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# Early Thermalization in kenitic theory via sBBGKY

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The early thermalization puzzle—stemming from the unexpectedly early success of hydrodynamics in describing the quark–gluon plasma (QGP)—remains a central open question in relativistic heavy-ion collisions. To address this, **we develop a new theoretical framework, the spectral BBGKY hierarchy**, which is analytically equivalent to the Liouville equation and preserves time-reversal invariance while offering significant advantages for numerical implementation. **This reformulation provides a semi-analytic route to non-equilibrium, nonlinear many-body dynamics, encompassing both the conventional Boltzmann description and explicit two-body correlations** [1].
Applying this spectral nonlinear Boltzmann equation to a homogeneous massless system, we systematically investigated the timescales of linearization and thermalization. We identified a robust separation: the linearization time, at which the system begins to follow hydrodynamical evolution, is approximately half the thermalization time. **This result provides a quantitative resolution to the early thermalization puzzle by demonstrating that hydrodynamic applicability commences once the system enters the linearized regime, well before full local thermal equilibrium is established**. [2]

[1] arXiv: 2507.14243, Xingjian Lu, Shuzhe Shi.

[2] arXiv: 2509.xxxxx, Xingjian Lu, Shuzhe Shi.

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