Cooperativity and hydrodynamic interactions in externally driven semiflexible filaments

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We describe a simple simulation method that describes the hydrodynamics of semiflexible filaments immersed in a low Reynolds number fluid and analyze how multiple body cooperativity emerges due to the presence of hydrodynamic interactions (HI). We study the sedimentation of ensembles of filaments under an external force and also consider the propulsion of filaments subject to simple periodic driving. In both cases the dynamics shows qualitative differences due to the presence of HI[1].

1. For sedimentation, the effects of the HI include cooperative velocity and instabilities that can be understood from the interplay of deformations due to flexibility and hydrodynamic forces. We concentrate in the case of a pair of inextensible semiflexible filaments under a uniform constant force at low Reynolds numbers. We have analyzed the different regimes and the morphology of such polymers in simple geometries[2], which allow us to highlight the peculiarities of the interplay between elastic and hydrodynamic stresses. Cooperative and symmetry breaking effects associated to the geometry of the fibers gives rise to characteristic motion which give them distinct properties from rigid and elastic filaments.
2. We examine the problem of cooperativity induced by HI in the swimming of multiple flagellated objects, such as sperm cells. We concentrate on the two case studies of model semi-flexible inextensible filaments driven by an external oscillatory force and by an internal, force and torque-free mechanism, what we call swimmers. The velocity gain for swimming cooperatively depends both on the geometry and on the driving; as a result, a variety of situations are possible, and only in some of them swimming together becomes advantageous. Moreover, there is positive and negative cooperation depending on distance, frequency of drive, and flexibility. We find that in all geometries and drives, the hydrodynamics determine a directional instability such that filaments that profit from swimming together are driven apart from each other. Biologically, this implies that flagella need to synchronize in order to profit from swimming together[3].

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[1] I. Llopis, I. Pagonabarraga and M. Cosentino Lagomarsino, *s*ubmitted to Comp. Phys. Comm.
[2] I.Llopis, I.Pagonabarraga, M. Cosentino Lagomarsino and C.P. Lowe, Phys. Rev. E 76, 061901 (2007).
[3] I.Llopis, I.Pagonabarraga, M. Cosentino Lagomarsino and C.P. Lowe, *i*n preparation.
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