Asymptotic-preserving IMEX methods: bridging scales in hyperbolic and kinetic equations

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Many problems in physics and engineering involve multiple scales that, if not properly addressed, lead to severe numerical limitations on discretization parameters. In this talk, we will discuss the time discretization of multiscale time-dependent PDEs using Implicit-Explicit (IMEX) methods, with a special focus on hyperbolic and kinetic problems and their asymptotic-preserving (AP) properties. First, we will review the classical approach within Runge-Kutta methods, which involves partitioning the transport and source terms. This approach is suitable for numerically solving scaling limits that are dominated by a compressible fluid-dynamic behavior. Next, we will analyze the case of diffusive and/or low Mach number limits. We will show how to deal with the additional difficulties caused by stiffness in the characteristic velocities of the system, which can lead to a parabolic-type behavior. Finally, we will present recent generalizations, including the development of methods that allow for a unified treatment of different asymptotic limits, methods that combine a linearly-implicit treatment of stiff terms within the IMEX paradigm, as well as extensions of these ideas to multi-step methods.