Summary of Research

My primary research interest is statistical mechanics of driven, nonequilibrium systems. At present I am interested in studying the problem of front propagation in reaction diffusion systems and stochastic properties of interfaces in sandpile models. For my PhD thesis, I had worked on the effects of quenched spatial disorder on interacting many particle systems driven far from equilibrium by external fields. I am also interested in some topics in soft condensed matter (membranes, granular materials) and biophysics (thermal ratchets, protein folding). In the future I would like to pursue some of these topics more actively.

Interfacial fluctuations of a sandpile

Sandpile models are prototype models of studying self-organized criticality (SOC) in nonequilibrium systems. How are the surface fluctuations of a sandpile affected by SOC is a matter of renewed recent interest. We study both critical as well as noncritical sandpile models and discover that anomalous roughness is observed in the critical sandpiles. This surprising observation is traced to the presence of a nontrivial steady shape of the surface of a critical sandpile. We compute this nontrivial profile for a local limited sandpile and show that indeed the standard theories apply once this steady shape is taken into account [1].

Stochastic fronts in reaction-diffusion systems

Stochastic fronts in reaction diffusion system pose interesting problems, especially in connection with their deterministic macroscopic limit. We find that much of the dynamics of a lattice versions can be understood on the basis of a simplified picture based on the dynamics of the leading particle. Using this picture we compute analytically approximate expressions for quantities such as the front velocity and its diffusion coefficient with which the numerical results agree rather well [2]. However, the larger problem of connecting this leading particle approach to other approaches in the continuum limit still remains.

Fluctuation and relaxation of stochastic fronts: In an earlier work we had studied stochastic properties of fronts in reaction-diffusion systems. One of our important conjectures is that the so called stochastic *pulled* fronts (i.e. fronts in which the leading edge is dynamically important) show anomalous scaling. Although the asymptotic scaling is still believed to be governed by the standard KPZ theory, we argue that there are slow crossover regimes which can be described by the KPZ equation in one higher dimension than that of the front [3, 4].

Driven diffusive systems with quenched disorder

Exact results for a disordered driven lattice gas: Lack of detailed balance in systems driven far from equilibrium makes them hard to deal with within a universal formalism. Further, static spatial disorder, by breaking translational invariance, makes the characterization of the steady state all the more difficult. By using the principle of 'pairwise balance', we are able to write down the exact steady-state measure of the Disordered Drop-Push Process in any dimension for arbitrary disorder. This is the first instance of an exact determination of the steady state of a spatially disordered nonequilibrium system of interacting particles and allows us to compute exactly a number of physical quantities, such as, the steady-state current and static correlation functions [5, 6].

Different Steady State Regimes: It is important to classify qualitatively different sorts of macroscopic behaviour that can arise in disordered driven systems. One of our principal results is that, in one dimension, three distinct regimes of behaviour are possible. We find that disorder in the strongest form can make the steady-state current vanish in the thermodynamic limit. In a milder form, it may either give rise to a macroscopically homogeneous state or may lead to phase separation into macroscopic regions of low and high densities – in both cases the steady-state current is non-zero. Our results are based on extensive Monte Carlo studies and mean-field treatment of lattice gas models with asymmetric, site dependent hopping rates [6].

Dynamics of Fluctuations in the Steady State: Static disorder often introduces non-trivial correlations in the time evolution of stochastic systems. We find that the decay of fluctuations around the steady-state of disordered driven systems, measured by a two-point dynamical correlation function, behaves differently in different regimes. For systems with a non-zero steady-state current, we find that a simple heuristic criterion, based on the mean speed of the density fluctuations, determines whether static disorder is relevant (in the renormalization group sense) or not. Numerical studies of the disordered lattice gas models bear out our conclusion that disorder is irrelevant if this speed is non-zero. Vanishing of this speed changes the dynamical behaviour – concommittant with the large-scale phase separation [5].

Many of our results for the disordered particle systems, in one dimension, can be quite naturally translated and applied to the motion of an interface in a two dimensional environment with a certain type of quenched columnar disorder. The relevance criterion in terms of the speed of the fluctuations generalizes an earlier result pertaining to interface motion with point disorder [7].

References

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