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Quantum Complexity as Hydrodynamics

As a new step towards defining complexity for quantum field theories, we map Nielsen operator complexity for $SU(N)$ gates to two-dimensional hydrodynamics. We develop a tractable large N limit that leads to regular geometries on the manifold of unitaries as N is taken to infinity. To achieve this, we introduce a basis of non-commutative plane waves for the $\mathfrak{su}(N)$ algebra and define a metric with polynomial penalty factors. Through the Euler-Arnold approach we identify incompressible inviscid hydrodynamics on the two-torus as a novel effective theory of large-qudit operator complexity. For large N, our cost function captures two essential properties of holographic complexity measures: ergodicity and conjugate points.

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