DY 6: Quantum Dynamics, Decoherence, and Quantum Information I

Time: Monday 14:00–17:00 Location: ZEU 255

DY 6.1 Mon 14:00 ZEU 255

Attosecond dynamics and decoherence in neutron-H2 scattering — •C. Aris Dreismann[1], Evan Gray[2], and Tom Blach[2] — [1]Institute of Chemistry, TU Berlin, Germany — [2]Griffith University, School of Biomolecular and Physical Sciences, Brisbane, Australia

The standard theory of neutron scattering is based on time-dependent first order perturbation theory (Fermi's Golden Rule); see e.g. [1]. However, the characteristic time-window of neutron Compton scattering (NCS) in the energy transfer range of 1-100 eV lies in the attosecond range, in which the applicability of the Golden Rule becomes questionable. It is argued that, in the NCS physical context, quantum entanglement and decoherence play a significant role [2]. Results of current NCS experiments from H2 and D2 in the gas phase at T = 41 K are reported, showing that the measured Compton profiles reveal new features of quantum dynamics which contradict conventional theoretical expectations. The non-unitary dynamical character of this ultrafast scattering experiments is discussed, and the specific role of decoherence is pointed out. The presented results indicate that the new effect under investigation may play a significant role also in other scattering experimental fiels.

[1] G. L. Squires, Thermal Neutron Scattering, Dover (1996). [2] C. A. Chatzidimitriou-Dreismann and M. Krzystyniak, Laser Physics **20**, 990 (2010).

DY 6.2 Mon 14:15 ZEU 255

Environment-assisted transport and trapping in networks — •Oliver Mülken — Physikalisches Institut, Universität Freiburg, Freiburg, Germany

We study the dynamics and trapping of excitations for a networks with disorder coupled to an external environment. Using a quantum master equation approach, we calculate the survival probability Π(t) of the excitation and define different lifetimes τs of the excitation, corresponding to the duration of the decay of Π(t) in between two predefined values. We show that it is not possible to always enhance the overall decay to the trap. However, it is possible, even for not too small environmental couplings, to decrease certain lifetimes, leading to faster decay of Π(t) in these time intervals: there is an optimal environmental coupling, leading to a maximal decay for fixed disorder strength.

[1] Phys. Rev. E 82, 042104 (2010)

DY 6.3 Mon 14:30 ZEU 255

Quantum walk on a star graph with additional bonds — •Anastasiia Anishchenko, Alexander Blumen, and Oliver Mülken — Physikalisches Institut, Albert-Ludwigs Universität Freiburg; Germany

Continuous-time quantum walks (CTQW) are associated with coherent transport processes of, say, energy, mass or charge. CTQW are applicable to many fields of science from polymer physics to quantum computation. It has been shown in [1] that transfer processes depend on the network topology. Here, we concentrate on CTQW on star graphs, a regular structure that consists of N nodes, where the central node has degree N-1 and the other nodes are leaves with degree 1. There are three discrete eigenvalues for the Hamiltonian of such a system: E(1) = E(2) = ... = E(N-2) = 1; E(N-1) = 0; E(N) = N. For the complete graph of size N, where all the nodes are connected, there are two eigenvalues: E(N-1) = 0, and E(N) = N. The periodicity of regular networks such as stars or rings can be destroyed by adding randomly B additional bonds, see, e.g., Ref. [2]. This creates shortcuts, such that a walker can find a shorter way between pairs of sites than on the regular network. In the following we randomly add bonds to regular star graphs forbidding so-called self-connections, and investigate the transition from the regular star graph to the complete graph [3].

[1] O. Mülken, A. Blumen, Phys. Rev. E 71 (2005) 016101.

[2] O. Mülken, V. Pernice, and A. Blumen, Phys. Rev. E 76 (2007) 051125.

[3] A. Anishchenko, A. Blumen, and O. Mülken, in preparation.

DY 6.4 Mon 14:45 ZEU 255

Environmental induced diffusion in simple networks — •Piet Schijven, Oliver Mülken, and Alexander Blumen — Physikalisches Institut, Albert-Ludwigs Universität Freiburg, Freiburg, BW

This work centers on the behaviour of excitations over simple networks coupled to an external environment. Previous work focussed on the excitonic transport in the presence of a trap (sink) over a dimer, coupled to the environment through the Lindblad formalism [1,2].

A problem with this approach is that larger couplings lead to a quantum Zeno effect. We propose a resolution to this problem by introducing different Lindblad operators such that classical diffusion is obtained for larger coupling strengths. This allows us, in the spirit of the quantum stochastic walk (QSW) [3], to interpolate between classical diffusion and coherent energy transport [4]. To illustrate this process, the influence of tuning the coupling on both a 2-node (dimer) and a 3-node (trimer) network will be discussed.

[1] O. Mülken, L. Mühlbacher, T. Schmid and A. Blumen, Phys. Rev. E 81, 041114 (2010)

[2] O. Mülken and T. Schmid, Phys. Rev. E 82, 042104 (2010)

[3] J.D. Whitfield et. al. Phys. Rev. A 81, 022323 (2010)

[4] P. Schijven, A. Blumen and O. Mülken, in preparation.

DY 6.5 Mon 15:00 ZEU 255

Transition from hopping to band transport in topologically disordered one-particle systems — •Hendrik Niemeyer and Jochen Gemmer — University of Osnabrueck, Physics Departement

As a model system for amorphous materials we investigate a one-particle tight binding model with distance dependent hopping rates whose sites are randomly distributed according to a uniform probability distribution. Diffusion constants and mean free paths for this model can be estimated by integrating over the current autocorrelation function and by mapping the system either onto a linearized Boltzmann equation or onto a discrete diffusion equation. A transition from hopping (small mean free paths and diffusion constants coinciding with a classical random walk) to band transport can be found for increasing hopping ranges.

15 min. break.

DY 6.6 Mon 15:30 ZEU 255

Dynamics of the Rabi model on different time-scales — •Lutz Bakemeier[1], Andreas Alvermann[2], and Holger Fehske[1] — [1]Institut für Physik, Universität Greifswald, Deutschland — [2]Cavendish Laboratory, University of Cambridge, United Kingdom

The generic model of cavity QED, the Rabi model of a two-level system coupled to a quantum oscillator, features a number of interesting dynamical effects if one goes beyond the rotating wave approximation. Depending on the detuning, coupling strength and initial state preparation different types of collapse and revival of Rabi oscillations, as well as spin frequency renormalization or quasi-localization phenomena can be observed. Based on extensive numerical calculations we provide a comprehensive overview over these effects, thus mapping out the 'dynamical phase space' of the Rabi model. In search of a unifying description we ask to which extent the effects can be described with dynamical variational states based on superpositions of coherent oscillator states. The limits of validity of standard approximations, such as the semi-classical approximation and the rotating wave approximation, are also discussed.

DY 6.7 Mon 15:45 ZEU 255

Under what conditions do quantum systems thermalize? New insights from quantum information theory — •Christian Gogolin[1,2,3], Markus P. Müller[1,4], and Jens Eisert[1,5] — [1]Institute for Physics and Astronomy, Potsdam University, 14476 Potsdam, Germany — [2]Fakultät für Physik und Astronomie, Universitä Würzburg, Am Hubland, 97074 Würzburg, Germany — [3]Department of Mathematics, University of Bristol, University Walk, Bristol BS8 1TW, UK — [4]Institute of Mathematics, Technical University of Berlin, 10623 Berlin, Germany — [5]Institute for Advanced Study Berlin, 14193 Berlin, Germany

Quantum mechanics is generally regarded as a fundamental theory of physics. As such, it should be able to provide us with a microscopic explanation of all phenomena we observe in macroscopic systems, including irreversible processes such as thermalization. With new mathematical tools from quantum information theory becoming available, there has been a renewed effort to settle the old question of the emergence of classicality and irreversibly. The talk gives an overview over recent progress in the field. In particular it is shown how equilibration and a maximum entropy Jaynes'-principle emerge as a natural consequence of unitary time evolution without any (Markov) approximation, and under which conditions the equilibrium state of a small subsystem is diagonal in the local energy eigenbasis as well as when, and when not, equilibration towards a thermal Boltzmann state can happen.

DY 6.8 Mon 16:00 ZEU 255

The Periodically Driven Dicke Model — •Victor Manuel Bastidas Valencia[1], John Henry Reina[2], Benjamin Regler[1], Clive Emary[1], and Tobias Brandes[1] — [1]Institut für Theoretische Physik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Deutschland — [2]Universidad del Valle, Departamento de Fisica, A. A. 25360, Cali, Colombia

We study the nonequilibrium quantum phase transition (NEQPT) in a periodically-driven Dicke model. The normal-superradiant quantum phase transition in equilibrium conditions has been extensively studied [1,2]. However, the physics of superradiance in nonequilibrium conditions is not completely understood. In order to investigate the nonequilibrium properties of the quantum phase transition in the case of time-dependent atom-field coupling we derive two effective time-independent Hamiltonians by using the rotating wave approximation (RWA) and perturbation theory in the high-driving frequency regime. These effective Hamiltonians allow the description of the quantum phase transition using the well known formulation of quantum phase transitions in time-independent systems. However, in the nonequilibrium case, the character of the quantum phase transition is dynamical and the spectrum of the effective Hamiltonians corresponds to the quasienergy spectrum of the original driven system in perturbation theory.

[1] R. H. Dicke, Phys. Rev. 93, 99 (1954).
[2] C. Emary and T. Brandes, Phys. Rev. E 67, 066203 (2003).

DY 6.9 Mon 16:15 ZEU 255

Gibbs states, exact thermalization of quantum systems, and a certifiable quantum algorithm for preparing thermal states — •Arnau Riera, Christian Gogolin, and Jens Eisert — Institute for Physics and Astronomy, University of Potsdam, 14476 Potsdam, Germany

We present three results related to the emergence of thermal states in quantum physics: a) It is known that if a system and its suitable environment are in a microcanonical ensemble, the system is found in a canonical or Gibbs state. Here we introduce precise conditions for the stronger statement of canonical ensembles to emerge for almost all pure states in the subspace corresponding to the energy interval defined by the microcanonical ensemble: This argument makes an idea due to Goldstein et al.\ fully rigorous, including error bounds when employing counting arguments and introducing a precise weak coupling limit, completing an idea going back to Schr{\"o}dinger in 1952.\ b) We establish conditions when subsystems of quenched quantum systems equilibrate to Gibbs states, addressing thermalization – in contrast to equilibration – in non-equilibrium many-body dynamics. c) We finally present a first quantum algorithm for preparing Gibbs states with a certified runtime, including full error estimates, complementing quantum Metropolis algorithms which are expected to be efficient but have no known runtime estimate.

Invited Talk DY 6.10 Mon 16:30 ZEU 255

The multiscale dynamics of lightning and of terrestrial gamma-ray flashes — •Ute Ebert — CWI Amsterdam, The Netherlands — Eindhoven Univ. Techn., The Netherlands

Today most research on cloud-to-ground lightning concentrates on lightning protection. But reserach on lightning physics received a new boost through the discovery of transient luminous events above active thunderstorms in 1990 and of terrestrial gamma-ray flashes from thunderstorms in 1994. In particular, sprite discharges that develop at 40 to 90 km altitude are the first lightning phenomena whose dynamics we now start to understand quantitatively. Sprites are up-scaled versions of streamer discharges, that play an important role in lightning, sparks and high voltage technology.

I will discuss how to bridge the 10 orders of magnitude between the underlying electron-molecule collisions and the km long lightning strokes. I will sketch the hierarchy of dynamical phenomena, and I will focus on: 1. the nonlinear dynamics of sprite and streamer discharges. They are modeled by reaction-drift-diffusion equations and form finger-like structures, that are similar to fingers in two-fluid-flow, in dendritic solidification fronts etc. 2. the single electron dynamics within the streamer. If the field at the finger tip is sufficiently enhanced, the electron density approximation breaks down locally, and electrons run away. This is a possible cause of terrestrial gamma-ray flashes.

Find more information on http://homepages.cwi.nl/~ebert.