

# On Barad

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## Abstract

This essay explores the foundational relationship between mathematics, physical law, and existence through a reconsideration of classical and quantum spaces, termed Minkowski and Schrödinger spaces, respectively. Drawing from and critiquing philosophical frameworks such as Karen Barad's agential realism and Donna Haraway's situated knowledges, the essay rejects probabilistic interpretations of quantum mechanics and instead asserts that physical laws are expressions of mathematical structure, not merely empirical regularities. Through the analysis of boundary conditions, eigenvalue problems, and the mapping between Schrödinger's equation and the Einstein field equations, the author argues for a unifying framework rooted in information. The conclusion suggests that the universe is ultimately structured by relationships of information, and that further study of these relationships may reveal deep connections between matter, measurement, beauty, and design.

## The Edge of Measure

In *Meeting the Universe Halfway*, Karen Barad draws attention to a critical insight borrowed from Niels Bohr: the concept of “position”, and, by extension, any physical property, is not something given in advance by nature. Instead, it emerges from the specific circumstances of measurement.

Barad writes:

First, according to Bohr, the concept of position (like all concepts) cannot be taken for granted; rather, it must be defined by the circumstances required for its measurement.

At first glance, this may seem like a cautious philosophical move, a way of emphasizing that our knowledge is conditioned by our instruments. But the reality is much deeper.

If we truly take Bohr's lesson seriously, then there is no “position” at all until a measurement is made. It is not that an object has an unknown position, hidden like a coin in a closed hand, it is that “position” as a property, and the very notion of an object having a position, simply does not exist prior to measurement.

This leads to a far more profound conclusion than even Barad explores: **Within the quantum domain, measure itself is impossible.**

The mathematical structure of quantum mechanics reveals this clearly. The Schrödinger equation, when separated into characteristic functions across space and time, imposes strict boundary conditions. Those boundary conditions, derived without philosophical speculation, directly from the formalism, tell us that within the quantum “region”, quantities like energy, momentum, and position are bound by Planck's constant,  $h$ . Inside this boundary, there is no possibility of making a measurement without collapsing the undifferentiated field of existence into something definite.

There is no measuring ruler inside a quantum region. There are no clocks. There is no position, no momentum, no energy as such. There is simply **being without measure**.

This is not merely a technical limitation. It is not that we lack good enough instruments. It is that measure, and with it separability, objecthood, and facticity, simply do not apply. The act

of measurement is not an act of uncovering a hidden fact. It is the creation of a boundary where none existed. Measurement is a kind of rupture, a violent imposition of limit and definition upon an otherwise limitless and undefined being.

In this sense, knowledge itself cannot be said to “reach into” the quantum domain.

Rather, knowledge can only arise after the boundary has been drawn.

## Existence Prior to Measurement – A Divergence from Barad

Karen Barad, following Niels Bohr, asserts that properties like position are not inherent features of objects prior to measurement but instead are defined only through specific experimental arrangements. As Barad puts it:

First, according to Bohr, the concept of position (like all concepts) cannot be taken for granted; rather, it must be defined by the circumstances required for its measurement.

This interpretation leans heavily toward a relational ontology where entities and their properties do not preexist but instead emerge through intra-actions: mutual entanglements of observer, instrument, and observed.

However, it is here that a sharp divergence arises. **Existence precedes measurement.**

The position, momentum, and time-coordinates of an event exist independently of any observer or act of measurement. The proton existed, and continues to exist, long before any scientist aimed an apparatus toward it. Many protons will live out their vast lives without ever being measured, yet their existence remains real and unaltered.

The spacetime structure that grounds this existence is the four-dimensional Minkowski space. This space is not just a passive backdrop; it is imbued with real mathematical structure:

- It possesses measurable properties (via L2, L3, L4, etc. norms, and others).
- It carries gravitational and electromagnetic influences at the invariant speed of light.
- It forms the foundational arena in which physical existence unfolds.

Within this space, entities have positions, momenta, and histories whether or not anyone is there to measure them.

Measurement, properly understood, is not the creation of reality but the formation of a relationship, a contact, between the apparatus (the agent of the scientist) and the entity (the proton, say).

Measurement changes both participants:

- The proton affects the measurement outcome.
- The measurement apparatus (and thereby the scientist) is affected by the proton.

However, there is a critical subtlety arising from quantum mechanics: At extremely small scales bounded by the uncertainty relations derived from the boundary conditions of Schrödinger's equation measure itself becomes impossible.

In this view, there are two distinct spaces within physical reality:

1. The external space: from the Heisenberg boundaries outward, governed by Einsteinian relativity, where classical measure is possible and operationally meaningful.
2. The internal space: within the Heisenberg boundaries, the relations  $\Delta E \Delta t = h$  and  $\Delta p \Delta x = h$ , measure, in the traditional sense, cannot be applied.

Thus, while existence persists in both spaces, the capacity for direct measurement dissolves in the internal space. It is not that entities cease to exist without measurement, but that within these extremely small regions, the very concept of measure loses applicability.

This fundamental recognition preserves the real existence of quantum systems while acknowledging the operational limits that quantum mechanics imposes without falling into the mistake of treating measurement as ontological creation.

## **One Universe, Two Spaces: Reconciling Barad's Quantum Continuum with Minkowski Boundaries**

Barad writes:

As far as we know, the universe is not broken up into two separate domains (i.e., the microscopic and the macroscopic) identified with different length scales with different sets of physical laws for each.

This is a central philosophical assertion in Barad's ontology: that the universe is unified, governed by a single, coherent set of physical laws, namely quantum mechanics, across all scales. Classical mechanics, in this view, is a limiting case or an approximation of quantum mechanics under specific conditions, much like geometrical optics is an approximation of wave optics when wavelengths are small relative to system dimensions. Barad's framing pushes back against any dualistic view that would separate reality into fundamentally distinct realms, and she uses this unification to ground her agential realist philosophy: since the quantum formalism is universal, so too is the entanglement of observer and observed, apparatus and phenomenon, across all interactions, not just in microscopic experiments.

However, from my standpoint, while I accept the unity of the universe, I am introducing a deeper mathematical and ontological structure: one universe, but two spaces. These are not "domains" with separate laws but rather regimes of mathematical applicability within the same universe.

- Schrödinger space is defined by the limits imposed by the Heisenberg uncertainty principle. Within this space, bounded by  $\Delta x \Delta p = h$  and  $\Delta E \Delta t = h$ , no classical measure can exist. The solutions here emerge from the separation of variables in Schrödinger's equation, with spatial components described by characteristic functions like cosine, and temporal components by complex exponentials via Euler's identity. These solutions define a probabilistic structure, not because the universe is "indeterminate," but because the mathematical space itself lacks a metric that would allow classical measurement.
- Minkowski space, by contrast, is the measurable continuum of special relativity. Here, we have the full apparatus of classical measurement: time, position, momentum, energy; all defined by spacetime coordinates and governed by the Einstein field equations. This space supports causality, signal propagation, and the full L2 norm structure needed for classical physics and general relativity.

From this perspective, measurement is not the origin of existence, but rather the creation of a bridge between these two mathematical spaces. The proton exists regardless of whether it is measured; it has spacetime coordinates, momentum, energy, and so on. But a measurement is an event that links Minkowski space to Schrödinger space through an apparatus: an agent that touches both the measurable and the immeasurable. The outcome of a measurement is not the creation of a phenomenon but the registration of a relationship between systems already embedded in a unified but internally differentiated universe.

Barad's agential realism captures this entanglement beautifully in spirit, but her dismissal of any distinction between micro and macro neglects the precise mathematical architecture that shows why measurement behaves differently at different scales. This distinction clarifies that the laws are unified, but the spaces in which they operate are not identical. The subtlety is essential: it avoids a metaphysical dualism while preserving the mathematical insight that Schrödinger and Einstein, perhaps deliberately, encoded in their respective formalisms.

## Mathematical Realism and the Axioms of Existence

Existence itself is taken as axiomatic in existentialist thought. Sartre famously declares that "existence precedes essence," insisting that for any being, being is primary and self-evident, coming before any defined nature or meaning. Simone de Beauvoir likewise treats human existence as the irreducible given, "it is axiomatic that humans are always already existents". To exist, in this view, is the foundation from which we build any understanding. This stands in stark contrast to many postmodern arguments in science and philosophy, which claim that even our most basic notions of reality and truth are socially constructed. For some postmodern theorists, "truth" is a contingent product of language games, power relations, or social narratives; in short, something we make rather than find. As one feminist epistemology puts it, " 'Truth' is a social construct, in the same way that 'objectivity' is". Such views suggest that reality itself has no independent anchor apart from our collective agreements.

Physics offers a different perspective. In science, we study the behaviour of physical things: particles, fields, forces; but always through mathematical modelling. The world of physics is not grasped by naked intuition but through equations and structures. From Newton's laws to Maxwell's field equations to the Schrödinger equation of quantum mechanics, we use mathematical formalism to capture patterns in experiments. Einstein put it succinctly: physics deals with mathematical concepts, which only "attain physical content" when we precisely relate them to observable phenomena. In this sense, the so-called "laws of physics" are not laws written into matter by nature, but mathematical frameworks she imposes. As philosopher Nancy Cartwright has argued, the fundamental equations of physics "do not describe true facts about reality. Rendered as descriptions of facts, they are false; amended to be true, they lose their fundamental, explanatory force". Newton's  $F = ma$  or Schrödinger's  $\Psi$ -equation do not by themselves tell us what objects really are; they are calculational tools that reliably predict how systems evolve.

Indeed, in modern physics even the properties we take as fundamental (mass, charge, spin, etc.) are understood only by their roles in the mathematics, not "in themselves." We never observe "mass" directly except via its dynamical effects (inertia, gravitation), and "charge" only by how fields and forces emerge in Maxwell's equations. The constants and quantities in our models exist only as fitting parameters that make the math work. As Cartwright notes, the equations of physics "do not tell what the objects in their domain do; if we try to think of them in this way, they are simply false". In other words, mass and charge are meaningful only insofar as they appear in consistent mathematical relationships. We have no separate ontology of "pure mass" or "pure charge" detached from theory; these features are manifested to us only through their consequences in experiments.

This leads to a kind of mathematical realism in the sciences. Whatever exists in physical theory necessarily appears through mathematical structure. In cosmology Max Tegmark has even hypothesized that "the physical universe is not merely described by mathematics, but is mathematics" – that external reality is a mathematical object. Whether or not one goes so far, the lesson remains: ontology (what exists) in physics is inextricably bound up with epistemology (how we know). Barad's agential realism captures this well. She emphasizes that phenomena, the entangled outcomes of interactions and measurements, are the only genuine reality we have access to, and these phenomena arise only within specific experimental and mathematical "cuts" of the world.

In Barad's view, one cannot divorce the material world from the descriptions and apparatus that bring it forth: we do not witness a preformed object but rather participate in its very becoming (to us) through theory-laden experiments. Crucially, Barad rejects any notion that science is just a human-imposed fiction; she maintains that scientific practices "are not merely language games or fictions produced only by human constructions". They are constrained by a reality that answers to our measurements, even as those measurements co-create what is seen.

In sum, if we accept that being (existence) is fundamental, then the only way we access that being in science is via mathematics. The world of matter and energy continuously "enters our presence" only through structures that we build in thought and experiment. Classical spacetime and quantum eigenvectors, the Minkowski manifold of relativity or the space of quantum mechanics, are not inert things but arenas of mathematical relations. Seen this way, existence in the physical realm is necessarily articulated by mathematical realist terms: we assume something is "there" and then discover that every attribute of it is revealed only by the consistency of the math. This tight coupling of ontology and epistemology, the idea that to exist is to be describable in mathematical form, provides a grounding that resists pure constructivism. Whether or not one labels it Platonic or structural realism, the working scientist's credo is clear: reality may be sublime and independent, but it is necessarily read through equations. The axioms of existence in physics are thus the axioms of math, and our theories become the languages in which existence is written.

In moving toward a conclusion, we find ourselves confronting a fundamental duality at the heart of physical theory: the relationship between matter and fields, and the distinct mathematical spaces in which each seems to reside.

Physics has long concerned itself with the study of fields and particles. Fields, as understood through the lens of classical and relativistic physics, are continuous and differentiable across spacetime. These are governed by the mathematical structure of Minkowski space, a Banach space equipped with the tools of measure theory. Within this space, the Einstein Field Equations elegantly describe the curvature of spacetime as induced by energy and momentum. This formulation presupposes a well-defined geometry: measurable, continuous, and integrable.

In contrast, quantum mechanics presents an altogether different kind of space, which we might call Schrödinger space. Governed by Schrödinger's equation, this space does not possess the properties of a Banach space; it lacks a classical measure in the same sense and resists formulation within a conventional Hilbert framework when taken in its most ontologically primitive form. Instead, Schrödinger space is defined through eigenvalue problems and characteristic functions. It is a space of potentiality and superposition, structured by quantized solutions rather than smooth continua.

Here, we arrive at a boundary condition that is not merely mathematical, but ontological. This boundary, the transition from Schrödinger space to Minkowski space, is the realm in which matter emerges: electrons, protons, neutrons, and other particles. It is, intriguingly, also the domain that Karen Barad identifies as the site of agential cuts: the intra-active becoming of phenomena through entanglement and measurement.

The correspondence between these boundaries and the Heisenberg Uncertainty Principle is striking. Heisenberg's limits mark precisely where the classical measure of Minkowski space fails, where simultaneous knowledge of position and momentum becomes fundamentally indeterminate. This indeterminacy is not merely a limitation of epistemology; it may be ontological, demarcating the boundary of existence itself. In this sense, Heisenberg has done more than provide a principle of measurement; he has identified the boundary between two distinct spaces of reality.

It is crucial to emphasize that quantum space is just as continuous in a mathematical sense as Minkowski space. However, it manifests physically only in discrete quanta: the eigenvalues that result from solving Schrödinger's equation. These are not arbitrary numbers but deeply constrained solutions that determine allowable energy levels, angular momentum, and other quantum properties. Thus, we are presented with a profound duality: two distinct physical spaces, Minkowski

space and Schrödinger space, each with its own mathematical foundation and governing laws. Minkowski space gives rise to the curvature of spacetime and classical causality; Schrödinger space governs the quantized behaviour of the micro-physical world. The dream of theoretical physics is to find a universality between these two great formalisms: to discover a unifying mathematical structure that encompasses both the Einstein Field Equations and the Schrödinger equation. Such a synthesis would not merely be a technical achievement, but a conceptual revolution: the realization that all of reality, from the quantum to the cosmological, unfolds within a single, coherent mathematical order. It is toward this synthesis that modern physics, in all its complexity and wonder, continues to strive.

## Conclusion

We have arrived at a crossroads in our understanding of physical reality. Two distinct mathematical spaces, Schrodinger space and Minkowski space, appear to govern two seemingly distinct domains of physical behaviour. Minkowski space, endowed with a Banach structure and associated measures, gives rise to the continuum of spacetime in which general relativity and the Einstein Field Equations operate. It is the space of gravitation, electromagnetism, and the classical continuum.

Schrodinger space, on the other hand, lacks measure in the conventional sense. It does not qualify as a Banach or Hilbert space. Yet, it is no less real. It is governed not by field equations but by eigenvalue structures derived from Schrodinger's equation. Here, the quantized nature of energy, spin, and angular momentum becomes apparent, not as a statistical phenomenon, but as a consequence of the mathematical structure of this space. There is no probability here, only boundary conditions and allowable solutions.

Remarkably, the boundary of each space is defined by the same principle: Heisenberg's uncertainty. The Heisenberg limit marks both the point where Minkowski measure breaks down and the domain where Schrodinger's solutions emerge. It is not a wall but a bridge, a transitional condition that delineates not two universes, but two interrelated mathematical spaces within one universe.

If we can find a formal mapping between the Einstein Field Equations and Schrodinger's equation, one that arises naturally from a deeper structure, then we approach the possibility of a unified theoretical framework. Such a framework would not merely unify physics; it would redefine what we mean by space, by law, and by existence itself.

This is not just the dream of theoretical physics. It is a recognition that our physical laws may all be emergent from a single underlying reality: a mathematical structure that chooses its form based on the space it governs. In this view, existence is not a mystery to be explained away by measurement, but a boundary condition written into the fabric of the universe itself.

In conclusion, the question of space, its constitution, properties, and boundaries, leads us ultimately to the question of information. The mathematical models we employ in physics are not arbitrary symbolic games; they are the embodiment of informational structures that govern both our theories and our interactions with the universe. The evolution of physics from classical to quantum, and from geometry to field theory, can be seen as an unfolding narrative of how information is organized, bounded, and transformed.

It is here that the insights of thinkers like Karen Barad and Donna Haraway prove essential. Barad's concept of agential realism, grounded in Bohr's interpretation of quantum mechanics, insists that boundaries are not pre-given but are enacted through intra-actions. Haraway, in parallel, pushes us to reject the fantasy of a detached observer and embrace the situated, embodied nature of knowledge. Despite certain foundational missteps, particularly with regard to the Bohr model, their work converges on a critical truth: knowledge, measurement, and material existence are not separate but co-constitutive.

This essay has argued that what we call matter and what we call field emerge from distinct mathematical spaces: spaces that are real not in a spatial sense, but in the sense of providing lawful structure to what can be known and what can be. These are not simply spaces of probability, nor are they reducible to traditional constructs such as Hilbert or Banach spaces. Rather, they are domains in which boundary conditions, characteristic functions, and eigenvalues define existence itself.

From this vantage point, everything becomes a question of boundaries, and every boundary is information. The universe is not a collection of things but a network of differentiations, of structured information in dynamic relation. The growth of knowledge, the emergence of particles, the bending of spacetime, and even the appearance of an observer are all facets of an evolving informational structure.

Thus, the future of theoretical physics may lie not merely in seeking a unified equation or reconciling frameworks, but in studying the intricacies and generative power of information itself. This path demands a deeper engagement with ontology, a reexamination of mathematics as more than a tool, and a recognition that the universe does not simply contain information; it is information.