PROGRAM AND ABSTRACT BOOKLET

WORKSHOP ON QUANTUM COHERENCE AND CORRELATIONS IN CONDENSED-MATTER AND COLD-ATOM SYSTEMS

University of Évora, Portugal, 11-15 October 2010

The Workshop

The workshop is promoted by the European Science Foundation Program INSTANS and several Portuguese projects. Our main aim is to generate a lively exchange of ideas between researchers working in the different but nevertheless related fields of ultra-cold atoms, quantum information, superconductivity, and spintronics.

Quantum many-body systems show a variety of striking phenomena not observed in ensembles of classical particles. Quantum interference, quantum coherence, quantum entanglement and quantum statistics - fermionic, bosonic or fractional - often conspire in producing intricate many-particle states, including macroscopically coherent phases - Bose-Einstein condensation, superconductivity, charge- and spin-density waves, to name but a few. The spectacular effects seen in transport experiments, for instance in the Quantum Hall Effect, in conductance quantization or in the Pauli blockade, also are related to the same quantum conspiracy. The aims of the workshop on "Quantum coherence and correlations in condensed-matter and cold-atom systems" will be both to elucidate the multiple facets of a very active field of research and to bridge the gaps between traditionally separate topics.

Location

The workshop will take place at:

Anfiteatro 131-A
Edifício do Espírito Santo
Universidade de Évora.

Organizing Committee

Miguel A. N. Araújo (Évora, Portugal)

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Sponsors

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PROGRAM

The lengths of both invited (45 minutes) and contributed talks (25 minutes) include at least 5 minutes of discussion.

Monday, October 11

8:30-9:00 Registration

9:00-9:10 Welcome

9:10-9:55 Invited: **José Tito Mendonça**
Nonlinear wave-wave and wave-particle processes in ultra-cold matter

9:55-10:20 Contributed: **Hugo Terças**
Rossby-Tkachenko waves in rapidly rotating Bose-Einstein condensates

10:20-10:45 Contributed: **Omjyoti Dutta**
Unconventional superfluidity of fermions in Bose-Fermi mixtures

10:45-11:15 Coffee break

11:15-11:40 Contributed: **Dmitry Mozyrsky**
Macroscopic quantum superpositions in cold atom systems

11:40-12:25 Invited: **Henrik Johannesson**
Two-impurity Kondo model at quantum criticality: Entanglement and spin-orbit interactions

12:25-12:50 Contributed: **Alexandros Metavitsiadis**
Transport properties of spin-$\frac{1}{2}$ Heisenberg chains coupled to a spin-S magnetic impurity

12:50-15:00 Lunch break

15:00-15:25 Contributed: **Alexey V. Ponomarev**
Mutual thermal equilibration within an isolated bipartite quantum system

15:25-16:10 Invited: **Caslav Brukner**
Classical limit of quantum fields

16:10-16:40 Coffee break

16:40-17:05 Contributed: **Maciej Misiorny**
Current-induced spin reversal in magnetic molecules/atoms

17:05-17:50 Invited: **Hai-Qing Lin**
Critical properties of the fidelity susceptibility

17:50-18:30 Special: **Francisco (Paco) Guinea**
Graphene, history and prospects

18:30 Reception at the University of Évora

Tuesday, October 12

9:00-9:45 Invited: **Patrick A. Lee**
Quantum spin liquid and superconductivity

9:45-10:30 Invited: **Zlatko Tešanovic**
High-temperature superconductors: from copper to iron

10:30-10:55 Contributed: **Antonio M. Garcia-Garcia**
Finite size effects in superconducting nanograins: from theory to experiments

10:55-11:25 Coffee break

11:25-12:10 Invited: **José Rodriguez**
Is superconductivity in iron-pnictide materials controlled by a quantum critical point into hidden magnetic order?

12:10-12:55 Invited: **Manuel Almeida**
CDW and superconducting ground states in quasi-1D systems; the $(Per)_2M(mnt)_2$ *salts*

12:55-15:00 Lunch break

15:00-15:45 Invited: **Giuseppe Mussardo**
Expectation values in the Lieb-Liniger Bose gas

15:45-16:30 Invited: **Rodrigo Pereira**
Spin-charge coupling effects on dynamics of one-dimensional systems

16:30-17:00 Coffee break

17:00-17:40 Short poster presentations

17:40 Poster session

19:00 Reception at Évora's City Hall

Wednesday, October 13

9:00-9:45 Invited: **Miguel A. Cazalilla**
Ultracold gases of Ytterbium: Ferromagnetism and Mott states in an SU(6) Fermi system

9:45-10:30 Invited: **Alejandro Muramatsu**
Correlated fermions on graphene-like lattices

10:30-11:00 Coffee break

11:00-11:25 Contributed: **Dariou Bercioux**
Topology-induced phase transitions in quantum spin Hall lattices

11:25-12:10 Invited: **Benedict N. Murdin**
The silicon crystal lattice as a model cold atom trap: coherent excitation of impurity atom Rydberg states

12:10-12:35 Contributed: **Mikhail Vasilevskiy**
Silicon nanocrystal surrounded by amorphous silicon: is it a quantum dot?

12:35 Lunch

14:00-20:00 Excursion

20:00 Banquet at *Adega do Alentejano*, Rua Gabriel V. do Monte Pereira, 21-A, 7000- 533 Évora (Telephone 266 744 447).

Thursday, October 14

9:00-9:45 Invited: **Yong P. Chen**
Recent experiments on 2D electron systems in GaAs and in graphene

9:45-10:30 Invited: **João Lopes dos Santos**
The graphene twisted bilayer: experimental and theoretical review

10:30-11:00 Coffee break

11:00-11:25 Contributed: **Aires Ferreira**
A unified description of the DC conductivity of monolayer and bilayer graphene based on resonant scatterers

11:25-11:50 Contributed: **Hector Ochoa**
Limits on transport properties of suspended graphene due to scattering by flexural phonons

11:50-12:15 Contributed: **Nicolas Garcia**
Ballistic resistance and high mobility in constrictions of 20nm thick packed graphene planes

12:15-15:00 Lunch break

15:00-15:25 Contributed: **Gunnar Möller**
Neutral fermion excitations and skyrmions in the $\nu = 5/2$ *Quantum Hall state*

15:25-16:10 Invited: **Allan MacDonald**
Spontaneous interlayer coherence in electronic bilayers

16:10-16:40 Coffee break

16:40-17:25 Invited: **José Ignacio Latorre**
Artificial gauge fields and tensor networks

17:25-17:50 Contributed: **Balazs Hetényi**
Approximate variational theory of bound excitons in insulators

Friday, October 15

9:00-9:45 Invited: **Vitalii Dugaev**
Two-dimensional electron system in periodic magnetic field

9:45-10:30 Invited: **German Sierra**
Infinite Matrix Product States and Conformal Field Theory

10:30-11:00 Coffee break

11:00-11:45 Invited: **Daniel Arovas**
What can we learn from quantum entanglement spectra?

11:45-12:30 Invited: **Sougato Bose**
Entanglement across a separation in spin chains: statics and dynamics

12:30 Closing address

POSTERS

Poster Session – 12/10/2010

	Name	Title
1	Sahid Ali	Excitation of classical and quantum wakefields in nanowires
2	Fábio Manuel Hipólito Vilas Boas	Conductivity in graphene nanoribbons
3	Gerson Duarte-Filho	Quantum dots chain: a circuit theory approach
4	Patrick Haase	Density of states for the Hubbard model with dispersive phonons
5	Una Karahasanovic	Quantum critical points are multicritical
6	Luca Leporii	(3+1) massive Dirac fermions with ultracold atoms in optical lattices
7	Yuriel Nunez-Fernandez	Chaos in liquid surface waves as the result of spatial geometric confinement
8	Matous Ringel	Multiphoton scattering on resonant atoms in 1D waveguide a path integral approach

Monday, October 11

NONLINEAR WAVE-WAVE AND WAVE-PARTICLE PROCESSES IN ULTRA-COLD MATTER

J. T. Mendonça

IPFN, Instituto Superior Técnico, Av. Rovisco Pais 1, 1049-001 Lisboa, Portugal

A new area of condensed matter physics has emerged in recent years, which could be called the physics of ultra-cold matter. It includes the steady-state properties of ultra-cold matter, as created by laser cooling processes in magneto-optical traps, and the time-varying regime of Bose Einstein condensates. Here we explore the elementary processes associated with wave-wave and wave-particle (atom) interactions. The waves considered in the case of ultra-cold matter in steady-state are the plasma-acoustic modes derived by [1] in the quasi-classical regime, and by [2] in the quantum regime. Light scattering by these collective oscillations of the ultra-cold gas, and their relation with the experiments will also be discussed. In what concerns Bose Einstein condensates, we explore the wave-particle effects associated with Bogoliubov oscillations, as discussed by [3], and the associated beam instabilities. Two counter-streaming BECs were considered in [4]. Rossby waves can also be shown to exist in rotating condensates [5].

9h10
Mon
1

[1] J.T. Mendonça, R. Kaiser, H. Terças and J. Loureiro, *Phys. Rev. A*, **78**, 013408 (2008).
[2] J.T. Mendonça, *Phys. Rev. A*, **81**, 023421 (2010).
[3] J.T. Mendonça, A. Serbeto and P.K. Shukla, *Phys. Lett, A*, **372**, 2311 (2008).
[4] H. Terças, J.T. Mendonça and G.R.M. Robb, *Phys. Rev. A*, **79**, 065601 (2009).
[5] H. Terças, J.P.A. Martins and J.T. Mendonça, submitted (2010).

ROSSBY-TKACHENKO WAVES IN RAPIDLY ROTATING BOSE-EINSTEIN CONDENSATES

H. Terças,[1] J. P. A. Martins[2], J. T. Mendonça[1,3]

1 CFIF, Instituto Superior Técnico, Av. Rovisco Pais 1, 1049-001 Lisboa, Portugal
2 CGUL/IDL, University of Lisbon, Edifício C8, 1749-016 Lisboa, Portugal
3 IPFN, Instituto Superior Técnico, Av. Rovisco Pais 1, 1049-001 Lisboa, Portugal

9h55
Mon
2

We predict a new collective mode in rotating Bose-Einstein condensates, which is very similar to the Rossby waves in geophysics. In the regime of fast rotation, the Coriolis force dominates the dynamics and acts as a restoring force for acoustic-drift waves along the condensate. We derive a nonlinear equation that includes the effects of both the zero-point pressure and the anharmonicity of the trap. It is shown that such waves have negative phase speed, propagating in the opposite sense of the rotation. We discuss a more general dispersion relation, where the well-knwon Tkachenko modes can be included as well.

[1] H. Terças, J. P. A. Martins and J. T. Mendonça (submitted)
[2] E. B. Sonin, Phys. Rev. A **71**, 011603(R) (2005).

UNCONVENTIONAL SUPERFLUIDITY OF FERMIONS IN BOSE-FERMI MIXTURES

O. Dutta[1] and M. Lewenstein[1,2]

1 ICFO-Institut de Ciències Fotòniques, Mediterranean Technology Park, E-08860 Castelldefels (Barcelona), Spain

2 ICREA-Instituci'o Catalana de Recerca i Estudis Avan¸cats, Lluis Companys 23, E-08010 Barcelona, Spain

Experimental realization of fermionic superfluidity in a quantum degenerate ultracold gas started a renewed interest in the field. Attraction between fermionic particles favours pairing of fermions resulting in superfluidity of the system. The paired fermions, known as Cooper pairs, can have different kinds of internal symmetries. The common ones found in nature have s-wave and d-wave internal structure and conserve parity and time reversal symmetry. In superfluid ^{3}He, the so-called A and A1 phases are characterized by Cooper pairs with nonzero magnetic orbital momenta. Cooper pairs with chiral $p_x + ip_y$-wave internal structure are believed to be responsible for the observed superfluidity of electrons in Strontium Ruthenate. When confined in a two dimensional geometry, excitations in a the chiral p-wave superfluid can become so called non-Abelian anyons. Apart from fundamental interest in the existence of such particles, non-Abelian anyons find remarkable applications in the field of quantum information for quantum memories and fault-tolerant quantum computation.

10h20
Mon
3

In the present paper, we discuss another way to generate high temperature unconventional superfluids in a Bose-Fermi mixture. We study the property of superfluidity in Bose-Fermi mixtures, where bosons are interacting via long-ranged dipolar interactions. First we study the boson-fermion interaction and the many-body effect of fermions on dressing the exci- tation spectrum of the condensate. We go beyond Migdals limit and include first order vertex corrections to study fermion self-energy in normal chennel as well as in the Cooper pair channel. In doing so, we include the full effect of retardation and strong momen- tum dependance of the bosonic excitation spectrum and bosonic propagator. By deriving a vertex-corrected strong-coupling Eliashberg equation, we predict that the vertex-corrected mechanism supports superfluids with p, f and h-wave pairing symmetries at experimentally feasible transition temperatureswe solve for transition temperatures in different angular mo- mentum channels. Further, we present a brief discussion regarding the possible occurrence of non-Abelian Majorana fermions for broken time-reversal p, f, and h-wave superfluids. We solve the Bugoliubov-deGennes equation for the p, f, and h-wave superfluids in the limit of large distance to find the Majorana bound states.

MACROSCOPIC QUANTUM SUPERPOSITIONS IN COLD ATOM SYSTEMS

D. Mozyrsky, D. Solenov

Los Alamos National Laboratory, Los Alamos, NM 87545, USA

We study macroscopic properties of a Bose-Einstein Condensate confined to a ring-shaped potential containing a tunnel barrier. We argue that due to the interplay between the Josephson energy and the kinetic energy of particles such system exhibits a set of metastable current-carrying states, similar to a conventional superconducting phase-qubit device [1]. These states can be controlled by rotating the tunnel barrier and, under the appropriate conditions, the system can be set in a superposition of two different persistent current states. We show that such state can be adequately described by an effective single body Schrodinger equation and evaluate parameters in this equation. We also discuss how the current- carrying states can be detected in the standard time of flight measurements and analyze possible scenarios for the outcomes of such measurements.

11h15
Mon
4

[1] D. Solenov and D. Mozyrsky, Phys. Rev. Lett **104**, 150405 (2010).

TWO-IMPURITY KONDO MODEL AT QUANTUM CRITICALITY: ENTANGLEMENT AND SPIN-ORBIT INTERACTIONS

Henrik Johannesson[1], Erik Eriksson[1], and David F. Mross[2]

1 Department of Physics, University of Gothenburg, SE 412 96 Gothenburg, Sweden
2 Department of Physics, MIT, Cambridge, MA 02139-4307, USA

11h40 Mon 5

After a brief review of two-impurity Kondo physics I will discuss recent work expanding on results in Ref. [1] where the critical behavior of a double quantum-dot realization of the two-impurity Kondo model (TIKM) in the presence of Rashba and Dresselhaus spin-orbit interactions is studied. In particular, we show that these interactions will destabilize the ordinary TIKM fixed point that governs the transition between the RKKY and Kondo-screened triplet states unless the spin-orbits couplings are fine-tuned. We also discuss how various symmetry-breaking interactions influence the leading corrections to the scaling of the block entanglement at the TIKM quantum critical point.

[1] D. F. Mross and H. Johannesson, Phys. Rev. B **80**, 155302 (2009).

TRANSPORT PROPERTIES OF SPIN-$\frac{1}{2}$ HEISENBERG CHAINS COUPLED TO A SPIN-S MAGNETIC IMPURITY

Alexandros Metavitsiadis

Department of Physics, University of Crete
and Foundation for Research and Technology Hellas

12h25 Mon 6

Quantum integrable systems are characterized by a macroscopic number of conservation laws affecting drastically the behavior of these systems. Particularly, as far as their transport properties are concerned, integrability may lead to ballistic transport of particular transport modes. One such example is the thermal transport in the one-dimensional, spin-$\frac{1}{2}$, anisotropic, with nearest neighbor interactions, Heisenberg model, giving an exceptional role to the thermal conductivity.
We propose the thermal conductivity as a unique probe [1,2] to study the effect of impurities on the pure Heisenberg model since the energy current relaxation is induced solely by the impurities. Using primarily numerical techniques, we study Kondo-type phenomena triggered by the screening of the impurity by the chain at low temperatures. We observe the cutting/healing behavior of the chain with decreasing temperature, a behavior which was first discussed for a Luttinger liquid with repulsive/attractive interactions [3].

[1] A. Metavitsiadis, arXiv: 1008.1524.
[2] A. Metavitsiadis, X. Zotos, O. S. Barišić and P. Prelovšek, Phys. Rev. B **81**, 205101 (2010).
[3] C. L. Kane and Matthew P. A. Fisher, Phys. Rev. Lett. **68**, 1220 (1992).

MUTUAL THERMAL EQUILIBRATION WITHIN AN ISOLATED BIPARTITE QUANTUM SYSTEM

Alexey V. Ponomarev, Sergey Denisov, Peter Hänggi

Institute of Physics, University of Augsburg, Augsburg, Germany

The derivation of thermodynamic phenomena from deterministic time-reversible dynamics is one of the ultimate goals of theoretical physics. This long standing and yet unsolved problem has sparked recently a new wave of activity in the quantum domain, where the thermalization conundrum has been studied either with a single isolated system, or with the system of interest coupled to a giant quantum bath, or, in the extreme, to the rest of the Universe. Here we show that two identical finite quantum systems, prepared initially at different temperatures, isolated from the environment and then brought into contact, relax to equilibrium states characterized by the same temperature, passing through a chain of intermediate thermal states. By this we demonstrate that such an archetypal thermodynamic process as a mutual temperature equilibration can be reproduced within an isolated finite composite quantum system.

15h00
Mon
7

[1] A. V. Ponomarev, S. Denisov, P. Hänggi, arXiv:1004.2232 (2010)

CLASSICAL LIMIT OF QUANTUM FIELDS

F. Costa[1] and Č. Brukner[1,2]

1 Faculty of Physics, University of Vienna, Vienna, Austria
2 Institute of Quantum Optics and Quantum Information (IQOQI), Austrian Academy of Sciences, Vienna, Austria

A characteristic feature of quantum fields is that, when the field is in the vacuum or in a low energy state, the von Neumann entropy associated with a region of space is proportional to the area of the region, rather than to the volume as is typical in classical systems. We study the effect of introducing an error in the measurement of the field observables, formalized as a coarse grain in phase space, for the case of a free Klein-Gordon field. We show that for sufficiently large coarse grain parameters the field's state becomes separable, its Wigner function becomes a positive probability distribution evolving according to a classical Liouville equation and the entropy of a region of space becomes proportional to the volume [1]. These results support the recent proposal according to which classical physics arise out of quantum physics under the restriction of coarse-grained measurements [2].

15h25
Mon
8

[1] F. Costa and Č. Brukner, in preparation.
[2] J. Kofler and Č. Brukner, Phys. Rev. Lett. **99**, 180403 (2007), ibid. 090403 (2008).

CURRENT-INDUCED SPIN REVERSAL IN MAGNETIC MOLECULES/ATOMS

J. Barnaś[1,2], M. Misiorny[1], I. Weymann[1]

1 Faculty of Physics, Adam Mickiewicz University, 61-614 Poznań, Poland
2 Institute of Molecular Physics, Polish Academy of Sciences, 60-179 Poznań, Poland

16h40 Mon 9

Transport properties of single molecules and atoms (both natural and artificial) are now experimentally accessible. Of particular interest are single-molecule magnets (SMMs) and magnetic atoms. At sufficiently low temperatures, such molecules/atoms exhibit an energy barrier for their spin reversal [1]. Switching of the corresponding spin can be achieved for instance via the phenomenon of quantum tunneling of magnetization. It has been also suggested that spin reversal can be achieved by spin-polarized current flowing through the molecule/atom [2-4]. The current-induced magnetic switching may become a key mechanism to be utilized in future devices, as it does not require application of an external magnetic field for spin manipulation. Spin effects, that arise in a SMM/atom due to stationary as well as time-dependent flow of spin-polarized electrons, will be addressed. First, the phenomenon of quantum tunneling of magnetic moment in an external time-dependent magnetic field will be briefly discussed. Then, we will consider how the strength of the molecule-electrode coupling qualitatively affects the transport properties of the system. For this purpose we have considered the model relevant to magnetic atoms/molecules characterized by uniaxial magnetic anisotropy. The molecule/atom is contacted to two metallic ferromagnetic leads. Transfer of electrons through the molecule/atom is assumed to occur via a single orbital level. Transport properties have been obtained by means of the master equation, real-time diagrammatic technique, as well as by the numerical renormalization group method. The main emphasis will be placed on the transport characteristics, like current, linear and nonlinear conductance, tunnel magnetoresistance (TMR), as well as spin and charge blockade. The situation with one electrode being nonmagnetic will also be considered. Transport characteristics in such a situation resemble those of spin diodes.

[1] L. Bogani and W. Wernsdorer, Nature Mater. **7**, 179 (2008).
[2] M. Misiorny and J. Barnaś, Phys. Rev. B **75**, 134425 (2007).
[3] M. Misiorny and J. Barna's, Phys. Status Solidi (b) **246**, 695 (2009).
[4] M. Misiorny, I. Weymann and J. Barnaś, Phys. Rev B **79**, 224420 (2009).

CRITICAL PROPERTIES OF THE FIDELITY SUSCEPTIBILITY

H. Q. Lin[1,2] and S. J. Gu[1]

1 Department of Physics and Institute of Theoretical Physics, The Chinese University of Hong Kong, Hong Kong, China
2 Beijing Computational Physics Center, Beijing, China

We study critical properties of the ground state fidelity susceptibility (FS) by analyzing its behavior in three well known models: (1) the one-dimensional asymmetric Hubbard model where we show that the FS could be used to identify the universality class of the quantum phase transitions such as the Kosterlitz-Thouless type and the Landau symmetry breaking type [1]; (2) the Lipkin-Meshkov-Glick model where we obtain explicitly the critical exponents of the FS and show that the FS is not always an extensive quantity [2]; (3) the Kitaev honeycomb model where we show that the scaling relation of the FS is proportional to $L^2 lnL$ in the gapless phase and to L^2 in the gapped phase. Thus the FS has its own distinct dimension instead of real system¡s dimension in different quantum phases and the extra dimension lnL could be used as a characteristic of the gapless phase [3].

17h05
Mon
10

[1] S. J. Gu, H. M. Kwok, W. Q. Ning, and H. Q. Lin, Phys. Rev. B **77**, 245109 (2008).
[2] H. M. Kwok, W. Q. Ning, S. J. Gu, and H. Q. Lin, Phys. Rev. E **78**, 032103 (2008).
[3] S. J. Gu and H. Q. Lin, Euro. Phys. Lett. **87**, 10003 (2009).

Tuesday, October 12

QUANTUM SPIN LIQUID AND SUPERCONDUCTIVITY

Patrick A. Lee

Department of Physics, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139

The RVB proposal of Anderson in 1987 as a theory of high T_c superconductors has revived the interest in quantum spin liquids, where Neel order is destroyed by quantum fluctuations. After a long search we finally have several experimental examples of spin liquids. There is evidence that these spin liquids possess gapless fermionic excitations called spinons. I will review the status of this field and remark on the relation to superconductivity.

9h00
Tue
1

HIGH TEMPERATURE SUPERCONDUCTORS: FROM COPPER TO IRON

Zlatko Tesanovic

Johns Hopkins University, Baltimore, Maryland

Two years ago, the discovery of high-temperature superconductivity in iron-pnictides reshaped the landscape of condensed matter physics. Until that time, for more than two decades, the copper-oxide materials were the only high-temperature superconductors and their mysterious properties loomed large as perhaps the greatest intellectual challenge in our field. Cuprates are strongly interacting systems, near to the so-called Mott insulating limit, in which electrons are made motionless by strong correlations. It is currently believed that much of their unusual behavior stems from such Mott correlations.

In contrast, at least several members of the newly discovered iron-based family of high-temperature superconductors exhibit a more moderate degree of correlations and do not appear to be near the Mott limit. Consequently, some of their properties might be easier to understand. In this talk, the basic ideas in theory of iron-pnictides will be introduced and illustrated with experimentally relevant examples. Particular attention will be paid to the interband resonant-pairing mechanism of multiband superconductivity and the renormalization group description of the underlying physics, the approach which by now has reached a certain level of consensus. This will be contrasted with strongly correlated cuprates, where a thousand fancy theoretical ideas bloom, from quantum fluctuations to Berry phases, from gauge field theory to non-Fermi liquids of various kinds to AdS/CMT duality, all vying for approval from a number of recent and occasionally conflicting experiments.

9h45
Tue
2

FINITE SIZE EFFECTS IN SUPERCONDUCTING NANOGRAINS: FROM THEORY TO EXPERIMENTS

Antonio M. García-García

CFIF, Instituto Superior Técnico, Universidade Técnica de Lisboa, Av. Rovisco Pais, 1049-001 Lisboa, Portugal

10h30 Tue 3

The first part of the talk is devoted to a theoretical description of finite size effects in Bardeen Cooper Schrieffer (BCS) superconductors [1]. Then we study superconductivity in single isolated Pb and Sn nanoparticles. In Sn nanoparticles we observe [2] giant oscillations in the superconducting energy gap with particle size leading to enhancements as large as 60. Theoretically, these finite size effects are described quantitatively by introducing finite-size corrections to BCS model. For Pb grains we have also observed that, at low temperatures, the superconducting gap diminishes as the grain size is reduced. By contrast, for sufficiently small grains, the gap is finite even for temperatures higher than then the mean field critical temperature. A model including thermal fluctuations and the leading low temperature corrections to mean field provides a quantitative description of the system. Our study paves the way to exploit quantum size effects in boosting superconductivity in nanograins.

[1] 'BCS theory for finite size superconductors' A. M. García-García, J. D. Urbina, E. Yuzbashyan, K. Richter and B. Altshuler, Phys. Rev. Lett. **100**, 187001 (2008).
[2] 'Observation of shell effects in superconducting nanoparticles of Sn' S. Bose, A.M. Garcia-Garcia, Miguel M. Ugeda, J. D. Urbina, C. H. Michaelis, I. Brihuega and K. Kern, Nature Materials **9**, 550 (2010).

IS SUPERCONDUCTIVITY IN IRON-PNICTIDE MATERIALS CONTROLLED BY A QUANTUM CRITICAL POINT INTO HIDDEN MAGNETIC ORDER?

J.P. Rodriguez

Department of Physics and Astronomy, California State University at Los Angeles

11h25 Tue 4

Stochiometric parent compounds of ferro-pnictide high-temperature superconductors display commensurate spin-density wave (cSDW) magnetic groundstates with ordered moments that can be a small fraction of the Bohr magneton. I review a recent theoretical proposal that attributes such weak cSDW behavior to proximity to hidden magnetic order [1]. Hidden magnetic order is predicted to exist at sufficiently weak Hund's rule coupling among the iron 3d orbitals. A quantum critical point (QCP) separates it from a cSDW groundstate at strong Hund's rule coupling. Despite the fact that the ordered magnetic moment at the QCP is extremely small, the critical spin-wave spectrum exhibits strong low-energy excitations at cSDW wave-vectors [2]. I fit this theoretical prediction to spin-wave spectra in iron-pnictide superconductors and their parent compounds that have been obtained recently by inelastic neutron scattering measurements. The fit notably accounts for the absence of softening at the Neel wave-vector (π, π). I also propose to model the electronic structure in iron-pnictide superconductors in terms of doped groundstates that exhibit such hidden magnetic order. Injecting mobile holes into hidden-order magnets can result in half-metal bands with Fermi surfaces that are centered at zero momentum. Furthermore, resonant scattering of such states with the above critical spin-waves can result in low-energy electronic excitations at momenta near those associated with cSDW order. These theoretical results are compared with the single-particle electronic spectrum of ferro-pnictide superconductor obtained by angle-resolved photo emission (ARPES) studies. Last, I shall explore the possibility that the exchange of virtual spin-wave excitations at the QCP acts as a pairing mechanism among low-energy electronic excitations in doped hidden-order magnets.

[1] J. P. Rodriguez and E. H. Rezayi, Phys. Rev. Lett. **103**, 097204 (2009).
[2] J.P. Rodriguez, Phys. Rev. B **82**, 014505 (2010).

CDW AND SUPERCONDUCTING GROUND STATES IN QUASI-1D SYSTEMS; THE (PER)2M(MNT)2 SALTS

Manuel Almeida[1], James S. Brooks[2]

1 ITN / CFMCUL, EN 10, P-2686-953 Sacavém, Portugal

2 NHMFL, Florida State University, Tallahassee, FL 32310, USA

The (Per)2[M(mnt)2] salts are a unique family of isostructural molecule based compounds containing both conducting stacks of partially oxidized perylene (per) molecules and anionic [M(mnt)2] stacks, which for some transition metal complexes (M= Ni, Pt, Pd and Fe) may have localized magnetic moments. The two types of chains (conducting and magnetic) in the crystal structure, are both prone to the instabilities typical of conducting and magnetic 1D systems. At low temperatures these compounds undergo a charge density wave (CDW) transition that in the case of paramagnetic counterions is also associated with a spin-Peierls transition in the magnetic chains. The low transition temperatures (8-12 K for M=Pt and Au) and the extreme anisotropic electronic band structure of these compounds make them unique systems to test the behaviour of CDW and magnetic chains under magnetic field.

The CDW state is quite sensitive and may be suppressed both by magnetic field and pressure. Magnetic fields of the order of the Pauli limit (23T) are enough to recover a high conductivity metallic state. However this CDW suppression presents a significant anisotropy demonstrating non-negligible orbital effects [1] and under higher magnetic fields a cascade of new field induced (FICDW) phases are observed in the M=Pt compound [2]. Pressure was found to induce also drastic changes in the ground states of these compounds. While the dimerised anion chain compounds (M=Fe, Co) present a quite robust ground state with anomalous pressure dependence [3], in the other compounds with regular anionic chains, moderated pressures ≈5 Kbar are enough to suppress the CDW and to recover a metallic state, as demonstrated by the presence of quantum oscillations of the magnetoresistance [4]. The periodicity of these oscillations and their angular (AMRO) dependence [5] indicate a Fermi surface close to that predicted from calculation based on high temperature and ambient pressure structure [6]. More recently in the M=Au compound it was found a superconducting (SC) state at 0.31 K, emerging above 5 kbar in the neighborhood of the CDW [7]. This relatively rare situation among molecular systems, which cannot be excluded also in the Pt compound, of a SC state emerging from a non magnetic state, will be discussed.

12h10
Tue
5

[1] D. Graf, J.S. Brooks, E.S. Choi, S. Uji, J.C. Dias, M. Matos, M. Almeida, Phys. Rev. B **69**, 125113-125117 (2004).

[2] D. Graf, E.S. Choi, J.S. Brooks, R.T. Henriques, M. Almeida, M. Matos, Phys. Rev. Lett. **93**, 076406 (2004).

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[4] D. Graf, J.S. Brooks, E.S. Choi, M. Almeida, R.T. Henriques, J.C. Dias S. Uji, Phys. Rev. B **75**, 245101 (2007).

[5] D. Graf, J.S. Brooks, E.S. Choi, M. Almeida, R.T. Henriques, J.C. Dias and S. Uji, Phys. Rev. B **80**, 155104. (2009).

[6] E. Canadell, M. Almeida, J. Brooks, Eur. Phys .J. B, **42**, 453 (2004).

[7] D. Graf, J.S. Brooks, M. Almeida, J.C. Dias, S. Uji, T. Terashima, M. Kimata, Eur. Phys. Lett., **85**, 27009 (2009).

EXPECTATION VALUES IN THE LIEB-LINIGER BOSE GAS

Giuseppe Mussardo

SISSA, Italy

15h00
Tue
6

The repulsive Lieb–Liniger model can be obtained as the non-relativistic limit of the Sinh–Gordon model: all physical quantities of the latter model (S-matrix, Lagrangian and operators) can be put in correspondence with those of the former. We use this mapping, together with the Thermodynamical Bethe Ansatz equations and the exact form factors of the Sinh–Gordon model, to set up a compact and general formalism for computing the expectation values of the Lieb–Liniger model both at zero and finite temperature. The computation of one-point correlators is thoroughly detailed and, when possible, compared with known results.

SPIN-CHARGE COUPLING EFFECTS ON DYNAMICS OF ONE-DIMENSIONAL SYSTEMS

Rodrigo G. Pereira

Instituto de Física de São Carlos, Universidade de São Paulo, São Carlos, Brazil

15h45
Tue
7

Recently there has been remarkable progress in the understanding of dynamical properties of one-dimensional systems beyond Luttinger liquid theory. In this talk I will address the effects of nonlinear dispersion on the dynamical structure factor of spin-1/2 fermions. In particular, I will discuss an approximation for the dynamic charge response of nonlinear spin-1/2 Luttinger liquids in the limit of small momentum. Besides accounting for the broadening of the charge peak due to two-holon excitations, the nonlinearity of the dispersion couples charge and spin degrees of freedom and gives rise to a two-spinon peak in the charge response. This provides some insight into the conditions under which spin-charge separation can be observed in the spectrum at finite energies and into the role played by integrability in the dynamics.

Wednesday, October 13

ULTRACOLD GASES OF YTTERBIUM: FERROMAGNETISM AND MOTT STATES IN AN SU(6) FERMI SYSTEM

Miguel A. Cazalilla[1]

1 CSIC, Madrid, Spain

9h00
Wed
1

It is argued that ultracold quantum degenerate gas of ytterbium ^{173}Yb atoms having nuclear spin $I = 5/2$ exhibits an enlarged SU(6) symmetry. Within the Landau Fermi liquid theory, stability criteria against Fermi liquid (Pomeranchuk) instabilities in the spin channel are considered. Focusing on the SU(n2) generalizations of ferromagnetism, it is shown within mean-field theory that the transition from the paramagnet to the itinerant ferromagnet is generically first order. On symmetry grounds, general SU(n) itinerant ferromagnetic ground states and their topological excitations are also discussed. These SU(n2) ferromagnets can become stable by increasing the scattering length using optical methods or in an optical lattice. However, in an optical lattice at current experimental temperatures, Mott states with different filling are expected to coexist in the same trap, as obtained from a calculation based on the SU(6) Hubbard model.

CORRELATED FERMIONS ON GRAPHENE-LIKE LATTICES

Z. Y. Meng[1], T. C. Lang[2], S. Wessel[1], F. F. Assaad[2], A. Muramatsu[1]

1 Institut für Theoretische Physik III, Universität Stuttgart, Pfaffenwaldring 57, 70550 Stuttgart, Germany

2 Institut für Theoretische Physik und Astrophysik, Universität Würzburg, Am Hubland, 97074 Würzburg, Germany

9h45
Wed
2

Free fermions on a two dimensional honeycomb lattice, like in graphene, are known to posses a dispersion relation at low energies that corresponds to massless relativistic fermions. When interactions become strong, several proposals like a metal-insulator transition or exotic phases such as gapless spin liquids, charge density wave, quantum spin Hall states, or superconductivity were made for a density of one fermion per site, or close to it. Here we show, by means of large-scale quantum Monte Carlo simulations of the Hubbard model on a honeycomb lattice at half-filling, that a gapped spin liquid emerges between the state described by massless Dirac fermions and an antiferromagnetically ordered Mott insulator [1]. This unexpected quantum-disordered state is found to be a short-range resonating valence-bond liquid, akin to the one proposed for high-temperature superconductors.

[1] Z.Y. Meng *et al.*, Nature **464**, 847 (2010).

TOPOLOGY-INDUCED PHASE TRANSITIONS IN QUANTUM SPIN HALL LATTICES

D. Bercioux[1], N. Goldman[2], D. F. Urban[3]

1 Freiburg Institute for Advanced Studies, Albert-Ludwigs-Universitat, D-79104 Freiburg, Germany
2 Center for Nonlinear Phenomena and Complex Systems - Université Libre de Bruxelles (U.L.B.), Code Postal 231, Campus Plaine, B-1050 Brussels, Belgium
3 Physikalisches Institut, Albert-Ludwigs-Universitat, D-79104 Freiburg, Germany

Physical phenomena driven by topological properties, such as the quantum Hall effect, have the appealing feature to be robust with respect to external perturbations [1]. Lately, a new class of materials has emerged manifesting their topological properties at room temperature and without the need of external magnetic fields. These topological insulators are band insulators with large spin-orbit interactions and exhibit the quantum spin-Hall (QSH) effect [2-7]. Here we investigate the transition between QSH and normal insulating phases under topology deformations of a two-dimensional lattice. We demonstrate that the QSH phase present in the honeycomb lattice looses its robustness as the occupancy of extra lattice sites is allowed [8]. Furthermore, we propose a method for verifying our predictions with fermionic cold atoms in optical lattices. In this context, the spin-orbit interaction is engineered via an appropriate synthetic gauge field.

11h00
Wed
3

[1] K. V. Klitzing, G. Dorda, and M. Pepper, Phys. Rev. Lett. **45**, 494 (1980).
[2] C. L. Kane and E. J. Mele, Phys. Rev. Lett. 95, 146802 (2005); Phys. Rev. Lett. **95**, 226801 (2005).
[3] B. A. Bernevig and S.-C. Zhang, Phys. Rev. Lett. **96**, 106802 (2006).
[4] B. A. Bernevig, T. L. Hughes, and S.-C. Zhang, Science **314**, 1757 (2006).
[5] M. Koenig et al., Science **318**, 766 (2007).
[6] A. Roth et al., Science **325**, 294 (2009).
[7] Y. Xia et al., Nature Phys. **5**, 398 (2009).
[8] D. Bercioux, N. Goldman, and D. F. Urban, arXiv:1007.2056, submitted to Nature Communications.

THE SILICON CRYSTAL LATTICE AS A MODEL COLD ATOM TRAP: COHERENT EXCITATION OF IMPURITY ATOM RYDBERG STATES

B.N. Murdin,[1] K. Litvinenko[1], G. Aeppli[2], P.T. Greenland[2], S.A. Lynch[2], N.Q. Vinh[3], B. Redlich[3], A.F.G. van der Meer[3], C.R. Pidgeon[4]

1 Advanced Technology Institute, University of Surrey, Guildford, England
2 London Centre for Nanotechnology, University College London, England
3 FOM Institute for Plasma Physics Rijnhuizen Nieuwegein, The Netherlands
4 Department of Physics, Heriot-Watt University, Edinburgh, Scotland

11h25 Wed 4

Coherent oscillation, where many particles cycle in phase, is responsible for classical phenomena like the emission of strong radio waves by many individual electrons in an antenna. At the quantum scale, coherent magnetic oscillations of spins are central to Magnetic Resonance Imaging and its analogues, in which coherence is excited and then reappears later producing a delayed radio pulse (the spin echo). Quantum computer logic will also rely on coherence, and spins are often chosen as qubits because they are only weakly connected to, and disturbed by, the environment. Paradoxically, connection with the outside world is crucial for control, making charge (i.e. orbital) oscillations in semiconductors attractive, although very difficult to realise by comparison with orbital coherence in insulators and very cold atoms in vacuum. I shall describe the population dynamics of electrons orbiting around phosphorus impurities in commercially-available silicon, and show that the lattice introduces no extra sources of decoherence than the phonon emission [1]. We have also demonstrated coherent control of quantum super-positions by observing orbital echoes the optical analogue of the spin echo - and a complete Rabi oscillation [2]. The results pave the way for new devices where information is stored in single electron orbits (coherent orbitronics) in silicon, the material that has dominated the classical computing industry for half a century.

[1] NQ Vinh et al, Proc Nat Acad Sci USA **105**, 10649 (2008)
[2] PT Greenland et al Nature **465**, 1057 (24 June 2010).

SILICON NANOCRYSTAL SURROUNDED BY AMORPHOUS SILICON: IS IT A QUANTUM DOT?

M. I. Vasilevskiy

Centro de Física, Universidade do Minho, 4710-057 Braga, Portugal

Recently, a new class of nanostructures based on hydrogenated amorphous silicon (a-Si:H) films with crystalline nano-regions (i.e. nanocrystals, NC's), has been proposed and studied experimentally [1,2]. Does such a NC, embedded in an amorphous matrix of the same material, possess the properties of a quantum dot (QD), i.e. whether there are electronic states localized in the crystalline grain, with only little extension to the surrounding amorphous matrix? The answer is not obvious because there is no well defined barrier at the NC/matrix interface in this case. In the present work, we address this question concerning conduction band electrons considered within the effective mass approximation.

From the quantum mechanical point of view, the problem can be formulated in the following way, could a completely random barrier confine an electron? It is directly connected with the well-known problem of Anderson localization in random potentials [3]. We use an approach based on the Fokker-Planck equation for the scattering amplitude and direct numerical simulation to study the electron localization in an inhomogeneous disorder potential produced by the amorphous matrix around a perfectly crystalline core. We shall formulate a simple criterion of localization in the NC which is determined by the reflection from the inhomogeneous random barrier. The proposed approach has allowed us for the investigation of the electron localization in a new class of random fields with a spatially dependent Gaussian correlation function. We obtained an explicit scaling equation describing the dependence of the reflection coefficient on the barrier width (L). We have found that confined states in the NC do arise as a consequence of the almost total reflection of the wavefunction by the barrier, which can be characteristic of either strong or weak localization. Moreover, there is a crossover in the scaling of the reflection coefficient with L, depending on the long-range behavior of the amplitude of the random potential.

12h10
Wed
5

The developed concept is applied to electrons in a simple band. Calculated spectral functions for Si-NC/a-Si:H will be presented and their relation with experiment will be discussed.

[1] M. Losurdo *et al*, Physica E **16**, 414 (2003).
[2] B. Rezek *et al*, Nanotechnology **20**, 045302 (2009).
[3] P. W. Anderson, Phys. Rev. **109**, 1492 (1958).

Thursday, October 14

RECENT EXPERIMENTS ON 2D ELECTRON SYSTEMS IN GAAS AND IN GRAPHENE

Yong P. Chen

Department of Physics and Birck Nanotechnology Center, Purdue University, West Lafayette, Indiana, USA

Two-dimensional electron systems (2DES) have been a rich condensed matter physics playground to study many effects of disorder, interaction, quantum coherence and correlations. In the first part of the talk, I will discuss some recent experiments in ultra-clean GaAs-based 2DES, yielding evidence for Wigner crystals of fractionally charged ($e/3$) quasiparticles near 1/3 fractional quantum Hall (QH) state and of skyrmions near ν=1 integer QH state. The observations point out the importance of interactions between such quasiparticle excitations. The second part of the talk will be dedicated to novel graphene-based 2DES structures that are difficult to realize in traditional semiconductors. We discuss QH effects measured in a heterostructure between a bilayer and a single layer graphene, and emerging opportunities brought by transferring graphene on almost arbitrary substrates with interesting electronic properties.

9h00
Thu
1

THE GRAPHENE TWISTED BILAYER: EXPERIMENTAL AND THEORETICAL REVIEW

J. M. B. Lopes dos Santos[1], N. M. R. Peres[2], A. H. Castro Neto[3]

[1] *CFP and Departamento de Física, Faculdade de Ciências, Universidade do Porto, 4169-007 Porto, Portugal*
[2] *Centro de Física and Departamento de Física, Universidade do Minho, P-4710-057, Braga, Portugal*
[3] *Department of Physics, Boston University, 590 Commonwealth Avenue, Boston, MA 02215,USA*

In graphite and few layer graphene, the top layer is often found rotated with respect to the others, commonly by small angle [1]. The basic theory for the electronic structure of a twisted bilayer was presented in [2], even before any measurements were available, predicting a behavior quite distinct from Bernal stacking. Since then, several experimental studies of Raman spectroscopy [3], and of scanning tunneling spectroscopy [4], as well as first principle calculations of electronic structure [5], have shed light on this system. Recently a different theoretical approach has proposed the possibility of the opening of a gap, at least for angles of rotation giving rise to specific commensurate structures [6]. In this lecture we will review these studies of the twisted graphene bilayer.

9h45
Thu
2

[1] Z. Y. Rong and P. Kuiper. *Phys. Rev. B*, 48(23):17427 – 17431, 1993. J. Hass,*et. al.*, *Phys. Rev. Lett.*, 100, 125504, 2008. François Varchon, *et al.*. *Phys. Rev. B*, 77(16):165415, 2008.
[2] J. M. B. Lopes dos Santos, N. M. R. Peres, and A. H. Castro Neto. *Phys. Rev. Lett.*, 99:256802, 2007.
[3] Zhenhua Ni, *et. al*, *Phys. Rev. B* , 77(23): 235403, 2008.
[4] Guohong Li, A. Luican, J. M. B. Lopes dos Santos A. H. Castro Neto A. Reina J. Kong and E. Y. Andrei. *Nature Physics*, 6, 109 (2010).
[5] Guy Trambly de Laissardiere, Didier Mayou, and Laurence Magaud. *Nano Lett., Amer. Chemical Soc.* 10,804-808, 2010.
[6] E. J. Mele, *Phys. Rev. B* , 81, 161405, 2010.

A UNIFIED DESCRIPTION OF THE DC CONDUCTIVITY OF MONOLAYER AND BILAYER GRAPHENE BASED ON RESONANT SCATTERERS

A. Ferreira[1], N. M. R. Peres[1]

1 Department of Physics and Center of Physics, University of Minho, P-4710-057, Braga, Portugal

11h00 Thu 3

We show that a coherent picture for the DC conductivity of monolayer and bilayer graphene emerges from considering that strong short-range potentials are the main source of scattering in these two systems. The origin of the strong short range potentials may lie in adsorbed hydrocarbons at the surface of graphene. The equivalence between results based on the partial wave description of scattering, the Lippmann-Schwinger equation and the T-matrix approach is established.

LIMITS ON TRANSPORT PROPERTIES OF SUSPENDED GRAPHENE DUE TO SCATTERING BY FLEXURAL PHONONS

Eduardo V. Castro[1], H. Ochoa[1], M. I. Katsnelson[2], R. V. Gorbachev[3], D. C. Elias[3], K. S. Novoselov[3], A. K. Geim[3], and F. Guinea[1]

1 Instituto de Ciencia de Materiales de Madrid (CSIC), Sor Juana Inés de la Cruz 3, E-28049 Madrid, Spain

2 Radboud University Nijmegen, Institute for Molecules and Materials, NL-6525 AJ Nijmegen, The Netherlands

3 School of Physics & Astronomy and Manchester Centre for Mesoscience & Nanotechnology, University of Manchester, Manchester M13 9PL, UK

11h25 Thu 4

The effect of scattering by out-of-plane (flexural) phonons on transport properties of doped suspended graphene is investigated [1]. Our results point out that scattering by flexural phonons constitutes the main limitation to electron mobility in these samples. In the free standing case (negligible strain), resistivity due to flexural phonons behaves as $\sim T^2/n$, where T is the temperature and n is the carrier concentration, and completely dominates over the in-plane phonon contribution. This result was confirmed by the experiments. Mobilities fall down to 4-7 m^2/Vs at $T = 200$ K, and the extrapolation to room temperatures yields to only 2-3 m^2/Vs. The situation changes when higher strains are considered. The rotational symmetry breaking implies a reduction of the density of states associated to the flexural branch, hence its effect on transport is partially suppressed. Then, applying strain is a good strategy to increase the mobility of suspended samples at room temperature. This analysis can be extended to bilayer graphene, since the theoretical scattering rates exhibit the same dependence on temperature, carrier concentration and strain.

[1] Eduardo V. Castro, H. Ochoa, M. I. Katsnelson, R. V. Gorbachev, D. C. Elias, K. S. Novoselov, A. K. Geim, and F. Guinea, arXiv:1008.2522 [cond-mat.mtrl-sci] (submitted to Phys. Rev. Lett.).

BALLISTIC RESISTANCE AND HIGH MOBILITY IN CONSTRICTIONS OF 20NM THICK PACKED GRAPHENE PLANES.

N. García*

Laboratorio de Física de Sistemas Pequeños, CSIC, Serrano 1444, Madrid, SPAIN.

In this work we analyze the resistance of approximately 20nm thick packed graphene planes in comparison with the resistance of single planes of graphene. This is done measuring the resistance on constrictions that we perform in the packed planes. It is found that this resistance becomes ballistic when the constrictions are of the order of 1 micrometer wide or smaller. On the other hand in graphene the resistances are in general smaller. This implicates that we have ballistic resistance on the packs and it is not so in the graphene, that in turn implicates that the mobilities in the packs are of the order of 6.106 cm2/V.s and the densities 109 electrons/cm2 that are two orders of magnitude larger the first and two order of magnitude the second that for the graphene. Also the densities and mobilities of graphite have to be reconsidered as due to large number of defects, irregularities and mismatches in the different areas of the sample. We have studied the measured resistance in terms of one electron picture but as such low densities the electron-electron interaction may be needed to be discussed.

11h50
Thu
5

*Work done in collaboration with S. Dusari, J. Barzola-Quiquia and P. Esquinazi (University of Leipzig, Germany)

NEUTRAL FERMION EXCITATIONS AND SKYRMIONS IN THE $\nu = 5/2$ QUANTUM HALL STATE

G. Möller,[1] A. Wójs,[1,2] S. H. Simon[3] and N. R. Cooper[1]

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[2] *Institute of Physics, Wroclaw University of Technology, Wroclaw, Poland*
[3] *Rudolf Peierls Centre for Theoretical Physics, 1 Keble Road, Oxford OX1 3NPO, UK*

We numerically study different aspects of the excitation spectra of the Moore-Read state. While the eigenstates of the Coulomb Hamiltonian are quantitatively different from the ideal behaviour expected for the low-lying excitations of the Moore-Read phase, we show that a number of qualitative features confirm the notion of a topological paired state at $\nu = 5/2$. In particular, the neutral fermion energy provides a clear signature of pairing.

We extend our study to include spinful excitations. In the presence of a spin-polarized groundstate, we expect that spin textures dominate the low-lying partially spin-polarized spectrum. Indeed, energetic considerations based on a spin-wave picture support the existence of skyrmion excitations in the Hall plateau below filling fraction $\nu = 5/2$ [1]. We confirmed this prediction numerically using exact diagonalisation. The case of $\nu = 5/2$ is particularly interesting as skyrmions have twice the charge of quasiparticles (qp's). This leads to rich physics of possible bound spin-textured quasiparticle states in interplay with disorder and the Zeeman effect. Our ED results confirm that skyrmion states are energetically competitive with quasiparticles at low Zeeman coupling [1]. We discuss possible experimental implications for the spin polarization of the $\nu = 5/2$ state.

15h00
Thu
6

[1] A. Wójs, G. Möller, S. H. Simon, and N. R. Cooper, Phys. Rev. Lett. 104, 086801 (2010).

SPONTANEOUS INTERLAYER COHERENCE IN ELECTRONIC BILAYERS

A.H. MacDonald

Department of Physics, University of Texas at Austin, Austin TX 78712 USA

15h25 Thu 7

States with spontaneous coherence between two groups of electrons, usually referred to as exciton condensate states, occur in semiconductor double-quantum-well systems in the limit of a strong external magnetic field. Exciton condensates exhibit a variety[1] of fascinating superconductor-like transport phenomena that are only partially understood[2,3,4]. I will explain how the presence of a strong magnetic field complicates transport phenomena and review the status of efforts to understood current experiments. I will also comment on the possibility of related phenomena occurring at higher temperatures and without an external magnetic field in ferromagnetic metals with carefully designed magnetic anisotropies, and in graphene based two-dimensional electron systems.

[1] J.P. Eisenstein and A.H. MacDonald, Nature **432**, 691 (2004).
[2] J.J. Su and A.H. MacDonald, Nature Physics **4**, 799 (2008).
[3] J.J. Su and A.H. MacDonald, Phys. Rev. B **81**, 184523 (2010).
[4] Dima Pesin and A.H. MacDonald, arXiv:1008nnnn.

ARTIFICIAL GAUGE FIELDS AND TENSOR NETWORKS

J. I. Latorre

Department ECM, Universitat de Barcelona, Spain

16h40 Thu 8

Ultracold gases allow for the possibility of simulating the interaction of quantum degrees of freedom with artificial non-dynamical gauge fields. The appropriate theoretical description for such experiments corresponds to a modified Hubbard model that can be analyzed using tensor networks techniques such as PEPS. We also discuss the possibility of simulating artificial gravitational backgrounds.

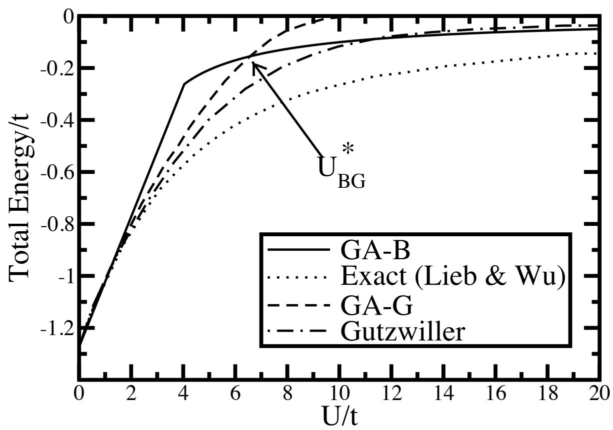
[1] O. Boada, A. Celi, J.I. Latorre, V. Pic, in preparation

APPROXIMATE VARIATIONAL THEORY OF BOUND EXCITONS IN STRONGLY CORRELATED SYSTEMS

B. Hetényi

Institute for theoretical physics, Graz University of Technology, Petersgasse 16, Graz, Austria

An approximate solution scheme, similar to the Gutzwiller approximation, is presented for the Baeriswyl and the Baeriswyl-Gutzwiller variational wavefunctions. The phase diagram of the one-dimensional Hubbard model as a function of interaction strength and particle density is determined. For the Baeriswyl wavefunction a metal-insulator transition is found at half-filling, where the metallic phase ($U < U_c$) corresponds to the Hartree-Fock solution, the insulating phase is one with finite double occupations arising from bound excitons. This transition can be viewed as the "inverse" of the Brinkman-Rice transition. Close to but away from half filling, the $U > U_c$ phase displays a finite Fermi step, as well as double occupations originating from bound excitons. As the filling is changed away from half-filling bound excitons are supressed. For the Baeriswyl-Gutzwiller wavefunction at half-filling a metal-insulator transition between the correlated metallic and excitonic insulating state is found. Away from half-filling bound excitons are suppressed quicker than for the Baeriswyl wavefunction. If time permits the development of momentum density functional theory for the Hubbard model, an extension of the approximation scheme presented here, will also be discussed.



17h25
Thu
9

Fig. 1: Comparison of the energy of the GA-B scheme (Gutzwiller approximation applied to the Baeriswyl wavefunction) to well known results: GA-G (Gutzwiller approximation applied to the GWF), exact Gutzwiller, and exact results. U^{*}_{BG} indicates the transition point for the Baeriswyl-Gutzwiller wavefunction.

[1] D. Baeriswyl in *Nonlinearity in Condensed Matter*, Ed. A. R. Bishop, D. K. Campbell, D. Kumar, and S. E. Trullinger, Springer-Verlag (1986).
[2] M. C. Gutzwiller, *Phys. Rev. Lett.*, **10** 159 (1963).
[3] B. Hetényi, to appear in *Phys. Rev. B*, see also arXiv.org:1008.1272 .

Friday, October 15

TWO-DIMENSIONAL ELECTRON SYSTEM IN PERIODIC MAGNETIC FIELD

V. K. Dugaev[1,2], M. Taillefumie[3], B. Canals[4], C. Lacroix[4], P. Bruno[5]

1 Department of Physics, Rzeszów University of Technology, Rzeszów, Poland

2 Department of Physics and CFIF, Instituto Superior Técnico, Lisboa, Portugal

3 Department of Physics, Norwegian University of Science and Technology, Norway

4 Institut Néel, CNRS, Grenoble, France

5 European Synchrotron Radiation Facility, Grenoble, France

9h00 Fri 1

We study the energy spectrum and electronic properties of two-dimensional electron gas in a periodic magnetic field of zero average with symmetry of triangular lattice. We demonstrate how the structure of electron energy bands can be changed with the variation in the field strength so that we can start from nearly free-electron gas and then transform it continuously to a system of essentially localized chiral electron states. We find that the electrons near some minima of the effective potential are responsible for occurrence of dissipationless persistent currents creating a lattice of current contours. The topological properties of the electron energy bands are also varied with the intensity of periodic field. We calculated the topological Chern numbers of several lower-energy bands as a function of the field. The corresponding Hall conductivity is nonzero, and when the Fermi level lies in the gap, it is quantized. We also considered the case of graphene and calculated the transformation of electron energy in the vicinity of Dirac points due to the periodic magnetic field. The spectrum at the Dirac point is not affected by the field but there appear a number of electron bands separated by the gaps. The energy spectrum is symmetric with respect to the electron-hole inversion, which is related to certain symmetry of the Hamiltonian in the periodic field. We also discuss the possible practical realization of the structures. One can use the magnetic nanolattice of magnetic cylinders with appropriate choice of parameters, which are quite achievable in the modern nanotechnology.

INFINITE MATRIX PRODUCT STATES AND CONFORMAL FIELD THEORY

German Sierra

CSIC, Madrid, Spain

9h45 Fri 2

MPS are the variational ansatzs underlying the DMRG. The standard MPS employ finite dimensional matrices which limits its application to critical systems where the entanglement entropy grows logarithmically with the size of the subsystems. Using CFT techniques we generalize the MPS to infinite dimensional matrices, that describes critical and non-critical systems on equal footing. If the ansatzs have SU(2) rotational invariance, then the associated parent Hamiltonians turn out to be given by the Haldane-Shastry Hamiltonian and non-abelian generalizations of it. The MPS so constructed share many features with the Fractional Quantum Hall wave functions obtained by similar CFT methods.

WHAT CAN WE LEARN FROM QUANTUM ENTANGLEMENT SPECTRA?

D. P. Arovas

Department of Physics, University of California at San Diego, La Jolla, California 92093, USA

11h00 Fri 3

I shall discuss aspects entanglement entropy and entanglement spectra, and in particular how they can reflect topological features of interacting quantum systems at zero temperature. I shall also discuss recent work with R. Thomale and B. A. Bernevig on the entanglement spectra of one-dimensional gapless spin systems. For the $S = \frac{1}{2}$ antiferromagnetic Heisenberg chain, we show how an "entanglement gap" gap fully separates a series of generic, high-lying "entanglement energy" levels, from a nearly-flat band of levels with specific multiplicities that uniquely define the ground-state and reveal information about the low-lying bulk excitations. This gap remains finite in the thermodynamic limit. This rich structure emerges only when the system is partitioned in momentum space, and not real space, and is understood in connection with the Haldane-Shastry model, whose ground state wavefunction is related to that of the $\nu = \frac{1}{2}$ Laughlin Fractional Quantum Hall state.

[1] H. Li and F. D. M. Haldane, *Phys. Rev. Lett.* **101**, 010504 (2008).
[2] Ronny Thomale, D. P. Arovas, and B. Andrei Bernevig, `arXiv:0912.0028` (*Phys. Rev. Lett.*, in press).
[3] R. Thomale, A. Sterdyniak, N. Regnault, and B. Andrei Bernevig, *Phys. Rev. Lett.* **104**, 180502 (2010).
[4] F. D. M. Haldane, *Phys. Rev. Lett.* **60**, 635 (1988).
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ENTANGLEMENT ACROSS A SEPARATION IN SPIN CHAINS: STATICS AND DYNAMICS

Sougato Bose

University College London

11h45 Fri 4

In this talk, I will present two schemes which would result in substantial entanglement between distant individual spins of a spin chain. One relies on a global quench of the couplings of a spin chain, while the other relies on a bond quenching at one end. Both of the schemes result in substantial entanglement between the ends of a chain so that such chains could be used as a quantum wire to connect quantum registers. I will also examine the resource of entanglement already existing between separated parts of a many-body system at criticality as the size of the parts and their separation is varied. This form of entanglement displays an interesting scale invariance.

Poster session

EXCITATION OF CLASSICAL AND QUANTUM WAKEFIELDS IN NANO-WIRES

S. Ali[1], J. T. Mendonça[1,2], H. Terças[1]

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Nanowires are especially attractive for nanoscience studies as well as for nanotechnology applications. Nanowires, compared to other low dimensional systems, have two quantum conned directions, while still leaving one unconned direction for electrical conduction. This allows nanowires to be used in applications where electrical conduction, rather than tunneling transport, is required. Because of their unique density of electronic states, nanowires in the limit of small diameters are expected to exhibit significantly different optical, electrical and magnetic properties from their bulk 3D crystalline counterparts.

SI 1

In the present work, we investigate the excitation of wake-fields in a nanowire due to the propagation of an electron current. Including the effects of plasmon dispersion (going beyond the Drude model for the electrical permittivity), we show that an electron current propagation axially can produce a wakefield which exhibits both classical and quantum features. The present work suggests a connection between the phenomenon of wake-field acceleration, an issue of major interest and widely studied in the context of plasma physics, and propagation of electron currents in condensed-matter systems.

CONDUCTIVITY IN GRAPHENE NANO-RIBBONS

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SI 2

We computed optical response of nano-ribbons, we calculated explicitly the velocity operator and its matrix element, which is required for the calculation of the conductivity. From the conductivity, we discussed the transmissivity of nano-ribbons. In order to establish a comparison point, we computed the transmissivity for the massive system using two different methods, namely: the combination of the optical conductivity with the behaviour of an electric field within a metallic interface between two media; the calculation of the trans- mission probability by Fermi's golden rule, within the Dirac cone approximation, therefore computing the transmission coefficient for this region.

QUANTUM DOTS CHAIN: A CIRCUIT THEORY APPROACH

G. C. Duarte-Filho[1], S. Rodríguez-Pérez[2], F. A. G. Almeida[3], A. M. S. Macêdo[2]

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In this work we study a mesoscopic device constituted of a chain of chaotic cavities connected to reservoirs via barriers of arbitrary transparencies. The study of this system is motivated by recent experiments [1] where a gradual transition is observed between a discrete chain regime and a continuous diffusive metal limit.
A powerful way to characterize the statistical properties of transport observables in mesoscopic systems is to study the full counting statistics (FCS) of transferred charge. In this approach, the information about the transmission probability of n charges and its cumulants is decoded from a generating function that can be obtained via a quantum circuit theory (QCT) [2]. Using the QCT we calculated the transmission eigenvalue density for a chain containing N quantum dots as a function of the barriers' transparencies. Our results show an interesting behavior of such density with respect to the emergence of Fabry-Perot modes inside the chain as we vary either N or the barriers' transparencies. We also analyzed the behavior of the Fano factor as N is increased and observed a crossover between the dot-chain regime and the diffusive wire limit. Our analysis is compatible with the results obtained by Belzig and Vanevic [3] for a chain with symmetric barriers. SI 3
We also study the quantum interference effects in the transport properties in this array of quantum dots. Through an efficient method which allow us to obtain the quantum corrections from the quantum circuit theory we were able to observe an anomalous behavior of such corrections as we increase the number of cavities which compose the circuit. We also calculate the universal fluctuations of conductance in this system.

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DENSITY OF STATES FOR THE HUBBARD MODEL WITH DISPERSIVE PHONONS

P. Haase, S. Fuchs, Th. Pruschke

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We extend the Hubbard-Holstein model to incorporate dispersive phonons. We integrate out the phonon degrees of freedom in favour of an attractive retarded density-density interaction. To solve the model we use a continuous-time quantum-Monte-Carlo impurity solver [1] and the dynamical mean field approximation [2]. To extract the density of States from our imaginary time data we use the maximum entropy method [3]. We vary the on-site interaction U and the electron-phonon coupling parameter g and observe a metal-insulator transition even at low values of U for sufficiently large values of g. SI 4

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[3] M. Jarrell, J. Gubernatis, Phys. Rep. **269**, 133 (1996).

QUANTUM CRITICAL POINTS ARE MULTICRITICAL

U. Karahasanovic[1], A. G. Green[1]
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Naked quantum critical points have not been observed experimentally; instead the formation of new phases near to itinerant electron quantum critical point has been seen in many compounds [1,2].
In the vicinity of a quantum critical point, quantum fluctuations drive the energy scales of many distortions of Fermi surface to zero. This opens up the possibility of weak interactions stabilizing new types of phases with free energies lowered due to the fluctuations. A simple physical picture of this is that certain deformations of Fermi surface enhance the phase-space available for the quantum fluctuations and hence lower the energy. This mechanism is known as *quantum order-by-disorder*.
We describe a unified analytical approach to treat these phases and investigate the reconstruction of phase diagram in the vicinity of the ferromagnetic quantum critical point, starting with the Hubbard
SI Hamiltonian. We consider the following phases: homogeneous ferromagnet, spatially modulated
5 ferromagnet [3], electron nematic and superconductor.

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(3+1) MASSIVE DIRAC FERMIONS WITH ULTRACOLD ATOMS IN OPTICAL LATTICES

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SI I discuss a cold-atoms set-up able to simulate (3+1) Dirac fermions and some applications, relevant
6 both in elementary particle and in condensed matter physics. I show in particular the possibility to add a tunable mass by using Bragg pulses, an effective external electromagnetic coupling and an internal interaction, also covariant. Finally I consider the 2D limit, describing the emergence of (2+1) Dirac fermions in presence of a strongly anisotropic lattice.

CHAOS IN LIQUID SURFACE WAVES AS THE RESULT OF SPATIAL GEOMETRIC CONFINEMENT

Y. Núñez-Fernández[1,2], C. Trallero-Giner[1]

1 Faculty of Physics, University of Havana, Cuba
2 Department of Physics, University of Minho, Portugal

We study the existence of chaos in the motion of liquid surface waves under adiabatic approximation. Considering that the fluid moves in a vertical cylindrical-shaped tank with cross section of truncated circle of radius R and length of rope $2a$, we analyze the influence of the geometry on the movement of waves in the following cases: $a/R < 1$ (two-dimensional lens), $a/R = 1$ (semicircle) and $a/R > 1$ (D-shape). We propose a mathematically exact representation for describing the velocity potential and the elongation (ξ) in the fluid surface, giving the spectrum of eigenvalues and oscillation modes for stationary states. Depending on the geometric factor a/R, the spectrum characteristics about nearest neighbor spacing (NNS) of eigenvalues show distributions ranging from Poisson to Wigner statistics, showing a transition from regular to chaotic motion. Using the exact representation for ξ, we obtain scars-like and speckle-like oscillation patterns, as representative elements of wave chaos. Also, it is proposed and calculated the information entropy associated to each oscillatory state of the system, giving a quantitative measure of the prevailing disorder. This work shows that as the geometric confinement moves away from the semicircular cylinder the chaotic nature of the motion is reinforced.

SI 7

MULTIPHOTON SCATTERING ON RESONANT ATOMS IN 1D WAVEGUIDE - A PATH INTEGRAL APPROACH

M. Ringel[1], V.Gritsev[1]

1 Department of Physics, University of Fribourg, Fribourg, Switzerland

We present a novel field-theoretical method to study a multiphoton scattering on resonant atoms in a 1D waveguide. The basic model is assumed to be the Dicke model with M atoms sitting at $x = 0$. This model happens to be exactly solvable via Bethe ansatz, and the scattering matrix for scattering of $N = 1, 2, 3$ photons, taking into account the full quantum dynamics of the atoms-photons system, has been derived by complicated calculations with Bethe wavefunction.

In our path integral formulation we make no reference to Bethe ansatz. Nevertheless, we are able to reproduce the exact scattering matrices by a relatively simple calculation. Moreover, the method allows us to consider initial states containing excited atoms as well as treat a time-dependent splitting of the atomic levels. Perturbative treatment of additional terms in the Hamiltonian is also possible. The method seems promising in tackling more some other problems too.

SI 8

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Évora and how to reach it

Évora is located in the south of Portugal, about 140 km east of Lisbon. The monumental feature of Évora - together with its picturesque aspect - made UNESCO include its historic centre in its list of cultural heritage of mankind. Follow this link (City of Évora) to find more.: http://home.dbio.uevora.pt/ femi/porttow/evora.html

Airport bus services:

The organizing commitee arranged special buses with departure from Lisbon airport around 8:00 pm on Sunday 10 October 2010, and from Évora with departure around 6:30 pm on Friday 15 October 2010, with arrival to Lisbon airport at around 8:00 pm. The use of these buses requires prior registration at the event secretary.

Bus Timetables

Find below the timetables for the connections Lisbon-Évora and Évora-Lisbon by bus. (Due to construction works there is no train connection during the period of the workshop.)

By bus:

From the Lisbon International Airport you should take a taxi or a bus to the bus station in Sete Rios, where you can take a direct bus to Évora. The journey will last approximately 1h40. Although there is no metro at the airport, in case you are elsewhere in Lisbon you may take the metro to the bus station (Jardim Zoológico metro station). This is the address of the Bus Station:

RNE - Rede Nacional de Expressos, Lda
Terminal Rodoviário de Sete Rios
Praça Marechal Humberto Delgado Estrada das Laranjeiras
1500-423 LISBOA

Below you will find departure and arrival timetables to and from Évora.

Bus Timetables

Lisboa → Évora (131 km)

Departure	Arrival	Price	Frequency
07:00	08:45	12.00	Except Saturdays and Sundays
08:00	09:30	12.00	Daily
08:00	09:45	12.00	Except Saturdays and Sundays
08:30	10:15	12.00	Daily
09:30	11:00	12.00	Daily
10:30	12:15	12.00	Daily
11:45	13:35	12.00	Daily
12:00	13:30	12.00	Daily
13:00	14:45	12.00	Mondays, Tuesdays, Wednesdays, Thursdays and Fridays
13:45	15:15	12.00	Daily
14:15	16:50	12.00	Daily
15:00	16:30	12.00	Fridays
15:00	16:40	12.00	Except Sundays
15:00	16:45	12.00	Sundays
16:00	17:45	12.00	Mondays, Tuesdays, Wednesdays, Thursdays, Fridays and Sundays
17:00	18:45	12.00	Daily
17:15	19:00	12.00	Daily
17:45	19:15	12.00	Daily
18:00	19:30	12.00	Mondays, Tuesdays, Wednesdays, Thursdays and Fridays
19:00	20:30	12.00	Except Sundays
19:00	20:40	12.00	Mondays, Tuesdays, Wednesdays, Thursdays, Fridays and Sundays
19:30	21:00	12.00	Daily
20:00	21:30	12.00	Sundays
20:30	22:15	12.00	Daily
21:30	23:15	12.00	Fridays
22:00	23:45	12.00	Daily
22:30	00:00	12.00	Sundays

Évora → Lisboa (131 km)

Departure	Arrival	Price	Frequency
06:00	07:45	12.00	Daily
07:00	08:30	12.00	Daily
07:30	09:00	12.00	Mondays, Tuesdays, Wednesdays, Thursdays and Fridays
08:00	09:45	12.00	Except Sundays
08:30	10:00	12.00	Daily
08:30	11:05	12.00	Daily
09:45	11:30	12.00	Daily
10:15	11:45	12.00	Daily
12:45	14:15	12.00	Daily
13:00	14:45	12.00	Except Saturdays and Sundays
14:00	15:30	12.00	Daily
14:45	16:15	12.00	Daily
15:00	16:45	12.00	Mondays, Tuesdays, Wednesdays, Thursdays and Fridays
16:00	17:30	12.00	Fridays
16:00	17:45	12.00	Mondays, Tuesdays, Wednesdays, Thursdays, Fridays and Sundays
16:00	17:45	12.00	Saturdays
17:30	19:00	12.00	Fridays
17:30	19:05	12.00	Sundays
17:30	19:15	12.00	Daily
18:15	19:45	12.00	Daily
19:00	20:45	12.00	Daily
19:30	21:15	12.00	Daily
20:00	21:45	12.00	Daily
21:00	22:45	12.00	Mondays, Tuesdays, Wednesdays, Thursdays, Fridays and Sundays
21:30	23:00	12.00	Sundays

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