TIFR Annual Report 2002-03
THEORETICAL PHYSICS

Condensed Matter Theory and Statistical Physics

Dynamics of a disordered, driven zero range process in one dimension

The time-dependent properties of a disordered, driven zero range process were studied. This is a stochastic lattice model in which particles hop to their right neighbour with quenched, site-dependent rates. The steady state of this model shows a phase transition, from a low density phase with a roughly uniform density profile to a high density phase in which a macroscopic number of particles condense onto the site with the lowest hopping rate. The dynamical properties of this model were characterised both in the steady state and while relaxing towards it. It was found that different time scales govern these two processes. In the steady state, a calculation of the speed of density fluctuations shows that there are regimes in the density-disorder plane in which this speed vanishes, implying anomalous transport. It was argued that when this speed is nonzero, the dynamical universality class remains the same as that of a pure system while it changes if the speed vanishes. This was verified by Monte Carlo simulations. For the relaxation to the steady state, an analytical argument with supporting numerical evidence was given for the form of the scaling function which describes the temporal growth of the condensate. The dynamic exponent deduced from the growth law via a scaling argument was found to agree with earlier results based on a deterministic model. (K. Jain and M. Barma)

Non-interacting Particles Moving on a Fluctuating Landscape

The problem of non-interacting particles moving on a fluctuating landscape under the influence of gravity brings out the strong effects produced by noisy force fields which are correlated in space and time. The problem is of interest because it can be mapped to that of a passive scalar (e.g. dye particles) spreading diffusively as they are carried along by the flow lines of a turbulent compressible fluid. The cases of particles moving with the flow (advection) and particles moving against the flow (anti-advection) are both studied. Monte-Carlo simulation studies show that the particles show clustering in both cases, with very strong clustering seen in the advection case. The density-density correlation function is found to be a scaling function of the separation scaled by the system size, indicative of phase separation. The scaling function diverges for small argument, indicating very strong clustering. (Apoorva Nagar and M. Barma)

Self-Organized Criticality

The Oslo rice-plie model was propsed as a simple theoretical model that captures essential features of experiments done on rice-piles by the Oslo group. In this model, if the local height of ricepiles exceeds a threshold, a grain moves down, and the critical height threshold is reset to a new random value. Earler studies of this model were mainly by numerical simulations. WIt was shown that this model has a very unusual algebraic structure, which allows one to determine the steady state analytically, and show that relaxation matrix has only one non-trivial eigenvalue. (D. Dhar)

Electroporation

Electroporation is a technique by which drugs and DNA material can be made to penetrate the external membranes of cells, by subjecting them to electric fields. The membranes develop temporary pores, when subjected to electric fields, and drugs pass through these pores into the cells. This technique is used to felicitate drug delivery into the nuclear region of cells in some kinds of cancer. As strong electric fields cause damage to tissue, it is important for optimal design of needles to determine the electric fields produced. An analytical perturbation series to calculate these in the six-needle array used in clinical practice has been developed, that is more efficient than the available numerical techniques using finite element methods. (D. Dhar with W. Krassowska of Duke University, and S. B. Dev of Gene Delivery and Expression Sciences, San Diego).

Fractionalization in Spin Liquid Mott Insulators

The conditions under which a spin-liquid Mott insulator defined by a Gutzwiller projected BCS state at half-filling is fractionalized were studied. A trial wave function for a vison, or Z(2) vortex, state by projecting an (hc/2e) vortex threading the hole of a cylinder or torus was constructed, and its overlap with the ground state using analytical and numerical calculations determined. It was found that generically this overlap vanishes in the thermodynamic limit and the spin-liquid is Z(2) fractionalized. However, for microscopic parameters appropriate for high Tc cuprates, the vison gap is estimated to be much smaller than the natural scale of the antiferromagnetic exchange energy J, due to the proximity to the bipartite symmetric point where the vison gap must vanish. This estimate of the vison gap is consistent with recent experimental bounds. [M. Randeria, N. Trivedi with A. Paramekanti (KITP, Santa Barbara)].

Angle-Resolved Photoemission Spectroscopy

Studies of the high Tc superconductors using their photoemission spectra were continued. Among the issues addressed were: (a) Coherent-to-incoherent crossover on the overdoped side of the cuprate phase diagram studied using intra-bilayer coherences and in-plane coherence probed by ARPES and in-pane transport data. (b) Spectral lineshape studies as a function of energy, momentum, temperature and doping to elucidate the non-Fermi-liquid behaviour above Tc. [M. Randeria with J. C. Campuzano and A. Kaminski (University of Illinois at Chicago) and M. R. Norman (Argonne National Labs)].