Physics > Biological Physics

Tensegrity and Motor-Driven Effective Interactions in a Model Cytoskeleton

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Actomyosin networks are major structural components of the cell. They provide mechanical integrity and allow dynamic remodeling of eukaryotic cells, self-organizing into the diverse patterns essential for development. We provide a theoretical framework to investigate the intricate interplay between local force generation, network connectivity and collective action of molecular motors. This framework is capable of accommodating both regular and heterogeneous pattern formation, arrested coarsening and macroscopic contraction in a unified manner. We model the actomyosin system as a motorized cat's cradle consisting of a crosslinked network of nonlinear elastic filaments subjected to spatially anti-correlated motor kicks acting on motorized (fibril) crosslinks. The phase diagram suggests there can be arrested phase separation which provides a natural explanation for the aggregation and coalescence of actomyosin condensates. Simulation studies confirm the theoretical picture that a nonequilibrium many-body system driven by correlated motor kicks can behave as if it were at an effective equilibrium, but with modified interactions that account for the correlation of the motor driven motions of the actively bonded nodes. Regular aster patterns are observed both in Brownian dynamics simulations at effective equilibrium and in the complete stochastic simulations. The results show that large-scale contraction requires correlated kicking.

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