Anderson localisation in spatially structured random regular graphs

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We study the localisation phase diagram of the Anderson model on random regular graphs (RRG) which are endowed with spatial structure. This is motivated by the heuristic connection between many-body localisation on the Fock space and Anderson localisation on high-dimensional graphs. The spatially structured hopping on the RRGs, that we introduce, can be thought of as a simple toy model for capturing rare, long-ranged resonances in the MBL problem which may lead to matrix elements between arbitrary pairs of sites on the Fock-space graph. To incorporate this into an RRG setting, we consider the situation where the hopping matrix element between any two nodes is finite but the magnitude typically decays with the distance between the nodes, with the distance set by the topology of the underlying RRG. Such family of models betrays a rich localisation phase diagram resulting from an interplay of the onsite disorder strength and the lengthscales which control the decay of the hopping matrix elements with the distance on the RRG. We uncover this phase diagram through a combination of numerical and analytical results. Our work can shed light onto how long-ranged resonances and their proliferation may drive the many-body localisation transition.

[1] BS, A. Dhar, S. Roy, arXiv: 2507.xxxxx.