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Towards a unifying picture of driven disordered systems

Disorder is ubiquitous in physical systems, and can radically alter their physical properties compared to their 'pure' counterparts. For instance, amorphous materials such as emulsions, foams, metallic glasses or biological tissues are all structurally disordered, and this has key implications for their rheological, mechanical or transport properties. Nevertheless, theoretical descriptions of such 'driven' amorphous materials remain challenging, despite of decades of extensive analytical and computational studies. The difficulties pertain to the interplay of competing sources of stochasticity, and to the resulting out-of-equilibrium nature of these systems. A standard model for amorphous materials, which allows to focus on the key role of their structural (positional) disorder, is provided by dense many-body systems of pairwise interacting particles. Here I will introduce an exact Dynamical Mean-Field Theory (DMFT) for these many-body systems, derived in the limit of infinite spatial dimension. In this framework, the many-body Langevin dynamics of the whole problem can be exactly reduced to a single scalar effective stochastic process, and dynamical observables such as pressure or shear stress can be computed for arbitrary driving protocols. Using this DMFT, we were in particular able to establish a direct equivalence between a global forcing (external shear) and a random local forcing (reminiscent of active matter), upon a simple rescaling of the control parameter (the accumulated strain). In this framework, global shear is thus simply a special case of a much broader family of local forcing, that can be explored by tuning its spatial correlations. Our predictions were moreover found to be in remarkably good agreement with two-dimensional numerical simulations. These results hint at a unifying framework for establishing rigorous analogies, at the mean-field level, between different families of driven disordered systems, such as sheared granular materials and active matter, or machine-learning algorithms.