Abstract Submitted
for the MAR17 Meeting of
The American Physical Society

Constructing the Bloch sphere without quantum mechanics

MICHAEL MAZUREK, Institute for Quantum Computing, MATTHEW PUSEY, ROBERT SPEKKENS, Perimeter Institute for Theoretical Physics, KEVIN RESCH, Institute for Quantum Computing — Quantum state and measurement tomography are standard analysis methods which find the quantum states and measurement operators that explain a set of experimental data. Once the quantum description of an experiment is found, it is often used to draw conclusions about the experiment, or to make predictions about future ones. However, these techniques cannot be used to identify possible deviations from quantum theory, as they assume the correctness of quantum mechanics. Here, we develop a quantum-free tomography technique that finds the generalized probability theory (GPT) that best fits our data. This GPT tomography technique is able to characterize the dimension and shape of the GPT state and effect spaces in an experiment, providing a predictive theory explaining the specific preparation and measurement procedures performed. We demonstrate our technique with an experiment manipulating the polarization degree-of-freedom of single photons. The GPT state and effect spaces we construct closely resemble the corresponding spaces for a qubit, and we place small upper bounds on the maximum amount our experiment may deviate from quantum theory.

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Date submitted: 11 Nov 2016

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