# Undulations and Dynamic Structure Factor of Membranes surrounded by viscoelastic continuous media

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In this talk I will first review the so-called "Zilman-Granek theory" for membrane dynamic structure factor in case of an embedding purely viscous solvent. I will derive the dispersion relation of a nearly flat membrane, namely the relaxation rate of a single membrane bending mode of wavenumber $q$. I will show how this relation leads to the anomalous subdiffusion of a membrane segment in the transverse direction with a mean square displacement (MSD) evolving as $\sim t^{2/3}$. In addition, the anomalous diffusion will be derived using a scaling hypothesis. I will then show how this anomalous diffusion leads to a stretched exponential decay of the dynamic structure factor of membrane phases at large wavenumbers $k$, $S(k,t) \sim e^{-(\Gamma_k t)^{2/3}}$, with a relaxation rate $\Gamma_k$ that scales as $\sim \kappa^{-1/2} k^3$, where $\kappa$ is the membrane bending modulus. A complementary scaling hypothesis will be used to derive the relaxation rate. I will briefly discuss a few experimental examples from the last decade.

Next I will generalize the dynamics to the case of a membrane surrounded by two semi-infinite viscoelastic fluids. By modeling the surrounding fluids as continuous media with frequency dependent shear modulii, $\mathrm{G}_1(\omega)$ and $\mathrm{G}_2(\omega)$, I will derive the dispersion relation for undulations. I will deduce the frequency-dependent transverse mean square displacement of a membrane segment and show that it is proportional to $\kappa^{-1/3}\left(\mathrm{G}_1(\omega)+\mathrm{G}_1(\omega)\right)^{-2/3}$. I will then consider the linear response of a membrane to external forces. Possible implications will be elucidated: (i) for experiments probing the viscoelasticity of cells and vesicles encapsulating and/or embedded in viscoelastic fluids, (ii) for the dynamic structure factor of such systems, and (iii) for lamellipodia dynamics.