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Geometry of Wave Propagation on Active Deformable Surfaces

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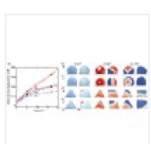
ABSTRACT

Fundamental biological and biomimetic processes, from tissue morphogenesis to soft robotics, rely on the propagation of chemical and mechanical surface waves to signal and coordinate active force generation. The complex interplay between surface geometry and contraction wave dynamics remains poorly understood, but it will be essential for the future design of chemically driven soft robots and active materials. Here, we couple prototypical chemical wave and reaction-diffusion models to non-Euclidean shell mechanics to identify and characterize generic features of chemomechanical wave propagation on active deformable surfaces. Our theoretical framework is validated against recent data from contractile wave measurements on ascidian and starfish oocytes, producing good quantitative agreement in both cases. The theory is then applied to illustrate how geometry and preexisting discrete symmetries can be utilized to focus active elastic surface waves. We highlight the practical potential of chemomechanical coupling by demonstrating spontaneous wave-induced locomotion of elastic shells of various geometries. Altogether, our results show how geometry, elasticity, and chemical signaling can be harnessed to construct dynamically adaptable, autonomously moving mechanical surface waveguides.





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