Effective models for low-dimensional strongly correlated systems
September 12-16 – Peyresq (France)

NB: timing is 45’+10’ for invited talks & 20’+5’ for contributed talks.

Monday Sept. 12

12:30 : LUNCH
14:45-15:00 : Presentation of the European Science Foundation (ESF) – Jakob YNGVASON (Standing Committee for Physical and Engineering Sciences)

15:00 – 19:00: Effective hamiltonians *(Chairman: Georges BATROUNI)*

15:00-16:00 : "Computing Effective Hamiltonians of Doped and Frustrated Antiferromagnets by CORE" – Assa AUERBACH
16:00-17:00 : "Numerical Contractor Renormalization applied to strongly correlated systems" – Sylvain CAPPONI

BREAK

17:30-18:30 : "Analytical effective theories for exotic magnets" – Roderich MÖSSNER
18:30-19:00 : "Phase separation in the two-dimensional Bose-Hubbard model with ring exchange” – Valery ROUSSEAU

19:30 : DINNER

Tuesday Sept. 13

8:45 – 12:15: Mott insulators & Quantum Magnetism *(Chairman: T. Maurice RICE)*

8:45-9:45 : "Effective Models of Frustrated Quantum Magnets" – Frédéric MILA
9:45-10:45 : "Spinon and Holon Spectra in One-Dimensional Mott Insulators” – Sadamichi MAEKAWA

BREAK

11:15-12:15 : "Insight from Path Integral Renormalization Group Method” – Masatoshi IMADA

12:30 : LUNCH
14:45 – 19:15 : Superconductors (Chairman: Didier POILBLANC)

14:45-15:45 : "The Luttinger Sum Rule in Doped Spin Liquids" – T. Maurice RICE
15:45-16:45 : "Spin fluctuations in cuprates as the key to high-$T_c$" – Peter PRELOVSEK

BREAK

17:15-18:15 : "Global phase diagram of the high-$T_c$ cuprates" – Shoucheng ZHANG
18:15-19:15 : "Unconventional superconductivity in non-centrosymmetric materials" – Manfred SIGRIST

19:30 : DINNER

Wednesday Sept. 14

8:45-12:15 : Competing phases (Chairman: Werner HANKE)

8:45-9:45 : "Phase diagram of the half-filled two-dimensional $SU(N)$ Hubbard-Heisenberg model" – Fakher ASSAAD
9:45-10:45 : "$d$-wave RVB states of fermionic atoms in optical lattices" – Matthias TROYER
11:15-12:15 : "Phase competition in transition metal oxides" – Adriana MOREO

12:30 : LUNCH

14:45 – 19:15 : Afternoon

FREE

19:30 : DINNER

Thursday Sept. 15

8:45 – 12:15 : Variational and other approaches (Chairman: Manfred SIGRIST)

8:45-9:45 : "Kosterlitz-Thouless critical behavior close to a two dimensional metal-insulator transition" – Sandro SORELLA
9:45-10:15 : "Supersolid bosons on the triangular lattice" – Stefan WESSEL

BREAK

10:45-11:45 : "Quantum-cluster theories from a variational perspective" – Michael POTTHOFF
11:45-12:15 : "Spiral Spin Density Waves and Transport Anisotropies in Underdoped Cuprate Superconductors" – Valeri KOTOV

12:30 : LUNCH
15:00 – 19:00: Progress in DMRG computations (Chairman: Alejandro MURAMATSU)

15:00-16:00: "Recent Developments in DMRG" – Steve WHITE
16:00-17:00: "Recent Developments in the DMRG applied to Quantum Chemistry and to Linear-Response Dynamics" – Reinhard NOACK

BREAK

17:30-18:30: "Applications of time-dependent DMRG" – Ulrich SCHOLLWÖCK
18:30-19:00: "Strongly Correlated Quantum Systems out of Equilibrium: Collapse and Revival Starting From a Luttinger Liquid" – Salvatore MANMANA

19:30: DINNER

Friday Sept. 16

9:00 – 12:00: Bosonic models (Chairman: Shoucheng ZHANG)

9:00-10:00: "Dynamics in the Boson Hubbard Model" – Richard SCALETTAR
10:00-10:30: "Monte Carlo study of a dynamic Hubbard model" – Frédéric HEBERT

BREAK

11:00-12:00: "Bose-Einstein Condensation with Path integrals" – Werner KRAUTH

12:30: LUNCH

14:00 – 17:30: Cyclic exchange & Cold atoms (Chairman: Frédéric MILA)

14:00-15:00: "Ring Exchanges and Supersolidity in solid 4He" – David CEPERLEY
15:00-16:00: "Superfluid to valence-bond-solid transition in a 2D hard-core boson model with 4-site interactions" – Anders SANDVIK

BREAK

16:30-17:30: "Numerically exact simulations for ultra-cold atoms in and out of equilibrium" – Alejandro MURAMATSU

19:30: DINNER

Saturday Sept. 17

Departure of bus to NICE at 10:00 am.
Abstracts

author: Fakher ASSAAD (Würzburg)
title: Phase diagram of the half-filled two-dimensional SU(\(N\)) Hubbard-Heisenberg model

abstract: We investigate the phase diagram of the half-filled SU(\(N\)) Hubbard-Heisenberg model with hopping \(t\), exchange \(J\) and Hubbard \(U\), on a two-dimensional square lattice. In the large-N limit, and as a function of decreasing values of \(t/J\), the model shows a transition from a d-density wave state to a spin dimerized insulator. A similar behavior is observed at \(N = 6\) whereas at \(N = 2\) a spin density wave insulating ground state is stabilized. The \(N = 4\) model, has a d-density wave ground state at large values of \(t/J\) which as a function of decreasing values of \(t/J\) becomes unstable to an insulating state with no apparent lattice and spin broken symmetries. In this state, the staggered spin-spin correlations decay as a power-law, resulting in gapless spin excitations at \(q = (\pi, \pi)\). Furthermore, low lying spin modes with small spectral weight are apparent around the wave vectors \(q = (0, \pi)\) and \(q = (\pi, 0)\). This gapless spin liquid state is equally found in the SU(4) heisenberg (\(U/t \rightarrow \infty\)) model in the self-adjoint antisymmetric representation. An interpretation of this state in terms of a pi-flux phase is offered. Our results stem from projective (\(T = 0\)) quantum Monte-Carlo simulations on lattice sizes ranging up to \(24 \times 24\).

author: Assa AUERBACH (Haifa)
title: Computing Effective Hamiltonians of Doped and Frustrated Antiferromagnets by CORE

abstract: A review of the CORE method as a systematic derivation of low energy effective hamiltonian will be given, with emphasis on Its differences and advantages over traditional perturbative (weak/strong links) real space RG. For the 2D Hubbard model we derive a plaquette boson-fermion model which connects to much of the low temperature phenomenology of high-\(T_c\) cuprates. For the \(S = 1/2\) Pyrochlore and Kagome antiferromagnets, the effective hamiltonians predict non magnetic, lattice symmetry breaking ground states with a large density of low energy singlets as previously observed in exact diagonalization studies.


author: Sylvain CAPPONI (Toulouse)
title: Numerical Contractor Renormalization applied to strongly correlated systems

abstract: We demonstrate the utility of the numerical Contractor Renormalization (CORE) method for strongly correlated systems by studying one and two dimensional model cases. We put a special emphasis on diagnostic tools (such as the density matrix of the local building block) to ascertain the validity of the basis truncation. This approach, giving complementary information to analytical treatments of the CORE Hamiltonian, can be used as a semi-quantitative numerical method.

abstract: Kim and Chan have found indications that solid $^4$He might be a supersolid. The tunnelling frequencies for ring exchanges in bulk solid helium were calculated [1] using Path Integral Monte Carlo by finding the free energy for making a path that begins with the atoms in one configuration and ends with a permutation of those positions. Those exchange frequencies are found to be described by a simple lattice model which does not show superfluid behavior. Calculations [2] of the ODLRO also do not show supersolid behavior. However, simulations of $^4$He absorbed in Vycor [3] find that $^4$He forms a layered structure with the first layer solid-like and highly localized, the second layer disordered with some atoms delocalized and possibly superfluid. This mechanism can only be relevant for bulk $^4$He for a very disordered crystal.


abstract: A few years ago, Hirsch introduced a new class of fermionic “dynamic” Hubbard models [1]. These models describe relaxation of atomic orbitals when electrons are added to orbitals already occupied, a phenomenon that is not included in the conventional Hubbard model. In practice, the relaxation of orbitals is described by an on-site repulsion that becomes a dynamic fluctuating variable. The inclusion of such a term may lead to the appearance of superconductivity.

So far, numerical studies of these models have been limited to very small clusters or to one dimensional systems [2]. We applied standard quantum Monte Carlo techniques (the determinant algorithm) to study in detail the properties of one of these models in two dimensions. We systematically compared our results with a normal Hubbard model. Our preliminary results show that the presence of the dynamic interaction improves the behavior of the pair-field susceptibility, hence showing the possible presence of superconductivity.


abstract: Recent progress on the path integral renormalization group (PIRG) method and applications to Hubbard-type models are discussed. Quantum-number projected PIRG enables us to study the phase diagram of the Hubbard model under geometrical frustration effects, revealing first-order Mott transition and emergence of quantum spin liquid phase on the verge of the transition. The results stimulated studies on the overall criticality of the Mott transition and suggested the breakdown of the Ginzburg-Landau-Wilson scenario in the quantum and marginally quantum regime of the transition, leading to a new universality class. The PIRG method has also been extended and been combined with the first-principles method for clarifying electronic structure of realistic systems.
Valery KOTOV (Lausanne)

**title:** Spiral Spin Density Waves and Transport Anisotropies in Underdoped Cuprate Superconductors

**abstract:** I will discuss the physics behind the incommensurate magnetism in the underdoped region and its relation to the anisotropies in DC and AC transport at low temperature (frequency). The emphasis will be on theories that address these issues starting from non-collinear (spiral) order in the ground state, rather than the “stripe” scenarios where collinear spin density waves co-exist with charge order.

In particular I will discuss, within the spiral approach: (1.) The change of the incommensurate direction by 45 degrees across the spin-glass–superconductor boundary in La$_{2-x}$Sr$_x$CuO$_4$ (LSCO), as well as more general theoretical issues related to the stability of the spiral states. (2.) Calculations of the transport anisotropy (in the spin-glass phase) in the low-temperature, variable-range hopping regime. We have found an anisotropy of 80-90 percent, in very good agreement with experiments in LSCO.


Werner KRAUTH (Paris)

**title:** Bose-Einstein Condensation with Path integrals

**abstract:** The concept of winding numbers allows to express the ‘superfluid density’ of a bosonic system in terms of path integrals. I will discuss that the ‘condensate fraction’ of an (ideal) Bose gas can be expressed through the probability distribution of the path-cycle lengths. This leads to a direct-sampling Monte Carlo algorithm for the ideal Bose gas.

Sadamichi MAEKAWA (Sendai)

**title:** Spinon and Holon Spectra in One-Dimensional Mott Insulators

**abstract:** The spin-charge separation is one of the key concepts in strongly correlated electron systems [1]. Motivated by the recent angle-resolved photoemission spectroscopy (ARPES) experiments in one-dimensional Mott insulators [2], we study the single-particle excitation in the one-dimensional Hubbard model at half-filling, and examine the evolution of the spinon and holon excitations by temperature and the interaction in the exact numerical diagonalization (ED), dynamical density matrix renormalization group (DDMRG) and determinantal quantum Monte Carlo (QMC) methods [3]. The ARPES data [2,4] are discussed in the light of the numerical results. This work has been done in collaboration with H. Matsueda, N. Bulut and T. Tohyama [3].

**author:** Salvatore MANMANA (Stuttgart and Marburg)
**title:** *Strongly Correlated Quantum Systems out of Equilibrium: Collapse and Revival Starting From a Luttinger Liquid*

**abstract:** Only little is known about the physics of time-dependent problems in the field of strongly correlated quantum systems due to the lack of effective controlled approaches. Recent progress for one-dimensional systems makes it possible to numerically study phenomena such as the collapse and revival of a Bose-Einstein condensate of bosonic atoms trapped in optical lattices [1]. In our approach, we investigate a similar situation for a system of spinless fermions on a one-dimensional lattice with nearest-neighbor repulsion $V$ and nearest-neighbor hopping $t$ at half filling. Starting from a Luttinger liquid phase we suddenly increase the interaction to a value associated with an insulating ground state. Using a variant of the time-dependent density matrix renormalization group method (DMRG) that approximates the time-evolution operator within a Krylov space, we observe oscillations in the coherence of $\langle n(k) \rangle$, while the local density $\langle n(i) \rangle$ remains constant for periodic systems (see Ref. [2] for preliminary results). The method can treat system sizes large enough to provide insight into the behavior in the thermodynamic limit.


---

**author:** Frédéric MILA (Lausanne)
**title:** *Effective Models of Frustrated Quantum Magnets*

**abstract:** Frustrated quantum magnets are a real challenge to theorists because standard analytical and numerical methods are in serious trouble in most cases. Significant progress has been recently achieved however on the basis of two kinds of effective models, Quantum Dimer Models and hard-core boson models. In the case of Quantum Dimer Models, I will review the evidence in favour of a Resonating Valence Bond (RVB) spin-liquid phase, and I will discuss under which circumstances such models might be good effective models. For hard-core boson models, which have been successfully used for quite some time for ladders and other non-frustrated models of coupled dimers, I will describe the specificities introduced by frustration (reduced kinetic energy, correlated hopping,...) and I will review our current understanding of such models.

---

**author:** Roderich MÖSSNER (Paris)
**title:** *Analytical effective theories for exotic magnets*

**abstract:** There has been tremendous progress – experimentally, numerically and analytically – in the study of exotic magnets over the last few years. In this talk, I will focus on simple theories, tractable to a large degree analytically, which allow the development of a qualitative understanding of the unusual phases and phase transition encountered in this field.
**author:** Adriana MOREO (Oak Ridge)
**title:** Phase competition in transition metal oxides

**abstract:** The properties of manganites, exhibiting colossal magnetoresistance, and high critical temperature cuprates are studied numerically using a variety of microscopic and phenomenological models. Inhomogeneous ground states are discovered in many regions of parameter space. It is shown how colossal magnetoresistance arises in manganites due to the peculiar reaction of complex inhomogeneous states to small disturbances. Comparison with experimental data lends support to our theoretical results. Based in similar inhomogeneous characteristics observed in models for high-$T_c$ cuprates, as well as in real materials using novel experimental approaches, we predict the possibility of colossal effects in the cuprates as well as an alternative mechanism for the onset of high-$T_c$ superconductivity. The interplay of magnetic, charge and lattice degrees of freedom will be discussed.

**author:** Alejandro MURAMATSU (Stuttgart)
**title:** Numerically exact simulations for ultra-cold atoms in and out of equilibrium

**abstract:** We discuss in this talk ground-state and nonequilibrium properties of ultracold atoms in optical lattices in the strongly correlated limit. Starting with bosonic [1] and fermionic [2,3] Mott-insulators on the basis of quantum Monte Carlo simulations, where local quantum criticality is displayed in one dimension, we continue with exact results for hard-core bosons in one dimension, showing their universal properties in equilibrium [4], and their nonequilibrium dynamics, where a quasi-condensate emerges at finite momentum from a Fock state [5]. Moreover, it will be shown that the free evolution of an initially confined quasi-condensate of hard-core bosons leads to a bosonic gas with a Fermi edge, and hence a fermionization that can only be obtained out of equilibrium [6].


**author:** Reinhard NOACK (Marburg)
**title:** Recent Developments in the DMRG applied to Quantum Chemistry and to Linear-Response Dynamics

**abstract:** I will discuss two new developments in DMRG methods. One is the use of ideas from quantum information theory to improve the convergence of DMRG calculations. I will concentrate on the application of these ideas to nonlocal problems such as quantum chemistry. The second is the formulation of efficient new methods to calculate dynamics in the time domain. In particular, I will compare the calculation of linear-response dynamics in the time domain with frequency-domain methods such as the dynamical DMRG (DDMRG).
Cluster approximations are promising approaches to low-dimensional systems of correlated electrons. Starting from the grand potential as a functional of the self-energy, non-perturbative and thermodynamically consistent approximations can be constructed by constraining the search for stationary points. This idea is characteristic for the self-energy-functional approach (SFA). The SFA can be used as a general framework to classify different existing and to develop new quantum-cluster theories. Different cluster schemes, including the cellular dynamical mean-field theory, the dynamical cluster approximation and the variational cluster-perturbation theory, will be discussed in the context of the competition between antiferromagnetism and d-wave superconductivity.

Spin fluctuations represent the lowest established energy scale in cuprates and are crucial for the understanding of anomalous normal state properties and superconductivity in these materials. I will describe the memory-function approach to the spin response in the $t-J$ model, which combined with numerical results for small systems are able to explain the anomalous scaling at low doping and the crossover to the Fermi-liquid-like behaviour in overdoped systems. Within the superconducting phase the theory reproduces the resonant peak and its peculiar double dispersion. Such spin fluctuations are then used as the input for the theory of superconductivity within the $t-J$ model, where we show that an important role is played also by the next-nearest-neighbour hopping parameter $t'$.

The Luttinger Sum Rule is usually considered for Landau Fermi liquids in which the single particle Green’s function $G(k,0)$ changes sign at the Fermi surface by passing thru’ infinity. However the general proof allows also for a sign change at which $G$ has a zero [1,2]. A recent analysis [3] considers a model of 2-leg Hubbard ladders weakly coupled by a small long range interladder tunneling. At half-filling a semimetallic state with small Fermi pockets is induced beyond a threshold tunneling strength. The sign changes in $G(k,0)$ relevant for the Luttinger Sum Rule now take place at surfaces with both zeroes and infinities. The zero surfaces differ from the minimum gap surfaces. The latter are often used in ARPES experiments on undercuprates to obtain an underlying Fermi surface but this procedure leads to problems with the Luttinger Sum Rule.

We show that hard-core and soft-core bosons in two dimensions with a ring exchange term exhibit a tendency for phase separation, while it was argued in literature that such systems could give rise to a Bose liquid phase.
author: Anders SANDVIK (Boston)
title: *Superfluid to valence-bond-solid transition in a 2D hard-core boson model with 4-site interactions*

abstract: I will discuss quantum Monte Carlo simulations of a square-lattice hard-core boson model which in addition to the standard hopping term $J$ includes a four-site interaction $K$ (the purely XY-like subset of all cyclic exchange terms on a plaquette). For increasing $K/J$, the ground-state superfluid stiffness is reduced, and for $K/J$ approximately 7.91 it vanishes. At the same point the ground state acquires a columnar order of the valence-bond-solid (VBS) type. This transition has been proposed as a candidate for deconfined quantum-criticality. However, the simulations have so far not confirmed this scenario. The finite-size scaling of the superfluid stiffness and the VBS order is puzzling, in that there is neither a clear-cut scaling consistent with a continuous transition obeying hyperscaling, nor clearly visible discontinuities indicative of a first-order transition. I will present the current state of the simulations and discuss the various possibilities for the nature of the transition.

author: Richard SCALETTAR (Davis)
title: *Dynamics in the Boson Hubbard Model*

abstract: I will summarize two of our group’s recent studies of the dynamical response of the boson Hubbard model. First, we investigate, with QMC simulations, the presence of solitons when a half-filled CDW phase is doped, and determine the associated excitation spectra. In the trapped case, the density profile exhibits the coexistence of Mott insulator, CDW, and superfluid regions. Second, using an exact numerical approach, we study the dipole oscillations of strongly correlated 1D bosons. Far from the regime where a Mott insulator appears in the system, damping is always present and increases for larger initial displacements of the trap, causing dramatic changes in the momentum distribution, $n(k)$. When a Mott insulator is present in the middle of the trap, the center of mass barely moves after an initial displacement, and $n(k)$ remains very similar to its ground state value.


author: Ulrich SCHOLLWÖCK (Aachen)
title: *Applications of time-dependent DMRG*

abstract: A major breakthrough has been provided by the extension of DMRG to the calculation of time-dependent properties also far from equilibrium. In this talk I will discuss the potential of this methodology by showing some applications to the time-evolution of pure and mixed states for the calculation of density evolutions, time-dependent Green’s functions, etc...
**author:** Manfred SIGRIST (Zürich)

**title:** Unconventional superconductivity in non-centrosymmetric materials

**abstract:** The recently discovered heavy Fermion superconductor CePt3Si displays various intriguing properties. The upper critical field exceeds the paramagnetic limit for all field directions. While NMR shows a Hebel-Slichter peak indicating a coherence enhancement, several thermodynamic quantities possess powerlaw behavior consistent with line nodes. The key to the understanding of these features lies in the antisymmetric spin-orbit coupling possible due to the lack of inversion symmetry in CePt3Si. Here even and odd parity pairing states can couple in a specific way. In a model calculation we show that the superposition of an s- and p-wave state can account for the observed phenomena. In addition it is found that in the high field regimes a helical superconducting phase is induced for certain field directions explaining the approximate isotropy of the critical field. Conclusions for other non-centrosymmetric superconductors will be drawn.

---

**author:** Sandro SORELLA (Trieste)

**title:** Kosterlitz-Thouless critical behavior close to a two dimensional metal-insulator transition

**abstract:** We present a variational paradigm to understand the physical properties close to a Mott insulator ground state. The wave function is described by an uncorrelated mean-field state and by a singular density-density Jastrow factor, required for the correct low momentum behavior of the charge correlations. Within this framework, the physical quantities described by this variational ansatz, are mapped onto finite temperature classical averages of a neutral Coulomb gas model in arbitrary dimensions, the positive charges correspond to the sites with doubly occupied sites (doblons) and negative ones to the empty sites (holons). In one dimension this model displays always a confined dielectric phase with a holon-doblon bound state at arbitrary large temperature, whereas in 2D a Kosterlitz-Thouless transition between a high temperature plasma phase with perfect screening and a confined low temperature dielectric phase is found. In the quantum analog described by our variational ansatz the inverse temperature corresponds to the strength of the correlation factor. Thus in one dimension we reproduce the known Mott insulating phase for arbitrary small value of the correlation strength and we obtain in this way all the known low energy properties of the Bethe ansatz exact solution of the Hubbard model at half filling. In two dimension the situation is much more interesting, because with the same ansatz, following the correspondence with the classical model, we predict (and verify numerically by quantum Monte Carlo) that the Mott insulating state appears only for large enough strength of the correlation, whereas below a critical value a charged metallic phase is stabilized with a plasmon gap and Friedel oscillations. The Mott insulating state is characterized by several unconventional properties in two dimensions. For instance the quasiparticle weight is vanishing with non universal power laws.
author: Matthias TROYER (Zürich)
title: *d*-wave RVB states of fermionic atoms in optical lattices

abstract: We study controlled generation and measurement of superfluid *d*-wave resonating valence bond (RVB) states of fermionic atoms in 2D optical lattices. Starting from loading spatial and spin patterns of atoms in optical superlattices as pure quantum states from a Fermi gas, we adiabatically transform this state to an RVB state by change of the lattice parameters. Results of exact time-dependent numerical studies for ladders systems suggest generation of RVB states on timescale smaller than typical experimental decoherence times. This study shows that today the technology exists to build an adiabatic quantum simulator capable of checking whether the Hubbard model on the square lattice has a *d*-wave superconducting ground state.


author: Stefan WESSEL (Stuttgart)
title: Supersolid bosons on the triangular lattice

abstract: We determine the phase diagram of hardcore bosons on a triangular lattice with nearest neighbor repulsion using quantum Monte Carlo simulations. Special attention is devoted to the stability of supersolid phases. Similar to the same model on a square lattice we find that for densities ρ < 1/3 or ρ > 2/3 a supersolid phase is unstable and the transition between a commensurate solid and the superfluid is of first order. At intermediate fillings 1/3 < ρ < 2/3 we find an extended supersolid phase even at half filling ρ = 1/2. We discuss the nature of the supersolid phase, its emergence from an order-by-disorder mechanism, and the possibility of realizing such phenomena in ultra-old atoms on optical lattices.

author: Steve WHITE (Irvine)
title: Recent Developments in DMRG

abstract: In the last two years ideas and people from the field of quantum information have had an enormous impact on DMRG and its capabilities. I will review these developments with examples from our own work on real time dynamics and finite temperature algorithms. I will briefly discuss recent advances in disordered systems, periodic boundary conditions, and two dimensions.

author: Shoucheng ZHANG (Stanford)
title: Global phase diagram of the high-\textit{T}_c cuprates.

abstract: We propose a bosonic effective quantum Hamiltonian based on the projected \textit{SO}(5) model with extended interactions, which can be derived from the microscopic models of the cuprates. The global phase diagram of this model is obtained using mean-field theory and the quantum Monte Carlo simulation. We show that this single quantum model can account for most salient features observed in the high-\textit{T}_c cuprates, with different families of the cuprates attributed to different traces in the global phase diagram. A particular prediction of this theory is the checkerboard state of the *d*-wave hole pairs formed at certain magic filling fractions. I shall describe various properties of this state and present evidence that this novel state has been detected in recent STM and transport experiments.
Participants

Fakher ASSAAD
Institut für Theoretische Physik und Astrophysik
Universität Würzburg
assaad@physik.uni-wuerzburg.de

Assa AUERBACH
Physics Department
Technion, Haifa
assa@physics.technion.ac.il

George BATROUNI
Institut Non Linéaire de Nice
University of Nice
george.batrouni@inln.cnrs.fr

Sylvain CAPPONI
Laboratoire de Physique Théorique
UMR5152 Toulouse
capponi@irsamc.ups-tlse.fr

David CEPERLEY
Beckman Institute
University of Illinois at Urbana-Champaign
ceperley@uiuc.edu

Werner HANKE
Institut für Theoretische Physik und Astrophysik
Universität Würzburg
hanke@physik.uni-wuerzburg.de

Frédéric HEBERT
Institut Non Linéaire de Nice
University of Nice
frédéric.hebert@inln.cnrs.fr

Masatoshi IMADA
Institute for Solid State Physics
University of Tokyo
imada@issp.u-tokyo.ac.jp

Valeri KOTOV
Institut de physique des phénomènes physiques
Ecole polytechnique fédér ale de Lausanne
valeri.kotov@epfl.ch

Werner KRAUTH
Laboratoire de Physique Statistique
Ecole Normale Supérieure de Paris
krauth@lps.ens.fr

Andreas LÄUCHLI
Institut Romand de Recherche Numérique en Physique des Matériaux
Ecole polytechnique fédérale de Lausanne
lauchli@comp-phys.org

Netanel LINDNER
Physics Department
Technion, Haifa
lindner@tx.technion.ac.il

Sadamichi MAEKAWA
Institute for Materials Research
Tohoku University, Sendai
maekawa@imr.tohoku.ac.jp

Matthieu MAMBRINI
Laboratoire de Physique Théorique
UMR5152 Toulouse
mambrini@irsamc.ups-tlse.fr

Salvatore MANMANA
Institut für theoretische Physik III
Universität Stuttgart
salva@theo3.physik.uni-stuttgart.de

Frédéric MILA
Institut de théorie des phénomènes physiques
Ecole polytechnique fédérale de Lausanne
Frederic.Mila@epfl.ch

Shin MIYAHARA
Department of Physics
Aoyama Gakuin University
miyahara@phys.aoyama.ac.jp

Adriana MOREO
Oak Ridge National Lab.
University of Tennessee
amoreo@utk.edu