Punyabrata Pradhan

Associate Professor

Theoretical Sciences

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Guidance of Students/Post-Docs/Scientists

a) Ph.D. Students

1. Dhiraj Tapader; Studies of hydrodynamics and fluctuations in mass transport processes; Under progress
2. Anirban Mukherjee; Studies of hydrodynamics and fluctuations in sandpiles; Under progress
3. Tanmoy Chakraborty; Studies of fluctuations and transport in active matter systems; Under progress
4. Deepshikha Das; Transport in many-particle system with time-dependent drive; Under progress; Sakuntala Chatterjee (Co-supervisor)
5. Animesh Hazra; Studies of absorbing phase transition; Under progress

Teaching

1. Autumn semester; PHY 104; Integrated PhD; 7 students
2. Spring semester; PHY 204; Integrated PhD; 5 students

Publications

a) In journals

1. Tanmoy Chakraborty, Subhadip Chakraborti, Arghya Das, and **Punyabrata Pradhan**, *Hydrodynamics, superfluidity, and giant number fluctuations in a model of self-propelled particles*, Physical Review E, 101, 052611, 2020
2. Dhiraj Tapader, **Punyabrata Pradhan**, and Deepak Dhar, *Density relaxation in conserved Manna sandpiles*, Physical Review E, 103, 032122, 2021

Talks / Seminars Delivered in reputed conference / institutions

1. Hydrodynamics,"superfluidity" and "giant" fluctuations in a model of self-propelled particles; Dec 3, 2020; Online presentation (at International Centre for Theoretical Sciences (ICTS), Bengaluru); One hour

Administrative duties

1. Library committee, Newsletter committee, various interview committees

Extramural Projects (DST, CSIR, DAE, UNDP, etc.)

1. Fluctuation and transport in the models of self-propelled particles; Science and Engineering Research Board (SERB, DST); 3 years; PI

Scientific collaborations with other national / international institutions (based on joint publications)

1. Joint publication with Deepak Dhar, Indian Institute of Science, Education and Research (IISER), Pune; Sl. No. 2; National

Areas of Research

Fluctuation relations in systems out of equilibrium, hydrodynamics of mass transport processes, single-file diffusion and transport through nanopores, etc.

We have been working along mainly two directions: The large-scale relaxation properties in active-matter systems (such as self-propelled particles) and that in threshold-activated systems (such as sandpile models). These two broad class of systems violate detailed balance due to the lack of time reversal symmetry and, upon tuning suitable parameter like global density, undergo two different kinds of nonequilibrium phase transitions. The active matter systems undergo a clustering transition, where, beyond a certain parameter value, a macroscopic cluster forms in the systems and mass fluctuation diverges in the translation-symmetry broken "ordered" phase (the phenomenon called "giant fluctuation"). On the other hand, the sandpile models exhibit, below a critical global density, an absorbing-phase transition, where mass fluctuation vanishes (the phenomenon called "hyper-uniformity"). Though these systems have been studied intensively throughout the past several decades, the theoretical understanding of the exact hydrodynamic structure, which is governed by various density-dependent transport coefficients, is still lacking. Following are the two important results we obtained in the previous year. First, in a model of interacting self-propelled particles, we show that the system undergoes a "superfluid-like" transition from a finitely conducting state to an infinitely conducting one, characterized by a divergence in the conductivity; the diverging conductivity greatly increases particle mobility and thus induces "giant" mass (particle number) fluctuations in the system. Second, in a variant of the Manna sandpile, which exhibits absorbing phase transition, we show that the bulk diffusivity diverges at the critical point and the particle transport becomes anomalous; indeed, relaxation of initially localized density profiles on infinite critical background exhibits a self-similar structure, where the width of the density perturbation grows in a super-diffusive fashion.

Plan of Future Work Including Project

1. Characterization of transport in interacting self-propelled particles: Large-scale spatio-temporal properties of systems consisting of self-propelled particles, which have been intensively explored in the past couple of decades, are usually characterized through phenomenological theories based on symmetries and conservation laws. However, the theoretical understanding of the exact hydrodynamic structure of these systems, except in a few special cases (e.g., those having product measure steady-state), is still lacking. Recently we have exactly calculated two density-dependent transport coefficients in a simple model of self-propelled particles (modeled through generalized exclusion processes having long-ranged particle hopping); we have shown that, upon tuning certain parameters, the system exhibits a "superfluid-like" phase transition where the particle mobility diverges in the symmetry-broken "ordered" phase (Phys. Rev. E 101, 052611, 2020). Indeed it would be quite interesting to characterize various other interacting self-propelled particle systems in terms of the transport coefficients, which govern large-scale hydrodynamic properties of the systems.

2. Characterization of transport in systems having absorbing phase transition: We aim to understand the exact hydrodynamic structure in a broad class of model systems, called conserved stochastic sandpiles, which are known to exhibit an absorbing phase transition upon tuning the global density. Recently, we have obtained hydrodynamics of a special class of stochastic sandpile models - the celebrated Manna sandpile and its variants (Phys. Rev. E 97, 062142, 2018; Phys. Rev. E 103, 032122, 2021). However, it is not clear that the other stochastic sandpiles (such as the Oslo ricepile model) would also possess the similar hydrodynamic structure. In future, we would like to characterize the relaxation properties of sandpiles in general.

3. Understanding the role of interactions on particle transport in systems with time-dependent driving: Recently we have studied the phenomenon of current reversal in the presence of space-time dependent driving in symmetric exclusion process having only hardcore interaction and in systems of

colloidal particles interacting through Weeks-Chandler-Anderson (WCA) potential. In these systems, under certain driving protocols and upon tuning certain parameters such as particle concentration, the time-averaged particle current is shown to reverse its direction (Phys. Rev. E 98, 052142, 2018). However, in the presence of inter-particle interactions (attractive or repulsive), there is no good analytic understanding of the above mentioned phenomenon of current reversal. In future, we would like to investigate the role of interaction on particle transport in simple analytically tractable model systems in the presence of a time-dependent driving force.

Any other Relevant Information including social impact of research

1. Man-power development through teaching and training of graduate students