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Emergence of slow modes and the memory of initial momentum anisotropy in rapidly-expanding quark-gluon plasma

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A crucial open question is why many models of expanding systems exhibit an apparent simplification in their description while gradients in the system are still large and hydrodynamics is not expected to apply. We discuss a new conceptual approach to understand the pre-equilibrium bulk evolution of a system in terms of a reduced set of slow modes. For concreteness we consider a kinetic theory describing a general expanding system with transverse flow and momentum space anisotropy. We find that these slow modes at early times give rise to far-from-equilibrium attractor behavior of moments of the distribution function. However, the slow modes are qualitatively distinct from hydrodynamic modes at early times, and only some of them evolve into hydrodynamic modes in the hydrodynamic limit. This framework suggests a general criterion for the presence of a simplified description even when gradients are large, if they are small compared to the energy gap between slow modes. This criterion can be satisfied in small systems, meaning that slow modes could be relevant for understanding flow-like correlations in small systems. We additionally find an attractor for the momentum space anisotropy that indicates the memory of initial anisotropy due to the presence of slow modes.

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