# Summary

**Event:** XV 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:** 4th to 15th October 2010.

**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) (scientific coordinator)
- 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)
- Prof. B. Coqblin (Université Paris-Sud, Orsay, France)
- 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. O.K. Andersen (Max-Planck-Institut, Stuttgart, Germany)
- Prof. A.E. Feiguin (University of Wyoming, Laramie WY, USA)
- Prof. H.R. Ott (ETH Zurich, Zurich, Switzerland)
- Prof. M. Potthoff (Universität Hamburg, Hamburg, Germany)

**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) | € 11,740.00 |
| • Participant fellowships[3] (fully or partially covering the accomodation expenses) | € 8,025.00 |
| • Logistic expenses (secretariat, stationery, Xerox, telephone, fax, postal expenses, coffee breaks) | € 1,500.00 |
| • Proceedings publication (extimate based on the last ten publications) | € 4,235.00 |
| Total | € 25,500.00 |

**Funding Balance:**

| | |
|---|---|
| • Dipartimento di Fisica "E.R. Caianiello" & Scuola di Dottorato in Fisica | € 15,160.00 |
| • IIASS[4] (registration fees included: 13 × € 350.00 minus VAT(20%)) | € 3,640.00 |
| • European Science Foundation (ESF): INTELBIOMAT Programme | € 6,000.00 |
| • European Physical Society (EPS) | € 700.00 |
| Total | € 25,500.00 |

**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 € 895.00, accommodation € 895.00, honorary € 1,145.00.

[3] The Course had 20 participants. 16 participants, among the youngest with the best CVs, received an average fellowship of € 500.00 each to cover their accommodation expenses. 7 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. A. E. Feiguin**: The density matrix renormalization group (DMRG) method and its time-dependent variants.
**Prof. H. R. Ott**: Experimental approaches to strong correlations.

**October 4**

| | |
|---|---|
| 08:00 - 08:50 | Registration. |
| 08:50 - 09:00 | Opening of the Training Course. |
| 09:00 - 11:00 | Prof. A. E. Feiguin: 1st Lesson. |
| 11:00 - 11:30 | Coffee Break. |
| 11:30 - 13:30 | Prof. H. R. Ott: 1st Lesson. |
| 13:30 - 15:30 | Lunch. |
| 15:30 - 16:20 | Participant presentations. |
| 16:20 - 16:30 | Break. |
| 16:30 - 18:30 | Prof. A. E. Feiguin - Prof. H. R. Ott: Training Session. |

**October 5**

| | |
|---|---|
| 09:00 - 11:00 | Prof. H. R. Ott: 2nd Lesson. |
| 11:00 - 11:30 | Coffee Break. |
| 11:30 - 13:30 | Prof. A. E. Feiguin: 2nd Lesson. |
| 13:30 - 15:30 | Lunch. |
| 15:30 - 16:00 | Miss A. Briffa: Generalising spin ice: the magnetic ground state of pyrochlore $Gd_2Ti_2O_7$. |
| 16:00 - 16:10 | Break. |
| 16:10 - 17:10 | Prof. A. E. Feiguin - Prof. H. R. Ott: Training Session. |
| 17:10 - 17:30 | Break. |
| 17:30 - 18:30 | Prof. A. E. Feiguin - Prof. H. R. Ott: Training Session. |

**October 6**

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|---|---|
| 09:00 - 11:00 | Prof. A. E. Feiguin: 3rd Lesson. |
| 11:00 - 11:30 | Coffee Break. |
| 11:30 - 13:30 | Prof. H. R. Ott: 3rd Lesson. |
| 13:30 - 15:30 | Lunch. |
| 15:30 - 16:00 | Dr. V. Brosco: Low-temperature conductivity of a low-density Rashba electron gas. |
| 16:00 - 16:10 | Break. |
| 16:10 - 17:10 | Prof. A. E. Feiguin - Prof. H. R. Ott: Training Session. |
| 17:10 - 17:30 | Break. |
| 17:30 - 18:30 | Prof. A. E. Feiguin - Prof. H. R. Ott: Training Session. |

**October 7**

| | |
|---|---|
| 09:00 - 11:00 | Prof. H. R. Ott: 4th Lesson. |
| 11:00 - 11:30 | Coffee Break. |
| 11:30 - 13:30 | Prof. A. E. Feiguin: 4th Lesson. |
| 13:30 - 15:30 | Lunch. |
| 15:30 - 16:00 | Mr. W. Brzezicki: Hidden Dimer Order in the Orbital Compass Model. |
| 16:00 - 16:10 | Break. |
| 16:10 - 17:10 | Prof. A. E. Feiguin - Prof. H. R. Ott: Training Session. |
| 17:10 - 17:30 | Break. |
| 17:30 - 18:30 | Prof. A. E. Feiguin - Prof. H. R. Ott: Training Session. |

**October 8**

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|---|---|
| 09:00 - 11:00 | Prof. A. E. Feiguin: 5th Lesson. |
| 11:00 - 11:30 | Coffee Break. |
| 11:30 - 13:30 | Prof. H. R. Ott: 5th Lesson. |
| 13:30 - 15:30 | Lunch. |
| 15:30 - 16:00 | Mr. S. Kourtis: Coexistence of superconducting and charge density wave states. |
| 16:00 - 16:10 | Break. |
| 16:10 - 17:10 | Prof. A. E. Feiguin - Prof. H. R. Ott: Training Session. |
| 17:10 - 17:30 | Break. |
| 17:30 - 18:30 | Prof. A. E. Feiguin - Prof. H. R. Ott: Training Session. |

# II Week

**Prof. O. K. Andersen**: Understanding the electronic structure of 3d-electron materials of recent interest, starting from LDA Wannier functions.
**Prof. M. Potthoff**: Variational principles for strongly correlated Fermi systems.

**October 11**

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|---|---|
| 09:00 - 11:00 | Prof. O. K. Andersen: 1st Lesson. |
| 11:00 - 11:30 | Coffee Break. |
| 11:30 - 13:30 | Prof. M. Potthoff: 1st Lesson. |
| 13:30 - 15:30 | Lunch. |
| 15:30 - 16:00 | Mr. N. Kumar: Magnetic properties of $EuPtSi_3$ single crystals. |
| 16:00 - 16:10 | Break. |
| 16:10 - 17:10 | Prof. O. K. Andersen - Prof. M. Potthoff: Training Session. |
| 17:10 - 17:30 | Break. |
| 17:30 - 18:30 | Prof. O. K. Andersen - Prof. M. Potthoff: Training Session. |

**October 12**

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|---|---|
| 09:00 - 11:00 | Prof. M. Potthoff: 2nd Lesson. |
| 11:00 - 11:30 | Coffee Break. |
| 11:30 - 13:30 | Prof. O. K. Andersen: 2nd Lesson. |
| 13:30 - 15:30 | Lunch. |
| 15:30 - 16:00 | Mr. N. Parragh: LDA+DMFT study of fotoemission and optical properties of $V_2O_3$. |
| 16:00 - 16:10 | Break. |
| 16:10 - 17:10 | Prof. O. K. Andersen - Prof. M. Potthoff: Training Session. |
| 17:10 - 17:30 | Break. |
| 17:30 - 18:30 | Prof. O. K. Andersen - Prof. M. Potthoff: Training Session. |

**October 13**

| | |
|---|---|
| 09:00 - 11:00 | Prof. O. K. Andersen: 3rd Lesson. |
| 11:00 - 11:30 | Coffee Break. |
| 11:30 - 13:30 | Prof. M. Potthoff: 3rd Lesson. |
| 13:30 - 15:30 | Lunch. |
| 15:30 - 16:00 | Mr. C. Thomas: Application of the S=1 underscreened Anderson lattice model to Kondo uranium and neptunium compounds. |
| 16:00 - 16:10 | Break. |
| 16:10 - 17:10 | Prof. O. K. Andersen - Prof. M. Potthoff: Training Session. |
| 17:10 - 17:30 | Break. |
| 17:30 - 18:30 | Prof. O. K. Andersen - Prof. M. Potthoff: Training Session. |

**October 14**

| | |
|---|---|
| 09:00 - 11:00 | Prof. M. Potthoff: 4th Lesson. |
| 11:00 - 11:30 | Coffee Break. |
| 11:30 - 13:30 | Prof. O. K. Andersen: 4th Lesson. |
| 13:30 - 15:30 | Lunch. |
| 15:30 - 16:00 | Mr. L. Vidmar: Gain of the kinetic energy of bipolarons in the t-J Holstein model based on electron-phonon coupling. |
| 16:00 - 16:10 | Break. |
| 16:10 - 17:10 | Prof. O. K. Andersen - Prof. M. Potthoff: Training Session. |
| 17:10 - 17:30 | Break. |
| 17:30 - 18:30 | Prof. O. K. Andersen - Prof. M. Potthoff: Training Session. |

**October 15**

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|---|---|
| 09:00 - 11:00 | Prof. O. K. Andersen: 5th Lesson. |
| 11:00 - 11:30 | Coffee Break. |
| 11:30 - 13:30 | Prof. M. Potthoff: 5th Lesson. |
| 13:30 - 15:30 | Lunch. |
| 15:30 - 16:30 | Prof. O. K. Andersen - Prof. M. Potthoff: Training Session. |
| 16:30 - 17:00 | Break. |
| 17:00 - 18:00 | Prof. O. K. Andersen - Prof. M. Potthoff: Training Session. |

# Description of the scientific content of and discussion at the event

**Professor Ole K. Andersen**
Max-Planck Institute for Solid-State Research
Stuttgart, Germany

**Understanding the electronic structure of 3d-electron materials of recent interest, starting from LDA Wannier functions.**

Lectures:
1. The single-particle picture. Periodic system of elements. Tight-binding description of the band structure of solids [1]. Löwdin downfolding and minimal basis sets Wannier functions [2].
2. Density-functional theory and its local approximation (LDA). Band-structure methods [1]. What electronic correlations may do to LDA bands: the Mott transition in $V_2O_3$ described in the dynamical-mean field approximation (DMFT) [3,4].
3. Transition-metal perovskites. Mott transition in a $3d(t_{2g})^1$ series; cation control [5]. Coulomb-enhanced spin-orbit coupling in the $4d(t_{2g})^5$ oxide $Sr_2RhO_4$ [6]. Pressure-induced metal-insulator transition in the $3d(t_{2g})\uparrow\uparrow\uparrow(e_g)^1$ oxide $LaMnO_4$ [7].
4. Trends in band structures of HTSC $d^{9-h}$ cuprates [8]. Superconductors from heterostructures of $d^7$ nickelates? [9].
5. Band structure and itinerant magnetism of the new iron-pnictide and chalcogenide superconductors [10].

**References** (most of these papers may be downloaded from http://www.fkf.mpg.de/andersen/):
[1] Richard M. Martin, "Electronic structure, basic theory and practical methods" (Cambridge Univ. Press 2005)
[2] E. Zurek et al. "Muffin-Tin Orbital Wannier-like functions for insulators and metals". ChemPhysChem 6 (2005), 1934.
[3] F. Lechermann et al. "Dynamical mean-field theory using Wannier functions: A flexible route to electronic structure calculations of strongly correlated materials". Phys. Rev. B 74 (2006), 125120.
K. Held et al. "Bandstructure meets many-body theory: the LDA + DMFT method". J. Phys.: Condens. Matter 20 (2008), 064202
[4] T. Saha-Dasgupta et al. "Electronic structure of V2O3: Wannier Orbitals from LDA-NMTO calculations." arXiv:0907.2841v1;
A.I Poteryaev et al, "Enhanced crystal-field splitting and orbital-selective coherence induced by strong correlations in V2O3". Phys. Rev. B 76 (2007), 085127
[5] E. Pavarini et al. "How chemistry controls electron localization in $3d^1$ perovskites: A Wannier-function study". New Journal of Physics 7 (2005), 188
[6] Liu Guo-Qiang Liu et al. "Coulomb-Enhanced Spin-Orbit Splitting: The Missing Piece in the Sr2RhO4 Puzzle". Phys. Rev. Lett. 101 (2008), 026408
[7] A. Yamasaki et al. "Pressure-Induced Metal-Insulator Transition in LaMnO3 is Not of Mott-Hubbard Type". Phys. Rev. Lett. 96 (2006), 166401.
[8] O.K. Andersen et al. "LDA energy bands, low-energy Hamiltonians, t', t'', tperp(k), and Jperp". J. Phys.Chem. Solids, 56, (1995), 1573;
E. Pavarini et al. "Band-structure trend in cuprates and correlation with T_{cmax}". Phys. Rev. Lett. 87 (2001), 047003;
P.R.C. Kent et al. "Combined density-functional and dynamical cluster quantum Monte Carlo calculations for three-band Hubbard models for hole-doped cuprate superconductors". Phys. Rev. B 78 (2008), 035132
[9] P. Hansmann et al. "Turning a Nickelate Fermi Surface into a Cupratelike One through Heterostructuring". Phys. Rev. Lett. 103 (2009), 016401
[10] A. Yaresko et al. "Interplay between magnetic properties and Fermi surface nesting in iron pnictides". Phys. Rev. B 79 (2009), 144421

**Training**: Students will perform simple analytical calculations demonstrating e.g. downfolding, and understanding covalency and itinerant magnetism via tight-binding.

# Professor Adrian E. Feiguin

Department of Physics and Astronomy
University of Wyoming
Laramie WY, USA


**The density matrix renormalization group (DMRG) method and its time-dependent variants.**

Lectures:

1. Exact diagonalization. Numerical Renormalization Group. Disentangling quantum many body states: the Schmidt decomposition and the density matrix transformation. The density matrix renormalization group method. Measuring observables. Targeting multiple states. Calculating gaps. Extension to higher dimensions. Quantifying entanglement
2. The wave-function transformation. Time evolution using DMRG. The Suzuki-Trotter decomposition. Adaptive tDMRG. Time-targeting methods. Time-evolution using the Krylov basis.
3. Applications of the tDMRG method. Calculating time-dependent correlation functions. Quenches and entanglement growth. Thermo-field formalism. Quantum purification. Evolution in imaginary time. Thermodynamics.
4. Matrix Product States and DMRG. MPS as a variational ansatz. The AKLT state. Projected Entangled Pair States (PEPS) Infinite Time Evolving Block Decimation method (iTEBD). Infinite size algorithms.
5. ALPS libraries. ALPS DMRG.

**References:**


1) S. R. White, Density matrix formulation for quantum renormalization groups. PRL 69,2863 (1992).
2) S. R. White, Density-matrix algorithms for quantum renormalization groups. PRB 48,10345 (1993)
3) U. Schollwöck, The density-matrix renormalization group. RMP 77, 259 (2005)
4) K. Hallberg, Density Matrix Renormalization: A Review of the Method and its Applications. arXiv:cond-mat/0303557
5) R. Noack and S. Manmana, Diagonalization- and Numerical Renormalization-Group-Based Methods for Interacting Quantum Systems. arXiv:cond-mat/0510321
6) Steven R. White and Adrian E. Feiguin, Real-Time Evolution Using the Density Matrix Renormalization Group Phys. Rev. Lett. 93, 076401 (2004)
7) A. J. Daley, C. Kollath, U. Schollwoeck, G. Vidal, Time-dependent density-matrix renormalization-group using adaptive effective Hilbert spaces. J. Stat. Mech.: Theor. Exp. (2004) P04005
8) G. Vidal, Efficient Simulation of One-Dimensional Quantum Many-Body Systems. Phys. Rev. Lett. 93, 040502 (2004)
9) G. Vidal, Classical Simulation of Infinite-Size Quantum Lattice Systems in One Spatial Dimension. Phys. Rev. Lett. 98, 070201 (2007)
10) Adrian E. Feiguin and Steven R. White, Time-step targeting methods for real-time dynamics using the density matrix renormalization group. Phys. Rev. B 72, 020404 (2005)
11) Adrian E. Feiguin and Steven R. White, Finite-temperature density matrix renormalization using an enlarged Hilbert space. Phys. Rev. B 72, 220401 (2005)
12) Peter Schmitteckert, Nonequilibrium electron transport using the density matrix renormalization group method. Phys. Rev. B 70, 121302 (2004)
13) F. Heidrich-Meisner, A. E. Feiguin, and E. Dagotto, Real-time simulations of nonequilibrium transport in the single-impurity Anderson model. Phys. Rev. B 79, 235336 (2009)
14) Luis G. G. V. Dias da Silva, F. Heidrich-Meisner, A. E. Feiguin, C. A. Büsser, G. B. Martins, E. V. Anda, and E. Dagotto, Transport properties and Kondo correlations in nanostructures: Time-dependent DMRG method applied to quantum dots coupled to Wilson chains. Phys. Rev. B 78, 195317 (2008)
15) K. A. Al-Hassanieh, A. E. Feiguin, J. A. Riera, C. A. Büsser, and E. Dagotto, Adaptive time-dependent density-matrix renormalization-group technique for calculating the conductance of strongly correlated nanostructures, Phys. Rev. B 73, 195304 (2006)
16) U. Schollwoeck, S. R. White, Methods for Time Dependence in DMRG. arXiv:cond-mat/0606018
17) U. Schollwoeck, The density matrix renormalization group in the age of matrix product states. arXiv:cond-mat/1008.3477
18) F. Verstraete, D. Porras, J. I. Cirac, DMRG and periodic boundary conditions: a quantum information perspective. Phys. Rev. Lett. 93, 227205 (2004)
19) F. Verstraete, J.I. Cirac, Matrix product states represent ground states faithfully. Phys. Rev. B 73, 094423 (2006)
20) F. Verstraete, M. M. Wolf, D. Perez-Garcia, J. I. Cirac, Criticality, the area law, and the computational power of PEPS. Phys. Rev. Lett. 96, 220601 (2006).
21) D. Perez-Garcia, F. Verstraete, M.M. Wolf, J.I. Cirac, Matrix Product State Representations. Quantum Inf. Comput. 7, 401 (2007)
22) F. Verstraete, J.I. Cirac, V. Murg, Matrix Product States, Projected Entangled Pair States, and variational renormalization group methods for quantum spin systems. Adv. Phys. 57,143 (2008)

**Professor Hans R. Ott**
ETH Zurich - Department of Physics
Laboratory for Solid State Physics
Zurich, Switzerland

**Experimental approaches to strong correlations.**

Lectures topics:
Fermi liquid, normal liquid 3He, Kondo (dilute and lattice), heavy-electron metals, non Fermi-liquid aspects
Superconductivity (key properties and related experiments)
Unconventional Superconductivity (examples and experiments)
Physics of low-dimensional systems (examples and experimental approaches)

# Professor Michael Potthoff

Institute for Theoretical Physics
University of Hamburg
Hamburg, Germany


**Variational principles for strongly correlated Fermi systems.**

Lectures:
1. Correlated electrons: Basic models and methods [1,2,3]
a) Electron correlations
b) Second quantization
c) Exact diagonalization
2. Variational wave functions [4,5]
a) Ritz variational principle
b) Hartree-Fock approximation
c) Gutzwiller wave function and Mott transition
d) Variation of matrix-product states
e) Variational density matrix
f) General approximation strategies
3. Green functions and perturbation theory [1,2,3,6]
a) Diagrammatic perturbation theory
b) Properties of Green functions
c) Luttinger-Ward functional
d) Dynamical functionals
4. Dynamical variational approximations [7,8,9,10]
a) Cluster-perturbation theory
b) Variational cluster approach
c) Dynamical mean-field theory
d) Cluster mean-field theories
5. Applications [4,6,7,8]
a) Collective magnetism
b) Mott transition
c) High-Tc superconductivity
d) Luttinger sum rule

**References:**


[1] J.W. Negele and H. Orland: "Quantum Many-Particle Systems" (Addison-Wesley)
[2] A.A. Abrikosow, L.P. Gorkov and I.E. Dzyaloshinski: "Methods of Quantum Field Theory in Statistical Physics" (Prentice-Hall)
[3] A.L. Fetter, J.D. Walecka: "Quantum Theory of Many-Particle Systems" (McGraw-Hill)
[4] F. Gebhard: "The Mott Metal-Insulator Transition" (Springer)
[5] U. Schollwoeck: "The density-matrix renormalization group in the age of matrix product states", arXiv:1008.3477
[6] M. Potthoff: "Non-perturbative construction of the Luttinger-Ward functional", Condens. Mat. Phys. 9, 557 (2006), cond-mat/0406671
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[8] Th. Maier, M. Jarrell, Th. Pruschke, M.H. Hettler: "Quantum Cluster Theories", Rev. Mod. Phys. 77, 1027–1080 (2005), arXiv:cond-mat/0404055
[9] M. Potthoff: "Systematics of approximations constructed from dynamical variational principles" in: "Effective models for low-dimensional strongly correlated electrons", Eds.: G. Batrouni and D. Poilblanc, p. 41 (AIP Proceedings), cond-mat/0511729
[10] M. Potthoff: "Dynamical variational principles for strongly correlated electron systems", Adv. Solid State Phys. 45, 135 (2005), cond-mat/0503715


**Training:** Blackboard discussions. Problem solving.

*05/10/2010*


## Miss Amy Briffa

School of Physics and Astronomy, University of Birmingham, United Kingdom


### Generalising spin ice: the magnetic ground state of pyrochlore $Gd_2Ti_2O_7$


**Abstract:** Recently there has been much interest in the magnetic monopole excitation of spin ice. This is a consequence of the 'ice rules' which give rise to a large low energy degeneracy. Both spin ice and gadolinium titanate have a pyrochlore lattice of corner sharing tetrahedra. In spin ice the strong crystal field interactions mean that the spins have an Ising character: they are constrained to point along the local tetrahedral axes. The degenerate ground state configurations consist of all tetrahedra containing two spins pointing inwards and the remaining two outwards (and, therefore, each tetrahedron has a ferromagnetic component). In contrast, in gadolinium titanate the antiferromagnetic nearest neighbour Heisenberg interaction is dominant, which is extremely frustrated on the pyrochlore lattice. This gives rise to a similar but much larger degeneracy than is seen in spin ice.

We investigate the residual degeneracy in gadolinium titanate. Firstly we enforce the Mössbauer experimental restriction that the spins are confined to planes perpendicular to the local crystal directions in order to reduce the degeneracy to a manageable level. This XY-like anisotropy can be seen to be a result of minimising the dipolar interactions. Our assumptions generate a more complex analogue of the ice rules for gadolinium titanate.

Theoretically the frustrated antiferromagnetic interaction leads to the absence of classical long range magnetic order in the ground state. $Gd_2Ti_2O_7$ shows precisely this behaviour by magnetically ordering well below the Curie-Weiss temperature as a result of other much weaker interactions becoming relevant. We require that our rules discussed above are also consistent with the neutron scattering experiments, which show a magnetic scattering vector k = (½ ½ ½). This turns out to lead to two distinct magnetic states which are unrelated to previous proposals. The energetics are complicated. The residual degeneracy appears to be lifted by a compromise between longer range Heisenberg and direct dipolar interactions of a similar energy scale.


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*06/10/2010*


## Dr. Valentina Brosco

Dipartimento di Fisica, Università degli Studi di Roma "La Sapienza", Italy


### Low-temperature conductivity of a low-density Rashba electron gas.


**Abstract:** Besides its fundamental relevance to the transport properties of a variety materials, the interplay between spin and orbital degrees of freedom is of crucial importance for spintronics experiments and applications. In these regards Rashba spin-orbit interaction arising in low dimensional heterostructures is of special interest. Indeed, as it has been demonstrated in recent experiments carried on LaAlO3/SrTiO3 interfaces and on surface states in surface alloys, it is possible to tune its strength via external gates and material engineering. Motivated by these experiments, in the present work we

investigate the consequences of low charge carrier densities on the low-temperature conductivity of a two-dimensional electron gas with strong Rashba spin-orbit coupling. We show how the small value of the Fermi energy compared to Rashba spin-orbit coupling leads to an effective reduction of the dimensionality. We analyze both the conductivity in Born approximation and the weak-localization correction.

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*07/10/2010*


## Mr. Wojciech Brzezicki

M. Smoluchowski Institute of Physics, Jagiellonian University, Krakow, Poland


### Hidden Dimer Order in the Orbital Compass Model


**Abstract:** We introduce an exact spin transformation that maps frustrated $Z_{i,j}Z_{i,j+1}$ and $X_{i,j}X_{i+1,j}$ spin interactions along the rows and columns of the orbital compass model (OCM) on an $L\times L$ square lattice to $(L-1)\times (L-1)$ quantum spin models with $2(L-1)$ classical spins. Using the symmetry properties we unravel the hidden dimer order in the OCM, with equal two-dimer correlations $\langle X_{i,i}X_{i+1,i}X_{k,l}X_{k+1,l}\rangle$ and $\langle X_{i,i}X_{i+1,i}X_{l,k}X_{l+1,k}\rangle$ in the ground state, which is independent of the actual interactions. This order coexists with Ising-like spin correlations which decay with distance.


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*08/10/2010*


## Mr. Stefanos Kourtis

Leibniz Institute for Solid State and Materials Research, Dresden, Germany


### Coexistence of superconducting and charge density wave states


**Abstract:** Phase coexistence is a subject relevant to several systems of interest in the scope of condensed matter physics. From optical lattices loaded with ultra-cold atoms to high temperature superconductors, the interplay between condensed phases is a decisive factor for the properties of the physical system under consideration. Here we consider conventional and unconventional charge density wave and superconducting states with or without the presence of spontaneous d-wave Fermi surface deformation (also called Pomeranchuk instability). In a numerical mean-field treatment we find that under certain circumstances these states can either compete or coexist, possibly giving rise to a staggered superconducting state.

*11/10/2010*


## Mr. Neeraj Kumar

Department of Condensed Matter Physics and Material Science, Tata Institute of Fundamental Research, Mumbai, India


### Magnetic properties of EuPtSi3 single crystals


**Abstract:** Single crystals of EuPtSi3, which crystallize in the BaNiSn3-type crystal structure, have been grown by high temperature solution growth method using molten Sn as the solvent. EuPtSi3 which lacks the inversion symmetry and has only one Eu site in the unit cell is found to be an antiferromagnet with two successive magnetic transitions at TN1 = 17 K and TN2 = 16 K, as inferred from magnetic susceptibility, heat capacity and 151Eu MÃ¶ssbauer measurements. The isothermal magnetization data for H // [001] reveal a metamagnetic transition at a critical field Hc = 1 T. The magnetization saturates to a moment value of 6.43 Î¼B/Eu above 5.9 T and 9.2 T for H // [001] and [100] respectively, indicating that these fields are spin-flip fields for the divalent Eu moments along the two axes. A magnetic (H, T) phase diagram has been constructed from the temperature dependence of isothermal magnetization data. In my talk Iâ€™ll show above mentioned results and discuss the possible origin of anisotropic behavior in EuPtSi3.


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*12/10/2010*


## Mr. Nicolaus Parragh

Vienna University of Technology, Austria


### LDA+DMFT study of fotoemission and optical properties of V2O3


**Abstract:** The metal-insulator transition (MIT) in Chromium-doped Vanadium Sesquioxide has received much attention since its discovery in 1969. After several attempts for describing it in the framework of single-band Hubbard models some key experiments revealed the intimate multi-band nature of this material. Here I will present the results of a recent experiment combining Infrared (IR), Scanning Photoemission Microscopy (SPEM) and X-ray Diffraction (XRD) and local density approximation + dynamical mean field theory (LDA+DMFT) calculations showing for the first time that microscopic islands characterized by bad metallic behaviour form close to the first order MIT. The bad metallicity is only partially reduced by applying pressure, pointing to a non-trivial interplay between the orbital degrees of freedom across different paths in the MIT of V2O3.

*13/10/2010*


## Mr. Christopher Thomas

Instituto de Fisica, Universidade Federal do Rio Grande do Sul, Porto Alegre - RS, Brazil


### Application of the S=1 underscreened Anderson lattice model to Kondo uranium and neptunium compounds


**Abstract:** Magnetic properties of uranium and neptunium compounds showing the coexistence of Kondo screening effect and ferromagnetic order are investigated within the Anderson lattice Hamiltonian with a two-fold degenerate f-level in each site, corresponding to 5f2 electronic configuration with S=1 spins. A derivation of the Schrieffer-Wolff transformation is presented and the resulting Hamiltonian has an effective f-band term, in addition to the regular exchange Kondo interaction between the S=1 f-spins and the s=1/2 spins of the conduction electrons. The obtained effective Kondo lattice model can describe both the Kondo regime and a weak delocalization of 5f-electron. Then we calculate the Kondo and Curie temperatures as a function of the Kondo exchange interaction constant J_K, the magnetic intersite exchange interaction J_H and the effective f-bandwidth. We deduce, therefore, a phase diagram which can yield the coexistence of Kondo effect and ferromagnetic ordering and can account for the pressure dependence of the Curie temperature of uranium compounds such as Ute.


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*14/10/2010*


## Mr. Lev Vidmar

Department for Theoretical Physics (F-1), Jozef Stefan Institute, Ljubljana, Slovenia


### Gain of the kinetic energy of bipolarons in the t-J Holstein model based on electron-phonon coupling


**Abstract:** Not long after discovery of cuprates a conjecture appeared that the onset of superconducting order is connected to lowering of the kinetic energy of charge carriers [1,2]. This was supported by the measurements of optical conductivity, which show a decreased sum-rule (and correspondingly the total kinetic energy) when entering the superconducting state [3]. In my seminar I will show that the formation of a bipolaron with d-wave symmetry [4] in context of the t-J model does not lead to lowering of the kinetic energy, calculated per hole. However, in the t-J Holstein model at the values of EPH coupling in the cross-over between the weak-coupling and strong-coupling regime we find a bipolaron which develops a lower effective mass than two unbound polarons and consequently lowers the total kinetic energy [5]. This effect is mostly pronounced for the parameters of the t-J model, which correspond to the experimentally relevant values for the cuprates. [1] J. E. Hirsch and F. Marsiglio: Physica C 162, 591 (1989) [2] J. E. Hirsch: Science 295, 2226 (2002) [3] H. J. A. Molegraaf, C. Presura, D. van der Marel, et al.: Science 295, 2239 (2002) [4] L. Vidmar, J. Bonca, S. Maekawa and T. Tohyama: Physical Review Letters 103, 186401 (2009) [5] L. Vidmar and J. Bonca: submitted

## 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

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