From collective fluctuations to the mechanical properties of model biological membranes using neutron spin echo spectroscopy

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Biomembranes, composed of lipids and proteins among other things, are dynamic platforms that accommodate a variety of cellular functions. While the role of structure in modulating those functions has garnered significant attention, the role of the membrane's dynamical properties has been less well appreciated. However, recent research using model lipid bilayers has begun to explore the hierarchy of deformation dynamics spanning sub ps to seconds that occur in these systems. Among these, the collective movements of two or more lipid molecules have been difficult to probe because of the nanometer length and nanosecond time scales of such movements and the fact that simultaneous determination of the structural and dynamical features is essential to fully understanding such motions. Neutron spin echo (NSE) spectroscopy, which uses Larmor precession of neutron spins to encode energy information in its spin state, is the quasi-elastic neutron scattering techniques with the highest energy resolution. We have been developing a technique using NSE to measure collective thermal fluctuations of membranes, such as undulation and thickness fluctuations, on the nanosecond time scale. Membrane theories tell us that undulation fluctuations can be used to estimate the elastic bending modulus of the membranes, while thickness fluctuations are sensitive to changes in the area compressibility modulus and membrane viscosity. We can thus estimate elastic and viscous properties of lipid membranes through the measurement of naturally occurring equilibrium thermal fluctuations of membranes without incorporating any probe molecules. This technique opens new avenues to the study of collective membrane dynamics. We will discuss recent results coupling NSE with static structural measurements, such as small-angle x-ray and neutron scattering, to provide new insights into the membrane's mechanical properties.