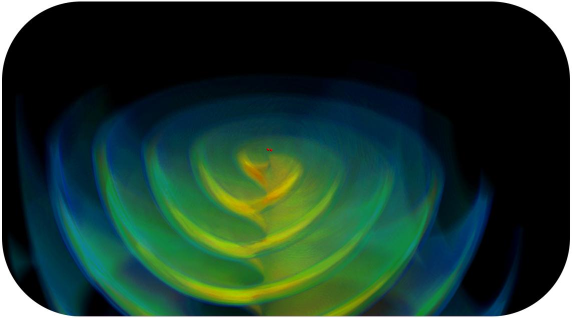
Simulating Generic Binary Neutron Star Mergers

Tim Dietrich
Albert Einstein Institute
December 14th 2016



BNS parameter space

Parameters:

- Mass M
- Mass ratio q
- Spin $\vec{S}^A, \vec{S}^B$
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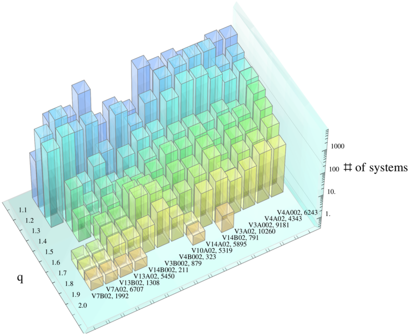
in situ models predict mass ratios up to $q \approx 1.8$
Recent observation of two $q \approx 1.3$ BNS systems

$\Rightarrow$ high-mass ratios are possible



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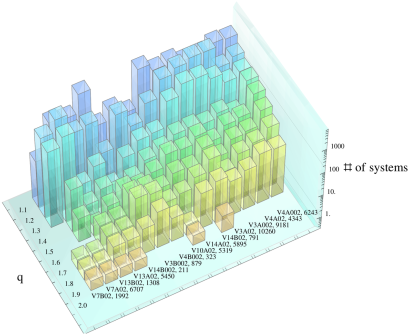

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$(\chi \sim 0.3 - 0.6)$
BNS observed up to 44Hz

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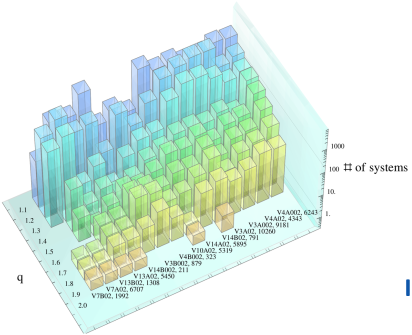

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Investigation of BNS parameter space

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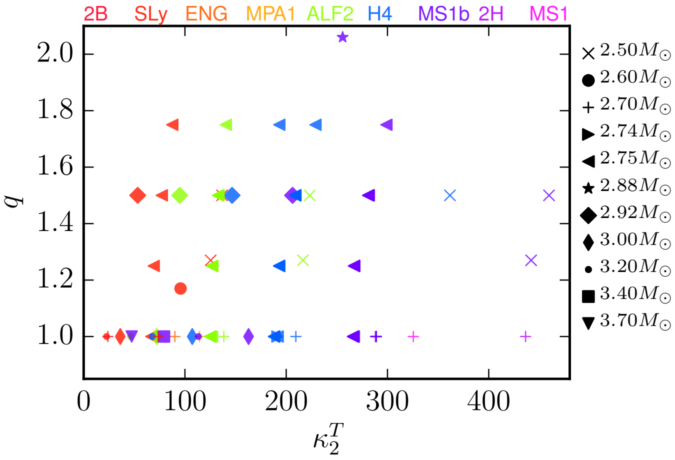

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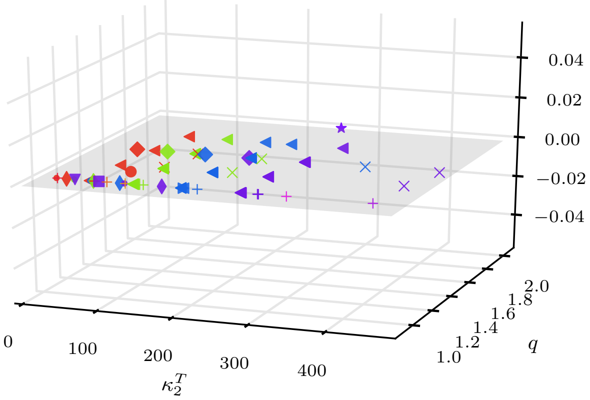

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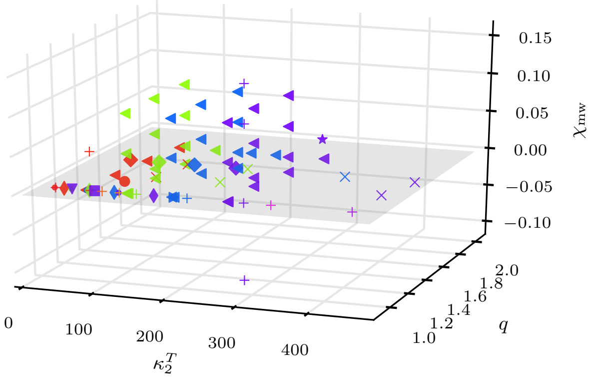
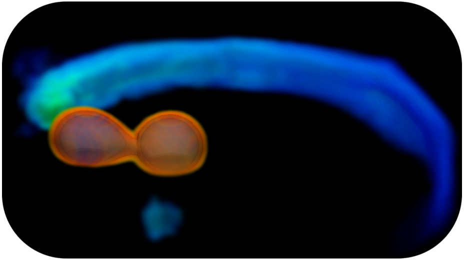
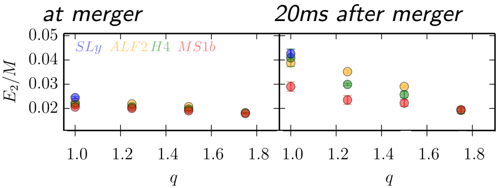


Effect of the mass-ratio



Effect of the mass-ratio: GW signal

Amount of radiated energy



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- subdominant modes become important for increasing q
- excitation of all modes in postmerger independent of q

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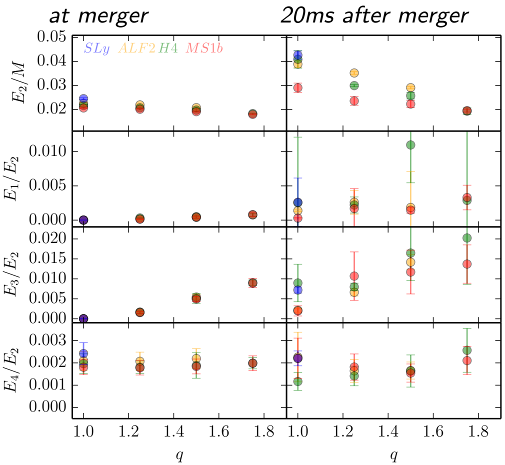

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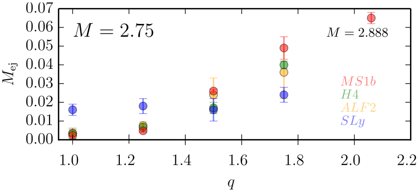

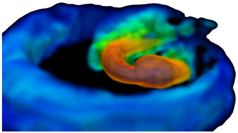

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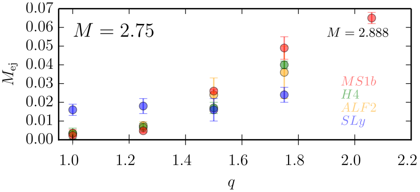

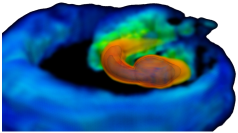

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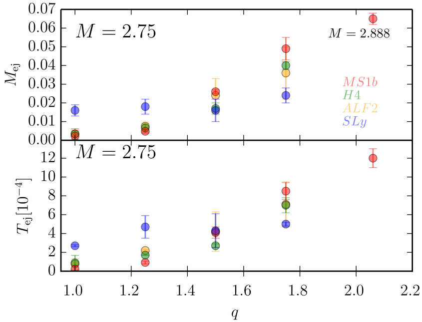

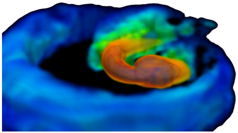

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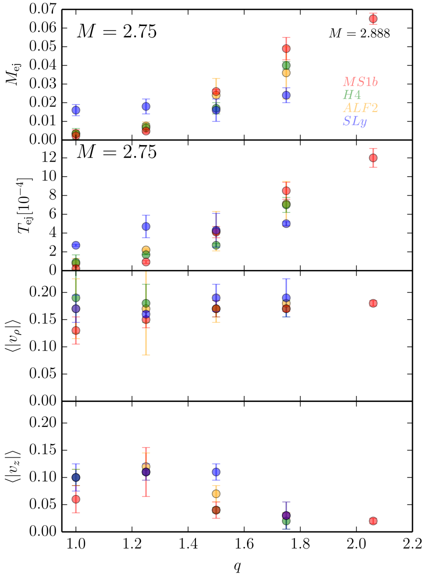

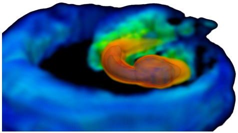

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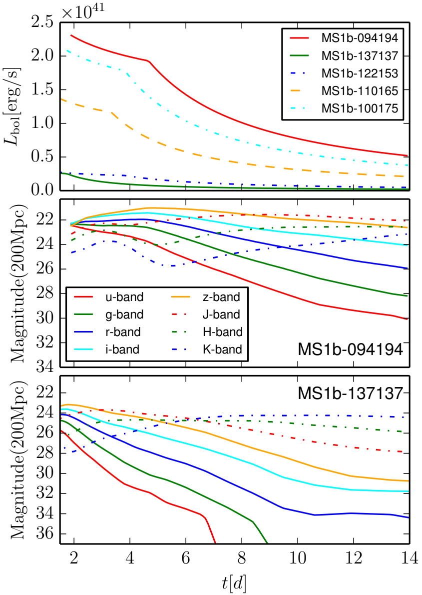
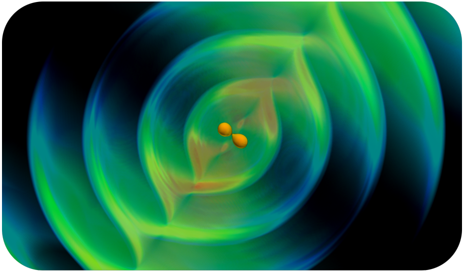


- kilonovae:
  - unequal mass ratios more luminous
  - peak luminosity at later times for large q
  - temperature at peak smaller for large q
- radio bursts:
  - higher fluency for larger q
  - peak time months/years later for large q

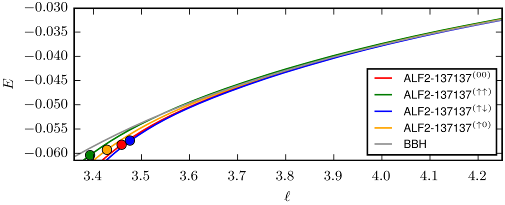
Effect of the Spin



Effect of the Spin: conservative dynamics

$E(\ell)$

E... binding energy $\quad \ell$ .. specific orbital angular momentum



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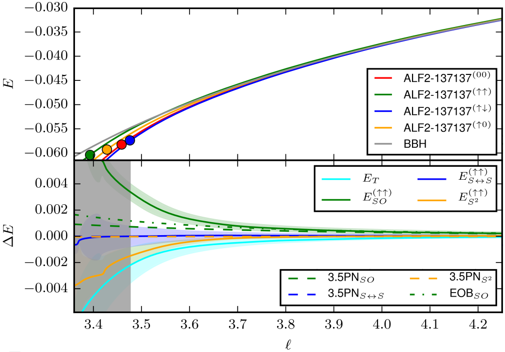

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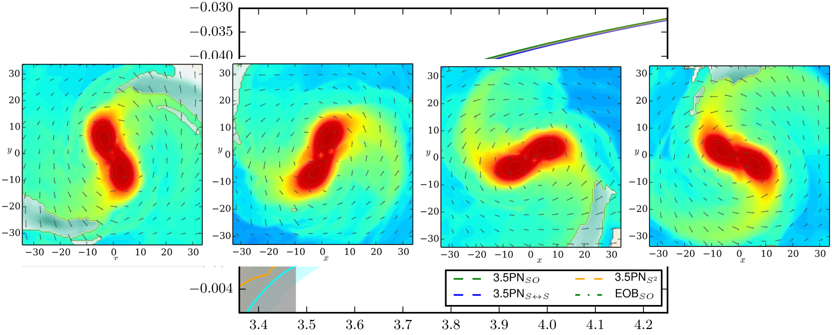

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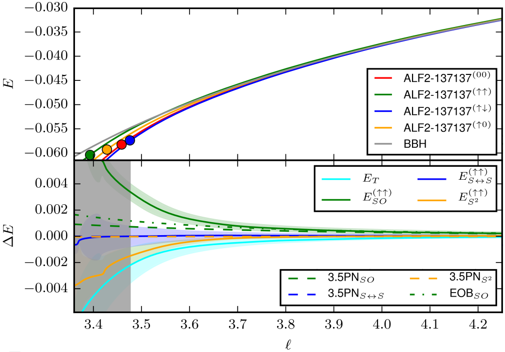

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$\Rightarrow$ E_{SO} independent of q and EOS

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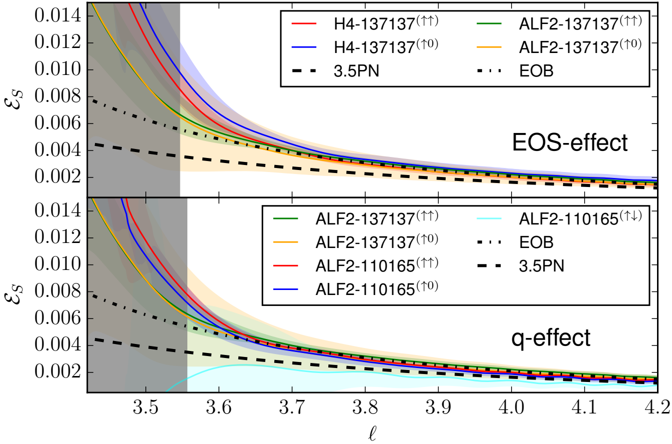

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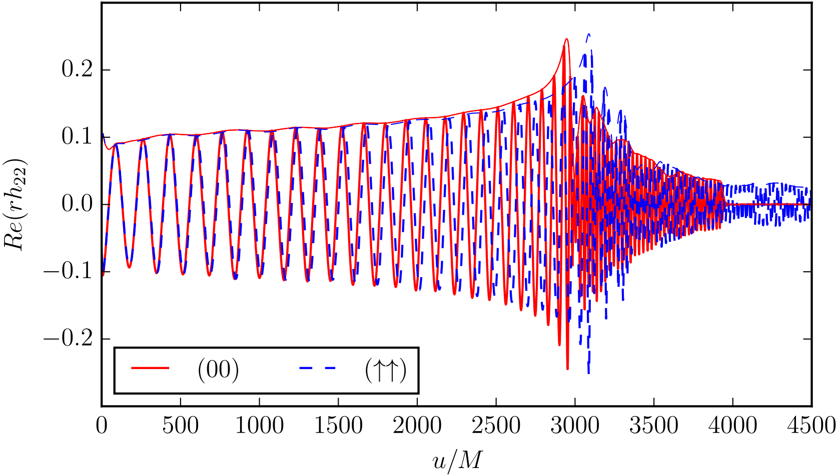

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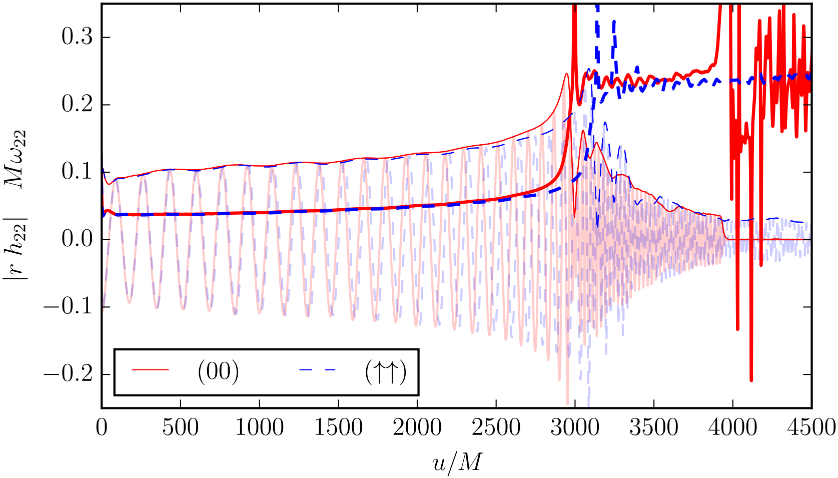

$\phi(t), M\omega(t) \quad \Rightarrow \quad \phi(M\omega)$

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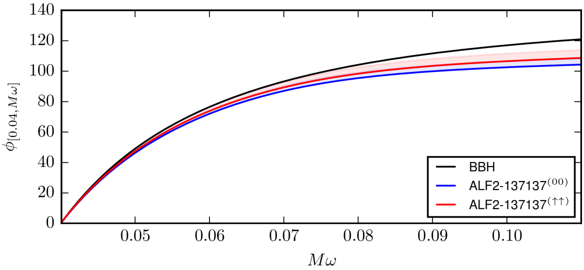

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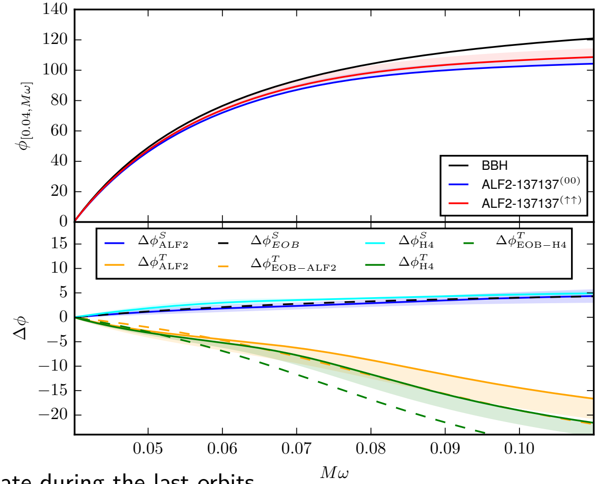
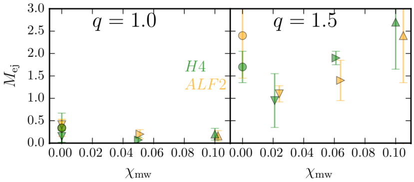


- tidal effects dominate during the last orbits
- neglecting spin would create biases in parameter estimation

Effect of the Spin: Ejecta & EM counterparts



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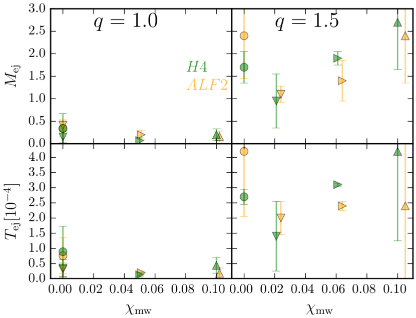

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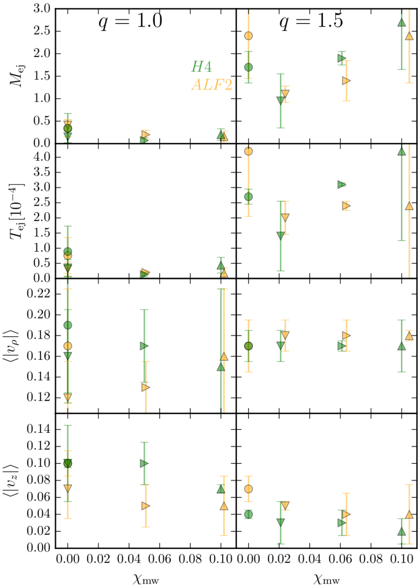

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Effect of the Spin: Precession

$M_A = 1.35 M_\odot$ and $M_B = 1.11 M_\odot$ for SLy-EOS

	chi^A	χ^B
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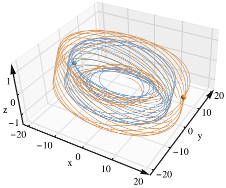

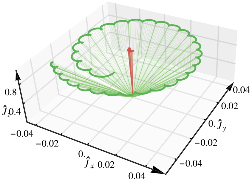

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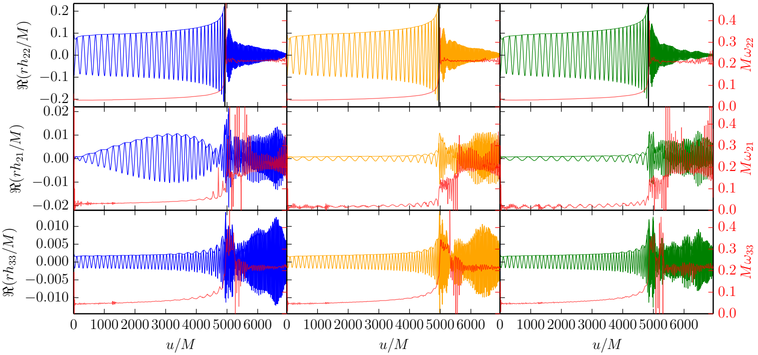

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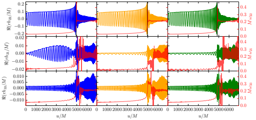

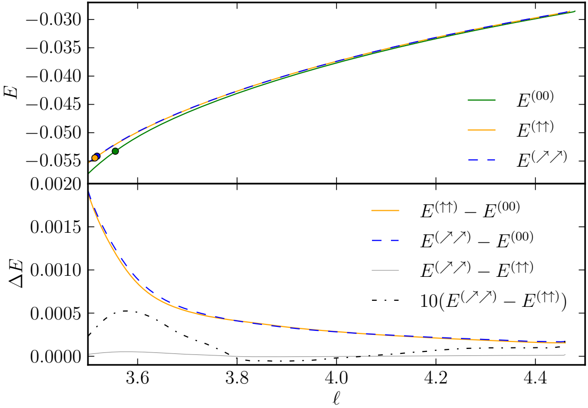

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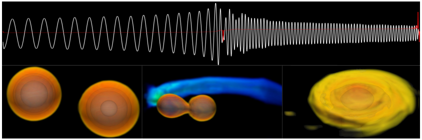
Improving Waveform accuracy

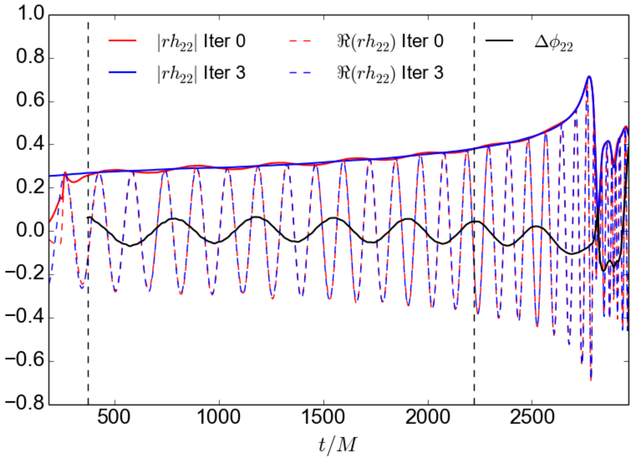


Improving the accuracy of our results

(1) eccentricity reduced data for GW modeling

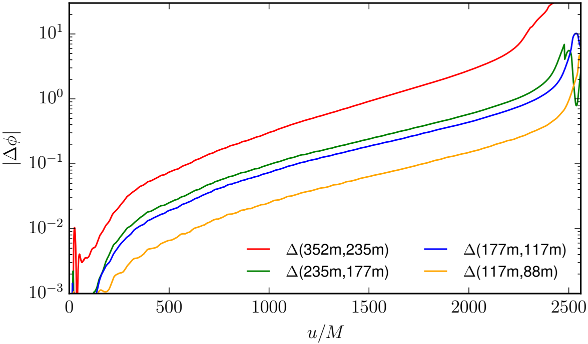
(2) implemented different flux and reconstruction methods ⇒ clean convergence across multiple resolutions

Eccentricity reduced data



- "real" systems will have negligible eccentricity
- low-eccentricity needed for accurate NR - AR work

Clean Convergence



- dominant error in BNS waveforms caused by finite resolution
- consistent convergence order across multiple resolutions and over time needed for error estimate

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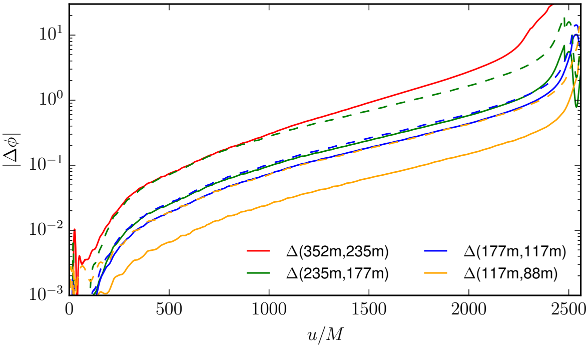

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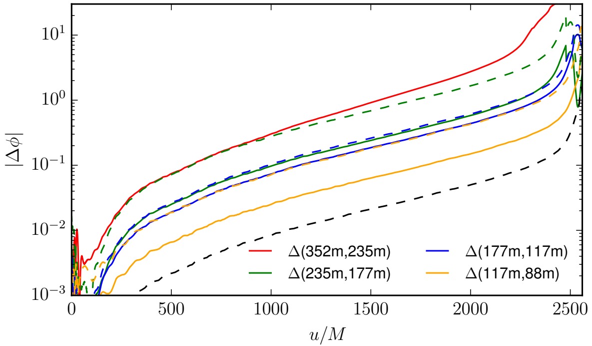

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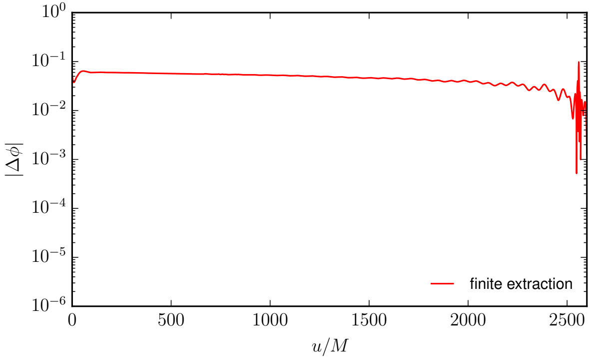
Proper Error Estimate and NR/AR comparisons



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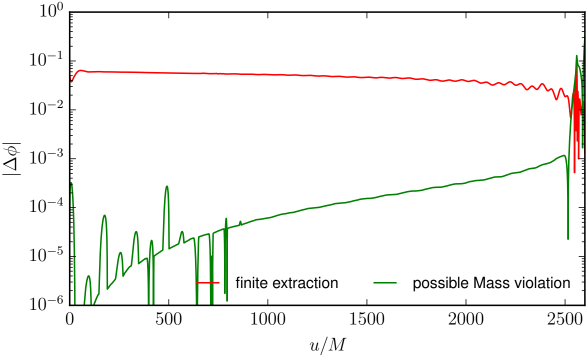

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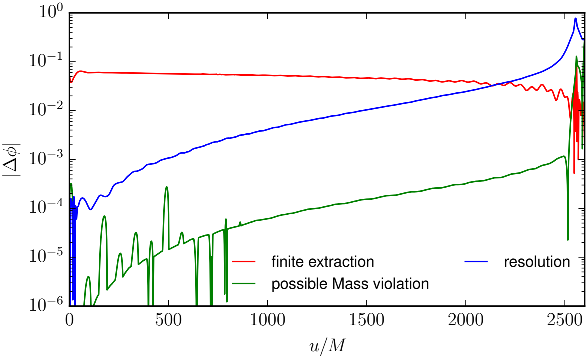

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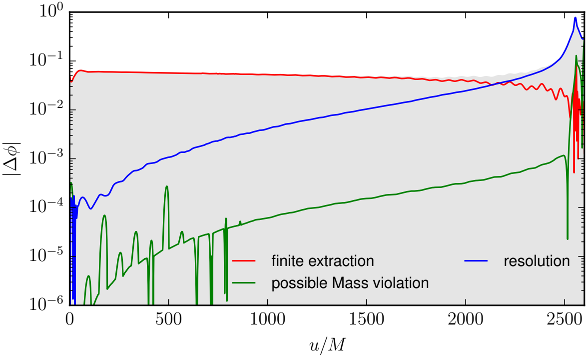

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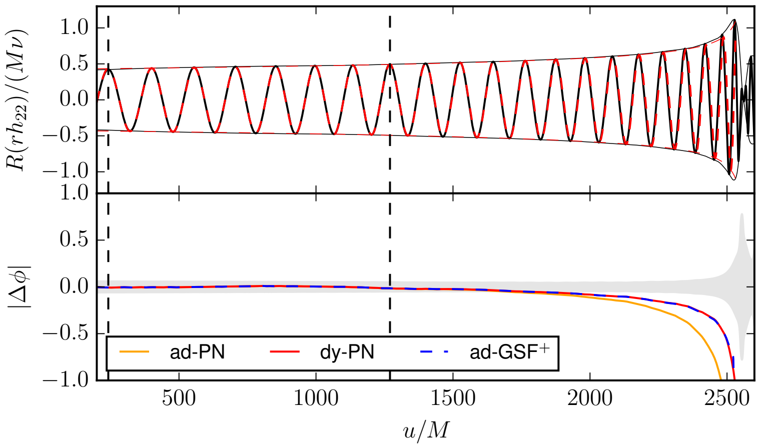

Summary

- Improvements in the construction of our initial data
- Large parameter space study regarding mass-ratio and spin
  - ejecta mass and luminosity increase for large q and aligned spin
- first precessing BNS merger
  - influence of precession small compared to spin-orbit effect
- improving accuracy and robust error budget allows further NR/AR improvements