Title: Mergers of Binary Black Holes as Burst Sources

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Abstract: TBA

Exploring the Use of Numerical Relativity Waveforms in Burst Analysis of Binary Black Hole Mergers

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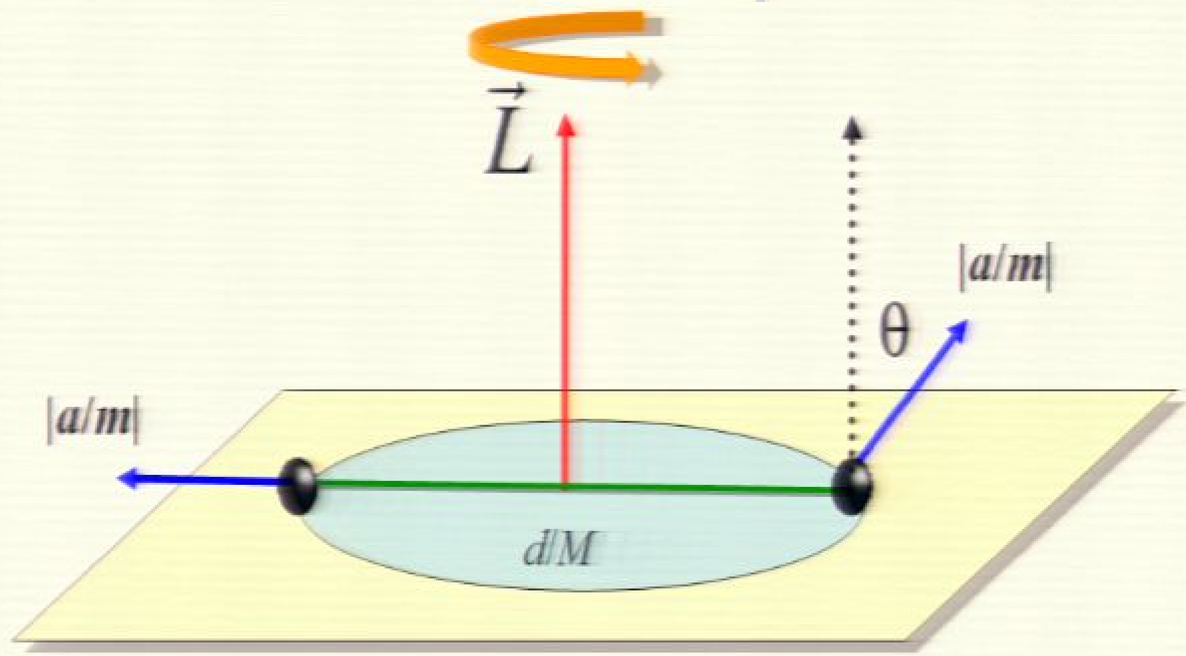
Motivation and Plan

- Highest SNR in ground-based detectors is from the merger and ringdown of compact objects, and provides the motivation for the current study
- We systematically study how the physical parameters of the system affect the detectability of BBH mergers in a burst search
- We focus on the effects of spin and its orientation

NR + noise ⟶ Omega algorithm* ⟶ Detection Efficiency

* https://geco.phys.columbia.edu/omega

NR Setup



- S-series (Herrmann, Hinder, Shoemaker, Laguna, Matzner, 2007):
  - Quasi-circular equal-mass, spinning BBH systems
  - equal magnitude spins, $|a/m|$
  - separated by d/M
  - spin orientations vary
- Choose d/M, $|a/m|$ and vary θ from 0 to 2π
- Five series: $(d/M, |a/m|) = \{ (6.2, 0.2), (6.2, 0.4), (6.2, 0.6), (8.0, 0.6), (10.0, 0.6) \}$

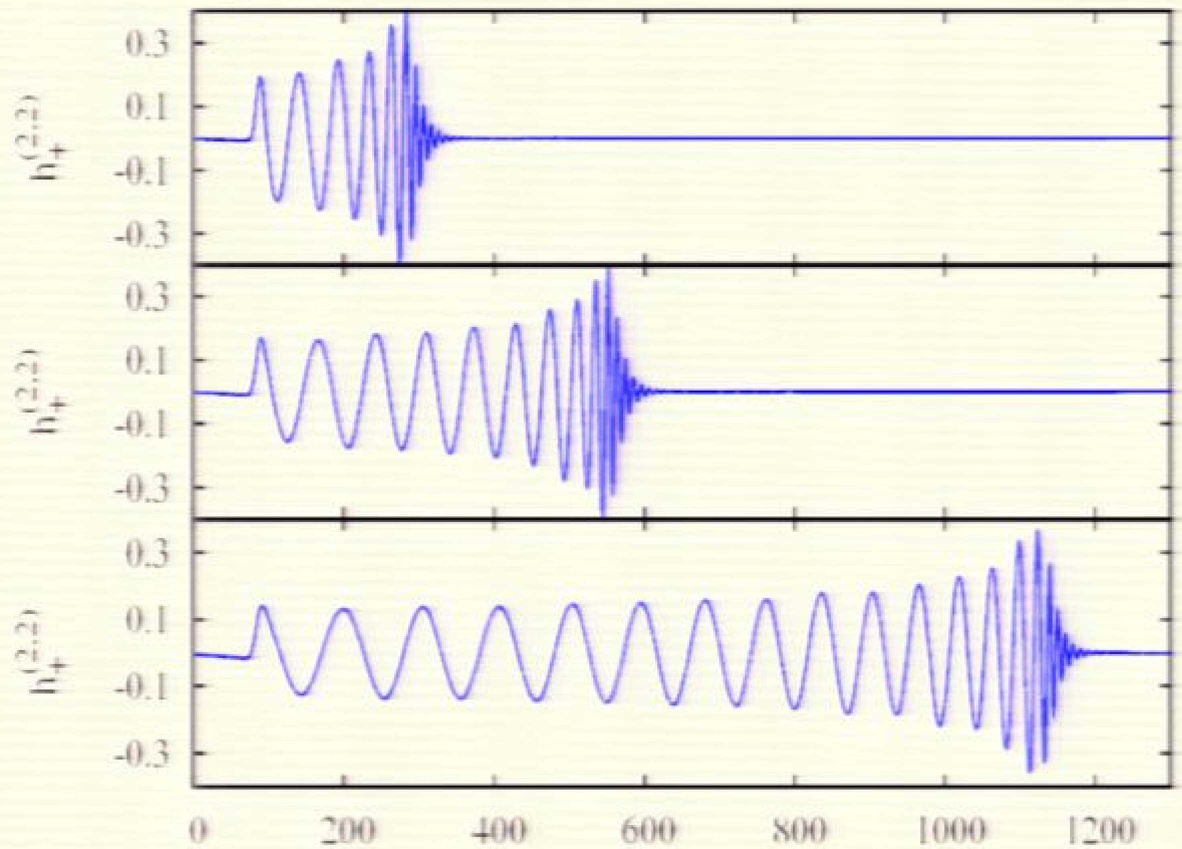
NR Waveforms

- Error estimates:
  - $d/M = 6.2$, $|a/m| = 0.6$: $\Delta\varphi \sim 0.01$, $\Delta A/A \sim 2\%$ (top)
  - $d/M = 10.0$, $|a/m| = 0.6$: $\Delta\varphi \sim 0.1$, $\Delta A/A \sim 5\%$ (bottom)

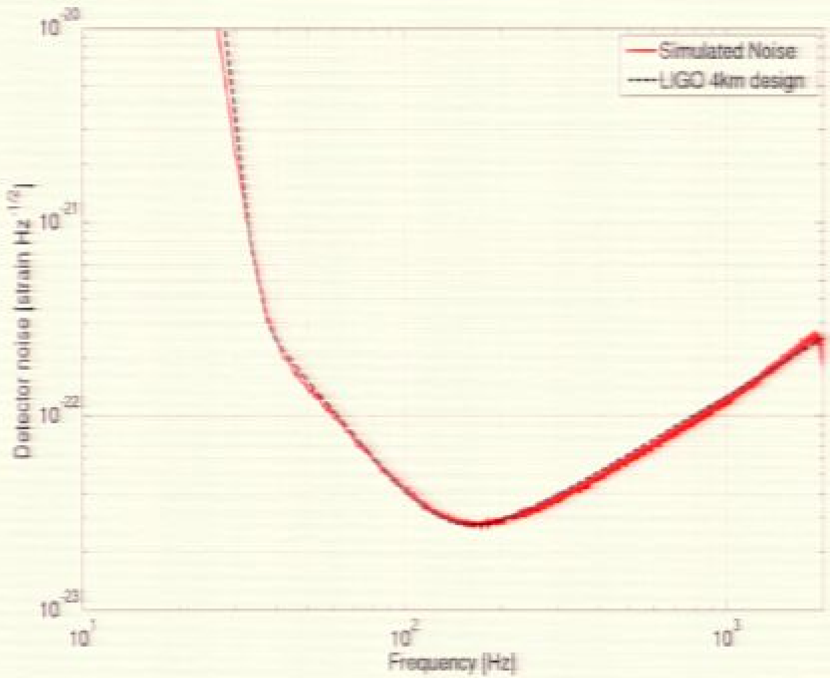
$d/M = 6.2$, $|a/m| = 0.6$, $\theta = 0^\circ$

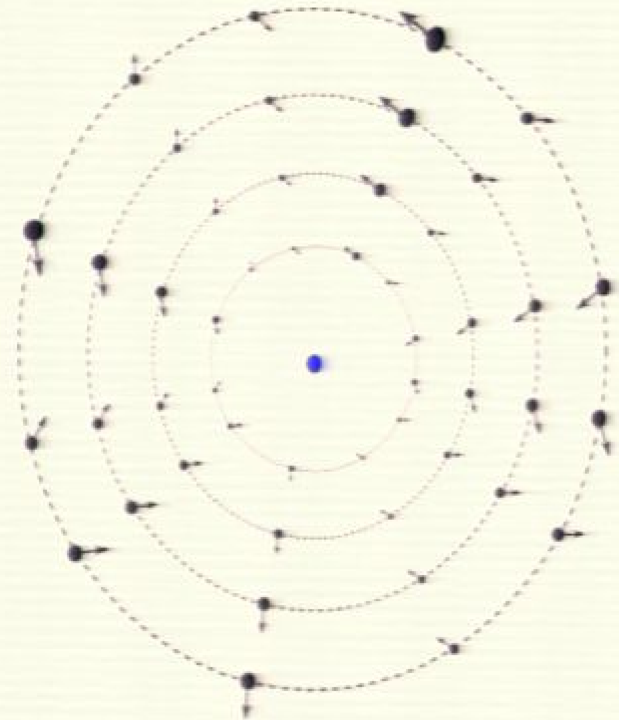
$d/M = 8.0$, $|a/m| = 0.6$, $\theta = 0^\circ$

$d/M = 10.0$, $|a/m| = 0.6$, $\theta = 0^\circ$



Burst Search Methods

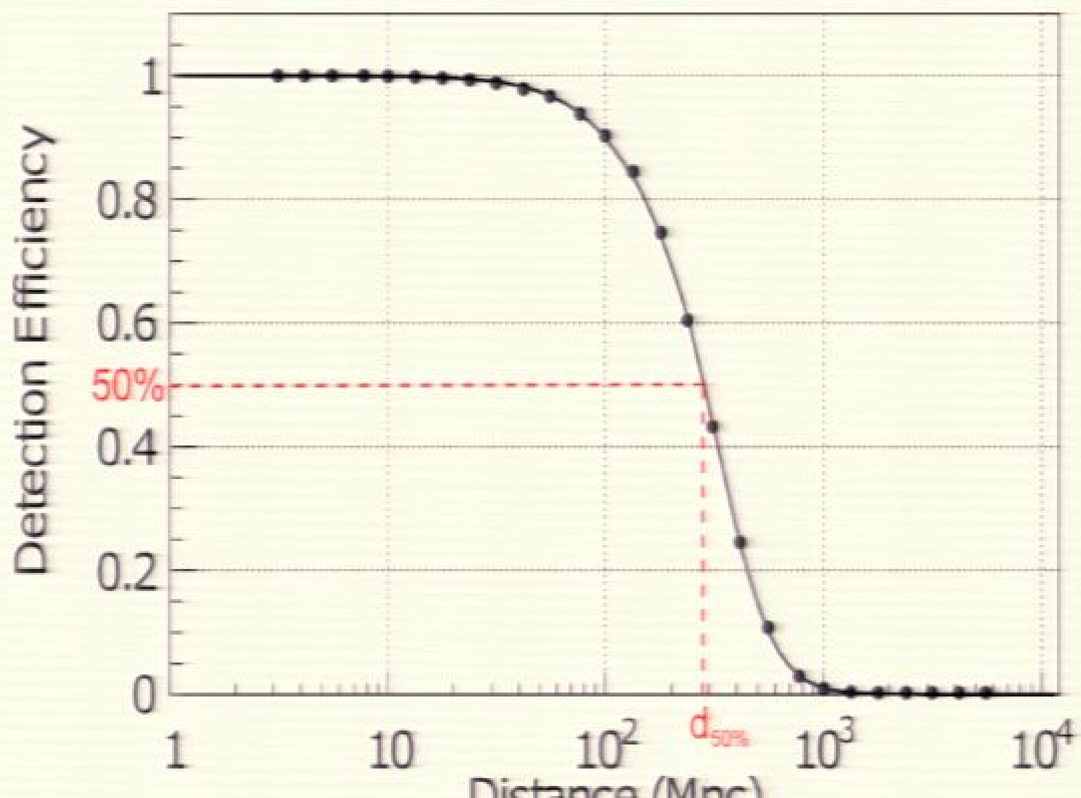




- Unmodeled burst searches can detect signals without assumption on waveform morphology by looking for excess signal energy in the strain time series
- Can potentially detect signals that other searches might miss
- NR waveforms are randomized over sky location and source inclination
- Scaled to produce 27 concentric shells of different radial distances to the detector
- Injected with Gaussian noise colored to mimic initial LIGO design sensitivity
- Combined signal and noise fed into the Omega as simulated detector output

Detection Efficiency

- Mass range: 80-350 $M_{\odot}$
- Threshold SNR of 5.5 used to identify which injections were found
- Detection efficiency is the ratio of hits over total injections per shell
- Uncertainty related to $1/N^{1/2}$, with N=13,354 injections per shell

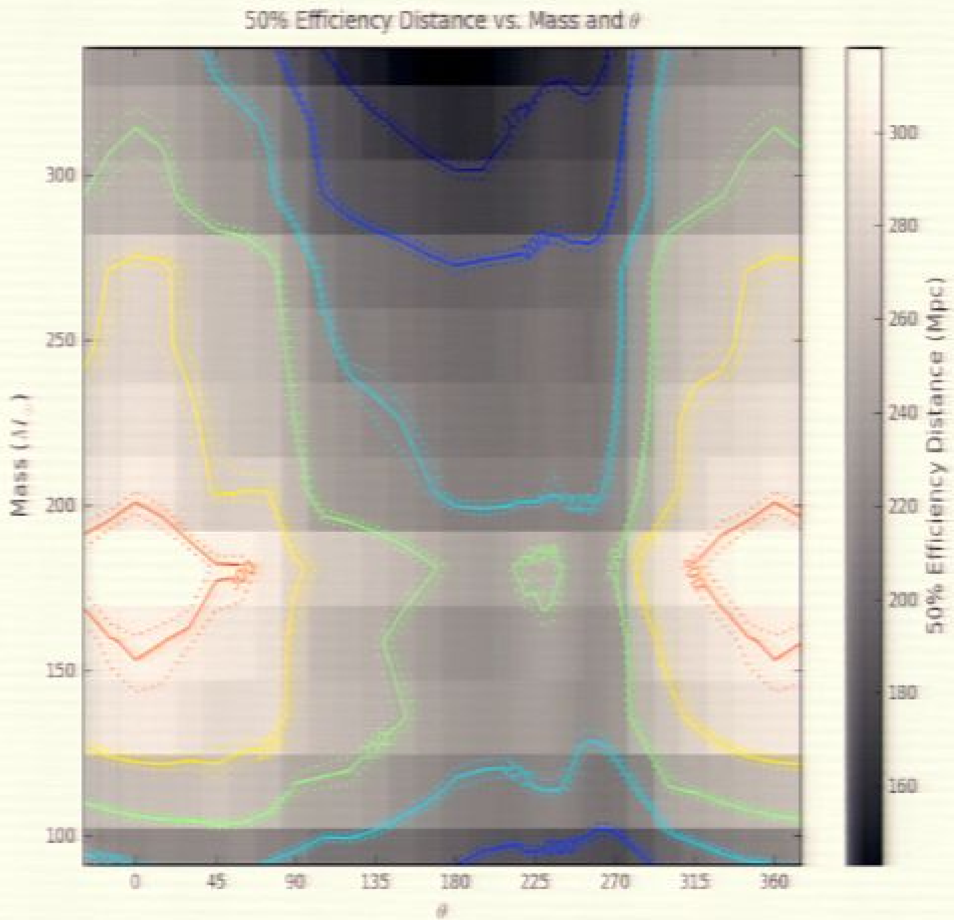


$d/M = 6.2$, $|a/m|=0.6$,

$\theta=0^{o}$

50% Efficiency Distance

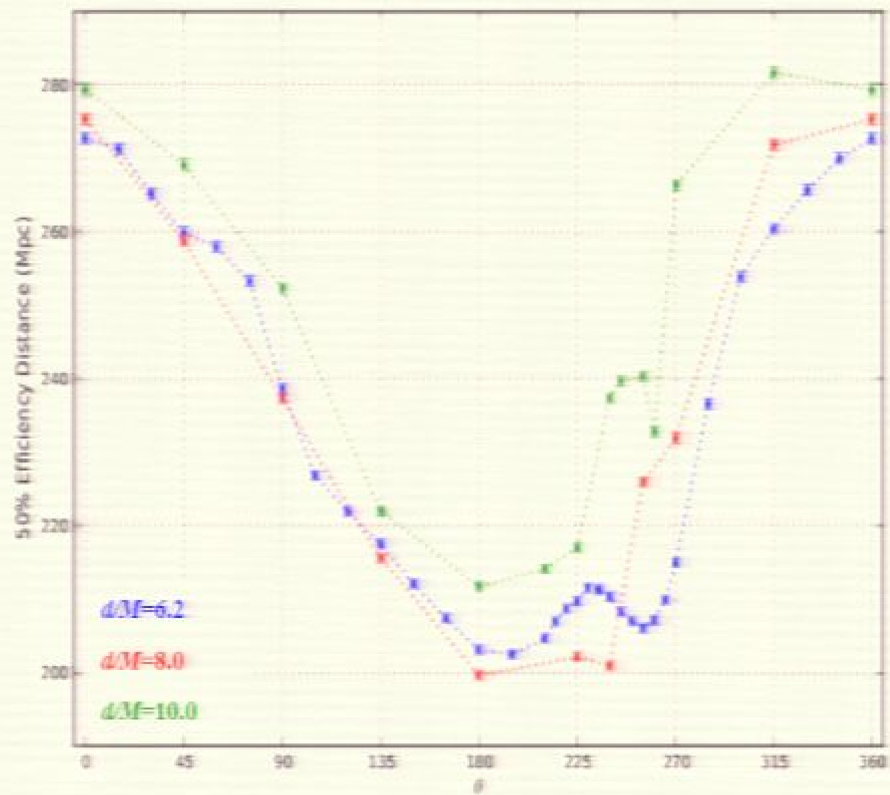
- Twelve $22.5 M_{\odot}$ bins
- Dependence on M_{sys}
- Dependence on θ
- Efficiency scales with the total angular momentum of the system
- "Blip" around 255° indicates more complex explanation needed



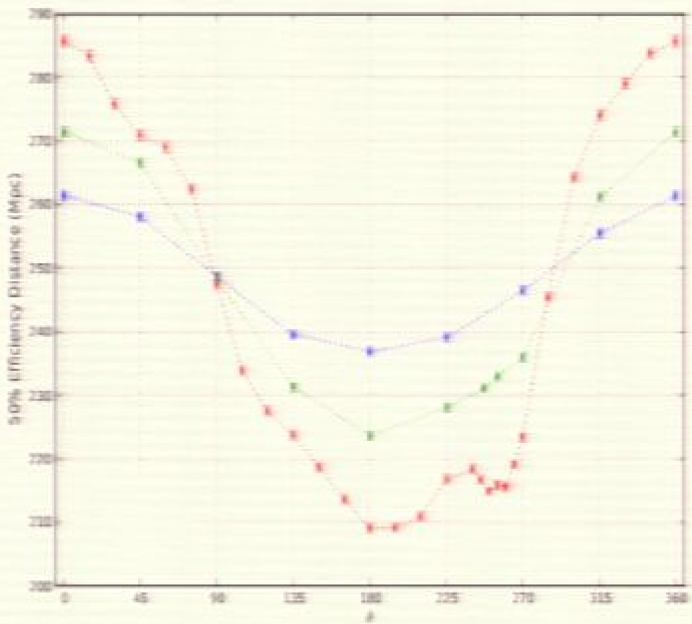
$d/M = 6.2, \quad |a/m| = 0.6$

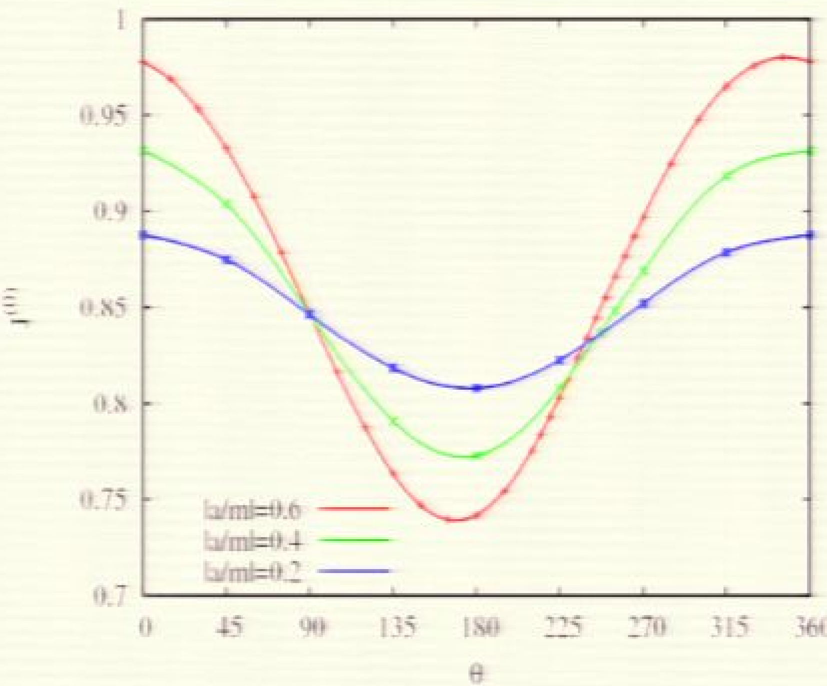
50% Efficiency Distance II

- 50% efficiency distance over entire mass range, 80-350 $M_\odot$
- $|a/m| = 0.6$, d/M varies
- Blip around 255° observed in all cases
- Qualitative behavior of the cases the same, despite differences in initial separation



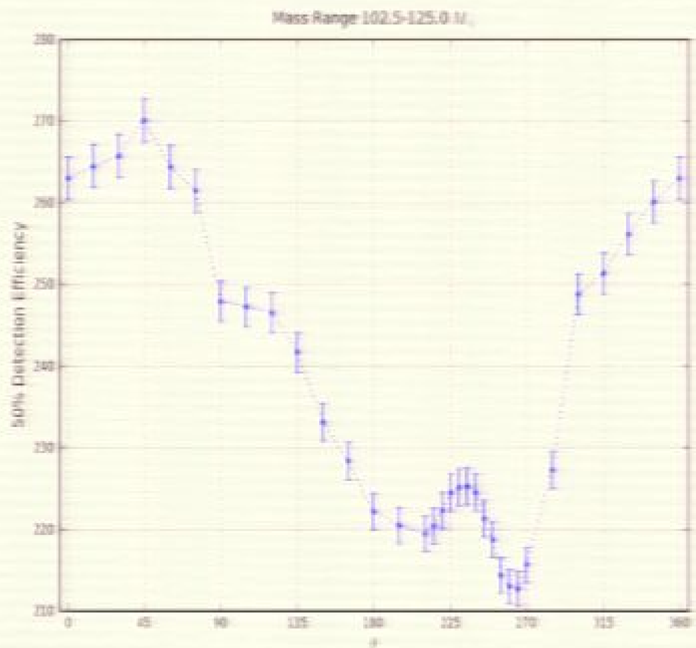
50% Efficiency Distance III

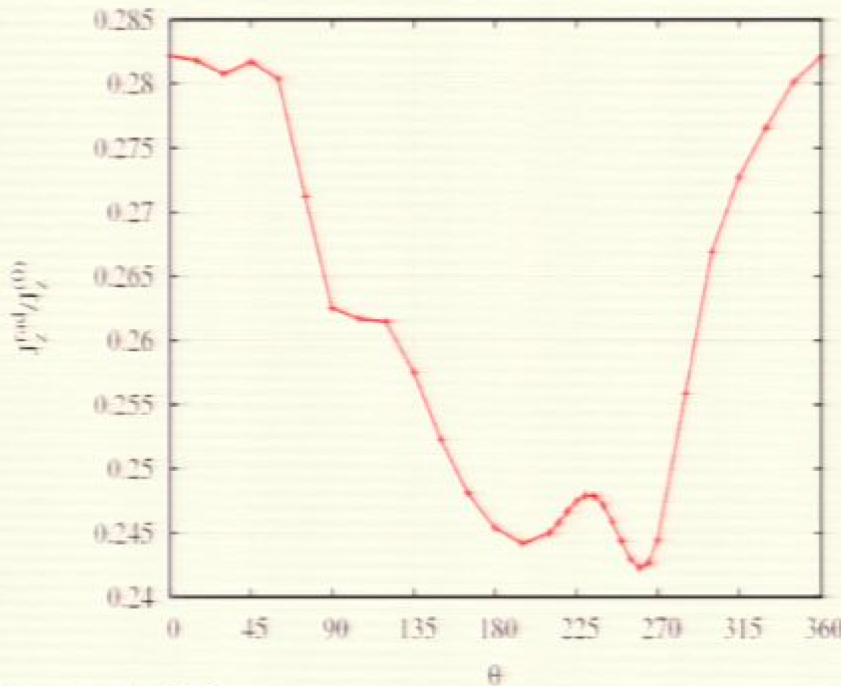




- *d/M*=6.2 constant, spin magnitudes vary
- Detection efficiency overall dependence on θ scales to the total amount of initial angular momentum of the system

The "Blip"





$d/M = 6.2, \ |a/m| = 0.6$

- The detection efficiency is directly related to the amount of angular momentum radiated.
- Bulk features from initial angular momentum, finer features from radiated angular momentum

Conclusions

- Systematically studied a system in which the black holes have variable spins
- Detection efficiency strongly correlated to the radiated angular momentum of the system
- OMEGA is sensitive enough to pick up these small changes in radiated angular momentum
- Importance of higher modes?