Odd elasticity in disordered chiral active materials

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Chirality, first proposed as handedness of a material's shape, can also refer to motion or trajectory of a preferred helical or rotational direction. This dynamic chirality is abundant in biological systems, of which the components become active via constant energy consumption (e.g., ATPs) to generate local stresses and/or torques. Examples include microtubules twisted by motor proteins, rotary clusters formed by microorganism or bacterial flagella, microswimmers with asymmetric shape and many more. These chiral active materials can exhibit unusual dynamics and mechanics due to breaking time reversal symmetry via energy injection and breaking parity via chirality. Among them, biological active gels with chiral components are frequently encountered, e.g., cytoskeleton (biofilament network) with motor proteins. These gels are generally highly disordered in space, yet can be considered to be isotropic at large scales. In terms of mechanics, they are known to show viscoelasticity with elastic compliance in short timescale. In this talk I will discuss a minimal model for such disordered systems with local active torques as input of chirality. To this aim, I use Cosserat continuum medium for the elastic potential, which accounts for the effect of local orientation of the material components, and thus interplays with chirality (i.e., local active torques). For dynamics, I apply the Poisson-bracket formalism to derive dynamic equations for macroscopic fields from microscopic quantities. This may have the advantage to more easily design or connect with agent-based simulations. Our results show that new elastic moduli naturally emerge due to these active torques in our model. One of them is the so-called odd elasticity, which anti-symmetrically couples two different types of shear deformations and stresses, i.e, one in pure shear and the other in simple shear direction. The other two moduli couple dilation with torques and rotations with pressure, respectively. In comparison with earlier work, which used `lattice' models to obtain odd elasticity, we found this oddity from a disordered model, which shall be closer to real biological systems. I will also discuss the effects of these emergent elastic moduli on elastostatics and elastodynamics of such chiral active materials, as oddity has been shown to exhibit interesting non-reciprocal response.