Active XY model on a substrate: Density fluctuations and phase ordering

Astik Haldar[1], Apurba Sarkar, Swarnajit Chatterjee, Abhik Basu
[1]*Saha Institute Of Nuclear Physics, Kolkata, India*

We explore the generic long wavelength properties of an active XY model on a substrate, consisting of collection of nearly phase-ordered active XY spins in contact with a diffusing, conserved species, as a representative system of active spinners with a conservation law. The spins rotate actively in response to the local density fluctuations and local phase differences, on a solid substrate. We investigate this system by Monte-Carlo simulations of an agent-based model, which we set up, complemented by the hydrodynamic theory for the system (using Renormalisation Group theory framework for nonlinear terms). We demonstrate that this system can phase-synchronize without any hydrodynamic interactions. Our combined numerical and analytical studies show that this model, when stable, displays hitherto unstudied scaling behavior: As a consequence of the interplay between the mobility, active rotation and number conservation, such a system can be stable over a wide range of the model parameters characterized by a novel correspondence between the phase and density fluctuations. In different regions of the phase space where the phase-ordered system is stable, it shows phase ordering which is generically either logarithmically stronger than the conventional quasi long range order (QLRO) found in its equilibrium limit, together with “miniscule number fluctuations”, or logarithmically weaker than QLRO along with “giant number fluctuations”, showing a novel one-to-one correspondence between phase ordering and density fluctuations in the ordered states. Intriguingly, these scaling exponents are found to depend explicitly on the model parameters. We further show that in other parameter regimes there are no stable, ordered phases. Instead, two distinct types of disordered states with short range phase-order are found, characterized by the presence or absence of stable clusters of finite sizes. In a surprising connection, the hydrodynamic theory for this model also describes the fluctuations in a Kardar-Parisi-Zhang (KPZ) surface with a conserved species on it, or an active fluid membrane with a finite tension, without momentum conservation and a conserved species living on it. This implies the existence of stable fluctuating surfaces that are only logarithmically smoother or rougher than the Edward-Wilkinson surface at two dimensions (2d) can exist, in contrast to the 2d pure KPZ-like “rough” surfaces.