Conference on Disorder and Correlations 2013

Program and Book of Abstracts

“Sapienza” University of Rome
Physics Department, Marconi Building, Aula Conversi
September 18-20, 2013

Organizers

M. Capone, S. Caprara, C. Di Castro, M. Grilli

Web:

http://discor2013.wordpress.com

Program

Wednesday, September 18

9:00 Opening

9:30 *Time cystals: can a diamagnetic current drive a charge density wave into rotation?*
Philippe Nozières, Institut Laue-Langevin, Grenoble

10:00 *Sub-ohmic two-level system representation of the Kondo effect and the Mott transition in infinite dimensions*
Michele Fabrizio, International School for Advanced Studies (SISSA), Trieste

10:30 *Kinetics of the disordered Bose gas with collisions*
Alexander Finkel’stein, Texas A&M University, College Station

11:00 Coffee Break

11:30 *Quantum Breathing of an Impurity in a One-dimensional Bath of Interacting Bosons*
Rosario Fazio, NEST and Scuola Normale Superiore, Pisa

12:00 *Tunnel-Fluctuoscopy: Fluctuation Induced Low-Bias Anomaly*
Andrey Varlamov, CNR-SPIN Rome

12:30 *Quantum control of a cuprate superconductor by impulsive stimulated Raman scattering*
Josè Lorenzana, CNR-ISC Rome
13:00-14:30 **Lunch**

14:30 *Magnetic Nanocontacts: Cute Physics in Tiny Places*
**Erio Tosatti**, International School for Advanced Studies (SISSA), Trieste

15:00 *Spin Current and Spin Seebeck Effect*
**Sadamichi Maekawa**, Advanced Science Research Center and CREST, Tokyo

15:30 *Structural metastability and high Tc superconductivity*
**Julius Ranninger**, Institut Neel, Grenoble

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16:30 *Coherent DC transport in biased Josephson trijunctions*
**Denis Feinberg**, Institut Neel, Grenoble

17:00 *Variations on the Spin Hall Effect in a Two-dimensional Electron Gas*
**Roberto Raimondi**, Roma 3 University, Rome

**Thursday, September 19**

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**Patrick Lee**, MIT Cambridge, MA

9:30 *Spectroscopic fingerprint of the interplay between the pseudogap, electron-boson coupling and superconductivity*
**Zhi-Xun Shen**, Stanford University, CA

10:00 *The Electronic Structure of Acceptors in Underdoped Cuprates*
**Maurice Rice**, ETH Zurich

10:30 *Charge nematicity in underdoped cuprate superconductors*
**Goetz Seibold**, Cottbus University

11:00 **Coffee Break**

11:30 *Iron Pnictides and Chalcogenides: doped Mott insulators, itinerant magnets or Hund's metals?*
**Gabriel Kotliar**, Rutgers University, Piscataway

12:00 *Superconductivity and charge bond order at the onset of spin-density-wave instability in a metal*
**Andrei Chubukov**, University of Wisconsin-Madison

12:30 *Leggett modes in iron-based superconductors as a probe of Time Reversal Symmetry Breaking*
**Lara Benfatto**, CNR-ISC, Rome

13:00-14:30 **Lunch**
14:30 *Superconductivity and Competing Order in the Two-Dimensional Hubbard Model*
**Walter Metzner**, Max Planck Institut for Solid State Research, Stuttgart

15:00 *Superconductivity and quantum phase transitions at oxide interfaces*
**Jérome Lesueur**, ESPCI, Paris

15:30 *Approaching an (unknown) phase transition in 2D*
**Sergey V. Kravchenko**, Northeastern University, Boston

**Friday, September 20**

9:00 *Statistical Physics of Compressed Sensing*
**Marc Mézard**, Ecole Normale Supérieure, Paris

9:30 *Mean field theory for glasses.*
**Giorgio Parisi**, “Sapienza” University of Rome

10:00 *New Metrics for Economic Complexity: Measuring the Intangible Growth Potential of Countries*
**Luciano Pietronero**, CNR-ISC and “Sapienza” University of Rome

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11:00 *Superfluidity of ultra cold atomic gases*
**Sandro Stringari** University of Trento and INO-CNR

11:30 *Disorder and interactions in low dimensional systems*
**Thierry Giamarchi**, University of Geneva

12:00 *Systematic investigation of the effects of disorder at the lowest order throughout the BCS-BEC crossover*
**Gian Carlo Strinati**, University of Camerino

12:30 – 14:00 *Lunch*

14:00 *Improper s-wave symmetry for the electronic pairing in iron-based superconductors*
**Sandro Sorella**, International School for Advanced Studies (SISSA), Trieste

14:30 *“Molecules” in solids and orbitally-selective Peierls transition*
**Daniel I. Khomskii**, University of Cologne

15:00 TBA
**Boris Altshuler**, Princeton University

15:30 TBA
**Claudio Castellani**, University Sapienza, Rome
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Abstracts

Wednesday, September 18

W1 9:30-10:00
Time crystals: can a diamagnetic current drive a charge density wave into rotation?

Philippe Nozieres
Institut Laue-Langevin, BP 156, 38042 Grenoble Cedex 9

It has been recently argued by Wilczek that an inhomogeneous system could rotate spontaneously in its ground state, hence a "time crystal" whose structure is periodic in time. Such a state would contradict the Ehrenfest theorem which precludes time dependence of any observable in a pure eigenstate. In order to clarify the physics behind that statement, we present a very simple model: a superfluid ring of charged particles threaded by a magnetic field, in which a charge density wave (CDW) appears spontaneously. An elementary calculation shows that the diamagnetic current does not drive rotation of the CDW, despite presence of non zero angular momentum.
Sub-ohmic two-level system representation of the Kondo effect and the Mott transition in infinite dimensions

Michele Fabrizio, Pier Paolo Baruselli, Rok Žitko.

1International School for Advanced Studies (SISSA), Via Bonomea 265, Trieste (Italy); 2Institut für Theoretische Physik, Technische Universität Dresden, 01062 Dresden, Germany; 3J. Stefan Institute, Jamova 39, SI-1000 Ljubljana (Slovenia)

It is well known that an Anderson impurity model in the local moment regime can be mapped onto a two-level system coupled to an ohmic bath, with the two levels representing the physical spin. We show that another mapping exists onto a two-level system coupled instead to a sub-ohmic bath, where the two levels represent now the charge degrees of freedom. In this new representation, the Kondo effect translates into the spontaneous breakdown of the local \( Z_2 \) symmetry associated to the two degenerate levels, which is indeed possible in the sub-ohmic regime.

When the same mapping is used to solve by DMFT a correlated lattice model in infinite dimensions, the outcome is that the correlated metal corresponds to a phase with spontaneous breaking of a \( Z_2 \) gauge-symmetry, which is actually possible in infinite dimensions, while the Mott transition signals the recovery of the symmetry in the insulating phase.

This result also enlightens why mean-field within the slave-boson representation and the Gutzwiller variational approaches seem to be particularly successful in describing correlated systems nearby a Mott transition.

References

W3 10:30-11:00
Kinetics of the disordered Bose gas with collisions

G. Schwiete ¹ and A. M. Finkel’stein ²,³

¹Dahlem Center for Complex Quantum Systems and Institut f"ur Theoretische Physik, Freie Universität Berlin;
²Department of Physics and Astronomy, Texas A&M University, College Station, Texas 77843-4242, USA,
³Department of Condensed Matter Physics, The Weizmann Institute of Science, 76100 Rehovot, Israel

I will discuss the relevance of interaction effects for the localization problem in the interacting disordered Bose gas. Based on calculations for the inter-particle scattering rates, we argue that if the number of particles is large enough the size of the expanding cloud may exceed the localization length. We describe the spreading of the wave packet in this regime as collision-induced diffusion. The obtained rate of expansion is consistent with the sub-diffusive spreading in non-linear disordered lattices observed in numerical simulations. A sub-diffusive spreading was also observed in an interacting cold atom system in the localized regime.

References
Quantum Breathing of an Impurity in a One-dimensional Bath of Interacting Bosons

Rosario Fazio
NEST, Scuola Normale Superiore and Istituto Nanoscienze-CNR, I-56126 Pisa, Italy (Italy)

By means of time-dependent density-matrix renormalization-group (TDMRG) we are able to follow the real-time dynamics of a single impurity embedded in a one-dimensional bath of interacting bosons. We focus on the impurity breathing mode, which is found to be well described by a single oscillation frequency and a damping rate. If the impurity is very weakly coupled to the bath, a Luttinger-liquid description is valid and the impurity suffers an Abraham-Lorentz radiation-reaction friction. For a large portion of the explored parameter space, the TDMRG results fall well beyond the Luttinger-liquid paradigm.

Electron tunneling spectroscopy pioneered by Esaki and Giaever offers a powerful tool for studying electronic spectra in superconductors. The phenomenological theory by Giaever and Megerle related the tunneling current to the electronic densities of states and to the difference of their equilibrium distribution functions in electrodes. This led to impressive discoveries having revealed, in particular, of the wide, pseudogap in the tunneling spectrum of superconductors above their critical temperatures.
However, it turns that this standard approach is insufficient to reveal the nontrivial, related to Andreev reflection of the tunneling electrons from superconducting fluctuation domains in the biased electrode, zero-bias anomaly carrying important information about the scattering, interactions, and decoherence.
Here, operating in frameworks of the microscopic theory of tunneling, we report the existence of a such low-energy singularity in a tunneling conductivity of $N$-$I$-$N(S)$ junction directly indicating on the presence of fluctuating Cooper pairs. Our findings mark a radical departure from the conventional picture of the ZBA and open new horizons for quantitative analysis of electronic spectra of superconductors in fluctuation regime.
Quantum control of a cuprate superconductor by impulsive stimulated Raman scattering

J. Lorenzana\textsuperscript{1}, B. Mansart\textsuperscript{2,3}, A. Mann\textsuperscript{2}, A. Odeh\textsuperscript{3}, M. Scarongella\textsuperscript{3}, M. Chergui\textsuperscript{3}, F. Carbone\textsuperscript{2}

\textsuperscript{1}ISC-CNR and Sapienza University of Rome, Piazzale Aldo Moro 2, 00185, Rome (Italy); \textsuperscript{2}Laboratory for Ultrafast Microscopy and Electron Scattering, ICMP, EPFL, CH-1015 Lausanne, Switzerland; \textsuperscript{3}Laboratory of Ultrafast Spectroscopy, ISIC, EPFL, CH-1015 Lausanne, Switzerland

It has been recently demonstrated that a pump pulse can generate coherent charge fluctuations in a superconductor through a stimulated Raman process\textsuperscript{1} paving the way to a new technique, Coherent Charge Fluctuation Spectroscopy (CCFS), to investigate pairing interactions and manipulate the superconducting wave function. We will present the basic phenomena involved and show how the technique bears a strong analogy with nuclear magnetic resonance (NMR) and electron paramagnetic resonance (EPR). The reflectivity of the system gets modulated by the coherent charge fluctuation of the condensate. A resonance at the Mott scale (2.6eV) allows to identify a high-energy excitation which is coupled to the superconducting quasiparticles which suggest that non-retarded interactions are involved in the pairing as suggested by unconventional theories of superconductivity\textsuperscript{2}.

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\item \textsuperscript{2}P. W. Anderson, Science 316, 1705 (2007).
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Nanoscale metal contacts through a bridging magnetic atom or molecule, including break junctions and STM tunneling, provide direct access to single impurity Kondo, whose spectral function is revealed by a bias dependent current anomaly. Unlike quantum dots, here the physics is controlled by atomic details, both geometric and electronic, demanding some kind of ab initio approach upon which the many body Kondo calculations could be grounded. I will first describe our previous density functional scattering approach to the ballistic conductance, and its quantitative success in non-Kondo magnetic junctions.\cite{1} Although their mean field character does not include Kondo, they can be put to work to build quantitative Anderson models of predictive quality. A first exercise – a Ni impurity in an Au nanowire -- reveals a dramatic geometry dependence.\cite{2} It also illustrates the circumstance leading to ferromagnetic Kondo screening, a phenomenology not yet experimentally pursued and which we propose for future search.\cite{2,3,4} Finally, we predict that even the simplest S=1/2 molecular radical, NO should lead to Kondo screening and an observable anomaly when adsorbed on Au surfaces -- a prediction strikingly confirmed by recent data by S. Modesti.\cite{5}

References

(*)In collaboration with P.P. Baruselli, M. Fabrizio, S. Modesti, R. Requist, A. Smogunov

\cite{1} A. Smogunov et al., Phys. Rev. B. 73, 075418 (2006).
\cite{2} P. Lucignano et al., Nat. Materials 8, 563 (2009).
\cite{3} P. Gentile et al., EPL 87, 27014 (2009).
\cite{5} R. Requist, S. Modesti, et al., to be published.
Spin Current and Spin Seebeck Effect

Sadamichi Maekawa,1,2
1Advanced Science Research Center, Japan Atomic Energy Agency, Tokai 319-1195 (Japan); 2CREST, Japan Science and Technology Agency, Tokyo 102-0075 (Japan)

When metals and semiconductors are placed in a temperature gradient, the electric voltage is generated. This mechanism to convert heat into electricity, the so-called Seebeck effect, has attracted much attention as the mechanism for utilizing wasted heat energy [1].

Ferromagnetic insulators are good conductors of spin current, i.e., the flow of electron spins [2]. When they are placed in a temperature gradient, generated are spin current and the spin voltage [3], i.e., spin accumulation. Once the spin voltage is converted into the electric voltage by the inverse spin Hall effect in attached metal films, the electric voltage is obtained from heat energy [4-5]. This is called the spin Seebeck effect (SSE).

Here, we present the basic concept of SSE [6] and discuss about SSE in a variety of magnetic systems.

References
W9 15:30-16:00
Structural metastability and high $T_c$ superconductivity

Julius Ranninger
Institut NEEL, CNRS and Université Joseph Fourier, BP 166, 38042 Grenoble-Cedex 9, France

Apart from their well established features of strongly correlated systems, High Temperature Superconductors, and specifically the cuprates, distinguish themselves by their dynamical local lattice instabilities. They are associated to stereo-chemical configurations, dynamically fluctuating between kinked Cu(II)-O-Cu(II) and straight Cu(III)-O-Cu(III) molecular bonds, making up the square CuO$_2$ planes, with corresponding Cu-O bond-lengths of 1.94 and 1.84 Angstroms. The parent phase of the superconducting cuprates -the pseudo-gap phase- can be envisaged as an ensemble of itinerant holes in a metastable crystalline structure in which polaronically self-trapped pairs of them start to pop in and out of existence below a certain temperature $T^*$. $T^*$, which designates the onset for resonant pairing, shows an experimentally established strong negative isotope effect. Modeling the self-induced dynamical disorder of such a scenario in terms of an effective Feshbach type local Boson-Fermion exchange coupling acting on molecular clusters, the spectral properties of the single-particle excitations are controlled by a competition between: (i) local phase correlation between momentarily self-trapped bound hole pairs and their itinerant counterpart of unbound pairs of holes passing momentarily through such deformable molecular clusters and (ii) the non-local phase correlation of such composite entities at different molecular clusters, arising from the quantum statistics of the bosonic components of the local molecular states. The bare itinerant holes, to start with, end up in this process as itinerant bound hole pairs, which drag along with them a dynamically coupled to them electron with opposite spin. These leads to a characteristic S-like shaped in-gap structure of the single-particle excitations, which join up the remnants of upper and lower Bogoliubov branches in a continuous way. Upon decreasing the temperature toward $T_c$, the spectral weight of the in-gap excitation gradually piles up near the Bogoliubov branches as precursors of a true superconducting phase.
Coherent DC transport in biased Josephson trijunctions

Denis Feinberg,1 Régis Mélin,1 Thibaut Jonckheere,2 Jérôme Rech,2 Thierry Martin,2 Benoît Douçot,3 Andreas Pfeffer,4 J. E. Duvauchelle,4 Hervé Courtois,1 and François Lefloch,4
1Institut Néel, CNRS and Grenoble University, Grenoble, France; 2CPT, CNRS and University Aix-Marseille, Marseille, France; 3LPTHE, CNRS and Paris 6 University, Paris, France; 4SPSMS/LaTEQS, CEA-INAC and Grenoble University, Grenoble, France.

The Josephson effect couples two superconductors by a weak link. At equilibrium (zero bias), DC phase-coherent Cooper pair transport is controlled by the junction phase. With a voltage bias, the AC Josephson effect appears together with DC subgap quasiparticle transport. Coexistence of DC pair and quasiparticle transport is possible only if the junction is irradiated by a suitable microwave field.

The present work instead considers novel devices (Trijunctions) where three superconductors are coupled together. New transport channels appear that considerably open the range of possible Josephson effects. Biasing independently two contacts, commensurate combinations of voltage lead to multipair resonances, where (at least two) pairs simultaneously cross the junction while conserving their energy [1]. At lowest order, those nonlocal quartets coexist as a phase-coherent DC channel, together with dissipative DC quasiparticle channels. Therefore, phase and voltage are independent control parameters for a DC quartet current. In addition, phase-sensitive DC quasiparticle currents are possible.

I will present theoretical results for trijunctions made of: i) tunneling contacts with arbitrary transparency; ii) quantum dots where a dramatic enhancement of the multipair resonances can be obtained by tuning the dot energies [2]; iii) metallic contacts. I will also present the first experimental results for long diffusive Aluminium-Copper trijunctions [3]. Strong resonances in the trijunction conductance when one contact is a zero voltage, and the others at V and -V, manifest for V well above the Thouless energy. This rules out phase locking of otherwise AC currents and points towards the quartet channel as a phase-coherent coupling of all three superconductors.

References

The spin Hall effect has emerged over the last decade as one of the most promising transport paradigm in spintronics. Perhaps, the main reason is due to the potential for an all-electrical control of the electron spin via the spin-orbit interaction. The latter, which arises as a consequence of the breaking of the inversion symmetry, may manifest in a number of ways, ranging from intrinsic bulk and structure inversion asymmetry as well as extrinsic effects due to impurities. After the initial discovery in semiconductors, the spin Hall effect has been reported also in various metallic systems and is also presently investigated in the two-dimensional electron gas existing at oxides interfaces.

In this paper, I will present various results concerning the spin Hall effect in a two-dimensional electron gas obtained over the last few years. In particular, I will show that, by using a SU (2) formulation, the different sources of spin-orbit interaction may be described in an elegant and unified way. Secondly, I will analyze the Onsager relations in the presence of SU(2) external potentials and their experimental implications. Thirdly, I will derive a general connection between the spin Hall effect and the associated spin-heat response, showing how the latter can be more efficient than the charge-heat one as a converter.

References
The quantum spin liquid is a state where magnetic order has been destroyed by quantum fluctuations. It has long been expected that the low energy excitations may be spinons which carry spin $\frac{1}{2}$ and emergent gauge fields. These excitations may be gapped or gapless. Recently several experimental candidates have been discovered. I shall discuss the theory and the experimental evidence and propose new experiments to probe these emergent excitations.
T2 9:30-10:00
Spectroscopic fingerprint of the interplay between the pseudogap, electron-boson coupling and superconductivity

Zhi-Xun Shen
Stanford University, 450 Serra Mall, Stanford, California 94305–2004, USA

In this talk, I will survey recent photoemission results from high temperature superconductors, focusing on the complex phase diagram and insights gained, in particular, the issue of pseudogap and its intertwined relationship with superconductivity. I will also discuss the issue of mode coupling and incipient charge order, and their relationship with pseudogap and superconductivity.
T3 10:00-10:30
The Electronic Structure of Acceptors in Underdoped Cuprates

Jia-Wei Mei¹, Alexey Soluyanov¹ & T.M. Rice¹²
¹Institute of Theoretical Physics, ETH Zurich Switzerland;
²Brookhaven National Labs. Upton NY USA.

In the most studied cuprate superconductors, e.g. La$_{2-x}$Sr$_x$CuO$_4$, the dopant acceptor lies close to a CuO$_2$ plane and a single hole enters the CuO$_2$ plane leading to a localized S=1/2 spin in the vicinity of the acceptor. This leads to magnetic inhomogeneity as well the charge inhomogeneity from the acceptor’s charge. NMR studies [1] on single layer Hg1201 however report a strongly reduced magnetic inhomogeneity. In Hg1201 the O-dopant enters the Hg layer halfway between CuO$_2$ planes so that the spins associated with holes moving in the two nearby CuO$_2$ planes are correlated with each other by super exchange through the O defect. The experimental fact that the magnetic inhomogeneity is suppressed relative to the charge channel suggests that the two holes form a singlet ground state. Recently, neutron scattering measurements by Li et al [2] reported two weakly-dispersive magnetic modes in Hg1201 and interpreted these two triplet modes as the fingerprint of circulating orbital currents in the CuO$_6$ octahedra. However, this scenario is challenged by recent NMR measurement on apical O-sites, where no static magnetic fields from circulating orbital currents were detected in Hg1201 [3]. This suggests that these two weakly dispersive magnetic excitations could be triplet excited states above the singlet ground state and motivates us to examine the spin correlations of the dopant holes around a O-defect. Joergensen et al[4] found that at underdoping the O-dopant is at a O(4) site which is displaced towards one of the Hg atoms to form a single strong Hg-O(4) bond ~2 Å in length. LDA calculations [5] show that the pair of holes associated with the O-dopant, are distributed between the Hg-O(4) antibonding state and the nearby pair of CuO$_2$ layers. We model the vicinity of the O-acceptor by a small cluster and find that superexchange in this cluster stabilizes a singlet groundstate with a pair of lower energy triplet excited states [6].

References
T4 10:30-11:00
Charge nematicity in underdoped cuprate superconductors

G. Seibold,1 C. Di Castro,2 M. Grilli,2 J. Lorenzana 2
1Institut für Physik, BTU Cottbus, PBox 101344, 03013 Cottbus (Germany);
2ISC-CNR, CNISM and Dipartimento di Fisica, University of Rome 'La Sapienza',
Piazzale Aldo Moro 2, 00185, Rome (Italy)

A low energy incommensurate spin response has been detected in many high-
temperature superconductors. Moreover, it is now possible in both LSCO and YBCO
materials to prepare samples with predominantly one twin domain of the
orthorhombic structure which allows to elucidate the symmetry of these magnetic
excitations in the copper oxygen planes. For example, in the LSCO system below the
doping concentration x=0.055 one finds a one-dimensional magnetic scattering along
the diagonal direction which is even static but the spin excitations become two-
dimensional at higher energies and approach those of the undoped antiferromagnet.
Contrary to the LaBaCuO and LaNdCuO compounds where the static
incommensurate spin modulation is due to the formation of charge stripes along the
CuO direction, no associated charge order has been found in the spin glass phase. In
order to explain this puzzling situation we propose a model where doping of holes
favors the formation of stripe segments which are composed of vortex-antivortex
pairs and constitute nematic seeds. The associated dipoles can be mapped to Ising
variables with orientation determined by the sign of the vorticity at the extremes.
Within the extended Hubbard model we find that the length and orientation of
segments is governed by the ratio between next-nearest and nearest neighbor hopping
and limited by the long-range Coulomb interaction. The influence of the structural
distortion and the interaction between segments leads to a charge nematic with ferro
orientation of the Ising variables. We show that this state implies an incommensurate
response in the spin channel which is in agreement with elastic neutron scattering
data from lanthanum cuprates in the spin-glass phase. Furthermore the spin dynamics
of a ferronematic can account for the crossover from one- to two-dimensional
magnetic fluctuations observed in these materials.

References
Iron Pnictides and Chalcogenides: doped Mott insulators, itinerant magnets or Hund's metals?

G. Kotliar
Rutgers University, Piscataway

Since the discovery of the iron based superconductors, there has been considerable discussion of the proper theoretical framework for describing these systems. In this talk we will review some experimental studies together with some LDA+DMFT results for these compounds, to outline a road to distinguish between these pictures.
Superconductivity and charge bond order at the onset of spin-density-wave instability in a metal

Andrey V Chubukov,
University of Wisconsin-Madison, 1150 University ave., Madison, WI 53706

We revisit the issue of superconductivity at the quantum-critical point (QCP) between a 2D paramagnet and a spin-density-wave metal with ordering momentum $(\pi, \pi)$. This problem is highly non-trivial because the system at criticality displays a non-Fermi liquid behavior and because the effective coupling constant for the pairing is generally of order one, even when the actual interaction is smaller than fermionic bandwidth. Perturbative studies have found that the renormalizations of the pairing vertex are stronger than in BCS theory and hold in powers of $\log^2 (1/T)$, like in color superconductivity. We analyze the full gap equation and argue that, for QCP problem, summing up of the leading logarithms does not lead to a pairing instability. Yet, we show that superconductivity has no threshold and appears even is the coupling is artificially set to be small. We discuss the interplay between contributions to superconductivity from fermions displaying Fermi-liquid and non-Fermi liquid behavior. We compare d-wave superconductivity with an instability towards d-wave charge bond order and show that the latter is a threshold problem. As a consequence, bond order only emerges below a certain doping. We discuss the scenario that a competition between superconductivity and bond order leads to a pseudogap behavior in hole-doped cuprates. We argue that there is no such effect at electron doping..

References
T7 12:30-13:00

Leggett modes in iron-based superconductors as a probe of Time Reversal Symmetry Breaking

M. Marciani,\textsuperscript{1} L. Fanfarillo,\textsuperscript{1,2} C. Castellani\textsuperscript{1} and L. Benfatto\textsuperscript{1}

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The discovery of superconductivity in pnictides in 2008 renewed the theoretical interest in the physics of multiband superconductors. Indeed, since the very beginning it has been proposed that a possible source of pairing in pnictides is a spin-fluctuation mediated repulsion between electron and hole bands located at different positions of the Brillouin zone. In this sense, pnictides would be very different from other multiband superconductors, as e.g. MgB\textsubscript{2}, where the pairing has a dominant intraband character. This has profound consequences in the physical response of these systems, as we emphasized e.g. in the evaluation of the Hall effect above T\textsubscript{c} [1]. In this talk I will address instead the consequences of the interband nature of the interaction for the behavior of the low-energy superconducting collective modes below T\textsubscript{c}. In particular the so-called Leggett-like phase mode changes drastically when pairing is provided by an interband mechanism, which leads to the coexistence of bonding and antibonding superconducting channels. Indeed, in the usual two-band description of pnictides the Leggett mode is absent, and it becomes allowed only when a three-band description including the repulsion between the two hole bands is included. This has interesting and profound consequences on the recent on-going discussion on the possible presence of a time-reversal-symmetry-breaking superconducting state in pnictides, since the existence of a massless Leggett mode becomes a distinct signature of such a phase.

References
Superconductivity and Competing Order in the Two-Dimensional Hubbard Model

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Using a recently developed renormalization group method for fermionic superfluids [1], we determine conditions for d-wave superconductivity in the ground state of the two-dimensional Hubbard model at moderate interaction strength, and we compute the pairing gap in the superconducting regime [2]. A pairing instability signaled by a divergent flow in the Cooper channel leads to a superconducting state in all studied cases. The next-to-nearest neighbor hopping t’ plays a crucial role in the competition between antiferromagnetism and superconductivity. A sizable t’ is necessary to obtain a sizable pairing gap. We also discuss the possibility of charge order with d-wave symmetry [3,4].

References
It has been shown that a two-dimensional electron gas (2DEG) forms at the interface between two insulators such as LaAlO$_3$ and SrTiO$_3$ [1], which is a superconductor [2]. We discovered that the interface between a Mott insulator (LaTiO$_3$) and a band insulator (SrTiO$_3$) is superconducting [3]. Thanks to magneto-resistance measurements at very high field, and a self-consistent modeling of the quantum well, we showed that superconductivity is intimately related to the presence of highly mobile carriers whose density can be modulated electrostatically [4].

The unique possibility of modulating the superfluid density continuously by simply tuning a gate voltage opens new perspectives to tackle fundamental issues in condensed matter physics. Here, we present the magnetic-field-driven quantum phase transition that occurs in electrostatically gated superconducting LaTiO$_3$/SrTiO$_3$ interfaces [5]. Through a finite-size scaling analysis, we show that it belongs to the (2+1)D XY model universality class. The system can be described as a disordered array of superconducting puddles coupled by a 2DEG and, depending on its conductance, the observed critical behaviour is single (corresponding to the long-range phase coherence in the whole array) or double (one related to local phase coherence, the other one to the array). Taking into account the two types of carriers described previously, a phase diagram illustrating the dependence of the critical field on the 2DEG conductance is constructed, and shown to agree with theoretical proposals [6]. Moreover, by retrieving the coherence-length critical exponent $\nu$, we show that the quantum critical behaviour can be clean or dirty according to the Harris criterion, depending on whether the phase-coherence length is smaller or larger than the size of the puddles.

The spin susceptibility of strongly correlated electrons in a low-disorder 2D electron system exhibits a sharp increase tending to a divergence at a finite electron density. Surprisingly, this behavior is due to the divergence of the effective mass rather than that of the $g$-factor. Our results provide clear evidence for an interaction-induced phase transition to a new phase that may be a precursor phase or a direct transition to the long sought-after Wigner solid.

Compressed sensing is a major new topic in information theory. Starting from the observation that interesting signals can be compressed, and thus are sparse in some representation, it aims at acquiring data directly in a compressed way, using then computational methods to reconstruct the original signal. It opens the way to faster, less destructive, and more effective signal acquisition, with possible applications in many branches of science, from magnetic resonance imaging to astronomy, tomography, or gene interaction network reconstruction.

The big challenge of compressed sensing is to be able to reconstruct faithfully the original signal -which can involve millions of variables- using the smallest possible number of measurements. Recent developments [1,2], using concepts and methods developed in the last fourty years in the statistical physics of disordered systems allow to understand the existence of reconstruction thresholds due to phase transitions, and to design new protocols which minimize the number of measurement where the phase transition occurs, going thus beyond standard approaches based on convex optimization.

The talk will review the basics of compressed sensing and describe the spectacular progress that can be made using various statistical physics ideas, from spin glass theory to crystal nucleation.

References
F2 9:30 – 10:00

**Mean field theory for glasses.**

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In this talk I will review some of the recent progresses that have been done in the mean field theory approach to glasses, using both the replica method and the mode coupling equations, stressing their mutual relations.

Many point will be addressed: the definition of complexity and the replica potential, the recently introduced realistic glasses models, the construction of effective action for glasses, the computation of the corrections to mean field theory and renormalization group computations.

References


New Metrics for Economic Complexity: Measuring the Intangible Growth Potential of Countries

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Abstract: Economic Complexity is a new line of research which portrays economic growth as an evolutive process of ecosystems of technologies and industrial capabilities. Complex systems analysis, simulation, systems science methods, and big data capabilities offer new opportunities to empirically map technology and capability ecosystems of countries and industrial sectors, analyse their structure, understand their dynamics and measure economic complexity. This approach provides a new perspective for data-driven new economic thinking. In particular here we discuss how it is possible to assess the competitiveness of country and complexity of products starting from the archival data on export flows. According to the standard economic theory the specialization of countries towards certain specific products should be optimal. The observed data show that this is not the case and that diversification is actually more important as in bio-systems.

The crucial challenge is therefore how to turn these qualitative observations into quantitative variables. We have introduced a new metrics for the Fitness of countries and the Complexity of products which corresponds to the fixed point of the iteration of two nonlinear coupled equations in the spirit of Google Page Rank algorithm. The information provided by the new metrics can be used in several ways. The comparison of the Fitness with the country GDP per capita gives an assessment of the non-expressed potential of growth of a country. This can be used as a predictor of GDP evolution or stock index and sectors performances. The global dynamic in the Fitness-Income Plane reveals, however, a large degree of heterogeneity which implies that countries can evolve with different level of predictability according to the specific zone of the Fitness-Income plane they belong to. When dealing with heterogeneous dynamics the usual tools of linear regressions become inappropriate. Making reliable predictions of growth in the context of economic complexity will then require a paradigm shift in order to catch the information contained in the complex dynamic patterns observed. These methods and concepts can give concrete contributions, as other possible applications, to risk analysis, investment opportunities analysis, policy-modelling of country growth and industrial planning.

References
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F4 11:00-11:30
Superfluidity of ultra cold atomic gases

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In the talk I will review the most recent theoretical and experimental advances in the study of superfluid phenomena in ultracold atomic gases. These include the dynamic behavior of superfluid gases confined in harmonic traps, the quenching of the moment of inertia, the structure of quantized vortices, the propagation of second sound at finite temperature and the determination of the superfluid density, the observation of the lambda transition and the new effects caused by spin-orbit coupling, like the emergence of rotons and of the stripe phase. Both Bose and Fermi superfluids will be considered.
Disorder and interactions in low dimensional systems

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The interplay between disorder and interactions is one of the most fascinating phenomena in quantum many body physics. This competition is particularly strong when dealing with one dimensional systems. Indeed in that case the disorder effects are at their maximum and for noninteracting particles lead to a localization of all states, while the interactions lead also to unusual states such as the Tomonaga-Luttinger liquid. I will discuss this physics focusing in particular on the case of bosonic systems. Indeed for bosons new experimental systems stemming both from condensed matter, with localized spins, and for cold atomic gases with realizations of bosons in a disordered or bichromatic potentials have been realized.
I will compare the theoretical predictions with experiments and discuss some of the open theoretical challenges.
A systematic investigation of the effects of disorder on the BCS-BEC crossover at the lowest order in the impurity potential is presented for the normal phase above the critical temperature $T_c$. Starting with the t-matrix approach for the clean system, by which pairing correlations between opposite-spin fermions evolve from the weak-coupling (BCS) to the strong-coupling (BEC) limits by increasing the strength of the attractive inter-particle interaction, \textit{all} possible diagrammatic processes are considered where the effects of a disordered potential are retained in the self-energy at the lowest order. An accurate numerical investigation is carried out for all these diagrammatic terms, to determine which of them are mostly important throughout the BCS-BEC crossover. Explicit calculations for the values of $T_c$ and chemical potential are carried out. In addition, the effect of disorder on the single-particle spectral function is analyzed, and a correlation is found between an increase of $T_c$ and a widening of the pseudo-gap at $T_c$ on the BCS side of unitarity in the presence of disorder, while on the BEC side of unitarity the presence of disorder favors the collapse of the underlying Fermi surface. The present investigation is meant to orient future studies when the effects of disorder will be considered at higher orders, with the purpose of limiting the proliferation of diagrammatic terms in which interaction and disorder are considered simultaneously.
Improper s-wave symmetry for the electronic pairing in iron-based superconductors

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By means of space-group symmetry arguments, we argue[1] that the electronic pairing in iron-based high temperature superconductors shows a structure which is a linear combination of planar s-wave and d-wave symmetry channels, both preserving the 3-dimensional A_{1g} irreducible representation of the corresponding crystal point-group. We demonstrate that the s- and d-wave channels are determined by the parity under reflection of the electronic orbitals through the iron planes, and by improper rotations around the iron sites.

We provide evidence of these general properties by performing accurate quantum Monte Carlo ab-initio calculations of the pairing function, for a FeSe lattice with tetragonal experimental geometry at ambient pressure.

Our theory can rationalize and explain a series of contradictory experimental findings, such as the observation of twofold symmetry in the FeSe superconducting phase, the anomalous drop of T_c with Co-impurity in LaFeAsO_{(1-x)}F_x, the s-to-d-wave gap transition in BaFe$_2$As$_2$ under K doping, and the nodes appearing in the LiFeAs superconducting gap upon P isovalent substitution.

References
Close to Mott transition several novel states can appear. In particular, “molecular clusters” can be formed in the solid, such as dimers, trimers, etc. In my talk I will illustrate such phenomena, especially dimer formation, on many examples (pyroxenes; La$_4$Ru$_2$O$_{10}$; Li$_2$RuO$_3$; M1 and M2 phases of VO$_2$; V and Cr hollandites). Several general conclusions will be drawn, e.g. that for ions with $S>1/2$ the dimers can be not only singlet, but also “ferromagnetic”. The concept of orbitally-selective Peierls transitions will be proposed and justified.