Summary

Event: XVI Training Course in the Physics of Strongly Correlated Systems.
Venue: International Institute for Advanced Scientific Studies "E.R. Caianiello" (IIASS).
Location: Vietri sul Mare (Salerno, Italy).
Period: 3rd to 14th October 2011.
Organizing Institutions:
- Dipartimento di Fisica "E.R. Caianiello" – Università degli Studi di Salerno, Italy
- International Institute for Advanced Scientific Studies "E.R. Caianiello" (IIASS), Italy

Organizing Committee:
- Prof. F. Mancini (Università degli Studi di Salerno and IIASS, Italy)
- Dr. A. Avella (Università degli Studi di Salerno, Italy)

International Advisory Board:
- Prof. A.S. Alexandrov (Loughborough University, Loughborough , UK)
- Prof. E. Bauer (Technische Universität, Wien, Austria)
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- Prof. C. Di Castro (Università degli Studi di Roma "La Sapienza", Roma, Italy)
- Prof. F. Guinea (Instituto de Ciencia de Materiales, Madrid, Spain)
- Prof. W. Nolting (Humboldt-Universitat zu Berlin, Berlin, Germany)
- Prof. A.M. Oles (Jagellonian University, Krakow, Poland)
- Prof. N.M. Plakida (Joint Institute for Nuclear Research, Dubna, Russia)
- Prof. M. Sigrist (ETH, Zurich, Switzerland)

Lecturers:
- Prof. J.A. Mydosh (Leiden University, Leiden, Netherlands)
- Prof. Th. Pruschke (University of Göttingen, Göttingen, Germany)
- Prof. U. Schollwöck (Ludwig-Maximilians-Universität München, München, Germany)
- Prof. D. Singh (Oak Ridge National Laboratory, Oak Ridge TN, USA)

Sponsoring Institutions:
- Dipartimento di Fisica "E.R. Caianiello" & Scuola di Dottorato in Fisica – Università degli Studi di Salerno, Italy
- International Institute for Advanced Scientific Studies "E.R. Caianiello" (IIASS), Italy
- European Science Foundation (ESF): INTELBIOMAT Programme
- European Physical Society (EPS)
- Regione Campania[1], Italy
- Ministero dell'Università, Istruzione e Ricerca[1], Italy

Expenditures Balance:

• Lecturers[2] (travel, accomodation, honorary)	€ 11,496.00
• Participant fellowships[3] (fully or partially covering the accomodation expenses)	€ 7,593.00
• Logistic expenses (secretariat, stationery, Xerox, telephone, fax, postal expenses, coffee breaks)	€ 1,500.00
• Proceedings publication (estimate based on the last eleven publications)	€ 4,096.00
Total	€ 24,685.00

Funding Balance:

• Dipartimento di Fisica "E.R. Caianiello" & Scuola di Dottorato in Fisica	€ 13,435.00
• IIASS[4] (registration fees included: 15 × € 350.00)	€ 5,250.00
• European Science Foundation (ESF): INTELBIOMAT Programme	€ 6,000.00
Total	€ 24,685.00

Notes:

[1] Funds not yet and not surely awarded. If any fund will be awarded, it will partially compensate the costs beard by the Dipartimento di Fisica "E.R. Caianiello" and the Scuola di Dottorato in Fisica.

[2] Each of the four lecturers spent one week at the Course. The average expenditure per lecturer breaks down as follows: travel € 874.00, accommodation € 857.00, honorary € 1,143.00.

[3] The Course had 20 participants. 11 participants, among the youngest with the best CVs, received an average fellowship of € 690.00 each to cover their accommodation expenses. 5 participants had their registration fees waived on account of the reduced funding capabilities of their hosting institutions.

[4] IIASS also provided its main lecture hall well furnished with beamer, overhead projector, white- and black- boards and its computer room with more than 15 computers connected to the Internet.

Final programme of the meeting

I Week

Prof. J. A. Mydosh: From Kondo and Spin Glasses to Heavy Fermions, Hidden Order and Quantum Phase Transitions
Prof. D. Singh: The Solid State as a Fabric for Intertwining Chemical Bonding, Electronic Structure and Magnetism

October 3	
08:00 - 08:50	Registration.
08:50 - 09:00	Opening of the Training Course.
09:00 - 11:00	Prof. J. A. Mydosh.
11:00 - 11:30	Coffee Break.
11:30 - 13:30	Prof. D. Singh.
13:30 - 15:30	Lunch.
15:30 - 17:00	Participant presentations.
17:00 - 17:30	Break.
17:30 - 18:00	Mr. M. Abram: Statistically-consistent Gutzwiller Approach (SGA) for t-J-U model.
18:00 - 18:30	Mr. Á. Bácsi: Mean-field quantum phase transition in graphene and in general gapless systems.

October 4	
09:00 - 11:00	Prof. D. Singh.
11:00 - 11:30	Coffee Break.
11:30 - 13:30	Prof. J. A. Mydosh.
13:30 - 15:30	Lunch.
15:30 - 16:00	Mr. E. Bennett: Depicting spin with Majorana fermions.
16:00 - 16:10	Break.
16:10 - 17:10	Prof. J. A. Mydosh - Prof. D. Singh: Training Session.
17:10 - 17:30	Break.
17:30 - 18:30	Prof. J. A. Mydosh - Prof. D. Singh: Training Session.

October 5	
09:00 - 11:00	Prof. J. A. Mydosh.
11:00 - 11:30	Coffee Break.

11:30 - 13:30	Prof. D. Singh.
13:30 - 15:30	Lunch.
15:30 - 16:00	Dr. G. Bertaina: BCS-BEC crossover in two dimensions and the role of polarons and molecules: a Quantum Monte Carlo study.
16:00 - 16:10	Break.
16:10 - 17:10	Prof. J. A. Mydosh - Prof. D. Singh: Training Session.
17:10 - 17:30	Break.
17:30 - 18:30	Prof. J. A. Mydosh - Prof. D. Singh: Training Session.

October 6	
09:00 - 11:00	Prof. D. Singh.
11:00 - 11:30	Coffee Break.
11:30 - 13:30	Prof. J. A. Mydosh.
13:30 - 15:30	Lunch.
15:30 - 16:00	Mr. W. Brzezicki: Entangled spin-orbital phases in the d9 models.
16:00 - 16:10	Break.
16:10 - 17:10	Prof. J. A. Mydosh - Prof. D. Singh: Training Session.
17:10 - 17:30	Break.
17:30 - 18:30	Prof. J. A. Mydosh - Prof. D. Singh: Training Session.

October 7	
09:00 - 11:00	Prof. J. A. Mydosh.
11:00 - 11:30	Coffee Break.
11:30 - 13:30	Prof. D. Singh.
13:30 - 15:30	Lunch.
15:30 - 16:00	Mr. J. Buhmann: Normal state charge transport of overdoped cuprates.
16:00 - 16:10	Break.
16:10 - 17:10	Prof. J. A. Mydosh - Prof. D. Singh: Training Session.
17:10 - 17:30	Break.
17:30 - 18:30	Prof. J. A. Mydosh - Prof. D. Singh: Training Session.

II Week

Prof. Th. Pruschke: Landau's Fermi Liquid Concept to the Extreme: the Physics of Heavy Fermions
Prof. U. Schollwöck: Simulations using matrix product states

October 10	
09:00 - 11:00	Prof. Th. Pruschke.
11:00 - 11:30	Coffee Break.
11:30 - 13:30	Prof. U. Schollwöck.
13:30 - 15:30	Lunch.
15:30 - 16:00	Mr. M. Capati: Nematic phase without Heisenberg physics in FeAs planes.
16:00 - 16:10	Break.
16:10 - 17:10	Prof. Th. Pruschke - Prof. U. Schollwöck: Training Session.
17:10 - 17:30	Break.
17:30 - 18:30	Prof. Th. Pruschke - Prof. U. Schollwöck: Training Session.

October 11	
09:00 - 11:00	Prof. U. Schollwöck.
11:00 - 11:30	Coffee Break.
11:30 - 12:30	Prof. Th. Pruschke.
12:30 - 13:30	Prof. U. Schollwöck.
13:30 - 15:30	Lunch.
15:30 - 16:00	Mr. M. Wysokiński: Magnetization curve of liquid helium 3 within statistically-consistent mean-field approach to Hubbard model: comparison with experiment.
16:00 - 16:10	Break.
16:10 - 17:10	Prof. Th. Pruschke - Prof. U. Schollwöck: Training Session.
17:10 - 17:30	Break.
17:30 - 18:30	Prof. Th. Pruschke - Prof. U. Schollwöck: Training Session.

October 12	
09:00 - 11:00	Prof. Th. Pruschke.
11:00 - 11:30	Coffee Break.
11:30 - 13:30	Prof. U. Schollwöck.
13:30 - 15:30	Lunch.

15:30 - 16:00	Dr. A. Isidori: Quantum criticality of dipolar spin chains.
16:00 - 16:10	Break.
16:10 - 17:10	Prof. U. Schollwöck: Training Session.
17:10 - 17:30	Break.
17:30 - 18:30	Prof. U. Schollwöck: Training Session.

October 13	
09:00 - 11:00	Prof. U. Schollwöck.
11:00 - 11:30	Coffee Break.
11:30 - 12:30	Prof. Th. Pruschke.
12:30 - 13:30	Prof. U. Schollwöck.
13:30 - 15:30	Lunch.
15:30 - 16:00	Mr. A. Kreisel: Elastic constants and ultrasonic attenuation in the cone state of the frustrated antiferromagnet Cs_2CuCl_4.
16:00 - 16:10	Break.
16:10 - 17:10	Prof. Th. Pruschke: Training Session.
17:10 - 17:30	Break.
17:30 - 18:30	Prof. Th. Pruschke: Training Session.

October 14	
09:00 - 11:00	Prof. Th. Pruschke.
11:00 - 11:30	Coffee Break.
11:30 - 13:30	Prof. Th. Pruschke.
13:30 - 15:30	Lunch.
15:30 - 16:00	Mr. P. Marra: Fingerprints of Orbital Physics in Magnetic RIXS.
16:00 - 16:30	Mr. K. Nishiguchi: Theoretical study of superconductivity in multi-layered cuprates.
16:30 - 17:00	Break.
17:00 - 17:30	Mr. M. Nuss: Quantum Impurity Models in and out of equilibrium studied by means of Variational Cluster Perturbation Theory.
17:30 - 18:00	Mr. V. Pokorný: Electrical conductivity of the strongly disordered Anderson model.
18:00 - 18:30	Dr. S. Taioli: Is contact potential the hallmark of the fermion-fermion interaction?
18:30 – 18:40	Closing of the Training Course.

Description of the scientific content of and discussion at the event

Professor John A. Mydosh

Kamerlingh Onnes Laboratorium and Lorentz-Instituut
Leiden Universiteit
Leiden
Netherlands

Title: From Kondo and Spin Glasses to Heavy Fermions, Hidden Order and Quantum Phase Transitions

Lectures will present a broad overview of the basic experimental phenomena and physical properties of the following topics:

1) Kondo effect, Ref. J.Phys.Soc.Jpn. 74, January 2005.
2) Spin glasses, Ref. J. A. Mydosh, Spin Glasses: An Experimental Introduction (London: Taylor and Francis, 1993).
3) Giant magnetoresistence, Ref. G. Binasch et. al., Phys.Rev.B 39, 4828(1989) and M. N. Baibich et al., Phys.Rev.Lett. 61, 2472(1988).
See also online Scientific Background on the Noble Prize in Physics and Noble Lectures –A. Fert and P. Grünberg, in Rev.Mod. Phys. 80, 1517 and 1531(2007).
4) Magnetoelectrics and multiferroics, Ref. M. Fiebig, J.Phys.D: Appl.Phys. 38, R123(2005), S-W. Cheong and M. Mostovoy, Nature Mater. 3, 13(2007), and R. Ramesh and N. A. Spalding, Nature Mater. 3, 21(2007).
5) High temperature superconductors, Ref. Y. Li, et al., Nature 455, 372(2008), ibid 468, 283(2010) and R-H He et al., Science 331, 1579 (2011).
6) Applications of superconductivity, Ref. G. W. Crabtree and D. R. Nelson in Physics Today, April 1997 and online brochure from American Superconductor – “Superconductor Power Cables”
7) Heavy fermions, Ref. A. C. Hewson, The Kondo Problem to Heavy Fermions (Cambridge University Press, 1993), G. R. Steward, Rev.Mod.Phys. 78, 743(2006) and C. Pfleiderer, Rev.Mod.Phys. 81, 1551(2009).
8) Hidden order in URu2Si2, Ref. J. A. Mydosh and P. M. Oppeneer, Rev.Mod.Phys. 84, xxx(2011), arXiv:1107.0258.
9) Modern experimental methods in correlated electron systems, Ref. J. A. Mydosh and P. M. Oppeneer, Rev.Mod.Phys. 84, xxx(2011), arXiv:1107.0258
10) Quantum phase transitions, Ref. Subir Sachdev, Quantum Phase Transitions (Cambridge University Press, 2011), Second Edition.

Professor Thomas Pruschke

Institute for Theoretical Physics
University of Göttingen
Göttingen
Germany

Title: Landau's Fermi Liquid Concept to the Extreme: the Physics of Heavy Fermions

Tentative lecture titles:

Monday, October 10th	2h	Repititorium – The free electron gas (Notation, important quantities and basic results)

Tuesday, October 11th	1h	Landau's Fermi Liquid Theory part I (Screening in the electron gas, fundamental assumptions, quasi-particle picture, electrons and holes, fundamental relations)
Wednesday, October 12th	2h	Landau's Fermi Liquid Theory part II (physical properties, failure of the model, counterexamples)
Thursday, October 13th	1h	Heavy Fermions part I (What are Heavy Fermions, important experimental observations, relation to the Kondo problem)
Friday, October 14th	4h	Heavy Fermions part II (origin of heavy masses, slave bosons, heavy quasiparticles, magnetism and superconductivity, quantum criticality)

References and suggested Reading:

1. Ashcroft and Mermin, *Solid State Physics*
2. Nozières and Pines, *Theory Of Quantum Liquids*
3. Hewson, *The Kondo Problem to Heavy Fermion*
4. Mahan, *Many-Particle Physics*
5. Stewart, *Heavy Fermion Systems*, Rev. Mod. Phys. 1984
6. Georges et al., *Dynamical mean-field theory of strongly correlated fermion systems and the limit of infinite dimensions*, Rev. Mod. Phys. 1996
7. Bulla et al., *The numerical renormalization group method for quantum impurity systems*, Rev. Mod. Phys. 2008

Intended Problem assignments:

Monday, October 10th: Physical quantities for the free electron gas (analytical)
Tuesday, October 11th: Anderson and Kondo model – basic properties (analytical)
Wednesday, October 12th: Dynamical mean-field theory with NRG – basic ideas and how to use it (numerical, code provided)
Thursday, October 13th: Dynamical mean-field theory with NRG – application to heavy fermion models (numerical, code provided)

Professor Ulrich Schollwöck

Department für Physik
Ludwig-Maximilians-Universität München
München
Germany

Title: Simulations using matrix product states

Lectures:
1) Matrix product states I
- why are strongly correlated quantum states difficult?
- introduction to entanglement theory

- representing states as matrix product states
- overlaps/expectation values in MPS

2) Matrix product states II
- orthonormalizing matrix product states
- compressing matrix product states
- general properties of correlations in matrix product states

3) Real and imaginary time-evolutions using matrix product states
- Trotter decompositions
- imaginary time-evolution for ground states
- real time-evolution for quench dynamics

4) Variational ground state searches with matrix product states
- Matrix product operators
- Variational search methods

5) Outlook
- connections to the Numerical Renormalization Group
- extending the range of time-dependent simulations
- going towards two dimensions

References:
There exist several reviews, which cover the topic of the lectures quite well and in some detail. Students can follow up from those to the original references, which however are often quite arcane.

1) U. Schollwöck, Rev. Mod. Phys. 77, 259 (2005)
2) U. Schollwöck, Ann. Phys. 326, 96 (2011)
3) F. Verstraete, V. Murg, J.I. Cirac, Adv. Phys. 57, 143 (2008)

The lectures will follow the notation and spirit of 2), but also take from 1) and 3). 3) gives a more quantum information based perspective, 1) is "old-fashioned" in the sense that matrix product states do not figure very prominently, but it makes more of a connection to a statistical physics perspective (more DMRG like, as in previous Vietri courses). Reading Noack/Manmana and Feiguin in earlier Vietri books could also be helpful, but is not necessary.

Problem classes:
1) Exact diagonalization (Lanczos) - programming
Decomposition of states as MPS - programming
Calculating entanglement of simple states - analyt.
2) The AKLT model as the simplest non trivial MPS
Constructing the MPS of the AKLT model - analyt.
Calculating its correlators - analyt.
3) Working out Trotter decompositions of simple Hamiltonians - analytical, programming
Orthonormalize and compress MPS - programming
4) Time-evolutions with MPS - programming

Professor David Singh

Oak Ridge National Laboratory
Oak Ridge TN
USA

Title: The Solid State as a Fabric for Intertwining Chemical Bonding, Electronic Structure and Magnetism

Lectures:
1: “First Principles Calculations: The Glue that Binds Materials and Models”

General introduction to density functional theory, approaches and some words about applications of density functional theory. Also a brief introduction to the LAPW method, which would be helpful for the afternoon session.

2: "The Wacky World of Perovskites"

Some of the physics observed in perovskites emphasizing mostly structure and its interplay with properties. Also ferroelectricity.

3: "Magnetism and Superconductivity"

This is about unconventional superconductors, especially the interplay of magnetism with the Fermi surface and what can be learned from first principles. The examples will be ruthenates and iron-pnictides, but other materials will be mentioned as well.

4: "Thermoelectrics: Getting a Grip on Heat"

The basics of thermoelectric materials are discussed along with Boltzmann transport theory as may be applied from first principles band structures.

5: "Electronic Structure and Chemical Bonding"

This is about the interplay of electronic structure and bonding using various examples. It is also intended as an opportunity for students to participate.

Training sessions:

Brief introduction to the LAPW method (if not in the morning) and hands on with the ELK code.

03/10/2011

Mr. Marcin Abram

Condensed Matter Theory and Nanophysics Department, Marian Smoluchowski Institute of Physics, Jagiellonian University, Kraków, Poland

Statistically-consistent Gutzwiller Approach (SGA) for t-J-U model

Abstract: A Statistically-consistent Gutzwiller Approximation (SGA), which has been developed very recently in our group by J. Jędrak, J. Kaczmarczyk and J. Spałek [arXiv:1008.0021v2] is introduced and compared with the well-known Gutzwiller Approximation (GA). Application to the Hubbard and t-J-U models is discussed in detail. For the t-J-U model a coexistence of antiferromagnetism (AF) and superconductivity (SC) is examined.

03/10/2011

Mr. Ádám Bácsi

Department of Physics, Budapest University of Technology and Economics, Budapest, Hungary

Mean-field quantum phase transition in graphene and in general gapless systems

Abstract: In the seminar I will study the quantum critical properties of antiferromagnetism in graphene at zero temperature within mean-field (MF) theory. The resulting exponents differ from the conventional MF exponents describing finite temperature transitions. I will show that this description can be generalized for general gapless systems in which the density of states has power-law dependence, i.e., g(e)~e^r, r>-1. For r>2, the conventional MF exponents are recovered, while for -1<r<2, the exponents vary significantly with r. This extends the MF universality class of quantum-critical phase transitions, covering a much broader region of values of critical exponents than that of the conventional Landau theory. (The seminar is based on Phys. Rev. B 82, 153406 (2010).)

04/10/2011

Mr. Edmund Bennett

School of Physics & Astronomy, University of St. Andrews, St. Andrews, Scotland

Depicting spin with Majorana fermions

Abstract: My research considers the analysis of quantum critical points using a Majorana fermion [1] representation of spin. Majorana fermions are a useful spin representation as they obey Wick's theorem and automatically provide the correct (S^{a})^{2} = 1/4 for stationary spin-1/2 lattice spins [2]. Furthermore, the representation of valence bond type operators and spin operators is equally simple in this formalism. I shall demonstrate a mean-field theory developed in terms of "valence bond" operators made from of Majorana fermions. These mean-field equations are then Fourier transformed, giving us access to the partition function for these systems. Methods of this type will hopefully demonstrate that Majorana fermions are a novel and powerful method of depicting spin in condensed matter systems. [1] W. Mao, P. Coleman, C. Hooley & D. Langreth; PRL, 91, 20, p. 2072031-2072034; 2003 [2] Quantum Field Theory in Condensed Matter Physics, 2nd Edition, Alexei M. Tsvelik, CUP; 1996

05/10/2011

Dr. Gianluca Bertaina

Institute of Theoretical Physics, EPFL, Lausanne, Switzerland

BCS-BEC crossover in two dimensions and the role of polarons and molecules: a Quantum Monte Carlo study

Abstract: We investigate the crossover from Bardeen-Cooper-Schrieffer (BCS) superfluidity to Bose-Einstein condensation (BEC) in a two-dimensional Fermi gas at $T=0$ using the fixed-node diffusion Monte Carlo method. We calculate the equation of state and the gap parameter as a function of the interaction strength, observing large deviations compared to mean-field predictions. In the BEC regime our results show the important role of dimer-dimer and atom-dimer interaction effects that are completely neglected in the mean-field picture. We also consider the highly polarized gas and the competition between a polaronic and a molecular picture.

06/10/2011

Mr. Wojciech Brzezicki

Marian Smoluchowski Institute of Physics, Jagiellonian University, Krakow, Poland

ENTANGLED SPIN-ORBITAL PHASES IN THE d9 MODELS

Abstract: The phase diagram of the spin-orbital (SO) Kugel-Khomskii (d9) model posed a challenging theoretical problem [1], yet it is still unknown. Here we investigate the phase diagrams of the d9 model,depending on Hund's exchange J_h and the e_g orbital splitting E_z, for a bilayer and a monolayer square lattice using Bethe-Peierls-Weiss methodwith exact diagonalization of a cubic or square cluster coupled to its neighbors in ab planes by the mean-field (MF) terms. The cluster MF method confirms existence of singlet phases similar to those obtained by variational wave functions [2], and enables finite SO order parameter independent of spin and orbital ordering. For a bilayer we obtain phases with interlayer spin singlets stabilized by holes in 3z^2-r^2 orbitals and with alternating plaquette valence-bond (PVB) as well as two new phases with SO entanglement, in addition to the antiferromagnetic (G-AF, A-AF) and ferromagnetic (FM) order. For a monolayer we obtained at temperature T=0: (i) the PVB phase, (ii) two AF phases with either 3z^2-r^2 or x^2-y^2 orbitals occupied, and (iii) a FM phase. However, after including thermal fluctuations (T>0) we found the same entangled SO phases as for a bilayer at T=0. This shows that both quantum and thermal fluctuations can stabilize phases with exotic SO order while the classical spin order is destroyed. [1] L. F. Feiner, A. M. Ole\'s, and J. Zaanen, Phys. Rev. Lett. \textbf{78}, 2799 (1997). [2] A. M. Ole\'s, Acta Phys. Polon. A \textbf{115}, 36 (2009).

07/10/2011

Mr. Jonathan Buhmann

Institute for Theoretical Physics, ETH Zurich, 8093 Zurich, Switzerland

Normal state charge transport of overdoped cuprates

Abstract: Fermi Surface Dependence of Normal State Charge Transport of Overdoped Cuprates Jonathan Buhmann, Matthias Ossadnik, T.M. Rice and Manfred Sigrist Institute for Theoretical Physics, ETH Zürich We study charge transport properties in the normal state of heavily overdoped high-temperature superconducting cuprates. We analyze the effect of strongly anisotropic quasiparticle scattering on transport life times within a semiclassical approach based on the Boltzmann transport theory. The scattering rates are determined by a renormalization group calculation to one loop corrections to the quasiparticle self energy. We solve the linearized Boltzmann equation numerically including the full angular and radial dependence of the distribution function. The dependence of the transport life times and the resulting resistivity on the geometry of the Fermi surface and temperature is

discussed. This study is motivated by the correlation between charge transport and superconductivity for Tl_{2}Ba_{2}CuO_{6+x} reported by Abdel-Jawad et at. [1] and the non-perturbative linear temperature dependence of the anisotropic part of the quasiparticle life times found within a functional renormalization group study [2]. In addition, N. Hussey et al. [3] have experimentally probed the resistivity in La_{2-x}Sr_{x}CuO_{4} for several doping levels and found anomalous scaling behavior which we aim to discuss within our theoretical study. [1] M. Abdel-Jawad et al.; Nature Physics 2, 821 (2006) [2] M. Ossadnik et al.; Phys. Rev. Lett. 101 256405, (2008) [3] R.A. Cooper et al.; Science 323 603-607, (2009)

10/10/2011

Mr. Matteo Capati
Department of Physics, Università Sapienza di Roma , Italy

Nematic phase without Heisenberg physics in FeAs planes

Abstract: We use Monte Carlo simulations and analytical arguments to analyze a frustrated Ising model with nearest neighbour antiferromagnetic coupling and next nearest neighbour coupling. The model is inspired on the physics of pnictide superconductors and to some extent we argue that it can be more representative of this physics than the Heisenberg counterpart. Parameters are chosen such that the ground state is a columnar or striped state, as observed experimentally, but is close to the transition to the simple Neel ordered antiferromagnetic state. We find that a nematic phase is induced by finite size effects and argue that this explains experiments in imperfect samples which find a more robust nematic state as the quality of the sample decreases. Including the effect of a weak coupling with the lattice we find that a structural transition occurs associated with a nematic phase, with a magnetic transition occurring at a lower temperature. These two transitions merge into a single structural and magnetic transition with a stronger first-order character for larger spin-lattice couplings. These two situations are in agreement with the different phenomenologies found in different families of pnictides.

11/10/2011

Mr. Marcin Wysokiński
Department of Physics,Jagiellonian University, Kraków, Poland

Magnetization curve of liquid helium 3 within statistically-consistent mean-field approach to Hubbard model: comparison with experiment

Abstract: We study theoretically the Hubbard model in order to calculate magnetization in high magnetic field and apply the results to the liquid helium 3 close to the solidification and at low temperature. For this, we employ the Gutzwiller's mean-field approach with additional statistical consistency conditions [1] on correlated fermion system and in the case of an almost half-filled band. It is in a semiquantitative agreement with the experimentally measured magnetization curve [2]. We study our model for selected types of lattices: simple cubic, face-centered cubic, and triangular. The last case models behavior of solid helium 3 deposited on graphite [3]. [1] J. Jędrak, J. Kaczmarczyk, and J. Spałek, arXiv:1008.0021v1 [cond-mat.str-el] [2] S. Wiegers, P. Wolf, and L. Puech, Phys. Rev. Lett. 66, 2895–2898 (1991) [3] H. Nema, A. Yamaguchi, T. Hayakawa, and H. Ishimoto, Phys. Rev. Lett. 102, 075301 (2009)

12/10/2011

Dr. Aldo Isidori
Institut für Theoretische Physik, Goethe-Universität Frankfurt, Frankfurt am Main, Germany

Quantum criticality of dipolar spin chains

Abstract: I will show that a one-dimensional chain of Heisenberg spins, interacting with long-range dipolar forces in a magnetic field perpendicular to the chain, exhibits a quantum critical point belonging to the two-dimensional Ising universality class. Within linear spin-wave theory (corresponding to the Gaussian approximation in field theory) the long-wavelength magnon dispersion is characterized by a logarithmic singularity in the magnon velocity for vanishing momenta, due to the peculiar behavior of dipole-dipole interactions in one-dimension. However, in the vicinity of the critical point this logarithmically divergent term is renormalized to zero by the effects of quantum fluctuations, signaling the reemergence of scale invariance, in accordance with the Ising critical scenario. The quantum critical regime, where linear spin-wave theory becomes infrared divergent, is studied using the non-perturbative density-matrix and functional renormalization group methods. On the disordered side of the transition the Ginzburg regime, where non-Gaussian fluctuations play an important role, is found to be rather broad.

13/10/2011

Mr. Andreas Kreisel
Institut für Theoretische Physik, Goethe Universität Frankfurt, Germany

Elastic constants and ultrasonic attenuation in the cone state of the frustrated antiferromagnet Cs$_2$CuCl$_4$

Abstract: In an external magnetic field perpendicular to the plane of the layers, the quasi two-dimensional frustrated antiferromagnet Cs$_2$CuCl$_4$ exhibits a magnetically ordered ``cone state'' at low temperatures. In this state the component of the magnetic moments in field direction is finite, while their projection onto the plane of the layers forms a spiral. We present both theoretical and experimental results for the magnetic-field dependence of the elastic constants and the ultrasonic attenuation rate in the cone state. Our theoretical analysis is based on the usual spin-wave expansion around the classical ground state of a Heisenberg model on an anisotropic triangular lattice with Dzyaloshinskii--Moriya interactions. Magnon-phonon interactions are modeled by expanding the exchange interactions up to second order in powers of the phonon coordinates. As long as the external magnetic field is not too close to the critical field where the cone state becomes unstable, we obtain reasonable agreement between theory and experiment, suggesting that at least in this regime magnons behave as well-defined quasiparticles. We also show that the assumption of well-defined magnons implies that at long wavelengths the ultrasonic attenuation rate in the cone state of Cs$_2$CuCl$_4$ is proportional to the fourth power of the phonon momentum.

14/10/2011

Mr. Pasquale Marra
IFW Dresden, Germany

Fingerprints of Orbital Physics in Magnetic RIXS

Abstract: Resonant Inelastic X-ray Scattering (RIXS) has become nowadays one of the main experimental techniques to investigate elementary excitations in strongly correlated materials, and above all, cuprates. We describe a simple way to analytically calculate the scattering intensities in the case of copper L edge in the single ion picture. We use this result to obtain the scattering intensities of spin waves in systems with different orbital ground states. It occurs that even in this case, RIXS intensities behave differently depending on the type of orbital order.

14/10/2011

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Theoretical study of superconductivity in multi-layered cuprates

Abstract: Since Kamerlingh Onnes discovered the superconducting phase transition in Hg 100 years ago, followed by Bednorz and Müller who have opened a new avenue for the high-Tc superconductivity in cuprates in 1986, superconductivity has been one of the main topics in condensed-matter physics. Multi-layered cuprates, typically HgBa2Ca_{n-1}Cu_nO_{2+2n+δ} and Bi_2Sr_2Ca_{n-1}Cu_nO_{4+2n+δ}, have the highest-Tc to date, on which my talk will be focused. There are n-layers of Cu0_2 planes in a unit cell, which determines the electron structure of the compound. One of the key questions is that Tc systematically varies with the number of CuO_2 planes. Namely, Tc increases as we go from n=1 to n=3, with the tri-layered Hg-series with n=3 being the highest Tc superconductor (Tc=135K) at ambient pressure, while Tc starts to decrease for n≧4. The reason for this behavior is still not fully understood. We have studied the superconductivity in the multi-layered cuprates by solving the Eliashberg equation for the multi-orbital Hubbard model with the random-phase approximation (RPA) and with the fluctuation-exchange approximation (FLEX). The hopping parameters are obtained by downfolding from the first principles calculations based on density functional theory (DFT) for the Hg-series cuprates HgBa_2Ca_{n-1}Cu_nO_{2+2n+δ} (n=1, 2, 3). We then discuss on possible factors that may determine Tc in multi-layered cuprates for different numbers of CuO_2 planes such as inter-layer single electron hopping and inter-layer Cooper pair hopping.

14/10/2011

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Quantum Impurity Models in and out of equilibrium studied by means of Variational Cluster Perturbation Theory

Abstract: We study the single impurity Anderson model by means of variational cluster perturbation theory (VCA). Results for dynamic correlation functions and static expectation values in all parameter regimes are shown to be in good agreement with renormalization group, quantum Monte Carlo and analytic results. We address the question whether the elusive low energy properties of the model are properly reproduced within the framework of VCA. Based on the good results in equilibrium we extend the formalism, using Keldysh Green's function, to the non-equilibrium situation and study the long time / steady state behavior. The method is shown to be a flexible tool in treating many-impurity models in any configuration and dimension in the strong-, weak- and intermediate coupling region.

14/10/2011

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Electrical conductivity of the strongly disordered Anderson model

Abstract: We propose a renormalization scheme of the Kubo formula for the electrical conductivity using the asymptotic limit to high spatial dimensions. We utilize the dominance of a pole due to maximally crossed diagrams in the electron-hole irreducible vertex to an approximate diagonalization of the Bethe-Salpeter equation for the two-particle Green function and a non-perturbative representation of the electrical conductivity. The latter is then obtained without the necessity of separate evaluation of the mean-field (Drude) term and vertex corrections. The electrical conductivity calculated in this way remains non-negative also in the strongly disordered regime where the localization effects become

significant and the negative vertex corrections in the standard Kubo formula overweight the positive Drude term.

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Is contact potential the hallmark of the fermion-fermion interaction?

Abstract: We develop a theoretical method to describe contact interaction in mean-field theories of many-fermion systems, using the low-energy T-matrix of the pair potential to rigorously define the effective radius of the interaction. One of the main consequences of our approach is the possibility to investigate finite-density effects, which are outside the range of validity of approximations based on delta-like potentials. We apply our method to the calculation of density dependent properties of an ultracold gas of 6Li atoms at unitarity, whose two-body interaction potential is calculated using ab-initio quantum chemistry methods. We find that density effects will be significant in ultracold gases with densities one order of magnitude higher than those attained in current experiments.

Assessment of the results and impact of the event on the future direction of the field

The principal aim of the School was to introduce the young researchers to a number of aspects of the theory of strongly correlated systems, presenting the theoretical framework as well as some experimental and numerical results. The importance of this field has been growing during the latest years, mainly after the discovery of the high-T_c superconductors. This is a consequence of the very interesting and unusual properties exhibited by these systems (e.g., cuprates, manganites, vanadates, ruthenates, etc.) that could potentially lead to relevant technological applications. Furthermore, this field is of central importance to the study of puzzling and current problems such as the variety of metal-insulator transitions, the anomalous behaviors of heavy-fermion and mixed valence compounds, the oddities of quantum magnetism, the coexistence of several ordered phases such as the ferro- and the antiferro- magnetic phases and the superconducting one, the competition between itinerancy and localization, the effect of disorder, the hierarchy of the interactions, the quantitative description of real materials. On the experimental side, many results are being consolidated; this is due to the improvement in the quality of the samples, which has eliminated many of the uncertainties in the interpretation of data. On the contrary, the theoretical frame is still far from being satisfactory.

The course is not organized as usual workshops or schools where many formal lectures are delivered in a quite short period of time and no real contact develops between the many lecturers and the audience. Instead, as the main aim of this course is on training, TC on SCS are organized on two weeks with only two senior researchers per week. Our main idea is to put together few seniors and not many young researchers in a closed environment for a quite long period of time within an informal atmosphere. In the morning, each senior researcher will deliver a lecture, whereas the afternoon sessions are devoted to training and all efforts should be put on introducing the young researchers to specific problems, on guiding them in their solution, on helping them to become more familiar with different approaches and on starting new collaborations. The participants will also be encouraged to present their own activity. Our past experience with the previous courses suggests that the lecturers themselves should shape, under our supervision, the afternoon sessions according to the specificities of the subject of their lectures (coding in the computer room, problem solving, round table, brainstorming, journal club, ...).

The School was held over two weeks, with morning and afternoon sessions. The main courses were scheduled from Monday to Friday, two per week. Two plenary lectures were given during the morning. The lectures started at 9:00 a.m. and lasted two hours each, with a coffee break of 30 minutes, thus each mini-course was allocated 10 hours. The afternoon training sessions started at 3:00 p.m. and lasted around three hours. The afternoon activities aimed principally to increase discussions among the young researchers and between the young researchers and the lecturers. During the first afternoon each participant introduced himself and his scientific activity to the audience and some of them were given the possibility to deliver a 25 minutes seminar in the following afternoon sessions. The senior scientists run the other afternoon activities through Training Sessions, including tutorials and computer-based practice where appropriate. The young researchers could therefore profit from the training of the senior scientists not only from the content of the traditional courses, but also from the afternoon discussions. It is worth recalling that the concentration of the activities in a small village (Vietri sul Mare, Salerno) where both the Institute and the Hotel are located (200 meters away from each other), strongly enhanced the opportunities of informal contacts and discussions.

The purposes of this Training Courses included the promotion of scientific excellence by contributing to the advancement of science through exchange, and to create the conditions for experienced researchers to impart their knowledge and experience to young researchers at doctoral and post-doctoral level. Indeed, young scientists from various European countries were present, and 3 out of the 4 lecturers were European. As a matter of fact, this Training Course provided an opportunity for both the senior and the younger researchers to create a network of scientific relations and possible collaborations. Joint work to write down the lecture notes has been achieved in some cases, leading to further scientific cooperation. To advertise the Training Course and to encourage the participation of the researchers an Announcement and the Poster was sent to more than 300 Universities, Institutes and Laboratories, all over Europe. The Announcement was also personally sent to more than 2000 Professors and researchers in many European Universities and to Coordinators of Italian Ph.D. programmes in Physics. Moreover, the Announcement has been electronically published on the electronic Conference information services of the Institute of Physics, of AIP, and many others. From the standpoint of the world scientific community, the outcome of this Training Course is going to be spread by means of the publication of the lectures and of the afternoon seminars by the American Institute of Physics (AIP) in a book edited by the organizers (in preparation).

In the past years we organized the following events (http://scs.sa.infn.it/TC):
I TC: 18th to 30th November 1996.
Lecturers: K. Hallberg, N.M. Plakida, J. Spalek
II TC: 13th to 25th October 1997.
Lecturers: F. Guinea, K. Maki, A. Moreo
III TC: 14th to 26th September 1998.
Lecturers: G. Kotliar, M. Randeria, J. Ranninger, S. Sorella
IV TC: 11th to 22nd October 1999.
Lecturers: A.F. Barabanov, W. Nolting, A.M. Oles, A. Ruckenstein
V TC: 30th Oct. to 10th Nov. 2000.
Lecturers: S. Alexandrov, L. Maritato, N.M. Plakida, A.M. Tsvelik
VI TC: 8th to 19th October 2001.
Lecturers: P. Coleman, C. Di Castro, P. Prelovsek, C.M. Varma.
Web page: http://scs.sa.infn.it/TCVI
VII TC: 14th to 25th October 2002.
Lecturers: N. Andrei, F.F. Assaad, J.T. Devreese, Y. Izyumov, J. Tempere.
Web page: http://scs.sa.infn.it/TCVII
VIII TC: 6th to 17th October 2003.
Lecturers: A. Georges, M. Imada, M.L. Kulic, A. Muramatsu.
Web page: http://scs.sa.infn.it/TCVIII
IX TC: 4th to 15th October 2004.
Lecturers: K. Maki, H. Matsumoto, R. Noack, M. Sigrist.
Web page: http://scs.sa.infn.it/TCIX
X TC: 3rd to 14th October 2005.
Lecturers: B. Coqblin, T. Giamarchi, W. Metzner, W. von der Linden.
Web page: http://scs.sa.infn.it/TCX
XI TC: 2nd to 13th October 2006.
Lecturers: M. Fabrizio, D. Poilblanc, R. T. Scalettar, D. van der Marel.
Web page: http://scs.sa.infn.it/TCXI
XII TC: 1st to 12th October 2007.
Lecturers: S. Haas, M. Jarrell, H. v. Löhneysen, V. Zlatic.
Web page: http://scs.sa.infn.it/TCXII
XIII TC: 6th to 17th October 2008.
Lecturers: G. Aeppli, P. Littlewood, M. Sigrist, M. Troyer.
Web page: http://scs.sa.infn.it/TCXIII
XIV TC: 5th to 16th October 2009.
Lecturers: V.I. Anisimov, A.W. Sandvik, G. Sawatzky, D. Vollhardt.
Web page: http://scs.sa.infn.it/TCXIV
XV TC: 4th to 15th October 2010.
Lecturers: O.K. Andersen, A.E. Feiguin, H.R. Ott, M. Potthoff.
Web page: http://scs.sa.infn.it/TCXV

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