In-Out Ontology: A Directional Framework for Cosmic Emergence and Quantum Reality

Kyoung-il Ko*

ABSTRACT
This paper introduces and formalizes In-Out Ontology (IOO) as a foundational metaphysical framework for understanding emergence, quantum reality, and consciousness. Centered on the dynamics of In-Out Indistincts (IOIs) – ontological primitives held in a balanced superposition of inward and outward directional modes – IOO reinterprets quantum phenomena, spacetime, and cognition through a generative, relational lens. We construct the formal architecture of In-Out Entanglement (IOE) and define IOE field as the directional interaction field responsible for dimensional/structural emergence. Euler's identity is reframed as an ontological archetype of IOIs, while the general wave function Ψ expresses IOIs in contextual entanglement. The global IOE field since cosmic emergence is proposed as the ontological source of gravitational coherence. IOO further offers a reinterpretation of decoherence, affective valence, and qualia as outcomes of recursive directional differentiation. Integrating recent developments in quantum foundations and cognitive science, IOO proposes an ontological ground that reframes physical law, interpretive models of quantum mechanics (QM), and the architecture of consciousness. The paper concludes by suggesting new directions for cosmology, cognition, and complexity science rooted in the in-out dynamic.

Keywords: Quantum Mechanics; Relational Cosmology; Ontology; Complexity; Emergence; Wavefunction; Symmetry; Decoherence; Consciousness; space-time

1. Introduction

The interpretive landscape of QM is diverse in approaches. The Copenhagen interpretation addresses the measurement problem by treating it as a limitation of knowledge rather than confronting its ontological

* gokyoungil@korea.ac.kr

implications. The Many-Worlds interpretation (Everett, 1957) elegantly preserves unitarity yet leaves the branching of worlds conceptually opaque. Bohmian mechanics (Bohm, 1952) restores determinism through the introduction of a guiding wave, though this wave itself remains ontologically underdefined. QBism (Fuchs, 2014) takes a radically subjective turn, interpreting the quantum state as a personal tool for assigning beliefs, thereby placing the burden of interpretation onto the psychology of agents. Across these frameworks, the quantum state operates as a remarkably successful predictive tool. Yet we still lack a solid explanation of what reality really is at the quantum level. Superposition and entanglement are common and well-documented phenomena, but we don't fully understand how they actually work. Moreover, when it comes to measuring quantum stuff, the basic process behind what happens is still a mystery.

In light of these challenges, IOO seeks not only to offer an ontological foundation for physics and science at large, but also to reevaluate the assumption that entities such as objects, events, or states are ontologically primitive. These notions, we contend, are emergent from ontic IOIs which do not exist as things but as in-out symmetric states prior to in-out differentiation. What if the most fundamental layer of reality lies not in what is, but in what emerges from the co-arising of inwardness and outwardness as ontogenic momentum? IOO thus posits a pre-categorical substrate, an ontological minimalism where the cosmos unfolds not from atoms, nor from strings, but from IOIs that precede the logic of differentiation. We begin, then, with several general reflections. Why, after a century of quantum mechanics' empirical triumphs, does its interpretative core remain unsettled? Why do observers, measurements, and collapses appear as ontological anomalies rather than natural consequences of the theory's framework? The answer, we suggest, lies in the absence of a coherent pre-phenomenal ontology, which IOO seeks to fill.

This work unfolds in four movements. First, we formalize In-Out Ontology not by postulating fixed primitives, but by engaging in thought experiments that reveal the inadequacy of any ontology built solely on external observables or internal states. The ontic IOIs arise from the collapse of these distinctions. They are neither observers nor systems, neither particles nor waves, but the ground from which such distinctions emerge through relation. Second, we turn to cosmic emergence. From the dynamics of IOIs, we derive a model in which space-time and other structures emerge. Third, an ontological interpretation of QM becomes imperative. IOO does not merely interpret the quantum formalism but provides it with a foundational basis. Lastly, we address emergence of subjectivity. The self, whether particle or person, arises from in-out symmetry of IOIs. Identity is thus not substance, but rhythm – a tempo of emergence, modulated through layered differentiations. Across these sections, IOO recasts quantum theory not as a contradiction to classical physics, but as a natural extension of it.

2. Formalizing In-out Ontology

IOO helps fix a missing piece in how we understand reality as being built on relations. Pure relationalism falters before the problem of identity: if all entities are constituted solely by their relations, why do some patterns repeat with consistency, such as the indistinguishability of electrons across space and time? What enforces the integrity of form across contexts? To answer these challenges, IOO grounds relational emergence in the recursive IOE. IOIs don't just relate to each other; they form the very potential for any relationship to exist. Their IOE simultaneously creates their mutual in-out relation (Ko, 2021). The outside isn't simply what's beyond the inside; instead, every time a boundary emerges, it is also the emergence of both orientation and a field.

To further develop IOO and understand the nature of IOIs, we begin by creating thought experiments that challenge the usual idea of a clear line between inner and outer. From there, first imagine an entity that possesses no innate separation between what is itself and what is not. It does not yet experience inner or outer, self or world, form or environment. It is only through entanglement with others that structure emerges. Then, let's extend this line of thought into the domain of motion. Consider an entity moving at the speed of light. From its own perspective (if such a perspective can be meaningfully ascribed) time ceases to pass, and space collapses into an infinitesimal singularity. There is no before or after, no here or there. From such a stance, temporality and spatiality are not dimensions of experience but constructs that only arise when motion is slowed, when differentiation has begun to structure it. Motion, causality, and temporal succession require the emergence of in and out, but IOIs, by their definition, precede such emergence. Here, their resemblance to quantum nonlocality is not incidental. Just as entangled quantum states defy classical spacetime constraints, indicating a realm where separation does not imply independence, entangled IOIs construct a field of their in-out for each other.

2.1. In-Out Superposition

Just as a quantum system is described in a superposition of states until measured, an entity in the In-Out framework could exist in an indistinctive state until context or interaction determines its role. Then, to develop the idea that IOIs are the origin of quantum phenomena, we need to clarify how IOIs provide the fundamental structure from which quantum behavior emerges. This requires addressing key aspects such as superposition, entanglement, measurement, and spacetime emergence within the in-out framework. Let's refine and develop this idea systematically.

In quantum mechanics, wave-particle duality implies that before measurement, a system exists in a superposition of states. In in-out sense, we can understand this with the idea that an entity is neither distinctly In nor Out until an interaction collapses it into a specific state. The quantum wavefunction (ψ) could be understood as already a mathematical representation of IOIs.

As such, IOIs exist in a third ontological mode: they are neither particles nor waves. Instead, an IOI is defined by relational constraint: its behavior emerges through contextual entanglement and is modulated by its in-out ratio and magnitude. In this view, the IOI is not a pre-existing object in space or time. It begins in an in-out symmetric superposition – a pre-categorical potential, undefined until it entangles. This entanglement does not occur *in* space and time; it brings space and time into being as directional structures. Quantum superposition, then, reflects this underlying condition. IOIs do not sit between fixed outcomes but hover within a balanced field of potential directions. When entanglement occurs, this symmetry breaks, and the IOI unfolds into structured reality. In this light, quantum superposition is not strange; It is the ground logic of IOIs before directional commitments are made. In-out superposition, therefore, is not a state of uncertainty between fixed outcomes. It is a symmetric, pre-differentiated ground, from which reality unfolds through entangled becoming.

IOIs are defined by their relational entanglement across inward and outward directional modes, making them ideal for representation by Euler's formula or by a general wave function Ψ (i.e., an IOI in context). Each IOI is in-out symmetric, exhibiting both ±in and ±out. Let's define the default, pre-dimensional state of a single IOI a

$$|\Omega\rangle := \mathrm{IOI}_0 \tag{1}$$

Where $|\Omega\rangle$ is the ground in-out-neutral state. It satisfies:

$$\hat{I}\,|\Omega\rangle = \hat{O}\,|\Omega\rangle = |\Omega\rangle \tag{2}$$

indicating that it is neither inward nor outward until co-entangled. This state is unpolarized, non-directional, and pre-interactional. It is a default state from which in-out duals emerge through IOE. Then, we define the default IOI as a phase-balanced superposition:

$$|\Omega\rangle = \frac{1}{2}\left(|+\mathrm{In}\rangle + |-\mathrm{In}\rangle + |+\mathrm{Out}\rangle + |-\mathrm{Out}\rangle\right) \tag{3}$$

Alternatively, using complex exponential form, inspired by Euler's identity:

$$|\Omega\rangle = \cos\theta\cdot|\,\mathrm{In}\rangle + i\sin\theta\cdot|\,\mathrm{Out}\rangle \tag{4}$$

In IOO, Euler's formula emerges as an ontological exemplar of in-out dynamics. It encodes the very structure of in-out recursion. Thus, we define the real component ($\cos\theta$) as the inward dimension and the imaginary component ($i \sin\theta$) as the outward dimension. In this formulation, the complex exponential manifests the ontic grammar of in-out as mutually generative, irreducibly coupled movements. More broadly, the co-emergence of in-out is also naturally reflected in the formal frameworks of physical theory. The Hamiltonian effectively captures the simultaneous presence of motion (outward) and stored energy (inward), acting as a measure of the total energy within a system. Conversely, the Lagrangian articulates the balance between dynamic evolution (outward) and the constraints (inward) that shape its path. In essence, these fundamental mathematical constructs demonstrate that describing Nature comprehensively requires integrating both its inward components and its outward components (Ko, 2024).

2.2. Are IOIs a Hidden Variable?

Quantum non-locality was first introduced in the influential argument by Einstein, Podolsky, and Rosen (1935), who claimed that quantum mechanics offers an incomplete description of reality. They proposed the existence of

"hidden variables" that predetermine the outcomes of quantum measurements. Building on this idea, Bell (1964) later developed a formal inequality to test whether such hidden-variable theories could be reconciled with quantum predictions. This theorem showed that no theory that relies on "local hidden variables" can match the statistical predictions that QM makes. In other words, Bell proved that if reality works the way Einstein and his colleagues suggested (with local hidden variables), then certain experimental results would be impossible. However, subsequent experiments since the 1980s have reinforced the conclusion that nature is non-local. This goes against our everyday intuition about how things should work, but it's what the evidence overwhelmingly suggests.

When we consider IOIs, they are distinct from hidden variables in a crucial ontological sense. Hidden variables are generally understood as concealed properties that influence or govern measurement outcomes within a pre-establihed reality. IOIs, by contrast, are characterized as "in-out incompletes" whose very nature serves as the precondition for generating dynamics and emergence of structures.

2.3. In-Out Entanglement

A single IOI intrinsically sustains four directional valence states (±in, ±out) forming a fundamental Eulerian structure. These directional components encode the complex phase space of an IOI, where the in-valence aligns with integrative real-axis behavior and the out-valence with differentiative imaginary rotation. This internal configuration spans a full quadrature of phase potential, analogous to the unit circle governed by Euler's identity.

When two IOIs interlock their directional valences, they form a phase-locked entangled spinor, whereby the in-out flows of each IOI saturate and complete one another across their shared IOE field. This coupling transcends spatial adjacency, occurring instead through directional resonance – each IOI stabilizing within the other's reciprocal phase inversion. The IOE field mediates both rotational coherence and measurement actualization, acting as the ontological substrate for observable symmetry operations.

Just as SU(2) encapsulates internal symmetry transformations in quantum mechanics, and EPR pairs exhibit entanglement across spatial separation, IOO describes a coherence across a non-spatial, directionally conserved in-out phase field. Within this framework, spin-½ behavior naturally emerges when two IOIs configure themselves into mutually orthogonal in-out phase relations, constituting the minimal recursive unit of ontic torsion. This torsion encodes a topological resistance to full rotation, requiring a 4π cycle to return to identity – a hallmark trait of spin-½ entities. Represent each IOI as a two-component directional spinor:

$$\Psi_A = \begin{pmatrix} A_{\text{in}} \\ A_{\text{out}} \end{pmatrix}, \quad \Psi_B = \begin{pmatrix} B_{\text{in}} \\ B_{\text{out}} \end{pmatrix} \tag{5}$$

We impose a reciprocal saturation constraint linking the directional channels across the entangled pair as:

$$A_{\text{in}} = B_{\text{out}} = -B_{\text{in}} = -A_{\text{out}} \tag{6}$$

This reciprocal saturation relation reflects the ontological equivalence of directional valences up to sign inversion, expressing a zero-sum-like conservation of in-out valence. It states that when A moves inward (A_{in}), this simultaneously determines B's outward flow (B_{out}) and the corresponding inversions in the complementary channels. The resulting entangled spinor states become:

$$\Psi_A = \begin{pmatrix} \phi \\ -\phi \end{pmatrix}, \quad \Psi_B = \begin{pmatrix} -\phi \\ \phi \end{pmatrix} \tag{7}$$

where ϕ\phi is a complex phase amplitude characterizing the shared directional valence.
These spinors are antisymmetric under exchange:

$$\Psi_A \otimes \Psi_B = -\Psi_B \otimes \Psi_A \tag{8}$$

This antisymmetry is not an arbitrary postulate but arises structurally from the directional saturation of the IOE field. The pair exhausts the full in-out valence capacity of their entangled configuration; no third IOI can enter

without violating phase balance. This manifests as a Pauli-like exclusion principle, understood here not as a statistical or empirical rule but as a structural ontological constraint.

Critically, the absence of shared spatial location is a defining feature, not a deficiency. The IOIs are entangled in a non-local directional phase space, where their orthogonality is defined by reciprocal directional phase opposition rather than Cartesian geometry. Conservation of in-out flow – distributed across complementary phase inversions – constitutes the fundamental invariant of this ontological framework. What quantum mechanics represents as spin entanglement, IOO indicates interaction of directional valence across the IOE field.

In classical relational theories, relata are presumed to precede relation. In-Out Ontology departs from this assumption at its root. IOIs are not pre-formed individuals entering into later interaction. Rather, they are defined to be pre-relational entities whose individuation emerges through in-out entanglement. Their ontological status is not that of substance but of generative one. Indeed, the search for an emergent notion of spacetime has become a popular and active area of research (e.g., Van Raamsdonk, 2010; Susskind, 2016; Seiberg, 2006; Padmanabhan, 2015; Christensen Jr, 2024; Fullwood & Vedral, 2025).

Recent developments in relational ontologies increasingly emphasize that quantum states are not descriptions of isolated, absolute objects, but are defined only in terms of the interactions between systems. In this view, reality is not built from self-contained entities, but from the relations themselves. For example, Rovelli's Relational Quantum Mechanics (RQM) argues that the properties of any quantum system only make sense relative to another system (Rovelli, 1996, 2016). John Wheeler's idea of a participatory universe proposes that observers are not detached spectators but active participants in bringing about reality. Smolin is also widely recognized as a relational ontologist. In "*The Singular Universe and the Reality of Time*" (2014, with philosopher Unger), he takes this further: laws of nature themselves evolve, and this evolution is only intelligible if one adopts a relational and temporal ontology.

What we call an in/out distinction (e.g., boundary, identity, direction) is not a primitive property but rather the crystallized surface of an ongoing IOE. This avoids the contradiction of assuming pre-given distinguishable notions while still allowing for interaction to take place. Then, at each emergent scale (whether particle, molecule, cell, brain, or social group) emergent I/O ratios act as a stabilizing principle that resolves indistinction into form. Yet this resolution is never final; each layer of identity becomes the inward component of a broader IOE. Through this view, the IOE field becomes a unifying substrate where nested systems don't just coexist, but inherit their structure from the same foundational logic. Furthermore, what holds these resolutions together is the each IOI's in-resolutions: the inward anchoring that grants phase stability across the outward radiation of difference. Then, this IOE explanation naturally goes into Cosmic Scale event.

3. Cosmic Emergence

The Big Bang, in the light of IOO, is neither a singularity in space nor an absolute beginning in time. It is not the origin of everything but the phase-shifted culmination of entangled IOIs achieving directional coherence.

3.1. Directional Resonance and the Global IOE Field

The Big Bang, viewed through the lens of In-Out Ontology (IOO), is neither a spatial singularity nor an absolute temporal origin. It does not signify the beginning of existence, but rather the phase-shifted culmination of extensive IOI entanglement, in which distributed directional interactions achieve coherent asymmetry. This event marks the transition from pre-structured in-out symmetry into globally organized valence fields.

Each IOI exists not as an isolated bearer of valence but as a dynamic node whose inward and outward components emerge relationally from its entanglement with others. The interactive medium—the IOE field—is not a passive backdrop but a structured matrix of ongoing directional exchanges. Formally, each IOI's state is expressed as a two-component vector:

$$\Psi^{(A)} = \begin{pmatrix} \psi_{\text{in}}^{(A)} \\ \psi_{\text{out}}^{(A)} \end{pmatrix} \tag{9}$$

The state $\Psi^{(A)}$ of IOI A is fully determined by its phase relations with all other entangled IOIs within the field. The directional emergence obeys the mutual coherence conditions:

$$\psi_{\text{in}}^{(A)} = i\kappa \sum_{k \neq A} \psi_{\text{out}}^{(k)}, \quad \psi_{\text{out}}^{(A)} = \kappa \sum_{k \neq A} \psi_{\text{in}}^{(k)} \tag{10}$$

where κ is a coupling constant quantifying the strength of recursive resonance, and i introduces a $\pi/2$ phase rotation, signifying the orthogonal inversion from outward excitation to inward integration. These relations encapsulate a recursive in-out resonance pattern: each IOI's inward component emerges as the collective inward-facing phase convergence of others' outward tendencies; its outward component manifests as the divergent phase dispersion of others' inward structure. This resonance is not reducible to local causality or spatial propagation; rather, it is grounded in the field-level directional coherence of the IOE. Cosmic emergence thus unfolds as a bifurcation of directional modes:

- **The outward-directed mode:** dimensional expansion, field propagation, and the differentiation.
- **The inward-directed mode:** recursive convergence, memory formation, and binding.

In this framework, each IOI is simultaneously the convergence point of others' outward expressions and a contributor to the inward coherence of others. The cosmos is therefore not constituted by isolated particles but by in-out relational fields recursively cohering into layered structures of emergence.

Accordingly, the Big Bang or cosmic emergence is reinterpreted as the threshold at which vast numbers of IOIs, initially in symmetric in-out superposition, differentiated into coupled directional modes. This process generated multi-level emergent structures such as particles and dimensions. Ontologically, the cosmos is not composed of singular IOIs but is itself the IOE field.

3.2. The I/O Ratio: Constructive Rule

In IOO, every level of dimensional complexity, every specific directional difference, and all measurable sizes come from the entangled field of IOIs. Think of it this way: the vast cosmic processes we observe – like stars forming from nuclear fusion, atoms coming together, the glow of the cosmic microwave background, and the development of galaxies – can all be seen as a continuous unfolding within this IOE field. These processes are not driven by external rules, but by the logic of how in-out directions become entangled and how they resonate.

From this perspective, the in-out ratio is not just something we measure afterward. It is also the active force that helps IOIs organize themselves, become stable, and evolve. So, what we perceive as empty space is not a container for matter; it is the ever-changing surface created by IOIs continually finding and losing coherence. There is no literal point in space where everything began (no geometric singularity); instead, the singularity was a maximal in-out indistinction of IOIs – a state before space emerged.

Each distinction that emerges from this unfolding process becomes stable because it achieves a specific in-out ratio. This ratio does not just manage how things interact; it actually sets up the basic conditions for any meaningful interaction to happen in the first place. Through this stabilization, IOIs can influence each other in a looping pattern, building a self-referential structure. This means the in-out behavior at one level or moment becomes the guiding force for the next. Accordingly, structure is not imposed from outside; it grows through both internal resonance and outward development.

From this recursive process, we can understand that there are stabilized meta-in-out layers. These layers act like guiding principles, controlling how things move from an entangled, undifferentiated state to distinct, observable separations. They set the boundaries for what in-out ratios are possible, while also directing how groups of IOIs become coherent. These meta-structural fields are not separate from the cosmos; they are woven into its very fabric, operating as higher-order principles that connect properties like scalarity, directional potential, dimensionality, and the fundamental laws of structure and dynamics within the evolving universe. Through these, IOO explains not only how space and form originate, but also the repeating logic that sustains their ongoing development.

3.3. The Global IOE Field and Gravity

Within the architecture of IOO, it becomes conceptually coherent and ontologically necessary to recognize the global IOE field not as a derived feature of matter or energy, but as the primary generative pattern from which gravity appears. Here, gravity is understood as a tension towards inwardness, emerging from the continuous organization of IOIs throughout the developing cosmos.

Emergence of the global IOE field, where IOIs begin to distinguish between inward and outward, starts a wave of organized interaction that forms all subsequent structures. What we see on a large scale as time, expansion, or physical dimensions is thus the path of a global IOE pattern, a curved relationship born from the earliest connections.

While Einstein's general relativity describes gravity as the curvature of spacetime caused by energy and momentum, the IOE field does not exist within spacetime; it exists before it and generates it. What we perceive as energy and mass are, in this view, stable, repeating connections of IOIs. These areas where inward tendencies intensify create what we call gravitational wells. In IOO, outward tendencies show up as the expansion of the universe, differentiation, and the flow of time. Meanwhile, inward tendencies lead to organization, clustering, and the formation of stable structures. Gravity can be simply the name we give to the overall bias towards integration within the IOE field, a directional pull that binds things together rather than just bending them.

This new way of thinking offers a different perspective on gravity. General relativity is based on specific equations, quantum gravity uses networks (Penrose, 1971) or loops (Rovelli & Smolin, 1995), and string theory uses vibrating strings (Scherk & Schwartz, 1974). IOO, however, suggests that what underlies all these models is the coherence of IOE. In this account, matter does not create gravity. Instead, the repeated inward folding of IOIs generates both matter and the consistent behavior of gravity.

Conceptually, one can begin to formalize this. We might relate the curvature of the IOE field to mathematical descriptions of space, reinterpret energy and momentum as the density of these directional tendencies, and introduce an IOE field tensor. This tensor, denoted $I_{\mu\nu}$, would represent the directional resonance structure of the entangled field. This could lead to a direct analog of Einstein's equation:

$$I_{\mu\nu} - \frac{1}{2} g_{\mu\nu} I = \kappa \mathcal{V}_{\mu\nu} \tag{11}$$

Here, $\mathcal{V}_{\mu\nu}$ would describe the flow of these directional tendencies rather than classical energy and momentum. It would capture the dynamic balance of inward and outward tendencies as they organize or spread out within the overall IOE structure. While this equation is just a foundational idea for future work, it offers a different perspective on how we understand gravity.

4. Ontological Interpretation of QM

IOIs naturally exist in a state of superposition, meaning they are not distinctly in or out until they become entangled. This can also be understood through a Qubit in QM: it stays in a mixed, undecided state until a measurement forces it to settle into a definite outcome through decoherence (Zurek, 2003). Such emergence of direction as a relational construct fits well with Constructor Theory (Deutsch, 2013), which reframes fundamental physics in terms of possible and impossible transformations. IOO takes this further, suggesting that physical laws are not just given to us; they are built from within through the recursive entanglement of IOIs. What emerges, then, is a cosmos not governed by external law but composed by relation (Dijkgraaf, 2018).

IOO enters precisely at this juncture. As noted above, it not only does accommodate the mathematical formalism of QM but also offers a minimal ontological reinterpretation that reframes the observed structure as a consequence of complex-valued I/O dynamics.

4.1. Interpretative Layer

IOO posits that structure arises from the entangled reciprocity where one entity's inside corresponds to another's outside (Ko, 2021). It is built through how one IOI's outwardness connects with another's inwardness, mutually generating inner and outer realities. While QM describes how systems behave, IOO explains what systems are and why they behave that way. It turns quantum paradoxes – such as superposition, measurement, and nonlocality – into natural consequences of a fundamental, pre-differentiated ontological field.

This foundational understanding of reality, rooted in IOO, offers a novel perspective on long-standing cosmological challenges. Specifically, traditional cosmology has long struggled with a primordial question that precedes all others: how did the cosmos emerge from nothing? The concept of "nothing" itself remains ontologically indefinite, and efforts to resolve this paradox have often introduced assumptions whose ontological implications are as profound as the universe they seek to explain. Several dominant models reflect this challenge.

Quantum fluctuation models propose that a vacuum state, while seemingly empty, is inherently unstable and capable of giving rise to spacetime through quantum tunneling events (Tryon, 1973; Vilenkin, 1982). Cyclic cosmologies posit an eternally rebounding universe, eliminating the need for an absolute beginning by embedding origin within recurrence (Steinhardt & Turok, 2002). Multiverse hypotheses envision our universe as one among countless others emerging from a high-dimensional inflationary field or string landscape (Linde, 1986; Tegmark, 2003). Meanwhile, modern variants of philosophical idealism propose that physical reality itself is emergent from an underlying field of consciousness or phenomenological structure (Kastrup, 2019; Hoffman & Prakash, 2014).

Against this backdrop, IOO offers a distinct alternative. It does not begin with a vacuum, a landscape, or a metaphysical mind, but with the minimal ontological condition: IOIs. The original state is not a void but a superposed in-out substrate. It is neither substance nor absence but a fertile indistinction. IOO thereby minimizes ontological inflation. It does not posit hidden variables, multiversal hierarchies, or idealist fields beyond empirical reach. Instead, it proposes that the simplest irreducible condition – the coexistence of in and out – is sufficient to explain emergence itself. In this way, IOO positions itself not merely as a theory of origin but as a generative principle: a minimal and operational ontological base from which cosmic emergence, quantum reality, and cognitive formation can coherently unfold.

In the AdS/CFT correspondence (Maldacena, 1998; Gubser et al., 1998; Witten, 1998), spacetime emerges from quantum entanglement, particularly through the entanglement structure of the boundary field theory. From an IOO perspective, the fundamental entanglement of IOIs form in-out configurations, establishing an initial relational structure. As these configurations co-resonate, dimensional emergence occurs—aligning with the idea that increasing entanglement correlates with the formation of extended spacetime. However, while AdS/CFT describes emergent spacetime within a specific duality framework, In-Out Ontology provides a comprehensive ontological foundation. Specifically, it attempts to explain why entanglement itself is a fundamental organizing principle. By grounding AdS/CFT in a more primitive in-out framework, IOO offers an ontological basis that complements and potentially extends the current understanding of spacetime emergence.

4.2. IOO as Generative Ontology

In the context of quantum foundations, RQM offers an ontological departure from the notion of absolute states, proposing instead that physical quantities are fundamentally relational. This perspective aligns deeply with the foundational principles of IOO. RQM asserts that no observer-independent state can be meaningfully ascribed to a quantum system. Rather than modifying quantum mechanics to accommodate our intuitive notions of reality, Rovelli proposes that we recalibrate our understanding of the world to fit the structure of quantum theory itself – currently our most successful description of motion. Just as the abandonment of absolute simultaneity resolved interpretive issues surrounding Lorentz transformations, many of the conceptual paradoxes in quantum mechanics dissolve once we accept that the state of a system is always observer-dependent, much like simultaneity in special relativity. There is no essential divide between quantum and macroscopic systems; all systems are, fundamentally, quantum. Moreover, given current empirical evidence, there is no need to posit hidden variables or supplementary mechanisms. In RQM, the state of a system gains meaning only in relation to an observer. It is therefore incoherent to speak of an absolute, observer-independent state – such a notion has no place within a fully relational framework.

IOO extends this idea by grounding such relationality in the very origin of structure itself. Where RQM highlights that different observers may attribute different states to the same event, IOO proposes that such divergence is not merely an interpretive artifact, but a fundamental necessity arising from directional distinctions. In this light, what RQM treats as the fundamental relativity of state becomes, within IOO, the expression of a more generative organization of reality. This organization reveals that existence is always an unfolding between inward wholeness and outward participation of IOIs. Hence, RQM and IOO meet at the level of relational principles.

4.3. Decoherence

Quantum decoherence can be reinterpreted as a dynamic realization of IOE and valence transformation at the macroscopic level. When IOIs interact, they enter a state of recursive entanglement, and this interaction breaks their initial symmetry. As a result, their in-out states become asymmetrically configured. This process gives rise to the IOE field, a relational space where directionality and coherence emerge together as mutually shaping acts. Here, coherence and asymmetry are not sequential, but coupled acts of directional performance. As this entanglement deepens, specific directional alignments stabilize across the IOE field. These entangled relationships can be expressed as:

$$|\Psi_{\text{sys+env}}\rangle = \alpha\,|M\rangle\otimes|E_M\rangle + \beta\,|N\rangle\otimes|E_N\rangle \tag{12}$$

In IOO, each element like $|M\rangle \otimes |E_M\rangle$ represents a specific interaction pattern. The outward component $|M\rangle$ actively shapes its surrounding field, while the inward component $|E_M\rangle$ integrates that shaping into a stable, coherent structure. This means IOIs become relationally entangled through the IOE field. As this happens, their superpositions become directionally activated; in other words, each IOI's in-out superposition aligns with others, forming stable interaction patterns.

The outward component expresses the multiple ways relationships can unfold across the field. Meanwhile, the inward component integrates these expressions into a unified coherence. So, the IOE field is not just a passive container; it is the active medium where distinct directions and integrative coherence emerge together. Within this framework, decoherence is the stabilization of these in-out asymmetries at the field level, not a loss of superposition. The IOI does not stop superposing; it begins to perform. IOO then interprets the phenomenon of branching not as a multiplication of separate realities, but as the rich, multi-layered activity of IOIs dynamically generating and cohering emergent directional configurations within the IOE field. To articulate this mechanism formally, we begin by recognizing that each IOI exists in a state of in-out superposition:

$$|\Omega_k\rangle = \alpha_k\,|\text{in}\rangle_k + \beta_k\,|\text{out}\rangle_k \tag{13}$$

where $\alpha_k, \beta_k \in \mathbb{C}$ and $|\alpha_k|^2 + |\beta_k|^2 = 1$. This defines the directional valence configuration of IOI k. Interaction occurs through the IOE field $\mathcal{F}$, encoding directional coherence:

$$\mathcal{F}_{ij} = \gamma_{ij} \cdot \langle \text{in}j \,|\, \text{out}i \rangle \tag{14}$$

γ_{ij} represents a field coherence coefficient (such as phase compatibility or scalar alignment). The full entangled system is expressed as:

$$|\Psi\rangle = \bigotimes_{k=1}^{N} \left(\alpha_k\,|\text{in}\rangle_k + \beta_k\,|\text{out}\rangle_k\right) \tag{15}$$

With directional entanglement constructed by:

$$|\Psi_{\text{ent}}\rangle = \sum_{i\neq j} \mathcal{F}_{ij}\left(|\text{out}\rangle_i \otimes |\text{in}\rangle_j\right) \tag{16}$$

Decoherence is defined not as collapse but as stabilized directional asymmetry:

$$\lim_{t\to t'} \frac{d}{dt}\left(\mathcal{F}_{ij}\right) \to 0 \tag{17}$$

Branching is the scalar multidirectional engagement of IOI k:

$$\mathcal{B}_k = \left\{\mathcal{F}_{kj}^{(1)}, \mathcal{F}_{kj}^{(2)}, \ldots, \mathcal{F}_{kj}^{(n)}\right\} \tag{18}$$

which represents the set of directional alignments IOI k performs. The standard quantum expression $|M\rangle\otimes|E_M\rangle$ is reformulated in IOO as:

$$\mathcal{F}_{ME} = \langle E_{M,\text{in}} \,|\, M_{\text{out}} \rangle \tag{19}$$

Finally, the IOE field interaction operator is given by:

$$\mathcal{H}_{\text{IOE}} = \sum_{i,j} \mathcal{F}_{ij} \cdot \left(|\text{out}\rangle_i \otimes \langle \text{in}|_j\right) \tag{20}$$

This operator governs the directional emergence of structure across the IOE field.

In IOO, the outward component actively shapes its surrounding field, and the inward component integrates that shaping into a stable, coherent structure. This means IOIs become relationally entangled through the IOE field, leading to the directional activation of their superpositions and the formation of interaction patterns. Within this framework, decoherence is the stabilization of these in-out asymmetries at the field level, interpreting branching as the multiple activity of IOIs dynamically generating directional configurations and exploring them within the IOE field.

Building on this framework for quantum reality, we now extend our inquiry to the fundamental nature of subjective experience. The same principles of directional differentiation and integrative flow that underpin cosmic emergence and quantum reality also offer a robust framework for comprehending consciousness and affective states.

5. In-Out Valence

Panpsychism suggests that consciousness is a basic feature of all matter, implying that even elementary particles may possess a simple form of awareness (Skrbina, 2017). IOO shares this core idea. However, instead of attributing proto-consciousness to particles, it derives from IOIs – the ontological generators from which both matter and mind emerge.

IOIs are not particles, nor are they just abstract possibilities. They are real, foundational entities held in an inherent state of in-out superposition. This superposition is not just a passive potential, but a generative condition. IOIs possess within themselves the capacity for directional articulation. Yet, this capacity does not express itself alone. It unfolds through the relational entanglement field, where inward and outward flows interact, synchronize, and recursively shape one another.

Within this dynamic, the very roots of consciousness become clear. Consciousness is not added onto structure from outside, nor is it merely a by-product of complex calculations. Instead, it emerges naturally from the layered resonance of IOIs as they engage each other directionally. Each inward tendency contributes to the stabilization of outward expressions, while outward projections foster an expanding, multi-level inward coherence from the encompassing field. This recursive development of organizational complexity allows IOIs to develop their generative capacity.

Agency, in this view, is not externally imposed but emergent. It unfolds as IOIs attain increasing coherence across layered entanglements, gradually acquiring stability and influence. Capacities such as decision-making, attention, intention, and self-reflection are not mere byproducts of complexity, but higher-order expressions of directional recursion – IOIs becoming more fully what they are ontologically poised to be: not just generators, but creators of coherence, differentiation, and integrative flow.

5.1. Affect

The valence of experience, often thought of only in terms of psychology or affective neuroscience, is now being explored in wider discussions about existence and evolution. These new conversations often point to the basic back-and-forth pattern of in-out structure. For example, Peil (2014, 2015) proposes a model of emotion that redefines it as a primary sensory system, potentially the first to have emerged in living organisms. She argues that emotion's fundamental function is self-regulation. In contrast to models that treat affect as the outcome of higher-order appraisal, her framework posits emotion as evolutionarily primary, emerging alongside the earliest living systems as a means of guiding survival through internal assessments of coherence or dissonance with the environment. Even in simple organisms such as *E. coli*, she identifies rudimentary affective dynamics in the form of approach-avoidance behaviors triggered by molecular feedback systems. Crucially, emotion in this schema serves as a continuous ontological gauge: positive valence marks systemic alignment and adaptive fit, while negative valence signals a disruption or misalignment requiring correction. Affect thus becomes not merely an inner state or reaction to external stimuli but a biologically instantiated feedback mechanism for real-time existential evaluation. This redefinition enables emotion to be recontextualized as a primordial form of sense-making. By interpreting affect as the organism's intrinsic registration of being-in-relation, Peil restores emotion to its rightful ontological status as a primary mode of engagement with the world.

Earlier precedents to this view appear in the neurophenomenological work of Damasio (1999), who describes "the feeling of what happens" as a basic way our bodies register states that shape conscious self. His somatic marker hypothesis explains how our decisions are rooted in bodily feelings, with internal signals influencing future

actions. In a more evolutionarily primal register, Panksepp's affective neuroscience (1998) posits subcortical emotional systems – such as CARE, SEEKING, and PANIC – Panksepp argued that emotions are deeply rooted in ancient, subcortical neural circuits shared by all mammals. His groundbreaking work proposed that there exist several primary emotional systems such as the SEEKING system (which drives exploration and motivation), the FEAR system (which prepares an organism for danger), and the RAGE system (which underlies anger responses), among others like CARE, PLAY, and LUST. This focus on emotional also connects with older philosophical ideas that considered direction to be fundamental to how the mind works. For instance, Spinoza's *Ethics* (1677) viewed affect as a reflection of how our basic drive to exist (conatus) shifts. Joy, in his view, meant an increase in out power to act, while sadness meant a decrease. More recently, Metzinger (2003), in *Being No One*, saw the self not as a fixed thing but as a constantly updated "self-model" that processes information through input-output loops. In a more speculative but highly relevant way, Thompson (2007) proposed that consciousness naturally arises from how an organism actively engages with its environment. His emphasis on autopoiesis (self-creation) and structural coupling points to a dynamic blending of inner and outer.

While these theories are strong and well-supported, they often do not fully explore how their ideas apply to layered processes or how they might scale up. This is where IOO comes in. It provides these affect models with a firmer, more precise, and even mathematical foundation. Their crucial insights are not just compatible with IOO; they are precisely what we can re-examine and understand through the specific in-out directions and ratios, or in-out valence.

5.2. Qualia

Each IOI begins in a balanced state, where its inward and outward aspects are symmetric. Then, it exhibits four basic valences: inward-positive (in^+), inward-negative (in^-), outward-positive (out^+), and outward-negative (out^-). From this fundamental symmetry, IOO develops its model of consciousness, feelings (affect), and how we experience reality (phenomenality). Once IOE occurs, four primary directional flows emerge:

- **in^+ :** Integration, coherence, or care.
- **in^- :** Contraction, withdrawal, or defensive interiorization.
- **out^+ :** Articulation, exploration or participatory becoming-with.
- **out^- :** Severance, dissociation, or entropic dispersion.

These four flows form the basic structure of consciousness and how we feel and think**.** From these, IOO identifies two main ways the valence organize themselves:

Valence Type	Description
Basic valence	This is simply the direct, dimensional direction.
Quadrant valence	This is more complex combinations that emerge when the basic valences interact across the in-out axis (which represents Being and Becoming). These interactions form higher-level structures for our experience.

Quadrant valence shows how different scalar valence fields recursively connect, building the very architecture of our experience. This includes both our felt sense of space (topology) and observable changes in an underlying field. In this model, qualia are not simply mental representations. Instead, they are intricate patterns of flow, blending quantitative and qualitative aspects. These patterns are shaped by how entangled IOIs interact and influence each other's magnitude, or scalar properties, and their phase, or position in a cycle. This supports Chalmers' idea of needing a richer understanding of reality to solve the "hard problem" of consciousness (Chalmers, 1995). This model also helps explain how our subjective experiences, or qualia, and our intentions can come from the complex IOE fields. In In-Out Ontology, qualia are like organized flows of basic information, and consciousness itself is simply the repeating pattern of IOE. As IOIs engage with their context, each one evolves to have a propensity for directional expression, leaning either inward or outward. As these directional inclinations build up across a network of IOIs, distinct qualities or feelings start to show up.

Specifically, each IOI is defined not by location or representation, but by a directional valence pairing:

$$I \in \{\text{in}^+, \text{in}^-\}, \quad O \in \{\text{out}^+, \text{out}^-\} \tag{21}$$

These form the coordinate basis of an IOI's state. Transitions between IOI states – whether cognitive, emotional, attentional, or affective – can be described as mappings across this two-axis valence space:

$$V_{i\to j} : (I_i, O_i) \to (I_j, O_j) \tag{22}$$

Since there are four possible I/O pairs, this framework yields a 4 × 4 valence transition matrix, comprising 16 distinct directional transformations. Each entry in this matrix corresponds to a specific ontological mode of phase realignment, coherence shift, or directional tension:

From \ To	**(in⁺, out⁺)**	**(in⁺, out⁻)**	**(in⁻, out⁺)**	**(in⁻, out⁻)**
(in⁺, out⁺)	Integrative openness	Overintegrative collapse	Openness with inward dissipation	Downward drift toward isolation
(in⁺, out⁻)	Reactive adaptation	Hermetic stillness	Contained centering to expressive imbalance	Lock-in of dissonance
(in⁻, out⁺)	Insight via chaos	Integration from disruption	Reengagement toward unity	Refracted fragmentation
(in⁻, out⁻)	Rising impulse for restoration	Defensive closure	Return to coherence	Recursive collapse

These transitions and their associated semantic descriptions are not merely metaphorical moods or reactive patterns; they represent ontological events. IOO asserts that every qualitative shift in cognition corresponds to a valence-phase transformation, signifying a reconfiguration in the field entanglement of an IOI.

A growing body of cognitive and neurocomputational research has begun to render consciousness not as an isolated phenomenon but as a field of recursive, informational, and energetic dynamics. IOO contributes a unifying ontological substrate beneath this structure – clarifying not only how such processes arise, but why they are possible at all. In this context, IOO offers a foundational meta-structure: not merely a conceptual scaffold but a (pre-)geometric substrate from which such architectures can be seen to emerge.

Across the expanding landscape of cognitive research – spanning mathematical neurophenomenology, active inference theory (Friston, 2006, 2010), and embodied enactivism (Thompson, 2007) – a common architecture emerges: experience as a recursive field of inferential updating, metabolic regulation, and adaptive behavior. But what remains largely ungrounded is the ontological origin of this structure – the directional condition that renders such recursive processes meaningful. IOO provides this missing substrate by positing that cognition and consciousness are scalar modulations of directional coherence across IOE fields.

5.3. Contemporary Models of Cognition and Reframing

In the domain of neurophenomenology and related cognitive models, IOO reframes the entire field as a valence-topological manifold. Within this manifold, every conceptual point precisely encodes the phase coherence of an IOI in directional terms – representing its current I/O state and its potential trajectory, $V_{i\to j}$.

Model Feature	**Ontological Reframing**
Probability over inferred states (Da Costa et al, 2024)	Ontological points within a directional valence manifold (the IOE field), representing actual In-Out states.
Free-energy minimization (Friston, 2010)	The scalar cost of maintaining directional coherence across IOIs entangled in asymmetric in-out superposition.
Markov blankets and precision-weighting	Topologically defined stabilization zones for coherence dynamics and their boundaries.

Attention and temporality	The recursive rhythm of phase alignment and directional modulation within the IOE field.
Bayesian mechanics	Phase transitions within the IOE field – these are real ontic events, not merely epistemic updates of belief.

Where other models often see cognition as simply updating beliefs by reducing prediction errors, IOO redefines this process. It views it as a topological realignment within a valence field. In this framework, attention becomes the way phase-locked coherence is modulated, memory is the entropic imprinting of past directional states, and surprise is a directional asymmetry.

The metabolic cost associated with consciousness, typically discussed in active inference and Bayesian mechanics (Ramstead et al., 2023), is more than just thermodynamic in IOO; it is ontological. To stabilize an IOI in a high-coherence state such as ν (out^+, in^+), a recursive investment of energy is required to preserve phase-locked directional integration. Conversely, shifts towards such as ν (in^-, out^-) indicate a breakdown in this coherence. Furthermore, time is not treated as a linear background. In this view, Da Costa et al.'s treatment of temporal structure and phenomenality gains deeper ontological meaning: time itself is emergent directional rotation.

Where current models offer detailed mappings of behavior, affect, and inferential flow, IOO reveals the topological terrain from which these emerge. Every belief, every act of attention, and every stage of memory or confusion constitutes a traversal of the valence transition matrix ν. While the scale and specific combinations of these events can be highly complex, the underlying transitions are fixed. There are no other ways for this to occur beyond the defined in-out dynamics; it is ontologically predestined.

What Da Costa et al. express in terms of belief fields and free-energy gradients, IOO interprets as real-time scalar modulations across entangled directional valence. The IOE field does not sit beneath cognition – it is at least proto-cognition, at its ontic root. Time, energy, and attention become coordinates not of symbolic analysis but of scalar coherence. What Varela (1996) intuited, and Friston formalized, IOO grounds. It gives structure to the recursive dance between inner and outer, sense and synthesis, surprise and belief. In doing so, it offers not just a meta-theory of cognition, but a complex grammar of being.

6. Concluding Remarks

This study has proposed a foundational reorientation of ontology, proposing that what underlies all phenomena is not substance, spacetime, or information, but the relational configuration of IOIs. The cosmos, in this ontological vision, is neither a container nor a collection, but an in-out resonance – the IOE field whose valence modulations give rise to all that appears as form, force, and thought.

Every IOI possesses both an inward and an outward aspect, which are fundamentally symmetric as a minimal ontological condition. Each inwardness resonates with an other's outwardness, creating the conditions for entanglement and emergence. The dynamic coupling of in and out is the fundamental driving force of reality. Things like dimensions, identity, how things interact, and even time itself, all come about because of this linking.

IOO is not meant to negate or compete with existing theories. It does not propose different equations or try to overturn the well-established scientific understanding we have. Instead, it suggests a more fundamental ontological logic that might help explain why the mathematics of relativity and quantum theory work so well. Indeed, it is miraculous – what Wigner (1990) once called the "unreasonable effectiveness of mathematics" in the natural sciences. In-Out Ontology does not seek to diminish this wonder but to deepen it. It proposes that the effectiveness of mathematical formalism arises from a more fundamental in-out structure of reality, where the very notion of "equals" expresses in-out symmetry.

From within this framework, several critical implications also emerge. The dimensions of spacetime appear not as containers, but as stabilized resonance patterns among IOIs, modulated by their directional patterns and ratios. Properties such as mass, charge, and spin are no longer abstract givens, but consequences of asymmetric in-out configurations at the Big Bang. The enigma of entanglement dissipates, for IOIs don't merely entangle across spacetime, but instead co-create relative spacetime for one another since the cosmic emergence.

Consciousness, in IOO, is not an incidental byproduct of neural complexity but the dynamic modulation of valence and information across IOIs. It emerges as a gradient of ontic differentiation, continually tracing the tensions and resolutions of inward and outward flows, modulating sense, agency, and relational knowing.

To move beyond ontological interpretation into formalization, IOO invites multiple lines of development. It suggests a new kind of algebra where operations don't simply act on states, but are the recursive shifts between

in and out, grounding ontological superposition and entanglement in dynamic recursion. Furthermore, it necessitates a topologically upgraded complex model. This is not a theory to be pinned down to a single structure, but a field of emergence where geometry, algebra, and dynamics converge under in-out relations. Then, IOO's role is not to provide all the answers, but rather to serve as a starting point for asking new questions.

References

Bell, J. S. (1964). On the Einstein Podolsky Rosen paradox. *Physics Physique Fizika*, 1(3), 195–200. https://doi.org/10.1103/physicsphysiquefizika.1.195

Bohm, D. (1952). A suggested interpretation of the quantum theory in terms of "hidden" variables. *Physical Review*, 85, 166–179. https://doi.org/10.1103/physrev.85.180

Chalmers, D. J. (1995). Facing up to the problem of consciousness. *Journal of Consciousness Studies*, 2(3), 200–219. http://consc.net/papers/facing.html

Christensen Jr., W. J. (2024). Between quantum mechanics and general relativity. *Journal of Modern Physics*, 15, 1199–1228. https://doi.org/10.4236/jmp.2024.158049

Da Costa, L., Sandved-Smith, L., Friston, K. J., Ramstead, M. J. D., & Seth, A. K. (2024). A mathematical perspective on neurophenomenology. *arXiv preprint*, arXiv:2409.20318.

Damasio, A. R. (1999). *The feeling of what happens: Body and emotion in the making of consciousness*. Harcourt Brace and Co

Deutsch, D. (2013). Constructor theory. *Synthese*, 190(18), 4331–4359. https://doi.org/10.1007/s11229-013-0279-z

Einstein, A., Podolsky, B., & Rosen, N. (1935). Can quantum-mechanical description of physical reality be considered complete? *Physical Review*, 47(10), 777–780. https://doi.org/10.1103/physrev.47.777

Everett, H. (1957). "Relative state" formulation of quantum mechanics. *Reviews of Modern Physics*, 29, 454–462. https://doi.org/10.1103/revmodphys.29.454

Friston, K. (2006). A free energy principle for the brain. *Journal of Physiology–Paris*, 100(1–3), 70–87. https://doi.org/10.1016/j.jphysparis.2006.10.001

Friston, K. (2010). The free-energy principle: A unified brain theory? *Nature Reviews Neuroscience*, 11(2), 127–138. https://doi.org/10.1038/nrn2787

Fuchs, C. A., Mermin, N. D., & Schack, R. (2014). An introduction to QBism with an application to the locality of quantum mechanics. *American Journal of Physics*, 82(8), 749–754. https://doi.org/10.1119/1.4874855

Fullwood, J., & Vedral, V. (2025). Geometry from quantum temporal correlations. *Physical Review A*, 111(5), 052438. https://doi.org/10.1103/physreva.111.052438

Gubser, S. S., Klebanov, I. R., & Polyakov, A. M. (1998). Gauge theory correlators from non-critical string theory. *Physics Letters B*, 428(1–2), 105–114. https://doi.org/10.1016/s0370-2693(98)00377-3

Hoffman, D. D., & Prakash, C. (2014). Objects of consciousness. *Frontiers in Psychology*, 5, 577. https://doi.org/10.3389/fpsyg.2014.00577

Kastrup, B. (2019). *The Idea of the World: A Multi-Disciplinary Argument for the Mental Nature of Reality*. Iff Books..

Kauffman, K. P. (2015). Emotional sentience and the nature of phenomenal experience. *Progress in Biophysics and Molecular Biology*. http://dx.doi.org/10.1016/j.pbiomolbio.2015.08.003

Ko, K.-I. (2021). Structure is what inside-outside duality makes of it: A foundation of quantum social science. *Academia Letters*, Article 3541. https://doi.org/10.20935/AL3541

Ko, K.-I. (2024). From in-out duality to the foundation of social quantum mechanics. *Open Journal of Applied Sciences*, 14, 893–926. https://doi.org/10.4236/ojapps.2024.144060

Linde, A. D. (1986). Eternally existing self-reproducing chaotic inflationary universe. *Physics Letters B*, 175(4), 395–400. https://doi.org/10.1016/0370-2693(86)90611-8

Maldacena, J. (1999). The large-N limit of superconformal field theories and supergravity. *International Journal of Theoretical Physics*, 38(4), 1113–1133. https://doi.org/10.1063/1.59653

Metzinger, T. (2003). *Being no one: The self-model theory of subjectivity*. MIT Press.

Padmanabhan, T. (2015). Emergent gravity paradigm: Recent progress. *Modern Physics Letters A*, 30(03n04), 1540007. https://doi.org/10.1142/s0217732315400076

Panksepp, J. (1998). *Affective neuroscience: The foundations of human and animal emotions*. Oxford University Press.

Peil, K. T. (2014). Emotion: The self-regulatory sense. *Global Advances in Health and Medicine*, 3(2), 80–108. https://doi.org/10.7453/gahmj.2013.058

Penrose, R. (1971). Angular momentum: An approach to combinatorial space-time. In *Quantum Theory and Beyond* (pp. 151–180). Cambridge University Press.

Ramstead, M. J. D., et al. (2023). On Bayesian mechanics: A physics of and by beliefs. *Interface Focus*, 13(3), 20220029. https://doi.org/10.1098/rsfs.2022.0029

Rovelli, C. (1996). Relational quantum mechanics. *International Journal of Theoretical Physics*, 35(8), 1637–1678. https://doi.org/10.1007/bf02302261

Rovelli, C. (2016). An argument against the realistic interpretation of the wave function. *Foundations of Physics*, 46, 1229–1237. https://doi.org/10.1007/s10701-016-0032-9

Rovelli, C., & Smolin, L. (1995). Spin networks and quantum gravity. *Physical Review D*, 52(10), 5743–5759. https://doi.org/10.1103/physrevd.52.5743

Scherk, J., & Schwarz, J. H. (1974). Dual models for non-hadrons. *Nuclear Physics B*, 81(1), 118–144. https://doi.org/10.1016/0550-3213(74)90010-8

Seiberg, N. (2006). Emergent spacetime. *arXiv preprint* hep-th/0601234.

Skrbina, D. (2017). Panpsychism. In E. N. Zalta (Ed.), *The Stanford Encyclopedia of Philosophy* (Spring 2021 Edition). Metaphysics Research Lab, Stanford University. https://plato.stanford.edu/archives/spr2021/entries/panpsychism/

Spinoza, B. de. (1677). *Ethics* (E. Curley, Trans.). In *The Collected Works of Spinoza* (Vol. 1). Princeton University Press, 1985.

Steinhardt, P. J., & Turok, N. (2002). A cyclic model of the universe. *Science*, 296(5572), 1436–1439. https://doi.org/10.1126/science.1070462

Susskind, L. (2016). ER = EPR, GHZ, and the consistency of quantum measurements. *Fortschritte der Physik*, 64(1), 72–83. https://doi.org/10.1002/prop.201500094

Tegmark, M. (2003). Parallel universes. *Scientific American*, 288(5), 40–51. https://doi.org/10.1038/scientificamerican0503-40

Thompson, E. (2007). *Mind in life: Biology, phenomenology, and the sciences of mind*. Harvard University Press.

Tryon, E. P. (1973). Is the universe a vacuum fluctuation? *Nature*, 246(5433), 396–397. https://doi.org/10.1038/246396a0

Unger, R. M., & Smolin, L. (2014). *The singular universe and the reality of time: A proposal in natural philosophy*. Cambridge University Press. https://doi.org/10.1017/cbo9781139696487

Van Raamsdonk, M. (2010). Building up space–time with quantum entanglement. *International Journal of Modern Physics D*, 19(14), 2429–2435. https://doi.org/10.1142/s0218271810018529

Varela, F. J. (1996). Neurophenomenology: A methodological remedy for the hard problem. *Journal of Consciousness Studies*, 3(4), 330–349.

Vilenkin, A. (1982). Creation of universes from nothing. *Physics Letters B*, 117(1–2), 25–28. https://doi.org/10.1016/0370-2693(82)90866-8

Wigner, E. P. (1990). The unreasonable effectiveness of mathematics in the natural sciences. In *Mathematics and Science* (pp. 291–306). https://doi.org/10.1007/978-3-642-78374-6_41

Witten, E. (1998). Anti de Sitter space and holography. *arXiv preprint* hep-th/9802150.

Zurek, W. H. (2003). Decoherence, einselection, and the quantum origins of the classical. *Reviews of Modern Physics*, 75(3), 715. https://doi.org/10.1103/revmodphys.75.715