Finite Volume Method for Special Relativistic Fluid Dynamics

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Abstract:

Relativity is a necessary ingredient for describing astrophysical phenomena involving compact objects such as core collapse supernovae, formation of black holes, micro-quasars, active galactic nuclei, superluminal jets and gamma-ray bursts. General relativistic effects must be considered when strong gravitational fields are encountered as, for example, in the case of coalescing neutron stars or near black holes when spacetime is highly curved. There are, however, astrophysical phenomena which involve flows at relativistic speeds but no strong gravitational fields, and thus at least certain aspects of these phenomena can be described within the framework of special relativity.

We intend to use FVM to formulate equations for special relativistic conservation laws, which are hyperbolic. We will encounter the well-studied Riemann problem and explore methods to solve it in the relativistic setting. We will explore approximate Riemann solvers such as the HLL and HLLC methods, which are widely used in relativistic fluid simulations. To validate our approach we will demonstrate some simulations of simple yet interesting systems like relativistic shock tube, astrophysical jets (collimated outflows), and blast waves . Additionally, we will compare them to the non-relativistic simulations of the same phenomena and analyze how relativistic effects become significant by varying the initial velocity and Lorentz factor across different regimes.

References:

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