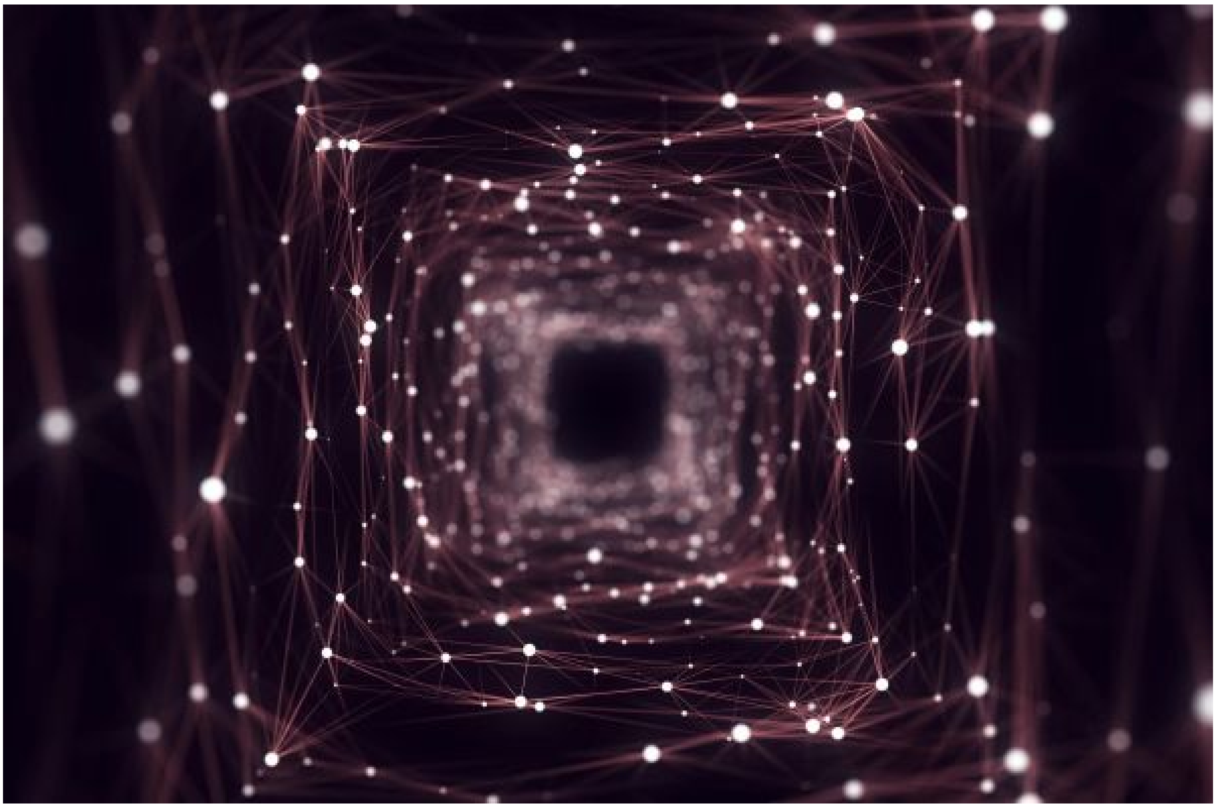

Many-body localization: current status and open questions

Researchers present an extensive review of many-body localization (MBL) -a phenomenon that prevents quantum many-body systems from reaching equilibrium- focusing on the main numerical results and the remaining open questions.

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When many quantum particles evolve over time, they typically end up arriving to an equilibrium state through a process called thermalization. Something similar happens in many classical systems. For example, if you place an ice cube in a thermos with water, the ice melts and the final (equilibrium) state is just colder water than before.

In classical physics, complex systems eventually reach equilibrium (if you wait long enough, the ice always melts). However, certain quantum many-body systems defy this norm. For them, thermalization does not occur, and the system remains out of equilibrium. This behavior is due to many-body localization (MBL), a mechanism that retains the system's initial conditions over time.

However, a central question remains unanswered: why does MBL occur, and under what conditions? Seeking to consolidate the knowledge accumulated over decades, ICFO researchers **Dr. Piotr Sierant** and **ICREA Prof. Maciej Lewenstein**, together with collaborators of Abdus Salam International Centre of Theoretical Physics, Jozef Stefan Institute, University Ljubljana and Uniwersytet Jagiellonski, have presented a comprehensive overview of the current understanding of the MBL phenomenon. The review, published in Reports on Progress in Physics, focuses on recent numerical results and highlights the critical open questions in the field.

The article also gives a concise historical overview, describes the key features of MBL, discusses the recent experiments and their remaining challenges, and qualitatively characterizes the challenges associated with the interpretations of numerical data, which to this day remain inconclusive.

Researchers highlight that the primary obstacle in numerical experiments lies in the rapid increase in computational complexity as the number of particles and the desired simulation time grow. To accurately emulate a relevant MBL system, both parameters must be sufficiently large, which typically pushes the problem beyond the capabilities of even the most advanced supercomputers. This limitation underscores the potential of quantum computers, which, as the authors suggest, "might open an entirely new chapter in MBL studies."

Reference:
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