



Students' retreat 2016

Innsbruck

Feb 28th - Mar 2nd



DFG Deutsche
Forschungsgemeinschaft

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Welcome address

Welcome to this year's PhD students' retreat of the DFG research group FOR1807 from February 28th to March 2nd in Innsbruck. In this booklet you will find general information on the schedule, the abstracts of the students' talks, a list of the participants, and some (hopefully) useful information on accomodation and Innsbruck's public transport.

The official part of the workshop will begin Monday morning 9:00 at Innsbruck university (room *HSB 2*). The general schedule is:

9:00 – 12:30	Lectures on Many-Body-Localization on Monday and Tuesday, students talks on Wednesday
13:30 – 17:30	Students talks on Monday and Tuesday
19:00 – 22:00	Possibility to present and discuss presentations for DPG spring meeting in Regensburg

The lectures are held by Jens Bardarson and Frank Pollmann from *Max-Planck Institute for Physics of Complex Systems* in

Dresden and are meant to give both a theoretical and conceptual introduction into the notion of Many-Body-Localization accompanied by educational examples in physical systems.

Furthermore, since the meeting is going to be held right before the DPG spring meeting in Regensburg, there will be the possibility to present and discuss the presentations for the DPG meeting. Therefore the room *HSB 2* at Innsbruck university can be accessed until 22:00 in the evening.

We hope you'll enjoy your time in Innsbruck!



Accommodation and public transport

We have reserved rooms for all participants at

Garni-Technikerhaus

Fischnalerstraße 26

6020 Innsbruck

<http://www.garni-technikerhaus.at>

If you are arriving by train or Fernbus at the main station, take the bus *line R* heading to *Rehgasse* and exit at the stop *Technikerhaus* just in front of the accommodation. The cheapest way for using the bus is buying *5-Fahrtentickets*, so tickets for 5 rides at the selling machines for 8 Euro.

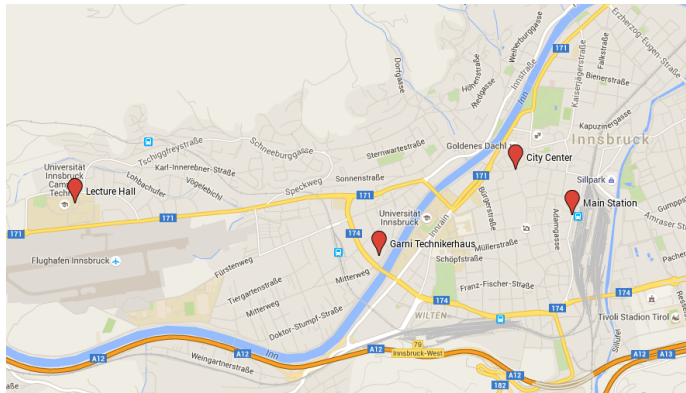
The lectures and talks will take place at

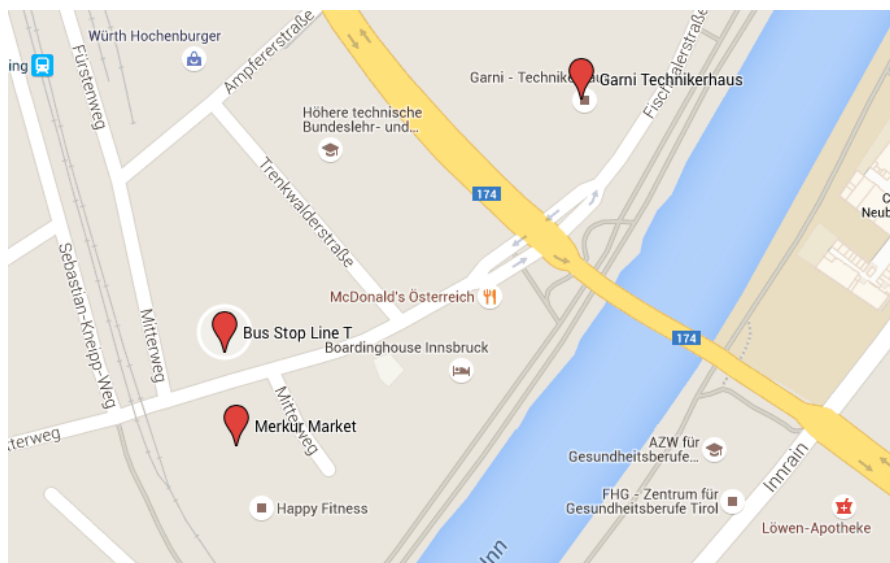
HSB2 Campus Technik

Technikerstrasse 13

6020 Innsbruck

To get there from the accommodation take the bus *line T* heading to *Völs EKZ-Cyta* leaving from the stop *Mitterweg Unterführung* opposite of the Merkur market next to the McDonalds close to the Technikerhaus. Get off at the busstop *Technik*. For details see the maps on the next two pages.





Talks Monday, February 29th

Large scale QMC on a spin=1/2 XY-model with ring exchange on a Kagome lattice

Monday
Feb 29th
13:30 – 14:15

Maximilian Lohöfer
Aachen

In 2011 L. Dang S. Inglis and R. Melko investigated a ferromagnetic spin-1/2 XY-Model on a Kagome-lattice that shows signs of a quantum spin liquid and is treatable with Quantum Monte Carlo (QMC) sign problem free. So far only thermodynamic properties of this system have been investigated. They show a quantum phase transition from a superfluid to a quantum spin liquid phase. Here we show large scale QMC simulation results of dynamic quantities such as the longitudinal and transversal spin structure factor. Employing a state of the art stochastic series expansion algorithm combined with stochastic analytic continuation, we have access to the full spectral information of the system in high quality. Allowing insight into the time resolved correlations of a spin liquid with high numerical accuracy for the first time.

Chiral Spin Liquids in frustrated quantum magnetism

Alexander Wietek
Innsbruck

Monday
Feb 29th
14:15 – 15:00

Topological states of matter as spin liquids are of fundamental interest in contemporary condensed matter physics. Chiral Spin liquids have recently been found in extended Heisenberg models on the kagome lattice. We demonstrate that these spin liquids can be understood in terms of Gutzwiller projected parton wavefunctions by directly comparing the groundstates of these models from exact diagonalization to the parton wavefunctions. Furthermore we present results where similar chiral spin liquid phases can be found in phase diagrams on the triangular lattice and in a class of $SU(N)$ models.

Non equilibrium behavior in spin ice $Dy_2Ti_2O_7$

Andre Sokolowski
Berlin

Monday
Feb 29th
15:30 – 16:00

This presentation focuses on the spin ice system $Dy_2Ti_2O_7$ (DTO). The geometrical frustration in these systems inhibits the formation of a single ground state configuration [1], but recent studies reveal a possible onset of an ordered state at very long waiting times [2]. I will present our latest experiments of the out-of-equilibrium (ac susceptibility and heat conductivity) and in-equilibrium (neutron scattering and heat capacity) state of DTO.

[1] Mostame, S.; Castelnovo, C.; Moessner, R. & Sondhi, S. L., arXiv, 2013, 09, 1

[2] Pomaranski, D et al., Nat Phys, Nature Publishing Group, 2013, 9, 353-356

Monday
Feb 29th
16:00 – 16:30

DMRG as an impurity solver for DMFT

Nils-Oliver Linden
München

We present a new impurity solver for dynamical mean-field theory based on imaginary-time evolution of matrix product states. This converges the self-consistency loop on the imaginary-frequency axis and obtains real-frequency information in a final real-time evolution. Relative to computations on the real-frequency axis, required bath sizes are much smaller and less entanglement is generated, so much larger systems can be studied.

Monday
Feb 29th
16:30 – 17:00

Dynamics of photo excitations in 1D-Hubbard systems

Thomas Köhler
Göttingen

We compute the dynamics following a photo excitation in one dimensional Hubbard systems at different temperatures T using matrix product state (MPS) approaches. We discuss the effect of temperature on the propagation of these excitations and give an outlook for systems with time dependent Hamiltonians.

U(1)-invariant tensor networks, an MPS realization

Sebastian Paeckel
Göttingen

Monday
Feb 29th
17:00 – 17:30

In this tutorial i'm going to present exemplary how to incorporate abelian symmetries into a Matrix-Product state formulation of quantum systems. In contrast to common literature the focus is onto the technical issues arising when implementing the usual matrix operations in a block diagonal fashion in order to improve the performance of MPS calculations whilst the representation theoretical background is considered only whenever necessary. Thereby i hope to give a practical insight into a subject which may be a key issue to push forward the developement of MPS formalism.

Talks Tuesday, March 1st

Properties of the single-site reduced density matrix in the Bose-Bose resonance model in equilibrium and in quantum quenches

Tuesday
Mar 1st
13:30 – 14:15

Florian Dorfner
München

We study properties of the single-site reduced density matrix in the Bose-Bose resonance model as a function of system parameters. This model describes a single-component Bose gas with a resonant coupling to a molecular state, here defined on a lattice. Our main goal is to demonstrate that the eigenstates of the single-site reduced density matrix have characteristic properties in the various quantum phases of this system. Since the Hamiltonian conserves only the global particle number but not the number of bosons and molecules individually, these eigenstates, referred to as optimal modes, can be nontrivial linear combinations of bare eigenstates of the molecular and boson particle number. We numerically analyze the optimal modes and their weights, the latter giving the importance of the corresponding state, in the ground state of the Bose-Bose resonance model. For the ground state, we find that the single-site von Neumann entropy is sensitive to the position of the phase boundaries. We explain the structure of the optimal modes and their weight spectra using perturbation theory and via a comparison to results for the one-species Bose-Hubbard model. We further study the dynamical evolution of the optimal modes and of the single-site entanglement entropy in two quantum quenches that cross phase boundaries

between different phases of the model. For our numerical calculations, we use exact diagonalization and the time-evolving block decimation method.

Dynamics of fermions in a cavity-induced artificial magnetic field by exact diagonalization

Stefan Wolff
Bonn

Tuesday
Mar 1st
14:15 – 15:00

We show how the coupling of a fermionic quantum gas trapped in an optical lattice to a single mode of an optical cavity induces a self-organization process. Via a feedback-mechanism of the atoms with the photon-field of the cavity in combination with a vertical running optical pump laser, an effective artificial magnetic field, felt by the fermions, is created. This flux can play a similar role as strong external magnetic fields in quantum Hall systems and might give access to novel topological phases. We present results on the real-time dynamics of this open system, which is accessed by the exact diagonalization of the corresponding Lindblad-operator. Furthermore we investigate the asymptotic behavior, by finding the stationary states in different symmetry sectors of the Lindbladian and complement our results with adiabatic elimination techniques concerning the cavity field.

Electron-phonon scattering in one-dimensional systems

Tuesday
Mar 1st

15:30 – 16:15

Christoph Brockt
Hannover

We present a study of the scattering of an electronic wave packet by local phonon modes on a one-dimensional lattice. The problem is addressed both numerically and analytically. For the numerical part we use a newly developed method for simulating the time evolution of systems with large local Hilbert spaces. It combines the time-evolving block-decimation algorithm with a dynamical optimization of the local boson basis. The optimal boson modes cannot only be used to speed up the simulations but also for gaining insight into the physics of the system.

Thermodynamic and spectral properties of one-dimensional electron-phonon models in the adiabatic limit

Tuesday
Mar 1st

16:15 – 17:00

Manuel Weber
Würzburg

In one-dimensional electronic systems at half-filling, electron-phonon coupling can lead to lattice dimerization accompanied by charge-density or bond-density wave order. According to Peierls' theorem, the ground state is ordered for any nonzero coupling when quantum lattice fluctuations are neglected. In this adiabatic limit, the lattice displacements become classical variables that can be sampled in a Monte Carlo simulation. For each phonon configuration, the resulting fermionic Hamiltonian can be diagonalized exactly. Considering the Holstein model and the Su-Schrieffer-Heeger model, we study the formation of the Peierls-insulating ground states as a function of temperature. At low temperatures, we

observe a peak in the specific heat associated with the opening of a band gap, and the formation of shadow bands as well as polaron signatures in the single-particle spectrum.

Efficiency of the Hybrid Quantum Monte Carlo method for Hubbard type models

Stefan Beyl
Würzburg

Tuesday
Mar 1st
17:00 – 17:30

The Hybrid Quantum Monte Carlo method has the potential advantage of reaching very large system sizes for Hubbard type models since it can scale linearly with the euclidean volume. Here we argue that the performance of the method is strongly dimension dependent. In the one-dimensional case, the fact that the fermion matrix has no zeros leads to a stable algorithm which scales more efficiently than generic auxiliary field method. In two dimensions the fermionic matrix has zeros thereby leading to a breakdown of ergodicity. We propose to use a complex Hubbard Stratonovich transformation to avoid this problem.

Talks Wednesday, March 2nd

Interaction effects on topologically protected edge states in d-wave superconductors like high-Tc YBCO[†]

Wednesday
Mar 2nd
9:00 – 9:45

Johannes Hofmann
Würzburg

Nodal topological superconductors display zero-energy Majorana flat-bands at generic edges. The flatness of these edge bands, which is protected by time-reversal and translation symmetry, gives rise to an extensive ground state degeneracy and a diverging density of states. Therefore, even arbitrarily weak interactions lead to an instability of the flat-band edge states towards time-reversal and translation-symmetry broken phases, which lift the ground-state degeneracy. We employ Monte Carlo simulations combined with mean-field considerations to examine the instabilities of the flat-band edge states of d_{xy} -wave superconductors. We find that attractive interactions induce a complex s -wave pairing instability together with a density wave instability. Repulsive interactions, on the other hand, lead to ferromagnetism mixed with spin-triplet pairing at the edge. We discuss the implications of our findings for experiments on cuprate high-temperature superconductors.

[†] <http://arxiv.org/abs/1512.04547>

Variational cluster approximation for superconductivity in the Kondo lattice model

Benjamin Lenz
Göttingen

Wednesday
Mar 2nd
9:45 – 10:30

The variational cluster approximation (VCA) allows to study broken symmetry phases of various lattice models at zero temperature. However, most research has been done on electron systems without coupling to additional spins. Here, we investigate the Kondo lattice model (KLM) - a paradigmatic model for heavy fermion materials which contains interactions between electrons and localized spins. We first focus on the antiferromagnetic ground state in the half-filled KLM and compare our finite-size extrapolated VCA results to those of other established techniques, like Quantum Monte Carlo. We further ask for the existence of superconductivity at finite doping in this model, motivated by findings for heavy fermion systems and dynamical mean-field theory (DMFT)[1]. We probe the system for s- and d-wave superconductivity and present an analysis of the different ground states of the model which emerge when tuning the electron filling and exchange coupling strength J .

[1] Bodensiek, Zitko, Vojta, Jarrell, and Pruschke, PRL 110, 146406 (2013).

Finite-T dynamics with variational cluster approximation

Mirco Marahrens
Stuttgart

Wednesday

Mar 2nd

11:00 – 11:30

In this short technical talk I will present the planned project $P7_N$ with the mentioned topic. It is related to the work on the matrix product state approaches of the workgroup in Göttingen. This talk contains mainly the theoretical background of the project, e.g. Cluster Perturbation Theory and Variational Cluster Approximation at finite temperature and an introduction to multi-orbital Hamiltonians. Further I would like to present some results on time-dependence of excitations in the Kugel-Khomskii model with an $SU(2) \times SU(2)$ symmetry at $T = 0$, which is part of my current work.

Effective One-Dimensional Models from Matrix Product States

Frederik Keim
Dortmund

Wednesday

Mar 2nd

11:30 – 12:15

Effective models in second quantization are a powerful tool in understanding the low energy physics of condensed matter systems. Analytical approaches to derive them are, however, limited to special cases. We present a largely unbiased variational method to derive an effective model on the bi-linear level, based on the framework of matrix product states (MPS). Using the transfer matrix method, MPS work very efficiently in the thermodynamic limit for one-dimensional systems. We show how to derive an expression for the local creation operator of the elementary excitation and validate it by using it to compute the spectral weight. We also discuss the progress in and the challenges of taking the approach beyond the bi-linear level.

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