From bacteria to chromosomes: 
hydrodynamic self-organization of biological active matter

Abstract:

The three-dimensional spatiotemporal organization of genetic material inside the cell nucleus remains an open question in cellular biology. During the time between two cell divisions, the functional form of DNA in cells, known as chromatin, fills the cell nucleus in its uncondensed polymeric form, which allows the transcriptional machinery to access DNA. Recent in vivo imaging experiments have cast light on the existence of coherent chromatin motions inside the nucleus, in the form of large-scale correlated displacements on the scale of microns and lasting for seconds. To elucidate the mechanisms for such motions, we have developed a coarse-grained active polymer model where chromatin is represented as a confined flexible chain acted upon by active molecular motors, which perform work and thus exert dipolar forces on the system. Numerical simulations of this model that account for steric and hydrodynamic interactions as well as internal chain mechanics demonstrate the emergence of coherent motions in systems involving extensile dipoles, which are accompanied by large-scale chain reconfigurations and local nematic ordering. Comparisons with experiments show good qualitative agreement and support the hypothesis that long-ranged hydrodynamic couplings between chromatin-associated active motors are responsible for the observed coherent dynamics. The connection between our model and mechanisms proposed for self-organization of other biological systems including bacterial suspensions will also be discussed.