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Title

Reaching infinity: free hyperboloidal evolution using conformal methods in spherical symmetry

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Abstract

Gravitational wave radiation, our window for probing the strong field and dynamical regime of gravity, is unambiguously defined only at infinity, a region of spacetime difficult to reach from a numerical point of view. A convenient way of including infinity in numerical relativity simulations is by means of hyperboloidal foliations, which consist of smooth spacelike slices that reach future null infinity ($\mathscr{I}^+$) - the location in spacetime where light rays arrive and thus where signals can be unambiguously extracted and global properties of spacetimes measured. We approach the hyperboloidal initial value problem for the Einstein equations through conformal compactification methods and expressed them in terms of unconstrained evolution schemes (following [1]), for which we choose the widely used BSSN and conformal Z4 formulations. The main difficulty of the implementation is that the resulting system of PDEs includes formally diverging terms at null infinity that require a special treatment and a careful choice of gauge conditions. In this first step in spherical symmetry, we present stable numerical evolutions of a massless scalar field coupled to the Einstein equations [2, 3], as well as simulations with strong field data, including the collapse of a scalar field perturbation into a black hole and a scalar field perturbing a Schwarzschild black hole trumpet geometry. These successful results make this approach of the hyperboloidal initial value problem a good candidate for more general numerical setups, like its implementation in a 3D code. The final goal of this work is to provide a far-field numerical framework based on the hyperboloidal evolution that will effectively include null infinity in simulations of compact object mergers, hoping to reduce the systematic errors in current gravitational wave extraction and so provide more accurate waveforms.

References

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