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A well balanced finite volume scheme for general relativity

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In this talk we present a second order accurate well balanced (WB) finite volume (FV) scheme for modelling the dynamics of the matter and the dynamics of the space-time according to the theory of general relativity [1].

In particular, we consider the general relativistic magnetohydrodynamics (GRMHD) equations, the first order CCZ4 formulation (FO-CCZ4) of the Einstein field equations [3] as well as the fully coupled FO-CCZ4 + GRMHD system. Moreover, we present preliminary results regarding a novel first-order reduction of the teleparallel gravity field equations in the pure-tetrad formulation (TEGR).

The new well balanced finite volume scheme exploits the knowledge of an equilibrium solution of interest when integrating the conservative fluxes, the nonconservative products and the algebraic source terms, and also when performing the piecewise linear data reconstruction [2]. This results in a rather simple modification of the underlying second order FV scheme, which, however, being able to cancel numerical errors committed with respect to the equilibrium component of the numerical solution, substantially improves the accuracy and long-time stability of the numerical scheme when simulating small perturbations of stationary equilibria. In particular, the need for well balanced techniques appears to be more and more crucial as the applications increase their complexity.

We close the presentation with a series of numerical tests of increasing difficulty, where we study the evolution of small perturbations of accretion problems and of stable TOV neutron stars, and with an outlook on our future research directions.

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