A hydrodynamic description of actin cortex using a polymerizing active gel theory with nematic and polar order

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Abstract

Living cells undergo constant morphological changes, adhesion, locomotion, and division, all orchestrated by the intricate network of the cytoskeleton. Among its components, the actin cortex, a thin layer beneath the plasma membrane, holds particular significance. This dynamic structure not only shapes cellular morphology but also governs the mechanical properties of cells. Perturbations in the actin cortex dynamics can lead to the formation of protrusions and the contractile ring essential for cell division. In this study, we delve into the dynamics of actin filaments within the cortex and investigate the potential ramifications of cortex instability. Employing a hydrodynamic model of active gels, we focus on the polymerization process at the membrane, resulting in the emergence of an actin cortex exhibiting nematic and polar phase transitions. Furthermore, we observe the formation of dynamic protrusions beyond a critical activity threshold. By extending the polymerization dynamics to a two-dimensional surface, we explore its role in stabilizing topological defects. Our findings reveal the intricate interplay between polymerization and isotropic active contractile stress, unveiling multiple phases such as active foams, tissue-like structures, and a sea of stable topological defects arranged in near-perfect crystalline order. Furthermore, we explore the effects of active anisotropic stress, leading to the formation of new structures like filaments and stress fibers. This study explores various phases for polar, nematic, and combined polar-nematic active fluids, highlighting scenarios where both orders must be jointly considered and coupled.

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