Seminar

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Institute for Plasma Research

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Title: Ratchet effects and collective dynamics in passive and active systems

Speaker: Ms. Anshika Chugh
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Date: 10th June 2024 (Monday)

Time: 03.30 PM

Venue: Seminar Hall, IPR

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Abstract

Transport, in general, makes use of gradients in a system. However, in systems as small as a cell in a human body, fluctuations become comparable to the gradients.. Surprisingly, protein motors in a human body are an excellent example of an efficient tiny machine capable of inter-cellular transport despite the significant noise or fluctuations in the background medium [1]. Taking inspiration from the working of a protein motor, several models have been explored within the framework of 'ratchet systems' to make efficient use of thermal noise to generate useful work. Ratchet mechanism is a novel way to generate directed motion by breaking spatial and temporal symmetries in a system with no external bias [2]. Spatial symmetry is usually broken by employing an asymmetric potential called 'ratchet'. Ratchets do not overcome poor conductivity with strong gradients, but rather use non-directional sources of energy like heat or chemical energy to power unidirectional transport, making the ratchet a 'Maxwell's demon'.

The first part of the work explores the constructive role of noise which can be used to extract work in the form of directed motion. This Thesis explores ratchet systems powered by various sources of non-directional energy. It investigates two categories: those driven externally by an unbiased time periodic drive (passive systems) [3] and those propelled by spontaneously self-driven particles known as "active" particles (active systems) [4], capable of self-propulsion through internal fuel. The presence of directed motion is addressed by analyzing the system using various diagnostics.

In the second part of the work, ratchet is used as a substrate or physical boundary rather than an asymmetric potential. Motion of active or passive particles in such geometries can result in collective effects, such as bacterial development in biofilms or the construction of tissues through collective cell aggregation, to mention a few. Different morphological states result from constrained geometry of different dimensions [5]. Furthermore, in a system composed of a mixture of active and passive particles, the impact of activity on a group of passive particles is discussed. It is found that active particles can trigger the crystallization of passive particles [6].

Apart from being problems of fundamental interest, these studies have several implications for drug delivery, understanding cell movement through pores and veins in biological systems, creating novel materials through self-assembly, separation of particles among others.

References:

[1] RD Astumian et al, Physics Today 55 (11), 33-39 (2002)
[2] P Reimann, Physics Reports 361 , 57-265 (2002)
[3] A Chugh et al, Physica A 593, 126913 (2022)
[4] A Chugh et al, Scientific Reports 13, 16154 (2023)
[5] A Chugh et al, arXiv:2403.04075 (2024)
[6] A Chugh et al, Manuscript under preparation (2024)