Summary

Event: XVII 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: 1st to 12th October 2012.
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:

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

Lecturers:

- Professor Andrey Chubukov (University of Wisconsin-Madison, USA)
- Professor John M. Tranquada (Brookhaven National Laboratory, USA)
- Professor Alexander Lichtenstein (University of Hamburg, Germany)
- Professor Thomas Vojta (Missouri University of Science and Technology, 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

Expenditures Balance:

• Lecturers[1] (travel, accommodation, honorary)	€ 15,176.00
• Participant fellowships[2] (fully or partially covering the accommodation expenses)	€ 8,997.00
• Logistic expenses (secretariat, stationery, Xerox, telephone, fax, postal expenses, coffee breaks)	€ 1,500.00
• Proceedings publication (estimate based on the last publications)	€ 3,000.00
Total	€ 28,673.00

Funding Balance:

• Dipartimento di Fisica "E.R. Caianiello" & Scuola di Dottorato in Fisica	€ 13,384.00
• IIASS[3] (registration fees included: 21 × € 350.00)	€ 9,289.00
• European Science Foundation (ESF): INTELBIOMAT Programme	€ 6,000.00
Total	€ 28,673.00

Notes:

[1] Each of the four lecturers spent one week at the Course. The average expenditure per lecturer (€ 3,794.00) breaks down as follows: travel € 1,064.00, accommodation € 926.00, honorary € 1,804.00 (the honorary - € 800.00, in principle - includes the refund of the 30% taxes paid on the greater part of the travel, accommodation and honorary itself … Italian regulations madness).

[2] The Course had 25 participants. 13 participants, among the youngest with the best CVs, received an average fellowship of € 692.00 each to cover their accommodation expenses. 4 participants had their registration fees waived on account of the reduced funding capabilities of their hosting institutions.

[3] 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

Professor Andrey Chubukov: Superconductivity from repulsive interactions
Professor John M. Tranquada: Spins, Stripes, and Superconductivity in Hole-Doped Cuprates

	October 1
08:00 - 08:50	Registration.
08:50 - 09:00	Opening of the Training Course.
09:00 - 11:00	Prof. A. Chubukov.
11:00 - 11:30	Coffee Break.
11:30 - 13:30	Prof. J. M. Tranquada.
13:30 - 15:30	Lunch.
15:30 - 16:30	Participant presentations.
16:30 - 17:00	Break.
17:00 - 17:30	Mr. E. Bennett: Majorana Dimerised Order in Magnetic Systems.
17:30 - 18:00	Mr. A. Eberlein: Functional renormalization group study of fluctuation effects in fermionic superfluids.
18:00 - 18:30	Mr. D. Golež: Nonequillibrium dynamics of polaron systems.

	October 2
09:00 - 11:00	Prof. J. M. Tranquada.
11:00 - 11:30	Coffee Break.
11:30 - 13:30	Prof. A. Chubukov.
13:30 - 15:30	Lunch.
15:30 - 16:00	Mr. F. Hofmann: (Non-equilibrium) Self-energy-functional theory and conserving approximations.
16:00 - 16:10	Break.
16:10 - 17:10	Prof. A. Chubukov - Prof. J. M. Tranquada: Training Session.
17:10 - 17:30	Break.
17:30 - 18:30	Prof. A. Chubukov - Prof. J. M. Tranquada: Training Session.

October 3	
09:00 - 11:00	Prof. A. Chubukov.
11:00 - 11:30	Coffee Break.
11:30 - 13:30	Prof. J. M. Tranquada.
13:30 - 15:30	Lunch.
15:30 - 16:00	Mr. E. Kamil: Reduced Density Matrix functional theory- A suitable vehicle to import explicit correlations.
16:00 - 16:10	Break.
16:10 - 17:10	Prof. A. Chubukov - Prof. J. M. Tranquada: Training Session.
17:10 - 17:30	Break.
17:30 - 18:30	Prof. A. Chubukov - Prof. J. M. Tranquada: Training Session.

October 4	
09:00 - 11:00	Prof. J. M. Tranquada.
11:00 - 11:30	Coffee Break.
11:30 - 13:30	Prof. A. Chubukov.
13:30 - 15:30	Lunch.
15:30 - 16:00	Mr. P. Marra: Probing the Phase of the Superconducting Order Parameter via Resonant Inelastic X-ray Scattering.
16:00 - 16:10	Break.
16:10 - 17:10	Prof. A. Chubukov - Prof. J. M. Tranquada: Training Session.
17:10 - 17:30	Break.
17:30 - 18:30	Prof. A. Chubukov - Prof. J. M. Tranquada: Training Session.

October 5	
09:00 - 11:00	Prof. A. Chubukov.
11:00 - 11:30	Coffee Break.
11:30 - 13:30	Prof. J. M. Tranquada.
13:30 - 15:30	Lunch.
15:30 - 16:00	Dr. S. Mukherjee: Possible symmetry of the order parameter in noncentrosymmetric superconductor Li_2Pt_3B.
16:00 – 16.30	Mr. G. Niksic: SDW and the pseudogap in cuprates.
16:30 - 16:45	Break.
16:45 - 17:30	Prof. A. Chubukov - Prof. J. M. Tranquada: Training Session.
17:30 - 17:45	Break.
17:45 - 18:30	Prof. A. Chubukov - Prof. J. M. Tranquada: Training Session.

II Week

Professor Alexander Lichtenstein: Correlation effects in solids: from DFT to DMFT
Professor Thomas Vojta: Phases and phase transitions in disordered quantum systems

October 8	
09:00 - 11:00	Prof. A. Lichtenstein.
11:00 - 11:30	Coffee Break.
11:30 - 13:30	Prof. Th. Vojta.
13:30 - 15:30	Lunch.
15:30 - 16:00	Mr. D. Nozadze: Composition-tuned quantum smeared phase transitions.
16:00 - 16:10	Break.
16:10 - 17:10	Prof. A. Lichtenstein - Prof. Th. Vojta: Training Session.
17:10 - 17:30	Break.
17:30 - 18:30	Prof. A. Lichtenstein - Prof. Th. Vojta: Training Session.

October 9	
09:00 - 11:00	Prof. Th. Vojta.
11:00 - 11:30	Coffee Break.
11:30 - 13:30	Prof. A. Lichtenstein.
13:30 - 15:30	Lunch.
15:30 - 16:00	Mr. V. Quito: Bilinear and biquadratic random spin-1 chain.
16:00 - 16:10	Break.
16:10 - 17:10	Prof. A. Lichtenstein - Prof. Th. Vojta: Training Session.
17:10 - 17:30	Break.
17:30 - 18:30	Prof. A. Lichtenstein - Prof. Th. Vojta: Training Session.

October 10	
09:00 - 11:00	Prof. A. Lichtenstein.
11:00 - 11:30	Coffee Break.
11:30 - 13:30	Prof. Th. Vojta.
13:30 - 15:30	Lunch.
15:30 - 16:00	Mr. R. Rausch: Phase diagram of a chemically disordered and magnetically concentrated system.
16:00 - 16:10	Break.
16:10 - 17:10	Prof. A. Lichtenstein - Prof. Th. Vojta: Training Session.
17:10 - 17:30	Break.
17:30 - 18:30	Prof. A. Lichtenstein - Prof. Th. Vojta: Training Session.

October 11	
09:00 - 11:00	Prof. Th. Vojta.
11:00 - 11:30	Coffee Break.
11:30 - 13:30	Prof. A. Lichtenstein.
13:30 - 15:30	Lunch.
15:30 - 16:00	Mr. E. Sarvestani: Josephson supercurrent in a graphene-superconductor junction.
16:00 - 16:10	Break.
16:10 - 17:10	Prof. A. Lichtenstein - Prof. Th. Vojta: Training Session.
17:10 - 17:30	Break.
17:30 - 18:30	Prof. A. Lichtenstein - Prof. Th. Vojta: Training Session.

October 12	
09:00 - 11:00	Prof. A. Lichtenstein.
11:00 - 11:30	Coffee Break.
11:30 - 13:30	Prof. Th. Vojta.
13:30 - 15:30	Lunch.
15:30 - 16:00	Mr. M. Sayad: Mean-Field Theory of the Time-Dependent Kondo Effect.
16:00 - 16:30	Mr. G. Sica: High temperature superconductivity from realistic long-range Coulomb and Fröhlich interactions.
16:30 - 17:00	Break.
17:00 - 17:30	Dr. S. Slizovskiy: Nonlinear magnetization in graphene.
17:30 - 18:00	Mr. B. Tomasello: Quantum Dynamics in Spin Ice.
18:00 - 18:10	Closing of the Training Course.

Description of the scientific content of and discussion at the event

Professor Andrey Chubukov

Physics Department
University of Wisconsin-Madison
Madison, WI
USA

Title: Superconductivity from repulsive interactions

Lecture 1
Superconductivity -- the basics
Fermi liquid, pairing interaction, gap equation
Pairing with non-zero angular momentum
Electron-phonon coupling
Eliashberg theory of superconductivity

Lecture 2
Kohn-Luttinger mechanism of superconductivity
Effective pairing interaction
Kohn anomaly, Friedel oscillations
Larger angular momentum limit
p-wave pairing for fermions without a lattice
d-wave pairing in the Hubbard model at small density and/or small interaction

Lecture 3
Renormalization group approach
Patch models
Parquet RG flow
Examples: cuprates near van Hove doping, grapheme, pnictides

Lecture 4
Pairing mediated by collective bosons
Effective interaction mediated by collective bosons – derivation
Spin-fluctuation mediated pairing
Pairing by charge fluctuations
Color superconductivity

Lecture 5
Superconductivity near a quantum-critical point (QCP)
Generic Eliashberg-type analysis
Pairing near a ferromagnetic and a nematic QCP
Pairing near an antiferromagnetic QCP
Role of phase fluctuations

Bibliography
Lecture 1
A.A. Abrikosov, L.P. Gorkov and I.E. Dzyaloshinski, Methods of Quantum Field Theory in Statistical Physics, Dover Publications, (1975).
E. M. Lifshitz and L. P. Pitaevski, Statistical Physics, (Pergamon Press, 1980).
Lecture 2

W. Kohn and J. M. Luttinger, Phys. Rev. Letters, 15, 524 (1965).
D. Fay and A. Layzer, Phys. Rev. Lett. 20, 187 (1968).
M. Baranov, A. V. Chubukov, and M. Yu. Kagan, Int. J. Mod. Phys. 6, 2471 (1992).
R. Hlubina, Phys. Rev. B 59, 9600 (1992).
S. Raghu, S. A. Kivelson, and D. J. Scalapino, Phys. Rev B 81, 224505, (2010).
Lecture 3
A.T. Zheleznyak, V.M. Yakovenko, and I.E. Dzyaloshinskii, Phys. Rev. B 55, 3200 (1997).
K. Le. Hur and T.M. Rice, Annals of Physics, 325, 1452 (2009).
A.V. Chubukov, Physica C 469, 640 (2009).
R. Thomale et al. , Phys. Rev. B 80, 180505 (2009).
Fa Wang et al Phys. Rev. Lett. 102, 047005 (2009).
J. Gonzalez, Phys. Rev. B {\bf 78}, 205431 (2008).
R. Nandkishore, L. Levitov, A. Chubukov, arXiv:1107.1903.
Lecture 4
N. F. Berk and J.R. Schrieffer, Phys. Rev. Lett. 17, 433 (1966).
D.J. Scalapino, Phys. Rep. 250, 329 (1995).
P. Monthoux, A. V. Balatsky, and D. Pines, Phys. Rev. Lett. 67, 3448 (1991).
M. Capone, C. Castellani, M. Grilli, arXiv:1003.1042
A. Chubukov and J. Schmalian, Phys. Rev. B 57, R11085 (1998).
Lecture 5
Max A. Metlitski, Subir Sachdev, New J.Phys.12:105007,2010.
Ar. Abanov, Andrey V. Chubukov, A. M. Finkel'stein, Europhys. Lewtt. v54, p488 (2001).
Eun-Gook Moon, Andrey V. Chubukov, arXiv:1005.0356.
V. J. Emery and S. A. Kivelson, Nature 374, 434 (1995).

Professor John M. Tranquada

Condensed Matter Physics & Materials Science Department
Brookhaven National Laboratory
Upton, NY
USA

Title: Spins, Stripes, and Superconductivity in Hole-Doped Cuprates

Lecture 1: Introduction to the cuprates
a) Lattice and electronic structure; spectroscopic characterizations [1]
b) Spin fluctuations in the superconducting phase [2,3]

Lecture 2: Neutron scattering and antiferromagnetism
a) How and what one measures with neutron scattering [4,5]
b) Antiferromagnetism, superexchange, and spin waves [2]

Lecture 3: Other magnetic probes, with application to cuprates
a) Magnetic susceptibility [6]
b) Muon spin rotation and nuclear magnetic resonance [7]

Lecture 4: Model systems for doped antiferromagnets
a) Charge and spin stripe order in layered transition-metal oxides [8]
b) Spin-density-wave state of chromium; 2-leg ladder systems [9,10]

Lecture 5: Stripes in cuprates
a) Detection and analysis of stripe order [11]
b) Coexistence of stripe order and superconductivity [12]

References:

1. Secs. I-III of "Doping a Mott Insulator: Physics of high-temperature superconductivity," P. A. Lee, N. Nagaosa, and X.-G. Wen, Rev. Mod. Phys. 78, 17 (2006). http://link.aps.org/doi/10.1103/RevModPhys.78.17
2. "Neutron Scattering Studies of Antiferromagnetic Correlations in Cuprates," in Handbook of High-Temperature Superconductivity, edited by J. R. Schrieffer and J. S. Brooks (Springer, 2007), Chap. 6. http://arxiv.org/abs/cond-mat/0512115
3. "Progress in Neutron Scattering Studies of Spin Excitations in High-Tc Cuprates," M. Fujita, ..., and J. M. Tranquada, J. Phys. Soc. Jpn. 81, 011007 (2012). http://jpsj.ipap.jp/link?JPSJ/81/011007/
4. Chaps. 1, 2, 5, 7 of "Neutron Scattering with a Triple-Axis Spectrometer," G. Shirane, S. M. Shapiro, and J. M. Tranquada, (Cambridge University Press, 2002).
5. "Magnetic Neutron Scattering", I.A. Zaliznyak and S.-H. Lee, in Modern Techniques for Characterizing Magnetic Materials, (Springer, 2005). http://neutrons.phy.bnl.gov/references.shtm
6. "Spin susceptibility of underdoped cuprate superconductors: Insights from a stripe-ordered crystal," M. Hücker, G. D. Gu, and J. M. Tranquada, Phys. Rev. B 78, 214507 (2008). http://prb.aps.org/abstract/PRB/v78/i21/e214507
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10. "Surprises on the Way from One- to Two-Dimensional Quantum Magnets: The Ladder Materials," E. Dagotto and T. M. Rice, Science 271, 618 (1996). http://dx.doi.org/10.1126/science.271.5249.618

11. "Structural aspects of materials with static stripe order," M. Hücker, Physica C 481, 3 (2012). http://dx.doi.org/10.1016/j.physc.2012.04.035
12. "Transport properties of stripe-ordered high Tc cuprates," Qing Jie et al., Physica C 481, 46 (2012). http://dx.doi.org/10.1016/j.physc.2012.04.003
13. Special Issue: "Stripes and Electronic Liquid Crystals in Strongly Correlated Materials", Physica C 481 (2012). http://www.sciencedirect.com/science/journal/09214534/481

Training topics (Journal club):

1. "Quantum oscillations and the Fermi surface in an underdoped high-Tc superconductor," Nicolas Doiron-Leyraud et al., Nature 447, 565-568 (2007)
http://www.nature.com/nature/journal/v447/n7144/full/nature05872.html
and/or
"Electron pockets in the Fermi surface of hole-doped high-Tc superconductors," David LeBoeuf et al., Nature 450, 533-536 (2007).
http://www.nature.com/nature/journal/v450/n7169/full/nature06332.html
2. "Loss of nodal quasiparticle integrity in underdoped $YBa_2Cu_3O_{6+x}$," D. Fournier et al., Nature Physics 6, 905–911 (2010).
3. "Magnetic-field-induced charge-stripe order in the high-temperature superconductor $YBa_2Cu_3O_y$," Tao Wu et al., Nature 477, 191–194 (2011).
http://www.nature.com/nature/journal/v477/n7363/full/nature10345.html
4. "Long-Range Incommensurate Charge Fluctuations in $(Y,Nd)Ba_2Cu_3O_{6+x}$,"
G. Ghiringhelli et al., Science 337, 821 (2012).
http://www.sciencemag.org/content/337/6096/821.abstract
5. "Direct observation of competition between superconductivity and charge density wave order in YBa$_2$Cu$_3$O$_y$," J. Chang et al., arXiv:1206.4333v2.
http://arxiv.org/abs/1206.4333

Professor Alexander Lichtenstein

Institute of Theoretical Physics
University of Hamburg
Hamburg
Germany

Title: Correlation effects in solids: from DFT to DMFT

Lecture 1: Electronic structure of solids
a) Density Functional Theory (DFT) [1]
b) Methods of band structure calculations [2]

Lecture 2: Correlated electrons systems
a) Electronic correlations in atoms and crystals [3]
b) Theoretical description of electron correlations [4]

Lecture 3: Local correlations for adatoms
a) Numerical solution of Anderson impurity model [5]
b) Kondo effect for realistic systems [6]

Lecture 4: Dynamical Mean-Field Theory (DMFT)
a) DMFT for model systems [7]
b) DFT+DMFT for real materials [8]

Lecture 5: Non-local correlation effects
a) Electron correlations: beyond DMFT [9]
b) Effects of non-local interactions [10]

References:
[1] "The ABC of DFT", Kieron Burke (2007), http://dft.uci.edu/sites/default/files/g1.pdf
[2] "Electronic Structure: Basic Theory and Practical Methods", Richard M. Martin, Cambridge University Press, 2004
[3] "Electronic Structure of Strongly Correlated Materials", Vladimir Anisimov, Yuri Izyumov, Springer, 2010
[4] "Condensed Matter Field Theory", Alexander Altland, Ben Simons, Cambridge University Press, 2010
[5] "Continuous-time Monte Carlo methods for quantum impurity models", Emanuel Gull, Andrew Millis, Alexander Lichtenstein, Alexey Rubtsov, Matthias Troyer, and Philipp Werner, Rev. Mod. Phys. 83, 349 (2011)
[6] "The Kondo problem to heavy fermions", Alexander Hewson, Cambridge University Press, 1997
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[8] "Electronic structure calculations with dynamical mean-field theory", G. Kotliar, S. Savrasov, K. Haule, V. Oudovenko, O. Parcollet, and C. Marianetti, Rev. Mod. Phys. 78, 865 (2006)
[9] "Dual fermion approach to nonlocal correlations in the Hubbard model", A. Rubtsov, M. Katsnelson, and A. Lichtenstein, Phys. Rev. B 77, 033101 (2008)
[10] "Dual boson approach to collective excitations in correlated fermionic systems", A. Rubtsov, M. Katsnelson, and A. Lichtenstein, Annals of Physics 27,1320 (2012)

Professor Thomas Vojta
Department of Physics
Missouri University of Science and Technology
Rolla, MO
USA

Title: Phases and phase transitions in disordered quantum systems

Lectures:

1. Phase transitions and quantum phase transitions
a) review of basic concepts (first-order vs continous transitions, Landau theory, critical behavior, universality, scaling)
b) introduction to quantum phase transitions (experimental examples, quantum scaling, quantum-to-classical mapping)

2. Phase transitions in disordered systems
a) types of disorder (random mass and random fields)
b) Harris criterion and the stabilty of clean critical points
c) Imra-Ma argument and destruction of phase transitions by random fields
d) rounding of first-order phase transitions by disorder

3. Strong-disorder renormalization group
a) basic idea of the strong-disorder renormalization group
b) renormalizing the random transverse-field Ising chain
c) exotic infinite-randomness critical point

4. Griffiths phases
a) rare regions and large fluctuations
b) classical Griffiths singularities
c) quantum Griffiths singularities

5. Smeared phase transitions
a) rare regions in metallic systems (dissipation, freezing transition)
b) smearing of quantum phase transitions in metals
c) smeared transitions in system with correlated disorder

Training sessions:

Participants will explore the topics discussed in the lectures by working out specific examples
1. Quantum-to-classical mapping of the transverse-field Ising model
2. Harris criterion and Imry-Ma argument for correlated disorder
3. Random-singlet phase in disordered Heisenberg chain via strong-disorder RG
4. Percolation quantum phase transitions I
5. Percolation quantum phase transitions II

References:

I will expect the participants to have some basic knowledge of conventional phase transitions at the level of a graduate class in statistical physics. This material will be briefly reviewed in the first lecture, but if you never learned it, you may want to consult a text book, for example:

R.K. Pathria and P.D. Beale, Statistical Mechanics, Elsevier (2011), chapter 12
P.M. Chaikin and T.C. Lubensky, Principles of condensed matter physics, Cambridge (1995), chapter 4
J. Cardy, Scaling and Renormalization in Statistical Physics, Cambridge (1996), chapters 1 and 2
N. Goldenfeld, Lectures on phase transitions and the renormalization group, Perseus (1992), chapters 2, 3, and 5

Reading material for the individual lectures:
I list both reviews (marked by *) and some influential original papers):

Lecture 1:
[1]* S. Sachdev, Quantum phase transitions, Cambridge (1999), chapters 1, 2, and 3
[2]* T. Vojta, Quantum phase transitions in electronic systems, Ann. Phys. (Leipzig) 9, 403 (2000), http://arxiv.org/abs/cond-mat/9910514
[3]* M. Vojta, Quantum phase transitions, Rep. Prog. Phys. 66, 2069 (2003), http://arxiv.org/abs/cond-mat/0309604

Lecture 2:
[4]* J. Cardy, Scaling and Renormalization in Statistical Physics, Cambridge (1996), chapter 8
[5]* T. Vojta, Rare region effects at classical, quantum, and nonequilibrium phase transitions, J. Phys. A 39, R143 (2006), http://arxiv.org/abs/cond-mat/0602312, section 3.1
[6] Y. Imry and S.-k. Ma, Random-Field Instability of the Ordered State of Continuous Symmetry, Phys. Rev. Lett. 35, 1399 (1975)
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Lecture 3:
[8]* F. Igloi and C. Monthus, Strong disorder RG approach of random systems, Physics Reports 412, 277 (2005), http://arxiv.org/abs/cond-mat/0502448
[9] S.-k. Ma, C. Dasgupta, and C.-k. Hu, Random Antiferromagnetic Chain, Phys. Rev. Lett. 43, 1434 (1979)
[10] D.S. Fisher, Critical behavior of random transverse-field Ising spin chains, Phys. Rev. B 51, 6411 (1995)

Lecture 4:
[11]* T. Vojta, Rare region effects at classical, quantum, and nonequilibrium phase transitions, J. Phys. A 39, R143 (2006), http://arxiv.org/abs/cond-mat/0602312
[12] H. Rieger and A.P. Young, Griffiths singularities in the disordered phase of a quantum Ising spin glass, Phys. Rev. B 54, 3328 (1996), http://arxiv.org/abs/cond-mat/9512162
[13] M. Guo, R.N. Bhatt, and D.A. Huse, Quantum Griffiths singularities in the transverse-field Ising spin glass, Phys. Rev. B 54, 3336 (1996), http://arxiv.org/abs/cond-mat/9605111

Lecture 5:
[14]* T. Vojta, Quantum Griffiths effects and smeared phase transitions in metals: theory and experiment, J. Low Temp. Phys. 161, 299 (2010), http://arxiv.org/abs/1005.2707
[15] T. Vojta, Disorder-induced rounding of certain quantum phase transitions, Phys. Rev. Lett. 90, 107202 (2003), http://arxiv.org/abs/cond-mat/0212305
[16] J.A. Hoyos and T. Vojta, Theory of smeared quantum phase transitions, Phys. Rev. Lett. 100, 240601 (2008), http://arxiv.org/abs/0802.2303

01/10/2012

Mr. Edmund Bennett

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

Majorana Dimerised Order in Magnetic Systems

Abstract: My research considers the analysis of quantum critical points (QCPs) 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. I consider a 3D Ising model in an applied transverse field, which is an adequate model of the ferromagnetic material $LiHoF_4$, which exhibits a QCP. A Majorana dimerisation decoupling and a Ising magnetic decoupling may be used on equal footing in models describing this system and suggest the presence of order above the QCP, therefore giving insight into the behaviour of the material in this regime. I present a mean-field (saddle-point) approximation and gaussian corrections to this theory. [1] W. Mao, P. Coleman, C. Hooley & D. Langreth; PRL, 91, 20, p. 2072031-2072034; 2003

01/10/2012

Mr. Andreas Eberlein

Department Quantum Many Body Systems, Max Planck Institute for Solid State Research, Stuttgart, Germany

Functional renormalization group study of fluctuation effects in fermionic superfluids

Abstract: We study ground state properties of the attractive Hubbard model at weak coupling with the aim of finding an efficient description of the effective Nambu two-particle vertex in a singlet superconductor. We decompose the vertex into a sum of interaction channels, each capturing a particular singular dependence on external momenta and frequencies. Using the functional renormalization group, we derive flow equations for the interaction channels on one-loop level. We compute the frequency dependence of the self-energy as well as the momentum and frequency dependence of the two-particle vertex. Our results for the impact of fluctuations on the superconducting gap are in good agreement with the literature.

01/10/2012

Mr. Denis Golež

F1, Institute Jozef Stefan IJS, Slovenia, Slovenia

Nonequillibrium dynamics of polaron systems

Abstract: Polaron is a quasi-particle, which is formed by a charged particle and accompanied polarisation field. As electron is moving throught the crystal its interacting with the lattice creates deformation. This deformation acts as a effective potential well, which lowers the mobility of the quasiparticle. In previous years theoretical research was limited on the equilibrium properties of the systems. However, as experiments starts probing physical properties far beyond the linear response regime, the interest on the correlated phenomena out of the equilibrium rapidly starts to grow in fields like the transport in nanosystems, ultra-cold atomic gasses and time resolved optical spectroscopy (pump and probe experiments). I will represent the nonequillibrium dynamics of the Holstein polaron problem driven by a constant or pulse modulated electric field. In the case of constant electric field the crucial condition for emergence of the quasi-stationary current in the system driven by constant electric field is the existence of the bath, which can absorb energy, while for pulse modulated field we can analyse the relaxation dynamics.

02/10/2012

Mr. Felix Hofmann

I. Institut für Theoretische Physik, University of Hamburg, Germany

(Non-equilibrium) Self-energy-functional theory and conserving approximations

Abstract: The self-energy-functional theory [1] provides a general framework for the systematic construction of non-perturbative, thermodynamically consistent approximations in order to study strongly correlated systems in the thermodynamical limit in and out of equilibrium and proves to respect particle number and spin conservation laws [2]. On the space of self-energies a functional can be constructed which is stationary at the physical self-energy and equals the physical grand canonical potential when evaluated at the latter. Without approximating the (formally unknown) functional, the variational principle can be evaluated by restricting the self-energies to a subspace of (numerically) solvable reference systems. This is done self consistently, such that the results are obtained in the thermodynamical limit. By choosing appropriate classes of reference systems, theories like variational-cluster-approach (VCA) and dynamical-mean-field-theory (DMFT) can be derived from SFT as well as improved variants. Likewise, SFT allows for studying phases and phase transitions (by numerical means) as for example the Mott metal-insulator transition, magnetic phase transitions or the transition from antiferromagnetic to the superconducting phase in Hubbard-like and spin models. [1] M. Potthoff, AIP Conf. Proc. 1419, pp. 199-258 (2011) [2] F. Hofmann and M. Potthoff, to be publishe.

03/10/2012

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Reduced Density Matrix functional theory- A suitable vehicle to import explicit correlations

Abstract: A variational formulation for the calculation of interacting fermions system based on density matrix functional theory is presented. This formulation allows importing explicit many particle effects into standard density functional theory based calculations and also

avoids ambiguities of double counting terms inherent to other approaches. Local approximation for explicit correlations is introduced and the resulting constrained impurity problem is solved using resolvent expansion/Quantum Master equation technique developed in the field of Open quantum system.

04/10/2012

Mr. Pasquale Marra

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Probing the Phase of the Superconducting Order Parameter via Resonant Inelastic X-ray Scattering

Abstract: The capability to probe the dispersion of elementary spin, charge, orbital, and lattice excitations has positioned Resonant Inelastic X-ray Scattering (RIXS) at the forefront of photon science. Here we develop the scattering theory for RIXS on superconductors, calculating its momentum-dependent scattering amplitude. Considering superconductors of various symmetries we show that the low- energy scattering is strongly affected by the superconducting gap and coherence factors. This establishes RIXS as a tool to disentangle pairing symmetries and to probe the elementary excitations of unconventional superconductors.

05/10/2012

Dr. Soumya Mukherjee

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Possible symmetry of the order parameter in noncentrosymmetric superconductor Li_2Pt_3B

Abstract: The nature of the order parameter symmetry in the noncentrosymmetric superconducting compound LI_2Pt_3B seems to be an interesting and long lasting problem as findings of some experiments contradict others. The most nearest in nature of this compound is Li_2Pd_3B, which shows s-wave kind of behaviour and this is widely accepted and verified. On the other hand the nature of the order parameter in the Pt compound is still full of contradictions. Based on a spin fluctuation mechanism we describe the possible nature and symmetry of the order parameter in this compound which also follow experimental findings. This work predicts some s(+-) type of order parameter with line nodes as the possible candidate. Mystery still remains regarding the explanation of the NMR experiment and this will be explained. More accurate theory/experiment are needed to verify/clarify these prediction/mystery.

05/10/2012

Mr. Goran Niksic

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SDW and the pseudogap in cuprates

Abstract: We investigate the SDW susceptibility around the pseudogap temperature T* in a realistic three-band model of the CuO_2 planes in high-Tc cuprates. This approach starts from initially empty copper orbitals and metallic oxygen holes which then hybridise with the copper sites. The magnetic scattering of two oxygen holes in the hybridised ground state introduces k-dependent spectral weights and projectors which can lead to a suppression of the logarithmic singularity (commensurate SDW response) even at the van Hove doping, in the presence of even slight disorder. We find the three-band structure, site-selective scattering, and small amount of disorder to be the minimal elements of complexity which cumulatively enable the incommensurate SDW response to survive up to optimal doping without involving superconductivity. The supression of the commensurate response already at one-loop level corresponds to the crossover from the weak-coupling to the strong-coupling regime, characteristic of complex materials.

08/10/2012

Mr. David Nozadze

Missouri university of science and technology, USA

Composition-tuned quantum smeared phase transitions

Abstract: Phase transitions in random systems are smeared if individual spatial regions can order independently of the bulk system. We study such smeared phase transitions in substitutional alloys $A_{\{1-x\}}B_x$ that can be tuned from an ordered phase at composition x=0 to a disordered phase at x=1. We show that the ordered phase develops a pronounced tail that extends over all compositions x<1. Using optimal fluctuation theory, we derive the composition dependence of the order parameter and other quantities in the tail of the smeared phase transition. We also investigate the influence of spatial disorder correlations on smeared phase transitions. As an example, we demonstrate that the composition-driven ferromagnetic-to-paramagnetic quantum phase transition in $Sr_{\{1-x\}}Ca_xRuO_3$ is completely destroyed by the disorder introduced via the different ionic radii of the randomly distributed Sr and Ca ions. We find that the ferromagnetic phase is significantly extended by the disorder and develops a pronounced tail over a broad range of the composition x. These findings are explained by our model of smeared quantum phase transitions in itinerant magnets.

09/10/2012

Mr. Victor Quito

Department of Condensed Matter Physics, Institute of Physics Gleb Wataghin, Unicamp - Campinas, Brazil

Bilinear and biquadratic random spin-1 chain

Abstract: In this talk I will present our results concerning random isotropic spin 1 chains with first neighbor interactions that include the usual bilinear Heisenberg term but additionally consider a biquadratic $\left(S_{i}\cdot S_{i+1}\right)^{2}$ interaction, using the Strong Disorder Renormalization Group technique. I will start reviewing the known results for the bilinear chain in the scope of the SDRG method, either in the limit of strong and weak disorder, showing the different phases that can emerge. Latter I will show our phase diagram as function of the ratio between bilinear and biquadratic terms for the strong disorder regime, particularly for the cases where the system presents the higher SU(3) symmetry.

10/10/2012

Mr. Roman Rausch

Institute of Theoretical Physics, University of Hamburg, Hamburg, Germany

Phase diagram of a chemically disordered and magnetically concentrated system

Abstract: We present self-consistent CPA-RKKY calculations of the critical temperatures of the antiferromagnetic phases within the pure Kondo-lattice model (sc and fcc lattices). Extending the results to chemical and magnetic disorder, we are able to calculate the phases of the concentrated spin system $Eu_{1-x}Gd_{x}S$ which agree well with the experiment. This substance also shows a spin-glass phase whose origin is briefly discussed from a proposed microscopic principle.

12/10/2012

Mr. Mohammad Sayad

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Mean-Field Theory of the Time-Dependent Kondo Effect

Abstract: We propose a generalization of the hybridization mean-field theory [1,2] to Kondo systems far from thermal equilibrium. This time-dependent mean-field approach is used to study the formation or breaking of a Kondo singlet on the time axis. To this end we consider a Kondo impurity on a one-dimensional tight-binding chain as well as on two- and three-dimensional clusters after a sudden change of the exchange-coupling strength. We present results for the ground-state and the finite-temperature equilibrium phase diagram of the

Kondo Hamiltonian and for the non-equilibrium final-state dynamics after a quench through the phase boundary and discuss the time-dependent competition of the Kondo effect with the RKKY interaction for systems with two magnetic impurities. [1] C. Lacroix and M. Cyrot, Phys. Rev. B 20, 1969 (1979) [2] D. Newns and N. Read, Advances in Physics 36, 799 (1987).

12/10/2012

Mr. Gerardo Sica

Dipartimento di Fisica "E.R. Caianiello", Università degli Studi di Salerno, Italy

High temperature superconductivity from realistic long-range Coulomb and Fröhlich interactions

Abstract: It has been recently found that in highly polarizable ionic lattices the bare long-range Coulomb and electron-phonon (Fröhlich) interactions almost negate each other resulting in a short-range polaronic spin-exchange Jp(u) of phononic origin that depends on the effective on-site interaction u coming from the competition between repulsive Hubbard-U and attractive on-site Fröhlich interaction. Different from the well-known t-J model, Jp(u) is not responsible for antiferromagnetism but for the formation of small and superlight bound states of two polarons (bipolarons) that condense with a critical temperature well in exceed of 100K. The effective on-site term, limiting the double occupancy, reduces the inter-site polaron exchange Jp resulting in a transition from small to large bipolarons at some critical value of u that accounts for the BEC/BCS crossover.

12/10/2012

Dr. Sergey Slizovskiy

Dept. of Physics, Loughborough University, UK

Nonlinear magnetization in graphene

Abstract: We discuss the magnetization of graphene in a strong magnetic field on a free-electron level. We show that the magnetization exhibits non-linear behaviour as a function of the applied field, reflecting the strong non-analyticity of the two-dimensional effective action of Dirac electrons. The necessary values of the magnetic field to observe this non-linearity vary from a few Teslas for clean samples to few tens of Teslas for lower-quality samples. In the light of these calculations, we discuss the effects of disorder and interactions as well as the experimental conditions under which the predictions can be observed.

Mr. Bruno Tomasello

SEPnet: Kent University & ISIS (STFC spallation facility at the Rutherford Appleton Laboratory), UK

Quantum Dynamics in Spin Ice

Abstract: Spin Ice is one of hottest spots in condensed matter physics. This class of magnetic pyrochlores, namely Ho2Ti2O7 and Dy2Ti2O7 , exhibits a wide variety of exotic features at very low temperatures. These are mainly driven by the macroscopic degeneracy that characterizes the ground state [1]. Such degeneracy arises because of the particular arrangement of the Rear Earth (RE) ions (Ho3+or Dy3+) along the pyrochlore lattice (corner-sharing tetrahedra). Each of the magnetic dipoles (spins) sits, indeed, on the vertex of a tetrahedron and is forced, by a strong Crystal Field (CF), to point along the local <111> direction (easy axis). Hence every spin has only two possible configurations: to be pointing inward or outward of the tetrahedron. These geometrical constraints on the spins, together with their magnetic interactions, is what gives Spin Ice its characteristic geometrical frustration [1]. Such frustration not only accounts for a broad range of experimental measurements, it represents also the keystone for the most remarkable feature in Spin Ice: the emergent magnetic monopoles [2]. These quasiparticles attracts a lot of interest both from a fundamental point of view (as an example of fractionalisation in three dimensions) as well as, more speculatively, for the possibility of new technologies exploiting them ("magnetricity" [3,4]). However, despite the variety of experiments [3-7], a complete and unique description for the dynamics of such monopoles is still missing . Indeed the theoretical models studied to date feature classical Ising spins and therefore the only mechanism for monopole transport in these models is thermal diffusion. In contrast some experiments [6] suggest that the temperature dynamics are characterised by intrinsic temperature-independent timescales.Here we investigate the role of quantum dynamics for the monopoles in the low temperature regime. In Spin Ice, indeed, the hopping of a magnetic monopole, from one site to the next, consists of the flip of a large spin from a configuration, along the easy axis, to the opposite one. At very low temperatures, this requires quantum-mechanical tunnelling through a large anisotropy barrier. Starting from a single RE3+ ion picture we analyze the interplay between the Crystal Field environment (measured via neutron scattering on RE-titanates; RE2Ti2O7) and internal magnetic fields (from Montecarlo simulations) acting on the spin. We found that quantm mechanics gives very interesting insights in the zero-temperature physics of this system. In particular, by means of fields transverse to the easy axis, we find a quantum spin flip (tunnelling) between the two opposite configurations. Remarkably when the transverse field is tuned across the values obtained by the Montecarlo simulations the range of frequencies spans the same order of magnitudes found among the different experiments. These results suggest that our quantum-mechanical theory provides a self consistent description for the hopping of monopoles, and more in general may also give an important contribution in interpreting some of the current experimental puzzles about dynamics in these systems. [1] S.Bramwell and M.Gingras, Science 294 (2001); [2] C.Castelnovo et al. Nature 451 (2008) ; [3] S.Bramwell et al. Nature 461 (2009) ; [4] S.Giblin et al. Nature-Phys 7 (2011); [5] S.Dunsiger et al PRL 107 (2011) ; [6] K.Matsushira et al. JPSJ 80 (2011) ; [7] S.Blundell PRL 108 (2012) ;

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
XVI TC: 3rd to 14th October 2011.
Lecturers: J.A. Mydosh, T. Pruschke, U. Schollwöck, D. Singh
Web page: http://scs.sa.infn.it/TCXVI

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