Cytoplasmic Rotation in a Coarse-Grained Model of Cortical Microtubules and Asymmetric Motor Composites

A. Ravichandran[1], **T. Auth**[1], **G. Vliegenthart**[1] **and G. Gompper**[1]

[1] *Theoretical Soft Matter and Biophysics, Institute of Complex Systems and Institute for Advanced Simulation, Forschungzentrum Jülich , 52425 Jülich, Germany*
Corresponding Author: a.ravichandran@fz-juelich.de

Motor proteins, such as kinesins, are molecular machines that hydrolyse ATP to perform mechanical work on microtubules (MTs) to drive motility in cells. This is important for processes such as cytokinesis, localization of organelles, and cytoplasmic streaming [1]. The recent work of Lu *et al.* has shown in vivo that microtubule sliding, induced by kinesin-1 is important for normal oocyte cytoplasmic rotation, a process required for efficient localization of mRNAs and proteins during oogenesis in Drosophilia [2]. Namely, free microtubules are observed to move against cortically anchored microtubules generating forces that contribute to cytoplasmic streaming.

To elucidate the relation of microscopic mechanisms to the macroscopic properties, we use a two dimensional Brownian dynamics model [3]. Circularly confined polar filaments are modelled as a linear rigid chain of penetrable beads that mutually attract each other by depletion forces. Motors are harmonic force dipoles that move on the filaments in the direction of MT polarisation, and pull cross-linked filaments with them [4]. In this work we study the effect of both, tetrameric and dimeric motors. Tetrameric motors have two motile arms that cross-link two neighbouring MTs, while dimeric motors have one motile arm, and another anchored arm, similar to kinesin-1.

We show that tetrameric motors bundle MTs, and do not lead to motility. Unlike tetrameric motors that induce relative tangential stress only in the case of aligned MTs, kinesin-1-like, dimeric motors induce stresses in the case of both anti-aligned and aligned MTs. This leads to perpetual motility in a layer of MTs close to the confinement edge, where filaments are distinctly more anti-aligned. Higher densities of motors do not change the organization of filaments, but induce more stress and propel filaments faster. The structures consist of large nematically aligned droplets with point defects at the boundary.

References

[1] Michael P. Sheetz, Nature Reviews MCB **2**, 392-396, (2001)

[2] W. Lu, M. Winding, M. Lakonishok, J. Wildonger, and V. I. Gelfand, PNAS **113**, E4995-E5004, (2016)

[3] Masoud Abkenar, Kristian Marx, Thorsten Auth, and Gerhard Gompper **88**, 062314, (2013)

[4] D. A. Head, G. Gompper, and W. J. Briels, Soft Matter **7**, 3116-3126, (2011)