Ⓤ International Journal of Quantum Foundations **12** (2026) 85-137 Ⓤ

Original Paper

Distributed Presence: A Structural Ontological Framework for Randomness and Quantum Phenomena

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Received: 3 February 2026 / Accepted: 16 February 2026 / Published: 17 February 2026

Abstract: Despite the empirical robustness of quantum mechanics, foundational questions regarding the ontological status of the quantum state and the origin of probability remain unresolved. This work introduces **Distributed Presence (DP)**, a structural ontological framework that addresses these issues by reinterpreting quantum phenomena through the lens of a system's modaldistribution across its state space. Crucially, this distribution is distinct from spatial extension; it describes how a system ontologically exists across mutually exclusive possibilities prior to interaction. Departing from epistemic interpretations that assume definite pre-measurement values, DP posits that distributed presence is a fundamental feature of physical reality. Consequently, probability is not introduced as a primitive axiom but emerges operationally from the geometric reconfiguration of this presence, offering a structural derivation of the Born rule. This perspective provides a unified conceptual basis for superposition, measurement collapse, and entanglement. Specifically, entanglement is defined as the non-factorizability of presence fractions within a composite state space. From this standpoint, non-local correlations are understood as consequences of a shared modal structure (an ontological unity) rather than dynamical signal transmission, ensuring full compatibility with relativistic causality. Formulated within a Euclidean geometric setting chosen for ontological transparency, the framework complements the standard Hilbert-space formalism. By grounding randomness and quantum behavior in the logic of distributed presence, this work bridges the conceptual gap between unitary evolution and definite outcomes, offering a coherent alternative to both wave-function realism and purely informational interpretations.

Keywords: Distributed presence, Quantum mechanics interpretation, Measurement problem, Probability interpretation, Wave-particle behavior, Wave function collapse, Quantum dice, Presence fraction, Structural Framework, Ontological Framework, Ontological interpretation

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1. Introduction

More than a century after its formulation, quantum mechanics remains without a single, universally accepted interpretation. While its mathematical formalism yields predictions of unparalleled accuracy, profound conceptual disagreements persist regarding the ontological status of quantum states, the nature of probability, and the mechanism of measurement. The spectrum of existing interpretations (from the Copenhagen instrumentalism to the many-worlds realism) reflects not merely philosophical preference, but a genuine, unresolved tension at the foundations of the theory. [1]

In recent decades, foundational research has increasingly shifted toward ontological analyses that seek to clarify the underlying structure presupposed by the quantum formalism. Results in ψ-ontology strongly suggest that the quantum state cannot be reduced to a mere catalog of epistemic ignorance. [2] Concurrently, approaches grounded in fuzzy logic and many-valued semantics have challenged the *classical binary conception of presence* when describing quantum properties. Modern reassessments of Bell's theorem, moreover, indicate that non-local correlations may call for a re-examination of structural and space-time assumptions, rather than the postulation of dynamical signal transmission. Together, these developments motivate the search for a conceptual framework capable of articulating a coherent ontological picture without altering the empirical content of quantum mechanics.

A central theme unifying these debates is the nature of *intrinsic randomness* in quantum systems. Unlike classical randomness, which is typically attributed to complexity or incomplete knowledge, quantum randomness appears irreducible within the standard theoretical framework. Experimental *violations of Bell inequalities* rule out classical hidden-variable reconstructions, reinforcing the view that quantum indeterminacy is not merely epistemic. Yet the ontological meaning of such intrinsic randomness remains insufficiently clarified: what, precisely, is random, and in what sense does this randomness belong to the physical system itself?

This paper addresses these questions by introducing and analysing the concept of **Distributed Presence (DP)** as a *structural-ontological framework* for interpreting randomness and probability in quantum systems. [3] Within this perspective, physical systems are understood as exhibiting a *distributed presence* across their state space prior to interaction, rather than possessing sharply localized properties. *Probability, on this view, does not express ignorance about pre-existing definite states, but reflects the structure of this distributed presence.* Importantly, the present work does not propose a modification or replacement of the standard Hilbert-space formalism; rather, it offers a conceptual and ontological analysis intended to clarify how quantum probabilities and phenomena such as superposition, interference, measurement, and entanglement may be understood structurally.

The core idea of DP can be illustrated through a simple, finite-state model, a "*quantum die*." In this model, a die is not treated as a dynamical object moving in physical space, but as a *structural object* whose identity is exhausted by the set of its possible states. Prior to interaction, the die's presence is distributed over those states in proportion to a well-defined **Presence Fraction**. This distribution is not a sign of missing information, but a fundamental mode of realisation. Probability emerges operationally as the ratio of the *presence fraction* associated with a given state to the total presence over the whole state space, thereby providing a *structural derivation of the Born rule* without treating probability as a primitive postulate. [16]

Methodologically, the framework is developed using a geometric, Euclidean representation, chosen deliberately for ontological transparency rather than as a competing formalism. Within DP, phase is not treated as an ontological property of the state itself; instead, interference arises from the *algebraic combination of signed presence components*, while phase functions as a parameter governing *structural orientation.* The analysis remains fully compatible with standard quantum mechanics and is intended to complement, rather than supplant, existing mathematical formulations.

Although the present study is formulated within the domain of physics, the introduction of *foundational structural concepts* necessarily intersects with philosophical considerations concerning existence, probability, and reality. Accordingly, the primary aim of this work is to establish a coherent ontological basis upon which the *probabilistic and non-local features* of quantum mechanics can be conceptually understood. By *prioritising structural clarity* over premature formal generalisation, this framework lays the groundwork for future mathematical and empirical developments, offering a realist, structurally grounded narrative for making sense of quantum theory.

2. Structural Ontology and State Space

2.1. Structural Objects

This section introduces the notion of a structural object as an ontological category suited to systems whose behavior cannot be adequately characterized within the classical dynamical framework. In classical descriptions, physical objects are typically conceived as entities composed of spatial parts, persisting through continuous trajectories in physical space and time. Their states describe configurations of pre-existing objects whose identities are maintained independently of any particular state description.

By contrast, a structural object is not defined by motion, trajectory, or internal composition. Its identity does not derive from underlying constituents or from continuous dynamical evolution in physical space. Instead, what characterizes a structural object is the structure of its available states. These states are mutually exclusive at the level of outcomes, yet together they define the object's ontological identity. [13]

From this perspective, the object does not exist first as an independent entity that subsequently occupies one of its states. Rather, the collection of possible states constitutes the object itself. The object's identity is entirely specified by the structure of its state space, without invoking an additional physical substratum or hidden layer beneath it. In this sense, a structural object is not something over and above its state space; its ontological presence is exhaustively determined by how it is structurally represented within that space.

Importantly, this conception does not presuppose how many states are realized at a given moment, nor how transitions between states may occur. At this stage, the framework is intentionally pre dynamical and pre probabilistic. The role of structural objects is to provide an ontological foundation upon which notions such as distributed presence, probability, and state localization can later be articulated in a clear and non-epistemic manner. Subsequent sections will realize this abstract definition through concrete systems that serve as minimal and transparent exemplars of structural objects.

2.2. Distributed Presence

Once a system is understood as a *structural object*, its mode of presence must be reconsidered accordingly. Classical ontology implicitly treats presence as sharp: an object either exists in a given state or it does not. This assumption is adequate for macroscopic composite objects whose constituents can be independently localized and tracked through space and time.

For structural objects, however, this assumption is no longer warranted. Since such an object is constituted by its state space and does not exist independently of its states, no single state is privileged a priori as fully exhausting its presence. As a result, presence itself cannot be treated as an all or nothing attribute tied to a unique state.

Instead, *the presence of a structural object is distributed across its available states.* [14] This distribution does not represent ignorance about which state the object "really" occupies, nor does it encode incomplete knowledge. Rather, it expresses how the object itself is realized within its state space prior to any interaction that enforces localization.

In this framework, mutually exclusive states do not correspond to alternative realities among which the object secretly chooses. They represent distinct structural modes through which the object participates in its state space in a non-exclusive manner. The object is present in multiple states at once, not by being fragmented into parts, but by existing as a single indivisible entity whose realization is spread across structurally defined possibilities.

Distributed ontological presence should therefore be understood as a fundamental ontological feature of structural objects. At this level, no assumptions are made concerning dynamics, temporal evolution, or probabilistic interpretation. The concept merely asserts that presence need not be sharply confined to a single state prior to interaction. This shift provides a conceptual basis for phenomena that appear paradoxical from a classical standpoint (such as intrinsic randomness, non-local correlations, and the necessity of state selection) without invoking additional explanatory mechanisms.

2.3. Sharp vs Distributed Presence

Classical ontology is governed by the Law of Excluded Middle: a system either occupies a given state or it does not, with no intermediate possibility. For macroscopic composite objects, this binary notion of presence is well justified, as such objects are constituted by localized components whose configurations are well defined at all times.

However, once the object is treated as structural, whose identity is exhausted by its state space, this binary notion becomes inadequate. As argued above, the presence of such an object may be distributed across mutually incompatible states prior to interaction. In this regime, the classical application of the Law of Excluded Middle to state occupancy no longer applies straightforwardly.

To capture this distinction, the concept of distributed presence is introduced. A system exhibits distributed presence when its presence is not confined to a single state, but is instead shared across multiple states within its state space. Unlike sharp presence, distributed presence does not assign full presence to one state while excluding all others. Presence itself admits degrees of realization across structurally defined alternatives.

Crucially, structural distribution of presence is not a claim about uncertainty, ignorance, or incomplete information but it is ontological rather than epistemic. The system does not possess a sharp but unknown state; rather, its mode of presence prior to interaction is genuinely non-exclusive. This distinction separates classical objects, which necessarily exhibit sharp presence, from foundational structural objects, whose presence is inherently distributed in the absence of localization.

2.4. Structural Propositions of Distributed Presence

The preceding analysis can be summarized in a small number of structural propositions.

Before stating the following propositions, we introduce the term presence fraction PF_i

as a normalized structural quantity associated with each admissible state s_i, representing the relative structural share of the system's distributed presence assigned to that state. A detailed construction of PF_i from underlying presence weights is provided in Section 4-4.

Proposition 1 (Normalization and Boundedness of Presence Fraction)

For a system described within the distributed presence framework, the presence fraction PF_i assigned to each state s_i satisfies

$$0 \leq PF_i \leq 1, \quad \sum_i PF_i = 1 \tag{1}$$

This condition does not function as an axiom of probability theory, nor does it encode statistical frequency or epistemic uncertainty. Instead, it expresses a structural constraint: at any interaction event, the system's entire presence must be realized through exactly one state. [15] Normalization therefore reflects the boundedness and completeness of distributed presence, not probabilistic consistency.

Proposition 2 (Structural Criterion for Distributed Presence)

A system exhibits distributed presence if and only if there exists no state s_i such that

$$PF_i = 1 \tag{2}$$

prior to interaction. Equivalently, distributed presence corresponds to a non-trivial distribution in which

$$0 < PF_i < 1 \tag{3}$$

for more than one state.

This criterion is ontological rather than epistemic. It signifies that the system's presence is structurally distributed across multiple states, not that the actual state is unknown. These propositions are structural in character: they are neither axioms of a probabilistic formalism nor statements of dynamical law, and they presuppose no hidden variables or underlying mechanisms.

2.5. Structural Presence, Modal Distribution, and the Absence of Dynamics

A recurring source of conceptual tension in ontological interpretations of quantum mechanics arises from the tendency to conflate **structural change** with **physical dynamics**, and **distributed existence** with **spatial extension**. The framework of distributed presence explicitly rejects both identifications.

2.5.1. Modal, Not Spatial, Distribution

When we state that a physical system possesses a distributed presence, this *distribution is **not spatial***. No claim is made that the system is physically smeared across ordinary three-dimensional space. [4] Instead, *the distribution is* ***modal***: it is defined over the system's space of possible states. [5]

Formally, the presence fraction

$$\Pi = \{\Pi_i\} \tag{4}$$

is a measure over a state space (classical or quantum), not over space-time. Each Π_i quantifies the degree to which the system is structurally present in the possibility corresponding to state i, prior to interaction.

This distinction is crucial for philosophical clarity. *Modal distribution* concerns how a system exists across possibilities, not where it exists in space. As such, distributed presence does not imply spatial nonlocality in the classical sense, nor does it conflict with relativistic locality.

2.5.2. Structural Interference and the Necessity of Relational Terms

Because presence is constructed from **signed structural components** S_i, the total presence associated with a composite configuration is not generally a simple sum of independent contributions. [6] Instead, the full structure takes the form

$$\Pi(x) = \Pi_L(x) + \Pi_R(x) + \Pi_{LR}(x), \tag{5}$$

where the relational term Π_{LR} arises unavoidably from the algebraic structure

$$(S_L + S_R)^2 = S_L^2 + S_R^2 + 2S_L S_R. \tag{6}$$

The relational component is therefore not an auxiliary postulate but a **structural consequence** of representing presence via signed components whose squares define physically admissible (non-negative) presence fractions. [7] Phenomena such as interference minima correspond to cases of **structural cancellation**, where the total presence at a configuration vanishes even though individual modal contributions are nonzero.

2.5.3. Parametric Reconfiguration versus Physical Dynamics

Within this framework, apparent "motion" in state space (such as the rotation of a quantum die induced by a classical control parameter) does not represent physical time evolution governed by a dynamical law (e.g. Schrödinger evolution). [8] Instead, it is a case of **parametric structural reconfiguration**.

The underlying presence structure does not propagate, flow, or evolve causally. Rather, the parameterization by which the structure is described changes. The distinction is analogous to changing coordinates on a fixed geometric object: the description varies, while the object itself does not undergo a physical process.

Consequently, Distributed Presence is fundamentally **non-dynamical**. [9] It specifies what structural possibilities exist and how they are related, not how physical systems evolve in time.

2.5.4. Collapse as Single-Channel Interaction

What is traditionally called 'wave function collapse' is reinterpreted as a single-channel interaction event between the system and its environment. Owing to interaction constraints, only one compatible structural channel can be accessed, resulting in a global reconfiguration and localization of the system's distributed presence in state space.

This interaction does not destroy or dynamically modify the global presence structure. Instead, it **selects** one pre-existing modal channel for physical realization. The apparent discontinuity of collapse reflects a transition from *modal structure* to actual interaction, not a superluminal physical process.

2.5.5. The Role of the Speed of Light

The speed of light c plays no role in constraining the existence or reconfiguration of presence structures, precisely because these structures are non-dynamical and modal. There is no signal, energy, or information propagating across space when the presence structure is reparameterized or globally constrained.

The constraint imposed by c applies exclusively at the level of **physical interaction** that is, when a localized measurement or environmental coupling occurs. In this sense:

$$\text{Structural change} \neq \text{causal signal transmission.} \tag{7}$$

This separation allows the framework to account for Bell-type nonlocal correlations through **ontological unity in state space**, while remaining fully compatible with *relativistic causality* and the no-signaling theorem.

2.5.6. Summary

Distributed Presence introduces a clear stratification:

- ***Modal structure*** (presence over state space): non-spatial, non-dynamical, unconstrained by c.
- **Physical interaction** (measurement, coupling): localized, single-channel, causally constrained by c.

By maintaining this distinction, the framework dissolves long-standing confusions surrounding interference, collapse, and nonlocality, not by modifying quantum predictions, but by clarifying the ontological status of the structures that underlie them.

3. Dice as Structural Realization

Throughout this work, dice-based terminology is employed as a finite and structurally complete realization within abstract state space. The dice construction is not intended as a literal physical model, nor as a metaphor replacing standard formalism. Rather, it functions as a structural instantiation designed to make the ontological features of distributed presence explicit in a geometrically transparent manner.

All definitions, propositions, and results formulated in this framework are expressed at the level of abstract state spaces and do not depend on the macroscopic physical properties of dice. The dice-based realization is therefore methodologically auxiliary: it can be removed entirely without affecting the conceptual content, scope, or conclusions of the framework. Its role is to provide a minimal and accessible structural setting in which distributed and non-sharp presence can be analyzed without invoking microscopic dynamics or Hilbert-space machinery.

3.1. Classical Dice

From a classical perspective, a die is a rigid geometric body (typically cubic) commonly used as a paradigmatic system for generating discrete random outcomes. In its standard form, a die consists of a finite number of faces, conventionally treated as equiprobable states, although more general configurations with non-uniform distributions are possible.

A classical die admits two physically distinct regimes:

- Static die: a die at rest in mechanical equilibrium on a supporting surface, where a single face is definitively in contact with the surface.
- Dynamic die: a die in motion, typically during a throw, undergoing rotation and lacking mechanical equilibrium.

In scientific analysis, the physically relevant outcome is determined by the resting face, defined as the face in contact with the supporting surface once equilibrium is reached. For a static die, this condition is unambiguous: exactly one face is fully settled and uniquely determines the outcome.

For a dynamic die, no such unique resting face exists. Nevertheless, for any instantaneous geometric orientation, each face possesses a well-defined resting component, determined by its orientation relative to the supporting surface. These resting components characterize how each face contributes structurally to the possibility of rest.

The resting component of face i, denoted A_i, is defined as the signed horizontal projection of that face onto the surface. If A is a characteristic length scale associated with the face and θ_i is the angle between the face and the surface, then

$$A_i = A\cos\theta_i \tag{8}$$

The sign reflects the directional contribution of each face to resting, rather than a spatial distance. Faces oriented toward the surface carry a positive contribution, while those oriented away carry a negative one.

Accordingly, a dynamic die does not instantiate a single resting configuration but instead encodes a distributed structural relation to the surface through the set $\{A_i\}$. All faces contribute simultaneously, even in the absence of equilibrium. This distributed configuration provides the structural input for the abstraction developed in the next subsection.

Figure 1 illustrates resting components for a two-dimensional die in dynamic and static states.

3.2. Quantum Dice

The quantum die is introduced as an abstract construct in state space, derived structurally from the resting components of a classical dynamic die. [10] Each state of the quantum die corresponds to a face of the classical die, and the size associated with each state is taken to be proportional to the resting component of the corresponding classical face.

As the geometric orientation of the classical die is parametrized, the angles θ_i vary continuously, leading to a continuous reassignment of the values A_i. In the quantum-die representation, this corresponds to a continuous structural reassignment of state sizes in state space. Importantly, this dependence on orientation should not be interpreted as a fundamental dynamical evolution in state space, but rather as a geometric parametrization reflecting changing structural projections of the classical configuration. (Figure 2)

The significance of the quantum die does not lie in the classical motion that motivates its construction, but in the resulting structural description: a system whose existence is not localized in a single state, but distributed across multiple states according to well-defined geometric weights. In this representation, presence is no longer binary but shared among states in a controlled and structurally specified manner.

At this stage, two distinct perspectives can be distinguished:

- Dynamic analysis: the behavior of the die as a physical object evolving in real space.
- *Structural analysis*: the representation of the system as an abstract entity in state space, characterized by a distribution of presence across states.

The present work adopts the structural perspective as primary. The die is analyzed not in terms of forces, trajectories, or temporal evolution, but in terms of how its presence is

Figure 1. Illustration of resting components for a two-dimensional die in dynamic and static states.

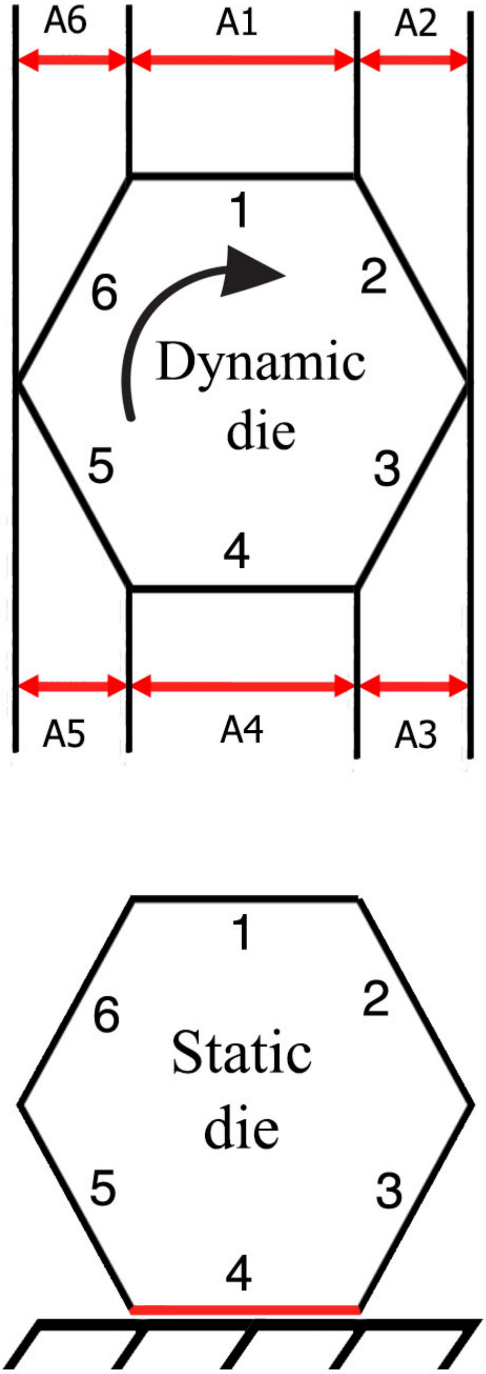
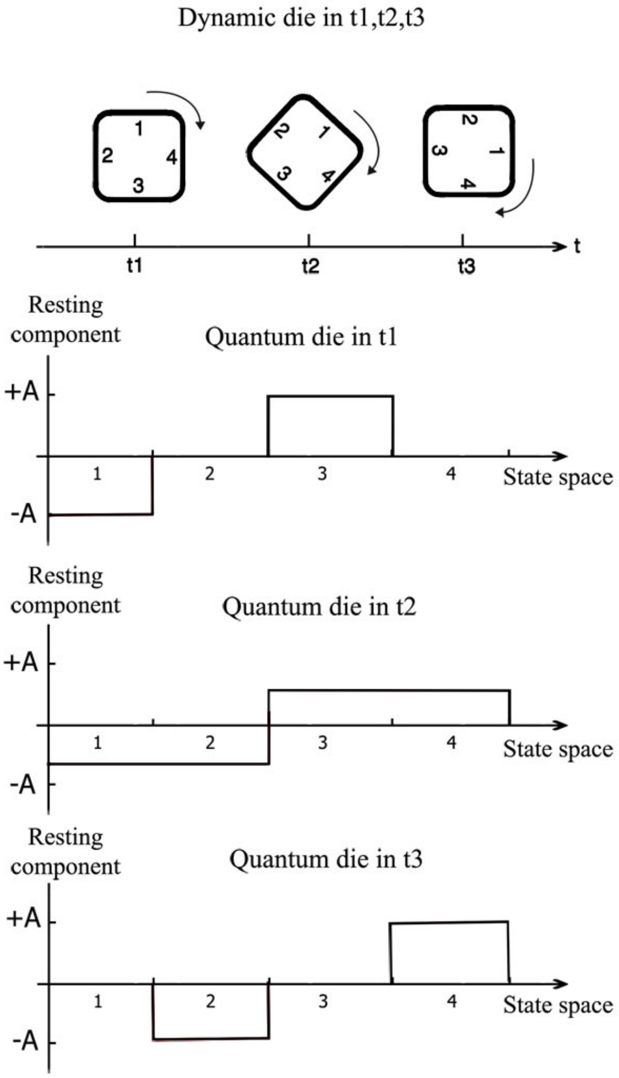


Figure 2. Continuous structural reassignment of state sizes corresponding to geometric orientation.



structurally distributed over its possible states. This shift of framing is essential for the subsequent analysis of probability, randomness, and state localization as consequences of structure rather than ignorance or hidden dynamics.

In the following sections, the quantum die will serve as a minimal and conceptually transparent realization for exploring these ideas. Before proceeding further, however, additional conceptual tools are required to clarify how this structural distribution is quantified and how it relates systematically to the notion of distributed presence.

3.3. Ontological Status of the Quantum Die

The analysis presented in this work is structural rather than dynamical in scope. No trajectories, equations of motion, or assumptions about underlying microstates are introduced at this stage. This methodological choice is deliberate and reflects the limited ontological aim of the framework: to clarify how quantum states are constituted prior to interaction, rather than how they evolve continuously in time.

Within this perspective, the quantum die does not possess a definite state before interaction, nor is there a privileged fact of the matter regarding which face is "actually realized" in advance. [11] Instead, it is described as a single system whose ontological presence is distributed across its admissible states. This distribution represents a genuine feature of the system itself and should not be interpreted as epistemic uncertainty or lack of information. [12]

The joint structural realization of multiple states is therefore structural rather than dynamical. Interaction with the environment does not reveal a pre-existing outcome, but instead enforces a structural transition in which distributed presence becomes localized in a single interaction channel. In this sense, localization is not an uncovering of prior definiteness, but a reconfiguration of the system's ontological structure under constraint.

This position differentiates the present framework from classical stochastic descriptions and hidden-variable approaches, while remaining compatible with the empirical content of quantum mechanics. Although geometric constructions motivate the model, the underlying ontology refrains from assuming state definiteness or dynamical determinism at the pre-interaction level. The quantitative characterization of distributed presence (including its normalization, the role of signed components, and the necessary appearance of cross-terms when such components are combined) is developed in the following sections.

3.4. Structural Dynamics and the Status of Time in the Distributed Presence Framework

Foundational physical theories are often expected to provide explicit equations governing the continuous time evolution of states. The distributed presence (DP) framework is consistent with approaches in quantum foundations where kinematical and structural constraints are fixed prior to the introduction of dynamical laws.

The primary objective of DP is to clarify the structure of quantum states prior to interaction, not to furnish a complete dynamical account of their evolution. Quantities such as distributed presence Π_i characterize how a system exists across its state space before localization. These quantities define an ontological state structure rather than a trajectory in time. Accordingly, the framework addresses the question what a state is before addressing how it evolves.

Time evolution is therefore not taken as a fundamental primitive within DP. Instead, a sharp distinction is drawn between continuous dynamical descriptions and interaction-induced structural transitions. Between interactions, the system is characterized by a stable presence distribution subject to structural constraints, such as conservation of total (signed) presence,

$$\sum_i |\Pi_i| = const \tag{9}$$

No additional evolution equation is postulated at this level.

Change becomes physically significant only at interaction events, where coupling to the environment enforces a single interaction channel. This enforcement leads to a global reallocation of distributed presence, corresponding operationally to observation or collapse. Within DP, such collapse is not a dynamical projection in time, but a structural selection constrained by the ontology of distributed presence.

Clarification on the Speed of Light and Non-locality.

The DP framework posits that the presence structure Π_i is non-dynamical: for a given configuration it is static and does not evolve by a local differential equation. The speed of light c constrains only the physical interaction layer (the coupling of the environment to a single channel) not the structural distribution itself. Non-locality is therefore structural, not dynamical, and no superluminal signaling is possible. The instantaneous structural reconfiguration upon interaction respects the causal constraints imposed by c at the interaction layer, because the selection of a channel is a boundary condition, not a signal propagating within the structural layer.

Collapse as a Boundary Interaction.

Collapse is an interaction event at the boundary, not an intrinsic dynamical process. The system can couple only through a single channel with environment, which enforces a structural selection (reconfiguration) of the pre-existing distributed presence. This selection is instantaneous in the structural description but respects the causal constraints imposed by c at the interaction layer. Parametric changes (e.g., rotating a classical die) induce a change in the representation of the quantum die's state, but this change is a parametric structural reconfiguration, not an intrinsic dynamical evolution. The structural configuration is defined by external parameters, and altering the parameter changes the representation without invoking an equation of motion.

In this sense, DP replaces continuous time evolution with law-like structural constraints governing how presence distributions may be reconfigured under interaction. [17] These constraints are not probabilistic postulates, but consequences of the single-channel character of interaction and the prior distribution of ontological presence. The resulting notion of "structural dynamics" affirms that change is real and constrained, while remaining non-describable by a local differential equation in time.

It would therefore be a category mistake to require a Schrödinger-type equation at this level of formulation. The DP framework is not presented as a complete dynamical reformulation of quantum mechanics, but as a foundational account of state structure upon which probabilistic and measurement-related phenomena are grounded. Any fully dynamical extension (should it be required) must be constructed on top of this clarified ontological layer rather than presupposed within it.

In summary, the absence of an explicit equation of motion reflects a deliberate framing choice: priority is given to ontological structure over temporal evolution. The framework specifies how quantum states are constituted and constrained, while leaving the development of detailed dynamical laws as a subsequent and logically dependent step.

3.5. Structural Reconfiguration, State Space, and the Absence of Signal Propagation

This subsection clarifies a set of conceptual distinctions underlying the distributed-presence framework, with the explicit aim of preventing a misinterpretation of structural change as dynamical signal propagation or superluminal causal influence.

3.5.1. Distributed Presence as Ontological Structure

Within the distributed -presence framework, a physical system prior to interaction is not characterized by a definite state or location, but by a **distributed presence** defined over its state space. This presence distribution is an intrinsic ontological feature of the system, not a representation of epistemic ignorance. The quantities Π_i describe the fraction of presence associated with different states and collectively define a single global structure. [20]

3.5.2. Signed Components and Structural Relationality

The components of presence are fundamentally **signed**, allowing for constructive and destructive structural combinations. As a consequence, relational terms (e.g., Π_{ij}) arise necessarily from the algebraic composition of presence components and are required to maintain basis-independence of the total structure. Structural cancellation, including cases where the total presence vanishes at specific configurations, is therefore an ontological property rather than an interference artifact.

3.5.3. Time Dependence Without Causal Dynamics

The presence distribution $\Pi_i(t)$ may exhibit continuous time dependence. However, this temporal dependence does not represent physical motion, transport, or causal propagation. Time here functions as a **parameter of structural reconfiguration**, reflecting changes in boundary conditions or external constraints, rather than an intrinsic dynamical evolution governed by local equations of motion.

Accordingly, the "motion" of a structural wave in state space should be understood as a change in the global pattern of presence, not as the displacement of a physical entity.

3.5.4. Structural Change Versus Signal Transmission

A crucial distinction must be drawn between **global structural reconfiguration** and **signal transmission**. Signal transmission requires (i) localized controllability, (ii) a causal channel, and (iii) operational accessibility by independent observers. Structural presence satisfies none of these conditions. Although the structure is globally defined, it does not carry energy, cannot be locally modulated to encode information, and cannot be accessed except through localized interaction events. [19]

Therefore, even instantaneous or global changes in the presence structure do not constitute signal propagation.

3.5.5. State Space and the Category Error of Spatial Projection

The state space on which distributed presence is defined is not identical to physical space, even when its coordinates are related to spatial degrees of freedom. Projecting structural change in state space onto physical space and interpreting it as spatial propagation constitutes a category error. The mapping from state space to physical space is interpretive rather than dynamical and does not generate a physical velocity.

3.5.6. Role of Interaction and the Emergence of Relativistic Constraints

Relativistic constraints, including the speed of light c, apply exclusively at the level of **physical interaction** between the system and its environment. Interactions are local, single-channel events through which the global structure becomes physically accessible. It is at this interaction layer (not at the structural level) that causal ordering and relativistic bounds are enforced.

In this sense, relativistic causality is not imposed on the ontological structure itself, but emerges from the conditions under which structure can be physically realized and observed.

3.5.7. Quantum Systems as Structurally Reconfiguring Entities

When generalized from dice-like systems to quantum particles, the framework suggests that a quantum particle is not a localized object in motion, but a **structurally reconfiguring pattern of presence** in state space. Measurement outcomes do not track the trajectory of an underlying object but correspond to interaction-induced selections from a pre-existing global structure. [18]

Concluding Remark

Structural change within the distributed-presence framework should therefore be understood as a global reorganization of ontological possibilities rather than as a dynamical or causal process. This distinction allows the framework to accommodate nonlocal correlations and time-dependent structures while remaining fully consistent with the non-signaling requirement and relativistic causality.

4. Mathematical Framework of Distributed Presence

4.1. Structural State Space

We consider a physical system whose possible modes of occurrence are represented by a discrete structural state space

$$S = \{s_1, s_2, \ldots, s_n\}. \tag{10}$$

The elements of S are mutually exclusive structural states characterizing the possible modes in which the system may exist prior to interaction.

This construction introduces a geometric state space with limited ontological scope; no Hilbert space structure is assumed at this stage. At this stage of analysis, no assumptions are made concerning linearity, inner products or equations of motion. This restriction reflects the limited ontological scope of the framework rather than a rejection of standard quantum formalism.

4.2. Formal Minimalism of Distributed Presence

As emphasized in Section 4.1, the purpose of the present framework is not to introduce a fully developed mathematical theory, but to provide a minimal formal scaffold sufficient to explicitly fix the ontological hierarchy underlying distributed presence. This subsection therefore restricts itself to the lowest possible level of formal articulation required to avoid conceptual ambiguity, particularly between ontological structure and probabilistic description.

Let G denote a geometric state space chosen for *ontological clarity* and relativistic compatibility (see Section 3). From G, we consider a finite or discrete set of structurally distinguishable states

$$S = \{s_i\} \subset G. \tag{11}$$

No additional algebraic or topological structure is assumed on S at this stage.

4.2.1. Ontological Primitive

The fundamental ontological primitive of the DP framework is defined as a presence distribution

$$\Pi : S \to \mathbb{C}, \tag{12}$$

where each value $\Pi_i \equiv \Pi(s_i)$ represents the complex valued degree of ontic presence associated with the structural state s_i.

It is crucial to stress that Π is not interpreted as a probability amplitude, nor as a wave function in the standard quantum mechanical sense. At this level, Π is postulated solely as a structural assignment of distributed presence over the state space S. No normalization condition, dynamical evolution, or Hilbert space structure is imposed.

4.2.2. Presence Fraction as a Derived Quantity

From the primitive distribution Π, a real, non-negative scalar quantity (termed the presence fraction) is introduced as a derived measure:

$$PF_i := |\Pi_i|^2 \in \mathbb{R}^+ \tag{13}$$

The presence fraction PF_i quantifies the structural weight associated with the state s_i and is not an independent ontological variable. Its role is strictly secondary to Π, arising from the minimal requirement that structural presence admits an experimentally accessible scalar manifestation.

This construction should not be confused with probabilistic postulation: the squared modulus operation is introduced here purely as a structural extraction rule, not as an axiom motivated by statistical arguments.

4.2.3. Empirical Identification with Probability

At the empirical level, observed outcome frequencies are identified with the presence fraction via

$$P(i) \equiv PF_i \tag{14}$$

This identification constitutes an empirical closure rather than a foundational assumption. Probability, within the distributed presence framework, therefore appears not as a primitive concept, but as an emergent description of the underlying structural distribution of presence. The Born type rule is thus interpreted as a consequence of structural ontology, not as an independent probabilistic principle (see Section 6).

4.2.4. Scope and Delimitations

The minimal formalism introduced here deliberately excludes:

- any commitment to Hilbert space structure,
- any specification of dynamical laws,
- any assumption of temporal evolution,
- and any identification of Π with a ψ-ontic quantum state.

These elements may appear as effective or representational tools at later stages (Section 8), but they play no role at the level of ontological grounding established in this subsection. The formal hierarchy

$$G \to S \to \Pi \in \mathbb{C} \to |\cdot|^2 \in \mathbb{R}^+ \tag{15}$$

summarizes the entire mathematical commitment of distributed presence at its most fundamental level.

4.3. Distributed Presence

To each state $s_i \in S$, we assign a fundamental ontological quantity called distributed presence

$$\Pi : S \to \mathbb{C}, \quad \Pi(s_i) := \Pi_i \tag{16}$$

The quantity Π_i is introduced as an ontological quantity within the present interpretive framework, dimensionless, and structurally defined. In general formulations, it may be signed or complex-valued. The sign or phase carried by Π_i encodes structural orientation and mode of emergence, and has no probabilistic interpretation; in particular, negative or complex values do not correspond to negative probability.

In classical dice, the distributed presence is uniform, real, and strictly positive, reflecting sharp localization under equilibrium. In quantum dice (introduced here as structural realizations rather than physical analogues) the distribution of Π_i arises from geometric projections in state space and may take positive, negative, or phase valued forms. In the simplest realization considered,

$$\Pi_i \propto \cos\theta_i \tag{17}$$

4.4. Presence Fraction (PF)

The Presence Fraction (PF) is defined as the normalized magnitude of distributed presence:

$$PF_i := \frac{|\Pi_i|}{\sum_{j=1}^{n} |\Pi_j|} \tag{18}$$

By construction,

$$PF_i \geq 0, \quad \sum_i PF_i = 1 \tag{19}$$

Mathematically, PF is a normalized weight distribution over the discrete set S. It is neither a probability measure derived from statistics, nor a field, nor a density on a manifold. Rather, it is a normalized weight function whose operational interpretation coincides with probability.

4.5. Ontological Status and Probability

The Presence Fraction is ontic: it specifies how the actual presence of the system is distributed across mutually exclusive states prior to interaction. Within this framework, the operational probability of observing state s_i is identified as

$$P(s_i) \equiv PF_i \tag{20}$$

Within this framework identification reflects a structural reading of probability. No additional squaring postulate or statistical assumption is introduced at the ontological level.

4.6. Structural Randomness

A system exhibits intrinsic randomness if and only if its presence is non localized,

$$\exists i \neq j \text{ such that } PF_i > 0 \text{ and } PF_j > 0 \tag{21}$$

Randomness is thus understood as:

- structural rather than dynamical,

- intrinsic rather than epistemic,
- Randomness is not attributed to hidden variables within the scope of the present framework. A fully localized system, for which $PF_k = 1$, is non-random in this sense.

4.7. Geometric State Function ψ

For representational convenience, we introduce a derived geometric state function

$$\psi : S \to \mathbb{C}, \quad \psi_i := \sqrt{PF_i} \tag{22}$$

where the square root is understood in a structural (not probabilistic) sense and may carry sign or phase information.

The function ψ is not fundamental. All ontological content resides in the Presence Fraction. Depending on the dimensional structure of the state space, ψ_i may take real, signed, vectorial, or complex forms, but always such that

$$|\psi_i|^2 = PF_i, \tag{23}$$

without invoking linear superposition, inner products, or any Hilbert space ontology.

4.8. Collapse and Entanglement (Structural Statements)

Within the distributed presence framework, collapse is described as a structural localization event,

$$\{PF_i\} \longrightarrow \{PF_i'\}, \quad PF_k' = 1 \tag{24}$$

Entanglement corresponds to non-factorizability of joint presence distributions:

$$PF_{AB}(i,j) \neq PF_A(i)PF_B(j) \tag{25}$$

Both phenomena are properties of ontic presence structure and should not be interpreted as dynamical signal transmission.

4.9. Mathematical Scope and Limitations

At the present stage of development:

- no linear structure on S is assumed,
- no inner product is defined,

- no dynamical evolution law is postulated,
- ψ is restricted to a scalar representation.

These restrictions are methodological rather than fundamental. They are imposed to preserve ontological transparency at the foundational level and do not preclude richer mathematical extensions in later developments of the framework.

The present formalism should be read as a foundational, ontology-level structural framework that precedes, rather than replaces, standard Hilbert-space quantum mechanics.

5. Structural Manifestations of Distributed Presence in Dice-Like Systems

This section clarifies how superposition, collapse, and wave like behavior arise within the distributed presence framework as structural features of state space presence, rather than as dynamical processes or epistemic descriptions. The dice-like system serves as a minimal structural realization, introduced for conceptual transparency rather than as a literal physical model.

5.1. Structural Superposition

Within the distributed presence framework, superposition is not defined as a formal linear combination of states, but as a *distributed mode of presence* across a discrete state space. Ordinary macroscopic objects exhibit binary presence: their components are either fully present in a given state ($PF = 1$) or absent from it ($PF = 0$). By contrast, a structurally fundamental object (such as a die analyzed at the level of state space) exhibits fractional presence across multiple admissible states.

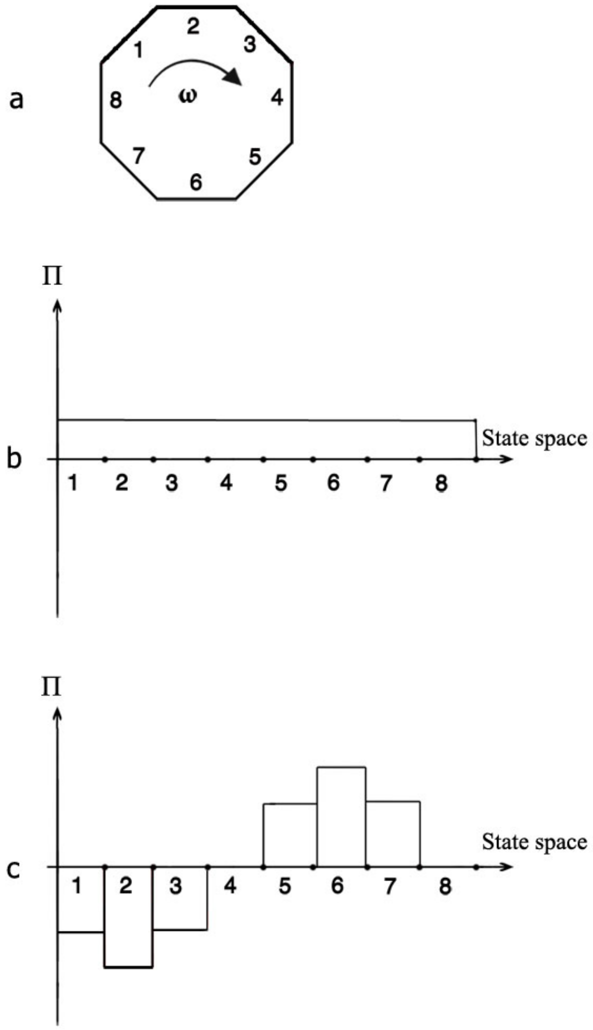
For a symmetric n-state die, the presence fraction is uniformly distributed (Figure 3),

$$PF_i = \frac{1}{n}, \quad \sum_i PF_i = 1 \tag{26}$$

In this configuration, no individual state fully exhausts the presence of the system. Instead, the die exists as a single indivisible entity whose presence is jointly realized by the entire set of mutually exclusive states. This condition defines structural superposition: a joint structural realization across mutually exclusive states within state space, without decomposition into parts and without appeal to epistemic uncertainty.

For quantum dice abstracted from asymmetric classical configurations, the distribution of presence is generally non uniform. Nevertheless, the defining feature remains unchanged: superposition refers to *ontologically distributed presence*, not to statistical ignorance or unresolved dynamics.

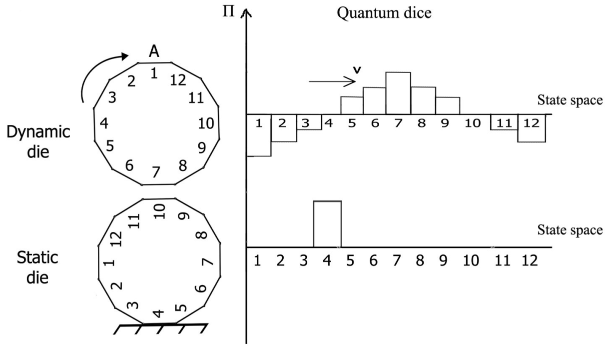
Figure 3. Uniform distribution of presence fraction for a symmetric configuration.



5.2. Structural Collapse via Single Channel Contact

A dynamically free die does not privilege any particular channel of interaction with its environment. By contrast, a static die necessarily establishes contact with the environment through exactly one face. This exclusivity is structural: at any given interaction, only one state can mediate physical coupling. (Figure 4)

Figure 4. Structural localization resulting from single channel contact with the environment.



From a structural perspective, environmental contact modifies the relational status of the corresponding state. The contact state becomes structurally dominant with respect to interaction, while the remaining states lose relevance for physical realization. As a result, the distributed presence reorganizes according to

$$PF_{contact} \to 1, \quad PF_{others} \to 0. \tag{27}$$

Collapse is therefore not described as a dynamical process propagating in time, but as a global structural localization event imposed by the requirement of single channel interaction. The outcome is definite, while the specific selection of the contact channel remains intrinsically unpredictable, being unconstrained by further structural parameters within the present framework.

Example: Two-State System Asymmetric Distributed Presence

Consider a structural object with two admissible states $\{|1\rangle, |2\rangle\}$, described at the most fundamental level by signed structural components:

$$S_1 = \frac{\sqrt{3}}{2}, \quad S_2 = \frac{1}{2}$$

These components belong to the underlying structural layer of DP and are not directly observable. From them one constructs the presence weights

$$\Pi_1 = |S_1|^2 = \frac{3}{4}, \quad \Pi_2 = |S_2|^2 = \frac{1}{4}$$

In this minimal two-state case, where no relational (interference) structure is involved, the total presence satisfies $\sum_i \Pi_i = 1$. Consequently, the presence fractionsthe normalized, operational quantitiescoincide with the presence weights:

$$PF_1 = \frac{3}{4}, \quad PF_2 = \frac{1}{4}$$

Before interaction, the system is genuinely distributed: it is not in one definite state with unknown probability, but ontologically present across both admissible states with unequal structural weight. The asymmetry between PF_1 and PF_2 is therefore structural rather than epistemic.

Upon a single-channel interaction (measurement), the systems entire presence is realized through exactly one admissible channel. The probability of realizing $|1\rangle$ or $|2\rangle$ is identified as

$$P(i) \equiv PF_i,$$

which follows from the structural accounting of presence, not from an independent probabilistic postulate.

After localization (e.g., outcome $|1\rangle$):

$$S'_1 = 1, \quad S'_2 = 0 \quad \Rightarrow \quad \Pi'_1 = 1, \quad \Pi'_2 = 0 \quad \Rightarrow \quad PF'_1 = 1, \quad PF'_2 = 0.$$

The system has thus undergone a structural reconfiguration from distributed presence to sharp presence.

This is also presented in tabular form:

Table 1. Comparison of Distributed Presence and Sharp Localization

State	**Before interaction (Distributed Presence)**	**After interaction (Sharp Localization)**
$\|1\rangle$	$S_1 = \sqrt{3}/2, \quad PF_1 = 3/4$	$S'_1 = 1, \quad PF'_1 = 1$
$\|2\rangle$	$S_2 = 1/2, \quad PF_2 = 1/4$	$S'_2 = 0, \quad PF'_2 = 0$
Total	$\sum \Pi_i = 1$	$\sum \Pi'_i = 1$

This example highlights two key features of DP:

(a) Presence fractions need not be equal asymmetry is structural, not epistemic.

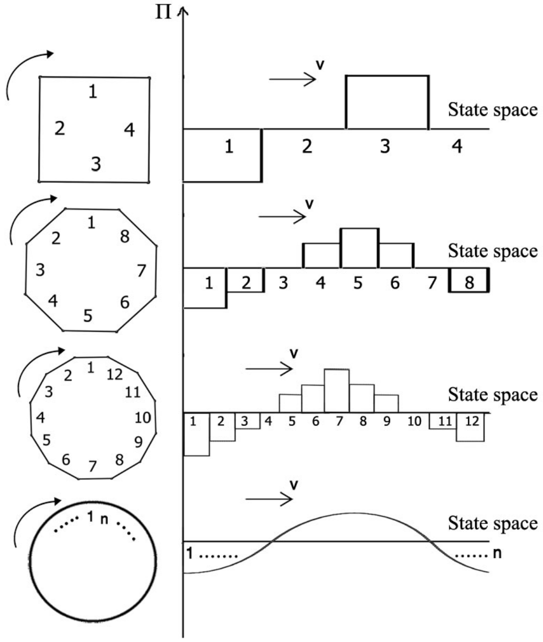
(b) Localization is a transition from one legitimate mode of structural existence (distributed) to another (sharp), not a "disturbance" of an unknown pre-existing state.

5.3. Distributed Presence and Wave-Like Behavior

When a classical die rotates freely, each face carries a nonzero resting component determined by its instantaneous orientation. In the quantum dice abstraction, this induces a distributed allocation of presence across the state space. For a sufficiently large number of states, the presence fraction approaches a smooth profile over the state index, exhibiting a wave like form.

Crucially, this wave like distribution is structural and static, not dynamical. Its shape is fixed by the geometric relations among the resting components, while changes in orientation merely shift the distribution across the state space without altering its form. Phase corresponds to the global orientation of the configuration and acquires physical significance only through relative phase relations between systems.

Figure 5. Wave-like profile of distributed presence arising from geometric relations.



In contrast, a static configuration enforces structural localization, yielding a single dominant state. Wave like and particle like manifestations therefore do not represent dual physical properties, but rather two structural regimes of the same ontological framework, determined by whether presence is distributed or localized.

Summary Statement

Within the distributed presence framework, superposition, collapse, and wave-like behavior emerge as structural consequences of distributed presence and single channel interaction. No dynamical collapse mechanisms or physical wave propagation in space are assumed. The analysis remains purely structural, preserving ontological clarity while remaining compatible with standard quantum descriptions at an operational level.

6. Structural Emergence of Probability and the Born Rule

This section examines how quantum-mechanical probability, and in particular the Born rule, arises within the DP framework as a structural consequence of distributed presence. The analysis is formulated to maintain a strictly non circular logical order, in which probabilistic notions enter only after the underlying ontological structure has been specified. The resulting chain of relations is summarized schematically in Figure 6.

6.1. Distributed Presence as an Ontological Primitive

Dice-like systems are characterized by a non-binary mode of presence: prior to interaction, the system is present across multiple admissible states of its context dependent state space

$$S_\lambda = \{s_i\} \tag{28}$$

This distributed presence is introduced as an ontological structural feature of the system. At this level, no appeal is made to chance, frequency, or statistical probability. The description is therefore pre probabilistic in scope.

6.2. Weight Function and Distributed Presence

Each structural state s_i is associated with a non-negative Weight Function W_i, determined exclusively by structural and geometric considerations.

The distributed presence corresponding to state i, denoted Π_i, is defined as an unnormalized share of presence,

$$\Pi_i \propto W_i \tag{29}$$

The set $\{\Pi_i\}$ is not normalized and carries no probabilistic interpretation. It represents how presence is structurally apportioned across the state space.

6.3. Geometric Origin of the Quadratic Structure

For dice-like systems, the weight function admits a factorization into two independent geometric contributions,

$$W_i \propto \text{Mass Fraction} \times \text{Exposure Fraction} = MF_i \times EF_i \tag{30}$$

If θ_i is the angle between the state normal and the interaction direction, both fractions are geometrically proportional to $\cos\theta_i$:

$$MF_i \propto \cos\theta_i, \quad EF_i \propto \cos\theta_i \tag{31}$$

Consequently, the ontological weight function assumes a quadratic form:

$$W_i \propto \cos^2\theta_i. \tag{32}$$

This quadratic dependence appears prior to normalization and prior to any empirical interpretation.

6.4. Presence Fraction via Structural Normalization

Physical interaction is constrained to occur through a single effective channel at each event. This single channel constraint imposes a structural closure condition on the distributed presence.

To encode this condition, the distributed presence is normalized, defining the Presence Fraction

$$PF_i := \frac{\Pi_i}{\sum_j \Pi_j} = \frac{W_i}{\sum_j W_j} \tag{33}$$

This step reflects a structural consistency requirement arising from the nature of interaction and does not, by itself, introduce probability.

6.5. Probability as an Empirical Identification

Probability enters the framework only at the empirical level of repeated observations. The Presence Fraction PF_i represents a structural potential associated with each state.

Within the distributed presence framework, the Presence Fraction PF_i is an ontological quantity that characterizes the mode of presence of a system relative to a given state. A value $PF_i = 1$ corresponds to full structural presence in that state, while $PF_i = 0$ corresponds to complete absence. Intermediate values $0 < PF_i < 1$ do not represent partial actuality or epistemic uncertainty, but rather a genuine mode of potential presence intrinsic to the system prior to interaction. Because physical interaction is constrained to occur through a single effective channel, only one state can be fully actualized in each event. Under repeated interactions, empirical outcome frequencies are observed to converge toward the relative distribution of these potential presences. Probability is therefore not introduced as an independent postulate, but is operationally interpreted as the empirical manifestation of distributed presence, leading to the identification

$$P(i) \equiv PF_i. \tag{34}$$

It is crucial to clarify that the above relation is not derived from a dynamical process of outcome selection (which remains conceptually distinct), but is identified as the unique correspondence between the normalized structural measure of ontological presence and its empirical realization. In this sense, the Born rule is not introduced as an ad hoc statistical axiom, but emerges as the empirical manifestation of a deeper geometric constraint imposed by the structure of distributed presence.

6.6. Structural Form of the Born Rule

Inserting the geometric form of W_i into the expression for PF_i yields

$$P(i) = \frac{\cos^2\theta_i}{\sum_j \cos^2\theta_j} \tag{35}$$

For a finely resolved state space, angular completeness implies

$$\sum_j \cos^2\theta_j \longrightarrow 1 \tag{36}$$

This leads directly to the geometric form of the Born rule:

$$P(i) = \cos^2\theta_i \tag{37}$$

Within the present framework, this expression is obtained as a structural outcome, not as an independent postulate.

6.7. Structural Resolution of the Circularity Objection

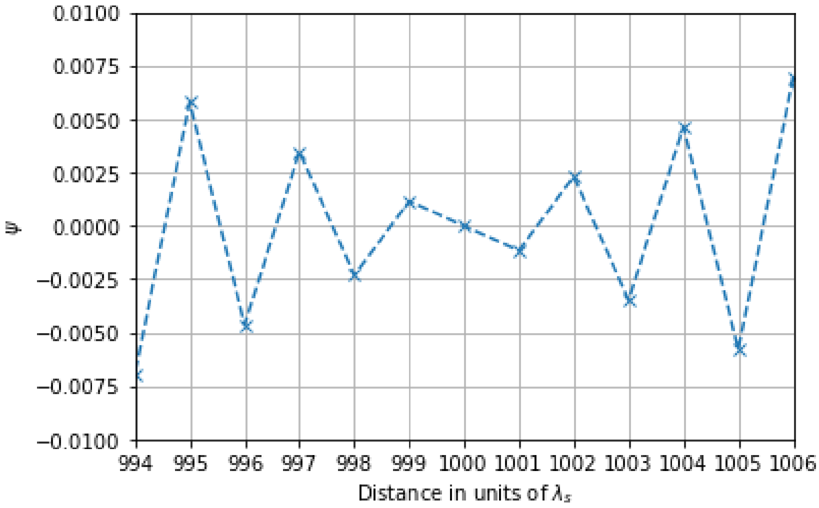
The potential circularity objection is avoided by a strict separation between ontological structure and empirical interpretation:

- Pre-probabilistic structure: W_i is defined geometrically.
- Quadratic precedence: The quadratic form emerges before normalization.
- Structural normalization: Normalization encodes the single channel constraint.
- Empirical identification: Probability appears only through $P(i) \equiv PF_i$.

The resulting one directional chain is:
Geometry $\rightarrow W_i \rightarrow \Pi_i \rightarrow PF_i \rightarrow P(i)$.

In this sense, the Born rule appears as a non-circular structural manifestation of distributed presence in state.

Figure 6. Schematic representation of the structural emergence of probability and the Born rule.



6.8. Generality of the Born-rule derivation

Discrete case

For a system with finitely many admissible states s_i, DP distinguishes three levels:

1. signed structural components S_i,
2. presence weights Π_i constructed from them,
3. normalized presence fractions PF_i.

In the simplest discrete case without relational structure,

$$\Pi_i = |S_i|^2,$$

The identification

$$P(i) \equiv PF_i$$

is not a probabilistic axiom but a structural statement: at an interaction event, the systems entire presence must be realized through exactly one admissible channel.

Finite-dimensional Hilbert space

For systems described by a finite-dimensional complex vector space, an arbitrary normalized quantum state

$$|\psi\rangle = \sum_i c_i |i\rangle$$

is read in DP as directly specifying the signed components:

$$S_i = c_i \in \mathbb{C}.$$

The presence weights are then

$$\Pi_i = |c_i|^2,$$

and normalization of the state ensures $\sum_i \Pi_i = 1$, so that

$$PF_i = |c_i|^2.$$

Thus, the Born rule emerges unchanged, but its interpretation shifts: $|c_i|^2$ quantifies the structural share of distributed presence, while the complex phase of c_i encodes structural orientation.

Continuous spectra

For observables with continuous spectra (e.g. position x), the state space is treated as the limit of increasingly fine discrete decompositions. The signed components become a complex-valued field $S(x)$, and the presence weight becomes a density

$$\Pi(x) = |S(x)|^2.$$

The probability of realizing the system within a region $[a, b]$ is then

$$P(x \in [a, b]) = \int_a^b \Pi(x)dx,$$

which is the continuous analogue of summing presence fractions over discrete channels.

No additional postulate is introduced in passing from discrete to continuous systems. The same structural ruleprobability as realized presence fractionapplies throughout. DP therefore does not seek to re-derive the Hilbert-space formalism, but to provide a structural-ontological reading in which the Born rule is no longer primitive, but reflects how presence is constituted and normalized.

7. Measurement and Structural Collapse

In the distributed presence (DP) framework, measurement does not introduce additional physical postulates beyond those already specified at the structural level. Rather than being treated as an external intervention, a dynamical evolution, or an observer dependent act, measurement is understood as the physical realization of a structural transition already implicit in the ontological scheme developed in Section 3.

This section situates the structural notions of presence fraction, intrinsic structural randomness, and collapse within the physical context of measurement, clarifying the emergence of outcome definiteness, the global character of collapse, and the structural origin of irreversibility.

7.1. Measurement as Environment Induced Structural Transition

Within DP, collapse is not formulated as a dynamical process, nor as a wave function update or information theoretic revision. Instead, it is treated as a structural transition of presence fractions induced by coupling to an environment.

Prior to measurement, the system is characterized by a normalized presence fraction distribution

$$\{PF_i\}, \quad \sum_i PF_i = 1, \tag{38}$$

with at least two non-zero components. This distribution represents distributed ontic presence, not epistemic uncertainty or incomplete knowledge.

Role of the environment

Measurement occurs when the system becomes coupled to an environment in such a way that:

- a structural constraint is imposed, and
- interaction is restricted to a single effective structural channel.

This restriction is not dynamical but relational and geometric: at a given interaction event, the system can physically engage the environment through only one state of its state space.

Structural collapse

Under such coupling, the distributed presence becomes structurally unstable. The imposed constraint enforces a reconfiguration of presence fractions,

$$\{PF_i\} \longrightarrow \{PF_i'\}, \quad PF_k' = 1, \quad PF_{i\neq k}' = 0. \tag{39}$$

No new equations are required, and no modification of the structural formalism of Section 4 is introduced. Measurement is therefore not an additional axiom, but a physical instantiation of an already defined structural rule.

Crucially, the environment does not dynamically select an outcome; it enforces an exclusivity condition that leaves only one state ontically accessible.

7.2. Global versus Local Collapse

Collapse is often interpreted as a local physical event occurring at a specific spatial point or subsystem. The DP framework does not adopt this interpretation.

Because presence fractions are defined over the entire structural state space, collapse necessarily acts on the whole distribution:

$$\{PF_i\}_{\text{entire space}} \quad \longrightarrow \quad \text{single localized configuration} \tag{40}$$

There is no meaningful sense in which one part of the state space collapses while other parts remain unchanged. Even when triggered by spatially localized interaction, collapse is global and indivisible.

This perspective is incompatible with:

- partial or staged collapses,
- dynamically propagating local projections,
- hybrid classical-quantum pictures in which subsystems update independently.

Such views presuppose localized ontic states or dynamical propagation mechanisms, neither of which belong to the DP ontology. In DP, nonlocality is not dynamical; it reflects the fact that the ontic object of collapse is the entire presence distribution, not localized material content.

7.3. Outcome Definiteness and Structural Irreversibility

Origin of outcome definiteness

Outcome definiteness follows directly from single channel structural exclusivity. At the interaction event, structural constraints enforce that at most one state can retain

$$PF = 1 \tag{41}$$

Given normalization and conservation of total presence, no alternative distribution can coexist with the realized one. No residual unrealized structure remains.

Structural origin of irreversibility

Irreversibility in DP is neither thermodynamic nor dynamical. It arises because:

- the pre measurement distribution corresponds to a structurally unconstrained configuration,
- the post measurement distribution corresponds to a highly constrained one.

Reversing collapse would require undoing the environmental structural constraint itself, not merely reversing motion or dynamics. Once system-environment coupling has occurred, such reversal is structurally excluded.

Relation to standard quantum dynamics

This account:

- does not invoke the Schrödinger equation,

- does not rely on unitary time evolution,
- does not treat decoherence as a fundamental ontological mechanism.

While such tools may provide effective descriptions in other frameworks, DP does not require them to account for outcome definiteness or irreversibility.

Conceptual Summary

- Measurement is a structural transition, not a dynamical update.
- Collapse is environment induced, but not environment driven.
- Collapse is global, single channel, and indivisible.
- Definiteness and irreversibility arise from structural constraints, not from dynamics or information theory.

In this sense, Section 7 completes the structural translation of distributed presence ontology into a coherent and realist account of measurement, without importing the standard dynamical postulates of quantum mechanics.

8. Relation to the Quantum Mechanical Formalism (Structural Mapping, Not Formal Reconstruction)

The distributed presence (DP) framework is not presented as a reconstruction or reformulation of the quantum mechanical formalism. Its aim is instead interpretative and structural: to clarify how the standard quantum formalism can be understood as an effective representational scheme for a deeper geometric and ontological description based on distributed presence.

Accordingly, this section establishes a precise mapping between DP quantities and their quantum mechanical counterparts, while maintaining a clear distinction between ontological structure and representational formalism.

8.1. Presence Fraction and the Status of the Wave Function

In DP, the fundamental ontological quantity is the presence fraction distribution

$$\{PF_i\}, \quad \sum_i PF_i = 1 \tag{42}$$

defined over a geometric state space $S = \{s_i\}$. This distribution characterizes how the system's presence is structurally apportioned across mutually exclusive states, independently of observation or inference.

For compact representation, a geometric encoding is introduced:

$$\psi_i := \sqrt{PF_i} \tag{43}$$

This function carries no independent ontological content beyond that of PF_i; it is introduced solely for representational convenience.

From the DP perspective, the quantum mechanical wave function ψ_{QM} is understood as:

- a coordinate dependent representation of such an encoding,
- expressed in a linearized space for calculational efficiency,
- endowed with mathematical structure (complexity, linearity, normalization) that reflects the chosen representation rather than fundamental ontology.

The wave function is therefore repositioned, not discarded: it encodes distributed presence without being itself ontologically primitive.

8.2. Why Hilbert Space Appears

Hilbert space is commonly regarded as fundamental within quantum mechanics. In DP, it is treated as an emergent representational arena that becomes natural under specific circumstances.

When the geometric state space admits:

- high symmetry,
- stable orthogonal decompositions,
- and well defined modal directions,

it is mathematically efficient to embed the geometric encoding ψ into a linear vector space equipped with an inner product. Hilbert space then arises as a compact language for describing the underlying structure.

From this standpoint:

- Hilbert space functions as a representation, not a physical substrate;
- linear superposition reflects representational linearity, not ontological multiplication;
- inner products provide computational structure rather than physical overlap of states.

The DP-QM correspondence may thus be summarized schematically as:

$$(S, \{PF_i\}, \psi) \longleftrightarrow (H, |\psi\rangle), \tag{44}$$

with the mapping being many to one, underscoring that Hilbert space does not uniquely encode physical ontology.

8.3. Geometry, Structure, and Dynamics

In DP, the fundamental description of a system is given by a geometric state space whose organization is directional and relational, not algebraically postulated. Linear or complex structures are not assumed a priori but may arise as effective tools when the geometry supports them.

Presence originates structurally through non negative weights W_i,

$$PF_i := \frac{W_i}{\sum_j W_j} \tag{45}$$

which define the ontic distribution of presence across state space.

Dynamics, by contrast, enters only parametrically. In dice based realizations, classical geometric variables $\theta_i(t)$ evolve in time and modulate the weight functions, inducing time dependence in $PF_i(t)$ and its encoding $\psi_i(t)$. Dynamics therefore modulates an existing structure rather than generating distributed presence.

This separation replaces the single kinematical role played by the wave function in standard quantum mechanics.

8.4. Structural Selection and Collapse

Interaction with the environment is constrained to a single effective channel. This enforces a structural transition:

$$PF_k = 1, \quad PF_{i\neq k} = 0 \tag{46}$$

Collapse is thus understood as a structural selection rule, not as a dynamical projection in Hilbert space. No additional dynamical postulate is required at the ontological level; representational updates in quantum mechanics reflect this underlying structural change.

8.5. Superposition Revisited

Within DP, superposition is reinterpreted as distributed ontic presence across mutually exclusive states. The system remains a single entity whose presence is non classically extended over its state space.

This perspective avoids ambiguity between epistemic, instrumental, and many worlds readings. Superposition acquires a direct geometric meaning, expressing how presence is structured rather than how algebraic objects are combined.

8.6. Schrödinger Dynamics as an Effective Description

For representational convenience, one may combine structural and parametric elements as:

$$\psi_i(t) = \sqrt{PF_i} e^{i\theta_i(t)} \tag{47}$$

Within DP, this complex function is not a fundamental physical entity. If the parametric phases vary smoothly and the representation space is taken to be complex and linear, the Schrödinger equation

$$i\hbar \frac{\partial \psi}{\partial t} = H\psi \tag{48}$$

emerges as an effective description of phase evolution in this representational space.

From the DP viewpoint, Schrödinger dynamics is representational rather than ontological: it encodes parametric change of an underlying structural distribution rather than governing the fundamental evolution of reality.

8.7. Double–Slit Interference in the Distributed Presence Framework

8.7.1. Introduction

Within the **Distributed Presence (DP)** framework, interference in the two-slit experiment is not interpreted as the propagation or superposition of traveling waves in time. Instead, it manifests as a **static structural arrangement** determined entirely by geometry.

Prior to any interaction with the detection screen, the system occupies both slit-associated channels through a distribution of **signed presence components** (Π_L, Π_R), quantities that can be positive or negative depending purely on geometric projection.

8.7.2. Relation to the Quantum Amplitude Formalism

In DP, Π is the ontological primitive: a real structural property of the system. The familiar quantum state ψ serves only as a representational tool that allows one to extract the channel contributions $\Pi_L(x)$, $\Pi_R(x)$ and the relational component $\Pi_{LR}(x)$ for empirical comparison.

Unlike the Copenhagen view, ψ is not regarded as a physical entity but as a convenient coordinate-like device; the presence Π reflects the actual distribution of the system's structural reality.

8.7.3. Structure of Presence Before Detection

The slit-associated quantities Π_L and Π_R are **signed** because they are analogues of the cosine-projected "resting components" familiar from the dice model.

This has an important consequence: simple addition

$$\Pi(x) = \Pi_L(x) + \Pi_R(x) \tag{49}$$

cannot, in general, reproduce the correct total presence, because signed components may partially cancel.

8.7.4. Structural Combination and Necessity of the Interference Term

The correct composition requires:

$$\Pi(x) = \Pi_L(x) + \Pi_R(x) + \Pi_{LR}(x), \tag{50}$$

with:

$$\Pi_L(x) = |\psi_L(x)|^2, \quad \Pi_R(x) = |\psi_R(x)|^2, \tag{51}$$

$$\Pi_{LR}(x) = 2\mathrm{Re}[\psi_L(x)\psi_R^*(x)]. \tag{52}$$

Here, Π_{LR} is **not** an extra assumption or dynamical interference effect.

It arises inevitably from the algebraic expansion of the **signed pre-normalized contributions**:

$$(S_L + S_R)^2 = S_L^2 + S_R^2 + 2S_L S_R, \tag{53}$$

where S_L, S_R are the signed components underlying Π_L, Π_R. For two structural channels L and R, the total presence at a configuration x is

$$\Pi(x) = |S_L(x) + S_R(x)|^2 = \Pi_L(x) + \Pi_R(x) + \Pi_{LR}(x),$$

where

$$\Pi_{LR}(x) = 2\,\mathrm{Re}[S_L^*(x) S_R(x)].$$

If the components S_i were restricted to non-negative real numbers, the relational term would always be positive and destructive interference would be impossible. The existence of interference minima—configurations with $\Pi(x) = 0$ despite $\Pi_L(x) \neq 0$ and $\Pi_R(x) \neq 0$—therefore requires components that can differ in sign or phase.

Within DP, phase is thus a structural-algebraic necessity. It encodes the relative orientation of presence contributions. Alignment leads to reinforcement; opposition leads to cancellation. Phase is not a mysterious add-on to quantum states, but the parameter that makes structural interference mathematically and ontologically possible.

8.7.5. Interpretation of Bright and Dark Fringes

- **Bright fringes** occur when $\Pi_{LR}(x)$ reinforces $\Pi_L(x) + \Pi_R(x)$, yielding structural admissibility.
- **Dark fringes** occur when $\Pi_{LR}(x)$ is sufficiently negative to cancel out the sum of single-channel terms, producing $\Pi(x) = 0$. In DP this represents **structural exclusion**, not absence of measurement due to dynamics.

8.7.6. Geometry as the Sole Source of Spatial Dependence

The spatial modulation that often expressed in standard quantum mechanics as a phase shift $\Delta\phi(x)$, is here understood as a **geometry-imposed structural angular relation** between the two channels:

$$\Delta\phi(x) = \frac{2\pi}{\lambda}\frac{dx}{l} \tag{54}$$

where d is slit separation, L is the screen distance, and λ is the wavelength parameter.

This phase is not a dynamical evolution: it is a timeless geometric correlation embedded in the experimental arrangement.

8.7.7. Symmetric Numerical Example

In a symmetric setup:
$\Pi_L = 0.5, \quad \Pi_R = 0.5.$

- **Central maximum** ($\Delta\phi = 0$)

$\cos\Delta\phi = 1 \implies \Pi_{LR} = 1$
$\Pi(0) = 0.5 + 0.5 + 1 = 2$ (bright fringe).

- **First minimum** ($\Delta\phi = \pi$)

$\cos\pi = -1 \implies \Pi_{LR} = -1$
$\Pi(x_1) = 0.5 + 0.5 - 1 = 0$ (dark fringe).
The total presence vanishes exactly through structural cancellation.

8.7.8. Contrast with Standard Interpretations

- **Copenhagen**: ψ is epistemic; collapse is a dynamical process. DP: Π is ontic; collapse is structural selection.
- **Many-Worlds**: all branches persist physically. DP: multiple presence channels exist pre-interaction, but only one structure is realized at measurement.

- **Bohmian Mechanics**: particles have hidden trajectories guided by a wave. DP: no hidden variables; the *geometry of distributed presence* accounts for observed patterns.

8.7.9. Structural versus Dynamical Interference in the Double-Slit Experiment

In the standard formulation of quantum mechanics, the interference pattern observed in the double-slit experiment is typically interpreted as arising from the dynamical interference of propagating wave-like entities. Whether understood literally or operationally, this view presupposes a form of wave evolution whose superposition produces constructive and destructive interference at the detection screen.

Within the Distributed Presence (DP) framework, this interpretation is fundamentally revised. Interference is not the result of a dynamical process occurring in time, nor of waves propagating through space. Instead, it is a structural feature of the system's distributed presence. The presence associated with each slit constitutes a signed structural contribution within a single, unified spatial configuration. The resulting interference pattern emerges from the composition of these contributions, rather than from any time-dependent cancellation or reinforcement of physical waves.

Accordingly, waves in DP are not physical entities that propagate through space. The wave function retains its role as a computational and representational tool, while the ontologically primitive element is the distributed presence itself, understood as a non-dynamical structural configuration of the space–system composite. Dark fringes in the interference pattern correspond to regions of structural exclusion, where the total presence vanishes due to the relational composition of contributions, not to the cancellation of propagating amplitudes.

This structural interpretation also clarifies the role of the speed of light. Since no physical wave propagation is involved, the speed of light does not constrain the formation of the interference structure itself. Instead, relativistic speed limits apply exclusively to physical interactions, such as detection events, energy exchange, or information transfer. The limitation imposed by the speed of light is therefore taken as a higher-level relativistic principle, fully respected by DP, while the distributed presence remains non-dynamical and non-propagating.

In this way, DP preserves relativistic causality and the non-signaling requirement, while providing a coherent ontological account of quantum interference that avoids the need for superluminal or dynamical explanations.

8.7.10. Summary for Reviewers

Double–slit interference in DP is explained entirely by the geometry of signed distributed presence.

The relational term Π_{LR} is not optional, it is the structural consequence of working with signed channel components and is indispensable for basis-independent reconstruction of the total presence.

Interference fringes thus represent purely geometric selection effects in the ontic distribution, rather than wave-dynamical phenomena.

8.8. What Is Clarified and What Is Not Claimed

Clarified

- 0ntological meaning of the quantum state;
- 0epresentational role of Hilbert space;
- 0tructural origin of superposition, collapse, and interference;
- with nonlocal correlations without signaling.

Not Claimed

- ǫmplete computational replacement of quantum mechanics;
- ull dynamical theory or operator algebra;
- predictive superiority over standard QM.

The contribution of DP is conceptual and structural: it clarifies what the quantum formalism represents and why it is effective, by grounding it in a geometric ontology of distributed presence.

9. Entanglement, Nonlocality, and Bell Type Constraints (A Structural-Ontological Perspective)

This section examines entanglement and Bell type correlations from the perspective of the distributed presence (DP) framework. The emphasis here is ontological and structural, not predictive. Rather than proposing an alternative computational model for Bell experiments, the analysis clarifies how Bell type phenomena can be situated within a non-separable realist ontology based on distributed presence.

Within this framing, Bell's theorem is treated primarily as a constraint on ontological structure, delimiting the class of admissible frameworks, rather than as a test that necessitates superluminal causation or the abandonment of realism.

9.1. Structural Non-Separability of Presence

In DP, a physical system is fundamentally characterized by its presence fraction PF_i, which specifies how the system's total presence is structurally distributed over a discrete state space S,

$$\sum_i PF_i = 1 \tag{55}$$

For a composite system AB, classical separability corresponds to a factorizable joint distribution,

$$PF_{AB}(i,j) = PF_A(i)PF_B(j) \tag{56}$$

Entanglement, within DP, is identified by the failure of this condition, [21]

$$PF_{AB} \neq PF_A \times PF_B \tag{57}$$

This non factorizability is not introduced as a dynamical interaction or as an effect propagating between subsystems. Instead, it reflects the ontological situation in which, following joint preparation, the subsystems no longer constitute independently existing entities. Their presence is distributed over a single composite state space, giving rise to a unified distributed presence structure.

Entanglement is thus understood as structural non-separability, rather than as nonlocal coupling between pre-existing independent systems.

9.2. Ontological Unity and the Absence of Dynamical Signaling

A persistent concern in the interpretation of entanglement is its apparent tension with relativistic causality. DP addresses this issue by maintaining a strict distinction between ontological unity and dynamical signaling.

Within DP, collapse is not conceived as a space time process that propagates between distant regions. As discussed earlier, it corresponds to a global structural transition induced by the enforcement of a single interaction channel through environmental coupling.

In this setting:

- no physical signal is transmitted between spatially separated subsystems,
- no controllable influence is conveyed across distance,
- local marginal presence fractions remain invariant under distant measurement choices.

Observed correlations arise because the entangled subsystems are components of a single ontological structure, not because one subsystem dynamically affects the other. Nonlocality in DP is therefore structural rather than causal, and is compatible with the non-signaling requirement.

9.3. Bell's Theorem as an Ontological Constraint

From the DP perspective, Bell's theorem is most naturally interpreted as a constraint on factorizable ontologies. Bell type inequalities are derived under assumptions that include joint probability factorizability,

$$P(a,b|x,y) = \int d\lambda \rho(\lambda) P(a|x,\lambda) P(b|y,\lambda) \tag{58}$$

which encodes an underlying ontological separability of subsystems conditioned on hidden variables λ.

DP does not adopt this separability assumption at the ontological level. For entangled systems, presence fractions are defined over a unified composite structure and do not decompose into independent subsystem contributions. As a consequence, the premises required for standard Bell type inequalities are not satisfied.

Within this framing, Bell's theorem does not diagnose a failure of locality or realism per se, but delineates the limits of ontologically separable descriptions. [22] Non separable, non-signaling realist frameworks (such as DP) remain conceptually admissible.

9.4. Scope of the Present Analysis

The present contribution is deliberately restricted to a structural and ontological level. No attempt is made here to reproduce quantitative Bell test correlation functions, evaluate CHSH bounds, or model detector settings operationally. These tasks require additional dynamical and measurement theoretic assumptions that lie beyond the current scope.

Collapse in DP should therefore not be interpreted as an instantaneous physical process on a space time hypersurface. It represents a reconfiguration of presence within an abstract state space, not a causal influence propagating through space time. Accordingly, no preferred foliation, simultaneity structure, or superluminal mechanism is assumed.

Within this limited but well defined scope, DP establishes:

- structural incompatibility with factorizable hidden variable ontologies,
- conceptual placement outside the domain addressed by standard Bell inequalities,
- consistency with experimentally observed non signaling correlations.

A quantitative reconstruction of Bell test statistics would require an extended operational and dynamical layer, building on the ontological clarification provided here. Such developments are logically subsequent and left for future investigation.

Summary of Section 9

Within the distributed presence framework:

- entanglement corresponds to structural *non separability of presence*,
- nonlocality reflects ontological unity rather than causal influence,
- Bell's theorem functions as a constraint on separable ontologies,
- experimental Bell type violations are conceptually accommodated without invoking superluminal dynamics or hidden variables.

In this way, Bell type phenomena are situated within DP as natural consequences of a distributed mode of presence, completing the structural ontology developed throughout this work, without extending the claims beyond the intended conceptual scope.

10. DP in Quantum Phenomena: Conceptual Placement and Boundaries

(Structural-Ontological Clarification)

This section situates the distributed presence (DP) framework within the conceptual landscape of quantum foundations. Its purpose is not to introduce new formal elements or to compete with the predictive apparatus of quantum mechanics, but to clarify how core quantum notions are to be understood within a structural-ontological framing based on distributed presence.

The emphasis is therefore on boundary setting and conceptual placement, particularly in areas where interpretive ambiguity and referee concern most often arise: probability, collapse, wave-particle duality, entanglement, and nonlocality.

10.1. The Nature of Presence Distribution: Ontological Not Logical or Epistemic

In the Distributed Presence (DP) framework, the concept of distribution is used in a restricted and technical sense. It does not refer to uncertainty of knowledge, imprecision of description, or indeterminacy of truth values.

Specifically:

Presence distribution in DP $\neq$ epistemic uncertainty,

Presence distribution in DP $\neq$ many valued truth,

Presence distribution in DP = structural distribution of presence.

The primitive quantity of the framework, the Presence Fraction PF_i, specifies how a system's presence is distributed over the states of its state space,

$$PF_i := \frac{|\Pi_i|}{\sum_{j=1}^{n} |\Pi_j|}, \quad PF_i \in [0,1], \quad \sum_i PF_i = 1 \tag{59}$$

Despite its numerical form, PF_i is not probabilistic or semantic in nature. It denotes fractional presence, not partial belief or graded truth.

This sharply distinguishes DP from fuzzy set theory, where membership functions are defined relative to concepts, predicates, or knowledge states and carry no ontological commitment. Distribution of presence characterizes a real, structural mode of presence of physical systems.

10.2. Dice as Structural Archetypes

Dice are employed in DP not as metaphors or pedagogical analogies, but as structural archetypes: macroscopic systems that instantiate the same ontological pattern proposed for quantum entities in a transparent and finite setting.

From a structural point of view, a die exemplifies:

- a discrete and finite state space,
- mutually exclusive outcomes upon interaction,
- a pre-interaction mode of structural presence not confined to a single state.

In this sense, dice and quantum systems belong to the same ontological category within DP: both are defined by their state spaces, and both exhibit distributed presence prior to interaction.

10.3. Collapse, Superposition, and the Status of the Wave Function

Within DP, collapse is not modeled as a local or time propagating dynamical process. It is interpreted as a structural transition imposed by the restriction that interaction with an environment occurs through a single effective channel.

Superposition corresponds to the presence of non-zero presence fractions across mutually exclusive states. The wave function ψ, when introduced, serves as a compact representational encoding of the underlying presence distribution and carries no independent ontological status.

These notions (collapse, superposition, and probability) are thus grounded in a common structural ontology rather than treated as separate or competing concepts.

10.4. Wave-Particle Duality as a Category Distinction

From the DP perspective, wave-particle duality reflects a distinction of descriptive level rather than a physical dichotomy:

- particle like behavior corresponds to localized interaction,
- wave like behavior corresponds to distributed presence.

A system may therefore possess spatially distributed presence while participating in localized interactions, without invoking mutually exclusive physical pictures. Accordingly, wave-like and particle-like behaviors do not represent competing physical realities, but rather constitute two structural descriptions of a single underlying mode of presence.

10.5. Entanglement and Structural Non Separability

In the Distributed Presence framework, entanglement is defined structurally by the failure of factorization of presence fractions,

$$PF_{AB} \neq PF_A \times PF_B \tag{60}$$

This relation expresses ontological non-separability rather than any form of dynamical influence, causal propagation, or signal exchange. Once entangled, subsystems no longer constitute independently existing entities but instead form a single, unified presence structure with multiple interaction sites.

10.6. Structural Nonlocality and No Signaling

Nonlocality in DP is strictly structural. Because no propagating process, signal, or controllable influence is postulated, the framework is consistent with the non-signaling requirement by construction.

Correlations arise from shared ontological structure rather than from information transfer or causal exchange between distant systems.

10.7. Structural Transition and the Status of Dynamics

In the Distributed presence (DP) framework, entanglement and the consequent restriction to a single effective joint channel are not construed as dynamical processes unfolding in time. Rather, they are treated as primitive ontological structural features of interaction-induced realization.

The transition from multiple admissible joint channels to a single effective channel is therefore not derived from an underlying dynamical law, nor from a collapse mechanism (such as GRW) or a stochastic evolution equation. Instead, it is posited as a minimal structural postulate: only those joint configurations that admit a globally consistent presence realization remain admissible.

Crucially, this postulate imposes a consistency constraint on the ontology of the state, analogous to a boundary condition in the space of admissible realizations, rather than implying a physical force or causal propagation. Consequently, it introduces no signaling and remains compatible with relativistic causality.

While this structural account provides a coherent basis for observed correlations, the formulation of an explicit, time-resolved dynamical theory compatible with this framework lies beyond the scope of the present work and remains an open problem for future research.

10.8. Geometric State Space and Relativistic Compatibility

DP adopts a geometric and relational conception of state space for ontological clarity, without treating Hilbert space as a fundamental physical arena. Presence Fraction is defined over this abstract state space and does not correspond to any field or substance evolving in space time.

As a consequence:

- collapse is not a space time event,
- no preferred foliation or simultaneity structure is assumed,
- no superluminal process is introduced.

In this respect, DP is conceptually compatible with relativistic viewpoints while remaining neutral with respect to specific space time interpretations.

10.9. What Distributed Presence Is Not

(Boundary Setting Subsection)

To avoid misclassification of DP within existing approaches, several distinctions should be stated explicitly.

- DP is not a theory of semantic vagueness (e.g., fuzzy logic).

Presence distribution in DP does not concern degrees of truth, semantic vagueness, or logical indeterminacy, but the structural distribution of physical presence itself.

- DP is not a ψ-ontic theory.

The wave function is not ontologically primitive in DP. Ontic commitment is carried by the Presence Fraction; ψ, when used, is a derived representational encoding satisfying

$$|\psi_i|^2 = PF_i. \tag{61}$$

- DP is not a propensity or dispositional account.

Presence is not a tendency, power, or disposition toward outcomes; it is an actual distributed mode of presence prior to interaction.

These distinctions are not alternative formulations of DP, but delimit the ontological boundaries within which the framework is defined.

Table 2. Ontological Comparison

Interpretation	Ontology of Quantum State	Randomness	Collapse
Copenhagen	Instrumental	Fundamental, unexplained	Postulated
Many Worlds	Universal wave function	Apparent	Eliminated
Bohmian	Particles + pilot wave	Epistemic	None
QBism	Agent belief	Subjective	Belief update
Distributed Presence(DP)	Distributed ontic presence	Structural	Structural tra

Table 3. Conceptual & Structural Comparison

Feature	Distributed Presence DP	Standard QM	Fuzzy Set Theory
Ontic Commitment	Yes (PF)	Ambiguous	No
Nature of Probability	Fractional presence	Born rule	Membership
Superposition	Distributed presence	Vector sum	Not applicable
Collapse	Structural	Dyn/Postulate	Not applicable
Role of ψ	Representation of PF	Fundamental/Instrumental	Absent

10.10 Relation to existing approaches

(A) DP and Relational Quantum Mechanics (RQM)

RQM holds that physical properties are only defined relative to other systems, denying an observer-independent quantum state. DP agrees that definiteness arises only through interaction, but diverges ontologically: the signed-component structure $\{S_i\}$ is taken to be objective and observer-independent. Distributed presence exists prior to, and independently of, any relational context; interaction merely selects one channel from a real but distributed structure.

(B) DP and QBism

QBism interprets quantum states and probabilities as agents' degrees of belief, with the Born rule as a normative constraint. DP rejects this epistemic stance. Presence fractions PF_i are not beliefs but structural features of the system itself. The Born rule expresses how distributed presence maps onto realized outcomes, independently of any agent.

(C) DP and Ontic Structural Realism (OSR)

DP is broadly sympathetic to OSR in treating structure as ontologically fundamental. However, it goes beyond standard OSR by providing:

1. a concrete account of measurement as single-channel interaction,
2. a structural derivation of the Born rule,
3. an explicit role for phase as structural orientation grounding interference.

In this sense, DP can be seen as a physically explicit realization of the structural realist program.

Scope Clarification

The distributed presence framework does not aim to modify or replace the standard predictive formalism of quantum mechanics. Its contribution lies in introducing distributed presence as a primitive ontological magnitude, irreducible to probabilistic ignorance, modal actuality, logical fuzziness, or wave function realism.

11. Discussion and Outlook

11.1. Summary of Core Structural Claims

The analysis developed in this work supports a small set of tightly connected structural claims that together define the DP framework.

(1) Ontological status of Presence Fraction (PF).

The *Presence Fraction* PF_i characterizes how a physical system's existence is structurally distributed over the elements of its state space prior to interaction. It is not a measure of ignorance, belief, or statistical frequency, but an intrinsic ontological property of the system as represented in state space. Formally,

$$PF_i = \frac{W_i}{\sum_j W_j}, \quad \sum_i PF_i = 1 \tag{62}$$

where W_i denotes the weight associated with state i. The normalization expresses completeness of presence, not probabilistic normalization in an epistemic sense.

(2) Structural emergence of the Born rule.

Within DP, the Born rule is not postulated as a fundamental axiom. Instead, it arises as a structural consequence of the geometry of distributed presence. In the resting-component construction developed earlier, the weights take the form

$$W_i \propto \cos^2 \theta_i, \tag{63}$$

which directly yields

$$P(i) = PF_i \propto \cos^2 \theta_i. \tag{64}$$

The characteristic quadratic dependence of quantum probabilities thus reflects geometric structure rather than an independent probabilistic postulate.

(3) Collapse as a structural, non-dynamical transition.

State reduction is interpreted not as a physical process evolving in time, but as a structural reconfiguration of presence. Collapse occurs when interaction with an environment enforces a restriction to a single effective interaction channel. No space-time propagation, physical signal, or causal mechanism is invoked. The transition is global and structural, not dynamical.

(4) Entanglement as ontological non-factorizability.

Entanglement is characterized by the failure of presence fractions to factorize,

$$PF_{AB} \neq PF_A \times PF_B \tag{65}$$

This expresses ontological non-separability rather than superluminal influence. From the DP perspective, Bell-type correlations constrain attempts to impose separable ontological structures on composite systems; they do not require dynamical nonlocal signaling.

11.2. Ontological Position of Distributed Presence

DP adopts an explicitly ontological stance while avoiding several common interpretational pitfalls.

Against epistemic probability.

Probability is not epistemic within DP. The identification $P(i) = PF_i$ provides an operational reading of distributed presence, not a statement about incomplete knowledge of an underlying definite state.

Distinction from semantic vagueness.

Distributed presence does not refer to degrees of truth, linguistic indeterminacy, or fuzzy-logic membership. It describes the fractional presence of a single, indivisible system across mutually exclusive states. Its distributed character is structural and ontological, not semantic.

Autonomy of the ontology.

DP does not treat Hilbert space, wave functions, or observer-dependent updates as ontologically primitive. Instead, it operates in geometric state spaces chosen for ontological transparency, with the standard quantum formalism regarded as a powerful (possibly emergent) representational layer rather than the fundamental arena of existence.

11.3. Present Scope and Explicit Limitations

The current formulation of DP is intentionally limited, and these limitations are methodological rather than incidental.

- **Absence of intrinsic dynamics.**

  No fundamental dynamical law analogous to the Schrödinger equation is postulated. Temporal dependence enters only parametrically and does not constitute primitive state-space dynamics.

- **Restricted representational role of ψ.**

  Real, non-negative encodings such as $\psi_i = PF_i$ are used solely as representational devices. No commitment is made to complex amplitudes, vector spaces, or operator structures as ontological primitives.

- **Deliberate structural simplifications.**

  Linearity, inner products, operator algebras, and tensor-product constructions are set aside to preserve ontological clarity. This reflects a foundational choice, not a denial of their effectiveness in standard quantum mechanics.

- **Empirical development.**

  Although the framework is, in principle, empirically distinguishable, explicit experimental protocols sensitive to its structural features have not yet been specified. Detailed phenomenological analysis is deferred to future work.

11.4. Directions for Further Development

Natural extensions of the DP framework include:

(i) deriving intrinsic structural dynamics governing the evolution of presence distributions;

(ii) formalizing shared state spaces for composite and multi-system configurations;

(iii) identifying experimental regimes sensitive to structural features specific to DP; and

(iv) exploring extensions to relativistic and field-theoretic contexts, where Hilbert-space structures may emerge as effective descriptions.

Closing Outlook

Distributed Presence should be understood as a foundational research program rather than a completed theory.Its central contribution is to demonstrate that probability, collapse, and entanglement can be coherently grounded in a single ontological principle: the distributed presence of physical systems in state space. By shifting attention from dynamical mechanisms to structural relations, DP suggests that much of the conceptual tension surrounding randomness and nonlocality arises from unexamined ontological commitments rather than from empirical necessity. [23]

Whether developed into a more comprehensive dynamical framework or retained as a deeper ontological substrate beneath standard quantum mechanics, DP offers a unified and structurally transparent perspective. In this sense, it aims not to compete with the predictive success of quantum theory, but to clarify the kind of reality that such a theory may be understood to describe.

Acknowledgements

The author acknowledges that he has used AI-based translation and editing tools during the preparation of this manuscript. These tools were used to assist in the translation and clarity of the material. Responsibility for all ideas, conceptual content, interpretations, and scientific conclusions lies solely with the author.

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