Against the Ontologization of Probability: Records, Events, and the Limits of Structural Realism

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Abstract

This note argues that probabilistic structure should not be treated as ontologically primitive. Instead, probability is indexed to conditions of recordability: it organizes spaces of possible records rather than properties of events as such. This yields a principled separation between the ontology of processes and the formal structures used to describe possible outcomes.

On this view, the probabilistic formalism of quantum theory underdetermines ontology: it constrains what can be said about observable outcomes without fixing the nature of underlying processes. Consequently, attempts—such as in strong forms of Ontic Structural Realism—to infer ontology directly from probabilistic or correlational structure rest on an unargued transition from representational to ontological structure. The paper concludes that any such transition requires independent philosophical justification.

Keywords: probability; measurement; recordability; ontology; structural realism; quantum mechanics

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1 Introduction

A recurring move in contemporary philosophy of physics is to infer ontology directly from the formal structure of physical theory. In particular, versions of Ontic Structural Realism (OSR) take relations, correlations, or probabilistic structures exhibited by quantum theory to be ontologically fundamental [1].

This move, however, presupposes that formal structure transparently reflects ontological structure. The present paper challenges this presupposition. In particular, it argues that probabilistic structure is not a feature of events as such, but is instead indexed to conditions under which events can be stably registered.

The central claim is:

> Probability is not an ontological feature of events themselves, but a representational structure defined relative to conditions of recordability.

More precisely, probabilities organize spaces of possible records, not spaces of events. Events and processes may occur independently of any particular act of observation, but probability acquires determinate meaning only relative to systems capable of producing and stabilizing records.

If this is correct, then the probabilistic and correlational structures emphasized by OSR cannot be straightforwardly interpreted as ontological primitives. Rather, they belong to a representational layer that presupposes conditions of access, registration, and comparison. The transition from formal structure to ontology therefore requires independent justification, and cannot be read directly off the mathematical apparatus of physical theory.

2 Events, Records, and Probability

We distinguish three levels:

1. **Events:** physical processes that occur.

2. **Records:** physically instantiated, stable, and re-identifiable states of a system that encode the occurrence of events.

3. **Probabilities:** structures organizing possible records.

A record is a physically instantiated, stable, and re-identifiable state of a system that encodes the occurrence of an event. Recordability requires (i) stability, (ii) distinguishability, and (iii) reproducibility under conditions of access. Without such conditions, probability lacks a well-defined domain.

Events may occur independently of any observer; probability, however, is defined only relative to conditions of recordability. However, probability does not attach directly to events. Rather, it is defined over classes of possible *records*.

> No record $\Rightarrow$ no well-defined probability.

This does not deny that processes occur without observation. It asserts that probability, as a meaningful concept, presupposes a space of distinguishable outcomes — that is, conditions of recordability.

This perspective aligns with measurement-theoretic approaches, in which numerical representation is grounded in empirical procedures of comparison and registration. In such frameworks, probability is not taken as a primitive feature of reality, but as a structure emerging from systems of measurement and representation [2, 3, 4].

3 Probability as Representational Structure

Probabilistic formalisms, including those in quantum theory, organize expectations about possible outcomes. They do not, by themselves, establish the ontology of what exists independently of recording conditions.

Even in objective interpretations, probability is defined only relative to distributions of recorded outcomes. This does not establish probability as an ontological feature of events, but as a structure over possible records. Without such distributions, probability lacks operational meaning.

Thus:

> Probability tracks possible records under conditions of access; it does not constitute the ontology of the underlying process.

This perspective is consonant with interpretations that treat quantum probabilities as expectational rather than ontological, such as QBism and ψ-epistemic approaches, where probabilities encode agents' degrees of belief or information about possible outcomes, rather than properties of underlying reality [5, 6].

Example. Consider radioactive decay. A decay event may occur independently of observation, but a probability distribution (e.g., exponential decay law) is defined only over classes of possible records (detector counts, traces, timestamps). This illustrates the distinction: event $\neq$ record, record $\neq$ probability, and probability organizes possible records rather than events as such.

Formally, a probability space $(\Omega, \mathcal{F}, \mu)$ presupposes a set of possible records Ω and a σ-algebra $\mathcal{F}$ of distinguishable subsets. (i.e., without conditions of recordability), probabilities are not well-defined.

Probability is not defined over events as such, but over measurable sets of possible records. Without measurability, probability is undefined.

This position is not anti-realist. Events and processes may be fully mind-independent. What is denied is only the ontological status of probabilistic structure. Probability is epistemic with respect to records, not anti-realist with respect to events.

Even objective interpretations of probability presuppose conditions of recordability. Propensity accounts require repeatable experimental conditions; frequentist probabilities require limiting frequencies of recorded outcomes; and GRW-type collapse probabilities are defined over possible measurement results. Thus, even "objective" probabilities are indexed to possible records, not to events as such.

Distinct ontological frameworks can generate identical probabilistic structures. Bohmian mechanics, Everettian quantum mechanics, GRW-type theories, and various ψ-epistemic models all reproduce the Born rule for measurement outcomes. Therefore, probabilistic structure underdetermines ontology, and cannot by itself license ontological commitment.

Predictive equivalence does not fix ontological commitment.

Probability is thus best understood as a second-order structure: it organizes possible records, rather than constituting the ontology of events or processes themselves.

4 Kolmogorovian Probability as a Formally Well-Defined but Non-Ontological Structure

The Kolmogorov framework defines probability as a triple $(\Omega, \mathcal{F}, \mu)$, where Ω is a set, $\mathcal{F}$ is a σ-algebra of subsets, and μ is a normalized measure. This construction is mathematically precise and internally consistent. However, its formal clarity should not be mistaken for ontological content.

Formally, a probability space presupposes a set of possible records Ω and a σ-algebra $\mathcal{F}$ of distinguishable subsets. Without conditions of recordability, probabilities are not well-defined.

The key point is that neither Ω nor $\mathcal{F}$ are derived within the theory. They are specified externally. The elements $\omega \in \Omega$ are not observations, nor outcomes in any operational sense; they are abstract points in a measure space. Likewise, $\mathcal{F}$ is not a set of empirically given events, but a closure structure imposed on subsets of Ω.

This leads to a fundamental asymmetry:

- The Kolmogorov formalism constrains how probabilities behave once defined.
- It does not constrain what they are defined *over*.

Consequently, the same formal structure can be instantiated over arbitrarily chosen symbolic domains. One may take any finite or infinite set of labels, impose a σ-algebra, and define a measure satisfying $\mu(\Omega) = 1$. The resulting structure will be mathematically valid regardless of whether it corresponds to any physical or experimental situation.

In this sense, Kolmogorov probability is *structurally invariant under reinterpretation*: it is indifferent to the meaning of its underlying domain. This invariance is precisely what limits its ontological significance.

Absence of Record-Generating Mechanism

Crucially, the Kolmogorov framework contains no operation of the form:

$$\text{records} \longrightarrow \Omega$$

That is, it does not specify how observed data, measurement outcomes, or physically instantiated records give rise to the set Ω or the σ-algebra $\mathcal{F}$. The construction presupposes that such a mapping has already been performed.

As a result, the formalism operates on a domain that is not itself grounded within the theory. The connection between probability and experiment is therefore not internal to the Kolmogorov framework, but imposed externally through interpretation and modeling.

Implication

It is therefore naive to assume that specifying a triple $(\Omega, \mathcal{F}, \mu)$ suffices to obtain empirical confirmation. The formal validity of a probability space does not entail its applicability to any real system.

Kolmogorovian probability should thus be understood as a theory of internally consistent measure-theoretic structures, not as a theory of probability as it arises from experimental practice.

Probability acquires empirical meaning only when the mapping from records to events is explicitly specified. Without such a mapping, the formal structure remains representational rather than ontological.

Remark 1 *Coherence is not imposed by Kolmogorov axioms; it is induced by the structure of recordability. The axioms merely formalize constraints already implicit in the recording procedure.*

5 σ-Algebra as a Formal Closure Structure Without Ontological Content

In the Kolmogorov framework, the σ-algebra $\mathcal{F}$ is introduced as a collection of subsets of Ω closed under complement and countable unions. This structure is essential for defining a probability measure $\mu : \mathcal{F} \to [0, 1]$ and ensuring internal consistency of probabilistic operations.

However, the σ-algebra itself does not describe any physical or observational structure. It is not derived from empirical procedures, nor does it encode mechanisms of observation, detection, or registration.

Formally, $\mathcal{F}$ satisfies:

- $\Omega \in \mathcal{F}$,
- if $A \in \mathcal{F}$, then $A^c \in \mathcal{F}$,
- if $A_1, A_2, \dots \in \mathcal{F}$, then $\bigcup_{i=1}^{\infty} A_i \in \mathcal{F}$.

These properties ensure that probabilities can be consistently assigned and manipulated. But they do not imply that the sets in $\mathcal{F}$ correspond to physically distinguishable or experimentally accessible events.

Independence from Observation

The definition of $\mathcal{F}$ is independent of any procedure of recordability. One may freely choose $\mathcal{F}$ (subject to the closure axioms) without reference to:

- measurement resolution,
- distinguishability of outcomes,
- stability or reproducibility of records.

As a result, $\mathcal{F}$ may contain sets that have no operational meaning, i.e., sets that cannot be realized, detected, or distinguished in any experimental context.

Role in the Formalism

The role of $\mathcal{F}$ is purely structural:

- it defines the domain of the measure μ,
- it ensures closure under probabilistic operations,
- it provides a minimal framework for defining measurable functions and expectations.

Thus, $\mathcal{F}$ is not a representation of reality, but a formal device required to make the measure-theoretic machinery well-defined.

Implication

The σ-algebra should not be interpreted as a set of real or observable events. It is a formal closure structure introduced to support the definition of μ over Ω.

Without an explicit mapping from records to elements of $\mathcal{F}$, the σ-algebra remains an abstract construct with no empirical content.

Therefore, $\mathcal{F}$ does not describe the structure of reality, but only the structure of the formal system used to assign probabilities.

6 Implications for Structural Realism

Ontic Structural Realism often infers from the success of quantum formalism that structure — particularly correlational or probabilistic structure — is ontologically fundamental.

However, if probabilistic structure is tied to conditions of recordability, then this inference is not straightforward.

> OSR risks confusing the structure of recordable outcomes with the structure of reality itself.

See also Halvorson [7] for arguments that formal structure alone does not fix ontology.

Quantum theory may constrain what can be said about events and their correlations, but it does not, on its own, license a direct transition from formal structure to ontology.

A useful distinction here is between epistemic and ontic readings of structure. While it is uncontroversial that scientific theories capture structural relations in an epistemic sense, it does not follow that such structure is ontologically fundamental. In particular, probabilistic and correlational structures are tied to conditions of recordability and prediction, and thus remain epistemically indexed. Treating them as ontological primitives risks conflating representational structure with the structure of reality itself.

Probabilistic structure presupposes a domain of distinguishable outcomes. Formally, a probability measure μ requires a σ-algebra $\mathcal{F}$ over a set Ω of possible records. Without recordable relata, Ω is undefined, and probabilistic structure cannot be ontologically primitive.

Thus, probabilistic structure presupposes distinguishability, which in turn presupposes recordability, and ultimately physically instantiated systems. This blocks attempts to treat probabilistic relations as fundamental without relata.

6.1 Quantum Formalism and Recordability

Quantum theory provides a clear illustration of the distinction between events and their probabilistic representation. The Born rule assigns probabilities to measurement outcomes, but these probabilities are defined over possible records rather than over events as such. Similarly, density matrices and POVMs (positive operator-valued measures) formalize the structure of possible measurement results, not the intrinsic ontology of processes.

Decoherence further reinforces this point: it explains the emergence of stable records through interaction with the environment, rather than grounding probability as an ontological primitive. Thus, the probabilistic structure of quantum theory is best understood as organizing possible records under specific conditions, rather than describing the fundamental nature of reality.

7 On What May Be Ontologically Prior

The present analysis does not commit to a specific ontological picture of reality, nor does it attempt to determine what is fundamentally primary. Its aim is more limited: to clarify the status of probability relative to events and records.

Within this perspective, events, records, and probabilities appear at different levels of dependence. Events presuppose a domain in which something can occur; records presuppose stability and distinguishability; probabilities presuppose a space of possible records.

This layered dependence suggests that probability cannot be ontologically primitive. However, rather than replacing it with a new candidate for fundamental ontology, it is sufficient to note that any meaningful use of probability presupposes conditions under which distinctions can arise, be maintained, and be re-identified.

These conditions are not themselves probabilistic or representational. They do not form a theory within the present account, but indicate a level of description that precedes the introduction of events, records, and probabilistic structure.

In this sense, probability belongs to a derived layer: it organizes possible records once conditions of recordability are in place. The present analysis therefore refrains from proposing a positive ontology, and instead identifies a constraint: probabilistic structure cannot be ontologically primary, since it presupposes a domain of distinguishable and stable outcomes.

Ontology, whatever its final form, must account for these preconditions rather than be inferred from probabilistic structure alone.

8 Conclusion

Events and processes may be ontologically real. Stable structures may likewise be ontologically real. However, probability belongs to a different level: it is a representational framework organizing spaces of possible records under specific conditions of access and registration.

This implies a principled separation between the ontology of processes and the formal structures used to describe possible outcomes. Probabilistic and correlational structures do not attach to events as such, but to classes of possible records, and therefore cannot, without further argument, be taken as ontological primitives.

Consequently, attempts to read ontology directly off probabilistic structure — as in strong forms of Ontic Structural Realism — rest on an unargued transition from representational structure to ontological commitment. If probabilistic structure is indexed to conditions of recordability, then its ontological status cannot be established by appeal to formalism alone.

The burden therefore shifts: structural realism must provide an independent justification for treating probabilistic or correlational structure as fundamental, rather than presupposing that the structure of theory is the structure of reality.

The structure of theory is not, without argument, the structure of reality.

References

[1] J. Ladyman and D. Ross, *Every Thing Must Go: Metaphysics Naturalized*. Oxford University Press, 2007.

[2] D. Krantz, R. D. Luce, P. Suppes, and A. Tversky, *Foundations of Measurement, Vol. 1*. Academic Press, 1971.

[3] P. Suppes, *Representation and Invariance of Scientific Structures*. CSLI Publications, 2002.

[4] B. van Fraassen, *The Empirical Stance*. Yale University Press, 2002.

[5] C. A. Fuchs, "Qbism: The perimeter of quantum bayesianism," *arXiv preprint arXiv:1003.5209*, 2014.

[6] M. F. Pusey, J. Barrett, and T. Rudolph, "On the reality of the quantum state," *Nature Physics*, vol. 8, pp. 475–478, 2012.

[7] H. Halvorson, "What scientific theories could not be," *Philosophy of Science*, vol. 79, pp. 183–206, 2012.

[8] J. Worrall, "Structural realism: The best of both worlds?" *Dialectica*, vol. 43, pp. 99–124, 1989.

[9] S. French, *The Structure of the World*. Oxford University Press, 2014.

[10] L. Ballentine, *Quantum Mechanics: A Modern Development*. World Scientific, 1998.