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The Quantum pigeonhole principle and localizing Kochen-Specker contextuality with weak measurements

The pigeonhole principle: “If you put three pigeons in two pigeonholes at least two of the pigeons end up in the same hole” is an obvious yet fundamental principle of Nature as it captures the very essence of counting. However we have showed that in quantum mechanics this is not true! We find instances when three quantum particles are put in two boxes, yet no two particles are in the same box. Furthermore, we show this is only one of a host of related quantum effects and that it points to a very interesting structure of quantum mechanics that was hitherto unnoticed. Our results shed new light on the very notions of separability and correlations in quantum mechanics and on the nature of interactions. It also presents a new role for entanglement, complementary to the usual one.
Finally, I review how weak values and weak measurements represent a new class of experiments to test quantum contextuality. We have showed that using pre- and post-selected states along with many existing proofs of the Kochen-Specker theorem, it is possible to localize the violation of noncontextuality to specific observables where it can be probed using weak measurements. We have analyzed several important Kochen-Specker examples in detail, and introduced a framework for a more general set of experimental tests based on known proofs of the Kochen-Specker theorem. The underlying ontological models that are used in these arguments are explored detail, and connections are made to pre- and post-selected state paradoxes such as the 3-box paradox, the quantum Cheshire Cat, and the quantum pigeonhole principle, as well as to the Mean King’s problem.

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