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Statistical mechanics of slow dynamics: glasses and beyond

Systems which relax slowly and eventually fall out of equilibrium are widespread in classical (soft) condensed-matter. The paradigmatic example are liquids which when supercooled end up forming glasses. I will review the phenomenology of the glass transition, as the template for dynamical arrest in classical many-body systems more broadly. I will then address the question of how to describe this physics theoretically. I will focus on a perspective whereby complex slow relaxation is a consequence of (emergent) constrained dynamics. A key insight is that the interesting structure is not encountered in static configurations but in trajectories of the dynamics, which requires the use a “statistical mechanics of trajectories” based on the mathematics of large deviations. Slow dynamics is then seen as a consequence of phase transitions occurring in space-time (rather than in space as in the standard equilibrium case). I will also discuss the wider application of these concepts to other non-equilibrium systems, both classical and quantum.