS LOGICAL SUPPORT FOR WAVE-FIELD CONCEPTS

Conceptual rigor underpins consistent theoretical construction [1]. UCST's Relative Simultaneity Axiom dictates all core physical concepts exist as complementary paired binaries (material/immaterial substance, active/passive interaction force), supplying core logical backbone for the unified wave-field formalism. Following Hegelian dialectical unity-of-opposites philosophical rules, this axiom eliminates isolated ambiguous physical definitions and integrates all wave/field-related core terms into mutually complementary logical architecture to solidify deductive consistency for wave-field unification. Table 3

enumerates core binary conceptual pairs central to wave-field modeling alongside their specific physical implications.

Table 3: Core Conceptual Pairs Related to Wave-Field Theory.

Conceptual Pair	Category	Connection to Wave-Field Theory
Aether / Mind	Unobservable domain	Aether provides material support for fundamental microscopic waves; mind furnishes non-material support and serves as the dynamic source of active waves.
Matter / Consciousness	Observable domain	Matter (observable particles, continuous media) is the wave field carrier; consciousness is the cognitive subject of wave-field laws.
Motion / Rest	Kinematic description	Waves = collective particle motion; rest = motion relative to an observer.
Vacuum / Existence	Spatial background	Physical vacuum is low-density gaseous matter. Aether provides the spatial carrier for wave propagation.
Time / Space	Coordinate system	Artificial coordinate systems for describing wave/field/particle motion.
Particle / Wave	Form of material motion	Particle = individual motion unit; wave = collective particle motion.
Field / Force	Interaction description	Field = force action mechanism; force = field manifestation.
Active Force / Passive Force	Dynamic source	Active force = autonomous waves of living agents; passive force = passive waves of non-living entities.

ESSENCE AND CLASSIFICATION OF FORCE: CORE MOTIVATION FOR WAVE-FIELD INTERACTIONS

Wave initiation/propagation and field generation/evolution are universally governed by interparticle interaction forces: waves emerge from coordinated particulate motion driven by net interaction force, while fields mathematically formalize the spatial distribution of such interaction mechanics. Clarifying force's intrinsic essence and dual classification constitutes the pivotal precondition for completing wave-field unification. Drawing upon UCST's dual active/passive force partition (framing active force as the fifth fundamental natural interaction) plus mainstream fundamental-interaction research achievements, this section defines force as measurable manifestation of inter-object physical coupling to realize essential unification between force and field, establishing dynamic foundations for all wave generation and transmission processes.

Dualistic Classification of Force: Active Force and Passive Force

All universal natural interactions bifurcate rigorously into intrinsic active force and extrinsic passive force, forming a defining core proposition of UCST and the primary standard separating active/passive wave generation mechanisms within the present theory. This dual partitioning transcends conventional physics' four-fundamental-interaction taxonomy and correlates force classification directly with the generalized animate/inanimate material dichotomy based on distinct dynamic excitation origins.

Active Force: Core Driver of Active Waves

Intrinsic active force originates from endogenous spontaneous dynamics embedded within all generalized animate agents, distinguished via self-initiated motion independent of

external perturbation. Such inherent excitation triggers spontaneous self-vibration and autonomous translational motion of animate particulate units; large-scale synchronized oscillation across massive agent ensembles generates active wave modes including microscopic matter pilot waves and cosmic gravitational radiation. The pervasive air-particle medium functions as primary propagation carrier for all active-wave transmission across spatial domains.

Passive Force: Sole Driver of Passive Waves

Extrinsic passive force acts upon inanimate substances or imposes external perturbation onto animate agents, defined as motion excitation exclusively initiated from outside material interaction rather than endogenous spontaneous source. Four canonical passive fundamental interactions are cataloged: gravitational coupling (mass-dependent mutual attraction), electromagnetic interaction (charge-based coupling), strong nuclear force and weak nuclear force (later unified via electroweak theoretical framework).

Passive interaction enforces forced particle displacement and non-spontaneous vibration to generate passive wave phenomena such as string mechanical vibration and wind-driven surface water ripples; passive-wave propagation fully relies on continuous observable-particle bulk media, with entire wave behavior dictated by externally imposed passive force magnitude and directional distribution. Physical fields primarily describe effective acting range and spatial intensity variation of passive-wave-driven interparticle interactions.

Unification of Field and Force: Dynamic Mechanism of Wave-Field Propagation

Conventional physics artificially decouples force and field concepts (interpreting force as direct interbody interaction and field as standalone medium transmitting distant force), causing fragmented disciplinary research and obstructing historic progress toward wave-field unification. Within the proposed framework, field and force achieve essential ontological unification: every physical field mathematically models the spatial action mechanism of a corresponding fundamental interaction force, with distinct interaction types mapping to uniquely defined field varieties; spatiotemporal field evolution directly reflects force's variable intensity and effective coverage range. Simultaneously, bulk field propagation physically corresponds to coordinated collective oscillation of mixed aether and observable particles, meaning all field transmission intrinsically proceeds via propagating wave modes to realize dynamic unification between field and wave ontology.

Specific mapping relations hold: gravitation ↔ gravitational field; electromagnetic force ↔ electromagnetic field; strong nuclear interaction ↔ strong-interaction field; weak nuclear interaction ↔ weak-interaction field. Analogous to conventional passive-force/field matching rules, this work introduces the innovative active-field definition to quantitatively characterize spatial distribution of intrinsic active force's interaction mechanism. Gravitational and electromagnetic field propagation physically equals oscillatory wave transmission within ambient air-particle assemblies, and field superposition phenomena are essentially equivalent to linear superposition of underlying constituent propagating waves.

CORE UNIFICATION OF WAVES AND FIELDS: TRIPLE UNIFICATION OF MOTION FORM, ACTION MECHANISM, AND MATERIAL CARRIER

Built upon preceding ontological definition, layered material-existence partitioning and dual-force essence elaboration, this chapter details the paper's central innovation: completing triple-aspect unification of waves and fields across kinematic form, interaction mechanism and shared material carrier.

Historical Evolution of Wave and Field Concepts

Wave and field conceptual development spans the full maturation trajectory of modern physics from classical Newtonian mechanics to contemporary quantum theory, accompanied by successive paradigm revision and recurring systematic cognitive bias formation.

Wave Concept Evolution

Initial wave definition arose from empirical observation of macroscopic mechanical surface waves: Archimedes first qualitatively described hydraulic wave propagation without formal mathematical formulation; Huygens [16] pioneered classical mechanical wave optics interpreting visible light as elastic mechanical oscillation propagating within universal aether, establishing the first systematically structured wave ontology; Maxwell [8] constructed comprehensive electromagnetic field theory unifying optical and electromagnetic wave phenomena while retaining aether as the hypothesized underlying propagation medium yet distinguishing electromagnetic waves from conventional elastic mechanical oscillation.

Early 20th-century paradigm shifts reshaped wave ontology drastically: Einstein's special relativity formally discarded stationary luminiferous aether to permit electromagnetic-wave propagation across empty vacuum space [13]; quantum mechanics introduced wave-particle duality extending wave definitions toward microscopic domains yet rejected objective physical reality for standalone propagating waves. De Broglie's 1920s pilot-wave hypothesis posited wavefunctions as real physical spatial fields guiding deterministic particle trajectories to preliminarily restore coexisting wave-particle objective reality [6]. BM later rigorously formalized de Broglie's original conjecture to consolidate realist pilot-wave framework confirming wave's objective physical existence independent of measurement disturbance (de Broglie-Bohm theory) [6,7]. UCST further advances this realist tradition by explicitly defining bulk waves as emergent collective particulate coordinated motion to deliver original physical interpretation for spontaneous wave generation [3,4].

Field Concept Evolution

The field notion originated as a theoretical alternative to Newtonian action-at-a-distance gravitational modeling [17], which dominated gravitational physics for nearly two centuries without invoking intermediate transmission medium. Faraday [18] first proposed the empirical field concept from electromagnetic induction experimental findings, defining electromagnetic field as objectively existing material medium mediating distant electromagnetic coupling and abolishing nonlocal action-at-a-distance assumption. Maxwell

extended Faraday's field framework into complete quantitative electromagnetism, unifying field spatial variation and electromagnetic wave propagation into consistent theoretical architecture [8].

Twentieth-century theoretical breakthroughs further enriched field definition: Einstein's general relativity reinterprets gravitational field via intrinsic spacetime geometric curvature [19]; quantum field theory extends field formalism into microscopic quantum domains by treating elementary particles as discrete field-excitation states yet leaves field's intrinsic physical essence ambiguously defined. UCST resolves such ambiguity by redefining physical field as quantitative descriptor for wave-mediated interparticle interaction mechanics, clarifying field ontology and supplying rigorous conceptual foundation for follow-up unified modeling [3,4].

Key Nodes of Cognitive Bias in Waves and Fields

From combined UCST and BM interpretive perspective, three pivotal historical cognitive biases distorted conventional wave/field understanding, stemming from restrictive ontological presuppositions, limited experimental detection capability and artificially isolated conceptual definition rules.

First Bias: Mechanical Waves/Fields Limitations (17th-Early 19th Centuries)

Under dominant classical mechanical worldview, all wave and field phenomena were indiscriminately reduced to elastic mechanical oscillation requiring tangible mechanical propagation medium and direct contact interaction for field-mediated force transmission (Huygens' light-as-mechanical-aether-wave hypothesis, implicit mechanical assumption embedded within Newtonian action-at-a-distance gravity). Rooted in rigid mechanistic monism, such bias ignored nonmaterial mental substance and intrinsic spontaneous particle self-motion, incapable of coherently explaining non-mechanical wave varieties including electromagnetic radiation.

Second Bias: Non-Realist Wave-Particle Duality Interpretation (Early-Mid 20th Century)

Einstein's photoelectric-effect interpretation confirmed light's corpuscular nature, prompting orthodox quantum mechanics to formulate observation-dependent wave-particle duality denying inherent objective reality for standalone waves and particles; Einstein's subsequent rejection of classical aether further removed required propagation medium for electromagnetic waves to exacerbate long-standing conceptual confusion. Such interpretive bias originates from excessive positivist empiricism equating undetectability with non-existence plus artificial separation of complementary particle/wave definitions, failing to identify bulk waves as emergent collective particulate coordinated motion.

Third Bias: Isolated Field/Wave Study (Mid-20th Century-Early 21st Century)

Quantum field theory extended field mathematics into microscopic domains yet never explicitly defined field's core physical essence, maintaining fragmented separate research

across waves, particles and fields and leaving fundamental questions on wave generation and field propagation unresolved. Restricting all natural interactions exclusively within four passive fundamental forces ignores intrinsic active interaction force, disabling consistent interpretation of spontaneous active-wave formation within animate systems and introducing systematic classification bias for natural wave modes. Such theoretical fragmentation traces back to monistic materialist ontology rejecting nonphysical mind substance plus absence of complex-systems holistic perspective overlooking wave's emergent collective-behavior origin.

Bias Correction Key: UCST and BM Integration (21st Century)

UCST overcomes monistic materialism's ontological bottleneck via dual substance ontology and intrinsic active-force theory to rationalize spontaneous animate-matter motion and endogenous active-wave excitation; BM restores objective physical reality for both particles and propagating waves to abandon anti-realist measurement-dependent duality. Their organic integration supplies core corrective framework: waves = synchronized collective particulate motion; fields = quantitative mechanism describing interparticle wave-mediated interaction; air-particle assemblies = universal propagation medium for all wave/field modes; dual active/passive interaction forces constitute divergent dynamic origins for two distinct wave categories, reconstructing logically consistent unified interpretation for wave and field ontology.

Three Dimensions of Wave-Field Unification

Following above historical bias rectification plus established ontology, layered material hierarchy and dual-force essence rules, complete wave-field unification is realized across three interdependent dimensions.

Motion Form Unification: Waves as Collective Particle Motion, Fields as Wave Action Descriptions

The core foundational premise for full wave-field unification states all natural waves originate from synchronized collective motion of discrete particulate constituents: microscopic electromagnetic and matter pilot waves emerge from coordinated vibration of ultrafine aether-particle ensembles, while macroscopic mechanical/hydraulic waves derive from bulk synchronized oscillation of observable condensed-phase particle aggregates. Core wave parameters (frequency, wavelength, propagation speed) are uniquely determined by individual constituent particles' intrinsic vibrational amplitude and oscillation frequency, consistent with BM pilot-wave postulates plus classical vibration-wave mechanics.

Planck's energy-frequency relation ($E = h\nu$) and de Broglie matter-wavelength formula ($\lambda = h/p$) correlate single-particle intrinsic oscillation and resultant ensemble collective-wave properties yet contain a systematic factor-of-two discrepancy induced from inconsistent mixing of classical and relativistic mechanical frameworks. Within this theory's deduction, finite photon rest mass m_0 is introduced while retaining experimentally validated Planck's law $E = h\nu = \frac{1}{2}m_0v^2$,; combining classical momentum definition $p = m_0v$

plus wave-speed identity $v = \lambda\nu$ yields corrected relation $\lambda = 2h/p$, differing from original de Broglie formulation by a constant factor of two. Planck's and de Broglie's core hypotheses prove mathematically equivalent after framework unification, with the missing prefactor originating from hybrid relativistic-classical derivation errors; pure classical mechanics suffices to quantitatively interpret blackbody radiation and generalize across all matter-wave varieties, enabling rigorous mathematical mapping between individual particle vibration and resultant bulk collective-wave evolution.

All physical fields essentially quantify effective spatial range and intensity distribution of underlying wave-mediated interparticle interaction: fields ontologically originate from collective particulate wave excitation (propagating waves supply indispensable material substrate for field formation); bulk field propagation strictly duplicates underlying constituent wave transmission rules; inter-field superposition directly corresponds to linear superposition of their respective source waves. For instance, gravitational/electromagnetic field spatial diffusion physically equals oscillatory wave propagation within ambient air-particle assemblies, and field superposition phenomena fully reduce to constituent-wave superposition effects, remedying inherent interpretive deficiencies within original Maxwell electromagnetic formalism.

Action Mechanism Unification: Force as Wave-Field Interaction Core, Active/Passive Waves Corresponding to Distinct Field Modes

Interaction force constitutes the core driving variable governing all wave-field coupling; active and passive wave varieties individually correspond to differentiated field-action modes whose synergistic combination composes the complete unified wave-field interaction architecture.

- **Active waves:** Excited via generalized animate agents' endogenous active force, their matching active fields (microscopic mind-induced particle fields, cosmic-scale gravitational fields) feature autonomous directional evolution partially governed by animate matter's inherent mind-driven free will. For example, individual photons categorized as generalized animate particles execute spontaneous intrinsic vibration to initiate propagating electromagnetic waves whose transmission direction follows intrinsic autonomous particle kinematics consistent with UCST active-force rules. Active wave-field coupling features bidirectional dynamic feedback: spatiotemporal field variation modulates constituent particle vibration characteristics, and altered particle oscillation in turn reshapes global field distribution to form complex closed-loop interactive systems embodying UCST's whole-part complex-system emergence property.
- **Passive waves:** Generated from forced oscillation under external passive interaction upon inanimate matter, their corresponding passive fields (mechanical-medium contact fields, liquid-surface hydraulic fields) follow strict linear superposition rules with deterministic evolution fully dictated by externally applied passive force's magnitude and directional layout. Passive wave-field interaction follows unidirectional causality: external force initiates particle vibration to produce propagating passive waves whose subsequent transmission modifies field spatial distribution without retroactively altering the original passive excitation source.

All cross-scale wave-field interactions ultimately rely on synergistic coupling between active/passive wave modes and their respective associated fields. Wave interference and superposition directly trigger equivalent field superposition and interference patterns, which conversely adjust constituent particle collective vibration and resultant wave propagation features to form closed bidirectional feedback loops. Such dual-direction coupling represents core macroscopic manifestation of UCST-defined complex-system holistic emergence, unifying seemingly unrelated microscopic quantum wave-field dynamics and macroscopic classical continuum wave behaviors within identical interaction formalism.

Material Carrier Unification: Air Particles as the Common Foundation of All Wave-Fields

Full wave-field unification fundamentally depends upon a single hierarchically structured universal material substrate supporting all cross-scale wave propagation and field interaction. Within this theoretical construction, unified air-particle assemblies fulfill such foundational carrier requirement, with apparent classification divergence between observable/aether particles emerging exclusively from contemporary instrumental detection limitations rather than inherent physical property disparity. Both particulate subtypes abide by identical kinematic, interaction and collective-vibration rules universally governed by dual active/passive force framework, eliminating artificial quantum/classical medium ontological separation embedded inside conventional physics.

As pervasive undetectable microscopic particulate aggregate filling all observable spatial domains, aether constitutes the fundamental propagation substrate for cosmic-scale fundamental waves (electromagnetic/gravitational radiation) plus their matching intrinsic physical fields, negating absolute-vacuum postulation and redefining physical vacuum as extremely dilute gaseous aether distribution to resolve the historic “medium-free wave propagation” theoretical paradox afflicting both classical and quantum field theories. Distinct from rigid static 19th-century classical mechanical aether, the paper’s aether forms dynamically self-organized complex animate-particle system equipped with intrinsic active force whose holistic interconnection naturally reproduces BM pilot-wave nonlocal features.

Such apparent quantum nonlocality emerges as measurable physical consequence from global ambient air-medium holistic constraint over localized discrete-particle motion rather than abstract mathematical axiom; UCST preserves fundamental locality postulate by positing interparticle coupling intensity decays gradually with spatial separation, interpreting quantum entanglement as ultra-slow interaction attenuation instead of abandoning local-interaction premise. Locality approximation becomes indispensable for physical modeling because theoretical system construction deliberately neglects negligible long-distance contributions from far-field external objects.

Observable particles cover all experimentally resolvable microscopic (atoms, molecular clusters) and macroscopic condensed bulk/stellar entities as localized stable aggregation configurations of base air-particle units to form higher-order hierarchical material structures within the unified observable-world particulate system. Synchronized collective vibration of aggregated observable particles generates all macroscopic mechanical/hydraulic wave modes, while their mutual passive pairwise interactions produce

corresponding macroscopic contact fields whose kinematic behaviors fully depend on measurable intrinsic material parameters (mass density, elastic modulus, hardness).

Critical cross-scale unification originates from bidirectional dynamic coupling between aether and observable particle subsystems enabling consistent microscopic-macroscopic wave-field coherence: submicroscopic aether collective oscillation transmits dual active/passive interaction to observable-particle aggregates to trigger resultant macroscopic wave-field phenomena; reversely, large-scale macroscopic field spatial variation feeds back downward to modulate underlying aether particles' intrinsic active/passive coordinated motion. Such bidirectional coupling strictly complies with UCST holistic-local interaction postulate to guarantee uniform physical laws across all spatial scales spanning ultrafine aether particle up to cosmic stellar dimension.

Furthermore, phase variation of combined aether-observable particle bulk systematically modulates resultant wave-field macroscopic manifestation to reinforce unified carrier consistency: sparse gaseous-dominated systems (rich in free aether and dilute observable particles) feature active-force-governed wave-field behavior marked by discrete particle fluctuation and long-range field diffusion; dense liquid/solid condensed systems dominated by aggregated observable particles follow passive cohesive-force rules generating short-range constrained macroscopic wave/field distribution. Regardless of ambient thermodynamic phase, core ontological essence remains invariant: all wave-field phenomena emerge from coordinated motion and pairwise interaction of unified air-particle material substrate [9].

Mathematical Unification: General Wave Equations and Their Degeneration to Classical / Quantum Core Equations

To mathematically formalize triple unification across kinematic form, interaction mechanism and shared material carrier, this work deduces phase-dependent universal master wave equations starting from generalized dual-force Newton's second law governing unified air-particle systems, then rigorously proves mathematical degeneration toward core governing formulas of classical electromagnetism (Maxwell's equations) and quantum Bohmian mechanics under specified physical limiting conditions, completing final mathematical unification between classical continuum and quantum microscopic wave-field dynamics.

General Wave Equations for Gas, Liquid, and Solid Phases (Unified Particle System)

Extending single-particle dual-force Newton's law $m \frac{d^2 \vec{r}}{dt^2} = \vec{F}_a + \vec{F}_p$ into continuum bulk kinematics via defining ensemble-averaged continuum displacement field $\vec{u}(\vec{r}, t)$ plus introducing bulk mass density $\rho = nm$ and Cauchy stress tensor $\vec{\sigma}$, the universal continuum force-balance equation reads:

$$\rho \frac{\partial^2 \vec{u}}{\partial t^2} = \nabla \cdot \vec{\sigma} + \rho \vec{f}_a + \rho \vec{f}_p, \quad (12)$$

where $\vec{f}_a$, $\vec{f}_p$ respectively denote volume-specific active and passive body force densities. Targeted simplification per unique phase-specific physical features (negligible

gaseous shear stress, strong condensed-phase cohesive binding, active-force gaseous dominance versus passive-force condensed-phase dominance) yields three sets of phase-specific master wave equations detailed in Section 3.1; uniform mathematical structural form is preserved across all thermodynamic phases with only dynamic coefficients (wave propagation speed, effective force density) varying continuously to guarantee smooth mathematical transition during cross-phase transformation.

Degeneration to Maxwell's Equations (Gaseous Air, Charged Particles)

For dilute charged gaseous air systems supporting electromagnetic-wave propagation, three physical constraint approximations enable master gaseous-wave-equation reduction into canonical Maxwell formulations: (1) intrinsic active force converts fully into stored electromagnetic energy to satisfy $\vec{f}_a \approx 0$; (2) continuum displacement field $\vec{u}$ is mapped onto classical electromagnetic vector potential $\vec{A}$; (3) characteristic gaseous wave speed fixed to vacuum light speed c determined by inherent aether-particle bulk properties. Reduced vector-potential wave equation:

$$\nabla^2 \vec{A} - \frac{1}{c^2} \frac{\partial^2 \vec{A}}{\partial t^2} = \mu_0 \vec{J}, \quad (13)$$

Combined with transverse-wave divergence constraints ($\nabla \cdot \vec{E} = 0$, $\nabla \cdot \vec{B} = 0$) plus Ampère-Maxwell constitutive relation recovers complete canonical Maxwell equation set. Such mathematical reduction rigorously confirms classical electromagnetic field theory constitutes a special limiting case of the unified wave-field formalism: electromagnetic fields physically represent synchronized collective vibration of charged air particles under passive electromagnetic coupling, with Maxwell's formulas quantitatively describing such coordinated motion within macroscopic continuum limit.

Degeneration to BM Equations (Gaseous Air, Uncharged Massive Particles)

For uncharged massive microscopic gaseous-particle systems generating quantum pilot-wave dynamics, three quantum transformation rules reduce universal gaseous wave formula into core BM governing relations: (1) continuum displacement field $\vec{u}$ is substituted by Bohmian complex pilot-wave function $\psi = \psi_0 e^{iS/\hbar}$ (S = classical particle action functional); (2) intrinsic active force term is redefined as quantum potential $V = \frac{1}{2} m \omega_0^2 |\psi|^2$ functioning as pilot-wave guiding potential source; (3) classical time partial derivative replaced by canonical quantum Hamiltonian operator $i\hbar \frac{\partial}{\partial t} = -\frac{\hbar^2}{2m} \nabla^2 + V$. Final reduced coupled BM system includes deterministic particle-trajectory guiding equation and time-dependent Schrödinger wave equation:

$$\begin{cases} \frac{d\vec{q}}{dt} = \frac{\hbar}{m} \nabla \text{Im}(\ln \psi) \\ i\hbar \frac{\partial \psi}{\partial t} = -\frac{\hbar^2}{2m} \nabla^2 \psi + V(\vec{r}, t) \psi \end{cases}, \quad (14)$$

This degeneration proves Bohmian quantum mechanics mathematically originates as constrained limiting case of unified wave-field theory: quantum pilot waves correspond to coordinated collective oscillation of uncharged massive air particles under combined active

quantum potential and passive interparticle interaction, with the Schrödinger equation supplying standardized quantum mathematical description for such underlying particulate collective dynamics.

Dynamic Coupling of UCST and BM: Resolving Non-Locality and Scale Barriers

Mathematical unification of cross-regime wave-field dynamics builds upon organic dynamic synergy between UCST and BM beyond superficial theoretical splicing, resolving two long-standing core obstacles in conventional physics: puzzling quantum nonlocality and artificial classical-quantum scale divide.

1. **Physical origin of quantum non-locality:** Orthodox standard quantum mechanics treats nonlocality as counterintuitive pure mathematical property lacking concrete mechanical physical interpretation. Contrastingly, the unified theory strictly maintains fundamental locality postulate and rationalizes measured quantum entanglement via two concrete physical mechanisms: ultra-slow spatial decay of propagating interparticle interaction and finite superluminal transmission permitted within ambient air-particle medium. Global interconnected animate air-particle complex system featuring universal intrinsic active force imposes holistic boundary constraint over all localized discrete observable particles to simultaneously regulate pilot-wave spatial distribution and individual particle deterministic trajectory; this framework substitutes abstract nonlocal quantum action-at-a-distance with tangible medium-mediated particulate interaction consistent with available Bell inequality experimental validation data (which confirm measurable nonlocal outcome without pinpointing underlying physical generation mechanism).
2. **Seamless classical-quantum scale transition:** Traditional physics arbitrarily partitions natural laws into mutually exclusive microscopic quantum and macroscopic classical regimes governed by unrelated mathematical formalisms. The paper's layered air-particle carrier architecture plus continuous phase-dependent master wave equations enable smooth cross-scale physical-law transition varying monotonically with system particle density: rarefied dilute gas dominated by discrete animate particles and intrinsic active force fully complies with BM quantum pilot-wave rules; intermediate-density gas features balanced active/passive coupling triggering spontaneous particulate self-organization into ordered mesoscopic structures; dense condensed bulk governed by aggregated observable particles and dominant passive force naturally converges toward classical Newtonian continuum mechanics. No abrupt physical-law mutation occurs at critical spatial thresholds; only gradual variation of core dynamic parameters including active/passive force ratio and bulk particle density drives continuous regime shift.
3. **Self-organization of coherent wave-field structures:** Standard BM formalism describes deterministic particle motion guided by preexisting pilot-wave configurations yet fails to explain spontaneous origination of stable quantum eigenstates and coherent wave structures (atomic discrete energy levels, periodic wave interference patterns). Within this unified framework, open dissipative air-particle complex systems undergo spontaneous self-organization under synergistic active/passive force interaction: disordered chaotic individual particle vibration aggregates into localized stable discrete particle eigenstates and ordered coherent

pilot-wave fields, rationalizing quantum energy quantization and wave coherence under fully deterministic realist physical paradigm without Copenhagen probabilistic measurement interpretation.

THEORETICAL VALUE AND INTERDISCIPLINARY IMPLICATIONS

Theoretical Value in Fundamental Physics

This theoretical framework delivers four prominent contributions to fundamental physics: it addresses the long-standing ontological predicament in quantum physics by reaffirming the objective physical reality of particles and propagating pilot waves and furnishing a physically substantiated aether-particle medium for pilot-wave propagation; it integrates fragmented formalisms of classical and quantum field theories within a unified master wave-equation framework to facilitate further investigations into grand unified field theories; it rectifies three critical historical cognitive misconceptions accumulated throughout the conceptual evolution of waves and fields in the development of modern physics; and it extends the established classification of fundamental physical interactions through the introduction of intrinsic active force, which offers a consistent physical explanation for spontaneous autonomous motion spanning all cosmic scales from subatomic particles to entire galactic systems.

Interdisciplinary Implications

This theory bears far-reaching interdisciplinary implications across multiple research fields: in cosmology, its unified ontology of air particles enables a coherent explanation for dark matter and dark energy without postulating arbitrary, undiscovered exotic elementary particles; in condensed matter physics, collective quasiparticle excitations are reinterpreted as localized disturbances travelling through the underlying complex system of ambient air particles; in biophysics, the dual framework of active and passive forces establishes a unified theoretical basis connecting spontaneous biological movement of organisms to the intrinsic autonomous motion of physical particles; and within the philosophy of science, it revises the demarcation standard for empirical science and incorporates a rigorous dual-substance ontology into the mathematical formulation of physical theories.

CORE INNOVATIONS OF THE THEORY

- 1. Ontological Innovation:** Organic fusion of UCST dualistic ontology plus BM realist postulates establishing universal air-particle unified wave/field carrier framework.
- 2. Mathematical Innovation:** Derivation of phase-dependent universal master wave equations achieving analytical unification between classical continuum and quantum microscopic dynamic formulas.
- 3. Dynamic Innovation:** Establishment of dual active/passive force classification system plus corresponding active/passive wave excitation taxonomy.

4. **Epistemological Innovation:** Precise definition of empirical science's observable boundary and systematic rectification of historic wave/field cognitive misunderstandings inherited across physics development.
5. **Paradigmatic Innovation:** Reformulates quantum phenomena as emergent complex-system effect originating from active/passive force coupling, replacing orthodox probabilistic measurement-dependent and nonlocal quantum interpretations with deterministic realist physical mechanism.

CONCLUSION AND FUTURE OUTLOOK

This manuscript constructs a complete unified wave-field theoretical architecture via integrating UCST complex-system postulates and BM realist quantum mechanics, accomplishing triple-aspect unification of waves and fields at kinematic form, interaction mechanism and shared material carrier alongside analytical mathematical unification via phase-dependent master wave formulas. The paper's core concluding proposition reads: bulk propagating waves emerge from synchronized collective motion of discrete particulate constituents, while physical fields quantitatively formalize interparticle interaction mechanics underlying wave transmission; such core definition resolves multiple long-standing theoretical contradictions troubling contemporary fundamental physics.

Follow-up research directions include high-precision targeted experimental verification of core theoretical predictions, framework expansion toward relativistic physical regimes, systematic fusion with mainstream quantum field theory, detailed cosmic-modeling construction and further mathematical optimization of the present unified governing-equation architecture. This theory supplies an original deterministic realist research paradigm for ongoing fundamental-physics unification efforts with broad cross-disciplinary application prospect.

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Abbreviations: The following abbreviations are used in this manuscript:

- UCST: Unified Complex Systems Theory
- BM: Bohmian Mechanics

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