Tug of war: The dynamics of flagellar motor with multiple stators

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In a single flagellar motor, there are multiple stator units that drive the rotation of the flagellar filaments. Here, we introduce a "tug-of-war" model for the flagellar motor where each individual stator can generate either positive or negative torque depending on its relative mechano-chemical state with respect to the rotor. The key ingredient of our model is that the instantaneous chemical switching (stepping) rate of a stator depends on the torque it generates: stators that generate negative torque switch faster. We show that the experimentally observed torque-speed relationship can be explained by the moving time and waiting time of the motor and their different dependences on the load. The model reveals the dependence of the motor dynamics on the number of stators. In particular, we show that the maximum speed of the motor is independent of the number of stators, which agrees with recent resurrection experiments at near zero loads [Yuan & Berg, PNAS 105, 1182-1185, 2008]. The model is also used to study stepping statistics in single flagellar motor and understand different noise sources for rotational speed fluctuation. Finally, our model can be generalized to study other motor system with multiple power generating units. Part of the work is published in [Meacci & Tu, PNAS 106, 3746-3751, 2009].

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