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The Infinitesimally Punctured Wave: A Corpuscular Visualisation of Wave-Particle Duality

Florentin Smarandache[1,*]

[1] Department of Mathematics & Sciences, University of New Mexico, Gallup, NM 87301, USA
* Correspondence: smarand@unm.edu

Abstract: Wave-particle duality remains one of the most puzzling aspects of quantum mechanics, traditionally expressed through complementary experimental outcomes such as the double slit interference pattern and the photoelectric effect. This short article proposes an alternative conceptual model—the Infinitesimally Punctured Wave—in which a quantum object is visualised as an aggregation of infinitely many infinitesimally spaced particles. When these particles are densely packed, the ensemble appears as a continuous wave; when a measurement isolates a single constituent, particle-like behaviour emerges. The model is situated alongside established alternative interpretations (e.g., de Broglie–Bohm pilot wave theory, wave packet descriptions) and linked to Neutrosophic Quantum Theory, which supplies a logical framework for handling indeterminacy. By offering a concrete visual metaphor, the punctured wave picture aims to bridge the discrete continuous divide and stimulate further discussion on the foundations of quantum mechanics.

Keywords: wave-particle duality, infinitesimally punctured wave, quantum foundations, quantum interpretation, Neutrosophic Quantum Theory, indeterminacy, corpuscular model.

1. Introduction

Since the early twentieth century, quantum mechanics has forced physicists to accept that elementary entities such as photons and electrons display both wave-like and particle-like characteristics. Classic demonstrations are the interference fringes of the double-slit experiment (wave-like) and the quantised energy transfer of the photoelectric effect (particle-like). The Copenhagen interpretation reconciles these phenomena by invoking complementarity: the observed property depends on the experimental arrangement, and the underlying quantum state is described by a wave function that encodes probabilities rather than a tangible physical wave. Nevertheless, the dualistic language has spurred numerous alternative interpretations that seek a more intuitive ontology. De Broglie–Bohm's pilot-wave theory separates a point-like particle from a guiding wave, whereas wave-packet formulations represent a localized particle as a superposition of many plane waves.

Building on this tradition, we introduce the *Infinitesimally Punctured Wave* (IPW) model. In this picture, a quantum object consists of an infinite set of discrete "sub-particles" positioned at infinitesimal distances from one another. Their dense packing creates the illusion of a continuous wave, yet each sub particle retains individuality, allowing the ensemble to manifest particle-like responses when probed locally. The IPW model therefore offers a visual and conceptual bridge between the discrete and continuous descriptions of quantum objects. It also dovetails with Neutrosophic Quantum Theory (NQT), which employs a three valued logical system—truth (T), falsity (F), and indeterminacy (I)—to capture the partial, ambiguous nature of quantum states. By interpreting the punctured wave as a physical embodiment of indeterminacy, the model gains a rigorous logical underpinning.

2. Core Concepts and Proposed Model

2.1. Wave-Particle Duality Recap

The wave character of quantum entities becomes apparent through phenomena such as interference and diffraction, exemplified by the classic double slit experiment and Bragg scattering in crystalline lattices.

Conversely, the particle nature manifests itself in processes that involve discrete energy exchanges, notably the photoelectric effect and Compton scattering, where individual quanta are absorbed or emitted.

Both aspects are experimentally verified, yet a single ontological picture that accommodates them simultaneously remains elusive.

2.2. The Infinitesimally Punctured Wave (IPW)

Imagine an endless chain of infinitesimally tiny particles arranged along a curve, each separated from its neighbour by an immeasurably small distance ε ($\varepsilon \to 0$). Because ε is vanishingly minute, the entire assembly looks to any macroscopic observer like a smooth, continuous line or a sinusoidal wave.

When an experiment probes the collective properties of the whole—such as measuring phase differences across many of these sub-particles—the ensemble behaves coherently, generating the familiar interference patterns characteristic of wave phenomena.

Conversely, when a measurement isolates a single sub-particle—e.g., by detecting photon absorption—the response is sharply localized, reproducing the particle-like outcomes observed in quantised interactions.

In this way, the infinitesimally punctured wave model reconciles wave and particle behaviours by assigning them to different observational scales within a single underlying structure.

2.3. Neutrosophic Logical Framework

The infinitesimally punctured wave acquires a rigorous interpretative backbone when it is cast within Neutrosophic logic, a three-valued extension of classical binary logic.

In this scheme the traditional dichotomy of true versus false is supplemented by an independent indeterminacy component, allowing a richer description of quantum states that are neither wholly wave-like nor entirely particle-like. Within the IPW picture the collective amplitude of the densely packed particles corresponds to the “Truth” dimension, reflecting the probability amplitude that governs the coherent wave behaviour observed in interference experiments.

The occasional detection of a single constituent particle maps onto the “Falsity” dimension, representing the discrete, localized events characteristic of the photoelectric or Compton effects.

The infinitesimal gaps that separate neighbouring sub-particles embody the “Indeterminacy” dimension, capturing the unresolved micro-structure that gives rise to the punctured appearance of the wave and accounts for the intrinsic quantum uncertainty that manifests as decoherence or partial entanglement.

By translating the geometric configuration of the punctured wave into the *T-F-I* triad, the model gains a formal language capable of expressing partial entanglement, observer-dependent effects, and the gradual loss of coherence, as articulated in Neutrosophic Quantum Theory.

Moreover, the notion of a Neutrosophic qubit—a superposition over true, false, and indeterminate states—offers a natural extension of the standard qubit, providing a conceptual bridge between the physical picture of an aggregate of infinitesimal particles and a mathematically consistent description of quantum information that embraces indeterminacy as a fundamental element rather than a mere epistemic limitation.

This synthesis positions the infinitesimally punctured wave not only as a visual metaphor but also as a physically motivated instantiation of Neutrosophic logic, thereby enriching both the interpretative landscape of quantum mechanics and the logical foundations of Neutrosophic physics.

2.4. The Infinitesimally Punctured Wave (IPW): A Visual Bridge Between Wave-Particle Duality and Neutrosophic Logic

The figure below illustrates how the densely packed lattice of infinitesimal sub-particles maps onto the three Neutrosophic truth values, thereby providing a concrete visual analogue for the dual wave-particle behaviour. The diagram visually represents a quantum object not as a purely continuous wave or a discrete particle, but as an aggregation of infinitely many infinitesimally spaced "sub-particles."

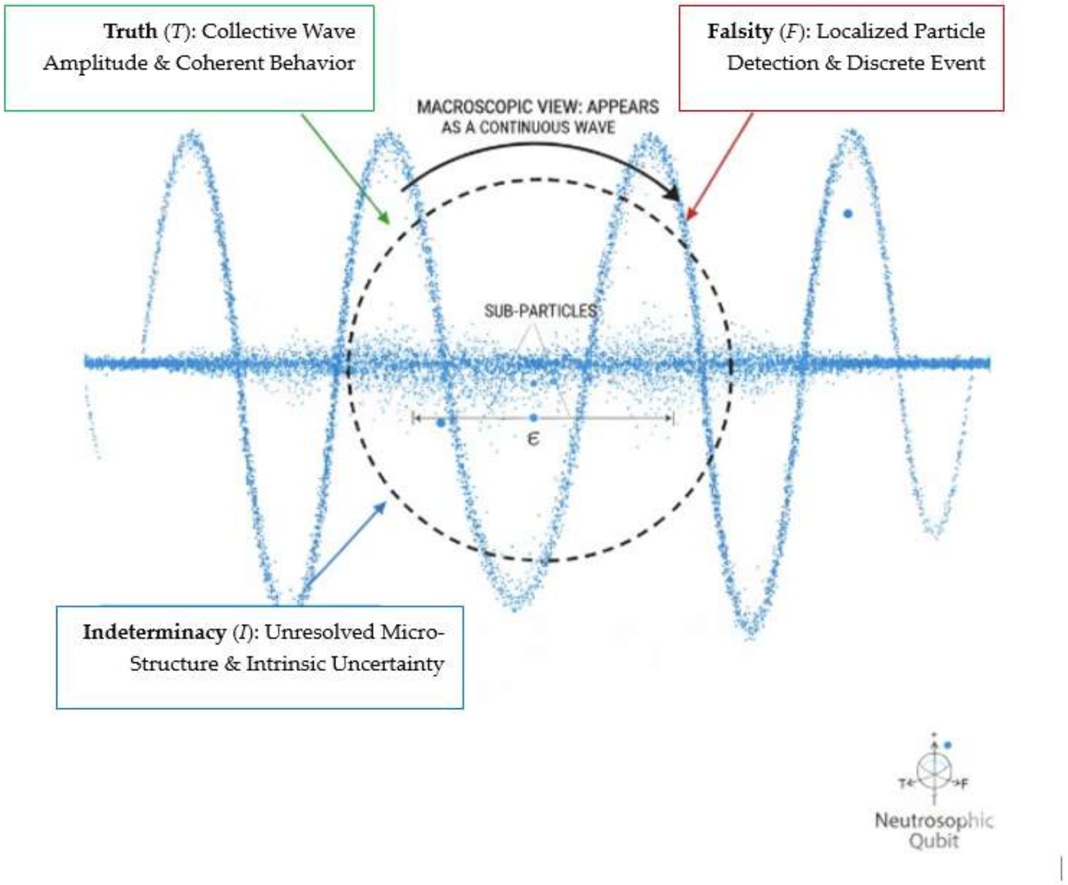

Figure 1. Schematic of the IPW ontology and its mapping onto the Neutrosophic truth values *T*, *F*, *I*.

In summary, the IPW model depicted in this figure offers a concrete visual metaphor for wave-particle duality, where the same underlying structure (an aggregation of sub-particles) gives rise to both wave and particle behaviors depending on the scale of observation. It further enriches this picture by connecting these emergent behaviors and the underlying structure to the rigorous logical framework of Neutrosophic Quantum Theory.

2.5. Relation to Existing Interpretations

Before presenting the comparative matrix, it is useful to recall why any new picture of wave-particle duality must be situated among the many proposals that already populate the foundations of quantum mechanics.

Each established interpretation offers a distinct way of reconciling the apparently contradictory wave and particle aspects, either by postulating additional dynamical entities (as in pilot-wave theory), by redefining the mathematical representation of a localized quantum object (as in the wave-packet picture), or by expanding the logical vocabulary used to describe quantum states (as in Neutrosophic Quantum Theory).

The Infinitesimally Punctured Wave (IPW) seeks to inherit the explanatory strengths of these approaches while providing a concrete visual metaphor: a continuum that is, in fact, a densely packed lattice of infinitesimal particles.

The table below summarises the core idea of each interpretation and highlights the specific way in which IPW connects to it.

Table 1. Correspondence between IPW and three major quantum-foundations interpretations.

Interpretation	Core Idea	Connection to IPW
Pilot-Wave (de Broglie–Bohm)	Point-like particle guided by a real wave field	IPW replaces a single guiding wave with a dense lattice of sub-particles that collectively act as the guiding field.
Wave-Packet	Localised superposition of plane waves	IPW can be seen as a spatial analogue: a "packet" formed by tightly packed particles rather than overlapping frequencies.
Neutrosophic Quantum Theory	Uses *T*/*F*/*I* to model partial truth, falsity, and indeterminacy of quantum states	The infinitesimal gaps between particles embody indeterminacy (*I*); the overall wave reflects a weighted truth (*T*), while the isolated particle outcome reflects falsity (*F*).

3. Discussion

3.1. Advantages

The dotted-line metaphor supplies an intuitive visual that can be easily conveyed to students and lay audiences, offering a concrete picture of the underlying structure. Because the model ties wave-like and particle-like behaviour to the scale at which the system is examined, it naturally explains why distinct experiments emphasize different facets of the same quantum object. Moreover, the proposal does not clash with the Schrödinger equation; it simply furnishes an alternative ontological interpretation that can be translated into the usual wave-function formalism.

3.2. Potential Challenges

Nevertheless, several challenges remain. Rendering the infinitesimal separation between constituent points into a rigorous mathematical expression demands careful handling of limits and distribution theory. Demonstrating empirical differences between the punctured-wave picture and conventional quantum mechanics is difficult, since most tests lack the resolution to probe sub-Planckian structures, and designing novel experiments capable of such discrimination is non-trivial. Extending the concept to relativistic quantum field theory also poses difficulties, as the framework must accommodate particle creation and annihilation processes that are intrinsic to field-theoretic descriptions.

3.3. Future Directions

Future work could focus on constructing a formalism that treats the punctured wave as the continuum limit of a discretised field, perhaps by employing lattice-gauge methods. Another promising avenue is to investigate whether the punctured-wave representation sheds light on quantum decoherence, modeling environmental interactions as disturbances that "tear" the apparent continuity and reveal the underlying discrete elements. Finally, exploring links with stochastic electrodynamics may prove fruitful, as vacuum fluctuations could be interpreted as the background punctures that generate observable wave phenomena.

4. Conclusions

The Infinitesimally Punctured Wave offers a fresh visual and conceptual approach to the enduring puzzle of wave-particle duality. By envisaging a quantum object as an infinite chain of infinitesimally spaced particles, the model reconciles wave-like interference with particle-like localisation through a scale dependent perspective. Its alignment with Neutrosophic Quantum Theory provides a logical scaffold for handling indeterminacy, while its similarity to pilot wave and wave packet ideas ensures compatibility with existing interpretational families. Though further mathematical development and experimental scrutiny are required, the IPW framework enriches the dialogue on quantum foundations and may inspire new ways of teaching, visualising, and perhaps eventually testing the deep structure of quantum reality.

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