Collective effects in intracellular transport

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Eukaryotic cells present a very complex network of "highways" on which materials like vesicles or organelles are actively transported. The carriers are molecular motors that produce mechanical work by the hydrolization of ATP. Each motor has a specific molecular structure that determines its mechanical properties like the velocity or the direction in which it walks along the biofilament. Moreover molecular motors exhibit rich dynamics: motors attach or detach from the biofilaments, motors that walk in the same direction can cooperate in the transport of the same cargo [1] while motors that walk in different directions can play a "tug of war" [2] when attached at the same cargo. Many models have been proposed to study molecular motors at different scales ranging from mechanochemical models for a single motor [3] to continuum models which describe large motor ensembles walking on the same track [4, 5].

We have modeled the molecular motors like Brownian motors that walk in a high viscous fluid. In particular, we are intersted in the study of the hydrodynamic interactions between ensembles of motors walking on the same track. To study such interactions, we have developed a numerical model that permits us to couple the ratchet-like movement of motors to the cytoplasmic fluid they move in.

We have studied the velocities of ensembles of motors as a function of the concentration of motors, the fluid viscosity and the ratio between the dimension of the motor and the ratchet period. In all cases we have found a marked dependence of the motors' average velocity on their concentration. We have assessed the relative relevance of direct motor-motor interaction and dynamical coupling trough the solvent in the collective perspective of motor transport.

As a first result, we have found that for low concentration of motors the hydrodynamic coupling speeds up the motors while for high concentration values the excluded volume interaction between motors dominates and prevents motors to move in agreement with previous results on a simplified discrete 2D model [8]. In particular, while rising the motors' concentration, we find that motors move in a coordinate way that speeds motors ensembles velocity up to 50 times the speed of a single motor. Moreover we noticed the formation of big clusters whose size scales with motors number. A preliminary analysis shows that their formation is strongly affected by the constraint imposed on motors trajectories on the biofilament (1D or 2D). Surprisingly the velocity of these structures, that are stable for long times compared with typical time scales of a single motor, is lower than the velocity we measured before clustering for the same motors' concentration.

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