International Conference

Physics of Low-Dimensional Conductors:

Problems and Perspectives

March, 25-28, 2012
Institute of Physics, Zagreb, Croatia

Programme and Abstracts

Coorganizers

Sponsorship

Supported by

F2E.ifs.hr

ISBN: 978-953-7666-08-8

International Conference

Physics of Low-Dimensional Conductors: Problems and Perspectives

March 25-28, 2012
Institute of Physics, Zagreb, Croatia

Program and Abstracts

pldc-pp@ifs.hr
http://pldc-pp.ifs.hr

The International conference “Physics of Low-Dimensional Conductors: Problems and Perspectives” is organized by the Institute of Physics and Faculty of Science, University of Zagreb, Zagreb, Croatia.

The Conference is sponsored by the Croatian Academy of Sciences and Arts.

The organization of the Conference is supported in part by the F2E project 65/10, (http://f2e.ifs.hr) of Unity through Knowledge Fund (UKF, http://www.ukf.hr)

Physics of Low-Dimensional Conductors: Problems and Perspectives

CIP available from the National and University Library, Zagreb, Croatia, under number 801100

ISB: 978-953-7666-08-8

Editors: Ivan Balog, Osor S. Barišić and Ana Smontara, Institute of Physics, Zagreb

Cover design: Jovica Ivkov, Institute of Physics, Zagreb

Committees and Boards

Chair Persons

Ana Smontara (Institute of Physics, Zagreb)

Denis K. Sunko (Faculty of Science, University of Zagreb)

Program Committee

Ivo Batistić (Faculty of Science, University of Zagreb)

Aleksa Bjeliš (Faculty of Science, University of Zagreb)

Antonije Dulčić (Faculty of Science, University of Zagreb)

László Forró (EPFL, Lausanne)

Ivan Kupčić (Faculty of Science, University of Zagreb)

Ivana Mrkonjić (MSES, Zagreb)

Ana Smontara (Institute of Physics, Zagreb)

Denis K. Sunko (Faculty of Science, University of Zagreb)

Eduard Tutiš (Institute of Physics, Zagreb)

Katarina Uzelac (Institute of Physics, Zagreb)

Local Organizing Committee

Ivan Balog (Institute of Physics, Zagreb)

Osor S. Barišić (Institute of Physics, Zagreb)

Jovica Ivkov (Institute of Physics, Zagreb)

Jagoda Lukatela (President, retired scientific advisor)

Petar Popčević (Institute of Physics, Zagreb)

Kristijan Velebit (Institute of Physics, Zagreb)

Contents

Dear friends and colleagues,

We are pleased to welcome you to the conference **Physics of low-dimensional conductors: Problems and Perspectives (PLDC-PP),** in Zagreb, Croatia, on March 25-28, 2012.

The conference intends to provide an overview of modern investigations into low-dimensional conductors, with an emphasis on open problems. Both in one and two dimensions, the underlying main theme is the competition of collective degrees of freedom, sometimes leading to physically relevant crossover regimes, coupling (super) conductivity, magnetism, and elasticity. A strong interplay of experimental and theoretical insight is thus indispensable in order to disentangle the dominant effects.

The occasion is to celebrate the 70th birthday of Professor Slaven Barišić (University of Zagreb), whose contributions to this subject matter over the past four decades have become standard textbook and reference material in condensed matter theory. The organizers wish to provide a level field for the exchange of ideas among researchers actively concerned with the physical reality of low-dimensional conductors, hoping for significant contributions from the participants as well as the invited speakers.

We have tried to include as much free time and social events as possible within the limitations of a three-day schedule, also to stimulate the exchange of ideas and promote collaboration. We invite you to take part in these events and enjoy them.

On behalf of the Program and Organizing committees of PLDC-PP, we are glad that you have chosen to participate in this event. We hope it will contribute to your professional development and relationships, and leave pleasant memories for a long time.

Sincerely,

Ana Smontara and Denis Sunko
Conference chairs

Slaven Barišić was born on Jan. 26, 1942, in Pleternica. He graduated in physics in 1964 at the Faculty of Science of the University of Zagreb, and obtained a Doctorat du 3ème cycle in 1968, and a PhD in 1971 at the Faculté de Sciences, Université de Paris, in Orsay, under the mentorship of Prof. J. Friedel.

From 1965 to 1972 he was an assistant, and then an associate scientist, at the Institute of Physics in Zagreb. From 1967 to 1971 he was a research associate at the Centre National de la Recherche Scientifique, Orsay, France. In 1972 he became an assistant, in 1976 associate, and in 1979 a full professor at the Physics Department of the Faculty of Science in Zagreb.

His research area is in theoretical condensed matter physics, especially phase transitions in low-dimensional conducting systems. Already in Orsay, under the guidance of J. Friedel, in a series of works comprising Ref. [1], he gave an important conceptual contribution, by formulating a broadly accepted and used, theory of electron-phonon coupling and Coulomb screening in the tight binding regime. Since then the efficiency and versatility of this approach as applied to anisotropic systems has been widely and profoundly confirmed, starting from A15 compounds in the sixties, inorganic chain compounds and organic Bechgaard salts in the seventies and eighties, and the high-temperature layered superconductors in last twenty-five years. Within this framework, in collaboration with leading American and Russian theorists, and with his younger colleagues in Zagreb, Barišić made a number of particularly noticeable breakthroughs in the explanations of phase diagrams and fluctuations in strongly correlated electron and electron-phonon systems. The reference [2] devoted to the role of Umklapp coupling in the subtle phase diagram of Bechgaard salts is the very well-known work from this group. The complementary line of research of Barišić and collaborators was devoted to statistical properties, particularly to strong critical fluctuations in numerous cases of low dimensional instabilities and phase transitions, the reference [3] being an important early achievement within this scope.

Soon after the discovery of the superconducting cuprates, he contributed [4] a simple physical interpretation of the LTT tilt in $La_{2-x}Ba_xCuO_4$, interesting because it strongly depresses the superconductivity. Associating it with the splitting of the degeneracy of the two in-plane metallised oxygen sites, he established a physical motivation to investigate the role of the oxygens in the superconducting transition. Systematic studies based on this main idea over the past twenty years have recently led to the development of a broad theoretical framework [5] to understand the cuprates across all of their phase diagram, still vigorously pursued as of this writing, characteristically, both without regard for the theoretical mainstream, and in close and open-minded contact with experiment.

Prof. Barišić is the author or co-author of roughly a hundred original and review articles, mostly published in reputable international journals, and 34 invited lectures at international conferences. He was a co-organizer of three international conferences and

co-editor of two of their proceedings. As a teacher he has reorganized the basic course *Solid State Physics,* and introduced two new courses, *Irreversible Processes* and *Theory of Phase Transitions*. As Chairman of the Physics Department of the Faculty of Science, he carried out a reform of the study of physics. He is member of editorial boards and a reviewer for several Croatian and international journals.

Prof. Barišić was the first chairman of the Theoretical Physics Section of the Institute of Physics of the University of Zagreb (1972–1981), chairman of the Physics Department of the Faculty of Science (1977–1978), vice-rector of the University of Zagreb (1984–1986), and Dean of the Science Departments of the Faculty of Science (1986–1988). He was the first (1991–1992) and last (1998–2000) advisor to the late first President of the Republic of Croatia dr Franjo Tuđman, for science, education, and development strategy, member of the Steering Committee of the University of Zagreb (1993–1996), first president of the National Council for High Education (1994–2000), and co-founder of the Military-technical Advisory Board of the Croatian Ministry of Defence.

Prof. Barišić is a member of: the Croatian Physical Society, of which he became the first president in 1990, French Physical Society, Institute of Physics (UK), European Physical Society, Croatian Academy of Arts and Sciences, and European Academy of Science, Arts and Humanities (Paris). He is recipient of the *Ruđer Bošković* award in 1976, *Memorial Medal of the Homeland War* in 1992, and *Order of the Croatian Morning Star with the effigy of Ruđer Bošković* in 1997.

Aleksa Bjeliš

1. S.Barišić, J.Labbé and J.Friedel
Tight Binding and Transition-Metal Superconductivity
Phys. Rev.Letters, 25, 919 (1971)

2. S.Barišić and S.Brazovskii
Superconductivity and Repulsive Interactions in Linear Chain Materials
Recent Developments in Condensed Matter Physics
ed. J.T. Devreese (Plenum, New York) Vol. 1, 327 (1981)

3. S.Barišić and P.G. de Gennes
Upper Critical Field of Weakly Coupled Linear Chains
Sol.St.Comm., 6, 281 (1968)

4. S.Barišić, J.Zelenko
Electron mechanism for the structural phase transition in $La_{2-x}Sr_xCuO_4$
Sol.St.Commun. 74, 367 (1989)

5. S. Barišić and O.S. Barišić
Approaching Large U_d *High-*T_c *Cuprates from the Covalent Side*
J.Supercond. Nov. Magn., DOI 10.1007/s10948-012-1461-0 (2012)

**Biographical facts according to the Croatian Academy of Sciences and Arts, http://info.hazu.hr*

Timetable and Program

Sunday, March 25 – Arrivals

18:00 -20:00	**Registration**
18:00 -	**Welcome drink**

Monday March 26 – morning

08:45	**WELCOME ADDRESS**	
	Session I - chairman Antonije Dulčić	
09:00	**Aleksa Bjeliš** (I) Field induced density waves: orbital quantization, Pauli splitting, magnetic breakdown...	17
09:40	**Serguei Brazovskii** (I) Lessons from theory of organic conductors since Zagreb 1980	18
10:20	**Davor Pavuna** (I) Direct ARPES and superconductivity on in-situ grown ultra-thin high-T_C films	35
10:45-11:10	**Coffee break**	
	Session II - chairman John R. Cooper	
11:10	**Henri Alloul** (I) Evidence for distinct ranges and gaps for the superconductivity and the pseudogap from high field transport measurements of the superconducting fluctuations in $YBa_2Cu_3O_{6+x}$	19
11:50	**Sergey Artemenko** (I) Non-stationary regime of conduction in one-dimensional system of interacting electrons pinned by a defect	20
12:30	**Eduard Tutiš** (I) Metal-semiconductor transitions for electrons in kagome planes	36
12:55-15:00	**Lunch break**	

I - Invited lecture (40 min or 25 min)
C - Contributed lecture (20 min)

Monday March 26 – afternoon

	Session III - chairman Henri Alloul	
15:00	**Thierry Giamarchi** (I) Transport in Luttinger liquids	21
15:40	**Neven Barišić** (C) The scattering rates in cuprates	41
16:00	**Vittorio Cataudella** (C) Relevance of charge-lattice interaction in underdoped cuprates	42
16:20-16:45	**Coffee break**	
	Session IV - chairman Eduard Tutiš	
16:45	**Antonije Dulčić** (I) Extent of superconducting fluctuations above T_c in $YBa_2Cu_3O_{7-\delta}$ single crystals	37
17:10	**Osor S. Barišić** (C) Diagrammatic content of the dynamical mean-field theory: Holstein polaron problem in finite dimensions	43
17:30	**Ivan Kupčić** (C) Optical and transport properties of multiband Peierls-CDW systems - the bad metal $BaVS_3$	44
17:50	**Ivan Balog** (C) Inhomogeneities at all scales at a phase transition altered by disorder	45

Tuesday March 27 - morning

	Session V - chairman László Forró	
09:00	**John R. Cooper** (I) Some recent experimental studies of cuprate and pnictide superconductors	22
09:40	**Ivan Božović** (I) Solving the puzzle of high-T_c superconductivity in cuprates one atomic layer at a time	24
10:20	**Amit Keren** (I) A magnetic analog of the isotope effect in cuprates	38
10:45-11:10	**Coffee break**	
	Session VI - chairman Sasha Alexandrov	
11:10	**Nikolay Plakida** (I) Spin excitations and mechanism of superconductivity in cuprates	25
11:50	**Robert Comès** (I) Strong 1-D effects in single layer Hg cuprates	26
12:30	**Zoran Radović** (C) Dominant second harmonic in the Josephson current-phase relation: manifestation of the long-range spin-triplet proximity effect	46
12:50-14:30	**Lunch break**	

Tuesday March 27 - afternoon

	Session VII - chairman Nikolay Plakida	
14:30	**Antonio Bianconi** (I) The role of elasticity in high temperature superconductivity and its implication on T_c amplification: scale invariant ordering of oxygen interstitials in cuprates	27
15.10	**Titusz Fehér** (I) 2D magnetism in κ-(BEDT-TTF)$_2$Cu[N(CN)$_2$]Cl, a spin-1/2 antiferromagnet with Dzyaloshinskii-Moriya interaction	39
15:35-16:45	**Poster session & Coffee break**	
16:45-19:00	**Tour of Zagreb**	

Wednesday March 28 - morning

	Session VIII - chairman Jean-Paul Pouget	
09:00	**Sasha Alexandrov** (I) Theory of high temperature superconductivity in polar doped insulators	29
09:40	**László Forró** (I) Quo vadis organic conductors	30
10:20	**Natasha Kirova** (I) Modeling of nonlinear and non-stationary multi-vortex behavior of CDWs in restricted geometries of mesa junctions	40
10:45-11:10	**Coffee break**	
	Session IX - chairman Robert Comès	
11:40	**Jean–Paul Pouget** (I) $BaVS_3$: a model system for the interplay between charge, spin, orbital and structural degrees of freedom	31
12:10	**Martin Dressel** (I) Charge order and superconductivity in low-dimensional organic conductors	32
12:30	**Tomaž Mertelj** (C) Doping dependence of femtosecond quasi-particle relaxation dynamics in $Ba(Fe,Co)_2As_2$ single crystals: possible evidence for normal state nematic fluctuations	47
12:50-15:00	**Lunch break**	

Wednesday March 28 - afternoon

	Session X - chairman Thierry Giamarchi	
15:00	**Alfred Zawadovski** (I) Theory of the Raman scattering by localized excitations in metallic glasses: boson peak	33
15.40	**Claude Bourbonnais** (I) Anomalous quantum criticality in unconventional superconductors: what can be learned from organics	34
16:20-16:45	**Closing remarks** (Serguei Brazovskii)	
16:45-17:10	**Coffee**	
19:30-	**Banquet**	

List of posters

Field induced density waves: orbital quantization, Pauli splitting, magnetic breakdown...

Aleksa Bjeliš[1]

[1]*Faculty of Science, University of Zagreb, Zagreb, Croatia*

From the very beginning of the theoretical work organized by Slaven Barišić, a particular attention has been paid to low energy regime of charge or spin density wave [C(S)DW] ordered states. In various specific situations very often one encountered phenomena which appeared to have wider conceptual significances. The first such case was the temperature variation of CDWs in TTF-TCNQ which led us to a very intriguing picture of deeply (meta) stable periodic configurations in a strongly chaotic phase space due to the competition of two weakly coupled periodic patterns. The analogous situation has been encountered later on in a different context of anisotropic ferroelectric-like materials with two competing periodicities. It has been well-known already from the seminal experimental and theoretical work on the Bechgaard salt $(TMTSF)_2PF_6$ that in the systems possessing or being susceptible to density wave orderings the external magnetic field often brings an additional complexity into their phase diagrams. Three characteristic examples will be reviewed here. Firstly, due to the competition of the Pauli splitting and the orbital quantization in the quasi-one-dimensional band with imperfect nesting, the CDW in the magnetic field may disappear and then reappear through the cascade of field-induced SDWs. This behaviour has been observed in few organic and inorganic materials. The second example is the Bechgaad salt $(TMTSF)_2ClO_4$ with the SDW order sensitive to the strength of anion ordering which introduces transverse dimerization in the conducting band. Besides the orbital quantization, one has to take into account the magnetic breakdown contribution due to the tunnelling between two sub-bands. Even more, since the effective potential induced by anion ordering is strong, this tunnelling has to be treated exactly, and not in the usual quasi classical way. Finally the energy gain due to the magnetic breakdown opens a possibility of a new mechanism of stabilization of a field induced DWs. Choosing, unlikely to the standard field-induced SDW regime, a wave vector which is far from the almost perfect nesting value, one gets weak barriers between, now large, pockets. The tunnelling through these barriers gives an energy gain that enables a new type of DW ordering induced exclusively by the magnetic breakdown mechanism.

Lessons from theory of organic conductors since Zagreb 1980

Serguei Brazovskii[1]

[1]*Laboratorie de physique théorique et modèles statistiques, CNRS, Université Paris Sud, Orsay, France*

Before and through the D-day of discovery of the superconductivity in organic crystals, the theory view on origin of their phase diagram was a frontal competition of big quantities – the electronic interactions. It is not much different in today's popular approach to strongly correlated systems (from organic to cuprates, polymers, etc) where other big quantities – electrons' repulsion and the bandwidth are in comparison. Another philosophy was forwarded in Zagreb soon after the D-day: big parameters determine a basic model for the whole family of materials which does not change essentially. There are small, usually symmetry defined, perturbations that play the game. Quoting S. Barišić: "This interpretation explains the observations in $(TMTSF)_2PF_6$ as a result of competition of the two small (off-chain) parameters, g^3 and J, rather than as a result of the accidental cancelation of the large coupling constants $2g^2$ and g^1". With all inevitable confusions through decades, this path has led to integrating phenomena of the $4K_F$ anomaly, of anionic and structureless phase transitions, to discovery and understanding of the charge ordering with ferroelectricity, and now it is leading to ferroelectric conducting polymers - prone to applications.

Evidence for distinct ranges and gaps for the superconductivity and the pseudogap from high field transport measurements of the superconducting fluctuations in $YBa_2Cu_3O_{6+x}$

F. Rullier-Albenque[1], Henri Alloul[2]

[1]*Service de Physique de l'Etat Condensé, CEA Saclay, France*
[2]*Laboratoire de Physique des Solides, Orsay, France*

Since its discovery, the origin of the pseudogap has remained a very controversial issue in the physics of cuprates. It has been assigned either to preformed Cooper pairs or to a large variety of distinct orders some of them competing with superconductivity. Here we show that refined studies of the contribution of superconducting fluctuations (SCF) to the ab-plane conductivity give conclusive evidences on both aspects. The SCF paraconductivity has been determined accurately in a series of $YBa_2Cu_3O_{6+x}$ single crystals using high magnetic fields to restore the normal state behavior.[1] This allows us to determine within the same set of transport measurements both the field $H'_c(T)$ and the temperature T'_c above which the SCFs are fully suppressed, and the pseudogap temperature T^*. A careful investigation near optimal doping shows that T^* becomes smaller than T'_c, which unambiguously evidences that the pseudogap cannot be assigned to preformed pairs.[2] In the nearly optimally doped samples, the SCF contribution to conductivity can be accounted for by Gaussian Aslamazov-Larkin fluctuations in the Ginzburg-Landau approach.[3] A phase fluctuation contribution might be invoked in the most underdoped sample in a T range which increases when controlled disorder is introduced by electron irradiation. Finally, the analysis of the fluctuation magnetoconductance allows us to determine the critical fields $H_{c2}(0)$) which are found to be very similar to $H'_c(0)$ and to increase with hole doping. These two depairing fields which are directly connected to the magnitude of the superconducting gap therefore follow the evolution of T_c, which is at odds with the sharp decrease of the pseudogap with increasing hole doping.

[1] F. Rullier-Albenque, *et.al.*, Phys. Rev. Lett. **99** (2007) 027003

[2] H. Alloul, *et.al.*, Europhys. Lett. **91** (2010) 37005

[3] F. Rullier-Albenque, *et.al.*, Phys. Rev. B **91** (2011) 014522

Non-stationary regime of conduction in one-dimensional system of interacting electrons pinned by a defect

Sergey Artemenko[1], Pavel Aseev[1], Dmitriy Shapiro[1]

[1]*V.A. Kotelnikov Instute of Radioengineering and Electronics of the Russian Academy of Sciences, Moscow, Russia*

We study transport properties of one-dimensional (1D) system of interacting electrons pinned by an impurity or non-ideal contact of the 1D system with current leads of higher dimension. Both long-range Coulomb interaction and short-range interaction induced by screening of the interaction by metallic gate are studied using an approach based on the concept of Luttinger liquid. As density-density correlation function of such a system has a quasi-periodic component with the period equal to mean distance between the electrons, and this component decays slowly (in case of Coulomb interaction, even slower than any power law), such a system can be considered as a 1D analogue of the Wigner crystal.[1]

In case of short-range interaction, conduction of such a system is known to exhibit I-V curves characterized by power-law conductivity at low voltages [1]. We predict a new dynamic regime of conduction corresponding to sliding of the 1D Wigner crystal depinned by the applied voltage exceeding a threshold value related to the defect potential renormalized by 1D fluctuations. In this regime the dc current is accompanied by current oscillations with the wash-board frequency $f = I/e$. I-V curves and the ac current generated by sliding are calculated. I-V curves are shown to be sensitive to spin bias applied to the contacts. There is a similarity with the depinning of charge density waves in quasi-1D compounds.

[1] T. Giamarchi, *Quantum Physics in One Dimension*, (Clarendon Press, Oxford, 2003).

Transport in Luttinger liquids

Thierry Giamarchi[1]

[1]*DPMC-MaNEP, University of Geneva, 24 Quai Ernest Ansermet, 1211 Geneva, Switzerland*

Interactions in one dimensional systems lead to remarkable properties and in particular to the quite unusual Luttinger liquid features. These features manifest themselves in particular in the transport properties, where the interplay of interactions and umklapp processes leads to anomalous transport.

I will show how the transport properties can be computed, and how they can be used to probe the Luttinger liquid nature of the material. I will discuss mostly the organic conductors, but also spin ladders for which similar Luttinger liquid properties can be analyzed.

Some recent experimental studies of cuprate and pnictide superconductors

John R. Cooper[1]

[1]*Cavendish Laboratory, University of Cambridge, U.K.*

In the first part of this talk I will report some new measurements [1] of the temperature (T) dependent static magnetic susceptibility, $\chi(T)$ of relatively large single crystals of $YBa_2Cu_3O_{6+x}$ above the superconducting transition temperature (T_c) with magnetic field applied parallel and perpendicular to the CuO_2 planes. Measurements have been made for 9 values of x between 0.38 and 0.95, with T_c from 14 to 93 K. We argue that for $YBa_2Cu_3O_{6+x}$, as well as for $YBa_2Cu_4O_8$ and $Bi_{1.85}Sr_{2.15}CaCu_2O_{8+x}$, the T-dependent magnetic anisotropy $\chi_c(T)$ - $\chi_{ab}(T)$ well above T_c arises from the pseudogap combined with substantial g-factor anisotropy which is at the higher end of values observed for insulating Cu^{2+} salts. This may well point towards a Mott-Hubbard or heavy Fermion type of picture, where there is a local moment on the Cu sites, rather than a band interpretation. In this regard we note that the strange "non-states-conserving" property of the pseudogap [2] could be connected with a feature of Kondo physics where an applied magnetic field "digs a hole" in the Kondo resonance at the Fermi energy (E_F). This occurs because it suppresses spin-flip scattering and hence reduces the transfer of spectral weight to E_F from localized states at higher and lower energies. In the present case this magnetic field would be a molecular field arising from the anti-ferromagnetic interaction with neighbouring Cu ions.

We have previously found that a pseudogap formula derived for a nodal, V-shaped density of states gives an excellent description of the entropy and $\chi(T)$ of several families of hole-doped cuprates [2,3] over a wide range of hole concentrations(p). Fits to the present $\chi(T)$ anisotropy data require an extra, weakly T- dependent, contribution for most values of x, which may be connected with the electron pockets seen by high field quantum oscillation studies. As T is reduced, deviations from these fits can be used to define onset temperatures for superconducting fluctuations which are to 30-50 K above T_c.

In the second part of the talk I will report data obtained in a systematic differential heat capacity study [4] of the hole-doped pnictide superconductor $Ba_{1-x}K_xFe_2As_2$ from 2 to 350 K in applied fields up to 13 T. The K content, x, was varied from 0 to 1 in steps of 0.1, giving p values (holes per Fe atom) between 0 and 0.5. Here the parent (p = 0) state is a semi-metallic spin density wave (SDW) that is gradually suppressed by hole doping. Among numerous interesting results we see the coexistence of SDW and superconducting order for x = 0.2, an unexpectedly sharp peak in the superconducting condensation energy at x = 0.4 and a broader dome in T_c with a maximum value of 40 K. The low-T normal state electronic specific hea increases approximately linearly with x, while there is a corresponding decrease at high temperature, which we attribute to a growth in low energy electron correlations. Both the

zero-field data and the field-dependence give clear evidence for three distinct superconducting gaps, which are presumably associated with different Fermi surface sheets. Corresponding measurements of $\chi(T)$ have also been made and will be compared with the electronic entropy obtained from the heat capacity.

[1] I. Kokanović, J.R. Cooper and K.Iida, preprint (2012).

[2] J.W. Loram, J. Luo J.R. Cooper, W.Y. Liang and J.L. Tallon, J Phys. Chem. Solids **62** (2001) 59

[3] S.H. Naqib, J.R. Cooper and J.W. Loram, Phys. Rev. B **79** (2009) 104519

[4] J.G. Storey, J.W. Loram, J.R. Cooper, Z. Bukowski and J. Karpinski, preprint (2012)

Solving the puzzle of high-T_c superconductivity in cuprates one atomic layer at a time

Ivan Božović[1]

[1]*Brookhaven National Laboratory, Upton NY 11973, USA*

We use atomic-layer-by-layer molecular beam epitaxy (ALL-MBE) to synthesize atomically smooth thin films, multilayers and superlattices of cuprates and other complex oxides. In this talk, I will review our recent experiments on such films and superlattices that probe the basic physics of high-temperature superconductivity (HTS).

Some key questions in HTS physics about the dimensionality, relevant interactions, the roles of (in)homogeneity and fluctuations – are answered as follows. (i) In an isolated single CuO_2 plane without holes, quantum spin liquid forms.[1] (ii) In an isolated CuO_2 plane doped with holes, HTS can occur with Tc higher than in the bulk.[2] (iii) HTS cuprate samples can be quite homogeneous (have a very uniform SC gap, etc.).[3] (iv) HTS and antiferromagnetism separate on the scale of 1 Å in space and 1 eV in energy.[4] (v) Pseudogap and SC states mix on the 1,000 Å length scale ("Giant Proximity Effect").[5] (vi) *In-plane* charge excitations are strongly coupled to *out-of-plane* lattice vibrations.[6] (vii) Strong *phase* fluctuations drive the SC transition, but 10-15 K above T_c they fade out.[7]

[1] Suter *et al.*, Phys. Rev. Lett. **106** (2011) 237003

[2] Božović *et al.*, Phys. Rev. Lett. **89** (2002) 107001

[3] Abbamonte *et al.*, Science **297** (2002) 581

[4] Božović *et al.*, Nature **422** (2003) 873

[5] Božović *et al.*, Phys. Rev. Lett. **193** (2004) 157002

[6] Gedik *et al.*, Science **316** (2007) 425

[7] Sochnikov *et al.*, Nature Nanotech. **5** (2010) 516

Spin excitations and mechanisms of superconductivity in cuprates

Nikolay Plakida[1]

[1] *Joint Institite for Nuclear Research, Dubna*

Microscopic theory of spin excitations in strongly-correlated electronic systems within the t-J model is formulated and an exact representation for the dynamic spin susceptibility is derived. In the normal state, the excitation spectrum reveals a crossover from spin-wave-like excitations at low doping to overdamped paramagnons above the optimal doping. At low temperatures, the resonance mode at the antiferromagnetic wave vector emerges which is explained by a weak damping of spin excitations at this wave vector, while an opening of a superconducting gap plays a minor role.[1] In discussing mechanisms of high-T_c superconductivity in cuprates, a major role of spin excitations induced by a kinematic interaction in the Hubbard model is stressed. At the same time, contributions from electron-phonon interaction and the inter-site Coulomb interaction are suppressed in the case of the d-wave pairing.[2]

[1] A. A. Vladimirov, *et al.*, Phys. Rev. B **83** (2011) 024411

[2] N. M. Plakida, arXiv:1110.6715 (cond-mat)

Strong 1-D effects in single layer Hg cuprates

Stephan Megtert[1], Manuel Izquierdo[2], Veio Honkimaki[3], Dorothé Colson[4], Helène Raffy[5], Robert Comès[5]

[1]*Unité Mixte de Physique, UMR137 CNRS/THALES,F91767 Palaiseau cedex*
[2]*Synchrotron SOLEIL, L'Orme des Merisiers St. Aubin, BP48-F91192 Gif sur Yvette*
[3]*European Synchrotron Radiation Facility(ESRF), BP220, F38043 Grenoble Cedex 9*
[4]*CEA Saclay, IRAMIS, SPEC(CNRS URA2464), F91191 Gif sur Yvette*
[5]*Laboratoire de Physique des Solides, Université Paris-Sud 11, CNRS UMR 8502, F91405 Orsay*

X-ray scattering from one layer Hg cuprates, near optimal doping, reveals that O_3 atoms aggregate to form long chains (over 75 unit cells) in both tetragonal directions. Correlated, are transverse and longitudinal displacements of the nearby pairs of Hg, and Cu atoms from 2 CuO_2 layers, above and below the main O_3 array. Within the bulk crystal this creates local linear channels. In each, a 3-D unit consisting of one interstitial oxygen and displaced nearby atoms, is repeated periodically with the average lattice constant. Uncorrelated with each others, they are probably conducting. Indeed, a much weaker 1-D scattering, from incommensurate periodic lattice distorsions at the wave vectors q_1=0.42 and q_2=0.84 a*, remind the $2k_F$ and $4k_F$ scattering from 1-D conductors. Such strong 1-D features, without coupling at lowest temperatures, are unique to Hg cuprates, and could perhaps, explain their higher T_c compared to other cuprates. Giant Kohn anomalies or Friedel oscillations, at local levels,and related instabilities, may have to be considered to understand their electronic properties.

The role of elasticity in high temperature superconductivity and its implication on T_C amplification: scale invariant ordering of oxygen interstitials in cuprates

Antonio Bianconi[1]

[1]*Superstripes, Department of Physics, Sapienza University of Rome, Rome, Italy*

The tuning of the Fermi level in the proximity of a band edge in a metal has been proposed as the mechanism for high temperature superconductivity in intermetallics by Labbé, Barišić, and Friedel [1]. The idea of shape resonance in superconducting gaps [2] is an extension of this idea including the exchange interaction, giving the non diagonal coupling terms, for the pair transfer of pairs at the band edge of a 1D band to second pairs in a band with high Fermi energy and viceversa. Polarons in cuprates have been related by Barišić to Crystal-Field effects [3] in agreement with the key role of lattice effects and strain [4] for polaron formation and self-organization in La_2CuO_4. [5] where the idea of 1D band and polaron organization into wires meet. Here we report recent evidence that also oxygen interstitials in the La_2O_{2+y} spacer layers of La_2CuO_{4+y} high-T_c superconductors order in 1D superstripes characterized by a scale free distribution up to the micron scale. Intriguingly, the scale invariant distribution of dopants and local lattice distortions enhance superconductivity at high temperature.[6] The time resolved evolution of the defects nucleation, growth and organization have been investigated by x-ray diffraction under continuous x-ray illumination.[7] The new insight in the complexity of the well-known superconducting material La_2CuO_{4+y} has allowed us to understand and demonstrate some necessary steps to 'write' superconducting wires on the micrometre scale. In conclusion the proximity to a Lifshitz transition for a vanishing Fermi surface is an essential feature of high temperature superconductors. The scale invariant structural complexity is shown to be a generic essential feature of high temperature granular superconductors in agreement with the theoretical results for the amplification of the Insulator to Superconductor transition temperature on annealed complex networks.[8,9]

[1] J. Labbé, S. Barišić, and J. Friedel , Phys. Rev. Lett. **19** (1967) 1039

[2] A. Perali, A. Bianconi, A. Lanzara, and N. L. Saini, Sol. State Commun. **19** (1996) 186

[3] S. Barišić and I. Batistić, Europhys. Lett. **8** (1989) 765

[4] S. Agrestini, N L Saini, G Bianconi and A Bianconi, J. Phys. A: Math. Gen. **36** (2003) 9133

[5] A. Bianconi, Sol. State Commun. **91** (1994) 1; A. Bianconi and M. Missori, Sol. State Commun. **91** (1994) 287

[6] M. Fratini, N. Poccia, A. Ricci, G. Campi, M. Burghammer, G. Aeppli, and A. Bianconi, Nature **466** (2010) 841

[7] N. Poccia, M. Fratini, A. Ricci , G. Campi, L. Barba, A. Vittorini-Orgeas, G. Bianconi, G. Aeppli and A. Bianconi, Nature Materials **10** (2011) 726

[8] Ginestra Bianconi, arXiv:1111.1160 (2011)

[9] Ginestra Bianconi, APS march meeting at Session D54: Focus Session: Complex and co-evolving networks - Foundations in Complex Networks, February 27, 2012 Abstract: D54.00006

Theory of high temperature superconductivity in polar doped insulators

Sasha Alexandrov[1]

[1]*Instituto de Fisica Gleb Wataghin Universidade Estadual de Campinas, Brazil, and Loughborough University, United Kingdom*

In the last two decades there have been tremendous attempts to built an adequate theory of high-temperature superconductivity. Most studies used some model Hamiltonians with input parameters not directly related to the material. The dielectric response function of electrons in strongly correlated high-temperature superconductors is apriori unknown. Hence one has to start with the generic Hamiltonian including unscreened Coulomb and Froehlich electron-phonon interactions operating on the same scale since any ad-hoc assumption on their range and relative magnitude might fail. Moreover, both interactions are quite strong (of the order of 1 eV) compared with the low Fermi energy of doped carries because of a poor screening by non- or near-adiabatic carriers. In those conditions the BCS-Eliashberg theory is not applicable. Using the generic Hamiltonian with the unscrened Coulomb and electron-phonon interactions I have built the analytical theory of high-temperature superconductivity predicting the critical temperature in excess of a hundred Kelvin without any adjustable parameters in polar doped insulators. The many-particle electron system is described by an analytically solvable polaronic tJp Hamiltonian with reduced hopping integral, t, allowed double on-site occupancy, large phonon-induced antiferromagnetic exchange, Jp > t, and a high- temperature superconducting state of small superlight bipolarons protected from clustering. Here I outline major steps of the theory suggesting that the true origin of high-temperature superconductivity is found in a proper combination of strong electron-electron correlations with a significant finite-range (Froehlich) EPI.

Quo vadis organic conductors

László Forró[1]

[1]*École Polytechnique Fédérale de Lausanne, Lausanne, Switzerland*

Since half a century organic conductors represent one of the most creative domains of condensed matter physics. The Zagreb-group, led by Slaven Barišić, was on the forefront of this research.

In this presentation, a critical view of the field will be attempted...

$BaVS_3$: a model system for the interplay between charge, spin, orbital and structural degrees of freedom

Jean-Paul Pouget[1], P. Foury-Leylekian[1]

[1]*Laboratoire de Physique des Solides, Université Paris-Sud, CNRS UMR 8502, 91405 Orsay, France*

$BaVS_3$ is a bad metal whose structure consists of a hexagonal packing of quasi-one-dimensional (1D) chains of face-sharing VS_6 octahedra running along c. Band structure calculation reveals three t2g bands crossing the Fermi level which are partly occupied by the 3d1 V electron: two narrow bands built with degenerate e(t2g) orbitals and one quasi-1D dispersive band along c* built with the dz orbital. The localized e(t2g) electrons are responsible for the magnetism of $BaVS_3$ and the delocalized dz electrons for its anisotropic metallic character. At T_P=70 K and atmospheric pressure (P), $BaVS_3$ undergoes a second order metal-to-insulator transition, corresponding to a Peierls transition which stabilizes a superstructure where the V chains are tetramerized. The Peierls instability is caused by the formation below T* 170 K of $2k_F$=1/2c* charge density wave (CDW) in the 1D dz electronic sub-band. From the $2k_F$ component one deduces that the CDW involves dz electrons per V. The remaining electrons per V, which account for the Curie constant of the localized magnetism of $BaVS_3$, belong to the e(t2g) states. Coulomb repulsions between these electron species stabilizes also below T_P an orbital order consisting in an out of phase modulation between the dz and e(t2g) densities. Below TP non paired e(t2g) electrons remain magnetically active. Their spin develop antiferromagnetic (AF) correlations which drive $BaVS_3$ into a triply incommensurate magnetic order below T_N=31K.

In this talk we present some basic aspects of the Peierls transition of $BaVS_3$ [1]. We determine in particular the CDW phase diagram under P which shows a vanishing of the second order Peierls transition together with a commensurate-incommensurate first order de-locking transition of the $2k_F$ wave vector.[2] The drop of T_P can be quantitatively understood by the decrease of the electron-hole condensate lifetime due to enhancement of the hybridization between the dz and e(t2g) levels when P increases. We also present a resonant magnetic X-ray scattering determination of the complex magnetic structure of $BaVS_3$ which incorporates both the AF like order of the e(t2g) spins with the dz singlet pairs stabilized below T_P.[3]

[1] For a recent review see: P. Foury-Leylekian, Ph. Leininger, V. Ilakovac, Y. Joly, S. Bernu, S. Fagot and J.-P. Pouget, Physica B, DOI: 10.1016/j.physb.2012.01.008.

[2] S. Bernu, P. Fertey, J.-P. Itié, H. Berger, P. Foury-Leylekian, and J.-P. Pouget (submitted)

[3] Ph. Leininger, V. Ilakovac, Y. Joly, E. Schierle, E. Weschke, O. Bunau, H. Berger, J.-P. Pouget, and P. Foury-Leylekian, Phys. Rev. Lett. **106** (2011) 167203

Charge order and superconductivity in low-dimensional organic conductors

Martin Dressel[1], N. Drichko[1], S. Kaiser[1], T. Rõõm[2], D. Hüvonen[2], U. Nagel[2], M. Masino[3], A. Girlando[3], A. Greco[4], J. Merino[5], J. A. Schlueter[6]

[1]*1.Physikalisches Instnstitut, Universität Stuttgart, Stuttgart, Germany*
[2]*Nat. Inst. of Chem. Phys. and Biophys., Tallinn, Estonia*
[3]*Dip. Chim., INSTM-UdR Parma, Parma Univ. Parma, Italy*
[4]*UNR-CONICET, Rosario, Argentina*
[5]*Dep. Fìs. Teòr. Mat. Cond., Univ. Autònoma Madrid, Spain*
[6]*Mat. Sci. Div., Argonne Nat. Lab., Illinois, U.S.A*

Some of the two-dimensional quarter-filled BEDT-TTF salts are superconductors, while some of them remain metallic down to low temperatures; others undergo a sharp metal to insulator transition. Why do these materials behave electronically so differently although they are similar in structure? Optical spectro-scopy reveals that these compounds are subject to charge order to a different degree. The interplay of charge order and superconductivity suggests that superconductivity is mediated by charge order fluctuations. We present infrared and THz investigations on these two-dimensional organic metals with a quarter-filled conduction band, in particular T_c = 5 K superconductor β"-(BEDT-TTF)$_2$SF$_5$CH$_2$CF$_2$SO$_3$. Raman and infrared measurements indicate a charge disproportionation of 02e. The optical conductivity evidences inter-action of the charge carriers with charge-order fluctuations: Strong localization due to nearest neighbor Coulomb interaction significantly reduces the spectral weight of the Drude response and an intense charge-fluctuation band forms around 300 cm^{-1}. Several observations provide evidence that the charge carriers interact with charge fluctuations: the linear dependent spectral weight of the Drude component, and most important intensity of the collective charge-order excitation at 30 cm^{-1} that is linked to the intensity of Drude response. Below 5 K we observe a superconducting gap (2Δ = 12 cm^{-1}). All observations suggest that superconductivity in this compound is mediated by charge-order fluctuations.

[1] S. Kaiser *et al.*, Phys. Rev. Lett. **105** 2010 206402

[2] M. Glied *et al.*, Synth. Met. **159** 2009 1043

[3] N. Drichko *et al.*, Physica B **404** 2009 490

[4] N. Drichko *et al.*, Phys. Rev. B **74** 2006 235121

[5] J. Merino, A. Greco, N. Drichko and M. Dressel, Phys. Rev. Lett. **96** 2006 216402

[6] M. Dressel and N. Drichko, Chemical Review **104** 2004 5689

[7] M. Dressel, N. Drichko, J. Schlueter and J. Merino, Rev. Lett. **90** 2003 167002

Theory of the Raman scattering by localized excitations in metallic glasses: boson peak

István Tüttő[1], Alfréd Zawadowski[2]

[1]*Wigner Research Centre for Physics, Hungarian Academy of Sciences*
[2]*Institute of Physics, Budapest University of Technology and Economics*

The theory of Raman scattering in dirty metals is reviewed, where the electron transferred between different (angular momentum) channels. The Drude peak is characterized by the elastic scattering time of the electrons.[1] In case of glassy system an additional peak, so called boson peak occurs, which is usually associated with excitations of localized vibrations. As their occupations are increasing with increasing temperature the intensity of peak is increasing also. The position of the peak is determined by the spectra of the localized vibrations. Recently, the boson peak has been observed by the Munich group[2] by studying $Ni_{67}Zr_{33}$ glasses. However, surprisingly the intensity of the peak decreasing by increasing the temperature, thus not the occupations of the excitations dominate that dependence. In the electron scattering due to localized vibration the ratio of the amplitude of the localized vibration and the Fermi wave length plays a crucial role. As the temperature is increased the vibrational amplitude may exceed the Fermi wave length and the intensity decreases due to the Debye-Waller factor. Analyzing the spectrum the inelastic scattering time is in accordance with the resistivity and the boson peak follows the Debye-Waller prediction.

[1] A. Zawadowski and M. Cardona, Phys. Rev. B **42** (1990) 10375

[2] B. Muschler, I. Tüttő, A. Zawadowski, J. Balogh, R. Hackl, Phys. Rev. B **84** (2011) 104104

Anomalous quantum criticality in unconventional superconductors: what can be learned from organics

Claude Bourbonnais[1]

[1]*Regroupement Quebecois des Materiaux de Pointe, Département de physique, Université de Sherbrooke, Canada and and Canadian Institute for Advanced Research, Toronto*

The Bechgaard salts series of low dimensional organic conductors stand out as prototypical compounds where unconventional superconductivity interacts with antiferromagnetism. This interaction not only yields a characteristic sequence of instabilities in which spin-density-wave and superconducting orders succeed one another under pressure, but it also leads to various nonFermi liquid anomalies. Among these linear temperature resistivity [1] and Curie-Weiss nuclear spin relaxation rate [2a] are found to correlate in strength with both the amplitude of spin correlations and Cooper pairing or the size of T_c. This gives rise to an extended range of quantum criticality under pressure that disagrees with the conventional scheme of quantum critical phenomena. We shall discuss how the renormalization group approach to the quasi-one dimensional electron gas model with nesting deviations can capture the origin of interaction between Cooper and spin-density-wave pairings and how it governs the correlation between the normal state anomalies and T_c over the broad range of pressure where superconductivity is found in these materials.[2b]

[1] N. Doiron-Leyraud *et al.*, Phys. Rev. B **80** (2009) 214531; Eur. Phys. J.B **78** (2010) 23

[2] a) C. Bourbonnais and A. Sedeki, Phys. Rev. B **80** (2009) 85105; b) A. Sedeki et al., arXiv: 1202.2099

Direct ARPES and superconductivity on *in-situ* grown ultra-thin high-T_C films

Davor Pavuna[1]

[1]*CREAM, ICMP, EPFL, Lausanne, Switzerland*

In the past decade we have systematically probed low energy electronic structure and measured properties of high-T_c films under different degree of epitaxial strain. [1-5] In overdoped in-plane compressed LSCO-214 films we doubled T_c, from 20 to 40 K, yet Fermi surface (FS) remained essentially two-dimensional (2D) [1]. In contrast, *tensile* strained films exhibit 3D dispersion; T_c is drastically reduced. [2] It seems that the in-plane compressive strain pushes the apical oxygen away from the CuO_2 plane [1-3], enhances the 2D character of the dispersion and enhances T_c, while the tensile strain seems to act in the opposite direction and the resulting dispersion is 3D. [2-5] Evidently, such studies are directly relevant for the mechanism of high-T_c. As the actual lattice of cuprates consists of rigid CuO_2 planes that alternate with softer 'reservoir' our results tend to rule out 2D rigid lattice mean field models [3]. We have also mapped the 3D FS topology from the observed wavevector quantization in cuprate films thinner than 18 units cells.[5] We have grown doped Bi-2201 thin films and performed XRD, transport and in-situ ARPES studies. In collaboration with collegaus at BNL, we have studied the field effect in new heteroepitaxial cuprate structures. Very large fields and induced changes in surface carrier density enable large shifts in the critical temperature (T_c). We were able to substantially vary T_c with the field [6] and observed striking superconductor-insulator quantum phase transition in $La_{2-x}Sr_xCuO_4$ films that poses profound challenge to contemporary theory.

[1] M. Abrecht *et al.*, Phys. Rev. Lett. (2003) 057002

[2] D. Cloetta *et al.*, Phys. Rev. B **74** (2006) 014519

[3] D. Pavuna *et al.*, J. Phys. **108** (2008) 012040

[4] C. Cancellieri *et al.*, Phys. Rev. B **76** (2007) 174520

[5] D. Ariosa *et al.*, Appl. Phys. Lett. **92** 2008 092506

[6] A.T. Bollinger *et al.*, Nature **472** (2010) 458

Metal-semiconductor transitions for electrons in kagome planes

Eduard Tutiš[1], Ivo Batistić[2], Jaćim Jaćimović[3], László Forró[3]

[1]*Institut za fiziku, Zagreb, Croatia*
[2]*Faculty of Science, Zagreb, Croatia*
[3]*École Polytechnique Fédérale de Lausanne, Lausanne, Switzerland*

(EDT-TTF-$CONH_2$)$_6$ [$Re_6Se_8(CN)_6$] is recently synthesized compound composed of layers with kagome structure.[1] Above 180 K the material is 2D-homogenous bad metal, or semiconductor, depending on pressure;[2] below 180 K the electrons charge-order into chains, with the antiferromagnetic correlations developing below 100 K.[1] The concentration is 2/3 electrons per node, at which Dirac point coincides with the Fermi level in the weak coupling limit. The experiments imply, however, that electron-electron and electron-phonon interactions are substantial in (EDT-TTF-$CONH_2$)$_6$ [$Re_6Se_8(CN)_6$]. At 1/3 filling the kagome lattice exhibits two particular features: the robustness of the Dirac points towards gap opening in the limit of weak electron-electron and electron-phonon couplings; and the frustration governing charge and spin ordering at strong coupling. For (EDT-TTF-$CONH_2$)$_6$ [$Re_6Se_8(CN)_6$] we propose a variety of extended Hubbard –Holstein model to explore the crossovers observed around 180 K and 100 K, charge and spin ordering instabilities, and to examine the conduction mechanism in various phases.

[1] S. A. Baudron *et al.*, J. Am. Chem. Soc. **127** 2005 11785

[2] A. Olariu *et al.*, preprint 2011

Extent of superconducting fluctuations above T_c in $YBa_2Cu_3O_{7-\delta}$ single crystals

M. S. Grbić[1], M. Požek[1], D. Paar[1], V. Hinkov[2], M. Raichle[2], D. Haug[2], B. Keimer[2], N. Barišić[3], Antonije Dulčić[1]

[1]*Department of Physics, Faculty of Science, University of Zagreb, P.O. Box 331, HR-1002 Zagreb, Croatia*
[2]*Max-Planck-Institut fur Festkorperforschung, D-70569 Stuttgart, Germany*
[3]*1. Physikalisches Institut, Universitat Stuttgart, D-70550 Stuttgart, Germany*

Microwave absorption measurements in magnetic fields from zero up to 16 T were used to determine the temperature range of superconducting fluctuations above the superconducting critical temperature T_c in HTSC. This experimental method is free from arbitrary assumptions about subtracting the nonsuperconducting contributions to the total measured signal, and/or theoretical models to extract the unknown parameters. Within the sensitivity of the method, the fluctuation regime is found only within a fairly narrow region above T_c (7-8 K in the nearly optimally doped samples, to at most 23 K in deeply underdoped samples), which falls well below the pseudogap temperature T^*. Also important is that the observed $ab-$plane, and $c-$axis fluctuation conductivities follow the same temperature dependences above T_c, with only a scaling factor which reflects the anisotropy in the sample. Hence, superconducting fluctuations are found to exhibit 3D character in spite of the exsisting quasi 2D structural feature of these compounds.

[1] M. S. Grbić, M. Požek, D. Paar, V. Hinkov, M. Raichle, D. Haug, B. Keimer, N. Barišić, and A. Dulčić, Phys. Rev. B **83** (2011) 144508

[2] M. S. Grbić, N. Barišić, A. Dulčić, I. Kupčić, Y. Li, X. Zhao, G. Yu, M. Dressel, M. Greven, and M. Požek, Phys. Rev. B **80** (2009) 094511

A magnetic analog of the isotope effect in cuprates

Amit Keren[1]

[1]*Department of Physics, Technion - Israel Institute of Technology, Haifa, 32000, Israel*

Since the discovery of high temperature superconductivity in the cuprates, it has been speculated that their pairing mechanism is due to magnetic interactions. However, this was never demonstrated in the laboratory. Such a demonstration would require an experiment similar to the isotope effect in metallic superconductors, namely, a measurement of T_c versus the strength of the magnetic coupling J, with no other structural changes. We have done this experiment using the $(Ca_xLa_{1-x})(Ba_{1.75-x}La_{0.25+x})Cu_3O_y$ system with its 4 different families having different T_c^{max}, but identical structures. For each family, we measured the Néel Temperature T_N, the anisotropies of the magnetic interactions, the spin glass temperature T_g of underdoped samples, the carrier density n, the superconducting carrier density n_s, and, of course, T_c from under to overdoped compounds. Our measurements allow us to demonstrate that $T_c = cJn_s$ and more.

2D magnetism in κ-(BEDT-TTF)$_2$Cu[N(CN)$_2$]Cl, a spin-1/2 antiferromagnet with Dzyaloshinskii-Moriya interaction

Titusz Fehér[1], Ágnes Antal[1], Bálint Náfrádi[2], László Forró[2], András Jánossy[1]

[1]*Budapest University of Technology and Economics, Institute of Physics and Condensed Matter Research Group of the Hungarian Academy of Sciences, P.O. Box 91, H-1521 Budapest, Hungary*
[2]*Institute of Physics of Complex Matter, FBS, Swiss Federal Institute of Technology (EPFL), CH-1015 Lausanne, Switzerland*

Field-induced antiferromagnetic (AF) magnetization and fluctuations are observed above the zero-field ordering temperature by electron spin resonance in κ-(BEDT-TTF)$_2$Cu[N(CN)$_2$]Cl, a quasi two-dimensional (2D) Heisenberg antiferromagnet. In this system the Dzyaloshinskii-Moriya (DM) antisymmetric exchange interaction is the main source of anisotropy, while the anisotropy of diagonal exchange and the *g* factor are weak, as well as inter-layer coupling. A magnetic field perpendicular to the DM vector induces AF magnetization, whereas fields parallel to the DM vector have negligible effect. The difference in the orientation of the DM vectors and the *g* factor tensors in adjacent layers allow a distinction between 3D and 2D correlations. We show that magnetization is induced independently in adjacent layers, and prove that the magnetic ordering is determined mostly by intra-layer interactions.

Modeling of nonlinear and non-stationary multi-vortex behavior of CDWs in restricted geometries of mesa junctions

Tianyou Yi[1], Natasha Kirova[2], Serguei Brazovskii[1]

[1]*LPTMS UMR 8626, Univeristé Paris-sud, Orsay, France*
[2]*LPS UMR 8502, Univeristé Paris-sud, Orsay, France*

Electronic crystals (EC) present a common form of charges organization. They take forms of Wigner crystals at hetero-junctions and nano-wires, CDWs in chain compounds, SDWs in organic conductors, stripes in doped oxides. CDW is a particular kind of EC: most accessible experimentally and best treatable theoretically. In the CDW ground state, the elementary units can be readjusted by absorbing or rejecting pairs of electron. Such a process should go via topologically nontrivial configurations: solitons and dislocations – the CDW. An experimental access to those states came from studies of nano-fabricated mesa-junctions, from the STM and from the coherent X-ray diffraction. We performed a program of modeling of stationary states and of their transient dynamic for the CDW in restricted geometries. The model takes into account multiple fields in their mutual nonlinear interactions: the complex order parameter of the CDW, the distributions of the electric field, the density and the current of normal carriers. We find that vortices are formed in the junction when the voltage across, or the current through, exceed a threshold; the number of vortices increases step-wise - in agreement with experiments. The vortex core concentrates the total voltage drop, working as a self-tuned microscopic tunnelling junction, which might give rise to observed peaks of the inter-layer tunneling. The studied reconstruction in junctions of the CDW may be relevant to modern efforts of the field-effect transformations in strongly correlated materials which also show a spontaneous symmetry breaking.

[1] Y. Latyshev *et al.*, Phys. Rev. Lett. **96** (2006) 116402

The scattering rates in cuprates

Neven Barišić[1]

[1]*CEA, Saclay, France*

In high-temperature superconducting cuprates at intermediate hole concentrations (p), the peculiar high-temperature metallic phase features a robust planar linear in T resistivity ($\rho \propto T$), and the deviation from this behavior upon cooling marks the opening of a partial gap (pseudogap) on some parts of the Fermi surface. Contrary to conventional wisdom, we find in the pseudogap phase of structurally simple $HgBa_2CuO_{4+\delta}$ [1] that the planar resistivity above the superconducting transition temperature exhibits a quadratic in T dependence ($\rho \propto T^2$), as in conventional Fermi liquids. By combining our results with prior work, we determine the universal CuO_2-sheet resistance and arrive at a novel phase diagram containing four characteristic temperatures ($T_c < T' < T^{**} < T^*$): T^* coincident with the onset of $\mathbf{q} = 0$ magnetic order [2]; T^{**} that we tentatively associate to a separate magnetic transition; T', which marks the onset of superconducting fluctuations [3] and finally T_c. We further demonstrate that scattering rates associated with $\rho \propto T^2$ and $\rho \propto T$ do not change throughout the entire accessible doping range ($0.01 < p < 0.33$).

This work was done in collaboration with Y. Li, G. Yu, X. Zhao, M. Dressel, A. Smontara, M. Greven.

[1] N. Barišić, *et al.*, Phys. Rev. B **78** (2008) 054518

[2] Y. Li, *et al.*, Nature **455** (2008) 372

[3] M. S. Grbić, *et al.*, Phys. Rev. B **80** (2009) 094511

Relevance of charge-lattice interaction in underdoped cuprates

Vittorio Cataudella[1], Giulio De Filippis[1]

[1]*CNR-Spin and Dip. di Scienze Fisiche, Università di Napoli "Federico II", Napoli, Italy*

We provide evidence in favor of a relevant charge-lattice coupling in the under-doped phase of cuprates. We show that a number of experimental observations: i) the anomaly of the half breathing bond stretching phonon occuring at half-way to the Brillouin zone boundary in the [100]-direction[1], ii) the kinks observed in Angle Resolved Photoemission Spectra (ARPES)[1], iii) the multi-peak structure of the optical conductivity in the infrared region[2,3] and iv) the anomalous temperature dependence of the ARPES in undoped cuprates[4] are explained by the cooperative coupling of holes to magnetic and lattice fluctuations. This scenario is supported by the analysis of the ground and excited state properties of one and two holes in the t-t'-t"-J model and Hubbard Model, including the charge-lattice interaction with local and breathing modes, through exact diagonalization techniques, diagrammatic Quantum Monte Carlo approaches and self-consistent methods.

[1]] G. De Filippis, V. Cataudella, R. Citro, C. A. Perroni, A.S. .Mishchenko, and N. Nagaosa, European Phys. Lett. **91** 2010 47007

[2] De Filippis, V. Cataudella, A. S. Mishchenko, C.A. Perroni and N. Nagaosa, Phys. Rev. B **80** 2009 195104

[3] A. S. Mishchenko, N. Nagaosa, Z.-X. Shen, G. De Filippis, V. Cataudella, T.P. Devereaux, C. Bernhard, K.W. Kim, and J. Zaanen, Phys. Rev. Lett. **100** 2008 166401

[4] V. Cataudella, G. De Filippis, A. S. Mishchenko, and N. Nagaosa, Phys. Rev. Lett. **99** 2007 226402

Diagrammatic content of the dynamical mean-field theory: Holstein polaron problem in finite dimensions

Osor S. Barišić[1]

[1]*Institute of Physics, Bijenička 46, Zagreb, Croatia*

Polaronic effects have often been observed in temperature dependences of the DC conductivity and thermopower, in characteristic frequency behavior of the optical conductivity and/or in diffuse scattering of X-rays and neutrons. Cases of polaron-like distribution of photoelectron intensity from ARPES measurements for many materials including copper-oxides and manganites with colossal resistivity have been reported.

From the theoretical point of view, closely related to the ARPES measurements are calculations of the electron Green function in the deformation field. A method which has gained a lot of attention in last two decades is the dynamical mean field theory (DMFT). While in the limit of infinite system dimensionality the DMFT may provide exact results for some models, it is generally an approximate approach.

A few remarks concerning the approximate nature of the DMFT may be found in literature. The first is that the DMFT omits spatial fluctuations, but retains the nontrivial dynamics of temporal on-site fluctuations. The second explains the DMFT as a method that reduces the original lattice problem to an impurity embedded in a host, where the properties of the latter are determined self-consistently. In works that discuss the DMFT from the diagrammatic point of view, one may find claims that the DMFT can be formally derived by disregarding the momentum conservation at the internal vertices of the self-energy. The question which then arises is weather the DMFT can be directly related to a particular class of self-energy diagrams?

It is shown, in the context of the Holstein polaron problem [1], that the answer to this question is positive and that the DMFT corresponds to the summation of the special class of local diagrams in the skeleton expansion of the self-energy. In real space representation, these local diagrams are characterized by the absence of vertex corrections involving phonons at different lattice sites [2,3]. Thus, for finite dimensional systems the DMFT cannot correctly describe either the adiabatic [4] spreading of the polaron over multiple lattice sites or its slow translation. However, it reproduces well the polaron properties in the Lang-Firsov limit.

[1] O.S.Barišić and S.Barišić, Eur. Phys. J. B **64** (2008) 1

[2] O.S.Barišić, Phys. Rev. Lett. **98**(2007) 209701

[3] O.S.Barišić, Phys. Rev. B **76** (2007) 193106

[4] O.S.Barišić and S.Barišić, Eur. Phys. J. B **54** (2006) 1

Optical and transport properties of multiband Peierls-CDW systems – the bad metal $BaVS_3$

Ivan Kupčić[1], Z. Rukelj[1], S. Barišić[1]

[1]*Department of Physics, Faculty of Science, University of Zagreb, P.O. Box 331, HR-10002 Zagreb, Croatia*

One of the central questions regarding the optical and transport properties of different systems with competing charge and spin orderings is to derive the microscopic form of the generalized susceptibility in the way consistent with fundamental relations from classical and quantum electrodynamics. In this work, we consider the incommensurate Peierls-CDW (PCDW) problem and study the effects of CDW phase fluctuations on the generalized susceptibility using the microscopic model with minimal set of model parameters. The connection between the ampliton and phason self energies and the leading coefficients in the Landau free energy is established first. The structure of the infrared conductivity in the PCDW pseudogap regime is calculated as well. Such analysis is analogous to Moriya's theory of spin fluctuations in itinerant magnetic systems. A slightly different approach is used to determine the form of the quantum transport equations for general values of temperatures. The solution of these equations in the ordered PCDW state is given. Finally, we briefly discuss the situation encountered in the bad metal $BaVS_3$, with two t_{2g} bands at the Fermi level. In this case, the CDW instability of the wide band electrons competes with the SDW instability of electrons in the narrow band. The optical and transport properties of $BaVS_3$ reflect the main features of this competition.

Inhomogeneities at all scales at a phase transition altered by disorder

Ivan Balog[1], Katarina Uzelac[1]

[1]*Institute of Physics, Zagreb*

We have done [1] a finite size scaling study of a continuous phase transition altered by the quenched bond disorder, investigating systems at quasicritical temperatures of each disorder realization by using the “Equilibriumlike invaded cluster algorithm" [2]. Our results indicate that in order to access the thermal critical exponent y_τ, it is necessary to average the free energy at quasicritical temperatures of each disorder configuration. Despite the thermal fluctuations on the scale of the system at the transition point, we find that spatial inhomogeneities form in the system and become more pronounced as the size of the system increases. This leads to different exponents describing rescaling of fluctuations of observables in disorder and thermodynamic ensembles.

[1] I.Balog and K.Uzelac, Phys. Rev. E **85** (2012) 030101(R)

[2] I.Balog and K.Uzelac, Phys. Rev. E **77** (2008) 050101(R)

Dominant second harmonic in the Josephson current-phase relation: manifestation of the long-range spin-triplet proximity effect

Zoran Radović[1]

[1] *University of Belgrade, Department of Physics, Serbia*

I will present theoretical study of the Josephson effect and pairing correlations in planar SFF'S junctions that consist of conventional superconductors connected through two metallic monodomain ferromagnets. Both singlet and triplet pair amplitudes, the Josephson current-phase relations, and density of states for arbitrary orientation of magnetizations are calculated from the self-consistent solutions of Eilenberger equations in the clean limit and for moderate disorder in ferromagnets. In highly asymmetric SFF'S junctions the long-range spin-triplet proximity effect manifests itself as a dominant second harmonic in the Josephson current-phase relation $I(\phi)$,[1] and gives distinctive tunneling conductance spectra.[2] Unambiguous detection of the long-range spin-triplet proximity effect by tunneling spectroscopy and experimental realization of the Josephson junctions ground state degeneracy (like at $0-\pi$ transtions) is accessible for small interface roughness and moderate disorder in ferromagnets at low temperatures. The half-periodicity of $I(\phi)$ in the considered junctions can be used for quantum interferometers (SQUIDs) which operate with two times smaller flux quantum and can exhibit the superposition of macroscopically distinct quantum states in the absence of an external magnetic field.

[1] L. Trifunović, Z. Popović and Z. Radović, Phys. Rev. B **84** (2011) 064511

[2] M. Knežević, L. Trifunović and Z. Radović, Phys. Rev. B (to be published, 2012)

Doping dependence of femtosecond quasi-particle relaxation dynamics in $Ba(Fe,Co)_2As_2$ single crystals: possible evidence for normal state nematic fluctuations

Tomaž Mertelj[1], Lj. Stojchevska[1], J. H. Chu[2], I. R. Fisher[2], D. Mihailović[1]

[1]*Complex Matt. Dept., J. Stefan Institute, Ljubljana, Slovenia*
[2]*Geb. Lab. Ad. Mat., Dep. Appl. Phys., Stanford Univ., USA*

We systematically investigate the photoexcited (PE) quasi-particle (QP) relaxation and low-energy electronic structure in electron doped $Ba(Fe_{1-x}Co_x)_2As_2$ single crystals as a function of Co doping, $0 \leq x \leq 0.11$. The evolution of the photoinduced reflectivity transients with x proceeds with no abrupt changes. In the orthorhombic spin-density-wave (SDW) state a bottleneck associated with a partial charge-gap opening is detected, similar to previous results in different SDW iron-pnictides. The relative charge gap decreases with increasing x. In the superconducting (SC) state an additional relaxational component appears due to a partial destruction of the SC state proceeding on a sub-0.5-picosecond timescale. From the SC component saturation behavior the optical SC-state destruction energy, $U_p/k_B = 0.3$ K/Fe, is determined near the optimal doping. The subsequent relatively slow recovery of the SC state indicates clean SC gaps. The T- dependence of the transient reflectivity amplitude in the normal state is consistent with the presence of a pseudogap in the QP density of states. The polarization anisotropy of the transients suggests that the pseudogap-like behavior might be associated with nematic electronicfluctuations persisting up to $T \simeq 200$ K at any x. The second moment of the Eliashberg function, obtained from the relaxation rate in the metallic state at higher-T, indicates a moderate electron phonon coupling, $\lambda \leq 0.3$, that decreases with increasing doping.

Effects of the Coulomb gap on electrical transport and magnetic properties of doped polyaniline

Mirko Baćani[1], Ivan Kokanović[1], Mario Novak[1], Dinko Babić[2]

[1]*University of Zagreb, Faculty of Science, Department of Physics, Bijenička 32, 10000 Zagreb, Croatia*
[2]*Institute for Medical Research and Occupational Health, Ksaverska 2, 10000 Zagreb, Croatia*

We have carried out a comparative experimental study of the electrical conductivity σ and magnetic susceptibility χ of own-made polyaniline (PANI) pellets doped either with HCl or dodecybenzenesulfonic acid (DBSA). These two quite opposite types of doped PANI show remarkable similarities in temperature (T) dependences of σ and χ, and there are strong arguments in favour of the underlying physics being the same. For all samples, we find that σ at low T is governed by the variable-range hopping (VRH) in a homogeneously disordered three-dimensional system of coupled one-dimensional chains. Depending on the doping and corresponding disorder level, the VRH exponents are either 1/2, 2/5 or 1/4, and at higher T in many of the samples we find the exponent 1 that signifies the nearest-neighbour hopping. All these exponents are predicted in a theory of Fogler, Teber and Shklovskii for the charge transport in coupled chain-like conductors, and conditions for their appearance depend on disorder and T. Changes from one exponent into another appear at crossover temperatures T^*, where there are also noticeable features in $\chi(T)$. This coupling of charge and spin is discussed in the spirit of $k_B T^*$ being the thermal energy which causes an enhancement of the density of delocalised (Pauli) spins at the expense of localised (Curie) spins as T rises above T^*.

Polaron formation in graphene nanoribbons

Ivo Batistić[1], Avadh Saxena[2], Alan Bishop[2]

[1]*Faculty of Science, University of Zagreb, Zagreb, Croatia*
[2]*Los Alamos National Laboratory, NM, USA*

The tight-binding model, commonly used to describe trans- and cis-polyacetylene and other conducting polymers, can also be applied to study polaron formation in the recently synthesized graphene nanoribbons. Within the model we find that the stability of a polaron is strongly dependent not only on the type of the ribbon (armchair vs. zig-zag), but also on the ribbon width. The formation of polaron implies the existence of localized energy states within the electronic band and localized lattice deformation as well as localized phonon excitations. All these properties can be calculated within the tight-binding model, which in turn can be used as a reference for a comparison with experimental measurements on optical, electronic and transport properties of graphene nanoribbons with differing width and type.

Ir-Study on $\alpha - ET_2I_3$ under hydrostatic pressure

Rebecca Beyer[1], Neven Barišić[1], Natalia Drichko[1], Martin Dressel[1]

[1] *1. Physikalisches Institut, Universität Stuttgart, Germany*

The two dimensional organic crystal $\alpha - ET_2I_3$ undergoes a metal-insulator transition at T_{MI} = 135 K, identified as a charge-order transition. NMR[1] and Raman[2] measurements under hydrostatic pressure found a small charge disproportion even in the metallic state, which strongly increases below the transition temperature. Dc-conductivity and Hall[3] effect measurements showed a strong dependence of the transition temperature on external pressure of ΔT(p) = 10 K/kbar and eventually the formation of a Zero-Gap-State above 15 kbar, identified by a constant conductivity but decreasing mobility of the electrons, as predicted predicted by theory[4] for a moderate uniaxial pressure.

A FTIR-spectroscopy setup with a colfinger and a piston clamp cell with diamond window was set up. External pressures up to 12 kbar can be applied and the reflectivity can be measured from 100 cm^{-1} up to 14000 cm^{-1} and down to T = 10 K. By addressing the vibrational and the electronic parts of the optical spectrum at the very same time, the influence of the applied pressure on the transition temperature, the charge disproportion and the gap energ was investigated.

[1] Y. Takano, K. Hiraki, H.M. Yamamoto, T. Nakamura, T. Takahashi, J. Phys. Chem. Solids **62** 2001 393

[2] R. Wojciechowski, K. Yamamoto, K. Yakushi, Phys. Rev. B **67** 2003

[3] N. Tajima, M. Tamura, Y. Nishio, K. Kajita, Y. Iye, J. Phys. Soc. Jpn **69** 2000 534

[4] S. Katayama, A. Kobayashi, Y. Suzumura, J. Phys. Soc. Jpn **75** 2006 054705

Superconductor within insulator: case of titanium nitride

Ante Bilušić[1,2], D. Kolak[2], V. M. Baturina[3], T. I. Vinokur[4], C. Strunk[2]

[1]*Faculty of Science, University of Split, Croatia*
[2]*University of Regensburg, Germany*
[3]*Institute of Semiconductor Physics, Russia*
[4]*Argonne National Laboratory, Argonne, USA*

The superconductor-insulator phase transition (SIT) in disordered thin films remains one of the major puzzles of low temperature physics. It can be induced either by external magnetic field or disorder level generally modulated by film thickness. The films being on the insulating side of the critical region are of special interest since they show a number of interesting physical phenomena, like huge and non-monotonic magnetoresistance,[1] and switching in current-voltage (I-V) characteristics.[2] Theoretical model of SIT [3] predicts that films being on the insulating side of the transition exhibit superinsulating state of matter, characterized by spontaneously created, separated, and phase incoherent superconducting islands. In this work we show that insulating TiN thin films show non-linear current-voltage characteristic. This offers evidence that the superinsulating state is described by charge Berezhinskii-Kosterlitz-Thouless phase transition, as predicted by the model.[3] Our results also show that switching in I-V of TiN is not solely caused by electron overheating, as in case of a-InOx.[4]

[1] Baturina *et al.*, Phys. Rev. Lett. **99** 2007 257004

[2] Sambandamurthy *et al.*, Phys. Rev. Lett. **94** 2005 017003

[3] Vinokur *et al.*, Nature **452** 2008 613

[4] Ovadia *et al.*, Phys. Rev. Lett. **102** 2009 176802

Transport properties of 1T-TaS_2 single crystal

Jovica Ivkov[1], Kristijan Velebit[1], Petar Popčević[1], Ana Smontara[1], Ante Bilušić[1,2], Helmuth Berger[3], László Forró[3]

[1]*Institut za fiziku, Zagreb, Croatia*
[2]*Department of Physics, Faculty of Science, University of Split, Croatia*
[3]*École Polytechnique Fédérale de Lausanne, Lausanne, Switzerland*

1T-TaS_2 is a quasi-two-dimensional transition-metal dichalcogenide in which charge density wave (CDW) behavior coexists with strong electron-electron correlations. Below 180 K, 1T-TaS_2 is a Mott insulator in which commensurate CDW orders the tantalum atoms in star-shaped clusters with a long-range superlattice structure. Above the CDW transition temperature, 1T-TaS_2 becomes nearly commensurate and a pattern of approximately hexagonal insulating commensurate CDW domains and triangular pieces of metallic phase is formed.

We have undertaken a systematic study of the 1T-TaS_2 transport properties (particularly the thermal conductivity and the Hall coefficient) from 2 to 360 K, to our knowledge for the first time in both cooling and heating regime in such a wide temperature range.[3,4] The effect of the hysteresis on the transport properties of the compound has also been addressed. We discuss our findings with the main emphasis on the changes in the phonon scattering and charge carriers in the relevant CDW states.

[1] J. A.Wilson, F. J. DiSalvo, S. Mahajan, Adv. Phys. **24** (1975) 117

[2] B. Sipos, A. F. Kusmartseva, A. Akrap, H. Berger, L. Forró, Nature Mater. **7** (2007) 960

[3] M. D. Nunez-Regueiro, J. M. Lopez-Castillo, C. Ayache, Phys. Rev. Lett. **18** (1985) 1931

[4] R. Inada, Y. Onuki, S. Tanuma, Phys. Lett. **69A** (1979) 453

Microscopic origins of the pseudogap in cuprates

Goran Nikšić[1], D. K. Sunko[1], S. Barišić[1]

[1]*Department of Physics, Faculty of Science, University of Zagreb, POB 331, HR-10002 Zagreb, Croatia*

We study the effects of copper-oxygen and oxygen-oxygen hybridisation on the antiferromagnetic (pseudo)gap in slightly underdoped superconducting cuprates, in the limit of infinite bare on-site repulsion on the coppers. The non magnetic reference states of the hole encompass hybridized copper-oxygen states and intermittently localized copper states. The kinematic interaction causing the (pseudo)gap is the scattering of two hybridized copper-oxygen holes, propagating in the open planar bands, on the copper sites where the double occupation is forbidden. We solve a simple magnetic gap equation with the corresponding vertex, and show that it helps to understand the step-function shaped gap seen in ARPES. We relate the latter to the rotation of peaks observed in the neutron scattering patterns.

Effects of absorbed hydrogen on transport properties of Zr_2Fe metallic glass

Mario Novak[1], Ivan Kokanović[1]

[1]*Faculty of Science, Department of Physics, University of Zagreb*

Extensive study of charge transport properties of Zr_2Fe metallic glass was done by applying low temperature transport and magnetic measurements. To get a deeper insight into the physics of the charge transport, hydrogen doping was used. Hydrogen forms hybridisation bonds with the Zr_2Fe matrix, which influences the level of disorder and electronic structure of the system. It was found that the high-temperature transport is governed by the weak localisation with a dominant electron-phonon dephasing process, whereas, at the low temperatures the spin-orbit interaction starts to dominate over the electron-phonon interaction. At even lower temperatures the electron-electron and the spin-fluctuation corrections to the conductivity overpower the spin-orbit interaction, which results in formation of a broad minimum in the conductivity. Furthermore, at the low temperatures, magnetoresistance shows a deviation from the usual quadratic law and the Hall constant shows a significant increase in its magnitude, which is ascribed to the presence of the spin-orbit interaction. Finally, absorbed hydrogen significantly influences the transport properties of Zr_2Fe metallic glass, by reducing the electrical conductivity, and increasing the magnitude of the magnetoresistance and the Hall effect.

Magnetic ordering of $Co_{0.33}NbS_2$ under pressure

Petar Popčević[1], Igor Smiljanić[1], Ante Bilušić[1,2], Ana Smontara[1], Ivo Batistić[3], Helmuth Berger[4], Jaćim Jaćimović[4], László Forró[4], Neven Barišić[1], Edo Tutiš[1]

[1]*Institu za fiziku, Zagreb, Croatia*
[2]*University of Split, Croatia*
[3]*Faculty of Science, University of Zagreb, Croatia*
[4]*École polytechnique fédérale de Lausanne, Switzerland*

2H-NbS_2 is a layered material that has a superconducting transition at 6 K and this transition is pressure independent.[1] Upon intercalation of Co atoms between NbS_2 metallic layers superconductivity is suppressed. Co atoms in $Co_{0.33}NbS_2$ form triangular lattice and at ambient pressure there is antiferromagnetic ordering at 26 K. Hidrostatic pressure suppresses the ordering to lower temperatures[2] and at p = 2 GPa magnetic ordering disappears. The ordering mechanism is not fully understood yet, although super-exchange and RKKY interactions are natural candidates. At pressures above 3 GPa minimum in resistivity followed by logarithmic rise of resistivity with lowering temperature appears. This indicates Kondo screening of magnetic moments on Co ions and Kondo spin liquid formation. No superconductivity was found between these two phases down to dilution temperatures.[3] Disappearance of magnetic ordering with pressure is confirmed with elastic neutron scattering experiment and phase diagram of $Co_{0.33}NbS_2$ is presented.

[1] R. E. Jones, *et al.*, Phys. Rev. B **6** (1972) 835.

[2] N. Barišić, *et al.*, Phys. Rev. B **84** (2011) 075157.

[3] J. Jaćimović, *et. al.*, to be published.

Microscopic theory of the Peierls-CDW pseudogap state - from X-ray scattering to mid-infrared conductivity

Zoran Rukelj[1], Ivan Kupčić[1], Slaven Barišić[1]

[1] *Department of Physics, Faculty of Science, University of Zagreb, P.O. Box 331, HR-10002 Zagreb, Croatia*

Starting with the microscopic Hamiltonian for electrons and phonons in the incommensurate Peierls CDW (PCDW) model, we determine the mean-field PCDW equation, the PCDW equation with Gaussian fluctuations included, and the leading coefficients in the Landau free energy. We calculate the magnitude of the CDW as a function of both temperature and the effective electron-electron interaction for the cases with and without Gaussian fluctuations. Finally, the structure of the generalized susceptibility is determined in the PCDW pseudogap state and in the ordered PCDW state. We use these general results to show how the phason/ampliton self-energy and the high-energy longitudinal/transverse conductivity are affected by the Gaussian phase fluctuations.

Optical conductivity of the nano-textured phase in 1T-TaS_2

Kristijan Velebit[1,3], P. Popčević[1], E. Tutiš[1], A. Smontara[1], H. Berger[2], L. Forró [2], M. Eichler[3], D. Wu [3], N. Barišić[1,3], M. Dressel[3]

[1]*Institut za fiziku, Zagreb, Croatia*
[2]*Lab. Phys. Compl. Matt., EPFL, Lausanne, Switzerland*
[3]*1. Physikalisches Institut, Universität Stuttgart, Germany*

1T-TaS_2 is known to form a peculiar nearly commensurate charge density wave (NC-CDW) phase in which the domains of commensurate charge density wave (CDW) phase, several nanometers in size, are separated by a roughly triangular pieces of metallic phase.[1] Contrary to pure 1T-TaS_2, where commensurate-CDW/Mott state develops below 180 K, non-metallic NCCDW state may be preserved in slightly doped or pressurized 1T-TaS_2, down to very low temperature, where it turns superconducting.[2] It has been argued that superconductivity arises in triangular metallic parts, while DC conductivity is dominated by weak links between them. Here we report the reflectance of pure and intercalated 1T-TaS_2, measured between 23 K to 290 K, over a frequency range of 30 cm^{-1} - 37000 cm^{-1}, as well as the optical conductivity derived through Kramers-Kronig analysis. Contrary to simple expectations, where two regions of NCCDW phase would show at different frequencies, the measured optical conductivity does not show the separate contribution from CDW and metallic regions. Instead, we observe a single, wide, metallic contribution, extending to 400 cm^{-1}, on the top of which the phonon contribution shows above 40 cm^{-1}.

[1] A. Spijkerman, Phys. Rev. B **56** 1997 13757

[2] B. Sipos, Nature Mater. **7** 2008 960; P. Xu, Phys. Rev. B **81** 2010 172503

Competition between superconductivity and charge density wave in the qausi-1D organic conductor TTF[Ni(dmit)$_2$]$_2$

Kaddour Wafa[1], Auban-Senzier Pascale[1], Pasquier Claude[1]

[1]*LPS, Université Paris Sud, Orsay, France*

In 1986, superconductivity (SC) was discovered in the 1D organic salt TTF[Ni(dmit)$_2$]$_2$ with T_C=1.62 K under an applied hydrostatic pressure of 7 kbar [1,2]. At that time, structural fluctuations in this system were suspected to induce a charge density wave (CDW) instability at low pressure. This system is also original by the incommensurate charge transfer of 0.77 between anions and cations which differs from 'standard' charge transfer salts.Our work is special because we try to understand the competition between superconductivity and a paramagnetic state (CDW) in contrast with the other studies where superconductivity was studied near a magnetic state such as spin density wave (SDW). The problem of competition between SC and CDW states has also rose a renewal interest recently in chalcogenides following the discovery of SC in pnictides.

Transport measurements were performed on the title compound in order to understand the effect of the pressure, the temperature, the magnetic field and the applied current on the resistivity of this compound so we can observe the different phase transitions. The results we obtained allowed us to revisit the pressure-temperature phase diagram of the TTF[Ni(dmit)$_2$]$_2$ and better understand how SC emerges from a CDW state. We started to establish the principal characteristics of the superconducting state versus the pressure (critical temperature, upper critical field, critical current…) and the specific phenomena to the coexistence of the SC/CDW.

[1] L. Brossard, *et.al.*, Physica B **143** 1986 378

[2] L. Brossard, *et.al.*, Phys. Rev. B **42** 1986 3935

List of participants

Sasha Alexandrov
Loughborough University
Loughborough, UK
a.s.alexandrov@lboro.ac.uk

Henri Alloul
Univbersité Pars Sud
Orsay, France
henri.alloul@u-psud.fr

Sergey Artemenko
Kotelnikov Institute of Radioengineering and Electronics of Russian Academy of Sciences
Moscow, Russia
art@cplire.ru

Mirko Baćani
University of Zagreb, Faculty of Science
Zagreb, Croatia
mbacani@phy.hr

Ivan Balog
Institute of Physics
Zagreb, Croatia
balog@ifs.hr

Neven Barišić
CEA, Saclay, France
neven.barisic@u-psud.fr

Osor S. Barišić
Institute of Physics
Zagreb, Croatia
obarisic@ifs.hr

Slaven Barišić
University of Zagreb, Faculty of Science
Zagreb, Croatia
sbarisic@phy.hr

Ivo Batistić
University of Zagreb, Faculty of Science
Zagreb, Croatia
ivo@phy.hr

Rebecca Beyer
1.Physikalisches Institut
Stuttgart, Germany
rebecca.beyer@pi1.physik.uni-stuttgart.de

Antonio Bianconi
University of Rome "La Sapienza"
Rome, Italy
antonio.bianconi@roma1.infn.it

Ante Bilušić
Department of Phyisics
Faculty of Science, University of Split,
Split, Croatia
bilusic@pmfst.hr

Aleksa Bjeliš
University of Zagreb, Faculty of Science
Zagreb, Croatia
bjelis@phy.hr

Claude Bourbonnais
Universite de Sherbrooke
Sherbrooke, Canada
Claude.Bourbonnais@usherbrooke.ca

Marko Bosiočić
University of Zagreb, Faculty of Science
Zagreb, Croatia
bosiocic@phy.hr

Ivan Božović
Brookhaven National Laboratory
Upton, USA
bozovic@bnl.gov

Sergei A. Brazovskii
Université Paris Sud
Paris, France
brazov@lptms.u-psud.fr

Hrvoje Buljan
University of Zagreb, Faculty of Science
Zagreb, Croatia
hbuljan@phy.hr

Riccarda Caputo
EMPA, Swiss Federal Laboratories for Materials Testing and Research
Duebendorf, Switzerland
Riccarda.Caputo@empa.ch

Vittorio Cataudella
Università di Napoli "Federico II"
Napoli, Italia
cataudella@na.infn.it

Robert Comès
Université Pars Sud
Orsay, France
robertcomes@numericable.fr

John R. Cooper
Cavendish Laboratory, University of Cambridge
Cambridge, UK
jrc19@cam.ac.uk

Tonči Cvitanić
University of Zagreb, Faculty of Science
Zagreb, Croatia
tonci.cvitanic@gmail.com

Martin Dressel
Universität Stuttgart
Stuttgat, Germany
dressel@pi1.phsyik.uni-stuttgart.de

Antonije Dulčić
University of Zagreb, Faculty of Science
Zagreb, Croatia
adulcic@phy.hr

Titusz Fehér
Budapest University of Technology and Economics
Budapest, Hungary
tif@esr.phy.bme.hu

László Forró
Ecole Polytechnique Federale de Lausanne (EPFL)
Lausanne, Switzerland
laszlo.forro@epfl.ch

Thierry Giamarchi
University of Geneva
Geneva, Switzerland
Thierry.Giamarchi@unige.ch

Mihael Grbić
University of Zagreb, Faculty of Science
Zagreb, Croatia
mgrbic@phy.hr

Jovica Ivkov
Institute of Physics
Zagreb, Croatia
ivkov@ifs.hr

Amit Keren
Technion
Haifa, Israel
phkeren@gmail.com

Natasha Kirova
Université Paris Sud
Orsay, France
kirova@lps.u-psud.fr

Ivan Kokanović
University of Zagreb, Faculty of Science
Zagreb, Croatia
kivan@phy.hr

Ivan Kupčić
University of Zagreb, Faculty of Science
Zagreb, Croatia
kupcic@phy.hr

Boran Leontić
University of Zagreb, Faculty of Science, Department of Physics
Zagreb, Croatia
bleontic@phy.hr

Jagoda Lukatela
Institute of Physics
Zagreb, Croatia
dada@ifs.hr

Tomaž Mertelj
Institute Jozef Stefan
Ljubljana, Slovenia
tomaz.mertelj@ijs.si

Goran Nikšić
University of Zagreb, Faculty of Science
Zagreb, Croatia
gniksic@phy.hr

Mario Novak
Department of Physics, Faculty of Science, University of Zagreb
Zagreb, Croatia
mnovak@phy.hr

Dalibor Paar
University of Zagreb, Faculty of Science
Zagreb, Croatia
dpaar@phy.hr

Davor Pavuna
Ecole Polytechnique Federale de Lausanne (EPFL)
Lausanne, Switzerland
davor.pavuna@epfl.ch

Damjan Pelc
University of Zagreb, Faculty of Science
Zagreb, Croatia
damjan.pelc@gmail.com

Nikolay Plakida
Joint Institute for Nuclear Research
Dubna, Russia
plakida@theor.jinr.ru

Petar Popčević
Institute of Physics
Zagreb, Croatia
ppopcevic@ifs.hr

Jean-Paul Pouget
Université Paris Sud
Orsay, France
pouget@lps.u-psud.fr

Miroslav Požek
University of Zagreb, Faculty of Science
Zagreb, Croatia
mpozek@phy.hr

Zoran Radović
Institute of Physics
Belgrade, Serbia
zradovic@ff.bg.ac.rs

Zoran Rukelj
University of Zagreb, Faculty of Science
Zagreb, Croatia
rukelj@gmail.com

Ana Smontara
Institute of Physics
Zagreb, Croatia
ana@ifs.hr

Denis Sunko
University of Zagreb, Faculty of Science
Zagreb, Croatia
dks@phy.hr

Denis Stanić
Department of Physics, University of J. J. Strosmayer Osijek
Osijek, Croatia
denis.stanic@fizika.unios.hr

Juraj Szavits-Nossan
Institute of Physics
Zagreb, Croatia
juraj@ifs.hr

Eduard Tutiš
Institute of Physics
Zagreb, Croatia
edo@ifs.hr

István Tüttő
Wigner Research Centre for Physics, Hungarian Academy of Sciences
Budapest, Hungary
tutto.istvan@wigner.mta.hu

Katarina Uzelac
Institute of Physics
Zagreb, Croatia
katarina@ifs.hr

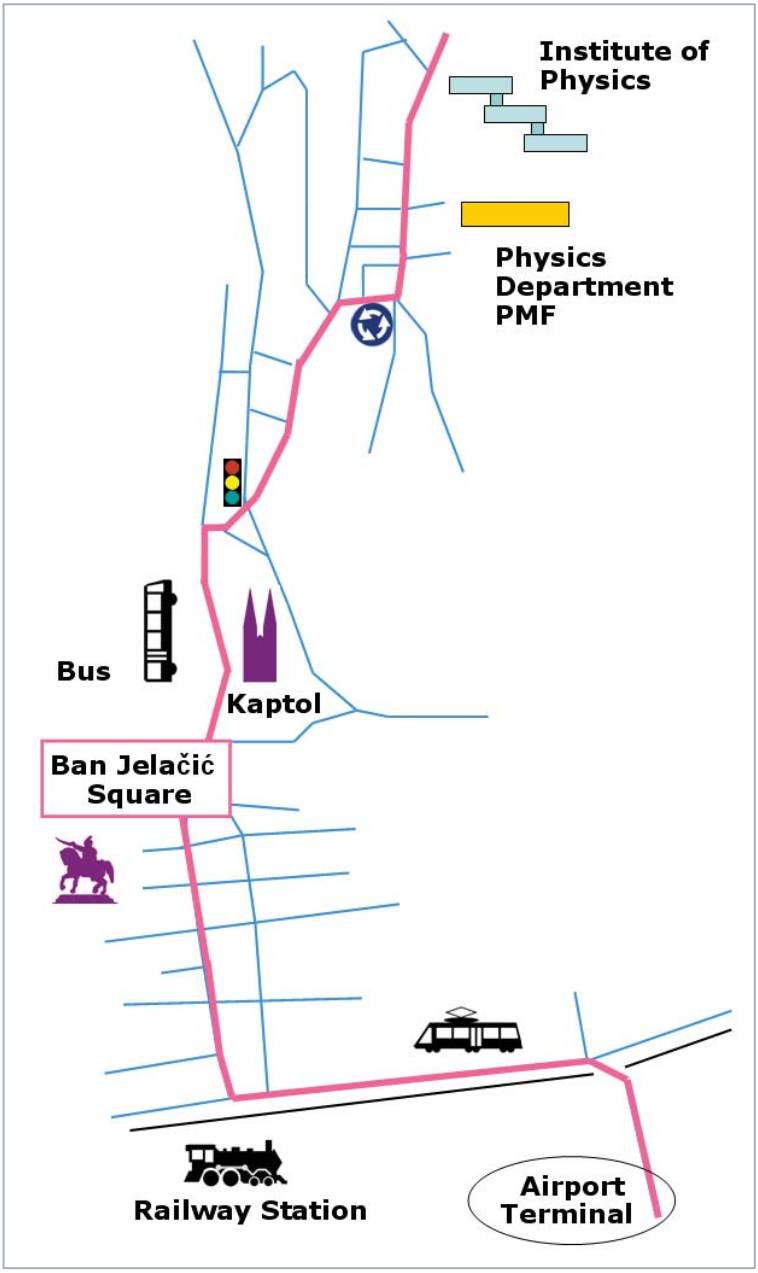
Kristijan Velebit
Institute of Physics
Zagreb, Croatia
kvelebit@ifs.hr

Tomislav Vuletić
Institute of Physics
Zagreb, Croatia
tvuletic@ifs.hr

Kaddour Wafa
Université Paris Sud
Orsay,Paris
wafa.kaddour@u-psud.fr

Alfred Zawadovski
Department of Theoretical Physics
Budapest, Hungary
zawa @phy.bme.hu

Ivica Živković
Institute of Physics
Zagreb, Croatia
zivkovic@ifs.hr



Useful information can be found on the official website of The Zagreb Tourist Board:

http://www.zagreb-touristinfo.hr/?l=e

Zagreb
CROATIA

http://pldc-pp.ifs.hr pldc-pp@ifs.hr

Design: Jovica Ivkov