Tug-of-war between elastically coupled molecular motors

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Intracellular transport is based on molecular motors that pull cargos along cytoskeletal filaments. Many cellular cargos are observed to move bidirectionally, with fast transport in both directions. This behavior can be understood as a stochastic tug-of-war (ToW) between two teams of antagonistic motors. The original ToW model introduced in [1] was based on two simplifying assumptions: (i) both motors move with the same velocity in the direction of the stronger motor, and (ii) this velocity matching and the associated force balance arise immediately after the rebinding of an unbound motor to the filament.

In this study, [2] we extend the ToW model by including an elastic coupling between the antagonistic motors, and by allowing the motors to perform discrete motor steps. Each motor step changes the elastic coupling and generates a force that acts on all motors. Depending on the strength and stability of the motors (characterised by their stall and detachment forces), as well as on the stiffness of the elastic coupling, the motors can perform multiple steps before they reach a state of force balance.

In general, the ToW model with elastic coupling is found to generate a lower average force between the motors compared to the original model. The behavior of the latter model is recovered in the limit of small unbinding rates of the motors. In all cases, we determine the time needed to reach a state of force balance. This time scale becomes larger when the elastic coupling becomes weaker.

[1] M. I. J. Müller, S. Klumpp, and R. Lipowsky, PNAS 105, 4609 - 4614 (2008).

[2] M. C. Ucar and R. Lipowsky (in preparation).