Propagation of dipoles in non-linear elastic media

Guglielmo Saggiorato[1] and Martin Lenz[1]

[1]*LPTMS, CNRS, Univ. Paris-Sud, Université Paris-Saclay, 91405 Orsay, France*

How do forces propagate through complex media, such as the cytoskeleton? Previous works highlighted that dipoles applied to a non-linear network of fibers are distorted by the medium itself. At large distances the dipole is amplified and rectified always towards an effective contractile dipole independent on the nature of the applied dipole [1]. Indeed, under high-enough load fibers buckle and create a rope-like medium around the local dipole. One possible consequence for the cell is that the cytoskeleton can serve as an active regulator of the propagation of local forces (e.g. exerted by myosin) to upper scales. We generalize this result to all non-linear materials and for generic dipoles. We find that also neutral local dipoles (neither contractile nor extensile) are rectified, and that the rectification direction depends on the medium non-linear response, e.g. strain-softening or strain-stiffening. This implies that the effect is not restricted to rope-like media only. Moreover two fundamentally different non-linear contributions are systematically present in a non-linear medium: geometrical and material ones. The rectification direction is tuned by the material non-linearities. The geometrical ones, instead, cannot be tuned and shift the threshold from contractile to extensile materials. Our results are validated by simulations with finite elements of a hyper-elastic material which interpolates between strain-stiffening and softening response.

[1] Ronceray, P., Broedersz, C.P., and Lenz, M. (2016). Fiber networks amplify active stress. PNAS *113*, 2827–2832.