ICTS Condensed Matter Programme 2011 Conference

Dec 19 - 22, 2011

Abstracts

at

Department of Physics,

Indian Institute of Science, Bangalore 560012, India

Organizing Institutions

International Centre for Theoretical Sciences
Department of Theoretical Physics
Tata Institute of Fundamental Research
Homi Bhabha Road,
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Indian Institute of Science
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ICTS Condensed Matter Programme 2011

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Programme

Monday December 19, 2011

9:00 am – 9:30 am	***Registration***
9:30 am – 9:45 am	***H.R.Krishnamurthy / Spenta Wadia*** **Welcoming remarks**
9:45 am – 10:30 am	***C N R Rao*** **New routes to multiferroics and magnetoelectrics**
10:30am – 11:00 am	**TEA BREAK**
11:00am – 11:45 am	***Peter Littlewood*** **Polariton Condensation and Collective Dynamics**
11:45am – 12:30 pm	***A.K.Sood*** **Femtosecond spectroscopy of electron and phonon relaxation in iron pnictide superconductors**
12:30 pm – 1:30 pm	**LUNCH**
1:30 pm – 2:15 pm	***D.D Sarma*** **The curious case of NiS**
2:15 pm – 3:00 pm	***Sriram Shastry*** **Extremely Correlated Fermi Liquids**
3:00 pm – 3:30 pm	**TEA BREAK**
3:30 pm – 4:15 pm	***Antoine Georges*** **Strong correlations from Hund's rule coupling**
4:15 pm – 5:00 pm	***Mohit Randeria*** **Viscosity of Strongly Interacting Fermi Systems**
5:00 pm – 5:30 pm	**BREAK**
5:30 pm – 7:30 pm	**FELICITATION FUNCTION** **For Prof. T.V.Ramakrishnan in faculty Hall, IISc.**

Tuesday December 20, 2011

09:00 am – 09:45 am *Zahid Hasan*
Topological surface states in topological insulators

09:45 am -10:30 am *Ashvin Vishwanath*
Topological phases in correlated solids

10:30 am – 11:00 am **TEA BREAK**

11:00 am – 11:45 am *Jay Deep Sau*
The return of Majorana : the end of a 75 year-old search?- looking for Majorana fermions in condensed matter

11:45 am – 12:30 pm *G. Baskaran*
Quantum spin liquids – A status report

12:30 pm – 1:30 pm **LUNCH**

1:30 pm – 2:15 pm *Krishnendu Sengupta*
Dynamics of ultracold atoms in optical lattices

2:15 pm – 3:00 pm *Arun Paramekanti*
Chiral Mott insulator of bosons in a fully frustrated boson Hubbard model

3:00 pm – 3:30 pm **TEA BREAK**

3:30 pm – 4:15 pm *Pinaki Majumdar*
Thermal fluctuations in Fermi superfluids

4:15 pm – 5:00 pm *E. MÜller-Hartmann*
Wannier functions for hybridizing states of transition metal oxide chains and ladders

5:00 pm – 5:45 pm *Arghya Taraphder*
Preformed excitons and charge-density waves in transition metal dichalcogenides

Wednesday December 21, 2011

09:00 am – 09:45 am ***David. E. Logan***
Two-channel Kondo physics in impurity chains and rings

09:45 am -10:30 am ***Pratap Raychaudhuri***
Phase fluctuations and pseudogap state in a disordered conventional superconductor, NbN

10:30 am – 11:00 am **TEA BREAK**

11:00 am – 11:45 am ***S. Ramakrishnan***
Strongly correlated superconductivity in non-magnetic d-band superconductors

11:45 am – 12:30 pm ***K. Maiti***
Dichotomy of pseudogap and SDW phase in $CaFe_2As_2$ - an ARPES study

12:30 pm – 1:30 pm **LUNCH**

1:30 pm – 2:15 pm ***Suchitra Sebastian***
Nodal pocket yielding multiple quantum oscillation frequencies in the underdoped cuprate $YBa_2Cu_3O_{6+x}$

2:15 pm – 3:00 pm ***Maurice Rice***
A Phenomenological Theory of the Anomalous Pseudogap Phase in UnderdopedCuprates

3:00 pm – 3:30 pm **TEA BREAK**

3:30 pm – 4:15 pm ***Sasha Finkelstein***
Quantum kinetic approach to the calculation of thermal transport and the Nernst effect

4:15 pm – 5:00 pm ***Chandan Dasgupta***
Phenomenological Theory of Superconductivity in the Cuprates

5:00 pm – 5:45 pm ***S Ramasesha***
Correlated Electronic Structure of Some Conjugated Electronic Materials

Thursday December 22, 2011

09:00 am – 09:45 am ***Ravin Bhatt***
Two small new pieces in a tale of two giants

09:45 am -10:30 am ***Sudhanshu Mandal***
Anderson Enigma in disordered superconductors

10:30 am – 11:00 am **TEA BREAK**

11:00 am – 11:45 am ***Arindam Ghosh***
Non-Universal Conductance Fluctuations in Graphene

11:45 am – 12:30 pm ***A K Raychaudhuri***
Ferromagnetic insulating state : Is it an electron glass

12:30 pm – 1:30 pm **LUNCH**

1:30 pm – 2:15 pm ***Vikram Tripathi***
Transport in dilute magnetic semiconductor heterostructures

2:15 pm – 3:00 pm ***R. Shankar***
Anomalous Quantum Hall states in an optical lattice

3:00 pm – 3:45 pm ***V B Shenoy***
Fermions in synthetic non-Abelian gauge fields

3:45 pm – 4:00 pm **Concluding remarks**

4:00 pm – 4:30 pm **High Tea**

Abstracts

New routes to multiferroics and magnetoelectrics

C.N.R.Rao
Director, International Centre for Material Science
National Research Professor and Honorary president
Linus Pauling Research Professor
Jawaharlal Nehru Centre for Advanced Scientific Research
Jakkur, Bangalore

Abstract:

Multiferroics are materials which possess both ferroelectric and ferromagnetic properties. Clearly, there is a contradiction here since ferromagnetism requires d-electrons while ferroelectricity generally occurs only in the absence of d-electrons. Several multiferroics demonstrating magnetoelectric coupling effects have, however, been discovered in the past few years, but they generally make use of alternative mechanisms in attaining these properties. Several new ideas and concepts have emerged in the past two years, typical of them being magnetic ferroelectricity induced by frustrated magnetism, lone pair effect, charge-ordering and local non-centrosymmetry. We shall examine multiferroic properties of $BiMnO_3$ in some detail. Charge-order driven magnetic ferroelectricity is interesting in that it occurs in a large number of rare earth manganites, $Ln_{1-x}A_xMnO_3$ (Ln = rare earth, A = alkaline earth), well known for colossal magnetoresistance, electronic phase separation and other properties. Recently, several families of fascinating multiferroics and magnetoelectrics, where ferroelectricity is magnetically driven, have been discovered. In this presentation, we discuss novel routes to multiferroics, with specific examples of materials and their characteristics.

Reference: C.N.R. Rao and C.R. Serrao, J. Mater. Chem. **17**, 4931 (2007).

Polariton Condensation and Collective Dynamics

Peter Littlewood

Cambridge University, UK

Abstract:

Macroscopic phase coherence is one of the most remarkable manifestations of quantum mechanics, yet it seems to be the inevitable ground state of interacting many-body systems. In the last two decades, the familiar examples of superfluid He and conventional superconductors have been joined by exotic and high temperature superconductors, ultra-cold atomic gases, both bosonic and fermionic, and recently systems of excitons, magnons, and exciton-photon superpositions called polaritons, the subject of this talk. An exciton is the solid-state analogue of positronium, made up of an electron and a hole in a semiconductor, bound together by the Coulomb interaction. The idea that a dense system of electrons and holes would be unstable toward an excitonic (electrical) insulator is one of the key ideas underlying metal-insulator transition physics. The further possibility that an exciton fluid would be a Bose-Einstein condensate was raised over 40 years ago, and has been the subject of an extensive experimental search in a variety of condensed matter systems. Such a condensate would naturally exhibit phase coherence. Lately, some novel experiments with planar optical microcavities make use of the mixing of excitons with photons to create a composite boson called a polariton that has a very light mass, and is thus a good candidate for a high-temperature Bose condensate. Good evidence for spontaneous coherence has now been obtained[1], though there are special issues to resolve considering the effects of low dimensionality, disorder, strong interactions, and especially strong decoherence associated with decay of the condensate into environmental photons --- since the condensate is a special kind of laser [2]. Polariton systems also offer an opportunity to use optical pumping to study a system outside equilibrium. Methods of adiabatic rapid passage can be used to populate the energy spectrum, and therefore to excite many body collective modes in analogy to a quantum quench. In extended systems this is predicted to lead to instabilities of the strongly driven phase (Bogoliubov) and amplitude (Higgs) modes[3].

References:

[1] For a brief review, see D.Snoke and P.B. Littlewood, "Polariton Condensates", Physics Today, **63**, 42-47 (2010)

[2] J. Keeling, F. M. Marchetti, M. H. Szymanska, P. B. Littlewood, "Collective coherence in planar semiconductor microcavities", Semiconductor Science and Technology, **22**, R1-26 (2007).

[3] R.T. Brierley, P.B. Littlewood, and P.R. Eastham, "Amplitude mode dynamics of polariton condensates", Phys. Rev. Lett. **107**, 040401 (2011)

Femtosecond spectroscopy of electron and phonon relaxation in iron pnictide superconductors

A. K. Sood
Department of Physics, Indian Institute of Science, Bangalore

Abstract:

This talk will cover our recent work on femtosecond time-resolved reflectivity pump-probe experiments carried out using 40fs laser pulses on parent and doped 122 iron pnictide single crystals. We will show that temperature-dependence of photo-excited carriers in undoped and doped 122 systems reveal information about the spin-density and superconductivity gaps. We will present anomalies in acoustic phonons observed by picosecond ultrasonic spectroscopy and coherent optical phonons across the superconducting and spin-density wave phase transitions.

The curious case of NiS

D. D. Sarma
Solid State and Structural Chemistry Unit,
Indian Institute of Science, Bangalore 560012, India

Abstract:

Hexagonal NiS exhibits a typically paramagnetic metallic state (~ 10^{-5} Ω-cm) at room temperature. On lowering the temperature, it exhibits a first order phase transition at about 263 K. Besides changes in lattice parameters, NiS becomes antiferromagnetic in the low temperature phase. There is a huge array of experimental results available for this system; these suggest a rather unusual ground state of NiS. For example, an intriguing aspect of this phase transition is the transport property, which shows an almost temperature independent resistivity (10^{-3} Ω-cm) down to the lowest temperature (~ 4 K) measured. Obviously, such anomalous transport behaviour cannot be readily categorised as either a metallic one or an insulating one. This has naturally led to several conflicting descriptions of the ground state of NiS from different groups, some attributing the ground state to an anomalous antiferromagnetic insulating state with exceptionally small transport gap, while others claiming it to be an antiferromagnetic metal. This controversy has been additionally fuelled by observations that there is a strong decrease in the number of carriers in the low temperature phase in addition to a loss in the low energy spectral weight in the optical absorption; however, the Drude peak appears to persist, though with a reduced weight, even in this unusual low T phase. So far, it has not been possible to have a conclusive understanding of the nature of the ground state of NiS in spite of the huge body of experimental results being available for both high and low temperature phases.

This makes it interesting to investigate the electronic structure of NiS using ab initio approaches, since the large body of experimental results pertaining to electronic properties, such as electron excitation spectra (photoemission spectra), optical conductivity, Hall measurements, and magnetic state, provides an ideal test-bed for the validity of any interpretation based on such calculations. In this talk, I shall present our recent results on the electronic structure of hexagonal NiS and show that the phase transition at 263 K together with these properties can be understood in terms of a paramagnetic metal to an antiferromagnetic low-density metal transition.

This work has been carried out by Swarup Panda, Indra Dasgupta (both from Indian Association for the Cultivation of Science, Kolkata) and D. D. Sarma.

Relevant references:

Phase transition: Sparks *et al*, JAP 34,1191(1963); Trahan *et al*, PRB, **2**, 2859 (1970)
Transport: Rechard *et al*, J. App Phys, **44,** 1682 (1973)
Magnetic properties: Sparks *et al*, JAP, **34**, 1191 (1963) ; Coey *et al*, PRL, **32**, 1257 (1974)
Hall data: Ohtani *et al*, J. Phys Soc Japan, **37**, 701 (1974);
Photoemission investigations: Nakamura *et al*, PRL, **73**, 2891 (1994); Sarma *et al*, PRL, **80**, 1284 (1998)
Optical data: Barker *et al*, PRB, **10**, 987 (1974); Okamura *et al*, SSC, **112**, 91 (1999)
Earlier theoretical work: Anisimov *et al*, PRB, **44**, 943 (1991); Usuda *et al*, J. Phys Soc Japan, **69**, 744 (1999)

Extremely Correlated Fermi Liquids

Sriram Shastry
UC Santa Cruz

Abstract:

A new framework is reported for calculating the properties of extremely correlated electronic systems with eliminated double occupancy. Based on Schwinger's approach to field theory, it avoids using auxiliary variables, and leads to a low (particle) density expansion with equations that approximately double the complexity of the standard theory for interacting electrons. Concrete results for the one electron spectral function of the t-J model are presented. These show considerable promise in the context of cuprate superconductors. A distinguishing characteristic of this theory is the   low energy long wavelength asymmetry between adding holes and particles. Prospects for its experimental observation are discussed.

References:

1 Extremely Correlated Fermi Liquids', B. S. Shastry, arXiv:1102.2858 (2011), Phys. Rev. Letts. **107**, 056403 (2011).
2 Dynamical Particle Hole Asymmetry in Cuprate Superconductors', B. S. Shastry, arXiv:1110.1032 (2011)

Strong correlations from Hund's rule coupling

Antoine Georges
College de France and Ecole Polytechnique, Paris

Abstract:

The proximity of a Mott insulating state (``Mottness'') is responsible for strong correlations in a number of materials, especially oxides of 3d transition metals. In this talk, I will emphasize that the Hund's rule coupling induces strong correlation effects in materials which are not close to a Mott insulator. This is especially relevant to oxides of 4d transition metals such as ruthenates, and also possibly to iron-based superconductors. The Hund's rule coupling will be shown to have antagonistic ("Janus-faced") effects on the Mott gap and on the quasiparticle coherence scale. For Hund's correlated materials, the self-consistent embedded-atom construction at the heart of Dynamical Mean-Field Theory proves to be especially relevant.

References:

J.Mravlje et al, Phys.Rev.Lett. **106**, 096401 (2011);
L.'de Medici et al. Phys. Rev. Lett **107**, 256401 (2011)

Viscosity of Strongly Interacting Fermions

Mohit Randeria
Ohio State University

Abstract:

The viscosity of strongly interacting quantum fluids has recently been examined in diverse areas of physics — black holes and string theory, quark-gluon plasmas and cold atoms—which, at first sight, appear to have little in common. In this talk I will discuss these connections and focus on the bulk and shear viscosity of ultracold Fermi gases, for which the most controlled experiments should be possible. I will discuss viscosity sum rules, exact relations between transport and thermodynamics across the entire BCS-BEC crossover, and describe implications for the strongly interacting unitary regime.

Topological Surface States in Topological Insulators and Superconductors

Zahid Hasan
Princeton University

Abstract:

Topological Insulators are a new phase of electronic matter which realizes a quantum-Hall-like topological state in the bulk matter via spin-orbit interaction but unlike the quantum Hall liquids can be turned into superconductors. In this talk, I will first briefly review the basic Z2 theory and subsequent experimental discovery of 3D topological insulators. I will then discuss experimental results that demonstrate the properties of topological insulators such as spin-momentum helical locking, non-trivial Berry's phases, mirror Chern number, absence of backscattering or no U-turn, protection by time-reversal symmetry and the existence of room temperature topological order. I will also report the possible exotic roles of superconductivity and magnetism in doped topological insulators and their potential applications.

Topological Phases in Correlated Solids

Ashvin Vishwanath
UC Berkeley

Abstract:

I will discuss recent proposals of novel correlated phases that may be realized in transition metal oxides with strong spin orbit interactions. First, I will describe properties of the Weyl semimetal, a three dimensionalanalog of graphene with unusual topological properties including surface states that take the form of 'Fermi arcs'. Possible realization in a family of iridium oxides with pyrochlore structure is proposed, and comparison with existing experiments will be made. A second family of iriates has been proposed to realize a quantum spin liquid, via mapping to the Kitaev honeycomb lattice model. We will discuss unusual superconducting states that are expected to emerge on doping these systems.

The return of Majorana : the end of a 75 year old search? - looking for Majorana fermions in condensed matter systems.

Jay Deep Sau
University of Maryland, College Park

Abstract:

Majorana fermions are hitherto unobserved exotic excitations, which are their own anti-particles. Despite the nomenclature, Majorana fermions are neither fermions nor bosons but have novel exchange statistics that categorizes them as non-Abelian anyons. Non-Abelian anyons are particles whose exchange is described by a non-Abelian braid matrix instead of the positive sign and negative sign for bosons and fermions respectively. Non-Abelian anyons are associated with a ground state degeneracy of the entire system, which cannot be broken by any external fields. Observing such a topologically robust ground state degeneracy would itself be a fundamental breakthrough in physics. Moreover, a topological ground state degeneracy can be used to create topological quantum computers which are free of the decoherence problem. The Majorana fermion was postulated to describe neutrinos in 1935, but they have never been directly identified experimentally in spite of intensive search in several exotic solid state systems (e.g. specialized and highly fragile fractional quantum Hall states). I will describe our work which suggests that topological superconductors containing Majoranas are fairly generic and a large class of spin-orbit coupled systems can be used to realize Majorana fermions. In fact, the interface of a semiconductor (InAs) and superconductor (Al) in the appropriate parameter regime should have exotic topological properties and Majorana Fermions, in both one, two dimensional and in principle even in three dimensional systems. Possible experimental tests of these ideas range from simple tunneling experiments to test the existence of zero-energy Majorana states to explicit demonstration of non-Abelian statistics through tunneling coupled nanowire arrays and interferometry. Finally, we will discuss how the spin-orbit coupled models motivate an intrinsically number conserving microscopic model of a topological superconductor mediated by attractive interactions, which supports Majorana fermions. The bosonization approach used to study this one-dimensional model makes transparent the connection between the topological order described by Majorana fermions and the emergent Ising order in such spin-orbit coupled superconductors.

Quantum Spin Liquids - A Status Report

G Baskaran.
Institute of Mathematical Sciences, Chennai, India

Abstract:

Quantum spin liquid represents a family of paramagnetic state of interacting spins (Anderson). An unconventional mean field theory (Baskaran, Zou and Anderson) and a gauge field theory (Baskaran, Anderson) of quantum spin liquids have helped, in the last 2 decades, to discover (Wen) quantum order and classify spin liquids using projective symmetry group. Emergent gauge fields in spin liquids, under certain conditions, give rise to Majorana fermion or SU(2)_K Non Abelian anyons character to spinon excitations in 2D, making them potential qbit candidates for topological quantum computation. An exact and extended Fermi surface in the quantum spin liquid has also been realized (Santosh, Shankar and Baskaran) in a Kitaev spin model. On the experimental front novel materials in the ET salt family, pyrochlores, iridates etc. that support spin liquid states have started emerging in the scene. It has been suggested (Baskaran) recently that quantum spin liquid state of an allotrope of a neutral (undoped) graphene, might support high Tc superconductivity.

Dynamics of ultracold atoms in optical lattices

K Sengupta
Department of Theoretical Physics,
Indian Association for the Cultivation of Science,
Kolkata, India

Abstract:

In this talk, I am going to address the dynamics of ultracold bosons in optical lattice for both linear ramp and periodic driving protocols and discuss their properties under such non-equilibrium conditions.

Chiral Mott insulator of bosons in a fully frustrated boson Hubbard model

Arun Paramekanti
Condensed Matter Theory Group
University of Toronto

Abstract:

Josephson junction arrays in a magnetic field, and recent developments in creating synthetic magnetic fields for cold atomic gases, may enable one to study the effect of ``kinetic frustration'' on the Bose Hubbard model. Using a combination of density matrix renormalization group and Monte Carlo simulations, we study the phase diagram of the fully frustrated Bose Hubbard model, with half a flux quantum per plaquette, on a 2-leg ladder. We find and describe a novel Chiral Mott insulator state of bosons in this model at intermediate Hubbard repulsion, sandwiched between a superfluid state with staggered loop currents and a conventional Mott insulator. We discuss connections to electronic states with staggered loop currents and quantum magnets with vector chiral order.

Thermal fluctuations in Fermi superfluids

Pinaki Majumdar
Harish Chandra Research Institute, Allahabad, India

Abstract:

The ground state of a superfluid can be captured quite well within a mean field picture, even at strong coupling. Finite temperature, however, brings to life fluctuations of the `pairing field' which are not captured by mean field theory. The fluctuations primarily involve the phase of the pairing field at strong coupling, and both the amplitude and phase at intermediate coupling. These control the celebrated BCS-BEC crossover. I will discuss a method inspired by the Hubbard-Stratonovich transformation but involving multiple auxiliary classical fields which represent competing channels of long range order. The essentially exact handling of amplitude and phase fluctuations of the auxiliary field within a Monte Carlo scheme allows us to capture the finite temperature BCS-BEC crossover and establish the `metal-insulator' boundary in that problem. I will also discuss the performance of this method in capturing the superfluid-insulator transition in disordered systems, and the coexistence of superfluidity and density wave order for trapped fermions in an optical lattice.

Wannier functions for hybridizing states of transition metal oxide chains and ladders

E. Müller-Hartmann
Institut für Theoretische Physik, Universität zu Köln 77
Zülpicher Strasse, D-50937 Köln, Germany

Abstract:

The talk starts with a tutorial recollection of the Zhang-Rice paper of 1988 which introduced an oxygen hybridizing Wannier state for the 3-band model of copper oxide planes, thereby estabishing not only the concept of what is known as the "Zhang-Rice-singlet", but also a decent perturbative treatment of the 3-band model. For one-dimensional transition metal oxide systems one might tend to expect that poor localization of the Wannier states makes a corresponding treatment fail. We will show that on the contrary one obtains exponentially localized Wannier states, if one only includes into the modeling those oxygen ions which don't contribute directly to the superexchange ("spectator ions"). Several specific examples are given.

Preformed excitons and charge-density waves in transition metal dichalcogenides

A. Taraphder
Indian Institute of Technology, Kharagpur, India

Abstract:

Over the last decade, careful experiments on several transition metal dichalcogenides have thrown up fascinating new challenges and contradicted the traditional view of nesting- or band Jahn-Teller views of the ubiquitous charge density wave instabilities. An intrinsically strong coupling view of the charge density wave state as a Bose condensation of a preformed, normal state excitonic liquid, then emerges as an attractive alternative. We show that this exotic view naturally rationalises a wide range of physical responses in two important members in this series, 2H-TaSe2^(1) and 1T-TiSe2 (2). Using local density approximation plus multi-orbital dynamical mean field theory, we show how spectral and transport responses are quantitatively accounted for in an excitonic liquid scenario. Based thereupon, we claim that the low temperature broken symmetry states should be viewed as instabilities of such a novel "normal" state.

References:

(1) A. Taraphder, S. Koley, N S Vidhyadhiraja and M. Laad, Phys. Rev. Lett. **106**, 236405 (2011)

(2) S. Koley, M. Laad, N. S. Vidhyadhiraja and A. Taraphder; to be submitted..

Two-channel Kondo physics in impurity chains and rings

David E Logan
University of Oxford, UK.

Abstract:

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Phase fluctuations and pseudogap state in a disordered conventional superconductor, NbN

Pratap Raychaudhuri
Tata Institute of Fundamental Research, Mumbai
(http://www.tifr.res.in/~superconductivity/)

Abstract:

In a conventional superconductor, it is normally believed that the transition from a superconducting to a normal state is caused by quasiparticle excitations alone and fluctuation is the phase of the order parameter plays a negligible role on the superconducting state. In this talk, I will review our experimental investigations using scanning tunneling spectroscopy, penetration depth and transport measurements, on two situations when phase fluctuations become important in a conventional superconductor. The first situation deals with very thin films of NbN, with thickness less than the superconducting coherence length. The superconducting transition is these 2-dimensional films are governed by the Kosterlitz-Thouless-Berizinski (KTB) transition, where the superconducting state is destroyed through a proliferation of vortex-antivortex pairs. I will show that while KTB theory provides a consistent description of the variation of superfluid density below TKTB, and resistivity above TKTB, the vortex core energy is different from the value given by the 2D-XY model, which is commonly invoked to understand this transition. The second situation deals with 3-dimensional NbN films when strong disorder is introduced in the form of defects in the crystalline lattice. In the presence of strong disorder we observe that the superconducting state become susceptible to phase fluctuations. Consequently, we observe a pronounced pseudogap state above Tc, where the signature of a gap in the electronic excitation spectrum persists up to a much higher temperature. I will describe the relevance of these measurements on the pseudogap state observed in cuprates (and more recently on pnictides).

References:

1. A. Kamlapure et al., Appl. Phys. Lett. **96**, 072509 (2010).
2. M. Mondal et al., Phys. Rev. Lett. **106,** 047001 (2011).
3. M. Mondal et al., Phys. Rev. Lett. **107**, 217003 (2011).

Strongly correlated superconductivity in non-magnetic d-band superconductors

S.Ramakrishnan, *H.R. Naren and A. Thamizhavel*

Department of Condensed Matter Physics and Materials Science,Tata Institute Of Fundamental Research, Mumbai-400005, India

Abstract:

Chalcogenides of Platinum group of metals have attracted considerable attention of solid state chemists in recent years due to their relevance in catalysis and materials science. However, from a physicist point of view, they are interesting materials which have cage like structures and exhibit a variety of forms such as, small band gap semiconductors, insulators and superconductors. We have shown that a single crystal of $Rh_{17}S_{15}$ [1] exhibits strongly correlated superconductivity presumably due to the high density of states of d-bands at the Fermi level. The possibility of the presence of high density of states is supported by the structure (Pm3m) where some of the Rh-Rh bonds than those observed in pure Rh metal. We observed reduction of strong correlations when Rh is substituted by Ir. Moreover, in isostructural $Pd_{17}Se_{15}$ (where the Pd-Pd distances are larger those in a pure Pd metal), one observes conventional superconductivity below 2.3 K with intermediate electron-phonon coupling. Finally, we believe that the study of superconductivity in Platinum group of chalcogenides offers new vistas to investigate the strong electron-electron correlations in non-magnetic d-band superconductors.

References:

[1] H. R. Naren, A. Thamizhavel, A. K. Nigam and S. Ramakrishnan, Phys. Rev. Lett.**100**, 026404 (2008); Journal of Physics : Condensed Matter. **23,** 055601 (2011) and references cited therein.

Dichotomy of pseudogap and SDW phase in $CaFe_2As_2$ - an ARPES study

K Maiti
Tata Institute of Fundamental Research
Mumbai, India

Abstract:

Fe-based superconductors has generated a great deal of attention to study the interplay between magnetism and superconductivity. It is believed that Fe d states derive the superconducting phase in these systems. Employing high resolution photoemission spectroscopy, we observe signature of SDW transition and pseudogap in $CaFe_2As_2$ - the electronic states responsible for pseudogap are different from the electronic states responsible for SDW transitions. p-states appears to play a significant role in deriving the properties of these materials.

Nodal pocket yielding multiple quantum oscillation frequencies in the underdoped cuprate $YBa_2Cu_3O_{6+x}$

Suchitra Sebastian
Quantum Matter Group, Cavendish Laboratory, Cambridge University, U.K

Abstract:

Quantum oscillations have proved a vital tool in uncovering the electronic structure underlying the normal state of the underdoped cuprates. Our experiments have established that quasiparticles in this regime are governed by fermi dirac statistics, yet a comprehensive description of the fermi surface geometry remains elusive. The location, carrier type, and multiplicity of fermi pockets that constitute the electronic structure are still the subject of intense debate, with complementary experiments and techniques yielding seemingly dichotomous interpretations. We use an array of quantum oscillation measurements in the underdoped cuprate $YBa_2Cu_3O_{6+x}$ in tandem with results from complementary experimental techniques to distinguish between alternative Fermi surface possibilities; evidence strongly points to a Fermi surface comprising a nodal pocket, giving rise to the multiple observed quantum oscillation frequencies. We present a model of an electronic structure driven by bidirectional low Q charge vectors as potentially yielding such a nodal Fermi surface.

A phenomenological theory of the anomalous pseudogap phase in underdoped cuprates

Maurice Rice
Institut f. Theoretische Physik, HIT K 43.1
Wolfgang-Pauli-Str. 27, 8093 Zürich
SWITZERLAND

Abstract:

A consistent theoretical description of the many anomalous properties that characterize the pseudogap phase in the underdoped region of the cuprate phase diagram has proved challenging. The consistent progress in spectroscopic and other experiments suggests a phenomenological approach. An ansatzbased on analogies to the transition to Mott localization at weak coupling in lower dimensional systems, has been proposed by Yang, Rice and Zhang*. This ansatz has had success in describing a wide range of experiments**. The motivation underlying this ansatz is described and some comparisons to experiment are reviewed. Implications for a more microscopic theory are discussed together with the relation to theories that start directly from microscopic strongly coupled Hamiltonians.

References:

- *K-Y.Yang,T.M.Rice & F.C.Zhang, Phys. Rev. B73,174501 (2006)
- ** T. M. Rice, K.-Y. Yang & F. C. Zhang, arXiv 1109.0632

Quantum kinetic approach to the calculation of thermal transport and the Nernst effect

Sasha Finkel'stein
Weizmann Institute of Science, Israel

Abstract:

My talk will include a general description of the quantum kinetic approach for studying thermal phenomena, but mainly I will concentrate on the Nernst effect in amorphous superconducting films. I will use this example to discuss some subtle issues in the theoretical study of thermal phenomena that we encountered while calculating the Nernst coefficient. In particular, I will explain how the Nernst theorem (the third law of thermodynamics) imposes a strict constraint on the magnitude of the Nernst effect.

Phenomenological Theory of Superconductivity in the Cuprates

Chandan Dasgupta
Centre for Condensed Matter Theory,
Department of Physics, Indian Institute of Science,
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Abstract:

A phenomenological Ginzburg-Landau-like theory of high-temperature superconductivity in the cuprates is proposed in which the free energy of a cuprate superconductor is expressed as a functional of the complex spin-singlet pair amplitude associated with nearest-neighbor sites of the square planar Cu lattice. The coefficients appearing in the free energy functional are determined as functions of the hole density and the temperature from comparison with experiments. A combination of analytic approximations, numerical minimization and Monte Carlo simulations is used to work out a number of consequences of the proposed functional. In underdoped systems, there can be a rapid crossover of the magnitude of the pair amplitude from small to large values as the temperature is lowered. This crossover temperatures is identified with the observed pseudogap temperature. The thermodynamic superconducting phase-coherence transition occurs at a lower temperature and describes superconductivity with d-wave symmetry. The calculated dependence of the transition temperature on the hole density has the observed parabolic shape. The results for the superfluid density, the local gap magnitude, the specific heat with and without a magnetic field, and vortex properties are compared successfully with those of experiments. We also obtain the electron spectral density as influenced by the coupling between the electrons and Cooper-pair fluctuations above the transition temperature and show that several features observed in Angle Resolved Photoemission Spectroscopy experiments emerge naturally in this description. These features include "Fermi arcs" with temperature dependent length and an antinodal pseudogap which fills up linearly as the temperature is increased toward the pseudogap temperature.

This talk is based on work done in collaboration with Sumilan Banerjee and T. V. Ramakrishnan.

Correlated Electronic Structure of Some Conjugated Electronic Materials

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Abstract:

In this talk I will discuss some of the recent results from DMRG study of several interesting conjugated polymers. These are modeled by the Pariser-Parr-Pople model which includes long range electron correlations. I will first discuss why DMRG is successful even though interactions are long ranged. Then I will discuss the results on our studies of fused azulenes which is expected to show multiferroic properties. If it is found to be true, this will be the first example of an organic multiferroic. Then we will discuss the nonlinear optical properties of the diradical system - dicyclo penta fused polyacenes. This will be followed by a discussion of the results on the transverse substituted polyacetylenes.

TWO SMALL NEW PIECES IN A TALE OF TWO GIANTS

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Abstract:

Two of the most important ideas in condensed matter physics arose in the middle of the twentieth century from the research of two giants – Nevill Mott and Philip Anderson. Dubbed the Mott and Anderson viewpoints of the metal-insulator transition, they have given rise to thousands of investigations and research papers over the last half-century, and continue to be of active study.

This talk will discuss two recently uncovered aspects of the work of Mott and Anderson. In the first part, we study the effect of disorder on the electronic states of the Hubbard model, its consequences for the metal-insulator transition, and the implications that follow. In the second part, we study the effect of rare fluctuations in Anderson's 1958 model for localization. We find singularities separating typical Anderson localized states from rare fluctuation Lifshitz type states. This implies that the model displays richer behavior than has been previously recognized, and further that Anderson's original model may be the most appropriate platform for an in-depth study of rare fluctuation effects in quantum condensed matter systems.

Anderson Enigma in Disordered Superconductors

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Abstract:

More than five decades ago Anderson argued, in a seminal paper, that the superconducting gap remains unchanged in presence of nonmagnetic disorder. In the basis of exact eigen states with disorder, Cooper pairs are formed between time reversed partners, interaction potential and hence the order parameter remain unchanged. Gorkov independently in a perturbative treatment showed that the critical temperature is independent of disorder up to 1/Kl , where K is the Fermi momentum and l is the mean free path. This result is known as Anderson Theorem. In this talk, I will show that even though the disorder configuration averaged value of the order parameter remains unchanged for low disorder, the variance of it is long ranged, i.e., the order parameter becomes long-ranged correlated disorder. Therefore the scattering life time of a Cooper pair may be defined and its dependence on 1/Kl has been determined. The life time of Cooper pair is four orders of magnitude higher than the life time of an electron. This finite life time of a Cooper pair is shown to be responsible for reducing superconducting transition temperature as nearly proportional to 1/Kl . This has been compared with old and new data; the theory satisfactorily explains the data for higher Kl .

Non-Universal Conductance Fluctuations in Graphene

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Abstract:

In mesoscopic disordered metals, when the sample size is smaller or in the order of the phase coherence length, the electrical conductance fluctuates with an universal magnitude $\sim e^2/h$ as a function of Fermi energy, magnetic field or disorder, irrespective of material properties, device geometry or dimensionality. Such "universality" of mesoscopic conductance fluctuations in graphene is however more complex, because of the existence of valleys in graphene. Experimentally, very little is known on the influence of valleys on the mesoscopic fluctuations, although it has been theoretically suggested that it can become a direct probe to study the valley degeneracy and inter/intra-valley scattering processes. Here we show that the magnitude of mesoscopic conductance fluctuations in graphene increases four times near the Dirac point compared to the high density regime, indicating a density dependent crossover from orthogonal to symplectic universality class. Since the valleys represent a spin-like quantity, it allows the valley degree of freedom to be a new physical resource for a wide variety of applications, ranging from valley-based quantum computation, to valley filters or polarizers, and in this context our experiments provide a new access to study and exploit valley coherent regime in graphene.

Ferromagnetic insulating state : Is it an electron glass

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Abstract:

The physics of Ferromagnetic Insulating state in hole doped manganites has been a topic of considerable interest. It has been shown recently that this phase (a) has no magnetoresistance, (b) has strong non-linear conduction that may arise from hot carrier effects and (c) that a moderate pressure can destabilize the insulating state to a metallic phase and under high pressure there is signature that the moment collapses. (d) shows conduction that shows variable range hopping with a Coulomb gap.

The presence of a Coulomb gap and recent theoretical /simulation studies have raised the possibility of existence of a Coulomb glass of polarons in the low doped manganites where the hole concentration is less than the critical concentration of metallic state formation.

We have investigated extensively the glassy phase in hole doped manganites using noise as a probe. In particular, we have investigated the possibility of electrons /holes decoupling from the bath using noise as a probe. In addition to enhanced 1/f noise which shows a freezing at low T, the noise becomes strongly non-Gaussian.

These systems show an interesting behavior where the electron “electron temperature” as measured by the Nyquist noise shows decoupling from the bath temperature (which is the temperature of the phonons). This essentially leads to break down of fluctuation-dissipation theorem which we take as a signature of non-ergodicity and the glassy behavior.

Transport in dilute magnetic semiconductor heterostructures

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Abstract:

We study experimentally and theoretically the resistivity and its noise in semiconductor heterostructures δ-doped with Mn. The two-dimensional nature of transport as well as ferromagnetism make their properties different from their three-dimensional counterparts. We observe anomalies in the temperature dependence of resistivity and noise in both metallic and insulating samples and interpret them as evidence for significant ferromagnetic correlations. The insulating samples are particularly interesting as they provide valuable clues to the nature of ferromagnetism in these structures. At low carrier densities, we show how the interplay of disorder and nonlinear screening leads to the formation of hole puddles in the transport layer. We find that in this droplet phase, ferromagnetic correlations result in anomalies in the resistivity at temperatures below the Curie temperature, and even in the absence of long-range ferromagnetic order. This is to be contrasted with bulk Mn-doped semiconductors where resistivity anomalies are expected above and near to the Curie temperature, and are associated with a ferromagnetic phase transition. The ferromagnetic correlations also affect the resistivity noise directly through their effect on the fluctuations of relative orientations of the magnetization at the droplets and indirectly through their effect on the hole number fluctuations. We propose simple models for the resistivity noise in the droplet phase in the presence of these ferromagnetic correlations. Finally, we discuss possible models for ferromagnetism that are consistent with the observed behaviour of resistivity and its noise in these heterostructures.

References::

V. Tripathi, K. Dhochak, B. A. Aronzon, V. V. Rylkov, A. B. Davydov, B. Raquet, M. Goiran and K. I. Kugel, Phys. Rev. B **84**, 075305 (2011).

Anomalous Quantum Hall states in an optical lattice

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Abstract:

We analyze the physics of cold atoms in honeycomb optical lattices with non time-reversal- symmetric spin-orbit couplings and on-site repulsion. Such a system, at half filling and large on-site repulsion has been proposed as a possible realization of the Kitaev model. The spin-orbit couplings break the spin degeneracy and, for strong enough coupling, there are four non-overlapping bands in the non-interacting limit. These bands carry non-zero Chern number and therefore the non-interacting system at 1/4 and 3/4 filling is an anomalous quantum Hall system characterised by chiral edge states. We have investigated the effect of interactions using the variational cluster perturbation theory and conclude that the chiral edge states persist in a finite range of interaction and hopping parameter space.

Fermions in synthetic non-Abelian gauge fields

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Abstract:

After a brief review of ideas of experimental generation of non-Abelian gauge fields, I shall discuss the physics of interacting fermions in their presence. The experimentally generated gauge field induce a generalized spin-orbit interaction for the two component fermions. I shall demonstrate that on increasing the strength of the gauge field, a BCS superfluid that is realized in the presence of weak attraction in the absence of the gauge field, is driven to BEC state. The BEC state is a condensate of a new kind of nematic bosons, which we call "rashbons", whose properties are determined solely by the gauge field and not by the strength of the attraction between the fermions. The rashbon-BEC is shown to have a transition temperature of the order of the Fermi temperature suggesting a route to enhancing the transition temperature in weakly attracting systems using spin-orbit interaction. I shall then discuss the experimental signatures of the phenomenon. Finally, I will make a proposal of using a non-Abelian gauge field in a conjunction with another potential for the realization of interesting condensed matter Hamiltonians such as the spherical geometry quantum Hall system.

Work done in collaboration with J. P. Vyasanakere(IISc) and Sudeep Ghosh(IISc)

References:

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