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Unraveling QGP and jet physics via perturbing attractors

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The rapid longitudinal expansion characteristic of heavy-ion collisions leads to universal attractor behavior of the resulting drop of Quark-Gluon Plasma already at very early times. Assuming approximate boost invariance, we incorporate transverse dynamics and parton evolution by linearizing the Mueller-Israel-Stewart theory around the attractor. This yields a system of coupled ordinary differential equations which describe the proper-time evolution of perturbations encoding the transverse structure of the initial and jet energy deposition across a wide range of geometric configurations and parton energy loss scenarios. The late-time asymptotic behavior of the solutions is described by transseries which manifest the stability of the attractor against transverse perturbations, as well as a dominant power-law series attributed to the parton source. Although most of the physically relevant initial information resides in the exponentially suppressed transseries corrections to the evolution along the attractor, they are not yet negligible at freeze-out. These findings advocate for a simple numerical approach to QGP dynamics which accounts for the transverse dynamics and jet-medium interactions via a finite set of Fourier modes. Physical observables can be expressed in terms of the asymptotic data evaluated at freeze-out. We demonstrate the efficacy of this approach in describing key observables such as collectivity across various system scales, as well as the consequential effects of jet wakes.

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