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Deconstructing Relativistic Hydrodynamics

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Despite its success, it remains unclear why relativistic hydrodynamics is applicable in heavy-ion collisions given that local deviations from equilibrium can be very large, especially at early times. In fact, the state-of-the-art hydrodynamic modeling of the quark-gluon plasma is based on Israel-Stewart models of viscous fluid dynamics, whose general behavior in the far-from-equilibrium regime is unknown. In this talk, I review the current understanding of such models and present new fundamental constraints on the magnitude of viscous corrections in such theories, which can be especially relevant for small systems. These constraints, in particular, suggest the need of alternative viscous fluid formulations that do not follow Israel and Stewart's approach. With this goal, I present a new formulation of viscous fluid dynamics is presented in terms of a controlled derivative expansion of suitably defined out of equilibrium local temperature, fluid velocity, and chemical potential variables which is proven to be causal, stable, and has less degrees of freedom and free parameters than Israel-Stewart models.