Stochastic dynamics of filament buckling by molecular motors

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We study buckling instabilities of filaments in biological systems. Filaments of the cytoskeleton are semiflexible polymers, i.e. their bending energy is comparable to the thermal energy such that they can be viewed as elastic rods on the nanometer scale, which exhibit pronounced thermal fluctuations. Like macroscopic elastic rods, filaments can undergo a mechanical buckling instability under a compressive load.

In the first part of the talk we review how the thermal fluctuations affect the buckling of filaments. In terms of phi^4 model we introduce an analytical model for buckling of filaments or elastic rods in two spatial dimensions in the presence of thermal fluctuations. We calculate the resulting shift of the critical force (Euler force) by fluctuation effects and the mean projected length of the filament in the force direction as a function of applied force. Our analytical results are confirmed by Monte Carlo simulations. We also perform Monte Carlo simulations in higher spatial dimensions. In cells, compressive loads on filaments can be generated by molecular motors. In the second part of the talk we investigate how the stochastic nature of such motor-generated forces influences the buckling behavior of filaments and motors. We investigate a system in which a group of motors moves along an immobilized filament carrying a second filament as a cargo. The cargo-filament is pushed against the wall and eventually buckles. The force-generating motors can stochastically unbind and rebind to the filament during the buckling process. We formulate a stochastic model of this system and calculate the mean first passage time for the unbinding of all linking motors which corresponds to the transition back to the unbuckled state of the cargo filament. We also introduce the mean field model for the problem and compare its solution with the fully stochastic model. Our predictions could be tested in future experiments.