A Paradigm Shift in Quantum Entanglement Interpretation: Reevaluating Bell's Theorem

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Abstract. This study critically examines the prevailing interpretations of Bell's theorem in quantum entanglement, a cornerstone of modern physics. We employ a theoretical framework that integrates recent advancements in quantum information theory and relativistic quantum mechanics. By applying rigorous mathematical analysis to experimental data, we reveal inconsistencies in conventional understandings that have significant implications for the philosophy of quantum mechanics. Our results suggest a reconceptualization of entanglement phenomena, advocating for a paradigm shift in how we approach quantum theories. These findings not only challenge long-standing beliefs but also pave the way for novel experiments and technological applications in quantum computing and communication.

Keywords: Quantum Entanglement, Bell's Theorem, Quantum Information Theory, Relativistic Quantum Mechanics, Locality, Realism, Quantum Computing, Quantum Cryptography, Interpretation of Quantum Mechanics

Introduction

Quantum entanglement remains one of the most puzzling and intriguing phenomena in physics, often regarded as a hallmark of quantum mechanics. As we advance into the 2024-2026 period, the implications of entanglement stretch far beyond theoretical physics, impacting quantum computing, cryptography, and our understanding of the universe's fundamental structure. Despite decades of research, the interpretations of entangled states and their relation to locality and realism continue to spur debate among scientists. The relevance of Bell's theorem, which articulates the impossibility of local hidden variable theories, is increasingly paramount as empirical techniques evolve, allowing for unprecedented tests of its implications. This paper aims to dissect the established perceptions surrounding Bell's theorem and contend that a critical reevaluation is not only warranted but essential for the progression of quantum physics. We first establish the historical context of Bell's theorem, highlighting its foundational role in quantum theory, followed by an exploration of contemporary developments that have emerged in light of new experimental findings. Our methodology employs a hybrid approach, combining theoretical analysis with experimental data to identify discrepancies in existing interpretations. The implications of our findings extend to both philosophical discussions and practical applications in quantum technologies. We conclude by proposing an integrative framework that reconciles these discrepancies, presenting a pathway for future research that embraces a holistic understanding of entanglement. This paper is structured as follows: we will first review the historical background of Bell's theorem, followed by our methodology, results, and finally, a discussion exploring the implications of our findings.

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