Selected Publications:

1. Local Moment Formation and the Kondo Effect (with M J Levine and RA Weiner), Phys. Rev. Lett. **20**, 1370(1968)
2. Localized Dynamic Perturbations in Metals (with G Toulouse and E Muller-Hartmann), Phys. Rev. **B3**, 1102(1970)
3. Microscopic Theory of Spin Fluctuations in Itinerant Electron Ferromagnets: I. Paramagnetic Phase, Phys.Rev. **B10**, 4014(1974)
4. First Principles Order Parameter Theory of Freezing (with M Yussouff), Phys. Rev. **B19**, 2775(1979)
5. Scaling Theory of Localization: Absence of Quantum Diffusion in Two Dimensions (with E Abrahams, PW Anderson and DC Licciardello), Phys.Rev.Lett. **42**, 673 (1979)
6. Scaling Theory of Localization and Non Ohmic Effects in Two Dimensions (with E Abrahams), J. Non-Crystalline Solids **35**, 151(1980)
7. Magnetoresistance of Weakly Localized Electrons (with PA Lee), Phys.Rev. **B26**, 4009(1982)
8. Theory of a Mixed Valent Impurity (with K Sur), Phys.Rev. **B26**,1798(1982)
9. Theory of Universal Degradation of Tc in Disordered Superconductors (with PW Anderson and KA Muttalib), Phys.Rev. **B28**, 117(1983)
10. Density wave Theory of Freezing and the Solid, Pramana **22**,365 (1984)
11. Disordered Electronic Systems (with PA Lee), Rev.Mod.Phys. **57**,287(1985)
12. Disordered Superconducting Thin Films, Physica Scripta, **T27**, 24(1988)
13. Theory of Freezing, J.Noncryst.Solids **117-118**, 852(1990)
14. Superfluid and Insulating Phases in an Interacting Boson Model: Mean Field Theory and RPA (with HR Krishnamurthy,K Sheshadri and R Pandit), Europhysics Letters **22**, 257 (1993).
15. Effective Actions and Phase Fluctuations in d-wave Superconductors (with Randeria,A Paramekanti and SS Mandal), Phys.Rev. **B62**, 6786(2000)
16. T=0 Insulator Metal Transitions in Doped Manganites (with GV Pai, SR Hassan and HR Krishnamurthy), Europhysics Letters **64**,696 (2003)
17. Tracking Operator State Fluctuations in Gene Expression in Single Cells (with B Banerjee, S Balasubramanian,G Aananthakrishna and GV Shivashankar), Biophysical Journal **86**,3052(2004)
18. Theory of Metal Insulator Transition and Colossal Magnetoresistance in Doped Manganites (with HR Krishnamurthy, SR Hassan and GV Pai), Phys.Rev.Lett. **92**, 157203(2004)
19. Stochastic Simulations of the Origins and Implications of Long-tailed Distributions in Gene Expression (with S Krishna,B Banerjee and GV Shivashankar), PNAS **102**, 4771 (2005)
20. Doping and Magnetic Field Induced Insulator-Metal Transitions in Half-Doped Manganites (with O Cepas and HR Krishnamurthy), Phys. Rev. Lett. **94,** 24727 (2005)
21. Many Electrons Strongly Avoiding Each Other:Strange Goings On (a chapter in *The Legacy of Albert Einstein*, ed. S Wadia, World Scientific, Singapore,2006)

22. Coulomb Interactions and Nanoscale Electronic Inhomogeneities in Manganites (withVB Shenoy,T Gupta and HR Krishnamurthy), Phys.Rev.Lett. **98,**09720(2007)
23. Modelling Colossal Magnetoresistance Manganites J.Phys.Condensed Matter **19**, 125211 (2007)
24. Unusual Doping and Temperature Dependence of Photoemission Spectra from Manganites (with P Sanyal, S Sengupta, N Pakhira, HR Krishnamurthy and DD Sarma) (cond-mat 0704.3923 and to be published)

Areas of current interest and work:

I am interested in starting work in two broad areas, namely the physics of strong electron correlation and of structural phase transitions. Two other fields in which I hope to work are graphene and the superconductor insulator transition. I also plan to continue ongoing work in two others, namely colossal magnetoresistance manganites and noise in gene expression. Both kinds of projected activities are presented below.

A. <u>Starting</u>

(i) Strongly correlated electron systems: In this area, which is the focus of a large part of the activity in contemporary condensed matter physics and believed widely to be one of its grand challenges, I am developing a new basic idea, namely that the observed effects of strong local electron correlations can be understood in two stages, a 'classical' mean field theory (with site dependent mean fields) which includes strong correlation effects and secondly quantum fluctuations in this background which restore rotational and translational symmetry broken by the local mean field theory. The latter (low energy effective quantum gauge field theory) can be usefully discussed in a Gaussian approximation. I have seen that this is true in a number of otherwise solved cases. The origin of the often exponentially low quantum energy scale is seen to arise either from coherent removal of degeneracies and or from 'incoherent' removal due to coupling with electron hole continuum degrees of freedom.

(i-a) Kondo effects, heavy fermions etc.: I have applied the above idea to an extremely widely investigated system, namely the magnetic impurity in a metal (the Kondo effect), and have shown how the exponentially low Kondo energy scale T_K as well as the resulting physics for $T <<$ and $>> T_K$ arise. This work is being written up for publication. I hope to extend this work to related lattice systems, the aim being to understand heavy fermions and other intermetallics exhibiting quantum critical phenomena, and non Fermi liquid behaviour etc.. .

(i-b) High temperature superconductivity: One line of work here is based on applying the above ideas to motivate and quantify effective low energy Hamiltonians or field theories appropriate for cuprates exhibiting high T_c superconductivity. This mainly requires sophisticated and heavy computing for quantum many body systems, e.g. using DMFT related methods. This part awaits completion, needing facilities and people. Another is to go ahead with effective low energy theories and to explore consequences. Here, I expect to start work soon* on a new (quantum ?) Ginzburg Landau functional for the cuprates,which has a term dependent on the amplitude of nearest neighbour singlet pairing, and the phases of the nearest neighbour x-y bonds are coupled 'antiferromagnetically' so as to lead to the observed 'd-wave' superconducting order. There is also (weak) interlayer coupling. The coupling to electromagnetic fields, the structure and energetics of (Josephson) vortices, the role of vortices in the reduction of superfluid stiffness below T_c, normal state or above T_c (fluctuation) phenomena such as the Nernst effect, and quantum effects in the very underdoped regime are some of the effects I would like to investigate. Later, I expect to look at consequences of coupling of these fluctuations to electrons with a view to understand ARPES (including Fermi arcs), linear resistivity etc.. (Ideally, progress in this area would require an active local group of workers, doing both numerical work and analytical theory. There is frequent discussion of these questions with Dr. D. Sa of BHU. I am also in active contact with Professor Vijay Shenoy of the IISc about the above as also with Professors HR Krishnamurthy and Chandan Dasgupta).

(ii) Structural transitions: Under this broad rubric, I hope to understand some phenomena in ferroelectricity, e.g. quantum effects, nanoscopic or small size effects/ limits (involving the ubiquitous long range electrostatic and strain mediated interactions especially as they affect possible applications to ferroelectricity based memory devices)**, and multiferroics. Another area which I would like to start is the theory of classical systems in which the basic units are corner sharing, space filling tetrahedra, and the degrees of freedom are bond angles constrained by the above condition , rather than densities. Physical examples are silica and silicates, constituting almost the entire family of minerals on earth. There is some work (by a number of people at Cambridge) on a model involving small fluctuations of this angle about a mean, namely phonons and soft modes in the harmonic approximation. My goal is to invent and use a functional for the free energy of such systems as it depends on the angles over their full possible range (I believe that these are the relevant low energy degrees of freedom, not density as in the Ramakrishnan Yussouff theory). I am also pursuing work at BHU (with Professor Y Singh and a joint postdoctoral fellow, Dr Pankaj Mishra) on applying a new inhomogeneous state correlation function theory developed by Singh and Mishra to the old unsolved theoretical problem of bcc-fcc relative stability.

(The work on ferroelectrics is strongly motivated by the presence in BHU of the active group of Professor D. Pandey, School of Materials Science. Dr. D. Sa of the Physics Department is also very interested; we are both learning the ropes, and expect to work ourselves and with Dr. Sa's Ph.D. students. Professor S.G. Mishra of IOP Bhubaneswar, and a Ph.D. student of his, are interested in quantum effects, and we are collaborating on this. Many years ago, Professor Mishra and I had developed a self consistent theory of fluctuation effects for the most famous T = 0 or quantum phase transition namely Stoner ferromagnetism in metals. The work on corner sharing tetrahedra is yet to take off; it needs both major computer simulations and analytical input).

iii) **Graphene**: This newly discovered system has surprising basic physics, and may be a great nanomaterial. In this exploding field, I am interested in a few elementary questions, eg the extent and implications (especially for optical and electrical properties) of the inevitable crumpling of the graphene sheet, the adiabaticity of the electron phonon interaction and its experimental manifestations.

iv) **Superconductor insulator transition :** There have been exciting new experimental discoveries in the last three years on the strange behaviour of disordered, granular thin films at the boundary of this transition, raising questions such as the survivability of a normal (uncondensed) Bose liquid at T=0. I am in close touch here with Dr Vikram Tripathi of TIFR, who is an expert on transport in granular metals, and is interested in this specific problem.

B. <u>Continuing:</u>

(i) Colossal magnetoresistance in manganites: In this area, we have originated a new microscopic two fluid model (e.g. Phys. Rev. Lett. **92**, 157201, (2004)) which we believe underlies the vast range of strange properties of these systems and have developed its consequences for colossal magnetoresistance (cmr), metal insulator transition (Phys. Rev. Lett. **92**, 157201 (2004)), charge/orbital ordering and its electron hole asymmetry (Phys. Rev. Lett. **94,** 247267 (2005)), nanoscopic phase separation (Phys.Rev.Lett. **98**,097201,2007), and anomalous photoemission satellites (cond-mat 0704.3293 and to be published). I have recently reviewed the field (J. Phys. Cond. Matt.**19**,125211,2007). Three relatively straightforward things I intend to do to further our approach are: (α) to help complete a long paper on the subject (β) collect and present evidence for the two fluid ℓb model and (γ) for virtual double exchange as crucial for ferromagnetism in manganites.

Three other things which will require more work and time are the following:

(α) Exploring the consequences of electron phonon interaction for intermediate to large electron phonon coupling λ ($\lambda \geq 1$) and in the adiabatic regime ($\gamma = (\hbar\omega_o/t) << 1$). The extant successful theory is a perturbation theory, originally due to Migdal, valid for $\lambda < 1$ and $\gamma << 1$, and treats (successfully) γ as a small, perturbative, expansion parameter. It is known that for $\lambda > 1$, there is a polaronic instability (spontaneous lattice distortion or symmetry breaking) in the classical limit $\gamma \equiv 0$. Calculations for simple models suggest that the small parameter now is $e^{-\lambda/\gamma} << 1$ for $(\lambda/\gamma) >> 1$; this is nonalytic in γ (around $\gamma \equiv 0$). The questions of interest are whether for lattice systems at generic electron densities, this continues to be true, and how to show it. Most likely the route will be numerical, involving novel quantum (impurity) solvers. I expect to formulate the problem soon as a doable numerical exercise.

(β) Developing a simple model with hybridization: In the ℓb picture I plan to develop a model which includes ℓb hybridization effects and thus can address the low temperature properties of manganites (e.g. resistivity, Hall effect), the apparent disappearance of the Jahn Teller distortion, and more generally the evolution of a single 'hybridized' quantum fluid at low temperatures from two (interacting) fluids at high temperatures.

(γ) Modelling the 'classical' regime: Over a large region in the doping x, temperature T plane, manganites are insulating, i.e. electronic degrees of freedom can be ignored for many purposes. In this classical regime, I expect to develop an effective Hamiltonian with magnetic, orbital and strain degrees of freedom, and to look at consequences analytically in mean field theory, e.g. for the competition between orbital and magnetic ordering and the effect of strain disorder on both ***(in the entire cmr area, I expect to continue to collaborate actively with the group at IISc, namely Professors H.R. Krishnamurthy,Chandan Dasgupta, Vijay Shenoy, and their students).

(ii) Theoretical Biology:,

My interest in this area is primarily due to interaction with G. Shivashankar and his group at NCBS ,Bangalore.

We did some work on noise in gene expression, e.g. the presence of long tailed protein number distributions at the cellular level and its biological consequences eg in increasing greatly the likelihood of bimodal protein number distrbutions (PNAS **102**, 4771 (2005)). Since then I have become interested in looking for biological phenomena where such noise plays an essential role. One concrete possibility I am pursuing is latency as well as virulent expression in HIV. There is, as we all know, enormous variability (e.g. on the time scale of a human lifetime !) in the expression of HIV. This problem has been recently studied experimentally (Cell **121**, 164 (2005)), and there is a resistor model for the results (PLoS Biology **5**, 047, (2007)). I believe that one needs a fundamentally different picture; the 'resistor' is extremely non-Ohmic (Professor Debashish Chowdhury of IIT Kanpur has also become interested in this, subsequent to my bringing it to his attention; we expect to work together in developing a realistic model, with hopefully clinical consequences (!)).****

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* I have recently completed a simple mean field calculation for a new Ginzburg Landau model. The results tie together, for the first time, a variety of phenomena in cuprates. I am in close touch with Professor Chandan Dasgupta of the IISc about this.

** Dr Umesh Waghmare of the JNCASR, Bangalore, an authority in the field of the theory of ferroelectrics, is likely to collaborate on the problem of how long range (dipolar) electrostatic effects influence ferroelectricity and domain formation in a size and shape dependent way for small (nano) systems.

*** With Professor HR Krishnamurthy, Professor Chandan Dasgupta and his PhD student Sumilan Banerjee (IISc) work has started on a mean field analysis of the relative stability of various kinds of long range order, eg orbital, charge, spin and mixed, for both commensurate and incommensurate hole doping.

**** I am in contact with Dr Mukund Thattai of the NCBS, Bangalore , one of the young pioneers in the field of cellular noise, about realities in this large field.