Punyabrata Pradhan

Associate Professor
Theoretical Sciences
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Dr. Punyabrata Pradhan obtained B. Sc. (1998) and M. Sc. (2000) degrees from the University of Calcutta, Kolkata, India and Ph. D. degree (2006) from the Tata Institute of Fundamental Research, Mumbai, India. After doing postdoctoral research in the Israel Institute of Technology - Technion, Haifa, Israel (2006 - 2009) and in the University of Stuttgart, Germany (2009 - 2011), Dr. Pradhan joined the S. N. Bose National Centre for Basic Sciences, Kolkata, India (2011 - present).

Supervision of Research / Students

Ph.D. Students

1. Sayani Chatterjee; Additivity property and mass fluctuation in conserved-mass transport processes (registered for Ph.D. in the University of Calcutta); ongoing (thesis to be submitted soon).
2. Arghya Das; Thermodynamic characterisation of nonequilibrium steady states and study of phase transitions (registered for Ph.D. in the University of Calcutta); ongoing (thesis to be submitted soon).
3. Subhodip Chakraborti; Studies of fluctuations in systems of self-propelled particles (registered for Ph.D. in the University of Calcutta); ongoing.
4. Amal Garai; Fluctuations in nonequilibrium steady states and single-file diffusion; ongoing.
5. Dhiraj Tapader (under SERB/DST project); Studies of higher dimensional mass transport processes; ongoing.

Projects of M.Sc./ M.Tech./ B.Tech./ Post B.Sc. students

1. Dhiraj Tapader (M.Sc.); S. N. Bose National Centre for Basic Sciences (under SERB/DST project); Studies of higher dimensional mass transport processes (work report to be submitted soon); ongoing.

Post Doctoral Research Scientists

1. Subhashis Rana

Teaching activities at the Centre

1. 6th semester; Advanced statistical mechanics (PHY 603); advanced level (post M. Sc., designed for research); 10 students (credit 5 + audit 5).
2. 2nd semester; Computational methods in physics II (PHY 204); M. Sc. level (designed for research); 11 students (credit 7 + audit 4).

Publications in journals

1. Subhadip Chakraborti, Shradha Mishra, and **Punyabrata Pradhan;** *Additivity, density fluctuations, and nonequilibrium thermodynamics for active Brownian particles*; Physical Review E; 2016; **93**; 052606.
2. Rakesh Chatterjee, Sakuntala Chatterjee, and **Punyabrata Pradhan**; *Symmetric exclusion processes on a ring with moving defects;* Physical Review E; 2016; **93**; 062124.
3. Arghya Das, Sayani Chatterjee, and **Punyabrata Pradhan;** *Spatial correlations, additivity and fluctuations in conserved-mass transport processes*; Phys. Rev. E; 2016; **93**; 062135.

Lectures Delivered

1. Additivity and fluctuations in nonequilibrium; S. N. Bose National Centre for Basic Sciences; Kolkata; January; 2017; a talk delivered in a conference.
2. Additivity, hydrodynamics and mass distributions in nonequilibrium mass transport processes; Saha Institute of Nuclear Physics (SINP); Kolkata; December; 2016; an invited talk delivered in an international conference.
3. Hydrodynamics of mass transport processes and Einstein relation; Jawaharlal Nehru University (JNU); New Delhi; December; 2016; an invited talk delivered.
4. Sandpiles, ricepiles and other mass transport processes; Tata Institute of Fundamental Research (TIFR); Mumbai; November; 2016; an invited talk delivered in a meeting.
5. Additivity and mass fluctuations in mass transport processes; Presidency University; Kolkata; October; 2016; a colloquium delivered (designed mainly for students).
6. Additivity and mass fluctuation in nonequilibrium mass transport processes; TIFR Centre for Interdisciplinary Sciences (TCIS); Hyderabad; September; 2016; an invited talk delivered.

Membership of Committees

External Committee

Doctoral (Ph.D. thesis) committee for Ms. Karthika at the Indian Institute of Space Science and Technology, Thiruvananthapuram, India.

Internal Committee

Doctoral (Ph.D. thesis) committees; interview committees (doctoral and post-doctoral admissions); library committee; computer service cell advisory committee; short-listing committee (scientist-C); purchase committees; creche committee.

Sponsored Projects

1. "Additivity Principle and Thermodynamic Characterization of Mass Transport Processes" (EMR/2014/000719); SERB (DST, India); 2015 – 2018.
2. "Interacting particles in a periodically moving potential" and "Studies of fluctuations in self-propelled particles"; Thematic Unit of Excellence on computational material science under DST (Nanomission); 2012 – 2018.

Conference / Symposia / Workshops / Seminars etc. organized

1. Discussion meeting on the occasion of 60 years of Broadbent and Hammersley (1957) paper on percolation phenomena; January 23 - 24, 2017; S.N. Bose National Centre for Basic Sciences, Kolkata; one of the conveners

Collaborations including publications (Sl. No. of paper/s listed in 'Publications in Journals' jointly published with collaborators)

National

1. Dr. Shradha Mishra, IIT - BHU (Sl. no. 1)

Significant research output / development during last one year

General research areas and problems worked on

Formulation of thermodynamics in various mass transport processes and active matters (self-propelled particles), having a nonequilibrium steady state, in terms of an equilibrium-like chemical potential. Studies of transport properties in systems having a time-periodic steady state.

Interesting results obtained

1. We have characterized the steady-state spatial structure, by exactly calculating the spatial correlation functions (related to structure factor), in a broad class of conserved-mass transport processes governed by chipping, diffusion, and coalescence of masses. We find that the spatial correlations are in general short-ranged in space, with correlation length being finite. Consequently, on a large length scale (much larger than the correlation length in the system), these transport processes possess a remarkable thermodynamic structure in the steady state: The processes have an equilibrium-like additivity property and, consequently, a fluctuation-response relation. Additivity property has been used to theoretically obtain subsystem mass distributions, which are described by gamma distribution. Our theoretical results have been verified to have an excellent agreement with simulations. Interestingly, gamma-like distributions have been observed in various experiments in the past (concerning self-assemblies in materials and force fluctuations in granular matter), which could be understood in the light of the results of this work. Moreover, our work could help us to formulate a unified thermodynamic framework for driven systems in general.
2. In this work, we study particle-number fluctuations in interacting self-propelled particles, in the context of a particular system, called active Brownian particles (ABPs), consisting of repulsive disks with random self-propulsion velocities. We demonstrate, in the regime of homogeneous phase, that an equilibrium-like additivity property leads to subsystem particle-number distributions in the system. The crucial ingredient of this theory is a nonequilibrium fluctuation-response relation (FR) between compressibility and number-fluctuation or variance, which is a direct consequence of additivity. We believe additivity could be the missing link, providing a unified characterization of a broad range of phenomena in the self-propelled particles observed in the past.
3. In this work, we have studied, motivated by the recent experiments on colloidal particles driven by moving lasers, the effect of a periodically moving external potential on a system of hard-core particles diffusing in a confined geometry (*e.g.*, a one-dimensional ring) in a setup of a very simple and paradigmatic model-system, called symmetric simple exclusion process (SSEP). We find that, depending on the structure of the external potential, spatial structures may be quite complex, *e.g.,* multiple peaks and troughs could develop in a traveling density-wave-like patterns. Consequently, the particle current is described by higher order spatial correlations (extending beyond neighbouring-particle correlations). Interestingly, irrespective of these details, the particle current does show polarity reversal and nonmonotonicity (appearance of peak as well as trough in the current) upon variation of particle density and velocity of the external potential. On a general ground, our results could be useful in the context of externally stirred fluids, such as micro-fluidic or micro-electromechanical devices and a driven assembly of nano-particles, etc.

Proposed research activities for the coming year

1. We would like to obtain hydrodynamic description in various conserved-mass transport processes, which could help one to understand various fluctuation relations, if any, in these systems in a dynamical setting and would certainly put our previous findings (see sl. no. 1 in 'Interesting results obtained') on a much stronger ground.
2. We would like to extend our previous work for active Brownian particles (see sl. no. 2 in 'Interesting results obtained') to other systems of self-propelled particles, which could help one to understand the general structure in many living systems, *e.g.*, bacterial colonies, fish schools, flocks of birds as well as in nonliving systems, *e.g.*, photo-activated or chemically powered colloids, etc.
3. We plan to explore if the striking features discovered in our previous work (see sl. no. 3 in 'Interesting results obtained'), *e.g.*, the polarity reversal of current upon tuning certain parameters, would persist in particle transport even in a more realistic system of particles, driven in a confined geometry.