Many-body localisation escapes to two dimensions

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Many-body localisation (MBL) provides a mechanism to avoid thermalisation in interacting systems. It is well understood that the MBL phase can exist in closed one-dimensional systems subjected to random disorder, quasiperiodic modulations, or homogeneous electric fields. However, the fate of MBL in higher dimensions remains unclear. Although some older experiments on randomly disordered two-dimensional (2D) systems have observed an alleged MBL phase on intermediate time scales, recent theoretical works show that the phenomenon cannot persist indefinitely or in the thermodynamic limit due to rare regions of weak potential and avalanche instability.

On the other hand, quasiperiodic systems do not host rare regions, and the avalanche instability is avoided; yet, the existence of an MBL phase in these systems remains largely unexplored to date. Here, we investigate the localisation properties of the many-body 2D Aubry-André quasiperiodic model by studying its out-of-equilibrium dynamics [1]. We show that a stable MBL phase exists at long timescales, and potentially even in the thermodynamic limit, in contrast to the random-disorder case. Surprisingly, we find that a sub-dimensional network of deterministic lines of weak potential – naturally appearing in these systems – supports transport while keeping localised regions untouched.

Our theoretical proposal was recently tested in experiments with ultracold atoms, which confirmed the stability of quasiperiodic many-body localisation [2].

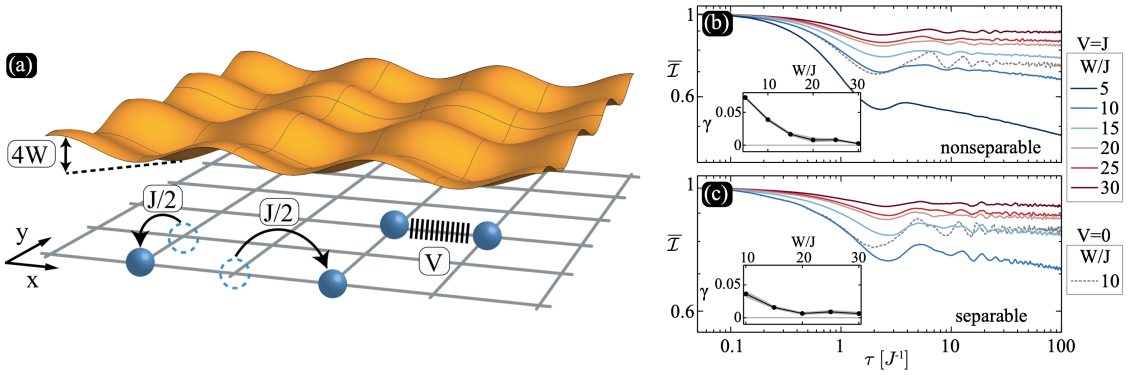

***Figure**: (a) Sketch of the system studied in this work. The kinetic energy of the particles is determined by a uniform hopping parameter J. The particles are subjected to an external incommensurate potential of strength W and interact via nearest-neighbour coupling V. (b), (c) Dynamics of the particle imbalance for different potential strengths, shown for two different realisations of the model in (a). Insets show the fitted power-law decay exponent for each coloured curve, which tends to zero for large W, indicating the localised nature of the system.*

References:

[1] A. Štrkalj, E. V. H. Doggen, and C. Castelnovo, Phys. Rev. B 106, 184209 (2022).
[2] Junhyeok Hur, et al, arXiv:2508.20699 (2025)