DY 8: Quantum Dynamics, Decoherence, and Quantum Information I

Time: Tuesday 10:00–13:00 Location: H38

DY 8.1 Tue 10:00 H38

Density dynamics in the anisotropic Heisenberg spin-1/2 chain at high temperatures: A current-autocorrelation approach to finite time and length scales — •Robin Steinigeweg — Institute for Theoretical Physics, Technical University of Braunschweig, Mendelsohnstr. 3, D-38106 Braunschweig, Germany

The transport of magnetization is investigated for the anisotropic Heisenberg spin-1/2 chain in the limit of high temperatures. The approach is essentially based on a connection between the evolution of the variance of an inhomogeneous nonequilibrium density and the current-autocorrelation function at finite times. Although this relationship is not restricted to the case of diffusive transport, it allows to extract a quantitative value for the diffusion constant in that case. By means of numerically exact diagonalization we indeed observe diffusive behavior for anisotropies which are larger than 1 and additionally confirm the diffusion coefficients which were obtained for these anisotropies from nonequilibrium bath scenarios.

DY 8.2 Tue 10:15 H38

Dissipative Excitonic Dynamics with Trapping — •Oliver Mülken, Tobias Schmid, Alexander Blumen, and Lothar Mühlbacher — Institut für Physik, Universität Freiburg, Freiburg, Germany

The trapping of excitations in systems coupled to an environment allows to study the quantum to classical crossover by different means. We show how to combine the phenomenological description by a non-hermitian Liouville-von Neumann Equation (LvNE) approach in the Lindblad form to the numerically exact Path Integral Monte-Carlo (PIMC) method, and examplify our results by considering coupled two-level systems. By varying the coupling strenght to the environment we are able to estimate the parameter range in which the LvNE approach yields satisfactory results. Moreover, by matching the PIMC results with the LvNE calculations we have a powerful tool to extrapolate the numerically exact PIMC method to long times.

References:
[1] Mülken et al., Phys. Rev. Lett 99, 090601 (2007).
[2] Mülken, Schmid, Blumen, and Mühlbacher, submitted (2009).
[3] Mülken and Mühlbacher, in preparation (2009)

DY 8.3 Tue 10:30 H38

Cold and hot finite quantum systems in contact: energy flow and temperature equilibration — •Alexey V. Ponomarev, Sergey Denisov, and Peter Hanggi — Institute of Physics, University of Augsburg, Germany

Relaxation toward the canonical state is commonly attributed to a situation where a small system of interest is coupled to a huge one (the Universe, a heat bath, etc). Here we focus on the case of two identical quantum systems composed of a finite number of bosons. Both the systems are initially prepared in Gibbs states at different temperatures, $\rho_A(T_A)$ and $\rho_B(T_B)$, and isolated from the external environment. Then the systems are brought into a thermal contact.

We demonstrate that the energy starts to flow from a "hot" system to a "cold" one until the system energies equilibrate. There are two possible distinguishable relaxation regimes. In the first regime, each of the systems evolves toward the state characterized by the arithmetic average of their initial density matrices, $\rho_A(T_A)/2 + \rho_B(T_B)/2$. The second regime substantiates what we would expect from the equilibration of two big, classical bodies: (i) both the quantum systems relax to the thermal (Boltzmann) states with equal temperatures; and (ii) the relaxation process has a quasistatic character, i. e. each system passes through a chain of intermediate thermal (Boltzmann) states. With that, we show for the first time that a non-equilibrium thermodynamic process can be reproduced within an isolated finite bipartite quantum system.

DY 8.4 Tue 10:45 H38

Quantum non demolition measurement of a single nuclear spin in a room temperature solid — Phillip Neumann[1], Johannes Beck[1], Matthias Steiner[1], Helmut Rathgen[1], •Florian Rempp[1], Navid Zarrabi[1], Florian Dolde[1], Philip Hemmer[2], Fedor Jelezko[1], and Jörg Wrachtrup[1] — [1]Universität Stuttgart, Deutschland — [2]A&M University,Texas

The measurement process and its interpretation are in the focus of quantum mechanics since its early days. Today's ability to isolate single quantum objects allows experimental demonstration of former "gedankenexperiments" like measurement induced quantum state collaps. Rapidly growing quantum technologies explore fundamental aspects of measurements in quantum computing, however for solid state systems such experiments require operation at very low temperatures. Here we show that projective quantum measurement can be performed on a single nuclear spin in diamond under ambient conditions. Using quantum non demolition (QND) readout we are able to detect quantum jumps and the quantum Zeno effect emphasising the addressability of fundamental questions of quantum mechanics in solids. Single shot measurements with fidelities exceeding 0.9 enable efficient state initialization, quantum error correction and entanglement pumping that is crucial for quantum information processing including measurement based schemes and distributed quantum networks.

DY 8.5 Tue 11:00 H38

The speed of Markovian relaxation towards the ground state — •Malte Vogl, Gernot Schaller, and Tobias Brandes — Institut für Theoretische Physik, Hardenbergstr. 36, D-10623 TU Berlin

For sufficiently low reservoir temperatures, it is known that open quantum systems subject to decoherent interactions with the reservoir relax towards their ground state in the weak coupling limit. Within the framework of quantum master equations, this is formalized by the Born-Markov-secular (BMS) approximation, where one obtains the system Gibbs state with the reservoir temperature as a stationary state. When the solution to some problem is encoded in the (isolated) ground state of a system Hamiltonian, decoherence can therefore be exploited for computation. The computational complexity is then given by the scaling of the relaxation time with the system size n.

In this contribution [1] we study the relaxation behavior for local and non-local Hamiltonians that are coupled dissipatively with local and non-local operators to a bosonic bath in thermal equilibrium. We find that relaxation is generally more efficient when coherences of the density matrix in the system energy eigenbasis are taken into account. In addition, the relaxation speed strongly depends on the matrix elements of the coupling operators between initial state and ground state.

We show that Dicke superradiance is a special case of our relaxation models and can thus be understood as a coherence-assisted relaxation speedup.

[1.] M. Vogl, G. Schaller, and T. Brandes, arxiv:0908.1026v1.

DY 8.6 Tue 11:15 H38

Validity of the Landauer's principle in the quantum regime — •Stefanie Hilt[1], Janet Anders[2], Eric Lutz[1], and Saroosh Shabbir[2] — [1]Department of Physics, University of Augsburg, 86135 Augsburg, Germany — [2]Department of Physics, University College London, London, WC1E 6BT, UK

Landauer's principle gives a lower bound to the heat dissipated during the erasure of information. It is a key component of quantum information processing, since it provides a fundamental connection between information theory and thermodynamics. The validity of the erasure principle has been challenged constantly, especially in the quantum regime where entanglement plays an important role. We show that the Landauer bound holds even in the strong-coupling quantum regime.

DY 8.7 Tue 11:30 H38

Transport dynamics below the localization length in the 3-d Anderson model — •Jochen Gemmer[1], Robin Steinigeweg[2], and Hendrik Niemeyer[1] — [1]University Osnabrueck, Physics Departement — [2]University Braunschweig, Physics Departement

As wellknwon the Anderson model shows localization at all energies if the on-site disorder exeeds some critical value. However, below the critical disorder there are non-localized energy regimes, furthermore there may be relevant spatial dynamics on scales below the localization length at all regimes. We analyze those dynamics finding that they may be described as diffusive with quantitative diffusion coefficients and meaningful mean free paths, particle velocities, etc. This is shown to hold for all degrees of disorder up to the critical disorder.

DY 8.8 Tue 11:45 H38

Open quantum systems: The Third Law and the conundrum of negative specific heat — •Peter Hänggi — Universität Augsburg, Institut für Physik, Universitätsstr. 1, 86135 Augsburg

We consider the validity of the Third Law in open quantum systems and evaluate the specific heat C. Two routes for obtaining C are presented. The first one uses the measurement of the expectation of the system Hamiltonian while the second one is based on the reduced partition function of the open quantum system, which is the ratio of the partition functions of system plus bath and of the bath alone. Both descriptions yield results which are consistent with the Third Law of thermodynamics. Interestingly, the two methods produce different results that disagree even in their leading quantum corrections at high temperatures. As specific examples we use (i) a damped two-level fluctuator, (ii) a damped harmonic oscillator and (iii), a free particle coupled with finite friction strength to a bath. For zero coupling this latter system presents an exception to the validity of the Third Law (ideal gas of free particles). We detect parameter regimes for which the specific heat C of the open system is negative. This issue is contrasted with thermodynamic rigorous stability criteria and resolved.
References:
[1-3] G. Ingold, P. Hänggi, and P. Talkner: *Specific heat anomalies of open quantum systems*, Phys. Rev. **E 79**, 061105 (2009); P. Hänggi, G. L. Ingold, and P. Talkner: *Finite quantum dissipation: the challenge of obtaining specific heat*, New J. Phys. **10**, 115008 (2008); P. Hänggi and G. L. Ingold: *Quantum Brownian motion and the third law of thermodynamics* Acta Physica Polonica **B 37**, 1537 (2006).

DY 8.9 Tue 12:00 H38

Simple stochastic simulation of open quantum systems — •Jürgen T. Stockburger — Universität Ulm, Institut für Theoretische Physik, 89069 Ulm

The quantum dynamics of a system coupled to a reservoir with Gaussian quantum fluctuations can be recast in the form of a stochastic Liouville-von Neumann (SLN) equation involving noise forces which are classical variables bearing the spectral properties of quantum statistical fluctuations [1]. Until recently, related numerical methods used either a linear or a normalized, nonlinear SLN equation. Linear equations yield simulations that are simple and stable but resource-intensive. Normalized equations yield faster convergence but suffer from instabilities, which have so far been curable [2] only by resorting to complicated algorithms. New hybrid or “soft normalization” methods lead to simulations which combine the advantages of both earlier approaches.

[1] Stockburger, J.T. and Grabert, H., *Phys. Rev. Lett.* **88**, 170407 (2002)

[2] Stockburger, J.T., *Chem. Phys.* **296**, 159 (2004)

DY 8.10 Tue 12:15 H38

Optimal coherent control of noisy and open quantum systems — •Rebecca Schmidt, Joachim Ankerhold, and Jürgen T. Stockburger — Universität Ulm, Institut für Theoretische Physik, 89069 Ulm

The coherent optimal control of quantum dynamics has become an important design paradigm in modern tailored-matter applications such as quantum information processing and ultracold atoms in addition to its established use in chemical physics. We extend Krotov’s formulation of optimal control theory to noisy and open quantum systems, using an exact stochastic model for the quantum fluctuations of reservoir modes [1]. As a non-trivial test model we demonstrate optimal control of the harmonic oscillator under the control of simultaneous linear and parametric driving fields. As a concrete result, we find the potential of cooling translational motion without reference to internal degrees of freedom.

[1] Stockburger, J.T. and Grabert, H., *Phys. Rev. Lett.* **88**, 170407 (2002)

Invited Talk DY 8.11 Tue 12:30 H38

Quantum search algorithms and quantum communication on networks — •Gregor Tanner and Birgit Hein — School of Mathematical Sciences, University of Nottingham, University Park, Nottingham NG7 2RD, UK

Quantum search algorithms - both for an ordered list and on an extended network - are based on propagating a well known initial quantum state into a localised target state. Grover’s algorithm, one of the corner stones of modern quantum information theory, predicts a square root speed up of a search protocol based on wave mechanics compared to a ”classical” search. I will discuss extensions of Grover’s ideas to searches on networks. I will summarise the connections between quantum random walks, quantum searches and quantum graphs, and will offer a new interpretation of a quantum search in terms of avoided crossings and localised defect states.

Setting up a communication channel between two parties is in fact closely related to a two-way search. Starting from this observation, it will be shown that wave mechanics can be used to send signals efficiently between a sender and a receiver where neither party knows the address of the other. Possible experimental realisations will be discussed.