Modern Aspects of Quantum Physics

Book of Abstracts

INVITED TALKS

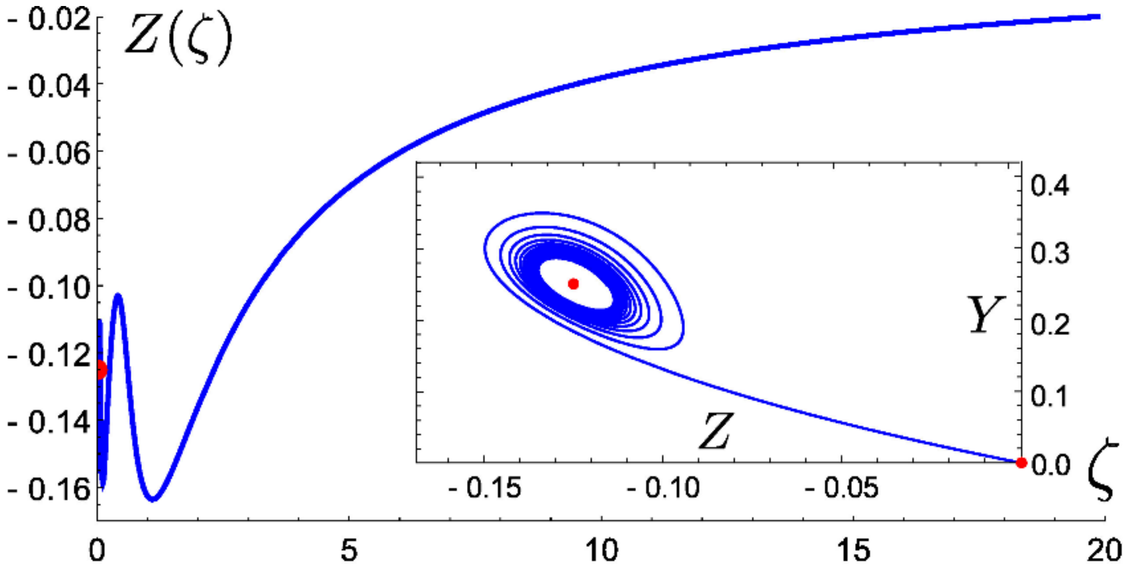
Ivan Balog (Institute of Physics, Zagreb)

Title

Metal-semimetal transition in Weyl fermions as a self-focusing phenomenon in non-linear diffusion

Abstract

The transition between semimetal and diffusive phases driven by disorder in relativistic semimetals has been attracted considerable interest due to recent discovery of Weyl and Dirac semimetals [1]. It is widely believed that it can be described by the fixed point of the U(N) Gross-Neveu model in the limit of N → 0. We reconsider this problem using functional renormalization group [2]. We show that the Gross-Neveau fixed point is infinitely unstable in the relevant limit. Surprisingly, we find a mapping from the problem of the renormalization group flow of the disorder distribution in the disordered Weyl system to the problem of fluid flow in a porous medium. We discover that the transition is controlled by a non-analytic fixed point drastically different from the fixed point of the U(N) Gross-Neveu model. It can be viewed as a self-similar solution to the porous medium equation whose non-analytic behavior provides a mechanism for generating a finite density of states at the nodal point. The implications of the nonanalyticity of the fixed point will also be discussed.



Caption: Fixed point solution to the functional renormalization group equation for d=3 expressed as a backward self-similar solution to the porous medium equation. The inset shows the representation which clarifies the nature of non-analyticity of the FP.

[1] S.-Y. Xu, I. Belopolski, N. Alidoust, M. Neupane, G. Bian, C. Zhang, R. Sankar, G. Chang, Z. Yuan, C.-C. Lee, S.-M. Huang, H. Zheng, J. Ma, D. S. Sanchez, B. Wang, A. Bansil, F. Chou, P. P. Shibayev, H. Lin, S. Jia, and M. Z. Hasan, Science **349**, 613 (2015).
[2] I.Balog, D.Carpentier and A.A.Fedorenko, arXiv:1710.07932 (2017)

Ticijana Ban (Institute of Physics, Zagreb)

Title

Cooling of atoms using an optical frequency comb

Abstract

Laser cooling and trapping brings atomic and molecular physics to one of the most exciting frontiers in science, with applications ranging from atom interferometry and optical frequency standards to high precision spectroscopy and ultracold chemistry. Regardless of such a great importance, laser cooling techniques are still limited to atoms with simple energy level structure and closed transitions accessible by current continuous wave (CW) laser technology. Laser cooling of more complex atomic species and molecules, or even simple atoms with strong cycling transitions in the vacuum ultraviolet (VUV) where generation of CW laser light is demanding, still remains an experimental challenge.
The aforementioned problems can be approached by using mode-locked femtosecond lasers with high pulse repetition rates which produce stabilized optical frequency combs (FCs), as proposed in [1,2]. However, experimental demonstrations of the FC cooling are still scarce in literature and limited to FC cooling of atoms on the two-photon transition [3] and FC cooling of trapped ion with strong cycling transition in UV [4]. In order to fully explore the potential of FC for the cooling of atoms and molecules further experiments are Indispensable.
In this talk, our recent results on frequency comb cooling of rubidium atoms on a dipole-allowed transition at 780 nm will be presented and our initial steps toward the realization of the frequency comb induced cavity cooling will be introduced.

[1] D. Kielpinski, Phys. Rev. A **73**, 063407 (2006).
[2] D. Aumiler and T. Ban, Phys. Rev. A **85**, 063412 (2012).
[3] A. M. Jayich, X. Long, and W. C. Campbell, Phys. Rev. X **6**, 041004 (2016).
[4] J. Davila-Rodriguez, A. Ozawa, T. W. Hansch, and T. Udem, Phys. Rev. Lett. **116**, 043002 (2016).

Angelo Bassi (University of Trieste)

Title

Gravitational decoherence and gravitational wave function collapse

Abstract

Gravitational decoherence and gravitational wave function collapse will be presented as two related but conceptually distinct ideas. Some of the most popular models will be reviewed, in particular the Diosi-Penrose model and the Schroedinger-Newton equation, with an emphasis on their conceptual status, stage of development, and experimental implications.

Sebastian Blatt (University of Munich "Ludwig-Maximilians" and Max Planck Institute for Quantum Optics, Garcing)

Title

Towards quantum many-body physics with Sr in optical lattices

Abstract

The widespread use of ultracold fermionic strontium atoms in optical lattices for precision measurements [1] has led to the availability of many advanced tools and techniques for these atoms. With the recent realization of degenerate gases of all Sr isotopes [2] and the development of fermionic quantum gas microscopes for alkali metal atoms [3-6], a new frontier has opened for quantum simulations and quantum information processing with fermionic Sr-87. Many applications in quantum state engineering and quantum simulation require internal-state-dependent control of the atomic motion. In the Sr atom, there exist so-called tuneout wavelengths, where only one of the clock states is trapped and the other state can move freely [7]. Because of the (in principle) exact cancellation of the other state's polarizability at the tuneout wavelengths, it should be possible to realize spin-dependent lattices with high fidelity. Here, we report on progress towards a new experiment for quantum simulations with Sr in state-dependent optical lattices.

[1] A. Ludlow et al., Rev. Mod. Phys. **87**, 637 (2015)
[2] S. Stellmer et al., Ann. Rev. of Cold Atoms and Molecules 2, World Scientific (2014)
[3] L. Cheuk et al., Phys. Rev. Lett. **114**, 193001 (2015)
[4] M. F. Parsons et al., Phys. Rev. Lett. **114**, 213002 (2015)
[5] E. Haller et al., Nature Physics **11**, 738 (2015)
[6] A. Omran et al., Phys. Rev. Lett. **115**, 263001 (2015)
[7] M. S. Safronova et al., Phys. Rev. A **92**, 040501 (2015)

Daniel Braun (University of Tübingen "Eberhard Karls")

Title

Entanglement and the truncated moment problem

Abstract

The "entanglement problem" is to decide whether a given quantum state of a composite system is entangled over a chosen partition or not. We show that it can be mapped to the "truncated moment problem" studied in mathematics, for which recently a complete solution was found in the sense of a necessary and sufficient condition. It gives rise to a hierarchy of semi-definite programs corresponding to state extensions with polynomial constraints, and the positive-partial-transpose criterion as a first step, that generalizes and unifies on an abstract level previous approaches such as the Doherty-Parrilo-Spedalieri hierarchy. Flat extensions play a crucial role and are a systematic ingredient that allows us to prove separability of a state and obtain its explicit decomposition into a convex sum of product states. The approach is very flexible and general. It can accommodate naturally missing experimental data, symmetries, and subsystems of different dimensions.

[1] Entanglement and the truncated moment problem, Fabian Bohnet-Waldraff, Daniel Braun, Olivier Giraud, Phys. Rev. A 96, 032312 (2017);
[2] Partial transpose criteria for symmetric states, Fabian Bohnet-Waldraff, Daniel Braun, Olivier Giraud, Phys. Rev. A 94, 042343 (2016);
[3] Tensor Representation of Spin States, O. Giraud, D. Braun, D. Baguette, T. Bastin, and J. Martin, Phys. Rev. Lett. 114, 080401 (2015)

Andreas Buchleitner (University of Freiburg "Albert-Ludwigs")

Title

Interference of indistinguishable particles: from dynamics to statistics

Abstract

Many-particle dynamics bear surprising phenomena already on the level of the interference of many-particle amplitudes, even in the absence of interactions. Questions arise such as what distinguishes quantum statistical from bona fide many particle interference effects? How are the latter affected by the particles' mutual degree of (in-)distinguishability? What can we learn from many-particle interference patterns, and can these be employed as (novel) diagnostic tools? The talk will discuss selected examples of many-particle quantum transport, with the particles' indistinguishability as a genuine source of complexity, and elaborate on the basic principles which determine the structure of many-particle interferences.

Hrvoje Buljan (University of Zagreb)

Title

Engineering Weyl fermions and anyons

Abstract

I will present two topics of research in our group related to synthetic topological quantum matter [1]: (i) topological phases in 3D optical lattices, more specifically a proposal for experimental realization of Weyl semimetals in ultracold atomic gases [2], and (ii) anyons [3,4]. I will present one possible route to engineer anyons in a 2D electron gas in a strong magnetic field sandwiched between materials with high magnetic permeability, which induce electron-electron vector interactions to engineer charged flux-tube composites [3]. I will also discuss intriguing concepts related to extracting observables from anyonic wavefunctions [4]: one can show that the momentum distribution is not a proper observable for a system of anyons [4], even though this observable was crucial for the experimental demonstration of Bose-Einsten condensation or ultracold fermions in time of flight measurements. I will show how time of flight measurements can be used to extract anyonic statistics [4].

[1] N. Goldman, G. Juzeliunas, P. Ohberg, I. B. Spielman, Rep. Prog. Phys. **77**, 126401 (2014).
[2] Tena Dubček, Colin J. Kennedy, Ling Lu, Wolfgang Ketterle, Marin Soljačić, Hrvoje Buljan, *Weyl points in three-dimensional optical lattices: Synthetic magnetic monopoles in momentum space*, Phys. Rev. Lett. **114**, 225301 (2015).
[3] M. Todorić, D. Jukić, D. Radić, M. Soljačić, and H. Buljan, *The Quantum Hall Effect with Wilczek's charged magnetic flux tubes instead of electrons*, Phys. Rev. Lett. **120**, 267201 (2018).
[4] Tena Dubček, Bruno Klajn, Robert Pezer, Hrvoje Buljan, Dario Jukić, *Quasimomentum distribution and expansion of an anyonic gas*, Phys. Rev. A **97**, 011601(R) (2018).

Michele Burrello (Niels Bohr Institute, Copenhagen)

Title

Dyonic zero-energy modes

Abstract

One-dimensional systems with topological order are intimately related to the appearance of zero-energy modes localized on their boundaries. The most common example is the Kitaev chain, which displays Majorana zero-energy modes and it is characterized by a two-fold ground state degeneracy related to the global Z_2 symmetry associated with fermionic parity. By extending the symmetry to the Z_N group, it is possible to engineer systems hosting topological parafermionic modes. In this work, I address one-dimensional systems with a generic discrete symmetry group G. I will define a ladder model of gauge fluxes that generalizes the Ising and Potts models and displays a symmetry broken phase. Through a non-Abelian Jordan-Wigner transformation, I will map this flux ladder into a model of dyonic operators, defined by the group elements and irreducible representations of G. I will show that the so-obtained dyonic model has topological order, with zero-energy modes localized at its boundary. These dyonic zero-energy modes are in general weak topological modes, but strong dyonic zero-modes appear when suitable position-dependent couplings are included.

Pasquale Calabrese (SISSA, Trieste)

Title

Entanglement and thermodynamics in non-equilibrium isolated quantum systems

Abstract

Entanglement and entropy are key concepts standing at the foundations of quantum and statistical mechanics. In the last decade the study of the non-equilibrium dynamics of isolated quantum systems revealed that these two concepts are intricately intertwined. Although the unitary time evolution ensuing from a pure initial state maintains the system globally at zero entropy, at long time after the quench local properties are captured by an appropriate statistical ensemble with non zero thermodynamic entropy, which can be interpreted as the entanglement accumulated during the dynamics. Therefore, understanding the post-quench entanglement evolution unveils how thermodynamics emerges in isolated quantum systems.

Rosario Fazio (ICTP, Trieste)

Title

Boundary time-crystals

Abstract

I boundary time-crystals where continuous time-translation symmetry breaking occurs at the boundary (or generically in a macroscopic portion) of a many-body quantum system. After introducing their definition and properties, I analyse in details a solvable model. I will provide examples of other systems where boundary time crystalline phases can occur. The existence of the boundary time crystals is intimately connected to the emergence of time-periodic steady state in the thermodynamic limit of a many-body open quantum system. Connection to quantum synchronisation will be also discussed.

Andrea Gambassi (SISSA, Trieste)

Title

Dynamical transitions, universality, and chaos in prethermal states

Abstract

Recent experimental progresses in the physics of ultracold atomic gases have revived the interest in the dynamics of thermally isolated quantum statistical systems after a sudden change (quench) of their control parameters, which provides access to novel non-equilibrium quantum states of matter and to long-lived pre-thermal states.
Analogously to phase transitions in equilibrium, collective non-equilibrium behaviours may emerge in these states, with an associated dynamical critical point characterised by scale invariance and universality. In addition to scaling at short times and aging with universal exponents, systems quenched close to such a dynamical critical point may display a chaotic behaviour induced by non-equilibrium fluctuations.

Salvatore Marco Giampaolo (Ruđer Bošković Institute, Zagreb)

Title

The Frustration in being Odd: area law violation in local systems

Abstract

I demonstrate the existence of a new quantum phase of matter that arises in antiferromagnetic spin chains with a weak frustration -just one bond in a large chain-. This is the case, for instance, of systems with an odd number of spins with periodic boundary conditions. Such new phase is extended, gapless, but not relativistic: the low-energy excitations have a quadratic (Galilean) spectrum. Locally, the correlation functions on the ground state do not show significant deviations compared to the non-frustrated case, but correlators involving a number of sites (or distances) scaling like the system size display new behaviors. In particular, the von Neumann entanglement entropy is found to follow new rules, for which neither area law applies, nor one has a divergence of the entropy with the system size. Such very long-range correlations are novel and of potential technological interest. I illustrate such new phase in a few prototypical chains using numerical simulations and I study analytically the paradigmatic example of the Ising chain. Through these examples we argue that this phase emerges generally in (weakly) frustrated systems with discrete symmetries.

Thomas Sand Jespersen (Niels Bohr Institute, Copenhagen)

Title

Electron pairing and superconductivity in mesoscopic complex oxide devices

Abstract

In recent years the conducting electron system at the interface of bulk insulating $LaAlO_3$ and $SrTiO_3$ has attracted considerable attention in part due to a unique combination of properties such as electrostatic gatability, which is at the heart of the success of semiconductor technology, and the appearance of gate-tunable superconducting, metallic, insulating and magnetic ground states. I will present results of low temperature transport in LAO/STO mesoscopic interferometers sketched by scanning probe lithography, and in quantum dot devices fabricated by means of conventional electrostatic gating. The quantum dots exhibit effectively attractive electron-electron interactions and electron pairing is observed outside the parameter regimes of superconductivity. The consequences of the pairing for the allowed transport processes and excitation spectrum is discussed.

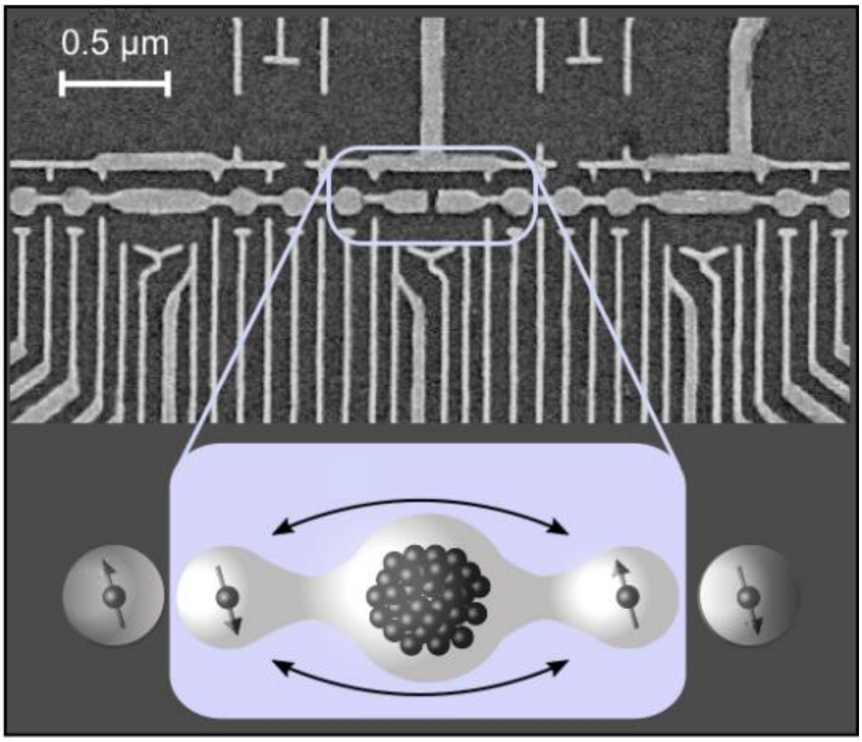
Ferdinand Kuemmeth (Niels Bohr Institute, Copenhagen)

Title

Moore's law meets spin qubits

Abstract

Modern computers process information classically, using the charge of large ensembles of electrons. Quantum effects remain a detail rather than a resource. As miniaturization of transistors is approaching economic, thermal, and atomic limits, Moore's law looses its validity, but gives way to fundamentally new ways of processing information that are fundamentally quantum. I will explain how we fabricate tiny transistors and semiconducting islands in which quantum effects and single-electron processes dominate. At temperatures below 1 Kelvin the spin states associated with individual electrons can be initialized in entangled spin states, manipulated coherently, and monitored as they evolve in time. I will illustrate these techniques in the context of our most recent experiments, in which we coherently exchange two spins between distant quantum dots in a GaAs crystal. The high speed we achieve is important for developing qubit circuits for quantum computers, whereas the dynamics of entangled states provides insight into the physical environment of these fascinating quantum devices.



Satya Majumdar (University of Paris-Sud, Orsay)

Title

Kinetic energy of a trapped Fermi gas at finite temperature

Abstract

We study the statistics of the kinetic (or equivalently potential) energy for N non-interacting fermions in a 1d harmonic trap of frequency \omega, at finite temperature T. Remarkably, we find an exact solution for the full distribution of the kinetic energy, at any temperature T and for any N. As a function of temperature T, and for large N, we identify: (i) a quantum regime, for T \sim \hbar \omega, where quantum fluctuations dominate and (ii) a thermal regime, for T \sim N \hbar \omega, governed by thermal fluctuations. We show how the mean, the variance, as well as the large deviation function associated with the distribution of the kinetic energy cross over from the quantum to the thermal regime as T increases.

Hrvoje Nikolić (Ruđer Bošković Institute, Zagreb)

Title

The origin of Casimir effect: Vacuum energy or van der Waals force?

Abstract

In the literature on Casimir effect there are two approaches that make the same measurable predictions but offer very different explanations on the conceptual level. According to one approach the effect has origin in vacuum energy, while according to another it has origin in van der Waals forces. To resolve the resulting conceptual confusion, I discuss the conceptual aspects of Casimir effect from several different points of view. This includes fundamental particle physics (general principles of quantum electrodynamics), condensed matter physics (electrodynamics in continuous media) and non-relativistic quantum mechanics (a toy model with only a few degrees of freedom). All points of view lead to the conclusion that, at the fundamental microscopic level, Casimir effect originates from van der Waals forces, while the vacuum energy approach is an effective theory valid only at the macroscopic level.

Lode Pollet (University of Munich "Ludwig-Maximilians")

Title

The scratched-XY model in 2D

Abstract

I show that the 2D classical XY model with disordered scratches can host a new mechanism to destroy superfluidity. Instead of the vortex-pair unbinding mechanism described by the Berezinskii-Kosterlitz-Thouless physics theory we found by contrast a strong randomness criticality characterized by a non-universal jump of the superfluid stiffness. The strong randomness criticality can be described by an asymptotically exact semi-renormalization group theory, previously developed for the superfluid-insulator transition in one-dimensional disordered quantum systems, whose physics I will connect to. Numerical simulation unambiguously establish that this theory indeed describes the physics of the classical 2D XY model with disordered scratches.

Guido Pupillo (University of Strasbourg)

Title

Algebraic localization of long-range quantum models

Abstract

Several atomic, molecular, and optical systems, as well as certain condensed matter models, exhibit long-range interactions that decay with distance r as a power law $1/r^{\alpha}$. In this talk, we will present recent results for the localization properties of correlation functions of long-range quantum models in the presence of disorder. The latter is usually associated with exponential localization of wave functions and correlations. We demonstrate that in most situations power-law interactions imply algebraic decay of correlations. We will discuss the generality of these results and their application to experiments in atomic and molecular physics.

Alessandro Silva (SISSA, Trieste)

Title

Quantum many-body Kapitza phases of periodically driven spin systems

Abstract

As realized by Kapitza long ago, a rigid pendulum can be stabilized upside down by periodically driving its suspension point with tuned amplitude and frequency. In this talk I will discuss a many-body analogue of this phenomenon: the stabilization by just driving periodically a single parameter of an otherwise unstable phase of matter against all possible fluctuations of its microscopic degrees of freedom. In particular, I will focus on the physics of quantum spin chains with long-range interactions, discussing in detail the non-equilibrium phase diagram in the presence of a periodic drive as a function of frequency and amplitude.

Andrea Trombettoni (CNR & SISSA, Trieste)

Title

Off-Diagonal Long-Range Order in One-Dimensional Quantum Systems

Abstract

A quantum system exhibits off-diagonal long-range order (ODLRO) when the largest eigenvalue of the one-body-density matrix scales as N, where N is the total number of particles. More generally, if the largest eigenvalue scales as N^C to define the scaling exponent C, then C=1 corresponds to ODLRO and C=0 to the single-particle occupation of the density matrix orbitals. When 0<C<1, C can be used to quantify deviations from ODLRO. In this talk I discuss the behaviour of the exponent C in a variety of one-dimensional bosonic and anyonic quantum systems. For the 1D Lieb-Liniger Bose gas we find that for small interactions C is close to 1. 1D anyons provide the possibility to fully interpolate between C=1 and 0. I will finally focus on the Tonks-Girardeau limit, in which C approaches the value 1/2, discussing the case in which the gas is trapped in a general confining potential and showing the universality of the scaling of the largest eigenvalue of the one-body-density matrix with the number of particles. If time allows, I will also present recent results for the Lieb-Liniger model in a periodically time-dependent external potential.

CONTRIBUTED TALKS

Sumanta Das (Niels Bohr Institute, Copenhagen)

Title

Hybrid quantum interfaces for future quantum technologies

Keywords: Hybrid Quantum Systems, Quantum Networks

Abstract

We study hybrid interfaces consisting of various quantum systems and their application in novel quantum technologies. In particular we investigate two kinds of exotic structures, (a) a superconducting (SC) qubit - organic molecule hybrid interface and, (b) a SC qubit – quantum dot (QD) hybrid interface. We propose methods for achieving the strong coupling regime in such hybrid structures at the single photon level. As a first step towards future quantum networks we discuss schemes for generating entanglement over long distance using such interfaces.

Felicitas Hellbach (University of Konstanz)

Title

Quantum correlated photons generated by non-local electron transport

Abstract

Since the realization of high quality superconducting microwave cavities, one can envisage the possibility to investigate the coherent interaction of light and matter[1-3]. We study a parallel double quantum dot device operating as single electron splitter interferometer, with each dot linearly coupled to a local photon cavity. We explore how quantum correlation and entanglement between the two oscillators is generated by the coherent transport of a single electron passing simultaneous through the two different dots. We calculate the covariance by use of a diagrammatic perturbative expansion (Keldysh Green's functions) to the fourth order in the dot-oscillator interaction strength, taking into account vertex diagrams. Furthermore, we see that the Cauchy-Schwarz inequality can be violated

[1] A. Stockklauser et. al., Phys. Rev. X, 7 011030 (2017)
[2] X. Mi et al., Science 355, 156-158 (2017)
[3] J. J. Viennot et. al., Science 349, 408-411 (2015)

Edvin G. Idrisov (University of Luxembourg)

Title

Dephasing in a Mach-Zehnder Interferometer by an Ohmic Contact

Keywords: quantum interference, coherence, nonequilibrium transport, quantum Hall effect, open system

Abstract

We study dephasing in an electronic Mach-Zehnder (MZ) interferometer based on quantum Hall edge states by a micrometer-sized Ohmic contact embedded in one of its arms. We find that at the filling factor one, as well as in the case where an Ohmic contact is connected to a MZ interferometer by a quantum point contact that transmits only one electron channel, the phase coherence may not be fully suppressed. Namely, if the voltage bias and the temperature are small compared to the charging energy of the Ohmic contact, the free fermion picture is manifested, and the visibility saturates at its maximum value. At large biases, namely when the charging energy much smaller than the applied bias, the visibility decays in a power-law manner [1]. Our theoretical model can be checked using the experimental technique presented in Ref. [2].

[1] Edvin G. Idrisov, Ivan P. Levkivskyi, and Eugene V. Sukhorukov, Phys. Rev. Lett. **121**, 026802 (2018)
[2]S. Jezouin, Z. Iftikhar, A. Anthore, F. D. Parmentier, U. Gennser, A. Cavanna, A. Ouerghi, I. P. Levkivskyi, E. Idrisov, E. V. Sukhorukov, L. I. Glazman, F. Pierre, Nature **536**, 58–62 (2016)

Ivor Krešić (Institute of Physics, Zagreb. University of Strathclyde, Glasgow)

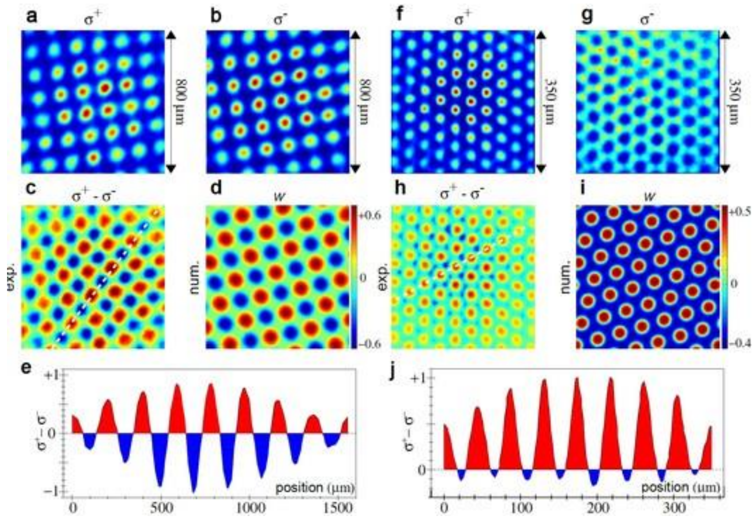
Title

Spontaneous light-mediated magnetism of cold atoms in the transverse plane

Keywords: self-organization, magnetism, light-mediated interaction, cold atoms, open systems

Abstract

Laser driven cold atomic ensembles with feedback hold potential for application in quantum technologies of the future [1]. We present an approach to induce strong magnetic interactions between atoms on a self-organized lattice using diffraction of light [2]. Diffractive propagation of structured light fields leads to an exchange between phase and amplitude modulated planes which can be used to couple atomic degrees of freedom via optical pumping nonlinearities. In the experiment a cold cloud of Rb atoms placed near a retro-reflecting mirror is driven by a detuned pump laser. We demonstrate spontaneous dipolar magnetic ordering in the Zeeman sublevels of the atomic ground state: anti-ferromagnetic structures on a square lattice and ferrimagnetic structures on a hexagonal lattice in zero and a weak longitudinal magnetic field, respectively (Fig. 1). In addition to the dipolar spin magnetization order, we also observe quadrupolar ordering, corresponding to modulations in the atomic quantum coherence [3].



Caption: Magnetic ordering (experiment and simulations). a)-e) Antiferromagnetic ordering on a square lattice for zero B-field. f)-j) Ferrimagnetic ordering on a hexagonal lattice for a longitudinal B-field of 120 mG.

References: [1] H. Ritsch, P. Domokos, F. Brennecke, and T. Esslinger, Rev. Mod. Phys. 85, 553 (2013). [2] I. Kresic, G. Labeyrie, G. R. M. Robb, G.-L. Oppo, P. M. Gomes, P. Griffn, R. Kaiser, and T. Ackemann, Commun. Phys. 1, 33 (2018). [3] G. Labeyrie, I. Kresic, G. R. M. Robb, G.-L. Oppo, R. Kaiser, and T. Ackemann, Optica (in press) (2018).

Bertrand Lacroix-A-Chez-Toine (University of Paris-Sud)

Title

Non-interacting trapped Fermi gases in hard edge potentials

Keywords: Random Matrix Theory, extreme value statistics, correlated variables

Abstract

In typical cold atom experiments, the atomic gas is confined in a trapping potential, creating finite edges to the density of particles. Although great attention has been devoted to understand the physics in the bulk of the gas, fewer works concentrated on the interesting edge physics. We focus on non-interacting Fermi gases for which interesting spatial properties arise from the Pauli exclusion principle. In a series of recent works using connection to random matrix theory (see 1.), the spatial statistics of a system of fermions was studied in 'soft' potentials, e.g. harmonic traps, both in the bulk and at the edge of the gas. It allowed to put firmer ground on the local density approximation in the bulk while it gave a new description of the spatial properties at the edge. These properties are universal in the sense that they do not depend on the precise shape of the smooth trapping potential. We recently extended these results to the case of 'hard-edge' potentials, e.g. hard box potentials, for which the edge properties are quite different. In this case also there exists a connection with random matrix theory, albeit from a different universality class. As an application of our results, we compute the statistics of extreme value observables of the Fermi gas, e.g. the position of the fermion closest to the wall.

References: 1. D.S. Dean, P. Le Doussal, S.N. Majumdar, G. Schehr, Phys. Rev. A **94**, 063622 (2016).

Dominik Maile (University of Tübingen “Eberhard Karls”)

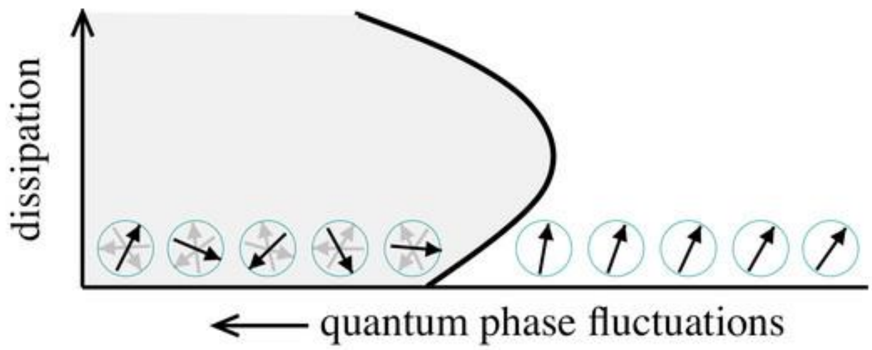
Title

Quantum phase transition with dissipative frustration

Keywords: Quantum phase transition, dissipation, quantum frustration, Josephson junctions

Abstract

We study the quantum phase transition of the one-dimensional phase model in the presence of dissipative frustration, provided by an interaction of the system with the environment through two non-commuting operators. Such a model can be realized in Josephson junction chains with shunt resistances and resistances between the chain and the ground. Using a self-consistent harmonic approximation, we determine the phase diagram at zero temperature which exhibits a quantum phase transition between an ordered phase, corresponding to the superconducting state, and a disordered phase, corresponding to the insulating state with localized superconducting charge. Interestingly, we find that the critical line separating the two phases has a non monotonic behavior as a function of the dissipative coupling strength. This result is a consequence of the frustration between (i) one dissipative coupling that quenches the quantum phase fluctuations favoring the ordered phase and (ii) one that quenches the quantum momentum (charge) fluctuations leading to a vanishing phase coherence. Moreover, within the self-consistent harmonic approximation, we analyze the dissipation induced crossover between a first and second order phase transition, showing that quantum frustration increases the range in which the phase transition is second order. The non monotonic behavior is reflected also in the purity of the system that quantifies the degree of correlation between the system and the environment, and in the logarithmic negativity as entanglement measure that encodes the internal quantum correlations in the chain.



Caption: Sketch of the phase diagram of the 1D phase model with dissipative frustration. The critical line between the ordered phase and the disordered phase displays a non monotonic behavior.

References: D. Maile et al., Phys. Rev. B **97**, 155427 (2018)

Paola Ruggiero (Scuola Normale Superiore, Pisa and ICTP, Trieste)

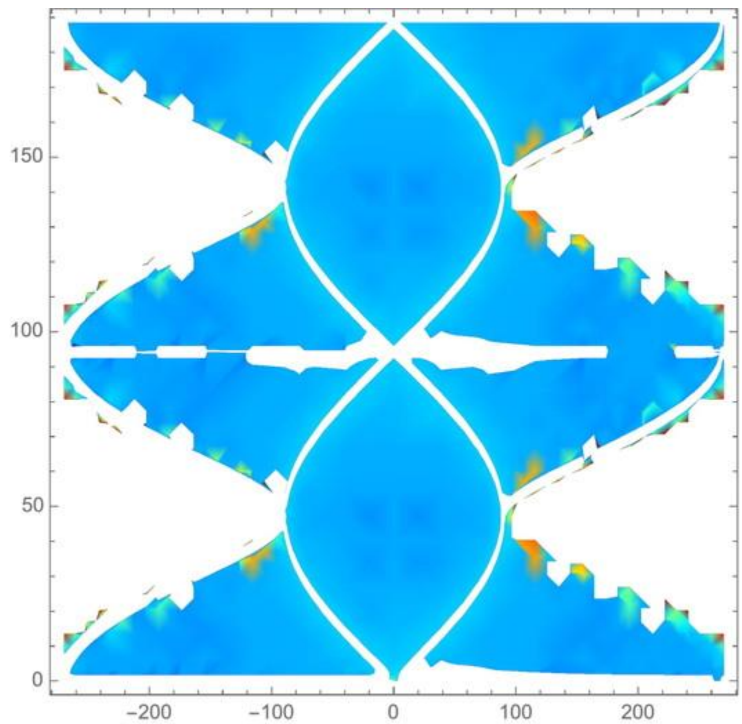
<u>*Title*</u>

CFT on top of a breathing Tonks-Girardeau gas

<u>*Keywords*</u>: CFT in curved space, inhomogeneous systems, out-of-equilibrium

<u>*Abstract*</u>

Conformal field theory (CFT) has been extremely successful in describing universal effects in critical one-dimensional (1D) systems, in situations in which the bulk is uniform. However, in many experimental contexts, such as quantum gases in trapping potentials and in several out-of-equilibrium situations, systems are strongly inhomogeneous. Recently it was shown that the CFT methods can be extended to deal with such 1D situations: the system's inhomogeneity gets reabsorbed in the parameters of the theory, such as the metric, resulting in a CFT in curved space. Here in particular we make use of CFT in curved spacetime to deal with the out-of-equilibrium situation generated by a frequency quench in a Tonks-Girardeau gas in a harmonic trap. We show compatibility with known exact result and use this new method to compute new quantities, not explicitly known by other methods (to the best of our knowledge) such as the dynamical fermionic propagator and one particle density matrix at different times.



Caption: Density plot of the fermionic propagator after a frequency quench.

References: SciPost Phys. **2**, 002 (2017) SciPost Phys. **2**, 012 (2017) SciPost Phys. **3**, 019 (2017)

Christophe Texier (University of Paris-Sud)

Title

Anderson localisation and directed polymers in random media

Keywords: Anderson localisation, directed polymer in random media

Abstract

I will discuss a new connection between two different problems: the quantum localisation of a wave solution of the Schrödinger equation with a random potential and the counting of equilibria of a directed polymer in a random medium (DPRM).
Using the Kac-Rice formula, it is possible to express the mean number of equilibria of a DPRM in terms of functional determinants. In the one-dimensional situation, these functional determinants can be calculated thanks to the Gelfand-Yaglom method, showing that the mean number of equilibria of the DPRM growth exponentially with the length of the polymer, with a rate controlled by the generalized Lyapunov exponent (GLE) of the localisation problem (cumulant generating function of the log of the wave function).
The GLE is solution of a spectral problem studied by combining numerical approaches and WKB-like approximation.
Furthermore, the formalism can be extended in order to obtain the number of equilibria at fixed energy, providing the (annealed) distribution of the energy density of the line over these equilibria.

References: Yan V. Fyodorov, Pierre Le Doussal, Alberto Rosso and Christophe Texier, *Exponential number of equilibria and depinning threshold for a directed polymer in a random potential*, Annals of Physics **397**, 1-64 (2018)