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

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Goals

- Use numerical relativity (NR) waveforms to explore detectability of binary black hole coalescences with gravitational wave burst techniques

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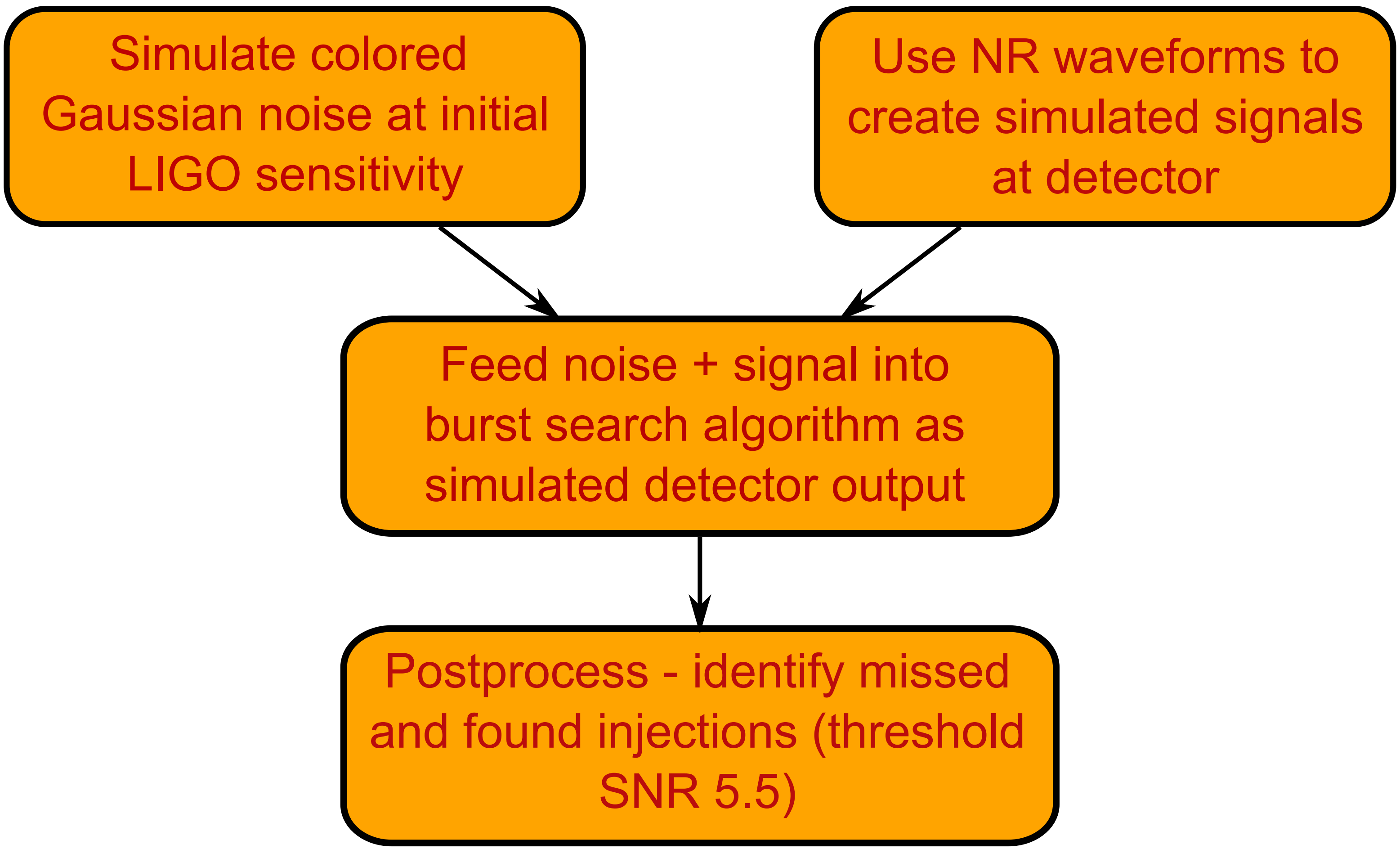
- Systematically probe the parameter space from both numerical and data analysis sides
  - Numerical: Simulation resolution, duration, inclusion of different spherical harmonic modes, etc.
  - DA: Black hole masses, spins, mass ratio, orbit eccentricity, etc.
- Large parameter space; this is a work-in-progress!

Overview


Simulate colored Gaussian noise at initial LIGO sensitivity
Use NR waveforms to create simulated signals at detector
Feed noise + signal into burst search algorithm as simulated detector output
Postprocess - identify missed and found injections (threshold SNR 5.5)

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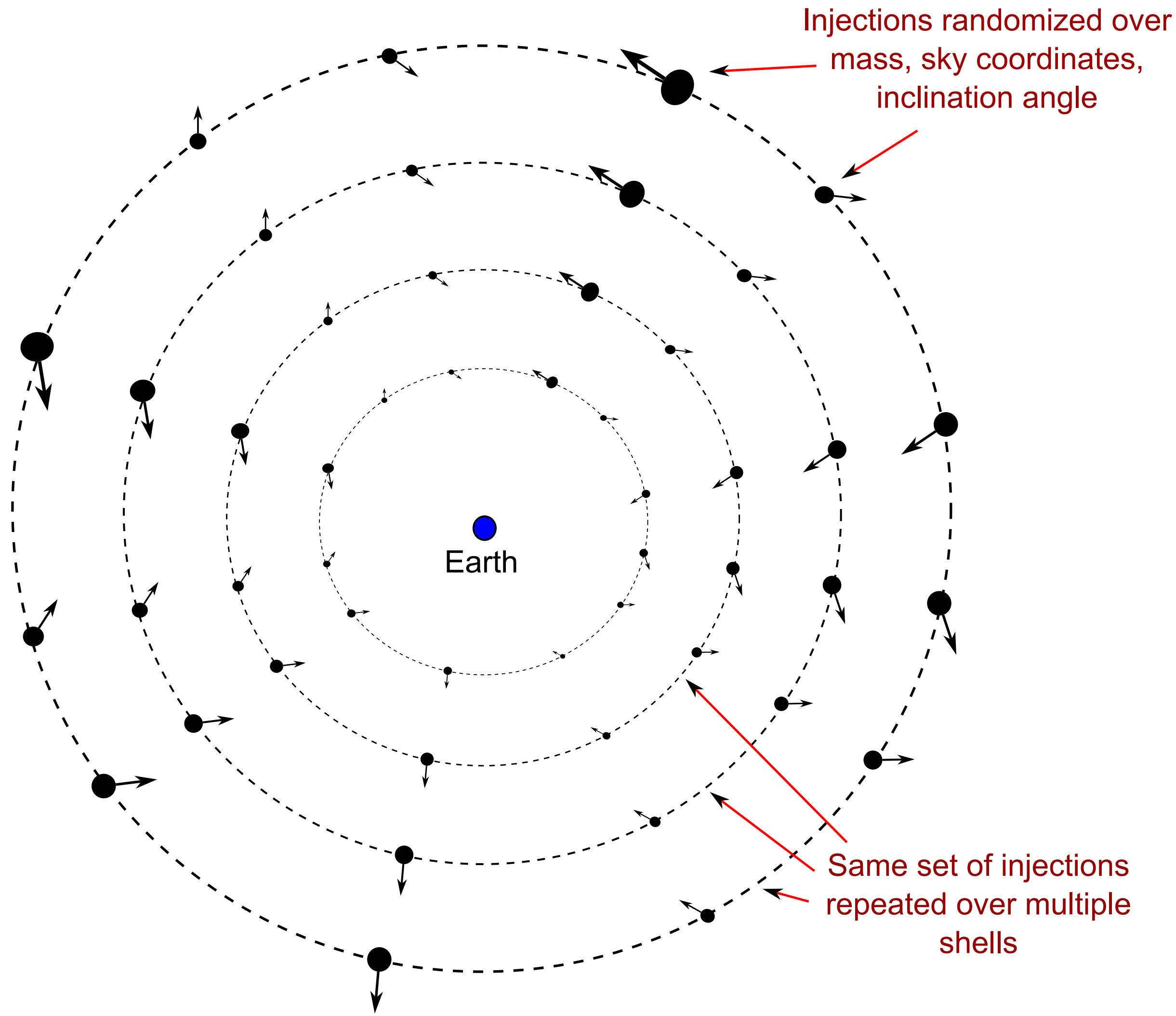
Injections randomized over
mass, sky coordinates,
inclination angle
Earth
Same set of injections
repeated over multiple
shells

Omega-pipeline

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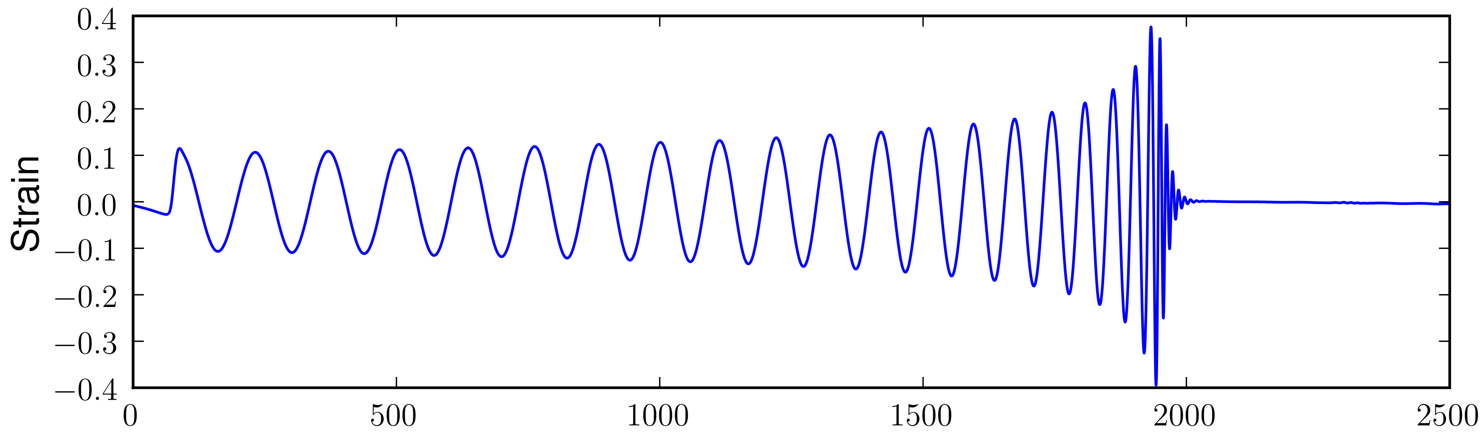
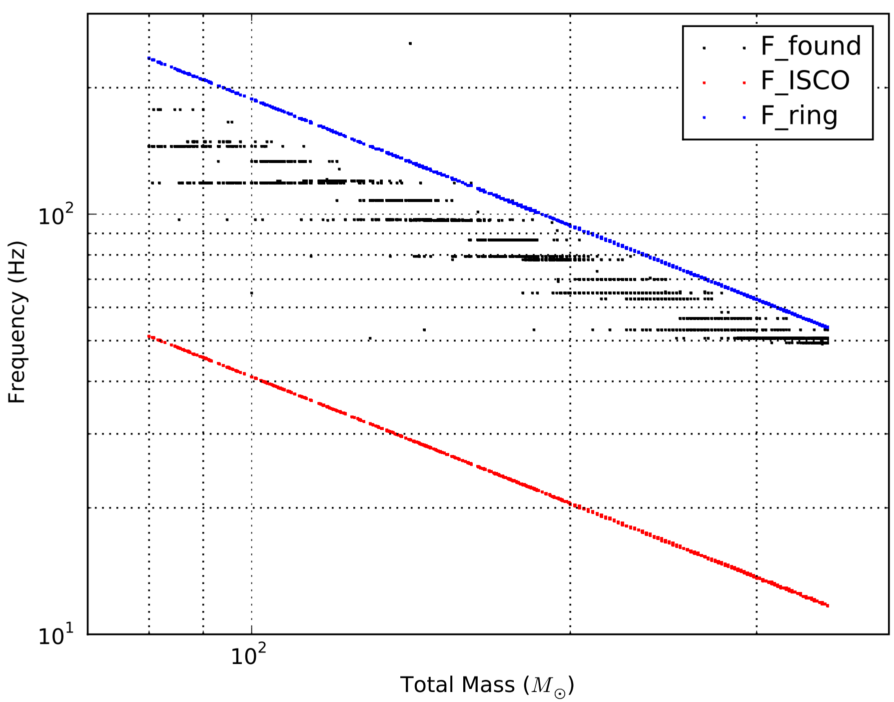
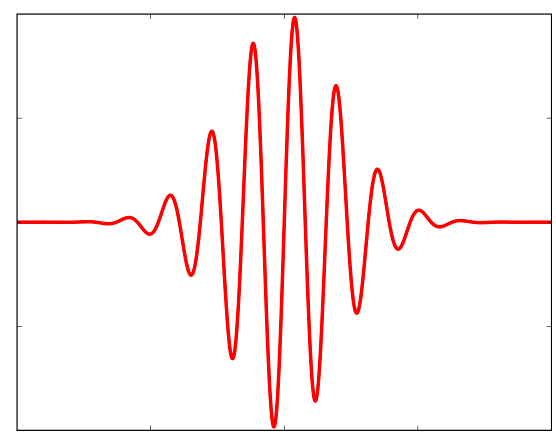
- Signal is decomposed into a basis of complex exponentials characterized by central time, frequency, and quality factor Q - equivalent to matched filtering against a basis of sine-Gaussians in whitened data

Omega-pipeline







NR Waveforms

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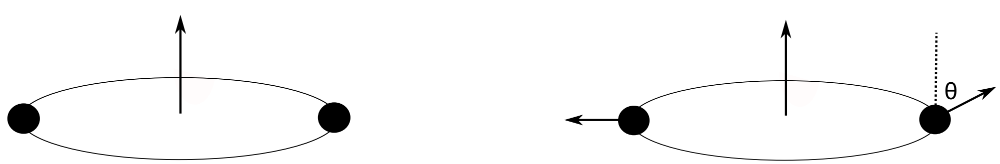
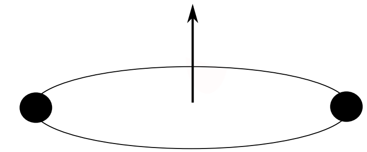
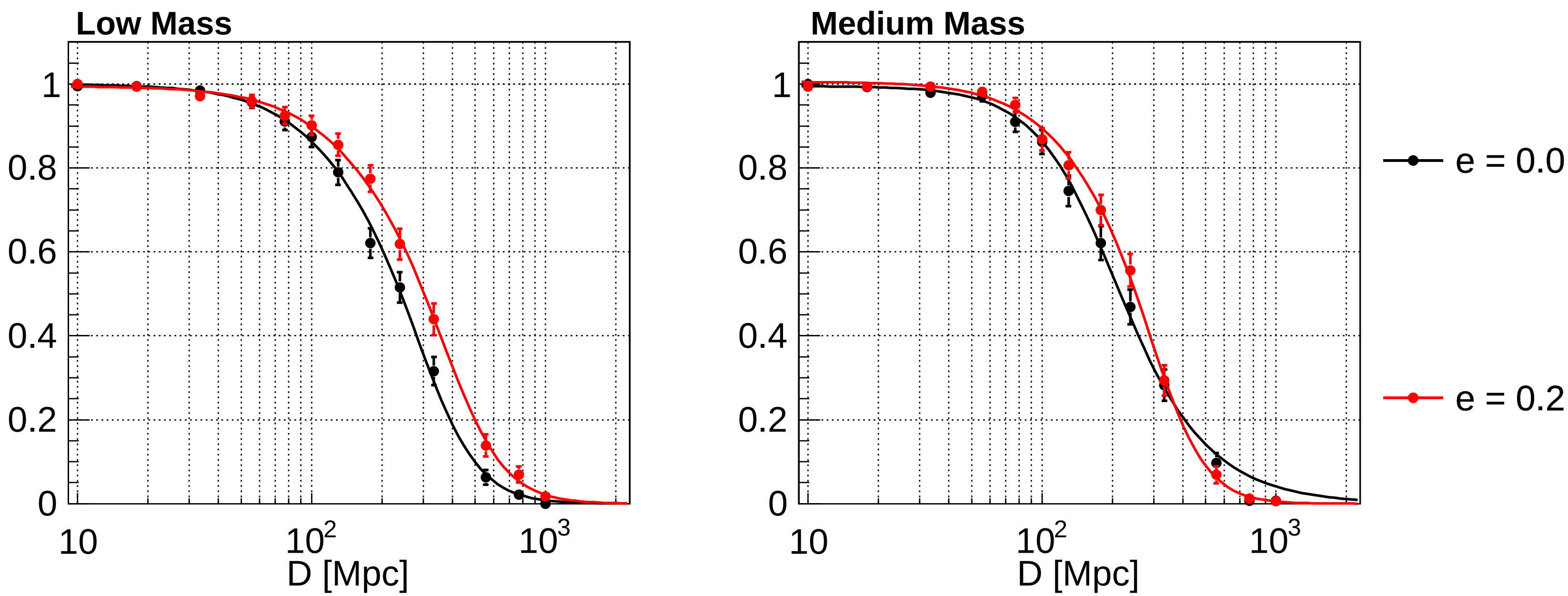
- Three runs presented here (all equal-mass):
  - Nonspinning, eccentric orbit (Hinder, Herrmann, Shoemaker, Laguna PRD 2008)
  - Spin $a = 0.6$, variable orientation (Old runs: Herrmann, Hinder, Shoemaker, Laguna, Matzner PRD 2007. New runs: James Healy 2009)
  - Spin $a = 0.2$, variable orientation (James Healy 2009)



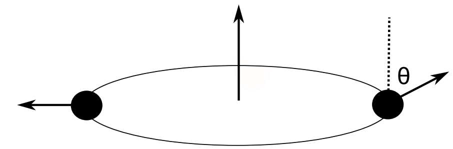
Eccentric

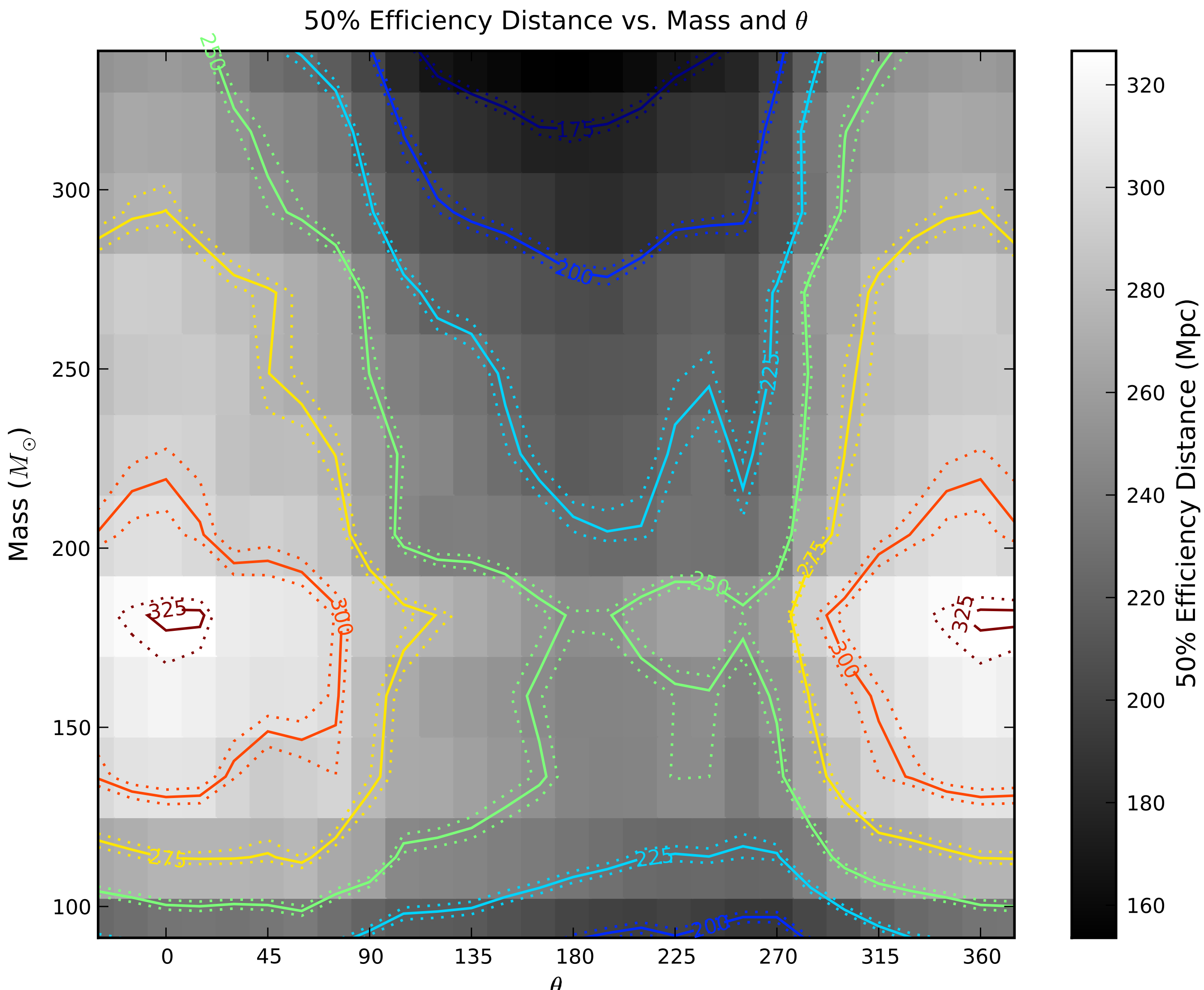




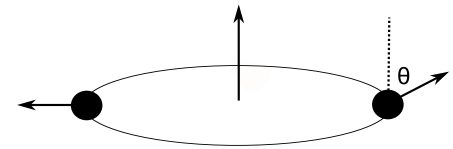
Mass Range	e	50% Distance (Mpc)
$80 - 200 M_\odot$	0.0	241 ± 7
	0.2	305 ± 9
$200 - 300 M_\odot$	0.0	217 ± 8
	0.2	251 ± 7

Spinning, $a = 0.6$

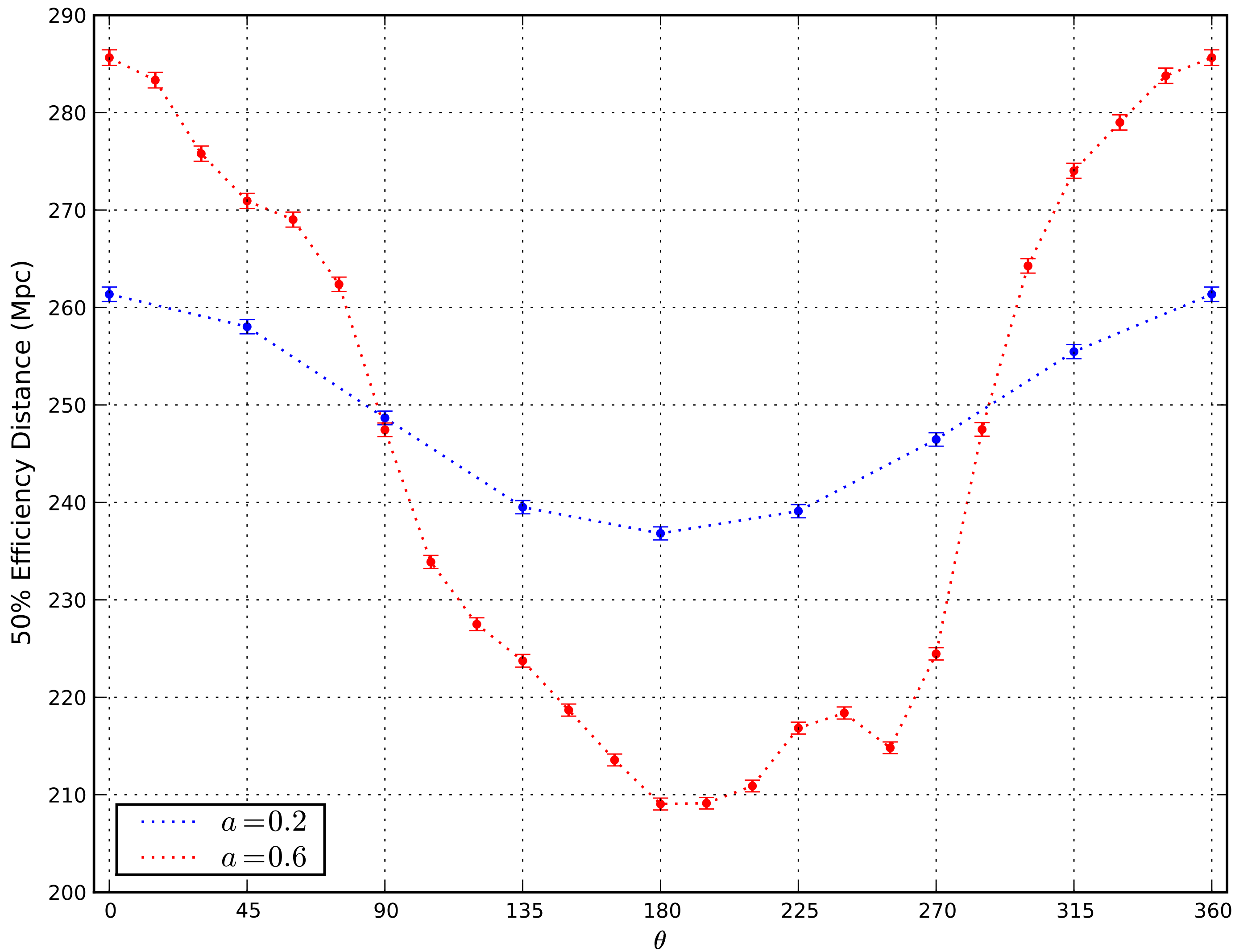




Spinning Comparison



Focusing on $100 - 300 M_\odot$:



Conclusions

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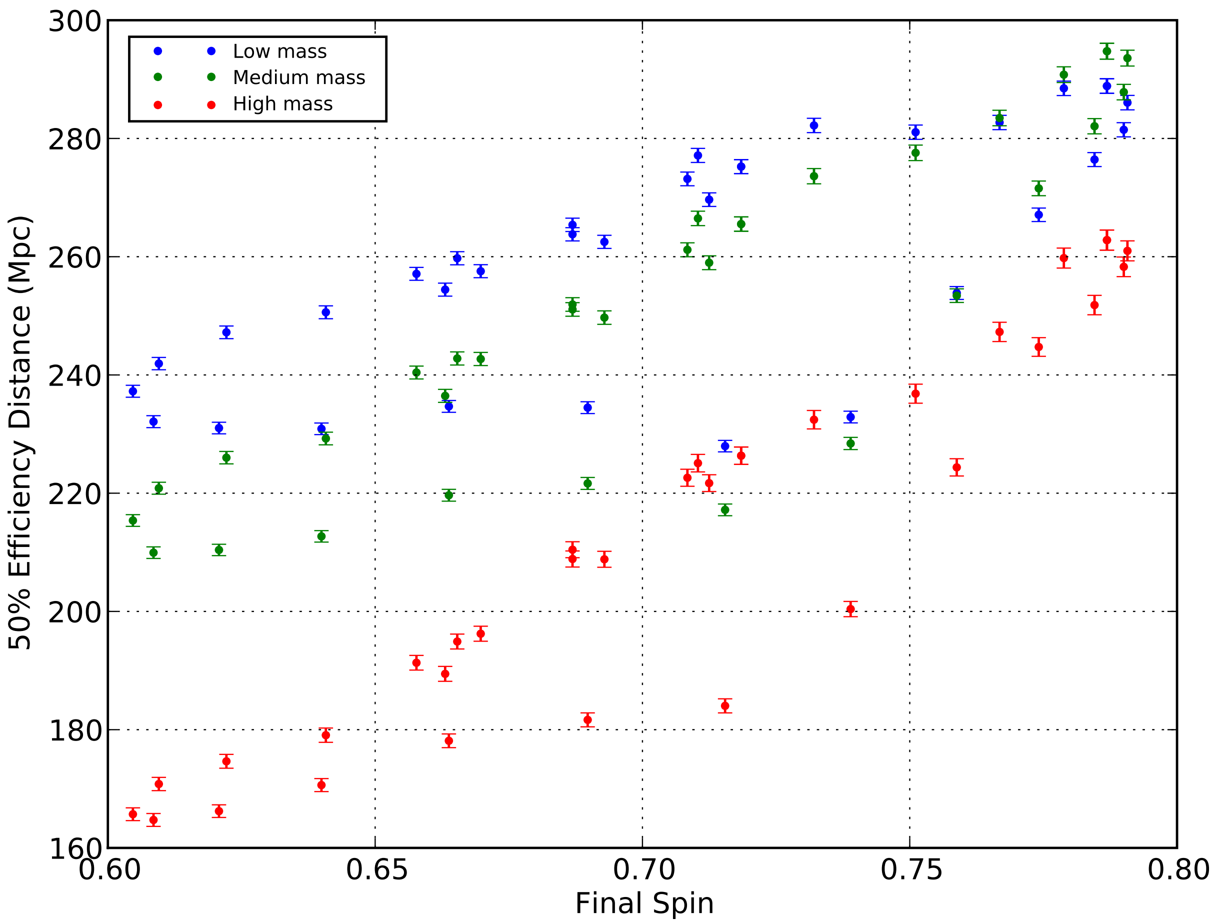
- The eccentricity of the orbit shows an effect - we are currently planning to explore this further
- Spin orientation and magnitude also show a noticeable impact on detection efficiency - distance appears to go roughly as projection of spin on orbital angular momentum
- Other results (not shown here) indicate that spherical harmonic modes aside from the dominant quadrupole mode ($\ell = 2$, $|m| = 2$) do not have an impact on detection efficiency for the runs we've studied

Looking Ahead

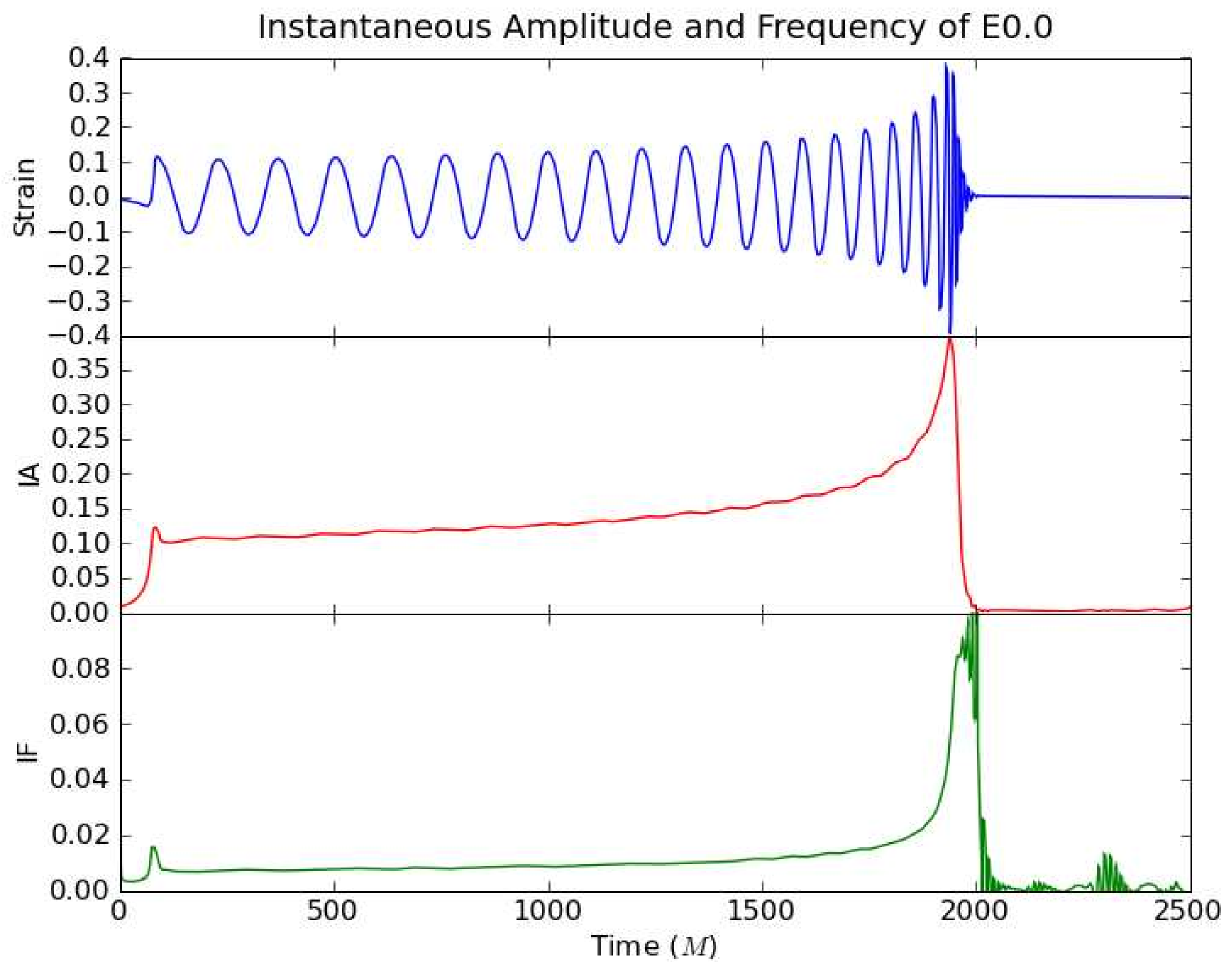
For the near future, we plan to:

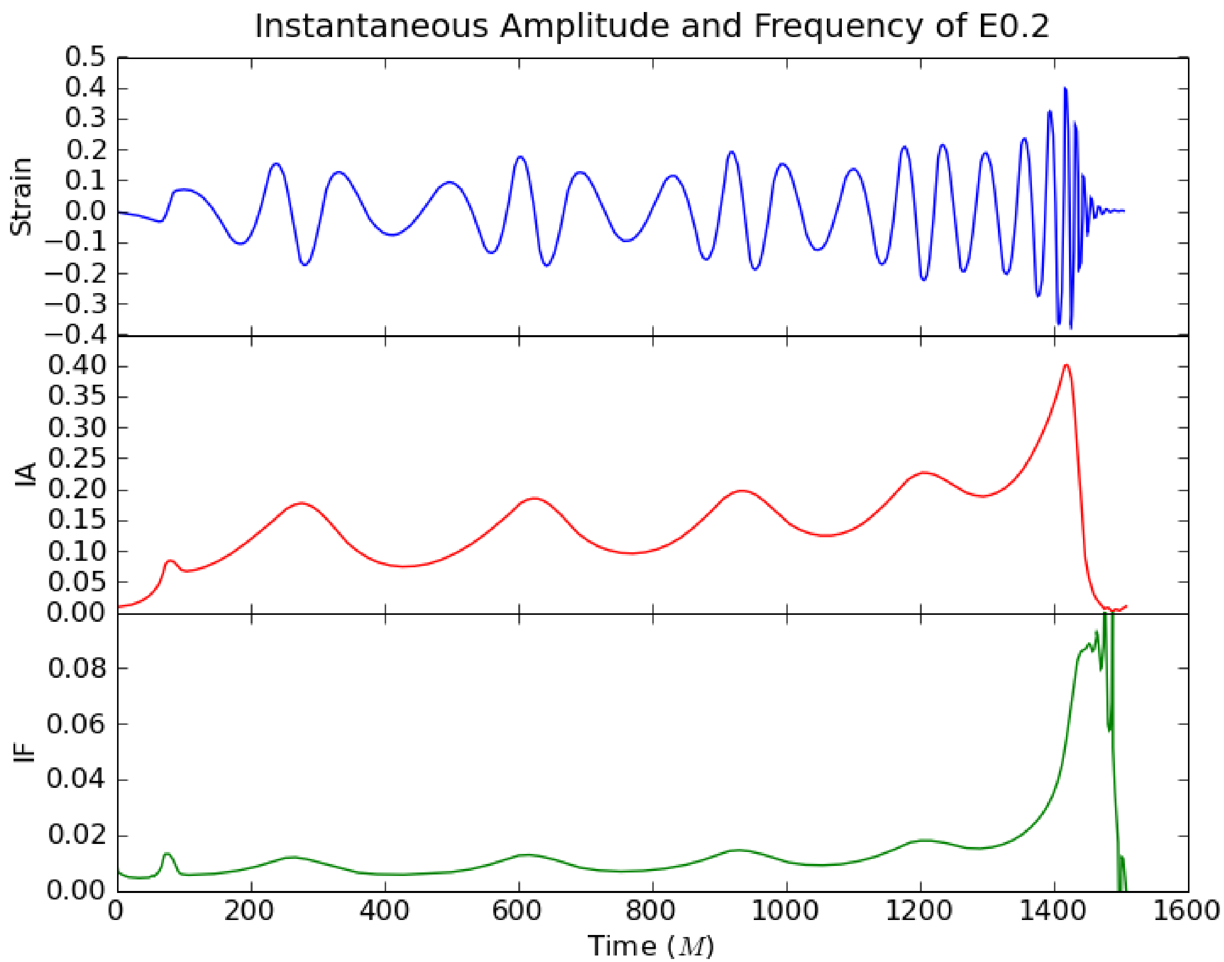
- Fill in more eccentricities
- Span more spin orientations
- Start to explore the effect of mass ratio
- Start to look more closely at numerical parameters (resolution, initial data, etc.)

Other goals include removing source distance as a parameter, looking at sky location, trying full-pipeline runs, using glitchy noise, etc.



Low mass
Medium mass
High mass
300
280
260
240
220
200
180
160
0.60
0.65
0.70
0.75
0.80
Final Spin
50% Efficiency Distance (Mpc)


Instantaneous Amplitude and Frequency of E0.0
Strain
IA
IF
Time (M)
0.4
0.3
0.2
0.1
0.0
−0.1
−0.2
−0.3
−0.4
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0.08
0.06
0.04
0.02
0.00
0
500
1000
1500
2000
2500


Instantaneous Amplitude and Frequency of E0.2
Strain
0.5
0.4
0.3
0.2
0.1
0.0
−0.1
−0.2
−0.3
−0.4
IA
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
IF
0.08
0.06
0.04
0.02
0.00
0
200
400
600
800
1000
1200
1400
1600
Time (M)