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High-order hierarchical dynamic domain decomposition method for the Boltzmann equation

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In this work, we present a high-order hierarchical dynamic domain decomposition method for the Boltzmann equation based on moment realizability matrices, a concept introduced by Levermore, Morokoff, and Nadiga. This criterion is used to dynamically partition the two-dimensional spatial domain into two regimes: the Euler regime, and the kinetic regime. The key advantage of this approach lies in the use of Euler equations in regions where the flow is near hydrodynamic equilibrium, and the Boltzmann equation where strong non-equilibrium effects dominate, such as near shocks and boundary layers. This allows for both high accuracy and significant computational savings, as the Euler solver is considerably cheaper than the kinetic Boltzmann model.
We implement a coupling mechanism between the two regimes capable of preserving the high-order accuracy of both Euler and kinetic solvers, and we use state-of-the-art numerical techniques. This combination enables robust and scalable simulations of multi-scale kinetic flows with complex geometries.
Joint work with Lorenzo Pareschi (University of Ferrara & Heriot-Watt University), Thomas Rey (Université Côte-d'Azur) and Tommaso Tenna (Université Côte-d'Azur & University of Rome "La Sapienza").

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