Analyzing many-body localization with a quantum computer

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Probing and exploring quantum many-body systems out of equilibrium

Bloch, Immanuel
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A semi-classical limit for the many-body localization transition

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Statistical mechanics is the framework that connects thermodynamics to the microscopic world. It hinges on the assumption of equilibration. Isolated quantum systems need not equilibrate; this is the phenomenon of many-body localization (MBL). While a detailed understanding of MBL and the associated delocalization transition is beginning to emerge in one dimension, relatively little is known about higher dimensions.

In this talk, I will present a minimal tractable model for MBL in all spatial dimensions. Specifically, I will analyze a disordered Floquet circuit composed of Clifford gates. As the system has no conservation laws, it ought to thermalize to infinite temperature. We will find however that it need not: in one dimension, the system is always localized, while in higher dimensions, it exhibits both delocalized and localized phases. The localized phase consists of well-defined metallic puddles embedded in an insulating matrix. When the puddles percolate, the system delocalizes; this maps the dynamical transition to critical percolation. I will finally comment on the stability of the phases to generic perturbations away from the Clifford class.

Landau-Lifshitz-Gilbert-Brown magnetization dynamics: functional formalism and numerical integration

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The dissipative dynamics of a classical magnetic moment is successfully described by a stochastic generalization of the Landau-Lifshitz-Gilbert equation proposed by Brown about 50 years ago (the so-called sLLG equation). This equation has regained interest recently thanks to its use to model spin-transfer via the addition of a spin-torque. Since the noise appears multiplicatively, special care has to be taken with the discretization of this first-order differential equation.

I will discuss how to present the sLLG equation in a form that accommodates for any discretization scheme thanks to the inclusion of a drift term. The generalized equation ensures the conservation of the magnetization modulus and the approach to the Gibbs-Boltzmann equilibrium in the absence of non-potential and time-dependent forces. I will next construct the generating functional formalism for any discretization prescription. This formalism serves as a starting point to prove the equilibrium fluctuation-dissipation theorem and out of equilibrium fluctuation theorems by using a linear transformation of the dynamic and auxiliary fields, and to study different aspects of the out-of-equilibrium dynamics of magnets. Extensions to colored noise, micro-magnetism and disordered problems are straightforward.

Finally, I introduce a numerical method to integrate the stochastic Landau-Lifshitz-Gilbert equation in spherical coordinates for generic discretization schemes. This method conserves the magnetization modulus and ensures the approach to equilibrium under the expected conditions. We put this algorithm to the test on a benchmark problem: the dynamics of a uniformly magnetized ellipsoid. We investigated the

influence of various parameters, and in particular, we analyzed the efficiency of the numerical integration, in terms of the number of steps needed to reach a chosen long-time with a given accuracy.

These results were published in:

Numerical integration of the stochastic Landau-Lifshitz-Gilbert equation in generic time-discretisation schemes
Federico Romá, Leticia F. Cugliandolo, Gustavo S. Lozano
arXiv:1403.4822, Phys. Rev. E 90, 023203 (2014)

Magnetization dynamics: path-integral formalism for the stochastic Landau-Lifshitz-Gilbert equation
Camille Aron, Daniel G. Barci, Leticia F. Cugliandolo, Zochil Gonzalez Arenas, Gustavo S. Lozano
arXiv:1402.1200, J. Stat. Mech. (2014) P09008

Statistical Mechanics of Periodically Driven Closed Quantum Systems

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Introducing explicit time-dependence makes the behavior of a quantum system immensely more intriguing than the static problem. For example, while eigen-spectrum of a two-level system is trivial, the behavior of a two level system under a simple sinusoidal drive has remained unsolved till date. However, for system with many-degrees of freedom, a unified general picture emerges in the asymptotic limit of long drive duration. This picture draws heavily on the information theoretic approach of reproducing equilibrium statistical mechanics. In this presentation we discuss the general framework and illustrate it considering different cases of interest, namely, the case of certain integrable systems and generic systems. Quantum interference nevertheless produce unexpected results like
dynamical many-body freezing as will be demonstrated in the context of the Ising and the XY-chain
in periodic transverse field.

Quantum and classical in adiabatic computation

Green, Andrew George
(University College London, London Centre for Nanotechnology, Physics, London, United Kingdom)

Aspects of floquet fractional chern insulators

Grushin, Adolfo G.
(Max Planck Institute for the Physics of Complex Systems (MPIPKS), Max Planck Institute for the Physics of Complex Systems, Condensed Matter, Dresden, Germany)

Transport properties and condensation phenomena of interacting bosons in the non-equilibrium regime

Heidrich-Meisner, Fabian
(LMU Munich, Arnold Sommerfeld Center for Theoretical Physics, Faculty of Physics, Munich, Germany)

A mechanism for transport in nearly many-body localized systems

Huveneers, Francois
(Université Paris Dauphine, CEREMADE, Paris, France)

MBL features in a disordered quantum Ising chain

Kjäll, Jonas A.
(Stockholms universitet, Fysikum, Stockholm, Sweden)

Quantum dynamics of strongly interacting spins and photons

Lukin, Mikhail
(Harvard University, Department of Physics, Cambridge, USA)

Relaxation Dynamics in Qubit Chains

Marquardt, Florian
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In this talk I will present our theoretical results on the relaxation dynamics in chains of superconducting qubits. When the qubits are coupled capacitively, they can be made to form the quantum transverse Ising model. In addition, it is quite straightforward to produce non-integrable extensions of that model. In this sense, one has available a quantum simulator that can both be verified (in the integrable limit) and be used to study thermalization physics (when tuning away from integrability). Readout and manipulation of this system will be possible via circuit cavity QED tools (e.g. dispersive QND readout), giving rise to interesting questions about the interplay between weak measurements and quantum many-body dynamics.

Dissipative Floquet Topological Systems

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Motivated by recent pump-probe spectroscopies, we study the effect of phonon dissipation and potential cooling on the nonequilibrium distribution function in a Floquet topological state. To this end, we apply a Floquet kinetic equation approach to study graphene irradiated by a circularly polarized laser, a system which is predicted to be in a laser induced quantum Hall state. We find that the initial electron distribution shows an anisotropy with momentum dependent spin textures whose properties are controlled by the switching-on protocol of the laser. The phonons then smoothen this out leading to a non-trivial isotropic nonequilibrium distribution which has no memory of the initial state and initial switch-on protocol, and yet is distinct from a thermal state. An analytical expression for the distribution at the Dirac point is obtained that is relevant for observing quantized transport. We also present results for the Hall conductance both for the closed system after a quench switch on protocol of the laser, as well as the open system coupled to a reservoir of phonons.

Phase transitions in spin dynamics under time-dependent fields

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Phase transitions in spin dynamics under time-dependent fields

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Spin dynamics under time dependent field with and without dissipation effects [1] exhibits various types of phase transitions. We study an ensemble of spins (atoms with a discrete energy states) in a cavity under periodic driving field (AC field):

As a function of photon number a kind of phase transition takes place, i.e., between a region of the vacuum-field Rabi splitting (a hybridization between a cavity (resonator) and cooperative spin systems) [2,3] at low density of light and a region of the standard Rabi oscillation in large density where the light is treated as a classical field. In dissipative environments, we obtained of a phase diagram of the steady states in which a new type of ordered state of driven state appears in a region of strong coupling constant (g) and driving force (x) [4]. For the appearance of the new ordered state, the degeneracy of the Floquet quasi-energy (Coherent-Destruction of Tunneling) plays an important role.

We also report a kind of first order phase transition of a uniaxial anisotropic system with large S under a sweeping field, which corresponds to the Stoner-Wohlfarth transition [5], which can be understood from a view point of successive Landau-Zener transitions. This phenomenon corresponds to Landau-Zener transition of the Floquet quasi-eigenstate of the Rabi-oscillation in an AC field. [6].

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Conservation laws in localized systems

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Localized and integral systems are similar in several respects. For instance, both types of systems do not thermalize or display level repulsion in level spacing statistics. Integrable models have an infinity of non-trivial dynamical conservation laws which can often be derived systematically. Here, we demonstrate how a similar exercise can be performed for systems with localized energy eigenstates. Starting with a simple model of non-interacting particles hopping on a one-dimensional lattice subject to a disorder potential, we obtain conservation laws as infinite series in the hopping. We show that the existence of the conservation laws are related to the convergence of these series. In particular, for a system with a localization-delocalization transition, we show that the series fail to converge at the transition point and everywhere in the delocalized phase. Thus, the set of conservation laws functions as an "order parameter" for the transition. We also discuss applications to systems with mobility edges and interactions (many-body localization).

Phenomenology of many body localized phases

Oganesyan, Vadim
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Encoding the structure of many-body localization with matrix product operators

Pekker, David
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Anderson insulators are non-interacting disordered systems which have localized single particle eigenstates. The interacting analogue of Anderson insulators are the Many-Body Localized (MBL) phases. The natural language for representing the spectrum of the Anderson insulator is that of product states over the single-particle modes. We show that product states over Matrix Product Operators of small bond dimension is the corresponding natural language for describing the MBL phases. In this language all of the many-body eigenstates are encode by Matrix Product States (i.e. DMRG wave function) consisting of only two sets of low bond-dimension matrices per site: the Gi matrix corresponding to the local ground state on site i and the Ei matrix corresponding to the local excited state. All 2n eigenstates can be generated from all possible combinations of these matrices.

Quenches and localization in disordered quantum systems

Rigol, Marcos
(The Pennsylvania State University, Department of Physics, University Park, USA)

Interactions and dissipation in Floquet-Bloch systems

Rudner, Mark
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Recently many authors have explored possibilities for dynamically altering band structures through the application of time-periodic driving fields. Particular excitement surrounds the possibility of controlling the topology of the resulting "Floquet bands," which are described by an even richer topological classification than that of conventional topological insulators. While many schemes have been proposed for realizing interesting Floquet band structures, crucial questions remain about the filling of the corresponding time-dependent single particle states, as well as the roles of interactions and dissipation. In this work we study the roles of interactions, heating, and dissipation in the population kinetics of one dimensional many-particle Floquet systems. While a naive picture might lead one to expect rapid heating of any strongly driven interacting system, we find wide parameter regimes in which non-trivial Floquet state distributions are obtained at intermediate and long times. Prospects for obtaining and probing the physics of many-body Floquet systems will be discussed.

Many-body mobility edge in a mean-field quantum spin glass

Scardicchio, Antonello
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The quantum random energy model provides a mean-field description of the equilibrium spin glass transition. We show that it further exhibits a many-body localization - delocalization (MBLD) transition when viewed as a closed quantum system. The mean-field structure of the model allows an analytically tractable description of the MBLD transition using the forward-scattering approximation and replica techniques. Numerical exact diagonalization is in very good agreement with these theoretical results. The many-body mobility edge lies at energy density significantly above the equilibrium spin glass transition, indicating that the closed system dynamics freezes well outside of the canonical glass phase. However, there is no infinite temperature localized phase, as seen in short-ranged models. The structure of the critical states changes continuously with the energy density, raising the possibility of a family of critical theories for the MBLD transition.

Suppressing excitations during passage through critical points: A tale of two rates

Sengupta, Krishnendu
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Probing the many-body localization transition with matrix elements of local operators

Serbyn, Maksym
(University of California, Berkeley, Physics, Berkeley, California, USA)

An Introduction to Many Body Localization (Theory)

Sondhi, Shivaji
(Max Planck Institute for the Physics of Complex Systems, Condensed Matter Theory, Dresden, Germany)

Quantum glasses and many-body delocalization transitions

Vasseur, Romain
(UC Berkeley, Physics, Berkeley, USA)

New frontiers in optical lattice dynamics

Weld, David
(University of California, Santa Barbara (UCSB), Physics, Santa Barbara, USA)