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Using adaptiveness and causal superpositions against noise in quantum metrology

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A well-established approach to enhance precision of quantum metrological protocols involves preparing multiple probes in an entangled state before interaction with the measured system. Fundamental precision limits for such entanglement-based protocols have been known for more than decade. Nevertheless, quantum mechanics permits more advanced strategies that employ quantum error correction, adaptive preparation of probe states, and even non-trivial causal structures. Specifically, preparing causal superposition of different orders in which probes interact with the system may give some metrological advantage. In our work (Phys. Rev. Lett. 131 (9), 090801), we derive fundamental, asymptotically saturable bounds for both adaptive and causal-superpositions enhanced strategies. Remarkably, we demonstrate that these sophisticated strategies achieve the same asymptotic precision precision as standard entanglement-based approaches. However, employing causal superpositions and adaptiveness can offer some advantage for a finite number of channel uses.

Primary author: KURDZIALEK, Stanislaw (Faculty of Physics, University of Warsaw)

Presenter: KURDZIALEK, Stanislaw (Faculty of Physics, University of Warsaw)

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