2023 HEP Workshop

AXIS Lab Report

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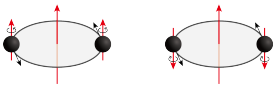
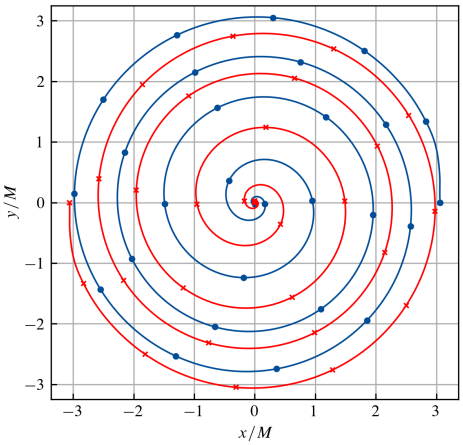
About Numerical Relativity

- Numerically simulating the predictions of the theory of GR.
- Target to study strong-field gravitational dynamics and radiation phenomena.
- Obtained accurate GW waveforms can be use to detect GWs.
- Many effective methods (both include theoritic and numerical) developed.

Spin BBH

- Researching the mass, momentum, and spin of black hole binary systems, studying the resulting orbits and gravitational waveforms.
- Reimplementing the effects based on the direction of spin [Campanelli 2006] with different coordinate systems and gauge conditions, aiming to achieve qualitatively similar results to previous research.
- Additionally, calculating the energy and angular momentum emitted during the merger process using two different methods to ensure consistency.

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2
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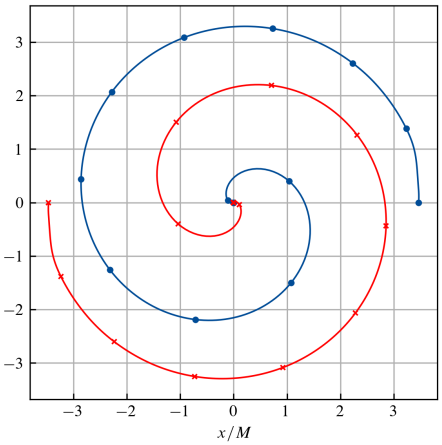
y/M
−3 −2 −1 0 1 2 3
x/M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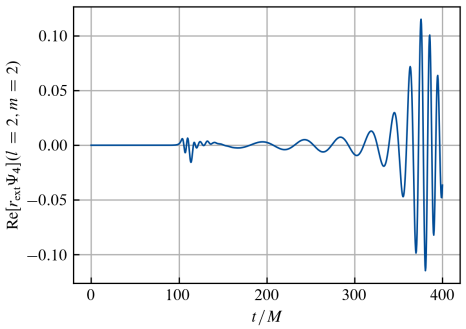
x/M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0.05
0.00
−0.05
−0.10
Re[r_ext Ψ4](l = 2, m = 2)
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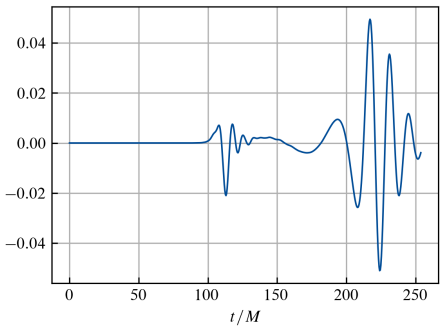
t/M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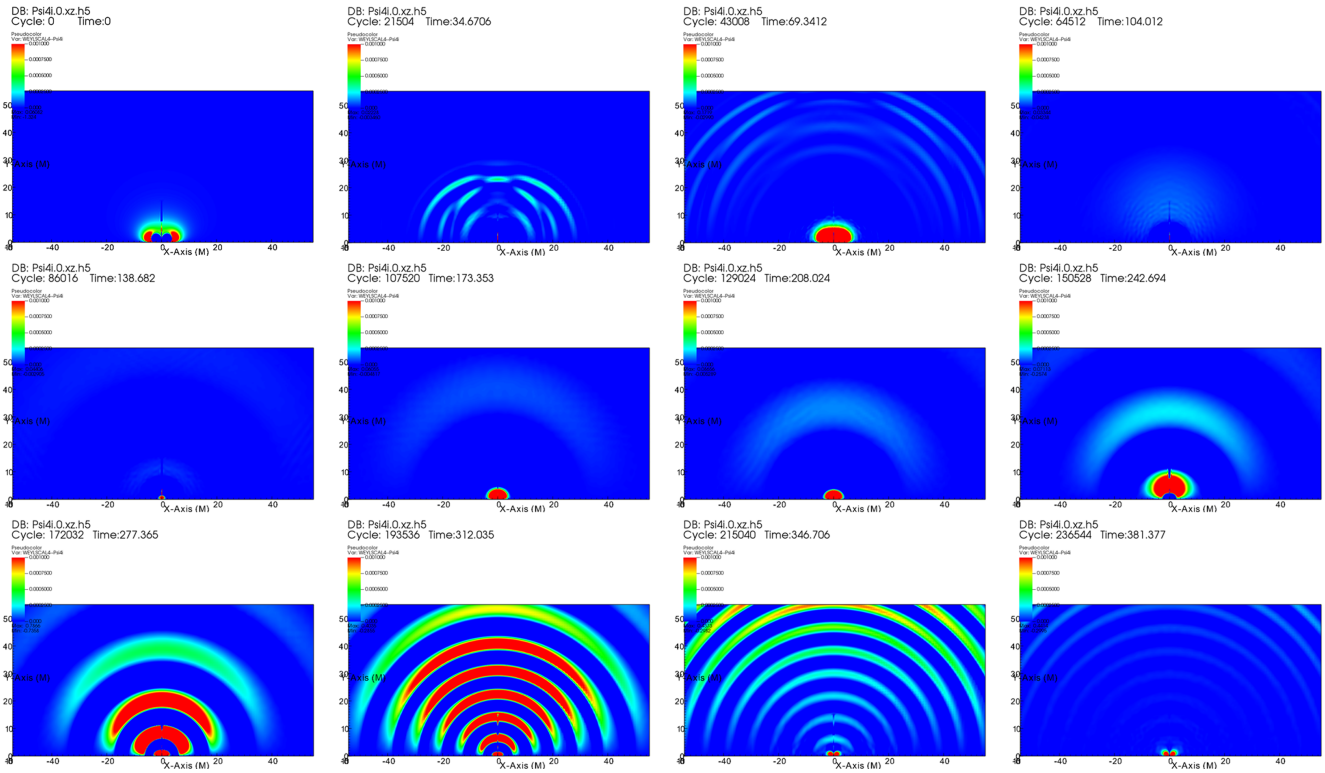
0 50 100 150 200 250
t/M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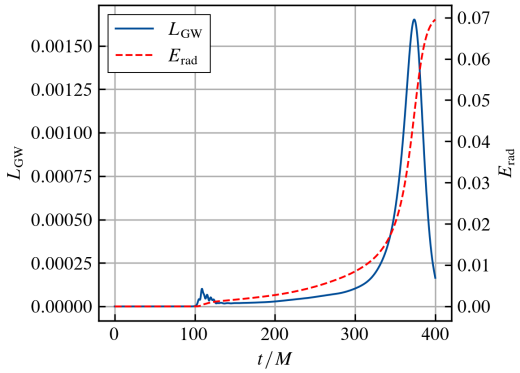
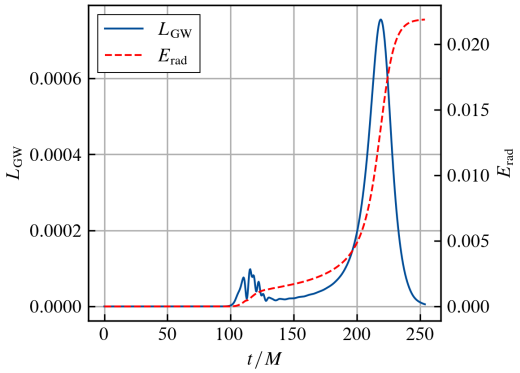
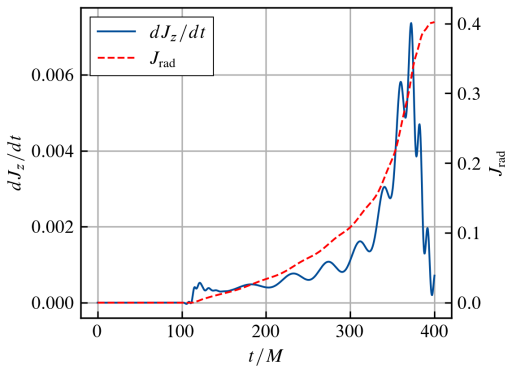
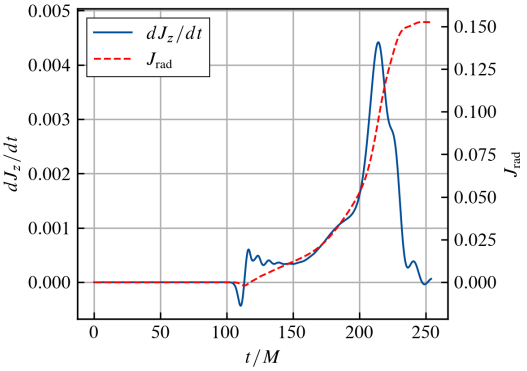
Y-Axis (M)
X-Axis (M)


$L_{\rm GW}$
$E_{\rm rad}$
t/M


$L_{\rm GW}$
$E_{\rm rad}$
t/M


dJ_z/dt
$J_{\rm rad}$
t/M


dJ_z/dt
$J_{\rm rad}$
t/M

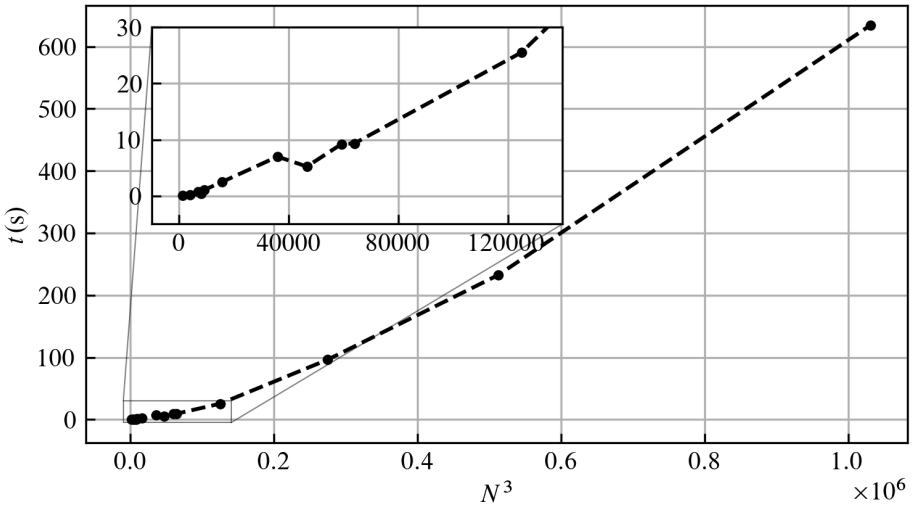
Develope new program

Einstein Toolkit

- A collection of various programs required for NR research.
- It is possible to use various and already validated programs. However...
  - Many are implemented a long time ago, and as such, some require improvement.
  - It can be challenging to find user manuals, making them difficult to use.
  - Some lack features necessary for current research.

N Puncture Solver

- First project in the development of an independent NR program.
- The existing program (TwoPunctures) could only set initial data for up to two black holes.
- Code developed to configure initial data for three or more black holes.
- Adopted commonly used CTT decomposition and Bowen-York solution, solving partial differential equations using the Biconjugate Gradient Stabilized Method (BiCGSTAB).
- Currently in the stage of checking convergence and accuracy; if sufficient, can be utilized in the study of dynamics involving three or more black holes.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500
400
300
200
100
0
t (s)
30
20
10
0
0
40000
80000
120000
0.0
0.2
0.4
0.6
0.8
1.0
N 3
×10^6