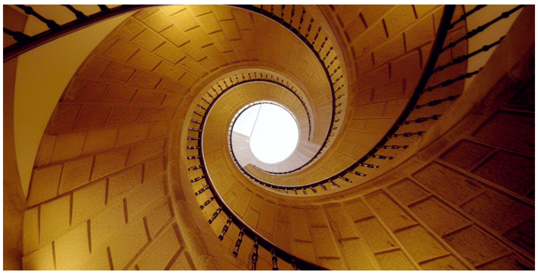

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Quantum circuits measuring weak values and Kirkwood–Dirac quasiprobability distributions, with applications

Weak values [1] and the Kirkwood-Dirac (KD) quasiprobability distribution [5, 3], recently connected with one another, have been associated with both foundational issues in quantum theory as well as advantages in quantum metrology. For example, the nonclassicality of weak values and KD distributions has been linked to quantum advantage in metrology [2] and quantification of quantum information scrambling [4]. Both weak values and KD distribution can be experimentally measured via weak measurements involving pre- and post-selection of carefully chosen observables. However, measurements schemes that can be implemented using currently relevant quantum circuit architectures without post-selection are only now beginning to appear.

We introduce an unified framework to express both KD quasiprobability functions and weak values in terms of more fundamental quantities, known as Bargmann invariants, that characterize the relational properties of a set of quantum states. This framework allows to use the recently proposed cycle test circuit [6] to measure these invariants and directly estimate weak values and KD distributions without the need of post-selection. We compare the performance of these circuits with the usual strategies for measuring weak values and quantum state tomography. Our circuits also allow to measure out-of-time-ordered correlators (OTOCs), which quantify information scrambling, and the quantum Fisher information in post-selected parameter estimation. Another practical application of these circuits is the estimation of the spectrum of a d -dimensional mixed quantum state ρ via direct estimation of $\mathrm{Tr}(\rho^n)$ for $n = 1, ..., d$. This scheme can also be adapted to estimate only the biggest eigenvalue of the spectrum, requiring simpler circuits. We expect that this unified framework based on Bargmann invariants will be appealing and provide practical recipes for experimental implementations of the analyzed applications.

On a more foundational side, we study how the negativity and imaginarity of Bargmann invariants, weak values and KD distributions can be understood as witnesses of quantum set coherence, that acknowledges coherence of a set of states as a basis-independent property. This relationship may help understanding certain problems of interest, like the connection between the nonclassicality of OTOCs and scrambling of information for quantum computation.
This poster present the results from [7].

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