PROGRAM AND ABSTRACT BOOKLET

WORKSHOP ON CORRELATIONS, CRITICALITY, AND COHERENCE IN QUANTUM SYSTEMS

University of Évora, Portugal, 6-10 October 2014

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, computational condensed matter physics, AdS/CFT correspondence, and quantum information theory.

The main focus areas of the workshop will be quantum criticality and exotic ground states, topological matter and Dirac materials, AdS/CFT correspondence, and quantum information. 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 Evora 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)

José M. P. Carmelo (Minho, Portugal)

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Nikola Paunkovic (IT-IST, Lisbon, Portugal)

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Spanish Ministry of Economy and Development (MECD Grant No. FIS2011-23713)

Marie Curie Initial Training Network SPINOGRAPH

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Centro de Física da Universidade do Porto

Fundação Eugénio de Almeida

Câmara Municipal de Évora

This workshop is dedicated to the memory of Shi-Jian Gu, speaker of previous workshops held in Évora.

In Memoriam - Shi-Jian Gu (Speaker in the Workshop on Correlations and Coherence in Quantum Matter Évora, Portugal, 10-14 November 2008)

My long time best friend, Shi-Jian Gu, an outstanding young condensed matter theorist, passed away on September 28, 2014 at the untimely age of 40, following a five year battle with cancer. My great sorrow is beyond words. My memories of Shi-Jian go back to the year 2000, when we embarked upon our first collaboration, a study of the Kondo system, and coauthored a paper on that subject. At that time, Shi-Jian was a Ph.D. student. He went on to win China's National top 100 best Ph.D. thesis award. He also was a member of the team which won a 2nd class in the highly prestigious Chinese National Natural Science Award.

Shi-Jian visited the Chinese University of Hong Kong (CUHK) in 2003 and joined CUHK in 2004, remaining there until his death. Over the years, including in the period 2009-2014, when he was suffering from cancer, he educated several students and postdoctoral fellows, taught undergraduate as well as graduate courses, and contributed to the physics department in many ways.

Shi-Jian's research areas were condensed matter theory and quantum information. I will not go into details on Shi-Jian's contributions, other than to point out that three of his works he did while in Hong Kong, one on a spin model, one on a fermion model, and another where the fidelity susceptibility was invented, each attracted great attention. The famed Web of Science placed the latter work among the top 1% important papers in 2007 in that extremely vital field. It is not an exaggeration to say that Dr. Gu pioneered the use of fidelity susceptibility in identifying quantum phase transitions. His contributions were widely acknowledged. His review article on fidelity susceptibility attracted considerable interest and provoked many subsequent investigations. Last year, Shi-Jian was nominated to 2014 Annual Tan Kah Kee Young Scientist Award.

Aside from being an outstanding young scientist, Shi-Jian's easy-going personality was manifested when working with his students, postdoctoral fellows, and senior scientists. He was highly motivated, very hard-working, and intensely interested in science, while at the same time exhibiting courage and toughness in dealing with his tragic illness. Four days before his premature death, one of his recent works was accepted for publication in Europhysics Letters. The loss of Shi-Jian to his family, friends, and students is incalculable. We can only wish that he has gone in peace. He will be forever remembered by those of us fortunate to have known him.

Shi-Jian, one of my life's greatest treasures has been having you as a collaborator and friend. If there will be a second life, I wish to be your friend and to work with you once again.

Hai-Qing Lin

PROGRAM

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

Sunday, 5 October

15:00 - 15:15 Opening of the I2CAM Sponsored Tutorial Day

15:15 - 16:30 Lecturer: **Anders Sandvik**
Quantum criticality and their computational studies

16:30 – 16:45 Discussions

16:45 - 17:15 Break

17:15 - 18:30 Lecturer: **Miguel Costa**
An introduction to the AdS/CFT duality

18:30 – 18:45 Discussions

<u>**Monday, 6 October**</u>

9:00 Welcome

09:10 – 9:40 Invited: **Henrik Johannesson**
Synthetic helical liquid in a quantum wire

9:40 – 10:10 Invited: **Karl Landsteiner**
Anomalous Transport in Anti de-Sitter Space

10:10 – 10:30 Contributed: **Alexander A. Zyuzin**
Chiral electromagnetic waves in Weyl semimetals

10:30 – 11:00 Coffee break

11:00 – 12:00 Invited colloquium: **Miguel Costa**
Thermodynamics of the BMN matrix model at strong coupling

12:00 – 12:20 Contributed: **Emilia da Silva**
Holographic relaxation of finite size isolated quantum systems

12:20 – 12:40 Contributed: **Erik S. Sørensen**
Dynamics at a quantum critical point: combining quantum Monte Carlo and holography

12:40 Lunch break

15:00 – 15:30 Invited: **Stephan Rachel**
From correlated topological insulators to iridates and spin liquids

15:30 – 16:00 Invited: **Maria Daghofer**
Topologically nontrivial phases in correlated multi-orbital systems

16:00 – 16:20 Contributed: **S. Kourtis**
Strongly correlated topological states of spinless fermions in two-dimensional lattices

16:20 – 16:50 Coffee break

16:50 – 17:20 Invited: **Gerardo Adesso**
Quantum correlations as local coherence: applications to metrology

17:20 – 17:40 Contributed: **F. Illuminati**
Understanding quantum phases of matter: entanglement, frustration, and local convertibility

17:40 – 18:00 Contributed: **Daniel Arovas**
Topological obstructions to band insulator behavior in non-symmorphic crystals

18:00 – 18:15 In memoriam by **Hong-Gang Luo**
Shi-Jian Gu

Tuesday, 7 October

09:00 – 9:30 Invited: **Pedro Schlottmann**
Crossover from non-Fermi liquid to Fermi liquid behavior and the superconductivity dome in heavy electron systems

09:30 – 10:00 Invited: **Assa Auerbach**
Transport theory of strongly interacting bosons and short coherence length superconductors

10:00 – 10:20 Contributed: **L. Ortenzi**
Structural origin of the anomalous temperature dependence of the local magnetic moments in the $CaFe_2As_2$ *family of materials*

10:20 – 10:50 Coffee break

10:50 – 11:20 Invited: **Ribhu Kaul**
Spin-liquid behavior of a simple spin model on the triangular lattice

11:20 – 11:50 Invited: **Stephen Powell**
Scaling dimensions of higher-charge monopoles at deconfined critical points

11:50 – 12:10 Contributed: **B. Valenzuela**
Microscopic nematicity in iron superconductors

12:10 – 12:30 Contributed: **Shenglong Xu**
Sign problem free Monte Carlo simulation of itinerant ferromagnetism

12:30 Lunch break

15:00 – 15:30 Invited: **Susanne Viefers**
Rotational properties of two-component Bose gases in the lowest Landau level

15:30 – 16:00 Invited: **Hong-Gang Luo**
Kondo and Fano resonance in correlated impurity systems

16:00 – 16:20 Contributed: **D. Hoffmann**
Measurement of T^* *in the BEC-BCS crossover regime*

16:20 – 16:50 Coffee break

16:50 – 17:20 Poster presentations (2 minutes each)

17:20 Poster session I

Wednesday, 8 October

09:00 – 9:30 Invited: **Leonid Levitov**
Chern bands and topological currents in graphene superlattices

09:30 – 10:00 Invited: **Andrea Young**
Tuning and probing symmetry breaking in graphene quantum Hall ferromagnets

10:00 – 10:20 Contributed: **J. L. Lado**
Non-collinear magnetic phases and edge states in graphene quantum Hall bars

10:20 – 10:50 Coffee break

10:50 – 11:50 Invited colloquium: **Francisco (Paco) Guinea**
Graphene as an anharmonic membrane

11:50 – 12:20 Invited: **Ivan Brihuega**
Point defects as a source of local magnetic moments on graphene layers

12:20 – 12:40 Contributed: **B. Amorim**
Thermodynamics of Quantum Crystalline Membranes

12:40 – 13:00 Contributed: **A. Cortijo**
Large conduction band and Fermi velocity spin splittings due to Coulomb interactions in single-layer MoS_2

13:00 Lunch break

14:50 Social program
Includes guided visits to specific Évora's historical sites and to interesting exhibitions in the Forum Eugénio de Almeida (http://www.fundacaoeugeniodealmeida.pt).

20:00 Banquet

Thursday, 9 October

09:00 – 9:30 Invited: **Netanel Lindner**
Engineering new non-Abelian systems: fractionalized Majorana fermions and beyond

09:30 - 09:50 Contributed: **R. Queiroz**
Helical Majorana state in strongly disordered superconductors

09:50 – 10:20 Invited: **Erez Berg**
Coherent transmutation of electrons into fractionalized anyons

10:20 – 10:50 Coffee break

10:50 – 11:20 Invited: **Marcos Rigol**
Quantum quenches in the thermodynamic limit

11:20 – 11:50 Invited: **Fabien Alet**
Participation spectroscopy and entanglement Hamiltonian of quantum spin model

11:50 – 12:10 Contributed: **G. van Miert**
Spin-orbit coupling in graphynes

12:10 – 12:30 Contributed: **John R. Tolsma**
Orbital order and effective mass enhancement in t_2g two-dimensional electron gases

12:30 Lunch break

15:00 – 15:30 Invited: **Ricardo Mendes Ribeiro**
Full relativistic calculations on 2D materials

15:30 – 16:00 Invited: **Didier Poilblanc**
Studying correlated systems with PEPS

16:00 – 16:20 Contributed: **Giandomenico Palumbo**
Induced topological order at the boundary of 3D topological superconductors

16:20 – 16:50 Coffee break

16:50 – 17:20 Poster presentations (2 minutes each)

17:20 Poster session II

Friday, 10 October

09:00 – 10:00 Invited colloquium: **Dionys Baeriswyl**
Thermodynamic limit and order parameter of the reduced BCS Hamiltonian

10:00 – 10:20 Contributed: **S. V. Mironov**
In-plane FFLO states in superconductor-ferromagnet structures

10:20 – 10:40 Contributed: **E. C. Marino**
Quantum valley Hall effect and other emergent phenomena induced by the electromagnetic interaction in graphene

10:40 – 11:10 Coffee break

11:10 – 11:40 Invited: **Zhong-Bing Huang**
Theoretical and experimental study of aromatic hydrocarbon superconductors

11:40 – 12:00 Contributed: **R. Roldán**
Effects of strain in MoS_2*: bandgap engineering and valley polarized current*

12:00 – 12:20 Contributed: **Luca Chirolli**
Zero-bias conductance peak in detached flakes of superconducting 2H-TaS probed by scanning tunneling spectroscopy

12:20 Summary and closing remarks

Complementary program

The workshop participants are invited to attend the following University of Évora seminar also held in Anfiteatro 131-A

14:30 – 15:00 Seminar: **B. Hetényi**
A comprehensive theory of transport: distinguishing insulators, conductors, superconductors, and bosonic superfluids

POSTERS

Poster Session I (7/10/2014)

	Name	Title
1	A. C. S. Costa	Monogamy and backflow of mutual information in non-Markovian thermal baths
2	N. M. Gergs	Topological ordered states and disorder
3	J. D. Gouveia	Spiral ferrimagnetic phases in the 2D Hubbard model
4	Rafael Hipolito	Error mitigation schemes for the control of noisy quantum systems via Martin-Siggia-Rose and Schwinger-Keldysh field theory techniques
5	Adam Iaizzi	Magnetization jumps in 1D valence bond solids
6	Alexander Moreno	Charge and spin fractionalization beyond the Luttinger liquid paradigm
7	Leandro O. Nascimento	Unitarity of theories containing fractional powers of the d'Alembertian operator
8	Hui Shao	Topological properties of the deep valence-bond-solid states of the JQ_3 model
9	Abhay C. Shastry	Local temperature and voltage measurement of a quantum system far from equilibrium
10	Vítor Rocha Vieira	Non-Markovian effects in electronic and spin transport

Poster Session II (9/10/2014)

	Name	Title
1	D. S. Antonenko	Decay of a supercurrent in diffusive SNS-junctions
2	Yu.V. Bludov	Nonlinear surface polaritons, supported by graphene structures
3	T. Čadež	Geometric phases and qubit manipulation in a driven quantum dot
4	R. de Gail	Topological aspects of the twisted graphene bilayer
5	N. A. Garcia	Quantum Spin Hall phase in multilayer graphene lattice
6	B. Hetényi	A comprehensive theory of transport: distinguishing insulators, conductors, superconductors, and bosonic superfluids
7	V. Kornich	Nuclear spin relaxation in Rashba nanowires
8	A. M. Marques	Frustrated Josephson junction arrays with multiband superconducting elements
9	B. Mera	Semi-Classical Phase Space dynamics for the Quantum Toffoli Gate
10	Hector Ochoa	Novel platforms for topological phases in 2D materials

EPL Presentation Award 2014

The workshop sponsor Europhysics Letters has promoted a competition for best posters displayed in each of the two poster sessions. A small panel of judges from the organizing committee and invited speakers will go around the poster display of both poster sessions at a set time. Certificates will be given to the winners.

Social Program

Wednesday, 8 October
Departure from the University at 14:50

The Eugénio de Almeida Foundation

The workshop social program is sponsored by the Eugénio de Almeida Foundation (http://www.fundacaoeugeniodealmeida.pt), based in Évora, which is a private law institution in the public interest. It was created in 1963 and has recently celebrated its 50th anniversary. The mission of the Eugénio de Almeida Foundation seeks the integrated development of the Évora region, by creating cultural, educational and social opportunities for all people. Its main core activities are focused on the promotion of: contemporary art and culture; knowledge; reflection and debate; conservation and upgrading of heritage; active citizenship; training of social organisations and players; action-research projects, particularly on Volunteering. The social program includes guided visits to interesting exhibitions in the Forum Eugénio de Almeida as well as to the Palace of Counts of Basto, which in the XVI Century was the residence of the young King D. Sebastião.

Exhibitions in the Forum Eugénio de Almeida

MARTA PALAU
Tránsitos de Naualli
Temporary exhibition room (1st floor)

In the year in which we celebrate the 150th anniversary of the Portuguese-Mexican diplomatic relations, the Fórum Eugénio de Almeida presents the exhibition Tránsitos de Naualli by Mexica artist Marta Palau. Confronted with a worldview driven by the logic of power, the artist proposes artistic creation as an option that maintains a commitment to reality, while seeking to restore our relationship with the land, memory, and thought; recognizing forms of resistance in the essence of rituals and myths. In the figure of the Naualli—a witch, seer, or healer— Palau finds a symbolic representation of a creative power that, through art, calls for a resistance based on an active imagination, reconciling the archaic with the present, leading to the discovery of new ways of how to interpret our individual and collective traits. Tránsitos de Naualli proposes a journey through some of the paths taken by this Naualli: her celebration of the feminine, her attention to the myths of origin and the myths of migration, her devotion to the magical and prophetic. Conjuring signs from the past, Palau never neglects the present: in her artwork the contemporary is always of a profound and vital importance.

CARLOS FADON VICENTE
Scenes: on duets and diaries
Temporary exhibition room (2nd floor)

Scenes: on duets and diaries by Carlos Fadon Vicente—one of the most prominent photographers in the Brazilian artistic and photographic scene, and one of the pioneers of Brazilian telematic art—is his first major exhibition in Europe. Vicente's body of work reveals a personal microcosm and a unique ability to develop a distinctive language endowed with great aesthetic sensibility, and exceptional technical quality. Interlacing different works from different periods of his career, the exhibition's main theme is focused on urban landscape. Emphasizing the question of the reality of the photographic image per se, the status of visual representation constitutes the exhibition's conceptual core. In most cases, its composing elements mirror the appropriation and transposition of collage and montage models. Diverse aesthetical formulations offer the viewer the possibility for multiple readings.

KERSTIN ERGENZINGER
Studies for Longing/Seeing
Rostrum room (floor 0)

Studien zur Sehnsucht [Studies for Longing/Seeing] is a space-related, reactive installation. The sculptures are connected to a geophone and to a seismograph, and move in response both to the microseismic pulse of the exhibition-space, and the fine shifting and tilting of the floor caused by the visitors' weight and movements. The German artist explores the concept of Sehnsucht in relation to the nostalgic idealization of nature and landscape, here symbolized by mountains. The kinetic sculptures can be seen as pseudo-scientific simulations of a landscape that, as a whole, work as a 'longing-machine'. Real-time seismic data recorded at the sculptures' location—representing the 'reality' of the space—fuses with associative simulation (fiction) to create continually changing appearance of the installations.

Palace of Counts of Basto

Located at the highest point of the city, the Palace of Counts of Basto is situated behind the Cathedral, next to Sertório Tower, within a patio named St. Michael Patio (Páteo de São Miguel). Next to the patio is the St. Michael Hermitage. At the time of the Christian conquest in 1165, the palace must have already been part of the Moorish Alcazar, its northern side part of the defensive structure of the old wall of the city.

The most important architectural changes made since the original construction of the palace, date from the first third of the 16th century. In effect, the only vestiges of the earliest style used (Gothic) were found on the ground floor of the Palace. The upper floor has beautiful windows, with horseshoe archways divided in the middle by elegant columns, examples of Luso-Moorish art.

The most representative architectural feature, which is still evident in the most recent constructions in the exterior projections of the Palace – perhaps the pretext of the residence of the young King D. Sebastião – is found in the two covered galleries which were built, one facing the patio an the other the garden. Elegant Tuscan-style colonnades support a structure decorated with classic motifs in a regular rhythm of metops and triglyphs.

Nowadays the architectural structure of the various buildings, which comprise the ancient palace grounds, is witness to the longevity and importance that the St. Michael Patio has enjoyed throughout the history of Évora. Inside the Palace, the beautiful frescoes which adorn the ceilings and walls of some of the rooms deserve mention:

The Hall of Love presents an elliptical plan and 12 panels with frescoes, made by the painter Francisco de Campos and dated 1578. Here we find representations of classical and profane themes, such as nymphs and deities, all characters of love tales - The Metamorphoses, by Ovid.

The frescoes of the Hall of Virtue refer to an exaltation of the main virtues of the noble of the sixteenth century, symbolically represented in the figures of birds such as the stork, the eagle or the peacock. It is thought that the paintings in this room have been executed between 1580-83 by Tomás Luis, an English artist of the mannerist school of Francisco de Campos.

The Hall of Fame is composed by 28 panels with frescoes, also conducted by the painter Tomás Luis. It is thought that the panels of this room were designed to represent the glories of the Battle of Alcazarquivir. Given the tragic outcome of this battle, the frescoes were painted to evoke other glorious deeds of D. Diogo de Castro, the 3rd Major-Captain of Évora, namely in the Battle of La Goleta, in Tunis, in 1535. It is thanks to the restoration efforts of the Count of Vill'Alva, the Founder of the Eugénio de Almeida Foundation, in the late 1950's, that this monumental complex reveals today its architectural and archaeological treasures. The St. Michael Patio also houses the head office of the Foundation, as well as the Archives and Library of the Eugénio de Almeida House and a Carriage Collection.

ABSTRACTS OF THE INVITED AND CONTRIBUTED TALKS

Sunday, 5 October

QUANTUM CRITICALITY AND THEIR COMPUTATIONAL STUDIES

Anders W. Sandvik

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

15h15 Sun 1

Changing some parameter in a quantum many-body system regulates the strength of quantum fluctuations and can lead to a transition between two types of ground states. Such quantum phase transitions strictly occur at zero temperature T, but the existence of a $T = 0$ quantum-critical point also influences the behavior in a wide $T > 0$ regime, where various scaling behaviors can be observed. In this tutorial lecture I will discuss quantum phase transitions and their manifestations in the setting of $S = 1/2$ quantum spin models in one, two, and three dimensions. Numerical simulations are playing an increasingly important role in research on many-body ground states and quantum phase transitions, and I will give an introduction and illustrative results based on exact diagonalization in one dimension and quantum Monte Carlo simulations in two and three dimensions.

Recommended related reading:

A. W. Sandvik, *Computational Studies of Quantum Spin Systems*, AIP Conf. Proc. **1297**, 135 (2010) [arXiv:1101.3281].

R. K. Kaul, R. G. Melko, A. W. Sandvik, *Bridging lattice-scale physics and continuum field theory with quantum Monte Carlo simulations*, Annu. Rev. Con. Mat. Phys. 4, 179 (2013) [arXiv:1204.5405].

AN INTRODUCTION TO THE ADS/CFT DUALITY

Miguel Costa

Department of Physics, University of Porto, Portugal

17h15 Sun 2

The gauge/gravity duality is a remarkable equivalence between gravitational theories in (d+1)-dimensions and gauge theories in d-dimensions, establishing a holographic map between a theories with gravity and others without. Since its discovery, this duality has changed our views both of the strong and the gravitational interactions. More recently, the duality has also been used to explore the physics of strongly correlated systems that share common properties with condensed matter systems. In this lecture I will introduce the gauge/gravity duality, trying to explain in simple terms how this equivalence can be formulated without assuming much knowledge of String Theory.

Monday, 6 October

SYNTHETIC HELICAL LIQUID IN A QUANTUM WIRE

H. Johannesson

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

9h10 Mon 1

Topological insulators are new phases of quantum matter characterized by an insulating gap in the bulk and gapless edge or surface states. In the case of an ideal 2D topological insulator, the edge states form a 1D helical liquid, with electrons of opposite spins propagating in opposite directions, Given the right conditions, these spin-filtered states may serve as ballistic conduction channels, holding promise for future applications in electronics/spintronics. Unfortunately, the reactivity and "softness" of present experimental realizations of 2D topological insulators make them unsuitable for applications. Alternative realizations of 1D helical liquids are therefore in high demand.
In this talk I will begin by giving an elementary introduction to the subject of 2D topological insulators and their helical edge states. I will then discuss a new idea how to "do away with" the topological insulator, and instead produce a helical liquid in a quantum wire by performing a trick with a modulated Rashba interaction $\hbar\omega$ [1].

1. G. I. Japaridze, H. Johannesson, and M. Malard, Phys. Rev. B **89**, 201403(R) (2014).

ANOMALOUS TRANSPORT IN ANTI DE-SITTER SPACE

Karl Landsteiner

Instituto de Física Teórica, IFT-UAM/CSIC, Universidad Autonoma de Madrid

9h40 Mon 2

I will discuss how anomalous transport phenomena can be understood via the AdS/CFT correspondence. After a short review of the correspondence I will discuss several anomaly related transport phenomena, such as the Chiral Magnetic Effect (CME), the Chiral Separation Effect (CSE) or the Axial Magnetic Effect (AME). Then I will try to draw lessons from AdS/CFT results for condensed matter systems, in particular Weyl semi-metals.

CHIRAL ELECTROMAGNETIC WAVES IN WEYL SEMIMETALS

Alexander A. Zyuzin[1], Vladimir A. Zyuzin[2]

1 Department of Physics, University of Basel, Klingelbergstrasse 82, CH-4056 Basel, Switzerland
2 Department of Physics, University of Florida, Gainesville, FL 32611-8440, USA

Weyl semimetal is a new topological phase of matter recently proposed theoretically, [1, 2, 3]. The band structure of the Weyl semimetal consists of points in momentum space at which the valence and conduction bands touch. Weyl points always appear in pairs of opposite chiralities, which is required by the fermion-doubling theorem [4] and are separated in momentum space if the time reversal or inversion symmetries are broken. One of the unique properties of Weyl semimetals is the chiral anomaly [5, 6, 7]. It results in the non conservation of the number of particles of the given chirality in the presence of the electromagnetic field. Another unique property of the Weyl semimetal is the semi-quantized anomalous Hall effect [3].
We show that Weyl semimetals with broken time-reversal symmetry is an optically gyrotropic media and can host chiral electromagnetic waves. The magnetization in the system that results in a momentum space separation of a pair of opposite chirality Weyl nodes is also responsible for the non-zero gyration vector in the system. We then show that in the region where the magnetization flips its directions (magnetic domain wall) there exist a chiral electromagnetic field localized at the domain wall and propagating along it. The direction of propagation is determined by the sign of the gyrotropy factor. Such magnetic domain walls might appear naturally in the Weyl semimetal materials, or, for example, they can be created with a help of a ferromagnetic material placed in proximity. The chiral electromagnetic wave propagating at the domain walls is an analog of quantum Hall state for photons.

10h10
Mon
3

1. X. Wan, A. M. Turner, A. Vishwanath, and S. Y. Savrasov, Phys. Rev. B **83**, 205101 (2011).
2. K. Y. Yang, Y. M. Lu, and Y. Ran, Phys. Rev. B **84**, 075129 (2011).
3. A. A. Burkov and L. Balents, Phys. Rev. Lett. **107**, 127205 (2011).
4. H. B. Nielsen and N. Ninomiya, Nucl. Phys. B **185**, 20 (1981).
5. A. Aji, Phys. Rev. B **85**, 241101 (2012).
6. D. T. Son and N. Yamamoto, Phys. Rev. Lett. **109**, 181602 (2012).
7. A. A. Zyuzin, S. Wu, and A. A. Burkov, Phys. Rev. B **85**, 165110 (2012).

THERMODYNAMICS OF THE BMN MATRIX MODEL AT STRONG COUPLING

Miguel Sousa Costa

Departamento de Física e Centro de Física do Porto, Faculdade de Ciências da Universidade do Porto, Rua do Campo Alegre, 687, 4169007 Porto, Portugal

11h00
Mon
4

We construct the black hole geometry dual to the deconfined phase of the BMN matrix model at strong t Hooft coupling. We approach this solution from the limit of large temperature where it is approximately that of the non-extremal D0-brane geometry with a spherical S8 horizon. This geometry preserves the SO(9) symmetry of the matrix model trivial vacuum. As the temperature decreases the horizon becomes deformed and breaks the SO(9) to the SO(6) O(3) symmetry of the matrix model. When the black hole free energy crosses zero the system undergoes a phase transition to the confined phase described by a Lin-Maldacena geometry. We determine this critical temperature, whose computation is also within reach of Monte Carlo simulations of the matrix model. The scaling behaviour of the free energy, entropy and horizon size earlier derived in the literature follows from a simple scaling symmetry of the gravity action. We also determine the asymptotic gravity data in terms of normalizable modes near the boundary.

HOLOGRAPHIC RELAXATION OF FINITE SIZE ISOLATED QUANTUM SYSTEMS

Javier Abajo-Arrastia[1], Emilia da Silva[1], Esperanza Lopez[1], Javier Mas[2], Alexandre Serantes[2]

1 Instituto de Física Teórica IFT UAM/CSIC, C-XVI, Universidad Autónoma de Madrid, 28049 Cantoblanco, Madrid, Spain

2 Departamento de Física de Partículas, Universidade de Santiago de Compostela, and Instituto Galego de Física de Altas Enerxías IGFAE, E-15782 Santiago de Compostela, Spain

12h00
Mon
5

We study holographically the out of equilibrium dynamics of a finite size closed quantum system in 2 + 1 dimensions, modelled by the collapse of a shell of a massless scalar field in AdS_4. In global coordinates there exists a variety of evolutions towards final black hole formation which we relate with different patterns of relaxation in the dual field theory. For large scalar initial data rapid thermalization is achieved as a priori expected. Interesting phenomena appear for small enough amplitudes. Such shells do not generate a black hole by direct collapse, but quite generically, an apparent horizon emerges after enough bounces off the AdS boundary. We relate this bulk evolution with relaxation processes at strong coupling which delay in reaching an ergodic stage. Besides the dynamics of bulk fields, we monitor the entanglement entropy, finding that it oscillates quasi-periodically before final equilibration. The radial position of the travelling shell is brought in correspondence with the evolution of the pattern of entanglement in the dual field theory. We propose, thereafter, that the observed oscillations are the dual counterpart of the quantum revivals studied in the literature. The entanglement entropy is not only able to portrait the streaming of entangled excitations, but it is also a useful probe of interaction effects.

1. S. Ryu and T. Takayanagi, Phys. Rev. Lett. 96, 181602 (2006).
2. J. Abajo-Arrastia, J. Aparicio and E. Lopez, JHEP 1011, 149 (2010).
3. P. Bizon and A. Rostworowski, Phys. Rev. Lett. 107, 031102 (2011).

DYNAMICS AT A QUANTUM CRITICAL POINT: COMBINING QUANTUM MONTE CARLO AND HOLOGRAPHY

Erik S. Sørensen[1]

1 Department of Physics and Astronomy, McMaster University, Hamilton, Ontario, Canada

The real time dynamics near quantum critical points have proven very challenging to obtain both from a numerical and analytical perspective. Here we focus on the superfluid-insulator transition occurring for bosons on a lattice. New large-scale QMC results have made it possible to obtain very precise results for many quantities in particular the frequency dependent conductivity at imaginary frequencies. Since the numerical results remain confined to imaginary times/frequencies additional tools are needed to extend the results to the rest of the complex plane. Here, recent insights from conformal field theory and holography have yielded a wealth of information that combined with the QMC results yield quantitative and experimentally testable results for the frequency-dependent conductivity near the quantum critical point. [1]

12h20
Mon
6

1. W. Witczak-Krempa, E. S. Sørensen, S. Sachdev, Nature Physics 10, 361 (2014).

FROM CORRELATED TOPOLOGICAL INSULATORS TO IRIDATES AND SPIN LIQUIDS

Stephan Rachel

Institute for Theoretical Physics, TU Dresden, Dresden, Germany

The non-interacting topological insulators (TIs) have attracted great interest in the last decade. While this class of materials is today well-understood, the effect of electron-eletron interactions in such systems remains in general elusive. In this talk, I will address two different aspects of interactions in 2D topological band structures: (i) in some cases, strongly interacting TI models can be used to describe the exotic magnetic properties of certain transition metal oxides. (ii) in other cases, strong interactions can drive a TI into spin-liquid phases.

15h00
Mon
7

TOPOLOGICALLY NONTRIVIAL PHASES IN CORRELATED MULTI-ORBITAL SYSTEMS

M. Daghofer

Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany

15h30
Mon
8

Interaction between itinerant carriers and localized spins on frustrated lattices can stabilize topologically nontrivial electronic bands, quantum anomalous Hall states [1]. If these bands are moreover nearly flat, they are in many respects similar to a Landau level, with a non-coplanar spin background taking the role of the magnetic field. In this case and for partly filled bands, longer-range Coulomb repulsion can then induce states that are like lattice-analogs of fractional Quantum-Hall (FQH) states, but do not require an external magnetic field. It turns out that both the e_g and the t_{2g} orbital manifold show such topologically nontrivial bands with strongly reduced dispersion [2] when they are put onto a triangular lattice. In particular, a t_{2g}-orbital system on a triangular lattice supports a spin-chiral magnetic ordering pattern with precisely the required topologically non-trivial and flat bands for wide and realistic parameter regimes. Exact-diagonalization methods reveal signatures of a FQH-like ground state [3,4]. Moreover, we also find states that go beyond the physics of Landau levels: In analogy to supersolids with coexisting charge order and superfluidity, they show a combination of conventional (charge) and topological order and are made possible by the frustration of the underlying triangular lattice [5].

1. J. W. Venderbos *et al.*, Phys. Rev. Lett. **109**, 166405 (2012).
2. J. W. Venderbos *et al.*, Phys. Rev. Lett. **107**, 116401 (2011).
3. J. W. Venderbos *et al.*, Phys. Rev. Lett. **108**, 126405 (2012).
4. S. Kourtis *et al.*, Phys. Rev. B **86**, 235118 (2012).
5. S. Kourtis and M. Daghofer, arXiv:1305.6948.

STRONGLY CORRELATED TOPOLOGICAL STATES OF SPINLESS FERMIONS IN TWO-DIMENSIONAL LATTICES

S. Kourtis and M. Daghofer

Institute for Theoretical Solid State Physics, IFW Dresden, 01171 Dresden, Germany

16h00
Mon
9

The formation of fractional quantum-Hall (FQH) states in lattice systems without externally applied magnetic fields – dubbed fractional Chern insulators (FCI) – is a recent and promising theoretical proposal that has the potential to render the FQH effect experimentally more accessible. The paradigmatic FCIs are found when interacting electrons with frozen spin degree of freedom populate relatively flat topological bands, with the interaction strength being smaller than the gap to other bands. Strong interactions that mix bands, on the other hand, may give rise to competition between topological and conventional charge order. After discussing this competition, I will introduce a class of states in which FCI topological order is induced by the presence of a charge-density wave and will present numerical evidence for this coexistence. Finally, based on these compositely ordered states, I will provide a recipe for topological order out of a topologically trivial band structure.

1. S. Kourtis and M. Daghofer, arXiv:1305.6948 (2013).
2. S. Kourtis, T. Neupert, C. Chamon, and C. Mudry, Phys. Rev. Lett. **112**, 126806 (2014) .

QUANTUM CORRELATIONS AS LOCAL COHERENCE: APPLICATIONS TO METROLOGY

Gerardo Adesso

School of Mathematical Sciences, The University of Nottingham, Nottingham NG7 2RD, United Kingdom

Quantum metrology exploits quantum mechanical laws to improve the precision in estimating technologically relevant parameters such as phase, frequency, or magnetic fields. Probe states are usually tailored on the particular dynamics whose parameters are being estimated. We introduce the interferometric power of a bipartite quantum state as a figure of merit which quantifies the precision, measured by quantum Fisher information, that such a state enables for the estimation of a parameter embedded in a unitary dynamics applied to one subsystem only, in the worst-case scenario where a full knowledge of the generator of the dynamics is not available a priori. This quantity is proven to be a faithful and computable measure of quantum correlations beyond entanglement, both for finite-dimensional and infinite-dimensional systems. Quantum correlations of the "discord" type are thus identified as resources equivalent to coherence in all local bases. We discuss qualitative and quantitative results both for qubit-based metrology, and for optical interferometry with Gaussian probes. We investigate theoretically and experimentally the power of general quantum correlations even under high levels of noise, assessing their potential for real-world quantum technology.

16h50
Mon
10

1. D. Girolami *et al.*, Phys. Rev. Lett. **112**, 210401 (2014).
2. G. Adesso, Phys. Rev. A **90**, 022321 (2014).

UNDERSTANDING QUANTUM PHASES OF MATTER: ENTANGLEMENT, FRUSTRATION, AND LOCAL CONVERTIBILITY

F. Illuminati

Dipartimento di Ingegneria Industriale, Università degli Studi di Salerno

I will review some recent results in the characterization of quantum phases of matter applying tools of quantum information theory. In particular, I will discuss the entanglement, local convertibility, and correlation properties of quantum ground states (GS) and show that the GSs realizing maximum spontaneous breaking of the Hamiltonian symmetries are the most classical ones [1]. I will then consider the characterization of quantum frustration [2,3] and discuss how valence bond states are associated to a transition from geometric to quantum frustration. Finally, I will discuss the interplay between bipartite and multipartite entanglement in models that support topological order, in particular the one-dimensional cluster model endowed with symmetry-protected topological degeneracy. I will show that in the topologically ordered GSs of such models two-point bipartite entanglement vanishes identically, while genuine multipartite entanglement is always present [4]. This result vindicates Wen's view of novel quantum orders without symmetry breaking as due to long-range patterns of multipartite entanglement.

17h20
Mon
11

1. M. Cianciaruso, L. Ferro, S. M. Giampaolo, and F. Illuminati, arXiv:1408.1412 (2014).
2. S. M. Giampaolo, G. Gualdi, A. Monras, and F. Illuminati, Phys. Rev. Lett. **107**, 260602 (2011).
3. U. Marzolino, S. M. Giampaolo, and F. Illuminati, Phys. Rev. A **88**, 020301(R) (2013).
4. S. M. Giampaolo, B. Hiesmayer, and F. Illuminati, arXiv:1403.7184, and New J. Phys. (2014), to appear.

TOPOLOGICAL ORDER AND ABSENCE OF BAND INSULATORS AT INTEGER FILLING IN NON-SYMMORPHIC CRYSTALS

D. Arovas

Physics Department, University of California, San Diego, USA

17h40
Mon
12

Band insulators appear in a crystalline system only when the filling – the number of electrons per unit cell and spin projection – is an integer. At fractional filling, an insulating phase that preserves all symmetries is a Mott insulator, i.e. it is either gapless or, if gapped, displays fractionalized excitations and topological order. We raise the inverse question – at an integer filling is a band insulator always possible? Here we show that lattice symmetries may forbid a band insulator even at certain integer fillings, if the crystal is non-symmorphic – a property shared by a majority of three-dimensional crystal structures. In these cases, one may infer the existence of topological order if the ground state is gapped and fully symmetric. This is demonstrated using a non-perturbative flux threading argument, which has immediate applications to quantum spin systems and bosonic insulators in addition to electronic band structures in the absence of spin-orbit interaction.

1. Nature Physics 9, 299 (2013) .

Tuesday, 7 October

CROSSOVER FROM NON-FERMI LIQUID TO FERMI LIQUID BEHAVIOR AND THE SUPERCONDUCTIVITY DOME IN HEAVY ELECTRON SYSTEMS

Pedro Schlottmann

Department of Physics, Florida State University, Tallahassee, FL 32306, USA

Landau's Fermi liquid theory has been successful in describing the low energy properties of most normal metals. Numerous U, Ce and Yb based heavy fermion systems display deviations from Fermi liquid behavior, known as non-Fermi liquid behavior, which can be tuned by alloying (chemical pressure), hydrostatic pressure or the magnetic field. In most cases the systems are close to the onset of antiferromagnetism and the non-Fermi liquid behavior is attributed to a quantum critical point (QCP). Some of the properties are quite universal and independent of the type of QCP.

A nested Fermi surface together with the remaining interaction between the carriers after the heavy particles are formed may give rise to itinerant antiferromagnetism. The model under consideration consists of an electron pocket and a hole pocket, separated by a wave vector $\mathbf{Q}$, and Fermi momenta k_{F1} and k_{F2}, respectively.[1] The order is gradually suppressed by increasing the mismatch of the two Fermi momenta and a QCP is obtained as $T_N \to 0$.

9h00 Tue 1

For critical mismatch of the Fermi vectors (tuned QCP) the specific heat over T increases as $-\ln(T)$ as T is lowered[1,2] and the linewidth of the quasi-particles is linear in T and ω.[3] With increasing nesting mismatch and decreasing temperature the specific heat and the linewidth display a crossover from non-Fermi liquid ($\sim T$) to Fermi liquid ($\sim T^2$) behavior.[3] The quasi-particle linewidth is relevant to the electrical resistivity and the width of the inelastic neutron scattering quasi-elastic peak.[4]

If in addition the vector $\mathbf{Q}$ is commensurate with the lattice (Umklapp with $\mathbf{Q} = \mathbf{G}/2$), pairs of electrons can be transferred between the pockets. To avoid the QCP this process may lead to superconductivity and a superconducting dome above the quantum critical point. We investigate the conditions under which such a dome arises. The crossover from Fermi liquid to non-Fermi liquid in the specific heat remains unchanged.[5]

All of the above is consistent with experimental results for systems with a SDW QCP.

[1] P. Schlottmann, Phys. Rev. B **59**, 12379 (1999).
[2] P. Schlottmann, Phys. Rev. B **68**, 125105 (2003).
[3] P. Schlottmann, Phys. Rev. B **73**, 085110 (2006).
[4] P. Schlottmann, Phys. Rev. B **74**, 235103 (2006).
[5] P. Schlottmann, Phys. Rev. B **89**, 014511 (2014).

TRANSPORT THEORY OF STRONGLY INTERACTING BOSONS AND SHORT COHERENCE LENGTH SUPERCONDUCTORS

Assa Auerbach

Department of Physics, Technion, Haifa, Israel

Charge 2e bosons models serve as a paradigm for unconventional superconductors, which are characterized by short coherence length, and strong quantum fluctuations. In the "normal state" above T_c, bosonic transport is quite different than expected Fermi liquid theory of metals. I will review recent results [1-3] on the resistivity, optical conductivity (real and imaginary) and Hall coefficient of lattice bosons, and the O(2) bosonic field theory. A universal scaling relation between superfluid density and linear resistivity slope is predicted and compared to recent systematic measurements in cuprates. Another key prediction of the bosonic theory is the softening of an amplitiude (Higgs) mode in the optical conductivity as the system becomes close to a quantum critical point. Recent experimental observations of this mode in thin superconducting films will be discussed.

9h30
Tue
2

[1] Netanel H. Lindner and Assa Auerbach, Phys. Rev. B81, 054512, (2010).
[2] Snir Gazit, Daniel Podolsky, and Assa Auerbach, Phys. Rev. Lett. 110, 140401 (2013).
[3] Snir Gazit, Daniel Podolsky, Assa Auerbach, and Daniel P. Arovas, Phys. Rev. B 88, 235108 (2013).

STRUCTURAL ORIGIN OF THE ANOMALOUS TEMPERATURE DEPENDENCE OF THE LOCAL MAGNETIC MOMENTS IN THE CAFE$_2$AS$_2$ FAMILY OF MATERIALS

L. Ortenzi,[1,2] H. Gretarsson,[2,3] S. Kasahara,[4] Y. Matsuda,[4] T. Shibauchi,[5,4] K. D. Finkelstein,[6] W. Wu,[3] S. R. Julian,[3] Young-June Kim,[3] I. I. Mazin,[7] and L. Boeri[8]

1 Institute for Complex Systems (ISC), CNR, U.O.S. Sapienza, v. dei Taurini 19, 00185 Rome, Italy
2 Max-Planck-Institut f ür Festkörperforschung, Heisenb ergstraße 1, D-70569 Stuttgart, Germany
3 Department of Physics, University of Toronto, 60 St. George St., Toronto, Ontario, M5S 1A7, Canada
4 Department of Physics, Kyoto University, Kyoto 606-8502, J apan
5 Department of Advanced Materials Science, The University o f Tokyo, Japan
6 Cornell High Energy Synchrotron Source, Cornell Universit y, Ithaca, New York 14853, USA
7 code 6390, Naval Research Laboratory, 4555 Overlook Avenue SW, Washington, DC 20375, USA
8 Institute for Theoretical and Computational Physics, TU Gr az, Petersgasse 16, 8010 Graz, Austria.

10h00
Tue
3

We report a combination of Fe Kβ x-ray emission spectroscopy and *ab*-intio calculations to investigate the correlation between structural and magnetic degrees of freedom in $CaFe_2(As_{1-x}P_x)_2$.[1] The puzzling temperature behavior of the local moment found in rare earth-doped $CaFe_2As_2$ [*H. Gretarsson, et al., Phys. Rev. Lett.* **110**, *047003 (2013)*] is also observed in $CaFe_2(As_{1-x}P_x)_2$. We explain this phenomenon based on first-principles calculations with scaled magnetic interaction. One scaling parameter is sufficient to describe quantitatively the magnetic moments in both $CaFe_2(As_{1-x}P_x)_2$ ($x = 0.055$) and $Ca_{0.78}La_{0.22}Fe_2As_2$ at all temperatures. The anomalous growth of the local moments with increasing temperature can be understood from the observed large thermal expansion of the *c*-axis lattice parameter combined with strong magnetoelastic coupling. These effects originate from the strong tendency to form As-As dimers across the Ca layer in the $CaFe_2As_2$ family of materials. Our results emphasize the dual local-itinerant character of magnetism in Fe pnictides.

1. L. Ortenzi *et al.* arXiv:1408.4058 (2014).

SPIN-LIQUID BEHAVIOR OF A SIMPLE SPIN MODEL ON THE TRIANGULAR LATTICE

Ribhu K. Kaul

Department of Physics, University of Illinois, Urbana, Illinois

10h50 Tue 4

I will report on numerical studies of phase transition between competing magnetic (M) and valence bond solid states (VBS) using unbiased quantum Monte Carlo methods in various sign-problem free models on both bipartite and non-bipartite lattice in two dimensions. On bipartite lattices the transition between these two phases is a direct second order critical point – here we find consistency with various aspects of the "deconfined" criticality scenario. In contrast, on non-bipartite lattices an intermediate phase appears between M and VBS, which we conjecture is a quantum spin liquid.

SCALING DIMENSIONS OF HIGHER-CHARGE MONOPOLES AT DECONFINED CRITICAL POINTS

Stephen Powell[1] and G. J. Sreejith[2]

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2 Nordita, KTH Royal Institute of Technology and Stockholm University, Roslagstullsbacken 23, SE-106 91 Stockholm, Sweden

11h20 Tue 5

The classical cubic dimer model has a columnar ordering transition that is continuous and described by a critical Anderson–Higgs theory containing an SU(2)-symmetric complex field minimally coupled to a noncompact U(1) gauge theory [1,2,3]. Defects in the dimer configuration correspond to monopoles of the gauge theory, with charge determined by the deviation from unity of the dimer occupancy. By introducing such defects into Monte Carlo simulations of the dimer model at its critical point, we determine the scaling dimensions of the corresponding operators under the renormalization group. These results shed light on the deconfined critical point of spin-$\frac{1}{2}$ quantum antiferromagnets, which belongs in the same universality class [4]. Our results provide the first direct determination of these scaling dimensions, which are crucial in deciding the fate of the critical point on lattices of different symmetry groups.

1. F. Alet et al., Phys. Rev. Lett. **97**, 030403 (2006).
2. S. Powell and J. Chalker, Phys. Rev. Lett. **101**, 155702 (2008).
3. D. Charrier, F. Alet, and P. Pujol, Phys. Rev. Lett. **101**, 167205 (2008).
4. T. Senthil et al., Science **303**, 1490 (2004); Phys. Rev. B **70**, 144407 (2004).

MICROSCOPIC NEMATICITY IN IRON SUPERCONDUCTORS

B. Valenzuela, L. Fanfarillo, A. Cortijo

Instituto de Ciencia de Materiales de Madrid, Madrid, España

Iron superconductors are multiorbital systems described by a Hamiltonian with on-site interactions that includes the Hubbard coupling and the Hund coupling. It is believed that the phase diagram can be understood with this Hamiltonian with the Hund coupling playing a major role. Experimentally, a significant anisotropy is present in the normal state of iron superconductors in several probes addressing electronic degrees of freedom, the so-called nematic phase. There is a controversy of whether nematicity has magnetic or orbital-ordering origin although recent experiments favors the first scenario. A nematic phase is also found in cuprates and it is believed to be key to understand high temperature superconductivity. In pnictides, it has been mostly described with a phenomelogical Landau model with magnetic origin[1]. However to date there is not an understanding of how nematicity depend on on-site interactions and on the orbital degree of freedom. Another interesting aspect is the non trivial topology of the Gamma hole pocket in iron superconductors arising from the orbital degree of freedom[2]. In this work we derive the effective Landau model from a microscopic Hamiltonian[3] to address the dependence of the Landau coefficients on the Hund coupling, Hubbard coupling, the orbital content and the topological aspects. We analyze the susceptibility for a two orbital model[4] and find that 1. Due to the topology of the Gamma pocket (a vortex) there are regions of the Brillouin zone where the scattering is suppressed. This fact could explain the experimetal anisotropy found in these compounds. 2. The susceptibility possess terms that renormalized the Hubbard interaction and the Hund's interaction. 3. The orbital ordering is generated dynamically. We believe that these results can be generalized to the more realistic five orbital model since the topological aspect is also present.[5]

11h50

Tue

6

1. R.M. Fernandes, A.V. Chubukov et al. Phys. Rev. B 85, 024534 (2012); R. M. Fernandes, et al. Nat. Phys. 10, 97 (2014).
2. Y. Ran, R. Wang, A. Vishwanath, and D.-H Lee, Phys. Rev. B 79, 014505 (2009).
3. B. Valenzuela, E. Bascones, and M.J. Calderon, Phys. Rev. Lett. 105 207202 (2010).
4. M.J. Calderon, B. Valenzuela, and E. Bascones, New J. Phys. 11, 013051 (2009).
5. L. Fanfarillo, A. Cortijo, and B. Valenzuela, in preparation.

SIGN PROBLEM FREE MONTE CARLO SIMULATION OF ITINERANT FERROMAGNETISM

Shenglong Xu[1], Yi Li[1,2], Congjun Wu[1]

1 Department of Physics, University of California, San Diego, La Jolla, California 92093, USA
2 Princeton Center for Theoretical Science, Princeton University, Princeton, New Jersey 08544, USA

12h10 Tue 7

It has been proven that the ground states of two dimensional P orbital Hubbard model are fully polarized in strong coupling limit [1], and that this model is free of the sign problem. Based on these exact results, we use Quantum Monte Carlo simulation to study the thermodynamic properties of itinerant ferromagetism at various fillings and interaction strength. The compressibility exhibits the itinerant nature while the spin susceptibility follows Curie-Weiss law in the high temperature region. As the temperature is lowered, the spin susceptibility deviates from CW behavior, and different critical phenomena are observed for SU(2) and easy axis Hund's coupling.

1. Y. Li, E. H. Lieb, and C. Wu, Phys. Rev. Lett **112**, 217201 (2014)

ROTATIONAL PROPERTIES OF TWO-COMPONENT GASES IN THE LOWEST LANDAU LEVEL

S. Viefers

Department of Physics, University of Oslo, Norway

In recent years there has been substantial interest in the study of strongly correlated states of cold atoms, analogous to exotic states known from low-dimensional electron systems – one 'holy grail' being experimental realisation of quantum Hall-like states in atomic Bose condensates. In particular there have been many studies on the rotational properties of cold atom systems, as rotation is the conceptually simplest way of simulating a magnetic field for electrically neutral bosonic or fermionic atoms. Even richer physics is expected in the case of *two-species* gases, such as mixtures of two types of bosonic atoms, since (for species-independent interactions), the system then possesses an additional pseudospin symmetry.

15h00 Tue 8

In this talk I will give an introduction to the field, followed by some recent results[1] on the rotational properties of two-species Bose gases in the low-angular momentum regime of the lowest Landau level. Interestingly, an experimental realisation of this regime for single species Bose gases was reported recently[2]. In particular we show that, contrary to expectations, trial wave functions of the composite fermion (CF) type, known from quantum Hall physics, give a very accurate description of the low energy states of this system. It is also shown how working only with a certain subset of possible CF candidate wave functions constitutes a major computational simplification without much loss of accuracy for the low-lying states. Finally I will briefly discuss some striking mathematical identities between seemingly different CF candidate states, of interest for a better understanding of the CF method in general[3].

1. M. L. Meyer, G. J. Sreejith, and S. Viefers, Phys. Rev. A **89**, 043625 (2014).
2. N. Gemelke, E. Sarajlic, and S. Chu, arXiv:1007.2677.
3. A. C. Balram, A. Wojs, and J. K. Jain, Phys. Rev. B **88**, 205312 (2013).

KONDO AND FANO RESONANCES IN CORRELATED IMPURITY SYSTEMS

H.-G. Luo[1,2]

1 Center for Interdisciplinary Studies Key Laboratory for Magnetism and Magnetic Materials of the MoE, Lanzhou University, Lanzhou 730000, China
2 Beijing Computational Science Research Center, Beijing 100084, China

In this talk, I will give a general review of our works on the Kondo effect in correlated impurity systems like adatom on metallic surface and/or graphene[1,2]. I will mainly focus on the lineshape of the Kondo resonance, which involves the Fano resonance, a quantum mechanical interference phenomenon. In different parameter regimes (Kondo, mixed valence, and empty orbital regimes), the Kondo resonance can show rich lineshape ranged from symmetric Lorentz peak, to peak-dip structure, even to anti-resonance due to Fano resonance[2]. These lineshapes can interpret the scanning tunneling spectroscopy in a unified way[1,2]. Finally, I will discuss the Kondo resonance in the carbon nanotube quantum dot with spin-orbit coupling[3], which has been verified in recent experiments[4-6].

15h30
Tue
9

1. H.-G. Luo, T. Xiang, X.Q. Wang, Z. B. Su, and L. Yu, Phys. Rev. Lett. **92**, 256602 (2004); Phys. Rev. Lett. **96**, 019702 (2006).
2. Lin Li, Yang-Yang Ni, Yin Zhong, Tie-Feng Fang, H.-G. Luo, New J. Phys. **15**, 053108 (2013).
3. Tie-Feng Fang, Wei Zuo, and H.-G. Luo, Phys. Rev. Lett. **101**, 246805 (2008).
4. Y. W. Lan *et al.*, Carbon **50**, 3748 (2012). 5. J. P. Cleuziou *et al.*, Phys. Rev. Lett. **111**, 136803 (2013).
6. R. A. Lai, H. O. H. Churchill, and C. M. Marcus, Phys. Rev. B **89**, 121303 (2014).

MEASUREMENT OF T* IN THE BEC-BCS CROSSOVER REGIME

D. Hoffmann[1], T. Paintner[1], B. Deissler[1], C. Chin[2], J. Hecker Denschlag[1]

1 Institut für Quantenmaterie, Universität Ulm, Germany
2 James Franck Institute, University of Chicago, USA

We investigate a mixture of atoms and paired atoms (molecules) in the BEC-BCS crossover regime. For a given temperature, a thermodynamic equilibrium forms between the number of atoms and pairs. We use a 50-50 (30-70) mix of two lowest ^{6}Li spins states and set their interaction by choosing a scattering length with the help of the Feshbach resonance at 832 G. We then determine the crossover temperature T^* by measuring the temperature at which there is an equal mix of pairs and atoms. In general, T^* differs from the critical temperature T_c for the superfluid transition and thus holds additional information which can be used to better understand pairing and pair-correlations.

16h00
Tue
10

Wednesday, 8 October

CHERN BANDS AND TOPOLOGICAL CURRENTS IN GRAPHENE SUPERLATTICES

Leonid Levitov

MIT, USA

This talk will argue that electron bandstructure of superlattices induced in graphene by hexagonal-boron-nitride (G/h-BN) acquires a topological character in the regime when coupling to the substrate opens up gaps in the electron spectrum. We show that a finite valley Chern invariant arises in commensurate stackings, yielding topological bands, but vanishes for incommensurate stackings; the topological characteristics of electrons in G/h-BN heterostructures can be controlled by their crystal axes alignment. We further propose an all-electrical method for mapping out Berry's curvature and valley Chern numbers. We will also discuss recent experimental study of gate-tunable topological currents in graphene superlatices. Topological currents flow in opposite directions in different graphene valley, resulting in long-range valley currents, which we excite and detect by a nonlocal measurement.

9h00
Wed
1

TUNING AND PROBING SYMMETRY BREAKING IN GRAPHENE QUANTUM HALL FERROMAGNETS

A.F. Young

Department of Physics, Massachusetts Institute of Technology

In monolayer and bilayer graphene, the carbon sublattices endow the electron wavefunctions with an additional valley degeneracy. At high magnetic fields, this manifests as highly symmetric multicomponent Landau levels, in which the dominant mechanism for symmetry breaking is due to electronic interactions. In this talk, I will discuss our recent efforts to probe and manipulate the resulting many body ground states. First I will describe experiments on charge neutral monolayer graphene, in which the nature of the symmetry breaking within the combined spin/valley space is directly linked to the edge state structure. Using large in-plane magnetic fields, we induce a quantum spin Hall (QSH) effect analogous to time reversal symmetry protected topological insulators but protected by an emergent spin-rotation symmetry. The properties of the resulting helical edge states can be modulated by balancing the applied field against an intrinsic antiferromagnetic instability, which tends to spontaneously break the spin-rotation symmetry. In the resulting canted antiferromagnetic (CAF) state, we observe transport signatures of gapped edge states, which constitute a new kind of one-dimensional electronic system with tunable band gap and associated spin-texture. Finally I will discuss recent experiments in bilayer graphene, where the sublattices giving rise to the valley degeneracy are on different layers. We use this fact to capacitively detect the layer polarization in bilayer graphene, allowing us to directly constrain the order parameter across a wide range of parameters.

9h30
Wed
2

NON-COLLINEAR MAGNETIC PHASES AND EDGE STATES IN GRAPHENE QUANTUM HALL BARS

J. L. Lado, J. Fernández-Rossier

International Iberian Nanotechnology Laboratory (INL), Av. Mestre José Veiga, 4715-330 Braga, Portugal

Application of a perpendicular magnetic field to charge neutral graphene is expected to result in a variety of broken symmetry phases, including antiferromagnetic, canted and ferromagnetic. All these phases open a gap in bulk but have very different edge states and non-collinear spin order, recently confirmed experimentally. Here we provide an integrated description of both edge and bulk for the
10h00 various magnetic phases of graphene Hall bars making use of a non-collinear mean field Hubbard model.
Wed Our calculations show that, at the edges, the three types of magnetic order are either enhanced (zigzag)
or suppressed (armchair). Interestingly, we find that preformed local moments in zigzag edges inter-
3 act with the quantum Spin Hall like edge states of the ferromagnetic phase and can induce back-scattering.

1. D. A. Abanin, P. A. Lee, and L. S. Levitov, Phys. Rev. Lett. 96, 176803 (2006).
2. A. F. Young, C. R. Dean, L. Wang, H. Ren, P. Cadden- Zimansky, K. Watanabe, T. Taniguchi, J. Hone, K. L. Shepard, and P. Kim, Nat Phys 8, 550 (2012).
3. A. F. Young, J. D. Sanchez-Yamagishi, B. Hunt, S. H. Choi, K. Watanabe, T. Taniguchi, R. C. Ashoori and P. Jarillo-Herrero, Nature 505, 528 (2014).
4. J. L. Lado, J. Fernandez-Rossier, arXiv:1406.6016 (2014)

GRAPHENE AS AN ANHARMONIC MEMBRANE

F. Guinea

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Graphene has been described as the strongest material in nature, when the elastic properties are normalized by its thickness. It is, at the same time, the thinnest crystalline membrane, and simple estimates suggest that it should also be the most anharmonic system. Recent experiments suggest that elastic properties, such as the Young modulus, have a non homogeneous dependence on the concentration
10h50 of defects, and graphene actually becomes stiffer with a small number of vacancies. An explanation of
Wed these results in terms of the general theory of membranes, and novel effects which can be expected in
4 graphene due to its anharmonic properties will be discussed, see[1].

1. "Stiffening graphene by controlled defect creation", Guillermo López-Polín, Cristina Gómez-Navarro, Vincenzo Parente, Francisco Guinea, Mikhail I. Katsnelson, Francesc Pérez-Murano, Julio Gómez-Herrero, arXiv:1406.2131 (2014).

POINT DEFECTS AS A SOURCE OF LOCAL MAGNETIC MOMENTS ON GRAPHENE LAYERS

I. Brihuega

Dept. de Física de la Materia Condensada, Universidad Autónoma de Madrid, Madrid, Spain

Exploiting the synergy between magnetism and the extraordinary properties of graphene has been pursued since its first isolation in 2004. The use of spin as an additional degree of freedom would represent a tremendous boost to the versatility of graphene based devices. From a theoretical point of view, the basics of inducing local magnetic moments on graphene layers are rather simple. Removing a single p_z orbital from the π-graphene system generates a half-filled π-state at the Fermi energy and a local magnetic moment emerges due to electron-electron repulsion [1-2]. Here, I will show how we use a scanning tunneling microscope to explore this possibility at an atomic level. In particular, I will concentrate on atomic vacancies and hydrogen atoms which are considered as ideal candidates to induce graphene magnetism. I will mainly focus on our investigations, at the atomic scale, of the impact that such point defects have in the structural, electronic and magnetic properties of graphene layers grown on different substrates as SiC, metals or graphite surfaces, where the pure bidimensionality of graphene gives to these atomic defects a critical role [3-6].

11h50
Wed
5

1. Lehtinen, P. O.; et al, Phys. Rev. Let, **93**, 187202 (2004).
2. Palacios, J. J.; Fernández-Rossier, J.; Brey, L. Physical Review B, **77**, 195428 (2008).
3. M. Ugeda, I. Brihuega, F. Guinea and J. M. Gómez-Rodríguez, Phys. Rev. Lett **104**, 096804 (2010).
4. M. M. Ugeda, et al. , Phys. Rev. Lett **107**, 116803 (2011).
5. M.M. Ugeda, et al. Phys Rev. B, **85**, 121402 (R) (2012).
6. H. González-Herrero, unpublished.

THERMODYNAMICS OF QUANTUM CRYSTALLINE MEMBRANES

B. Amorim[1], R. Roldán[1], E. Cappelluti[2], A. Fasolino[3], F. Guinea[1], M. I. Katsnelson[4]

1 Instituto de Ciencia de Materiales de Madrid, CSIC, Cantoblanco E28049 Madrid, Spain

2 Istituto dei Sistemi Complessi, CNR, U.O.S. Sapienza, v. dei Taurini 19, 00185 Roma, Italy

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

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

We investigate the thermodynamic properties and the lattice stability of two-dimensional crystalline membranes, such as graphene and related compounds, in the low temperature quantum regime $T \to 0$. A key role is played by the anharmonic coupling between in-plane and out-of-plane lattice modes that, in the quantum limit, has very different consequences from those in the classical regime. The role of retardation, namely of the frequency dependence, in the effective anharmonic interactions turns out to be crucial in the quantum regime. We identify a crossover temperature, T^*, between classical and quantum regimes, which is $\sim 70-90$ K for graphene. Below T^*, the heat capacity and thermal expansion coefficient decrease as power laws with decreasing temperature, tending to zero for $T \to 0$ as required by the third law of thermodynamics.

12h20
Wed
6

1. B. Amorim, R. Roldán, E. Cappelluti, A. Fasolino, F. Guinea, and M. I. Katsnelson, Phys. Rev. B **89**, 224307 (2014).

LARGE CONDUCTION BAND AND FERMI VELOCITY SPIN SPLITTINGS DUE TO COULOMB INTERACTIONS IN SINGLE-LAYER MOS_2

Y. Ferreirós[1], A. Cortijo[1]

Instituto de Ciencia de Materiales de Madrid, CSIC, Cantoblanco, 28049 Madrid, Spain.

12h40 Wed 7

We study the effect of Coulomb interactions on the low energy band structure of single-layer transition metal dichalcogenide semiconductors using an effective low energy model. We show how a large conduction band spin splitting and a spin dependent Fermi velocity are generated in MoS_2, as a consequence of the difference between the gaps of the two spin projections induced by the spin-orbit interaction. The conduction band and Fermi velocity spin splittings found are in agreement with the optical absorption energies of the excitonic peaks A, B measured in the experiments.

1. Y. Ferreirós and A. Cortijo. arXiv:1403.5283.

Thursday, 9 October

ENGINEERING NEW NON-ABELIAN SYSTEMS: FRACTIONALIZED MAJORANA FERMIONS AND BEYOND

Netanel Lindner

Physics Department, Technion Israel Institute of Technology

9h00 Thu 1

Non-Abelian topological phases of matter can be utilized to encode and manipulate quantum information in a non-local manner, such that it is protected from imperfections in the implemented protocols and from interactions with the environment. We consider the possibility to engineer new non-Abelian systems by introducing defects into pre-existing topological phases. We show that such defects bind zero modes which exhibit a new form of non-Abelian statistics. We discuss two routes for utilizing these zero modes to obtain a system capable of performing topological operations which are universal for quantum computation purposes. The first route involves arrays of defects in Abelian quantum Hall states. We show that a judicial coupling of the zero modes in such a system leads to a new topological phase, which can harbor excitations with computationally universal braid statistics. Second, we consider defects in non-Abelian phases. We show that even if the braid statistics of the underlying phase are not universal, in some cases the defects can be used to perform universal topological operations.

HELICAL MAJORANA STATE IN STRONGLY DISORDERED SUPERCONDUCTORS

R. Queiroz and A. P. Schnyder

Max Planck Institute for Solid State Research, Heisenbergstrasse 1, 70569 Stuttgart, Germany

9h30 Thu 2

Fully gapped superconductors with dominant triplet pairing have been shown to be topologically non-trivial in two and three dimensions [1]. Consequently, they allow for linearly dispersive surface-states with Majorana character protected by symmetry. In this presentation we look at the interplay between edge, bulk, and impurity states on the boundary of topological superconductors without inversion center and discuss their stability under strong disorder in finite lattices of two and three dimensions. We show that a delocalized state at exactly zero energy always exists from weak to strong disorder and study the localization transition of states within the superconducting gap. We see that ingap states are fully coupled and undergo a critical transition for disorder strengths comparable with the system's bandwidth as the surface density of states is highly enhanced.

1. P. M. R. Brydon, A. P. Schnyder, and C. Timm, Phys. Rev. B **84**, 020501(R) (2011).
2. R. Queiroz and A. P. Schnyder, arXiv:1409.7893 (2014)

COHERENT TRANSMUTATION OF ELECTRONS INTO FRACTIONALIZED ANYONS

Erez Berg[1], Maissam Barkeshli[2], and Steven Kivelson[3]

1 Department of Condensed Matter Physics, Weizmann Institute of Science, Rehovot, Israel
2 Station Q, Microsoft Research, Santa Barbara, Californa, USA
3 Department of Physics, Stanford University, Stanford, California, USA

Electrons have three quantized properties: charge, spin, and Fermi statistics, that are directly responsible for a vast array of phenomena. Here we show how these properties can be coherently and dynamically stripped from the electron as it enters certain exotic states of matter known as quantum spin liquids (QSL). In a QSL, electron spins collectively form a highly entangled quantum state that gives rise to emergent gauge forces and fractionalization of spin, charge, and statistics. We show that certain QSLs host distinct, topologically robust boundary types, some of which allow the electron to coherently enter the QSL as a fractionalized quasiparticle, leaving its spin, charge, or statistics "at the door". We use these ideas to propose a number of universal, "smoking-gun" experimental signatures that would establish fractionalization in QSLs.

9h50
Thu
3

QUANTUM QUENCHES IN THE THERMODYNAMIC LIMIT

Marcos Rigol

Department of Physics, The Pennsylvania State University, University Park, Pennsylvania 16802, USA

Studies of the quantum dynamics of isolated systems are currently providing fundamental insights into how statistical mechanics emerges under unitary time evolution. Thermalization seems ubiquitous, but experiments with ultracold gases have shown that it need not always occur, particularly near an integrable point. Unfortunately, computational studies of generic (nonintegrable) models are limited to small systems, for which arbitrarily long times can be calculated, or short times, for which large or infinite system sizes can be solved. Consequently, what happens in the thermodynamic limit after long times has been inaccessible to theoretical studies. In this talk, we introduce a linked-cluster based computational approach that allows one to address the latter question in lattice systems [1–3]. We provide numerical evidence that, in the thermodynamic limit, thermalization occurs in the nonintegrable regime but fails at integrability. A phase transition-like behavior separates the two regimes.

10h50
Thu
4

1. M. Rigol, Phys. Rev. Lett. **112**, 170601 (2014).
2. B. Wouters, J. De Nardis, M. Brockmann, D. Fioretto, M. Rigol, and J.-S. Caux, Phys. Rev. Lett. **113**, (2014).
3. M. Rigol, arXiv:1407.6357.

PARTICIPATION SPECTROSCOPY AND ENTANGLEMENT HAMILTONIAN OF QUANTUM SPIN MODELS

Fabien Alet, David Luitz, Nicolas Laflorencie

Laboratoire de Physique Théorique, CNRS, Université de Toulouse, France

11h20
Thu
5

In this talk, I will summarize our recent developments [1] in the field of participation spectroscopy of condensed matter systems, *i.e.* statistical study of coefficients of ground-state wave-functions expanded in a given basis. We have developed quantum Monte Carlo methods to study participations entropies and spectra, which are related to inverse participation ratios appearing in various subfields of physics. Subleading terms in the scaling of participations entropies contain universal information on the physics at play: I will provide several examples in quantum magnetism where subleading terms detect and characterize continuous and symmetry breakings without specifying an order parameter. I will highlight analogies and differences with the more familiar entanglement entropies and spectra, and in particular point out that participation spectroscopy can validate boundary entanglement Hamiltonians as well as improve Monte Carlo measurements of entanglement.

1. D.J. Luitz, F. Alet and N. Laflorencie, Phys. Rev. Lett. **112**, 057203 (2014); Phys. Rev. B **89**, 165106 (2014); D.J. Luitz, X. Plat, N. Laflorencie and F. Alet, Phys. Rev. B, in press (2014); for a review see D.J. Luitz, N. Laflorencie and F. Alet, J. Stat. Mech. (2014) P08007

SPIN-ORBIT COUPLING IN GRAPHYNES

G. van Miert, V. Juričić, C. Morais Smith

Institute for Theoretical Physics, Centre for Extreme Matter and Emergent Phenomena, Utrecht University, Leuvenlaan 4, 3584 CE Utrecht, The Netherlands

11h50
Thu
6

Graphynes represent an emerging family of two-dimensional carbon allotropes that recently attracted much interest due to the tunability of the Dirac cones in the band structure. We explore the effects of spin-orbit couplings, both Rashba and intrinsic ones, in these systems. First, we develop a general method to address spin-orbit couplings within tight-binding theory. We then apply this method to describe the effects of spin-orbit couplings in α, β, and γ-graphyne. We show how spin-orbit couplings can lead to various effects related to both topological and non-topological properties of their band structures. In α-graphyne, as in graphene, the Rashba spin-orbit coupling splits each Dirac cone into four, whereas the intrinsic spin-orbit coupling opens a topological gap. In β-graphyne, intrinsic spin-orbit coupling yields high- and tunable Chern-number bands, which may host both topological and Chern insulators, in the presence and absence of time-reversal symmetry, respectively [1]. On the other hand, Rashba spin-orbit coupling can be used to control the position and the number of Dirac cones in the Brillouin zone. Finally, the Rashba spin-orbit coupling can close the band gap in γ-graphyne [2].

1. G. van Miert, C. Morais Smith, and V. Juričić, Phys. Rev. B **90**, 081406(R) (2014).
2. G. van Miert, V. Juričić, and C. Morais Smith, arXiv:1409.0388 .

ORBITAL ORDER AND EFFECTIVE MASS ENHANCEMENT IN T_{2G} TWO-DIMENSIONAL ELECTRON GASES

John R. Tolsma[1], Marco Polini[2],Alessandro Principi[3] , Allan H. MacDonald[1]

1 Department of Physics, University of Texas as Austin, Austin, Texas 78712, USA
2 NEST, Instituto Nanoscienze-CNR and Scuala Normale Superiore, I56126 Pisa, Italy
3 Department of Physics and Astronomy, University of Missouri, Columbia, Missouri 65211, USA

It is now possible to prepare d-electron two-dimensional electron gas systems that are confined near oxide heterojunctions and contain t_{2g} electrons with a density much smaller than one electron per metal atom. I will discuss a generic model that captures all qualitative features of electron-electron interaction physics in t_{2g} two-dimensional electron gas systems, and the use of a GW approximation to explore t_{2g} quasiparticle properties in this new context. t_{2g} electron gases contain a high density isotropic light mass xy component and low-density xz and yz anisotropic components with light and heavy masses in orthogonal directions. The high density light mass band screens interactions within the heavy bands. As a result the GW approximation predicts a weakly wavevector dependent electron self-energy and this property results in large effective mass enhancement in the anisotropic bands. When the density in the heavy bands is low, the different anisotropies in the two heavy bands favors orbital order. I will discuss these results in the context of recently reported magnetotransport experiments.

12h10
Thu
7

FULL RELATIVISTIC CALCULATIONS ON 2D MATERIALS

R. Mendes Ribeiro

Department of Physics and Center of Physics, University of Minho, Portugal

Single layer transition metal dichalcogenides (TMDC) show positive prospects for optoelectronic applications. Although these layers are atomically thin, they are excelent light absorbers. Band-gap photoluminescence (PL) [1,2],controlled valley polarization [3-5], second harmonic generation [6,7], strain-induced optical gap modulation [8,9], have been observed in these materials, among other phenomena. In this communication, we will focus on the importance of full relativistic density functional theory calculations on TMDCs. In particular, we studied the optical conductivity of the semiconducting TMDCs. We find that this class of materials present large optical response due to the phenomenon of *band nesting* [10]. Given that 2D crystals are atomically thin and naturally transparent, our results show that it is possible to have strong photon-electron interactions even in 2D. The photocarrier relaxation pathway and its relation to band nesting is also studied [11].

15h00
Thu
8

1. A. Splendiani *et al.*, MoS2. Nano Lett. **10**, 1271–1275 (2010).
2. K. F. Mak, C. Lee, J. Hone, J. Shan, T. F. Heinz, Phys. Rev. Lett. **105**, 136805 (2010).
3. K. F. Mak, K. He, J. Shan, T. F. Heinz, Nat. Nanotechnol. **7**, 494–498 (2012).
4. D. Xiao, G.-B. Liu, W. Feng, X. Xu, W. Yao, Phys. Rev. Lett. **108**, 196802 (2012).
5. T. Cao *et al.*, Nat. Commun. **3**, 887 (2012).
6. N. Kumar *et al.*, Phys. Rev. B **87**, 161403(R) (2013).
7. H. L. Zeng *et al.*, Sci. Rep. **3**, 1608 (2013).
8. K. He, C. Poole, K. F. Mak, J. Shan, Nano Lett. **13**, 2931–2936 (2013).
9. J. Feng, X. F. Qian, C. W. Huang, J. Li, Nat. Photonics **6**, 865–871 (2012).
10. A. Carvalho, R. M. Ribeiro, A. H. Castro Neto, Phys. Rev. B **88**, 115205 (2013).
11. D. Kozawa *et al.*, Nat. Commun. **5** 4543 (2014).

STUDYING CORRELATED SYSTEMS WITH PEPS

Didier Poilblanc

Laboratoire de Physique Théorique, CNRS-UMR5152, Université de Toulouse III, France

15h30 Thu 9

Projected Entangled Pair States (PEPS) provide a unique framework giving access to detailed entanglement features of correlated (spin or electronic) systems. I will show how to use PEPS, for example, to compute e.g. the Entanglement Spectrum and the Entanglement Hamiltonian resulting from a partition of an (infinite) cylinder. This will be illustrated in simple cases for which the electronic/spin systems can be described in term of very simple PEPS representation like AKLT and topological RVB spin liquids (with or without a magnetic field). A simple bulk-edge "holographic" correspondence is presented. I will also explain the power of the method to reveal long range topological order, i.e. in the absence of any local order.

INDUCED TOPOLOGICAL ORDER AT THE BOUNDARY OF 3D TOPOLOGICAL SUPERCONDUCTORS

Peter Finch, James de Lisle, Giandomenico Palumbo, Jiannis K. Pachos

School of Physics and Astronomy, University of Leeds, Leeds, LS2 9JT, United Kingdom

16h00 Thu 10

We present tight-binding models of 3D topological superconductors in class DIII that support a variety of winding numbers. We show that gapless Majorana surface states emerge at their boundary in agreement with the bulk-boundary correspondence. At the presence of a Zeeman field the surface states become gapped and the boundary behaves as a 2D superconductor in class D. Importantly, the 2D and 3D winding numbers are in agreement signifying that the topological order of the boundary is induced by the order of the 3D bulk. Hence, the boundary of a 3D topological superconductor in class DIII can be used for the robust realisation of localised Majorana zero modes.

1. Peter Finch, James de Lisle, Giandomenico Palumbo, Jiannis K. Pachos, arXiv:1408.1038.

Friday, 10 October

THERMODYNAMIC LIMIT AND ORDER PARAMETER OF THE REDUCED BCS HAMILTONIAN

O. El Araby[1] and D. Baeriswyl[2]

1 Institute of Theoretical Physics, University of Amsterdam, NL-1090 Amsterdam
2 Department of Physics, University of Fribourg, Ch-1700 Fribourg

9h00
Fri
1

The reduced BCS Hamiltonian, the cornerstone of the microscopic theory of superconductivity, is usually treated in mean-field approximation. This appears to be appropriate for large system sizes because it is widely accepted that for this model mean-field theory becomes exact in the thermodynamic limit. While this assertion has been proven for some specific quantities such as the ground state energy and the free energy, it is not clear whether it is true in general. We have now addressed this issue in detail by studying Richardson's exact solution for large system sizes [1], which was possible thanks to recent algorithmic progress [2, 3]. We could confirm that some quantities, for instance the ground state energy and a pseudospin-pseudospin correlation function, are accurately predicted by mean-field theory. However, discrepancies between mean-field theory and exact predictions persist for other correlation functions and for the fidelity susceptibility, even for large system sizes where these quantities have visibly converged to well-defined limits. Our results indicate that there exist non-perturbative corrections beyond mean-field theory for the critical behavior. As a bi-product of our studies we have discovered that a "canonical" order parameter used for a definitive number of particles is equal to the largest eigenvalue of Yang's reduced density matrix. This result reconciles the order parameter concept with the notion of off-diagonal long-range order.

1. O. El Araby and D. Baeriswyl, Phys. Rev. B 89, 134521 (2014).
2. A. Faribault, O. El Araby, C. Sträter and V. Gritsev, Phys. Rev. B 83, 235124 (2011).
3. O. El Araby, V. Gritsev and A. Faribault, Phys. Rev. B 85, 115130 (2012).

IN-PLANE FFLO STATES IN SUPERCONDUCTOR-FERROMAGNET STRUCTURES

S. V. Mironov[1,2], A. S. Mel'nikov[2,3], A. I. Buzdin[1,4]

1 University Bordeaux, LOMA UMR-CNRS 5798, Talence Cedex, France
2 Institute for Physics of Microstructures, Nizhny Novgorod, Russia
3 Lobachevsky State University of Nizhni Novgorod, Nizhni Novgorod, Russia
4 Institut Universitaire de France, Paris, France

10h00
Fri
2

We demonstrate that in a wide class of multilayered superconductor-ferromagnet structures (e.g., S/F bilayers, S/F/N systems, and S/F/F' spin valves with non-collinear magnetic moments in F/F' bilayer) the vanishing Meissner effect signals the appearance of the in-plane Fulde-Ferrell-Larkin-Ovchinnikov (FFLO) modulated superconducting phase [1]. In contrast to the bulk superconductors the FFLO instability in these systems can emerge at temperatures close to the critical one and is effectively controlled by the S layer thickness and the angle between magnetization vectors in the F/F' bilayers. The predicted FFLO state is revealed through the critical temperature oscillations vs the perpendicular magnetic field component.

1. S. Mironov, A. Mel'nikov and A. Buzdin, Phys. Rev. Lett. 109, 237002 (2012).

QUANTUM VALLEY HALL EFFECT AND OTHER EMERGENT PHENOMENA INDUCED BY THE ELECTROMAGNETIC INTERACTION IN GRAPHENE

E. C. Marino[1], L. O. Nascimento[1,2], V. S. S. Alves [1], C. Morais Smith[2]

1 Instituto de Fisíca, Universidade Federal do Rio de Janeiro, Brazil
2 Department of Theoretical Physics, University of Utrecht, Utrecht, The Netherlands

We use Pseudo Quantum Electrodynamics (PQED), a strictly 2D theory, in order to describe the full electromagnetic interaction of the p-electrons of graphene in a consistent formulation. By including the effects of the interaction on the vacuum polarization tensor and on the electron self-energy, we achieve the following physical results. a) QVHE - We predict the onset of a spontaneous (interaction-driven) Quantum Valley Hall effect (QVHE) below a critical temperature of the order of 0.05 K. The transverse (Hall) valley conductivity is evaluated exactly and shown to coincide with the one in the usual Quantum Hall effect. b) DC-conductivity - By considering the corrections induced by PQED in the vacuum polarization tensor or, equivalently, in the current correlator, up to two-loops, we are able to obtain a smooth zero-frequency limit in Kubo's formula. Thereby, we obtain in zeroth order, the usual expression for the minimal DC-conductivity plus higher-order corrections due to the interaction. These make our result, to the best of our knowledge, the closest to the experimental value. c) Gap and Midgap States - We study the effects of the interaction on the electron self-energy and show that this produces a shift in the electron propagator poles. The energy spectrum is such that a set of P- and T- symmetric gapped electron energy eigenstates are dynamically generated, with an infinite number of midgap states. This discrete set of states are related to the QVHE in similar way the Landau levels are related to the ordinary Quantum Hall Effect

10h20
Fri
3

THEORETICAL AND EXPERIMENTAL STUDY OF AROMATIC HYDROCARBON SUPERCONDUCTORS

Zhong-Bing Huang[1,2], Xun-Wang Yan[2], Guo-Hua Zhong[3], Hai-Qing Lin[2]

1 Faculty of Physics and Electronic Technology, Hubei University, Wuhan, 430062, China
2 Beijing Computational Science Research Center, Beijing, 100084, China
3 Center for Photovoltaics and Solar Energy, Shenzhen Institutes of Advanced Technology, Chinese Academy of Sciences, China

In this talk, I will report our theoretical and experimental study on the electronic, magnetic and pair binding properties of recently discovered aromatic hydrocarbon superconductors, including K-doped picene, phenanthrene, and dibenzopentacene. Our quantum Monte Carlo simulations show that the spin polarized state is realized for charged molecules in the physical parameter region, which provides a reasonable explanation of local spins observed in experiments. The first-principles calculations indicate that all K-doped aromatic hydrocarbons are stabilized in an antiferromagnetic ground state, with spins antiparalleling between two molecular layers. The magnetic moment in these materials is increased with increasing the number of benzene rings, while it is not sensitive to the arrangement of benzene rings. In K-doped picene and phenanthrene, the negative pair binding energy obtained from the one-orbital Hubbard model suggests that electron correlation alone is not enough for the formation of Cooper pairs, and electron-phonon interaction should play an important role in superconductivity.

11h10
Fri
4

EFFECTS OF STRAIN IN MOS_2: BANDGAP ENGINEERING AND VALLEY POLARIZED CURRENT

R. Roldán

Instituto de Ciencia de Materiales de Madrid, CSIC, Madrid, Spain

Graphene has represented in the past 10 years the most promising new material for a new generation of electronic devices and for the investigation of fundamental physics. The effective employment of graphene-based materials in low-energy electronics is however challenging by the difficulty of opening a bandgap without affecting the mobility and the electronic properties. New actors have however recently entered on the stage, in particular metal-transition dichalcogenides, as MoS_2 and similar compounds. Also these materials, like graphene, can be exfoliated to reach atomically thickness. In advantage, they present an intrinsic bandgap whose nature and size results to be highly sensitive to the number of layers and to external conditions (strain, pressure, electric fields, etc).

11h40 Fri 5

Here we demonstrate the possibility to control at a local scale the electronic and optical properties by means of local strain. Lattice corrugations are induced in few-layer MoS_2 samples by means of controlled delamination on an elastic substrate [1]. Local strain is monitored through the phonon resonance energies in Raman spectroscopy, and the local direct bandgap is measured by photoluminescence. The direct correlation between these features proves the feasibility to control the bandgap at a local scale by means a suitable pattern of strain. To understand these results, we develop a proper tight-binding model for MoS2 under non-uniform conditions, accounting for the local modulation of the hopping integrals. Such analysis suggests a possible change between direct- to indirect-bandgap upon strain at a local scale, and a possible unnelffect in large wrinkles. Furthermore, we will show that inhomogeneous strain with the appropriate geometry can be used to induce valley polarized currents in MoS_2 [2].

1. Castellanos-Gomez, A., Roldán, R., Cappelluti, E., Buscema, M., Guinea, F., van der Zant, H.S.J., and Steele, G.A. Nano Letters, **13**, 5361 (2013)
2. Rostami, H., Roldán, R., *et al.* (in preparation).

ZERO-BIAS CONDUCTANCE PEAK IN DETACHED FLAKES OF SUPERCONDUCTING $2H$-TAS$_2$ PROBED BY SCANNING TUNNELING SPECTROSCOPY

J. A. Galvis[1], L. Chirolli[2], I. Guillamón[1,3], S. Vieira[1,3], E. Navarro-Moratalla[4], E. Coronado[4], H. Suderow[1,3], F. Guinea[2,3]

1 Laboratorio de Bajas Temperaturas, Departamento de Física de la Materia Condensada, Instituto de Ciencia de Materiales Nicólas Cabrera, Condensed Matter Physics Center (IFIMAC), Universidad Autónoma de Madrid, E-28049 Madrid, Spain

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

3 Unidad Asociada de Bajas Temperaturas y Altos Campos Magnéticos, UAM, CSIC, Cantoblanco, E-28049 Madrid, Spain

4 Instituto de Ciencia Molecular (ICMol), Universidad de Valencia, Catedrático José Beltrán 2, 46980 Paterna, Spain

Single unit cell $2H$-TaS$_2$ presents a 2D Fermi surface characterized by three pockets centered around K, K' and Γ points of the Brillouin zone. Non-simply connected Fermi surface promotes non- conventional superconductivity mediated by short range Coulomb repulsion, that favors a Kohn-Luttinger pairing. We model 2D superconductivity with unconventional sign changing gap function between the K and K', that gives rise to an odd-parity triplet pairing. We show that, due to the peculiar band structure of TaS$_2$, single layers can show induced nodal superconductivity on the Γ even-parity pocket. In other dichalchogenides, such as MoS$_2$, the band structure is different and nodal superconductivity is not expected. At the scale of the induced nodal gap, the physics is governed by an anisotropic Dirac equation that comes from expansion around the nodal points. Due to sign change in the gap, scattering against defects can induce Andreev bound states.

12h00 Fri 6

We show that a weak scatterer, such as the STM tip, can behave as a non-perturbative probe at the scale of the induced nodal gap and generate virtual Andreev states on the Γ pocket around the tip position, without affecting superconducting correlations in the K and K' pockets, and lead to a zero bias peak in the tunneling conductance characterized by a large broadening on order of the gap. These expectations show consistency with STM measurements on the surface of superconducting $2H$-TaS$_2$ metal dichalcogenide, that report an anomalous tunneling conductance with a strong zero bias peak in single unit cell or very thin layers of superconducting 2H-TaS$_2$ detached from the surface.

Comparison between theory and experimental data points out that flakes of TaS$_2$ may show sign changing superconductivity. We expect that this has some consequences, in particular for future experiments in multiband and sign changing systems.

J. A. Galvis, *et al.*, Phys. Rev. B **89**, 224512 (2014).

ABSTRACTS OF THE POSTER PRESENTATIONS

Poster session I

MONOGAMY AND BACKFLOW OF MUTUAL INFORMATION IN NON-MARKOVIAN THERMAL BATHS

A. C. S. Costa[1], R. M. Angelo[1], M. W. Beims[1]

1 Department of Physics, Federal University of Paraná, Curitiba, Brazil

PS-I 1

We investigate the dynamics of information among the parties of tripartite systems. We start by proving two results concerning the monogamy of mutual information. The first one states that mutual information is monogamous for generic tripartite pure states. The second shows that, in general, mutual information is monogamous only if the amount of genuine tripartite correlations is large enough. Then, we analyze the internal dynamics of tripartite systems whose parties do not exchange energy. In particular, we allow for one of the subsystems to play the role of a finite thermal bath. As a result, we find a typical scenario in which local information tends to be converted into delocalized information. Moreover, we show that (i) the information flow is reversible for finite thermal baths at low temperatures, (ii) monogamy of mutual information is respected throughout the dynamics, and (iii) genuine tripartite correlations are typically present. Finally, we analytically calculate a quantity capable of revealing favorable regimes for non-Markovianity in our model.

TOPOLOGICAL ORDERED STATES AND DISORDER

N. M. Gergs, L. Fritz, D. Schuricht

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We study one-dimensional electrons in topologically ordered states associated with Majorana edge modes. Performing a density matrix renormalisation group study of the corresponding spin-1/2 chain we find that disorder as well as interaction individually stabilise the topological ordering. We further investigate the interplay of interaction and disorder.

SPIRAL FERRIMAGNETIC PHASES IN THE 2D HUBBARD MODEL

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We address the possibility of spiral ferrimagnetic phases in the mean-field phase diagram of the two-dimensional (2D) Hubbard model. For intermediate values of the interaction U ($6 \lesssim U/t \lesssim 11$) and doping n, a spiral ferrimagnetic phase is the most stable phase in the (n, U) phase diagram. Higher values of U lead to a non-spiral ferrimagnetic phase. If phase separation is allowed and the chemical potential μ replaces the doping n as the independent variable, the (μ, U) phase diagram displays, in a considerable region, a spiral (for $6 \lesssim U/t \lesssim 11$) and non-spiral (for higher values of U) ferrimagnetic phase with fixed particle density, $n = 0.5$, reflecting the opening of an energy gap in the mean-field quasi-particle bands.

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ERROR MITIGATION SCHEMES FOR THE CONTROL OF NOISY QUANTUM SYSTEMS VIA MARTIN-SIGGIA-ROSE AND SCHWINGER-KELDYSH FIELD THEORY TECHNIQUES

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We consider the basic quantum control task of obtaining a target unitary operation (i.e., a quantum gate) via external control fields coupled to the quantum system, while simultaneously compensating for time-dependent noise. We address this issue of control and error correction by means of a formulation rooted in the MSR approach to noisy, classical, out-of-equilibrium statistical-mechanical systems. To do this, we express the noisy control problem as a path integral, and integrate out the noise to arrive at an effective, noise-free description. To illustrate the approach, we consider a single spin-s degree of freedom (with s arbitrary) in the presence of Gaussian-correlated, time-dependent noise, though our approach can be generalized to more complicated systems and noise distributions. Success with control is characterized via a "fidelity", which measures the overlap between the ideal (i.e., noise-free) evolution and the noisy one. To make connection with MSR, we reformulate the fidelity in terms of a Schwinger-Keldysh path integral, with the added twist that the "forward" and "backward" branches of the contour are inequivalent with respect to noise. We explore the effective, noise-free quantum description, and discuss how to evaluate the path integral systematically to arbitrary order in the noise strength via a diagrammatic expansion. This path-integral approach affords a natural way to study the control problem for arbitrary s under a unified protocol, valid from the qubit limit (i.e., $s = 1/2$) to the classical limit (i.e., $s \to \infty$).

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MAGNETIZATION JUMPS IN 1D VALENCE BOND SOLIDS

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A valence bond solid (VBS) is a long-range nonmagnetic state with broken lattice symmetries that can appear in certain quantum spin systems with competing interactions. Recent innovations in models and simulation techniques have enabled large scale numerical studies of these states and associated quantum phase transitions from the standard magnetic (Néel, for two or more dimensions) or power-law critical states (in one dimension). These studies have found evidence for the fractionalization of triplons into deconfined or nearly deconfined spinons (spin-1/2 bosons) in the VBS phase and at critical points. We here study the VBS and magnetization as a function of an external magnetic field in an extended Heisenberg model, known as the J-Q model, in one dimension. Using the stochastic series expansion (SSE) quantum monte carlo method with directed loop updates, we find discontinuities in the induced magnetization from a partially magnetized to a fully polarized state. We characterize the phases and the first-order quantum phase transition.

CHARGE AND SPIN FRACTIONALIZATION BEYOND THE LUTTINGER LIQUID PARADIGM

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We find different kind of charge and spin fractional excitations in the Luttinger Liquid (LL) phase of the one-dimensional t-J model [1,2] that go beyond of the already known spin-charge separation and of the chiral-charge fractionalization predicted at low energies by the LL theory [3]. Depending on the interaction constant J and on the electronic density n two main regimes are identified: one regime where $v_s > v_c$ and another where $v_s < v_c$, where $v_{c(s)}$ is the charge(spin) velocity. At low energies, i.e for $k \sim k_F$, complete spin-charge separation is present in both regimes as it is expected from the LL theory [4]. For $v_s > v_c$ and $k > k_F$ the spinon starts to carry a fraction of charge that increases with k while the holon still continues carrying only charge. For $v_s < v_c$ and $k > k_F$ the role of the spin a charge degrees of freedom is reversed and now the holon carries a fraction of spin that increases with k while the spinon still continues carrying almost no charge. These results are an evidence that the usual low energy picture of pure-spin and pure-charge separation cannot be held anymore at high energies.

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UNITARITY OF THEORIES CONTAINING FRACTIONAL POWERS OF THE D'ALEMBERTIAN OPERATOR

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We examine the unitarity of a class of generalized Maxwell U(1) gauge theories in (2+1) D containing the pseudodifferential operator $\Box^{1-\alpha}$, for $\alpha \in [0, 1)$. We show that only Quantum Electrodynamics and its generalization known as Pseudo Quantum Electrodynamics (PQED), for which $\alpha = 0$ and $\alpha = 1/2$, respectively, satisfy unitarity. The latter plays an important role in the description of the electromagnetic interactions of charged particles confined to a plane, such as in graphene or in hetero-junctions displaying the quantum Hall effect.

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TOPOLOGICAL PROPERTIES OF THE DEEP VALENCE-BOND-SOLID STATES OF THE JQ_3 MODEL

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By using the ground-state projector quantum Monte Carlo (PQMC) simulations[1-2], we study the topological properties of the valence-bond-solid states of the JQ_3 model on the square lattice[3-4]. The topological winding number is shown to be an emergent quantum number in the thermodynamic limit for the JQ_3 model in the VBS state.
We also prove that the energy gap between different winding number sectors is due to the domain walls appearing in the topological nontrivial state, and the energy difference is proportional to the number of domain walls.

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LOCAL TEMPERATURE AND VOLTAGE MEASUREMENT OF A QUANTUM SYSTEM FAR FROM EQUILIBRIUM

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Local temperature and voltage is defined by the measurement of a floating thermoelectric probe. We consider quantum conductors with large thermal and electrical bias, and obtain local measurements with large deviations from the results of Linear Response Theory.
We also consider the temperature measurement of a quantum system where one of the terminals is held at absolute zero. It is shown that local temperatures close to absolute zero can exist in a system far from equilibrium. The applicability of the third law of thermodynamics is discussed.

NON-MARKOVIAN EFFECTS IN ELECTRONIC AND SPIN TRANSPORT

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Non-equilibrium processes in open quantum systems can be generically described within the framework of the Lindblad master equation i.e. without a memory kernel. This statement holds even for processes where information can flow-back from the environment to the system. However, for non-Markovian dynamics, the set of conditions to ensure the positivity of the density matrix for all times is not known, making difficult the explicit construction of non-Markovian Lindblad operators.
Using the Keldysh non-equilibrium Green's functions, we explicitly solve a generic quadratic model of electrons coupled at $t = 0$ to a set of wide-band baths characterised by temperature and chemical potential. We identify the equivalent Lindblad operator describing the evolution of the density matrix and show that the resulting dynamical process is generically non-Markovian. We further discuss the cases in which Markovian dynamics is recovered.
We apply our approach to a simple model for electronic transport thought a one dimensional wire coupled at $t = 0$ to wide-band metallic leads, and to a $X - Y$ spin chain attached to two contacts.

Poster session II

DECAY OF A SUPERCURRENT IN DIFFUSIVE SNS-JUNCTIONS

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A nondissipative supercurrent state of an SNS-junction is metastable with respect to the formation of a finite-resistive state. This transition is driven by fluctuations, thermal at high temperatures and quantum at low temperatures. We evaluate the life time of such a state due to quantum fluctuations in the limit when the supercurrent is close to critical one. The decay probability is determined by the instanton action for the superconducting phase difference across the junction. The crucial point is calculating the effective capacity of the junction, which is done using the formalism of the nonlinear diffusive sigma model. As a generalization of our approach we present the general expression for the effective capacity of a mesoscopic conductor in terms of its transmission coefficients. PS-II 1

NONLINEAR SURFACE POLARITONS, SUPPORTED BY GRAPHENE STRUCTURES

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We analyze the propagation of electromagnetic waves along the surface of a nonlinear dielectric medium covered by a graphene monolayer, and along nonlinear metamaterial based on graphene multilayer. We reveal that nonlinear dielectric, covered with graphene, can support and stabilize nonlinear transverse electric (TE) plasmon polaritons. We demonstrate that these nonlinear TE modes have a subwavelength localization in the direction perpendicular to the surface, with the intensity much higher than that of an incident wave which excites the polariton. We also demonstrate that multilayer nonlinear graphene-based metamaterial is described by discrete nonlinear Schrödinger equation, and they can support stable discrete TM- polarized plasmon solitons. PS-II 2

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GEOMETRIC PHASES AND QUBIT MANIPULATION IN A DRIVEN QUANTUM DOT

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I will present a novel approach to manipulate the spin of an electron in a moving quantum dot (QD) in a one-dimensional (1D) system in the presence of time-dependent spin-orbit interaction (SOI). The exact quantum solution is connected to the solutions of two independent, driven classical harmonic oscillators. I will focus on cyclic evolutions of the Hamiltonian and show that after the evolution, the spin rotation is proportional to the area of a closed loop in the parameter space of the time-dependent quantum dot position and the amplitude of a fictitious classical oscillator driven by the time-dependent SOC strength. By an appropriate choice of parameters, arbitrary spin rotations may be performed on the Bloch sphere. The total phase acquired during the cyclic evolution can be decomposed into dynamical and geometric part. For the system considered I will give analytical expressions for the geometric phase in both non-adiabatic and adiabatic regime. The double degeneracy of the Kramers states can be lifted by an external magnetic field and I will present analytical results for the case of the magnetic field along the direction of the effective field induced by the moving QD due to the SOI.

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TOPOLOGICAL ASPECTS OF THE TWISTED GRAPHENE BILAYER

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The electronic properties of two-dimensional graphitic devices are strongly influenced by the number of graphene layers. Whereas the monolayer band structure is linear at low-energy, the bilayer has a quadratic dispersion. Each system is also associated with a Berry phase of either (monolayer) or 2 (bilayer) around the degeneracy point of the structure [1]. Graphene bilayer with a twist [2], one layer being slightly misoriented relative to the other, is a new system, which can interpolate between the two situations. For large rotations (misorientations) the two layers are decoupled and the band structure replicates that of the monolayer. On the other hand, for small rotations relative to Bernal stacking, one should recover the bilayer structure. Indeed, band deformations, involving the Dirac cones of each layer, have been observed experimentally [3,4]. We have developed a simple theoretical model [5] based on a previous continuum analysis [2,6], which describes the motion of the cones of different layer, depending on the twist angle. These two cones are separated for a non-zero rotation due to the rotation of the Brillouin zone of the upper layer relative to the lower one and eventually merge to create a quadratic dispersion in case of perfectly AB-stacked bilayer. This merging is accompanied with peculiar topological properties, since it is derived via symmetry arguments of our Hamiltonian that the two cones each carry the same Berry phase, around the two Dirac points, for a given energy level. This has to be contrasted with previous study of merging of Dirac cones where the Berry phases are opposite [7]. This topological scenario has been successfully tested through the quantum Hall effect where the robust zero-energy Landau level predicted, which cannot be lifted by relatively strong magnetic field, was effectively observed, [8].

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QUANTUM SPIN HALL PHASE IN MULTILAYER GRAPHENE

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We address the question of whether multilayer graphene systems are Quantum Spin Hall (QSH) insulators. Since Spin-Orbit (SO) couples p_z orbitals with p_x and p_y of opposite spins, these orbitals cannot be neglected anymore, therefore we use a four orbital tight-binding model in the Slater-Koster approximation with intrinsic Spin-Orbit interaction. With such a model we obtain gapped bulk states and gapless edge states for odd number of layers N, while for even N the edge states are always gapped.

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To completely determine if the QSH phase is present we calculate for different number of layers both the Z_2 invariant for different stackings (only for inversion symmetric systems), and the density of states at the edge of semi-infinite graphene ribbon with armchair termination.

We find that systems with even number of layers are normal insulators while systems with odd number of layers are QSH insulators, regardless of the stacking.

We acknowledge financial support by Marie-Curie-ITN 607904-SPINOGRAPH.

A COMPREHENSIVE THEORY OF TRANSPORT: DISTINGUISHING INSULATORS, CONDUCTORS, SUPERCONDUCTORS, AND BOSONIC SUPERFLUIDS

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The Drude weight (D_c), the quantity which distinguishes metals from insulators, is proportional to the second derivative of the ground state energy with respect to a flux at zero flux. The same expression also appears in the definition of the Meissner weight, (n_s) the quantity which indicates superconductivity, as well as in the definition of non-classical rotational inertia of bosonic superfluids (I_{nc}). A question thus arises: given that the three quantities are mathematically equivalent, even though they describe very different physics, how can one distinguish them? Scalapino, White, and Zhang [1] provided an answer by noting that the derivative is ambiguous: it can be interpreted as the adiabatic derivative (defined by staying on the same state as a function of the flux) or the so called "envelope" derivative, defined based on the actual ground state for any value of the flux. In this talk it will be shown that this scheme is inadequate for a number of reasons: it does not apply in one dimension, it distinguishes only two categories (paired systems are not distinguished from bosonic superfluids), and it is not applicable to variational theory. Also the solution [2] to the problem will be presented. PS-II 6 To solve the problem, one first casts the current as a Berry phase [3]. The current expression is also ambiguous, it can be interpreted as the average of the total momentum, or the sum of the averages of the momentum of each particle, or the sum over the average of the momentum of pairs of particles, etc. From these distinct expressions for the current one can derive distinct transport susceptibilities; the first case corresponding to D_c, the second to I_{nc}, the third to n_s. The justification for the scheme is the sensitivity of each quantity to off-diagonal long-range order (ODLRO). I_{nc} is sensitive to ODLRO in the first order reduced density matrix (RDM), n_s to ODLRO in the second order RDM, and D_c to ODLRO in the N-order reduced density matrix, where N denotes a thermodynamically large number. These results coincide with the well-known results of Yang [4], as well as the insulation theory of Kohn [4].

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NUCLEAR SPIN RELAXATION IN RASHBA NANOWIRES

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We study the nuclear spin relaxation in a ballistic nanowire with hyperfine and Rashba spin-orbit interactions (SOI) and in the presence of magnetic field and electron interactions. The relaxation rate shows pronounced peaks as function of magnetic field and chemical potential due to van Hove singularities in the Rashba bands. As a result, the regimes of weak and strong SOIs can be distinguished
PS-II by the number of peaks in the rate. The relaxation rate increases with increasing magnetic field if both
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FRUSTRATED JOSEPHSON JUNCTION ARRAYS WITH MULTIBAND SUPERCONDUCTING ELEMENTS

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Motivated by the multiband scenario for the iron-based superconductors, we study frustration effects in a clean multiband superconductor and in a rhombi chain of Josephson junctions with two-band superconducting elements at the spinal positions. Frustration is induced by repulsive interband interactions and leads to chiral superconducting states with broken time-reversal symmetry. The temperature evolution of the interband interactions (or gap functions) may lead to transitions to or from chiral configurations for the superconducting phases of a three-band superconductor. For the rhombi chain, we show that when half flux quantum threads each rhombus plaquette (full frustration case), new phase configurations of
PS-II the rhombi chain appear which are characterized by the doubling of the periodicity of the energy density
8 along the chain, with every other two-band superconductor locked in a sign-reversed state. Near full frustration and for equal Josephson couplings, plateaus are observed in the energy-phase plots and the respective supercurrent along the chain is blocked, with the plateaus becoming wider as the Josephson couplings are decreased.

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SEMI-CLASSICAL PHASE SPACE DYNAMICS FOR THE QUANTUM TOFFOLI GATE

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To be able to compare classical and quantum complexity classes one needs to establish a relation between quantum and classical systems. In this sense, we tried to understand the classical limit of an arbitrary finite-dimensional quantum system undergoing unitary dynamics. To study such a limit, it is more suitable to introduce the so-called coherent states [1,2] associated to the symmetry group of the problem. The coherent states are nearest to classicality because they minimize uncertainty relations. The quantum dynamics can then be mapped to dynamics in a symplectic manifold, $\mathbb{CP}^{n-1}$, in analogy with the scenario of classical mechanics, with Hamilton's function given by the expected value in the coherent states. PS-II 9

The Toffoli gate [3] is very important in computation because it provides a minimal set of universal gates for reversible computation. It is represented, in the context of the quantum circuit paradigm of quantum computation, by a unitary matrix. We've studied the Hamiltonian dynamics in this specific case.

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NOVEL PLATFORMS FOR TOPOLOGICAL PHASES IN 2D MATERIALS

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We[1] propose to engineer time-reversal-invariant topological insulators in two-dimensional (2D) crystals of transition metal dichalcogenides (TMDCs). We note that, at low doping, semiconducting TMDCs under shear strain will develop spin-polarized Landau levels residing in different valleys. We argue that gaps between Landau levels in the range of 10∼100 Kelvin are within experimental reach. In addition, we point out that a superlattice arising from a Moiré pattern can lead to topologically non-trivial subbands. As a result, the edge transport becomes quantized, which can be probed in multi-terminal devices made using strained 2D crystals and/or heterostructures. The strong d character of valence and conduction bands may also allow for the investigation of the effects of electron correlations on the topological phases. Motivated by recent STM/STS experiments,[2] we study graphene (Gr) on iridium (Ir), with islands of an
PS-II ordered lead (Pb) monolayer intercalated between them. While the Gr layer is structurally unaffected by
10 the presence of Pb, its electronic properties change dramatically. Regularly spaced resonances appear. We interpret these resonances as the effect of strong and spatially modulated spin-orbit fields induced in Gr layer by the proximity of Pb. We present a phenomenological theory including all the spin-orbit terms allowed by the reduced symmetry of the Gr/Pb system, which reproduces qualitatively the reported STS spectra. According to this model, the electronic spectrum has, in addition to confined electronic states, a series of gaps with non trivial topological properties which resemble the Bernevig-Zhang model of the quantum spin Hall effect.

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Participants

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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 Rodoviário de Sete Rios
Praça Marechal Humberto Delgado - Estrada das Laranjeiras
1500-423 LISBOA

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

Bus Timetables

Bus Timetables

LISBOA → ÉVORA (131 Kms)

Departure	Arrival	Price	Frequency
07:00	08:45	12.50	Except Saturdays and Sundays
08:00	09:30	12.50	Daily
08:00	09:45	12.50	Saturdays and Sundays
08:30	10:15	12.50	Daily
09:30	11:00	12.50	Daily
10:30	12:15	12.50	Daily
11:45	13:35	12.50	Daily
12:00	13:30	12.50	Daily
13:00	14:45	12.50	Except Saturdays and Sundays
13:45	15:15	12.50	Daily
14:15	16:50	12.50	Daily
15:00	16:30	12.50	Fridays
15:00	16:40	12.50	Except Sundays
15:00	16:45	12.50	Sundays
16:00	17:45	12.50	Except Saturdays
17:00	18:30	12.50	Daily
17:00	18:45	12.50	Daily
17:15	19:00	12.50	Daily
17:45	19:15	12.50	Daily
18:00	19:30	12.50	Except Saturdays and Sundays
19:00	20:30	12.50	Sundays
19:00	20:40	12.50	Except Saturdays
19:30	21:00	12.50	Daily
20:00	21:30	12.50	Sundays
20:30	22:15	12.50	Daily
21:30	23:15	12.50	Fridays
22:00	23:45	12.50	Daily
22:30	00:00	12.50	Sundays

Bus Timetables

Bus Timetables

ÉVORA → LISBOA (131 Kms)

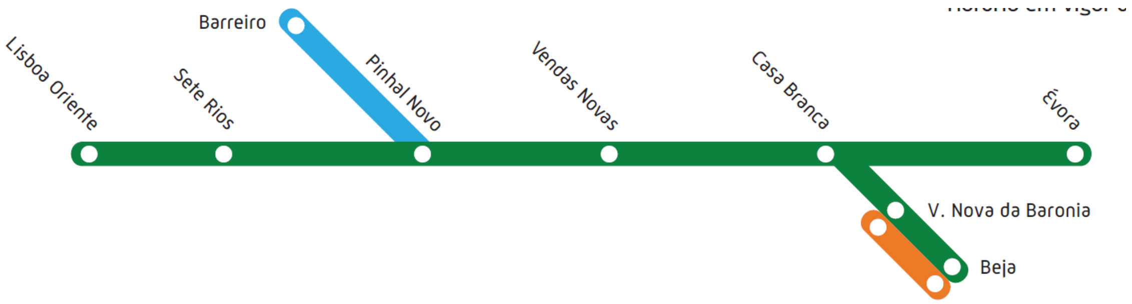
Departure	Arrival	Price	Frequency
06:00	07:45	12.50	Daily
07:00	08:30	12.50	Daily
07:30	09:00	12.50	Except Saturdays and Sundays
08:00	09:45	12.50	Except Sundays
08:30	10:00	12.50	Daily
08:30	11:05	12.50	Daily
09:45	11:30	12.50	Daily
10:15	11:45	12.50	Daily
12:30	14:15	12.50	Except Saturdays and Sundays
13:00	14:30	12.50	Daily
14:00	15:30	12.50	Daily
14:45	16:15	12.50	Daily
15:00	16:45	12.50	Except Saturdays and Sundays
16:00	17:30	12.50	Fridays
16:00	17:45	12.50	Saturdays
16:00	17:45	12.50	Except Saturdays
17:30	19:00	12.50	Fridays
17:30	19:05	12.50	Sundays
17:30	19:15	12.50	Daily
18:15	19:45	12.50	Daily
19:00	20:45	12.50	Daily
19:30	21:15	12.50	Daily
20:00	21:45	12.50	Daily
20:00	21:45	12.50	Sundays
21:00	22:45	12.50	Except Saturdays
21:30	23:00	12.50	Sundays

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.

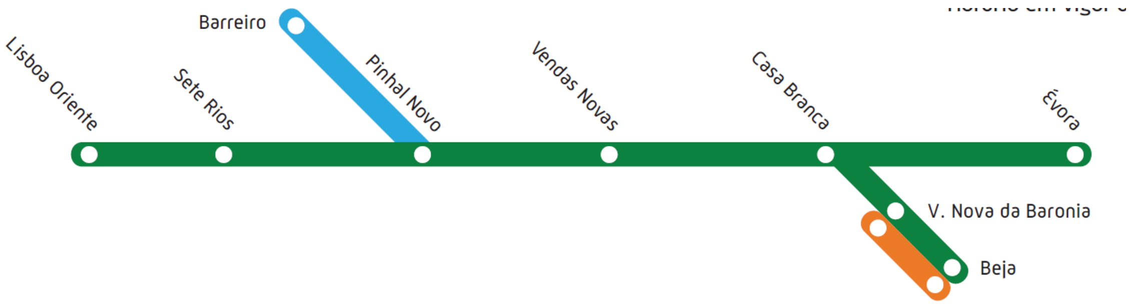
Train Timetables



Monday to Friday (Except Public Holidays)

Categoria Category	R REGIONAL	URBANO	IC	IC	URBANO	IC	IC	R REGIONAL	URBANO	IC	IC	URBANO	IC	IC
Número Number	4801	17205	590	581	17213	592	583	4805	17245	596	587	17253	598	589
Característica Characteristic	1							1						
Observações Remarks			[R]	[R]		[R]	[R]			[R]	[R]		[R]	[R]
Lisboa Oriente P			6:50			8:50				16:50			18:50	
Entrecampos			6:59			8:59				16:59			18:59	
Sete Rios			7:04			9:04				17:04			19:04	
Pragal			7:15			9:15				17:15			19:15	
Barreiro		6:55	|		8:55	|			16:55	|		18:55	|	
Pinhal Novo		7:13	|		9:13	|			17:13	|		19:13	|	
Pinhal Novo			7:38			9:38				17:38			19:38	
Poceirão			7:47			|				|			|	
Fernando Pó			7:52			|				|			|	
Pegões			7:57			|				|			|	
São João das Craveiras			8:01			|				|			|	
Vendas Novas			8:09			10:01				18:01			20:01	
Casa Branca C			8:22			10:14				18:14			20:14	
Casa Branca P			8:23			10:15				18:15			20:15	
Évora C			8:33			10:25				18:25			20:25	
Casa Branca P				8:28			10:19				18:21			20:19
Alcáçovas				8:36			10:27				18:29			20:27
Vila Nova da Baronia	7:08			8:48			10:38	13:29			18:43			20:38
Alvito	7:15			8:54			10:45	13:36			18:50			20:45
Cuba	7:25			9:05			10:55	13:46			19:00			20:55
Beja C	7:40			9:19			11:10	14:01			19:15			21:10

Train Timetables



Saturdays, Sundays and Public Holidays

Categoria Category	URBANO	IC	IC	URBANO	IC	IC	URBANO	IC	IC
Número Number	17215	594	585	17243	596	587	17251	598	589
Característica Characteristic									
Observações Remarks		R	R		R	R		R	R
Lisboa Oriente P		9:50			16:50			18:50	
Entrecampos		9:59			16:59			18:59	
Sete Rios		10:04			17:04			19:04	
Pragal		10:15			17:15			19:15	
Barreiro	9:25	|		16:25	|		18:25	|	
Pinhal Novo	9:43	|		16:43	|		18:43	|	
Pinhal Novo		10:38			17:38			19:38	
Poceirão		|			|			|	
Fernando Pó		|			|			|	
Pegões		|			|			|	
São João das Craveiras		|			|			|	
Vendas Novas		11:01			18:01			20:01	
Casa Branca C		11:14			18:14			20:14	
Casa Branca P		11:15			18:15			20:15	
Évora C		11:25			18:25			20:25	
Casa Branca P			11:19			18:21			20:19
Alcáçovas			11:27			18:29			20:27
Vila Nova da Baronia			11:38			18:43			20:38
Alvito			11:45			18:50			20:45
Cuba			11:55			19:00			20:55
Beja C			12:10			19:15			21:10

HOW TO CONNECT TO WIRELESS NETWORK:

1st STEP:

1- Enable **Wireless connection**

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

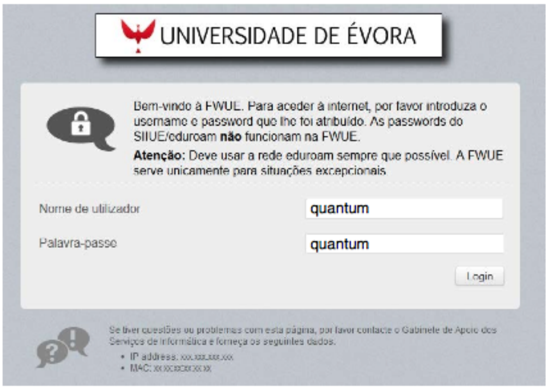
3- Configurations:

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.

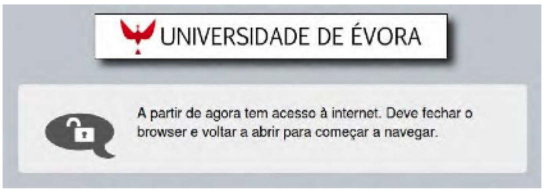
The first time you enter FWUE the Internet access is disabled. When trying to access any page will be redirected to the following page:



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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