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Generic dynamical features and thermalisation of isolated many-body quantum systems

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Nonequilibrium dynamics of isolated many-body quantum systems is a highly interdisciplinary subject covering a broad range of physics scales, from string theory and black holes to condensed matter and atomic physics. The connection between black hole physics and unitary quantum dynamics emerges from holographic dualities that relate certain quantum field theories to gravitational theories. On the experimental side, unitary quantum dynamics is investigated with cold atoms, ion traps and nuclear magnetic resonance platforms. Studies of black hole information loss, quantum chaos, thermalisation in isolated quantum systems, many-body localization and quantum speed limits consider similar dynamical quantities. They include the survival probability, density imbalance and out-of-time-ordered correlator (OTOC). We characterize the evolution of these quantities at different time scales. Given the complexity of out-of-equilibrium many-body quantum systems, we take the same approach as Wigner when studying heavy nuclei and employ full random matrices from the Gaussian orthogonal ensemble. We use the analytical results obtained with full random matrices to identify general features and bounds for the dynamics of realistic interacting systems. The basis of our analysis is the probability of finding the initial state later in time (survival probability). This quantity is related to the analytic continuation of the partition function used to study conformal field theories with holographic duals and to describe the time behavior of large anti-de Sitter black holes. Our analytical expression for the survival probability covers the entire duration of the evolution. Following the same steps for its derivation, we find analytical expressions for the density imbalance and OTOC. At long times, these isolated but complex finite quantum systems thermalize. We argue that the mechanism for thermalisation is quantum chaos. Even though the time scale on which chaotic behavior holds is finite, it can be much larger than any physical time scale.

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