Mechanics of entropic biopolymer networks from the thermodynamics of molecular motors

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Abstract

Contractile biopolymer networks, such as the actomyosin meshwork of animal cells, are ubiquitous in living organisms and contribute in a large part to their function such as muscle contraction or embryonic morphogenesis. Their contractility relies on the active behaviour of molecular motors which crosslink the biopolymer of the network and can transduce at the molecular scale chemical energy into mechanical work (Jülicher et al, *Rev Mod Phys* 69, 1997).

The active gel theory (Kruse et al, *Eur Phys J E* 16, 2005), which provides a thermodynamic framework for these materials, has been mostly used in conjunction with the assumption that the microstructure of the biopolymer network is based on rigid rods (Liverpool and Marchetti, *Phys Rev Lett* 97, 2006). However, experimentally, crossed-linked actin networks exhibit entropic elasticity (Gardel et al, *Science* 304, 2004). Here we combine an entropic elasticity kinetic theory, in the spirit of the Green and Tobolsky model (*J Chem Phys* 14, 1946) of transiently crosslinked networks, with an active flux modelling motor activity (arXiv:2405.07287). We determine this active flux using Onsager reciprocal relations applied at the microscopic scale of individual motors. We derive the macroscopic active stress that arises from the resulting dynamics and obtain a closed-form model of the macroscopic mechanical behaviour. Although similar to models commonly chosen in the active gel theory, the choice of entropic elasticity provides it with specific features of quantitative importance (Etienne et al, *Proc Natl Acad Sci USA* 112, 2015). Additionally, the analytical clarity of the derivation allows us to give microscopic interpretation of macroscopic active behaviours of contractile networks.

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