Seminar

Title: Collective dynamics of active or self-propelled particles

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e-link: https://meet.google.com/zjm-gffq-qfy

Natural world is abundant with fascinating collective behavior among biological entities over an extensive range of scales. Areal display of a flock of birds is a paradigmatic example. Likewise, cytoskeletal filaments inside cells are known to exhibit collective dynamics and patter formation in the microscales. Various eukaryotic cells at various stages of life are known to exhibit collective dynamics to perform important biological tasks. Collective motion of a school of fish in large oceans is an another well known instances of biological collective behavior. Even at more larger scales, human crowd is known to performs collective dynamics. Above mentioned non-equilibrium biological systems are also known as living matter or living active matter, where the driving energy is injected at the smallest scales of the system, unlike energy injection at the largest scales in driven passive systems, such as steering a cup of tea. Motivated by living active matter, several synthetic particles have been synthesized in recent past that exhibit self-propulsion akeen to their biological counterparts. Due to several potential applications in some of the key areas, such as healthcare, environmental sustainability, climate changes, and more, a great amount of effort is being put world-wide to understand the properties of self-propelled particles or active systems.

In this Thesis, several problems in active matter physics have been addressed employing minimal models in two dimensions, using several particle based numerical simulation schemes. These problems are mainly categorized into four components. First, a small system of repulsive, point-like model of active or self-propelled particles of finite mass is investigated for their collective behavior. Essential differences between inertial and non-inertial collective behavior and effective thermodynamic properties are addressed. Self-propulsion or motility of the particles in the non-inertial limit is known to exhibit phase separation into a high and a low density phase, and consequent coexistence of these phases. The phenomenon is known as motility induced phase separation or MIPS. Second component of the Thesis is the detailed investigation of softness and inertia of the finite size particles on MIPS and the investigation of the spatio-temporal properties of the particles in different MIPS phases. Alignment interaction between active entities of several class of self-propelled particles is found to be responsible for various interesting collective dynamical properties. The third component of the Thesis deals with the investigation of collective dynamics of various non-reciprocal alignment interaction between the particles. Several interesting results due to the incorporation of the non-reciprocal alignment interaction are addressed in the Thesis. Final part of the Thesis investigates the effect of active particles in passive shear flows. This preparatory work opens a new dimension of understanding shear flow and corresponding shear instabilities in presence of active or self-propelled particles. In addition to the problems from physical point of view, mentioned above, large scale CPU and GPU parallel numerical solvers, based on Brownian, Langevin, and Molecular Dynamics schemes, that have been used to address the problems of the present Thesis are developed. Several unsolved problems arising form this Thesis are highlighted that may bring further insights in our understanding this cross-disciplinary field of science. Furthermore, possibilities of realizing synthetic active particles in low temperature plasma experiments is discussed.