Search sensitivity for Gravitational Waves from Black Hole Capture Events

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Introduction

- Black Holes in dense stellar environments can undergo dynamical interactions that can lead to flyby encounters, highly eccentric orbits or direct captures.
- We study the direct capture scenario, which is a strong field interaction, hence NR waveforms are needed.
- Using these NR waveforms we study the sensitivity of the cWB all-sky short-duration search to gravitational waves from Black Hole Capture events during O2.

Astrophysical Scenarios

- Binary black holes form either in isolated evolution or dynamically

  At merger: $\hookrightarrow$ circularized $\hookrightarrow$ may have significant eccentricity

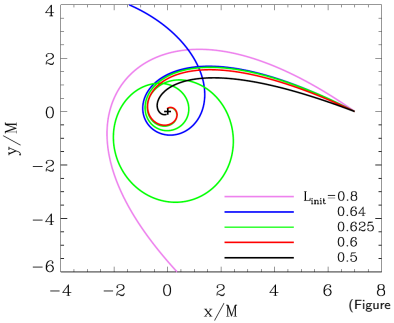
- An example of dynamical formation is radiation-driven direct capture:

  Close encounter $\rightarrow$ become bound $\rightarrow$ quickly merge

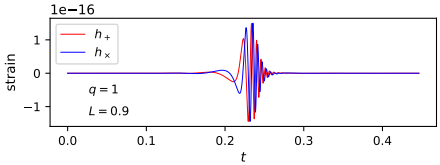
- Direct capture is possible mainly in Globular Clusters and Galactic Nuclei as single-single interaction or binary-single interaction

Capture Waveforms

- Use NR waveforms described in Bae et al. (2017), (arXiv:1701.01548),
  "Gravitational Radiation Driven Capture in Unequal Mass Black Hole Encounters"
- Radiated energy is maximal at the boundary flyby / capture
- Use only waveforms leading to capture
- 4 different mass ratios $q = m_1/m_2 = [1, 2, 4, 8]$
- 2 waveforms for each mass ratio with different initial angular momentum (impact parameter)

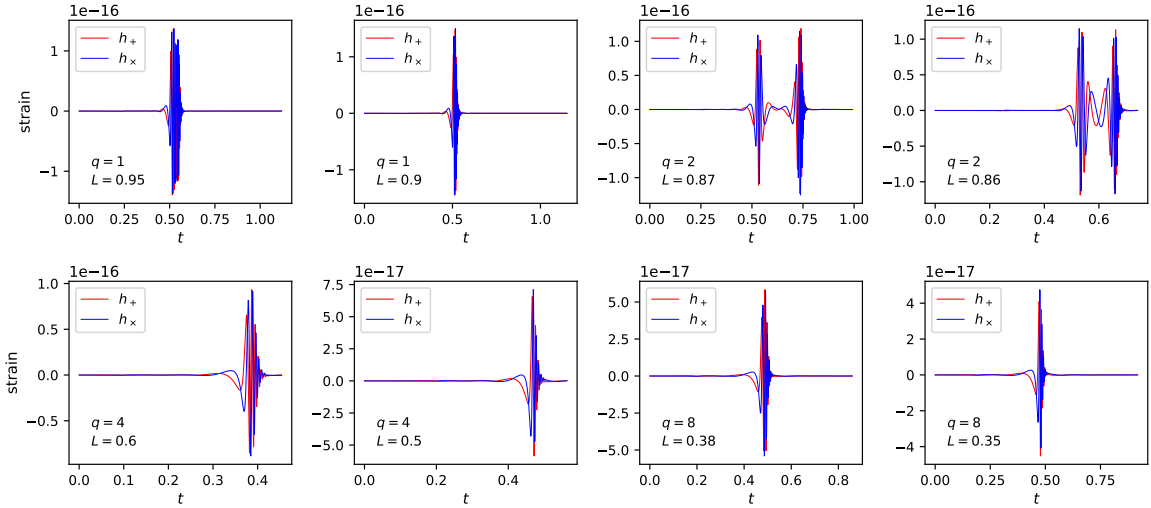


(Figure from Bae et al.)



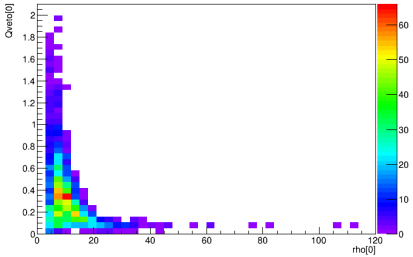
Time domain waveform example with total mass $100 M_\odot$ at 10 kpc

Capture Waveforms ($M_{\rm tot} = 100 M_\odot, D_L = 10\,{\rm kpc}$)

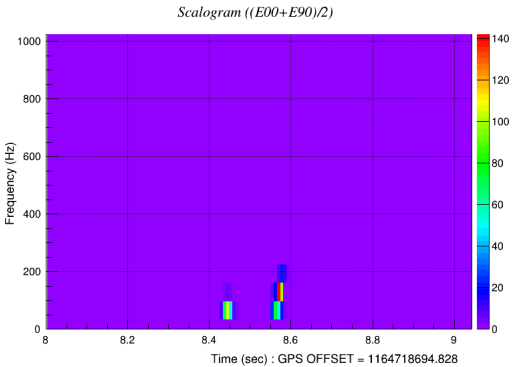


Analysis

- Utilize the cWB all-sky short-duration search with O2 settings
- Evaluate the sensitive distance to BH capture events during O2
- Part of parameter space (small $M_{\rm tot}$, high q) are affected by blip glitches



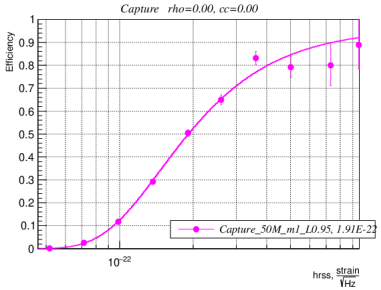
2D-histogram of detection statistics (rho) and blip glitch identifier (Qveto), $(M_{\rm tot} = 10M_\odot,\ q = 4)$

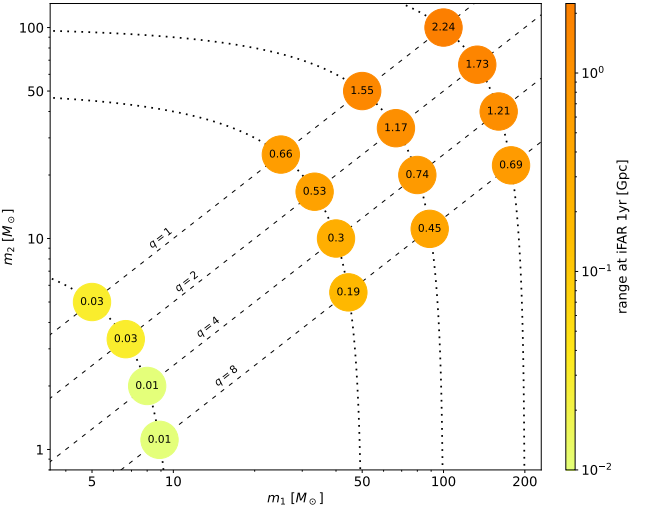


Reconstructed time-frequency map in L1 $(M_{\rm tot} = 100M_\odot,\ q = 2)$

Search Sensitivity

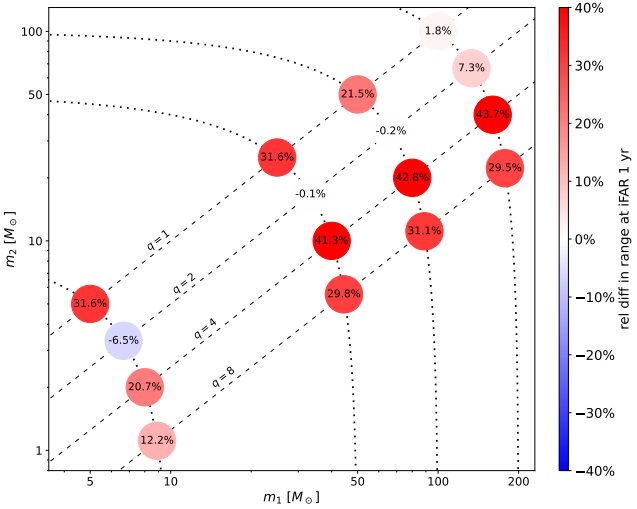
- Injection of waveforms for 4 different total masses: (10, 50, 100, 200) $M_\odot$
- Find detection efficiency at an iFAR of 1 yr
- Convert to distance and compute sensitive volume





Search Sensitivity

- Comparison of range at iFAR 1 yr for 2 different impact parameters
- Relative difference in range for the first set with larger impact parameter compared to the second set with smaller impact parameter
- In general: Larger impact parameter → more energy radiated in GW → farther range
- But depends also on the particular spectral content of the signal



Conclusion / Outlook

- cWB all-sky search is sensitive to Black Hole Capture events
- A dedicated search towards such events is useful
- In this work work we estimate a horizon distance at iFAR 1 yr
- Currently we are writing a paper on these results (O2)
- We plan to extend the study to hyperbolic events
- We plan to target the search towards better sensitivity for BH captures and flyby encounters

Thanks for your attention!