Internal Webinar

Phase Separation in Active Brownian Particles Under Imposed Background Flows

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The phase separation due to the motile nature of finite-size self-propelling particles is a well-known phenomenon, commonly known as motility-induced phase separation (MIPS). In nature, many motile organisms show a phase separation and MIPS have been used to explain the aforementioned observation. More often than not these organisms grow and thrive in a fluid environment. It is known that when the background flow becomes chaotic it acts as a mixture. Now, the question is how the phase separation due to these motile organisms will be affected by the background flow in which they grow and thrive. To address this question we consider a large number (N) of finite-size isotropic self-propelling particles (SPP), which are being advected by the four-roll mill flow. We have taken this four-roll mill flow because it mixes the scalar field very well even though this flow is laminar. The SPPs follow the active Brownian particle (ABP) dynamics and show MIPS for packing fraction ($\phi >\sim 0.4$). In this study, we are maintaining a packing fraction value of 0.7. The fluid characteristic velocity and self-propulsion speed of SPP are the two relevant velocity scales. The two relevant time scales are the inverse of fluid characteristic vorticity and rotational diffusivity of SPPs. We define two dimensionless quantities based on the ratio of these four scales: 1) scaled time is the ratio of SPP to fluid time scale; 2) scaled velocity is the ratio of SPP to fluid velocity. Based on these dimensionless numbers, we observe three distinct distribution regimes for SPPs. When scaled velocity is small (<<1) the flow dominates the dynamics of SPPs and shows a homogeneously mixed phase. When scaled velocity is large (>>1) the motility of the SPPs dominates the dynamics and shows MIPS regime. When scaled velocity is moderate ~1, we observe that based on the time scale, it can either show a moderately mixed homogeneous phase (scaled time is small) or it can show a novel phase, that emerges due to interplay between flow topology and motile, finite-size nature of SPPs at large scales times. We call this novel phase flow-induced phase separation (FIPS). To get a better understanding of the system on the dimensionless number we show a phase diagram in scaled-time scaled-velocity phase space. We have also characterized the drift velocity and diffusivity from the mean-squared displacement, giant number fluctuation, radial distribution function, and cluster-size distribution to develop a detailed understanding of this system.

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