PARIS EDGE 2017

CUTTING-EDGE TOPICS IN QUANTUM MATERIALS

OCTOBER 16-19, 2017 - ESPCI PARIS

INTERNATIONAL CONFERENCE

- UNCONVENTIONAL SUPERCONDUCTORS
- METALS WITH REMARKABLE TRANSPORT PROPERTIES
- TOPOLOGICAL PHASES
- NON-EQUILIBRIUM PHYSICS IN CORRELATED MATERIALS

INVITED SPEAKERS

Adriano Amaricci – SISSA, Trieste
James Analytis - UC Berkeley
Kamran Behnia – ESPCI Paris
Nicolas Bergeal – ESPCI Paris
Andrei Bernevig* – Princeton
Silke Biermann – Ecole Polytechnique
Anna Boehmer – Ames Lab
Anthony Carrington – U. Bristol
Andrey Chubukov – U. Minnesota
Piers Coleman – Rutgers
JC Seamus Davis – Cornell
Michele Fabrizio – SISSA, Trieste
Yann Gallais – U. Paris Diderot
Antoine Georges* – Collège de France
Claudio Giannetti - U. Cattolica Brescia
Fréderic Hardy – KIT, Karlsruhe
Masatoshi Imada – U. Tokyo
Aharon Kapitulnik – Stanford
Marino Marsi – U. Paris Sud
Jernej Mravlje – Jozef Stefan, Ljubljana
Takashi Oka – MPI Dresden
Cathérine Pepin - CEA Saclay
Suchitra Sebastian – Cambridge
Greg Stewart – U. Florida
Matthew D. Watson – Diamond
Philipp Werner – U. Fribourg

**to be confirmed*

ORGANIZING COMMITTEE
Luca de' Medici – ESPCI Paris
Massimo Capone – SISSA Trieste
Benoit Fauqué – ESPCI Paris
Marco Schirò – CNRS @ CEA Saclay

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PARIS EDGE 2017

Organising Committee :

- **Luca de' Medici (ESPCI, Paris)**
- **Massimo Capone (SISSA, Trieste)**
- **Benoit Fauqué (ESPCI paris and Collège de France)**
- **Marco Schirò (CNRS and CEA saclay)**

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Secretary : Marie-France Mariotto (LPS, U. Paris-Sud)

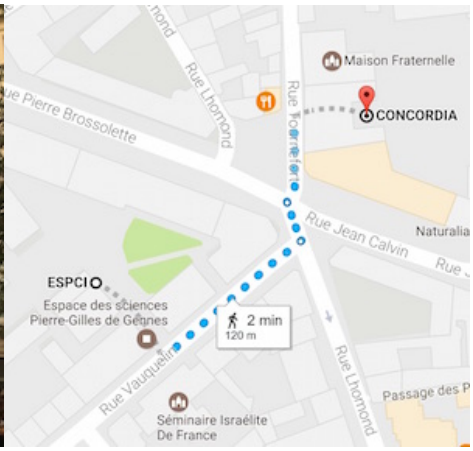
The conference will be held in the :

Ecole Supérieure de Physique et Chimie Industrielles de la Ville de Paris (ESPCI), 10 rue Vauquelin, 75005 Paris:

Conference sessions will be held in the Amphithéatre Langevin, Building N, 2nd floor

Coffee breaks will take place in the Salle Champetier, Building N, ground floor

Lunches and the poster session/aperitif will be hosted in the Espace Concordia (41 rue Tournefort) just outside ESPCI, entrance from the small nearby Place Lucien-Herr (map)



Wednesday October 18th, 19:00 :

The conference dinner (by invitation or optional reservation only) will be hosted in the panoramic restaurant "Ciel de Paris", located on the 56th floor of the Tour Montparnasse, with one of the most dramatic views of the city of Paris.

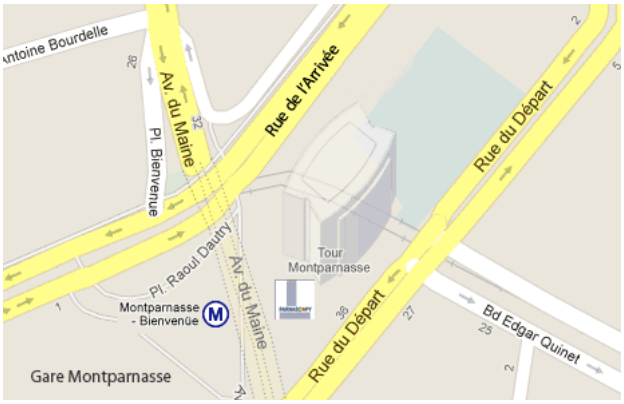
Restaurant Le ciel de Paris

Tour Montparnasse 56ème étage
33 avenue du Maine
75015 Paris

Restaurant access**: lift « Le ciel de Paris » at ground floor of Tour Montparnasse**

Accès Métro/RER

Métro : Station « Montparnasse-Bienvenue » ligne 4,6,12,13
Bus : Ligne 28,58,82,88,89,91,92,94,95,96
Parking
Rue du Départ ou rue de l'Arrivée 4e sous sol - zone C, puis accès par l'extérieur à l'entrée principale de la Tour (sortir côté rue de l'Arrivée)



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Program

	MON 16/10	TUE 17/10	WED 18/10	THU 19/10
08:30	registration			
08:50	opening			
09:00	JC Davis	Fabrizio	Behnia	Bernevig
09:35	Biermann	Marsi	Kapitulnik	Coleman
10:10	Andersen	Mazza	Fratini	Carpentier
10:30	Lafuerza	Aguiar	Humbert	Plucinski
10:50	coffee break			
11:30	Watson	Oka	Mravlje	Amaricci
12:05	Analytis	Giannetti	Bergeal	Bibes
				Perkins
12:40	Drechsler	Peronaci	Marrache	Vivek
13:00	lunch			
14:30	Stewart	Bohmer	Chubukov	
15:05	Carrington	Gallais	Pepin	
15:40	coffee break			
16:20	Imada	Hardy	Georges	
16:55	Werner	Fanfarillo	Taillefer	
17:15		Paul	Jeong	
17:35	Poster-aperitif	Walmsley		
19:00			Conference Dinner	

Monday, October 16th

8 :50 – 9 :00 : Opening and Welcome

SESSION 1 – chair: D. Roditchev (ESPCI-Paris)

9 :00 – 9 :35 : **J.C. Séamus Davis (**Cornell University) *Visualizing Orbital-Selective Mottness & Superconductivity*

9 :35 – 10 :10 : **Silke Bierman** (Ecole Polytechnique) *TBA*

10 :10 – 10 :30 : **Brian Andersen** (U. Copenhagen) *Theoretical studies of orbital selective pairing*

10 :30 – 10 :50 : **Sara Lafuerza** (ESRF Grenoble) *Evidence of Mott physics in hole-doped $BaFe_2As_2$ from x-ray emission and absorption spectroscopies*

10 :50 – 11 :30 : COFFEE BREAK

SESSION 2 – chair: K. van der Beek (Ecole Polytechnique)

11 :30 – 12 :05 : **Matthew D Watson** (Diamond / St. Andrews) *The effects of nematic order on the electronic structure of FeSe*

12 :05 – 12 :40 : **James Analytis** (UC Berkeley) *Transport properties of unconventional superconductors in extreme magnetic fields and the possible role of quantum criticality*

12 :40 – 13:00 : **Stefan-L. Drechsler** (IFW Dresden) *Constraints on the coupling to low-energy bosons in Fe based superconductors - van Hove singularities as a convenient measure of the strength of the el-el interaction*

13 :00 – 14 :30 : LUNCH BREAK

SESSION 3 – chair: H. Alloul (U. Paris-Sud)

14 :30 – 15 :05 : **Greg R. Stewart** (University of Florida) *Common Themes in Unconventional Superconductors?/$U_{1-x}Th_xBe_{13}$ in Detail*

15 :05 – 15 :40 : **Antony Carrington** (University of Bristol) *Pressure tuning of CDW state in cuprates*

15 :40 – 16 :20 : COFFEE BREAK

SESSION 4 – chair: H. Alloul (U. Paris-Sud)

16 :20 – 16 :55 : **Masatoshi Imada** (University of Tokyo) *Superconductivity and inhomogeneity in and out of equilibrium*

16 :55 – 17 :30 : **Philipp Werner** (University of Fribourg) *Electronic order in light-driven materials*

17:35 – 19:30 : **POSTER SESSION** WITH APERITIF

Tuesday, October 17th

SESSION 5 – chair: M. Schirò (CEA-Saclay)

9 :00 – 9 :35 : **Michele Fabrizio** (SISSA, Trieste) *Cooling quasiparticles in A_3C_{60} fullerides by excitonic mid-infrared absorption*

9 :35 – 10 :10 : **Marino Marsi** (University Paris Saclay) *Ultrafast evolution of a prototype out-of-equilibrium Mott-Hubbard material*

10 :10 – 10 :30 : **Giacomo Mazza** (Ecole Polytechnique) *From Sudden quench to adiabatic dynamics in the attractive Hubbard model*

10 :30 – 10 :50 : **Maria Carolina Aguiar de Oliveira** (U. Minas Gerais) *Spinon and bound-state excitation light cones in Heisenberg XXZ chains*

10 :50 – 11 :30 : COFFEE BREAK

SESSION 6 – chair: R. Lobo (ESPCI-Paris)

11 :30 – 12 :05 : **Takashi Oka** (Max Planck, Dresden) *Control of Quantum Matter by Floquet Engineering*

12 :05 – 12 :40 : **Claudio Gianetti** (Universitá Cattolica del Sacro Cuore, Brescia) *Ultrafast orbital manipulation and Mott physics in superconducting copper oxides*

12:40 – 13:00 : **Francesco Peronaci** (CEA-Saclay) *Strong correlations in the transient dynamics of driven lattice quantum systems*

13 :00 – 14 :30 : LUNCH BREAK

SESSION 7 – chair: M. Capone (SISSA - Trieste)

14 :30 – 15 :05 : **Anna Böhmer** (Ames Laboratory) *Interplay of nematicity, magnetism and superconductivity in FeSe*

15 :05 – 15 :40 : **Yann Gallais** (Université Paris Diderot*) Nematic fluctuations and criticality in unconventional superconductors*

15 :40 – 16 :20 : COFFEE BREAK

SESSION 8 – chair: B. Andersen (U. Copenhagen)

16 :20 – 16 :55 : **Frédéric Hardy** (Karlsruher Institut für Technologie, Karlsruhe) *Nodal Superconductivity and Strong Fluctuations in FeSe single crystals*

16 :55 – 17 :15 : **Laura Fanfarillo** (SISSA Trieste) *Orbital Selectivity: exploring the phase diagram of Iron Based Superconductors*

17:15 – 17:35 : **Indranil Paul** (CNRS/U. Diderot) *Lattice Effects on Nematic Quantum Criticality in Metals*

17:35 – 17:55 : **Philip Walmsley** (Stanford University) *Evidence of incoherent carriers associated with resonant impurity levels and their influence on superconductivity in the anomalous superconductor Pb1-xTlxTe*

Wednesday, October 18th

SESSION 9 – chair: J. Lesueur (ESPCI-Paris)

9 :00 – 9 :35 : **Kamran Behnia** (ESPCI, Paris) *Thermal transport in strontium titanate*

9 :35 – 10 :10 : **Aharon Kapitulnik** (Stanford University) *Thermal diffusivity in Strongly Correlated Oxides*

10 :10 – 10 :30 : **Simone Fratini** (CNRS/Néel) *The anderson transition in deformable lattices and the puzzle of Mooij correlat*ions

10 :30 – 10 :50 : **Vincent Humbert** (U. Illinois) *Disorder-Induced Metallic Phases in NbSi Thin Films*

10 :50 – 11 :30 : COFFEE BREAK

SESSION 10 – chair: K. Behnia (ESPCI-Paris)

11 :30 – 12 :05 **: Jernej Mravlje** (Jozef Stefan Institute, Ljubljana) *DMFT insights to incoherent transport in strongly correlated metals*

12 :05 – 12 :40 : **N**. **Bergeal** (ESPCI Paris) *Superfluid stiffness in oxide interfaces*

12:40 – 13:00 : **Claire Marrache-Kikuchi** (CNRS/U. Paris-Sud) *Crossover from impurity-controlled to granular superconductivity in* $(TMTSF)_2ClO_4$

13 :00 – 14 :30 : LUNCH BREAK

SESSION 11 – chair: L. Taillefer (U. Sherbrooke)

14 :30 – 15 :05 : **Andrey V Chubukov** (*University of Minnesota*) *The origin of the orbital order in Fe-superconductors: is FeSe special?*

15 :05 – 15 :40 : **Cathérine Pepin** (CEA-Saclay) *Topology and the Pseudo-Gap state of the Cuprates*

15 :40 – 16 :20 : COFFEE BREAK

SESSION 12 – chair: Y. Uemura (Columbia)

16 :20 – 16 :55 : **Antoine Georges** (Collège de France) *Closing the gaps in our understanding of the pseudogap*

16 :55 – 17 :15 : **Louis Taillefer** (Université de Sherbrooke) *The quantum critical point of cuprate superconductors*

17:15 – 17:35 : **Jaehong Jeong** (LLB, CEA-Saclay) *Time-reversal symmetry breaking hidden order in* $Sr_2(Ir,Rh)O_4$

19:00 CONFERENCE DINNER (upon invitation or optional reservation only)

Thursday, October 19th

SESSION 13 – chair: M. Gabay (U. Paris-Sud)

9 :00 – 9 :35 : **B. Andrei Bernevig** (Princeton University) *Topological Quantum Chemistry*

9 :35 – 10 :10 : **Piers Coleman** (Rutgers University) SmB_6*: Skyrme insulator on the brink of superconductivity?*

10 :10 – 10 :30 : **David Carpentier** (ENS Lyon) *Ballistic Transport, Quantum Fluctuations and the Chiral Anomaly of Weyl Fermions*

10 :30 – 10 :50 : **Lukasz Plucinski** (FZ Juelich) *Band structure engineering in 3D topological insulators*

10 :50 – 11 :30 : COFFEE BREAK

SESSION 14 – chair: P. Coleman (Rutgers)

11 :30 – 12 :05 : **Adriano Amaricci** (SISSA, Trieste) *Strong Correlation Effects in Topological Quantum Phase Transitions*

12 :05 – 12 :25 : **Manuel Bibes** (CNRS/Thales) *Giant topological Hall effect from magnetic skyrmion bubbles in correlated manganite thin films*

12:25 – 12:45 : **Natalia Perkins** (U. Minnesota) *Probing spinon nodal structures in three-dimensional Kitaev spin liquids*

12:45 – 13:05 **: Manali Vivek** (U. Paris-Sud) *Orbital Control of functionalities in 3d Perovskite Oxides*

POSTER SESSION on Monday 16th, 17:35 – 19:30

Please send to the conference email address or bring on a USB key to the organizers 1-2 slides for a flash presentation to be held during the session

Invited Talks

Strong Correlation Effects in Topological Quantum Phase Transitions

A. Amaricci[1], M. Capone[1], G. Sangiovanni[2], J. Budich[3] , B.Trauzettel[2]

[1] **Scuola Internazionale Superiore di Studi Avanzati (SISSA), Via Bonomea 265, 34136 Trieste, Italy**
[2] **Institut für Theoretische Physik und Astrophysik, Universität Würzburg, Am Hubland, D-97074 Würzburg, Germany**
[3] **Institute for Theoretical Physics, University of Innsbruck and Institute for Quantum Optics and Quantum Information, Austrian Academy of Sciences, 6020 Innsbruck, Austria**

Topological Quantum Phase Transitions (TQPT) are characterized by changes in global topological invariants, beyond the conventional paradigm of local order parameters. The recent progress in identifying topological states in strongly correlated compounds and hetero-structures, pushed attention to the effects of the electronic interaction in TIs.

Here, we demonstrate that interaction can change the conventional portrait of TQPT[1-3]: we uncover a topological transition of first-order character occurring for strong enough interaction. Our study reveals the existence of a quantum critical endpoint, associated with an orbital instability, on the transition line between a TI and a trivial insulator[1,2]. We show that the conventional paradigm of continuous TQPT breaks down: The change of the topological invariants takes place without energy gap closing but preserving the symmetries protecting the topological phase.

Finally, we address the fate of the helical edge states in TIs showing that Time-Reversal Symmetry (TRS) opposes to the strong interaction effects via edge states reconstruction mechanism[4]: The progressive penetration of the edge states into the bulk. We show that this process survives the presence of anti-ferromagnetic ordering[5].

References

1. **Amaricci, J. C. Budich, M. Capone, B. Trauzettel and G. Sangiovanni, Phys. Rev. Lett. 114, 185701 (2015)**
2. **Amaricci, J. C. Budich, M. Capone, B. Trauzettel and G. Sangiovanni, Phys. Rev. B 93, 235112 (2016)**
3. **Roy, P. Goswami, and J. D. Sau, Phys. Rev. B 94, 041101(R) (2016)**
4. **Amaricci, G. Sangiovanni, L. Privitera, J. C. Budich, M. Capone and B. Trauzettel, in preparation (2017)**
5. **Amaricci, J. C. Budich, M. Capone and B. Trauzettel, in preparation (2017)**

Transport properties of unconventional superconductors in extreme magnetic fields and the possible role of quantum criticality

Ian M. Hayes[1,2], Nikola Maksimovic[1,2], Ross D. McDonald[3], Nicholas P. Breznay[1,2], and James G. Analytis[1,2]

[1] Department of Physics, University of California, Berkeley, California 94720, USA.
[2] Materials Science Division, Lawrence Berkeley National Laboratory, Berkeley, California 94720, USA.
[3] Los Alamos National Laboratory, Los Alamos, New Mexico 87545, USA

Many exotic metallic systems have a resistivity that varies linearly with temperature, and it is thought that the physics behind this is connected to the mechanism behind high-temperature superconductivity in the cuprates and iron pnictides. Although this phenomenon has attracted considerable attention, it is unclear how the relevant physics manifests in other transport properties, for example their response to an applied magnetic field. We report measurements of the high-field magnetoresistance and Hall effect some exotic superconductors and find an unusual relationship between how field and temperature affect the transport of these systems. Our data suggests that magnetic fields probe the same physics that gives rise to the T-linear resistivity, providing a new experimental clue to this long-standing puzzle [1]

References

M. Hayes et al. Nature Physics 12, 916–919 (2016)

Dilute metallicity and superconductivity in strontium titanate

Xiao Lin, Carl Willem Rischau, Clément Collignon, Benoît Fauqué and Kamran Behnia

LPEM-ESPCI, PSL research University, 10 Rue Vauquelin, 75005 Paris France

Oxygen-deficient strontium titanate is the most dilute superconductor currently known. Its superconducting critical temperature shows a non-monotonic evolution with the change in carrier density [1]. The persistence of superconductivity in the dilute limit, its possible connection with ferroelectric instability [2] and its disappearance when carrier concentration exceeds two percent remain open questions up to this date.

Is electrical resistivity decreases by several orders of magnitude upon cooling and follows a T2 behavior in the low-temperature limit, as expected in a Fermi liquid [3]. Above 100 K, extraction the quasi-particle mean-free-path from Drude conductivity yields a distance shorter than the electron wave-length and the interatomic distance [4]. Thus, strontium titanate becomes a strange or bad metal well below room temperature and its resistivity cannot be accounted for by electron-phonon scattering à la Bloch–Grüneisen. Providing an account of this observation emerges as a challenge to theory.

References

X. Lin et al., Phys. Rev. Lett. 112, 207002 (2014).
C. W. Rischau et al. Nature Physics, 13, 643 (2017).
X. Lin, B. Fauqué & K. Behnia, Science 349, 945 (2015).
X. Lin et al. npj Quantum Materials 2:41 (2017).

Superfluid stiffness in oxide interfaces

G. Singh[1,2] , A. Jouan[1,2] , L. Benfatto[3,4] , F. Couedo[1,2] , P. Kumar[5] , A. Dogra[5] , R. Budhani[6] , S. Caprara[4,3] , M. Grilli[4,3] , E. Lesne[7] , A.Barthélémy[7] , M. Bibes[6] , C. Feuillet-Palma[1,2] , J. Lesueur[1,2] , N. Bergeal[1,2]

[1] **Laboratoire de Physique et d'Etude des Matériaux, ESPCI Paris, PSL Research University, CNRS, 10 Rue Vauquelin - 75005 Paris, France.**
[2] **Université Pierre and Marie Curie, Sorbonne-Universités,75005 Paris, France.**
[3] **Institute for Complex Systems (ISC-CNR), UOS Sapienza, Piazzale A. Moro 5, 00185 Roma, Italy**
[4] **Dipartimento di Fisica Universita di Roma\La Sapienza", piazzale Aldo Moro 5, I-00185 Roma, Italy.**
[5] **National Physical Laboratory, Council of Scientific and Industrial Research (CSIR) Dr. K.S. Krishnan Marg, New Delhi-110012, India.**
[6] **Condensed Matter Low Dimensional Systems Laboratory, Department of Physics, Indian Institute of Technology, Kanpur 208016, India.**
[7] **Unité Mixte de Physique CNRS-Thales, 1 Av. A. Fresnel, 91767 Palaiseau, France.**

The large diversity of exotic electronic phases displayed by two-dimensional superconductors confronts physicists with new challenges. In LaAlO3/SrTiO3 heterostructures, a gate tunable superconducting electron gas is confined in a quantum well at the interface between two insulating oxides1. Remarkably, the gas coexists with both magnetism2 and strong Rashba spin-orbit coupling3. However, both the origin of superconductivity and the nature of the transition over the entire doping range remain elusive4. We will present resonant microwave transport experiments that enable to extract the superfluid stiffness and the superconducting gap energy of the LaAlO3/SrTiO3 interface as a function of carrier density. In (001)-oriented interface, we show that the phase diagram of the system is controlled by the competition between electron pairing and phase coherence4. The analysis of the superfluid density also reveals that only a very small fraction of the electrons condenses into the superconducting state, which we relate to the filling of specific orbitals in the interfacial quantum well. In (110)-oriented interface, we observe a crossover between single-band to two-band superconductivity driven by electrostatic doping.

References

A. D. Caviglia et al. Nature 456, 624 (2008).
J. Bert, et al. Nature Phys. 7, 767771 (2011).
A. D. Caviglia et al. Phys. Rev. Lett. 104, 126803 (2010).
C. Richter et al. Nature 502, 528531 (2013).
G. Singh et al, arXiv:1704.03365

Topological Quantum Chemistry

B.A. Bernevig[1]

[1] **Princeton University**

The past decade has seen tremendous success in predicting and experimentally discovering distinct classes of topological insulators (TIs) and semimetals. We review the field and we propose an

electronic band theory that highlights the link between topology and local chemical bonding, and combines this with the conventional band theory of electrons. Topological Quantum Chemistry is a description of the universal global properties of all possible band structures and materials, comprised of a graph theoretical description of momentum space and a dual group theoretical description in real space. We classify the possible band structures for all 230 crystal symmetry groups that arise from local atomic orbitals, and show which are topologically nontrivial. We show how our topological band theory sheds new light on known TIs, and demonstrate the power of our method to predict a plethora of new TIs.

TBA

Silke Biermann[1]

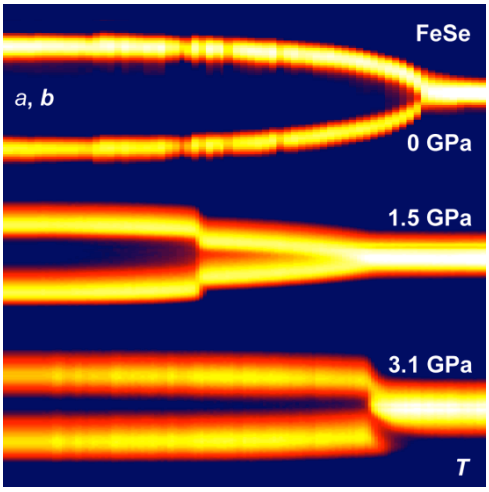
[1] **Ecole Polytechnique**

Interplay of nematicity, magnetism and superconductivity in FeSe

Anna E. Böhmer[1]

[1] **Ames Laboratory, USDOE, Ames, IA, 50011, USA**

Stripe-type antiferromagnetic order is a common ground state in iron-based materials. It necessarily entails an orthorhombic distortion of the tetragonal crystal structure. Superconductivity in these systems typically emerges when magnetic order is sufficiently suppressed via chemical substitution or application of external pressure. In some materials, an orthorhombic distortion without magnetic order (the “nematic” phase) is found and, in a few cases, “C4”-type antiferromagnetic order exists in a tetragonal lattice. FeSe is well-known for its orthorhombic phase in the absence of magnetic order at ambient pressure, which could be considered an extreme case of the nematic phase. We studied the orthorhombic distortion and the ordered magnetic hyperfine field of single-crystalline FeSe under pressure. The orthorhombic distortion is found to couple cooperatively to pressure-induced magnetism in an intermediate pressure range [1]. On the high-pressure side, evidence for a break-down of this coupling is found. Similarities between FeSe and the (electron-and hole-doped) prototypical iron-based superconductor $BaFe_2As_2$ are discussed.



Orthorhombic in-plane lattice parameters, *a* and *b*, of FeSe as a function of temperature, *T*, at three differrent pressures.

References

K. Kothapalli*, A. E. Böhmer*, W. T. Jayasekara, B. G. Ueland, P. Das, A. Sapkota, V. Taufour, Y. Xiao, E. E. Alp, S. L. Bud'ko, P. C. Canfield, A. Kreyssig and A. I. Goldman, Nature Communications 7, 12728, (2016).

This work was supported by the Department of Energy, Basic Energy Sciences, Division of Materials Sciences and Engineering, under Contract No. DE-AC02-07CH11358.

Pressure tuning of CDW state in cuprates

Antony Carrington[1]

[1] **HH Wills Physics Laboratory, University of Bristol, Bristol, England.**

In the underdoped cuprates, both incommensurate charge density wave (CDW) order and the pseduogap phase are known to exist in the same part of the phase diagram as superconductivity. It has been conjectured that fluctuations in either or both of these may be a contributing factor towards the high temperature superconductivity. An increase in effective mass suggestive of a quantum critical point has been observed close to optimal doping [1] which is also close the end point of the CDW and psedogap phases. Also, a dip in T_c at doping (p) close to 0.12 suggests that static CDW order may suppress superconductivity.

Here I will review our experiments to investigate the evolution of the properties of cuprates with hydrostatic pressure. In $YBa_2Cu_4O_8$ (Y124) we found that as maximal T_c is approached using pressure the effective mass measured by quantum oscillations decreases [2], in sharp contrast to the doping studies. The experiments suggest that pressure stabilises the CDW and thus reduces fluctuations. This is further supported by high field (B=37T) measurements of the Hall coefficient (R_H) of $YBa_2Cu_3O_{7-d}$ (Y123) with doping 0.11 at high pressures. Here we find almost no change in the sign changing temperature dependence of R_H, again suggesting that pressure does not affect the CDW and thus the dip in T_c at doping 0.12 is not caused by the CDW.

References

1- B. J. Ramshaw et al. Science 348, 317 (2015).
2- C. Putzke et al. Science Advances 2, e1501657 (2016).

The origin of the orbital order in Fe-superconductors: is FeSe special?

Andrey V Chubukov

University of Minnesota

Magnetism and nematic order are the two non-superconducting orders observed in iron-based superconductors. To elucidate the interplay between them and ultimately unveil the pairing mechanism, several models have been investigated. In models with quenched orbital degrees of freedom, magnetic fluctuations promote stripe magnetism which induces orbital order. In models with quenched spin degrees of freedom, charge fluctuations promote spontaneous orbital order which induces stripe magnetism. I will discuss our RG-based approach, in which we treat

magnetic and orbital fluctuations on equal footing. Key to our approach is the inclusion of the orbital character of the low-energy electronic states into renormalization group analysis. Our results show that in systems with large Fermi energies, such as BaFe2As2, LaFeAsO, and NaFeAs, orbital order is induced by stripe magnetism. However, in systems with small Fermi energies, such as FeSe, the system develops a spontaneous orbital order, while magnetic order does not develop. I further discuss recent results on d-wave nematic susceptibility in the limit of zero momentum and a finite frequency and compare the results with Raman data on NaFeAs and FeSe. I argue that for the first material, the data are consistent with the magnetic scenario for nematicity, but for FeSe the data are well described within orbital (d-wave charge Pomeranchuk) scenario.

References

A. V. Chubukov, M. Khodas, and R.M. Fernandes, Phys. Rev. X 6, 041045 (2016).
A. Klein et al, arXiv:1708.05308

SmB_6: Skyrme insulator on the brink of superconductivity?

Piers Coleman

Center for Materials Theory, Rutgers University

SmB6, an ultra-narrow gap insulator discovered more than 50 years ago, poses a paradox. On the one hand, current theory and some experiments indicate that SmB6 is likely a topological insulator. On the other hand, this system has been long known to display a large bulk linear specific heat[1,2] and recent dHvA measurements[3] suggest that it contains a Fermi surface which responds to the Lorentz force, but is insulating. Optical measurements also reveal that this insulator is an AC conductor, with a large ingap ac conductivity and also exhibits a thermal conductivity that is proportional to the applied field[4], a feature reminiscent of an unpinned vortex lattice. These paradoxical results, if true, suggest an very unusual kind of insulator [5,6,7].

I'll argue that the apparent presence of a Fermi surface of nominally neutral quasiparticles which nevertheless respond to a Lorentz force requires broken Gauge invariance, which normally would imply superconductivity. This leads us to propose the concept of a "Skyrme insulator"[6]: a condensate

with a Meissner stiffness which is nevertheless topologically unable to support the quantization of circulation.

The Skyrme insulator theory allows us to understand the linear specific heat of SmB$_{6}$ in terms of a neutral Majorana Fermi sea, and the theory predicts that in a screened environment at below fields of order a Gauss, SmB$_{6}$ will develop a Meissner effect[6].

References

[*]Work done in collaboration with Onur Erten, Po-Yao Chang and Alexei Tsvelik, supported by US Department of Energy Grants FG02-99ER45790 and DE-AC02-98CH10886.
[1]K. Flachbart, M. Reiffers, and S. Janos, Journal of Less Common Metals 88, L11 (1982).
[2]N. J. Laurita, et al, Phys. Rev. B 94, 165154 (2016).
[3]B. S. Tan, et al, Science 349, 287 (2015).
[4]S. Sebastian et al. 2016 APS March meeting, Nature Physics in press (2017).
[5]Ganputhy Baskaran, 1507.03477 (2015).
[6]Onur Erten, Po-Yao Chang, Piers Coleman and Alexei Tsvelik, Phys. Rev. Lett. 119, 057603 (2017).
[7] Debanjian Chowdury, Inti Sodemann, T. Senthil, 1706.00418 (2017).

Visualizing Orbital-Selective Mottness & Superconductivity

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In Cu-based HTS materials, the undoped phase is a robust Mott insulator while, in Fe-based HTS materials, the undoped phase is generally not an insulator. Thus, proximity to a Mott insulator appears neither indispensable nor universal to HTS. However, theory has long indicated that Fe-based materials could still be governed by strong electronic correlations proximate to a Mott insulator if an orbital selective Mott phase (OSMP) exists.

One signature of OSMP would be orbital selective Cooper pairing, where electrons of a specific orbital character predominantly form the Cooper pairs. We developed orbital-resolved STM electronic

visualization techniques and revealed that, in superconducting FeSe, the Cooper pairing is orbital selective predominantly for the Fe-dyz orbitals (1).

A second signature of OSMP would be orbital-dependent coherence in the normal state band structure. To check this, we visualize quasiparticle scattering interference resolved by orbital content in the FeSe normal state. The QPI data reveal strong orbitally selective differences between quasiparticle weight Z_m values associated with specific Fe orbitals (2). Moreover, these are comparable to the Z_m deduced independently from the properties of the orbital selective Cooper pairing (1).

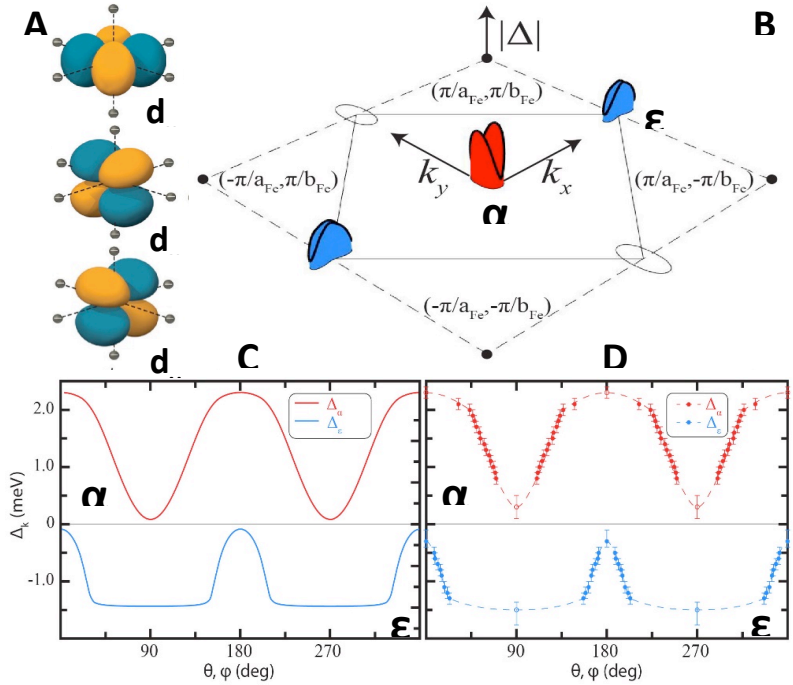

Figure 1A The three active d-orbitals on each Fe atom. B. Measured momentum space structure $D_i(k)$ of superconducting energy gaps of FeSe C. Theoretically predicted angle dependence of $\Delta_\alpha(k)$; $\Delta_\varepsilon(k)$ in FeSe if Cooper pairing predominantly occurs for electrons in d_{yz} orbitals. D. Measured $\Delta_\alpha(k)$; $\Delta_\varepsilon(k)$ in FeSe.

References

Sprau P. O. *et al.* Discovery of Orbital-Selective Cooper Pairing in FeSe.*Science 357,* 75 (2017)

Kostin, A, *et al.* Visualizing Orbital-Selective Quasiparticles in FeSe *to appear PNAS* (2017)

Cooling quasiparticles in A_3C_{60} fullerides by excitonic mid-infrared absorption

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A fresh inroad in the ever-surprising physics of alkali-doped fullerides has been the behavior under intense infrared (IR) impulse excitation. Signatures attributable to a transient superconducting state extending up to temperatures ten times higher than the equilibrium $T_c \sim 20K$ have been discovered [1] in K_3C_{60} after ultra-short pulsed IR irradiation. Motivated by the observation that the phenomenon is observed in a broad pumping frequency range that coincides with the mid-infrared electronic absorption peak still of unclear origin, we advance here a radically new mechanism [2]. First, we argue that this broad absorption peak represents a "super-exciton" involving the promotion of one electron from the t_{1u} half-filled state to a higher-energy empty t_{1g} state, dramatically lowered in energy by the large dipole-dipole interaction acting in conjunction with the Jahn-Teller. Both long-lived and entropy-rich because they are triplets, the IR-induced excitons act as a sort of cooling mechanism by absorbing thermally excited quasiparticle-quasihole spin-triplet excitations, which permits transient superconductive signals to persist up to much larger temperatures.

References

M. Mitrano et al. "Possible light-induced superconductivity in K3C60 at high temperature", Nature 530, 461 (2016)
A. Nava, C. Giannetti, A. Georges, E. Tosatti, and M. Fabrizio, unpublished (2017) https://arxiv.org/abs/1704.05613

Nematic fluctuations and criticality in unconventional superconductors

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The spontaneous appearance of nematicity, a state of matter that breaks rotation but not translation symmetry, is ubiquitous in many iron based superconductors (Fe SC), and may have relevance for the cuprates as well. Here I will review recent electronic Raman scattering experiments which report the presence of critical electron nematic fluctuations in the tetragonal phase of several Fe SC systems [1,2,3]. I will focus in particular on the compound FeSe where the effect of both chemical (isovalent substitution with of Se with S) and physical pressure on nematic degrees of freedom have been studied [4, 5]. I will discuss in particular the possible relevance of nematic quantum criticality in enhancing T_c. I will also present recent results on the cuprate Bi2212, where similar charge fluctuations are observed near the end-point of the pseuddopap, in the overdoped regime. I will however highlight key differences with regards to the nematic fluctuations observed in Fe SC, and assess their link with the pseudogap phase.

References

[1] Y. Gallais et al. Phys. Rev. Lett. 111, 267001 (2013)
[2] Y. Gallais and I. Paul, C. R. Phys. 17, 133 (2016)
[3] Y. Gallais et al. Phys. Rev. Lett. 116, 017001 (2016)
[4] P. Massat at al. PNAS 113, 9177 (2016)
[5] P. Massat et al., D. Farina et al. submitted

Closing the gaps in our understanding of the pseudogap

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2 Flatiron Institute – CCQ, Simons Foundation, New York

In this talk, I will review recent theoretical progress in understanding the pseudogap phenomenon in the two-dimensional Hubbard model, in relation to hole-doped cuprate superconductors. I will show that two independent computational methods (cluster extensions of dynamical mean-field theory, and lattice diagrammatic Monte Carlo) yield quantitatively consistent results. These two methods indicate that short-range antiferromagnetic correlations are responsible for the opening of the pseudogap in the strong-coupling regime. The Fermi surface is strongly modified by interactions, and a pseudogap only opens when this surface is hole-like. For small to moderate ratios of t'/t, the collapse of the pseudogap is found to coincide with the Lifshitz transition of the Fermi surface from hole-like to electron-like, in agreement with experimental observations. These findings can be rationalized within an SU(2) gauge theory of a metal with short-range fluctuating antiferromagnetic order, in which topological order is responsible for the reconstruction of the Fermi surface into pockets.

This talk is based on collaborations with Wei Wu, Michel Ferrero, Evgeny Kozik, Matthias Scheurer, Shubhayu Chatterjee and Subir Sachdev.

Ultrafast orbital manipulation and Mott physics in superconducting copper oxides

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The short-range interactions among the electrons occupying the copper and oxygen orbitals represent the universal underlying mechanism of many exotic properties of copper oxides, such as the intrinsic nanoscale electronic inhomogeneity, the ubiquitous antinodal pseudogap and the onset of high-temperature superconductivity. Recently, the use of ultrashort light pulses has been introduced as a "non-conventional" control parameter [1] to transiently manipulate the electronic occupation of the Cu-3d and O-2p orbitals and investigate the fundamental interactions that drive the relaxation towards the correlated ground state.

Here I will review the most recent discoveries obtained via the ultrafast manipulation of the orbital occupation in cuprates. I will show the existence of a high-temperature crossover at optimal doping between the physics of a doped Mott insulator to that of a more coherent metal [2,3]. Finally, I will briefly discuss the possibility of using ultrashort pulses to non-thermally quench the phase coherence of the superconducting condensate [4].

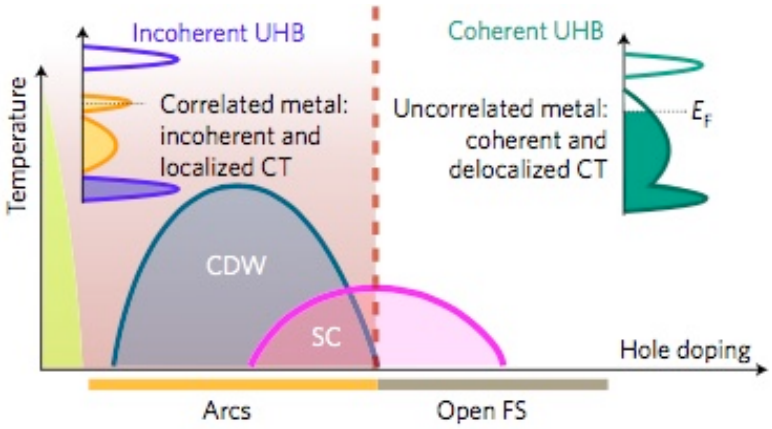

Figure 1: Cartoon of the non-equilibrium *p–T* phase diagram of copper. The pink, blue and green areas delimit the superconducting (SC) dome, the charge-ordered (CDW) state and the antiferromagnetic insulator, respectively

References

C. Giannetti et al., "Ultrafast optical spectroscopy of strongly correlated materials and high-temperature superconductors: a non-equilibrium approach" Advances in Physics 62:2, 58-238 (2016).
S. Peli et al., "Mottness at finite doping and charge instabilities in cuprates" Nature Physics 13, 806-811 (2017).
F. Cilento et al., "Dynamics of correlation-frozen antinodal quasiparticles in superconducting cuprates". Available at arXiv:1703.03877.
F. Boschini et al., "Collapse of high-Tc superconductivity via ultrafast quenching of the phase coherence". Available at arXiv:1707.02305.

Nodal Superconductivity and Strong Fluctuations in FeSe single crystals

Frédéric Hardy [1], Minqguan He [1], Liran Wang [1], Thomas Wolf [1],Robert Eder [1], Peter Schweiss [1], Michael Merz [1], and Christoph Meingast [1]

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We present a comprehensive study of the thermodynamics (heat capacity, thermal expansion and magnetization) of FeSe single crystals grown in different conditions. In the cleaner crystals, we found strong evidence for the existence of lines of nodes in agreement with a '*s*+*d*'-wave superconducting ground state. The inferred average value of the energy gaps are in excellent agreement with recent BQPI/STM measurements. The impact of disorder is also discussed. In magnetic field, we found evidence for the existence of strong superconducting fluctuations and we re-examine the (H,T) phase diagram of FeSe.

Title:Superconductivity and inhomogeneity in and out of equilibrium

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Severe competition of superconductivity and spatial charge inhomogeneity including stripe and phase separation is a long-standing issue of correlated electron systems. Emergent effective attraction of carriers generated from Coulomb repulsion leading to charge/spin stripe or inhomogeneous ground states competing with uniform superconducting excited states is a universal phenomenon and the competition occurs in the energy scale of 10 K at realistic parameters for cuprate superconductors [1-3]. Such competition generates a mechanism that dramatically enhances the superconductivity accompanied by Higgs oscillation away from equilibrium by irradiating laser [4]: First, the effective attractive interaction of carriers is enhanced by the dynamical localization, which drives the system into strong coupling regions. Secondly, the irradiation allows reaching enhanced superconductivity dynamically stabilized without deteriorating into equilibrium inhomogeneity that suppresses superconductivity.

References

1. **H.-H. Zhao, K. Ido, S. Morita, M. Imada, Phys. Rev. B 96, 085103 (2017).**
2. **K. Ido, T. Ohgoe, M. Imada, unpublished.**
3. **M. Hirayama, Y. Yamaji, T. Misawa, M. Imada, arXiv:1708.07498.**
4. **K. Ido, T. Ohgoe, M. Imada, Sci. Adv. 3, e1700718 (2017).**

Thermal diffusivity in Strongly Correlated Oxides

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Transport in non-quasiparticle regimes requires a new framework and has become a subject of intense theoretical and experimental efforts in recent years. In particular, the diffusivity (electrical and/or thermal) was singled out as a key observable for incoherent non-quasiparticle transport, possibly subject to fundamental quantum mechanical bounds. Following a review of previous experimental results on bad metallic behavior, we will introduce new results on transport in strongly correlated electron systems with strong electron-phonon interaction. These results suggest that when neither well-defined electron nor phonon quasiparticles are present, thermal transport exhibits a collective `soup-like' behavior of strongly coupled electrons and phonons characterized by a diffusion constant $D \sim v_S^2 \tau$, where $v_S$ is the characteristic `soup' velocity, and scattering of both electrons and phonons thermal relaxation time saturates at a quantum rate $\tau \sim \hbar / k_B T$ [1].

References

[1] J.-C. Zhang, E. M. Levenson-Falk, B. J. Ramshaw, D. A. Bonn, R. Liang, W. N., Hardy, S. A. Hartnoll, A. Kapitulnik, PNAS 114 (21), 5378 (2017).

Ultrafast evolution of a prototype out-of-equilibrium Mott-Hubbard material

G. Lantz[1,2], B. Mansart[1], D. Grieger[3], D. Boschetto[4], N. Nilforoushan[1], E. Papalazarou[1], N. Moisan[1], L. Perfetti[5], V.L.R. Jacques[1], D. Le Bolloch[1], C. Laulhé[6,7], S. Ravy[1,6], J.-P. Rueff[6], T.E. Glover[8], M.P. Hertlein[8], Z. Hussain[8], S. Song[9], M. Chollet[9], M. Fabrizio[3] and M. Marsi[1]

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The study of photoexcited strongly correlated materials is attracting growing interest since their rich phase diagram often translates into an equally rich out-of-equilibrium behavior. With femtosecond optical pulses, electronic and lattice degrees of freedom can be transiently decoupled, giving the opportunity of stabilizing new states inaccessible by quasi-adiabatic pathways. The prototype Mott-Hubbard material V2O3 presents a transient non-thermal phase developing immediately after ultrafast photoexcitation and lasting few picoseconds. Recent results on this model system will be presented, combining different ultrafast techniques (time-resolved photoemission, reflectivity, and FEL-based X-ray diffraction), and corroborated by a theoretical interpretation [1]

For both the insulating and the metallic phase, the formation of the transient configuration is triggered by the excitation of electrons into the bonding a1g orbital, and is then stabilized by a lattice distortion characterized by a hardening of the A1g coherent phonon, in stark contrast with the softening observed upon heating. These results show the importance of selective electron-lattice interplay for the ultrafast control of strongly correlated materials.

References

1. **G. Lantz et al., Nature Communications 7, 13917 (2017)**

DMFT insights to incoherent transport in strongly correlated metals

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The electronic transport is one of the most poorly understood aspects of strongly correlated electron systems. The resistivity is often found at large temperatures to exceed the Mott-Ioffe-Regel (MIR) value that corresponds to a scattering event every lattice spacing.

We investigated this bad-metallic regime for a doped Mott insulator using the dynamical mean-field theory (DMFT) and high-temperature expansion approaches. The DMFT equations are solved using the state-of-the art quantum-Monte-Carlo and numerical renormalization group methods. The consistency between the obtained results demonstrates their accuracy. Along resistivity we calculated also the single-particle spectral functions and the charge compressibility. When resistivity exceeds the MIR value, the quasiparticles melt and one enters into a regime in which the scattering rate (diffusion constant) saturate and the carrier density (charge compressibility) drops as 1/T. In this regime characterized by T-linear resistivity, the bad-metal is somewhat similar to a doped semiconductor dominated by the temperature evolution of the carrier number rather than the scattering.

I will discuss the relevance of the results for the behavior found in real materials and optical lattices and critically compare them against other theoretical approaches.

References

E. Perepelitsky, A. Galatas, J. Mravlje, R. Zitko, E. Khatami, B. S. Shastry, and A. Georges; Phys. Rev. B 94, 235115 (2017).
X. Deng, J. Mravlje, R. Zitko, M. Ferrero, G. Kotliar, and A. Georges, Phys. Rev. Lett. 110, 086401 (2013)..

Control of Quantum Matter by Floquet Engineering

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Realizing new quantum states in solid state materials is of fundamental interest. I will explain several ideas based on Floquet engineering, i.e., control of quantum states by time periodical external fields.

(1) Control of topology by circularly polarized laser (CPL)

By applying CPL to materials such as 2D, 3D Dirac semimetals and Mott insulators, one can transform them into Floquet Chern insulator, Floquet Weyl semimetal [1], and even induce scalar chirality [2].

(2) Landau quantization in oscillating magnetic fields [3]

We studied the one particle dynamics of non-relativistic electrons in oscillating magnetic fields. To our surprise, we found that the Floquet quasi-energy becomes flat, as in Landau quantization, when the ratio between the cyclotron and the field frequencies takes a magic number. We also found that the

heterodyne response, i.e., frequency shifted linear relation between the input electric field and output current, becomes quantized for the Hall component.

This work has been done in collaboration with Leda Bucciantini, Sota Kitamura, and Sthitadhi Roy.

References

L. Bucciantini, S Roy, S Kitamura, T Oka, Phys. Rev. B 96, 041126 (2017)
S. Kitamura, T. Oka, H. Aoki, Phys. Rev. B 96, 014406 (2017)
T. Oka, L. Bucciantini, Phys. Rev. B 94, 155133 (2016)

Topology and the Pseudo-Gap state of the Cuprates

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The Pseudo-Gap state in under-doped cuprates remains the key mystery for the understanding of those compounds. Recently, a new concept has been introduced, that this state of matter could be controlled by topology. In this talk we review the two main forms of topological states, in real and momentum space that are specific to quantum matter. We show how each of them can account in a different way for the phase diagram of the cuprates, and in particular the under doped region between the Mott insulator at very low oxygen doping, and the metallic state at high doping. We then describe how skyrmions can emerge in the pseudo-spin space, related to an emerging SU(2) symmetry, and argue that proliferation of such skyrmions can account for a number of experimental properties of the pseudo-gap phase

Common Themes in Unconventional Superconductors?/$U_{1-x}Th_xBe_{13}$ in Detail

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Although there are at least nine classes of seemingly disparate unconventional superconductors (UcS), in fact there are a number of fundamental similarities amongst these materials. Recently, an attempt was made[1] to compare all UcS with the goal of pointing out commonalities. A number of the characteristics that determine unconventional (i. e. not electron-phonon mediated) superconductivity will be reviewed, with an overview of how these various properties compare between the nine classes. As an example, the properties of the superconductors in the $U_{1-x}Th_xBe_{13}$ phase diagram will be considered and intercompared, with statements made about the type of superconductivity vs x.

References

G. R. Stewart, Advances in Physics 66, 75 (2017) http://dx.doi.org/10.1080/00018732.2017.1331615

The effects of nematic order on the electronic structure of FeSe

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The appearance of high-temperature superconductivity in the Fe-based superconductors is likely to be linked to the other ordered states found in their phase diagrams. Certain systems, including FeSe, exhibit an unusual `nematic' phase where fourfold symmetry of the lattice is spontaneously broken without long-range magnetic order. Angle-resolved photoelectron spectroscopy (ARPES) measurements of FeSe give a unique insight into the electronic structure in the nematic phase. Here I will argue that our high-resolution ARPES results obtained on twinned samples [1,2] which trace the evolution of the Fermi surface with temperature point towards a “unidirectional nematic bond ordering”. I will additionally present ARPES results on ``detwinned” FeSe crystals [3], revealing a remarkable anisotropy which is hidden in measurements of twinned samples: only the electron pocket oriented along the longer orthorhombic axis is observed by ARPES.

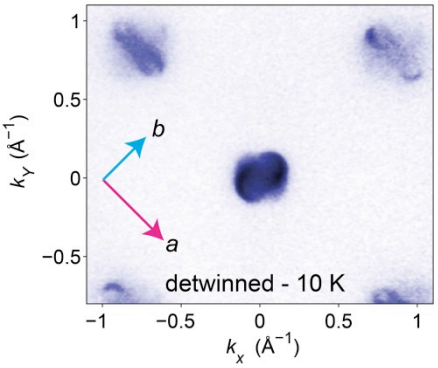

Figure 1: ARPES measurement of the low temperature Fermi surface of FeSe in a “detwinned” sample [3].

References

M. D. Watson et al. “Evidence for unidirectional nematic bond ordering in FeSe”, Phys. Rev. B 94, 201107(R) (2016)

M. D. Watson et al. “Shifts and Splittings of the Hole Bands in the Nematic Phase of FeSe”, J. Phys. Soc. Jpn. 86, 053703 (2017)

M. D. Watson et al. “Electronic anisotropies revealed by detwinned ARPES measurements of FeSe” , to appear, New Journal of Physics, (2017) arXiv:1705.02286

Electronic order in light-driven materials

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The prospect of nonequilibrium control of material properties has caught the interest of the condensed matter community. In particular, recent experiments demonstrating a light-enhanced superconducting-like state in cuprates and fulleride compounds or enhanced gaps in excitonic insulators have triggered theoretical studies on order parameter dynamics in photo-doped or phonon-driven lattice systems.

We use time-dependent mean-field theory and nonequilibrium dynamical mean field theory to simulate symmetry-broken states in light-driven systems. In particular, we consider parametric phonon driving in the Holstein model [1], and show that despite an effective strengthening of the electron-phonon coupling, the nonthermal energy distribution in the driven state generically leads to a weakening of the superconducting order.

As a second example, we study the order parameter dynamics in an excitonic insulator after photo-excitation [2]. We find that the combination of photo-induced Hartree shifts and the massive phase mode induced by electron-phonon coupling results in an enhancement of the order and the gap, in good agreement with time-resolved photoemission measurements [3].

References

Y. Murakami, N. Tsuji, M. Eckstein and P. Werner, Phys. Rev. B 96, 045125 (2017)
Y. Murakami, D. Golez, M. Eckstein, and P. Werner, arXiv:1707.07706
S. Mor et al., Phys. Rev. Lett. 119, 086401 (2017)

Contributed Talks

Theoretical studies of orbital selective pairing

Brian M. Andersen[1], Andreas Kreisel[2], Peter J. Hirschfeld[3,4], Peter O. Sprau[3,4], Andrey Kostin[3,4], J. C. Seamus Davis[3,4]

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After a brief overview of recent experimental evidence for orbital selectivity (OS) in the iron-based superconductors, I will outline our theoretical framework for including OS in the pairing kernel of these materials. This theory consists of modified spin-fluctuation generated pairing which includes renormalized quasiparticles renormalized spin susceptibilities by the orbital-dependent quasi-particle weights, Z-factors. The proposed theory allows for very good description of the superconducting gap in materials such as LiFeAs, FeSe, and FeSe/STO. In the second part of the talk, I will discuss our recent progress in extending this theory to understand the pairing in other systems, and I will discuss the quantitative details of the Z-factors, and how they depend on interactions and, for example, the existence of nematicity in some of these systems

References

1. **Andreas Kreisel, Brian M. Andersen, P. O. Sprau, A. Kostin, J. C. Séamus Davis, and P. J. Hirschfeld, Orbital selective pairing and gap structures of iron-based superconductors, Phys. Rev B 95, 174504 (2017)**
2. **P. O. Sprau, A. Kostin, A. Kreisel, A. E. Boehmer, V. Taufour, P. C. Canfield, S. Mukherjee, P. Hirschfeld, B. M. Andersen, J. C. Seamus Davis, Discovery of Orbital-Selective Cooper Pairing in FeSe, Science 357, 75 (2017).**

Giant topological Hall effect from magnetic skyrmion bubbles in correlated manganite thin films

L. Vistoli[1], Wenbo Wang[2], A. Sander[1], Qiuxiang Zhu[1], B. Casals[3], R. Cichelero[3], A. Barthélémy[1], S. Fusil[1], G. Herranz[3], Weida Wu[2], V. Garcia[1] and M. Bibes[1]*

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Strong electronic correlations can produce remarkable phenomena such as metal-insulator transitions and greatly enhance superconductivity, thermoelectricity, or optical non-linearity[1]. In correlated systems, spatially varying *charge* textures also amplify magnetoelectric effects or electroresistance in mesotructures. However, how non-coplanar *spin* textures may influence electron transport in the presence of correlations remains unclear. In this talk we will demonstrate a very large topological Hall effect (THE)[2,3] in thin films of a lightly electron-doped manganite. Magnetic force microscopy reveals the presence of magnetic bubbles, whose density *vs.* magnetic field peaks near the THE maximum, as is expected to occur in skyrmion systems[4]. The THE critically depends on carrier concentration and diverges at low doping, near the metal-insulator transition. We will discuss the strong amplification of the THE by correlation effects and give perspectives for its non-volatile control by electric fields.

References

[1] **M. Imada, A. Fujimori, Y. Tokura, *Rev. Mod. Phys.* 1998, *70*, 1039.**
[2] **N. Nagaosa, Y. Tokura, *Nature Nanotech.* 2013, *8*, 899.**
[3] **P. Bruno, V. K. Dugaev, M. Taillefumier, *Phys. Rev. Lett.* 2004, *93*, 96806.**
[4] **N. Kanazawa, M. Kubota, a. Tsukazaki, Y. Kozuka, K. S. Takahashi, M. Kawasaki, M. Ichikawa, F. Kagawa, Y. Tokura, *Phys. Rev. B* 2015, *91*, 41122.**

Ballistic Transport, Quantum Fluctuations and the Chiral Anomaly of Weyl Fermions

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The so-called chiral anomaly denotes the non-conservation of chirality of quantum relativistic massless fermions. Quite remarkably it was shown recently to be tightly related to the anomalous positive magneto-conductance of Weyl semi-metals. Here we study the magneto-conductance of such a Weyl semi-metal but in a short junction in which transport is ballistic. Hence the conductance depends solely on the number of conducting channels of the junction. In the presence of a magnetic field, this conductance fluctuates, manifesting the quantum fluctuations of the density of states. However, for a short enough junction or at high enough temperature, a monotonously increasing conductance is recovered : this is an unambiguous manifestation of the chiral anomaly in this ballistic regime. Moreover we show that the semi-classical description of transport, used recently to capture the Weyl anomaly in diffusive conductors, is unable to describe the anomalous low magnetic field behavior of ballistic Weyl junctions.

Spinon and bound-state excitation light cones in Heisenberg XXZ chains

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We investigate the out-of-equilibrium dynamics after a local quench that connects two spin-1/2 XXZ chains prepared in the ground state of the Hamiltonian in different phases, one in the ferromagnetic phase and the other in the critical phase. We analyze the time evolution of the on-site magnetization and bipartite entanglement entropy via adaptive time-dependent density matrix renormalization group. In systems with short-range interactions, such as the one we consider, the velocity of information transfer is expected to be bounded, giving rise to a light-cone effect. Interestingly, our results show that, when the anisotropy parameter of the critical chain is sufficiently close to that of the isotropic ferromagnet, the light cone is determined by the velocity of spin-wave bound states that propagate faster than single-particle ("spinon") excitations. [This work is published as Physical Review B **95**, 045125 (2017).]

Constraints on the coupling to low-energy bosons in Fe based superconductors – van Hove singularities as a convenient measure of the strength of the el-el interaction

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Although the Fe-based superconductors (FeSC) were discovered ten years ago, there is still no consensus on the relevant microscopic pairing mechanism(s) and main interactions involved. Also a consistent interpretation of their normal state properties is still lacking. Especially the strength of the *el-el* interaction and correlation effects are under debate. Here, we examine several materials and illustrate various problems and concepts that are generic for all FeSC. Based on empirical observations and qualitative insight from DFT, we show that the superconducting (SC) and normal

state properties of the FeSC can be described semi-quantitatively within multiband MIGDAL-ELIASHBERG theory. We account for the large high-energy mass renormalization (MR) phenomenologically and a moderate low-energy bosonic MR, in accord with constraints provided by thermodynamic, optical, and ARPES data. When seen in this way, most FeSCs with T_c < 40~K, studied so far, are found to belong to an *intermediate* coupling regime at odds with the strong coupling scenarios suggested in the early period of the FeSC history. Strong coupling scenarios might be relevant near quantum critical points (QCP) like in P doped Ba122 and near LIFSHITZ transitions. The support of SC by intraband *el-ph* coupling or *el-orbital fluctuations* [11 and phonon anomalies [2,3] are briefly addressed, too.

We discuss the band shifts [4] as counter parts of the high-energy MR measured conveniently by the positions of VAN HOVE singularities (VHS) and compare them with available slave boson and DMFT calculations from the literature as well as the nature of a suggested QCP [5] in the *h*-overdoped systems AFe_2As_2 (A=K, Rb, Cs). Using high-precision full relativistic GGA-calculations for the total DOS at $E_{F,}$, we arrive at a milder MR for Cs122 and the *same* MR for K122 and Rb122 at variance with other studies. The importance of the spin-orbit coupling is supported by GW-calculations [4]. We stress the anomalous behavior of the WILSON ratio in these compounds and the lacking correlation between the maximum of the spin susceptibility $\chi(T)$ and the hole doping ratio x in overdoped $Ba_{1-x}K_xFe_2As_2$ systems. From the calculated mass anisotropies of all Fermi surface sheets, only the ε-pocket near the corner of the BZ is compatible with the observed anisotropy of the upper critical field H_{c2}, pointing to its dominant role in the SC of these three systems. At high fields only that band survives as evidenced by a *single*-band elliptical angular mass anisotropy [6]. Finally, a general doping phase diagram shown in Fig. 1 is proposed. The QCP slightly below the 0.5 hole doping is ascribed to the vicinity of an orthorhombic stripe-phase triggered by the d_{xz} /d_{yz} derived VAN HOVE singularity close to E_F (at -14.5 meV for KFe_2As_2 (K122) according to ARPES) in qualitative accord with DMFT and GW calculation and ^{75}As NMR data [7]. Its puzzling absence in a recent STT study for $CsFe_2As_2$ [8] is ascribed to critical stripe fluctuation causing a local splitting of the tetragonal symmetry and yielding an additional MR seen in the large SOMMERFELD constant γ, but being detrimental for d_{x2-y2} pairing in contrast to Sr_2RuO_4 where the VHS approaching E_F strengthens also the SC pairing [9]. Here, it enhances the MR, only, being detrimentally for SC and this explains the lowest T_c for Cs-122.

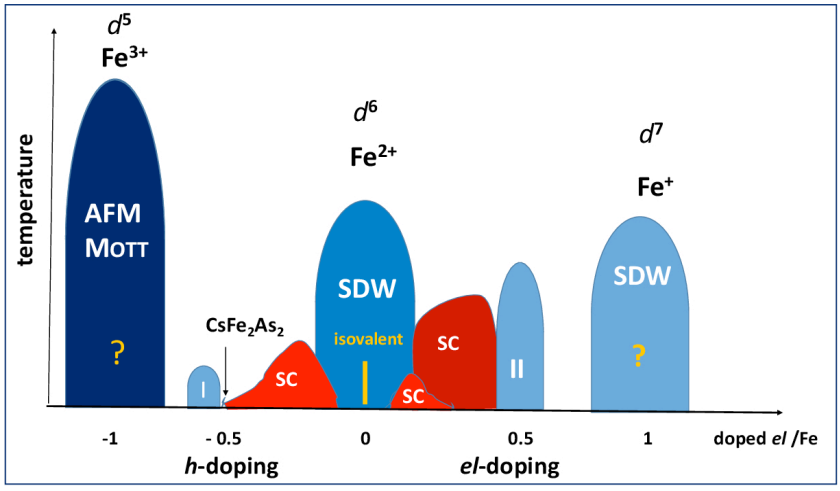

Figure 1: Proposed phase diagram for superconducting (SC,red) and competing magnetic phases (blue) as a function of charge doping in Fe pnictides. Phase I - a combined charge, orbital, and spin ordered phase near a quantum critical point responsible for the most pronounced non-Fermi liquid properties in Cs122 [7]. Yellow line: isovalent/no doping for such systems as Li(Na)FeAs, P-doped Ba(Sr)-122 and bulk FeSe where the competing magnetic SDW magnetic stripe-phase is absent or strongly

suppressed. Phase II - observed but not yet characterized experimentally. The hypothetical SDW or ferromagnetic phase around Fe^{+} is our suggestion. Bright (dark red) regions: 122 and H doped La-1111 (under pressure) [10] FeSC , respectively.

References

1. **S. Johnston, M. Abdel-Hafiez, L. Harnagea, *et al.*, Phys. Rev. B 89, 134507 (2014).**
2. **V. Ivanov, A. Ivanov, *et al.* J. Supercond. Nov. Mat. 29, 3035 (20016).**
3. **Y. Naidyuk *et al.* , Phys. Rev. B 90, 094505 (2014).**
4. **J. Tomczak, *et al.* Phys. Rev. Lett. 109, 237010 (2012).**
5. **F. Eilers. K. Grube, D. Zocco, *et al.,* Phys. Rev. Lett. 116, 237003 (2016).**
6. **T, Terashima, M. Kimata, *et al*, J. Phys. Soc. Jpn. 78, 060504 (2009).**
7. **Z.T. Zhang, D. Dmytrieva, S. Molatta, *et al.,* arXiv:1703.00780 (2017).**
8. **H.Yang *et a*l .Phys. Rev. B 93, 224516 (2016).**
9. **Stepke, L. Zhao, M.E. Barber *et al.,* Science 355 (6321) eaaf9398 (2017).**
10. **N. Kawaguchi, Fujiwara, S. Iimura, *et al.* PRB 94, 161104 (2016)**

Orbital Selectivity: exploring the phase diagram of Iron Based Superconductors

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The analysis of correlation in iron-based superconductors (IBS) is challenged by the multi-orbital character of these systems. Many experiments call for an orbital-dependent character of correlations with the simultaneous presence of strong- and weak-correlated electrons [1].

In this talk I explain this effect as a consequence of the effective “orbital decoupling” induced by the Hund’s coupling in multiorbital system [2]. I discuss the nature of the Hund’s metal and its connection to the half-filled Mott physics [2]. Then I show how the orbital selectivity affects the phase diagram of IBS. In particular I explain how nematicity emerges at the Hund's metal crossover and how correlations severely constrain feasible orbital-ordered states [3] and I discuss the consequences of the orbital selectivity on the superconductivity, in particular concerning the pairing symmetry [4]

References

1. **L. De Medici, Springer Series in Materials Science, Vol. 211, 409 (2015)**
2. **L. Fanfarillo and E. Bascones, Phys. Rev. B 92, 075136 (2015)**
3. **L. Fanfarillo, G. Giovannetti, M. Capone and E. Bascones, Phys. Rev. B 95, 144511 (2017)**
4. **L. Fanfarillo, A. Valli, M. Capone, in preparation**

The Anderson transition in deformable lattices and the puzzle of MOOIJ correlations

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Two major unsolved issues in the physics of disordered metals are the nature of the metal-insulator transition (MIT) and its relation to their remarkable transport properties: these systems commonly display a breakdown of Matthiessen's rule as well as the emergence of Mooij correlations — upon increasing randomness, the slope of ρ(T) linearly correlates with the T=0 intercept, changing sign at the Mott-Ioffe-Regel limit[1]. While scattering by phonons is obviously a key ingredient in the resistivity, Anderson suggested[2] that electron-phonon interactions should also be considered for a proper understanding of the MIT.

I will show that these two issues are intimately related, as they can both be explained via the interplay of static randomness and local lattice deformations. First, the response of the atomic lattice to the inhomogeneous electron density leads to the opening of a mobility gap, confirming Anderson's initial suggestion that the nature of the MIT is deeply modified[3]. Second, such interplay is already present far from the critical region, where it is responsible for the non-Fermi liquid behavior observed in a variety of experimental systems[4].

References

1. **P. Lee and T.V. Ramakrishnan, Rev. Mod. Phys. 57, 287 (1985).**
2. **P. W. Anderson, Nature 235, 163 (1972).**
3. **D. Di Sante, S. Fratini, V. Dobrosavljevic and S. Ciuchi, Phys. Rev. Lett. 118, 036602 (2017).**
4. **S. Ciuchi, D. Di Sante, V. Dobrosavljevic and S. Fratini, in preparation**

Disorder-Induced Metallic Phases in NbSi Thin Films

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Destruction of superconductivity in disordered thin films is commonly described by a direct quantum phase transition toward an insulating phase. This Superconductor-to-Insulator Transition (SIT) is associated with the competition between superconductivity, Coulomb interactions and Anderson localization [1].

Thin metal-alloy films are model systems to study this transition as disorder can be tuned by different means such as a modification of the composition, thickness, or by applying a heat treatment. I will present results obtained on an emerging metallic phase, in the vicinity of the SIT and experimentally revealed in amorphous Nb_xSi_{1-x} thin films via transport measurements by finely tuning disorder [2]. The observation of this metal, theoretically unpredicted, has raised the question of the mechanisms at play near the SIT, as well as of the nature of the possible ground states. A careful analysis of transport measurements allows to address these questions by revealing build-in electronic inhomegeneities and the decisive role of Coulomb interactions.

References

1. **V. Dobrosavljevic, T. Nandini, and J. M. Valles eds. *Conductor insulator quantum phase transitions*. Oxford University Press (2012)**
2. **F. Couëdo et al., *Scientific reports* 6, 35834 (2016)**

Time-reversal symmetry breaking hidden order in Sr2(Ir,Rh)O4

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Layered 5*d* transition iridium oxides, $Sr_2(Ir,Rh)O_4$, are described as unconventional Mott insulators with strong spin-orbit coupling. The undoped compound, Sr_2IrO_4, is a nearly ideal two-dimensional pseudospin-1/2 Heisenberg antiferromagnet, similarly to the insulating parent compound of high-temperature superconducting copper oxides. Using polarized neutron diffraction, we here report a hidden magnetic order [1] in pure and doped $Sr_2(Ir,Rh)O_4$, distinct from the usual antiferromagnetic pseudospin ordering. We find that time-reversal symmetry is broken while the lattice translation invariance is preserved in the hidden order phase. The onset temperature matches that of the odd-parity hidden order recently highlighted using optical second-harmonic generation experiments. The novel magnetic order and broken symmetries can be explained by the loop-current model, previously predicted for the copper oxide superconductors.

Reference

1. **Jaehong Jeong et al, Nat. Comms., 8, 15119 (2017). http://dx.doi.org/10.1038/ncomms15119.**

Evidence of Mott physics in hole-doped $BaFe_2As_2$ from x-ray emission and absorption spectroscopies

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A recent theoretical model of coexisting strongly and weakly correlated electrons has successfully explained a wealth of experiments on quasiparticle mass enhancements in electron- and hole-doped $BaFe_2As_2$ (d^6 configuration) [1]. Here Mott correlations increase upon approaching the half-filled configuration favored by Hund's coupling and thus a concomitant buildup of the Fe local moment is expected.

In order to track the doping evolution of the rapidly fluctuating local moments we used x-ray emission and absorption spectroscopy (XES-XAS) at beamline ID26 of the ESRF synchrotron. Single crystals of K- and Cr-doped $BaFe_2As_2$ were measured at room temperature. The *Kβ* XES spectra, which are strongly sensitive to the magnitude of the local 3*d* spin moment [2], were analyzed by the integrated absolute difference (IAD) method [3] where the IAD values reflect the relative evolution of the moment. These were further rescaled taking into account covalency effects encoded in the XAS data. As shown in Fig. 1, our results show a clear monotonic increase of the Fe local moment with hole-doping providing a high-energy experimental evidence of the Hund-Mott physics model.

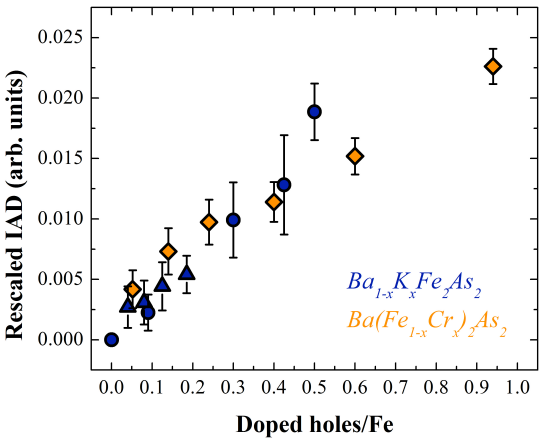

Figure 1: IAD values derived from the *Kβ* XES and XAS spectra of $Ba_{1-x}K_xFe_2As_2$ and $Ba(Fe_{1-x}Cr_x)_2As_2$ as a function of doped holes/Fe (x/2 and 2x for K- and Cr-doping compounds respectively).

References

1. L. de' Medici, G. Giovannetti, and M. Capone, Physical Review Letters 112, 177001 (2014)
2. P. Glatzel and U. Bergmann, Coordination Chemistry Reviews 249, 65 (2005)
3. G. Vankó, T. Neisius, G. Molnar, F. Renz, S. Karpati, A. Shukla, and F. M. F. de Groot, The Journal of Physical Chemistry B 110, 11647 (2006)

Crossover from impurity-controlled to granular superconductivity in $(TMTSF)_2ClO_4$

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The organic superconductor $(TMTSF)_2ClO_4$ is an archetypal quasi-1D non-*s*-wave superconductor [1,2]. It also exhibits an order-disorder transition, due to ClO_4 tetrahedral anions orientation at T_{AO} = 24 K, that can be controlled by the cooling rate across T_{AO} [2]. Thus, this compound provides a rare opportunity to precisely study how non-*s*-wave superconductivity evolves with disorder.

In this study, we performed simultaneous measurements of the *c*-axis resistivity and AC susceptibility of $(TMTSF)_2ClO_4$ single crystals, under precise control of the cooling rate across T_{AO}. The measurements were performed below 1 K, using a dedicated compact susceptometer [3]. Higher cooling rates increase the residual resistance and reduce T_c (Fig. 1), as expected for the destruction of non-*s*-wave superconductivity by non-magnetic impurities [2]. However, when the disordered volume fraction increases, the critical temperatures derived from resistivity and from susceptibility deviate from each other, while superconducting shielding is incomplete and dissipation finite. All these features indicate that superconductivity becomes inhomogeneous at high disorder.

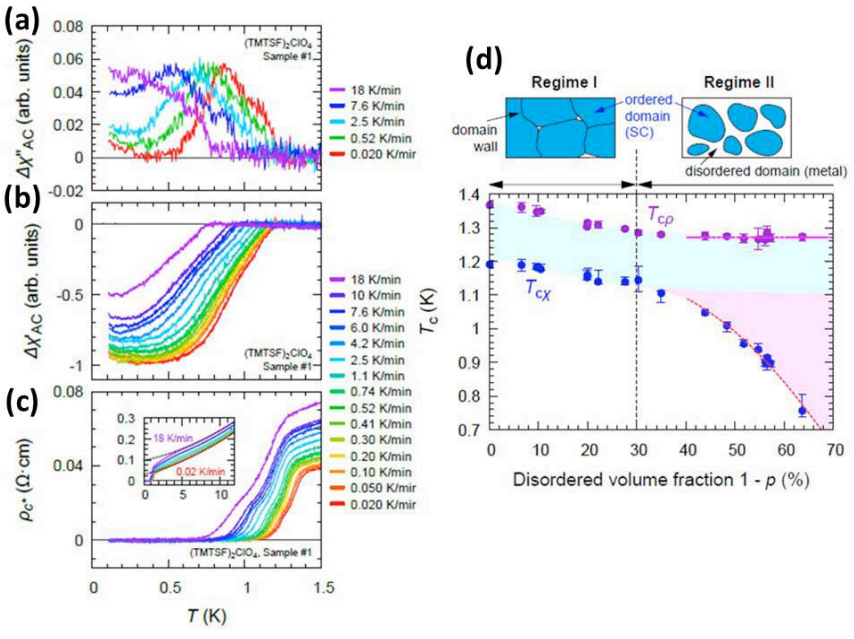

Figure 1: Imaginary (a) and Real (b) parts of the AC susceptibility and c-axis resistivity (c) as a function of the temperature for a $(TMTSF)_2ClO_4$ single crystal, cooled with various cooling rates across the anion-order temperature T_{AO} = 24 K. (d) Evolution of the critical temperatures derived from resistivity ($T_{c\rho}$) and from susceptibility ($T_{c\chi}$) with the disordered volume fraction.

References

1. **For recent reviews, see: S. E. Brown, *Physica C* 514, 279 (2015); D. Jerome and S. Yonezawa, *C. R. Physique* 17, 357 (2016).**
2. **S. Yonezawa *et al.*, *Phys. Rev. B.* 85, 140502R (2012).**
3. **S. Yonezawa *et al.*, *Rev. Sci. Instrum.* 86, 093903 (2015).**

From Sudden quench to adiabatic dynamics in the attractive Hubbard model

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We study the crossover between the sudden quench limit and the adiabatic dynamics of superconducting states in the attractive Hubbard model. We focus on the dynamics induced by the change of the attractive interaction during a finite ramp time which is varied in order to track the evolution of the dynamical phase diagram from the sudden quench to the equilibrium limit. Two different dynamical regimes are realized for quenches towards weak and strong coupling interactions. At weak coupling the dynamics depends only on the energy injected into the system, whereas a dynamics retaining memory of the initial state takes place at strong coupling. We show that this is related to a sharp transition between a weak and a strong coupling quench dynamical regime, which defines the boundaries beyond which a dynamics independent from the initial state is recovered. Comparing the dynamics in the superconducting and non-superconducting phases we argue that this is due to the lack of an adiabatic connection to the equilibrium ground state for non-equilibrium superconducting states in the strong coupling quench regime.

References

G. Mazza arXiv 1708.01096

Lattice Effects on Nematic Quantum Criticality in Metals

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Understanding the properties of a metal close to a nematic quantum critical point is an essential step towards our quest to comprehend the low temperature properties of several correlated electron systems such as the iron and the copper based high temperature superconductors. While this topic

has been studied extensively in the past, the influence of electron-lattice coupling, which is invariably present, has not been examined adequately. In this work we show how, even if the nematic transition is established by electron-electron interaction, symmetry allowed electron-lattice interaction is a relevant perturbation that changes the quantum critical properties qualitatively. In particular, as a result of this interaction the critical fluctuations are mostly cutoff by the non-critical lattice shear modes. The thermodynamics remain Fermi liquid type even right at the quantum critical point, while, depending on the Fermi surface geometry, either the entire Fermi surface stays cold, or at most there are hot spots. We also discuss how this physics affects superconductivity in the vicinity of the nematic quantum critical point.

References

1. **Paul and M. Garst, "Lattice effects on nematic quantum criticality in metals", Phys. Rev. Lett. 100, 227601 (2017)**
2. **D. Labat and I. Paul, "Pairing instability near a lattice-influenced nematic quantum critical point", arXiv:1703.04146.**

Probing spinon nodal structures in three-dimensional Kitaev spin liquids

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We propose that resonant inelastic X-ray scattering (RIXS) is an effective probe of the fractionalized excitations in three-dimensional (3D) Kitaev spin liquids. While the non-spin-conserving RIXS responses are dominated by the gauge-flux excitations and reproduce the inelastic-neutron-scattering response, the spin-conserving (SC) RIXS response picks up the Majorana-fermion excitations and detects whether they are gapless at Weyl points, nodal lines, or Fermi surfaces. As a signature of symmetry fractionalization, the SC RIXS response is suppressed around the Γ point. On a technical level, we calculate the exact SC RIXS responses of the Kitaev models on the hyperhoneycomb, stripyhoneycomb, hyperhexagon, and hyperoctagon lattices, arguing that our main results also apply to generic 3D Kitaev spin liquids beyond these exactly solvable models

References

1. **G. B. Halasz, N. B. Perkins, and J. van den Brink, PRL117, 127203 (2016)**
2. **G. B. Halasz, B. Perreault, N. B. Perkins, accepted in PRL (2017)**

Strong correlations in the transient dynamics of driven lattice quantum systems

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The field of the out-of-equilibrium dynamics of strongly correlated systems has experienced a fast growth in the last years, motivated by experimental advances in cold-atom manipulation and ultrafast spectroscopy of solids, as well as by fundamental theoretical questions about the evolution of quantum systems.

Here we present results on the transient dynamics of an Hubbard model - a prototype example of strong correlation physics - in presence of an interaction which is periodically modulated in time. We use dynamical mean-field theory (DMFT) with a strong coupling solver (NCA) and consider the paramagnetic phase of the Hubbard model. We show that the system under periodic driving eventually reaches the infinite temperature limit, and discuss different heating regimes as well as the conditions under which the system synchronizes or not with the drive.

Band structure engineering in 3D topological insulators

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We will present our recent combined experimental and theoretical results on the band structure engineering in 3D TI bilayers [1] and superlattices [2]. These studies show how new topologies emerge in complex structures, as compared to the routine Fermi level control by alloying [3, 4]. Our results provide a starting point in search for novel TI phases such as QAH in atomically thin heterostructures.

MBE growth of Sb_2Te_3 and Bi_2Te_3 leads to the p-type and n-type material respectively, due to the low formation energy of charged vacancies and antisites. Growing one of these materials on top of the other leads to the vertical p-n junction where the Fermi level position at the surface can be controlled by the thickness of the two layers [1].

The Bi_1Te_1 stoichiometry results from combining two Bi_2Te_3 quintuple layers with one Bi bilayer in the unit cell. In such superlattice new dual topological properties emerge, the material is simultaneously a topological crystalline insulator and a weak topological insulator [2]. This opens up the possibility of controlling the topological protection on different surfaces selectively by breaking respective symmetries.

References

1. **M. Eschbach, et al., "Realization of a vertical topological p-n junction in epitaxial Sb2Te3/Bi2Te3 heterostructures", Nature Comm. 6, 8816 (2015).**
2. **M. Eschbach, et al., "Bi1Te1 is dual topological insulator", Nature Communications 8, 14976 (2017).**
3. **Weyrich, et al., "Growth, characterization, and transport properties of ternary (Bi1-xSbx)2Te3 topological insulator layers", J. Phys. Cond. Matter 28, 495501 (2016).**
4. **J. Kellner, et al., "Tuning the Dirac point to the Fermi level in the ternary topological insulator (Bi1-xSbx)2Te3", Appl. Phys. Lett. 107, 251603 (2015).**

The quantum critical point of cuprate superconductors

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Cuprates exhibit exceptionally strong superconductivity, with critical temperatures and magnetic fields that can exceed 100 K and 100 T, respectively. However, the nature of the electron interactions responsible for the strong pairing is still not clear.

I will present recent experimental studies performed using high magnetic fields to suppress superconductivity and access the non-superconducting ground state of cuprates in the $T = 0$ limit. These reveal the presence of a quantum critical point in the phase diagram of cuprates [1,2,3], where the enigmatic pseudogap phase ends, around which the superconducting phase forms a dome, and at which the resistivity exhibits an anomalous linear dependence on temperature [4,5].

In particular, our recent measurements of the normal-state specific heat $C(T)$ down to very low temperature (0.5 K) reveal clear thermodynamic signatures of a quantum critical point, with C/T showing a sharp peak at the pseudogap critical doping p^*, and $C/T \sim \log(1/T)$ at $p = p^*$. Strong similarities with the quantum critical point at which antiferromagnetic order ends in organic [6], iron-based [7], heavy-fermion [8] and electron-doped cuprate [9] superconductors suggest that antiferromagnetic spin correlations also play a fundamental role in hole-doped cuprates. The outstanding questions are : Does antiferromagnetic order extend up to the critical point in hole-doped cuprates ? Is long-range order necessary to open a (pseudo)gap and generate anomalous, non-Fermi-liquid, scattering and mass renormalization down to $T \sim 0$?

References

[1] S. Badoux *et al.*, Nature 531, 210 (2016).
[2] C. Collignon *et al.*, Phys. Rev. B 95, 224517 (2017).
[3] B. Michon *et al.*, to be published.
[4] R. Daou *et al.*, Nat. Phys. 5, 31 (2009).
[5] L. Taillefer, Annu. Rev. Condens. Matter Phys. 1, 51 (2010); arXiv:1003.2972.
[6] N. Doiron-Leyraud *et al.*, Phys. Rev. B 80, 214531 (2009).
[7] T. Shibauchi, A. Carrington, Y. Matsuda, Annu. Rev. Condens. Matter Phys. 5, 113 (2014).

[8] P. Monthoux, D. Pines, G. G. Lonzarich, Nature 450, 1177 (2007).
[9] N. P. Armitage, P. Fournier, R. L. Greene, Rev. Mod. Phys. 82, 2421 (2010).

Orbital Control of functionalities in 3d Perovskite Oxides

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Transition metal 3d oxide perovskites exhibit a wide array of interesting electronic states. Moreover, select interfaces and surfaces of bulk insulating phases host 2D electron liquids (2DEL) where large (Rashba) spin-orbit interactions, ferroelectricity, superconductivity and magnetism can be tuned with doping or strain. These multi-functionalities stem from the interplay of the kinetics of 3d electrons in the perovskite structure, of the Rashba energy and of the confinement of the carriers. We highlight this through the study of electronic states at the surface of strontium titanate (STO) and calcium titanate (CTO). For both, the 2DEL originates from oxygen vacancies created at the boundary by UV illumination or capping with ultra-thin aluminum layers. Our analytical study of the band structure of STO reveals the existence of 2D topological states in the 2DEL leading to 1D edge states[1]. For CTO, we demonstrate using DFT studies how rotations of the TiO_2 octahedra and local correlations (Hubbard U) impact the metallic character of the 2DEL and the magnetic polarization. The physics behind this system bears a strong resemblance to that of the nickelates.

References

1. M. Vivek, M.O. Goerbig, and M. Gabay., Phys. Rev. B 95, 165117 (2017)

Evidence of incoherent carriers associated with resonant impurity levels and their influence on superconductivity in the anomalous superconductor Pb1-xTlxTe

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In this experimental study of the Fermi surface of $Pb_{1-x}Tl_xTe$ we firmly establish the correlation between the onset of anomalously high temperature superconductivity and the presence of resonant impurity states (associated with the Tl impurities) at the Fermi level. In doing so, we rule out the scenario where additional valence band maxima play a role in superconductivity by proving that these remain below the Fermi level at all compositions studied. Through comparison to non-superconducting $Pb_{1-x}Na_xTe$ we conclude that these resonant impurity states, introduced extrinsically to the host material by the Tl impurities, are providing the pairing interaction for superconductivity. We establish these results from a combination of magnetotransport (Shubnikov de Haas oscillations and Hall coefficient) and Angle Resolved Photoemission Spectroscopy (ARPES) measurements presented herein.

References

1. M. Eee et al., “how to cite a citation” Science 100, 234 (2018)
2. Y. Ou and L.D. Landau, Nature Communications 48, 1 (2015) http://dx.doi.org/10.1038/ncomms12345.

Posters

Chain Superconductivity in $YBa_2Cu_4O_8$

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The specific heat of Y124 is measured in an applied magnetic field along each of the orthogonal crystallographic directions in order to observe how the oxygen chain respond to magnetic field

Charge Order and Superconductivity in Underdoped Y123 Under Pressure

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In underdoped cuprates, the interplay between superconductivity, charge ordered (CDW) and pseudogap phases is of particular interest. The doping for which the CDW is strongest coincides with a dip in T_c [1] suggesting that these two phases are in direct competition and that the CDW suppresses superconductivity. Additionally, the x-ray intensity from the CDW modulation decreases below T_c and increases with the suppression of T_c with a magnetic field [2].

The temperature dependence of the Hall coefficient in high magnetic fields (36T) and under hydrostatic pressure (2.6GPa) has been measured to further elucidate the interplay between superconductivity and CDW phase. Although T_c is increased by 10K at 2.6GPa, there is no appreciable effect on R_H suggesting that although superconductivity is enhanced, there is no corresponding suppression of the CDW.

References

5. **R.X. Liang *et al*, Phys. Rev. B 73, 180505 (2006)**
6. **J. Chang *et al*, Nat. Phys. 8, 871 (2012)**

Experimental and theoretical study of self-doped oxygen states in the high temperature superconductor parent compound BaBiO3

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The perovskite oxide BaBiO3 is a high Tc superconductor parent compound which exhibits a unique self-doping of holes into the oxygen 2p band. Here we study the oxygen states in detail from both a theoretical perspective as well as through X-ray absorption, emission, and photoelectron spectroscopies. The X-ray spectroscopy verifies the results of Density Functional Theory (DFT) in the Local Density Approximation (LDA) regarding the overall band-structure featuring strong O 2p character of the empty anti-bonding combination of the hybridized Bi 6s and O 2p A1g-symmetric states. Such a large O 2p hole density should generally result in substantial satellite structure in the O 1s XPS spectrum not seen in our surface cleaned single crystals. Our exact diagonalization calculation of small clusters demonstrates that the expected satellites are strongly suppressed for large Bi 6s-O 2p A1g symmetry hybridization. This analysis demonstrates the dominant in of the effective bismuth 6s-oxygen 2p hybridization which is the largest energy scale in the problem.
This provides further insight into the importance of self-doped oxygen 2p states in this high Tcfamily of oxides

References

1. **Arthur W. Sleight,Physica C 514, 152 (2015).**
2. **Kateryna Foyevtsova, Arash Khazraie, Ilya Elmov, and George A. Sawatzky Phys. Rev. B, 91, 121114(R) (2015).**

Pseudo-spin-flop transition in the phase diagram of cuprates at high magnetic field

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The experimentally measured phase diagram [1] of cuprate superconductors in the temperature-applied magnetic field plane illuminates key issues in understanding the physics of these materials. At low temperature, the superconducting state gives way to a three-dimensional charge order with increasing magnetic field; both orders coexist in a small intermediate region. The charge order transition is strikingly insensitive to temperature, and reaches quickly a transition temperature close to the zero-field superconducting transition temperature. We argue that such a transition cannot be described by simple competing orders formalism. Moreover, we find that the presence of the coexistence phase depends crucially on the relative masses and coupling strength of the two orders. Finally, we show that this sharp switch from superconductivity to charge order can be understood as a pseudo-spin-flop transition in the framework of the SU(2) theory [2] of cuprate superconductors

References

1. **D. LeBoeuf et al., Nat. Phys. 9, 79 (2013)**
2. **K. B. Efetov, H. Meier and C. Pepin, Nat. Phys. 9, 442 (2013)**

Full Spin Polarization and Half-Integer Quantum Hall Effect in a Coupled Electron-Hole System

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Band inverted InAs/GaSb quantum wells (QWs) are known to be a two-dimensional topological insulator (2D TI) [1]. Recently, strained InAs/$In_xGa_{1-x}Sb$ QWs have been shown to be a promising system for a robust TI phase with higher bulk insulation [2,3]. Here, we report on magneto-transport measurements in InAs/$In_{0.25}Ga_{0.75}Sb$ QWs as a function of gate voltage, which allows us to tune the Fermi level across the topological band gap formed by electron-hole hybridization. We find that over a range of gate voltages around the charge neutrality point (CNP), both electronlike and holelike carriers become fully spin polarized. Analysis of the Shubnikov-de Haas oscillations reveals a nonzero Berry phase which varies across p around the CNP, indicating a half-integer quantum Hall effect of each type of carriers. We explain the observed π Berry phase as a result of momentum-dependent coupling of electron and hole wave functions. The large and tunable hybridization between the valence and conduction bands in this system thus makes it a unique platform for studying multi-carrier transport phenomena. This work was supported by JSPS KAKENHI (Grant No. JP15H05854).

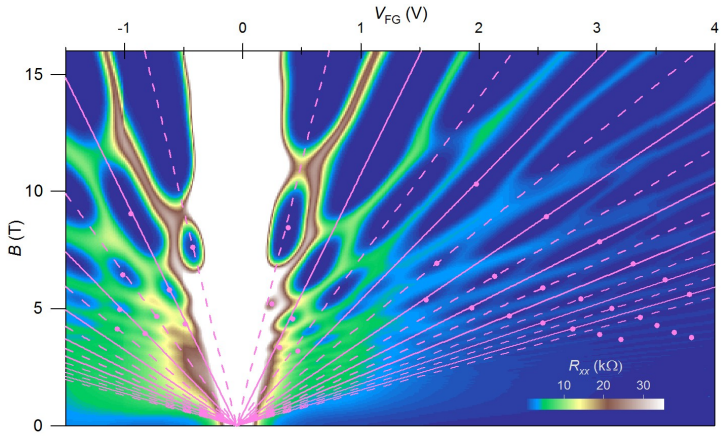

Figure 1: Landau fan diagram of InAs/In0.25Ga0.75Sb QWs. Color map of longitudinal resistance Rxx vs gate voltage VFG and magnetic field B at the temperature T = 0.02 K.

References

1. **C. Liu et al., Phys. Rev. Lett. 100, 236601 (2008)**
2. **T. Akiho et al., Appl. Phys. Lett. 109, 192105 (2016)**
3. **L. Du et al., arXiv:1608.06588 (2016)**

Charge ordering and metal-insulator transitions in the extended Hubbard model

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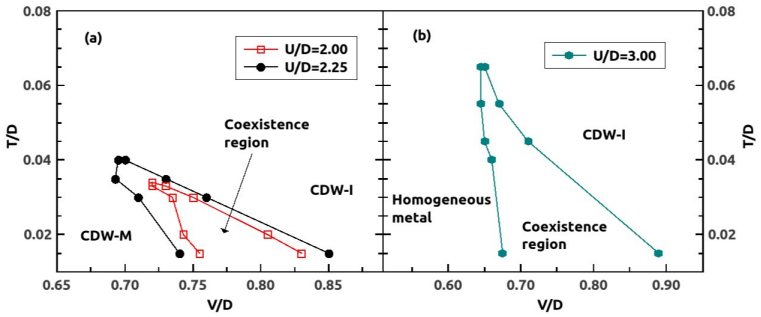

Figure 1: Coexistence regions between (a) CDW-M and CDW-I phases and (b) homogeneous metal and CDW-I phase for different values of *U*; *D* corresponds to the half-bandwidth of the non-interacting model.

We study the interplay between local electronic correlation *U* and the interaction *V* between electrons that occupy nearest neighbor lattice sites by considering the extended Hubbard model, solved within Dynamical Mean Field Theory. For small values of *U*, we see a continuous transition between a metal with charge ordering (CDW-M phase) and an insulator with characteristics of both Wigner and Mott insulators (CDW-I phase). As *U* increases, we observe a coexistence region between CDW-M and CDW-I phases. When the interaction *U* further increases, the CDW-M phase disappears and the system goes through a discontinuous transition between a homogeneous metal and the insulator, with the presence of the respective coexistence region. We go beyond the small temperatures considered previously and find that, for fixed *U*, the range of *V* where the coexistence regions exist decreases with increasing *T* and vanishes at a critical value of it, as can be seen in Figure 1.

References

1. **D. LeBoeuf et al., Nat. Phys. 9, 79 (2013)**
2. **K. B. Efetov, H. Meier and C. Pepin, Nat. Phys. 9, 442 (2013)**

Chromium analogues of iron-based superconductors

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The present talk encompasses the results of our studies of $BaCr_2As_2$, the Cr equivalent of the 122 iron-based superconductor (FeSC) $BaFe_2As_2$. In the respective compound, Cr nominally hosts 4 electrons in its *d* orbitals, whereas Fe hosts six, placing Cr on the other side of half-filling. Therefore, one expects behaviour of the Cr compound that is specular to $BaFe_2As_2$. We conducted DFT+DMFT studies on the PM and G-type AFM phase as well as slave-spin mean field (SSMF) calculations on the PM phase [1]. We show that dynamical correlations are necessary to narrow the discrepancy between the Sommerfeld coefficient as accessed by theoretical studies and the experimental value. Through SSMF one finds that the $BaCr_2As_2$ mirrors the BaFe2As2 compressibility. We infer that, similar to $BaFe_2As_2$, $BaCr_2As_2$ can be pushed into the SC regime with the proper amount of electron doping and/or negative pressure, introducing a new, interesting family of SCs.

References

M. Edelmann, G. Sangiovanni, M. Capone, L. de' Medici, Phys. Rev. B 95, 205118 (2017) https://doi.org/10.1103/PhysRevB.95.205118.

Unconventional superconductivity by point contact spectroscopy in the k-(BEDT-TTF)$_2$X family

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We report an experimental investigation of the superconducting state in the quasi-two-dimensional organic charge-transfer salts k-(BEDT-TTF)$_2$X family. The different compounds tested, representing an effective chemical pressure, were X=$Cu(NCS)_2$, $H_8Cu[N(CN)_2]Br$ and $D_8Cu[N(CN)_2]Br$. The technique used in order to follow the evolution with chemical pressure of the superconductivity order parameter symmetry was the point contact spectroscopy (N-I-S Junction). We have measured the differential conductance as a function of temperature, magnetic field and bias voltage. Results are in good agreement with recent theoretical and STM studies[1] which supports a d-wave superconductivity picture

Reference

D. Guterding et al, Phys. Rev. Lett. 116, 237001 (2016)

Signatures of the Mott transition in the antiferromagnetic state of the two-dimensional Hubbard model

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The properties of a phase with large correlation length can be strongly influenced by the underlying normal phase. We illustrate this by studying the half-filled two-dimensional Hubbard model using cellular dynamical mean-field theory with continuous-time quantum Monte Carlo. Sharp crossovers in the mechanism that favors antiferromagnetic correlations and in the corresponding local density of states are observed. These crossovers occur at values of the interaction strength U and temperature T that are controlled by the underlying normal-state Mott transition [1].

We also study the fate of this scenario as a function of hole doping by mapping the Néel state and by studying its interplay with the pseudogap and the d-wave superconducting state [2].

References

1. **L. Fratino et al., "Signatures of the Mott transition in the antiferromagnetic state of the two-dimensional Hubbard model" Phys. Rev. B 95, 235109 (2017) https://journals.aps.org/prb/abstract/10.1103/PhysRevB.95.235109**
2. **L. Fratino, P. Sémon, M. Charlebois, G. Sordi, and A.-M. S. Tremblay, in preparation**

Origin of the Large Anisotropic g Factor of Holes in Bismuth

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Spin-orbit interaction modifies the g-factor of mobile electrons in crystals. In principle, one may expect that first-principle band calculations yield an exact determination of the g-factor of electrons, since it is the one-body physics. However, the band calculation under the magnetic field is not so straightforward. Actually, no satisfactory explanations of the large anisotropic g-factor of holes in

bismuth, which is the typical material of Dirac electron systems, has put forward for more than a half century. In this work, we report for the first time a theoretical solution to this longstanding puzzle based on the multiband k.p theory [1]. Furthermore, we present new experimental results, which provide a convincing crosscheck for the proposed theoretical solution. Beyond the emblematic case of bismuth, our approach opens new directions for future studies on other systems in which spin-orbit interaction plays a major role.

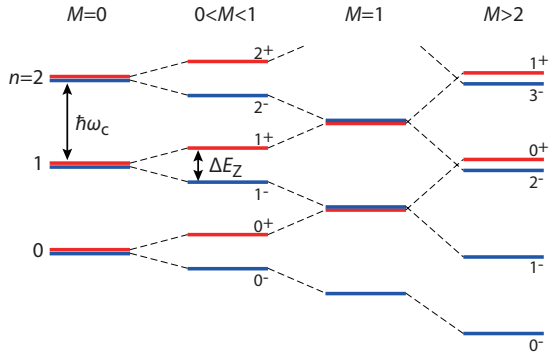

Figure 1: Energy levels under a magnetic field for different ratio $M=\Delta E_z/\hbar\omega_c$. For holes at the *T*-point of bismuth, *M* >2 and highly anisotropic, which has been a mystery for more than a half century.

References

1. **Y. Fuseya et al., Phys. Rev. Lett. 115, 216401 (2015).**

Superconductivity and Rashba spin-orbit coupling in $LaAl_{1-x}Cr_xO_3/SrTiO_3$ interfaces.

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A rather unique feature of the two-dimensional electron gas (2-DEG) formed at the interface between the two insulators $LaAlO_3$ and $SrTiO_3$ is to host both gate-tunable superconductivity and strong spin-orbit coupling. In the present work, we use the disorder generated by Cr substitution of Al atoms as a tool to explore in further details the nature of superconductivity and spin-orbit coupling in these interfaces. A reduction of the superconducting T_c is observed with Cr doping consistent with an increase of electron-electron interaction in presence of disorder. The evolution of spin-orbit coupling with gate voltage and Cr doping is extracted from magneto-transport experiments. The corresponding spin diffusion length is found to be essentially independent of the disorder in agreement with a

D'Yakonov-Perel mechanism where the spin-orbit relaxation time varies inversely with the elastic scattering time. In addition, we show that the strength of the spin-orbit coupling increases linearly with the carrier density of the 2-DEG and therefore the interfacial electric field E_z in agreement with a Rashba type of spin-orbit interaction.

Electron spin resonance of non-centrosymmetric $Yb_2Co_{12}P_7$

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Polycrystalline samples of $Yb_2Co_{12}P_7$ have been investigated by the local probe technique electron spin resonance (ESR) in the temperature range between 4 and 300 K. A temperature evolution of complex ESR spectra confirm the previously reported ferromagnetic (FM) ordering of the cobalt sub-lattice at T_C = 136K and a magnetic transition below T_M ~5 K that is likely associated with ordering of the ytterbium ions [1]. The low temperature electrical resistivity is likely dominated by magnetic scattering rather than heavy Fermi-liquid behavior. The data of transport and ESR studies suggest disordered magnetism and strong short-range FM correlations well above T_M.

The origin of ESR [2] and a possible interplay of crystal field effects, magnetic anisotropy, valence fluctuations, or Kondo physics are discussed.

References

1. **J.J. Hamlin et al., Philosophical Magazine 92, 647 (2012)**
2. **V.A. Ivanshin et al., Physics of Metals and Metallography 118, 341 (2017)**

Superconductivity via Electron Doping in the Bismuth Perovskites

Khazraie[1,2] , K. Foyevtsova [1,2], I.Elfimov[1,2] and G. Sawatzky[1,2]

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We present Density functional Theory calculations of $LaLuO_3/SrBiO_3$ Superlattices. We demonstrate the possibility of simultaneous electron and hole doping of $SrBiO_3$ [1] at its interfaces due to polarity of $LaLuO_3$ [2].

References

K.Foyevtsova, A. Khazraie, I.Elfimov, G. Sawatzky PRB 91 , 121114(R) (2015). DOI:10.1103/PhysRevB.91.121114
A. Khazraie, K.Foyevtsova, I.Elfimov, G. Sawatzky to be submitted.

Correlated electronic structure of electron-doped Sr_2IrO_4

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The spin-orbit system Sr_2IrO_4 has raised tremendous interest recently, due to intriguing similarities to the high-T_c superconducting copper oxides.We study the evolution of the electronic structure of Sr_2IrO_4 upon doping using a combination of ab-initio density functional theory and two state-of-the-art many-body techniques. The effects of spin-orbit coupling, distortions of the oxygen octahedra and Hubbard interactions are included on a first-principles level.

We compare our results with recent photoemission data, and find good agreement with experiment.

Insights into hole-doped cuprates from calculations of angle-dependent magnetoresistance

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The phase diagram of the cuprate high-temperature superconductors is both complicated and contentious. Information on the Fermi surface geometry of these materials at various dopings, temperatures, and magnetic fields can provide a great deal of insight into the phase diagram: the shape of the Fermi surface not only specifies the symmetry of an ordered phase but also may indicate its ordering wavevector. Angle-dependent magnetoresistance (ADMR) is a powerful probe of Fermi surface geometry and scattering. But the Fermi surface geometry can not be extracted directly from experiments; rather, simulations and experiments must be used in concert to determine a likely Fermi surface geometry. We show how calculations of ADMR in a magnetic breakdown model can explain surprising data from overdoped Tl2201 [1]. We also use ADMR calculations to illuminate how ADMR measurements of Hg1201, a model underdoped cuprate, could answer an open question about the ordering in the underdoped regime

References

1. **S.K. Lewin et al., "Angle-dependent magnetoresistance oscillations of cuprate superconductors in a model with Fermi surface reconstruction and magnetic breakdown" Physical Review B 92, 195130 (2015)**

Hallmark of the pseudogap in the superconducting state of cuprate

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We study the temperature-dependent electronic Raman response of a slightly underdoped single crystal of $HgBa_2Ca_2Cu_3O_4$ [1]. Our main finding is that the superconducting pair-breaking peak is associated with a dip on its higher-energy side, disappearing together at Tc. This result reveals a key aspect of the unconventional pairing mechanism: spectral weight lost in the dip is transferred to the pair-breaking peak at lower energies. This conclusion is supported by cellular dynamical mean-field theory on the Hubbard model [2], which is able to reproduce all the main features of the Raman response and explain the peak-dip behavior in terms of a nontrivial relationship between thesuperconducting phase and the pseudogap. We confirmed this results on others compounds revealing his universality.

We tracked this structure with doping on $Bi_2Sr_2CaCu_2O_8$ [3]. The pseudogap survives in the overdoped region and then disappears above p = 0.225, wich corresponds to the normal state disappearance of the pseudogap in coincidence with a Lifshitz transition [4], showing his relation with the Fermi surface topology. This suggests a vertical ending line of the pseudogap in the T-p phase diagram

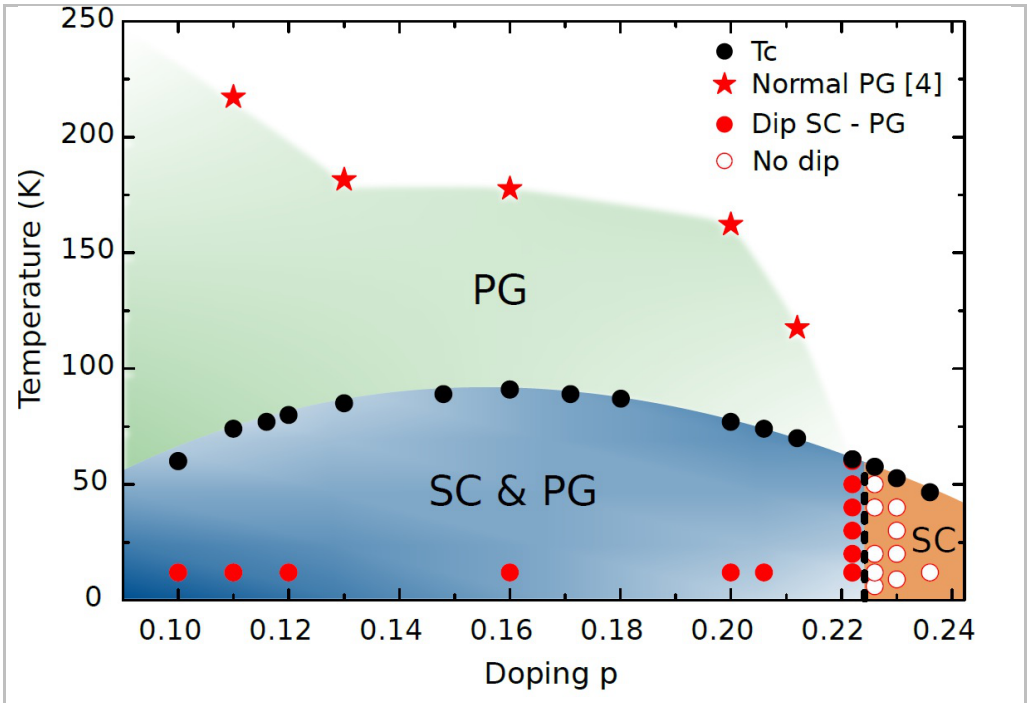

Figure 1: Temperature-doping phase diagram of Bi-2212, showing the PG in the normal and SC phases. The normal state PG which develops between T* and Tc are extracted fro [4]. The dip is the PG-related

feature in the SC state. The PG collapses abruptly (vertical line) between p = 0.222 and p = 0.226 in the SC state.

References

1. **Loret et al. - Phys. Rev. Lett. 116, 197001 (2016)**
2. **Kotliar et al. - Phys. Rev.Lett. 87, 186401 (2001)**
3. **Benhabib et al. - Phys.Rev.Lett 114, 147001 (2015)**
4. **Loret et al. - Phys.Rev. B 96, 094525 (2017)**

Thermal transport in strontium titanate

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Strontium titanate has attracted attention across a variety of research topics ranging from superconductivity to thermoelectricity passing by ferroelectricity [1, 2, 3]. Here, we present an extensive study of thermal conductivity in pure and niobium-doped strontium titanate over a wide (1.8K to 300K) range of temperature. At low temperature, the lattice thermal conductivity evolves faster than T^3, a hallmark of Poiseuille flow of phonons [4]. Well above the structural transition at 105K, but below the Debye temperature, thermal conductivity follows a T^{-1} temperature dependence with a scattering time proportional to the Planck time. Doping with niobium introduces disorder and mobile electrons. It allows us to open a new window to the strength of electron-phonon coupling and to study the way phonon modes get localized with increasing disorder.

References

1. J. F. Schooley, W. R. Hosler, and M. L. Cohen, Phys. Rev. Lett., 12, 474 (1964).
2. X. Lin, Z. Zhu, B. Fauqué, and K. Behnia, Phys. Rev. X, 3, 021002 (2013).
3. D. Bäuerle, D. Wagner, M. Wöhlecke, B. Dorner and H. Kraxenberger. B - Condensed Matter, 38, 335 (1980).
4. H. Beck, P. F. Meier, A. Thellung, Phys. Stat. Sol. (a), 24, 11, 1974.

Thickness-Driven Metal-Insulator Transition in $CaVO_3$: A Resonant Inelastic X-ray Scattering Study

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Controlling transport and magnetic properties in the ultra-thin limit is a prerequisite toward design of more complex heterostructures where emergent phenomena have been widely predicted. Thickness-driven metal-insulator transitions (MIT) in thin films have been reported in recent years in a broad swathe of correlated 3d and 5d transition metal oxides [1-5]. Resonant inelastic x-ray scattering (RIXS) is uniquely suited to address this MIT as it probes the charge, orbital and spin excitations in both metallic and insulating phases and is sensitive to even 1 unit cell films. We report on the evolution of RIXS spectra across the thickness-driven MIT in $CaVO_3$. Bulk $CaVO_3$ is a correlated paramagnetic metal but with decreasing thickness it evolves toward an insulating state. Our RIXS spectra reveal a continuous reduction of electronic bandwidth across the MIT. Our results show that the thickness-driven MIT results from Mott-like correlations that can host charge or spin ordering.

References

1. Y. Feng et al., Sci. Rep., 6, 22382 (2016).
2. R. Scherwitzl, Phys. Rev. Lett., 106, 246403 (2011).
3. P.D.C King, Nat. Nano., 9, 443 (2014).
4. K. Yoshimatsu et al., Phys. Rev. Lett., 104, 147601 (2010).
5. A. Biswas et al., arXiv:1508.04929v2 (2016).

Evolution of spectral and transport quantities with doping in the SU(2) theory of cuprates

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Recent transport experiments in the cuprate superconductors shed new light on the connection between the enigmatic pseudogap phase and the evolution of the electronic dispersion under doping. The latter is known to evolve from Fermi arcs measured by ARPES in the underdoped regime, to a large hole Fermi surface at high doping, as seen e.g. in quantum oscillation measurements. Combined Hall number and resistivity measurements at high magnetic field showed that the carrier density sharply changes from p to 1+p at the pseudogap critical doping p*, linking the opening of the pseudogap to a change in electronic dispersion.

The SU(2) theory of cuprates shows that antiferromagnetic short range interactions cause the arising of both charge and superconducting orders, which are related by an SU(2) symmetry. The fluctuations associated with this symmetry form a pseudogap phase, which was shown to account for Raman, ARPES and strange metal experimental evidence. Here we derive the renormalised electronic propagator under the SU(2) dome, and calculate the spectral functions and transport quantities of the renormalised bands. We show that their evolution with doping matches both spectral and transport measurements.

Phase diagram of a spin-orbit coupled three-orbital Hubbard model

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The phase diagram of a three orbital model in the presence of e-e interaction, Hund's coupling and a local Spin Orbit Coupling (SOC), will be presented. The resulting interplay between the full rotational invariant Kanamori interaction and band-structure features due to SOC will be discussed alongside with the various emergent phases. This study address several recent issues in the field of correlated spin-orbital metals and Mott insulators, including, e.g., the relativistic Mott insulating state of iridates [1].

References

1. B. J. Kim et al., Phys.Rev.Lett. 101, 076402 (2008) https://doi.org/10.1103/PhysRevLett.101.076402

Strong chiral phase in topological Kondo insulators

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We consider the simplest variant of a Kondo insulator where a doublet of localized *f*-electrons hybridizes with spin-degenerate conduction electrons. We point out that the effective four-band model of such systems can possess a chiral symmetry, which results from the symmetry of *f*-orbitals involved in the hybridization. In particular, tetragonal Kondo insulators with chiral symmetry exhibit a non-trivial topological phase when the band-width of conduction electrons sets the largest energy scale. Implications for rare-earth based compounds are discussed.

Magnetic field induced emergent inhomogeneity in a superconducting film with weak and homogeneous disorder

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The effect of increasing non-magnetic disorder on a superconducting state has been of interest for a long time [1] [2]. Performing Scanning tunneling Microscopy (STM) and transport measurements on a nearly homogeneous conventional weakly disordered superconducting film, we see that increasing magnetic field (B) has the same effect on the superconducting state as increasing disorder. With application of B, instead of forming vortex lattice, the sample develops superconducting islands separated by chains of vortices, and with increasing B, this granularity increases progressively as predicted by numerical simulations before [3]. Destruction of superconductivity occurs by phase fluctuation among these islands giving rise to pseudo-gap state [1]. The persistence of soft gap within vortex cores at all fields is also indicative of the fact that phase fluctuation is more favorable than breaking the cooper pair. Our experimental results are supported by our numerical simulations.

References

1. **M. Mondal. et. al,''Phase Fluctuations in a Strongly Disordered s-Wave NbN Superconductor Close to the Metal-Insulator transition'', Phys. Rev. Lett. 106, 047001 (2011).**
2. **Ghosal, M. Randeria, and N. Trivedi," Inhomogeneous pairing in highly disordered s-wave superconductors", Phys. Rev. B. 65, 014501 (2001).**
3. **Y. Dubi, Y. Meir and Y. Avishai," Island formation in disordered superconducting thin films at finite magnetic fields", Phys. Rev. B. 78, 024502 (2008).**

3D Dirac cone signature in the optical conductivity of $BaNiS_2$

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$BaCo_{1-x}Ni_xS_2$ is a quasi-2D Mott system, where electron_doping drives the antiferromagnetic and insulating phase at x=0 to a metallic and paramagnetic one at the critical value x_{cr} = 0.22 [1]. ARPES measurements on high-quality single crystals of $BaNiS_2$ and band structure calculations suggest a moderate renormalization effect due to weak electronic correlations and a large Rashba coupling amplified by a huge staggered crystal field [2]. ARPES and Quantum Oscillation measurements allowed to propose the first experimental Fermi surface in which a 3D Dirac cone, presumably symmetry protected, emerged in middle of GM direction [3].

In this context, we measured the optical conductivity on the ab-plane of the highly conducting $BaNiS_2$ at various temperatures. These actually indicated a large thermal evolution with an unconventional linear behavior in the optical conductivity versus the wavenumber, recently explained and observed in 3D Dirac semimetal [4, 5]. A comparative study of the optical conductivity experimental and simulated from ab initio calculations including a Hubbard repulsion term, U will be discuss in order to understand the role of the 3D Dirac cone in optical conductivity of $BaNiS_2$.

References

1. **S. Shamoto et al., J. Phys. Soc. Jpn, 66, 1138 (1997).**
2. **D. Santos-Cottin et al., Nat. Commun 7, 11258. (2016).**
3. **Publications in preparation (2017)**
4. **R. Y. Chen et al., Phys Rev B 92, 075107 (2015)**
5. **T. Timusk et al., Phys Rev B 87, 235121 (2013)**

Interplay of Correlations and Kohn Anomalies in Three Dimensions: Quantum Criticality with a Twist

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A general understanding of quantum phase transitions in strongly correlated materials is still lacking. By exploiting a cutting-edge quantum many-body approach, the dynamical vertex approximation, we make important progress, determining the quantum critical properties of the antiferromagnetic transition in the fundamental model for correlated electrons, the Hubbard model in three dimensions. In particular, we demonstrate that—in contradiction to the conventional Hertz-Millis-Moriya theory—its quantum critical behavior is driven by the Kohn anomalies of the Fermi surface, even when electronic correlations become strong [1].

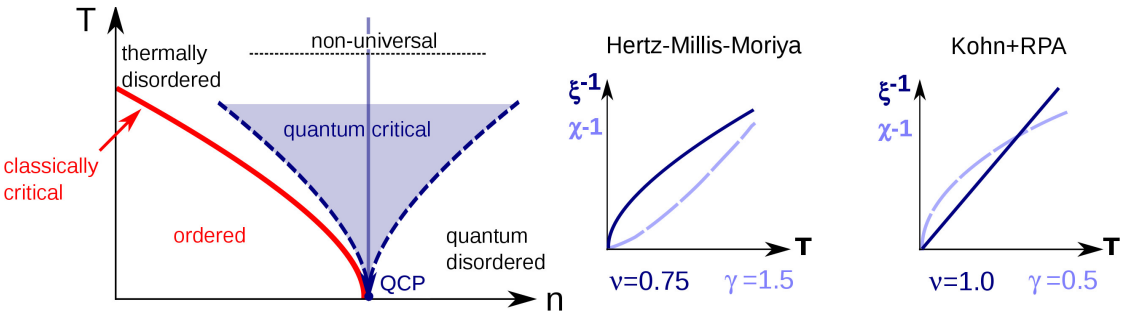

Figure 1: Generic phase diagram of classical as well as quantum phase transitions. At the quantum critical point (QCP) at (T = 0; n = n_c), an abrupt change of the ground state of the system takes place (left panel). The blue shaded region marks the quantum critical regime, where the (quantum) critical exponents and show universal behavior. The temperature dependences of magnetic susceptibility and correlation length in this region, calculated from Hertz-Millis-Moriya theory (for d = 3, SDW ordering and z = 2) and in presence of Kohn anomalies at the Fermi surface, are shown (right panel).

References

1. **T. Schäfer, A. A. Katanin, K. Held and A. Toschi, arXiv:1605.06355v2 (2017) (to appear in Phys. Rev. Lett. (July 2017))**

Nature of the Mott Transition in the Presence of Hund's Coupling

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Within the context of Dynamical Mean Field Theory (DMFT), we study the character of the doping-driven Mott-transition for multi-orbital Hubbard models with Hund's coupling. Motivated by recent findings, we investigate the metal-insulator phase transition as well the corresponding coexistence region for 2- and 3- band models and various temperatures.

Pressure – Temperature phase diagram of superconducting FeSe single crystals studied by complementary probes

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In addition to its low pressure nematic state [1,2,3], FeSe shows a pressure-induced magnetic (AFM) order [4] simultaneously where T_c increases strongly, from 9K up to 35K at 6-7GPa.

We confirm, thanks to XRD under high pressure (HP), that its low T orthorhombic distortion is retained in the region of SC/AFM coexistence [5]. Moreover, at P>7GPa, the decrease of T_c is found concomitant with the formation of a new polymorph, with an orthorhombic Pnma structure, characterized by a 3D network of face sharing $FeSe_6$ octahedra [6]. This 3D phase coexists with the low pressure 2D form up to the highest pressure studied.

We have also studied the magnetism of FeSe by performing RIXS at K-edge of iron. The EXAFS spectra measured at 10K/HP are strongly modified at 7GPa, corresponding to the change from the tetrahedral to the octahedral coordination of Fe in the Pnma structure. More interestingly the XES spectra measured at the K b' line shows a significant increase related to the enhancement of the local Fe magnetic moment occurring in the FeSe 3D form [7]. Finally, our neutron diffraction experiments under HP-lowT have not revealed any detectable long range magnetic order associated to the intermediate pressure-induced AFM phase or to the 3D HP polymorph despite its higher iron magnetic moment.

References

[1] S. Karlsson, P. Toulemonde *et al.*, Supercond. Sci. Technol. **28**, 105009 (2015).
[2] P. Massat, P. Toulemonde, Y. Gallais *et al.,* PNAS USA **113**, 9177 (2016).
[3] L. Fanfarillo, J. Mansart, P. Toulemonde, H. Cercellier, P. Le Fèvre, F. Bertran, B. Valenzuela, L. Benfatto, V. Brouet, Phys. Rev. B **94**, 155138 (2016).
[4] M. Bendele *et al.,* Phys. Rev. B **85**, 064517 (2012).
[5] K. Kothapalli *et al.,* Nat. Comm. **7**, 12728 (2016).
[6] V. Svitlyk, M. Raba, V. Dmitriev, P. Rodière, P. Toulemonde, D. Chernyshov, M. Mezouar, Phys. Rev. B 96, 014520 (2017).
[7] B. Lebert, V. Balédent, P. Toulemonde, J. M. Ablett, and J.-P. Rueff, in preparation.

Spin-to-charge conversion through Rashba coupling in $SrTiO_3$-based two-dimensional electron gases

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The quasi 2D electron system (q2DES) that forms at the interface between $LaAlO_3$ (LAO) and $SrTiO_3$ (STO) has attracted much attention from the oxide electronics community [1]. Among its many low dimensional physical effects, the strong Rashba spin-orbit coupling present at the interface could be exploited for spin-to-charge interconversion, which presents advantages for the future of spintronics.

We will present experiments performed on the q2DES formed at NiFe/LAO/STO and NiFe/(metal)/STO heterostructures. We investigating the nature of the inverse Edelstein effect (responsible for the spin-to-charge conversion) through a combination of spin pumping, magnetotransport, spectroscopy and gating experiments. We found a highly efficient spin-to-charge conversion which is tunable by a gate voltage [2]. Results were then interpreted in terms of a crossover between the occupancy of one to several bands with different orbital characters and different spin-orbit textures

References

1. **S. Gariglio, M. Gabay, J. M. Triscone, APL Materials 4, 60701 (2016)** http://dx.doi.org/10.1063/1.4953822
2. **E. Lesne, D. C. Vaz, et al., Nature Materials 15, 1261 (2016)** https://dx.doi.org/10.1038/nmat4726

Enhanced electronic compressibility in FeSe induced by Hund's coupling

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Iron-based superconductors are multiorbital systems in which Hund's coupling plays a key role. A divergence in the electronic compressibility has been found very recently [1] in multiorbital models relevant for these materials. This divergence leads to an instability of the system, which may enhance some boson-mediated pairing mechanisms relevant for superconductivity.

FeSe, the simplest of the iron-based superconductors, has a critical temperature of 8 K which becomes larger with increasing pressure, reaching a maximum value of 37 K at P~9 GPa. Moreover, a monolayer of FeSe over a substrate of $SrTiO_3$ has shown a T_c higher than 100 K. We have studied the electronic compressibility of the normal non-magnetic phase in FeSe bulk at different pressures and in a monolayer. The results [2] show that a divergence of the electronic compressibility is found in a model for this compound under pressure, following similar trends than the critical temperature, and that this phenomenon occurs in the frontier between a normal and an orbitally decoupled (“Hund's”) metal.

References

1. Luca de' Medici, Phys. Rev. Lett. 118, 167003 (2017)
2. Pablo Villar Arribi and Luca de' Medici, in preparation.

Photoemission spectra of charge density wave states in cuprates

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Angle-resolved photoemission spectroscopy(ARPES) experiments have reported many exotic properties of cuprates, such as Fermi arc at normal state, two gaps at superconducting state and particle-hole asymmetry at the antinodal direction[1]. On the other hand, a number of inhomogeneous states or so-called charge density waves(CDW) states have also been discovered in cuprates by many experimental groups. The relation between these CDW states and ARPES spectra is unclear. With the help of Gutzwiller projected mean-field theory[2], we can reproduce the quasiparticle spectra in momentum space. The spectra show strong correspondence to the experimental data with afore-mentioned exotic features in it.

References

1. Vishik et al, PNAS 109, 18332-18337(2012).
2. W. Tu and T.K. Lee, Sci. Rep. 6, 18675(2016).

Probing the Gap Structure of KFe_2As_2

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KFe2As2 is the end member of the $(Ba_{1-x}K_x)Fe_2As_2$ series of iron-pnictide superconductors. Previous measurements have suggested the gap structure of KFe_2As_2 is nodal, either accidentally or due to the symmetry of the pairing state, in contrast with the rest of the series. Our measurement of the magnetic penetration depth appears to show that λ (T) does not saturate down to 50 mK, in-line with previous measurements, but the temperature dependence is not linear with T, as would be expected for a nodal gap. To provide further information about the structure of the energy gap., we explore the effect of non-linear, field dependant, corrections, as well as the influence of disorder, on λ (T).

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