IllinoisGRMHD+HARM3D: Next-Generation Binary Neutron Stars Simulations

Leo Werneck
Z.B. Etienne, F.L. Armengol, S.C. Noble, B.J. Kelly
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Abstract

We present binary neutron star (BNS) merger simulations that use both **IllinoisGRMHD** and **HARM3D** to maximize physical realism while minimizing numerical errors. We have recently enhanced **IllinoisGRMHD** -- a rewrite of the dynamical-spacetime general relativistic magnetohydrodynamics (GRMHD) code of the Illinois group -- with a new equation of state (EOS) infrastructure that supports realistic, tabulated nuclear EOSs. We use this version to model BNS inspirals through merger and black hole (BH) formation on a Cartesian AMR grid structure. After the remnant spacetime has become nearly stationary, evolving the BH accretion disk on a moderate-resolution 3D Cartesian AMR grid over long timescales would be suboptimal, as angular momentum is spuriously lost due to numerical errors associated with GRMHD flows obliquely crossing coordinate lines. So instead we transfer the simulation data to a similarly EOS-enhanced, spherical-coordinate GRMHD code, **HARM3D**, which specializes in modeling BH accretion disks over long timescales. This enables us to efficiently and reliably model the accretion disk over the relatively long time scales required to generate theoretical predictions of the early EM counterpart.

BNS simulation using **IllinoisGRMHD**

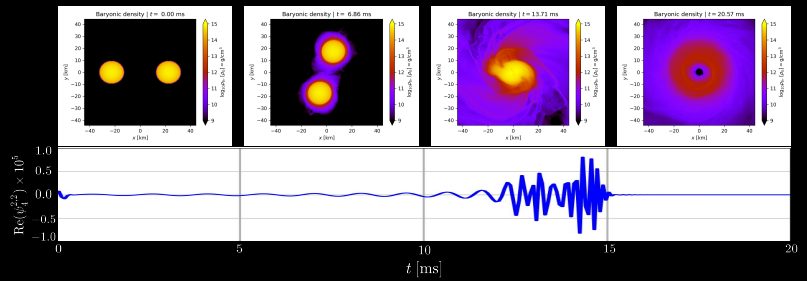

Fig. 1: Results from a BNS merger simulation. **Top:** Density snapshots. From left to right: initial data, inspiral, HMNS, and remnant BH+accretion disk.. **Bottom:** Dominant mode of Weyl scalar psi4.

The **HandOff** package

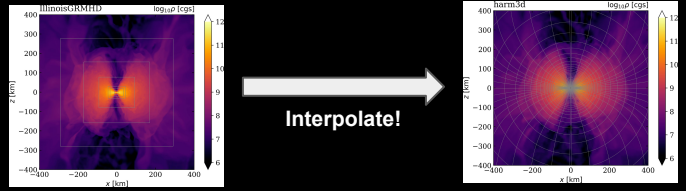

Fig. 2: Goal of the the core algorithm of the **HandOff** package

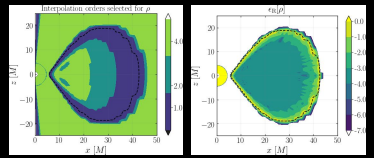

Fig. 3: Left: Interpolation order. **Right:** interpolation relative error.

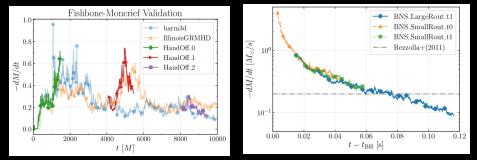

Fig. 4: Fidelity of the HandOff package. **Left:** Fishbone-Moncrief calibration test. **Right:** BNS simulation.

Results

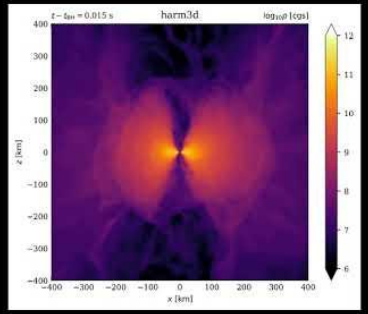

Fig. 5: BNS merger simulation with **IllinoisGRMHD+HARM3D.** Click the figure to watch the movie or go to **http://tinyurl.com/HandOffmovie**

Conclusions & Future work

- ★ Successfully used the **HandOff** package for both gamma-law ***and*** advanced EOS
- ★ Results will be the subject of upcoming papers
- ★ Future: perform **HandOff** simulations with advanced EOS *and neutrino physics* enabled