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WORKSHOP ON
INTEGRABILITY AND ITS BREAKING
IN STRONGLY CORRELATED AND
DISORDERED SYSTEMS

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BOOK OF ABSTRACTS

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PREFACE

The physical consequences of integrability and its (weak) breaking in many body systems manifest themselves in systems such as cold atoms and conductor-insulator transitions in one dimension, as well as in specific spectral properties. It may also entail the absence of ergodicity, which in turn has deep implications on the dynamics.

The concept of integrability and its breaking is closely related to localizaton and diffusion in the Fock space of strongly disordered, interacting systems.

Finally, breaking of integrability may lead to highly non-perturbative phenomena such as the confinement of quasi-particle of topological type and decays of those with higher masses.

This workshop aims at exploring the various incarnations and effects of integrability and its breaking in many-body, strongly interacting and disordered systems, stimulating cross fertilization and discussions between researchers in the various subfields.

THE ORGANIZERS

T. Giamarchi (University of Geneva)
V. Gritsev (University of Fribourg)
M. Müller (ICTP Trieste)
G. Mussardo (SISSA Trieste)
A. Silva (ICTP Trieste)

ABSTRACTS OF TALKS

(sorted as per programme of the workshop)

Dynamical Theory of Superfluidity in One Dimension

Miguel A. Cazalilla
CSIC San Sebastian

A theory accounting for the dynamical aspects of the superfluid response of one dimensional (1D) quantum fluids is reported. In long 1D systems, the onset of superfluidity is related to the dynamical suppression of quantum phase slips at low temperatures. The effect of this suppression as a function of frequency and temperature is discussed within the framework of the relevant correlation function that is accessible experimentally, namely the momentum response function. Application of these results to the understanding of the superfluid properties of helium confined in nanometer-size pores, dislocations in solid ^{4}He, and ultra-cold atomic gases is also briefly discussed.

Universal energy fluctuations in driven thermally isolated systems

Anatoli Polkovnikov
Boston University

In this talk I will describe constraints of unitary dynamics on time evolution of driven thermally isolated systems. I will mention first consistency of unitary dynamics with laws of thermodynamics and show how unitarity trivially leads to quantum fluctuation theorems (Jarzynski and Crooks relations). Then I will describe fluctuation-dissipation relations satisfied by energy diffusion in such systems away from canonical equilibrium, which are direct consequence of these fluctuation theorems. From these relations I will derive universal width of energy fluctuations in driven isolated systems. I will discuss the role of integrability for these results and give specific illustrations including repeatedly driven quantum spin chains.

Quantum Quenches, Thermalization and Many-Body Localization

Rosario Fazio
SNS Pisa

We conjecture that thermalization following a quantum quench in a strongly correlated quantum system is closely connected to many-body delocalization in the space of quasi-particles. This scenario is tested in the anisotropic Heisenberg spin chain with different types of integrability-breaking terms. We first quantify the deviations from integrability by analyzing the level spacing statistics and the inverse participation ratio of the system's eigenstates. We then focus on thermalization, by studying the dynamics after a sudden quench of the anisotropy parameter. Our numerical simulations clearly support the conjecture, as long as the integrability-breaking term acts homogeneously on the quasiparticle space, in such a way as to induce ergodicity over all the relevant Hilbert space.

[1] E. Canovi, D. Rossini, R. Fazio, G. E. Santoro, and A. Silva Phys. Rev. B 83, 094431 (2011).

Generalized Thermalization in an Integrable Lattice System

Marcos Rigol
Georgetown University

Once only of theoretical interest, integrable models of one- dimensional quantum many-body systems can now be realized with ultracold gases. The possibility of controlling the effective dimensionality and the degree of isolation in the experiments have allowed access to the quasi-1D regime and the long coherence times necessary to realize integrable models. In general, in integrable quantum systems that are far from equilibrium, observables cannot relax to the usual thermal expectation values. This is because of the constraints imposed by the non-trivial set of conserved quantities that make these systems integrable. Experimentally, relaxation of the momentum distribution to a non-thermal expectation value was recently observed in a cold-atom system close to integrability. At integrability, it is natural to describe the observables after relaxation by an updated statistical mechanical ensemble: the generalized Gibbs ensemble (GGE), which is constructed by maximizing the entropy subject to the integrability constraints. In recent studies, the GGE has been found to accurately describe various observables in the steady state of integrable systems, but a microscopic understanding of its origin and applicability remains elusive. In this talk, we review some of the early results on this topic and discuss the justification of the GGE based on a generalized view of the eigenstate thermalization hypothesis, which was originally introduced to explain thermalization in nonintegrable systems.

Reference: A. C. Cassidy, C. W. Clark, and M. Rigol, Phys. Rev. Lett. 106, 140405 (2011).

Searching for the onset of thermalization in a 1D Bose gas

David Weiss
Penn State University

Atoms trapped in 2D optical lattices closely approximate the Lieb-Liniger model of a 1D Bose gas. Among the many features of this model that have been observed experimentally, perhaps the most striking is that these 1D gases are observed to not thermalize over long time scales. We are attempting to observe the onset of thermalization. Thermalization should only happen to the extent that the mapping to the integrable model is not exact, and so we are studying a nearly integrable many-body quantum system in what would be the "quantum KAM regime", if such a regime exists. The larger goal is to understand what conditions are required for an isolated many-body quantum system to be well-described by statistical mechanics. In the course of this work we have had to characterize in great detail the various heating mechanisms that can mask the underlying non-equilibrium evolution of cold atom experiments.

Weak Interaction Quenches and Thermalization in Quantum Many-Body Systems

Stefan Kehrein
LMU Munich

I will review recent work on quantum quenches in the Hubbard model and in quantum impurity models. The interaction quench in the Hubbard model permits to explore the opposite limit of the adiabatic switching procedure in the Landau Fermi liquid paradigm. The real time evolution shows the phenomenon of prethermalization, which is related to a universal relation between nonequilibrium and equilibrium expectation values for weak interaction quenches. Based on the flow equation method we will also find universal Crooks-like relations for the work distribution function for quenches in quantum impurity systems.

Quantum dynamics of split one dimensional condensates and prethermalization

Eugene Demler
Harvard University

Results of recent theoretical and experimental analysis of equilibration dynamics of coherently split one-dimensional Bose gases will be reviewed. It will be shown that one can characterize dynamical states of the system using measurements of full distributions of matter-wave interference patterns on different length scales. Existence of two physically distinct regimes of relaxation will be demonstrated, corresponding to phase diffusion and contrast decay. Experimental results suggesting the existence of an apparent steady state characterized by an effective temperature eight times lower than the initial equilibrium temperature of the system will be presented and theoretical arguments for the existence of such prethermalized state will be provided.

Non equilibrium quantum criticality in quantum gases and Josephson junctions subject to external noise

Ehud Altman
Weizmann Institute

We show that in certain quantum critical systems the ubiquitous 1/f noise acts as a marginal perturbation and gives rise to a new type of non-equilibrium critical state. We then use the new critical points as a basis for perturbative renormalization group analysis in real time to treat universal phenomena out of thermal equilibrium. In generic cases, when the critical steady states are unstable, a thermal state is established as a fixed point of the RG flow. We characterize universal crossovers within the thermal state that are controlled by the proximate non equilibrium critical point. We illustrate these general phenomena with specific examples describing Josephson junctions and ultra-cold atomic systems.

Quantum Quench in the Transverse Field Ising Chain

Fabian Essler
Oxford University

I consider the time evolution of observables in the transverse field Ising chain (TFIC) after a sudden quench of the magnetic field. I present exact analytical results for the asymptotic time and distance dependence of one- and two-point correlation functions of the order parameter. These results are obtained through two complementary approaches based on asymptotic evaluations of determinants and form-factor sums. The stationary value of the two-point correlation function is found to be non-thermal, but can be described by a generalized Gibbs ensemble (GGE). The approach to the stationary state can also be understood in terms of a GGE. Generalizations are discussed.

Understanding Quantum Quenches through a Numerical Renormalization Group

Robert Konik
Brookhaven National Laboratory

We use a numerical renormalization group adapted to continuum field theories to study quantum quenches in a number of systems. We will discuss results on thermalization in systems, both integrable and non-integrable, with a discrete Z2 symmetry as well as thermalization in the Lieb Liniger model in a trap.

David Alan Tennant
TU Berlin

TBA

Impurity dynamics in one-dimensional fermion gas

Mikhail Zvonarev
Harvard University

We consider the dynamics of initially localized wave packet interacting with one-dimensional fermion gas. We identify the relevant energy scales for the problem and discuss the crossover from the short- to long-time dynamics, especially focusing on the range of parameters relevant for the current (Cambridge, Innsbruck) and future experiment.

Dynamics of impurities in a one-dimensional bosonic gas

Francesco Minardi

LENS Florence

Ultracold atomic quantum gases provide a valuable setting to experimentally investigate one-dimensional systems. We use two different atomic species trapped in a collection of one-dimensional "tubes" generated by means of a strong optical lattice, that we are manipulate independently. We mainly focus on the dynamics of impurities initially confined and then released while immersed in a one-dimensional gas of bosonic atoms. The impurities undergo oscillations whose amplitude decreases as we increase the interactions with the background gas. In addition, we observe the collision between the impurities and the background gas with evidence of quantum reflection, i.e. reflection of the impurities also for attractive interactions.

Integrability and its Breaking in two problems from ultracold physics

Austen Lamacraft

University of Virginia

In this talk I will discuss two problems motivated by cold atom physics, in which integrability plays a major role. In the first, I consider the noise correlations in the expansion of an interacting 1D Bose gas from a regular array. Using an explicit form for the time dependent wavefunction due to Tracy and Widom, I show how to compute the density correlations in the expanded gas, which show a crossover from the bosonic to the fermonic Hanbury Brown and Twiss effect as interaction strength increases.

The second problem concerns the 1D quantum Rayleigh gas, a single impurity immersed in a 1D Fermi gas. When the masses of the impurity and gas particles coincide the system is integrable, and the impurity moves ballistically. When the masses differ, it is widely believed that diffusive motion should result. I will show how the mass difference gives rise to processes that result in a finite mobility for the impurity.

Magnetic and percolative Ising universality classes.
Results from integrable field theory

Aldo Delfino

SISSA Trieste

The Ising model provides the simplest illustration of ferromagnetism but also, when attention is moved from local (spin) to non-local (cluster) observables, of correlated percolation. We recall how integrable field theory and its non-integrable deformations allow the quantitative characterization of the magnetic universality class in two dimensions, and explain how the same is achieved in the percolative case.

What is hiding beneath 1D Fermi surface?

Adilet Imambekov
Rice University

We consider correlation functions of 1D quantum liquids beyond the conventional Luttinger liquid paradigm. We show that unlike in higher dimensions, large distance and time behavior of correlation functions is not controlled only by the excitations near Fermi surface, but by the excitations which involve states deep below the Fermi surface as well. Behavior of correlation functions beyond the Luttinger liquid picture is different for integrable and non-integrable systems. We will also comment on recent developments concerning non-universal prefactors in correlation functions and the fate of spin-charge separation beyond the Luttinger liquid theory.

Critical values of Yang-Yang functional in quantum sine-Gordon model

Sergei Lukyanov
Rutgers University

Over the long history of studies, a number of important facts about the quantum sine-Gordon model were discovered. Among them are truly elegant Fendley-Saleur-Zamolodchikov (FSZ) relations between the third Painlevé transcendent and the sine-Gordon zero-point energy at a special value of the coupling constant, where the theory exhibits N=2 supersymmetry. In the talk I will discuss a generalization of this result to arbitrary values of the coupling. The main player in the derivation of generalized FSZ relations is a Yang-Yang functional.

Experimental realization of underscreened antiferromagnetic and ferromagnetic Kondo problems

Gabriel Aeppli
University College London

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Change of level statistics in strongly disordered quantum systems and its implications for the theory of insulators

Lev Ioffe
Rutgers University

Similar to the integrability breaking, the transition between coherent and incoherent regimes in strongly disordered systems also shows up as a transition between different level statistics. I discuss application of this correspondence to the theory of insulators formed in very disordered superconductors and show the results of the numerical study of the transition in the spectra for the models that describe disordered superconductors. I argue that for this class of models the change in the statistics allows to locate transition with a good accuracy even for rathe small system sizes. The main physical conclusion of this study is that transition between weak and hard insulators (that are characterized by Arrhenius behavior of the resistivity and infinite gap respectively) happen as disordered is increased, at the same disorder strength for all temperatures.

Boris Altshuler
Columbia University

TBA

Non-Equilibrium Effects in Quantum Spin Ladders?

Christian Rüegg
PSI Villingen

The optimal energy scale of the exchange interactions and excellent low dimensionality of the prototypical metal-organic material (C5H12N)2CuBr4 are utilized to study the transport, thermodynamic and spectral properties of the quantum spin ladder and of the spin Luttinger-liquid (LL) and magnon Bose-Einstein Condensate (BEC) phases realized at low temperatures and in high magnetic fields in this model. Furthermore, the inherent chemical flexibility of this metal-organic compound enables studies by neutron scattering of the effects of bond randomness and of non-magnetic and magnetic dopants on the spin LL and magnon BEC. Bose glass phases form and the localized impurities dominate the physics near the intrinsic quantum critical points of the ladder. Quantum quenches by a rapidly changing magnetic field have been proposed as an interesting new direction, which remains to be explored in future experiments and will be discussed for this and related materials.

Quantum dynamics in a bosonic quantum gas

Corinna Kollath
University of Geneve

Atomic gases cooled to Nanokelvin temperatures are a new exciting tool to study a broad range of quantum phenomena. In particular, the outstanding degree of control which has been achieved over these quantum systems facilitates access to the dynamics of strongly correlated quantum many body physics. I will report on different non-equilibrium situations. The first is the almost adiabatic preparation of the gas by a slow parameter change. The second is the coupling to a dissipative local defect which induces atom losses as found for example in hybrid systems.

Dynamics in one dimension: integrability in and out of equilibrium

Jean-Sébastien Caux
University of Amsterdam

Over the last few years, integrability has become a method of choice for the calculation of equilibrium dynamical correlation functions of systems such as spin chains and interacting atomic gases, its main strength being its ability to go beyond commonly-used low-energy effective theories. After a brief review, this talk will present some new results on simple and more elaborate observables, with a discussion of their relevance to new types of experiments such as resonant inelastic x-ray scattering, and of their relation to new developments in Luttinger liquid theory. For out-of-equilibrium dynamics, most importantly following a sudden change in one of the global parameters of a system (quantum quench), integrability will be shown to be able to offer reliable results on (re)equilibration phenomena with potential applications in quantum dots, quantum magnets and atomic gases, this approach having the unique advantage of being applicable to arbitrary time scales.

Dynamical quantum simulations in an optical superlattice

Ulrich Schollwöck
LMU Munich

In this talk I want to present theoretical and experimental results measuring the relaxation of subsystems of a closed, strongly interacting quantum system (bosons in an optical superlattice) towards equilibrium. On timescales accessible both to theory and experiment, they agree very well, validating this dynamical quantum simulator. However, the experimental results achieved on longer timescales raise interesting unresolved theoretical issues.

Equilibration of quantum weakly nonlinear one-dimensional lattices

Vadim Oganesyan

City University of New York

We examine the process of equilibration in quantum weakly anharmonic lattices with finite energy per particle. Initial conditions where only very few Fourier modes are excited are found to be unstable yielding to an intermediate metastable state characterized by a sort of a generalized Gibbs ensemble, parametrized by momentum dependent analog of temperature. Wave kinetic phenomenology of this quantum metastable state and its relationship to the purely classical Fermi-Pasta-Ulam phenomena will be discussed.

Nonlinear response of driven interacting systems

Peter Prelovsek

University of Ljubljana

Nonlinear real-time response of interacting particles is studied on the example of 1D isolated system of spinless fermions driven by electric field, both in the metallic as well as in the Mott insulator regime. Using equations of motion and numerical methods we show that for a nonintegrable metallic case at finite temperatures the major effect of nonlinearity can be taken into account within an extended linear response formalism. On the other hand, integrable metallic system shows on constant driving damped oscillating current related but not equal to Bloch oscillations. Even more counterintuitive is the response within the insulator regime, which in spite of finite temperatures reveals a vanishing conductivity at low fields, reviving the possibility of an ideal insulator.

ABSTRACTS OF POSTERS

(in alphabetical order of presenting author)

Equivalence between a Class of Yangian Invariant Haldane–Shastry Like Spin Chains and One dimensional vertex models

Bireswar Basu-Mallick [a], Nilanjan Bondyopadhaya [b] and Kazuhiro Hikami [c]

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[c)] *Department of Mathematics, Naruto University of Education, Tokushima 772-8502, Japan*

We define a class of Y(sl(m|n)) Yangian invariant Haldane-Shastry (HS) like spin chains, by assuming that their partition functions can be written in a particular form in terms of the super Schur polynomials. Using some properties of the super Schur polynomials, we show that the partition functions of this class of spin chains are equivalent to the partition functions of a class of one-dimensional vertex models with appropriately defined energy functions. We also establish a boson-fermion duality relation for the partition functions of this class of supersymmetric HS like spin chains by using their correspondence with one-dimensional vertex models.

Presenting author's name

Nilanjan Bondyopadhaya

References:

1. B. Basu-Mallick, N. Bondyopadhaya and K. Hikami, SIGMA 6 (2010), 091, 13 pages
2. Hikami K., Exclusion statistics and chiral partition function, in Physics and Combinatorics 2000 (Nagoya), Editors A.N. Kirilov and N. Liskova, World Sci. Publ., River Edge, NJ, 2001, 22-48
3. Hikami K., Basu-Mallick B., Supersymmetric Polychronakos spin chain: motif, distribution function, and character, *Nuclear Phys. B* 566 (2000), 511-528
4. Sutherland B., Beautiful models. 70 years of exactly solved quantum many-body problems, World Scientific Publishing Co., Inc., River Edge, NJ, 2004.

Applicability of the generalized Gibbs ensemble after a quantum quench

Tommaso Caneva[1], Elena Canovi[2], Davide Rossini[3],
Giuseppe Santoro[4,5,6], Alessandro Silva[5]

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2. Institut für Theoretische Physik III, Pfaffenwaldring 57, D-70550 Stuttgart, Germany
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Elena Canovi

We investigate the out-of-equilibrium dynamics of the one-dimensional quantum Ising model in presence of disomogeneities, after a sudden quench in the transverse magnetic field. The statistical description of the order parameter correlations in the relaxation process towards equilibrium can be perfectly described by a generalized Gibbs ensemble, but only in the case of translational invariance. We show that, when translational invariance is broken by means of a perturbation in the boundary conditions or by adding randomness in the coupling strengths and/or in the local magnetic fields, the description in terms of the Gibbs ensemble progressively deteriorates.

Quantum pumping of interacting bosons in periodically modulating optical lattices

Roberta Citro[1] and Natan Andrei[2]

1.Department of Physics "E.R. Caianiello", University of Salerno, Via Ponte don Melillo, 84084 Fisciano (Sa), Italy

2. Center for Materials Theory, Serin Physics Laboratory, Rutgers University, Piscataway, New Jersey 08854-8019, USA

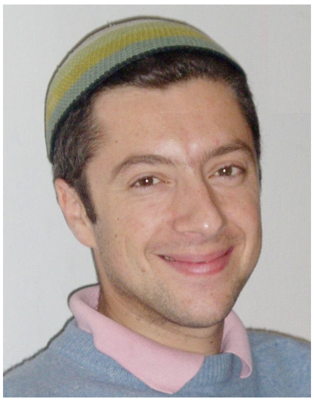
Roberta Citro

Quantum pumping in an interacting one-dimensional Bose-Einstein condensate is analyzed. It is shown that a spatially periodic potential, oscillating adiabatically in time with frequency ω_0 acts as a quantum pump inducing an atom current from broken spatiotemporal symmetries of the driven potential. The current generated by the pump is strongly affected by the interactions. It has a power law dependence on the frequency with the exponent determined by the interaction, while the coupling to the pump affects the amplitudes[1]. It depends on the phase difference between two umklapp terms of the drive, providing evidence for the full quantum character of the boson transport. The results suggest the realization of a quantum pump with laser-cooled atoms.

[1] R. Citro and N. Andrei, Phys. Rev. A **83**, 015601 (2011)

Non-equilibrium steady states of quantum systems driven by time-dependent noise: a real time RG approach

E.G. Dalla Torre, T. Giamarchi, E. Demler, E. Altman



E.G. Dalla Torre

It is well known that equilibrium quantum systems in the vicinity of a continuous phase transition show a universal scaling behavior, known as "quantum criticality". In a recent paper [1], we found specific examples of "non-equilibrium quantum criticality", occurring in quantum systems driven by time-dependent noise with 1/f spectrum. Here, we complement this result by studying small perturbations around the critical point, through an appropriate real-time renormalization group (RG) approach. We find that these perturbations lead to the generation of a finite effective temperature, which eventually destroys the critical state. As the effective temperature is perturbatively small, it is nevertheless possible to observe clear signatures of a continuous non-equilibrium transition at intermediate scales. We exemplify our general approach by computing exact analytic expressions for the RG flow of noise-driven shunted Josephson junctions and interacting particles in one dimension.

[1] E.G. Dalla Torre, E. Demler, T. Giamarchi, E. Altman, Nature Physics, 6, 806 (2010)

Magnetic order of Mn-doped ZnO:

A Monte Carlo simulation of Carriers Concentration's effect

L. B. Drissi*

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Recently, diluted Magnetic Semiconductors (DMS) doped with a small concentration of magnetic impurities, especially DMS doped with transition metal, inducing ferromagnetic DMSs have attracted a great interest. Using the Monte Carlo method within the Ising model, we study the magnetic properties of doped Mn ions in semi-conductor for different carrier's concentration. For the case of $Zn_{1-x}Mn_xO$, the results of our calculations show the effect of carriers in understanding the existence and the control of the magnetic order. We give also the exact values of carriers' concentration that should be adopted or avoided in order to get ferromagnetic phase with high Curie temperature.

Author: Lalla Btissam Drissi

Gaudin models solver based on the Bethe ansatz/ordinary differential equations correspondence

Alexandre Faribault[1] , Christoph Sträter[1], Omar El Araby[2], Vladimir Gritsev[2]

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2. Physics Department, University of Fribourg, Chemin du Musée 3, 1700 Fribourg, Switzerland

Omar El Araby

We present a numerical approach which allows the solving of Bethe equations whose solutions define the eigenstates of Gaudin models. By focusing on a new set of variables, the canceling divergences which occur for certain values of the coupling strength no longer appear explicitly. The problem is thus reduced to a set of quadratic algebraic equations. The required inverse transformation can then be realized using only linear operations and a standard polynomial root finding algorithm. The method is applied to Richardson's fermionic pairing model, the central spin model and generalized Dicke model.

Three-body loss and three-particle correlations in one-dimensional systems

E. Haller[1], M.J. Mark[1], J.G. Danzl[1], M. Rabie[1], K. Lauber[1], G. Pupillo[2] and H.-C. Nägerl[1]

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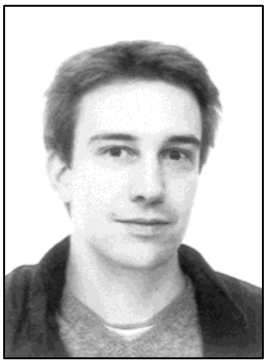
2) Institut für Theoretische Physik, Universität Innsbruck, Technikerstraße 25/2, A–6020 Innsbruck, Austria



Elmar Haller

We load a Bose-Einstein condensate of cesium atoms to an array of tube-like 1D traps generated by a 2D optical lattice potential, and we control the interaction strength by means of a 1D confinement-induced resonance [1]. Unlike for ultracold atoms in 3D geometry, which show a dramatic increase of three-body losses in the proximity of a Feshbach resonance, we observe a strong suppression of three-body losses in 1D. This suppression originates from a fermionization of the particles due to strong repulsive interactions, and it can be quantized by the local three-particle correlation function g_3. We observe a reduction of g_3 by three orders of magnitude for an increasing Lieb-Liniger interaction parameter γ, and we find excellent agreement of g_3 (γ) with theoretical predictions [2]. Understanding this suppression of g_3 and the break-down of this suppression is an important prerequisite to study thermalization in 1D systems.

[1] E. Haller, et al., Phys. Rev. Lett. 104 153203 (2010).
[2] D. Gangardt, and G. Shlyapnikov, Phys. Rev. Lett. 90 10401 (2003).

Kagome approximation for ^{3}He on Husimi lattice with two-, and three-spin exchange interactions

V. V. Hovhannisyan[1], N. S. Ananikian[1]

1. Department of Theoretical Physics, A. I. Alikhanyan National Science Laboratory, Alikhanian Br. 2, 0036 Yerevan, Armenia

The Ising approximation of the Heisenberg model in a strong magnetic field, with two-, and three-spin exchange interactions are studied on a Husimi lattice. This model can be considered as an approximation of the third layer of ^{3}He absorbed on the surface of graphite (kagome lattice). Using dynamic approach, we have found exact recursion relation for the partition function. For different values of exchange parameters and temperature, the diagrams of magnetization are plotted and showed that magnetization properties of the model vary from ferromagnetic to antiferromagnetic depending on the value of model parameters. For antiferromagnetic case magnetization plateau at 1/3 of saturation field is obtained. Lyapunov exponent for recursion relation are considered and showed absence of bifurcation points in thermodynamic limit. The Yang–Lee zeros are analyzed in terms of neutral fixed points and showed that Yang–Lee zeros of the model are located on the arcs of the circle with the radius R = 1.

Integrability of Heisenberg helimagnetic spin system with weak Dzyaloshinskii- Moriya interaction

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Abstract

The role of integrability of several nonlinear models plays a vital role in magnetization dynamics because integrable system admits soliton solution which supports the nonlinear spin excitations in the magnetic systems. We report such a class of integrable spin models in Heisenberg spin system with the addition of single-ion uniaxial anisotropy, antisymmetric spin-spin exchange interaction namely weak Dzyaloshinskii- Moriya (DM) interaction coupled with helimagnetic system in semiclassical limit. In these magnetic systems the governing dynamical equation is deduced to generalized nonlinear family of Schrödinger equations with the aid of Holstein- Primakoff (HP) transformation for the spin operators coupled with Glauber- coherent state representation. At the various order of the generalized evolution equation we identify several nonlinear integrable models by suitable rescaling and redefinition of parameters. These integrable models admit the soliton spin excitations could be exploited for ultrafast switching in the magnetic system which might have potential applications in high density data storage devices in the magnetic recording industry.

Presenting author's name: Dr. L. Kavitha

Statistical theory of prethermalization plateaus

Marcus Kollar[1], F. Alexander Wolf[1], Martin Eckstein[2]

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Marcus Kollar

A quantum many-body system which is prepared in the ground state of an integrable Hamiltonian does not directly thermalize after a sudden small parameter quench away from integrability. Rather, it will be trapped in a prethermalized state and can thermalize only at a later stage. We discuss several examples for which this prethermalized state shares some properties with the nonthermal steady state that emerges in the corresponding integrable system. These examples support the notion that nonthermal steady states in integrable systems may be viewed as prethermalized states that never decay further. Furthermore we show that prethermalization plateaus can be correctly predicted by generalized Gibbs ensembles, which are the appropriate extension of standard statistical mechanics in the presence of many constants of motion. This establishes that the relaxation behaviors of integrable and nearly integrable systems are continuously connected and described by the same statistical theory.

[1] M. Kollar, F.A. Wolf, and M. Eckstein, arXiv:1102.2117 (Phys. Rev. B, in press).

Reduced dynamics of a spin in the finite XY chain

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Reduced dynamics of a single spin in the finite XY spin chain with magnetic field is considered. At $t = 0$ a selected spin has an arbitrary polarization, while other $(N-1)$ spins of the chain are unpolarized and uncorrelated, i.e. constitute a thermal bath with infinite temperature. We derive an exact formula for $p^z(t)$ at arbitrary time (where p^z is a polarization of the selected spin along the magnetic field) as well as tractable assymptotics for specific time intervals. In particular we get a simple expression for times $t < t_{\rm th}$, where $t_{\rm th}$ is a time which is necessary for the most rapid spin wave to make a round trip over the whole chain. We observe a number of interesting finite-size effects, such as the abrupt transition from regular to irregular evolution at $t_{\rm th}$, and non-uniform distribution of energy between spins at large times (i.e. absence of complete thermalization). Also we find that $p^z(t)$ never changes its sign; this result is valid both for finite and for infinite chains. The contribution is partly based on ref.[1].

References

[1] O. Lychkovskiy, "Entanglement, decoherence and thermal relaxation in exactly solvable models", 2010, contribution to DICE-2010 Workshop, arXiv:1101.2535.

Lychkovskiy Oleg

Boundary bound states in spin-1 XXZ model and SUSY sine-Gordon model with Dirichlet boundary conditions

Chihiro Matsui
The University of Tokyo

Chihiro Matsui

We studied the ground state of the integrable spin-1 XXZ model with boundary magnetic field via the algebraic Bethe ansatz. Existence of the boundary bound states is discussed in relation with the value of boundary magnetic field. By introducing the inhomogeneity parameter, the boundary mass spectrum of the supersymmetric sine-Gordon model with the Dirichlet boundary conditions was also discussed. The result is compared with that derived from the boundary bootstrap approach.

[1] S. Skorik and H. Saleur (1995) J. Phys. A: Math. Gen. **28** 6605
[2] C. Ahn, R.I. Mepomechie, and J. Suzuki (2007) Nucl. Phys. **B767** 250

Non-Equilibrium Dynamics of two coupled 1D condensates of interacting atoms

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Clemens Neuenhahn

Motivated by recent experiments, we investigate the non-equilibrium dynamics of two interacting one-dimensional condensates following a quench of the tunnel-coupling to finite values. These coupled condensates provide a realization of the quantum sine-Gordon model, whose non-linear time-evolution after turning-on the coupling is studied using the semiclassical truncated Wigner approximation. We analyze the amplification of initial quantum fluctuations of the relative phase and observe the emergence of localized patterns in the phase-field.

Example of a Quantum Anomaly in the Physics of Ultracold Gases

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Maxim Olshanii

In this presentation, we propose an experimental scheme for the observation of a quantum anomaly—quantum-mechanical symmetry breaking—in a two-dimensional harmonically trapped Bose gas [1]. The anomaly manifests itself in a shift of the monopole excitation frequency away from the value dictated by the Pitaevskii-Rosch dynamical symmetry [2]. While the corresponding classical Gross-Pitaevskii equation and the hydrodynamic equations derived from it do exhibit this symmetry, it is—as we show in our paper—violated under quantization. The resulting frequency shift is of the order of 1% of the carrier, well in reach for modern experimental techniques. We propose using the dipole oscillations as a frequency gauge.

[1] Maxim Olshanii, Hélène Perrin, and Vincent Lorent, Phys. Rev. Lett. 105, 095302 (2010)
[2] L.P. Pitaevskii and A. Rosch, Phys. Rev. A 55, R853 (1997)

Finite temperature correlations in 1D Bose gas

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Miłosz Panfil

It is a well-known fact, that the Bose gas in one dimension is solvable in the sense of the Algebraic Bethe Ansatz. Therefore all the eigenstates of the system and the action of local operators on them are known a priori. Despite this, the calculation of correlation functions (especially analytically) remains an open question. We develop a general algorithm that in principle can be used to obtain any correlation at finite temperature, for concreteness focusing so far on the density-density correlations. This allows us to study effects of strong correlations intertwined with thermal fluctuations.

Dynamical symmetry approach to many-body systems

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Matous Ringel

We present a novel method to study quantum many-body systems which can be mapped on an effective spin system. The method is based on path integral formulation of the theory. We make use of the dynamical symmetry of the Hamiltonian and we convert the path integrals into a set of stochastic differential equations or, equivalently, to a Fokker-Planck equation.

For particular cases, the quantities of interest can be evaluated explicitly, while in general our formulation serves as a good starting point for various approximation schemes. We demonstrate the method on the problem of multiple-photon scattering on an atom and on the problem of spin diffusion.

Thermalization and ergodicity in many-body open quantum systems

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Davide Rossini

Recent experiments with cold atomic gases, including the observation of the absence of thermalization put forward some questions related to the integrability issue in such systems. For closed many-body systems, integrability plays a crucial role in the relaxation to the steady state. A chaotic system is generally expected to thermalize at the level of individual eigenstates, while in integrable systems steady states carry memory of initial conditions and are not canonical. Much less is known for open quantum systems.
We have performed extensive numerical investigations in many-body quantum systems locally coupled via Lindblad equation to an external bath. We provide evidence that quantum chaotic systems do thermalize, that is, after long time they reach an invariant ergodic state which is well approximated by the grandcanonical state. The resulting ergodic state does not depend on the details of the baths. For integrable systems the invariant state depends on the bath and is typically different from the grandcanonical state.

[1] M. Žnidarič, T. Prosen, G. Benenti, G. Casati, and D. Rossini
Phys. Rev. E **81**, 051135 (2010)

Exactly soluble Tomonaga-Luttinger model with non-linear dispersion

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The bosonization is a convenient tool to study the Tomonaga-Luttinger model of the spinless interacting electrons with linear dispersion. However, the application of the bosonization becomes difficult if we need to account for deviations from the linear electron dispersion. It is possible to construct a canonical transformation which maps the Tomonaga-Luttinger Hamiltonian on a Hamiltonian of weakly-interacting fermion quasiparticles [1,2]. When parameters of the original interacting Hamiltonian satisfy certain relation, the quasiparticles are free. In such a case the spectrum and the density-density propagator of the Tomonaga-Luttinger Hamiltonian with non-linear dispersion can be found exactly. If the exact solubility condition is weakly violated, a perturbation theory in powers of an irrelevant operator may be constructed [3].

A.V. Rozhkov

[1] D.C. Mattis and E.H. Lieb, J. Math. Phys. **6**, 304 (1965).
[2] A.V. Rozhkov, Eur. Phys. J. B **47**, 193 (2005).
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Local density of states of a quarter-filled one-dimensional Mott insulator with a boundary

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Dirk Schuricht

We study the low-energy limit of a quarter-filled one-dimensional Mott insulator. We analytically determine the local density of states in the presence of a strong impurity potential, which is modeled by a boundary. To this end we calculate the Green function using field theoretical methods.
The Fourier transform of the local density of states shows signatures of a pinning of the spin-density wave at the impurity as well as several dispersing features at frequencies above the charge gap. These features can be interpreted as propagating spin and charge degrees of freedom. Their relative strength can be attributed to the ``quasi-fermionic" behavior of charge excitations with equal momenta. Furthermore, we discuss the effect of bound states localized at the impurity. Finally, we give an overview of the local density of states in various one-dimensional systems and discuss implications for scanning tunneling microscopy experiments.

Riemannian geometry approach to quantum non-equilibrium many-body dynamics

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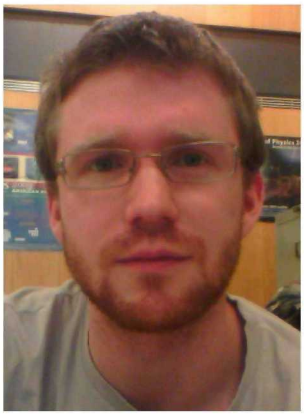

Michael Tomka

We want to study the influence of the geometry of a quantum systems underlying space of states on its quantum many-body dynamics. We observe an interplay between dynamical and topological ingredients of quantum non-equilibrium dynamics revealed by the geometrical structure of the quantum space of states. This interplay leads to non-equilibrium phase transition between two regimes: a regime of slow change of external parameters, where the non-equilibrium observables have a scaling behavior and a topology-dominated regime where these observables saturate.
This will be illustrated on the example of the anisotropic XY ring in a transverse magnetic field where additionally each spin is rotated around the applied magnetic field axis. Where we calculate the density of excitations as a function of the rotation speed of the spins.

New paradigm for the superfluid-insulator transition of bosons in disordered 1d traps

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Ronen Vosk

Ultracold bosons in one dimensional traps are typically weakly interacting, whereas the disorder potential is highly tunable. As the disorder is increased, the system undergoes a superfluid-insulator phase transition. However, the nature of the phase transition is not thoroughly understood.

We tackle this problem by mapping a system of interacting bosons in a realistic 1D random potential into an effective random Josephson array model. We argue that the transition is controlled by a strong randomness fixed point. We propose to detect signatures of the critical behavior using interference experiments which, we predict, exhibit universal mesoscopic fluctuations.[1]

[1] R. Vosk, and E. Altman, ArXiv:1104.2063