Efficient classical simulation of quantum computation beyond Wigner nonnegativity

Michael Zurel

Negativity in the Wigner function is a necessary condition for a quantum computational advantage in quantum computation with magic states on odd-dimensional qudits. In this setting, nonnegativity coincides with the existence of a noncontextual hidden variable model describing the computation, and so two traditional indicators of nonclassical behaviour align. But difficulty arises in trying to extend this condition to even dimensions due to the presence of state-independent proofs of contextuality like the Mermin square. Negativity in a quasiprobability function as a resource for quantum computation on qubits can be restored by relaxing some of the constraints that typically define quasiprobability representations. When similar relaxations are made in the odd-dimensional case, we show that we can efficiently classically simulate quantum computations on some states with negative Wigner functions. This allows for a broader class of magic state quantum circuits to be efficiently classically simulated than those covered by the stabilizer formalism and Wigner function methods.