MAR16-2015-002856
Abstract for an Invited Paper
for the MAR16 Meeting of
the American Physical Society

Nonlinear and nonlocal rheology of jammed matter

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Emulsions, foams, and grains all jam into a weakly elastic state when confined by pressure. By now the mechanics of jammed matter is well understood in the case of slow, weak, and homogeneous forcing – but in reality, it is rare for all three of these assumptions to hold. Here we demonstrate the complex rheology that results when jammed materials are forced at finite rate, finite amplitude, and finite wavelength. Using computer simulations, we subject dense soft sphere packings to a host of rheological tests, including stress relaxation, flow start-up, oscillatory shear, and standing wave forcing. These allow us to tease apart the influence of viscous, nonlinear, and nonlocal effects, and also to probe the link between particle dynamics and bulk response. We identify strain, time, and length scales that depend critically on the distance to the jamming transition, and which govern the onset of shear thinning, strain softening, and gradient elasticity.