Neutron Star Binaries

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Interplay Between Numerical Relativity and Data Analysis
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Introduction

- Neutron star systems + Magnetic fields (NS-NS, NS-BH)
- Numerical approach
  - Adaptive mesh refinement with shadow hierarchy
  - Generalized harmonic formulation for Einstein equations
  - High-resolution shock-capturing methods for MHD equations. (FD scheme with PPM)
- Initial data
  - Superposed boosted stars (TOV, rigidly or differentially rotating)
  - Seeded poloidal magnetic fields
  - Magnetized star data (Novak)
  - Binary data with generalized EOS from UWM

Neutron star merger I

- Superposed TOV stars

$$M = 0.89 M_\odot$$
$$R = 16.3\mathrm{km}$$

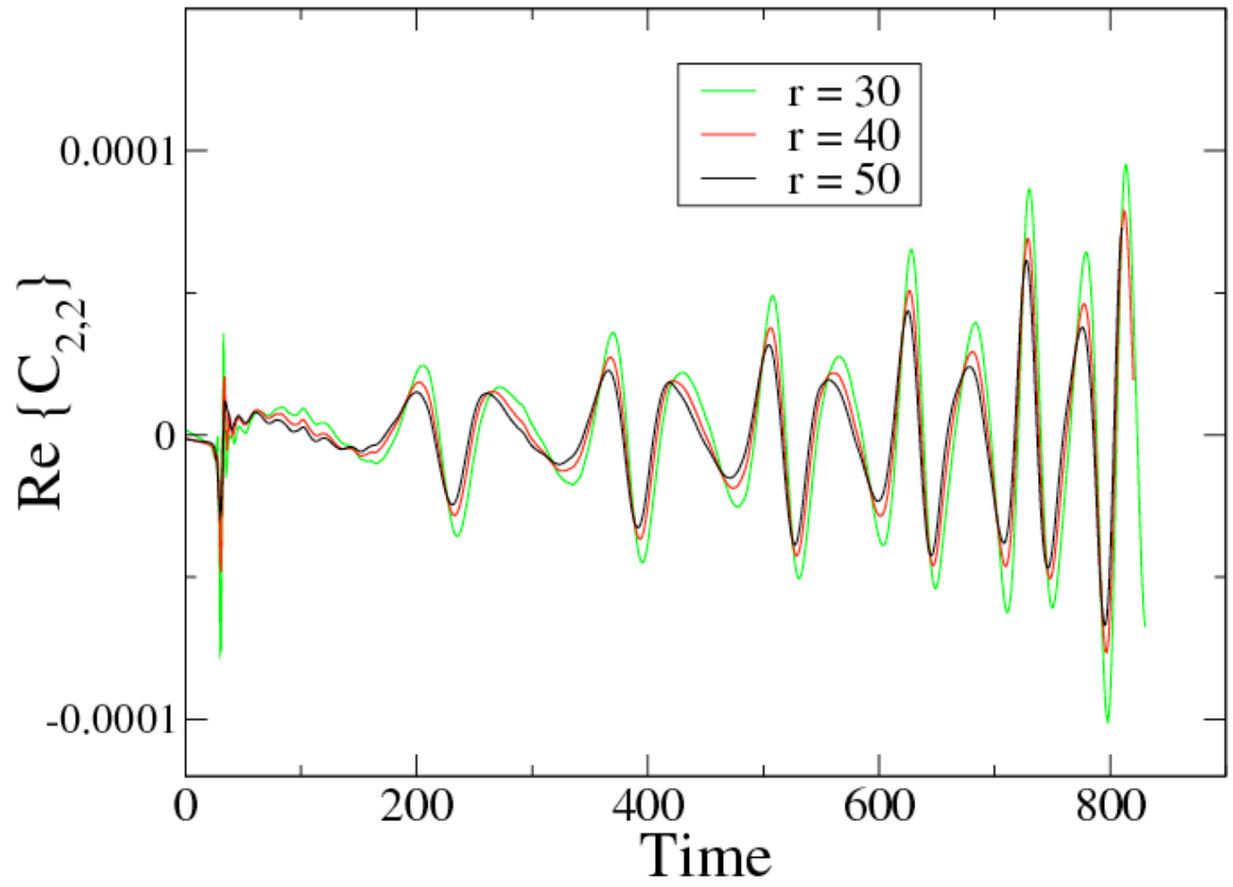
- Gamma-law EOS, Gamma=2

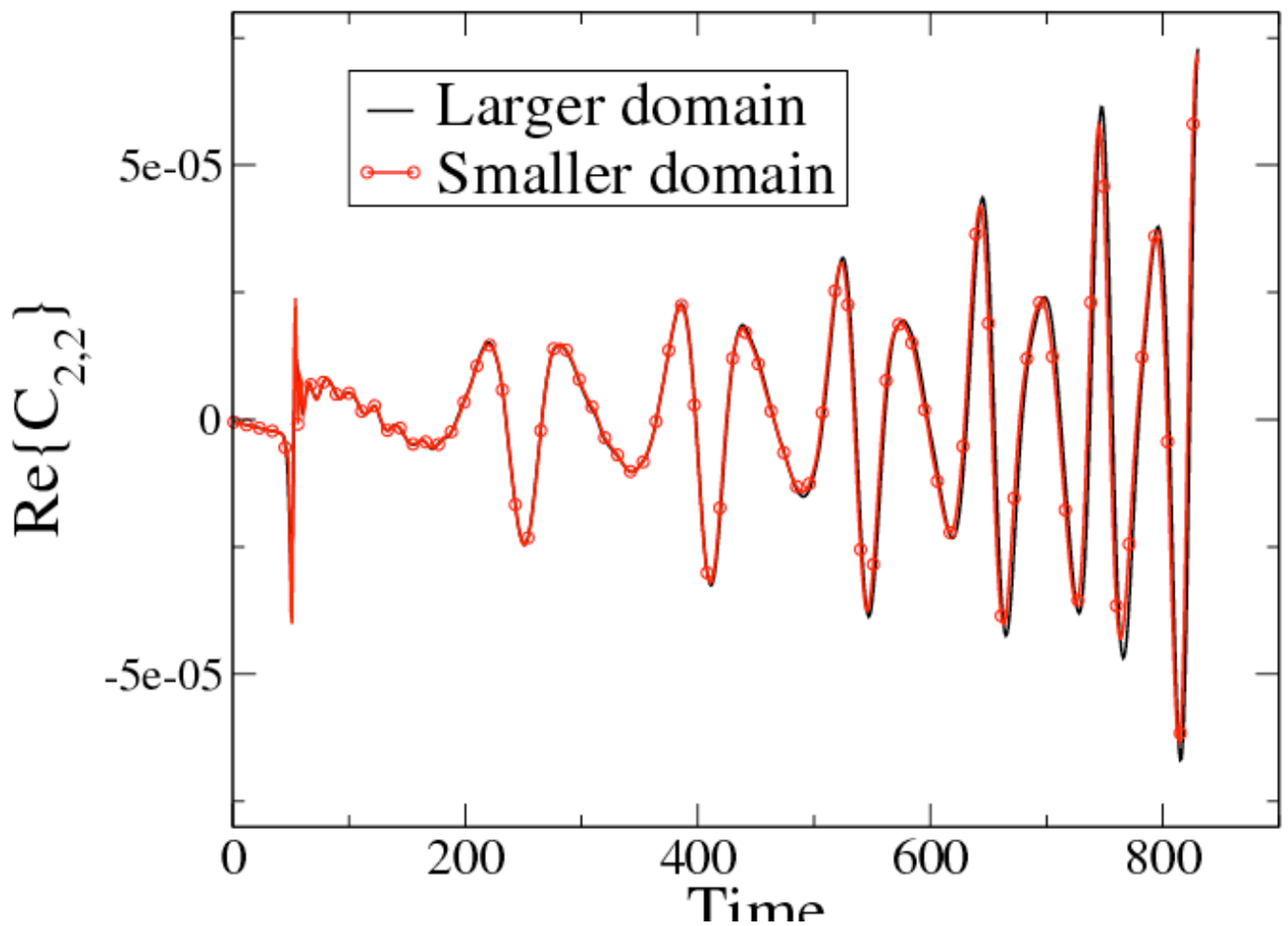
- Orbital radius ~3*R*, initially eccentric orbit

- Boundaries at 80*R* and 124*R*

- Prompt collapse to BH

- Simulations beyond BH continuing





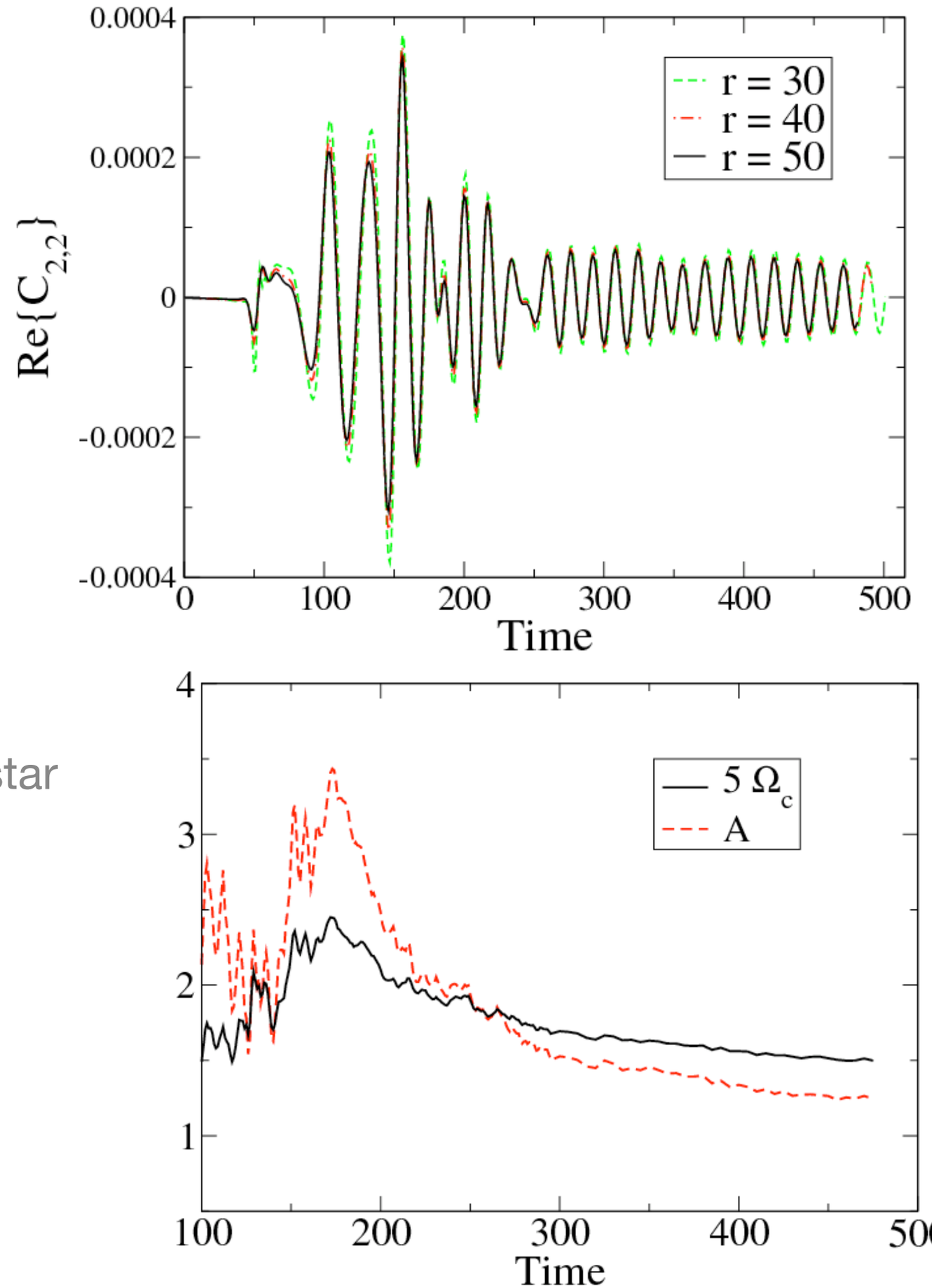
Neutron star merger II

- Superposed TOV stars

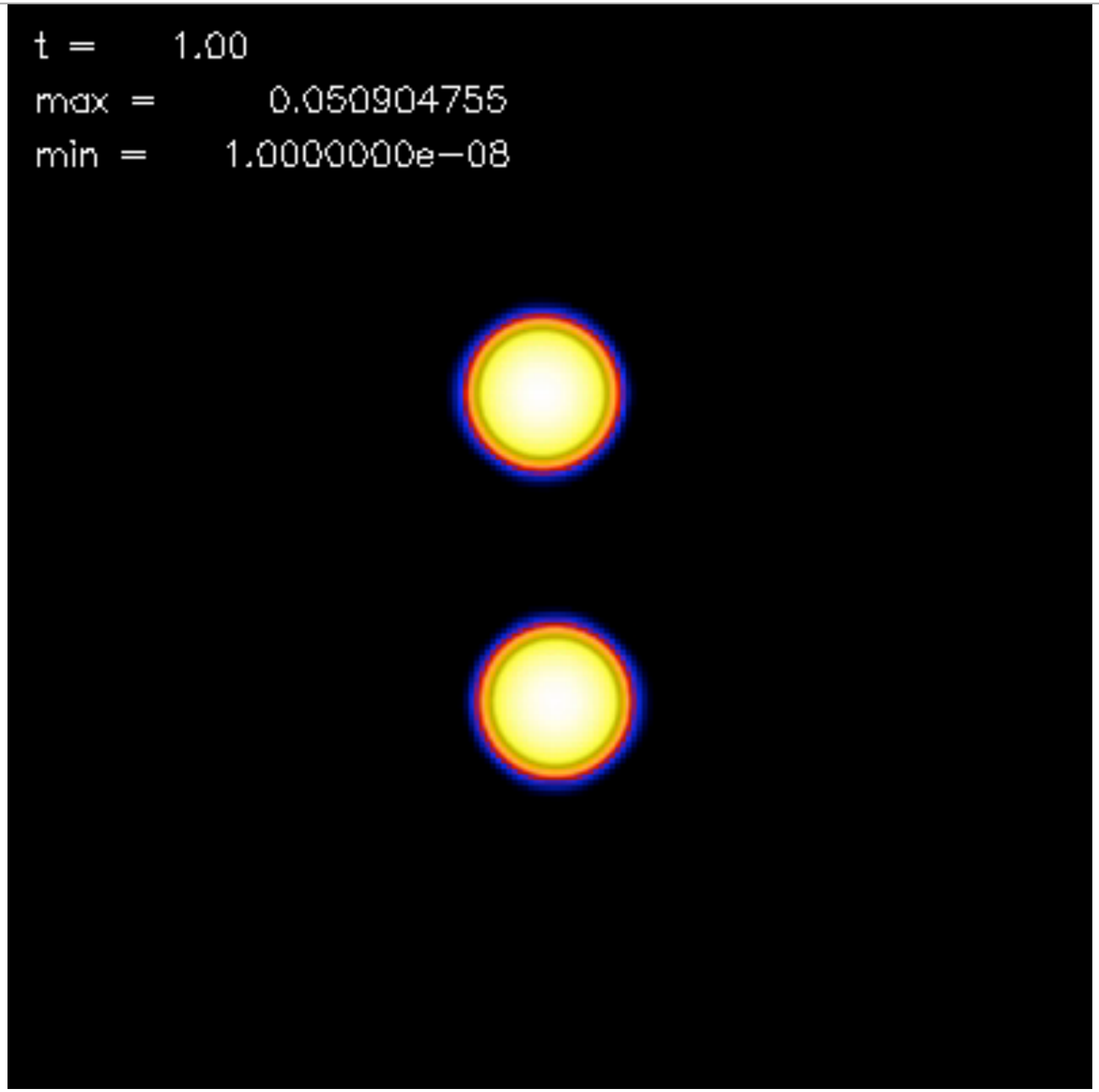
$$M = 0.89 M_\odot$$
$$R = 16.3\mathrm{km}$$

- Gamma=2 EOS
- Orbital radius ~2R
- Differentially rotating intermediate star
- Delayed collapse to BH

$$\Omega(r) = \frac{\Omega_c}{1 + A\, r^2 \sin^2\theta}$$



Neutron star merger II



Preliminary mergers with MHD

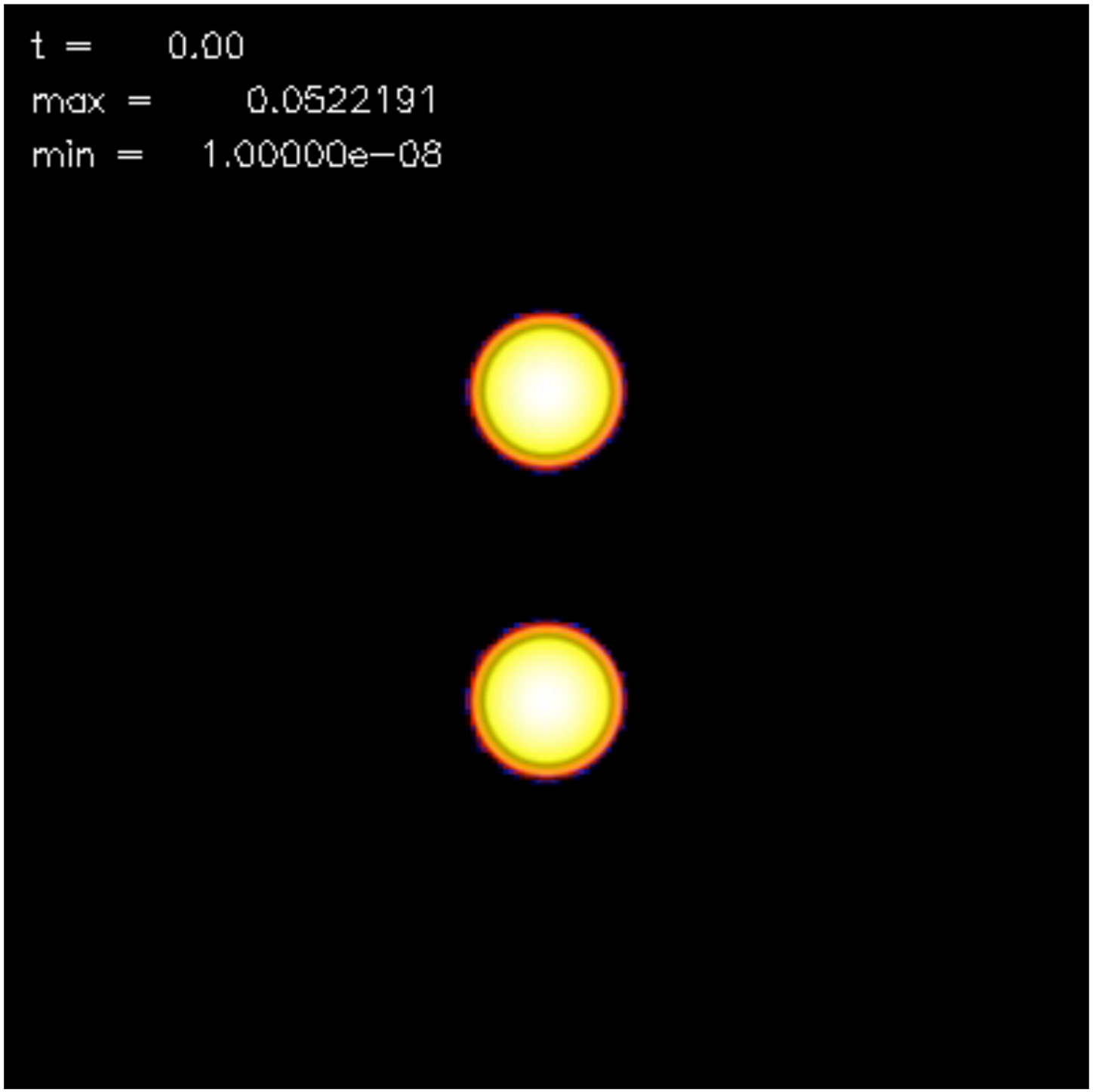
- Same setup as previous case

- Seeded poloidal magnetic field

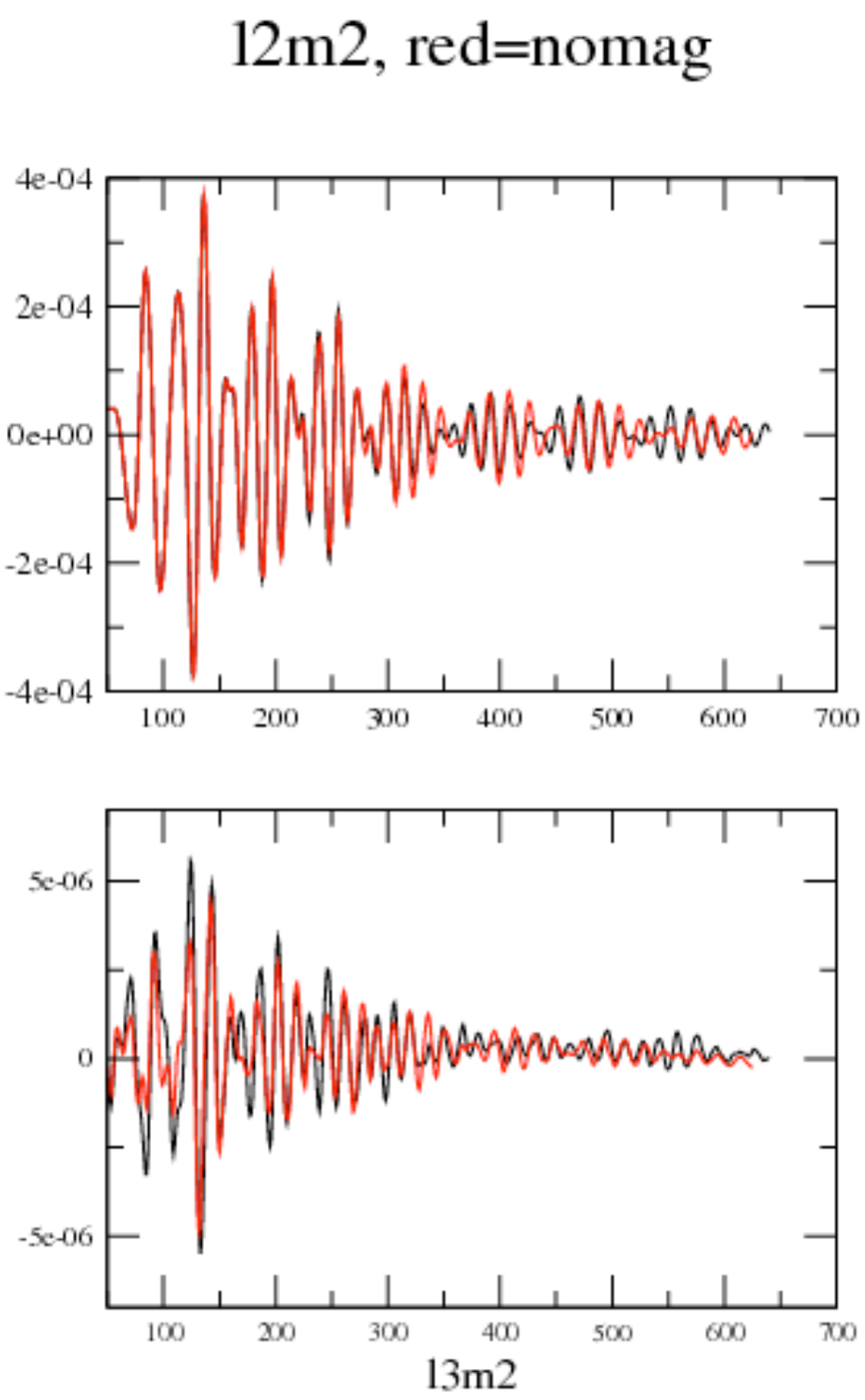
$$B = 10^{15}\,\mathrm{Gauss}$$

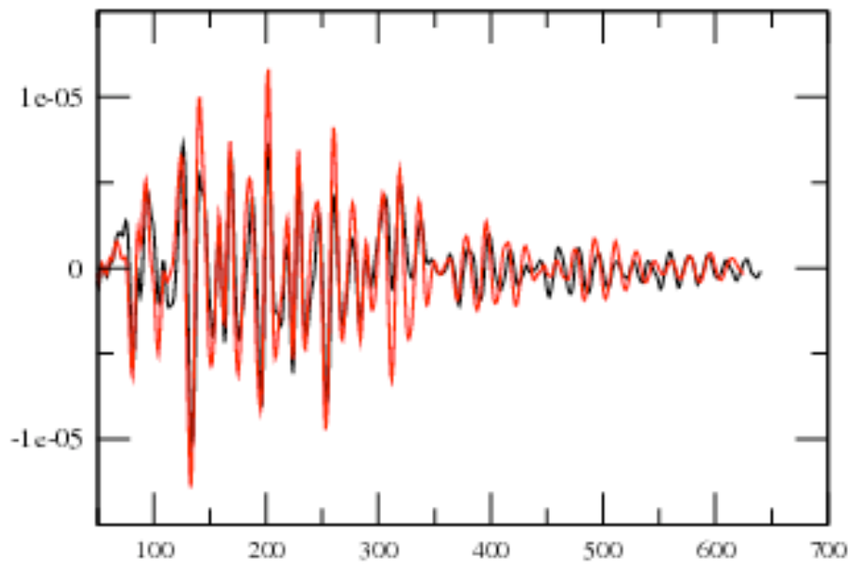
- Magnetic field allows for redistribution of angular momentum

- Delay in merger time owing to magnetic interactions and different post-merger evolution



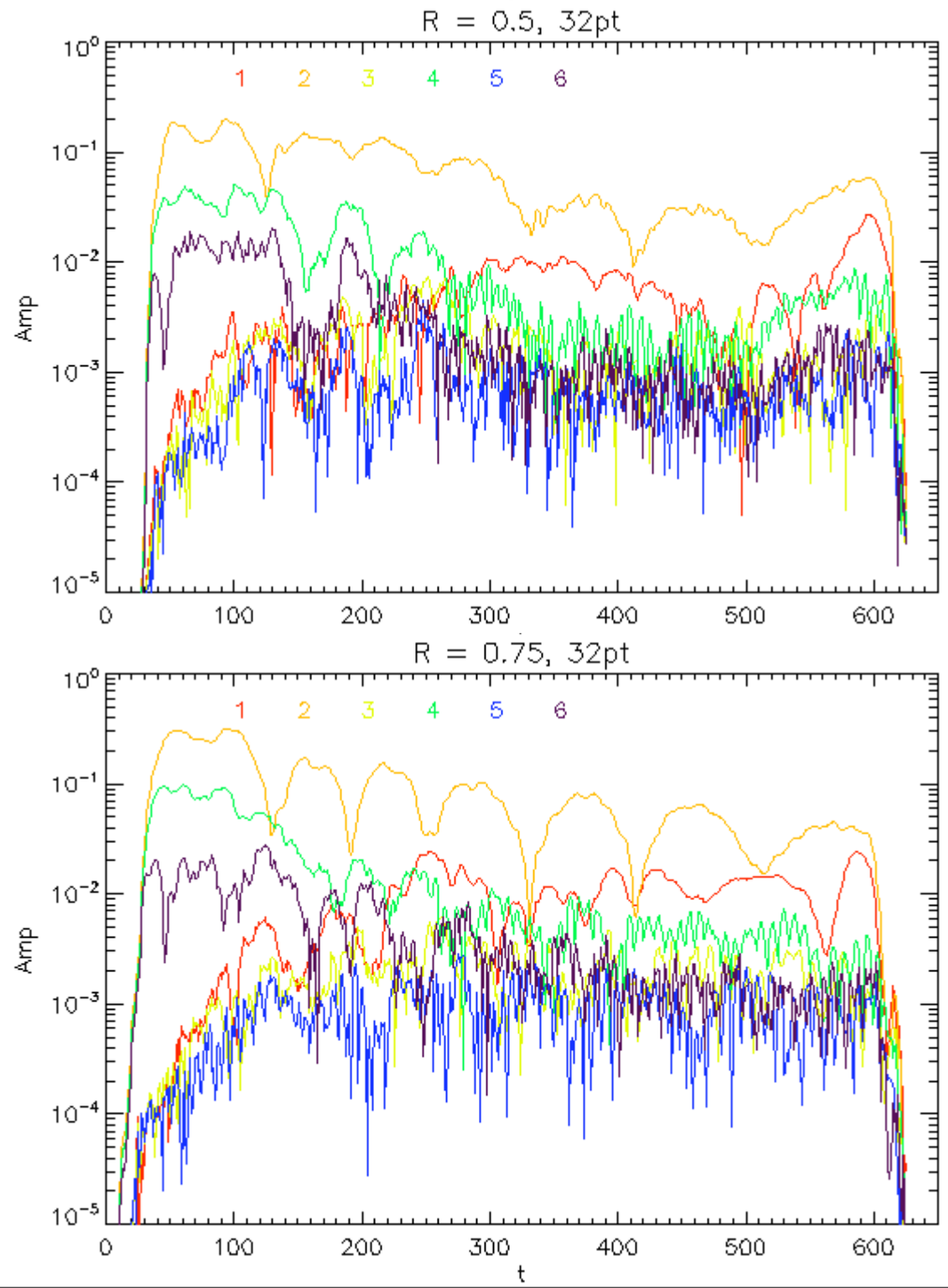
Under-resolved waveforms with MHD



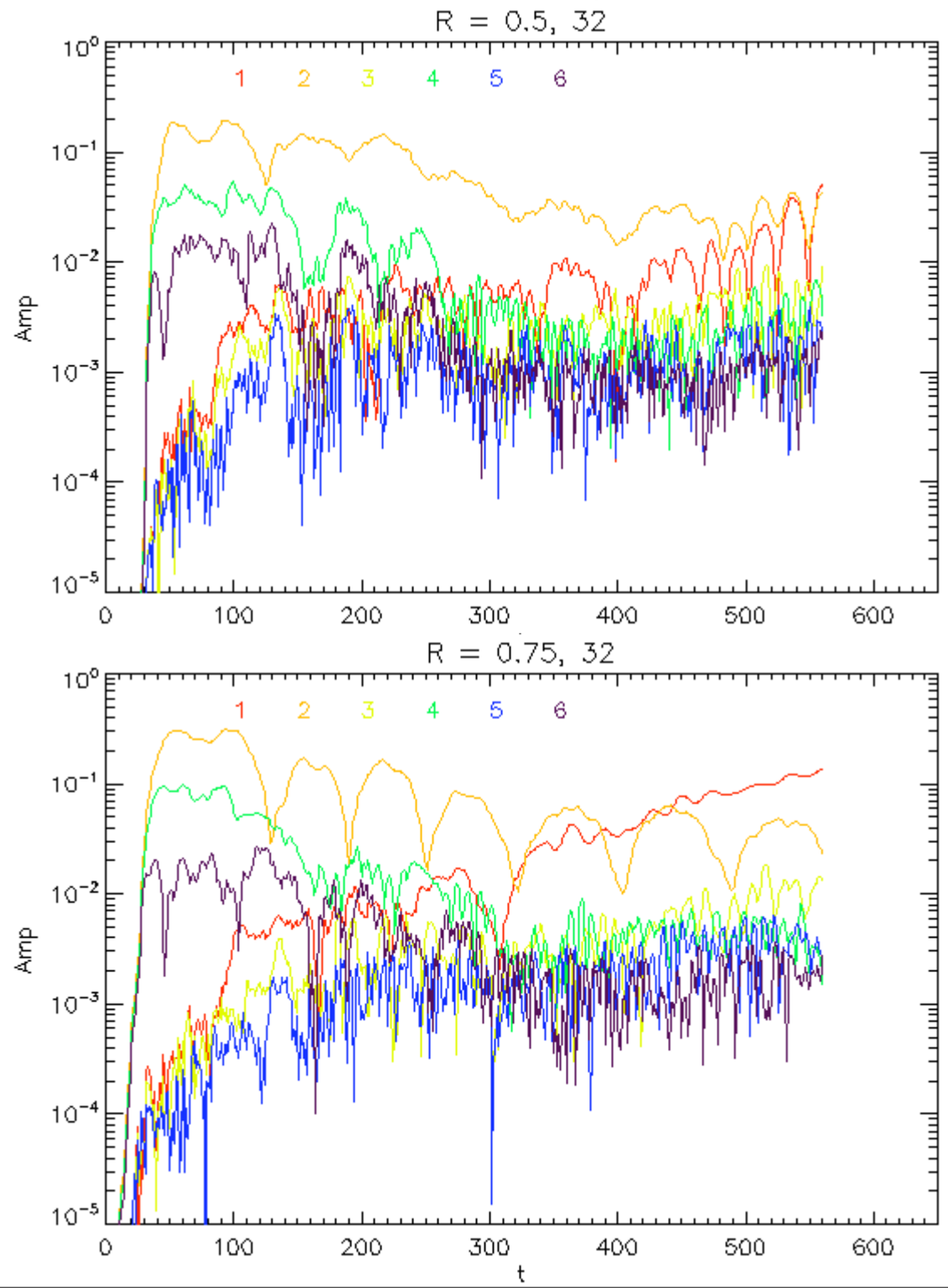


Mode comparison

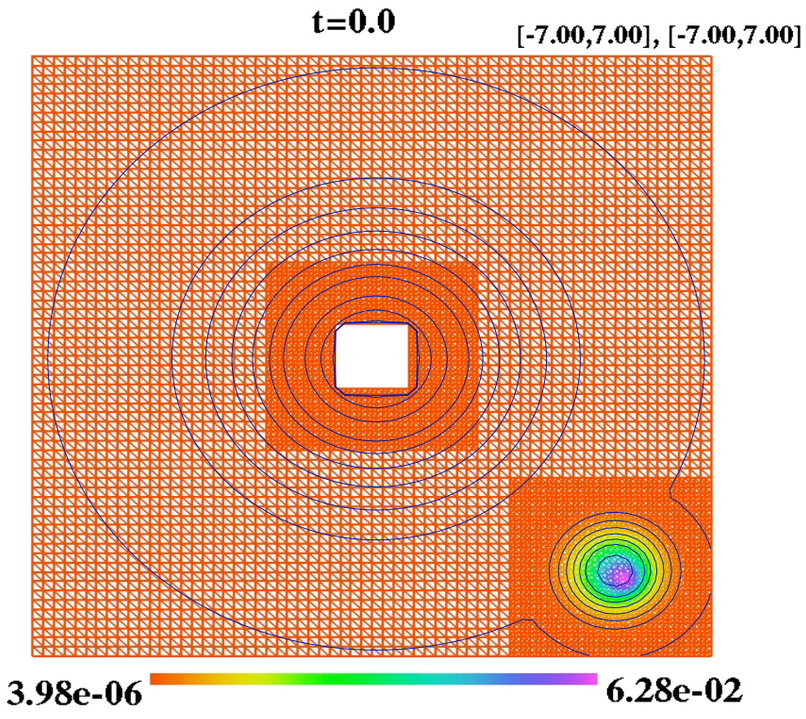
HD

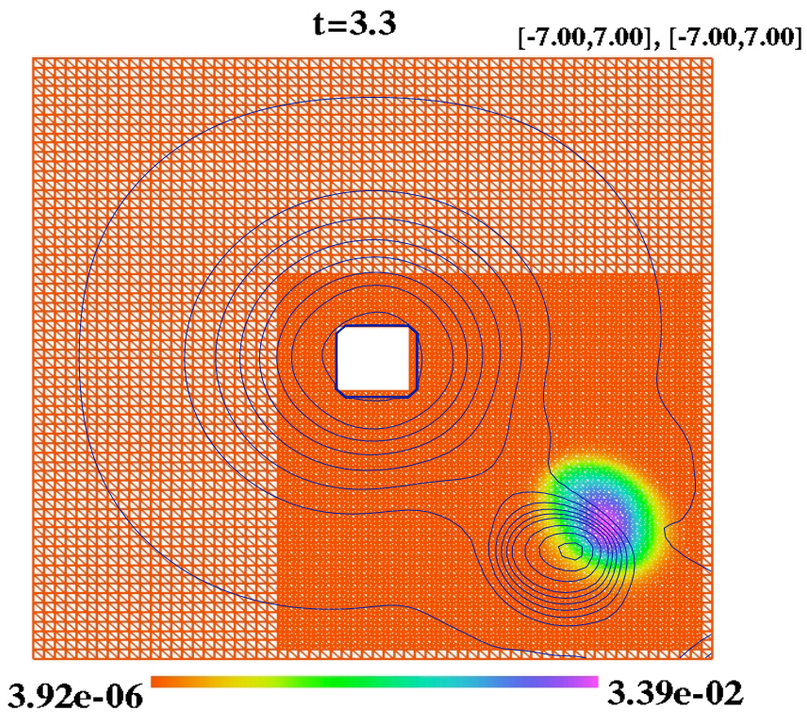


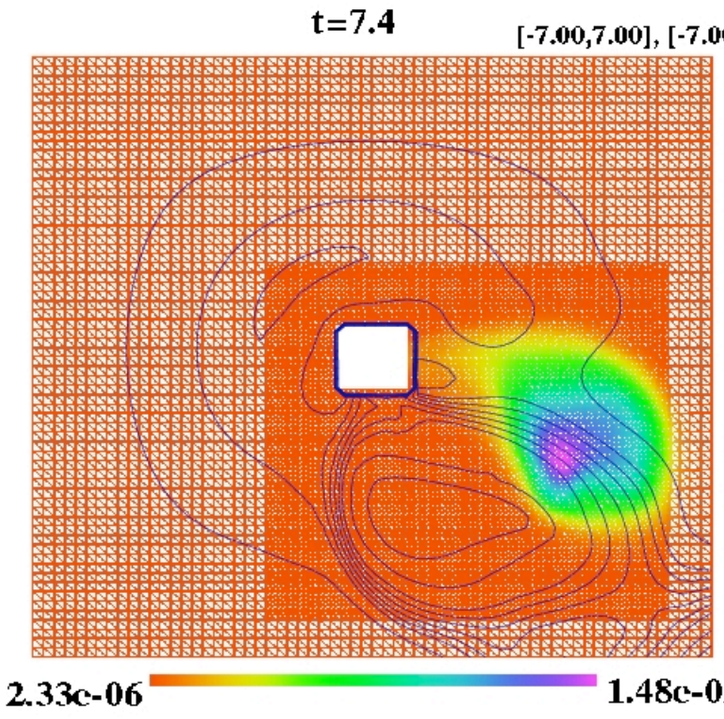
MHD



Neutron star and Kerr black hole

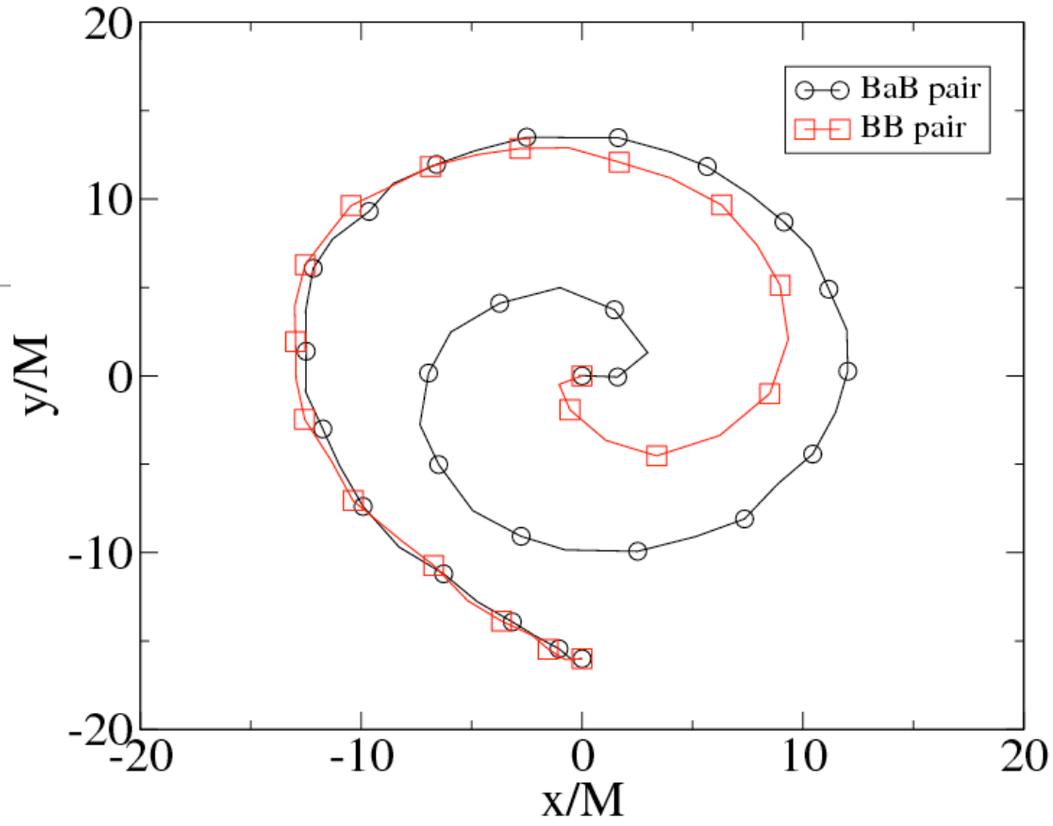


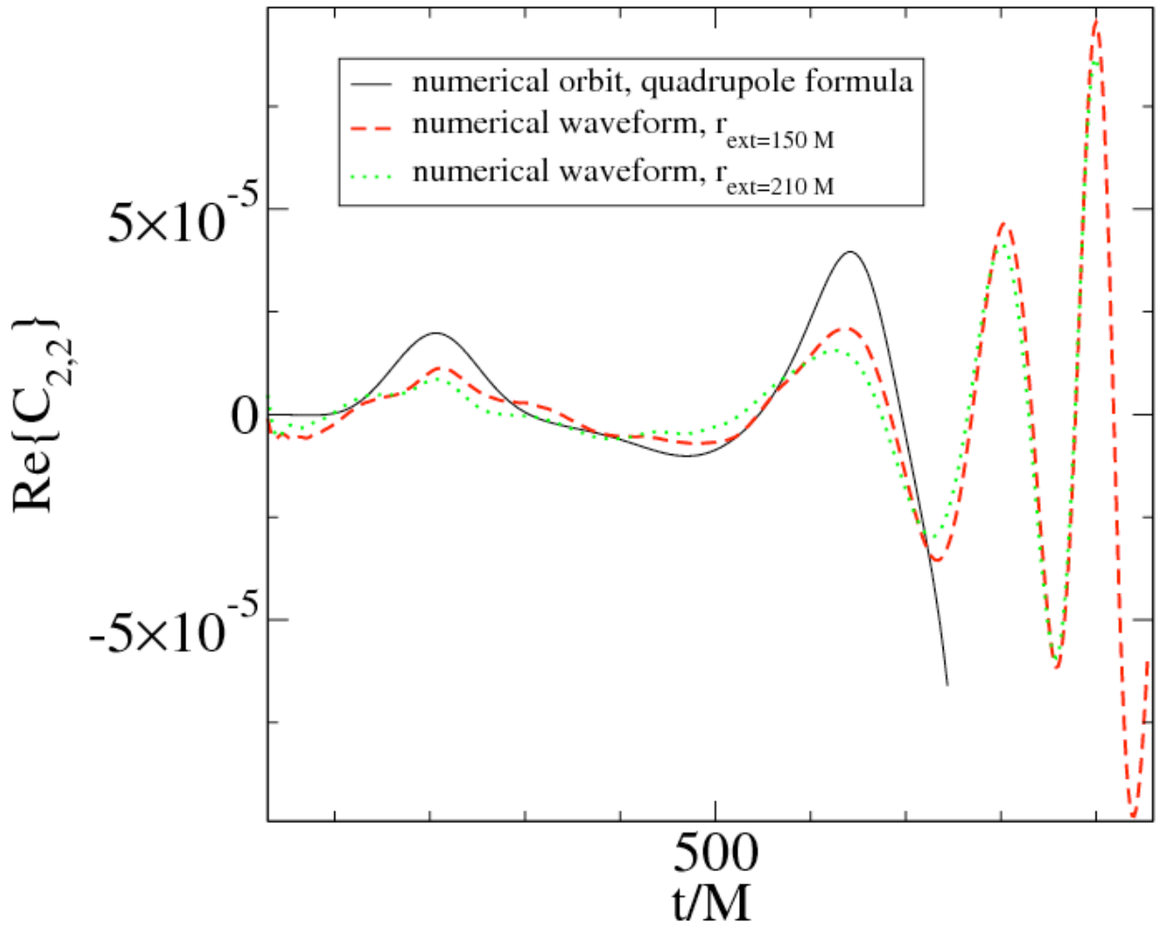


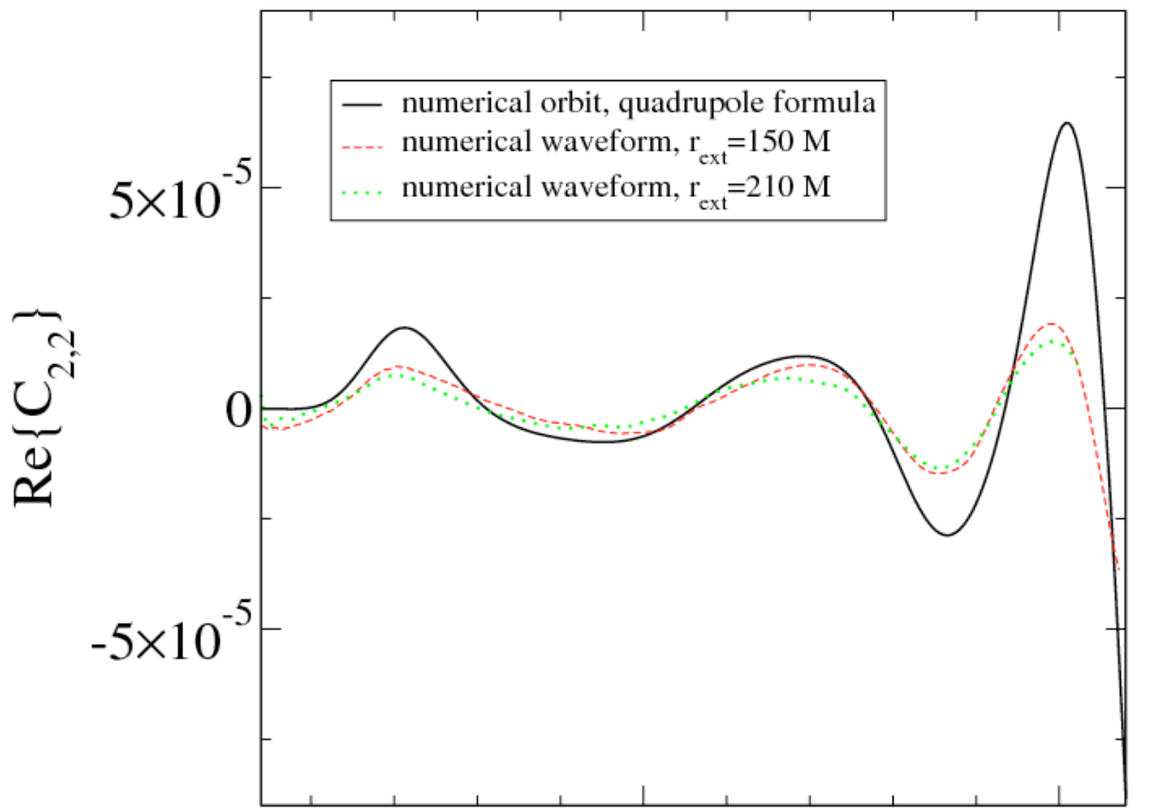


Boson stars

- BS-BS and BS-aBS mergers
- Medium and high angular momentae
- BS interactions at small distances







Palenzuela, Lehner, Liebling (2007)

Summary and outlook

- Now evolving NS-NS, NS-BH binaries
- Wave extraction in wave zone and will correct for gauge effects
- Generalized equations of state
- Parameter space explorations (magnetic field, spin, EOS, etc)
- Photons (down the road)
  - Radiation transfer
  - Radiation transport