Statistical perspectives on soft matter and biologically motivated systems

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by

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Declaration

I hereby declare that this dissertation represents my works in my own words and where others' ideas or words have been included, I have adequately cited and referenced the original sources. I also declare that I have adhered to all principles of academic integrity and honesty and have not misrepresented or fabricated or falsified any idea/data/fact/source in my thesis.

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Abstract

We elucidate the statistical physics descriptions for a class of soft and nonequilibrium systems in this thesis. In particular, we discuss fluid membranes in thermal equilibrium as well as driven out of equilibrium being in contact with an active fluid layer, and asymmetric exclusion processes on a ring with a pair of bottlenecks. We first discuss the equilibrium phase transitions in model two-component asymmetric inhomogeneous fluid membranes. To this end, we propose two coarse-grained models belonging to two different symmetries in the spirit of the Ginzburg-Landau approaches and analyse them. The models display miscibility phase transitions for the order parameter that describe the membrane composition. These transitions may be both first and second order through critical and tricritical points. In addition, the membrane fluctuations near the phase transitions are either enhanced or suppressed, depending upon the symmetry of the models and the nature of the miscibility phase transitions.

In the next chapter, we set up the effective two-dimensional dynamics of a fluid membrane with an ordered active polar fluid layer anchored to it in the hydrodynamic limit. We consider a free standing system and a system resting on a solid surface. We analyse the long wavelength linear stabilities in the models. The instabilities can be either static or moving, and may exist for both signs of a parameter that characterises the strength of the nonequilibrium active stresses in the models. We illustrate their dependences on the boundary conditions and the ordering directions of the active fluid layer.

In the last chapter, we consider asymmetric exclusion processes on a ring with a pair of point bottlenecks. The resulting steady state densities display a variety of profiles, including localised domain walls and their delocalisation, and confinement of delocalised domain walls, depending upon the microscopic bottleneck configurations. We argue that the steady state density profiles cannot be reliably used to gain information about the microscopic bottlenecks, due to screening of the weaker bottleneck by the stronger one. This reveals a notion of an underlying universality in the system.

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