Todd Squires

I. Microrheology of complex fluids

II Active, nonlinear and interfacial rheology

Soft materials -- which elude any simple "liquid or solid" classification -- are common in everyday life, from foods, to personal care products, to biology. The macro-scale continuum response of such materials generally derives from some microstructure on a smaller scale -- which could arise from e.g. suspended polymers, colloids, bubbles or drops, or surfactant structures like micelles. The study of how materials flow and deform under applied stress or strain is called rheology, and traditional rheological measurements are performed by shearing milliliter-scale samples in specially-designed geometries. In the first lecture, I will describe both traditional rheometry and the emerging technique of (passive) microrheology, in which the linear rheological response of a soft material is determined from the fluctuations of embedded colloidal probes. Introduced by Mason & Weitz in 1995, (passive) microrheology has proven enormously successful in characterizing a wide range of materials over wide ranges of frequencies, while offering substantial additional advantages. I will describe the technique in practice, as well as the theoretical foundations of (passive) microrheology. I will demonstrate a minimal set of conditions that are required for the core relation employed in microrheology -- the so-called Generalized Stokes-Einstein Relation, or GSER. I will also describe the consequences that ensue when these core conditions are violated -- in some cases, the GSER can be generalized still further, while in other cases it can not. For a review, see Squires & Mason, Ann. Rev. Fluid Mech. 42:413-438 (2010). In the second lecture, I will describe recent developments in microrheology. I will focus on two areas: active microrheology, which aims to probe the nonlinear response properties of a material, and interfacial microrheology, which probes the rheological response of complex fluid interfaces. Actively-driven probes can drive the microstructure of the soft material significantly out of equilibrium, which in turn can give rise to nonlinear rheological phenomena such as yield stresses, shear thinning and thickening, and normal stress differences. However, the linear-response formalism that underpins the theory of passive microrheology breaks down for non-linear microrheology, and we will describe the issues that arise. Secondly, I will describe some special advantages provided by microrheology in probing complex fluid interfaces, since the small scale of microrheological probes gives them an inherent sensitivity to the interfacial mechanics, rather than the properties of the bulk subphase. We will highlight with an example from our own work, in which we simultaneously visualize a deforming interface while measuring the rheology, which enables the rheological response to be correlated directly with the deforming microstructural components.