Abstract

Active systems, which contain both living and non-living components, display astounding statistical characteristics and group behavior. These systems consist of self-driven elements and self-propelled particles. The ability to transform stored energy into ordered movement is shared by a variety of organisms, including a swarm of myxobacteria, live cell cytoskeletons, bacterial suspensions, cell layers, terrestrial and aquatic animals, bird flocks and colloidal systems. Active matter systems are distinguished from other nonequilibrium systems by the fact that the energy input at the particle level causes the system to lose equilibrium.

In this thesis, we cover both the dynamics of a single polar particle as well as different features of a group of polar particles. Furthermore, we discuss different types of particles like active Brownian particles, run and tumble particles, and chiral active particles in different environments. With the help of Langevin dynamics, we design the system and observe the dynamics of the particle. This thesis is organized into seven chapters.

Chapter 1 is the historical context and description of active systems. The definition and fundamental characteristics of active systems are covered in this chapter. We also go through various methods for researching active systems, such as agent-based modeling. The remaining chapters are structured as follows. In Chapter 2, We model the dynamics of the particle on a two-dimensional periodic undulated surface. Where we study the dynamics of circular disk-shaped active particles on a two-dimensional periodic undulated surface. Each particle has an internal energy mechanism which is modeled by an active friction force and it is controlled by an activity parameter v_0. It acts as negative friction if the speed of the particle is smaller than v_0 and normal friction otherwise. Surface undulation is modeled by the periodic undulation of fixed amplitude and wavelength. The dynamics of the particle is studied for different activities and surface undulations (SU).

Three types of particle dynamics observed on varying activity and SU, confined, early time subdiffusion to diffusion and super diffusion to late time diffusion. An effective equilibrium is established by showing the Green–Kubo relation between the effective diffusivity and the velocity autocorrelation function for all activities and small SU. In Chapter 3, We introduce a minimal model for a run and tumble particles in the presence of passive particles. We numerically studied the effect of size of passive particle on their dynamics in the sea of active run and tumble particles (RTPs). We varied the size of passive particles comparable to RTPs to much larger. The density of passive particles is kept small. System is also studied for different activities of RTPs. We explored the dynamics from short to large time limit and found that dynamics is superdiffusive for short times and shows a crossover from diffusion to subdiffusion for large times. Interestingly crossover time increases on increasing size. Our results give more insight on the dynamics of passive particles in active medium and its comparison with corresponding equilibrium system.

In Chapter 4, We studied a different phase in the system in the presence of chirality. We studied a collection of chiral active particles (CAP) on a two dimensional substrate using extensive numerical study. Particles interact through soft repulsive interaction. The activity and chirality of particles is tuned by varying their self-propulsion speed and angular velocity respectively. Kinetics and steady state properties of particles are studied for different chirality and activity. The phase diagram of system on the plane of activity and chirality shows three distinct phases. For small chirality when activity is dominant, particles show enhanced dynamics and macroscopic phase separation of ordered clusters is observed. For moderate chirality, micro clustered phase is observed in which small clusters with moderate ordering are formed. For large chirality, when chirality dominates, no clustering is found because particle motion is mainly confined to its location. Our study gives a detailed insight into the effect of chirality on the properties of collection of CAP, which can be useful to understand the dynamics and steady state of many natural micro swimmers.

In Chapter 5 Using overdamped Langevin dynamics, we looked at the passive disk-shaped particles on a two-dimensional substrate that had external potential in various sizes. The transport properties of colloidal particles in active liquids have been studied extensively. However, the effect of active fluctuations on their phase behavior has received little attention, and it remains unclear. Here, we report a combined experimental and numerical investigation of passive colloids dispersed in active suspensions of bacteria. Our experiments reveal a dynamic clustering of passive colloids due to an emergent attractive interaction. The strength of this interaction is set by the size ratio of colloidal particles to the bacteria. As a result, the average size of the clusters is observed to grow with an increasing size ratio. Using extensive numerical simulations, we have explored the system over a broader range of parameters. The force calculations between a pair of colloidal particles dispersed in an active medium confirm an enhanced attractive interaction with an increasing size ratio. At large size ratios, the interaction strength is sufficiently strong, leading to phase separation of passive particles. These results are reminiscent of phase separation in equilibrium systems with depletion interaction and purely active systems.

Chapter 6, discusses the dynamics of a single particle on Lorentz lattice gas. We have a connected random lattice on which the dynamics of particles is studied. Three different kinds of dynamic is introduced. First case, motion of the particle on random network shows random diffusive dynamic. In the second case, particle choose either leftmost or rightmost path where particle motion is subdiffusive to ballistic at the late times. In the third case, the particle chooses the left or right path. And the motion of the particle is diffusive to ballistic at the late times. The thesis is finally concluded in Chapter 7 with a synopsis of all the chapters mentioned above with future prospects.