An experimental test of all theories with predictive power beyond quantum theory

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For almost a century much debate has surrounded the probabilistic nature and lack of predictive power of quantum theory with regards to measurement outcomes. Even with all the information available within quantum mechanics, the outcomes of certain experiments on members of entangled pairs are generally not predictable, which begs the question, can this probabilistic nature be alleviated by supplementing the wavefunction with additional information? A few specific models (e.g. Bell [1], Leggett [2]) have suggested a hidden parameter that would, if accessible, improve upon these predictions. The existence of such hidden variables has been falsified by numerous experiments [3,4].

We give a more general answer by experimentally bounding the predictive power, about measurements on members of entangled particles, of any alternative model [5,6]. As is the case in all falsifications of alternative models, our conclusions are based on the strength of correlations between measurement outcomes of entangled particles. Our experiment employs polarization-entangled photon pairs generated through SPDC and correlation measurements in up to fourteen bases [5,6]. We find that an alternative theory could improve the quantum predictionsby at most 16.5 percentage points.

Our experimental results are incompatible with any already known and yet-to-be-proposed alternative theories that could predict the outcomes of measurements on entangled particles with significantly higher probability than quantum theory, suggesting that quantum theory is optimal. Our conclusion is based on the natural assumption that all measurement settings have been chosen freely, which we precisely define, and that the presence of the detection loophole did not affect the measurement outcomes.

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