International Journal of Quantum Foundations **12** (2026) 55–98

Original Paper

Toward a Unified Framework of Physics: Insights from Dialectics, Quantum Theory, and Relativity

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Received: 14 September 2025 / Accepted: 3 June 2026 / Published: 6 June 2026

Abstract: One of the greatest unresolved problems in physics is the measurement problem in quantum mechanics where the role of observer-dependent phenomena or emergent properties is not fully accounted for. Another major area of research concerns our limited understanding of entanglement, a phenomenon where a change in particles in one location changes the particles in another location, even when separated by a large distance. The application of dialectics to interpret and understand the relevance of natural and physical phenomena is rapidly increasing, providing key new insights into the measurement problem and quantum entanglement. The central thesis of dialectics is its demonstration of how opposing states or parts synthesize together to create one greater whole system. Therefore, the authors present a review of the principles and latest research on dialectics and the role they play in understanding entanglement and quantum mechanics. Furthermore, we provide a comprehensive and critical comparison of the most relevant theories on quantum physics and relativity, highlighting the major research gaps in existing literature, and highlighting the potential broader significance of a dialectical approach. This review will lay the groundwork for developing a more comprehensive framework that can describe phenomena across all scales, from the subatomic to the cosmic. This understanding could lead to new insights into the nature of space, time, and matter, potentially unlocking advancements in fields such as quantum gravity, cosmology, and high-energy physics.

Keywords: Dialectics, opposites, thesis, quantum states, quantum system, synthesis

1. Introduction

Quantum physics provides a fundamental framework for describing matter, energy, and their interactions at microscopic scales [1]. The theory is based on well-established principles, including the Schrödinger equation governing the time evolution of quantum states, the de Broglie relation underlying wave–particle duality, and the Planck–Einstein relation connecting energy and frequency.

The dynamics of a quantum system are described by the Schrödinger equation,

$$i\hbar\, \partial\psi(\mathbf{r}, t)/\partial t = \hat{H}\psi(\mathbf{r}, t), \tag{1}$$

where $\hbar$ is the reduced Planck constant, $\psi(\mathbf{r}, t)$ is the wavefunction, t is time, and $\hat{H}$ is the Hamiltonian operator. This equation provides the standard mathematical framework for the time evolution of quantum states and forms the basis for understanding a wide range of quantum phenomena [2, 3, 4, 5]. Within this formalism, physical observables are derived from the wavefunction, while measurement outcomes are described probabilistically. The Born rule connects the quantum state to experimentally measurable quantities [6].

$$P(x) = |\Psi(x)|^2, \quad (2)$$

where $P(x)$ is the probability density of finding the particle at position x. $\Psi(x)|$ is the wavefunction of the quantum system at position x. Wave–particle duality is one of the central conceptual features of quantum mechanics and reflects the coexistence of complementary physical descriptions within a single theoretical framework [7, 8, 9]. In this context, the relationship between wave-like and particle-like descriptions can be viewed as a *dialectical structure*, where seemingly opposing classical pictures emerge from a unified quantum state.

This coexistence can be represented schematically as a superposition of complementary contributions,

$$\Psi = \alpha\Psi\text{wave} + \beta\Psi\text{particle}, \quad (3)$$

with normalization conditions

$$|\alpha|^2 + |\beta|^2 = 1. \quad (4)$$

Here, Ψ_{wave} and Ψ_{particle} denote different representational components of the same quantum state in an appropriate basis, while α and β quantify their relative contributions. From this perspective, wave and particle descriptions may be regarded as *opposites* in a classical sense, whereas quantum mechanics provides their unified description through the state vector. This “synthesis of opposites” is therefore not an additional physical principle, but an interpretative reflection of the standard Hilbert space structure of quantum theory.

Despite the success of this formalism, several foundational issues remain open. In particular, the interpretation of quantum measurement, the emergence of definite outcomes from superposition states, and the relation between complementary representations and physical reality continue to be actively debated. These challenges are especially evident in discussions of entanglement and the quantum-to-classical transition.

In this context, the present work emphasizes a structured representation of complementary quantum descriptions within a unified framework, highlighting the dialectical relationship between different physical pictures encoded in the wavefunction. The formulation remains fully consistent with standard quantum mechanics and does not modify its mathematical structure. Instead, it provides a compact interpretational viewpoint that clarifies how complementary descriptions arise from the same underlying quantum state.

1.1. **History of some of the major contributions to understanding quantum mechanics** Young created the basic idea for what is now considered the famous double-slit experiment [10]. In this experiment, a beam of particles (photons or electrons) is incident on a barrier containing two narrow slits, and the resulting intensity distribution is recorded on a detection screen. If the particles behaved classically, one would expect the total probability distribution to be given by an incoherent sum,

$$P(x) = P_1(x) + P_2(x), \tag{5}$$

where $P_1(x)$ and $P_2(x)$ correspond to the probabilities associated with each slit.

However, quantum mechanically the total wavefunction is given by the coherent superposition

$$\Psi(x) = \Psi_1(x) + \Psi_2(x), \tag{6}$$

and the observed intensity (probability density) on the screen is

$$P(x) = |\Psi(x)|^2 = |\Psi_1(x) + \Psi_2(x)|^2. \tag{7}$$

Expanding this expression yields

$$P(x) = |\Psi_1(x)|^2 + |\Psi_2(x)|^2 + 2\,\mathrm{Re}[\Psi^*(x)\Psi_2(x)]\,, \tag{8}$$

where the last term represents the interference contribution responsible for the observed fringe pattern. In contrast, when a which-path measurement is performed (i.e., when the particle is observed to determine which slit it passes through), the interference term is effectively suppressed due to decoherence or wavefunction collapse, leading to

$$P(x) \rightarrow |\Psi_1(x)|^2 + |\Psi_2(x)|^2. \tag{9}$$

This experiment was confounding in that when an observer or measurement apparatus is present, the interference pattern disappears and a particle-like distribution is obtained, whereas in the absence of which-path information a wave-like interference pattern emerges. This behavior is typically associated with the measurement process in quantum mechanics, where the act of observation is modeled as an interaction between the system and a measuring device that destroys phase coherence between quantum paths.

Therefore, according to Young's results and their quantum mechanical interpretation, measurement plays a crucial role in determining the observed outcome. However, the underlying mechanism by which quantum coherence is lost during observation constitutes the measurement problem in quantum mechanics. Young's contribution helped establish the wave theory of light and later wave mechanics, but it did not address the dynamical origin of measurement-induced decoherence or wavefunction collapse.

A set of ideas regarding the interpretation of quantum mechanics, developed through the work of Niels Bohr, Werner Heisenberg, and Max Born, became known as the Copenhagen interpretation [11]. It remains one of the most widely used conceptual frameworks for understanding quantum phenomena [1]. In this interpretation, a quantum system is described by a wavefunction that can exist in a superposition of multiple possible states prior to measurement. More precisely, the state of a system is represented as

$$\Psi = \sum_i c_i \psi_i \tag{10}$$

where ψ_i are the eigenstates of an observable and c_i are complex probability amplitudes satisfying $\sum_i |c_i|^2 = 1$. Upon measurement, the probability of obtaining a particular outcome ψ_k is given by

$$P_k = |c_k|^2, \tag{11}$$

in accordance with the Born rule.

In the Copenhagen interpretation, the measurement process is associated with a transition from a superposition of states to a single observed outcome, commonly referred to as wavefunction collapse. This implies that the act of measurement plays an essential role in determining the observed physical state of the system.

This framework significantly advanced the understanding of quantum phenomena by providing a consistent operational prescription for predicting experimental outcomes. However, it is fundamentally probabilistic in nature: it does not assign definite properties to physical systems prior to measurement, but instead only provides probability distributions for possible outcomes.

A key limitation of the Copenhagen interpretation is that it does not provide a dynamical description of either the origin of superposition or the mechanism of wavefunction collapse. As a result, the measurement process itself is introduced as an additional postulate rather than derived from the underlying unitary evolution of the Schro¨dinger equation.

Erwin Schr¨odinger formulated a thought experiment to demonstrate the issues he identified in the Copenhagen interpretation of quantum mechanics [12]. Schr¨odinger challenged the notion that a quantum system is physically distributed across the different components of a superposition. In his thought experiment, Schr¨odinger proposed placing a cat in a sealed box, along with a vial of poison, such that the cat's state remained hidden from observers [13]. The vial of poison is set to break and kill the cat if a specific quantum event, such as the decay of a radioactive atom detected by a Geiger counter, occurs [14]. Since radioactive decay is probabilistic and cannot be predicted for individual cases, the experiment lacks a means to determine whether the decay—and consequently, the vial's breaking—has happened, leaving the cat's fate indeterminate [14]. Schr¨odinger's thought experiment challenged the notion that a quantum state exists in superposition when not observed, arguing that the cat in the box could not possibly exist in multiple states despite being unseen. Schro¨dinger's experiment challenged Copenhagen's interpretation that the wave function collapse relies on observation [1]. While Schro¨dinger did not propose an alternative explanation for quantum mechanics, his cat thought experiment remains a crucial reference point for contemporary interpretations of the theory.

David Bohm introduced the concept of quantum decoherence, describing it as the "destruction of interference in the process of measurement" [15]. Quantum decoherence occurs when a quantum state interacts with its environment, causing the system to become entangled with that environment [15]. Formally, the combined system–environment state is described by a pure state $|\Psi_{SE}\rangle$, and the effective state of the system alone is obtained by tracing out the environment:

$$\rho_S = \mathrm{Tr}_E\left(|\Psi_{SE}\rangle\langle\Psi_{SE}|\right), \tag{12}$$

where ρ_S is the reduced density matrix of the system, Tr_E denotes the partial trace over environmental degrees of freedom, and $|\Psi_{SE}\rangle$ represents the joint system–environment state.

In the presence of environmental interaction, the off-diagonal elements of the density matrix decay over time:

$$\rho_{(ij)(t)} \approx (-\Gamma\, t)\,, \tag{13}$$

where $\rho_{ij}(t)$ are matrix elements of the system density matrix, t is time, and Γ is the decoherence rate characterising the strength of the system–environment interaction. The off-diagonal terms ($i \models j$) represent quantum interference, while the diagonal terms correspond to classical probabilities. A more general description of the dynamics of an open quantum system is given by the Lindblad master equation:

$$\frac{d\rho}{dt} = -\frac{i}{\hbar}[H,\rho] + \sum_k \left(L_k\rho\, L_k^\dagger - \frac{1}{2}\left(L_k^\dagger L_k\rho \,+\, \rho\, L_k^\dagger L_k\right)\right), \tag{14}$$

where ρ is the density matrix of the system and H is the Hamiltonian governing unitary evolution. The first term, $-\frac{i}{\hbar}[H,\rho]$, describes coherent Schr¨odinger evolution through the commutator $[H, \rho] = H\rho - \rho H$. The second term accounts for non-unitary effects due to the environment. Here, the operators L_k, known as Lindblad or jump operators, represent different decoherence or dissipation channels, and the summation runs over all such channels. The expression $\{L^\dagger L_k, \rho\}$ denotes the anticommutator, defined in general for operators A and B as $\{A, B\} = AB + BA$. Despite its success as a general framework for open quantum systems, there remains ongoing debate about whether decoherence alone fully resolves the quantum measurement problem.

The Ghirardi–Rimini–Weber (GRW) theory was the first spontaneous collapse model, leading to the development of several similar models in the following years [9]. The core idea behind collapse theories is that particles undergo spontaneous wave-function collapses, occurring randomly in both time and space. This approach avoids the ambiguous "observer" and "measurement" issues inherent in earlier interpretations, as the wave function collapses independently of observation.

In the density-matrix formulation, the GRW dynamics can be written as a modified master equation of the form:

$$\frac{d\rho}{dt} = -\left(\frac{i}{\hbar}\right)[H,\rho] + \lambda\, \Sigma\, (i \;=\; 1\; to\; N)\left(\int \quad L_{i(x)\rho} L_i^{\dagger(x)d^{3x}} - \rho \right), \tag{15}$$

where H is the Hamiltonian governing the unitary evolution, λ is the collapse rate per particle, N is the number of particles, and $L_i(x)$ is the localization (collapse) operator acting on particle i, given by

$$L_{i(x)} = \left(\frac{1}{2\pi a^2}\right)^{\frac{3}{4}} exp\,\left(-\frac{(x_i - x)^2}{4a^2}\right). \tag{16}$$

Here, x_i denotes the position operator of the i-th particle, x is the randomly selected collapse centre, and a is the characteristic localization length scale of the theory. The integral over x reflects the stochastic nature of collapse events distributed continuously in space. By introducing the role of time and space, GRW theories contribute to the understanding of the relationship between quantum mechanics and relativity, particularly regarding time and space. However, they do not explain why when, or how a wave function collapses, only that it happens randomly [16]. Succinctly speaking, all these theories have contributed toward understanding the physical universe. However, none of them provides a specific actual way to measure a physical system.

1.2. Philosophy of dialectics

Dialectics is a philosophical framework for understanding the dynamic and often contradictory nature of processes and structures in reality. It emphasizes that systems are not static but evolve through the interaction of opposing tendencies or complementary descriptions. In this sense, dialectical structures can be understood as tensions between competing principles that jointly determine the behavior of a system. In this section, we introduce the concept of dialectics, outline its historical development, and examine its applications in philosophical and scientific contexts. We then extend these ideas to quantum physics, where similar structural features appear in the form of complementary and competing descriptions of physical states. Dialectical thinking has a strong foundation in the history of philosophy, mathematics, and science [17, 18, 19]. Across several scientific domains, the evolution of systems can be interpreted as the interaction between opposing contributions. In a simplified dynamical form, such processes may be expressed as

$$\frac{dX}{dt} = F(X) - G(X), \tag{17}$$

where $F(X)$ and $G(X)$ represent competing mechanisms that drive the evolution of system X in opposing directions. More generally, a system may be decomposed into interacting components,

$$X = X^{(+)} + X^{(-)}, \tag{18}$$

where $X^{(+)}$ and $X^{(-)}$ denote opposing or complementary contributions whose relative balance determines the observed macroscopic behavior. Such competition can also be described in terms of iterative transformation rules,

$$S_{n+1} = T(S_n), \tag{19}$$

where T represents an update operator that maps a given state S_n to a new state S_{n+1} through the reconfiguration of competing structures. More abstractly, dialectical interactions may be represented as a structured combination of components,

$$E = A \oplus B, \tag{20}$$

where A and B denote opposing or complementary elements, and $\oplus$ denotes a nontrivial composition rule capturing their interaction and emergence of a unified description. This representation provides a structured way of describing systems in which observable outcomes emerge from the interplay of competing contributions rather than from a single dominant mechanism. Similar ideas have been discussed in various contexts of scientific development and conceptual modeling [20, 21].

1.3. History of some of the major contributions to understanding dialectics

The philosophy of dialectics dates to classical antiquity, notably to Plato (428–423 BC), who developed philosophical arguments through structured dialogue and debate [22]. A well-known form is the Socratic method, which proceeds through hypothesis elimination by identifying and rejecting claims that lead to contradictions [23, 24, 25]. In a related development, Aristotle argued that knowledge emerges through structured opposition, where a thesis is confronted by its antithesis and evaluated through rational discourse [26, 27]. In this framework, the removal of inconsistency leads to progressively more robust forms of understanding.

In later philosophical development, Georg Wilhelm Friedrich Hegel formalized dialectics as a general method of philosophical inquiry in his Science of Logic [28]. The Hegelian dialectic is commonly described as a three-stage process in which a thesis is opposed by an antithesis, and the resulting contradiction is resolved at a higher level through a synthesis [28]. This synthesis integrates elements of both opposing positions, forming a new conceptual structure that can itself function as a thesis in a continuing iterative process. In this sense, dialectical development is understood as a recursive progression toward increasingly comprehensive forms of knowledge.

The study of dialectics was further extended by Friedrich Engels, who applied dialectical reasoning to natural and scientific phenomena [28]. In Dialectics of Nature, Engels formulated three general laws governing dialectical processes: the unity and conflict of opposites, the transformation of quantity into quality (and vice versa), and the negation of the negation [28]. These principles describe systems in which structural change arises from internal contradictions and iterative transformation.

This general idea can be expressed in a compact dynamical form as

$$\frac{dX}{dt} = F(X) - G(X) + \lambda C(X) \tag{21}$$

where X denotes the state of the system, $F(X)$ and $G(X)$ represent opposing contributions driving the evolution in competing directions, and $C(X)$ encodes higher-order corrective or emergent interactions arising from their coupling. The parameter λ determines the strength of these nonlinear dialectical effects. This formulation captures the idea that system evolution is governed not by a single driving mechanism, but by the interaction and tension between opposing processes.

In the late 1970s, Marsha Linehan introduced dialectical thinking into clinical psychology through dialectical behavior therapy (DBT), an evidence-based cognitive-behavioral treatment designed to help individuals regulate thoughts, emotions, and behaviors by integrating opposing psychological states [29, 30, 31]. Linehan describes three foundational and seemingly paradoxical principles of dialectics in this framework as

i. Everything opposes each other and simultaneously synthesizes together. Everything comprises contradictions or opposing states. According to the principles of polarity, two opposing forces can both be true. Reality is not static but comprises two opposing states, a thesis and antithesis, in constant motion.

ii. Everything is separate and simultaneously connected. According to the principles of inter-relatedness and wholeness, each part of a system is of limited value unless the analysis of that system relates the part to the whole. Therefore, the identity of each part of a system exists and evolves relative to its interaction with each other and relative to the system as a whole [32].

iii. Everything is incompatible with everything else and simultaneously shares a continuous transactional relationship. Change is transactional with opposing states influencing and affecting each other reciprocally. It is the conflict, tension, and friction created between the thesis and antithesis forces within each system that produces change. The new state following change (the synthesis) also comprises polar forces, and thus change is continuous [33].

1.4. Dialectics in science

Dialectics can consistently be applied to all aspects of nature and science. For instance, In genetics, two opposing strands share a transactional relationship and synthesize together to create deoxyribonucleic acid (DNA). In neuroscience, two sympathetic and parasympathetic parts exist at opposing ends of one whole continuum and synthesize together to create the central nervous system; and two right and left hemispheres exist at opposing ends of one whole continuum and synthesize together to create the brain. In cell biology, two opposing chromosomes synthesize together to create a cell. In reproduction, two opposing male and female counterparts synthesize together to create an embryo. In other words, life is literally created through the synthesis of common, interlocking truths between opposing male and female counterparts. Artificial intelligence systems synthesize information from multiple sources, reconcile overlapping or complementary evidence, and filter conflicting information based on data quality and probabilistic inference in order to generate the most coherent and accurate response possible [34, 35]. To examine more closely, all objects in the universe are made of molecules, from living to inanimate objects. Figure 1 illustrates how molecules are created through a dialectical relationship.

Molecules can be interpreted as emerging from a dialectical relationship, as illustrated in Figure 1. In the case of water formation, hydrogen and oxygen atoms represent distinct interacting states that exhibit both opposition and complementarity. First, hydrogen and oxygen possess different polar characteristics that lead to attractive and repulsive interactions. Second, they exist as separate atomic constituents while simultaneously

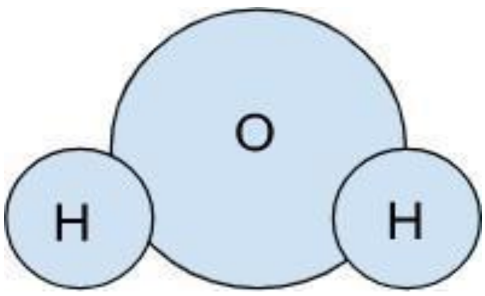

Figure 1: Illustration of the dialectical relationship in a water molecule.

forming a unified molecular structure. Third, although chemically distinct, they engage in a continuous dynamical exchange through electron sharing and electromagnetic interaction. This interaction can be represented in a simplified form using an effective coupling potential between the atoms:

$$V_{\text{int}}(r) = V_H(r) + V_O(r) + V_{HO}(r), \tag{22}$$

where $V_H(r)$ and $V_O(r)$ represent the intrinsic atomic contributions of hydrogen and oxygen, while $V_{HO}(r)$ describes the interaction potential responsible for chemical bonding. The stable molecular configuration arises when the total energy is minimized, i.e.,

$$\frac{dE_{tot}}{dr} = 0, \tag{23}$$

indicating an equilibrium state formed through the balance of opposing interactions.

From a structural perspective, the formation of water can also be expressed as a non-additive synthesis of components:

$$W \neq H + O,\ W = F(H, O), \tag{24}$$

where H and O denote hydrogen and oxygen states, respectively, and F represents a nonlinear composition rule that generates the emergent water molecule. This reflects the idea that the resulting structure contains properties that are not reducible to a simple sum of its parts. The synthesis of hydrogen and oxygen into water can therefore be interpreted as an emergent unity arising from interacting oppositional components. In this sense, the molecule exhibits both separability and unity: the constituent atoms retain identifiable properties while simultaneously forming a higher-order integrated structure. At a broader level, this perspective has been used to interpret complex physical systems as exhibiting unity-in-diversity, where global behavior emerges from interacting local components. In quantum theory, similar structural features appear in entangled systems, where measurement outcomes on one subsystem are correlated with those of another [36, 37, 38]. In such cases, the system cannot be fully described as a simple sum of independent parts but instead requires a holistic state description. Dialectical logic has therefore been proposed as a conceptual framework for describing such emergent correlations across both macroscopic and microscopic regimes [39].

Dialectics have been applied to interpret various processes, including science, art, and recent technological developments. This review explores how dialectics can be applied to quantum physics. We will review and discuss not only how dialectics are used to understand natural occurrences and physical systems but also demonstrate that dialectical methods can help address many unanswered questions arising from the philosophy of quantum mechanical concepts. The remainder of the article is organized as follows: Section 2 will discuss the relationship between quantum states and dialectics. Section 3 will discuss how dialectics build upon the previous literature in quantum physics. Section 4 discusses the unification problem between quantum physics and relativity and provides a review of the most relevant research in unifying them. Section 5 discusses implications and suggestions for future research. Section 6 discussed the comparison between dialectics and other unification theories. Finally, the conclusion is discussed in Section 7.

2. Quantum States and Dialectics

2.1. A dialectical interpretation

In this section, we apply dialectical concepts to quantum physics, where quantum states are defined as vectors in a Hilbert space and characterized by measurable observables such as energy, momentum, or position. Figure 2 illustrates different basis states $|A\rangle$, $|B\rangle$, $|C\rangle$, and $|D\rangle$. Each circle in Figure 2 represents a distinct quantum state that can be associated with a specific set of eigenvalues of an observable. In the measurement basis, these states are mutually exclusive in the sense that they are orthogonal:

$$\langle A|B\rangle = \langle A|C\rangle = \langle B|D\rangle = 0, \qquad A\neq B\neq C\neq D \tag{25}$$

However, quantum mechanics also allows for coherent superpositions of these states, such that a general state of the system is given by

$$|\psi\rangle = c_{A|A\rangle} + c_{B|B\rangle} + c_{C|C\rangle} + c_{D|D\rangle} \tag{26}$$

where $c_i \in C$ and $\Sigma\ |c_i|^2 = 1$. In this formulation, quantum states are not mutually exclusive at the level of state preparation, since multiple components contribute simultaneously to a single coherent state.

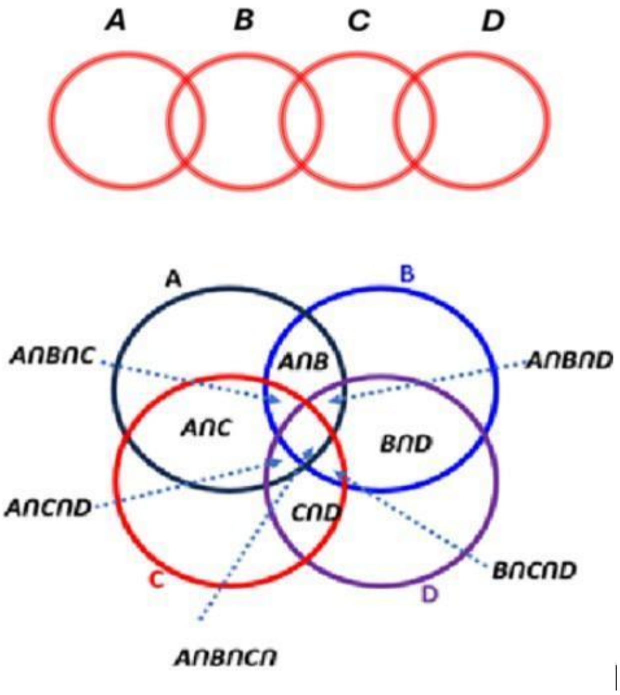

Figure 2: Representation of different quantum states A, B, C, and D, including their intersections and unification.

The probability of obtaining a given outcome upon measurement is given by the Born rule:

$$P\,(A) = |c_A|^2, \qquad P\,(B) = |c_B|^2, \tag{27}$$

In addition, quantum correlations are encoded in the density matrix

$$\rho = |\psi\rangle\langle\psi|, \tag{28}$$

which contains off-diagonal interference terms $c_i c^*_j$ that demonstrate that the components are not statistically independent but coherently linked. Figure 2 can therefore be interpreted as representing both (i) a discrete set of orthogonal basis states *A, B, C, D*, and (ii) a unified superposition state $|\psi\rangle$ spanning all of them. From this perspective, the composite label *ABCD* represents not a classical combination of states, but a single quantum state with multiple contributing amplitudes. The distinction between mutually exclusive and non-mutually exclusive descriptions depends on the measurement context. In classical physics, distinct states cannot coexist; however, in quantum theory, coexistence is encoded through superposition, and exclusivity emerges only upon measurement [40]. A dialectical interpretation of this structure highlights a tension between two complementary descriptions: (1) quantum states as distinct, orthogonal entities, and (2) quantum states as components of a unified coherent whole. The resolution of this tension occurs during measurement, where the superposition is reduced to a definite outcome. Returning to the broader dialectical framework, and drawing on ideas from Plato, Aristotle, Hegel, Engels, and Linehan, the structure in Figure 2 may be summarized as follows: (i) basis states are distinct and orthogonal yet contribute to a unified quantum state; (ii) the system is described by a coherent superposition rather than a classical mixture; (iii) apparent incompatibility arises from measurement context rather than intrinsic contradiction; and (iv) measurement produces a definite outcome from an underlying non-classical continuum.

This interpretation is consistent with a dialectical perspective where (i) opposing states, i.e., mutually exclusive and non-mutually exclusive, exist at the same time; (ii) opposing states, i.e., a quantum state and a superposition of states, exist at the same time; (iii) a quantum state is simply a part of one whole continuum or superposition of states.

2.2. Electromagnetic waves and dialectics

Applying the theory to the physical universe, Figure 3 presents a chain analysis illustrating how vulnerability factors and prompting events link behavior and consequences. The purpose of a chain analysis is to identify the antecedents of a problem behavior, its function, the mechanisms that maintain it, and potential points of intervention. From a systems perspective, such chained interactions can be interpreted as sequentially coupled processes in which each state evolves under the influence of preceding conditions. A useful physical analogy can be drawn from electromagnetic field theory, where coupled field equations describe mutual dependence between dynamical quantities. For example, Maxwell's equations capture how time-varying electric and magnetic fields generate one another:

$$\nabla \times \boldsymbol{E} = -\frac{\partial B}{\partial t}, \quad \nabla \times \boldsymbol{B} = \mu^0 J + \frac{\mu^0 \varepsilon^0 (\partial E)}{\partial t} \tag{29}$$

Here, variations in the electric field **E** induce changes in the magnetic field **B** and vice versa, forming a coupled dynamical system. In an analogous way, chain analysis describes a sequence of interacting states in which each element influences the next:

$$S_{n+1} = \mathrm{F}(S_n, E_n), \tag{30}$$

where S_n denotes the system state at step n, E_n represents environmental or contextual inputs, and F is an evolution rule governing transitions between states. Wave propagation provides a further physical analogy for such structured temporal evolution. A classical electromagnetic wave is described by oscillatory fields:

$$\mathbf{E}(x, t) = \mathbf{E}_0 \cos(kx - \omega t), \qquad \mathbf{B}(x, t) = \mathbf{B}_0 \cos(kx - \omega t), \tag{31}$$

where spatial and temporal variations produce alternating maxima and minima within a single continuous field. Quantum mechanics generalize this structure through the superposition principle. A quantum state is expressed as a linear combination of basis states as shown in Equation 10. For composite systems, quantum entanglement introduces non-separable correlations:

$$|\Psi\rangle = \Sigma\, c_{ij} |i\rangle_A \otimes |j\rangle_B \tag{32}$$

where entanglement occurs when the coefficients c_{ij} cannot be factorized into independent subsystem amplitudes. A clear distinction is therefore maintained between: (i) superposition, which refers to linear combination within a single system, and (ii) entanglement, which refers to non-factorizable correlations between subsystems.

From a spacetime perspective, a quantum state may be represented as

$$\Psi = \Psi(\mathbf{r}, t), \tag{33}$$

where **r** and *t* define the observational reference frame. Figure 3 therefore serves as a conceptual bridge between behavioral chain analysis, classical wave dynamics, and quantum evolution, all of which exhibit structured dependence between sequential or coupled components rather than isolated independent states.

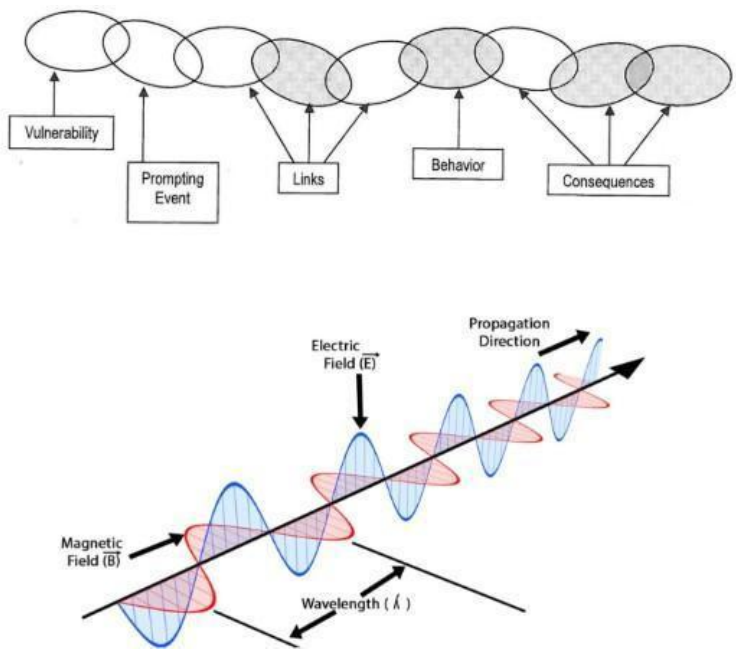

Figure 3: Illustration of the relationship between quantum states and dialectics. The chain analysis (top) of vulnerability-prompting events links behavior and consequences, demonstrating how change occurs over time. The lower panel shows electromagnetic wave propagation, where oscillating electric and magnetic fields illustrate continuous, coupled evolution in time and space.

The interpretation proposed by Klein [41] similarly emphasizes relational structure, in which measurement outcomes are defined relative to an observational context rather than as intrinsic properties of isolated systems. The wave comprises: (i) two opposing states, crest and trough (thesis-antithesis), which simultaneously oppose each other and synthesize together. (ii) Each peak and trough exist separately while simultaneously forming part of one whole continuous, inter-connected system. (iii) Although the crest and trough are incompatible with each other, they share a continuous, transactional relationship, (iv) The conflict, tension, and friction created between each crest and trough drive motion and change in the wave. The conflict is resolved through a synthesis. This resulting new state, the synthesis, also consists of opposing forces (new crest and trough), making change a continuous process. Quantum entanglement is a fundamental phenomenon in quantum mechanics where the quantum states of two or more particles become interconnected, such that the state of one particle cannot be described independently of the state of the others, regardless of the distance separating them [42]. The question remains exactly how this strange phenomenon occurs. Dialectics show us how opposing states exist simultaneously. For instance, when we focus on one point in the wave, we are observing a single quantum state. When viewed as one whole continuum, what we really observe is one greater, whole system or superposition of states. If one goes back and forth between looking at a part and the whole, what is physically observed is how a quantum state and superposition of states exist simultaneously. The only thing that changes is the perspective. The illustration of the wave with opposing troughs and crests shows how separate, opposing states are simultaneously entangled through a continuous, transactional relationship, creating one whole system [34]. Opposing states (the crest and trough) synthesize together to create a single interaction, and neither can exist without the other. Each synthesis becomes a new crest and trough, creating one whole, continuous and unified system. The dialectical law of the unity of opposites posits that all of nature contains contradictory, mutually dependent forces in a state of constant, inseparable motion which drives development. It is considered the most fundamental law of dialectics. Development is not merely linear; it occurs because all the separate parts of nature are interdependent, creating a single interaction within one interconnected whole system. The universe is one of those whole systems. Each quantum state simultaneously exists as part of one whole system or superposition of states where the state of each particle cannot be 0described independently of the others. The conflict between the parts, as well as between the parts and the whole, creates motion and change in each system. Each quantum state is a part which exists and evolves relative to its interaction with each other quantum state or part, and relative to the system as a whole. This is the essence of quantum entanglement.

Quantum entanglement is further described in Section 5 and illustrated in Figure 7: A dialectical interpretation of matter, energy, time, and space.

Quantum states exhibit superposition due to quantum mechanics, which allows particles to exist in multiple states simultaneously until measured [26]. This means a quantum system can be in a combination of all possible states, as described by a probability wave function. For instance, an electron can be in a superposition of two locations at once, collapsing to a single state upon observation. The idea that quantum systems operate independently of relativity is not well established and may be misleading. This is because quantum mechanics and relativity describe different aspects of physics. For instance, quantum mechanics addresses small-scale phenomena, while relativity explains space, time, and gravity at large scales and high speeds. Though quantum mechanics and special relativity has been unified in quantum field theory, general relativity, which encompasses gravity, has not yet been fully integrated with quantum theory, presenting a significant challenge in modern physics. From a dialectical perspective, quantum states exist in a state of superposition because a quantum system exists independently of relativity, that is, independently of any specific point in time and space which is what separates the various quantum states. It is only when relativity is introduced into the system, that is, the wave's state at a specific point in time and space, for instance when an observation or measurement is made, that one can observe one of the many possible definite and measurable states. This interpretation of quantum mechanics was introduced by Klein (2020) [41]. When a quantum system is observed or measured, it simultaneously undergoes another change besides those resulting from observer effects: Relativity, which refers to the specific point in time and space from which an observation or measurement occurs, is introduced into the quantum system.

2.3 Newton's third law of motion and dialectics

The impact of Isaac Newton's third law of motion fundamentally changed our understanding of the forces and interactions of the universe. Dialectics compare, contrast, and build upon Newton's theories in understanding quantum mechanics, gravitational states and motion with some key differences. First, Newton stated that when two objects interact with each other, the force exerted by the first object on the second is referred to as an action. Dialectically, this is referred to as a thesis. Newton states this action is then followed by a reaction (as the two states apply forces to each other of equal magnitude and opposite direction). Dialectically, this is referred to as the development of an antithesis which, while sharing common traits, contradicts and opposes the thesis. The only difference between the two theories here is their terminology. Second, Newton's third law states that the two forces are part of a single interaction. Dialectics explain how this single interaction is created: as two opposing forces (the parts) come together, they create a distinct third state which resolves the conflict between them through a synthesis (a greater whole). Third, Newton discovered that neither force exists without the other. This mutual dependence is explained by Engel's dialectical law of the unity of opposites which states that all things and processes contain contradictory, mutually exclusive, yet interdependent aspects. This law emphasizes the interdependence of all elements in the universe and how all things are connected. This is how quantum states are entangled. A dialectical perspective of the synthesis between opposing quantum states is illustrated in Figure 4.

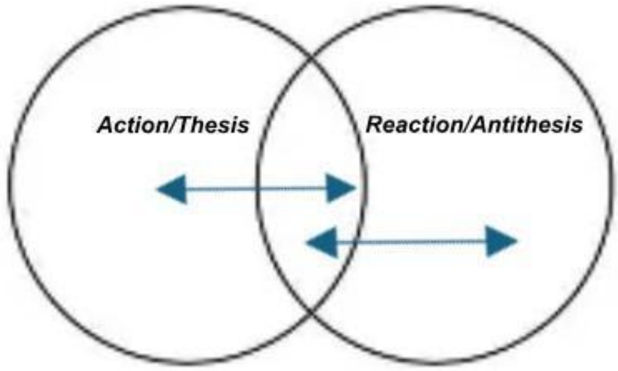

Figure 4: The synthesis of opposing states (action/thesis, reaction/antithesis) illustrates how opposing states are actually part of one single interaction and neither exists without the other.

As two opposing states come together, they create a distinct third group which resolves the conflict between them through synthesis. This synthesis resolves the conflict between the thesis and antithesis by reconciling their common truths, i.e., their equal magnitude, and forming a new thesis, thus creating a continuum of change. The synthesis contains common, interlocking parts because it contains elements of both the thesis and antithesis. In this way, dialectics build upon Newton's discovery that neither force exists without the other by showing how opposing forces or states are actually interdependent upon each other, or entangled, and as shown in figure 4. Fourth, one main difference between the two theories is that Newton describes an interactional relationship between two opposing objects, while dialectics describe a transactional relationship. Interaction refers to a two-way process A and B where two objects take turns sending and receiving messages and feedback [43, 44]. Mathematically, this can be expressed as:

$$A \rightarrow B\,(M_{AB}),\ B \rightarrow A\,(F_{BA}) \tag{34}$$

where M denotes a message and F denotes feedback. In a transactional relationship, forces are each considered to be both a sender and a receiver at the same time as demonstrated as Equation 38. This difference between interactional and transactional relationships is illustrated in Figure 5.

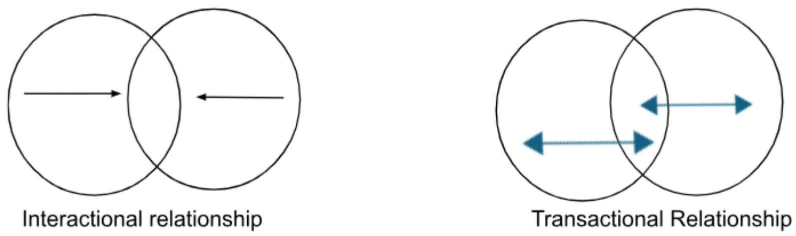

Figure 5: Plot of interactional and transactional relationships.

One example of the transactional relationship can be seen through time. The concept that time moves in a single, one-way direction is a fundamental aspect of our experience, where we perceive time as a sequence of past, present, and future events [45]. The arrow of time is the concept positing the ”one-way direction” or ”asymmetry” of time. It was developed in 1927 by the British astrophysicist Arthur Eddington. However, more recent research and theories in theoretical physics suggest that time may not exist in the way we perceive it but rather flows in both directions at the quantum level. CPLEAR research at CERN concluded that while macroscopic time moves forward, fundamental physics often allows for processes that are symmetrical or even move in reverse at the quantum level, moving both forward and backward simultaneously [45]. In more recent research scientists have designed quantum control protocols that generate more consistent processes with time flowing backward than forward [46]

A dialectical approach provides a new and fitting framework for understanding the phenomena of time moving in two directions at the same time. As illustrated in Figure 6, a dialectical approach would describe time as consisting of two opposing parts, the past (thesis) and the future (antithesis), which simultaneously synthesize together to create a single interaction: the present time. Each part, the past and the future, are separate states while simultaneously being part of one, greater whole continuous, interconnected and entangled system which is the continuum of time. The past and the future share a continuous, transactional relationship. Change is transactional with opposing states influencing and affecting each other reciprocally, or two-ways, where the past affects the future, and the future creates the past. As the past and the future come together, they create a distinct third group which resolves the conflict between them by means of a synthesis of common, interlocking truths: the present time. The past and the future

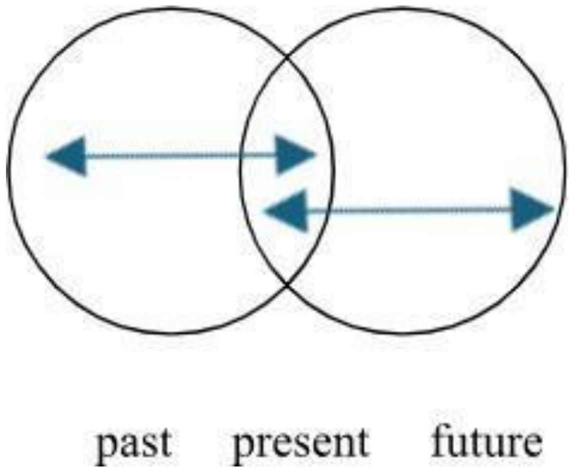

Figure 6: A dialectical interpretation of time.

are two parts of a single interaction, and neither can exist without the other. They are interdependent on each other to exist, and changes in either one will create changes in the other. Each part, the past and the future, affects the whole continuum of time, and the whole affects each of its parts. The identity of each part of a system, namely the past and the future, exists and evolves relative to its interaction with each other part and relative to the system as a whole [47]. It is the conflict, tension, and friction created between the thesis and antithesis forces within each system, namely the past and the future, that produces change. The new state following changes, the synthesis or present time, becomes a new thesis and antithesis, i.e., a new past and future, and thus time is continuous [33].

The logic of dialectics (i) supports the findings of CPLEAR and other research on the two-way relationship of time, (ii) provides a new framework from which to understand how time can exist or move in two opposing directions, backwards and forward simultaneously,
(iii) provides a more symmetrical representation of the universe, and (iv) supports the idea that opposing quantum states share a transactional, two-way relationship as opposed to a one-way relationship.

Returning to the relationship between Newton's work and dialectics, Newton discovered that opposing forces exist at the same time. Dialectical logic explains this phenomenon: opposing forces exist at the same time through a synthesis which resolves the conflict between them. Newton attributed motion to be created from one object acting upon another, causing its acceleration and changing its velocity. Dialectics suggest that when one object acts upon another, motion is created through the continuous transaction and synthesis between an opposing thesis and antithesis force, causing its acceleration and changing its velocity. In this way, dialectics provide a new and deeper look into the underlying mechanism that produces motion. Newton's laws assume absolute space and time, which become problematic when considering relativistic and quantum effects. At very small scales, where quantum mechanics dominate, Newtonian mechanics fail to accurately describe phenomena. This has led to the understanding that Newton's laws are not universally applicable but rather are limiting cases of more general frameworks that include quantum mechanics. Dialectics describe phenomena on large and small scales.

Newton's universal law of gravitation states that every particle in the universe attracts every other particle. (see Equation 39), and he developed a framework for understanding motion [43].

$$F = \frac{(G\, m_1 m_2)}{r^2} \tag{35}$$

where F is the gravitational force, m_1 and m_2 are the masses of the two particles, r is the distance between them, and G is the universal gravitational constant. Dialectical logic describes the exact mechanism for how all particles are interconnected and entangled. This phenomenon is explained by Engles law of the unity of opposites which states that opposing states are not merely contradictory but are interconnected and mutually dependent. This law emphasizes the interdependence of all elements in the universe, illustrating that unity (the whole) is essential for understanding the nature of reality.

The interplay between Newton's laws of motions and quantum mechanics illustrates the evolution of physics. Newton's laws of motions can be understood as emergent phenomena from the underlying principles of quantum mechanics [48]. It follows that Newton's laws of motion can therefore be applied to quantum states. Newton examined the relationship between objects and forces. In this paper, the authors examine the interaction between quantum states by expanding on Newton's "objects" to include "quantum states," where one quantum state is considered an object or force that acts upon another quantum state.

Newton's law states that for every action in nature, there is an equal and opposite reaction [48], as the two states apply forces to each other of equal magnitude and opposite direction, given by:

$$\frac{dp_1}{dt} = F_{12} + F_{11}, \quad \frac{dp_2}{dt} = F_{21} + F_{22}, \tag{36}$$

where $\mathbf{p}_1 = m_1\mathbf{u}_1$ and $\mathbf{p}_2 = m_2\mathbf{u}_2$. The internal and external forces acting on the particles due to sources outside the system are represented as $\mathbf{F}_{11}$, $\mathbf{F}_{22}$, $\mathbf{F}_{12}$, and $\mathbf{F}_{21}$, respectively. Mutual interaction between two particles occurs only when the internal forces comply with Newton's third law, which states that:

$$\mathbf{F}_{12} = -\mathbf{F}_{21}. \tag{37}$$

Newton's third law of motion, which states that for every action, there is an equal and opposite reaction, is consistent with the dialectical law of the unity of opposites. A simple mathematical description is thus explained. Let X be a phenomenon consisting of two contradictory but unified aspects, denoted by A and B. Then:

$$X = A \oplus B, \tag{38}$$

where $\oplus$ represents a dialectical unity in the form of a dynamic relation of contradiction and interdependence [49, 50]. Then the opposites satisfy:

$$A \neq B, \quad A \leftrightarrow B, \tag{39}$$

The dynamic interaction can be expressed as the struggle between A and B, which leads to transformation as:

$$\frac{dA}{dt}, \frac{dB}{dt} = f(A, B) \tag{40}$$

where $f(A, B)$ represents the dynamic influence of A and B upon one another. Then the unity through contradiction will only have a limiting case, which can be expressed as [51, 52]:

$$A \oplus B \longrightarrow \text{stable equilibrium (or vanishing interaction)}, \tag{41}$$

From a dialectical perspective, two opposing states resolve the conflict between them through a synthesis. This synthesis or resolution of conflict is what creates one whole continuum of equal magnitude and opposite direction. One example can be seen through the work of Albert Einstein where mass (an object's resistance to motion) would be considered a thesis, the speed of light squared (a state of motion) its antithesis, and the synthesis of common, interlocking truths between these two opposing states is energy. Energy is the distinct third group that is created (the synthesis) which resolves the conflict, tension, and friction between the thesis and antithesis. According to Hegel, a synthesis refers to the higher state of truth that merges a thesis with an antithesis. Energy is a synthesis of common, interlocking trusts and considered a higher truth because it contains elements of both mass and the speed of light. A summary comparing Newton's law and dialectics is illustrated in Table 1.

Table 1: A direct comparison between Newton's law and dialectics

Newton's Laws	**Dialectics**
One force is termed the action, the other the reaction	One force is termed the thesis, the other the antithesis
Two forces are part of a single interaction	This single interaction is created through a synthesis which resolves the conflict between them
Neither force exists without the other	This mutual dependence is explained by Engels' dialectical law of the unity of opposites
The two forces share an interactional relationship	The two forces share a transactional relationship
Opposing forces exist at the exact same time	Opposing forces exist at the same time through a synthesis
Forces occur in equal magnitude and opposite direction	The synthesis or resolution of conflict creates forces of equal magnitude and opposite direction
Motion is created from one object acting upon another, changing velocity	Motion is created through the conflict and synthesis between quantum states
Examines interactions between objects and forces	Examine interactions between quantum states
Describes phenomena on large scales	Describes phenomena on both large and small scales
Every particle attracts every other particle	Explains interconnection and entanglement of particles

2.3. Biological interpretation of the dialectic

Extending dialectical concepts from microscopic physics to macroscopic biological systems, we first consider a biological example. Over its life cycle, a butterfly undergoes distinct developmental stages, such as caterpillar and adult forms [53]. However, at any given moment in space and time, the organism exists in a single observable developmental state. From a process-oriented perspective, these stages can be interpreted as parts of a continuous life history rather than isolated entities. In this sense, the full life cycle may be viewed as a temporal continuum in which distinct stages are embedded within a single evolving process. This interpretation emphasizes continuity across time rather than simultaneous coexistence in the classical sense. A similar perspective arises in evolutionary biology, where opposing mechanisms interact to generate complex adaptive outcomes [54]. For example, natural selection and genetic variation represent complementary but competing processes that jointly shape evolutionary trajectories. Their interaction produces a unified evolutionary continuum of phenotypic change, rather than isolated static states.

2.4. Mathematical support for a dialectical approach

We now consider a more formal mathematical representation of dialectical structure. In recent work, dialectical processes have been modeled using set-theoretic and functional decompositions, where a complete dialectical system is represented in terms of interacting components corresponding to thesis, antithesis, and synthesis. A key starting point is Newton's third law, which states that for every action there is an equal and opposite reaction [55, 56]. Such symmetric interaction structures provide a useful analogy for dialectical opposition in dynamical systems.

A formal decomposition of any real-valued function can be given as follows. For a function $f(x)$, define its positive and negative components:

$$f^{+}(x) = \max(f(x), 0), \qquad f^{-}(x) = \max(-f(x), 0). \tag{42}$$

This allows the decomposition

$$f(x) = f^{+}(x) - f^{-}(x), \tag{43}$$

where $f^{+}(x)$ and $f^{-}(x)$ represent two opposing contributions, while their combination reconstructs the full system behavior. In a dialectical interpretation, $f^{+}(x)$ is associated with the thesis, $f^{-}(x)$ with the antithesis, and $f(x)$ with the resulting synthesis. This provides a mathematical representation of how opposing components can generate a unified outcome. More generally, a dialectical process may be represented as an operator acting on a state space:

$$\mathrm{D}[x] = S(x), \tag{44}$$

with

$$S(x) = T(x) + A(x), \tag{45}$$

where $T(x)$ denotes the thesis component, $A(x)$ the antithesis component, and $S(x)$ the resulting synthesis. Dynamic formulations of dialectical evolution can also be expressed using nonlinear differential equations [57, 58]. A simple example is

$$\frac{d\phi}{dt} = \phi - \phi^2, \tag{46}$$

where the linear term ϕ represents growth (thesis), the nonlinear saturation term $-\phi^2$ represents limiting contradiction (antithesis), and the steady-state solution corresponds to a synthesized equilibrium structure. This formulation illustrates how dialectical interactions can be represented as the balance between constructive and limiting processes within a single dynamical framework.

3. Dialectics build on previous literature in quantum physics

Now that a foundational understanding of dialectics has been established, we examine how a dialectical approach builds upon previously described interpretations of quantum mechanics.

3.1. Double slit experiment

The double-slit experiment suggests that particles exhibit both particle-like and wave-like characteristics, and that observing or measuring a quantum system affects the system Newton's law states that for every action in nature, there is an equal and opposite reaction [59]. How this influence occurs is known as the measurement problem in quantum mechanics. As Richard Feynman often said, all quantum mechanics can be understood by carefully examining the implications of this single experiment [60]. Klein's dialectical interpretation offers a novel approach to achieving this understanding (Klein, 2020) [41]. A dialectical interpretation of the double slit experiment suggests that particles and waves exist simultaneously in a state of superposition because a quantum system exists independently of relativity, that is independently of any specific point in time and space which is what separates the different quantum states Newton's law states that for every action in nature, there is an equal and opposite reaction [61]. It is only when relativity is introduced into the quantum system—referring to the particle or wave's state of existence at a specific point in time and space (such as during a measurement or observation)—that the system collapses into a single observable state. This interpretation is supported by the work of Shahriar S. Afshar who devised an experiment to determine the path taken by an electron in a double slit experiment Newton's law states that for every action in nature, there is an equal and opposite reaction [62, 63]. The results suggest that light can be measured as a wave and a particle simultaneously. Furthermore, the development of quantum computers is based on matters being held in more than one state at the same time [62, 63]. Shoichi Sakata describes the above scenario as a fundamental character of the dialectics of nature Newton's law states that for every action in nature, there is an equal and opposite reaction [64].

The wave-particle duality refers to the dialectical synthesis between wave and particle. A dialectical interpretation of the double-slit experiment suggests that (i) a particle and wave (the parts) oppose each other (i.e., conflict with each other) while simultaneously synthesizing together to create one greater continuum (the whole). (ii) They are distinct states that, together, create a superposition or entanglement of states. (iii) a particle and wave are incompatible with each other while simultaneously sharing a continuous, transactional relationship. (v) the conflict, tension, and friction that is created between a particle and wave produces changes in each state as well as the system as a whole through a synthesis, creating motion and change. (v) the concept of wave-particle duality refers to the synthesis of wave and particle.

3.2. Schrödinger's cat

Klein [41] examined Schrödinger's cat experiment from a dialectical perspective, framing the system in terms of two opposing classical outcomes: "alive" and "dead." In quantum mechanics, however, these outcomes correspond to components of a single coherent state rather than mutually exclusive classical realities. A quantum state of the system may be expressed as a superposition (Equation 10). The spatial and temporal dependence of the system is encoded in the state representation, which may be written more generally as $|\phi_i(x, y, z, t)\rangle$.

Bernard F. Schutz [65], in the context of general relativity, describes an inertial observer as a coordinate system for spacetime that records events via their spacetime coordinates (x, y, z, t). In this framework, measurement corresponds to an interaction localized in spacetime, and the observed outcome is defined relative to that coordinate system.

Thus, the quantum state may also be expressed as a spacetime-dependent field:

$$|\psi\rangle \equiv |\psi(x, y, z, t)\rangle. \tag{47}$$

From a standard quantum mechanical perspective, measurement is represented by projection onto an eigenstate:

$$|\psi\rangle \rightarrow \hat{P}k|\psi\rangle, \tag{48}$$

where $\hat{P}k$ is the projection operator associated with the observed outcome. A dialectical interpretation frames this structure as an interaction between (i) the quantum state as a set of coexisting potential outcomes and (ii) the spacetime-localized measurement event that selects a definite realization. The apparent "collapse" is then understood as the resolution of this interaction into a single observed outcome. In this view, Schrödinger's cat is not strictly a system that is simultaneously alive and dead in a classical sense, but rather a quantum system described by a superposition of correlated macrostates, with definite outcomes emerging only upon measurement. The resolution of the cat paradox is therefore that, prior to measurement, the system is described by a superposition spanning all possible outcomes, while at the point of observation the state is projected onto a single eigenstate consistent with the measurement context. This interpretation avoids attributing collapse to subjective observation and instead treats measurement as a physical interaction localized in spacetime, consistent with standard quantum theory.

The dialectical resolution of Schrodinger's cat is that the cat exists in a single quantum state at any specific point in time and space such as when an observation, measurement, or some other event occurs (in this case, that event is the release of gas which determines how much poison is exposed to the cat); and the cat simultaneously exists in a superposition of all possible states across any span of time and space.

3.3. Thought experiment supporting a dialectics interpretation of quantum mechanics

From a dialectical perspective, a cat can be understood as a system evolving through a continuous trajectory of states across time, corresponding to its biological development. For example, a newborn cat exhibits kitten-like structural and functional properties, which evolve over time into adult and later-life characteristics [66]. This evolution may be interpreted as a continuous dynamical process rather than a sequence of isolated static states. Mathematically, such temporal evolution can be represented as a trajectory in a state space:

$$S(t) = \mathrm{E}_t(S_0), \tag{49}$$

where $S(t)$ denotes the state of the organism at time t, S_0 is the initial state, and E_t is an evolution operator governing developmental change. In this sense, the "state" of the cat is not a single static configuration but a time-dependent continuum of biologically determined configurations. This interpretation reflects a classical dynamical system rather than a quantum superposition in a strict physical sense. Environmental conditions further influence this trajectory. The state evolution may be expressed conditionally as

$$S(t + \Delta t) = \mathrm{F}\, S(t),\ E(t)\,, \tag{50}$$

where $E(t)$ represents environmental inputs such as temperature, nutrition, or external hazards, and F encodes the interaction between internal biological dynamics and external conditions. For instance, extreme environmental conditions such as heat, cold, or lack of resources alter the trajectory of the system, potentially leading to pathological or lethal outcomes. These dependencies reflect general principles of physical interaction, consistent with Newtonian mechanics in the sense that systems evolve under the influence of external forces and constraints [67, 68].

3.4. Observer effects and reality

Klein [41] applied a dialectical approach to the interpretation of observer effects in quantum mechanics. In standard quantum theory, an observation corresponds to a physical interaction between a measuring device and a system, rather than a purely subjective act. Formally, this interaction is represented by the projection of a quantum state onto an eigen basis (see Equation 48). As represented in Equation 48, a physical coupling between two systems rather than a metaphysical influence of consciousness on matter. The observer effect therefore reflects interaction dynamics rather than ontological indeterminacy. A dialectical interpretation frames this interaction as a coupling between the quantum system and the measurement apparatus, where the resulting outcome emerges from their joint dynamics. However, this does not imply that physical systems lack definite properties prior to measurement in all interpretations; rather, quantum mechanics assigns probabilistic structure to those properties prior to observation. In broader philosophical terms, one may distinguish between different descriptive levels of reality. These include: (i) objective descriptions of physical systems, (ii) subjective descriptions based on observation and perception, (iii) their interaction through measurement, and (iv) the probabilistic structure described by the quantum state itself [69]. Objective descriptions refer to system-independent physical properties, while subjective descriptions depend on the observer's informational context. Measurement links these descriptions through a physical interaction process that produces definite outcomes from probabilistic states. The relation between these levels can be summarized as a mapping:

$$R : (\text{system}, \text{observer}) \rightarrow \text{measurement outcome}. \tag{51}$$

From this viewpoint, dialectical structure can be interpreted as the interaction between different descriptive frameworks rather than a literal physical mechanism governing quantum collapse. Ultimately, quantum mechanics remains consistent with the existence of objective physical states while also encoding fundamental limits on predictability prior to measurement. The resulting framework describes a probabilistic but well-defined physical theory in which outcomes emerge through interaction rather than observation alone [70].

Objective and subjective reality share a dialectical relationship, in which reality emerges through the synthesis of common, interlocking truths between these seemingly opposing states. For example, if a tree falls in a forest and no one is present to hear it, the synthesis of the objective and subjective aspects of the event can be expressed as: "A tree falls in a forest, and no one is present to hear the sound." In this view, opposing states of reality are integrated and reconciled at a higher level of understanding, producing a more comprehensive conception of reality. This illustrates the dialectical principle that objective and subjective reality, though distinct and often treated as opposites, interact to form a unified whole. In this sense, they may be understood as complementary aspects of reality whose relationship contributes to a broader and more complete understanding of truth.

3.5. Dialectics in particle physics

Dialectical interpretations have been applied to structural classifications in particle physics, particularly in the distinction between bosons and fermions. In the standard framework of quantum field theory, all elementary particles are categorized according to their exchange statistics. Bosons are symmetric under particle exchange, meaning their many-particle wavefunction satisfies

$$\psi(x_1, x_2) = \psi(x_2, x_1), \tag{52}$$

while fermions are antisymmetric,

$$\psi(x_1, x_2) = -\psi(x_2, x_1). \tag{53}$$

This distinction leads to fundamentally different collective behaviors: bosons can occupy identical quantum states, whereas fermions obey the Pauli exclusion principle. Despite this opposition in exchange symmetry, both classes are unified within the spin–statistics theorem, which links intrinsic spin to statistical behavior in relativistic quantum field theory. In this sense, bosons and fermions represent two complementary structures within a single unified quantum framework rather than independent ontological categories. More generally, quantum statistics arise from the representation theory of particle exchange. In three-dimensional space, the permutation group restricts particles to either bosonic or fermionic statistics. However, in lower-dimensional systems, this restriction is relaxed.

In two-dimensional systems, the braid group replaces the permutation group, allowing for intermediate exchange phases. This gives rise to quasiparticles known as anyons, whose exchange relation is

$$\psi(x_1, x_2) = e^{i\theta}\psi(x_2, x_1), \tag{54}$$

where θ can take continuous values between 0 (bosons) and π (fermions). Anyons have been experimentally realized in strongly correlated two-dimensional systems, particularly in fractional quantum Hall states and engineered topological materials [71, 72]. From a structural perspective, bosonic and fermionic behavior can thus be viewed as limiting cases of a broader statistical continuum. In this sense, anyonic statistics interpolate between these two regimes, rather than emerging as a direct "synthesis" of them in a literal physical sense. Within a dialectical interpretation, one may describe bosonic and fermionic statistics as complementary limiting structures whose interaction space becomes enriched in reduced dimensionality, giving rise to intermediate statistical phases. However, this should be understood as a conceptual analogy rather than a physical derivation. Thus, particle classification in quantum theory can be viewed as a hierarchy of symmetry constraints: (i) fermionic and bosonic statistics arise from permutation symmetry in three dimensions, (ii) intermediate anyonic statistics arise from braid-group representations in two dimensions, and (iii) all cases are unified within the broader framework of quantum field theory and many-body quantum mechanics. This suggests that "opposition" in particle behavior is not literal physical conflict, but rather the manifestation of underlying symmetry constraints that determine allowed quantum states.

3.6. Validation of dialectical interpretation of quantum mechanics

A dialectical interpretation is largely compatible with and may be viewed as a natural extension of previous interpretations of quantum mechanics and the physical realization (correspondence between theory and experiment) of quantum mechanics with some key differences. We will argue this point from three viewpoints. First, dialectic quantum mechanics is most compatible with quantum decoherence. Here, quantum decoherence argues that quantum states are never in perfect isolation, rather they interact with the rest of the universe, which breaks any initial eigenstate or superposition of eigenstates. For instance, the state of a quantum system can be described as a pure state $|\psi\rangle$, and the corresponding density matrix ρ is given by:

$$\rho = |\psi\rangle\langle\psi| \tag{55}$$

If the system interacts with its environment, the overall state of the combined system and environment can be described by the density matrix ρ_{SE}. Due to this interaction, the system S no longer evolves independently. To describe the system alone, the environmental degrees of freedom E are traced out, yielding the reduced density matrix:

$$\rho_S = Tr_{E(\rho_{SE})} \tag{56}$$

where $\mathrm{Tr}_E(\rho_{SE})$ denotes the partial trace over the environment. Over time, the reduced density matrix ρ_S evolves into a mixed state as a consequence of decoherence, which can be expressed as:

$$\rho_S = \sum_i p_i |\psi_i\rangle\langle\psi_i|, \tag{57}$$

where p_i represents the probability associated with the quantum state $|\psi_i\rangle$. In this mixed state, the off-diagonal elements of the density matrix, which represent quantum coherence between states, gradually approach zero due to environmental interactions. Consequently, the system transitions from quantum superpositions to classical probabilistic behavior. This process mathematically explains how quantum states lose coherence and appear to behave classically as they interact with their surroundings. The whole idea of quantum decoherence results in eigenstate mixing which is analogous to weak and strong wave turbulence theory and drives a wave description of a particle to a statistical description of a particle over a long timescale. A dialectical interpretation of quantum mechanics argues that such pure eigenstates are never pure and will mix over their evolution in spacetime. Measurements are regions of enhanced interaction that break these pure energy measurement eigenstates. In quantum mechanics, the measurement problem—more precisely, the problem of wavefunction collapse—is addressed by the Ghirardi–Rimini–Weber (GRW) theory [73]. The generalized relativistic wave function theory (GRW) presents an objective, spontaneous collapse mechanism that happens independently of observation, in contrast to the conventional interpretation of quantum mechanics, which holds that wavefunctions only collapse upon measurement [73]. Recall that in quantum mechanics, the evolution of the wave- function (t) is described by the Schrödinger equation (see Equation 1). Equation 1 predicts a smooth, unitary evolution of wavefunction over time. In the GRW Theory, the collapse occurs according to a Poisson process with a certain rate per particle, leading to a modified wavefunction. For instance, for a system of N particles, each particle undergoes collapse with a probability rate λ (typically chosen as $\lambda \approx 10^{-16}$ s^{-1} for each particle). Therefore, when a particle collapses at position x_0, the wavefunction is multiplied by a localization function $g(x - x_0)$, which is Gaussian in form:

$$g(x - x^0) = \frac{1}{(2\pi r_C^2)^{3/4}} \cdot exp\ exp\left[-\frac{(x-x^0)^2}{4r_C^2}\right], \tag{58}$$

where r_C is the localization length scale (typically chosen around $r_C \approx 10^{-7}$ m). The new wavefunction after collapse is represented as:

$$\psi'(x^1, x^2, \ldots, x_N) = \frac{g(x^1-x^0)\psi(x^1,x^2,\ldots,x_N)}{||g(x^1-x^0)\psi(x^1,x^2,\ldots,x_N)||} \tag{59}$$

where x_1 is the coordinate of the particle undergoing collapse, and the denominator ensures normalization of the wavefunction. Here we compare our interpretation of quantum mechanics to collapse theories such as the GRW theory Newton's law states that for every action in nature, there is an equal and opposite reaction [41]. As opposed to the Copenhagen interpretation, which maintains that a quantum system exists in a superposition of states until it is observed, at which point the wave function collapses into a definite state, the General Relativity theory suggests that the wave function collapses randomly and spontaneously, taking place independently of observation. Therefore, the GRW allows microscopic particles to exist in multiple states at once (superposition) and spontaneously collapse into a single quantum state Newton's law states that for every action in nature, there is an equal and opposite reaction [36]. Here, we find some correspondence as GRW theory posits that collapse of quantum states is only possible when an interaction between a pure state takes place with a large number of other pure states. Again, dialectical quantum mechanics is compatible with this theory as it is only relevant for pure quantum states when an interaction with other states is weak. Unlike GRW theory, where the collapse of the wavefunction is explicitly modeled as a spontaneous and random event, our approach does not specify the exact mathematical mechanism for this collapse. Instead, we posit that a significant deviation in the system's evolution operator (Hamiltonian) occurs due to interactions with the environment or the rest of the universe at the point of measurement. While the GRW theory provides a specific framework for collapse, we assume that these interactions lead to a measurable outcome without detailing how the collapse process unfolds. As the collapse is produced by a perturbed Hamiltonian, all measurements are unitarity preserving (for the entire state, not the pure state). Another interesting aspect is the de Broglie relation expressed as:

$$\lambda = \frac{h}{p} \tag{60}$$

where λ is the de Broglie wavelength and p is the momentum. In Equation (16), the de Broglie relation does not eliminate one pole (wave or particle) and does not keep them strictly separate (as in classical physics). However, it unites them in a new conceptual framework, such as the quantum domain, where the apparent opposites are complementary. The de Broglie relation is a dialectical synthesis, because it transforms the contradiction (wave vs. particle) into a higher-order unity (quantum object). In other words, the Planck constant h acts as a "mediator" that resolves the contradiction and makes the synthesis possible. We can even cast the de Broglie relation in the following symbolic dialectical form:

$$\text{Quantum object} = (\text{wave} \otimes \text{particle}) \xrightarrow{h} \text{synthesis} \tag{61}$$

Finally, we discuss the relation between dialectical quantum mechanics and the classical Copenhagen interpretation Newton's law states that for every action in nature, there is an equal and opposite reaction [62, 74]. The major issue with the classical interpretation is that it gives special weight to the nature of measurement operators. It is unclear how such operators are produced, how unitarity is guaranteed in their formulation, and how these measurement operators operate on particles. Our interpretation, while compatible with the idea of observer effect and measurement induced wavefunction collapse, prescribes the precise way this collapse would take place. Collapse to a measurement eigenstate will take place due to interaction with the rest of the universe at a particularly strong space-time point. Our interpretation guarantees unitarity and removes the arbitrary nature of the measurement operator in the Copenhagen interpretation in favor of strong nonlinear interactions (governed by a perturbing Hamiltonian) at a particular space-time point.

4. Quantum physics and relativity

A dialectical interpretation of quantum mechanics provides new information about its relationship with relativity, suggesting how they are interdependent on each other. Over the past few centuries, two theoretical frameworks have been developed that best describe how our universe works at its micro and macro levels. These two theories are quantum mechanics and general relativity [75].

The first theory, quantum mechanics, as discussed earlier in this paper, is the study of matter and its interactions with energy on the scale of atomic and subatomic particles, thus describing our universe at the micro level. In modern formulation, quantum mechanics is expressed through the dynamics of quantum states in Hilbert space:

$$i\hbar \frac{\partial}{\partial t} |\psi(t)\rangle = \hat{H} |\psi(t)\rangle \tag{62}$$

where $|\psi(t)\rangle$ is the quantum state and $\hat{H}$ is the Hamiltonian operator governing the system's evolution. Quantum mechanics encompasses three fundamental interactions within the Standard Model of particle physics [76]. These interactions are described by gauge field theories based on the symmetry group:

$$SU(3)_C x\, SU(2)_L x\, U(1)_Y, \tag{63}$$

corresponding respectively to: (i) electromagnetism (unified with the weak interaction at higher energies), (ii) the strong interaction which binds quarks into hadrons, and (iii) the weak interaction responsible for processes such as beta decay. The second theory, general relativity, encompasses gravity as a geometric property of spacetime [77]. In this framework, spacetime curvature is determined by the Einstein field equations:

$$G\mu\nu + \Lambda g\mu\nu = \left(\frac{8\pi G}{c^4}\right) T\mu\nu \tag{64}$$

where $G_{\mu\nu}$ is the Einstein tensor describing spacetime curvature, $T_{\mu\nu}$ is the stress-energy tensor, and Λ is the cosmological constant. Gravity is directly related to the structure of spacetime and describes the universe at macroscopic scales. Many scientists believe that unifying quantum mechanics and general relativity would provide a comprehensive framework for describing all physical phenomena within a single theoretical structure [75]. In a unified formulation, one seeks a theory in which both quantum dynamics and spacetime geometry emerge consistently from a deeper underlying structure.

4.1. History of some of the major contributions to unifying the fundamental elements and forces of the universe

In 1666, Isaac Newton developed what was widely regarded as the first great unification theory in physics [78]. His universal law of gravitation states that every particle in the universe attracts every other particle [78]. Newton developed a mathematical framework for understanding motion, from an apple falling from a tree to the motion of planets and their moons. His groundbreaking discoveries on gravity and the laws of motion started a scientific revolution which led to all the discoveries which followed and formed the fundamental foundation for modern physics. In 1865, James Maxwell developed the classical theory of electromagnetic radiation, which was the first theory to describe electricity, magnetism and light as different manifestations of the same phenomenon [79]. Maxwell demonstrated that electric and magnetic fields travel through space as waves moving at the speed of light, and his equations for electromagnetism have been called the second great unification in physics. In 1915, Albert Einstein expanded on the work of Newton and developed the theory of gravity, also known as the general theory of relativity, which remains the current description of gravitation in modern physics [80]. Albert Einstein is best known for his equation $E = mc^2$, which states that energy and mass (matter) are the same thing, just in different forms.

Beginning in the 1960s, several decades of research conducted by thousands of physicists put forth a theoretical framework called String theory which describes how the point-like particles are replaced by one-dimensional objects called strings that move through space and interact with each other [81]. In string theory, one of the vibrational states of the string corresponds to graviton, a quantum mechanical particle that carries the gravitational force, and has thus contributed toward developing a quantum theory of gravity [82]. String theory has contributed toward advances in mathematics, our understanding of black holes, early universe cosmology, nuclear physics, and condensed matter physics [82, 83]. Some of the problems with string theory, however, are that it does not provide an adequate definition of all things; it describes a complicated landscape of possible universes instead of providing a description of the real world; and it is widely considered to be beyond empirical testing, meaning that it cannot be proven [84].

In the mid-1970s, the Standard Model was the result of research conducted by thousands of physicists across the globe since the 1930s. The Standard Model of particle physics describes the fundamental structure of matter and demonstrates that everything in the universe is made from fundamental particles [85]. It has become established as a well-tested physics theory, accurately describing three of the four known fundamental forces (electromagnetic, weak and strong interactions) in the universe and classifying all known elementary particles. The Standard Model has become one of the greatest contributions to science and is widely considered the closest thing we have to a theory of everything. Its main drawback is that it is simply incompatible with gravity or relativity [84]. Since then, there have been several proposals for a theory of everything although none is currently universally accepted. A major problem for experimental tests of such theories is the energy scale involved, which is well beyond the reach of current accelerators. Trying to combine graviton with strong and electroweak interactions leads to fundamental difficulties, and the incompatibility of the two theories remains an outstanding problem in the field of physics.

5. Implications and suggestions for future research

5.1. A dialectical interpretation of matter, energy, time, and space

Here, the authors postulate that the same principles of a dialectical approach that describe quantum physics can also be applied to relativity. We discuss this for the sole purpose of highlighting the potential broader significance of a dialectical approach which can advance new research.

Klein (2018) [86] applied dialectical principles to matter, energy, time, and space. Mass (an object's resistance to motion) and the speed of light (a state of motion) oppose each other and synthesize together to create energy. Position and direction oppose each other and synthesize together to create space. Particles and antiparticles oppose each other and synthesize together to create matter. The past and the future oppose each other and synthesize together to create the present time. Matter and energy oppose each other and synthesize together to create quantum physics. Time and space oppose each other and synthesize together to create gravity or relativity. These are already established scientific facts which the authors illustrate in Figure 7.

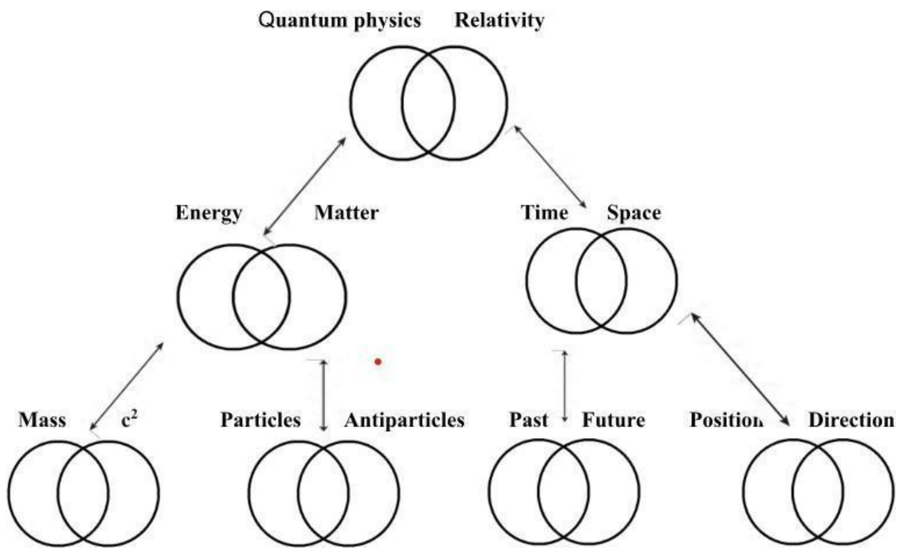

Figure 7: A dialectical interpretation of matter, energy, time, and space.

Figure 7 illustrates how the synthesis of common, interlocking truths creates a single interaction within one whole interdependent system where each part exists and evolves relative to its interaction with each other and relative to the system as a whole. This is the essence of entanglement. A dialectical interpretation of matter, energy, time, and space builds upon the work of Maxwell who demonstrated that electric and magnetic fields are two manifestations of the same phenomenon [84]. It builds upon the work of Einstein who demonstrated that energy and mass (matter) are interchangeable and different forms of the same (See Equation 71). Maxwell and Einstein's specific theories of interchangeability are examples of the dialectical law of the unity of opposites and law of the transition of quantity to quality. By demonstrating how everything in the universe may be connected, dialectics build on Newton's universal law of gravitation that states "every particle in the universe attracts every other particle [87], Figure 7 illustrates how dialectics build on Newton's third law of motion which states that forces always occur in pairs, creating a single interaction, and one body cannot exert a force on another without experiencing a force itself as discussed earlier in Equation 41. Dialectics is not only consistent with these discoveries and universal laws, it provides a broader framework for explaining, understanding, and connecting them. Therefore, one area for further research would be to develop experiments and mathematical formulas which can further test the transactional relationships as shown in Figure 6, a dialectical interpretation of matter, energy, time and space. Dialectical materialism, a philosophical approach commonly connected with Marxist thought, is the basis for dialectical views on matter, energy, time, and space. This viewpoint highlights how reality is dynamic and related, arguing that these ideas are crucial parts of a constantly changing and interconnected system instead of being fixed or distinct. Everything in the universe consists of matter, energy, time and/or space. These are the fundamental components of the universe upon which the four fundamental interactions act. A dialectical interpretation of matter, energy, time, and space offers a new perspective of quantum entanglement [84], showing how each separate part of nature affects the whole of nature and how the whole of nature affects each part. A dialectical interpretation of our universe shows how entanglement occurs because everything exists relative to everything else. It shows how nature consists of contradictions which are reconciled on a higher level of truth through synthesis, creating a single continuum of interconnectedness in a state of constant motion and change. This relationship is demonstrated by Einstein's theory of relativity [88] as:

$$E = mc^2 \tag{65}$$

where E, m, and c are the energy in Joules, mass in kg, and the speed of light in m/s, respectively. Equation 71 states that matter and energy are two variations of the same underlying reality. This suggests a dialectical relationship where one form of reality

may transition into another, and that matter can change into energy and vice versa. For instance, this relationship is directly demonstrated in particle annihilation in particle physics. A particle and its antiparticle annihilate one another when they meet one another, changing the particle's mass into photons of energy [88].

Another example of this interchangeability and connectivity exists between time and space. Spacetime is a unified continuum that is thought to include both time and space as intertwined elements. Time and space are interdependent, constantly changing, as shown by the dynamic nature of the continuum that is molded by the presence of matter and energy. This is a living example of the dialectical concept of transformation and interconnection. A prime example of this dialectical character is the spacetime fabric, which is experienced as gravity, is distorted by massive objects like planets and stars. Time dilation effects near massive objects or at high velocities show that this distortion also affects the passage of time. According to the dialectical interpretation, matter, energy, time, and space are not distinct entities but rather are in a constant state of interaction and evolution. Physical systems develop and evolve because of interactions between changes in one aspect and other aspects. For example, this interaction is best illustrated in cosmology by the universe's expansion. The energy of the universe, including dark energy, influences the speed of space expansion. The distribution of matter and the passage of time throughout the universe are impacted by this expansion. The dialectical interpretation emphasizes how these core ideas are interrelated and always changing and evolving, reflecting a dynamic and changing reality as opposed to a static one. Extremely high densities of compressed matter produce black holes, which cause a noticeable curvature in spacetime. Time dilation and space distortion around the black hole are caused by this strong gravitational field [89]. Extreme conditions cause significant changes in these basic concepts, as demonstrated by the dynamic transactions between matter, space, and time in black holes. An example is the Particles (matter) and their interactions, which arise from underlying fields, as explained by quantum field theory. Changes in these fields, which can be thought of as energy exchanges, are expressed in the production and destruction of particles. With particles and fields constantly undergoing change, this theory illustrates the dialectical interaction between matter and energy. Another example is the cosmic wave. So many years ago, the universe was much different from what we see today. This is what the cosmic microwave background radiation represents. Variations in space and time, as well as changes in matter and energy, are reflected in the properties and distribution of this radiation. A study of this radiation can reveal how the universe has changed over time in terms of both expansion (a change in space) and cooling (a change in energy). A dialectical perspective would describe the universe as being finite at any specific point or span in time and space (the parts), and simultaneously infinite in its quantum state of superposition (the whole). Finally, the unification of black holes and gravity through Stephen Hawking's work has been a significant milestone in the field of astrophysics. Stephen Hawking observed that black holes simultaneously (i.e., dialectically) both create and destroy energy, emitting particles and energy in the form of radiation in an area of space-time surrounding a black hole where the gravitational pull is so strong that nothing should be able to escape. From a dialectical perspective, black holes and gravity exist on one continuum. As a black hole and gravity come together, they create a distinct third group which resolves the tension between them by means of a synthesis. This synthesis solves the conflict between two opposing forces, namely a thesis and antithesis, by reconciling their common truths and forming a new thesis. The new state following change (the synthesis) also comprises polar forces, and thus change is continuous. A black hole and gravity share a dialectical relationship as they: (i) Oppose each other and synthesize together, (ii) Are each separate states (the parts) and parts of a single continuum (the whole), (iii) Are incompatible with each other and share a continuous, transactional relationship. This could explain how information is reciprocally exchanged between a black hole and gravity. Therefore, further exploring the dialectical relationship as it applies to aspects of time and space, including the relationship between black holes and gravity, would be one area for future research and potential advancement in the fields of astronomy and cosmology.

5.2. Unification problem between quantum mechanics and relativity

Klein (2020) examined the unification problem between quantum mechanics and relativity more closely from a dialectical perspective [80]. Everything in the universe comprises all or some of energy, matter, space, and time. As these four states come together, they create 13 possible states as shown in Figure 8: (1) all possible states at once (2) space, matter, and time (3) matter, time, and energy (4) space, time, and energy (5) matter, energy, and space (6) space and matter (7) matter and time (8) time and energy (9) space and energy (10) space (11) matter (12) time (13) energy (14) superposition of states. Set theory has already been identified as a suitable mathematical treatment of quantum systems considering the indistinguishability of quantum mechanical particles as well as an ontological extension to classical particles/elements required for macroscopic realness This concept of using set theory to evaluate the relationships between quantum sets has led to the recent development of quasi-set theory. Such advancements in the use of set theory are, however, not surprising from a dialectic point of view considering the essential elements of union, separation and intersection used to develop the axioms are all related to the philosophy of dialectics and the synthesis of states. Set theory and dialectics each operationalize the unification of sets.

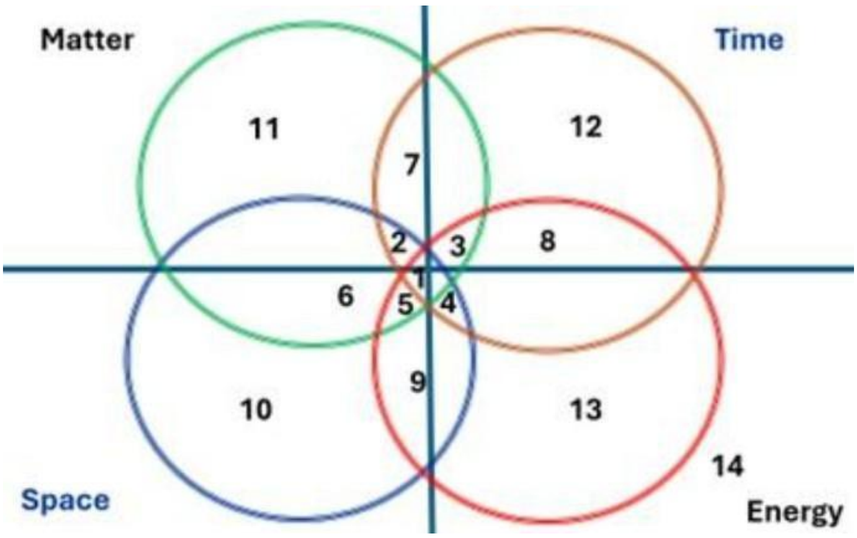

Figure 8: All possible states involving matter, energy, time, and space

Figure 8 illustrates all possible logical relationships between a finite collection of sets, namely energy, matter, time, and space. Four states come together to create 13 possible states. Nine new possible states of reality are created through a synthesis which resolves the conflict between opposing states. Dialectically, as a quantum system and relativity come together, they create a distinct third group that resolves the tension between them by means of a synthesis. This synthesis solves the conflict between two opposing states (a thesis and their antithesis) by reconciling their common truths. Speed is the one common trait or denominator that links quantum physics and relativity. Quantum physics comprises energy which contains speed. Relativity comprises time which contains speed. There are 10 possible states of reality that contain either energy or time and therefore contain speed. Speed connects quantum physics and relativity in another way. Relativity and quantum physics are both crucial to the foundations of how electromagnetic fields operate. Relativity is at work behind the scenes of many electromagnetic phenomena and quantum physics is crucial for understanding lasers (the basis of fiber optics). In fact, a common connection between the two theories is that they both developed from questions concerning electromagnetic radiation. Relativity developed from questions about the speed of light, and quantum physics was developed from questions about thermal radiation which is generated by the thermal motion of particles at high speed. This further supports the authors' postulation, and dialectical theory that speed is the common trait that links quantum physics and relativity. One area of further research includes further evaluation of the role of speed as a common denominator in developing a mathematical explanation for the unification between quantum physics and relativity.

5.3. Algebraic description of the dialectics of quantum systems and relativity

In mathematics, the intersection of two sets, namely a quantum system and relativity, is the set that contains all elements of quantum physics that also belong to relativity (or equivalently, all elements of relativity that also belong to quantum physics). In set theory, the union (∪) of a collection of sets is the set of all elements in the collection. As matter (M), energy (E), time (T), and space (S) intersect, quantum physics ($M \cup E$) becomes a set that contains 11 elements (nine states that contain speed, one state that contains space and matter, and one state of matter). Relativity ($T \cup S$) becomes a set that contains 11 elements (nine states that contain speed, one state that contains space and matter, and one state of space). Reconciling the states that contain the common interlocking of speed results in 10 possible states of reality coming together to form states 1, 2, 3, 4, 5, 7, 8, 9, 12, and 13. According to dialectical principles, reality is created through a union or synthesis of states that contain the common, interlocking trait of speed (see Figure 9.

As the literature shows, the problem with combining quantum physics and relativity is that relativity gives nonsensical answers when scaled down to quantum size, eventually leading to infinities in its description of gravity. Likewise, quantum physics encounters problems when blown up to cosmic dimensions, piling so much energy in the quantum field that it creates a black hole that causes the universe to fold in on itself. The dialectical relationship, which excludes states 6, 10, and 11 from the synthesis, subtracts tiny particles of matter and huge gravitational fields of space, thereby bridging the gap between quantum physics and relativity [90]. Quantum physics and relativity share a dialectical relationship as they: (i) Oppose each other and synthesize together, (ii) Are each separate states and part of one greater, whole continuum, (iii) Are incompatible with each other and share a continuous, transactional relationship. Similar to a set of meshing gears transmitting rotational motion, the relationship between quantum physics and relativity is not combined but transactional, and it is the conflict, tension and friction that is created between them that produces change. The new state following change (the synthesis) also comprises polar forces, and thus change is continuous. Therefore, one area for further research would be translating the algebraic description in Figure 9 into a more conceptualized mathematical formulation.

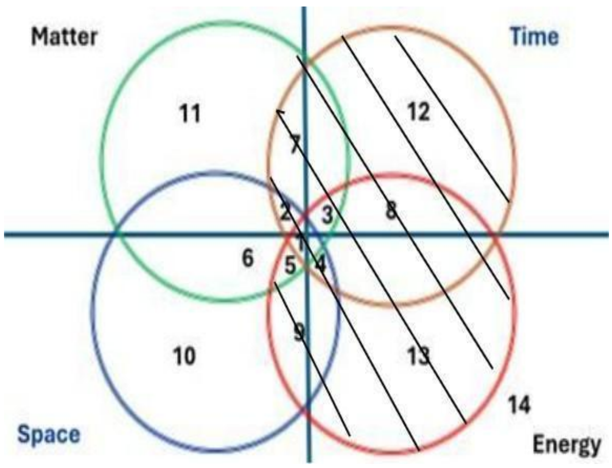

Figure 9: A dialectical interpretation of matter, energy, time, and space: the synthesis of all possible states that contain the common, interlocking trait of speed.

5.4. A dialectical interpretation of the fundamental forces

Continuing to expand on the dialectical approach, the authors apply the dialectical method to the four fundamental interactions of nature. For instance, opposing electromagnetic (thesis) and weak interactions (antithesis) are two parts which simultaneously synthesize together to create the electroweak interaction (a greater whole). Opposing states of time (thesis) and space (antithesis) are two parts which simultaneously synthesize together to create gravity (a greater whole). Opposing electric (thesis) and magnetic charges (antithesis) are two parts which simultaneously synthesize together to create electromagnetism (a greater whole). Strong interactions (which bind) and weak interactions (which decay) are two opposing parts which simultaneously synthesize together to create a nuclear interaction (a greater whole). Fermions and anti-fermions are two opposing parts which simultaneously synthesize together to create a weak interaction (a greater whole). Quarks (particles which have mass) and gluons (massless particles) are two opposing parts which simultaneously synthesize together to create a strong interaction (a greater whole). Gravity (which attracts) and electromagnetism (which repels) are two opposing parts which simultaneously synthesize together to create a greater whole. As the four fundamental forces come together, one can observe in Figure 10 a synthesis of states which contain the common, interlocking traits of attracting and binding. Dialectically, as the four fundamental forces come together, they create distinct new states that resolve the tension between them by means of a synthesis. This synthesis solves the conflict between two opposing states, a thesis which attracts/binds and an antithesis which repels/decays, by reconciling their common, interlocking traits, thus forming a new thesis that causes the process to begin again. Therefore, one area for future research would be to develop a mathematical formula to describe Figure 10, a dialectical interpretation of the fundamental forces. It is very noteworthy that the algebraic description for unifying matter, energy, time, and space, and the algebraic description for unifying the fundamental forces are identical.

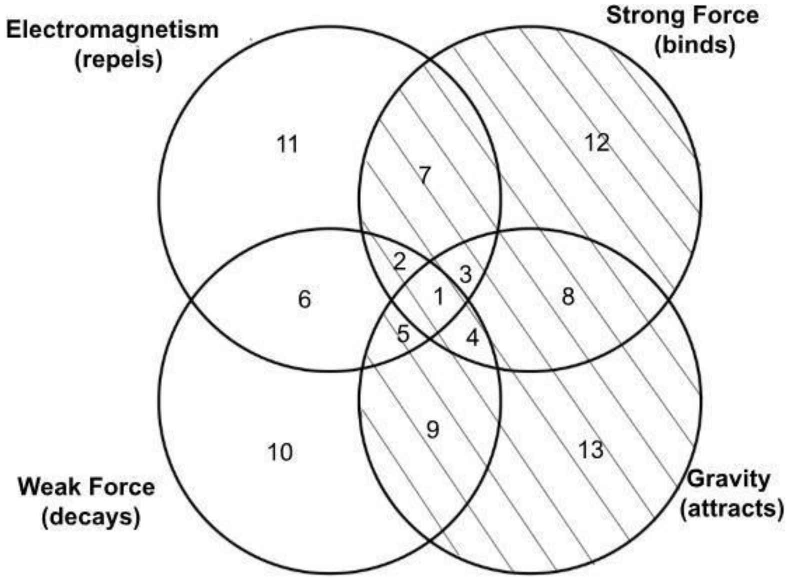

Figure 10: A dialectical interpretation of the fundamental forces

6. Comparison between dialectics and other unification theories

Dialectics compare, contrast, and build upon previously established unification attempts in several ways [91, 92]. Understanding these comparisons and relationships are necessary to identify gaps in research and guide future study. Here we compare the most relevant research in this area. We have previously discussed the relationship between Newton's universal law of gravity and dialectics. At its essence, dialectics is a simple application of Newton's third law in that, (i) it is the interaction between two opposing states, namely a quantum system and relativity, which creates motion and change, and (ii) a quantum system and relativity are two parts of a single interaction, and neither exists without the other. James Maxwell developed the classical theory of electromagnetic radiation, which was the first theory to describe electricity, magnetism and light as different manifestations of the same phenomenon [78]. Similarly, Albert Einstein discovered that energy and mass (matter) are the same thing, just in different forms. These are examples of Engel's dialectical law of the transformation of quantity into quality. This law states that gradual quantitative changes can lead to a sudden qualitative change. For example, heating water gradually increases its temperature (a qualitative change), but once it reaches 100 degrees Celsius, it transforms into steam (a qualitative change). The principle of transformation of quantity into quality illustrates how incremental, quantitative changes can culminate in a significant transformation or change. In this way, two opposing yet interdependent states share a transactional relationship, creating a single interaction and one greater whole continuum.

String Theory describes a complicated landscape of possible universes instead of providing a description of the real world. Dialectics bridges the gap between theory and the real world by explaining the relationship between subjective and objective reality, where each part of reality contributes toward a greater whole reality or higher truth. It provides a more clear and consistent description of the real world where reality is in a constant state of motion and change.

The standard model is widely considered the closest thing we have to a theory of everything, uniting all the fundamental particles of the universe. With future research, dialectics could serve as a bridge to understanding the relationship between the standard model and gravity. Summary of recommendations for future research includes:

i. To ensure that the theory is mathematically consistent, not merely philosophical. Future study should provide a foundation for predicting measurable phenomena and linking the interpretation to existing quantum formalism. Specifically, the mathematical formulation of the quantum state should be understood and solved as it relates to the superposition of states through a dialectical interpretation.

ii. To translate visual and conceptual insights into algebraic equations, enabling other researchers to test, simulate, or expand this work, it is important to bridge abstract ideas with real-world physics. Therefore, it is recommended to develop a mathematical formulation to support Figure 9, linking it to an algebraic description of matter, energy, time, and space.

iii. To develop a mathematical formulation for Figure 10, an algebraic description of the fundamental forces or interactions of nature. This could provide a unified framework connecting dialectical reasoning with physical interactions, offering a potential path toward conceptual unification in physics.

6.1. Importance of a dialectical approach

There are several potential advantages to a dialectical interpretation of quantum mechanics compared with standard interpretational frameworks. First, it provides a conceptual reformulation of the measurement problem. In conventional quantum theory, a system is described by a wave function initially in a superposition of states, which appears to reduce to a single outcome upon measurement. This transition is typically postulated as a collapse process, without a fully specified mechanism for when or why it occurs. In a dialectical interpretation, this distinction is reframed rather than replaced. The quantum state is understood as simultaneously expressing both (i) a localized, context-dependent realization and (ii) a distributed structure across a space of possible outcomes. In this view, “collapse” is not treated as a physical discontinuity, but as the selection of a particular relational description of a system within a broader structure of possibilities. Second, this perspective offers an alternative way of interpreting quantum entanglement. Entangled systems are typically described as non-separable states in which subsystems cannot be assigned independent states. A dialectical reading interprets this as a structural relation in which apparently distinct components remain correlated within a unified description, rather than existing as fully independent entities. Third, the dialectical framework provides a reinterpretation of superposition. Instead of viewing a superposition solely as a pre-measurement state that is eliminated by observation, it is treated as a representation of the full set of physically accessible alternatives encoded in the quantum state. Individual outcomes correspond to particular realizations within this structure, rather than the destruction of the underlying state. Fourth, by emphasizing the relation between different descriptive levels (e.g., objective physical modeling and observer-dependent measurement outcomes), a dialectical approach offers a conceptual bridge between formal theory and its interpretation in experimental contexts. Finally, this perspective suggests a structural compatibility between quantum mechanics and relativity, in the sense that both theories describe relational frameworks rather than absolute states. While this does not constitute a unification of the theories, it highlights potential conceptual parallels in their treatment of physical description.

6.2. Criticisms of a dialectical approach

Two main criticisms can be identified. First, the dialectical framework remains primarily interpretive and therefore requires further formal development and empirical grounding. At present, it does not introduce new experimentally distinct predictions beyond standard quantum mechanics. However, from a methodological standpoint, interpretive frameworks can still play a productive role in generating new conceptual and mathematical directions for research. Second, scientific practice operates within established paradigms that define standards of explanation and validation. In this sense, dialectical approaches fall outside the dominant interpretational framework of contemporary physics. As Thomas Kuhn argues, normal science proceeds within paradigms that guide problem-solving activity, while paradigm shifts occur when accumulated anomalies challenge existing conceptual structures [93, 94]. From this perspective, scientific development is not purely cumulative but also structurally discontinuous. Historical transitions such as Ptolemaic to Copernican astronomy, Newtonian to relativistic physics, and classical to quantum theory illustrate how foundational assumptions can change under the pressure of new theoretical and empirical constraints. At the same time, Kuhn also emphasizes that paradigms are often incommensurable, meaning that competing frameworks may not be directly reducible to one another. This complicates evaluation but also enables conceptual innovation beyond existing assumptions. In this context, unresolved anomalies in current physical theory may be interpreted as indicators of conceptual incompleteness rather than empirical failure. As Einstein noted, progress in understanding often requires a revision of underlying conceptual frameworks rather than refinement of existing ones alone [95, 96].

7. Conclusion

The advancement of science can be described as a dialectical process, where the development of scientific knowledge and theories is not linear but rather involves the resolution of contradictions and the emergence of new concepts. This dialectical approach is evident in scientific revolutions and the continuous evolution of scientific thought. In this paper, a dialectical interpretation of quantum mechanics is presented, essentially expanding Newton’s third law to fundamental natural elements.

Over time, the evolution of dialectics has developed into a unified and coherent theoretical framework for understanding quantum mechanics and entanglement, filling gaps and building upon previous research while providing a symmetrical and more predictive representation of the universe and reality. Finally, this paper shows that a dialectical approach can provide insight into the complexities and paradoxes inherent in unifying quantum physics and relativity. Of course, unified field theory is an evolving concept in physics, still under research, with challenges largely stemming from the absence of a solid mathematical framework. Developing this framework requires deeper collaboration to create tools for standardizing and visualizing theory. A dialectical approach could serve as a bridge between quantum mechanics and relativity, offering a foundation for new mathematical formulas that could guide future experimental testing and studies.

8. Acknowledgement

We would like to acknowledge the outpatient behavioral health team and leadership at Memorial Regional Hospital, Hollywood, Florida, USA for their support and training in dialectical behavior therapy which became the foundation for this research.

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