# 1. Barrier formation and charging energy for metal/organic interfaces. From the monolayer to the single molecule limit: $C_{60}/Au(111)$ and $C_6H_6/Au(111)$

**Enrique Abad**, Y. J. Dappe, J.I. Martinez, J. Ortega, F. Flores,

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In this work we combine a DFT calculation of the structural and electronic properties of metal/organic interfaces with an analysis of the interface barrier formation based on the induced density of interface states model [1]. It is well-known that in these systems it is necessary to go beyond standard DFT to properly describe the transport energy gap and thus obtain a correct description of the electronic structure of the interface. Our analysis allows us to determine the charging energy ($U^{eff}$) of the molecule at the interface, correct the DFT transport energy gap and obtain a realistic metal/organic barrier height [2]. This method has been applied to the $C_{60}/Au(111)$ and benzene/Au(111) interfaces for various coverages, from the monolayer to the single molecule limit. Realistic benzene-gold distances have been calculated including the Van der Waals interaction [3] in the DFT calculations of the interface.

[1] F. Flores, J. Ortega, H. Vazquez, Phys. Chem. Chem. Phys. 11 (2009) 8658.
[2] E. Abad, C. González, J. Ortega and F. Flores, Org. Electron. 11 (2010) 332.
[3] Y. J. Dappe, M. A. Basanta, F. Flores and J. Ortega, Phys. Rev. B 74, 205434

# 2. Quantum pumping in graphene NIS junctions

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We investigate adiabatic quantum pumping across a normal metal-insulator-superconductor (NIS) junction in a monolayer of graphene. The pumped current is generated by periodic modulation of two gate voltages, applied to the insulating and superconducting regions respectively. In the limit of a thin barrier and in the bilinear response regime, the pumped current reaches a maximum for a finite barrier strength in contrast to conventional NIS junctions. The pumped current shows different behaviour in the retro and the specular Andreev reflection regime. We compare our results with NIN junctions and ultimately $I_p^{NIS} = 4I_p^{NIN}$ for $\epsilon = 0$. The present work can be implemented with current techniques.

# 3. Crossover between the Kondo effect for quantum dots and the 0.7 conductance anomaly for quantum point contacts

**F. Bauer**, J. Heyder, J. von Delft,

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It has been conjectured that the 0.7 conductance anomaly for transport through a quantum point contact (QPC) is closely related to the Kondo effect for transport through a quantum dot (QD). To study the relation between these two effects explicitly, we consider a 1-D quantum wire modelled by a tight-binding chain with short-ranged Coulomb interactions and a prescribed on-site potential, whose shape can be varied to mimic the smooth crossover from a double-barrier potential (QD geometry) to a single barrier potential (QPC geometry). We use the functional renormalization group to calculate the conductance, local density and local magnetization for an interacting quantum-system. Our results reveal both striking similarities and striking differences between the parameter-dependencies of the 0.7 anomaly and the Kondo effect.

## 4. Spectral Footprints of Single Impurity Scattering and Edge Disorder in Graphene Nanoribbons

**A. Bergvall** and T. Löfwander,
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We investigate the effects of impurity scattering and edge disorder on the local density of states in graphene nanoribbons. The Fourier transformed local density of states (spectral footprint) show distinct features that can be understood in terms of intra- and interband sub-band scattering processes. These features can be directly measured by scanning tunneling microscopy.

## 5. Local Impurities and Step Edges on Strong Topological Insulator surfaces

**Rudro R Biswas** *(Harvard, USA)* and Alexander V Balatsky *(LANL)*

We consider the problem of a local potential/magnetic impurity placed on a STI surface with a single Dirac species. Local impurities give rise to LDOS resonance(s) near the Dirac point. Magnetic impurities also give rise to spin textures that mediate unconventional RKKY interactions. When the chemical potential is at the Dirac point, these interactions conspire to ferromagnetically align random impurity spins in the direction normal to the surface, potentially helping to open a gap in the spectrum. We also consider scattering from step edges on the STI surface and discover that Time Reversal Symmetry imposes certain constraints on the scattering coefficients. Using these, we obtain the decay power laws for LDOS oscillations far from the step edge.

## 6. Experimental and theoretical study of the current fluctuations of an on-demand single electron source

**E. Bocquillon**,
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We present the measurement of the auto-correlations of the current emitted by a single electron source realized in a 2DEG. It periodically emits one electron followed by one hole along chiral edge states of the integer quantum Hall effect. AC current quantization has already demonstrated the emission, on average, of a single charge at each half-cycle [1]. Characterizing the source beyond the average quantities requires the measurement of current fluctuations to demonstrate that exactly one particle is emitted during each half-cycle. Experimental setup and measurements of fluctuations at gigahertz frequencies are presented [2]. Then, results are compared to two different theoretical models [3]. These tools demonstrate single particle emission under appropriate operating conditions.

[1] Fève G., Mahé A., Berroir J-M., Kontos T., Plaçais B., Glattli D.C., Cavanna A., Etienne B. and Jin Y., 2007 Science 316 1169
[2] Mahé A., Parmentier F. D., Bocquillon E., Berroir J-M., Glattli D. C., Kontos T., Plaçais B., Fève G., Cavanna A., Jin Y., arXiv:1004.1985v1
[3] Albert M., Flindt C., Büttiker M., arXiv:1004.4510v1

## 7. Andreev states as quasiparticule traps in superconducting atomic-contacts

**L. Bretheau** (landry.bretheau@cea.fr),
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We have measured the supercurrent through phase-biased superconducting atomic contacts. Atomic contacts are simple but generic Josephson weak links, with just a few conduction channels. In each channel, the supercurrent is carried by a pair of states, the so-called "Andreev bound states". The experimental results suggest that, under certain circumstances, quasiparticules get trapped in Andreev bound states, leading to a suppression of the supercurrent. A detailed characterization of the dynamics of this phenomenon is presented.

## 8.  Magnetotransport in graphene n-p junctions: a semiclassical perspective

**Pierre Carmier**,

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In this poster, I present a semiclassical approach to the study of electronic transport in graphene n-p junctions in the quantum Hall regime. The kind of transport featured in this configuration is different from what is commonly known in standard two-dimensional electron gases, since graphene's unusual band structure causes both a significant increase in the likeliness of inter-band tunneling via the Klein paradox and an anomalous quantum Hall effect. In the magnetic regime ($E < B$), I show the conductance of excited states is essentially zero, while that of the ground state depends on the boundary conditions considered at the edge of the ribbon. In the electric regime ($E > B$), I derive a semiclassical expression for the conductance from the Fisher-Lee-Baranger-Stone formulae making use of a semiclassical approximation to the single particle Green function. Behavior of the conductance is discussed and compared to experiments.

## 9.  Detection of finite frequency photo-assisted shot noise with a resonant circuit

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Photo-assisted transport through a mesoscopic conductor occurs when an oscillatory (AC) voltage is superposed to the constant (DC) bias which is imposed on this conductor. Of particular interest is the photo assisted shot noise, which has been investigated theoretically and experimentally for several types of samples. For DC biased conductors, a detection scheme for finite frequency noise using a dissipative resonant circuit, which is inductively coupled to the mesoscopic device, was developed recently [1]. We argue that the detection of the finite frequency photo-assisted shot noise can be achieved with the same setup, despite the fact that time translational invariance is absent here. We show that a measure of the photo-assisted shot noise can be obtained through the charge correlator associated with the resonant circuit, where the latter is averaged over the AC drive frequency. We test our predictions for a point contact placed in the fractional quantum Hall effect regime, for the case of weak backscattering. The Keldysh elements of the photo-assisted noise correlator are computed. For simple Laughlin fractions, the measured photo-assisted shot noise displays peaks at the frequency corresponding to the DC bias voltage, as well as satellite peaks separated by the AC drive frequency.

[1] M.Creux, E.Paladino, A.Zazunov, A. Crépieux et T.Martin, Phys. Rev. B 99 (2007)

## 10.  The n-channel Anderson Model: a Dual Approach

**Daniel Crow**,

*Department of Mathematics, Imperial College, London, UK*

We extend the renormalized perturbation theory for the single impurity Anderson model to the $n$-channel case with a Hund's rule coupling and show that the exact results for the spin, orbital and charge susceptibilities are obtained by working to second order in the renormalized couplings. A universal relation is obtained between the renormalized parameters, independent of $n$, in the Kondo regime. The renormalized parameters are deduced from numerical renormalization group calculations for the model with $n = 2$ and the Kondo temperature found to be exponentially suppressed by the Hund's rule exchange term $J_H$.

## 11.   Charge Fractionalization in a Mesoscopic Ring

**Wade DeGottardi**[1], Siddhartha Lal[1,2], Smitha Vishveshwara[1],
[1]*University of Illinois at Urbana-Champaign, USA and* [2]*Indian Institute of Science Education and Research, Kolkata.*

Luttinger liquid theory predicts the existence of fractionally charged quasiparticles in interacting one-dimensional systems. Unfortunately, the experimental observation of these excitations is easily obscured by the Fermi liquid properties of the leads. Here, we propose a means of bypassing this complication by measuring the time averaged power dissipated in a pickup loop proximate to a mesoscopic ring into which an electron has been tunneled. We demonstrate that this experimental setup provides a means of detecting charge fractionalization. The proposed measurements can distinguish charge fractionalization from similar phenomena such as quantum superpositions.

## 12.   Effective Equilibrium Description of Nonequilibrium Quantum Transport

**Prasenjit Dutt**,
*Department of Physics, Yale University, New Haven, CT 06520, USA*

Interacting quantum systems and nonequilibrium phenomena both pose fundamental challenges in theoretical physics. We focus on nonlinear electronic transport through a quantum dot maintained at finite bias, and following Hershfield [Phys. Rev. Lett. **70**, 2134 (1993)] express such nonequilibrium quantum impurity models in terms of the system's Lippmann-Schwinger operators. These scattering operators allow one to reformulate the nonequilibrium problem as an effective equilibrium problem associated with a modified Hamiltonian. This description facilitates the implementation of equilibrium many-body techniques for a nonequilibrium problem. We expand upon the work of Hershfield and show the equivalence of observables computed in the Schwinger-Keldysh approach and the effective equilibrium formalism. We then present a generating functional framework using an imaginary time formulation, which we use in developing a generic scheme for perturbative calculations in interacting theories, with particular reference to the Anderson model.

## 13. Disorder-induced critical scaling of polarization waves on a chain of resonators

**Sanli Faez** and Ad Lagendijk,
*FOM Institute for Atomic and Molecular Physics, Amsterdam, The Netherlands*
Yan V. Fyodorov and Alexander Ossipov,
*School of Mathematical Sciences, University of Nottingham, England*

Propagation of electromagnetic polar waves in a chain of near-resonant scatterer shows critical scaling behaviour due to the disorder induced Anderson transition. This localization transition in a formally one-dimensional system is attributed to the long-range dipolar interaction, which decays as $r^{-1}$ for polarization perpendicular to the direction of the chain. This scale-invariance is absent for polarization parallel to the direction of the chain, for which the interaction decays as $r^{-2}$ and all eigenmodes are localized. Despite some plausible similarities, the multifractal spectrum of this classical open system is different from the quantum system with a Hermitian random banded Hamiltonian. We support our results by theoretical and numerical evidence.

## 14. Adapted continuous unitary transformation to treat systems with quasiparticles of finite lifetime

**Tim Fischer**, Sebastian Duffe and Götz S. Uhrig,
*Lehrstuhl für theoretische Physik I, Otto-Hahn-Straße 4, D-44221 Dortmund, Germany*

An improved generator for continuous unitary transformations is introduced to describe systems with unstable quasiparticles. Its general properties are derived and discussed. To illustrate this approach we investigate the asymmetric antiferromagnetic spin-1/2 Heisenberg ladder, which allows for spontaneous triplon decay. We present results for the low energy spectrum and the momentum resolved spectral density of this system. In particular, we show the resonance behaviour of the decaying triplon explicitly.

## 15. What does STM tell us about disorder in exfoliated graphene sheets?

**Marco Gibertini**,
*Scuola Normale Superiore di Pisa, Italy.*

Understanding the source of electronic disorder in mechanically exfoliated graphene sheets supported by dielectric substrates is an important goal of graphene research. Recent STM studies by Y. Zhang *et al.* [Nature Phys. **5**, 722 (2009)] have identified strong point disorder sources present in these systems and measured the graphene charge density disturbance that they produce. In this poster we present recent results [M. Gibertini, A. Tomadin, M. Polini, and A.H. MacDonald, on the arXiv soon] of extensive numerical calculations based on a Dirac-Kohn-Sham self-consistent density-functional method we introduced earlier [M. Polini *et al.*, Phys. Rev. B **78**, 115426 (2008)]. We critically examine the method used by Zhang and collaborators to extract the electron density from STM data and demonstrate that the measurements are inconsistent with a $\pi$-band only model of charged impurities very close to the graphene layers.

## 16. The Josephson Laser

**Frans Godschalk**,
*The Kavli Institute of NanoScience, TU Delft, The Netherlands*

We describe a superconducting device capable of producing laser light in the visible range at half of the Josephson generation frequency. It consists of two single-level quantum dots embedded into a *p-n* semiconducting heterostructure and surrounded by a cavity supporting a single mode. The optical phase of the laser light is locked to the superconducting phase difference. We study decoherence and spontaneous switching in the device.

## 17. Dynamics of the Periodic Anderson Model: exhaustion effects and the interplay of scales

**Lucas Hollender**,
*Institute of Theoretical Physics, Cologne University, Germany*

We investigate the paramagnetic periodic Anderson model within the framework of dynamical mean field theory, using Wilson's numerical renormalization group approach to obtain the self energy of the effective impurity model. For a variety of homogeneous lattice types, we examine the exhaustion scenario where the conduction band is progressively emptied. It is found that the existence of a Mott transition in this regime is sensitive to the lattice type. We also consider a bipartite system (with two sublattices comprising inequivalent Andersonian sites), and study the interplay of Kondo and lattice coherence scales.

## 18.   Topological insulators and superconductors from the Dirac limit

**Pavan Hosur**,
*Department of Physics, University of California at Berkeley, USA*

In recent years, there has been a tremendous surge in interest in topological phases in condensed matter physics, sparked off by the prediction and discovery of the three dimensional time-reversal invariant $Z_2$ topological insulator in several materials. These phases all host protected surface states which can be exploited in various ways to get a plethora of fascinating phenomena. Here, we present a generic 'node-pairing' picture, obtained by stacking sheets of graphene-like Dirac semi-metals, to explain the formation of these surface states. We exemplify this within a simple cubic lattice model of the $Z_2$ topological insulator, and use the same idea to obtain 'chiral' topological insulator and superconductor phases. These phases are also studied using a lattice model with a three dimensional Dirac dispersion, where they are shown to result from natural perturbations that induce a gap. The Dirac limit also allows us to easily spot 'dualities' between various gapped phases. Among others, we find dualities between these three dimensional topological phases, and conventional ordered phases like Neel antiferromagnetism.

## 19.  Phase-Slip Oscillator

**Alina Hriscu** and Yuli Nazarov,
*TU Delft, The Netherlands*

We prove that experimental detection of quantum phase slips is achievable for small phase slip amplitudes, contrary to what is usually assumed, by making use of a driven oscillator. Such oscillator can be realized on the basis of a thin superconducting wire or a chain of Josephson junctions.
The first order correction to the amplitude of a damped-driven exhibits a cosine dependence on the charge induced by a gate electrode and very unusual oscillatory dependence on the drive/frequency.

## 20.  Quantum criticality of the kagome antiferromagnet with Dzyaloshinskii-Moriya interactions

**Yejin Huh**, Lars Fritz, and Subir Sachdev,
*Department of Physics, Harvard University, Cambridge, Massachusetts 02138, USA*

We investigate the zero-temperature phase diagram of the nearest-neighbor kagome antiferromagnet in the presence of Dzyaloshinksii-Moriya interaction. We develop a theory for the transition between $Z_2$ spin liquids with bosonic spinons and a phase with antiferromagnetic long-range order. Connections to recent numerical studies and experiments are discussed.

## 21.  Quantitative description of Josephson-like tunneling in quantum Hall bilayers at $\nu_T = 1$

**Timo Hyart** and Bernd Rosenow,

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At total filling factor $\nu_T = 1$, interlayer phase coherence in quantum Hall bilayers can result in a tunneling anomaly [1] resembling the Josephson effect in the presence of strong fluctuations [2]. The most robust experimental signature of this effect is a strong enhancement of the tunneling conductance at small voltages. The height and width of the conductance peak depend strongly on the area and tunneling amplitude of the samples, applied parallel magnetic field and temperature [1, 3]. We find that the tunneling experiments are in quantitative agreement with a theory which treats fluctuations due to meron excitations phenomenologically and takes tunneling into account perturbatively [4]. We also discuss the qualitative changes caused by larger tunneling amplitude [3] and provide a possible explanation for recently observed critical currents in counterflow geometry [5].

[1]  I. B. Spielman *et al.*, Phys. Rev. Lett. **84**, 5808 (2000); I. B. Spielman, Ph.D. thesis, Caltech (2004).

[2]  See G.-L. Ingold *et al.*, Phys. Rev. B **50**, 395 (1994) and references therein.

[3]  L. Tiemann *et al.*, Phys. Rev. B **80**, 165120 (2009).

[4]  A. Stern *et al.*. Phys. Rev. Lett. **86**, 1829 (2001); M. M. Fogler and F. Wilczek, Phys. Rev. Lett. **86**, 1833 (2001); L. Balents and L. Radzihovsky, Phys. Rev. Lett. **86**, 1825 (2001).

[5]  Y. Yoon *et al.*, Phys. Rev. Lett. **104**, 116802 (2010).

## 22.  A persistent current approach to conductance through interacting nanostructures

**Mari Ijäs** (mari.ijas@tkk.fi) and Ari Harju,

*Department of Applied Physics and Helsinki Institute of Physics, Aalto University, FI-02150 Espoo, Finland*

We study the magnetic field-induced persistent current through quantum dot structures by exact diagonalization of the Hubbard Hamiltonian. The on-site contribution of the Coulomb interaction is taken into account both within the lead and the nanostructure. For on-site energy tuned quantum dots we obtain current resonances and charging effects, along with resonance peak splitting for interacting systems. For the Aharonov-Bohm rings pierced by another flux we find non-trivial current behaviour as a function of the two fluxes and different flux periodicity for the current in the lead part of the structure, and within the Aharonov-Bohm ring. The effect of the inclusion of the second-neighbour hopping within the Aharonov-Bohm ring is discussed.

## 23. Influence of Interactions on Counting Statistics

**Dania Kambly**, Christian Flindt and Markus Büttiker

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Full counting statistics is the stochastic theory of mesoscopic transport. Recently it has been shown that the charge transport statistics for non-interacting electrons in a two-terminal system is always generalized binomial: it can be decomposed into independent single-particle events and the zeros of the generating function are real and negative [1]. Here, we investigate how the zeros of the generating function may move into the complex plane due to interactions [2]. The motion of the zeros can be detected using high order factorial cumulants as we demonstrate. As an illustrative example we consider transport through a Coulomb blockade quantum dot. Our findings are important for understanding the influence of interactions on counting statistics and the characterization in terms of zeros of the generating function provides us with a simple interpretation of recent experiments [3].

[1] A. G. Abanov and D. A. Ivanov, Phys. Rev. Lett. **100**, 086602 (2008), Phys. Rev. B **79**, 205315 (2009)
[2] D. Kambly, C. Flindt, and M. Büttiker, in preparation (2010)
[3] C. Flindt *et al.*, Proc. Natl. Acad. Sci. USA **106**, 10116 (2009), C. Fricke *et al.*, Appl. Phys. Lett. **96**, 202103 (2010)

## 24. Mapping interacting fermion systems on boson models in an arbitrary dimension: A new route for analytical and numerical investigations?

**E. Kandelaki** and **H. Meier**,

*Institut für Theoretische Physik III, Ruhr-Universität Bochum, 44780 Bochum, Germany*

The recently suggested bosonization scheme for interacting fermions in an arbitrary dimension [Phys. Rev. Lett. **103**, 186403 (2009) and arXiv:1001.1552] and its possible application for analytical and numerical studies are discussed. We report about the on-going numerical tests using the bosonization technique as a starting point for quantum Monte-Carlo calculations and present some first results for simple systems.

## 25. Energy relaxation and thermalization of hot electrons in quantum wires

**Torsten Karzig**,

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with Leonid I. Glazman *(Yale)* and Felix von Oppen *(Dahlem Center for Complex Quantum Systems)*

We develop a theory of energy relaxation and thermalization of hot carriers in real quantum wires. Our theory is based on a controlled perturbative approach for large excitation energies and emphasizes the important roles of the electron spin and finite temperature. Unlike in higher dimensions, relaxation in one-dimensional electron liquids requires three-body collisions and is much faster for particles than holes which relax at nonzero temperatures only. Moreover, co-moving carriers thermalize more rapidly than counterpropagating carriers. Our results are quantitatively consistent with a recent experiment.

## 26.  Signatures of critical full counting statistics in a quantum-dot chain

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with Felix von Oppen
*(Dahlem Center for Complex Quantum Systems)*

We consider current shot noise and the full counting statistics in a chain of quantum dots which exhibits a
continuous non-equilibrium phase transition as a function of the tunnel couplings of the chain with the elec-
trodes. Using a combination of analytical and numerical methods, we establish that the full counting statistics
is conventional away from the phase transition, but becomes, in a well-defined sense, essentially non-Gaussian
on the critical line, where the current fluctuations are controlled by the dynamic critical exponent $z$. We find
that signatures of the critical full counting statistics persist in quantum-dot chains of finite length.

## 27.  Theory of itinerant magnetic excitations in the spin-density wave phase of iron-based superconductors

**Johannes Knolle**,

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We study the spin wave excitations of the parent iron-based superconductors employing the three band model
which consists of one hole pocket centred around the $\Gamma$-point, and two elliptical electron pockets centred around
$(\pi,0)$ and $(0,\pi)$ points of the Brillouin zone (BZ), respectively. Without taking ellipticity into account, the spin
wave excitations are degenerate at $(\pi,0)$ and $(0,\pi)$ points representing the degeneracy of the underlying spin
state. The ellipticity removes the degeneracy and selects the required $(\pi,0)$ state. Simultaneously, it also leaves
only one gapless Goldstone mode. We analyse the dispersion of the spin waves along the symmetry points of the
first BZ for various strengths of the ellipticity parameter and compare the results with available experimental
data. We find that neutron scattering data on the damping of the spin waves and their dispersion can be well
described within the itinerant description.

## 28.   Charge transfer between epitaxial graphene and silicon carbide

**Sergey Kopylov**[1], Alexander Tzalenchuk[2], Sergey Kubatkin[3], Vladimir I. Fal'ko[1]
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We analyse doping of graphene grown on SiC in two models which differ by the source of charge transferred to
graphene, namely, from SiC surface and from bulk donors. For each of the two models, we find the maximum
electron density induced in monolayer and bilayer graphene, which is determined by the difference between the
work function for electrons in pristine graphene and donor states on/in SiC, and analyse the responsivity of
graphene to the density variation by means of electrostatic gates.

## 29.  Topological origin of subgap conductance in insulating bilayer graphene

**Jian Li**,
*University of Geneva, Switzerland*

The edges of graphene-based systems possess unusual electronic properties, originating from the non-trivial topological structure associated to the pseudo-spinorial character of the electron wave-functions. These properties, which have no analogue for electrons described by the Schrödinger equation in conventional systems, have led to the prediction of many striking phenomena, such as gate-tunable ferromagnetism and valley-selective transport. In most cases, however, the predicted phenomena are not expected to survive the influence of the strong structural and chemical disorder that unavoidably affects the edges of real graphene devices. Here, we present a theoretical investigation of the intrinsic low-energy states at the edges of electrostatically gapped bilayer graphene (BLG), and find that the contribution of edge modes to the conductance of realistic devices remains sizable even for highly imperfect edges. This edge conductance can dominate over the bulk contribution if the electrostatically induced gap is sufficiently large, and account for seemingly conflicting observations made in recent transport and optical spectroscopy experiments. Our results illustrate the robustness of phenomena whose origin is rooted in the topology of the electronic band-structure, even in the absence of specific protection mechanisms.

## 30.  Nonequilibrium transport properties of a molecular quantum dot coupled to one-dimensional correlated metallic reservoirs

**Stefan Maier** and Andreas Komnik,
*Institute of Theoretical Physics, Heidelberg University, Germany*

We investigate the transport properties of a quantum dot with a harmonic degree of freedom (Holstein phonon) coupled to correlated one-dimensional fermionic leads. We use the Tomonaga-Luttinger model to describe the interacting leads and determine the cumulant generating function of charge transfer for a specific set of system parameters. In the resonant case, we find in lowest order perturbation theory divergencies in the current and noise when the source-drain bias approaches the phonon energy. Using diagrammatic resummation techniques, we were able to regularise these expressions. In contrast, the lowest order correction in the off-resonant case remains finite. We attribute this to the strongly non-monotonic behaviour of the bare transmission coefficient with respect to the dot level energy.

## 31.  Piezoconductivity of gated suspended graphene

**M. V. Medvedyeva**,
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We investigate the conductivity of graphene sheet deformed over a gate. The effect of the deformation on the conductivity is twofold: The lattice distortion can be represented as pseudovector potential in the Dirac equation formalism, whereas the gate causes inhomogeneous density redistribution. We use the elasticity theory to find the profile of the graphene sheet and then evaluate the conductivity by means of the transfer matrix approach. We find that the two effects provide functionally different contributions to the conductivity. For small deformations and not too high residual stress the correction due to the charge redistribution dominates and leads to the enhancement of the conductivity. For stronger deformations, the effect of the lattice distortion becomes more important and eventually leads to the suppression of the conductivity. We consider homogeneous as well as local deformation. We also suggest that the effect of the charge redistribution can be best measured in a setup containing two gates, one fixing the overall charge density and another one deforming graphene locally.

## 32.   Strong correlations in spinful quantum wires with multiple dynamics

**Tobias Meng,**
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We consider a quantum wire with two subbands close to the Lifshitz transition, at which the second band starts to get filled as a function of an external gate voltage. This quantum phase transition is, generically, characterized by pronounced correlations because the electrons in the second subband are strongly interacting: the diverging density of states close to the band bottom leads to unitary two-particle scattering in the low-energy limit. Further interest arises from the coexistance of different dynamics. While the filled band is in a Luttinger liquid state, the critical one has a quadratic dispersion. We show how the qualitatively different behaviour of the two bands can be exploited to identify the leading and subsequent effects of electronic correlations, and characterize different strongly correlated regimes as a function of the system's parameters.

## 33.   The Ising-nematic transition in two-dimensional metals

**Max A. Metlitski** and Subir Sachdev,
*Harvard University, USA*

In recent years a lot of interest has been raised by quantum phase transitions involving a smooth disappearance of a Fermi-surface. As one approaches such critical points, the Landau-quasiparticle weight tends to zero, nevertheless, the Fermi surface remains sharply defined. One proposed example of such a transition is the development of Ising-nematic order in a metal. This order, associated with electronic correlations, which spontaneously break the square lattice symmetry to that of a rectangular lattice, has been observed in the enigmatic normal state of the cuprate superconductors by a number of recent experiments. Motivated by these findings, I will present the scaling theory of the Ising-nematic transition in a two-dimensional metal. The critical point is described by an infinite set of 2+1 dimensional local field theories, labelled by points on the Fermi surface. Scaling forms for the response functions are proposed, and supported by computations up to three loops.

## 34.   Non-equilibrium electron spectroscopy of Luttinger Liquids

**Mirco Milletari',**
*Max-Planck Institute FKF Stuttgart, Germany*

We theoretically study a Luttinger liquid (LL) driven out of equilibrium by injection of high-energy electrons. The electrons enter the LL locally, far away from any contacts, and at a fixed energy. Their spectral properties are detected at another spatial point some distance away by evaluating the average tunneling current from the LL into a resonant level with tunable energy. For energies slightly below the injection energy, the dependence of the detected current on the difference between injection and detection energies is described by a power law whose exponent depends continuously on the Luttinger parameter. In contrast, for tunneling into the chiral LL edge of a fractional quantum Hall state from the Laughlin sequence, we find that the detected current grows linearly with the energy difference, independent of the LL parameter determined by the inverse filling fraction. We develop a diagrammatic approach for the standard (non-chiral) LL which provides an intuitive physical picture for how the electrons can relax inside the wire.

## 35. Quantum critical point shifts under superconductivity: the pnictides and the cuprates

**Eun Gook Moon** and S. Sachdev,

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We compare the position of an ordering transition in a metal to that in a superconductor. For the spin density wave (SDW) transition, we find that the quantum critical point shifts by order $|\Delta|$, where $\Delta$ is pairing amplitude, so that the region of SDW order is smaller in the superconductor than in the metal. This shift is larger than the $\sim |\Delta|^2$ shift predicted by theories of competing orders which ignore Fermi surface effects. For Ising-nematic order, the shift from Fermi surface effects remains of order $|\Delta|^2$. We discuss implications of these results for the phase diagrams of the cuprates and the pnictides. We conclude that recent observations imply that the Ising-nematic order is tied to the square of the SDW order in the pnictides, but not in the cuprates.

## 36. Enhancement of superconductivity by Joule heating

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We consider mesoscopic superconductor − normal metal heterostructures out of equilibrium. Using the quasiclassical Green's functions approach in the "dirty" limit we derive the equations determining the current-voltage characteristics of the structure. We found a non-trivial behavior of the CVC-curve in an N-S-N junction (S-shaped CVC). Also, an enhancement of the superconducting properties of the system by feeding energy into it is possible similar to the Wyatt-Dayem effect.

## 37. Optical Hall conductivity in the graphene quantum Hall system

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We theoretically investigate the optical Hall conductivity $\sigma_{xy}(\varepsilon_F, \omega)$. Even in the optical region, the Hall plateaus are retained both in the ordinary 2DEG and in graphene in the quantum Hall regime, although the plateau height is no longer quantized in ac. In graphene $\sigma_{xy}(\varepsilon_F, \omega)$ reflects the unusual Dirac Landau level structure. These plateau structures have been also experimentally reported for 2DEG from Faraday rotation measurement in THz regime. We attribute the robustness of the optical plateau to the effect of Anderson localization. To investigate properties of localization further, a dynamical scaling analysis is performed for the optical Hall conductivity, which displays a well-defined dynamical scaling. A crossover from dc-like behaviour to the ac regime is identified and the dynamical critical exponents as well as the localization exponents are found to be similar for 2DEG $n = 1$ LL and graphene $n = 0$ LL with $z \sim 2$.

## 38.  Excitation spectrum of a 2D long-range Bose liquid with a supersymmetry

**E. V. Mozgunov** and M. V. Feigel'man

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Specific model of a 2D Bose liquid with non-relativistic supersymmetry [1,2] is studied numerically by a mapping to a classical Langevin dynamics [3,4]. The model contains dimensionless coupling constant $\alpha$. At small $\alpha \leq 1$ this model is very similar to the 2D Bose-liquid with pair-wise logarithmic interaction and thus exhibit superfluid ground state. At very large $\alpha \geq 35$ the ground state breaks rotational symmetry. We have studied the excitation spectrum of this model, like it was done in Ref. [5] for the model of quantum dimers at the Rokshar-Kivelson point [6]. The spectrum $\omega(q)$ we found contains a plasmon gap $\omega_0$ at $q = 0$ and a well-defined roton minimum at $q = q_0 = 2\pi\sqrt{n}$ with minimal excitation energy $\Delta$. The ratio $\Delta/\omega_0$ decreases sharply with $\alpha$ in the whole range of the strongly coupled Bose liquid $1 < \alpha < 35$, down to very small values $\leq 10^{-2}$. However, we could not detect, with our numerical accurace, a vanishing of the roton gap *before* 2D crystallization transition takes place at $\alpha = \alpha_c \approx 37$. We thus conclude that the ground-state is of superfluid nature (at $T = 0$) in the whole range of $\alpha < \alpha_c$ . In the crystalline state $\alpha > \alpha_c$ no well-defined low-energy excitations corresponding to shear modes was found.

[1]  M. V. Feigel'man and M. A. Skvortsov. Nucl. Phys. B 506 [FS], 665 (1997), arXiv:cond-mat/9703215v1
[2]  C. Kane, S. Kivelson, Lee and Zhang Phys. Rev. b (1991)
[3]  M. V. Feigel'man and A. M. Tsvelik, Sov.Phys. JETP (1982)
[4]  C.L. Henley, J. Phys.: Condens. Matter 16, S891 (2004).
[5]  A. M. Läuchli, S. Capponi and F. F. Assaad, J. Stat. Mech. (2008) P01010
[6]  D. Rokhsar and S. Kivelson, Phys. Rev. Lett. 61, 2376 (1988).

## 39.  Unconventional quantum magnetism in Fermi systems with magnetic dipolar interactions

**Benjamin Munoz Fregoso** *(University of Chicago, USA)* and Eduardo Fradkin *(University of Illinois Urbana Champaign)*

We study the magnetic structure of the ground state of an itinerant Fermi system of spin-$1/2$ particles with magnetic dipole-dipole interactions. We show that, quite generally, the spin state of particles depend on its momentum, i.e., spin and orbital degrees of freedom are entangled and taken separately are not "good" quantum numbers. Specifically, we consider a uniform system with non-zero magnetization at zero temperature. Assuming the magnetization is along $z$-axis, the quantum spin states are $k$-dependent linear combinations of eigenstates of the $\sigma^z$ Pauli matrix. This leads to novel spin structures in *momentum space* and to the fact that the Fermi surfaces for "up" and "down" spins are not well defined. The system still has a cylindrical axis of symmetry along the magnetization axis. We also show that the self energy has a universal structure which we determine based on the symmetries of the dipolar interaction and we explicitly calculated it in the Hartree-Fock approximation. We show that the bare magnetic moment of particles is renormalized due to particle-particle interactions and we give order of magnitude estimates of this renormalization effect. We estimate that the above mentioned dipolar effects are small but we discuss possible scenarios where this physics may be realized in future experiments. Ref: Phys. Rev. B 81, 214443 (2010)

## 40.  Kondo temperature in a quantum dot

**Seungjoo Nah**, Michael Pustilnik

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We discuss the dependence of the Kondo temperature $T_K$ in a quantum dot system on the gate voltage $V_g$ in the Coulomb blockade regime. We show that due to the finite size of the quantum dot (i.e. the finite single particle level spacing in a quantum dot) the Kondo temperature is greatly enhanced compared with that in the Anderson single impurity model.

## 41. Three dimensional loop models and the $CP^{n-1}$ sigma model

**A. Nahum** and J. T. Chalker,
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We consider the statistical mechanics of certain classical loop models in two and three dimensions. These models are parametrized by a loop fugacity $n$; when $n = 1$ the quantum to classical mapping of Gruzberg et al. and Beamond et. al relates them to Anderson localization in symmetry class C. We argue that they are also relevant to a large class of deterministic walks in random environments, such as zero lines of random complex functions in three dimensions. We show that in the scaling limit these loops are related to $SU(n)$ antiferromagnets and to the $CP^{n-1}$ sigma model, and deduce some consequences.

## 42. Superconductivity on the surface of topological insulators

**Titus Neupert**,
*Paul Scherrer Institute, Switzerland*

We study the superconducting instabilities of a single species of two-dimensional Rashba-Dirac fermions, as it pertains to the surface of a three-dimensional time-reversal symmetric topological band insulator. The superconducting order parameter has both $s$-wave and $p$-wave components. We identify one single superconducting regime, irrespective of the relative strength between singlet and triplet pair potentials. We construct explicitly the Majorana states bound to vortices in the superconducting order parameter. Finally, we propose a heterostructure that can host a one-dimensional chain of these Majorana fermions, where the coupling between them can be adjusted via the chemical potential.

## 43. Magneto-thermopower of a quantum dot: effects of Kondo channels asymmetry

**T. K. T. Nguyen**,
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We consider effects of magnetic field on the thermopower and thermoconductance of a single-electron transistor based on a quantum dot strongly coupled to one of the leads by a single-mode quantum point contact. We show appearance of two new energy scales: $T_{min} \sim |r|^2 E_C (B/B_C)^2$ depending on a ratio of magnetic field $B$ and the field $B_C$ corresponding to a full polarization of point contact and $T_{max} \sim |r|^2 E_C$ depending on a reflection amplitude $r$ and charging energy $E_C$. The behaviour of TCs is discussed in three regimes. The "giant Fermi liquid" regime in which $S_{max} \sim e^{-1}(T/T_{min})|r_\uparrow r_\downarrow| \ln(E_C/T_{min})$ is predicted for $T < T_{min}$. Proximity to "strong non-Fermi liquid" regime with $S_{max} \sim e^{-1}|r|\sqrt{T/E_C} \ln(E_C/T)$ can be seen at $T_{min} < T < T_{max}$. Perturbative "weak non-Fermi liquid" regime where $S_{max} \sim e^{-1}|r|^2 \ln(E_C/T)$ holds at $T_{max} < T < E_C$. We discuss similarities of the model with multi-channel Kondo systems and possible experimental tests for verification of the non-Fermi-liquid transport through the quantum dot systems.

## 44.   Attractive Impurities in a Quantum Wire: Bound States, Interference, and Fano resonances

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Gordey Lesovik,
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We study the effect of attractive impurities on the ballistic conductance of a quantum wire. Attractive impurities provide bound state levels which modify the continuum of propagating states by sharp anti-resonances; these manifest themselves in a full suppression of the transmission of one channel just before turn-on of the next channel. In the case of more than one impurity, multiple scattering between the impurities leads to transmission resonances; the latter bring the channels repeatedly to full transmission (as a function of gate bias). The interplay between these multiple scattering resonances and the anti-resonances (due to the bound states) leads to interesting Fano resonance structures in the conductance. By focusing on the concept of eigenchannels, we investigate these resonance features in the case of one and two impurities in detail and explain the general structure of the scattering problem for the case of $n$ impurities, where $n$ eigenchannels are affected by the presence of the impurities and, therefore, the conductance can at most be suppressed by $n$ quanta.


## 45.   Switchable ultrastrong coupling in circuit QED

**Borja Peropadre**,
*Instituto de Física Fundamental, CSIC, Spain*

We propose different designs of switchable coupling between a superconducting flux qubit and a microwave transmission line. They are based on two or more loops of Josephson junctions which are directly connected to a closed (cavity) or open transmission line. In both cases the circuit induces a coupling that can be modulated in strength, reaching the so-called ultrastrong coupling regime in which the coupling is comparable to the qubit and photon frequencies. Furthermore, we suggest a wide set of applications for the introduced architectures.


## 46.   Many-Body Physics in Carbon-Face FLG Systems

**Rosario E. V. Profumo**,
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Few layer graphene (FLG) systems grown on the carbon-face of SiC tend to be misoriented in a manner which suppresses electron tunneling between layers. Even when the graphene layers are electrically isolated in the sense of layer-by-layer charge conservation, they influence each other through strong inter-layer Coulomb interactions. We show these interactions have an important influence on these graphitic nanostructure properties. For example competition between intra- layer and inter-layer correlations influences the way in which charge in the buffer layer is screened by electrons distributed across the FLG systems. Interlayer electron-electron interactions also have a surprisingly strong influence on many-body Dirac velocity renormalizations. We will explain the reason why electron-electron interactions effects are strong and suggest experiments which will reveal their role.

## 47. Quantum phase transitions of polaritons in coupled-cavity/circuit QED systems

**S. Schmidt** and G. Blatter,
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Motivated by the success of engineering strong light-matter interaction in cavity/circuit QED systems, the Jaynes-Cummings-Hubbard Model (JCHM) has recently been introduced to describe a superfluid-Mott insulator transition of polaritons in an array of coupled cavities, each containing a single photonic mode interacting with a two-level system. We review recent theoretical results on the phase diagram, excitations and critical exponents of the JCHM [1,2]. Furthermore, we show that even in the simplest case of two coupled cavities a sharp non-equilibrium self-trapping transition exists, which is reminiscent of this equilibrium superfluid-Mott transition in an infinite array. The proposed system is realizable with the current generation of circuit-QED technology [3].

[1] S. Schmidt and G. Blatter, Phys. Rev. Lett. **103**, 086403 (2009).
[2] S. Schmidt and G. Blatter, Phys. Rev. Lett. **104**, 216402 (2010).
[3] S. Schmidt, D. Gerace, A.A. Houck, G. Blatter, and H.E Tureci, arXiv:1001.1677 (2010).

## 48. Coulomb interaction in graphene: Relaxation rates and transport

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We study electron transport in graphene with Coulomb interaction at finite temperatures by using Keldysh diagrammatics. In the case of clean graphene we obtain the total scattering rate, the transport scattering rate, and the energy relaxation rate at the Dirac point. The total scattering rate in graphene exhibits a non-Fermi-liquid behavior ($\propto |\alpha| T$). Unlike metals clean graphene has a finite conductivity due to the Coulomb interaction. For conductivity we obtain the same analytic behavior as was found using the Boltzmann approach [1,2]. We analyze the plasmon spectrum of graphene and formulate quantum kinetic equations to describe transport in the crossover between the Coulomb interaction dominated regime and the disorder dominated regime.

[1] L. Fritz et al., Phys. Rev. B 78:085416 (2008)
[2] A. Kashuba, Phys. Rev. B 78:085415 (2008)

## 49. High-frequency tails and the decay rate of high-energy excitations in correlated systems

**Matthias Sitte**,
*Institute of Theoretical Physics, University of Cologne, Germany*

For energies much larger than the bandwidth, the lifetime of a highly excited state becomes exponentially large. Similarly, the high-frequency tails of correlation functions decay exponentially. This response is due to a collective excitation of many discrete degrees of freedom. Such a many-particle scattering process describes, e.g., the decay of doublons in ultra-cold atom gases in optical lattices. Here, we investigate the shape of correlation functions at high frequencies for the spin 1/2 Heisenberg XXZ chain, a paradigm model for strongly correlated systems. Using exact diagonalization methods we calculate the correlation function of the staggered magnetization in frequency space and compare to analytical approaches.

## 50. Wannier representation of $\mathbb{Z}_2$ topological insulators

**Alexey Soluyanov** and David Vanderbilt,
*Rutgers University, USA*

We consider the problem of constructing Wannier functions for $\mathbb{Z}_2$ topological insulators in two dimensions. It is well known that there is a topological obstruction to the construction of Wannier functions for Chern insulators (IQHE insulators), but it has been unclear whether this is also true for the $\mathbb{Z}_2$ case. We consider the Kane-Mele tight-binding model, which exhibits both normal and topological insulating phases as a function of the model parameters. We do find a topological obstruction in the $\mathbb{Z}_2$ odd phase, but only if one insists on choosing a gauge that respects the time-reversal symmetry, corresponding to Wannier functions that come in time-reversal pairs. If instead we are willing to violate this gauge condition, a Wannier representation becomes possible. We present an explicit construction of Wannier functions for the topological phase of the Kane-Mele model and confirm that these Wannier functions correctly represent the electric polarization and other electronic properties of the insulator. The choice of a smooth gauge of the Bloch states for the general case of $\mathbb{Z}_2$ insulator is also discussed.

## 51. Ferromagnetic Semiconductor-Metal Transition in Heterostructures of EuO

**Tobias Stollenwerk**, Michael Arnold and Johann Kroha,
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We have developed a theory which describes the simultaneous para-to-ferromagnetic and semiconductor-to-metal transition in electron-doped EuO [1]. The increase of the Curie temperature in Gd-doped EuO is driven by low lying spin fluctuations on the impurity levels and the resulting effective transfer of spectral weight towards the chemical potential. Based on this work we investigate heterostructures of EuO in contact with a correlated metal which is believed to enhance the spin fluctuations on the defects in the semiconducting gap even further.

[1]  M. Arnold and J. Kroha, Phys. Rev. Lett. 100, 046404 (2008).

## 52. Excitonic condensation in two-layer graphene

**Y. Suprunenko**, V. Cheianov, V.I. Fal'ko,
*Physics Department, Lancaster University, UK*

The considered system consists of two parallel separately controlled graphene monolayers, in which external gates induce a finite density of electrons in one layer and holes in another layer. We analyse the symmetry of the excitonic state, classify possible phases, and build a phase diagram that takes into account the effect of the symmetry breaking due to the external electric and magnetic fields. Within the mean-field approach theory, for each of the identified phases we find a value of the gap at $T = 0$ and the critical temperature $T_c$. However, because of the presence of Goldstone modes with linear spectrum, the fluctuation of order parameter suppress the transition into the excitonic insulator state.

# 53. Transport in networks of Josephson junctions

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We study microscopically low-temperature transport in disordered two-dimensional arrays of Josephson junctions and granulated superconductors. The conductivity comes from the motion of charged bosonic excitations. In the whole insulating region of the phase diagram, both in the deep Coulomb-blockade regime and close to the superconductor-insulator transition (SIT), and at arbitrary disorder strength the conductivity obeys the activation law $\propto \exp(-E_g/T)$ with the activation gap $E_g$ independent or nearly independent of the temperature. Also, we derive an effective Ginzburg-Landau functional describing the excitations close to the SIT and show that the transition is of the first order in all three-dimensional and in most two-dimensional arrays.

# 54. Tunable band-gap versus electron localization in hydrogenated quasi-free-standing graphene

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We show by angle-resolved photoemission spectroscopy (ARPES) that a tunable gap in quasi-free-standing monolayer graphene on Au can be induced by hydrogenation [1]. The size of the gap can be controlled via hydrogen loading and reaches 1.0 eV for a hydrogen coverage of 8%. The local rehybridization from $sp^2$ to $sp^3$ in the chemical bonding is observed by x-ray photoelectron spectroscopy and x-ray absorption and allows for a determination of the amount of chemisorbed hydrogen. The hydrogen induced gap formation is completely reversible by annealing without damaging the graphene. Calculations of the hydrogen loading-dependent core level binding energies [2] and the spectral function of graphene are in excellent agreement with photoemission experiments. Hydrogenation of graphene gives access to tunable electronic and optical properties and thereby provides a model system to study hydrogen storage in carbon materials. Furthermore, we show that a new electronic state appears in quasi-free-standing hydrogenated graphene (H-graphene) upon electron doping [3]. This state can act as an electron acceptor level for the $\pi$ electrons of graphene. Its occupation can be controlled via the H/C ratio and allows for tuning graphene's doping level. Our calculations of the electronic structure of H-graphene indicate that this state is largely composed from hydrogen 1s orbitals. Despite the randomness of H this state remains extended while electron localization sets in for the ÏĂ states of graphene.

[1] D. Haberer, D. V. Vyalikh, S. Taioli, B. Dora, M. Farjam, J. Fink, D. Marchenko, T. Pichler, K. Ziegler, S. Simonucci, M. S. Dresselhaus, M. Knupfer, B. Büchner, and A. Grüneis, *Tunable bandgap in hydrogenated quasi-free-standing graphene*, NanoLetters accepted and in press (2010).

[2] S.Taioli, S. Simonucci, M. Dapor, *SURPRISES: when ab initio meets statistics in extended systems*, COMPUTATIONAL SCIENCE & DISCOVERY 2 (2009) 015002

[3] D.Haberer , L. Petaccia , M. Farjam , S. Taioli, S. A. Jafari, B. Dora, D. V. Vyalikh, T. Pichler, D. Alfé, S. Simonucci, M. S. Dresselhaus, M. Knupfer, B. Büchner, A. Grüneis, *Direct observation of a deep acceptor level in electron doped hydrogenated graphene*, submitted to Phys. Rev. Lett. (2010)

## 55. Dimensional crossover of the dephasing time in a mesoscopic ring

**Maximilian Treiber**,
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We consider dephasing by electron interactions in an almost isolated ring, where the amplitude of the Altshuler-Aronov-Spivak (AAS) oscillations reveals a crossover of the dephasing time to 0D behavior ($\tau_\phi \sim T^{-2}$) when T drops below the Thouless energy. 0D-dephasing is dominated by large energy transfers, only restricted by T due to Pauli blocking. Therefore, the observation of this hitherto elusive crossover would allow tests of the role of T as UV-cutoff in the theory of dephasing. We show how 0D behaviour can be extracted from the conductivity at given frequency $\sigma(\omega)$, by filtering the envelope of the magneto-resistance from the AAS-oscillations.

## 56. Inhomogeneity threshold in the dynamics of many QDs coupled to a cavity

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We study the time dynamics of a single boson coupled to a bath of two-level systems (quantum dots) with different excitation energies, described by an inhomogeneous Dicke model. Analysing the time-dependent Schroedinger equation, we find that at resonance the boson decays in time to an oscillatory state with a finite amplitude characterized by a single Rabi frequency if the inhomogeneity is below a certain threshold. In the limit of small inhomogeneity, the decay is suppressed and exhibits a complex (mainly Gaussian-like) behaviour, whereas the decay is complete and of exponential form in the opposite limit. For intermediate inhomogeneity, the boson decay is partial and governed by a combination of exponential and power laws. This dynamical phenomena also manifests itself in spectroscopy as line width narrowing. In the strong coupling regime the line width is given by the bare cavity line width instead of the distribution of quantum dots in energy that can be much wider than the former.

## 57. Flux guidance by antidot arrays in superconducting films

**J. I. Vestgaarden**,
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I simulate magnetic flux guidance by a an array of 40 antidots (non-conducting holes) in a superconducting strip. Simulation formalisms is quasi-static, macroscopic electrodynamics. The two main challenges are the non-locality characteristic for thin films and the extremely non-linear resistivity characteristic for strong-pinning type-II superconductors. The simulation matches perfectly with magneto-optical experiments on the same system and we can conclude that antidots are suitable for magnetic flux guidance.

## 58. About Superradiant Phase Transitions in Circuit QED

**Oliver Viehmann,**
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Circuit QED systems of artificial atoms interacting with microwaves have been proved to behave in many respects analogously to their counterparts with real atoms in cavity QED. However, it has been predicted recently that the analogy fails if a large number of (artificial) atoms couple strongly to the electromagetic radiation [1]: Whereas for real atoms no-go theorems rule out the possibility of a superradiant quantum phase transition as the coupling is increased [2], the standard description of circuit QED systems in terms of macroscopic quantities [1,3] does allow it.

We investigate the possibility of a superradiant quantum phase transition in circuit QED systems from a microscopic point of view. Our analysis challenges the applicability of the standard description of circuit QED systems in the regime under concern and indicates even a qualitative deviation from its prediction.

[1]  P. Nataf and C. Ciuti, arXiv:1006.1801v1.
[2]  K. Rząžewski, K. Wódkiewicz, and W. Żakowicz, Phys. Rev. Lett. 35, 432 (1975).
[3]  A. Blais, R.-S. Huang, A. Wallraff, S. Girvin, and R. Schoelkopf, Phys. Rev. A 69, 062320 (2004).

## 59. Response of a superconducting-normal weak link to irradiation

**Pauli Virtanen,**
*University of Würzburg, Germany*

The response of a diffusive superconductor–normal metal–superconductor junction under microwave irradiation can be obtained [1] based on the quasiclassical Green's function formalism. We show how an enhancement of the critical current is found due to the energy redistribution of the quasiparticles in the normal wire induced by the electromagnetic field. Predictions across a wide range of temperatures, frequencies, and radiation powers, both for the critical current and the current-phase relationship can also be resolved.

[1]  P. Virtanen, et al., Phys. Rev. Lett. 104, 247003 (2010).

## 60. Ground state of electronic excitations in graphene with a topological defect

**N.D. Vlasii,**
*Taras Shevchenko National University of Kyiv, Ukraine*

The influence of a topological defect in graphene on the ground state of electronic quasiparticle excitations is studied in the framework of the long-wavelength continuum model originating in the tight-binding approximation for the nearest-neighbour interaction in the graphitic lattice. We show that a topological defect that rolls up a graphitic sheet into a nanocone is represented by a pointlike pseudomagnetic vortex with a flux which is related to the deficit angle of the cone. The electronic system on a graphitic nanocone is found to acquire charge, as well as condensate and current of special type, in the ground state.

## 61.   Vacancies in non-collinear antiferromagnets

**Alexander Wollny**,
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2D quantum Heisenberg antiferromagnets provide a variety of interesting phenomena. The role of vacancies has been widely studied on the square lattice, e.g. in the context of cuprates, and is reasonably well understood.

For a system with geometrical frustration the situation is more difficult. Here a magnetically ordered state often displays non-collinear order which has a strong influence on the basic excitations of the system, the spin-waves. The simplest realization is the triangular lattice which shows a 120° spin structure. At the classical level, a vacancy induces a local distortion of the spin pattern which partially relieves the frustration.

We perform a classical Monte Carlo simulation which determines the structure of the distortion and shows that it declines exponentially. Thus, it does not correspond to a goldstone mode but can be interpreted as a local condensate of spin-waves. Taking this distortion into account, we study the spin-wave corrections to the classical ground state in linear order and discuss how the vacancy could be seen in a local susceptibility measurement.

## 62.   Roton Modes in 5/2 Quantum Hall Systems and Graphene

**Anthony R. Wright**,
*Max Planck Institute for Solid State Research, Germany*

Rotons are relatively rare. The collective excitation spectrum of superfluid Helium has been known to contain a roton mode for 60 years, and not surprisingly the same have been found in various superconductors. Under an intense magnetic field, a 2D electron gas can exhibit the same behaviour. I exploit a simple vortex-antivortex picture of the collective excitation spectrum of the $\nu = 5/2$ fractional quantum Hall effect, to demonstrate that the spectrum splits into two distinct branches depending on the occupancy of a non-Abelian Majorana mode in the vortex cores. Experimental verification of such splitting would be direct evidence of the existence of non-Abelian quasiparticles in $\nu = 5/2$ QHE systems.

## 63.   Multi-Scale Quantum Criticality: Pomeranchuk Instability in Isotropic Metals

**M. Zacharias**,
*Institute for Theoretical Physics, University of Cologne, Germany*

We study the Pomeranchuk instability of an isotropic metal in $D = 2$. The effective Ginzburg-Landau theory has two critical modes with different dynamics. A damped mode with a dynamical exponent $z = 3$ and a ballistic mode with $z = 2$. We find that the $z = 2$ mode governs the system at $T = 0$, although the $z = 3$ mode has the lower characteristic energy. At finite $T$, the two time scales yield a parametrically large quantum-to-classical crossover regime. This leads to an intricate interplay of classical and quantum fluctuations, As a result, we find the correlation length to be independent of the interaction strength. The phase diagram contains two crossover lines between the low temperature and the quantum critical regime, to which the thermodynamic quantities differ in sensitivity.