Long-range chaos-assisted tunneling for quantum simulation

Maxime Martinez*[1], Bertrand Georgeot[1], Gabriel Lemarié[1], Olivier Giraud[2], Denis Ullmo[2], Maxime Arnal[3], Gabriel Châtelain[3], Nathan Dupont[3], Juliette Billy[3], and David Guéry-Odelin[3]

[1]Laboratoire de Physique Théorique (LPT) – Université Toulouse III - Paul Sabatier, Centre National de la Recherche Scientifique – 118 route de Narbonne, 31062 Toulouse Cedex 4, France
[2]Laboratoire de Physique Théorique et Modèles Statistiques (LPTMS) – Université Paris-Sud - Paris 11, Centre National de la Recherche Scientifique : UMR8626 – Bâtiment 100 Université Paris-Sud Centre Scientifique d'Orsay 15 rue Georges Clémenceau 91405 Orsay cedex, France
[3]Laboratoire Collisions Agrégats Réactivité (LCAR) – Université Toulouse III - Paul Sabatier, Centre National de la Recherche Scientifique – 31062 Toulouse cedex 04 - France, France

Abstract

The quantum tunneling effect usually first evokes the textbook case of a classically forbidden
crossing of a potential barrier. However this phenomenon can be far richer in quantum systems
whose classical counterpart exhibits dynamics that can be both chaotic or regular depending on the initial conditions. Indeed, in the phase space of such systems, regular orbits form stable
islands, that can be seen as potential well, surrounded by a chaotic sea of unstable orbits (see
Fig). The tunneling oscillations between two neigbouring regular islands is then generically mediated by a state delocalized in the chaotic sea. This leads to sharp resonances in the tunneling oscillation frequencies, a phenomenon known as chaos-assisted tunneling [1].
From an experimental point of view, this rich physics can be simulated using driven optical lattices. We recently demonstrated [2] in collaboration with a team of experimentalist, the first
explicit observation of such tunneling resonances in a quantum system. In this work we show that the very same mechanism actually generates long-range hopping across distant sites of the
driven lattice, and we propose procedure for their experimental observation. These results open
the way to a new regime of tunability for quantum simulations, making possible to simulate classes of systems that are difficult to address by other means.

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*Speaker

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