The Twistor as a Relational Structure: An Ontological Reinterpretation of Penrose's Geometry in the Context of the Indeterminacy Space

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Abstract

In this paper, I propose an ontological reinterpretation of Roger Penrose's twistor theory in the context of the indeterminacy space Φ, understood as a pre-physical level of reality. I argue that the classical interpretation of the twistor as a photon's trajectory is ontologically flawed, as it reduces the structure of potentiality to a description of secondary physical phenomena. Instead, I introduce the twistor as a relational projection of local instability within the Φ field, constituting a structure of geometric readiness for the actualization of reality.

The paper develops the concept of the indeterminacy space as a nonlocal carrier of information, in which all possible configurations of reality coexist in a potential state. Intention is described as an operator $\hat{I}$ acting upon this space, reducing it to specific spacetime manifestations. In this framework, the twistor is neither a physical object nor a mathematical particle state, but a locally activated relational code triggered by fluctuations in the Φ field.

The proposed structure $\Phi \rightarrow \{\text{twistor}\} \rightarrow \{\text{spacetime}\}$ defines a new paradigm for the emergence of geometry from a level of informational potentiality and offers a coherent account of the collapse of reality in a nonlocal framework. This work opens new perspectives for the unification of twistor geometry with information theory, quantum physics, and the ontology of consciousness.

Contents

1 Introduction

Despite the successes of local models—such as general relativity, which assumes local dynamics of spacetime, and quantum field theory, which operates locally on Hilbert spaces—the problem of nonlocality observed in quantum experiments remains unresolved. There is a lack of a unified description of reality that would encompass both quantum and geometric mechanisms while also accounting for the deeper, ontological level from which physical structures emerge. A key aspect of this problem is the absence of a universal theory capable of operating simultaneously on the levels of information, geometry, and relationality—without presupposing the existence of spacetime.

One of the most refined theoretical frameworks attempting to transcend the classical spacetime model is Roger Penrose's twistor theory. [9] Introduced in the 1960s, this theory—based on complex geometry and null-type relations—offers a new method for encoding points in Minkowski space using geometric structures that are not themselves located in spacetime. Instead of describing physical phenomena as events occurring within spacetime, the twistor is treated as an object representing a relation from which a spacetime point may emerge.

Originally, this approach was envisioned as having the potential to resolve the discontinuity between quantum mechanics and general relativity. In practice, however, despite fascinating results in the area of scattering amplitudes and its profound contributions to complex geometry, twistor theory remains a partial theory, applicable only under specific conditions and lacking ontological clarity.

In particular, the twistor is often interpreted as the trajectory of a photon—that is, the path of a massless particle moving at the speed of light through flat spacetime. This interpretation is historically and formally understandable: the photon is the simplest physical object moving along a null curve, and the twistor operates precisely in the geometry of null structures. However, this identification leads to significant limitations. First, the photon as a physical state is a secondary phenomenon of quantum physics and cannot be treated as a fundamental structure. Second, if the twistor is to serve as a fundamental entity, it cannot be definitionally tied to something that itself results from higher-level physical dynamics. And third—and perhaps most importantly—the "photon-based" interpretation confines the theory to local applications and prevents a full reconstruction of the global structure of spacetime.

This issue—referred to here as the problem of twistor locality—remains one of the major unresolved challenges within Penrose's theory. The author himself has attempted to address it, especially in the context of curved spacetimes in general relativity, but without definitive success. As I will argue, this is not due to shortcomings in the mathematical formalism but stems from the ontological nature of the twistor as a local structure, activated in response to informational conditions on a deeper level of reality.

In this paper, I propose a resolution to this problem through a reinterpretation of the twistor's function as a relational structure that does not represent a particle's trajectory but rather encodes the conditions of geometric potentiality, locally activated as Φ fluctuations within the indeterminacy space. This space does not yet contain any geometric structures, but instead comprises a field of informational potentialities conditioned by intention, informational gradients, or other non-causal and nonlocal mechanisms. These fluctuations are described as the Φ, understood not as a space in itself but as a localized tension of readiness for collapse, triggered by geometric, informational, or intentional structures.

In my interpretation, the twistor is thus neither a physical entity nor a mathematical representation of a specific state. It is a structure of geometric readiness—a local response of the Φ to the possibility of collapse, that is, the actualization of a fragment of reality. In this view, the twistor does not contain information about the totality of reality—nor is it meant to. Its function is not to describe the world but to locally encode information about where and how the world could be actualized. This perspective helps explain why twistor theory—despite its elegance—has not achieved the status of a fully unifying theory: because it was never meant to, when judged through the lens of the structure it implicitly presupposes.

In the following sections of this work, I will analyze both the classical assumptions of twistor theory and the limitations arising from its photon-based interpretation. I will then introduce the structure of the indeterminacy space and its role as the condition of possibility for the actualization of reality. Within this context, I will define the twistor as a relational, non-spatial geometric structure, activated in response to local minima of informational entropy or at collapse points selected by consciousness or the observer. [8] The final parts of the paper will be devoted to the consequences of this reinterpretation—both for the formalism of geometry and for the ontology of physical theories and their potential unification.

The aim of this work is not to further develop the twistor formalism per se, but rather to understand its actual place in the hierarchy of reality's structures. I propose to consider the twistor as the first explicit object that may emerge from the indeterminacy space, but which itself does not serve a creative or organizing function. It is an expression of readiness, not an act; a projection, not a foundation.

In this view, twistor theory is embedded in a broader ontological continuum in which its limitations become comprehensible, and its structure—complementary to deeper layers of the organization of reality.

Twistor theory, proposed by Roger Penrose in 1967, was a response to a deep dilemma at the foundation of physics: how to describe the structure of reality without assuming spacetime as a given background, but rather deriving it from more fundamental principles. Penrose challenged the prevailing assumption in relativistic physics that space and time serve as the stage upon which phenomena unfold. Instead, he proposed that spacetime points are merely projections of more fundamental objects—so-called twistors.

The central idea of twistor theory is to replace classical spacetime points with a complex relational structure, in which the fundamental entities are not spatial locations but null-type relations between them. In this framework, null geodesics (paths of light) become more fundamental than the points themselves, which in traditional differential geometry are the basic elements of the spacetime manifold.

Formally, twistor space is typically denoted by $\mathbb{P}T$ or T, depending on the formulation. Any twistor $Z^\alpha \in \mathbb{C}^4$ can be expressed as a pair of complex spinors:

$$Z^\alpha = (\omega^A, \pi_{A'})$$

where:

- ω^A is the spinor encoding position coordinates,
- $\pi_{A'}$ is the spinor encoding momentum coordinates,

with spinor indices $A, A' = 0, 1$, corresponding respectively to position and momentum in the spinorial formulation. Importantly, these components do not carry direct physical meaning in the classical sense. Their connection to Minkowski spacetime is given by the so-called twistor incidence relation:

$$\omega^A = ix^{AA'}\pi_{A'}$$

where $x^{AA'}$ is the spinorial representation of a point in Minkowski spacetime. This relation shows that a given twistor can be identified with a family of null geodesics (light rays) passing through a particular spacetime point. In other words, a point in spacetime is the intersection of an infinite number of twistors—and a single twistor represents a potential light-like trajectory, independent of any specific spatial localization.

The advantage of this construction is that it entirely reformulates the concept of a spacetime point as a primary element. In classical differential geometry, a point defines possible trajectories. In twistor geometry, by contrast, it is the null trajectories that define points. This paradigm shift allows for the abandonment of local topology as a primitive structure in favor of a relational complex geometry.

This innovative approach enabled Penrose and other researchers to develop a variety of formalisms in which Minkowski space (i.e., flat spacetime) appears as a derived structure—an emergent phenomenon resulting from the intersections of twistor structures. Based on this foundation, it became possible to formulate alternative descriptions of field equations for massless particles (e.g., Maxwell or Dirac equations) in twistor space, as well as to derive significantly simplified scattering amplitude formulas—particularly in Witten's twistor program in the context of string theory and supersymmetry. [13]

Nevertheless, despite these successes, the classical interpretation of the twistor as a "light ray"—that is, as the representation of a photon trajectory—entails serious limitations.

First, in this view, the twistor is tightly bound to Minkowski space—that is, a flat space devoid of curvature and gravity. Attempts to generalize twistor formalism to curved spacetimes, such as those described by general relativity, face significant challenges. In particular, a well-defined incidence relation in a space with a variable metric is lacking, and local twistor structures do not "glue" coherently in a global framework. Penrose and other researchers (e.g., LeBrun, Mason, Woodhouse) developed various techniques for curved backgrounds (e.g., ambitwistors, twistor spaces of curved manifolds), but none of these constructions has achieved the status of a general theory. [5, 6]

Second, the photon-based interpretation confines the functionality of the twistor to a single type of physical entity: massless particles. However, contemporary physics demands a unifying framework—a theory capable of describing both massless and massive particles, both light and gravity, in a consistent manner. If the twistor is identified with the photon, it cannot fulfill this role. It becomes a specialized tool, applicable only to a narrow class of trajectories under specific geometric conditions, rather than a truly fundamental theory.

Third, identifying the twistor with a photon trajectory ties it ontologically to spacetime—the very structure it is intended to supersede. If a twistor is to represent a "light path," then it requires a geometric context—a metric, an affine connection, a definition of nullness—that is presupposed rather than derived. This leads to an internal tension within the theory: on one hand, the twistor is meant to describe something more fundamental than space and time; on the other, its physical interpretation already assumes the existence of those very structures. This circularity is a case of ontological presupposition, which calls for reconstruction.

The fourth issue concerns local versus global relationality. In its classical definition, the twistor operates locally: it represents a single null relation or a family of relations from a given spacetime point. It lacks, however, an internal structure capable of encoding the distribution of information at a global level—for instance, within the large-scale structure of cosmic space, in the presence of event horizons, cosmological entropy, or topological boundaries. In this sense, the twistor does not encode the global state of reality, but only its local "geodesic possibility." Thus, even though twistor mathematics allows for the description of local scattering processes, it does not yet provide tools for the global reconstruction of reality.

In summary, classical twistor theory represents a remarkable mathematical achievement that successfully redefines the concept of a spacetime point and offers an alternative geometric structure based on null relations. However, identifying the twistor with the trajectory of a photon—while historically justified—limits its potential as an ontological tool. It leads to erroneous causal implications, restricts the theory's generalization to curved spacetimes, and hinders the coherent description of global structures.

2 Limitations of the Classical Interpretation of Twistors as Photon Trajectories

In the common interpretive framework, Roger Penrose's twistor theory is based on the identification of a twistor with the trajectory of a massless particle—most often a photon—propagating at the speed of light in Minkowski spacetime. In this sense, a twistor represents a null relation, that is, a geodesic curve of zero type (null), which does not extend in time but retains a specific directional structure. Although this assumption is formally consistent with the mathematical construction, it carries ontological implications that merit critical analysis.

First, it should be emphasized that the photon, as a physical object, does not exist as a fundamental structure but rather as an excitation state of the electromagnetic field. The modern approach in quantum field theory does not treat particles as elementary entities, but as manifestations of the operation of physical principles: creation and annihilation operators, commutators, boundary conditions, and symmetries. A photon does not possess spatial localization in the classical sense, cannot be brought to rest, and does not exist in time—it is a product of the operation of a specific formalism within the bounds of an already organized spacetime. This means that the photon, as a phenomenal object, depends on the existence of a geometrical structure in which its parameters can be defined.

In this context, attributing to the twistor the role of a geometric representative of the photon leads to the assumption that the structure it represents is a fundamental phenomenon. However, if the photon is an excitation of a field within an already existing spacetime, then the twistor, as its representation, cannot be more fundamental than the structure of which it is a function. This would imply a reversal of effect into cause—which, from a logical standpoint, constitutes a causal fallacy. One cannot derive the principles of spatial formation from the description of something that itself requires the existence of space in order to exist as a possible state.

From the perspective of physical ontology, this means that the interpretation of twistors as "photon paths" confuses the level of description with the level of genesis. It is a classical case of blurring the boundary between code and phenomenon—between informational structure and its realization within a particular configuration. A photon is an empirical entity, recognized through interaction (e.g., the registration of photons in a detector). A twistor—in its purest form—is a geometric construct expressing a null condition: not a particle, but a geometric relation between points in complex projective space. Reducing the twistor to the function of representing a photon particle diminishes its meaning and transforms it from a tool for describing geometric potentiality into an object representing an empirical state. This is not only an unnecessary simplification but also a conceptual trap that has stalled the evolution of twistor theory toward a more fundamental framework.

There is also a significant issue concerning locality. A photon, as a null-type trajectory, propagates in a specific spacetime. A twistor—if it is to represent this trajectory—is likewise embedded within the geometry of that space. However, if the twistor is to be fundamental, it should represent a structure independent of the boundary conditions of any specific spacetime model. It should precede the choice of metric, topology, or curvature. In practice, however, the twistor construction functions correctly only in flat space or under conditions strongly constrained by local symmetry principles.

Attempts to generalize it to curved spacetimes encounter mathematical difficulties—which indicates that the twistor, when interpreted as a particle-representing structure, lacks the ontological flexibility necessary to serve as a foundation for a description of reality as a whole.

Thus, one may ask: if a twistor cannot serve as a representation of a photon trajectory, what is it truly? If it cannot fulfill the role of describing particles as elements of physical reality, what place should it occupy in the hierarchy of theoretical structures?

In my proposal, the answer is not to be sought in the domain of phenomena, but in the domain of potential structures—that is, structures that do not exist as realized, but as capable of becoming actualized. A twistor does not represent an entity—it represents the condition of its possibility. It does not describe a trajectory—it describes the structure within which a trajectory could arise, given appropriate informational conditions. In this sense, the twistor should be relocated from the level of physical phenomena to the level of informational metageometry.

From the perspective of the space of indeterminacy (Φ), which I discuss further in this work, a twistor may be understood as a local response of this space to the potential emergence of a spacetime configuration. This means that the twistor belongs neither to classical physics, nor to quantum physics, nor to Riemannian geometry as such. It resides on an intermediate level—the level of possibility activation. It is a conditional structure, not a present (actual) one, yet prepared for actualization. It is a code of an event, not the event itself. And precisely for this reason, its identification with the photon—as an empirically detectable and phenomenologically defined entity—is logically inadequate.

3 The Space of Indeterminacy as a Foundational Layer

A twistor cannot be considered a fundamental structure because it lacks global information and only represents local conditions of collapse readiness. To understand how such conditions emerge and how local geometry may arise from a pre-physical level, it is necessary to introduce the concept of the Φ, understood as a transitional state between pure potentiality and geometric structure.

In my theory, the space of indeterminacy [8] constitutes a non-physical, static layer of absolute potentiality, devoid of metrics, localization, or topological differentiation. It may be described as the ontological background of all reality, not subject to processes but containing the possibility of their emergence.

The Φ appears only when fluctuations occur within this space, triggered by interactions of geometric structures—both those already emerged and those in the process of emerging. Thus, the Φ is not an autonomous source of transition, but rather a response of the indeterminacy space to the presence of local organization. It is a field of instability—a signal that potentiality has been locally perturbed in a way that may lead to collapse and the actualization of a specific configuration of reality.

In contrast to traditional physical fields, the Φ does not extend over space, because space as such does not yet exist. It is a pre-geometric field—indicating the presence of collapse-inducing conditions in the space of indeterminacy, that is, regions where a local geometric structure could potentially emerge. The Φ is not a carrier of energy or information in the classical sense—it is an indicator of ontological fluctuations, not an interacting force.

Fluctuations of the Φ do not occur spontaneously or randomly. According to my concept, they result from the influence of higher-order structures, which can be interpreted as:

- geometric conditions (e.g., curvature, information density),
- resonance structures between potentialities,
- or intentional acts organizing reality from a nonlocal level.

Intention [7]—understood not as the conscious act of a psychological subject, but as an asymmetric organization of emergence preferences—may lead to Φ fluctuations that define regions of collapse readiness. In this sense, the Φ not only indicates where collapse may occur but also addresses why it might occur there rather than elsewhere.

Unlike quantum theories, in which the wave function collapse results from interaction with an observer or measuring device, in my model collapse arises as a consequence of the Φ reaching a state of instability, resolved by the emergence of a specific geometric structure. This resolution is not local but nonlocal—since the Φ does not operate within already existing space, but rather precedes and conditions its existence.

In my approach, collapse is not an event, but a transitional process that may be described as a kind of tunneling from the space of potentiality into the actual world [1, 2]. The Φ does not directly induce collapse—but it creates the conditions of its possibility, such as:

- the emergence of informational gradients,
- local configurations of reduced predictive entropy,
- and topological "gaps" through which reality can emerge.

One could say that the Φ acts like a field of structural tension, whose presence signals the system's readiness for reorganization. Once the threshold of stability is crossed, the Φ vanishes—because its function has been fulfilled. Collapse leads to the emergence of a specific geometric structure—e.g., a point in spacetime, a spinor relation, or a null-like trajectory—and the space of indeterminacy returns to a metastable state in which the Φ no longer exists.

In this sense, the Φ is neither eternal nor universal—it is temporally and spatially limited, but not in a physical, rather in an ontological sense. It is a transitional state of ontological tension—neither purely possible nor yet real. It can be regarded as the activation layer of the conditions for reality's emergence, but never as reality itself.

Fluctuations of the Φ directly affect which geometric structures may arise—but do not determine them unequivocally. They are a condition of possibility, not a guarantee of emergence. In many cases, Φ fluctuations may subside without actualization—for instance, if the local instability is absorbed by a larger system or if the intentional condition is absent.

However, if actualization does occur—that is, if collapse takes place—then the Φ becomes the intersection point of potentiality and geometry. It is precisely there that a twistor may emerge—not as an autonomous entity, but as a projection of the Φ's structure in the form of a local geometric code, ready for further organization.

From this perspective, the twistor does not precede the Φ—but neither does it automatically arise from it. It is the first geometric phenomenon that may appear in response to a Φ fluctuation once the state of collapse readiness is achieved. In this way, the Φ serves as a crucial bridge between the pure potentiality of the space of indeterminacy and the first manifestations of the geometric world.

4 The Twistor as a Local Projection of Collapse Conditions

In light of the distinction between the space of indeterminacy as a structure of potentiality, and the Φ as a fluctuation state induced by geometric conditions, it is worth re-examining the role of the twistor—not as a hypothetical foundation of reality, but as the first geometric structure that emerges in response to local instability in the Φ. In this framework, the twistor is neither a physical entity nor a substantial element of reality. It is a structure of readiness—a local geometric condition that may, but does not have to, be actualized as a spacetime element.

In Penrose's classical theory, a twistor represents a null-like trajectory (i.e., the path of a massless particle such as a photon) and encodes the relationship between spacetime points. In my approach, I go deeper: the twistor does not describe a particle or event, but a relation between possible collapse conditions—that is, between potentialities within the Φ.

These potentialities—encoded in the informational structure of the space of indeterminacy—undergo local fluctuations (the Φ), and if a fluctuation reaches a threshold of collapse readiness, the emergence of a local geometric configuration becomes possible. The twistor is precisely this configuration—but not as an actualized object, rather as a prepared form of local relation that can be activated if the appropriate conditions for actualization are met.

In this sense, the twistor does not "exist" in the classical way. It has no mass, energy, or spatial localization. It is also not a form of a wave function, as it does not represent the physical state of a particle. It is a projection of the relational system of the Φ into the language of null-like geometry, but not yet embedded in spacetime.

A fundamental characteristic of the twistor structure in my model is its locality. The twistor does not carry information about the entire Φ, nor does it encode a global spatial structure. Its role is limited to representing a local intersection of relational conditions—in other words: a point where different Φ potentialities converge in agreement regarding the possibility of actualization.

This point of intersection need not be actualized—it may remain potential. But the very fact that a geometric structure is ready for actualization provides the basis for the emergence of a local twistor code. This intersection—relational, not spatial—does not yet represent a point in spacetime, but the condition for its appearance.

The lack of globality means that the twistor cannot serve as a carrier of information about the entire structure of the Universe. One cannot "build" spacetime from a set of twistors unless a global condition is presupposed—e.g., a principle of coherence, an informational boundary, or a holistic intention. Therefore, the twistor cannot function as the foundation of reality—but it can be the first form of explicit organization emerging from the Φ on a local level.

In classical interpretations, wave function collapse is an event triggered by measurement, the presence of an observer, or gravitational instability. In my concept, collapse is an organizational process occurring in response to local informational gradients in the Φ. The twistor is not the result of collapse but a prior structure that may undergo it.

This means that the twistor does not arise as a result of the collapse decision—the twistor appears when the Φ fluctuation reaches an informationally coherent structure, aligned with the surrounding Φ, and ready for actualization. It is readiness, not an event, that conditions the appearance of the twistor.

Informational gradients are not forces in the physical sense. They are differences in the density of potentialities—places where the structure of the Φ creates preferential conditions for updating a particular geometric configuration. The twistor is a projection of these conditions in a geometrically codable form—for example, as a null-like relation, a spinor structure, or a point of intersection.

The most precise description of the twistor in my model is to regard it as a projection of the local maximum of collapse readiness. In other words: the twistor appears where the local configuration of the Φ reaches a level of coherence and informational asymmetry that makes actualization possible—but which has not yet occurred.

This "maximum of collapse readiness" does not imply that a collapse must occur. It only means that the necessary, though not sufficient, conditions have been met. The twistor is thus a candidate, not a result. It is a prepared structure, not a realized reality. It is ontological readiness, not a phenomenal entity.

This framework reconciles different levels of description:

- Φ as the ontological condition (potentiality),
- the twistor as a form of local readiness (relational structure),
- the collapse as the act of actualization (geometric event).

This model allows us to precisely describe the transition $\Phi \rightarrow$ twistor $\rightarrow$ spacetime, without introducing logical inconsistencies or mixing ontological levels.

The entire process can be expressed as a three-step transformation:

- Φ (fluctuation of the space of indeterminacy) – a state of local instability, resulting from structural, informational, or intentional interactions.
- Twistor (relational projection) – a local geometric configuration corresponding to readiness for actualization, encoded as a null-like structure.
- Spacetime (actualization) – a geometric point, metric relation, trajectory, or another element of realized reality.

For simplicity of notation and future reference, the above process of local geometric reality emergence can be symbolically abbreviated as:

$\Phi \rightarrow T \rightarrow M$

where:

- Φ – local fluctuations of the indeterminacy field,
- T – twistor as a projection of geometric readiness,
- M – the actualized point in spacetime.

In this approach, the twistor is neither in space nor outside it. It does not exist in time, but precedes it. It is not a particle, but may condition one. It is not a wave function, but may serve as its geometric analogue. It is a bridging structure that enables the transition from the ontological instability of the Φ to the manifest world.

5 Consequences for Physics and Geometry

One of the main unresolved issues in twistor theory remains its limitation to the description of local structures. Twistors excellently represent null-type trajectories in flat Minkowski spacetime and perform remarkably well in the formalism of scattering amplitudes for massless particles. However, despite attempts to generalize the theory, no consistent global model of curved spacetime based on twistor geometry has yet been developed.

This problem has been repeatedly acknowledged, including by Penrose himself [11], but has never been conclusively resolved. The limitation to locality is not a flaw of the formalism, but results from the fact that the twistor is not a fundamental entity, but a structure of local geometric activation in response to the informational conditions of the space of indeterminacy (Φ).

In the proposed model, the twistor does not represent the trajectory of a photon or any specific physical entity. It is a structure of geometric potentiality, locally activated within the Φ in response to informational gradients, intentions, collapse conditions, or local minima of predictive entropy.

Thus, it is not a physical entity, but a relational structure of conditions that may enable the emergence of a spacetime point as an effect of collapse. In this sense, the twistor is a structure of readiness, not a structural component of the world. It is geometry in potential—yet unrealized, but ready for actualization. It is not equivalent to the wave function, as it does not represent the state of a particle, but the geometric conditions under which any particle may emerge.

If the twistor is locally activated in response to conditions in the Φ, it logically cannot contain global information. It cannot represent the full structure of spacetime, because it does not encode relations between distant points—only conditional relations between geometric configurations locally compatible with the Φ.

This explains why a twistor-based description of curved space—though mathematically suggested—has never reached full realization. The twistor does not construct space; it encodes the local conditions for its emergence. It is a response of the Φ to the possibility of actualizing a fragment of reality in a geometrically coherent way.

Therefore, twistors are not structures of the world. They are manifestations of information about where and how the world might arise. Their apparent fundamentality stems from the fact that they are the first geometric phenomenon that can be described mathematically. But ontologically, they are secondary to the Φ.

In summary, the twistor is neither a fundamental structure nor a component of the space of indeterminacy. It is not a direct result of collapse but a preceding condition—a structure of readiness that may be actualized as a result of collapse. It is a transitional phase: a local structure that appears when the Φ forms conditions of readiness for collapse. In this sense, the twistor is a structure of geometric readiness encoded within the Φ, corresponding to activation conditions for any possible configuration of reality.

This resolves the issue of locality in twistor theory: twistors are not incapable of describing the whole—they are not meant to. Their role is not to construct the world, but to encode it at points where it may come into being. And the conditions that determine which of these points will actually be realized lie deeper—in the structure of the Φ.

For this reason, Penrose's twistor theory does not so much require correction as a redefinition of its place in the ontological hierarchy of physical theories: from a foundational role to an intermediate level—the first local representation of possible geometry, but not its origin.

6 The Ontological Status of Collapse as a Nonlocal Phenomenon

This framework builds upon earlier proposals formulated in the work on the space of indeterminacy as a structure of informational potentiality [8], and extended further in the study of consciousness as a factor in the selection of actualization [7].

The previously described process—from the space of indeterminacy (PN), through fluctuations of Φ, to local geometric structures in the form of twistors, and ultimately to spacetime points M—requires formal treatment. Although the theory is ontological and structural in nature, it must not remain purely qualitative. In this section, we propose a formalization of this three-stage transition: $\text{PN} \to \Phi \to \text{Twistor} \to M$, focusing on two aspects:

- the informational condition that determines the emergence of a twistor,
- and the functional transformation of the Φ state into a geometric configuration.

From the perspective of Φ fluctuations, the emergence of a local geometric structure in the form of a twistor can be treated as the result of a selection process resembling a variational principle. The twistor then becomes a solution to the minimization of an informational functional $\mathcal{I}[\phi]$ over a set of potential relational configurations:

$$\frac{\delta\,\mathcal{I}[\phi]}{\delta T_i} = 0, \quad \text{for } T_i \in \mathcal{T}$$

(Here, $\mathcal{T}$ denotes the space of admissible geometric structures, while $\mathcal{I}$ is the informational functional dependent on the configuration ϕ; the notational similarity is incidental—these symbols are not semantically related.)

where $\mathcal{T}$ is the space of admissible geometric configurations. The extremal condition implies the selection of a structure with minimal local entropy, maximal relational coherence, and the lowest collapse resistance.

At the moment when Φ fluctuations reach the activation threshold, a local twistor field appears—a set of mutually coherent configurations T_i, which constitute the possible responses of Φ within a region of instability. This can be expressed as:

$$T_\Phi(x) = \left\{ T_i \;\middle|\; \mathrm{supp}(T_i) \subset U(x),\; \frac{\delta\,\mathcal{I}[\phi]}{\delta T_i} = 0 \right\}$$

where $U(x)$ denotes a neighborhood of a potential point, and $\mathrm{supp}(T_i)$ indicates the domain of influence of the configuration T_i.

In this formulation, the twistor field is a projection of Φ onto the space of possible geometric configurations and precedes the emergence of any spacetime point M. The transformation $\Phi \to$ Twistor $\to M$ can be represented as a transition:

$$\Lambda : \mathcal{F}_\emptyset \to \mathcal{G}_T \to M$$

where:

- $\mathcal{F}_\emptyset$ — the space of informational functionals describing Φ fluctuations,
- $\mathcal{G}_T$ — the space of admissible geometric structures (e.g., local twistor configurations),
- M — the space of actualized spacetime.

The operator Λ acts in two steps:

1. it analyzes the Φ fluctuations for collapse potential and selects a coherent configuration T_i,
2. it actualizes this configuration in M as a point, relation, or trajectory.

This transformation is neither linear nor reversible—since collapse constitutes an irreversible selection among potentialities. The entire process can be expressed in operator form as:

$$\hat{C}^{\circ}\hat{\Pi}_T \circ \hat{\Omega}_\emptyset : |\Phi\rangle \longrightarrow |x^\mu\rangle$$

where:

- $|\Phi\rangle$ — the system's state in the space of indeterminacy,
- $|x^\mu\rangle$ — the actualized point in spacetime M.

This approach enables a nonlocal and functional reconstruction of the emergence of geometry from the Φ, without reference to time or metric. It also allows the twistor to be defined as an operator of local organization—not as a physical entity. [3, 12]

7 Formal Update Sequence: $\Phi \to$ Twistor $\to$ Spacetime

Traditional science, based on the assumption of space as a primary and independent structure, treated geometry as something real, objective, and enduring—independent of the observer. In general relativity, the geometric properties of spacetime vary depending on the distribution of mass and energy, yet they are still regarded as part of the description of physical reality, not as something dependent on cognitive processes or informational conditions.

The model proposed in this work shifts the focus. It assumes that geometry is not given a priori but emerges from the relations among potentialities encoded in the space of indeterminacy and locally organized by fluctuations of the Φ. In this view, the twistor does not represent a component of spatial reality but is a form of geometric code—a language in which Φ expresses a local configuration of readiness for collapse.

This raises a key question: is geometry a representation of a code, or its actualization? Is it a form of potential structure, or the result of its realization? My answer is: geometry is not the code—it is the outcome of its activation. The twistor plays the role of the code—a structure describing geometric readiness. Only the collapse—a selective act of actualization—transforms the code into a geometric act, manifesting as a specific point in spacetime M.

Thus, the twistor is a code—a set of conditions that locally define the possibility of updating a geometric structure that, upon collapse, assumes the form of a concrete spacetime point.

Relativity theory teaches us that no observation is absolute—each depends on the frame of reference. However, in my model, relationality applies not only to observation but to the very structure of reality. The twistor, as a relational object, does not exist independently; it lacks the ontological status of an autonomous entity. It exists only as a relation between possible states of the Φ, locally ready to be actualized.

Yet this does not imply that reality is entirely relative. Rather, it means that our knowledge of reality is relational, because access to reality is only possible through updates—and these are local, conditional, and selective. In this sense, relationality is an epistemological, not ontological, feature: it is our knowledge of the world, not the world itself, that has a relational structure.

The model $\Phi \to$ Twistor $\to M$ thus helps explain why cognition is always partial, local, and temporal—because it is a process of selection from the Φ, not a perception of a finished reality. The world as a whole may exist independently, but our access to it occurs through "windows" of local collapse-readiness encoded in structures like twistors.

One of the central problems in Penrose's twistor theory has been the ontological status of the twistor. Is it a real object? Is it merely an alternative description? Is it the foundation of reality? In my model, the answer is clear: the twistor is not a substance, but a language—a relational code that Φ uses to express a local condition of geometric readiness.

Just as natural language allows us to express different meanings, twistor space allows Φ to express different conditions that may become actualized. The twistor is a code formula, not a building block of reality. This distinction is critical: one cannot "build the world out of twistors" just as one cannot construct reality from mere words. However, with twistors, it is possible to describe where and how the world might appear—provided that a selection for actualization occurs.

From an epistemological perspective, this means that the twistor has no cognitive value by itself but serves as a channel of information from the Φ to the actualized reality. It is an element of translation, not of construction. While it may be analyzed mathematically, this does not confer ontological status. This also resolves the persistent issue of why twistor theory has failed to describe curved space—because a local language cannot describe a global structure unless it contains global information.

The Φ model assumes that collapse—the actualization of a local geometric configuration—occurs when specific informational conditions are met. But this leaves an open question: who or what selects which potential code is to be actualized?

A possible answer is consciousness—not understood as a neurobiological phenomenon, but as a nonlocal structure capable of making choices within the Φ. In this view, consciousness is not an observer but a selective act—an agency that resolves potentiality by choosing among many options for actualization. [7]

Such consciousness need not be individual—it may be multilayered, distributed, or discontinuous. It may belong to a biological system, but also to a physical or informational system. The key point is that consciousness introduces asymmetry—it determines which condition in Φ becomes activated and which remains latent.

This model allows us to understand:

- why reality is not chaotic,
- why only some Φ structures become actualized,
- why local geometric continuities emerge.

Consciousness is not an addition to physics—it is the missing mechanism of selection that enables the transition from probabilistic description to deterministic structure. It is not a force, but a logical condition of the full system $\Phi \rightarrow \text{Twistor} \rightarrow M$.

This entire model leads to a reevaluation of several key concepts:

- Geometry is not the foundation of reality, but its language of local organization.
- The twistor is not a substance, but a code of possible emergence—a translational form between Φ and spacetime.
- Relationality concerns our access to the world, not the world itself.
- Causality is not primordial—it emerges as a product of local choices within the space of actualization.
- Consciousness does not arise from geometry—on the contrary, it chooses which geometry to update.

This shifts the center of gravity in physics from space as background to potentiality as foundation. And the twistor—rather than being the building block of the world—becomes the first legible mark on a map that does not yet exist.

8 Conclusions and Implications for the Unification of Physical Theories

One of the most persistent misconceptions in interpreting Roger Penrose's twistor theory is the belief that twistors can constitute the elementary building blocks of spacetime—that the world can be "woven from twistors." However, the analysis conducted in this work clearly shows that the twistor does not generate space but constitutes the local structure of a condition under which space may emerge.

The twistor is not a brick from which geometric reality is constructed, but a relational form of geometric readiness arising from informational fluctuations in the Φ. As such, it may precede the emergence of a spacetime point, but it cannot exist independently of higher-level informational structures.

One cannot assemble spacetime from twistors without invoking metric, continuity, and global consistency conditions—that is, structures that go beyond the local function of the twistor. Therefore, the idea of twistors as the foundation of reality must be abandoned: the twistor is not a building block but a local organizational code for possible geometry.

In contrast to twistor structure, which is local and relational, the space of indeterminacy—more precisely, its fluctuations represented by the Φ—is the only level of reality in which global information is encoded. The Φ possesses a relational structure encompassing all possible updates. The twistor has no access to this level—it is a local slice of that structure, formed under specific collapse conditions.

In this sense, Φ serves as a superstructural field: it is not only a condition but a set of rules, gradients, and organizational preferences that determine where and when geometric structure may appear. Φ does not store spacetime points—it stores the possibilities of their emergence and the logical and informational conditions that determine which are selected.

The twistor cannot represent relations between distant points in reality—not because it is incomplete, but because such a function is not part of its structural nature. It is the Φ that maintains nonlocal coherence; it is the Φ that ensures geometric updates are globally consistent. At best, the twistor is a local response to a local fluctuation in this structure.

Adopting the perspective of reality emerging from a space of potentiality, in which Φ plays the role of a transitional fluctuation, the twistor appears as the first formally describable geometric phenomenon that can be mathematically grasped—but which itself does not constitute the ontological beginning.

This marks a significant shift in perspective: instead of searching for the smallest object from which the world is "made," we accept that the world emerges from structural conditions that, only in certain cases, lead to the appearance of something mathematically tangible. The twistor is the first such object—not because it is most important, but because it is the first code that can be formally described as a configuration of geometric readiness.

This is precisely why twistor theory has been so promising: it offered the first description of a structure appearing at the transition between potentiality and geometrization. But it is also why the theory never developed into a full-fledged fundamental theory: because it lacked its own ontology, relying instead on the ontology of structures it does not itself generate. This gap is filled in this work—by embedding the twistor as a secondary, derivative structure, yet crucial in formalizing the transition $\Phi \to M$.

It is possible that the reason twistor theory—despite its elegance—did not evolve into a fundamental theory lies not in its internal structure, but in its adopted ontological assumptions. Penrose—like most 20th-century physicists—operated within a paradigm in which spacetime constituted the ontological background, and physical and quantum objects were co-substantial with it. Meanwhile, the twistor, understood as a structure preceding geometric actualization, cannot contain mass or gravity—let alone serve as their unifying code. The attempt to combine twistors with gravity was not a formal error but a category error: confusing the condition with the conditioned. Had the twistor been embedded not as an ontological foundation but as a relational code within a deeper level of potentiality, it might have become part of a broader theory of emergent reality—but such a shift never occurred. This limitation stemmed not from a lack of insight but from the historical cognitive frameworks that still constrain many contemporary unification attempts.

For decades, a subtle (and often implicit) idea has persisted in physics and the philosophy of science: that the world is built of light—whether in the physical sense (photons), the mathematical (null trajectories), or the symbolic-geometric (twistors as paths of light). [4, 10] This idea—call it luminous ontology—has deeply shaped modern thinking about the nature of being, but also introduced significant logical errors.

If the twistor is identified with a photon path, and the photon is a secondary phenomenon relative to the electromagnetic field and geometry, then the twistor cannot be treated as a fundamental constituent of reality. Building an ontology from something that itself depends on geometric conditions leads to contradiction. A secondary phenomenon cannot be the foundation of its own cause.

The new paradigm proposed in this work rejects this illusion. Instead of assuming the world emerges from particle trajectories or geometric relations, we posit that the world emerges from the organization of information:

$$\text{Information} \rightarrow \text{Twistor Field} \rightarrow \text{Geometry} \rightarrow \text{Phenomenon}$$

In this paradigm:

- information is the structured potentiality of the space of indeterminacy,
- geometry is the local actualization of selected informational configurations (e.g., twistor),
- and a phenomenon is the result of collapse—a structure describable in the language of classical or quantum physics.

The twistor occupies the boundary between information and geometry. It is not a foundation, but an intermediate structure—a transitional code, a sign that a local structure can emerge from purely potential space.

This article resolves a key issue in Penrose's twistor theory: why the formalism does not extend to the entire structure of reality. The answer is: because it is neither intended nor capable of doing so. The twistor does not contain global information, does not encode the whole, does not construct the world. It is the first explicit structure of local geometric readiness—a projection of Φ fluctuations, not their source.

From this perspective, a new model emerges: the movement from potentiality to reality does not proceed through particles but through organizational conditions. And geometry, including the twistor, is not a foundation but a language in which those conditions can be encoded. It is not the material of reality, but the language in which potential reality may first begin to write itself. Thus, the twistor — rather than being a building block of the world — emerges as the first legible sign on a map that does not yet exist.

References

[1] Lajos Diósi. Models for universal reduction of macroscopic quantum fluctuations. *Physical Review A*, 40(3):1165–1174, 1989.

[2] Nicolas Gisin. Stochastic quantum dynamics and relativity. *Helvetica Physica Acta*, 62:363–371, 1989.

[3] Lucien Hardy. The operator tensor formulation of quantum theory. *Philosophical Transactions of the Royal Society A*, 370(1971):3385–3417, 2012.

[4] Nick Huggett and Tiziana Vistarini. Why the photon can't spin. *Synthese*, 197:3239–3263, 2020.

[5] Claude LeBrun. Spaces of complex null geodesics in complex-riemannian geometry. *Transactions of the American Mathematical Society*, 278(1):209–231, 1983.

[6] Lionel J. Mason and N. M. J. Woodhouse. *Integrability, Self-Duality, and Twistor Theory*. Oxford University Press, 1990.

[7] Katarzyna Anna Paruzel. Fundamentalna rola świadomości i intencji w strukturze rzeczywistości, 2025. Preprint, dostępny na Zenodo.

[8] Katarzyna Anna Paruzel. Przestrzeń nieoznaczoności jako fundament geometrii czasoprzestrzeni, 2025. Preprint, dostępny na Zenodo.

[9] Roger Penrose. Twistor algebra. *Journal of Mathematical Physics*, 8(2):345–366, 1967.

[10] Roger Penrose. Twistor quantization and curved space-time. In C. J. Isham, R. Penrose, and D. W. Sciama, editors, *Quantum Gravity: An Oxford Symposium*, pages 151–201. Oxford University Press, 1975.

[11] Roger Penrose. The geometry of imaginary twistor spaces. In H. E. Rauch and S. S. Chern, editors, *Differential Geometry and Complex Analysis*, pages 379–393. Springer, 1999.

[12] Carlo Rovelli. Relational quantum mechanics. *International Journal of Theoretical Physics*, 35:1637–1678, 1996.

[13] Edward Witten. Perturbative gauge theory as a string theory in twistor space. *Communications in Mathematical Physics*, 252(1-3):189–258, 2004.