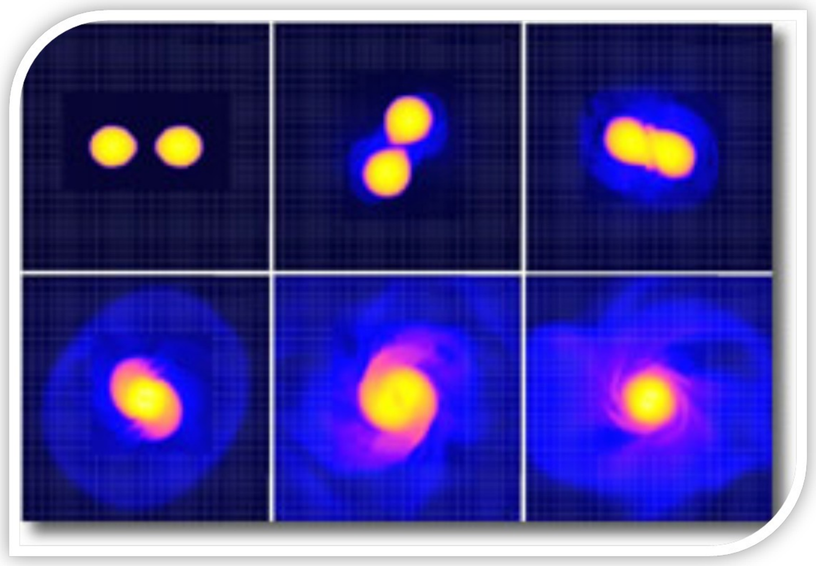
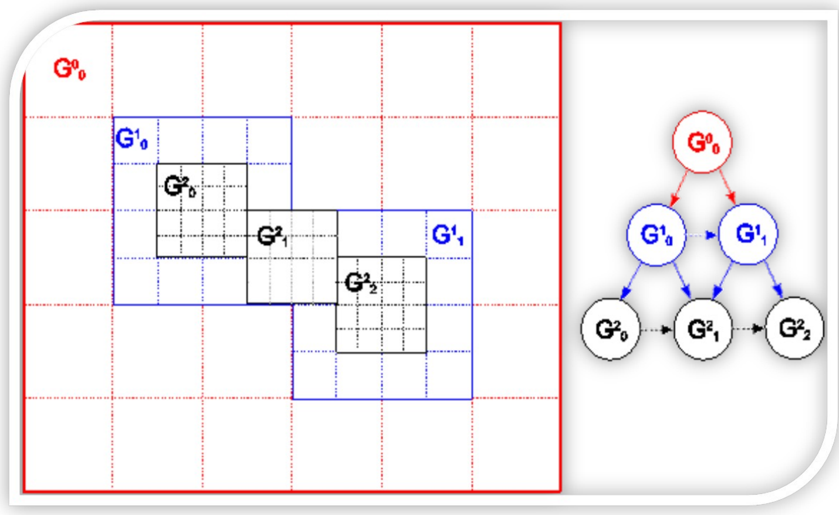


Binary Neutron Star Evolution with Adaptive Mesh Refinement Methods



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Introduction

Coalescing binary neutron stars (NSs) are considered to be strong candidates as sources of gravitational waves (GWs) detectable by both the existing ground-based detectors such as LIGO, VIRGO, GEO600, and TAMA300 and the future space-based detector LISA. Some studies also propose that coalescing binary NSs are the sources of short Gamma-ray burst (GRB) detected by advanced Gamma-ray observatories, such as CGRO and HETE II. In this work, we carry out numerical simulations of the evolution of equal-mass binary neutron star systems with **GR-Astro-AMR**, an adaptive mesh refinement enabled fully general relativistic hydrodynamic code developed and maintained by the **Washington University Gravity Group (WUGRAV)**. In particular, we first revisited the **premature collapse conjecture** by Wilson and Mathews, and then show some **waveforms** extracted from the simulations.

Premature Collapse Problem

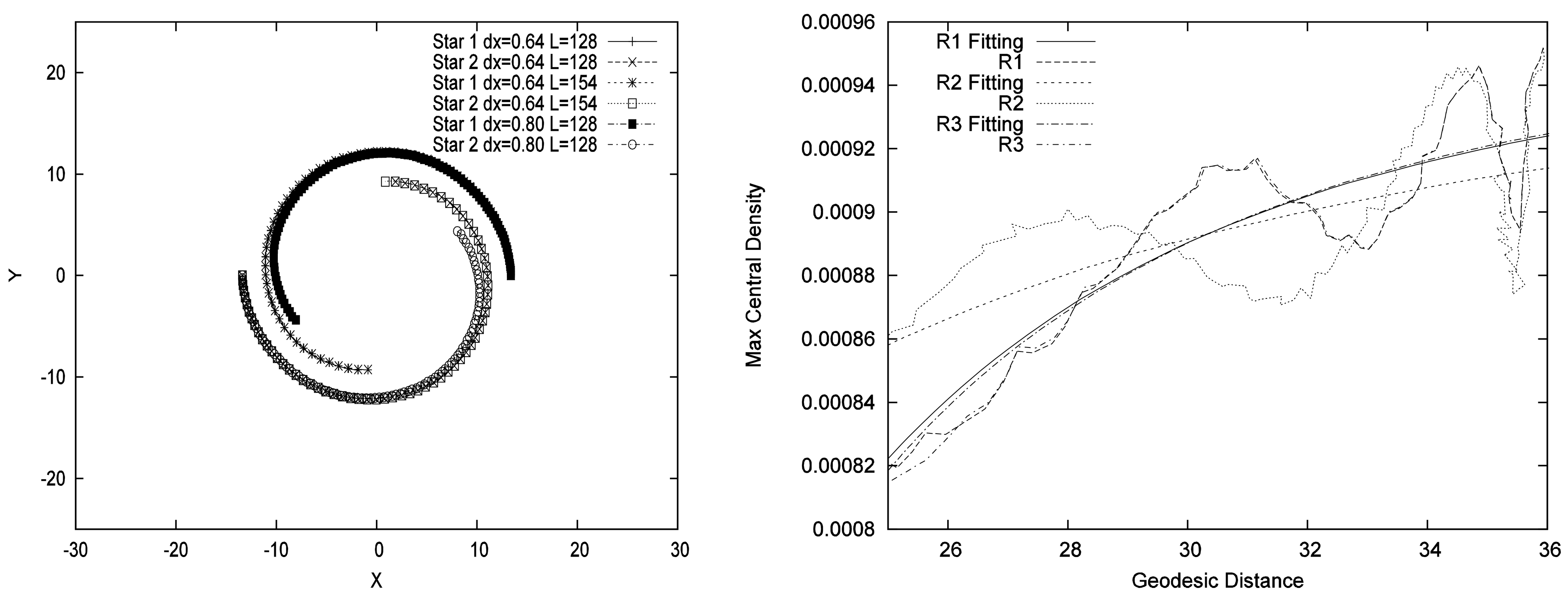
The premature collapse problem was first reported by Wilson et al. in 1995. They found that the two NSs were compressed by their mutual gravitational interactions in the inspiral phase and could collapse before merging. However, It was found analytically by Lai (1996), Flanagan (1998), and Thorne (1998) that the central density of individual star drops like

$$\frac{\delta\rho_c}{\rho_c} \propto -\alpha^6,$$

Where $\alpha \equiv R/D$, is the so called expansion parameter. R here is the stellar radius and D is the separation between two stars. We redefine the expansion parameter by replacing R with the proper radius of each star if isolated and replacing D with the geodesic distance between two maximum density points as the separation between two stars.

$$\frac{\rho_c - \rho_{c0}}{\rho_{c0}} = a \cdot \alpha^b = a \cdot \left(\frac{R_{pro}}{D_{geo}}\right)^b$$

Two coefficients a, b are then extracted from the simulation results.



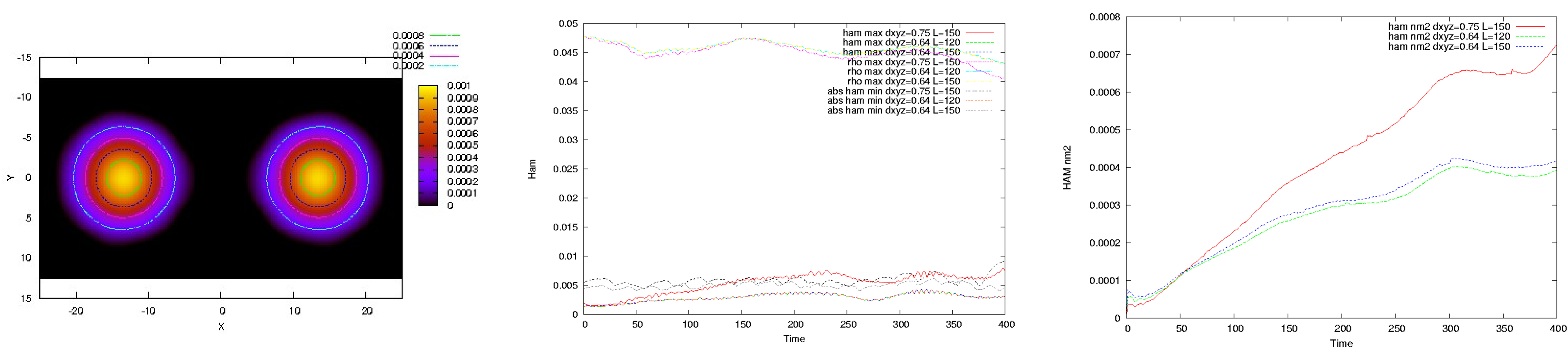
For three runs, R1, R2, and R3 with different numerical setups, we have a = −2.47, b = 3.90 for R1, a = −0.56, b = 2.21 for R2, and a = −2.78, b = 4.02 for R3.

Intial Data and Convergence Tests

We use the same initial data in all the simulations shown in this work. We start the simulations with the spectral data set of a CFQE equal mass irrotational binary NS system generated with LORENE by the Meudon Group. Two stars are identical and have the same polytropic EOS

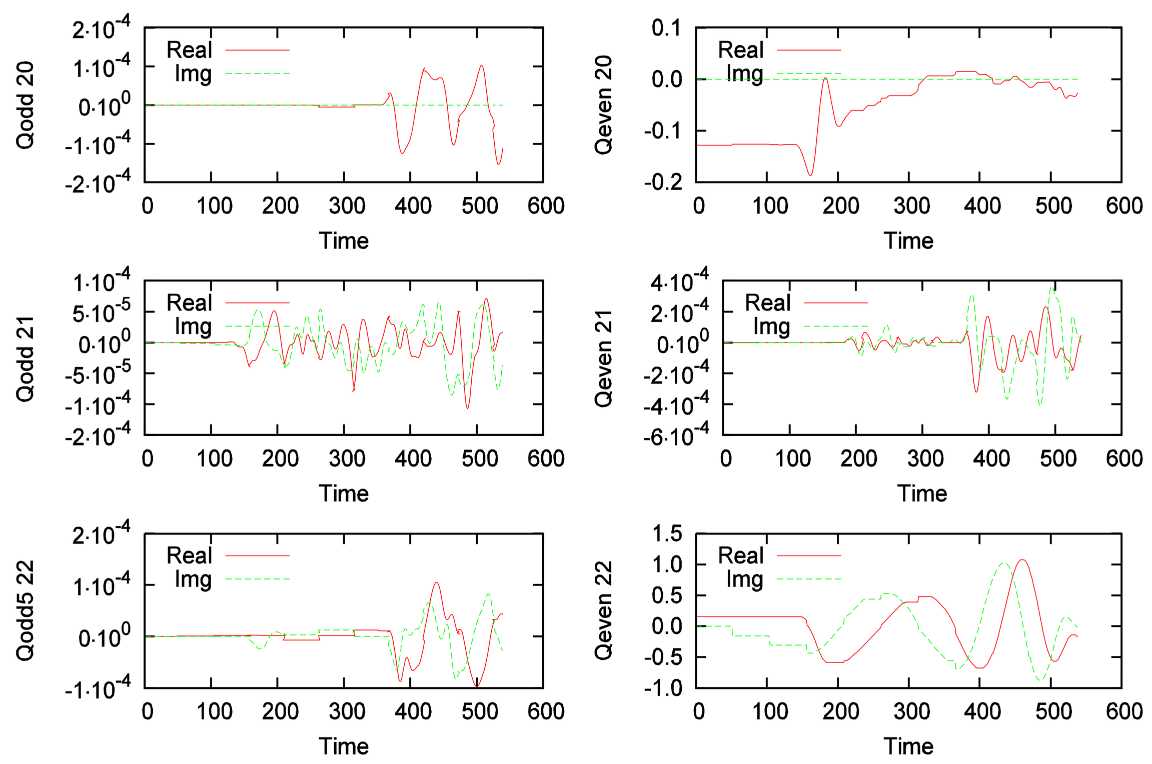
$$p(\rho) = K\rho^\Gamma$$

with Γ= 2 and K = 123.84. The initial coordinate separation between the two stars is 26.7 solar mass and the angular velocity = 2220.05 rad/s. The baryonic mass of each star is 1.625 solar mass. If each star is isolated, it will have an ADM mass of 1.515 solar mass and a proper radius of 11.986 solar mass. The ADM mass M of the binary system is 2.995 solar mass. The initial angular momentum J is 8.527 (solar mass)^2.



Gravitational Waves

The production run we carried out to study gravitational waves radiated during the evolution has 4 refinement and covers a region of (425.6 solar mass)^3. The grid size of the base grid is 2.8 solar mass, The GWs are extracted using a code based on the Moncrief's formalism. We show the waveforms with l = 2, m = 0, 1, 2.



Acknowledgement

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