TT 1: Tutorial: Nonequilibrium Renormalization Group Methods

This tutorial provides introductions to three essentially analytic renormalization-group-like approaches to the quantum many-body problem in non-equilibrium. They constitute versatile tools to investigate driven steady states as well as the nonequilibrium dynamics of correlated systems in different fields of growing interest such as, e.g., meso- and nanoscopic solid-state systems, as well as cold atomic gases.

Organizer: Volker Meden (RWTH Aachen)

Time: Sunday 16:00–18:15 Location: H 0110

Introductory Remarks

Tutorial TT 1.1 Sun 16:05 H 0110

From Lunar Motion to Real Time Evolution of Quantum Many-Body Systems — •Stefan Kehrein — Institute for Theoretical Physics, Georg-August-Universität Göttingen, 37077 Göttingen, Germany

While studying the real time evolution of quantum many-body systems is a fairly new topic in physics, the real time evolution of classical systems is an old one. In fact, this topic goes back to the very beginning of classical mechanics, namely its application to celestial mechanics. One of the important lessons learned in this classical setting is that naive application of perturbation theory can lead to secular terms in time which quickly invalidate the expansion. This observation gave rise to the development of canonical perturbation theory with much improved convergence properties.

In this lecture I will show how similar progress can be made for the calculation of the real time evolution of quantum systems by using unitary perturbation theory [1,2,3]. In addition, this approach permits one to deal with models with a nontrivial renormalization flow and to see how this affects the real time dynamics away from equilibrium.

[1] A. Hackl and S. Kehrein, Phys. Rev. B **78**, 092303 (2008)
[2] A. Hackl and S. Kehrein, J. Phys. C **21**, 015601 (2009)
[3] F. Essler, S. Kehrein, S. Manmana, and N. Robinson, Phys. Rev. B **89**, 165104 (2014)

5 min. break

Tutorial TT 1.2 Sun 16:50 H 0110

Functional Renormalization Group Approach to Nonequilibrium Transport through Mesoscopic Systems — •Severin Georg Jakobs — Institute for Theory of Statistical Physics, RWTH Aachen, 52056 Aachen, Germany

The transport properties of quantum dots and wires are strongly influenced by correlation effects like the Kondo effect or Luttinger liquid behavior. The theoretical description of these effects requires methods beyond plain perturbation theory or mean-field theory. In the last decade, the functional renormalization group (fRG) has been used extensively and successfully to investigate such situations. It is applicable if the interaction on the dot is weak to intermediate compared to the hybridization with the leads. This makes the method complementary to the real-time RG which applies to the opposite regime and which is described in the tutorial by Herbert Schoeller. The particular formulation of the fRG in the framework of Keldysh formalism allows to study time-dependent and steady-state nonequilibrium situations. In this tutorial I introduce the basic concepts of that method and discuss the choice of appropriate flow parameters. I discuss examples for steady-state transport at finite bias voltage and for the time-dependent transient regime.

5 min. break

Tutorial TT 1.3 Sun 17:35 H 0110

Real-Time RG: Nonequilibrium Properties of Open Quantum Systems — •Herbert Schoeller — Institute for Theory of Statistical Physics, RWTH Aachen, 52056 Aachen, Germany — JARA-Fundamentals of Future Information Technology

A tutorial introduction is presented for the description of nonequilibrium properties of few-level quantum sytems coupled to reservoirs as e.g. realized by quantum dot, spin boson or Kondo models. Within a quantum field theoretical framework in Liouville space it is shown how formally exact kinetic equations can be derived which can be systematically studied in terms of an effective Liouvillian. By using special resummation techniques via self-consistent perturbation theory and renormalization group methods it is shown how the time evolution and the stationary state can be studied in a nonequilibrium set-up. Various applications in the weak and strong coupling limit are presented.