TT 29: Focus Session: Dynamics in Many-Body Systems: Equilibration and Localization (joint session TT/DY)

Much progress has recently been made in realizing controlled and coherent many-body systems, in the fields of condensed matter as well as ultra-cold atomic systems. One of the most exciting developments in recent years is the realization that disorder and interactions together can lead to an entirely new form of localization, "many-body localization", the study of which is in its very infancy: nature, mechanism, and implications of many-body localisation are now subject of a rapidly developing field.

This Focus Session considers several aspects of many-body localisation: how to describe many-body localisation in a theoretical model; the roles of symmetry, topology, and of external driving; it also considers connections to the venerable field of Anderson localization. In addition, it features an account of recent experiments.

Organizers: Roderich Moessner and Frank Pollmann (MPI-PKS Dresden)

Time: Tuesday 9:30–13:00 Location: H 0104

Invited Talk TT 29.1 Tue 9:30 H 0104

Probing Non-Equilibrium Dynamics with Ultracold Atoms: from Quantum Magnetism to Many-Body Localization — •Immanuel Bloch — Fakultät für Physik, Ludwig Maximilians Universität, München, Germany — Max-Planck Institut für Quantenoptik, Garching b. München, Germany

Ultracold quantum gases are an ideal testbed to study non-equilibrium dynamics of closed quantum systems. Their isolation from the environment for example enables one to probe the dynamical evolution of high-energy states in strongly interacting quantum many-body system. In many of these cases, this can result in a breakdown of fundamental assumptions of statistical mechanics, leading to novel many-body paradigms such as, e.g., many-body localization. In my talk I will give several examples from recent experiments in our group where we have studied the quantum dynamics of spin-spirals in a Heisenberg ferromagnet, novel ordering phenomena in long-range interacting quantum magnets realized via Rydberg atoms and the observation of many-body localization in interacting fermionic quantum gases in disordered lattice potentials.

Invited Talk TT 29.2 Tue 10:00 H 0104

Many-Body Localization — •Dmitry Abanin — University of Geneva, Switzerland — Perimeter Institute for Theoretical Physics, Waterloo, Ontario, Canada

We are used to describing systems of many particles by statistical mechanics. However, the basic postulate of statistical mechanics – ergodicity – breaks down in so-called many-body localized systems, where disorder prevents particle transport and thermalization. In this talk, I will give an overview of recent developments in many-body localization. I will describe a phenomenological theory of the many-body localized (MBL) phase, based on new insights from quantum entanglement. I will argue that, in contrast to ergodic systems, MBL eigenstates are not highly entangled, but rather obey so-called area law, typical of ground states in gapped systems. I will use this fact to show that MBL phase is characterized by an infinite number of emergent local conservation laws, in terms of which the Hamiltonian acquires a universal form. Turning to the experimental implications, I will describe the response of an MBL systems to quenches: surprisingly, entanglement shows logarithmic in time growth, reminiscent of glasses, while local observables exhibit power-law approach to "equilibrium" values. I will support the presented theory with the results of numerical experiments, and close by discussing experimental implications and other directions in exploring ergodicity and its breaking in quantum many-body systems.

Topical Talk TT 29.3 Tue 10:30 H 0104

Long-Time Behaviour of Periodically Driven Many-Body Quantum Systems — •Achilleas Lazarides[1], Arnab Das[2], and Roderich Moessner[1] — [1]Max-Planck-Institut für Physik komplexer Systeme, Dresden, Germany — [2]Indian Association for the Cultivation of Science, Kolkata, India

We study the long-time behaviour of closed quantum systems under temporally periodic driving, arguably the simplest deviation from equilibrium. Drawing inspiration from current understanding of equilibration and thermalisation in closed quantum systems with a time-independent Hamiltonians we study the long-time behaviour of free, interacting and (many-body) localised systems under periodic driving.

15 min. break.

Topical Talk TT 29.4 Tue 11:15 H 0104

Many Body Localization and Eigenstate Order — •Shivaji Sondhi — Department of Physics, Princeton University, Princeton, NJ 08544, USA

Recent advances in our understanding of the quantum statistical mechanics of isolated quantum systems have focused attention on the properties of individual many body eigenstates of large systems. While these advances have deepened our understanding of thermal/ergodic systems, they are even more crucial for understanding the properties of many body localized systems where statistical mechanics breaks down. In particular, as I will describe, many body localized systems can exhibit phase transitions while remaining localized wherein the properties of their eigenstates change in singular fashion even as naive statistical mechanical averages are entirely smooth.

Invited Talk TT 29.5 Tue 11:45 H 0104

Anderson Transitions and Electron-Electron Interaction — •Alexander Mirlin — Karlsruhe Institute of Technology, 76131 Karlsruhe, Germany

Recent results on the interplay of Anderson localization and electron-electron-interaction effects will be reviewed.

TT 29.6 Tue 12:15 H 0104

Impact of the eigenstate thermalization hypothesis on the relaxation of significantly off-equilibrium initial states — Abdellah Khodja[1], Robin Steinigeweg[2], and •Jochen Gemmer[1] — [1]Department of Physics, University Osnabrück, Germany — [2]Institute for Theoretical Physics, Technical University Braunschweig, Germany

We investigate the connection between (a precisely stated version) of the eigenstate thermalization hypothesis (ETH) and initial state independent (ISI) equilibration of chosen observables. The focus is on a class of initial states that render the addressed observables significantly off-equilibrium, rather than on initial states contrived by quenches. An extensive numerical study on spin systems that goes beyond exact diagonalization indicates that the smallness of a certain ETH related quantity is indeed imperative to the occurence of ISI equilibration for the above class of initial states.

TT 29.7 Tue 12:30 H 0104

Typicality of Eigenstate Thermalization — •Peter Reimann — Theoretische Physik, Universität Bielefeld, Germany

Thermalization, i.e., the relaxation of a macroscopic system towards thermal equilibrium, is a very common and well-established experimental fact, but has still not been satisfacorily explained in terms of the basic laws of physics. Specifically, for isolated many-body systems, the so-called eigenstate thermalization hypothesis (ETH) has recently attracted much interest as a sufficient condition from which thermalization could be deduced. Here, this hypothesis is validated as a typicality property for the textbook example of a simple gas in a box: admitting some tiny uncertainty about the "true" value of a single model parameter, e.g. the particle interaction strength, ETH and thus thermalization are warranted for the overwheling majority of those slightly differing model parameter values.

TT 29.8 Tue 12:45 H 0104

Nonsmooth and level-resolved dynamics illustrated with a periodically driven tight binding model — •Jiang min Zhang and Masudul Haque — Max-Plank-Institute-PKS, Dresden, Germany

We point out that in the first order time-dependent perturbation theory, the transition probability may behave nonsmoothly in time and have kinks periodically. Moreover, the detailed temporal evolution can be sensitive to the exact locations of the eigenvalues in the continuum spectrum, in contrast to coarse-graining ideas. Underlying this nonsmooth and level-resolved dynamics is a simple equality about the sinc function $sinc(x) \equiv \sin x/x$. These physical effects appear in many systems with approximately equally spaced spectra, and is also robust for larger-amplitude coupling beyond the domain of perturbation theory. We use a one-dimensional periodically driven tight-binding model to illustrate these effects, both within and outside the perturbative regime.

[1] J. M. Zhang and Masudul Haque, arXiv:1404.4280.