ABSTRACT BOOK

RECENT ADVANCES IN BROAD-BAND SOLID-STATE NMR OF CORRELATED ELECTRONIC SYSTEMS

September 5-10 2010, Trogir, Croatia

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GENERAL INFORMATION

The international workshop on "Recent advances in broad-band solid-state NMR of correlated electronic systems" will take place on 5-10 September 2010, in Trogir, Croatia. The workshop is part of the SOLeNeMaR project (FP7 #229390) of the European Commission and will mark the foundation of the first solid-state NMR facility in Zagreb, established with the support of the SOLeNeMaR project and the Croatian Government (more information in poster session P-18).

The conference site and housing are within the walls of the historic town of Trogir, one of the UNESCO World Heritage Sites, situated close (6 km) to the international airport of Split (SPU).

The workshop is meant to bring together NMR experts and those interested in the local properties of complex materials, and to stimulate interest in NMR measurements and techniques. It will cover topical results on: high-Tc superconductors, cobaltates and pnictides, quantum magnetism, low-D organic conductors, heavy fermion conductors and complex systems, as well as advances in broad-band NMR techniques.

The target audience is both experimental and theoretical researchers in the field, as well as doctoral students and postdocs interested in broad-band NMR.

A specific ambition of the workshop is to foster the development of NMR expertise among young researchers, which is one of the formal goals of the above-mentioned SOLeNeMaR project. To this purpose ten grants will be made available from the project to cover all the expenses at the conference for selected young researchers.

VENUE

The ancient town of Trogir on the Croatian coast is closer to Split international airport than Split itself. It is one of only two towns on the Eastern Adriatic to have preserved intact a street plan dating before the Mongol invasion of 1242. The town hall in the main square will host the conference sessions, while coffee breaks will be held at the nearby open-air loggia, which served for solemn civic occasions during the Middle Ages. Both can be seen at http://whc.unesco.org/en/list/810/gallery. All conference hotels are impeccably restored 16th and 17th century town houses within the walls, with modern amenities. Most are appointed with similarly restored late 19th and early 20th century furniture. The total capacity of hotels in the old town is around 150 guests, so that most have been booked full for the purpose of the conference.


Sights
Hospital
Parking
Petrol station
Public toilet
Aci-marina
Taxi
Pharmacy
Post-office
Bank
Summer cinema
Pay phone
①HOTEL CONCORDIA
②HOTEL PAŠIKE
③HOTEL VILLA MERI
④VILLA SV.PETAR
⑤HOTEL TRAGOS
1. South Town Gate
2. Elementary School
3. Church and Monastery of St.Dominik
4. Belfry of Church of St. Michael
5. Kamerlengo Fortress
6. Monument Marmont
7. Tower of St. Mark
8. Bastion
9. North Town Gate
10. Remains of Town Walls
11. Church of our Lady of St. Carmel
12. Church of All Saints / Gallery
13. Church od St. Peter
14. Berislavić House
15. Town Museum, Collection of Stone Fragments / Garagnin Palace
16. Old and New Ćipiko Palace
17. Cathedral of St. Lovre
18. Town Hall
19. Church of St. John the Baptist
20. Town Square and Loggia with Clock Tower
21. Church of St. Barbara
22. Monastery of St. Nikola and Kairos Collection
⑥HOTEL TROGIR
⑦HOTEL PALACE DE ROSSI
⑧VILLA CARRARA
ARBANIJA SLATINE
SPLIT KAŠTELA
Kneza Trpimira
Alojzija Stepinca
TROGIR

PROGRAMME

	Monday	Tuesday	Wednesday	Thursday	Friday
8:30-8:45	**Opening**				
8:45-9:40	**P. Carretta**	**H. Alloul**	**C.Bourbonnais**	**S. Brown**	**P. Jeglič**
9:40-10:35	**H. Alloul**	**H.-J. Grafe**	**I. Kupčić**	**P. Mendels**	**M. Wencka**
10:35-11:05	**Coffee**	**Coffee**	**Coffee**	**Coffee**	**Coffee**
11:05-11:35	**C. Berthier**	**K. Kanoda**	**D. K. Morr**	W. G. Clark*	**Z. Jagličić**
11:35-12:00				A.V.Mahajan*	
12:00-12:05	**M.-H. Julien**	I. Mukhamedshin*	G. Lang*		P. Wzietek*
12:05-12:30				S. Kambe*	
12:30-12:35		R. Urbano*	Y. Laplace*		**Closing**
12:35-12:45				A.A.Gippius*	
12:45-12:55					**Lunch**
12:55-13:00	**Lunch**				
13:00-13:05					
13:05-13:30		**Lunch**	**Lunch**	**Lunch**	
13:30-13:45					
13:45-15:00					
15:00-15:55	**P. Carretta**	**C. Berthier**	Excursion	**V. Mitrović**	
15:55-16:25	**S. Krämer**	**A. Lascialfari**		A. Mounce*	
16:25-16:50				M. Grbić*	
16:50-16:55	**Coffee**	**Coffee**			
16:55-17:20				**Coffee**	
17:20-17:30	**M. Krusius**	A. Zorko*			Solenemar board meeting
17:30-17:50				Poster session*	
17:50-18:15		M. Klanjšek*			
18:15-18:20					
18:20-19:00					

* contributed

ORAL SESSION

Place: The town hall in the main square (Knežev dvor, Trg Ivana Pavla II, Trogir) will host the conference sessions, while coffee breaks will be held at the nearby open-air loggia.

Presentation time:

55 min. (50 min talk + 5 min Q/A)

30 min. (25 min talk + 5 min Q/A)

Oral presentations could only be presented by laptops. The Session room is provided with one laptop with LCD projector. Presenters should bring the presentation in CD or USB flash drive.

Presenters could use their own laptop during the speech, but we strongly recommend to use the laptop in the Session room.

POSTER SESSION

Place: Cate Dujšin-Ribar gallery

Poster Set-Up: Thursday morning (Sep 09)

Poster Session: Thursday (Sep 09) 17:30-19:00

Poster Removal: Friday afternoon (Sep 10)

Poster Size (max): 90 x 90 cm

INVITED LECTURES

NMR in correlated electron systems: Cuprates, cobaltates, fullerides…

Henri Alloul[1]

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Electron correlations in metallic systems induce quite unusual properties at variance with those expected for a Fermi liquid. Such systems display diverse competing ground states which depend sensitively on external parameters, such as doping, pressure etc… The resulting phase diagrams can be somewhat complicated with insulator to metal transitions, superconductivity, charge or spin ordering etc… In these lectures I shall insist on the fact that NMR, an experimental technique altogether sensitive to charge order, to static and dynamic magnetic properties, provides very powerful means to study the electronic properties of such systems and to sort out generic properties from those linked with specific material problems. Some of the important aspects revealed initially by NMR, such as the occurrence of a pseudogap in the phase diagram of High Tc cuprates, of charge disproportionation in highly doped Na coaltates will be taken as illustrations of the NMR capabilities. Emphasis will be given on the information which can be gained from the study of the incidence of impurities and controlled disorder on the physical properties of correlated electron systems. Finally, studies of the electronic dynamic magnetic properties through spin lattice T_1 NMR measurements will be illustrated in various cases, such as cuprates, cobaltates and at the Mott transition in alkali doped fullerides.

NMR in Quantum Spin Systems

C. Berthier[1], M. Horvatić[1], S. Krämer[1], H. Mayaffre[1], M. Takigawa[2], R. Stern[3], M. Klanjšek[4]

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[3]*National Institute of Chemical Physics and Biophysics, 12618,Tallinn, Estonia*
[4]*Jožef Stefan Institute, Jamova cesta 39, 1000 Ljubljana, Slovenia*

This lecture will begin by a brief description the overwhelming rich physics met in various quantum spins systems, starting from the well-known Heisenberg antiferromagnetic spin-1/2 chain up to the most recent developments. We shall then discuss the essential contributions that NMR can bring to that field, as compared to other techniques like EPR, and neutron scattering.

In a second part, we shall illustrate the power of NMR on a variety of different quantum spin systems: - quasi-1D systems, including spin-Peierls systems, frustrated $J_1 - J_2$ spin chains, spin-ladders, etc. - quasi-2D systems which display the rich physics of hardcore bosons on a lattice, with the possibilities of Bose-Einstein Condensation, supersolid phases, Wigner crystallization. The role of the magnetic field as a physical variable unravelling new quantum ground states will be particularly emphasized, as well as the possibilities offered by the use of very high magnetic fields obtained by using resistive magnets.

Antiferromagnetic and superconducting orders in quasi-one-dimensional organic conductors

Claude Bourbonnais[1], Abdelouahab Sedeki[1]

[1]*Regroupement Québécois des Matériaux de Pointe (RQMP), Département de physique Université de Sherbrooke, QC, Canada J1K-2R1*

The Bechgaard salts series $(TMTSF)_2X$ ($X=PF_6$, ClO_4, …) of organic conductors stands out as among the first superconductors showing a proximity between antiferromagnetism and superconductivity in their phase diagram under pressure **[1]**. The amplitude of spin correlations in the metallic state, as probed by the enhancement of NMR spin relaxation rate $1/T_1$ and linear-T resistivity, shows a remarkable correlation with the size of the superconducting T_c. Both features are captured from the renormalization group theory for the repulsive quasi-one-dimensional electron gas model **[2]**. In this work, we show how this approach can describe the interplay between the two interfering orders, and how this contributes to both the emergence of a Curie-Weiss type of enhancement for $1/T_1$ and an electron-electron scattering rate and electrical resistivity linear in temperature. The results are found to be in excellent agreement with a recent detailed experimental investigation of electrical transport of these materials **[1]**, which have established that the anomalous $1/T_1$ enhancement and linear-T resistivity are intimately linked to magnetism and the onset of superconductivity under pressure.

[1] N. Doiron-Leyraud et al., Phys. Rev. **80**, 214531 (2009)

[2] C. Bourbonnais and A. Sedeki, Phys. Rev. **80**, 85105 (2009); A. Sedeki, D. Bergeron and C. Bourbonnais, to be published (2010).

NMR and the quasi-one dimensional superconductors $(TMTSF)_2X$

Stuart Brown[1]

[1] *UCLA*

The quasi-one dimensional Bechgaard salts $(TMTSF)_2X$ were the first discovered of the molecular superconductors, and although the transition temperature is low, the systems remain of interest for a number of reasons, including the survival of superconductivity to very high magnetic fields [1,2], and novel normal state properties. Both likely result from spin fluctuations in association with the low dimensionality.

Superconductivity is observed in $(TMTSF)_2PF_6$ under pressure $P >$ 0.6GPa for $T \sim 1$K. At lower pressures, correlations are manifested in the stabilization of a spin-density wave (SDW) ground state. The antiferromagnetic fluctuations persist in the high-conductivity regime, as evidenced by enhanced nuclear spin-lattice relaxation rates. $1/T_1(T,P)$ is quite unusual, and was recently interpreted [3] as a consequence of the nature of the quasiparticles in a quasi-one dimensional system with imperfect nesting.

Superconductivity surviving to fields exceeding the paramagnetic limit H_P is well-known in molecular superconductors. In the case of the quasi-two dimensional materials such as κ-$(BEDT\text{-}TTF)_2Cu(NCS)_2$, it is sometimes attributed to the stabilization of inhomogeneous (FFLO) superconductivity for fields aligned with the conducting layers. The situation in $(TMTSF)_2X$ may be different, and we discuss the possibility of a field-inducted transition from singlet to triplet superconductivity.

[1] I. J. Lee, M. J. Naughton, G. M. Danner, and P. M. Chaikin, Phys. Rev. Lett. **78**, (1997) 3555

[2] J. Shinagawa, *et al.*, Phys. Rev. Lett. **98**, (2007) 147002

[3] C. Bourbonnais and A. Sedeki, Phys. Rev. B **80**, (2009) 085105

Basic aspects of Solid State NMR

Pietro Carretta[1]

[1]*Dipartimento di Fisica "A.Volta", University of Pavia - 27100 Pavia (Italy)*

A brief introduction to the basic aspects of solid state NMR and to the main quantities that are usually determined by this technique will be presented. The typical behaviour found in different systems will be illustrated through a series of paradigmatic examples.

NMR studies on the new iron pnictide superconductors

Hans-Joachim Grafe[1], Guillaume Lang[1], Franziska Hammerath[1], Dalibor Paar[2], Katarina Manthey[1], Madeleine Fuchs[1], Seung-Ho Baek[1], Bernd Büchner[1]

[1]*IFW Dresden, Institute for Solid State Research, P.O. Box 270116, D-01171 Dresden, Germany*
[2]*Department of Physics, Faculty of Science, University of Zagreb, P.O. Box 331, HR-10002 Zagreb, Croatia*

We summarize our Nuclear Magnetic Resonance (NMR) and Nuclear Quadrupole Resonance (NQR) results on the new iron pnictide superconductors in the normal and superconducting state [1-5]. The Knight shift, the quadrupole frequency, and the spin lattice relaxation rate show peculiar, doping dependent behaviour in the normal and superconducting state indicating that iron pnictides are unconventional superconductors with strong electronic correlations. We will discuss the influence of spin fluctuations as well as pseudo gap phenomena on the superconductivity, and the temperature dependence of the spin lattice relaxation rate and Knight shift in the superconducting state.

[1] H.-J. Grafe et al., Phys.Rev. Lett. **101** (2008) 047003 (2008)

[2] H.-J. Grafe et al., New Journal of Physics **11** (2009) 035002 (2009)

[3] R. Klingeler et al., Phys. Rev. B **81** (2010) 024506

[4] G. Lang et al., Phys. Rev. Lett. **104** (2010) 097001

[5] F. Hammerath et al., Phys. Rev. B **81** (2010) 140504(R)

Thermal Memory Cell

Zvonko Jagličić[1], Marko Jagodič[1], Janez Dolinšek[2]

[1]*Institute of Mathematics, Physics and Mechanic & Faculty of Civil and Geodetic Engineering Univeristy of Ljubljana, Jadranska 19, Ljubljana, Slovenia*
[2]*Jožef Stefan Institute, Jamova 39, Ljubljana, Slovenia*

A term "spin glass" usually denotes systems that possess two fundamental properties: frustration and randomness. These two properties lead to highly degenerate free-energy landscapes with several characteristic macroscopic magnetic properties: i) a large difference between field-cooled and zero-field-cooled magnetic susceptibilities below a freezing temperature, ii) the ZFC susceptibility exhibits a frequency-dependent cusp, iii) slow relaxation (aging) effects, and iv) a memory effect below the freezing temperature. The memory effect is observed by means of zero-field-cooled magnetization measurements with a stop during the cooling process at temperature below the freezing temperature.

The spin glass like magnetic properties in Taylor-phase complex intermetallic compound T-Al_3Mn, and its solid solutions with Pd and Fe, will be described with special emphasizes on the memory effect observed in this system.[1] We will show a new kind of memory element, a thermal memory cell, which exploit the memory effect.[2] In the thermal memory cell byte of digital information can be stored into the storage medium by pure thermal manipulation. Thermal inscription of information employs a specific temperature-time profile that involves continuous cooling and isothermal waiting time periods. We succeeded to thermally write arbitrary ASCII character into the thermal memory cell.

[1] J. Appl. Phys. **106** (2009) 043917

[2] Phys. Rev. B, **77** (2008) 064430-1

NMR methods for investigation of complex metallic alloys

Peter Jeglič[1], Martin Klanjšek[1], Matej Bobnar[1], Stanislav Vrtnik[1], Frank Haarmann[2], Janez Dolinšek[1]

[1]*Jožef Stefan Institute, Ljubljana, Slovenia*
[2]*Institut für Anorganische Chemie, RWTH Aachen, Germany*

Complex metallic alloys (CMA's) are intermetallic compounds characterized by (i) the large unit cells, comprising some tens up to thousands of atoms, (ii) the presence of well-defined atomic clusters, frequently of icosahedral point group symmetry and (iii) the occurrence of inherent disorder in an ideal structure [1]. In the last two decades there has been an increasing interest in CMA's due to the structural similarity of the atomic arrangement inside the unit cell with the short-range order structure of quasicrystals, which by definition have an infinite unit cell. This is why the CMA's are frequently referred to as approximants to the quasicrystals.

Because of the large size of the unit cell, the structural determination of CMA's is a complicated task. Diffraction methods are here an indispensable tool, whereas nuclear magnetic resonance (NMR) spectroscopy can offer complementary structural information on the local atomic scale [2-5]. The NMR spectra of quadrupolar nuclei such as ^{27}Al provide information on (i) the distribution of electric-field-gradient (EFG) tensors and the associated distribution of local atomic environments around the resonant nuclei, (ii) the number of crystallographically inequivalent lattice sites in the unit cell, and (iii) the local symmetry of the crystalline lattice. Various examples to demostrate the above aspects will be shown.

In addition, the ^{27}Al NMR experiments that prove a clathrate-like structure of Co_4Al_{13}, a traditional member of CMA's, will be presented. Recent X-ray investigation of high-quality single crystals in combination with theoretical calculations revealed a surprising analogy between Co_4Al_{13} [6] and intermetallic clathrates. Co-Al-Co molecular groups play a role of the guest ions trapped in cages formed by other Al and Co atoms. Two ^{27}Al NMR lines were identified in Co_4Al_{13}. The first one originates from Al atoms forming cages. The second line corresponds to Al sites with exceptionally large, almost axially symmetric EFG tensor, in perfect agreement with the presence of isolated Co-Al-Co molecular groups [5].

[1] K. Urban and M. Feuerbacher, J. Non-Cryst. Solids **334&335** (2004) 143.

[2] P. Jeglič et al., Phys. Rev. B **75** (2007) 014202.

[3] F. Haarmann, M. Armbrüster, Yu. Grin, Chem. Mater. **19** (2007) 1147.

[4] C.L. Condron, S.M. Kauzlarich, T. Ikeda, G.J. Snyder, F. Haarmann, and P. Jeglič, Inorg. Chem. **47** (2008) 8204.

[5] P. Jeglič et al., J. Alloys Comp. **480** (2009) 141.

[6] Yu. Grin, U. Burkhardt, M. Ellner, K. Peters, J. Alloys Comp. **206** (1994) 243.

Sodium cobaltates: A golden mine for solid-state NMR

Marc-Henri Julien[1]

[1]*Laboratoire National des Champs Magnétiques Intenses CNRS-UJF, 25 avenue des Martyrs, BP166, 38042 Grenoble Cedex 9, France*

The layered cobalt oxides AxCoO2 (A=Li,Na...) are extraordinary materials in more ways than one. They were first known in the 70s as intercalation compounds: LiCoO2 is actually used in the famous "Li-ion" batteries, which have largely contributed to the recent development of portable electronics. Interest in these materials had already been revived once in the 90s, following the demonstration of remarkable thermoelectric properties. But it was the discovery of superconductivity in 2002 (after intercalation of water molecules in NaxCoO2), as well as apparent similarities with the crystallographic and elctronic properties of the cuprate superconductors, which prompted a very wide popularity of these compounds. This presentation will primarily aim at giving an overview of the phase diagram of NaxCoO2 as seen by NMR measurements, while insisting on the striking peculiarity of this compound: the coupling between electronic properties and the network of sodium ions.

Collaborators: C. de Vaulx, H. Mayaffre, C. Berthier, M. Horvatic (Grenoble), P. Lejay, P. Strobel, H. Muguerra, P. Bordet, V. Simonet (Grenoble), C.T. Lin, D.P. Chen (MPI Stuttgart), J. Wooldridge, G. Balakrishnan, M.R. Lees (Coventry), V. Pralong, S. Hébert, A. Maignan (Caen)

[1] See for example Electronic Texture of the Thermoelectric Oxide Na075CoO2, M.-H. Julien et al., Phys. Rev. Lett. **100**, 096405 (2008)

NMR study on strongly correlated electrons in Q2D organics

Kazushi Kanoda[1]

[1]*Department of Applied Physics, University of Tokyo, Japan*

Mott transition is a metal-insulator transition induced by electron-electron Coulomb interaction. When the lattice is triangular, antiferromagnetically interacting spins suffer from geometrical frustration against ordering. So, the correlated electrons on triangular lattice in the vicinity of Mott transition are in an intriguing situation where both the charge and spin degrees of freedom possibly exhibit quantum fluctuations. The family of layered organic conductors, kappa-(ET)2X, whose bandwidth is comparable with the Coulomb repulsive energy and controllable by pressure, are model systems of interacting electrons on anisotropic triangular lattice.

In this conference, I review our NMR studies on kappa-(ET)2X, which revealed the criticality of Mott transition, the possible existence of spin liquid and the natures of superconductivity and vortices.

This presentation is based on collaborations with K. Miyagawa, F. Kagawa, Y. Shimizu, Y. Kurosaki, T. Furukawa, H. Hashiba, H. Oike, H. Taniguchi, S. Yamashita and Y. Nakazawa.

[1] F. Kagawa et al., Nature 436 (2005) 534; Nature Phys.5 (2009) 880.

[2] Y. Shimizu et al., PRL 91 (2003) 107001; Kurosaki et al., PRL95 (2005) 177001; Shimizu et al., PRB 70 (2006) 060510; PRB 81 (2010) 224508.

[3] K. Kanoda, chapter 22 in "The Physics of Organic Superconductors and Conductors," Edited by A. Lebed, Springer, 2008

Broadband NMR at ultra high magnetic fields up to 34 Tesla

Steffen Krämer[1], Mladen Horvatić[1], Claude Berthier[1], Francesco Aimo[1], Martin Klanjšek[2], Raivo Stern[3]

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[2]*Jožef Stefan Institute, SI-1000 Ljubljana, Slovenia*
[3]*NICPB, 12618 Tallinn , Estonia*

NMR is a powerful method for investigating many problems in physics and materials science. In particular, NMR is applied to study properties of condensed matter like quantum phase transitions in strongly correlated electron systems. When these phenomena occur at higher magnetic fields than 17 T, NMR is currently the *only* microscopic technique that provides access to local magnetic properties. Recently, we extended the NMR options at the *Laboratoire National des Champs Magnétiques Intenses* in Grenoble to ultra high magnetic fields up to 34 T, frequencies up to 1.5 GHz and temperatures as low as 50 mK. We present an overview of our technical efforts and current high field research projects.

By ^{1}H and ^{63,65}Cu NMR at 15-34 T and down to 0.4 K we identified the spin structure of azurite, $Cu_3(CO_3)_2(OH)_2$, a model system for the frustrated antiferromagnetic Heisenberg spin-1/2 chain of "distorted diamond" geometry [1]. By ^{29}Si NMR down to 50 mK we found an exotic and modulated Bose-Einstein Condensate of magnetic triplet excitations in the Han purple compound ($BaCuSi_2O_6$) above 23.5 T that will be discussed within the framework of different theoretical concepts [2].

[1] F. Aimo *et al.*, Phys. Rev. Lett. **102**, 127205/1-4 (2009) and unpublished.

[2] S. Krämer *et al.*, Phys. Rev. B **76**, 100406(R)/1-4 (2007) and unpublished.

NMR OF SUPERFLUID ^{3}He-B

M. Krusius[1]

[1]*Low Temperature Laboratory, Aalto University, Finland*

Superfluid ^{3}He is a charge-neutral Fermi system with coherent motion of ^{3}He particles with nuclear spin $I = \frac{1}{2}$. Its state is described with a multi-component order parameter field which can be mapped with NMR. Thus superfluid ^{3}He and NMR have been intimately interconnected since the discovery of the different superfluid ^{3}He phases in 1972. They are renowned for a number of unique NMR phenomena. The spin dynamics is dominated by the dipolar spin-orbit interaction from the Cooper pairing in BCS states. In transverse linear NMR this gives rise to magnetic field independent, but temperature and density dependent frequency shifts. The NMR line shape also displays sharp non-local collective spin-wave resonances. A most unusual property of the spin-orbit interaction is a field-independent temperature-dependent longitudinal resonance, which is observed with rf excitation applied along the static polarization field. Of recent interest are the different modes of spatially coherent order parameter precession. In the modern picture these can be understood as condensation of particle-like spin-wave excitations or magnons to Bose-Einstein condensate states.

The multi-component coherent order parameter field gives rise to a wealth of topologically stable structure, starting from 3-dimensional textures to point-like defects. Since the early eighties the main technique to study vortices has been uniform rotation, for which a rotating sub-millikelvin cryostat is required. So far seven different quantized vortex structures and many other topological defects have been identified in various states of rotating flow, including a two-phase sample where the two major phases ^{3}He-A and ^{3}He-B are separated by a stable first order AB interface. A brief overview is presented of the techniques for studying with sensitive continuous-wave NMR the peculiar resonance properties of the ^{3}He superfluids and the topology, structure, and dynamics of their order parameter fields.

Strong Cu-O hybridization in cuprate superconductors evidenced by NQR

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

The electric-field-gradient analysis of measured NMR/NQR data and resonant Raman scattering by Raman-active collective modes are powerfull tools which allow to study, respectively, the static quadrupole moment of the intracell electronic charge distribution and the corresponding quadrupole charge transfer fluctuations. Angle-resolved-photoemission spectroscopy (ARPES) represents another probe, additional to NQR, which reveals the static occupation of the copper and oxygen sites.

We first discuss experimental results regarding resonant Raman signals in the underdoped and insulating AFM cuprates, associated with the fluctuating stripes, the two-magnon excitations and the intracell oxygen-oxygen charge transfer fluctuations, to achieve the qualitative understanding of the static intracell charge distribution between one copper and two oxygen sites revealed by the NMR/NQR experiments. The possibility to measure signals in NMR/NQR experiments associated with the static oxygen-oxygen charge transfer is briefly discussed in this context. The intracell charge distribution in $La_{2-x}Sr_xCuO_4$, described in terms of the average hole number on copper sites n_d, is estimated from the measured $^{63}\nu_Q$ frequencies. n_d and the slope $\partial n_d/\partial\delta$ are also calculated using the Emery three-band model for both $U_d \to \infty$ and $U_d = 0$ and for the single-particle parameters extracted from ARPES experiments. The large difference between two sets of estimated values for n_d and $\partial n_d/\partial\delta$ is discussed in terms of the large U_d limit of the three-band model. It appears that, through the coupling with CDW and charge transfer fluctuations, the spin density fluctuations strongly affect those and other properties of cuprates.

NMR and MUSR on molecular nanomagnets

Alessandro Lascialfari[1], Ferdinando Borsa[2], Yuji Furukawa[3]

[1]*DISMAB, Università degli studi di Milano, Milano and Dip. di Fisica, Università degli studi di Pavia, Pavia, Italy*
[2]*Dip. di Fisica, Università degli studi di Pavia, Pavia, Italy*
[3]*Ames Laboratory and Dept. of Phys. and Astronomy, Iowa State University, Ames, Iowa, USA*

Since their discovery molecular nanomagnets, also called single-molecule magnets (SMM), have attracted a lot of scientists as they were promising systems for applications and offered the possibility to study fundamental physical properties in finite-size molecular systems whose units are replicated over a bulk quantity of sample. Among different experimental discoveries and theoretical treatments we recall the quantum tunneling of the magnetization, the evidence of the Berry phase, studies about quantum levels' crossing and many other issues regarding the spin dynamics in different temperature ranges. We report here a brief summary of the main MUSR and NMR studies on molecular nanomagnets in the last 15 years [1-3], whose results cover most of the above cited research fields.

[1] NMR in Magnetic Molecular Rings and Clusters, F. Borsa, A. Lascialfari, Y. Furukawa, in Novel NMR and EPR Techniques, eds. J. Dolinsek, M. Vilfan, S. Zumer, Springer (Berlin Heidelberg, 2006), pp.297-349

[2] NMR in magnetic single molecule magnets, F. Borsa, in NMR-MRI, MUSR and Mossbauer Spectroscopies in Molecular Magnets, eds.P. Carretta, A. Lascialfari, Springer Italia (2007)

[3] F. Borsa, Y. Furukawa, A. Lascialfari, Inorganica Chimica Acta 361 (2008) 3777–3784

Kagome Frustrated Antiferromagnets

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The frustration of antiferromagnetic interactions on the loosely connected kagome lattice associated to the enhancement of quantum fluctuations for S=1/2 spins was acknowledged long ago as a keypoint to stabilize novel ground states of magnetic matter. Only very recently, the model compound Herbersmithite, $ZnCu_3(OH)_6Cl_2$, could be synthesized and does not show any sign of freezing [1]. Its discovery has been coined as the "end to the drought of spin liquids".
I'll present first a short review of the major contributions of NMR to the study of earlier kagome-based frustrated antiferromagnets, spanning over the case of the (Cr^{3+} $S = 3/2$ kagome bilayer SrCrGaO, and the recent case of $S = 1/2$ Cu^{2+} based compound, Volborthite.
I will then discuss in detail our and others' results obtained over the recent years on Herbertsmithite and underline some of the pending issues. We will also discuss the specific NMR signature associated with unavoidable spinless defects in the kagome planes and how rewarding this "perturb to reveal approach" could be, in order to establish firmly the ground state of the kagome Heisenberg antiferromagnet. A comparison will be performed with other studies which give results which complement NMR[3-5].

[1] P. Mendels *et al*, Phys. Rev. Lett. **98**, 077204 (2007).

[2] A. Olariu *et al*, Phys. Rev. Lett. **100**, 087202 (2008).

[3] F. Bert *et al*, Phys. Rev. B **76**, 132411 (2007).

[4] A. Zorko *et al*, Phys. Rev. Lett. **101**, 026405 (2008).

[5] For a review, see P. Mendels and F.Bert, J. Phys. Soc. Jpn **1**, 011001 (2010).

Probing Magnetic Field Induced States in Unconventional Superconductors

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Applying a magnetic field to a superconductor is a powerful way of revealing the complexity of this macroscopic quantum state of matter. Even though the effects of the field in conventional type-II superconductors are well established, in a wide range of systems (such as the high-T_c, heavy fermions, and organic superconductors) the consequences are far from being understood. One possibility is that the magnetic field may affect the competition between superconductivity and antiferromagnetism (or other competing orders). Furthermore, an applied magnetic field may induce a novel superconducting state in which the momentum of the Cooper pairs is not equal to zero, but becomes finite and proportional to field, as predicted by Fulde, Ferrell, Larkin, and Ovchinnikov (FFLO). In this state the superconducting order parameter oscillates in real space. Heavy fermion superconductor $CeCoIn_5$ is a unique example of complex coexistence of a field induced magnetic order and the FFLO phases; and, thus, provides a strikingly rich ground to study the complex interplay between exotic superconductivity and magnetic degrees of freedom. In this talk, I will discuss how nuclear magnetic resonance (NMR), a microscopic probe sensitive to both magnetic and SC degrees of freedom, is used to probe microscopic nature of these exotic states.

Multiband Superconductivity in Spin Density Wave Metals

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Understanding the microscopic origin of thermodynamic phases with multiple order parameters (OP) is of great interest for correlated metals where superconductivity coexists with a density-wave state, giving rise to a multiband superconductor. The question of how phase-locking of the superconducting (SC) OP occurs is of particular interest in the electron-doped cuprates where experiments reported coexisting SC and spin density wave (SDW) states, and a transition of the SC OP from a $d_{x^2-y^2}$-wave to either an s- or $(d+is)$-wave symmetry with increasing doping.

In this talk, I discuss the emergence of two-band superconductivity with $d_{x^2-y^2}$- or s-wave symmetry in a commensurate SDW state. I show that the SDW coherence factors renormalize the momentum dependence of the SC gap. This yields an unconventional s-wave OP with a π-phase shift between the two bands, and line nodes along the boundary of the reduced Brillouin zone. In contrast, in the $d_{x^2-y^2}$-wave state, the OP is locked in-phase, with no additional line nodes. While in both cases, superconductivity is stabilized by interband Cooper pair scattering, the s-wave state is suppressed more quickly than the $d_{x^2-y^2}$-wave state with increasing SDW OP. Finally, I will discuss the implications of these results for NMR experiments in coexistence phases.

[1] J.-P. Ismer, I. Eremin, E. Rossi, D. K. Morr, and G. Blumberg, accepted for publication in Phys. Rev. Lett., arXiv:0907.1296.

From cuprates to pnictides: inherent duality in HT$_c$-materials (A new playground for NMR/NQR studies?)

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The heterogeneous coexistence of antiferromagnetism (SDW) and superconductivity on a mesoscopic scale was observed in iron-pnictides in many recent experiments. We suggest and discuss the scenario in which the heterogeneity is caused by formation of domain walls inherent to the SDW state of pnictides at a proper doping or under applied pressure. Superconductivity would emerge from the modulated SDW structure. The phenomenon is akin to the FFLO-phase in superconductors. The local suppression of SDW gap in a domain wall results in a finite density of states, corresponding to charge carriers moving along the walls. By analogy to cuprates, such domain walls may be considered as stripes. It is important that in both families of HT$_c$ compounds the spatial scales for heterogeneity vary in the range from one atomic size and up to thousands of angstroms. We discuss experiments that prove that SC in pnictides indeed emerges on the background of the soliton state and specially focus on the problems which may be studied with a help of NMR/NQR.

The work of L.P.G. was supported by the NHMFL through NSF cooperative agreement DMR-0654118 and the State of Florida, that of G.B.T. through the RFBR Grant N 10-02-01056.

Magnetic and physical properties of giant-unit-cell intermetallics

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Large unit cells containing up to a few thousand atoms, well organized clusters forming shells (often of icosahedral symmetry), an disorder caused by mixed occupancy of atoms at the same positions in unit cells and long range order are characteristic for quasicrystals. Such structure brings about untypical hybridization effects responsible for the formation of a pseudogap at the Fermi energy level. In such systems, electrons cannot move freely (the electronic conductivity is small), the atoms cannot oscillate collectively and exchange energy in the usual way (the heat conductivity is small) and electrons inbetween atoms bind the atoms stiffer to each other (the elasticy constant is very high at room temperature). The magnetic and physical properties, the specific heat and the electronic and thermal transport manifest themselves in the surface energy, the solid-solid friction, the wetting and the extraordinary mechanical properties. Thus quasicrystals are highly applicable alloys used in surface engineering as thick coatings, functional top surfaces to promote selectively specific reactions in catalysis, small mechanical devices requiring extreme elastic properties and for thermoelectric generators and fuel cells. Various properties of quasicrystals and their aproximants belonging to the Al-Ni-Co, Al-Pd-(Mn,Re), Al-Cu-(Ni,Fe), Zr-Cu-Ni-Al, Al-Mn-Fe, Al-Fe-Ni and Yb-Cu families synthesized in numerous phases will be presented. The overview through the physical phenomena in of the giant-unit-cell solids will be given beginning from the NMR. As spin probes, the ^{27}Al, ^{59}Co, ^{63}Cu and ^{1}H were used. For quasicrystals, a slow, low-energy, diffusive atomic motions persist down to low temperatures. The hydrogen diffusion constant exhibits strong temperature dependence and obeys classical Arrhenius thermally activated over-barrier hopping. The metallic Korringa relation shows in quasicrystaline lattices the cancellation of Kondo screening of the f-moments. The 1-D and 2-D NMR results will be supported by EPR, μ-SR, PPMS and SQUID measurements to show the investigated physical phenomenon from several points of view.

ORAL CONTRIBUTIONS

NMR spin echo study of RF-Induced Flux Lattice Annealing (RIFLA) in CuO superconductors

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A strained flux lattice configuration can be formed in a type II superconductor in a magnetic field by changing the field magnitude or alignment at a temperature well below the superconducting transition temperature. In this circumstance, the flux vortices are not pinned to pinning sites in the configuration with the lowest free energy. The rf pulses then used to obtain an NMR spin echo signal vibrate the flux lattice and can cause its configuration to change to one with a lower free energy. Here, this process is named RF-Induced Flux Lattice Annealing, or RIFLA. The result can be a progressive change in the local magnetic field at the sites of the nuclei following each pulse used to generate a sequence of spin echo signals. When this change in the local field between the dephasing and rephasing periods is large enough and different at different nuclear sites, the result is to reduce the amplitude of the echo from its value when changes in the local field between the dephasing and rephasing periods are absent. Upon starting a sequence of spin echo measurements in the strained flux lattice conditions, the amplitude of the first echo can be very small, and becomes progressively larger as the flux lattice is further annealed by additional pulses. Measurements and analysis of this RIFLA effect on the increase of the echo amplitude in a cuprate superconductor are presented, as well as reductions in the inductance of the NMR coil as the vortices become more strongly pinned by the annealing of the flux lattice.

Superconducting fluctuations probed by microwave absorption technique

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We use microwave absorption technique combined with an applied magnetic field (up to 16 T) to determine the transport properties around T_c in various families of cuprates (YBCO, Hg1201, LSCO, BSCCO). From these measurements we extract the temperature range where superconducting fluctuations start to contribute. In all the measured samples the fluctuation regime was found to be confined relatively close to T_c [1, 2, 3], with a tendency to increase by lowering the doping level. We discuss the results and compare them with those obtained by other techniques.

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

[2] M. S. Grbić, M. Požek, D. Paar, V. Hinkov, M. Raichle, D. Haug, B. Keimer, N. Barišić, A. Dulčić, arXiv:1005.4789v1

[3] M. S. Grbić et al., unpublished

Clarification of Quantum Criticality by Spin-echo decay method

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In order to diagnose the nature of quantum criticality, we have used the nuclear spin-echo decay rate $1/T_{2G}$, which is related to the static magnetic susceptibility at $q = Q$: $\mathrm{Re}\chi(Q,0)$, in combination with the spin-lattice relaxation rate $1/T_1T \propto [\mathrm{Im}\chi(Q,\omega)/\omega]_{\omega\sim 0}$. Based on the dynamical scaling law, the magnetic spin-spin correlation length ξ may be expressed as $1/(T_1T) \sim \xi^{z-1-\eta} \sim \xi^{z-1}$ and $(1/T_{2G})^2 \sim \xi^{1-2\eta} \sim \xi$ for the $d = 3, \eta = 0$ case. In the $d = 3$ antiferromagnetic heavy fermion compound USn_3, which is near a QCP, data for $(1/T_{2G})^2$ show that $\xi \propto T^{-3/4}$ above 100 K, as is expected for the quantum critical regime of a spin density wave (SDW) magnetic instability [1]. Observation that $T_1T/T_{2G}^2 \sim \xi^{2-z}$ remains T-independent at low temperatures leads to categorisation of the heavy fermion state of USn_3 in the overdamped regime with a dynamical critical exponent $z = 2$. We discuss the origin of the difference between the standard SDW and Kondo-breakdown type of quantum criticality in terms of new T_{2G} results in $YbRh_2Si_2$.

[1] S. Kambe, H. Sakai, Y. Tokunaga, T.D Matsuda, Y. Haga, H. Chudo and R.E. Walstedt, Phys. Rev. Lett. **102**, 037208 (2009).

Nuclear magnetic resonance in spin Luttinger liquids

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Effective low-energy description of interacting quantum particles in one dimension (1D) is called a Luttinger liquid (LL). Its main property is the existence of gapless excitations characterized by correlation functions decaying as power laws, with exponents being simple functions of the dimensionless exponent K. The physics of a LL is quite elegant as it is directed by two LL parameters only: exponent K and velocity of excitations u. Chains and ladders of antiferromagnetically coupled electronic spins are examples of LL's. Nuclear magnetic resonance (NMR) is a precise probe for the lattice dynamics on the frequency scale of 100 MHz, which coincides with the low-frequency part of electron spin fluctuations in spin systems. As such, NMR is an ideal tool for probing the spin LL physics in model materials.

We present an NMR study of two model materials: spin-ladder compound $CuBr_4(C_5H_{12}N)_2$ [1] and spin-chain compound $BaCo_2V_2O_8$. Once the exchange couplings between electronic spins are known, the LL theory of a 1D spin system (chain, ladder) is left without adjustable parameters. Weak exchange couplings between individual 1D spin systems, which are responsible for an emergence of 3D magnetic order at low temperature, are included in the theory within the random phase approximation. We show that such an extended LL theory can successfully account for several observables (order parameter, transition temperature, electron spin fluctuations) as obtained by NMR in rich phase diagrams of both model materials.

[1] M. Klanjšek *et al.*, Phys. Rev. Lett. **101**, 137207 (2008).

Nanoscale electronic order in iron pnictides

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In the iron pnictide superconductors, a controversial issue is the boundary between the static magnetism and superconductivity regions of the phase diagram of the main families, with reports so far of microscopic or mesoscopic ground-state coexistence, a second-order boundary, or a first-order boundary. Beyond the possible ground states, it remains unclear whether intrinsic electronic inhomogeneities and an associated order, short-range or more, can show up as in related transition metal oxides. Using a pnictide family (RFeAsO$_{1-x}$F$_x$, R = La or Sm) where dopant-disorder effects are minimized, we investigated the charge distribution using As nuclear quadrupole resonance [1]. Whereas undoped and optimally doped or overdoped compounds feature a single charge environment, two charge environments are detected in the underdoped region, irrespective of the ground state. Spin-lattice relaxation measurements show their coexistence at the nanoscale. Together with the quantitative variations of the spectra with doping, they point to a local electronic order in the iron layers, where low- and high-doping-like regions would coexist. Implications for the interplay of static magnetism and superconductivity are discussed.

[1] G. Lang *et al.*, Phys. Rev. Lett. **104** (2010) 097001

NMR study of superconductivity and magnetism in pnictides

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A strinking unexpected feature of the phase diagram of materials where unconventional superconductivity has been evidenced is the existence of a long range magnetic order adjacent to the superconductivity. Deciding if superconductivity and magnetism exclude each other or may coexist has been subject of intense debate, revived recently by the discovery of pnictides. We present NMR results on electron doped Ba(FexCo1-x)2As2 single crystals which demonstrates that for x=0.06, the sample experiences both full volume superconductivity (Tc=21K) and incommensurate spin density wave order (Tsdw=31K) on the same Fe sites, the magnetic order being unaffected by superconductivity. Our static and dynamic 75As NMR measurements allow us to rule out for the first time any possible phase segregation, even if it was to be nanometer sized. This is a strong support toward s+- superconductivity symmetry in these systems, as suggested by many theoretical reports. We also address the issue of the impact of the Co doping by its substitution directly inside the FeAs layer and show that it does lead to a remarkable electronic homogeneity in contrast with cuprates and other correlated materials.We will also present new results recently obtained in other pnictide families with various distances between Fe layers.

[1] Phys. Rev. B 80, 140501(R) (2009)

[2] The European Physical Journal B, vol 73, num 2, 161-166 (2010)

^{75}As NMR in Fe pnictide superconductors

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Discovery of superconductivity in Fe pnictides has caused a revival of interest in superconductors. A variety of studies are on to investigate the similarities and differences with phase diagram of high-Tc cuprates. An interesting series of samples is in the Ba(Fe, Ru)$_2$As$_2$ system. The Ru end-member is a non-superconducting conventional metal while the Fe end-member is magnetically ordered below about 140 K. A superconducting “dome” exists at intermediate compositions as for the high-Tc cuprates. We are carrying out ^{75}As NMR measurements on samples with various Ru contents in the above system. We will report our results of the variation with temperature and composition of the NMR shift and the spin-lattice relaxation rate 1/T$_1$ in the Ba(Fe, Ru)$_2$As$_2$ system.

Spin Density Modulation Near the Vortex Cores of $Bi_2Sr_2CaCu_2O_{8+\delta}$

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Spatially resolved NMR spin-lattice (T_1) and spin-spin (T_2) measurements are used to probe the microscopic structure of the vortex lattice in the highly anisotropic High Temperature Superconductor $Bi_2Sr_2CaCu_2O_{8+\delta}$. Results, differing from similar measurements in $YB_2Cu_3O_7$[1], are interpreted in the context of a long range spin density modulation in and outside the vortex core in accordance with previous LDOS "checkerboard" patterns found by STM[2]. Our model includes a checkerboard pattern of a Gaussian cosine decay from the vortex core, characterized by a amplitude and decay length, in addition to the diamagnetic contribution from vortices. Fitting this model to our data, we find that the amplitude increases and the decay length decreases with increasing external field and with this model we can also account for experimental T_1 relaxation rates. This work is supported by **DOE/BES: DE-FG02-05ER46248** and the NHMFL by NSF and the State of Florida.

[1] Mitrović, V.F. *et.al.* Nature **413**, 501(2001)

[2] Hoffman, J.E. *et al.* Science **295**, 466 (2002)

NQR study of the phase segragation and sodium ordering in cobaltates Na_xCoO_2

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We have investigated a set of sodium cobaltate samples with various sodium content ($0.67 \leq x \leq 0.75$) using Nuclear Quadrupole Resonance (NQR) [1]. The four different stable phases and an intermediate one have been recognized. The NQR spectra of ^{59}Co allowed us to differentiate clearly the pure phase samples which could be easily distinguished from multi-phase ones.

Systematic study of the $Na_{2/3}CoO_2$ compound using ^{23}Na and ^{59}Co NQR and NMR [2,3], allowed us to establish reliably the atomic order of the Na layers and their stacking between the CoO_2 slabs. We give evidence that the Na^+ order stabilizes non magnetic Co^{3+} ions on 25% of the cobalt sites arranged in a triangular sublattice. The transferred holes are delocalized on the 75% complementary cobalt sites which unexpectedly display a planar cobalt kagomé structure. These experimental results prove that both Curie-Weiss magnetism and metallic conductivity are provided by this kagomé sublattice of cobalt in sodium cobaltates.

This study was partly supported by the RFBR under project #10-02-01005.

[1] T.A. Platova, *et al.*, JETP Lett., **91** (2010) 457

[2] H. Alloul, *et al.*, EPL **85** (2009) 47006

[3] T.A. Platova, *et al.*, Phys. Rev. B **80** (2009) 224106

Field-dependence of Competing AFM and SC in underdoped (Ba1-xKx)Fe2As2

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We have investigated the electronic and magnetic properties of a high quality single crystal of (Ba0.84K0.16)Fe2As2 by bulk and high magnetic field NMR measurements. The magnetic susceptibility, the resistivity and the specific heat reveal a structural and an AFM transition around T0 = 110 K. Coexistence of AFM order and bulk SC is evident below Tc = 20 K as inferred from the 75As NMR spectra and spin-lattice relaxation rate, 1/T1. Based in our NMR results, the spin structure in the ordered state is determined to be AFM stripe-type in agreement with the neutron scattering data reported for the parent BaFe2As2. Surprisingly, the spontaneous internal hyperfine field Bint generated by the AFM order at the As site is enhanced by high magnetic fields with B perpendicular to the c-axis. As consequence, a possible enhancement of the ordered moment at the Fe site is suggested from our high field data. We thus conclude that the magnetic field may be considered as a tuning parameter on this material.

NMR study of the Tomonaga-Luttinger liquid state in the carbon nanotubes

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Carbon nanotubes (CNT) are perfect candidates to realize 1D electronic systems, such as described by the Tomonaga-Luttinger Liquid theory. Although the TLL behavior in the electronic transport was reported for metallic CNT, conductivity measurements can be spoiled by contact effects such as Coulomb blocade. On the other hand, NMR provides a non invasive probe of the electronic properties of a bulk system such as CNT bundles. I will present 13C NMR studies of the single and double wall nanotubes. Namely, in the single wall species (SWCNT) the nuclear relaxation study reveals that spin excitations are gapless down to at least 6K and the characteristic power law dependence of 1/(T1T) could be followed over two decades in temperature. The observed exponent is smaller than expected in the two-band model used to describe the metallic CNT. The field dependence of the relaxation rate indicates a frequency dependence of the correlation function, however its origin remains unclear.

Magnetism of the frustrated spin-2 triangular systems $NaMnO_2$

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Although numerical studies speak in favor of a non-collinear long-range magnetic order (LRO) on an isotropic spin-1/2 Heisenberg antiferromagnetic triangular lattice, for spatially anisotropic exchange, the ground-state phase diagram becomes considerably richer. LRO on two or three sublattices, incommensurate magnetic order, or various spin-liquid phases can be realized. Much less is known about about the case of integer spins.

We have investigated the spatially anisotropic spin-2 triangular system α-$NaMnO_2$ by means of local-probe techniques. Muon spin relaxation (μ^+SR) has provided the first evidence for a transition to a magnetically ordered state. Neutron diffraction confirmed that collinear AFM LRO order appears at T_N= 45 K [1]. The character of spin correlations above T_N is 1D despite the underlined 2D lattice [2]. From electron-spin-resonance (ESR) measurements we have determined the dominant magnetic anisotropy term, which assists in stabilizing the 3D order by suppressing spin fluctuations [3]. We have further investigated the development of spin correlations as well as the dynamics of spin excitations and the symmetry of LRO below T_N through ^{23}Na nuclear magnetic resonance (NMR). We shall compare our results obtaint for two polymorphs; α-$NaMnO_2$ and β-$NaMnO_2$.

[1] M. Giot et al., Phys. Rev. Lett **99** (2007) 247211

[2] C. Stock et al., Phys. Rev. Lett **103** (2009) 077202

[3] A. Zorko et al., Phys. Rev. B **77** (2008) 024412

POSTER CONTRIBUTIONS

NMR Investigations of Single-Crystalline d-Al-Ni-Co Decagonal Quasicrystal

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The crystallographic-direction-dependent NMR measurements were performed on the d-Al-Ni-Co quasicrystalline compound with composition $Al_{70}Ni_{20}Co_{10}$, by rotating the samples around the [00001] direction, a periodic direction along which the quasiperiodic planes are stacked, and around the [01000] and [$10\bar{1}00$] directions, which lie in the quasiperiodic plane and are orthogonal to each other in the 5D hyperspace. The ^{27}Al NMR rotation patterns were recorded in a magnetic field of 9.4 T. The line shapes appear resolved and enable extraction of the electric quadrupolar and magnetic Knight shifts, which were then reproduced by a simple model. With the additional physical-property measurements, such as the electrical and the thermal conductivity, the Hall coefficient, the thermoelectric power, the heat capacity and the magnetic susceptibility, our results add to the understanding of structural details and physical properties of the d-Al-Ni-Co phase.

Cryogenic static and magic-angle spinning NMR on superconductors

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Nuclear magnetic resonance has proven to be valuable in the study of superconductors, for static samples. The NMR signal reflects the local structure and dynamics. Site-specific information can be obtained with atomic resolution in a wide T range. Solid state NMR spectra of static samples are often very broad and difficult to interpret.

For many nuclei, a resolution improvement is achieved by rotating the sample about the "magic-angle". Magic-angle spinning (MAS) can provide resolution of inequivalent chemical sites, narrower and more intense signals. To date, most low T NMR studies have been performed on static samples due to technical limitations. In the world, there are only few MAS NMR probes operating below 70 K (cryoMAS).

Preliminary data will be presented here, where static NMR, MAS NMR and ab initio calculations will be combined on model materials. The target systems will include MgB_2 , YBCO and alkali fullerides.

NMR study of incommensurate helical magnetic order in the spin-chain cuprates $LiCu_2O_2$ and $NaCu_2O_2$

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A ^{7}Li NMR study of a $LiCu_2O_2$ single crystal without twinning was performed in the temperature range around the transition into the magnetically ordered state. The transition into the incommensurate (IC) low-temperature helical phase occurs in two successive stages at temperatures T_{c1} = 24.7 K and T_{c2} = 22.8 K. The ^{7}Li NMR line shape evolution was studied in detail in the temperature range 22 K – 25 K in an external field around 7.7 T applied along the main crystallographic axes. The observed ^{7}Li NMR spectra in the intermediate temperature range differ considerably from those obtained in the low-temperature phase ($T < T_{c2}$). This yields a clear signature of the different character of the IC magnetic structures of Cu^{2+} spins in the intermediate and low-temperature phases, respectively. The ^{7}Li NMR results are compared with the ^{23}Na NMR spectra obtained in a $NaCu_2O_2$ single crystal [1] and are discussed in terms of both helical and collinear IC magnetic structures of Cu^{2+} spins.

[1] A.A. Gippius et al., Physical Review B **77** (2008) 180403R

Nuclear Magnetic Resonance Experiments using Anvil Cells

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Pressure is an important tuning parameter for strongly correlated electronic systems, where various interesting ground states can be reached by applying high pressures. Nuclear magnetic resonance (NMR) experiments under pressure have been performed routinely by various groups using conventional piston-cylinder type clamp cells (limited to P $<\sim$35 kbar). Here I will discuss our recent efforts to perform NMR experiments using anvil cells containing microcoils [1,2]. Results from the first test cases will be presented to illustrate the sensitivity of the setup.

[1] J. Haase, S. K. Goh *et al.*, Rev. Sci. Instrum. **80** (2009) 073905

[2] T. Meissner, S. K. Goh *et al.*, J. Low Temp. Phys. **159** (2010) 284

Physical properties of $Zr_{50}Cu_{40-x}Al_{10}Pd_x$ bulk glassy alloys

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We performed a study of the magnetic properties, the specific heat, the electrical resistivity and the hydrogen diffusion constant for a series of compositions $Zr_{50}Cu_{40-x}Al_{10}Pd_x$ (x = 0–7 at. %), in order to determine their physical properties. The $Zr_{50}Cu_{40-x}Al_{10}Pd_x$ BGAs are nonmagnetic, conducting alloys, where the Pauli spin susceptibility of the conduction electrons is the only source of paramagnetism. The low-temperature specific heat indicates an enhancement of the conduction-electron effective mass below 5 K, suggesting that the $Zr_{50}Cu_{40-x}Al_{10}Pd_x$ BGAs are not free-electron-like compounds. The hydrogen self-diffusion constant D in hydrogen-loaded samples was determined by NMR in a fringe field of a superconducting magnet. The diffusion shows a classical over-barrier-hopping temperature dependence and is of comparable magnitude to the related icosahedral and amorphous $Zr_{69.5}Cu_{12}Ni_{11}Al_{7.5}$ hydrogen-storage alloys, so that $Zr_{50}Cu_{40-x}Al_{10}Pd_x$ BGAs are candidate materials for the hydrogen-storage applications. No correlation between the investigated physical parameters and the Pd content of the samples could be observed.

Charge Induced Vortex Lattice Instability

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It has been predicted that superconducting vortices should be electrically charged and that this effect is particularly enhanced for short coherence length, high temperature superconductors.[1,2] Hall effect[3] and nuclear magnetic resonance (NMR) experiments[4] suggest the existence of vortex charging, but the effects are small and the interpretation controversial. We show that the Abrikosov vortex lattice, characteristic of the mixed state of superconductors, will become unstable at sufficiently high magnetic field if there is charge trapped on the vortex core. Our ^{17}O NMR measurements of the magnetic fields generated by vortices in $Bi_2Sr_2CaCu_2O_{8+y}$ single crystals[5] provide evidence for an electrostatically driven vortex lattice reconstruction with the magnitude of charge on each vortex pancake between 2.1 and 2.5x$10^{-3}e$, depending on doping, in line with theory.[1,6]

[1] D.I. Khomskii and A. Freimuth, Phys. Rev. Lett **75** (1995) 1384.

[2] G. Blatter *et al.*, Phys. Rev. Lett **77** (1996) 566.

[3] S.J. Hagen, C.J. Lobb *et al.*, Phys. Rev. B **43** (1991) 6246.

[4] K.I. Kumagai, K. Nozaki, and Y. Matsuda, Phys. Rev. B **63** (2001) 144502.

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[6] D. Knapp, C. Kallin *et al.*, Phys. Rev. B **71** (2005) 064504.

Unusual disorder effects in $LaFeAs_{1-\delta}O_{0.9}F_{0.1}$ as revealed by NMR spectroscopy

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We report ^{75}As NMR measurements of the spin-lattice relaxation in the superconducting state of $LaFeAsO_{0.9}F_{0.1}$ and As-deficient sample, $LaFeAs_{1-\delta}O_{0.9}F_{0.1}$ with a drastic change of the $1/T_1$ temperature dependence below T_c from a T^3 for $LaFeAsO_{0.9}F_{0.1}$ to a T^5 for the latter. T_c and the slope of the upper critical field near T_c increase unexpectedly in the As-deficient sample. Our results are discussed in terms of non-universal SC gaps in Fe-pnictides and the effect of As deficiency as an exotic case when nonmagnetic 'smart' impurities even stabilize an $s_{\pm}-$wave superconductor as well as within a scenario of a disorder driven change to conventional s_{++}- superconductivity.

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[2] F. Hammerath et al., Phys. Rev. B rapid comm., accepted.

^{77}Se NMR study of λ-$(BETS)_2Fe_{1-x}Ga_xCl_4$ organic superconductors

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λ-$(BETS)_2FeCl_4$ is a molecular based charge transfer complex known as a system exhibiting a field induced superconductivity (FISC). The microscopic origin of this FISC is the so-called Jaccarino-Peter compensation mechanism, which was proved by our previous NMR study [1]. In order to investigate the electronic properties of the two dimensional BETS conducting layers free from the influence of magnetic Fe ions, we performed ^{77}Se NMR measurements on the isostructural λ-$(BETS)_2GaCl_4$ compound [2]. The broadening of NMR spectrum at low temperatures in the Ga compound was confirmed to be due to charge disproportionation in the BETS layers as it was found in the Fe compound. From the analysis of the anisotropy of the NMR shift and width we estimated that the degree of charge disproportionation in the Ga salt is smaller than that observed in the Fe salt. The present result clearly confirms that the magnetic Fe ions are not responsible for the broadening and that a charge disproportionated metallic state exists in the close vicinity of the superconducting phase of the Ga salt. We will also present our latest results on the electronic properties of the alloy system, λ-$(BETS)_2Fe_{1-x}Ga_xCl_4$.

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[2] K. Hiraki *et al.*, J. Phys. Soc. Jpn. **79**, (2010) : in press

Electron spin relaxation in solid ethanol: the effect of matrix disorder

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Coupling of the electron spin to disorder modes of various doped matrices has been extensively studied due to the sensitivity of the approach toward dynamical properties of the observed systems. Amorphous solids in comparison with crystals exhibit anomalous dynamics at low temperatures [1]. In this context the application of pulsed electron paramagnetic resonance (EPR) spectroscopy offers the advantage of studying local properties in the vicinity of paramagnetic center. Since solid ethanol can be prepared in phases characterized by different types of disorder, we have used it as a convenient model system for studying low-molecular weight solids by EPR [2]. Here we present electron spin-lattice relaxation data of TEMPO paramagnetic molecule incorporated in crystalline and glassy state of solid ethanol in the temperature interval well below the ethanol glass transition. The largest difference between the data can be detected at temperatures below 10 K and related to the presence of excess of low-energy excitations in glasses that are not present in crystals. These findings will be correlated with conclusions derived from nuclear magnetic resonance spectroscopy.

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[2] M. Kveder, D. Merunka, M. Jokić, J. Makarević, and B. Rakvin, Phys. Rev. B **80** (2009) 052201

Quantum critical dynamics in the one-dimensional spin chain systems Cu $(C_4H_4N_2)(NO_3)_2$ and $(phzH)_2CuCl_4H_2O$

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We present a comprehensive NMR study of the magnetic field-driven quantum phase transitions in the S=1/2 spin chain systems $Cu(C_4H_4N_2)(NO_3)_2$ and $(phzH)_2CuCl_4H_2O$. The static and dynamic experimental NMR properties are compared with both quantum Monte Carlo calculations and Luttinger liquid theory. The first compound, $Cu(C_4H_4N_2)(NO_3)_2$, is known to be one of the best realizations of the antiferromagnetic S=1/2 Heisenberg chain (AFHC) model with a low coupling constant J. The zero temperature

saturation field B_c = 14.9 T corresponds to a quantum critical point, where the system is driven from a Luttinger liquid state to ferromagnetic polarization. In the vicinity of this point in the corresponding B- and T- parameter space a divergent behavior of the nuclear ^{13}C-spin-lattice relaxation rate is observed and in good agreement with theory [1,2]. In addition, we present a detailed ^{14}N-study of the angular dependent hyperfine fields at the nitrogen sites in the nitrate groups. This allows to determine the EFG-Tensor, the distribution of nearby local spin moments and fortifies the comparibility between theory and experiment of the ^{13}C-results. The second compound, $(phzH)_2CuCl_4H_2O$, is a recently synthesized [3] spin chain system. ^{1}H- and ^{35}Cl-NMR experiments consistently yield a field- and temperature dependent behavior of $1/T_1$ similar to that of the first compound. But, in contrast, a pronounced second maximum is observed at about 3/4 of the saturation field B_c = 12.2 T. This effect is not found in the local or macroscopic magnetization, suggesting a more complicated magnetic interaction scheme.

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[2] H. Kühne et al., Phys. Status Solidi B **247**, 671 (2010)

[3] R. Schneider et al., Polyhedron **26**, 1849 (2007)

NMR study of superconducting and magnetic state in $CeCoIn_5$

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A heavy fermion superconductor $CeCoIn_5$, is believed to host a Fulde-Ferrell-Larkin-Ovchinnkov (FFLO) state at a restricted region at high field and at very low temperature. Recent NMR and neutron scattering studies discover a modulated magnetic order within the novel superconducting (SC) phase. We direct our attention to a puzzling interplay between the novel SC state and modulated magnetism of $CeCoIn_5$. ^{115}In and ^{59}Co-NMR have been measured for both the directions of $H//a$ and $H//c$-axis.

For $H//a$-axis, NMR spectra change dramatically below $T(H_c)$ upon entering the novel SC state. The most striking future is that a well-separated peak structure and characteristic broadening of the spectra of the In(2) site are observed only in the novel SC phase, indicating an appearance of finite hyperfine fields coupled to magnetic Ce moments. The magnetic ordering is never observed in the normal state and also in the BCS-SC phase. We will discuss a possible magnetic structure coupled inhomogeneous SC order parameter as expected in the FFLO phase.

For $H//c$-axis, well-separated peaks of the NMR spectra are observed at the Knight shift positions expected for the normal and SC state for $4.75T < H <$4.95T, suggesting the appearance of a nordal plane structure as expected for the FFLO phase. However, apparent magnetic ordering is not confirmed down to the lowest temperature ($\sim$40mK), different from the case for $H//a$-axis. We obtain also detail temperature and field dependences of the Knight shift in the superconducting state, and will discuss strong Pauli paramagnetic effects on the spatial distribution of the spin susceptibility in the vortex state of $CeCoIn_5$.

Superionic Conductivity and lithium quadrupolar interaction in Li_4C_{60}

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We report here the main results of our intensive studies on the ^{7}Li NMR properties of Li_4C_{60}, a lithium intercalated fulleride polymer.

On one hand, the temperature dependance of ^{7}Li NMR spin-lattice relaxation, together with DC and frequency dependent conductivity measurements, revealed uncorrelated ionic hopping across small energy barriers ($E_a \sim 200$ meV) with an ionic conductivity of $10^{-2}\,S/cm$ at room temperature, higher than in "standard" ionic conductors [1]. The discovery of such an extraordinary superionic conductivity in the fulleride polymer Li_4C_{60}, a crystalline material with no disorder, has attracted particular interest even outside the scientific community, as these results suggest novel applications of intercalated fullerides as electrodes in lithium ions batteries.

On the other hand, the investigation of the ^{7}Li quadrupolar interaction proved valuable especially at low temperatures, where the ions' motion freeze and the lithium quadrupolar features become more evident [2]. We could perform an accurate fit of the quadrupolar spectrum which allowed a comparison of the measured electric field gradient with the structural details of the compound, in particular with the lithium ions position refined from synchrotron and neutron diffraction.

[1] M.Riccò, M.Mazzani et al., *Phys. Rev. Lett.*, vol.102, No.14, 145901 (2009).

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NMR and NQR parameters of organic materials in the GIPAW density functional theory model

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Theoretical methods have always been an important support in analysis of NMR measurements. However, traditional approaches for real materials, for example these based on the quantum chemistry Gaussian code, are used only for a finite and small part of a sample which then models an infinite crystal. GIPAW (Gauge Including Projector Augmented Wave) is a density functional pseudopotential method introduced by Francesco Mauri and coworkers. It is possible to use this method for molecules, clusters, surfaces, real three-dimensional crystals and amorphous materials. These approaches, as well as related methods based on the orbital magnetization, are still in development. GIPAW already produces results for NMR and NQR parameters of many materials in a good agreement with experiments. Methods based on the GIPAW pseudopotentials, if coupled with LDA(GGA)+U techniques used for studies of structural and electronic properties of strongly correlated materials, could give a very good support for experiments in solid-state NMR of correlated electronic systems.

We present results for chemical shifts, as well as for coupling constants and asymmetry quadrupolar parameters, of two organic materials. The first one is ethanol, C_2H_5OH, where we study the molecule and the crystal. We also calculate NMR parameters of a more complex organic molecule proflavine $C_{13}H_{11}N_3$ (3,6-diaminoacridine), known as an intercalator in DNA and RNA. Computed parameters are compared with experimental data.

NMR study of Quantum Critical Behaviour in $NiCl_2$-$4SC(NH)_2$, a Quantum Antiferromagnet

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$NiCl_2$-$4SC(NH)_2$ (DTN) is an anisotropic Heisenberg spin chain, with a strong uniaxial single ion anisotropy ($\sim$ 9K), intra-chain coupling $J_c = 2.2$ K, and inter-chain coupling $J_{a,b} = 0.18$ K. It undergoes a magnetic field driven Bose-Einstein condensation (BEC) between two critical fields, $H_{c1} \sim 2.1$ T, and $H_{c2} \sim 12.6$ T, with $T_c \leq 1.2$ K. As a function of magnetic field, in the vicinity of the critical fields such a system will undergo a crossover from 1D quantum criticality to a gapped state through a 3D quantum critical regime. We report here the nuclear spin-lattice relaxation time (T_1) measurements, showing specific temperature dependence in these regimes. We discuss the ^{1}H T_1 rate in DTN, measured around H_{c2} for $T > 1.2$ K, in the context of this quantum criticality. The results in DTN are similar to those obtained in the 1-D spin-ladder system $CuBr_4(C_5H_{12}N)_2$, indicating the universal features of crossovers between different regimes [1].

[1] M. Klanjšek, et al, Phys. Rev. Lett **101** (2008) 137207, and unpublished.

Nuclear resonance of Fe_3Mo_3N near the quantum critical point

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We have recently found that an iron-based metallic magnet Fe_3Mo_3N with the η-carbide type crystal structure is a prototype of the strongly correlated electron system near the ferromagnetic quantum critical point [1]. This compound shows a lot of exotic properties such as a heavy electron character, a non-Fermi liquid behavior, a very sharp metamagnetic transition, onset of ferromagnetism by slight doping, etc.

The η-carbide type compounds are also of interest from the structural viewpoint. The Fe sites (16*d* and 32*e* sites in $Fd\bar{3}m$) forms the *stella quadurangula* (SQ, stellate tetrahedron) lattice [2], which is a promising candidate for the geometrically frustrated system. The SQ is a polyhedron as each face of a regular tetrahedron is capped by another tetrahedron, or two nested regular tetrahedra. In the SQ lattice, the SQs form a corner-shared network just like pyrochlore lattice. Hence, Fe_3Mo_3N is a good target to test the effect of geometric frustration in the metallic magnet.

In this presentation, we will report the results of N and Mo NMR (and NQR) measured to get microscopic information on the quantum criticality in Fe_3Mo_3N.

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[2] H. Nyman et al., J. Solid State Chem. **26** (1978) 123

Gap structure and vortex dynamics in $Ba(Fe_{0.93}Co_{0.07})_2As_2$ from NMR measurement in high magnetic field

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There is conflicting evidence in pnictide superconductors for fully gapped $s_{\pm}$ wave structure or gap nodes at the Fermi surface. Here we report measurements of the ^{75}As NMR Knight shift that suggest existence of two isotropic gaps on an optimally doped single crystal of $Ba(Fe_{0.93}Co_{0.07})_2As_2$. The measurements were done from 2 K to 300 K with external magnetic fields from 6.4 T to 24 T. The spin part of the Knight shift at low temperature($< T_c/3$) has linear temperature dependence. The diamagnetic vortex contribution to the Knight shift can be separated from the spin part at high magnetic field. Our results indicate two isotropic gaps on the Fermi surface, a conclusion is consistent with $s_{\pm}$ wave[1]. Additionally, we have measured the spin-spin relaxation time, T_2, arising from vortex dynamics. Below T_c, T_2 decreases followed by an abrupt increase at the vortex melting temperature. This work is supported by DOE/BES: **DE-FG02-05ER46248** and the NHMFL by NSF and the State of Florida.

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Magnetic dynamics in $K_3Fe_5F_{15}$ family of multiferroics

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Magnetoelectric multiferroics $K_3Fe_5F_{15}$, $K_3Fe_3Cr_2F_{15}$ and $K_3Cu_3Fe_2F_{15}$ were found to have magnetic transition at 122K, 36K and 28K, respectively, below which the splitting between zero-filed cooled and field cooled magnetization curves is present. In order to study the magnetic behaviour below this temperature, the detailed investigation of magnetic relaxation after change of the magnetic field and temperature is performed.

Slow relaxation on time scale of hours is in accordance with the splitting between zero-filed cooled and field cooled magnetization curves and a.c. magnetic susceptibility, as well as with onset of irreversibility of magnetization vs. field curves. Logarithmic relaxation of magnetization in time is a sign of the distributed barriers which block the magnetic moments against the reorientation. Temperature dependence of the logarithmic relaxation rate and other parameters could be understood within a model of thermal activation of magnetic moments of clusters distributed over barriers.

There are differences in temperatures and fields needed to induce the relevant relaxation of magnetization: while for $K_3Fe_5F_{15}$ the relaxation is observable even in 1T field in the whole temperature range, for $K_3Cu_3Fe_2F_{15}$ it is no more seen in 0.1T, and for $K_3Fe_3Cr_2F_{15}$ in 1T it is seen only at the lowest temperatures. The results point to the presence of two magnetic subsystems with different energy scales responsible for magnetic dynamics.

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New Facility for Broadband Solid State NMR and NQR in Zagreb, Croatia

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Given that nuclear magnetic resonance is today an unavoidable method in solid-state physics, we are complementing the infrastructure for materials research in Croatia by the introduction of a solid state NMR.

New laboratory for broadband NMR/NQR spectroscopy at the University of Zagreb, Croatia is established and equipped within the European FP7 project SOLeNeMaR[1] and with the support of Croatian Ministry of Science, Education and Sport. At present, the laboratory is equipped with two Tecmag Apollo spectrometers and an Oxford 12 T wide-bore sweepable magnet of medium homogeneity. The spectrometers cover frequency range 0.5 – 500 MHz. Four pulsed 1 kW amplifiers cover the whole frequency range. Flow cryostats for temperature range 1.5 K – 400 K with ϕ 6.25 cm sample space are available both for zero field measurements (NQR) and for measurements in magnetic field (NMR). The laboratory is open to proposals for scientific cooperation.

In addition to the establishment of the laboratory, SOLeNeMaR project is aimed to increase the human potential by exchange of knowledge, organization of workshops and seminars, developing cooperation with other NMR centres, and increasing visibility.

Thank you for contributing to this project.

[1] FP7-Capacities: #229390 Strengthening the SOLid-state research capacities in Zagreb by the introduction of the Nuclear Magnetic Resonance method (SOLeNeMaR)

Exploring the high-T transition in underdoped (Ba1-xKx)Fe2As2

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n contrast to the simultaneous structural and magnetic first order phase transition T0 previously reported, our detailed bulk and microscopic investigation on a (Ba0.84K0.16)Fe2As2 single crystal unambiguously revealed that the transitions are not concomitant with K-doping. The tetragonal (I4/mmm) - orthorhombic (Fmmm) structural transition occurs at Ts 110 K, followed by an adjacent antiferromagnetic (AFM) transition order at a slightly lower TN 102 K. As inferred from our nuclear magnetic resonance (NMR) experiments, the observation of hysteretic behavior and coexistence of the tetragonal and orthorhombic phases over a finite temperature range confirm the first order character of the structural transition and provide solid evidence that both Ts and TN are strongly related. Our data also shows that bulk superconductivity (SC) develops in the orthorhombic phase below Tc = 20 K and coexists with long ranged AFM. This new observation, Ts different from TN, firmly establishes another similarity between the hole-doped BaFe2As2 via K substitution and the electron-doped iron-arsenide superconductors.

Complex interplay of Ce 4f and Fe 3d magnetism in CeFe(As,P)O as seen from ^{31}P and ^{75}As NMR.

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The rare earth (R) transition metal (T) pnictides of RTPnO type(Pn:P or As) are the parent compounds to the high T_C superconductors like $CeFeAsO_{1-x}F_x$. Recent studies confirm that CeFePO is a heavy fermion metal having a high γ (= 700 mJ/mol K^2) value with strong correlations of 4f-electrons close to ferromagnetic (FM) instability [1]. CeFeAsO undergoes a structural transition (Tet.→Orth.) at 150 K followed by a AFM (of SDW type) transition at 145 K. Additionally here Ce orders AFM at T_N=4 K. Fe magnetism can be tuned by changing the lattice volume by means of chemical substitution. One approach is to substitute As by P. This is interesting because with increasing P doping one can move from AFM order state to FM fluctuating region. Moreover above a critical concentration the Fe magnetism vanishes and Ce orders FM [2]. Around this critical concentration SC might be found. Furthermore in the P rich region of the phase diagram coexistence of FM and Kondo interaction is observed. NMR provides a microscopic tool for studying the interplay between Ce 4f and Fe 3d magnetism. We report on ^{31}P (I=1/2) and ^{75}As (I=3/2) NMR studies on $CeFeAs_{1-x}P_xO$ with x=0, 0.05, 0.3, and 0.9.

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High field NMR study on $YBa_2Cu_3O_{6.54}$ and $YBa_2Cu_3O_{6.67}$

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Recently, a serials of quantum oscillation under high magnetic field were observed in underdoped YBCO single crystals[1,2,3,4,5,6].These important findings suggest a topological evolution of Fermi surface from small pocket in underdoped region to big pocket in overdoped region. But the mechanism is still unclear. Here, we will present some new results of high field NMR experiment up to 34 T on high-quality $YBa_2Cu_3O_{6.54}$ and $YBa_2Cu_3O_{6.67}$ single crystals. No evidence of long range magnetic ordering was observed in our experiment. However, an upturn behavior of $1/T_2$ of planar Cu was observed at low temperature for both samples and this behavior was enhanced by increasing field. Meanwhile, a two-shoulder structure in spectrum appeared only in $YBa_2Cu_3O_{6.67}$ sample with $1/T_2$ enhancement. More details will be discussed in this talk.

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NMR studies of uranium and transuranium compounds

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We review our recent NMR studies carried out in oxides and intermetallic compounds of the uranium and transuranium elements. Neptunium dioxide (NpO_2) was thought for many years to be an antiferromagnet; however, neither Mossbauer spectroscopy nor neutron diffraction detected any ordered moment below the transition temperature of 26 K. It is now recognized that the phase transition originates from octupole moments. The octupolar-order scenario was suggested initially by resonant X-ray scattering and then strongly supported by our ^{17}O NMR studies [1,2].

On the other hand, the low temperature phase transition in americium dioxide (AmO_2) was first reported from magnetic susceptibility data more than 30 years ago. These data show a broad maximum around $T_0 = 8.5$ K, which has been attributed to antiferromagnetic ordering. However, the latter interpretation was not consistent with other microscopic measurements performed around that time. Up to now, except for the susceptibility data, there have been no experimental results to support the occurrence of a bulk phase transition in AmO_2. Recently, we have successfully performed an ^{17}O NMR for the first time on this compound. Our results include a drastic broadening of the NMR spectrum, after a sudden drop of NMR signal intensity below T_0. These data provide the first microscopic evidence for a phase transition as a bulk property in this system [3].

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Observation of the Fermi Liquid Behavior in 122-Ironpnictides

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ab-plane dc resistivity has been measured in $Ba(Co_{0.08}Fe_{0.92})_2As_2$ and $Ba(Ni_{0.05}Fe_{0.95})_2As_2$ single crystals in a temperature range of 4 - 600 K. In the normal state, the resistivity displays a power law ($\rho(T) \sim T^n$) dependence, with the exponent n = 1.25 for $Ba(Co_{0.08}Fe_{0.92})_2As_2$ and n = 1.56 for $Ba(Ni_{0.05}Fe_{0.95})_2As_2$. Such a behavior is usually attributed to an underlying Quantum Critical Point (QCP). However, the analysis of the optical conductivity of several 122-pnictide compounds including the above ones, reveals two electronic subsystems (channels), one of which is temperature independent. Upon determining the contribution of the two channels in the dc resistivity, we find that the temperature-dependent channel exhibits a Fermi-liquid-like T^2 behavior.The latter extends to unprecedented 380 K and 280 K in Co-doped and Ni-doped samples, respectively, and is followed by the saturation in resistivity at elevated temperatures. Both, the scattering rate in the Drude contribution to the optical conductivity, and the excellent agreement with Kadowaki-Woods relation independently confirm the Fermi-liquid-like behavior and oppose the QCP scenario.

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^{1}H NMR of κ-(BETS)$_2$Mn(N(CN)$_2$)$_3$ organic metal

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Organic compound κ-(BETS)$_2$Mn(N(CN)$_2$)$_3$ is metallic at ambient pressure down to T_{MI}=25 K where it undergoes a metal-insulator transition (MIT) of unknown origin [1]. The ^{1}H NMR study presented here is an attempt to understand the nature of the MIT.

Angular and temperature dependences of ^{1}H NMR spectrum (which counts up to 8 resonance peaks depending on field direction) have shown that H atoms that belong to the BETS molecules experience dipolar hyperfile fields solely from Mn^{2+} ions located in the anion layers. ^{1}H spin-lattice relaxation rate, T_1^{-1}, measured in fields 1.4 and 7 T, agrees with the model of nuclear relaxation through fluctuations of dipolar hf field from Mn spins.

Upon cooling below T_{MI}, ^{1}H peaks abruptly broaden indicating to freezing of thermal fluctuations of Mn spins and formation of a short-range order. τ^{-1} , the Mn electronic spin-lattice relaxation rate extracted from $^{1}T_1^{-1}$ data, shows a distinct downturn at T_{MI} denoting a slow-down in Mn electron spin dynamics due to the formation of spin order. Therefore, NMR data reveal a magnetic transition coinciding with T_{MI} which may be responsible for the metal-insulator transition.

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Magnetic-field induced phases in the frustrated Heisenberg chain linarite

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The natural mineral linarite $Pb[Cu(SO_4)(OH)_2]$ has recently been shown to be an interesting material to study, since it has been suggested to belong to the class of 1D spin chains, where via the inclusion of next-nearest neighbor interactions magnetic frustration becomes an issue. According to Ref. [1], linarite can be understood as a nn-nnn spin chain with a ferromagnetic J_1 = -30 K and an antiferromagnetic J_2 = 15 K. Further, an ordered magnetic state is observed at $T_N \sim$ 2.7-2.85 K, and which is speculated to be of a helical nature as result of the frustration.

For such frustrated ferromagnetic spin chains, based on numerical calculations an instability of the fully polarized ferromagnetic state towards Bose condensation has been proposed [2]. It is predicted that this could lead to Tomonaga-Luttinger liquid behavior with multipolar magnetic excitations just below the saturation field. Furthermore, in the case of linarite with a possible helical ground state, other field-induced phases such as for instance an incommensurate-commensurate transition can be expected. To resolve these issues we started an extensive study combining magnetization, ESR and NMR, where several magnetic phase transitions were detected.

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