Second order Implicit-Explicit Total Variation Diminishing schemes for the Euler system in the low Mach regime

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In this work, we consider the development of implicit explicit total variation diminishing (TVD) methods (also termed SSP: strong stability preserving) for the compressible isentropic Euler system in the low Mach number regime. The scheme proposed is asymptotically stable with a CFL condition independent from the Mach number and it degenerates, in the low Mach number regime, to a consistent discretization of the incompressible system. Since it has been proved by Gottlieb, Tadmor and Shu in 2001 that implicit schemes of order higher than one cannot be TVD (SSP), we construct a new paradigm of implicit time integrators by coupling first order in time schemes with second order ones in the same spirit as highly accurate shock capturing TVD methods in space. For this particular class of schemes, the TVD property is first proved on a linear model advection equation and then extended to the isentropic Euler case. The result is a method which interpolates from the first to the second order both in space and time, which preserves the monotonicity of the solution, highly accurate for all choices of the Mach number and with a time step only restricted by the non stiff part of the system. One and two dimensional test cases showing that the method indeed possesses the claimed properties are also presented.