PROGRAM AND ABSTRACT BOOKLET

WORKSHOP ON CORRELATIONS, INTEGRABILITY, AND CRITICALITY IN QUANTUM SYSTEMS

University of Évora, Portugal, 24-28 October 2016

The Workshop

The workshop is promoted by several European and US projects and European and Chinese research centers. Our main aim is to generate a lively exchange of ideas between researchers working in the different but nevertheless related fields. Advances over the past ten years have seen an exciting confluence of the areas of strongly correlated many-body systems including integrable systems, computational condensed matter physics, AdS/CFT correspondence, and quantum information theory.

The main focus areas of the workshop will be integrable systems, quantum criticality, quantum information, cold atoms, non-equilibrium many-body systems and nonlinear phenomena, AdS/CFT correspondence, and correlations and topological matter. Analytical as well as computational approaches to problems in these areas will be discussed. It will bring together a number of established experts as well as many talented young scientists to further explore and exploit the connections between many body theory, quantum information, and quantum criticality. Invited speakers are drawn from the theoretical, experimental, and computational physics communities.

Workshop site

Previous workshops at Évora have been highly successful in drawing together leading researchers and young scientists. Workshops in Evora have actually a long tradition. The beautiful medieval town offers an ideal setting for bringing together people working in different but related fields. In the past, discussions often continued after the last session of the day. The month of October is an ideal period for visiting the Alentejo region, where excursions to the surroundings of Evora and its megalithic monuments can be made at moderate temperatures.

The workshop will take place at:

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

Organizing Committee

Miguel A. N. Araújo (Évora, Portugal)

Daniel Arovas (San Diego, USA)

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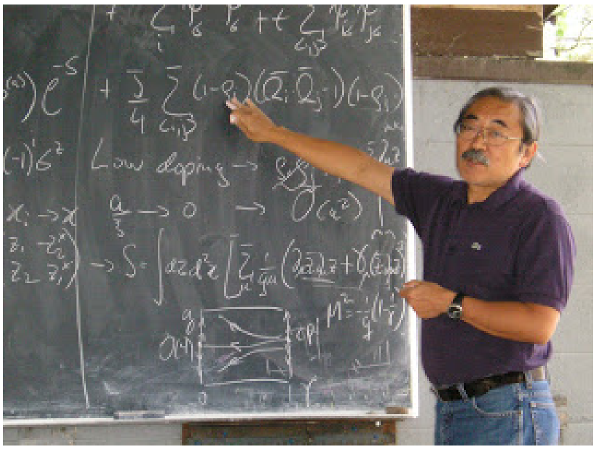
Ervideira Wine

Câmara Municipal de Évora

In Memoriam - Alejandro Muramatsu

This workshop is dedicated to the memory of Alejandro Muramatsu, invited speaker of one workshop (2010) and member of the organizing committee of two workshops (2012 and 2014) held in Évora.



On 16 November 2015 Alejandro succumbed to a battle with cancer. After finishing the diploma degree in physics in 1976 at the University of Buenos Aires, Alejandro moved to Germany for political reasons, related to the Argentina state-terrorism period. There he earned his Ph.D. degree in physics in 1981 at the University of Stuttgart. In the period 1981-85 he was a postdoctoral fellow in the Max-Planck-Institut für Festkörperforschung, Stuttgart, and in the Institute for Theoretical Physics, University of California, Santa Barbara. In 1985-86 Alejandro returned to the Max-Planck-Institut für Festkörperforschung where he was a research associated. In 1986-89 he had the status of "Akademischer Rat"at the University of Würzburg where he earned his Habilitation degree in 1989. In 1989-94 he was a "Oberassistent"at the University of Bayreuth and in 1994-96 an associate professor at the University of Augsburg. From 1996 and until his early dead in 2015, Alejandro was a professor of theoretical physics at the Institute for Theoretical Physics III, University of Stuttgart. He dedicated his life to researching in condensed-matter systems and was a leader of his Institute for Theoretical Physics III where he worked diligently to attract young researchers and students to the University of Stuttgart. Alejandro leaves behind his wife, Heidrun Scholz-Muramatsu, and a son, David Muramatsu. He was an invited speaker of the workshop on quantum coherence and correlations in condensed-matter and cold-atom systems held in Évora in October 2010 and an organizer of both the workshop on correlations and coherence in quantum systems held in Évora in October 2012 and the workshop on correlations, criticality, and coherence in quantum systems held Évora in October 2014.

PROGRAM

The lengths of both invited and contributed talks include at least 5 minutes of discussion.

Monday, 24 October

8:30 - 9:00 Registration

9:00 - 9:05 Welcome

9:05 - 9:40 Invited: **Pedro Schlottmann**
The topological Kondo insulator SmB6

9:40 - 10:15 Invited: **Norio Kawakami**
Correlated edge states in topological Mott insulators

10:15 - 10:35 Contributed: **Oleksandr Balabanov**
Symmetry-protected edge states in periodically driven band insulators

10:35 - 10:55 Coffee break

10:55 - 11:30 Invited: **Marcos Rigol**
Emergent eigenstate solution to quantum dynamics far from equilibrium

11:30 - 11:50 Contributed: **Rubem Mondaini**
Many body (de)localization in fermionic chains

11:50 - 12:10 Contributed: **Pedro Ribeiro**
Steady-state properties of a thermodynamically unbalanced Fermi gas

12:10 - 12:30 Contributed: **Max E. Sorantin**
Auxiliary master equation approach for strongly correlated quantum impurities out of equilibrium

12:30 Lunch break

15:00 - 15:30 In memoriam: Paco Guinea, Marcos Rigol, Stefan Wessel
Alejandro Muramatsu

15:30 - 16:30 Invited colloquium: **Francisco (Paco) Guinea**
Novel quantum effects in graphene and two dimensional dichalcogenides

16.40 - 17:00 Coffee break

16:50 - 17:25 Invited: **Shi-Ping Feng**
Doping and energy evolution of magnetic excitations in electron-doped cuprate superconductors

17:25 - 17:45 Contributed: **Eduardo V. Castro**
Raise and collapse of strain-induced pseudo-Landau levels in graphene

17:45 - 18:05 Contributed: **Mariana Malard**
Synthesizing Majorana zero-energy modes in a periodically gated quantum wire

Tuesday, 25 October

9:00 - 9:35 Invited: **Stefano Chesi**
Dephasing due to nuclear spins in large-amplitude electric dipole spin resonance

9:35 - 10:10 Invited: **Xin-Cheng Xie**
Dephasing and disorder effects in topological systems

10:10 - 10:45 Invited: **Jian-Ping Hu**
Genes for unconventional high temperature superconductors

10:45 - 11:05 Coffee break

11:05 - 11:40 Invited: **Johanna Erdmenger**
Entanglement entropy and quenches in an AdS/CFT Kondo model

11:40 - 12:15 Invited: **Ying-Dan Wang**
Optimization of STIRAP-based state transfer under dissipation

12:15 - 12:35 Contributed: **Filiberto Ares**
Complex geometry in the entanglement entropy of fermionic chains

12:35 Lunch break

15:00 - 16:00 Invited colloquium: **Qian Niu**
Geometric phase effects on electronic properties

16:00 - 16:35 Invited: **Maria A. H. Vozmediano**
Topological metal from a disordered class A insulator

16:35 - 16:55 Coffee break

16:55 - Poster presentations (2 minutes each) and poster session

Wednesday, 26 October

9:00 - 9:35 Invited: **Xenophon Zotos**
Magnetothermal transport in the S=1/2 XXZ chain

9:35 - 10:10 Invited: **Xi-Wen Guan**
Quantum criticality of one-dimensional attractive Hubbard model

10:10 - 10:30 Contributed: **Tilen Cadez**
One-electron singular spectral features of the 1D Hubbard model at finite magnetic field

10:30 - 10:50 Coffee break

10:50 - 11:50 Invited colloquium: **Tomaz Prosen**
Quasilocal charges in integrable lattice systems

11:50 - 12:10 Contributed: **Hans-Peter Eckle**
A generalization of the quantum Rabi model: exact solution and spectral degeneracies

12:10 - 12:45 Invited: **Alexander Stolin**
Classification of quantum groups

12:45 Lunch break

15:00 Évora has many historical sites that deserve your visit

17:30 Wine tasting in Ervideira Wine Tastings & Shop
Address: Rua 5 de Outubro, 56, Évora

19:30 Banquet in site to be announced

Thursday, 27 October

9:00 - 9:35 Invited: **Daniel Braak**
Integrable and non-integrable models in quantum optics

9:35 - 9:55 Contributed: **Michael Tomka**
Geodesic paths for quantum many-body systems

9:55 - 10:30 Invited: **Ofer Firstenberg**
Structured dressing for photon-photon interactions

10:30 - 10:50 Coffee break

10:50 - 11:25 Invited: **Michael Fleischhauer**
Reservoir-induced topology and symmetry protected topological order in open quantum chains

11:25 - 12:00 Invited: **Michael J. Hartmann**
Many-Body Interactions and Topological Order with Superconducting Circuits

12:00 - 12:35 Invited: **Philipp Schneeweiss**
Chiral nanophotonics and quantum optics

12:35 Lunch break

15:00 - 15:35 Invited: **Marco Di Liberto**
Interplay between topology and interactions in the SSH model: a dynamical perspective

15:35 - 16:10 Invited: **Vladimir V. Konotop**
Spin-orbit coupled BECs in lattices: gap solitons, vortices and Bloch oscillations

16:10 - 16:30 Contributed: **Krzysztof Bieniasz**
Analytical study of spin-orbital polarons in KCuF(3)

16:30 - 16:50 Coffee break

16:50 - 17:25 Invited: **Tao Xiang**
Charge dynamics of antiferromagnetic ordered Mott insulators

17:25 - 17:45 Contributed: **Daniel Huerga**
Antiferromagnetic Hamiltonians hosting valence bond crystals

17:45 - 18:05 Contributed: **Fatemeh Heydari-Nasab**
Stable checkerboard super-solid phase in binary hard-core Bose Hubbard mixture

Friday, 28 October

9:00 - 9:35 Invited: **Stefan Wessel**
Thermal scaling near 2D fermionic chiral Ising quantum critical points

9:35 - 10:10 Invited: **Mucio A. Continentino**
Scaling close to first order quantum phase transitions

10:10 - 10:45 Invited: **Jian-Xin Li**
Quantum phases emerged from the interplay between Mott physics and topology band

10:45 - 11:05 Coffee break

11:05 - 11:40 Invited: **Anders W. Sandvik**
Anomalous quantum-criticality with two length scales

11:40 - 12:00 Contributed: **Luca F. Tocchio**
Hidden Mott transition and large-U superconductivity in the two- dimensional Hubbard model

12:00 - 12:20 Contributed: **Natalia Lera**
Gapped electron fractionalization in robustly one dimensional Li(0.9)Mo(6)O(17)

12:20 - 12:40 Summary and closing remarks by **Henrik Johannesson**

12:40 Lunch

POSTERS

Poster Session (25/10/2016)

	Name	Title
1	Yuliy V. Bludov	Particle-antiparticle analogue mechanism of the vector matter-wave soliton's escape from the trap
2	R. G. Dias	Time evolution of localized states in geometrically frustrated lattices
3	A. M. Marques	Multi-hole edge states in SSH chains with interactions
4	B. Mera	Boltzmann-Gibbs states in topological quantum walks: Fidelity analysis of Phase Transitions
5	S. Nemati	New fingerprints of the entanglement on the thermodynamic properties
6	Pranay Patil	Indicators of Conformal Field Theory: entanglement entropy and multiple point correlators
7	Filipe Santos	Edge currents in frustrated Josephson junction ladders
8	Hui Shao	Stochastic analytic continuation method and Spectral functions of 2D Heisenberg model
9	Frederico Sousa	Adatom Induced Magnetism in Graphene
10	M. Yahyavi	Charge transport at ideal conductor-insulator interface
11	T. Mohammad Ali Zadeh	Dynamics of entanglement in the extended cluster spin-1/2 XX chain

ABSTRACTS OF THE INVITED AND CONTRIBUTED TALKS

Monday, 24 October

THE TOPOLOGICAL INSULATOR SMB_6

Pedro Schlottmann

Department of Physics, Florida State University, Tallahassee, Florida, USA

9h05 Mon 1

SmB_6 has been predicted to be a strong topological Kondo insulator and experimentally it has been confirmed that at low temperatures the electrical conductivity only takes place at the surfaces of the crystal. Quantum oscillations and ARPES measurements revealed several Dirac cones on the (001) and (101) surfaces of the crystal. We considered three types of surface Dirac cones with an additional parabolic dispersion and studied their Landau quantization and the expectation value of the spin of the electrons. The Landau quantization is quite similar in all three cases and would give rise to very similar de Haas-van Alphen oscillations [1]. The spin-momentum locking, on the other hand, differs dramatically [2]. Without the additional parabolic dispersion the spins are locked in the plane of the surface. The parabolic dispersion, however, produces a gradual canting of the spins out of the surface plane. The NMR Korringa relaxation and Knight shift of ^{11}B nuclei [3] in the topological Kondo insulator SmB_6 are discussed [4] and we explore the possibility of microwave transitions among the surface states. A second energy scale corresponding to "in-gap" bulk states play an important role at low T in the susceptibility, optical reflectivity and transmission, and inelastic neutron scattering. These states are very sensitive to an external magnetic field and have been ascribed to magnetic exciton bound states [5].

Work supported by the Department of Energy under grant No. DE-FG02-98ER45707.

[1] P. Schlottmann, AIP Advances **6**, 055803 (2016).
[2] P. Schlottmann, Philosophical Magazine, http://dx.doi.org/10.1080/14786435.2016.1178405
[3] T. Caldwell et al., Phys. Rev. B 75, 075106 (2007).
[4] P. Schlottmann, Phys. Rev. B **90**, 165127 (2014).
[5] P. Riseborough, Phys. Rev. B 68, 235213 (2003).

CORRELATED EDGE STATES IN TOPOLOGICAL MOTT INSULATORS

N. Kawakami, R. Peters, T. Yoshida

Department of Physics, Kyoto University, Kyoto, Japan

We study the correlation effects on a topological insulator and the resulting topological edge states. We first gives an example of topological Mott insulator in one dimension, where the bulk is in a correlated topological insulator, while the edge state is in a Mott insulating state [1]. We elucidate these properties by examining the bulk topological invariant and the entanglement spectrum of a correlated electron model. We clarify how gapless edge states in a non-interacting topological band insulator evolve into spinon edge states in a topological Mott insulator. Furthermore, we propose a topological Mott transition, which is a new type of topological phase transition. This unconventional transition occurs in spin liquid phases in the Mott insulator and is accompanied by zeros of the single-particle Green's function and a gap closing in the spin excitation spectrum. 9h40

We generalize this idea to a two-dimensional system in terms of a double-layer Kane-Mele model [2], and show a concrete example of topological Mott insulator in two dimensions. It is clarified how the topological Mott state evolves from the ordinary spin Hall insulating state with increasing the Hubbard interaction at a given temperature and then undergoes a phase transition to a trivial Mott insulating state. With a bosonization approach at zero temperature, we further address which collective excitations host gapless edge modes in the topological Mott insulating state. We further demonstrate an intriguing crossover behavior induced by the interplay between the topological structure and electron correlations; the topological properties are restored by temperature effects [2]. We show that this is rather ubiquitous for correlated topological materials. Mon 2

1. T. Yoshida et al, Phys. Rev. Lett. **112**, 196404 (2014).
2. T. Yoshida et al, Phys. Rev. **B93**, 045138 (2016), preprint

SYMMETRY-PROTECTED EDGE STATES IN PERIODICALLY DRIVEN BAND INSULATORS

Oleksandr Balabanov

Department of Physics, University of Gothenburg, SE 412 96 Gothenburg, Sweden

10h15
Mon
3

The symmetry-protected band insulators are usually identified by the existence of so-called symmetry-protected edge states in these materials. These states are robust to any perturbations that are localized on the edges and preserve the relevant symmetries. For periodically driven (Floquet) systems the symmetries are defined for the evolution operators and therefore any time-periodic perturbation to the Hamiltonian can be characterized as symmetry breaking or symmetry preserving. This suggests that the symmetry-protected end modes in Floquet theory should be robust to not only static but also to certain time-dependent perturbations. In this talk I will explicitly demonstrate this idea on the driven Su-Schrieffer-Heeger (SSH) model for polyacetylene. In particular, the behaviour of the protected edge states will be predicted based on the symmetry arguments and then confirmed using numerics.

EMERGENT EIGENSTATE SOLUTION TO QUANTUM DYNAMICS FAR FROM EQUILIBRIUM

Marcos Rigol

Department of Physics, The Pennsylvania State University, University Park, USA

The quantum dynamics of interacting many-body systems has become a unique venue for the realization of novel states of matter. In this talk, we will discuss how it can lead to the generation of time-evolving states that are eigenstates of emergent local Hamiltonians, not trivially related to the ones dictating the time evolution. We study geometric quenches in interacting fermionic and bosonic systems in one-dimensional lattices, and provide examples of experimentally relevant time-evolving states [1,2] that are either ground states or highly excited eigenstates of emergent local Hamiltonians [3].

10h55
Mon
4

1. M. Rigol and A. Muramatsu, Phys. Rev. Lett. **93**, 230404 (2004).
2. L. Vidmar, J.âĂŁP. Ronzheimer, M. Schreiber, S. Braun, S.âĂŁS. Hodgman, S. Langer, F. Heidrich-Meisner, I. Bloch, and U. Schneider, Phys. Rev. Lett. **115**, 175301 (2015).
3. L. Vidmar, D. Iyer, and M. Rigol, arXiv:1512.05373.

MANY BODY (DE)LOCALIZATION IN FERMIONIC CHAINS

R. Mondaini[1]

1 Beijing Computational Science Research Center, Beijing 100193, China

11h30 Mon 5

Many aspects of disordered isolated quantum many-body systems when taken out-of- equilibrium have been investigated in the recent years. These systems give rise to the so-called Many-body localization (MBL) phenomena that has been experimentally [1,2] and numerically [3] investigated. One interesting aspect of the MBL phase is that under the time evolution of the quenched disorder, information present in the initial preparation may survive for arbitrarily long times. In this talk we build on top of this concept to understand the role of random vector potentials in promoting localization, instead of random scalar potentials widely used in the literature. More precisely, we study the ergodic properties of excited states in a model of interacting fermions in quasi-one dimensional chains subjected to a random vector potential. In the non-interacting limit, we show that arbitrarily small values of this complex off-diagonal disorder triggers localization for the whole spectrum; the divergence of the localization length in the single particle basis is characterized by a critical exponent ν which depends on the energy density being investigated. When short-ranged interactions are included, the localization is lost and the system is ergodic regardless ofthe magnitude of disorder in finite chains. Our numerical results suggest a delocalization scheme for arbitrary small values of interactions. This can be traced by the complete absence of information of the initial conditions after relaxation dynamics, in parallel with the experimental probes using cold atoms in optical lattices systems. This finding indicates that the standard scenario of the many-body localization cannot be obtained in a model with random gauge fields [4].

1. M. Schreiber, S. S. Hodgman, P. Bordia, H. P. Luschen, M. H. Fischer, R. Vosk, E. Altman, U. Schneider, I. Bloch, Science **349**, 842 (2015) .
2. J.-Y. Choi, S. Hild, J. Zeiher, P. Schauß, A. Rubio-Abadal, T. Yefsah, V. Khemani, D. A. Huse, I. Bloch, and C. Gross, Science **352**, 1547 (2015) .
3. R. Mondaini, M. Rigol, Phys. Rev. A **92**, 041601(R) (2015) .
4. C. Cheng, R. Mondaini, arXiv preprint arXiv:1608.07287 (2016) .

STEADY-STATE PROPERTIES OF A THERMODYNAMICALLY UNBALANCED FERMI GAS

P. Ribeiro[1]

1 CeFEMA, Instituto Superior Técnico, Universidade de Lisboa Av. Rovisco Pais, 1049-001 Lisboa, Portugal

The current-carrying steady-state that arises in the middle of a metallic wire connected to macroscopic leads is characterized regarding its response functions, correlations and entanglement entropy. The spectral function and the dynamical structure factor show clear non-equilibrium signatures accessible by state-of-the-art techniques. In contrast with the equilibrium case, the entanglement entropy is extensive with logarithmic corrections at zero-temperature that depend on the wire-leads coupling and, in a non-analytic way, on voltage. This shows that some robust universal quantities found in gapless equilibrium phases do not persist away from equilibrium.

11h50
Mon
6

AUXILIARY MASTER EQUATION APPROACH FOR STRONGLY CORRELATED QUANTUM IMPURITIES OUT OF EQUILIBRIUM

M. Sorantin[1], A. Dorda[1], I. Titvinidze[1], W. von der Linden[1], A. Arrigoni[1]

1 Institute of theoretical and computational physics, University of technology, Graz, Austria

12h10 Mon 7

The auxiliary master equation approach [1,2] allows for an accurate and efficient treatment of correlated impurities out of equilibrium. The method is based upon a mapping onto an auxiliary open quantum system in which the impurity is coupled to bath orbitals as well as to a Markovian environment. The intervening auxiliary orbitals allow for a treatment of non-Markovian dynamics at the impurity. The time dependence of this auxiliary system is controlled by a Lindblad master equation whose parameters are used to optimize the mapping, which becomes exponentially exact upon increasing the number of bath orbitals [3]. Green's functions are evaluated by (non-hermitian) Lanczos exact diagonalisation [2] or by matrix-product states (MPS) [4]. Applications to nonequilibrium Dynamical Mean Field Theory (DMFT) [5] and a generalisation to treat periodically driven quantum systems within Floquet theory will be discussed. We present novel results of the (periodic-)steady state properties of an electric field driven mott insolator connected to non-interacting leads as a simplified model of a so called "Mott Solar Cell". The latter beeing a candidate of a highly efficient solar cell because of carier proliferation due to impact ionisation processes[6-8].

1. E. Arrigoni et al., Phys. Rev. Lett. **110**, 086403 (2013).
2. A. Dorda et al., Phys. Rev. B **89** 165105 (2014).
3. A. Dorda et al., arXiv **1608**, 04632 (2016).
4. A. Dorda et al., Phys. Rev. B **92**, 125145 (2015).
5. I. Titvinidze et al., Phys. Rev. B **92**, 245125 (2015).
6. E. Manousakis, Phys. Rev. B, **82**, 125109, (2010).
7. E. Assman et al., Phys. Rev. Lett. **110**, 078701 (2013).
8. M. Eckstein and P. Werner, Phys. Rev. Lett. **113**, 076405 (2014).

NOVEL QUANTUM EFFECTS IN GRAPHENE AND TWO DIMENSIONAL DICHALCOGENIDES

F. Guinea[1,2]

1 Imdea Nanoscience, Madrid, Spain
2 Department of Physics and Astronomy, University of Manchester, Manchester, UK

Graphene and other two dimensional materials provide an excellent platform where novel quantum effects can be observed. We describe a few examples:

- The nature of the edge states between graphene in the Quantum Hall regime and a superconductor, and the possibility of creating Majorana states[1].
- The interplay between lattice deformations and electrons in graphene and two dimensional dichalcogenides (TMDÂt's), and the extreme anharmonicity of graphene membranes[2-4].
- Effects due to the spin-orbit coupling in graphene intercalated with Pb, and in the TMDâĂŹs[5].

15h30
Mon
8

1. P. San-Jose, J. L. Lado, R. Aguado, F. Guinea, J. Fernández-Rossier, **Majorana Zero Modes in Graphene**, Phys. Rev. X **5**, 041042 (2015).
2. G. Lopez-Polin, C. Gomez-Navarro, V. Parente, F. Guinea, M. I. Katsnelson, F. Perez-Murano, J. Gomez-Herrero, **Increasing the elastic modulus of graphene by controlled defect creation**, Nat. Phys. 11, 26 (2015).
3. B. Amorim, A. Cortijo, F. de Juan, A. G. Grushin, F. Guinea, A. Gutiérrez-Rubio, H. Ochoa, V. Parente, R. Roldán, P. San-José, J. Schiefele, M. Sturla, M. A. H. Vozmediano, **Novel effects of strains in graphene and other two dimensional materials**, Physics Reports **617**, 1 (2016).
4. E. Khestanova, F. Guinea, L. Fumagalli, A. K. Geim, I. V. Grigorieva, **Graphene bubbles on a substrate: Universal shape and van der Waals pressure**, Nature Comm. **7** 12587 (2016).
5. F. Calleja, H. Ochoa, M. Garnica, S. Barja, J. J. Navarro, A. Black, M. M. Otrokov, E. V. Chulkov, A. Arnau, A. L. Vázquez de Parga, F. Guinea, R. Miranda, **Spatial variation of a giant spin-orbit effect induces electron confinement in graphene on Pb islands**, Nature Phys. **11**, 43 (2015).

DOPING AND ENERGY EVOLUTION OF MAGNETIC EXCITATIONS IN ELECTRON-DOPED CUPRATE SUPERCONDUCTORS

Shiping Feng[1], Pengfei Jing[1], Luling Kuang[1], Huaisong Zhao[2]

1 Department of Physics, Beijing Normal University, Beijing 100875, China

2 College of Physics, Qingdao University, Qingdao 266071, China

16h50 Mon 9

The interplay between antiferromagnetism and superconductivity in the electron-doped cuprate superconductors is well established by now [1-3], however, its full understanding is still a challenging issue. Within the framework of the kinetic energy driven superconducting mechanism [4,5], the doping and energy evolution of the magnetic excitations in the electron-doped cuprate superconductors is studied from low-energy to high-energy [6]. The spin self-energy is evaluated explicitly in terms of the collective charge carrier modes in the particle-hole and particle-particle channels, and employed to calculate the dynamical spin structure factor. It is shown that in analogy to the hole-doped case [7], the high-energy spin excitations in the superconducting-state retain roughly constant energy as a function of doping, with spectral weights and dispersion relations comparable to those in the corresponding normal-state. However, the hour-glass-shaped dispersion of the low-energy spin excitations that appears in the hole-doped side [7] is absent. The theory also shows that the commensurate resonance itself appears to be a common property for both electron- and hole-doped cuprate superconductors.

1. K. Ishii *et al.*, Nature. Commun. **5**, 3714 (2014).
2. M. Fujita *et al.*, Phys. Rev. Lett. **101**, 107003 (2008).
3. S. D. Wilson *et al.*, Phys. Rev. B **74**, 144514 (2006).
4. See, e.g., the review, S. Feng *et al.*, Int. J. Mod. Phys. B **29**, 1530009 (2015).
5. S. Feng, Phys. Rev. B **68**, 184501 (2003); S. Feng *et al.*, Physica C **436**, 14 (2006).
6. P. Jing *et al.*, unpublished.
7. S. Feng *et al.*, J. Magn. Magn. Mater. **374**, 624 (2015).

RAISE AND COLLAPSE OF STRAIN-INDUCED PSEUDO-LANDAU LEVELS IN GRAPHENE

Eduardo V. Castro[1,2] and María A. H. Vozmediano[3]

1 CeFEMA, Instituto Superior Técnico, Universidade de Lisboa, Portugal
2 Beijing Computational Science Research Center, China
3 Instituto de Ciencia de Materiales de Madrid, CSIC, Spain

Graphene and other 2D materials behave mechanically as 2D membranes embedded in 3D space. Lattice deformations occur easily and strongly impact the electronic properties of these materials. Limits on charge carrier mobility in graphene are imposed by dynamic lattice deformations [1], while in the novel 2D materials transition metal dichalcogenides, static deformations strongly affect the realization of topological superconductivity and associated Majorana Fermions [2]. But perhaps the most spectacular consequence is the observations of strain-induced 300 Tesla pseudo-magnetic field in some graphene nanobubbles [3]. Here we show why not all nanobubbles display the associated pseudo-Landau level spectrum expected for sky-high pseudo-magnetic fields [4]. The reason can be traced back to the Landau level collapse, predicted for graphene in perpendicular magnetic field (B) and transverse electric field (E) [5] but not yet observed. 17h25
The effect has its roots on the ultrarelativistic Dirac nature of charge carriers in graphene, which also allows Mon
strain to be sensed as magnetic field, and which dictates the Landau level collapse for $E > E_c = v_F B$, 10
where v_F is the effective speed of light in graphene – the Fermi velocity. For strained graphene, the presence of high pseudo-magnetic fields is accompanied by spatial dependent deformation potential. The later may easily lead to an electric field above the critical value E_c. Connection with experiments will be made by working out the numbers in the present theory [4].

1. E. V. Castro, H. Ochoa, M. I. Katsnelson, R. V. Gorbachev, D. C. Elias, K. S. Novoselov, A. K. Geim, F. Guinea, Phys. Rev. Lett **105**, 266601 (2010).
2. Linhu Li, E. V. Castro, P. D. Sacramento, accepted in Phys. Rev. B (2016).
3. N. Levy, S. A. Burke, K. L. Meaker, M. Panlasigui, A. Zettl, F. Guinea, A. H. Castro Neto, M. F. Crommie, Science **329**, 544 (2010).
4. E. V. Castro and M. A. H. Vozmediano, submitted (2016).
5. N. M. R. Peres and E. V. Castro, J. Phys.: Condens. Matter **19**, 406231 (2007).

SYNTHESIZING MAJORANA ZERO-ENERGY MODES IN A PERIODICALLY GATED QUANTUM WIRE

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5 Beijing Computational Science Research Center, Beijing, China

17h45 Mon 11

I will present a scheme for engineering a one-dimensional spinless p-wave superconductor hosting unpaired Majorana zero-energy modes, using an all electric setup with a spin-orbit coupled quantum wire in proximity to an s-wave superconductor. The required crossing of the Fermi level by a single spin-split energy band is ensured by employing a periodically modulated Rashba interaction, which, assisted by electron-electron interactions and a uniform Dresselhaus interaction, opens a gap at two of the spin-orbit shifted Fermi points. As the scheme calls for the assistance of electron-electron interactions, the microscopic Hamiltonian is cast in a low-energy effective bosonized description amenable to a renormalization group analysis. I will show the resulting phase diagram of the system and provide the minimum practical conditions for sustaining the topological phase in the laboratory.

1. Mariana Malard, George I. Japaridze, Henrik Johannesson, Phys. Rev. B **94**, 115128 (2016).

Tuesday, 25 October

DEPHASING DUE TO NUCLEAR SPINS IN LARGE-AMPLITUDE EDSR

Stefano Chesi

Beijing Computational Science Research Center, China

9h00 Tue 1

We have analyzed effects of the hyperfine interaction on electric dipole spin resonance (EDSR) when the amplitude of the quantum-dot motion becomes comparable or larger than the quantum dot's size [1]. Away from the well-known small-drive regime, the important role played by transverse nuclear fluctuations leads to a gaussian decay of spin coherence with characteristic dependence on drive strength and detuning. A characterization of spin-flip gate fidelity, in the presence of such additional drive-dependent dephasing, shows that vanishingly small errors can still be achieved at sufficiently large amplitudes. Based on our theory, we analyze recent EDSR experiments relying on spin-orbit interactions or the slanting field of a micromagnet. We find that such experiments are already in a regime with significant effects of transverse nuclear fluctuations and the form of decay of the Rabi oscillations can be reproduced well by our theory. We will also briefly discuss other aspects of our research on single and double quantum dots, regarding the controlled generation of Dicke states in the nuclear spin bath [2] and fast electron spin manipulation [3].

1. S. Chesi, L.-P. Yang, and D. Loss, Phys. Rev. Lett. **116**, 066806 (2016).
2. S. Chesi and W. A. Coish, Phys. Rev. B **91**, 245306 (2015).
3. S. Chesi *et al.*, Phys. Rev. B **90**, 235311 (2014).

DEPHASING AND DISORDER EFFECTS IN THE TOPOLOGICAL SYSTEMS

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Collaborative Innovation Center of Quantum Matter, Beijing 100871, China

The influence of dephasing and disorder effects in the topological systems, such as the quantum spin Hall effect (QSHE) system, the surface states of 3D topological insulators, and the Weyl semimetals (WSMs) is studied. For the 2D QSHE system, we find that the quantum conductance plateaus are robust against the normal dephasing but fragile with the spin dephasing, and thus these quantum plateaus only survive in mesoscopic samples. For the surface states of 3D topological insulators, we show that the combination of dephasing and impurity scattering can cause backscattering in the helical states. In WSMs, we predict the Goos-HÃd'nchen and the Imbert-Fedorov shifts exist for the reflection at the interface of two WSMs. We find that the IF shift originates from the topological effect of the system, and can be utilized to characterize the Weyl semimetals, to design valleytronic devices, and to measure the Berry curvature of the system. We also study the impurity scattering and disorder effects in the WSMs. We show that the topological IF shift also influences the single impurity scattering cross-section and gives rise to exotic transport properties of WSMs. Furthermore, we study the disorder induced localization in WSMs, and find three exotic quantum phase transitions.

9h35
Tue
2

GENES OF UNCONVENTIONAL HIGH TEMPERATURE SUPERCONDUCTORS

Jiangping Hu

Institute of Physics, Chinese Academy of Sciences, Beijing, China

10h10 Tue 3

In the past, both curates and iron-based superconductors were discovered accidentally. Lacking of successful predictions on new high Tc materials is one of major obstacles to reach a consensus on the high Tc mechanism. In this talk, we discuss a unified scheme to explain why the d-wave pairing symmetry and the s-wave pairing symmetry are robust respectively in cuprates and iron-based superconductors and explain their rareness as unconventional high Tc superconductors. We identify necessary electronic environments required for high Tc superconductivity that can serve as direct guiding rules to search for new high Tc materials. We predict that the third family of unconventional high Tc superconductors exist in the compounds which carry two dimensional hexagonal lattices formed by cation-anion trigonal bipyramidal complexes with a d? filling configuration on the cation ions. Their superconducting states are expected to be dominated by the d+id pairing symmetry and their maximum Tc should be higher than those of iron-based superconductors. Verifying the prediction can convincingly establish the high Tc superconducting mechanism and pave a way to design new high Tc superconductors?

1. J.P. Hu, et al, Phys. Rev. X**5**, 041012 (2015).
2. J.P. Hu, Sci. Bull. **61**, 561 (2016) . 3. J.P. Hu and J. Yuan, Front. of Phys. 11,117404 (2016)

ENTANGLEMENT ENTROPY AND QUENCHES IN AN ADS/CFT KONDO MODEL

J. Erdmenger[1,2]

1 Max Planck Institute for Physics, Munich, Germany
2 Address from October 2016: Theoretical Physics III, Würzburg University, Würzburg, Germany

Using generalizations of the AdS/CFT correspondence, we construct a model for a magnetic impurity coupled to a strongly correlated system. We calculate the entanglement and impurity entropies from the dual gravity model and compare to previous field theory results. We also study quantum quenches and find that the equilibration times are given by the fluctuation modes of the dual gravity model. Finally we calculate spectral functions using AdS/CFT techniques. These reflect the strong-coupling nature of the system considered.

11h05
Tue
4

1. J. Erdmenger, M. Flory, C. Hoyos, M. N. Newrzella and J. M. S. Wu, Fortsch. Phys. **64** (2016) 109.
2. J. Erdmenger, C. Hoyos, A. O'Bannon and J. Wu, JHEP **1312** (2013) 086.

OPTIMIZATION OF STIRAP-BASED STATE TRANSFER UNDER DISSIPATION

Ying-Dan Wang[1], Xiao-Bo Yan[1], Stefano Chesi[1,2]

1 Institute of Theoretical Physics, Chinese Academy of Sciences, Beijing, China
2 Institute of Computational Sciences Research Center, Beijing, China

11h40 Tue 5

Using a perturbative treatment, we quantify the influence of non-adiabatic leakage and system dissipation on the transfer fidelity of a stimulated Raman adiabatic passage (STIRAP) process. We find that, optimizing transfer time rather than coupling profiles, leads to a significant improvement of the transfer fidelity. The upper bound of the fidelity has been found as a simple analytical function of system cooperativities. We also provide a systematic approach to reach this upper bound efficiently.

COMPLEX GEOMETRY IN THE ENTANGLEMENT ENTROPY OF FERMIONIC CHAINS.

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2 Instituto de Biocomputación y Física de Sistemas Complejos, Universidad de Zaragoza, 50009 Zaragoza, Spain

3 Instituto de Física, Universidade de Brasília, 04455, 70919-970, Brasília, DF, Brazil

We review the asymptotic behavior of the entanglement entropy in the ground state of a free fermionic chain. We emphasize the relevant role that the geometry of Riemann surfaces plays in this subject.
On the one hand, we recollect the well known results from conformal field theory to determine the behavior of the entanglement entropy under conformal transformations.
On the other hand, we unravel a new symmetry for the entanglement entropy in non critical theories. This symmetry is based on the Möbius transformations on a compact Riemann surface associated to the Hamiltonian of the system. We argue how to extend these results to critical theories, supporting our conjectures with numerical tests.
Finally, we highlight the intriguing parallelism that exists between conformal symmetry in real space and Möbius transformations on the compact Riemann surface, trading the insertion points for the Fermi momenta.

12h15 Tue 6

1. F. Ares, J. G. Esteve, F. Falceto, A. R. de Queiroz, J. Stat. Mech. (2016) 043106.

GEOMETRIC PHASE EFFECTS ON ELECTRONIC PROPERTIES

Qian Niu[1,2]

1 Department of Physics, University of Texas, Austin, TX 78721, USA
2 School of Physics, ICQM and CICQM, Peking University, Beijing, China

15h00 Tue 7

Ever since its discovery the notion of Berry phase has permeated through all branches of physics.Over the past three decades it was gradually realized that the Berry phase of the electronic wavefunction can have a profound effect on material properties and is responsible for a spectrum of phenomena, such as polarization, orbital magnetism, various quantum, anomalous, or spin Hall effects, and quantum charge pumping. In this talk, I will present a semiclassical picture, to show how electronic properties, as linear and second order responses to electromagnetic fields, are affected by Berry curvatures in the momentum space.

1. Di Xiao, Mingche Chang and Qian Niu, Review of Modern Physics, 82, 1959 (2010).
2. Yang Gao, Shengyuan A. Yang and Qian Niu, Phys. Rev. Lett **112**, 166601 (2014).
3. Yang Gao, Shengyuan A. Yang and Qian Niu, Phys. Rev. B **91**, 214405 (2015).

TOPOLOGICAL METAL FROM A DISORDERED CLASS A INSULATOR

E. V. Castro[1], R. de Gail[2], M. P. López-Sancho[2], M. A. H. Vozmediano

1 CeFEMA, Instituto Superior Técnico, Universidade de Lisboa, Av. Rovisco Pais, 1049-001 Lisboa, Portugal
2 Instituto de Ciencia de Materiales de Madrid, CSIC, Sor Juana Inés de la Cruz 3, Cantoblanco, E-28049 Madrid, Spain

Topological matter is a trending topic in condensed matter: From a fundamental point of view it has introduced new phenomena and tools, and for technological applications, it holds the promise of basic stable quantum computing. Similarly, the physics of localization by disorder, an old paradigm of obvious technological importance in the field, continues revealing surprises when new properties of matter appear. This work deals with the localization behavior of electronic systems based on partite lattices with special attention to the role of topology. We find an unexpected result from the point of view of localization properties: A robust topological metallic state characterized by a non–quantized Hall conductivity arises from strong disorder in class A (time reversal symmetry broken) insulators. The key issue is the nature of the disorder realization: selective disorder in only one sublattice in systems based on bipartite lattices. The generality of the result is based on the partite nature of most recent 2D materials as graphene or transition metal dichalcogenides, and the possibility of the physical realization of the particular disorder demonstrated in graphene experiments. An anomalous Hall metal arises also when the original clean insulator is topologically trivial.

16h00
Tue
8

1. E. V. Castro, M. P. López-Sancho, M. A. H. Vozmediano, Phys. Rev. **B92**, 085410 (2015).
2. E. V. Castro, R. de Gail, M. P. López-Sancho, M. A. H. Vozmediano, unpublished.

Wednesday, 26 October

MAGNETOTHERMAL TRANSPORT IN THE S=1/2 XXZ CHAIN

X. Zotos

Department of Physics, University of Crete, GR-70013, Heraklion, Greece

9h00 Wed 1

We present a temperature and magnetic field dependence study of spin transport and magnetothermal corrections to the thermal conductivity in the spin $S = 1/2$ integrable easy-plane regime Heisenberg chain [1], extending an earlier analysis based on the Bethe ansatz method [2]. We critically discuss the low temperature, weak magnetic field behavior, the effect of magnetothermal corrections in the vicinity of the critical field and their role in recent thermal conductivity experiments in 1D quantum magnets.

1. C. Psaroudaki and X. Zotos, arXiv:1502.05557.
2. X. Zotos, Phys. Rev. Lett. **82**, 1764 (1999).

QUANTUM CRITICALITY OF ONE-DIMENSIONAL ATTRACTIVE HUBBARD MODEL

Xiwen Guan

Wuhan Institute of Physics and Mathematics, Chinese Academy of Sciences, Wuhan 430071, China
Department of Theoretical Physics, Research School of Physics and Engineering, Australian National University, Canberra ACT 0200, Australia

9h35 Wed 2

The low-energy physics of many strongly correlated systems in one dimension (1D) is described by the Tomonaga-Luttinger liquid (TLL) regardless of quantum statistics of the constituent particles. Such collective behavior is perceived as reflecting a universality class of quantum criticality near a quantum phase transition. In this talk, I will discuss the exact solution of the 1D attractive Hubbard model with magnetic fields in the context of quantum criticality. I will demonstrate that the 1D attractive Hubbard model provides a novel testing ground for understanding fundamental physics and universal critical properties of quantum many-body systems. A variety of important properties will be discussed in this talk, including a full phase diagram, Luttinger liquid, universal thermodynamics, pair fluctuations, dimensionless ratios and correlations etc.

ONE-ELECTRON SINGULAR SPECTRAL FEATURES OF THE 1D HUBBARD MODEL AT FINITE MAGNETIC FIELD

T. Čadež[1,2], J. M. P. Carmelo[3,2]

1 Department of Theoretical Physics, Jozef Stefan Institute, Ljubljana, Slovenia
2 Center of Physics of University of Minho and University of Porto, Oporto, Portugal
3 Department of Physics, University of Minho, Campus Gualtar, Braga, Portugal

We study the momentum, electronic density, spin density and interaction dependences of the exponents that control the (k, ω)-plane singular features of the spin up and down one-electron spectral functions of the 1D Hubbard model at finite magnetic field [1]. We define the usual half-filling concepts of one-electron lower and upper Hubbard band in terms of the rotated electrons associated with the model Bethe-ansatz solution. Our results further clarify the microscopic processes through which the pseudofermion dynamical theory [2,3] accounts for the one-electron matrix elements between the ground state and excited energy eigenstates.

10h10
Wed
3

1. J. M. P. Carmelo and T. Čadež, arXiv:1605.09620
2. J. M. P. Carmelo and K. Penc and D. Bozi, Nucl. Phys. B 725, 421 (2005); 737, 351 (2006) Erratum
3. J. M. P. Carmelo and L. M. Martelo and K. Penc, Nucl. Phys. B 737, 237 (2006).

QUASILOCAL CHARGES IN INTEGRABLE LATTICE SYSTEMS

T. Prosen
Faculty of mathematics and physics, University of Ljubljana

10h50 Wed 4

In the talk I review recent progress in understanding the notion of locality in integrable quantum lattice systems. The central concept are the so-called quasilocal conserved quantities, which go beyond the standard perception of locality. I will outline two systematic procedures to rigorously construct families of quasilocal conserved operators based on quantum transfer matrices, specializing on anisotropic Heisenberg XXZ spin-1/2 chain. Quasilocal conserved operators stem from two distinct classes of representations of the auxiliary space algebra, comprised of unitary (compact) representations, which can be naturally linked to the fusion algebra and quasiparticle content of the model, and non-unitary (non-compact) representations giving rise to charges, manifestly orthogonal to the unitary ones. Various condensed matter applications in which quasilocal conservation laws play an essential role shall be discussed, with special emphasis on their implications for anomalous transport properties (finite Drude weight) and relaxation to non-thermal steady states in the quantum quench scenario. For recent reviews on the subject, see [1,2].

1. T. Prosen, J. Phys. A: Math. Theor. **48**, 373001 (2015)
2. E. Ilievski, M. Medenjak, T. Prosen, L. Zadnik, J. Stat. Mech. (**2016**) 064008.

A GENERALIZATION OF THE QUANTUM RABI MODEL: EXACT SOLUTION AND SPECTRAL DEGENERACIES

Hans-Peter Eckle

Humboldt Study Centre, Ulm University, D-89069 Ulm, Germany

Recently Braak [1] presented an exact solution of the quantum Rabi model. In order to probe quantum Rabi physics over a wide range of parameters, Grimsmo and Parkins [2] have proposed an experimental quantum optics setup which allows for a generalization of the quantum Rabi model by including in the effective Hamiltonian an additional coupling between the two-level system and the single-mode cavity

$$\mathcal{H} = \omega a^\dagger a + \Delta\sigma_z + g\sigma_x(a + a^\dagger) + \gamma\sigma_z a^\dagger a = \mathcal{H}_{\mathrm{Rabi}} + \gamma\sigma_z a^\dagger a. \quad (3.1)$$

11h50 Wed 5

We generalize Braak's method to solve (3.1) exactly. Degeneracies in the spectrum develop in the deep–strong coupling regime $g/\omega > 1$. In the case of the pure Rabi model, $\mathcal{H}_{\mathrm{Rabi}}$, these emergent spectral degeneracies may be understood on the basis of an approximate even-odd parity symmetry, which, for finite Δ, becomes exact when $g/\omega \to \infty$.

Intriguingly, for the full Hamiltonian (3.1) our spectra reveal an onset of the degeneracies that is shifted towards smaller values of the Rabi coupling g compared to the pure Rabi model $\mathcal{H}_{\mathrm{Rabi}}$. This finding may indicate a hidden symmetry of the full model (3.1).

1. D. Braak, Phys. Rev. Lett. **107**, 100401 (2011).
2. A. L. Grimsmo and S. Parkins, Phys. Rev. A **87**, 033814 (2013).

CLASSIFICATION OF QUANTUM GROUPS

A. Stolin

Department of Mathematical Sciences, Chalmers University of Technology /University of Gothenburg, Sweden

12h10 Wed 6

The aim of my talk is to discuss relations between classification of Lie bialgebras/Quantum groups and new integrable models. More exactly, the classification of Lie bialgebras/Quantum groups leads to new solutions of the Yang-Baxter equation, which we use to deform XXX, XXZ and Gaudin/Gaudin-Richardson models. The first model of this type, the so-called Kulish model, appeared 20 years ago and it remains unsolved.

1. Kulish, P. P.; Stolin, A. A. Czechoslovak J. Phys. **47** (1997), no. 12, 1207âĂŞ1212.
2. Khoroshkin, S. M.; Pop, I. I.; Samsonov, M. E.; Stolin, A. A.; Tolstoy, V. N. Comm. Math. Phys. **282** (2008), no. 3, 625âĂŞ662.
3. António, N. Cirilo; ManojloviĂĞ, N.; Stolin, A. J. Math. Phys. **52** (2011), no. 10, 103501, 15 pp.
4. P Kulish, A Stolin and L H Johannesson, J. Phys.: Conf. Series, **532** (2014) 1742-6596 532 012012 doi:10.1088/1742-6596/532/1/012012

Thursday, 27 October

INTEGRABLE AND NON-INTEGRABLE MODELS IN QUANTUM OPTICS

D. Braak[1]

1 EP VI and Center for Electronic Correlations and Magnetism, Institute of Physics, University of Augsburg, Germany

9h00 Thu 1

The Quantum Rabi model, describing dipole interaction between a single mode of the radiation field and a two-level system, may be considered to be integrable if a criterion of quantum integrability suitable for systems with less than two continuous degrees of freedom is employed [1]. Diagonalization of the Hamiltonian corresponds to a solvable connection problem in the Bargmann space of analytic functions. I shall demonstrate that also more complicated models, non-integrable according to the proposed criterion, are exactly solvable within this framework [2]. Further generalizations with non-linear coupling [3,4] reveal close relations with the classical theory of asymptotic analysis in the complex domain.

1. D. Braak, Phys. Rev. Lett. **107**, 100401 (2011).
2. D. Braak, J. Phys. B: At. Mol. Opt. Phys. **46**, 224007 (2013).
3. S. Felicetti *et al.*, Phys. Rev. A **92**, 033817 (2015).
4. L. Duan, S. He, D. Braak and Q.-H. Chen, Europhys. Lett. **112**, 34003 (2015)

GEODESIC PATHS FOR QUANTUM MANY-BODY SYSTEMS

M. Tomka[1], T. Souza[1], S. Rosenberg[2], A. Polkovnikov[1]

1 Department of Physics, Boston University, 590 Commonwealth Ave., Boston, MA 02215, USA
2 Department of Mathematics and Statistics, Boston University, 111 Cummington Mall, Boston, MA 02215, USA

We propose a method to obtain optimal protocols for adiabatic ground-state preparation near the adiabatic limit, extending earlier ideas from [1] to quantum non-dissipative systems. The space of controllable parameters of isolated quantum many-body systems is endowed with a Riemannian quantum metric structure, which can be exploited when such systems are driven adiabatically. Here, we use this metric structure to construct optimal protocols in order to accomplish the task of adiabatic ground-state preparation in a fixed amount of time. Such optimal protocols are shown to be geodesics on the parameter manifold, maximizing the local fidelity. Physically, such protocols minimize the average energy fluctuations along the path. Our findings are illustrated on the Landau-Zener model and the anisotropic XY spin chain. In both cases we show that geodesic protocols drastically improve the final fidelity. Moreover, this happens even if one crosses a critical point, where the adiabatic perturbation theory fails.

9h35
Thu
2

1. D. A. Sivak and G. E. Crooks, Phys. Rev. Lett. **108**, 190602 (2012).

STRUCTURED DRESSING FOR PHOTON-PHOTON INTERACTIONS

O. Firstenberg

Department of Physics of Complex Systems, Weizmann Institute of Science, Rehovot 76100, Israel

9h55 Thu 3

Effective strong interactions between propagating photons are nowadays realized in cold atomic gases by coupling the photons to highly-excited Rydberg states. We study how spatial structuring of the dressing and auxiliary light fields can enhance and enrich these interactions.

RESERVOIR-INDUCED TOPOLOGY AND SYMMETRY PROTECTED TOPOLOGICAL ORDER IN OPEN QUANTUM CHAINS

M. Fleischhauer[1], D. Linzner[1], F. Grusdt[2], L. Wawer[1]

1 Department of Physics, University of Kaiserslautern, Kaiserslautern, Germany
2 Department of Physics, Harvard University, Cambridge, USA

10h50 Thu 4

We introduce a classification scheme for symmetry protected topological phases applicable to stationary states of open systems based on a generalization of the many-body polarization. The polarization can be used to probe the topological properties of non-interacting and interacting closed and open systems as well and remains a meaningful quantity even in the presence of moderate particle-number fluctuations. As examples, we discuss two open-system versions of a topological Thouless pump in the steady state of one-dimensional lattices driven by Markovian reservoirs [1]. In the analogous unitary system, the Rice-Mele model, symmetries enforce topological properties which lead to a non-trivial winding of the geometric Zak phase upon cyclic variations of model parameters. Associated with this is a winding of the many-body polarization, corresponding to a quantized transport in the bulk (Thouless pump). We here show that in the open system, where the Zak phase looses its meaning, the same symmetries enforce a winding of the generalized many- body polarization. This winding is shown to be robust against Hamiltonian perturbations as well as homogeneous dephasing and particle losses.

1. D. Linzner, L. Wawer, F. Grusdt, M. Fleischhauer, arxiv 1605.00756

MANY-BODY INTERACTIONS AND TOPOLOGICAL ORDER WITH SUPERCONDUCTING CIRCUITS

M. J. Hartmann

Institute of Photonics and Quantum Sciences, Heriot-Watt University Edinburgh EH14 4AS, United Kingdom

11h25 Thu 5

Lattices of superconducting resonators are currently emerging as a promising quantum simulation platform for quantum many-body systems of strongly interacting photons [1]. This interest is motivated by their options for strong effective photon-photon interactions, high precision control and measurement access, and the versatility of possible lattice architectures. One particularly appealing avenue is the possibility for coupling resonators not only via linear capacitive or inductive circuits but through a non-linear quantum circuit featuring Josephson junctions. If such non-linear couplings are implemented via a dc-SQUID, they can be driven and tuned via time-independent or even time-depended magnetic fluxes that are threaded through the SQUID loops. I will explain how this mode of operation can lead to interactions between excitations on different lattice sites that may even exceed on-site interactions. This scenario is somewhat complementary to naturally occurring interactions, which typically decay with distance, and leads to a rich non-equilibrium phase diagram [2]. In a second step, I will then consider time-dependent modulations of the coupling circuits and show how these can be used to implement four-body interactions and simulate the Hamiltonian of the Toric Code [3].

1. A. A. Houck, H. E. Türeci, and J. Koch, Nat. Phys. **8**, 292Ð299 (2012).
2. J. Jin, D. Rossini, R. Fazio, M. Leib, and M. J. Hartmann, Phys. Rev. Lett. **110**, 163605 (2013).
3. M. Sameti, A. Potocnik, D. E. Browne, A. Wallraff, and M. J. Hartmann, arXiv:1608.04565 (2016)

CHIRAL NANOPHOTONICS AND QUANTUM OPTICS

P. Schneeweiss[1]

1 Vienna Center for Quantum Science and Technology, Atominstitut, TU Wien, Stadionallee 2, 1020 Wien, Austria

Controlling the interaction of light and matter is the basis for diverse applications ranging from light technology to quantum information processing. Nowadays, many of these applications are based on nanophotonic structures. Remarkably, it turns out that the confinement of light in such nanostructures imposes an inherent link between its local polarization and its propagation direction, also referred to as spin-momentum locking of light [1]. This leads to chiral, i.e., propagation direction-dependent effects in the emission and absorption of light, and elementary processes of light-matter interaction are fundamentally altered. For example, when coupling plasmonic particles or atoms to evanescent fields, the intrinsic mirror symmetry of the particles' emission can be broken. With optical photons, this effect was e.g. observed in the interaction between single rubidium atoms and the evanescent part of a light field that is confined by continuous total internal reflection in a whispering-gallery-mode microresonator [2]. In the following, this allowed us to realize chiral nanophotonic interfaces in which the emission direction of light into the structure is controlled by the polarization of the excitation light [3] or by the internal quantum state of the emitter [4], respectively. Moreover, we employed this chiral interaction to demonstrate an integrated optical isolator [5] as well as an integrated optical circulator [6] which operate at the single-photon level and which exhibit low loss. The latter are the first two examples of a new class of nonreciprocal nanophotonic devices which exploit the chiral interaction between single quantum emitters and transversally confined photons.

12h00
Thu
6

[1] K. Y. Bliokh, F. J. Rodríguez-Fortuño, F. Nori, and A. V. Zayats, Spin-orbit interactions of light, Nature Photon. **9**, 796 (2015).
[2] C. Junge, D. O'Shea, J. Volz, and A. Rauschenbeutel, Strong coupling between single atoms and non-transversal photons, Phys. Rev. Lett. **110**, 213604 (2013).
[3] J. Petersen, J. Volz, and A. Rauschenbeutel, Chiral nanophotonic waveguide interface based on spin-orbit coupling of light, Science **346**, 67 (2014).
[4] R. Mitsch, C. Sayrin, B. Albrecht, P. Schneeweiss, and A. Rauschenbeutel, Quantum state-controlled directional spontaneous emission of photons into a nanophotonic waveguide, Nature Commun. **5**, 5713 (2014).
[5] C. Sayrin, C. Junge, R. Mitsch, B. Albrecht, D. O'Shea, P. Schneeweiss, J. Volz, and A. Rauschenbeutel, Nanophotonic Optical Isolator Controlled by the Internal State of Cold Atoms, Phys. Rev. X **5**, 041036 (2015).
[6] M. Scheucher, A. Hilico, E. Will, J. Volz, and A. Rauschenbeutel, Quantum optical circulator controlled by a single chirally coupled atom, arXiv:1609.02492 (2016).

INTERPLAY BETWEEN TOPOLOGY AND INTERACTIONS IN THE SSH MODEL: A DYNAMICAL PERSPECTIVE

M. Di Liberto[1]

1 INO-CNR BEC Center and Dipartimento di Fisica, Università di Trento, 38123 Povo, Italy

15h00
Thu
7

We consider two interacting bosons in a dimerised Su-Schrieffer-Heeger (SSH) lattice. We highlight the presence of a resonant scattering mechanisms provided by a bound state crossing the scattering continuum. For open boundary conditions and moderate interactions, we identify a rich variety of two-body states. In particular, edge bound states (EBS) are present even for the dimerisation that does not sustain single particle edge states. On the other hand, for large values of the interactions, we find a breaking of the standard bulk-boundary correspondence. We propose an experimental setup based on coupled optical fibers as quantum simulator of the two-body SSH model. Exploiting a mapping of two interacting particles in one dimension onto a single particle in two dimensions, this setup is able to reveal the localisation properties of the states as well as the closed channel population by using real space dynamics.

1. M. Di Liberto, A. Recati, I. Carusotto and C. Menotti, arXiv:1608.07341

SPIN-ORBIT COUPLED BECS IN LATTICES: GAP SOLITONS, VORTICES AND BLOCH OSCILLATIONS

V. V. Konotop[1], Y. V. Kartashov[2]

1 Centro de Física Teórica e Computacional, Faculdade de Ciencias and Departamento de Física, Faculdade de Ciencias, Universidade de Lisboa, Campo Grande, Ed. C8, Lisboa 1749-016, Portugal

2 ICFO-Institut de Ciencies Fotoniques, The Barcelona Institute of Science and Technology, 08860 Castelldefels (Barcelona), Spain and Institute of Spectroscopy, Russian Academy of Sciences, Troitsk, Moscow Region, 142190, Russia

15h35 Thu 8

Three different phenomena which can be observed in Spin-Orbit (SO) coupled BECs loaded in periodic potentials will be considered.

First, we report a diversity of stable one-dimensional gap solitons in a Zeeman lattice [1]. Such solitons, can be classified by the main physical symmetries they obey, i.e. symmetries with respect to parity, time, and internal degrees of freedom, i.e. spin, inversions.

Second, there will be presented families of multipole and half-vortex solitonsin 2D Zeeman lattices [2]. The obtained solutions may exist at any direction of the gauge field with respect to the lattice and can be found either in finite gaps (for repulsive inter-atomic interactions) or in a semi-infinite gap (for attractive interactions). The existence of half-vortices requires higher symmetry (the reflection with respect to the field direction). Stability of these modes makes them feasible for experimental observation.

Finally, we address Bloch oscillations of a spin-orbit coupled atom in periodic potentials of two types: optical and Zeeman lattices [3]. In the optical lattice SO coupling allows one to control the direction of atom motion and may lead to complete suppression of Bloch oscillations. In the case of Zeeman lattice the energy bands are shown to cross at the boundaries of the Brillouin zone resulting in doubling of period of Bloch oscillations. In this case the amplitude of oscillations is determined by the combined width of the crossing energy bands.

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2. V. E. Lobanov, Y. V. Kartashov, and V. V. Konotop,, Phys. Rev. Lett., **112**, 180403 (2014).
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ANALYTICAL STUDY OF SPIN-ORBITAL POLARONS IN $KCUF_3$

K. Bieniasz,[1,2,3] M. Berciu,[2,3] and A.M. Oleś [1,4]

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2 Department of Physics and Astronomy, University of British Columbia Vancouver, British Columbia, Canada V6T 1Z1
3 Quantum Matter Institute, University of British Columbia, Vancouver, British Columbia, Canada V6T 1Z1
4 Max-Planck-Institut für Festkörperforschung, Stuttgart, Germany

16h10
Thu
9

Correlated insulators are physical systems exhibiting a number of interesting and potentially useful phenomena, ranging from superconductivity and colossal magnetoresistance to topological phases to magnetic frustration and exotic long range order. Understanding of those systems is therefore of great importance, both for purely theoretical, as well as practical reasons. One of the key characteristics useful for the understanding of condensed matter systems is the electronic band structure, which can be investigated experimentally by photospectroscopy techniques such as ARPES. Nonetheless, the interpretation of such experiments depends on the development of a spectral theory, *i.e.*, a calculation of a spectral function, usually starting from an effective model.

In this work we present such a solution for copper-fluoride perovskite $KCuF_3$, a system of interest for its magnetic and orbital long range order. The coexistence of two distinct types of bosonic excitations in the system, along with the complicated form of the full Hamiltonian [1], have made this problem inaccessible and it remained unsolved until now, except for simplified subsystems with one of the degrees of freedom projected out [2]. We present an efficient variational calculation whose accuracy can be systematically improved by increasing the size of the variational space by expansion with respect to the number of excitations [3]. This technique allows for careful selection of both elementary physical processes as well as states included in the Hilbert space, generating a linear system of equations of motion for the Green's function, which can then be solved numerically. In this way we were able to calculate the system's Green's function for a variety of conditions to see the effect of different collective excitations on the system.

Work supported by the Polish National Science Center (NCN) under Projects 2012/04/A/ST3/00331 and 2015/16/T/ST3/00503.

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3. M. Berciu, H. Fehske, Phys. Rev. B **84**, 165104 (2011).

CHARGE DYNAMCS OF ANTIFERROMAGNETIC CORRELATED MOTT INSULATORS

X. J. Han[1], Y. Liu[2], Z. Y. Liu[3], X. Li[1], J. Chen[1], Z. Y. Xie[4], B. Normand[4], T. Xiang[1,5]

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2 LCP, Institute of Applied Physics and Computational Mathematics, Beijing 100088, People's Republic of China

3 Institute of Theoretical Physics, Chinese Academy of Sciences, Beijing 100190, People's Republic of China

4 Department of Physics, Renmin University of China, Beijing 100872, People's Republic of China 5 Collaborative Innovation Center of Quantum Matter, Beijing 100190, People's Republic of China

Weintroduce a slave-fermion formulation in which to study the charge dynamics of the half-filled Hubbard model on the square lattice. In this description, the charge degrees of freedom are represented by fermionic holons and doublons and the Mott-insulating characteristics of the ground state are the consequence of holonÍCdoublon bound-state formation. The bosonic spin degrees of freedom are described by the antiferromagnetic Heisenberg model, yielding long-ranged (NÍęel) magnetic order at zero temperature. Within this framework and in the self-consistent Born approximation, we perform systematic calculations of the average double occupancy, the electronic density of states, the spectral function and the optical conductivity. Qualitatively, our method reproduces the lower and upper Hubbard bands, the spectral-weight transfer into a coherent quasiparticle band at their lower edges and the renormalisation of the Mott gap, which is associated with holonÍCdoublon binding, due to the interactions of both quasiparticle species with the magnons. The zeros of the Green function at the chemical potential give the Luttinger volume, the poles of the self-energy reflect the underlying quasiparticle dispersion with a spin-renormalised hopping parameter and the optical gap is directly related to the Mott gap. Quantitatively, the square-lattice Hubbard model is one of the best-characterised problems in correlated condensed matter and many numerical calculations, all with different strengths and weaknesses, exist with which to benchmark our approach. From the semi-quantitative accuracy of our results for all but the weakest interaction strengths, we conclude that a self-consistent treatment of the spin-fluctuation effects on the charge degrees of freedom captures all the essential physics of the antiferromagnetic MottÍCHubbard insulator.Weremark in addition that an analytical approximation with these properties serves a vital function in developing a full understanding of the fundamental physics of the Mott state, both in the antiferromagnetic insulator and at finite temperatures and dopings.

16h50
Thu
10

1. 1. X. J. Han, Y. Liu, Z. Y. Liu, X. Li, J. Chen, Z. Y. Xie, B. Normand, T. Xiang, New J. Phys. **18** (2016) 103004. arXiv:1602.01276

ANTIFERROMAGNETIC HAMILTONIANS HOSTING VALENCE BOND CRYSTALS

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1 Institut für Theoretische Physik, Universität Stuttgart, Germany

2 Instituto de Física de Rosario, Consejo Nacional de Investigaciones Científicas y técnicas and Universidad Nacional de Rosario, Argentina

17h25 Thu 11

We present a method to construct translational and SU(2) invariant antiferromagnetic Hamiltonians hosting valence bond crystals (VBC) as their exact ground state within a finite region of the parameter regime. The method is based on a canonical mapping transforming the physical spins to *dimer fermions*. We construct the parent Hamiltonian of a columnar- and a staggered-VBC on the square lattice. We study their phase diagram by means of hierarchical mean-field theory and exact diagonalization of finite clusters. In both Hamiltonians, the VBCs transit to a collinear antiferromagnetic (CAF) phase through a region where intermediate phases appear when increasing the cluster size, suggesting the appearance of different competing length scales at the VBC-CAF transition. The method here presented can be readily applied to other lattices and VBC patterns.

STABLE CHECKERBOARD SUPER-SOLID PHASE IN BINARY HARD-CORE BOSE HUBBARD MIXTURE

F. Heydari-nasab, J. Abouie

Institute for Advanced Studies in Basic Sciences (IASBS)

We have studied the ground state phase diagram of a binary hard-core Bose-Hubbard model on the square lattice up to next nearest neighbor interactions with emphasis on the stability of checkerboard supersolidity induced by the difference in the nilpotency conditions [1] between two species. Supersolid phase is the coexistence of solid and superfluid order [2]. Using cluster mean field theory [3] we plotted phase diagrams and by linear spin-wave theory dispersion relations of different phases and stability of phases are considered.

17h45
Thu
12

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2. G. G. Batrouni, R. T. Scalettar, PRL **84**, 1599 (2000).
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Friday, 28 October

THERMAL SCALING NEAR 2D FERMIONIC CHIRAL ISING QUANTUM CRITICAL POINTS

S. Wessel, S. Hesselmann

Institute for Theoretical Solid State Physics, JARA-FIT, and JARA-HPC, RWTH Aachen University, 52056 Aachen, Germany

Spinless fermions on the honeycomb lattice (the spinless tV model) provide a minimal realization of lattice Dirac fermions. Nearest neighbor interactions (V) drive a quantum phase transition from a semi-metallic phase to a charge ordered phase, which spontaneously breaks the chiral Z_2 symmetry of the Dirac fermions. The critical theory is given by the Gross-Neveu-Yukawa theory, which describes the process of mass generation due to the broken chiral symmetry. At finite temperature the quantum critical point connects to a line of second order thermal phase transitions that restore the broken chiral symmetry. We employ a recent sign-problem-free continuous time quantum Monte Carlo method [1,2] to investigate the finite temperature phase diagram of the model [3]. Furthermore we give estimates for the critical exponents of the Gross-Neveu chiral Ising universality class by studying the extension of the quantum critical regime to finite temperatures.

9h00
Fri
1

1. E. F. Huffman et al., Phys. Rev. B **89**, 111101(R) (2014).
2. L. Wang et al., New J. Phys. **16**, 103008 (2014).
3. S. Hesselmann and S. Wessel, Phys. Rev. B **93**, 155157 (2016).

SCALING CLOSE TO FIRST ORDER QUANTUM PHASE TRANSITIONS

Mucio A. Continentino

Centro Brasileiro de Pesquisas Físicas
Rua Dr. Xavier Sigaud, 150, Urca, Rio de Janeiro, RJ, 22290-180, Brazil

9h35 Fri 2

We present a generalisation of the scaling theory of quantum critical phenomena for discontinuous or first order quantum phase transitions [1]. As a test for our predictions, we consider fluctuation induced first order transitions, specifically the case of a superconductor coupled to the electromagnetic field [2]. While the neutral superfluid has a quantum critical point (QCP) associated with a superfluid-insulator transition, the charged one has a discontinuous zero temperature transition due to the coupling to the gauge field. At finite temperatures, above this transition, the superconductor obeys scaling laws governed by critical exponents associated with the QCP of the neutral superfluid. In particular the correlation length exponent is given by $\nu = 1/(d+z)$, where d is the dimensionality of the system and z the dynamic critical exponent associated with the QCP of the neutral superfluid. As temperature further decreases approaching zero, bubbles of superconducting regions start to form with a well-defined characteristic length. In this region the correlation length saturates at a finite value and the specific heat is thermally activated due to gapped excitations in bubbles of finite size. We study other phase transitions where fluctuations arise from the proximity to another type of instability, for example the effect of superconducting fluctuations in an antiferromagnetic QCP. Finally, we compare some exact results obtained for discontinuous zero temperature transitions with those of the scaling theory.

1. M. A. Continentino, A. S. Ferreira, Physica A 339, 461 (2004).
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QUANTUM PHASES EMERGED FROM THE INTERPLAY BETWEEN MOTT PHYSICS AND TOPOLOGY BAND

Jian-Xin Li

National Laboratory of Solid State Microstructures and Department of Physics, Nanjing University, Nanjing 210093, China

The search for the exotic quantum phases constitutes one of the most important and hot issues in modern condensed matter physics. In this talk, I will present our recent theoretical investigations on the possible quantum phases and the quantum phase transitions realized in the half-filled Hubbard model on the triangular lattice with spin-dependent Kitaev-like hopping[1]. Using the variational cluster approach, we have mapped out its phase diagram, which contains a non-coplanar chiral magnetic order, an extended nonmagnetic insulating phase (NMI), and an interacting Chern insulator (CI). The transition from CI to NMI is characterized by the change of the charge gap from an indirect band gap to a direct Mott gap. The nonmagnetic insulator has been further classified into a gapless Mott insulator with a spinon Fermi surface and a fractionalized Chern insulator with nontrivial spinon topology, based on the slave-rotor mean-field theory. Our work highlights the rising field that interesting phases emerge from the interplay of band topology and Mott physics[2-4].

10h10
Fri
3

1. K. Li, S.L. Yu, Z.L. Gu, and J.X. Li, Phys. Rev. B **94**, 125120 (2016)
2. Z. L. Gu, K. Li, and J.X. Li, arXiv: 1512.05118 (2015)
3. K. Li, S.L. Yu and J.X. Li, New J. Phys. **17**, 043032 (2015)
3. S.L. Yu, X. C. Xie, and J.X. Li, Phys. Rev. Lett. **107**, 010401 (2011)

ANOMALOUS QUANTUM-CRITICALITY WITH TWO LENGTH SCALES

Anders W. Sandvik

Department of Physics, Boston University, Boston, Massachusetts, USA

11h05 Fri 4

Finite-size scaling is a well-established method for analyzing Monte Carlo simulation data close to critical points. Singular quantities scale as a power of the system size (length) L times a function of the ratio of the intrinsic correlation length and L. At a "deconfined" quantum critical point separating antiferromagnetic (Néel) and valence-bond solid (VBS) ground states in 2D quantum magnets, two divergent intrinsic length scales have been predicted [1]: In addition to the standard correlation length there is a faster diverging length, which can be taken as the width of a VBS domain wall. I will present evidence from quantum Monte Carlo simulations of the J-Q model (a Heisenberg model with added multi-spin interactions) [2] that the same length scale governs the size of a bound state of two spinons and that many other physical quantities are affected in an unexpected way, not predicted within the deconfined-criticality scenario as currently formulated. I will discuss a new hypothesis for the anomalous finite-size scaling in the presence of two divergent length scales and show supporting numerical data for the J-Q model. The proposal explains the so far enigmatic scaling anomalies and lends strong support to the continuous Néel–VBS transition.

1. T. Senthil *et al.*, Science **303**, 1490 (2004).
2. H. Shao, W. Guo, and A. W. Sandvik, Science **352**, 213 (2016).

HIDDEN MOTT TRANSITION AND LARGE-U SUPERCONDUCTIVITY IN THE TWO-DIMENSIONAL HUBBARD MODEL

Luca F. Tocchio, Federico Becca, and Sandro Sorella

CNR-IOM-Democritos National Simulation Centre and International School for Advanced Studies (SISSA), Via Bonomea 265, I-34136, Trieste, Italy

We consider the one-band Hubbard model on the square lattice by using variational and Green's function Monte Carlo methods, where the variational states contain Jastrow and backflow correlations on top of an uncorrelated wave function that includes BCS pairing and magnetic order. At half filling, where the ground state is antiferromagnetically ordered for any value of the on-site interaction U, we can identify a hidden critical point U_{Mott}, above which a finite BCS pairing is stabilized in the wave function. The existence of this point is reminiscent of the Mott transition in the paramagnetic sector and determines a separation between a Slater insulator (at small values of U), where magnetism induces a potential energy gain, and a Mott insulator (at large values of U), where magnetic correlations drive a kinetic energy gain. Most importantly, the existence of U_{Mott} has crucial consequences when doping the system: we observe a tendency to phase separation into a hole-rich and a hole-poor region only when doping the Slater insulator, while the system is uniform by doping the Mott insulator. Superconducting correlations are clearly observed above U_{Mott}, leading to the characteristic dome structure in doping. Furthermore, we show that the energy gain due to the presence of a finite BCS pairing above U_{Mott} shifts from the potential to the kinetic sector by increasing the value of the Coulomb repulsion.

11h40 Fri 5

L.F. Tocchio, F. Becca, and S. Sorella, arXiv:1607.06734.

GAPPED ELECTRON FRACTIONALIZATION IN ROBUSTLY ONE DIMENSIONAL $LI_{0.9}MO_6O_{17}$

Natalia Lera[1], J.V. Alvarez[1], J.W. Allen[2]

1 Departamento de Física de la Materia Condensada and Condensed Matter Physics Center (IFIMAC), Universidad Autónoma de Madrid, Instituto Nicolás Cabrera, Madrid 28049, Spain
2 Randall Laboratory of Physics, University of Michigan, Ann Arbor, Michigan 48109, USA

12h00
Fri
6

The angle resolved photoemission spectroscopy lineshapes of quasi one-dimensional (1d) Li0.9Mo6O17 display holon-spinon fractionalization and quantum critical (QC) scaling generic to 1d, but with major departures from the lineshape and scaling predicted by the one-band TomonagaLuttinger model. We show that the departures can be understood by explicitly accounting for the four modes arising from the two quasi-1d bands known to cross the Fermi energy in Li0.9Mo6O17. The key assumption is that the antisymmetric charge mode is gapped with a magnitude near the T of a mysterious 25K resistivity upturn. As a first approximation, the mode is both spinless and chargeless, consistent with there being no evidence for a charge or spin density wave accompanying the upturn. We sketch a probable role for the gap in controlling the resistivity upturn and point out that it also explains the lack of any evidence for crossover to a Fermi liquid down to the superconducting transition at 1.9K.

1. L Dudy et al., Jour. Of Phys: Cond Matt **5**, 014007 (2013)
2. M.-H. Wangbo and E. Canadell, J. Am. Chem. Soc. **110**, 358 (1988) and Z. S. Popovic et al, Phys, Rev. B **74** 045117 (2006).
3. F. Wang, J. V. Alvarez, et al , Phys. Rev. Lett. **96**, 196403 (2006)
4. F. Wang, J. V. Alvarez, et al, Phys. Rev. Lett. **103**, 136401 (2009)
5. N. Wakehman et al, Nat. Comm. **2**, 396 (2011)
6. J. Hager et al, Phys. Rev. Lett. **95**, 186402 (2005)
7. J. Choi et al., Phys. Rev. B **6**9, 085120 (2004)
8. M. Greenblatt et al, Solid State Commun **51**, 671 (1984)
9. T. Giamarchi, Chem. Rev. **104**, 5037 (2004)
10. N Lera and JV Alvarez Phys. Rev. B **92**, 174523 (2015)

ABSTRACTS OF THE POSTER PRESENTATIONS

Poster session

PARTICLE-ANTIPARTICLE ANALOGUE MECHANISM OF THE VECTOR MATTER-WAVE SOLITON'S ESCAPE FROM THE TRAP

Yuliy V. Bludov[1], Monica A. García-Ñustes[2]

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[2] *Instituto de Física - Pontificia Universidad Católica de Valparaíso, Avenida Brasil, Valparaíso, Casilla 2950, Chile.*

We show that a vector matter-wave soliton in Bose-Einstein condensate loaded into a optical lattice can escape from a trap formed by a parabolic potential, resembling a Hawking emission. The particle-antiparticle pair is emulated by a low-amplitude bright-bright soliton in two-component Bose-Einstein condensate with effective masses of opposite signs. It is shown that the parabolic potential leads to a spatial separation of BEC components. One component with chemical potential in a semi-infinite gap exerts periodical oscillations, while the other BEC component with negative effective mass escapes from the trap. The mechanism of atoms transfer from one BEC component to another by spatially periodic linear coupling term is discussed.

PS 1

TIME EVOLUTION OF LOCALIZED STATES IN GEOMETRICALLY FRUSTRATED LATTICES

R. G. Dias, J. D. Gouveia, I. A. Maceira

Department of Physics, I3N,
University of Aveiro,
Campus de Santiago, Portugal

PS 2

We study the slow time evolution of localized states of the open-boundary Lieb lattice when a magnetic flux is applied perpendicularly to the lattice and increased linearly in time. In this system, Dirac cones periodically disappear, reappear and touch the flat band as the flux increases. We show that the slow time evolution of a localized state in this system is analogous to that of a zero-energy state in a three-level system whose energy levels intersect periodically and that this evolution can be mapped into a classical precession motion with a precession axis that rotates as times evolves. Beginning with a localized state of the Lieb lattice, as the magnetic flux is increased linearly and slowly, the evolving state precesses around a state with a small itinerant component and the amplitude of its localized component oscillates around a constant value (below but close to 1), except at multiples of the flux quantum where it may vary sharply. This behavior reflects the existence of an electric field (generated by the time-dependent magnetic field) which breaks the C_4 symmetry of the constant flux Hamiltonian.

MULTI-HOLE EDGE STATES IN SSH CHAINS WITH INTERACTIONS

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1 Department of Physics & I3N, University of Aveiro, 3810-193 Aveiro, Portugal

We address the effect of nearest-neighbor electronic interactions on the topological properties of the Su-Schrieffer-Heeger (SSH) chain [1], with alternating hopping amplitudes t_1 and t_2. Both numerically and analytically, we show that the presence of interactions induces phase transitions between topologically different regimes [2]. In the particular case of the SSH chain with one hole, the V/t_2 vs. t_1/t_2 phase diagram has topological phases at diagonal regions of the phase plane. The interaction acts in this case as a passivation potential. For general filling of the SSH chain, different eigensubspaces of the SSH Hamiltonian may be classified as topologically trivial and non-trivial. The two-hole case is studied in detail and we show that a mapping can be constructed of the two-hole SSH eigensubspaces into one-particle states of a 1D tight-binding model with an interface between regions with different hopping constants and local potentials. In particular, one observes a state where the two holes occupy two consecutive edge states. This approach can be generalized for arbitrary filling and one expects the appearance of a cascade of edge states.

PS 3

1. W. P. Su, J. R. Schrieffer, and A. J. Heeger, Phys. Rev. Lett. **42**, 1698 (1979).
2. A. M. Marques and R. G. Dias, submitted.

BOLTZMANN-GIBBS STATES IN TOPOLOGICAL QUANTUM WALKS: FIDELITY ANALYSIS OF PHASE TRANSITIONS

B. Mera[1,2,3], C. Vlachou[4,5], N. Paunković[4,5], V. R. Vieira[1,2]

1 CeFEMA, Instituto Superior Técnico, Universidade de Lisboa, Av. Rovisco Pais, 1049-001 Lisboa, Portugal

2 Departamento de Física, Instituto Superior Técnico, Universidade de Lisboa, Av. Rovisco Pais, 1049-001 Lisboa, Portugal

3 Physics of Information and Quantum Technologies Group, Instituto de Telecomunicações, 1049-001 Lisbon, Portugal

4 SQIG-Security and Quantum Information Group, Instituto de Telecomunicações, 1049-001 Lisbon, Portugal

PS 4 *5 Departamento de Matemática, Instituto Superior Técnico, Universidade de Lisboa, Av. Rovisco Pais, 1049-001 Lisboa, Portugal*

We perform the fidelity analysis for Boltzmann-Gibbs-like states in order to investigate whether the topological order of one-dimensional fermionic systems at zero temperature is maintained at finite temperatures. We use quantum walk protocols that are known to simulate topological phases and the respective quantum phase transitions for chiral symmetric Hamiltonians. We show, by means of the fidelity analysis and the behaviour of edge states, that no thermal-like phase transitions occur as temperature increases, i. e., the topological behaviour is washed out gradually.

NEW FINGERPRINTS OF THE ENTANGLEMENT ON THE THERMODYNAMIC PROPERTIES

S. Nemati[1], S. Mahdavifar[2]

1 Department of Physics, University of Zanjan, Zanjan, Iran
2 Department of Physics, University of Guilan, Rasht, Iran

The realization that entanglement can affect macroscopic properties of solid-state systems is a challenge in physics. Theoretical physicists often consider entanglement between the nearest neighbor spins and try to find its characteristics in terms of macroscopic thermodynamic observables. Here, we focus on the entanglement between the 2nd, 3rd, and 4th neighbor spins in an exactly solvable model. We show that there is a much clearer fingerprint of long-distance entanglement on the thermodynamic properties like specific heat, magnetocaloric effect, and magnetic susceptibility. PS 5

PS 6

INDICATORS OF CONFORMAL FIELD THEORY: ENTANGLEMENT ENTROPY AND MULTIPLE POINT CORRELATORS

Pranay Patil, Ying Tang, Emanuel Katz, Anders W. Sandvik

Department of Physics, Boston University, 590 Commonwealth Avenue, Boston, Massachusetts 02215, USA

Entaglement entropy (EE) behavior is used as an indicator for conformal field theory (CFT) in many cases. Here we find that it is not a reliable way to assess the existence of a conformal description as EE may show the same behavior even in the absence of a CFT. We use constraints on correlation functions given by the CFT to show that even though the EE shows the right behavior, the CFT is missing in the case of the Amplitude Product State in 1D at criticality. We also explore the CFT on the critical JQ2 chain in more detail using the behavior of two point and three point correlation functions.

1. P. Calabrese, J. Cardy, J. Phys. A: Math. Theor. 42 (2009) 504005 .
2. I. Affleck, Phys. Rev. Lett. 55, 1355 (1985) .

EDGE CURRENTS IN FRUSTRATED JOSEPHSON JUNCTION LADDERS

F. D. R. Santos, A. M. Marques, and R. G. Dias

Department of Physics, I3N, University of Aveiro, 3810-193 Aveiro, Portugal

We present a numerical study of quasi-1D frustrated Josephson junction ladders with diagonal couplings and open boundary conditions, in the large capacitance limit. We derive a correspondence between the energy of this Josephson junction ladder and the expectation value of the Hamiltonian of an analogous tight-binding model, and show how the overall superconducting state of the chain is equivalent to the minimum energy state of the tight-binding model in the subspace of one-particle states with uniform density. To satisfy the constraint of uniform density, the superconducting state of the ladder is written as a linear combination of the allowed k-states of the tight-binding model with open boundaries. Above a critical value of the parameter t (ratio between the intra-rung and inter-rung Josephson couplings), the ladder spontaneously develop currents at the edges which spread to the bulk as t is increased until complete coverage is reached. Above a certain value of t, which varies with ladder size ($t = 1$ for an infinite-sized ladder), the edge currents are destroyed. The value $t = 1$ corresponds, in the tight-binding model, to the opening of a gap between two bands. We argue that the disappearance of the edge currents with this gap opening is not coincidental, and that this points to a topological origin for these edge current states.

PS 7

STOCHASTIC ANALYTIC CONTINUATION METHOD AND SPECTRAL FUNCTIONS OF 2D HEISENBERG MODEL

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3 Beijing National Laboratory for Condensed Matter Physics and Institute of Physics, Chinese Academy of Sciences, Beijing 100190, China

PS 8

Stochastic analytic continuation is a numerical method proposed to deal with the ill-posed problem of getting the real-frequency spectral function from the imaginary-time correlation function (obtained from QMC). Using a set of delta-functions to parametrize a spectrum, the solution is treated as a statistical-mechanics problem. we present a new development of this method where equal-weight delta-functions are used instead of the equal-distance ones. In addition to that, the featured part of the spectrum can be sampled sepertately. Both the accuracy and efficiency are improved significantly comparing to the previous sampling methods. As an application, and to catch up with the development of neutron scattering experiments, we study the spectral functions of 2D Heisenberg model.

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ADATOM INDUCED MAGNETISM IN GRAPHENE

Frederico Sousa[1], Eduardo V. Castro[1]

1 Departamento de Física and CeFEMA, Instituto Superior Técnico, Universidade de Lisboa, Portugal

The prospect of using graphene as a base for spintronics devices has led to many studies on its magnetic properties. Being a carbon based material, graphene displays a very weak magnetic response, with the absence of a ferromagnetic phase at low temperatures [1]. It is, however, possible to generate a magnetic behaviour by altering graphene. It has been shown that the introduction of adatoms in graphene can generate localized mangetic moments [2]. In these cases, disorder becomes a main protagonist: the adatoms position disorder can change the magnetic tendency from an antiferromagnetic to a ferromagnetic phase [3]. The relative position of the impurities with respect to the sublattices they are placed on also affects the magnetic response. The interaction between adatoms is ferromagnetic when they are in the same sublattice and antiferromagnetic when not [4]. Our work is focused on adatom-induced magnetism in graphene.

Using a simple mean field model, we were able to determine the critical temperature, along with its dependance on impurity concentration, for the cases of one lattice ferromagnetism and antiferromagnetism. For impurity concentrations of 10%, we obtained critical temperatures of 145 K for the former and 527 K for the latter case, using a coupling constant of JS = 3 eV. We found that a small amount of anisotropy can significantly alter the result, both quantitatively and qualitatively, introducing non linearity and a critical concentration in one lattice ferromagnetism. These features are absent in the isotropic case. PS 9

We used a recursive method to obtain the Green Function we computed the DOS for both magnetic phases. In one lattice ferromagnetism, at zero temperature, there is a spin resolved gap that develops just on eihter side of the zero energy level, sharing $E = 0$ as a gap edge. There is thus always a region where charge carriers are completely spin polarized. Due to the localization of tail states this should still be true even when the temperature is increased.

On the other hand, in the antiferromagnetic phase, the system does show a gap. We were able to see how temperature smoothes the DOS and closes the gap of the system and how it evolves with the adatom concentration.

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CHARGE TRANSPORT AT IDEAL CONDUCTOR-INSULATOR INTERFACE

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Topological phases (TPs) of condensed matter have been focus of much interest during the last years. The quantum Hall effect (QHE) [1,2] is the most prominent example of topological states of matter, which occurs when the time-reversal symmetry (TRS) is broken, as happens, for example, when a magnetic field perpendicular to the plane of the system is applied the longitudinal and transverse resistance exhibits plateaus and sharp peaks, respectively, indicating integer or fractional quantization. One of the trademark characteristics of quantum Hall systems is edge currents. Significant strides have been made for studying edge transport in the integer and fractional QHE. Transport properties such as Drude weight is a useful measure for distinguishing materials as insulators, metals, or superconductors. At finite temperatures, the
PS Drude weight corresponds to the strength of the $\delta-$function peak in the real part of the Kubo conductivity (at $\omega = 0$) which is a direct probe for the metal-insulator transition (MIT). Recently it was shown that the
10 Drude weight can also be cast in terms of a topological invariant [3]. Here, we address the question what happens in the interface of the ideal conductor and insulator (can one expect unusual transport properties at such interfaces)? In order to do so, we consider a sample of a 2D lattice which consists of two separate system: a normal tight-binding case and band insulator. The former is a simple ideal conductor with a Drude weight proportional to the kinetic energy. At half-filling, the latter system is a gapped insulator with a Drude weight of zero. We demonstrate the transport properties of this system at half-filling with particular attention to the interface.

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DYNAMICS OF ENTANGLEMENT IN THE EXTENDED CLUSTER SPIN-1/2 XX CHAIN

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We study the dynamics of entanglement in the extended cluster spin-1/2 XX chain, equivalent to a 1D spin-1/2 XX model with three-spin interaction (TSI)[1]. Selecting the nearest neighbor pair spins as an open quantum system, the rest of the chain plays the role of environment. The two-spin Heisenberg and the TSI interaction are responsible for coupling between system and environment. We show the existence of a critical value in the TSI, where the dynamics of concurrence changes from Markovian to the non-Markovian [2]. In the region with non-Markovian dynamics, entanglement sudden death in the system is observed [3]. By focusing on the nearest neighbor pair spins of the environment, we have shown that the dynamics of entanglement in the environment is sensitive to the Markovian and non-Markovian regions.

PS 11

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2. H.-P Breuer and F. Petruccione, The Theory of Open Quantum Systems (Oxford University Press, Oxford, 2007); Heinz-Peter Breuer, Elsi-Mari Laine, Jyrki Piilo, and Bassano Vacchini, Rev. Mod. Phys. **88**, 021002 (2016).
3. T. Yu, J. H. Eberly, Phys. Rev. Lett. **97**, 140403 (2006).

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Évora and how to reach it

Évora is located in the south of Portugal, about 130 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://www2.cm-evora.pt/guiaturistico/Ingles/itinerary.htm

Bus Timetables

Find below the timetables for the connections Lisbon-Évora and Évora-Lisbon both by train or bus.

By bus:

From the Lisbon International Airport you should take the metro red line, which is the only line available, to the end of the line (São Sebastião station). There you should change to the blue line, Amadora Este direction, and leave at Sete Rios Station (two metro stations). At the bus station in Sete Rios you can take a direct bus to Évora. The journey will last approximately 1h40. This is the address of the Bus Station:

RNE - Rede Nacional de Expressos, Lda
Terminal Rodoviario 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

Viagem de Ida:
LISBOA → EVORA (131 Kms)

Partida	Chegada	Preço	Enlaces	Período	Frequência
07:00	08:45	22.60			Excepto Sábados, Domingos e 2ªs Feiras se Feriado.
08:00	09:30	22.60			Diariamente
08:00	09:45	22.60			Aos Sábados, Domingos e 2ªs Feiras se Feriado.
08:30	10:15	22.60			Diariamente
09:30	11:00	22.60			Diariamente
10:30	12:15	22.60			Diariamente
11:45	13:35	22.60			Diariamente
12:00	13:30	22.60			Diariamente
13:00	14:45	22.60			Excepto Sábados e Domingos.
13:45	15:15	22.60			Diariamente
14:15	16:50	22.60			Diariamente
15:00	16:30	22.60			Às 6ªs Feiras (se 6ª Feira Feriado faz-se na Véspera, não no Feriado)
15:00	16:40	22.60			Excepto Domingos (ou 2ªs Feiras se Feriado).
15:00	16:45	22.60			Aos Domingos (ou 2ªs Feiras se Feriado)
16:00	17:45	22.60			Excepto Sábados.
17:00	18:30	22.60			Diariamente
17:15	19:00	22.60			Diariamente
17:45	19:15	22.60			Diariamente
18:00	19:30	22.60			Excepto Sábados e Domingos.
19:00	20:30	22.60			Aos Domingos (ou 2ªs Feiras se Feriado)
19:00	20:40	22.60			Excepto Sábados.
19:30	21:00	22.60			Diariamente
20:00	21:30	22.60			Aos Domingos (ou 2ªs Feiras se Feriado)
20:30	22:15	22.60			Diariamente
21:30	23:15	22.60			Às 6ªs Feiras (se 6ª Feira Feriado faz-se na Véspera, não no Feriado)
22:00	23:45	22.60			Diariamente
22:30	00:00	22.60			Aos Domingos (ou 2ªs Feiras se Feriado)

Bus Timetables

EVORA → LISBOA (131 Kms)

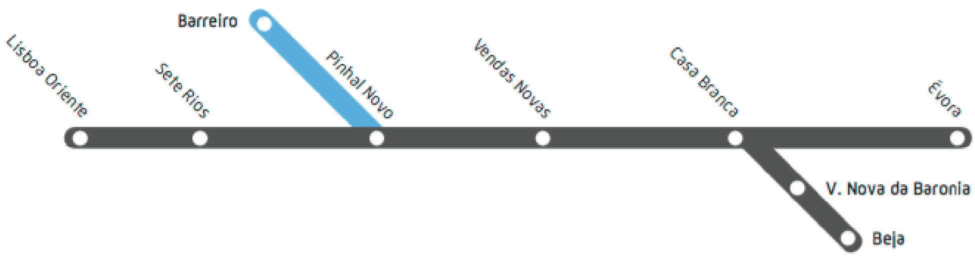
Partida	Chegada	Preço	Enlaces	Periodo	Frequência
06:00	07:45	22.60			Diariamente
07:00	08:30	22.60			Diariamente
07:30	09:00	22.60			Excepto Sábados e Domingos.
08:00	09:45	22.60			Excepto Domingos (ou 2ªs Feiras se Feriado).
08:30	10:00	22.60			Diariamente
08:30	11:05	22.60			Diariamente
09:45	11:30	22.60			Diariamente
10:15	11:45	22.60			Diariamente
12:30	14:15	22.60			Excepto Sábados, Domingos e 2ªs Feiras se Feriado.
13:00	14:30	22.60			Diariamente
14:00	15:30	22.60			Diariamente
14:45	16:15	22.60			Diariamente
15:00	16:45	22.60			Excepto Sábados e Domingos.
16:00	17:30	22.60			Às 6ªs Feiras (se 6ª Feira Feriado faz-se na Véspera, não no Feriado)
16:00	17:45	22.60			Aos Sábados
16:00	17:45	22.60			Excepto Sábados.
17:30	19:00	22.60			Às 6ªs Feiras (se 6ª Feira Feriado faz-se na Véspera, não no Feriado)
17:30	19:05	22.60			Aos Domingos (ou 2ªs Feiras se Feriado)
17:30	19:15	22.60			Diariamente
18:15	19:45	22.60			Diariamente
19:00	20:45	22.60			Diariamente
19:30	21:15	22.60			Diariamente
20:00	21:45	22.60			Diariamente
20:00	21:45	22.60			Aos Domingos e 2ªS Feiras se Feriado
21:00	22:45	22.60			Excepto Sábados.
21:30	23:00	22.60			Aos Domingos (ou 2ªs Feiras se Feriado)

By train:

From the Lisbon International Airport you should take the metro red line, which is the only line available, to the Oriente metro station (three metro stations). At the Oriente Railway Station you can take an intercity train to Évora. The journey will last approximately 1h.30.

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

Train Timetables

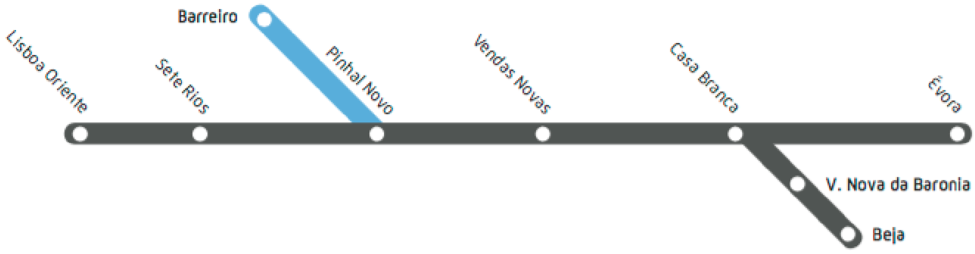


Segunda-feira a sexta-feira (exceto feriados oficiais)

Monday to Friday (Except Public Holidays)

Categoria Category	R Regional	Urbano	IC Intercidades	IC Intercidades	Urbano	IC Intercidades	IC Intercidades	R Regional	Urbano	IC Intercidades	IC Intercidades	Urbano	IC Intercidades	IC Intercidades
Número Number	4801	17205	590	581	17213	592	583	4803	17245	596	587	17253	598	589
Observações Remarks			R	R		R	R			R	R		R	R
Lisboa Oriente P			7:02			9:02				17:02			19:02	
Entrecampos			7:10			9:10				17:10			19:10	
Sete Rios			7:14			9:14				17:14			19:14	
Pragal			7:26			9:26				17:26			19:26	
Barreiro		6:55			8:55				16:55			18:55		
Pinhal Novo		7:13			9:13				17:13			19:13		
Pinhal Novo			7:48			9:48				17:48			19:48	
Poceirão			7:57											
Fernando Pó			8:01											
Pegões			8:06											
São João das Craveiras			8:10											
Vendas Novas			8:18			10:10				18:10			20:10	
Casa Branca C			8:31			10:23				18:23			20:23	
Casa Branca P			8:32			10:24				18:24			20:24	
Évora C			8:42			10:35				18:35			20:35	
Casa Branca P				8:35			10:30				18:29			20:25
Alcáçovas				8:44			10:39				18:38			20:34
Vila Nova da Baronia	7:08			8:55			10:50	13:29			18:49			20:44
Alvito	7:15			9:01			10:56	13:36			18:55			20:51
Cuba	7:25			9:12			11:07	13:46			19:06			21:01
Beja C	7:40			9:26			11:21	14:01			19:20			21:15

Train Timetables

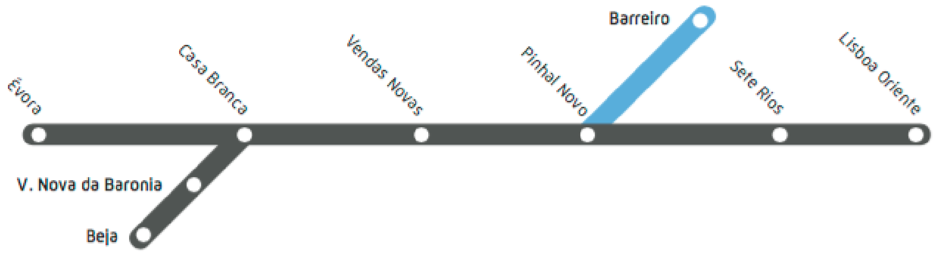


Sábados, domingos e feriados oficiais

Saturdays, Sundays and Public Holidays

Categoria Category	Urbano	Intercidades	Intercidades	Urbano	Intercidades	Intercidades	Urbano	Intercidades	Intercidades
Número Number	17215	594	585	17243	596	587	17251	598	589
Observações Remarks		R	R		R	R		R	R
Lisboa Oriente P		9:52			17:02			19:02	
Entrecampos		10:00			17:10			19:10	
Sete Rios		10:04			17:14			19:14	
Pragal		10:15			17:26			19:26	
Barreiro	9:25	|		16:25	|		18:25	|	
Pinhal Novo	9:43	|		16:43	|		18:43	|	
Pinhal Novo		10:32			17:48			19:48	
Poceirão		10:41			|			|	
Fernando Pó		10:45			|			|	
Pegões		10:50			|			|	
São João das Craveiras		10:54			|			|	
Vendas Novas		11:02			18:10			20:10	
Casa Branca C		11:15			18:23			20:23	
Casa Branca P		11:16			18:24			20:24	
Évora C		11:26			18:35			20:35	
Casa Branca P			11:19			18:29			20:25
Alcáçovas			11:28			18:38			20:34
Vila Nova da Baronia			11:39			18:49			20:44
Alvito			11:45			18:55			20:51
Cuba			11:56			19:06			21:01
Beja C			12:10			19:20			21:15

Train Timetables

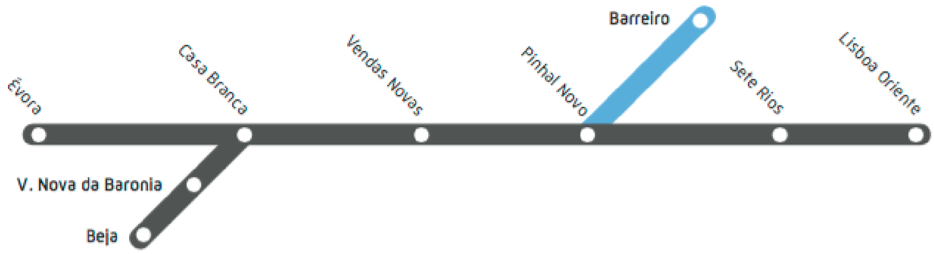


Segunda-feira a sexta-feira (exceto feriados oficiais)

Monday to Friday (Except Public Holidays)

Categoria *Category*		Intercidades	Intercidades	Urbano	Intercidades	Intercidades	Urbano	Regional	Intercidades	Intercidades	Urbano	Intercidades	Intercidades	Urbano	Regional
Número *Number*		580	690	17210	582	692	17218	4800	584	694	17238	586	696	17246	4802
Observações *Remarks*		R	R		R	R			R	R		R	R		
Beja	P	6:23			8:22			12:55	16:11			18:15			19:25
Cuba		6:35			8:34			13:07	16:23			18:27			19:37
Alvito		6:44			8:43			13:16	16:32			18:36			19:46
Vila Nova da Baronia		6:52			8:54			13:24	16:41			18:48			19:54
Alcáçovas		7:02			9:05				16:51			18:59			
Casa Branca	C	7:11			9:14				17:00			19:08			
Évora	P		7:06			9:06				16:57			19:06		
Casa Branca	C		7:16			9:16				17:07			19:16		
Casa Branca	P		7:17			9:17				17:08			19:17		
Vendas Novas			7:31			9:31				17:22			19:31		
São João das Craveiras			|			|				17:29			|		
Pegões			|			|				17:33			|		
Fernando Pó			|			|				17:38			|		
Poceirão			|			|				17:43			|		
Pinhal Novo			7:53			9:53				17:51			19:53		
Pinhal Novo			|	8:00		|	10:00			|	18:00		|	20:00	
Barreiro			|	8:18		|	10:18			|	18:18		|	20:18	
Pragal			8:14			10:14				18:14			20:14		
Sete Rios	C		8:24			10:24				18:24			20:24		
Entrecampos	C		8:28			10:28				18:28			20:28		
Lisboa Oriente	C		8:36			10:36				18:36			20:36		

Train Timetables



Sábados, domingos e feriados oficiais

Saturdays, Sundays and Public Holidays

Categoria Category		Intercidades	Intercidades	Urbano	Intercidades	Intercidades	Urbano	Intercidades	Intercidades	Urbano
Número Number		582	692	17222	584	694	17238	586	696	17246
Observações Remarks		R	R		R	R		R	R	
Beja	P	8:22			16:11			18:15		
Cuba		8:34			16:23			18:27		
Alvito		8:43			16:32			18:36		
Vila Nova da Baronia		8:54			16:41			18:48		
Alcáçovas		9:05			16:51			18:59		
Casa Branca	C	9:14			17:00			19:08		
Évora	P		9:06			16:57			19:06	
Casa Branca	C		9:16			17:07			19:16	
Casa Branca	C		9:17			17:08			19:17	
Vendas Novas			9:31			17:22			19:31	
São João das Craveiras						17:29				
Pegões						17:33				
Fernando Pó						17:38				
Poceirão						17:43				
Pinhal Novo			9:53			17:51			19:53	
Pinhal Novo				11:00			18:00			20:00
Barreiro				11:18			18:18			20:18
Pragal			10:14			18:14			20:14	
Sete Rios	C		10:24			18:24			20:24	
Entrecampos	C		10:28			18:28			20:28	
Lisboa Oriente	C		10:36			18:36			20:36	

HOW TO CONNECT TO WIRELESS NETWORK:

1st STEP:

1- Enable **Wireless connection**

2- Manually add **Wireless Network or Network Profile**

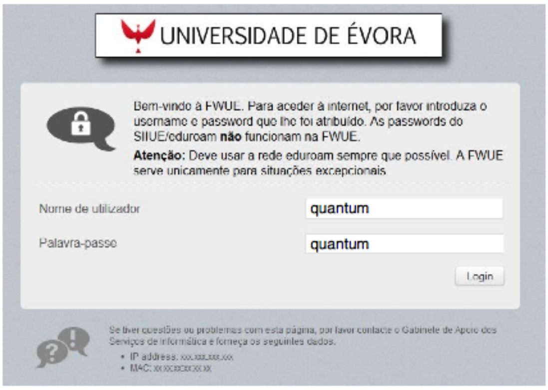
3- Configurations:

network's name: **FWUE**
security: **None** or **No Authentication (Open)**
select: **Start this connection automatically**
select: **Connect even if the network is not broadcasting**

2nd STEP:

Turn on your web browser.

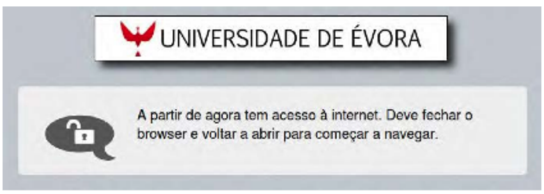
The first time you enter FWUE the Internet access is disabled. When trying to access any page will be redirected to the following page:



The access credentials are::

USERNAME: quantum
PASSWORD: quantum

After entering the credentials a second screen appears. It is not strictly necessary to restart the browser, it is only a recommendation to ensure compability.



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