# Acoustic Black Hole Analogue Model with exact Spacetime Representation

Roland Ewert and Stanislav Proskurov

*Institute of Flow Technology, Technical Acoustics*
*German Aerospace Center DLR, Braunschweig, Germany*

Starting with the work of W. Unruh in 1981, the intrinsic connection between sound propagation in an inhomogeneous flowing medium and wave propagation in curved space-time as described by general relativity theory (GRT) is studied in the framework of acoustics analogue models. Acoustic analogue models can be useful, on one hand, to solve acoustic problems with methods of GRT. On the other hand, to use the methods of fluid mechanics and acoustics to further shed light upon specific features of GRT. Although the aeroacoustics of sound propagating in flow is based on classic non-relativistic Newtonian physics in flat space-time, the solution can be equivalently described by an effective acoustic metric in 3+1-dimensional Lorentzian space-time. Specifically, a deep analogy between black holes with Schwarzschild metric and sound propagation in a simple supersonic sink flow (sonic black hole) can be established. The theoretical basics and the limits of acoustic analogue model are discussed. They can provide the kinematics of GRT in a Lorentzian space-time, but the dynamic field equations of GRT cannot be expressed in terms of an equivalent inhomogeneous acoustic wave equation with right-hand-side sources. The connection between the d'Alembertian operator of Lorentzian space-time and Pierce's convective wave equation imposes certain constraints on the solution that eventually yields only an approximative correspondence between acoustic and Schwarzschild metric. The extension of the acoustic analogue model by means of "Acoustic Perturbation Equations" (APE) to exactly represent the Schwarzschild metric is discussed. Results from acoustic black hole simulations are presented using modern methods of Computational Aeroacoustics (CAA) for the solution of Acoustic Perturbation Equations.