Localisation, Thermalisation and Time Crystals: Quantum Simulations of Disorder

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Dynamical quantum systems provide a rich playground to study a number of fundamental questions in quantum mechanics regarding localisation, ergodicity and entanglement growth. Classical methods such as tensor networks can be used to study these phenomena but are restricted to certain paradigms such as short-time simulations or systems with weak entanglement growth. It is thus not always clear from numerical simulations whether an observed physical phenomenon is an artefact of the structure imposed on the Hilbert space by the tensor network algorithm or is indeed a true reflection of a quantum mechanical system. In this work, we use a quantum computer to address this issue. We consider a Hamiltonian with disordered couplings and implement its dynamics on a quantum computer. We ask the following questions: can we observe a low dimensional discrete time crystal in an *interacting* system on a real quantum device? Can we observe the localisation/thermalisation transition on a quantum computer? If the ergodic regime is difficult to study with classical numerics, can the quantum computer provide more accurate results?