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An IMEX-DG solver for the compressible Navier-Stokes equations with a general equation of state

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The efficient numerical solution of the compressible Navier-Stokes equations poses several computational challenges. In particular, severe time restrictions are required by standard explicit time discretization techniques, especially for flow regimes characterized by low Mach number and moderate Reynolds number values. In this talk, we propose an efficient, accurate and robust solver for the compressible Navier-Stokes equation with general equation of state [1]. The method is based on an h-adaptive Discontinuous Galerkin spatial discretization and on an Additive Runge Kutta IMEX (ARK-IMEX) method for time discretization. It is tailored for low Mach number applications and allows to simulate this kind of regimes at a reduced computational cost, while maintaining full accuracy also in case of higher Mach number regimes. Following [2], with the aim of obtaining a robust method in the low Mach limit, we couple implicitly the energy equation to the momentum one, while treating the continuity equation in an explicit fashion. Moreover, in order to obtain an efficient formulation also in presence of non negligible viscous terms, we resort to an operator splitting approach. More in detail, as commonly done for instance in numerical models for atmospheric physics, we split the hyperbolic part of the problem, which is treated by an IMEX extension of the method proposed in [2], from the diffusive terms, which are treated implicitly.
The scheme has been implemented in the framework of the *deal.II* numerical library [3], whose adaptive mesh refinement capabilities, as mentioned above, are employed to enhance efficiency. The method is effective also for real gases equations of state such as van der Waals of stiffened gas equation of state and appropriate refinement indicators for real gas phenomena will be also introduced. A number of numerical experiments on classical benchmarks for compressible flows and their extension to real gases demonstrate the properties of the proposed scheme.

References

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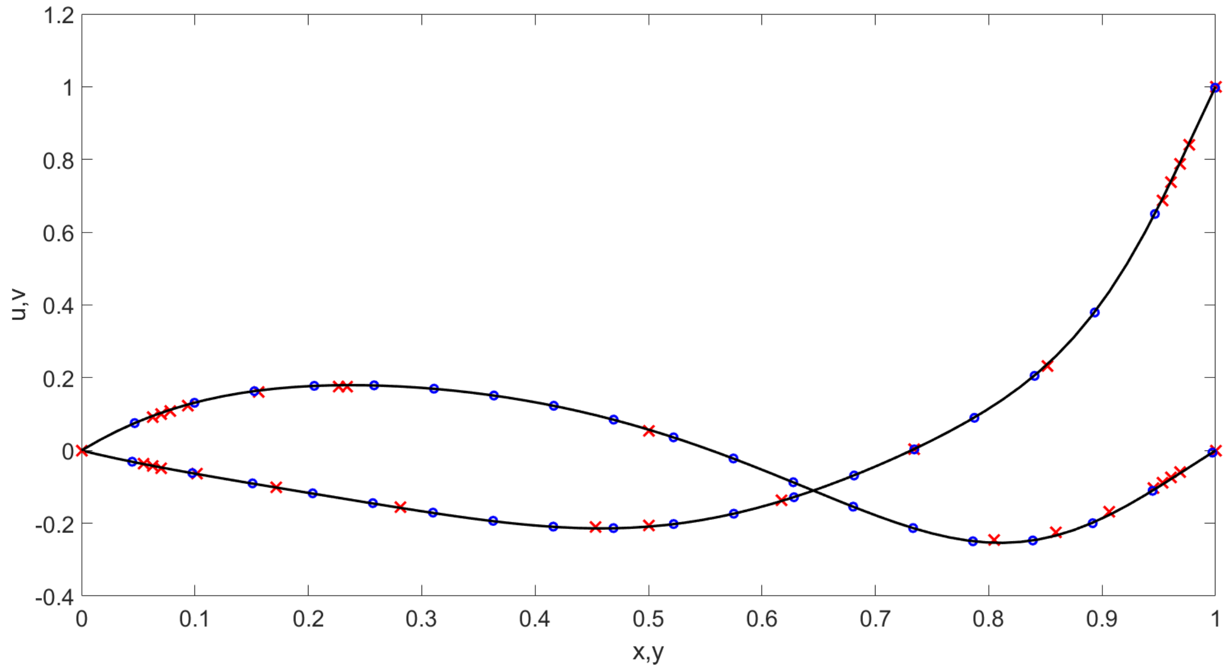

Figure 1: Computational results for the 2D lid-driven cavity.

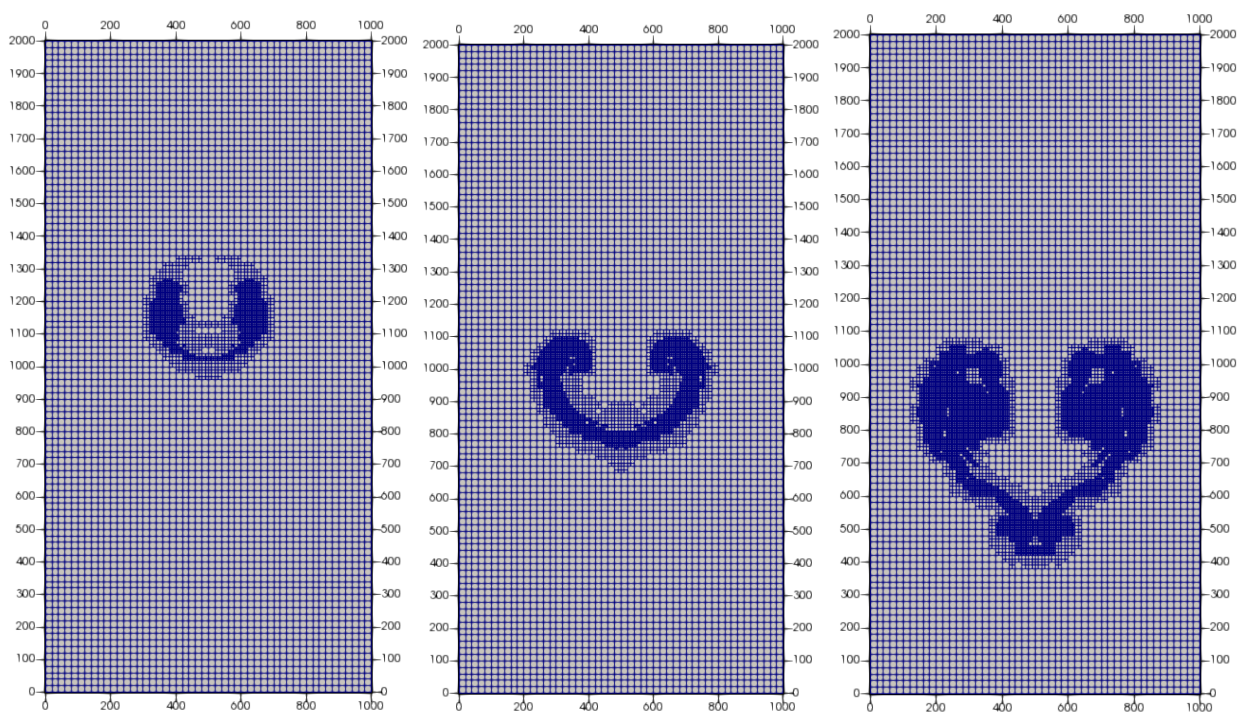

Figure 2: Adaptive mesh refinement for cold bubble.