Many-body localization and periodically driven systems

Abanin, Dmitry
(University of Geneva, Theoretical Physics, Geneva , Switzerland)

Periodic driving provides an efficient way of quantum control. In particular, in recent experiments driving was used to realize topological Bloch bands in optical lattices. In this talk, I will present several rigorous results regarding periodically driven many-body systems. First, I will derive strong bounds on the heating rates of generic many-body systems. I will introduce a new approach based on a series of local unitary transformations, and will use it to show that, at times shorter than the (parametrically long) heating time scale, system's dynamics is well described by a time-independent effective Hamiltonian. Our approach can be extended to analyze the effects of coupling to a heat bath and slow turn-on of the drive. Second, I will show that strong disorder can induce many-body localization (MBL) in periodically driven systems. This phase, realized at high driving frequency, is characterized by the absence of heating and emergence of a complete set of local integrals of motion. I will argue that at low driving frequency delocalization is inevitable. Therefore, there is an MBL-delocalization transition as a function of driving frequency. I will close by discussing experimental implications.

Geometric responses of Quantum Hall systems. Bulk and boundary

Abanov, Alexandre
(Stony Brook University, Physics and Astronomy, Stony Brook, USA)

The fractional quantum Hall effect (FQHE) is a fascinating physical phenomenon of quantization of the Hall conductance of two-dimensional electron gas in terms of fundamental constants. The phenomenon is observed at low temperatures and in strong magnetic fields. It is characterized by a formation of a collective state of electrons — an incompressible electron liquid. The responses of this rather exotic fluid to external electromagnetic and elastic perturbations are rather geometric in nature. These responses can be compactly described by the effective action of FQHE. In this talk I will consider the geometric part of the effective action for FQHE. It consists of three terms: Chern-Simons, Wen-Zee and gravitational Chern-Simons terms. I will show how to derive the geometric part of the effective action and will discuss the physical meaning of the corresponding linear responses of FQHE. In particular, I will discuss how geometric terms manifest on the boundary of FQHE droplet and talk about universality of Hall viscosity.

Normal modes of phase oscillations in inhomogeneous Josephson junction chains

Basko, Denis
(CNRS, Laboratoire de Physique et Modélisation des Milieux Condensés, Grenoble, France)

Elementary excitations of Josephson junction chains in the superconducting regime are small oscillations of the superconducting phase that can propagate along the chain. The subject of the talk is the effect of a spatial inhomogeneity in the chain on the normal modes of phase oscillations. First, I will discuss Anderson localization of the normal modes in a disordered chain. Then, I will turn to situations when spatial modulation of the chain parameters is introduced on purpose in the fabrication process. For such superconducting metamaterials, I will discuss the effect of spatial inhomogeneity on Josephson energy renormalization by coupling to normal modes, as well as its role in optimizing a superinductance.

Multifractality at Anderson transitions with Coulomb interaction

Burmistrov, Igor
(L.D. Landau Institute for Theoretical Physics, Mesoscopic physics, Chernogolovka, Moscow region, Noginskyi District, Russian Federation)

Mesoscopic fluctuations and correlations of the single-particle Green's function (including the local density of states) are studied near metal-insulator transitions in disordered interacting electronic systems. We show that the multifractal behavior of the local density of states survives in the presence of Coulomb interaction. We calculate the spectrum of multifractal exponents in $2+\varepsilon$ spatial dimensions for symmetry classes characterized by broken (partially or fully) spin-rotation invariance and show that it differs from that in the absence of interaction. We also estimate the multifractal exponents at the Anderson metal-insulator transition in 2D systems with preserved spin-rotation invariance.

Emergent Coulombic criticality and Kibble-Zurek scaling in a topological magnet

Castelnovo, Claudio
(University of Cambridge, Cavendish Laboratory, TCM group, United Kingdom)

When a classical system is driven through a continuous phase transition, its nonequilibrium response is universal and exhibits Kibble-Zurek scaling. We explore this dynamical scaling in the context of a three-dimensional topological magnet with fractionalized excitations, namely, the liquid-gas transition of the emergent mobile magnetic monopoles in dipolar spin ice. Using field-mixing and finite-size scaling techniques, we place the critical point of the liquid-gas line in the three-dimensional Ising universality class. We then demonstrate Kibble-Zurek scaling for sweeps of the magnetic field through the critical point. Unusually slow microscopic time scales in spin ice offer a unique opportunity to detect this universal nonequilibrium physics within current experimental capability.

Length distributions in loop soups

Chalker, John
(Oxford University, Theoretical Physics, United Kingdom)

We consider statistical ensembles of loops, such as the vortex lines of a smooth random two-component field in three space dimensions. These systems typically have phases in which the lengths of the longest loops are extensive. In such phases it is natural to ask about the distribution of loop lengths. Remarkably, the joint probability distribution of the lengths of the macroscopic loops can be calculated exactly. The distribution has a form that is known in the statistics literature as Poisson-Dirichlet, and depends on a single parameter, which is fixed by the loop fugacity and by symmetries of the ensemble. We show how to derive these results using $CP(n-1)$ or $RP(n-1)$ and $O(n)$ σ models together with replica techniques.

Microwave-induced resistance oscillations as a classical memory effect

Dyakonov, Michel
(Université Montpellier, Laboratoire Charles Coulomb, Montpellier, France)

Nearly 20 years ago Zudov, Du, Simmons, and Reno experimentally discovered huge microwave-induced resistance oscillations (MIRO) in high-mobility two-dimensional electron gas at low temperatures and moderate magnetic fields. This spectacular phenomenon with many very unusual features has attracted a lot of interest.

The mainstream theories describe MIRO as a quantum phenomenon and deal with quantum transitions between Landau levels in crossed electric and magnetic fields in the presence of electron scattering by different types of disorder.

In contrast, we demonstrate that MIRO can be fully understood as a *purely classical* memory effect caused by re-collisions of electrons with scattering centers after one or more cyclotron periods. We propose a new Drude-like approach taking account of such memory effects and find an excellent agreement between numerical simulations, analytical results, and experiment.

Cascade of phase transitions near quantum critical point

Efetov, Konstantin
(Ruhr-Universitaet- Bochum, Theoretische Physik III, Fakultaet fuer Physik und Astronomie, Germany)

Several well-known phenomena in the hole-doped cuprates like breaking of the rotational invariance, appearance of the pseudogap, charge modulation and d-wave superconductivity occur on a low energy scale of hundreds Kelvin. As it is not quite clear how to obtain these phases in an unified way from microscopic models of cuprates, we consider a low-energy model of fermions interacting with close to critical antiferromagnetic excitations. In contrast to a standard spin-fermion model, we assume in agreement with ARPES data that the fermion spectrum in the antinodal region is shallow, such that the 8 hotspots merge at not very weak interaction into 2 antinodal hot regions. In addition to the interaction via antiferromagnetic fluctuations, a long range part of the Coulomb interaction reducing the superconducting transition temperature is taken into the consideration.

It is demonstrated in the mean field approximation that the strongest instability in this situation is a Pomeranchuk instability leading at temperatures $T<T_{Pom}$, where T_{Pom} a critical temperature, to a deformation of the Fermi surface and breaking of the rotational symmetry. As a result, the charges on the „vertical“ and „horizontal“ O-atoms of the CuO lattice are different at $T<T_{Pom}$. Below T_{Pom} the Fermi surface remains ungapped and further phase transitions are possible.

Indeed, it turns out that a second critical temperature $T^*<T_{Pom}$ exists below which a d-wave excitonic insulator state with a gap in the antinodal region forms. Under the assumption of the momentum conservation in process of tunnelling between the layers it is characterized by orbital currents modulated with vectors $(\pm\pi/a_0, \pm\pi/a_0, \pm\pi/c_0)$ where a_0 and c_0 are lattice constants in the CuO plane and perpendicular to it, respectively, thus forming a 3D antiferromagnetic structure.
However, a more realistic diffusive tunneling results in the vanishing of the interlayer coupling of the orbital currents. Therefore the orbital

currents of different layers are not correlated and the state is intrinsically disordered in the c-direction. We identify this state as the pseudogap state in the cuprates. The gap in the fermionic spectrum of the pseudogap state is localized in the antinodal region and other instabilities of the ungapped parts of the Fermi surface are still possible.

We show that, in addition to the d-wave excitonic insulator, superconductivity and a charge density wave (CDW) can appear at temperatures T_c, $T_{CDW}<T^*$. Both the superconductivity and CDW have the d-wave symmetry. The d-wave symmetry of CDW is enforced by the long range part of the Coulomb interaction. The modulation vector of CDW is directed along the directions of the nematicity and is incommensurate with the spin modulation of the parent antiferromagnet. The obtained symmetry corresponds to a charge modulation on the O atoms along the bonds, while the charge on the Cu atoms is not modulated. Applying a magnetic field suppresses the superconductivity but stabilizes CDW.

The results of our theory can serve as an explanation of recent experiments on cuprates performed with the help of STM, NMR, hard and resonant soft X-ray scattering, neutron scattering, sound propagation, and with some other techniques.

Negative resistance, current vortices and other wonders of viscous electronics

Falkovich, Gregory
(Weizmann Institute of Science, Physics, Rehovot, Israel)

I describe the recent works with Levitov on currents flows in the regimes dominated by electron-electron interaction.

Appearance of electron viscosity breaks Ohm law and provides for nonlocal relation between current and electric field.

That gives rise to a new world of current flows which we started to explore.

Strongly disordered superconductors

Feigelman, Mikhail V.
(Russian Academy of Sciences, Landau Institute for Theoretical Physics, Moscow, Russian Federation)

Recent experiments on strongly disordered superconducting films demonstrated combination of unusual effects:
i) nonzero slope dH_{c2}/dT of the upper critical field at very low temperatures,
ii) Berezinsky-Kosterlitz-Thouless universal jump in presence of strong applied magnetic field, and
iii) low-temperature scaling of the critical current density near the upper critical field in the form $j\_c(H) \sim (H_{c2} - H)^{-3/2}$.
In my talk I will provide some qualitative understanding of the combination of these three apparently unrelated observations.

Heat transport in disordered many-body systems

Finkelstein, Alexander
(Texas A&M University, Department of Physics and Astronomy, College Station, USA)

We study thermal conductivity in the disordered two-dimensional electron liquid in the presence of long-range Coulomb interactions. The renormalization group analysis developed for thermal transport in the disordered Fermi liquid with a short-range interaction will be extended to include scattering processes induced by the long-range Coulomb interaction in the sub-temperature energy range.

On thermalization of the Fermi-Pasta-Ulam system, and nonlinearity induced destruction of Anderson Localization

Flach, Sergej
(Institute for Basic Science, Center for Theoretical Physics of Complex Systems, Also at: New Zealand Institute for Advanced Study, Massey University, New Zealand, Daejeon, Korea, Republic of)

tba

Are wavefunctions for a large number of electrons a legitimate scientific concept?

Fulde, Peter
(Max-Planck-Institut für Physik komplexer Systeme, Dresden, Germany)

It has been pointed out by W. Kohn that wavefunctions for more than thousand electrons run into the exponential wall problem. This would imply, that wavefunction-based electronic structure calculations for solids are not possible. It will be shown how the exponential wall is avaoided.

Errors in high speed optical fiber communications

Gabitov, Ildar
(The University of Arizona, Department of Mathematics, Tucson, USA)

Modern standards of high-speed data transmission impose strict requirements to the level of bit-error rate (BER~ 10^{-9}-10^{-12}). Spontaneous emission due to in-line optical amplifiers and optical fiber structural disorder represent main sources of errors in communication systems. Evaluation of statistical properties of these error is an important applied problem of the telecommunications industry. The standard method to determine the error rate is the direct BER measurement in fabricated transmission lines prior to installation. However this method is expensive and impractical in terms of design optimization of telecommunication links. Computer modeling at such small levels of errors is prohibitively expensive in terms of computer resources, and the existing algorithms (such as importance sampling) are not sufficient to solve this problem. The statistical properties of the error can be analyzed using instanton approach. Comparison with the experimental results showed a satisfactory agreement.

Weak measurements, coherence, and non- locality

Gefen, Yuval
(Weizmann Institute, Condensed Matter, Rehovot, Israel)

Unlike von Neumann’s collapse postulate, weak measurement (WM) provides us with a complementary tool to probe the quantum world: the detector gains information about the system (blurred by quantum noise, though) without (completely) destroying its quantum state. I will discuss how one can harness WM-based protocols to gain insight on quantum non-locality on the level of a single particle.

Topological superconductivity along a chain of magnetic atoms

Glazman, Leonid
(Yale University, Physics, New Haven, USA)

Chains of magnetic impurities embedded in a conventional s-wave superconductor may induce the formation of a topologically non-trivial superconducting phase. If such a phase is formed along a chain, then its ends carry Majorana fermions. We investigate this possibility theoretically, starting from the Shiba bound states induced by the individual magnetic impurities. While the resulting Hamiltonian has similarities with the Kitaev model for one-dimensional spinless p-wave superconductors, there are also important differences, most notably the long-range (power-law) nature of hopping and pairing as well as the complex hopping amplitudes. We develop an analytical theory, complemented by numerical approaches, which accounts for the electron long-range pairing and hopping via host material [1],magnetic order in the chain, spin-orbit coupling in the host superconductor, and the direct electron hopping between the impurity atoms [2]. The theory allows us to elucidate the domain of parameters favoring the formation of a topological phase and to find the spatial structure [2,3] of Majorana states appearing in that phase.

This talk is based on joint work with F. von Oppen, Falko Pientka, and Yang Peng.

[1] Falko Pientka, Leonid I. Glazman, and Felix von Oppen, Phys. Rev. B 88, 155420 (2013).
[2] Yang Peng, Falko Pientka, Leonid I. Glazman, and Felix von Oppen, Phys. Rev. Lett. 114, 106801 (2015).
[3] Falko Pientka, Leonid I. Glazman, and Felix von Oppen, Phys. Rev. B 89, 180505(R) (2014).

Low-frequency conductivity of disordered wires: integrability and instantons

Gruzberg, Ilya A.
(The Ohio State University, Physics, Columbus, USA)

Generic states of non-interacting electrons in disordered wires are localized, and the DC conductivity of a wire vanishes at zero temperature. However, the AC conductivity is non-vanishing, and its general form at low frequency, was obtained by Mott who used intuitive qualitative arguments. Then this formula was rigorously obtained by Berezinsky for a strictly one-dimensional (1D) disordered system. Using optimal fluctuation (instanton) methods, we compute the AC conductivity for a model of a disordered quasi-1D wire at low frequencies and large negative energies. Such instanton techniques were applied to the 1D case by Hayn and John. After some surprising cancellations, we obtain the Mott-Berezinsky formula. The present model is special in its high degree of symmetry, and our calculation uses the integrability of the saddle-point equations in an essential way. We consider whether Mott-Berezinsky formula would survive the loss of these features

Persistent currents for interacting bosons on a ring with a Gauge field

Hekking, Frank
(CNRS & Université Grenoble Alpes, LPMMC, Grenoble Cedex 9, France)

We consider interacting one-dimensional bosons on a tight ring trap subjected to a rotating barrier potential which induces an artificial U(1) gauge field.
This system defines the atomic counterpart of the rf-SQUID: the atomtronic quantum interference device (AQUID). We study the persistent currents induced by the gauge field. We show that the persistent current amplitude is maximal for intermediate interactions. This is due to the interplay of the effect of the barrier and the interactions. We demonstrate that AQUID constitutes a persistent current qubit and assess its quality, in terms of the resolution of the two lowest energy levels and their separation from the rest of

the many-body spectrum.

Non-ergodicity in many body systems and the phase diagram Josephson junction chain.

Ioffe, Lev
(LPTHE - Loboratoire de Physique Théorique et Hautes Energies, Paris, France)

At very high disorder a generic closed quantum systems becomes completely localized. I argue that this (may body) localization is preempted by a wide regime of non-ergodic behavior that displays a number of unusual properties. A good system to study these effects are Josephson junction arrays in a somewhat unusual regime.

Two parameter scaling in 1D topological Anderson insulators

Kamenev, Alex
(University of Minnesota, School of Physics and Astronomy, Department of Physics, Minneapolis, USA)

I will discuss extension of Khmelnitskii-Pruisken two-parameter scaling theory of IQHE onto other topologically non-trivial symmetry classes. The corresponding SUSY sigma-models are derived and analyzed. In 1D they could be solved exactly, yielding the quantitative RG flows and describing the nature of the
strange metal at the quantum phase transition points. The corresponding transport and dynamics appear to be given by Sinai diffusion. We also discuss possible experimental manifestations of these findings in Majorana quantum wires.

Collective phenomena in strongly correlated systems: Dual Boson approach

Katsnelson, Mikhail
(Radboud University Nijmegen, Institute for Molecules and Materials, Condensed Matter Theory, Nijmegen, Netherlands)

Collective excitations and nonlocal correlations play an important role in strongly correlated electron systems, especially in low dimensions. Dynamical Mean Field Theory, nowadays the standard approximation for correlated electronic systems, cannot capture these strongly nonlocal effects. The Dual Boson (DB) theory [1] was designed to treat the nonlocal interactions correctly, starting from a single-site reference problem. I will discuss both formal aspects of this method such as charge conservation in ladder DB approximation [2,3] and applications to various physical problems, including plasmons in strongly correlated systems [4], charge-density-wave instability in extended Hubbard model [5], and ultracold molecular gases with dipole-dipole interactions in optical lattices [6]. These examples show that DB, in particular, provides a prospective way to treat strongly correlated systems with long-range interactions.

[1] A. N. Rubtsov, M. I. Katsnelson, and A. I. Lichtenstein, Ann. Phys. (NY) 327, 1320 (2012).
[2] H. Hafermann, E. G. C. P. van Loon, M. I. Katsnelson, A. I. Lichtenstein, and O. Parcollet, Phys. Rev. B 90, 235105 (2014).
[3] E. A. Stepanov, E. G. C. P. van Loon, A. A. Katanin, A. I. Lichtenstein, M. I. Katsnelson, and A. N. Rubtsov, Phys. Rev. B (2016).
[4] E. G. C. P. van Loon, H. Hafermann, A. I. Lichtenstein, A. N. Rubtsov, and M. I. Katsnelson, Phys. Rev. Lett. 113, 246407 (2014).
[5] E. G. C. P. van Loon, A. I. Lichtenstein, M. I. Katsnelson, O. Parcollet, and H. Hafermann, Phys. Rev. B 90, 235135 (2014).
[6] E. G. C. P. van Loon, M. I. Katsnelson, and M. Lemeshko, Phys. Rev. B 92, 081106(R) (2015).

Screening of charge and structure in oxides

Littlewood, Peter
(University of Chicago, USA, Argonne National Laboratory, Director, Argonne, USA)

Heterostructure oxides offer the opportunity to build in electric fields by precise control of chemistry on the atomic scale, used recently to generate modulation doping of two- dimensional electron gases (2DEG) in oxides. The origin of the 2DEG, whether in pristine or defected materials, is under debate. I will discuss the role of surface redox reactions, in particular O vacancies, as the source of mobile carriers, and also discuss their role in the switching of ferroelectricity in ultra-thin films.
While electric charges can be screened by mobile carriers, the same is not true of strain fields, which have intrinsic long-range interactions that cannot be screened. When strain fields are produced as a secondary order parameter in phase transitions - as for example in ferroelectrics - this produces unexpected consequences for the dynamics of order parameter fluctuations, including the generation of a gap in what would otherwise have been expected to be Goldstone modes. In some cases, eg manganites and nickelates, other intra-cell modes can nonlinearly screen the order parameter, which produces a strong sensitivity of ordering to octahedral rotations, essentially a jamming transition. This is relevant for tuning entropic effects at phase transitions, perhaps to enhance electro-caloric effects.

Electrical and Thermal Transport in Inhomogeneous Luttinger Liquids

Matveev, Konstantin
(Argonne National Laboratory, Materials Science Division, Argonne, IL, USA)

We study the transport properties of long quantum wires by generalizing the Luttinger liquid approach to allow for the finite lifetime of the bosonic excitations. Our theory accounts for long-range disorder and strong electron interactions, both of which are common features of experiments with quantum wires. We obtain the electrical and thermal resistances and thermoelectric properties of such quantum wires. We cast our results in terms of the thermal conductivity and bulk viscosity of the electron liquid and give the temperature scale above which the transport can be described by classical hydrodynamics

Origin of spin dependent tunneling through chiral molecules

Michaeli, Karen
(Weizmann Institute of Science, Weizmann Institute of Science, Condensed Matter Physics, Rehovot, Israel)

The functionality of many biological systems depends on reliable electron transfer with minimal heating. Unlike man-made electric circuits, nature realizes electron transport via insulating chiral molecules. Electron transfer in cells occurs via tunneling---direct or in several steps---through organic molecules, most of which exhibit a helical structure. The high efficiency of electron transfer in these systems, especially over distances of nanometers and beyond, is unexpected for tunneling-based transport and is one of the most compelling questions in the field. Recent experiments have revealed that transport through such helix-shaped molecules strongly depend on the electron's spin. Theoretical attempts to explain this effect rely on large spin-orbit coupling, which is uncommon in organic materials. In this talk I will show that the helical geometry induces correlations between the spin of the transferred electrons and their flow direction. In the tunneling regime, these connections can explain the large spin polarization measured in experiments over an energy range of hundreds of meV, as well as the enhanced transmission through chiral molecules. The directionality generated by the locking of the electron spin and momentum may hold the key to understanding the extremely low dissipation of electric transfer through organic molecules despite strong molecular vibrations.

Classical impurities and boundary Majorana zero modes in quantum chains

Müller, Markus
(Paul Scherrer Institut and ICTP Trieste, Condensed Matter Physics , Villigen, Switzerland)

We study the response of classical impurities in quantum Ising chains. They entail an exact degeneracy which implies a Curie susceptibility in the magnetically disordered phase. The two ground states differ only close to the impurity, being related by the action of an explicitly constructed local operator. The critical response of a boundary impurity is logarithmically divergent and maps to the 2-channel Kondo problem, while it saturates for critical bulk impurities and in the ordered phase. The results for the Ising chain translate to the related problem of a resonant level coupled to a 1d p-wave superconductor or a Peierls chain, whereby the magnetic order is mapped to topological order. We find that the topological phase always exhibits a continuous impurity response to local fields as a result of the level repulsion of local levels from the boundary Majorana zero mode. In contrast the disordered phase generically features a discontinuous magnetization or charging response. This difference constitutes a robust and generic thermodynamic fingerprint of topological order in one dimension.

Many body localization and thermalization: insights from the entanglement spectrum

Nandkishore, Rahul
(University of Colorado at Boulder, Department of Physics and Center for Theory of Quantum Matter, Boulder, USA)

We study the entanglement spectrum in the many body localizing and thermalizing phases of one and two dimensional Hamiltonian systems, and periodically driven `Floquet' systems. We focus on the level statistics of the entanglement spectrum as obtained through numerical diagonalization, finding structure beyond that revealed by more limited measures such as entanglement entropy. In the thermalizing phase the entanglement spectrum obeys level statistics governed by an appropriate random matrix ensemble. For Hamiltonian systems this can be viewed as evidence in favor of a strong version of the eigenstate thermalization hypothesis (ETH). Similar results are also obtained for Floquet systems, where they constitute a result `beyond ETH', and show that the corrections to ETH governing the Floquet entanglement spectrum have statistical properties governed by a random matrix ensemble. The particular random matrix ensemble governing the Floquet entanglement spectrum depends on the symmetries of the Floquet drive, and therefore can depend on the choice of origin of time. In the many body localized phase the entanglement spectrum is also found to show level repulsion, following a semi-Poisson distribution (in contrast to the energy spectrum, which follows a Poisson distribution). This semi-Poisson distribution is found to come mainly from states at high entanglement energies. The observed level repulsion only occurs for interacting localized phases. We also demonstrate that equivalent results can be obtained by calculating with a single typical eigenstate, or by averaging over a microcanonical energy window - a surprising result in the localized phase. This discovery of new structure in the pattern of entanglement of localized and thermalizing phases may open up new lines of attack on many body localization, thermalization, and the localization transition.

Phenomenology of many-body localization

Oganesyan, Vadim
(City University, New York, College of Staten Island, Engineering Science and Physics, Staten Island, USA)

I will review recent progress on theory of many-body localization, mostly focusing on properties of the many-body localized phase itself. I will discuss explicit construction of effective Hamiltonians governing the dynamics of conserved quantities. The analysis reveals several inequivalent length scales in the system, some of which do not appear to diverge on the approach to the thermalized phase. Experimental protocols to measure these length scales will also be discussed.

Time-reversal symmetry and universal conductance fluctuations in a driven two-level system

Oliver, William D.
(Massachusetts Institute of Technology, Cambridge, USA)

In the presence of time-reversal symmetry, quantum interference gives strong corrections to the electric conductivity of disordered systems. The self-interference of an electron wave function traveling timereversed paths leads to effects such as weak localization and universal conductance fluctuations. Here, we investigate the effects of broken time-reversal symmetry in a driven artificial two-level system. Using a superconducting flux qubit, we implement scattering events as multiple Landau-Zener transitions by driving the qubit periodically back and forth through an avoided crossing. Interference between different qubit trajectories gives rise to a speckle pattern in the qubit transition rate, similar to the interference patterns created when coherent light is scattered off a disordered potential. Since the scattering events are imposed by the driving protocol, we can control the time-reversal symmetry of the system by making the drive waveform symmetric or asymmetric in time. We find that the fluctuations of the transition rate exhibit a sharp peak when the drive is time symmetric, similar to universal conductance fluctuations in electronic transport through mesoscopic systems.

Phase slips in a current-biased narrow superconductor strip

Ovchinnikov, Yury Nikolaevich
(RAS, L.D.Landau Institute for Theoretical Physics, Chernogolovka, Russian Federation)

Yu.N. Ovchinnikov, A.A. Varlamov

The theory of current transport in a narrow superconducting strip is revisited taking the effect of thermal fluctuations into account. The value of voltage drop across the sample is found as a function of temperature (close to the transition temperature, $T - T_c << T_c$) and bias current $J < J_c$ (J_c is the critical current calculated in the framework of the BCS approximation, neglecting thermal fluctuations). It is shown that careful analysis of vortices crossing the strip results in considerable increase of the activation energy.

Bose-condensation and superfluidity of magnons

Pokrovsky, Valery
(Texas A & M University and Landau Institute for Theoretical Physics, Physics Department, Department of Physics and Astronomy, Texas, USA)

We analyze the symmetry and coherence properties of the magnon Bose-Einstein condensate in Yttirum Iron Garnet films at room temperature discovered by the Münster experimental group (S.O. Demokritov) in 2006. In the work [1] we have shown that the magnon interaction causes spontaneous violation of the reflection symmetry and phase trapping. The symmetry and phase change at varying magnetic field in thinner films. Since the magnon condensate is coherent the natural question is whether the condensate is superfluid.[2] There are two main obstacles for superfluidity. The first is the dominance of the normal magnon density over the condensate in about 100 times. Our analysis shows that the velocity of the superfluid part is by 4-6 decimal orders larger than that of the normal part at the same field gradients. Thus, the spin current even in thick films is mainly due to condensate, i.e. superfluid. The second obstacle is the phase trapping that is inconsistent with the free motion whose phase changes linearly with coordinate. Therefore, the superfluid flow at slow velocity is inhomogeneous. In 1-d stationary flow the phase of the condensate on long intervals of remains close to the trapped values and changes by 2π on comparatively short intervals (phase solitons). The superfluid velocity remains almost zero between solitons and acquires finite value inside solitons. Thus, the current and number of magnons are not conserved locally transferring the spin momentum to the lattice, but they are conserved globally. All these phenomena are associated with dipolar forces. We propose several ways of realization of the superfluid flow of magnons and discuss their possible applications.

References

[1] F. Li, W.M. Saslow and V.L. Pokrovsky, Scientific Reports 3, 1372 (2013).
[2] C. Sun, T. Nattermann and V.L. Pokrovsky, Strange Superfluidity of magnons in Yttrium Iron Garnet. Submitted to Phys. Rev. Lett.

Many-body localization: Entanglement and efficient numerical simulations

Pollmann, Frank
(Max Planck Institute for the Physics of Complex Systems, Condensed Matter, Dresden, Germany)

Many-body localized (MBL) phases occur in isolated quantum systems when Anderson localization persists in the presence of finite interactions. It turns out that quantum entanglement is a very useful quantity to study these systems. First, we can use the entanglement of excited eigenstates to pinpoint the transition from an extended to a localized phase as the disorder strength is tuned. Second, the locality of eigenstates allows us to design algorithms to simulate these quantum many-body system efficiently.

Many-body localization in a quantum dot

Polyakov, Dmitry
(Karlsruher Institut für Technologie, Institut für Nanotechnologie, Karlsruhe, Germany)

I will discuss recent advances in our understanding of the interplay of disorder and interactions by focusing on the problem of interaction-induced hybridization of many-body states in a disordered quantum dot [1]. This problem bears similarity, conceptually, to that of Anderson localization of noninteracting particles---because it can be formulated in terms of quantum localization in Fock space of the interacting system [2]. As such, it has much in common with the problem of many-body localization in extended systems [3,4], where Anderson localization occurs both in Fock space and in real space.

The key issues that will be addressed include the position of the localization threshold for the eigenstates in Fock space (the localization-delocalization transition manifests itself, in particular, in the statistics of many-body energy levels) and the temporal relaxation of excited states in the finite correlated electron system (a „hot-electron state," a „typical" many-body state, a single-electron excitation added to a „thermal state").

[1] I.V. Gornyi, A.D. Mirlin, and D.G. Polyakov, Phys. Rev. B 93, 125419 (2016).
[2] B.L. Altshuler, Y. Gefen, A. Kamenev, and L.S. Levitov, Phys. Rev. Lett. 78, 2803 (1997).
[3] I.V. Gornyi, A.D. Mirlin, and D.G. Polyakov, Phys. Rev. Lett. 95, 206603 (2005).
[4] D.M. Basko, I.L. Aleiner, and B.L. Altshuler, Ann. Phys. (N.Y.) 321, 1126 (2006).

The quantum Hall effect, the θ angle, instantons and all that.

Pruisken, Adrianus
(University of Amsterdam, Institute of Theoretical Physics, ITFA, Physics, AMSTERDAM, Netherlands)

The quantum Hall effect is an outstanding laboratory for investigating and exploring topological principles in quantum field theory in general, and the strong coupling problems in QCD in particular. In this talk I review some of the highlights of more than three decades of research on the subject. This includes the laboratory experiments on the quantum Hall „plateau transitions" as well as the emergence of new concepts such as „super-universality" of quantum Hall physics.

Decoherence of a quantum two-level system by spectral diffusion

Schön, Gerd
(Karlsruhe Institute of Technology, Insitut für Theoretische Festkörperphysik, Physik, Karlsruhe, Germany)

We study the dephasing of an individual high-frequency tunneling two-level system (TLS) due to its interaction with an ensemble of low-frequency thermal TLSs which are described by the standard tunneling model (STM). We show that the dephasing by the bath of TLSs explains both the dependence of the Ramsey dephasing rate on an externally applied strain as well as its order of magnitude, as observed in a recent experiment [1]. However, the theory based on the STM predicts the Hahn-echo protocol to be much more efficient, yielding too low echo dephasing rates, as compared to the experiment. Also the strain dependence of the echo dephasing rate predicted by the STM does not agree with the measured quadratic dependence, which would fit to a high-frequency white noise environment. We suggest that few fast TLSs which are coupled much more strongly to the strain fields than the usual TLSs of the STM give rise to such a white noise [2]. This explains the magnitude and strong fluctuations of the echo dephasing rate observed in the experiment.

[1] J. Lisenfeld et al., Nature Sci. Rep. 6, 23786 (2016)
[2] S. Matityahu, A. Shnirman , G. Schön and M. Schechter, arXiv:1602.01453, Phys. Rev. B (to be published) (2016)

Superconductivity suppression in disordered films: Interplay of proximity to the 2D and 3D localization

Skvortsov, Mikhail A.
(Skoltech and Landau Institute for Theoretical Physics, Russian Federation)

Mikhail A. Skvortsov
Skolkovo Institute of Science and Technology
Landau Institute for Theoretical Physics

We consider superconductivity suppression in homogeneously disordered thin films. Anderson's theorem stating that the critical temperature is insensitive to the degree of disorder is violated in the vicinity of the Anderson localization transition. For strongly disordered films, the interplay between disorder and interaction effectively suppresses the BCS coupling constant, thereby reducing the critical temperature. For strictly 2D films, superconductivity suppression is coming from large scales (similar to the 2D localization), and summation of the leading logarithms can be performed with the help of Finkelstein's renormalization group. For thicker and sufficiently dirty films, there exists an additional effect originating from small scales (similar to the 3D localization). We calculate the corresponding contribution to the shift of the critical temperature and discuss its importance in the context of experimental situation.

Chiral anomaly and magneto-transport phenomena in Weyl metals

Spivak, Boris
(University of Washington, Department of Physics, Seattle, USA)

We present a theory of magnetotransport phenomena related to the chiral anomaly in Weyl semimetals. We show that conductivity, thermal conductivity, thermoelectric and the sound absorption coefficients exhibit strong and anisotropic magnetic field dependences. In the presence of a magnetic field the Wiedeman-Franz law in these materials can be violated. We also discuss properties of magneto-plasmons and magneto-polaritons, whose existence is entirely determined by the chiral anomaly. Finally, we discuss the conditions of applicability of the quasi-classical description of electron transport phenomena related to the chiral anomaly.

Topological phase transitions in the 1D multichannel Dirac equation with random mass and a random matrix model

Texier, Christophe
(Université Paris Sud, Laboratoire de Physique Théorique et Modèles Statistiques, Orsay, France)

We establish the connection between a multichannel disordered model --the 1D Dirac equation with NxN matricial random mass-- and a random matrix model corresponding to a deformation of the Laguerre ensemble. This allows us to derive exact determinantal representations for the density of states and identify its low energy ($\varepsilon \to 0$) behaviour $\rho(\varepsilon) \sim |\varepsilon|^{\alpha-1}$. The vanishing of the exponent α for N specific values of the averaged mass over disorder ratio corresponds to N phase transitions of topological nature characterised by the change of a quantum number (Witten index) which is deduced straightforwardly in the matrix model.

Magnetic field-dependent inhomogeneities and their effect on the magnetoresponse of 2D superconductors

Tripathi, Vikram
(Tata Institute of Fundamental Research, Department of Theoretical Physics, Mumbai, India)

We show that inhomogeneities in the spatial distribution of Cooper pairs and in the phase of the local superconducting order parameter in the vicinity of a superconductor-normal state transition (SNT) in two dimensions can be highly sensitive to a perpendicular magnetic field. We focus on the role of orbital effects in the field-dependence of local superfluid stiffness and superconducting phase disorder in homogeneously-disordered two-dimensional superconductor thin films. The relative importance of these orbital effects is analyzed in different physical regimes dominated by Coulomb blockade, thermal phase fluctuations and Aharanov-Bohm phase disorder respectively. Following this approach, we obtain explicit expressions for the field dependence of magnetoresistance and superfluid stiffness near the SNT, and attempt an understanding of some recent experimental findings.

References:
1. S. Sankar and V. Tripathi, arXiv:1603.06977

Geometric transport: quantum hall states

Wiegmann, Pavel
(University of Chicago, Kadanoff Ceneter for Theoretical Physics, Department of Physics, Chicago, USA)

Quantum Hall states are distinguished by a precise quantization of the Hall conductance in materials with imprecise characteristics.
A natural question is whether the Hall conductance is a unique precise characteristic.
Are there any other independent transport coefficients which are also precise on Quantum Hall H-plateaus?
New theoretical arguments indicate that there are at least two more independent precise characteristics albeit up to now only the Hall conductance is experimentally accessible. These characteristics appear as a response of states to a deformation of geometry. They are geometric transport coefficients.

On the Pruisken-Khmelnitskii RG flow for IQHE

Zirnbauer, Martin
(Universität zu Köln, Institut für Theoretische Physik, Physik, Köln, Germany)

The scaling behavior at the transition between plateaus of the Integer Quantum Hall Effect (IQHE) is traditionally interpreted on the basis of the Khmelnitskii-Pruisken renormalization group flow diagram conjectured from Pruisken's nonlinear sigma model. In recent work with Bondesan and Wieczorek [Phys. Rev. Lett. 112, 186803 (2014)] we identified a set of wave function observables which obey pure scaling laws at the critical point of the IQHE transition. This pure scaling behavior sheds new light on the precise nature of the critical point. In particular, it leads to the suggestion that the conformal fixed-point theory is given by Pruisken's nonlinear sigma model coupled to a Wess-Zumino-Witten model.